Draft

Environmental Impact Statement / Overseas Environmental Impact Statement

GUAM AND CNMI MILITARY RELOCATION

Relocating Marines from Okinawa, Visiting Aircraft Carrier Berthing, and Army Air and Missile Defense Task Force

Volume 9: Appendices

November 2009

Comments may be submitted to:

Joint Guam Program Office
c/o Naval Facilities Engineering Command, Pacific
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Guam and CNMI Military Relocation EIS/OEIS

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MARINE BIOLOGICAL SURVEY OF INNER APRA HARBOR, GUAM

by

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Review Draft

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Marine Technicians Chris Bassler and Jason Miller piloted the boats and served as diving safety officials. They also maintained communications with Port Operations during our field work.

Finally, we are especially grateful for the guidance provided by Dr. Mark Moese of Earth Tech, Inc. for acting as our liaison and project coordinator. His guidance and patience made the project possible.

INTRODUCTION

Inner Apra Harbor is a natural embayment formed by tectonic activity along the Cabras Fault, separating the volcanic Tenjo Block in central Guam from the limestone Orote Block immediately to the west (see Tracey et al., 1964 for structural details). Rotation of the Orote Block resulted in subsidence of the eastern portion of the block adjacent to the Cabras Fault line. Accompanying rotation, the sea flooded into the slumped areas, forming Apra Harbor, a deep-water lagoon bounded on the north by Cabras Island and the long, curving Glass Breakwater. Two rivers—the Apalacha and Atantano—drain the volcanic mountain land to the east of Apra Harbor and empty into the inner harbor (Randall and Holloman, 1974).

Although naturally formed, Inner Apra Harbor has been extensively modified by dredging, construction, and landfills by the U.S. Navy since 1945 (Paulay et al., 2001a). The inner harbor was dredged, changing the southernmost part of the original lagoon from a reef-choked, silty embayment into a harbor with a nearly uniform depth and mud bottom. Fill projects created the Dry Dock Peninsula, Polaris Point, and manmade shorelines along the northeastern and southeastern boundaries of the harbor. These and other developments in the outer harbor (e.g., construction of Glass Breakwater) reduced water exchange between the harbor and the Philippine Sea, creating a gradient of increasing turbidity, abundance of plankton and benthic suspension feeders, and finer sediments from the entrance to the outer harbor to the inner harbor environment. The only portion of the inner harbor remaining unchanged is the mangrove area at the mouth of the Atantano River.

Randall and Holloman (1974) reported living *Pocillopora* and *Porites* corals on the wharf and dock structures in the inner harbor. Paulay et al. (2001a) found that artificial surfaces in the inner harbor supported diverse fouling communities, including both indigenous and introduced species. They noted the presence of *Porites convexa*, known in Guam from only a few locations. They also remarked about the abundance of the hammer oyster *Malleus decurtatus* on wharf faces in Inner Apra Harbor.

Relocation of elements of the Marine Expeditionary Force (MEF) from Okinawa to Guam by the Marine Corps will require renovation of existing port facilities to accommodate MEF embarkation, as well as construction of various new operations facilities in support of the MEF mission. Furthermore, new training areas and associated facilities are proposed for selected areas on Guam. These developments require extensive surveys that locate, identify, and assesses the natural resources of Guam.

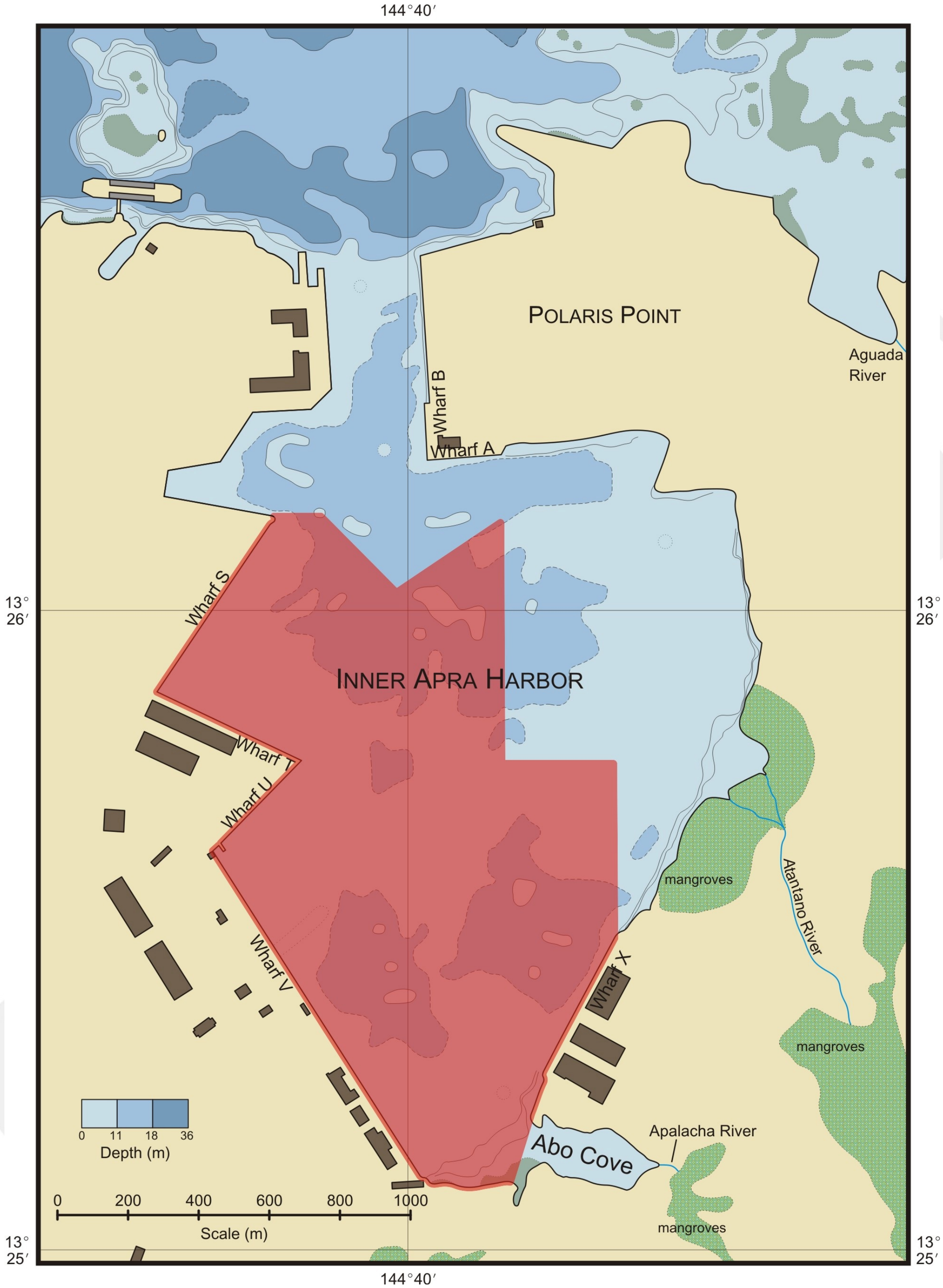

Figure 1. Map of Inner Apra Harbor showing geographic locations and the general survey area (shaded orange).

Scope of Work

The University of Guam Marine Laboratory was contracted to perform a study of marine communities in the southwestern half of Inner Apra Harbor (Figure 1) . The specific objectives of the study were:

- Quantitative assessments of corals
- Quantitative assessment of select macroinvertebrates
- Fish census
- Assessment of essential fish habitat
- Assessment of endangered species (both federally listed, proposed for listing, and candidate species and those similarly listed or otherwise recognized by Guam) to include abundance and preferred habitat, if any
- Survey areas will be subjectively evaluated using the four criteria for Habitat Areas of Particular Concern (HAPC): 1. the ecological function provided by the habitat is significant; 2. the habitat is sensitive to human-induced environmental degradation; 3. development activities are, or will be, stressing the habitat type; and 4. the habitat is rare

Data from the survey are expected to serve as a guide for decisions affecting land and coastal use for proposed construction and renovation of facilities and training sites on Department of Defense lands in Guam.

Methods

Sampling Site Selection

The general ecological condition of an approximately 145 ha area (Figure 2) was assessed by a modified manta tow method. Two observers were towed behind a boat piloted along the 6,188-m boundary of the study area. Visibility was limited to less than 5 m because of high turbidity of the water. The locations and general surface coverage of corals were noted by the observers. Based upon these observations, three sites (Abo Cove, Transect 1, and Transect 2) were selected for benthic surveys, and five sites (Wharves S, T, U, V, and X) were selected for surveys of vertical wharf faces (Figure 2). A 100-m transect line was established along the 2-m isobath at Abo Cove. For Transects 1 and 2, in open areas of the harbor floor away from wharves or the shoreline, a GPS-tracking unit in a waterproof housing was towed by a diver swimming along the harbor floor. Lengths of the tracks were calculated with SigmaScan Pro 5.0 (SPSS, Inc., 1999). At Wharves S, V, and X, 100-m transects were established. At Wharves T and U, 50-m transects were established, because access to larger wharf areas was not granted. GPS coordinates were recorded for the ends of all transects.

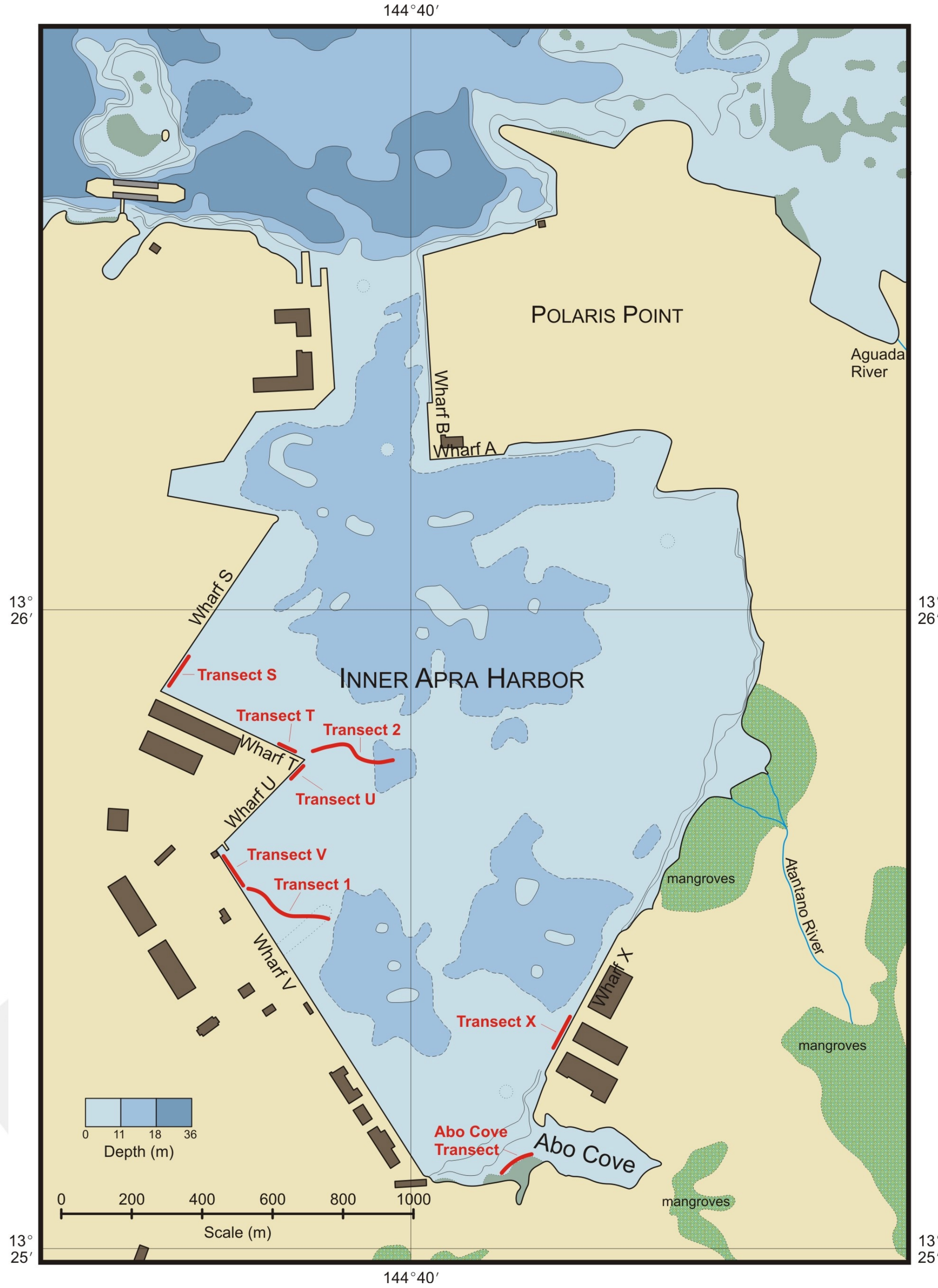

Figure 2. Map of Inner Apra Harbor showing locations of transects surveyed in this study.

Benthic Cover

Benthic quadrats were surveyed along transects established for coral, invertebrate, and fish surveys. Fifty-meter transects were installed at a fixed depth (3–5 m) at six sites throughout the inner harbor (Figure 2). Per transect, the percentage cover of algae, corals, and sponges in five 0.25-m^2 quadrats was quantified in situ, and the data were entered into a relational database (MS Access). The limited visibility in the inner harbor precluded documentation of benthic flora and fauna with photoquadrat records, but macro photographs of the representative species were taken. Voucher specimens of algae were collected to establish a reference collection of algae from Inner Apra Harbor. Explorative data analysis was performed through analysis of variance and non-metric multidimensional scaling. In situ cover estimates of turf algae were also troubled by poor visibility and, therefore, removed from the data set prior to analysis.

Corals

Coral communities were assessed quantitatively along the transects by an observer by the point-quarter method of Cottam et al. (1953). Points were assigned 3–10 m apart on each transect. Each point served as a focus of four equal-sized quadrants arrayed around the point. Within each quadrant, the coral closest to the central point was located. This coral's identity, distance from the point, length, and width were recorded. If no corals lay within 1 m of the point, that quadrant was recorded as having no corals. From the recorded data, community and species-specific population density of colonies, percent coverage, and frequency of occurrence were then computed with the following equations from Cottam et al. (1953):

Total Density Of All Colonies = Unit Area / (Average Point-To-Colony Distance)^2
Relative Density Of A Species = 100 * Number Of Colonies Of The Species / Number Of All Colonies
Absolute Density Of A Species = Percent Density * Total Density / 100
Total Percent Coverage Of All Species = Total Density * Average Coverage Of All Species
Relative Coverage Of A Species = Species Density * Average Coverage of the Species

Population data for each species were also calculated, including the number of colonies, average colony size, standard deviation of colony size, and minimum and maximum colony size. To record the less common species not recorded by the quantitative survey, a list of species was also assembled by swimming along the entire transects and recording all species seen within 2 m of the line. Species names followed Veron (2000).

Macroinvertebrates

All conspicuous solitary epibenthic macroinvertebrates occurring within 1 m of either side of the transect lines at Abo Cove and Wharves S, T, U, V, and X were identified and enumerated by an observer swimming along the transect line. For Transects 1 and 2, species of conspicuous epibenthic macroinvertebrates were recorded within 1 m of an imaginary line in front of an observer swimming over the harbor floor, as described above. For this study, conspicuous is defined as being larger than 50 mm in size and as being clearly visible to an observer without need of overturning rocks or digging into the substrate. Cryptic, microscopic, nocturnal, and highly motile species that avoid humans (e.g., crabs and shrimps) were not included within the scope of this study. Species diversity and abundance were recorded in 10-m intervals along the transect line. Therefore, for statistical purposes, each belt transect consisted of five to ten 20-m^2 replicate plots, except where noted.

Similarities in structure of macroinvertebrate assemblages for all transects were calculated by the Bray-Curtis similarity method, and the resulting matrix subjected to cluster analysis (group average method, fourth root-transformed data) and multidimensional scaling (MDS) analysis (fourth root-transformed data bootstrapped with n = 100 iterations) to investigate relationships between transects. Cluster and MDS analyses were performed with PRIMER v5 (Clarke and Gorley, 2001). Species of macroinvertebrates observed in the study area, but not encountered along the transect line, were also recorded but not included in the similarity analyses.

Fishes

Fishes were surveyed visually along transect lines. Observations were constrained by poor visibility and all species had to be counted on a single pass along the transect line. At Abo Cove, the line was deployed along the bottom as the diver observed and counted fishes. Along wharf faces, three transects were run (where possible), respective of depth, just below the surface (subsurface), at mid-depth (the principal transect line), and at the bottom of the wharf wall. All fishes observed 0.5m above or below the line, were counted on subsurface and mid-depth transects; at the bottom, all fishes observed 1 m to the seaward side (away from the wharf face) of the line were counted. At two stations located in open areas of the harbor away from wharves or the shoreline, GPS-tracking was used to census fishes. Here, one diver utilized a GPS unit set on timed-tracking mode and towed above him in a waterproof housing, recorded all benthic species observed within 1 m either side of an imaginary line directly in front of the diver (Colin and Donaldson, in review). Observations were recorded a during the course of the swim just above the bottom. Pelagic species could not be observed because of poor visibility. These methods provided estimates of density (no. individuals/m^2) for each species.

Fishes were identified to species. Identifications followed Myers (1999) and Myers and Donaldson (2003), except where more recent taxonomic studies were relevant. Reference photographs and video were taken with an underwater digital camera or underwater digital video camera, but image quality tended to be extremely poor because of turbid conditions.

For estimates of species diversity, standard measures of species richness, species diversity, and similarity were calculated and compared between stations with PRIMER vers. 5.2.2; DIVERSE PROCEDURE). Multidimensional scaling (PRIMER vers. 5.2.2; MDS procedure) was used to examine similarities between stations based upon Bray-Curtis coefficients calculated for each. This test indicates relative distances between samples based upon their similarities in assemblage structure. Points found close together represent samples that were very similar in species composition while those far away represented different assemblage structures (Clarke and Gorley, 2001). Analysis of Similarities (PRIMER, ver. 5.2.2;

ANOSIM procedure) was used to test the null hypothesis that there were no differences in assemblage structure between groups of samples at stations.

Essential Fish Habitat

Extremely poor visibility on transects at all stations limited the ability to collect data on essential fish habitat. Underwater photographs taken along the transect line to estimate benthic structure used by different species were essentially useless. Similarly, measures of rugosity (benthic structural complexity), limited to the edge of a shallow reef at Abo Cove, were made under near-zero visibility and were fraught with error. Therefore, it was possible only to make qualitative descriptions of habitats used by fishes.

RESULTS AND DISCUSSION

GPS coordinates for the locations of transects are reported in Table 2 and illustrated in Figure 1. No GPS data were captured for the distal ends of transects at Victor and X-ray wharves.

Table 1. GPS coordinates of transects surveyed in Inner Apra Harbor for this study.

			Start		Finish	
Study Site	Date	Length (m) (M)	Latitude (°N)	Longitude (°E)	Latitude (°N)	Longitude (°E)
Abo Cove	2008/05/29	100	13.41927	144.66937	13.41865	144.6692
Sierra Wharf	2008/05/29	100	13.25922	144.39646	13.25881	144.39616
Tango Wharf	2008/05/23	50	13.42973	144.66336	nd[1]	nd
Victor Wharf	2008/05/29	100	13.62535	144.66269	13.42627	144.66206
Uniform Wharf	2008/05/22	50	13.25687	144.39766	13.25706	144.39783
X-ray Wharf	2008/05/21	100	13.42399	144.67168	nd	nd
Transect 1	2008/05/29	260	13.42617	144.66239	13.42531	144.66441
Transect 2	2008/05/29	250	13.42946	144.66391	13.42916	144.66638

[1]No data recorded.

Benthic Cover

Table 2 shows the sampling effort of benthic surveys. The number of surveyed transects is a function of site accessibility, which was often limited by port operations and the size of the wharfs. Continued efforts to increase the number of transects at Uniform and Tango wharves were prevented as the team was denied access to the inner harbor on several occasions.

Table 2. Dates and sampling effort of benthic surveys.

Site	Date	# Transects	# Quadrats
Abo Cove	5-May-08	3	14
Sierra Wharf	21-May-08	2	10
X-ray Wharf	21-May-08	2	10
Uniform Wharf	22-May-08	1	5
Tango Wharf	23-May-08	1	5
Victor Wharf	23-May-08	2	10

Table 3 lists the 70 benthic taxa that were recorded and quantified during this study. The total number of taxa recorded is low compared to benthic surveys in other parts of the harbor. The average species richness of the quadrats is also low compared to similar studies in other parts of Guam. Figures 3 and 4 show a large difference in the total number of species and species richness between quadrats from Abo Cove and the wharf transects. The most authentic "natural" site (Abo Cove) is significantly less taxon-rich than the wharf sites (Tables 4 and 5). Turbidity and sediment deposition are most likely the most important causal factors for this difference. *Caulerpa verticillata* is a green alga that copes well with increased levels of sedimentation and reduced salinities. Exceptionally large specimens of this alga were found in Abo Cove, probably a result of relatively low herbivore pressure. The distribution of the seagrass species *Halophila japonica* also seems to be restricted to Abo Cove in the inner harbor.

Table 3. Taxonomic list of biotic categories observed in the benthic surveys.

Higher classification	Taxon
Chlorophyta - Ulvophyceae - Bryopsidales - Caulerpaceae	*Caulerpa serrulata*
Chlorophyta - Ulvophyceae - Bryopsidales - Caulerpaceae	*Caulerpa verticillata*
Chlorophyta - Ulvophyceae - Bryopsidales - Udoteaceae	*Halimeda gracilis*
Chlorophyta - Ulvophyceae - Bryopsidales - Udoteaceae	*Halimeda opuntia*
Chlorophyta - Ulvophyceae - Bryopsidales - Udoteaceae	*Rhipilia sinuosa*
Chordata - Ascidiacea - Phlebobranchia - Ascidiidae	*Phallusia julinea*
Chordata - Ascidiacea - Phlebobranchia - Ascidiidae	*Phallusia nigra*
Chordata - Ascidiacea - Phlebobranchia - Diazonidae	*Rhopalaea circula*
Chordata - Ascidiacea - Phlebobranchia - Diazonidae	*Rhopalaea* sp. 2–gold spot
Cnidaria - Anthozoa - Corallimorpharia - Actinodiscidae	*Discosoma* sp.

Higher classification	Taxon
Cnidaria - Anthozoa - Scleractinia - Acroporidae	*Astreopora* sp.
Cnidaria - Anthozoa - Scleractinia - Agariciidae	*Leptoseris mycetoseroides*
Cnidaria - Anthozoa - Scleractinia - Astrocoeniidae	*Stylocoeniella armata*
Cnidaria - Anthozoa - Scleractinia - Dendrophylliidae	*Tubastrea* sp.
Cnidaria - Anthozoa - Scleractinia - Faviidae	*Goniastrea retiformis*
Cnidaria - Anthozoa - Scleractinia - Faviidae	*Leptastrea bottae*
Cnidaria - Anthozoa - Scleractinia - Faviidae	*Leptastrea purpurea*
Cnidaria - Anthozoa - Scleractinia - Oculinidae	*Galaxea fascicularis*
Cnidaria - Anthozoa - Scleractinia - Pocilloporidae	*Pocillopora damicornis*
Cnidaria - Anthozoa - Scleractinia - Poritidae	*Alveopora* sp.
Cnidaria - Anthozoa - Scleractinia - Poritidae	*Porites densa*
Cnidaria - Anthozoa - Scleractinia - Poritidae	*Porites horizontalata*
Cnidaria - Anthozoa - Scleractinia - Poritidae	*Porites lichen*
Cnidaria - Anthozoa - Scleractinia - Poritidae	*Porites lobata*
Cnidaria - Anthozoa - Scleractinia - Poritidae	*Porites lutea*
Cnidaria - Anthozoa - Scleractinia - Poritidae	*Porites rus*
Cnidaria - Anthozoa - Scleractinia - Poritidae	*Porites solida*
Cnidaria - Anthozoa - Scleractinia - Siderastreidae	*Psammocora superficialis*
Ectoprocta - Gymnolaemata - Cheilostomata - Bugulidae	*Celleporaria sibogae*
Ectoprocta - Gymnolaemata - Cyclostomata - Lichenoporidae	*Lichenopora* sp.
Magnoliophyta - Liliopsida - Alismatales - Hydrocharitaceae	*Halophila japonica*
Mollusca - Bivalvia - Pterioida - Malleidae	*Malleus decurtatus*
Mollusca - Bivalvia - Veneroida - Chamidae	*Chama lazarus*
Ochrophyta - Phaeophyceae - Dictyotales - Dictyotaceae	*Dictyota adnata*
Ochrophyta - Phaeophyceae - Dictyotales - Dictyotaceae	*Dictyota bartayresiana*
Ochrophyta - Phaeophyceae - Dictyotales - Dictyotaceae	*Dictyota friabilis*
Ochrophyta - Phaeophyceae - Dictyotales - Dictyotaceae	*Lobophora variegata*
Ochrophyta - Phaeophyceae - Dictyotales - Dictyotaceae	*Padina boryana*
Porifera - Demospongiae - Dendroceratida - Darwinellidae	*Aplysilla* sp.
Porifera - Demospongiae - Dendroceratida - Dysideidae	*Dysidea* cf. *avara*
Porifera - Demospongiae - Dictyoceratida - Spongiidae	*Aplysina* sp. (yellow)
Porifera - Demospongiae - Dictyoceratida - Thorectidae	*Hyrtios* sp.
Porifera - Demospongiae - Hadromerida - Spirastrellidae	*Spheciospongia vagabunda*
Porifera - Demospongiae - Halichondrida - Halichondriidae	*Halichondria* sp.
Porifera - Demospongiae - Poecilosclerida - Anchinoidae	*Phorbas* sp.
Porifera - Demospongiae - Poecilosclerida - Desmacellidae	*Biemna fistulosa*
Porifera - Demospongiae - Poecilosclerida - Desmacellidae	*Neofibularia hartmani*
Porifera - Demospongiae - Poecilosclerida - Desmacididae	*Iotrochota protea*
Porifera - Demospongiae - Poecilosclerida - Guitarridae	*Tetrapocillon* sp.
Porifera - Demospongiae - Poecilosclerida - Microcionidae	*Clathria eurypa*
Porifera - Demospongiae - Poecilosclerida - Microcionidae	*Clathria mima*
Porifera - Demospongiae - Poecilosclerida - Microcionidae	*Clathria* sp. 1
Porifera - Demospongiae - Poecilosclerida - Microcionidae	*Echinochalina* sp.
Porifera - Demospongiae - Poecilosclerida - Mycalidae	*Ulosa spongia*
Porifera - Demospongiae - Poecilosclerida - Phoriospongiidae	*Psammoclemma* sp.
Porifera - Demospongiae - Poecilosclerida - Raspailiidae	*Ceratopsion* sp. 1
Prokaryota - Bacteria - Negibacteria - Cyanobacteria	*Calothrix scopulorum*
Prokaryota - Bacteria - Negibacteria - Cyanobacteria	*Lyngbya penicilliformis*

Higher classification	Taxon
Prokaryota - Bacteria - Negibacteria - Cyanobacteria	*Phormidium* cf. *dimorphum*
Prokaryota - Bacteria - Negibacteria - Cyanobacteria	*Symploca hydnoides*
Rhodophyta - Florideophyceae - Ceramiales - Rhodomelaceae	*Lophocladia* sp.
Rhodophyta - Florideophyceae - Corallinales - Corallinaceae	*Hydrolithon onkodes*
Rhodophyta - Florideophyceae - Corallinales - Corallinaceae	*Lithophyllum kotschyanum*
Rhodophyta - Florideophyceae - Corallinales - Corallinaceae	*Lithophyllum pygmaeum*
Rhodophyta - Florideophyceae - Corallinales - Corallinaceae	*Mesophyllum funafutiense*
Rhodophyta - Florideophyceae - Corallinales - Corallinaceae	*Pneophyllum conicum*
Rhodophyta - Florideophyceae - Halymeniales - Peyssonneliaceae	*Peyssonnelia boergesenii*
Rhodophyta - Florideophyceae - Halymeniales - Peyssonneliaceae	*Peyssonnelia inamoena*
Rhodophyta - Florideophyceae - Halymeniales - Peyssonneliaceae	*Peyssonnelia rubra*
Turf algae	Turf algae

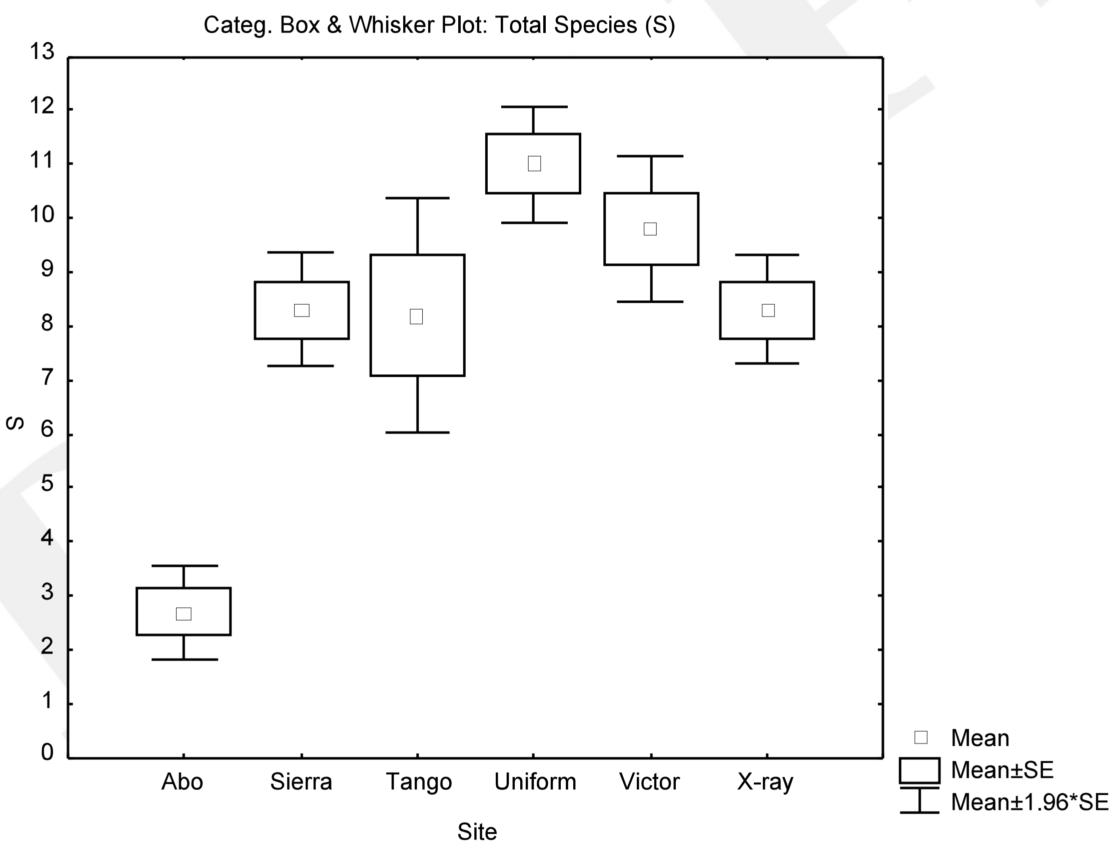

Figure 3. Total species (*S*) of quadrats per site. Abbreviations: Abo, Abo Cove; Sierra, Sierra Wharf; Tango, Tango Wharf; Uniform, Uniform Wharf; Victor, Victor Wharf; X-ray, X-ray Wharf.

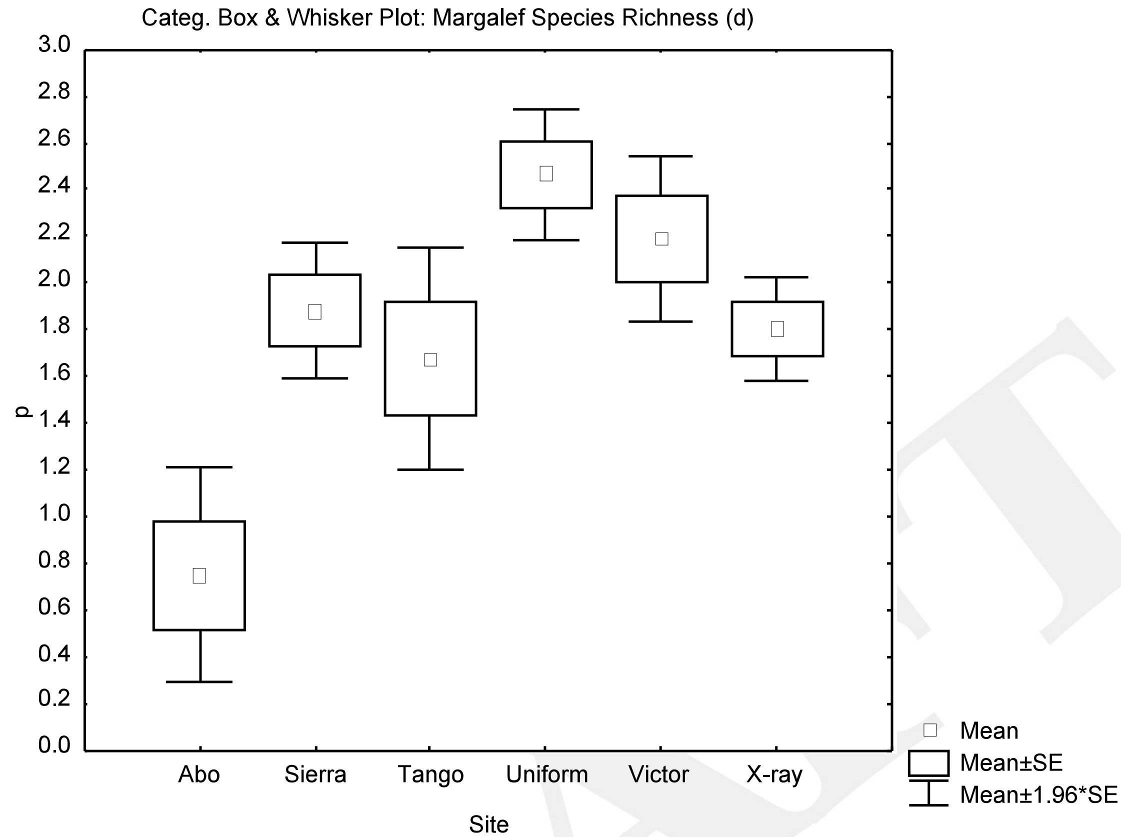

Figure 4. Margalef species richness (*d*) of quadrats per site. Abbreviations as in Figure 3.

Table 4. One-way Analysis of Variance (ANOVA) of *S* with Tukey HSD for unequal sample size as a post-hoc test. Differences significant at P < 0.05 are italicized. Abbreviations as in Figure 3.

	Abo	Sierra	Tango	Uniform	Victor	X-ray
Abo		*0.00*	*0.00*	*0.00*	*0.00*	*0.00*
Sierra	*0.00*		1.00	0.19	0.44	1.00
Tango	*0.00*	1.00		0.16	0.73	1.00
Uniform	*0.00*	0.19	0.16		0.90	0.19
Victor	*0.00*	0.44	0.73	0.90		0.44
X-ray	*0.00*	1.00	1.00	0.19	0.44	

Table 5. One-way ANOVA of *d* with Tukey HSD for unequal sample size as a post-hoc test. Differences significant at P < 0.05 are italicized. Abbreviations as in Figure 3.

	Abo	Sierra	Tango	Uniform	Victor	X-ray
Abo		*0.00*	0.13	*0.00*	*0.00*	*0.00*
Sierra	*0.00*		0.99	0.59	0.83	1.00
Tango	0.13	0.99		0.27	0.72	1.00
Uniform	*0.00*	0.59	0.27		0.97	0.46
Victor	*0.00*	0.83	0.72	0.97		0.66
X-ray	*0.00*	1.00	1.00	0.46	0.66	

Turbidity is high throughout the inner harbor, but the vertical orientation of hard substrates (and probably ship activity) at the wharves results in a lower amount of sediment deposition, favoring the growth of epilithic biota adapted to low light conditions. Although very different from Abo Cove, the benthic assemblages of the wharves contain interesting taxa as well. Some of the taxa recorded here do not appear in the most recent taxonomic treatises for Guam. For example, the very abundant *Celleporaria sibogae* and the rather uncommon *Lichenopora* sp. are most likely new bryozoan records for Guam, as this group has been virtually unstudied in the region (Paulay, 2003). Diversity measures mimic the differences in species richness between the inner harbor sites (Figure 5; Table 6). Sponges contribute most to the benthic diversity of the wharves. A number of these probably also constitute new records for Guam, and others are infrequently encountered elsewhere around the island as they are typically confined to deep water, caves, or other cryptic habitats.

Table 6. One-way ANOVA of *H′* with Tukey HSD for unequal sample size as a post-hoc test. Differences significant at P < 0.05 are italicized. Abbreviations as in Figure 3.

	Abo	Sierra	Tango	Uniform	Victor	X-ray
Abo		*0.01*	0.13	*0.00*	*0.00*	*0.00*
Sierra	*0.01*		1.00	0.64	0.14	0.73
Tango	0.13	1.00		0.69	0.53	0.94
Uniform	*0.00*	0.64	0.69		1.00	0.99
Victor	*0.00*	0.14	0.53	1.00		0.87
X-ray	*0.00*	0.73	0.94	0.99	0.87	

As found for taxonomic richness and diversity, the benthic assemblages of Abo Cove differ significantly from the wharf sites in having a low overall biotic cover (Figure 6; Table 7). As discussed before, this is a direct result of the Abo Cove site being a mostly horizontally oriented sedimentation flat. In contrast, the biotic assemblages of the wharfs are best developed on the shallow vertical surfaces. It is important to note, however, that corals are the main constituent of the biotic assemblages at Abo Cove, while the wharfs are predominantly covered by crustose algae and sponges (Figure 7).

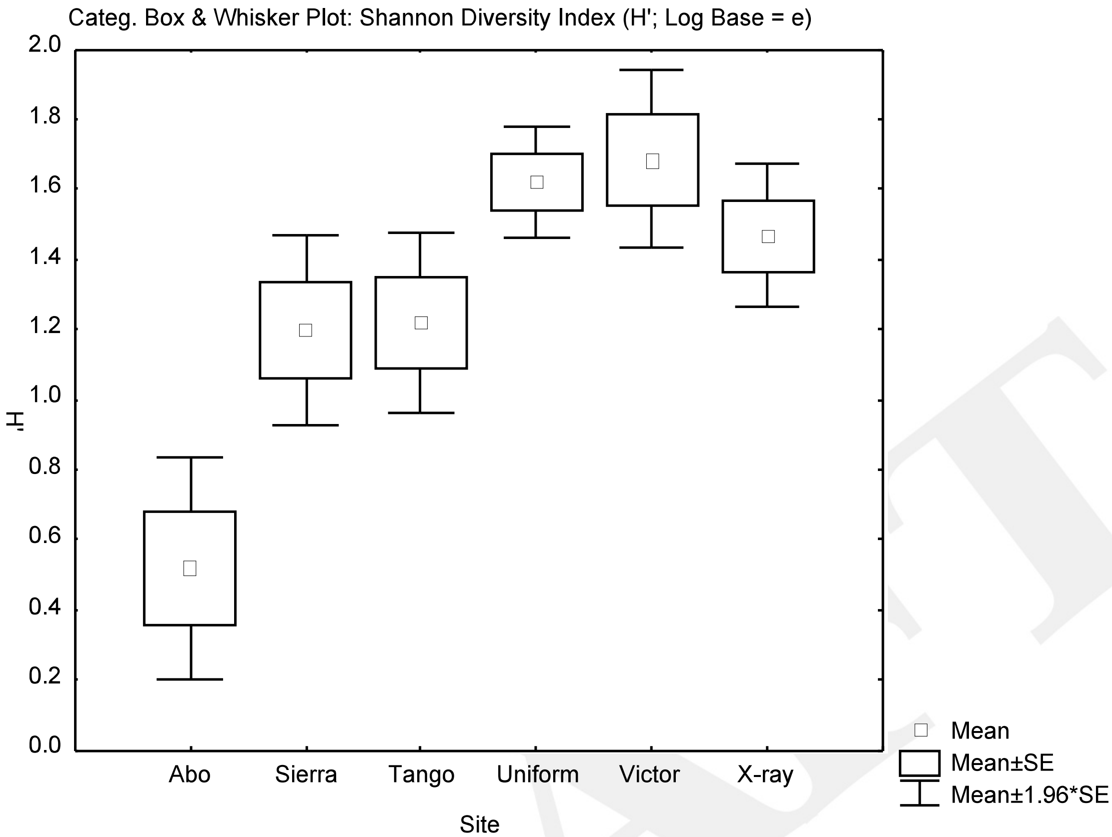

Figure 5. Shannon index (*H'*) of quadrats per site. Abbreviations as in Figure 3.

Table 7. One-way ANOVA of biotic cover with Tukey HSD for unequal sample size as a post-hoc test. Differences significant at $P < 0.05$ are italicized. Abbreviations as in Figure 3.

	Abo	Sierra	Tango	Uniform	Victor	X-ray
Abo		*0.00*	*0.02*	0.21	*0.01*	*0.01*
Sierra	*0.00*		0.98	1.00	1.00	1.00
Tango	*0.02*	0.98		0.87	0.92	0.92
Uniform	0.21	1.00	0.87		1.00	1.00
Victor	*0.01*	1.00	0.92	1.00		1.00
X-ray	*0.01*	1.00	0.92	1.00	1.00	

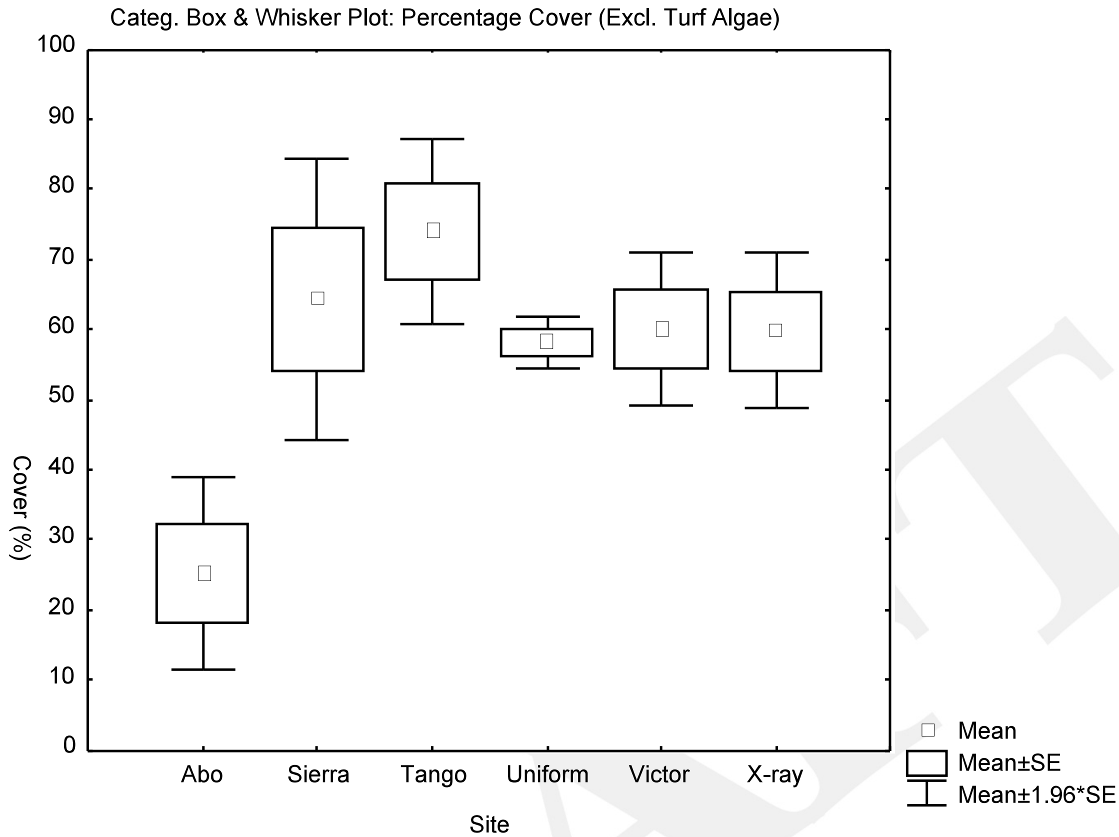

Figure 6. Biotic cover (excluding turf algae) of quadrats per site. Abbreviations as in Figure 3.

Non-metric multidimensional scaling (NMDS) was performed on the square root-transformed benthic data. The two-dimensional NMDS plot is an excellent representation of the biotic affinities between sites (low stress) and highlights the differences between Abo Cove and the Wharf sites in accordance with the above findings. Similarity is highest among the three southwestern wharves (Tango, Uniform, and Victor). Further multivariate analyses should reveal the main differences between the other sites and the most important indicator taxa in the data set.

Corals

Size-frequency distributions of the 13 species of scleractinian corals encountered on six transects in Inner Apra Harbor are presented in Table 8. An additional 13 species of scleractinian corals were observed on substrates adjacent to the transects (Table 3). Two species of non-scleractinian anthozoans were also recorded. Therefore, a cumulative total of 28 species of corals and related organisms, representing 11 families and 13 genera, was observed at the study site. This count represents a minimum, because several corals could be identified only to genus in the field and, therefore, may consist of more than one species.

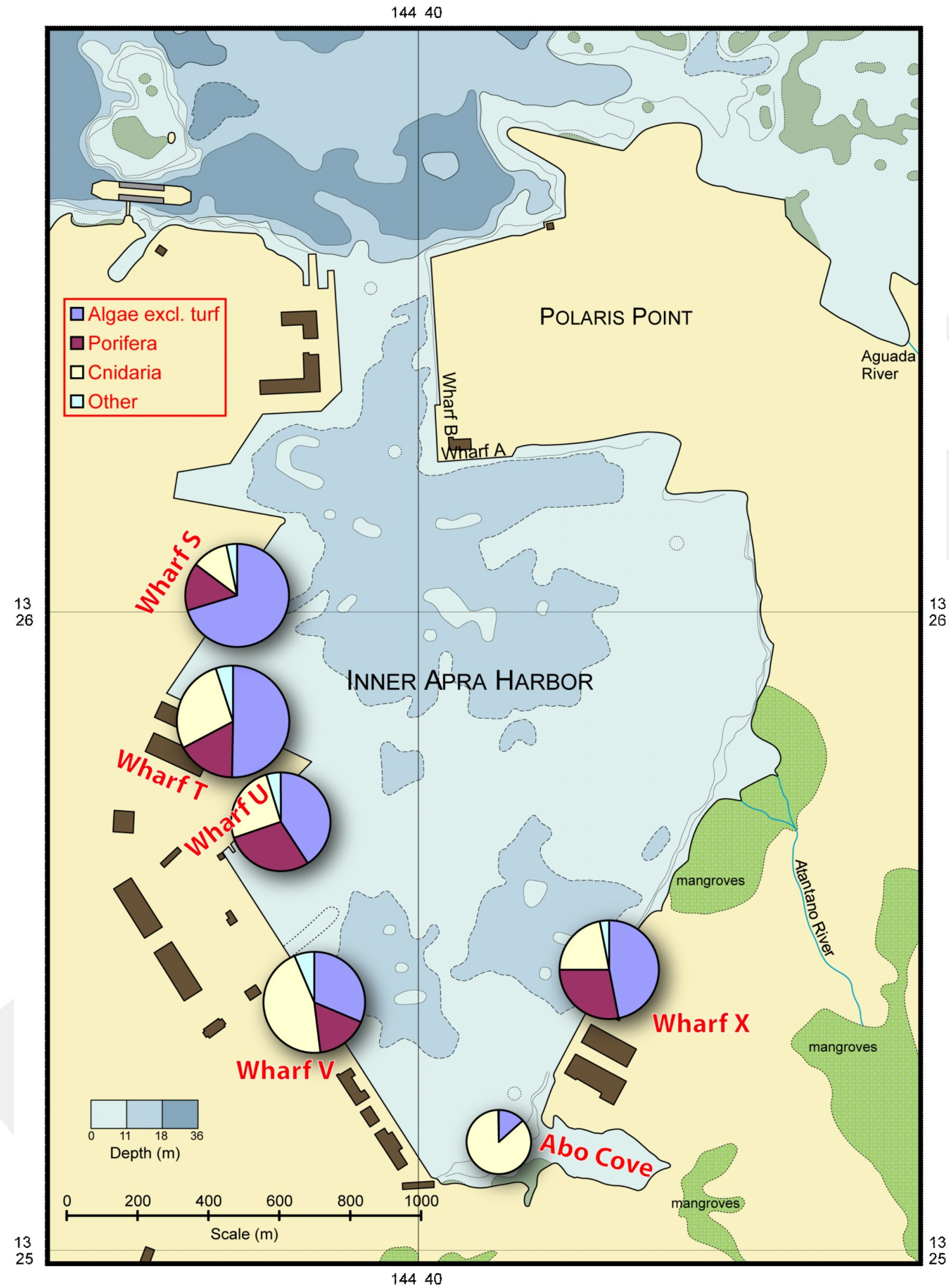

Figure 7. Pie charts displaying the percent cover of algae (Chlorophyta, Ochrophyta, Prokaryota, Rhodophyta), Porifera, Cnidaria, and other groups (Chordata, Magnoliophyta, Mollusca) for the different study sites. Size of the pie chart is proportional to the average total cover of benthic assemblages in the sampled quadrats. Biotic cover ranges from 25 % (Abo Cove) to 74 % (Tango Wharf).

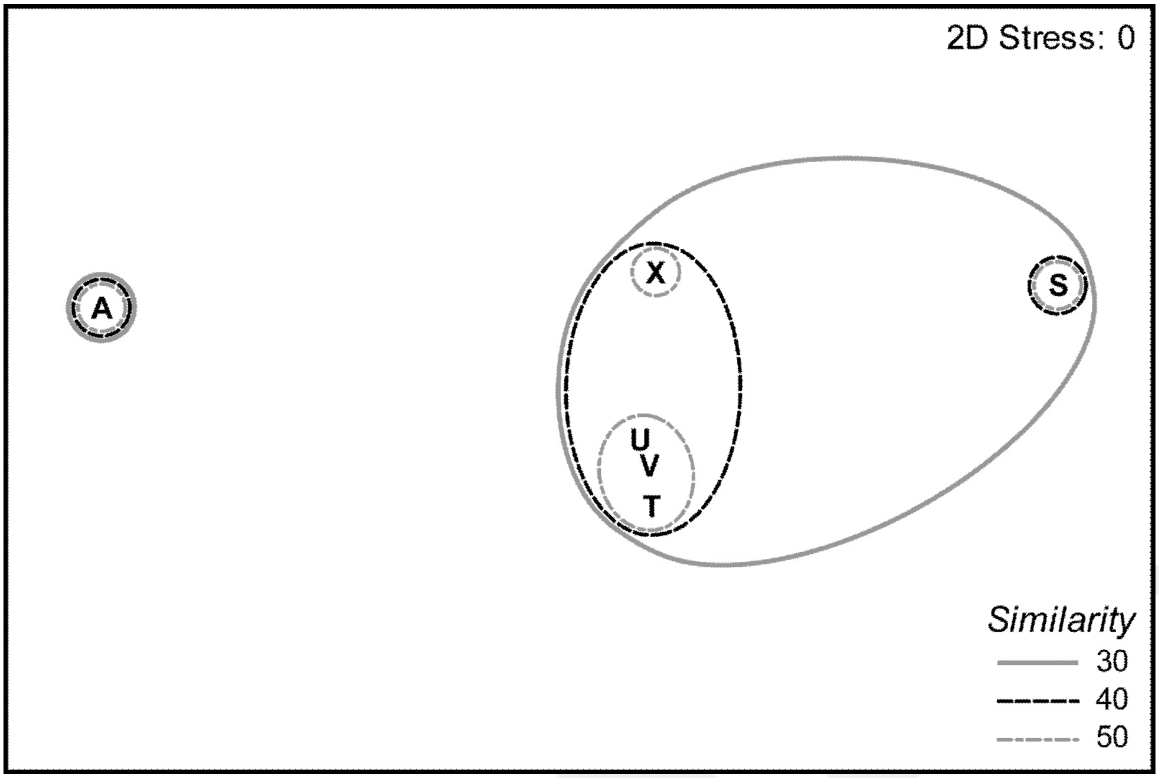

Figure 8. Non-metric multidimensional scaling (NMDS) plot of the six inner harbor sites. Bray-Curtis similarities obtained from a cluster analysis based on the benthic data (square root transformed) are overlaid. Abbreviations: A, Abo Cove; S, Sierra Wharf; T, Tango Wharf; U, Uniform Wharf; V, Victor Wharf; X, X-ray Wharf.

Species richness was highest at X-ray Wharf, where eight species occurred on the transect; only four species occurred on transects at Above Cove and Tango, Uniform, and Victor Wharves. *Porites lutea* and *Pocillopora damicornis* were the most common species, occurring on five of the six transects. Seven species occurred on only one transect, and three of these species were represented by single observations.

Quantitative analysis of the coral species encountered on transect is presented in Table 9. Poritid corals were predominant in coverage, averaging some 83% relative coverage on transects. Similarly, *Porites* spp. occurred at high frequencies on transects, although smaller species, such as *Pocillopora damicornis* and *Leptastrea purpurea*, exhibited high frequencies, as well.

The harbor floor consists of fine-grain sediments unsuitable for settlement by coral larvae. Consequently, few corals were encountered on Transects 1 and 2 on the harbor floor. Small colonies of *Porites lutea* were observed on scattered pieces of debris and old pilings that provided the only hard substrate available for settlement of larvae. With the exception of what

Table 8. Size-frequency distributions of coral species recorded on transects in Inner Apra Harbor. N = number of colonies. Mean, SD (standard deviation), and Range refer to colony coverage in cm^2.

Location	Habitat	Species	N	Mean	SD	Range
Abo Cove	Reef	*Porites* sp.	10	1291.9	1703.2	74.02–5013.98
		Goniastrea retiformis	4	12.7	15.0	3.93–34.99
		Porites lutea	7	1472.2	2624.4	45.95–7242.94
		Porites murrayensis	2	27.7	10.8	20.01–35.34
Wharf S	Wharf face	*Porites rus*	8	19.7	10.7	7.42–39.25
		Lobophyllia hataii	1	9.9	–	9.88
		Stylocoeniella armata	3	25.8	18.1	7.15–43.28
		Leptastrea purpurea	3	8.7	2.6	5.72–10.60
		Pocillopora damicornis	1	0.3	–	0.31
Wharf T	Wharf face	*Leptastrea purpurea*	5	11.7	11.3	0.55–29.10
		Porites lutea	10	99.3	191.2	2.64–631.43
		Pocillopora damicornis	3	25.0	29.1	1.65–57.59
		Porites sp.	2	4.1	0.0	4.10–4.10
Wharf U	Wharf face	*Porites lutea*	12	134.9	282.7	1.53–978.21
		Pocillopora damicornis	10	46.3	43.1	1.98–129.59
		Leptastrea purpurea	15	8.7	9.4	0.20–37.70
		Porites rus	2	1165.7	855.0	561.10–1770.29
Wharf V	Wharf face	*Leptastrea purpurea*	10	2.8	2.4	0.33–8.91
		Pocillopora damicornis	14	46.4	66.0	0.44–253.68
		Porites lutea	12	256.3	434.0	4.67–1555.09
		Stylocoeniella guntheri	3	236.2	406.9	0.55–706.07
Wharf X	Wharf face	*Porites lutea*	11	25.7	26.9	1.96–74.30
		Porites rus	7	640.3	866.3	3.77–2172.16
		Leptastrea purpurea	15	5.3	6.5	0.20–25.40
		Porites sp.	1	1.04	–	3.77
		Montipora sp.	2	12.9	5.1	9.30–16.49
		Porites australiensis	1	4.9	–	4.90
		Pocillopora damicornis	2	32.6	28.3	12.53–52.59
		Pavona explanulata	1	1.0	–	1.04

appeared to be the remains of an old pier extending perpendicular from Victor Wharf (Transect 1, Figure 1), the amount of debris was greater near the wharves. No corals were observed on the harbor floor at distances of 20 m or more.

The fourth root-transformed relative coral coverage data were analyzed by non-metric multidimensional scaling (NMDS). The two-dimensional NMDS plot (Figure 9) shows the biotic affinities between the sites (low stress) and reveals differences not only between Abo Cove and the wharf sites, but between Sierra Wharf and the four remaining wharves. Uniform and X-ray

Table 9. Population density, frequency, and coverage of coral species recorded on transects in Inner Apra Harbor.

Location	Habitat	Species	N	Relative Density	Absolute Density	Frequency	Coverage	Relative Coverage
Abo Cove	Reef	*Porites* sp.	10	0.43	0.06	0.60	80.98	81.58
		Goniastrea retiformis	4	0.17	0.03	0.20	0.32	0.32
		Porites lutea	7	0.30	0.04	0.30	17.62	17.75
		Porites murrayensis	2	0.09	0.01	0.10	0.35	0.35
Wharf S	Wharf face	*Porites rus*	8	0.50	0.04	0.60	1.01	61.78
		Lobophyllia hataii	1	0.06	0.01	0.20	0.05	3.33
		Stylocoeniella armata	3	0.19	0.02	0.40	0.42	26.02
		Leptastrea purpurea	3	0.19	0.02	0.40	0.14	8.77
		Pocillopora damicornis	1	0.06	0.01	0.20	0.00	0.10
Wharf T	Wharf face	*Leptastrea purpurea*	5	0.25	0.03	0.80	0.39	5.11
		Porites lutea	10	0.50	0.07	0.80	6.63	86.85
		Pocillopora damicornis	3	0.15	0.02	0.40	0.56	7.37
		Porites sp.	2	0.10	0.01	0.20	0.06	0.72
Wharf U	Wharf face	*Porites lutea*	12	0.31	0.30	0.800	39.80	35.63
		Pocillopora damicornis	10	0.26	0.25	0.600	11.39	10.20
		Leptastrea purpurea	15	0.38	0.37	1.000	3.20	02.87
		Porites rus	2	0.05	0.05	0.100	57.32	51.31
Wharf V	Wharf face	*Leptastrea purpurea*	10	0.26	0.10	0.50	0.29	00.62
		Pocillopora damicornis	14	0.36	0.15	0.80	6.78	14.55
		Porites lutea	12	0.31	0.13	0.50	32.13	68.93
		Stylocoeniella guntheri	3	0.08	0.03	0.10	7.40	15.88
Wharf X	Wharf face	*Porites lutea*	11	0.28	0.05	0.50	1.15	05.66
		Porites rus	7	0.18	0.03	0.50	18.34	89.92
		Leptastrea purpurea	15	0.38	0.06	0.70	0.49	02.40
		Porites sp.	1	0.03	0.00	0.10	0.02	0.08
		Montipora sp.	2	0.05	0.01	0.10	0.11	0.52
		Porites australiensis	1	0.03	0.00	0.10	0.02	0.10
		Pocillopora damicornis	2	0.05	0.01	0.20	0.27	1.31
		Pavona explanulata	1	0.03	0.00	0.10	0.00	0.02

Wharves cluster together, as do Tango and Victor Wharfs. Coral communities on the four southern wharves are more similar to each other than to either Sierra Wharf or Abo Cove.

Macroinvertebrates

The distribution and abundance of conspicuous solitary epibenthic macroinvertebrates occurring on 8 transects in Inner Apra Harbor are reported in Table 10

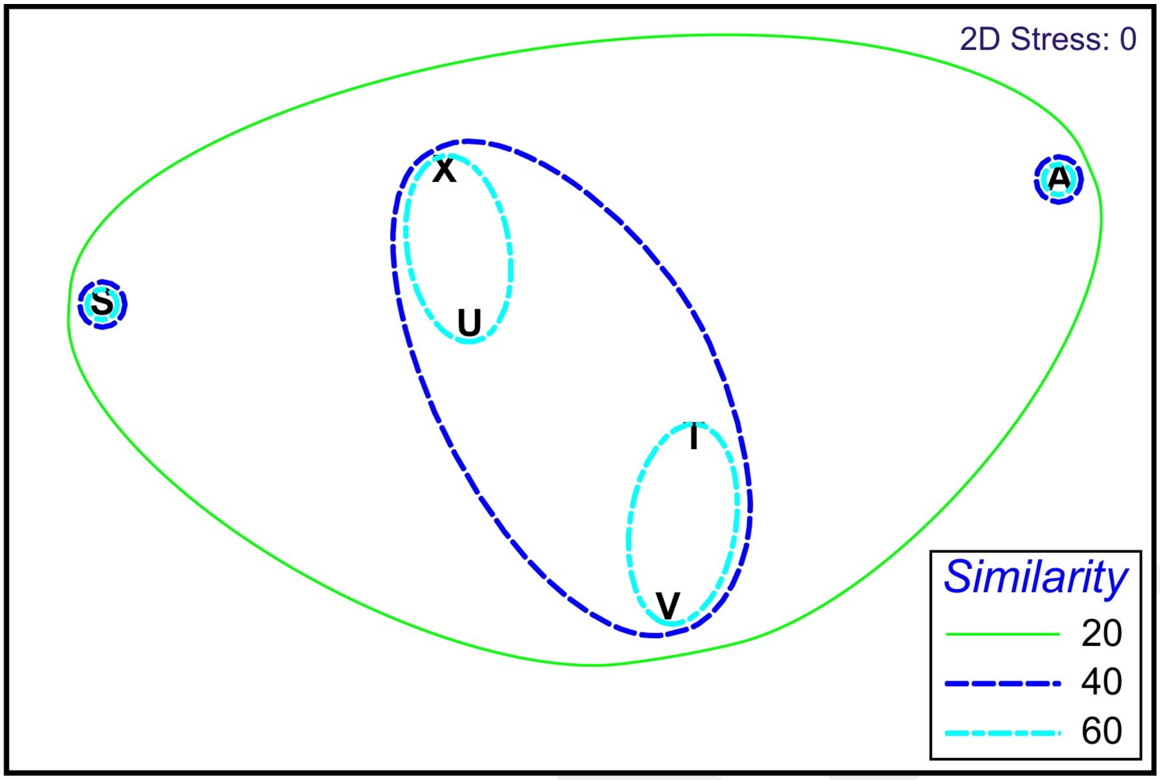

Figure 9. Non-metric multidimensional scaling (NMDS) plot of the six inner harbor transect sites. Bray-Curtis similarities obtained from a cluster analysis based on the coral data (fourth root-transformed) are overlaid. Abbreviations: A, Abo Cove; S, Sierra Wharf; T, Tango Wharf; U, Uniform Wharf; V, Victor Wharf; X, X-ray Wharf.

(colonial invertebrates are included in Table 3). Twenty species of solitary macroinvertebrates in four phyla were encountered on the transects, and 10 additional species were observed in areas adjacent to the transects (Table 11). Three of the species on transects occurred as single observations, and one species, *Phallusia nigra*, is reported as nonindigenous (Paulay et al., 2001a; Lambert, 2002, 2003). The greatest α diversity (i.e., 16 species, or 80% of the α diversity on transects) was found on the vertical face at Victor Wharf (Transect V), and the least (i.e., 8 species) on the coral reef at Abo Cove (Transect A). Bivalve molluscs and ascidians dominated the macroinvertebrate fauna in terms of both diversity and density. Remarkably, 100% of the macroinvertebrate species encountered on transects were suspension feeders. Of the total 30 species of solitary macroinvertebrates listed in Table 11, all but three are suspension feeders—the three being detritus feeders. The predominance of suspension feeders in lagoonal environments, such as the inner harbor, may be a result of nutrient enrichment by terrestrial run-off and the extended residence time of waters in the lagoon.

Table 10. Mean densities of conspicuous epibenthic invertebrates observed on transects in Inner Apra Harbor, Guam. Densities are reported as mean ± standard deviation in twenty 10-m^{-1} quadrats sampled along a 100-m transect, except at Wharf T and Wharf U, where ten 10-m^{-1} quadrats were sampled along a 50-m transect.

	Abo Cove	Wharf S	Wharf T	Wharf U	Wharf V	Wharf X
Cirripathes sp.					0.05 ± 0.22	
Spirobranchus giganteus	0.05 ± 0.22		0.90 ± 0.74	1.20 ± 1.69	0.35 ± 0.67	0.10 ± 0.31
Sabellastarte sanctijosephi	0.05 ± 0.22					
Arca ventricosa					0.05 ± 0.22	
Barbatia spp.	0.30 ± 0.47		0.40 ± 1.26			0.35 ± 0.93
Chama lazarus		7.25 ± 4.30	9.70 ± 2.54	7.90 ± 4.36	11.50 ± 11.37	6.20 ± 3.32
Chama spp.	0.05 ± 0.22	0.35 ± 0.67		0.50 ± 0.85		0.75 ± 1.25
Malleus decurtatus	3.15 ± 2.43	0.20 ± 0.52	4.10 ± 1.73	31.90 ± 27.65	93.40 ± 91.23	54.60 ± 39.55
Spondylus multimuricatus		1.65 ± 2.46	3.10 ± 2.08	2.30 ± 1.49	3.75 ± 3.01	3.05 ± 1.76
Spondylus squamosus		0.65 ± 0.93	0.40 ± 0.52	1.70 ± 1.25	2.15 ± 2.18	5.90 ± 4.76
Spondylus spp.			28.10 ± 9.10	19.90 ± 5.92	10.95 ± 10.65	20.00 ± 9.21
ostreid spp.		0.20 ± 0.70		0.30 ± 0.48	0.65 ± 0.99	0.50 ± 1.15
Septifer bilocularis			0.30 ± 0.95			0.25 ± 0.72
Ascidia ornata	0.20 ± 0.52			0.10 ± 0.32	0.15 ± 0.37	
Ascidia sp. 1[a,b]					0.40 ± 0.60	
Phallusia julinea		0.05± 0.22	0.40 ± 0.70	2.70 ± 2.45	5.45 ± 5.58	
Phallusia nigra				0.20 ± 0.42	0.50 ± 0.83	
Polycarpa spp.	0.55 ± 0.69	0.20 ± 0.52	1.10 ± 1.10	2.20 ± 1.87	1.40 ± 1.43	0.50 ± 0.76
Rhopalaea circula	0.05 ± 0.22	2.45 ± 1.99	63.30 ± 18.09	8.20 ± 5.69	11.60 ± 8.09	4.50 ± 4.51
Rhopalaea sp. 2–gold spot[a,c]			31.90 ± 11.44		1.35 ± 1.69	

[a]These identifications follow the morphospecies designated by Paulay et al. (2001b).
[b]*Ascidia* sp. A of Lambert (2003).
[c]*Rhopalaea* sp. A (n.sp.?) of Lambert (2003).

Table 11. Species of conspicuous epibenthic invertebrates observed on or adjacent to transects in Inner Apra Harbor, Guam. Observations of live specimens are denoted by filled circles (●), and records based on dead specimens are denoted by open circles (○).

	Harbor Floor 1	Harbor Floor 2	Abo Cove	Wharf S	Wharf T	Wharf U	Wharf V	Wharf X
Mastigias papua							●	●
Scyphozoa sp.–transparent				●		●	●	
Cirripathes sp.							●	
Zoanthus sp.							●	
Spirobranchus giganteus	●		●		●	●	●	●
Sabellastarte sanctijosephi			●					
Bittium sp.	●							
cf. *Styliola subula*				●	●	●	●	●
Arca ventricosa							●	
Barbatia spp.	●		●		●	●		●
Chama lazarus				●	●	●	●	●
Chama spp.			●	●				●
Malleus decurtatus	●		●	●	●	●	●	●
Spondylus multimuricatus				●	●	●	●	●
Spondylus squamosus	●			●	●	●	●	●
Spondylus varius						○		
Spondylus spp.	●				●	●		●
Hyotissa hyotis						○		
Saccostrea cf. *cucullata*	●	●						
ostreid spp.				●			●	●
Septifer bilocularis					●	●		●
Mespilia globulus						●		
Parasalenia gratiosa						●		
Ascidia ornata			●			●	●	
Ascidia sp. 1[a]							●	
Phallusia julinea				●	●	●	●	
Phallusia nigra						●	●	
Polycarpa spp.			●	●	●	●	●	●
Rhopalaea circula			●	●	●	●	●	●
Rhopalaea sp. 2–gold spot[a]					●	●	●	

[a]These identifications follow the morphospecies designated by Paulay et al. (2001b).

Densities of solitary macroinvertebrates ranged from less than 1 individual of a species to more than 90 individuals/10 m^2, with bivalve molluscs and ascidians being predominant. The hammer oyster *Malleus decurtatus* occurred in the greatest densities (up to 9.3 oysters/m^2 at Victor Wharf), with thorny oysters, *Spondylus* spp., and jewel box clams, *Chama* spp., also abundant. Among ascidians, *Rhopalaea circula* reached a density of 6.3 individuals/m^2 at Tango Wharf. The greatest total density was observed Victor Wharf (Transect V), where there were 143.7 macroinvertebrates/10 m^2; the lowest total density was 4.4 macroinvertebrates/10 m^2 at Abo Cove (Transect V). As noted above for benthic coverage, this pattern may be explained by the greater availability of hard substrate for post-larval settlement on the vertical faces of the wharves, as compared to the sediment-laden horizontal substrate on the reef at Abo Cove.

The harbor floor is largely depauperate of epibenthic macroinvertebrates. The substrate of the harbor consists predominately of a sticky, fine silt/mud sediment that is easily resuspended. As a result, the transect line sank from sight into the soft sediments. Further, any contact or near contact with the bottom by divers resuspended sediments and reduced visibility markedly. Therefore, we were not able to quantify macroinvertebrates on the harbor floor. However, seven epibenthic species were observed during two swimming transects (Transects 1 and 2). Observed species were associated with debris that provided hard substrate, with the exception of the detritivorous snail *Bittium* sp. Generally, the volume of debris, and therefore the number of macroinvertebrates, diminished with distance from the wharves. Although few epibenthic macroinvertebrates were observed on the harbor floor, large numbers of burrow openings were present, indicating an abundance infaunal organisms.

Comparison of macroinvertebrate community structure across transects by cluster analysis indicates considerable contrast for horizontal and vertical substrates (Figure 10). The macroinvertebrate community on vertical faces of the wharves form a single, large clade that is distinctly different than the community inhabiting the horizontal substrate at Abo Cove. As noted for benthic cover, similarity is high for Uniform and Victor Wharves. However, for solitary macroinvertebrates, X-ray Wharf is more similar to these communities than to the community at Tango Wharf.

Non-metric multidimensional scaling (NMDS) on the fourth root-transformed data further demonstrate the dissimilarity of macroinvertebrate assemblages on horizontal and vertical substrates (Figure 11). The Abo Cove macroinvertebrate community is distinctly different from the communities on the wharf faces, which clustered together. A stress level of 0.01 indicates a high level of significance in the relationships represented by this analysis.

Possibly the most abundant solitary invertebrates were neither epibenthic nor conspicuous. The pelagic thecosomate gastropod cf. *Styliola subula* was abundant in surface waters adjacent to all the wharves that we surveyed. Commonly known as sea butterflies, these free-swimming gastropods feed upon plankton, exhibiting diurnal migrations in pursuit of their prey. Although small (<1 cm) and transparent, the snails are important in marine food webs (Seibel and Diersson, 2003). Their sensitivity to temperature and acidity have led scientists to express concern over the possible effects of global climate change and ocean acidification upon the survival of these organisms and the consequent impacts on marine food webs (Seibel and Diersson, 2003; Orr et al., 2005).

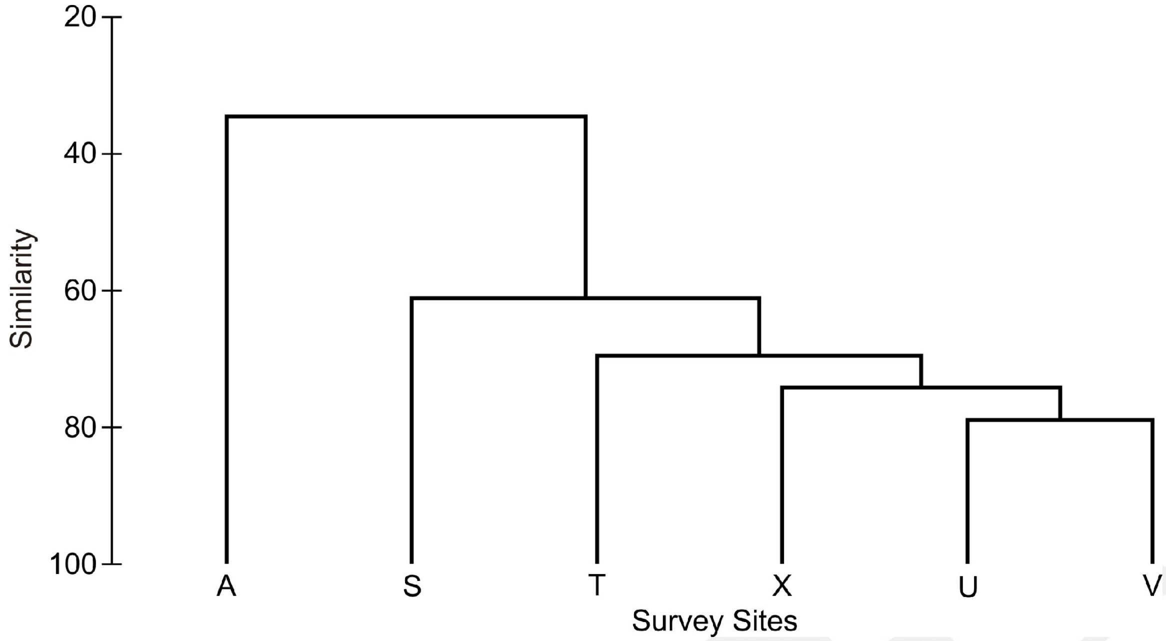

Figure 10. Cluster analysis (group averaging) of macroinvertebrate assemblage relationships between transects at Inner Apra Harbor study sites. Values of similarity (0 to 100%) were calculated in pair-wise comparisons with the Bray-Curtis similarity index and then assembled in a matrix prior to cluster analysis. Abbreviations: A, Abo Cove; S, Sierra Wharf; T, Tango Wharf; U, Uniform Wharf; V, Victor Wharf; X, X-ray Wharf.

We have no basis for statistical comparison of our data on macroinvertebrate populations in Inner Apra Harbor. The most recent survey (Paulay et al., 2001a) of the macroinvertebrate communities in the inner harbor focused primarily upon only three taxa (i.e., sponges, echinoderms, and ascidians), and their study was qualitative in structure.

Fishes

A checklist of species and their relative abundance (as percent) at each station is given in Table 12. Sixty-two species of fishes were observed on transects surveyed within the Apra Inner Harbor. While this number indicates an impoverished fish fauna (there are approximately 1,000 species of reef and nearshore fishes known from the Mariana Islands; Myers and Donaldson, 2003; unpublished data), the fauna seems representative of protected, turbid lagoons or bays of Guam (unpublished data). Further, at least three species appear to be invasive or new records for Guam and the Mariana Islands. One, *Neopomacentrus violescens* (Pomacentridae-damselfishes), has been reported previously (Myers, 1999; Myers and Donaldson, 2003). The other two, *Amblygliphididon ternatensis* (Pomacentridae) and *Rhamdia cypselurus* (Apogonidae-cardinalfishes) have not been reported previously from the Mariana Islands. Both occur elsewhere in the western Indo-Pacific region in natural habitats somewhat similar to those found in Inner Apra Harbor (Myers, 1999). Either both of these species have escaped detection

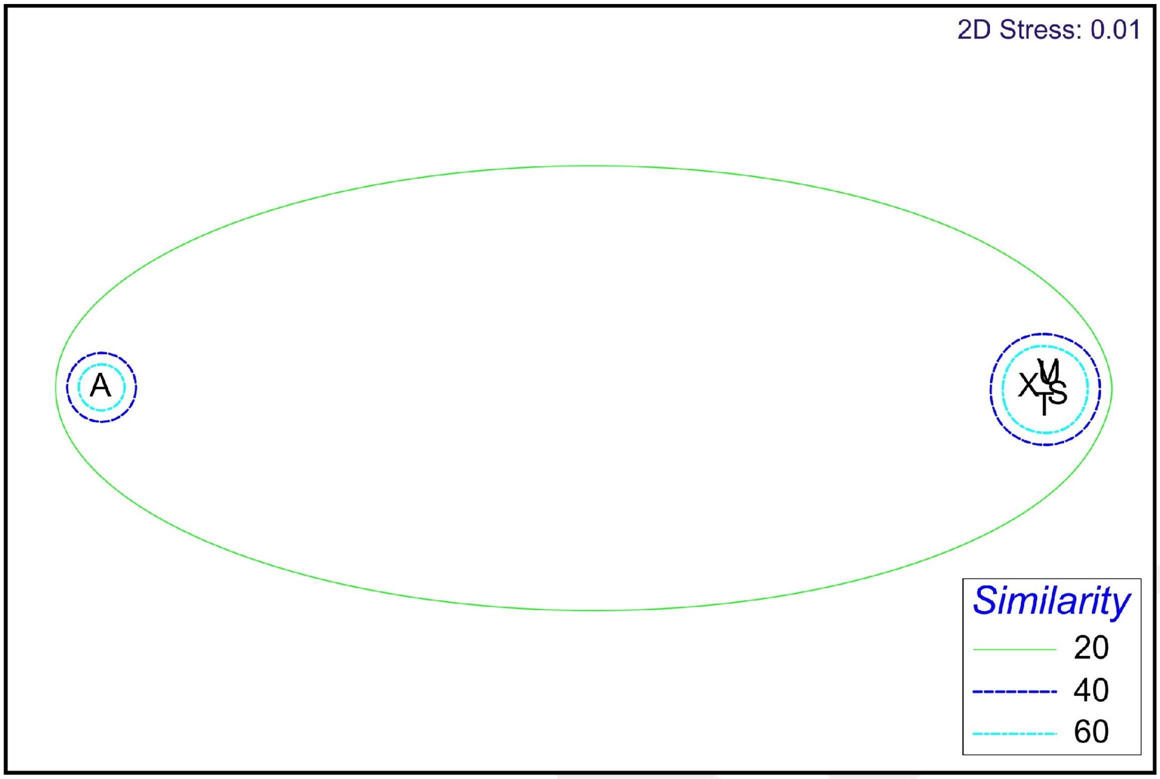

Figure 11. Non-metric multidimensional scaling (NMDS) plot of macroinvertebrate assemblages at the six inner harbor transect sites. Bray-Curtis similarities obtained from a cluster analysis based on the coral data (fourth root-transformed) are overlaid. Abbreviations: A, Abo Cove; S, Sierra Wharf; T, Tango Wharf; U, Uniform Wharf; V, Victor Wharf; X, X-ray Wharf.

previously, owing to the very turbid conditions found in the inner harbor, or they have been introduced, likely as larvae in bilge water of ships moored in the inner harbor, and have been seen for the first time during the present surveys,

Species richness (the number of species observed) between stations ranged from 2 (harbor floor, Transect 2) to 29 (UniformWharf–bottom, Transect U_B). Generally, species richness was greater on the bottom at stations, where debris provided shelter for various species. Some wharf walls (mid-depth transects), however, supported relatively high numbers of species, as well. Subsurface transects at all wharf stations tended to have the lowest number of species, with some exceptions, as did Abo Cove (Table F3). A measure of species diversity, Shannon's H' (Magurran, 1988), that adjusts species richness to consider also the influence of abundance, was highest along the mid-depth transect at Victor Wharf (Transect V_M), and then along the bottom transect at Uniform (Transect U_B). Species diversity was also relatively high on mid-depth transects at X-ray (Transect X_M) and Uniform (Transect U_M) Wharves, but also on subsurface transects at Tango (Transect T_S) and X-ray (Transect X_S) wharves. Corals, soft corals, and molluscs (mainly oysters) were present at these stations and appeared to be protected

Table 12. Relative abundance (%) of fishes observed on transects in Inner Apra Harbor. Survey sites are designated as follows: A = Abo Cove, S_M = Sierra Wharf mid-depth, S_S = Sierra Wharf subsurface, T_M = Tango Wharf mid-depth, T_S = Tango Wharf subsurface, T_B = Tango Wharf bottom, U_M = Uniform Wharf mid-depth, U_S = Uniform Wharf subsurface, U_B = Uniform Wharf bottom, V_M = Victor Wharf mid-depth, V_S = Victor Wharf subsurface, V_B = Victor Wharf bottom, X_M = X-Ray Wharf mid-depth, X_S = X-Ray Wharf subsurface, X_B = X-Ray Wharf bottom, O_1 = harbor floor 1, O_2 = harbor floor 2.

	Survey Sites																
Taxon	A	S_M	S_S	T_M	T_S	T_B	U_M	U_S	U_B	V_M	V_S	V_B	X_M	X_S	X_B	O_1	O_2
Family Clupeidae (herrings)																	
Spratelloides delicatulus	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Family Mugilidae (mullets)																	
Moolgarda seheli	5.3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Family Holocentridae (squirrelfishes)																	
Neoniphon opercularis	0	0	0	0	0.6	0	0	0	0.2	0	0	0	0	0	0	0	0
Sargocentron spiniferum	0	0	0	0.3	0	0	0	0	0	0	0	0	0	0	0	0	0
Family Serranidae (groupers)																	
Epinephelus maculatus	0	0	0	0	0	0	0	0	0.2	0	0	0	0	0	0	0	0
Family Apogonidae (cardinalfishes)																	
Apogon lateralis	0	97.5	64.4	28.2	0	5.8	0	0	44.6	0	0	75.4	58.9	0	89.2	0	0
Apogon leptacanthus	5.3	1	2.9	0	6	0	0	0	5	0	0	1	6	0	9	0	0
Archamia biguttata	0	0	0	0	1.2	0	0	0	2	0	0	0	0	0	0	0	0
Archamia fucata	0	0	0	0	0	5.8	0	0	0	0	0	14.1	0	0	0	0	0
Cheilodipterus quinquelineatus	68.2	0	0	0	1.2	0	0	3.1	0.2	5	0.6	3.6	0	0	0	0	0
Foa brachygramma?	0	0	0	0	0	0	0	0	0.2	0	0	0	0	0	0	0	0
Rhabdamia cypselurus?	0	0	2.3	57.6	68.3	0	0	0	20	0	0	0	1.8	0	0	0	0
Sphaeramia orbicularis	0	0	0	0	0	0	0	0	0	0	0	0	0	6	0	0	0
Family Carangidae (trevallys)																	
Caranx ignobilis	0	0	0	0.9	0	0	0	0	0	0	0	0.1	1.8	0	0	0	0
Caranx melampygus	0	0	0	0.3	0	0	0	0	0.2	0	0	0.1	0	0	0	0	0
Scomberoides lysan	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0
Gnathanodon speciosus	0	0	0	0	0	0	0	0	0	0	0.6	0.1	0	0	0	0	0
Family Lutjanidae (snappers)																	
Lutjanus ehrenbergi?	0	0	0	0	0	0	0	0	0.2	0	0	0	0	0	0	0	0
Lutjanus fulvus	5.3	0.1	0	0	0	11.6	0	0	0	0	0	0.3	0	0	0	0	0

Table 12. Continued.

Taxon	A	S_M	S_S	T_M	T_S	T_B	U_M	U_S	U_B	V_M	V_S	V_B	X_M	X_S	X_B	O_1	O_2
	Survey Sites																
Family Lethrinidae (emperors)																	
Lethrinus harak	0	0	0	0	0	0	1.6	0	0	0	0	0.1	0	0	0	0	0
Family Haemulidae (sweetlips)																	
Plectorhinchus albovittatus	0	0	0	0	0	0	0	0	0.2	0	0	0.1	0	0	0	0	0
Family Chaetodontidae (butterflyfishes)																	
Chaetodon auriga	0	0	0	0	0	0	0	0	0.4	0	0	0.1	0.6	1	0	0	0
Chaetodon bennetti	0	0.1	0	0	0	0	1.6	0	0.6	6	7	0.1	0	0	0	0	0
Chaetodon ephippium	0	0	0	0.6	0	5.8	0	0	1.2	0	0	0.2	3	0	0	0	0
Chaetodon lunula	0	0	0	0	0.6	0	0	0	0	1	0.6	0	0.6	0	0	0	0
Chaetodon lunulatus	0	0	0	0	1.2	0	0	0	0	0	0	0	1.8	0	0	0	0
Chaetodon unimaculatus	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
Chaetodon ulietensis	0	0	0	0.3	0.6	0	4.8	0	0.6	0	0	1	0	0	0	0	0
Heniochus chrysostomus	0	0	0	0	0	0	0	0	0.4	0	0	0	0	0	0	0	0
Family Pomacentridae (damselfishes)																	
Amblyglyphididon ternatensis	0	0	16.9	0	2.4	0	29	81.7	0	18	78.6	0	0	0	0	0	0
Abudefduf sexfasciatus	0	0	0	0	0	0	0	0	0	0	1.2	0	2.4	0	0	0	0
Chromis viridis	0	0.2	11.7	0.3	0	0	0	0	0	19.4	0	0	0	0	0	0	0
Chrysiptera traceyi	0	0	0.3	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Neopomacentrus violascens	0	0	0	0	4.8	0	0	6.1	10	0	0	0	0	1	0	0	0
Pomacentrus blue spot	0	0	0	0	0	0	0	9.1	0	0	0	0	10.1	0	0	0	0
Pomacentrus amboinensis	0	0	0	0.6	6.8	0	1.6	0	0.6	9.7	9.7	0	0	1	0	0	0
Pomacentrus pavo	0	0	0.3	0	11.1	0	3.2	0	0	7.2	5.7	0	1.2	1	0	0	0
Family Labridae (wrasses)																	
Cheilinus fasciatus	0	0	0	0	0	5.8	1.6	0	0	0	0	0	0	0	0	0	0
Cheilinus trilobatus	0	0	0	0	0	0	0	0	0	0	0	0.1	0	0	0	0	0
Family Blenniidae (blennies)																	
Ecsenius bicolor	0	0.1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Meiacanthus atrodorsalis	0	0	0	0	0	0	1.6	0	0	0	0	0	0	0	0	0	0
Petroscirtes mitratus	0	0	0	0.3	0	0	0	0	0	0	0	0	0	0	0	0	0
Blue dorsal spot tube blenny	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0

Table 12. Continued.

Taxon	Survey Sites																
	A	S_M	S_S	T_M	T_S	T_B	U_M	U_S	U_B	V_M	V_S	V_B	X_M	X_S	X_B	O_1	O_2
Family Gobiidae (gobies)																	
Amblygobius nocturnus	0	0	0	0	0	11.6	0	0	2.4	0	0	5	0	0	0	0	0
Amblygobius phaelena	0	0	1.5	0.3	0.6	0	1.6	0	0.2	0	1.2	0.2	0.6	0	0	0	0
Asterropteryx semipunctatus	0	0	0	0	0	0	0	0	0	0	0	0	0	5	0	0	0
Cryptocentrus strigilliceps	5.3	0	0	0	0	0	0	0	0	0	0	0	0	0	1.8	0	0
Cristatogobius sp. A	0	0	0	0	0	11.6	0	0	0.4	0	0	6	0	0	0	0	0
Ctenogobiops feroculus	5.3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	62.5	90
Gnatholepis cauerensis	5.3	0	0	0	0	5.8	0	0	4.2	0	0	0	0	0	0	0	0
Oplopomus oplopomus	0	0	0	0	0	0	0	0	0.2	0	0	0.2	0	0	0	12.5	0
Oxyurichthys papuensis	0	0	0	0	0	0	0	0	2.6	0	0	0.2	0	0	0	25	10
Paragobiodon lacunicolus	0	0	0	0	0	0	1.6	0	0	0	0	0	0	0	0	0	0
Priolepis cincta	0	0	0	0	0.6	0	0	0	0	3	0.6	0	0	0	0	0	0
Family Zanclidae (Moorish Idol)																	
Zanclus cornutus	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
Family Siganidae (rabbitfishes)																	
Siganus argenteus	0	0	0	0	0	0	0	0	0.2	0	0	0	0	0	0	0	0
Family Acanthuridae (surgeonfishes)																	
Acanthurus blochii	0	0	0	0.3	0	36.2	19.4	0	0	11.3	0	2.8	11.2	0	0	0	0
Acanthurus xanthopterus	0	0	0	2.5	0	0	32.4	0	0	15.4	0	0	0	1	0	0	0
Zebrasoma veliferum	0	0	0	0	0	0	0	0	0.6	0	0.6	0.1	1.8	0	0	0	0
Family Balistidae (triggerfishes)																	
Balistoides viridescens	0	0	0	0.3	0	0	0	0	0.6	0	0	0.1	0	0	0	0	0
Rhinecanthus aculeatus	0	0	0	0.3	0	0	0	0	0	0	0	0	0	0	0	0	0
Family Tetraodontidae (pufferfishes)																	
Canthigaster solandri	0	0	0	0.3	0	0	0	0	0.2	0	0.6	0	1.2	0	0	0	0
Total individuals	**19**	**1025**	**343**	**346**	**162**	**17**	**62**	**33**	**528**	**97**	**157**	**632**	**179**	**17**	**56**	**16**	**10**

by ship fenders that effectively prevented ship hulls from damaging these microhabitats, thus making them available to fishes for shelter.

Densities of fish species (no. individuals/m^2) at each station are given in Table 13. Small, structure-associated cardinalfishes had the greatest density among stations. *Apogon lateralis* (Apogonidae) densities where high at Sierra Wharf (20/m^2 at mid-depth and 4.4/m^2 at subsurface depth), Victor Wharf (4.5/m^2 at the bottom), Uniform Wharf (2.5/m^2 at the bottom), and X-ray Wharf (2.06/m^2 at mid-depth). Another cardinalfish, the apparently invasive *Rhabdamia cypselerus*, had relatively high densities at Sierra Wharf (8/m^2 at subsurface depth) and Tango Wharf (4/m^2 at mid-depth and 2/m^2 at subsurface depth). Both species tended to occur in aggregations of several individuals. The invasive damselfish, *Amblyglyphididon ternatensis* (Pomacentridae), was relatively dense at Victor Wharf (2.24/m^2 at mid-depth) and Sierra Wharf (1.16 per m^2 subsurface depth). This species occurred in aggregations as well; many were juveniles. Densities of other species were low to very low and ranged from 0.0033/m^2 to1.0/m^2 (Table 13).

The similarity of species composition between stations and transect depths was examined with multiple dimension scaling analysis (Figure 12). The meager fish assemblages of the two harbor floor transects (Transect 1 and Transect 2) formed a distinct group. The fish assemblages on the Abo Cove and Tango Wharf-bottom transects formed a group, as well. The mid-depth and subsurface transects at Uniform and Victor wharves formed a distinct group, too, as did the subsurface transect at X-ray Wharf. Finally, the fish assemblages on the subsurface transects at Sierra and Tango wharves, the mid-depth transects at Sierra, Tango and X-ray wharves, and the bottom transects at Uniform, Victor, and X-ray wharves, all formed a distinct group. A stress level of 0.11 indicated a moderate confidence in the analysis results (Clarke and Gorley, 2001). Analysis of similarity (ANOSIM) between stations (locality and depth treated as a station) indicated that there were only weakly significant differences between them (Global $R = 0.21$). Thus, the fish faunas of each tended to share many of the same species typical of protected and turbid waters, while differences can be attributed to the presence of seemingly unusual species (i.e., butterflyfishes normally seen in clear or less-turbid reef systems) associated with structure on some transects or the simple absence of species, other than some burrowing gobies, on others (i.e., Transect 1 and Transect 2).

Essential Fish Habitat

Qualitative measures of habitat utilization by fishes were limited to observations of association between species and habitat and microhabitat types (Table 14). Major habitat types were reefs (Abo Cove), wharves (all stations except Abo Cove and the harbor floor transects), or harbor floor. Microhabitats included corals, debris (hanging and deposited on the bottom), rubble, rocks, soft corals, sand, shells, or the water column), and wharf faces and pilings. Corals, soft corals, and shells were usually found on the wharf faces, as well.

Overall, wharves provided considerable habitat for a diverse array of fishes compared to the reef at Abo Cove or the harbor floor offshore from the wharves (Table 14). Microhabitats associated with wharves included coral, debris, shell, and soft corals that were attached to a wharf, the wharf wall and associated structures (pilings, fenders, pipes, cables, etc.), debris, rubble, rock, and sand at the base of the wharf wall, and the water column directly adjacent to the wharf. Most species were associated with one or more of these microhabitats. Benthic

Table 13. Density of fishes (no./m²) on transects in Inner Apra Harbor. Survey sites are designated as follows: A = Abo Cove, S_M = Sierra Wharf mid-depth, S_S = Sierra Wharf subsurface, T_M = Tango Wharf mid-depth, T_S = Tango Wharf subsurface, T_B = Tango Wharf bottom, U_M = Uniform Wharf mid-depth, U_S = Uniform Wharf subsurface, U_B = Uniform Wharf bottom, V_M = Victor Wharf mid-depth, V_S = Victor Wharf subsurface, V_B = Victor Wharf bottom, X_M = X-Ray Wharf mid-depth, X_S = X-Ray Wharf subsurface, X_B = X-Ray Wharf bottom, 1 = Transect 1 (harbor floor), 2 = Transect 2 (harbor floor).

	Survey Sites																
Taxon	A	S_M	S_S	T_M	T_S	T_B	U_M	U_S	U_B	V_M	V_S	V_B	X_M	X_S	X_B	1	2
Family Clupeidae (herrings)																	
Spratelloides delicatulus	0	0.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Family Mugilidae (mullets)																	
Moolgarda seheli	0.01	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Family Holocentridae (squirrelfishes)																	
Neoniphon opercularis	0	0	0	0	0.02	0	0	0	0.01	0	0	0	0	0	0	0	0
Sargocentron spiniferum	0	0	0	0.02	0	0	0	0	0	0	0	0	0	0	0	0	0
Family Serranidae (groupers)																	
Epinephelus maculatus	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
Family Apogonidae (cardinalfishes)																	
Apogon lateralis	0	20	4.4	2	0	0.01	0	0	2.5	0	0	4.5	2.06	0	0.5	0	0
Apogon leptacanthus	0.01	0.2	0.2	0	0.2	0	0	0	0.25	0	0	0.1	0.2	0	0.05	0	0
Archamia biguttata	0	0	0	0	0.04	0	0	0	0.1	0	0	0	0	0	0	0	0
Archamia fucata	0	0	0	0	0	1	0	0	0	0	0	0.89	0	0	0	0	0
Cheilodipterus quinquelineatus	0.13	0	0	0	0.04	0.01	0	0.02	0.01	0.1	0.02	0.23	0	0	0	0	0
Foa brachygramma?	0	0	0	0	0	0	0	0	0.01	0	0	0	0	0	0	0	0
Rhabdamia cypselurus?	0	0	8	4	2	0	0	0	0.01	0	0	0	0.06	0	0	0	0
Sphaeramia orbicularis	0	0	0	0	0	0	0	0	0	0	0	0	0	6	0	0	0
Family Carangidae (trevallys)																	
Caranx ignobilis	0	0	0	0.06	0	0	0	0	0	0	0	0.01	0.06	0	0	0	0
Caranx melampygus	0	0	0	0.02	0	0	0	0	0.05	0	0	0.01	0	0	0	0	0
Scomberoides lysan	0	0	0	10	0	0	0	0	0	0	0	0	0	0	0	0	0
Gnathanodon speciosus	0	0	0	0	0	0	0	0	0	0	0.02	0.01	0	0	0	0	0
Family Lutjanidae (snappers)																	
Lutjanus ehrenbergi?	0	0	0	0	0	0	0	0	0.01	0	0	0	0	0	0	0	0
Lutjanus fulvus	0.01	0.02	0	0	0	0.02	0	0	0	0	0	0.03	0	0	0	0	0
Family Lethrinidae (emperors)																	
Lethrinus harak	0	0	0	0	0	0	0.02	0	0	0	0	0.01	0	0	0	0	0
Family Haemulidae (sweetlips)																	
Plectorhinchus albovittatus	0	0	0	0	0	0	0	0	0.01	0	0	0.01	0	0	0	0	0
Family Chaetodontidae (butterflyfishes)																	
Chaetodon auriga	0	0	0	0	0	0	0	0	0.02	0	0	0.01	0.02	0.02	0	0	0
Chaetodon bennetti	0	0.02	0	0	0	0	0.02	0	0.03	0.12	0.22	0.01	0	0	0	0	0

Table 13.

Taxon	Survey Sites																
	A	S_M	S_S	T_M	T_S	T_B	U_M	U_S	U_B	V_M	V_S	V_B	X_M	X_S	X_B	1	2
Family Chaetodontidae (butterflyfishes)																	
Chaetodon ephippium	0	0	0	0.04	0	0.02	0	0	0.06	0	0	0.02	0.1	0	0	0	0
Chaetodon lunula	0	0	0	0	0.02	0	0	0	0	0.02	0.02	0	0.02	0	0	0	0
Chaetodon lunulatus	0	0	0	0	0.04	0	0	0	0	0	0	0	0.06	0	0	0	0
Chaetodon unimaculatus	0	0	0	0	0	0	0	0	0	0.02	0	0	0	0	0	0	0
Chaetodon ulietensis	0	0	0	0.02	0.02	0	0.06	0	0.03	0	0	0.1	0	0	0	0	0
Heniochus chrysostomus	0	0	0	0	0	0	0	0	0.02	0	0	0	0	0	0	0	0
Family Pomacentridae (damselfishes)																	
Amblyglyphididon ternatensis	0	0	1.16	0	0.08	0	0.36	0.54	0	0.36	2.24	0	0	0	0	0	0
Abudefduf sexfasciatus	0	0	0	0	0	0	0	0	0	0	0.04	0	0.08	0	0	0	0
Chromis viridis	0	0.04	0.8	0.02	0	0	0	0	0	0.4	0	0	0	0	0	0	0
Chrysiptera traceyi	0	0	0.02	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Neopomacentrus violascens	0	0	0	0	0.16	0	0	0.04	0.5	0	0	0	0	0.02	0	0	0
Pomacentrus blue spot	0	0	0	0	0	0	0	0.06	0	0	0	0	0.36	0	0	0	0
Pomacentrus amboinensis	0	0	0	0.04	0.22	0	0.02	0	0.03	0.2	0.3	0	0	0.02	0	0	0
Pomacentrus pavo	0	0	0.02	0	0.36	0	0.04	0	0	0.14	0.18	0	0.04	0.02	0	0	0
Family Labridae (wrasses)																	
Cheilinus fasciatus	0	0	0	0	0	0.01	0.02	0	0	0	0	0	0	0	0	0	0
Cheilinus trilobatus	0	0	0	0	0	0	0	0	0	0	0	0.01	0	0	0	0	0
Family Blenniidae (blennies)																	
Ecsenius bicolor	0	0.02	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Meiacanthus atrodorsalis	0	0	0	0	0	0	0.02	0	0	0	0	0	0	0	0	0	0
Petroscirtes mitratus	0	0	0	0.02	0	0	0	0	0	0	0	0	0	0	0	0	0
Blue dorsal spot tube blenny	0	0	0	0	0	0	0	0	0	0	0	0	0	0.02	0	0	0
Family Gobiidae (gobies)																	
Amblygobius nocturnus	0	0	0	0	0	0.02	0	0	0.12	0	0	0.05	0	0	0	0	0
Amblygobius phaelena	0	0	0.1	0.02	0.02	0	0.02	0	0.01	0	0.04	0.02	0.02	0	0	0	0
Asterropteryx semipunctatus	0	0	0	0	0	0	0	0	0	0	0	0	0	0.1	0	0	0
Cryptocentrus strigilliceps	0.01	0	0	0	0	0	0	0	0	0	0	0	0	0	0.01	0	0
Cristatogobius sp. A	0	0	0	0	0	0.02	0	0	0.02	0	0	0.06	0	0	0	0	0
Ctenogobiops feroculus	0.01	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.02	0.03
Gnatholepis cauerensis	0.01	0	0	0	0	0.01	0	0	0.21	0	0	0	0	0	0	0	0
Oplopomus oplopomus	0	0	0	0	0	0	0	0	0.01	0	0	0.02	0	0	0	0.004	0
Oxyurichthys papuensis	0	0	0	0	0	0	0	0	0.13	0	0	0.02	0	0	0	0.008	0.0033
Paragobiodon lacunicolus	0	0	0	0	0	0	0.02	0	0	0	0	0	0	0	0	0	0
Priolepis cincta	0	0	0	0	0.02	0	0	0	0	0.06	0.02	0	0	0	0	0	0

Table 13. Continued.

Taxon	Survey Sites																
	A	S_M	S_S	T_M	T_S	T_B	U_M	U_S	U_B	V_M	V_S	V_B	X_M	X_S	X_B	1	2
Family Zanclidae (Moorish Idol)																	
Zanclus cornutus	0	0	0	0	0	0	0	0	0.05	0	0	0	0	0	0	0	0
Family Siganidae (rabbitfishes)																	
Siganus argenteus	0	0	0	0	0	0	0	0	0.01	0	0	0	0	0	0	0	0
Family Acanthuridae (surgeonfishes)																	
Acanthurus blochii	0	0	0	0.02	0	0.05	0.24	0	0	0.22	0	0.18	0.4	0	0	0	0
Acanthurus xanthopterus	0	0	0	0.38	0	0	0.4	0	0	0.3	0	0	0	0.02	0	0	0
Zebrasoma veliferum	0	0	0	0	0	0	0	0	0.03	0	0.02	0.01	0.06	0	0	0	0
Family Balistidae (triggerfishes)																	
Balistoides viridescens	0	0	0	0.02	0	0	0	0	0.03	0	0	0.01	0	0	0	0	0
Rhinecanthus aculeatus	0	0	0	0.02	0	0	0	0	0	0	0	0	0	0	0	0	0
Family Tetraodontidae (pufferfishes)																	
Canthigaster solandri	0	0	0	0.02	0	0	0	0	0.01	0	0.02	0	0.04	0	0	0	0

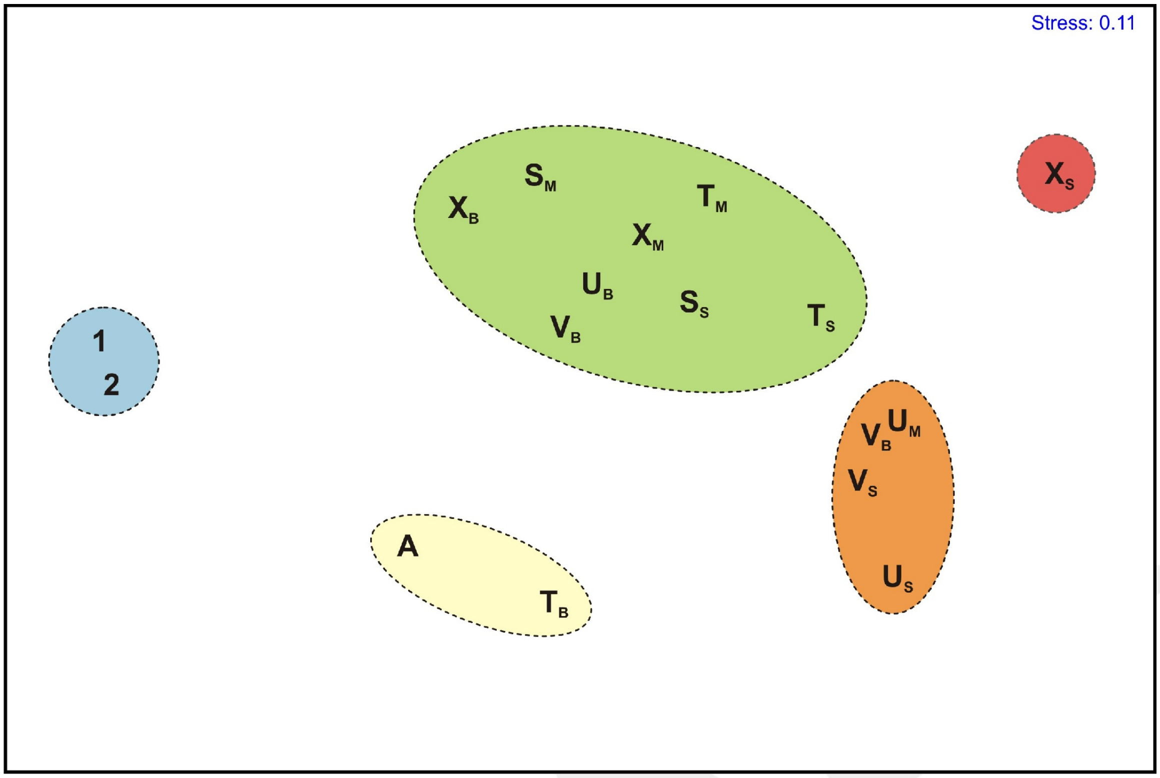

Figure 12. Multiple dimensional scaling (MDS) analysis of fish assemblages observed on transects in Inner Apra Harbor. Five distinct groups are recognized based upon similarities in fish faunal composition. Transect abbreviations are given in Table 12.

species such as cardinalfishes, damselfishes and gobies favored corals, debris, shells, sand, soft corals, and the wharf wall and pilings. Species that were active swimmers, such as butterflyfishes (Chaetodontidae), emperors (Lethrinidae), snappers (Lutjanidae), surgeonfishes (Acanthuridae), sweetlips (Haemulidae), trevallys and jacks (Carangidae), etc., were found in the water column directly adjacent to the wharves.

On the reef at Abo Cove, cardinalfishes were observed with corals or rock, gobies with sand, mullet (Mugilidae) with rubble or sand, and a snapper with sand (Table 14). Visibility was exceptionally poor at Abo Cove during the survey, and it is expected that other species listed for the wharf transects would be present as well, particularly at high tide. The harbor floor transects, also surveyed under conditions of poor visibility, had burrowing gobies associated with fine sand, only (Table 14).

Threatened and Endangered Species

High turbidity levels in Inner Apra Harbor limited visibility (<5 m)of highly motile species, especially vertebrate organisms. Despite this constraint, we observed a single green

Table 14. Habitat and microhabitat associations of fishes in the Inner Apra Harbor. Associations listed are based upon qualitative observations. Station codes are defined in Table F1. Habitat codes are: SB = soft bottom (harbor floor), R = coral reef, and W = wharf. Microhabitat codes are: C = coral, D = debris, Rb = rubble, Rk = rock, Sc = soft coral, Sd = sand, Sh = shell, Wc = water column, and Wp = wharf wall and pilings.

	Survey Sites																
Taxon	A	S_M	S_S	T_M	T_S	T_B	U_M	U_S	U_B	V_M	V_S	V_B	X_M	X_S	X_B	1	2
Family Clupeidae																	
Spratelloides delicatulus		W;Wc															
Family Mugilidae																	
Moolgarda seheli	R;Rb,Sd																
Family Holocentridae																	
Neoniphon opercularis					W;Wp				W;D								
Sargocentron spiniferum				W;Wp													
Family Serranidae																	
Epinephelus maculatus									W;D								
Family Apogonidae																	
Apogon lateralis		W;C,Wp	W;C,Wp	W;C,Wp		W;D			W;D			W;D	W;C		W;D		
Apogon leptacanthus	R;C,Rk	W;C,Sc	W;C,Wp		W;C,Wp				W;D			W;D	W;C		W;D		
Archamia biguttata					W;C,Wp				W;D								
Archamia fucata						W;D						W;D					
Cheilodipterus quinquelineatus	R;C,Rk				W;C,Wp			W;Wp	W;D	W;Wp	W;Wp	W;D					
Foa brachygramma?									W;D								
Rhabdamia cypselurus?			W;C,Wp	W;C,Wp	W;C,Wp				W;D				W;C				
Sphaeramia orbicularis														W;Wp			
Family Carangidae																	
Caranx ignobilis				W:Wc								W;Wc	W;Wc				
Caranx melampygus				W;Wc					W;Wc			W;Wc					
Scomberoides lysan				W;Wc													
Gnathanodon speciosus											W;Wc	W;Wc					
Family Lutjanidae																	
Lutjanus ehrenbergi?									W;Sd								
Lutjanus fulvus	R;Sd	W;Wc				W;Wc						W;Wc					
Family Lethrinidae																	
Lethrinus harak							W;Wc					W;Wc					
Family Haemulidae																	
Plectorhinchus albovittatus									W;D			W;Wc					
Family Chaetodontidae																	
Chaetodon auriga									W;D			W;Wc	W;Wp	W;Wp			
Chaetodon bennetti		W;Wc					W;Wc		W;D	W;Wc	W;Wc	W;Wc					
Chaetodon ephippium				W;Wc		W;Wc			W;D			W;Wc	W;Wp				
Chaetodon lunula					W;Wc					W;Wc	W;Wc		W;Wp				
Chaetodon lunulatus					W;Wc								W;Wp				
Chaetodon unimaculatus										W;Wc							
Chaetodon ulietensis				W;Wc	W;Wc		W;Wc		W;D			W;Wc					

Table 14. Continued.

Taxon	Survey Sites																
	A	S_M	S_S	T_M	T_S	T_B	U_M	U_S	U_B	V_M	V_S	V_B	X_M	X_S	X_B	1	2
Family Chaetodontidae																	
Heniochus chrysostomus									W;D								
Family Pomacentridae																	
Amblyglyphididon ternatensis			W;Wc		W;C,Sc		W;Wp	W;Wp		W;Wp	W;Wp						
Abudefduf sexfasciatus											W;Wp		W;Wp				
Chromis viridis		W;C,Wp	W;C,Wp	W;C,Wp						W;C,Wp							
Chrysiptera traceyi			W;Wp														
Neopomacentrus violascens					W;Wp			W;Wp	W;D					W;C,Wp			
Pomacentrus blue spot								W;Wp					W;Wp				
Pomacentrus amboinensis				W;Wp	W;Wp		W;Wp		W;D	W;Wp	W;Wp			W;Wp			
Pomacentrus pavo			W;D,Wp		W;C,Wp					W;Wp	W;Wp		W;Wp	W;Wp			
Family Labridae																	
Cheilinus fasciatus						W;Wc	W;Wc										
Cheilinus trilobatus												W;Wc					
Family Blenniidae																	
Ecsenius bicolor		W;Sh,Wp															
Meiacanthus atrodorsalis							W;Wp,Sh										
Petroscirtes mitratus				W;Sh,Wp													
Blue dorsal spot tube blenny														W;Wp			
Family Gobiidae																	
Amblygobius nocturnus						W;Wp			W;D,Sd			W;Sd					
Amblygobius phaelena			W;Wp	W;Wp	W;Wp		W;Wp		W;D,Sd		W;Wp	W;Sd	W;Wp				
Asterropteryx semipunctatus														W;Wp			
Cryptocentrus strigilliceps	R;Sd														W;Sd		
Cristatogobius sp. A						W;Sd			W;Sd			W;Sd					
Ctenogobiops feroculus	R;Sd															SB;Sd	SB;Sd
Gnatholepis cauerensis	R;Sd					W;Sd			W;Sd								
Oplopomus oplopomus									W;Sd			W;Sd				SB;Sd	
Oxyurichthys papuensis									W;Sd			W;Sd				SB;Sd	SB;Sd
Paragobiodon lacunicolus							W;C										
Priolepis cincta					W;Wp					W;Wp	W;Wp						
Family Zanclidae																	
Zanclus cornutus									W;Wc								
Family Siganidae																	
Siganus argenteus									W;Wc								
Family Acanthuridae																	
Acanthurus blochii				W;Wc		W;Wc	W;Wc			W;Wc		W;Wc	W;Wc				
Acanthurus xanthopterus				W'Wc			W;Wc			W;Wc				W;Wp			
Zebrasoma veliferum									W;Wc		W;Wc	W;Wc	W;Wc				

Table 14. Continued.

Taxon	Survey Sites																
	A	S_M	S_S	T_M	T_S	T_B	U_M	U_S	U_B	V_M	V_S	V_B	X_M	X_S	X_B	1	2
Family Balistidae																	
Balistoides viridescens				W;Wc					W;D,Wp			W;D,Wc					
Rhinecanthus aculeatus				W;Wp													
Family Tetraodontidae																	
Canthigaster solandri				W;Wp					W;D,Wp		W;D,Wc		W;Wp				

turtle from the boat in waters between Abo Cove and the southern end of Victor Wharf. *Chelonia mydas* is listed as a threatened species under the U.S. Endangered Species Act. The individual that we observed was small (0.5–1.0 m carapace length), and it dove immediately after a quick breath. Because of the fine-grained, muddy composition of the shoreline of Inner Apra Harbor, the beaches in the vicinity are not considered as potential nesting sites for endangered and threatened marine turtles known to occur in the seas around Guam. The nearest documented nesting beaches are near Gabgab Beach, in the outer harbor. Therefore, we presume the individual that we sighted was foraging.

Habitat Areas of Particular Concern (HAPC)

None of the three areas of Apra Harbor recognized by Paulay et al. (2001a) for their species richness and unique biota are encompassed by Inner Apra Harbor. These authors described the inner harbor as the most altered area with Apra Harbor, while remarking on the presence of uncommon species, such as *Porites convexa*, and the abundance of the hammer oyster *Malleus decurtatus* on wharf faces.

Inner Apra Harbor lies at the extreme end of the gradient of increasing turbidity, abundance of plankton and benthic suspension feeders, and finer sediments. The harbor continues to support thriving marine communities, despite the extensive dredging and filling operations that significantly altered the area after World War II. Data from this study indicate that Abo Cove is unique and deserves special attention in managing the natural resources of the inner harbor. As Paulay et al. (2001a) noted, Apra Harbor is unlike other major ports, where communities of marine organisms tend to be greatly degraded. Therefore, we advise decision-makers not to extrapolate data from the current study to other areas within Inner Apra Harbor that were not within the scope of this study, especially the inner Abo Cove embayment and the mangrove area at the mouth of the Atantano River.

SUMMARY

This study shows a clear difference between the most authentic inner harbor habitats at Abo Cove and the manmade wharfs. Because of its restricted spatial extent, the distinct benthic assemblages, and the relatively high coral cover, Abo Cove deserves special attention in managing the natural resources of the inner harbor. Ironically, the artificial and most anthropogenically impacted habitats of the wharfs might contribute most to the biotic richness and diversity of the inner harbor. The synoptic account of the benthic invertebrates is indicative of unique benthic fauna, especially so for the sponges. Hence, more extensive taxonomic surveys are warranted to assess the biological value of the inner harbor, as well as its potential as an area for potential establishment of invasive species.

The coral fauna of the study area consisted of 30 species, or about 10% of the coral fauna of Guam (see Randall, 2003). The predominant corals were massive *Porites* spp., one of which exceeded 1 m in diameter at Abo Cove. The coral assemblage in Inner Apra Harbor is characteristic of environments with high levels of sedimentation and turbidity, with the most common species, in order of tolerance to these conditions, being *Porites lutea*, *Pocillopora damicornis*, and *Leptastrea* *purpurea* (Amesbury et al., 1977). Coral species richness is highest on relatively sediment-free, hard substrates on vertical faces of wharves.

Macroinvertebrates communities in the inner harbor were only moderately diverse, with 30 species observed on or near transects. As for corals, availability of sediment-free hard substrate for sessile and sedentary macroinvertebrates is a limiting factor on horizontal surface. On the harbor floor, macroinvertebrates were limited to scattered debris that provided on the only hard substrate available. Macroinvertebrate assemblages in the inner harbor were dominated by suspension-feeding species, which comprised 100% of the species occurring on transects and 90% of all species observed. Except for a single species of marine snail, no macroinvertebrates were observed on the soft sediments of the harbor floor.

The species richness and diversity of the fish fauna within the Inner Harbor are relatively low compared to habitats elsewhere on Guam (Donaldson, unpublished data). However, the fauna is highly adapted and representative of protected and turbid habitats usually associated with mangroves, estuaries, and back reefs, with some exceptions. A considerable amount of habitat is provided by artificial shelter in the form of wharves, and the microhabitats found on or adjacent to those wharves was utilized by many species of fishes. Larval fishes of these species could have settled and recruited to these habitats and microhabitats, either through natural stochastic processes or by transport (i.e., bilge water), and became established at each of the stations. Many of the individuals of these species were juveniles or subadults. Alternatively, some species, particularly those that swim actively in the water column, may have colonized these habitats as adults after swimming to them from outside of the inner harbor.

Perhaps the only relatively unique species present at most or all stations are the bottom-dwelling, burrowing goby species that may be specific only to sand bottoms in back bay or estuarine areas. The extent of the distribution of these species is not well known, however, because of the generally poor visibility encountered in such areas (i.e., Inner Apra Harbor and Sasa Bay in western Guam, and the estuaries of the Pago, Ylig, and Talofofo Rivers in eastern Guam).

RECOMMENDATIONS

During the planning phase for construction and renovation of facilities and training sites surveyed in Inner Apra Harbor in this study, the following recommendations should be given consideration.

1. **Abo Cove and its associated coral reefs deserve special attention in managing the natural resources of the inner harbor.**
   Despite its restricted spatial extent, Abo Cove is unique within the inner harbor because of the coral reefs that have developed there. The reef is characterized by relatively high coral cover and the largest coral colonies in the area studied. Further, Abo Cove supports distinct benthic assemblages of sponges, corals, and macroinvertebrates (see Figures 8, 9, and 11). Therefore, renovation and construction activities requiring dredging and filling in and adjacent to Abo Cove should have the lowest priority. A minimum buffer zone of 400 feet should be maintained between Abo Cove and all dredge and fill activities in the inner harbor.

If Abo Cove is selected for development, a compensatory mitigation plan should be developed for review by the appropriate agencies and authorities. To the extent possible and appropriate, any mitigation project should be “on-site” and “in-kind” (PBS&J, 2008), with consideration given to relocation of the corals to a similar environment, like that in the outer portion of Sasa Bay in the outer harbor. Biological monitoring should be required for any project that is proposed for construction in the vicinity of Abo Cove.

2. **Floating turbidity curtains, extending from the surface to the lagoon floor, should be placed completely around all dredge and fill sites, and turbidity curtains should be routinely monitored and maintained to contain silt produced by construction.** Dredge and fill operations produce large quantities of fine silt particles suspended in the water column. Turbidity and sedimentation are significant problems for coral reefs surrounding high islands or in coastal areas of continents. Sediments may have an energetic cost to the coral that must cleanse its surface, resulting in slower growth rates and in less energy available for reproduction (Tomascik and Sander, 1987; Wolanski et al., 2003). Sediments can also interfere with larval recruitment on coral reefs by interfering with the chemosensory ability of coral larvae seeking the appropriate chemical signals from preferred settlement substrates, such as coralline algae (Richmond, 1997). Turbidity curtains can be effective in confining suspended sediments when properly deployed and maintained. Removal of the turbidity barriers and the related components is vital once the project activities are complete. Failure to do so can cause the barrier to come loose from its anchors and entangle benthic and other marine organisms (PBS&J, 2008).

3. **All dredge and fill operations should be suspended during the period of the annual coral spawning event in Guam waters.** Some 85% of reef-building corals are spawners, i.e., reproduction occurs after the release of gametes into the water, where fertilization takes place (Richmond, 1997). Multispecies mass-spawning events occur during limited periods each year. To maximize reproductive success, most spawning species release their gametes over a 5–8-day period that is related to the lunar cycle. Studies in Guam revealed that peak spawning occurs 7–10 days after the full moon in July (Richmond and Hunter, 1990). Because suspended sediments may interfere with egg-sperm interactions in the fertilization process (Richmond, 1997; Wolanski et al., 2003), dredge and fill operations can affect coral reproduction on reefs far down current of the actual construction activities.

   Construction windows are a management tool to map out the times of year during which coastal construction may be limited due to the presence of threatened or endangered species or other sensitive marine life (PBS&J, 2008). Construction windows may consider wildlife activity such as coral spawning and coral bleaching. U.S. Army Corps of Engineers permits for maintenance dredging of the Naval Base require that dredging operations cease during annual coral spawning periods in Guam (M.E. Guarin, P.E., Construction Management Engineer, NAVFAC OICC Marianas, personal communication, April 27, 2004).

4. **Marine biological communities should be monitored during and after dredge and fill operations in Inner Apra Harbor.** Monitoring studies on small, tropical islands have shown that precautions for environmental protection can limit the effects of dredge and fill operations on nearby marine communities.

Amesbury et al. (1982) identified few measurable effects related to construction of the airport runway extension at Weno Island, Chuuk [= Moen Island, Truk]. However, these authors reported that fluctuations in species richness, percent cover, and population density of several taxa occurred during the construction period. Where siltation was heaviest, the decline in coral coverage was significant, and no evidence of new coral recruitment was found one year after the completion of runway construction. Marine plants, macroinvertebrates, and reef fishes also declined at those monitoring stations that were inundated with sediments.

Biological monitoring should be required for any project that is proposed for construction in Inner Apra harbor , especially in the vicinity of Abo Cove, so that any damage to coral communities caused by sedimentation can be identified promptly and so that the necessary measures can be taken to minimize any damage. Monitoring is necessary to determine any direct or indirect biological impacts to the ecosystem caused by physical and/or chemical changes to the environment as a result of the project.

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ASSESSMENT OF BENTHIC COMMUNITY STRUCTURE IN THE VICINITY OF THE PROPOSED TURNING BASIN AND BERTHING AREA FOR CARRIER VESSELS NUCLEAR (CVN) APRA HARBOR, GUAM

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1 EXECUTIVE SUMMARY

One component of the planned move of the Marine Expeditionary Force from Okinawa to Guam is the provision to provide safe access and new berthing facilities for nuclear aircraft carriers (CVN) in Apra Harbor, Territory of Guam. In order to accomplish this task, areas of the entrance channel and turning basin in the southeastern part of the Harbor, as well as areas selected for berthing, will require dredging to a depth of 51.5 ft. below MLLW. Although much of this area was previously dredged in 1946 during the creation of the present configuration of Apra Harbor, the proposed dredging to accommodate the CVN will result in removal of existing benthic marine communities within the dredge footprint. In addition, there is potential for indirect effects to benthic communities adjacent to the footprint from environmental changes associated with the dredging operation.

In April-May 2009, surveys were conducted to collect data to provide preliminary evaluation of the composition of benthic community structure within the area that will be affected by the proposed CVN operation. The purpose of the surveys was explicitly not to initiate a time-course monitoring protocol to evaluate changes from the activity, nor to conduct investigations of population dynamics or life histories of individual species. However, a stated objective of the surveys was to acquire data that could provide input metrics for development of Habitat Equivalency Analysis (HEA) models that will be used to evaluate compensation for lost services.

Owing to a limited timeframe, methods were selected to maximize data collection with the shortest duration of fieldwork possible. Benthic community composition was evaluated using a photo-quadrat belt transect method (each belt transect encompassed 10 m^2 of contiguous benthic surface) using a digital camera mounted on a frame that standardized distance from the camera to the substratum. Data analysis for 67 transects was performed "*ex situ*" using a visual basic program, Coral Point Count with excel extensions [CPCe], that has gained wide acceptance for coral reef monitoring studies. All benthic cover analyses were performed by three separate investigators and the final data set contained complete investigator agreement on all point counts. Other data collected in the field included calibration-validation information for developing a map of coral cover using spectral signatures of remote sensing imagery, spectral reflectances of representative corals to develop a "stress index," and analysis of sediment samples to determine composition of material that will affect communities during dredging operations.

Survey results indicated that the CVN survey area consists of a heterogeneous mix of a variety of biotopes ranging from mud flats to algal meadows to a wide structural array of reef coral communities (in terms of both species assemblages and physical forms). Bray-Curtis similarity indices revealed 7 distinct community groups with respect to the "general classes" of transect cover (e.g., algae, coral, sponges, sediment). When "detailed classes"' containing all identified species and substratum types were analyzed, 16 distinct community groups emerge.

When data from all transects were combined, algae accounted for about 40% of benthic cover, coral 22%, sponges 3% and sediment (sand, mud, and rubble) 35%. Algae occurred on all but one transect, and corals were present at 52 of the 67 survey sites. On transects with sediment cover greater than approximately 75%, corals were not present. All transects containing coral also contained algae. Coral cover was dominated by a single species, *Porites rus*, which accounted for about 74% of total coral cover. Along with *P. rus*, the next three most abundant species (*Porites lutea*, *Pavona cactus*, and *Porites cylindrica*) accounted for 95% of coral cover.

Transects were divided into four "strata" depending on two sets of conditions: location within (Direct) or adjacent to (Indirect) the dredge footprint, and angle of bottom topography (Flat ≤15 °; Slope >15°). Each strata contained transects with attributes that encompassed all of the major biotopes, although mean coral cover was higher in the two Indirect strata (25% Flat; 38% Slope) compared to the two Direct strata (14% both Flat and Slope). Multivariate analyses of transect data consistently revealed that transects within strata did not fall into distinct groupings within the entire data set.

Application of calibration-validation data collected in the field to spectral signatures of remote sensing imagery was used to create a map of coral cover over the entire survey area. For the SRF alternative, coral of all classes covered approximately 39% of the bottom within the dredge footprint compared to 35.4% in the Polaris Point alternative. For both alternatives, the highest areas of coverage occurred in the lowest abundance class (0%<coral≤10%). Coverage of the two highest level (>50%) was higher in the Indirect strata compared to the Direct strata for both alternatives. Overall accuracy of the map product was about 76%, although the accuracy to differentiate areas with any level of coral from areas with zero coral was 91%.

In situ spectral reflectances measured at the surfaces of the two most abundant species of coral (*Porites rus*, *P. lutea*) were used to compute the Normalized Difference Vegetation Index (NDVI) for 27 sites in CVN survey area. NDVI is a relative scale indicating amount of chlorophyll present; higher values indicate more chlorophyll, and therefore lower "stress." Although NDVI increased slightly with depth, there was no apparent trend in the horizontal spatial distribution of NDVI. The lack of a spatial pattern suggests no difference in chlorophyll between the Direct and Indirect strata, and hence no difference in relative stress.

Counts of mobile invertebrates at all transect sites revealed considerably higher mean density in the two Indirect strata (26 Flat; 24 Slope) compared to the Direct strata (12 Flat, 7 Slope). Mobile invertebrate species composition consisted primarily of molluscs, with smaller contributions from echinoderms and crustacea. Populations of sessile macroinvertebrates (other than stony corals) consisted predominantly of a wide variety of sponges (Porifera), with smaller contributions from the ascidians, molluscs and polycheates. Mean values of sessile invertebrates were higher on the Slope strata (92 Direct; 119 Indirect) than the Flat strata (71 Direct; 86 Indirect).

Analysis of composition of surface sediment collected within the proposed dredge area revealed carbonate composition (by weight) ranging from 78% to 96%. The remaining percentage is considered non-carbonate terrigenous material. There is a general gradient of increasing carbonate content with increasing distance from the entrance of Inner Apra Harbor.

The results of these surveys provide a baseline overview of the composition of the benthic marine habitats within the area of Apra Harbor that will be influenced by the CVN project. These findings can provide data to address reef classification, metric variability, and reference conditions. Consequently, these survey results will be valuable for input to modeling efforts to determine compensatory mitigation, as well as for developing efficient and defensible long-term monitoring programs that may be required.

2 PURPOSE

The United States (U.S.) Department of the Navy (Navy) proposes to construct a wharf and associated shoreside facilities at Apra Harbor, Territory of Guam, to continue to provide support for visiting nuclear aircraft carriers (Carrier Vessels Nuclear, or CVN). CVN are accompanied by aircraft and escort combatant ships, collectively referred to as a Carrier Strike Group (CSG). Apra Harbor currently supports an average of two 1-week CSG port calls of 7-day duration per year. Under the proposed action, there would be approximately three 21-day visits per year, or aggregate thereof, to support the increased CSG presence in the Western Pacific and Indian Oceans. The extended visits require 100 percent shoreside utility capability (i.e., power, wastewater management, potable water supply) to minimize or eliminate reliance on shipboard systems while in port.

To support the activity, the Navy proposes to construct a wharf and supporting infrastructure in Outer Apra Harbor capable of berthing visiting CVNs. Two proposed action alternatives are (1) a new wharf at Polaris Point, or (2) a new wharf (replacing existing finger piers) at the Former Ship Repair Facility (SRF) (Figure 1). The berthing areas for both alternatives border the entrance to the Inner Apra Harbor channel. The navigational approach through the Outer Apra Harbor Channel toward Inner Apra Harbor would generally follow the existing approach but will require widening to 600 ft. The navigational depth requirement for a CVN is -49.5 ft Mean Lower Low Water (MLLW). This depth requirement is met between the Outer Apra harbor Channel entrance and the sharp bend toward Inner Apra Harbor. Dredging of specific areas will be required between the bend and the alternative wharf sites to deepen the existing turning basin north of the wharf sites. The total dredge volume anticipated for Polaris Point and Former SRF alternatives is estimated at 608,000 cubic yards (CY) (464,849 cubic meters [m^3]) and 479,000 CY (366,222 m^3), respectively, including 2 ft (0.6 m) for overdredge (total dredge depth = 51.5 ft [15.7 m]).

The final design of the wharf is pending. A steel pile supported concrete platform was recommended in the CVN-Capable Berthing Study. There will be cut and fill at the shoreline. It is likely that the material removed could be reused at the site. The dredging methodology has not been determined and may include either or both hydraulic and mechanical dredge. The substrate may have to be pretreated using a mechanical chisel to facilitate the “grabbing” by the clamshell claw of a mechanical bucket. Dredge material disposal has not been determined and would include upland placement or ocean disposal at a designated site.

These activities will result in loss of habitat, either through direct removal of dredged material, or indirect effects of the dredging, particularly from effects of dredge-suspended sediment. A key critical component of evaluating the potential magnitude of environmental impacts, as well as developing effective and practical valuation of lost values and functions is gaining an insight into the overall habitat composition of the affected area. Because the area of interest consists in part of coral reefs and coral communities, consideration of impacts to these habitats will be one of the primary foci of the mitigation process. As a result, understanding the overall reef community composition of the affected area is a necessary component of the planning process.

The intent of this document is to present the methods and results of field studies conducted in April-May 2009 to assess and describe qualitatively and quantitatively the benthic habitat in the area that will be affected by the proposed actions to accommodate the proposed CVN project. At the direction of the Navy, the purpose of this assessment was to employ the most efficient techniques in the limited time available to gain a fundamental understanding of the broad-spectrum composition of entire affected community, with particular emphasis on providing input to Habitat Equivalency (HEA) Models. In this context, a community is the combined set of species living in a given physical setting at a given time. The intent of the study was explicitly not to investigate structure or life-history of particular populations, defined as all of the individuals of a single species living in a given place at a given time. The report is also not intended to provide exhaustive species lists. As the actual area of field surveys encompassed approximately only 0.1% of the entire affected area, any notion of "all-inclusiveness" by any survey method would not be accurate owing to the small area of study.

It is important to also note that the study was not intended to be the first stage in a monitoring program to specifically evaluate actual effects of the proposed action. Other methodological approaches would likely be far more effective for such monitoring. For example the U.S. Environmental Protection Agency has developed a "Stony Coral Rapid Bioassessment Protocol" (Fisher 2007). In the explanation of the intent of the protocol, the author states ..."The protocol is intended for use in a long-term biocriteria monitoring program, which requires exploratory biological surveys to inform and mold the monitoring design and strategy. Biological surveys provide date to address reef classification, metric variability, size and number of sampling units and reference conditions. Consequently, these preliminary surveys are indispensable to developing an efficient and defensible long-term monitoring program."

This description of the exploratory biological survey fits the purpose and objectives of the work carried out in Apra Harbor for evaluation of the habitats within the influence of the CVN project. Should future "monitoring" become a requirement, sampling protocols such as developed by the EPA should certainly be considered.

3 METHODS

3.1 TRANSECT SURVEY SITE SELECTION

With a relatively large and heterogeneous survey area (>150 acres), selection of representative, and statistically valid discrete survey sites is critical. It is not possible to perform a power analysis as reef community structure is inherently non-random; reefs generally exhibit strong geomorphic and ecological zonation (this was confirmed for the CVN survey). Sixty-seven survey sites were selected to provide an adequately robust and logistically feasible sample size. Because a large percentage of the CVN turning basin and entrance channel are composed of sand, selection of survey sites by a completely random selection process ran the risk of under-representing the hard-bottom communities. As a result, survey site selection was conducted using a stratified-random approach. The scenario at the CVN site is well suited for stratified random sampling as the overall communities are heterogeneous, and similar sub-communities (strata) can be isolated (Cochran 1978).

The selected strata were based on two physical components of the study area. One set of strata is defined within the outline of the combined area to be dredged under both the Polaris Point and SRF alternatives (termed "Direct Impact" stratum), and a 200-m-wide area bordering the dredge area (termed "Indirect Impact" stratum). The second set of strata is defined by the slope of the reef, divided into “Flat" stratum with bottom slope less that 15° and “Slope” stratum with bottom angle greater than 15°. All strata are bounded by the 60-ft depth contour.

Figures 2-6 show the progression of steps used to develop a set of 67 survey sites within the four strata. Figure 2 shows a Quickbird color satellite image of the study area in southeastern outer Apra Harbor, with the two dredge alternatives (SRF and Polaris Pt) outlined in red and blue lines, respectively. The 200-m-wide indirect stratum is also shown, as is the 60-ft depth contour. Figure 3 shows the same image that is optically “stretched” to highlight the deep reef areas (~>50 ft.) within the dredge area. This figure illustrates that these deep reef areas are clearly visible in the imagery and that areas of coral or algae are distinguishable from sand or rubble substratum.

Figure 4 shows color-coded bathymetry of the study area derived from LIDAR and acoustic data. In order to define strata based on topographic slope, LIDAR data was converted to reef slope angle as shown in Figure 5. Trial runs testing various slopes indicated that 15° produced a consistent visible outline throughout the study area. Hence, strata were defined as “flat” with topographical gradients less than or equal to 15˚, and “slope” with topographic gradients greater than 15°. Figure 6 shows a final stratification product, with each of the four stratified zones shown in a different color. Fifteen data points are randomly placed (using MATLAB) into each of the four zones (Direct Impact Flat, Direct Impact Slope, Indirect

Impact Flat, Indirect Impact Slope). In addition, data points were placed within each of the SRF and Polaris Pt wharf outlines, and within a patch reef at the northwestern end of the Fairway Channel within the Direct Impact area, resulting in a total of 67 survey sites.

3.2 TRANSECT SURVEY METHODS

All fieldwork was carried out from April 26-May 7, 2009. Field surveys were conducted using SCUBA with divers working from one 25' and one 18' boat. All diving operations were under the supervision of a safety officer and complied with all applicable Navy regulations.

Field surveys were conducted using a "Photo-Quadrat Belt Transect Method." Variations of this method have been a standard for evaluating and monitoring coral reef community structure for decades (see review by Nadon and Sterling 2006), and are widely used at present by numerous coral reef monitoring and assessment programs including the Global Coral Reef Monitoring Network, the Florida Keys National Marine Sanctuary Monitoring Program, and the Southeast Coral Reef Monitoring Network Program.

Single transects were evaluated at each of 67 sampling points (Figure 7). Each transect was 10-m long. This length was chosen to minimize the chance that transects would cross geomorphologic or ecological zone boundaries. Benthic cover on each transect was recorded within 15 photo-quadrats that were contiguously placed along the length of the transect. Each photo-quadrat had the dimensions of 1 m x 0.66 m, proportional to a photographic frame, resulting in total area covered by each transect of 10 m^2. The origins of transect locations were marked by the location of a weighted buoy dropped from the surface at the GPS coordinates of the transect station location (Appendix A shows coordinates of each sampling transect).

Field surveys were carried out by navigating to the pre-determined origin of each transect using differential GPS (typical horizontal error in Apra Harbor <3 m, personal experience). A buoy with an anchor-weight was dropped from the surface to mark the station location on the reef surface. At the location of the weight, a diver reeled out a marked fiberglas tape. If the location occurred on a distinguishable slope, the transect line was laid to follow the depth contour; if there was no distinguishable slope, transect orientation was in a random direction. Photo-quadrat data was collected by the second diver using a digital SLR camera (14 mm lens with 114° diagonal field of view) mounted on a 4-legged PVC quadra-pod that positions the camera over the center of a 1 m x 0.67 m rectangular frame. The digital SLR contains a full-frame display that provides for *in situ* verification of each image. In addition to the transect photos, panoramic images of most transect sites were collected. At the conclusion of each field day, digital photos were copied onto separate media (e.g. hard drives).

An index of *in-situ* topographical relief (TR), or rugosity, was also measured on each transect as the ratio of a length of chain laid over the reef surface and the chord length of the transect line.

All photo-quadrats were analyzed in the lab by individuals who participated in the field work. Lab analysis employed the Coral Point Count with Excel Extensions (CPCe) software developed by the National Coral Reef Institute, which is a Visual Basic program for the determination of coral and substratum coverage using random point count methodology (see Kohler and Gill 2006 and www.nova.edu/ocean/cpce/ for complete descriptions of the software, and a list of 73 publications that have used the program for benthic community assessment). In brief, a matrix of 50 randomly distributed points was overlain on each photo-quadrat image, and the organism or substrate type lying beneath each point was identified to the lowest taxonomic classification possible. Customization options that were employed included determination of long diameters of coral colonies using the length calibration feature of the software. This feature allows for drawing measured lines across any objects on the image. Classification of growth forms into an index of morphology was also included in the data analysis.

In addition to coral and non-coral substratum, CPCe software-generated data products were used to assess benthic algae, motile macro-benthos and non-living categories of benthic cover (e.g., sand, mud, rubble). Zoom features of the software and the high resolution of the digital photographs (~10 megapixels) allowed delineation of corals to the level of distinguishing individual calices. Other "value-added" parameters, such as disease or bleaching, were evident on quadrat images. To evaluate consistency and estimate variability between investigators, a random sample of four transects was used for "training" and analysis was conducted jointly by all three observers. Subsequently, the remaining 63 transects were analyzed by all three investigators separately. At the conclusion of the analyses, results were compared, and any points that did not have complete agreement between investigators were jointly examined and defined by consensus to result in complete agreement of the data set.

3.3 REMOTE SENSING HABITAT MAPPING

All methods utilized in this report followed standard procedures for processing coral reef remote sensing imagery (e.g., Andréfouët et al. 2003, Green et al. 2000, Mumby et. al. 1998). The benthic habitat map was created based on commercially available satellite remote sensing imagery. A fully georeferenced Quickbird multispectral+panchromatic satellite image of Apra Harbor was purchased from the Image Library at DigitalGlobe.com (image data originally acquired February 18, 2007). The image had 7.9-ft (2.4-m) ground sample distance in the spectral (color) bands. The Quickbird image was processed to highlight submerged features, which revealed areas of different bottom composition (Figure 2).

Transect data represent a reef area of 670 m^2 (= 10 m x 1 m x 67 transects). The total reef area within the study region that is equal to or shallower than 60 ft. is approximately 728,000 m^2. Thus, the study area represented by the transects is about 0.1% of the entire area of interest. While the transect data are high in detail, they are of limited extent. Any inference about the totality of the study area would require significant extrapolation. Owing to the geomorphologic and ecological heterogeneity within Apra Harbor, such extrapolation would lead to an unknown degree of error. As the majority of Habitat Equivalency Assessment (HEA) models rely on metrics in terms of area-time (e.g. acre-years), minimizing the error of such metrics is paramount in maintaining optimal accuracy of model results (M. Donlan, personal communication).

To address the issue of developing area-wide marine community characterization, a remote sensing approach was used to characterize the marine environment. Remote sensing has two major advantages over discrete in-water survey methods. First, remote sensing provides a synoptic view that can provide a quantitative assessment of benthic cover for the entire 728,000 m^2 study area. The results provide important information about both the relative covers and the spatial distributions of the major reef bottom-types. Second, accuracy assessment is a routine part of remote sensing studies that enables identification and correction of errors in the analysis of the entire area of interest. Thus, accuracy assessment statistics provide a direct measure of the quality of the map product that is to be used for management decision-making.

We employed standard remote sensing practices for this study. The most recent, highest quality satellite imagery available from Quickbird (DigitalGlobe) and IKONOS (GeoEye) was obtained. Each of these sources provides very high-resolution (≤4 m ground sample distance) multispectral imagery.

Images were generated using a supervised classification approach: sea-truth calibration-validation (cal-val) data consisting of depth and benthic cover was determined at a set of georeferenced sites. It is important that cal-val data are at the same scale as the mapping unit, i.e. image pixels. For high-resolution imagery (small pixels), the preferred approach is to discretely sample small reef patches (roughly 2-3 times the area of a pixel) using photo-quadrats. We have found that a pooled composite of five photo-quadrats collected within an area of about 5 m^2 (analyzed in the lab as described above) provides a suitable overall value for each sea-truth site. Thus, cal-val data collection was conducted by acquiring five quadrat photos within an approximate area of 5 m^2 near the origin of each of the 67 transect locations. An additional 19 randomly selected sites were also evaluated for a total of 86 calibration-validation areas. The digital photographic images were analyzed for benthic cover as described above for the transect data using CPCe software.

These data were then used to train an image-object-based classifier. Image-objects are groups of connected pixels that share similar spectral signatures; that is, they are relatively homogenous patches of bottom-type at a constant depth on the reef. A classifier is simply a set of rules that a computer follows to assign appropriate labels to unknown observations, which in this case are image-objects. Once the classifier is trained with known image-objects, it is applied to the entire image, and the result is a thematic map showing the spatially-explicit, quantitative bottom cover at each pixel. An initial accuracy assessment was conducted to determine where errors occurred, followed by subsequent refinement of the classifiers to generate a new thematic map. We iterated this process until the map achieved an accuracy threshold of 75%.

Accuracy assessment is a critical component of the remote sensing and map-making process. Patterns in map accuracy guide the processing flow: if a particular map class exhibits low accuracy at one step in the processing, then the analysis is altered and the step is repeated. Accuracy is determined using the standard error matrix as described in Congalton and Green (1999). To populate the error matrix, we used the method of cross-validation. In cross-validation, all but one observation from the sea-truth data are used to build a classifier, and the classifier is tested on the withheld point. This process is repeated on every observation point in the data set. The result is the error matrix, with correct classifications on the diagonal and incorrect classification off-diagonal. Because each classifier is tested on a data point that was not used to build the classifier, the result is unbiased. Also, because the test classifiers use almost all the available data points, they more closely represent that classifier actually used to generate the image product (which used all data points). This is a more robust test of the classification than would be achieved by simply separating the sea-truth data into two halves (i.e., a "training" set and a "testing" set).

We also performed another analysis to determine overall reef rugosity, following the methods described in Brock et al. (2004) and Purkis et al. (2008). In this analysis, LIDAR data are processed to derive reef slope (vertical relief divided by horizontal distance) at each pixel in the scene. Since each pixel has the same horizontal distance, pixels with high slope indicate high vertical relief. Rugosity for a given pixel is calculated as the variance in the surrounding set of pixels; different rugosity scales simply incorporate different numbers of pixels. For example, for Quickbird with 2.4 × 2.4 m pixels, variance computed on a 3 × 3 window gives rugosity for a 51.84 m^2 area, while variance computed on a 5 × 5 window gives rugosity for a 144 m^2 area. Evaluating such different scales of rugosity has been shown to be an important tool for understanding functional aspects of reef communities, such as reef fish habitat utilization (Purkis et al. 2008).

In the lab, survey points were located on the geo-referenced satellite multispectral image which served as the basis for statistical image classification. “Training classes” (defined as the combination of geo-morphological zone and bottom cover) were created by assigning a class label to a survey point using the ground truth data for context. To spectrally define a “region of interest” for a training class, 20-30 adjoining pixels were isolated and included in the class. Because the same zone-cover combination could occur at different depths, the final classes could exhibit several different multispectral patterns. Thus, it was often necessary to merge several independent training classes to the same final class label. After the merging procedure, all training classes with the same spectral label were used to create the map showing the distribution of bottom cover over the reef. The resultant analysis produced maps showing six classifications of coral cover:

Class 1: coral = 0%
Class 2: 0% < coral ≤ 10%
Class 3: 10% < coral ≤ 30%
Class 4: 30% < coral ≤ 50%
Class 5: 50% < coral ≤ 70%
Class 6: 70% < coral ≤ 90%

3.4 NEAR-REAL-TIME ASSESSMENT OF CORAL STRESS

We measured and processed spectral reflectance *R* (implicitly a function of wavelength) for visible wavelengths (400–700 nm) following methods described in Hochberg and Atkinson (2006). The sampling unit consisted of a 2-m-long fiber optic cable (400 µm diameter) attached to an Ocean Optics USB2000 portable spectrometer (wavelength range 330–850 nm, with ~0.3-nm sample interval and ~1.3-nm optical resolution, wavelengths calibrated to Ocean Optics HG-1 Hg-Ar lamp), which in turn was operated by a palmtop computer. The spectrometer and computer were in a waterproof housing, which enabled the spectrometer to be fully diver-operated. The fiber optic cable connected to the spectrometer through the housing wall via a vacuum feedthrough (Ocean Optics). The fiber optic cable tip collected light over a solid angle of ~0.1 sr, which at a distance of 10 cm projected to a circular area of 10 cm^2 (diameter ~3.5 cm).

For each single measurement of *R*, a diver pointed the collecting tip of the fiber optic cable at the target on the coral and triggered acquisition (and storage on the palmtop) of the spectrum by pressing a button on the housing. Immediately thereafter, the diver pointed the collecting tip at a Spectralon (Labsphere) diffuse reflectance target (same depth as the target point on the coral) and triggered the storage of its spectrum. In this manner, both spectra could be acquired within 1–2

s. Because the spectrometer was a 12-bit system with limited dynamic response, we used a 10% reflectance Spectralon so that measured light intensity from the coral and the Spectralon were of the same order (coral *R* averages near 10%: Hochberg et al. 2004), thus maximizing the measurable coral signal. To ensure a constant ambient light field between the two measurements, the Spectralon was placed immediately adjacent to the target point on the coral, and the diver's position was held constant for the 1–2 s required for the measurements. If light flashes due to wave focusing were obvious at the time of sampling, we shaded both the coral and Spectralon from direct light so that they were illuminated only by the ambient diffuse light field. Spectra were acquired in units of digital counts.

We corrected all spectra for baseline electrical signal, then calculated *R* as the ratio of digital counts measured over the coral to the digital counts measured over the Spectralon, corrected to 100% reflectance, for each pair of measurements. We linearly interpolated *R* to 1-nm intervals over the wavelength range 400–700 nm, then filtered the result using the Savitsky–Golay method (Savitsky and Golay 1964; Steiner et al. 1972). For each coral, we measured 20-30 replicate *R*s across an area up to ~0.25 m^2 of coral surface (depending on colony size), and these were averaged for determination of NDVI. NDVI was calculated following Eq. 1, with NIR = 720 nm and RED = 673 nm.

3.5 INVERTEBRATE SURVEY METHODS

All visible unattached non-coral macro-invertebrates were identified and counted within one 25 x 4 m belt transect at each of 62 transect sites (Transects 15, 29, 52, 54 and 67 were not assessed for invertebrates). Surveys were conducted without manipulating the bottom (e.g., no rubble was turned) and only cursory checking of holes and crevices.

Taxa Richness data were collected by searching a 5 m belt centered on the transect and noting all visible unattached non-coral macro-invertebrates species. Search time varied, depending upon the amount of bottom time left after completing the quantitative data collection.

All individuals were identified to the lowest possible taxonomic level. Specimens not identified *in situ* were photographed and a portion taken as voucher for later identification in the lab or by an appropriate taxonomist as necessary. Abundance (density) of all sessile invertebrate taxa was assessed quantitatively using counts of all taxa within 0.5 m on either side of the 25m long transect line.

Surveys of transects 15, 49 and 61 were conducted during both day and night. Surveys of all other transects were conducted during the day only.

3.6 SEDIMENT COMPOSITION

As composition of sedimentary material (primarily calcium carbonate vs. terrigenous) has been shown to result in differential effects to corals, it was deemed important to determine composition of the sediments that will be dredged for the CVN project. Surface sediments were collected by divers at ten transect stations within the "Direct" impact strata. Collection sites were aligned roughly in a southeast-to-northwest orientation from stations near the mouth of Inner Apra Harbor and Sasa Bay, across the dredge area to the patch reef at the northwestern end of the Fairway.

Sediment samples were immediately sealed in vacuum bags and frozen until return to Honolulu. In the lab, sediment samples were dried and aliquots of approximately 20 g were weighed. Sediments were then subjected to repeated treatments of a 1N NaOAC buffered solution of HOAC until all carbonate material was dissolved. Dissolution was considered complete when additional treatments of HOAC produced no bubbling. Following completion of dissolution, samples were repeatedly rinsed with distilled DI water, dried, and weighed. Difference in weight of samples before and after acid treatment was used to determine carbonate and non-carbonate (i.e., terrigenous) fractions. Sediment composition analyses were conducted in the laboratory of Dr. Eric H. DeCarlo at the School of Ocean & Earth Science and Technology at UH Manoa. While time did not permit for inclusion in this document, residual sediment has been retained for analysis of organic fraction and mineralogical composition at a later date.

3.7 SURVEY PERSONNEL

The University of Hawaii (P. I.: S. Dollar) was responsible for overall coordination of all partners and facets of the project including field logistics, field sampling, data analysis, evaluation and compilation, interpretive results (including accuracy assessments) and report preparation. Dr. Dollar was also responsible for collection of all photo-transect data in the field and data transfer to Nova Southeastern University. Analysis of sediment composition was also conducted at the University of Hawaii.

Nova Southeastern University (P.I.: E. Hochberg) was responsible for providing personnel to assist in collection of field data, and data analysis of photo-transect data utilizing CPCe software, including multiple user accuracy assessments. Nova was also responsible for collecting all data, and developing remote sensing products, as well as collecting and processing all data for developing coral stress indices. Graduate students from NSU contribution to field work and data analysis were H. Hancock, C. LaPointe and M. Doctor. S. Dunne assisted with fieldwork, and A. Hudon assisted in the field and provided editorial support.

Invertebrate surveys were conducted by Dwayne Minton (U.S. Fish and Wildlife Service) and collaborative investigators from the University of Guam.

4 RESULTS

4.1 DESCRIPTIONS OF THE SURVEY AREA

The structure of the marine environment of the southeastern part of outer Apra Harbor containing the main channel and turning basin is composed primarily of three major regions. These three areas are 1) large flat-topped patch reefs; 2) dredged reefs in the turning basin and entrance channel; and 3) soft sediment areas in the turning basin and entrance channel.

The channel and turning basins are bordered by several large "patch reefs" that consist of shallow, flat-topped, steep-sided features. The largest three of these reefs are Jade and Western Shoals and Big Blue Reef (Figure 1). These reefs all consist of relatively flat, shallow upper surfaces that are covered primarily with sand, rubble and algae. The western facing slopes of Western Shoals and Big Blue Reef consist of near total cover of living corals to a depth of approximately 50 to 60 ft (15 to 18 m), where the slopes intersect the channel floor. Coral cover on the eastern slopes of these two reefs is more variable relative to the western slopes, possibly as a response to increased sediment loads in water flowing westward from Sasa Bay, or from resuspended sediment generated by ship movements within the approach channel to Inner Apra Harbor. Jade Shoals, located to the northeast of Western Shoals and Big Blue Reef, does not show the same degree of asymmetrical coral growth on the western edge, with most of the shoal ringed by slopes with high coral cover.

The area demarcated as the project area where dredging will take place for the CVN project presently does not contain any of the shallow shoal patch reefs (see Figure 4). This area was dredged in 1946 to allow safe access to the newly completed Inner Apra Harbor (R. Wescom, personal communication). As a result, the shallowest depth within the channel and turning basin is about 40 ft (12 m). It is likely that the large flat area in the southeastern end of the turning basin was another shoal area similar to the surrounding reefs prior to the 1946 dredging. Dredging likely removed the shallow area, resulting in the present configuration. While the top of the deep reef is essentially flat at a depth of approximately 40 ft (12 m), the remaining edges slope relatively steeply to the channel floor.

The dated dredging of the original channel suggests that much of the coral within the depth zone to be dredged for the CVN project (< 51.5 ft (15.7 m)) is regrowth following the 1946 dredging resulting in a community with a maximum age of 62 years.

4.2 DESCRIPTIONS OF BIOTOPES OF THE CVN SURVEY AREA

A biotope is defined as an area that is relatively uniform in environmental conditions and in its distribution of animal and plant life. Several distinct biotopes occur in the CVN area, distinguished by both physical structure and biotic composition. In addition, much of the CVN area consists of combinations or mixtures of the "pure" biotopes. Descriptions of all of these biotopes are presented below.

4.2.1 PORITES RUS "SUPRACOLONIES"

By far, the most common coral in Apra Harbor is *Porites Rus*. Colonies of *P. rus* can be massive, columnar, laminar, branching and encrusting, and single colonies can contain multiple growth forms. It is also common to see growth forms that fit under the definition coined by Pichon (1978) of "supracolonies." By this definition, one "colony" is a formation originating from one planula. As new colonies in close proximity grow in size, they fuse. Such a phenomenon, when constantly repeated, leads to a continuous living coral formation, composed of elements belonging to different generations. These conglomerate colonial structures, or supracolonies, may extend over tens or hundreds of square meters. In some instances supracolonies may be so large as to represent a whole ecological identity (i.e., sub-community) (Pichon 1978).

While *Porites rus* occurs throughout the survey area, it is particularly widespread on the outer (with respect to the CVN entry channel and tuning basin) sloping sides of the four large patch reefs (Jade, Western, Big Blue, and the unnamed reef). *Porites rus* occurs in a variety of contiguous supracolony structural forms that dominate the benthic surface. Most of these structures are composed of multitudes of overlapping thin semi-circular plates. Supracolonies have the form of vertical walls, massive dome-shaped structures, conical spires, masses of foliaceous cup-shaped and tabular plates (Figure 8). In addition, colonies and supracolonies of *P. rus* can assume a variety of branching forms that occur in contiguous thickets covering large sections of the benthic surface (Figure 9). It is also common to see multiple growth forms (branches growing out of laminar plates) (Figure 9).

4.2.2 MIXED CORAL COMMUNITIES

Coral community structure on some areas of the flatter sections of patch reef slopes as well as deep reef flats consisted of higher cover of a more diverse community than in the areas dominated solely by *Porites rus*. Along with *P. rus*, two branching species, *Porites cylindrica* and *Pavona cactus*, comprise substantial proportions of bottom cover (Figure 10). *Porites cylindrica* occurs as thin rounded upright branches, with individual branch separated each other by an encrusting matrix base. *Pavona cactus* occurs as thin, upright, contorted fronds, each attached to a solid base. Both of these corals grow in interconnected stands that can extend over large areas of the reef surface. In particular, on Transect 15, located on the eastern edge of the unnamed patch reef between Western Shoals and Big Blue Reef, *Pavona cactus*, *Porites cylindrica*, and *Porites rus* formed mixed complexes with substantial contributions from all three species (Figure 10). Thus, three of the four most abundant corals encountered in the CVN surveys (*P. rus*, *P. cylindrica* and *P. cactus*) often occur in what can described as indeterminate growth forms, in the form of supracolonies or spreading mats composed of multiple branches or fronds.

4.2.3 PATCH REEF MARGINS - PORITES LUTEA ZONE

Porites lutea generally occurs as hemispherical or helmet shaped colonies and are a major component of benthic cover on the margins of the tops of patch reefs in the CVN area. Water depth of these flats is the shallowest of all biotopes, and was generally in the range of 1-2 m. Within this zone, colonies of *P. lutea* are often densely packed together with adjacent colonies in contact with one another. Other dominant corals in this biotope included *Porites cylindrica* occurring in branched clusters, and *Porites rus*, which occurred primarily of flat-topped clusters of densely packed branches (Figure 11). Moving off the flat surfaces of the patch reefs, community structure rapidly changes to a more uniform cover of *P. rus* as described in the sections above.

4.2.4 PATCH REEF MARGINS - ACROPORA ASPERA MAT

Transect 9, located on the top of the northwestern edge of Western Shoals, consisted entirely of a contiguous mat of the branching coral *Acropora aspera* (Figure 12). The field of *A. aspera* was limited to the top of the patch reef, and did not extend beyond a depth of approximately 2-3 m, below which the benthic community was dominated by other species of *Porites* (Figure 12). This biotope was not observed anywhere else in the study area, at least in the vicinity of any of the other transects. The uniqueness of the biotope may be a result of orientation of the western edge of Western Shoals to the long axis of Outer Apra Harbor. During surveys, swells entering the Harbor mouth were breaking at the transect location. A distinctive characteristic of the *A. aspera* mat was the occurrence of large sections of dead branches that were encrusted with algae or cyanobacterial mats. As the dead portions of these *Acropora* stands were completely intact, the cause of mortality cannot be attributed to any type of physical forces applied to the fragile branching matrix.

In addition, there were distinct boundaries between areas of apparently healthy branches and patches of dead branches. Within the dead patches, there were also clumps of "new" live branches with no sign of any abnormalities. The likely cause of the patchy mortality of the *Acropora* field is infestation of a black sponge that occurred within the coral thicket, completely covering branches (Figure 12). While the smothering of live coral by the sponge may be the cause of mortality, the presence of the sponge appeared ephemeral, as it was not evident in much of the area of algal-encrusted coral skeletons. In addition, the presence of patches of apparently healthy coral resulting from either planular settlement or vegetative spreading within the thickets of dead branches suggests that there is an ongoing dynamic process of coral-sponge interactions of mortality and recovery within the biotope.

4.2.5 ALGAL BEDS

In addition to hermatypic corals, the other dominant benthos within the study area are macroalgae. While there are biotopes that consist of "coral-algal mixes" (see below), there are also areas of essentially pure stands of algae. Three genera of algae are most prevalent, and in some areas consist of nearly monospecific meadows that extend over hundreds of square meters. Probably the most common plant is the brown alga *Padina* spp, which was found throughout the survey area. This alga is characterized by large calcified, fan-shaped blades that grow in multiple clusters attached to rubble, sand or hard bottom (Figure 13). Also abundant is the calcareous green alga *Halimeda* spp., with fronds consisting of vertical series of connected flat segments. Much of the *Halimeda* observed in Apra Harbor was growing in dense beds over sandy bottoms. In these areas white calcified remains of plant segments form a component of the sandy substratum (Figure 13). The third dominant alga is *Dictyota* spp. which occurs as narrow, spirally twisting branches that are split on the ends. *Dictyota* was often seen in mats of mixed algae and mixed coral-algae, and was particularly abundant over sand-covered bottom (Figure 13).

4.2.6 RUBBLE, MUD AND SAND

Many regions of the CVN study area were not colonized by any epi-benthic biota. Benthic cover in these areas consisted of plains of fine grained sand-mud, primarily composed of calcium carbonate (Figure 14). Numerous burrows and mounds from infaunal organisms punctuated most of the sand-mud regions. In addition, the surface of the sediment was often covered with thin films of bacteria or micro-algae.

In addition to the sand-mud plains, some areas of the bottom were covered uniformly with a layer of mixed rubble and coarse sand. Most of the rubble is recognizable as dead coral fragments. The harbor floor fronting the shoreline off the SRF (Transects 52, 53,54, 67 and 67), and adjacent to the eastern tip of the Outer Apra Harbor entrance channel (Transects 57, 58) was composed almost entirely of rubble and sand (Figure 14).

4.2.7 MIXED CORAL-ALGAE

Several biotopes which comprise the majority of benthic cover consist of combinations of two or more of the "pure" communities described above. One of these combination biotopes can be termed "mixed coral-algae." One such combination consisted of hemispherical heads of *Porites lutea* amid stands of *Padina* spp. on the shallow tops and sides of patch reefs (Figure 15). In the deeper areas, particularly on the tops of the dredged platforms and pinnacles in the turning basin, combined algal-coral communities occurred in a variety of forms, including films of benthic bacteria on mud surfaces, short turfs on rubble fragments, and mats of *Halimeda* and *Dictyota* interspersed with colonies of *Porites* (Figure 15). A unique coral-algal assemblage occurred on Transect 9, where stands of living *Acropora aspera* were interspersed with sectors of dead branches encrusted with a layer of algal turf and cyanobacteria (Figure 12).

4.2.8 CORAL ON SEDIMENT

With the exception of stony coral skeletons, the substratum of the study area consists primarily of sediment of various grain sizes (mud, sand, rubble). As a result, an important aspect of coral community structure is the interaction between corals and soft sediment. Throughout the CVN study area, and particularly in the deeper survey sites, corals are growing on, or out of the sediment surface. *Porites rus*, in particular, occurs in a variety of growth forms that can be considered adapted to colonizing areas of soft sediment. Many of these colonies do not have solid attachment to the bottom, with upper living areas overlying a base of dead skeletal material that is partially buried in the mud (Figure 16). In addition, many colonies growing in areas of abundant sediment had portions of the colonies covered with fine-grained sand or mud. Supracolonies of *P. rus* in many of the deeper survey locations were made up of complexes of laminar plates comprised of sections of both dead and living tissue. Much of the dead plated surfaces on these structures contain an accumulation of fine grained sediment (Figure 17).

4.3 QUANTITATIVE EVALUATION OF BENTHIC COMMUNITY STRUCTURE

Photo-quadrats from 67 transects was analyzed using CPCe software to obtain a quantitative dataset that can be used to describe the community. Appendix B shows three representative quadrats from each transect to provide a view of the overall setting of each survey site. All photo-quadrats are available for post-processing at a future time if necessary.

Table 1 shows the mean percent cover of the "general classes" of benthic cover encountered in all transect photo-quadrats (Appendix C shows upper and lower 95% confidence limits for means of general classes of benthic cover on each transect). Percent cover is calculated as the proportion of total points that occur for each class. General classes consisted of Algae, Stony Coral, Sponges, Soft Coral, Ascidians, Echinoderms and Sediment. Sediment consisted of sand, mud and rubble. Algae and sediment each occurred on 66 transects, coral occurred on 52 transects, and sponges occurred on 55 transects. Ascidians occurred on 3 transects and echinoderms on 4 transects. In terms of ranges of cover of general classes, all classes had minimum cover of zero on at least one transect. Maximum transect cover of general classes ranged from 100% for algae and sediment, 88% for coral, 24% for sponges, 9% for soft coral, 1% for echinoderms, and about 0.3% for ascidians. Cumulative means of general classes for each transect reveal the overall pattern of decreasing algae and sediment with increasing coral cover (Figure 18).

Table 2 shows the percent cover of the "detailed classes" of benthic cover, which are defined as the 37 categories identified in transect photo-quadrats (Appendix D shows the upper and lower 95% confidence limits for the means of detailed classes). The most prevalent class of biota was mixed macroalgae, which occurred on 65 transects with a maximum transect cover of 74%. In terms of occurrence of single macroalgal species, the most common was *Halimeda*, which was present on 30 transects, with a maximum transect cover of 59%, followed by *Dictyota* (23 transects; max cover of 37%) and *Padina* (15 transects; max cover of 27%). With respect to distribution of corals, the most abundant was *Porites rus* which appeared on 47 transects with a maximum transect cover of 85%, followed by *Porites lutea* (26 transects; max of 37%), *Porites cylindrica* (18 transects; max of 12%) and *Pavona cactus* (13 transects; max transect cover of 43%).

Table 3 and Figures 19 and 20 show benthic cover of general classes separated into four strata (Direct-Flat, Direct Slope, Indirect Flat, Indirect Slope). Mean algal cover within strata varied from a low of 30.7% in the Indirect Slope stratum to a high of 47.9% on the Direct Slope transects. Mean coral cover had the mirror image with highest cover on the Indirect Slope (38.3%) and the lowest on the Direct Slope (14.4%). On the combined Direct strata transects, mean algal cover was 44.5%, while mean coral cover was 13.9%. On the combined Indirect transects, mean algal cover was 33.1% compared to mean coral cover of 31.9%. When all transects are combined, mean algal cover was 40.2% compared to mean coral cover of 21.9%.

When all species of coral are listed by order of abundance on transects, *Porites rus* was an order of magnitude higher than any other species, accounting for 74.4% of all coral (Table 4). Along with *Porites lutea*, *Pavona cactus*, and *Porites cylindrica*, the four most abundant species comprise about 95% of coral cover of the CVN survey area. When transects within a strata are ordered according to percent cover of *Porites rus*, the overall pattern of coral cover is similar in areas (Figure 21). In each zone, one-half of the transects had cover of *P. rus* less than 2% of bottom cover. Distribution of ranked order of *P. rus* throughout the other half of the transects within each strata occurred as a progressive increase with little overlap of mean cover up to the maximum value in each strata (Figure 21). As a result, the mean value of coral cover within any strata is influenced by both the relatively large number of transects with essentially no coral, as well as the steep gradient of increasing cover on transects that do contain coral.

Transect cover data were analyzed using the Bray-Curtis similarity index to construct cluster dendrograms (Figures 22 and 23). With a similarity threshold of 0.25, seven distinct clusters emerge from the general class data (Figure 22). Mean values of benthic cover of the general classes within each distinct cluster (Table 5) indicate that sediment cover dominates clusters 1 and 2, algae dominates clusters 3, 4, and 5, and coral dominates benthic cover in clusters 6 and 7 (Figure 22). These cluster groupings compare well with the general biotopes described in Section 4.2.

In order to select the most important community components in terms of percent of total variance explained, principal component analysis (PCA) was applied to the detailed class percent cover data. In PCA, the first principal component (PC) describes the highest proportion of variance in the data, the second PC describes the second highest proportion of variance, and so on. In the present data set, the first five PCs describe >90% of the variance (virtually all of the variability in the data is described by the first 14 PCs) (Figure 24). This result indicates that the data are essentially five-dimensional (as opposed to the 38 dimensions described by the individual detailed classes). By plotting the coefficient value for each PC against the individual detailed classes, it is possible to identify which detailed classes are responsible for each PC, and thus which detailed classes are responsible for the variance in the whole data set (Figure 24). For PC 1, the two detailed classes with the highest coefficient (absolute) values were mud and *Porites rus*. In PC 2, the two most important classes, other than the two from PC 1 (mud, *P. rus*), were mixed algae and *Halimeda* sp. In PC 3, the two most important additional classes were rubble and *P. lutea*. In PC 4, the two most important additional classes were *Padina* sp. and cyanobacteria. Finally, in PC 5, the two most important additional classes were turf algae and *Pavona cactus*. Together, these 10 classes are the most important to describe variability in benthic cover in the data set (Figure 24).

Bray-Curtis similarity cluster dendrograms for the ten detailed classes derived from the PCA provide a substantially more complex array than the general classes (Figure 23). At the 0.5 level, 14 detailed clusters emerge; 2 additional clusters consisting of single transects connect at higher levels. The two "unique" transects are 15, containing the unique attribute of 43% cover of *Pavona cactus*, and transect 9, which contained 34% turf algae (Table 5). When grouped by major habitat type, clusters 1-4 are sediment dominated, clusters 5-11 are macro-algal dominated, and clusters 12-15 are coral dominated.

Another method to demonstrate the relationship between the three major types of benthic cover (algae, sediment, coral) is with a ternary diagram (Figure 25). In this graphic, each vertex represents 100% cover for each bottom cover type, while edge of the triangle represents the "mixing line" between two cover types, with cover of the third type equal to zero. Points within the triangle represent mixing between all three classes.

Several interesting patterns emerge from the ternary plot. First, there are points that fall on the coral-algae and algae-sediment mixing lines, indicating that there are transects that include only there two cover types. However, there are no points on the coral-sediment mixing line, indicating that no coral occurs on transects without algae also occurring. Secondly, there is an empty area of the triangle defined in Figure 25 by a dashed line originating at the 100% coral vertex and extending to the mixing point of approximately 25% algae and 75% sediment. In the area above the line, coral cover is limited to no more than about 2% of bottom cover. Hence, when sediment cover exceeds approximately 75% of transect cover, there is essentially no coral cover. The relatively uniform distribution of points below the dashed line, where sediment cover is less than about 75% and coral cover above approximately 5%, indicates relatively even distribution between algae and coral throughout the survey area (Figure 25).

Transect points in Figure 25 are also color-coded by magnitude of rugosity index. With a single exception, all of the points lying on the sediment-algae mixing line are blue, indicating relatively low rugosity. There is a weak trend of increasing rugosity with increasing coral cover, as points with higher relative rugosity increase with proximity to the lower left corner of the plot.

Several statistical methods can be used to evaluate if transects within strata fall into distinct groupings. Classical multidimensional scaling (CMDS) can provide a qualitative sense of how similar the transect community structures are to each other. CMDS represents each transect by a single point, with transects having similar benthic community composition falling closer to each other than transects that are very different in terms of community structure. CMDS reduces the multi-dimensionality of the data so that they can be displayed two-dimensionally. When the first three dimensions of both the general (Figure 26) and ten detailed (Figure 27) classes are compared, clustering of points is not very evident, and the four strata appear evenly distributed across the data space. Such patterns indicate that there are no important differences between the four strata in terms of benthic community structure.

Principal component analysis (PCA) can also be used to reduce the dimensionality of the data space. Comparison of PCA of transects also give a qualitative representation of the similarities between transects. Again, there are no apparent trends or clusters in the general classes (Figure 28) or the detailed classes (Figure 29), indicating no differences between strata.

Finally, discriminant function analysis (DFA) can be performed using the general and detailed classes, respectively (Figures 30 and 31). DFA describes the separation of two or more predefined groups based on linear functions of multiple variables (Rencher 1995). As they are the linear combinations of the variables that best separate the groups, the discriminant functions describe the plane or planes on which the original multivariate data can be projected to optimally represent group configuration. DFA is equivalent to multivariate analysis of variance, which statistically describes group separation. In this case, again, the discriminant functions do not separate the strata, and thus the strata are not statistically different from each other in terms of benthic community structure. MANOVA tests confirm these results.

4.4 REMOTE SENSING ANALYSIS OF BENTHIC COMMUNITY STRUCTURE

A key component of the evaluation of environmental impacts and subsequent mitigation is gaining an insight into the overall habitat composition of the affected area. Because reef-building coral is a key component of the benthos, and a primary focus of regulatory considerations, understanding the overall coral community composition provides a good starting point for assessment of affected areas. One goal of the CVN survey is to create a benthic habitat map using state-of-the-art remote sensing technology that characterizes the overall composition of coral communities in the southeastern end of Outer Apra Harbor, Guam in the vicinity of the CVN channel and turning basin.

Analysis of remote sensing imagery acquired from airborne platforms has repeatedly demonstrated to be a useful tool for coral reef assessments. Appendix E lists approximately 40 peer-reviewed publications that demonstrate the use of remote sensing data for assessment or study of coral reef structure and function. These represent only a sample of the literature on the subject. Most of these papers focus on use of high-resolution multispectral imagery. Some of the papers discuss moderate-resolution multispectral imaging, and some discuss application of high-resolution LIDAR data to derivation of reef topography and rugosity. Papers discussing imaging spectrometry, sometimes referred to as hyperspectral imaging, are not included in the list because time constraints prohibit use of this technology for the current project (although future work could include hyperspectral analyses).

There are two main conclusions to draw from these (and other) papers. First, remote sensing is a well-established tool for observation of coral reefs. Second, given expert analysis and interpretation, under ideal conditions, remote sensing products typically achieve accuracies on the order of 80-90%. Thus, remote sensing products can be very accurate and provide critical information about the spatial distributions of important reef bottom-types (habitats). To acquire a commensurate data set entirely from in-water surveys is simply not logistically feasible. For the reader interested in becoming familiar with this field, we recommend the reviews by Kuchler et al. (1988), Green et al. (1996), Andréfouët et al. (2003) and Mumby et al. (2004), followed by the specific case studies listed in Appendix E.

Figure 32 shows the locations of 86 calibration-validation sites used to generate the classifiers for the benthic habitat maps. Figure 33 shows the final map produced by the supervised classification scheme described above for the Polaris Point and Former SRF alternatives, with the boundaries of the Direct and Indirect strata. Spectral resolution of the image allowed for distinction of six bottom classifications according to coral cover as described above.

A full cross-validation was used for error analysis. In cross-validation, all but one observation from the ground-truth data are used to build a classifier, which is tested on the withheld point. This process is repeated on every point in the data set. The result is a matrix of classification rates, with correct classifications on the diagonal and incorrect classification off-diagonal. Because each classifier is tested on a data point that was not used to build the classifier, the result is unbiased. Also, because the test classifiers use almost all the available data points, they more closely represent that classifier actually used to generate the image product (which used all data points). This is a more robust test of the classification than would be achieved by simply separating the sea-truth data into two halves (i.e., a "training" set and a "testing" set). It is important to note that this error matrix assesses the accuracy of the *classifier*, and it only represents the accuracy we would expect in the map product. The classifier is the set of decision rules that are used to assign class labels to unknown objects. For example, in cases of interactive photo-interpretation, the classifier is actually the thought and decision-making process inside the coral reef expert’s head. In the present case, the classifier is a computer-based, mathematical algorithm that has been “trained” with quantitative ground-truth data. Thus, the numbers in this table reflect the performance of that computer processing, given the available data. Because accuracy was assessed using full cross-validation, these values are unbiased estimates of the classification rates we would expect to find in the final map product.

Table 6 shows the confusion matrix (or error matrix) for the classification coral map created for the CVN area. The overall accuracy of the map is about 76%. Accuracy of differentiating between areas with zero coral and any of the other categories containing any amount of coral is about 91% (Table 6b). Hence, the map can provide a very accurate assessment of coral containing areas. Possible factors contributing to error were potential georeferencing offsets in the imagery and in the field, relative great depth of many of the survey stations, and high turbidity of the water column. Nevertheless, the level of accuracy of prediction of bottom cover is high compared to what would result from extrapolation from a relatively few survey points to the entire survey area.

Within Tables 6a, 6b, and 6c columns correspond with actual classes, while rows correspond with predicted classes. It is possible for an observation in any given actual class to be predicted as belonging either to that class (correct) or to any of the other classes (incorrect). In this case there are six classes; thus there are 36 possibilities. On the diagonal elements of the matrix, the predicted class is the same as the actual class. These elements represent correct classifications. For off-diagonal matrix elements, the predicted class is not the same as the actual class, and these elements represent confusions in the classification. The values in Table 6a are pixel counts: these are the observations for which we know both the actual and predicted classes. These counts can be interpreted in two useful ways.

The first interpretation is as the *producer* of the map (Table 6b). Matrix counts are converted to rates by dividing each element by its corresponding *column* total. These rates represent how often observations in a given class are assigned to each of the possible predicted classes. For example, 46.7% of the time, observations in the class "0% < coral ≤ 10%" are correctly classified (i.e., assigned to the correct predicted class). However, 12.3% of the time, observations in that class are incorrectly identified as belonging to the class "10% < coral ≤ 30%." These *producer* rates describe how well the classifier separates the observations into appropriate classes. (The classifier is the set of rules used to assign observations into classes, in this case multivariate quadratic classification functions.)

The second interpretation is as the *user* of the map (Table 6c). Matrix counts are converted to rates by dividing each element by its corresponding *row* total. These rates represent how often observations predicted to be in a given class are actually in that class, as opposed to actually belonging to another class. For example, 45.9% of the time, observations that are predicted to be "0% < coral ≤ 10%" do actually belong to that class. However, 16% of the time, those observations will actually belong to the class "10% < coral ≤ 30%." These *user* rates describe how well the map product (Figure 33) characterizes the survey area. In this example, 45.9% of the pixels in the map labeled as "0% < coral ≤ 10%" are correct, but 16% of those pixels are actually "10% < coral ≤ 30%."

The *user* rates allow for correction of area estimates. Using the same example as above, if the map predicts 100 m^2 to be "0% < coral ≤ 10%," then only 45.9 m^2 are actually that class, while 16 m^2 are "10% < coral ≤ 30%." This is the basis for the revised area estimates in Table 7.

Table 7 shows the area coverage of each corrected coral class in both square meters (m^2) and acres for each stratum for both the SRF and Polaris Point alternatives. Examination of the coral map and coverage table reveals several important points. The total area to be dredged is 71.18 ac (28 805 639 m^2) and 60.77 ac (245, 928 m^2) for Polaris Point and SRF, respectively. Based on pixel counts from the remote sensing map, total area with any level of coral coverage is 23.74 acres (96,083 m^2) for the SRF alternative and 25.20 acres (101,969 m^2) for the Polaris Point alternative. Hence, about 39% and 35.4% of the area to be dredged presently contains some level of coral coverage for the SRF and Polaris Point alternatives, respectively.

It is also evident that the area within the dredge boundaries contains relatively small areas of the densest classifications of very high cover (>50% coral). Areas that did contain the densest categories were generally along the sloping margins of the large patch reef outside of the dredge envelope. While the mapping results indicate that about 10-11% of bottom cover and 28-29% of coral cover for both alternatives is in the two highest cover classes (>50%), such areas are not concentrated in any particular biotope or region, but are spread across the dredge zones in relatively low densities (Figure 33).

Within the Direct strata for both the SRF and Polaris Point alternatives, the most-represented class is that of the lowest non-zero coral cover (Class 2 as described above). Of the area in both alternatives that contains any coral, the highest coverage is in the lowest cover level (0-10%). In both alternatives, about 60-62% of area with any coral cover is within Classes 2 and 3 (i.e., 0% < coral ≤ 30%).

It is also of interest to observe the pattern of coral coverage on the small oblong-shaped reef at the northernmost part of the sharp bend in the entrance channel. It is not apparent whether this area was previously dredged or has remained in a natural state. Results of mapping indicate that both the northern and southern "ends" of the reef contain coral predominantly in the higher cover classes (>50% cover). Similarly, the protruding finger at the western end of Jade Shoals that extends into the Direct Impact strata appears to contain relatively high coral cover (Figure 33).

The product of the mean coral abundance percentage and the area of the class can provide a weighted sum that can represent areas of "total coral" (Table 7). When cover is weighted in this manner, the 60% mean coral level contained the largest area for both alternatives. The 5% mean level contained the smallest weighted area for both alternatives. In terms of area of any level of coral cover, the Polaris Point alternative had slightly less cover than the SRF alternative (Table 7).

4.5 INDEX OF CORAL STRESS

We have developed a technique to quantify the stress status of individual *in situ* coral colonies using bio-optical measurements. These measurements provide an index to coral chlorophyll concentration, which is directly related to the integrated stress level of the coral. Corals contain within their tissues photosynthetic dinoflagellates called zooxanthellae. In this symbiosis, zooxanthellae receive protection, a stable light environment and nutrients from the coral (Muscatine 1967,1990). In turn, corals have the benefit of high productivity, and enhanced calcification (Gladfelter 1985).

Since corals and zooxanthellae participate in this mutualistic symbiosis, they are dependent upon each other to flourish. Stress to the coral invariably interrupts this balance, which in turn leads to declines in pigment concentrations through expulsion of zooxanthellae, loss of pigments directly, or both. When the stress is intense or prolonged, pigment loss can reveal the coral's underlying white carbonate skeleton, and the coral appears to have been "bleached." Though the magnitude of this stress response is variable, loss of pigments and/or zooxanthellae is ubiquitous and readily detectable through optical measurements (Hochberg et al. 2006).

Zooxanthellae pigments are the primary absorbing components of corals, and the optical signature (or, more simply, the color) of a coral is determined by its zooxanthellae density and pigment concentration (Hochberg et al. 2003). Inversely, the spectral reflectance of a coral can be used to quantitatively predict pigment concentrations (Hochberg et al. 2006). Spectral reflectance is the fraction of light that reflects from a material surface (i.e., not absorbed by the material) as a function of wavelength. Figure 34 (top) shows an example of coral spectral reflectances, highlighted with pertinent optical features. Based on the shape and magnitude of each spectrum, it is possible to derive corresponding pigment levels.

A common approach is to compute pigment levels on a relative scale, thus avoiding intercalibration issues. NDVI (Normalized Difference Vegetation Index) is one such index that is widely used as a measure of plant chlorophyll abundance and energy absorption (Myneni et al. 1995). NDVI is generally defined as

$$\mathrm{NDVI} = (R_{\mathrm{NIR}} - R_{\mathrm{RED}}) \div (R_{\mathrm{NIR}} + R_{\mathrm{RED}}), \qquad \text{(Eq. 1)}$$

where R_{NIR} is reflectance at a waveband in the near-infrared (in the range 700-1000 nm), and R_{RED} is reflectance at a waveband in the red (600-700 nm) portion of the spectrum. Higher NDVI values correspond to higher chlorophyll concentrations; NDVI values between 0.5 and 1.0 are typically considered to be chlorophyll-rich.

In all, we measured NDVI for a total of 153 individual colonies of *Porites rus* and *P. lutea* at 27 CVN survey sites (Table 8). Figure 35 shows mean NDVI for each sampling site (4-13 corals per site), pooling the species. Figure 34 (bottom) also shows NDVI calculated for the same corals as in Figure 35, using 720 nm for the NIR waveband and 673 nm for the RED waveband.

There is no apparent trend in the horizontal spatial distribution of NDVI, though all values in this study would be generally considered to represent high chlorophyll content. NDVI does increase slightly with depth (not shown), which is a typical response to compensate for lower light (Falkowski et al. 1990).

Figure 36 shows the distribution of NDVI separated by species and by survey stratum. There is a good deal of overlap between species/strata, but a one-way ANOVA does find at least one significant difference in group means ($p << 0.05$). A post-hoc multiple comparison using Tukey-Kramer criteria finds that Direct-Flat *P. lutea* has mean NDVI significantly different (at level $\alpha = 0.05$) from Direct-Flat *P. rus*, Direct-Slope *P. rus*, Indirect-Flat *P. rus* and Indirect-Slope *P. lutea*.

Despite the statistical differences, it is difficult to discern a trend in NDVI with respect to location in the survey area. The exception is that NDVI seems to increase with depth, though this increase is otherwise independent of location. The overall interpretation is that chlorophyll was relatively abundant in all corals across the CVN survey area. This in turn indicates that the corals in the area were not generally stressed at the time of measurement.

4.6 SIZE-FREQUENCY ANALYSIS

Analysis of size-frequency of populations of corals can be an important tool to assess change across space and time (e.g., Bak and Meesters 1998, Meesters et al. 2001, Zvuloni et al. 2008, Viehman et al. 2009). However, while coral colony size frequency distributions can reveal important characteristics of populations on a reef, the metric, like all others, has certain limitations. As pointed out by Bak and Meesters (1998), size is generally dependent on species identity and on environmental setting, with variation between sites small in some species and large in others. Other confounding factors are that size is not always directly related to age, particularly in larger colonies that may not actually consist of true single colonies (Hughes and Jackson 1980). Hence, these authors indicate that the impact of the environment on variation in colony size can be great in some species and low in others. As a result, meaningful use of size-frequency is essentially species and site-specific, requiring the understanding of individual species' life histories under particular environmental regimes.

In addition, and perhaps most relevant for the CVN survey area, certain methodological criteria must be met before the metric of size-frequency can be assumed to provide valid measurements. These criteria include the ability to accurately and reproducibly differentiate colonies. Bak and Meesters (1998) point out the problem of defining individual colonies can usually be overcome, with the exception of branching colonies. Zvuloni et al. (2008) point out that the use of any correction factors to accurately estimate size-frequency of coral colonies is weakened when colonies are large relative to the frame of reference, and that colony size must be small in relation to the sampling unit (quadrat or transect). All of these factors, understanding size relationships for individual species in a particular setting, delineation of discrete colonies from non-discrete colonial growth forms (e.g., branching and conglomerate growth forms), and large colony size relative to sampling unit, come into play with respect to evaluation of coral populations in Apra Harbor.

Acknowledging these limitations, size-frequency of coral colonies was evaluated from transect photo-quadrats using a built-in function of CPCe software to determine greatest chord length. Colonies lying partially within the frame were measured as the section bounded by the quadrat. Correction factors developed by Zvuloni et al. (2008) were not applied as these empirical factors were developed using computer simulations with all colonies of a size that was small compared to the sampling unit. Such a condition clearly did not apply to the coral populations in Apra Harbor (see section 4.2). In addition, use of the "center rule" (Zvuloni et al. 2008) where colonies with centers within the sampling unit are included, but those with centers outside the sampling unit excluded, is not possible with photo-quadrats as centers of colonies outside the sample frame are not visible. As a result, there is an inherent bias in the size-frequency data toward smaller distributions as colonies on the boundaries of the sampling frame will appear smaller than actual size.

Size-frequency distribution of the longest chord length of the four most abundant corals in the CVN survey area are shown as histograms in Figure 37. Histograms are arranged left-to-right by coral species and top-to-bottom by survey stratum, and show mean values determined across all transects within a given stratum for seven size classes ($x < 2$, $2 \leq x < 5$, $5 \leq x < 10$, $10 \leq x < 20$, $20 \leq x < 40$, $40 \leq x < 80$, and $80 \leq x < 160$ cm). For all four corals in all four strata, the least abundant size classes are the smallest ($x<2$ cm) and largest ($80 \leq x < 160$ cm). Of the four species, the largest size occurs predominantly for *Porites rus*, and occasionally for the branching growth forms of *Porites cylindrica* and *Pavona cactus*. *Porites lutea*, which occurs as discrete hemispherical or lobate colonies was never encountered with a long dimension greater than 80 cm. While the mean number of colonies of *Porites rus* varied within each size class in each stratum, the pattern of size class abundance was similar in all stratum (Figure x). In all strata, the two size classes with a lower bound of 5 cm and an upper bound of 20 cm were the most abundant.

Size class distributions of the two branching species (*Porites cylindrica*, *Pavona cactus*) were similar in all strata, although the mean number of small (<10 cm) colonies of *P. cactus* was substantially higher in the Direct Slope stratum than elsewhere. *Porites lutea*, which occurred very rarely in the Direct Impact stratum, had identical patterns of size-frequency distribution in both the Indirect Flat and Indirect Slope strata (Figure x).

4.7 INVERTEBRATE COMMUNITY COMPOSITION

Summaries of invertebrate occurrence, in terms of mobile and sessile species are shown in Tables 9 and 10. Counts of mobile and sessile invertebrates at each transect within each strata are shown in Appendices F and G, respectively. Taxa richness for all invertebrate species is shown in Appendix H.

A total of 55 mobile species from 45 genera were encountered. The grand totals of the mean occurrence of mobile species (individuals per 100 m^2) were higher in both Indirect strata than Direct strata, and higher on the flats of each strata relative to the slopes (Table 9). With one exception, the most abundant phylum in each strata was the Mollusca, followed in order by the Echinodermata, Crustacea, Platyhelminthes, and Cnidaria (the exception being slightly higher crustaceans than echinoderms in the Indirect Slope stratum). Overall, abundance of each phylum was also greater in the indirect strata than direct strata.

A total of 62 sessile species from 34 genera were encountered during surveys (Table 10). Unlike mobile species, the grand totals of the means (individuals per 25 m^2) were higher in both Slope Strata compared to both Flat strata. Overall, there was no consistent pattern of greater abundance between the Direct and Indirect areas. The overwhelmingly dominant phylum of sessile invertebrates in all strata was the Porifera, followed by the Ascidia, and with minor contributions from the Molluscs and Polycheates (Table 10). Probably the most conspicuous member of the Porifera within the survey area was the "elephant-ear sponge" (*Ianthella* spp.), with individuals up to one meter in width commonly occurring in the deeper areas of the harbor floor (Figure 38).

Invertebrate surveys were replicated at three transects during the day and night. The grand total of counts on the three transects was higher at night than during day (Table 11). The greatest difference occurred on Transect 49, where a total of 144 individuals were counted at night compared to 10 during the day. The predominant difference was the occurrence of 117 crustacea at night compared to none during the day. Taxa richness at night was also greater on all transects compared to daytime (Table 12). The greatest difference again occurred on Transect 49 where 15 species of crustacea were encountered at night compared to none during the day.

4.8 SEDIMENT COMPOSITION

The interaction of suspended sediment with benthic communities, particularly corals, will be a topic of considerable importance in estimating the effects of the proposed dredging necessary for the CVN project. It has been documented that effects to corals from increased sedimentation rates can be a function of the composition of the sediment (in terms of carbonates and non-carbonates), as well as the duration and intensity of the sedimentation event (e.g., Weber et al. 2006, Te 2001).

In order to evaluate if such differential effects may be a consideration, composition of surface sediment throughout the Direct Impact area of the CVN survey site was evaluated (Figure 39). Percent calcium carbonate ranged from 79% to 96% (Figure 40), with the lowest value occurring at Transect 50, and the highest at Transects 55 and 35. With the exceptions of the peak values at Transects 55 and 35, there is a rough pattern of increasing percentage carbonate with distance toward the northwest (away from the sources of terrigenous input). Composition at all of the sampling sites seaward of the main dredge area (No's 25, 62, 14 and 4) ranged from 87% to 92% calcium carbonate.

While the landmass of Guam is composed of lithified calcium carbonate, terrigenous-derived sediment is likely to have a substantial carbonate fraction that will not be distinguishable from sediment of marine origin. However, any landmass supporting plant growth will also likely contain erodable soil fractions consisting of both organic material and other non-carbonate minerals. The observed rough gradient of increasing carbonates with distance from the sources of terrigenous material likely reflects such input from erosion and surface discharge. Relative to the total sediment mass, the non-carbonate fractions are relatively small, particularly in the outer regions of the dredge area that are closest to the large patch reefs that border the turning basin.

5 CONCLUSIONS AND DISCUSSION

The results of the surveys described in this report provide a baseline overview of the composition of the benthic marine habitats within the area of Apra Harbor that will be influenced by the CVN project. These findings provide data to address reef classification, metric variability, and reference conditions. Consequently, these surveys results will be valuable for input to modeling efforts to determine compensatory mitigation, as well as for developing future work, particularly with respect to developing efficient and defensible long-term monitoring programs that may be required.

Several major points emerge from the results of these surveys. First, when the entire "reef" community of the CVN area is considered, it is often viewed in a "coral-centric" context, as corals are both the most visually appealing and conspicuous assemblages. However, results of the present surveys indicate that the area is actually more of an algae reef, as overall algal cover (40%) is almost twice overall coral cover (22%). This is particularly true in the Direct Impact strata, where mean coral cover is about 14% of bottom cover for both the Slope and Flat zones. While it is clear that the regulatory process focuses on the coral component, it should be recognized that such an emphasis does not truly represent the whole integrated community.

It is also apparent that the marine habitats are extremely heterogeneous in terms of benthic composition. For instance, Transects 15 (Indirect Slope) and 16 (Indirect Flat) are located less than 50 m apart, and at similar depths (45, 51 ft. respectively). Both had about the same algal cover (~11-13%), but vastly different coral cover (69% T-15; 2% T-16) and sediment cover (14% T-15; 84% T-16). The vastly different composition within a small area indicates substantial variability, which was commonly observed throughout much of the region of study. In addition, multivariate analyses show that benthic communities within strata do not describe discrete groupings that separate the strata.

All of these results indicate that reasonable estimation of impacts is highly dependent on using appropriate survey methods. Because they are limited in area of coverage, and require substantial time in the field, traditional transect methods may not be the most appropriate tool for the question at hand. Based on remote sensing imagery, the area of the Direct Impact strata at depths equal to or shallower than 60 ft (merging the SRF and Polaris Pt. footprints) is about 330,220 m^2. It would take about 330 transects covering 10 m^2 to assess 1% of this region. Even with the relatively rapid *ex situ* field method used in the present study, it would take approximately 55 field days to produce such results, with an even longer amount of time necessary to evaluate the Indirect Strata, as it is larger in size (398,137 m^2). Using estimates of field time per transect for *in situ* methods utilized by Resource Agencies (~3 per day), would require on the order of at least 200 days of field time to survey 1% of the Direct and Indirect areas of concern. Even with such enormous investments of time, there is no certainty that extrapolating data from 1% of the area to the entire region of interest, without utilizing other methods, will provide a valid interpretation on the larger scale.

Similar concerns have obviously occurred in many other studies, and have led to such techniques as Manta tows (e.g., Hill and Wilkinson 2004, Kenyon et al. 2006). Several studies comparing field methods for evaluating reef community structure suggest that many smaller sampling units provide a better estimate than fewer, larger units. For example, Kinzie and Snider (1978) found that the best procedure for evaluating reef composition was to make as many "quick and dirty" short transects as possible, rather than few very detailed surveys. The application of remote sensing to coral reef science, discussed throughout this report, is specifically aimed at providing methods to accurately assess large-scale composition and function of reef communities. Hence, it is of utmost importance that the appropriate methods are utilized to support collecting the best and most appropriate data to answer the question at hand.

Another important issue that emerges from the CVN surveys is that the study area within Apra Harbor represents what may be considered a somewhat unique coral reef setting. Particularly within the dredging envelop, virtually the entire non-living benthic surface consists of calcareous sediment, ranging in grain size from fine silty muds to coral rubble. In addition, in areas where the predominant grain size is in the mud-silt range, sediment is easily re-suspended with subsequent re-deposition. As a result, all of the biotic components of the community must have the physiological adaptations to deal with a physical environment characterized by soft bottoms.

Roy and Smith (1971) were perhaps the first to point out that…"*Lack of light and excessive sediment deposition rates are factors limiting coral reef development. The presence of very turbid water and muddy bottom does not mean, however, that coral growth is prohibited."* These authors go on to describe two distinctly different coral reef communities that both grow on muddy bottoms in Fanning Lagoon. They note that reefs in turbid water (31% coral cover) were ecologically different in terms of such factors as predominant growth forms than communities in clear water (62% cover), but both have the ability to clean themselves of sediment with no lasting impacts, and both are considered equally viable "coral reefs."

A very similar pattern of community composition appears to occur in the CVN survey area. Corals that inhabit the area, and predominantly *Porites rus*, must have the physiological ability to withstand the existing sediment regime. The relatively small number of coral species that make up the preponderance of the coral community may be limited to those with the physiological capability to deal with consistent sediment resuspension and settlement, as well as limited unsedimented surfaces for settlement. As the majority of the Direct impact strata were previously dredged approximately 65 years ago, it can be assumed that the existing communities, particularly on the flat areas, consist primarily of regrowth. As corals occur throughout the area, although with patchy distribution, it is evident that recolonization occurred under high sediment regimes. Observations of corals growing out of the mud, and with areas of muddy deposition on otherwise healthy colonies, indicate that these species have the physiological capabilities to deal well with the existing conditions. In addition, the overwhelming preponderance of *Porites rus* in terms of both area cover and structural magnitude on the patch reef slopes facing away from the turning basin indicate that this species is particularly well adapted to the entire range of physical oceanographic conditions in Apra Harbor.

6 REFERENCES CITED

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TABLE 1. Summary table of general classes of benthic cover on 67 transects in CVN study area of southwestern outer Apra Harbor determined from point counts of photo-quadrats using CPCe software.

TRANSECT NUMBER	ALGAE	CORAL	SOFT CORAL	SPONGE	ASCIDIAN	ECHINO-DERM	SEDIMENT	TOTAL
1	12.00	52.55	0	20.36	0	0	15.09	100
2	73.33	10.80	0	8.13	0	1.07	6.67	100
3	32.00	1.45	0	3.09	0	0	63.45	100
4	36.93	51.33	0	5.87	0	0	5.87	100
5	8.80	70.93	0	17.73	0	0	2.53	100
6	24.13	62.53	0	13.20	0.13	0	0	100
7	18.13	68.80	1.73	0.40	0	0.13	10.80	100
8	16.13	66.00	0	10.13	0	0	7.73	100
9	53.47	21.73	0	23.60	0	0	1.20	100
10	82.46	0.92	0	1.23	0	0.31	15.08	100
11	92.80	0	0	3.07	0	0	4.13	100
12	99.87	0	0	0.00	0	0	0.13	100
13	26.93	61.60	0	3.60	0	0	7.87	100
14	33.87	48.13	0	3.20	0.27	0	14.53	100
15	11.07	68.53	0	6.53	0	0	13.87	100
16	12.93	1.87	0	1.33	0	0	83.87	100
17	36.67	14.40	0	5.87	0	0	43.07	100
18	52.93	27.07	0	1.47	0	0	18.53	100
19	34.27	51.60	0	2.13	0	0	12.00	100
20	90.27	3.33	0	1.07	0	0	5.33	100
21	50.27	20.80	0	0.93	0	0	28.00	100
22	89.20	3.33	0	0.53	0	0	6.93	100
23	63.33	15.33	0	5.73	0	0	15.33	100
24	32.80	4.00	0	0.00	0	0.13	63.07	100
25	61.87	4.00	0	0.80	0	0	33.33	100
26	82.27	4.80	0	1.20	0	0	11.73	100
27	53.73	1.73	0	1.07	0	0	43.47	100
28	5.07	84.53	0	0.00	0	0	10.40	100
29	32.13	40.53	0	0.00	0	0	27.33	100
30	13.60	52.67	8.67	0.13	0	0	24.93	100
31	61.20	30.67	0	2.13	0.13	0	5.87	100
32	4.13	0.80	0	0.00	0	0	95.07	100
33	38.13	1.60	0	0.53	0	0	59.73	100
34	54.80	6.40	0	2.27	0	0	36.53	100
35	23.71	0	0	0.00	0	0	76.29	100
36	3.20	0	0	0.67	0	0	96.13	100
37	20.80	0	0	0.40	0	0	78.80	100
38	0.31	0	0.62	0.00	0	0	99.08	100
39	73.87	5.47	0	0.13	0	0	20.53	100
40	28.13	16.13	0	0.93	0	0	54.80	100
41	65.00	0.86	0	5.86	0	0	28.29	100
42	1.08	0	0	0.00	0	0	98.92	100
43	49.33	34.67	0	1.73	0	0	14.27	100
44	72.13	2.53	0	0.80	0	0	24.53	100
45	66.53	21.07	0	1.73	0	0	10.67	100
46	26.13	19.87	0	0.40	0	0	53.60	100
47	62.80	0.67	0	0.00	0	0	36.53	100
48	37.07	6.00	0	0.00	0	0	56.93	100
49	18.80	48.13	0	3.47	0	0	29.60	100
50	82.67	0	0	0.53	0	0	16.80	100
51	86.15	0.46	0	0.62	0	0	12.77	100
52	8.53	0	0	2.53	0	0	88.93	100
53	0.00	0	0	0.00	0	0	100.00	100
54	21.47	0	0	2.40	0	0	76.13	100
55	23.47	36.93	0	4.80	0	0	34.80	100
56	26.00	12.53	0	6.67	0	0	54.80	100
57	50.67	0	0	0.40	0	0	48.93	100
58	26.40	0	0	2.27	0	0	71.33	100
59	19.33	24.53	0	1.47	0	0	54.67	100
60	85.47	10.00	0	1.60	0	0	2.93	100
61	2.40	86.80	0	6.67	0	0	4.13	100
62	21.87	65.20	0	1.60	0	0	11.33	100
63	7.73	87.87	0	4.00	0	0	0.40	100
64	7.14	0	0	0.14	0	0	92.71	100
65	87.87	0.80	0	1.07	0	0	10.27	100
66	8.14	0.00	0	0.00	0	0	91.86	100
67	56.80	0.27	0	1.33	0	0	41.60	100

TABLE 2. Summary table of percent benthic cover of detailed classes on 67 transects in CVN study area of southwestern Apra Harbor, Guam.

	ALGAE									CORAL																					ECHINODERMS			SEDIMENT				
TRANSECT NUMBER	*Caulerpa* sp.	Coralline algae	Cyanobacteria	*Dictyota* sp.	*Halimeda* sp.	*Hydrolithon gardineri*	Mixed/Unidentified	*Padina* sp.	Turf Algae	*Acropora aspera*	*Acropora nasuta*	*Astreopora myriophthalma*	*Astreopora randalli*	*Fungia echinata*	*Galaxea horrescens*	*Herpolitha limax*	*Lobophyllia (cf.) hataii*	*Lobophyllia corymbosa*	*Lobophyllia hemprichii*	*Montipora verrucosa*	*Pachyseris speciosa*	*Pavona cactus*	*Pavona varians*	*Pocillopora damicornis*	*Porites cylindrica*	*Porites lutea*	*Porites rus*	Soft Coral	Sponge	Ascidian	*Acanthaster planci*	*Bohadshi* sp.	*Holothuria* sp.	Dead Coral	Mud	Rubble	Sand	TOTAL
1	0	0	0.18	0	0	0	0.18	0	11.6	0	0	0	0	0	0	0	0	0	0	0	0	15	0	0	1.5	0.2	36	0	20	0	0	0	0	0	1.45	13.6	0	100
2	0	6.1	12.5	0	0	0	45.5	0	9.2	0	0	0.8	0	0	0	0	0	0	0	0.3	0	0	0	0	0	0.9	8.8	0	8.1	0	1.1	0	0	0.1	3.2	3.33	0	100
3	0	0	24.6	0.73	0.91	0	3.64	0	2.18	0	0	0.9	0	0	0	0	0	0	0	0	0	0	0	0	0	0.2	0.4	0	3.1	0	0	0	0	0	34.0	29.5	0	100
4	0	0	0	0	0	0	18.4	0	18.5	0	0	0	0	0	0	0	0	0	0	0	0.1	11	0	0	0	0	40	0	5.9	0	0	0	0	0	0.93	4.93	0	100
5	0	0	0	0	0	0.8	1.2	0	6.8	0	0	0	0	0	0	0	0	0	0.7	0	0.1	28	0	0	0	1.2	41	0	18	0	0	0	0	0	1.6	0.93	0	100
6	0	0	0	0.13	0.27	0	0.4	23.1	0.27	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.1	0	62	0	13	0.1	0	0	0	0	0	0	0	100
7	0.1	3.6	0.8	0.13	3.6	0.1	2.93	1.47	5.33	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.1	8.3	25	36	1.7	0.4	0	0	0.13	0	0.1	0.93	1.6	8.1	100
8	0	0.1	0	0	1.33	0	4.67	4.67	5.33	0	0	0	0	0	0	0	0	0	0	0	0	0.7	0	0	0	0.4	65	0	10	0	0	0	0	0	7.07	0.67	0	100
9	0	0.1	0	0	4.0	0	14.3	0.8	34.3	19	0	0	0	0	0	0	0	0	0	0	0	0	0	0.3	0	0	2.3	0	24	0	0	0	0	0.8	0.13	0.27	0	100
10	0	1.2	9.54	7.08	12.6	0	48.6	0	3.38	0	0	0	0	0	0.2	0	0	0	0.2	0	0	0	0	0	0	0.3	0.3	0	1.2	0	0	0.31	0	0	14.5	0.62	0	100
11	0	0	0	0	34.3	0	58.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3.1	0	0	0	0	0	3.07	1.07	0	100
12	0	0	0	0	59.1	0	40.8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.13	0	0	100
13	0	2.1	0	0	0	0	0.67	0	24.1	0	0	0	0	0	0	0	0	0	0	0	0	11	0.1	0	1.1	0	50	0	3.6	0	0	0	0	0	3.6	4.13	0.1	100
14	0	0.1	0	0	0	0	24.0	0	9.73	0	0	0	0	0	0.1	0.1	0	0.7	0	0	0	3.3	0	0	0	0	44	0	3.2	0.3	0	0	0	0	4.4	10.1	0	100
15	0	0	0	0	0	0	7.87	0	3.2	0	0	0	0	0	0	0.1	0	0	0	0	0	43	0	0.3	2	0	23	0	6.5	0	0	0	0	0.4	12.4	1.07	0	100
16	0	0	0	0	0	0	5.73	6	1.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1.9	0	0	1.3	0	0	0	0	0	83.3	0.53	0	100
17	0	0.1	0	0.4	8.93	0	19.7	1.33	6.13	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.1	2.1	10	1.7	0	5.9	0	0	0	0	0	25.6	17.5	0	100
18	0	0	0.27	5.73	0	0	43.5	0	3.47	0	0	0	0	0	0	0	0.3	0	0	0.3	0	0	0	0	0	0	27	0	1.5	0	0	0	0	0	10.7	7.87	0	100
19	0	0	0	0	0	0	19.2	0	15.1	0	0	0	0	0	0	0.8	0	0	0	0	0	0	0	0	0	0	51	0	2.1	0	0	0	0	0	7.2	4.8	0	100
20	0	0	0	11.5	37.2	0	41.6	0	0	0	0	0	0	0.3	0	2.5	0	0	0	0	0	0.5	0	0	0	0	0	0	1.1	0	0	0	0	0	5.33	0	0	100
21	0	0	6.4	0.13	2.27	0	32.3	2.67	6.53	0	0	0	0.1	0	0	0	0	0	0.1	0	0	0	0	0	0	0	21	0	0.9	0	0	0	0	0	24.8	3.2	0	100
22	0	0.3	12.7	1.2	17.6	0	53.1	0	4.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3.3	0	0.5	0	0	0	0	0	6.0	0.93	0	100
23	0	0	0.67	0	0.8	0	60.7	0	1.2	0	0	0	0	0	0	0.4	0	0	0	0	0	0	0.3	0	0	1.6	13	0	5.7	0	0	0	0	0	15.3	0	0	100
24	0	0	0	0	9.73	0	23.1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	0	0	0	0	0	0	0.13	0	63.1	0	0	100
25	0.4	0.3	36.1	1.73	0.4	0	19.7	0	3.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.7	3.3	0	0.8	0	0	0	0	0	32.4	0.93	0	100
26	0	0	15.5	0	2.93	0	59.3	0.8	3.73	0	0	0	0	0	0	0	0	0	0.8	0	0	0	0	0	0	0	4	0	1.2	0	0	0	0	0	10.8	0.93	0	100
27	0	0.3	4	0	0	0	43.9	0	5.6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1.7	0	1.1	0	0	0	0	0	42.4	1.07	0	100
28	0	0.4	0.27	0	0	0	0.4	0	4.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	85	0	0	0	0	0	0	0.4	2.53	7.47	0	100
29	0	0.3	0.53	0	0.67	0	16.9	0	13.7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1.3	37	2	0	0	0	0	0	0	0	26.5	0.8	0	100
30	0	0	0.27	0	0	0	2.93	0	10.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1.1	31	21	8.7	0.1	0	0	0	0	0	20.8	4.13	0	100
31	0	0.3	0.67	1.6	0	0.4	50.9	0	7.33	0	0	0	0.5	0	0	0.3	0	1.6	0.4	0	0.1	0	0	0	0	0	28	0	2.1	0.1	0	0	0	0	4.67	1.2	0	100
32	0	0	0.4	0	0	0	3.73	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.8	0	0	0	0	0	0	0	95.1	0	0	100
33	0	0	0.53	7.07	8.27	0	21.1	0	1.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.5	1.1	0	0.5	0	0	0	0	0	55.6	4.0	0.1	100
34	0	0.1	0.93	7.07	0	0	41.6	0	5.07	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6.4	0	2.3	0	0	0	0	0	30.3	6.27	0	100
35	0	0	16.4	0	0	0	7.29	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	76.3	0	0	100
36	0	0	2.4	0	0	0	0.8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.7	0	0	0	0	0	96.1	0	0	100
37	0	0	0.8	0	0	0	20.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.4	0	0	0	0	0	78.8	0	0	100
38	0	0	0.31	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.6	0	0	0	0	0	0	99.1	0	0	100
39	0	0.3	1.07	11.1	28.4	0	32.4	0	0.67	0	0	0	0	0	0	0	0	0	0	0	0	3.1	0	0	0	0	2.4	0	0.1	0	0	0	0	0	18.7	1.87	0	100
40	0	0	0	3.07	0	0	15.2	0	9.87	0	0	1.1	0	0	0.8	0	0	0	0	0	0	0	0	0	0.1	2.5	12	0	0.9	0	0	0	0	0	54.5	0.27	0	100
41	0	0	0	13.4	0	0	47.3	0	4.29	0	0	0	0	0	0.3	0	0	0	0	0	0	0	0	0	0	0	0.6	0	5.9	0	0	0	0	0	28.3	0	0	100
42	0	0	0	0	0	0	0.31	0	0.77	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	98.9	0	0	100
43	0	2	0	4.27	0	0	34.4	0	8.67	0	0	0	0	0	0	0.7	0	0	0	0	0	0	0	0	0.1	1.3	33	0	1.7	0	0	0	0	0	7.87	6.4	0	100
44	0.1	0	0.13	0	1.07	0	67.6	0	3.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2.5	0	0.8	0	0	0	0	0	23.3	1.2	0	100
45	0	0	0	36.7	0	0	27.1	0	2.8	0	0	0	0	0.4	0	3.3	0	0	0	0	0	2.5	0	0	3.3	0	11	0	1.7	0	0	0	0	0	6.8	3.87	0	100
46	2.5	0.7	1.73	5.87	2.27	0	12.0	0	1.07	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.3	12	0	7.9	0	0.4	0	0	0	0	0	51.3	2.27	0	100
47	0	0	1.87	7.87	1.87	0	50.7	0	0.53	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.1	0.5	0	0	0	0	0	0	0	36.0	0.53	0	100
48	0.4	0	0.4	0	0	0	36.3	0	0	0	0	0	0	0	0	0	0	0	0	0	4.1	0	0	0	0	0	1.9	0	0	0	0	0	0	0	56.9	0	0	100
49	0	0	0.53	0	0	0	2.93	0	15.3	0	0	0	0	0	0	0.3	0	0	0	0	0	0	0	0	8.7	0.1	39	0	3.5	0	0	0	0	0	19.9	9.73	0	100
50	0	0	0.13	0	21.7	0	60.8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.5	0	0	0	0	0	16.8	0	0	100
51	0	0	0	9.69	2.77	0	73.7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.5	0	0	0.6	0	0	0	0	0	12.8	0	0	100
52	0	0	0.13	0	6.0	0	1.47	0	0.93	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2.5	0	0	0	0	0	35.9	53.1	0	100
53	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	100	0	0	100
54	0	0	0	0.53	0	0	11.6	9.33	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2.4	0	0	0	0	0	75.6	0.53	0	100
55	0	0	1.2	0	0	0	14.0	0	8.27	0	0	0.9	0	0	0	0	0	0	0	0	0	0	0	0	0	0.7	35	0	4.8	0	0	0	0	0	32.9	1.87	0	100
56	0	0	0.13	0	0	0	20.4	0	5.47	0	0	0	0	0	0	0.7	0	0	0	0	0.1	0	0	0	0.4	0	11	0	6.7	0	0	0	0	0	54.7	0.13	0	100
57	0	0	0	0	0.13	0	50.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.4	0	0	0	0	0	21.1	27.9	0	100
58	0	0	0.93	0	2.4	0	16.0	7.07	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2.3	0	0	0	0	0	29.7	41.6	0	100
59	0	0	3.87	0	0	0	12.9	0	2.53	0.4	0	0	0	0	0	0	0	0	0.1	0	0	0	0	0	0.8	0.1	23	0	1.5	0	0	0	0	0	50	4.67	0	100
60	0	0	0	0	0	0	62.9	20.1	2.4	0	0	0	0	0	0	0	0	0	0	0	0	0.1	0.1	1.6	0	5.9	2.3	0	1.6	0	0	0	0	0	1.47	1.33	0.1	100
61	0	0	0	0	0	0	0.53	0	1.87	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2.5	1.1	83	0	6.7	0	0	0	0	0	1.07	3.07	0	100
62	0	0.1	0	10.5	0	0	7.33	0	3.87	0	0	0	0	0	0	0	0	0	0	0	0	0.3	0	0	4.8	0	60	0	1.6	0	0	0	0	0	7.07	4.27	0	100
63	0	1.2	0	0	0	0	3.33	1.73	1.47	0	17	0	0	0	0.3	0	0	1.1	0	0	0	0	0	0.4	4.9	0	64	0	4	0	0	0	0	0	0.27	0.13	0	100
64	0	0	1	0	0.29	0	5.86	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.1	0	0	0	0	0	92.7	0	0	100
65	0	0	0	0	0	0	60.5	27.3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.1	0	0.5	0.1	0	1.1	0	0	0	0	0	9.47	0.8	0	100
66	0	0	0	0	0.14	0	7.86	0.14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	91.7	0.14	0	100
67	0	0	0.0	0	2.0	0	53.5	1.3	0	0	0	0	0	0	0	0	0	0	0	0	0	0.3	0	0	0	0.3	0	0	1.3	0	0	0.0	0.0	0	17.9	23.7	0	100

TABLE 3. Point count and percent cover of general classes of benthic cover on 67 transects within four strata in the CVN study area of Apra Harbor.

DIRECT FLAT														
POINT COUNTS								PERCENT COVER						
Transect	Algae	Coral	Echino.	SoftCor	Sponge	Sediment	Total	Algae	Coral	Echino.	SoftCor	Sponge	Sediment	Total
5	66	532	0	0	133	19	750	8.8	70.9	0	0	17.7	2.5	100
11	696	0	0	0	23	31	750	92.8	0	0	0	3.1	4.1	100
23	475	115	0	0	43	115	748	63.5	15.4	0	0	5.7	15.4	100
25	464	30	0	0	6	250	750	61.9	4.0	0	0	0.8	33.3	100
26	617	36	0	0	9	88	750	82.3	4.8	0	0	1.2	11.7	100
31	459	230	0	0	16	44	749	61.3	30.7	0	0	2.1	5.9	100
32	31	6	0	0	0	713	750	4.1	0.8	0	0	0	95.1	100
34	411	48	0	0	17	274	750	54.8	6.4	0	0	2.3	36.5	100
35	166	0	0	0	0	534	700	23.7	0	0	0	0	76.3	100
38	2	0	0	4	0	644	650	0.3	0	0	0.6	0	99.1	100
39	554	41	0	0	1	154	750	73.9	5.5	0	0	0.1	20.5	100
40	211	121	0	0	7	411	750	28.1	16.1	0	0	0.9	54.8	100
42	7	0	0	0	0	643	650	1.1	0	0	0	0	98.9	100
43	370	260	0	0	13	107	750	49.3	34.7	0	0	1.7	14.3	100
46	196	149	0	0	3	402	750	26.1	19.9	0	0	0.4	53.6	100
47	471	5	0	0	0	274	750	62.8	0.7	0	0	0	36.5	100
50	620	0	0	0	4	126	750	82.7	0	0	0	0.5	16.8	100
54	161	0	0	0	18	571	750	21.5	0	0	0	2.4	76.1	100
57	380	0	0	0	3	367	750	50.7	0	0	0	0.4	48.9	100
59	145	184	0	0	11	410	750	19.3	24.5	0	0	1.5	54.7	100
62	164	489	0	0	12	85	750	21.9	65.2	0	0	1.6	11.3	100
Subtotal	6666	2246	0	4	319	6262	15497	43.0	14.5	0	0	2.1	40.4	100

DIRECT SLOPE														
POINT COUNTS								PERCENT COVER						
Transect	Algae	Coral	Echino.	SoftCor	Sponge	Sediment	Total	Algae	Coral	Echino.	SoftCor	Sponge	Sediment	Total
4	277	385	0	0	44	44	750	36.9	51.3	0	0	5.9	5.9	100
10	536	6	2	0	8	98	650	82.5	0.9	0.3	0	1.2	15.1	100
12	749	0	0	0	0	1	750	99.9	0	0	0	0	0.1	100
14	254	361	0	0	24	109	748	34.0	48.3	0	0	3.2	14.6	100
21	377	156	0	0	7	210	750	50.3	20.8	0	0	0.9	28.0	100
22	669	25	0	0	4	52	750	89.2	3.3	0	0	0.5	6.9	100
27	403	13	0	0	8	326	750	53.7	1.7	0	0	1.1	43.5	100
33	286	12	0	0	4	448	750	38.1	1.6	0	0	0.5	59.7	100
37	52	0	0	0	1	197	250	20.8	0	0	0	0.4	78.8	100
44	541	19	0	0	6	184	750	72.1	2.5	0	0	0.8	24.5	100
45	499	158	0	0	13	80	750	66.5	21.1	0	0	1.7	10.7	100
48	278	45	0	0	0	427	750	37.1	6	0	0	0	56.9	100
49	141	361	0	0	26	222	750	18.8	48.1	0	0	3.5	29.6	100
51	560	3	0	0	4	83	650	86.2	0.5	0	0	0.6	12.8	100
52	64	0	0	0	19	667	750	8.5	0	0	0	2.5	88.9	100
53	0	0	0	0	0	600	600	0	0	0	0	0	100	100
55	176	277	0	0	36	261	750	23.5	36.9	0	0	4.8	34.8	100
58	198	0	0	0	17	535	750	26.4	0	0	0	2.3	71.3	100
Subtotal	6060	1821	2	0	221	4544	12648	47.9	14.4	0	0	1.7	35.9	100

INDIRECT FLAT														
POINT COUNTS								PERCENT COVER						
Transect	Algae	Coral	Echino.	SoftCor	Sponge	Sediment	Total	Algae	Coral	Echino.	SoftCor	Sponge	Sediment	Total
2	550	81	8	0	61	50	750	73.3	10.8	1.1	0	8.1	6.7	100
3	176	8	0	0	17	349	550	32.0	1.5	0	0	3.1	63.5	100
6	181	469	0	0	99	0	749	24.2	62.6	0	0	13.2	0	100
7	136	516	1	13	3	81	750	18.1	68.8	0.1	1.7	0.4	10.8	100
9	401	163	0	0	177	9	750	53.5	21.7	0	0	23.6	1.2	100
13	202	462	0	0	27	59	750	26.9	61.6	0	0	3.6	7.9	100
16	97	14	0	0	10	629	750	12.9	1.9	0	0	1.3	83.9	100
18	397	203	0	0	11	139	750	52.9	27.1	0	0	1.5	18.5	100
24	246	30	1	0	0	473	750	32.8	4	0.1	0	0	63.1	100
29	241	304	0	0	0	205	750	32.1	40.5	0	0	0	27.3	100
36	24	0	0	0	5	721	750	3.2	0	0	0	0.7	96.1	100
56	195	94	0	0	50	411	750	26.0	12.5	0	0	6.7	54.8	100
60	641	75	0	0	12	22	750	85.5	10	0	0	1.6	2.9	100
Subtotal	3487	2419	10	13	472	3148	9549	36.5	25.3	0.1	0.1	4.9	33	100

INDIRECT SLOPE														
POINT COUNTS								PERCENT COVER						
Transect	Algae	Coral	Echino.	SoftCor	Sponge	Sediment	Total	Algae	Coral	Echino.	SoftCor	Sponge	Sediment	Total
1	66	289	0	0	112	83	550	12.0	52.5	0	0	20.4	15.1	100
8	121	495	0	0	76	58	750	16.1	66.0	0	0	10.1	7.7	100
15	83	514	0	0	49	104	750	11.1	68.5	0	0	6.5	13.9	100
17	275	108	0	0	44	323	750	36.7	14.4	0	0	5.9	43.1	100
19	257	387	0	0	16	90	750	34.3	51.6	0	0	2.1	12	100
20	677	25	0	0	8	40	750	90.3	3.3	0	0	1.1	5.3	100
28	38	634	0	0	0	78	750	5.1	84.5	0	0	0	10.4	100
30	102	395	0	65	1	187	750	13.6	52.7	0	8.7	0.1	24.9	100
41	455	6	0	0	41	198	700	65.0	0.9	0	0	5.9	28.3	100
61	18	651	0	0	50	31	750	2.4	86.8	0	0	6.7	4.1	100
63	58	659	0	0	30	3	750	7.7	87.9	0	0	4.0	0.4	100
64	50	0	0	0	1	649	700	7.1	0	0	0	0.1	92.7	100
65	659	6	0	0	8	77	750	87.9	0.8	0	0	1.1	10.3	100
66	57	0	0	0	0	643	700	8.1	0	0	0	0	91.9	100
67	426	2	0	0	10	312	750	56.8	0.3	0	0	1.3	41.6	100
Subtotal	3342	4171	0	65	446	2876	10900	30.7	38.3	0	0.6	4.1	26.4	100

ALL STRATA														
POINT COUNTS								PERCENT COVER						
Transect	Algae	Coral	Echino.	SoftCor	Sponge	Sediment	Total	Algae	Coral	Echino.	SoftCor	Sponge	Sediment	Total
1-67	19555	10657	12	82	1458	16830	48594	40.2	21.9	0	0.2	3.0	34.6	100

TABLE 4. Prevalence of all coral species identified in photo-quadrats ranked in decreasing order from in point counts from photo-quadrat transect data collected in the CVN survey area.

Coral Species	Count	Fraction	Percentage	Cumulative Pecentage
Porites rus	7935	0.745	74.458	74.458
Porites lutea	959	0.090	8.999	83.457
Pavona cactus	849	0.080	7.967	91.423
Porites cylindrica	409	0.038	3.838	95.261
Acropora aspera	147	0.014	1.379	96.641
Acropora nasuta	130	0.012	1.220	97.861
Herpolitha limax	69	0.006	0.647	98.508
Pachyseris speciosa	35	0.003	0.328	98.836
Astreopora myriophthalma	26	0.002	0.244	99.080
Lobophyllia corymbosa	25	0.002	0.235	99.315
Pocillopora damicornis	24	0.002	0.225	99.540
Lobophyllia hemprichii	17	0.002	0.160	99.700
Acrhelia horrescens	12	0.001	0.113	99.812
Astreopora randalli	5	0.000	0.047	99.859
Fungia echinata	5	0.000	0.047	99.906
Montipora verrucosa	4	0.000	0.038	99.944
Pavona varians	4	0.000	0.038	99.981
Lobophyllia (cf.) hataii	2	0.000	0.019	100.000
TOTAL CORAL POINTS	10657			

TABLE 5. Mean percent benthic cover of clusters derived from Bray-Curtis similarity indices. Top table shows means for six general classes shown in Figure 22. Bottom table shows means for ten detailed classes shown in Figure 23. Note that the values for the detailed clusters do not add to 100% owing to cover of the various uncommon classes that were not included in the 10 detailed groups. For example, in cluster 16, the 10 classes only sum to ~56%. This cluster contains a single transect (#9) that had a very high cover of *A. aspera* , which is not in the subset of 10 detailed classes because it only occurs on this single transect. However, the relatively high cover of turf algae on this transect resulted in separation to a unique cluster.

GENERAL

Cluster	Algae	Coral	Echinoderm	Soft Coral	Sponge	Sediment	TOTAL
1	10.6	0.2	0	0	0.7	88.4	100
2	30.7	11.2	0	0	2.1	56.0	100
3	58.8	22.8	0.1	0	5.7	12.6	100
4	87.9	2.4	0	0	1.1	8.6	100
5	61.3	2.4	0	0	1.4	34.9	100
6	14.0	70.5	0	0.2	7.7	7.7	100
7	27.6	47.1	0	1.2	2.8	21.3	100

DETAILED

Cluster	Mud/Sand	*Porites rus*	Mixed Algae	*Halimeda sp.*	Rubble	*Porites lutea*	*Padina sp.*	Cyanobacteria	Turf Algae	*Pavona cactus*	TOTAL
1	97.0	0.1	1.8	0	0	0	0	0.7	0.1	0	100
2	78.5	0	11.2	0	0.3	0.5	3.8	4.3	0.3	0	99
3	55.2	8.1	20.1	2.9	1.6	1.0	0	1.0	2.9	0	93
4	31.5	1.1	12.1	3.7	28.5	2.2	1.7	12.3	2.5	0	96
5	8.6	4.1	51.6	8.3	1.5	0.3	0.2	12.6	5.2	0	92
6	17.1	3.9	65.7	6.6	0.3	0.5	0	0.2	1.1	0	95
7	5.5	1.2	61.7	0	1.1	3.2	23.7	0	1.2	0.1	98
8	34.2	2.3	45.9	0.5	2.0	0	0	1.7	3.9	0	91
9	19.5	0	52	1.1	25.8	0.1	0.7	0	0	0	99
10	11.0	23.8	37.6	0.5	4.5	0.3	0.5	1.5	5.8	0.5	86
11	9.0	0.8	44.2	33.3	1	0	0	0.4	0.2	1.2	90
12	8.0	37.4	13.5	6.6	5.6	0.2	0	0.2	12.2	7.5	91
13	3.0	69.8	2.8	0.3	2.6	0.2	4.9	0	2.8	0.2	87
14	12.4	23.3	7.9	0	1.1	0	0	0	3.2	42.8	91
15	16.1	19.5	7.6	1.4	2.2	30.9	0.5	0.5	9.8	0	89
16	0.1	2.3	14.3	4.0	0.3	0	0.8	0	34.3	0	56

Table 6a. Confusion matrix for satellite-derived habitat map of CVN survey area. Values are counts of pixels. Diagonal values represent correct classifications; off-diagonal values are misclassifications. To read the table, find the column of the ACTUAL CLASS of interest, then find the row of the PREDICTED CLASS to see how often the former is predicted to be the latter.

		ACTUAL CLASSES					
		coral = 0%	0% < coral ≤ 10%	10% < coral ≤ 30%	30% < coral ≤ 50%	50% < coral ≤ 70%	70% < coral ≤ 90%
PREDICTED CLASSES	coral = 0%	**1508**	85	51	11	15	25
	0% < coral ≤ 10%	80	**129**	45	9	12	6
	10% < coral ≤ 30%	39	34	**59**	15	15	19
	30% < coral ≤ 50%	8	1	5	**42**	16	0
	50% < coral ≤ 70%	10	26	12	25	**127**	10
	70% < coral ≤ 90%	15	1	1	1	5	**33**

Table 6b. Confusion matrix for satellite-derived habitat map of CVN survey area. Values are classification rates (units %). Diagonal values represent correct classifications; off-diagonal values are misclassifications. To read the table, find the column of the ACTUAL CLASS of interest, then find the row of the PREDICTED CLASS to see the rate at which the former is predicted to be the latter. This table evaluates the ability of the classification algorithm to assign observations into appropriate classes (the so-called "producer's accuracy"). For example, 46.7% of the time, the class "0% < coral ≤ 10%" is accurately predicted to be "0% < coral ≤ 10%." Conversely, 12.3% of the time, the same class is incorrectlypredicted to be "10% < coral ≤ 30%."

		ACTUAL CLASSES					
		coral = 0%	0% < coral ≤ 10%	10% < coral ≤ 30%	30% < coral ≤ 50%	50% < coral ≤ 70%	70% < coral ≤ 90%
PREDICTED CLASSES	coral = 0%	**90.8**	30.8	29.5	10.7	7.9	26.9
	0% < coral ≤ 10%	4.8	**46.7**	26	8.7	6.3	6.5
	10% < coral ≤ 30%	2.3	12.3	**34.1**	14.6	7.9	20.4
	30% < coral ≤ 50%	0.5	0.4	2.9	**40.8**	8.4	0
	50% < coral ≤ 70%	0.6	9.4	6.9	24.3	**66.8**	10.8
	70% < coral ≤ 90%	0.9	0.4	0.6	1	2.6	**35.5**

Table 6c. Confusion matrix for satellite-derived habitat map of CVN survey area. Values are observation rates (units %). Diagonal values represent correct classifications; off-diagonal values are misclassifications. To read the table, find the row of the PREDICTED CLASS of interest, then find the column of the ACTUAL CLASS to see the rate at which the former represents the latter. This table evaluates how well the classification product - i.e., the map - represents reality on the ground (the so-called "user's accuracy"). For example, 45.9% of the time, observations predicted as "0% < coral ≤ 10%" are actually that class. Conversely, 16% of the time, observations predicted to be that class are actually "10% < coral ≤ 30%." The rates in this table allow for adjustment of class area estimates.

		ACTUAL CLASSES					
		coral = 0%	0% < coral ≤ 10%	10% < coral ≤ 30%	30% < coral ≤ 50%	50% < coral ≤ 70%	70% < coral ≤ 90%
PREDICTED CLASSES	coral = 0%	**89**	5	3	0.6	0.9	1.5
	0% < coral ≤ 10%	28.5	**45.9**	16	3.2	4.3	2.1
	10% < coral ≤ 30%	21.5	18.8	**32.6**	8.3	8.3	10.5
	30% < coral ≤ 50%	11.1	1.4	6.9	**58.3**	22.2	0
	50% < coral ≤ 70%	4.8	12.4	5.7	11.9	**60.5**	4.8
	70% < coral ≤ 90%	26.8	1.8	1.8	1.8	8.9	**58.9**

TABLE 7. Coral cover for Direct and Indirect strata of SRF and Polaris Pt. alternatives of CVN project, Apra Harbor Guam derived from corrected classified habitat map using Quickbird satellite image. Coral cover is shown as area of 6 classes in top tables, and as weighted sums in bottom tables.

AREA (i.e., number of pixels multiplied by 5.76 m²/pixel)

Coral Level	SRF					
	DIRECT		INDIRECT		TOTAL	
	m^2	acres	m^2	acres	m^2	acres
coral = 0%	149,841	37.03	189,026	46.71	338,867	83.74
0% < coral ≤ 10%	34,445	8.51	53,436	13.20	87,880	21.72
10% < coral ≤ 30%	24,123	5.96	37,204	9.19	61,327	15.15
30% < coral ≤ 50%	9,274	2.29	34,502	8.53	43,776	10.82
50% < coral ≤ 70%	18,190	4.49	44,628	11.03	62,819	15.52
70% < coral ≤ 90%	10,051	2.48	21,266	5.25	31,317	7.74
TOTAL W/CORAL	**96,083**	**23.74**	**191,036**	**47.21**	**287,119**	**70.95**

Coral Level	POLARIS PT.					
	DIRECT		INDIRECT		TOTAL	
	m^2	acres	m^2	acres	m^2	acres
coral = 0%	186,065	45.98	219,997	54.36	406,063	100.34
0% < coral ≤ 10%	37,411	9.24	54,541	13.48	91,953	22.72
10% < coral ≤ 30%	26,058	6.44	38,523	9.52	64,581	15.96
30% < coral ≤ 50%	9,590	2.37	32,527	8.04	42,117	10.41
50% < coral ≤ 70%	17,960	4.44	41,898	10.35	59,858	14.79
70% < coral ≤ 90%	10,950	2.71	19,642	4.85	30,591	7.56
TOTAL W/CORAL	**101,969**	**25.20**	**187,131**	**46.24**	**289,100**	**71.44**

WEIGHTED SUMS

Coral Level	SRF					
	DIRECT		INDIRECT		TOTAL	
	m^2	acres	m^2	acres	m^2	acres
5%	1,722	0.43	2,672	0.66	4,394	1.09
20%	4,825	1.19	7,441	1.84	12,265	3.03
40%	3,709	0.92	13,801	3.41	17,510	4.33
60%	10,914	2.70	26,777	6.62	37,691	9.31
80%	8,041	1.99	17,013	4.20	25,054	6.19
TOTAL	**29,211**	**7.22**	**67,703**	**16.73**	**96,915**	**23.95**

Coral Level	POLARIS PT.					
	DIRECT		INDIRECT		TOTAL	
	m^2	acres	m^2	acres	m^2	acres
5%	1,871	0.46	2,727	0.67	4,598	1.14
20%	5,212	1.29	7,705	1.90	12,916	3.19
40%	3,836	0.95	13,011	3.21	16,847	4.16
60%	10,776	2.66	25,139	6.21	35,915	8.87
80%	8,760	2.16	15,713	3.88	24,473	6.05
TOTAL	**30,454**	**7.53**	**64,295**	**15.89**	**94,749**	**23.41**

Table 8. Normalized Difference Vegetation Index (NDVI) for *Porites rus* and *P. lutea* in CVN survey area of Apra Harbor. Each row in the table represents an individual coral colony. Mean spectral reflectance R(λ) for each colony was calculated from 15-20 measurements.NDVI was calculated as [R(720) - R(673)] / [R(720) + R(673)]. NDVI is a relative index that increases with increasing chlorophyll content to a maximum value of one.

DIRECT - FLAT			
TRANSECT	SPECIES	DEPTH (m)	NDVI
5	*Porites rus*	18.0	0.603
5	*Porites rus*	18.0	0.727
5	*Porites rus*	18.0	0.641
5	*Porites lutea*	18.0	0.692
5	*Porites rus*	18.0	0.674
5	*Porites rus*	18.0	0.737
25	*Porites lutea*	15.2	0.657
25	*Porites lutea*	15.2	0.677
25	*Porites lutea*	15.2	0.622
25	*Porites rus*	15.2	0.665
25	*Porites rus*	15.2	0.523
25	*Porites lutea*	15.2	0.652
26	*Porites rus*	14.9	0.679
26	*Porites rus*	14.9	0.616
26	*Porites rus*	14.9	0.549
26	*Porites rus*	14.9	0.646
26	*Porites rus*	14.9	0.615
31	*Porites rus*	16.8	0.717
31	*Porites lutea*	16.8	0.818
31	*Porites rus*	16.8	0.729
31	*Porites rus*	16.8	0.633
31	*Porites rus*	16.8	0.696
32	*Porites lutea*	14.6	0.708
32	*Porites lutea*	14.6	0.807
32	*Porites lutea*	14.6	0.802
32	*Porites lutea*	14.6	0.762
32	*Porites lutea*	14.6	0.832
32	*Porites lutea*	14.6	0.647
40	*Porites lutea*	14.6	0.829
40	*Porites lutea*	14.6	0.702
40	*Porites lutea*	14.6	0.580
40	*Porites lutea*	14.6	0.766
43	*Porites rus*	14.0	0.528
43	*Porites rus*	14.0	0.741
43	*Porites lutea*	14.0	0.742
43	*Porites rus*	14.0	0.551
43	*Porites rus*	14.0	0.683
46	*Porites rus*	15.2	0.578
46	*Porites rus*	15.2	0.631
46	*Porites lutea*	15.2	0.678
46	*Porites lutea*	15.2	0.756

DIRECT - SLOPE			
TRANSECT	SPECIES	DEPTH (m)	NDVI
14	*Porites rus*	16.2	0.586
14	*Porites lutea*	16.2	0.716
14	*Porites rus*	16.2	0.673
14	*Porites lutea*	16.2	0.575
14	*Porites rus*	16.2	0.660
21	*Porites lutea*	16.5	0.768
21	*Porites rus*	16.5	0.596
21	*Porites rus*	16.5	0.648
21	*Porites lutea*	16.5	0.799
21	*Porites lutea*	16.5	0.676
22	*Porites rus*	15.2	0.681
22	*Porites rus*	15.2	0.688
22	*Porites rus*	15.2	0.669
22	*Porites rus*	15.2	0.586
22	*Porites rus*	15.2	0.619
44	*Porites rus*	14.9	0.622
44	*Porites lutea*	14.9	0.658
44	*Porites lutea*	14.9	0.516
44	*Porites rus*	14.9	0.649
44	*Porites rus*	14.9	0.613
44	*Porites lutea*	14.9	0.768
45	*Porites lutea*	14.9	0.719
45	*Porites rus*	14.9	0.612
45	*Porites rus*	14.9	0.628
45	*Porites rus*	14.9	0.536
45	*Porites lutea*	14.9	0.492
51	*Porites lutea*	3.7	0.632
51	*Porites lutea*	3.0	0.518
51	*Porites lutea*	2.7	0.599
51	*Porites lutea*	4.0	0.521
51	*Porites rus*	3.4	0.585
51	*Porites lutea*	4.6	0.661
53	*Porites lutea*	18.3	0.717
53	*Porites lutea*	18.3	0.633
53	*Porites lutea*	18.3	0.728
53	*Porites lutea*	18.3	0.705
53	*Porites lutea*	18.3	0.732

INDIRECT - FLAT			
TRANSECT	SPECIES	DEPTH (m)	NDVI
2	*Porites rus*	16.2	0.608
2	*Porites rus*	16.2	0.692
2	*Porites rus*	16.2	0.687
2	*Porites rus*	16.2	0.575
2	*Porites lutea*	16.2	0.777
18	*Porites rus*	16.5	0.737
18	*Porites rus*	16.5	0.562
18	*Porites rus*	16.5	0.547
18	*Porites lutea*	16.5	0.682
18	*Porites lutea*	16.5	0.726
18	*Porites rus*	16.5	0.686
24	*Porites lutea*	0.9	0.653
24	*Porites lutea*	0.9	0.647
24	*Porites lutea*	0.9	0.625
24	*Porites lutea*	0.9	0.649
24	*Porites lutea*	0.9	0.618
29	*Porites lutea*	0.9	0.575
29	*Porites lutea*	0.9	0.667
29	*Porites lutea*	0.9	0.702
29	*Porites lutea*	0.9	0.608
29	*Porites lutea*	0.9	0.727
29	*Porites rus*	0.9	0.425
56	*Porites rus*	16.8	0.720
56	*Porites rus*	16.8	0.663
56	*Porites rus*	16.8	0.634
56	*Porites lutea*	16.8	0.757
56	*Porites rus*	16.8	0.542
60	*Porites lutea*	0.9	0.776
60	*Porites lutea*	0.9	0.558
60	*Porites lutea*	0.9	0.727
60	*Porites rus*	0.9	0.610
60	*Porites lutea*	0.9	0.729
60	*Porites rus*	0.9	0.663

INDIRECT - SLOPE			
TRANSECT	SPECIES	DEPTH (m)	NDVI
15	*Porites lutea*	13.7	0.437
15	*Porites lutea*	13.7	0.612
15	*Porites rus*	13.7	0.577
15	*Porites rus*	13.7	0.647
15	*Porites lutea*	12.2	0.527
15	*Porites rus*	12.8	0.732
15	*Porites lutea*	12.2	0.760
15	*Porites lutea*	12.8	0.689
15	*Porites rus*	12.8	0.637
15	*Porites rus*	13.1	0.670
15	*Porites lutea*	12.2	0.722
15	*Porites rus*	12.2	0.687
15	*Porites rus*	11.6	0.608
17	*Porites lutea*	2.4	0.525
17	*Porites lutea*	2.4	0.556
17	*Porites rus*	2.4	0.635
17	*Porites rus*	2.4	0.588
17	*Porites lutea*	2.4	0.522
17	*Porites rus*	2.4	0.588
17	*Porites lutea*	2.4	0.608
19	*Porites rus*	15.2	0.658
19	*Porites rus*	15.2	0.796
19	*Porites rus*	15.2	0.842
19	*Porites rus*	15.2	0.719
19	*Porites rus*	15.2	0.680
19	*Porites rus*	15.2	0.673
30	*Porites lutea*	3.7	0.602
30	*Porites rus*	3.7	0.649
30	*Porites lutea*	3.7	0.630
30	*Porites rus*	3.7	0.621
30	*Porites lutea*	3.7	0.606
30	*Porites rus*	3.7	0.555
30	*Porites rus*	3.7	0.586
41	*Porites rus*	12.8	0.685
41	*Porites lutea*	12.8	0.660
41	*Porites rus*	12.8	0.716
41	*Porites rus*	12.8	0.673
41	*Porites lutea*	12.8	0.697
65	*Porites lutea*	2.1	0.533
65	*Porites lutea*	2.1	0.715
65	*Porites lutea*	2.1	0.638
65	*Porites lutea*	2.1	0.609

TABLE 9. Mean (SE) density of mobile invertebrates (individuals per100 m^2) by strata.

			STRATA			
Phylum	**Genus**	**Species**	**Direct-Flat**	**Direct-Slope**	**Indirect-Flat**	**Indirect-Slope**
Cnidaria	Boloceroides	mcmurrichi	0.05 (0.01)	0 (0)	0 (0)	0 (0)
Cnidaria Total			0.05 (0.01)	0 (0)	0 (0)	0 (0)
Crustacea	Alpheus	sp.	0 (0)	0 (0)	0 (0)	0.07 (0.02)
	Calcinus	minutus	0.15 (0.03)	0.31 (0.08)	0.75 (0.22)	0.21 (0.06)
		pulcher	0.05 (0.01)	0.38 (0.1)	0.33 (0.1)	1 (0.27)
		spp.	0.1 (0.02)	0.13 (0.03)	0.75 (0.22)	0.93 (0.25)
	crab	sp.	0 (0)	0 (0)	0 (0)	0.07 (0.02)
		sp. (blue)	0.05 (0.01)	0 (0)	0 (0)	0 (0)
	Dardanus	guttatus	0 (0)	0 (0)	0.17 (0.05)	0 (0)
	Palaemonid	sp.	0 (0)	0 (0)	0 (0)	0.07 (0.02)
	Periclimenes	soror	0.05 (0.01)	0 (0)	0.08 (0.02)	0 (0)
	Saron	marmoratus	0 (0)	0.06 (0.02)	0 (0)	0 (0)
	seethrough shrimp	(blank)	0.2 (0.04)	0.13 (0.03)	0 (0)	0.14 (0.04)
	shrimp	sp. (clear)	0 (0)	0.06 (0.02)	0 (0)	0 (0)
		sp. (goby)	0.05 (0.01)	0 (0)	0.58 (0.17)	0 (0)
Crustacea Total			0.65 (0.15)	1.06 (0.27)	2.67 (0.77)	2.5 (0.67)
Echinodermata	Actinpyga	mauritiana	0 (0)	0 (0)	0.08 (0.02)	0 (0)
	Bohadschia	argus	0.05 (0.01)	0 (0)	0.33 (0.1)	0.14 (0.04)
	Culcita	novaeguineae	0.35 (0.08)	0.19 (0.05)	0.17 (0.05)	0.07 (0.02)
	Echinaster	luzonicus	0 (0)	0.06 (0.02)	0 (0)	0 (0)
	Echinometra	mathei	0.05 (0.01)	0.06 (0.02)	0.42 (0.12)	0.29 (0.08)
	Echinostrephus	aciculatus	0 (0)	0 (0)	0.92 (0.27)	0.14 (0.04)
	Echinothrix	sp.	0 (0)	0 (0)	0.08 (0.02)	0 (0)
	Euapta	godeffroyi	0 (0)	0.06 (0.02)	0 (0)	0 (0)
	Holothuria	atra	0 (0)	0 (0)	1.75 (0.51)	0.79 (0.21)
	Linkia	laevigata	0 (0)	0 (0)	0 (0)	0.14 (0.04)
		multifera	0 (0)	0 (0)	0.17 (0.05)	0.07 (0.02)
	Ophiocoma	sp.	0 (0)	0 (0)	0 (0)	0.07 (0.02)
	Ophiomastix	caryophyllata	0 (0)	0.25 (0.06)	0 (0)	0.07 (0.02)
	Ophiurid	sp.1	2.15 (0.48)	0.06 (0.02)	0 (0)	0.14 (0.04)
		sp.2 (small)	0.05 (0.01)	0 (0)	0 (0)	0 (0)
	Pearsonothuria	graeffei	0 (0)	0.19 (0.05)	0 (0)	0.07 (0.02)
Echinodermata Total			2.65 (0.59)	0.88 (0.22)	3.92 (1.13)	2 (0.53)
Mollusca	Cerithium	columna	1.4 (0.31)	2.44 (0.61)	2.67 (0.77)	1.43 (0.38)
	Chromodoris	fidelis	0.05 (0.01)	0 (0)	0 (0)	0 (0)
	Clypeomorus	nympha	0.4 (0.09)	0 (0)	0.42 (0.12)	2.36 (0.63)
	Coralliophila	violacea	1.5 (0.34)	1.69 (0.42)	5.83 (1.68)	14 (3.74)
	Cymatium	nicobaricum	0 (0)	0 (0)	0 (0)	0.07 (0.02)
		sp.	0 (0)	0 (0)	0.08 (0.02)	0 (0)
	Cypraea	contaminata	0 (0)	0 (0)	0 (0)	0.07 (0.02)
		erosa	0 (0)	0 (0)	0 (0)	0.07 (0.02)
		mappa	0 (0)	0.06 (0.02)	0 (0)	0 (0)
	Euplica	deshayesii	0.35 (0.08)	0.19 (0.05)	9 (2.6)	0.36 (0.1)
	Glossodoris	atromarginata	0.05 (0.01)	0 (0)	0 (0)	0.14 (0.04)
	Habromorula	spinosa	0 (0)	0.75 (0.19)	0.17 (0.05)	0.64 (0.17)
	Hypselodoris	whitei	0 (0)	0 (0)	0 (0)	0.07 (0.02)
	Lambis	lambis	0.1 (0.02)	0.13 (0.03)	0.08 (0.02)	0.07 (0.02)
	Mitra	sp.	0 (0)	0.06 (0.02)	0 (0)	0 (0)
	Nerita	sp.	0 (0)	0 (0)	0.08 (0.02)	0 (0)
	Noumea	angustolutea	0 (0)	0.06 (0.02)	0 (0)	0 (0)
	Pteraeolidia	ianthina	0 (0)	0 (0)	0 (0)	0.07 (0.02)
	snail	spp.	0.05 (0.01)	0 (0)	0 (0)	0 (0)
	Strombus	gibberulus	0 (0)	0.06 (0.02)	0.17 (0.05)	0 (0)
		luhuanus	4.9 (1.1)	0 (0)	0.25 (0.07)	0.14 (0.04)
	Thais	sp.	0 (0)	0 (0)	0.08 (0.02)	0 (0)
	Trochus	niloticus	0 (0)	0 (0)	0.42 (0.12)	0 (0)
	Vasum	turbinellus	0 (0)	0 (0)	0 (0)	0.07 (0.02)
Mollusca Total			8.8 (1.97)	5.44 (1.36)	19.25 (5.56)	19.57 (5.23)
Platyhelminthes	flatworm	sp.	0 (0)	0.06 (0.02)	0 (0)	0 (0)
Platyhelminthes Total			0 (0)	0.06 (0.02)	0 (0)	0 (0)
Grand Total			12.15 (2.72)	7.44 (1.86)	25.83 (7.46)	24.07 (6.43)

TABLE 10. Mean (SE) density of sessile invertebrates (individuals per 25 m^2) by strata.

Phylum	Genus	Species	STRATA			
			Direct-Flat	Direct-Slope	Indirect-Flat	Indirect-Slope
ASCIDIA	Ascidia	sp.	0.1 (0.02)	0.06 (0.02)	0.08 (0.02)	0.14 (0.04)
	Clavelina	moluccensis	1.35 (0.3)	0.69 (0.17)	0.08 (0.02)	0 (0)
	Lissoclinum	calycis	0.05 (0.01)	0 (0)	0.08 (0.02)	0.21 (0.06)
	Phallusia	julinea	2.95 (0.66)	3.94 (0.99)	3.5 (1.01)	10.43 (2.79)
	Polycarpa	sp.	0.7 (0.16)	0.75 (0.19)	0.83 (0.24)	1.71 (0.46)
	Rhopalaea	crassa	0.65 (0.15)	0.88 (0.22)	0.92 (0.27)	2 (0.53)
		sp.	3.8 (0.85)	5.56 (1.39)	3.75 (1.08)	6.29 (1.68)
ASCIDIA Total			9.6 (2.15)	11.88 (2.97)	9.25 (2.67)	20.79 (5.56)
MOLLUSCA	Pinctada	sp.	0.4 (0.09)	0.56 (0.14)	0.83 (0.24)	0.86 (0.23)
MOLLUSCA Total			0.4 (0.09)	0.56 (0.14)	0.83 (0.24)	0.86 (0.23)
POLYCHEATA	Sabellastarte	indica	0 (0)	0 (0)	0 (0)	0.43 (0.11)
POLYCHEATA Total			0 (0)	0 (0)	0 (0)	0.43 (0.11)
PORIFERA	Aplysinella	rhax	7.95 (1.78)	14.38 (3.6)	10.5 (3.03)	7.57 (2.02)
	Axinella	sp.	0 (0)	0 (0)	0.67 (0.19)	0.07 (0.02)
	Axynissa	sp.	2.75 (0.61)	4.81 (1.2)	3.92 (1.13)	3.57 (0.95)
	Callyspongia	diffusa	3.6 (0.8)	6.38 (1.6)	0.33 (0.1)	1.64 (0.44)
		sp.	0.45 (0.1)	0.06 (0.02)	0.58 (0.17)	0.71 (0.19)
	Ceratopsion	sp.	4.1 (0.92)	2.56 (0.64)	3.17 (0.92)	1.93 (0.52)
	Chelonaplysilla	sp.	0.05 (0.01)	0.19 (0.05)	0 (0)	0.14 (0.04)
	Cinachyra	sp.	0.05 (0.01)	0.13 (0.03)	0.08 (0.02)	0.29 (0.08)
	Clathria	basilana	0.85 (0.19)	0.13 (0.03)	0.08 (0.02)	1.64 (0.44)
		eurypa	4.25 (0.95)	5.69 (1.42)	6.08 (1.76)	3 (0.8)
		hirsuta	0.05 (0.01)	0.94 (0.24)	0.42 (0.12)	0.71 (0.19)
		mima	0.3 (0.07)	0.81 (0.2)	0.58 (0.17)	0.64 (0.17)
		sp.	0.1 (0.02)	0.19 (0.05)	0.17 (0.05)	0.36 (0.1)
	Corticum	sp.	0.05 (0.01)	0.5 (0.13)	0.08 (0.02)	0.57 (0.15)
	Craniella	abracadabra	0 (0)	0.06 (0.02)	0 (0)	0 (0)
	Dragmacidon	sp.	2.05 (0.46)	2 (0.5)	0.25 (0.07)	4.5 (1.2)
		(blank)	0.25 (0.06)	0 (0)	0 (0)	0 (0)
	Dysidea	sp.	0.2 (0.04)	0.38 (0.1)	0.33 (0.1)	0.93 (0.25)
	Haliclona	(Reniera)	3.4 (0.76)	6.19 (1.55)	2.08 (0.6)	4.71 (1.26)
		sp. (blue)	3.65 (0.82)	2.5 (0.63)	3.25 (0.94)	7.43 (1.99)
	Hyrtios	altum	0.05 (0.01)	0.06 (0.02)	1.17 (0.34)	1.79 (0.48)
		erecta	0 (0)	0.06 (0.02)	0.42 (0.12)	0 (0)
	Ianthella	basta	0.35 (0.08)	1.75 (0.44)	0.67 (0.19)	0.36 (0.1)
		ditrochota	0 (0)	0 (0)	0 (0)	0.14 (0.04)
	Iotrochota	baculifera	0.2 (0.04)	0.31 (0.08)	0 (0)	0.21 (0.06)
		ditrochota	2 (0.45)	4.06 (1.02)	5.42 (1.56)	1.71 (0.46)
		protea	8.9 (1.99)	6.5 (1.63)	4.83 (1.39)	7.43 (1.99)
	Liosina	cf. granulosa	1.8 (0.4)	3.88 (0.97)	4.25 (1.23)	5.93 (1.58)
	Melophlus	sarasinorum	0.75 (0.17)	1.5 (0.38)	3 (0.87)	1.93 (0.52)
	Monanchora	clathrata	0.05 (0.01)	0.25 (0.06)	0 (0)	0 (0)
	Paratetilla	bacca	0.05 (0.01)	0 (0)	0 (0)	0.07 (0.02)
	Plakina	sp.	0.3 (0.07)	1.13 (0.28)	0.58 (0.17)	0.29 (0.08)
	Porifera	sp.1 (Sponge tough)	0.1 (0.02)	0.13 (0.03)	0 (0)	0.07 (0.02)
		sp.10 (Fake myrmekioderma)	0 (0)	0.06 (0.02)	0 (0)	0 (0)
		sp.11 (Haliclona osiris)	0 (0)	0 (0)	0 (0)	0.07 (0.02)
		sp.12 (white Dysidea 166)	0 (0)	0.06 (0.02)	0 (0)	0 (0)
		sp.13 (Dysidea/Clathria like 179-180)	0.05 (0.01)	0 (0)	0 (0)	0 (0)
		sp.14 (brown Xestospongia-like 183)	0 (0)	0 (0)	0.08 (0.02)	0 (0)
		sp.2 (Sponge green)	0 (0)	0 (0)	0 (0)	0.07 (0.02)
		sp.3 (orange/red Haliclona like)	0.65 (0.15)	0.38 (0.1)	1.42 (0.41)	0.79 (0.21)
		sp.4 (Dysidea like 0021)	0 (0)	0 (0)	0 (0)	0.07 (0.02)
		sp.5 (white Callyspongia)	0 (0)	0 (0)	0 (0)	0.14 (0.04)
		sp.6 (green Clathria)	0 (0)	0.19 (0.05)	0.17 (0.05)	0 (0)
		sp.7 (green/purple Tedania 141)	0 (0)	0.19 (0.05)	0 (0)	0 (0)
		sp.8 (Haliclona gracilis)	0 (0)	0 (0)	0.08 (0.02)	0 (0)
		sp.9 (black net cover 101)	0 (0)	0 (0)	0.08 (0.02)	0 (0)
	Pseudoceratina	sp.	0.65 (0.15)	0.38 (0.1)	0.42 (0.12)	0.21 (0.06)
	Sylissa	massa	1.5 (0.34)	3.06 (0.77)	4.92 (1.42)	7.71 (2.06)
	Tedania	meandrica	2.55 (0.57)	2.13 (0.53)	2.33 (0.67)	4.21 (1.13)
		sp.	0.05 (0.01)	0 (0)	0.08 (0.02)	0 (0)
	Ulosa	spongia	3.55 (0.79)	4.19 (1.05)	2.08 (0.6)	7.5 (2)
	Xestospongia	carbonaria	2 (0.45)	0.88 (0.22)	11 (3.18)	15.29 (4.09)
		exigua	1.3 (0.29)	0.63 (0.16)	0.42 (0.12)	0.36 (0.1)
PORIFERA Total			60.95 (13.63)	79.63 (19.91)	76 (21.94)	96.79 (25.87)
Grand Total			70.95 (15.86)	92.06 (23.02)	86.08 (24.85)	118.86 (31.77)

TABLE 11. Macro Invertebrate counts on three tramsects (15, 49, 61) during the day and at night. Surveys were conducted on the same belt transect.

			15		49		61	
Phylum	**Genus**	**Species**	**Day**	**Night**	**Day**	**Night**	**Day**	**Night**
Cnidaria	Ceriantharia	sp.				1		
Cnidaria Total						1		
Crustacea	Alpheus	sp.				1		
	Calcinus	pulcher					4	
		spp.						4
	Carupa	ohashi						1
	Cinetorhynchus	concolor		1		18		
		hawaiiensis		9		72		7
		hendersoni				1		
		reticulatus				3		
	Dardanus	guttatus						1
	Galtheid	sp.		1				
		sp.1				1		
		sp.2				2		
	Palaemonid	sp.		1		1		
	Periclimenes	sp.				1		1
	Portunid	sp.2						1
		sp.3				4		
		sp.4		1				
		sp.5		1				
		sp.6		5				
		sp.7		1				
	Saron	marmoratus		2				
		sp.				2		
	Shrimp	sp.				4		
	Thalamita	cerasma		1		4		1
		sp.				3		
	Xanthid	sp.		1				
Crustacea Total				24		117	4	16
Echinodermata	Echinometra	mathei		4	1	3		3
	Euapta	godeffroyi				1		1
	Linkia	guildingi						2
		multifera						4
	Ophiurid	sp.1					2	3
	Phyllacanthus	imperialis						5
	Tripneustes	gratilla				1		
Echinodermata Total				4	1	5	2	18
Mollusca	Cerithium	columna	3	6		1	2	21
		echinatum		2				
		sp.						1
	Clypeomorus	nympha	1				2	16
	Coralliophila	violacea	15	8	5		19	9
	Costellarid	sp.				1		
	Cypraea	carneola						1
		mappa			1			
		tigris						1
		vitellus		1				
	Drupella	rugosa		1				
		sp.		1				
	Euplica	deshayesii		4	3	1		
	Habromorula	spinosa				1	2	1
	Jorunna	funebris				1		
	Vexillum	sp.				16		
Mollusca Total			19	23	9	21	25	50
Grand Total			19	51	10	144	31	84

TABLE 12. Macro Inverebrate Taxa Richness at three sites during the day and at night. Surveys were conducted on the same belt transects.

TRANSECT			15		49		61	
Phylum	**Genus**	**Species**	**Day**	**Night**	**Day**	**Night**	**Day**	**Night**
Cnidaria	Aptasia	sp.						1
	Ceriantharia	sp.				1		
Cnidaria Total						1		1
Crustacea	Alpheus	sp.				1	1	
	Atergatis	latissimus				1		
	Calcinus	pulcher					1	
		spp.						1
	Carupa	ohashi						1
	Cinetorhynchus	concolor		1		1		
		hawaiiensis		1		1		1
		hendersoni				1		
		reticulatus				1		
	Dardanus	guttatus						1
	Galtheid	sp.		1				
		sp.2				1		
	Glatheid	sp.1				1		
	Palaemonid	sp.		1		1		
	Periclimenes	sp.				1		1
	Portunid	sp.2						1
		sp.3				1		
		sp.4		1				
		sp.5		1				
		sp.6	1	1				
		sp.7		1				
		sp.8		1				
	Saron	marmoratus		1				
		sp.				1		
	Shrimp	sp.				1		
	Stenopus	hispidus						1
	Thalamita	cerasma		1		1		1
		sp.				1		
	Xanthid	sp.		1				
Crustacea Total			1	12		15	2	8
Echinodermata	Echinometra	mathei		1	1	1		1
	Euapta	godeffroyi				1		1
	Leiaster	lechii						1
	Linkia	guildingi						1
		multifera						1
	Ophiactis	savignyi						1
	Ophiurid	sp.1					1	1
	Phyllacanthus	imperialis						1
	Tripneustes	gratilla				1		
Echinodermata Total				1	1	3	1	8
Mollusca	Arca	avellana		1				
		ventricosa	1	1		1	1	1
	Cerithium	columna	1	1		1	1	1
		echinatum		1				
		sp.						1
	Chama	iostoma			1	1		
	Clypeomorus	nympha	1				1	1
	Conus	geographicus						1
	Coralliophila	violacea	1	1	1		1	1
	Costellarid	sp.				1		
	Cypraea	carneola						1
		mappa			1			
		tigris						1
		vitellus		1				
	Dendropoma	maxima	1	1			1	1
	Drupella	rugosa		1				
		sp.		1				
	Euplica	deshayesii		1	1	1		
	Habromorula	spinosa				1	1	1
	Isognomon	sp.			1	1	1	1
	Jorunna	funebris				1		1
	Lithophagia	sp.	1	1	1	1	1	1
	Malleus	decurtatus	1					
	Spondylous	violacenscens					1	
	Vexillum	sp.				2		
Mollusca Total			7	11	6	11	9	13
Polychaeta	Sabellastarte	spectabilis		1	1	1	1	
Polychaeta Total				1	1	1	1	
Grand Total			8	25	8	31	13	30

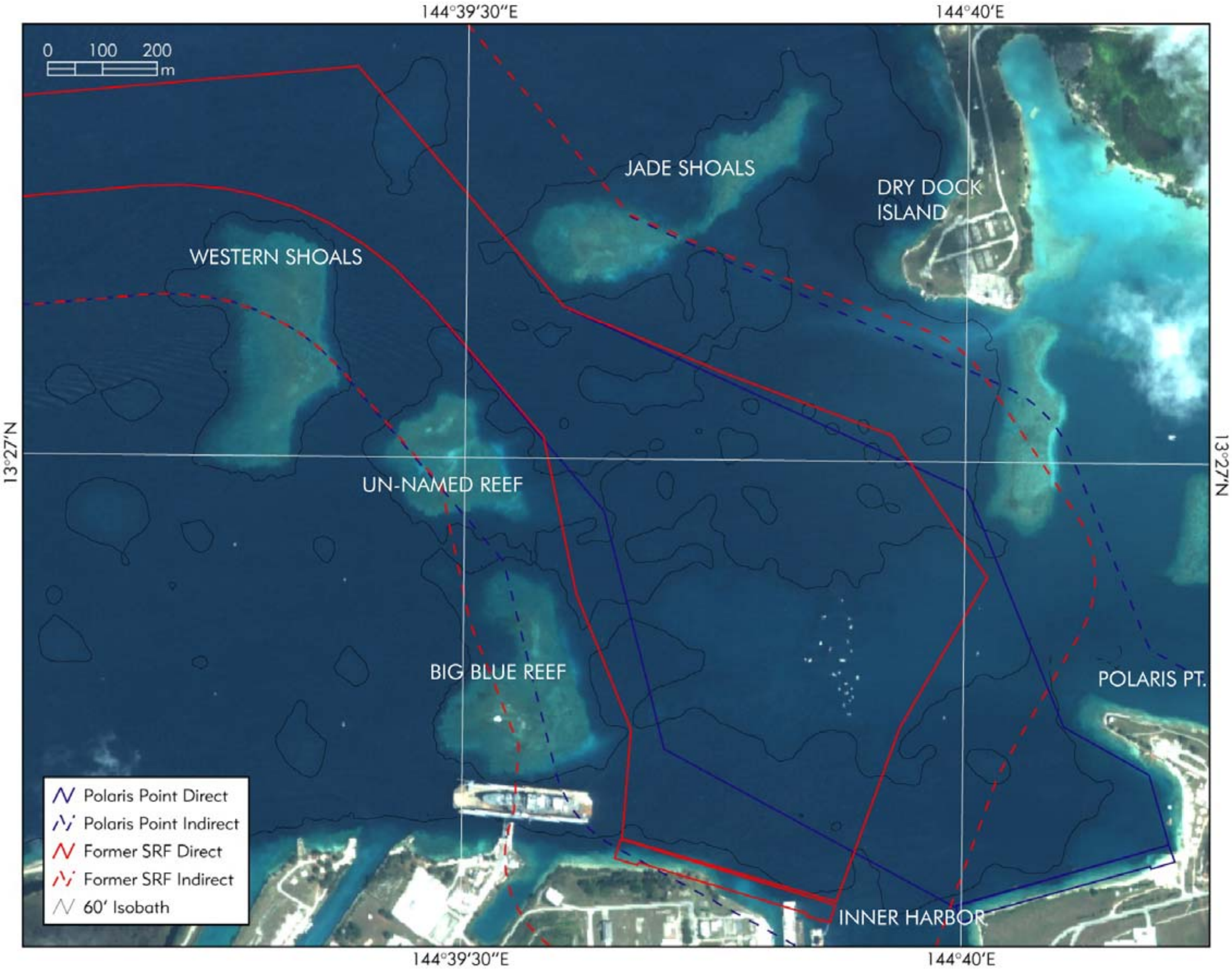


FIGURE 1. Quickbird satellite image of southeastern Apra Harbor, Guam showing outlines of proposed alternatives for the CVN (Carrier Vessel Nuclear) transit, turning basin and berthing facilities. "SRF" option is shown in red; Polaris Point alternative is shown in blue. "Direct" areas (solid lines) indicate footprint within which dredging will take place; "Indirect" areas (dashed lines) delineate an envelope 200 m wide around each Direct alternative boundary. Also shown in black is the 60-foot depth contour, which marks the deepest survey depth within the project boundaries.

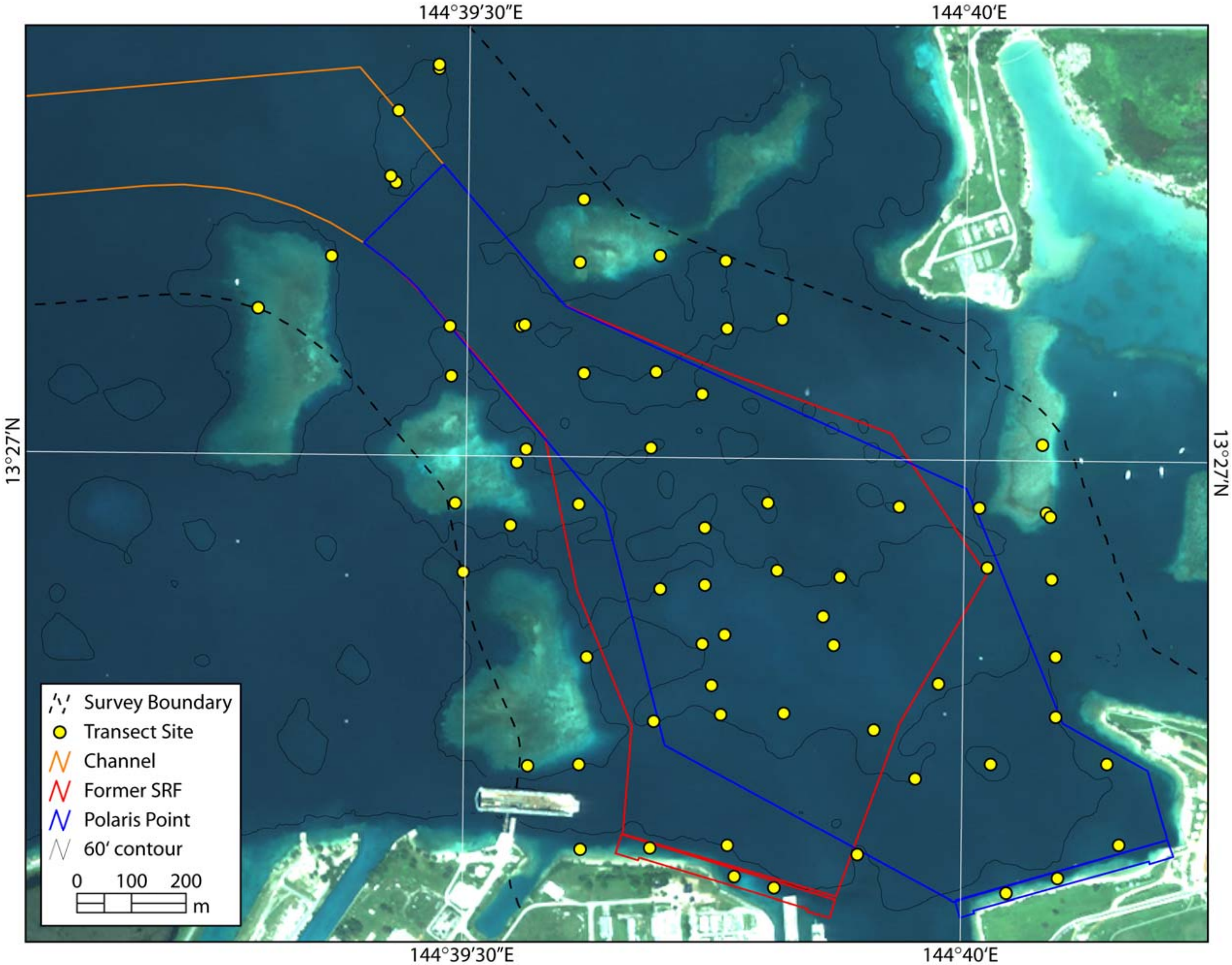


FIGURE 2. RGB (red-green-blue) image of study area. Image source is Quickbird satellite, acquired in 2003. Also shown are boundaries of SRF and Polaris Pt. CVN alternatives (red and blue lines, respectively), a 200-m (656 ft.) indirect impact buffer zone (dashed black line), and 60 ft. depth contour. Yellow circles are stratified random sampling points selected in four strata: 1) Dredge area "flat"; 2) Dredge area "slope"; 3) Indirect "flat", and 4) Indirect "slope". Fifteen (15) points are within each strata, with additional points added in the SRF and Polaris Wharf locations for a total of 67 sampling sites.

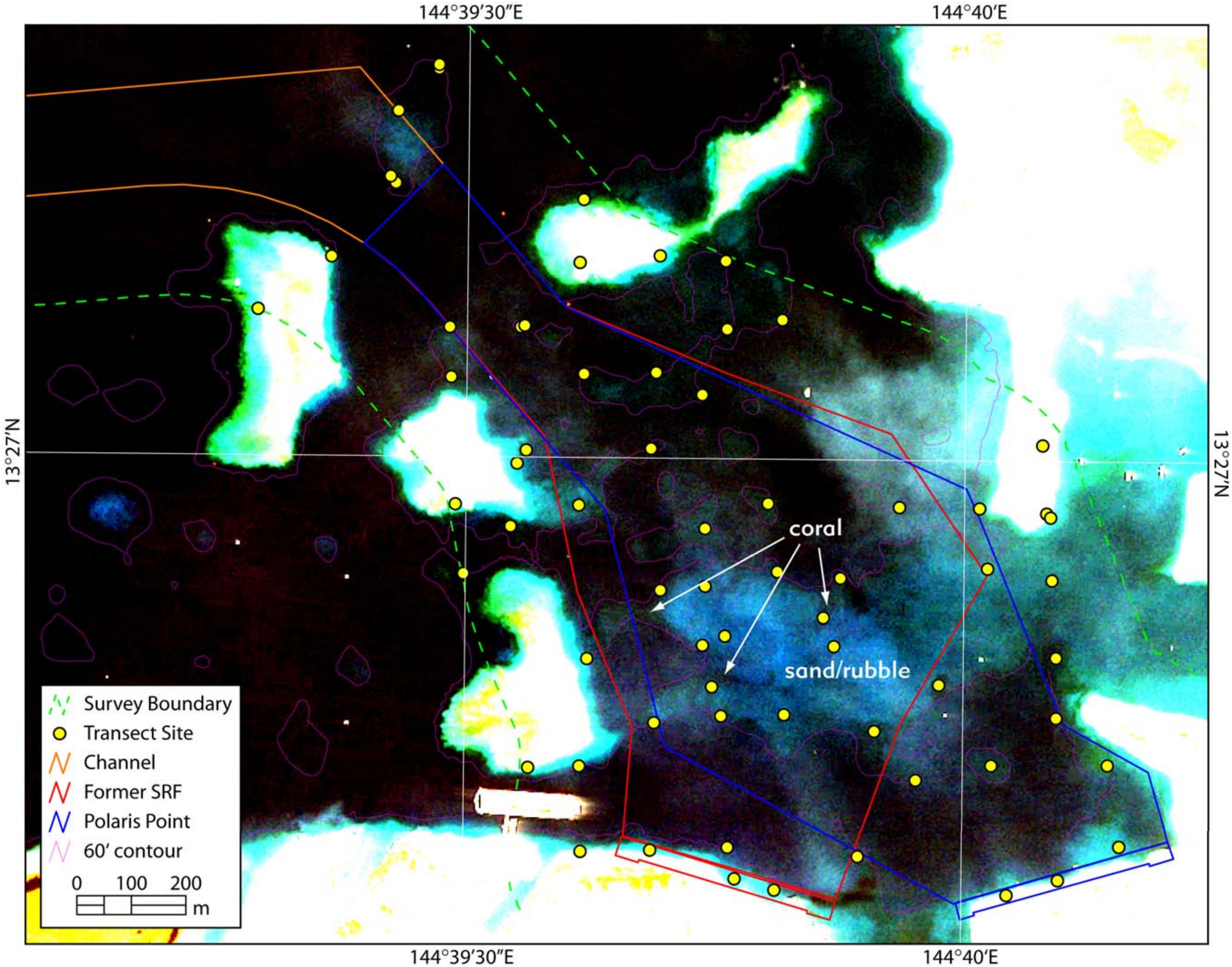


FIGURE 3. RGB (red-green-blue) image of study area (same as Figure 1) optically color-stretched to highlight deep reef areas within the CVN dredge area. Bright areas on the deep reef are likely sand/rubble, while darker areas, particularly on the reef edge are likely coral/algal rich.

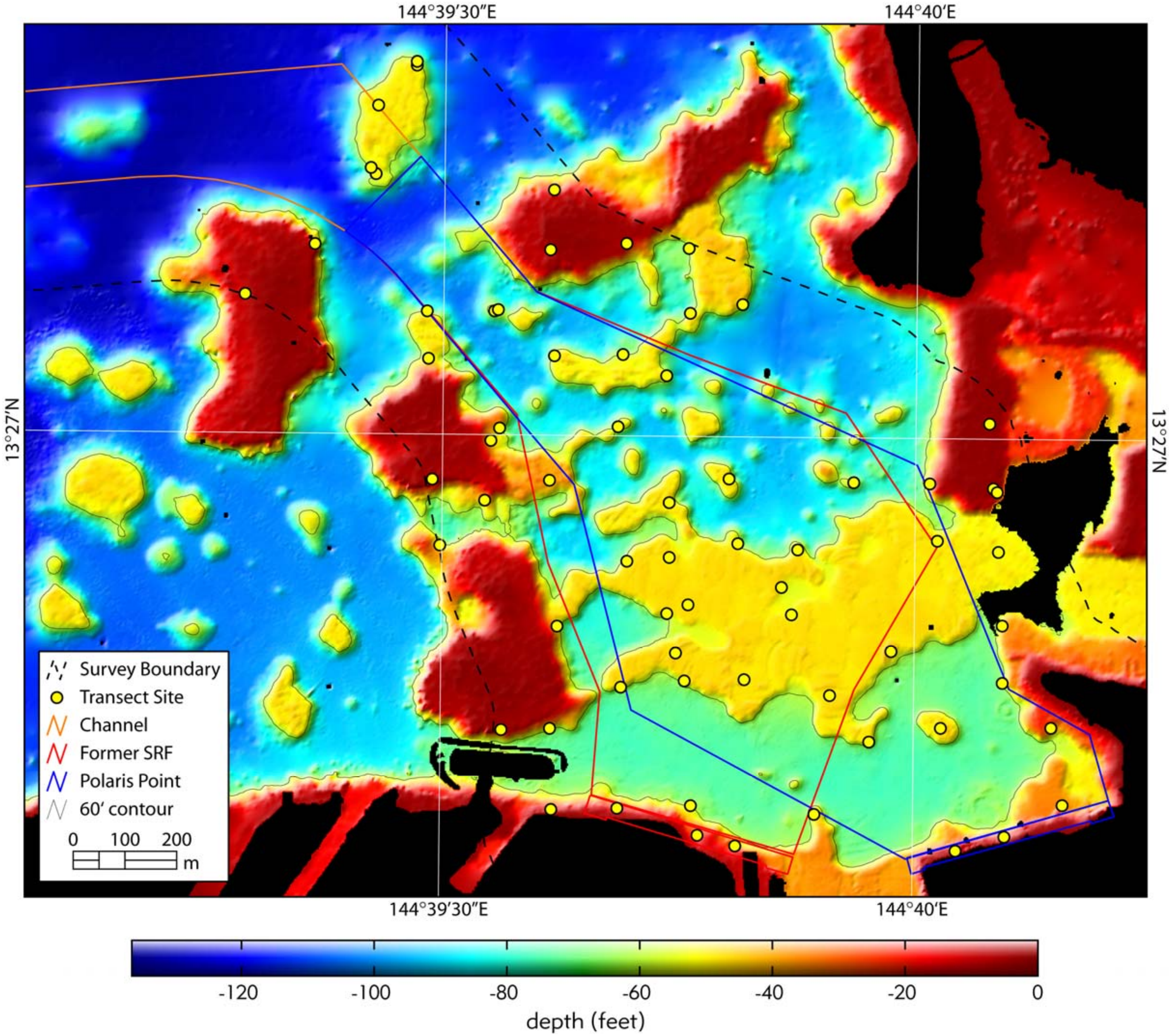


FIGURE 4. Color-coded bathymetry of CVN survey area generated from LIDAR (light detection and ranging) and acoustic surveys (data provided by TEC.

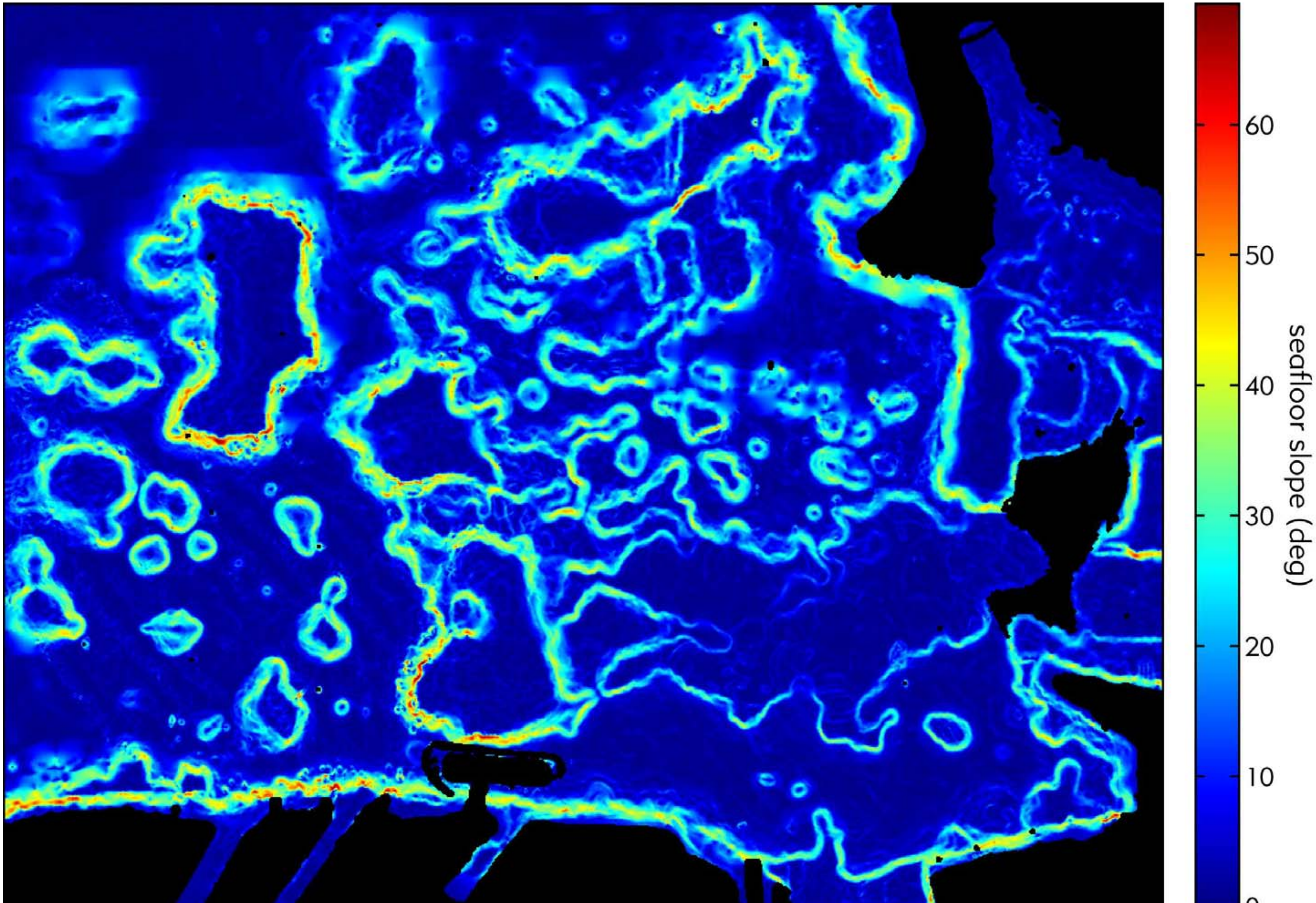


FIGURE 5. Color-coded slope (degrees) of bathymetry of CVN survey area generated from LIDAR (light detection and ranging) and acoustic surveys (data provided by TEC).

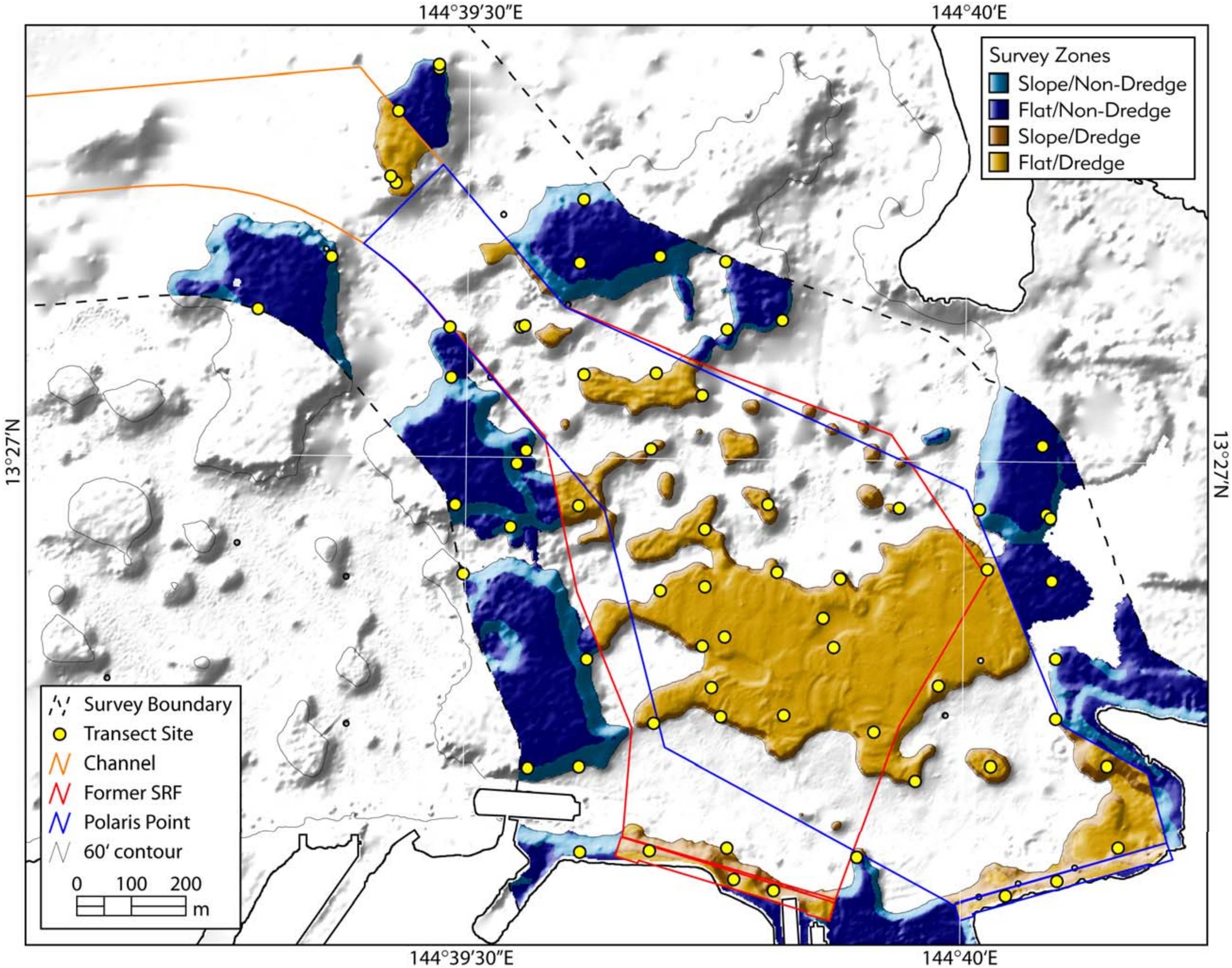


FIGURE 6. Final stratification product showing four zones used for random stratified sampling replicating GIS product Figure 1 provided by USFWS. Zones are bounded by 60-foot depth contour and 200-m wide indirect impact zone. Dredge "flat" (light brown) and Indirect Impact "flat" (dark blue) areas have <15° seafloor gradient; Dredge slope (dark brown) and Indirect Impact slope (light blue) have ≥15° seafloor gradient. Fifteen data points are randomly selected in each strata using MATLAB. Extra points are added to each berthing area for a total of 67 sampling stations.

FIGURE 7. Satellite image of southwestern Apra Harbor showing locations of 67 transect stations that were surveyed for benthic community composition. Black hatched areas delineate the "Direct" Impact area where dredging will take place, including the areas for both the SRF and Polaris Point alternatives, and the blue hatched area delineates the "Indirect" Impact area which has been deemed to have the potential to be affected by sediment created by the dredging. The lines within the perimeters of each area differentiate "slope" areas with bottom topography greater than 15°, and "flat" areas with slope angle less than 15°.

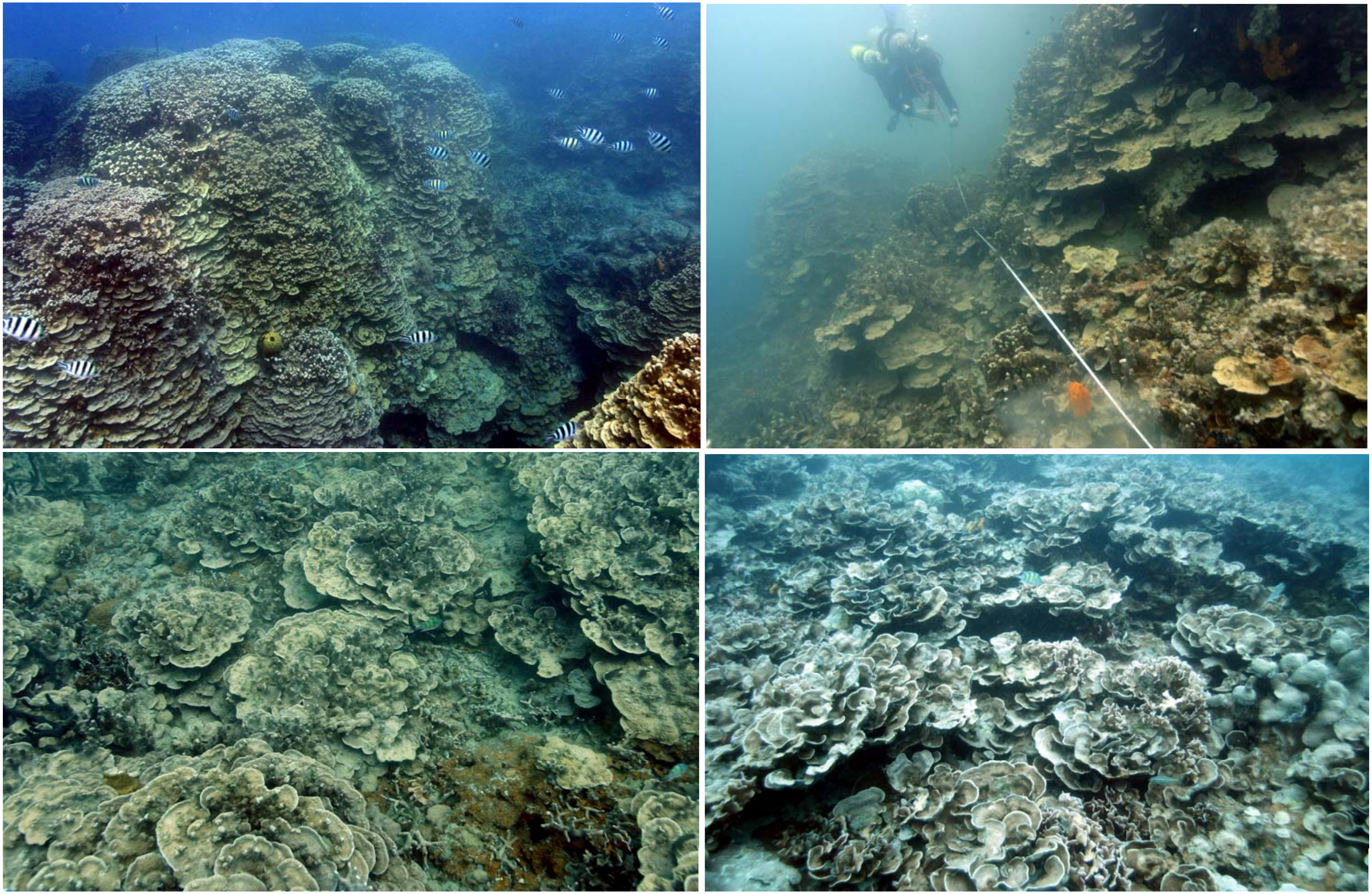


FIGURE 8. Various plating and laminar growth forms of *Porites rus* that occur throughout the CVN survey area. Photo at upper left shows a "supracolony" of *P. rus* comprised of the amalgamation of numerous smaller colonies that measures approximately 12 m in length. Photo at upper right shows overlapping laminar plates growing on the near-vertical face of the lower part of a patch reef slope. Bottom photos show two views of deep reef flats covered with overlapping amalgamated plates of semi-circular plates that fuse to form nearly mono-specific complexes.

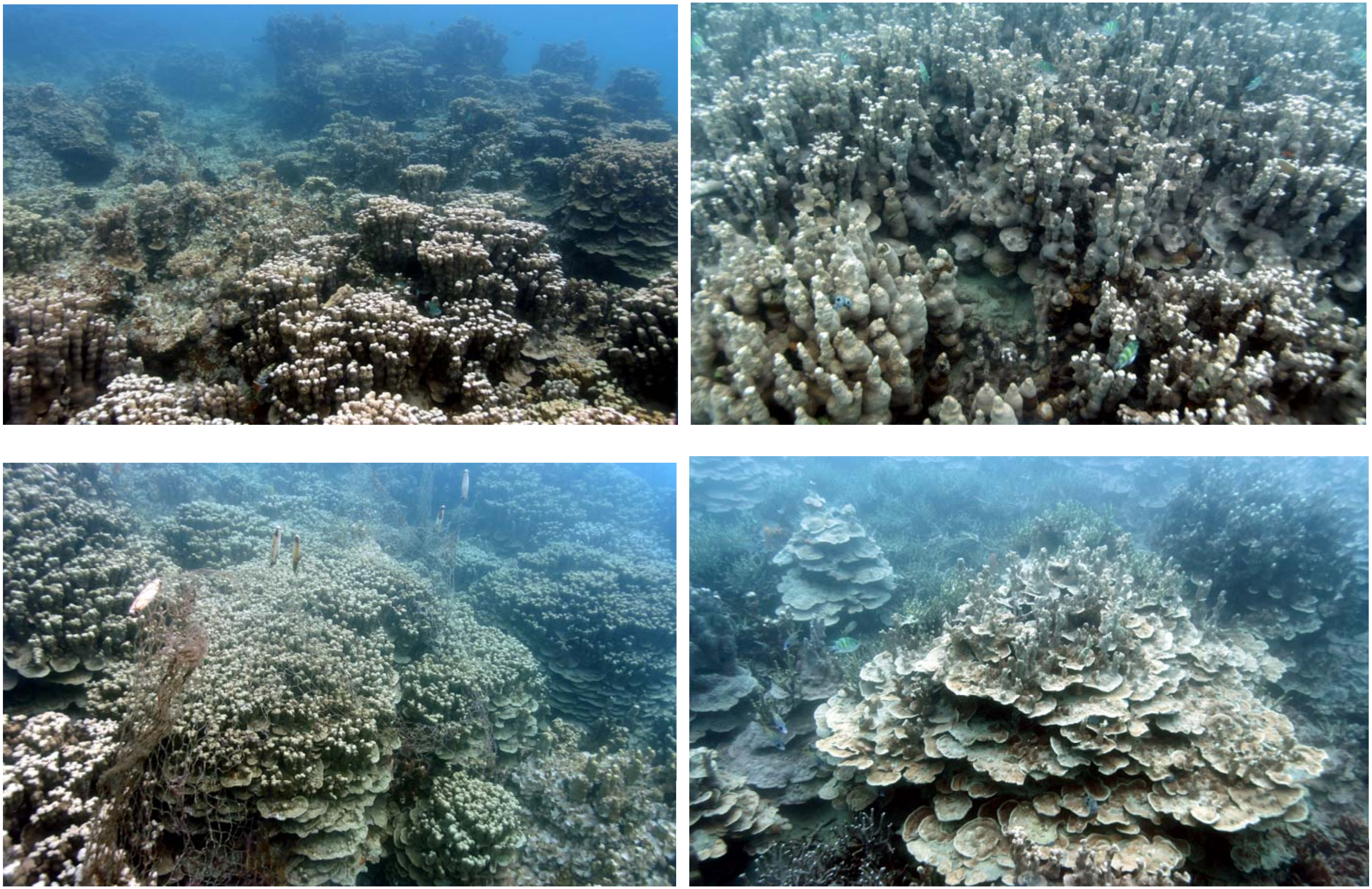


FIGURE 9. Various branching growth forms of *Porites rus* that occur throughout the CVN survey area. Photo at lower left shows monofilament fence net tangled on coral colonies in the vicinity of Transect 6. Photo at lower right shows colony of *P. rus* near Transect 15 with upper portion consisting of upright branches growing out of laminar plates.

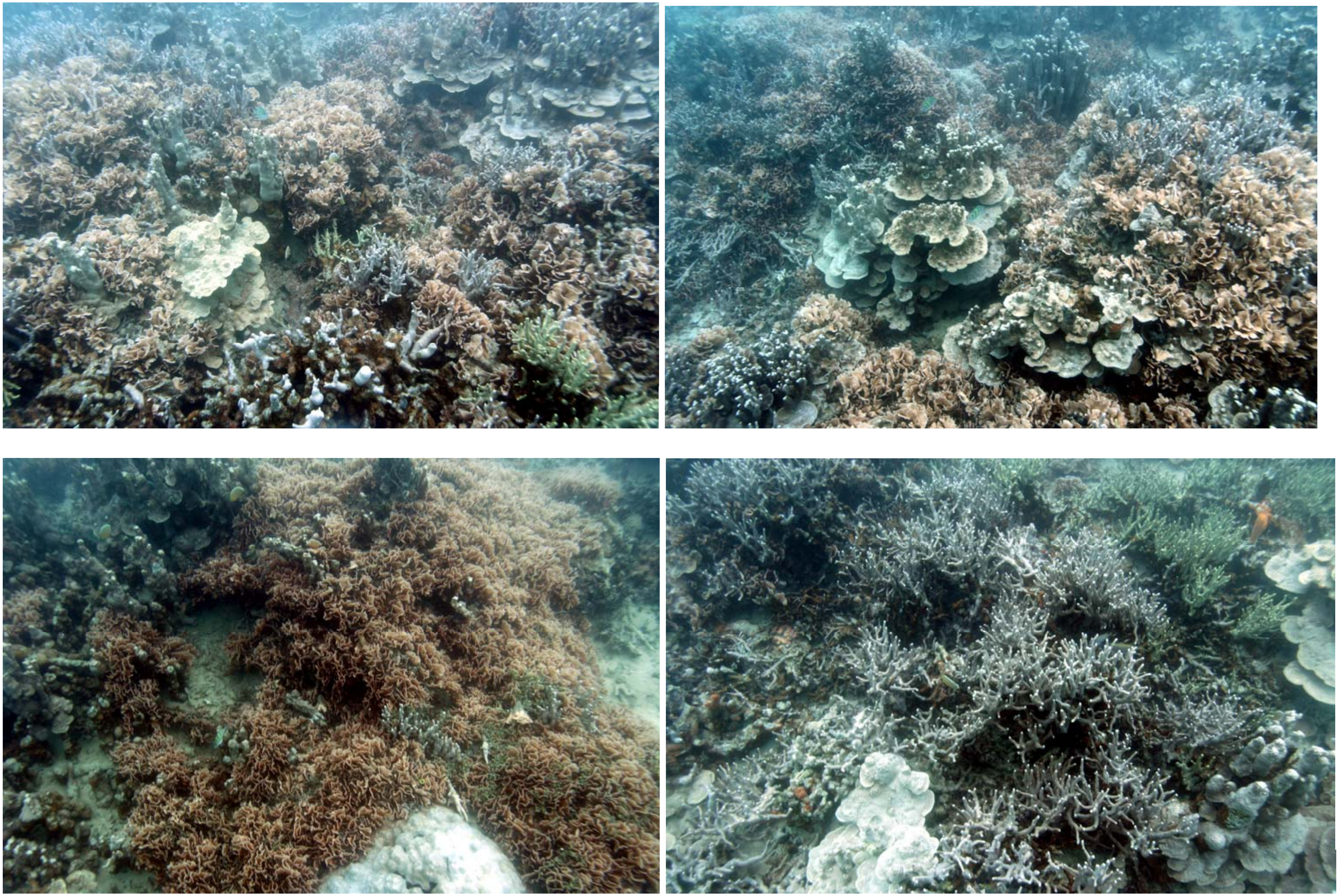


FIGURE 10. High coral cover communities in the vicinity of Transect 15 comprised of mixed assemblages of species including *Porites rus*, *P. cylindrica*, and *Pavona cactus*.

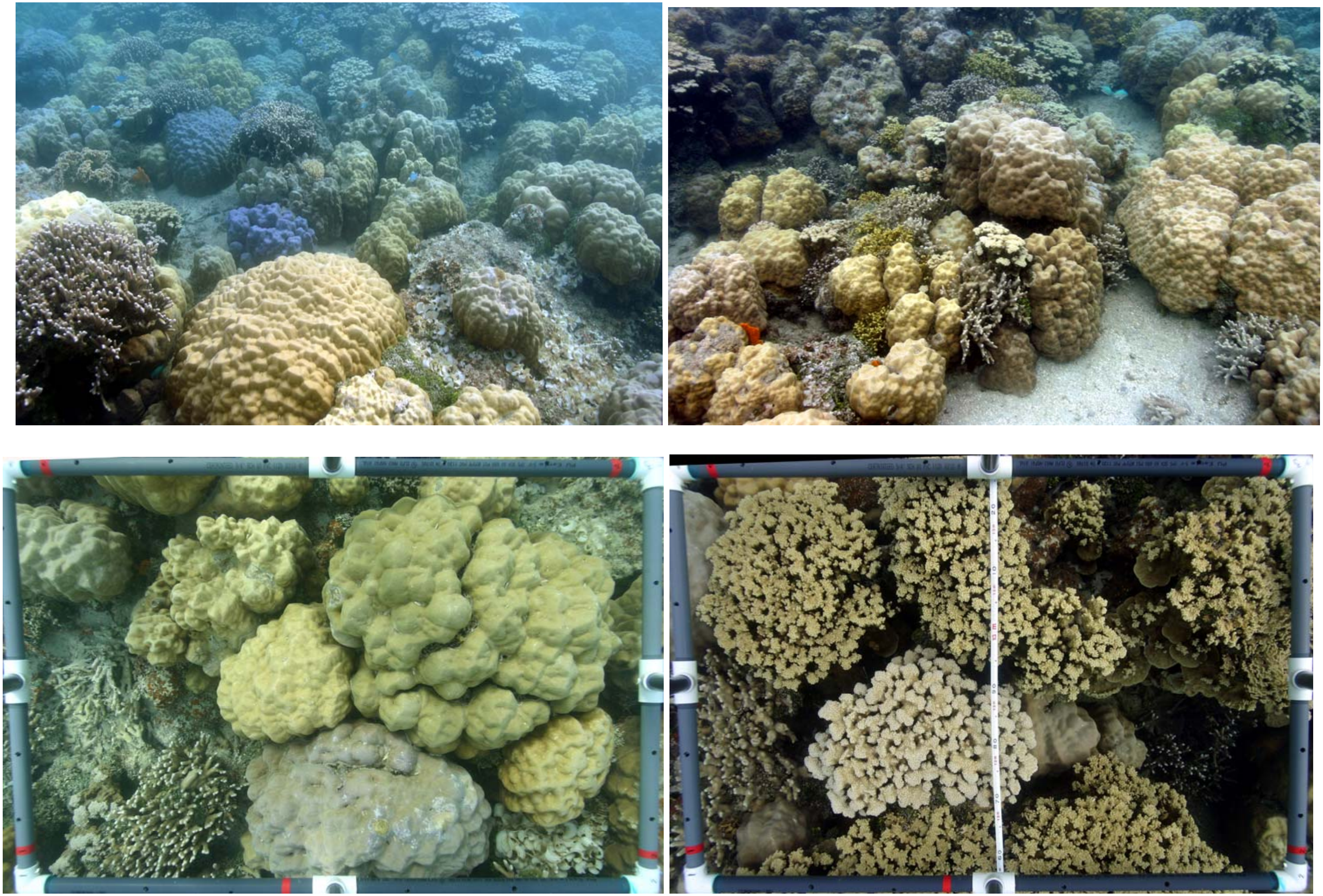


FIGURE 11. Benthic cover of upper edges of patch reefs in the CVN study area can be dominated by hemispherical colonies of *Porites lutea* (Transect 21, upper left; Transect 7 upper right). Photo-quadrats from Transect 7 show areas of tightly packed colonies of *P. lutea* (bottom left) and a knobby, short-branched growth form of *Porites rus* (bottom right).

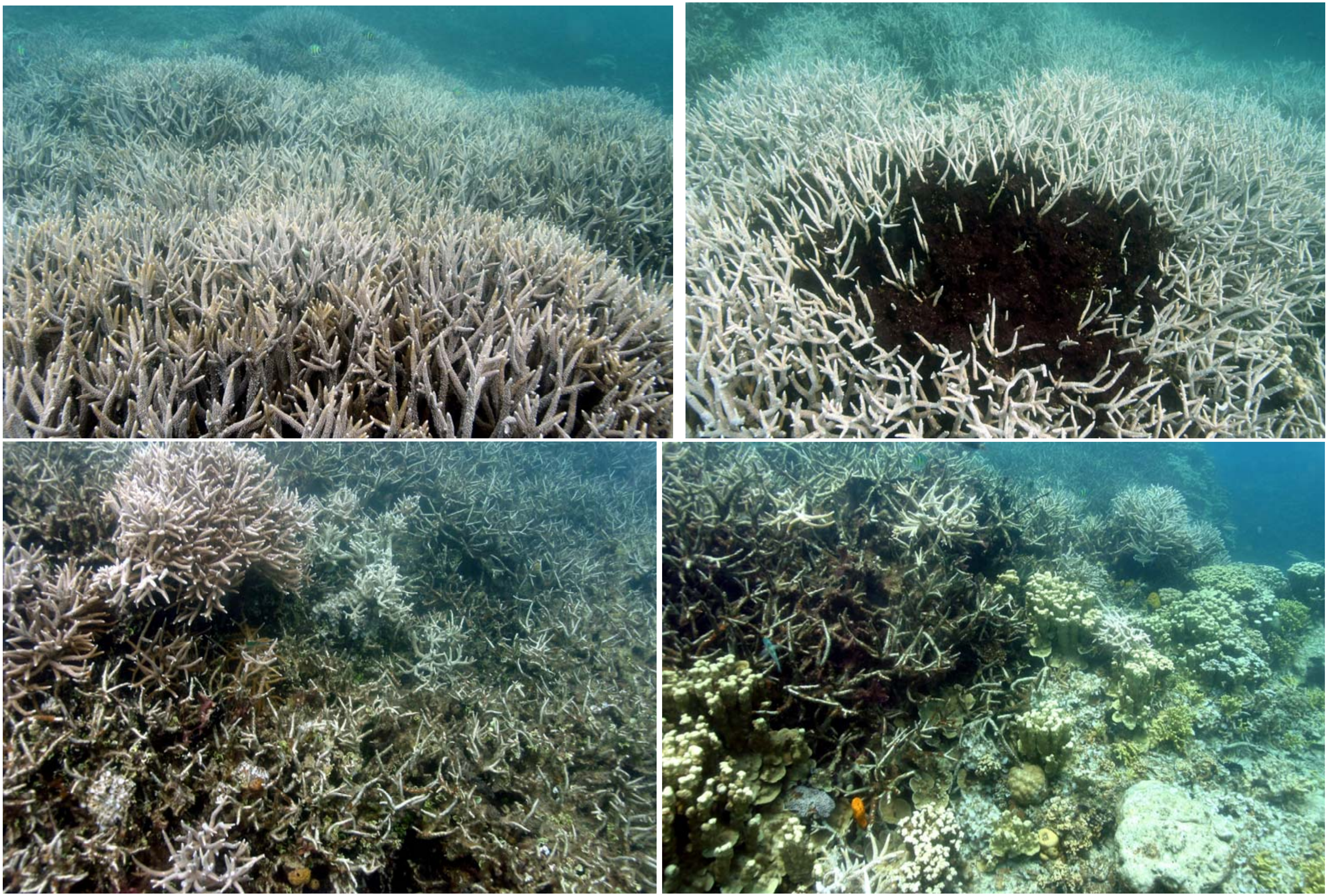


FIGURE 12. Monospecific field of *Acropora aspera* located on the top of the western side of Western Shoals (Transect 9) (top left). Areas of the stand were overgrown by dense patches of the black sponge, resulting in mortality to sections of the field of *Acropora* (top right). Area of dead algal encrusted branches of *A. aspera* interspersed with clusters of either newly recruited, or unaffected branching coral (bottom left). Boundary of the *A. aspera* field is clearly delineated at a depth contour just off the top of the patch reef on the western side of Western Shoals (bottom right).

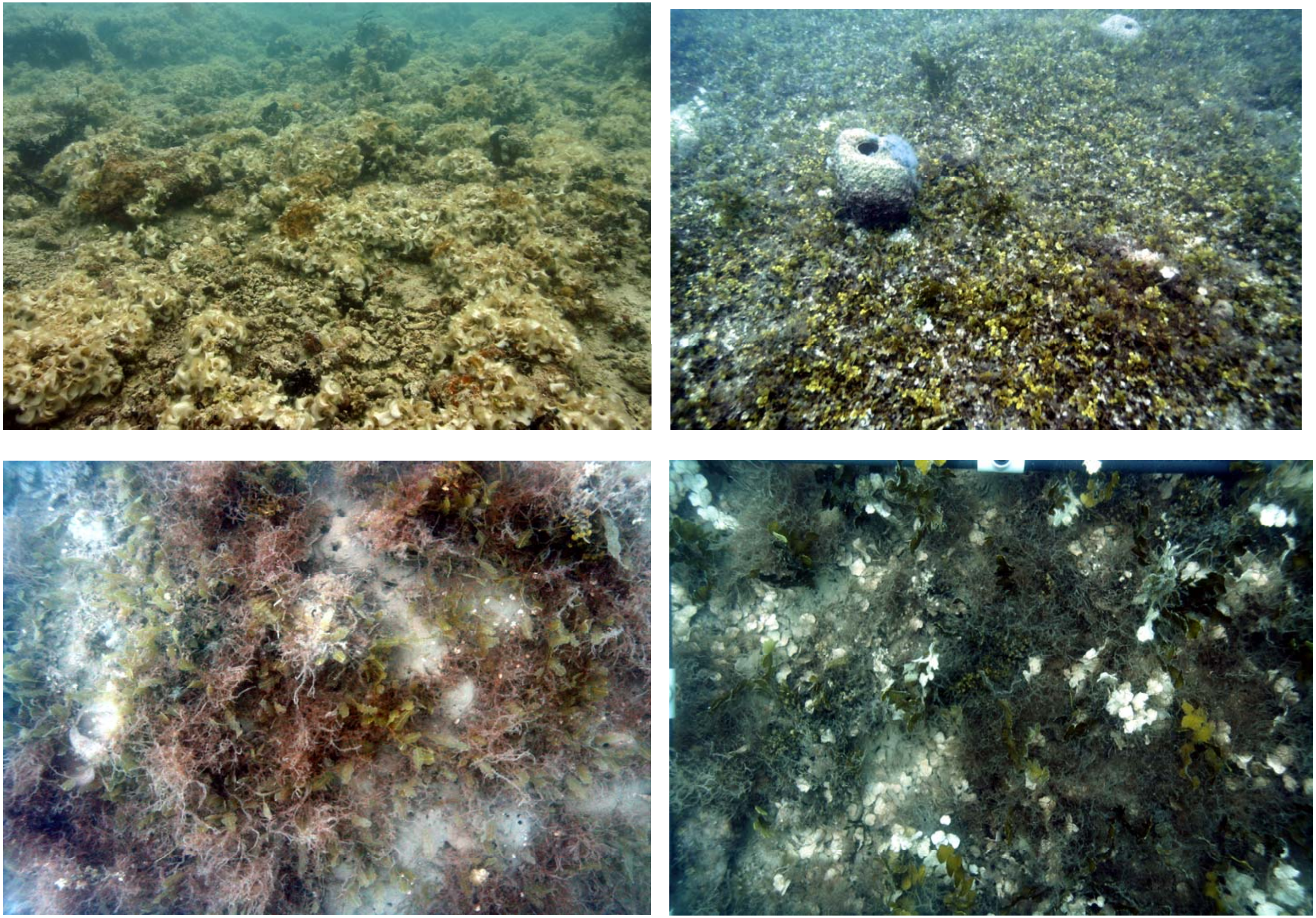


FIGURE 13. Algae dominated areas of the CVN study area include mats of *Padina* spp (top left) and *Halimeda* spp. (top right). Common mixed algal assemblages included *Dictyota* sp. and *Caulerpa* spp. (bottom left), and *Dictyota* and *Halimeda* (bottom right).

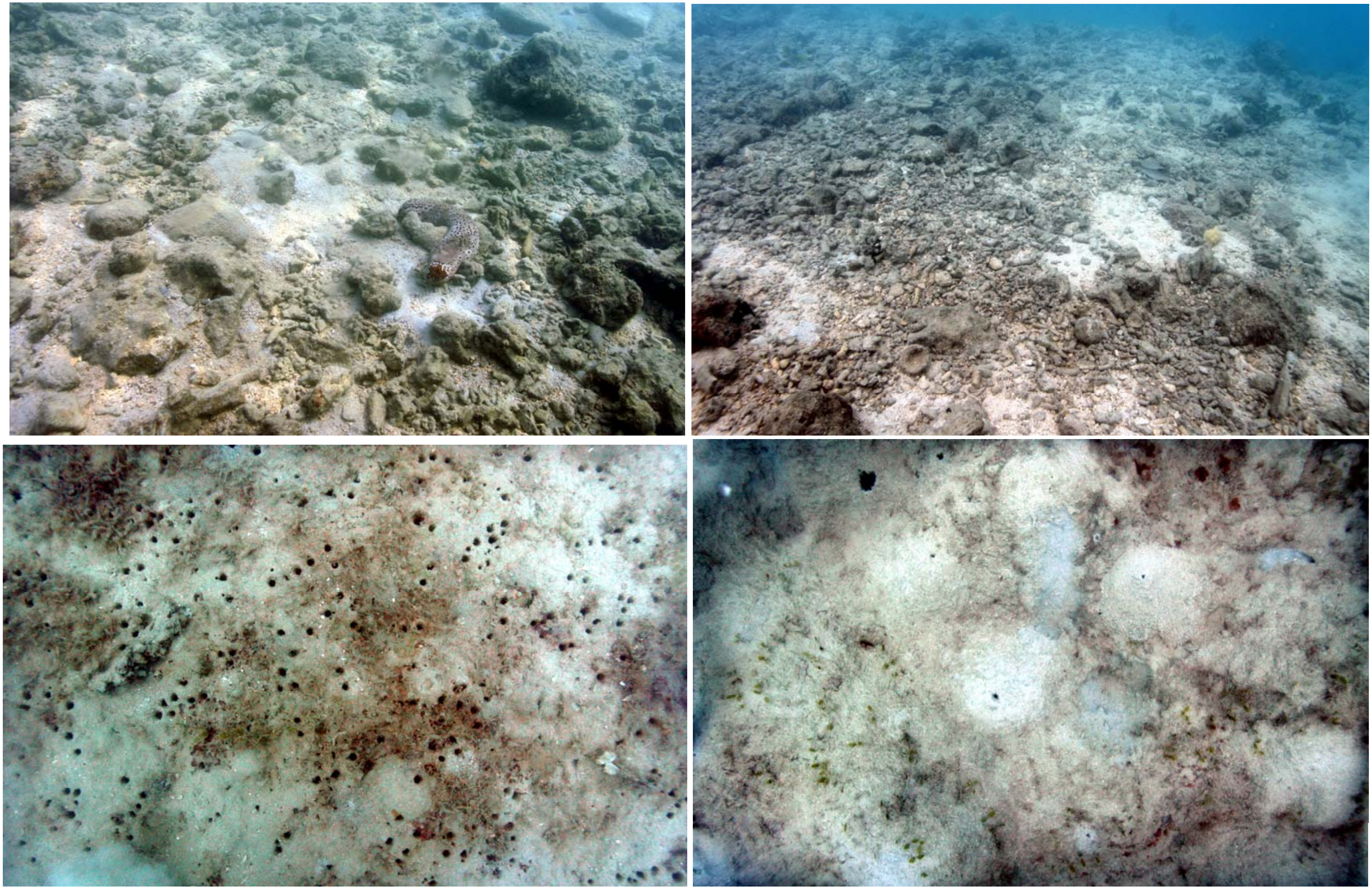


FIGURE 14. Bottom cover consisting of sand-rubble at Transects 67 (upper left) and 58 (upper right). Fine-grained calcareous mud comprising the benthic surface typically contains numerous burrow holes, and is covered with brown or black bacterial films (Transect 35 at lower left; Transect 32 lower right).

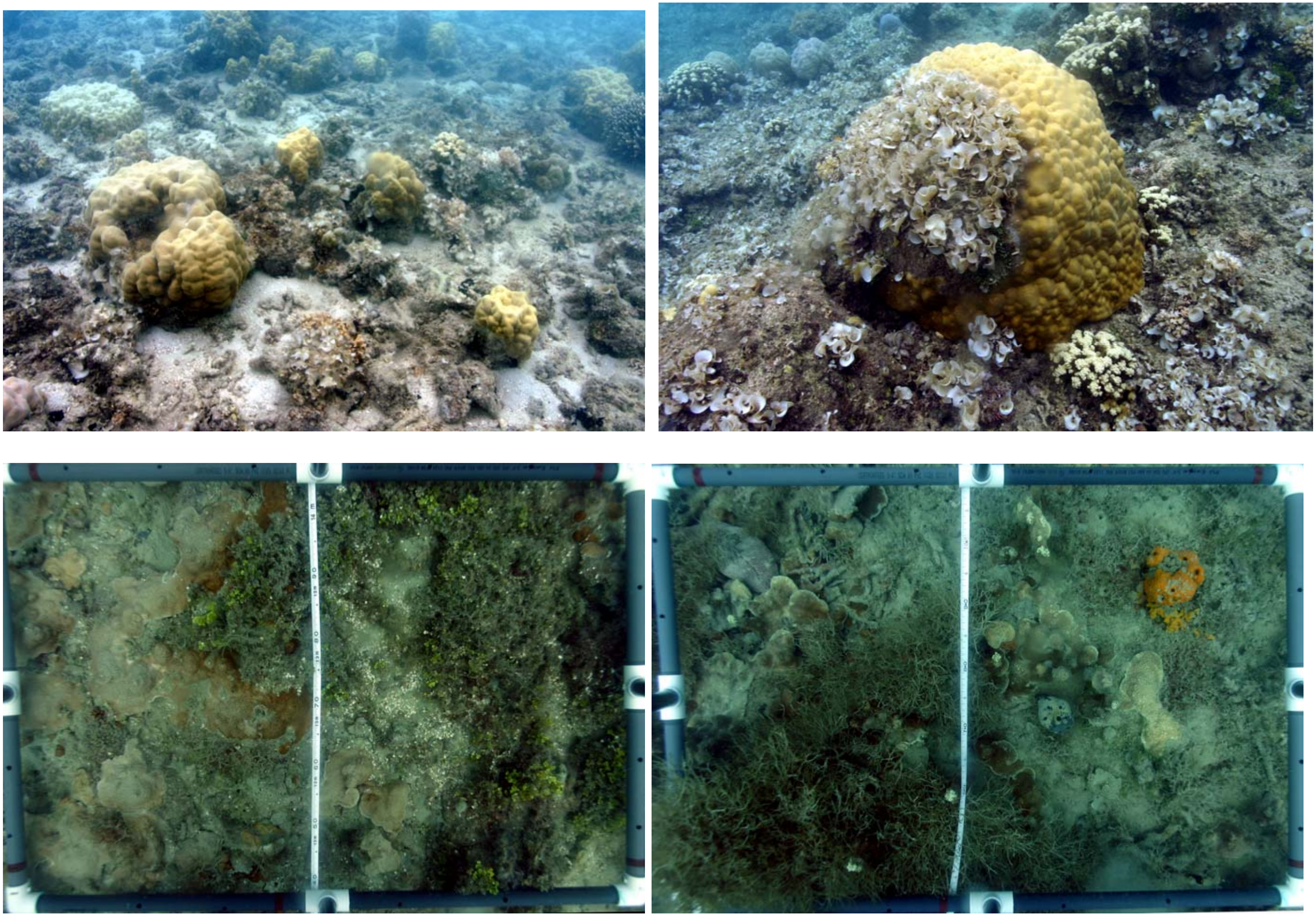


FIGURE 15. Representative areas of mixed algae and coral. Tops of large patch reefs were typically populated with hemispherical heads of *Porites lutea* amid clumps of *Padina* (Transect 17, top left; Transect 60 top right). Bottom row shows photo-quadrates occupied by corals and *Halimeda* (Transect 21, bottom left), and *Dictyota* (Transect 43, bottom right).

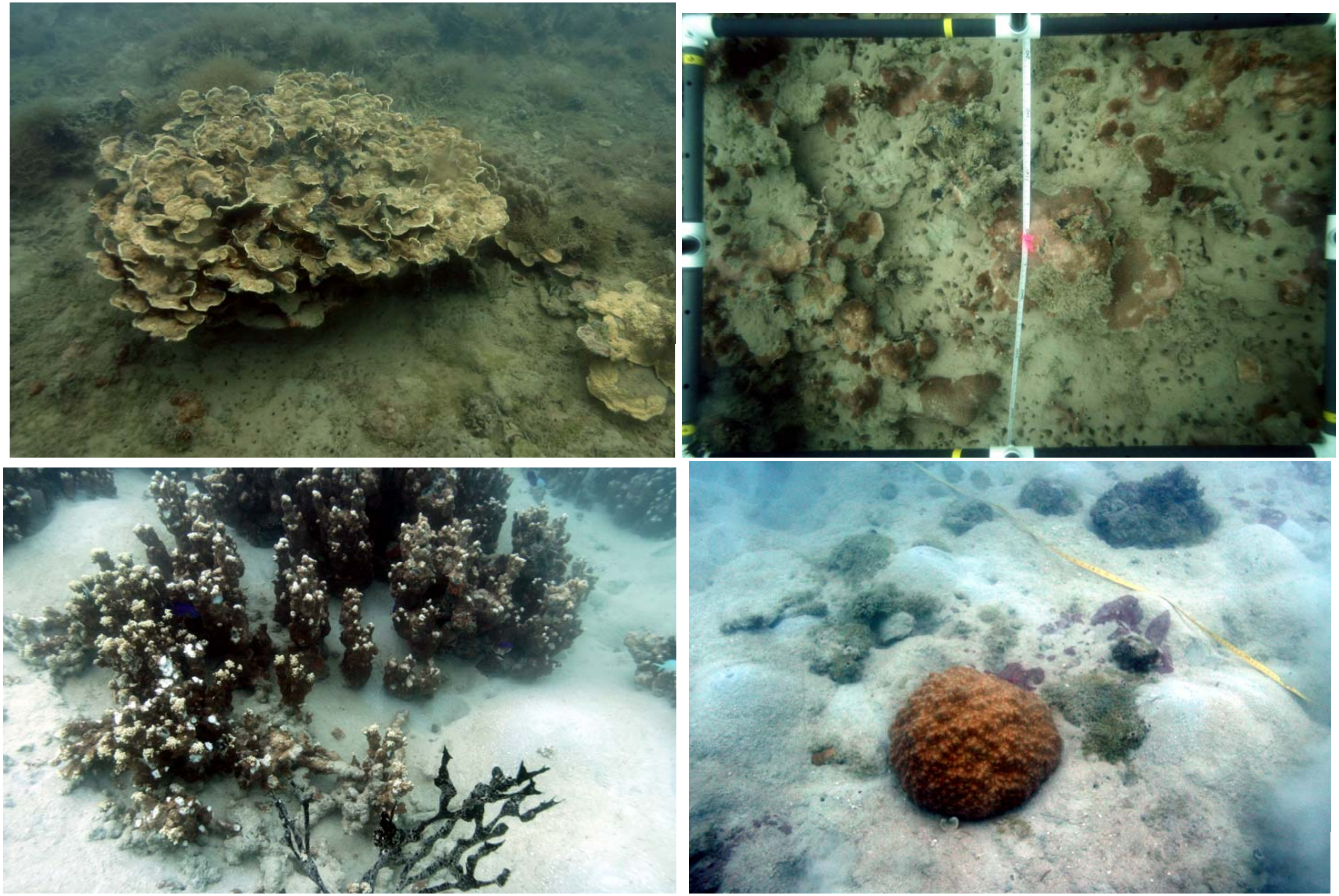


FIGURE 16. Examples of corals in the CVN study area growing on sandy substratum.. Various growth forms of *Porites rus* include large undercut structures with the growing surfaces raised above the sediment surface near Transect 45 (top left), smaller encrusting plates or lobes on the sediment surface on Transect 56 (upper right) and columnar branches growing out of the sediment near Transect 16 (lower left). A hemispherical colony of *Astreapora myriophthalma* growing on the sand at Transect 32 is shown at bottom right.

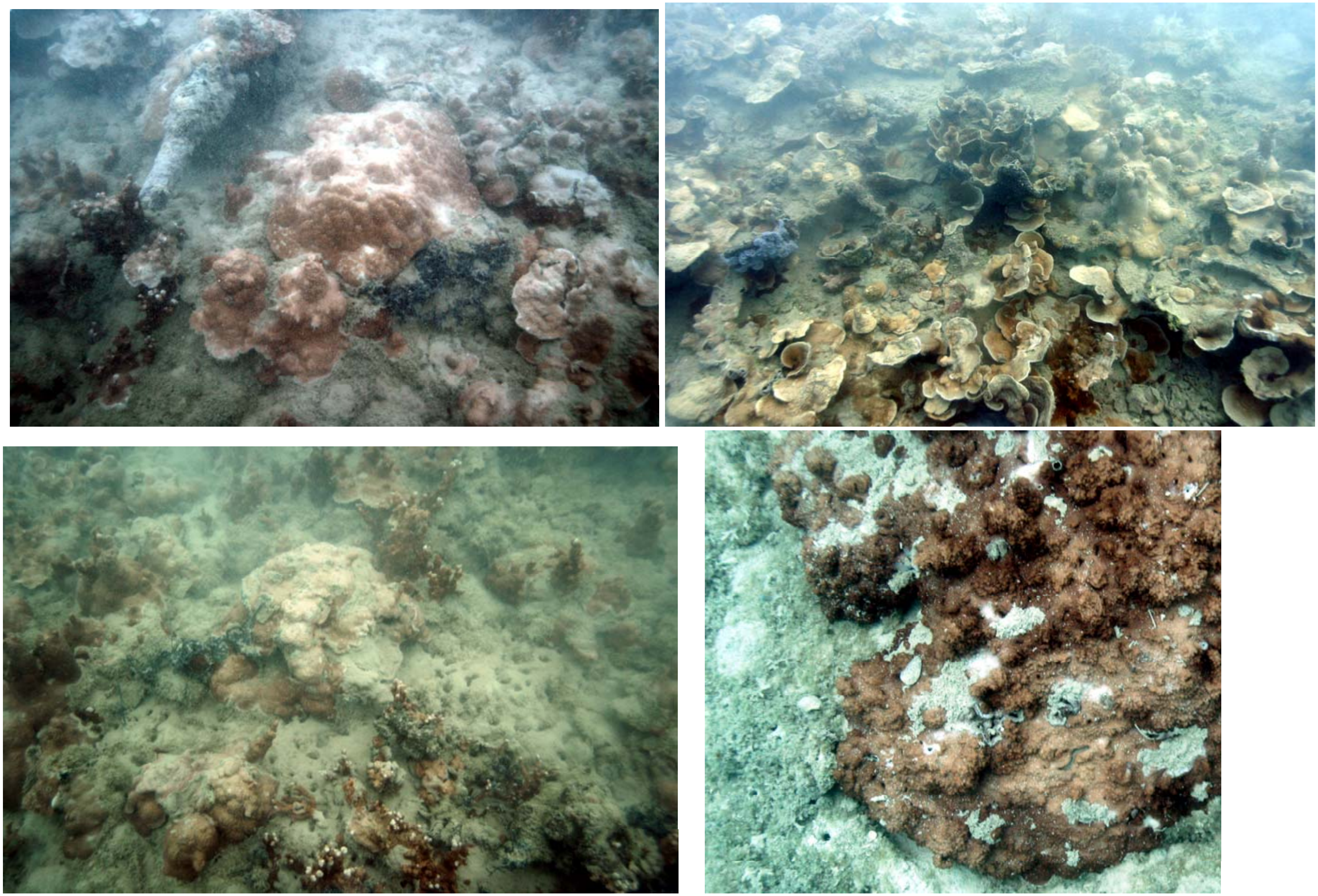


FIGURE 17. Colonies of *Porites rus* growing with upper living surfaces partially covered with sediment. Photos on upper and lower left in the vicinity of Transect 56, while upper and lower right are from the vicinity of Transect 21.

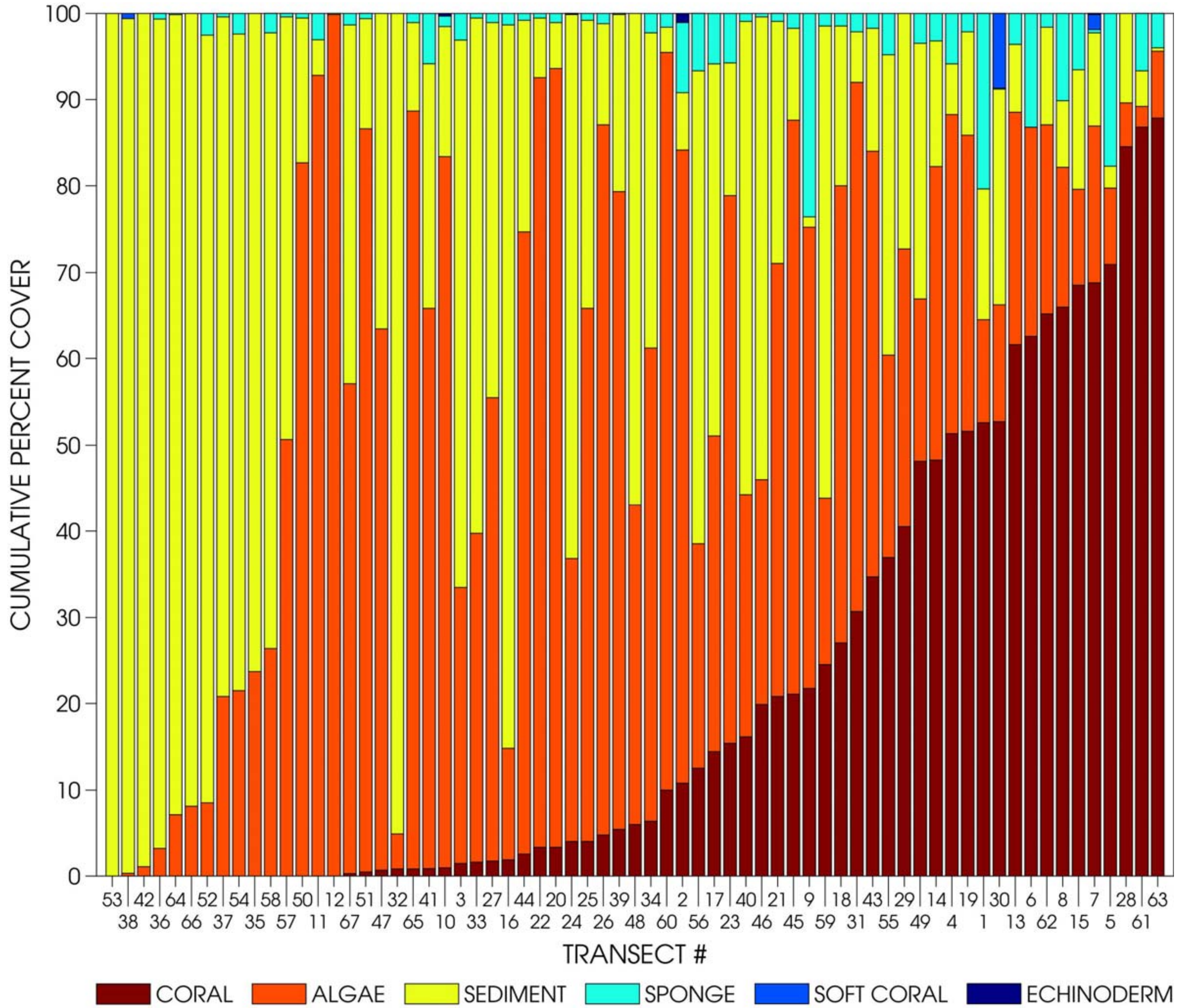


FIGURE 18. Stacked bar graph showing cumulative percent covers for each general class in each transect. Transects are arranged in order of lowest to highest coral cover.

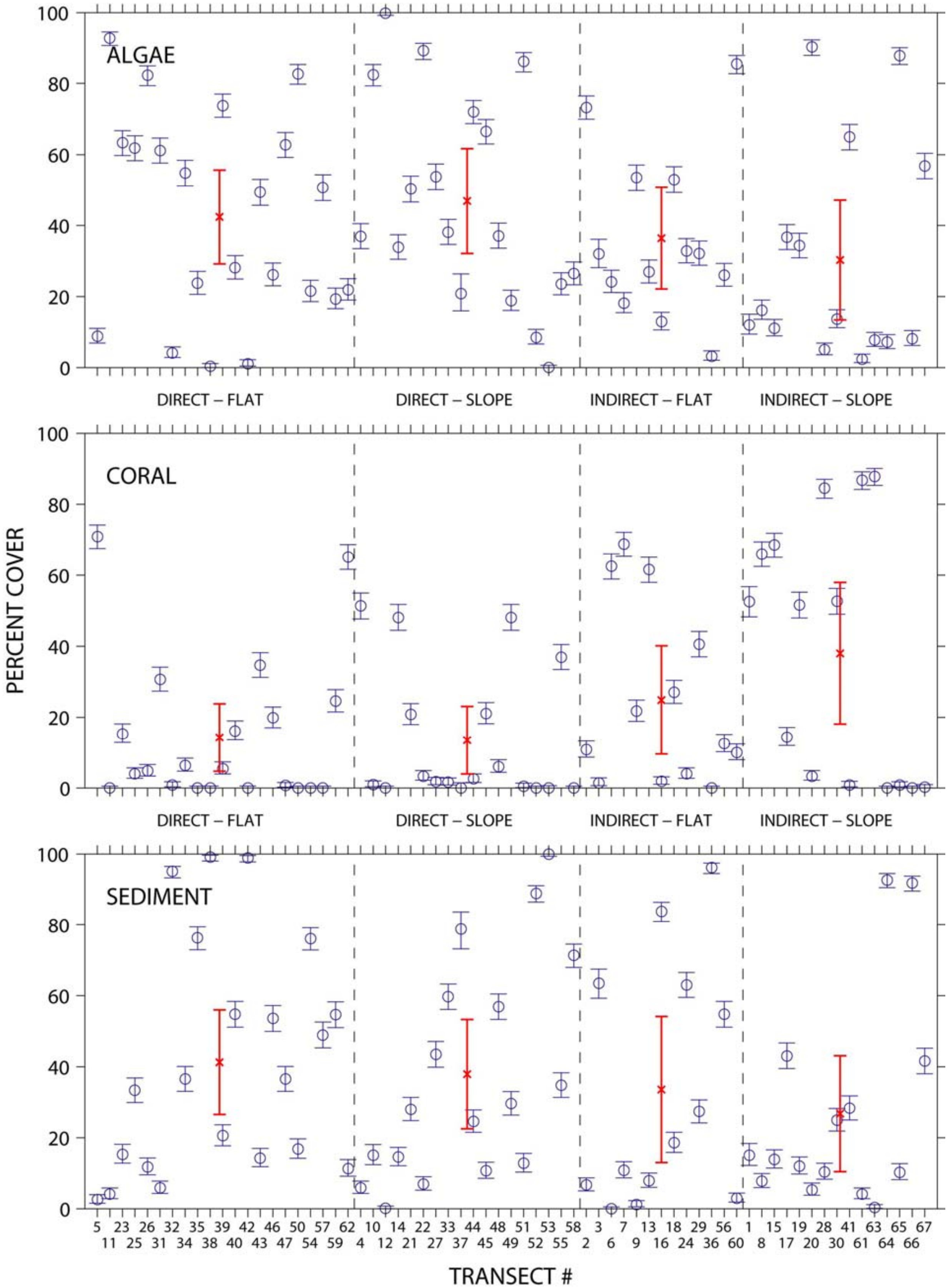


FIGURE 19. Percent covers of algae (top), coral (middle) and sediment (bottom) on each transect in each strata. Blue circles show percent cover in each transect calculated as the number of points identified as a given class divided by the total number of points in the transect, then multiplied by 100. Error bars on blue circles are computed by fitting a binomial distribution to each proportional cover, and show lower and upper 95% confidence intervals based on binomial distribution. Red crosses show mean percent covers for each class in each survey stratum; error bars are ±95% confidence intervals on the mean.

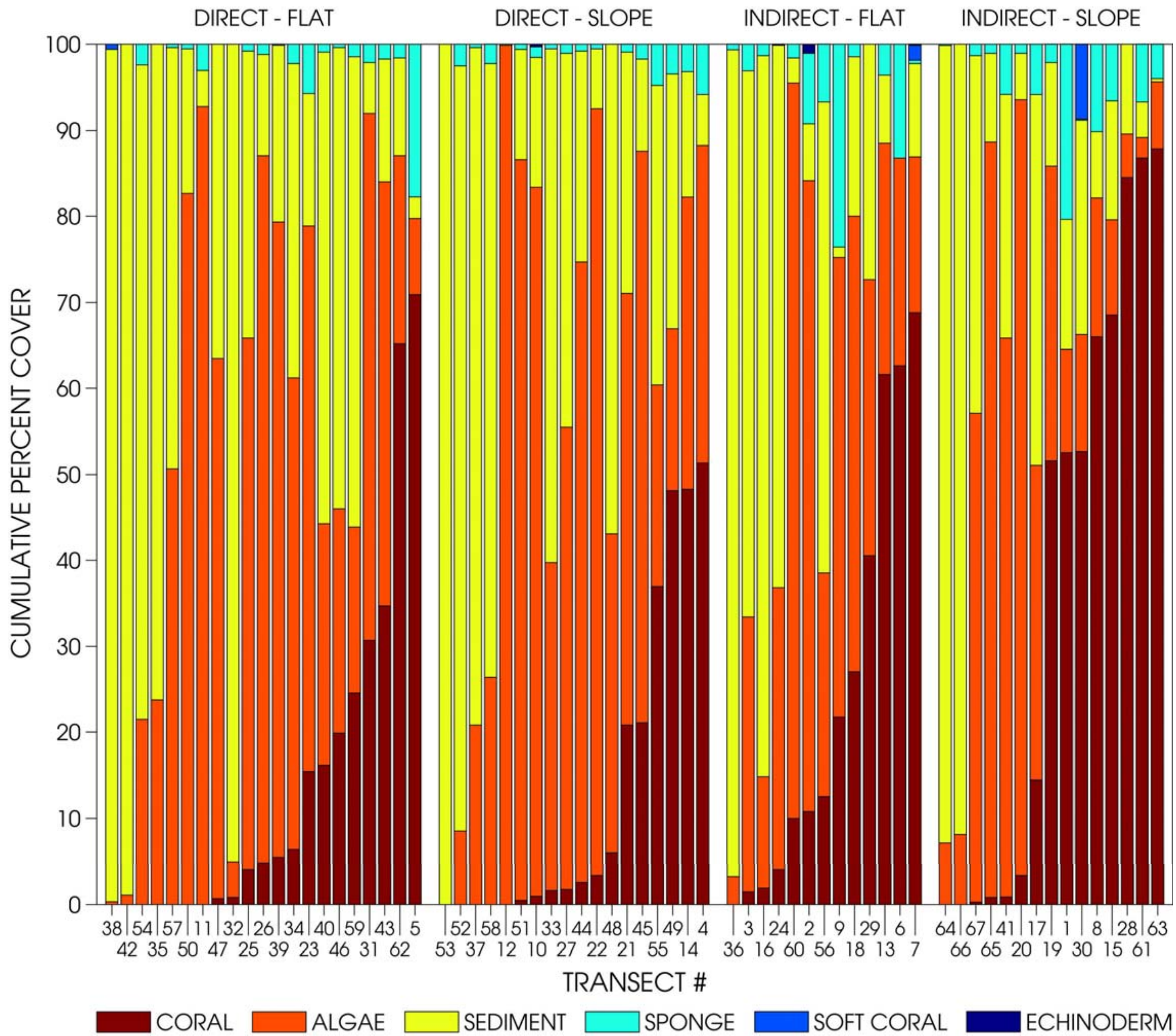


FIGURE 20. Stacked bar graph showing cumulative percent covers for each general class in each transect, arranged by survey stratum. Within each stratum, transects are arranged in order of lowest to highest coral cover. Coral, algae and sediment cover vary widely within each stratum; overall, the Indirect–Slope stratum has slightly higher coral cover than the other three strata.

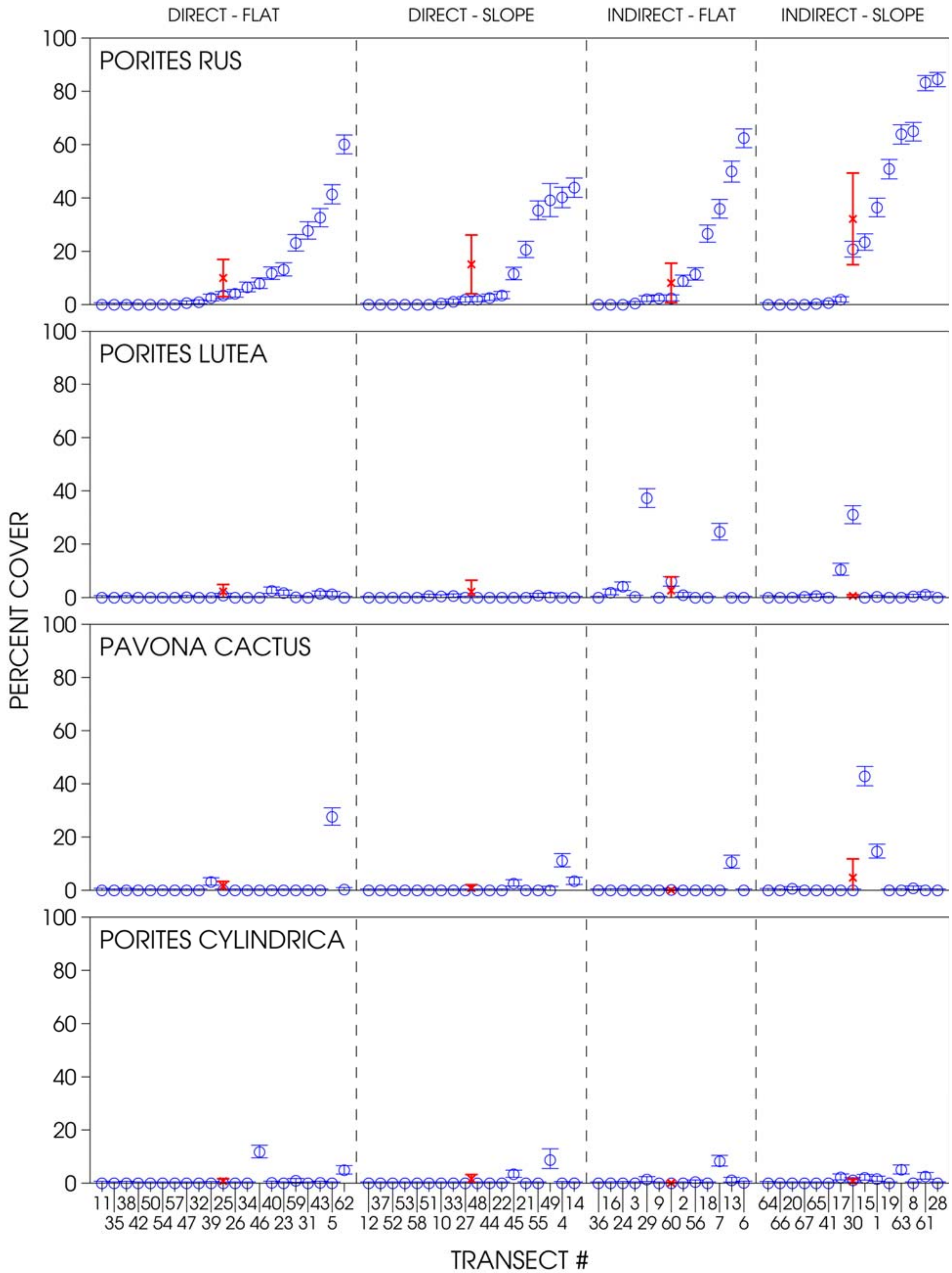


FIGURE 21. Percent covers on each transect in each zone of *Porites rus* (top), *Porites lutea* (upper-middle), *Pavona cactus* (lower-middle) and *Porites cylindrica* (bottom). Blue circles show percent cover in each transect calculated as the number of points identified as a given class divided by the total number of points in the transect, then multiplied by 100. Error bars on blue circles are computed by fitting a binomial distribution to each proportional cover; error bars show lower and upper 95% confidence intervals based on binomial distribution. Red crosses show mean percent covers for each class in each survey stratum; error bars are ±95% confidence intervals on the mean. Transects within each stratum are arranged in increasing cover of *P. rus*.

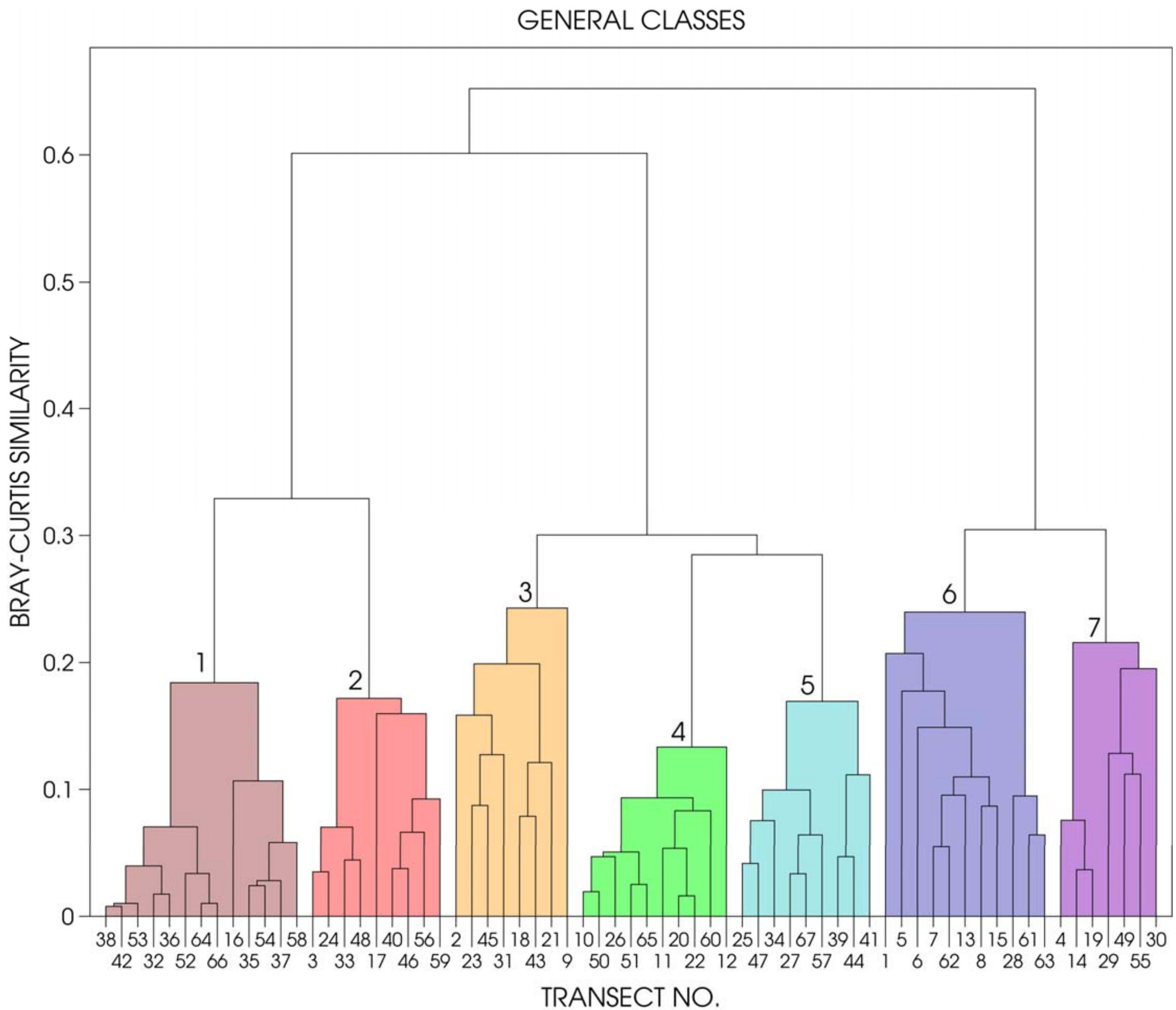


FIGURE 22. Cluster analysis dendrogram using percent covers of general classes. Vertical distances are calculated a pairwise Bray-Curtis similarity between 67 transects. Clusters are determined using average linkage and a threshold of 0.25. In general, sediment dominates clusters 1 and 2; algae dominates clusters 3, 4 and 5; and coral dominates clusters 6 and 7. See Table 5 for mean percent covers in each cluster.

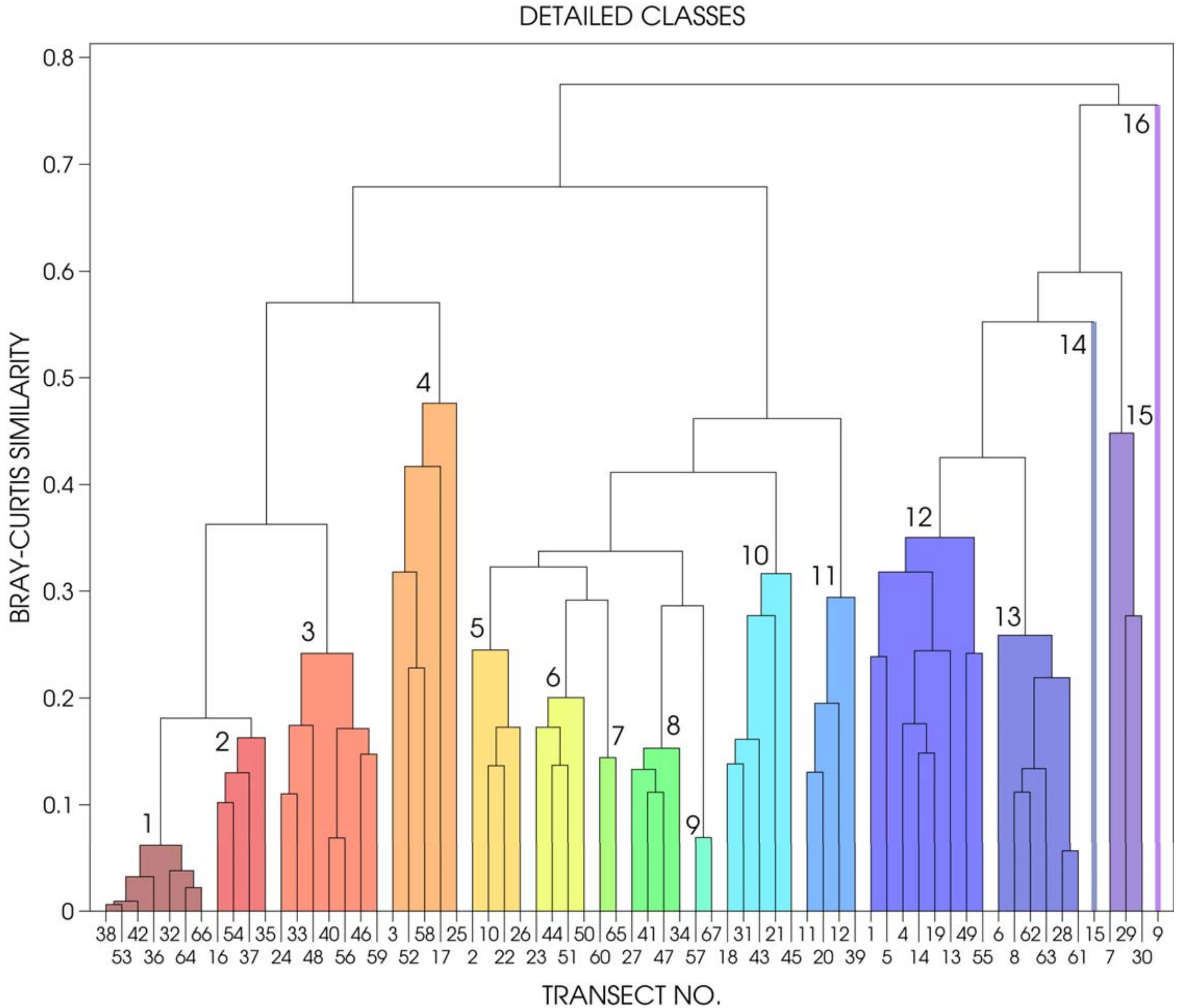


FIGURE 23. Cluster analysis dendrogram using percent covers of the subset of 10 detailed classes. Distances are calculated a pairwise Bray-Curtis similarity between transects. Clusters are determined using average linkage and visual inspection of dendrogram. See Table 5 for mean percent covers in each cluster.

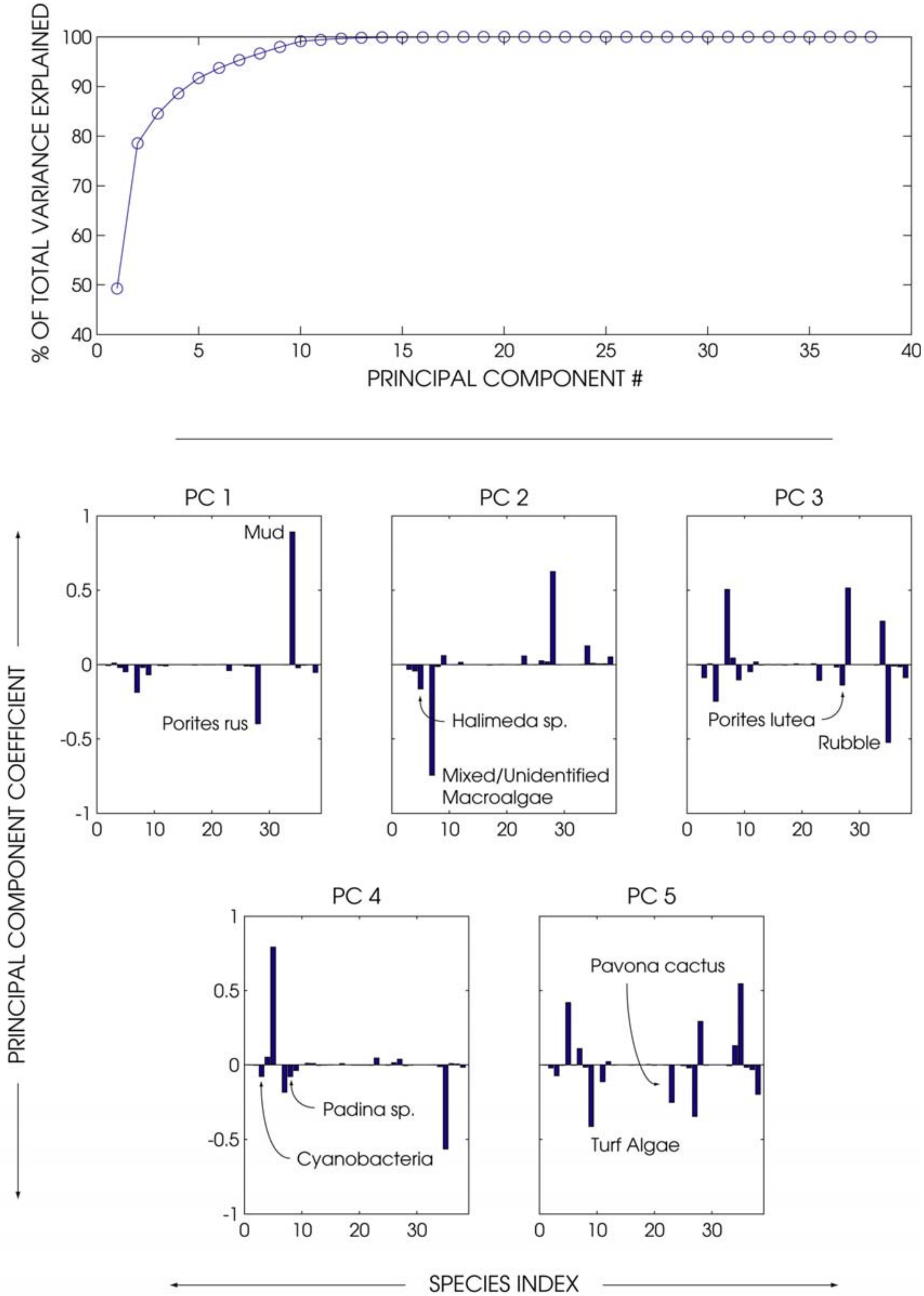


FIGURE 24. Selection of 10 detailed classes that contribute most to variance in the data set. Principal component analysis (PCA) was used to explain total variance in the detailed class percent cover data. The first five PCs describe >90% of the variance (virtually all of the variability in the data is described by the first 14 PCs) (Top). Plotting the coefficient value for each PC against the individual detailed classes, it is possible to identify which detailed classes are responsible for each PC, and thus which detailed classes are responsible for the variance in the whole data set (Bottom). In PC 1, the two detailed classes with the highest coefficient (absolute) values were mud and *Porites rus*. In PC 2, the two most important classes, other than the two from PC 1 (mud, *P. rus*), were mixed algae and *Halimeda* sp. In PC 3, the two most important additional classes were rubble and *P. lutea*. In PC 4, the two most important additional classes were *Padina* sp. and cyanobacteria. Finally, in PC 5, the two most important additional classes were turf algae and *Pavona cactus*.

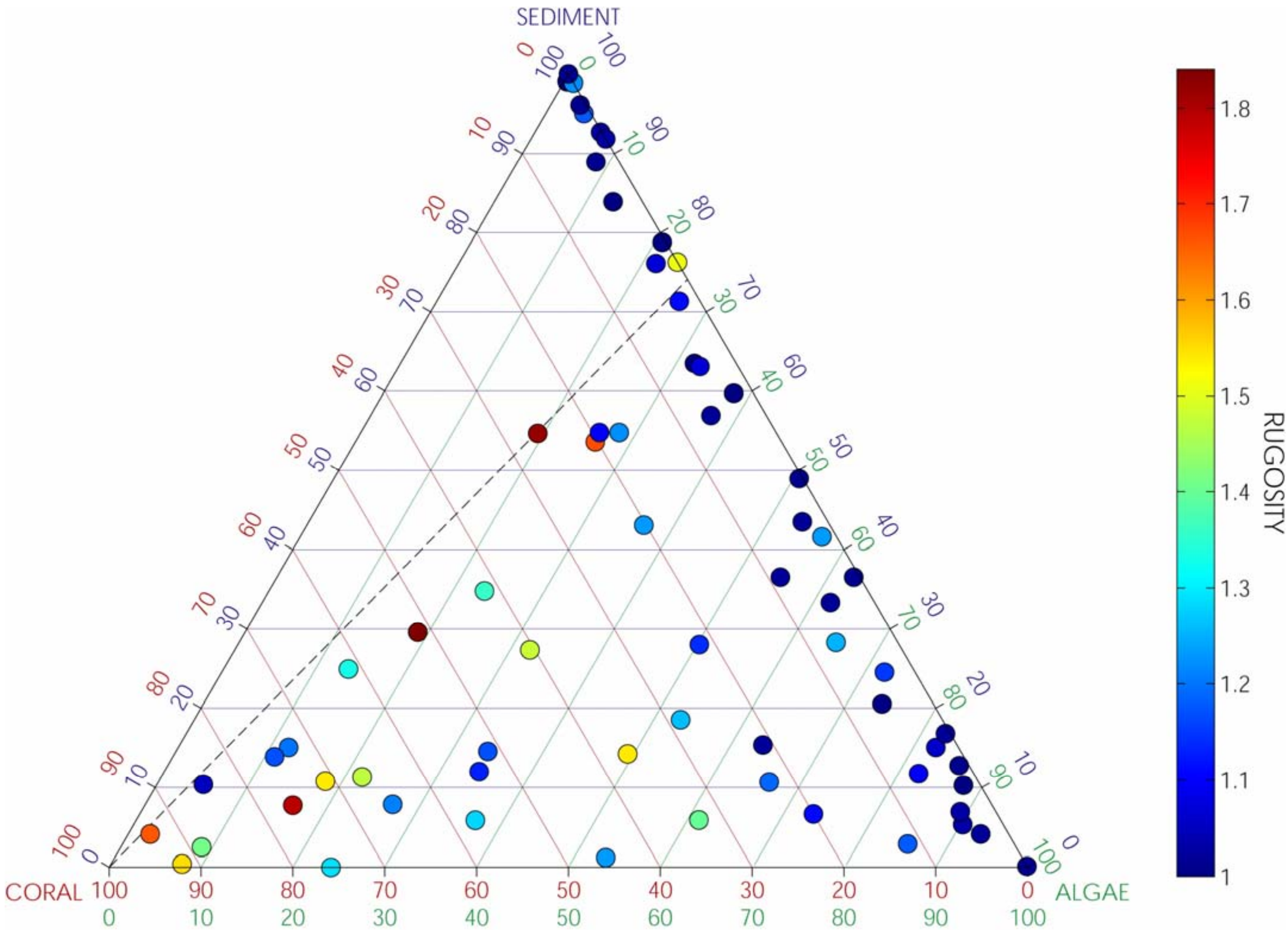


FIGURE 25. Ternary diagram showing relationship coral, algae and sediment percent cover at each transect. Vertices represent 100% cover of the respective classes. Edges of the triangle represent mixing lines between two classes, with the other class at 0% cover (e.g., the bottom of the triangle is mixing between coral and algae, with no sediment). Points within the triangle represent mixing between all three classes. The dashed line shows an apparent threshold in community structure: above the line, essentially no coral occurs. In addition, no coral occurs without the presence of algae. Color of points represents chain rugosity index. There is a weak trend of increasing rugosity with increasing coral cover.

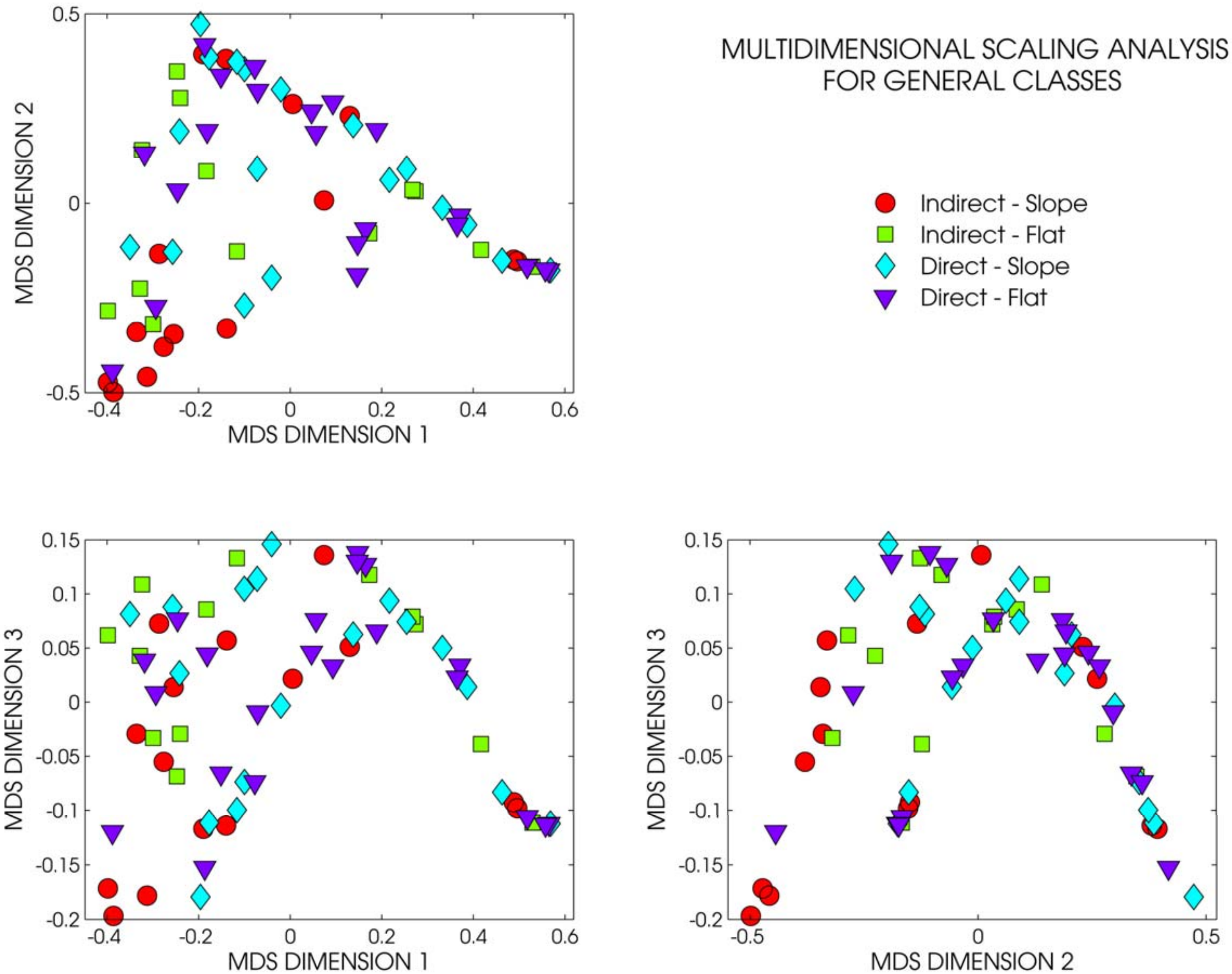


FIGURE 26. Plots of classical multidimensional scaling (CMDS), which give a qualitative sense of how near or far points are from each other, or in this case how similar the transect community structures are to each other. CMDS reduces the dimensionality of the data so that they can be displayed two-dimensionally. Each transect is represented by a single point representing six general classes, and transects that have similar benthic communities appear closer to each other than transects that are very different in terms of community structure. Comparisons of the first three dimensions indicate that clustering of points is not very evident, and the four strata appear evenly distributed across the data space. This indicates that there is no important difference between the different strata in terms of benthic community structure.

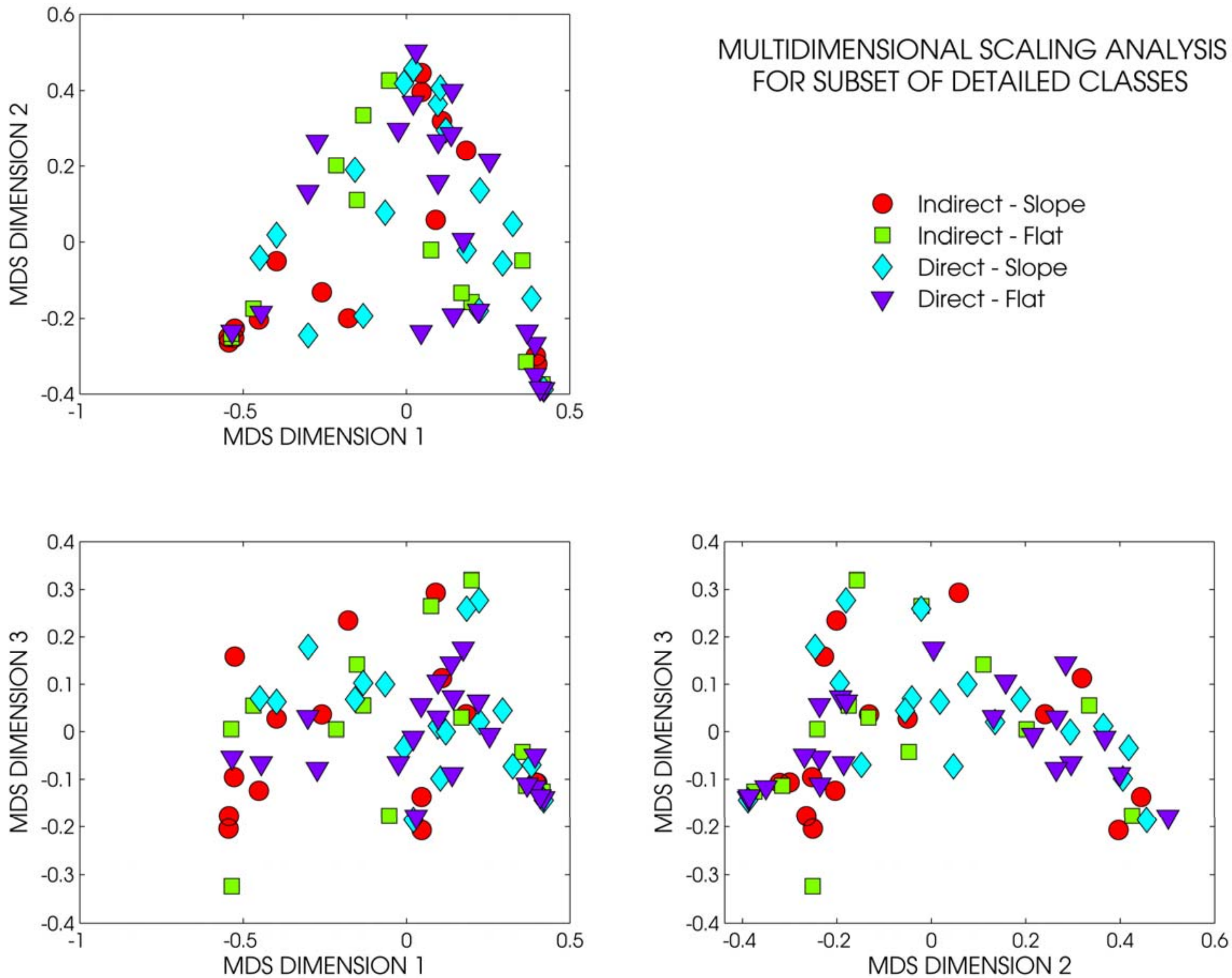


FIGURE 27. Plots of classical multidimensional scaling (CMDS), which give a qualitative sense of how near or far points are from each other, or in this case how similar the transect community structures are to each other. CMDS reduces the dimensionality of the data so that they can be displayed two-dimensionally. Each transect is represented by a single point representing ten detailed classes, and transects that have similar benthic communities appear closer to each other than transects that are very different in terms of community structure. Comparisons of the first three dimensions indicate that clustering of points is not very evident, and the four strata appear evenly distributed across the data space. This indicates that there is no important difference between the different strata in terms of benthic community structure.

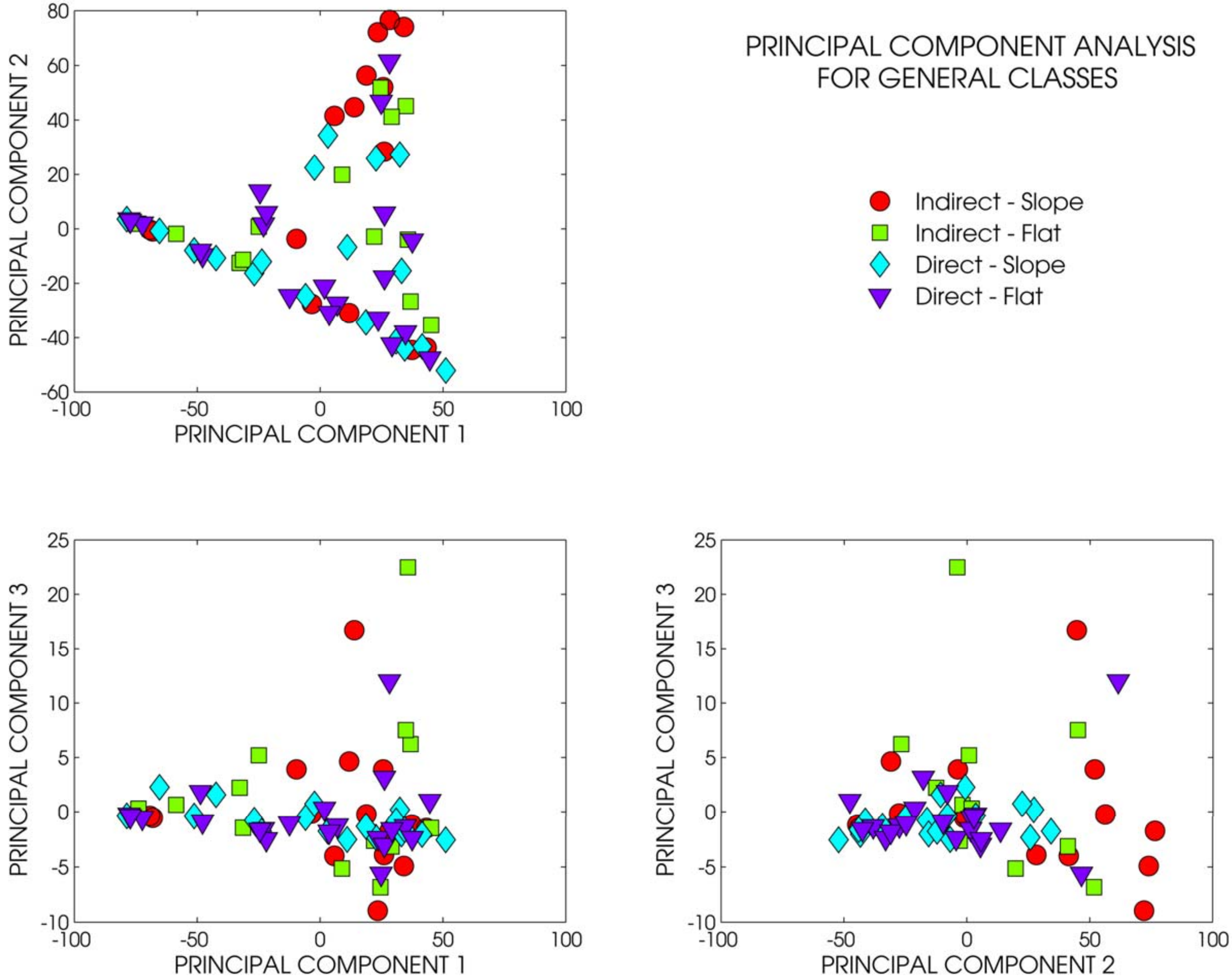


FIGURE 28. Plots of component analysis (PCA) that reduce the dimensionality of the data space for six general classes. As with multidimensional scaling, these plots also give a qualitative representation of the similarities between transects. Again, there are no apparent trends or clusters, indicating no overall differences between strata.

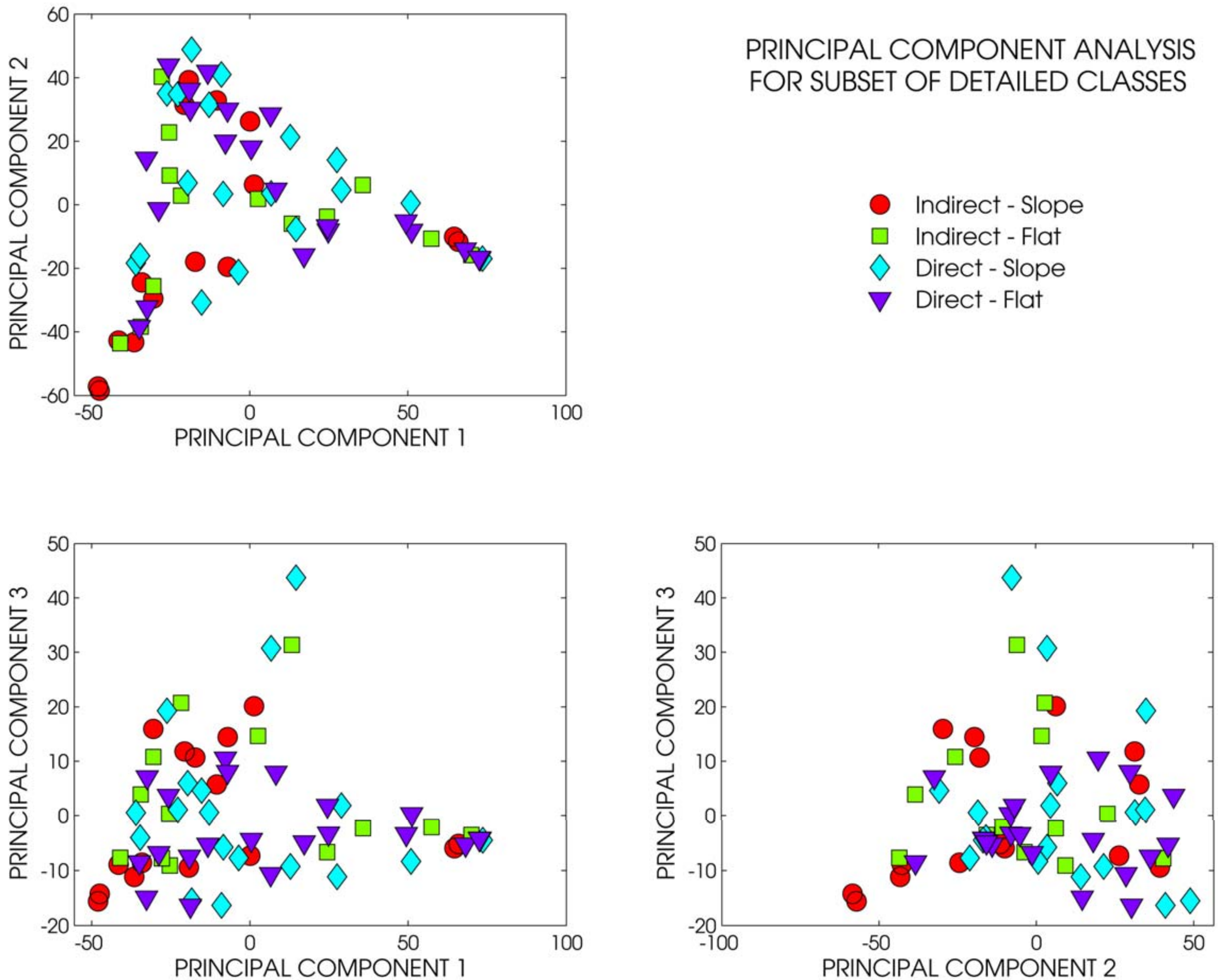


FIGURE 29. Plots of component analysis (PCA) that reduce the dimensionality of the data space for ten detailed classes. As with multidimensional scaling, these plots also give a qualitative representation of the similarities between transects. Again, there are no apparent trends or clusters, indicating no overall differences between strata.

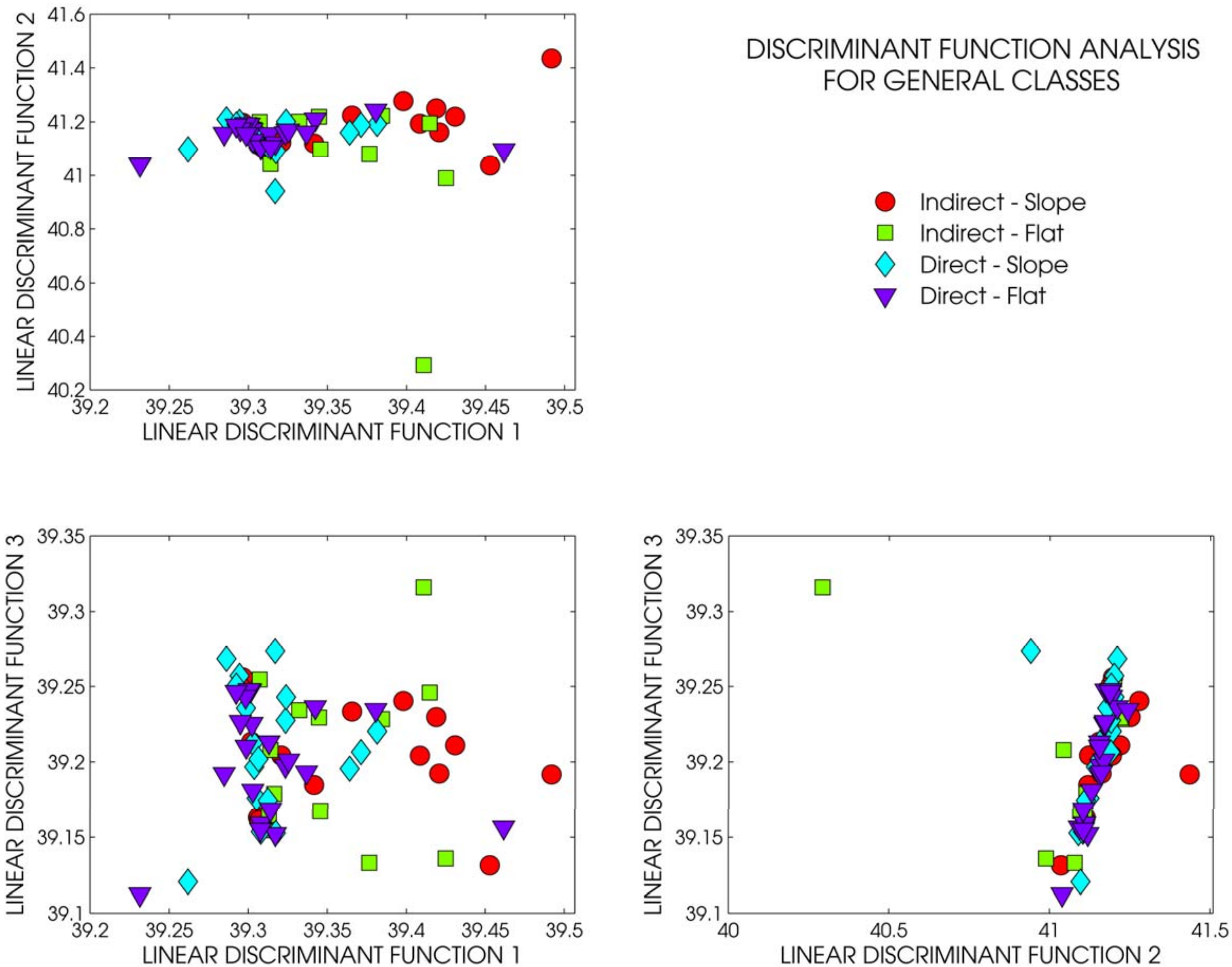


FIGURE 30. Plots showing results of discriminant function analysis (DFA) performed using six general classes. DFA describes the separation of two or more predefined groups based on linear functions of multiple variables. In this case, the discriminant functions do not separate the strata, and thus the strata are not statistically different from each other in terms of benthic community structure

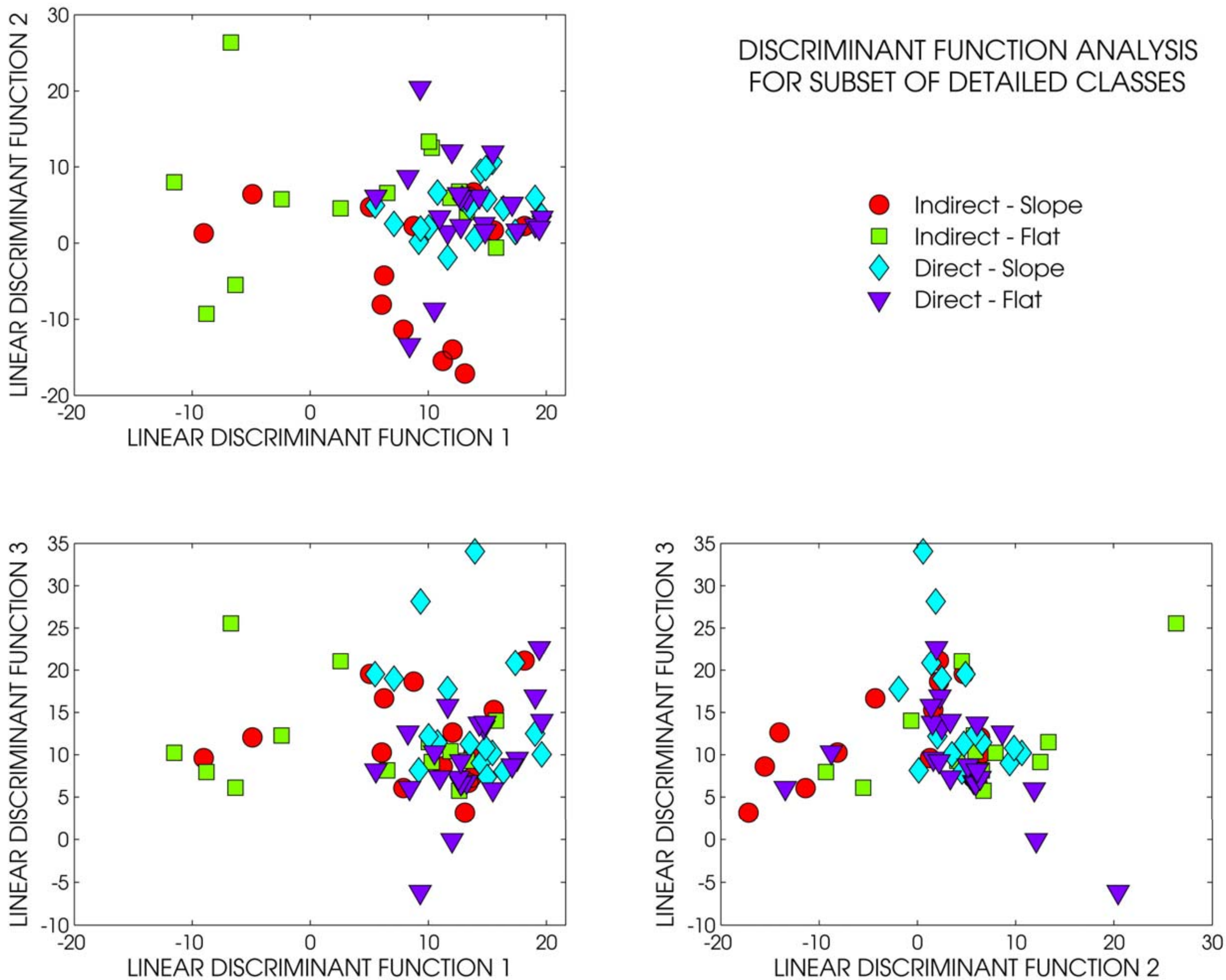


FIGURE 31. Plots showing results of discriminant function analysis (DFA) performed using ten detailed classes. DFA describes the separation of two or more predefined groups based on linear functions of multiple variables. In this case, the discriminant functions do not separate the strata, and thus the strata are not statistically different from each other in terms of benthic community structure

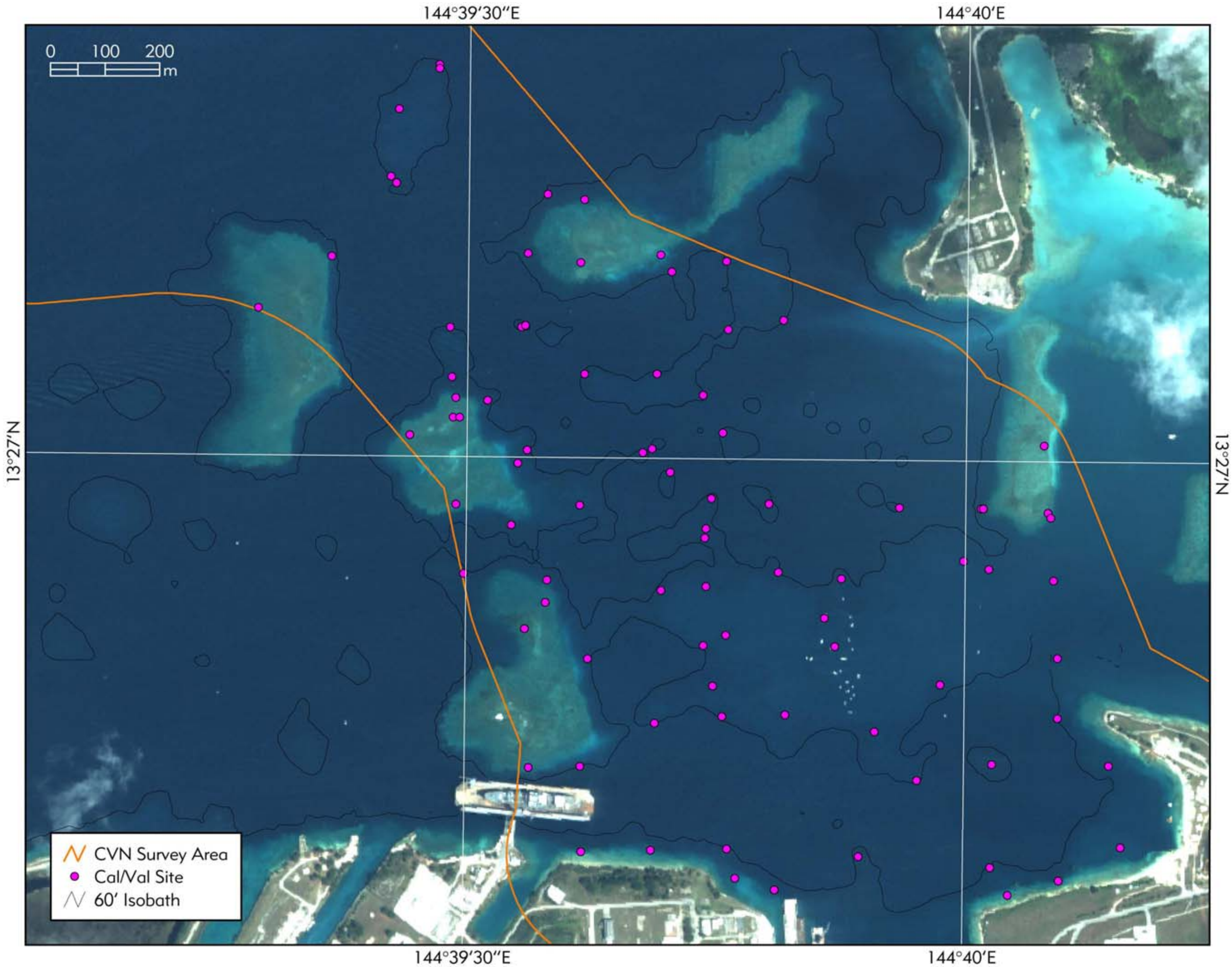


FIGURE 32. Satellite image of CVN region of Apra Harbor showing locations of calibration-validation sites used for generating classifiers for benthic habitat maps.

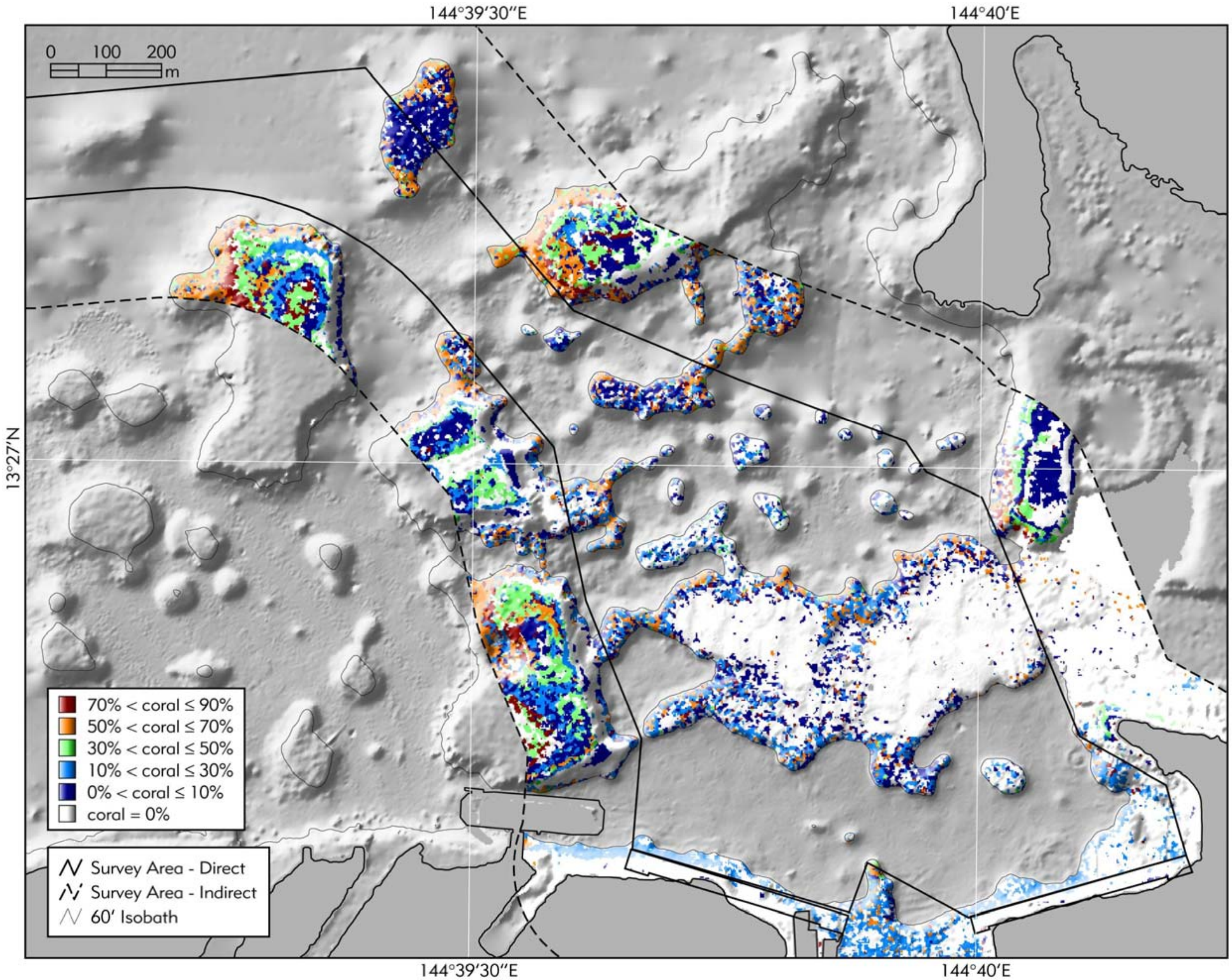
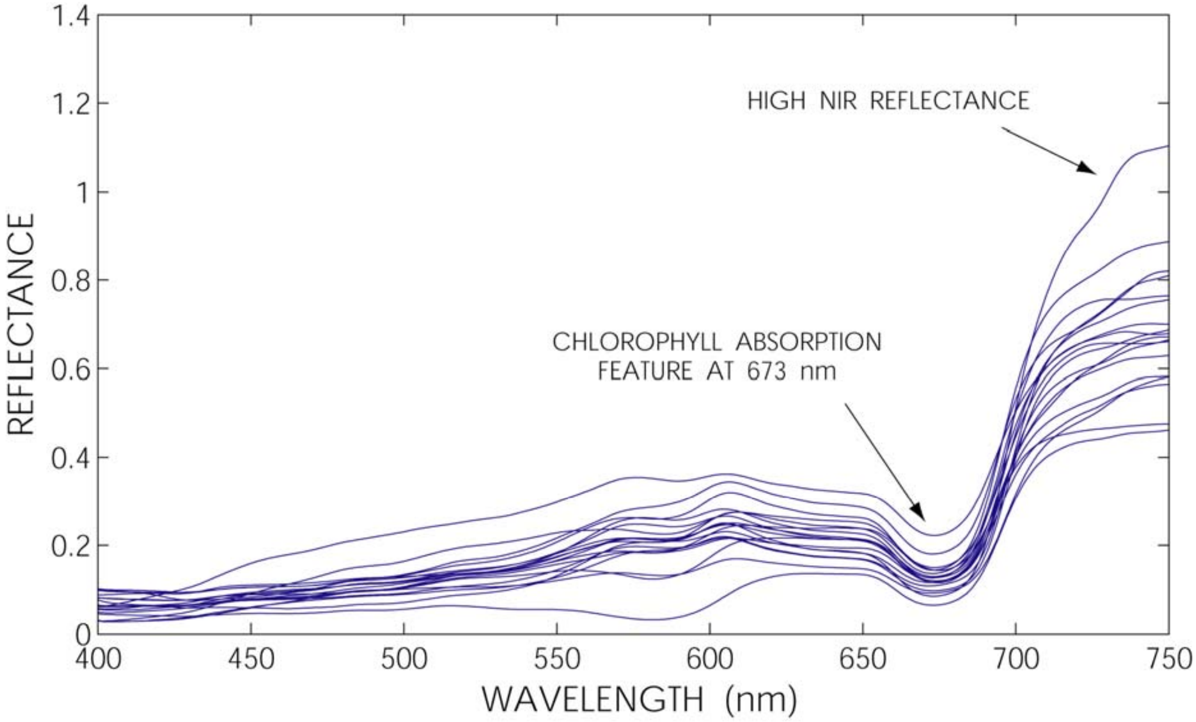


FIGURE 33. Classification map showing percent cover of coral in CVN survey area. Cal/val data were co-located with pixels in the Quickbird image, which were used to build a set of classification rules (quadratic classifier using Mahalanobis distance). The classification rules were applied to the entire Quickbird image. The resulting map was masked to show only the reef surface within the study area to a depth of 60 feet.



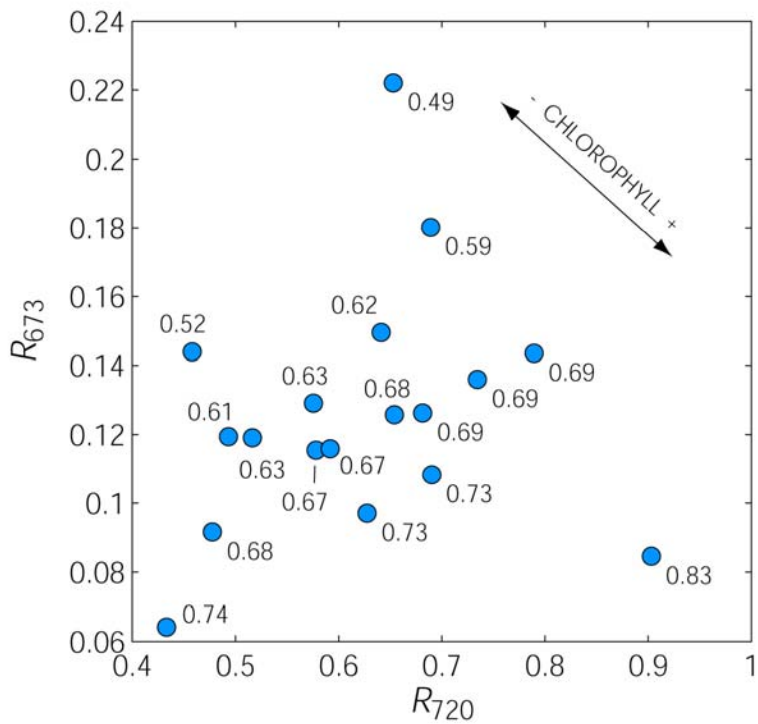


FIGURE 34. Example of NDVI (Normalized Difference Vegetation Index) for selected corals in CVN survey. Top panel shows spectral reflectance of 18 different corals. Higher reflectance indicates brighter/paler color. Even though some corals are brighter than others, all corals have a strong chlorophyll signature, evidenced by an absorption feature at 673 nm and high NIR reflectance. Bottom panel shows R_673 plotted against R_720 for each of the corals in the top panel. Each dot is labeled with its corresponding NDVI value. Chlorophyll concentration increases toward the bottom right and decreases toward the top left of the plot.

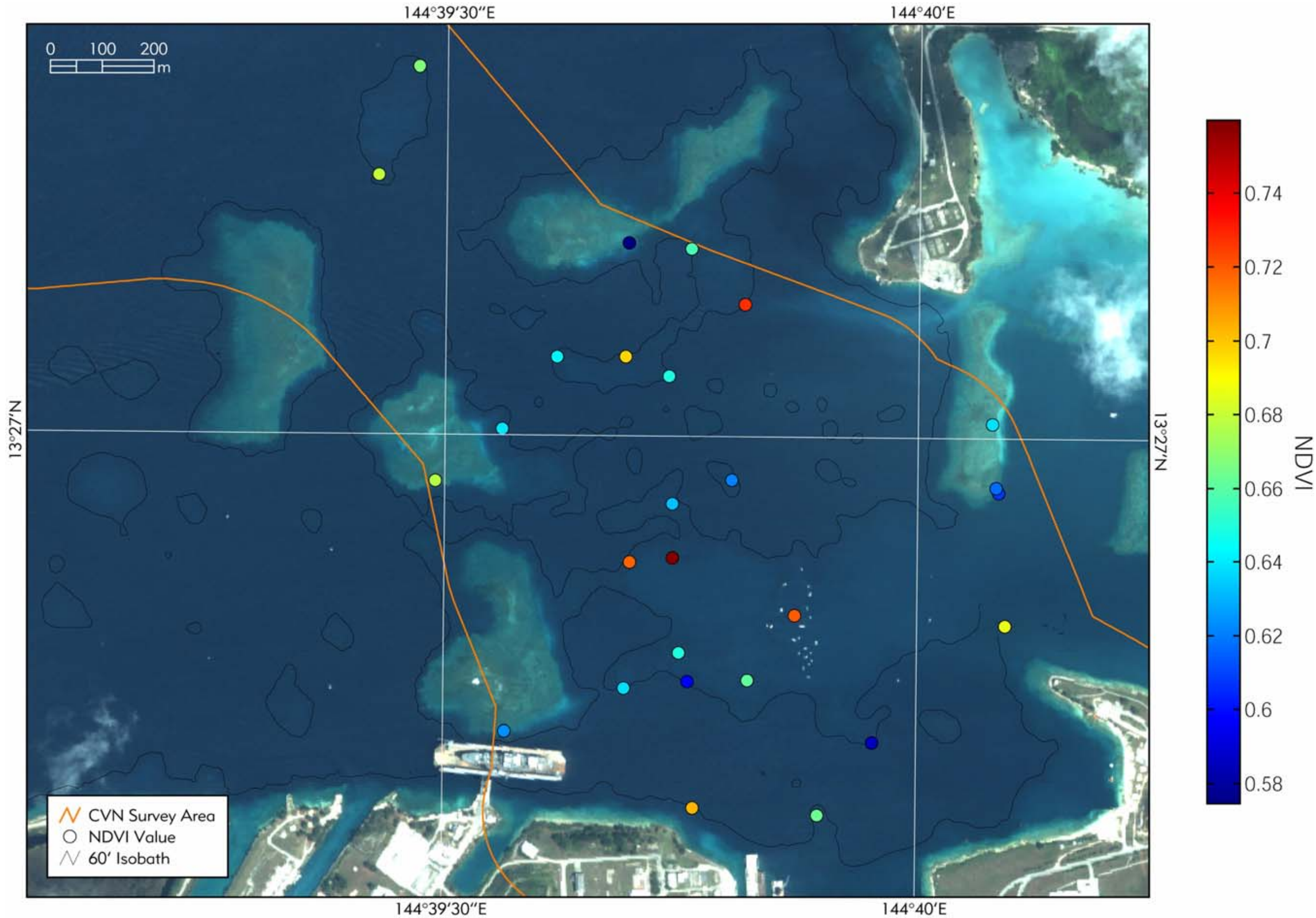


FIGURE 35. Normalized Difference Vegetation Index (NDVI) for 27 sites in CVN survey area. NDVI is computed from spectral reflectances of corals measured in situ. It is a relative scale indicating amount of chlorophyll present; higher values indicate more chlorophyll. Values are averages of 4-6 corals at each site.There is no apparent trend in the horizontal spatial distribution of NDVI, though all values in this study would be generally considered to represent high chlorophyll content. NDVI does increase slightly with depth (not shown).

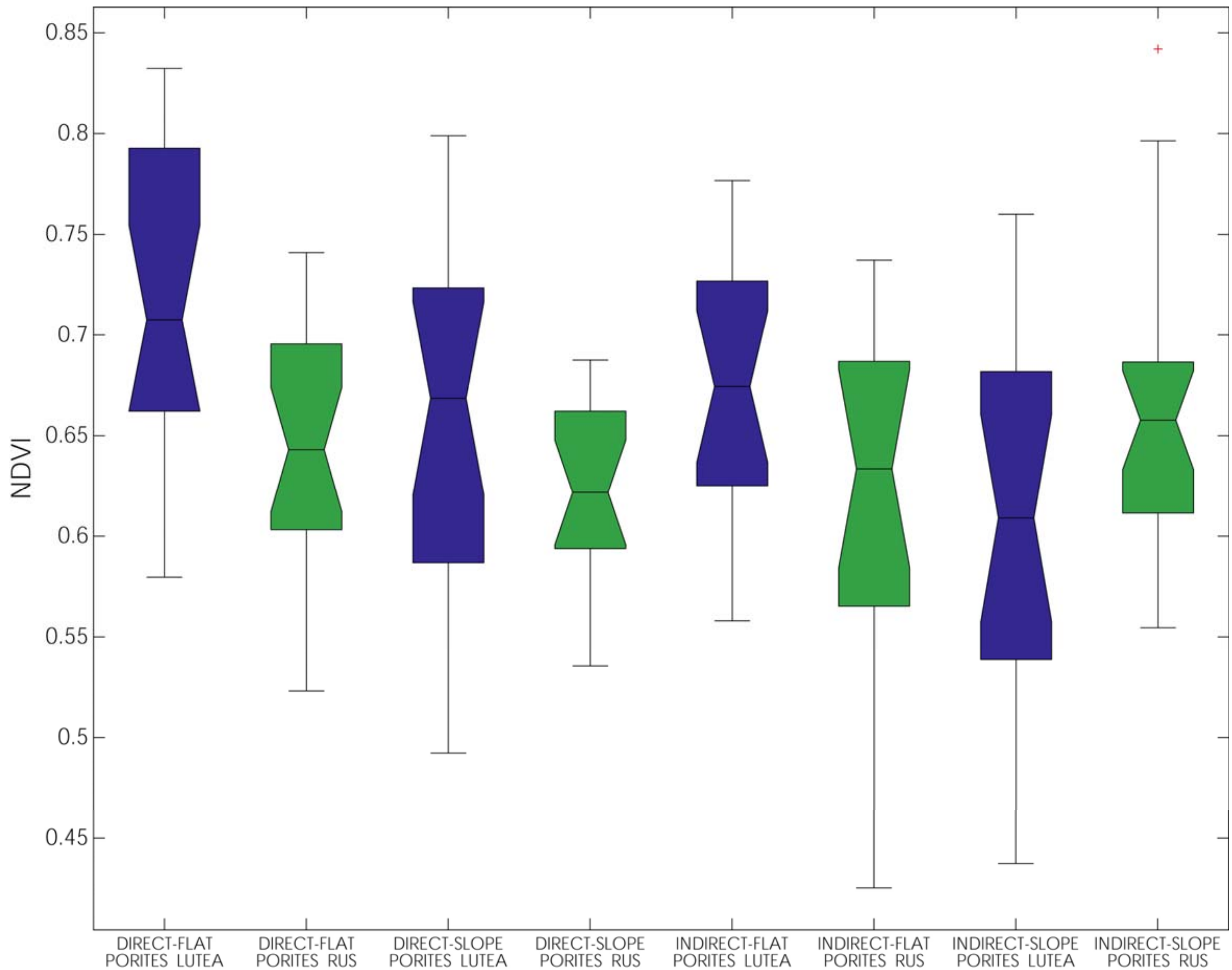


FIGURE 36. Distribution of Normalized Difference Vegetation Index (NDVI) by survey strata for the two most abundant corals (*Porites rus* [green], *P. lutea* [blue]) in the CVN survey area. On each box, the central mark is the median, the upper and lower edges of the box are the first and third quartiles, respectively, the whiskers extend to the most extreme data points not considered outliers, and outliers are plotted individually. Following the 1.5*IQR rule, there is only a single outlier, occurring in Indirect-Slope/*Porites rus*. All of the corals in all of the strata generally share the same range of NDVI, though within strata *P. lutea* tends to have a slightly wider distribution and slightly higher values.

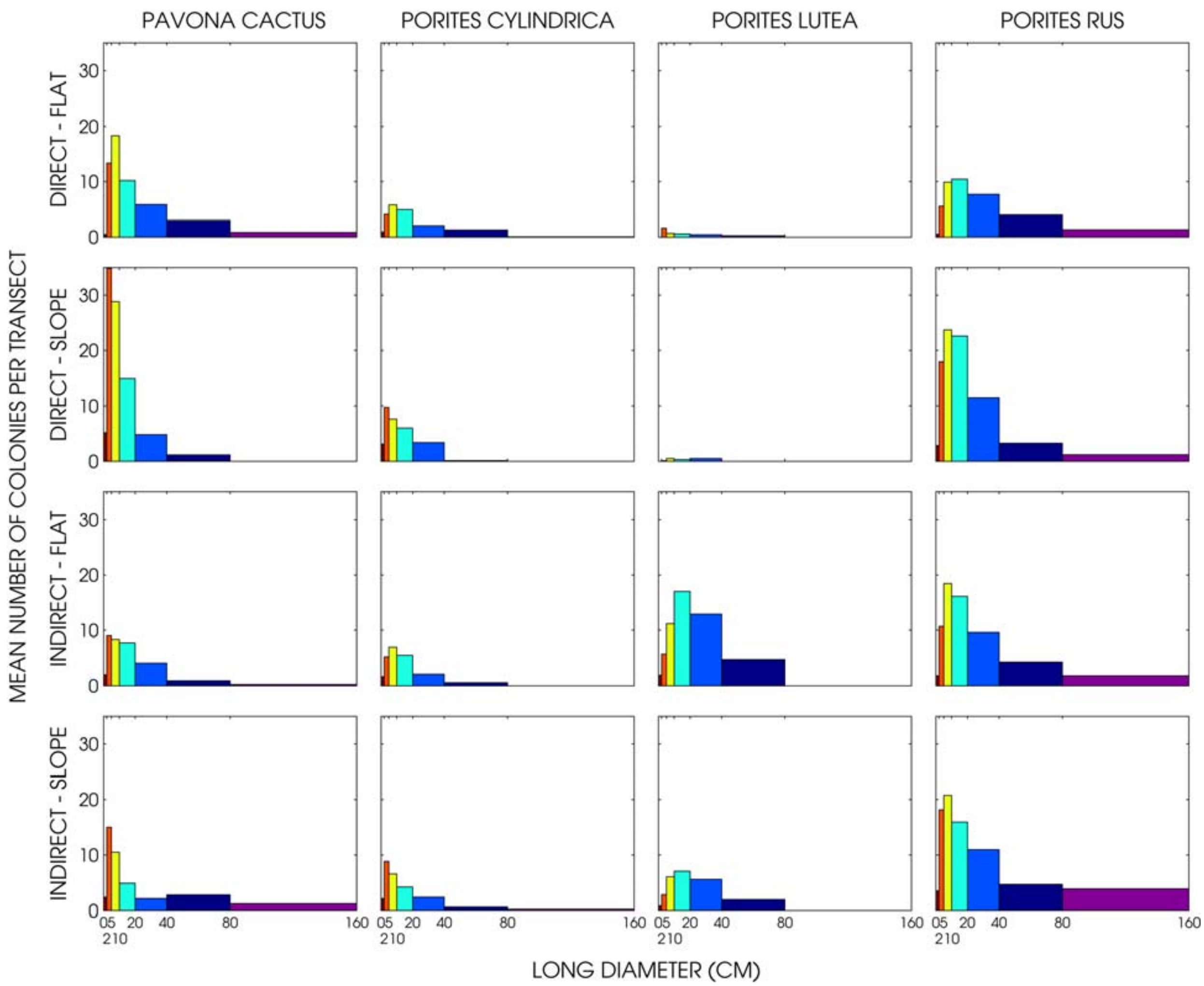


FIGURE 37. Size-frequency distribution of the four most abundant corals in Apra survey area. Histograms are arranged left-to-right by coral species and top-to-bottom by survey stratum. Histograms show mean values determined across all transects within a given stratum. Size classes are $x < 2$, $2 \le x < 5$, $5 \le x < 10$, $10 \le x < 20$, $20 \le x < 40$, $40 \le x < 80$, and $80 \le x < 160$.

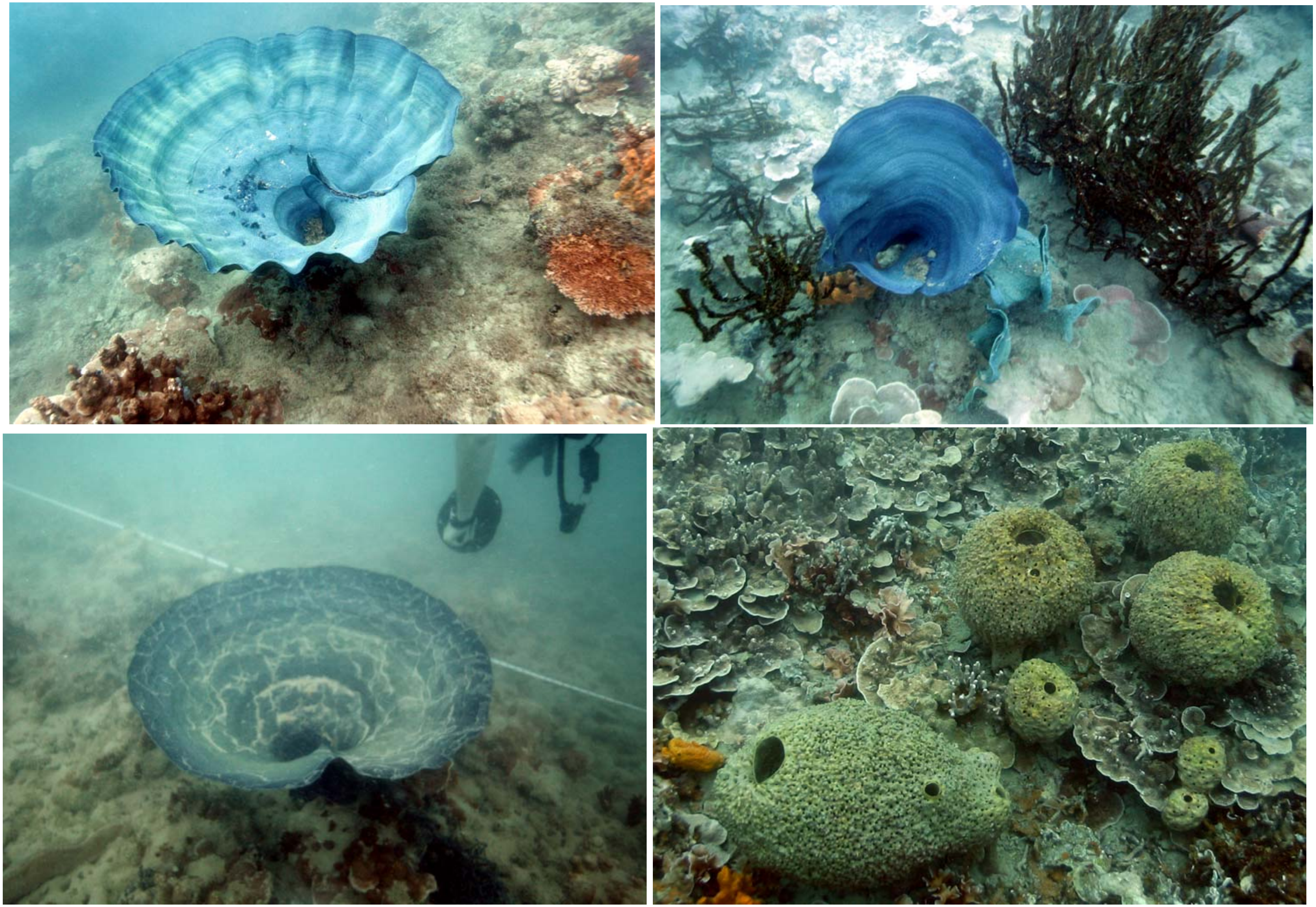


FIGURE 38. Four photographs of large sponges common in Apra Harbor. Blue "elephant ear" sponges (*Ianthella* sp.) commonly occur in the deeper regions of the Apra Harbor turning basin. The upper photos are from Transect 31, photo at lower left from Transect 56, and photo at lower right from Transect 1.

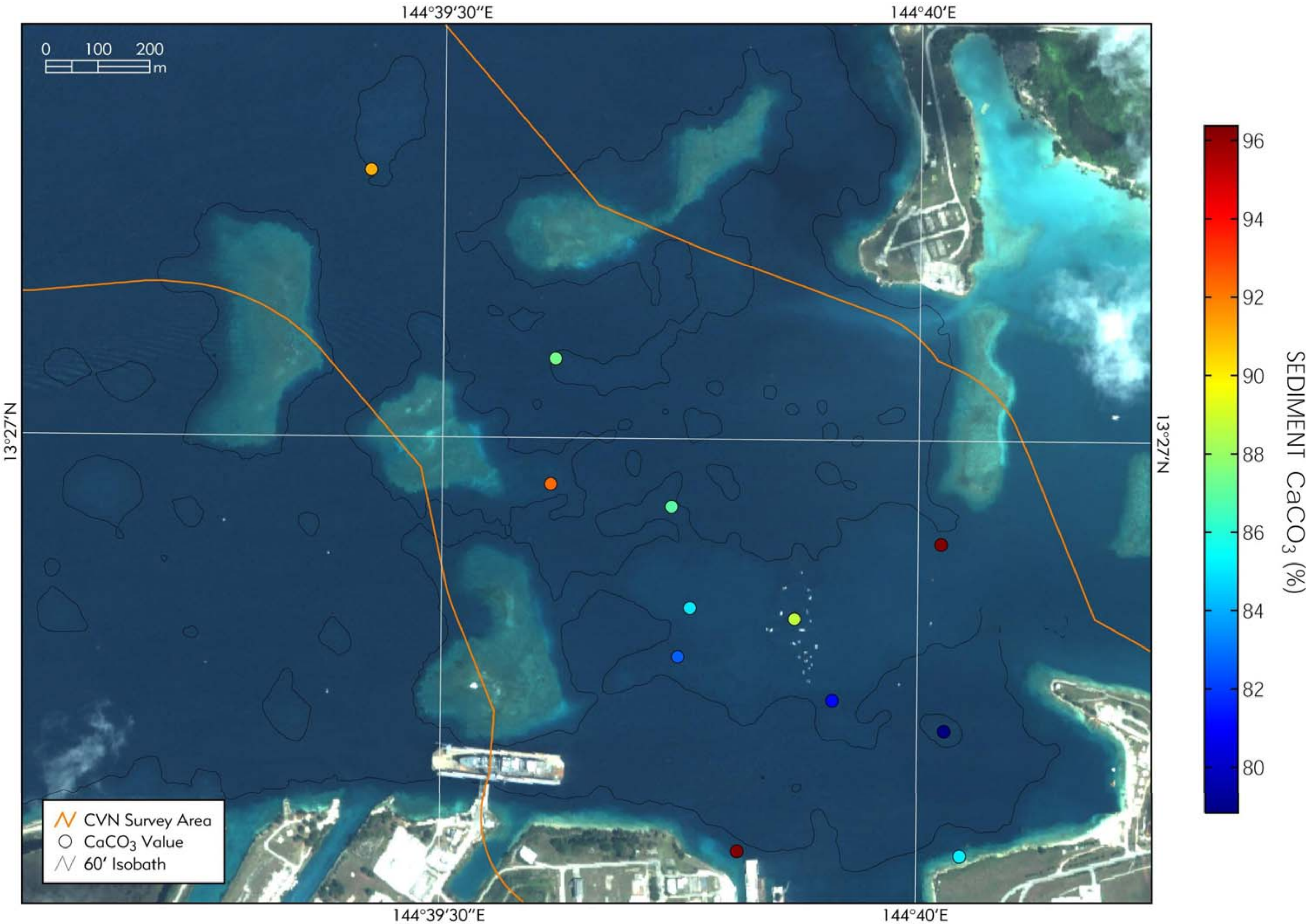


FIGURE 39. CVN survey area showing percent of $CaCO_3$ in surface sediment samples collected at twelve transect sites.

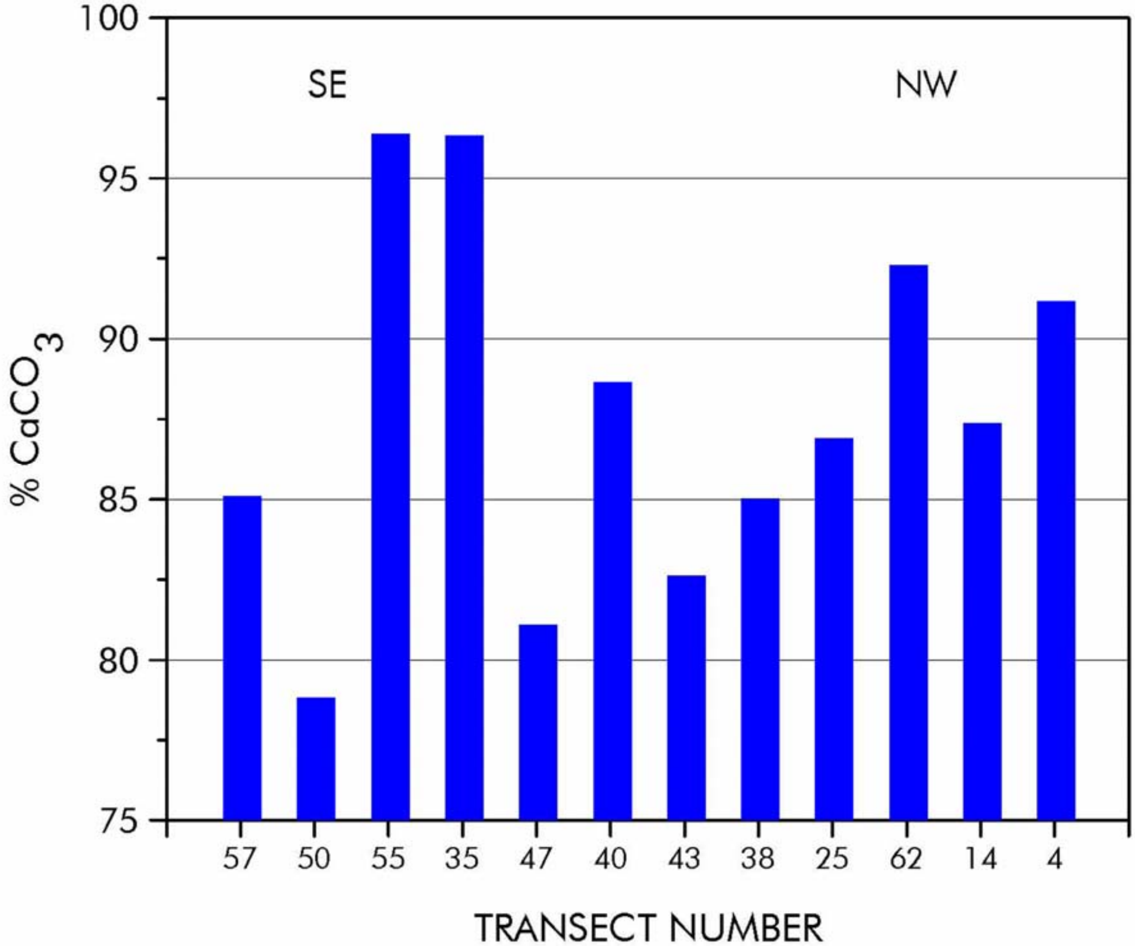


FIGURE 40. Percent calcium carbonate composition of sediment samples collected at 12 transect locations with the Direct Impact strata of the CVN study area in southeastern Apra Harbor, Guam. Sampling locations extended from the southeast (SE) to northwest (NW) from near the mouth of Inner Apra Harbor to the submerged patch reef at the northern end of the Fairway. For location of sampled transects, see Figure 39.

APPENDICES

BENTHIC SURVEYS OF SOUTHEASTERN APRA HARBOR
IN THE VICINITY OF THE CVN PROJECT

Jyly 2009

APPENDIX A. Coordinates and strata designations for 67 transect sites in southeastern outer Apra Harbor surveyed for CVN benthic assessment.

TRANSECT NUMBER	LABEL	LATITUDE	LONGITUDE	STRATA		DEPTH (ft)
				Direct/Indirect	Flat/Slope	
1	CVN-I-S1	13.4565	144.6578	Indirect	Slope	55
2	CVN-I-F1	13.4564	144.6578	Indirect	Flat	52
3	CVN-I-F2	13.4557	144.6571	Indirect	Flat	47
4	CVN-D-S1	13.4546	144.6570	Direct	Slope	58
5	CVN-D-F1	13.4545	144.6571	Direct	Flat	57
6	CVN-I-F3	13.4543	144.6602	Indirect	Flat	11
7	CVN-I-F4	13.4532	144.6602	Indirect	Flat	3
8	CVN-I-S2	13.4533	144.6560	Indirect	Slope	22
9	CVN-I-F5	13.4524	144.6548	Indirect	Flat	8
10	CVN-D-S2	13.4521	144.6580	Direct	Slope	60
11	CVN-D-F2	13.4522	144.6592	Direct	Flat	55
12	CVN-D-S3	13.4522	144.6593	Direct	Slope	57
13	CVN-I-F6	13.4513	144.6580	Indirect	Flat	46
14	CVN-D-S4	13.4514	144.6603	Direct	Slope	54
15	CVN-I-S3	13.4501	144.6593	Indirect	Slope	51
16	CVN-I-F7	13.4499	144.6592	Indirect	Flat	45
17	CVN-I-S4	13.4534	144.6615	Indirect	Slope	11
18	CVN-I-F8	13.4533	144.6626	Indirect	Flat	57
19	CVN-I-S5	13.4523	144.6636	Indirect	Slope	56
20	CVN-I-S6	13.4521	144.6627	Indirect	Slope	55
21	CVN-D-S5	13.4514	144.6615	Direct	Slope	56
22	CVN-D-S6	13.4511	144.6623	Direct	Slope	57
23	CVN-D-F3	13.4502	144.6614	Direct	Flat	60
24	CVN-I-F9	13.4503	144.6680	Indirect	Flat	2
25	CVN-D-F4	13.4488	144.6623	Direct	Flat	48
26	CVN-D-F5	13.4493	144.6634	Direct	Flat	48
27	CVN-D-S7	13.4492	144.6656	Direct	Slope	58
28	CVN-I-S7	13.4492	144.6670	Indirect	Slope	37
29	CVN-I-F10	13.4492	144.6681	Indirect	Flat	5
30	CVN-I-S8	13.4491	144.6681	Indirect	Slope	12
31	CVN-D-F6	13.4478	144.6616	Direct	Flat	49
32	CVN-D-F7	13.4479	144.6623	Direct	Flat	47
33	CVN-D-S8	13.4481	144.6636	Direct	Slope	58
34	CVN-D-F8	13.4480	144.6646	Direct	Flat	48
35	CVN-D-F9	13.4482	144.6671	Direct	Flat	49
36	CVN-I-F11	13.4480	144.6682	Indirect	Flat	51
37	CVN-D-S9	13.4469	144.6623	Direct	Slope	53
38	CVN-D-F10	13.4471	144.6627	Direct	Flat	46
39	CVN-D-F11	13.4474	144.6643	Direct	Flat	50
40	CVN-D-F12	13.4469	144.6645	Direct	Flat	48
41	CVN-I-S9	13.4467	144.6683	Indirect	Slope	42
42	CVN-D-F13	13.4463	144.6663	Direct	Flat	44
43	CVN-D-F14	13.4462	144.6625	Direct	Flat	44
44	CVN-D-S10	13.4456	144.6615	Direct	Slope	59
45	CVN-D-S11	13.4457	144.6626	Direct	Slope	48
46	CVN-D-F15	13.4458	144.6637	Direct	Flat	48
47	CVN-D-F16	13.4455	144.6652	Direct	Flat	47
48	CVN-D-S12	13.4458	144.6683	Direct	Slope	58
49	CVN-D-S13	13.4450	144.6691	Direct	Slope	35
50	CVN-D-F17	13.4450	144.6672	Direct	Flat	48
51	CVN-D-S14	13.4447	144.6659	Direct	Slope	51
52	CVN-D-S15	13.4435	144.6615	Direct	Slope	14
53	CVN-D-S16	13.4436	144.6627	Direct	Slope	56
54	CVN-D-F18	13.4431	144.6629	Direct	Flat	24
55	CVN-D-S17	13.4429	144.6635	Direct	Slope	30
56	CVN-I-F12	13.4434	144.6650	Indirect	Flat	48
57	CVN-D-F19	13.4428	144.6675	Direct	Flat	3
58	CVN-D-S18	13.4431	144.6683	Direct	Slope	14
59	CVN-D-F20	13.4436	144.6694	Direct	Flat	34
60	CVN-I-F13	13.4492	144.6581	Indirect	Flat	3
61	CVN-I-S10	13.4489	144.6590	Indirect	Slope	37
62	CVN-D-F21	13.4492	144.6602	Direct	Flat	37
63	CVN-I-S11	13.4481	144.6583	Indirect	Slope	49
64	CVN-I-S12	13.4467	144.6604	Indirect	Slope	49
65	CVN-I-S13	13.4449	144.6594	Indirect	Slope	5
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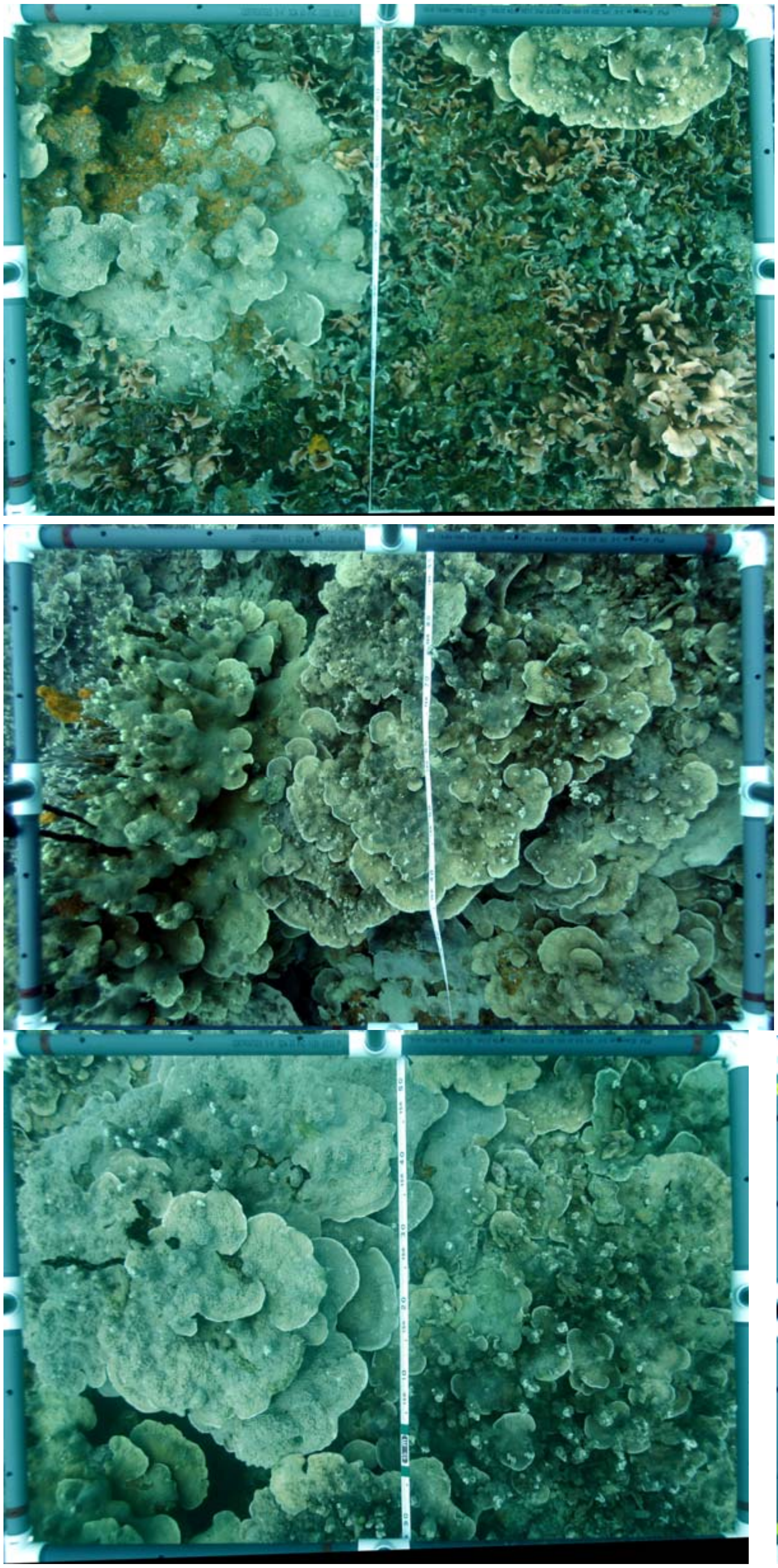
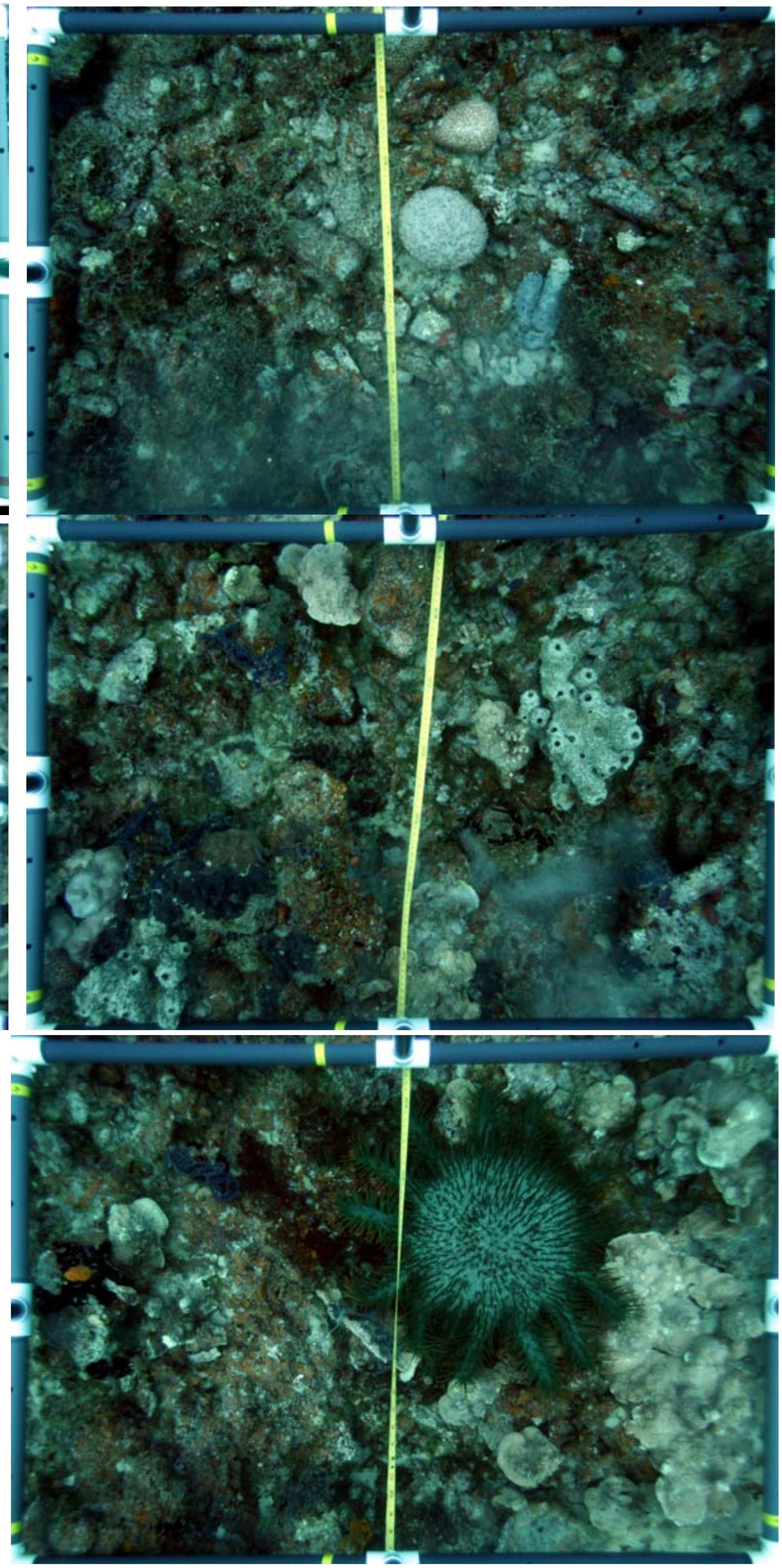
67	CVN-I-S15	13.4435	144.6603	Indirect	Slope	9





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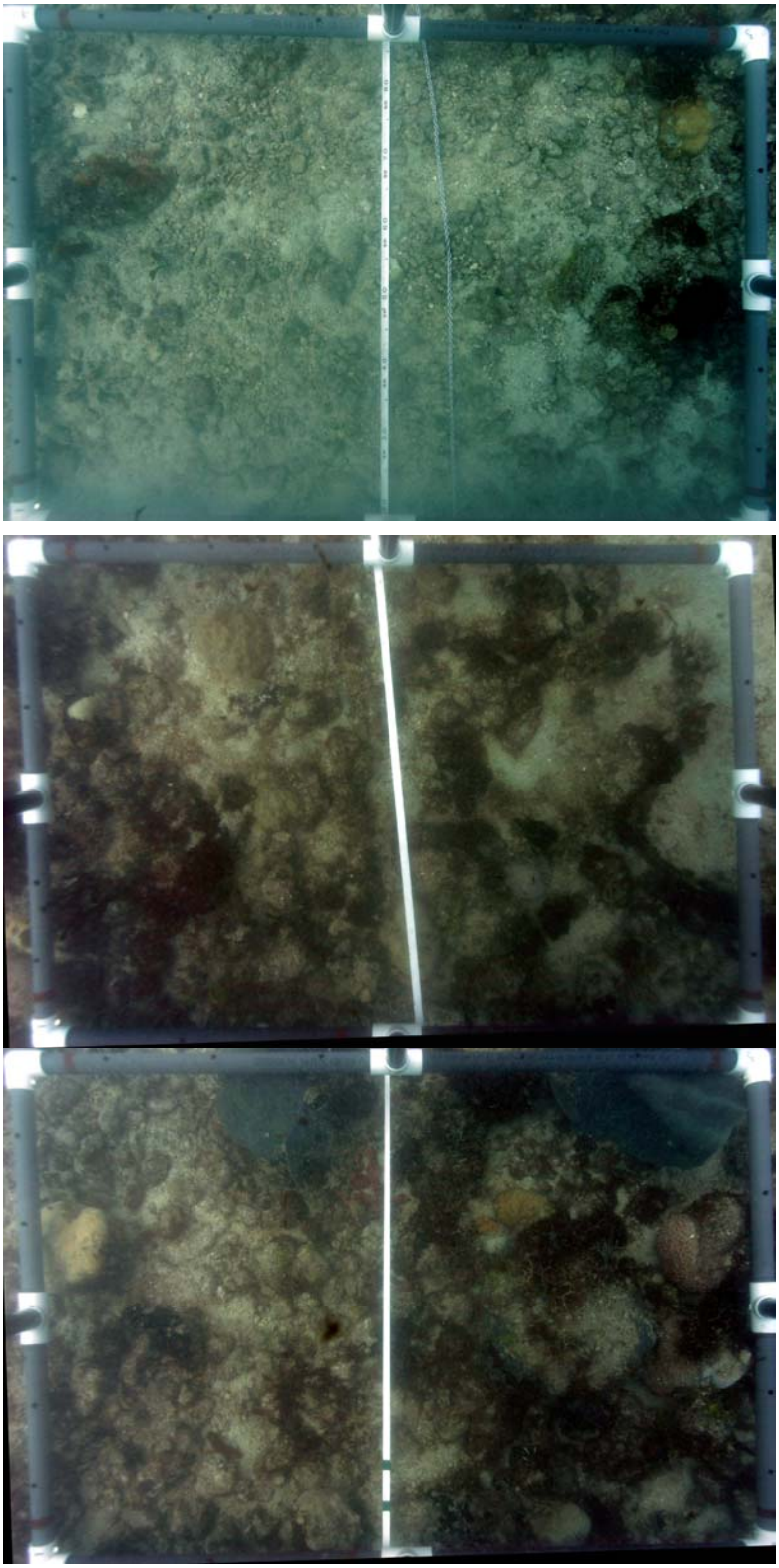

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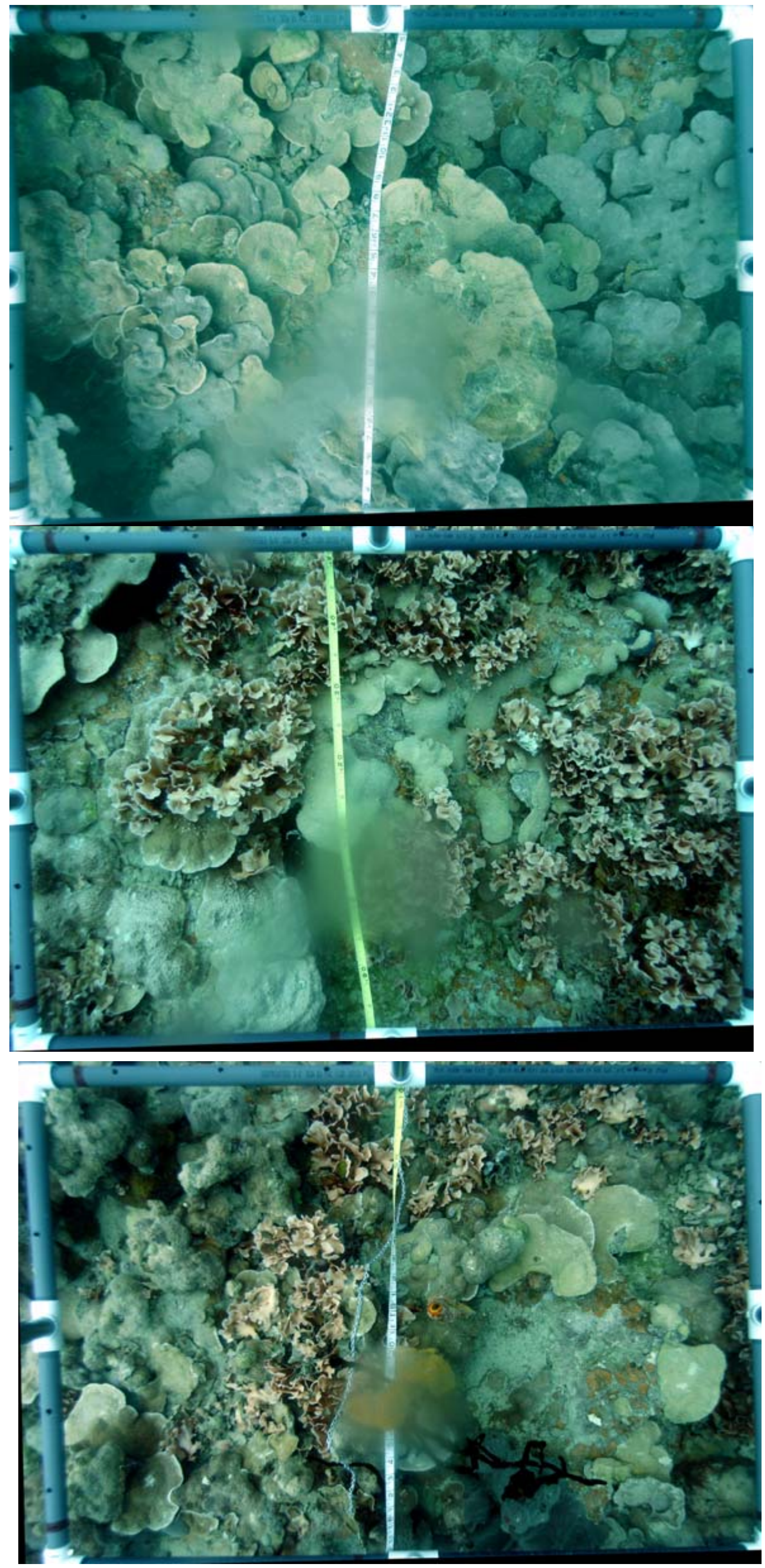

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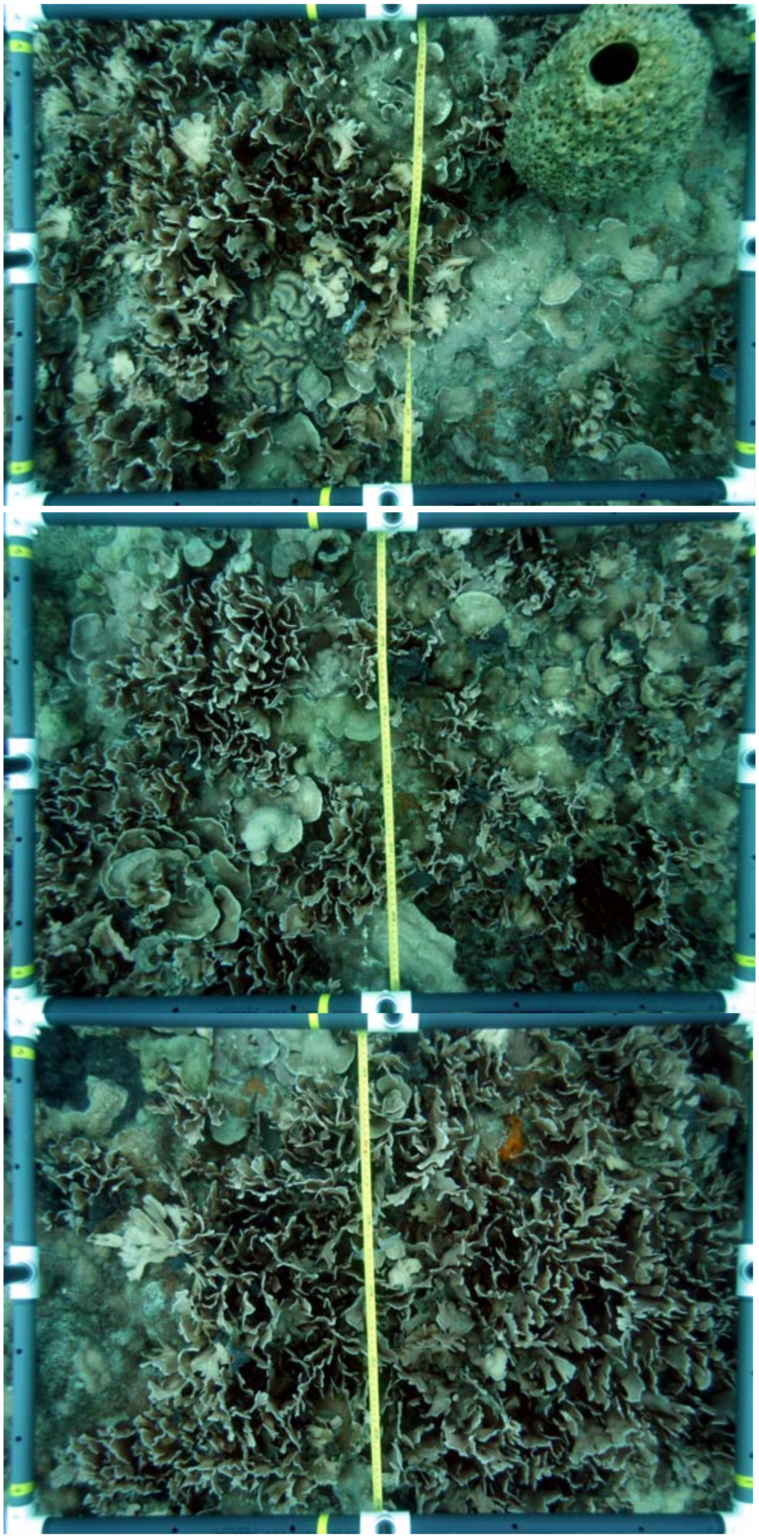
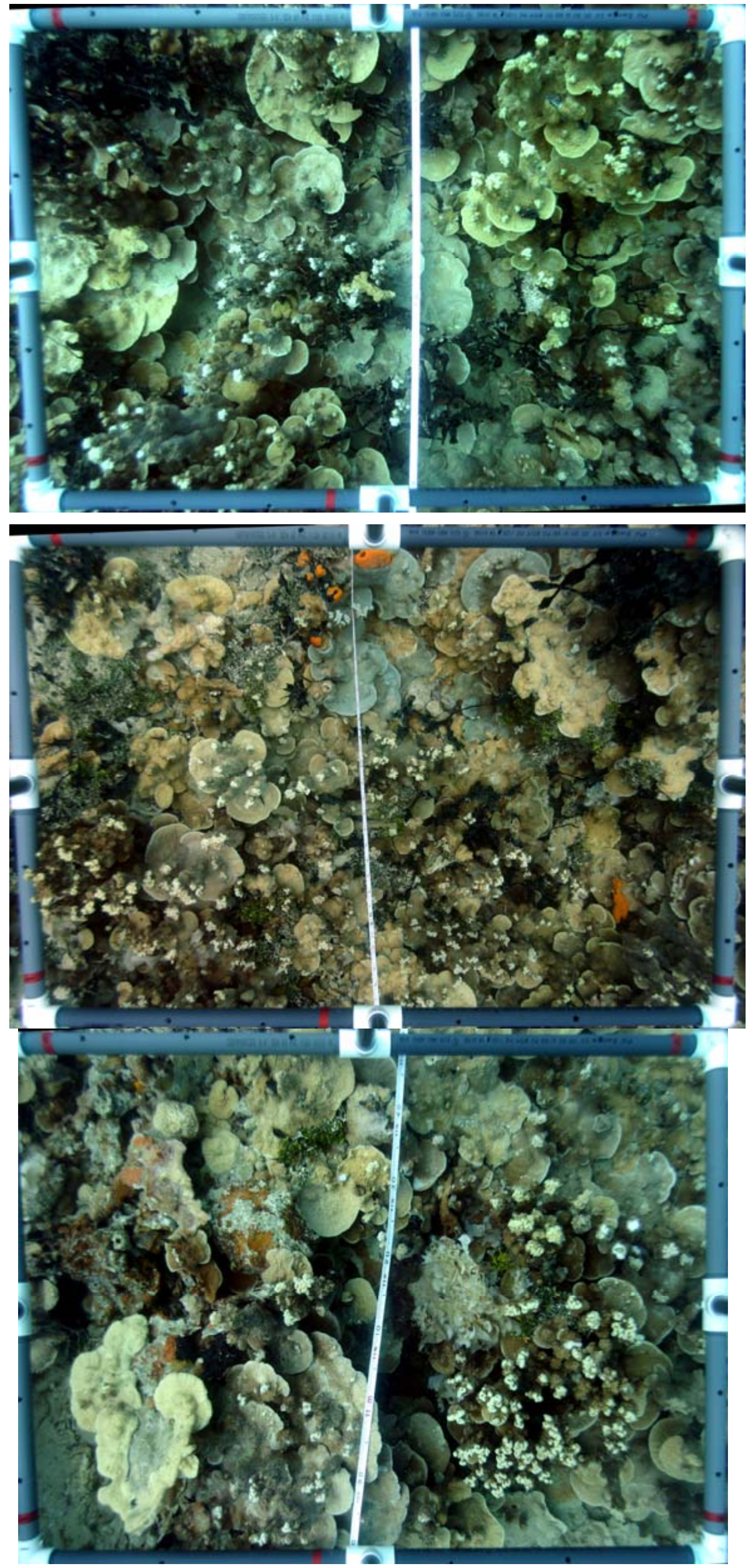


TRANSECT 5

TRANSECT 6

TRANSECT 7



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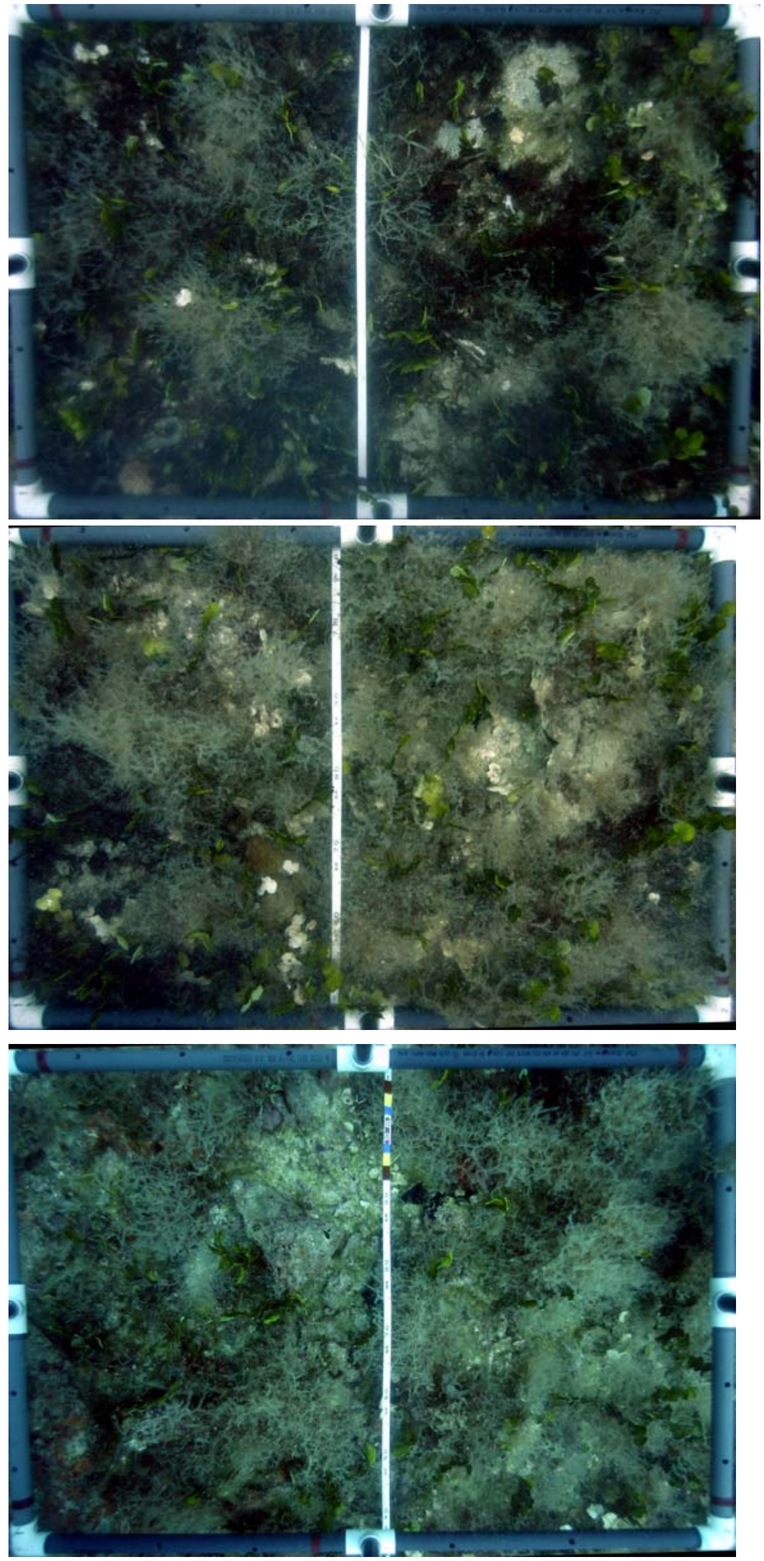

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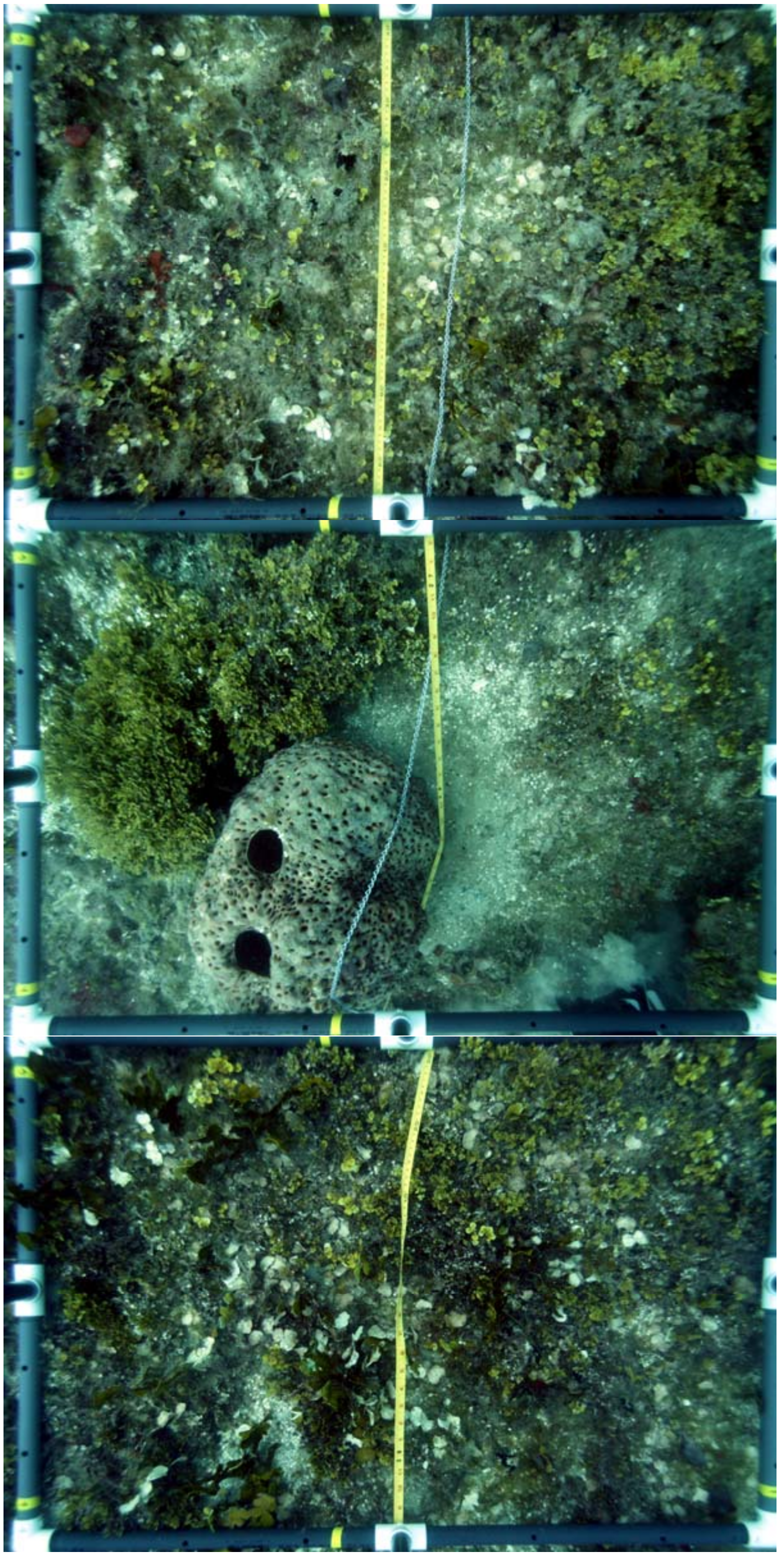

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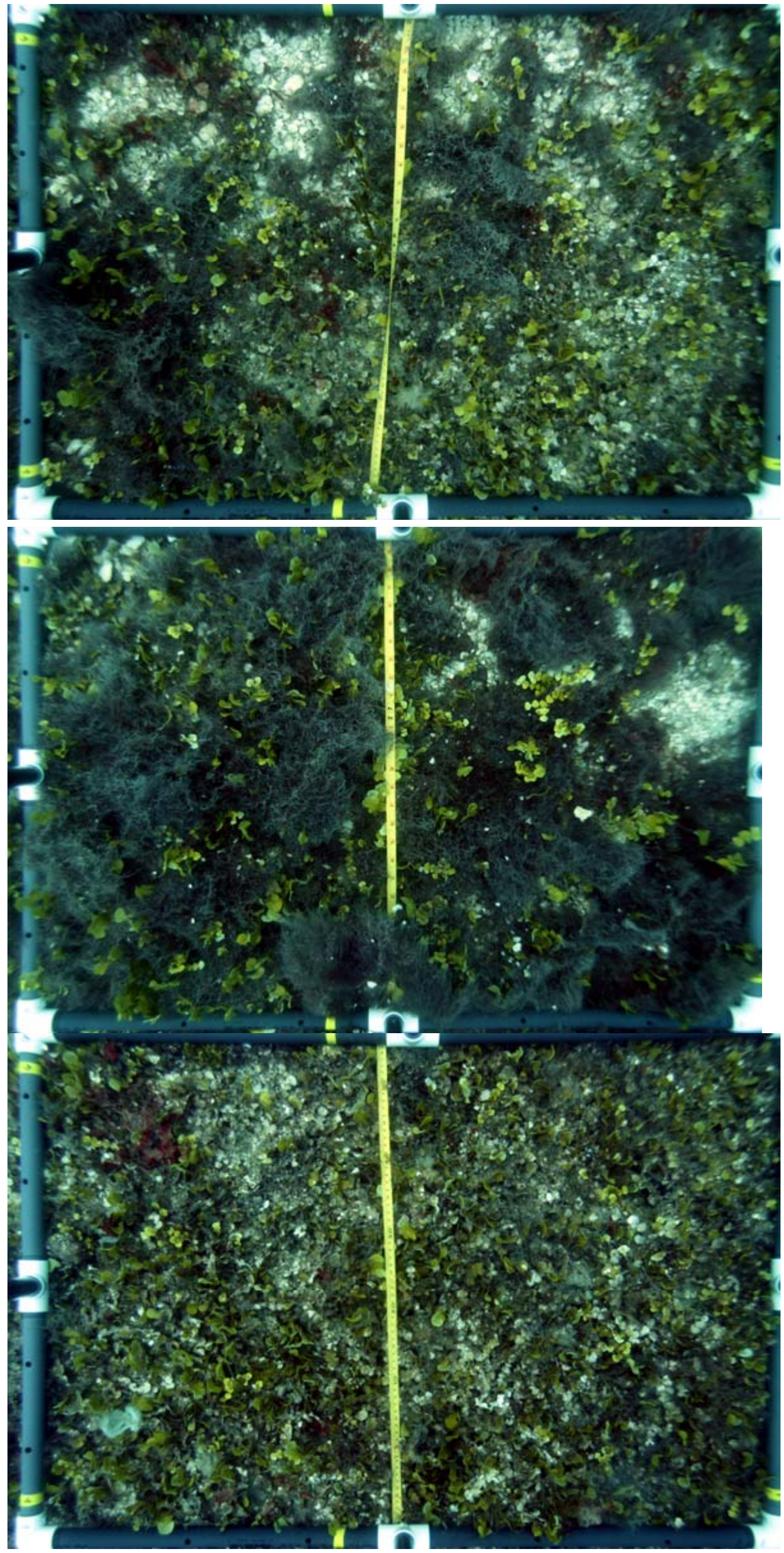

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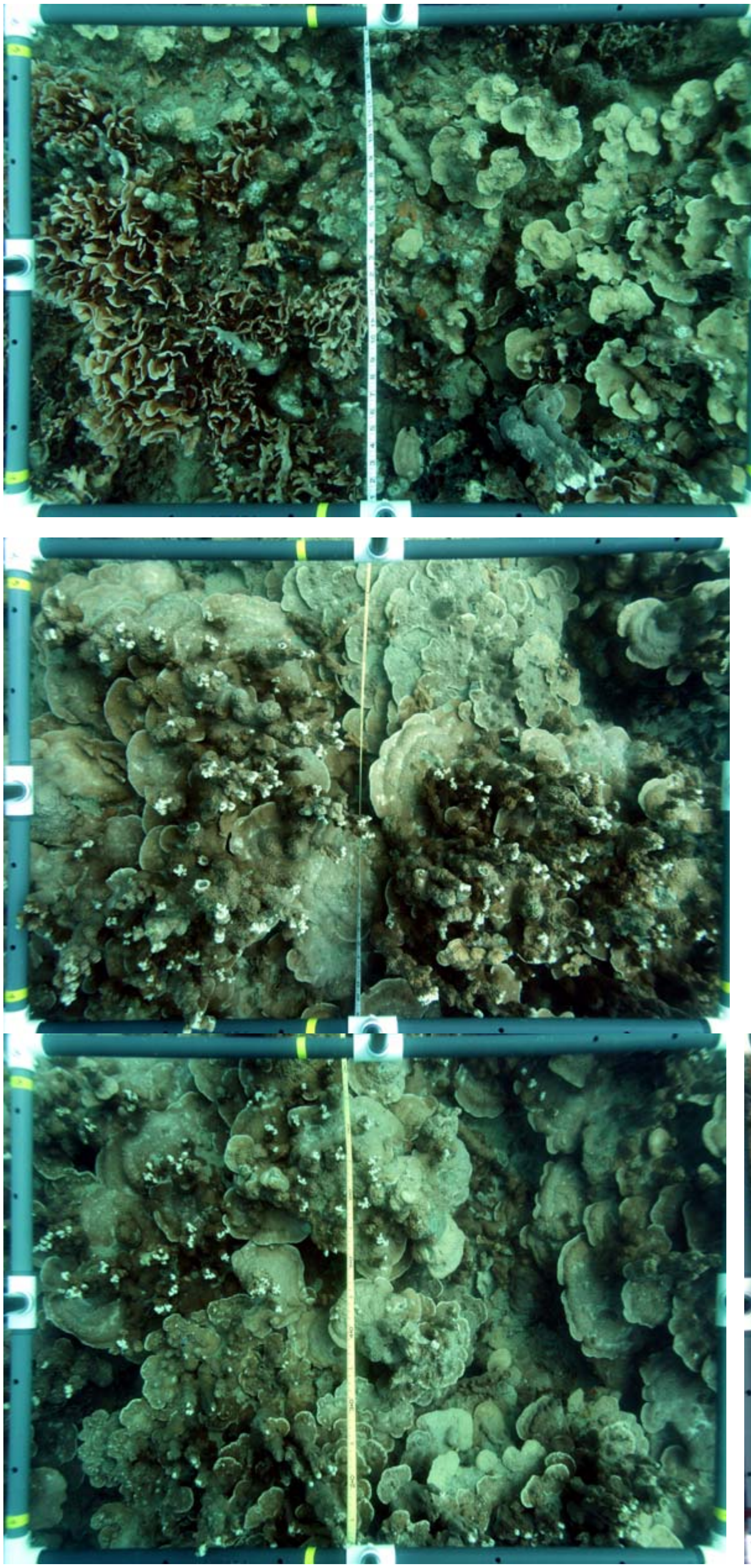

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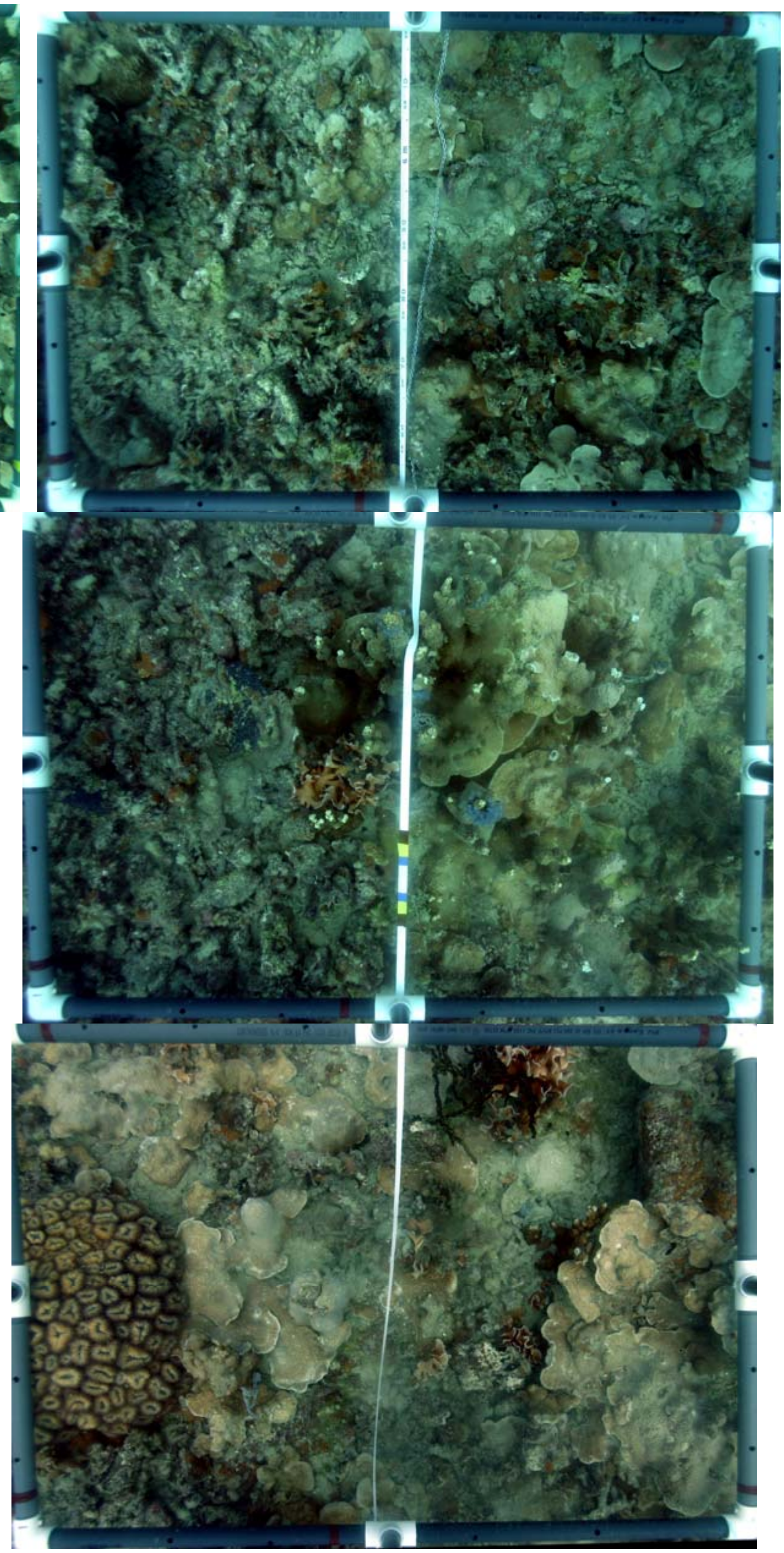

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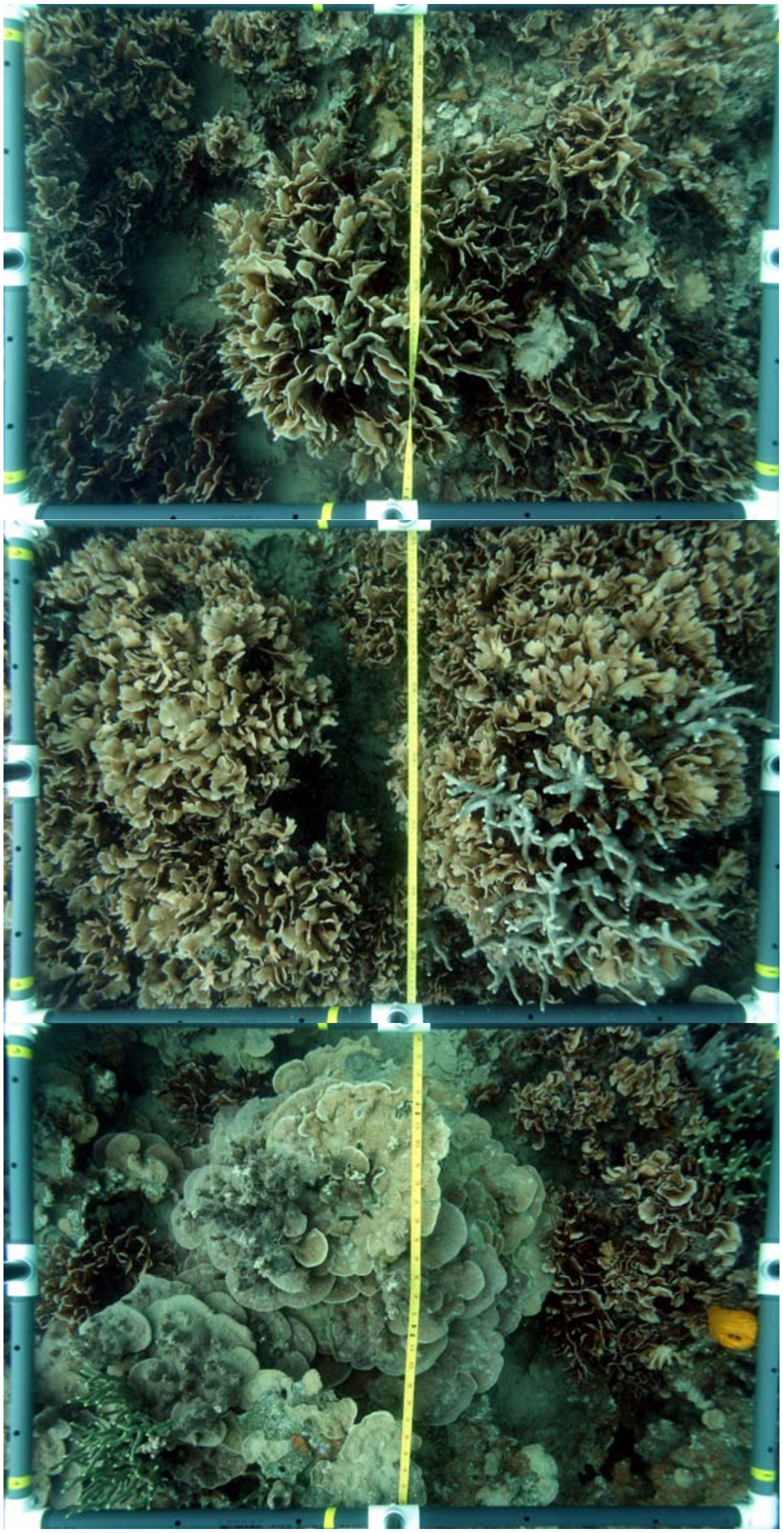

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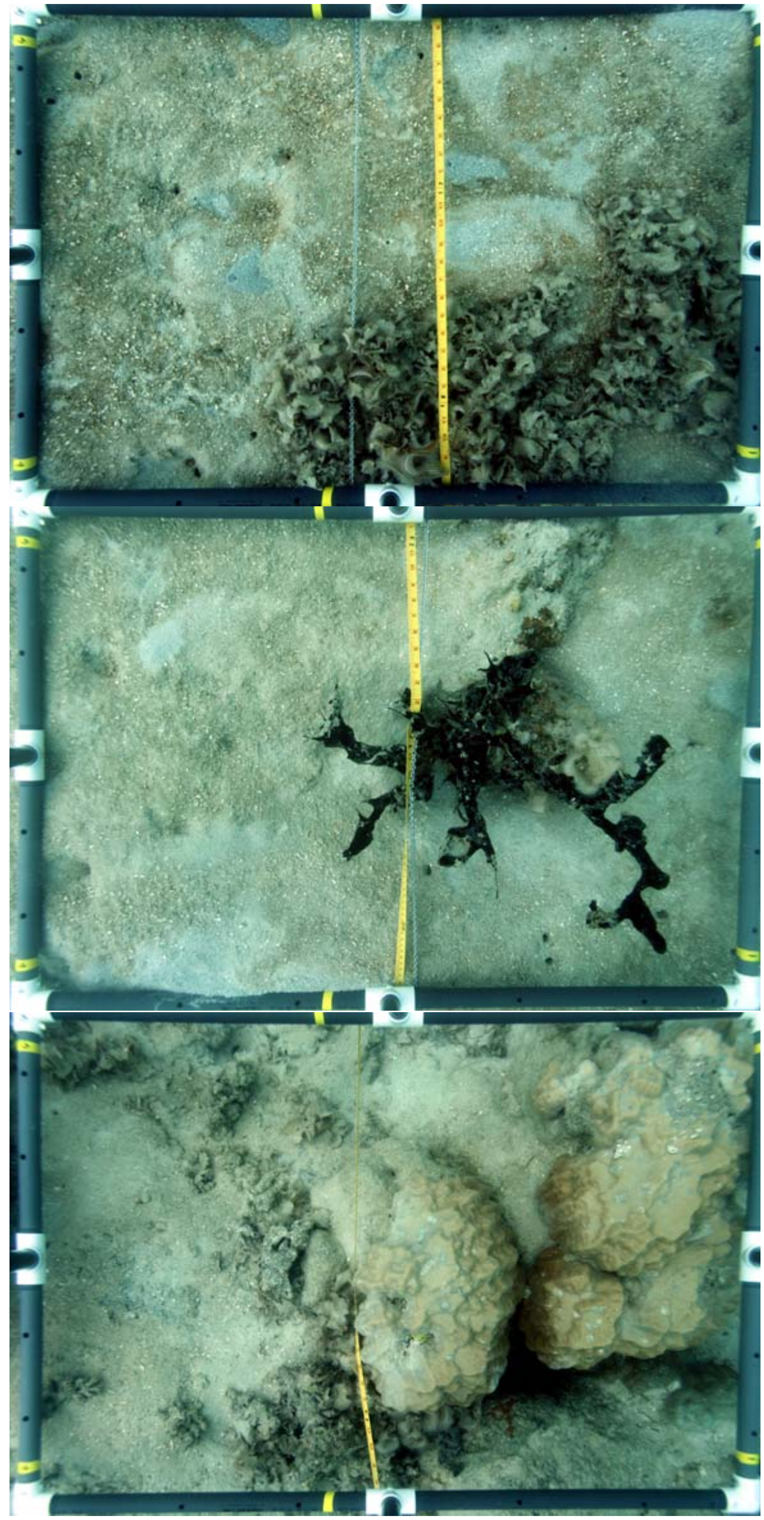

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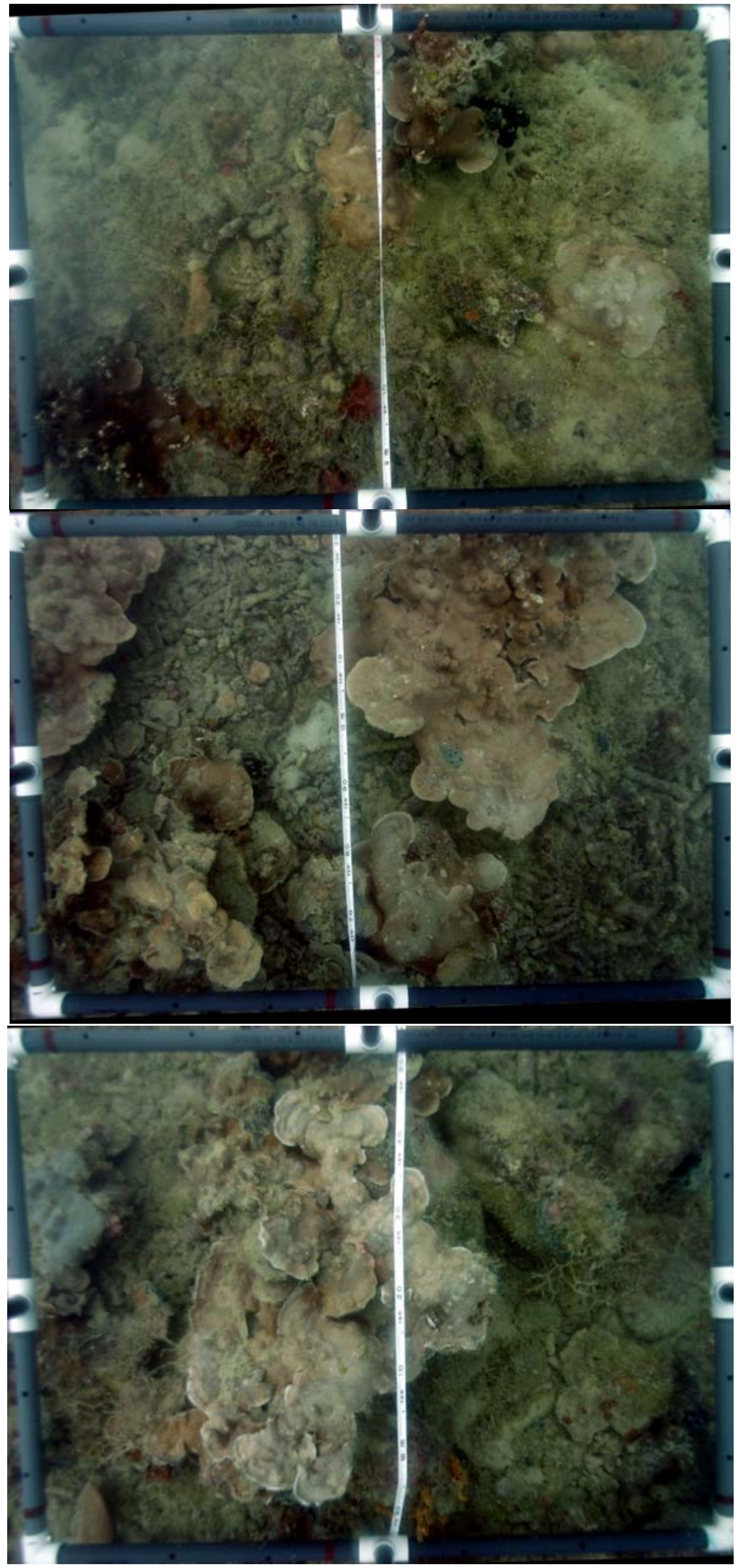

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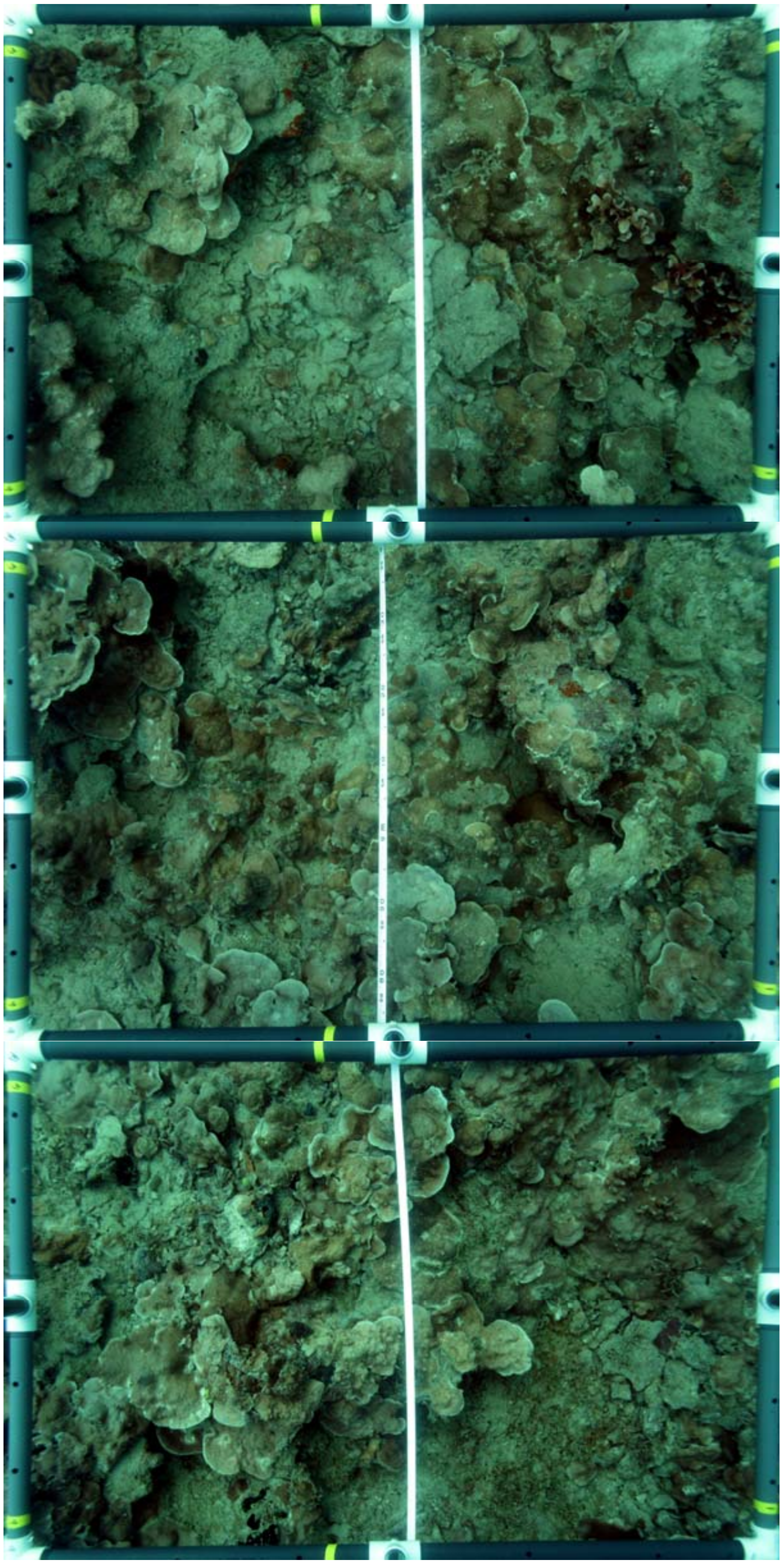

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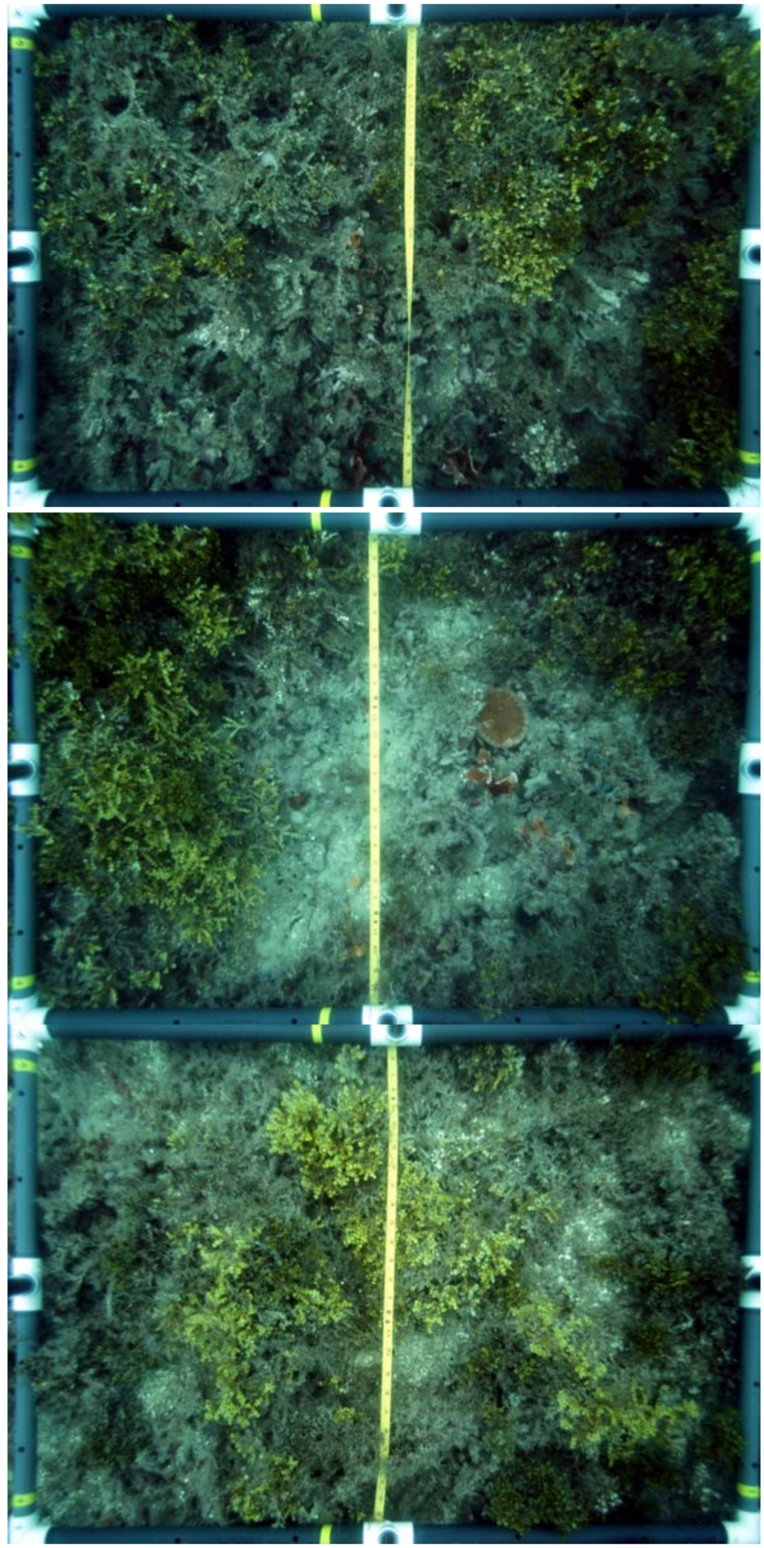

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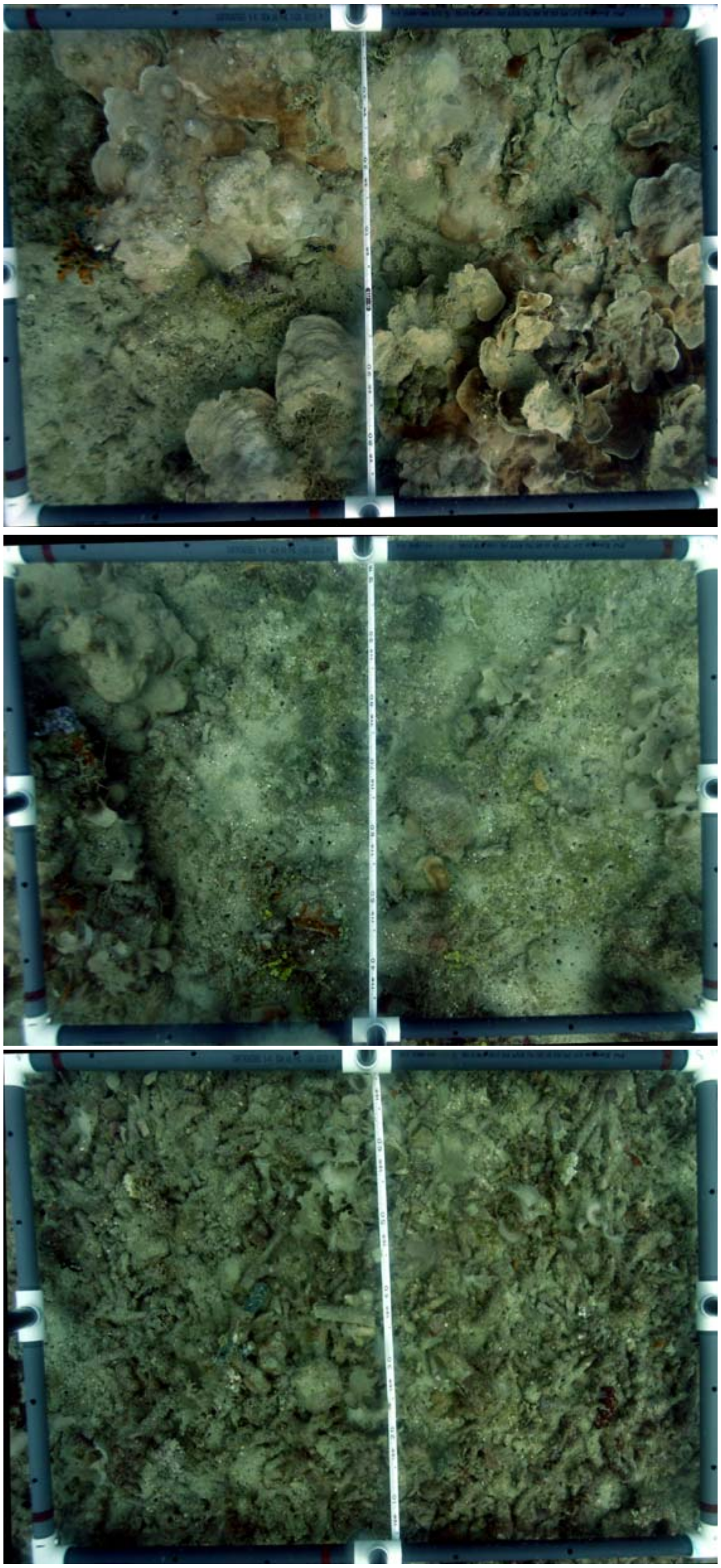

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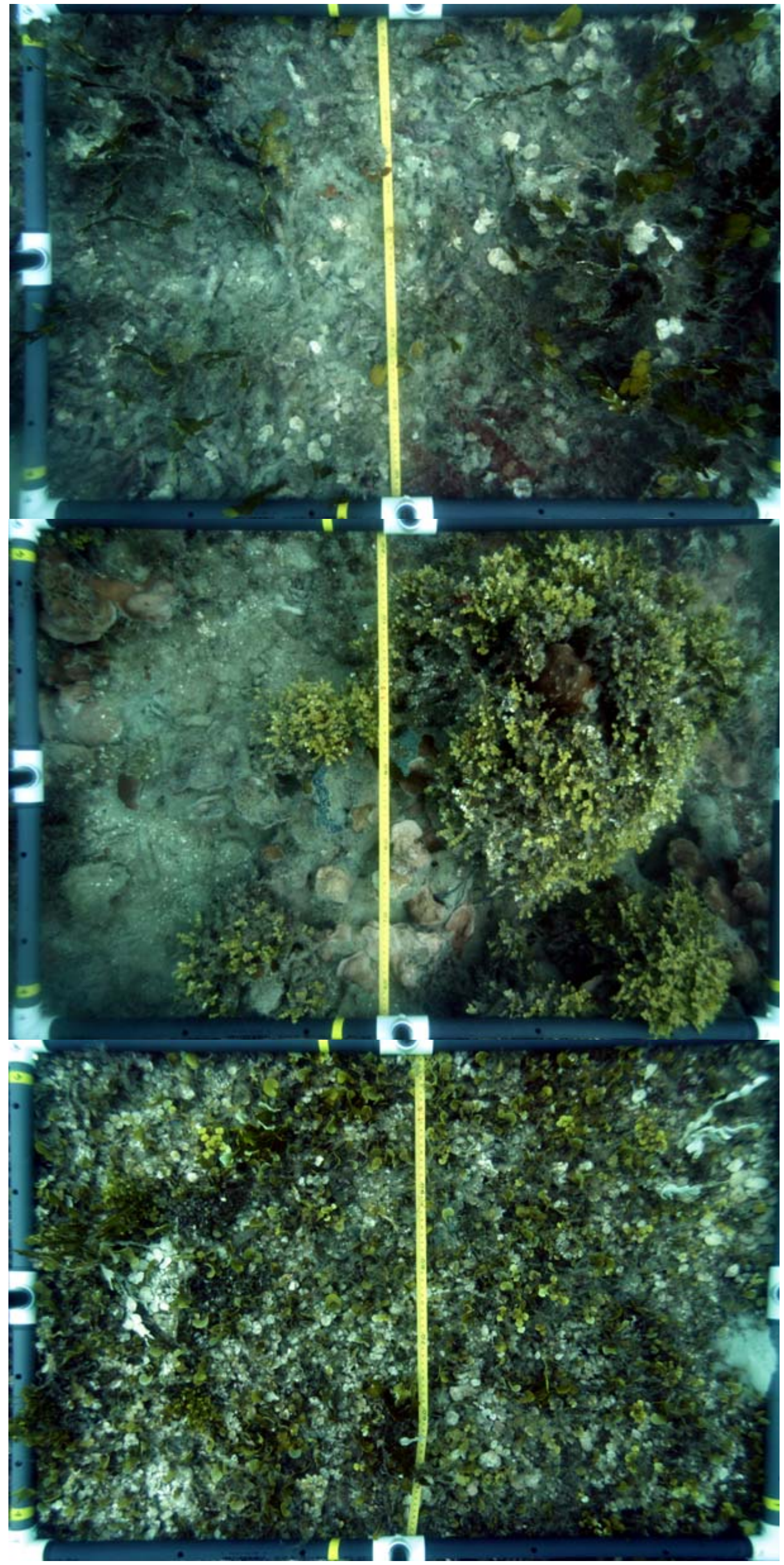

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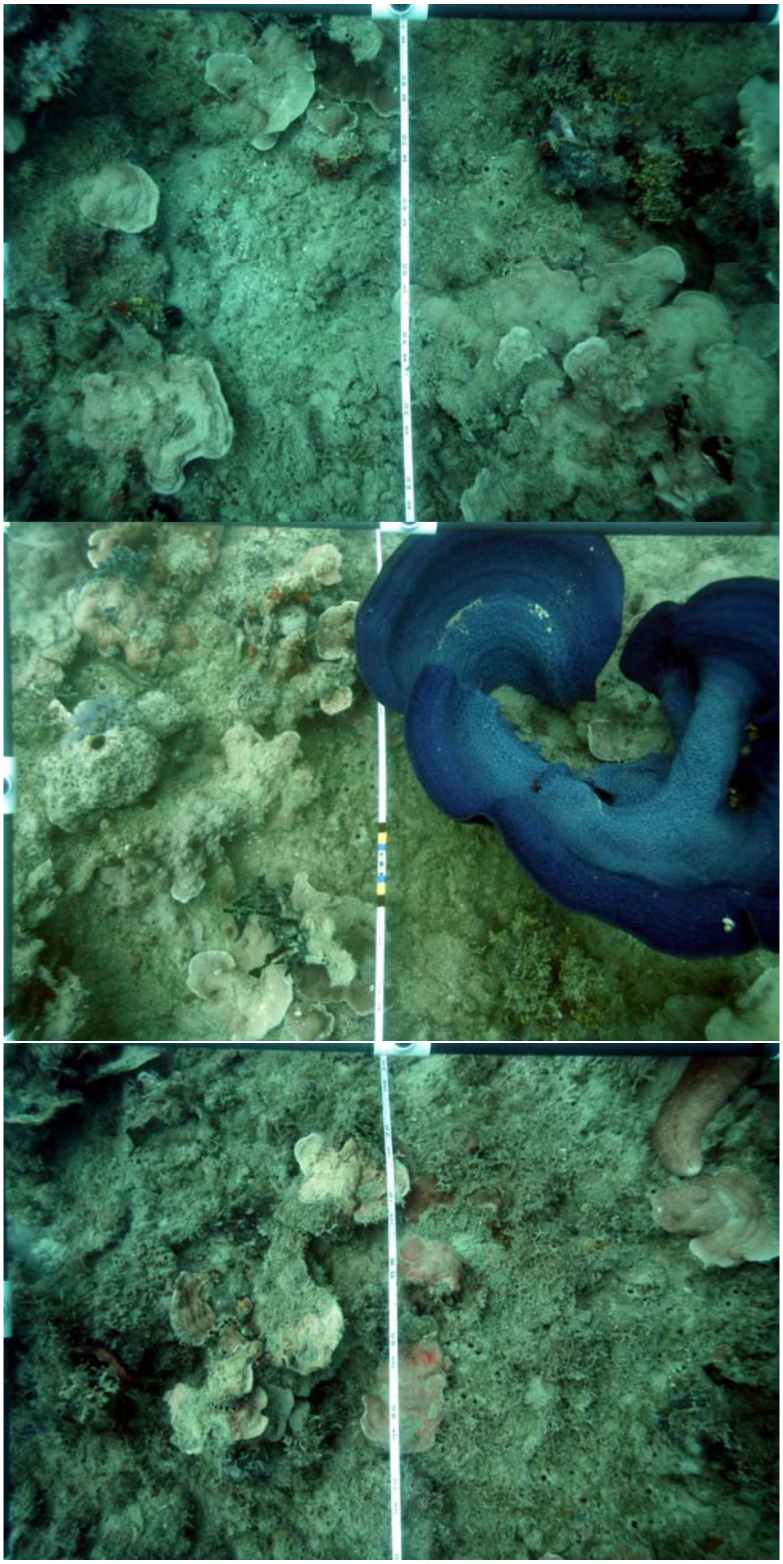

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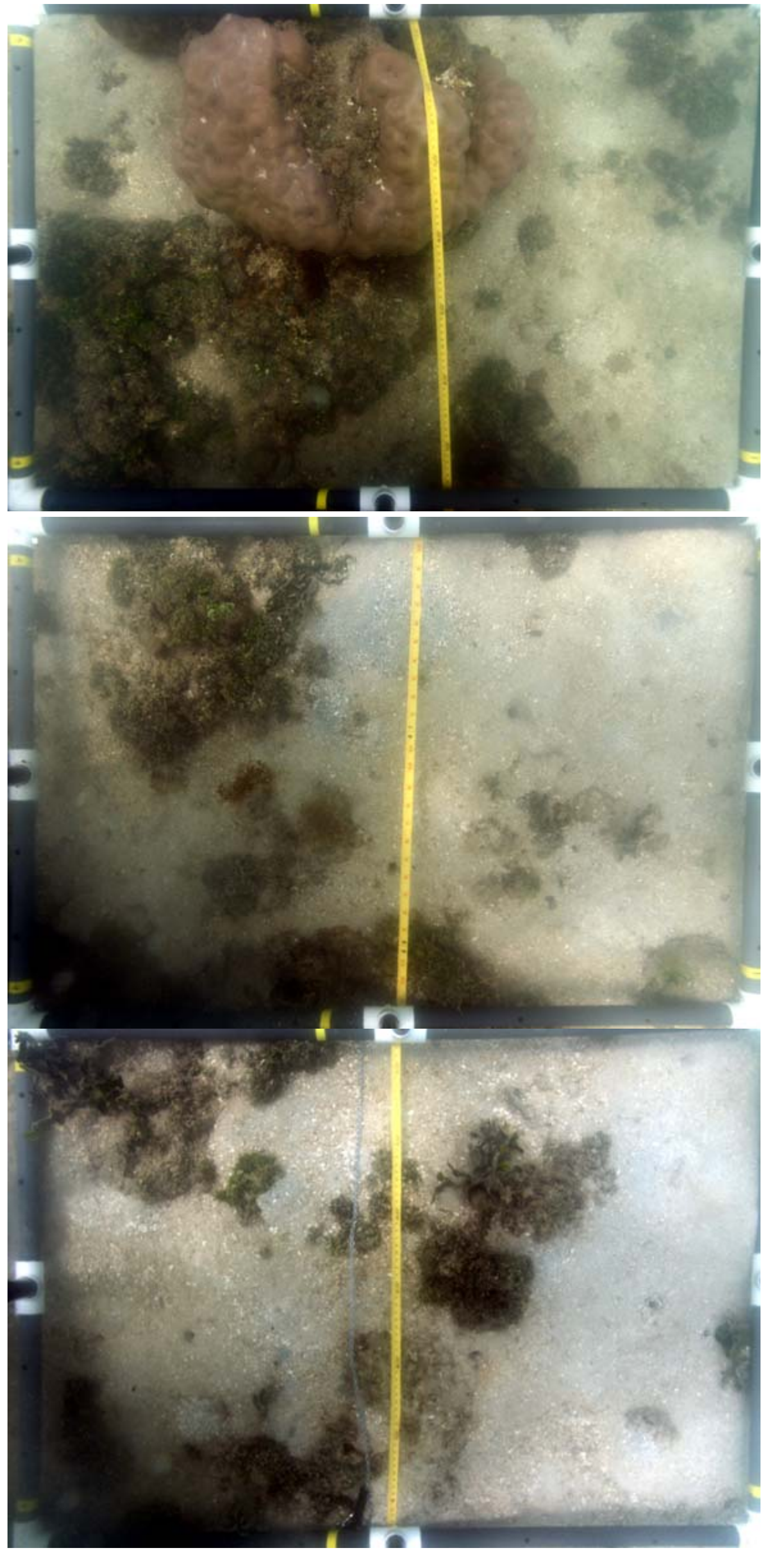

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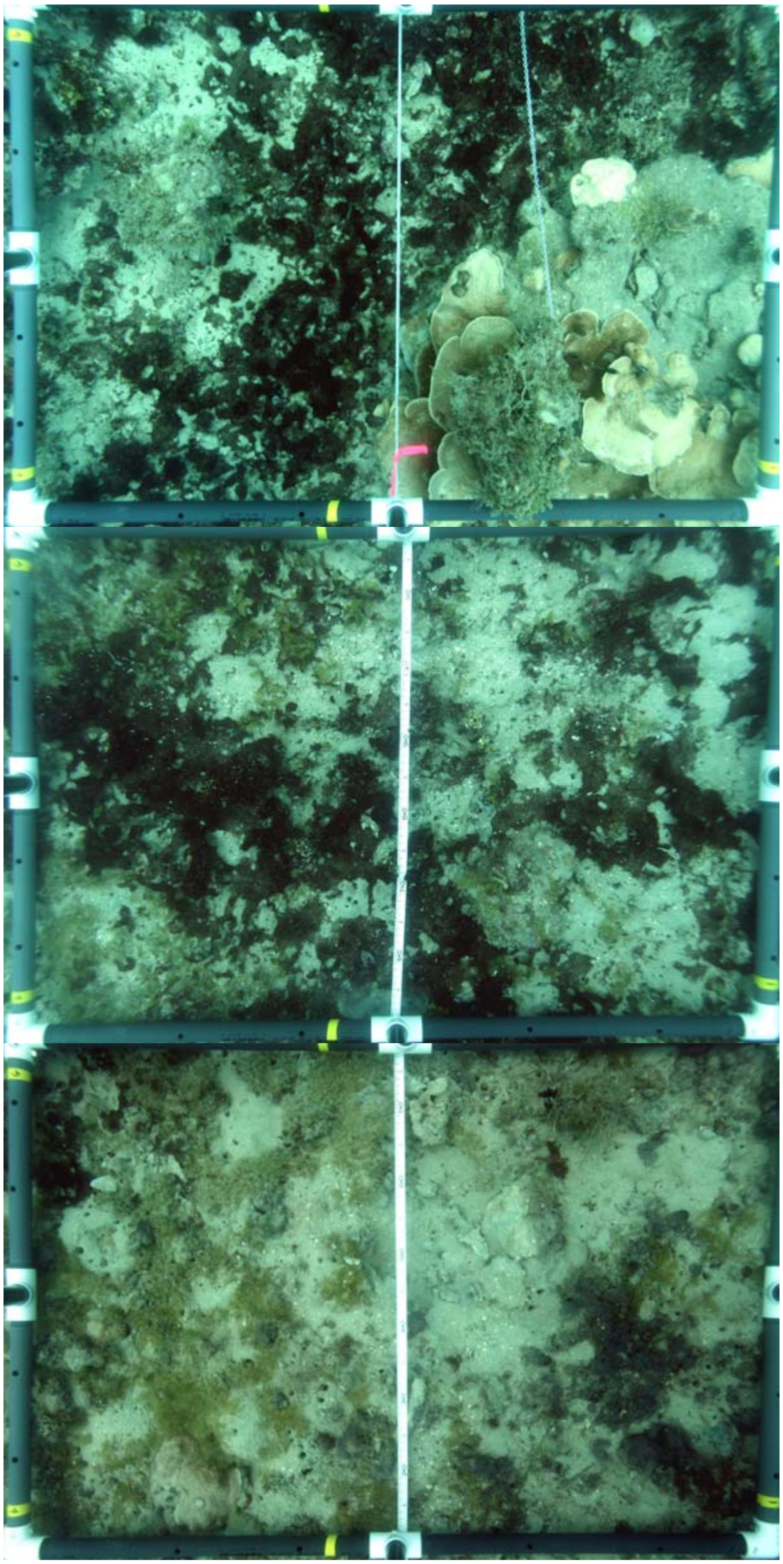

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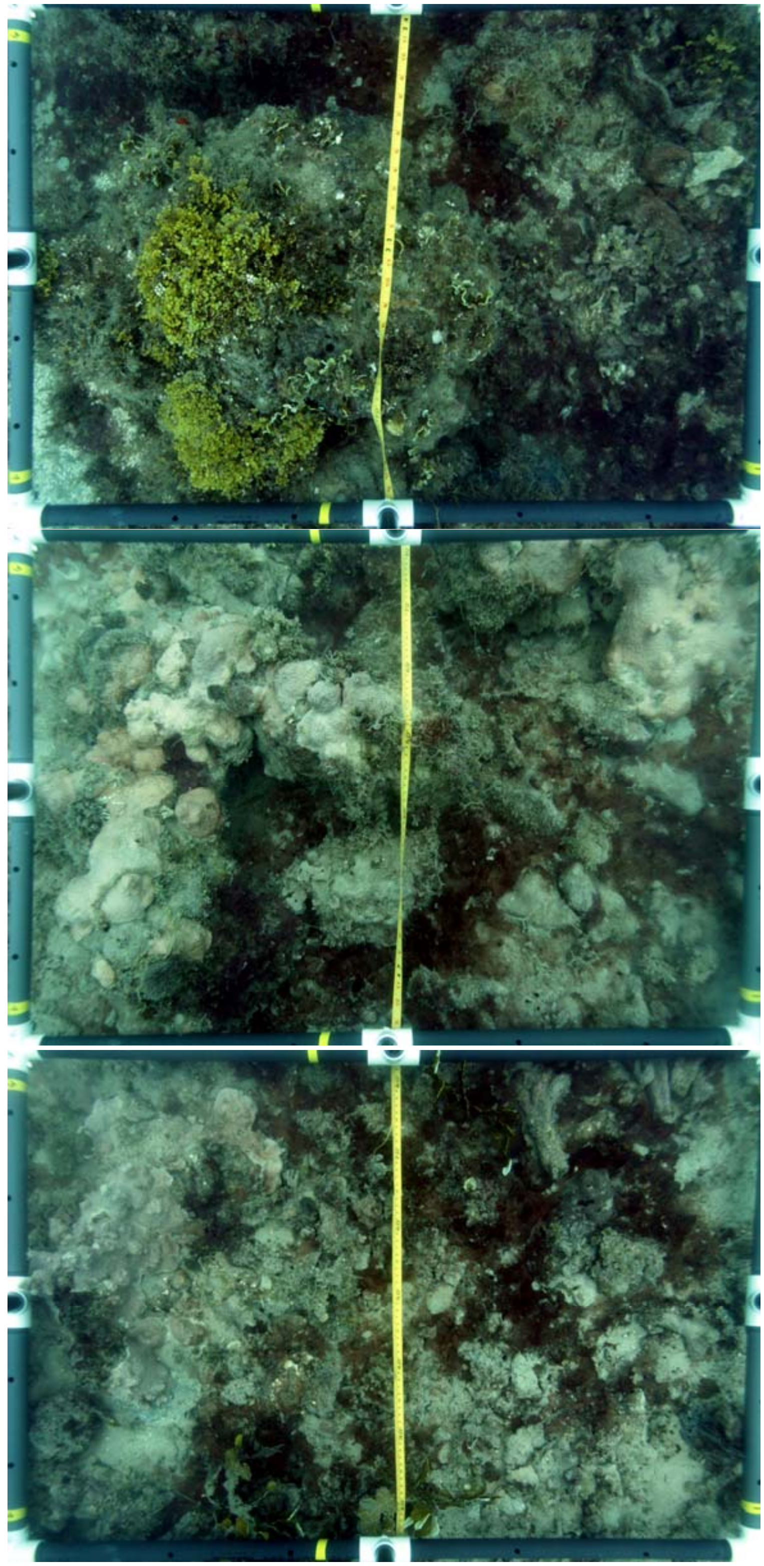

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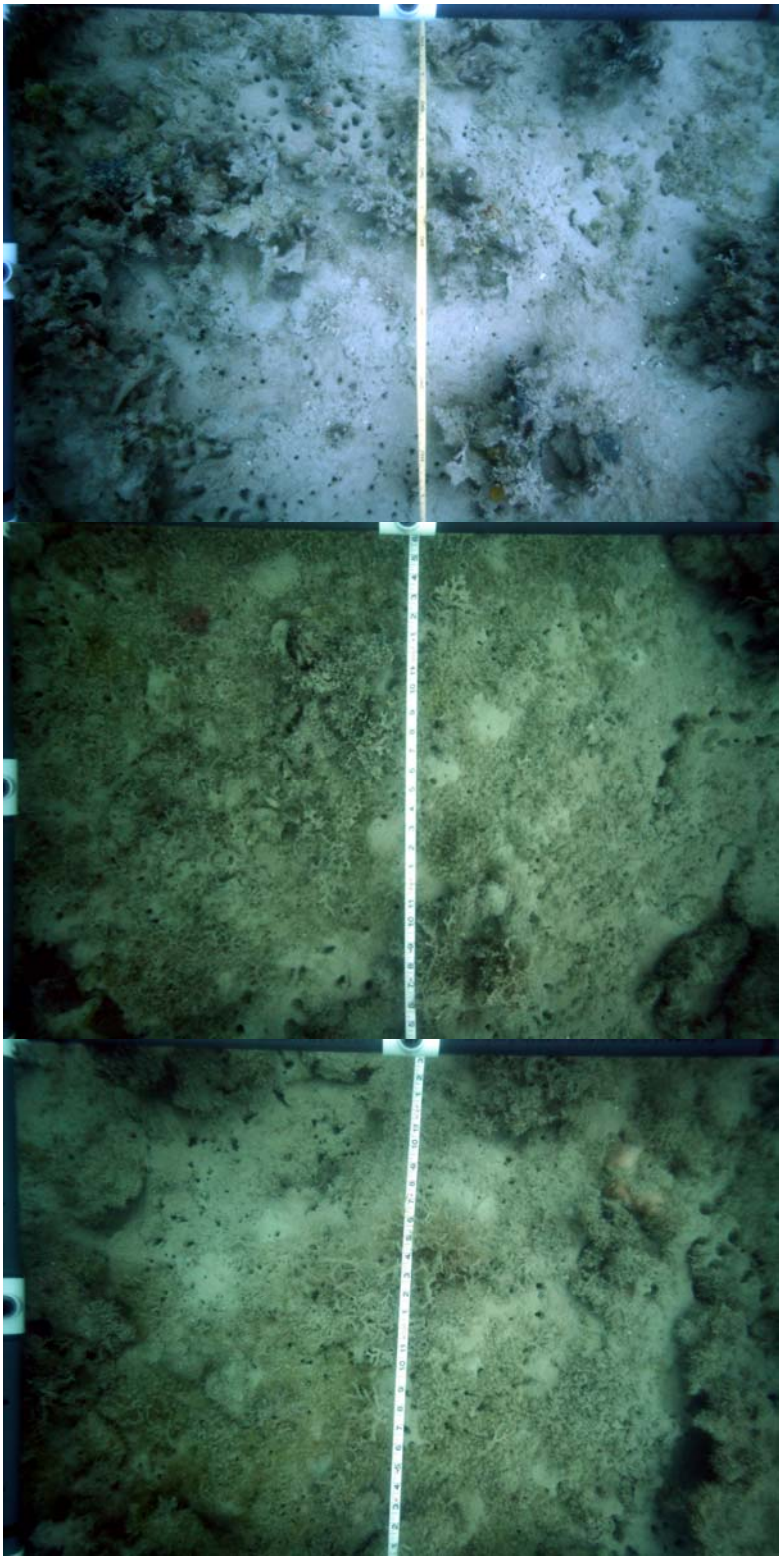

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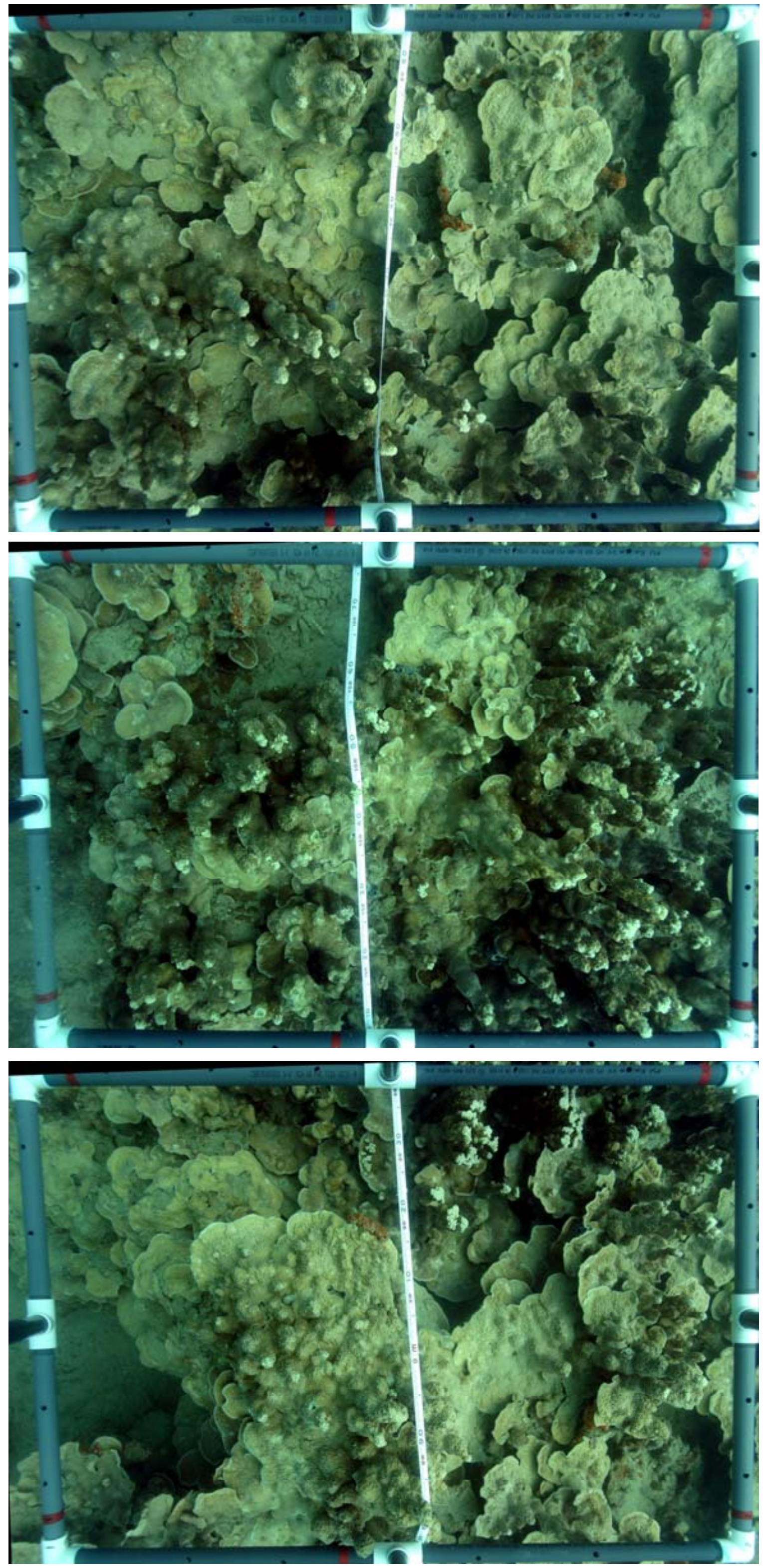

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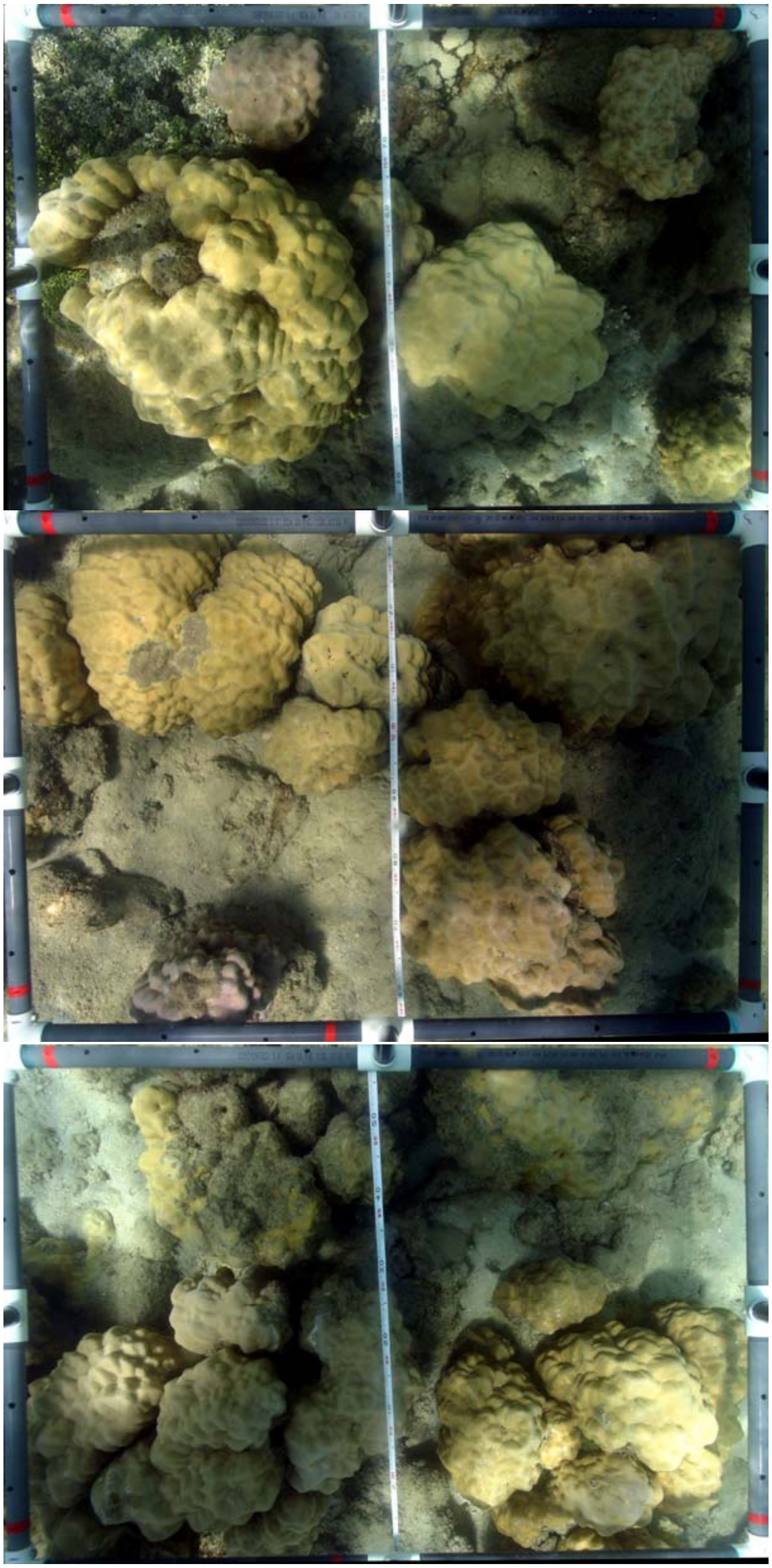

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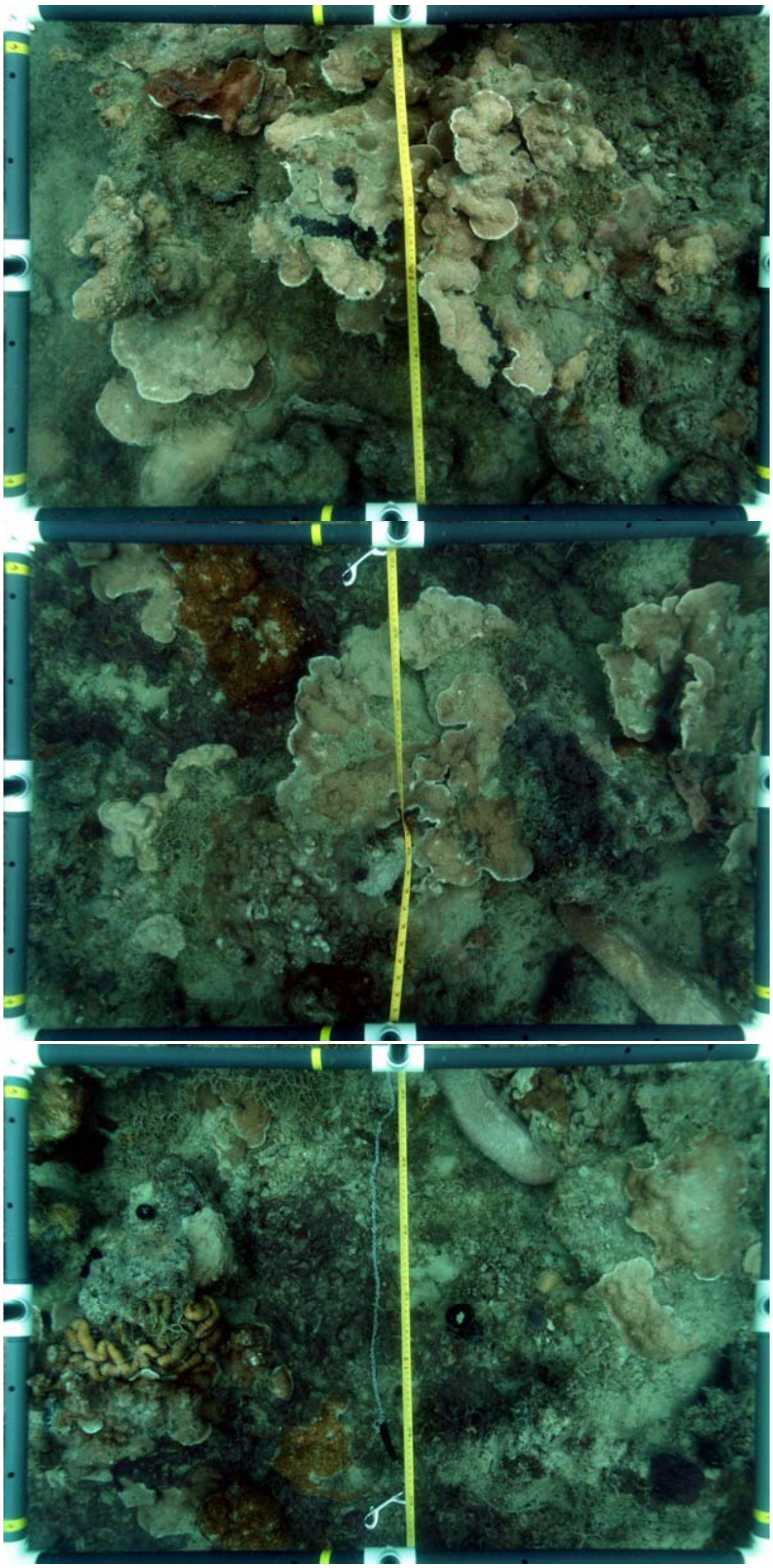
TRANSECT 30



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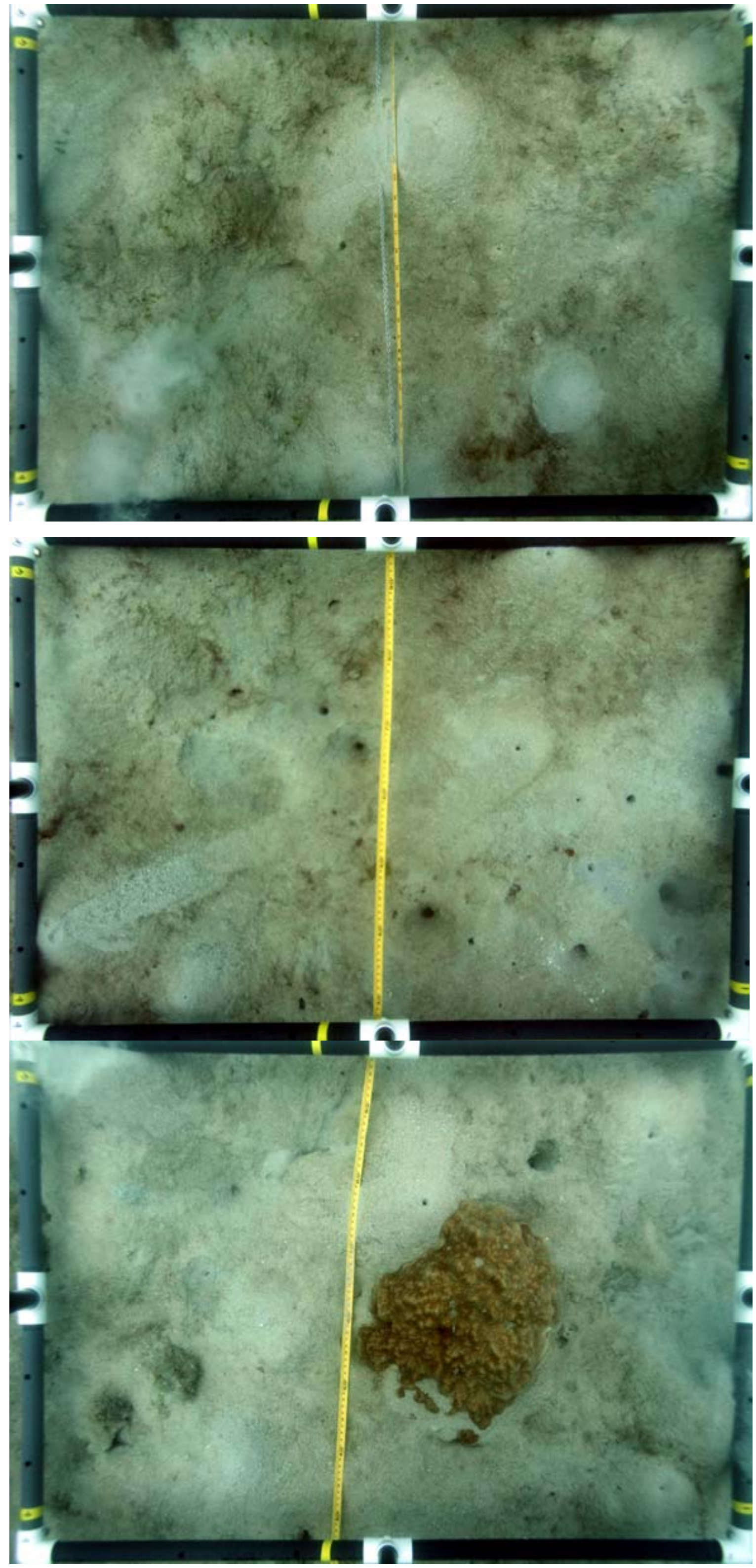

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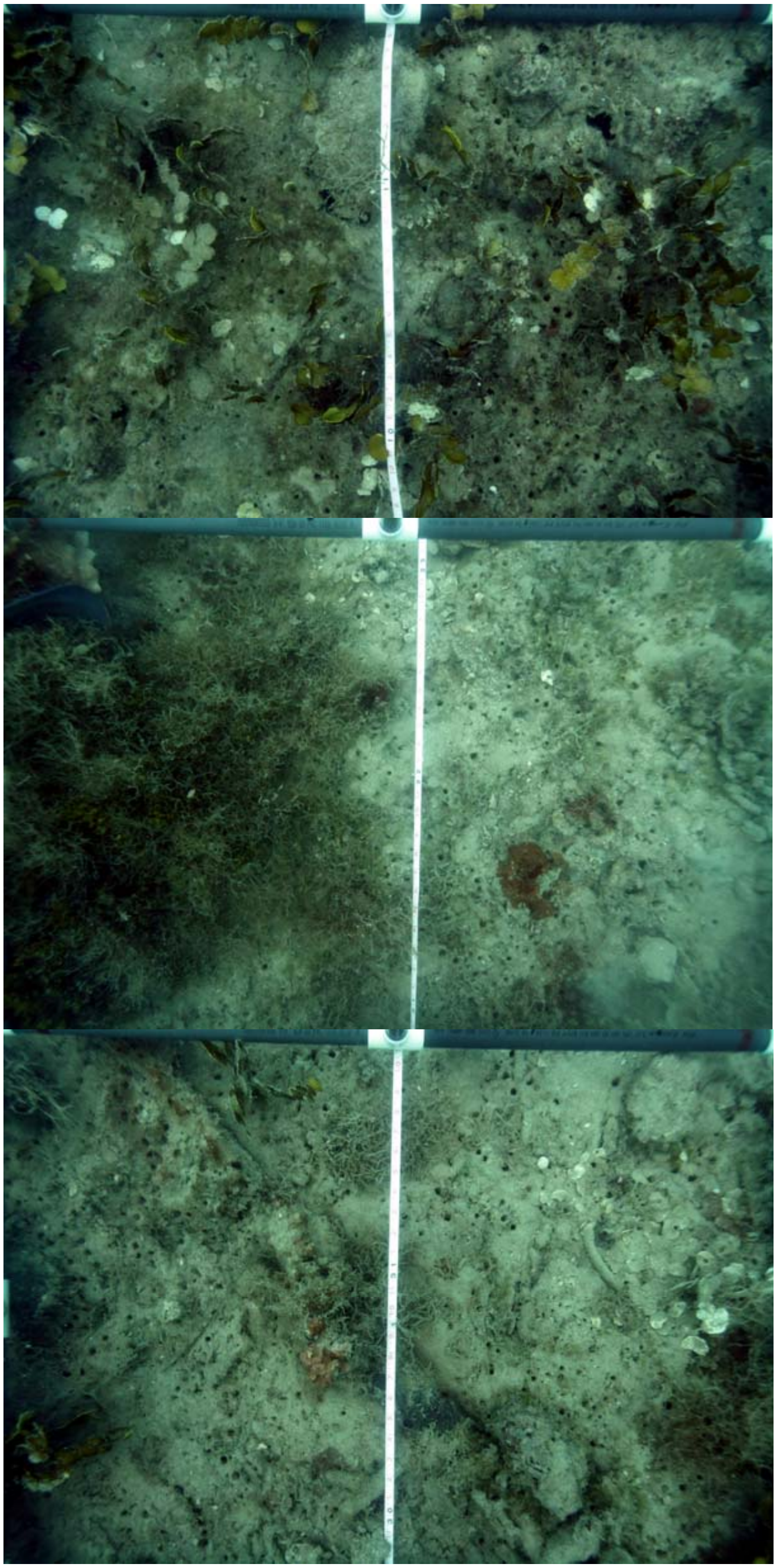

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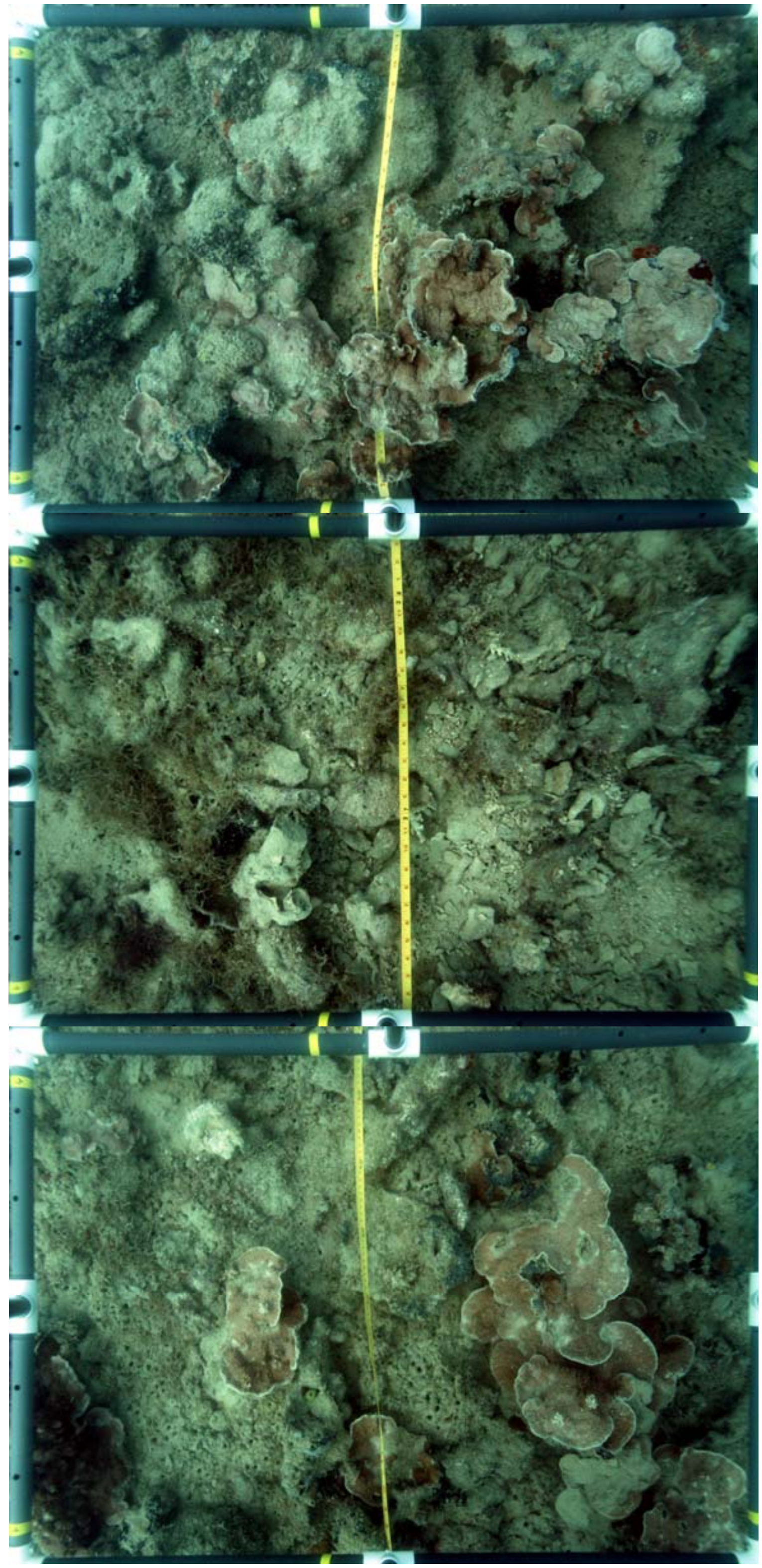

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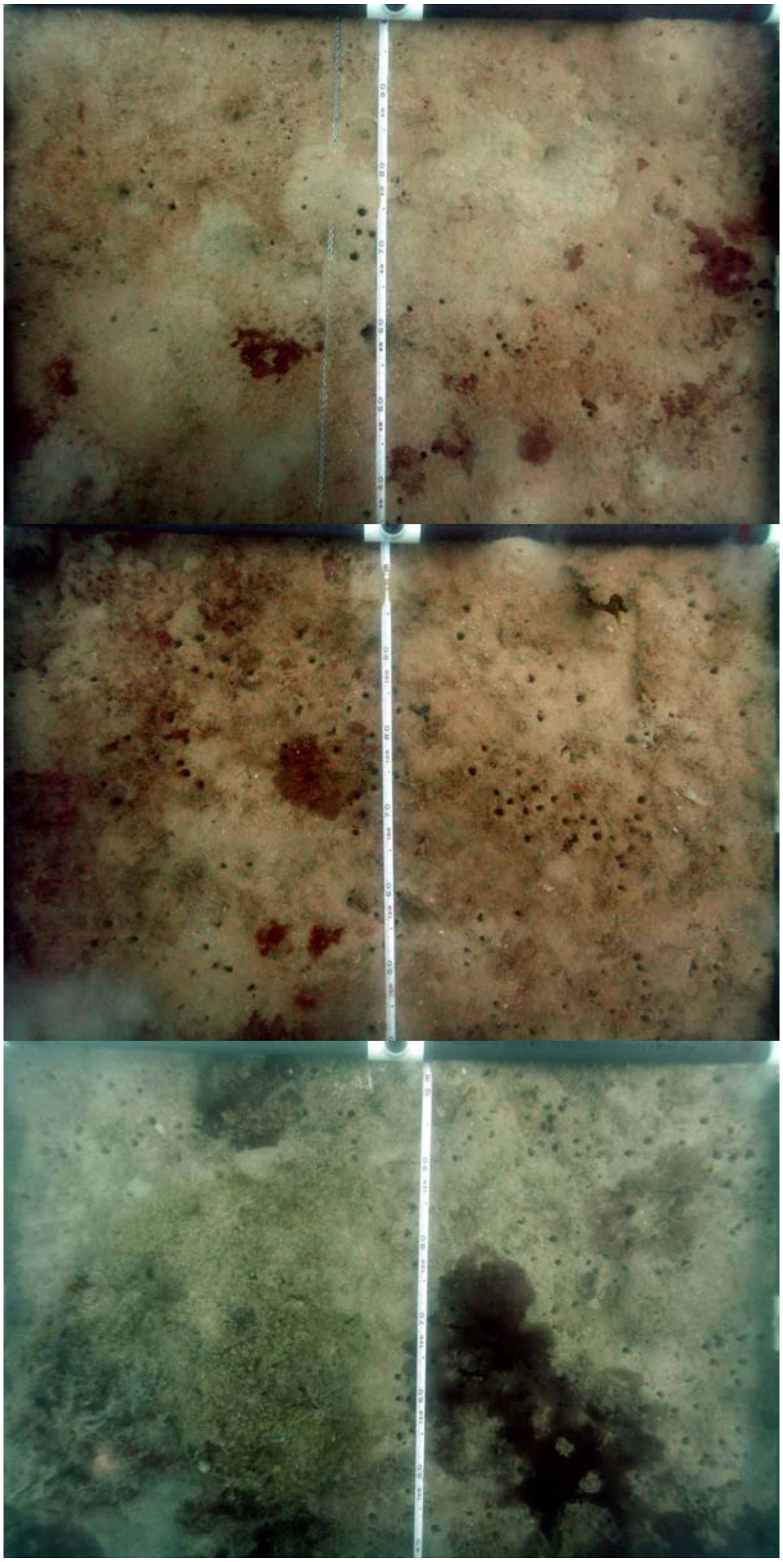

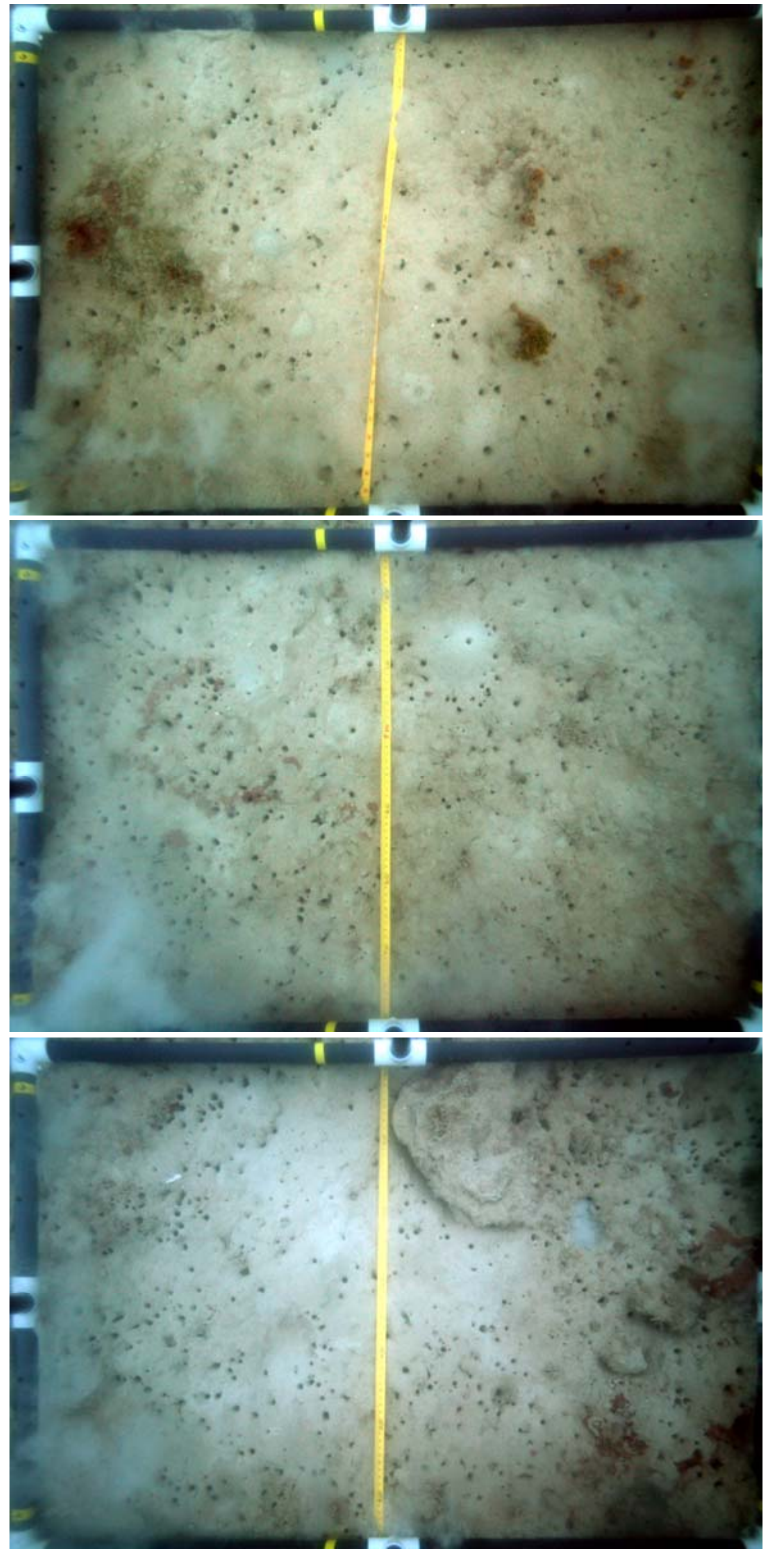

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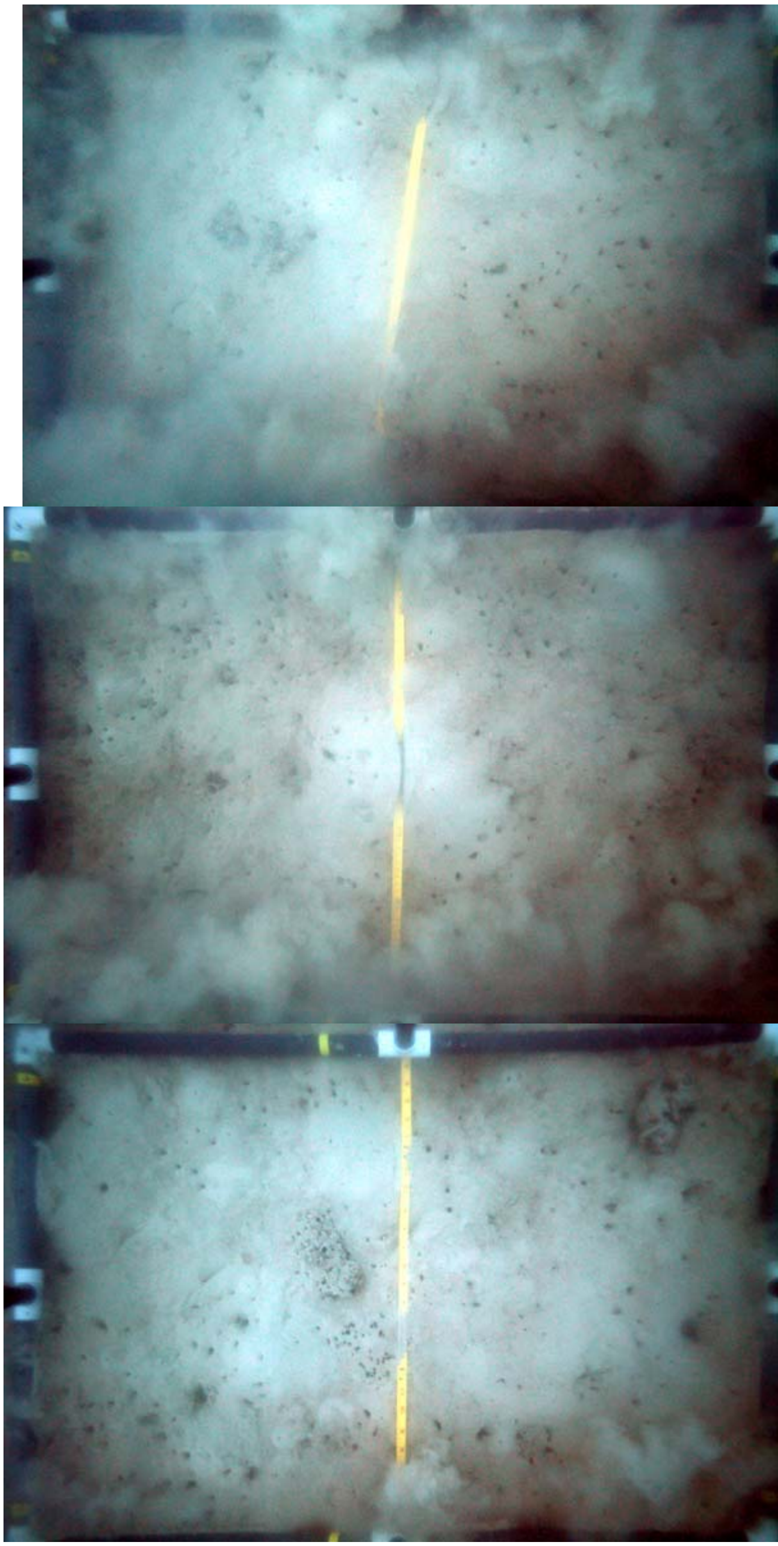
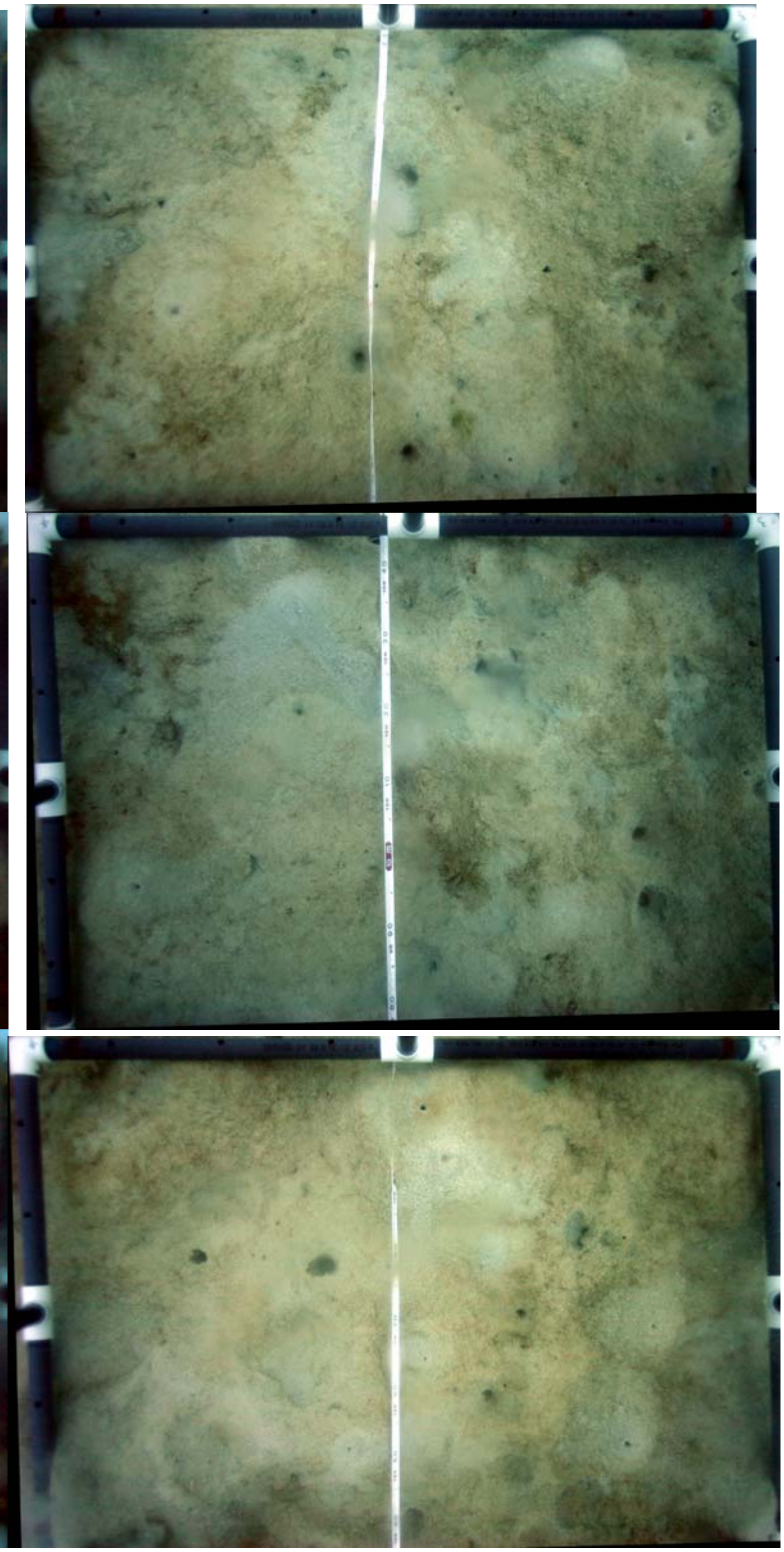
TRANSECT 36





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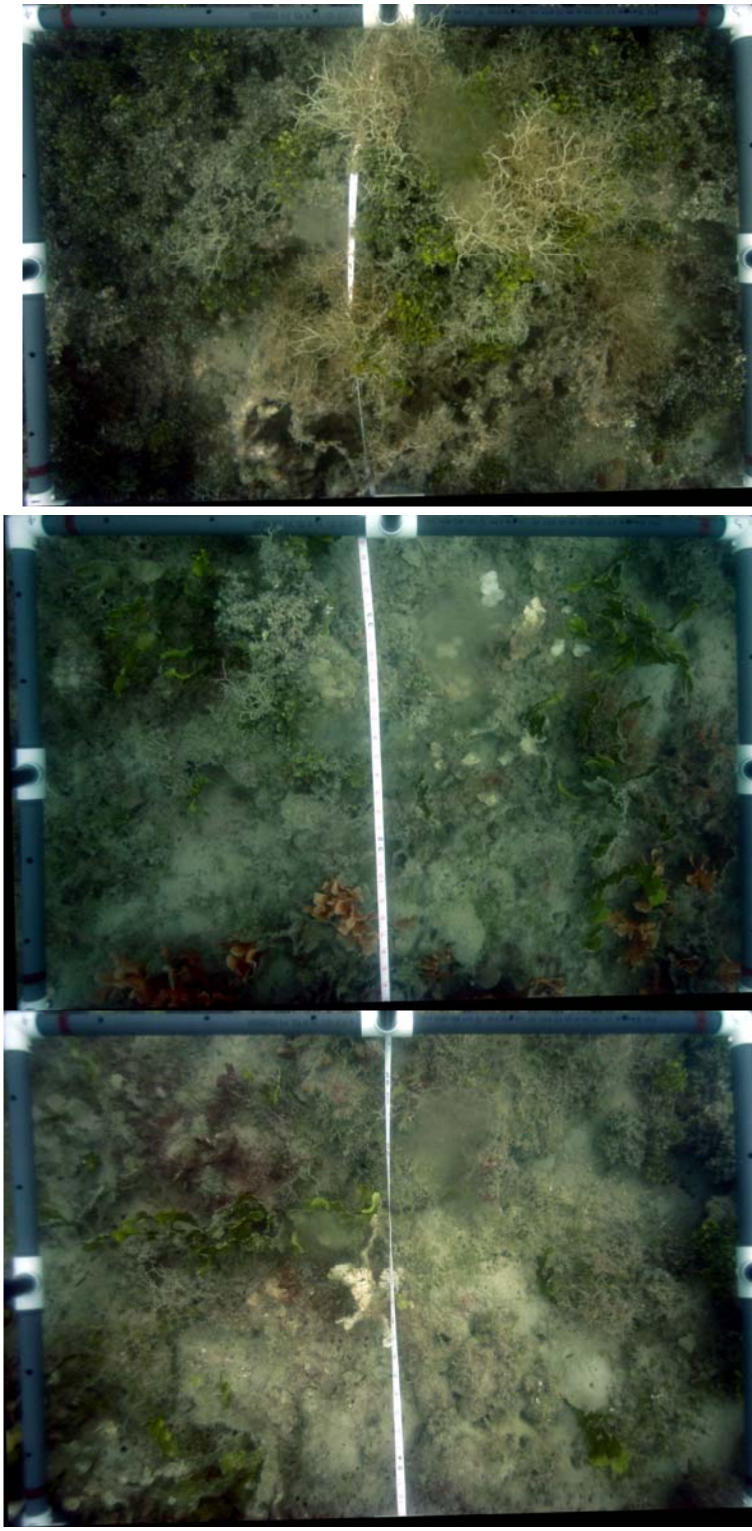
TRANSECT 38



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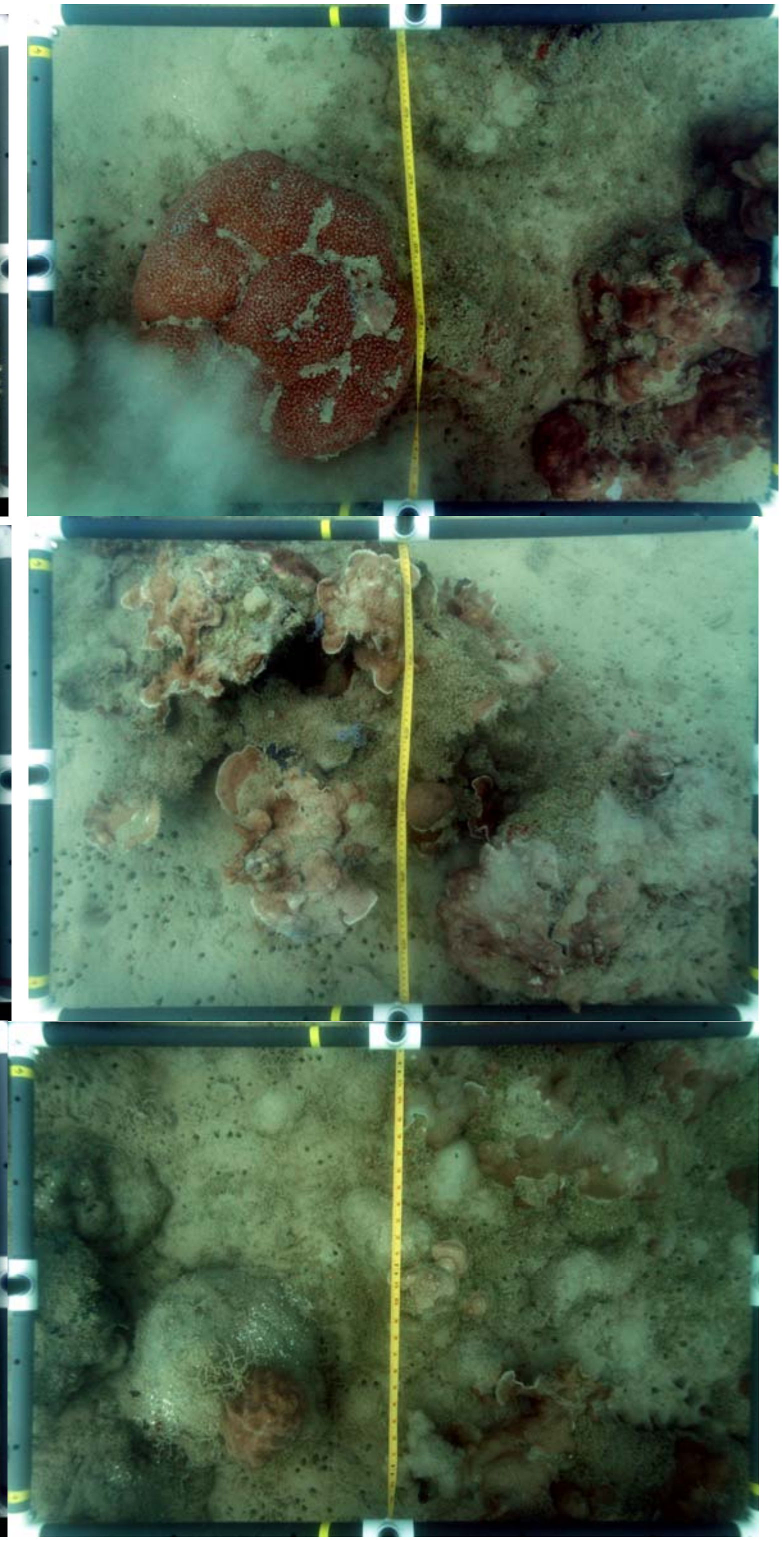

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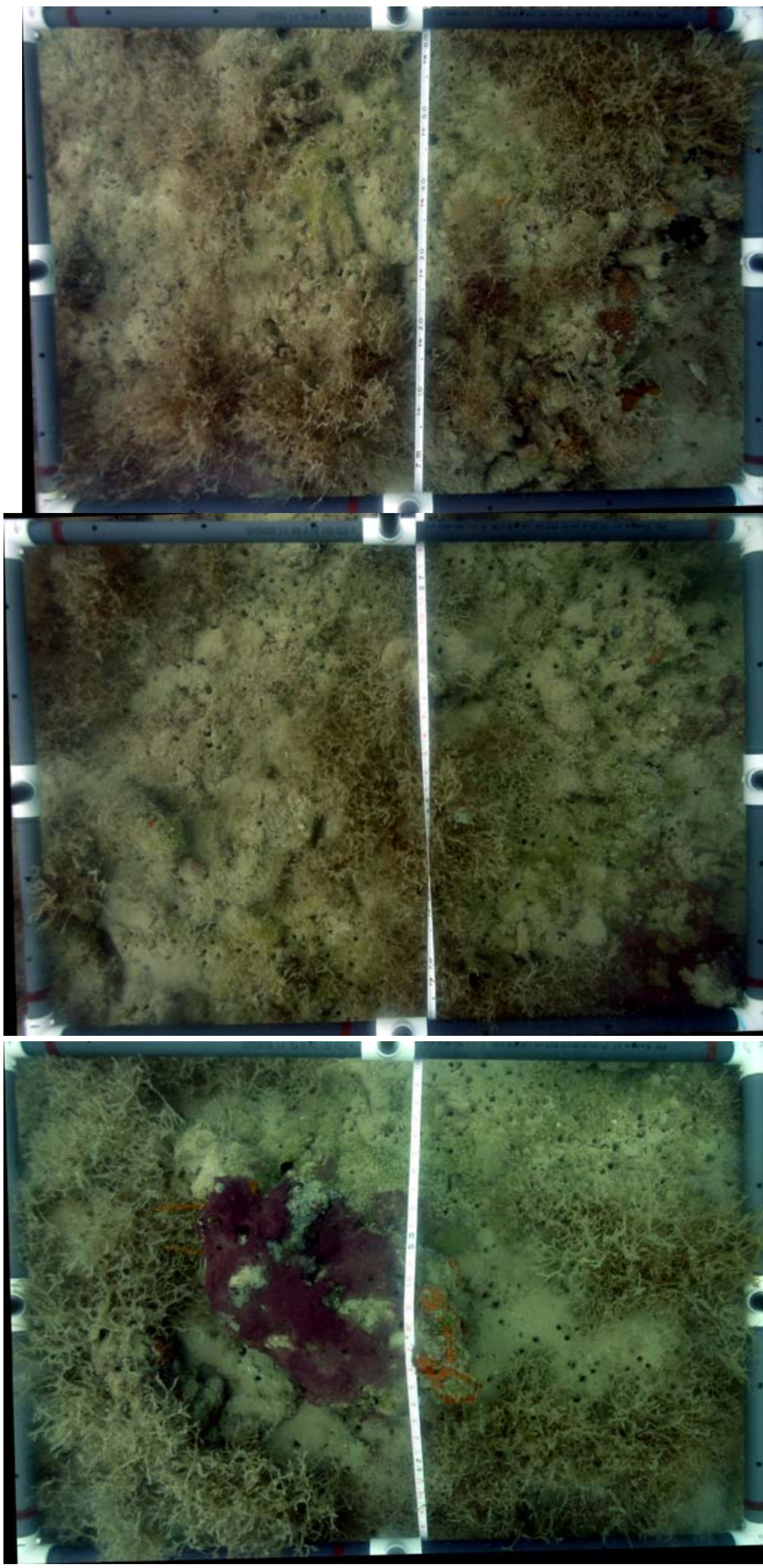

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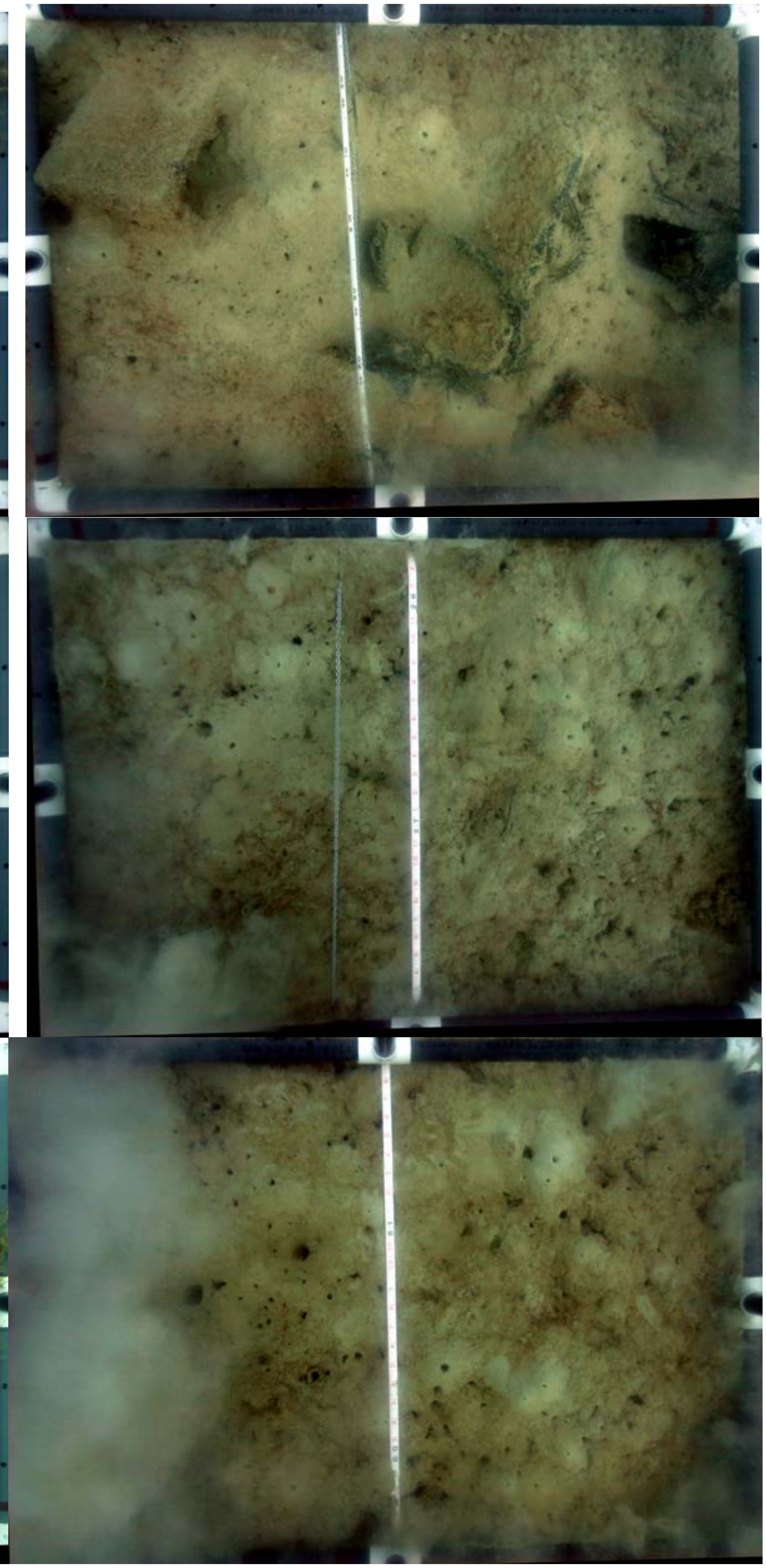

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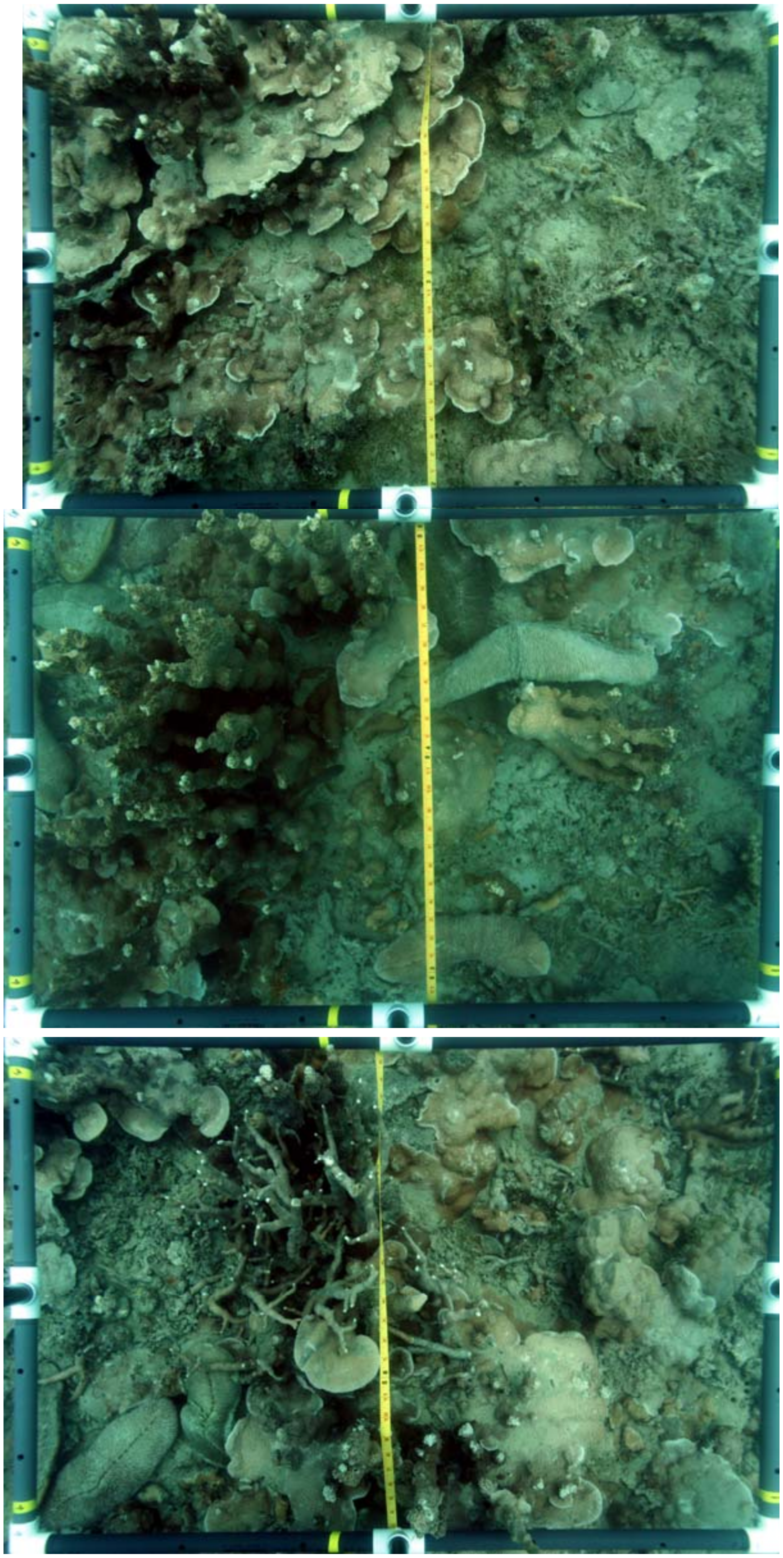

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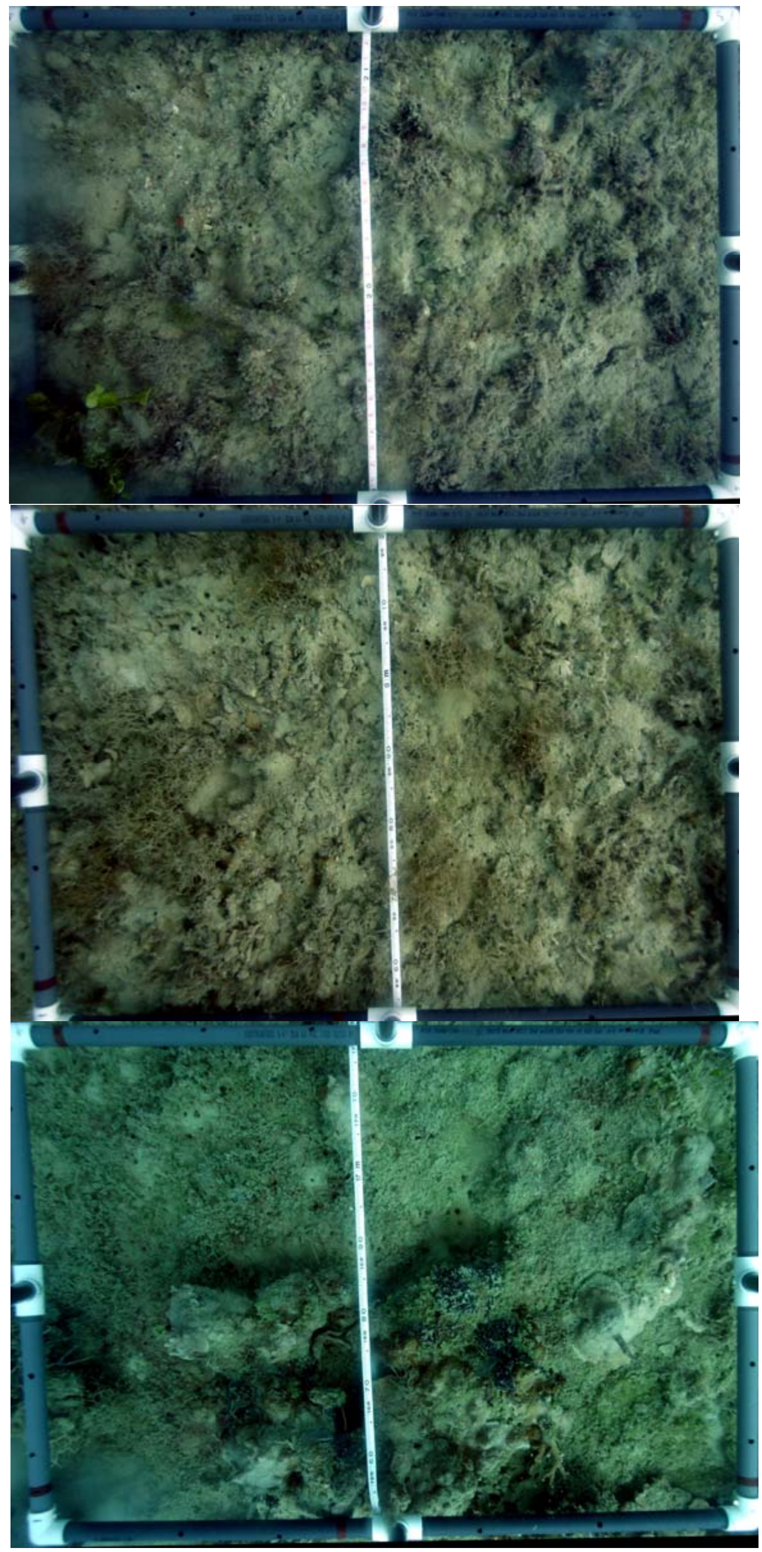

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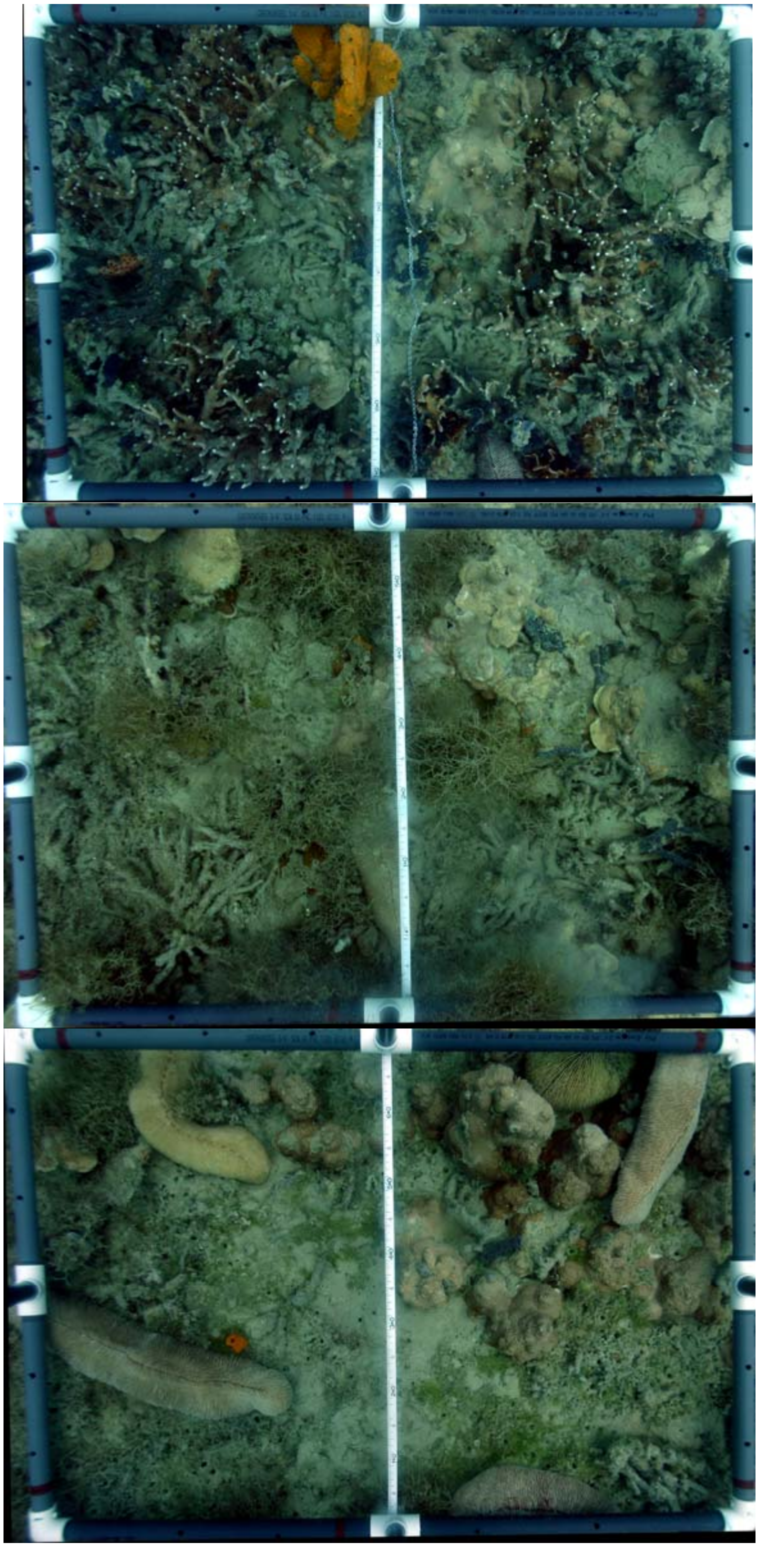

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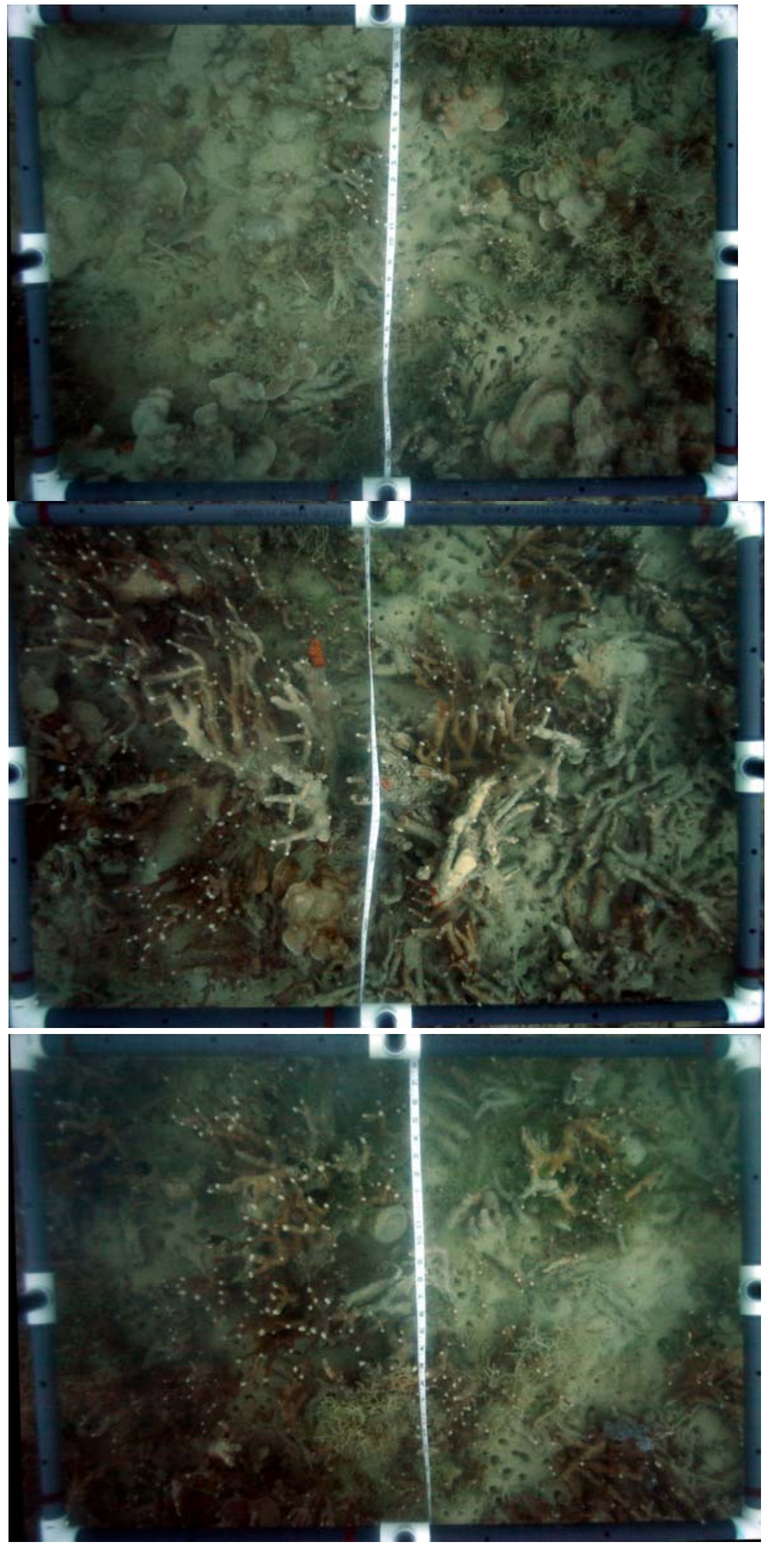

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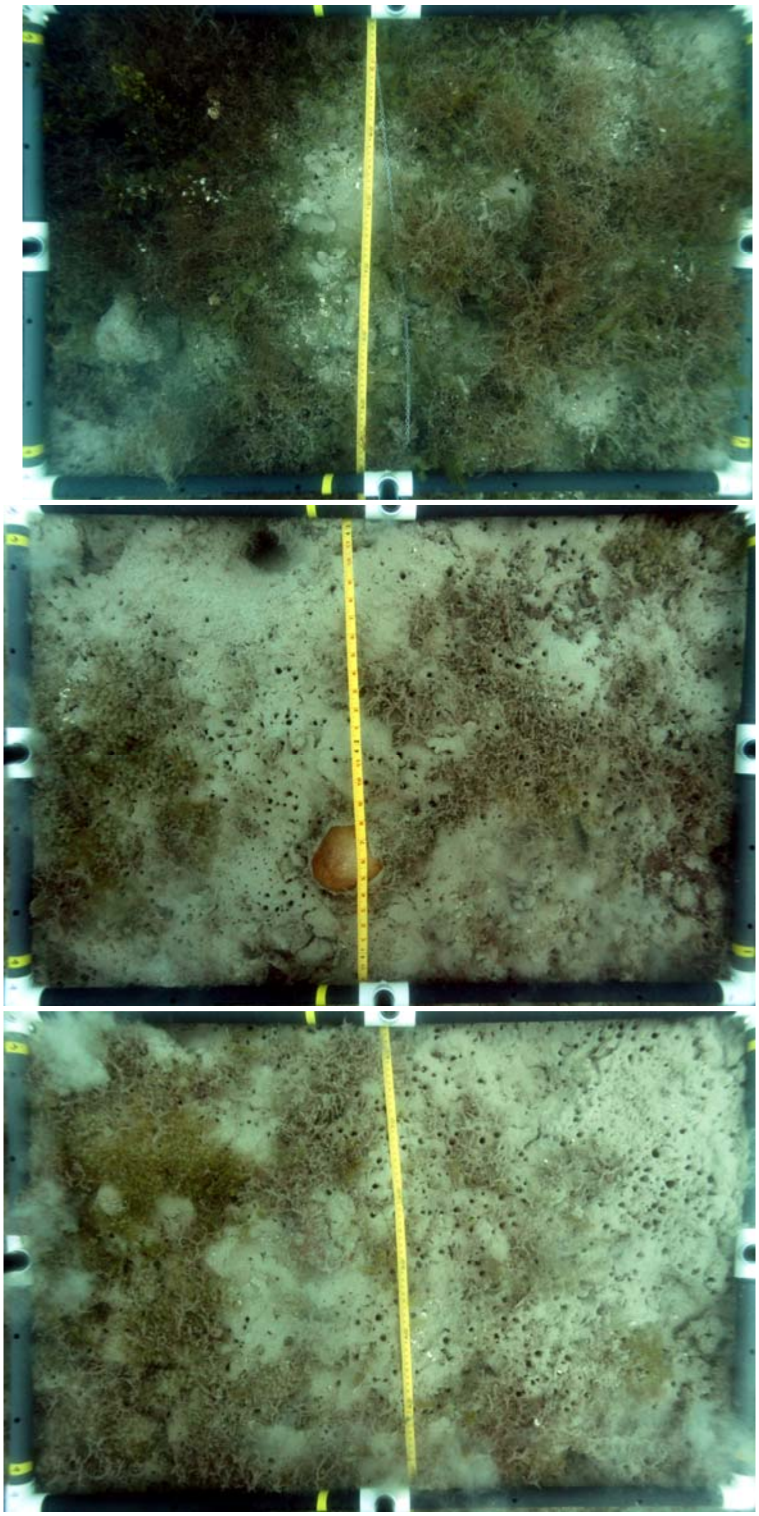

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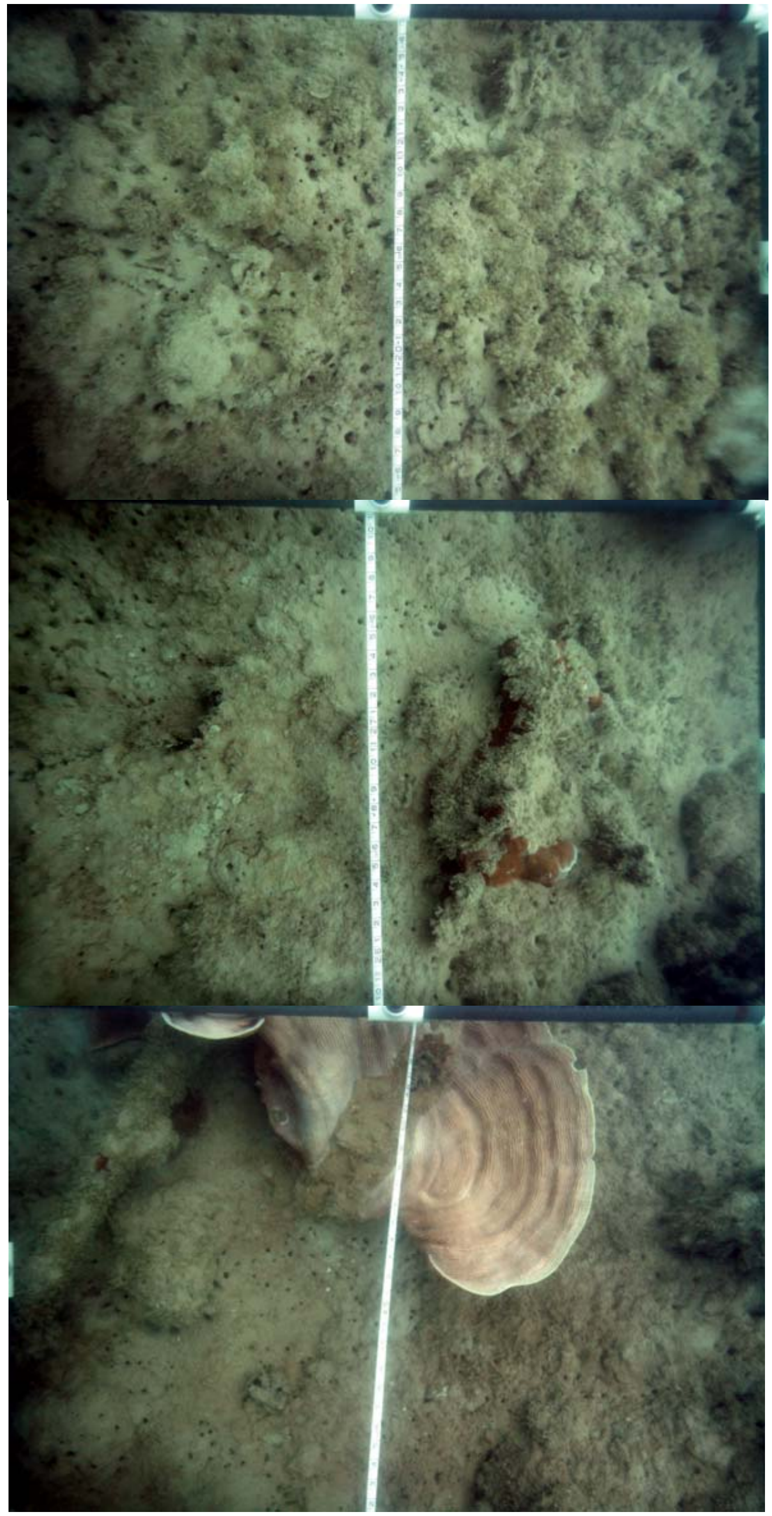

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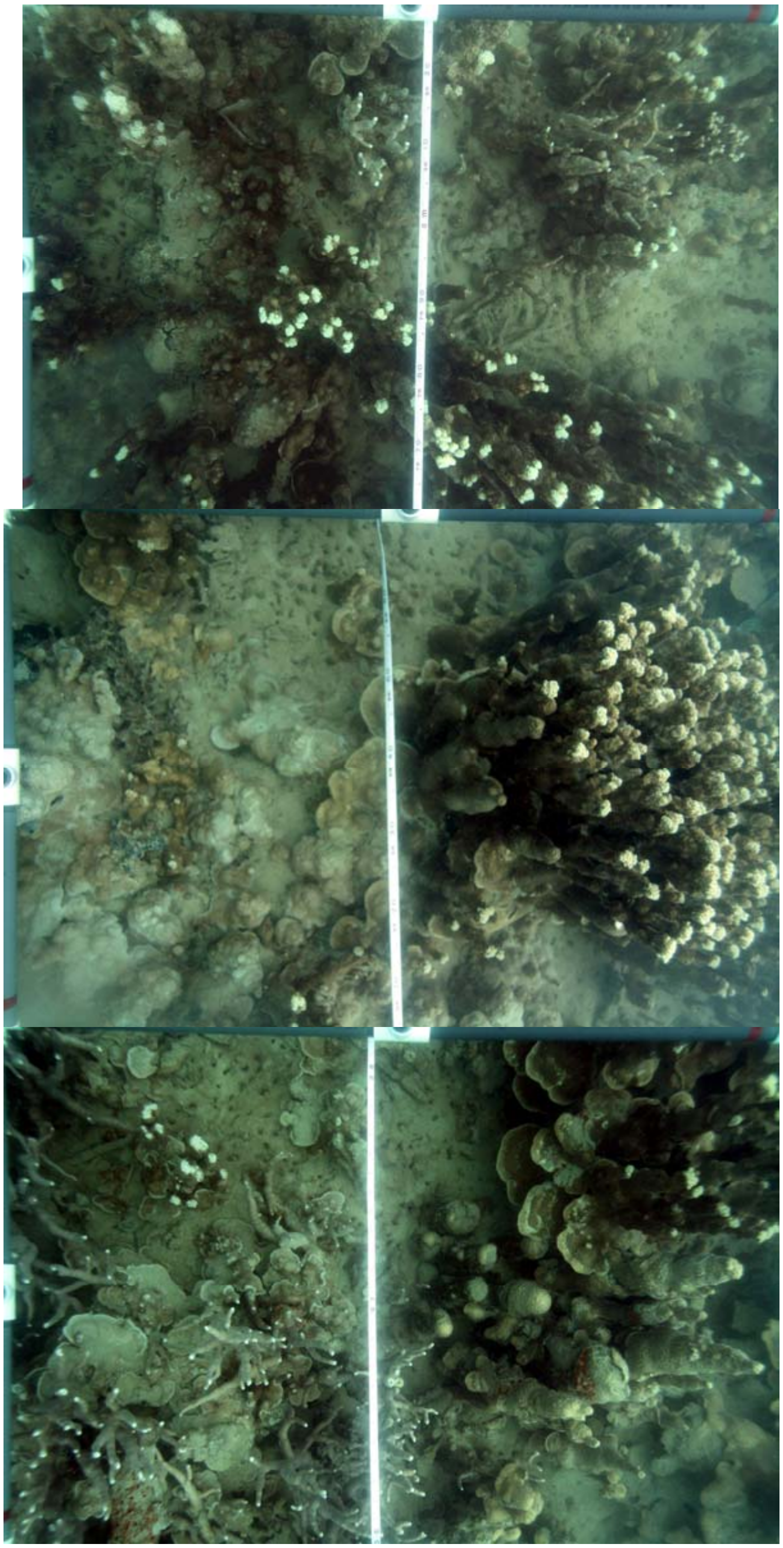

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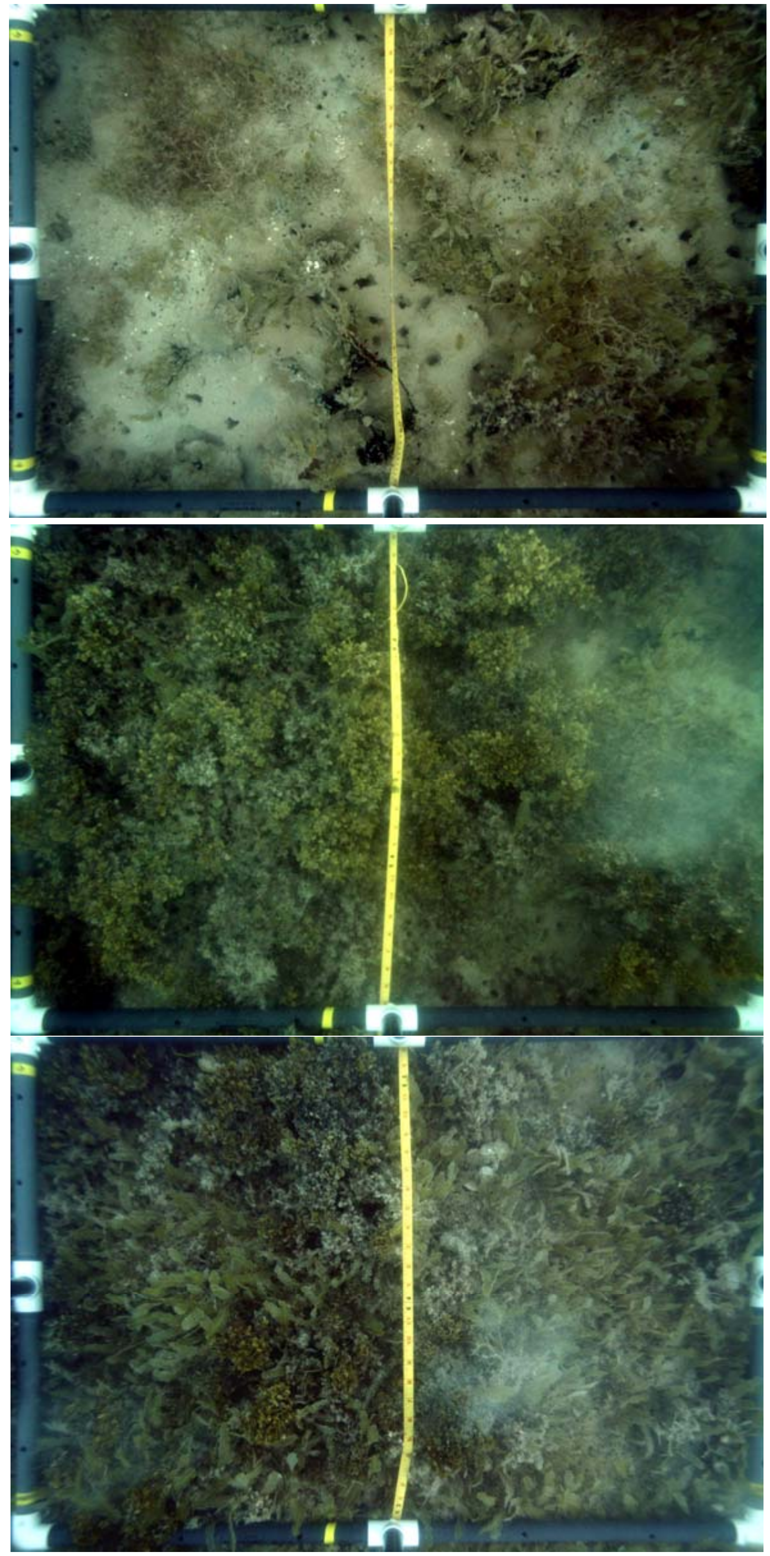

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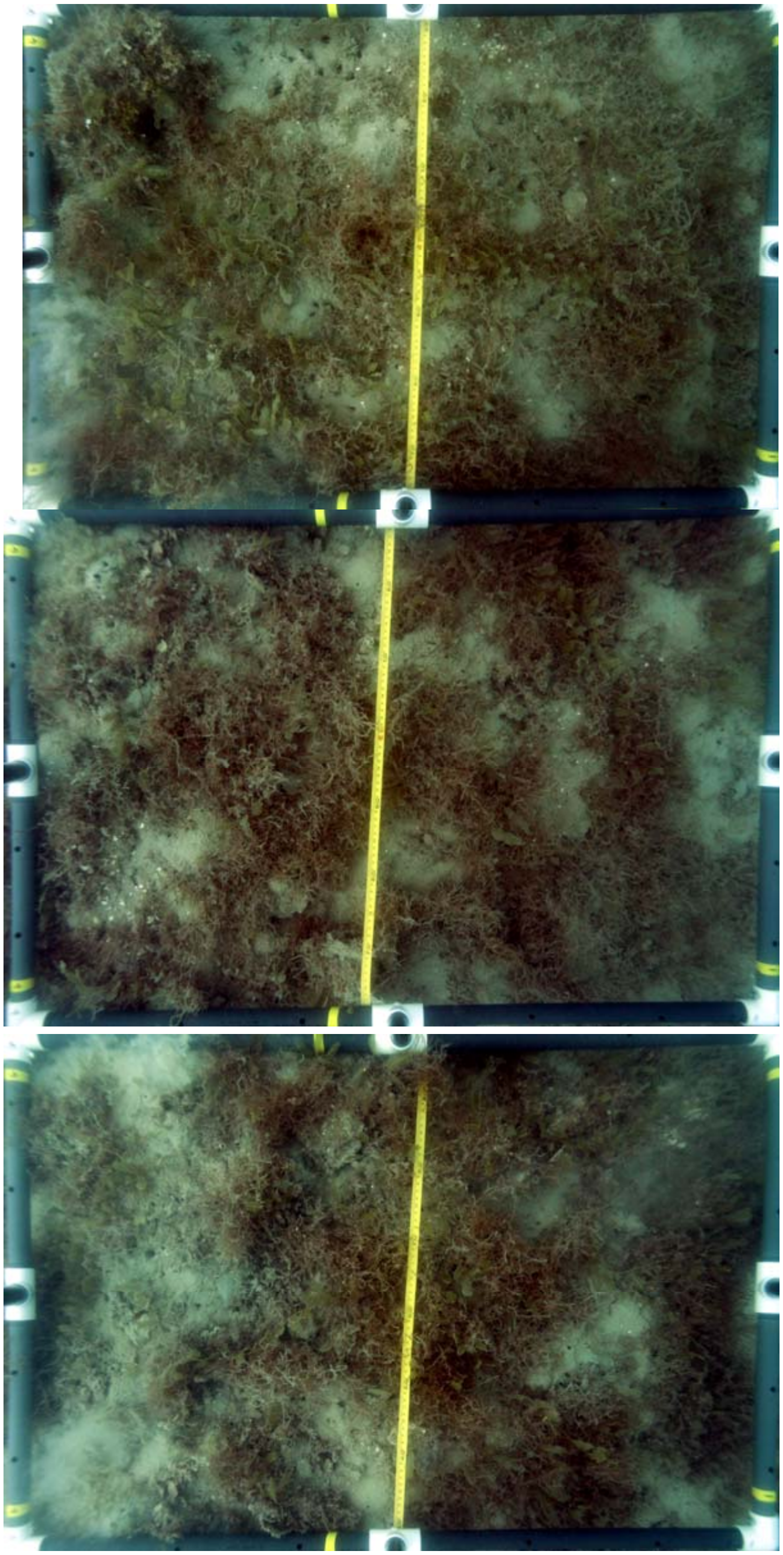

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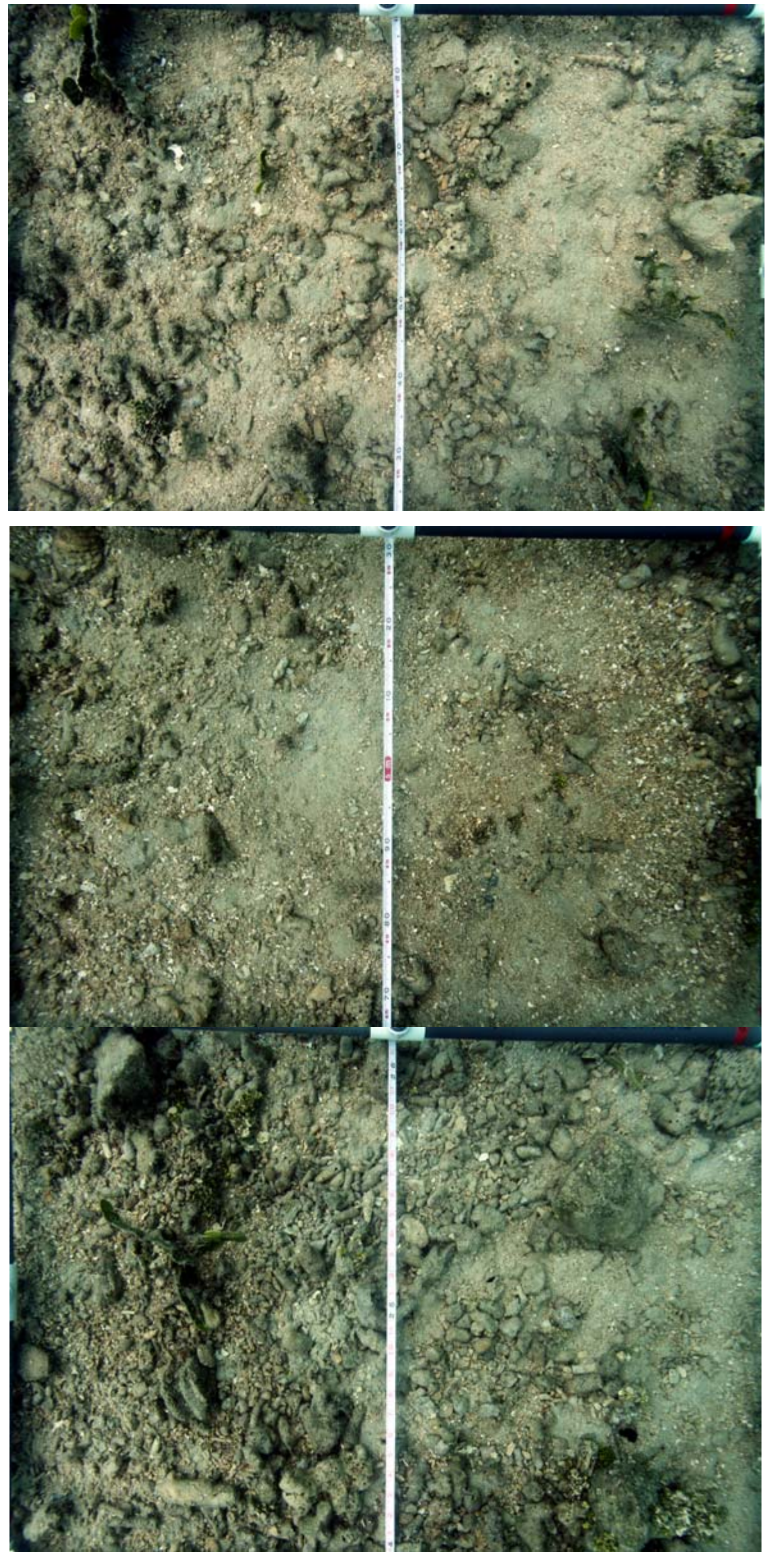

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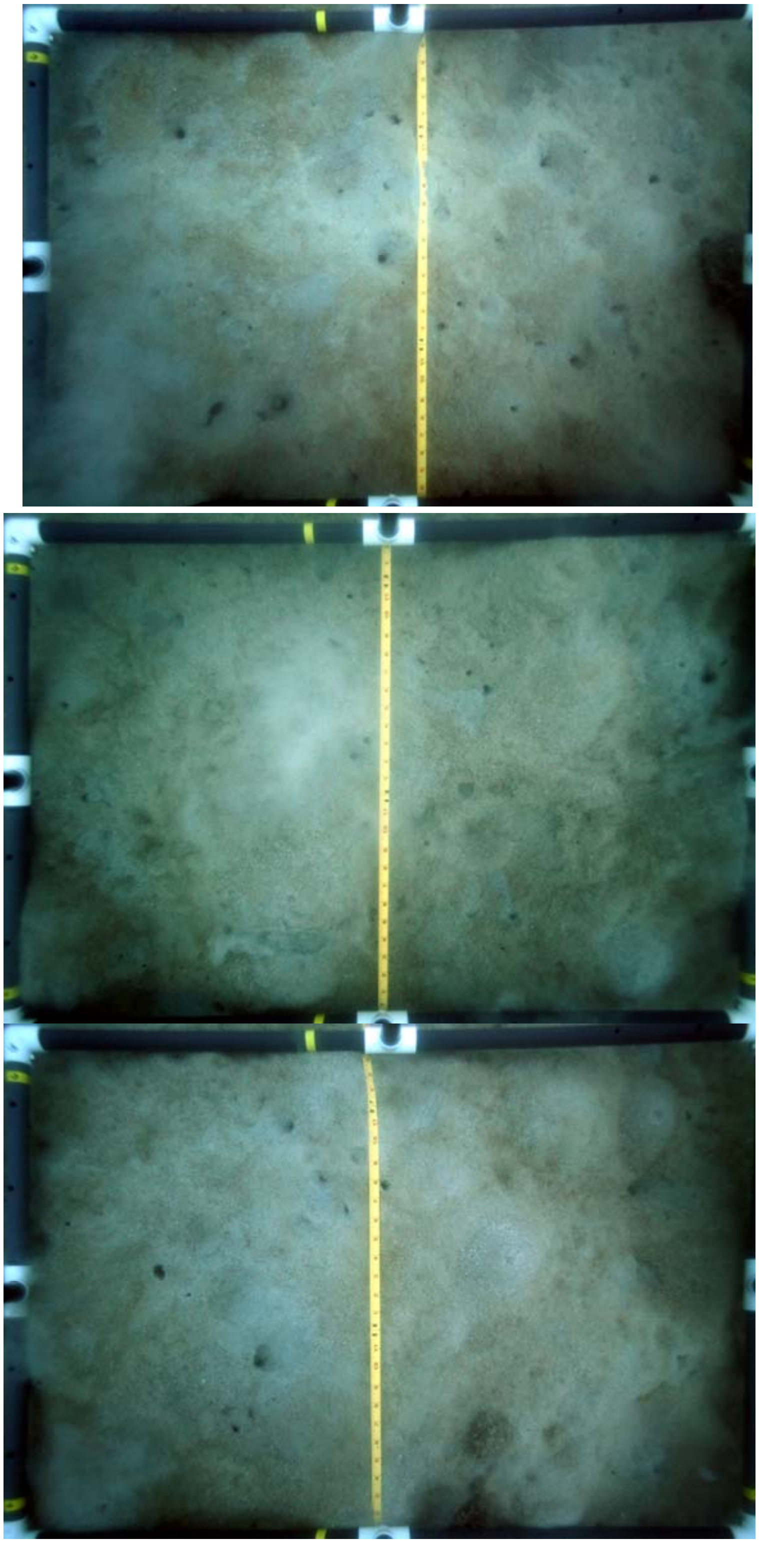

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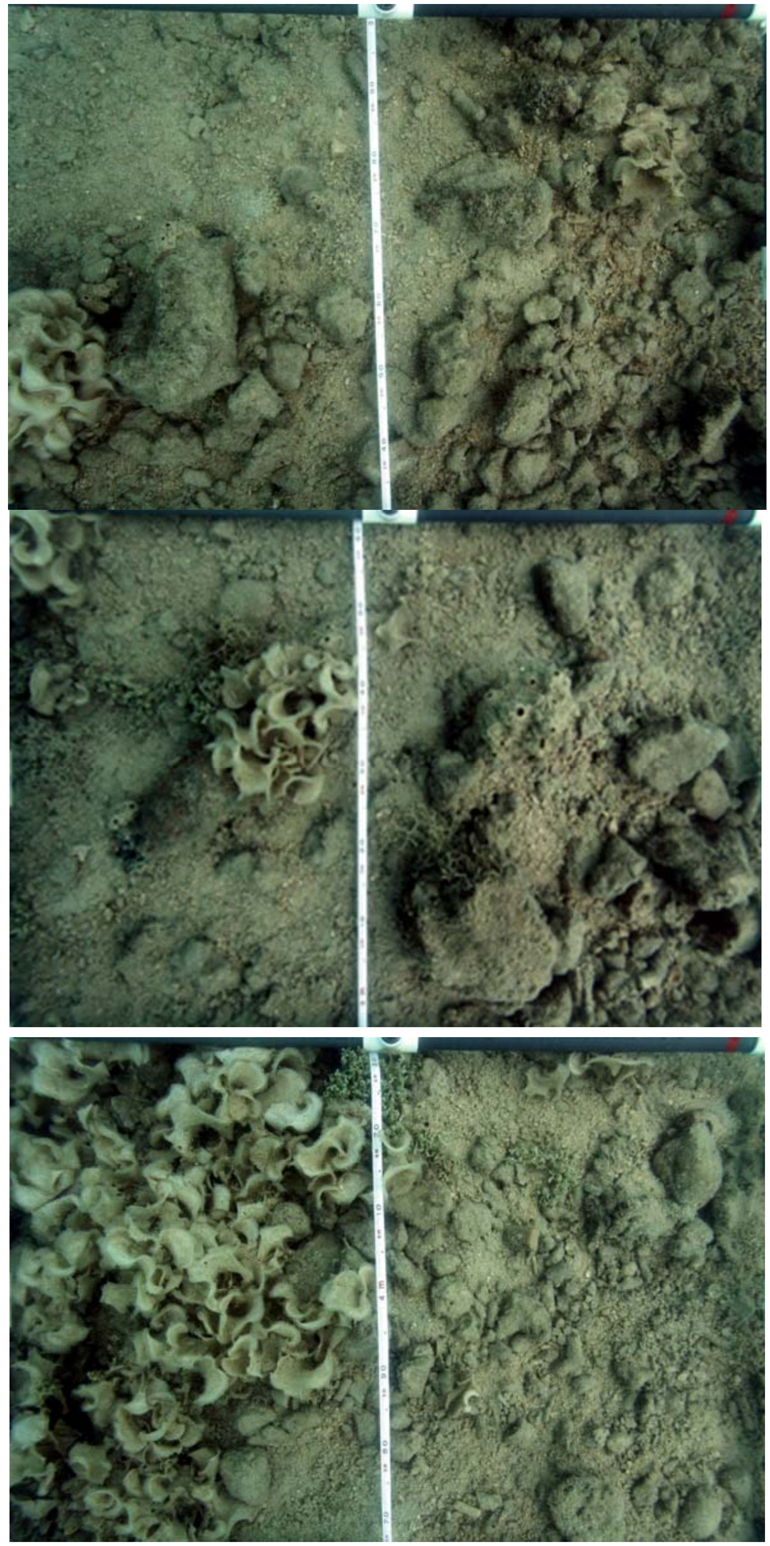

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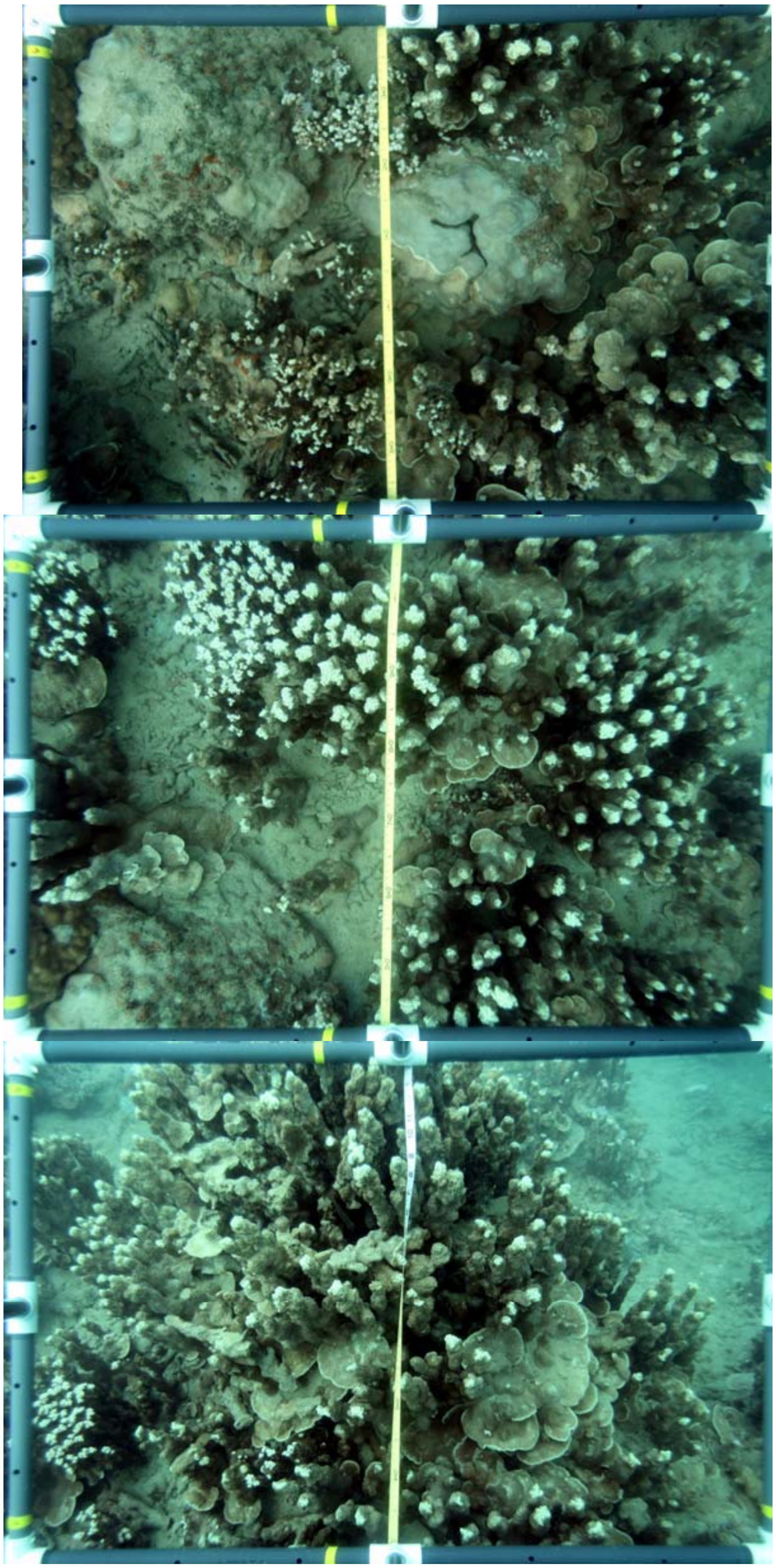

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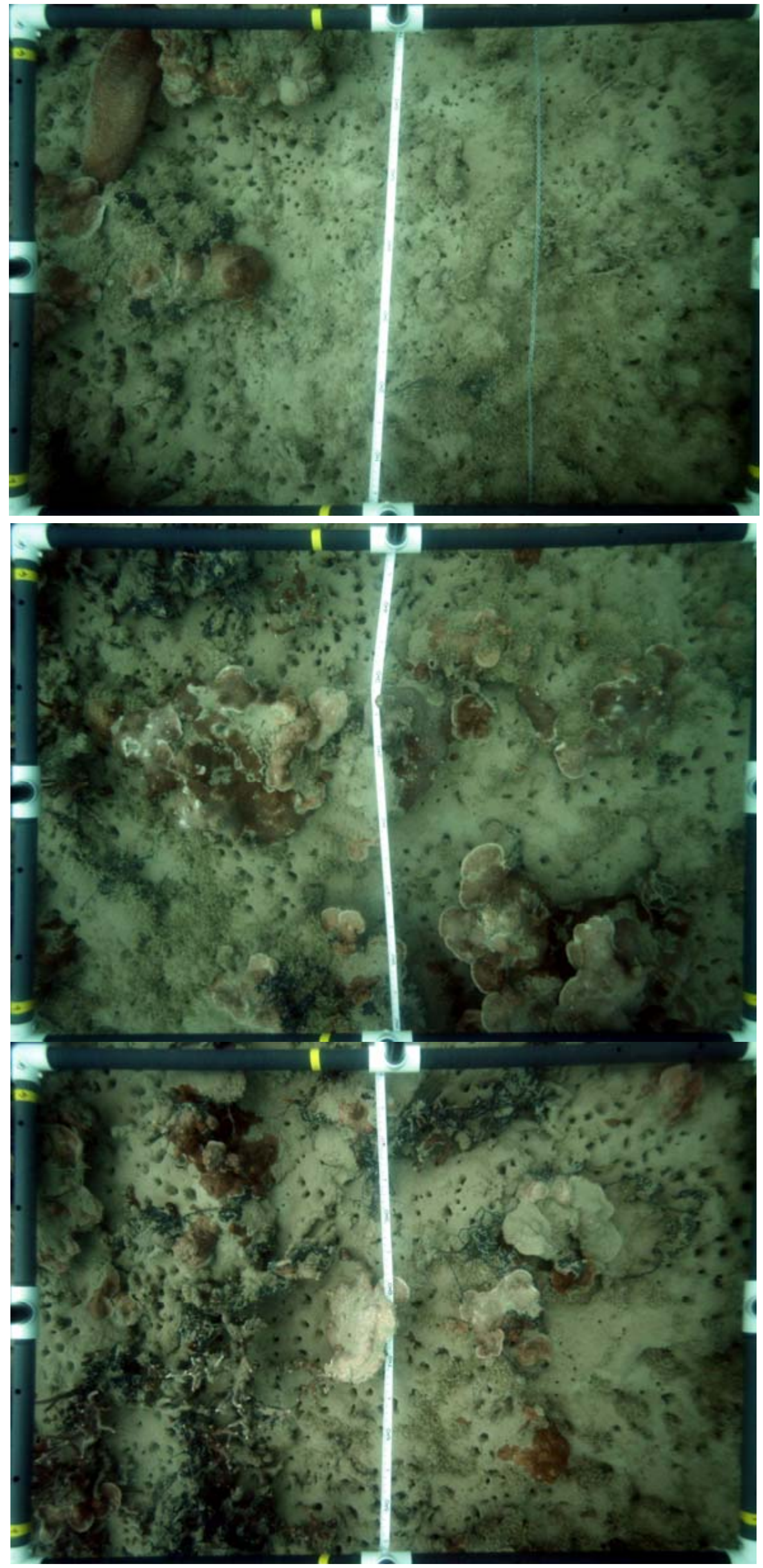

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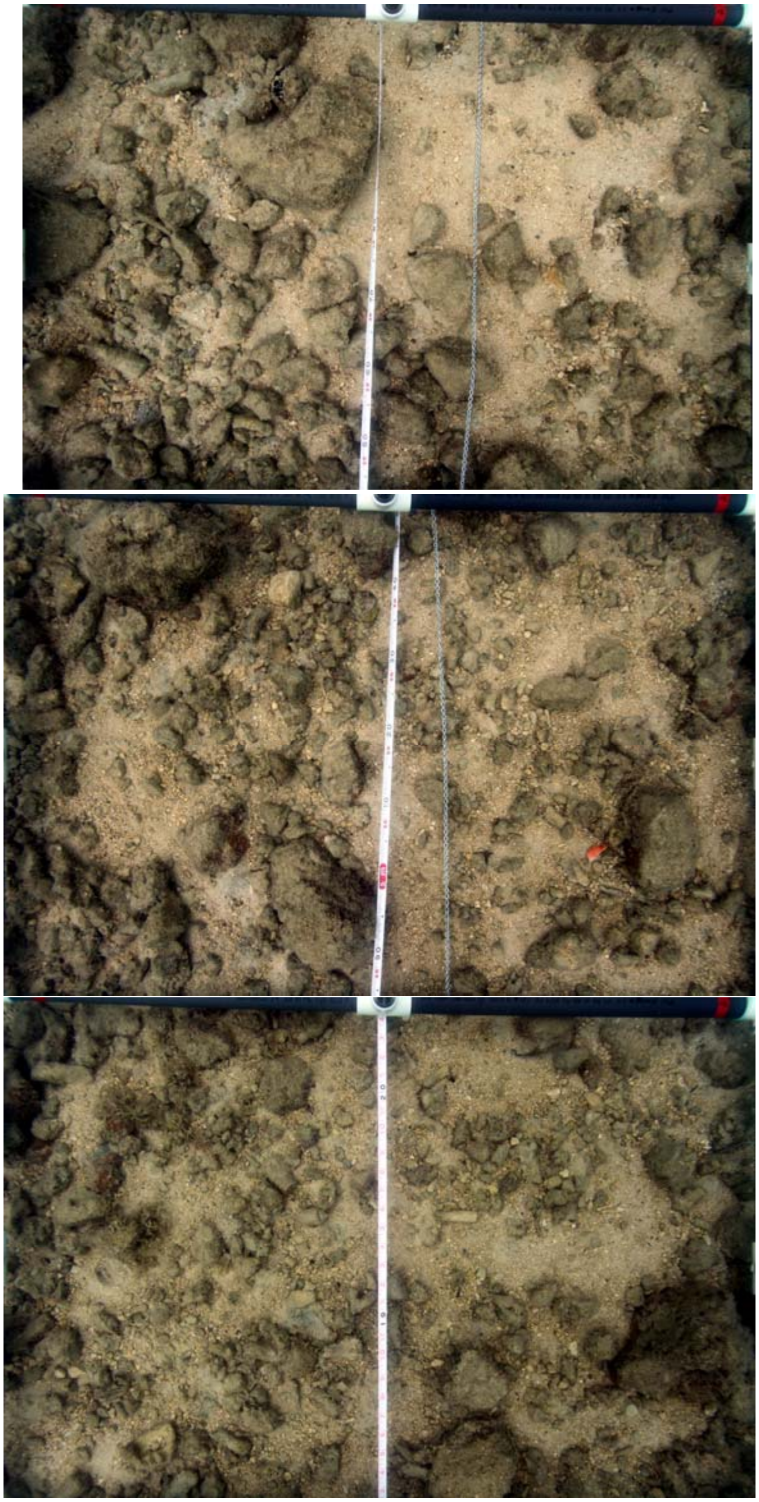

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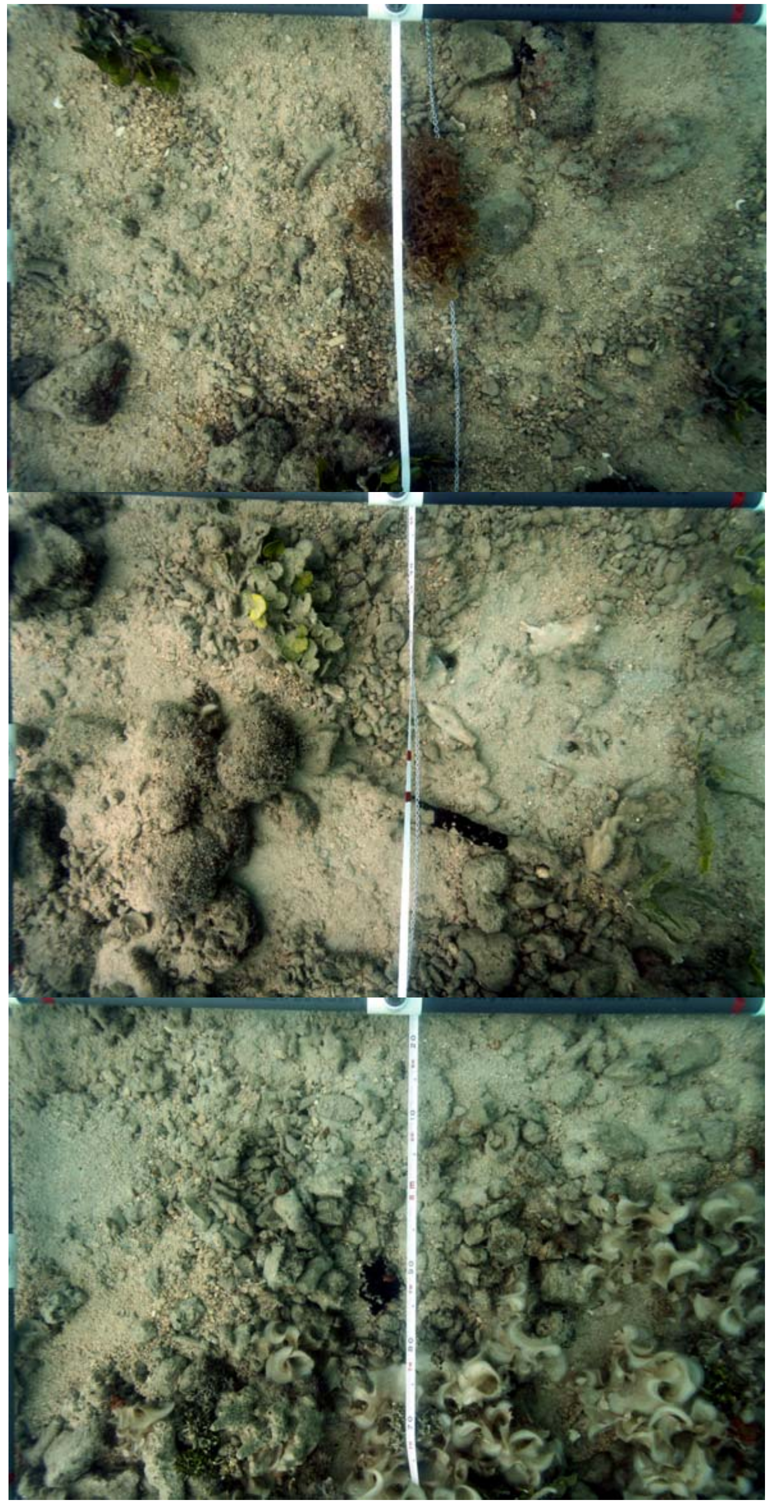

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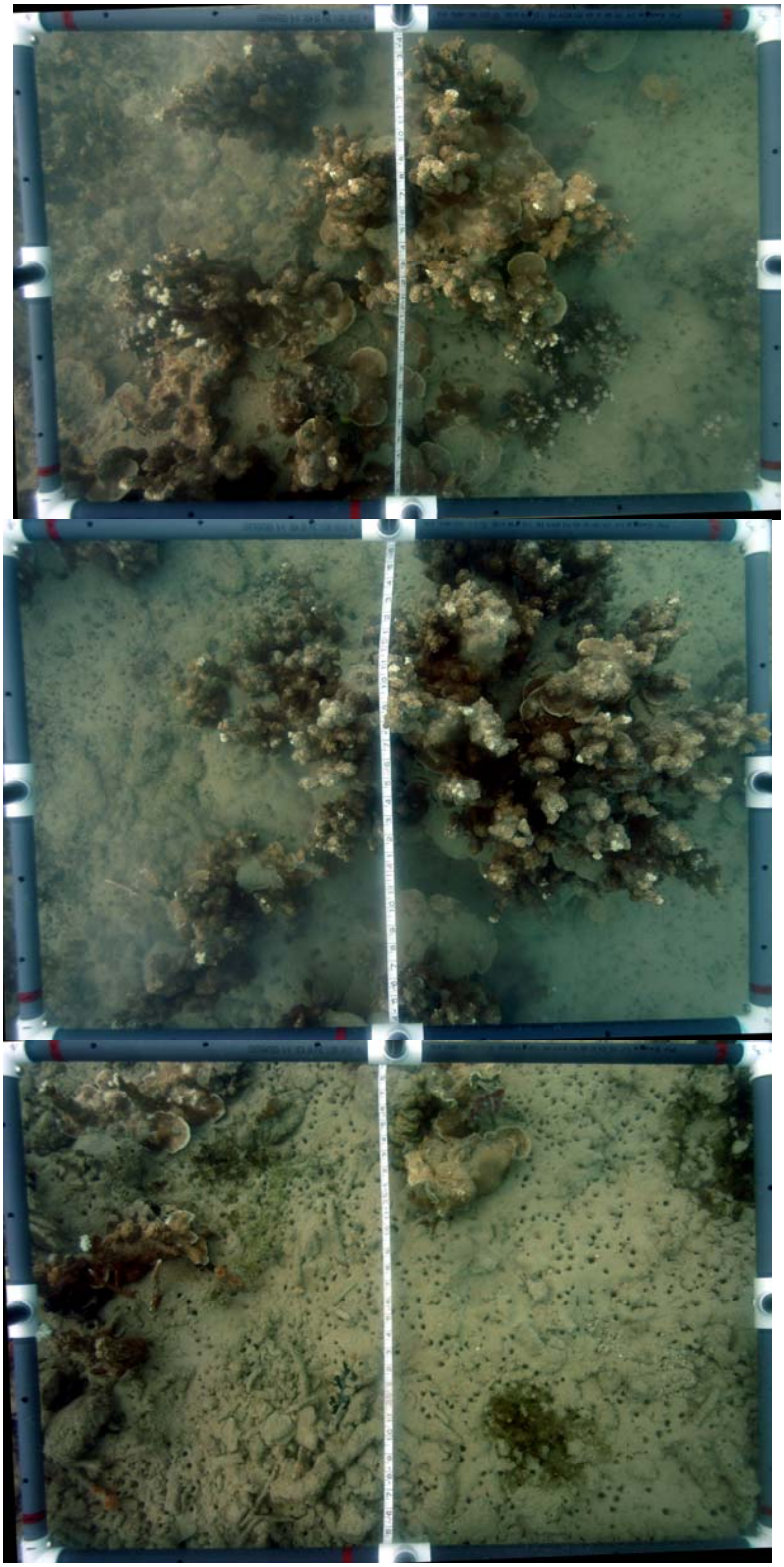

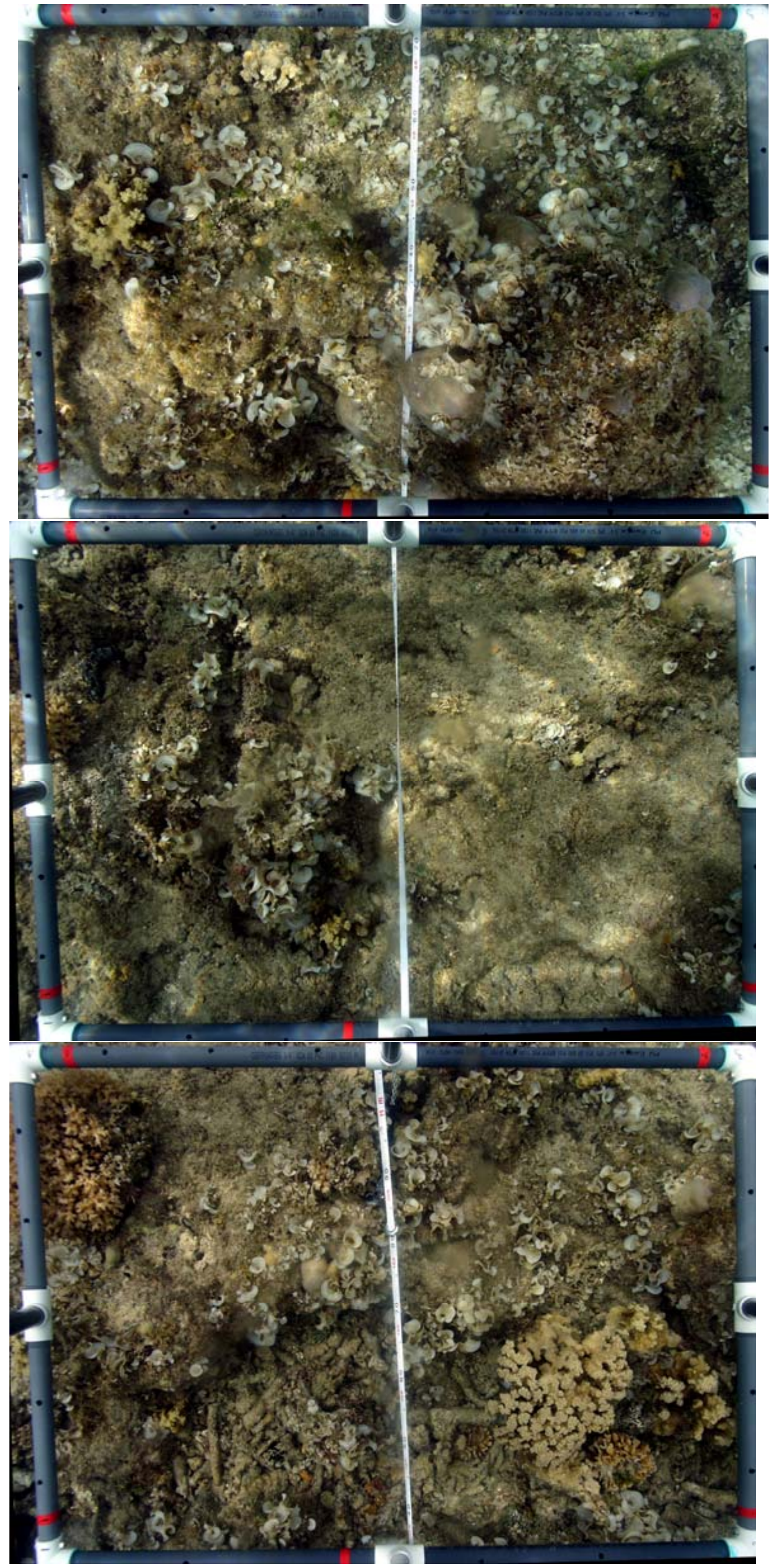

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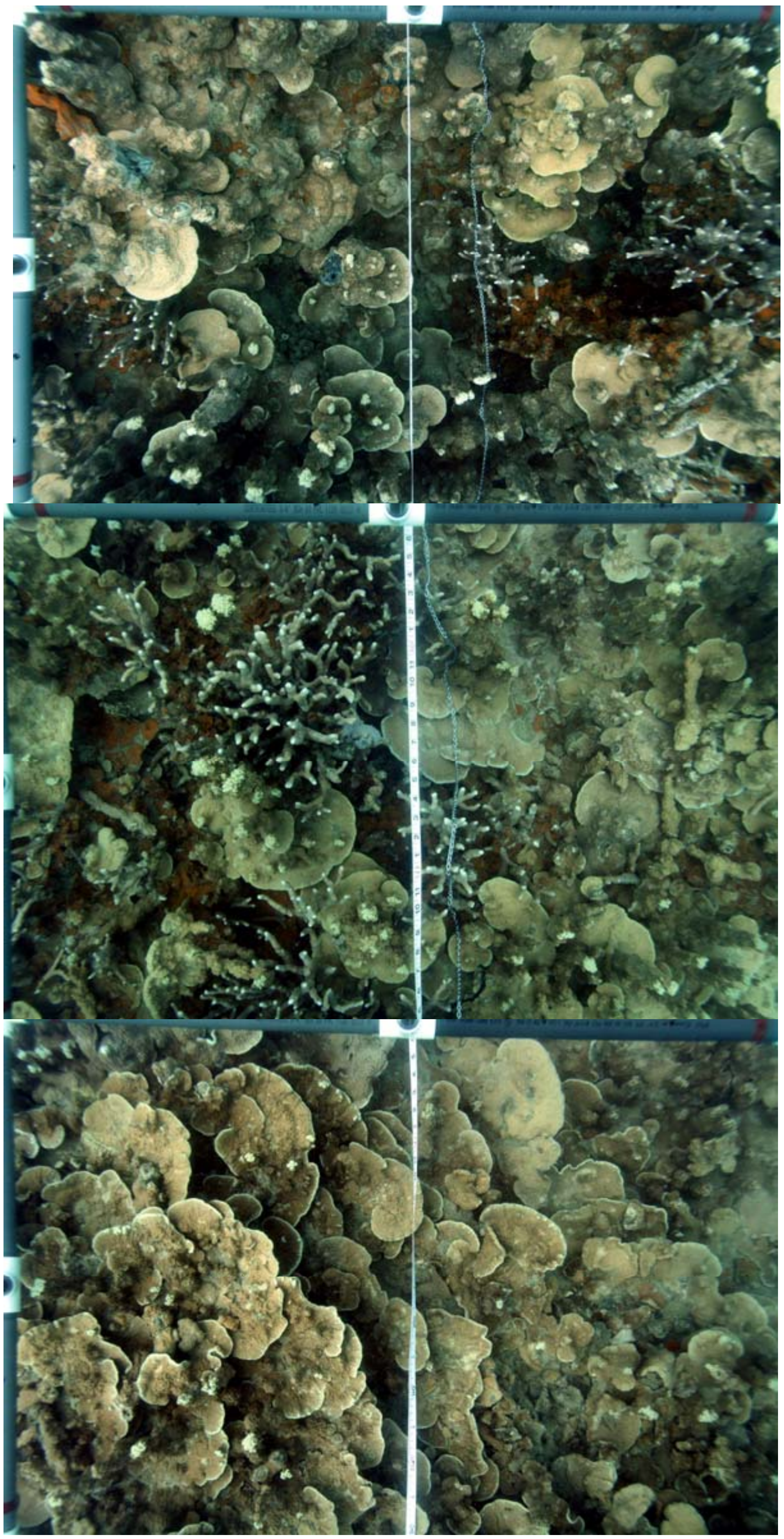
TRANSECT 60



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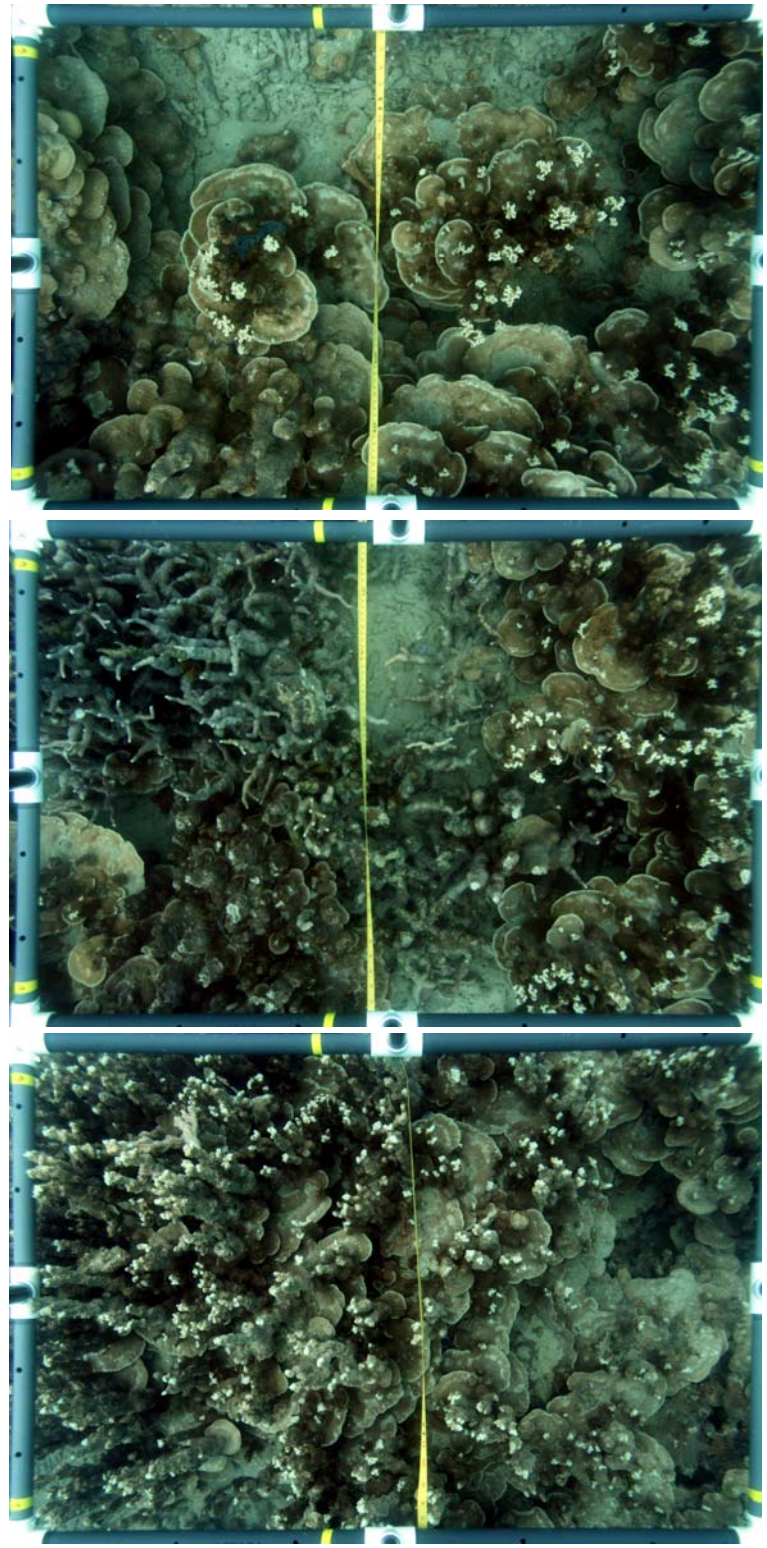

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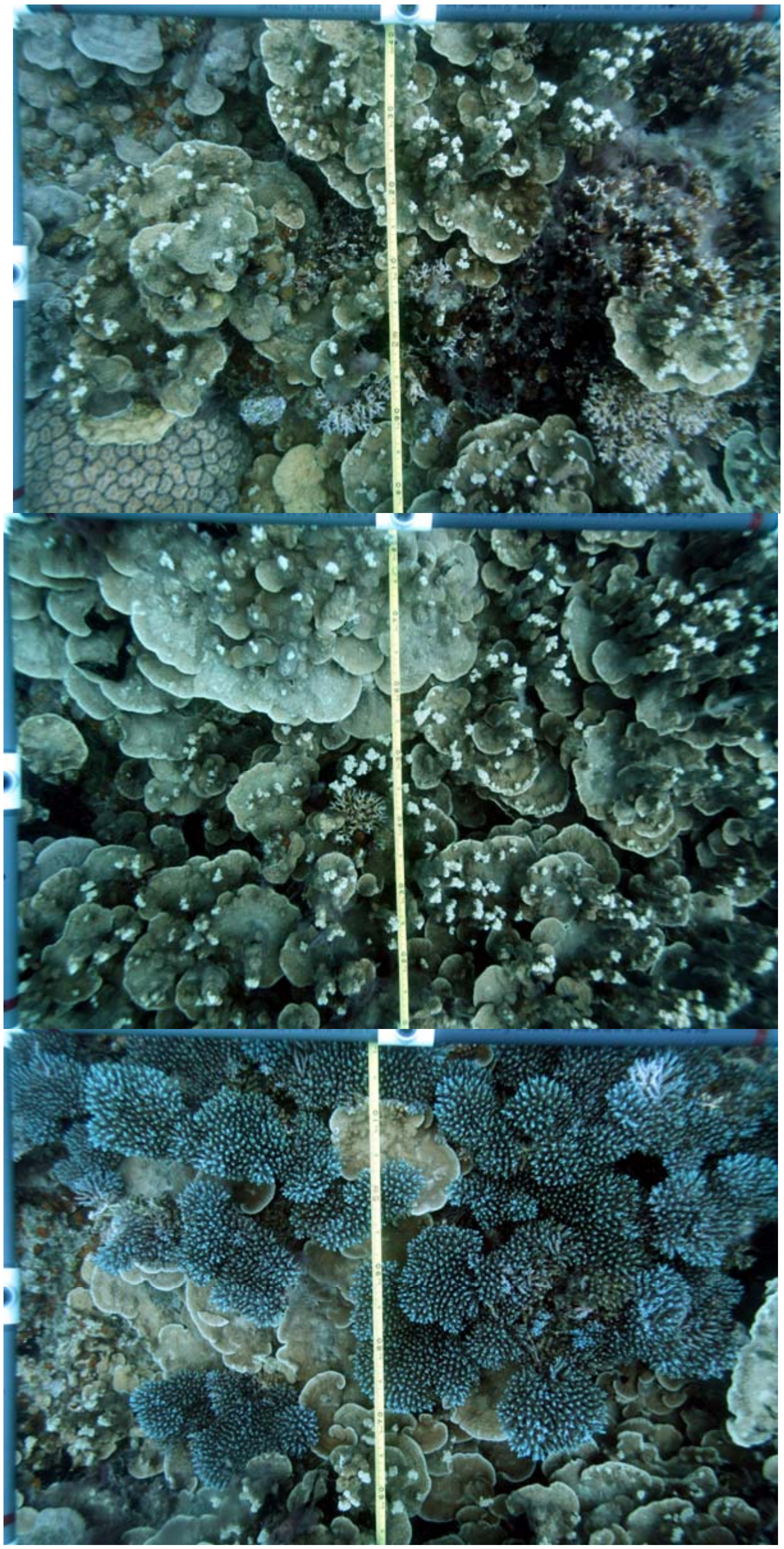

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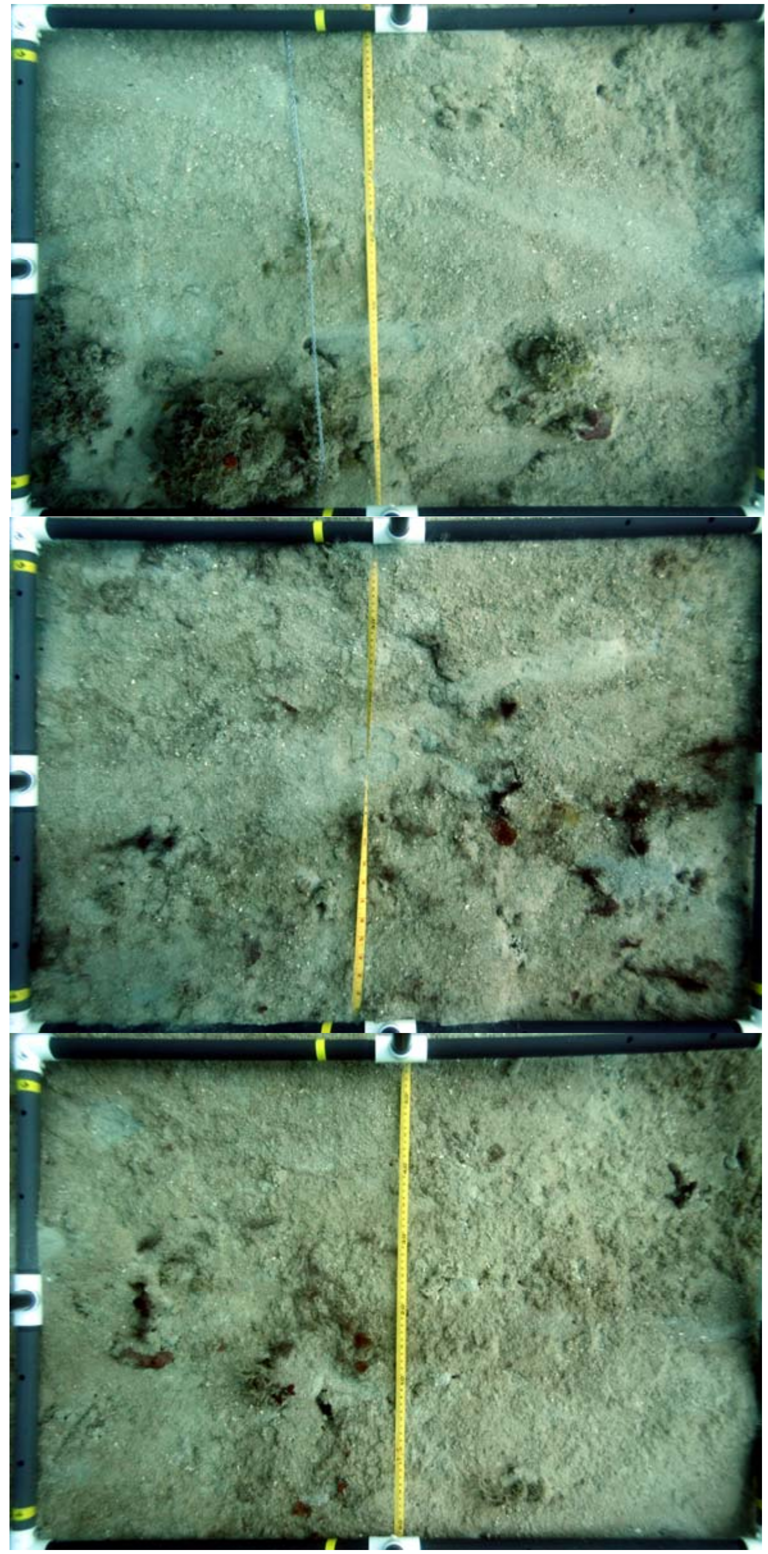
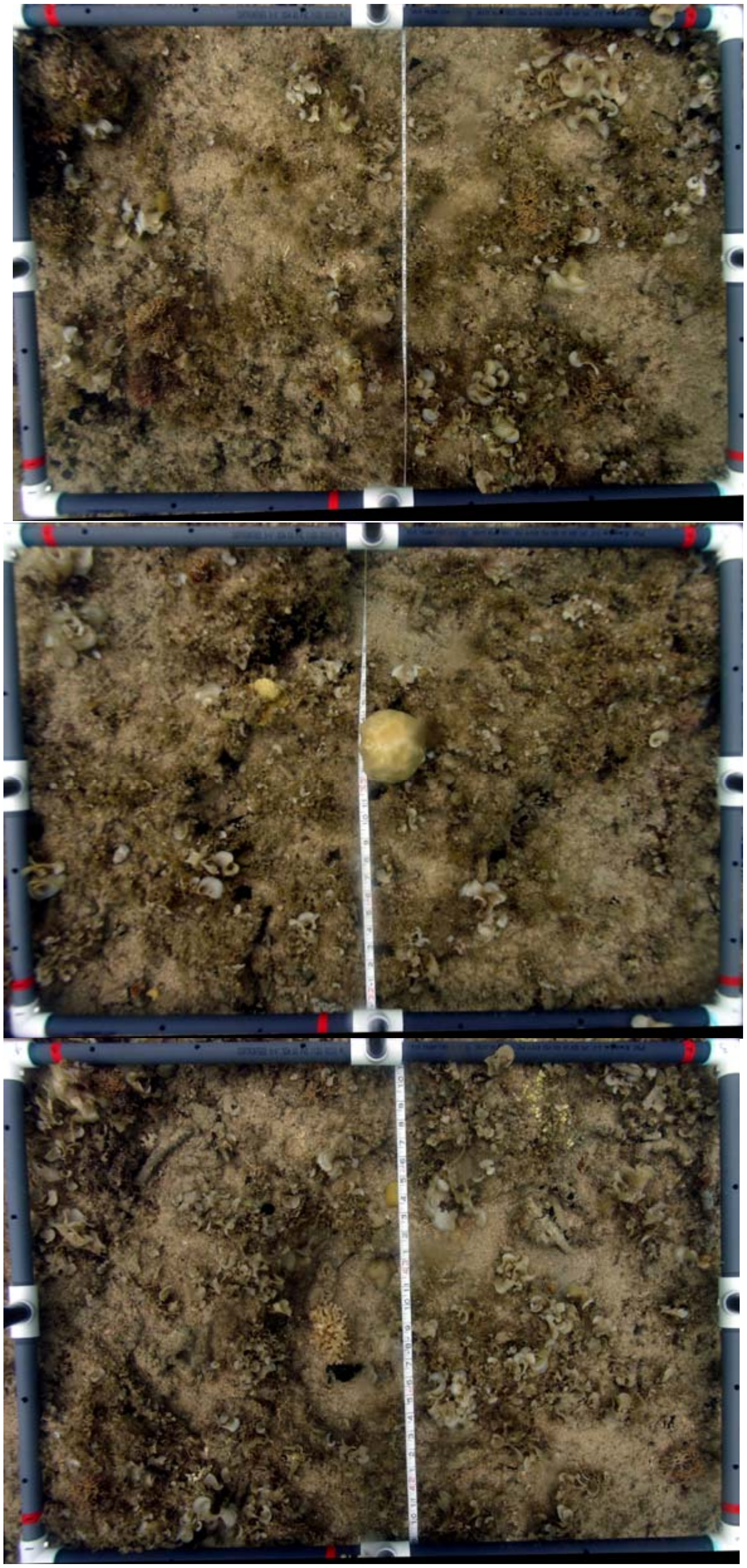
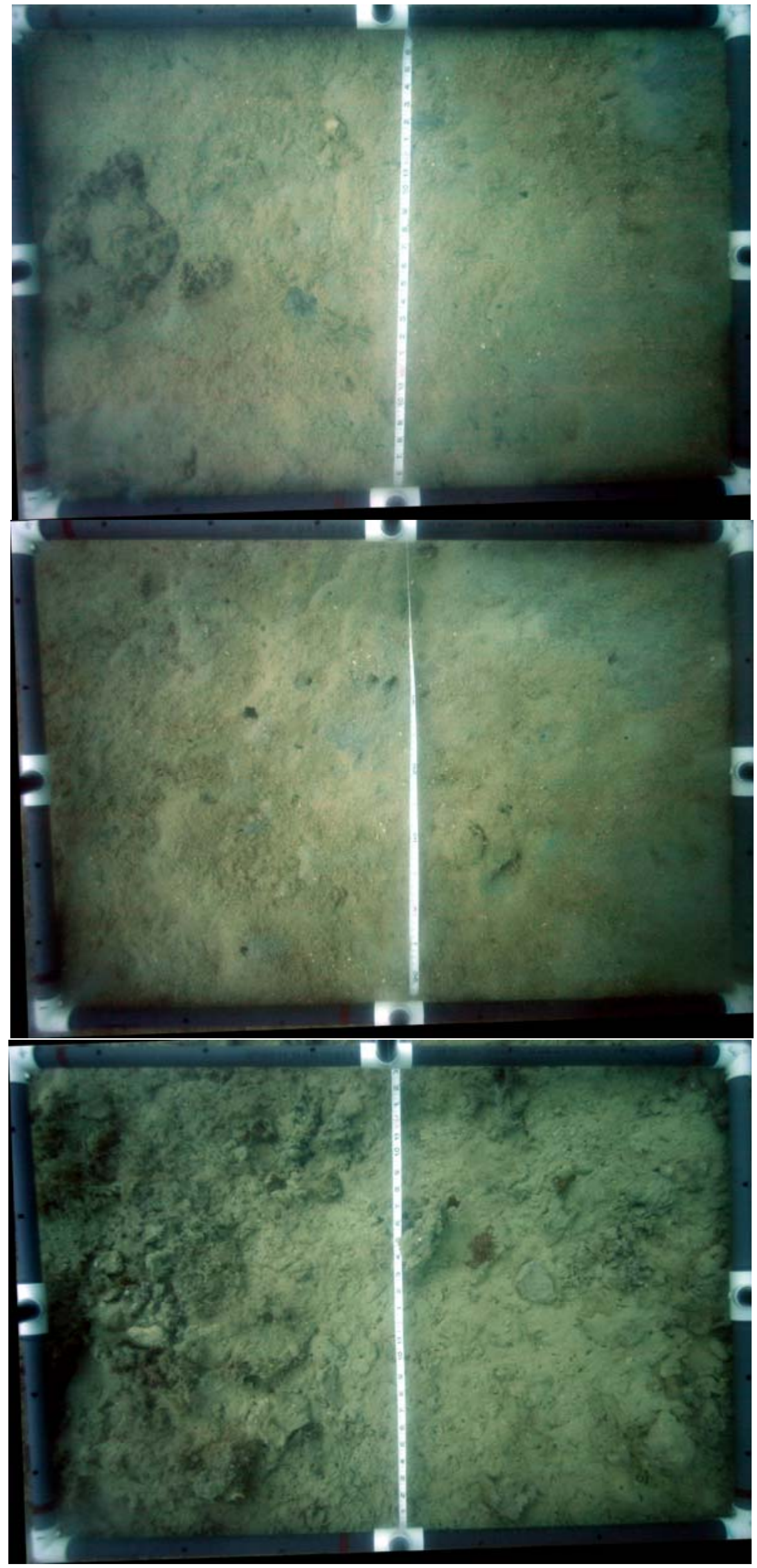


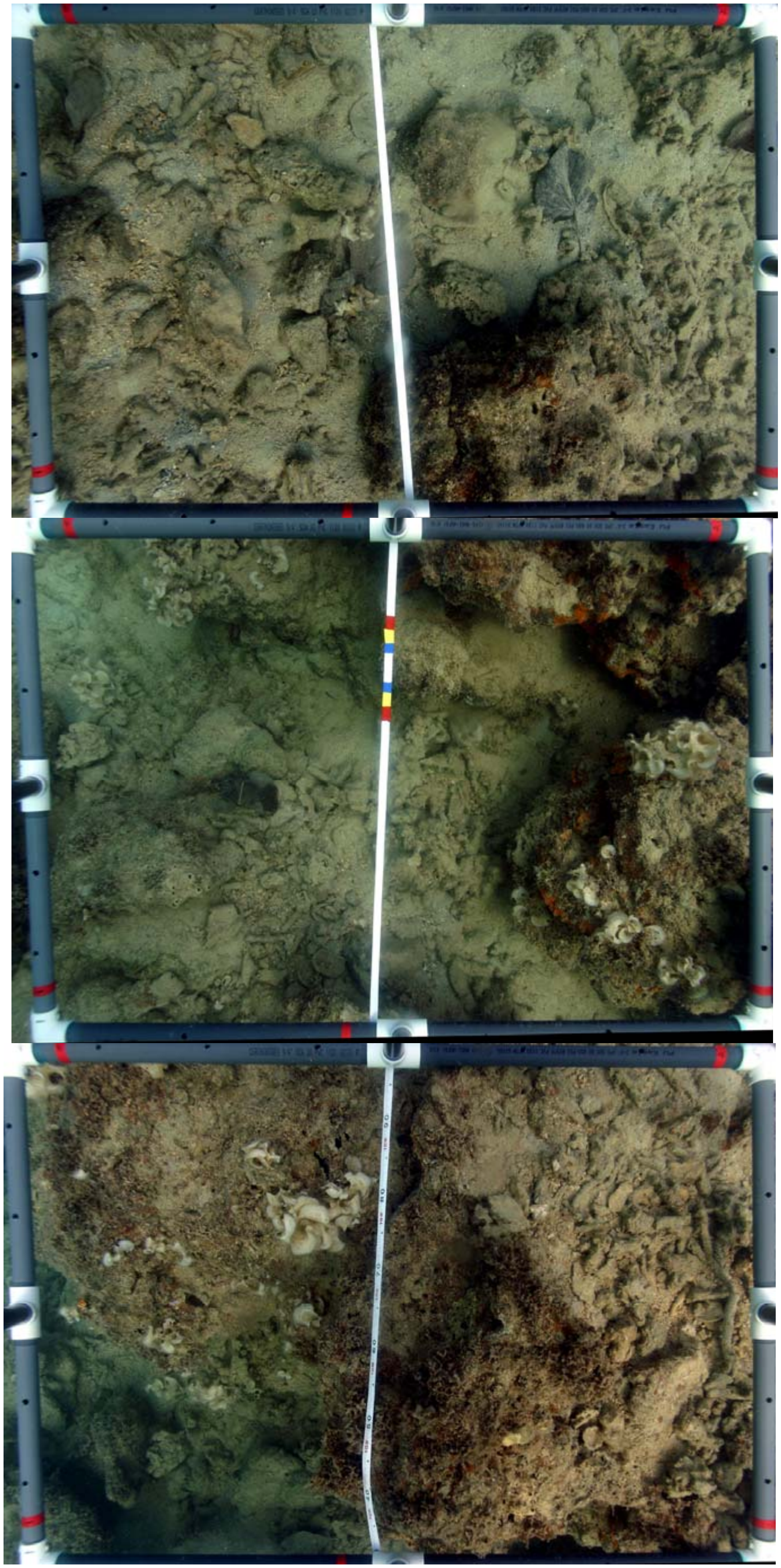
TRANSECT 64





TRANSECT 65

TRANSECT 66



TRANSECT 67

APPENDIX C. Means and 95% upper and lower 95% confidence limits (CI) of percent benthic cover of general classes from photo-quadrat transects in the CVN survey area of Apra Harbor, Guam.

TRANSECT	ALGAE		CORAL		SOFT CORAL		SPONGE		ECHINODERMS		ASCIDIAN		FISH		SEDIMENT	
	MEAN	CI	MEAN	CI	MEAN	CI	MEAN	CI	MEAN	CI	MEAN	CI	MEAN	CI	MEAN	CI
1	12	9.4 15	52.5	48.3 56.8	0	0 0.7	20.4	17.1 24	0	0 0.7	0	0 0.7	0	0 0.7	15.1	12.2 18.4
2	73.3	70 76.5	10.8	8.7 13.2	0	0 0.5	8.1	6.3 10.3	1.1	0.5 2.1	0	0 0.5	0	0 0.5	6.7	5 8.7
3	32	28.1 36.1	1.5	0.6 2.8	0	0 0.7	3.1	1.8 4.9	0	0 0.7	0	0 0.7	0	0 0.7	63.5	59.3 67.5
4	36.9	33.5 40.5	51.3	47.7 55	0	0 0.5	5.9	4.3 7.8	0	0 0.5	0	0 0.5	0	0 0.5	5.9	4.3 7.8
5	8.8	6.9 11.1	70.9	67.5 74.2	0	0 0.5	17.7	15.1 20.7	0	0 0.5	0	0 0.5	0	0 0.5	2.5	1.5 3.9
6	24.1	21.1 27.4	62.5	59 66	0	0 0.5	13.2	10.9 15.8	0	0 0.5	0.1	0 0.7	0	0 0.5	0	0 0.5
7	18.1	15.4 21.1	68.8	65.3 72.1	1.7	0.9 2.9	0.4	0.1 1.2	0.1	0 0.7	0	0 0.5	0	0 0.5	10.8	8.7 13.2
8	16.1	13.6 19	66	62.5 69.4	0	0 0.5	10.1	8.1 12.5	0	0 0.5	0	0 0.5	0	0 0.5	7.7	5.9 9.9
9	53.5	49.8 57.1	21.7	18.8 24.9	0	0 0.5	23.6	20.6 26.8	0	0 0.5	0	0 0.5	0	0 0.5	1.2	0.6 2.3
10	82.5	79.3 85.3	0.9	0.3 2	0	0 0.6	1.2	0.5 2.4	0.3	0 1.1	0	0 0.6	0	0 0.6	15.1	12.4 18.1
11	92.8	90.7 94.5	0	0 0.5	0	0 0.5	3.1	2 4.6	0	0 0.5	0	0 0.5	0	0 0.5	4.1	2.8 5.8
12	99.9	99.3 100	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0.1	0 0.7
13	26.9	23.8 30.3	61.6	58 65.1	0	0 0.5	3.6	2.4 5.2	0	0 0.5	0	0 0.5	0	0 0.5	7.9	6 10
14	33.9	30.5 37.4	48.1	44.5 51.8	0	0 0.5	3.2	2.1 4.7	0	0 0.5	0.3	0 1	0	0 0.5	14.5	12.1 17.3
15	11.1	8.9 13.5	68.5	65.1 71.8	0	0 0.5	6.5	4.9 8.5	0	0 0.5	0	0 0.5	0	0 0.5	13.9	11.5 16.5
16	12.9	10.6 15.5	1.9	1 3.1	0	0 0.5	1.3	0.6 2.4	0	0 0.5	0	0 0.5	0	0 0.5	83.9	81 86.4
17	36.7	33.2 40.2	14.4	12 17.1	0	0 0.5	5.9	4.3 7.8	0	0 0.5	0	0 0.5	0	0 0.5	43.1	39.5 46.7
18	52.9	49.3 56.6	27.1	23.9 30.4	0	0 0.5	1.5	0.7 2.6	0	0 0.5	0	0 0.5	0	0 0.5	18.5	15.8 21.5
19	34.3	30.9 37.8	51.6	48 55.2	0	0 0.5	2.1	1.2 3.4	0	0 0.5	0	0 0.5	0	0 0.5	12	9.8 14.5
20	90.3	87.9 92.3	3.3	2.2 4.9	0	0 0.5	1.1	0.5 2.1	0	0 0.5	0	0 0.5	0	0 0.5	5.3	3.8 7.2
21	50.3	46.6 53.9	20.8	17.9 23.9	0	0 0.5	0.9	0.4 1.9	0	0 0.5	0	0 0.5	0	0 0.5	28	24.8 31.4
22	89.2	86.8 91.3	3.3	2.2 4.9	0	0 0.5	0.5	0.1 1.4	0	0 0.5	0	0 0.5	0	0 0.5	6.9	5.2 9
23	63.3	59.8 66.8	15.3	12.8 18.1	0	0 0.5	5.7	4.2 7.6	0	0 0.5	0	0 0.5	0.3	0 1	15.3	12.8 18.1
24	32.8	29.4 36.3	4	2.7 5.7	0	0 0.5	0	0 0.5	0.1	0 0.7	0	0 0.5	0	0 0.5	63.1	59.5 66.5
25	61.9	58.3 65.4	4	2.7 5.7	0	0 0.5	0.8	0.3 1.7	0	0 0.5	0	0 0.5	0	0 0.5	33.3	30 36.8
26	82.3	79.3 84.9	4.8	3.4 6.6	0	0 0.5	1.2	0.6 2.3	0	0 0.5	0	0 0.5	0	0 0.5	11.7	9.5 14.3
27	53.7	50.1 57.3	1.7	0.9 2.9	0	0 0.5	1.1	0.5 2.1	0	0 0.5	0	0 0.5	0	0 0.5	43.5	39.9 47.1
28	5.1	3.6 6.9	84.5	81.7 87	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	10.4	8.3 12.8
29	32.1	28.8 35.6	40.5	37 44.1	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	27.3	24.2 30.7
30	13.6	11.2 16.3	52.7	49 56.3	8.7	6.8 10.9	0.1	0 0.7	0	0 0.5	0	0 0.5	0	0 0.5	24.9	21.9 28.2
31	61.2	57.6 64.7	30.7	27.4 34.1	0	0 0.5	2.1	1.2 3.4	0	0 0.5	0.1	0 0.7	0	0 0.5	5.9	4.3 7.8
32	4.1	2.8 5.8	0.8	0.3 1.7	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	95.1	93.3 96.5
33	38.1	34.6 41.7	1.6	0.8 2.8	0	0 0.5	0.5	0.1 1.4	0	0 0.5	0	0 0.5	0	0 0.5	59.7	56.1 63.3

APPENDIX C (cont.).

TRANSECT	ALGAE		CORAL		SOFT CORAL		SPONGE		ECHINODERMS		ASCIDIAN		FISH		SEDIMENT	
	MEAN	CI	MEAN	CI	MEAN	CI	MEAN	CI	MEAN	CI	MEAN	CI	MEAN	CI	MEAN	CI
34	54.8	51.2	6.4	4.8	0	0	2.3	1.3	0	0	0	0	0	0	36.5	33.1
		58.4		8.4		0.5		3.6		0.5		0.5		0.5		40.1
35	23.7	20.6	0	0	0	0	0	0	0	0	0	0	0	0	76.3	73
		27		0.5		0.5		0.5		0.5		0.5		0.5		79.4
36	3.2	2.1	0	0	0	0	0.7	0.2	0	0	0	0	0	0	96.1	94.5
		4.7		0.5		0.5		1.5		0.5		0.5		0.5		97.4
37	20.8	15.9	0	0	0	0	0.4	0	0	0	0	0	0	0	78.8	73.2
		26.4		1.5		1.5		2.2		1.5		1.5		1.5		83.7
38	0.3	0	0	0	0.6	0.2	0	0	0	0	0	0	0	0	99.1	98
		1.1		0.6		1.6		0.6		0.6		0.6		0.6		99.7
39	73.9	70.6	5.5	4	0	0	0.1	0	0	0	0	0	0	0	20.5	17.7
		77		7.3		0.5		0.7		0.5		0.5		0.5		23.6
40	28.1	24.9	16.1	13.6	0	0	0.9	0.4	0	0	0	0	0	0	54.8	51.2
		31.5		19		0.5		1.9		0.5		0.5		0.5		58.4
41	65	61.3	0.9	0.3	0	0	5.9	4.2	0	0	0	0	0	0	28.3	25
		68.5		1.9		0.5		7.9		0.5		0.5		0.5		31.8
42	1.1	0.4	0	0	0	0	0	0	0	0	0	0	0	0	98.9	97.8
		2.2		0.6		0.6		0.6		0.6		0.6		0.6		99.6
43	49.3	45.7	34.7	31.3	0	0	1.7	0.9	0	0	0	0	0	0	14.3	11.8
		53		38.2		0.5		2.9		0.5		0.5		0.5		17
44	72.1	68.8	2.5	1.5	0	0	0.8	0.3	0	0	0	0	0	0	24.5	21.5
		75.3		3.9		0.5		1.7		0.5		0.5		0.5		27.8
45	66.5	63	21.1	18.2	0	0	1.7	0.9	0	0	0	0	0	0	10.7	8.5
		69.9		24.2		0.5		2.9		0.5		0.5		0.5		13.1
46	26.1	23	19.9	17.1	0	0	0.4	0.1	0	0	0	0	0	0	53.6	50
		29.4		22.9		0.5		1.2		0.5		0.5		0.5		57.2
47	62.8	59.2	0.7	0.2	0	0	0	0	0	0	0	0	0	0	36.5	33.1
		66.3		1.5		0.5		0.5		0.5		0.5		0.5		40.1
48	37.1	33.6	6	4.4	0	0	0	0	0	0	0	0	0	0	56.9	53.3
		40.6		7.9		0.5		0.5		0.5		0.5		0.5		60.5
49	18.8	16.1	48.1	44.5	0	0	3.5	2.3	0	0	0	0	0	0	29.6	26.4
		21.8		51.8		0.5		5		0.5		0.5		0.5		33
50	82.7	79.8	0	0	0	0	0.5	0.1	0	0	0	0	0	0	16.8	14.2
		85.3		0.5		0.5		1.4		0.5		0.5		0.5		19.7
51	86.2	83.3	0.5	0.1	0	0	0.6	0.2	0	0	0	0	0	0	12.8	10.3
		88.7		1.3		0.6		1.6		0.6		0.6		0.6		15.6
52	8.5	6.6	0	0	0	0	2.5	1.5	0	0	0	0	0	0	88.9	86.5
		10.8		0.5		0.5		3.9		0.5		0.5		0.5		91.1
53	0	0	0	0	0	0	0	0	0	0	0	0	0	0	100	99.4
		0.6		0.6		0.6		0.6		0.6		0.6		0.6		100
54	21.5	18.6	0	0	0	0	2.4	1.4	0	0	0	0	0	0	76.1	72.9
		24.6		0.5		0.5		3.8		0.5		0.5		0.5		79.1
55	23.5	20.5	36.9	33.5	0	0	4.8	3.4	0	0	0	0	0	0	34.8	31.4
		26.7		40.5		0.5		6.6		0.5		0.5		0.5		38.3
56	26	22.9	12.5	10.2	0	0	6.7	5	0	0	0	0	0	0	54.8	51.2
		29.3		15.1		0.5		8.7		0.5		0.5		0.5		58.4
57	50.7	47	0	0	0	0	0.4	0.1	0	0	0	0	0	0	48.9	45.3
		54.3		0.5		0.5		1.2		0.5		0.5		0.5		52.6
58	26.4	23.3	0	0	0	0	2.3	1.3	0	0	0	0	0	0	71.3	68
		29.7		0.5		0.5		3.6		0.5		0.5		0.5		74.5
59	19.3	16.6	24.5	21.5	0	0	1.5	0.7	0	0	0	0	0	0	54.7	51
		22.3		27.8		0.5		2.6		0.5		0.5		0.5		58.3
60	85.5	82.7	10	7.9	0	0	1.6	0.8	0	0	0	0	0	0	2.9	1.8
		87.9		12.4		0.5		2.8		0.5		0.5		0.5		4.4
61	2.4	1.4	86.8	84.2	0	0	6.7	5	0	0	0	0	0	0	4.1	2.8
		3.8		89.1		0.5		8.7		0.5		0.5		0.5		5.8
62	21.9	19	65.2	61.7	0	0	1.6	0.8	0	0	0	0	0	0	11.3	9.2
		25		68.6		0.5		2.8		0.5		0.5		0.5		13.8
63	7.7	5.9	87.9	85.3	0	0	4	2.7	0	0	0	0	0	0	0.4	0.1
		9.9		90.1		0.5		5.7		0.5		0.5		0.5		1.2
64	7.1	5.3	0	0	0	0	0.1	0	0	0	0	0	0	0	92.7	90.5
		9.3		0.5		0.5		0.8		0.5		0.5		0.5		94.5
65	87.9	85.3	0.8	0.3	0	0	1.1	0.5	0	0	0	0	0	0	10.3	8.2
		90.1		1.7		0.5		2.1		0.5		0.5		0.5		12.7
66	8.1	6.2	0	0	0	0	0	0	0	0	0	0	0	0	91.9	89.6
		10.4		0.5		0.5		0.5		0.5		0.5		0.5		93.8
67	56.8	53.2	0.3	0	0	0	1.3	0.6	0	0	0	0	0	0	41.6	38
		60.4		1		0.5		2.4		0.5		0.5		0.5		45.2

APPENDIX D. Means and upper and lower bounds of 95% confidence limits (CL) of detailed percent benthic cover from photo-quadrat transects in the CVN survey area of Apra Harbor, Guam.

TRANSECT	*Caulerpa* sp.		Coralline algae		Cyanobacteria		*Dictyota* sp.		*Halimeda* sp.		*Hydrolithon gardineri*		Mixed Macroalgae		*Padina* sp.		Turf Algae	
	MEAN	CL	MEAN	CL	MEAN	CL	MEAN	CL	MEAN	CL	MEAN	CL	MEAN	CL	MEAN	CL	MEAN	CL
1	0	0 0.7	0	0 0.7	0.2	0 1	0	0 0.7	0	0 0.7	0	0 0.7	0.2	0 1	0	0 0.7	11.6	9.1 14.6
2	0	0 0.5	6.1	4.5 8.1	12.5	10.2 15.1	0	0 0.5	0	0 0.5	0	0 0.5	45.5	41.9 49.1	0	0 0.5	9.2	7.2 11.5
3	0	0 0.7	0	0 0.7	24.5	21 28.4	0.7	0.2 1.9	0.9	0.3 2.1	0	0 0.7	3.6	2.2 5.6	0	0 0.7	2.2	1.1 3.8
4	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	18.4	15.7 21.4	0	0 0.5	18.5	15.8 21.5
5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0.8	0.3 1.7	1.2	0.6 2.3	0	0 0.5	6.8	5.1 8.8
6	0	0 0.5	0	0 0.5	0	0 0.5	0.1	0 0.7	0.3	0 1	0	0 0.5	0.4	0.1 1.2	23.1	20.1 26.3	0.3	0 1
7	0.1	0 0.7	3.6	2.4 5.2	0.8	0.3 1.7	0.1	0 0.7	3.6	2.4 5.2	0.1	0 0.7	2.9	1.8 4.4	1.5	0.7 2.6	5.3	3.8 7.2
8	0	0 0.5	0.1	0 0.7	0	0 0.5	0	0 0.5	1.3	0.6 2.4	0	0 0.5	4.7	3.3 6.4	4.7	3.3 6.4	5.3	3.8 7.2
9	0	0 0.5	0.1	0 0.7	0	0 0.5	0	0 0.5	4	2.7 5.7	0	0 0.5	14.3	11.8 17	0.8	0.3 1.7	34.3	30.9 37.8
10	0	0 0.6	1.2	0.5 2.4	9.5	7.4 12.1	7.1	5.2 9.3	12.6	10.2 15.4	0	0 0.6	48.6	44.7 52.5	0	0 0.6	3.4	2.1 5.1
11	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	34.3	30.9 37.8	0	0 0.5	58.5	54.9 62.1	0	0 0.5	0	0 0.5
12	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	59.1	55.5 62.6	0	0 0.5	40.8	37.3 44.4	0	0 0.5	0	0 0.5
13	0	0 0.5	2.1	1.2 3.4	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0.7	0.2 1.5	0	0 0.5	24.1	21.1 27.4
14	0	0 0.5	0.1	0 0.7	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	24	21 27.2	0	0 0.5	9.7	7.7 12.1
15	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	7.9	6 10	0	0 0.5	3.2	2.1 4.7
16	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	5.7	4.2 7.6	6	4.4 7.9	1.2	0.6 2.3
17	0	0 0.5	0.1	0 0.7	0	0 0.5	0.4	0.1 1.2	8.9	7 11.2	0	0 0.5	19.7	16.9 22.8	1.3	0.6 2.4	6.1	4.5 8.1
18	0	0 0.5	0	0 0.5	0.3	0 1	5.7	4.2 7.6	0	0 0.5	0	0 0.5	43.5	39.9 47.1	0	0 0.5	3.5	2.3 5
19	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	19.2	16.4 22.2	0	0 0.5	15.1	12.6 17.8
20	0	0 0.5	0	0 0.5	0	0 0.5	11.5	9.3 14	37.2	33.7 40.8	0	0 0.5	41.6	38 45.2	0	0 0.5	0	0 0.5
21	0	0 0.5	0	0 0.5	6.4	4.8 8.4	0.1	0 0.7	2.3	1.3 3.6	0	0 0.5	32.3	28.9 35.7	2.7	1.6 4.1	6.5	4.9 8.5
22	0	0 0.5	0.3	0 1	12.7	10.4 15.3	1.2	0.6 2.3	17.6	14.9 20.5	0	0 0.5	53.1	49.4 56.7	0	0 0.5	4.4	3 6.1
23	0	0 0.5	0	0 0.5	0.7	0.2 1.5	0	0 0.5	0.8	0.3 1.7	0	0 0.5	60.7	57.1 64.2	0	0 0.5	1.2	0.6 2.3
24	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	9.7	7.7 12.1	0	0 0.5	23.1	20.1 26.3	0	0 0.5	0	0 0.5
25	0.4	0.1 1.2	0.3	0 1	36.1	32.7 39.7	1.7	0.9 2.9	0.4	0.1 1.2	0	0 0.5	19.7	16.9 22.8	0	0 0.5	3.2	2.1 4.7
26	0	0 0.5	0	0 0.5	15.5	13 18.3	0	0 0.5	2.9	1.8 4.4	0	0 0.5	59.3	55.7 62.9	0.8	0.3 1.7	3.7	2.5 5.4
27	0	0 0.5	0.3	0 1	4	2.7 5.7	0	0 0.5	0	0 0.5	0	0 0.5	43.9	40.3 47.5	0	0 0.5	5.6	4.1 7.5
28	0	0 0.5	0.4	0.1 1.2	0.3	0 1	0	0 0.5	0	0 0.5	0	0 0.5	0.4	0.1 1.2	0	0 0.5	4	2.7 5.7
29	0	0 0.5	0.3	0 1	0.5	0.1 1.4	0	0 0.5	0.7	0.2 1.5	0	0 0.5	16.9	14.3 19.8	0	0 0.5	13.7	11.3 16.4
30	0	0 0.5	0	0 0.5	0.3	0 1	0	0 0.5	0	0 0.5	0	0 0.5	2.9	1.8 4.4	0	0 0.5	10.4	8.3 12.8
31	0	0 0.5	0.3	0 1	0.7	0.2 1.5	1.6	0.8 2.8	0	0 0.5	0.4	0.1 1.2	50.9	47.3 54.6	0	0 0.5	7.3	5.6 9.4
32	0	0 0.5	0	0 0.5	0.4	0.1 1.2	0	0 0.5	0	0 0.5	0	0 0.5	3.7	2.5 5.4	0	0 0.5	0	0 0.5
33	0	0 0.5	0	0 0.5	0.5	0.1 1.4	7.1	5.3 9.1	8.3	6.4 10.5	0	0 0.5	21.1	18.2 24.2	0	0 0.5	1.2	0.6 2.3

TRANSECT	*Acropora aspera*		*Acropora nasuta*		*Astreopora myriophthalma*		*Astreopora randalli*		*Fungia echinata*		*Galaxea horrescens*		*Herpolitha limax*		*Lobophyllia* (cf.) *hataii*		*Lobophyllia corymbosa*		*Lobophyllia hemprichii*	
	MEAN	CL	MEAN	CL	MEAN	CL	MEAN	CL	MEAN	CL	MEAN	CL	MEAN	CL	MEAN	CL	MEAN	CL	MEAN	CL
1	0	0 0.7	0	0 0.7	0	0 0.7	0	0 0.7	0	0 0.7	0	0 0.7	0	0 0.7	0	0 0.7	0	0 0.7	0	0 0.7
2	0	0 0.5	0	0 0.5	0.8	0.3 1.7	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5
3	0	0 0.7	0	0 0.7	0.9	0.3 2.1	0	0 0.7	0	0 0.7	0	0 0.7	0	0 0.7	0	0 0.7	0	0 0.7	0	0 0.7
4	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5
5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0.7	0.2 1.5
6	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5
7	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5
8	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5
9	19.2	16.4 22.2	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5
10	0	0 0.6	0	0 0.6	0	0 0.6	0	0 0.6	0	0 0.6	0.2	0 0.9	0	0 0.6	0	0 0.6	0	0 0.6	0.2	0 0.9
11	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5
12	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5
13	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5
14	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0.1	0 0.7	0.1	0 0.7	0	0 0.5	0.7	0.2 1.5	0	0 0.5
15	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0.1	0 0.7	0	0 0.5	0	0 0.5	0	0 0.5
16	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5
17	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5
18	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0.3	0 1	0	0 0.5	0	0 0.5
19	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0.8	0.3 1.7	0	0 0.5	0	0 0.5	0	0 0.5
20	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0.3	0 1	0	0 0.5	2.5	1.5 3.9	0	0 0.5	0	0 0.5	0	0 0.5
21	0	0 0.5	0	0 0.5	0	0 0.5	0.1	0 0.7	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0.1	0 0.7
22	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5
23	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0.4	0.1 1.2	0	0 0.5	0	0 0.5	0	0 0.5
24	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5
25	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5
26	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0.8	0.3 1.7
27	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5
28	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5
29	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5
30	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5
31	0	0 0.5	0	0 0.5	0	0 0.5	0.5	0.1 1.4	0	0 0.5	0	0 0.5	0.3	0 1	0	0 0.5	1.6	0.8 2.8	0.4	0.1 1.2
32	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5
33	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5

APPENDIX D. (cont.)

TRANSECT	Caulerpa sp.		Coralline algae		Cyanobacteria		Dictyota sp.		Halimeda sp.		Hydrolithon gardineri		Mixed Macroalgae		Padina sp.		Turf Algae	
	MEAN	CL	MEAN	CL	MEAN	CL	MEAN	CL	MEAN	CL	MEAN	CL	MEAN	CL	MEAN	CL	MEAN	CL
34	0	0 0.5	0.1	0 0.7	0.9	0.4 1.9	7.1	5.3 9.1	0	0 0.5	0	0 0.5	41.6	38 45.2	0	0 0.5	5.1	3.6 6.9
35	0	0 0.5	0	0 0.5	16.4	13.8 19.4	0	0 0.5	0	0 0.5	0	0 0.5	7.3	5.5 9.5	0	0 0.5	0	0 0.5
36	0	0 0.5	0	0 0.5	2.4	1.4 3.8	0	0 0.5	0	0 0.5	0	0 0.5	0.8	0.3 1.7	0	0 0.5	0	0 0.5
37	0	0 1.5	0	0 1.5	0.8	0.1 2.9	0	0 1.5	0	0 1.5	0	0 1.5	20	15.2 25.5	0	0 1.5	0	0 1.5
38	0	0 0.6	0	0 0.6	0.3	0 1.1	0	0 0.6	0	0 0.6	0	0 0.6	0	0 0.6	0	0 0.6	0	0 0.6
39	0	0 0.5	0.3	0 1	1.1	0.5 2.1	11.1	8.9 13.5	28.4	25.2 31.8	0	0 0.5	32.4	29.1 35.9	0	0 0.5	0.7	0.2 1.5
40	0	0 0.5	0	0 0.5	0	0 0.5	3.1	2 4.6	0	0 0.5	0	0 0.5	15.2	12.7 18	0	0 0.5	9.9	7.8 12.2
41	0	0 0.5	0	0 0.5	0	0 0.5	13.4	11 16.2	0	0 0.5	0	0 0.5	47.3	43.5 51.1	0	0 0.5	4.3	2.9 6.1
42	0	0 0.6	0	0 0.6	0	0 0.6	0	0 0.6	0	0 0.6	0	0 0.6	0.3	0 1.1	0	0 0.6	0.8	0.3 1.8
43	0	0 0.5	2	1.1 3.3	0	0 0.5	4.3	2.9 6	0	0 0.5	0	0 0.5	34.4	31 37.9	0	0 0.5	8.7	6.8 10.9
44	0.1	0 0.7	0	0 0.5	0.1	0 0.7	0	0 0.5	1.1	0.5 2.1	0	0 0.5	67.6	64.1 70.9	0	0 0.5	3.2	2.1 4.7
45	0	0 0.5	0	0 0.5	0	0 0.5	36.7	33.2 40.2	0	0 0.5	0	0 0.5	27.1	23.9 30.4	0	0 0.5	2.8	1.7 4.2
46	2.5	1.5 3.9	0.7	0.2 1.5	1.7	0.9 2.9	5.9	4.3 7.8	2.3	1.3 3.6	0	0 0.5	12	9.8 14.5	0	0 0.5	1.1	0.5 2.1
47	0	0 0.5	0	0 0.5	1.9	1 3.1	7.9	6 10	1.9	1 3.1	0	0 0.5	50.7	47 54.3	0	0 0.5	0.5	0.1 1.4
48	0.4	0.1 1.2	0	0 0.5	0.4	0.1 1.2	0	0 0.5	0	0 0.5	0	0 0.5	36.3	32.8 39.8	0	0 0.5	0	0 0.5
49	0	0 0.5	0	0 0.5	0.5	0.1 1.4	0	0 0.5	0	0 0.5	0	0 0.5	2.9	1.8 4.4	0	0 0.5	15.3	12.8 18.1
50	0	0 0.5	0	0 0.5	0.1	0 0.7	0	0 0.5	21.7	18.8 24.9	0	0 0.5	60.8	57.2 64.3	0	0 0.5	0	0 0.5
51	0	0 0.6	0	0 0.6	0	0 0.6	9.7	7.5 12.2	2.8	1.6 4.3	0	0 0.6	73.7	70.1 77	0	0 0.6	0	0 0.6
52	0	0 0.5	0	0 0.5	0.1	0 0.7	0	0 0.5	6	4.4 7.9	0	0 0.5	1.5	0.7 2.6	0	0 0.5	0.9	0.4 1.9
53	0	0 0.6	0	0 0.6	0	0 0.6	0	0 0.6	0	0 0.6	0	0 0.6	0	0 0.6	0	0 0.6	0	0 0.6
54	0	0 0.5	0	0 0.5	0	0 0.5	0.5	0.1 1.4	0	0 0.5	0	0 0.5	11.6	9.4 14.1	9.3	7.3 11.6	0	0 0.5
55	0	0 0.5	0	0 0.5	1.2	0.6 2.3	0	0 0.5	0	0 0.5	0	0 0.5	14	11.6 16.7	0	0 0.5	8.3	6.4 10.5
56	0	0 0.5	0	0 0.5	0.1	0 0.7	0	0 0.5	0	0 0.5	0	0 0.5	20.4	17.6 23.5	0	0 0.5	5.5	4 7.3
57	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0.1	0 0.7	0	0 0.5	50.5	46.9 54.2	0	0 0.5	0	0 0.5
58	0	0 0.5	0	0 0.5	0.9	0.4 1.9	0	0 0.5	2.4	1.4 3.8	0	0 0.5	16	13.4 18.8	7.1	5.3 9.1	0	0 0.5
59	0	0 0.5	0	0 0.5	3.9	2.6 5.5	0	0 0.5	0	0 0.5	0	0 0.5	12.9	10.6 15.5	0	0 0.5	2.5	1.5 3.9
60	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	62.9	59.4 66.4	20.1	17.3 23.2	2.4	1.4 3.8
61	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0.5	0.1 1.4	0	0 0.5	1.9	1 3.1
62	0	0 0.5	0.1	0 0.7	0	0 0.5	10.5	8.4 13	0	0 0.5	0	0 0.5	7.3	5.6 9.4	0	0 0.5	3.9	2.6 5.5
63	0	0 0.5	1.2	0.6 2.3	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	3.3	2.2 4.9	1.7	0.9 2.9	1.5	0.7 2.6
64	0	0 0.5	0	0 0.5	1	0.4 2	0	0 0.5	0.3	0 1	0	0 0.5	5.9	4.2 7.9	0	0 0.5	0	0 0.5
65	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	60.5	56.9 64.1	27.3	24.2 30.7	0	0 0.5
66	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0.1	0 0.8	0	0 0.5	7.9	6 10.1	0.1	0 0.8	0	0 0.5
67	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	2	1.1 3.3	0	0 0.5	53.5	49.8 57.1	1.3	0.6 2.4	0	0 0.5

TRANSECT	Acropora aspera		Acropora nasuta		Astreopora myriophthalma		Astreopora randalli		Fungia echinata		Galaxea horrescens		Herpolitha limax		Lobophyllia (cf.) hataii		Lobophyllia corymbosa		Lobophyllia hemprichii	
	MEAN	CL	MEAN	CL	MEAN	CL	MEAN	CL	MEAN	CL	MEAN	CL	MEAN	CL	MEAN	CL	MEAN	CL	MEAN	CL
34	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5
35	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5
36	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5
37	0	0 1.5	0	0 1.5	0	0 1.5	0	0 1.5	0	0 1.5	0	0 1.5	0	0 1.5	0	0 1.5	0	0 1.5	0	0 1.5
38	0	0 0.6	0	0 0.6	0	0 0.6	0	0 0.6	0	0 0.6	0	0 0.6	0	0 0.6	0	0 0.6	0	0 0.6	0	0 0.6
39	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5
40	0	0 0.5	0	0 0.5	1.1	0.5 2.1	0	0 0.5	0	0 0.5	0.8	0.3 1.7	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5
41	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0.3	0 1	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5
42	0	0 0.6	0	0 0.6	0	0 0.6	0	0 0.6	0	0 0.6	0	0 0.6	0	0 0.6	0	0 0.6	0	0 0.6	0	0 0.6
43	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0.7	0.2 1.5	0	0 0.5	0	0 0.5	0	0 0.5
44	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5
45	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0.4	0.1 1.2	0	0 0.5	3.3	2.2 4.9	0	0 0.5	0	0 0.5	0	0 0.5
46	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5
47	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5
48	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5
49	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0.3	0 1	0	0 0.5	0	0 0.5	0	0 0.5
50	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5
51	0	0 0.6	0	0 0.6	0	0 0.6	0	0 0.6	0	0 0.6	0	0 0.6	0	0 0.6	0	0 0.6	0	0 0.6	0	0 0.6
52	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5
53	0	0 0.6	0	0 0.6	0	0 0.6	0	0 0.6	0	0 0.6	0	0 0.6	0	0 0.6	0	0 0.6	0	0 0.6	0	0 0.6
54	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5
55	0	0 0.5	0	0 0.5	0.9	0.4 1.9	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5
56	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0.7	0.2 1.5	0	0 0.5	0	0 0.5	0	0 0.5
57	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5
58	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5
59	0.4	0.1 1.2	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0.1	0 0.7
60	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5
61	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5
62	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5
63	0	0 0.5	17.3	14.7 20.2	0	0 0.5	0	0 0.5	0	0 0.5	0.3	0 1	0	0 0.5	0	0 0.5	1.1	0.5 2.1	0	0 0.5
64	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5
65	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5
66	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5
67	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5

APPENDIX A. (cont.)

TRANSECT	Montipora verrucosa		Pachyseris speciosa		Pavona cactus		Pavona varians		Pocillopora damicornis		Porites cylindrica		Porites lutea		Porites rus		Soft Coral		Sponge	
	MEAN	CL	MEAN	CL	MEAN	CL	MEAN	CL	MEAN	CL	MEAN	CL	MEAN	CL	MEAN	CL	MEAN	CL	MEAN	CL
1	0	0 0.7	0	0 0.7	14.5	11.7 17.8	0	0 0.7	0	0 0.7	1.5	0.6 2.8	0.2	0 1	36.4	32.3 40.5	0	0 0.7	20.4	17.1 24
2	0.3	0 1	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0.9	0.4 1.9	8.8	6.9 11.1	0	0 0.5	8.1	6.3 10.3
3	0	0 0.7	0	0 0.7	0	0 0.7	0	0 0.7	0	0 0.7	0	0 0.7	0.2	0 1	0.4	0 1.3	0	0 0.7	3.1	1.8 4.9
4	0	0 0.5	0.1	0 0.7	11.1	8.9 13.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	40.1	36.6 43.7	0	0 0.5	5.9	4.3 7.8
5	0	0 0.5	0.1	0 0.7	27.6	24.4 30.9	0	0 0.5	0	0 0.5	0	0 0.5	1.2	0.6 2.3	41.3	37.8 45	0	0 0.5	17.7	15.1 20.7
6	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0.1	0 0.7	0	0 0.5	62.4	58.8 65.9	0	0 0.5	13.2	10.9 15.8
7	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0.1	0 0.7	8.3	6.4 10.5	24.5	21.5 27.8	35.9	32.4 39.4	1.7	0.9 2.9	0.4	0.1 1.2
8	0	0 0.5	0	0 0.5	0.7	0.2 1.5	0	0 0.5	0	0 0.5	0	0 0.5	0.4	0.1 1.2	64.9	61.4 68.4	0	0 0.5	10.1	8.1 12.5
9	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0.3	0 1	0	0 0.5	0	0 0.5	2.3	1.3 3.6	0	0 0.5	23.6	20.6 26.8
10	0	0 0.6	0	0 0.6	0	0 0.6	0	0 0.6	0	0 0.6	0	0 0.6	0.3	0 1.1	0.3	0 1.1	0	0 0.6	1.2	0.5 2.4
11	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	3.1	2 4.6
12	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5
13	0	0 0.5	0	0 0.5	10.5	8.4 13	0.1	0 0.7	0	0 0.5	1.1	0.5 2.1	0	0 0.5	49.9	46.2 53.5	0	0 0.5	3.6	2.4 5.2
14	0	0 0.5	0	0 0.5	3.3	2.2 4.9	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	43.9	40.3 47.5	0	0 0.5	3.2	2.1 4.7
15	0	0 0.5	0	0 0.5	42.8	39.2 46.4	0	0 0.5	0.3	0 1	2	1.1 3.3	0	0 0.5	23.3	20.3 26.5	0	0 0.5	6.5	4.9 8.5
16	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	1.9	1 3.1	0	0 0.5	0	0 0.5	1.3	0.6 2.4
17	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0.1	0 0.7	2.1	1.2 3.4	10.4	8.3 12.8	1.7	0.9 2.9	0	0 0.5	5.9	4.3 7.8
18	0.3	0 1	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	26.5	23.4 29.8	0	0 0.5	1.5	0.7 2.6
19	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	50.8	47.2 54.4	0	0 0.5	2.1	1.2 3.4
20	0	0 0.5	0	0 0.5	0.5	0.1 1.4	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	1.1	0.5 2.1
21	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	20.5	17.7 23.6	0	0 0.5	0.9	0.4 1.9
22	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	3.3	2.2 4.9	0	0 0.5	0.5	0.1 1.4
23	0	0 0.5	0	0 0.5	0	0 0.5	0.3	0 1	0	0 0.5	0	0 0.5	1.6	0.8 2.8	13.1	10.7 15.7	0	0 0.5	5.7	4.2 7.6
24	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	4	2.7 5.7	0	0 0.5	0	0 0.5	0	0 0.5
25	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0.7	0.2 1.5	3.3	2.2 4.9	0	0 0.5	0.8	0.3 1.7
26	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	4	2.7 5.7	0	0 0.5	1.2	0.6 2.3
27	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	1.7	0.9 2.9	0	0 0.5	1.1	0.5 2.1
28	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	84.5	81.7 87	0	0 0.5	0	0 0.5
29	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	1.3	0.6 2.4	37.2	33.7 40.8	2	1.1 3.3	0	0 0.5	0	0 0.5
30	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	1.1	0.5 2.1	30.9	27.6 34.4	20.7	17.8 23.7	8.7	6.8 10.9	0.1	0 0.7
31	0	0 0.5	0.1	0 0.7	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	27.7	24.6 31.1	0	0 0.5	2.1	1.2 3.4
32	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0.8	0.3 1.7	0	0 0.5	0	0 0.5
33	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0.5	0.1 1.4	1.1	0.5 2.1	0	0 0.5	0.5	0.1 1.4

TRANSECT	Acanthaster planci		Bohadshi sp.		Holothuria sp.		Unidentified Ascidian		Unidentified Fish		Dead Coral		Mud		Rubble		Sand	
	MEAN	CL	MEAN	CL	MEAN	CL	MEAN	CL	MEAN	CL	MEAN	CL	MEAN	CL	MEAN	CL	MEAN	CL
1	0	0 0.7	0	0 0.7	0	0 0.7	0	0 0.7	0	0 0.7	0	0 0.7	1.5	0.6 2.8	13.6	10.9 16.8	0	0 0.7
2	1.1	0.5 2.1	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0.1	0 0.7	3.2	2.1 4.7	3.3	2.2 4.9	0	0 0.5
3	0	0 0.7	0	0 0.7	0	0 0.7	0	0 0.7	0	0 0.7	0	0 0.7	34	30 38.1	29.5	25.7 33.5	0	0 0.7
4	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0.9	0.4 1.9	4.9	3.5 6.7	0	0 0.5
5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	1.6	0.8 2.8	0.9	0.4 1.9	0	0 0.5
6	0	0 0.5	0	0 0.5	0	0 0.5	0.1	0 0.7	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5
7	0	0 0.5	0.1	0 0.7	0	0 0.5	0	0 0.5	0	0 0.5	0.1	0 0.7	0.9	0.4 1.9	1.6	0.8 2.8	8.1	6.3 10.3
8	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	7.1	5.3 9.1	0.7	0.2 1.5	0	0 0.5
9	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0.8	0.3 1.7	0.1	0 0.7	0.3	0 1	0	0 0.5
10	0	0 0.6	0.3	0 1.1	0	0 0.6	0	0 0.6	0	0 0.6	0	0 0.6	14.5	11.8 17.4	0.6	0.2 1.6	0	0 0.6
11	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	3.1	2 4.6	1.1	0.5 2.1	0	0 0.5
12	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0.1	0 0.7	0	0 0.5	0	0 0.5
13	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	3.6	2.4 5.2	4.1	2.8 5.8	0.1	0 0.7
14	0	0 0.5	0	0 0.5	0	0 0.5	0.3	0 1	0	0 0.5	0	0 0.5	4.4	3 6.1	10.1	8.1 12.5	0	0 0.5
15	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0.4	0.1 1.2	12.4	10.1 15	1.1	0.5 2.1	0	0 0.5
16	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	83.3	80.5 85.9	0.5	0.1 1.4	0	0 0.5
17	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	25.6	22.5 28.9	17.5	14.8 20.4	0	0 0.5
18	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	10.7	8.5 13.1	7.9	6 10	0	0 0.5
19	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	7.2	5.5 9.3	4.8	3.4 6.6	0	0 0.5
20	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	5.3	3.8 7.2	0	0 0.5	0	0 0.5
21	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	24.8	21.7 28.1	3.2	2.1 4.7	0	0 0.5
22	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	6	4.4 7.9	0.9	0.4 1.9	0	0 0.5
23	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0.3	0 1	0	0 0.5	15.3	12.8 18.1	0	0 0.5	0	0 0.5
24	0	0 0.5	0	0 0.5	0.1	0 0.7	0	0 0.5	0	0 0.5	0	0 0.5	63.1	59.5 66.5	0	0 0.5	0	0 0.5
25	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	32.4	29.1 35.9	0.9	0.4 1.9	0	0 0.5
26	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	10.8	8.7 13.2	0.9	0.4 1.9	0	0 0.5
27	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	42.4	38.8 46	1.1	0.5 2.1	0	0 0.5
28	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0.4	0.1 1.2	2.5	1.5 3.9	7.5	5.7 9.6	0	0 0.5
29	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	26.5	23.4 29.8	0.8	0.3 1.7	0	0 0.5
30	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	20.8	17.9 23.9	4.1	2.8 5.8	0	0 0.5
31	0	0 0.5	0	0 0.5	0	0 0.5	0.1	0 0.7	0	0 0.5	0	0 0.5	4.7	3.3 6.4	1.2	0.6 2.3	0	0 0.5
32	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	95.1	93.3 96.5	0	0 0.5	0	0 0.5
33	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	55.6	52 59.2	4	2.7 5.7	0.1	0 0.7

APPENDIX A. (cont.)

TRANSECT	Montipora verrucosa		Pachyseris speciosa		Pavona cactus		Pavona varians		Pocillopora damicornis		Porites cylindrica		Porites lutea		Porites rus		Soft Coral		Sponge	
	MEAN	CL	MEAN	CL	MEAN	CL	MEAN	CL	MEAN	CL	MEAN	CL	MEAN	CL	MEAN	CL	MEAN	CL	MEAN	CL
34	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	6.4	4.8 8.4	0	0 0.5	2.3	1.3 3.6
35	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5
36	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0.7	0.2 1.5
37	0	0 1.5	0	0 1.5	0	0 1.5	0	0 1.5	0	0 1.5	0	0 1.5	0	0 1.5	0	0 1.5	0	0 1.5	0.4	0 2.2
38	0	0 0.6	0	0 0.6	0	0 0.6	0	0 0.6	0	0 0.6	0	0 0.6	0	0 0.6	0	0 0.6	0.6	0.2 1.6	0	0 0.6
39	0	0 0.5	0	0 0.5	3.1	2 4.6	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	2.4	1.4 3.8	0	0 0.5	0.1	0 0.7
40	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0.1	0 0.7	2.5	1.5 3.9	11.6	9.4 14.1	0	0 0.5	0.9	0.4 1.9
41	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0.6	0.2 1.5	0	0 0.5	5.9	4.2 7.9
42	0	0 0.6	0	0 0.6	0	0 0.6	0	0 0.6	0	0 0.6	0	0 0.6	0	0 0.6	0	0 0.6	0	0 0.6	0	0 0.6
43	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0.1	0 0.7	1.3	0.6 2.4	32.5	29.2 36	0	0 0.5	1.7	0.9 2.9
44	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	2.5	1.5 3.9	0	0 0.5	0.8	0.3 1.7
45	0	0 0.5	0	0 0.5	2.5	1.5 3.9	0	0 0.5	0	0 0.5	3.3	2.2 4.9	0	0 0.5	11.5	9.3 14	0	0 0.5	1.7	0.9 2.9
46	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0.3	0 1	11.7	9.5 14.3	0	0 0.5	7.9	6 10	0	0 0.5	0.4	0.1 1.2
47	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0.1	0 0.7	0.5	0.1 1.4	0	0 0.5	0	0 0.5
48	0	0 0.5	4.1	2.8 5.8	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	1.9	1 3.1	0	0 0.5	0	0 0.5
49	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	8.7	6.8 10.9	0.1	0 0.7	39.1	35.6 42.7	0	0 0.5	3.5	2.3 5
50	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0.5	0.1 1.4
51	0	0 0.6	0	0 0.6	0	0 0.6	0	0 0.6	0	0 0.6	0	0 0.6	0.5	0.1 1.3	0	0 0.6	0	0 0.6	0.6	0.2 1.6
52	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	2.5	1.5 3.9
53	0	0 0.6	0	0 0.6	0	0 0.6	0	0 0.6	0	0 0.6	0	0 0.6	0	0 0.6	0	0 0.6	0	0 0.6	0	0 0.6
54	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	2.4	1.4 3.8
55	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0.7	0.2 1.5	35.3	31.9 38.9	0	0 0.5	4.8	3.4 6.6
56	0	0 0.5	0.1	0 0.7	0	0 0.5	0	0 0.5	0	0 0.5	0.4	0.1 1.2	0	0 0.5	11.3	9.2 13.8	0	0 0.5	6.7	5 8.7
57	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0.4	0.1 1.2
58	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	2.3	1.3 3.6
59	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0.8	0.3 1.7	0.1	0 0.7	23.1	20.1 26.3	0	0 0.5	1.5	0.7 2.6
60	0	0 0.5	0	0 0.5	0.1	0 0.7	0.1	0 0.7	1.6	0.8 2.8	0	0 0.5	5.9	4.3 7.8	2.3	1.3 3.6	0	0 0.5	1.6	0.8 2.8
61	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	2.5	1.5 3.9	1.1	0.5 2.1	83.2	80.3 85.8	0	0 0.5	6.7	5 8.7
62	0	0 0.5	0	0 0.5	0.3	0 1	0	0 0.5	0	0 0.5	4.8	3.4 6.6	0	0 0.5	60.1	56.5 63.7	0	0 0.5	1.6	0.8 2.8
63	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0.4	0.1 1.2	4.9	3.5 6.7	0	0 0.5	63.9	60.3 67.3	0	0 0.5	4	2.7 5.7
64	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0.1	0 0.8
65	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0.1	0 0.7	0	0 0.5	0.5	0.1 1.4	0.1	0 0.7	0	0 0.5	1.1	0.5 2.1
66	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5
67	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0.3	0 1	0	0 0.5	0	0 0.5	1.3	0.6 2.4

TRANSECT	Acanthaster planci		Bohadshi sp.		Holothuria sp.		Unidentified Ascidian		Unidentified Fish		Dead Coral		Mud		Rubble		Sand	
	MEAN	CL	MEAN	CL	MEAN	CL	MEAN	CL	MEAN	CL	MEAN	CL	MEAN	CL	MEAN	CL	MEAN	CL
34	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	30.3	27 33.7	6.3	4.6 8.2	0	0 0.5
35	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	76.3	73 79.4	0	0 0.5	0	0 0.5
36	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	96.1	94.5 97.4	0	0 0.5	0	0 0.5
37	0	0 1.5	0	0 1.5	0	0 1.5	0	0 1.5	0	0 1.5	0	0 1.5	78.8	73.2 83.7	0	0 1.5	0	0 1.5
38	0	0 0.6	0	0 0.6	0	0 0.6	0	0 0.6	0	0 0.6	0	0 0.6	99.1	98 99.7	0	0 0.6	0	0 0.6
39	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	18.7	15.9 21.6	1.9	1 3.1	0	0 0.5
40	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	54.5	50.9 58.1	0.3	0 1	0	0 0.5
41	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	28.3	25 31.8	0	0 0.5	0	0 0.5
42	0	0 0.6	0	0 0.6	0	0 0.6	0	0 0.6	0	0 0.6	0	0 0.6	98.9	97.8 99.6	0	0 0.6	0	0 0.6
43	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	7.9	6 10	6.4	4.8 8.4	0	0 0.5
44	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	23.3	20.3 26.5	1.2	0.6 2.3	0	0 0.5
45	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	6.8	5.1 8.8	3.9	2.6 5.5	0	0 0.5
46	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	51.3	47.7 55	2.3	1.3 3.6	0	0 0.5
47	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	36	32.6 39.6	0.5	0.1 1.4	0	0 0.5
48	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	56.9	53.3 60.5	0	0 0.5	0	0 0.5
49	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	19.9	17.1 22.9	9.7	7.7 12.1	0	0 0.5
50	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	16.8	14.2 19.7	0	0 0.5	0	0 0.5
51	0	0 0.6	0	0 0.6	0	0 0.6	0	0 0.6	0	0 0.6	0	0 0.6	12.8	10.3 15.6	0	0 0.6	0	0 0.6
52	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	35.9	32.4 39.4	53.1	49.4 56.7	0	0 0.5
53	0	0 0.6	0	0 0.6	0	0 0.6	0	0 0.6	0	0 0.6	0	0 0.6	100	99.4 100	0	0 0.6	0	0 0.6
54	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	75.6	72.4 78.6	0.5	0.1 1.4	0	0 0.5
55	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	32.9	29.6 36.4	1.9	1 3.1	0	0 0.5
56	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	54.7	51 58.3	0.1	0 0.7	0	0 0.5
57	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	21.1	18.2 24.2	27.9	24.7 31.2	0	0 0.5
58	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	29.7	26.5 33.1	41.6	38 45.2	0	0 0.5
59	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	50	46.4 53.6	4.7	3.3 6.4	0	0 0.5
60	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	1.5	0.7 2.6	1.3	0.6 2.4	0.1	0 0.7
61	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	1.1	0.5 2.1	3.1	2 4.6	0	0 0.5
62	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	7.1	5.3 9.1	4.3	2.9 6	0	0 0.5
63	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0.3	0 1	0.1	0 0.7	0	0 0.5
64	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	92.7	90.5 94.5	0	0 0.5	0	0 0.5
65	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	9.5	7.5 11.8	0.8	0.3 1.7	0	0 0.5
66	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	91.7	89.4 93.6	0.1	0 0.8	0	0 0.5
67	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	0	0 0.5	17.9	15.2 20.8	23.7	20.7 26.9	0	0 0.5

APPENDIX E. Selected Multispectral Remote Sensing Reference

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APPENDIX F. Counts of mobile invertebrates along 25 x 4 m belt transects.

Count of Taxa			Strata	Site Number																																				
			Direct-Flat																				Direct-Flat	Direct-Slope																Direct-Slope
Phylum	Genus	Species	5	11	23	25	26	31	32	34	35	38	39	40	42	43	46	47	50	57	59	62	Total	4	10	14	21	22	27	33	37	44	45	48	49	51	53	55	58	Total
Cnidaria	*Boloceroides*	*mcmurrichi*				1																	1																	
Cnidaria Total						1																	1																	
Crustacea	*Alpheus*	sp.																																						
	Calcinus	*minutus*											1							2			3										1				1		3	5
		pulcher																				1	1					3											3	6
		spp.	1													1							2				2													2
	crab	sp.																																						
		sp. (blue)									1												1																	
	Dardanus	*guttatus*																																						
	Palaemonid	sp.																																						
	Periclimenes	*soror*												1									1																	
	Saron	*marmoratus*																																				1		1
	seethrough shrimp	(blank)							1				1							2			4							1									1	2
	shrimp	sp. (clear)																																				1		1
		sp. (goby)										1											1																	
Crustacea Total			1						1		1	1	2	1		1				4		1	13				2	3		1			1				1	2	7	17
Echinodermata	*Actinpyga*	*mauritiana*																																						
	Bohadschia	*argus*														1							1																	
	Culcita	*novaeguineae*			3		1							1		1	1						7					1				1	1							3
	Echinaster	*luzonicus*																						1																1
	Echinometra	*mathei*					1																1												1					1
	Echinostrephus	*aciculatus*																																						
	Echinothrix	sp.																																						
	Euapta	*godeffroyi*																														1								1
	Holothuria	*atra*																																						
	Linkia	*laevigata*																																						
		multifera																																						
	Ophiocoma	sp.																																						
	Ophiomastix	*caryophyllata*																						2	1	1														4
	Ophiurid	sp.1	38				2	1														2	43					1												1
		sp.2 (small)										1											1																	
	Pearsonothuria	*graeffei*																						3																3
Echinodermata Total			38		3		4	1				1		1		2	1					2	53	6	1	1		2				2	1		1					14
Mollusca	*Cerithium*	*columna*	21					1	1										1	2	1	1	28	30	5								1			1			2	39
	Chromodoris	*fidelis*															1						1																	
	Clypeomorus	*nympha*	7																			1	8																	
	Coralliophila	*violacea*	8			1				1						1						19	30									12			7			8		27
	Cymatium	*nicobaricum*																																						
		sp.																																						
	Cypraea	*contaminata*																																						
		erosa																																						
		mappa																																	1					1
	Euplica	*deshayesii*	6						1														7												3					3
	Glossodoris	*atromarginata*						1															1																	
	Habromorula	*spinosa*																																				12		12
	Hypselodoris	*whitei*																																						
	Lambis	*lambis*																		2			2					2												2
	Mitra	sp.																									1													1
	Nerita	sp.																																						
	Noumea	*angustolutea*																									1													1
	Pteraeolidia	*ianthina*																																						
	snail	spp.			1																		1																	
	Strombus	*gibberulus*																																					1	1
		luhuanus																		98			98																	
	Thais	sp.																																						
	Trochus	*niloticus*																																						
	Vasum	*turbinellus*																																						
Mollusca Total			42		1	1		2	2	1						1	1		1	102	1	21	176	30	5		2	2				12	1		11	1		20	3	87
Platyhelminthes	flatworm	sp.																												1										1
Platyhelminthes Total																														1										1
Grand Total			81		4	2	4	3	3	1	1	2	2	2		4	2		1	106	1	24	243	36	6	1	4	7		2		14	3		12	1	1	22	10	119

APPENDIX F. (cont.)

Count of Taxa																															
			Indirect-Flat												Indirect-Flat	Indirect-Slope														Indirect-Slope	GRAND
Phylum	Genus	Species	2	3	6	7	9	13	16	18	24	36	56	60	Total	1	8	15	17	19	20	28	30	41	61	63	64	65	66	Total	TOTAL
Cnidaria	*Boloceroides*	*mcmurrichi*																													1
Cnidaria Total																															1
Crustacea	*Alpheus*	sp.																				1								1	1
	Calcinus	*minutus*			2	5	1				1				9				1							2				3	20
		pulcher			2		1	1							4	2		1							7	4				14	25
		spp.			9										9		11					1						1		13	26
	crab	sp.																									1			1	1
		sp. (blue)																													1
	Dardanus	*guttatus*					2								2																2
	Palaemonid	sp.														1														1	1
	Periclimenes	*soror*	1												1																2
	Saron	*marmoratus*																													1
	seethrough shrimp	(blank)																						1			1			2	8
	shrimp	sp. (clear)																													1
		sp. (goby)									7				7																8
Crustacea Total			1		13	5	4	1			8				32	3	11	1	1			2		1	7	6	2	1		35	97
Echinodermata	*Actinpyga*	*mauritiana*												1	1																1
	Bohadschia	*argus*				1					1			2	4				2											2	7
	Culcita	*novaeguineae*	1										1		2									1						1	13
	Echinaster	*luzonicus*																													1
	Echinometra	*mathei*			3	1								1	5											1		3		4	11
	Echinostrephus	*aciculatus*												11	11													2		2	13
	Echinothrix	sp.			1										1																1
	Euapta	*godeffroyi*																													1
	Holothuria	*atra*									13			8	21													11		11	32
	Linkia	*laevigata*																										2		2	2
		multifera			1		1								2		1													1	3
	Ophiocoma	sp.																				1								1	1
	Ophiomastix	*caryophyllata*																		1										1	5
	Ophiurid	sp.1																							2					2	46
		sp.2 (small)																													1
	Pearsonothuria	*graeffei*														1														1	4
Echinodermata Total			1		5	2	1				14		1	23	47	1	1		2	1		1		1	2	1		18		28	142
Mollusca	*Cerithium*	*columna*	12	9	1		5	3			1	1			32	5	2	3			1			1	3	4	1			20	119
	Chromodoris	*fidelis*																													1
	Clypeomorus	*nympha*			3		1	1							5	15		1							1	16				33	46
	Coralliophila	*violacea*	10		11		10	38						1	70	48	21	29				19			27	52				196	323
	Cymatium	*nicobaricum*															1													1	1
		sp.												1	1																1
	Cypraea	*contaminata*																										1		1	1
		erosa																										1		1	1
		mappa																													1
	Euplica	*deshayesii*	28	1	8	1	66				1			3	108		1	1						1				2		5	123
	Glossodoris	*atromarginata*																									2			2	3
	Habromorula	*spinosa*			1			1							2							3			2	4				9	23
	Hypselodoris	*whitei*																										1		1	1
	Lambis	*lambis*							1						1													1		1	6
	Mitra	sp.																													1
	Nerita	sp.					1								1																1
	Noumea	*angustolutea*																													1
	Pteraeolidia	*ianthina*																										1		1	1
	snail	spp.																													1
	Strombus	*gibberulus*									2				2																3
		luhuanus									3				3				1									1		2	103
	Thais	sp.											1		1																1
	Trochus	*niloticus*					1							4	5																5
	Vasum	*turbinellus*																										1		1	1
Mollusca Total			50	10	24	1	84	43	1		7	1	1	9	231	68	25	34	1		1	22		2	33	76	3	9		274	768
Platyhelminthes	flatworm	sp.																													1
Platyhelminthes Total																															1
Grand Total			52	10	42	8	89	44	1		29	1	2	32	310	72	37	35	4	1	1	25		4	42	83	5	28		337	1009

APPENDIX G. Counts of sessile invertebrates within 25 x 1 m belt transects.

Count of Taxa			Strata Site Number																																					
			Direct-Flat																				Total	Direct-Slope																Total
Phylum	Genus	Species	5	11	23	25	26	31	32	34	35	38	39	40	42	43	46	47	50	57	59	62		4	10	14	21	22	27	33	37	44	45	48	49	51	53	55	58	
ASCIDIA	*Ascidia*	sp.			1														1				2																1	1
	Clavelina	*moluccensis*		9	15				3														27		8	2					1									11
	Lissoclinum	*calycis*				1																	1																	
	Phallusia	*julinea*	10		5	2	1	7	2	5				2		7					3	15	59	7	7	2	3		2	3	3	4			7			17	8	63
	Polycarpa	sp.	3				1	1		1				1					1		5	1	14	1								4			5				2	12
	Rhopalaea	*crassa*	1	1	3		1			2			1						1			3	13	1	2			1	1	2	2	1	1		1		1	1		14
		sp.	4		9	10	9	10	5	6	1	1	4	2	1	3		2	5		1	3	76	4	11	6	11	4	12	9	3	6	2	5		1	3	5	7	89
ASCIDIA Total			18	10	33	13	12	18	10	14	1	1	5	5	1	10		2	8		9	22	192	13	28	10	14	5	15	14	9	15	3	5	13	1	4	23	18	190
MOLLUSCA	*Pinctada*	sp.																			3	5	8												9					9
MOLLUSCA Total																					3	5	8												9					9
POLYCHEATA	*Sabellastarte*	indica																																						
POLYCHEATA Total																																								
PORIFERA	*Aplysinella*	*rhax*	16	2	15	3	10	21	1	36	6		9	20		3	8	1	8				159	23	36	27	27	23		14	9	15	5	4		9	20	7	11	230
	Axinella	sp.																																						
	Axynissa	sp.	2			1	3	13		8	4		1	1	6	8	3	1				4	55	1	7	3	6	7	7	7	1	12	1		18			7		77
	Callyspongia	*diffusa*	15		5	1	2	11	1	4	5		2	14		12							72	23	20	25	6			7	3	7	2			1		8		102
		sp.														1			1			7	9												1					1
	Ceratopsion	sp.	3			3	11	8		23				10		11						13	82	6		2	8	2		1		10						12		41
	Chelonaplysilla	sp.								1													1					3												3
	Cinachyra	sp.																			1		1	1		1														2
	Clathria	*basilana*						1									16						17	1											1					2
		eurypa	4		11	16	16	15		12	1			1	1	6	1		1				85	9	17	16	8	12	6	11	5	1				1	4		1	91
		hirsuta			1																		1	1	1	13														15
		mima				1			1									2			2		6	2		2			2			1				3			3	13
		sp.															2						2								1			1			1			3
	Corticum	sp.			1																		1	1	2	3				1									1	8
	Craniella	*abracadabra*																								1														1
	Dragmacidon	sp.							7		4	1			13			2	6		8		41	1	6	5					6		1			3	2		8	32
		(blank)								4				1									5																	
	Dysidea	sp.																1	2		1		4				3						1	1					1	6
	Haliclona	(Reniera)	2		3	7	14	7		7	3		10			9		4	2				68		21	11		11	1	8	6	17	6	3			14		1	99
		sp. (blue)	8			1		6	1	1	2					10	18		4	1	4	17	73	14	3		1		1						19			2		40
	Hyrtios	*altum*			1																		1			1														1
		erecta																													1									1
	Ianthella	*basta*			4	1		1										1					7		7	2		3			1		1				1		13	28
		ditrochota																																						
	Iotrochota	*baculifera*											2								2		4			3				1						1				5
		ditrochota	16		14					1	3		1	3		2							40	22	16	10				6	4						7			65
		protea	4		8	15	7	8	11	12	7	3	7	23	1	12	6		8	34	11	1	178	1	10	4	16	9		3	3	6	7	8	3	2		5	27	104
	Liosina	*cf. granulosa*	3		8	1	5	2	3					2	1		1			4	6		36	1	4	12					1		1		9		3	1	30	62
	Melophlus	*sarasinorum*	10		4										1								15	15	5	4														24
	Monanchora	*clathrata*																			1		1													3			1	4
	Paratetilla	*bacca*																				1	1																	
	Plakina	sp.					1	3		2													6		1	11	1			2	1	1						1		18
	Porifera	sp.1 (Sponge tough)				1	1																2			1			1											2
		sp.10 (Fake myrmekioderma)																							1															1
		sp.11 (Haliclona osiris)																																						
		sp.12 (white Dysidea 166)																													1									1
		sp.13 (Dysidea/Clathria like 179-180)											1										1																	
		sp.14 (brown Xestospongia-like 183)																																						
		sp.2 (Sponge green)																																						
		sp.3 (orange/red Haliclona like)									1	1	2					2	5	1	1		13							1	4					1				6
		sp.4 (Dysidea like 0021)																																						
		sp.5 (white Callyspongia)																																						
		sp.6 (green Clathria)																						1	1	1														3
		sp.7 (green/purple Tedania 141)																						2		1														3
		sp.8 (Haliclona gracilis)																																						
		sp.9 (black net cover 101)																																						
	Pseudoceratina	sp.	2			1		1		3							4		2				13	1					1			3	1							6
	Sylissa	*massa*	2		1	2	8	7	1					1		5	2					1	30	5	11	3			4		5	4	2		9			6		49
	Tedania	*meandrica*	9			1		3		4			2	1		4	6		1		7	13	51	3	2	7	2			2	1	4			2			8	3	34
		sp.			1																		1																	
	Ulosa	*spongia*			1	7	3	6		3	6		3	10		5	1	2	12		12		71		12	9	2	1	2	4		8	2		24				3	67
	Xestospongia	*carbonaria*				2				5	2						12		11			8	40		1			2			1	2			5	1			2	14
		exigua		19			3	2											1		1		26		2	1	2	2			1	2								10
PORIFERA Total			96	21	78	64	84	115	26	126	44	5	40	87	23	88	80	16	64	40	57	65	1219	134	186	179	82	75	25	68	55	93	30	17	91	25	52	57	105	1274
Grand Total			114	31	111	77	96	133	36	140	45	6	45	92	24	98	80	18	72	40	69	92	1419	147	214	189	96	80	40	82	64	108	33	22	113	26	56	80	123	1473

APPENDIX G. (cont.)

Strata Site Number																															
Indirect Flat															Total	Indirect-Slope														Total	GRAND
Phylum	Genus	Species	2	3	6	7	9	13	16	18	24	36	56	60		1	8	15	17	19	20	28	30	41	61	63	64	65	66		TOTAL
ASCIDIA	*Ascidia*	sp.		1											1					1	1									2	6
	Clavelina	*moluccensis*							1						1																39
	Lissoclinum	*calycis*	1												1			3												3	5
	Phallusia	*julinea*	11	4	5		3	14		1		1		3	42	12	15	11	1	16	1	15	17	10	24	16	3	5		146	310
	Polycarpa	sp.	1					3				1		5	10	2		8		2			7	2	2			1		24	60
	Rhopalaea	*crassa*	3	3		3		1					1		11	4	11				2	1		2	3	2			3	28	66
		sp.	15	5	7			6	1	3		4	4		45	13	1	4		12	4			9	15	23	7			88	298
ASCIDIA Total			31	13	12	3	3	24	2	4		6	5	8	111	31	27	26	1	31	8	16	24	23	44	41	10	6	3	291	784
MOLLUSCA	*Pinctada*	sp.										1		9	10					1			5				1	5		12	39
MOLLUSCA Total												1		9	10					1			5				1	5		12	39
POLYCHEATA	*Sabellastarte*	indica																				2	4							6	6
POLYCHEATA Total																						2	4							6	6
PORIFERA	*Aplysinella*	*rhax*	41	37						4		3	41		126	26	11	3		12	21			19			2		12	106	621
	Axinella	sp.											8		8			1												1	9
	Axynissa	sp.	4	36		1				2			3	1	47	9		4	1	8	9	9	2	2			5	1		50	229
	Callyspongia	*diffusa*	2									2			4					6	11						6			23	201
		sp.						7							7	2		5							1	2				10	27
	Ceratopsion	sp.	5				6	14	1				5	7	38	3		15			1	2		6						27	188
	Chelonaplysilla	sp.																1						1						2	6
	Cinachyra	sp.									1				1			2					1		1					4	8
	Clathria	*basilana*											1		1	6									15	2				23	43
		eurypa	19	45			6							3	73	6	2		7	11	5	1		3	4	1	2			42	291
		hirsuta				1						4			5										6	1	3			10	31
		mima										7			7	2	4										3			9	35
		sp.							1			1			2				2	2	1									5	12
	Corticum	sp.										1			1					5	3									8	18
	Craniella	*abracadabra*																													1
	Dragmacidon	sp.							1	2					3					13			26	24						63	139
		(blank)																													5
	Dysidea	sp.						2		2					4		3	1				1		6	1		1			13	27
	Haliclona	(Reniera)	5	2						1			17		25	6		3		3	10			29			15			66	258
		sp. (blue)	6	1	9			21			1		1		39	15	5	18		16		22	3		18	5	2			104	256
	Hyrtios	*altum*											14		14	21	4													25	41
		erecta		1						3		1			5																6
	Ianthella	*basta*	2										6		8						2			2			1			5	48
		ditrochota																									2			2	2
	Iotrochota	*baculifera*																		1							2			3	12
		ditrochota	32	31				2							65	14				9	1									24	194
		protea	18	14		2		1	1		1	11	6	4	58	13	2	1	21	18	1	2	18	21			4		3	104	444
	Liosina	*cf. granulosa*	23	7			5		3	2	4		2	5	51	9	9		29	10		4	6	6	5	3	2			83	232
	Melophlus	*sarasinorum*	1	4			25	6							36	3	2				3				1	17	1			27	102
	Monanchora	*clathrata*																													5
	Paratetilla	*bacca*																1												1	2
	Plakina	sp.	4		3										7		1				1						1		1	4	35
	Porifera	sp.1 (Sponge tough)																									1			1	5
		sp.10 (Fake myrmekioderma)																													1
		sp.11 (Haliclona osiris)																					1							1	1
		sp.12 (white Dysidea 166)																													1
		sp.13 (Dysidea/Clathria like 179-180)																													1
		sp.14 (brown Xestospongia-like 183)									1				1																1
		sp.2 (Sponge green)														1														1	1
		sp.3 (orange/red Haliclona like)								10		7			17				2	1	8									11	47
		sp.4 (Dysidea like 0021)																						1						1	1
		sp.5 (white Callyspongia)																						2						2	2
		sp.6 (green Clathria)		2											2																5
		sp.7 (green/purple Tedania 141)																													3
		sp.8 (Haliclona gracilis)		1											1																1
		sp.9 (black net cover 1		1											1																1
	Pseudoceratina	sp.	4									1			5			1						2						3	27
	Sylissa	*massa*	19	6	24			5						5	59	7	22	12		9	9	18	6	2	9	6	4	4		108	246
	Tedania	*meandrica*			5	7		16							28	2		23		13	1		13	1	2	1	2	1		59	172
		sp.			1										1																2
	Ulosa	*spongia*	11				3			4		6	1		25		23			10	2	21	14	16	3	1	8	4	3	105	268
	Xestospongia	*carbonaria*			36		42	9	4	6			16	19	132		23	37	22		2	2			14	40	12	61	1	214	400
		exigua					2			2				1	5				1					1				3		5	46
PORIFERA Total			196	188	78	11	89	83	11	38	8	44	121	45	912	145	111	128	85	147	91	82	90	144	80	79	79	74	20	1355	4760
Grand Total			227	201	90	14	92	107	13	42	8	51	126	62	1033	176	138	154	86	179	99	100	123	167	124	120	90	85	23	1664	5589

APPENDIX H. Taxa Richness of all invertbrate species for each survey site

			Direct-Flat																			
Phylum	**Genus**	**Species**	**5**	**11**	**23**	**25**	**26**	**31**	**32**	**34**	**35**	**38**	**39**	**40**	**42**	**43**	**46**	**47**	**50**	**57**	**59**	**62**
Ascidia	Ascidia	sp.			1					1									1			1
	Clavelina	moluccensis	1	1	1	1	1	1	1	1												1
	Phallusia	julinea	1		1	1	1	1	1	1	1	1	1	1	1	1		1	1		1	1
	Polycarpa	sp.	1				1	1		1				1					1		1	1
	Rhopalaea	crassa	1	1	1	1	1	1	1	1	1	1	1	1		1			1			1
		sp.	1		1	1	1	1	1	1		1	1	1	1	1	1	1	1		1	1
Ascidia Total			5	2	5	4	5	5	4	6	2	3	3	4	2	3	1	2	5		3	6
Cnidaria	Anthozoa	sp.																				
	Boloceroides	mcmurrichi				1																
	Entacmaea	quadricolor																				
	Pennaria	disticha																				
Cnidaria Total						1																
Crustacea	Alpheus	sp.						1		1						1						1
	Aniculus	sp.																				
	Calcinus	minutus		1	1				1		1	1	1		1			1	1	1	1	
		pulcher		1	1				1		1	1	1		1			1	1	1	1	1
		spp.	1													1						
	Carupa	ohashii																				
	crab	sp.		1	1				1		1	1	1		1			1	1	1	1	
		sp. (blue)		1	1				1		1	1	1		1			1	1	1	1	
		sp. (gall)														1						
	Dardanus	guttatus																				
	Echinometra	mathei																				
	Hapalocarcinus	marsupialis																				
	Hermit	spp.																				
	Palaemonid	sp.																				
	Periclimenes	soror												1								
	Portunid	sp.6																				
		sp.7																				
		sp.9																				1
	Saron	marmoratus																				
	Shrimp	sp.	1																			
		sp. (clear)		1	1				1		1	1	1		1			1	1	1	1	
		sp. (Fungia)				1				1												
		sp. (goby)		1	1		1		1	1	1	1	1	1	1			1	1	1	1	
	Thalamita	sp.1																				
	Xanthid	sp.																				
Crustacea Total			2	6	6	1	1	1	6	3	6	6	6	2	6	3		6	6	6	6	3
Echinodermata	Acanthaster	planci																				
	Actinopyga	mauritiana																				
	Bohadschia	argus		1	1				1		1	1	1		1	1		1	1	1	1	
	Ceriantharia	sp.																				1
	Cerithium	columna					1															
	Culcita	novaeguineae		1	1		1		1		1	1	1	1	1	1	1	1	1	1	1	
	Echinaster	luzonicus		1	1				1		1	1	1		1			1	1	1	1	
	Echinometra	mathei					1															
	Echinostrephus	aciculatus																				
	Echinothrix	calamaris																				
	Entacmaea	quadricolor																				
	Euapta	godeffroyi																				
	Holothuria	atra		1	1				1		1	1	1		1			1	1	1	1	
	Linkia	laevigata																				
		multifera																				
	Ophiocoma	sp.																				
	Ophiomastix	caryophyllata		1	1				1		1	1	1		1			1	1	1	1	
	Ophiurid	sp.1	1				1	1														1
		sp.2 (small)		1	1				1		1	1	1		1			1	1	1	1	
	Pearsonothuria	graeffei		1	1				1		1	1	1		1			1	1	1	1	
Echinodermata Total			1	7	7		4	1	7		7	7	7	1	7	2	1	7	7	7	7	2
Mollusca	Arca	sp.	1																			
		ventricosa					1			1												1
	Barbatia	sp.																				
	Cerithium	columna	1	1	1			2	1	1	1	1	1	1	1			1	1	1	1	2
		echinatum														1						
		sinensis																				
	Chama	iostoma																				
		lazarus														1						1
	Chromodoris	fidelis															1					
	Clypeomorus	nympha	1																			1
	Conus	sp.																				
	Coralliophila	violacea	1			1				1						1						
	Cymatium	nicobaricum																				
		sp.																				
	Cypraea	annularis																				
		carneola																				
		contaminata																				
		erosa																				
		isabella																				
		mappa				1										1						
	Dendropoma	maxima																				1
	Diodora	sp.																				
	Drupella	elata																				1
		sp.																				
	Euplica	deshayesii	1	1	1				1		1	1	1	1	1			1	1	1	1	1
	Gastrochaena	sp.						1														
	Gastrochaenea	sp.																				
	Glossodoris	atromarginata		1	1			1	1		1	1	1		1			1	1	1	1	
	Habromorula	spinosa	1																			
	Hypselodoris	whitei																				
	Isognomon	perna														1						
		sp.						1														
	Lambis	lambis		1	1				1		1	1	1		1			1	1	1	1	
	Lithophagia	sp.	1			1	1	1		1				1		1						1
	Malleus	decurtatus					1							1		1						1
	Mitra	sp.																				
	Modulus	sp.	1																			
	Morula	uva																				
	Nassarius	castus				1																
	Noumea	angustolutea																				
	Octopus	sp.																				
	Pectinidae	sp.1																				
		sp.2																				
	Pedum	spondyloideum																				
	Pinctada	sp.																			1	1
	Pteraeolidia	ianthina																				
	snail	spp.		1	1				1		1	1	1		1			1	1	1	1	
	Spondylous	violacenscens																				
	Streptopinna	saccata					1															
	Strombus	gibberulus		1	1				1		1	1	1		1			1	1	1	1	
		luhuanus		1	1				1		1	1	1		1			1	1	1	1	
	Thais	sp.																				
	Trochus	niloticus																				
	Vasum	turbinellus																				
	Vexillum	sp.																				
Mollusca Total			8	7	7	4	4	6	7	4	7	7	7	4	7	7	1	7	7	7	8	11

Platyhelminthe	Flatworm	sp.		1	1				1		1	1	1		1			1	1	1	1	
Platyhelminthes Total				1	1				1		1	1	1		1			1	1	1	1	
Polychaeta	Sabellastarte	indica																				
		spectabilis																				1
Polychaeta Total																						1
Porifera	Aka	sp.																				
	Aplysinella	rhax	1	1	1	1	1	1	1	1	1	1	1	1		1	1	1	1			
	Axinella	sp.																				
	Axynissa	sp.	1			1	1	1	1	1	1		1	1	1	1	1	1				1
	Callyspongia	diffusa	1		1	1	1	1	1	1	1		1	1		1			1			
		sp.														1			1			1
	Ceratopsion	sp.	1			1	1	1		1				1		1	1					1
	Chelonaplysilla	sp.								1												
	Cinachyra	sp.	1																		1	
	Clathria	basilana						1									1					
		eurypa	1		1	1	1	1		1	1		1	1	1	1	1		1			1
		hirsuta			1																	
		mima				1		1	1			1						1			1	
		sp.													1		1					
	Corticum	sp.			1																	
	Craniella	abracadabra																				
	Dragmacidon	sp.							1	1	1	1		1	1			1	1		1	
	Dysidea	sp.								1	1			1				1	1		1	
	Haliclona	(Reniera)	1	1	1	1	1	1	1	1	1		1			1		1	1			1
		sp. (blue)	1			1		1	1	1	1		1	1		1	1		1	1	1	1
	Hyrtios	altum			1																	
		erecta																				
	Ianthella	basta		1	1	1	1	1		1		1	1			1		1			1	
	Iotrochota	baculifera											1								1	
		ditrochota	1	1	1					1	1		1	1		1						
		protea	1		1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	Leucetta	cf. chagosensis																				
	Liosina	cf. granulosa	1		1	1	1	1	1	1				1	1		1			1	1	1
	Lissoclinum	calycis				1																
	Melophlus	sarasinorum	1	1	1			1							1							
	Monanchora	clathrata													1						1	
	Paratetilla	bacca																				1
	Plakina	sp.				1	1	1		1							1					1
	Porifera	sp.1 (Sponge tough)				1	1			1												
		sp.10 (Fake myrmekioderma)																				
		sp.11 (Haliclona osiris)																				
		sp.12 (white Dysidea 166)																	1			
		sp.13 (Dysidea/Clathria like 179-180)											1									
		sp.14 (brown Xestospongia-like 183)																				
		sp.2 (Sponge green)																				
		sp.3 (orange/red Haliclona like)									1	1	1					1	1	1	1	
		sp.4 (Dysidea like 0021)																				
		sp.5 (white Callyspongia)																				
		sp.6 (green Clathria)																				
		sp.7 (green/purple Tedania 141)																				
		sp.8 (Haliclona gracilis)																				
		sp.9 (black net cover 101)																				
	Pseudoceratina	sp.	1			1		1		1			1			1	1		1			
	Rhabdastrella	sp.																				
	Sylissa	massa	1		1	1	1	1	1	1			1	1		1	1		1			1
	Tedania	meandrica	1			1		1		1	1		1	1		1	1		1		1	1
		sp.			1																	
	Ulosa	spongia			1	1	1	1	1	1	1		1	1		1	1	1	1		1	
	Xestospongia	carbonaria				1				1	1						1		1			1
		exigua		1		1	1	1											1		1	
Porifera Total			15	6	15	20	14	19	11	21	14	6	16	14	8	15	15	10	17	4	14	13
Grand Total			31	29	41	30	28	32	36	34	37	30	40	25	31	30	18	33	43	25	39	36

			Direct-Slope															
Phylum	**Genus**	**Species**	**4**	**10**	**14**	**21**	**22**	**27**	**33**	**37**	**44**	**45**	**48**	**49**	**51**	**53**	**55**	**58**
Ascidia	Ascidia	sp.												1				1
	Clavelina	moluccensis		1	1	1				1	1		1				1	
	Phallusia	julinea	1	1	1	1	1	1	1	1	1	1		1		1	1	1
	Polycarpa	sp.	1								1			1			1	1
	Rhopalaea	crassa	1	1			1	1	1	1	1	1	1	1		1	1	1
		sp.	1	1	1	1	1	1	1	1	1	1	1		1	1	1	1
Ascidia Total			4	4	3	3	3	3	3	4	5	3	3	4	1	3	5	5
Cnidaria	Anthozoa	sp.																
	Boloceroides	mcmurrichi																
	Entacmaea	quadricolor																
	Pennaria	disticha																
Cnidaria Total																		
Crustacea	Alpheus	sp.															1	
	Aniculus	sp.																
	Calcinus	minutus	1	1	1				1	1		1			1	1		1
		pulcher	1	1	1		1		1	1		1			1	1		1
		spp.				1												
	Carupa	ohashii																
	crab	sp.	1	1	1				1	1		1			1	1		1
		sp. (blue)	1	1	1				1	1		1			1	1		1
		sp. (gall)																
	Dardanus	guttatus																
	Echinometra	mathei																
	Hapalocarcinus	marsupialis																
	Hermit	spp.																
	Palaemonid	sp.																
	Periclimenes	soror																
	Portunid	sp.6																
		sp.7																
		sp.9																
	Saron	marmoratus															1	
	Shrimp	sp.																
		sp. (clear)	1	1	1				1	1		1			1	1	1	1
		sp. (Fungia)									1							
		sp. (goby)	1	1	1		1		1	1		1			1	1	1	1
	Thalamita	sp.1																
	Xanthid	sp.																
Crustacea Total			6	6	6	1	2		6	6	1	6			6	6	4	6
Echinodermata	Acanthaster	planci																
	Actinopyga	mauritiana																
	Bohadschia	argus	1	1	1				1	1		1			1	1		1
	Ceriantharia	sp.																
	Cerithium	columna																
	Culcita	novaeguineae	1	1	1		1		1	1	1	1	1		1	1		1
	Echinaster	luzonicus	1	1	1				1	1		1			1	1		1
	Echinometra	mathei												1				
	Echinostrephus	aciculatus																
	Echinothrix	calamaris																
	Entacmaea	quadricolor																
	Euapta	godeffroyi									1							
	Holothuria	atra	1	1	1				1	1		1			1	1		1
	Linkia	laevigata																
		multifera																
	Ophiocoma	sp.																
	Ophiomastix	caryophyllata	1	1	1				1	1		1			1	1		1
	Ophiurid	sp.1					1											
		sp.2 (small)	1	1	1				1	1		1			1	1		1
	Pearsonothuria	graeffei	1	1	1				1	1		1			1	1		1
Echinodermata Total			7	7	7		2		7	7	2	7	1	1	7	7		7
Mollusca	Arca	sp.																
		ventricosa											1					
	Barbatia	sp.																
	Cerithium	columna	1	1	1		1		1	1		1			1	1	1	1
		echinatum				1												
		sinensis																
	Chama	iostoma												1				
		lazarus															1	
	Chromodoris	fidelis																
	Clypeomorus	nympha																
	Conus	sp.																
	Coralliophila	violacea									1			1			1	
	Cymatium	nicobaricum																
		sp.																
	Cypraea	annularis																
		carneola																
		contaminata																
		erosa																
		isabella																
		mappa												1				
	Dendropoma	maxima																
	Diodora	sp.															1	
	Drupella	elata																
		sp.																
	Euplica	deshayesii	1	1	1	1			1	1		1		1	1	1		1
	Gastrochaena	sp.																
	Gastrochaenea	sp.																
	Glossodoris	atromarginata	1	1	1				1	1		1			1	1		1
	Habromorula	spinosa															1	
	Hypselodoris	whitei																
	Isognomon	perna																
		sp.												1				
	Lambis	lambis	1	1	1		1		1	1		1			1	1		1
	Lithophagia	sp.					1				1			1			1	
	Malleus	decurtatus															1	
	Mitra	sp.				1												
	Modulus	sp.																
	Morula	uva																
	Nassarius	castus																
	Noumea	angustolutea				1												
	Octopus	sp.									1							
	Pectinidae	sp.1																
		sp.2																
	Pedum	spondyloideum																
	Pinctada	sp.												1				
	Pteraeolidia	ianthina																
	snail	spp.	1	1	1				1	1		1			1	1		1
	Spondylous	violacenscens																
	Streptopinna	saccata																
	Strombus	gibberulus	1	1	1		1		1	1		1			1	1		1
		luhuanus	1	1	1				1	1		1			1	1		1
	Thais	sp.																
	Trochus	niloticus																
	Vasum	turbinellus																
	Vexillum	sp.																
Mollusca Total			7	7	7	4	4		7	7	3	7	1	7	7	7	7	7

APPENDIX H. (cont.)

Platyhelminthe	Flatworm	sp.	1	1	1				1	1		1			1	1		1
Platyhelminthes Total			1	1	1				1	1		1			1	1		1
Polychaeta	Sabellastarte	indica																
		spectabilis									1			1			1	
Polychaeta Total											1			1			1	
Porifera	Aka	sp.																1
	Aplysinella	rhax	1	1	1	1	1	1	1	1	1	1	1		1	1	1	1
	Axinella	sp.																
	Axynissa	sp.	1	1	1	1	1	1	1	1	1	1		1			1	1
	Callyspongia	diffusa	1	1	1	1	1		1	1	1	1			1	1	1	
		sp.												1				
	Ceratopsion	sp.	1		1	1	1		1		1						1	
	Chelonaplysilla	sp.					1											
	Cinachyra	sp.	1		1													
	Clathria	basilana	1											1				
		eurypa	1	1	1	1	1	1	1	1	1	1		1	1	1	1	1
		hirsuta	1	1	1													
		mima	1		1			1			1				1	1		1
		sp.						1		1			1			1		1
	Corticum	sp.	1	1	1				1			1						1
	Craniella	abracadabra			1													
	Dragmacidon	sp.	1	1	1		1			1		1			1	1		1
	Dysidea	sp.				1						1	1					1
	Haliclona	(Reniera)		1	1		1	1	1	1	1	1	1			1		1
		sp. (blue)	1	1		1		1						1			1	1
	Hyrtios	altum			1													
		erecta								1								
	Ianthella	basta	1	1	1	1	1		1	1	1	1			1	1		1
	Iotrochota	baculifera			1				1						1			
		ditrochota	1	1	1				1	1	1					1		
		protea	1	1	1	1	1		1	1	1	1	1	1	1		1	1
	Leucetta	cf. chagosensis																
	Liosina	cf. granulosa	1	1	1	1	1			1	1	1		1		1	1	1
	Lissoclinum	calycis																
	Melophlus	sarasinorum	1	1	1		1											
	Monanchora	clathrata													1			1
	Paratetilla	bacca																
	Plakina	sp.		1	1	1	1		1	1	1						1	
	Porifera	sp.1 (Sponge tough)			1			1								1		
		sp.10 (Fake myrmekioderm		1														
		sp.11 (Haliclona osiris)																
		sp.12 (white Dysidea 166)								1								
		sp.13 (Dysidea/Clathria like 179-180)																
		sp.14 (brown Xestospongia-like 183)																
		sp.2 (Sponge green)																
		sp.3 (orange/red Haliclona like)							1	1		1			1			
		sp.4 (Dysidea like 0021)																
		sp.5 (white Callyspongia)																
		sp.6 (green Clathria	1	1	1													
		sp.7 (green/purple	1		1													
		sp.8 (Haliclona gracilis)																
		sp.9 (black net cover 101)																
	Pseudoceratina	sp.	1					1			1	1						
	Rhabdastrella	sp.														1		
	Sylissa	massa	1	1	1		1	1	1	1	1	1		1		1	1	
	Tedania	meandrica	1	1	1	1			1	1	1	1		1			1	1
		sp.																
	Ulosa	spongia		1	1	1	1	1	1		1	1		1		1		1
	Xestospongia	carbonaria		1			1			1	1			1	1			1
		exigua		1	1	1	1			1	1							
Porifera Total			22	22	27	14	17	11	16	19	18	16	5	11	11	14	11	20
Grand Total			47	47	51	22	28	14	40	44	30	40	10	24	33	38	28	45

			Indirect-Flat												Indirect-Slope													
Phylum	**Genus**	**Species**	**2**	**3**	**6**	**7**	**9**	**13**	**16**	**18**	**24**	**36**	**56**	**60**	**1**	**8**	**15**	**17**	**19**	**20**	**28**	**30**	**41**	**61**	**63**	**64**	**65**	**66**
Ascidia	Ascidia	sp.		1	1												1		1	1					1		1	
	Clavelina	moluccensis	1	1		1		1	1						1	1								1	1			
	Phallusia	julinea	1	1	1		1	1	1	1		1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	Polycarpa	sp.	1				1	1	1			1	1	1	1		1		1			1	1	1			1	
	Rhopalaea	crassa	1	1		1		1	1				1		1	1	1		1	1	1		1	1	1	1		1
		sp.	1	1	1			1	1	1		1	1		1	1	1		1	1			1	1	1	1		
Ascidia Total			5	5	3	2	2	5	5	2		3	4	2	5	4	5	1	5	4	2	2	4	5	5	3	3	2
Cnidaria	Anthozoa	sp.	1																									
	Boloceroide	mcmurrichi													1													
	Entacmaea	quadricolor			1		1																					
	Pennaria	disticha												1														
Cnidaria Total			1		1		1							1	1													
Crustacea	Alpheus	sp.	1		1			1						1	1		1				1				1			
	Aniculus	sp.													1													
	Calcinus	minutus		1	1	1	1		1	1	1	1						1	1	1		1	1		1	1		1
		pulcher		1	1		1	1	1	1	1	1			1		1	1	1	1		1	1	1	1	1		1
		spp.														1					1						1	
	Carupa	ohashii			1																							
	crab	sp.		1					1	1	1	1						1	1	1		1	1			1		1
		sp. (blue)		1					1	1	1	1						1	1	1		1	1			1		1
		sp. (gall)																										
	Dardanus	guttatus					1																					
	Echinometr	mathei													1													
	Hapalocarc	marsupialis												1														
	Hermit	spp.			1																							
	Palaemonid	sp.													1													
	Periclimene	soror	1												1													
	Portunid	sp.6															1											
		sp.7					1																					
		sp.9																										
	Saron	marmoratus																										
	Shrimp	sp.																										
		sp. (clear)		1					1	1	1	1						1	1	1		1	1			1		1
		sp. (Fungia)											1															
		sp. (goby)		1					1	1	1	1						1	1	1		1	1			1		1
	Thalamita	sp.1																			1							
	Xanthid	sp.																									1	
Crustacea Total			2	6	5	1	4	2	6	6	6	6	1	2	6	1	3	6	6	6	3	6	6	1	3	6	2	6
Echinoderm	Acanthaste	planci	1																									
	Actinopyga	mauritiana												1														
	Bohadschia	argus		1		1			1	1	1	1		1				1	1	1		1	1			1	1	1
	Cerianthari	sp.																										
	Cerithium	columna																										
	Culcita	novaeguineae	1	1					1	1	1	1	1		1			1	1	1		1	1			1		1
	Echinaster	luzonicus		1					1	1	1	1						1	1	1		1	1			1		1
	Echinometr	mathei			1	1								1											1		1	
	Echinostrep	aciculatus												1													1	
	Echinothrix	calamaris			1																						1	
	Entacmaea	quadricolor				1																						
	Euapta	godeffroyi																										
	Holothuria	atra		1					1	1	1	1		1				1	1	1		1	1			1	1	1
	Linkia	laevigata																									1	
		multifera			1		1	1								1												
	Ophiocoma	sp.																			1							
	Ophiomasti	caryophyllata		1					1	1	1	1						1	1	1		1	1			1		1
	Ophiurid	sp.1																						1				
		sp.2 (small)		1					1	1	1	1						1	1	1		1	1			1		1
	Pearsonoth	graeffei		1					1	1	1	1			1			1	1	1		1	1			1		1
Echinodermata Total			2	7	3	3	1	1	7	7	7	7	1	5	2	1		7	7	7	1	7	7	1	1	7	6	7
Mollusca	Arca	sp.																										
		ventricosa			1	1		1					1		1	1	1				1			1	1			
	Barbatia	sp.																			1							
	Cerithium	columna	1	1			1	1	1	1	1	1					1	1	1	1		1	1			1		1
		echinatum				1									1	1								1	1			
		sinensis			1																							
	Chama	iostoma														1					1							
		lazarus	1					1								1					1						1	
	Chromodor	fidelis																										
	Clypeomor	nympha			1		1	1							1		1							1	1			
	Conus	sp.														1												
	Coralliophil	violacea	1		1		1	1						1	1	1	1				1			1	1			
	Cymatium	nicobaricum																									1	
		sp.												1														
	Cypraea	annularis																									1	
		carneola													1	1											1	
		contaminata																									1	
		erosa																									1	
		isabella			1											1												
		mappa																										
	Dendropom	maxima				1	1	1						1		1	1				1			1	1		1	
	Diodora	sp.																										
	Drupella	elata																										
		sp.	1																		1							
	Euplica	deshayesii	1	1	1	1	1		1	1	1	1		1		1	1	1	1	1		1	1			1	1	1
	Gastrochae	sp.															1											
	Gastrochae	sp.																							1			
	Glossodoris	atromarginata		1					1	1	1	1						1	1	1		1	1			1		1
	Habromoru	spinosa			1		1	1									1				1			1	1			
	Hypselodor	whitei																									1	
	Isognomon	perna																										
		sp.			1									1	1	1					1			1			1	
	Lambis	lambis		1					1	1	1	1						1	1	1		1	1			1	1	1
	Lithophagia	sp.	1		1	1	1	1						1	1		1				1			1	1		1	
	Malleus	decurtatus	1					1								1	1								1			
	Mitra	sp.																										
	Modulus	sp.					1																					
	Morula	uva																			1							
	Nassarius	castus																										
	Noumea	angustolutea																										
	Octopus	sp.																										
	Pectinidae	sp.1																							1			
		sp.2																									1	
	Pedum	spondyloideum																							1			
	Pinctada	sp.	1			1						1		1					1			1	1		1	1	1	
	Pteraeolidi	ianthina																									1	
	snail	spp.		1					1	1	1	1						1	1	1		1	1			1		1
	Spondylous	violacenscens													1									1				
	Streptopinn	saccata			1																							
	Strombus	gibberulus		1					1	1	1	1						1	1	1		1	1			1		1
		luhuanus		1					1	1	1	1				1		1	1	1		1	1			1	1	1
	Thais	sp.											1															
	Trochus	niloticus					1							1														
	Vasum	turbinellus																									1	
	Vexillum	sp.														1												
Mollusca Total			8	7	10	6	9	9	7	7	7	8	2	8	8	14	10	7	8	7	11	8	8	9	12	8	17	7

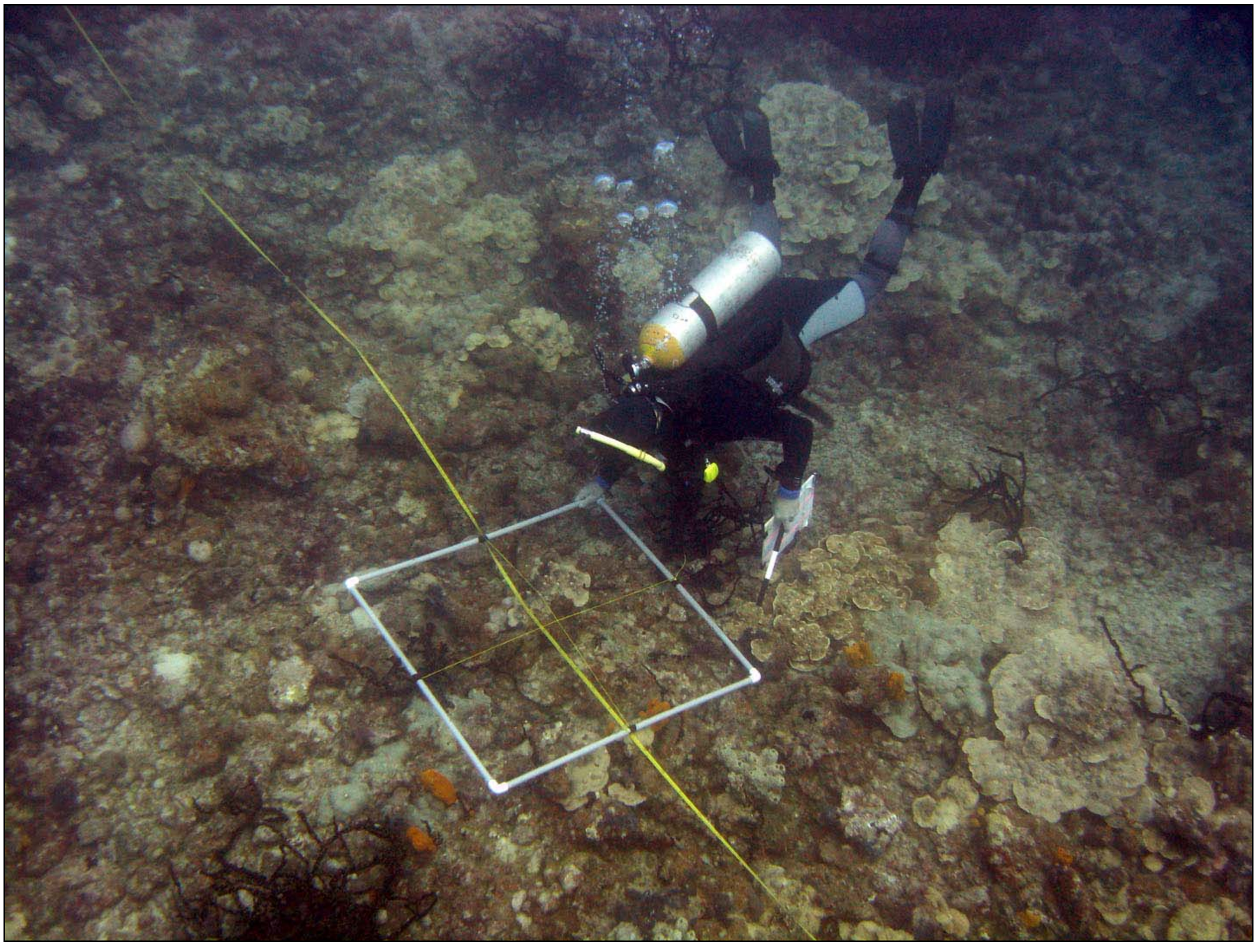
APPENDIX H. (cont.)

Platyhelmir	Flatworm	sp.		1					1	1	1	1						1	1	1		1	1			1		1
Platyhelminthes Total				1					1	1	1	1						1	1	1		1	1			1		1
Polychaeta	Sabellastart	indica																			1	1						
		spectabilis	1		1		1									1	1				1			1	1		1	
Polychaeta Total			1		1		1									1	1				2	1		1	1		1	
Porifera	Aka	sp.																										
	Aplysinella	rhax	1	1				1		1		1	1		1	1	1		1	1			1			1		1
	Axinella	sp.											1				1											
	Axynissa	sp.	1	1		1			1	1			1	1	1		1	1	1	1	1	1	1			1	1	
	Callyspongi	diffusa	1							1		1	1						1	1						1		1
		sp.				1		1							1		1				1			1	1			
	Ceratopsior	sp.	1				1	1	1				1	1	1		1			1	1		1					
	Chelonaplys	sp.															1						1					
	Cinachyra	sp.							1		1			1			1				1	1		1			1	
	Clathria	basilana		1							1		1		1									1	1			
		eurypa	1	1			1	1	1				1	1	1	1	1	1	1	1	1		1	1	1	1	1	
		hirsuta				1						1												1	1	1		
		mima										1			1	1										1		
		sp.							1			1						1	1	1								
	Corticum	sp.										1							1	1								
	Craniella	abracadabra																										
	Dragmacido	sp.							1	1									1			1	1					
	Dysidea	sp.	1			1		1		1						1	1				1		1	1		1	1	
	Haliclona	(Reniera)	1	1						1			1		1		1		1	1			1			1		
		sp. (blue)	1	1	1			1	1	1	1		1	1	1	1	1		1		1	1		1	1	1		
	Hyrtios	altum		1				1	1				1		1	1												
		erecta		1						1		1																
	Ianthella	basta	1	1									1							1			1			1		
	Iotrochota	baculifera																	1							1		
		ditrochota	1	1				1							1	1			1	1	1					1		
		protea	1	1		1		1	1		1	1	1	1	1	1	1	1	1	1	1	1	1			1		1
	Leucetta	cf. chagosensis														1					1							
	Liosina	cf. granulosa	1	1			1		1	1	1		1	1	1	1	1	1	1		1	1	1	1	1	1	1	
	Lissoclinum	calycis	1														1											
	Melophlus	sarasinorum	1	1		1	1	1							1	1	1		1	1				1	1	1		
	Monanchor	clathrata																										
	Paratetilla	bacca															1											
	Plakina	sp.	1		1											1				1						1		1
	Porifera	sp.1 (Sponge tough)																								1		
		sp.10 (Fake myrmekioderma)																										
		sp.11 (Haliclona osiris)																				1						
		sp.12 (white Dysidea 166)																										
		sp.13 (Dysidea/Clathria like 179-180)																										
		sp.14 (brown Xestospongia-like 183)									1																	
		sp.2 (Sponge green)													1													
		sp.3 (orange/red Haliclona like)								1		1						1	1	1								
		sp.4 (Dysidea like 0021)																					1					
		sp.5 (white Callyspongia)																					1					
		sp.6 (green Clathria)		1																								
		sp.7 (green/purple Tedania 141)																										
		sp.8 (Haliclona gracilis)		1																								
		sp.9 (black net cover 101)		1																								
	Pseudocera	sp.	1					1				1					1				1		1					
	Rhabdastre	sp.																										
	Sylissa	massa	1	1	1			1	1	1	1		1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	
	Tedania	meandrica			1	1	1	1					1		1		1		1	1		1	1	1	1	1	1	
		sp.			1																							
	Ulosa	spongia	1	1			1		1	1		1	1			1		1	1	1	1	1	1	1	1	1	1	1
	Xestospong	carbonaria			1		1	1	1	1			1	1		1	1	1		1	1			1	1	1	1	1
		exigua					1			1				1				1					1				1	
Porifera Total			18	18	6	7	8	14	13	14	7	11	17	10	17	15	20	10	18	18	15	10	18	13	11	21	10	6
Grand Total			37	44	29	19	26	31	39	37	28	36	25	28	39	36	39	32	45	43	34	35	44	30	33	46	39	29

Appendix J

Supplemental Marine Surveys

1. DRAFT Comparison of a Photographic and an *In Situ* Method to Assess the Coral Reef Benthic Community in Apra Harbor, Guam. July 10, 2009.



Photograph by Dave Burdick

DRAFT

Comparison of a Photographic and an *In Situ* Method to Assess the Coral Reef Benthic Community in Apra Harbor, Guam

July 10, 2009

United States Department of the Interior

FISH AND WILDLIFE SERVICE

Pacific Islands Fish and Wildlife Office
300 Ala Moana Boulevard, Room 3-122, Box 50088
Honolulu, Hawaii 96850

In Reply Refer To:
12200-2008-FA- 0142

JUL 10 2009

Ms. Karen Sumida
Naval Facilities Engineering Command Pacific
258 Makalapa Dr. Suite 100
Pearl Harbor, Hawaii 96860-3134

Ms. Sumida:

The U.S. Fish and Wildlife Service is submitting the Draft Final Report "Comparison of a Photographic and an *In Situ* Method to Assess the Coral Reef Benthic Community in Apra Harbor, Guam" in support of the ongoing CVN Wharf construction project, Apra Harbor, Guam. The draft report compares data collected using a photographic method to data collected using *in situ* methods. We are concerned about the comparability of the data collected by the two methods and the density-based and coral colony size data collected using the photographic method in this study. The scientific validity of some of the data collected by the photographic method may be compromised. Please review the report and contact us to set up a meeting to discuss these concerns.

We appreciate the opportunity to coordinate with the U.S. Navy on the proposed project. If you have any questions regarding this report, please contact Marine Ecologist Dwayne Minton by telephone at (808) 792-9445.

Sincerely,

Gina Shultz
Acting Field Supervisor

cc: ACOE, Honolulu
USEPA region IX, Hawaii
NMFS-PIRO, Honolulu
GEPA, Guam
DAWR, Guam
GCMP, Guam

DRAFT

Comparison of a Photographic and an *In Situ* Method to Assess the Coral Reef Benthic Community in Apra Harbor, Guam

Prepared by

Dwayne Minton[1], Dave Burdick[2], Joost den Haan[3], Steve Kolinski[4], and Tom Schils[3]

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Prepared for

Naval Facilities Engineering Command Pacific
Pearl Harbor, Hawaii

July 10, 2009

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Cover Photo: A diver collects coral data *in situ* on a reef in Apra Harbor, Guam (photo by Dave Burdick).

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Executive Summary

Many methods exist to assess coral reef benthic communities, all of which have specific advantages and limitations. Selecting an appropriate method is one of the most important decisions made by researchers and must consider the project-specific objectives; the type, resolution, and precision of the data to be collected; and the site-specific conditions of the study area. In this study, an *in situ* quadrat method (ISM) and a photographic quadrat method (PM) were compared using eight different data types collected on a heterogeneous coral reef in Apra Harbor, Guam. These data types included: 1) percent cover of all benthic taxa, 2) density of coral colonies, 3) size of coral colonies, 4) number of coral fragments, 5) percent of coral colonies undergoing complete fission, 6) percent mortality of colonies having undergone complete fission, 7) occurrence of gross growth or tissue loss anomalies on coral, and 8) taxonomic richness. Data collected using each method were compared to assess the direct comparability of the methods when describing the coral reef community within the same site and to assess the similarity of the communities described by each method across the study area.

Two survey teams collected data at a total of 30 randomly selected sites from four strata. The strata included slope (0-15 degree or >15 degrees) and type of project impact anticipated (Direct dredging or Indirect project-related risk). Each team collected data within the same 10 x 1 m belt transect. Methodological errors associated with the collection of density-based coral data for the PM resulted in Coral Colony Density and the number of Coral Fragments being overestimated. It may be possible to apply mathematical corrections to correct the problems observed with the PM density-based data, but this would require re-analysis of all photographs, introduce a different form of error into the estimates, and, in the case of this specific project, may not even be possible to use. No corrections were applied to the any of the PM data in time for inclusion in this report and all interpretation of the density-based results takes the known overestimation into consideration. Additionally, Coral Colony Size data collected by the PM was not a true measure of coral colony size and, therefore, no statistical analysis was conducted with the data set. Both methodological problems associated with the PM may be solvable by photographing areas of the bottom that lie outside of the photo-quadrat.

Analyses were conducted at different levels of taxonomic resolution: 1) “All Taxa,” where all taxa as identified by each method were used; 2) “Reduced Taxa,” where the taxa were lumped to create the same taxonomic groupings for each method (*e.g.*, all individual species of *Halimeda* were lumped into *Halimeda* spp. if one method did not distinguish between separate *Halimeda* species); and 3) “Grouped Taxa,” where all taxa were lumped into the broad categories of Algae, Coral, Cyanobacteria, Soft Coral, Sponge, Other and Unknown. For benthic percent cover data, two additional analyses were conducted using coral taxa only and general coral morphologies only.

Overall, the ISM and PM compared poorly. When comparing data collected at the same site, the two methods significantly differed for every variable examined except coral growth anomalies, for which none were observed by either method. The communities described by each method across the study area were also significantly different except at the coarsest levels of taxonomic resolution (*i.e.*, Grouped Taxa and Coral Morphologies). Both methods were able to distinguish differences among the strata when using the benthic cover data with both coral and non-coral

taxa included. However, the PM did not distinguish between strata when only coral cover was used in the analysis, whereas the ISM did.

Differences between the methods were associated primarily with the ability of the methods to identify Taxon Richness at the sites. The PM identified significantly fewer taxa (28 total taxa) compared to the ISM (184 total taxa) and found an average of 24.8 ± 1.8 fewer taxa per site than did the ISM.

On coral reefs, three-dimensional relief, or bottom rugosity, is often correlated with species richness and community structure. The ISM and PM responded differently to changes in rugosity. Data collected by the PM changed little or not at all with changes in rugosity. This is consistent with what would be expected when a three-dimensional structure is reduced into a flat, two-dimensional planar view. In contrast, data collection for the ISM was correlated in rugosity as would be expected because bottom rugosity is often correlated with Taxon Richness and community structure on coral reefs.

The coral *Porites rus* was a dominant component of the coral reef community at many sites. The similarity of the communities described by the PM and ISM improved when *P. rus* was a dominant component of the reef community. The PM could readily identify *P. rus* and the method may perform similarly to ISM in situations where the benthic community has low Taxon Richness and the common organisms can be easily identified in photographs. However, even when *P. rus* was dominant, the community described by the PM was still significantly different from the ISM. While *P. rus* may have dominated at a site, it did not exclude all other taxa, and this remaining Taxon Richness appears to have been captured by the ISM but not the PM.

Every method has its limitations in what types of data can be provided and under what field conditions it can adequately perform. It is important to understand these limitations and to select the most appropriate method to meet specific requirements of each individual project. The most likely preferred option will be some combination of *in situ* and photographic methods. While only *in situ* data collected by the ISM team and photographic data collected by the PM team were compared in this study, it is important note that both teams collected data with a mixture of photography and *in situ* methods. This highlights the importance combining methods as appropriate to take advantage of each method's individual strengths.

1.0 Introduction

Many different methods exist to assess coral reef benthic communities. This diversity of methods has generated considerable debate over which is the most appropriate to use and has resulted in multiple studies that have compared the data generated by two or more of these approaches (Chiappone and Sullivan 1991, Leonard and Clarke 1993, Brown et al. 2004, Beenaerts and Vanden Berghe 2005, Lam et al. 2006, Nadon and Stirling 2006, Alquezar and Wayne Boyd 2007, Bakus et al. 2007, Cabaitan et al. 2007, Leujak and Ormond 2007). The general consensus of these studies is that most methods have advantages and limitations, which must be considered in relation to the project-specific objectives, the environmental and/or ecological conditions of the study area (*e.g.*, depth, ocean condition, geomorphology, natural community variability etc.), and the resources (*e.g.*, time, expertise, cost etc.) available.

One drawback of these studies is that they have, almost exclusively, used percent cover and species richness as the primary data variables for comparison. However, other types of data (*e.g.*, size frequency, density, etc.) have become more common in studies of coral reef ecosystems and are desirable to collect (van Woesik and Done 1997, Bak and Meesters 1998, Oigman-Pszczol and Creed 2004, Smith et al 2005). No studies were located comparing methods using these types of data.

Additionally, comparison studies have tended to focus on only a single level of taxonomic resolution, often conducting analyses at a coarse taxonomic resolution (*e.g.*, live coral, algae etc.) or on a single component of the overall coral reef community (*e.g.*, hard corals only). All methods have limitations in the taxonomic resolution that can be achieved. Different levels of taxonomic resolution are needed to address different science, management and regulatory questions, so it is critical to know how methods compare at differing taxonomic scales so that the most appropriate method for answering project-specific questions can be selected.

Finally, previous comparison studies have focused on the direct comparability of two or more methods employed within relatively few sites. While valuable, this type of comparison overlooks the potential situation in which two or more methods could have low direct comparability within an individual site, but may produce estimates that are indistinguishable over larger spatial areas. This scenario could arise in habitats where the natural biological variability exceeds the error between the methods, and sufficient sampling cannot be conducted, perhaps for cost or time reasons. In this situation, a variety of methods may provide the same end result.

This comparison study resulted from the U.S. Navy's desire to use a less field-intensive method to collect benthic coral reef survey data to meet U.S. environmental regulatory requirements in support of dredging approximately 50 acres of submerged reef to construct a nuclear aircraft carrier (CVN) berthing facility and turning basin in Apra Harbor, Guam. In this study, we compare two commonly used methods to collect coral reef benthic data: an *in situ* quadrat method (ISM) and a photo-quadrat method (PM).

In situ quadrats have long a long history of use in the marine environment. This method is generally cost effective because it requires little expensive field equipment and it is capable of producing data with a high level of taxonomic resolution (Hill and Wilkinson 2004). The method is generally preferred for locating small or cryptic organisms (Lessios 1996) because observers are able to effectively search highly three-dimensional substratum. However, the method is potentially field intensive, which depending upon environmental conditions can lead to increased cost. In its purist form (*e.g.*, not combined with some photography), it produces no permanent record that can be consulted or used to cross-check the data collected.

With the technological advances in digital photography, photo-quadrats have become increasingly popular for collecting coral reef benthic data. A primary advantage of photographic methods is that data can be collected quickly in the field, reducing the field time and potentially allowing for increased sample sizes. A permanent record of what is photographed at the site can be made, which can be useful for cross-checking data for errors or, in some cases, to assist with identification. While the method may save time in the field, it can be time intensive during post-field photographic analysis. In general, taxonomic resolution may be low and small or cryptic organisms may be difficult to identify, but recent advances in digital photo resolution may be improving this limitation. Photographic methods reduce three-dimensional topographic relief into a two-dimensional planar projection resulting in the under-sampling of any organisms on vertical or over-hanging surfaces. Finally, expensive equipment is necessary to conduct the method (Hill and Wilkinson 1994, English et al. 1997).

This study addresses two questions: (1) do the data obtained by the *in situ* method and the photographic methods directly compare to each other, and (2) are the benthic communities described by these two methods the same over a larger spatial area? To answer these questions, we used multiple benthic coral reef data sets and conducted analyses at multiple levels of taxonomic resolution. The data sets included: 1) percent cover of all benthic taxa, 2) density of coral colonies, 3) size of coral colonies, 4) number of coral fragments, 5) percent of coral colonies undergoing complete fission, 6) percent mortality of colonies having undergone complete fission, 7) occurrence of gross growth or tissue loss anomalies on coral, and 8) taxonomic richness.

2.0 Methods

2.1 Survey Sites

Thirty survey sites (Figure 2.1) were selected from 60 random locations in Apra Harbor within the proposed project area of the CVN pier, turning basin, and entrance channel. Sites were restricted to depths ≤18 meters (m) because the direct project impacts are anticipated to occur no deeper. Additionally, this depth provided adequate time for the completion of the ISM data collection at a site in a single non-decompression dive. Some sites within the study area were known to contain no coral colonies. For the purpose of this comparison, sites that did not contain both algae and coral were excluded from selection. The physical attributes of all sites are included in Appendix A.

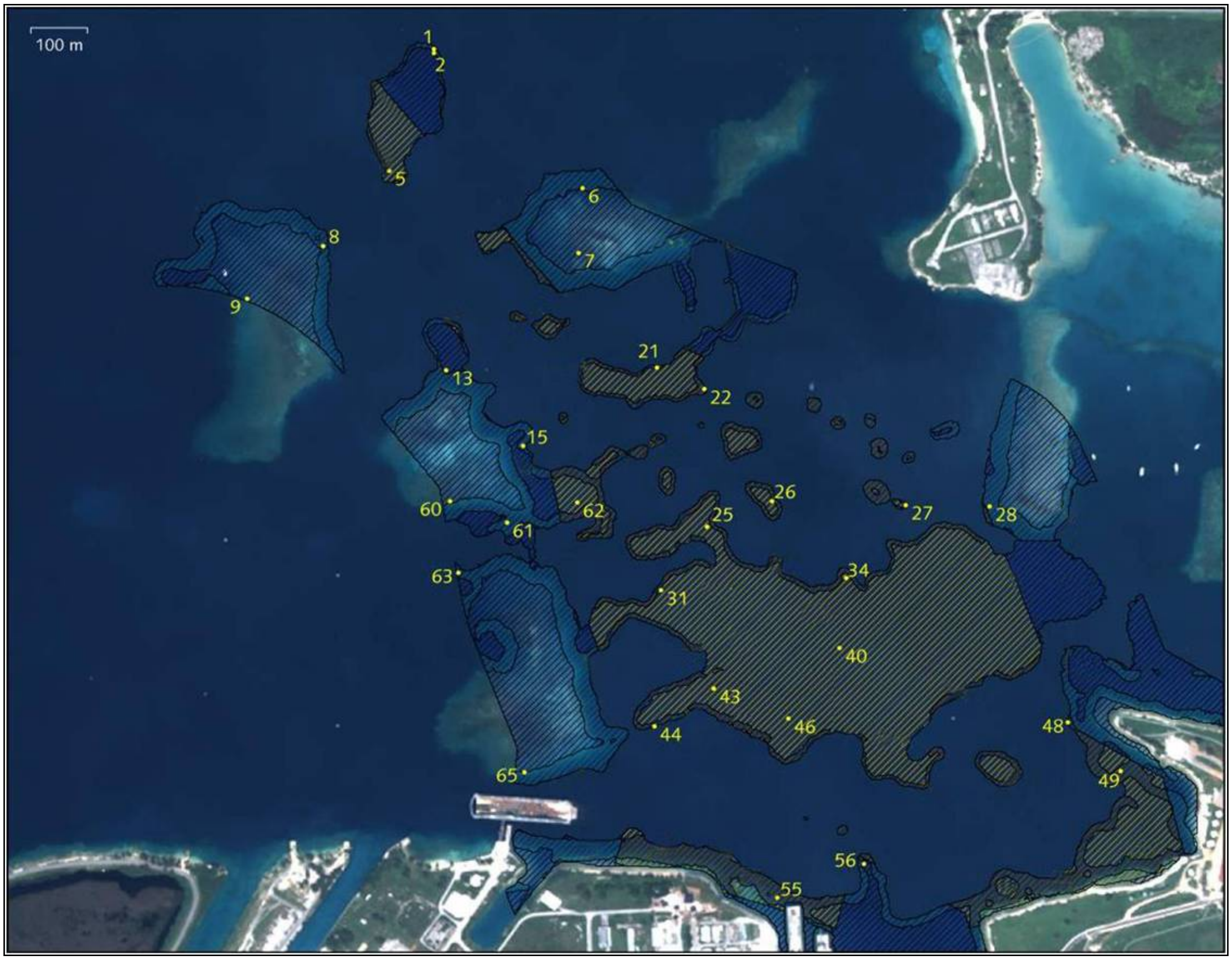


Figure 2.1. Map of the 30 survey sites analyzed in this study. Hatched areas are shallower than 18 m and comprised the survey area. Four strata were created: Indirect Impact-Slope, Indirect Impact-Flat, Direct Impact-Slope, and Direct Impact-Flat.

The survey sites were stratified by slope (0-15 degree or >15 degrees) and type of project impact anticipated (Direct dredging or Indirect project-related risk). A stratified sampling design is warranted when distinct community types are known to occur within the study area or if it is desirable to ensure adequate sampling within specific areas so that estimates within those areas can be made (Cochran 1977, Bakus 2007). In this study, the Direct-Indirect stratum was developed based upon dredge-fill footprints for the dredging alternatives considered as part of the proposed CVN project. This stratum was necessary to meet CVN project-specific goals. While this stratum was not specifically biologically based, the footprint for the proposed dredging alternative attempted to avoid sites with "significant" coral habitat. This provided an unexpected biological relevance to this seemingly non-biological stratum. Sites were distributed as evenly as possible among the four strata, but logistical constraints did not allow for a perfectly balanced design.

2.2 Variables Collected

Data for eight benthic community variables were collected (Table 2.1). These variables represent the data requested by the Federal environmental regulatory agencies to assess potential project-related impacts to coral reef communities.

Table 2.1. Variables and metrics selected for data collection as part of marine resource surveys conducted in Apra Harbor, Guam in support of the CVN project.

Variable	Metric
Benthic organism cover by species (or lowest possible taxonomic level)	Percent of bottom covered
Coral colony density by species (or lowest possible taxonomic level) and morphological form	# of colonies/m^2
Coral colony size	# of colonies/m^2 in each of nine size categories (<2cm, 2 to <5 cm, 5 to <10 cm, 10 to <20 cm, 20 to <40 cm, 40 to <80 cm, 80 to <160 cm, 160 to <320 cm, ≥320 cm)
Coral fragments	Number and size of fragments (see colony size above)
Coral colony fission[1]	Percent of colonies having undergone complete fission
Partial coral colony mortality	Percent mortality on colonies that have undergone complete fission
Occurrence of gross growth anomalies and/or anomalous patterns of tissue loss by coral species (or lowest possible taxonomic level)	% of colonies showing the described condition
Taxon Richness	Number of taxa

[1]Fission is partial mortality of a coral colony that results in separation of a colony into pieces that are genetically identical (*i.e.*, ramets) and remain attached to the substratum.

2.3 Deployment of Transect Lines

To avoid interfering with each other, only one team collected data at a site at a time. At almost all sites, the PM team conducted their data collection first. Using predetermined criteria, the first team on-site laid a calibrated 25-m transect line on the benthic substrate. Transect lines were left securely attached to the bottom until both teams had finished their data collection, usually within a few days of each other. All but one dive was conducted between 27 April 2009 and 12 May 2009. A single ISM dive (site 55) was conducted on 26 May 2009 to collect Benthic Cover data.

Survey teams used handheld GPS units to locate sites. A weighted surface float was deployed to mark the site and serve as the starting point for the transect line. The transect line was stretched across the benthic substrate starting at the float's weight. When a discernable slope was observed, the line was run along the depth contour. If no discernable slope was observed, the line was run north, provided it could fit entirely on the flat area. If the flat area began to slope, the line was turned to maintain a constant depth. At most sites, the entire 25-meter transect line was laid in a straight line.

2.4 Photographic Method

Procedures for conducting the PM were based on previously published protocols (Hill and Wilkinson 2004; English et al. 1997). Surveys were conducted by three divers. Digital photographs were collected by one diver using a digital SLR camera (14 mm lens with 114° diagonal field of view) mounted on a 4-legged PVC quadra-pod. The quadra-pod positioned the camera over the center of a 1 x 0.67 m rectangular frame. The digital SLR contained a full-frame display that provided for *in situ* verification of each image. Dual stereo strobes were used on some deeper transects (*e.g.*, >10 m) if the particulate load of the water column was not deemed sufficient to cause excessive backscatter. Fifteen photo-quadrats were collected contiguously along the 10-m length of transect, resulting in 10 m^2 photographed at each site. Upon completion of the photo-quadrats, a taxa list of all corals to the lowest possible taxonomic level was compiled within the general area of the transect (~5 m wide belt centered on the 25-m transect line), and descriptive notes on the overall biotic and geomorphological setting were recorded. All photographs and incidental observational data were collected by Dr. Steve Dollar.

A second diver laid the transect line as described above. A third diver collected *in-situ* topographical relief, or rugosity. Rugosity was measured on each transect as the actual length of chain laid over the reef surface divided by the transect length. For this index, a value of one represents a perfectly flat surface with no relief. Three different divers rotated through these two tasks. Prior to starting the fieldwork, all personnel were trained and calibrated to ensure consistency.

A total of 446 photo-quadrats (for Site 1, only 11 images were processed) were analyzed one at a time using the Coral Point Count with Excel Extensions (CPCe) software developed by the National Coral Reef Institute (Kohler and Gill 2006). Fifty randomly placed points laid over each quadrat (total of 22,150 points) were independently identified to the lowest possible taxonomic level by three different analysts. For all points where at least one analyst was in disagreement, all three analysts and the lead principle investigator for the photo-analysis (Dr. Eric Hochberg) examined the point and came to consensus on its final identification. The agreement rate between analysts (*i.e.*, number of points for which all three analyst agreed) was approximately 85 percent (~19,000 points).

For other data types, each analyst identified all discernible coral colonies, including coral fragments. Individual coral colonies were identified by tissue and or skeletal boundary separation on all sides. Corals were counted if any part of the colony was included in the frame. Corals were considered fragments if they were broken off the bottom, but still had living tissue. Recently broken fragments were not observed and were not counted. For each colony/fragment, analysts determined the length of the longest viewable dimension. The size of the quadrat frame limited the largest dimension that could be measured to 120 cm (the diagonal distance). For each analyst, the data were compiled by transect, and averaged to produce the final data. All photo-quadrats were analyzed in the lab by the individuals who conducted the field work.

Colonies undergoing complete fission were identified from digital images by Dr. Steve Dollar. Fission was defined as whole colonies that were completely split into at least two distinct sections by an area of non-living tissue. For each colony having undergone complete fission, the percent of dead tissue was visually estimated. Large colonies of *Porites rus* with multiple plates interspersed with living and dead tissue, and branching species, were ignored. Additionally, colonies with gross growth anomalies were noted in digital photographs when present. Other unusually conditions were also recorded, and the percent of the colony affected was visually estimated.

All data for the PM were collected by Dr. Steve Dollar of Marine Resources Consultants and Dr. Eric J. Hochberg, Mr. Mitchell B. Doctor, Ms. Harmony A. Hancock, and Mr. Christopher J. Lapointe, all of the National Coral Reef Institute, Oceanographic Center, Nova Southeastern University.

2.4.1 Methodological Errors

Two methodological problems were identified with all density data collected using the PM. In brief, criteria used for including boundary corals (*i.e.*, those only partially within a quadrat) can result in significantly biased density estimates (Zvuloni et al. 2008). By counting a boundary coral that has any piece of the colony in the quadrat, too many corals have been included in the density estimate for the PM, resulting in an overestimation (Zvuloni et al.'s Type II error). While Zvuloni et al. (2008) provide information on a possible correction factor, no adjustment was made to the PM data in time to be included in this report. Additionally, each image was processed independently and due to the contiguous arrangement of the quadrats (*i.e.*, fifteen photo-quadrats were laid end to end to make 10 x 1 m belt transect), corals along a shared quadrat edge were counted twice, further inflating all density estimates. Where relevant, interpretation of results will be done taking this known overestimation into consideration. The following PM data have this "Type II" error: Coral Colony Density, Coral Colony Size, and Coral Fragments.

An additional issue was identified with the Coral Colony Size data. Size measurements were not made of the entire coral colony, but only the longest visible dimension in the photo-quadrat. As a result, the PM measured the longest planar coral dimension occurring in the quadrat and not the planar size of a coral colony. The Coral Colony Size data are, therefore, skewed toward smaller sizes when compared to a true coral colony size frequency distribution. The nature of the skew cannot be predicted because, with a randomly placed quadrat, at least half of the boundary colonies are expected to have their longest dimension outside of the quadrat. These boundary corals will be forced randomly into any size class below its true size, and therefore the Coral Colony Size as measured by the PM does not reflect the true size of the corals within the project area. For example, a boundary coral sized as 5 cm by the PM could actually be 120 cm if only a small portion is viewable within the photo-quadrat boundary or 11 cm if almost half of it is within the photo-quadrat. No correction was made to the PM Coral Colony Size data in time to be included in this report. Therefore, no meaningful statistical comparison can be conducted.

2.5 *In situ* Method

Three ISM divers collected the data along the same pre-determined 10 x 1 m belt transect used for the PM. One diver located all coral colonies whose center lay within the belt transect and identified them to the lowest taxonomic level. Colonies were individually distinguished by a variety of factors including color, morphology, but most importantly tissue and or skeletal boundary separation. The vast majority of colonies were fairly simple to distinguish based on these four parameters; however, three species did provide greater challenge and required more time for distinguishing individuals. Delineation of individuals of *Porites rus* (a dominant coral constituent at many of the sites) often involved following and delineating the entire length of the tissue and skeletal boundary as intra-colony variation in color, morphology and incomplete fusion of overlapping or adjacent tissue areas occurred. Skeletal formation and direction often formed the major basis of colony delineation for *Porites cylindrica* (a minor coral constituent at the sites sampled) when tissue necrosis at branch bases and partial burial was found. Thick, extensive fields of *Pavona cactus* encountered at four of the sites could not reliably be distinguished on an individual colony basis. At one of these sites, *P. cactus* measures were not made. At three of these sites, measurements were made specific to recognizable clumps or aggregations and labeled as such. Such data were collected as a methodological means to allow compensatory mitigation equity to ultimately be achieved (a regulatory requirement), but were not included in the analysis of methods comparability. With consistent and careful application of this approach, the ISM team was confident that coral colonies were consistently delineated at all sites.

Coral fragments were defined as any unattached coral piece physically dissociated from a "parent" colony of skeletal and tissue material. All coral fragments were counted, identified to the lowest possible taxonomic level, and sized separately. At three sites where *P. cactus* fragments could not be easily counted, their presence was simply noted. Fragments that were obviously recently broken (*e.g.*, broken surface bone-white with rough intact skeletal porosity and no apparent overgrowth) were also not counted because it was assumed that these coral pieces were broken as a result of this study. The longest axis of each coral colony and fragment was measured using a meter stick with 10-cm gradations or, for smaller colonies, a flexible 1 cm delineated measuring tape. Based on their measured size, colonies were placed into one of nine size classes: <2 cm, 2 to <5 cm, 5 to <10 cm, 10 to <20 cm, 20 to <40 cm, 40 to <80 cm, 80 to <160 cm, 160 to <320 cm, and ≥320 cm.

If separate pieces of attached tissue appeared to be a part of a single individual colony (based on color, morphology and or skeletal connectivity), the separate pieces were considered an individual colony that had undergone complete fission and a visual estimate of percent tissue mortality was made. A fissioned colony was sized as a single measure across the longest diameter of the underlying skeleton (when readily discernable) or between the outermost boundaries of the furthest pieces of colony tissue.

All coral data were collected in 1-m intervals using a 1 m^2 quadrat frame. Care in identification of colony centers and boundary delineations helped ensure that colonies that crossed multiple quadrats were counted only once within each 10 m transect. For any colony that could not be positively identified in the field, multiple photographs were taken at different scales to assist with later identification. Photographs were taken perpendicular to and 0.5 m above the substratum every half-meter along the entire length of the 10-m belt transect. In addition, a series of images of the general habitat was collected along each 10 m belt transect. All photos were archived.

Two divers collected benthic composition data which included percent cover estimates for all algae, coral, and sessile invertebrate taxa. Ten 1 x 0.67 m quadrats were placed within the first 6 meters of the 10 x 1 m belt transect. Within each quadrat, the percent cover of *all* benthic taxa was visually estimated to the nearest 1 percent cover. To assist with visual estimates, each quadrat was strung to contain a grid in which each square represented 1.5 percent of the quadrat. When appropriate, overlying algae were gently waved aside so that estimates could be made down through the "canopy" layers. As a result, a total coverage estimate in excess of 100 percent could result if a community had well-developed canopy and/or understory layers. Taxa that were rare were assigned a cover of one percent. All taxa were identified to the lowest possible taxonomic level and, as necessary, specimens were collected to confirm field identifications in the laboratory. All quadrats were photographed to assist with data verification and for archiving.

The collection of Benthic Cover data in a 6 m^2 belt transect for the ISM (compared to a 10 m^2 belt for the PM) would not affect the statistical comparison of the two methods. Percent cover data is a relative measure and independent of area. It is, therefore, appropriate for this comparison to be conducted. Additionally, the objective of this study was to compare the data collected by each method, so as long the data collected by both methods are unbiased and represents the same thing (*e.g.*, percent cover of the bottom, density of coral colonies, size of coral colonies) then a comparison is appropriate.

The primary drawback of using a smaller belt transect to estimate Benthic Cover for the ISM compared to the PM is that the smaller belt transect may introduce additional variability across the larger spatial scale to the ISM's Benthic Cover estimates. This could potentially obscure real differences between the methods when comparing the communities described by each method (see study question 2 in section 1.0). The structure of the data allowed for a direct 6 m^2 to 6 m^2 comparison to be conducted between the two methods, but this would have require additional work to re-sort the PM data into a comparable form, for which the timeline of the study did not permit. More importantly, it would not be a fair assessment of the PM because it would artificially limit the full data set collected by the method.

Time permitting, upon completing the 10 x 1 meter belt transect, divers visually surveyed an approximately 5-meter wide belt to either side of the transect line and noted any benthic species not observed within the belt transect. In general, insufficient bottom time existed to spend more than a few minutes conducting visual surveys for Taxon Richness. For six survey sites, a second coral diver collected Taxon Richness data for approximate 30 minutes. This resulted in more than twice the number of taxa found at those sites (29.7 ± 2.4 coral taxa vs. 13.4 ± 1.2 coral taxa) and suggests that the Taxon Richness at the study sites is much higher than that estimated by the ISM. For the analysis of Taxon Richness in this report, only taxa observed within the belt transects were included.

2.6 Statistical Analysis

2.6.1 Overview

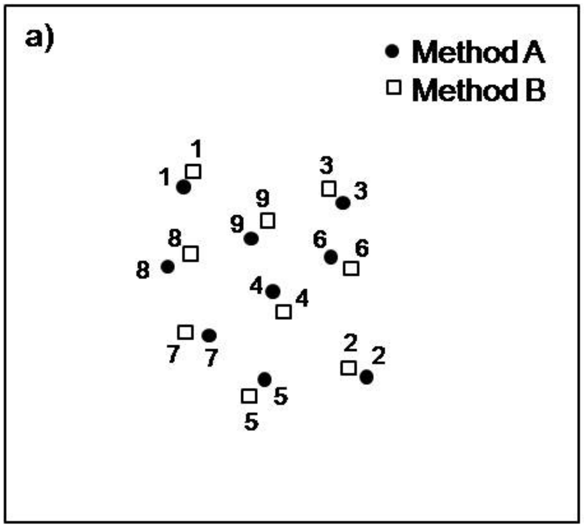
The statistical analysis was conducted to address two questions: (1) do the data obtained by the *in situ* method and the photographic methods directly compare to each other, and (2) are the benthic communities described by these two methods the same over a larger spatial area? Assuming each question is true or false, three potential outcomes are possible and would be illustrated by specific results and patterns within the data. These outcomes are:

1. A "best" case outcome would be the PM and ISM method would be directly comparable within sites, and the communities describe by the PM and ISM would not be significantly different (Figure 2.2a).

   The data collected by each method at the same site (hereafter, a method-site pair) would be identical. For a single variable (*e.g.*, total number of taxa), the value estimated by the two methods at the same site would be equal. For multiple variables (*e.g.*, percent cover of all benthic taxa), the similarity between the two sites could be calculated and would be equal to one. Additionally, a 60 x 60 matrix of all sites (30 PM sites and 30 ISM sites) could be created that includes the similarity between all method-sites. The similarity between the method-sites pairs would be the highest compared to the other 59 similarity values for each method-site (*i.e.*, Rank = 1). Cluster plots (see section 2.6.3) were used to visually display trends in the benthic community. In these plots, each point represents a description of the entire benthic community at a given site as described by one of the methods. The distance between any two points in the plot is directly related to the similarity of the community represented by those two points. Points that are close to each other in the figure are more similar to each other than points that are separated by a larger distance. In a cluster plot, the point representing the PM at a given site would lie closest to the point representing the ISM at the same site. The cluster of all points for the PM would be intermixed with the points for the ISM, signifying that the communities that have been described by the two methods are the same.

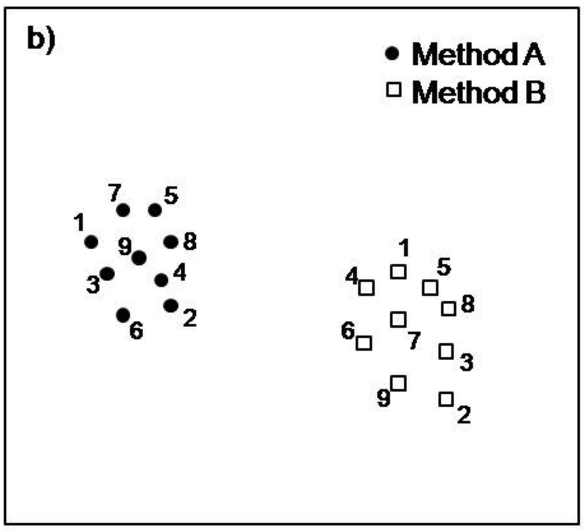
2. In contrast, a "worst" case outcome would occur if the methods were not directly comparable within sites and the communities described by the PM and ISM were significantly different from each other (Figure 2.2b).

   The data collected by each method within the same site would be significantly different. For a single variable, the values estimated by each method at the same site would be significantly different from each other. For multiple variables, the similarity between the method-site pair would be less than one and would not have the highest similarity value when compared to the other 59 similarity values (*i.e.*, Rank > 1). In a cluster plot, the two points representing the method-site pair would not lie closest to each other. The cluster of all points for the PM would be spatially distinct (*i.e.*, significantly different) from those for the ISM, signifying that the communities that have been described by the two methods are not the same.



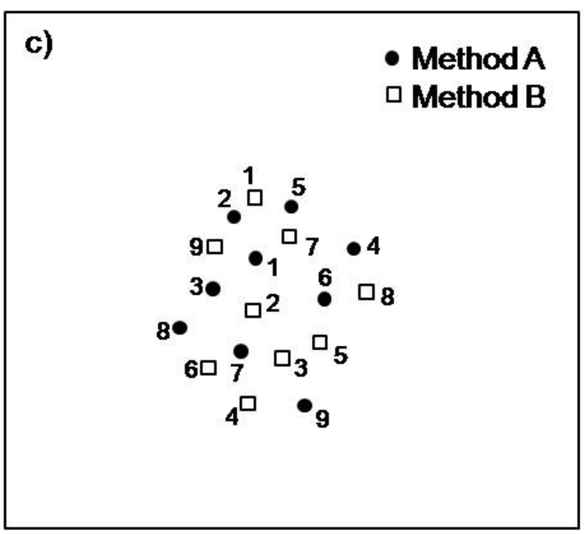
For the nine hypothetical sites surveyed, the method-site pairs (*e.g.*, A_1 and B_1) are aligned closest to each other in the cluster diagram, showing the two methods are directly comparable. In an idealized univariate model, A_1-B_1=0, and in the idealized multivariate model, the Similarity between A_1 and B_1 (S_{A_1,B_1}) = 1.

The cluster of points for the two methods overlap. The community described by Method A cannot be distinguished from that described by Method B.



The nine hypothetical survey sites cluster separately by method type. Method-site pairs (*e.g.*, A_1 and B_1) are not aligned together showing poor comparability between the two methods. In this case, the univariate model would result in A_1-B_1≠0, and for the multivariate model, S_{A_1,B_1}<1.

The clusters of points do not overlap. The community described by Method A is different from that described by Method B.



For the nine hypothetical sites surveyed, method-site pairs (*e.g.*, A_1 and B_1) do not align together showing poor comparability between the two methods.

However, the points for the two methods overlap. While the two methods are not directly comparable, the natural variability in the community is greater than the error between the two methods. With a sample size of nine, the community described by Method A cannot be distinguished from that described by Method B.

Figure 2.2. A hypothetical comparison study that sampled nine sites using two methods. Three potential outcomes for this study include: a) methods are directly comparable ("best" case); b) methods are not directly comparable and the communities described by each method are significantly different ("worst" case); and c) methods are not directly comparable, but the communities described by the two methods do not significantly differ ("inconclusive" case).

3. An “inconclusive” outcome would occur when the PM and ISM method are not directly comparable within sites, but the communities described by the PM and ISM across a larger spatial scale are not significantly different (Figure 2.2c). In this situation, the sample size was inadequate to show any difference in the community because the natural biological variability was larger than the error between the two methods. If a statistically adequate sample size was obtained, this inconclusive outcome would result in a “worst” case outcome.

   The data collected by the PM and ISM method within the same site would be significantly different and appear in the data as described above for the “worst” case outcome. In a cluster plot, the two points representing a method-site pair would not lie closest to each other, but the cluster of all points for the PM would be intermixed with the points for the ISM, signifying that the communities that have been described by the two methods are indistinguishable.

2.6.2 Data Reconciliation

Prior to conducting any comparison, data collected within each method and between each method was examined to ensure consistency in taxonomy. It is critical to any comparison analysis that the same organism receive the same name.

Data were visually investigated at the level of each site. If large differences in taxa were noted between different abundance measures (*e.g.*, between benthic cover and coral density) within the same method type they were investigated in more detail at the quadrat level. A similar cross-check was conducted between the two methods for data of the same type (e.g., within coral densities). Most differences were the result of observers placing different taxonomic names on the same organism. If this occurred, consensus was reached among the taxonomic experts involved in collecting the data in question and that name was assigned and used in the analysis. By crossing checking the data in this way, one mislabeled site within the PM data set was fortuitously identified and corrected prior to conducting any statistical analysis.

Each coral colony was assigned a morphology based on their taxa or direct observation in the field or from photographs (Appendix B). All density data was standardized to number of individuals per 10 m^2.

2.6.3 Comparison of Methods

The direct comparability of the ISM and PM were made using paired data at each of the sites. For univariate summary data (*e.g.*, total Coral Colony Density), either a paired t-test (Zar 1998) or a one sample Wilcoxon test (Hollander and Wolfe 1999) was used. Normality of the data was assessed using normal probability plots and the Anderson-Darlington test for normality (Stephens 1979). Where data were found to be non-normal, non-parametric tests were used. Follow-up tests were conducted using ANCOVA to examine the influence of strata and rugosity on the paired data, provided that the diagnostics (see below) used to assess the appropriateness of the ANCOVA analysis did not indicate serious assumption violations that would compromise the result.

For multivariate data, a Bray-Curtis similarity matrix (Bray and Curtis 1957) was generated using all sites and both methods (a 60 x 60 matrix). Similarity values range from 0-1, with a value of one meaning perfect agreement and value of zero meaning prefect disagreement. If the methods were directly comparable, the similarity of the described community for the method-site pair would be equal to one and would have rank of one. A one-sided Wilcoxon was used to test if the observed rank was greater than one.

Standard diagnostic procedures pertinent to the selected test were conducted on all analyses to assess the appropriateness of the statistical test for use with the data. Any violations of test assumptions were assessed for their potential impact on the results. If any violation was determined to compromise the test results, the analysis was discarded.

2.6.4 Comparison of Communities

Potential differences in the communities described by the two methods were examined using the suite of non-parametric multivariate procedures included in the PRIMER statistical software package (Plymouth Routines in Multivariate Ecological Research) (Clarke and Warwick 2001). These procedures have gained widespread use in the marine ecological community and have significant advantages compared to the standard parametric procedures (see Clarke 1993 for additional information).

The community data were generally analyzed at three different levels of taxonomic resolution. The levels of taxonomic resolution, going from finest resolution to coarsest, were: 1) "All Taxa," where all taxa as identified by each method were used; 2) "Reduced Taxa," where the taxa were lumped to create the same taxonomic groupings for each method (*e.g.*, all individual species of *Halimeda* were lumped into *Halimeda* spp. if one method did not distinguish between separate *Halimeda* species); and 3) "Grouped Taxa," where all taxa were lumped into Algae, Coral, Cyanobacteria, Soft Coral, Sponge, Other and Unknown. For benthic percent cover data, two additional analyses were conducted using coral taxa only and general coral morphologies only.

Prior to analysis, data were square-root transformed and a Bray-Curtis similarity matrix was generated (Clarke and Warrick 2001, Clarke and Gorley 2006). An ANOSIM with 1000 permutations was used to test for significant differences between methods and among strata. Any observed differences were further investigated using a SIMPER analysis and by overlaying variables (*e.g.*, rugosity) and taxa on non-metric multidimensional scaling (nMDS) plots to explore patterns (Clarke and Gorley 2006). The SIMPER analysis identifies the contribution that taxa within the community make to any observed differences. Interactions between the factors were explored using second order methods (Clarke et al. 2006). Correlations between the community patterns and rugosity, depth, and Taxon Richness were tested using the BEST procedure in the PRIMER package (Clarke and Gorley 2006). To control the overall Type I error rate for each data set, an adjusted α_{crit}=0.01 was used when assessing significance. This adjustment to the critical value was applied only when test involved repeated analyses using the same data (*e.g.*, benthic percent cover data that is examined at multiple taxonomic resolutions). This adjusted α_{crit} would maintain an overall error rate of less than 0.05.

3.0 Results

3.1 Taxon Richness

3.1.1 Comparison of Methods

The ISM found an average of 24.8 ± 1.8 more taxa at a site than did the PM (Paired t-test, T=-13.64; df=29; p<0.001). The ISM found more taxa in every taxonomic group except soft corals, for which only one taxa was identified by both the ISM and PM (Table 3.1).

The two methods became more comparable with increasing rugosity (ANCOVA; F=11.72, df=1,25; p=0.002). The two methods responded differently to changes in rugosity. The number of taxa found by the PM did not change with rugosity (Figure 3.1). In contrast, the ISM had a significant negative correlation (Pearson; r=-.527; p=0.003); at higher rugosity, the ISM found fewer taxa. Total Taxon Richness did not vary by strata.

The number of taxa found often strongly correlated with area searched (Arrhenius 1920, Preston 1962). The larger an area searched, the more taxa that are generally identified. Only taxa found within the 10 x 1 m belt transect were included in this analysis. For the ISM, the Taxon Richness for all taxa other than coral were obtained from a 6 x 1 m belt transect. The ISM's belt transect was 40 percent smaller than that used by the PM, but still managed to identify 11.5 times more non-coral taxa (11 taxa for the PM versus 126 for the ISM).

The Shannon-Wiener Index (H') was calculated using the Benthic Cover data. The ISM had a significantly greater H' than the PM (Paired t-test, T=-7.38; df=29; p<0.001). A significant strata affect was also observed (ANCOVA; F=3.38, df=3,55;p=0.024) where Direct Flat and Indirect Slope were different. No relationship between H' and rugosity was found.

Table 3.1. The Taxon Richness found by the PM and ISM. The values represent the total number of taxa per taxonomic group found by the two methods over the course of this study.

	PM	ISM
Algae	8	62
Coral	16	58
Cyanobacteria	1	12
Other	0	2
Soft Coral	1	1
Sponge	1	49
	27	184

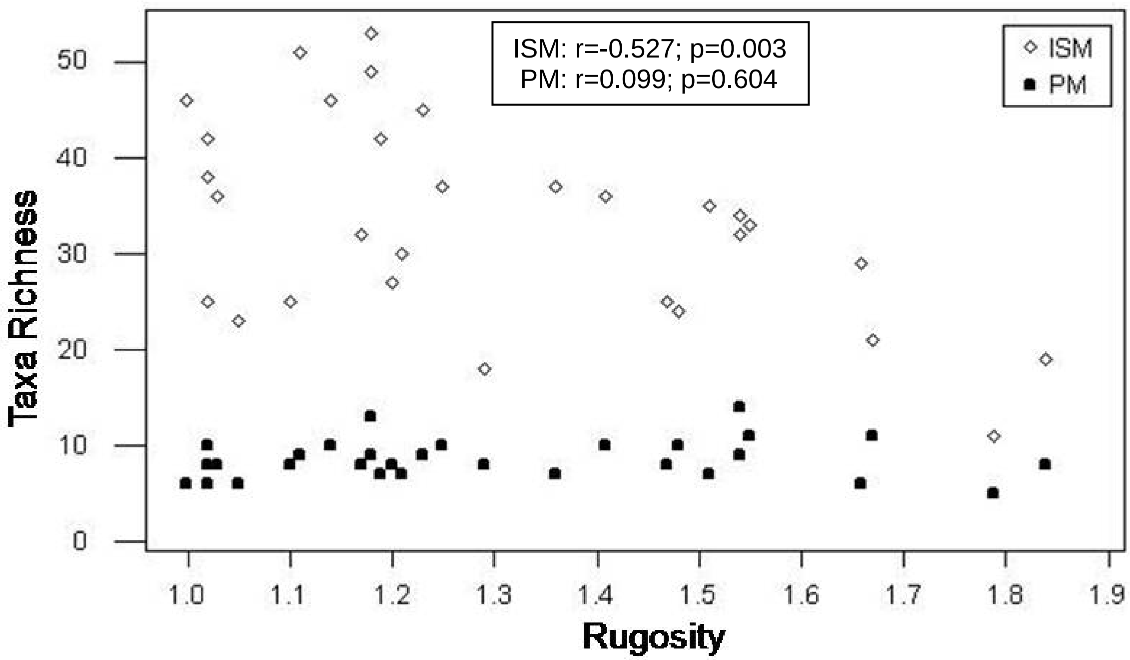


Figure 3.1. Taxon Richness found at a site using the ISM was negatively correlated with rugosity. No relationship was found between Taxon Richness and rugosity for the PM. This different relationship with rugosity resulted in greater comparability between the ISM and PM at higher rugosity, where Taxon Richness appeared reduced.

A 60x60 Bray-Curtis Similarity matrix was generated using square-root transformed data from all method-sites. If the methods were directly comparable, the similarity value between the community described by the ISM and PM at the same site (*i.e.*, method-site pair) would be equal to one and would have a rank of one for that method-site.

The method-site pairs had an average similarity of only 0.15 and, with a median rank of 32, ranked significantly lower than one (Table 3.2). This means that the community described at a site using the PM was more similar to 31 other communities described at other sites by either method than it was to the community at the same site described using the ISM. Comparability between the two methods improved when only coral Taxon Richness was considered. The similarity increased to 0.49, but the rank continued to be significantly lower than one.

Table **3.2.** The mean (±SE) similarity between the method-site pairs and its median (with interquartile range) rank when compared to the 59 other similarity values for the method site. If the methods are directly comparable, the method-site pairs would have a similarity value of one and a rank of one.

Taxa Resolution	Similarity	Rank	Wilcoxon Test
All	15 (0.7)	32 (30-36.8)	W=1830; p<0.001
Coral	48.8 (2.4)	10.5 (4-25)	W=1485; p<0.001

3.1.2 Comparison of Communities

3.1.2.1 All Taxa

When the presence and absence of taxa were examined, the ISM and PM described significantly different benthic communities (ANOSIM; R=0.989; p=0.001). A nMDS plot was generated. Each point in the plot represents a description of the entire benthic community based on the presence of All Taxa at a given site as described by either the PM or the ISM. The distance between any two points is directly related to the similarity of the community represented by those two points. Points that are close to each other in the figure are more similar to each other than points that are separated by a larger distance. The nMDS plots showed that the method-site pairs were not adjacent and that the points associated with each method were not intermixed (Figure 3.2). The nMDS plot showed two distinct clusters of points corresponding exclusively with the two methods.

A significant strata effect was found (ANOSIM; R=0.146; p=0.004), but the second-order analysis revealed a significant interaction term. Examining each method independently, the ISM

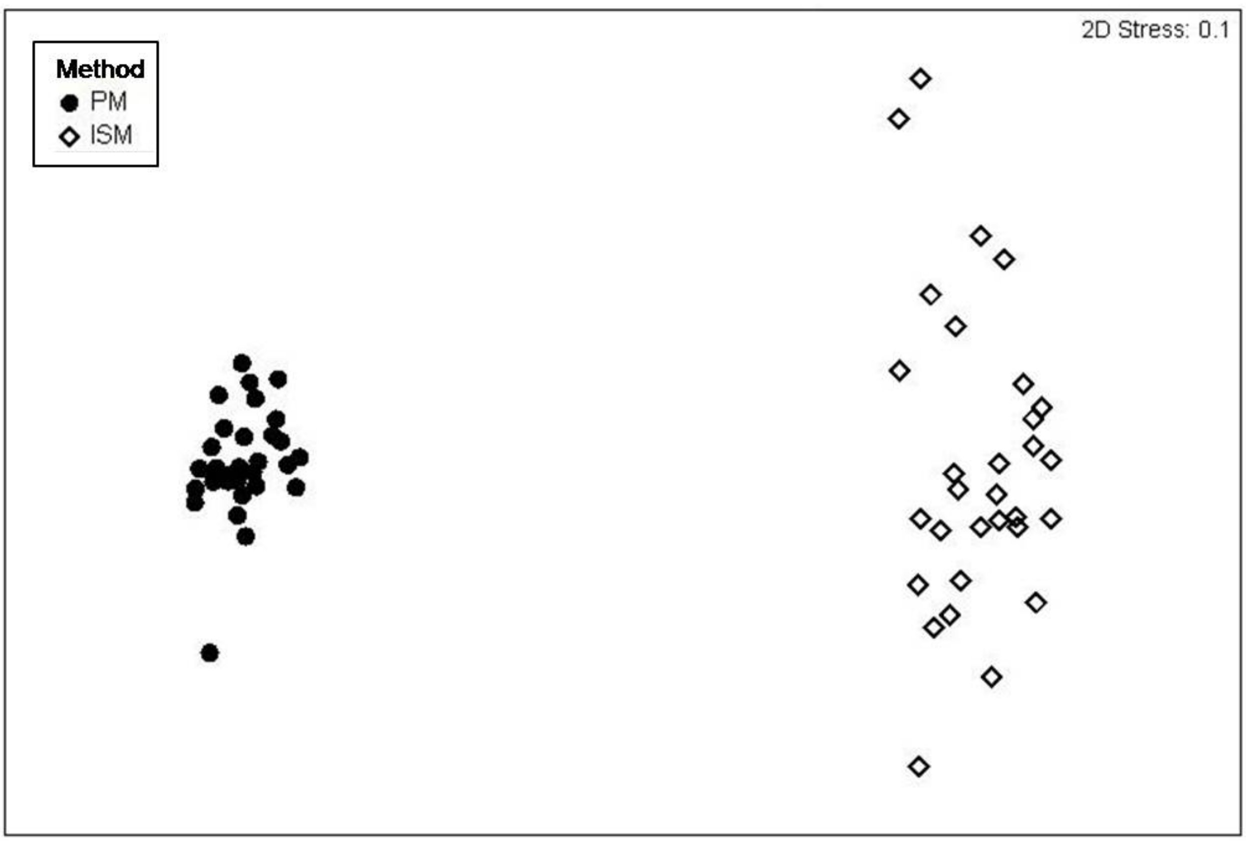


Figure 3.2. The nMDS plot for Taxon Richness. Symbols represent the benthic community described by either the ISM or PM at a survey site. The stress value is a measure of the distortion between the distance of the rankings in the nMDS configuration and the analogous rankings in the similarity matrix. A stress value of 0.1 falls within the range indicating that the plot represents a useful two-dimensional representation.

found significant differences among the strata (ANOSIM; R=0.213; p=0.003), but the PM did not. The ISM distinguished the Direct from Indirect strata. Analysis of the nMDS plot for the ISM data showed some overlap of the Direct and Indirect clusters (Figure 3.3). Examining the three "anomalous" Indirect points, it is apparent that these points have clustered where expected considering the environmental conditions at these three sites. Sites 1 and 2 are on a deepwater patch reef and have clustered with Site 5, which is on the same patch reef but happens to be within the dredge area (see Figure 1.1). Site 56 is in deep water at the mouth of the inner harbor channel and has clustered with other deep water sites in the vicinity (*e.g.*, Sites 46, 55 etc.).

The tighter clustering of the Direct Impact points compared to the Indirect points would be consistent with a biological community that has lower natural variability than the community within the Indirect strata. The overall greater spread of Indirect points and the apparent presence of four smaller clusters (Figure 3.3) are consistent with survey sites scattered across multiple patch reefs and on different sides (*e.g.*, windward vs. leeward) of the patch reefs. The heterogeneity of both Direct and Indirect sites as shown by their spread in the nMDS plot was consistent with personal observation.

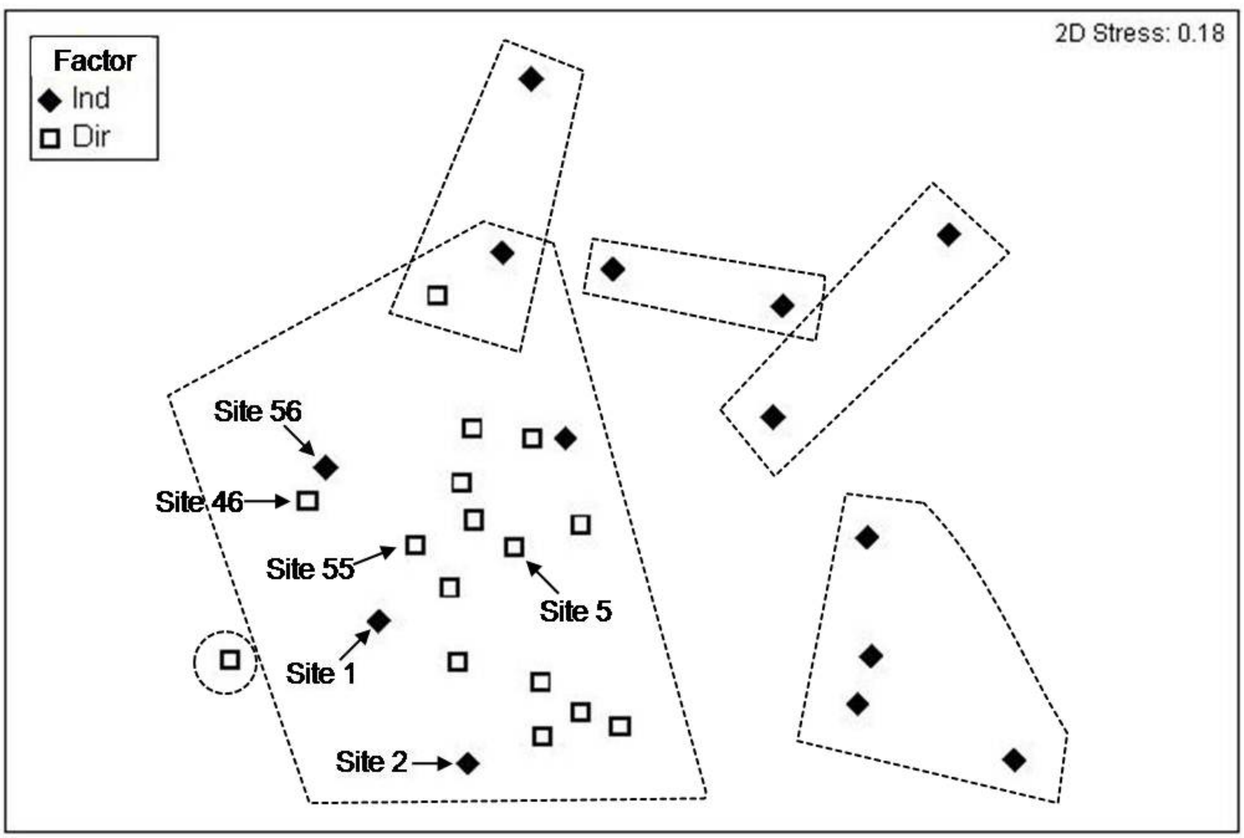


Figure 3.3. The nMDS plot for Taxon Richness by Indirect and Direct factors using the ISM data only. Each symbol represents the benthic community described by the ISM at a specific survey site. Dashed lines enclose clusters with at least 40% similarity, showing similarity among the Direct Impact sites, and higher heterogeneity among the Indirect sites. See text for discussion of Sites 1, 2, 5, 46, 55, and 56. A stress value of 0.18 falls within the range indicating that the plot represents a useful two-dimensional representation.

3.1.2.2 Coral

When only coral Taxon Richness was analyzed, the coral communities described by the PM were significantly different from those described by the ISM (ANOSIM; R=0.385; p=0.001). Examination of the nMDS (Figure 3.4) showed that the method-site pairs do not lie close to each other. Also, two ISM sites were clustered among the PM sites. These two sites (Sites 8 and 28) had fewer coral taxa (Site 6 = 1 coral taxon; Site 8 = 4 coral taxa; Site 28= 2 coral taxa) than the other ISM sites (mean ± SE: 8 ± 0.6 coral taxa). This lower coral Taxon Richness is in line with that estimated by the PM (3 ± 0.3 coral taxa). No significant differences were found among the strata.

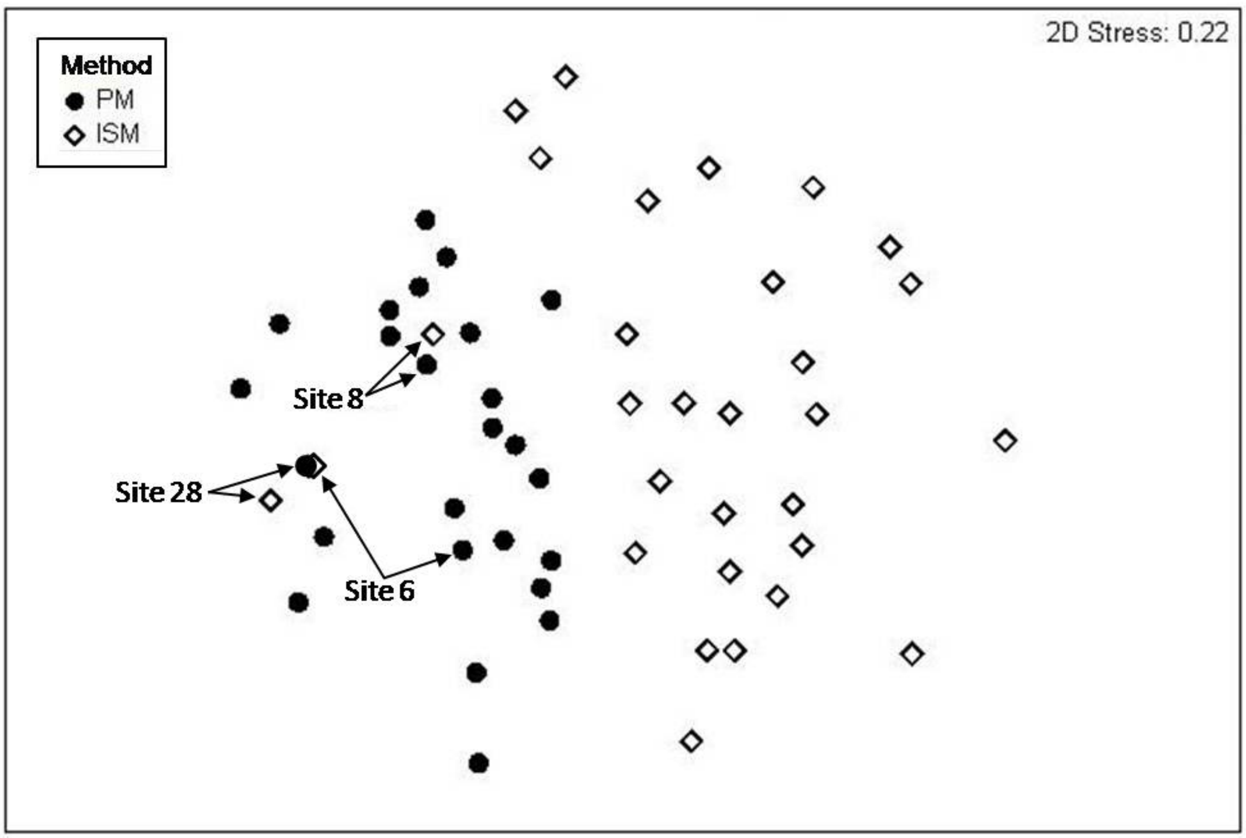


Figure 3.4. The nMDS plot for Coral Taxon Richness. Symbols represent the coral community described by either the ISM or PM at a survey site. See text for discussion of Sites 6, 8, and 28. Due to the high stress value, this figure should be viewed with caution.

3.2 Benthic Cover

3.2.1 Comparison of Methods

Benthic Cover is best analyzed using a multivariate approach that takes into account all of the data simultaneously. Therefore no summary statistics (*e.g.*, overall totals) were calculated or compared using univariate pair-wise statistical approaches. While extensive tables of percent cover means could be generated, they would create extensive tables that would have little relevance to this study. For this reason, only multivariate statistical approaches were conducted for the Benthic Cover data.

A 60x60 Bray-Curtis Similarity matrix was generated using square-root transformed data from all method-sites. If the methods were directly comparable, the similarity value between the community described by the ISM and PM at the same site (*i.e.*, method-site pair) would be equal to one and would have a rank of one for that method-site.

At each level of taxonomic resolution examined, the method-site pairs ranked significantly lower than one (Table 3.3). The similarity of the two methods increased from 0.36 to 0.89 as the taxonomic resolution became more coarse. However, even at the coarsest taxonomic grouping (*i.e.*, Grouped), the two methods did not achieve the top-ranked similarity.

For cover of coral by colony morphology, the comparability between the two methods improved, but the rank was still significantly greater than one (Wilcoxon; $W=595$; $p<0.001$). While still having a median rank significantly higher than one, the inter-quartile range encompassed the expected value, showing that at some sites the two methods are comparable in describing the coral community by colony morphology.

Table 3.3. The mean (±SE) similarity between the method-site pairs and its median (with interquartile range) rank when compared to the 59 other similarity values for the method-site. If the methods are directly comparable, the method-site pairs would have a similarity value of one and a rank of one. All = finest taxonomic resolution, Reduced = intermediate taxonomic resolution, Grouped = coarsest taxonomic resolution (*i.e.*, Algae, Coral, Sponge, ect.); Coral Only = finest taxonomic resolution specific to corals; Coral Morph = groupings based on general morphological form.

Taxa Resolution	Similarity	Rank	Wilcoxon Test
All	35.7 ± 1.9	25.5 (13-33)	W=1830, p<0.001
Reduced	56.8 ± 2.0	11.0 (2.3-18)	W=1326, p<0.001
Grouped	85.7 ± 0.8	6.0 (2-12)	W=1431, p<0.001
Coral Only	66.8 ± 3.0	3.0 (1-10)	W=820, p<0.001
Coral Morph	74.8 ± 3.0	2.0 (1-5)	W=595; p<0.001

3.2.2 Comparison of Communities

3.2.2.1 All Taxa (Finest Taxonomic Resolution [*e.g.*, finest resolution achievable by each method])

When All Taxa were analyzed, a significant difference was found between the communities described by the ISM and PM (ANOSIM; $R=0.803$; $p=0.001$). The nMDS plot (Figure 3.5) showed two distinct clusters of points, one corresponding with each of the methods. A significant strata effect was observed (ANOSIM; $R=0.194$; $p=0.001$). No evidence of an interaction between the factors was found. Multiple comparisons revealed that the strata sorted

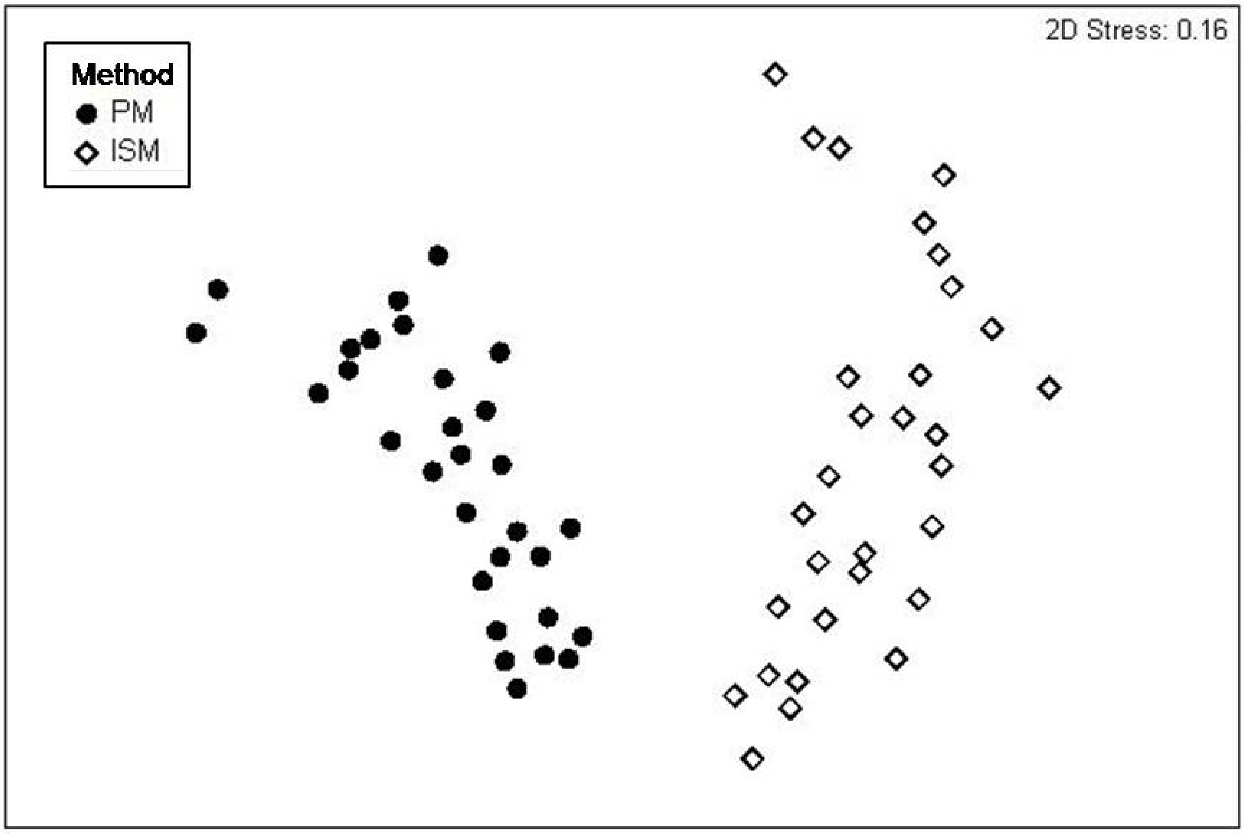


Figure 3.5. The nMDS plot for Benthic Cover of All Taxa. Symbols represent the benthic community described by either the ISM or PM at a survey site. A stress value of 0.16 falls within the range indicating that the plot represents a useful two-dimensional representation.

primarily by impact type with the exception of the Indirect-Flat and Direct-Slope strata, which did not differ. A SIMPER analysis showed that no single taxa explained a majority of the difference between the methods or among the strata, rather the differences between the methods and among the strata were associated with differences in taxonomic resolution. The ISM found more taxa, many of which were presumably lumped into higher taxonomic groupings by the PM (*e.g.*, *Halimeda* spp., algae spp. etc.)

3.2.2.2. Reduced Taxa (Intermediate Taxonomic Resolution [*e.g.*, mainly genera and broader])

When the Reduce Taxa were analyzed, the same patterns as observed for the All Taxa analysis persisted. The two methods continued to be significantly different (ANOSIM; R=0.538; p=0.001). In the nMDS plot (Figure 3.6), the distance between the cluster of points for each method has decreased when compared to the All Taxa analysis (Figure 3.5). The lower edges of the two clusters were nearly touching. The distance between the clusters is related to their similarity, so the sites along the bottom of the two clusters are more similar than those at the top. However, even with this apparent lessening of distance between the clusters, the two methods still described significantly different communities.

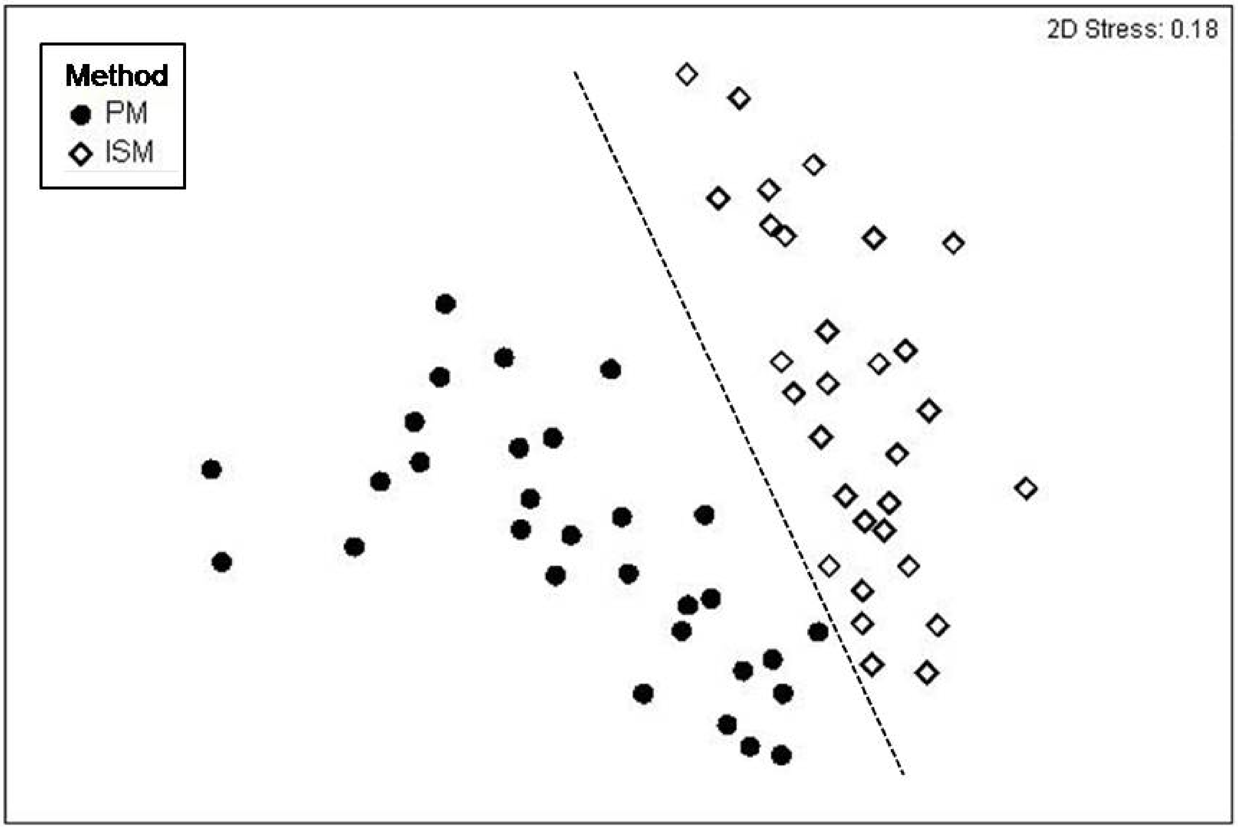


Figure 3.6. The nMDS plot for Benthic Cover of Reduced Taxa. Symbols represent the benthic community described by either the ISM (right of dotted line) or PM (left of dotted line) at a survey site. A stress value of 0.18 falls within the range indicating that the plot represents a useful two-dimensional representation, but is sufficiently high that the figure should be viewed with caution.

The distance between the two clusters was related to the abundance of *Porites rus* at a site. At sites dominated by *P. rus*, the communities described by the two methods were more similar than at sites with low *P. rus* abundance (Figure 3.7b). The communities described by each method became less similar as the amount the *P. rus* decreased and other organisms, primarily marine algae (Figure 3.7a, c, and d) replaced it. This increasing difference between the two methods was associated with the greater taxonomic resolution possible with the ISM compared with the PM (Figure 3.8). As these taxa became more abundant in the community, the similarity between the communities described by the two methods decreased.

Both methods showed significant differences among the strata (ANOSIM; R=0.173; p=0.002). Multiple comparisons showed a similar pattern of differences as that observed with All Taxa, but the differences were not as pronounced (*e.g.*, smaller R-values). In general, communities at Direct Impact sites were significantly different from those at Indirect Impact sites, with the exception of the Indirect-Flat and Direct-Slope strata, which did not significantly differ.

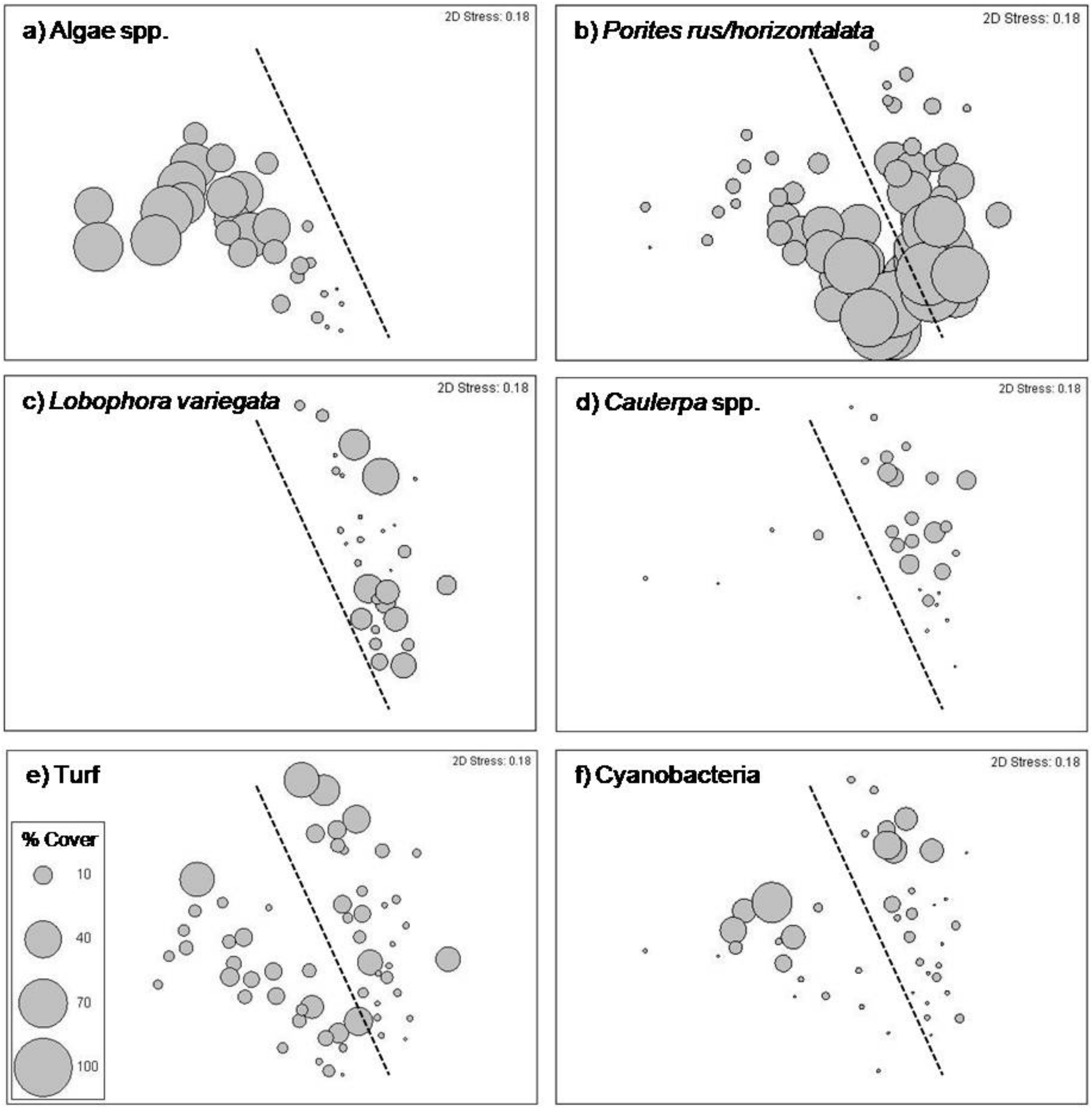


Figure 3.7. The percent cover of six taxa that explained >5% of the difference between the ISM (right of dotted line) and PM (left of dotted line) methods overlain on the nMDS plot from Figure 3.6. a) algae spp. (17.9% of the difference explained); b) *Porites rus/horizontalata* (10.4%); c) *Lobophora variegate* (6.8%); d) *Caulerpa* spp. (5.6%); e) turf (5.4%); f) cyanobacteria spp. (5.2%). Differences in the percent cover of these taxa accounted for 51.3% of the observed dissimilarity between the two methods. Additionally, *P. rus/horizontalata* and algae spp. account for approximately 30% of the observed dissimilarity between the strata.

Differences in the strata appear to be related to changes in cover of *P. rus* and algae (Figure 3.7a, b). As *P. rus* decreased, it was replaced primarily by algae taxa (algae spp. for PM and numerous algae taxa for ISM). Changes in the cover of *P. rus* and algae spp. accounted for approximately 30% of the difference among the strata.

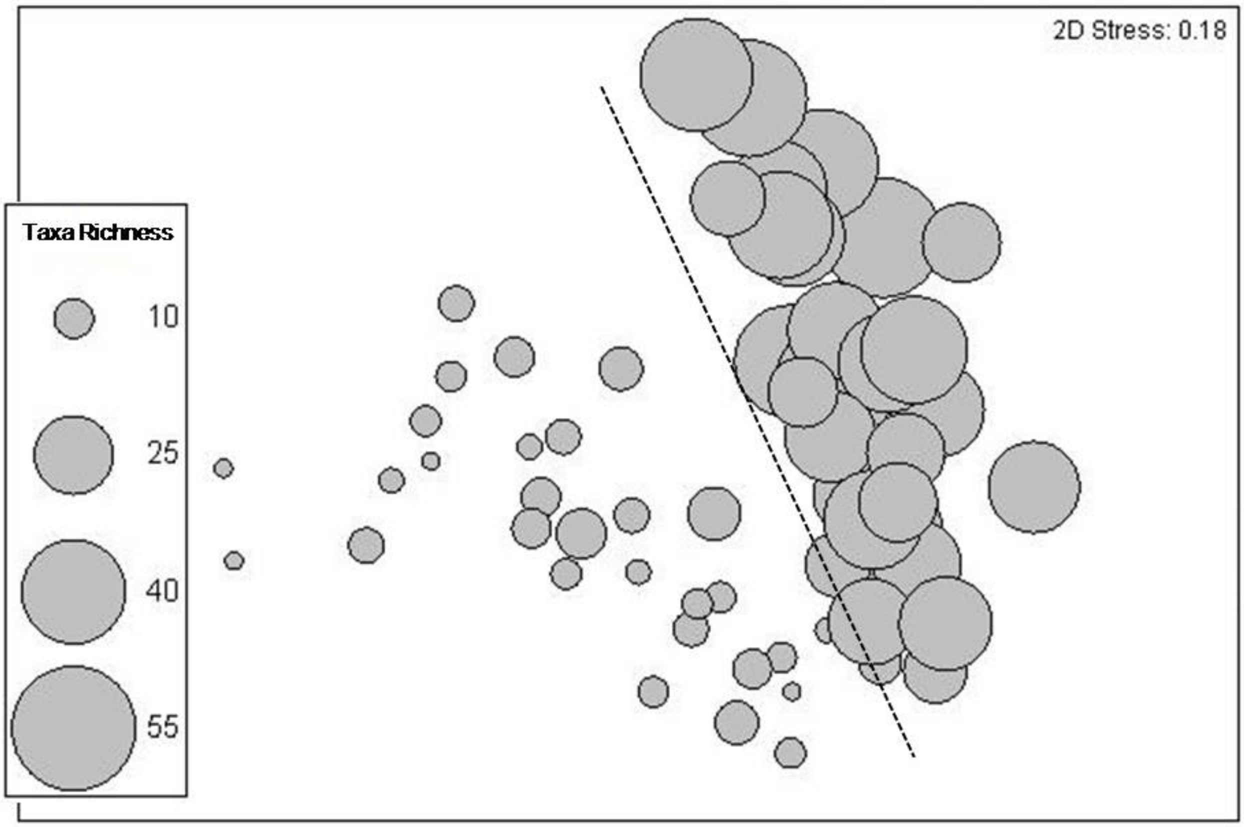


Figure 3.8. The difference between the ISM (right of dotted line) and PM (left of dotted line) is significantly correlated with Taxon Richness (ρ=0.402; p=0.01). The ISM identified more taxa than the PM.

3.2.2.3 Grouped Taxa (Coarsest Taxa Resolution [e.g., algae, coral, other etc.])

When the taxa were combined into coarse taxonomic groups, no significant difference was found between the ISM and PM (ANOSIM; R=0.022; p=0.299). The nMDS plot showed the clusters of points corresponding to the ISM and PM overlapped. However, even though the communities described by each method could not be distinguished, the direct comparability between the two methods was low. Rarely were method-site pairs nearest to each other (*e.g.*, see Site 7 as compared to Site 1 in Figure 3.9). A significant strata effect was found (ANOSIM; R=0.142; p=0.008), but only the Indirect-slope differed from all other strata. No other differences were found.

3.2.2.4 Coral Taxa

No significant difference was found between the ISM and PM when cover of coral taxa were analyzed (ANOSIM; R=-0.001; p=0.419). The nMDS plot (Figure 3.10) showed an unusual pattern of points. Points for the two methods overlap on the right side of the plot, showing a high amount of similarity in the communities described by the two methods. The sites had high cover of *P. rus*. The dominance of *P. rus* decreased moving left across the plot, and the communities described by the two methods began to show evidence of divergence as the points

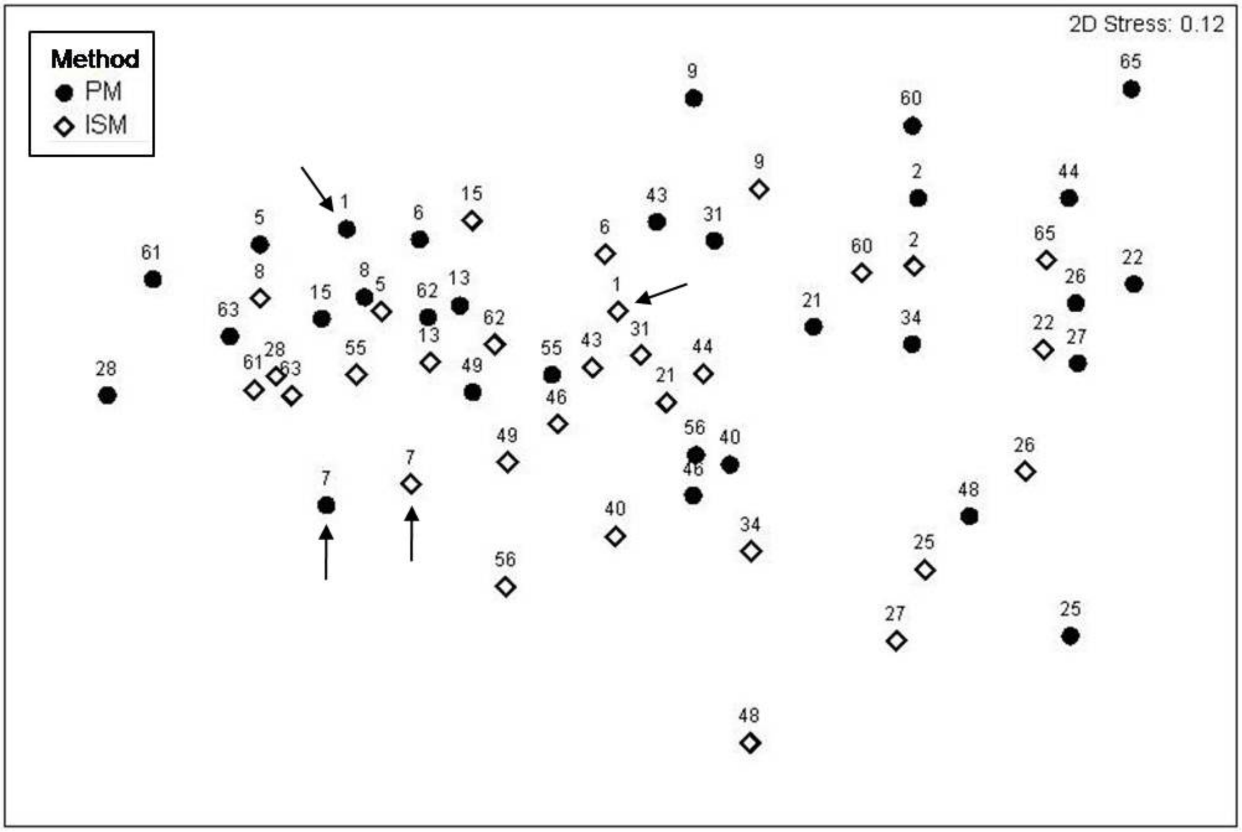


Figure 3.9. The nMDS plot for Benthic Cover of Grouped Taxa. Symbols represent the benthic community described by either the ISM or PM at a survey site. Numbers correspond to the survey site identification (see Figure 1.1). The communities described by the two methods did not differ. However, method-site pairs were not nearest to each other for most sites (*e.g.*, compare Site 7 with Site 1 [marked with arrows]), showing poor direct comparability between the ISM and PM. A stress value of 0.12 falls within the range indicating that the plot represents a useful two-dimensional representation.

began to “fan” apart. This divergence is associated with taxonomic richness, which increases toward the top of the plot (Figure 3.10).

No significant differences were found among the strata (ANOSIM; R=0.055; p=0.075), but a second order analysis revealed an interaction among the factors. When the methods were examined independently, no significant strata effect was found for the PM. For ISM significant effect was found (ANOSIM; R=0.095; p=0.001); coral communities on the Indirect-Slopes significantly differed from all other strata. No other differences were observed.

3.2.2.5 Coral Morphological Groups

When the coral community was examined at the morphological level, the ISM and PM showed no significant difference between the methods (ANOSIM; R=-0.068; p=0.986) or among the strata (ANOSIM; R=0.056; p=0.093). Agreement between the two methods was associated with the percent cover of *P. rus* at a site (Figure 3.11). The comparability of the two methods increased as the percent cover of *P. rus* increased.

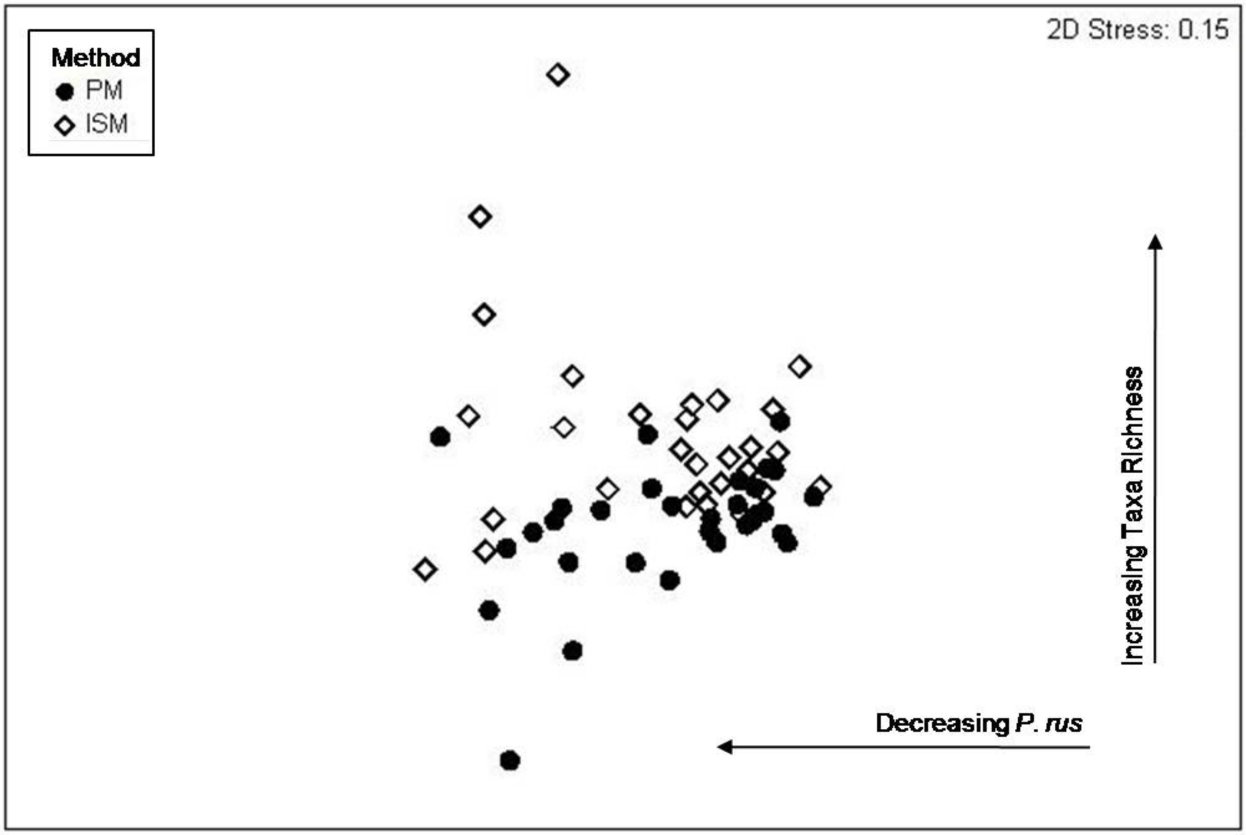


Figure 3.10. The nMDS plot for percent cover of Coral Taxa. Symbols represent the benthic community described by either the ISM or PM at a survey site. The communities described by the two methods did not differ. A stress value of 0.15 falls within the range indicating that the plot represents a useful two-dimensional representation.

3.3 Coral Colony Density

The PM systematically overestimated the true Coral Colony Density (see section 2.4.1). While not ideal, a known overestimation in one set of data does not necessarily preclude a statistical analysis because the overestimation can be incorporated into the interpretation of the results. An initial analysis was conducted on the Coral Colony Density data, but additional problems with the PM data set were found. Specifically, a data inconsistency, separate from the overestimation described above, was identified. The inconsistency was corrected but not the systematic overestimation. The new data was received too late (24 days after the agreed upon date) to re-run the analyses in time for inclusion in this report. While no statistical comparison could be run, the failure of the PM to produce timely and appropriate Coral Colony Density data demonstrates that the two methods are not directly comparable within the scope of this study and, therefore, it is concluded at this time that the PM was unable to describe the coral community using Coral Colony Density.

3.4 Coral Colony Size

Multiple methodological problems were identified with the Coral Colony Size data collected by the PM (see section 2.4.1). In addition to the overestimation error associated with the Coral

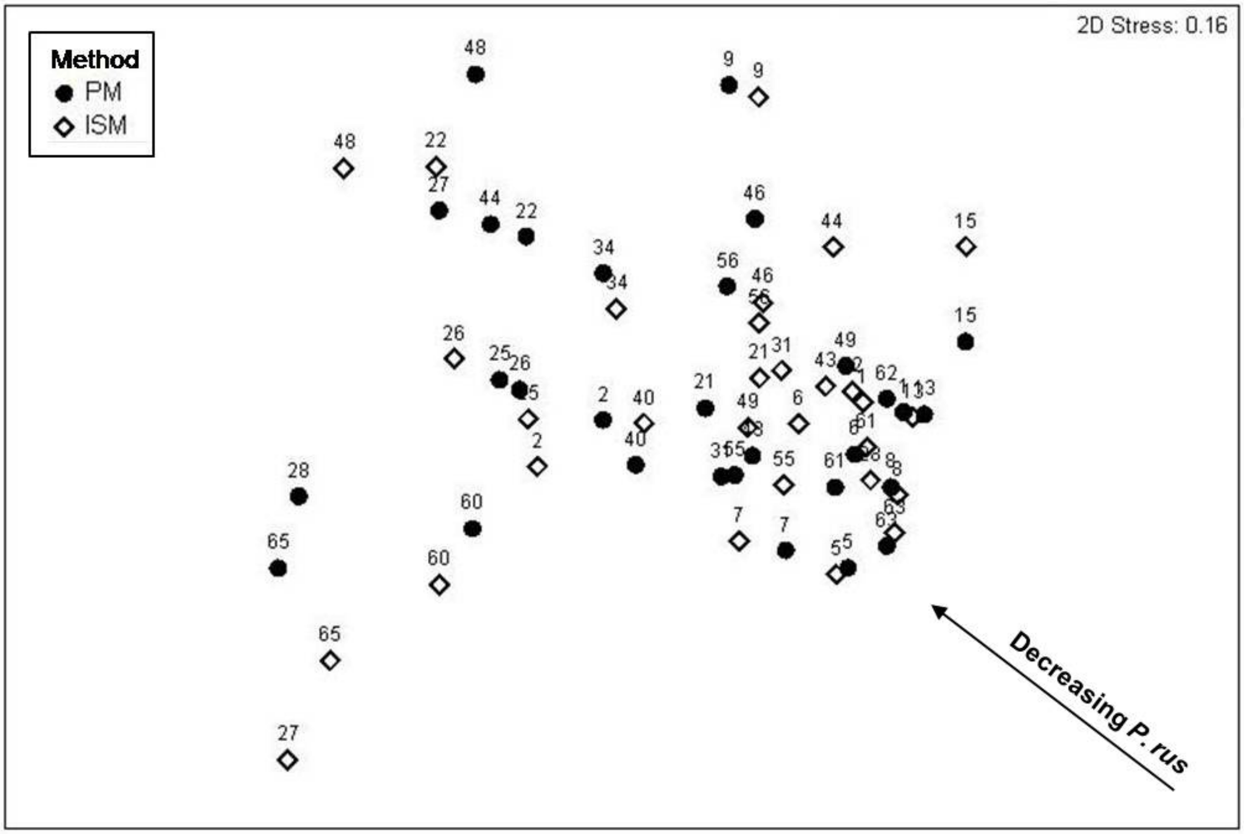


Figure 3.11. The nMDS plot for percent cover of coral taxa by general morphology. Symbols represent the benthic community described by either the ISM or PM at a survey site. Numbers correspond to the survey site identification (see Figure 1.1). The communities described by the two methods did not differ. Based on the proximity of the method-site pairs, the direct comparability between the methods was good for some sites (e.g., Sites 5, 6, 9, 34 etc.), but not all. However, overall methods were not directly comparable. A stress value of 0.16 falls within the range indicating that the plot represents a useful two-dimensional representation.

Colony Densities, the size estimates as provided by the PM do not actually measure individual coral colony size. Size measurements were not made of the coral colony, only the longest visible dimension within the photo-quadrat. This artificially truncated any colony that extended beyond the border of the photo frame into a randomly-selected smaller size class with a maximum size limitation of 120 cm (the diagonal dimension of the photo-quadrat). As a result, the data collected has no easily interpretable biological or ecology meaning.

This issue may not be correctable without collecting additional photo-quadrats adjacent to the original ones in order to assess border colonies. While no analysis could be run, the lack of appropriate Coral Colony Size data resulting from the PM demonstrates that the two methods are not directly comparable in this study and that the PM was unable to describe the size frequency distribution of the coral community.

<u>3.5 Coral fragments</u>

A total of 1588 coral fragments from nine species were found (Table 3.4.), but the number of fragments found by the PM is known to be overestimated (see section 2.3.1). *Porites* *rus/horizontalata* accounted for over 54% of all observed fragments. Fragments were observed at every site but one (site 22), but the ISM found fragments at more sites (26 of 29) than the PM (22 of 29 sites).

The ISM found significantly more total fragments at a site than the PM (1-sample Wilcoxon; W=107; p=0.030). The ISM found more fragments for every species except *Pavona cactus* and *P. varians* (only one fragment found). Due to insufficient bottom time, the ISM was unable to count *P. cactus* fragments at Sites 1, 13, and 15, which were three of the six sites where *P. cactus* fragments were found by the PM and accounted for 60% of the *P. cactus* fragments counted by the PM. At sites where fragments of *P. cactus* were counted by both methods, nearly identical fragment total were found by the ISM (111 *P. cactus* fragments) compared to the PM (108 *P. cactus* fragments).

However, when the known overestimation present in the PM coral fragment data is considered, the differences between the two methods may be magnified. The true difference in the coral fragment data collected by the ISM and PM is larger than is shown here. Unfortunately, without correcting the PM coral fragment data it is impossible to guess at the magnitude of overestimation.

The comparability between the methods was significantly affected by strata (ANCOVA; F=3.07, df= 3,24; p=0.047), but follow-up pairwise multiple comparisons were not sensitive enough to detect differences among them.

Comparability between the methods decreased with increasing rugosity (ANCOVA; F=8.82, df= 1,24; p=0.007). At low rugosity, the two methods found similar numbers of fragments, but the

Table 3.4. Total number of fragments (n) and their percent of the total (%) found using the PM and ISM.

	PM		ISM	
Taxa	n[1]	%	n	%
Acropora formosa	0	0	1	0.1
Acropora spp. (corymbose)	12	1.8	34	3.6
Pavona cactus	268	40.4	111[2]	11.7
Pavona decussata	0	0	26	2.7
Pavona varians	1	0.2	0	0
Pectinia paeonia	0	0	5	0.5
Pocillopora damicornis	3	0.5	13	1.4
Porites cylindrica	125	18.8	141	14.8
Porites rus/horizontalata	254	38.3	620	65.2
TOTAL	663		951	

[1]Counts made by the PM are known to be overestimates (see section 2.4.1).
[2]Fragments were too numerous to count at Sites 1, 13, and 15 and are not included in this value.

difference between the methods increased as rugosity increased. When examined, the total number of coral fragments found using the PM was uncorrelated with rugosity (Pearson Product Moment; r= 0.250, p=0.190), whereas fragments found with the ISM increased with rugosity (Pearson Product Moment; r= 0.609, p<0.001).

Cover of *Porites rus* was significantly correlated with rugosity (Pearson Product Moment; r= 0.656, p<0.001) and was most likely the primary source of increasing topographic complexity within the survey area. For both methods, *P. rus* was a significant source of coral fragments (Table 3.4). The slope of the relationship between *P. rus* fragments and *P. rus* cover was steeper for the ISM than the PM (Figure 3.12). The correlation was also weaker for the ISM, as shown by the greater scatter of points. This different relationship between the two methods for the detection of *P. rus* fragments with changes in *P. rus* cover was responsible for lower comparability between the two methods at higher rugosity..

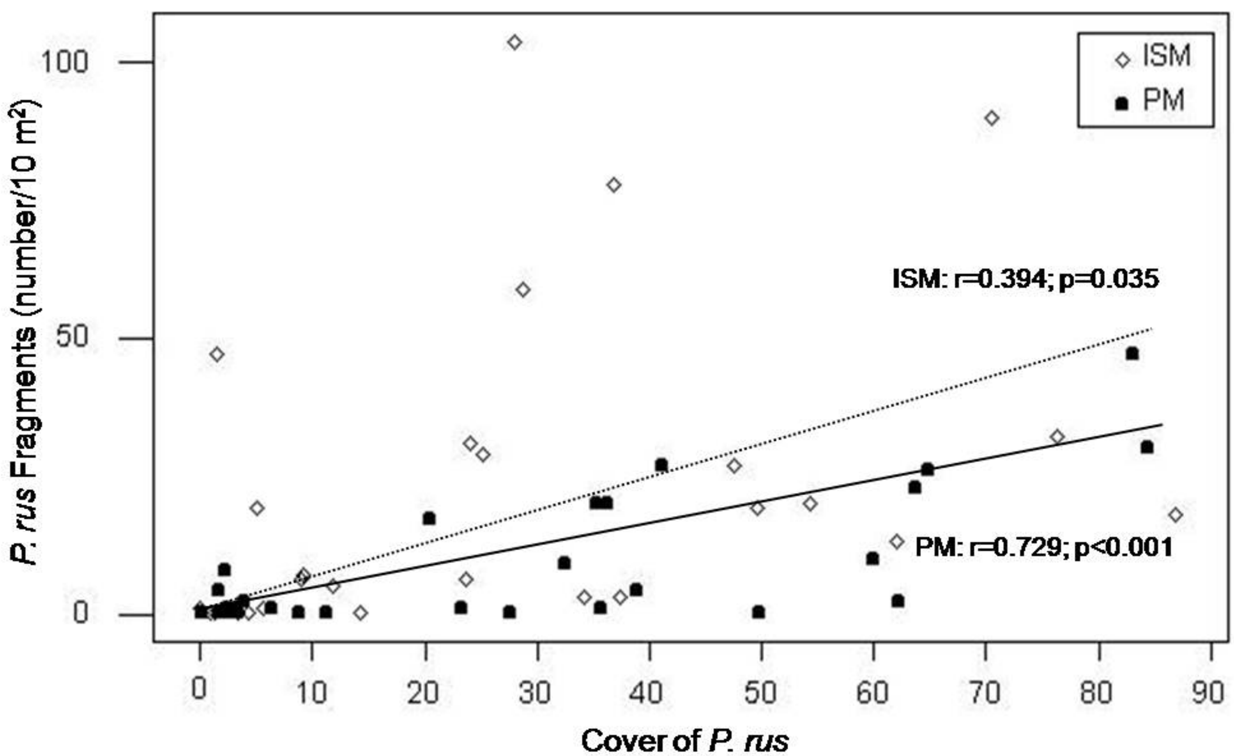


Figure 3.12. The slope of the relationship between *Porites rus* fragments and *P. rus* cover is steeper (yet more variable) for the ISM (dotted line) than for the PM (solid line). Both ISM and the PM correlations are significant.

3.6 Percent Colonies with Complete Fission and Percent Colony Mortality

The ISM found a significantly higher proportion of the colonies at a site that had undergone complete fission than did the PM (Paired t-test; t=-8.22; df=28; p<0.001). The ISM identified 20 taxa having undergone complete fission, whereas the PM identified five taxa (Table 3.5). Of the colonies undergoing complete fission, the ISM estimated a significantly higher percent mortality that the PM (Paired t-test; t=-7.96; df=28; p<0.001).

Two taxa for which more than one colony was identified having undergone complete fission were identified by both methods. For *Pavona cactus*, the ISM found over five times more colonies undergoing fission than did the PM. For *Porites rus*, this value was even higher; the ISM identified 34 times more colonies having undergone complete fission compared to the PM. For both taxa, the average percent mortality of those colonies that had undergone complete fission did not differ.

Table 3.5. Mean (±SE) percent of colonies per site undergoing complete fission and mean (±SE) percent mortality of colonies that have undergone complete fission.

	% Fission		% Mortality[1]	
Taxa	PM	ISM	PM	ISM
Acropora formosa/aspire	-	0.3 ± 0.3	-	15
Astreopora myriophthalma	-	2.2 ± 1.8	-	60.8 ± 2.2
Favites russelli	-	3.4 ± 3.4	-	65
Galaxea fascicularis	-	4.3 ± 3.5	-	5.0 ± 0.8
Herpolitha weberi	-	3.4 ± 3.4	-	6
Hydnophora exesa	-	0.5 ± 0.5	-	4
Lobophyllia hemprichii	-	1.7 ± 1.7	-	35
Montipora grisea	-	0.5 ± 0.5	-	2
Montipora sp.	0.4 ± 0.4	-	25	-
Pachyseris speciosa	1.1 ± 1.1	3.4 ± 3.4	6	2
Pavona cactus	0.3 ± 0.2	1.6 ± 0.9	40.3 ± 10.1	38.7 ± 4.7
Pavona cf. bipartita	-	3.4 ± 3.4	-	7
Pavona decussata	-	0.1 ± 0.1	-	2
Pectinia paeonia	-	0.5 ± 0.5	-	25
Pocillopora damicornis	-	1.3 ± 1.2	-	55.0 ± 5.3
Porites cf. solida	-	1.7 ± 1.7	-	55
Porites cylindrica	-	11.9 ± 3.7	-	36.7 ± 5.0
Porites lobata	-	2.3 ± 2.3	-	7
Porites lutea	<0.1 ± <0.1	10.1 ± 5.0	7	27.4 ± 4.7
Porites rus/horizontalata	0.3 ± 0.2	10.1 ± 1.6	32.8 ± 7.8	38.6 ± 4.9
Psammocora contigua	-	0.3 ± 0.3	-	8

[1]No SE for n=1 colony

3.7 Coral Growth Anomalies

Neither method noted the presence of gross growth anomalies at any site. The PM noted the presence of several "unusual" conditions (Table 3.6). These "unusual" conditions were not collected as part of the data for the ISM. The PM observed these unusual conditions in photographs at 13 of the 30 survey sites.

Table 3.6. "Unusual" coral conditions noted by the PM.

Site	Symptom	Coral	Note
5	"blue nodes"	*Porites lutea*	-
	"pink spot"	*Porites rus*	Observed on 2 colonies
7	discoloration	*P. lutea*	4 colonies
	"pink spot"	*P. lutea*	2 colonies
	"pink discolor"	*P. lutea*	-
21	bleaching	No ID provided	-
22	bleaching	*P. rus*	2 colonies
25	bleaching	*P. rus*	3 colonies
26	bleaching	*P. rus*	3 colonies
27	bleaching	*P. rus*	1 colony
31	"pink spot"	*P. rus*	5 colonies
	bleaching	*P. rus*	2 colonies
34	bleaching	*P. rus*	1 colony
40	bleaching	*P. rus*	3 colonies
43	bleaching	*P. rus*	1 colony
46	bleaching	No ID provided	-
65	bleaching	*P. lutea*	1 colony

4.0 Discussion

One of the most important decisions a field researcher must make is the selection of a survey method that will perform in the site-specific conditions of the study area to collect the target data with the resolution, precision, and accuracy necessary to achieve the research or survey objectives. This study compared the performance of a photo-quadrat method and an *in situ* quadrat method in the collection of a suite of coral reef benthic data within a heterogeneous coral reef ecosystem. While the primary goal of this study was to assess how well the two methods compared in a specific location (near Polaris Point, Apra Harbor, Guam), it was hoped that the study would also reveal some general insights into the wider applicability of each method. It is important to note that this report draws no conclusion about which method is "better." This conclusion involves a value judgment that can only be made after considering the project-specific objectives; the type, resolution, and precision of the data to be collected; and the site-specific conditions of the study area.

4.1 Method Comparison

Overall, the data collected by the PM and ISM at the same sites compared poorly (Table 4.1). This poor comparability resulted primarily from the different taxonomic resolutions achievable with each method. Almost seven times more taxa were identified by the ISM than were identified by the PM (an average of 25 more taxa per site). Not surprisingly, similarities in the data collected by the two methods increased as data were lumped into coarser taxonomic groups. However, even at the coarsest taxonomic resolution (*i.e.*, Grouped Taxa, where data were combined into broad categories as simple and encompassing as coral, algae, sponge etc.), a statistically significant difference remained between the two methods (Table 3.2).

The simplest explanation for the discrepancy in taxonomic resolution between the PM and ISM is that many taxa could not be identified from the photographs. This has been observed in other studies, where taxonomic richness from a PM approach is low relative to other *in situ* methods (Foster et al. 1991, Miller et al. 2003). When making observations *in situ*, it is possible for observers to examine organisms from multiple angles, pick them up, and collect specimens, if necessary, for later laboratory identification by taxonomic specialists. This is not possible with the PM alone.

In this particular study, it is also possible that the observers conducting the ISM had more experience working in Guam and a wider range of taxonomic expertise than the observers who employed the PM. The ISM team included a phycologist, a sponge expert, a general invertebrate specialist, and multiple coral biologists. All of these individuals had considerable experience working in Guam and the Mariana Islands. The PM team was limited only to several experienced coral biologists and this may have resulted in reduced taxonomic resolution for the non-coral taxa. However, even the coral Taxon Richness revealed by the PM was approximately a quarter of that revealed by the ISM, so differences in taxonomic expertise alone do not seem to fully explain the discrepancies between the two methods. The only way to fully address this particular issue is to have the same personnel conduct both the ISM and PM, which was not possible given the project-specific limitations underlying this study.

On coral reefs, rugosity is often correlated with species richness and community structure (Idjadi & Edmunds 2006, Pratchett et al 2008 and references therein, Alvarez-Philip et al. 2009). A potential shortcoming of the PM is its reduction of a three-dimensional habitat into a flat, two-dimensional planar projection (Hill and Wilkinson 2004). As a result, the performance of the PM can decrease with increasing rugosity (Hill and Wilkinson 2004). In contrast, the ISM can accommodate changes in rugosity because observers are able to examine vertical surfaces from multiple angles, look beneath overhanging features, and spot organisms in interstitial spaces in the reef.

In this study, benthic rugosity had an important and somewhat unexpected influence on the results of the analysis. The coral *P. rus*, which has a variable and highly rugose growth form, was significantly correlated with rugosity. As *P. rus* increased in dominance, however, Taxon Richness at the site tended to decline for the ISM or remain constant in the case of the PM. As a result, the comparability of the methods was often uncorrelated with rugosity because the potential difficulties for the PM associated with higher rugosity were off-set by improved

Table 4.1. Summary of the findings for the direct comparison of the ISM and PM. These analyses examined whether the data collected by the two methods at the same site were statistically different. "Data Different" summarizes the result of the statistical analyses that tested for significant differences in the data collected for the ISM and PM (Yes=data were significantly different; No=data were not significantly different.

Variable	Data Different? Yes	No	Notes
Taxon Richness			
Total Taxon Richness	X		ISM>PM; rugosity significant
Shannon-Weiner Index	X		ISM>PM; strata significant
All Taxa	X		
Coral Taxa	X		
Benthic Cover			
All	X		
Reduced	X		
Grouped	X		
Coral	X		
Coral Morph	X		
Coral Colony Density			
Coral Taxa	†		PM was unable to provide revised data within the agreed study timeline
Coral Morphology	†		PM was unable to provide revised data within the agreed study timeline
Coral Colony Size			
Size Frequency	†		PM was unable to provide required measures of coral colony size for comparison
Coral Fragments			
Total Fragments	X		ISM>PM; rugosity and strata significant
Percent Fission			
% Fission	X		ISM>PM
Percent Mortality			
% Mortality	X		ISM>PM
Coral Growth Anomalies			
% Occurrence		X	Gross anomalies were not identified within the communities by either method

†No statistical comparison of the methods was conducted for data on Coral Colony Density (section 3.3) and Coral Colony Size Class (section 3.4), but a determination of not comparable was made for this study based on the failure of the PM to produce appropriate data for analysis. See appropriate results section for additional information on each analysis.

performance of the PM with the decrease in Taxon Richness. When rugosity effects were seen (*i.e.*, decrease in Taxon Richness, increase in number of coral fragments), they were consistent with what would be expected when a three-dimensional structure is reduced into a planar view: for the PM, data changed little or not at all with changes in rugosity while the ISM did change.

4.2 Community Comparisons

Ultimately, the goal of any comparison of methods comparison should be to determine whether the communities described by each method are similar. At finer taxonomic resolutions, the two methods failed to describe the same coral reef benthic community (Table 4.2) when using either Taxon Richness or Benthic Cover data. Only when taxa were lumped into coarse groups (*i.e.*, Grouped Taxa and Coral Morphology) did the methods describe similar communities. However, based on the direct comparison of the methods, this positive result should be viewed with caution

Table 4.2. Summary of the findings for comparison of the communities described by the ISM and PM. These analyses examined whether the two methods described statistically different communities over the study area. "Data Different" summarizes the result of the statistical analyses that tested for significant differences between the communities described by the ISM and PM (Yes= communities described by the two methods were significantly different; No= communities described by the two methods were not significantly different).

Variable	Data Different? Yes	Data Different? No	Notes
Taxon Richness			
All Taxa	X		strata significant (ISM only)
Coral Taxa	X		
Benthic Cover			
All	X		strata significant
Reduced	X		strata significant
Grouped		X	strata significant
Coral	X		strata significant (ISM only)
Coral Morph		X	
Coral Colony Density			
Coral Taxa	†		PM was unable to provide revised data within the agreed study timeline
Coral Morphology	†		PM was unable to provide revised data within the agreed study timeline
Coral Colony Size			
Size Frequency	†		PM was unable to provide required measures of coral colony size for comparison

†No statistical comparison of the methods was conducted for data on Coral Colony Density (section 3.3) and Coral Colony Size Class (section 3.4), but a determination of not comparable was made for this study based on the failure of the PM to produce appropriate data for analysis. See appropriate results section for additional information on each analysis.

because it represents an "inconclusive" outcome (see section 2.6.1), which has resulted most likely from insufficient sampling within the study area. Adequate statistical sampling could result in a significant difference being found for both the Grouped Taxa and the Coral Morphology. It is currently unclear as to what sampling effort would be.

It was apparent from the analyses conducted at different levels of taxonomic resolution, that identifying Taxon Richness is important for distinguishing spatial variability within the study area. As the taxa resolution became more coarse, the ability to detect differences between strata decreased (*i.e.*, the R-statistic of the ANOSIM decreases). When using benthic cover data, both methods were able to similarly distinguish the Indirect-Slope from the other strata. When only the coral taxa were considered, however, the PM was no longer able to distinguish and strata, whereas the ISM continued to distinguish the Indirect-Slope from the others (Figure 4.1). This result is troubling considering the widespread use of photographic methods to collect coral cover data in the absence of non-coral taxa. Whether this result is specific to this study is unclear and warrants additional investigation from the scientific community.

The similarity of the communities described by the PM and ISM improved when *P. rus* was a dominant component of the reef community. The PM did well identifying the benthic cover provided by *P. rus* and the method may perform similarly to ISM in situations where the benthic community has low Taxon Richness and the common organisms can be easily identified in photographs. However, even when *P. rus* was dominant, the community described by the PM was still significantly different from the ISM. While *P. rus* may have dominated at a site, it did not exclude all other taxa, and this remaining Taxon Richness appears to have been captured by the ISM but not the PM.

4.3 Density-based and Coral Colony Size Data

One of the primary objectives of this study was to compare the performance of the PM and ISM across a wide variety of data types. The PM traditionally has been used for collection of benthic cover data, which continues to be a mainstay of coral reef ecology. Data on coral colony density and colony size have become more common because of the potential demographic information they contain (Hall and Hughes 1996, Bak and Meesters 1998, Birkeland 1999, Meesters et al. 2001), which is missing from benthic cover data alone (Bak and Meesters 1998). Collection of density-based data requires that observers delineate coral colonies and use appropriate quadrat sampling methods to avoid over- or underestimations.

In this study it was not possible and/or appropriate to compare Coral Colony Density and Coral Colony Size data collected by the two methods. Methodological issues (see section 2.4.1) and data inconsistencies either precluded analysis entirely (in the case of the Coral Colony Size data) or left insufficient time to complete the analysis for inclusion in this report (in the case of Coral Colony Density data).

Concerns about insufficient quadrat size and criteria for delineating certain coral taxa have been raised and are valid for consideration and discussion. The optimal quadrat size would sample enough area to capture sufficient numbers of individuals to achieve high statistical

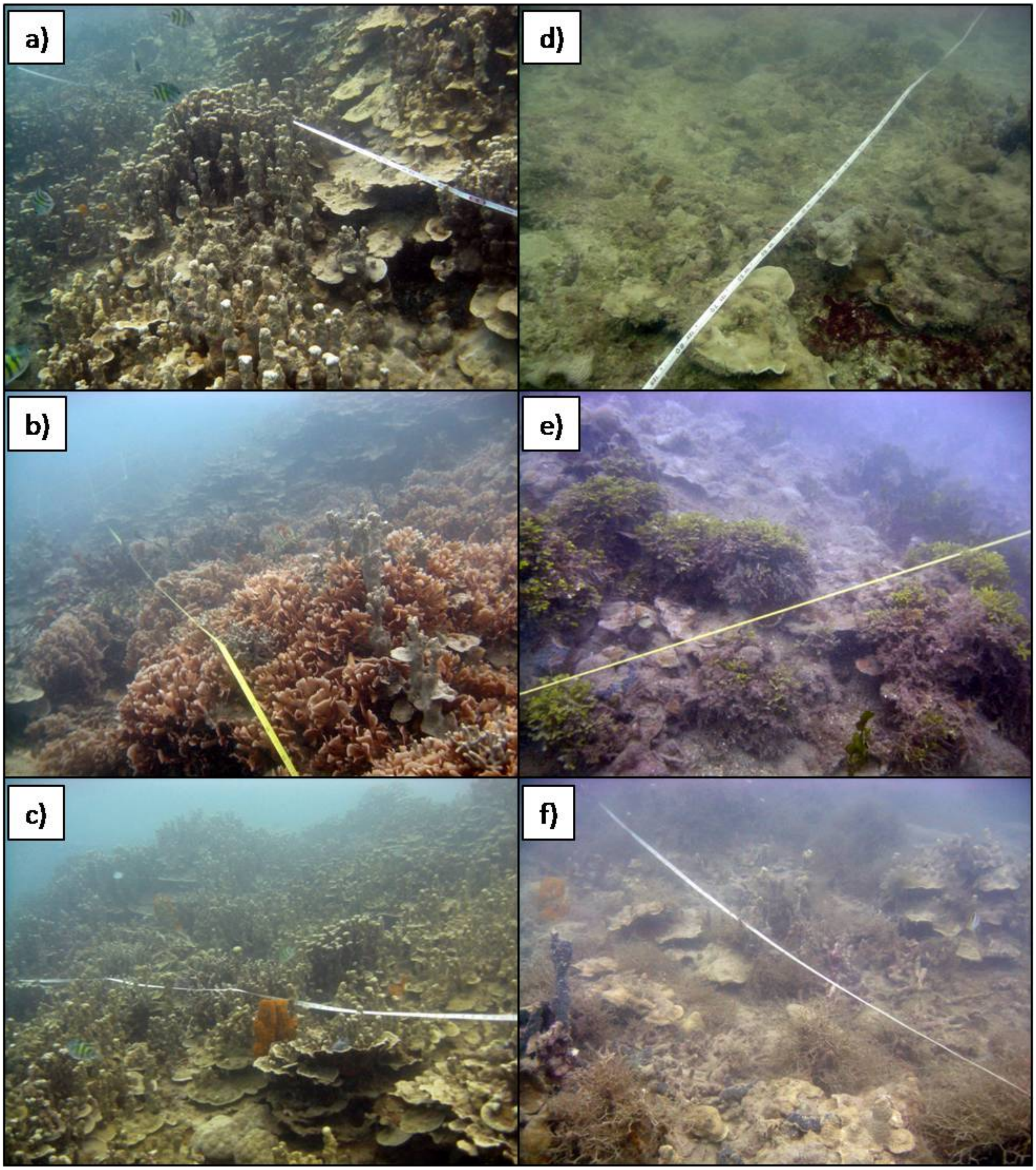


Figure 4.1. Habitat photos taken at three Indirect-Slope (a,b,c) and three Direct-Slope (d,e,f) sites. When only the benthic cover of coral taxa were used in the analysis, the PM was unable to distinguish between the coral communities within these two strata, whereas the ISM showed significant differences. Representative photos for each site were selected for clarity. Sites were selecting by ordering all sites within a strata from “nicest” to “worst” and selecting the middle three sites. a) Site 8 (Indirect-Slope), b) Site 15 (Indirect-Slope), c) Site 61 (Indirect-Slope), d) Site 21 (Direct-Slope), e) Site 22 (Direct-Slope), f) Site 44 (Direct-Slope).

precision (Krebs 1989). Thus, quadrat size should be directly related to the size of the organisms being sampled. Using the center of the colony as the sole determinant of whether a colony is included within the quadrat (as per the ISM in this study) reduces the effective size of all colonies to a single point. Therefore, density sampling is unbiased regardless of quadrat size when using the colony-center rule. In this case, quadrat size affects only the precision of the density estimate. Quadrats that are too small will vary widely in number of colonies captured and result in a higher variance for the estimated mean density. Quadrats that are too large limit the sample size, resulting in lower precision of the estimates. Optimal quadrat size can be calculated following the methods of Hendricks or Wiegert, as detailed in Krebs (1989), but such calculations were beyond of the scope of this study. In this study, the ISM employed the colony-center rule and also had an effective quadrat size of 10 m^2 for all density-based data.

Because colonies along the edges of the photo-quadrats were not entirely visible, the PM as employed in this study, was unable to use the colony-center rule to determine if a colony should be included within a quadrat. However, counting colonies in which any part is within the quadrat leads to disproportionate sampling of larger colonies and overestimation of colony density, which Zvuloni et al. (2008) refer to as a Type II condition. The only way to correct the resulting error is to count corals that occur exclusively within the quadrat frame, leading to a Type I condition (Zvuloni et al 2008). With a Type I condition, quadrat size become significant for the PM, because any coral that is larger than that quadrat frame will be excluded from any density and colony size estimate, making any correction to the Type I bias (underestimation of true density) problematic. Zvuloni et al. (2008) conclude that "…the method of photo-quadrats combined with the corrected type I approach is best for reefs with coral colonies that are small relative to the size of the sampling units" [page 151].

Potential solutions may exist to correct the problems observed with the PM density-based and Coral Colony Size data and allow for a statistical comparison in the future (Zvuloni et al. 2008), but caution should used when applying any mathematical correction for density estimates because corrected estimated densities may not result in an increase in accuracy (Bakus et al. 2007). These mathematical corrections (Zvuloni et al. 2008) would require re-analysis of all photographs, introduce a different form of error into the estimates, and, in the case of this study, may not even be possible to use. A better approach may be to alter the PM to allow for a larger area of view of the bottom (*e.g.*, take additional photos around each photo-quad) so that it can be determined if a colony's center is within the photo-quadrat. This solution, as demonstrated by Zvuloni et al. (2008), is the simplest approach to handle the methodological error that resulted in density overestimates by the PM in this study. This "colony-center" solution would also allow for appropriate sizing of coral colonies, because the colonies whose centers appear in the quadrat would be entirely visible to the photo-analyst and could be appropriately sized.

Three coral taxa present in the study area have the potential to be problematic for delineating individual colonies. We consulted with numerous coral scientists experienced in Apra Harbor or with these specific species regarding colony delineation of these species. The general consensus of these scientists was that while difficult, if given adequate time, colonies of these taxa could be successfully delineated. Additionally, three *in situ* surveys, one conducted directly within the project area (Smith 2007), and two in a nearby area within Apra Harbor that has the same taxa (Smith 2004, Smith and Marx 2006), were conducted by Navy biologists using methods that required successful colony delineation. Some of these documents have been used as supporting studies for Navy environmental compliance documents, including for conducting assessments of project impacts (Marine Resource Consultants 2007) and associated habitat equivalency analysis (Del Vecchi and Donlon 2007). In none of these documents do the authors or contributing coral reef scientists express concerns about using the colony-based information in Apra Harbor. While errors of subjectivity are certain to exist (subjective errors are not restricted to any single method), the authors of this report are confident that with consistent and careful application of the described boundary delineation rules (see section 2.5), that coral colonies were consistently delineated at all sites unless otherwise noted. Regardless, concerns about quadrat size and criteria for delineating certain coral taxa does not preclude analysis of the density-based data.

4.4. Selecting a Method

When conducting benthic surveys of coral reefs, no single method is the proverbial "silver bullet." Every method has its limitations in what types of data can be provided and under what field conditions it can adequately perform. It is important to understand these limitations and to select the most appropriate method to meet specific requirements of each individual project.

Overall, the PM and ISM compared poorly in this study. Not only did the two methods fail to compare well when collecting data within the same site, but they often described significantly different coral reef communities over a larger spatial scale.

To achieve the level of resolution described in this report, the ISM required considerable field expertise. Compared to the PM, more time was needed in the field to collect data using the ISM, but depending upon the desired taxonomic resolution (*e.g.*, fine or coarse) and the type of data collected (*e.g.*, benthic cover or organism density), the in-field time may not be significantly higher. However, in a heterogeneous environment, or an environment that allows for limited time in the field (*e.g.*, deep water surveys), the PM may be a preferable method to collect some types of data (*i.e.*, benthic cover) provided the desired taxonomic resolution is coarse and the common organisms at the study site are readily distinguishable in the photographs. Under these conditions, the PM may provide more precise estimates of benthic cover because of the greater replication that would be possible over a given time compared to the ISM.

In this study, cost and time savings were not achieved by using the PM compared to the ISM for collecting the desired data. The PM failed to produce the complete data set and for three of the eight variables, the data were known to be overestimated or failed to actually measure the target variable. Data provided by the PM took longer overall to obtain than with the ISM, which is consistent with findings from other studies (Leonard and Clarke 1993) and in the review of methods provided by Hill and Wilkinson (2004). Additionally, the primary purposes for collecting the data in Apra Harbor using the PM was to obtain information that could be used to describe the marine environment potentially impacted by the proposed CVN project. Any marine survey intended to describe the coral reef community should include a comprehensive assessment of Taxon Richness, which was not achieved with the PM.

When one of the primary goals of a project is to survey Taxon Richness, the ISM has the added flexibility to easily incorporate surveys for other organisms, such as mobile invertebrate taxa and fish. In some cases, these organisms can be surveyed by the same divers conducting benthic work (provided they have the taxonomic expertise) or can be conducted at the same time and from the same support platform. This will achieve greater cost efficiency for field work. The photographic method makes this integration more problematic because many of these mobile organisms cannot be effectively sampled using the PM as employed here, and efforts to combine the survey methods together will result is substantially longer in field times, thus eliminating a potential strength of the PM.

The ISM, while able to collect all of the planned data types without known methodological issues and within the timeframe of the project, did have shortcomings. Limits on diver bottom time resulted in data collection occurring in smaller belt transects within some sites for density-based data (5 of 29 Coral Colony Density sites) and at all sites for the Benthic Cover data. While this may not be an issue depending upon the natural variability within a site, it could result in increased variability in estimates made over multiple sites over a larger spatial scale. Additionally, in some situations and locations, there may not be sufficient time to complete the entire data collection on a single dive. However, with adequate attention to detail and time, the ISM should result in data that is unbiased as a result of systematic methodological problems.

Photographic methods are usually considered to have high precision and accuracy when compared to *in situ* methods. While the accuracy of both method was not directly assessed here, the precision of each method can be examined. In all cases in this study where precision was directly estimated (*i.e.*, a standard error of the mean calculated), the ISM had greater or similar precision than the PM. This has been shown elsewhere (Dethier et al 1993), but this result may be study-specific.

Finally, photographic methods are generally considered to have less subjectivity than *in situ* methods, but this may not always be the case (Dethier et al. 1993). However, all data collection that requires observers to make a decision (*e.g.*, visually estimates of cover, taxa identification) has some level of subjectivity associated with it. If either method is employed conscientiously and observers are trained and experienced, this subjectivity should be reduced.

In reality, the most likely preferred option for collecting data to determine proposed project impacts will be some combination of methods. For example, many protocols combine *in situ* and photographic quadrat methods to achieve their project objectives. While only *in situ* data collected by the ISM team and photographic data collected by the PM team were compared in this study, it is important note that both teams collected data with a mixture of photography and *in situ* methods. This highlights the importance combining methods as appropriate to take advantage of each method's individual strengths.

4.5 Adjustment Functions

Limited availability of resources, especially in-field expertise and funding, may be a driving consideration when choosing the best available method and may result in the selection of method that is not the best to meet the project objectives. In this situation, it is logical to wonder if an adjustment factor could be used to convert the data collected by one method into that provided by another method that may have collected data more appropriate to the project-specific objectives but which was not used for other reasons (*e.g.*, cost, lack of trained staff etc.).

Given the results of this study, it would seem theoretically possible to adjust one method to reflect another, but such effort would present numerous challenges. First, it would not be practicable to account for taxa that were not observed, and any adjusted data would still have lower taxonomic diversity and would be missing other data types for those taxa. Second, a series of adjustments would be needed because the differences between the methods are likely not consistent across taxa or community types. Additionally, each data type collected (*e.g.*, Taxon Richness, Benthic Cover etc.) would require its own adjustment function. These functions would be variable-, taxa-, and site-specific and considerable up-front investment would be needed to generate them. It would be more efficient to use the method that produces the appropriate data at the desired resolution from the beginning and forego any adjustment unless the cost to sample adequately across the project area is prohibitive enough to warrant the up-front investment in order to use the less appropriate method.

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Appendix A

Site Characteristics for all thirty survey sites used in this study. Data include Latitude, longitude, strata designation, measured rugosity and depth.

Site	Lat.	Long.	Impact	Slope-Flat	Strata	Rugosity	Depth (m)
1	13.4564757	144.657779	Ind	Slope	Ind-Slope	1.20	15
2	13.4564106	144.65778	Ind	Flat	Ind-Flat	1.11	17
5	13.4545173	144.657067	Dir	Flat	Dir-Flat	1.41	18
6	13.4542649	144.660238	Ind	Flat	Ind-Flat	1.29	5
7	13.4532235	144.660182	Ind	Flat	Ind-Flat	1.54	2
8	13.4532929	144.655993	Ind	Slope	Ind-Slope	1.79	9
9	13.4524357	144.654761	Ind	Flat	Ind-Flat	1.23	3
13	13.4513168	144.658029	Ind	Flat	Ind-Flat	1.21	14
15	13.4501143	144.659303	Ind	Slope	Ind-Slope	1.17	14
21	13.4513924	144.661484	Dir	Slope	Dir-Slope	1.14	17
22	13.4510526	144.662263	Dir	Slope	Dir-Slope	1.03	17
25	13.4488413	144.662329	Dir	Flat	Dir-Flat	1.02	14
26	13.4492632	144.663388	Dir	Flat	Dir-Flat	1.02	14
27	13.4492185	144.665582	Dir	Slope	Dir-Slope	1.05	17
28	13.4492096	144.666956	Ind	Slope	Ind-Slope	1.48	7
31	13.4478152	144.661586	Dir	Flat	Dir-Flat	1.18	15
34	13.4480385	144.664619	Dir	Flat	Dir-Flat	1.51	15
40	13.44691	144.664519	Dir	Flat	Dir-Flat	1.25	14
43	13.4462403	144.662465	Dir	Flat	Dir-Flat	1.54	14
44	13.4456241	144.661496	Dir	Slope	Dir-Slope	1.19	15
48	13.4457521	144.668274	Dir	Slope	Dir-Slope	1.02	17
49	13.4449795	144.669146	Dir	Slope	Dir-Slope	1.84	9
55	13.442889	144.663539	Dir	Slope	Dir-Slope	1.36	9
56	13.4434443	144.664951	Ind	Flat	Ind-Flat	1.10	17
60	13.4492142	144.658116	Ind	Flat	Ind-Flat	1.18	1
61	13.4488759	144.65905	Ind	Slope	Ind-Slope	1.66	12
62	13.4492118	144.660198	Dir	Flat	Dir-Flat	1.47	9
63	13.4480662	144.65826	Ind	Slope	Ind-Slope	1.55	12
65	13.4448671	144.659377	Ind	Slope	Ind-Slope	1.00	2

Appendix B

Coral colony morphology assigned to coral taxa found in this study.

<table>
<tr><th>Branching, Large</th><th>Corymbose/Tabulate</th><th>Encrusting</th><th>Massive/lobate</th></tr>
<tr><td>Acropora aspera
Acropora formosa
Porites cylindrica</td><td rowspan="5">Acropora latistella group
Acropora nasuta group
Acropora cf. aculeus</td><td rowspan="11">Caryophylliidae sp.
Cyphastrea serailia
Cyphastrea spp.
Favites russelli
Hydnophora exesa
Hydnophora microconos
Leptoseris incrustans
Leptastrea purpurea
Leptastrea sp.
Montipora cf. danae
Montipora cf. verrilli
Montipora grisea
Montipora verrilli
Montipora spp.
Pavona cf. bipartita
Pavona meandrina
Pavona sp.
Pavona varians/venosa
Pachyseris speciosa
Pectinia paeonia
Stylocoeniella armata</td><td rowspan="11">Astreopora gracilis
Astreopora myriophthalma
Astreopora randalli
Astreopora spp.
Astreopora spp.
Diploastrea heliopora
Favia favus/mathaii/pallida
Lobophyllia corymbosa
Lobophyllia hemprichii
Porites australiensis
Porites lobata
Porites lutea
Porites murrayensis
Porites solida
Porites cf. stephensoni
Porites sp.
Porites spp. (massive)</td></tr>
<tr><th>Branching, Medium</th></tr>
<tr><td>Psammocora contigua</td></tr>
<tr><th>Branching, Small</th></tr>
<tr><td>Galaxea horrescens
Pocillopora damicornis
Psammocora sp.</td></tr>
<tr><th>Disk</th><th>Folaceous</th></tr>
<tr><td>Ctenactis echinata
Fungia scutaria
Fungia sp.
Fungia sp.1
Fungiidae spp.
Herpolitha limax
Herpolitha weberi</td><td>Pachyseris speciosa</td></tr>
<tr><th>Mixed</th><th>Frond</th></tr>
<tr><td>Montipora cf. undata
Porites horizontalata
Porites rus</td><td>Pavona cactus
Pectinia paeonia</td></tr>
<tr><th>Submassive</th><th>Submassive with fronds</th></tr>
<tr><td>Galaxea fascicularis
Montipora floweri</td><td>Pavona decussata</td></tr>
</table>

Quantitative Assessment of the Reef Fish Communities in Apra Harbor, Guam

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Executive Summary

This report represents a quantitative assessment of the reef fish communities within Apra Harbor, Guam, in response to the Department of Navy's proposal to construct a pier for the mooring of a nuclear aircraft carrier (CVN). Underwater visual surveys were conducted to quantify species richness, abundance, and biomass of reef fish communities within and adjacent to the proposed project area. A total of 119 species representing 28 families were recorded. Multivariate analyses indicated that fish assemblages largely grouped along a depth/habitat gradient and diversity and biomass were greatest at sites of high coral cover. It is apparent that most low diversity sites will be directly impacted, while 50% of sites dominated by coral and having the most significant fish assemblages will also be directly affected. On average, the families Acanthuridae, Caesionidae, Lutjanidae, Scaridae, and Lethrinidae had the highest biomass per transect, and commercially important groupers of the family Serranidae were more common than anticipated, yet still rare. Given the magnitude of the proposed dredging project, there will undoubtedly be major impacts on the reef fish communities present. However, of particular concern is the fate of sites which will be indirectly impacted, as some of these contain diverse fish assemblages.

Introduction

Reef fish assemblages vary considerably over multiple spatial scales. This 'patchy' nature of most reef fish communities is easily explained by the variability in environmental parameters, such as nutrient availability, water quality, and most importantly habitat structure. Habitat structure plays a very important role in structuring reef fish communities because many species are dependent on certain habitats at both small and large spatial scales.

Predicting the response of reef fish communities to habitat disturbance, however, is much more complicated. Such predictions rely on the magnitude of environmental impact and the mobility and site-fidelity of particular species. Reef fish are arguably less affected than other reef organisms to many physical disturbances. However, there are many species which are highly site attached and remain within a very small home range throughout their entire lives.

This report represents a quantitative assessment of the reef fish communities within Apra Harbor, Guam, in response to the Department of Navy's proposal to construct a pier for the mooring of a nuclear aircraft carrier (CVN). This will require an area of ~100 acres to be greater than 51.5 feet in depth and will be accomplished by seafloor dredging. Therefore, this report summarizes baseline information on fish communities and the potential threats to these communities, be they direct or indirect, from the proposed project as part of a pre-impact Environmental Impact Assessment.

Methods

Underwater visual surveys were conducted to quantify species richness, abundance, and size structure of fish communities at 58 randomly selected sites in Apra Harbor. These sites lie within the proposed dredge project area of the CVN pier, turning basin, and entrance channel (Figure 1). The original 67 sites were reduced to 58 in this study as sites extremely close together were grouped in order to eliminate spatial autocorrelation (e.g., sites 1 and 2, 4 and 5, 11 and 12, 15 and 16, 29 and 30, and 37 and 38). In addition, sites 44, 56, and 66 were not completed because visibility at these sites remained too poor for visual census throughout the duration of the survey period. Depths of sites ranged from <1 to 18 meters, which is where the majority of any potential impacts resulting from the dredge project are anticipated to occur. Sites were stratified by slope (0-15° and >15°) and by anticipated project impact (direct impact – dredging, or indirect impact - project related risk).

At each site, a team of two divers swam along three 25 meter transects. All transects followed the pre-determined depth contour of the respective site. The divers swam side by side along each transect, with one diver recording all species from those families heavily targeted by fishing, i.e., Acanthuridae, Caesionidae, Carangidae, Labridae, Lethrinidae, Lutjanidae, Haemulidae, Mullidae, Scaridae, Serranidae, and Siganidae, and the other diver recording non-target species from the following familes: Aulostomidae, Balistidae, Blennidae, Chaetodontidae, Cirrhitidae, Diodontidae, Fistularidae, Gerreidae, Microdesmidae, Monacanthidae, Mugilidae, Nemipteridae, Ophichthidae, Pomacanthidae, Pomacentridae, Synodontidae, and Tetraodontidae. Highly cryptic species from families such as the Apogonidae and Holocentridae were not counted. Both divers estimated size of each fish (total length) to the nearest 5 cm.

As well as fish abundance and size structure the observers recorded the dominant habitat type at each site as either coral-dominated, macroalgae-dominated, rubble-dominated, or sand-dominated. A more detailed assessment of the benthic habitat was performed by another survey team. There was one additional site unique to all others which we referred to as a ‘dump site’ as the benthic habitat at this site was comprised entirely of cinder blocks that had been deposited onto the seafloor, creating an artificial habitat.

Analysis

Univariate measures of mean density and biomass were calculated for each family at each site, along with species richness and measures of diversity. Differences in mean biomass between direct and indirect impact sites were assessed for each family using Kruskal-Wallis tests. Fish community patterns were assessed through clustering and ordination of the Sites x Species data matrix. Prior to analysis the data was ln(x+1) transformed to help normalize the distribution of the data and to weight less-abundant species more heavily thereby emphasizing community dynamics over the dynamics of the most abundant species in the dataset. The Bray-Curtis measure of similarity was applied to the transformed data matrix which was then subject to ordination through nonMetric Multidimensional Scaling. All analyses were done using the Community Analysis Package in PRIMER 6.0.

Results & Discussion

We recorded 119 species across 28 families during our surveys although the actual number was slightly higher as we grouped some species that were hard to differentiate in low visibility conditions. The acanthurids *Ctenochaetus striatus* and *Acanthurus nigrofuscus* were grouped, as were *A. nigricauda* and *A. blochii*. A number of similar looking *Pomacentrus* spp. from the Pomacentridae were also grouped as were all *Halichoeres* spp. from the family Labridae. From the 119 species recorded, this was reduced to 65 for multivariate analysis. The 54 species removed were extremely rare and would only contribute extra noise to the analysis.

We tabulated abundance and biomass data for all species into 15 and 13 families and/or family groupings respectively (Tables 1 & 2). Biomass estimates were obtained using length-weight relationships extracted from Fishbase (Froese & Pauly 2009) for each species. The most numerically dominant families were Pomacentridae, Scaridae, Caesionidae, and Acanthuridae (Table 1). On average, the acanthurids had the highest mean biomass per transect (871 g ±219), followed by the caesionids (394 g ±147), the lutjanids (371 g ±106), the scarids (341 g ±61), and the lethrinids (261 g ±39) (Table 2). Members of the family Serranidae (commercially important groupers) were more common than originally expected. These were most abundant and speciose at sites with high coral cover. Unfortunately, sites with the highest grouper density and biomass will be directly impacted.

The multivariate analyses indicate fish assemblages are largely grouping out along a depth/habitat gradient with those sites dominated by coral having the most speciose and abundant fish assemblages (Figure 2A, B, & D). Biomass of commercially important species is highest at the coral-dominated sites while those sites dominated by sand have depauperate fish communities (Figure 3). When analyses were performed with depth as a factor, there was a strong grouping among sites below 12 meters. The greater variability in fish assemblages among sites within the depth range 12-18 meters is likely explained by previous dredging of many of these sites. When sites were coded for their location with respect to future direct or indirect impacts of dredging (Figure 2C) it can be seen that many of the low diversity sites will be directly affected. However, 50% (9 of 18) of those sites dominated by coral will also be directly affected and these sites have the most significant fish assemblages. We also found that for eight of eleven commercially important fish categories, mean biomass per transect was greater for sites with direct project impacts anticipated. However, because of high variability in the data, these differences were only significant for the lutjanids (Kruskal-Wallis $H = 4.5$, $P < 0.05$) while the scarids had a significantly greater mean biomass in sites that will be indirectly affected (Kruskal-Wallis $H = 9.0$, $P < 0.05$).

Among the major habitat types, those dominated by coral and sand had the least similar fish communities, which is not surprising given that coral-dominated sites have high habitat complexity while sand-dominated sites naturally lack fish habitat. Sites dominated by coral were generally the most speciose and diverse whereas the opposite was true for sand-dominated sites (Figure 3). The species most responsible for this difference were *Amblyglyphidodon curacao* and *Chlorurus sordidus*, whose abundance increased by an order of magnitude in coral-dominated sites, and *Chrysiptera cyanea*, whose abundance was greater in sand dominated sites. In general, the vast majority of species recorded increased in abundance at coral-dominated sites.

The lone 'dump site' (site 42) stood out as a unique site with a high mean dissimilarity value compared with other habitats. This was driven by an unusually high abundance of *Cheilinus fasciatus*, *Caranx papuensis*, and *Lutjanus fulvus* which apparently favored the artificial habitat, and a very low abundance of pomacentrid species (*Amblyglyphidodon curacao*, *Chrysiptera cyanea*, and *Chromis viridus*) that are very common in most other habitats. Such pomacentrids are closely associated with benthic habitats which were apparently not available at the artificial reef.

Conclusions

Given the magnitude of the proposed dredging project, there will be major impacts on the reef fish communities present. Site attached species such as those from the families Pomacentridae and Chaetodontidae will be heavily influenced by changes in habitat structure. In fact, pomacentrids are commonly used to measure community change across sites because of their high abundance, small home ranges, and site specificity. In this study, they represented over 60% of the total fish abundance across sites. However, this does not imply that more mobile species will not be unaffected by the same factors, but their mobility potentially enables them to be less influenced by small-scale changes. Nevertheless, the nature of the proposed dredging project will create both small- and large-scale changes in benthic habitat across the study area.

Of particular concern are the high-diversity, high biomass sites which will be directly impacted. Sites of interest include 4 and 10 near the entrance of the channel east of Western Shoals (WS; Figure 1). These coral-rich sites contain a high biomass of commercially important species, including serranid species which are now rare on Guam. Other notable sites which will be directly impacted are 21, 25, 26, 31, 33, 34, 35, 49, and 59 most located within the channel. Perhaps the most important consideration is the fate of sites which will be indirectly impacted as some of these sites contain diverse fish assemblages and attract SCUBA divers. Predicting the impact on the fish communities at these sites is difficult because it will be highly dependent on the impact to the benthic habitat at these sites. Sites in close proximity to dredging will likely suffer more than others, although the effect on highly mobile species could be variable.

The major source of bias in the quantification of fish communities among sites was the variability in water visibility. Many sites within the channel and near the Navy dry dock (DD; Figure 1) had poor visibility. Three sites (56, 44, and 66) had to be removed from the study because visibility was too poor to see anything beyond ~1.5 meters after two attempts on separate days. Poor visibility at a given site would have a negative influence on the estimated abundance of highly mobile species, while the influence on site attached species would be considerable but of lesser concern. Therefore, it is likely that water visibility had a significant effect on the reported richness and abundance of species at many sites.

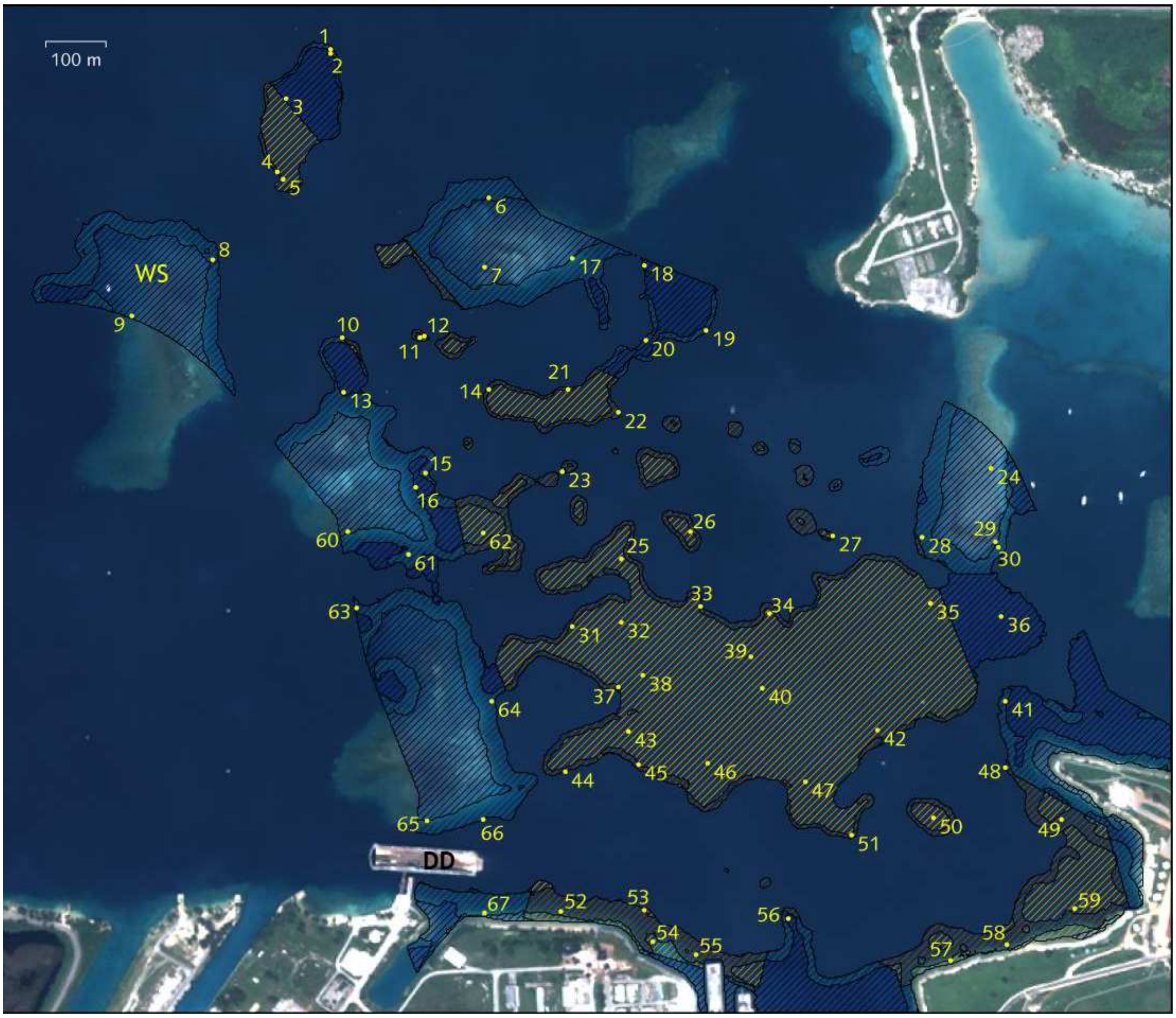

Figure 1. Map of 67 original survey sites within the proposed dredging impact area in Apra Harbor, Guam. Hatched areas are shallower than 18 meters and comprised the survey area. WS = Western Shoals, DD = Navy Dry Dock.

Table 1. Mean density per transect of major fish categories at each site organized by dominant habitat type. Shaded sites represent those with an anticipated direct impact from dredging.

Habitat	Site	*Acanthuridae*	*Caesionidae*	*Carangidae*	*Chaetodontidae*	*Labridae*	*Lethrinidae*	*Lutjanidae*	*Mullidae*	*Other*	*Pomacanthidae*	*Pomacentridae*	*Scaridae*	*Serranidae*	*Siganidae*	*Tetra-odontiformes*
CORAL	1	14.3	63.3	-	5.3	5.7	1.0	0.3	1.0	22.3	-	122.3	8.7	0.3	-	0.7
CORAL	4	15.7	52.7	-	7.7	8.0	-	2.3	0.3	3.7	-	174.0	33.7	0.7	-	1.0
CORAL	6	8.3	-	-	10.7	3.3	-	-	0.3	1.7	-	33.3	14.0	-	-	-
CORAL	8	20.7	-	0.3	8.7	8.0	-	2.3	-	56.7	-	1146.7	4.3	0.7	-	2.3
CORAL	9	9.7	-	-	8.7	10.7	-	-	1.0	30.3	-	222.0	10.3	-	0.7	1.3
CORAL	10	10.0	21.3	-	9.0	6.0	1.0	0.7	0.7	11.0	-	90.3	10.3	2.0	-	0.7
CORAL	25	9.7	27.3	0.3	8.0	5.3	1.7	19.7	0.3	10.3	-	63.0	15.3	0.3	8.3	5.7
CORAL	26	4.0	10.7	-	3.0	3.7	1.7	3.0	0.3	1.7	-	11.3	3.0	0.3	-	0.7
CORAL	28	4.7	-	-	9.0	6.7	-	1.0	-	0.7	-	109.3	19.7	-	-	-
CORAL	29	4.0	-	-	4.7	2.3	1.7	-	-	1.0	-	17.0	21.3	-	-	1.7
CORAL	35	5.0	-	-	3.7	3.3	0.7	3.3	-	-	-	14.0	1.0	-	0.3	-
CORAL	36	2.3	0.7	-	5.0	3.0	0.7	5.3	0.3	0.7	-	15.3	0.3	-	0.7	0.3
CORAL	49	1.7	-	-	5.3	0.7	0.3	1.7	-	-	-	47.0	8.7	-	-	-
CORAL	55	13.7	51.7	0.3	6.0	3.7	0.3	-	-	9.0	-	215.3	1.3	-	-	1.0
CORAL	59	4.3	-	-	1.3	5.0	0.7	1.0	2.0	5.3	-	27.0	9.0	-	-	1.0
CORAL	61	8.3	1.3	-	8.3	3.3	0.3	-	-	1.0	-	40.3	2.3	-	-	0.7
CORAL	62	2.3	0.3	-	2.7	2.0	0.7	-	-	27.3	-	31.3	2.7	-	-	0.7
CORAL	63	16.7	1.3	-	6.7	2.0	2.0	3.7	-	1.3	0.3	13.7	1.3	-	-	0.7
DUMP	42	2.7	6.0	5.3	4.0	15.0	-	5.0	-	1.3	-	-	-	-	0.3	0.3
MAC	7	2.3	-	-	3.0	3.7	1.0	-	-	0.7	-	6.3	70.7	-	0.3	-
MAC	11	-	21.3	-	-	0.3	0.7	-	0.3	-	-	27.7	-	-	-	-
MAC	14	1.0	-	-	0.3	0.3	-	-	-	2.0	-	5.3	0.7	-	-	0.3
MAC	16	8.0	10.3	-	6.3	5.0	0.7	1.0	0.3	0.7	-	55.7	11.3	-	1.0	0.7
MAC	18	2.0	2.3	-	1.7	0.7	0.7	-	-	1.3	-	2.7	0.3	0.3	-	-
MAC	19	1.3	-	-	-	-	-	-	-	0.3	-	2.0	-	-	-	-
MAC	20	2.0	1.0	-	1.7	0.7	-	-	-	1.0	-	0.7	1.0	-	-	-
MAC	21	2.7	18.0	-	1.7	4.0	1.0	10.0	1.0	1.3	-	41.7	4.7	0.7	2.0	0.7
MAC	22	2.3	-	-	1.3	1.0	0.3	-	-	0.7	-	0.3	4.0	-	-	1.0
MAC	23	5.0	17.0	-	3.7	0.7	0.3	7.7	0.7	0.7	-	92.0	0.7	-	1.7	0.7
MAC	27	0.3	-	-	0.7	-	-	-	-	-	-	1.3	-	-	-	-
MAC	33	4.0	2.0	-	1.0	0.3	1.3	5.0	1.0	3.0	-	17.0	1.0	-	0.3	-
MAC	34	0.7	0.3	12.3	2.0	1.3	1.7	2.3	0.3	1.0	-	28.3	2.3	-	0.7	0.3
MAC	39	13.3	1.7	-	7.0	3.3	0.3	5.0	-	0.7	-	52.3	3.0	-	-	-

Table 1. Continued…

Habitat	Site	*Acanthuridae*	*Caesionidae*	*Carangidae*	*Chaetodontidae*	*Labridae*	*Lethrinidae*	*Lutjanidae*	*Mullidae*	*Other*	*Pomacanthidae*	*Pomacentridae*	*Scaridae*	*Serranidae*	*Siganidae*	*Tetraodontiformes*
MAC	40	-	-	-	1.7	-	-	1.3	0.3	-	-	10.0	-	-	-	-
MAC	45	3.0	1.7	-	2.7	1.0	0.7	3.7	-	1.0	-	11.3	12.3	-	-	-
MAC	46	2.3	-	-	2.3	2.3	0.7	1.0	-	1.0	-	21.3	4.7	-	-	-
MAC	50	3.0	-	0.3	5.3	3.3	2.0	8.0	-	6.0	-	17.3	2.7	-	0.7	-
MAC	60	11.7	-	-	2.7	7.3	-	-	-	2.3	-	20.7	21.7	-	2.3	1.0
MAC	65	17.0	-	0.3	5.0	3.0	2.0	-	0.3	18.3	-	11.3	21.0	-	1.0	1.0
RUBBLE	3	1.7	1.7	-	5.7	3.0	0.7	-	-	1.0	-	15.3	3.3	0.3	-	0.3
RUBBLE	13	6.0	-	-	2.0	2.3	-	-	-	8.3	-	13.3	1.3	0.3	-	1.3
RUBBLE	17	4.3	-	-	2.3	1.3	-	-	-	5.0	-	72.0	75.0	-	-	0.3
RUBBLE	24	4.7	-	-	2.3	4.3	2.0	-	0.7	1.7	-	1.7	32.3	-	0.7	0.7
RUBBLE	41	0.3	-	-	1.0	1.7	0.7	2.7	-	3.0	-	1.3	-	0.3	-	0.7
RUBBLE	52	1.7	-	-	1.3	0.3	2.3	0.7	0.3	17.0	-	11.3	2.7	-	-	1.3
RUBBLE	54	5.0	0.3	1.0	2.0	2.0	0.3	-	-	3.3	-	65.3	2.3	-	-	2.0
RUBBLE	57	3.0	-	3.0	1.3	1.7	0.7	-	-	1.0	-	5.3	22.0	-	0.3	0.7
RUBBLE	58	4.0	-	-	2.0	1.7	0.7	-	-	0.7	-	23.3	5.3	-	-	2.3
RUBBLE	67	19.3	-	-	4.7	3.0	2.0	-	0.7	2.3	-	5.0	11.7	-	-	-
SAND	31	9.3	9.7	-	1.7	1.3	1.0	4.7	0.7	1.3	-	58.0	0.3	-	-	0.7
SAND	32	2.0	-	-	-	-	-	0.7	-	-	-	9.0	-	-	-	-
SAND	37	0.3	-	-	0.3	0.3	-	-	-	-	-	8.7	-	-	0.7	-
SAND	43	-	-	-	-	-	-	-	-	0.3	-	0.3	-	-	-	-
SAND	47	-	0.3	0.3	-	-	0.3	-	-	-	-	5.7	-	-	-	-
SAND	48	-	-	0.7	1.3	-	0.3	0.7	-	-	-	1.3	-	-	-	-
SAND	51	-	-	-	-	-	-	-	-	-	-	4.7	-	-	-	-
SAND	53	0.3	-	1.3	-	-	1.7	0.3	-	-	-	2.7	-	-	-	-
SAND	64	0.7	-	-	0.3	1.3	-	-	-	0.3	-	8.7	1.3	-	-	0.3

Table 2. Mean biomass (g) per transect of commercially important fish categories at each site organized by habitat type. Shaded sites represent an anticipated direct impact from dredging.

Habitat	Site	*Acanthuridae*	*Caesionidae*	*Carangidae*	*Haemulidae*	*Labridae*	*Lethrinidae*	*Lutjanidae*	*Mullidae*	*Other*	*Scaridae*	*Serranidae*	*Siganidae*	*Tetra-odontiformes*
CORAL	1	6696	6080	-	-	1374	801	344	12	-	848	38	-	398
CORAL	4	8587	5056	-	-	677	-	3352	57	-	2157	422	-	749
CORAL	6	90	-	-	-	144	-	-	23	-	1377	-	-	-
CORAL	8	4271	-	236	-	775	-	409	-	-	947	499	-	712
CORAL	9	397	-	-	-	315	-	-	19	-	463	-	28	104
CORAL	10	1135	2091	-	-	1198	304	477	552	-	704	1619	-	398
CORAL	25	1243	2601	137	-	852	946	2641	30	-	725	126	1732	1896
CORAL	26	872	231	-	-	120	781	579	1	-	54	74	-	368
CORAL	28	97	-	-	-	456	-	223	-	-	356	-	-	-
CORAL	29	166	-	-	-	84	261	-	-	-	856	-	-	320
CORAL	35	293	-	-	-	185	215	358	-	-	13	-	8	-
CORAL	36	148	107	-	-	309	294	860	30	-	64	-	49	135
CORAL	49	46	-	-	-	1	54	142	-	-	207	-	-	-
CORAL	55	4107	-	71	-	108	360	-	-	-	103	-	-	424
CORAL	59	154	-	-	956	502	109	132	30	-	1167	-	-	8
CORAL	61	107	60	-	-	121	95	-	-	-	93	-	-	15
CORAL	62	213	9	-	-	326	597	-	-	-	99	-	-	65
CORAL	63	3324	128	-	-	427	740	811	-	-	24	-	-	241
DUMP SITE	42	449	1824	1485	-	1226	-	595	-	-	-	-	112	-
MAC	7	84	-	-	-	51	237	-	-	-	1329	-	8	-
MAC	11	-	341	-	-	52	941	-	0	-	-	-	-	-
MAC	14	10	-	-	-	5	-	-	-	-	12	-	-	26
MAC	16	290	992	-	-	651	355	541	57	-	588	-	40	259
MAC	18	150	224	-	-	6	109	-	-	-	8	126	-	-
MAC	19	19	-	-	-	-	-	-	-	-	-	-	-	-
MAC	20	635	-	-	-	10	-	-	-	-	398	-	-	-
MAC	21	602	1728	-	-	252	506	4459	337	-	408	147	215	368
MAC	22	794	-	-	-	85	448	-	-	-	219	-	-	326
MAC	23	1027	-	-	-	38	299	1131	29	-	91	-	149	436
MAC	27	1	-	-	-	-	-	-	-	-	-	-	-	-
MAC	33	3553	128	-	-	21	323	872	130	130	141	-	25	-
MAC	34	81	9	9941	-	27	457	171	23	-	150	-	2	135
MAC	39	1797	115	-	-	68	107	592	-	-	96	-	-	-

Table 2. Continued…

Habitat	Site	*Acanthuridae*	*Caesionidae*	*Carangidae*	*Haemulidae*	*Labridae*	*Lethrinidae*	*Lutjanidae*	*Mullidae*	*Other*	*Scaridae*	*Serranidae*	*Siganidae*	*Tetra-odontiformes*
MAC	40	-	-	-	-	-	-	149	12	-	-	-	-	-
MAC	45	37	41	-	-	5	374	199	-	-	115	-	-	-
MAC	46	63	-	-	-	66	77	324	-	-	135	-	-	-
MAC	50	201	-	1404	-	206	963	951	-	-	132	-	45	-
MAC	60	488	-	-	-	11	-	-	-	-	452	-	50	129
MAC	65	1603	-	137	-	67	724	-	23	-	1020	-	30	129
RUBBLE	3	79	160	-	-	197	374	-	-	-	293	214	-	135
RUBBLE	13	420	-	-	-	37	-	-	-	-	127	197	-	142
RUBBLE	17	63	-	-	-	103	-	-	-	-	1091	-	-	-
RUBBLE	24	151	-	-	-	5	316	-	7	-	1147	-	28	91
RUBBLE	41	8	-	-	-	161	162	271	-	-	-	126	-	163
RUBBLE	52	134	-	-	-	5	751	44	1	132	5	-	-	118
RUBBLE	54	964	32	278	-	295	54	-	-	-	263	-	-	162
RUBBLE	57	16	-	81	-	66	109	-	-	401	155	-	2	2
RUBBLE	58	316	-	-	-	167	109	-	-	-	266	-	-	96
RUBBLE	67	1537	-	-	-	768	528	-	15	-	892	-	-	-
SAND	31	2874	928	-	-	83	269	706	-	-	6	-	-	820
SAND	32	76	-	-	-	-	-	153	-	-	-	-	-	-
SAND	37	1	-	-	-	6	-	-	-	-	-	-	10	-
SAND	43	-	-	-	-	-	-	-	-	-	-	-	-	-
SAND	47	-	9	97	-	-	23	-	-	-	-	-	-	-
SAND	48	-	-	194	-	-	107	45	-	-	-	-	-	-
SAND	51	-	-	-	-	-	-	-	-	-	-	-	-	-
SAND	53	29	-	388	-	-	887	7	-	-	-	-	-	-
SAND	64	38	-	-	-	29	-	-	-	-	17	-	-	26

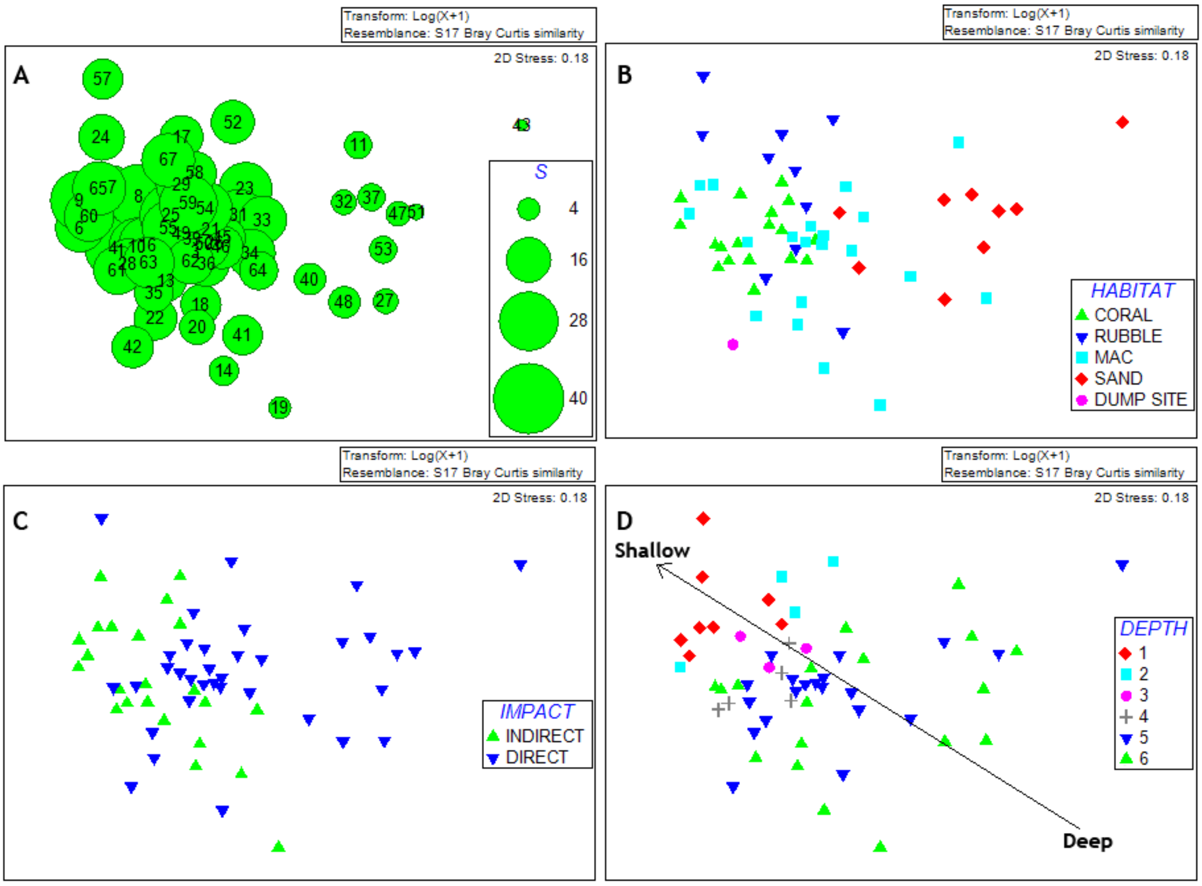

Figure 2. The nMDS plots showing the spatial similarity of reef fish assemblages from all surveyed sites at the species level with A) bubble size representing species richness with site numbers labeled, B) dominant habitat type overlaid, C) type of anticipated impact from CVN dredging project overlaid, and D) depth overlaid. In D, depth **1** represents depths <10 ft, **2** = 11-20 ft, **3** = 21-30 ft, **4** = 31-40 ft, **5** = 41-50 ft, and **6** = 51-60 ft.

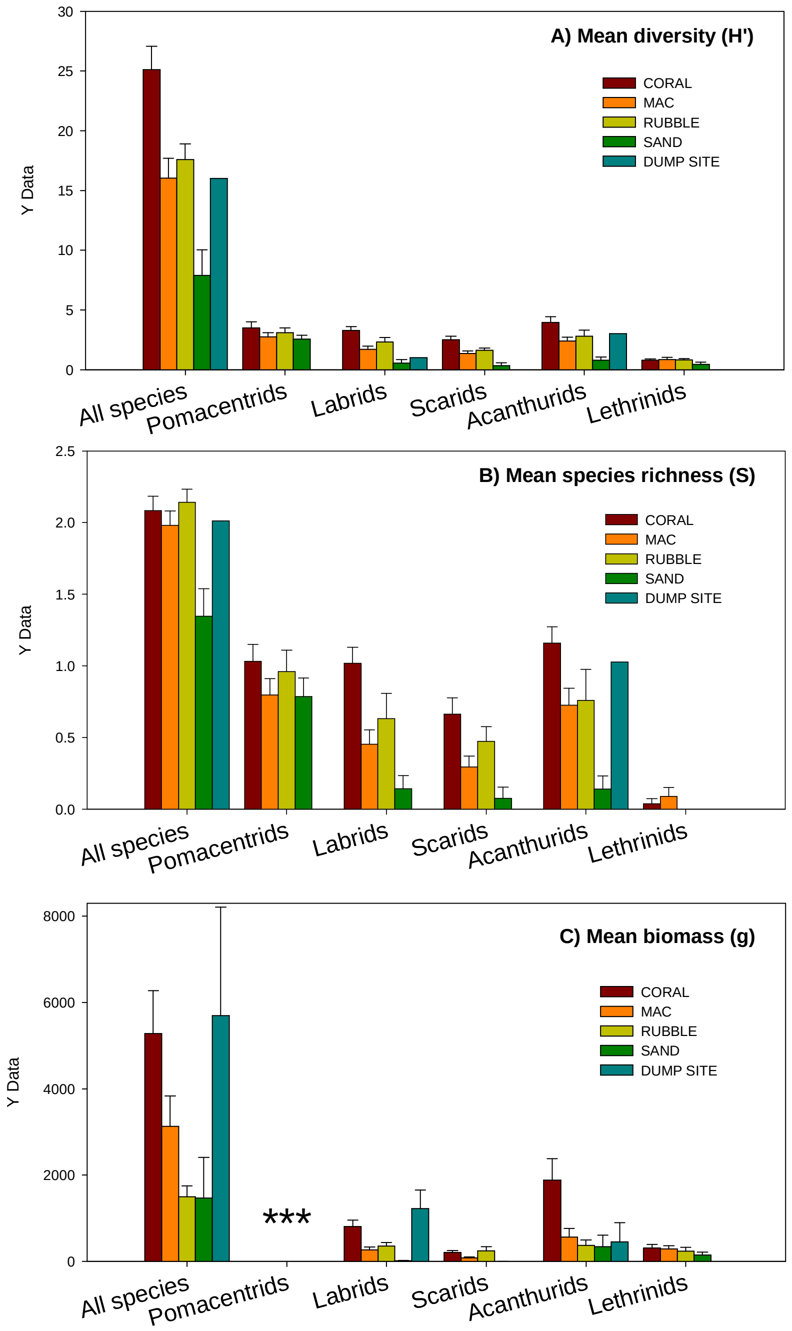

Figure 3. Histograms showing A) the mean diversity value (Shannon diversity H'), B) the mean species richness (total number of species S), and C) the mean biomass in grams for all fish and the most common families by habitat type. *** Biomass was not estimated for the family Pomacentridae.

Appendix K

Additional Reports – Aircraft Carrier

Architect-Engineering Services for Environmental Planning Support
Strategic Forward Basing Initiatives and Related Technical Services and Activities
At Various Navy and Marine Corps Locations, Pacific Basin and Indian Ocean Areas
Contract No. N62742-06-D-1870
Amendment No. 0024

Dredged Material Upland Placement Study
Apra Harbor, Guam

Final Report

Prepared For:

Department of the Navy
Naval Facilities Engineering Command Pacific
258 Makalapa Drive, Suite 100
Pearl Harbor, Hawaii 96860-3134

May 2008

NAVFAC Naval Facilities Engineering Command PACIFIC DIVISION

TEC Inc. Joint Venture
A Joint Venture of TEC Inc., Earth Tech, Inc., and EDAW, Inc.

WESTON SOLUTIONS

Dredged Material Upland Placement Study
Apra Harbor, Guam

Final Report

Prepared For:

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May 2008

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LIST OF ACRONYMS AND ABBREVIATIONS

ANSI	American National Standards Institute
ARG	Amphibious Readiness Group
ARPA	Archaeological Resources Protection Act
BMPs	Best Management Practices
CAA	Clean Air Act
CAD	Confined Aquatic Disposal
CDF	Confined Disposal Facility
CERCLA	Comprehensive Environmental Response, Compensation and Liability Act
CFR	Code of Federal Regulations
CO	Carbon Monoxide
COMNAVREGMAR	Commander, U.S. Navy Region Marianas
CVN	Carrier Vessel Nuclear
CWA	Clean Water Act
CZMA	Coastal Zone Management Act
CZMP	Coastal Zone Management Program
DMMP	Dredged Material Management Plan
DMPF	Dredged Material Processing Facility
DoD	Department of Defense
DON	Department of Navy
EEZ	Exclusive Economic Zone
EIS	Environmental Impact Statement
ER-M	Effects Range - Median
ESA	Endangered Species Act
ESQD	Explosive Safety Quantity Distance
FAA	Federal Aviation Administration
FWCA	Fish and Wildlife Coordination Act
FY	Fiscal Year
GEDA	Guam Economic Development Authority
GEPA	Guam Environmental Protection Agency
HHFP	Helber, Hastert, & Fee, Planners
HUD	U.S. Housing and Urban Development
LPC	limiting permissible criteria
MPRSA	Marine Protection, Research and Sanctuaries Act
MLLW	Mean Lower Low Water
MOU	Memorandum of Understanding
NAAQS	National Ambient Air Quality Standards
NAVFAC PAC	U.S. Naval Facilities Engineering Command, Pacific
NEPA	National Environmental Policy Act
NHPA	National Historic Preservation Act
NMFS	National Marine Fisheries Service
NO_X	Oxides of Nitrogen
O&M	Operations and Maintenance
ODMDS	Ocean Dredged Material Disposal Site
PCB	Polychlorinated biphenyls

PM_{10}	Particulate Matter 10 Microns or Less
PWC	United States Navy Public Works Center
RCRA	Resource Conservation and Recovery Act
RHA	Rivers and Harbors Act
SARA	Superfund Amendments and Reauthorization Act
SO_X	Oxides of Sulfur
SP	Solid Phase
SPP	Suspended Particulate Phase
SRF	Ship Repair Facility
T-AKE	Advanced Auxiliary Dry Cargo Ships
U.S.	United States
USACE	United States Army Corps of Engineers
USC	United States Code
USEPA	United States Environmental Protection Agency
USFWS	United States Fish and Wildlife Service
WRDA	Water Resources Development Act

UNITS OF MEASURE

a	acre
dBA	A-weighted decibels
cy	cubic yards
ft	feet
ha	hectare
km	kilometers
m	meters
m^2	square meters
m^3	cubic meters
mcy	million cubic meters
mi	miles
mm	millimeter
ppm	parts per million
sf	square foot
%	percent
µg/kg	microgram per kilogram

EXECUTIVE SUMMARY

A Phase I Dredged Material Management Plan (DMMP), Commander, United States [U.S.] Navy Region Marianas (COMNAVREGMAR), Guam (MEC Analytical System [MEC]-Weston Solutions Inc.[Weston] 2005), was developed to assist the Navy to complete the proposed construction dredging projects in an efficient, environmentally sound, logistical feasible and cost effective manner. The Phase I DMMP identified potential placement and beneficial use alternatives for the successful management of dredged material from planned construction dredging projects. In the three years following the development of the Phase I DMMP, changes to the Navy's waterfront functional plans and new mission preparedness objectives have subsequently required a review and update of the Phase I DMMP. This Upland Placement Study is essentially a revision, or update, to the Phase I DMMP developed by Weston in 2005. This study revisits each dewatering site and beneficial use alternative proposed in the Phase I DMMP, and addresses the viability of each alternative with respect to new dredging requirements and construction schedules. Recently developed waterfront functional plans for Sierra Wharf, Victor and Uniform Wharves, and feasibility studies for the construction of a Carrier Vessel Nuclear (CVN) capable berth (TEC Inc. JV 2008) were used to assist in the reevaluation of potential management alternatives.

Vessels with deep drafts, including scheduled operations with a Carrier Vessel Nuclear (CVN) 68 and CVN 78, and increased ship visits are anticipated for Apra Harbor (Helber, Hastert & Fee, Planners [HHFP] 2003b; TEC Inc. JV 2008). Maintenance and construction dredging will be required to accommodate these new, larger vessels and increased traffic.

To accommodate further operational needs, the Navy proposed two construction projects to increase design depths of Inner and Outer Apra Harbor (HHFP 2003b; TEC Inc. JV 2008-in progress). P-433, scheduled for Fiscal Year (FY)10, will dredge approximately 508,877 cubic yards (cy) (389,064 cubic meters [m^3]) of sediment along Sierra and Tango Wharves. The unscheduled CVN capable berth project is estimated to require between 478,900 cy and 758,000 cy (366,145 m^3 and 579,533 m^3) of sediment to be dredged depending on which alternative CVN site is selected (Table ES-1). Together, the P-433 and CVN projects result in the need to manage an additional volume of 987,777 cy to 1,266,877 cy (755,209 m^3 and 968,597 m^3), depending on the final CVN alternative selected.[1]

Mechanical dredging is the recommended dredging method and has been used in past Guam dredging projects. While the production volume is considerably less than the volume dredged by other means (i.e., hydraulically), the nature of mechanically dredged material is better suited for the management alternatives described herein. As stated in the Phase I DMMP, a bulking factor of 10 percent (%) should be applied to dredged volume during mechanical dredging. Dredged volumes used in this report do not include a bulking factor to be consistent with other concurrent studies (TEC Inc. JV 2008-in progress).

[1] Dredge volumes include a 2-foot overdredge.

Table ES-1. Estimated Future Construction Dredge Material Generation for U.S. Navy, Apra Harbor, Guam

Project	Year	Volume Requiring Management (cy)[1]
P-502	2008	98,300[2]
P-433	2010	508,877
CVN Wharf - Former SRF Parallel to Shore	Unscheduled	478,900[3]
CVN Wharf Alternative - Polaris Point Parallel to Shore		758,000[3]
CVN Wharf Alternative - Polaris Point Diagonal		672,400[3]

[1] Dredged volumes include a two feet (ft) overdredge allowance and no bulking factor.
[2] Dredged material to be placed in Orote Airfield CDF and is not included in the total dredged volume to be managed.
[3] Dredged volumes include channel, turning basin, and wharf.

In total, 27 dewatering sites were considered in the Phase I DMMP and reevaluated as part of this study. This study has determined that six dewatering sites and three beneficial use alternatives are considered to be logistically, technically, and economically feasible.

Six sites have been identified as potential dewatering site alternatives for dredged material resulting from P-433 and CVN (Figure ES-1):

1. Polaris Point - 44.3 acre (a) (17.9 hectare [ha]) site located on Polaris Point;
2. Field 5 - 53.2 a (21.5 ha) site located northwest of the Commissary, between and Marine Drive and Sumay Drive;
3. Commercial Port Field 1 - 36.9 a (14.9 ha) site located within Commercial Port property on Cabras Island;
4. Field 3 - 16.0 a (6.5 ha) site located south of the Navy Exchange Center and Commissary;
5. Field 4 - 26.6 a (10.8 ha) site located northwest of the Commissary, between Shoreline Drive and Marine Drive; and
6. PWC Compound - 27.8 a (11.3 ha) site located between Marine Drive and Sumay Drive at the former PWC Compound.

Polaris Point and Field 5 are large enough to accommodate the dredged material for both construction dredging projects (Table ES-2). All dewatering facilities have the capacity to store material from P-433, with the exception of Field 3. Field 3 must be used in conjunction with another alternative due to limited capacity. Dredging, rehandling, and placement costs are estimated to range from $88.10/cy (Field 5) to $119.05/cy (Commercial Port 1)[2].

Beneficial use includes a wide variety of options that utilize dredged material for a productive purpose. Beneficial uses of dredged material may make traditional placement of dredged material unnecessary or at least reduce the level of disposal. The beneficial use alternatives discussed in this report are identified as proposed projects in the Waterfront Function Plan (HHFP 2003b) and Ordnance Function Plan (HHFP 2003a), with the exception of the proposed Commercial Port expansion. Three beneficial use alternatives were evaluated: (1) magazine construction, (2) landfill daily cover, and (3) construction fill for Commercial Port expansion.

[2] Unit costs assume facilities are used to their maximum capacity.

Assuming that further geotechnical and chemical analyses prove the dredged material is suitable for all the identified beneficial uses, each of the alternatives are feasible and recommended.

Table ES-2. Greatest Capacity Design Specifics for Dewatering Facility Alternatives

	Field 3	Field 4	Field 5	PWC Compound	Commercial Port Field 1		Polaris Point
					East	West	
Site Area (a)	16.0	26.6	53.2	27.8	22.7	14.2	44.3
Dike Center Line Perimeter (ft)	2,965	5,600	7,000	5,000	4,600	4,750	5,900
Dike Width (ft)	8	8	12	12	12	12	12
Dike Elevation (ft)	18.5	16.00	26.00	19.00	15.00	6.25	31.00
Dredged Material Lift Height (ft)	16.50	14.00	24.00	17.00	13.00	4.25	29.00
Dike Volume (cy)	129,005	185,837	606,667	242,778	145,667	33,811	711,278
Internal Volume (cy)	296,915	414,968	1,453,237	519,684	330,428	63,554	1,361,372
Total Capacity (cy)	425,920	600,805	2,059,904	762,461	476,095	97,365	2,072,649
					573,459		
Sufficient Capacity for each individual project?	No	P-433	P-433 and CVN	P-433	P-433		P-433 and CVN
Sufficient Capacity for both projects?	No	No	Yes	No	No		Yes

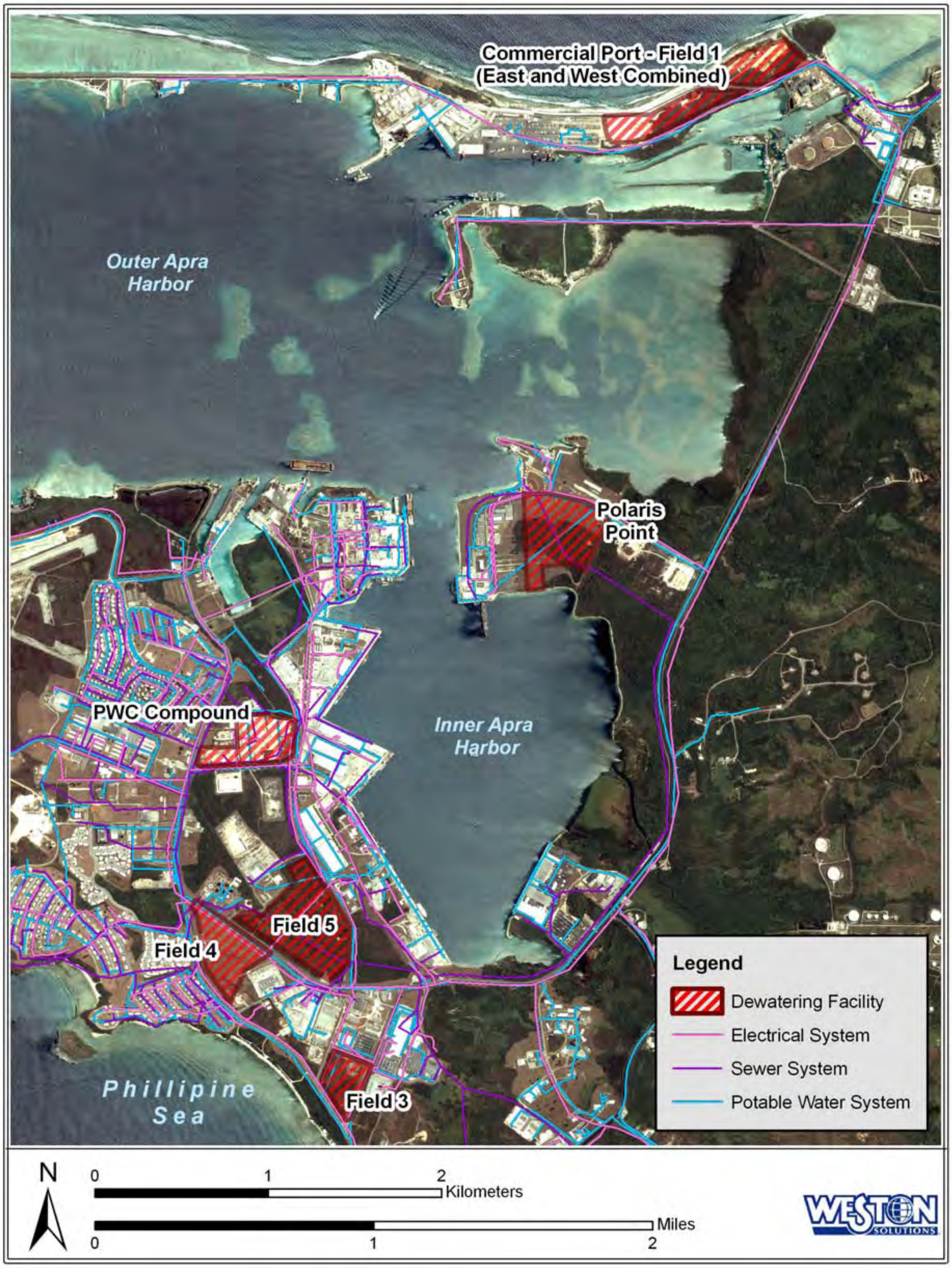

Figure ES-1. Location Map of Feasible Dewatering Sites.

Recommendations

Based on this preliminary evaluation, Polaris Point, Field 5, Field 4, Field 3, PWC Compound, and Commercial Port Field 1 are recommended for dewatering dredged material generated from the P-433 and CVN capable berthing projects. Polaris Point or Field 5 can be designed to accommodate the total volume from these construction projects. Due to their location and proximity to active areas within the base, PWC Compound and Fields 3, 4, and 5 have the potential to cause traffic and air quality impacts. These impacts are generally considered to be temporary and manageable. Construction and placement-related activities in PWC Compound, Field 4, or Commercial Port Field 1 may cause exterior noise levels within the adjacent housing complexes to temporarily exceed U.S. Housing and Urban Development (HUD) and Department of Defense (DoD) guidelines for residential areas. Construction and placement-related activities along the south end of Field 3 may cause noise levels at the adjacent beach to be elevated relative to the American National Standards Institute (ANSI) noise guideline for neighborhood parks.

Based on this preliminary evaluation, all feasible beneficial use alternatives are recommended assuming dewatered dredged material is chemically and geotechnically suitable. Utilizing dewatered dredged material for the Commercial Port expansion project would conserve other material resources for construction projects that have more rigorous geotechnical requirements (e.g., homogenization and sheer strength).

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1.0 PURPOSE AND NEED FOR ACTION

1.1 Introduction

The directive of the Commander of United States [U.S] Navy Region Marianas (COMNAVREGMAR) is to provide logistical and training support for U.S. Armed Forces and its Allies operating in the Western Pacific and Asia. A necessary component of the support program is to ensure adequate navigation depth for current and future operational requirements.

Apra Harbor, Guam is home to the Military Sealift Command, Maritime Prepositioning Ship Squadron 3, Submarine Squadron 15, and the U.S. Navy Public Works Center (PWC). The Military Sealift Command and the Maritime Prepositioning Ship Squadron are responsible for the sea transportation of equipment and supplies to deployed forces, and for maintenance and ship engineering support. Submarine Squadron 15 was created to improve the readiness of the Pacific submarine force and to provide logistical support, training, and maintenance (Global Security 2002). The PWC, Guam, is responsible for facility maintenance, utilities, environmental, transportation, engineering, and construction support.

An integral part of the Navy's mission and operational preparedness is to support forces transiting through and based in Apra Harbor, Guam. Vessels with deep drafts, including Carrier Vessel Nuclear (CVN) 68 and CVN 78, and increased ship visits are anticipated for Apra Harbor (Helber, Hastert & Fee, Planners [HHFP] 2003b; TEC Inc. JV 2008-in progress). Maintenance and construction dredging will be required to accommodate these new, larger vessels and increased traffic. Without dredging, the ability of the Navy to support its mission may be compromised. Consequently, management of Apra Harbor dredged material, in a manner consistent with the Navy's mission, is a high priority.

1.2 Background

The current design depths of Inner Apra Harbor are not sufficient to support proposed vessel berthing requirements. Current design depths for Inner Apra Harbor are -40 feet (ft) (-12.2 meters [m]) through the entrance to Inner Apra Harbor and adjacent to Alpha and Bravo Wharves, -35 ft (-10.7 m) in the north (along Mike - Tango Wharves and in the north-central and eastern portions) and -32 ft (-9.8 m) in the south (X-Ray to Uniform Wharves). Maintenance dredging was conducted in November 2003 for the first time since 1978. The 25-year hiatus in dredging activities resulted in a loss of approximately 5 ft (1.5 m) of navigation depth, due to sediment inputs from local streams and rivers and sediment transport from storms. The decreased navigation depth increases the potential risk of vessel groundings in Inner Apra Harbor. Beginning in 2003, maintenance dredging has resulted in approximately 160,000 cubic yards (cy) (122,336 cubic meters [m^3]) of dredged material being placed in confined dewatering facilities located within the Ship Repair Facility (SRF) and at Orote Airfield. Construction dredging was completed in 2007 as part of the P-431 project. P-431 increased the waters depths from -35 ft (-10.7 m) in the entrance channel and adjacent to Alpha and Bravo Wharves to -40 ft (-12.7 m). Construction dredging activities resulted in approximately 407,000 cy (311,174 m^3) of dredged material being placed in a dewatering facility located at Field 5.

To accommodate further operational needs, the Navy proposed three construction projects (identified as P-502, P-433, and an unscheduled project for the berthing of a CVN) to increase design depths of Inner and Outer Apra Harbor (HHFP 2003b; TEC Inc. JV 2008-in progress). Beginning fiscal year (FY) 2008, the first project (P-502) will dredge approximately 98,300 cy (75,156 m^3) along Kilo Wharf. The second project (P-433), scheduled for FY 2010, will dredge approximately 508,877 cy (389,064 m^3) of sediment along Sierra and Tango Wharves. The final proposed project (currently unscheduled and referred to herein as the CVN project), will dredge between 478,900 cy and 758,000 cy (366,145 m^3 and 579,533 m^3), depending on the final site selected, in Outer Apra Harbor. A total volume of 987,777 cy to 1,266,877 cy (755,209 m^3 and 968,597 m^3) of material will need to be managed from these proposed construction projects. Dredged volumes include a two-ft overdredge allowance; however, they do not include a bulking factor to be consistent with other concurrent studies (TEC Inc. JV 2008 - in progress).

1.3 Purpose and Need

A Phase I Dredged Material Management Plan (DMMP), COMNAVREGMAR, Guam (MEC-Weston 2005), was developed to assist the Navy to complete the proposed construction dredging projects in an efficient, environmentally sound, logistical feasible and cost effective manner. The Phase I DMMP identified potential placement and beneficial use alternatives for the successful management of dredged material from planned construction dredging projects.

In the three years following the development of the Phase I DMMP, changes to the Navy's waterfront functional plans and new mission preparedness objectives have subsequently required a review and update of the Phase I DMMP. The purpose of this report is to reevaluate potential locations for dewatering facilities and beneficial use alternatives as presented in the Phase I DMMP, determine if any additional locations for dewatering facilities or beneficial use alternatives have become available in the three years since the Phase I DMMP study was completed, and provide sound management recommendations. In keeping with the Navy's sustainable planning policies, a key component of this study is to identify management alternatives that dewater the maximum amount of dewatered dredged material and minimize the acreage of Navy lands required, with little or no significant environmental impact.

Management of dredged material from these projects required the identification of feasible dewatering placement sites on the Naval Complex, and the potential beneficial use of the dewatered dredged material in planned construction projects. The evaluation of management alternatives (placement and beneficial use) included technical, logistical and economic feasibility, and consideration of the potential for environmental and social impacts. Each of these evaluative criteria is described below:

- <u>Technical Feasibility:</u> This criterion assessed the existing physical conditions and geotechnical considerations of each proposed management alternative. Based on the available data and certain assumptions regarding site conditions, (i.e., infiltration rates, bearing capacity, anticipated settlement, etc.) each alternative was assessed for consistency with the proposed use (e.g., dredged material dewatering and storage). Other general site conditions such as vegetative cover, shape of the site, and ability to develop the proposed alternative based on current and proposed land use were also considered. A site was rejected if it was not technically feasible to implement.

- Logistical Feasibility: Logistical feasibility included evaluations of the operational aspects of an alternative, such as capacity of the alternative to accommodate the projected volume of dredged material associated with each planned construction dredging project. Other factors included the ability to place construction or dredging equipment on site, access to and egress from the site, and schedule. Coordination will be necessary between dredged material management activities and naval operations. A site was rejected if it was not logistically feasible to implement.

- Economic Feasibility: This criterion focused on the cost of the alternative relative to the capacity volume of dredged material accommodated by the alternative. Unit costs used to derive cost estimates for each management alternative were standardized to provide equitable comparisons among potential alternatives. Alternative sites that required special construction efforts were evaluated by assessing the cost relative to the benefit gained in regards to capacity and beneficial use opportunities. A placement site or beneficial use alternative was rejected if estimated costs for one or more elements of the alternative were significantly higher (e.g., order of magnitude) than the range of costs normally encountered with the management of dredged material.

- Environmental Impacts: This criterion focused on the identification of potential environmental impacts resulting from the implementation of each alternative. A placement or beneficial use alternative was rejected if it had one or more impacts to sensitive resources or receptors that would likely be unacceptable or difficult to mitigate below a level of significance.

- Social Acceptability: This criterion focused on the identification of potentially adverse impacts to aesthetic resources, recreational uses, or to vehicle traffic patterns. A project alternative was rejected if it had one or more elements that would likely be unacceptable to naval personnel and/or residents of the Apra Harbor Naval Complex.

1.4 Regulatory Environment

Federal laws and regulations designed to protect the environmental, cultural, historical and coastal resources, and commerce in waters of the U.S. and its territories may be applicable to the dredging and placement activities described in this DMMP. The Navy will comply with laws and regulations that are relevant to dredging and subsequent management of dredged material, including those described below (Guam Environmental Protection Agency [GEPA] 2000, Lauter-Reinmann 1998, and Schroeder et al. 2001):

Clean Water Act (CWA) or Federal Water Pollution Control Act
The CWA established the basic structure for regulating discharges of pollutants into waters of the U.S. Section 404 of the CWA authorizes the Secretary of Army to issue permits for the discharge of dredged or fill material into U.S. waters. The U.S. Army Corps of Engineers (USACE) and U.S. Environmental Protection Agency (USEPA) are responsible for regulating the discharge of dredged or fill material, and to ensure such discharges do not adversely affect

waters of the U.S. The USACE is responsible for evaluating potential alternatives to discharge activities. The USEPA is responsible for environmental oversight of any USACE proposed disposal decision. Section 401 of the CWA indicates that activities resulting in discharge to waters of a state or territory must comply with all applicable state or territorial water quality standards. Guam's Water Quality Standards were recently revised and approved in 2001. Any discharge or runoff from dewatering facilities to waters of the U.S. would be regulated under the CWA.

Coastal Zone Management Act (CZMA) and Amendments
The CZMA was established to preserve, protect, develop and where possible, restore and enhance the Nation's coastal resources. States and territories are encouraged to develop coastal zone management programs (CZMPs) to manage economic growth in conjunction with the protection of natural resources, diminution of coastal hazards, improvement of water quality, and sustainable coastal development. The CZMA required that federal activities adhere to the policies established under each state's CZMP. A CZMP is in effect for Guam, and addresses coastal related issues involved with the construction dredging.

Endangered Species Act (ESA)
The ESA provides for the conservation of ecosystems that support threatened and endangered plant and animal species. The ESA allows for the determination and development of the threatened and endangered species list. The ESA protects threatened and endangered species by prohibiting federal agencies from authorizing, funding, or carrying out any action that would jeopardize such species, or destroy or modify its critical habitat. The U.S. Fish and Wildlife Service (USFWS) and the National Marine Fisheries Service (NMFS) administer provisions under the ESA. Several endangered species inhabit areas within the Apra Harbor Naval Complex; consequently, identification and development of placement alternatives must consider applicable ESA requirements.

Fish and Wildlife Coordination Act (FWCA)
The FWCA provides that whenever the waters or channel of a body of water are modified by a federal agency, the agency must first consult with the USFWS, NMFS, and state or territorial agencies representing local fish and wildlife resources. The review agencies identify potential adverse impacts to wildlife resources and propose measures that would eliminate or reduce any possible damages or losses to those resources. Since dredging activities and potential nearshore placement alternatives are considered as part of this DMMP, coordination with these agencies may be required.

National Environmental Policy Act (NEPA)
The NEPA is a national policy for the protection of the environment. It is designed to prevent or eliminate damage to the environment and support the health and welfare of the individual. The NEPA is intended to develop the understanding of the ecological systems and natural resources important to the Nation, establish a process of environmental review and public notification for federal planning and decision making. The NEPA requires federal agencies to develop an environmental impact statement (EIS), which considers potential environmental impacts, unavoidable, adverse environmental effects, and project alternatives before a decision is made to implement a federal project.

Rivers and Harbors Act (RHA)
Section 10 of the RHA prohibits the building of wharves, piers, jetties, and other structures without approval from the USACE. Dredging activities (excavation) or dredged placement activities (fill) within navigable waters also requires the approval of the USACE.

Resource Conservation and Recovery Act (RCRA)
This Act controls the generation, transportation, treatment, storage and disposal of hazardous wastes. Guidelines for management of non-hazardous wastes are also provided. The USEPA is designated as the administrating agency of this Act. Beneficial use alternatives identified as part of this DMMP will require that materials be RCRA compliant.

Executive Order 13089 – Coral Reef Protection
Executive Order 13089 was established for the protection of U.S. coral reef ecosystems. It states that all Federal agencies conducting activities potentially affecting coral reef ecosystems within waters of the U.S. need to identify operations that may affect the coral reef ecosystems, use their jurisdiction to protect and enhance the conditions of the systems, and ensure that any actions authorized, funded, or implemented will not degrade the conditions required to sustain healthy coral reef ecosystems. Executive Order 13089 also provides for the implementation of measures needed to research, monitor, manage and restore affected coral reef ecosystems, including measures to reduce impacts from pollution, sedimentation and fishing. To protect the reef community, construction dredging activities will use best management practices (BMPs) to control the potential release of material that may lead to increases in suspended material into the water.

Magnuson-Stevens Fishery Conservation and Management Act
This Act was established to provide for the management of fish and other species within the Exclusive Economic Zone (EEZ) through Regional Fishery Management Councils. The Act requires national fishery conservation and management for the sustained participation of fishery dependent communities, and minimizes economic impacts to such communities. It also identifies overfished species and rebuilds those stocks, and identifies and protects essential fish habitat that may potentially be impacted by activities conducted under federal permits, licenses or other such authorities. This Act may be applicable to designated areas within the Apra Harbor Complex.

National Historic Preservation Act (NHPA)
The NHPA provides for a National Register of Historic Places to include districts, sites, buildings, structures, and objects significant in American history, architecture, archaeology, and culture. Section 106 of the National Historic Preservation Act requires Federal agencies to consider potential impacts on historic properties resulting from federal activities and provides for the Advisory Council on Historic Preservation a reasonable opportunity to comment on such activities. Goals of this act are to seek ways to avoid, minimize, or mitigate any adverse effects on historic properties. Placement site considerations must include NHPA guidance when historical resources are present.

Archaeological Resources Protection Act (ARPA)
The primary purpose of the ARPA is for the protection of archaeological resources (being at least 100 years or older), and sites that are on public or Indian lands, and to support the exchange of information between governmental authorities, the professional archaeological community,

and other stakeholders having collections of archaeological resources. The ARPA mandates that archaeological resources or sites may not be excavated, removed, damaged or altered. Placement site considerations include ARPA guidance when archaeological resources are present.

Several Acts listed by GEPA (2000) as pertaining to dredging activities on Guam do not apply to the proposed construction dredging within the Inner Apra Harbor discussed in this DMMP. Placement of dredged material into confined facilities does not require guidance by the Marine Protection, Research and Sanctuaries Act (MPRSA). The Inner Apra Harbor is under the authority and jurisdiction of the U.S. Navy and is not utilized for private commerce; therefore, the Merchant Marine Act is not applicable. Inner Apra Harbor is not a Superfund site; therefore, the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) as amended by Superfund Amendments and Reauthorization Act (SARA) do not apply. In addition, the Toxic Substances Control Act does not apply because Polychlorinated biphenyls (PCB) concentrations in the material to be dredged are well below 50 parts per million (ppm). The Water Resource Development Act (WRDA) provides for the conservation of water resources, and is biennially renewed to authorize the USACE to perform specific actions leading to the improvement of rivers and harbors of the U.S. However, the proposed construction related dredging activities are not a component of current or any proposed WRDA legislation, therefore, WRDA would not apply.

Although the dredged material management alternatives discussed herein will occur almost entirely within Navy property (with the exception of the possible beneficial use of dredged material for the proposed Commercial Port Expansion), Guam laws and regulations may apply.

2.0 PROJECT DESCRIPTION AND DREDGING REQUIREMENTS

2.1 Description of Apra Harbor Naval Complex

The Apra Harbor Naval Complex comprises 4,575 acres (a) (1,852 hectares [ha]) on lands surrounding Apra Harbor. It is located on the west central coast of Guam, approximately 8 miles (mi) (12.8 kilometers [km]) southwest of Hagatna, the capital city (Figure 1). The naval complex consists of the Main Base, the Fuel and Supply Department, and the PWC. The development of the complex, including fast land creation and wharf construction following World War II, resulted in the division of Apra Harbor into an inner and outer harbor. The majority of Department of the Navy (DON) operations occur on lands bordering Inner Apra Harbor. The 750 ft (228 m) wide entrance to Inner Apra Harbor occurs at its northern end, between the lands occupied by the former SRF on the west and Polaris Point on the east. Inner Apra Harbor is approximately 0.8 mi (1.3 km) wide and 1.5 mi (2.4 km) long covering a total of 650 a (263 ha). Mangrove and wetland habitats, associated with the Aplacho and Atantano Rivers, are located along the eastern edge of Apra Harbor, while the southern and western boundaries of Inner Apra Harbor are developed and support Navy operations. The Naval Complex also encompasses Camp Covington and the Orote Peninsula.

Located within the Naval Complex are seven active wharves in Inner Apra Harbor and three active wharves in Outer Apra Harbor (Figure 2). The COMNAVREGMAR Waterfront Function Plan (HHFP 2003b) describes current activities for each of the Naval Complex's wharves. Alpha and Bravo Wharves, located on the southwest corner of Polaris Point, are designated as berths for submarines and the submarine tender USS Frank Cable (AS-40). The northwest corner of Polaris Point, facing Outer Apra Harbor, is the location of the "former" Charlie Wharf. The former SRF includes the wharves Lima, Mike, November, Oscar, Papa, and Quebec, and is currently leased to Guam Shipyard Inc. through the Guam Economic Development Authority (GEDA). Guam Shipyard Inc. uses this land to continue to provide ship repair, maintenance, and support to the Navy.[3] The general-purpose wharves Romeo, Sierra, Tango, Uniform, and Victor are located along the western side of Inner Apra Harbor. Uniform Wharf is currently not operational for naval berthing due to earthquake damage sustained in 1993; however, wharf improvements are planned for FY 2010 to provide "cold iron" berthing support for the Amphibious Readiness Group (ARG). The supply wharf, X-Ray, is located in the southeast corner of Inner Apra Harbor. Delta and Echo refueling wharves are located in Outer Apra Harbor adjacent to Dry Dock Island. Kilo Wharf is also located in the Outer Apra Harbor, on the Orote Peninsula, and is used for on-loading and off-loading of ammunitions from ordnance supply ships and occasional carrier berthing.

[3] The term "SRF" will be used throughout this report to maintain consistency with other existing documentation.

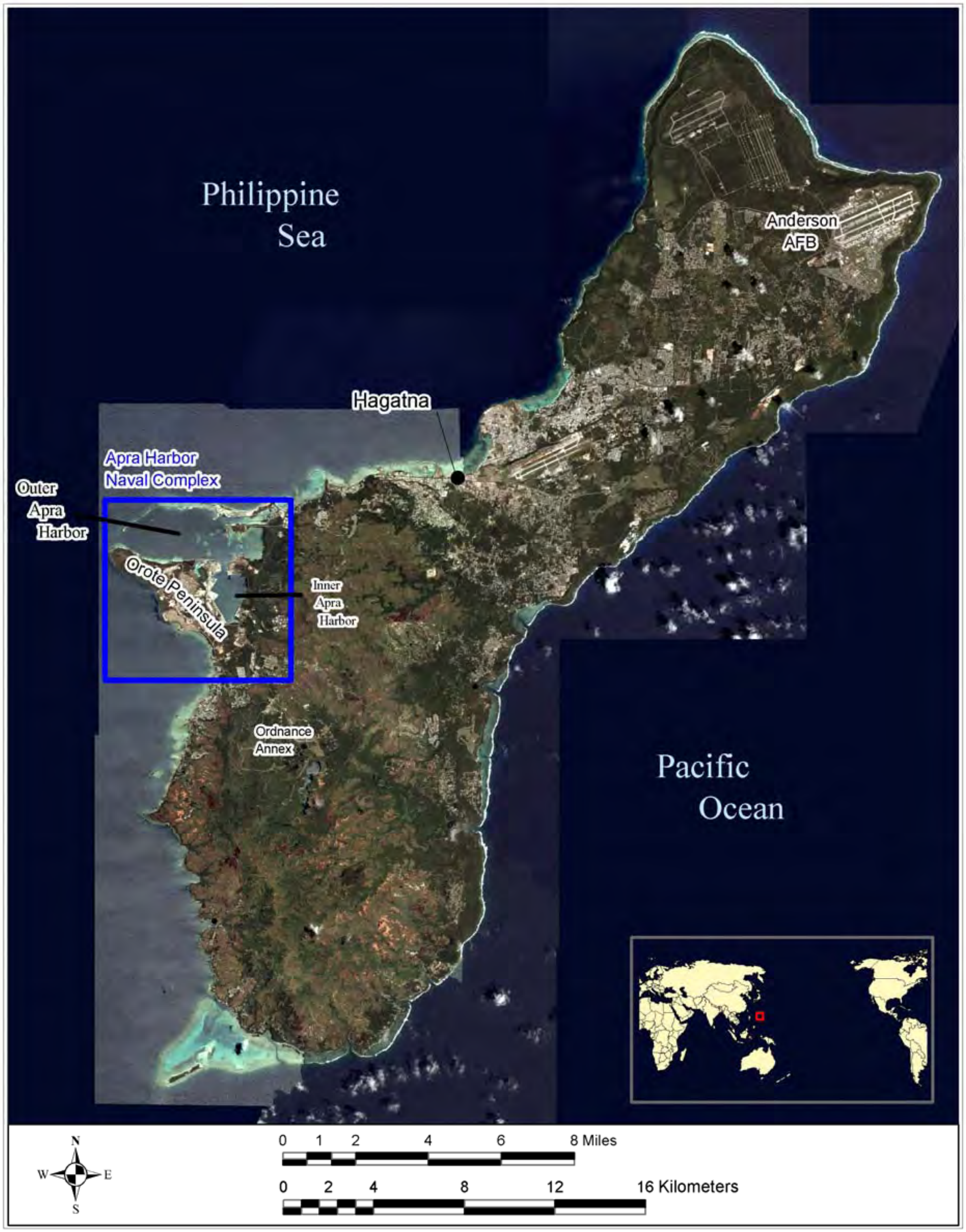


Figure 1. Guam General Vicinity Map.

Figure 2. Location of Navy Wharves throughout Inner and Outer Apra Harbor.

2.2 Dredging Requirements

Dredging is the removal of sediment in its natural or recently deposited state by mechanical or hydraulic means. The "dredging and disposal process" is defined as the excavation, transport, and placement of dredged material. Following excavation, dredged material can be transported from the dredging site to the placement site via the dredge itself, or by barge, pipeline, truck, rail, or a combination thereof. Placement sites may be located in open-water, nearshore, or upland locations. A comprehensive DMMP requires an examination of the compatibility between the dredging equipment and techniques used for excavation, the transport of the material from the dredging site to the placement area, and the management of the placement area. This document reevaluates dredging and transportation techniques, placement options and beneficial use alternatives as recommended in the Phase I DMMP with consideration for recent adjustments to the Navy's operational requirements.

2.2.1 Dredge Areas, Quantities and Characteristics

The COMNAVREGMAR Waterfront Function Plan (HHFP 2003b) detailed three separate project areas proposed for construction dredging and their associated design depths. These projects were identified as P-431, P-518, and P-436. As a result of these three projects, approximately 695,000 cy (531,366 m^3) of sediment was dredged. In the three years following the development of the Phase I DMMP, dredging associated with P-431 was successfully completed with approximately 407,000 cy (311,174 m^3) of dredge material being placed in an upland dewatering facility. Both P-518 and P-436, originally scheduled for FY 2007 and FY 2009, respectively, have been cancelled. However, additional dredging associated with several new projects has been identified. First, P-502, scheduled for FY 2008, requires 98,300 cy (75,156 m^3) of sediment to be dredged in association of the Kilo Wharf expansion (Table 1). It should be noted that an evaluation conducted by Moffatt and Nichol (2007) determined that the dredged material generated by the P-502 Kilo Wharf project can be placed in the existing Orote Airfield Confined Disposal Facility (CDF). Therefore, this material is not included in the total volume of dredged material to be managed herein. Second, P-433, scheduled for FY 2010, requires 508,877 cy (389,064 m^3) of sediment to be dredged in association with anticipated berthing requirements at Sierra Wharf. Third, an unscheduled project associated with the construction of a CVN capable berth requires between 478,900 cy and 758,000 cy (366,145 m^3 and 579,533 m^3) of sediment to be dredged. P-439, also scheduled for FY 2010, does not require dredging in association with Uniform and Victor Wharves improvements. Together, the P-433 and CVN projects result in the need to manage an additional volume of 987,777 cy to 1,266,877 cy (755,209 m^3 and 968,597 m^3), depending on the final CVN alternative selected. Dredged volumes include a 2-ft overdredge allowance; however they do not include a bulking factor to be consistent with other concurrent studies (TEC Inc. JV 2008 – in progress).

Table 1. Estimated Future Construction Dredge Material Generation for U.S. Navy, Apra Harbor, Guam

Project	Year	Volume Requiring Management (cy)[1]
P-502	2008	98,300[2]
P-433	2010	508,877
CVN Wharf - Former SRF Parallel to Shore	Unscheduled	478,900[3]
CVN Wharf Alternative - Polaris Point Parallel to Shore		758,000[3]
CVN Wharf Alternative - Polaris Point Diagonal		672,400[3]

[1] Dredged volumes include a 2 ft overdredge allowance and no bulking factor.
[2] Dredged material to be placed in Orote Airfield CDF and is not included in the total dredged volume to be managed.
[3] Dredged volumes include channel, turning basin, and wharf.

Dredged material from each of the proposed construction projects has been evaluated in accordance with three national testing manuals: *Evaluation of Dredged Material Proposed for Discharge in Waters of the U.S. – Testing Manual (Inland Testing Manual*; USEPA and USACE 1998), *Evaluation of Dredged Material Proposed for Disposal and Island, Nearshore, or Upland Confined Disposal Facilities – Testing Manual (Upland Testing Manual*; USACE 2003), and *Evaluation of Dredged Material Proposed for Ocean Disposal – Testing Manual (Ocean Testing Manual*; USEPA and USACE 1991).

P-502

Construction dredging at Kilo Wharf is proposed as Project P-502 in order to maintain the operational preparedness of the Navy to support new T-Class Combat Logistics Force ships (e.g., Advanced Auxiliary Dry Cargo Ships [T-AKE] and Ammunitions Ships) and to provide temporary mooring of larger transient vessels in Guam. This project was originally designed to extend the existing Kilo Wharf 285 ft (86.9 m) to the west and 115 ft (35.1 m) to the east, and deepen the extended areas to -56 ft (-17.1 m) mean lower-low water (MLLW). The Kilo Wharf design has been modified, eliminating the east expansion and extending the west expansion to 400 ft (121.9 m). The area fronting the wharf would be construction dredged to -45 ft (-13.7 m) MLLW with 2-ft (0.6-m) overdredge allowance (Figure 3). P-502 is scheduled for FY 2008 and will generate a cut volume of approximately 92,800 cy (70, 951 m^3) of dredged material in the vicinity of Kilo Wharf. Accounting for the 2-ft overdredge allowance, approximately 98,300 cy (75,158 m^3) of dredged material will be generated. The dredged material generated from the P-502 project was recommended for placement into the existing Orote Airfield CDF (Moffatt and Nichol 2007).

Results of the dredged material evaluations for P-502 were presented in both the *Dredged Material Management Plan: Sampling and Analysis of Sediments for Construction Dredging at Kilo Wharf – Final Report* (Weston and Belt Collins 2005) and *Dredged Material Sampling and Tier III Analysis Evaluation for Apra Harbor Projects (P-436, P-502, P-518), Guam – Final Report* (Weston 2007). The former report evaluated the potential environmental impacts P-502 project dredged material may have if placed in an upland dewatering facility. Potential

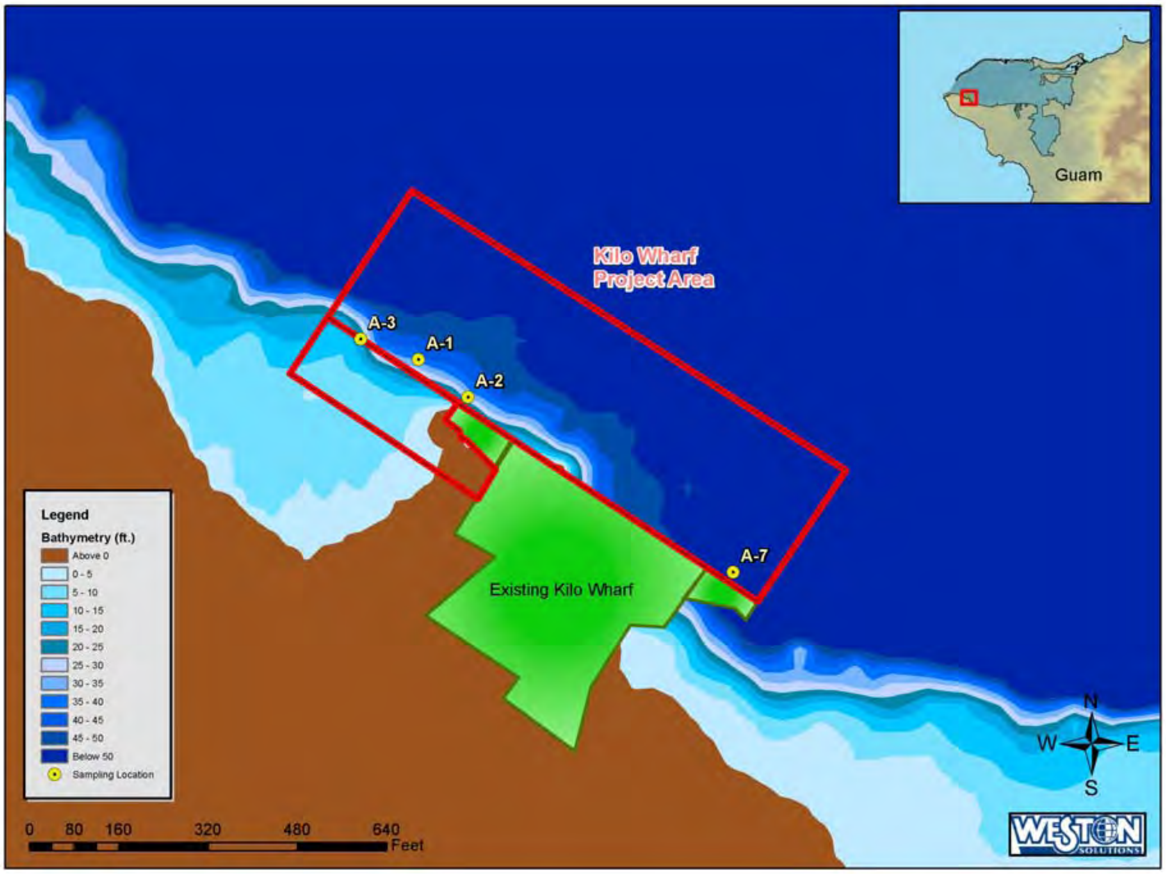


Figure 3. Dredge Footprint for P-502, Kilo Wharf, Outer Apra Harbor, Guam

environmental impacts included runoff associated with rain, leachate associated with foundation soils, effluent discharge from pore water, and excess carrier water and volatilization of volatile organics. The report indicated P-502 project dredged material was not expected to cause any adverse environmental impacts and was suitable for placement in the existing Orote Airfield and SRF dewatering facility sites, and the proposed Polaris Point, Commercial Port, Field 3 and Field 5 dewatering facility sites. The latter report (Tier III evaluation) evaluated the suitability of P-502 project dredged material for ocean disposal, assuming an Ocean Dredged Material Disposal Site (ODMDS) is designated for Guam. The report indicated P-502 project dredged material was suitable for ocean disposal.

P-433

Construction dredging along Sierra and Tango Wharves is proposed as part of Project P-433 in order to maintain the operational preparedness of the Navy to provide “cold iron” berthing for extended transient ships including those in the ARG and additional shore side support. The area along the wharves would be construction dredged to -38 ft MLLW (-11.6 m) with a 2-ft (0.6-m) overdredge allowance (Figure 4). P-433 is scheduled for FY 2010 and will generate a cut volume of approximately 246,264 cy (188,282 m^3) of dredged material in the vicinity of Sierra and Tango Wharves. Accounting for the 2-ft overdredge allowance, approximately 508,877 cy (389,064 m^3) of dredged material will be generated.

Figure 4. Dredge Footprint for P-433, Sierra Wharf, Inner Apra Harbor, Guam

Although dredged material evaluations have not been completed specifically under the P-433 project scope, the proposed P-433 dredge footprint is consistent with the proposed dredge footprint under the P-436 project scope. Results of the dredged material evaluations for P-436 were presented in the *Phase I Dredged Material Management Plan for Apra Harbor, Guam* (MEC-Weston 2005), *Dredged Material Long-Term Management Strategy: Phase II Guam, Evaluation of Environmental Effects for Dewatering and Management of Materials from MCON P-518 and P-436 – Final Report* (Weston 2005b), and the *Dredged Material Sampling and Tier III Analysis Evaluation for Apra Harbor Projects (P-436, P-502, P-518), Guam – Final Report* (Weston 2007).

Sediment chemistry results presented in Phase I were provided solely as a screening tool. The Phase I preliminary assessment determined that none of the analytes tested in the sample collected adjacent to Sierra Wharf exceeded the PWC Landfill acceptance criteria for daily cover.

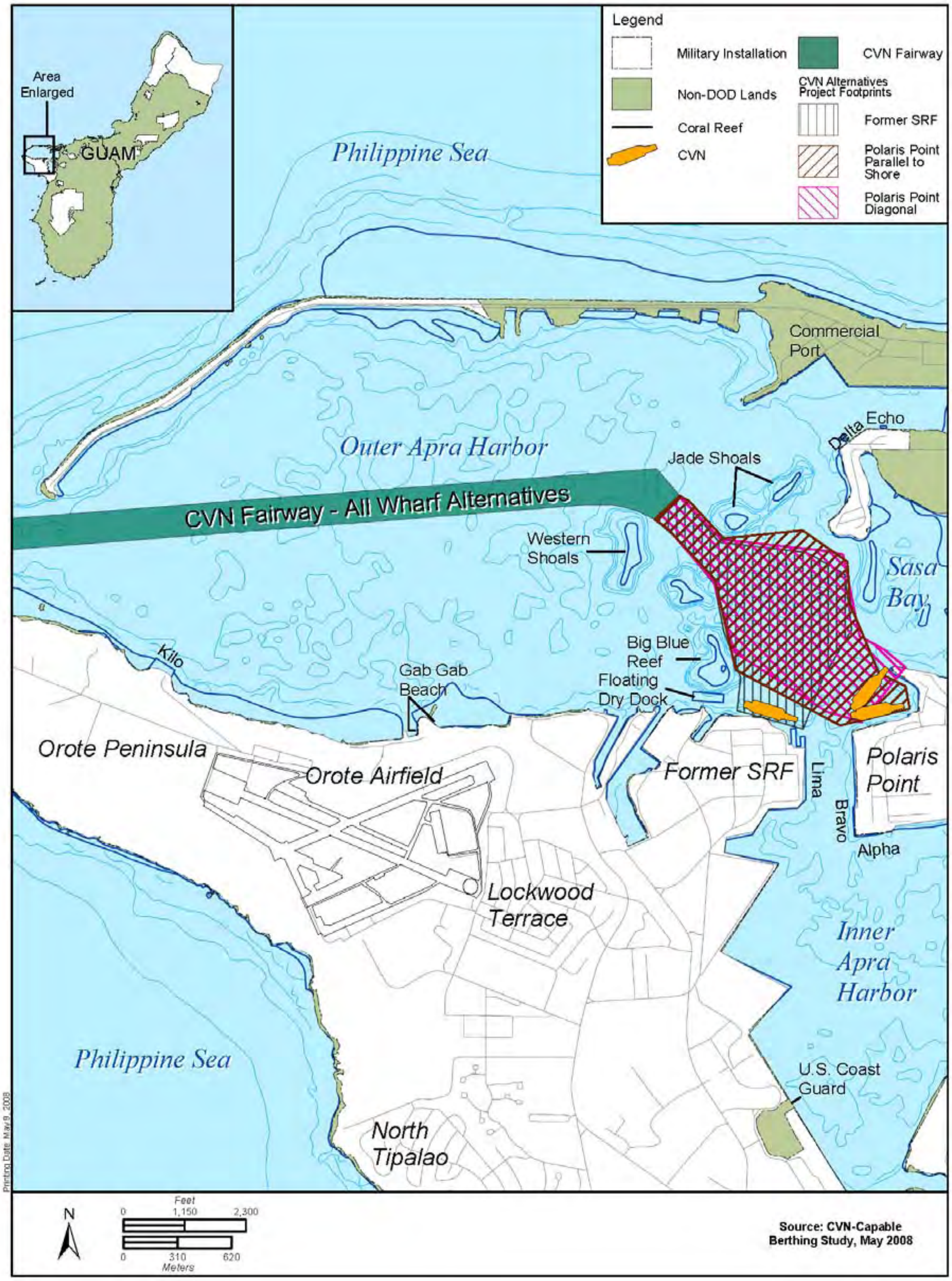
The Phase II report evaluated potential environmental impacts P-436 project dredged material may have if placed in an upland dewatering facility. Potential environmental impacts included runoff associated with rain, leachate associated with foundation soils, effluent discharge from pore water and excess carrier water, and volatilization of volatile organics. The report indicated P-436 project dredged material was not expected to cause any adverse environmental impacts with the exception of minimal detectable odors at all sites and potential volatized mercury exposures downwind of Field 3. With the implementation and enforcement of maximum exposure times for workers and residents downwind of Field 3, P-436 project dredged material was determined to be suitable for placement in the proposed Commercial Port, Field 3, and Field 5 dewatering facility sites.

The Tier III report evaluated the suitability of P-436 project dredged material for ocean disposal, assuming an ocean dredged material disposal site (ODMDS) is designated for Guam. The report indicated that the majority of P-436 project dredged material was suitable for ocean disposal. Proposed dredged material from an area fronting Oscar, Papa, Quebec, and Romeo Wharves did not meet the limiting permissible criteria (LPC) requirements for ocean disposal. It should be noted that this area is not within the proposed P-433 dredge footprint. Proposed dredged material immediately adjacent to Sierra Wharf was recommended for ocean disposal despite not meeting the LPC requirements for ocean disposal. This recommendation was made despite slight toxicity observed in only one amphipod solid phase (SP) test and based on the high survival of all test organisms in suspended particulate phase (SPP) tests, *Neanthes arenaceodentata* high survival in SP tests, relatively low contaminant concentrations, tissue concentrations below published relevant effects levels and low total PCB tissue concentrations (<20 microgram per kilogram [µg/kg]).

CVN Capable Berth

To accommodate the berthing of a CVN for 21-day visits to Apra Harbor, the Navy proposes construction dredging for the development of a deep water wharf at one of three alternative sites within the harbor, and along access fairways to the selected site. The selection of the appropriate site for the berthing of larger vessels will be based on engineering, environmental, regulatory, and economic feasibility.

Three wharf alternatives, or sites, have been identified for the potential construction of a deep water wharf in Apra Harbor, Guam. The sites are on either side of the entrance to Inner Apra Harbor. These include two sites on Polaris Point near the former Charlie Wharf (one parallel and one diagonal to shore) and one site at the former SRF site (Figure 5).



From TEC Inc. JV 2008-in progress

Figure 5. Dredge Footprint for CVN Alternatives, Outer Apra Harbor, Guam

The sites at Polaris Point are located in Outer Apra Harbor at the northern end of Polaris Point in a cove situated east of the Inner Harbor entrance channel. In one alternative, the berth would be parallel to the coastline; and in a second alternative the berth would be aligned diagonally from the northwest corner of Polaris Point to the point bounding the northern side of the cove. Steel sheet pile caisson foundations from the former wharf lay offshore from this site, and water depths in the area range from -20 to -80 ft (-6.1 to -24.4 m) MLLW. The dredge footprint for these two potential sites includes the area fronting the wharf, a turning basin northwest of the site, and an access fairway (CVN Fairway) trending to the northwest from the turning basin to Outer Apra Harbor. Dredging will occur to -49.5 ft (-15.1 m) MLLW in all areas with an additional 2-ftt overdredge allowance. Accounting for the 2-ft overdredge allowance, the Polaris Point – Parallel to Shore alternative will generate a volume of approximately 758,000 cy (579,533 m^3) of dredged material. Accounting for the 2-ft overdredge allowance, the Polaris Point–Diagonal alternative will generate a volume of approximately 672,400 cy (514,087 m^3) of dredged material.

The SRF site is located in Outer Apra Harbor, west of the Inner Harbor entrance channel and north of the former Navy SRF complex, which is currently the Guam Shipyard. Water depths in this area range from -20 to -73 ft (-6.1 to 22.3 m) MLLW, with the exception of a shallow reef that lies immediately north of the site. The dredge footprint for this potential site includes the area fronting the wharf, and similar turning basin and access fairway (CVN Fairway) identified for the Polaris Point sites. Like Polaris Point, if this site is selected, dredging will occur to -49.5 ft (-15.1 m) MLLW with a 2-ft overdredge allowance. Accounting for the 2-ft overdredge allowance, the Former SRF – Parallel to Shore alternative will generate a volume of approximately 478,900 cy (366,145 m^3) of dredged material.

Results of dredged material evaluations conducted in Outer Apra Harbor in support of the potential CVN berthing alternative were presented in the *Sediment Characterization for Construction Dredging at Charlie, Sierra and SRF Wharves, Apra Harbor, Guam – Final Report* (Weston 2006). The purpose of this report was to delineate the distribution and magnitude of chemicals of potential concern within material to be dredged from the three CVN alternative sites. The sediment chemistry results were compared to previous studies conducted within Apra Harbor (MEC-Weston 2005, Weston 2005a, Weston 2005b, Weston and Belt Collins 2006) to assist with the selection of appropriate management options (e.g., placement of material in a dewatering facility and eventual beneficial use) for sediment dredged during the deep water wharf (CVN capable berth) construction project. None of the Outer Apra Harbor samples representing proposed dredged material exceeded effects-range median (ER-M) values. ER-M values are a screening tool to assess potential significance of elevated sediment-associated contaminants of concern, in conjunction with biological analyses.

2.2.2 Dredging Methods

There are two general types of dredging operations: mechanical dredging and hydraulic dredging. The operations vary by the method used to loosen the material from its *in-situ* state and transport the material from the seafloor to the water surface. Mechanical dredging is typically conducted using a grab or bucket, such as a clamshell dredge. Hydraulic dredging is typically conducted using a cutter suction (pipeline) dredge or hopper dredge. It should be noted that dredged material from Apra Harbor may contain submerged ordnance and explosives.

Regardless of the selected dredging method, mechanical or hydraulic, BMPs will be required to appropriately screen for submerged ordnance and explosives (TEC JV, Inc. 2008-in progress).

The Phase I DMMP presents a detailed discussion comparing mechanical and hydraulic dredging techniques (MEC-Weston 2005). For the purposes of this study, the Phase I DMMP recommendation to use mechanical dredging was determined to be consistent with the current objectives and is summarized below.

2.2.2.1 Mechanical Dredging

Mechanical dredging is the recommended dredging method, and has been used in past Guam dredging projects. While the production volume is considerably less than the volume dredged by other means (i.e., hydraulically), the nature of mechanically dredged material is better suited for the management alternatives described herein. As stated in the Phase I DMMP, a bulking factor of 10% should be applied to dredged volume during mechanical dredging. Dredged volumes used in this report do not include a bulking factor to be consistent with other concurrent studies (TEC Inc. JV 2008 in progress). The dewatering time for mechanically dredged material is less than the dewatering time for hydraulically dredged material.

2.2.2.2 Hydraulic Dredging

Construction dredging within Inner Apra Harbor with a cutter suction dredge was not the recommended method for the Phase I DMMP due to the high volume of water and navigational constraints caused by the discharge line. The water content of hydraulically dredged material is much higher than that of mechanically dredged material. Production volume can range from four to six times the dredged volume (DON 2003). Upland placement of this volume will require more space and ocean disposal by dump scows will require more trips than mechanically dredged material. In addition, the pipeline used in cutter suction dredging may impede naval operations and potentially effect safe navigation within Inner Apra Harbor. Consequently, development and design of proposed alternatives included in this DMMP assume that material will not be hydraulically placed.

Again, high water content of hopper dredged materials would result in long dewatering times and larger dewatering areas. In addition, hopper dredging is typically used as an alternative to hydraulic cutterhead dredging when bottom dumping or when a large distance between the dredge site and placement area precludes the use of a cutterhead dredge. Neither situation is relevant to the construction dredging project in this DMMP. Consequently, design and development at proposed alternatives included in this DMMP do not include consideration for hopper dredging.

2.2.3 Dredged Material Rehandling

Rehandling is the process of loading, transporting, and offloading dredged material, and applies to upland placement alternatives. The process is highly dependent on the type of dredging method employed and the location of the placement area. Rehandling is often the most important factor in determining the economic feasibility of a dredging project since costs increase with the number of times dredged material is re-handled. Dredged material rehandling should be evaluated in the early stages of the planning process using the following criteria:

- Available Means of Rehandling
- Nature of Material (Wet/Dry)
- Annual Volume of Dredged Material
- Duration of Project
- Estimated Cost of Available Transport Modes
- Technical, Environmental, Legal, and Federal Agency Regulations (Herbich 2000)

For the purposes of this study, the recommendations made in the Phase I DMMP were determined to be consistent with the current objectives and are summarized below.

Several dredging scenarios involving various dredging, transport, and disposal methods were considered in the Phase I DMMP: (1) mechanical dredging and mechanical offloading upland; (2) mechanical dredging and hydraulic offloading upland; (3) hydraulic dredging and hydraulic offloading upland; (4) mechanical dredging and mechanical near-shore disposal; (5) hydraulic dredging and hydraulic near-shore disposal; and (6) mechanical dredging and in-water disposal.

Of the six dredging and rehandling scenarios considered, mechanical dredging and mechanical offloading for upland or near shore disposal were the most feasible based on dewatering site capacity, dewatering time, and environmental and navigational considerations and constraints. The increased volume of dredged material associated with hydraulic dredging and offloading required larger capacity placement facilities and produced larger volumes of decanted water that may have compromised marine resources in either Inner or Outer Apra Harbor. In addition, the increased water content associated with hydraulic dredging and offloading extended dewatering times, delaying the use of dredged material for beneficial use. The discharge line used in cutter suction dredging may have limited naval operations in Inner Apra Harbor during dredging activities. The navigational constraints imposed by the hydraulic discharge line may have also restricted naval operations and potentially increased navigational hazards within Inner Apra Harbor.

Mechanical dredging and offloading must consider interchange loading and unloading operations to accommodate the specific site needs in terms of efficiency and cost. This assessment utilizes the same assumptions as the Phase I DMMP; the dredged material will be offloaded from the scow at Alpha, Delta/Echo, or Uniform wharves. Alpha Wharf is a general-purpose wharf with 520 linear ft (158 m) of berth space. Delta/Echo Wharves are refueling and homeporting docks with 1,600 linear ft (488 m) of berth space. Uniform Wharf is a general-purpose wharf with 1,200 linear ft (366 m) of berth space.

2.2.4 Potential Dredged Material Management Alternatives

The dredged material management alternatives examined for the Phase I DMMP included the placement of material into confined placement, open-water placement, and contained aquatic disposal (CAD). Eventual beneficial use alternatives with the dewatered dredged material include bulkhead construction fill material, magazine/berm construction, landfill cover, and shoreline restoration. In total, 27 alternatives were considered in the Phase I DMMP and reevaluated as part of this study (Table 2; Figure 6). During the course of this study, it was determined that five dewatering sites and four beneficial use alternatives were considered to be logistically, technically, and economically feasible (highlighted in Table 2). Feasible dewatering facility alternatives are presented in Section 3.2. Feasible beneficial use alternatives are presented in Section 3.4.

2.2.4.1 Confined Placement (Dewatering Facilities)

Upland confined placement and nearshore confined placement were recommended management alternatives in the Phase I DMMP (MEC-Weston 2005). This study solely recommended the use of upland confined placement, or dewatering facilities for the temporary storage of dredged material. Conventional open water placement and contained aquatic disposal sites were and still remain infeasible management alternatives within the scope of this document because an ocean disposal site has not be designated. However, efforts are currently underway to designate an ODMDS in Guam. Dewatering facilities are engineered structures for containment of dredged material. Dewatering facilities are bound by confinement dikes or structures to enclose the disposal area, thereby isolating the dredged material from its surrounding environment. An upland dewatering facility consists of a fully diked facility located above the water line and out of wetland areas.

Dewatering facilities may be used for either coarse or fine-grained material. The material is placed into the facility either hydraulically or mechanically. Placing the material directly in to the facility from the dredging site through pipelines is the most economical method. The dredged material consists of a certain percentage of slurry when it is pumped into the facility. Depending on the placement method, slurry material initially deposited in the dewatering facility may occupy from 1.1 times (mechanical placement) to five to 10 times (hydraulic placement) its original volume due to water content. Design of the dewatering facility must account for this additional volume (production volume; Section 2.2.2.1) during the drying phase. Following placement, the finer sediments are allowed to consolidate, settle, and dewater. Water evaporates or percolates through the dike walls or into the ground. Facilities that use weirs to enable surface water to exit the facility must be designed with sufficient retention times to ensure adequate sediment settling will occur.

Dredged material placement within a dewatering facility has several benefits. Dewatering facilities can prevent or substantially reduce the amount of dredged material re-entering the environment when the facility is properly designed, operated, and maintained. Dewatering facilities can provide either a temporary or permanent storage location for dredged material that will naturally vegetate if left undisturbed. Finally, dewatering facilities can be used as processing and/or blending areas for beneficial use activities.

The size, design and cost of a dewatering facility are site-specific. Factors considered in the design of a dewatering facility include: the location, physical nature of sediments to be placed (e.g., grain size, organic content, etc.), physical nature of project footprint, chemical nature of sediments (contaminated vs. clean), volume of sediments to be stored, placement method, and the length of time material will be stored at the facility. Depending on the design, operation and maintenance (O&M) costs of the dewatering facility will vary.

The use of dewatering facilities is a long-term or short-term solution for the management of material dredged from Inner and Outer Apra Harbor. Material may be stored indefinitely in the facility or temporarily placed for dewatering prior to beneficial use.

2.2.4.2 Potential Beneficial Uses

Dredged material provides a manageable and valuable resource. As such, beneficial use is a desired management option. Beneficial use alternatives evaluated for the Phase I Guam DMMP included construction fill material, magazine construction, daily landfill cover, and shore line restoration (MEC-Weston 2005). Factors that were considered in the evaluation of beneficial use alternatives included the identification of local needs and opportunities for beneficial use, geotechnical and sediment chemistry requirements, distance from the dredging site or dewatering site to the location of beneficial use, site accessibility, handling requirements, and capacity of beneficial use in relation to the volume of dredged material available.

This study reviewed the findings of the Phase I DMMP and determined four categories of beneficial use alternatives continues to provide feasible management option for Apra Harbor dredged material. These beneficial use alternatives include: construction fill material, magazine construction, daily landfill cover and shoreline restoration. Section 3.4 of this report or the Phase I DMMP (MEC-Weston 2005) presents a detailed discussion of these alternatives. For all of the beneficial use alternatives discussed in this report, the material must first be placed in an upland dewatering facility. After the material is sufficiently dry, the material would be available for beneficial use alternatives in planned construction activities.

Table 2. Summary of Dewatering Facility Options and Beneficial Use Alternatives

ID	Site	Capacity	Primary Constraints	Phase I DMMP Determination
Dewatering Facility Options				
1	Polaris Point Field	2,072,649 cy	Relocation of utilities, loss of recreational facilities, within Explosive Safety Quantity Distance (ESQD)	Feasible
2	Ordnance Annex - Near Main Gate	41,584 cy	Insufficient capacity, limited access, environmental	Infeasible
3	Ordnance Annex - Near Fena Reservoir	27,941 cy	Insufficient capacity, limited access, environmental	Infeasible
4	Field 1	54,539 cy	Transport distance, proximity to recreational land uses	Infeasible
5	Field 2	94,773 cy	Proximity to utilities, recreational land uses	Infeasible
6	Field 3	425,920 cy	Relocation of utilities	Feasible
7	Field 4	600,805 cy	Relocation of utilities	Feasible
8	Field 5	2,059,904 cy	Relocation of utilities, removal of abandoned structures	Feasible
9	PWC Compound	762,461 cy	Relocation of utilities, removal of abandoned structures	Feasible
10	Ship Repair Facility - Existing Site	16,000 cy	Insufficient capacity, removal of existing dredged material	Infeasible
11	Marina	17,381 cy	Insufficient capacity, limited access	Infeasible
12	Orote Airfield – Existing Site	71,900 cy	Removal of existing dredged material	Infeasible
13	Dry Dock Island	59,876 cy	No existing berthing or staging areas, limited access	Infeasible
14	Commercial Port - Field 1 (East and West Combined)	573,459 cy	Removal of limestone escarpment, limited staging areas	Feasible
15	Commercial Port - Field 2	730,721 cy	Loss of wetland habitat	Infeasible
Beneficial Use Alternatives				
A	Polaris Point - North Park and Beach Nearshore Placement/Fast Land	695,000 cy	Loss of marine habitat, incompatible with land use designation	Infeasible
B	Polaris Point - Charlie Wharf Rehabilitation	27,000 cy	Geotechnical suitability of dewatered material	Feasible
C	Polaris Point - Bravo Wharf Expansion	5,300 and 10,700 cy	Availability of dewatered material/coordinated schedule	Infeasible
D	Polaris Point - Alpha Wharf Nearshore Placement/Fast Land	152,500 cy	Loss of marine habitat, not planned	Infeasible
E	Ordnance Annex – Magazine Construction	89,450 cy	Geotechnical suitability of dewatered material, availability of dewatered material/coordinated schedule	Feasible
F	PWC Landfill – Daily Cover	18,200 - 22,620 cy/year	TCLP tests, availability of dewatered material/coordinated schedule	Feasible
G	Uniform Wharf Rehabilitation	5,000 cy	Availability of dewatered material/coordinated schedule	Infeasible
H	Ship Repair Facility – Abandoned Cove Nearshore Placement/Fast Land	42,667 cy	Loss of marine habitat	Infeasible
I	IR Landfill – Capping Material	4,000 cy	At capacity, no access	Infeasible
J	Kilo Wharf Expansion	40,000 cy	Limited landside access	Infeasible
K	Orote Peninsula – Magazine Construction	102,400 cy	No waterside access, environmental	Infeasible
L	Commercial Port Expansion	1,500,000 cy	Geotechnical suitability of dewatered material, availability of dewatered material/coordinated schedule	Feasible
	Highlighted Options = Feasible Alternatives			

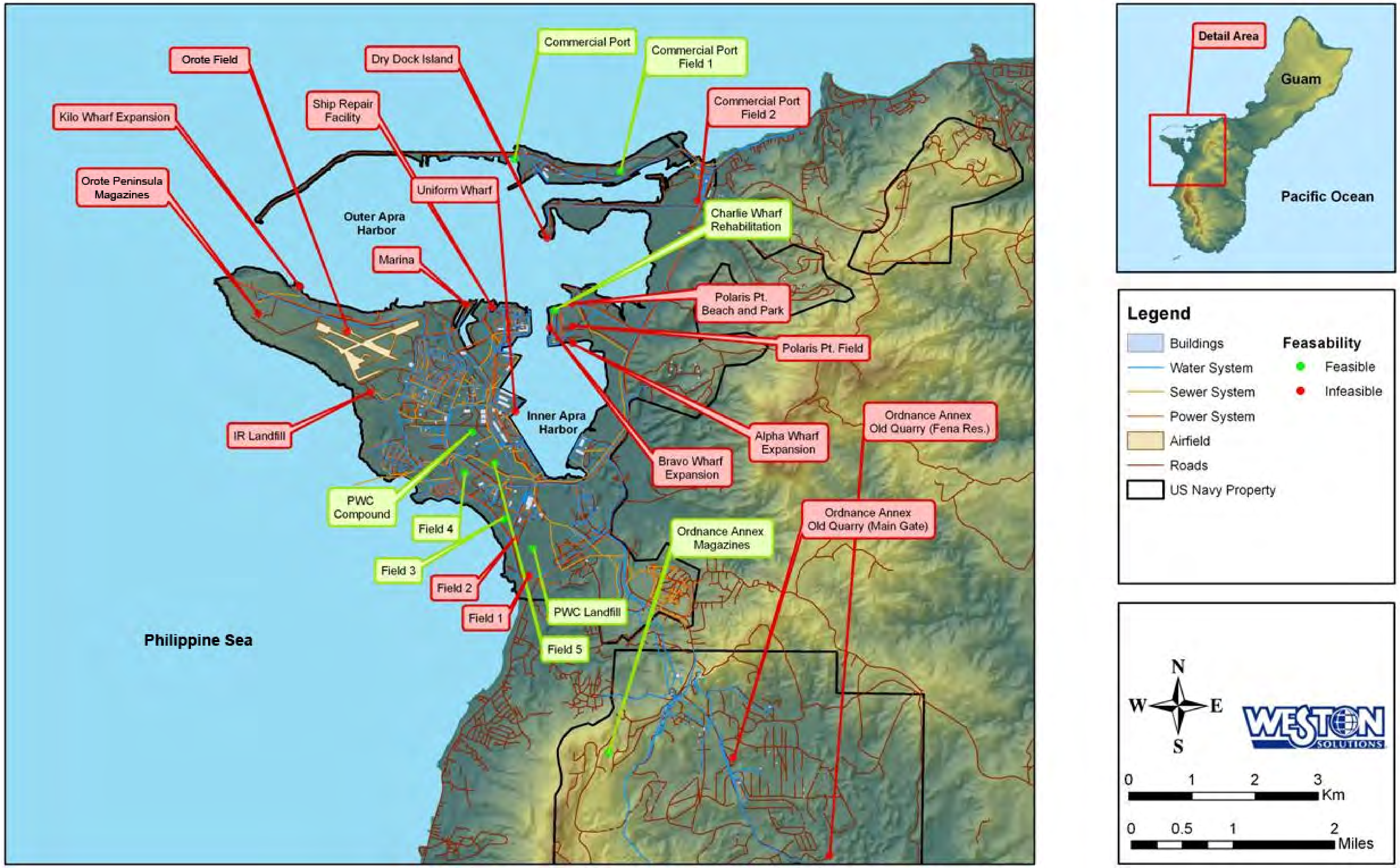


Figure 6. Overview Map of Potential Dewatering Facilities and Beneficial Use Alternatives, Apra Harbor Naval Complex, Guam

3.0 DESCRIPTION AND EVALUATION OF FEASIBLE ALTERNATIVES

This section provides an overview of dewatering and beneficial use alternatives determined to be feasible for the management of material from the proposed construction dredging projects P-433 and the selected CVN alternative. The proposed alternatives described in this chapter include dewatering sites where dredged material could be stored and allowed to dry, and potential beneficial use alternatives where dewatered dredged material could be used for planned construction projects, potential wharf expansion projects, or ongoing operations requiring fill or construction material (Figure 7). All feasible dewatering sites described in this study were considered as potential sources of material for all potential beneficial use alternatives. Alternatives that did not meet the purpose and need of the study were eliminated from further evaluation.

3.1 Formulation and Evaluation of Alternatives

This Upland Placement Study is essentially a revision, or update, to the Phase I DMMP developed by Weston in 2005. This study revisits each dewatering site and beneficial use alternative proposed in the Phase I DMMP and addresses the viability of each alternative with respect to new dredging requirements and construction schedules. Recently developed waterfront functional plans for Sierra Wharf, Victor, and Uniform Wharves and feasibility studies for the construction of a CVN capable berth (TEC Inc. JV 2008- in progress) were used to assist in the reevaluation of potential management alternatives.

Originally, the design and evaluation of potential dewatering site and beneficial use alternatives were based on multiple sources of information including data from preliminary reconnaissance surveys, an extensive literature review, and communications with Navy and other appropriate personnel (e.g., Commercial Port). The evaluation considered management strategies previously developed for Inner Apra Harbor (Olin-Estes et al. 2002); existing and future land uses of the Apra Harbor Naval Complex (HHFP 2003b); industry-accepted standards for dredged material management and beneficial use (e.g., USACE 1987) and the reasonableness of the alternatives from a technical and economic perspective (NEPA 1969 [42 United States Code (USC) §4321, et. Seq] as implemented by the Council on Environmental Quality regulations 40 Code of Federal Regulations [CFR] Parts 1500-1508).

As part of the alternative formulation process, a reconnaissance survey of the Apra Harbor Naval Complex was conducted in December 2003, which included interviews with COMNAVREGMAR and U.S. Naval Facilities Engineering Command, Pacific (NAVFAC PAC) personnel and visits to potential dewatering and beneficial use locations. The physical/chemical characteristics of sediments associated with the proposed construction dredging projects were used to evaluate the potential for environmental impacts (see Section 2.2.1).

This evaluation includes a description of capacity and costs associated with each alternative. Previous evaluation of the existing conditions of land use (air quality, soils [geology], waters [ground, surface, and marine], and biological and cultural resources) are detailed in the Phase I

DMMP (MEC- Weston 2005). The economical, technical, and logistical feasibility was evaluated at each alternative, along with environmental impacts and social considerations.

3.1.1 Assumptions

Evaluation of the alternatives required several universal assumptions regarding capacity requirements, construction schedules, dewatering times, and cost standards. Descriptions of the assumptions are as follows:

Capacity Assumptions
As discussed in the Phase I DMMP (MEC-Weston 2005) and to be consistent with other concurrent studies (TEC Inc. JV 2008- in progress), mechanical dredging is recommended for Inner Apra Harbor due to considerations based on the volume of dredged material to be managed, environmental, dewatering time, and navigational constraints. Mechanical dredging may increase the volume of cut material by 10% bulking factor; however, this is not included in capacity assumptions to be consistent with other concurrent studies (TEC Inc. JV 20008-in progress). A 2-ft overdredge allowance is factored into the capacity assumptions. As such, the anticipated volume of material requiring placement associated with each of the planned P-433 and the selected CVN alternative construction projects is 508,877 cy (389,064 m^3), and between 478,900 cy and 758,000 cy (366,145 m^3 and 579,533 m^3), respectively. Greatest capacity is determined by the volume of the dike relative to the volume of material within the facility. The greatest capacity was determined to be at a dike height where the volume of the dike is approximately 50% of the volume of material within the facility. A description of the calculations used to determine volume of the facilities is provided in Appendix C of the Phase I DMMP (MEC-Weston 2005).

Construction Scheduling Assumptions
The duration of each of the construction dredging projects depends upon the volume of material to be dredged, production schedule, type of equipment, and number of vehicles in operation at the job site. Based on recent mechanical dredging operations in Apra Harbor using current dredge equipment available in Guam for the P- 431 project, the average dredging production rate is 800 cy (612 m^3) per day (personal communications with Black Construction, Guam). This rate was applied to the P-433 and the CVN alternative construction projects, assuming a seven day work week. The P-433 project (508,877 cy [389,064 m^3]) would take approximately 1.7 years to complete. The selected CVN alternative (between 478,900 cy and 758,000 cy [366,145 m^3 and 579,533 m^3]) would take approximately 1.6 to 2.6 years to complete. However, a larger dredge and crane operation is expected to be utilized for these dredge projects, costs associated with mobilizing a dredger from the continental U.S. have been included. It should be noted that scheduling may be delayed due to typhoons, especially between the months of January and July.

Dewatering Time Assumptions
After adequate drying time, dredged material will be available for potential beneficial use. Drying times will vary according to the size of the dewatering site, the height of dredged material within the site (herein referred to as "lift"), sediment characteristics, and environmental conditions. Passive or active dewatering technologies may be applied at each dewatering site to decrease drying times. Passive dewatering systems allow water to naturally evaporate into the atmosphere or drain into the soil. Active dewatering systems decrease drying time by diverting

water off the site or into a specially designed infiltration area. Estimates are based on observations of P-431 dredged material placed on Field 5. This material was dewatered within 2 to 10 months (personal communications with Black Construction, Guam) and therefore available for beneficial use soon after placement. Prior to beneficial use, a geotechnical evaluation must be conducted to confirm moisture content is adequate for the selected beneficial use.

Environmental Assumptions

Independent of each alternative, the material will have to be offloaded at a wharf. For dewatering site alternatives located in the northern part of Inner Apra Harbor or Outer Apra Harbor it is assumed that dredged material will be offloaded at Alpha Wharf or Delta/Echo Wharves; for dewatering site alternatives located in the southern part of Inner Apra Harbor it is assumed material will be offloaded at Uniform Wharf.

Noise levels from mechanical dredging and offloading 50 ft (15 m) from the source are estimated to range from 80 to 92 A-weighted decibels (dBA) (USEPA 1971, DON 2003) and levels are estimated to decrease by 6 dBA for each doubling of distance from the noise source. Buildings at Alpha, Delta/Echo and Uniform wharves are approximately 130 to 250 ft (40 to 75 m) from offloading areas; therefore, noise levels at those distances are estimated to range from 74 to 86 dBA outdoors and 54 to 71 dBA indoors (15 to 20 dBA less). These noise levels are similar to or slightly higher than acceptable noise levels for industrial lands. The Federal Aviation Administration (FAA) generally considers average outdoor noise levels equal to or less than 75 dBA acceptable; whereas, the Department of Defense (DoD) considers average outdoor noise levels up to 84 dBA acceptable with appropriate indoor noise reduction (DON 2003).

In order to utilize Uniform Wharf, maintenance and repairs may be required. Uniform Wharf has sustained significant earthquake damage that could prohibit prolonged use of a crane on the bulkhead. Recent dredging operations have used Uniform Wharf for offloading, rehandling, and transporting of dredged material. Consequently, Uniform Wharf may be sufficiently stable to permit similar operations of the planned construction projects. However, availability of Uniform Wharf may be limited due to upgrades scheduled in FY 2011 (MCON P-439).

Cost Assumptions

Preliminary costs estimates for the dredging and construction activities are provided by TEC Inc. and are consistent with other concurrent studies (TEC Inc. JV 2008 - in progress). Actual unit costs and mobilization/demobilization (mobe/demobe) costs may vary depending on several factors, including contractor availability, local skilled labor and labor rates, and construction schedule. Cost estimates for each dewatering alternative were standardized in order to compare amongst the alternatives. Costs are based on mechanical dredging and offloading for all dewatering site alternatives due to the infeasibility of hydraulic dredging as discussed in Section 2.2.2.

Dredging costs, consistent with TEC Inc. JV (2008-in progress), are estimated to be $20.26/cy. Mobilization of dredge equipment is estimated to be $9,208,320. Dredged material placement costs ($40.52/cy) include preparing the wharf for offloading of dredged material by crane and the relocation and placement of dredged material at the dewatering site. Dredged material will be confined by earthen perimeter dikes built to an elevation that will accommodate the material generated for each project, plus a minimum of 2 ft freeboard. Crest widths range from 8 to 12 ft, depending upon the size of the facility. All of the dike will be constructed with on-site material by using previously placed dewatered dredged material. A rehandling cost to build the perimeter dike is estimated to be $16.50/cy. An additional cost for site preparation ($5,000/acre) is included. Indirect construction costs include geotechnical analysis, design and specifications, crust management plan, storm water management plan, infrastructure relocation, lighting and fencing, and miscellaneous job site costs need to be considered. An overall 10% contingency is included and is consistent with TEC JV (2008 –in progress).

3.1.2 Feasibility Evaluation Criteria

Alternatives were evaluated based on several criteria associated with their ability to meet the purpose and need, and include technical, logistical and economic feasibility, and environmental and social considerations. These criteria are described below.

Technical Feasibility
This criterion assesses the existing physical conditions and geotechnical considerations of each proposed management alternative. Based on the available data, site conditions such as infiltration rates, bearing capacity, and anticipated settlement were assessed for consistency with the requirements of the proposed management alternatives. Other general site conditions include vegetative cover, shape of the site, and the ability to develop the proposed alternative based on current and proposed land use. A management alternative was rejected if it was not technically feasible to implement.

Logistical Feasibility
This criterion focused on the operational aspects of an alternative, such as the ability of the site to accommodate the dredged material, the ability of the site to support placement of construction or dredging equipment, ingress and egress from the site, schedule, and coordination of dredged material management activities with naval operations. A project alternative was rejected if it was not logistically feasible to implement.

Economic Feasibility
This criterion focused on the cost of the alternative relative to the capacity volume of dredged material accommodated by the alternative. Unit costs used to build cost estimates for each dewatering alternative are consistent with the CVN study (TEC Inc. JV 2008 in progress) and were standardized in order to permit equitable comparison of the alternatives. Alternatives that required special construction efforts will need to be evaluated by assessing the cost relative to the benefit gained in regards to capacity and beneficial use opportunities.

Environmental Impacts
This criterion focused on the identification of potential environmental impacts from implementation of each alternative. A project alternative was rejected if it had one or more impacts to sensitive resources or receptors that would likely be unacceptable or difficult to mitigate below a level of significance.

Social Acceptability
This criterion focused on the identification of potentially adverse impacts to aesthetic and/or visual resources, recreational uses, and vehicle traffic patterns. A project alternative was rejected if it had one or more elements that would likely be unacceptable to the residents of the Naval Complex.

3.1.3 Purpose and Need Requirements

Dredging of Inner and Outer Apra Harbor is required to fulfill planned functions of the Apra Harbor Naval Complex in support of U.S. Armed Forces operating in the western Pacific. This study is being developed to provide for the management of the material that will be generated as a consequence of these dredging projects. In order to satisfy the purpose and need requirements, the dewatering alternatives evaluated must first provide for the anticipated volume of material generated from the proposed construction projects. Only those dewatering alternatives that provide sufficient capacity to accommodate material from all three projects together or for the total volume of any one project by itself were considered feasible. Additionally, it was necessary for all alternatives (dewatering and beneficial use) to be technically, logistically, and economically feasible with acceptable environmental and social impacts. If any one of the criteria was not met, the alternative was rejected from further consideration.

This evaluation is being conducted for the management of between 987,777 cy and 1,266,877 cy (755,209 m^3 and 968,597 m^3) of sediment to be generated from two projects (Table 3). The first, P-433, is scheduled for FY 2010 and requires 508,877 cy (389,064 m^3) of sediment to be managed upland in association with anticipated berthing requirements at Sierra Wharf. The second, an unscheduled project associated with the construction of a CVN capable berth, requires between 478,900 cy and 758,000 cy (366,145 m^3 and 579,533 m^3) of sediment to be managed. These volumes include a 2-ft overdredge allowance and no bulking factor.

Table 3. Volume of Material Requiring Management by Construction Project

	P-433	CVN Minimum volume Alternative	CVN Maximum volume Alternative	Total Volume (CVN min. plus P-433)	Total Volume (CVN max. plus P-433)
Dredge Volume with a 2 ft overdredge (cy)	508,877	478,900	758,000	987,777	1,266,877

3.2 Dewatering Facility Alternatives

All dewatering site alternatives maximize the available area of land to minimize lift heights and thereby reduce dredged material drying time. While smaller acreage alternatives may present fewer social and environmental impacts, these sites require higher dike elevations, greater lift heights, and longer drying times. Consequently, alternatives with the largest areas provide dewatered material for beneficial use in the least amount of time and are the most economical to construct.

The following dewatering facility sites were determined to be feasible management alternatives during the initial Phase I DMMP study (MEC-Weston 2005). Due to changes in planned construction projects, a re-evaluation of sites previously found suitable and unsuitable was conducted. Six previously recommended dewatering facilities were re-evaluated and are still considered to be viable management alternatives by their ability to meet current capacity needs. They include Polaris Point, Field 5, Commercial Port Field 1, Field 3, Field 4, and PWC. Existing dewatering facilities at Orote Airfield would be available for reuse if a beneficial reuse was identified for the dried dredged material. This study assumes a Orote Airfield will not have capacity.

Six sites have been identified as potential dewatering site alternatives for dredged material resulting from P-433 and CVN (Figure 7): (1) a 44.3 a (17.9 ha) site located on Polaris Point, referred to as Polaris Point Field; (2) a 53.2 a (21.5 ha) site located northwest of the Commissary, between and Marine Drive and Sumay Drive, referred to as Field 5; (3) a 36.9 a (14.9 ha) site located on Commercial Port property on Cabras Island, referred to as Commercial Port Field 1; (4) a 16.0 a (6.5 ha) site located south of the Navy Exchange Center and Commissary, referred to as Field 3; (5) a 26.6 a (10.8 ha) site located northwest of the Commissary, between Shoreline Drive and Marine Drive, referred to as Field 4; and (6) a 27.8 a (11.3 ha) site located between Marine Drive and Sumay Drive at the PWC Compound, referred to as PWC Compound. Polaris Point Field and Field 5 are large enough to accommodate the dredged material for both construction dredging projects (Table 4). All dewatering facilities have the capacity to store material from P-433, with the exception of Field 3. Field 3 must be used in conjunction with another alternative due to limited capacity.

Table 4. Greatest Capacity Design Specifics for Dewatering Facility Alternatives

	Field 3	Field 4	Field 5	PWC	Commercial Port 1		Polaris Point
					East	West	
Site Area (a)	16.0	26.6	53.2	27.8	22.7	14.2	44.3
Dike Center Line Perimeter (ft)	2,965	5,600	7,000	5,000	4,600	4,750	5,900
Dike Width (ft)	8	8	12	12	12	12	12
Dike Elevation (ft)	18.5	16.00	26.00	19.00	15.00	6.25	31.00
Dredged Material Lift Height (ft)	16.50	14.00	24.00	17.00	13.00	4.25	29.00
Dike Volume (cy)	129,005	185,837	606,667	242,778	145,667	33,811	711,278
Internal Volume (cy)	296,915	414,968	1,453,237	519,684	330,428	63,554	1,361,372
Total Capacity (cy)	425,920	600,805	2,059,904	762,461	476,095	97,365	2,072,649
					573,459		
Sufficient Capacity for each individual project?	No	P-433	P-433 and CVN	P-433	P-433		P-433 and CVN
Sufficient Capacity for both projects?	No	No	Yes	No	No		Yes

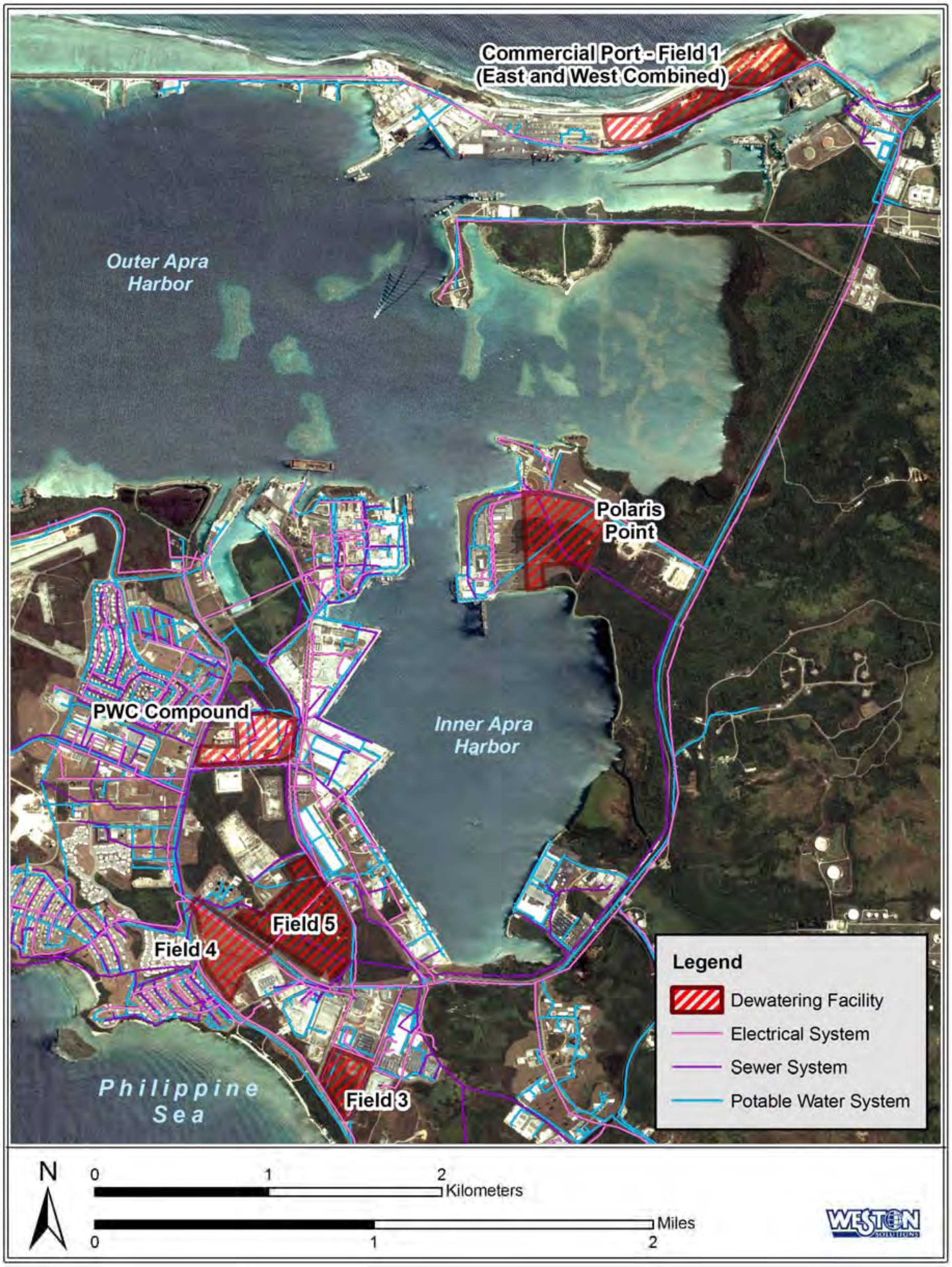


Figure 7. Location Map of Feasible Dewatering Sites.

A comparison of dredging and dewatering facility construction costs for each alternative are presented in Table 5. Costs ranged from $88.10/cy (Field 5) to $119.05/cy (Commercial Port). Unit costs are for comparative use only and assume facilities are used to their maximum capacity. Cost assumptions are provided in Section 3.1.1.

Table 5. Cost Comparison Based on Design Specifics for Dewatering Facility Alternatives

	Field 3	Field 4	Field 5	PWC	Commercial Port 1		Polaris Point
					East	West	
Greatest Capacity at Each Site (cy)	425,920	600,805	2,059,904	762,461	476,095	97,365	2,072,649
A. Dredging							
Mob/Demob Costs	$ 9,208,320	$ 9,208,320	$ 9,208,320	$ 9,208,320	$ 9,208,320	$ 9,208,320	$ 9,208,320
Dredging Costs @$20.26/cy	$ 8,629,139	$ 12,172,316	$ 41,733,655	$ 15,447,467	$ 9,645,678	$ 1,972,608	$ 41,991,875
Munition Screening	$ 4,259,200	$ 6,008,053	$ 20,599,040	$ 7,624,613	$ 4,760,947	$ 973,647	$ 20,726,493
Subtotal A	**$ 22,096,659**	**$ 27,388,689**	**$ 71,541,015**	**$ 32,280,400**	**$ 23,614,945**	**$ 12,154,575**	**$ 71,926,689**
B. Dewatering Facility Construction Costs							
Dredge Placement - Upland ($40.52/cy)	$ 17,258,278	$ 24,344,632	$ 83,467,310	$ 30,894,933	$ 19,291,356	$ 3,945,216	$ 83,983,751
Site Prep $5000/a	$ 80,000	$ 133,000	$ 266,000	$ 139,000	$ 113,500	$ 71,000	$ 221,500
Rehandling to construct perimeter berm @ $16.50/cy	$ 2,064,079	$ 2,973,393	$ 9,706,667	$ 3,884,444	$ 2,330,667	$ 540,972	$ 11,380,444
Subtotal B	**$ 19,402,358**	**$ 27,451,025**	**$ 93,439,977**	**$ 34,918,378**	**$ 21,735,523**	**$ 4,557,189**	**$ 95,585,695**
Subtotal (A+B)	**$ 41,499,017**	**$ 54,839,714**	**$ 164,980,992**	**$ 67,198,778**	**$ 45,350,467**	**$ 16,711,763**	**$ 167,512,384**
Contingency (10%)	$ 4,149,902	$ 5,483,971	$ 16,498,099	$ 6,719,878	$ 4,535,047	$ 1,671,176	$ 16,751,238
TOTAL	**$ 45,648,919**	**$ 60,323,685**	**$ 181,479,091**	**$ 73,918,655**	**$ 49,885,514**	**$ 18,382,940**	**$ 184,263,623**
UNIT COST ($/cy)[1]	**$ 107.18**	**$ 100.40**	**$ 88.10**	**$ 96.95**	**$ 104.78**	**$ 188.81**	**$ 88.90**
					$ 119.05		

[1] Unit costs assume facilities are used to their maximum capacity.

3.2.1 Polaris Point Field Confined Upland Dewatering Site

3.2.1.1 Description

The Polaris Point Field Confined Upland Dewatering Site is situated on the undeveloped lands occupying the central and southeastern portions of Polaris Point. The site is bounded by Inner Apra Harbor to the south, a fence line to the east, and Polaris Point Road to the north and west. A site map showing the location of the dewatering facility is shown in Figure 8. A dewatering site with a footprint size of 44.3 a (17.9 ha) is large enough to accommodate the dredged material for both construction dredging projects. The maximum capacity that could be stored at this site is approximately 2,072,649 cy (1,584,654 m^3). This assumes a dike height of 31 ft (9.4 m) and would require 711,278 cy (543,811 m^3) of dike material. The footprint size was considered the maximum size that could be constructed on the vacant lands south of Polaris Point Road and east of existing and planned facilities. Earthen dikes will form the exterior walls of the dewatering site.

Mechanically dredged material will be excavated using a clamshell dredge and placed in an adjacent dump scow. Tugs will transport the scow approximately 0.5 mi (0.8 km) to Alpha Wharf. Material will be offloaded at or adjacent to Alpha Wharf using a 30-ton crane equipped with a 15-cy clamshell. Then material will be loaded into 20-ton sealed-end dump trucks. The transportation route to the dewatering site extends approximately 0.25 mi (0.4 km) along Polaris Point Road to an unimproved dirt access road. Material will be dumped at the dewatering site and will be spread evenly to keep dike height to a minimum and increase drying time. Dried dredged material will be used to increase dike height as facility fills.

3.2.1.2 Capacity

As previously discussed, the Polaris Point dewatering site can be designed to contain up to an estimated 2,072,649 cy (1,584,654 m^3) of dredged material from the proposed construction dredging projects. This is sufficient capacity for both P-433 and CVN projects. The 44.3 a (17.9 ha) dewatering site will be constructed with an earthen dike with side slopes of one vertical on three horizontal. The perimeter along the centerline of the dike is approximately 5,900 ft (1,798 m). The conceptual design for the dewatering site associated with Polaris Point is summarized in Table 4.

3.2.1.3 Costs

The cost estimates for the placement of P-433 and CVN at Polaris Point are summarized in Table 5. Estimated costs are based on dredging, placement, and rehandling in the dewatering facility. The total project cost for P-433 is estimated to be $45,239,000. The total project costs for CVN are estimated to range between $42,574,000 and $67,386,000. Cost to hold P-433 and CVN are estimated to range between $87,813,000 and $112,625,000. Cost assumptions are provided in Section 3.1.1. Costs related to relocation of water and sewer lines needs to be considered.

Figure 8. Polaris Point Field Confined Upland Dewatering Site.

3.2.1.4 Existing Conditions

Existing conditions, including land use, air quality, geology, water quality, biological resources, and cultural resources are described in detail in the Phase I DMMP. Since the development of the Phase I DMMP in 2005, existing environmental resources at this site have not significantly changed. The Polaris Point dewatering facility site was determined to be a feasible management alternative during the initial Phase I DMMP study (MEC-Weston 2005).

Long-term environmental impacts caused by migration of chemical contaminants to water and exposure of sensitive organisms are not expected. Impacts to marine water quality during transport of scows to the offloading site at Alpha Wharf could be minimized by BMPs (if necessary) such as restricting load volumes to avoid over-flow during transport.

No impacts to sensitive habitats or sensitive species will occur from the construction of the dewatering site. There will be a conversion of urban/alien grassland to unvegetated sediment with the construction of the dewatering site. Approximately 50 a of disturbed open woods will be cleared. Should the site present an attractive nuisance for migratory birds (e.g., standing water, scavenging of food from placed material), reflective flagging and/or other management practices may be used to discourage bird use.

No impacts to cultural resources are expected from the construction of the dewatering site. The following sections describe the potential impacts a dewatering facility at Field 5 may have on the environmental resources.

<u>Noise</u>
Noise levels should be within acceptable criteria for industrial lands located on Polaris Point during construction of most of the dike, but may temporarily exceed ANSI criteria while the southwestern portion of the dike is under construction. Noise levels at the recreational fields, beach, and day use areas located on the northern portion of Polaris Point would be exceeded during dike construction.

<u>Air Quality</u>
Air emissions and fugitive dust will be generated by heavy equipment and trucks during construction of the containment dikes. Emissions will include those typical of fossil-fuel combustion sources and include carbon monoxide (CO), oxides of nitrogen (NO_x), oxides of sulfur (SO_x), and inhalable particulate matter of 10 microns or less in size (PM_{10}). These emissions represent temporary construction impacts. Depending upon the phase of construction and the number and types of equipment in operation, control measures may be required to reduce SO_2 emissions within the nonattainment area. BMPs such as water spray could be used to minimize fugitive dust impacts.

<u>Odor</u>
Odors associated with dredged material drying may be expected at distances up to 0.2 mi (0.3 km) from the proposed dewatering facility. However, volatilization rates were considered to be too small to pose a public health or safety hazard (Olin-Estes et al. 2002).

3.2.1.5 Feasibility Evaluation

In summary, review of all available information suggests that this alternative is feasible and meets the purpose and need. Polaris Point is large enough to accommodate the dredged material for both construction dredging projects (Section 3.2). Assuming existing water and sewer lines are relocated; this alternative is technically, logistically, and economically feasible. All environmental and social impacts are determined to be minimal and temporary.

3.2.2 Field 5 Confined Upland Dewatering Site

3.2.2.1 Description

The Field 5 Confined Upland Dewatering Site is situated between Marina Drive and Sumay Drive. The Field 5 site is large enough to accommodate the dredged material for both construction dredging projects. A site map showing the location of the dewatering facility and transportation routes from Uniform Wharf are shown Figure 9. A dewatering site with a footprint size of 53.2 a (21.5 ha) will be constructed. The maximum capacity that could be stored at this site is approximately 2,059,904 cy (1,574,910 m^3). This assumes a dike height of 26 ft (7.9 m) and would require 606,667 cy (463,830 m^3) of dike material. The dewatering facility for Field 5 was designed to the maximum size that could be located on vacant lands between Marina Drive, Sumay Drive, and existing facilities. Earthen dikes will form the exterior walls of the dewatering site.

Mechanically dredged material will be excavated using a clamshell dredge and placed in an adjacent dump scow. Tugs will transport the scow approximately 0.5 mi (0.8 km) to Uniform Wharf. Material will be offloaded at the wharf using a 30-ton crane equipped with a 15-cy clamshell bucket. Then material will be offloaded into sealed-end dump trucks for transportation to the dewatering facility. The transportation route to the dewatering site extends approximately 1.2 mi (1.9 km) along Sumay Drive to an access road. Material will be offloaded and spread evenly to keep dike height and drying time to a minimum at the dewatering site. Dried dredged material will be used to increase dike height as facility fills.

3.2.2.2 Capacity

As previously discussed, the Field 5 dewatering site can be designed to contain up to an estimated 2,059,904 cy (1,574,910 m^3) of dredged material from the proposed construction dredging projects. This is sufficient capacity for both P-433 and CVN projects. The 53.2 a (21.5 ha) dewatering site will be constructed with an earthen dike with side slopes of one vertical on three horizontal. The perimeter along the centerline of the dike is approximately 7,000 ft (2,134 m). The conceptual design for the dewatering site associated with Field 5 is summarized in Table 4.

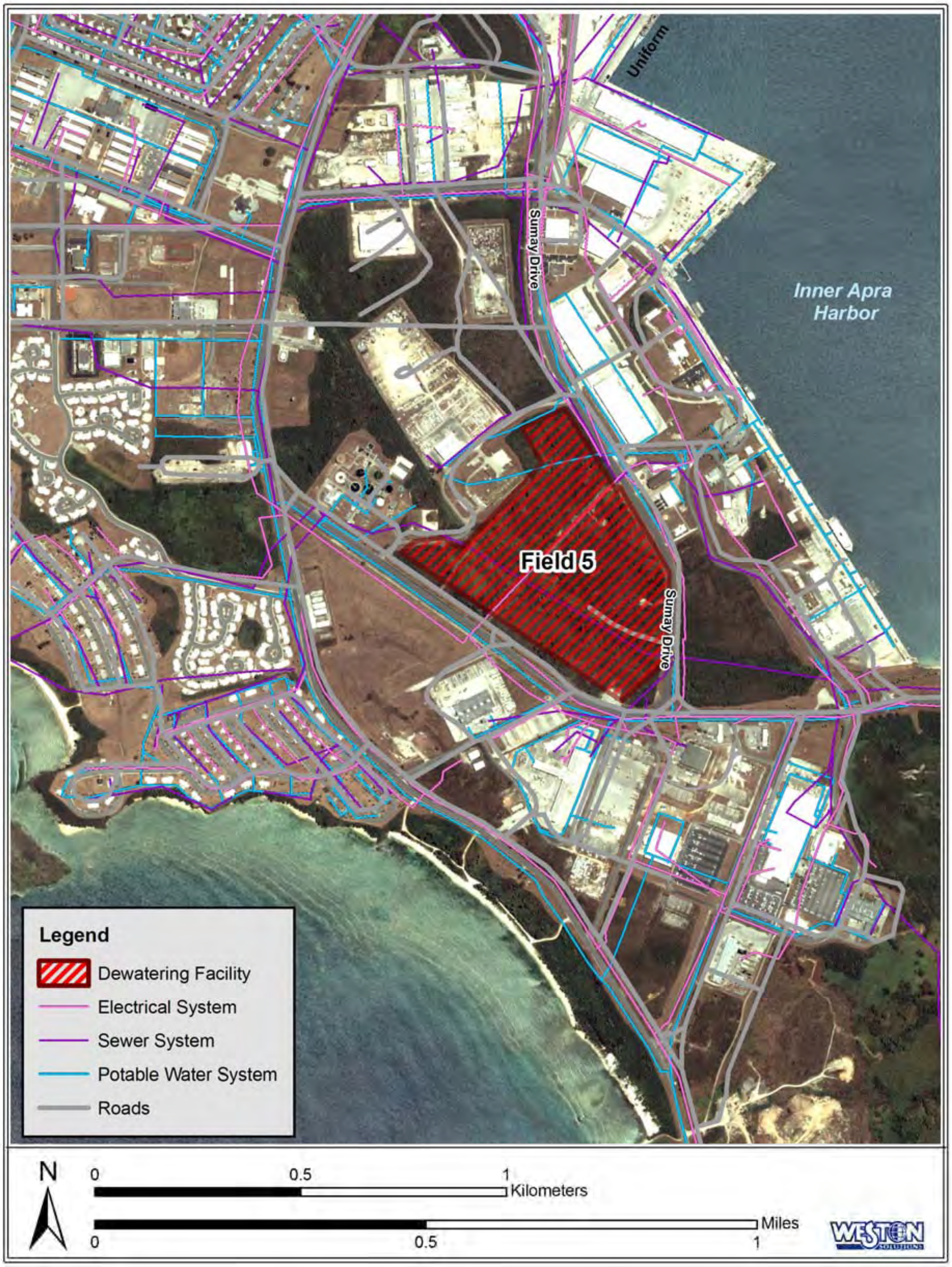


Figure 9. Field 5 Confined Upland Dewatering Site.

3.2.2.3 Costs

The cost estimates for the placement of P-433 and CVN at Field 5 are summarized in Table 5. Estimated costs are based on dredging, placement and rehandling in the dewatering facility. The total project cost for P-433 is estimated to be $44,832,000. The total project costs for CVN are estimated to range between $42,191,000 and $66,780,000. Cost to hold P-433 and CVN are estimated to range between $87,023,000 and $111,612,000. Additional costs for rerouting of electric lines will need to be considered. Cost assumptions are provided in Section 3.1.1.

3.2.2.4 Existing Conditions

Existing conditions, including land use, air quality, geology, water quality, biological resources and cultural resources are described in detail in the Phase I DMMP. Since the development of the Phase I DMMP in 2005, existing environmental resources at this site have not significantly changed with one exception: a portion of the site was disturbed for the placement of a CDF (Figure 10 and Figure 11). Dredged material from MCON P-431 was placed in this facility to dewater. The Field 5 dewatering facility site was determined to be a feasible management alternative during the initial Phase I DMMP study (MEC-Weston 2005).

Long-term environmental impacts caused by migration of chemical contaminants to water and exposure of sensitive organisms are not expected. Impacts to marine water quality during transport of scows to the offloading site at Uniform Wharf could be minimized by BMPs (if necessary) such as restricting load volumes to avoid over-flow during transport.

No impacts to sensitive habitats or sensitive species would occur from the construction of the dewatering site. Approximately 75% of the site was previously cleared of tangantangan forest for placement of dredged material from MCON P-431. Construction of the dewatering site would result in the conversion of the remaining 25% of tangantangan forest to unvegetated sediment. Should the site present an attractive nuisance for migratory birds (e.g., standing water, scavenging of food from placed material) reflective flagging and/or other management practices may be used to discourage bird use.

No impacts to cultural resources are expected from the construction of the dewatering site.

The following sections describe the potential impacts a dewatering facility at Field 5 may have on the environmental resources.

<u>Noise</u>
Outdoor noise levels near workplace buildings located within 200 ft (61m) of the proposed dewatering facility will be near 80 dBA when the northeast and south edges of the dike are constructed. This level exceeds the recommended levels by the FAA, but is within the DoD acceptable range. Noise levels inside the building will be approximately 60 dBA during construction. Noise levels should be within acceptable criteria for industrial lands during construction of most of the dike, but would temporarily exceed criteria while the northeast portion of the dike is under construction.

Figure 10. Existing Conditions in 2007 at Field 5 Dewatering Facility, Cell 1, between Sumay and Marina Drives, Apra Harbor, Guam

Figure 11. Existing conditions in 2007 at Field 5 Dewatering Facility, Cell 2, between Sumay and Marina Drives, Apra Harbor, Guam.

Air Quality

Air emissions and fugitive dust will be generated by heavy equipment and trucks during construction of the containment dikes. Emissions will include those typical of fossil-fuel combustion sources and include CO, NO_x, SO_x, and PM_{10}. These emissions represent temporary construction impacts. Depending upon the phase of construction and the number and types of equipment in operation, control measures may be required to reduce SO_2 emissions within the nonattainment area. BMPs such as water spray could be used to minimize fugitive dust impacts.

Odor

Odors associated with dredged material drying may be expected at distances up to 0.2 mi (0.3 km) from the proposed dewatering facility. However, volatilization rates were considered to be too small to pose a public health or safety hazard (Olin-Estes et al. 2002).

3.2.2.5 Feasibility Evaluation

In summary, a review of all available information suggests that this alternative is feasible and meets the purpose and need. Field 5 is large enough to accommodate the dredged material for both construction dredging projects (Section 3.2). This alternative is currently being used and is technically, logistically, and economically feasible. All environmental impacts are determined to be minimal and temporary. While social impacts from noise and traffic are potentially problematic due to the location and duration of activities at this facility, they do not render this alternative infeasible, providing appropriate management plans are developed.

3.2.3 Commercial Port Field 1 Confined Upland Dewatering Site

3.2.3.1 Description

The Commercial Port Field 1 site is located on Cabras Island on Commercial Port property. The proposed dewatering site is predominately open space with a mixture of concrete and alien grassland. The dewatering facility for Commercial Port Field 1 was designed to the maximum size that could be located on vacant lands west of the Piti power plant and east of the Commercial Port container storage area. Approximately 36.9 a (14.9 ha) of undeveloped land located between Cabras Road (Route 11) and Coral Road, and east of the container yard can accommodate approximately 573,459 cy (438,441 m^3) of dredged material. The Commercial Port Field 1 site is large enough to accommodate the dredged material from P-433 assuming improvements to the site are made. The preparation of the site for placement will involve removal of a 50-ft (15.2 m) limestone escarpment that is located in the eastern cell; all material greater than 30 ft (9.1 m) in elevation will need to be removed in order to achieve the capacity requirements. In addition, the northern edge of dike in the eastern cell extends along the coastline and will require armament to prevent erosion of dike during high energy storms. A site map showing the location of the dewatering facility is shown Figure 12.

Figure 12. Commercial Port Field 1 Confined Upland Dewatering Site.

The creation of a dewatering site within Commercial Port will facilitate the use of dried dredged material for the port expansion project. In order to help Guam meet its responsibilities as a transshipment hub, the Port Authority of Guam has developed a master plan that will expand the current port footprint to include new deepwater cargo piers, upgraded fisheries facilities, expanded container lay-down areas, an industrial park, and cruise-ship facilities. A substantial volume of fill material will be required for these capital improvement projects. The Navy and the Government of Guam have signed a memorandum of understanding (MOU) regarding the use of any dredged material deemed appropriate for fill material and to establish procedures for the determination of the use of the dredged material as fill material for use by the Port Authority of Guam (MOU April 2001; in Appendix D of Phase I DMMP [MEC-Weston 2005]).

Mechanically dredged material will be excavated using a clamshell dredge and placed in an adjacent dump scow. Tugs will transport the scow approximately 0.5 mi (0.8 km) to Delta or Echo Wharf. Material will be offloaded at the wharf using a 30-ton crane equipped with a 15-cy clamshell bucket. Then material will be loaded into sealed-end dump trucks for transportation to the dewatering facility. The transportation route to the dewatering site extends approximately 2.5 mi (4 km), along Causeway Road, north on Marina Road and to Route 11 (Figure 12). At the dewatering site material will be offloaded and spread evenly to keep dike height and drying time to a minimum. Dried dredged material will be used to increase dike height as facility fills.

3.2.3.2 Capacity

As previously discussed, the Commercial Port Field 1 dewatering site can be designed to contain up to an estimated 573,459 cy (438,441 m^3) of dredged material from the proposed construction projects. This is sufficient capacity for the entire P-433 project. The dewatering site is bisected by Route 11 to form two dewatering cells. The eastern cell (22.7 a [9.2 ha]) can be designed to contain approximately 476,095 cy (364,001 m^3) and the western cell (14.2 a [5.7 ha]) can be designed to contain up to an estimated 97,365 cy (74,441 m^3). The dewatering site will be constructed with an earthen dike with side slopes of 1 vertical on 3 horizontal. The perimeter along the centerline of the dike is approximately 4,750 ft (1,448 m) in the western cell and 4,600 ft (1,402 m) in the eastern cell. The conceptual design for the dewatering site associated with Commercial Port Field 1 is summarized in Table 4.

3.2.3.3 Costs

The cost estimate for the placement of P-433 at Commercial Port is summarized in Table 5. The estimated cost is based on dredging, placement and rehandling in the dewatering facility. The total project cost for P-433 is estimated to be $60,582,000. Cost assumptions are provided in Section 3.1.1.

3.2.3.4 Existing Conditions

Existing conditions, including land use, air quality, geology, water quality, biological resources and cultural resources are described in detail in the Phase I DMMP. Since the development of the Phase I DMMP in 2005, existing environmental resources at this site have not significantly changed. The Commercial Port Field 1 dewatering facility site was determined to be a feasible management alternative during the initial Phase I DMMP study (MEC-Weston 2005).

Long-term environmental impacts caused by migration of chemical contaminants to water and exposure of sensitive organisms are not expected. Impacts to marine water quality during transport of scows to the offloading site (either Delta/Echo Wharves) could be minimized by BMPs (if necessary) such as restricting load volumes to avoid over-flow during transport. Marine waters adjacent to the eastern cell are classified as good (M2). Design specifications will need to include BMPs to prevent drainage into the ocean.

There would be a conversion of 36.9 a (15.0 ha) of partly vegetated, urban land to unvegetated sediment with the construction of the dewatering site. Should the site present an attractive nuisance for migratory birds (e.g., standing water, scavenging of food from placed material) reflective flagging and/or other management practices may be used to discourage bird use.

No impacts to cultural resources are expected from the construction of the dewatering site.

The following sections describe the potential impacts a dewatering facility at Field 5 may have on the environmental resources.

Noise
Outdoor noise levels near workplace buildings located within 250 ft (76 m) will be near 80 dBA when the eastern edge of the dike is constructed, exceeding the recommended levels by the FAA, but within the DoD acceptable range. Noise levels inside buildings will be approximately 60 dBA during construction. Noise levels should be within acceptable criteria for industrial lands during construction of most of the dike, but may temporarily exceed criteria while the western portion of the dike is under construction.

Air Quality
Air emissions and fugitive dust will be generated by heavy equipment and trucks during construction of the containment dikes. Emissions will include those typical of fossil-fuel combustion sources and include carbon monoxide (CO), oxides of nitrogen (NO_x), oxides of sulfur (SO_x), and inhalable particulate matter of 10 microns or less in size (PM_{10}). These emissions represent temporary construction impacts. Depending upon the phase of construction and the number and types of equipment in operation, control measures may be required to reduce SO_2 emissions within the nonattainment area. BMPs such as water spray could be used to minimize fugitive dust impacts.

Odor
Odors associated with dredged material drying may be expected at distances up to 0.2 mi (0.3 km) from the proposed dewatering facility.

3.2.3.5 Feasibility Evaluation

In summary, a review of all available information suggests that this alternative is feasible and meets the purpose and need. The dewatering site can accommodate dredged material associated with P-433. This alternative is technically, logistically, and economically feasible. All environmental impacts are determined to be minimal and temporary. While social impacts from noise and traffic are potentially problematic due to the location and duration of this facility they due not render this alternative infeasible, providing appropriate management plans are developed.

3.2.4 PWC Compound Confined Upland Dewatering Site

3.2.4.1 Description

The PWC Compound Confined Upland Dewatering Site is bounded by Harbor Drive to the south, Marine Drive to the west, Sumay Drive to the east and NOB Hill Bowl Theater to the north. A dewatering site with a footprint size of 27.8 a (11.3 ha) will be constructed to provide capacity for dewatering of material from P-433 construction dredging project. The maximum capacity that could be stored at this site is approximately 762,461 cy (582,943 m^3). This assumes a dike height of 19 ft (5.8 m) and would require 242,778 cy (185,617 m^3) of dike material. A site map showing the location of the dewatering facility is shown in Figure 13.

Mechanically dredged material will be excavated using a clamshell dredge and placed in an adjacent dump scow. Tugs will transport the scow approximately 0.5 mi (0.8 km) to Uniform Wharf. Material will be offloaded at the wharf using a 30-ton crane equipped with a 15-cy clamshell bucket. Then material will be loaded into sealed-end dump trucks for transportation to the dewatering facility. The transportation route to the dewatering site extends approximately 0.25 miles (0.4 km), along Sumay Drive to an access road on Harbor Drive. At the dewatering site material will be offloaded and spread evenly to keep dike height and drying time to a minimum. Dried dredged material will be used to increase dike height as facility fills.

3.2.4.2 Capacity

As previously discussed, the PWC Compound dewatering site can be designed to contain up to an estimated 762,461 cy (582,943 m^3) of dredged material from the proposed construction projects. This is sufficient capacity for the entire P-433 project. The 27.8 a (11.3 ha) dewatering site will be constructed with an earthen dike with side slopes of 1 vertical on 3 horizontal. The perimeter along the centerline of the dike is approximately 5,000 ft (1,524 m). The conceptual design for the dewatering site associated with PWC Compound is summarized in Table 4.

3.2.4.3 Costs

The cost estimates for the placement of P-433 at PWC Compound are summarized in Table 5. Estimated costs are based on dredging, placement and rehandling in the dewatering facility. The total project cost for P-433 is estimated to be $49,336,000. Additional site preparation costs including the removal of abandoned buildings needs to be considered. Cost assumptions are provided in Section 3.1.1.

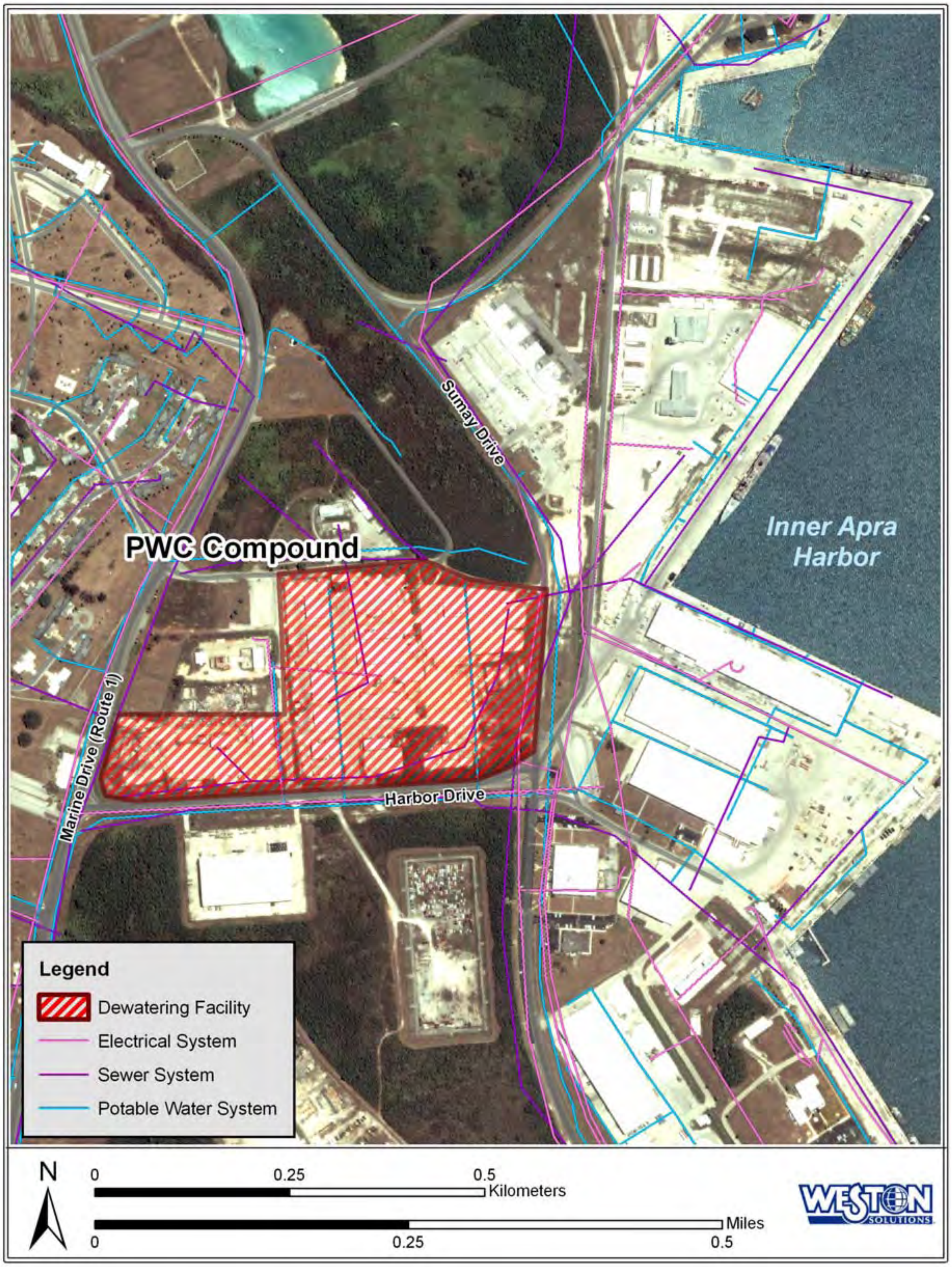


Figure 13. PWC Compound Confined Upland Dewatering Site.

3.2.4.4 Existing Conditions

Existing conditions, including land use, air quality, geology, water quality, biological resources and cultural resources are described in detail in the Phase I DMMP. Since the development of the Phase I DMMP in 2005, existing environmental resources at this site have not significantly changed and are discussed in further detail in this initial study. PWC Compound dewatering facility site was determined to be a feasible management alternative during the initial Phase I DMMP study (MEC-Weston 2005).

Long-term environmental impacts caused by migration of chemical contaminants to water and exposure of sensitive organisms are not expected; there are no surface waters or wetlands on this site.

No impacts to sensitive habitats or sensitive species will occur from the construction of the dewatering site. There will be a conversion of urban/alien grassland to unvegetated sediment with the construction of the dewatering site.

No impacts to cultural resources are expected from the construction of the dewatering site.

The following sections describe the potential impacts a dewatering facility at the PWC Compound may have on the environmental resources.

<u>Noise</u>
The Lockwood Terrace residential area is located approximately 200 ft (61 m) from the western edge of the PWC Compound; in addition, the closest industrial buildings are located approximately 200 ft (61 m) form the eastern edge of the PWC Compound. Outdoor noise levels may exceed 80 dBA when the work is being conducted in the portion of the PWC Compound that is adjacent to these homes and buildings. These levels exceed the FAA recommended levels of 75 dBA. Exterior noise levels associated with this alternative will exceed the HUD guideline for residential areas. Noise levels inside adjacent buildings will be approximately 60 dBA (20 dBA less) during construction. Noise levels should be within acceptable criteria for industrial lands during construction of most of the dike, but may temporarily exceed criteria while the dike is under construction.

<u>Air Quality</u>
Air emissions and fugitive dust will be generated by heavy equipment and trucks during construction of the containment dikes. Emissions will include those typical of fossil-fuel combustion sources and include carbon monoxide (CO), oxides of nitrogen (NO_x), oxides of sulfur (SO_x), and inhalable particulate matter of 10 microns or less in size (PM_{10}). These emissions represent temporary construction impacts. Depending upon the phase of construction and the number and types of equipment in operation, control measures may be required to reduce SO_2 emissions within the nonattainment area. BMPs such as water spray could be used to minimize fugitive dust impacts.

Odor

Odors associated with dredged material drying may be expected at distances up to 0.2 mi (0.3 km) from the proposed dewatering facility. However, volatilization rates were considered to be too small to pose a public health or safety hazard (Olin-Estes et al. 2002).

3.2.4.5 Feasibility Evaluation

In summary, a review of all available information suggests that this alternative is feasible and meets the purpose and need. The dewatering site can accommodate dredged material associated with P-433. Assuming the removal of approximately 20 buildings, this alternative is technically, logistically, and economically feasible. All environmental impacts are determined to be minimal and temporary. Social impacts from noise may be potentially problematic due to the location and duration of this facility; however they due not render this alternative infeasible, providing appropriate management plans are developed. Destruction or movement of structures identified as cultural resources may need to be evaluated prior to construction.

Purpose and Need

In summary, a review of all available information suggests that this alternative is feasible and meets the purpose and need. The dewatering site can accommodate dredged material associated with P-433. This alternative is technically, logistically and economically feasible. All environmental impacts are determined to be minimal and temporary. Social impacts from noise may be problematic due to the location and duration of activities proposed for this facility.

3.2.5 Field 3 Dewatering Site

3.2.5.1 Description

The Field 3 Dewatering Site is situated on undeveloped lands south of the Commissary. The site is bounded on the east by Route 2B (Exchange Road), on the south by Shoreline Drive and on the west by an unmarked north-south arterial connecting Shoreline Drive with Marine Drive, passing to the west of the Commissary. The Field 3 site, with a footprint size of 16.0 a (6.5 ha), will be constructed to provide capacity for dewatering of material from P-433 construction dredging project. The maximum capacity that could be stored at this site would be approximately 425,920 cy (325,639 m^3). This assumes a dike height of 18.5 ft (5.6 m) and a lift height of 16.5 ft (5.0 m). A site map showing the location of the dewatering facility is shown in Figure 14.

Mechanically dredged material will be excavated using a clamshell dredge and placed in an adjacent dump scow. Tugs will transport the scow approximately 0.5 mi (0.8 km) to Uniform Wharf. Material will be offloaded at the wharf using a 30-ton crane equipped with a 15-cy clamshell bucket. Material will be offloaded directly into sealed-end dump trucks for transportation to the dewatering facility. The transportation route to the dewatering site extends approximately 1.75 miles (2.8 km). At the dewatering site material will be offloaded and spread evenly to keep dike height and drying time to a minimum. Earthen dikes will form the exterior walls of the dewatering site. Dried dredged material will be used to increase dike height as facility fills.

Figure 14. Field 3 Confined Upland Dewatering Site.

3.2.5.2 Capacity

As previously discussed, the Field 3 dewatering site can be designed to contain up to an estimated 425,920 cy (325,639 m^3). This is not sufficient capacity for the entire P-433 project; however it could be used in conjunction with other sites. The 16.0 a (6.5 ha) dewatering site will be constructed with an earthen dike with side slopes of 1 vertical on 3 horizontal. The perimeter along the centerline of the dike is approximately 2,965 ft (904 m). The conceptual design for the dewatering site associated with Field 3 is summarized in Table 4.

3.2.5.3 Costs

The cost estimate for the placement of P-433 at Field 3 is summarized in Table 5. The estimated cost is based on dredging, placement, and rehandling in the dewatering facility. The total project costs for 425,920 cy (325,639 m^3) of P-433 material is estimated to be $45,650,000. Consideration for removal of a water line needs to be considered. Cost assumptions are provided in Section 3.1.1.

3.2.5.4 Existing Conditions

Existing conditions, including land use, air quality, geology, water quality, biological resources, and cultural resources, are described in detail in the Phase I DMMP. Since the development of the Phase I DMMP in 2005, existing environmental resources at this site have not significantly changed and are discussed in further detail in this initial study. The Field 3 dewatering facility site was determined to be a feasible management alternative during the initial Phase I DMMP study (MEC-Weston 2005).

Long-term environmental impacts caused by migration of chemical contaminants to water and exposure of sensitive organisms are not expected; there are no surface waters or wetlands on this site. Impacts to marine water quality during transport of scows to the offloading site at Uniform Wharf could be minimized by BMPs (if necessary) such as restricting load volumes to avoid over-flow during transport.

No impacts to sensitive habitats or sensitive species will occur from the construction of the dewatering site. There will be a conversion of urban/alien grassland to unvegetated sediment with the construction of the dewatering site.

Field 3 is located in an area thought to be part of the historical Orote Village; however, artifacts related to the village have not been found within the proposed dewatering site (Lauter-Reinmann 1998). While two concrete pads (TN-8) are located in the northeastern portion of Field 3, they are not eligible to be listed on the National Register. Therefore, no impacts to cultural resources are expected from the construction of the dewatering site.

The following sections describe the potential impacts a dewatering facility at Field 3 may have on the environmental resources.

<u>Noise</u>

The Autoport Facility, Commissary, and Naval Exchange are the closest facilities to the proposed dewatering site. The distance will vary depending on the location of construction activities. The distances between the proposed facility and the Autoport will range from approximately 250 to 1,000 ft (76 to 304 m). The distances between the proposed facility and Commissary will range from approximately 400 to 1,500 ft (122 to 457 m). The distances between the proposed facility and the Naval Exchange will range from approximately 600 to 2,100 ft (183 to 640 m). Construction noise levels will range from 55 to 83 dBA outside the Autoport Facility, 50 to 79 dBA outside the Commissary, and from 47 to 75 dBA outside the Naval Exchange. Therefore, average exterior noise levels during construction will be expected to meet FAA (average of 75 dBA or less) and DoD (up to 84 dB outdoors with indoor noise reduction) guidance levels for industrial lands.

Distances between the proposed facility and Dadi Beach, south of Shoreline Drive, range from approximately 400 to 1,400 ft (122 to 427 m). Noise levels will range between 53 and 77 dBA at the beach during construction of the dikes. Therefore, noise levels at the beach will be elevated relative to the ANSI noise guideline of 55 dBA for neighborhood parks when construction activities occur along the south end of the dewatering site.

Distances between the proposed dike and the South Tipaloa housing development range from approximately 2000 to 4000 ft (610 to 1220 km). Construction noise levels will attenuate to approximately 49 to 65 dBA outside the residences, and will be approximately 20 dBA less indoors with doors and windows closed. Therefore, average noise levels during construction of the dewatering site would be expected to be within the HUD guidance level of 65 dB for residential exterior noise levels.

<u>Air Quality</u>
Air emissions and fugitive dust will be generated by heavy equipment and trucks during construction of the containment dikes. Emissions will include those typical of fossil-fuel combustion sources and include CO, NO_x, SO_x, and PM_{10}. These emissions represent temporary construction impacts. Depending upon the phase of construction and the number and types of equipment in operation, control measures may be required to reduce SO_2 emissions within the nonattainment area. BMPs such as water spray could be used to minimize fugitive dust impacts.

<u>Odor</u>
Odors associated with dredged material drying may be expected at distances up to 0.2 mi (0.3 km) from the proposed dewatering facility. However, volatilization rates were considered to be too small to pose a public health or safety hazard (Olin-Estes et al. 2002).

3.2.5.5 Feasibility Evaluation

In summary, a review of all available information suggests that this alternative is feasible and meets the purpose and need. The dewatering site can accommodate a portion of the dredged material associated with P-433. Assuming the relocation of a water line, this alternative is technically, logistically, and economically feasible. All environmental and social impacts are determined to be minimal and temporary.

<u>Purpose and Need</u>
In summary, a review of all available information suggests that this alternative is feasible and meets the purpose and need. The dewatering site can accommodate a portion of the volume of P-433 assuming that an existing water line is relocated. This alternative is technically, logistically,

and economically feasible. All environmental and social impacts are determined to be minimal and temporary.

3.2.6 Field 4 Dewatering Site

3.2.6.1 Description

The Field 4 Dewatering Site is situated on the undeveloped lands near the Tipaloa housing complex. The site is bounded by Shoreline Drive to the west and Marine Drive to the east. The Field 4 site, with a footprint size of 26.6 a (10.8 ha), will be constructed to provide capacity for dewatering of material from P-433 construction dredging project. The maximum capacity that could be stored at this site would be approximately 600,805 cy (459,348 m^3). This assumes a dike height of 16 ft (4.9 m) and a lift height of 14 ft (4.3 m). A site map showing the location of the dewatering facility is shown in Figure 15.

Mechanically dredged material will be excavated using a clamshell dredge and placed in an adjacent dump scow. Tugs will transport the scow approximately 0.5 mi (0.8 km) to Uniform Wharf. Material will be offloaded at the wharf using a 30-ton crane equipped with a 15-cy clamshell bucket. Material will be offloaded directly into sealed-end dump trucks for transportation to the dewatering facility. The transportation route to the dewatering site extends approximately 1.2 mi (0.9 km), along Sumay Drive to an access road. At the dewatering site material will be offloaded and spread evenly to keep dike height and drying time to a minimum. Earthen dikes will form the exterior walls of the dewatering site. Dried dredged material will be used to increase dike height as facility fills.

3.2.6.2 Capacity

As previously discussed, the Field 4 dewatering site can be designed to contain up to an estimated 600,805 cy (459,348 m^3). This is sufficient capacity for the entire P-433 project. The 26.6 a (10.8 ha) dewatering site will be constructed with an earthen dike with side slopes of one vertical on three horizontal. The perimeter along the centerline of the dike is approximately 5,600 ft (1,707 m). The conceptual design for the dewatering site associated with Field 4 is summarized in Table 4.

3.2.6.3 Costs

The cost estimate for the placement of P-433 at Field 4 is summarized in Table 5. The estimated cost is based on dredging, placement, and rehandling in the dewatering facility. The total project cost for P-433 is estimated to be $51,091,000. Consideration for removal of power lines needs to be considered. Cost assumptions are provided in Section 3.1.1.

Figure 15. Field 4 Confined Upland Dewatering Site.

3.2.6.4 Existing Conditions

Existing conditions, including land use, air quality, geology, water quality, biological resources and cultural resources are described in detail in the Phase I DMMP. Since the development of the Phase I DMMP in 2005, existing environmental resources at this site have not significantly changed and are discussed in further detail in this initial study. The Field 4 dewatering facility site was determined to be a feasible management alternative during the initial Phase I DMMP study (MEC-Weston 2005).

Long-term environmental impacts caused by migration of chemical contaminants to water, and exposure of sensitive organisms are not expected; there are no surface waters or wetlands on this site.

No impacts to sensitive habitats or sensitive species will occur from the construction of the dewatering site. There will be a conversion of urban/alien grassland to unvegetated sediment with the construction of the dewatering site.

While two Quonset huts are located on the edge of Field 4, they are not eligible to be listed on the National Register. Therefore, no impacts to cultural resources are expected from the construction of the dewatering site.

The following sections describe the potential impacts a dewatering facility at Field 4 may have on the environmental resources.

<u>Noise</u>
The Tipaloa residential area is located 200 ft (61 m) from the southeastern edge of Field 4; in addition, industrial buildings are located 200 ft (61 m) from the southern edge of Field 4. Outdoor noise levels may exceed 80 dBA during work in the portion of Field 4 that is adjacent to these homes and buildings. These levels exceed the FAA recommended levels of 75 dBA. The HUD guideline for an acceptable exterior noise level is 65 dBA, which also applies to DoD housing. Thus, exterior noise levels associated with this alternative will exceed the HUD guideline. Noise levels inside adjacent buildings will be approximately 60 dBA (20 dBA less) during construction. Noise levels should be within acceptable criteria for industrial lands during construction of most of the dike, but may temporarily exceed criteria while the southern portion of the dike is under construction.

<u>Air Quality</u>
Air emissions and fugitive dust will be generated by heavy equipment and trucks during construction of the containment dikes. Emissions will include those typical of fossil-fuel combustion sources and include CO, NO_x, SO_x, and PM_{10}. These emissions represent temporary construction impacts. Depending upon the phase of construction and the number and types of equipment in operation, control measures may be required to reduce SO_2 emissions within the nonattainment area. BMPs such as water spray could be used to minimize fugitive dust impacts.

Odor

Odors associated with dredged material drying may be expected at distances up to 0.2 mi (0.3 km) from the proposed dewatering facility. However, volatilization rates were considered to be too small to pose a public health or safety hazard (Olin-Estes et al. 2002).

3.2.6.5 Feasibility Evaluation

In summary, a review of all available information suggests that this alternative is feasible and meets the purpose and need. The dewatering site can accommodate dredged material associated with P-433. Assuming the relocation of overhead power lines, sewer lines, and water lines, this alternative is technically, logistically, and economically feasible. All environmental impacts are determined to be minimal and temporary. Social impacts from noise and traffic may be potentially problematic due to the location and duration of this facility; however, they do not render this alternative infeasible, providing appropriate management plans are developed.

Purpose and Need

In summary, a review of all available information suggests that this alternative is feasible and meets the purpose and need. The dewatering site can accommodate the volume of P-433 assuming power lines are relocated. This alternative is technically, logistically, and economically feasible. All environmental impacts are determined to be minimal and temporary. Social impacts from noise and traffic may be problematic due to the location and duration of activities proposed for this facility.

3.3 Existing Dewatering Facility Alternatives

SRF and Orote Airfield are existing dewatering sites that are currently, or projected to be, at capacity with maintenance dredged material and P-502 construction dredged material. These alternatives assume that the dredged material currently placed at these CDFs could be removed for beneficial use prior to the dredging of the proposed construction projects.

The SRF is located to the west of the Inner Apra Harbor entrance channel and is bounded to the north by Outer Apra Harbor, Sumay Cove to the west, and general purpose wharves to the south. The SRF site is located on fill land in a highly developed, urban area, although many of the buildings are no longer in use. The primary function of property within the SRF is for industrial or maintenance purposes. The SRF property is currently under lease to the GEDA. The Guam Shipyard, Inc. is responsible for support, maintenance, and repair of naval vessels (HHFP 2003b). There are two wetlands located approximately 600 ft (183 m) southwest of the site.

The existing CDF was constructed for management of dredged material from the Phase I maintenance dredging project at Victor and X-Ray Wharves, Inner Apra Harbor, Guam. The acreage of the existing CDF at the SRF is approximately 2 a (0.8 ha). Utilizing the same dike configuration and lift heights, the maximum capacity of the site is 16,000 cy (12, 233 m^3).

The Orote Airfield CDF is located on Orote Point, bounded by Orote Point Road to the north, and Orote Airfield runways to the south. The airstrip is still active and is designated as a historic site, thus the required 16.5 ft (5 m) setbacks from the runway limit the area available for disposal (Schroeder et al. 2001). The Orote Airfield is located on the Orote Peninsula, a limestone plateau that slopes from 80 ft (24 m) in the east to 200 ft (61 m) in the west. It is populated by a mixture of urban and alien grasslands and tangantangan forest (DON 2001a). Limestone forest occurs along the cliffs immediately to the north of the Orote Airfield dewatering site and along the southern cliffs of the peninsula. Limestone forest is a preferred habitat for several endangered birds of Guam.

The existing CDF was constructed for management of dredged material from the Phase I maintenance dredging project at Victor and X-Ray Wharves, Inner Apra Harbor, Guam. The acreage of the existing site at Orote Airfield is approximately 16.8 a (6.8 ha). Utilizing the same property and potentially the same berm structures, the maximum capacity of this site is 71,900 cy (54,975 m^3).

The capacity of the existing CDFs at SRF and Orote Airfield is insufficient to accommodate the volume of dredged material for the proposed dredging projects in this DMMP. However, they are designated CDFs containing dewatered dredged material and may be considered resources for the management of material.

3.4 Beneficial Use Alternatives

Beneficial use includes a wide variety of options that utilize dredged material for a productive purpose. Beneficial uses of dredged material may make traditional placement of dredged material unnecessary, or reduce the level of disposal. The broad categories of beneficial uses, based on the functional use of the dredged material or site, defined by the USACE (1987) are as follows:

- Habitat restoration/enhancement (wetland, upland, island, and aquatic);
- Beach nourishment;
- Aquaculture;
- Parks and recreation (commercial and non-commercial);
- Agriculture/horticulture/forestry;
- Mine and quarry reclamation;
- Landfill cover for solid waste management;
- Shoreline stabilization;
- Industrial and commercial use;
- Material transfer (fill, dikes, roads, etc.); and
- Construction material.

Many of the designated beneficial use alternatives are not appropriate for dredged material from Apra Harbor and are discussed below:

- **Habitat restoration/enhancement (wetland, upland, island, and aquatic)**: No projects are identified, therefore an evaluation cannot be conducted to determine if the dewatered dredged material is suitable for use.
- **Beach nourishment**: Guam does not have a policy regarding beach nourishment. Coastal erosion is not a major issue for Guam because of soil types and because of barrier/fringe/patch reef system of protection. Assuming requirements would be similar

to the State of Hawaii, dredged material from Apra Harbor for use in beach nourishment does not meet the engineering requirements (HDLNR 2005). Dewatered dredged material from in and outer Apra Harbor does not meet the majority of the guidelines, which include less than 6% fines, no more than 50% of fill material with a grain diameter less than 0.125 millimeter (mm), dominantly composed of naturally occurring carbonate beach or dune sand, and free of contaminants of any kind such as excessive silt, organic matter, clay, or any other pollutant that would produce an undesirable condition to the beach or water quality.

- **Aquaculture**: This beneficial use alternative consists of the construction of a facility with a primary function of dredged material containment and a secondary function for aquaculture operations. Creating an aquaculture facility in the Apra Harbor Complex does not meet the Navy's purpose and need.
- **Parks and recreation (commercial and non- commercial)**: The parks and recreation beneficial use alternative consists of the construction of a park or recreational facility following closure of the CDF. Conversion of the CDF to a parks and recreation facility requires the closure and capping of the dewatering facility. Currently, the Navy's purpose and need is to continue to use the CDF for the management of the dredging projects previously discussed. An eventual closure and creation of a recreation facility may be suitable in the future, but has not been identified in Navy planning documents.
- **Agriculture/horticulture/forestry**: The feasibility of beneficially using dredged material as topsoil is primarily dependent on two site related factors: the location of the end use site relative to the dredge material source; and the top soil demand relative to quantities of dredged material available. Secondary logistical factors are process related and include the demand rate of the final topsoil product in quantity per year, the production rates of dredged material, dewatering and other processing rates. The factors affecting feasibility are highly dependent on the specific project. At a minimum, the project location and quantity demand must be selected prior to conducting a detailed logistical feasibility analysis. Dredged material from a marine environment requires treatment to wash or reduce salinity concentrations in order to make the material suitable for flora and fauna. A study conducted for the Island of Oahu in Hawaii determined the market for topsoil is declining and may not sustain the development of a topsoil treatment facility (Belt Collins 2002). Creating topsoil treatment facility in the Apra Harbor Complex does not meet the Navy's purpose and need.
- **Mine and quarry reclamation**: Dredged material from P-433 and CVN is likely suitable for mine and quarry reclamation. However, no reclamation projects are identified.
- **Shoreline Stabilization**: Shore erosion is a major problem along many ocean, bay, and estuary shorelines due to wave action, sea level rise, and/or subsidence. Shoreline restoration is the process of restoring and/or mitigating a shoreline to its original or desired position following any natural or man-made disturbance. The use of clean dredged material in shoreline restoration projects provides environmental and economic benefits. Shoreline restoration has the potential to create habitat and improve water quality while reducing the loss of valuable waterfront property. Stabilization and enhancement of eroding shorelines with dredged materials may also help reduce the volume and frequency of future maintenance dredging. While, no shoreline restoration projects are identified in this document, material from Inner Apra Harbor that is compatible with receiver site in terms of grain size, and that is relatively free of contaminants, would be suitable for shoreline restoration.

- **Construction Products**: Use of dewatered dredged material as an aggregate in concrete or asphalt would require the material to be transported to a processing facility and separated into specific size fractions (by pretreatment washing and possible size fractionation using hydrocyclones). The appropriate granular fractions recovered can then be sold for direct use as an aggregate in concrete or in asphalt pavement that utilize solidification technologies. Sand could be used by the construction industry as an addition in Portland cement. An alternative beneficial use option would need to be identified for the remaining fine-grained material. Based on a previous evaluation for Pearl Harbor (Belt Collins 2002), only 25% of dredged material would be useable as aggregate. Separation of the coarse grained material for use as an aggregate would require the development of a dredged material processing facility (DMPF). Currently, a DMPF has not been constructed in Guam. A DMPF would need to be developed to physically separate the grain size fractions of the dredged material.

  Belt Collins (2002) concluded that basaltic and limestone sand, as well as gravels, generated from a DMPF in Hawaii could be used as aggregates in asphalt and concrete. In Hawaii, the estimated costs for construction of a pilot facility to demonstrate the effectiveness of treating dredged material for specific beneficial use options would be comprised of an initial capital of $16-$20 million for construction of the facility, $1 million for design, and an annual operating cost of the DMPF of approximately $1.5 million. Additional operation costs include the transport of material from the CDF to the DMPF. Revenue would be generated from the sale of the aggregate materials. Sand produced from the DMPF could potentially be sold at a rate of $37.50/cy and gravel could be sold at a rate of $22.50/cy (Belt Collins 2002). It is assumed the costs for Hawaii would be similar as Guam; however, the demand may be less on Guam.

  Using dried dredged material from CDFs in the production of construction blocks and bricks has successfully been demonstrated, mostly in pilot studies, to be a viable beneficial use option. However, this technology is not readily available. Manufacturing of blocks, bricks, and tiles from dredged material would require the development of a DMPF in Guam. Belt Collins (2002) determined that although the development of a DMPF to produce construction materials (blocks, bricks) was technically feasible, market demands dictate that construction blocks and bricks need to be consistent in color and composition. Due to the inherent variability of dredged material, construction blocks made from dredged material would not be of consistent color and composition. Further, the production of construction blocks would likely require the use of Portland cement as a binder that would result in a low-strength block that does not meet industry standards. Due to lack of a strong market for the products and the low-quality product that is produced from dredged material, this technology is not a feasible alternative for the Navy nor does it meet their purpose and need.

3.4.1 Economic Benefits

The productive use of dredged material provides tangible and intangible benefits that enhance the environment, the local community, and society. Economic benefits can be seen in cost savings from more effective port and channel maintenance dredging, and using dredged material in other beneficial applications, such as construction. Long-range planning for dredged material management should consider future needs of the public and private sectors and what applications would provide the greatest economic benefit. Beneficial uses may be incorporated in planning for public recreation applications, environmental enhancement, and beach and shore protection.

3.4.2 Social Benefits

Social benefits are generally a direct consequence of the particular beneficial use adopted. The most tangible direct benefit enjoyed by the local community is financial. This may be in the form of reduced community costs for a construction project, or increased community income through improved agriculture, fisheries, tourism, product manufacturing, or job creation. Improved beaches may also boost tourism.

Another important social benefit is improvements to the environment, and recreational and sporting opportunities. The local landscape may be enhanced through changes in topography and introduction of new plant and wildlife species. Enhancements to sporting activities, such as fishing, swimming, surfing, sailing, water skiing, and wildlife observation, will usually result in a better quality of life.

Beneficial reuse reduces the need for new CDFs. Valuable land would available for alternative uses, including those uses that produce revenue.

The following sections present descriptions of potential beneficial use alternatives of dredged material identified by USACE (1987) that may be applicable to use in the Apra Harbor Complex.

3.4.3 Material Transfer

Dewatered dredged material is commonly used for commercial/industrial sites, including port facilities. The applicability of dredged material to a particular construction project depends on the physical and engineering properties of the material and the specific requirements of the project. However, if the material has poor foundation qualities, a suitable additive such as cement may be added to increase shear strength and bearing capacity. Material dredged from Inner Apra Harbor may be used in the construction of magazines. Magazines are areas designated for the storage of explosives and ammunition, and are designed according to the type and amount of ordnance to be stowed. Dewatered dredged material can be used in the actual magazine construction or as earthen berms between two adjacent magazines or in the construction storage pads. The use of dredged material for the construction of magazines may decrease project costs by eliminating or reducing the amount of off-site material normally used in their construction. Specific examples of this beneficial use are described below.

3.4.3.1 Market Demand

Due to concerns over potential liability, the Navy's preferred beneficial use of dredged material is to remain on DoD lands. Therefore, a consumer based market demand assessment is not relevant to this evaluation. The total estimated cost for excavation of material from the dewatering site (\$3/cy, \$3.92/m^3), transportation (\$2/cy, \$2.62/m^3), and rehandling of the material to the Ordnance Annex for beneficial use (\$2/cy, \$2.62/m^3) is \$7/cy (\$9.16/m^3).

3.4.3.2 Construction of Magazines: Ordnance Annex Magazines

The Ordnance Annex for the Apra Harbor Naval Complex is approximately 6 mi (9.6 km) southeast of Inner Apra Harbor in south central Guam (Figure 16). Ammunition storage at naval installations consists of various types of open storage and magazines, depending upon the nature of the material to be stowed.

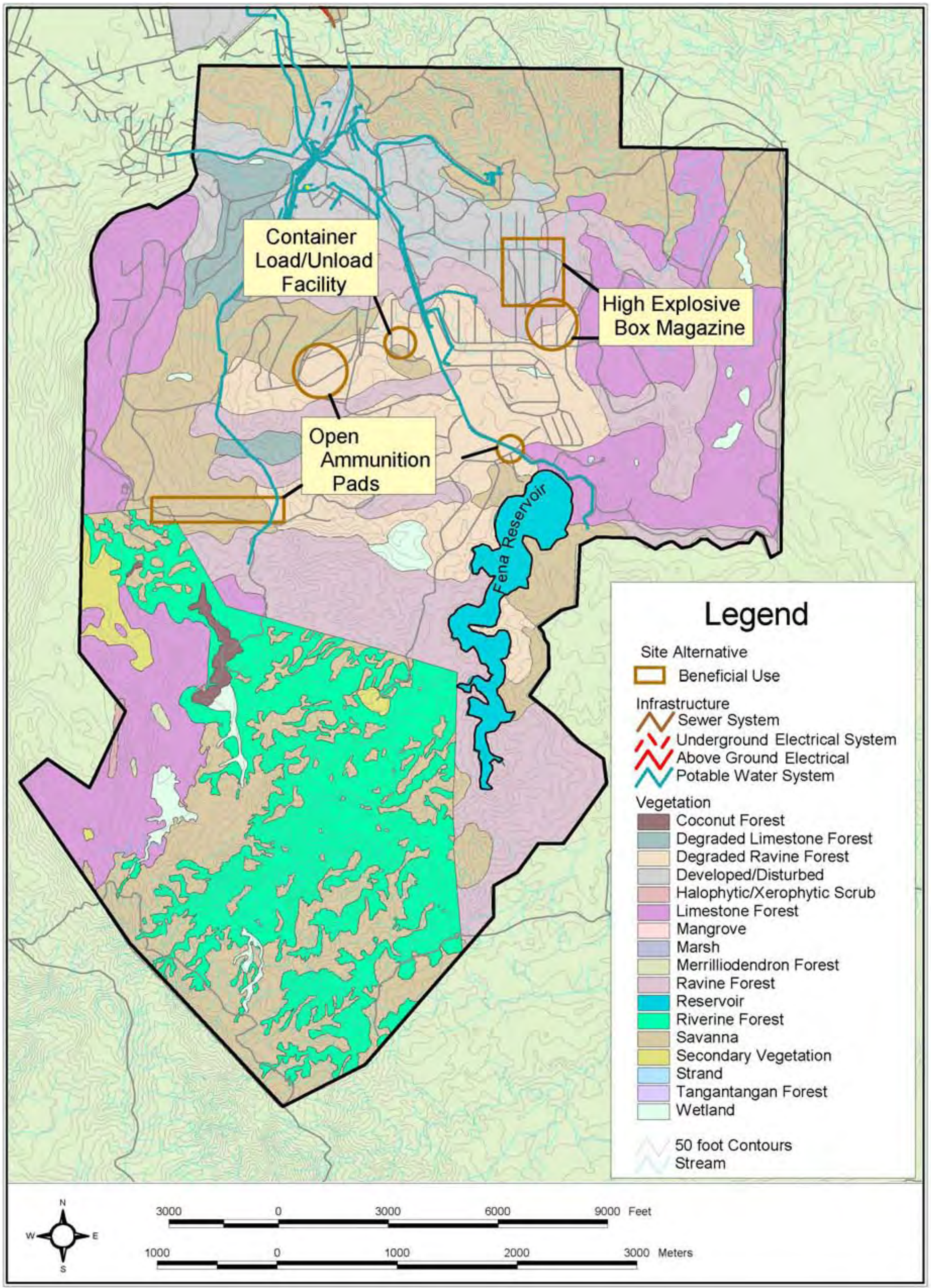


Figure 16. Potential Beneficial Use Alternative within the Ordnance Annex.

The Ordnance Function Plan (HHFP 2003a) proposes several construction projects to increase ordnance handling capacities and to provide for operational improvements at the Ordnance Annex. The proposed timeline indicates that these projects will be initiated in 2008. Several of these projects include the construction of earthen berms in the designs. Dredged material could be used for these projects in the construction of barricades or cover, or as effective strategies for reducing risks associated with the storage of hazardous ordnance materials. The alternative would include the beneficial use of dredged material dewatered at one or more dewatering sites. After dewatering and consolidation, the dredged material would be removed from the dewatering site, and transported and offloaded at the Ordnance Annex site(s) (MEC-Weston 2005). Ordnance magazine construction includes a container holding yard, open ammunition storage, and high explosive storage.

Capacity: Conceptual design specifications for barricades and earth cover requirements were obtained from the Navy publication "NAVSEA OP 5" (DON 2001b). Construction of container holding yards, open ammunition storage, and high explosive magazines are planned. The total capacity for these three Ordnance Annex construction projects for beneficial use alternatives discussed below would be 47,350 cy (36,204 m^3). This includes the construction of three container holding yards, planned for FY 2008, with 40,000 square feet (sf) (3,716 square meters [m^2]) concrete pads in each holding yard and a barricade surrounding the north and east sides of the holding yard consisting of 5,250 cy (4,014 m^3) of material, based on the dimensions described in the Phase I DMMP (MEC- Weston 2005). Another project includes the construction of nine 9,350 sf (868 m^2) open ammunition storage pads with earthen berms to provide intraline distance protection between any two potential explosive sites. The construction of nine 9,350 sf (868 m^2) open ammunition storage pads requires 30,000 cy (22,938 m^3) of material for barricade construction. In addition, the construction of the high explosive magazines includes two 8,000 sf (743 m^2) magazines, with a capacity of material required for earth cover of 12,100 cy (9,251 m^3). The details of these capacity estimates are discussed in detail in the Phase I DMMP (MEC-Weston 2005).

Cost: This alternative would provide capacity for 47,350 cy (36,202 m^3). Estimated total cost to remove dredged material from a dewatering site, and transportation and offloading at the beneficial use sites is $331,450, which represents $7/cy ($9.16/m^3). These costs are within the expected cost for relocation of material, and therefore are feasible. Costs for construction of the magazines beneficial use projects are not included in this estimate.

Existing Conditions: Land use, air quality, geology, water quality, biological resources, and cultural resources are described in detail in the Phase I DMMP. Since the development of the Phase I DMMP in 2005, existing environmental resources at this site have not significantly changed and are discussed in further detail in this initial study. The Ordnance Annex Magazine Construction was determined to be a feasible beneficial use alternative during the initial Phase I DMMP study (MEC-Weston 2005).

Temporary impacts from noise and air emissions may result due to the use of dewatered dredged material for the Ordnance Annex beneficial use projects. Excavation, removal, and transportation of dewatered dredged material to project sites will take one to two months. Dewatered dredged material would be trucked from one or more of the on base dewatering site alternatives considered in this report and/or from the existing SRP CDF and Orote Airfield CDF. At distances beyond 400 ft (122 m) from the road, noise levels will be less than 75 dBA, which is generally compatible with industrial activities. However, the truck route will pass within 300 to 3,200 ft (91 to 975 m) of the Apra Heights housing development. Exterior noise levels will range from 44 to 77 dBA at those distances, which may exceed the HUD guideline level of 65 dBA for residences closest to the transportation route.

Air emissions will result from truck trips from the dewatering site to the Ordnance Annex, and from the operation of equipment during excavation of the dewatering site and offloading of material at the Ordnance Annex project sites. Operation of stationary equipment such as crane engines will require approval from GEPA, which will ensure that the emissions do not exceed National Ambient Air Quality Standards (NAAQS) or prevention of achievement of plans developed under the Clean Air Act (CAA).

3.4.3.3 Construction of Magazines: Orote Peninsula Magazines

The Orote Peninsula magazine site is approximately one mi (1.6 km) from the western tip of Orote Peninsula. The Orote Peninsula is a limestone plateau with elevations of approximately 120 ft (36.6 m) at the proposed magazine site . The area is populated with urban or alien grasslands and tangantangan forests (DON 2001 a). Limestone forests occur along the limestone cliffs to the north and south of the site and are a preferred habitat for several endangered bird species of Guam.

This alternative would beneficially use dredged material from the proposed construction projects in barricades and box magazine earth cover at the Orote Peninsula magazine site. Ammunition storage at naval installations consists of various types of open storage and magazines, depending upon the nature of the material to be stowed. Barricades and earth cover are effective strategies for reducing the damaging effects of explosions , fire, and fragments. The Ordnance Function Plan (HHFP 2003a) sites two ammunition storage construction projects at the Orote Peninsula magazine site for 2008, including Open Ammunition Storage and Non-Propagation Wall/Earth Covered Magazines.

Capacity: The total volume of material for the two Orote Peninsula magazine construction projects would be 102,400 cy (78,295 m^3), which assumes 20,400 cy (15,598 m^3) would be used for barricades in the construction of six 9.350 sf (869 m^2) open ammunition storage pads and 82,000 cy (62,697 m^3) would be used for earth cover in the construction of 17 4,800-sf (446 m^2) box magazines.

Cost: This alternative would provide capacity for 102,400 cy (78,295 m^3). Estimated total cost to remove dredged material from a dewatering site, and transportation and offloading at the beneficial use sites is $716,800, which represents $7/cy ($9.16/m^3). These costs are within the expected cost for relocation of material and therefore are feasible. Costs for construction of the magazines beneficial use projects are not included in this estimate.

Existing Conditions: Land use, air quality, geology, water quality, biological resources, and cultural resources are described in detail in the Phase I DMMP. Since the development of the Phase I DMMP in 2005, existing environmental resources at this site have not significantly changed. The Construction of Magazines at Orote Peninsula were initially determined to be infeasible in the Phase I DMMP study because the construction at the Orote Peninsula magazine site was slated for FY 2006 (MEC-Weston 2005). However, because construction at this site has not yet occurred, beneficial use at this site is now possible.

Temporary environmental impacts to the native avifauna in the limestone forests would occur. Noise levels during construction and/or transportation of dredged material to the construction sites could exceed 60 dBA in the limestone forests adjacent to the project site. Excavation, removal, and transportation of dewatered dredged material to project sites will take one to two months.

Temporary environmental impacts are possible due to beneficial use of material at this site. Limestone forests occur along the limestone cliffs to the north and south of the site and are a preferred habitat for several endangered bird species of Guam.

3.4.3.4 Construction of Magazines: Other Magazines

Additional magazine sites may be required depending on the relocation of military troupes. The capacity would potentially be in the same range as that described for the Ordnance Annex and Orote Peninsula Magazines. Costs would be similar to that of the Ordnance Annex with modifications based on transportation to the site of construction.

3.4.4 Industrial and Commercial Development

Industrial and commercial development near waterways can be aided by the availability of fill material from nearby dewatering sites. The use of dredged material as fill to expand or enhance port-related facilities may be a viable beneficial use alternative because dredged material is typically in surplus from local dredging activities. This may also be a viable option for contaminated dredged material since dredged material used in such construction projects may be amended, stabilized, or isolated as part of the project. Amendments include crushed glass, lime, cement, and fly ash that can be used for this purpose. The type, combination, and amount of amendment material depends on the moisture content, the amount of fines (clays and silts), and organic content of the dredged material. Greater amounts of amendments are typically required if the dredged material has a high clay and/or organic content. The amount and type of amendment will also be dictated by the required physical properties of the finished product. Such amendments can also be used to stabilize contaminants, making this a potential use for contaminated dredged material. Proven methods have been developed for land improvement by filling the site with sand or fine sediments, such as consolidated clay and silt/clay, produced by maintenance dredging. Specific drying techniques may increase the suitability of material for use as fill. The use of fine sediments often requires various dewatering techniques, most commonly subdividing the placement area into cells and filling individual cells to a limited depth on a rotational basis to allow adequate time for dewatering of the material while filling another cell. As each cell dries, low ground-pressure agricultural or earth-moving equipment is used to rework the filled area mixing coarse-grained material or admixtures with the fine-grained material.

3.4.4.1 Market Demand

Due to concerns over potential liability, the Navy's preferred beneficial use of dredged material is to remain on DoD lands. Therefore, a consumer based market demand assessment is not relevant to this evaluation. The total estimated cost for excavation of material from the dewatering site ($3/cy, $3.92/m^3), transportation ($2/cy, $2.62/m^3), and rehandling of the material at the commercial port expansion site ($2/cy, $2.62/m^3) is $7/cy ($9.16/m^3). The cost will vary depending upon transportation distance and the volume of material actually used for this alternative.

3.4.4.2 Commercial Port Expansion

The Port Authority of Guam operates the largest U.S. deepwater port in the Western Pacific. Located in the northeast corner of Outer Apra Harbor (Figure 17), the Commercial Port currently handles about two million tons of cargo a year. In order to help Guam meet its responsibilities as a transshipment hub, the Port Authority of Guam has developed a master plan that will expand the current port footprint to include new deepwater cargo piers, upgraded fisheries facilities, expanded container lay-down areas, an industrial park, and cruise-ship facilities. A substantial volume of fill material will be required for these capital improvement projects. The Navy and the Government of Guam have signed a MOU regarding the use of any dredged material deemed appropriate for fill material and to establish procedures for the determination of the use of the dredged material as fill material for use by the Port Authority of Guam (MOU April 2001; in Appendix D of Phase I DMMP [MEC-Weston 2005]). Conceptual plans indicate that there may be a need for 1.5 million cy for terminal expansion, and 600,000 sf (55,742 m^2) for a proposed new deep wharf in Outer Apra Harbor (Weston 2005). Making dredged material available to the Port for their use in planned port expansion construction projects represents a potential beneficial use alternative.

This alternative includes the removal of dewatered dredged material from the dewatering site(s) and transporting it to the Commercial Port for the Port of Authority of Guam's use in their development of the Commercial Port. The engineering properties of the dewatered dredged material would need to be tested to provide information for planning purposes regarding the appropriate application of dredged material for Commercial Port development projects.

Capacity: Designs have not been finalized; however, a "concept sketch" was provided by the Port Authority of Guam during the December 2003 site visit. The sketch shows that approximately 1.5 million cy of dewatered dredged material fill may be required for the development of Commercial Port (Figure 17). Plans include the construction of a deep-water wharf and the reclamation of 600,000 sf (55,742 m^2) of land at the Glass Breakwater between Hotel Wharf and the Shell fuel pier.

Cost: The cost to excavate, transport, and offload construction dredged material from the on-base dewatering sites to the port will be approximately $7/cy ($9.16/m^3). Cost estimates are within the standard range for moving of material, therefore economically feasible. Transportation costs will be reduced for the Government of Guam and security issues will be eliminated for the Navy if Commercial Port Field 1 is used.

Existing Conditions: Land use, air quality, geology, water quality, biological resources, and cultural resources are described in detail in the Phase I DMMP. Since the development of the Phase I DMMP in 2005, existing environmental resources at this site have not significantly changed and are discussed in further detail in this initial study. The Commercial Port Expansion was determined to be a feasible beneficial use alternative during the initial Phase I DMMP study (MEC-Weston 2005).

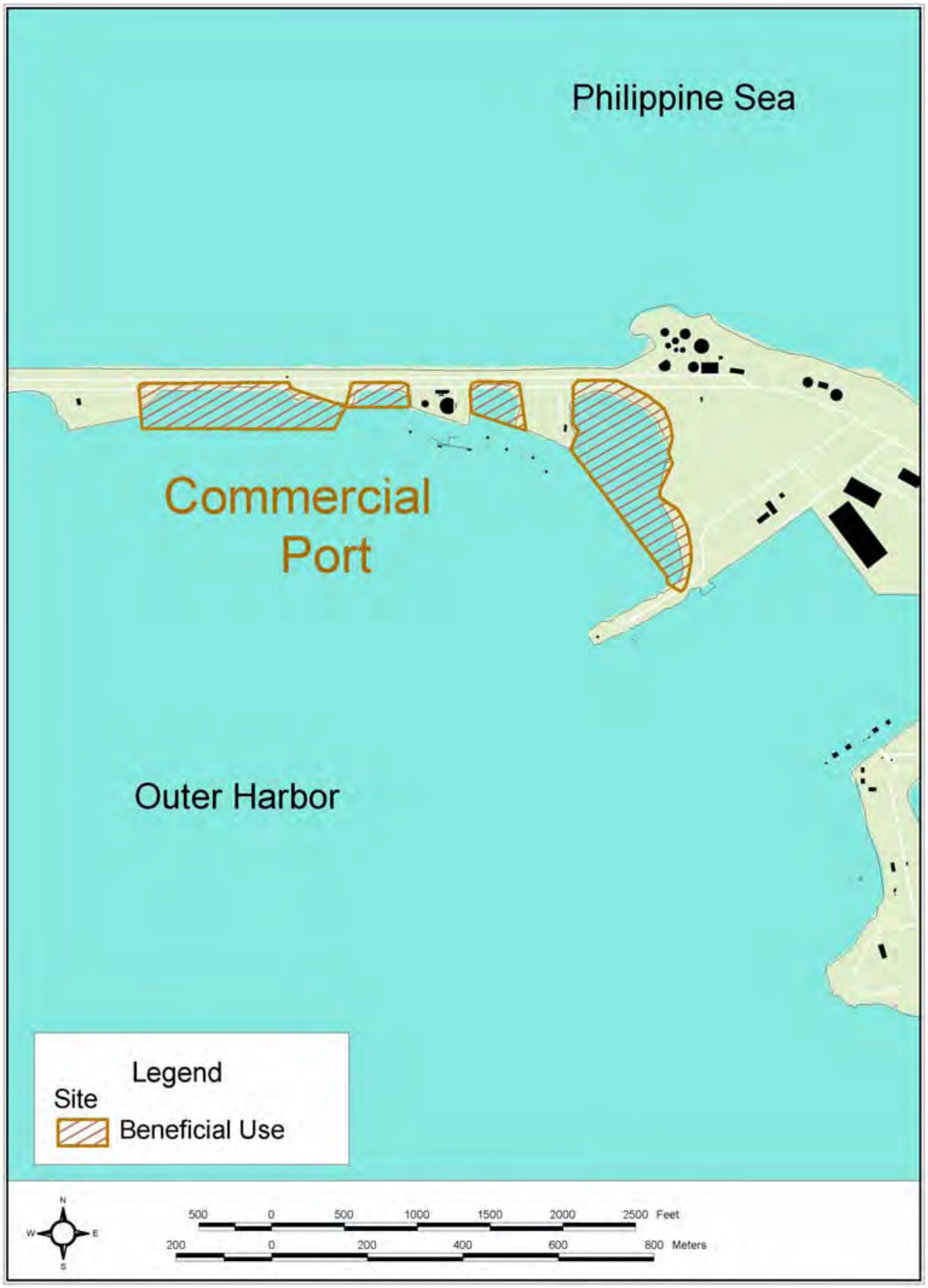


Figure 17. Commercial Port Expansion Beneficial Use Site.

No impacts to existing conditions are expected from noise levels associated with truck hauling of dewatered dredged material from one or more of the dewatering site alternatives considered in this report. At distances beyond 400 ft (122 m) from the road, noise levels are less than 75 dBA, which is generally compatible with industrial activities. Noise impacts would be minimized if material was dewatered at Commercial Port Field 1.

No impacts to existing conditions are expected from air emissions associated with the operation of equipment during excavation at the dewatering site, truck trips from the dewatering site(s) to the port, and from offloading material to stockpile areas at the port. Operation of stationary equipment such as crane engines will require approval from GEPA, which will ensure that the emissions do not exceed NAAQS, or prevention of achievement of plans developed under the CAA. Air quality impacts would be minimized if material was dewatered at Commercial Port Field 1.

Impacts to waters, biological resources, and cultural resources as a result of port expansion construction projects will need to be addressed as part of the Commercial Port project, and are outside the scope of this Upland Placement Study.

3.4.5 Landfill Cover for Solid Waste Management

Dried dredged material may be used as daily landfill cover. The solid waste in a sanitary landfill is covered daily with clean material. The location of a sanitary landfill is often constrained by the availability of cover material. Dredged material typically possesses important cover material characteristics such as workability, moderate cohesion, and low permeability. In addition, all forms of dredged material from silts to gravel make excellent cover, with the exception of peat and highly organic material. In order for dredged material to be economically feasible for daily cover, the landfill should be located less than 50 mi (80 km) from the dredged material supply. Sealed end dump truck hauling should be used as the transportation mode to the landfill. Dredged material from Inner Apra Harbor that passes a paint filter test and is RCRA compliant is a potential beneficial resource that can be used as landfill cover, such as in the specific landfill described below.

3.4.5.1 Market Demand

Due to concerns over potential liability, the Navy's preferred beneficial use of dredged material is to remain on DoD lands. Therefore, a consumer based market demand assessment is not relevant to this evaluation. The total cost associated with the beneficial use of dredged material for daily landfill cover includes the removal of material from the on base dewatering site, transporting to and off loading at the landfill. Minor incidental costs also will be incurred to periodically test the material to ensure its suitability for daily cover. The total estimated cost for excavation of material from the dewatering site ($3/cy; $3.92/m^3), transportation to the landfill ($2 to $3/cy [$2.62 to $3.92/m^3] depending upon distance), and rehandling of the material at the beneficial use sites ($2/cy; $2.62/m^3).

3.4.5.2 PWC Landfill

The PWC Landfill is located south of Inner Apra Harbor, comprising lands east of the Autoport Facility and Field 2 (refer to Subsection 3.2.4) (Figure 13). It is bounded to the west by Perimeter Road "B" and by Shoreline Drive and wetlands to the east. The landfill is approximately 40 a (16 ha) in size and serves as the primary landfill site for the Apra Harbor Naval Complex. The PWC landfill is currently in use with an estimated 15 to 20 years of continued service; however, the total remaining capacity is not known (Pers. Comm. Cruz 2004). Currently, material from various construction projects is used for daily cover. There is an ongoing and constant need for clean daily cover material at the PWC Landfill (Pers. Comm. Cruz 2004).

Capacity: The solid waste in the PWC landfill is covered daily with a minimum of six inches of clean material. Daily landfill cover requirements range between 18,200 and 22,620 cy/year (13,916 and 17,292 m^3/year; Pers. Comm. Cruz 2004). Beneficial use of construction dredged material at the PWC landfill may begin as early as FY 2008.

Cost: The annual cost to excavate, transport, and rework the material at the PWC landfill will range from $127,400 to $204,400, representing an average cost of $7 cy ($9.16 m^3). The use of dewatered dredged material for beneficial use is economically feasible. The cost to deliver (22,620 cy/yr) dewatered material to the landfill from a dewatering facility for 15 years (the estimated life of the landfill after 2008) is $2,375,100.

Existing Conditions: Land use, air quality, geology, water quality, biological resources, and cultural resources are described in detail in the Phase I DMMP. Since the development of the Phase I DMMP in 2005, existing environmental resources at this site have not significantly changed, and are discussed in further detail in this initial study. The PWC Landfill was determined to be a feasible beneficial use alternative during the initial Phase I DMMP study (MEC-Weston 2005).

No major impacts of transportation of dewatered dredged material to residential areas are expected, due to truck hauling of dredged material from one or more of the on-base dewatering site alternatives. At distances beyond 400 ft (122 m) from the road, noise levels are less than 75 dBA, which is generally compatible with industrial activities. Noise levels from earth moving equipment at the landfill would represent no change to existing noise levels at the landfill.

No impacts associated with air emissions are expected due to operation of equipment during excavation of material from the dewatering site and from truck trips from the dewatering site to the landfill. Operation of stationary equipment such as crane engines will require approval from GEPA, which will ensure that the emissions do not exceed NAAQS or prevention of achievement of plans developed under the CAA. There would be no change in air emissions of equipment used at the landfill with this alternative.

No change in land use will occur as a result of this alternative. No impacts to waters, including groundwater, would occur with this alternative. No impacts to wetlands located 300 ft (91 m) to the east of the landfill would occur. No impacts to sensitive species would occur from the excavation of construction dredged material from dewatering sites or its transport and use at the PWC Landfill. No impacts to cultural resources would occur from the use of dewatered dredged material at the landfill.

3.4.5.3 Other Landfills

When the PWC Landfill is full, other landfill options will be implemented. As a consequence, these landfills are also possible beneficial use sites because they will also have a need for clean daily cover material. Costs would be similar to that described above for the PWC site with differences associated with transportation, specific to the location of any other landfill option.

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FINAL REPORT

CVN-CAPABLE BERTHING STUDY

Apra Harbor, Commander Navy Region Marianas
Territory of Guam

July 2008

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FINAL REPORT
CVN Capable Berthing Study

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ACRONYMS AND ABBREVIATIONS

AHWWTP	Apra Harbor Wastewater Treatment Plan
ANSI	American National Standards Institute
ASTM	American Society for Testing and Materials
ATFP	Anti-Terrorism/Force Protection
AWWA	American Water Works Association
BMP	Best Management Practice
BOW	Bilge Oily Waste
BOWCA	Bilge Oily Waste Collection Ashore
BOWTS	Bilge Oily Waste Treatment System
CATV	Cable Television
CHT	Collection-Holding-Transfer
CVN	Carrier Vessel Nuclear
CY	Cubic Yard
DHI	Danish Hydraulic Institute
DoD	Department of Defence
EHSS	Electronic Harbor Security System
EL	Elevation
ELW	Extreme Low Water
EPR	ethylene propylene rubber
ESS	Explosive Safety Submittal
FPC	Facilities Planning Criteria
FWTP	Fena Water Treatment Plant
FY	Fiscal Year
GEDCA	Guam Economic Development and Commerce Authority
gpd	Gallons per Day
gpm	Gallons per Minute
h:v	Horizontal to Vertical
I/I	Infiltration/Inflow
ITG	Interim Technical Guidance
ITN	Information Transfer Node
kV	kilovolt
LOA	Length Overall
$ M	Million US Dollars
m	meter
m^2	square meters
MEC	Munitions and Explosives of Concern
MG	Million Gallons
MGD	Million Gallons per Day
MLLW	Mean Lower Low Water
Mph	miles per hour
MVA	Megavolt Asynchronous Current
MWR	Morale, Welfare and Recreation
NAVFAC	Naval Facilities Engineering Command
NCTS	Navy Computer and Telecommunications Systems
NOSSA	Naval Ordnance Safety and Security Activity
NPS	National Pipe Straight Thread
PCC	Portland Cement Concrete
PEO Carriers	Program Executive Officer for Aircraft Carriers
PSB	port security barriers
psi	Pounds per Square Inch
psig	Pounds per Square Inch Gauge
RPZ	Reduced Pressure Backflow-Prevention Assembly
SCDB	Ship's Characteristic DataBase
SCFM	Standard Cubic Feet per Minute
SPS	Sewage Pump Station
SRF	Ship Repair Facility
SWOB	Ship Waste Offloading Barge
SWWCA	Ship Waterwaste Collection Ashore
UFC	Unified Facilities Criteria
YON	Yard Oiler Navy Barge

Executive Summary

Commander Pacific Fleet requires dedicated nuclear aircraft carrier (CVN) berthing capability on Guam to support current and projected future Fleet warfighting readiness and presence requirements in the PACOM WESTPAC AOR. The focus of this study is the conceptual design of the dredging, waterfront structures, utilities, and security improvements necessary to provide a dedicated wharf facility at Naval Base Guam to support approximately three CVN visits per year, nominally up to 21 days per visit. Wharf infrastructure requirements for these visits are more robust than current design criteria for traditional transient berths but less than that of homeport berths. Therefore, this study breaks new ground in developing the appropriate design criteria.

Description of Alternatives

Previous studies identified three possible site locations and multiple configurations at each site. Further refinement led to the two sites and three alignments selected for this study. The initial portion of this study reviewed the alignments and optimized them to the greatest extent possible, given the data provided[1]. These sites/alignments are identified as follows:

- Alternative 1 - Former Ship Repair Facility (SRF)
- Alternative 2 - Polaris Point Parallel to Shore
- Alternative 3 - Polaris Point Diagonal Offshore

<u>Alternative 1 - Former SRF</u>. This site is located at the northern shore of the former Ship Repair Facility, currently under leasehold to the Guam Economic Development and Commerce Authority (GEDCA) and operated by the Guam Shipyard. Figure G-1 shows the overall layout for this alternative.

The selected alignment follows the current shore line as it extends from the end of the finger pier at Lima Wharf in a northwesterly direction toward the current location of the floating dry dock AFDB-8. For purposes of this study, the berth face runs approximately along the EL –50 feet Mean Lower Low Water (MLLW) contour. This alignment results in a temporary access impediment to AFDB-8 only when the CVN is at berth. The wharf structure clears the channel allowing ships to navigate safely along the dry dock entrance channel when the CVN is not berthed.

Alternative 1 is the lowest cost alternative, estimated at roughly $317 million. This site offers the least amount of dredging and related coral mitigation costs.

<u>Alternative 2 - Polaris Point Parallel to Shore</u>. This site is located at the northern shore of Polaris Point at the location of former Charlie wharf. The location (east and west) is set to minimize the impact to navigation along the channel leading into the inner harbor. The berth is located (north and south) to run approximately along the EL –50 feet MLLW contour to minimize dredging. Alternative 2 is shown on Figure G-2.

[1] Further refinement may be needed during final engineering design.

Figure G-1 CVN Berth at Former SRF

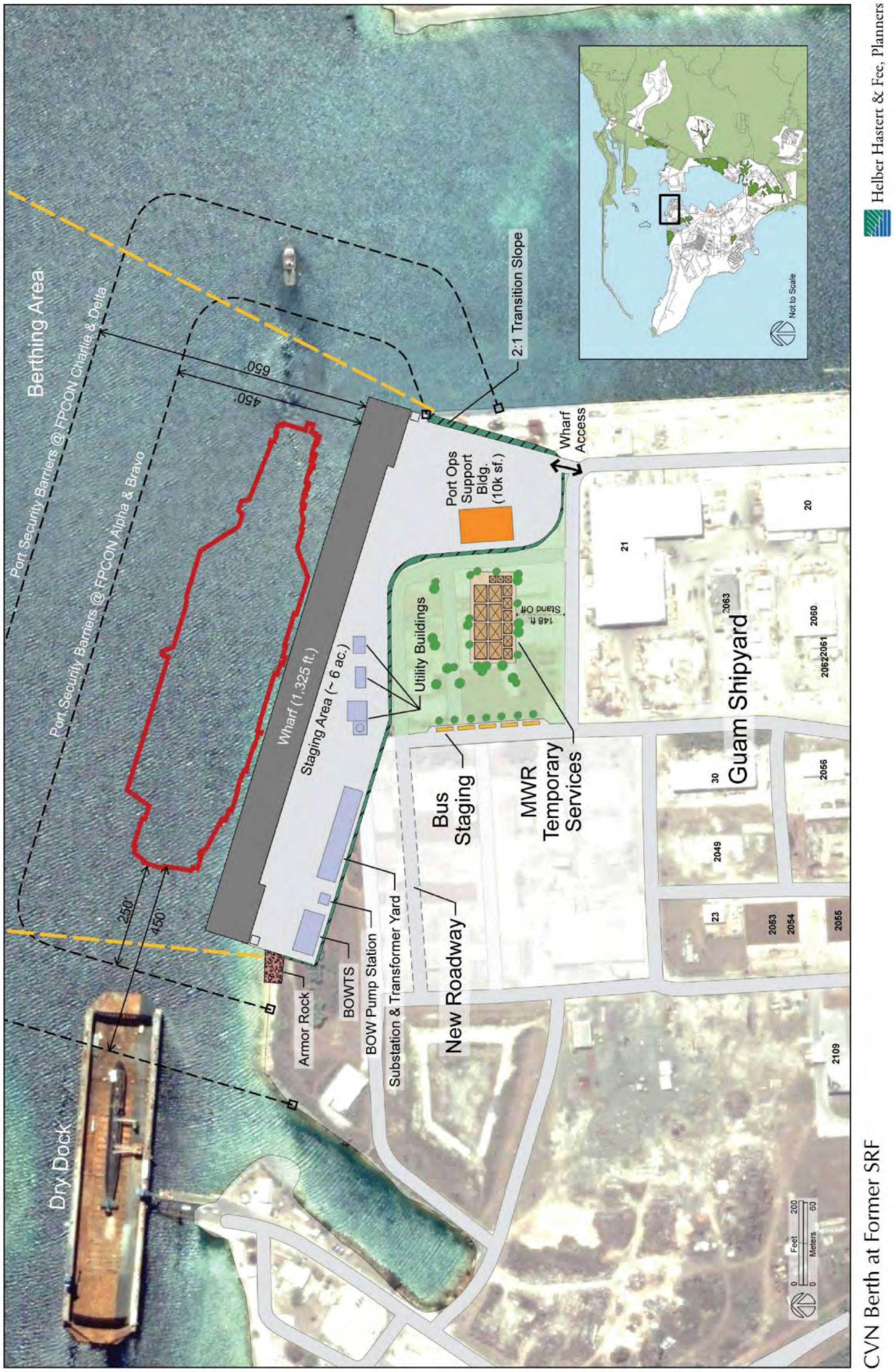
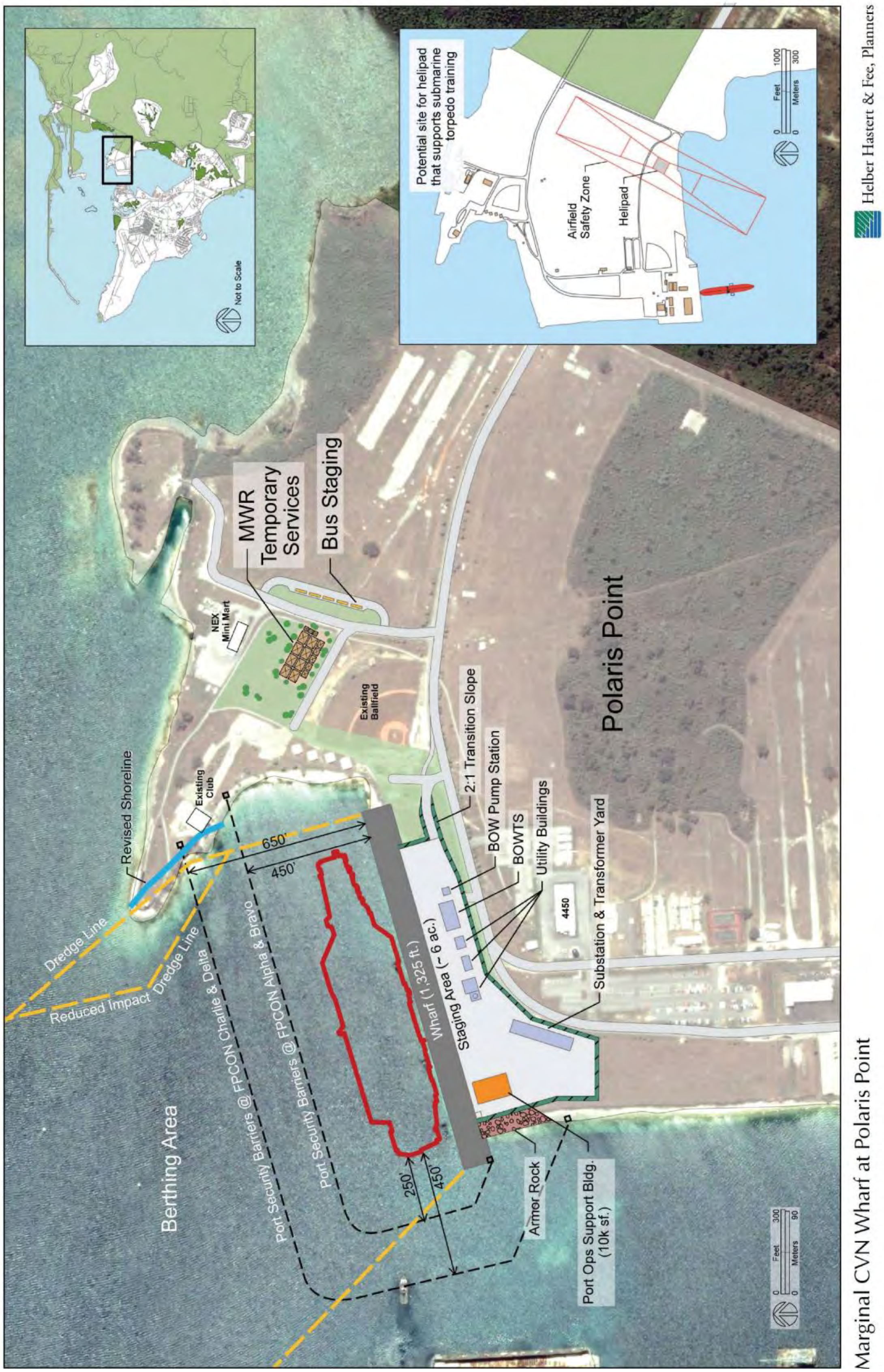


Figure G-2 Marginal CVN Wharf at Polaris Point



There are two dredging alternatives for the Polaris Point Parallel to Shore alignment. The first alignment (Alt. 2) sets the berth width at 600 feet as interpreted from the defined “slip width” in *ITG Facilities Homeporting Criteria for Nimitz Class Aircraft Carriers, 3 November 1998.* The north point must be removed in this alternative, as shown in the figures. A “reduced impact” Alternative (Alt. 2A) is proposed whereby the berth width is slightly less than 600 feet inside the bay, near the bow of the CVN, and the dredged area follows the existing contours of the northern point. The alternative dredge plans are shown in Figures N-2 and N-7 for Alternatives 2 and 2A, respectively.

Alternative 2 is the mid-range cost alternative with a total estimated cost of roughly $339 million. The primary reason for the high cost is the additional dredging and coral mitigation costs. The reduced impact, Alternative 2A, reduces the cost to $324 million, bringing it closer to Alternative 1, but still higher overall. The reason for the higher cost is the additional dredging required between the berth and the turning basin when compared to Alternative 1.

Alternative 3: Polaris Point Diagonal Offshore. This site is also located at the northern shore of Polaris Point. The pier spans across the existing bay, and is located so the abutments are on shore at each end. Alternative 3 is shown on Figure G-3.

Alternative 3 is the highest cost alternative with a total estimated cost of roughly $368 million. This alternative has the highest cost structural element, but offers some reduced dredging over Alternative 2, and reduced marine revetment costs over the other two marginal wharf alternatives.

CVN Capable Berth Criteria

CVN class 68 and 78 vessels have been evaluated in this assessment based on guidance provided by Naval Facilities Engineering Command (NAVFAC) Pacific and applicable Unified Facilities Criteria (UFC) documents. Site specific information was obtained through a field visit conducted from 01 October 2007 through 05 October 2007 and discussions with personnel from NAVFAC Marianas, NAVFAC Pacific, Base personnel, and various contractors with experience in Guam. This information forms the basis of engineering analysis and cost estimates presented in this preliminary report.

Table ES-1 provides a summary of project criteria used for preliminary design and cost estimating the critical elements for the CVN capable berth.

Figure G-3 Diagonal CVN Wharf at Polaris Point

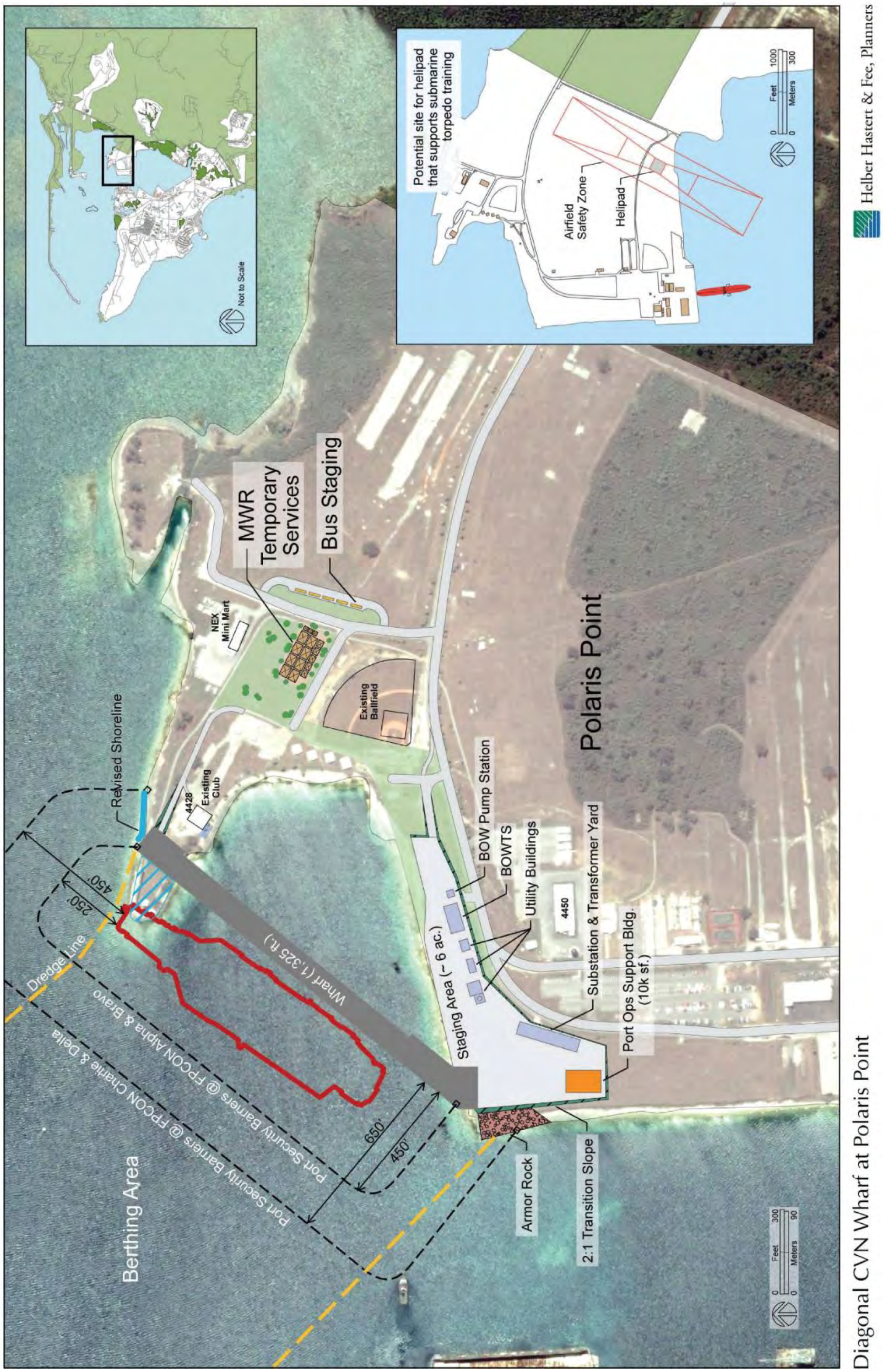


Table ES-1
Summary of Project Criteria for CVN-Capable Berth

System	Criteria	Requirement		Source	Notes
		CVN 68	CVN 78		
Navigation / Dredging	Channel / Fairway Width	600 ft.	600 ft.	ITG - Facilities Homeporting Criteria for Nimitz Class Aricraft Carriers (3 NOV 98), Section 2-2.g.	
	Channel Bend	2,000 ft. - 10,920 ft. radius	2,000 ft. - 10,920 ft. radius	Unified Facilities Criteria (UFC 4-150-06) Military Harbors and Coastal Facilities, section 5-6.2.2.2.	The UFC stipulates a minimum radius of bend of 1,200 ft-2,000 ft with tug assistance, but based on the vessel size and the angle of deflection (54 degrees) the recommended radius is 10 times LOA of the vessel, for 10,920 ft for the CVN class.
	Turning Basin	minimum radius .75 times Length Overall (LOA), optimal radius 2 times LOA	minimum radius .75 times LOA, optimal radius 2 times LOA	Unified Facilities Criteria (UFC 4-150-06) Military Harbors and Coastal Facilities, section 5-6.2.4.2. Interim Technical Guidance (ITG) - Facilities Homeporting Criteria for Nimitz Class Aricraft Carriers (3 NOV 98), Section 2-2.f. Unified Facilities Criteria (UFC 4-159-02) Engineering and Design of Military Ports section 3-6.c.	
	Berthing Area Width and Length	Width:600 ft * Length:1,325 ft	None provided Assume same as for CVN 68	ITG - Facilities Homeporting Criteria for Nimitz Class Aricraft Carriers (3 NOV 98), Section 2-3.a.	* 600 ft width applies to 'slip width'. 800 ft slip width with CVN on opp. berth. (240 ft clearance between). Actual 'berth width' not defined.
	Dredge Depth	-49.5 ft. at MLLW	-49.5 ft. at MLLW	ITG - Facilities Homeporting Criteria for Nimitz Class Aricraft Carriers (3 NOV 98), Section 2-3.b. Facilities Planning Criteria for the CVN 78 Class (PMS 378 Rev July 2007) Section 3.2.1. Interim Technical Guidance (ITG) CVN Dredge Depth Criteria (06 MAR 07)	
Structural	Wharf Width	90 ft.	90 ft.	Interim Technical Guidance (ITG) - Facilities Homeporting Criteria for Nimitz Class Aricraft Carriers (3 NOV 98), Section 4-1.a.	The wharf is not used for maintenance which would requre a wider wharf. Vessels are not berthed on both sides.

Table ES-1
Summary of Project Criteria for CVN-Capable Berth

System	Criteria	Requirement		Source	Notes
		CVN 68	CVN 78		
Structural (con't)	Wharf Length	1,325 ft.	1,292 ft.	ITG - Facilities Homeporting Criteria for Nimitz Class Aricraft Carriers (3 NOV 98), Section 2-3.c. Facilities Planning Criteria for the CVN 78 Class (PMS 378 Rev July 2007)	Total wharf length for Alternative 3 is 1545 ft; required by site topography and the need to provide on-shore abutments to resist seismic and berthing loads. The length would be the same for the CVN 68 or CVN 78.
	Wharf Deck Height	Elev +12 ft.	Elev +12 ft.	ITG - Facilities Homeporting Criteria for Nimitz Class Aricraft Carriers (3 NOV 98), Section 4-2.b.	The significant wave height and final deck elevation need to be confirmed.
	Pier Strength	Live Load = 800 psf min.		As above, Section 4-3.a.	
	Mobile Crane Load	2 - 140 ton mobile cranes		As above, Section 4-3.b.	
	Bollards	100 ton, 100 ft spacing	100 ton, 100 ft spacing	As above, Section 4-3.d.	
	Storm Bollards	4 - 200 ton bollards at each end of wharf	4 - 200 ton bollards at each end of wharf	As above, Section 4-3.d.	Location must be back from the face of wharf beyond 90 ft. Since lateral soil strength is not yet determined, wharf deck is extended to support these bollards. Final design may allow these to be on shore for Alternatives 1 and 2 only.
Supporting Facilities	Security Measures	Electronic Harbor Surveillance System		OPNAVINST 5530.14D, Appendix VIII - Waterside and Waterfront Security Draft UFC 4-025-01 Security Engineering: Waterfront Security UFC 4-021-02NF Security Engineering: Electronic Security Systems	Minimum requirements include electronic water/waterside security system (CCTV, associated alarms, surface craft or swimmer detection, and underwater detection). Local components of EHSS require integration into the base-wide ESS
		Perimenter Fencing		UFC 4-025-01 DRAFT Waterfront Security Design (24 July 05)	Concrete barriers with fencing on top of barriers
	Laydown Area	5 Acres (+/-)		IITG - Facilities Homeporting Criteria for Nimitz Class Aricraft Carriers (3 NOV 98), Section 4-4.c.	Laydown area for temporary visits not defined; however, area is fully utilized for buildings, transit shed, equipment, etc.
	Port Operations Building	10,000 sf Storage Shed		COMNAVMAR	Provide bathroom only - office not required in buildiing.

Table ES-1
Summary of Project Criteria for CVN-Capable Berth

System	Criteria	Requirement		Source	Notes
		CVN 68	CVN 78		
MWR Services	Open Pad Area	8500 sf - 12,000 sf		Interviews with NAVBASE Guam MWR personnel and guidance from NAVFAC	
	Road/Parking Improvements	Bus staging, parking, etc.		As above	
	Electrical Service	208V 3-Phase Recept. Bank		As above	
Bilge Oily Waste	Peak Quantity	80,000 gpd	82,000 gpd	Per Table C-5 in UFC 4-150-02 for CVN 68 to 77 and FPC for the CVN 78 Class (Review Draft, REV 1, July 2007).	
	Average Quantity	35,000 gpd	38,000 gpd	Per Table C-5 in UFC 4-150-02 for CVN 68 to 77 and FPC for the CVN 78 Class (Review Draft, REV 1, July 2007).	
	Design Rate	90 gpm	90 - 180 gpm*	Per Table C-5 in UFC 4-150-02 for CVN 68 to 77, FPC for the CVN 78 Class (Review Draft, REV 1, July 2007 & Guidance provided in "CVN 68 UTILITY RQMTS with CVN 78 NOTES FOR GUAM 21 Aug 07" document.	* Clarification provided from the Program Executive Officer for Aircraft Carriers (PEO CARRIERS) per email dated 24Sept07. The CONOPS for the CVN 78 is to use only one pump, limiting the output to 90 gpm.
Wastewater	Average Daily Flow	550,000 gpd	550,000 gpd	Per UFC 3-240-2N, using 100 gpcd and 5,000 personnel for both CVN 68 and 78 plus additional 10% for escort ships accompanying the CVN during the 21-day visit.	Based on information provided in Setiadi/Belt Collins report 28Sept2006, rev 21Jan2007.
	Design Rate	4 pumps at 400 gpm each*	Fwd, stbd side: 250 gpm Aft, stbd side: 500 gpm**	*Per Guidance provided in "CVN 68 UTILITY RQMTS with CVN 78 NOTES FOR GUAM 21 Aug 07" document, assume 3 CHT pumps operating at 400 gpm each (design for 1,200 gpm).	**Per notes provided on "CVN 68 UTILITY RQMTS with CVN 78 NOTES FOR GUAM 21 Aug 07" document - Recommend providing CHT requirements for CVN 68, which has a larger output of 1,200 gpm.
Potable Water	Average Demand	185,000 gpd	235,000 gpd	Per Table C-4 in UFC 4-150-02 for CVN 68 (with Air Wing or Troops Aboard) & Guidance provided in "CVN 68 UTILITY RQMTS with CVN 78 NOTES FOR GUAM 21 Aug 07" document.	Per notes provided on "CVN 68 UTILITY RQMTS with CVN 78 NOTES FOR GUAM 21 Aug 07" document - Recommend providing water demands for CVN 78.
		18,500 gpd*	23,500 gpd*	*Assuming 10% for escort ships accompanying the CVN during the 21-day visit.	*CVN escort ships' water demand.

Table ES-1
Summary of Project Criteria for CVN-Capable Berth

System	Criteria	Requirement		Source	Notes
		CVN 68	CVN 78		
Potable Water (con't)	Design Rate	1,000 gpm	1,000 gpm	Based on UFC 4-150-02 for Active Berthing for all berth lengths up to 2,000 feet, plus 500 gpm for each additional 2,000 ft.	
	Minimum Pressure	40 psi	40 psi	Based on UFC 4-150-02 for Active Berthing. Minimum pressure required at the most remote outlet on the pier, downstream of a backflow preventer.	
Steam	Constant	7500 lb/h*	Not req'd	Table 1 MIL-HDBK 1025/2; Table B-1 UFC 2150-02, CVN -78 FPC July, 2007	*Includes 50% for Air Wing on board
	Intermittent	7200 lb/h	Not req'd	Table 1 MIL-HDBK 1025/2; Table B-1 UFC 2150-02, CVN -78 FPC July, 2007	Use 70F outside design temperature.
Compressed Air	Design Rate	2400 scfm	Not req'd	Table B-2 UFC 2150-02; Table 5, MIL-HDBK 1025/2, CVN -78 FPC July, 2007	
Pure Water	Peak Rate	150 gpm	100 gpm	"CVN 68 Utility Requirements with CVN 78 notes for Guam 21 August, 2007 document.	
	Design Rate	20,000gal/day	20,000gal/day	"CVN 68 Utility Requirements with CVN 78 notes for Guam 21 August, 2007 document.	
Shore Power	Peak Demand	21 MW @ 4,160V	30 MW @ 13,800V*	Per Table C-7 in UFC 4-150-02 for Aircraft Carriers & Guidance provided in "CVN 68 UTILITY RQMTS with CVN 78 NOTES FOR GUAM 21 Aug 07" document.	*25 MW without Air Wing
Information Systems	Capacity	200 pr copper; 48-strand fiber optic cable; provision for CATV connection	*	Per Table C-8 in UFC 4-150-02 for CVN 68, Guidance provided in "CVN 68 UTILITY RQMTS with CVN 78 NOTES FOR GUAM 21 Aug 07" document, and based on NCTS discussions.	* None provided in UFC documents. Assume same as CVN 68.

Engineering Analysis

The pertinent aspects of the CVN Capable Berthing Study are:

- Wave Conditions (coastal engineering)
- Dredging & Navigation (dredging)
- Waterfront Structures (structural)
- Backlands, Drainage, Security & Support (civil)
- Steam, Compressed Air & De-ionized Water (mechanical)
- Bilge Oily Waste (BOW), Wastewater, Potable Water (sanitary engineering)
- Electrical Power Distribution, Communications System (electrical engineering)

Wave Conditions

The Alternative 3 - Polaris Point Diagonal site was found to be the most exposed to extreme waves with the highest wave crest elevation. This was due to the alignment to incoming waves. Alternative 1 - Former SRF was the least exposed, as the waves approach in the alongshore direction and has a slightly lower wave crest elevation. Wave height calculations were approximated using available studies and will require greater refinement and calibration through additional modeling before a reliable design wave crest height and associated wave forces can be used for final design. The difference between the wave crest elevation and the underside of the deck will determine the wave pressure (uplift) for which the deck and piling must be designed.

Dredging & Navigation

Dredging will be required for all alternatives to improve navigation. Dredging is required to: (1) widen the channel approach to the turning basin to a minimum of 600 feet; (2) create a turning basin with a minimum radius of 1,200 feet; and (3) provide a berth in front of the wharf structure of at least 1,325 feet long x 600 feet wide. Minimum depth for all is -49.5 feet MLLW. Realignment of the channels leading to the turning basin and berth will require relocation of the current aids to navigation, including channel buoys and range lights. The volume of dredging is the least with Alternative 1 - former SRF and greatest with Alternative 2 - Polaris Point Parallel to Shore (full-width berth).

Dredging will have direct impacts on coral. The impact on coral was avoided where practical while still meeting operational requirements. For example, three channel fairways were assessed. The fairway that would have the least direct impact on coral was selected although it would be the most challenging from a CVN navigation perspective.

The analysis of potential indirect impacts, which are related to sediment plumes possibly travelling from the dredging location to remote locations during construction, has not been fully assessed. Potential indirect impacts could be impacts to coral and/or turbidity in the water column. It is anticipated that silt curtains and other Best Management Practices (BMPs) plans implemented during construction can effectively mitigate indirect impacts. However, to be conservative in the cost estimating of this CVN study, the assumption is the entire eastern edge of Big Blue Reef would be indirectly impacted by all alternatives, because of its proximity to the turning basin dredging activities in all alternatives.

Alternative 2, Polaris Point, if constructed to meet the guidance criteria of a 600-foot wide berth, would result in the removal of the point of land (and associated coral) located north of the proposed wharf (Figure N-2). Alternative 2A was developed specifically to avoid this loss and minimize the amount of dredging by reducing the berth width to 440 feet at the bow of the vessel (Figure N-7). This alternative was reviewed and approved by the harbor pilots and Navy Base personnel, and CPF/NAVSEA provided verbal concurrence with the Alternative 2A configuration.

The disposal of dredge material is dependent upon available disposal options, each with different associated cost factors. Possible options include: 1) ocean disposal (an ocean disposal site has not been designated, but is proposed by USEPA); 2) uplands placement (current method in Apra Harbor; potential upland dewatering sites have been identified); and 3) beneficial use (fill material for the staging areas for example, up to 62,000 cubic yards). An assessment of disposal options based on laboratory data will be required to support the Army Corps of Engineers permit application. For cost estimating purposes, it is assumed dredging shall be accomplished using a closed bucket clamshell dredge and dredged material would be placed upland. This is the most conservative cost assumption.

Naval Ordnance Safety and Security Activity (NOSSA) Instruction (NOSSAINST) 2080.15A states that an Explosive Safety Submittal (ESS) may be required for construction dredging in areas known, or suspected, to contain Munitions of Explosive Concern (MEC). Based on current information and knowledge of site history, it is NOSSA's opinion that an ESS would not be required at this time. Therefore, costs for ordnance screening of dredge materials are not included in the project cost estimate. A draft "Request for a NOSSA ESS Determination" is included as part of the DD1391 documentation and must be updated and submitted, during project design.

Historically, contaminated soils have been found adjacent to shipyard activities. However, results from initial sampling and analysis of potential dredged material near the former SRF site showed low site sediment contamination. Therefore, costs for hazardous waste handling and disposal, associated with highly contaminated dredged material, are not included in the cost estimates for dredging. Additional dredged material characterization may be done if the SRF site alternative is selected as the final wharf site.

Waterfront Structures

Three alternative types of waterfront structures were considered for general site compatibility, constructability, costs, and seismic performance. These were: (1) pile-supported wharf deck, (2) sheet pile bulkhead wharf, and (3) a concrete caisson wharf. While both the sheet pile bulkhead wharf and the concrete caisson wharf are used in Apra Harbor, it was determined that the pile supported wharf deck was the best alternative due to its documented superior seismic performance and relative costs. Steel piles were chosen over prestressed concrete piles due to the anticipated variable bearing depth (i.e., the length of steel piles can be field adjusted more easily than concrete piles). Costs were developed for the pile-supported wharf for all three alternatives. The caisson wharf would be much more costly than the pile supported wharf; and although the initial cost of the sheet pile bulkhead maybe slightly less, the life-cycle costs and the seismic risks make this option less desirable than the pile supported deck option.

The wharf structure for Alternatives 1 and 2 are identical, and are of typical construction. Alternative 3 is in deeper water without the benefit of an under-deck embankment, and thus requires a unique structural system. The bridge-like configuration of Alternative 3 lends itself to having two abutments (one at each end) where the structure comes onshore. These abutments are needed to carry the seismic loads of the entire wharf, as the long length of the in-water piles is not suitable for this task. The abutments provide the only access to the structure. The longer in-water pile lengths with their larger diameter, as well as the addition of the two abutments, makes this structural alternative considerably more expensive that the structure of the other two alternatives.

The proposed deck elevation for all three alternatives is currently set at +12 feet MLLW at the berth face to comply with wave overtopping requirements.

Backlands, Drainage, Security & Support

A staging area of approximately 6 acres is provided for each alternative, based upon reported needs of various users and *ITG Facilities Homeporting Criteria for Nimitz Class Aircraft Carriers, 3 November 1998*, which calls for a minimum 5 acre staging area. The staging area is contiguous with the wharf in Alternatives 1 and 2, and immediately adjacent to the wharf in Alternative 3. Staging areas for all alternatives can be constructed with a minimal amount of disturbance to existing structures, roads, and utilities. In Alternatives 1 and 2, the staging area matches grade with the backside of the wharf and is sloped to a maximum of 1 percent (%) for drainage. The elevation of the staging area requires fill to raise grade to the level indicated. At the former SRF site, trenching for utilities and drainage system into potentially contaminated soil is avoided because the staging area site is elevated. The elevation at Alternative 3 is set lower than the others as there is no need to match grade along the backside of the wharf; only a ramp up to the abutment is needed. This reduces the amount of fill material. By using dredge material as fill, disposal costs are reduced and the costs for imported borrow is avoided. The raised staging areas also provide additional site security and protection against flooding during typhoons. Finally, it is beneficial to port operations to have the staging areas close to the berth face. Utility buildings are sited within the area reducing the length of utility runs to the berth face.

Drainage for all alternatives includes collecting the sheet flow off of the pavement via perimeter swales and catch basins into an underground pipe system. Storm water collected can be cleaned to local water quality standard using BMPs and a cyclonic separator before being discharge through a new harbor outfall. The drainage system for the Polaris Point Diagonal alternative was somewhat more expensive that the other two alternatives, because the overall flow distances dictated two systems, each requiring a separator and outfall.

Landside and waterside Antiterrorism Force Protection (ATFP) security requirements were established from the *Draft Unified Facilities Criteria (UFC) 4-025-01 – Waterfront Security Design (24-4-05)*. Landside security is provided by hardened perimeter fencing and controlled access. Waterside security is provided by floating port security barriers that are deployed when the CVN is at berth. Security is enhanced by hardened watch towers and patrol by the Harbor Patrol. Security may be a greater concern at the former SRF site due to its proximity to the commercial ship repair facility. Polaris Point; however, is isolated and has no commercial activity within its perimeter. The Polaris Point Parallel to Shore alternative offers better security than the Polaris Point Diagonal Offshore alternative because the former has only one point of entry to the secure perimeter, while the latter has a potential of intrusion from the opposite shoreline. All alternatives will have the same security measures (i.e. hardened fencing, two watch towers, controlled access point, and floating port security barriers). The Polaris Point Diagonal Offshore alternative will require the longest line of floating barriers, and it is expected there will be a somewhat longer time to deploy and retrieve this system. This is due to the longer length of the wharf and the need to wrap the barriers around the bow and stern of the CVN as shown on Figures C-1, C-2 and C-3.

All alternatives include electronic surveillance (Closed Circuit Television), associated alarms, surface craft or swimmer detection, and underwater detection) defined as Electronic Security Systems on the landside and Electronic Harbor Security Systems (EHSS) on the waterside. Local components of both systems require integration into the base-wide security system. Included are both infrastructure and equipment costs. Infrastructure cast are included in this study while the procurement and installation of equipment is funded outside of MCON.

The following support buildings are required to support CVN operations (building sizes are approximate):

- Port Operations Support Building (10,000 square feet storage shed with bathroom)
- Air Compressor Building (1,162 square feet)
- Water Treatment Building (1,216 square feet)
- Boiler House (2,010 square feet)
- Fuel Tank (13,210 gallon), surrounded by a containment berm (968 square feet)
- Electrical Substation (10,125 square feet)
- BOW Pump Station (625 square feet)
- Bilge Oily Waste Treatment System (BOWTS) – (5,000 square feet)

All buildings will be designed to the current Guam building code, modified by applicable UFC criteria. Buildings will be designed to criteria for typhoon winds, seismic events, ATFP, sustainability, and other issues in accordance with UFC 1-200-01. It should be noted that none of the proposed buildings are considered occupied structures, and thus will not require radon mitigation measures. If future plans include occupied buildings to support the CVN Berth, such as constructing an office in the Port Operations Building, a passive radon mitigation system shall be incorporated into the building design.

Steam, Compressed Air & Pure Water

Saturated steam (150 pounds per square inch gauge [psig]) is used by CVN 68 class vessels to supply shipboard laundry and galley facilities, in addition to any supplementary heating requirements. The steam demand is what is required by the berthed vessel crew complement with an embarked air wing. The actual requirements remain a subject of debate, and at this writing criteria based upon the tropical climate conditions in Guam was used, in lieu of criteria for colder CONUS regions. Steam is not required for CVN 78.

A compressed air system is required for CVN 68 at all active berths. Under emergency conditions, the vessel compressed air system will be used to “top off” any compressed air demand. Typically, the vessel requirement for 125 psig compressed air should be at a minimum commercial quality. However, it is presumed that the air may also be used for breathing and thus shall meet the requirements of Class D breathing air as described by American National Standards Institute (ANSI) G-7.1-1989. Both the steam and compressed air requirements and conditions are defined by MIL-HDBK 1025/2, and UFC manual 2150-02.

The Grade A pure water is being provided to meet the ship’s needs for active berthing.

The possibility of using temporary portable equipment was evaluated and determined not feasible due to procurement costs, maintenance, storage when not in use; and labor for set-up, tearing down, and certification.

Bilge Oily Waste (BOW)

The existing BOW systems at Apra Harbor Naval Complex are inadequate to handle the CVN BOW requirements of either CVN 68 or CVN 78 for a 21-day duration. Therefore, it is recommended that a permanent BOW collection and treatment system be constructed near the location of the proposed berth. The BOW collection and treatment system will consist of a combined gravity and force main collection system, a BOW pump station, and a Bilge Oily Waste Treatment System (BOWTS) as indicated on Figure M-2 for the former SRF location and on Figure M-6 for the Polaris Point location.

Wastewater

The existing wastewater collection system at Apra Harbor Naval Complex is inadequate to handle the CVN wastewater requirements of either CVN 68 or CVN 78 for a duration of 21 days. Depending on the selected berthing location, upgrades will be required for various portions of the landside wastewater collection system.

Proposed improvements to the wastewater system at Apra Harbor Naval Complex are programmed under upcoming projects P-262 and P-534. The scopes of these projects are to correct existing structural and capacity deficiencies in the system. Neither of these projects will upgrade the system to accommodate the additional capacity required to support the CVN berthing. Therefore, the recommended wastewater system improvements to support the CVN berthing will be independent of those proposed in P-262 and P-534.

For the proposed berthing at the former SRF site location, a separate and dedicated wastewater collection system sized to handle only the CVN loadings is recommend. This dedicated system will include the construction of three new submersible type sewage pump stations and 6,700 linear feet of associated force mains as indicated on Figures M-3 and M-4. In addition to the pressurized systems, approximately 4,420 linear feet of new gravity sewers are recommended, of which 2,720 linear feet of 15-, 18-, and 24-inch relief sewer lines are proposed along Marine Drive to increase capacity of the existing sewer trunkline “A” for the CVN berthing.

For the proposed berthing at the Polaris Point site location, upgrades to the existing SPS No. 9, associated force main, and trunkline “B” are necessary to accommodate the additional flows from a CVN. Unlike the former SRF facility option, a separate and dedicated system for the CVN may not be feasible due to the limited corridor space available along Marine Drive resulting from project P-494. Therefore, the proposed improvements to the wastewater collection system will include the construction of a new submersible type sewage pump station, a new dry pit – wet well type pump station to replace the aging SPS No. 9, and 14,800 linear feet of associated force mains as indicated on Figures M-7 and M-8. In addition to the pressurized systems, approximately 4,940 linear feet of new gravity sewer lines are recommended, of which 4,420 linear feet of 8-, 12-, 15-, and 21-inch relief sewer lines are proposed along Marine Drive to increase capacity of the existing sewer trunkline “B” for the CVN berthing.

Potable Water

The existing potable water system at Apra Harbor Naval Complex was found to be adequate to handle the larger potable water requirements of a CVN 78. Therefore, no major water system improvements will be required for this option. Water system improvements will be limited to the construction of a new 8-inch service lateral to the berthing site and the associated pierside water outlets as shown on Figure M-5 for the former SRF site and on Figure M-9 for the Polaris Point location.

Electrical Power Distribution and Communications System

The existing power and communications infrastructure is not adequate to support either the CVN 68 or CVN 78 berthing. Upgrades to provide required system capacity include a new GPA 34.5 kV feeder from Piti Power Plant, construction of a new shore power substation including four step-down transformers with 34.5, 13.8, and 4.16 kilovolt (kV) switchgear, new communications ductbanks, and various electrical distribution system enhancements as required.

Summary of Projects and Costs

The project costs are summarized in Table ES-2. Referring to the table, there are many line items required to develop a fully functional support berth for CVN visits. When comparing the proposed sites, there are two types of line items to evaluate: those that are mutual to both sites, such as fairway dredging, and those that are site-specific, such as berth dredging and construction, and certain utilities costs. The site-specific line items provide the information necessary to determine the more favorable site and berth alignment.

Estimated costs for each line item are included in the table, and the total estimated cost for each Alternative is provided. Costs are presented in Fiscal Year (FY) 2011 Guam Costs. An escalation factor of 1.0867; October 2007 to October 2011, was used for time escalation, and estimates were developed using either actual Guam costs, or an Area Cost Factor of 2.64 was used to escalate baseline cost taken from the Unified Facilities Criteria (UFC).

Table ES-2 Summary of Project Descriptions and Costs ($,000's, FY 2011, Guam)

Project Item	Alternative 1 Former SRF Facility	Alternative 2 Polaris Point Parallel to Shore[1]	Alternative 3 Polaris Point Diagonal Offshore
Project General Conditions	**$16,381**	**$17,839**	**$21,030**
Mob/Demob and Housing	**$9,308**	**$10,136**	**$11,949**
Dredge Fairway, Turning Basin and Berth; Mob/Demob	478,900 CY **$ 38,313**	993,200 CY (ALT. 2) **$ 69,570** 758,000 CY (ALT. 2A) **$ 55,276**	672,400 CY **$ 50,073**
Munition Screening (N/A – NAVFAC Guidance)	**$ 0**	**$ 0** (ALT. 2) **$ 0** (ALT. 2A)	**$ 0**
Coral Mitigation ($430/m2 – Agency Recommendation)	**$ 19,566**	**$ 23,068** (ALT. 2) **$ 22,495** (ALT. 2A)	**$ 21,466**
Adjust Navigation Markers	**$2,026**	Same as Alternative 1 **$ 2,026**	Same as Alternative 1 **$ 2,026**
Wharf / Pier Construction incl. Camels	90'x1325' Pile Supported Concrete Deck Structure **$ 92,868**	90'x1325' Pile Supported Concrete Deck Structure **$ 92,868**	90'x1545' Pile Supported Concrete Deck w/ conc. abutments each end **$ 148,328**
Marine Revetment	Quarry Stone & Riprap **$ 10,205**	Quarry Stone & Riprap **$ 10,205**	Quarry Stone & Riprap **$ 2,230**
Site Work and Floating Barriers	Demo, fill, pavements, drainage, security **$ 24,004**	Demo, fill, pavements, drainage, security **$ 24,909**	Demo, fill, pavements, drainage, security **$ 22,288**
Buildings	Misc. Buildings **$ 9,547**	Misc. Buildings **$ 9,547**	Misc. Buildings **$ 9,835**
Steam / Air / Pure Water	Construct new systems **$ 10,081**	Same as Alternative 1 **$ 10,259**	Same as Alternative 1 **$ 10,259**
Electrical and Communications	34.5 kV feeder, upgrades at GPA,comm.,lighting **$ 59,616**	34.5 kV feeder, upgrades at GPA,comm.,lighting **$ 38,300**	Same as Alternative 2 **$ 38,300**
Bilge Oily Waste	90gpm BOW System **$ 4,580**	90gpm BOW System **$ 4,580**	Same as Alternative 2 **$ 4,580**
Wastewater	SWWCA & Dedicated Collection to Trunk 'A' **$ 19,500**	SWWCA; Upgrade SPS No.9, Main&Sewer Lines **$ 24,660**	Same as Alternative 2 **$ 24,660**
Potable Water + Electrical for BOW, WW, Water systems	Pierside Work & Connect to Exist. Water System **$ 560**+**$330** Misc.Elect	Pierside Work & Connect to Exist. Water System **$ 610**+**$280** Misc.Elect	Same as Alternative 2 **$ 610**+**$280** Misc Elect
SUB-TOTALS	**$ 316,885**	**$ 338,857** (Alt. 2) **$ 323,990** (Alt. 2A)	**$ 367,914**
Estimated 1391 Cost[(2)]	**$ 388 Million (M).**	**$ 416 M** (Alt. 2) **$ 397 M** (Alt. 2A)	**$ 453 M**

1. There are two dredging alternatives for the Polaris Point Parallel to Shore alignment. ALT. 2 requires the removal of the north point, and ALT. 2A is a reduced impact alternative which preserves the point.

2. Estimated 1391 costs include contingency (10%), Post Construction Award Services (PCAS) (1%), Guam Gross Receipts Tax (4%), Design-Build Services (4%) and Supervision, Inspection and Overhead (SIOH – 6.2%) to provide a better approximation of programming costs..

Construction Phasing for Incremental Funding

A construction schedule for design-build was assumed at 48 months for Alternative 1 - Former SRF and Alternative 2 - Polaris Point Parallel to Shore options and 54 months for Alternative 3 - Polaris Point Diagonal option. The starting point for each was assumed at mid-fiscal year, thus the schedule covers 5 fiscal years. An additional 6 months is required for the construction of the wharf in Alternative 3 due to its increase length, deep water piling, and abutments at each end.

The various major elements of work for Alternatives 1 and 2 were scheduled over the duration indicated as described below. Work for Alternative 3 is similar except that the wharf construction continues into the 5th year.

Table ES-3 Construction Phasing for Incremental Funding

Year 1 (6 mos.)	Activity
Dredging	Design
Wharf Construction	Design (75%)
Site Work	
Buildings	
Steam, Air, Pure Water	
Bilge Oily Waste Systems	
Wastewater Systems	Design
Potable Water System	
Electrical Utilities	
Year 2 (12 mos.)	
Dredging	Mobilize dredge; dredge berth, turning basin, and fairway (25%); place quarry run on berth slope
Wharf Construction	Complete design; order piling; mobilize; place armor stone (42%); drive pipe piling (29%); construct deck (8%)
Site Work	Design
Buildings	Design (50%)
Steam, Air, Pure Water	Design (33%)
Bilge Oily Waste Systems	Design
Wastewater Systems	PS Equipment and Material Ordering; Construct Pump Stations (33%)
Potable Water System	
Electrical Utilities	Design; Construct Duct System (17%)
Year 3 (12 mos.)	
Dredging	Complete dredging of fairway; navaids; closeout
Wharf Construction	Complete placing armor stone; complete driving pipe piling; construct deck (58%)
Site Work	Mobilization; demolition; earthwork; storm drain; substructures
Buildings	Complete design; mobilization & material procurement; construct air, water, & steam buildings (75%)
Steam, Air, Pure Water	Complete design; mobilization & material procurement; install mechanical systems (13%)
Bilge Oily Waste Systems	BOWTS Equipment & Material Ordering; Construct BOWCA and BOW

Table ES-3 Construction Phasing for Incremental Funding

Wastewater Systems	Complete pump stations; construct FM & sewers (50%); construct SWWCA
Potable Water System	Construct pier-side water lines & outlets; supply lateral to pier; commissioning & closeout
Electrical Utilities	Complete duct system; cable procurement; substation and wharf equipment procurement
Year 4 (12 mos.)	
Dredging	
Wharf Construction	Complete deck; install fender piles & fenders; close out (Alts 1 & 2)
Site Work	Paving; security & fencing (67%)
Buildings	Complete air, water, & steam buildings; construct transit shed; construct misc. bldgs (33%)
Steam, Air, Pure Water	Install mechanical (93%)
Bilge Oily Waste Systems	Construct BOWTS; commissioning & closeout
Wastewater Systems	Complete FM & sewers; commissioning & closeout
Potable Water System	
Electrical Utilities	Construct electrical; commissioning & closeout
Year 5 (6 mos., 12 mos. Alt 3)	
Dredging	
Wharf Construction	Complete deck; install fender piles & fenders; close out (Alts 3 only)
Site Work	Complete all remaining work & close out
Buildings	Complete other buildings & close out
Steam, Air, Pure Water	Complete mechanical installation; start up and commissioning; close out
Bilge Oily Waste Systems	
Wastewater Systems	
Potable Water System	
Electrical Utilities	

To complete the work according to the schedule, the following funding requirements are necessary (Table ES-4), expressed as percentage of total funds.

Table ES-4 Incremental Funding Over Construction Period

Year	Alt 1	Alt 2	Alt 3
1	6%	6%	6%
2	34%	34%	29%
3	38%	38%	33%
4	20%	20%	25%
5	2%	2%	7%
Total	100%	100%	100%

Phasing of CVN 68 and CVN 78 Requirements

Structural, dredging, and civil requirements are essentially the same for both the CVN 68 and CVN 78, thus there is no opportunity to phase-in the construction for these items. Utility demands for steam, compressed air, and pure water are expected to remain the same, decrease, or be eliminated for the CVN 78 class. Thus, the need for these facilities at the commissioning of the berth remains unchanged.

The demands for BOW, wastewater and potable water systems are also the same for CVN 68 and CVN 78 vessels, and thus no project phasing is possible.

The electrical and communications base infrastructure required to support both the CVN 68 and CVN 78 is similar, with the exception that upgrading the electrical system to accommodate the CVN 78 will require two additional 13.8 kV switchgear sections with associated 15 kV feeder cables and power receptacles. The cost of a future project to provide two additional 13.8 kV switchgear sections, associated 15 kV feeder cables, and power receptacles is approximately $500,000.

Site Selection Pros and Cons

Various pros and cons for each site alternative have been developed and these are detailed in Chapter 7. The pros and cons focus primarily on the engineering aspects of the projects, and no attempt was made to judge one site as superior to another based on non-quantifiable or subjective data. The pros and cons developed in this study are summarized in Table ES-5.

Table ES-5 Summary of Pros & Cons for the Alternatives

Alternative 1 - Former SRF Facility		Alternative 2 - Polaris Point Parallel to Shore Alternative 2A (Reduced Impact)		Alternative 3 - Polaris Point Diagonal Offshore	
Pros	**Cons**	**Pros**	**Cons**	**Pros**	**Cons**
GENERAL NOTES					
Lowest overall project cost			Higher overall project cost than Alt. 1		Highest overall project cost
	Demolition required and possible contaminated soils	"Greenfield" site Minimal contamination expected		"Greenfield" site Minimal contamination expected	
	Requires renegotiation of leasehold to reduce Guam Shipyard footprint	Land not encumbered		Land not encumbered	
Contiguous with backlands – allows more efficient operations		Contiguous with backlands – allows more efficient operations			Non-contiguous with backlands – less efficient operations
NAVIGATION, DREDGING and CORAL IMPACTS					
	Port pilots least preferred alignment	Alignment preferred by port pilots	Alt 2A berth has reduced with (440 feet vs 600 feet) at CVN bow		
	Restricts access to drydock AFDB-8 when CVN at berth				
Least dredging overall	Contaminated dredged material, if encountered, may require special handling		Alt. 2 most dredging. Alt 2A reduces dredging by 24% of Alt. 2.	Less dredging than Alt. 2	More dredging than Alt 1
Least direct impact to coral (least mitigation cost)	Closest to Big Blue coral reef	Alt 2A reduces coral impact (lower mitigation cost) vs. Alt 2 and Alt.3.	Alt 2: Highest estimated coral area impacted (mitigation costs). Alt 2A: Saves North Point and reduces estimated mitigation costs vs. Alt 2	Less coral impact (mitigation costs) than Alt 2 or Alt 2A	Higher estimated coral mitigation costs than Alt 1. Dredging removes end of North Point and associated coral

Table ES-5 Summary of Pros & Cons for the Alternatives

Alternative 1 - Former SRF Facility		Alternative 2 - Polaris Point Parallel to Shore Alternative 2A (Reduced Impact)		Alternative 3 - Polaris Point Diagonal Offshore	
Pros	**Cons**	**Pros**	**Cons**	**Pros**	**Cons**
STRUCTURAL and COASTAL CONSIDERATIONS					
Typical pile supported wharf construction		Typical pile supported wharf construction			Unique and more costly structural system
Suitable for both piles supported deck & sheet pile bulkhead	Caissons would be problematic given the extra dredging needed	Suitable for both piles supported deck & sheet pile bulkhead	Caissons would be problematic given the extra dredging needed	Suitable for both piles supported deck & caisson	Steel sheet piles bulkhead not advised
Slightly less exposed than the Polaris Pt. sites to extreme waves			Slightly more exposed than the SRF site to extreme waves		More exposed than the other sites to extreme waves
UTILITIES					
Existing Steam Plant is under the control of Base Operation Support Contractor (BOSC) for the Government. Possible use of existing steam system.	Existing air system is under control of Guam Shipyard. Assume new system is required. Existing steam system requires repairs and capacity expansion.		Requires construction of new plant for steam & air		Same as Alt. 2
Lower project cost for wastewater systems.	More pump stations than other Alt.s will result in higher life cycle costs and additional operational requirements.	Proposed wastewater system improvements will increase the capacity and improve the reliability of the existing infrastructure which will benefit other facilities in Polaris Point and neighboring areas.	Part of force main route outside Navy property. Uncertain how this might impact project	Same as Alt. 2	Same as Alt. 2
			Higher project costs for wastewater system due to length of forced mains required		Same as Alt. 2
	Higher project cost for electrical power service	Lower project cost for electrical power service		Same as Alt. 2	
	Higher project cost for communications	Lower project cost for communications		Same as Alt. 2	

Conclusions and Recommendations

There are advantages and disadvantages to locating the CVN berth at the former SRF site or at the Polaris Point site. One common conclusion is the pile supported marginal wharf (Alternatives 1 and 2) is the preferred structural system. The diagonal pier at Polaris Point is the least preferred alternative because of seismic considerations, inconvenient berth access, high structural costs, exposure to extreme wave events, and direct dredging impact to the northern tip of Polaris Point.

Alternative 2 is not a preferred alternative because of the greater direct impacts to coral compared to Alternative 2a. Alternative 2A and Alternative 1 can be viewed as comparable. The primary differences, from the engineering perspective, are:

- Electrical Power Costs, which are higher at the former SRF site
- Dredging Costs, which are higher at the Polaris Point site
- Wastewater Costs, which are higher at the Polaris Point site

The results of this engineering investigation indicate that Alternative 1 - Former SRF, is the lowest cost alternative. This is primarily due to the differences in dredging volumes and the estimated coral mitigation costs.

A sediment sampling and analysis plan will be completed as a requirement to obtain a dredging permit. Soil contamination, if present, will be discovered during this process. If the soils are found to be contaminated, project costs may have to be adjusted.

Ultimately, final site selection will be influenced by multiple factors, many of which are outside the scope of this study. Examples are: CVN repair/maintenance. on and off-base traffic, sailor "Quality of Life," AT/FP, safety and drydock access.

Recommendations:

Because impact to coral is a factor in site selection, the coral reef stakeholders (agencies) were asked to review the project footprints and propose a rough estimate of monetary cost per square foot of direct impact to coral. The coral mitigation costs presented reflect stakeholder "worst case scenario" input of $430 per square meter of impact. It is recommended that agencies and the Navy continue to work together to reduce the worst case cost scenario.

Recommendation for Additional Studies:

Additional studies and investigations are required to complete the final design. Other studies could be conducted to provide alternatives to the proposed concepts of this study. The studies are described below:

- A site specific CVN Dredge Depth Study will be required to be performed by NAVFAC LANT CIENG/NSWCCD and coordinated with NAVSEA 08, AIRPAC, and Program Executive Officer for Aircraft Carriers.
- Complete a localized geotechnical investigation at the selected site for purposes of finalizing pile lengths and determining subsurface conditions in preparation for final design.

- Prepare a dredge material disposal study to compare various options for beneficial reuse of the materials (including that already identified in this project), identifying possible users or uses on other projects, in order to minimize ocean disposal. Study should also consider methods of uplands disposal of contaminated but non-hazardous materials, possibly by incorporating such materials into the project.
- Complete additional detailed and calibrated coastal engineering studies, including: a) deployment of instrument at the site to monitor actual conditions for calibrating numerical models; b) dynamic berthing analysis for operating conditions; c) final determination of wave heights, run-up, and impact for pile-supported structures.
- For Alternative 1, complete a site-specific hazardous materials subsurface investigation immediately on and off-shore in the vicinity of the proposed wharf. This may be combined with the sediment sampling plan required to obtain dredging permits.
- For Alternative 1, as may be required, complete an evaluation of the benefits and costs of rotating the AFDB-8 one hundred eighty degrees so that access to the dock is from the west. This will mitigate any concerns that this site negatively impacts the operator of the dry dock or has security concerns.
- Prepare a report detailing the criteria, requirements, and configuration of the Electronic Harbor Security Systems (EHSS) for the selected site, including integration of such system into current and future port-wide security systems.
- During final design stages, complete periodic reports that 1) refine and update the project schedule, 2) identify logistic concerns, and 3) identify critical resource usage of this project against the background of all other projects expected to proceed forward.

Other studies that could be of benefit include:

- Additional evaluation of innovative structural concepts, like floating piers.
- Performance-based interpretation of CVN berthing requirements.

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1.0 INTRODUCTION

1.1 Background

Apra Harbor currently supports an average of 1-2 Carrier Strike Group (CSG) port visits per year. Carrier Vessel Nuclear (CVN) vessels have historically berthed at Kilo Wharf because it is the only wharf that meets CVN draft requirements of -50 feet Mean Lower Low Water (MLLW).

There are four major drawbacks to continued use of Kilo Wharf for future CVN visits to Guam. First, Kilo Wharf presently lacks full “hotel” utilities services necessary to support a CVN vessel if the onboard engineering plant is not fully operating. Second, Kilo Wharf does not have the required length to properly berth the CVN. Third, wind and wave conditions at Kilo Wharf during various times of the year (particularly October) limit the operations at the berth. In a study for the expansion of Kilo Wharf, HPA concluded that wind and short and long period waves control the overall berth availability. The total estimated downtime was determined to be 15.2% annually and 28.6% in October. Fourth, and most importantly, Kilo Wharf is the only dedicated ordnance wharf in the Western Pacific Region. The wharf ordnance operations demand are projected to increase, resulting from programmed Navy and Air Force buildup and Marines’ relocation. Current demand for ordnance operations at Kilo Wharf is 55 ordnance ship visits of 4-5 day duration per year. For as many as 90 days of the year, Kilo Wharf is not available due to weather or maintenance activities. Kilo Wharf is operating at capacity and past CVN visits were disruptive to ordnance operations. Therefore, a new CVN capable wharf at Apra Harbor is essential to ensure uninterrupted Department of Defense ordnance operations and to minimize other logistic impacts that result from CVN visits.

Commander Pacific Fleet wishes to conduct operations that will bring a CVN 68, and later CVN 78, to Guam. The planning scenario is three 21-day CVN visits per year. The mission and thus the design criteria are unique, as neither the CVN Homeport configuration nor the Port of Call configuration exactly matches the needs of the 21-day visit, as described in *ITG Facilities Homeporting Criteria for Nimitz Class Aircraft Carriers, 3 November 1998*. This study therefore breaks new ground in developing criteria for the project.

1.2 Purpose and Objectives

The Purpose of the CVN Capable Berthing Study is to define and estimate costs for the infrastructure required to permit the berthing of CVN class vessels at Apra Harbor, Guam. The study evaluated the requirements for dredging, wharf/pier construction, full utilities requirements to support the CVN 68 and CVN 78 class vessels, and additional support infrastructure for backlands operations and security.

Previous studies had identified three possible site locations and multiple configurations at each site. Further refinement led to the two sites and three alignments selected for this study. These sites/alignments are identified as follows:

- Alternative 1 - Former Ship Repair Facility (SRF)
- Alternative 2 - Polaris Point Parallel to Shore
- Alternative 3 - Polaris Point Diagonal Offshore

This report provides preliminary engineering analyses, project descriptions, descriptions of pros and cons for each site, and cost estimates that may help facilitate a decision regarding a preferred site for the CVN berth.

Figure 1-1 provides an overview of the three alternatives and the proposed 600 foot wide entrance fairway and turning basin.

1.3 Description of Alternatives

Drawings, images from three-dimensional (3D) models, and 3D animations of the facilities for the alternatives are included at the end of this report.

Alternative 1 - Former SRF. This site is located at the northern shore of the former Ship Repair Facility, currently under leasehold to the Guam Economic Development and Commerce Authority (GEDCA) and operated by the Guam Shipyard.

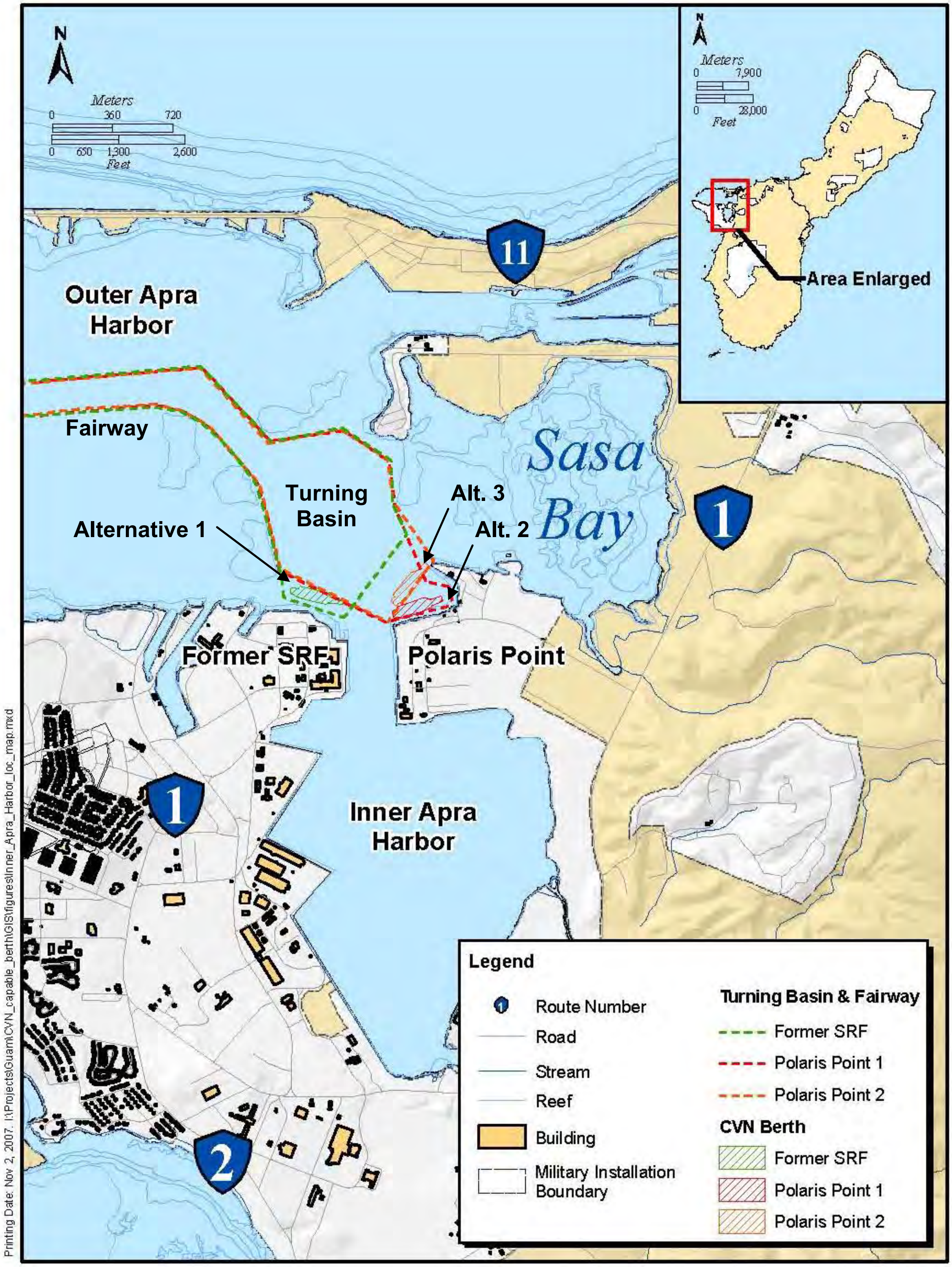
The selected alignment follows the current shore line as it extends from the end of the finger pier at Lima Wharf in a northwesterly direction toward the current location of the floating dry dock AFDB-8. For purposes of this study, the berth face runs approximately along the EL –50 feet MLLW contour. This alignment results in a temporary access impediment to AFDB-8 only when the CVN is at berth. The wharf structure clears the channel allowing ships to navigate safely along the dry dock entrance channel when the CVN is not berthed.

Alternative 2 - Polaris Point Parallel to Shore. This site is located at the northern shore of Polaris Point. The location (east and west) is set to minimize the impact to navigation along the channel leading into the inner harbor. The berth is located (north and south) to run approximately along the EL –50 feet MLLW contour to minimize the dredging at Polaris Point.

There are two dredging alternatives for the Polaris Point Parallel to Shore alignment. The first alignment, Alternative 2 sets the berth width at 600 feet as interpreted from the defined “slip width” in *ITG Facilities Homeporting Criteria for Nimitz Class Aircraft Carriers, 3 November 1998.* The north point must be removed in this alternative, as shown in the figures. A “reduced impact”, Alternative 2A, is proposed whereby the berth width is slightly less than 600 feet inside the bay, near the bow of the CVN, and the dredged area follows the existing contours of the northern point.

Alternative 3 - Polaris Point Diagonal Offshore. This site is also located at the northern shore of Polaris Point. The pier spans across the existing bay, and is located so the abutments are onshore at each end.

Figure 1-1 Location Map



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2.0 GENERAL CONSIDERATIONS AND CRITERIA

2.1 CVN Capable Berth Criteria Summary

CVN class 68 and 78 vessels have been evaluated in this assessment based on guidance provided by NAVFAC Pacific and applicable Unified Facilities Criteria (UFC) documents. Vessel characteristics are summarized in Table 2.1-1. Site specific information was obtained through a field visit conducted from 01 October 2007 through 05 October 2007 and discussions with personnel from NAVFAC Marianas, NAVFAC Pacific, Base personnel, and various contractors with experience in Guam. This information forms the basis of engineering analysis and cost estimates presented in this preliminary report.

Table 2.1-1 Vessel Characteristics

Vessel Characteristic	CVN 68	CVN 78
LOA	1,123 ft	1,092 ft
Length at waterline	1,040 ft	1,040 ft
Beam, with removable appurtenances	280 ft	280 ft
Beam, without appurtenances	256 ft	256 ft
Beam at waterline	134 ft	134 ft
Draft, max	40.8 ft	40.8 ft
Displacement	104,200 LT	104,400 LT
Height at light load (air draft)	215 ft	215 ft

Table 2.1-2 provides a summary of project criteria used for preliminary design and cost estimating the critical elements for the CVN Capable berth. Additionally, a full list of reference documents used to produce this study is provided in Chapter 10, References. This chapter provides detailed information regarding the general considerations and describes the application of CVN Berth criteria used for this study.

2.2 Navigation Channel and Turning Basin Geometry

The navigation analysis effort looked at three alternative channel alignments and their impact to navigation and existing coral. Two alignments (Option 2 and Option 3, Figures N-5 and N-6) set out to improve the navigation by eliminating the tight angle bend around Western Shoals. Option 1 (Figure N-4) follows the current fairway alignment, widening it to the required 600 ft. Options 2 and 3 provide operational benefits by allowing for unassisted CVN transiting to and from the turning basin. These options, however, required dredging through the coral shoals, significantly increasing the dredging volume and direct impact (removal) on the coral. These options have therefore have been discarded from further analysis. All of the turning basin and berthing options are thus based upon channel alignment Option 1. Both the CVN 68 and CVN 78 require a constant minimum depth of -49.5 feet MLLW throughout the channel and the turning basins. Minimum channel width was determined to be 600 feet while the minimum turning basin radius is 1,200 feet.

Tug assistance at all times is assumed. No provisions are available for emergency exiting of the harbor without tug assistance.

Table 2.1-2
Summary of Project Criteria for CVN-Capable Berth

System	Criteria	Requirement		Source	Notes
		CVN 68	CVN 78		
Navigation / Dredging	Channel / Fairway Width	600 ft.	600 ft.	ITG - Facilities Homeporting Criteria for Nimitz Class Aricraft Carriers (3 NOV 98), Section 2-2.g.	
	Channel Bend	2,000 ft. - 10,920 ft. radius	2,000 ft. - 10,920 ft. radius	Unified Facilities Criteria (UFC 4-150-06) Military Harbors and Coastal Facilities, section 5-6.2.2.2.	The UFC stipulates a minimum radius of bend of 1,200 ft-2,000 ft with tug assistance, but based on the vessel size and the angle of deflection (54 degrees) the recommended radius is 10 times LOA of the vessel, for 10,920 ft for the CVN class.
	Turning Basin	minimum radius .75 times Length Overall (LOA), optimal radius 2 times LOA	minimum radius .75 times LOA, optimal radius 2 times LOA	Unified Facilities Criteria (UFC 4-150-06) Military Harbors and Coastal Facilities, section 5-6.2.4.2. Interim Technical Guidance (ITG) - Facilities Homeporting Criteria for Nimitz Class Aricraft Carriers (3 NOV 98), Section 2-2.f. Unified Facilities Criteria (UFC 4-159-02) Engineering and Design of Military Ports section 3-6.c.	
	Berthing Area Width and Length	Width:600 ft * Length:1,325 ft	None provided Assume same as for CVN 68	ITG - Facilities Homeporting Criteria for Nimitz Class Aricraft Carriers (3 NOV 98), Section 2-3.a.	* 600 ft width applies to 'slip width'. 800 ft slip width with CVN on opp. berth. (240 ft clearance between). Actual 'berth width' not defined.
	Dredge Depth	-49.5 ft. at MLLW	-49.5 ft. at MLLW	ITG - Facilities Homeporting Criteria for Nimitz Class Aricraft Carriers (3 NOV 98), Section 2-3.b. Facilities Planning Criteria for the CVN 78 Class (PMS 378 Rev July 2007) Section 3.2.1. Interim Technical Guidance (ITG) CVN Dredge Depth Criteria (06 MAR 07)	
Structural	Wharf Width	90 ft.	90 ft.	Interim Technical Guidance (ITG) - Facilities Homeporting Criteria for Nimitz Class Aricraft Carriers (3 NOV 98), Section 4-1.a.	The wharf is not used for maintenance which would requre a wider wharf. Vessels are not berthed on both sides.

Table 2.1-2
Summary of Project Criteria for CVN-Capable Berth

System	Criteria	Requirement		Source	Notes
		CVN 68	CVN 78		
Structural (con't)	Wharf Length	1,325 ft.	1,292 ft.	ITG - Facilities Homeporting Criteria for Nimitz Class Aricraft Carriers (3 NOV 98), Section 2-3.c. Facilities Planning Criteria for the CVN 78 Class (PMS 378 Rev July 2007)	Total wharf length for Alternative 3 is 1545 ft; required by site topography and the need to provide on-shore abutments to resist seismic and berthing loads. The length would be the same for the CVN 68 or CVN 78.
	Wharf Deck Height	Elev +12 ft.	Elev +12 ft.	ITG - Facilities Homeporting Criteria for Nimitz Class Aricraft Carriers (3 NOV 98), Section 4-2.b.	The significant wave height and final deck elevation need to be confirmed.
	Pier Strength	Live Load = 800 psf min.		As above, Section 4-3.a.	
	Mobile Crane Load	2 - 140 ton mobile cranes		As above, Section 4-3.b.	
	Bollards	100 ton, 100 ft spacing	100 ton, 100 ft spacing	As above, Section 4-3.d.	
	Storm Bollards	4 - 200 ton bollards at each end of wharf	4 - 200 ton bollards at each end of wharf	As above, Section 4-3.d.	Location must be back from the face of wharf beyond 90 ft. Since lateral soil strength is not yet determined, wharf deck is extended to support these bollards. Final design may allow these to be on shore for Alternatives 1 and 2 only.
Supporting Facilities	Security Measures	Electronic Harbor Surveillance System		OPNAVINST 5530.14D, Appendix VIII - Waterside and Waterfront Security Draft UFC 4-025-01 Security Engineering: Waterfront Security UFC 4-021-02NF Security Engineering: Electronic Security Systems	Minimum requirements include electronic water/waterside security system (CCTV, associated alarms, surface craft or swimmer detection, and underwater detection). Local components of EHSS require integration into the base-wide ESS
		Perimenter Fencing		UFC 4-025-01 DRAFT Waterfront Security Design (24 July 05)	Concrete barriers with fencing on top of barriers
	Laydown Area	5 Acres (+/-)		IITG - Facilities Homeporting Criteria for Nimitz Class Aricraft Carriers (3 NOV 98), Section 4-4.c.	Laydown area for temporary visits not defined; however, area is fully utilized for buildings, transit shed, equipment, etc.
	Port Operations Building	10,000 sf Storage Shed		COMNAVMAR	Provide bathroom only - office not required in buildiing.

Table 2.1-2
Summary of Project Criteria for CVN-Capable Berth

System	Criteria	Requirement		Source	Notes
		CVN 68	CVN 78		
MWR Services	Open Pad Area	8500 sf - 12,000 sf		Interviews with NAVBASE Guam MWR personnel and guidance from NAVFAC	
	Road/Parking Improvements	Bus staging, parking, etc.		As above	
	Electrical Service	208V 3-Phase Recept. Bank		As above	
Bilge Oily Waste	Peak Quantity	80,000 gpd	82,000 gpd	Per Table C-5 in UFC 4-150-02 for CVN 68 to 77 and FPC for the CVN 78 Class (Review Draft, REV 1, July 2007).	
	Average Quantity	35,000 gpd	38,000 gpd	Per Table C-5 in UFC 4-150-02 for CVN 68 to 77 and FPC for the CVN 78 Class (Review Draft, REV 1, July 2007).	
	Design Rate	90 gpm	90 - 180 gpm*	Per Table C-5 in UFC 4-150-02 for CVN 68 to 77, FPC for the CVN 78 Class (Review Draft, REV 1, July 2007 & Guidance provided in "CVN 68 UTILITY RQMTS with CVN 78 NOTES FOR GUAM 21 Aug 07" document.	* Clarification provided from the Program Executive Officer for Aircraft Carriers (PEO CARRIERS) per email dated 24Sept07. The CONOPS for the CVN 78 is to use only one pump, limiting the output to 90 gpm.
Wastewater	Average Daily Flow	550,000 gpd	550,000 gpd	Per UFC 3-240-2N, using 100 gpcd and 5,000 personnel for both CVN 68 and 78 plus additional 10% for escort ships accompanying the CVN during the 21-day visit.	Based on information provided in Setiadi/Belt Collins report 28Sept2006, rev 21Jan2007.
	Design Rate	4 pumps at 400 gpm each*	Fwd, stbd side: 250 gpm Aft, stbd side: 500 gpm**	*Per Guidance provided in "CVN 68 UTILITY RQMTS with CVN 78 NOTES FOR GUAM 21 Aug 07" document, assume 3 CHT pumps operating at 400 gpm each (design for 1,200 gpm).	**Per notes provided on "CVN 68 UTILITY RQMTS with CVN 78 NOTES FOR GUAM 21 Aug 07" document - Recommend providing CHT requirements for CVN 68, which has a larger output of 1,200 gpm.
Potable Water	Average Demand	185,000 gpd	235,000 gpd	Per Table C-4 in UFC 4-150-02 for CVN 68 (with Air Wing or Troops Aboard) & Guidance provided in "CVN 68 UTILITY RQMTS with CVN 78 NOTES FOR GUAM 21 Aug 07" document.	Per notes provided on "CVN 68 UTILITY RQMTS with CVN 78 NOTES FOR GUAM 21 Aug 07" document - Recommend providing water demands for CVN 78.
		18,500 gpd*	23,500 gpd*	*Assuming 10% for escort ships accompanying the CVN during the 21-day visit.	*CVN escort ships' water demand.

Table 2.1-2

Summary of Project Criteria for CVN-Capable Berth

System	Criteria	Requirement		Source	Notes
		CVN 68	CVN 78		
Potable Water (con't)	Design Rate	1,000 gpm	1,000 gpm	Based on UFC 4-150-02 for Active Berthing for all berth lengths up to 2,000 feet, plus 500 gpm for each additional 2,000 ft.	
	Minimum Pressure	40 psi	40 psi	Based on UFC 4-150-02 for Active Berthing. Minimum pressure required at the most remote outlet on the pier, downstream of a backflow preventer.	
Steam	Constant	7500 lb/h*	Not req'd	Table 1 MIL-HDBK 1025/2; Table B-1 UFC 2150-02, CVN -78 FPC July, 2007	*Includes 50% for Air Wing on board
	Intermittent	7200 lb/h	Not req'd	Table 1 MIL-HDBK 1025/2; Table B-1 UFC 2150-02, CVN -78 FPC July, 2007	Use 70F outside design temperature.
Compressed Air	Design Rate	2400 scfm	Not req'd	Table B-2 UFC 2150-02; Table 5, MIL-HDBK 1025/2, CVN -78 FPC July, 2007	
Pure Water	Peak Rate	150 gpm	100 gpm	"CVN 68 Utility Requirements with CVN 78 notes for Guam 21 August, 2007 document.	
	Design Rate	20,000gal/day	20,000gal/day	"CVN 68 Utility Requirements with CVN 78 notes for Guam 21 August, 2007 document.	
Shore Power	Peak Demand	21 MW @ 4,160V	30 MW @ 13,800V*	Per Table C-7 in UFC 4-150-02 for Aircraft Carriers & Guidance provided in "CVN 68 UTILITY RQMTS with CVN 78 NOTES FOR GUAM 21 Aug 07" document.	*25 MW without Air Wing
Information Systems	Capacity	200 pr copper; 48-strand fiber optic cable; provision for CATV connection	*	Per Table C-8 in UFC 4-150-02 for CVN 68, Guidance provided in "CVN 68 UTILITY RQMTS with CVN 78 NOTES FOR GUAM 21 Aug 07" document, and based on NCTS discussions.	* None provided in UFC documents. Assume same as CVN 68.

The determination of the channel and turning basin geometry needed to support berthing of CVN 68 or CVN 78 class vessels at either the SRF or Polaris Point sites is based on guidance provided by various Navy criteria, input from the pilots operating in Apra Harbor, and physical constraints imposed in the Harbor (e.g., coral beds that must be protected). Table 2.1-2 summarizes the key guidance criteria used by the Navy in the design of military harbors, the recommendations provided in the feasibility study for CVN berthing at Apra Harbor, and recommendations for turning basin sizes for the four berthing options currently under consideration:

- *Interim Technical Guidance (ITG) – Facilities Homeporting Criteria for Nimitz Class Aircraft Carriers (12-12-01)*

  This ITG specifies the optimal turning basin to provide a 2,200 foot radius. A basin which provides a radius of 1,650 feet is identified as the absolute minimum, provided tug assistance is available.

- *Unified Facilities Criteria – Engineering and Design of Military Ports (1-18-04)*

  This UFC indicates that a vessel can normally be turned comfortably in a radius twice its length, which for a CVN 68/78 would correspond with a turning basin which provides a 2,148 foot radius. Where maneuverability is not important the basin may be reduced to a radius equal to the length of the vessel (1,092 feet). This may be further reduced, but the vessel must be turned around some fixed point, must utilize the ship's anchor and/or require tug assistance.

- *NAVFAC–Site Specific Report SSR-2983-SHR CVN Berthing Feasibility Study for Apra Harbor, Guam (2-05)*

  This report repeats the criteria from the 12-01 ITG for an optimal turning basin with a diameter of 4,400 feet (2,200 foot radius). It does however indicate that a minimum size of 1,648 feet is adequate (which is very close to the 1,650 foot minimum identified in the ITG) and the figures included in the report seems to illustrate this size turning basin. No discussion is provided; however, regarding operational assumptions or limitations associated with the less-than optimal turning basin.

2.2.1 Channel and Turning Basin Criteria

All three documents referenced above are consistent in the requirements for channel and berth widths; identifying the required inner channel width of 600 feet and a berth/slip width of 600 feet. The minimum berth length identified by the UFC is 1,325 feet.

The primary constraints on determining viable channel and turning basin geometry are the coral reefs and the existing shoreline. In developing the proposed navigation geometry, therefore, the minimum channel and berth/slip width was used and aligned to the extent possible with existing deep water (deeper than EL -50 feet MLLW) in the Harbor for each of the three proposed berth options. Alternative turning basins were then prepared utilizing three guidance criteria (2,200 foot radius optimal, 1,650 foot radius minimal and 1,092 foot radius minimal) to identify the potential impacts of each. Refer to Figures N-1 to N-3 to see these illustrated for each of the berthing alternatives being considered. The optimal 2,200 foot radius and the minimal 1,650 foot radius were both rejected for all options as these would involve significant upland excavation and demolition of landside facilities or complete removal of the sensitive coral reefs. The criteria of providing a basin with a radius equal to the ship's length will however fit within the harbor without significant loss of coral habitat, and in fact will completely avoid the four sensitive reefs. The recommended basin for each of the berthing options, however is somewhat larger based on an approximate best fit within the confines of the harbor, avoiding the coral reefs and expanding upon the 1,092 feet up to existing EL -50 feet MLLW bathymetric contours. This approach increases the size of the basin without incurring additional dredging. This size turning basin will require tug assistance, although the criticality of this is mitigated by the relatively small angle of rotation that the CVN will have to make in order to berth (starboard to) at the various berthing options being considered.

The recommended basins are as follows:

- Berthing Alternative 1 – 1,230 feet radius
- Berthing Alternative 2/2A – 1,230 feet radius
- Berthing Alternative 3 – 1,200 feet radius

2.2.2 Channel Bend Geometry Criteria

A channel bend will be required to transition from the first reach of the Inner Channel to the Turning Basin and then lead to the Berth. In order to avoid the four sensitive coral reefs and make best use of existing deep water in the harbor, the channel must make a bend of 54 degrees. This is a relatively large bend requiring a widening of the channel through the bend. The criteria used for designing channel bends depend upon:

- the angle of channel deflection,
- the speed and properties of he vessel using the channel,
- the characteristics of the channel,
- the visibility, obstructions, and aids to navigation in the vicinity of the bend, and
- human elements.

The general rules governing the determination of the radius of curvature for a channel bend are:

- minimum radius equal to 3,000 feet (914.4 meter [m]) for a ship under its own power, and
- radius equal to 1,200 feet to 2,000 feet (365.8 m to 609.6 m) for vessels with tug assistance.

The criteria for larger vessels and a channel bend of this degree would indicate a radius of 10,920 feet (3,328.4 m) for a CVN 68/78 Class vessel under its own power. Complying with these criteria would require complete removal of the Western Shoals and the adjacent reef bed, resulting in a complete loss of the sensitive coral habitat (Figure N-5). This alternative was therefore not carried forward.

Figure N-6 illustrates an alternative to the optimal radius bend; which will provide a straight channel leading directly into the turning basin. This alternative reduces the impact to the coral reefs, when compared to the optimal channel bend geometry shown in Figure N-5, and will allow CVN class vessels to transit the Inner Channel under their own power with no tug assistance outside of the turning basin and berthing areas. The potential loss of coral was significant and this alternative was dismissed from further investigation.

Using the less stringent criteria of a 2,000 foot radius bend (assuming tug assistance) would avoid the coral. This alternative is shown on Figure N-4. The usability of this relatively tight bend can be improved by the Pilot's use of the existing deep water north of the proposed channel as a turning flare that requires no dredging to construct. If it is determined this flare is needed, additional navigation aids may be required to designate this area.

2.2.3 Channel Depth Criteria

In March 1997 the Navy prepared an *ITG – CVN Dredge Depth Criteria (ITG 97)* which was intended to define depth criteria for Nimitz Class Aircraft Carriers. The ITG was a summary of the quantitative analysis that was performed in San Diego for determining dredge depths for several Military Construction Projects relating to CVN Homeporting. In November 1998 an *ITG – Facilities Homeporting Criteria for Nimitz Class Aircraft Carriers (ITG 98)* was prepared to further refine dredge depth requirements as well as to provide guidance for the planning and design of homeport facilities, including minimum channel, berth and turning basin width and depth requirements.

ITG 97 discussed 11 factors affecting water depth requirements and required dredge depths for Nimitz Class Aircraft Carriers transiting to and moored at homeports, ports of call, and shipyards. The ITG also provided specific criteria guidance for all but three of these factors that would be associated with operations at Apra Harbor. Specific criteria were provided for static draft (including mean static draft, trim and list), depth requirements to accommodate appendages, and the draft effect of salinity and temperature. Specific criteria were also provided for dynamic draft conditions created by squat and heel, but indicated the need for specific analysis of ship's motion in the Outer Channel resulting from wind and wave action. Standards were also promulgated for underkeel clearances.

Not addressed were the additional dredging depths that are a result of advance maintenance dredging and typical overdredge tolerances. Advance maintenance dredging is typically performed in areas that experience ongoing sedimentation and is intended to defer maintenance dredging for some predicted period of time. A review of past maintenance dredging frequency and periodic condition surveys indicates that sedimentation is not a serious concern in Apra Harbor. Therefore, advance maintenance dredging does not appear to be warranted. Overdredge tolerance can be affected by the choice of dredging equipment, but as a standard practice 2 feet is typically used for contracting.

Table 2.2-1 illustrates the analysis of water depth requirements as described in ITG 97 for Apra Harbor under either shipyard or homeport operations of a CVN class vessel.

Table 2.2-1 Summary of Dredge Depth Criteria

	Homeport Depths (feet)				Shipyard Depths (feet)			
	Berth	Turning Basin	Inner Channel	Outer Channel	Berth	Turning Basin	Inner Channel	Outer Channel
Draft	40.8	40.8	40.8	40.8	37.9	37.9	37.9	37.9
Trim	0.8	0.8	0.8	2.1	0.8	0.8	0.8	2.1
List	1.4	1.4	-	-	1.4	1.4	-	-
Appendages	-	-	-	-	-	-	-	-
Salinity & Temp.	-	-	-	-	-	-	-	-

Table 2.2-1 Summary of Dredge Depth Criteria

	Homeport Depths (feet)				Shipyard Depths (feet)			
	Berth	**Turning Basin**	**Inner Channel**	**Outer Channel**	**Berth**	**Turning Basin**	**Inner Channel**	**Outer Channel**
Motions / Component[2]	-	-	-	a	-	-	-	a
Squat	-	-	1.0	1.3	-	-	1.0	1.3
Heel	-	-	0.8	-	-	-	0.8	-
Clearance	6.0	6.0	6.0	2.0	6.0	6.0	6.0	2.0
Nominal Depth	49.0	49.0	49.4	46.2 + a	46.1	46.1	46.5	43.3 + a
Advanced Maintenance	0	0	0	0	0	0	0	0
Contract Depth	49.0	49.0	49.4	46.2 + a	46.1	46.1	46.5	43.3 + a
Overdredge	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0
Permitted Depth	51.0	51.0	51.4	48.2 + a	48.1	48.1	48.5	45.3 + a

All elevations indicated are provided relative to MLLW. The depths shown include Design Depth (also called nominal or project depth), Contract Depth (which includes advance maintenance but not overdredge tolerance), and Permitted Depth (which includes overdredge tolerance).

ITG 97, however defines minimum water depth requirements of 50.0 feet of water for Entrance Channels, -49.5 feet at MLLW, or -45.5 Extreme Low Water (ELW) (whichever is deeper) for Inner Channels, Turning Basins and Berths. ELW at Apra Harbor is equal to -1.6 feet MLLW, so that -45.5 feet ELW equals -47.1 feet MLLW. The minimum required depth for the channel, turning basin and berth area for this project is therefore -49.5 feet MLLW.

2.2.4 Berth Width Criteria

The criteria cited discusses the required berth width for CVN, defined as that distance perpendicular to the wharf face which is free from obstacles above the required dredged depth. The berth width and the berth length form a rectangle ("the dredge box"). In some cases the dredge box may be a lowered area in front of the berth face surrounded by higher sea bottom (typically called a "bathtub") to which there may be only one entrance. Other times the berth width may be determined by an adjacent berthing structure, in which case the berth width may be included in or defined by the slip width (physical distance between the two berth faces).

The berth/slip width for a CVN berth is set at 600 feet. An obstacle above the required dredged depth within the dredge box makes the berth non-compliant. Depending upon the extent and the location of the encroachment, safe berthing may or may not be possible. This issue is further discussed for Alternative 2, Polaris Point Parallel to Shore.

[2] Variable derived from coastal analysis but not germane to this study.

2.2.5 Recommendations

The -49.5 foot MLLW requirement presents the minimum depth requirement for the Inner Channel, Turning Basin, and Berths at Apra Harbor for CVN vessel calls. The existing water at the Entrance Channel is well in excess of -50 feet MLLW and no dredging is required there. An additional 2 feet for overdredge tolerance will be added for the evaluation of dredge quantities for regulatory (permit) purposes and for contracting flexibility. The estimated dredge volumes for each alternative with channel options are provided in Table 2.2-2.

Table 2.2-2 Estimated Dredge Volumes

	Dredge Volume (to EL -49.5 feet MLLW (CY)	2-Foot Overdredge Tolerance (CY)	Total (CY)
Former SRF (with Channel Option 1)	342,200	136,700	478,900
Former SRF (with Channel Option 2)	1,838,400	208,200	2,046,600
Former SRF (with Channel Option 3)	751,200	158,400	909,600
Polaris Point Parallel to Shore (with Channel Option 1)	803,700	189,500	993,200
Polaris Point Parallel to Shore - Reduced Impact (with Channel Option 1)	587,700	170,300	758,000
Polaris Point Diagonal Offshore (with Channel Option 1)	503,700	168,700	672,400

2.3 Aids To Navigation

In order to accommodate the widened channel, turning basin, and approaches to the three berthing alternatives, the existing aids to navigation will require modification. The primary Inner Harbor Channel (also termed the Fairway) for the Apra Outer Harbor is marked at the entrance with two lighted buoys designated as: “Fl G 4s” and “Fl R 4s.” The centerline of this channel is defined for navigation by the Entrance Range lights designated “QY” and “Iso Y 6s.” Because the proposed realignment and widening of this channel is not symmetrical with the current centerline, relocation of the Entrance Lighted Buoy “Fl R 4s” and both range lights “QY” and “Iso Y 6s” will be required.

The Approach Channel to the Inner Harbor is also proposed to be realigned and widened to transit CVNs from the Entrance to the proposed Turning Basin. The alignment of this channel is currently designated by range lights “Q R” and “Iso R 6s.” Additionally, the channel limits are marked with lighted buoys to warn pilots of the shoals that the channel passes between. To minimize the direct impact of dredging on these shoals, which have been identified as having significant coral resources, the Approach Channel is proposed to be realigned. This will require relocation of both range lights “Q R” and “Iso R 6s” to redefine the channel centerline. For the berthing alternatives at Polaris Point, the range lights will have to be raised to be seen above the deck of the berthed CVN (for other ships transiting the channel). The lighted buoys don’t appear to conflict with the proposed channel.

The proposed enlargement of the turning basin will also require relocation or removal of two other buoys. One is a mooring buoy located at the eastern edge of the proposed basin and the other is Lighted Buoy “9” just north of the mooring buoy.

Although the two Inner Harbor Channel realignment options have been discarded from further study, theoretically these options would also require changes be made to the navigation aids. These alternatives would require relocation or removal of the Dry Dock Point West Entrance Day Beacon “2”. Both options would also necessitate installation of lighted buoys to designate the remaining shoals following construction of the channel through the existing shoals.

Figure N-8 illustrates the buoys and range lights that will have to be relocated or removed. This figure uses Alternative 1 – Former SRF to illustrate the impact, but the aids to navigation that are affected are the same for each of the three alternatives being considered.

2.4 Dredging

Regardless of which alternative site and berth alignment is selected, dredging will be required in order to meet CVN capable berthing criteria.

Dredging in Apra Harbor is complicated by a number of factors, including but not limited to: (1) the current lack of an ocean disposal site; (2) the need to protect coral assets; (3) possible need to provide munitions and UXO screening prior to disposal; (4) possible sediment contamination; (5) long distance from the U.S.-based dredging fleet and the cost to mobilize a U.S.-hull dredge (Jones Act); and (6) possible use of dredged materials as fill on the project in lieu of imported barrow materials trucked-in from other areas on Guam. These factors are further discussed below.

Tradition methods of dredging in Apra Harbor include drag buckets, clam-shell buckets, and barge-mounted excavators. This equipment can be obtained locally in Guam. For larger projects, hydraulic suction dredging is more economical due to its greater productivity, providing there is sufficient quantity of dredging to cover the costs of mobilizing the equipment. The Jones Act requires all U.S. dredging (including Guam) to utilize U.S. hulls (top-side equipment can be foreign made). The closest available fleet is on the U.S. West Coast. Depending upon business conditions on the West Coast at the time of the project, this fleet may or may not be economically available.

For cost estimating purposes it is assumed dredging shall be accomplished using a closed bucket clamshell dredge, and upland disposal. This provides a suitable cost cushion in the event that ocean disposal is not available or permitted, and that due to economic conditions on the West Coast, mobilization to Guam is not cost effective. When estimating dredge quantities, an overdredge tolerance of 2 feet was assumed above required dredge depths, and advance maintenance dredging was assumed not to be necessary.

Advance maintenance dredging is typically performed in areas that experience ongoing sedimentation and is intended to defer maintenance dredging for some predicted period of time. A review of past maintenance dredging frequency and periodic condition surveys indicates that sedimentation is not a serious concern in Outer Apra Harbor. Therefore, advance maintenance dredging does not appear to be warranted. Overdredge tolerance can be affected by the choice of dredging equipment, but as a standard practice 2 feet is typically used for contracting.

2.4.1 Dredge Material Disposal

U.S. Environmental Protection Agency (USEPA) is proposing to designate an ocean disposal site for dredged materials that meet USEPA and Army Corps of Engineers testing criteria. The candidate locations are approximately 10 to 12 nautical miles west of Apra Harbor. While it is possible that the site will be designated in time for this project, the assumption for cost estimating purposes is upland placement, which represents a worst case cost scenario. In other U.S. locations, ocean disposal of dredged material a short distance off-shore is less expensive than upland placement. Beneficial use is another option and the cost would vary with proposed use.

Previous sediment testing in Apra Harbor has shown that the vast majority of the sediment would be suitable for ocean disposal (Sediment Characterization for Construction Dredging at Charlie, Sierra and SRF Wharves, Apra Harbor, Guam. Weston Solutions. August 2006). Limited testing was previously conducted in the vicinities of the wharf locations proposed by this study. No additional testing was done as part of this study. Laboratory analysis of the sediment will be completed to determine the disposal options in support of the Army Corps of Engineers permit application.

Historically, contaminated soils have been found adjacent to shipyard activities. However, results from initial sampling and analysis of potential dredged material near the former SRF site showed low site sediment contamination. Therefore, costs for hazardous waste handling and disposal, associated with highly contaminated dredged material, are not included in the cost estimates for dredging. Additional dredged material characterization may be done if the SRF site alternative is selected as the final wharf site.

2.4.2 Coral Impacts and Mitigation Costs

Every attempt was made to reduce potential dredging impacts to coral while still complying with published design criteria for CVN navigation. The selection of the “sharp bend” fairway option and proposing Alternative 2A, a reduced impact version of Alternative 2, are examples of proposing reducing coral loss. Where there was a choice, high quality coral (high in biodiversity and percent cover) was protected over low quality coral (low in biodiversity and percent coverage).

Dredging activities may adversely impact coral reefs in two ways: direct and indirect impacts. The direct impact of dredging is the physical removal of coral by dredging activities. Indirect impacts could occur from the resuspension of and deposition of marine sediments on coral during dredging activities. During the preparation of the CVN Environmental Impact Statement (EIS), wave and sediment transport analysis will be conducted to assess potential indirect impacts to coral.

BMPs, including deployment of silt curtains during construction, are proposed to avoid indirect coral impacts. This feasibility study relied primarily on the August 2007 marine survey: Ecological Assessment of Stony Corals and Associated Organisms, prepared for Naval Facilities Engineering Command Pacific (NAVFAC 2007). Quantitative estimates of coral cover, utilizing the Point Centered Quarter method were utilized to assess the area of potential dredging activities. After project footprints were proposed, it became apparent that an area outside of the August 2007 survey area in the vicinity of the fairway sharp bend would also be dredged. In this CVN capable berthing study, the shoal location is referred to as the fairway “elbow”. Towed video was used to qualitatively assess this site in (NAVFAC, November 2007, unpublished). Based upon the video coverage, the shoal is believed to support dense coral, with over 90% cover to a depth of -70 ft MLLW. With the assistance of the authors of the 2007 marine surveys, a conceptual qualitative map of coral coverage and biodiversity was prepared. The project dredging footprints were overlaid on this map.

The methodology used in this study for approximating the area of coral impacted and coral mitigation costs in this CVN study was as follows:

1. overlay the dredging footprint over the conceptual coral mapping;

2. calculate the area (square meters [m^2]) of coral removed by construction in four project areas: elbow, fairway, turning basin, and wharf construction area for each alternative.

   Conservative cost assumption for all alternatives: That the eastern edge of Big Blue Reef is lost due to indirect impacts. This is believed to be improbable if BMPs are properly employed. However, in the absence of more definitive information, it is one way to allow for the possibility of some indirect impacts. For this assumption, it was logical to choose the eastern edge of Big Blue Reef, since it is closest to the actual dredging footprint.

3. Estimate the amount of coral present. Multiply area impacted (m^2) by a percent of coral coverage, as recommended by author of the 2007 coral study:

   a. elbow: 90% coverage

   b. fairway: 16% coverage

   c. turning basin: 21% coverage

   d. wharf areas:

      i. Polaris Point = 13%

      ii. Former SRF = negligible (this area was described as having less than 0.25% coverage in the biological survey)

   e. east side of Big Blue Reef (indirect impact) = 21% coverage

4. Calculate the mitigation costs

On March 25, 2008, regulatory agencies were provided draft copies of this report, the coral maps with project footprints and the August 2007 marine survey. The Navy requested assistance in developing a unit mitigation cost per area of coral lost for budget programming purposes. This cost estimate was acknowledged to be a best guess based on available information. It would be proposed in advance of planned sediment analysis, marine surveys and final design drawings.

On April 18, 2008 the agencies (U.S. Fish and Wildlife Service, National Marine Fisheries Service, USEPA, and Guam Department of Agriculture) collectively responded and the emailed response is attached to this report as Appendix C. Based on recent Kilo Wharf Extension (P-502) negotiations, the agencies calculated a mitigation cost of $1,740,000 per acre of coral loss ($430 per m^2). The Kilo Wharf coral mitigation unit cost is variable, based on assumptions, and lower unit costs can be derived. For cost conservatism, the CVN cost estimates proposed in this report assume the $430 per m^2 unit cost.

The agency letter provides total cost estimates for Alternative 2 and 2A based on the assumption that the entire dredged area is covered in coral. These cost estimates were $108.36 million and $102.5 million for Alternatives 2 and 2A, respectively. The agencies acknowledged these are worst case scenarios that could be amended based on review of information that will be available in the future. The Navy's proposed mitigation costs for the four alternatives range from $19,566,075 to $23,068,000, which are considerably less than the worst case scenario. The Navy figures are based upon quantitative estimates of the actual percentage of the sea floor covered by coral. It should be noted, that most of the proposed project area is soft unconsolidated sediment which is not suitable for coral growth or recruitment (refer to *Ecological Assessment of Stony Corals and Associated Organisms, prepared for Naval Facilities Engineering Command Pacific* [NAVFAC 2007] for additional details on the coral surveys).

2.4.3 Ordnance Safety

Naval Ordnance Safety and Security Activity (NOSSA) Instruction (NOSSAINST) 2080.15A states that an Explosive Safety Submittal (ESS) may be required for construction dredging in areas known, or suspected, to contain Munitions of Explosive Concern (MEC). Based on current information and knowledge of site history, it is NOSSA's opinion that an ESS would not be required, at this time. Therefore, costs for ordnance screening of dredge materials are not included in the project cost estimate. A draft "Request for a NOSSA ESS Determination" is included as part of the DD1391 documentation and must be updated and submitted, during project design.

Summary of site history research findings:

- The Apra Harbor area did experience hostile activity during WWII.
- Inner Apra Harbor was dredged, 1944-1946. Historical ordnance disposal records contain no reports of ordnance found during dredging operations.
- Modern Explosive Ordnance Disposal records contain no reports of ordnance discovered in the project dredging areas.
- Current and historical ammunition wharves are Kilo and Hotel wharves, and neither is close to the project dredging areas.
- Extensive coral surveys have been conducted, and no ordnance has been sighted in the project dredging areas.
- Archaeological surveys have researched, visually identified, and inventoried sunken planes and ships in Apra Harbor. There are no known sunken ships or planes in the project dredging areas.

2.5 Staging Area, Buildings and Security

For staging area needs, the *ITG–Facilities Homeporting Criteria for Nimitz Class Aircraft Carriers (12-12-01)* suggests a minimum area for a CVN homeport location of 5 acres. No minimum requirements have been defined for a CVN 21-day port of call visit. Thus, the areas developed in this study are based upon reported needs by various users.

The following support buildings are required to support CVN operations (building sizes are approximate):

1. Port Operations Support Building (10,000 square feet storage shed with bathroom)
2. Air Compressor Building (1,162 square feet)
3. Water Treatment Building (1,216 square feet)
4. Boiler House (2,010 square feet)
5. 13,210 Gallon Fuel Tank [surrounded by berm] (968 square feet)
6. Electrical Substation (10,125 square feet)
7. BOW Pump Station (625 square feet)
8. Bilge Oily Waste Treatment System (BOWTS) – (5,000 square feet)

Buildings are essentially the same for all alternatives, only the specific location of each relative to the wharf varies. All buildings will be designed to the current Guam building code, modified by applicable UFC criteria. Buildings will be designed to criteria for typhoon winds, seismic event, ATFP, sustainability, and other issues in accordance with UFC 1-200-01. Foundations can be shallow if soil improvement methods are utilized to consolidate the fill materials and native soils beneath to preclude liquefaction. Otherwise, deep foundations will be required. Buildings will be all-concrete construction, with doors, windows, and other openings designed and detailed for high winds. Buildings have appropriate ATFP set-backs from the secured perimeter to resist attack.

It should be noted that none of the proposed buildings are considered occupied structures, and thus will not require radon mitigation measures. If future plans include occupied buildings to support the CVN Berth, such as constructing an office in the Port Operations Building, a passive radon mitigation system shall be incorporated into the building design.

Landside and waterside security requirements were established from *UFC 4-025-01 – (Draft) Waterfront Security Design (24-4-05).* The perimeters of staging areas are designed against vehicle intrusion with hardened security fencing (security fencing supported on concrete vehicle barriers). In areas inaccessible to vehicles such as rock revetments and beach shorelines, only security fencing is used to prevent pedestrian intrusion. The wharf access control point, via the staging area or directly from an approach ramp, will be at a guard booth controlling active vehicle barriers (hydraulic bollards and traffic spikes) for the inspection of vehicles.

Watch towers are required for the berth. Criteria require that they be at least 30 to 50 feet above the wharf, positioned to monitor the waterfront, spaced at approximately 1,000-foot intervals, and that they be hardened and secured by fencing. The towers will be sized to support 2 personnel with HVAC, water, sewage, telephone, fire alarm, security power circuits, etc, but designed to be operated by single person.

Floating port security barriers (PSB) are required to surround the CVN while it is at berth. The recommended minimum barrier standoff requirement is 250 feet from the CVN hull, comprised of 200 feet standoff for FPCONs ALPHA and BRAVO plus a boat penetration distance of 50 feet. In the event that FPCON CHARLIE and DELTA are declared, the PSB's will need to be relocated to the greater standoff distance, 200 feet beyond that of Alpha/Bravo. The locations are shown in Figures G-1, G-2, and G-3. This may cause significant interference with operations in adjacent areas. However, FPCON CHARLIE and DELTA are not expected to last an extensive length of time.

It is understood that Navy security boats will be positioned in Apra Harbor in a readied state less than two nautical miles from any of the alternative site locations for security response.

Observations and General Recommendations

The following observations and recommendations are applicable to both the SRF and Polaris Point sites.

The staging area for the CVN services are configured and sized to provide unimpeded access to the wharf, and a reasonable amount of area for operations, staging, and support. In addition, adequate areas to accommodate the various buildings listed in the previous section and associated parking are provided. The alternatives are laid out to reduce demolition of nearby buildings and roadways to a minimum.

As there is ample suitable fill material available from dredging, it is reasonable to save upland disposal costs by using the nearshore dredged material to construct the entire staging area to relatively the same elevation as the wharf. For Alternatives 1 & 2, the staging area will be sloped landward at 1%, the same as the wharf deck, providing for a consistent surface for forklifts or other moving equipment on and off the new asphalt concrete pavement. This eliminates the need to have ramp(s) up to the back edge of the wharf. For Alternative 3, the staging area is not contiguous with the wharf, thus ramps to the wharf deck are provided.

Another benefit to elevating the staging area pad is to protect the area from possible typhoon inundation and damage. For this reason each alternative layout shows varying amounts of armor rock protection at vulnerable locations to prevent erosion of the fill and damage to the pavement. Also the concrete cut-off wall at the back of the wharf has been extended and/or angled to retain some of the nearby fill material for the staging area.

Elevating the pad above the surrounding grade enhances security. The wharf and the staging area will have a level line of sight. The elevated pad will be surrounded by a 2:1 h:v slope with a hardened fence along the top. This will make incursions through the fence much more difficult. When possible, the watch towers are shown constructed on the pad near the back of the wharf. Per Draft UFC 4-025-01, two towers are warranted for the size of the facility. This increases their observation level while keeping them in a secure area. The locations shown on the figures are subject to final determination.

In each alternative, security is enhanced by a combined single entrance and exit ramp to the surrounding grade. Access to the facility is controlled by a guard building at the entrance and protected by hydraulic bollards and traffic spikes. Traffic queuing is afforded to various degrees in each alternative layout. Each layout is designed so that rejected vehicles can turn around without being boxed in from behind. This eliminates the possibility that a vehicle would have to drive past the check point and make a U-turn and leave. For additional protection, the entrance ramps are also situated a reasonable distance from the asset.

An enclave gate and concrete sidewalk along the entrance side of the ramp is also provided for pedestrians. Pedestrian access is controlled by the same guard booth as the vehicles.

OPNAVINST 5530.14D, Appendix VIII - Waterside and Waterfront Security, “Security of Waterfront Assets Matrix in U.S. Navy Controlled Ports” provides criteria for security for various classes of facilities including CVN. Minimum requirements include electronic water/waterside security system (Closed Circuit Television [CCTV], associated alarms, surface craft or swimmer detection, and underwater detection) along with the other physical security elements addressed above. Draft UFC 4-025-01 Security Engineering: Waterfront Security delineates electronic surveillance as Electronic Security Systems on the landside and Electronic Harbor Security

Systems (EHSS) on the waterside. An Electronic Security System is defined in Draft UFC 4-025-01 as the integrated electronic system that encompasses interior and exterior Intrusion Detection Systems, CCTV systems for assessment of alarm conditions, Automated Access Control Systems, Data Transmission Media, and alarm reporting systems for monitoring, control, and display. Criteria for Electronic Secutity Systems are found in UFC 4-021-02NF Security Engineering: Electronic Security Systems. EHSS is not similarly defined in Draft UFC 4-025-01, but can be reasonably assumed to include all of the above plus systems for detection of in-water and underwater threats. A specific UFC for EHSS is not known to exist. Current development of state-of-the-art systems is underway at SPAWARSYSCEN, San Diego. Local components of both systems require integration into the base-wide electronic security system. Included are both infrastructure and equipment costs. Infrastructure costs are included in this study while the procurement and installation of equipment should be funded by separate centrally-managed funding outside of MCON appropriation.

2.6 Steam, Compressed Air & Pure Water

Criteria

Saturated steam (150 psig) is used by CVN 68 class vessels to supply shipboard laundry and galley facilities, in addition to any supplementary heating requirements. The demand is that required by the berthed vessel crew complement with an embarked air wing. Criteria for tropical climate conditions were applied, in lieu of criteria for colder CONUS regions. Steam is not required for CVN 78.

A compressed air system is required for CVN 68 at all active berths. Under emergency conditions, the vessel compressed air system will be used to "top off" any compressed air demand. Typically, the vessel requirement for 125 psig compressed air should be at a minimum commercial quality. However, it is presumed that the air may also be used for breathing and thus shall meet the requirements of Class D breathing air as described by ANSI G-7.1-1989. Both the steam and compressed air requirements and conditions are defined by MIL-HDBK 1025/2, and UFC manual 2150-02.

The Grade A pure water is being provided to meet the ship's needs for active berthing.

The CVN 78 class carriers will require neither steam nor compressed air. The Grade A pure water requirements are as defined by ITG Facilities Planning Criteria Document for the CVN 78 Class (PMS 378, revision 1 dated July 2007).

Observations and General Recommendations

The mechanical utility systems include high pressure steam, medium pressure compressed air and Grade A pure water. These pipelines will be routed in a dedicated utility gallery parallel to the face of the wharf.

Facilities for steam and compressed air are currently located at dock-side Lima Wharves, which could be extended to a new CVN berth located at the former SRF site (Alternative 1). However, compressed air is currently under the control of the commercial contractor, Guam Ship Yard, and may or may not be available for Navy use. The steam utility is managed by the Base Operation Support Contractor, but is not in use (i.e., in dry layup). Correspondence with NAVFAC Marianas personnel indicates that there are a number of projects required to bring the facility back on line. These include: relocation of the boiler plant equipment from Kilo Wharf to replace one of the two existing boilers; repairs to the other remaining boiler system; and replacement of the current temporary metal building with a permanent concrete/masonry building meeting current typhoon and seismic resistance criteria. Even with the proposed projects the final capacity of the steam plant will be insufficient to meet both current demands and future CVN demand. In order to ensure availability, the costs for independent new system for SRF are included in this study. It may be possible to combine the two systems and provide a highly redundant configuration, or it may be possible to expand the current plant to provide additional capacity in conjunction with the proposed improvements. In either case, the costs for the combination of capacity increases along with repairs/modifications of the existing plant to meet current demand are considered to be essentially the same as the construction of a new facility at the CVN wharf site.

Steam, compressed air, and pure water utilities do not exist at Polaris Point. Thus, the systems must be constructed in their entirety.

The steam and compressed air will be generated locally at the wharf. The pure water will take potable water from the existing infrastructure and further treat it to Grade A quality at the wharf in a dedicated treatment facility. The supplied quantities are based on the berthing of either CVN 68 or CVN 78 class vessels with the greater requirements of the two classes determining the utility sizing.

The potential for providing steam, compressed air, and pure water using temporary, portable, generation systems was considered. This option was deemed impractical for the following reasons.

- Lack of locally available temporary equipment implies the Navy must purchase and store the portable versions of the permanent plants. No savings in capital costs is envisioned between portable and permanent, unless the portable equipment can be put to use elsewhere in the harbor when the CVN is not a berth. Portable equipment must be stored between use, thus requiring similar building areas to that of the permanent plant.
- In lieu of this, portable equipment could be leased and shipped to Guam for each visit. However, this increases costs and adds to the lead time for arranging for shipment to the facility. The availability and reliability of supply would be questionable and would require significant planning in anticipation of each visit which may not be practical based on the notification lead time for each visit.
- The operational costs would be more than permanent systems as there are additional costs in mobilizing the portable equipment to the site, setting up and tearing down, and maintenance costs for each visit. The level of operational personnel would be equivalent thus there is no savings in terms of labor.
- Extensive testing and commissioning would be required for the systems for each visit.

For these reasons this report is based on providing permanent systems.

2.7 Bilge Oily Waste (BOW) Systems

Criteria

The bilge is a storage compartment located at the bottom of the hull of a ship where water from various parts of the vessel is collected. Bilge water typically contains about 1% of oil and grease and some heavy metals and organic contaminants. Therefore, this waste water must be treated prior to discharge. Due to its composition, pre-treatment of bilge waste is necessary prior to discharge into a domestic wastewater treatment system.

Criteria for the quantity and design rate of BOW for various types of ships are provided in *UFC 4-150-02, Dockside Utilities for Ship Service*. Detailed design criteria regarding the collection, transport, and treatment of the bilge oily waste is provided in *UFC 4-832-01N, Design: Industrial and Oily Wastewater Control.* According to Table C-5 provided in Appendix C of UFC 4-150-02, the following shore service requirements for various classes of CVNs are required, as summarized in Table 2.7-1.

Table 2.7-1 Shore Services for Aircraft Carriers – Oily Waste/Waste Oil Discharge

Ship Symbol	Pump Station	Pump	Pump Rating (gpm)	Qpeak (gpd)	Qave (gpd)	Discharge Connection Location	Discharge Connection Size
CVN 65	1	1A	200	35,000	35,000	2 Connections @ Main Deck: Frame 146 Starboard; Frame 149 Port	2.5 inches
		1B	200				
CVN 68 to 71	1	1A	90	80,000	35,000	2 Connections @ Main Deck: Frame 128 (512 foot aft of FP) Port, Frame 170 (680 foot aft of FP) Starboard	2.5 inches
CVN 72 to 77	1	1A	90	80,000	35,000	3 Connections @ Main Deck: Frame 128 (512 foot aft of FP) Port, 2 each @ Frame 170 (680 foot aft of FP) Starboard	2.5 inches
		1B	90				

**Note: Shaded row presents criteria applicable to a CVN 68.*

For a CVN 68, the design bilge oily waste flow quantities for peak and average day are 80,000 gallons per day (gpd) and 35,000 gpd, respectively. The pumping rate is 90 gallons per minute (gpm).

No criteria are provided in the UFC documents for a CVN 78. Based on information provided in the review draft document of the Facilities Planning Criteria (FPC) for the CVN 78 Class, REV 1, July 2007, BOW generated from the CVN 78 will be comprised of a steady quantity of 8,000 gpd of oily water with an initial discharge of 52,000 gallons. Waste oil generated from the CVN 78 will total 30,000 gallons per offload occurrence. No discharge quantity of aircraft waste fuel or average and peak discharge rates were provided in the review draft FPC. Based on the available information in the FPC, the average discharge rate used for this analysis was calculated using the combined output of the steady discharge rate of 8,000 gpd plus one 30,000 gallon offload occurrence of waste oil per day; totaling 38,000 gpd. Similarly, the peak discharge rate used for this analysis was calculated using the combined output of the initial discharge of 52,000 gallons plus one 30,000 gallon offload occurrence of waste oil per day; totaling 82,000 gpd.

The review draft FPC for the CVN 78 indicated that the BOW pumping rate will range from 90 to 180 gpm. Clarification provided from the Program Executive Officer for Aircraft Carriers (PEO Carriers) indicated that the concept of operations for the CVN 78 is to operate only one pump at a time. Therefore, although this vessel is equipped with two 90 gpm pumps, the BOW output from the vessel will be limited to 90 gpm.

The design criteria for the BOW system for the CVN 68 and 78 are similar, with slightly higher average and peak discharge rates estimated for the CVN 78 of 38,000 gpd and 82,000 gpd, respectively. Since the pumping rate for both carrier types are the same and there is less than a 10% difference between their respective average and peak flow rates, construction phasing for the BOW system for the CVN 68 and the CVN 78 will not result in a significant economic benefit. For this reason, the analysis performed in the subsequent chapters will be based on providing the facilities required to accommodate the ultimate BOW requirements of the CVN 78.

Observations and General Recommendations

The following observations and recommendations are applicable to the SRF and Polaris Point sites.

There are two existing BOWTS located in the Apra Harbor Naval Complex. The first BOWTS was constructed in 1997 and is located at Victor Wharf. The design capacity of this system is 150 gpm and is equipped with a load equalization tank of 50,000 gallons. The second BOWTS was constructed at Polaris Point under MCON Project P-250 in 2005. This system was designed primarily to handle the BOW generated by submarines and the tender docked at Polaris Point. This system has a design capacity of 40 gpm and is equipped with a load equalization tank of 20,000 gallons.

Based on discussions with Port Operations, the BOWTS at Polaris Point has yet to be placed in operation. This facility has been idle for approximately 2 years due to construction deficiencies. Currently, the BOWTS at Victor Wharf is used to process all BOW generated by the ships berthed at Apra Harbor. A mobile BOWTS unit is available; however, this unit has an extremely low processing capacity and will not be able to handle the BOW requirements of a CVN.

There is currently no BOW collection system available to convey BOW to the BOWTS at Victor Wharf. BOW is collected from each ship using ship waste offloading barges (SWOB). Port Operations currently operates three SWOBs. The largest is a yard oiler Navy barge (YON) which was converted to a SWOB. The capacity of the YON is 350,000 gallons, while the two other SWOBs have a capacity of 70,000 gallons each.

Based on previous experience with carriers being berthed at Apra Harbor, extreme stress was placed on both the existing BOWTS at Victor Wharf and the SWOBs. Personnel at Port Operations highly recommend a new BOWTS and BOW collection system to be constructed for the CVN near the proximity of the berthing location.

2.8 Wastewater Systems

Criteria

Wastewater generated onboard a ship is collected in the ship's Collection-Holding-Transfer (CHT) system. This wastewater is primarily domestic in nature, but is typically more concentrated than typical domestic wastewater. When docked, waste collected in the CHT system must be discharged to a landside sanitary sewer system for treatment and disposal.

Criteria for the design discharge rate of the CHT systems for various types of ships are provided in *UFC 4-150-02, Dockside Utilities for Ship Service*. According to Table C-6 provided in Appendix C of UFC 4-150-02, the following shore service requirements for various classes of CVNs are required, as summarized in Table 2.8-1.

Table 2.8-1 Shore Services for Aircraft Carriers – Sanitary (CHT) Discharge

Ship Symbol	Pump Station	Pump	Pump Rating (gpm)	Discharge Connection Location	Discharge Connection Size
CVN 65	1	1A	400	6 Connections; 5 @ Main Deck; 1 @ 02 Level as follows: 67P (320 feet aft); 02-80S (348 feet aft); 97P (428 feet aft); 103S (452 feet aft); 162S (688 feet aft); 197P (828 feet aft)	4 inches
		1B	400		
	2	2A	400		
		2B	400		
	3	3A	400		
		3B	400		
	4	4A	400		
		4B	400		
	5	5A	400		
		5B	400		
	6	6A	400		
		6B	400		
	7	7A	400		
		7B	400		
CVN 68 to 71	1	1A	400	4 Connections @ Main Deck; located as follows: Frame 113-114 Port, Frame 126-127 Starboard, Frame 178-179 Port, Frame 183-184 Starboard	4 inches
		1B	400		
	2	2A	400		
		2B	400		
CVN 72 to 77	1	1A	400	4 Connections @ Main Deck; located as follows: Frame 113-114 Port, Frame 68-69 Starboard, Frame 183-184 Port, Frame 194-195 Starboard	4 inches
		1B	400		
	2	2A	400		
		2B	400		

**Note: Shaded row presents criteria applicable to a CVN 68.*

A CVN 68 is equipped with a total of four pumps, each with a capacity of 400 gpm. Clarification provided by NAVFAC Pacific, indicate that three CHT pumps may operate concurrently, resulting in a combined flow rate of 1,200 gpm.

No criteria are provided in the UFC documents for a CVN 78. Based on information provided in the review draft document of the Facilities Planning Criteria (FPC) for the CVN 78 Class, REV 1, July 2007, the forward starboard side of the CVN 78 is equipped with 250 gpm pumps and the aft starboard side is equipped with 500 gpm pumps. Since the pumping requirements for a CVN 68 are greater than the CVN 78, the flow rate of 1,200 gpm will be used for planning purposes per guidance provided by NAVFAC Pacific.

A significant increase in wastewater flows to the Apra Harbor Wastewater Treatment Plant (AHWWTP) is anticipated during the 21-day CVN visit. Criteria for the average daily flow quantities are provided in UFC 3-240-2N, Wastewater Treatment Systems, Augmenting Handbook. This report utilizes a CVN 68's complement of approximately 5,000, plus an additional 10% for the CVN's escort ships, for the analysis of the wastewater treatment system. The resulting estimated average daily flow to the plant will increase by 550,000 gpd. The CVN 78's complement and escort ships will be similar to that of the CVN 68.

Observations and General Recommendations

Based on the location selected for the CVN berthing, various gravity sewers, pump stations, and force mains will be impacted. A schematic of the existing wastewater system is shown on

Figure M-1. The following is a description of the portion of the wastewater collection system that will be impacted as a result of the CVN berthing location.

Former SRF Site Conditions

Wastewater generated at the former SRF site enters Sewage Pump Station (SPS) No. 18. SPS No. 18 pumps waste flows through a 6-inch force main to Trunkline “D” located along Sumay Drive. Trunkline “D” discharges into SPS No. 16. SPS No. 16 is a major pump station in the wastewater collection system, receiving flows from a majority of the Apra Harbor wharves and associated facilities. SPS No. 16 pumps waste flows through a 12-inch force main to Trunkline “A” located along Marine Drive. Trunkline “A” is the primary collection sewer which receives flow from almost all of the main base facilities prior to entering the AHWWTP.

Polaris Point Site Conditions

Wastewater generated at Polaris Point enters SPS No. 9. SPS No. 9 conveys this flow through approximately 13,500 linear feet of 8-inch force main to Trunkline “B”, near the intersection of Marine Drive and Bright Road. Trunkline “B” is the primary collection sewer which receives flow from the outlying areas and a small portion of the main base prior to entering the AHWWTP.

Previous Wastewater System Assessments

Previous studies performed by Setiadi/Belt Collins in 28 September 2006 (rev. 31 January 2007) and Parsons in April 2007 evaluated the condition and capacity of the existing wastewater system serving the Apra Harbor Naval Complex. Analyses performed in these studies assumed full wharf occupancy, restored housing assets, and the completion of future bachelor housing facilities. These previous wastewater system assessments also applied the loadings of a CVN carrier docked at Kilo Wharf and Delta/Echo wharves. Based on the existing wastewater system schematic illustrated on Figure M-1, a CVN carrier docked at Kilo Wharf will impact SPS No. 32, gravity sewers in the Lockwood Terrace and Sumay Housing area, and a portion of trunkline “A”. A CVN carrier docked at Delta/Echo wharves will impact the SPS at Delta/Echo wharves, SPS No. 9 at Polaris Point, the associated force mains, and trunkline “B” as indicated on Figure M-1. The results of these studies identified current deficiencies associated with various portions of the wastewater collection and treatment systems, initiating the development of projects P-262 and P-534.

Project P-262 is scheduled for Fiscal Year (FY) 2008 – 2009 and is currently undergoing a 60% design review process for the “Request-For-Proposal” document. The scope of P-262 includes increasing the capacity of SPS No. 16 from 0.54 MGD (375 gpm) to 1.0 MGD (695 gpm) to meet current flow conditions. The pump station will be designed such that it can be upgraded to accommodate a defined future flow. As flow increases due to future development, the capacity of SPS No. 16 and associated force main will be increased to 3.0 MGD (2,080 gpm). The future loading used to develop the ultimate design capacity of SPS No. 16 does not include the loading of a CVN vessel. Project P-262 also includes restoring the design average daily flow capacity of the AHWWTP to its original design capacity of 4.3 MGD.

Project P-534 is scheduled for FY 2009. The scope of P-534 includes various wastewater system improvements throughout the Apra Harbor Naval Complex. This project has undergone several scope changes. The most current rendition of the scope for this project includes the following improvements:

- Pump Station Replacement/Repair:
  - ***SPS No. 18***
  - SPS No. 22
  - SPS No. 10
  - SPS No. 7
- Force Main Replacement:
  - ***From SPS No. 18***
  - From SPS at Delta/Echo
- Gravity Sewer Replacement/Relief Sewers:
  - ***Trunkline "D" (between SPS No. 18 and 16, approximately 2,100 linear feet)***
  - From SPS No. 32 to AHWWTP, including ***portion of Trunkline "A"*** (approximately 7,600 linear feet)
  - ***Replace sewers in Guam Shipyard***
  - ***Portions of Trunkline "B"***
- Miscellaneous:
  - Victor Wharf Coast Guard CHT risers and force mains
  - SCADA work at AHWWTP

Although, some of the improvements proposed in P-534 include portions of the wastewater system that will be impacted by the CVN berthing (highlighted in bold italicized font in the list above), none of these improvements will be designed to provide additional capacity for the CVN berthing. Based on discussions with the design consultants for P-534, the intent of that project is to correct only the existing deficiencies in the wastewater system.

Based on the current schedules for P-262 and P-534, both projects should commence prior to the proposed CVN berthing. Neither scope of projects P-262 or P-534 includes additional capacity for the CVN berthing. Both are limited to correcting the existing deficiencies in the wastewater system. Therefore, the improvements proposed in this study are based on accommodating only the loadings of the CVN. All other deficiencies will be corrected under P-262 and P-534. Detailed descriptions of the proposed wastewater system improvements for the CVN berth at the former SRF site and the Polaris Point site are provided in Chapters 4 and 5, respectively.

<u>Apra Harbor Wastewater Treatment Plant (AHWWTP)</u>

All wastewater generated in the Apra Harbor Naval Complex and neighboring outlying naval areas are processed at the AHWWTP. Therefore, regardless of the location selected for the proposed CVN berthing, the total wastewater generated by the CVN will be processed at the AHWWTP. Project P-262 proposes to restore the design average daily flow capacity of the plant to 4.3 MGD. This project is scheduled for FY 2008 – 2009.

An infiltration/inflow (I/I) survey report prepared in February 2007 indicated high infiltration rates due to structural defects in the wastewater collection system. This results in increased loadings, especially during the wet weather season. Based on influent data collected at the AHWWTP between January 2001 and August 2007, flows ranged between 0.81 MGD to 8.78 MGD. A program to replace sewer lines recommended in the February 2007 I/I report will mitigate the infiltration problem, thus reducing the extraneous loadings to the AHWWTP. According to AHWWTP personnel, the current influent flow to the plant is typically 2.9 MGD during dry weather conditions.

Based on the improvements proposed in the I/I study and P-262, the average daily flow of 0.55 MGD from the CVN and its escort ships can be processed at the AHWWTP.

2.9 Potable Water

Criteria

According to *UFC 4-150-02, Dockside Utilities for Ship Service*, potable water should be provided for all berthing spaces. Regardless of the type of ship berthed, potable water must be supplied at a rate of 1,000 gpm for all berth lengths up to 2,000 feet, with a minimum residual pressure of 40 pounds per square inch (psi) downstream of a backflow preventer located at the most remote outlet on the pier. The wharf length for a CVN 68 is 1,325 feet and for a CVN 78 is 1,292 feet. Since both wharf lengths are less than 2,000 feet, a minimum flow rate of 1,000 gpm is necessary for both CVN 68 and CVN 78, as prescribed in UFC 4-150-02.

The flow rate requirement of 1,000 gpm at the berthing location will have a localized impact on the potable water distribution system, but will not likely have an effect on the treatment and storage facilities. However, the increase in the total daily water demand required for the CVN during the 21-day visit will impose a stress to the existing treatment and storage facilities. Criteria for the daily potable water demand for various types of ships are provided in UFC 4-150-02. According to Table C-4 provided in Appendix C of UFC 4-150-02, the following shore service requirements for various classes of CVNs are summarized in Table 2.9-1.

Table 2.9-1 Shore Services for Aircraft Carriers – Potable Water

Ship Symbol	Normal Requirement with Ships Complement (gpd)	Requirement with Air Wing or Troops Aboard (gpd)	Station Location (feet)	Station Height (feet)
CVN 65	100,000	140,000	105S, 148 PS, 220P	MAIN DECK
CVN 68	100,000	185,000	300S, 540S	36

**Note: Shaded row presents criteria applicable to a CVN 68.*

The potable water demand for a CVN 68 is 185,000 gpd. No criteria are provided in the UFC documents for a CVN 78. The potable water demand for a CVN 78 is 235,000, based on information provided in the review draft document of the Facilities Planning Criteria (FPC) for the CVN 78 Class, Rev. 1, July 2007. With an additional water demand of 10% required for the CVN's escort ships, the total potable water demand for a CVN 68 and CVN 78 are 203,500 gpd and 258,500 gpd, respectively.

Observations and General Recommendations

Potable water for the naval facilities located at the Apra Harbor Naval Complex, neighboring outlying areas, Naval Hospital, Nimitz Hill, and NCTAMS WESTPAC Barrigada is supplied by the Fena Water Treatment Plant (FWTP). Upgrades to the facility under P-256 have been completed, restoring the capacity of the plant to 13.5 MGD. Based on future navy water demands established in a utility system assessment of the potable water system dated January 2005, plus current water usage by the government of Guam areas, the average daily water demand is estimated as 11.3 MGD. The daily potable water requirements for a CVN 68 and

CVN 78 are 0.204 MGD and 0.256 MGD, respectively. Therefore, no improvements are necessary at the FWTP to accommodate the CVN water demands.

There are two main storage tanks supplying water the Apra Harbor Naval Complex and neighboring outlying areas. The Apra Heights Tank has a storage capacity of 5.0 million gallons (MG) and serves a majority of the Apra Harbor Naval Complex. The Tupo Tank also has a storage capacity of 5.0 MG and serves the outlying areas, including Polaris Point. Based on the location of the proposed CVN berthing, the storage capacity of one of these tanks will be impacted. This is discussed further in later chapters.

The adequacy of the transmission and distribution system piping network was determined using a computer water modeling program. The existing hydraulic model was developed by Engineering Concepts, Inc. in 2005. This model was updated to include recently completed and proposed improvements to the water system. The water system was evaluated based on its ability to supply 1,000 gpm at the berthing location with a minimum pressure of 40 psi. The results of the water model for each alternative site are presented in later chapters.

2.10 Power and Communications

Descriptions of the existing electrical power and communications systems serving the Apra Harbor Naval Complex were based on information presented in the various utility system studies conducted for the installation, information provided by NAVFAC Marianas utility system and NCTS (Navy Computer and Telecommunications Systems) Guam personnel. Key information on the electrical distribution system that will be in place by the time this project is slated for execution was obtained from RFP documents for FY08 MCON Project P-494*,* Harden Electrical System Main Base Distribution/Substation, U.S. Navy PWC/COMNAVMAR, Guam, M.I. Per guidance provided by NAVFAC Pacific Planning, projects programmed for and before the FY 2009 will be assumed to be completed and “existing” for this analysis. Projects programmed for FY 2010 and beyond will not be considered in this analysis. A discussion of each system follows.

2.10.1 Power Distribution System Background

The GIMDP Electrical Engineering Assessment Guam briefly covered supply of electrical power requirements for a CVN 68, but not a CVN 78. The assessment did not involve a full electrical system capacity analysis, particularly in consideration of the improvements planned to be implemented under FY08 MCON Project P-494. It made gross assumptions and addressed concepts for utilizing standby generation available at Orote Power Plant and at the GPA Piti Power Generating Station. There was no dialog with GPA to obtain costs for improvements that GPA would have to implement to accommodate the CVN berth. Rough Order of Magnitude estimates were given as follows:

- CVN at SRF: $78 million with backup generation from Piti, $82 million with backup generation from Orote
- CVN at Polaris: $59 million with backup generation from Piti, $65 million with backup generation from Orote

The Orote Power Plant contains three 6.6 Megawatt (MW) diesel engine generators totaling 19.8MW. It is not capable of supporting a single CVN 68 at full load. Additionally, its capacity is needed to support critical Main Base Loads during an extended outage such as the Apra Harbor Wastewater Treatment Plant, the NEX, Cold Storage Facilities and other critical base facilities.

The aforementioned GIMDP Study did not provide details on how electrical system improvements would be made to support the CVN. While it mentions backup generation, it does not address redundancy to maintain power to the CVN if there should be a feeder or transformer failure. The GIMDP study report appears to imply that the new GPA 34.5 kV feeder to either berth site would be dedicated to the berth and not integrated into the base electrical system.

During the team's data gathering visit to the island, there appeared to be strong interest in obtaining a power supply scheme to either berthing site that would provide for redundancy. Base personnel also indicated that it would be better if the new 34.5 kV feeder proposed to supply the CVN berth could be used to enhance the Main Base electrical system, particularly if the CVN berth is not in use for most of the year. Subsequent direction received indicates that it is not necessary to have redundant power feeds to the berth substation, but redundant transformers should be provided at the berth substation to maintain shore power service if a transformer fails.

Following receipt of the RFP documents for FY 2008 MCON Project P-494, the project team exchanged information with MK Engineers (the Prime Consultant for P-494), to develop a scheme that would meet the desired objectives. The objectives included power to the CVN berths with non-redundant feeders and redundant transformer capacity, and utilization of the new 34.5 kV GPA feeder to enhance the reliability of the Main Base distribution system.

The scheme developed for the former SRF berthing option includes a non-redundant feeder from SRF Substation to the SRF Berth Substation, redundant transformers, upgrade of two existing 34.5 kV feeders between Orote Substation and former SRF Substation, upgrade of the 34.5 kV X20 feeder from Piti 34.5 kV Switching Station to Orote Substation, and addition of a new 34.5 kV feeder from Piti 34.5 kV Switching Station to Orote Substation. The latter two tasks are necessary to maintain single contingency redundancy to the Main Base electrical system with the addition of the CVN loads.

The scheme developed for the Polaris Point berthing options include a new non-redundant 34.5 kV feeder from the Piti 34.5 kV Switching Station to the Polaris Point Berth Substation and redundant transformers. Since this feeder does not interconnect into the Main Base distribution system, it neither degrades, nor enhances the Main Base distribution system. In this scheme, while it is ultimately desirable to upgrade the 34.5 kV X20 feeder to achieve single contingency redundancy for the main base distribution system as other projects increase the Main Base power demand, it is not within the scope of this project to do so.

The resultant schemes are described in the electrical power system descriptions that follow.

2.10.2 Electrical Distribution System

Criteria

CVN 68 requires 21MW at 4,160V and the anticipated load for CVN 78 is 30MW at 13,800V.

The electrical base infrastructure required to support both the CVN 68 and CVN 78 is similar, with the exception that upgrading the electrical system to accommodate the CVN 78 will require two additional 13.8 kV switchgear sections with associated 15 kV feeder cables and power receptacles.

Observations and General Recommendations

The electrical distribution system on the Main Base will be undergoing major upgrades under FY 2008 MCON Project P-494. Three new substations will be constructed (Cold Storage Substation, Orote Substation and SRF Substation), and on-base 13.8 kV overhead lines will be converted to underground distribution systems to improve reliability and minimize susceptibility to typhoon damage. In addition, new 34.5 kV underground express feeder circuits will be constructed between the Orote Substation and the SRF Substation.

There are planned follow-on projects to P-494 which are presently identified as P-495 and P-496. P-495 is presently in the scope validation and DD1391 preparation phase. P-496 has yet to be programmed and scoped.

None of the three projects include the capacity to support a CVN berth at either site.

An inquiry made to GPA via NAVFAC Marianas confirmed that there is space for just one additional 34.5 kV feeder circuit breaker at their Piti 34.5 kV Switching Station that can be used to enhance the capacity of the Main Base electrical system or provide power for a CVN berth.

This evaluation is built upon the electrical distribution system and substations that will be in place following completion of *FY08 MCON Project P-494, Harden Electrical System Main Base Distribution/Substation.* There are three 34.5 kV overhead feeders supplying power to the Main Base electrical system. GPA Circuits X20 and X21 originate in the Piti 34.5 kV Switching Station and GPA Circuit X36 originates in the GPA Apra Substation. At present Circuits X21 and X36 consist of 927.2 kcmil AAAC conductors with a capacity of roughly 50 MVA. Circuit X20 utilizes #4/0 copper conductors and should be reconductored by GPA to 927.2 kcmil AAAC conductors to increase its capacity to match Circuits X21 and X36.

Details regarding the electrical distribution system for a CVN berth at the former SRF site are in Chapter 4, and Chapter 5 provides details for the Polaris Point site.

2.10.3 Communications System

Criteria

CVN 68 and CVN 78 require the same communications system interface, and the communications system base infrastructure required to support both the CVN 68 and CVN 78 is identical.

Observations and General Recommendations

Base communications system infrastructure consists of Central Office Building 3012 with Information Transfer Node (ITN) buildings located throughout the Base for area connectivity. In addition to the Base communications system needs, the existing communications system primary backbone infrastructure has capacity for 24 concurrent shipboard locations, including necessary fiber optic, telephony, and CATV requirements.

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3.0 STRUCTURAL CONSIDERATIONS

3.1 Coastal Environment and Operational Limitations

A brief coastal engineering study was performed to determine coastal conditions at the two sites (SRF and Polaris Point) during extreme weather events (typhoons). The purpose of the study was to determine survivability of particular conceptual designs, design parameters, and to a lesser extent define the operational environment. Danish Hydraulic Institute (DHI) MIKE-21 Spectral Wave module was used to model Apra Harbor. The model includes a new generation spectral wind-wave module based on unstructured meshes, and simulates the growth, decay and transformation of wind-generated waves and swells in offshore and coastal areas. This study relies upon and extends the work of two previous Apra Harbor studies (References):

- *Moffatt & Nichol (2007), Coastal Engineering Design Basis and Dynamic Ship Mooring Analysis, Final Report, FY08 MCON Project P-502, Kilo Wharf Extension, COMNAVMARIANAS, Main Base, Guam.*

- *Thompson, E. F. and Scheffner, N. W. (2002), Typhoon-induced Stage-Frequency and Overtopping Relationships for the Commercial Port Road, Territory of Guam. U.S. Army Corps of Engineers, Engineer Research and Development Center, Coastal and Hydraulics Laboratory Report, ERDC/CHL TR-02-01.*

Wave agitation in Apra Harbor under normal operational conditions does not appear to be a typical problem. The configuration of Apra Harbor further prevents large wind-waves from being generated within the confines of the Harbor during operational conditions.

Potentially hazardous wave conditions within Apra Harbor occur mainly during periods of strong westerly winds when swell passes through the west-facing Harbor Entrance.

Historically, the extreme winds on Guam have come from a single source - typhoons. The strongest wind gust experienced in recent history on the island is estimated to be about 200 mph during Typhoon Karen (November, 1962) and 170 mph during Typhoon Paka (December, 1997). Most storms are seen to move in from the east-southeast but exhibit wide dispersion after moving west of Guam. Storms that pass to the south of Guam typically bring higher winds than storms passing the same distance to the north.

3.1.1 Bathymetry

Three separate sources of bathymetry were used to construct a composite numerical model bathymetry used in the numerical simulations. Inside the harbor, detailed bathymetric soundings were available from a 2001 LIDAR survey as well as an updated multi-beam survey performed in 2005. For areas immediately offshore of the harbor, the bathymetry was supplemented by information from C-MAP and digitized NOAA nautical chart 81054.

The dry dock facility AFDB-8 to the west of the former SRF site was not included in the existing bathymetry. The potential relocation/re-orientation of the dry dock facility is under consideration and its current position can not be guaranteed. Simulations without the dry dock are considered to be conservative, as the presence of the dry dock will shelter the project sites to wave exposure from the westerly directions.

Due to the known effects of deep-draft navigation channels on wave propagation, the proposed channel and turning basin options were analyzed to look at any potential effects that could be felt at the project sites. Test simulations were conducted with these layout alternatives, and results indicate negligible changes at either project site, and therefore all simulations were conducted with the existing bathymetry.

3.1.2 Wave Analysis - General

Waves at the project site are from two sources. The first and primary source of wave energy is the typhoon-induced deep water waves that are transmitted through the harbor entrance. The second source of wave energy is locally generated wind-waves created inside the harbor by typhoon winds. For the typhoon-induced wave propagation simulations, each of the thirty events listed in Reference (a) were propagated through the harbor entrance, at the corresponding still water level (including surge and tide). No winds were included in the propagation simulations.

As a check, the results of the model were compared to those obtained in the two earlier studies (References a and b). The comparison was performed at a point south of Cabras Island, as that was the location of the USACE results (Ref b). There are some differences between the three sets of results, but the comparison is reasonable and provides confidence in the present model's ability in simulating the propagation of wave energy into the harbor[3].

3.1.3 Wave Analysis at the Sites, Immediately Off-shore

Results for both propagated and wind-generated waves, for all thirty typhoon events, were extracted at two locations representative of conditions and water depths immediately off-shore of the project sites. The SRF location was at water depth -73 feet MLLW and the Polaris Point location was at water depth -62 feet MLLW. There is little difference between the two locations for the larger wave heights. For the smaller wave heights, the SRF location in general shows slightly greater wave exposure. For all the events, the shallow shoal and reef areas immediately west of the site locations affords sheltering due to increased dissipation in incident wave energy as a result of bottom friction and wave breaking.

Extreme value analyses were performed for the total significant wave height series at both site locations. The return levels associated with return periods of 2, 5, 10, 25, 50 and 100 years are shown in Table 3.1-1 and Table 3.1-2.

Table 3.1-1 Extreme Values of Significant Wave Height at Former SRF Site

Return Period (Years)	**2**	**5**	**10**	**25**	**50**	**100**
Significant Wave Height (feet)	1.1	2.9	3.9	5.2	6.2	7.1

Table 3.1-2 Extreme Values of Significant Wave Height at Polaris Point Site

Return Period (Years)	**2**	**5**	**10**	**25**	**50**	**100**
Significant Wave Height (feet)	0.9	2.8	4.0	5.5	6.7	7.7

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[3] The present model (as well as those used in the previous studies) is completely un-calibrated, and only default recommended parameters have been used in the model setups. Calibration of the model is beyond the scope of this report.

3.1.4 Storm Surge Water Elevations

Storm surge is caused by wind stress on the water surface and the effects of atmospheric pressure reduction. Apra Harbor's location on the west side of Guam protects it from the worst effects of storm surge from storms moving from east to west, the most common movement. A tropical cyclone passing north of the Harbor would pose the greatest threat to Apra Harbor of storm surge due to wind stress.

An extreme value analyses was performed on the total water levels (of tide and storm surge offshore of the Harbor, as shown in Table 3.1-3). These levels only provide a rough indication of the extreme levels to be expected at the sites, and for a more accurate determination of site-specific water levels, regional and local hydrodynamic modeling (with tidal and meteorological forcing) is recommended.

Table 3.1-3 Extreme Value Analysis of Total Water Level (offshore of Apra Harbor)

Return Period (Years)	2	5	10	25	50	100
Total Water Level (feet MLLW)	2.4	3.1	3.6	4.2	4.6	4.9

3.1.5 Wave Crest Elevations at the Sites

In order to evaluate the survivability of the pile-supported deck structure for extreme events, the wave crest elevation of the maximum sized wave must be determined and compared with the proposed deck elevation. Both the significant wave height and the total water level contribute to the calculation. However, the extreme 100 year event for both need not occur at the same time. Indeed, given the relatively sheltered west-side location of the Harbor, the two happening together is extremely unlikely. For purposes of this analysis, the 100 year significant wave height and the 25 year total water level event were used. To find the wave-crest height, the crest elevation of the maximum wave above still water must be found, where still water elevation is the 25 year total water level elevation.

It should be noted that these calculations are only approximate and additional studies and calibration of the model needs to be completed prior to final design of the structures. The preliminary wave crest elevation analysis suggests 15.3 feet MLLW at the Polaris Point site and 14.4 feet MLLW at the former SRF site.

Using slightly relaxed criteria of 50 year wave and 50 year water level, the preliminary wave crest elevation analysis suggests 14.1 feet MLLW at the Polaris Point site and 13.5 feet MLLW at the former SRF site.

3.2 Structural Design Criteria

The following Military Publications, Design Manuals, and Instructions are used for design:

- *Interim Technical Guidance (ITG) – Facilities Homeporting Criteria for Nimitz Class Aircraft Carriers, 3 November 1998.*
- *Unified Facilities Criteria (UFC), UFC 1-200-01 Design: General Building Requirements, July 2002*
- *UFC 4-150-06, Military Harbors and Coastal Facilities, 12 December 2001 (formerly Design Manuals DM 26.1, 26.2, and 26.3)*

- *UFC 3-440-05N, Tropical Engineering*
- *UFC 4-152-01, Piers and Wharves*
- *UFC 4-159-03, Mooring Design*
- *UFC 1-200-01, General Building Requirements (formerly Structural Engineering Concrete Structures, DM 2.04)*
- *UFC 4-150-06, Military Harbors and Coastal Facilities*
- *Technical Report TR-2069-SHR, Design Criteria for Earthquake Hazard Mitigation of Navy Piers and Wharves, March 1997*

Additional documents

- 2006 International Building Code (for seismic design)
- Geotechnical Letter Report by Diaz Yourman & Associates for CVN Berthing Study, Apra Harbor, Guam, October 9, 2007

The facility will be designed for a minimum 25 year service life as required by UFC 4-151-10, General Criteria for Waterfront Construction, Section 5-1, Service Life with a preference to increase service life to 50 or 75 years using concrete service life modeling techniques not yet codified in UCF criteria. The vertical steel pipe piles will be protected by a marine coating system and a cathodic protection system according to MIL 1004.10, Electrical Engineering Cathodic Protection

The following ship characteristics were used for the conceptual fender design and for determining the berthing loads that the wharf must resist.

• Draft (feet)	40.8
• Displacement – Maximum (LTons)	104,200
• Length (feet)	1123
• Breadth at waterline (feet)	134
• Breadth at flight deck (feet)	280
• Height at light load (feet)	215

Bollards with a rating of at least 100 tons will be spaced at 100 feet centers along the berth. Storm bollards with a rating of at least 200 tons will be provided at each end of the berth, 100 feet behind the face of wharf.

Two floating “barge” type structures approximately 50-feet wide x 60-feet long will be installed as camels for berthing (see Figure S-2). Yokahama or Seaward fenders will be installed outboard of the camels. This will provide approximately a 60-foot standoff between the pierhead line and the ship’s hull to allow clearance for the ship’s elevators. An additional spare camel will be provided.

Design Loads

Seismic design will generally conform to *UFC 4-152-01, Design Piers and Wharves.*

Live Loads:

- Uniform Deck LL = 800 psf
- Crane Load = 140-ton mobile crane
- Truck Load = HS20-44
- Fork Lift = 20 ton capacity
- Gantry crane – none
- Loads from extreme wave impact – to be determined during final engineering design

Mooring Loads: Standard bollards as discussed above are used for the cost estimate. For this study, it is assumed that the mooring forces will not govern the structural design of the wharf. Seismic loads are greater than the mooring loads.

Berthing Loads: A conceptual fender design includes determining the berthing energy to be absorbed by the fender system and selecting the size and types of fenders. The design will assume the entire energy is absorbed at one camel and the berthing angle is 6 degrees. The approach velocity is 0.20 feet per second. The maximum berthing force transmitted to the wharf will be determined from the force/deflection properties of the fender selected assuming the fender is compressed to its maximum rated capacity.

3.3 Alternative Wharf Structures

In order to accommodate the proposed sites' topographical and environmental conditions in the most economical manner, a brief study was undertaken to review various structure-type options available for the wharf. Based upon previous studies conducted in the mid-90s to determine the optimal retaining structures for the Pier 400 Landfill project in the Port of Los Angeles, the all-vertical pile supported wharf on armored sloped embankment is selected as the preferred alternative, based upon historically excellent seismic performance and economical costs, for berths approximately 50-feet in depth. It should be noted that virtually all new berth construction along the seismically active continental U.S. West Coast is of this type.

However, Apra Harbor is also subjected to typhoon induced storm waves, which can damage the pile supported wharf if special precautions and designs are not implemented. These precautions are not usually required for the other two structure types. Thus, while the all-vertical pile supported deck is preferred for seismic reasons, the caisson and sheet pile bulkhead concepts are more inherently resistive to wave impact, and thus preferred in locations exposed to extreme wave events.

In addition to the all-vertical pile supported deck concept, two other structure types common to Guam were reviewed. The options are:

- Tied-back steel sheet pile bulkhead, which represents the majority of wharf construction in the Inner Harbor and is also being used in MCON P-431 Alpha-Bravo Wharf Improvements.

- Concrete caisson, similar to that used in the construction of the Kilo Wharf, and the Kilo Wharf Extension (MCON P-502).

Any of the three options is possible for the three alternatives, although there are practical limitations as indicated. For the remainder of this study, it is presumed that the all-vertical pile supported deck wharf is the preferred alternative, based upon perceived benefits, risks, and costs. Final design, using refined data, analyses, and costs, may indicate one of the other alternatives, especially the sheet pile bulkhead wall, is better suited.

3.3.1 Pile Supported Wharf Deck

The berthing structure is a concrete deck superstructure 90 feet wide by 1,325 feet long, supported by all-vertical piling. When all piles are installed vertically, the deck and piles resist lateral loads as a ductile moment-resisting frame. This allows the wharf to flex slightly during an earthquake without serious damage. Piling is driven through the surficial shoreline materials to underlying rock below. Batter-piling are not used due to the high seismic activity of the Island and the documented poor seismic performance of batter piles in wharf construction.

Both prestressed concrete piling and steel piling were considered for the structure. Generally, prestressed concrete piles are preferred in a marine environment due to their inherent corrosion resistance capacity. These can be installed at sites with sands and bay mud, and even very dense sands with the aid of jetting. However, at sites with limestone, rock, or similar materials, concrete piles require difficult and expensive pre-drilling to penetrate the rock. Steel piles were selected due to the highly variable soil strata expected at the site. Given that either type of pile would be imported into Guam, steel lends itself better to on-site lengthening/shortening to match the variability in the bearing depth and embedment. During final design after additional site subsurface investigations have determined the actual bearing elevations, the steel vs. concrete issue can be revisited. Concrete could then be selected if a cost savings to do so was apparent. With modern coatings and suitably maintained cathodic protection systems, steel piles can easily obtain a 50-year life or more.

A flat plate (i.e., beam-less) concrete deck structure was selected. In addition to excellent seismic performance, the concrete flat slab is very durable in the marine environment and can support a variety of loads. The concrete flat plate is of uniform thickness. No beams protrude below the soffit of the deck. This arrangement offers additional clearance to extreme wave conditions. This type of construction is common in ports along the Pacific Rim and has the following advantages:

- Simplified forming over beam and slab.
- Improved corrosion resistance (fewer corners than in beam & slab construction; corners allow chloride ion ingress from two directions, thus accelerating the time to corrosion).
- Forgiving of misplaced piles. Piles that have been driven such that the pile butt is up to one foot out of alignment can be accepted with additional deck reinforcing only. Forming can be easily accommodated vice having to meet tighter location criteria for beams.

The underlying embankment slopes upward from EL -50 MLLW to EL +7 MLLW[4]. Some dressing of the existing slope will be required to prepare the slope for the rock. The slope is

[4] Final elevation still to be determined based upon final coastal engineering evaluation.

protected with large armor rock over a filter course of quarry run. For cost purposes, a slope 3 to 1 h:v was selected for the temporary dredge slope and 1.5 to 1 feet h:v for the quarry run and final armor rock placement[5].

The sloped embankment and armor rock also provide lateral support for the piling against seismic, mooring, and berthing forces. The rock and sloped embankment are an integral part of the entire structure. A similar structure was constructed for the two CVN berths at North Island, San Diego. Since the seismic conditions for San Diego and Guam are very similar, and the structure meets current CVN requirements, this structure has been used for planning purposes at this site with modifications to reflect the needs of this project and advances in seismic engineering since the construction of the San Diego wharves.

3.3.2 Sheet Piles Bulkhead Wharf

Sheet pile bulkhead construction is has long been considered economical in many ports and military harbors due to its simplicity, ease and speed of construction, available U.S. suppliers, and costs, when considered for non-seismic berths to 30 or 35 foot depth. Unfortunately, many times these systems were installed without adequate protection (coatings and/or cathodic protection) and thus earned a bad reputation for durability. However, with proper modern coatings and periodically maintained cathodic protection systems, the expected life is 50 years or more.

For berths greater than 30 feet water depth and in seismic areas, such as this project, the advantages of sheet pile bulkheads quickly disappear. Sheet pile bulkheads have performed badly in severe seismic events, such as the 1993 7.7M Guam earthquake. Most of the wharves experienced some degree of structural damage, ground cracking and settlement, liquefaction, and lateral spreading. Underground utility lines and structures located within the affected areas were damaged, and significant settlement of trench backfill occurred. The worst damage occurred along portions of the Victor, Uniform, Sierra, and X-Ray Wharves, with Sierra experiencing lateral displacements of 4 to 6 feet. The primary cause was liquefaction of loose material placed behind the bulkhead during construction and the subsequent failure of the tie back system.

While the bulkheads and backfill can be designed for these seismic events, the need to use very large and heavy sheet pile sections negates the cost effectiveness they once enjoyed. They also tend to fail in a non-yielding manner, which cause abrupt and not-easily-repaired failures. The deeper berths require more retained fill and hence larger soil retaining stresses. Furthermore, these heavy sections are only produced by one or two foreign mills[6] and require long lead times for large quantities. To resist the lateral forces caused by the seismic event, tie-back system should be pile supported, which introduces more cost-inefficiencies. Liquefaction of the backlands still remains a problem unless soil improvement techniques (surcharging, stone columns, and dynamic deep compaction being the most common) are incorporated.

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[5] Final slope to be determined during final design and based upon geotechnical parameters selected after a site-specific subsurface investigation.

[6] American produced Pipe piles are sometimes used in-lieu of the heavier H-Sections as the primary load carrying member in a king-pile system. The need to specially fabricate pipe piles with the interlocks to connect to the adjacent infill sheets raises the cost typically over that of supplying the proprietary foreign H-shapes. Thus if the "Buy-American" clause is maintained for the sheet pile procurement, there is this option albeit a more expensive option.

Nonetheless, a new steel sheet bulkhead system was proposed by the design-build contractor for the extension of the Bravo wharf, in-lieu of the pile-supported deck system originally proposed on the contract drawings[7].

3.3.3 Concrete Caisson Wharf

Concrete caissons are commonly used in Asia and ports in the Canadian Northwest (Vancouver B.C, in particular). They are particularly useful in areas of large tidal fluctuations. A caisson structure was used in the construction of the Kilo Wharf. This type of construction is also employed where extreme waves are known to occur that could uplift and destroy a pile supported wharf. This is the primary reason that caissons were utilized in both the original construction and the planned extension (MCON P-502).

The caisson is constructed in the dry (typically in a graving yard or dry dock), floated into place and sunk, and founded on a dredged and prepared gravel foundation. The cells of the caisson are then filled with soil and Portland Cement Concrete (PCC) paving is placed on top to provide the working surface. Because caissons are stand-alone units, they can be used in off-shore installations by themselves (as is the case in a portion of the Kilo Wharf facility) or backfilled to provide a contiguous area with the backlands.

Similar to the sheet pile bulkhead, the caisson has a history of poor seismic performance, the primary example being Kobe Port during the Hyogoken Nanbu 6.8 M event of 1995. In this case, the primary mode of failure was lateral movement (up to 25 feet) and rotation of the top of the caissons (tipping) due to foundation failure. Both were due to liquefaction of the retained and supporting materials.

Due to the need to have a level foundation for the full width of the caisson, additional dredging/excavation is necessary to cut out and level the area behind the selected berth face. Alternatively, the caisson can be placed further offshore in deeper water, which could require placing a gravel pad to raise the elevation of the foundation to an appropriate level. In addition to the cost for concrete, dry construction and launching, and towage to the site, the added costs of foundation preparation and dredging/excavation makes caissons the most expensive option of the three.

Caisson fabrication in Guam is problematic. There is essentially only one facility capable of fabricating and launching the caissons in a timely manner: AFDB-8. This floating dry dock is currently the property of the Guam Shipyard, and may not be available for use in construction of the caissons. MCON P-502 Kilo Wharf Extension, when bid, will provide additional insight into the construction opportunity for caissons in Guam. Other foreign fabricators may be able to provide caissons in cost effective manner, even though transportation costs may be high. There may be other options such as partial construction on land, launching into nearby shallow waterway, and finishing construction in deeper water. None of these options have been evaluated in any detail for this study.

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[7] It is assumed that the primary reason for the use of the sheet pile wall system was that it was already being used to upgrade the majority of the Alpha-Bravo project, and switching to a completely new system of construction did not justify the additional mobilization and project initiation costs.

4.0 ALTERNATIVE 1 – FORMER SRF

This site is located at the northern shore of the former SRF, currently under leasehold to the Guam Economic Development and Commerce Authority (GEDCA) and operated by the Guam Shipyard.

4.1 Dredging

The guidance criteria define the required berth for a CVN 68 or CVN 78 as 1,325 feet long x 600 feet wide at minimum dredged depth or below. Figure N-1 illustrates the required berthing for this alternative, which shows the 1,325 foot long berth tying directly to the turning basin 600 feet away from the face of wharf (consistent with the 600 foot wide berthing criteria). The existing shoreline is dressed to slopes of 3:1 h:v to prepare the embankment for quarry run placement and armor rock.

4.1.1 Berth Alignment

Three potential berth alignments were studied evaluate the impact of the new wharf on the access to the adjacent AFDB-8 drydock. Two alignments were discarded, and one final alignment was developed for this site. The selected Minimal Impact alignment follows the current shore line as it extends from the end of the finger pier at Lima Wharf in a north-westerly direction toward the current location of the floating dry dock AFDB-8. The precise final location in the onshore-offshore direction is subject to refinement and minor adjustment during final engineering design. The exact location is a function of the specific geotechnical requirements of the site, and the possible need to use the existing finger piers as confined disposal sites for any contaminated dredge materials found during the course of final design and/or construction. For purposes of this study, the berth face runs approximately along the EL -50 feet MLLW contour.

The alignment study mentioned above was undertaken to review the impacts of various alignments had on access to AFDB-8 by ships entering and exiting the dry dock. The bearing (SE to NW) is the same for all three, only the proximity to land and the resulting amount of dredging needed to construct the wharf varied. A security concern was identified in having a possible foreign ship at the commercial ship repair facility pass close by the berthed CVN on its way to the AFDB-8. Each of the sub alternatives addressed this concern. The three alignments reviewed are:

Significant impact: The location of the berth permanently blocked access to AFDB-8 as it is currently configured. The wharf structure extended farthest into the channel and, with the coral reef on the opposite side, effectively precludes any ship from navigating around the obstruction. A possible mitigation would be to turn AFDB-8 180 degrees so that access would be from the opposite end. The port pilot estimated that this would add no more than 30 minutes to the commute time. The security concern is eliminated.

Minimal impact: Selected Alignment. This alignment temporarily blocks access to AFDB-8 as it is currently configured only when the CVN is at berth. The wharf structure is placed further back towards land, requiring some additional dredging but clears the channel allowing ships to navigate safely along the dry dock entrance channel when the CVN is not berthed. A possible mitigation would be to turn AFDB-8 180 degrees so that access would be from the opposite end. The port pilot estimated that this would add no more than 30 minutes to the commute time. The security concern is eliminated, as the foreign vessel could physically not use the channel while the CVN is at berth

No impact: This alignment clears the channel and provides continuous access to AFDB-8 at all times, even with the CVN berthed and the floating security barriers in-place. To achieve this, the wharf is constructed in a recess created along the shoreline that consumes significant amounts of existing land area and generates considerable soil excavation/dredging quantities to obtain the desired offset from the channel. Given the location, such excavated soil materials would be assumed to be contaminated, requiring special handling. The security concern would have to be addressed by other means.

4.1.2 Potential Impact to Coral & Mitigation Costs

It is believed there will be minimal direct impact to coral related to dredging the turning basin, approach to the berth, of the berthing area itself. The former SRF site itself does not contain any appreciable quantities of coral directly in front of the proposed berth area. Alternatively, there may be indirect impact due to sediment transport over the adjacent Big Blue Reef.

Using the methodology described in Section 2.4-2, the estimated area of coral impact is 45,500 m^2 (Drawing A-1). Using the unit cost of $430/$m^2$, the coral impact mitigation cost is estimated at $19,566,000. The impact area includes the eastern edge of Big Blue Reef, in a preliminary attempt to capture potential indirect impacts, as described in Section 2.4-2.

4.2 Coastal Engineering Considerations

Results from the initial investigation (see Section 3.1.5) suggest that the extreme wave event just off-shore of the berth face will have a 14.4 foot maximum crest elevation. This will not affect the stability of either the caisson or the sheet pile bulkhead wall, but will require special design of the pile supported wharf, as the wave crest elevation is approximately 2.4 feet higher than the deck elevation. At the former SRF site, the primary wave energy is directed along shore rather than perpendicular to shore. This suggests that rock dike wave protection could be installed at the northeast end to mitigate wave impact under the deck.

Final design may require special mitigations, such as the installation of better wave-energy absorbing armor protection, heavier armor, higher deck elevation, deck designed for uplift, lowered crest elevation of the embankment below the deck, and a run-up/over-topping catch basin behind the embankment crest to relieve wave pressures. The extent of these mitigation measures can only be determined during final design and after the wave analysis, begun in this study, is calibrated and confirmed and the relative costs for abatement vs. strengthening are evaluated. In the extreme, costs for abatement/strengthening may tip the benefit-cost balance towards the sheet pile bulkhead option.

4.3 Berthing Structure Alternatives

Either the pile supported wharf or the sheet pile bulkhead wharf is suitable for the former SRF location. While the caisson option could be constructed, additional costs will be incurred for temporary shoring to retain the earth while a pocket is dredged for the caissons. The option to move the caissons off-shore into deeper water is not available due to the proximity of the AFDB-8 entrance channel.

The area behind is vacant for the construction of pile supported anchor system for the tie-backs of the sheet pile bulkhead wall. For economy, the location of the wall is set so that the amount dredging required in front of the wall to reach EL -50 feet MLLW can be used to fill the space behind the wall.

The deck elevation is currently set at +12 feet MLLW. This elevation was chosen to conform to surrounding land elevations (for access and visibility) while still providing a deck elevation that minimizes overtopping (for the bulkhead and caisson options) and potential deck uplift (for the pile-supported deck option).

The wharf plan for Alternative 1 is shown in Figure S-1. The face of wharf is located near the existing -50 ft water depth to minimize dredging and landside demolition. The structure is located 100 feet away from the approach channel leading into the floating dry dock. The concrete deck is 90 feet wide by 1325 feet long. It is 115 feet wide where the storm bollards are installed.

The typical wharf section is shown in Figure S-2. After the berth and embankment are dredged, the embankment is covered with “quarry run” rock and larger armor stone. Then steel pipe piles are installed. If large armor stones (i.e., greater than 500#) are needed due to shore protection requirements, the piling can be driven first and the armor stones placed second, although care must be utilized in the placement so that the piles are not damaged or dislocated. The piles support temporary formwork to construct the cast-in-place reinforced concrete deck. A concrete plug is cast inside the top 15 to 20 feet of the steel pipe pile with reinforcing that extends into the concrete deck. This serves as the pile-to-deck seismic moment connection. Fenders and bollards are attached to the deck with special embedded anchor bolts. Ladders and other miscellaneous metals complete the structure. The utilities are installed in the trench extending the full length of the wharf. These are connected to shore by installing sleeves and duct banks inside the concrete slab.

4.4 Demolition and Site Preparation

Site preparation will require the grubbing and removal of all ground cover for construction of the staging area. This will include the demolition and removal of a minor building (approximately 700 square feet – assumed to be removed by the Guam Shipyard per direction from COMNAVMAR personnel) and the removal of about 3,400 square feet of the end of inner finger pier. The remaining portions of this finger pier and the other finger pier closest to the channel, both of which are bulkhead supported, will remain and will be built into the embankment/dike under the wharf. There will be some minor roadway removal around the demolished building and re-alignment of some utility lines along E-Street near the demolished building location. The pavement over the finger piers will be pulverized and left in place. The soil in the other areas will be scarified and re-compacted to prevent differential settlement before the fill material is placed. The water areas between the slips will be filled and the entire site will be raised to grade indicated using reclaimed dredged materials. Soil improvement methods may need to be utilized to consolidate the various soil fills to prevent liquefaction.

4.5 Shoreside Improvements

4.5.1 Staging Area

The former SRF location provides for an approximate 6.0 acre staging area immediately along side the back of the wharf (Figure C-1). The staging area will be sloped landward at 1%, the same as the wharf deck. The entire area will be paved with asphalt concrete over crushed base. All underground utilities and storm drains, building and light standard foundations will be installed prior to paving.

4.5.2 New Buildings

Building requirements are common for all Alternatives and they are described in Section 2.5. The building locations for Alternative 1 – Former SRF are shown on Figure C-1.

4.5.3 Improvements for Morale, Welfare and Recreation (MWR) Services

The Navy MWR area for supporting CVN activities will be situated on a 4 acre lot to the west of the access control point for the staging area (Figures G-1 and C-1). There are nine existing structures totaling about 36,500 square feet that will need to be razed (assume buildings will be removed by the Guam Shipyard) and about 43,900 square feet of roadway servicing the buildings to be removed. Subsequently, the area will be graded and landscaped for lawn and trees. It is assumed that lawn will be supported by a permanent irrigation system. A 3-inch thick asphalt lot about ½ acre in size will be constructed for locating the following temporary facilities:

- Food and beverage booths
- 500 seating area
- 40 phone bank seats
- Parking for visitor and rental cars (100 stalls)
- Portable restrooms
- Laundry facilities
- Temporary lighting
- Trash dumpsters

The MWR area will need electrical, water, telephone, and sewer connections. The area will be enclosed by a 900-foot long chain link fence and will have multiple locking swing gate entry points. One of the gates will have a permanent turnstile and guard shack. Additional parking for five buses will be provided in a 10 foot wide by 300-foot long turnout on the east side of Main Street.

4.5.4 Security

Both watch towers are located just behind and at either end of the wharf. The transfer shed is located on the east side of the staging area just west of the facility entrance. The entrance is accessed from the frontage road along the channel between the Outer and Inner Harbors. One small building, approximately 720 square feet, at the corner of E Street and Main Street will need to be demolished with a portion of the roadway around it. Armor rock is located west of the wharf and configured to protect the elevated pad

4.5.5 Stormwater Drainage Systems

A concrete swale, to collect surface flow, will run east to west along the perimeter of the pad on the east side and will subdivide the pad on the west side. Flow captured in catch basins will be conveyed through two separate concrete storm drains pipe systems. Following the last catch basin and before discharge, the storm water will be treated in each system by inline cyclonic separators to remove oil, grease, and trash. The separators will collect and retain the undesirable material for the first ½ inch of rainfall that occurs. Greater flows will bypass the separator. Discharge from the separators will be to an outfall to the Outer Harbor and at the channel connecting the Outer and Inner Harbors.

4.6 Waterside Security

Criteria for placement of floating PSB are provided in Section 2.5. The type of barrier will be selected during final engineering design. PSBs will be stored when not deployed for the CVN in the Inner Harbor to reduce exposure to wave action and reduce congestion in the Outer Harbor. The clump anchors for the barriers will be kept on station and a small marker buoy will be attached to the buoy as well as being tethered to the submerged anchor chain. Navy response boats for security deployment will be stationed elsewhere in Apra Harbor. An Electronic Security System on the landside and an Electronic Harbor Security System on the waterside will be provided as described in Section 2.5 above.

4.7 Collateral Equipment

Collateral equipment such as power cables, ship-to shore conveyor, mooring lines, and material handling (forklifts) will be stored in the Port Operations Support Building when not needed. Fenders will be permanent installations on the wharf and the camels will be moved to the Inner Harbor to reduce exposure to wave action when not deployed for the CVN. Costs for collateral equipment are included in this study.

4.8 Utilities

4.8.1 Steam System

The steam system will be designed in accordance with *UFC 4-150-02 Design: Dockside Utilities for Ship Service and UFC 4-213-10 Design: Graving Drydocks.* UFC 4-150-02 requires that the steam service supplied to the ships be 150 psig saturated steam (Tsat = 365°F). Since the Berth is to be constructed in a tropical region, freeze protection measures will not be required. The saturated steam properties should be in accordance with Table 4.8-1.

Table 4.8-1 Steam Properties

Property	Vapor	Liquid
Enthalpy (BTU/lb)	1,195	338
Specific Volume (cubic feet/lb)	2.74	0.01819

Wharf steam capacity requirements will be in accordance with steam loads stated in *UFC-4150-02 and the Ship's Characteristic Data Base (SCDB)*. If the capacities are different for similar vessels, the larger of the two demands will be used, unless otherwise instructed by NAVSEA or NAVFAC. The vessel types anticipated to berth at the Wharf will include: CVN 68, and CVN 78 class vessels. Steam capacity requirements for the different vessel classes per *UFC 4-150-02* and/or SCDB are listed in Table 4.8-2.

Table 4.8-2 Design Vessel Steam Demands

Vessel	Vessel Class	Intermittent Load (lb/hr)	Constant Load (lb/hr)
CVN	CVN 68	7,200	7,500
CVN	CVN 78	Not Required	Not Required

The maximum steam consumption based on the single largest steam-consuming ship at the wharf will be that of the CVN 68. UFC 4-150-02 (Revised 12 May, 2003) lists the constant load demand for the CVN 68 class vessels at 7,500 lb/hr. The intermittent load is based on winter severity region. The proposed site of the berth is outside the five zones described in UFC 4-150-02, and UFC 2150-02. UFC 4-150-02 does not indicate a value for the intermittent load. MIL-HDBK 1025/2 however, does indicate that for an outside design temperature of 70°F, the intermittent steam demand for a Nimitz class carrier is an additional 7,200 lb/h. The total steam supply will be 14,700 lb/hr comprising:

- Constant (Laundry/Galley) -7,500 lb/hr
- Intermittent (Max. Heating) -7,200 lb/hr

The latent heat of vaporization at the design conditions is approximately 857 BTU/lb. The corresponding heat flow is 10,455,400 BTU/hr.

Steam piping will be designed in accordance with *UFC-3-430-09N Design: Exterior Distribution of Steam, High Pressure Water, Chilled Water, Natural Gas, and Compressed Air*.

System redundancy and capacity is defined in UFC 3-430-08N, paragraph 3.2.1. Two fire tube scotch marine oil fired boilers (312 HP, 12,200 lbs/hr capacity), together providing 166% capacity[8], will be installed in a boiler house complete with condensate collection systems, deaeration and feedwater forwarding systems. The boilers will be manifolded into an 8-inch, insulated carbon steel pipe. Two welded 6-inch steam wharf supply pipes will run underground/under deck from the boiler house to the wharf utility gallery, wherein a 6-inch steam main will be installed to supply three steam shore tie riser locations. The two supplies will supply steam to either end of the utility gallery main to create a loop. The 8-inch boiler header will provide taps for high pressure, intermediate and low pressure steam to supply boiler burner fuel atomization, deaerator scrubbing steam and any other miscellaneous process steam requirements.

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[8] Current and proposed future capacity of the existing steam plant at SRF is limited to 2 boilers at 8,625 lbs/hr each. Allowing for 5,000 lbs/hr for current usage, which is expected to continue, only 12,250 lbs/hr is available for CVN (2 x 8,625 – 5,000 = 12,500). With a demand of 12,200 lbs/hr without the air wing and 14,700 lbs/hr with the air wing, the SRF plant provides only 100% and 83% capacity, respectively. This does not conform to UFC 3-430-08N criteria.

Wharf high pressure steam branches will each be isolated from the manifold via new 6-inch, manually operated, 150 Class welded end gate valves. Steam piping will be pitched down 0.2% (2½ inch per 100 feet) in the direction of flow. All low points will have trapped drip pockets in accordance with *MIL-HDBK 1003/8A.* Steam piping will be anchored between expansion joints and at riser locations. The length of piping sections between anchors will be limited to keep the thermal expansion of each section to no more than 4 inch.

Shore-ties branching from the wharf main will terminate above deck of the wharf. Three shore-tie stations will be provided on the wharf itself. The location of the risers will accommodate the locations of the utility brows for the moored design vessels. Steam shore-ties will be served by a minimum 4-inch riser complete with riser isolation valve. The shore-tie positions will be protected by a pipe rail guard. The manual riser valves will be above the top of the wharf deck.

The welded manifolds will be of the same piping as the riser and will consist of six 2-inch threaded hose connections complete with welded isolation valves suitable for steam service. Two of the six connections will be spare connections. Each 2 inch hose connection will have a socket welded, ½ inch diameter hose bleed valve between the hose connection isolation valve and the ship-side end of the hose connection.

All steam piping will be welded pre-engineered, pre-insulated, and in accordance with MIL-HDBK 1003/8A and ASME B31.1 (No flanged connections will be used except at equipment nozzles). Where permitted, flanges will be of the weld neck type for piping 2½ inch or larger, and socket weld type for 2 inch and smaller. All flanges will conform to ANSI B16.5 150 Class. Pipe material will be American Society for Testing and Materials (ASTM) A-53 Gr. B ERW for 2½ inch or larger piping, and ASTM A-106 seamless carbon steel for 2 inch or smaller piping. For pipe diameters 2½ inch or larger pipe wall thickness will be standard wall. For piping 2 inch and smaller, minimum nominal wall thickness will be Schedule 80 for welded ends and “Extra Strong” for threaded end piping.

The condensate from the vessels will not be collected. Only condensate formed in the distribution pipeline will be collected and sent back to the boiler house. The condensate collection system will consist of piping main drip/trap stations along the steam line spaced approximately 200 feet apart. The drip/trap stations will consist of a welded 6 inch condensate pocket, steam trap, complete with inline strainer, insulated piping and trap isolation and bypass valves. The pocket will have a 2 inch cleanout line welded at its end with a ball or gate valve to permit drainage of condensate during warm up and emptying of pocket prior to an extended wharf steam main outage. The sloped condensate will be piped to condensate collection vessel with integral pump in the utility trench. There will be drip/trap stations at every shore-tie riser. All steam traps will be of the float and thermostatic type. Condensate piping will be either ASTM A-106 seamless, schedule 80 for socket welded piping or “Extra Strong” for threaded piping.

Pipes will typically be supported by slide or roller supports mounted on wall brackets in the utility gallery. The steam pipe will be located such that there is ample clearance for the sloping of the piping and access to the drip/trap stations. The lateral motion of the pipes due to thermal expansion will be restrained with pipe guides. Due to the space constraints in the trench, pipe stresses due to thermal expansion will be accommodated by weld-end bellows type expansion joints. The riser connections will be positioned at anchor locations. This will preclude the lateral motion of risers due to axial expansion of the Wharf main.

The minimum insulation thickness for steam piping NPS 2 inch to NPS 6 inch is 3 inches.

4.8.2 Pure Water System

The pure water system for the wharf will be designed in accordance with the draft of CVN 78 FPC. The pure water requirements for the wharf will be based on the requirements of the vessel with the largest pure water consumption, as shown in Table 4.8-3.

Table 4.8-3 Design Vessel Pure Water Demands

Vessel	Class	Normal Requirement for ship's complement (gpd) @ (gpm)	Normal requirement including troops/air wing (gpd) @ (gpm)
CVN	CVN 68	20,000 @ 150	20,000 @ 150
CVN	CVN 78	20,000 @ 150	20,000 @ 150

Piping will be sized in accordance with *UFC 4-150-02* for a peak rate of flow of 150 gpm having a residual pressure of 40 psi at the most remote outlet. Pipe and fittings will comply with MIL-HDBK-1005/7A Water Supply Systems.

The source of the pure water will be from the existing potable water infrastructure. This potable water will be treated to Grade A quality. A dedicated, structure will house the treatment equipment. Two 6 inch wharf supply pipes will run underground/under deck from the treatment building to the wharf utility gallery. The two supplies will supply pure water to either end of the utility gallery main to create a loop. The utility gallery piping will consist of a NPS 6 inch main run in the wharf utility gallery to supply three water shore tie riser locations. The two legs of the wharf main will be isolated from the treatment building mains by new 6 inch, manually operated, 125/150 Class flanged end gate valves.

Three, 4 inch branch connections will be provided to shore-ties at the wharf. The risers will be located to accommodate the utility brows of the moored design vessels. The risers will each have a 4 inch RPZ backflow preventer in accordance with AWWA Manual M14, Recommended Practice for Backflow Prevention and Cross-Connection Control. The ship's hose connections will be 2 ½ inches.

The pure water piping in the gallery will be flanged ductile iron in accordance with AWWA C151 and AWWA C115. The flange rating will be ANSI 125/150 Class in accordance with ANSI B16.5. Buried potable water piping will have restrained mechanical joints and thrust blocking at changes in direction greater than 45 degrees. The piping will have an epoxy external coating. The piping will be cement-mortar lined in accordance with AWWA C104.

4.8.3 Compressed Air

Compressed air system will be designed in accordance with *UFC 3-150-02 Design: Dockside Utilities for Ship Service, UFC 4-213-10 Design: Graving Drydocks, UFC 3-430-09N Design: Exterior Distribution of Steam, High Pressure Water, Chilled Water, Natural Gas, and Compressed Air and DM-3.5 Design Manual Compressed Air and Vacuum Systems*.

Compressed air system will be sized by the largest vessel requirement, shown in Table 4.8-4.

Table 4.8-4 Design Vessel Low Pressure Compressed Air Flow Rates

Vessel	Class	Quantity SCFM	Minimum Branch Pipe Size NPS (inches)	Minimum Risers per Berth
CVN	CVN 68	2,400	4	5
CVN	CVN 78	Not Required	N/A	N/A

The largest consumer of compressed is the CVN 68 class which requires 2,400 Standard Cubic Feet per Minute (SCFM) compressed air at a terminal pressure of 125 psig.

Compressed air piping will be designed as per *UFC 2150-02 Dockside Utilities for Ship Service and UFC 3-430-09N Design: Exterior Distribution of Steam, High Pressure Water, Chilled Water, Natural Gas, and Compressed Air*. The piping will be sized based on a maximum pressure drop of 5 psi from the tie in point to the furthest hose connection.

The new wharf main will be a NPS 6 inch run in the utility gallery between five NPS 4 inch branch lines and same sized risers will tie into the new wharf main. Each riser will consist of an isolation valve located above the wharf deck, and a welded-pipe manifold. Each manifold will consist of three NPS ¾ inch, three NPS 1¼ inch maintenance and repair connections. One of each size of connection is a spare. In addition the manifold will have two 4 inch ship's hose connections, one active and one spare. The 4 inch connections will be ANSI 150 Class flanges with blind flange covers. Each hose connection will have an isolation valve. Each hose connection will have a ½ inch hose bleed valve downstream of the hose connection isolation valve.

The utility gallery piping will be pre-engineered welded pipe. The risers will be ASTM A53 or A105 standard wall carbon steel. The ½ inch and 1¼ inch piping will be socket welded schedule 80 and Extra Strong wall thickness where pipe will be threaded to accept threaded adaptors for the hose connections. The end connections of the maintenance hook ups will match the type used by the shipyard.

4.8.4 Bilge Oily Waste (BOW) System

As previously presented in Section 2.7, this discussion on the BOW system Will be based on providing the facilities required to accommodate the ultimate requirements of the CVN 78. According to the review draft FPC with guidance provided by PEO Carriers, the BOW system shall be adequately sized to handle a pumping rate of 90 gpm with an average daily flow rate of 38,000 gpd and a peak flow rate of 82,000 gpd, as required for a CVN 78.

The existing bilge oily waste systems at Apra Harbor Naval Complex are inadequate to handle the CVN BOW requirements of either CVN 68 or CVN 78 for a duration of 21 days. Mobile BOWTS units are available; however, these units are typically small and will not be able to process the amount of BOW generated by a carrier. Therefore, it is recommended that a BOW collection and treatment system be constructed near the location of the proposed berth. The BOW collection and treatment system will consist of a combined gravity and force main collection system, a BOW pump station, and a BOWTS as indicated on Figure M-2.

The bilge oily waste transfer and collection system will be constructed concurrently with the site work while the construction of the bilge oily waste treatment system will commence upon completion of the staging area. This portion of the improvements is anticipated to take approximately two years to complete.

4.8.5 Wastewater System

As previously presented in Section 2.8, the wastewater system requirements for a CVN 68 is greater than or equivalent to that of a CVN 78. Therefore, the wastewater infrastructure improvements proposed for the CVN 68 will be applicable to the CVN 78. According to applicable UFC documents and guidance provided by NAVFAC Pacific, the existing wastewater infrastructure was evaluated based on handling an additional flow rate of 1,200 gpm and an average daily flow of 550,000 gpd required for the CVN 68 berthing.

The existing wastewater system serving the former SRF site includes SPS Nos. 18 and 16 and Trunklines “D” and “A”. The existing capacities of these pump stations and trunklines was found to be inadequate to handle the wastewater generated from either a CVN 68 or 78. There are plans to upgrade the capacities of SPS Nos. 18 and 16 under P-262 and P-534; however, these plans do not include the flows from a carrier. Therefore, the scope of these existing projects will need to be expanded or supplementary upgrades will need to be proposed under a separate project to account for the additional flows from the CVN.

In lieu of upgrading the existing wastewater infrastructure, alternate options include transporting the wastewater from the ship’s CHT using tanker trucks to the AHWWTP and construction of a temporary holding tank at the berthing location to contain and manage the discharge to the existing wastewater system. Due to the quantity and duration of the wastewater generated from a CVN, these options are not feasible. Transporting the wastewater using 5,000-gallon capacity tanker trucks will require over 100 roundtrips from the berthing location to the AHWWTP. Constructing a storage tank to contain the wastewater will require proper and careful management of the discharges for the entire duration of the CVN visit to prevent sewage spills in the system.

P-262 and P-534 are scheduled for implementation in FY 2009. The progress and design status of these projects indicate that the CVN loadings should be handled through separate supplementary wastewater system upgrades. These upgrades will be designed to handle only the flows from the CVN and will not be sized to provide additional capacity in the system. This will require the construction of three new submersible sewage pump stations and 6,700 linear feet of associated force mains as indicated on Figures M-3 and M-4. In addition to the pressurized systems, approximately 4,420 linear feet of new gravity sewers are recommended, of which 2,720 linear feet of 15-, 18-, and 24-inch relief sewer lines are proposed along Marine Drive to increase capacity of the existing sewer trunkline “A” for the CVN berthing.

Majority of the wastewater system improvements required to support the CVN berthing are located backlands and will not be dependent on the construction schedule of the wharf. This portion of the improvements is anticipated to take a minimum of three years to complete. Therefore, this work may be initiated during the early stages of the CVN berthing project so that all infrastructure improvements are in place for the CVN berthing. The ship wastewater collection ashore system will be located at the berthing wharf and construction of this portion of the improvements will take place concurrently with the wharf site work.

4.8.6 Potable Water System

As previously presented in Section 2.9, the potable water flow rate required for active berthing is based on the wharf length and not on the type ship berthed. According to applicable UFC documents, 1,000 gpm must be provided for all berth lengths up to 2,000 feet, with a minimum residual pressure of 40 psi downstream of a backflow preventer located at the most remote outlet on the pier. The wharf length for both a CVN 68 and CVN 78 are less than 2,000 feet. Therefore, both ships will require a minimum flow rate of 1,000 gpm with a residual pressure of 40 psi.

According to applicable UFC documents and guidance provided in the review draft FPC, the daily average potable water requirements, with air wing or troops aboard, for a CVN 68 is 185,000 gpd and for a CVN 78 is 235,000 gpd. Therefore, the existing potable water system will be evaluated based on its ability to supply a minimum flow rate at the berthing location of 1,000 gpm at 40 psi and satisfy an average daily demand of 235,000 gpd. Typically, the flow rate requirement will have a localized impact on the existing water distribution system while the average daily demand will effect the potable water treatment and storage facilities.

Potable water is supplied to the former SRF site from the Apra Heights Tank system. In addition to the former SRF site, the Apra Heights Tank supplies water to a majority of the Apra Harbor Naval Complex. Based on the water demands of the service area and the maximum fire flow requirements, the storage capacity of the tank was evaluated based on criteria provided in *UFC 3-230-19N*. The storage capacity required, including the larger water demand of a CVN 78, was calculated to be 2.6 MG. The Apra Heights Tank has a capacity of 5.0 MG. Therefore, no improvements are required for the Apra Heights Tank for the berthing of either a CVN 68 or CVN 78 at the former SRF site.

Approximately 1,200 linear feet of 10-inch water line along the entrance road to the former SRF site will be replace with a 12-inch water line under project P-494 (FY 2008). In addition to this project, approximately 2,200 linear feet of 16-inch water line along Sumay Drive is currently being replaced with an 18-inch main. These improvements were incorporated in the water system model used to evaluate the capacity of the existing potable water system. The results of the model indicates that more than 1,000 gpm can be provided at pressures exceeding 40 psi to the berthing site at the former SRF site. Therefore, no major water system improvements will be required for this option. Water system improvements will be limited to the construction of a new 8-inch service lateral to the berthing site and the associated pierside water outlets as shown on Figure M-5.

The potable water system improvements required to support the CVN are located along and adjacent to the proposed berthing location. The pierside water lines and outlets will be constructed concurrently with the wharf site work. Construction scheduling of the supply lateral to the wharf shall be coordinated with other adjacent site improvements. This portion of the improvements is anticipated to take less than a year to complete.

4.8.7 Power

Present Situation

P-494 will construct a new SRF Substation to support planned waterfront upgrades for Sierra, Romeo, and Uniform Wharves and existing SRF loads. The SRF Substation will be fed from the new Orote Substation with two 34.5 kV circuits, each with conductors capable of roughly 25 MVA, but with duct capacity that will enable doubling the capacity of each circuit.

The scope of P-494 does not include capacity to accommodate the CVN without additional circuits and 34.5 kV switchgear additions.

Recommendations

- Provide a new 34.5 kV feeder circuit breaker in the GPA Piti 34.5 kV Switching Station (By GPA).
- Upgrade existing GPA 34.5 kV Overhead Feeder Circuit X20 between Piti 34.5 kV Switching Station and Orote Substation from #4/0 AWG copper conductors to 927.2 kcmil AAAC conductors. (By GPA)
- Provide a new underground, concrete encased, 34.5 kV feeder circuit from the GPA Piti 34.5 kV Switching Station to new Bus D in the Orote Substation. The feeder is to consist of two sets of 3-750 kcmil copper conductors with ethylene propylene rubber (EPR) insulation rated for 35 kV, 133% insulation level.
- Provide additions to the Orote Substation 34.5 kV switchgear, including a new bus tie circuit breaker and a new GPA incoming main circuit breaker to form new Bus D.
- Provide the second set of 3-750 kcmil copper conductors with EPR insulation rated for 35 kV, 133% insulation level to each of the two express feeders connecting SRF Substation to Orote Substation. Conductors will be provided in ducts installed under P-494.
- Provide a new CVN Berth Substation consisting of a switchgear building, a transformer yard, 34.5 kV indoor metal-clad switchgear, 13.8 kV indoor metal-clad switchgear, 4.16 kV indoor metal-clad switchgear, two 20/26/33 MVA transformers, two 12/16/20 MVA transformers, one zigzag grounding transformer, and miscellaneous substation electrical systems.
- Provide one underground, concrete-encased, 34.5 kV express feeder circuits from the SRF Substation to the CVN SRF Berth Substation. The feeder circuit will consist of two sets of 3-750 kcmil copper conductors with insulation rated for 35 kV, 133 % insulation level.
- Provide a supervisory control and data acquisition system remote terminal unit in the CVN SRF Berth Substation to integrate with the SCADA system provided under P-494.
- Provide 13.8 kV and 4.16 kV shore power mounds, feeder conductors, control wiring, and ducts for connection to the CVN Berth Substation.
- Provide 13.8 kV feeders, pad-mounted transformers, and secondary electrical systems to support BOWTS, wastewater pumping stations, and MWR facilities.
- Provide wharf operational and security lighting using high-mast steel poles with metal-halide luminaires.

4.8.8 Communications

Present Situation

Existing infrastructure at the former SRF site is not adequate to support the CVN information system requirements. The nearest ITN is Building 3169, which contains fiber optic and CATV connectivity only. Closest telephony connection is at Central Office Building 3012. Ductbanks from the former SRF site to these buildings do not exist.

Recommendations

- Provide a new concrete-encased ductbank from the CVN Berth to the nearest ITN located at Building 3169. A 48-strand fiber optic cable will be provided from ITN Building 3169 to the CVN Berth.
- Provide a new concrete-encased ductbank from ITN Building 3169 to Central Office Building 3012. A 200-pair copper cable will be provided from Building 3012 to the CVN Berth via ITN Building 3169.
- Provide three communications system interface enclosures at the CVN Berth; one enclosure will be provided at each end and one at the center. The center enclosure will have capacity for 2-T1 interfaces, 200-pair copper, and CATV. Each end enclosure will have capacity for 1-T1 interface, 100-pair copper, and CATV.
- Provide an interface enclosure for MWR facilities, including provisions for portable payphone connections.

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5.0 ALTERNATIVE 2 – POLARIS POINT PARALLEL TO SHORE

This site is located at the northern shore of Polaris Point. The location (east and west) is set to minimize the impact to navigation along the channel leading into the inner harbor. The berth is located (north and south) to run approximately along the EL –50 feet MLLW contour to minimize the dredging at Polaris Point.

5.1 Dredging

There are two dredging alternatives for the Polaris Point Parallel to Shore alignment. The first alignment (Alt. 2) sets the berth width at 600 feet which is consistent with the criteria for slip width found in *ITG Facilities Homeporting Criteria for Nimitz Class Aircraft Carriers, 3 November 1998.* The north point must be removed in this alternative, as shown in the figures. A reduced impact alternative (Alt. 2A) is illustrated whereby the berth width is less than 600 feet inside the bay, near the bow of the CVN, and the dredged area follows the existing contours of the northern point.

The guidance criteria define the required berth for a CVN 68 or CVN 78 as 1,325 feet long x 600 feet wide (600 feet for a "slip"). Figure N-2 illustrates the dredging footprint for this alternative. To comply with the criteria, coral and the adjacent land mass at the point would be dredged. Alternative 2A (Figure N-7) was developed to minimize the dredging and excavation at Polaris Point, but reduces the minimum berth width to 440 feet at the bow of the vessel. This alternative may require a variance from the Navy's standard criteria, albeit the "slip width" criterion does not strictly apply to this berth scenario. Port Operations personnel and the Harbor Pilots were consulted, and they indicated the concept is acceptable with regard to navigation and berthing a CVN vessel in the designated berth area. Also, CPF/NAVSEA provided verbal concurrence with the Alternative 2A configuration.

5.1.1 Potential Impact to Coral & Mitigation Costs

<u>Point Removed (Alt. 2)</u>: The Polaris Point site itself does not contain any appreciable quantities of coral directly in front of the proposed wharf; however, recent coral surveys indicated there is coral present on the north side of the northern point. Under the alternative where the northern point is completely removed, the direct coral impacts are increased.

<u>Reduced-Impact (Alt 2A)</u>: Preserving the point reduces dredging and the related direct impacts to coral.

Using the methodology described in Section 2.4-2, the estimated area of coral impact for Alternative 2 is 53,650 m^2 (Figure A-2) and Alternative 2A (Figure A-3) is 52,313 m^2. Applying a unit cost of $430/$m^2$, the coral impact mitigation cost is estimated at $23,068,000 for Alternative 2 and $22,495,000 for Alternative 2A. The impact areas include the eastern edge of Big Blue Reef, in a preliminary attempt to capture potential indirect impacts, as described in Section 2.4-2. Alternative 2A was proposed specifically to minimize the impact to coral.

5.2 Coastal Engineering Considerations

Results from the initial investigation (see Section 3.1.5) suggest that the extreme wave event just off-shore of the berth face will have a 15.3 foot maximum crest elevation. This will not affect the stability of either the caisson or the sheet pile bulkhead wall, but will require special design of the pile supported wharf, as the wave crest elevation is approximately 3.3 feet higher than the deck elevation. At the Polaris Point site the primary wave energy is directed more to perpendicular to shore rather than along shore. Thus, this site is more prone to direct attack from storm waves.

Final design may require special mitigations, such as the installation of better wave-energy absorbing armor protection, heavier armor, higher deck elevation, deck designed for uplift, lowered crest elevation of the embankment below the deck, and a run-up/over-topping catch basin behind the embankment crest to relieve wave pressures. The extent of these mitigation measures can only be determined during final design and after the wave analysis, begun in this study, is calibrated and confirmed and the relative costs for abatement vs. strengthening are evaluated. In the extreme, costs for abatement/strengthening may tip the benefit-cost balance towards the sheet pile bulkhead option.

5.3 Berthing Structure Alternatives

Either the pile supported wharf or the sheet pile bulkhead wharf is suitable for the Polaris Point Parallel to Shore location. While the caisson option could be constructed, additional costs will be incurred for temporary shoring to retain the earth while a pocket is dredged for the caissons. There is the option to move the caissons off-shore into deeper water; however this quickly approaches the 3rd alternative, Polaris Point Diagonal Offshore, and is thus not considered.

The area behind is vacant for the construction of pile supported anchor system for the tie-backs of the sheet pile bulkhead wall. For economy, the location of the wall is set so that the amount dredging required in front of the wall to reach EL -50 feet MLLW can be used to fill the space behind the wall.

The deck elevation is currently set at +12 feet MLLW. This elevation was chosen to conform to surrounding land elevations (for access and visibility) while still providing a deck elevation that minimizes overtopping (for the bulkhead and caisson options) and potential deck uplift (for the pile-supported deck option).

The wharf plan for Alternative 2 is shown in Figure S-3. The structure is identical to Alternative 1 except the west end extends over the existing slope near the entrance to the inner harbor. The location east and west is set to minimize the impact to navigation along the channel leading into the inner harbor and to minimize the dredging at Polaris Point.

The typical wharf section is the same as Figure S-2 for Alternative 1.

5.4 Demolition and Site Preparation

Site preparation will require the grubbing and removal of all ground cover for construction of the staging area. This will include the demolition and replacement in-kind of three minor buildings (totaling approximately 940 square feet). There will be some minor roadway removal and possibly re-alignment of utility lines along this portion of roadway. The soil will be scarified and re-compacted before the fill material is placed to prevent differential settlement.

5.5 Shoreside Improvements

5.5.1 Staging Area

The Polaris Point Parallel to Shore Alternative provides for approximately 5.8 acre staging area immediately along side the back on the wharf (Figure C-2). The staging area will be sloped landward at 1%, the same as the wharf. The entire area will be paved with asphalt concrete over crushed base. All underground utilities and storm drains, building and light standard foundations will be installed prior to paving.

The layout provides access from Polaris Point Road with a short one-way access lane cut through the apex of the softball field lot. This provides queuing for about 12 vehicles without obstructing Polaris Point Road or the right hand turn-off to the softball diamond. Vehicles denied entry will be have room to back up on to the turn-off road and return back down Polaris Point Road. The driveway entrance/exit is quite a bit longer than that for the former SRF site except that the slope is not as steep.

5.5.2 New Buildings

Building requirements are common for all Alternatives and they are described in Section 2.5. The building locations for the Alternative 2 at Polaris Point are shown on Figure C-2.

5.5.3 Improvements for MWR Services

The Navy MWR area for supporting CVN activities will be situated on a 2.4 acre lot north of the existing baseball field on Polaris Point (Figures G-2, and C-2). The MWR is located about 500 feet north of the access control point for the staging area. There is a 7,200 square foot building pad that will need to be razed before that area can be graded and landscaped for lawn and trees. It is assumed that lawn will be supported by a permanent irrigation system. A 3-inch thick asphalt lot about ½ acre in size will be constructed for locating the following temporary facilities:

- Food and beverage booths
- 500 seating area
- 40 phone bank seats
- Parking for visitor and rental cars (100 stalls)
- Portable restrooms
- Laundry facilities
- Temporary lighting
- Trash dumpsters

The MWR area will need electrical, water, telephone, and sewer connections. The area will be enclosed by a 1,300-foot long chain link fence and will have multiple locking swing gate entry points. One of the gates will have a permanent turnstile and guard shack. A loop road will be constructed off of the east side of the Polaris Point access road. The loop road will have a 10 foot wide by 300-foot long turnout on the west side to park five buses.

5.5.4 Security

There is only one watch tower planned for the staging area. This is located at west corner of the staging area. It is assumed that the existing tower near the end of Polaris Point is in an appropriate location to cover the CVN asset. However, it may be necessary to upgrade the facility and/or provide additional security in accordance with the *draft UFC 4-025-01*.

5.5.5 Stormwater Drainage Systems

The drainage system for the staging area will rely on a continuous straight concrete swale running from east to west to collect runoff from the pavement into a series of catch basins. The swale on the eastern side of the area borders the southerly perimeter and on the west side runs through the middle of the paved area. A cyclonic storm water separator is located beneath the last catch basin and the outfall is located on the east end of the channel between the Apra Inner and Outer Harbors. Armor rock is featured from the wharf to about 100 feet south of the outfall and protects the staging area slope on the west side.

5.6 Waterside Security

Criteria for placement of floating PSB are provided in Section 2.5. The type of barrier will be selected during final engineering design. PSBs will be stored when not deployed for the CVN in the Inner Harbor to reduce exposure to wave action and reduce congestion in the Outer Harbor. The clump anchors for the barriers will be kept on station and a small marker buoy will be attached to the buoy as well as being tethered to the submerged anchor chain. Navy response boats for security deployment will be stationed elsewhere in Apra Harbor. An Electronic Security System on the landside and an Electronic Harbor Security System on the waterside will be provided as described in Section 2.5 above.

5.7 Collateral Equipment

Collateral equipment such as power cables, ship-to shore conveyor, mooring lines, and material handling (forklifts) will be stored in the Port Operations Support Building when not needed. Fenders will be permanent installations on the wharf and the camels will be moved to the Inner Harbor to reduce exposure to wave action when not deployed for the CVN.

5.8 Utilities

5.8.1 Steam System

Except for lengths of piping from the wharf structure and water source to the steam production plant, there are no differences in terms of Steam systems between this Alternative and that described for Alternative 1, Former SRF.

5.8.2 Pure Water System

Except for lengths of piping from the wharf structure and water source to the pure water production plants, there are no differences in terms of Pure Water systems between this Alternative and that described for Alternative 1, Former SRF.

5.8.3 Compressed Air

Except for lengths of piping from the wharf structure and to the compressed air production plants, there are no differences in terms of compressed air systems between this Alternative and that described for Alternative 1, Former SRF.

5.8.4 Bilge Oily Waste (BOW) System

As previously presented in Section 2.7 this discussion on the BOW system will be based on providing the facilities required to accommodate the ultimate requirements of the CVN 78. According to the review draft FPC with guidance provided by PEO Carriers, the BOW system shall be adequately sized to handle a pumping rate of 90 gpm with an average daily flow rate of 38,000 gpd and a peak flow rate of 82,000 gpd as required for a CVN 78.

The existing bilge oily waste systems at Apra Harbor Naval Complex are inadequate to handle the CVN BOW requirements of either CVN 68 or CVN 78 for a duration of 21 days. Mobile BOWTS units are available; however, these units are typically small and will not be able to process the amount of BOW generated by a carrier. Therefore, it is recommended that a permanent BOW collection and treatment system be constructed near the location of the proposed berth. The BOW collection and treatment system will consist of a combined gravity and force main collection system, a BOW pump station, and a BOWTS as indicated on Figure M-6.

5.8.5 Wastewater System

As previously presented in Section 2.8, the wastewater system requirements for a CVN 68 is greater than or equivalent to that of a CVN 78. Therefore, the wastewater infrastructure improvements proposed for the CVN 68 will be applicable to the CVN 78. According to applicable UFC documents and guidance provided by NAVFAC Pacific, the existing wastewater infrastructure was evaluated based on handling an additional flow rate of 1,200 gpm and an average daily flow of 550,000 gpd required for the CVN 68 berthing.

The existing wastewater system serving Polaris Point includes SPS No. 9 and Trunkline “B”. The existing capacities of this pump station and main sewer trunkline were found to be inadequate to handle the wastewater generated from either a CVN 68 or CVN 78. Therefore, the existing wastewater infrastructure must be upgraded to handle the additional sewer flows from the CVN berthed at Polaris Point.

In lieu of upgrading the existing wastewater infrastructure, alternate options include transporting the wastewater from the ship’s CHT using tanker trucks to the AHWWTP and construction of a temporary holding tank at the berthing location to contain and manage the discharge to the existing wastewater system. Due to the quantity and duration of the wastewater generated from a CVN, these options are not feasible. Transporting the wastewater using 5,000-gallon capacity tanker trucks will require over 100 roundtrips from the berthing location to the AHWWTP. Constructing a storage tank to contain the wastewater will require proper and careful management of the discharges for the entire duration of the CVN visit to prevent sewage spills in the system.

It is recommended that a new SPS No. 9 and corresponding force main be constructed to accommodate both the current wastewater flows generated in the Polaris Point tributary area and the additional wastewater loading form the CVN. This is in contrast to two separate pump station force main system, one for the CVN and one for the existing waste loadings at Polaris Point.

The recommendation is warranted due to the deteriorated structure condition of the existing SPS No. 9, which was placed on the Tier 1 prioritization list for replacement. Concerns with safety, design and condition of the pump station was based on an inspection performed in February 2006.

Secondly, with the existing utilities in Marine Drive and plans to upgrade the existing overhead electrical distribution system to an underground system, there may not be sufficient space in the underground corridor to accommodate two force mains.

The proposed wastewater system improvements include the construction of a new submersible type sewage pump station, a new dry pit – wet well type pump station to replace the aging SPS No. 9, and 14,800 linear feet of associated force mains as indicated on Figures M-7 and M-8. In addition to the pressurized systems, approximately 4,940 linear feet of new gravity sewer lines are recommended, of which 4,420 linear feet of 8-, 12-, 15-, and 21-inch relief sewer lines are proposed along Marine Drive to increase capacity of the existing sewer trunkline “B” for the CVN berthing.

5.8.6 Potable Water System

As previously presented in Section 2.9, the potable water flow rate required for active berthing is based on the wharf length and not on the type ship berthed. According to applicable UFC documents, 1,000 gpm must be provided for all berth lengths up to 2,000 feet, with a minimum residual pressure of 40 psi downstream of a backflow preventer located at the most remote outlet on the pier. The wharf length for both a CVN 68 and CVN 78 are less than 2,000 feet. Therefore, both ships will require a minimum flow rate of 1,000 gpm with a residual pressure of 40 psi.

According to applicable UFC documents and guidance provided by in the review draft FPC, the daily average potable water requirements, with air wing or troops aboard, for a CVN 68 is 185,000 gpd and for a CVN 78 is 235,000 gpd. Therefore, the existing potable water system will be evaluated based on its ability to supply a minimum flow rate at the berthing location of 1,000 gpm at 40 psi and satisfy an average daily demand of 235,000 gpd. Typically, the flow rate requirement will have a localized impact on the existing water distribution system while the average daily demand will effect the potable water treatment and storage facilities.

Potable water is supplied to Polaris Point from the Tupo Tank system. In addition to Polaris Point, the Tupo Tank supplies water to areas outside of the Apra Harbor Naval Complex and up north to NCTAMS WESTPAC Barrigada, including GovGuam and navy areas in between. Based on the water demands of the service area and the maximum fire flow requirements, the storage capacity of the tank was evaluated based on criteria provided in *UFC 3-230-19N*. The storage capacity required, including the larger water demand of a CVN 78, was calculated to be 4.2 MG. The Tupo Tank has a capacity of 5.0 MG. Therefore, no improvements are required for the Tupo Tank for the berthing of either a CVN 68 or CVN 78 at Polaris Point.

Project P-431 is currently ongoing and proposes to improve the water distribution lines within Polaris Point. Approximately 5,000 linear feet of 8 and 12-inch water lines supplying water to Polaris Point will be replaced with a 16-inch main. The 6-inch water lines along the wharf areas will be replaced with 8-inch lines. A new fire pump house is also proposed under this project.

These improvements were incorporated in the water system model used to evaluate the capacity of the existing potable water system. The results of the model indicates that more than 1,000 gpm can be provided at pressures exceeding 40 psi to the berthing site at Polaris Point. Therefore, no major water system improvements will be required for this option. Water system improvements will be limited to the construction of a new 8-inch service lateral to the berthing site and the associated pierside water outlets as shown on Figure M-9.

5.8.7 Power

Present Situation

The electrical infrastructure at Polaris Point is capable of support planned upgrades ongoing at Alpha and Bravo Wharves under MCON Project P-431 and new projects such as MCON Project P-465, Consolidated SLC Training & CSS-15 HQ Facility, and P-528, Construct Torpedo Exercise Support Building.

The electrical infrastructure at Polaris Point is incapable of accommodating the CVN Polaris Point Berth without major improvements and additions.

Recommendations

- Provide a new 34.5 kV feeder circuit breaker in the GPA Piti 34.5 kV Switching Station (By GPA).
- Provide a new CVN Berth Substation consisting of a switchgear building, a transformer yard, 34.5 kV indoor metal-clad switchgear, 13.8 kV indoor metal-clad switchgear, 4.16 kV indoor metal-clad switchgear, two 20/26/33 MVA transformers, two 12/16/20 MVA transformers, one zigzag grounding transformer, and miscellaneous substation electrical systems.
- Provide a new underground, concrete-encased, 34.5 kV feeder circuit from the GPA Piti 34.5 kV Switching Station to the new Polaris Point CVN Berth Substation. The feeder is to consist of two sets of 3-750 kcmil copper conductors with EPR insulation rated for 35 kV, 133% insulation level.
- Provide a supervisory control and data acquisition system remote terminal unit in the CVN Polaris Point Berth Substation to integrate with the SCADA system provided under P-494.
- Provide 13.8 kV and 4.16 kV shore power mounds, feeder conductors, control wiring, and ducts for connection to the CVN Polaris Point Berth Substation.
- Provide 13.8 kV feeders, pad-mounted transformers, and secondary electrical systems to support BOWTS, wastewater pumping stations, and MWR facilities.
- Provide wharf operational and security lighting using high-mast steel poles with metal-halide luminaires.

5.8.8 Communications

Present Situation

Existing ITN Building 4434 located at Polaris Point near the proposed Berth has capacity to support CVN information system requirements. This building contains connectivity for fiber optic, telephony, and CATV.

Recommendations

- Provide a new concrete-encased ductbank from the CVN Berth to the nearest Information Transfer Node (ITN) located at Building 4434. Connection will be via the existing manhole adjoining the ITN. One 48-strand fiber optic cable and a 200-pair copper cable will be provided from ITN Building 4434 to the CVN Berth.
- Provide a new concrete-encased ductbank from ITN Building 4434 to an existing manhole on Marine Drive and separated by a minimum of 50 feet from the existing ductbank. This ductbank will provide for critical information system redundancy at Polaris Point.
- Provide three communications system interface enclosures at the CVN Berth; one enclosure will be provided at each end and one at the center. The center enclosure will have capacity for 2-T1 interfaces, 200-pair copper, and CATV. Each end enclosure will have capacity for 1-T1 interface, 100-pair copper, and CATV.
- Provide an interface enclosure for MWR facilities, including provisions for portable payphone connections.

6.0 ALTERNATIVE 3 – POLARIS POINT DIAGONAL OFFSHORE

This site is located at the northern shore of Polaris Point. The pier spans across the existing bay, and is located so the abutments are on solid ground on either end.

6.1 Dredging

The guidance criteria define the required berth for a CVN 68 or CVN 78 as 1,325 feet long x 600 feet wide. Figure N-3 illustrates this for the berthing alternative considered.

6.1.1 Potential Impact to Coral & Mitigation Costs

There will be direct impact to coral related to dredging the turning basin and approach to the berth. Recent coral surveys indicated there is coral present on the north side of the northern point, which is removed under this alternative.

Using the methodology described in Section 2.4-2, the estimated area of coral impact for Alternative 3 is 49,920 m^2 (Figure A-4). Applying a unit cost of \$430/m^2, the coral impact mitigation cost is estimated at \$21,466,000 for Alternative 3. The impact area includes the eastern edge of Big Blue Reef, in a preliminary attempt to capture potential indirect impacts, as described in Section 2.4-2.

6.2 Coastal Engineering Considerations

Results from the initial investigation (see Section 3.1.5) suggest that the extreme wave event just off-shore of the berth face will have a 15.3 foot maximum crest elevation. At this berth alignment at the Polaris Point site the primary wave energy is directed almost perpendicular to the structure rather than along shore. Thus of the three alternatives, this site is the most prone to direct attack from storm waves.

Final design for the piles supported deck may require special mitigations, such as higher deck elevation and/or a deck designed for uplift, as the wave crest elevation is approximately 3.3 feet higher than the deck elevation. For the caisson, the stability of the structure will need to be checked to resist the wave forces crashing against the face. The extent of these mitigation measures can only be determined during final design and after the wave analysis, begun in this study, is calibrated and confirmed and the relative costs for abatement vs. strengthening are evaluated.

6.3 Berthing Structure Alternatives

Either the pile supported wharf or the caisson bulkhead wharf is suitable for the Polaris Point Diagonal Offshore Shore location. While the caisson option could be constructed, additional costs will be incurred to raise the foundation elevations from near -70 feet MLLW to approximately -50 feet MLLW by filling the low spots with gravel. The primary disadvantage here is the total blocking off of the beach from the bay waters. This would create a small tidal pool behind the caissons and an artificial means to ensure flushing of the pool would need to be created. This could be done by proving and alternative connection to the bay.

The sheet pile bulkhead is not considered for this alternative since the 90 foot wide wharf width does not provide adequate stability in a double-wall configuration and the need for a double wall adds significantly to the costs. Traditionally off-shore sheet pile bulkheads were constructed using a series of circular interconnected cellular cofferdams. These have a poor history of seismic performance (due to their reliance on the interlock joints between sheets for resistance against bursting forces) and thus were not considered.

The deck elevation is currently set at +12 feet MLLW. This elevation was chosen to conform to surrounding land elevations (for access and visibility) while still providing a deck elevation that minimizes overtopping (for the caisson options) and potential deck uplift (for the pile-supported deck option). For the pile supported deck option, a higher deck elevation could be selected during final design as an option to reduce (or eliminate) the need for strengthening the deck for wave impact and uplift.

The wharf plan for Alternative 3 is shown in Figure S-4. It is located so the abutments are on solid ground at each end. The deck incorporates all the features of the other alternatives but is longer in order to extend onto the shore.

The typical wharf section is shown in Figure S-5. The deck structure is similar to the marginal wharf alternatives, as described in Section 4.3 above. The piles are larger than the other alternatives in order to provide better lateral capacity and to prevent buckling in the deep water when subjected to wave forces.

The abutment plan and sections are shown in Figure S-6. As discussed above, the wharf is anchored to shore at each abutment. The group of 48-inch pipe piles at each abutment provides the primary lateral resistance. The plan view shows the pile layout and the utility trench extending to shore. All utilities connect to shore at the south abutment. Section A shows the seismic moment frame transverse to the shoreline. This includes three rows of piles and a 4 foot thick concrete slab. Section B shows how the utility trench is incorporated into the deck. Three sides of the abutment have a vertical wall to contain the landside soils as shown in Sections A and B. The north abutment is not shown but is similar to the south abutment.

6.4 Demolition and Site Preparation

Site preparation will require the grubbing and removal of all ground cover for construction of the staging area. This work will also be done for the ramp leading up to the east end of the wharf. This will include the demolition and removal of three minor buildings (totaling approximately 940 square feet) and a watch tower on Polaris Point. There will be some minor roadway removal and possibly re-alignment of utility lines along this portion of roadway. The soil will be scarified and recompacted before the fill material is placed to prevent differential settlement.

6.5 Shoreside Improvements

6.5.1 Staging Area

The Polaris Point Diagonal Offshore Alternative provides for approximately 6.0 acre staging area connected to the side the west side of the back of the wharf for 125 feet (Figure C-3). An additional 25 feet of access can be made available if the watch tower is relocated away from the back of the wharf. From the back of the wharf, the staging area will be sloped landward at 1/2%, but will have a cross slope to the southeast of 1%. The entire area will be paved with asphalt concrete over crushed base. All underground utilities and storm drains, building and light standard foundations will be installed prior to paving.

The layout provides access from Polaris Point Road with a short one-way access lane cut through the apex of the softball field lot. This provides queuing for about 12 vehicles without obstructing Polaris Point Road or the right hand turn-off to the softball diamond. Vehicle denied entry will be have room to back up on to the turn-off road and return back down Polaris Point Road. The driveway entrance/exit is quite a bit longer than that for the former SRF site except that the slope is not as steep.

Therefore, the layout is essentially the same as the Polaris Point Parallel to Shore Alternative. The exception to this is the wharf cut-off wall will be extended along the north side of the staging area to provide access for beach goers to Griffin Beach up to the +2.8 MLLW water line. To provide for a staging area comparable in size to the Polaris Point Parallel to Shore Alternative it is necessary to extend it further to the south. This results in a slightly different drainage plan with the outfall some what further to the south in Inner Apra Harbor.

6.5.2 New Buildings

Building requirements are common for all Alternatives and they are described in Section 2.5. The building locations for the Alternative 3 at Polaris Point are shown on Figure C-3.

6.5.3 Improvements for MWR Services

The Navy MWR area for supporting CVN activities will be situated on a 2.4 acre lot north of the existing baseball field on Polaris Point (Figures G-3 and C-3). The MWR is located about 500 feet north of the access control point for the staging area. There is a 7,200 square foot building pad that will need to be razed before that area can be graded and landscaped for lawn and trees. It is assumed that lawn will be supported by a permanent irrigation system. A 3-inch thick asphalt lot about ½ acre in size will be constructed for locating the following temporary facilities:

- Food and beverage booths
- 500 seating area
- 40 phone bank seats
- Parking for visitor and rental cars (100 stalls)
- Portable restrooms
- Laundry facilities
- Temporary lighting
- Trash dumpsters

The MWR area will need electrical, water, telephone, and sewer connections. The area will be enclosed by a 1,300-foot long chain link fence and will have multiple locking swing gate entry points. ne of the gates will have a permanent turnstile and guard shack. A loop road will be constructed off of the east side of the Polaris Point access road. The loop road will have a 10 foot wide by 300-foot long turnout on the west side to park five buses.

6.5.4 Security

Due to the orientation of the wharf and the dredging required at the end of the point, the existing guard tower will need to be demolished. A replacement tower is shown at the back side of the east end of the wharf. It is planned that access to the tower will be from the wharf.

To provide direct access to this tower, and additional access to the wharf and especially to the storm bollards on the east end of the wharf, an auxiliary access road is shown at Polaris Point. The spacing between the storm bollards is 20 feet. Therefore, there will be room for vehicle access. The main entrance has a sidewalk and pedestrian gate for enclave control, but this auxiliary roadway could also serve this purpose. There will be the same security features (gates, traffic spikes, retractable bollards, and guard booth) installed at this location as at the main entrance to the staging area. In addition, the layout provides for easy turn around for vehicle denied access.

6.5.5 Stormwater Drainage Systems

Surface flow is directed toward the west and south perimeters of the staging area and is intercepted by a concrete swale. The layout of the staging area intercepts surface flow from the southeast. Therefore, a catch basin is also featured to intercept this flow. (However, more refined topographical and planimetric information may demonstrate that this catch basin may be eliminated and the total design flow reduced accordingly.) The storm drain path is the same alignment as the swale, southward and then westward. The cyclonic separator is located in the southwest corner of the staging area and the outfall is located on the east end of the channel between the Apra Inner and Outer Harbors. Armor rock is featured from the back of the wharf to about 250 feet southward along the channel. The rock configuration is the same as for the Polaris Point Parallel to Shore Alternative. However, additional rock is planned on the east side of the staging area at the west end of Griffin Beach, to protect the concrete cut-off wall return from undercutting action by waves.

6.6 Waterside Security

Criteria for placement of floating PSB are provided in Section 2.5. The type of barrier will be selected during final engineering design. PSBs will be stored when not deployed for the CVN in the Inner Harbor to reduce exposure to wave action and reduce congestion in the Outer Harbor. The clump anchors for the barriers will be kept on station and a small marker buoy will be attached to the buoy as well as being tethered to the submerged anchor chain. Navy response boats for security deployment will be stationed elsewhere in Apra Harbor. An Electronic Security System on the landside and an Electronic Harbor Security System on the waterside will be provided as described in Section 2.5 above.

6.7 Collateral Equipment

Collateral equipment such as power cables, ship-to shore conveyor, mooring lines, and material handling (forklifts) will be stored in the Port Operations Support Building, when not needed. Fenders will be permanent installations on the wharf and the camels will be moved to the Inner Harbor to reduce exposure to wave action when not deployed for the CVN.

6.8 Utilities

6.8.1 Steam System

Except for lengths of piping from the wharf structure and water source to the steam production plant, there are no differences in terms of Steam systems between this Alternative and that described for Alternative 1, Former SRF.

6.8.2 Pure Water System

Except for lengths of piping from the wharf structure and water source to the pure water production plants, there are no differences in terms of Pure Water systems between this Alternative and that described for Alternative 1, Former SRF.

6.8.3 Compressed Air

Except for lengths of piping from the wharf structure and to the compressed air production plants, there are no differences in terms of compressed air systems between this Alternative and that described for Alternative 1, Former SRF.

6.8.4 Bilge Oily Waste (BOW) System

Similar to the parallel berthing alignment (refer to discussion in Section 5.8.4), a permanent BOW collection and treatment system will also be required for the diagonal alignment. The configuration of the BOW system within the staging and wharf areas will be similar to that shown for the parallel alignment on Figure M-6.

6.8.5 Wastewater System

Improvements to the landside wastewater infrastructure will be similar for either the parallel or diagonal berthing alignments. Refer to Section 5.8.5 for the discussion on the proposed improvements. The configuration of the ship wastewater collection ashore (SWWCA) system located in the staging and wharf areas will be similar to that shown for the parallel alignment on Figure M-7.

6.8.6 Potable Water System

Similar to the parallel berthing alignment, no major water system improvements will be required for this option. Water system improvements will be limited to the construction of a new 8-inch service lateral to the berthing site and the associated pierside water outlets. The configuration of the water lines located in the staging and wharf areas will be similar to that shown for the parallel alignment on Figure M-9.

6.8.7 Power

The electrical infrastructure required for the diagonal berth alignment will be similar to the parallel to shore berth alignment at Polaris Point.

6.8.8 Communications System

The communications system infrastructure required for the diagonal berth alignment will be the same as for the parallel to shore berth alignment.

7.0 COMPARISON OF ALTERNATIVES (PROS/CONS)

The advantages and disadvantages of each project site are outlined below, and Table 7-1 at the end of this chapter summarizes the pros and cons.

7.1 Dredging

Alternative 1 – Former SRF would result in the least volume of dredging.

Estimated coral impact mitigation costs range from $19,566,000 for Alternative 1 to $23,068,000 for Alternative 2 (full impact).

There are options for the management of dredged material once it is removed from the ocean. These options may include ocean disposal (pending site designation by USEPA), upland placement and beneficial use. The dredged material will undergo rigorous testing to determine the most suitable option. Segregation of dredged materials and multiple management options may be required for the dredged material if test results vary throughout the dredge footprint. These decisions will be made during final design and documented in the Army Corps of Engineers permit application. Upland placement is the disposal assumption used for the cost estimates, and it is likely to be the most expensive option.

7.2 Demolition and Site Preparation

All three alternatives will require the demolition of existing structures, removal of some road surfaces, and minor relocation of related utilities. At Polaris Point, demolished structures will be replaced in-kind outside of the staging area sites. Based on conversations with base personnel, the metal buildings at the former SRF project site are assumed to be removed as part of the Guam Shipyard footprint reduction. These structures will not be replaced. Beyond this, Alternative 1 will require the removal of the end of one of the SRF finger piers and the obsolescence of both piers slips, as they will be filled in. Therefore, there will be a slight disadvantage in not having these slips available for future use. The slips will not be replaced. This has not been evaluated in economic terms since with the proposed reduction of the Guam Shipyard footprint; these slips have no foreseeable purpose. Alternatives 2 and 3 will require the removal of the watchtower on Polaris Point. This will be of minor consequence, since pairs of new watch towers are indicated for all Polaris Point Alternatives to protect the asset.

After demolition all sites will be prepared in the same manner and selected material from the project dredging will be used to construct the elevated grades for the staging areas. The size of the staging area to be paved for all the alternatives is relatively the same at approximately 6 acres. Although the layouts for Alternatives 2 and 3 are almost identical, Alternative 3 requires about half as much fill because the top of pavement elevations away from wharf are set lower. This is done in part to reduce the surcharge behind the proposed seawall along the length of Griffin Beach and because the staging area extends further south.

From the standpoint of meeting the criteria for staging area size, proximity to the wharf, and security, all three sites are comparable. However, Alternatives 1 and 2 are preferable because they afford a longer access area that is directly alongside the back of the wharf. Alternative 3 access is limited to the far ends of the wharf. Thus more congestion of equipment and personnel in these locations during times of high activity would be expected.

Alternative 1 relies on a longer drainage system, which has two outfalls, while the other alternatives each have only one outfall. Therefore, from a water quality discharge permitting standpoint, the Alternatives 2 and 3 are more preferable.

The costs for the civil improvements differ for a variety of reasons. Alternative 2 has the overall highest cost due to more earthwork. Alternative 1 has a higher cost than Alternative 3 because of additional storm drainage needs and somewhat more earthwork.

7.3 Structural Design

The marginal wharf alternatives at the former SRF and Polaris Point Parallel to Shore sites are very similar, but the Polaris Point site is more exposed to storm waves, as noted below. This may result in higher costs at the Polaris Point alternatives for special mitigation measures. The sites are suitable for either the pile-supported deck option or the tied-back sheet pile bulkhead option, with the former being preferred for better seismic performance while the latter may be more resistive to extreme wave event and less expensive from an initial construction point of view. The caisson option is not recommend due to extensive additional costs without any significant additional benefits over the other options.

The diagonal offshore alternative at Polaris Point is the least preferred alternative related to structural design. Construction in deeper water will result in larger diameter piles, and very large concrete abutments are required to anchor the structure to land at either end. More of the structure will be constructed using expensive water-borne equipment than with the other two alternatives. This site is suitable for either the pile supported deck option or the concrete caisson option, with the former being preferred for better seismic performance and lower costs. The sheet pile bulkhead option is not recommended due to historically poor seismic performance. All structures will have to be designed to resist the forces of wave impact.

7.4 Coastal Engineering Considerations

The former SRF site is the preferable site because the primary wave energy is directed alongshore rather than perpendicular to shore. This suggests that rock dike wave protection could be installed at the northeast end to mitigate wave impact under the deck. At the Polaris Point site the primary wave energy is directed more to perpendicular to shore rather than along shore. This site is thus more prone to direct attack form storm waves, and the diagonal alternative is the most prone to direct attack from storm waves of the three.

7.5 Shoreside Improvements

The shoreside improvements are basically equal for all alternatives with regard to construction and related costs.

There are potentially additional security concerns for the former SRF site because of the adjacent commercial ship yard, which could employ foreign workers and/or repair foreign vessels.

The Polaris Point Diagonal Offshore berth is not contiguous to land, and thus the operations will be less efficient than the marginal wharf alternatives. In addition, Polaris Point is not contiguous with Main Base, and thus visiting sailors will need to be bussed to the facilities at Main Base.

7.6 Waterside Security Improvements

Waterside security improvements are essentially the same for all alternatives. The depth of water for Alternative 3, Polaris Point Diagonal Offshore makes installation slightly more costly.

7.7 Collateral Equipment

Collateral equipment will be the same for each alternative. Access to Alternative 3, Polaris Point Diagonal Offshore from the ends only (rather from adjacent backlands for the other alternatives) makes handling the collateral equipment slightly more labor intensive.

7.8 Utilities

7.8.1 Steam, Compressed Air, and Pure Water

There is a possible opportunity to re-use the existing steam plant at SRF, provided certain repairs, improvements, and capacity-expansion projects are made. Some of these are already being programmed, while others await approval. However, for the currently planned projects, capacity expansion is not included. The existing plant is unable to accommodate both the current demand and the new CVN demand. The costs for a completely new system and the costs for upgrades/expansion of the existing system are considered essentially equivalent at this level of study. Therefore, it is assumed that new facilities will need to be constructed for all alternatives, thus there are no distinguishing pros/cons for either site.

7.8.2 Bilge Oily Waste (BOW) System

For the BOW system improvements, there are no distinct pros/cons for either site since the improvements will be localized at the berthing location (i.e. none/minimal improvements outside of the staging area) and the same improvements are required for both sites.

7.8.3 Wastewater System

For the Wastewater system improvements, the Polaris Point site may be disadvantaged because a portion of the force main route will be outside of Navy property. The impact this will have on the project is uncertain at this time. The work will need to be coordinated with GovGuam and may become a "non-issue" at the time of project design and construction.

The overall project cost is higher at Polaris Point primarily because the length of forced mains that must be constructed far exceed those required at former SRF site.

However, an advantage to the Polaris Point site is that the improvements proposed will increase the capacity and improve the reliability of the existing aging wastewater infrastructure, which will be a benefit to other facilities located in Polaris Point and neighboring areas.

The disadvantage of the former SRF site is that this option adds three new submersible pump stations to the wastewater system, compared to one new submersible pump station plus one replacement pump station at Polaris Point. The life-cycle cost for the SRF option will be higher than Polaris Point (power requirement, maintenance, etc.).

7.8.4 Potable Water System

For the Potable Water system improvements, there are no distinct pros/cons for either site since the improvements will be localized at the berthing location (i.e. none/minimal improvements outside of the "staging area") and the same improvements are required for both sites.

7.8.5 Power

The electrical power costs between the two berthing sites differ significantly, and it is the need to upgrade the GPA X20 circuit and increased primary 34.5 kV feeder circuit distance that makes the SRF Berth option more expensive from an electrical power standpoint.

7.8.6 Communication Systems

The cost to construct communication system infrastructure; fiber optic, CATV and telephony systems, is greater at the former SRF site. This is because the nearest existing buildings that contain connectivity for fiber optic, telephony and CATV are further from the berth.

Existing infrastructure at the former SRF site is not adequate to support the CVN information system requirements. The nearest Information Transfer Node (ITN) is Building 3169, which contains fiber optic and CATV connectivity only. Closest telephony connection is at Central Office Building 3012. Ductbanks from the former SRF site to these buildings do not exist.

Existing ITN Building 4434 located at Polaris Point near the proposed Berth has capacity to support CVN information system requirements. This building contains connectivity for fiber optic, telephony, and CATV.

Table 7-1 Summary of Pros & Cons for the Alternatives

Alternative 1 - Former SRF		Alternative 2 - Polaris Point Parallel to Shore Alternative 2A (Reduced Impact)		Alternative 3 - Polaris Point Diagonal Offshore	
Pros	**Cons**	**Pros**	**Cons**	**Pros**	**Cons**
GENERAL NOTES					
Lowest overall project cost			Higher overall project cost than Alt. 1		Highest overall project cost
	Demolition required and possible contaminated soils	"Greenfield" site Minimal contamination expected		"Greenfield" site Minimal contamination expected	
	Requires renegotiation of leasehold to reduce Guam Shipyard footprint	Land not encumbered		Land not encumbered	
Contiguous with backlands – allows more efficient operations		Contiguous with backlands – allows more efficient operations			Non-contiguous with backlands – less efficient operations
NAVIGATION, DREDGING and CORAL IMPACTS					
	Port pilots least preferred alignment	Alignment preferred by port pilots	Alt 2A berth has reduced with (440 feet vs 600 feet) at CVN bow		
	Restricts access to drydock AFDB-8 when CVN at berth				
Least dredging overall	Contaminated dredged material, if encountered, may require special handling		Alt. 2 most dredging. Alt 2A reduces dredging by 24% of Alt. 2.	Less dredging than Alt. 2	More dredging than Alt 1
Least direct impact to coral (least mitigation cost)	Closest to Big Blue coral reef	Alt 2A reduces coral impact (lower mitigation cost) vs. Alt 2 and Alt.3.	Alt 2: Highest estimated area coral impacted (mitigation costs). Alt 2A: Saves North Point and reduces estimated mitigation costs vs. Alt 2	Less coral impact (mitigation costs) than Alt 2 or Alt 2A	Higher estimated coral mitigation costs than Alt 1. Dredging removes end of North Point and associated coral

Table 7-1 Summary of Pros & Cons for the Alternatives

Alternative 1 - Former SRF		Alternative 2 - Polaris Point Parallel to Shore Alternative 2A (Reduced Impact)		Alternative 3 - Polaris Point Diagonal Offshore	
Pros	**Cons**	**Pros**	**Cons**	**Pros**	**Cons**
STRUCTURAL and COASTAL CONSIDERATIONS					
Typical pile supported wharf construction		Typical pile supported wharf construction			Unique and more costly structural system
Suitable for both piles supported deck & sheet pile bulkhead	Caissons would be problematic given the extra dredging needed	Suitable for both piles supported deck & sheet pile bulkhead	Caissons would be problematic given the extra dredging needed	Suitable for both piles supported deck & caisson	Steel sheet piles bulkhead not advised
Slightly less exposed than the Polaris Pt. sites to extreme waves			Slightly more exposed than the SRF site to extreme waves		More exposed than the other sites to extreme waves
UTILITIES					
Existing Steam Plant is under the control of Base Operation Support Contractor (BOSC) for the Government. Possible use of existing steam system	Existing air system is under control of Guam Shipyard. Assume new system is required. Existing steam system requires repairs and capacity expansion.		Requires construction of new plant for steam & air		Same as Alt. 2
Lower project cost for wastewater systems.	More pump stations than other Alt.s will result in higher life cycle costs and additional operational requirements.	Proposed wastewater system improvements will increase the capacity and improve the reliability of the existing infrastructure which will benefit other facilities in Polaris Point and neighboring areas.	Part of force main route outside Navy property. Uncertain how this might impact project	Same as Alt. 2	Same as Alt. 2
			Higher project costs for wastewater system due to length of forced mains required		Same as Alt. 2
	Higher project cost for electrical power service	Lower project cost for electrical power service		Same as Alt. 2	
	Higher project cost for communications	Lower project cost for communications		Same as Alt. 2	

8.0 PROJECT CONSIDERATIONS AND COST ESTIMATES

8.1 Project Considerations

8.1.1 Equipment and Material Staging

This project will utilize specialize heavy equipment for construction. Two of the largest pieces are both waterborne and will require mobilization from the West Coast of the U.S. mainland. These are (1) a large floating crane barge with pile driving equipment and (2) a dredger. The floating crane barge will be used to drive the seaward rows of piling. Depending upon size and reach, a land-based rig can drive the first and possibly second landward row of piles for Alternative 1 and 2 and the abutment piling for Alternative 3. The land-based crane can probably be obtained locally. The crane barge could also be used in the dredging of the wharf embankments, placing of quarry-run materials and armor stone. If suction-cutter head hydraulic dredging equipment is mobilized, the crane barge, equipped with a clam-shell or environmental bucket can be utilized to assist in the dredging, especially those areas that the hydraulic dredge can not reach. Other equipment such as smaller cranes, concrete pumps, small barges, tug boats, excavation equipment can be obtained locally.

Local equipment using smaller cranes and excavators on smaller spud-barges has been used typically in Apra Harbor on smaller projects. The Inner Harbor Channel was dredged using such equipment during the MCON P-431, Alpha & Bravo Wharf Improvements. The requirements of this project will, more than likely, preclude the use of such equipment.

This project will utilize non-indigenous materials, including: steel pipe piles and steel shapes, concrete forms, miscellaneous metals, fenders, bollards, steel reinforcing and cement for concrete, asphalt, and mechanical equipment and piping for steam, compressed air, and pure water. Some assembly of these items on Guam will be required. Local aggregates for concrete, road base, asphalt paving, and possibly armor rock may be used. All imported materials will come through either the local commercial port or be specially shipped by barge. Most materials will come from the U.S. West Coast. Special items not subject to the “Buy American” clause may come from Asian sources.

8.1.2 Phasing of CVN 78 Requirements

Structural, dredging, and civil requirements are essentially the same for both the 68 and 78 class CVN, thus there is no opportunity to phase-in the construction for these items. Utility demands for steam, compressed air, and pure water are expected to remain the same, decrease, or be eliminated for the CVN 78 class. Thus, the need for these facilities at the commissioning of the berth remains unchanged

BOW Systems – The design criteria for the CVN 78 call for slightly greater waste quantities than that of the CVN 68. The pumping rate from the vessels is the same for both carrier types. The difference in the average and peak flow rates between the CVN 78 and CVN 68 is less than 10%. Due to the relatively small increase in capacity required for the CVN 78, there is no substantial economic benefit to phase the design and construction of the BOW system.

Wastewater Systems – The design criteria for the CVN 68 are greater than or equivalent to that of a CVN 78. Therefore, improvements implemented for the CVN 68 will be applicable for that of the CVN 78.

Potable Water System – The design criteria for the CVN 78 are greater than or equivalent to that of a CVN 68. Therefore, the potable water requirements for a CVN 78 were used to evaluate the existing potable water system. The analysis indicates that the landside water system is capable of satisfying the demands of a CVN 78, thus also complying with the requirements of a CVN 68. The only improvements necessary will be localized at the berthing / staging areas. These improvements will be virtually identical for either the CVN 68 or CVN 78 vessels.

The electrical and communications base infrastructure required to support both the CVN 68 and CVN 78 is similar, with the exception that upgrading the electrical system to accommodate the CVN 78 will require two additional 13.8 kV switchgear sections with associated feeder cables and power receptacles. The 13.8 kV feeder cables for the CVN 78 will be provided in the wharf utility trench, which will be constructed during the CVN 68 project with enough capacity to support the additional cabling.

8.2 Cost Estimates

8.2.1 Cost Estimate Basis and Assumptions

Most costs were derived using average construction methods, materials, labor, and equipment as they would be applicable for construction on the mainland U.S., using actual costs plus 28% for contractor's overhead & profit. Costs thus determined were multiplied by the following factors:

Design contingency	1.1000
Area Cost Factor	2.6400
Escalation	1.0867
Total Factor	3.1650

Costs provided by the U.S. Navy were assumed to be time-independent, Guam specific costs and thus not multiplied by the factors. An example of these costs is mitigation cost for potential coral impact.

When available, unit production rates, materials, labor costs, crew sizes, material costs, and equipment costs were obtained from *RS Means Heavy Construction Cost Data, 21st edition, 2007*. When required (particularly for marine work), crew costs and production rates were built-up using industry standard rates and productivity, assuming work along the Gulf Coast (which is normally regarded as having and area cost factor = 1). In some cases, *RS Mean's* rates were modified based upon experience.

For comparison with *RS Means*, a number of key rates (e.g., concrete, reinforcing, formwork, piles) were developed using Guam labor rates and productivity, material purchase on U.S. West Coast (where applicable) and transportation/freight to Guam, additional OH and profit, and other local factors. These were compared with *RS Means* rates (average U.S. mainland) multiplied by the Area Cost Factor and Escalation. A significant difference was identified, where the factored U.S. Mainland rates were much higher than the local Guam rates. The difference was attributed to a market factor which accounts for the unmitigated increases in costs in Guam due to: disparities in supply and demand, labor shortages, shipping bottlenecks, shortage of local equipment, and expected boom in the local economy.

Estimated construction cost for dredging includes dredging (clamshell), barge transport and placement at an upland dewatering site. Dredge volumes are based on dredging to a depth of -49.5 feet plus two feet of overdepth dredging within the footprint of the channel, turning basin and berthing area. Overdepth dredging is limited to dredging below -49.5 feet only in those areas currently shallower than -49.5 feet. Methodology for assigning costs for coral mitigation is described in Section 2.2-4. The unit cost is $\$430/m^2$. Dredging includes preparation of temporary slopes for the berths and adjacent areas ready for placement of quarry-run and armor stones.

Quarry run rock materials and armor stones for all Alternatives are assumed to be locally obtainable and hauled over road by conventional trucks from a quarry on Guam.

Estimated construction costs for the wharf structures were based upon both measured and assumed quantities and the unit prices developed as described above. The average pile length was assumed since site specific subsurface information is not available. Actual lengths could be quite different. Steel piles are assumed to be shipped in convenient lengths with a factory coating and field-spliced on site. Piles are driven from a floating rig. Cost of deck construction includes falsework and forming, reinforcing, concrete placement, and finishing. For Alternative 3, additional construction costs of the two end abutments are included. The wharf structure is assumed complete with the placement of the bollards, fenders, and miscellaneous metals.

The majority of the civil site work is routine construction: grubbing, grading and drainage, base materials, paving, trenching and backfilling for underground utilities and storm water drainage systems, fencing, and traffic control. Imported fill is required for the project to raise surrounding grade to the level of the back edge of the wharf (Alternatives 1 & 2), and to provide a protected and level area for Alternative 3. Fill materials are assumed to be suitable reclaimed dredged materials. The work will also include the construction of various buildings and plants for utility service, plus guard booths, and watch towers. Work is measured using the site development drawings and the various units indicated in the cost estimate.

BOW Systems – budgetary costs developed for these improvements were based on bid tabulations and construction costs of existing BOW collection and treatment systems on Guam. The cost data were modified to reflect various differences to achieve an appropriate cost that would be consistent with the proposed improvements. Based on the source of the data, applicable escalation rates were applied to provide costs consistent with the current construction environment in Guam.

Wastewater and Potable Water Systems – budgetary costs developed for these improvements were based on bid tabulations and construction costs obtained from similar infrastructure improvement projects in Guam. The cost data were modified to reflect various differences to achieve an appropriate cost that would be consistent with the proposed improvements. Based on the source of the data, the applicable escalation rates were applied to provide costs consistent with the current construction environment in Guam.

Electrical cost estimates are based on engineering experience with similar infrastructure projects recently developed on Guam. Costs are loaded with prime and subcontractor markups and reflect actual Guam construction costs.

Construction Phasing for Incremental Funding

A construction schedule for design-build was assumed at 48 months for Alternative 1 - Former SRF and Alternative 2 - Polaris Point Parallel to Shore options and 54 months for Alternative 3 -

Polaris Point Diagonal option. The starting point for each was assumed at mid-fiscal year, thus the schedule covers five (5) fiscal years. An additional 6 months is required for the construction of the wharf in Alternative 3 due to its increase length, deep water piling, and abutments at each end.

The various major elements of work for Alternatives 1 and 2 were scheduled over the duration indicated as described below. Work for Alternative 3 is similar except that the wharf construction continues into the 5th year. The construction phasing is summarized in Table 8.2-1.

Table 8.2-1 Construction Phasing for Incremental Funding

Year 1 (6 mos.)	Activity
Dredging	Design
Wharf Construction	Design (75%)
Site Work	
Buildings	
Steam, Air, Pure Water	
Bilge Oily Waste Systems	
Wastewater Systems	Design
Potable Water System	
Electrical Utilities	
Year 2 (12 mos.)	
Dredging	Mobilize dredge; dredge berth, turning basin, and fairway (25%); place quarry run on berth slope
Wharf Construction	Complete design; order piling; mobilize; place armor stone (42%); drive pipe piling (29%); construct deck (8%)
Site Work	Design
Buildings	Design (50%)
Steam, Air, Pure Water	Design (33%)
Bilge Oily Waste Systems	Design
Wastewater Systems	PS Equipment and Material Ordering; Construct Pump Stations (33%)
Potable Water System	
Electrical Utilities	Design; Construct Duct System (17%)
Year 3 (12 mos.)	
Dredging	Complete dredging of fairway; navaids; closeout
Wharf Construction	Complete placing armor stone; complete driving pipe piling; construct deck (58%)
Site Work	Mobilization; demolition; earthwork; storm drain; substructures
Buildings	Complete design; mobilization & material procurement; construct air, water, & steam buildings (75%)
Steam, Air, Pure Water	Complete design; mobilization & material procurement; install mechanical systems (13%)
Bilge Oily Waste Systems	BOWTS Equipment & Material Ordering; Construct BOWCA and BOW
Wastewater Systems	Complete pump stations; construct FM & sewers (50%); construct SWWCA

Table 8.2-1 Construction Phasing for Incremental Funding

Potable Water System	Construct pier-side water lines & outlets; supply lateral to pier; commissioning & closeout
Electrical Utilities	Complete duct system; cable procurement; substation and wharf equipment procurement
Year 4 (12 mos.)	
Dredging	
Wharf Construction	Complete deck; install fender piles & fenders; close out (Alts 1 & 2)
Site Work	Paving; security & fencing (67%)
Buildings	Complete air, water, & steam buildings; construct transit shed; construct misc. bldgs (33%)
Steam, Air, Pure Water	Install mechanical (93%)
Bilge Oily Waste Systems	Construct BOWTS; commissioning & closeout
Wastewater Systems	Complete FM & sewers; commissioning & closeout
Potable Water System	
Electrical Utilities	Construct electrical; commissioning & closeout
Year 5 (6 mos., 12 mos. Alt 3)	
Dredging	
Wharf Construction	Complete deck; install fender piles & fenders; close out (Alts 3 only)
Site Work	Complete all remaining work & close out
Buildings	Complete other buildings & close out
Steam, Air, Pure Water	Complete mechanical installation; start up and commissioning; close out
Bilge Oily Waste Systems	
Wastewater Systems	
Potable Water System	
Electrical Utilities	

To complete the work according to the schedule, the following funding requirements are necessary (Table 8.2-2), expressed as percentage of total funds.

Table 8.2-2 Incremental Funding Over Construction Period

Year	Alt 1	Alt 2	Alt 3
1	6%	6%	6%
2	34%	34%	29%
3	38%	38%	33%
4	20%	20%	25%
5	2%	2%	7%
Total	100%	100%	100%

8.2.2 Phasing of CVN 68 and CVN 78 Requirements

Structural, dredging, and civil requirements are essentially the same for both the CVN 68 and CVN 78, thus there is no opportunity to phase-in the construction for these items. Utility demands for steam, compressed air, and pure water are expected to remain the same, decrease, or be eliminated for the CVN 78 class. Thus, the need for these facilities at the commissioning of the berth remains unchanged.

The demands for BOW, wastewater and potable water systems are also the same for CVN 68 and CVN 78 vessels, and thus no project phasing is possible.

The electrical and communications base infrastructure required to support both the CVN 68 and CVN 78 is similar, with the exception that upgrading the electrical system to accommodate the CVN 78 will require two additional 13.8 kV switchgear sections with associated 15 kV feeder cables and power receptacles. The cost of a future project to provide two additional 13.8 kV switchgear sections, associated 15 kV feeder cables, and power receptacles is approximately $500,000.

9.0 CONCLUSIONS AND RECOMMENDATIONS

There are advantages and disadvantages to locating the CVN berth at the former SRF site or at the Polaris Point site. One common conclusion is the pile supported marginal wharf (Alternatives 1 and 2) is the preferred structural system. The diagonal pier at Polaris Point is the least preferred alternative because of seismic considerations, inconvenient berth access, high structural costs, exposure to extreme wave events, and direct dredging impact to the northern tip of Polaris Point.

Under Alternative 2, dredging removes of the northern tip of Polaris Point and associated coral; therefore, this alternative is less preferred than Alternative 2A, which specifically avoids this loss of coral. Alternative 2A and Alternative 1 can be viewed as comparable. The primary differences, from the engineering perspective, are:

- Electrical Power Costs, which are higher at the former SRF site
- Dredging Costs, which are higher at the Polaris Point site
- Wastewater Costs, which are higher at the Polaris Point site

The results of this engineering investigation indicate that Alternative 1, Former SRF, is the lowest cost alternative. This is primarily due to the differences in dredging volumes and the estimated coral mitigation costs.

A sediment sampling and analysis plan will be completed as a requirement to obtain a dredging permit. Soil contamination, if present, will be discovered during this process. If the soils are found to be contaminated, project costs may have to be adjusted.

Ultimately, final site selection will be influenced by multiple factors, many of which are outside the scope of this study. Examples are: CVN repair/maintenance. on and off-base traffic, sailor “Quality of Life,” AT/FP, safety and drydock access.

Recommendations:

Because impact to coral is a factor in site selection, the coral reef stakeholders (agencies) were asked to review the project footprints and propose a rough estimate of monetary cost per square foot of direct impact to coral. The coral mitigation costs presented reflect stakeholder “worst case scenario” input of $430 per square meter of impact. It is recommended that agencies and the Navy continue to work together to reduce the worst case cost scenario.

Recommendation for Additional Studies:

Additional studies and investigations are required to complete the final design. Other studies could be conducted to provide alternatives to the proposed concepts of this study. The studies are described below:

- A site specific CVN Dredge Depth Study will be required to be performed by NAVFAC LANT CIENG/NSWCCD and coordinated with NAVSEA 08, AIRPAC, and PEO Carriers.
- Complete a localized geotechnical investigation at the selected site for purposes of finalizing pile lengths and determining subsurface conditions in preparation for final design.

- Prepare a dredge material disposal study to compare various options for beneficial reuse of the materials (including that already identified in this project), identifying possible users or uses on other projects, in order to minimize ocean disposal. Study should also consider methods of uplands disposal of contaminated but non-hazardous materials, possibly by incorporating such materials into the project.
- Complete additional detailed and calibrated coastal engineering studies, including: a) deployment of instrument at the site to monitor actual conditions for calibrating numerical models; b) dynamic berthing analysis for operating conditions; c) final determination of wave heights, run-up, and impact for pile-supported structures.
- For Alternative 1, complete a site-specific hazardous materials subsurface investigation immediately on and off-shore in the vicinity of the proposed wharf. This may be combined with the sediment sampling plan required to obtain dredging permits.
- For Alternative 1, as may be required, complete an evaluation of the benefits and costs of rotating the AFDB-8 one hundred eighty degrees so that access to the dock is from the west. This will mitigate any concerns that this site negatively impacts the operator of the dry dock or has security concerns.
- Prepare a report detailing the criteria, requirements, and configuration of the Electronic Harbor Security Systems (EHSS) for the selected site, including integration of such system into current and future port-wide security systems.
- During final design stages, complete periodic reports that 1) refine and update the project schedule, 2) identify logistic concerns, and 3) identify critical resource usage of this project against the background of all other projects expected to proceed forward.

Other studies that could be of benefit include:

- Additional evaluation of innovative structural concepts, like floating piers.
- Performance-based interpretation of CVN berthing requirements.

10.0 REFERENCES

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TECHNICAL DRAWINGS LIST

G-1 CVN Berth at Former SRF
G-2 Marginal CVN Wharf at Polaris Point
G-3 Diagonal CVN Wharf at Polaris Point

N-1 Berthing Alternative 1 – Former SRF
N-2 Berthing Alternative 2 – Polaris Point Parallel to Shore
N-3 Berthing Alternative 3 – Polaris Point Diagonal Offshore
N-4 Channel Alternative 1 – Minimum Radius Channel Bend
N-5 Channel Alternative 2 – Optimal Radius Channel Bend
N-6 Channel Alternative 3 – No Channel Bend
N-7 Berthing Alternative 2A – Polaris Point Parallel to Shore
N-8 Aids to Navigation
N-9 Proposed Drydock Relocation
C-1 Alternative 1 – Former SRF Facility – Civil
C-2 Alternative 2 – Polaris Point Parallel to Shore – Civil
C-3 Alternative 3 – Polaris Point Diagonal Offshore – Civil
S-1 Alternative 1 – Former SRF Facility - Wharf Plan
S-2 Alternative 1 & 2 – Former SRF Facility – Wharf Section
S-3 Alternative 2 – Polaris Point Parallel to Shore – Wharf Plan
S-4 Alternative 3 – Polaris Point Diagonal Offshore – Wharf Plan
S-5 Alternative 3 – Polaris Point Diagonal Offshore – Wharf Section
S-6 Alternative 3 – Polaris Point Diagonal Offshore – Abutment Plan & Sections
M-1 Apra Harbor Naval Complex Wastewater System Schematic
M-2 Former SRF Facility Alternative Bilge Oily Waste System Improvements
M-3 Former SRF Facility Alternative Wastewater System Improvements (1 of 2)
M-4 Former SRF Facility Alternative Wastewater System Improvements (2 of 2)
M-5 Former SRF Facility Alternative Potable Water System Improvements
M-6 Polaris Point Alternative Bilge Oily Waste System Improvements
M-7 Polaris Point Alternative Wastewater System Improvements (1 of 2)
M-8 Polaris Point Alternative Wastewater System Improvements (2 of 2)
M-9 Polaris Point Alternative Potable Water System Improvements
M-10 Alternative 1 – Former SRF Facility – Steam, Pure Water & Compressed Air System
M-11 Alternative 2 – Polaris Point Parallel to Shore – Steam, Pure Water & Compressed Air System
M-12 Alternative 3 – Polaris Point Diagonal Offshore – Steam, Pure Water & Compressed Air System
E-1A Alternative 1 - SRF Berth Electrical Site Plan
E-1B Alternative 1 - SRF Berth 34.5 kV System One-Line Diagram
E-1C Alternative 1 - SRF Berth Communications System Site Plan
E-2A Alternative 2 & 3 - Polaris Point Berth Electrical Site Plan
E-2B Alternative 2 & 3 - Polaris Point Berth 34.5 kV System One-Line Diagram
E-2C Alternative 2 & 3 - Polaris Point Berth Communications System Site Plan
E-3 Berth Substation 34.5 kV Switchgear One-Line Diagram
E-4 Berth Substation 13.8 kV Switchgear One-Line Diagram
E-5 Berth Substation 4.16 kV Switchgear One-Line Diagram
E-6 Berth Substation Building Electrical Equipment Plan
E-7 Berth Substation 34.5 kV Switchgear Elevation

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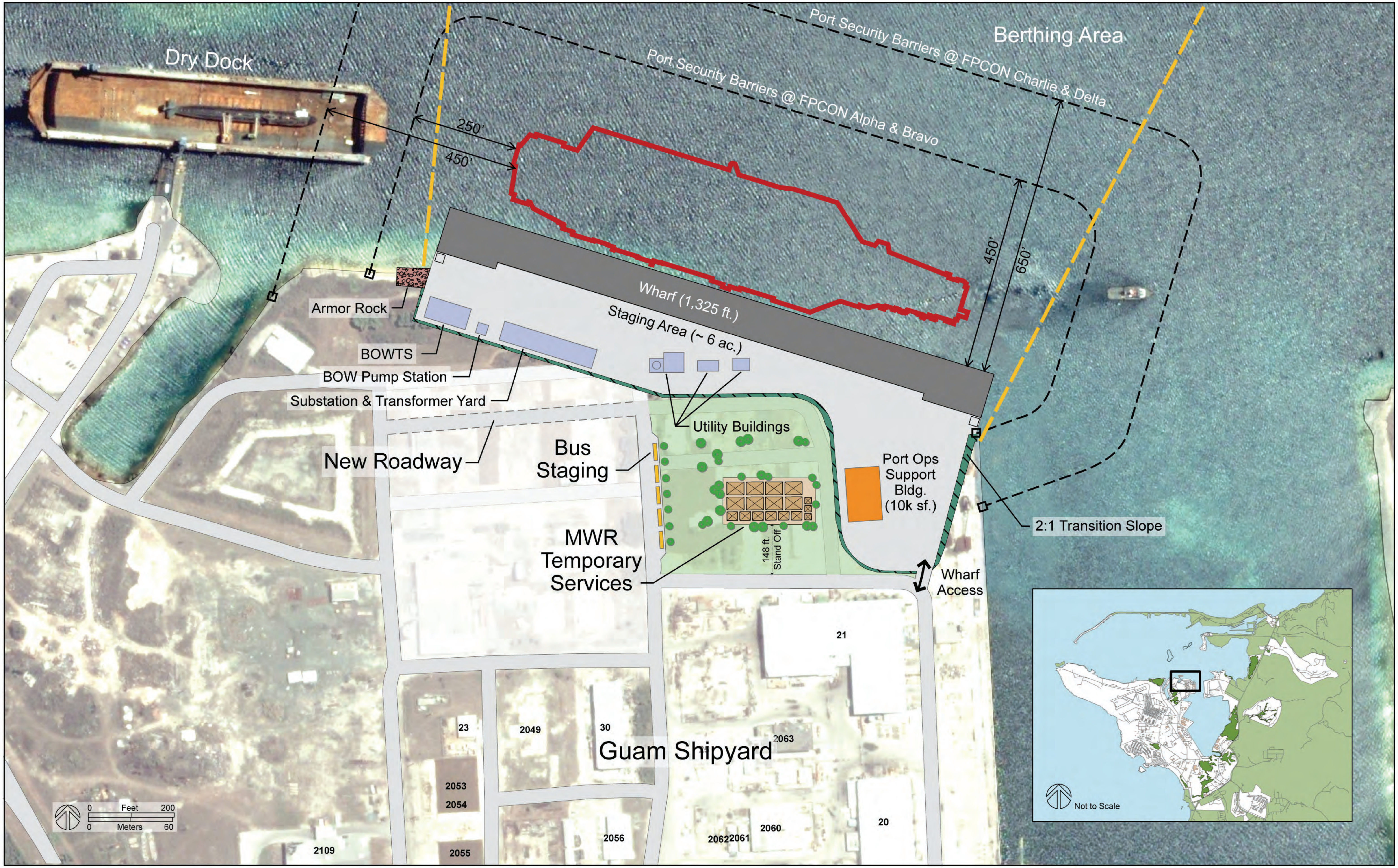
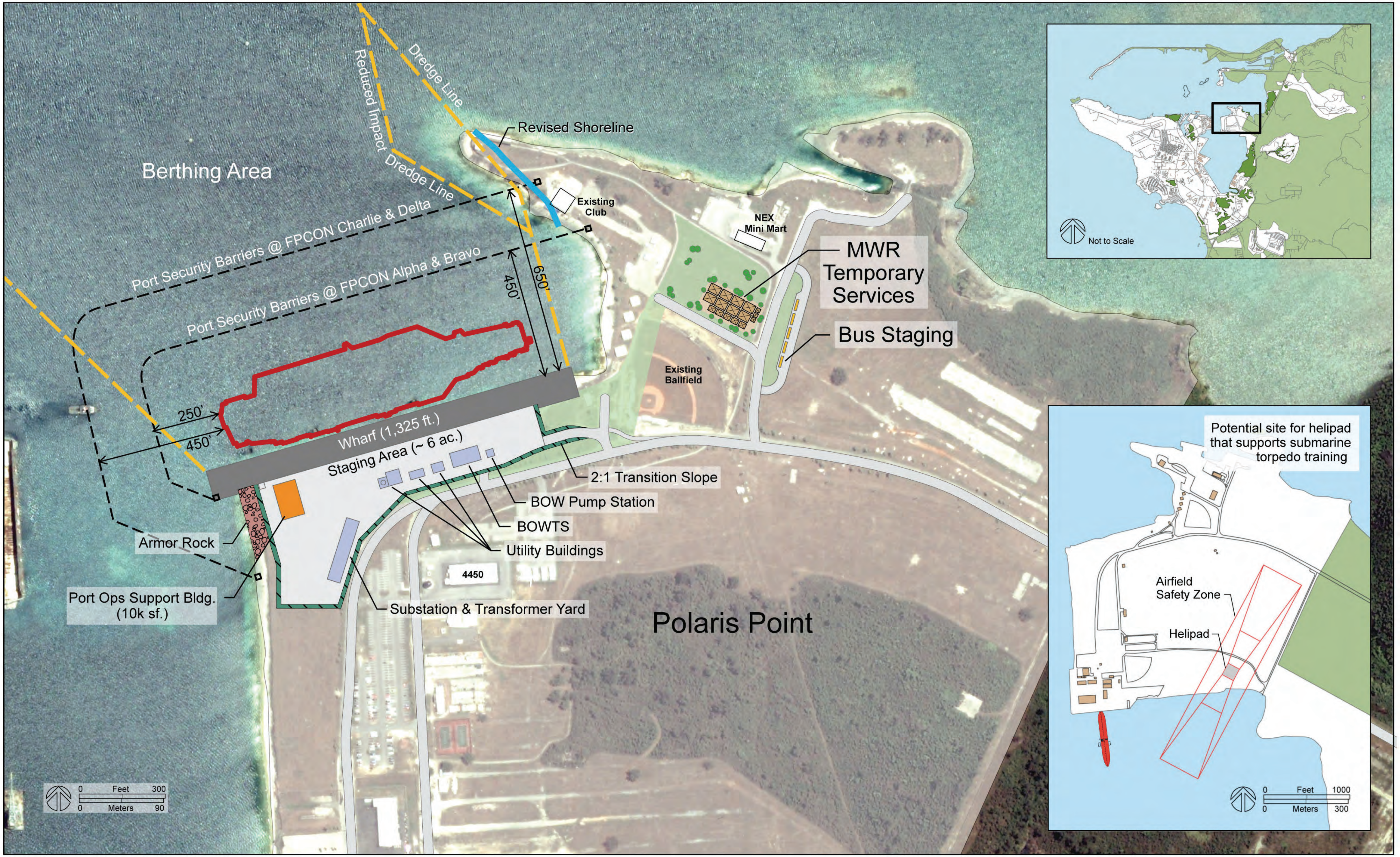
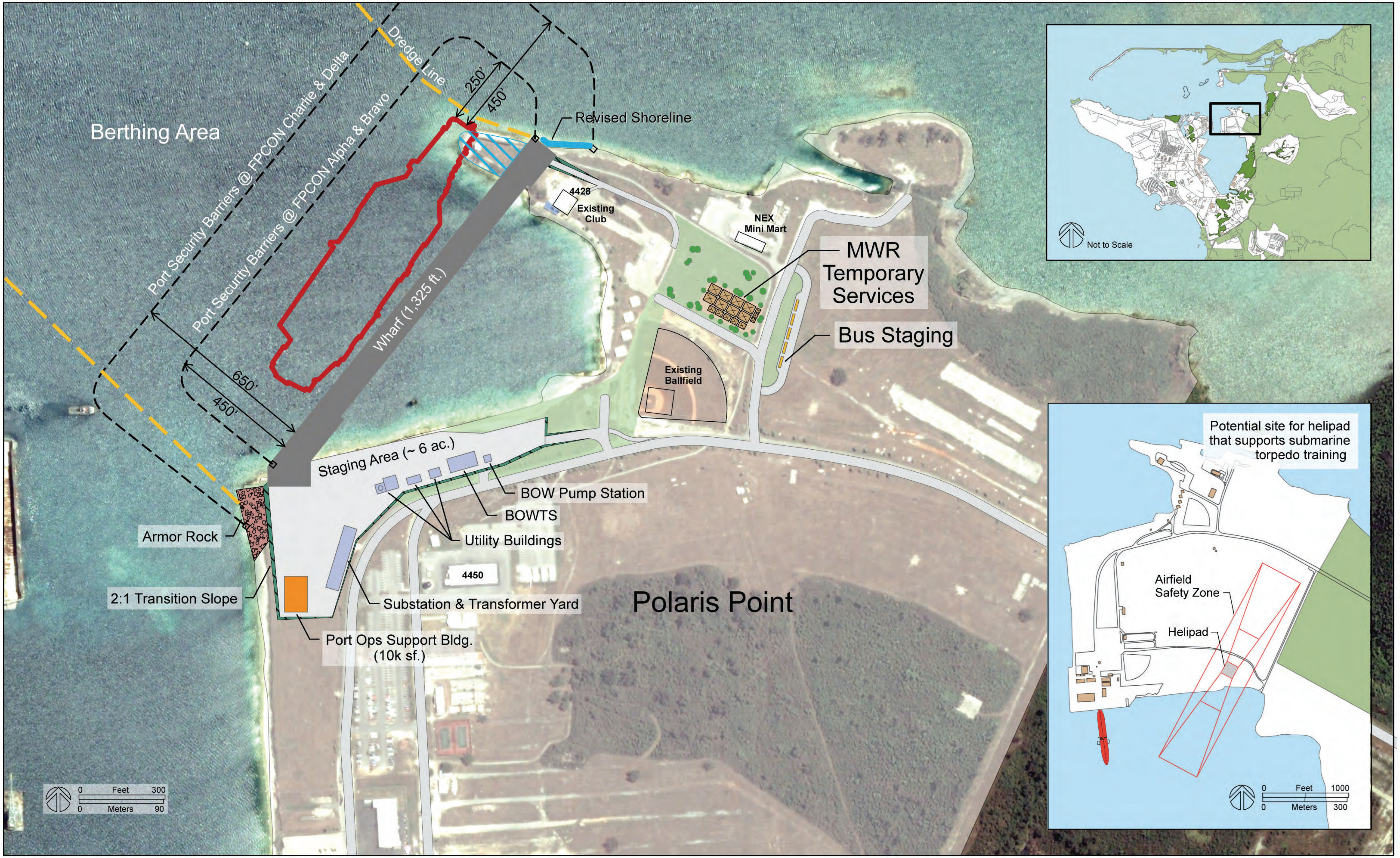


CVN Berth at Former SRF

Helber Hastert & Fee, Planners

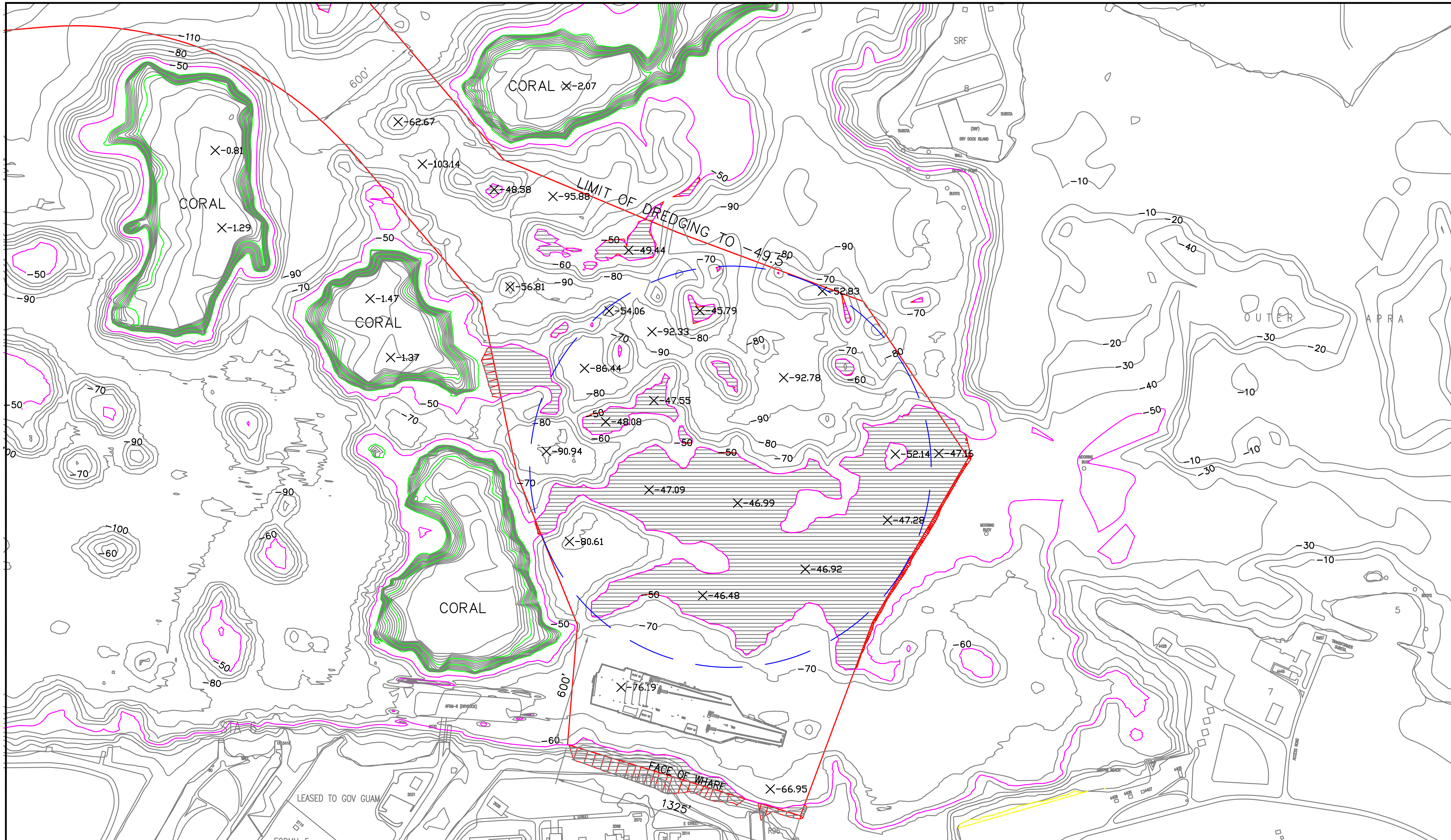


Marginal CVN Wharf at Polaris Point



Diagonal CVN Wharf at Polaris Point

Helber Hastert & Fee, Planners



LEGEND

DREDGE AREA

UPLAND EXCAVATION

CORAL REEFS IDENTIFIED IN AUGUST 2007 CORAL STUDY

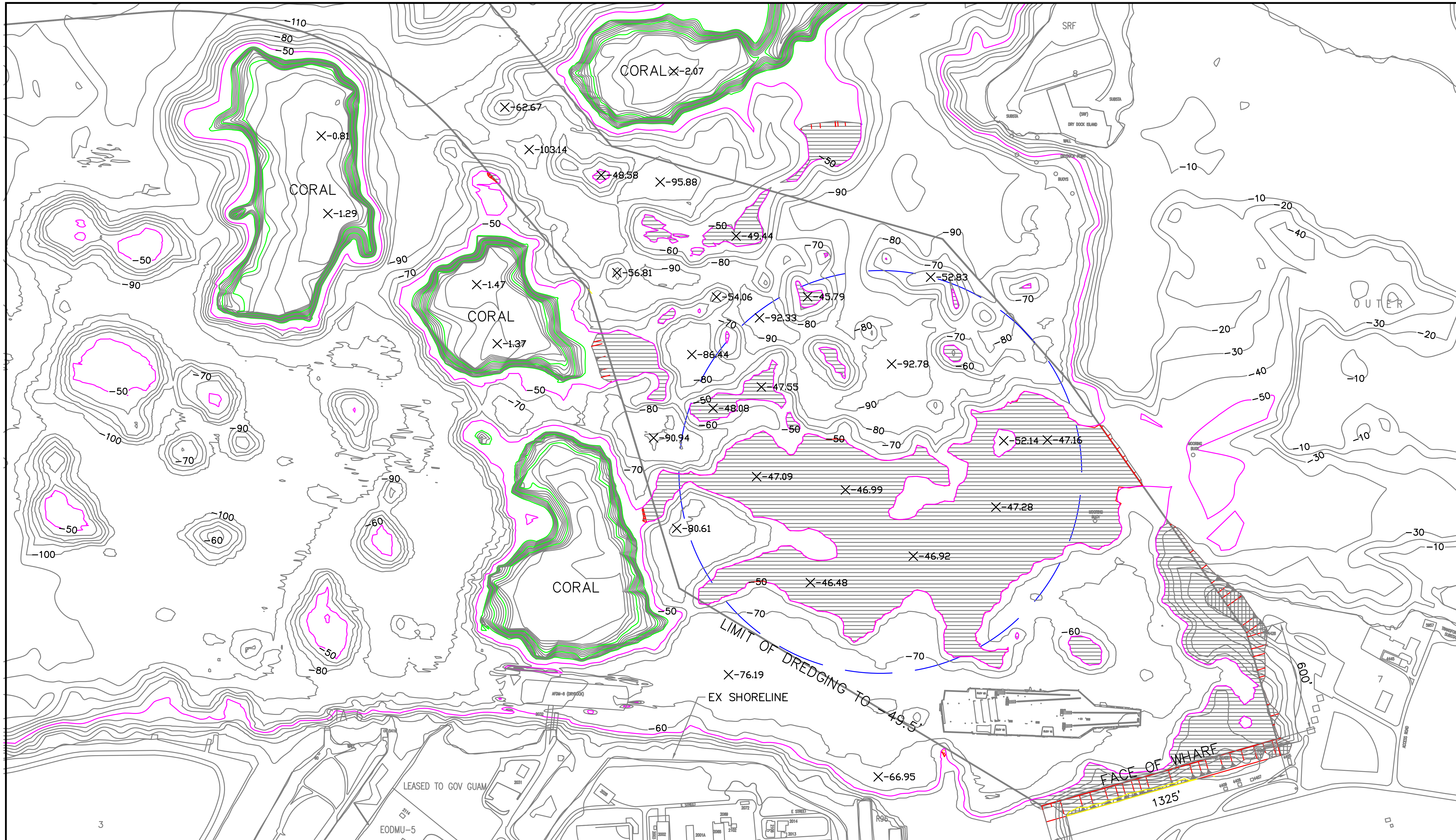
EMBANKMENT DREDGING OR EXCAVATION

MINIMUM TURNING BASIN RADIUS = 1092' (CVN LOA)

0 500 1000 FT.

1"=500'

COMPANY LOGO HPA 6700 E. PACIFIC COAST HIGHWAY SUITE 180 LONG BEACH, CALIFORNIA 90803	NAVFAC	DEPARTMENT OF THE NAVY NAVAL FACILITIES ENGINEERING COMMAND NAVFAC PACIFIC PEARL HARBOR, HI	DATE 5/29/08
		APRA HARBOR GUAM, MARIANA ISLANDS GUAM CVN-CAPABLE BERTHING STUDY	FIGURE NUMBER N-1
		ALTERNATIVE 1 FORMER SRF FACILITY	



LEGEND

DREDGE AREA

UPLAND EXCAVATION

CORAL REEFS IDENTIFIED IN AUGUST 2007 CORAL STUDY

MINIMUM TURNING BASIN RADIUS = 1092' (CVN LOA)

EMBANKMENT DREDGING OR EXCAVATION

1"=500' 0 500 1000 FT.

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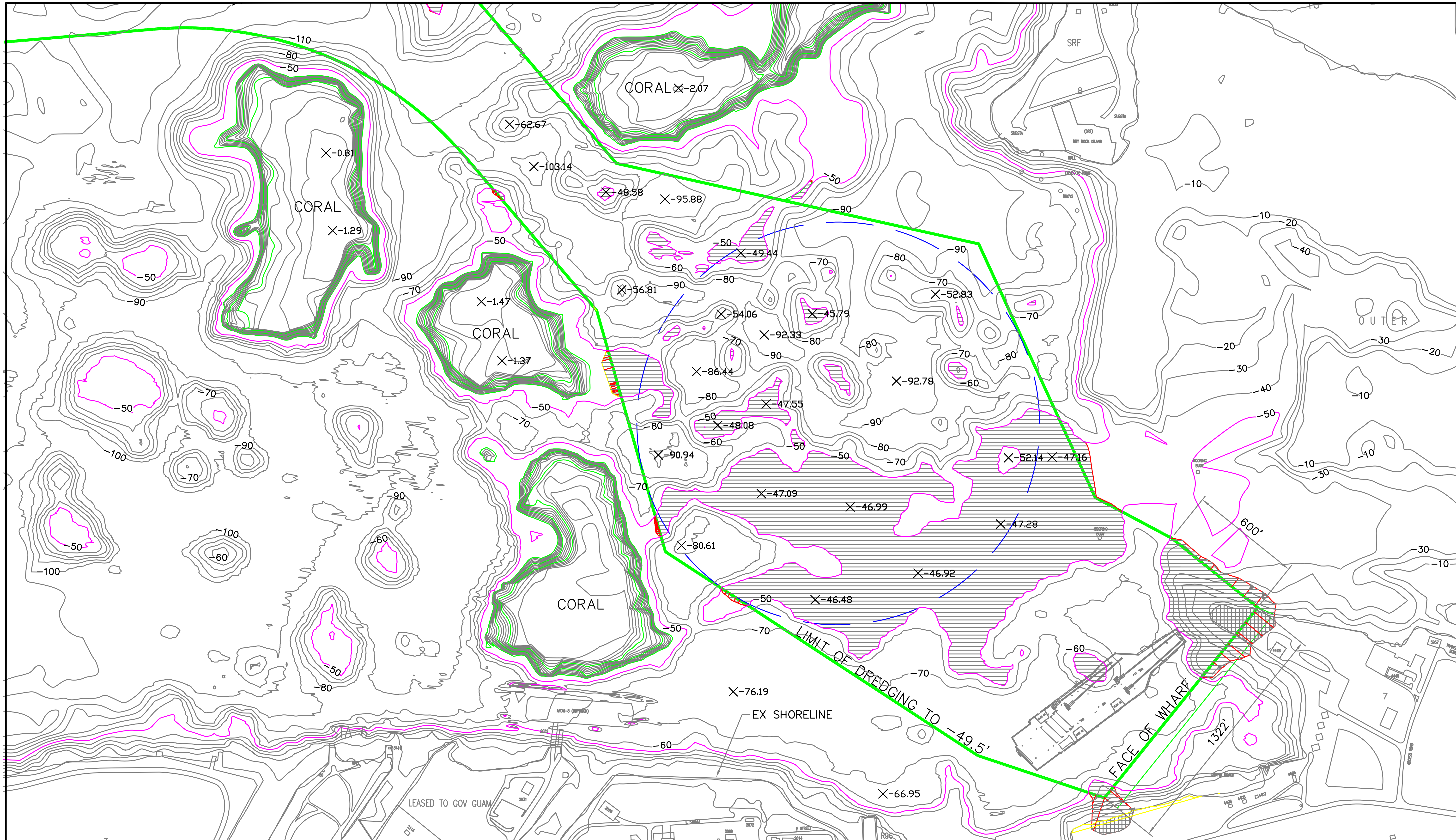
APRA HARBOR — GUAM, MARIANA ISLANDS

GUAM CVN-CAPABLE BERTHING STUDY

ALTERNATIVE 2
POLARIS POINT PARALLEL TO SHORE

DATE 3/14/08

FIGURE NUMBER N-2



LEGEND

DREDGE AREA

UPLAND EXCAVATION

CORAL REEFS IDENTIFIED IN AUGUST 2007 CORAL STUDY

MINIMUM TURNING BASIN RADIUS = 1092' (CVN LOA)

EMBANKMENT DREDGING OR EXCAVATION

0 500 1000 FT.

1"=500'

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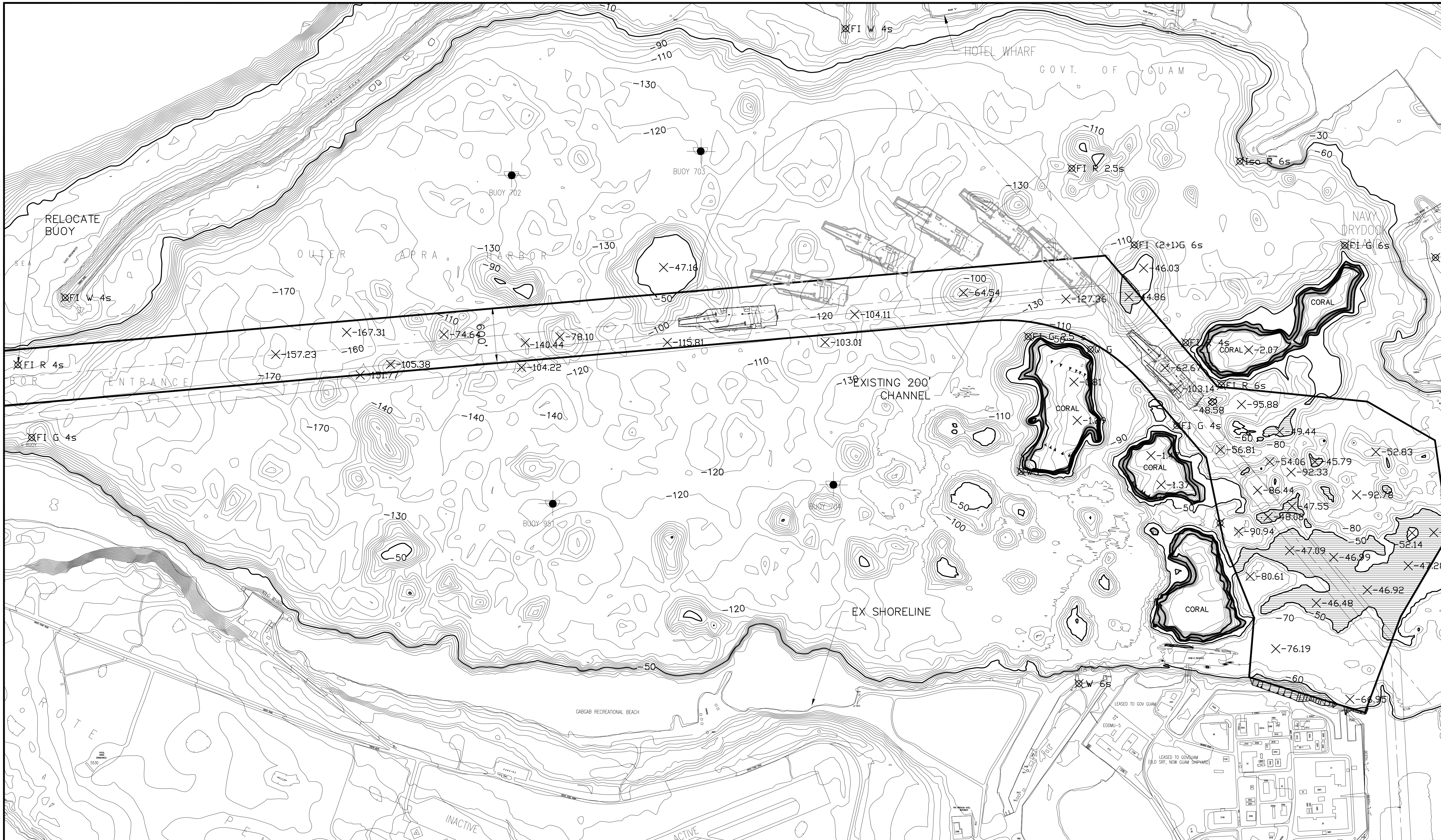
GUAM CVN-CAPABLE BERTHING STUDY

BERTHING ALTERNATIVE 3
POLARIS POINT DIAGONAL OFFSHORE

DATE
5/29/08

FIGURE NUMBER
N-3



LEGEND

DREDGE AREA

CORAL REEFS IDENTIFIED IN AUGUST 2007 CORAL STUDY

EMBANKMENT DREDGING OR EXCAVATION

1"=1000' 0 1000 2000 FT.

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GUAM CVN-CAPABLE BERTHING STUDY

CHANNEL ALTERNATIVE 1
MINIMUM RADIUS CHANNEL BEND

DATE 3/14/08

FIGURE NUMBER N-4

LEGEND

DREDGE AREA

CORAL REEFS IDENTIFIED IN AUGUST 2007 CORAL STUDY

EMBANKMENT DREDGING OR EXCAVATION

1"=1000' 0 1000 2000 FT.

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DEPARTMENT OF THE NAVY — NAVFAC PACIFIC — NAVAL FACILITIES ENGINEERING COMMAND, PEARL HARBOR, HI	DATE 3/14/08	
APRA HARBOR — GUAM, MARIANA ISLANDS	FIGURE NUMBER	
GUAM CVN-CAPABLE BERTHING STUDY	N-5	
CHANNEL ALTERNATIVE 2 OPTIMAL RADIUS CHANNEL BEND		

LEGEND

DREDGE AREA

CORAL REEFS IDENTIFIED IN AUGUST 2007 CORAL STUDY

EMBANKMENT DREDGING OR EXCAVATION

0 1000 2000 FT.
1"=1000'

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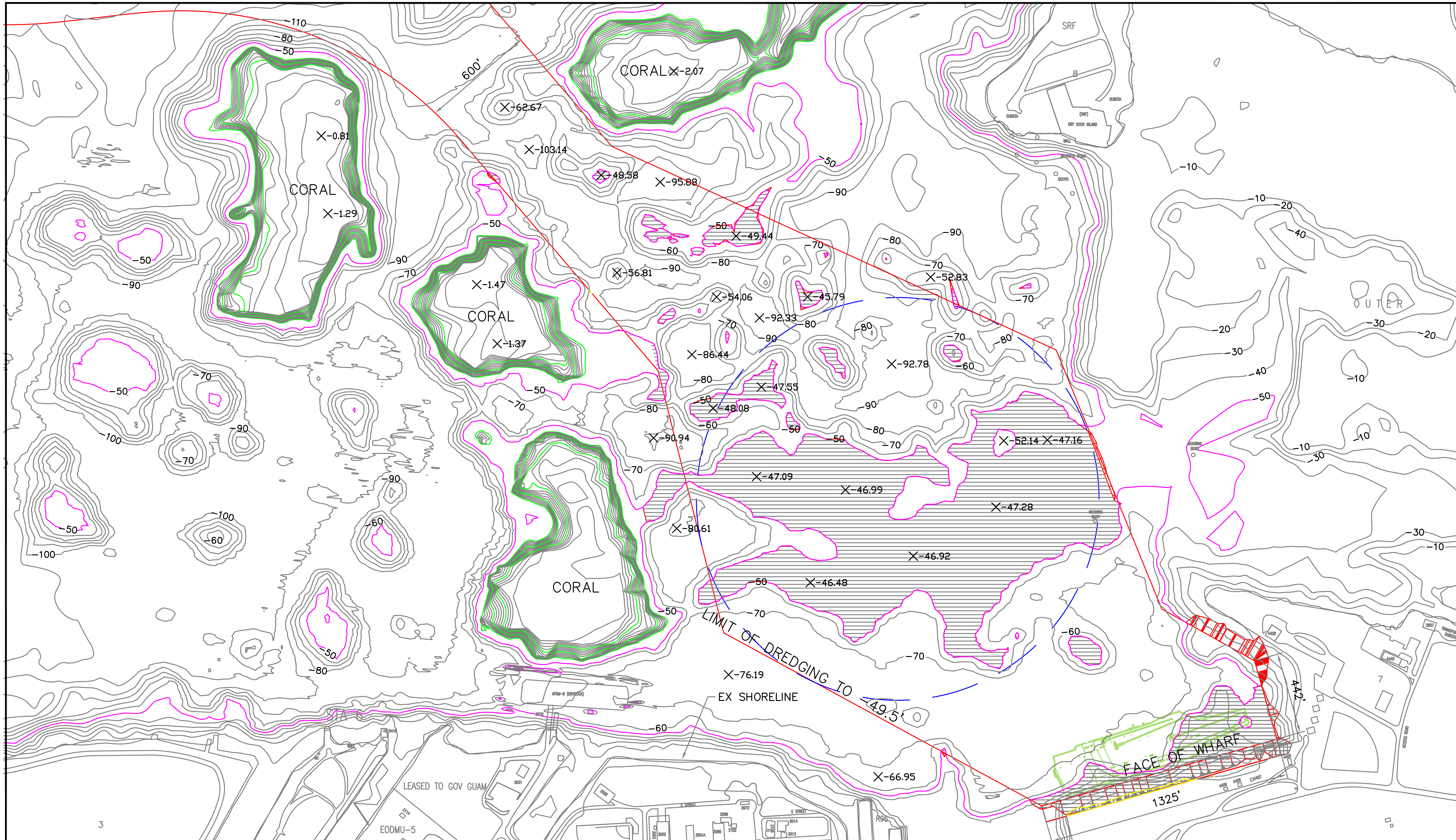
CHANNEL ALTERNATIVE 3
NO CHANNEL BEND

DATE
3/14/08

FIGURE NUMBER
N-6



LEGEND

DREDGE AREA

UPLAND EXCAVATION

CORAL REEFS IDENTIFIED IN AUGUST 2007 CORAL STUDY

MINIMUM TURNING BASIN RADIUS = 1092' (CVN LOA)

EMBANKMENT DREDGING OR EXCAVATION

1"=500' 0 500 1000 FT.

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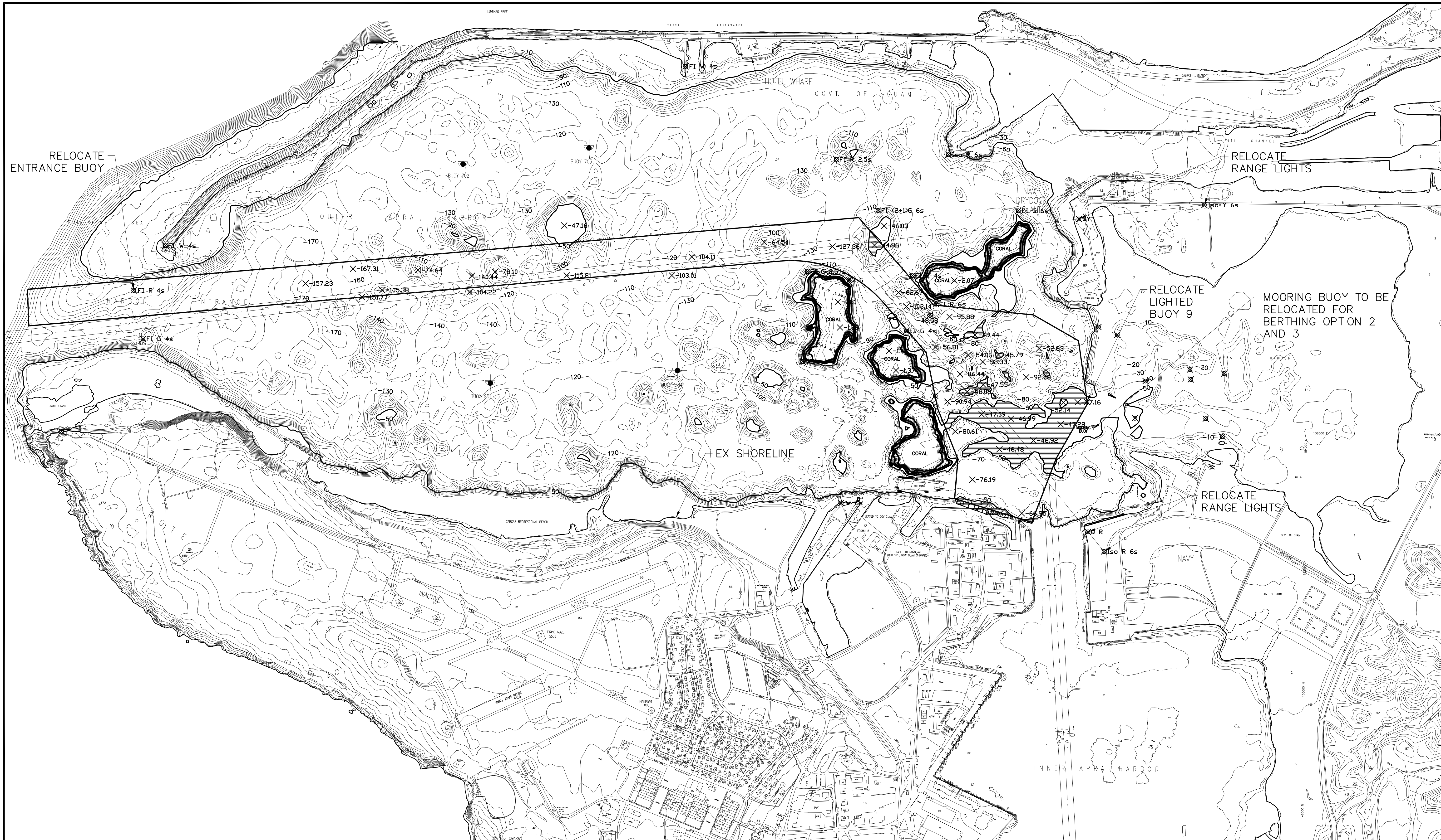
GUAM, MARIANA ISLANDS
GUAM CVN-CAPABLE BERTHING STUDY

BERTHING ALTERNATIVE 2A
POLARIS POINT PARALLEL TO SHORE

DATE
5/29/08

FIGURE NUMBER
N-7



LEGEND

DREDGE AREA

CORAL REEFS IDENTIFIED IN AUGUST 2007 CORAL STUDY

EMBANKMENT DREDGING OR EXCAVATION

1"=1500' 0 1500 3000 FT.

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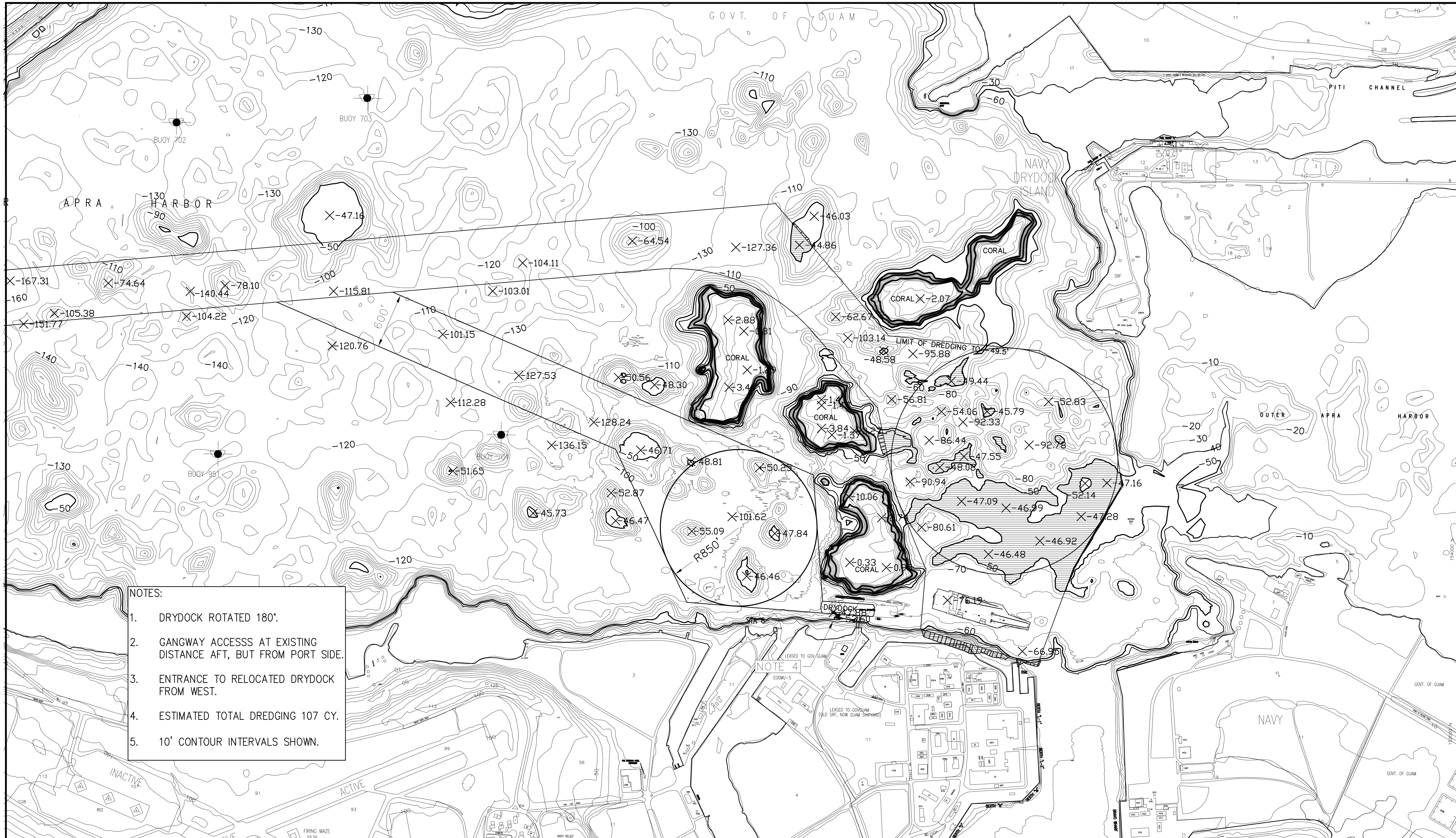
NAVFAC	APRA HARBOR — GUAM, MARIANA ISLANDS — GUAM CVN-CAPABLE BERTHING STUDY — AIDS TO NAVIGATION	FIGURE NUMBER N-8



NOTES:

1. DRYDOCK ROTATED 180°.
2. GANGWAY ACCESSS AT EXISTING DISTANCE AFT, BUT FROM PORT SIDE.
3. ENTRANCE TO RELOCATED DRYDOCK FROM WEST.
4. ESTIMATED TOTAL DREDGING 107 CY.
5. 10' CONTOUR INTERVALS SHOWN.

LEGEND

- DREDGE AREA
- UPLAND EXCAVATION
- CORAL REEFS IDENTIFIED IN AUGUST 2007 CORAL STUDY
- EMBANKMENT DREDGING OR EXCAVATION

0 1000 2000 FT.
1"=1000'

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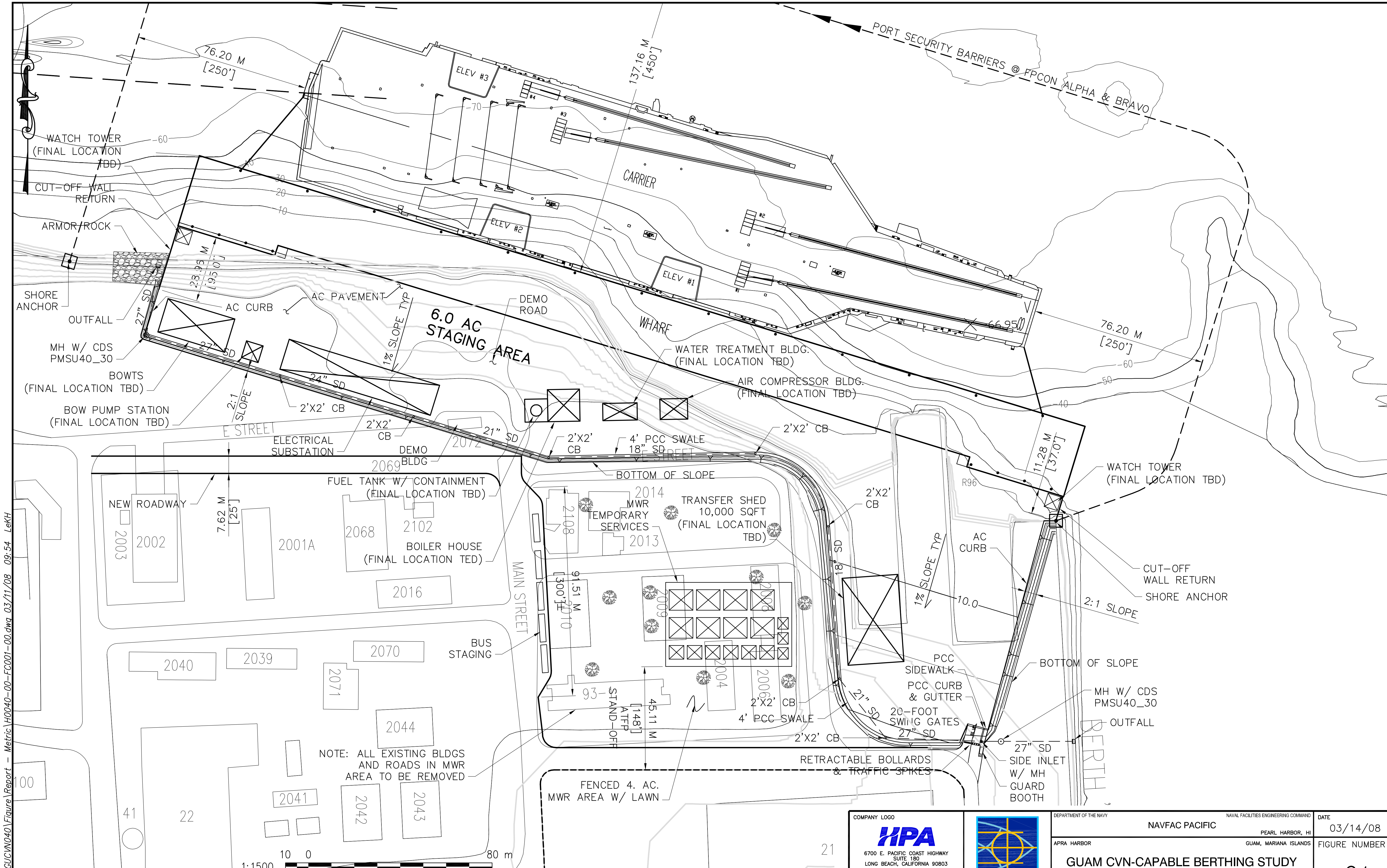
APRA HARBOR | GUAM, MARIANA ISLANDS

GUAM CVN-CAPABLE BERTHING STUDY

PROPOSED DRYDOCK RELOCATION

DATE 3/14/08

FIGURE NUMBER N-9



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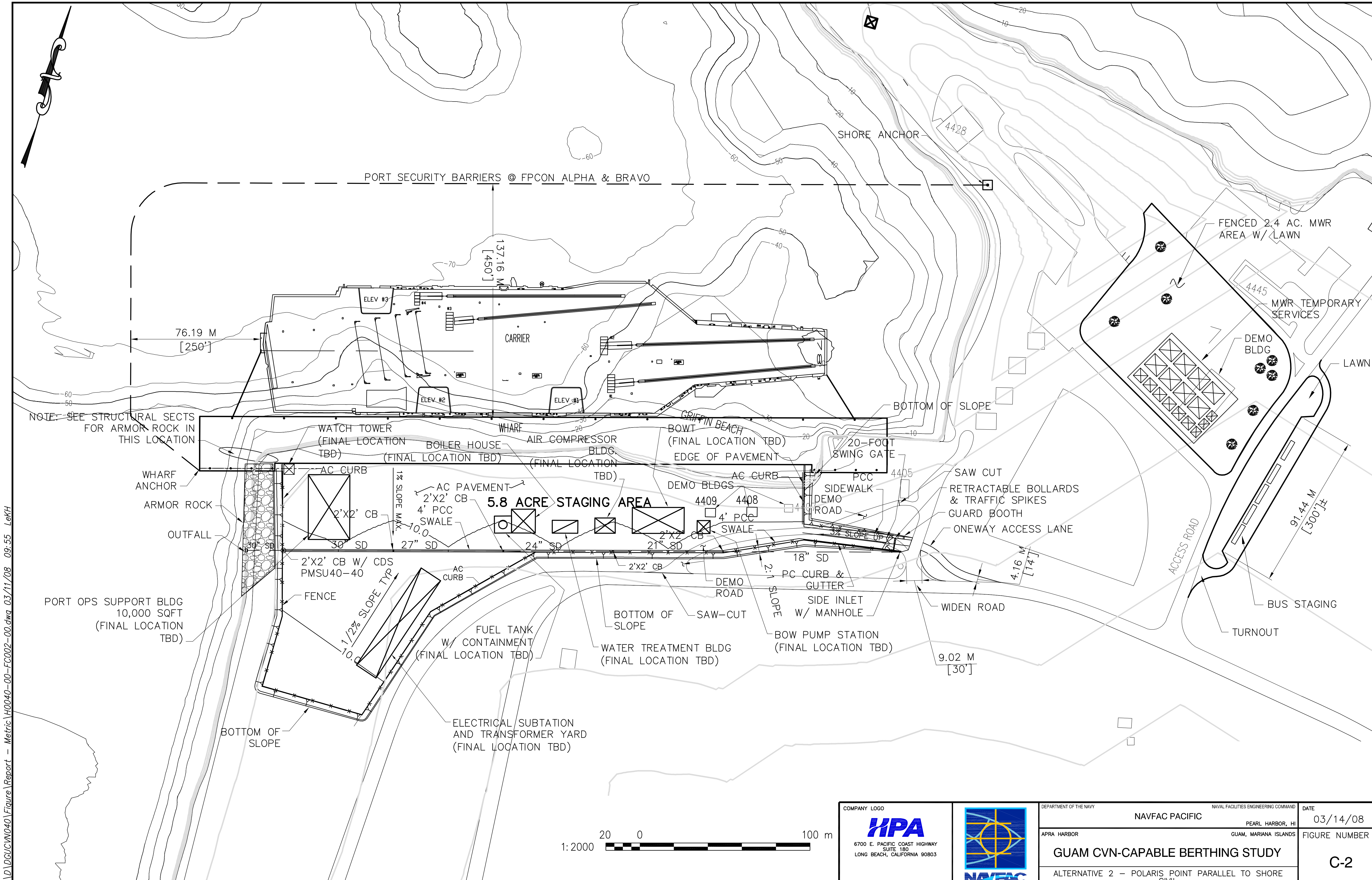
HPA 6700 E. PACIFIC COAST HIGHWAY SUITE 180 LONG BEACH, CALIFORNIA 90803	NAVFAC	NAVFAC PACIFIC, PEARL HARBOR, HI	03/14/08
		APRA HARBOR — GUAM, MARIANA ISLANDS	FIGURE NUMBER
		GUAM CVN-CAPABLE BERTHING STUDY	C-1
		ALTERNATIVE 1 – FORMER SRF FACILITY CIVIL	



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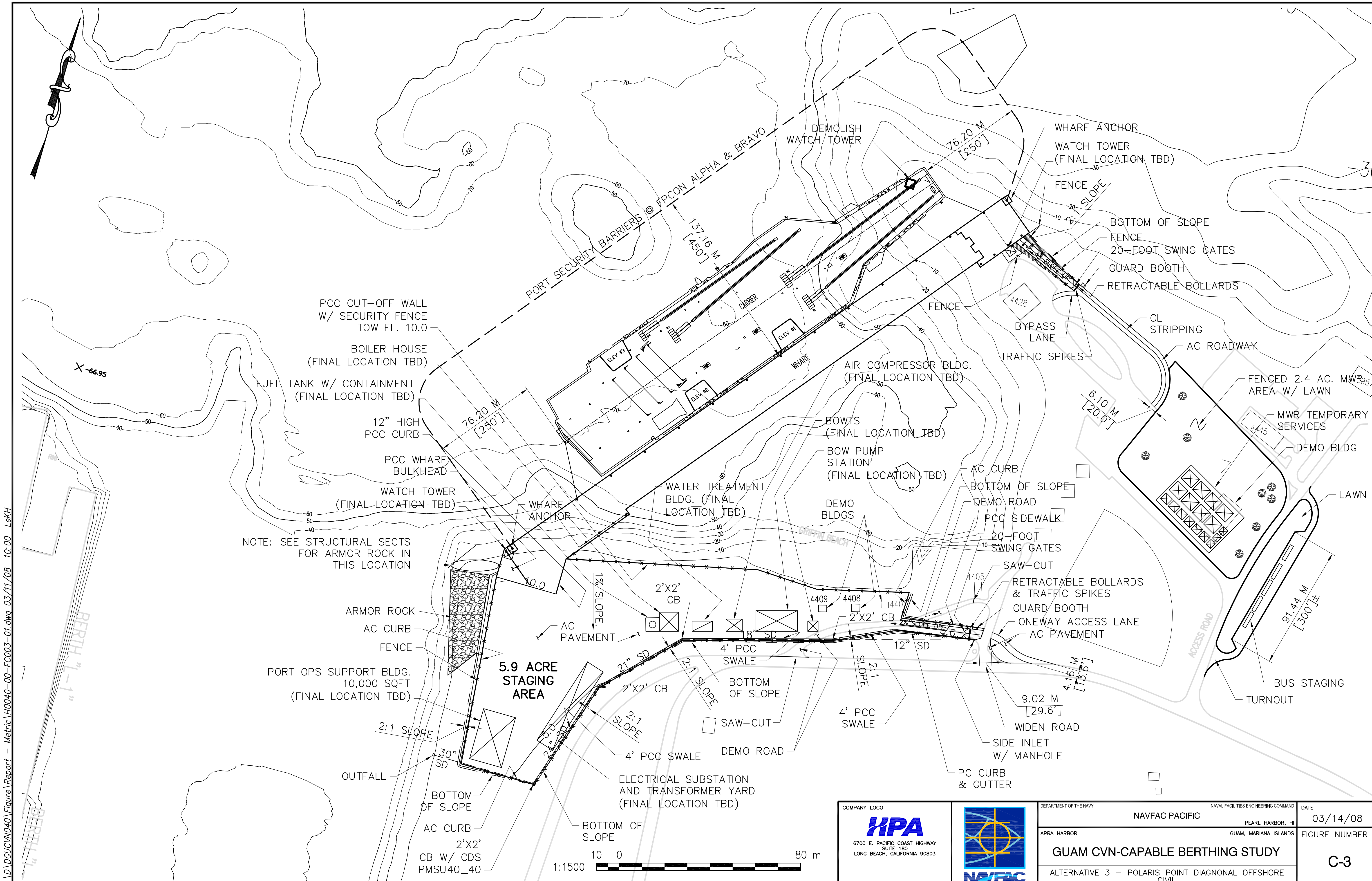
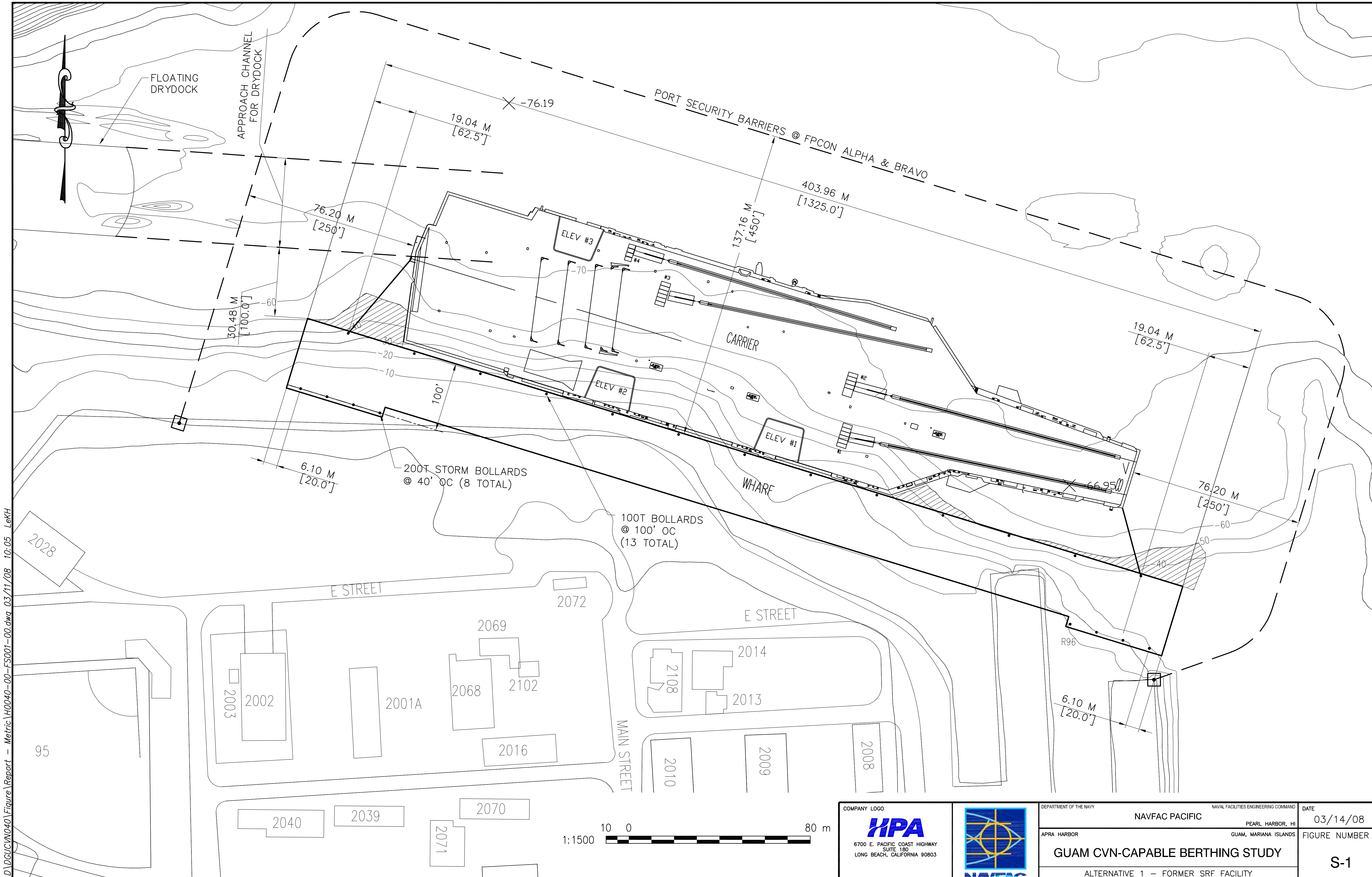
GUAM CVN-CAPABLE BERTHING STUDY

ALTERNATIVE 2 – POLARIS POINT PARALLEL TO SHORE
CIVIL

DATE 03/14/08

FIGURE NUMBER C-2


DEMOLISH WATCH TOWER
76.20 M [250']
WHARF ANCHOR
WATCH TOWER (FINAL LOCATION TBD)
FENCE
2:1 SLOPE
BOTTOM OF SLOPE
FENCE
20-FOOT SWING GATES
GUARD BOOTH
RETRACTABLE BOLLARDS
PORT SECURITY BARRIERS @ FPCON ALPHA & BRAVO
137.16 M [450']
CARRIER
WHARF
ELEV #1
ELEV #2
ELEV #3
FENCE
4428
BYPASS LANE
TRAFFIC SPIKES
CL STRIPPING
AC ROADWAY
PCC CUT-OFF WALL W/ SECURITY FENCE TOW EL. 10.0
BOILER HOUSE (FINAL LOCATION TBD)
FUEL TANK W/ CONTAINMENT (FINAL LOCATION TBD)
12" HIGH PCC CURB
76.20 M [250']
PCC WHARF BULKHEAD
WATCH TOWER (FINAL LOCATION TBD)
WHARF ANCHOR
NOTE: SEE STRUCTURAL SECTS FOR ARMOR ROCK IN THIS LOCATION
AIR COMPRESSOR BLDG. (FINAL LOCATION TBD)
BOWTS (FINAL LOCATION TBD)
BOW PUMP STATION (FINAL LOCATION TBD)
WATER TREATMENT BLDG. (FINAL LOCATION TBD)
DEMO BLDGS
GRIFFIN BEACH
6.10 M [20.0']
FENCED 2.4 AC. MWR AREA W/ LAWN
MWR TEMPORARY SERVICES
4445
DEMO BLDG
LAWN
AC CURB
BOTTOM OF SLOPE
DEMO ROAD
PCC SIDEWALK
20-FOOT SWING GATES
SAW-CUT
RETRACTABLE BOLLARDS & TRAFFIC SPIKES
GUARD BOOTH
ONEWAY ACCESS LANE
AC PAVEMENT
4405
4409
4408
ACCESS ROAD
91.44 M [300']±
ARMOR ROCK
AC CURB
FENCE
PORT OPS SUPPORT BLDG. 10,000 SQFT (FINAL LOCATION TBD)
5.9 ACRE STAGING AREA
1% SLOPE
10.0
AC PAVEMENT
2'X2' CB
2'X2' CB
18" SD
12" SD
4' PCC SWALE
21" SD
2:1 SLOPE
BOTTOM OF SLOPE
2:1 SLOPE
2'X2' CB
2:1 SLOPE
4.16 M [13.6']
9.02 M [29.6']
WIDEN ROAD
SIDE INLET W/ MANHOLE
BUS STAGING
TURNOUT
2:1 SLOPE
30" SD
OUTFALL
24" SD
5.0
SAW-CUT
4' PCC SWALE
4' PCC SWALE
DEMO ROAD
PC CURB & GUTTER
ELECTRICAL SUBSTATION AND TRANSFORMER YARD (FINAL LOCATION TBD)
BOTTOM OF SLOPE
AC CURB
2'X2' CB W/ CDS PMSU40_40
BOTTOM OF SLOPE
BERTH "L-1"
BERTH "L"
X -66.95
10 0 80 m
1:1500
COMPANY LOGO
HPA
6700 E. PACIFIC COAST HIGHWAY SUITE 180 LONG BEACH, CALIFORNIA 90803
NAVFAC
DEPARTMENT OF THE NAVY
NAVAL FACILITIES ENGINEERING COMMAND
NAVFAC PACIFIC
PEARL HARBOR, HI
APRA HARBOR
GUAM, MARIANA ISLANDS
GUAM CVN-CAPABLE BERTHING STUDY
ALTERNATIVE 3 - POLARIS POINT DIAGONAL OFFSHORE CIVIL
DATE
03/14/08
FIGURE NUMBER
C-3
T:\D\DGUCVN040\Figure\Report - Metric\H0040-00-FC003-01.dwg 03/11/08 10:00 LeKH



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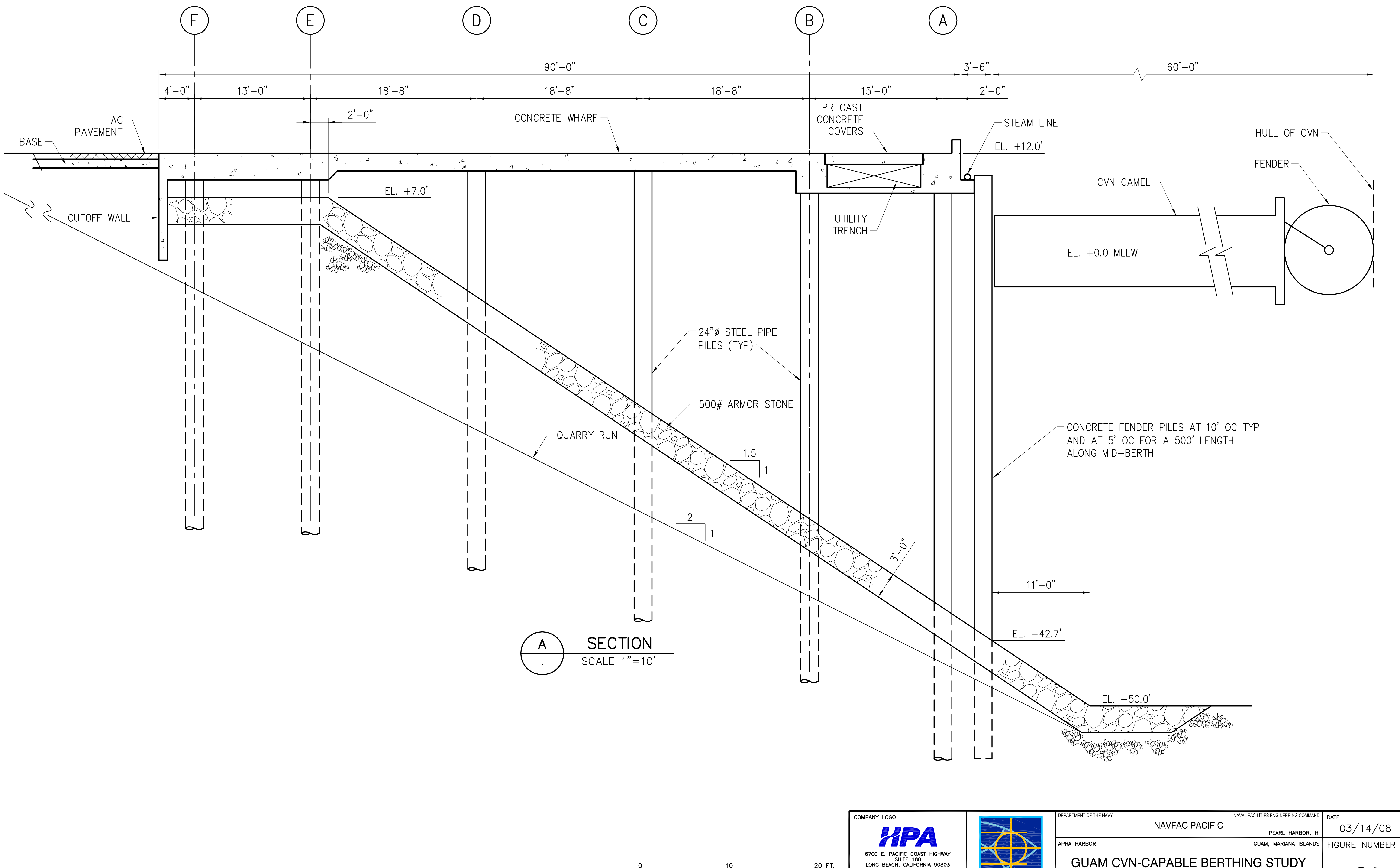
COMPANY LOGO HPA 6700 E. PACIFIC COAST HIGHWAY SUITE 180 LONG BEACH, CALIFORNIA 90803	NAVFAC	DEPARTMENT OF THE NAVY / NAVAL FACILITIES ENGINEERING COMMAND NAVFAC PACIFIC PEARL HARBOR, HI APRA HARBOR / GUAM, MARIANA ISLANDS GUAM CVN-CAPABLE BERTHING STUDY ALTERNATIVE 1 – FORMER SRF FACILITY WHARF PLAN	DATE 03/14/08 FIGURE NUMBER S-1



A SECTION
SCALE 1"=10'

COMPANY LOGO

HPA
6700 E. PACIFIC COAST HIGHWAY
SUITE 180
LONG BEACH, CALIFORNIA 90803

NAVFAC

DEPARTMENT OF THE NAVY
NAVAL FACILITIES ENGINEERING COMMAND
NAVFAC PACIFIC
PEARL HARBOR, HI

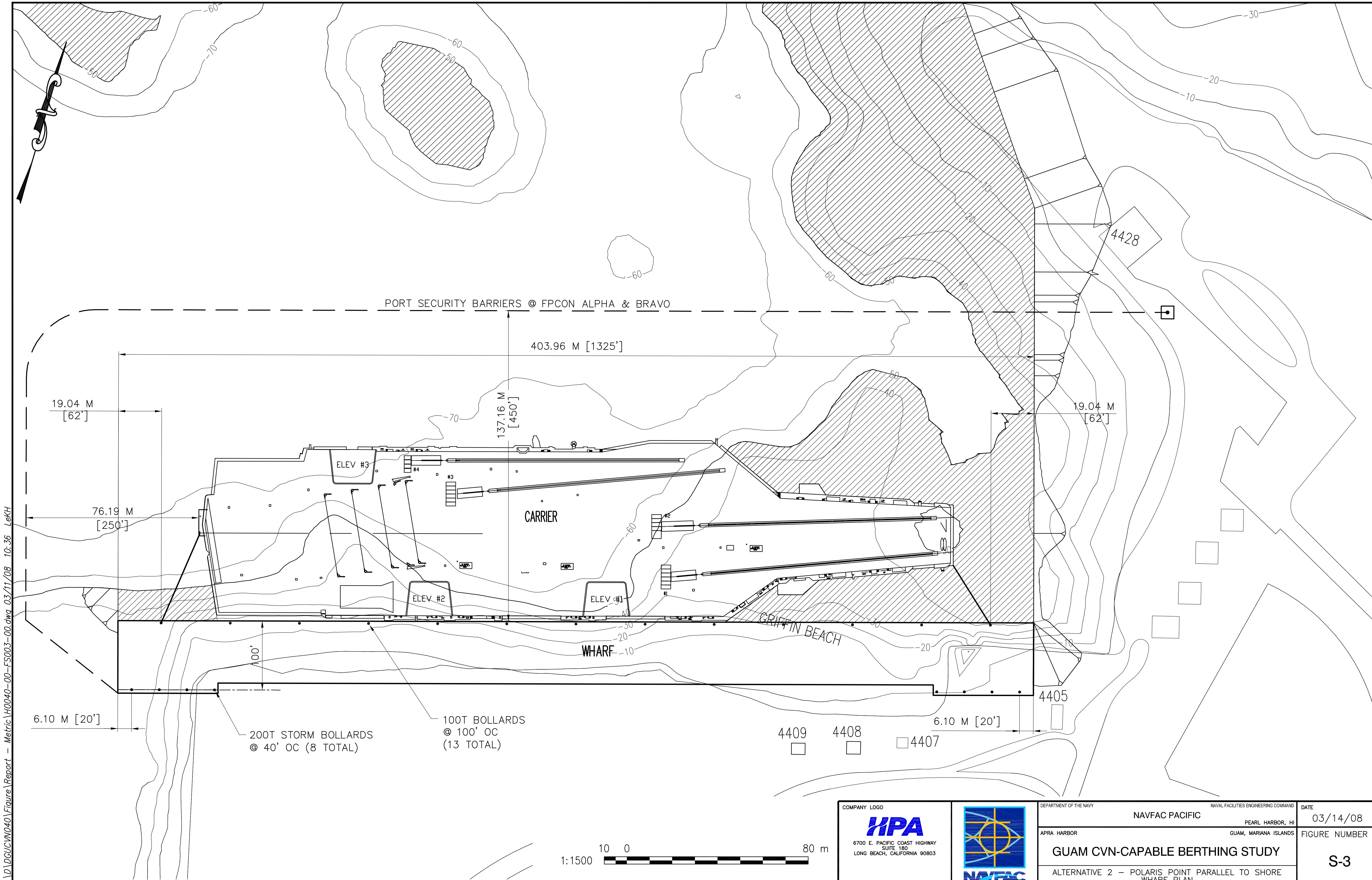
APRA HARBOR
GUAM, MARIANA ISLANDS

GUAM CVN-CAPABLE BERTHING STUDY

ALTERNATIVE 1 & 2 – FORMER SRF FACILITY
WHARF SECTION

DATE
03/14/08

FIGURE NUMBER
S-2



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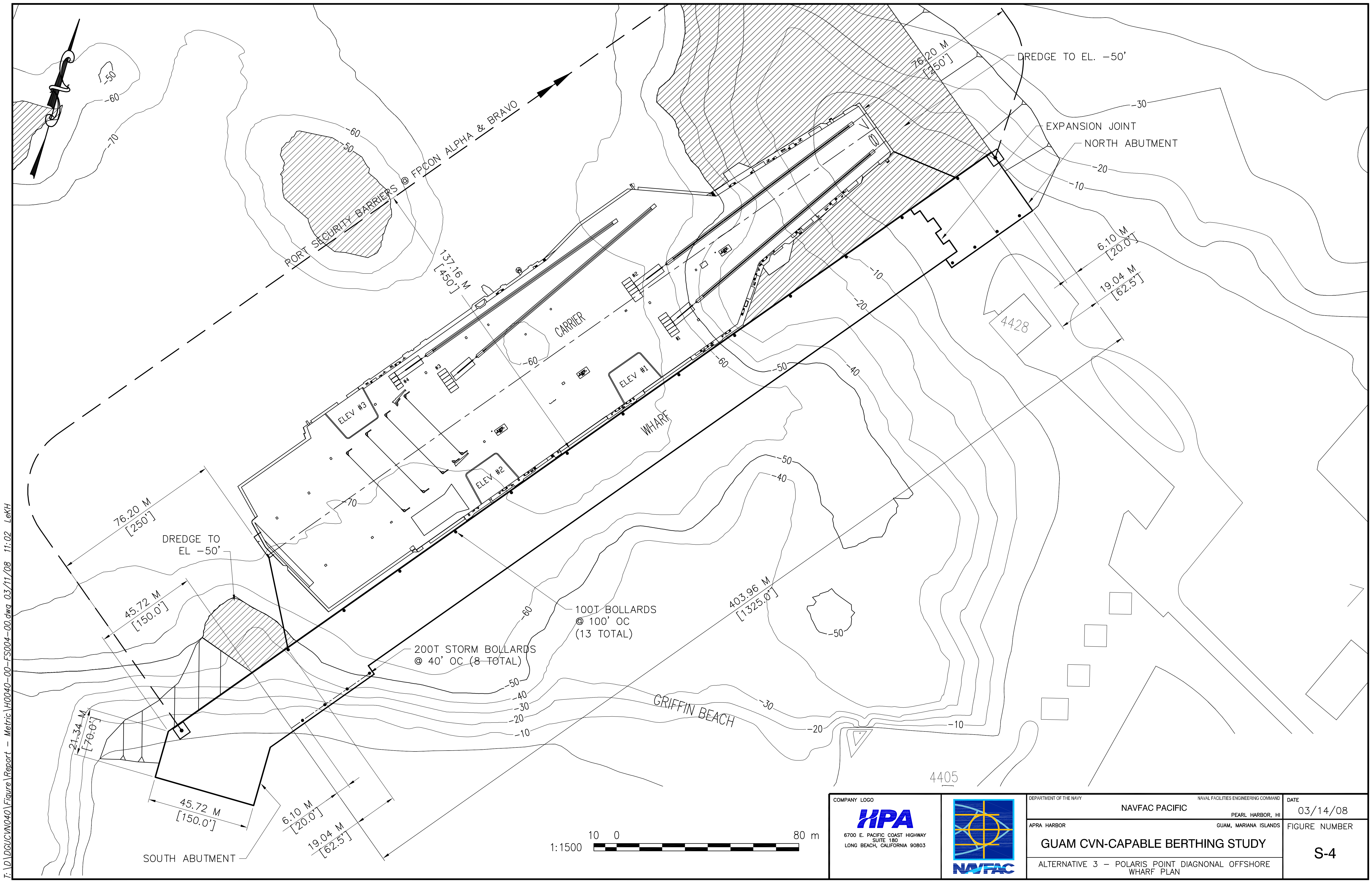
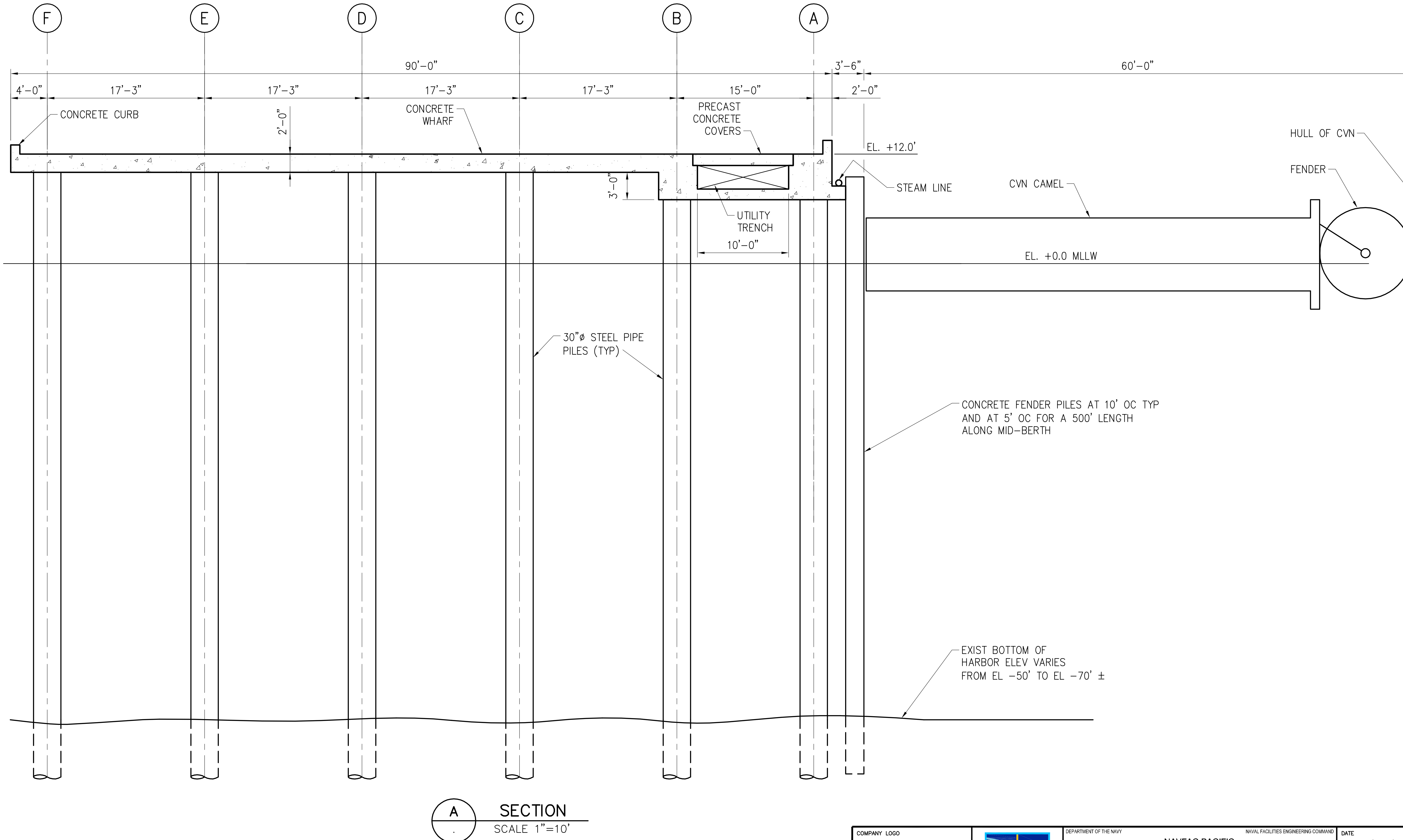

PORT SECURITY BARRIERS @ FPCON ALPHA & BRAVO
DREDGE TO EL. -50'
76.20 M [250']
EXPANSION JOINT
NORTH ABUTMENT
137.16 M [450']
CARRIER
WHARF
ELEV #1
ELEV #2
ELEV #3
6.10 M [20.0']
19.04 M [62.5']
4428
76.20 M [250']
DREDGE TO EL -50'
45.72 M [150.0']
100T BOLLARDS @ 100' OC (13 TOTAL)
200T STORM BOLLARDS @ 40' OC (8 TOTAL)
403.96 M [1325.0']
GRIFFIN BEACH
21.34 M [70.0']
45.72 M [150.0']
6.10 M [20.0']
19.04 M [62.5']
SOUTH ABUTMENT
4405
1:1500
10 0 80 m
T:\D\DGUCVN040\Figure\Report - Metric\H0040-00-FS004-00.dwg 03/11/08 11:02 LeKH
COMPANY LOGO
HPA
6700 E. PACIFIC COAST HIGHWAY SUITE 180 LONG BEACH, CALIFORNIA 90803
NAVFAC
DEPARTMENT OF THE NAVY
NAVAL FACILITIES ENGINEERING COMMAND
NAVFAC PACIFIC
PEARL HARBOR, HI
APRA HARBOR
GUAM, MARIANA ISLANDS
GUAM CVN-CAPABLE BERTHING STUDY
ALTERNATIVE 3 - POLARIS POINT DIAGNONAL OFFSHORE WHARF PLAN
DATE
03/14/08
FIGURE NUMBER
S-4

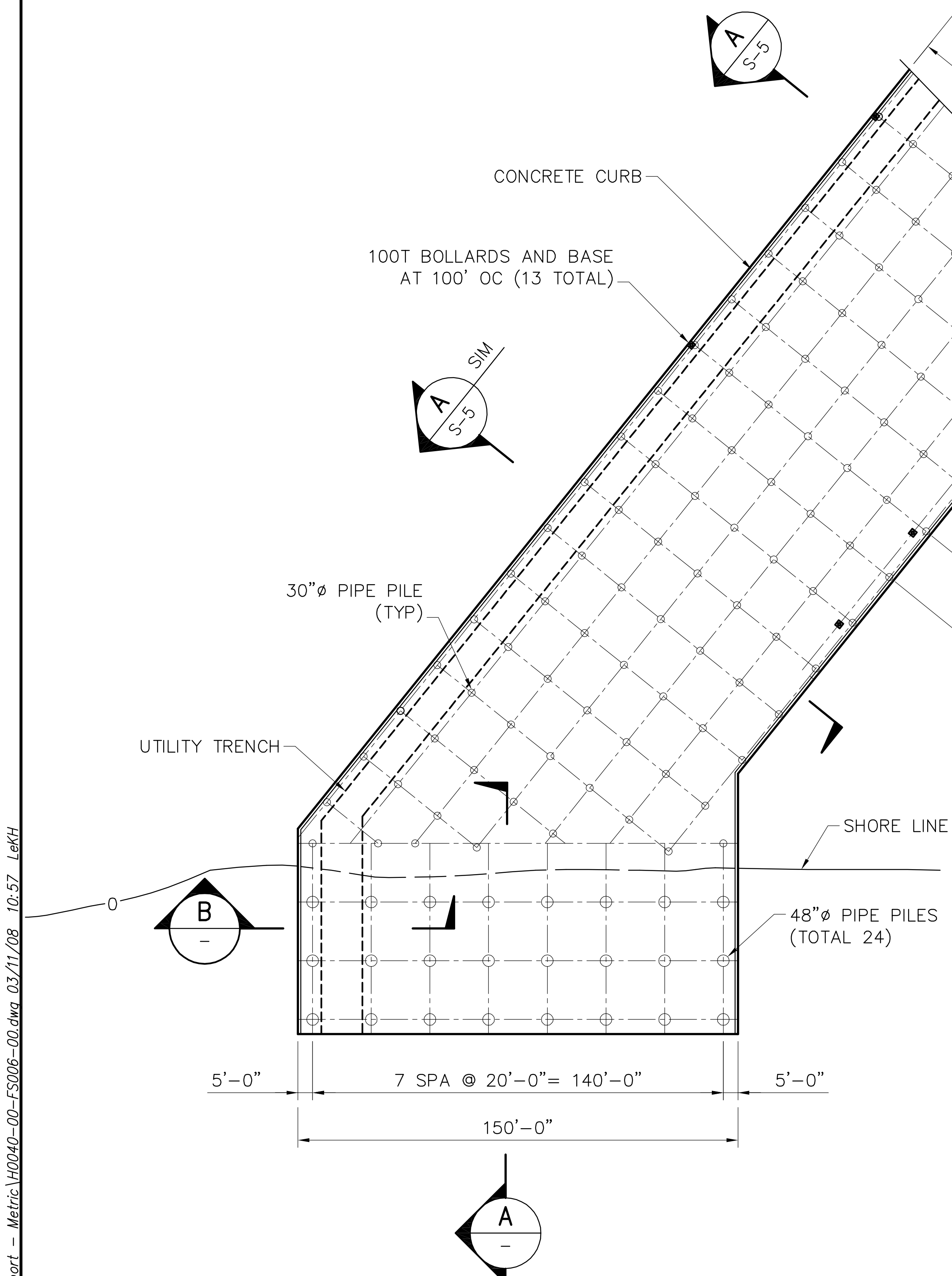


A SECTION
SCALE 1"=10'

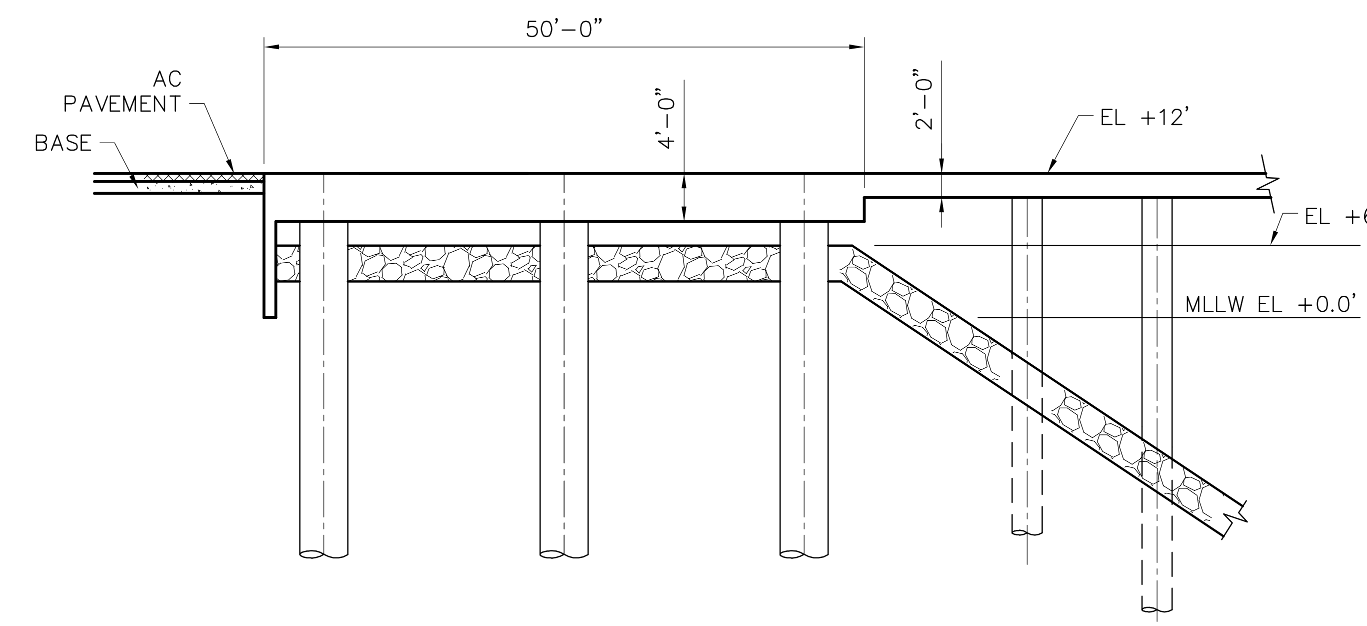
0 10 20 FT.

T:\D\DGUCVN040\Figure\Report - Metric\H0040-00-FS005-00.dwg 12/11/07 13:57 LeKH

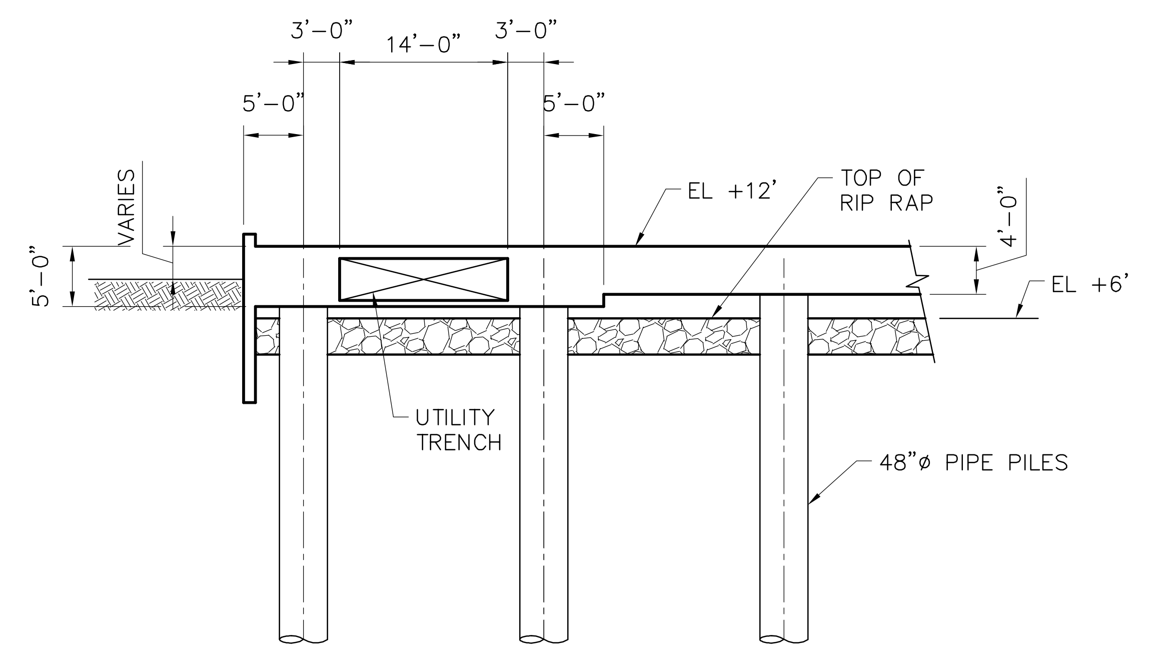
COMPANY LOGO HPA 6700 E. PACIFIC COAST HIGHWAY SUITE 180 LONG BEACH, CALIFORNIA 90803	NAVFAC	DEPARTMENT OF THE NAVY — NAVAL FACILITIES ENGINEERING COMMAND NAVFAC PACIFIC PEARL HARBOR, HI	DATE 03/14/08
		APRA HARBOR — GUAM, MARIANA ISLANDS GUAM CVN-CAPABLE BERTHING STUDY ALTERNATIVE 3 – POLARIS POINT DIAGONAL OFFSHORE WHARF SECTION	FIGURE NUMBER S-5



ABUTMENT PLAN
SCALE 1"=50'-0"



A – SECTION
SCALE 1/16"=1'-0"

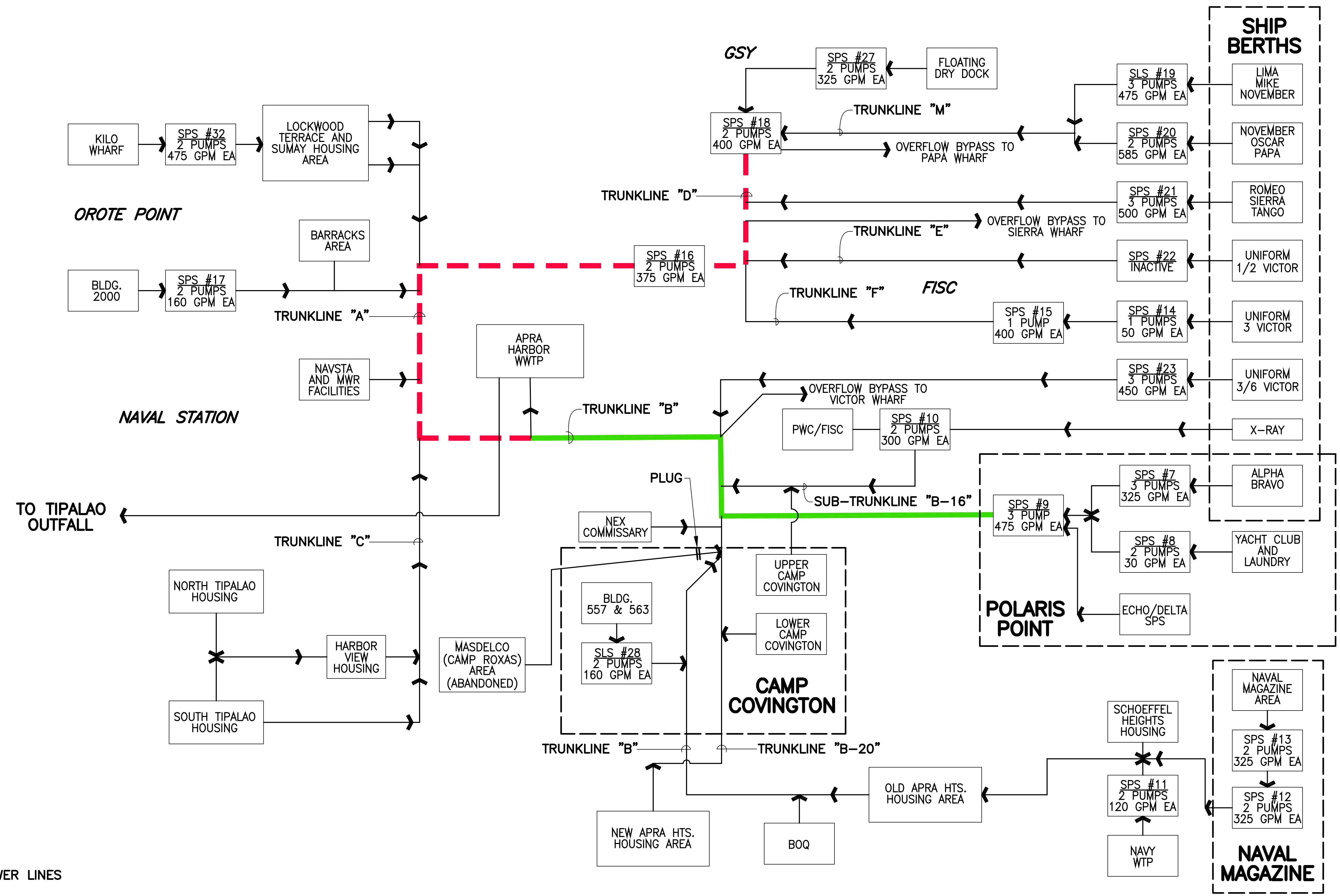


B – SECTION
SCALE 1/16"=1'-0"

0 50 100 FT.
1"=50'
0 10 20 30 FT.
1/16"=1'-0"

COMPANY LOGO HPA 6700 E. PACIFIC COAST HIGHWAY SUITE 180 LONG BEACH, CALIFORNIA 90803	NAVFAC	DEPARTMENT OF THE NAVY — NAVAL FACILITIES ENGINEERING COMMAND NAVFAC PACIFIC PEARL HARBOR, HI APRA HARBOR — GUAM, MARIANA ISLANDS GUAM CVN-CAPABLE BERTHING STUDY ALTERNATIVE 3 – POLARIS POINT DIAGONAL OFFSHORE ABUTMENT PLAN & SECTIONS	DATE 03/14/08 FIGURE NUMBER S-6

T:\D\DGUCVN040\Figure\Report – Metric\H0040-00-FS006-00.dwg 03/11/08 10:57 LeKH



LEGEND:

SEWER LINES

DIRECTION OF FLOW

FLOW FROM FORMER SRF FACILITY

FLOW FROM POLARIS POINT

SOURCE: GUAM NAVAL BASE WASTEWATER SYSTEM UTILITY TECHNICAL STUDY, APRIL 2007

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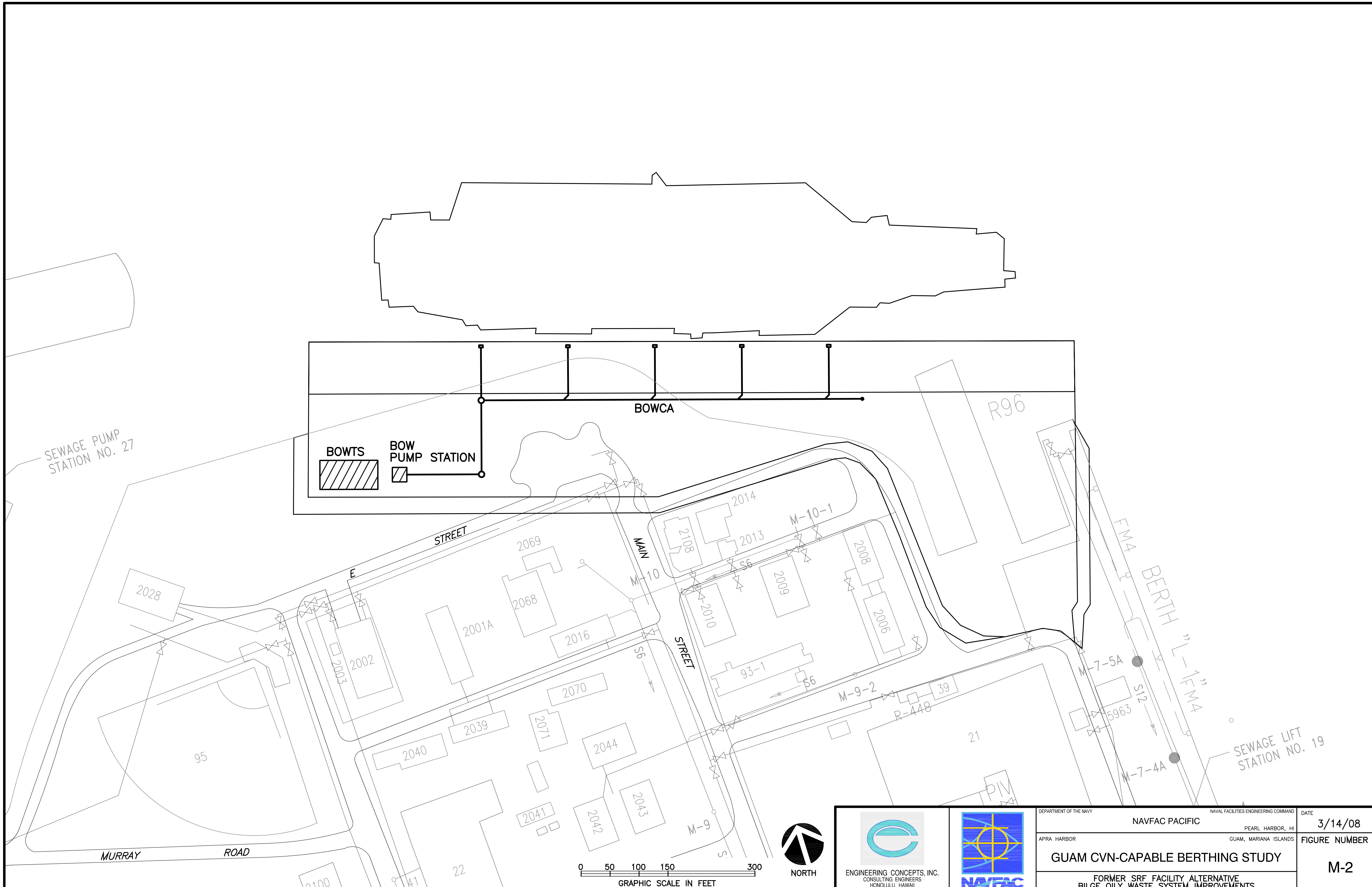
		APRA HARBOR / GUAM, MARIANA ISLANDS / GUAM CVN-CAPABLE BERTHING STUDY	FIGURE NUMBER M-1
		APRA HARBOR NAVAL COMPLEX WASTEWATER SYSTEM SCHEMATIC	



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APRA HARBOR — GUAM, MARIANA ISLANDS

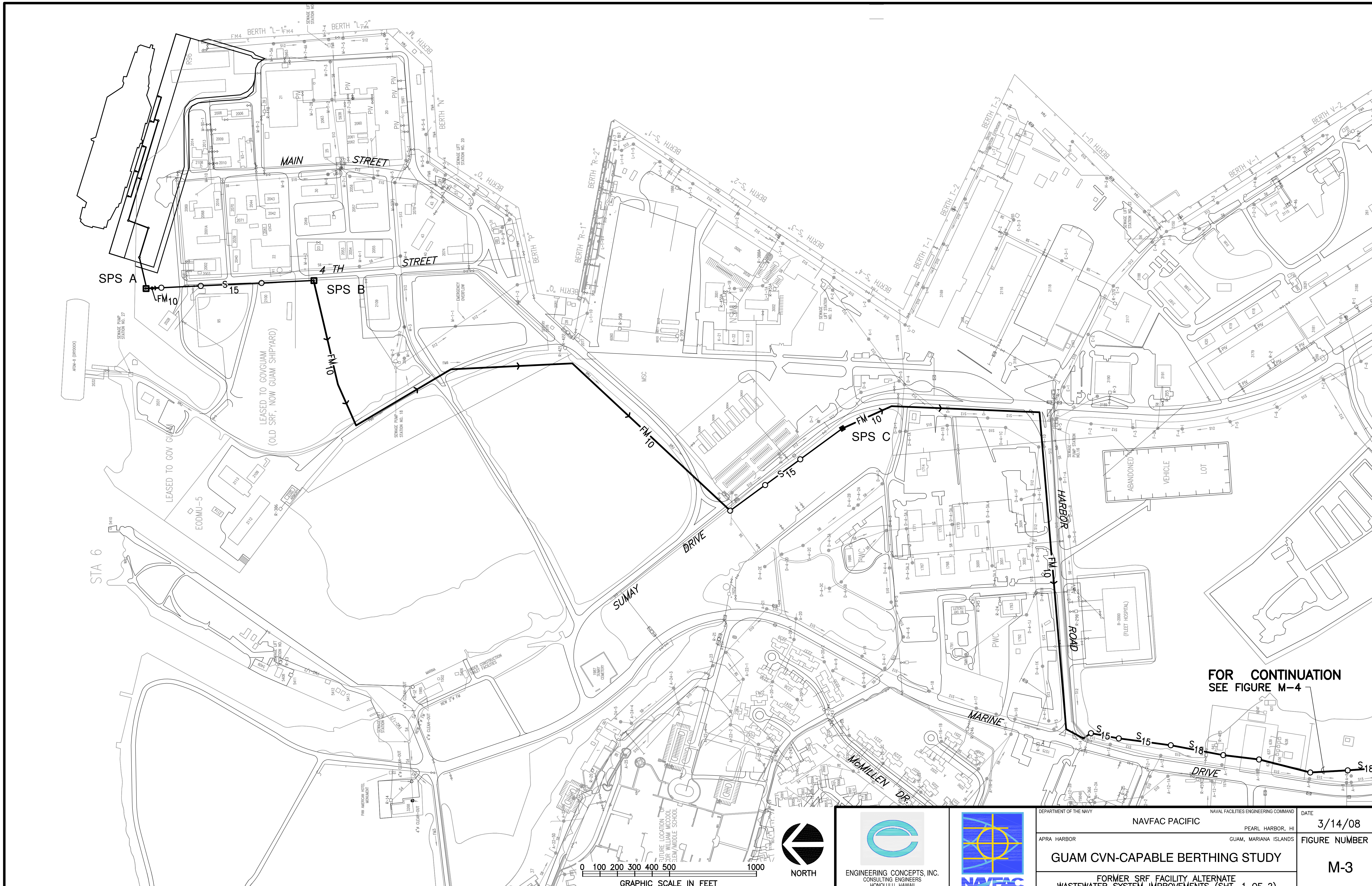
GUAM CVN-CAPABLE BERTHING STUDY

FORMER SRF FACILITY ALTERNATIVE
BILGE OILY WASTE SYSTEM IMPROVEMENTS

DATE 3/14/08

FIGURE NUMBER M-2

Mar 05, 2008-10:04am
N:\CAD\DWG\2007\0735-GUAM CVN BERTHING\FIGURES\fig-m2.dwg



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APRA HARBOR — GUAM, MARIANA ISLANDS

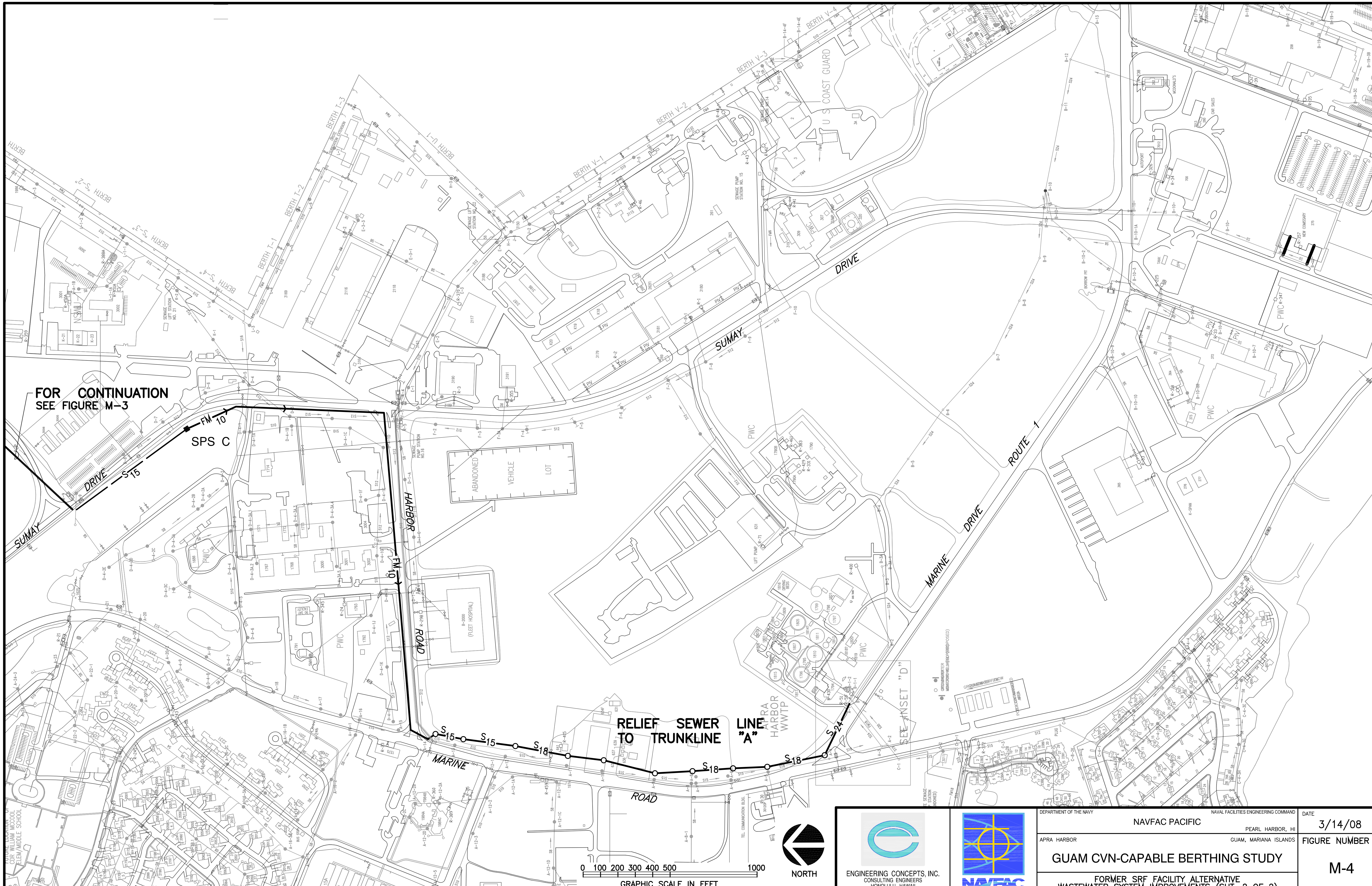
GUAM CVN-CAPABLE BERTHING STUDY

FORMER SRF FACILITY ALTERNATE
WASTEWATER SYSTEM IMPROVEMENTS (SHT. 1 OF 2)

DATE 3/14/08

FIGURE NUMBER M-3

Mar 05, 2008-10:06am
N:\CAD\DWG\2007\0735-GUAM CVN BERTHING\FIGURES\fig-m3&m4.dwg



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GUAM CVN-CAPABLE BERTHING STUDY

FORMER SRF FACILITY ALTERNATIVE
WASTEWATER SYSTEM IMPROVEMENTS (SHT. 2 OF 2)

DATE 3/14/08

FIGURE NUMBER M-4

Mar 05, 2008-10:06am
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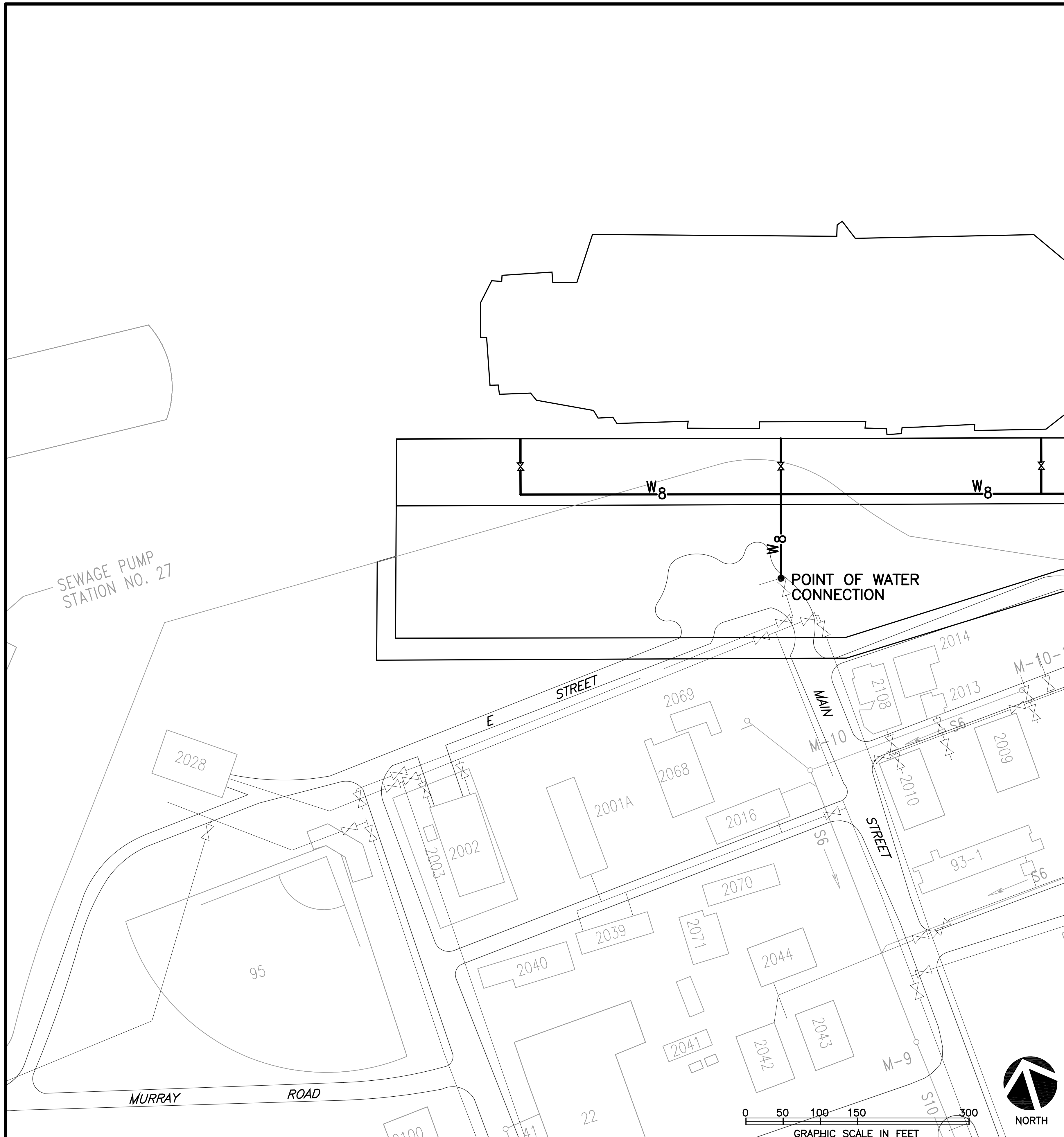

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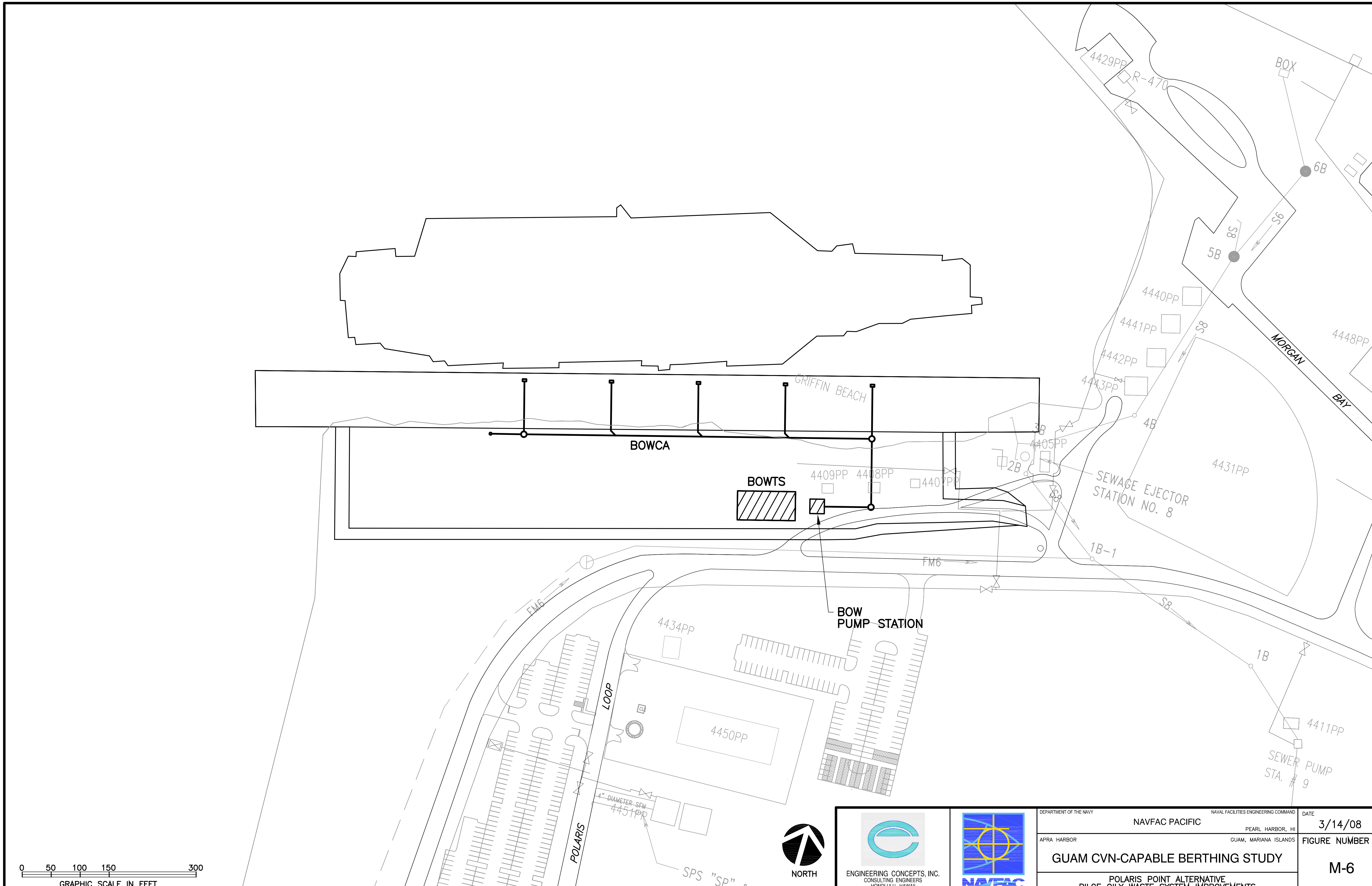
DEPARTMENT OF THE NAVY / NAVAL FACILITIES ENGINEERING COMMAND NAVFAC PACIFIC PEARL HARBOR, HI		DATE 3/14/08
APRA HARBOR / GUAM, MARIANA ISLANDS GUAM CVN-CAPABLE BERTHING STUDY		FIGURE NUMBER M-5
FORMER SRF FACILITY ALTERNATIVE POTABLE WATER SYSTEM IMPROVEMENTS		

Mar 05, 2008-10:08am
N:\CAD\DWG\2007\0735-GUAM CVN BERTHING\FIGURES\fig-m5.dwg



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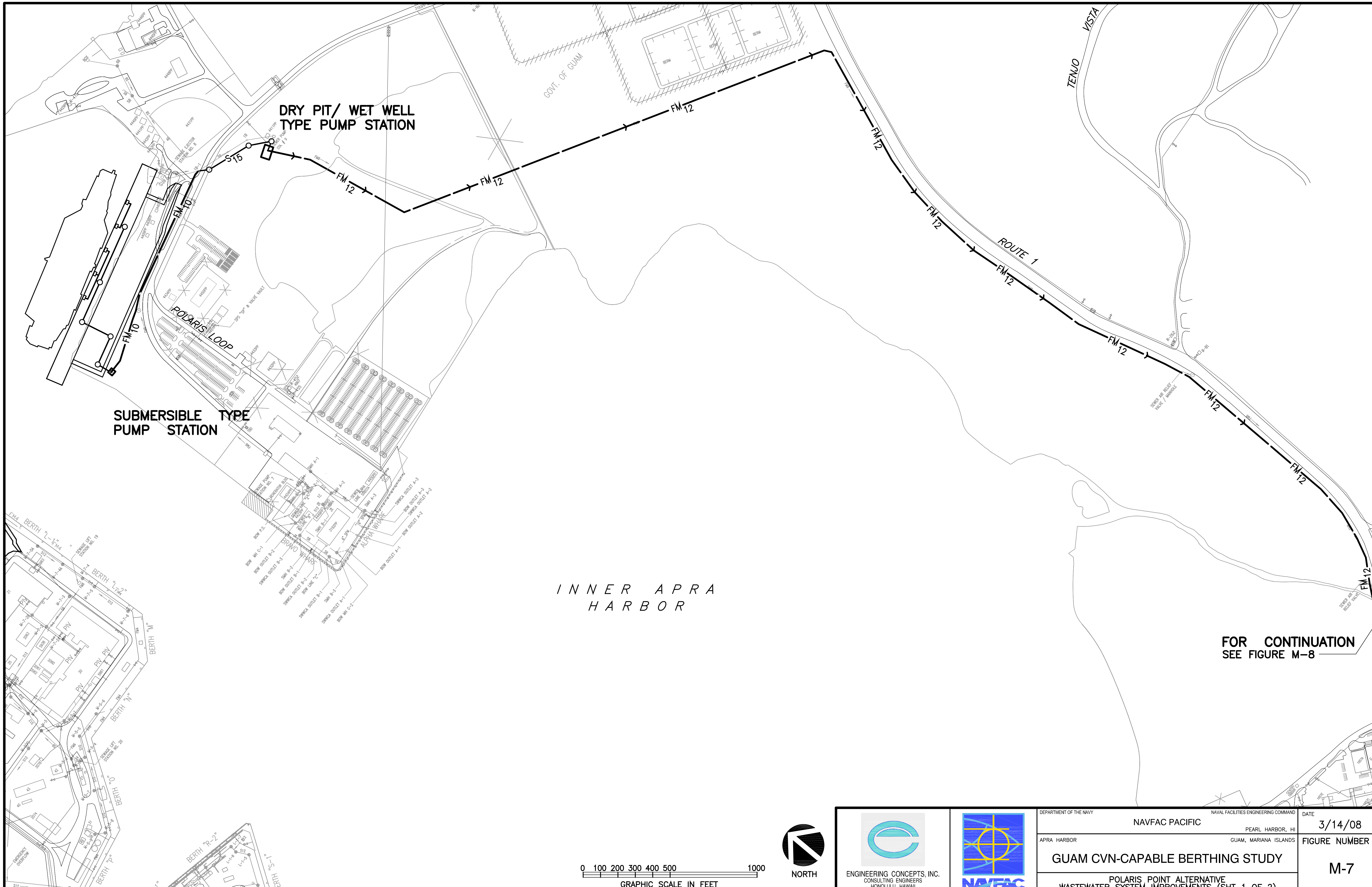
APRA HARBOR | GUAM, MARIANA ISLANDS

GUAM CVN-CAPABLE BERTHING STUDY

POLARIS POINT ALTERNATIVE
BILGE OILY WASTE SYSTEM IMPROVEMENTS

DATE 3/14/08

FIGURE NUMBER M-6



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N:\CAD\DWG\2007\0735-GUAM CVN BERTHING\FIGURES\fig-m7&m8.dwg

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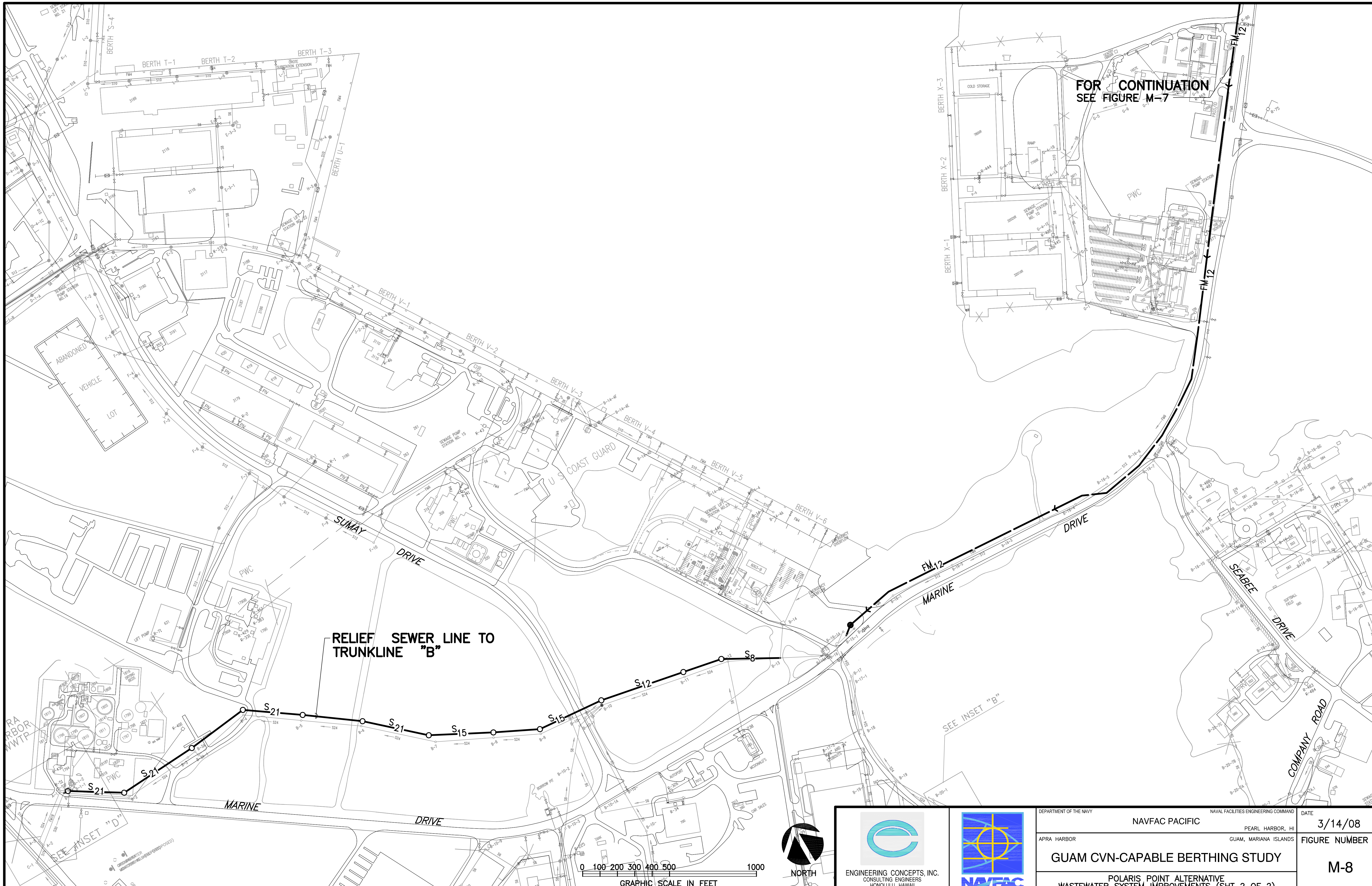
GUAM, MARIANA ISLANDS

GUAM CVN-CAPABLE BERTHING STUDY

POLARIS POINT ALTERNATIVE
WASTEWATER SYSTEM IMPROVEMENTS (SHT 1 OF 2)

DATE
3/14/08

FIGURE NUMBER
M-7



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APRA HARBOR
GUAM, MARIANA ISLANDS

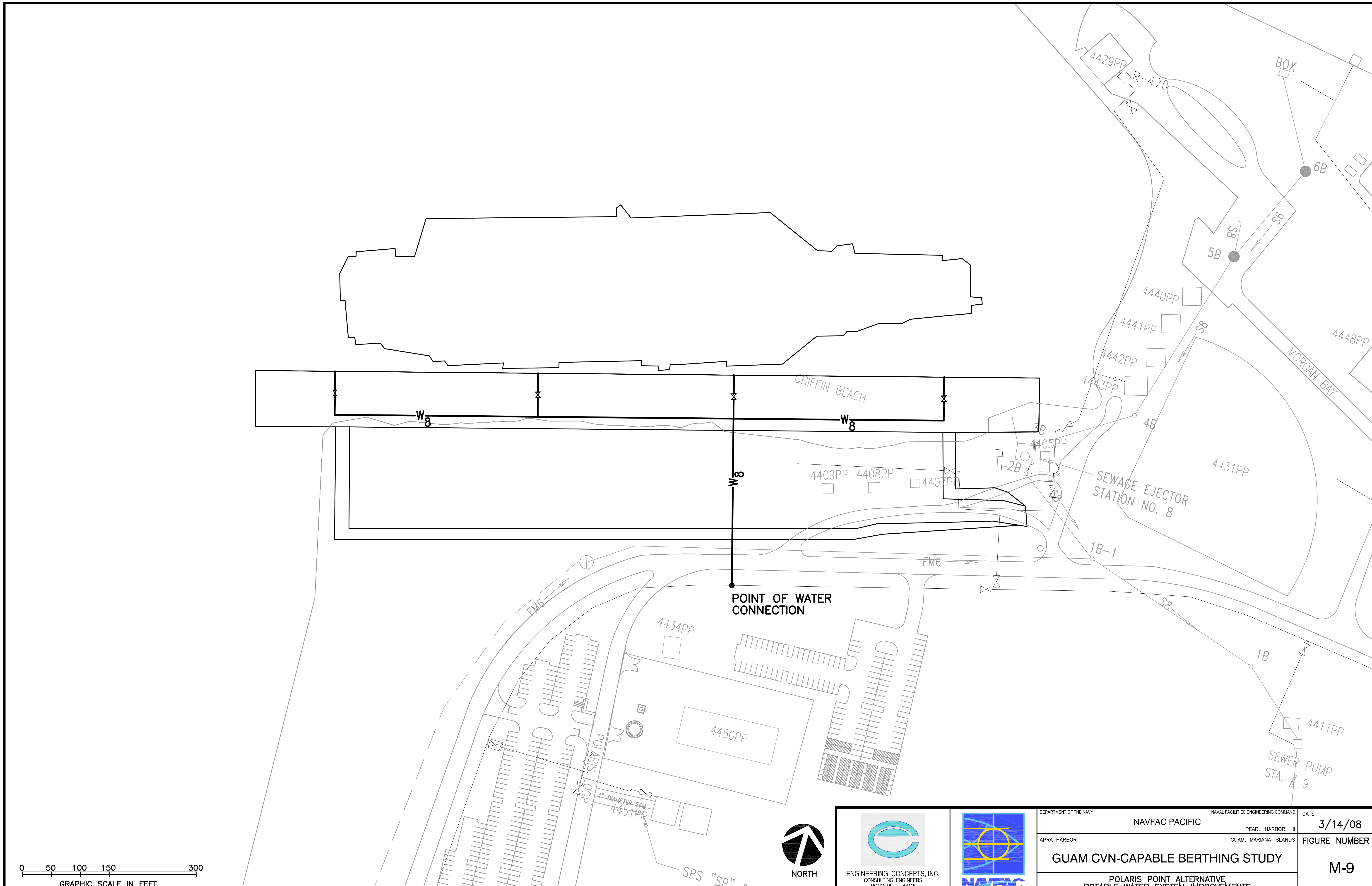
GUAM CVN-CAPABLE BERTHING STUDY

POLARIS POINT ALTERNATIVE
WASTEWATER SYSTEM IMPROVEMENTS (SHT 2 OF 2)

DATE
3/14/08

FIGURE NUMBER
M-8

Mar 05, 2008–10:11am
N:\CAD\DWG\2007\0735–GUAM CVN BERTHING\FIGURES\fig–m7&m8.dwg



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GUAM CVN-CAPABLE BERTHING STUDY

POLARIS POINT ALTERNATIVE
POTABLE WATER SYSTEM IMPROVEMENTS

DATE 3/14/08

FIGURE NUMBER M-9

Mar 05, 2008-10:12am
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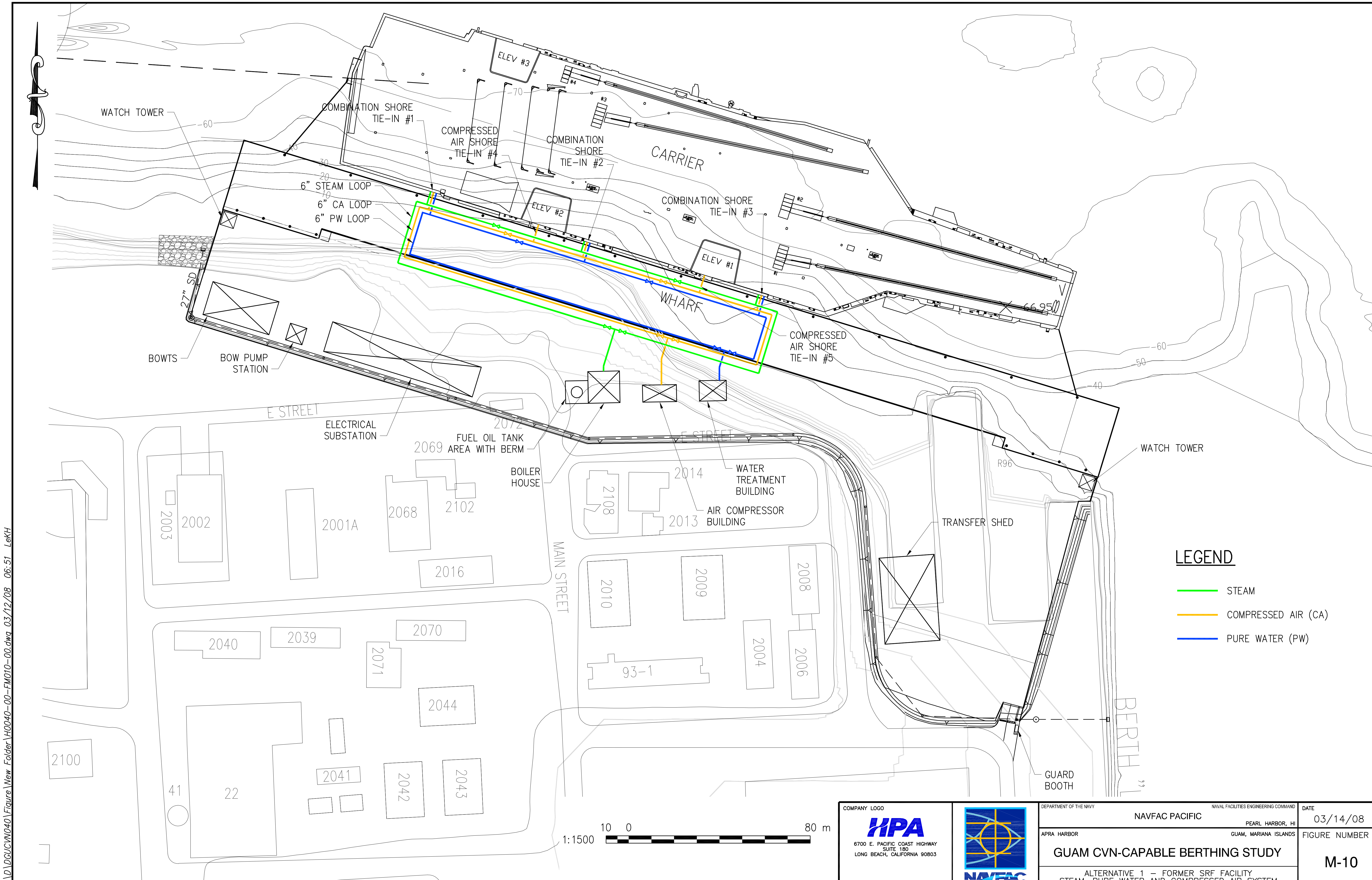

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COMPANY LOGO
HPA
6700 E. PACIFIC COAST HIGHWAY SUITE 180 LONG BEACH, CALIFORNIA 90803

NAVFAC

DEPARTMENT OF THE NAVY — NAVAL FACILITIES ENGINEERING COMMAND
NAVFAC PACIFIC
PEARL HARBOR, HI

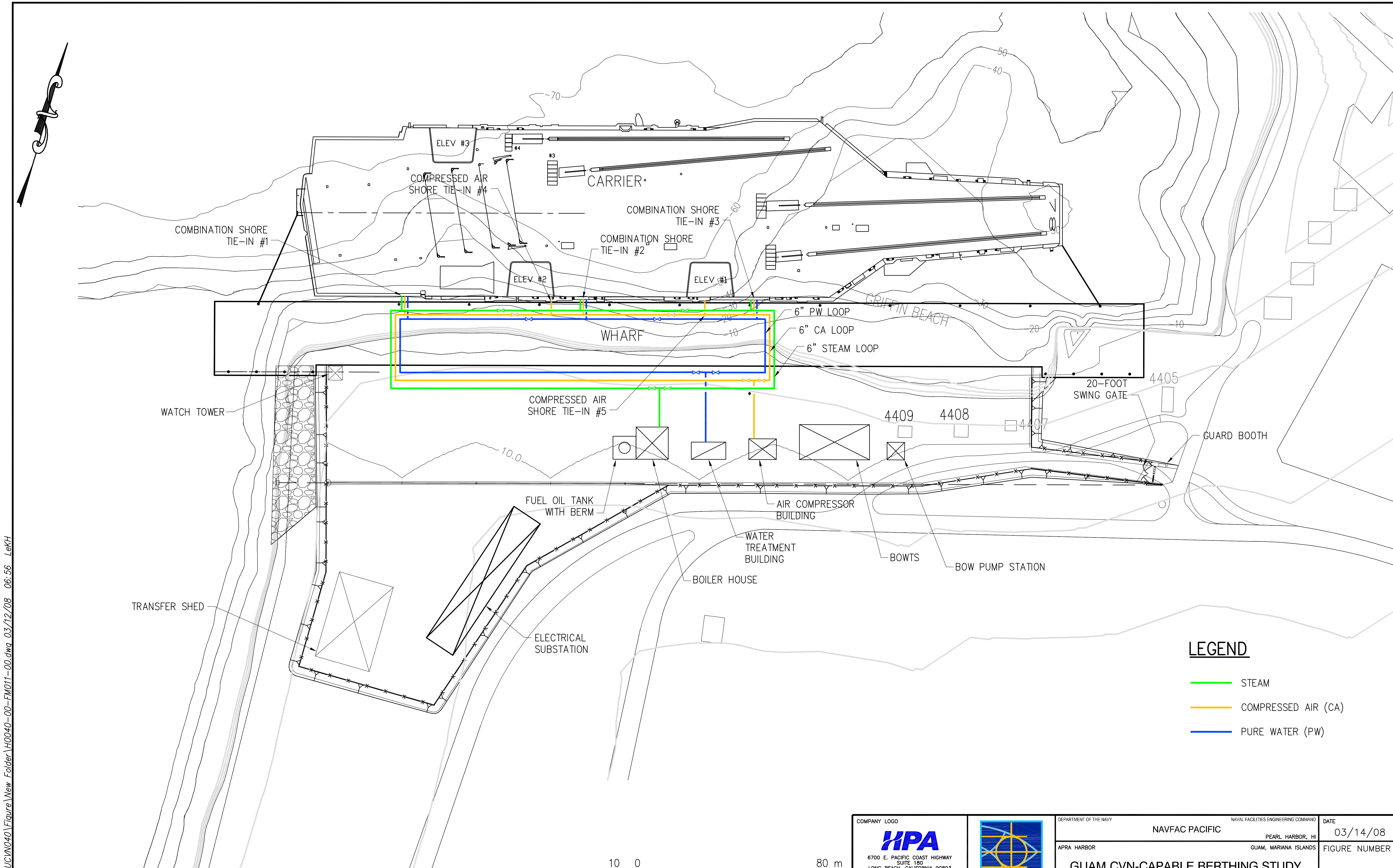
APRA HARBOR — GUAM, MARIANA ISLANDS

GUAM CVN-CAPABLE BERTHING STUDY

ALTERNATIVE 1 – FORMER SRF FACILITY
STEAM, PURE WATER AND COMPRESSED AIR SYSTEM

DATE 03/14/08

FIGURE NUMBER M-10



COMPANY LOGO

HPA
6700 E. PACIFIC COAST HIGHWAY SUITE 180 LONG BEACH, CALIFORNIA 90803

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DEPARTMENT OF THE NAVY
NAVAL FACILITIES ENGINEERING COMMAND
NAVFAC PACIFIC
PEARL HARBOR, HI

APRA HARBOR
GUAM, MARIANA ISLANDS

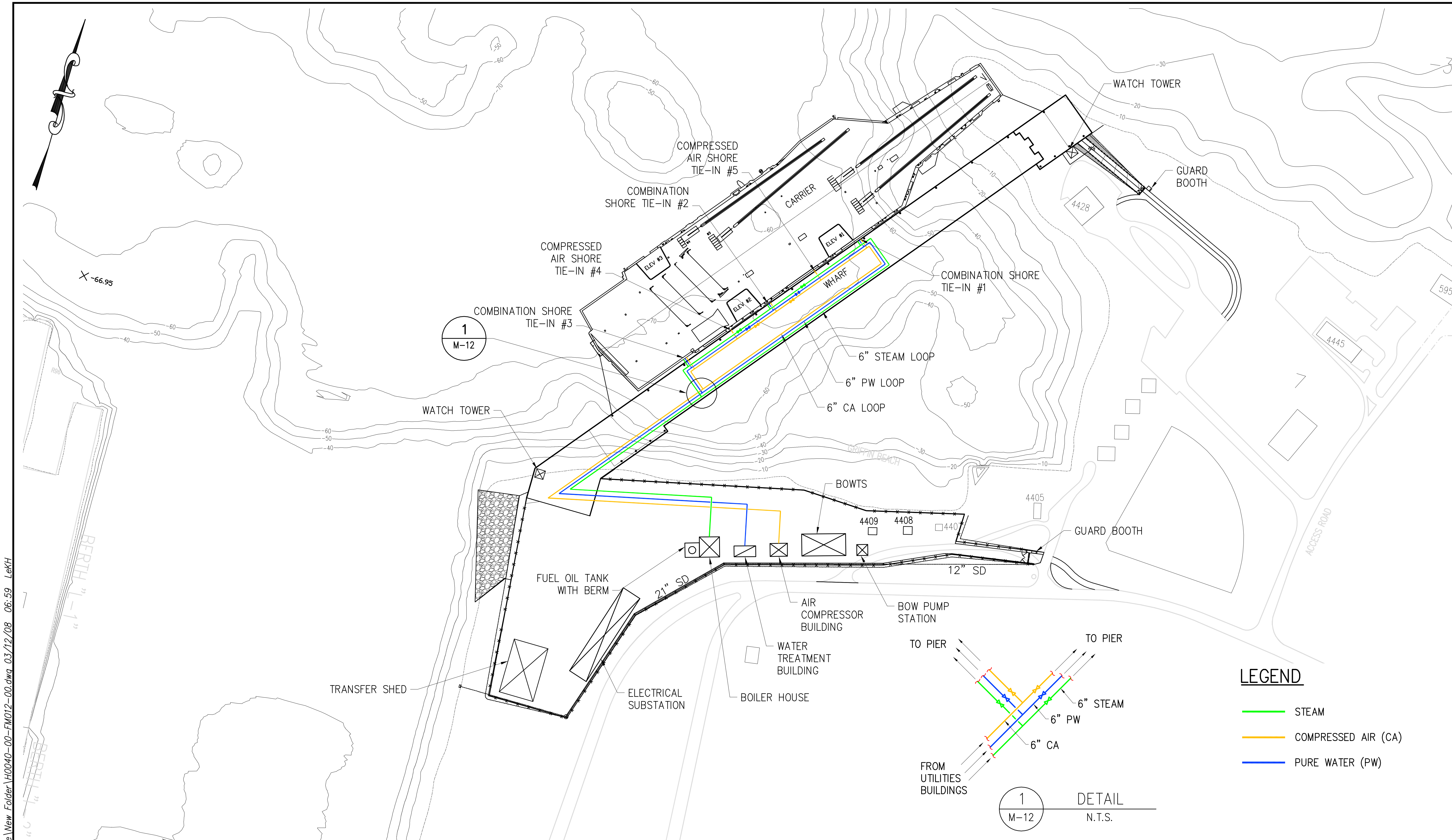
GUAM CVN-CAPABLE BERTHING STUDY

ALTERNATIVE 2 – POLARIS POINT PARALLEL TO SHORE STEAM, PURE WATER AND COMPRESSED AIR SYSTEM

DATE 03/14/08

FIGURE NUMBER M-11

T:\D\DGUCVN040\Figure\New Folder\H0040-00-FM011-00.dwg 03/12/08 06:56 LeKH



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COMPANY LOGO

HPA

6700 E. PACIFIC COAST HIGHWAY SUITE 180 LONG BEACH, CALIFORNIA 90803

NAVFAC

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NAVFAC PACIFIC

PEARL HARBOR, HI

APRA HARBOR | GUAM, MARIANA ISLANDS

GUAM CVN-CAPABLE BERTHING STUDY

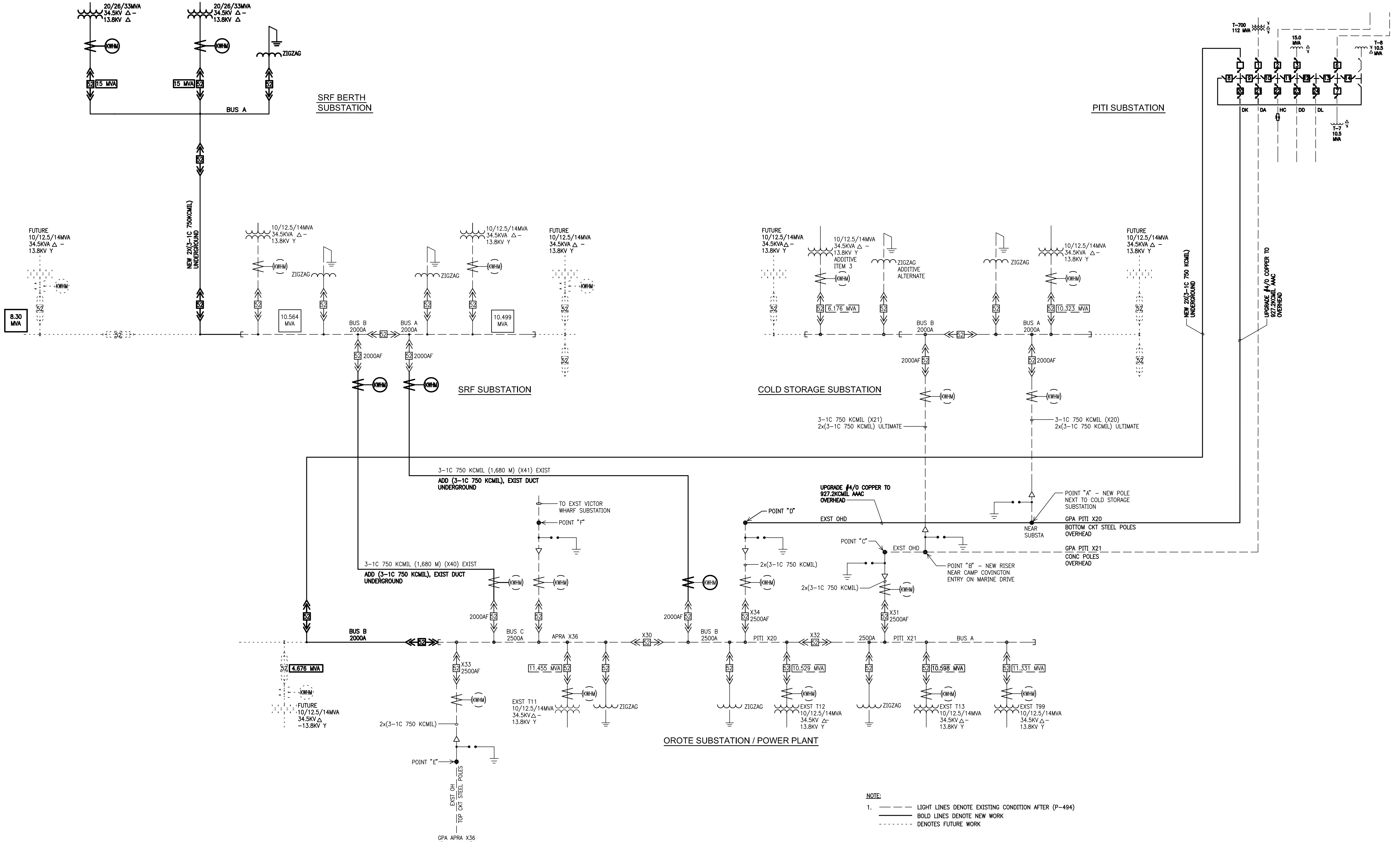
ALTERNATIVE 3 – POLARIS POINT DIAGNONAL OFFSHORE STEAM, PURE WATER AND COMPRESSED AIR SYSTEM

DATE 3/14/08

FIGURE NUMBER M-12

1 ALTERNATIVE 1 – SRF BERTH ELECTRICAL SITE PLAN
NO SCALE

COMPANY LOGO	DEPARTMENT OF THE NAVY / NAVAL FACILITIES ENGINEERING COMMAND	NAVFAC PACIFIC / PEARL HARBOR, HI	DATE 03/14/08
	APRA HARBOR / GUAM, MARIANA ISLANDS	GUAM CVN-CAPABLE BERTHING STUDY / ALTERNATIVE 1 – SRF BERTH ELECTRICAL SITE PLAN	FIGURE NUMBER E-1A



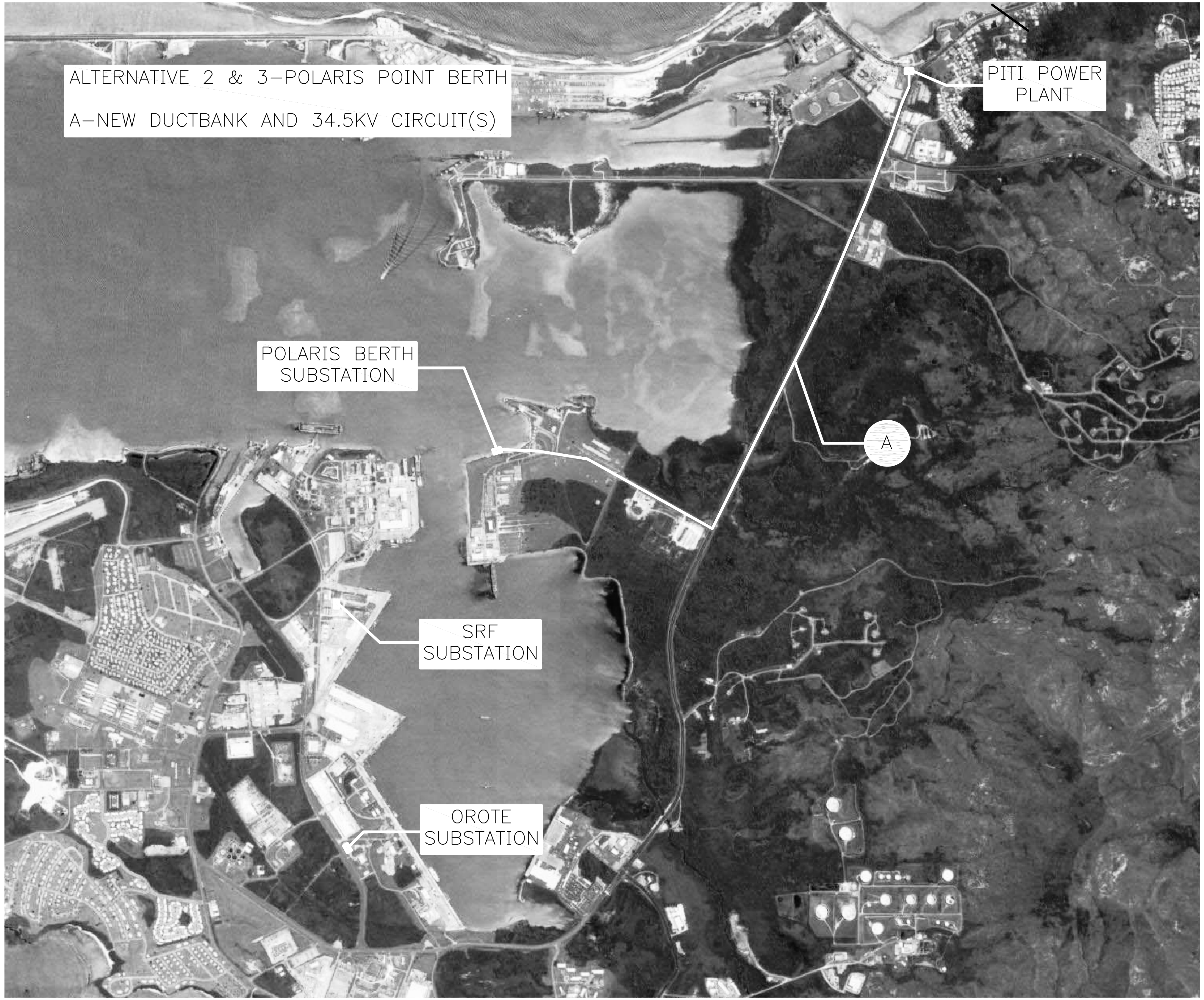
1 ALTERNATIVE 1 – SRF BERTH 34.5KV SYSTEM ONE-LINE DIAGRAM
NO SCALE

COMPANY LOGO		DEPARTMENT OF THE NAVY / NAVAL FACILITIES ENGINEERING COMMAND — NAVFAC PACIFIC, PEARL HARBOR, HI	DATE 03/14/08
CONSULTING ELECTRICAL ENGINEERS	NAVFAC	APRA HARBOR, GUAM, MARIANA ISLANDS — GUAM CVN-CAPABLE BERTHING STUDY — ALTERNATIVE 1 – SRF BERTH 34.5KV SYSTEM ONE-LINE DIAGRAM	FIGURE NUMBER E-1B

1 ALTERNATIVE 1 – SRF BERTH COMMUNICATIONS SYSTEM SITE PLAN

NO SCALE

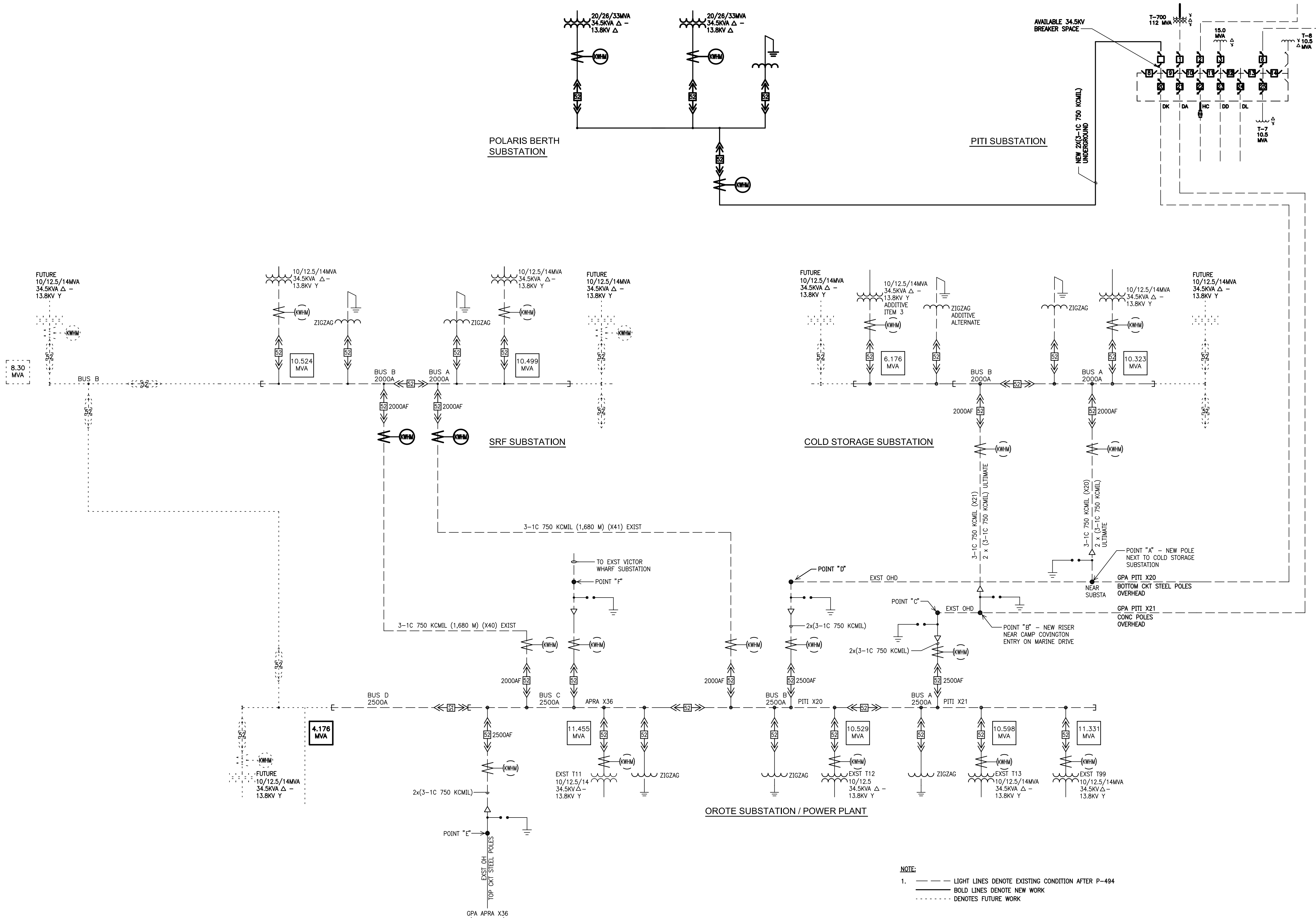
COMPANY LOGO CONSULTING ELECTRICAL ENGINEERS	NAVFAC	DEPARTMENT OF THE NAVY · NAVAL FACILITIES ENGINEERING COMMAND · NAVFAC PACIFIC · PEARL HARBOR, HI	DATE 03/14/08
		APRA HARBOR · GUAM, MARIANA ISLANDS · GUAM CVN-CAPABLE BERTHING STUDY · ALTERNATIVE 1 – SRF BERTH COMMUNICATIONS SYSTEM SITE PLAN	FIGURE NUMBER E-1C



1 ALTERNATIVE 2 & 3 – POLARIS POINT BERTH ELECTRICAL SITE PLAN

NO SCALE

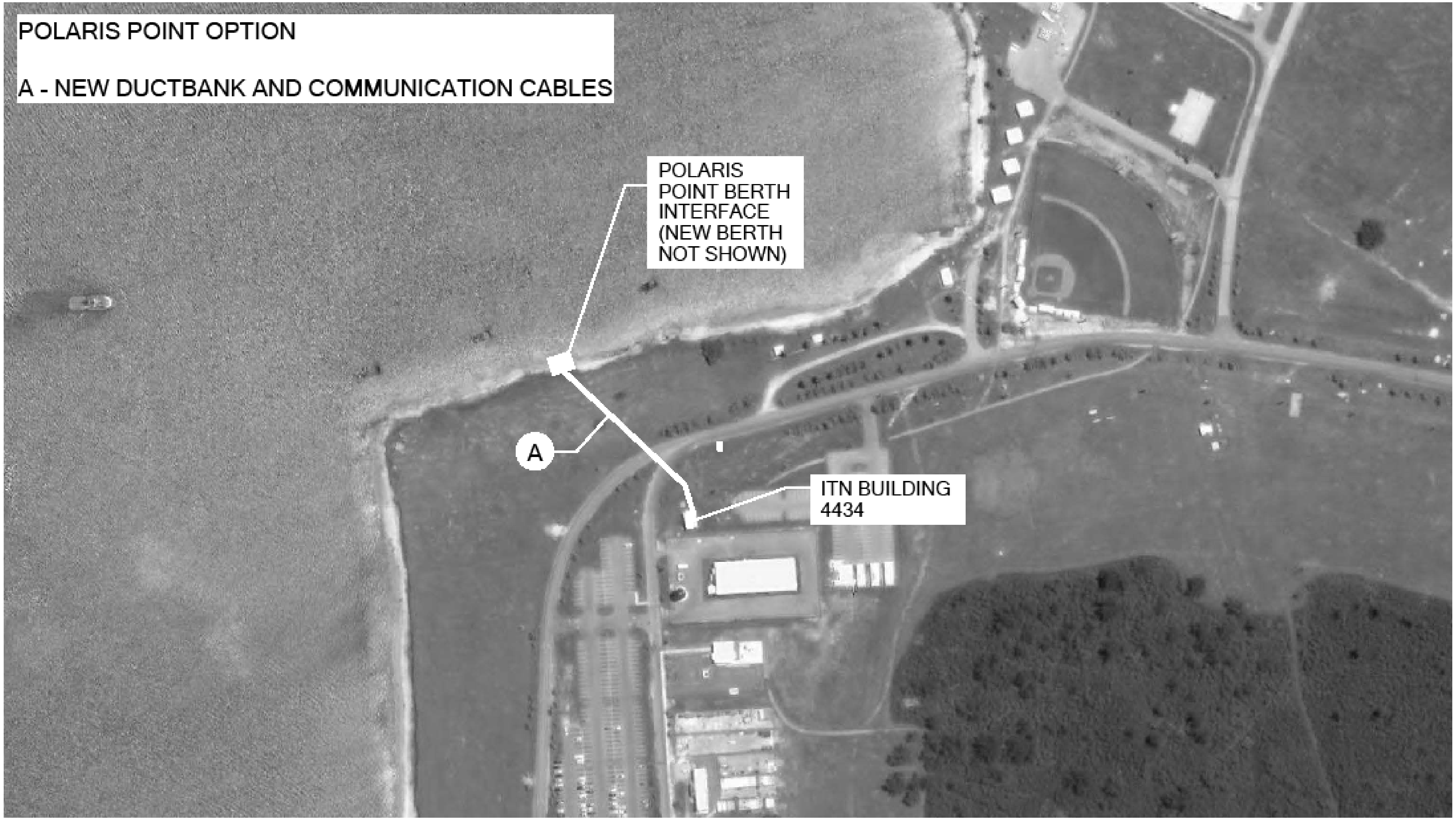
COMPANY LOGO	DEPARTMENT OF THE NAVY / NAVAL FACILITIES ENGINEERING COMMAND	NAVFAC PACIFIC / PEARL HARBOR, HI	DATE 03/14/08
	APRA HARBOR / GUAM, MARIANA ISLANDS	GUAM CVN-CAPABLE BERTHING STUDY	FIGURE NUMBER E-2A
		ALTERNATIVE 2 & 3 – POLARIS POINT BERTH ELECTRICAL SITE PLAN	



1 ALTERNATIVE 2 & 3 – POLARIS POINT BERTH 34.5KV SYSTEM ONE-LINE DIAGRAM

NO SCALE

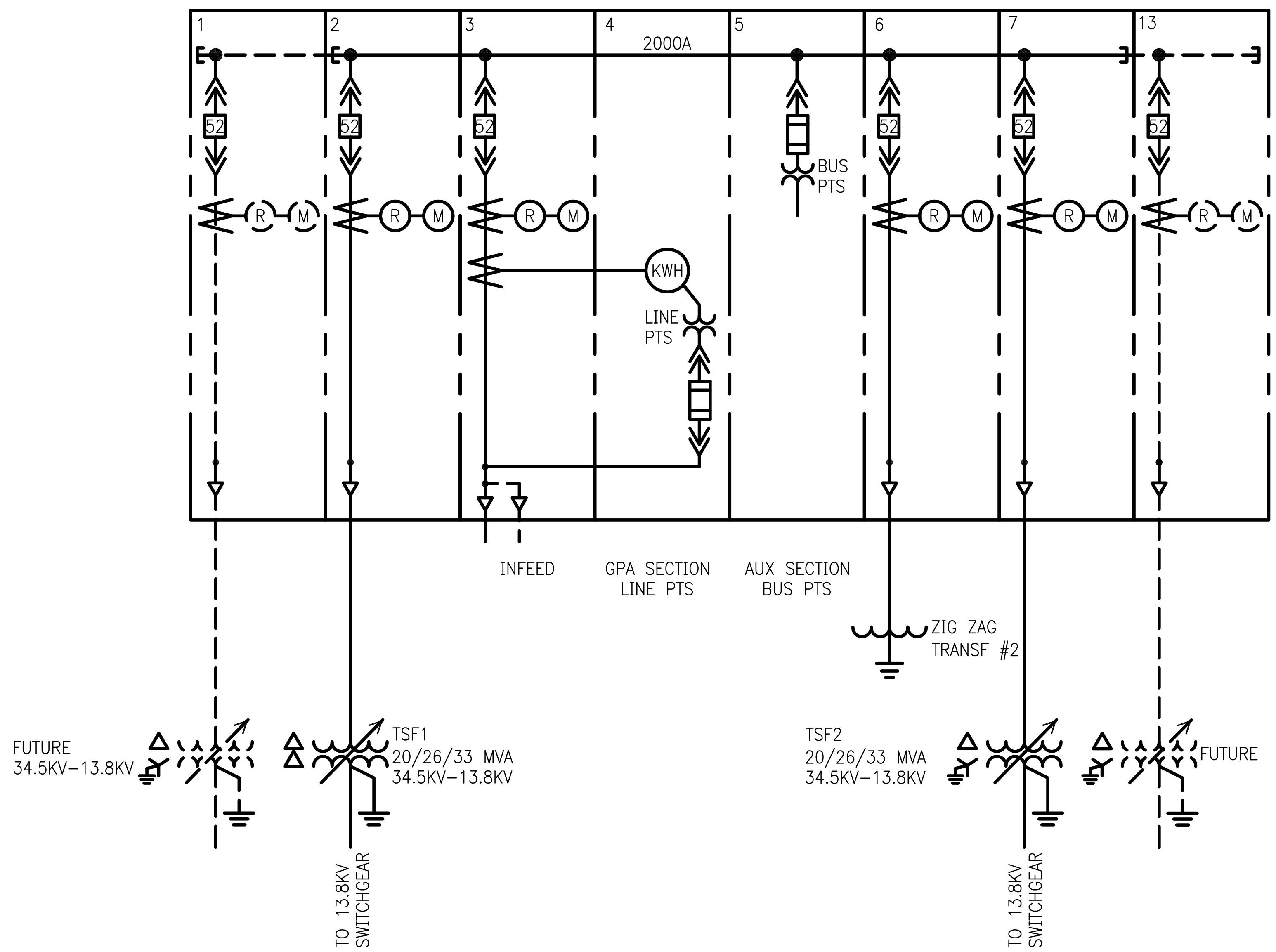
COMPANY LOGO		DEPARTMENT OF THE NAVY / NAVAL FACILITIES ENGINEERING COMMAND — NAVFAC PACIFIC — PEARL HARBOR, HI	DATE 03/14/08
CONSULTING ELECTRICAL ENGINEERS	NAVFAC	APRA HARBOR — GUAM, MARIANA ISLANDS — GUAM CVN-CAPABLE BERTHING STUDY	FIGURE NUMBER
		ALTERNATIVE 2 & 3 – POLARIS POINT BERTH 34.5KV SYSTEM ONE-LINE DIAGRAM	E-2B



1 ALTERNATIVE 2 & 3 – POLARIS POINT BERTH COMMUNICATIONS SYSTEM SITE PLAN

NO SCALE

COMPANY LOGO	DEPARTMENT OF THE NAVY / NAVAL FACILITIES ENGINEERING COMMAND NAVFAC PACIFIC PEARL HARBOR, HI		DATE 03/14/08
	APRA HARBOR / GUAM, MARIANA ISLANDS GUAM CVN-CAPABLE BERTHING STUDY ALTERNATIVE 2 & 3 – POLARIS POINT BERTH COMMUNICATIONS SYSTEM SITE PLAN		FIGURE NUMBER E-2C



NOTES:

1. ———— BOLD LINES DENOTE NEW WORK
   – – – – DENOTES FUTURE WORK

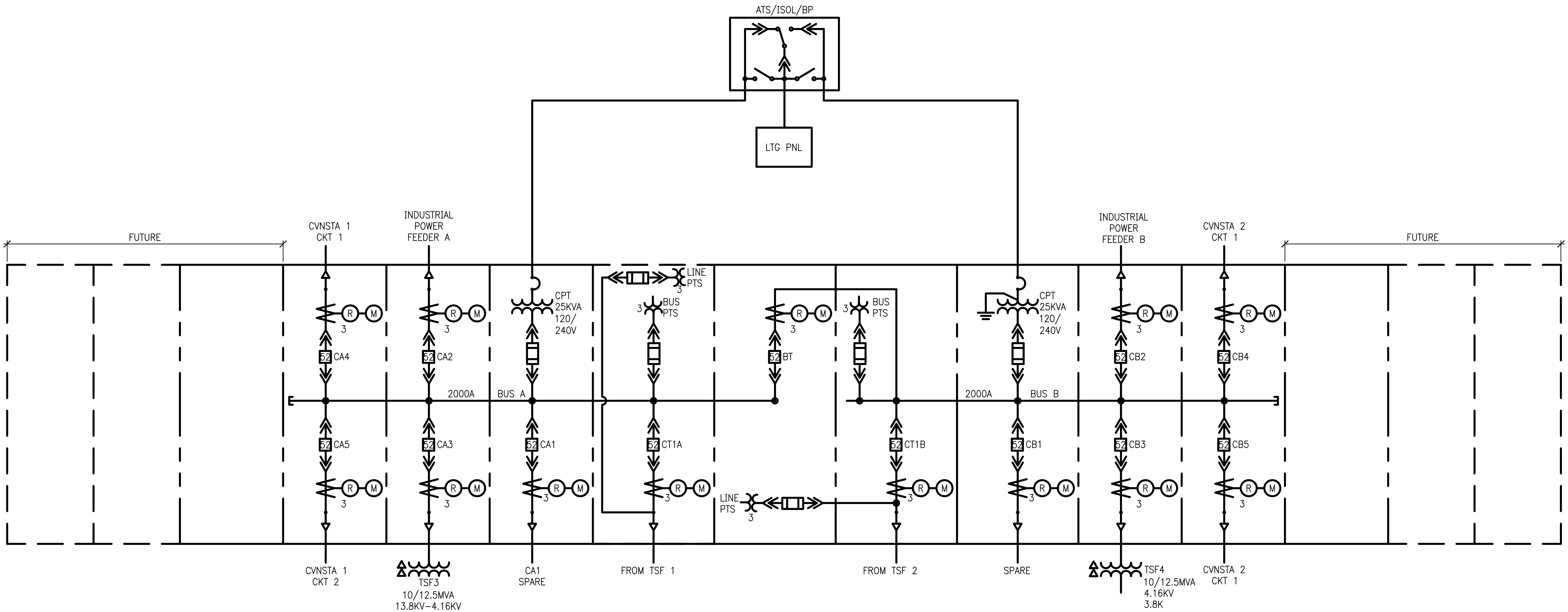
2. CTS WILL BE MULTI–RATIO; CTS FOR KWHM'S SHALL BE REVENUE GRADE.

1 BERTH SUBSTATION
34.5KV SWITCHGEAR ONE–LINE DIAGRAM
NO SCALE

COMPANY LOGO
CONSULTING ELECTRICAL ENGINEERS

DEPARTMENT OF THE NAVY — NAVAL FACILITIES ENGINEERING COMMAND
NAVFAC PACIFIC
PEARL HARBOR, HI
APRA HARBOR — GUAM, MARIANA ISLANDS
GUAM CVN-CAPABLE BERTHING STUDY
BERTH SUBSTATION
34.5KV SWITCHGEAR ONE–LINE DIAGRAM

DATE 03/14/08
FIGURE NUMBER E-3

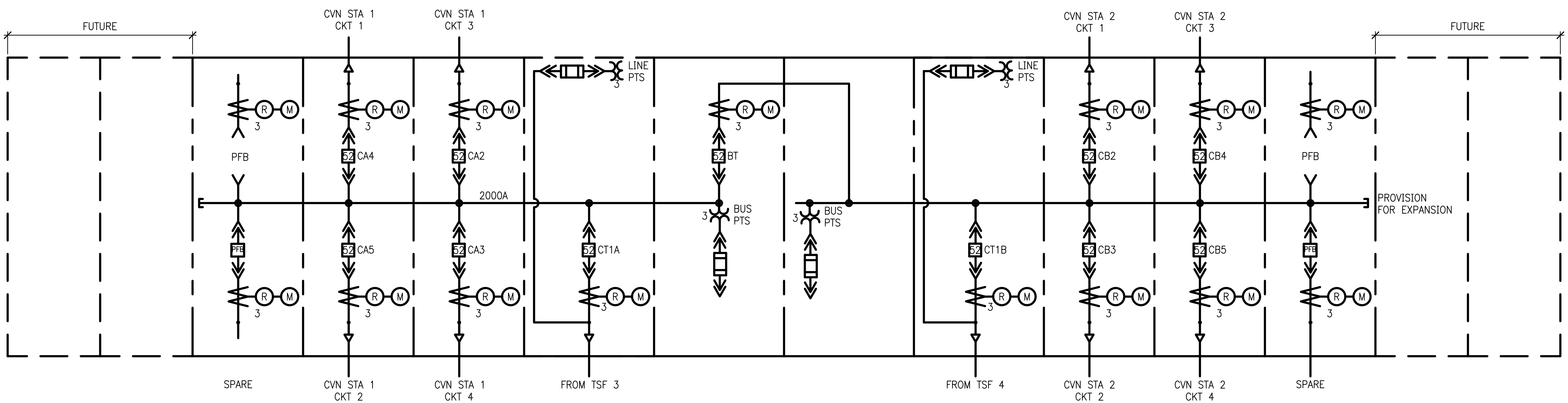


1

BERTH SUBSTATION
13.8KV SWITCHGEAR ONE–LINE DIAGRAM

NO SCALE

COMPANY LOGO		DEPARTMENT OF THE NAVY / NAVAL FACILITIES ENGINEERING COMMAND	DATE
CONSULTING ELECTRICAL ENGINEERS	NAVFAC	NAVFAC PACIFIC PEARL HARBOR, HI	03/14/08
		APRA HARBOR / GUAM, MARIANA ISLANDS GUAM CVN-CAPABLE BERTHING STUDY BERTH SUBSTATION 13.8KV SWITCHGEAR ONE–LINE DIAGRAM	FIGURE NUMBER E-4



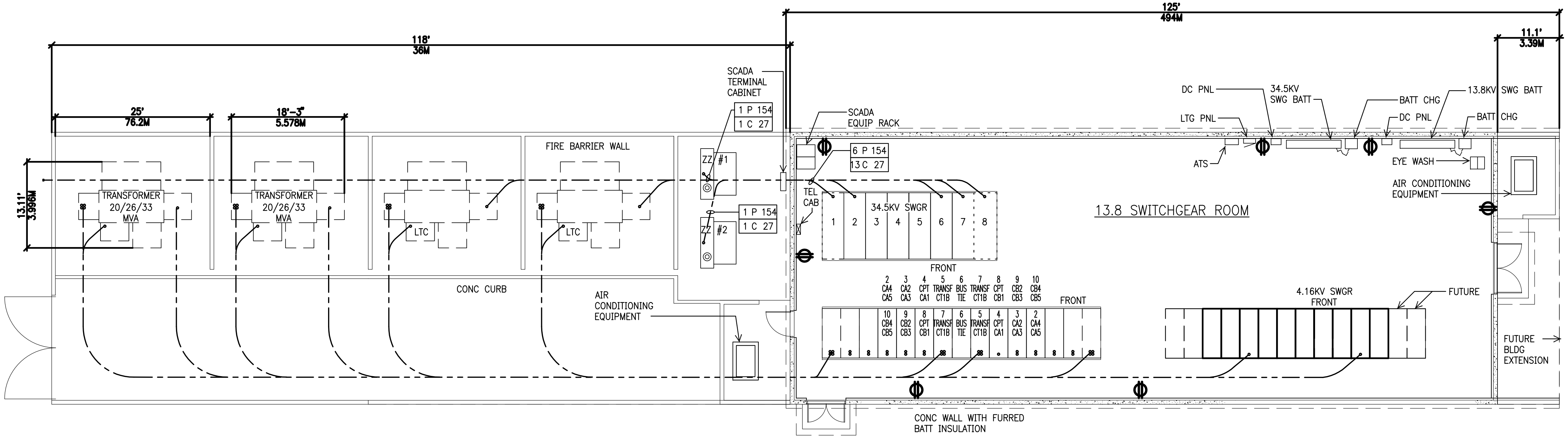
1 BERTH SUBSTATION
4.16KV SWITCHGEAR ONE-LINE DIAGRAM
NO SCALE

COMPANY LOGO

CONSULTING ELECTRICAL ENGINEERS

DEPARTMENT OF THE NAVY
NAVFAC PACIFIC
NAVAL FACILITIES ENGINEERING COMMAND
PEARL HARBOR, HI
APRA HARBOR
GUAM, MARIANA ISLANDS
GUAM CVN-CAPABLE BERTHING STUDY
BERTH SUBSTATION
4.16KV SWITCHGEAR ONE-LINE DIAGRAM

DATE
03/14/08
FIGURE NUMBER
E-5



GRAPHIC SCALE

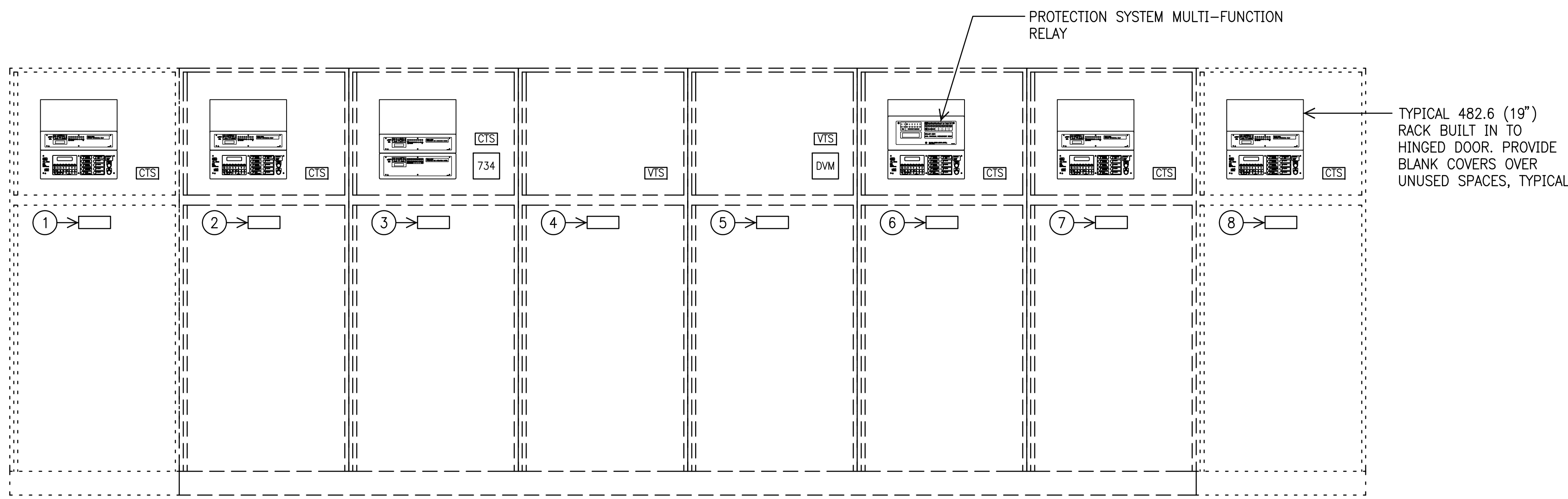
0 5 10 15 20 25 m

1:250

1 BERTH SUBSTATION BUILDING ELECTRICAL EQUIPMENT PLAN

NO SCALE

COMPANY LOGO		DEPARTMENT OF THE NAVY — NAVFAC PACIFIC — NAVAL FACILITIES ENGINEERING COMMAND, PEARL HARBOR, HI	DATE 03/14/08
	NAVFAC	APRA HARBOR — GUAM, MARIANA ISLANDS — GUAM CVN-CAPABLE BERTHING STUDY	FIGURE NUMBER
		BERTH SUBSTATION BUILDING ELECTRICAL EQUIPMENT PLAN	E-6



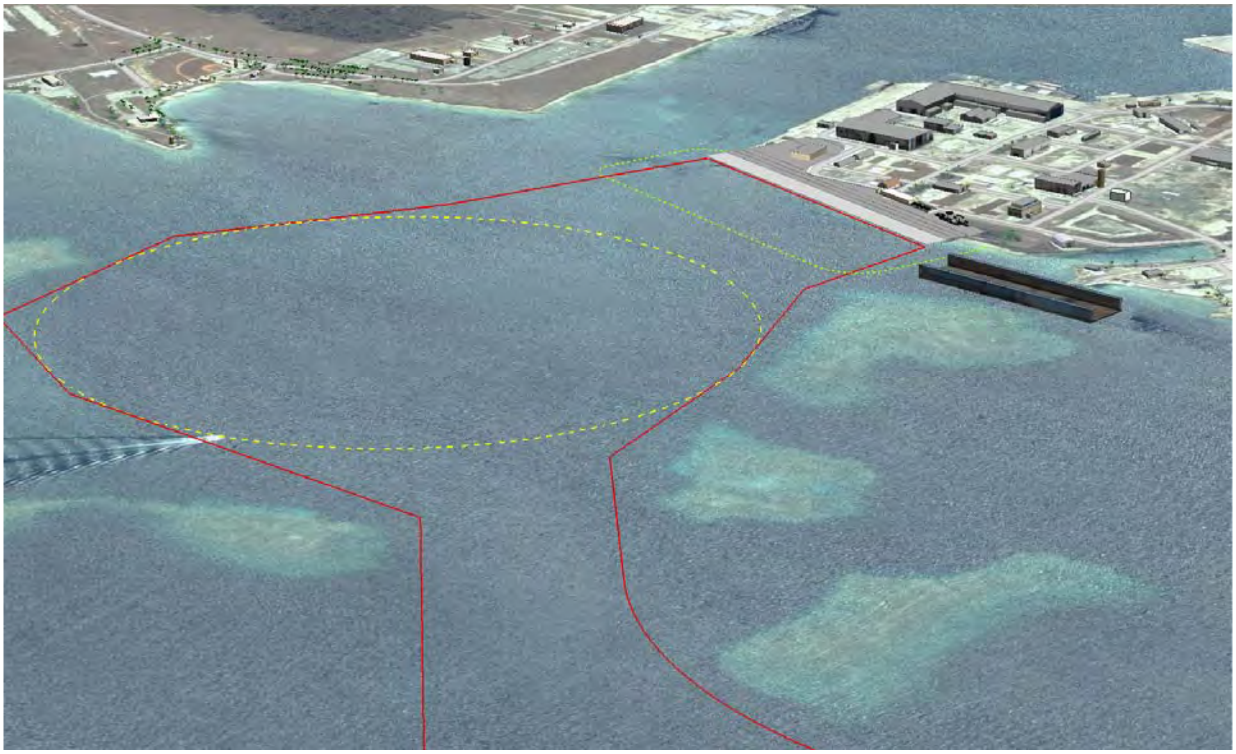
1 BERTH SUBSTATION 34.5KV SWITCHGEAR ELEVATION
NO SCALE

COMPANY LOGO CONSULTING ELECTRICAL ENGINEERS	NAVFAC	DEPARTMENT OF THE NAVY — NAVAL FACILITIES ENGINEERING COMMAND NAVFAC PACIFIC PEARL HARBOR, HI	DATE 03/14/08
		APRA HARBOR — GUAM, MARIANA ISLANDS GUAM CVN-CAPABLE BERTHING STUDY BERTH SUBSTATION 34.5KV SWITCHGEAR ELEVATION	FIGURE NUMBER E-7

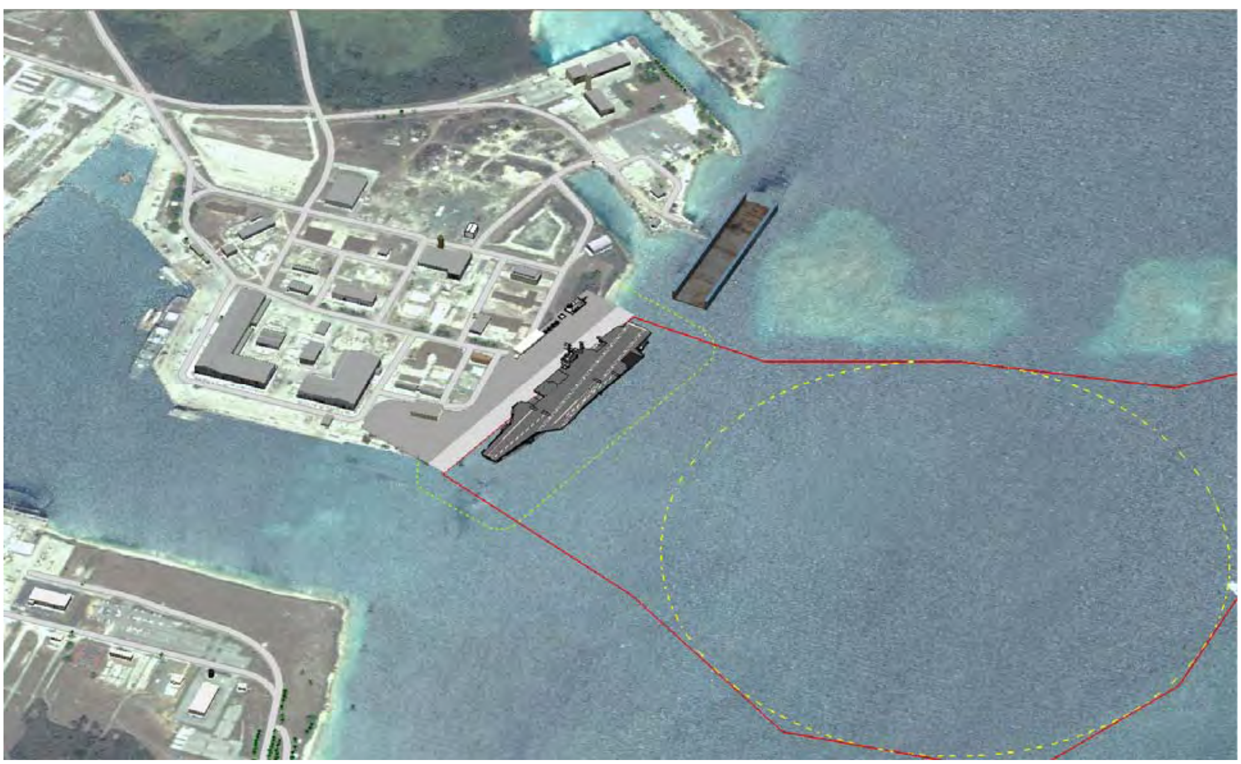
APPENDIX A

3D ANIMATIONS (CD Enclosed)
AND 3D MODEL IMAGES

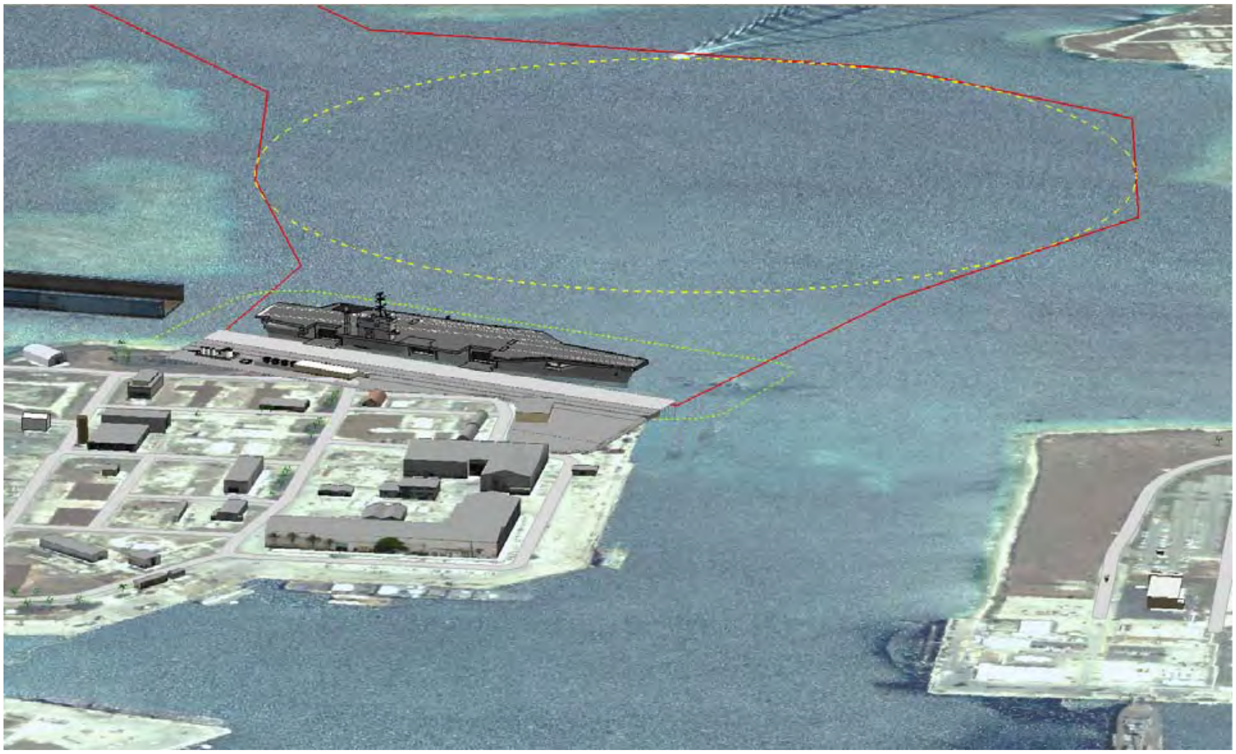
Alternative 1 – Former SRF



Alternative 1 – Image 1



Alternative 1 – Image 2



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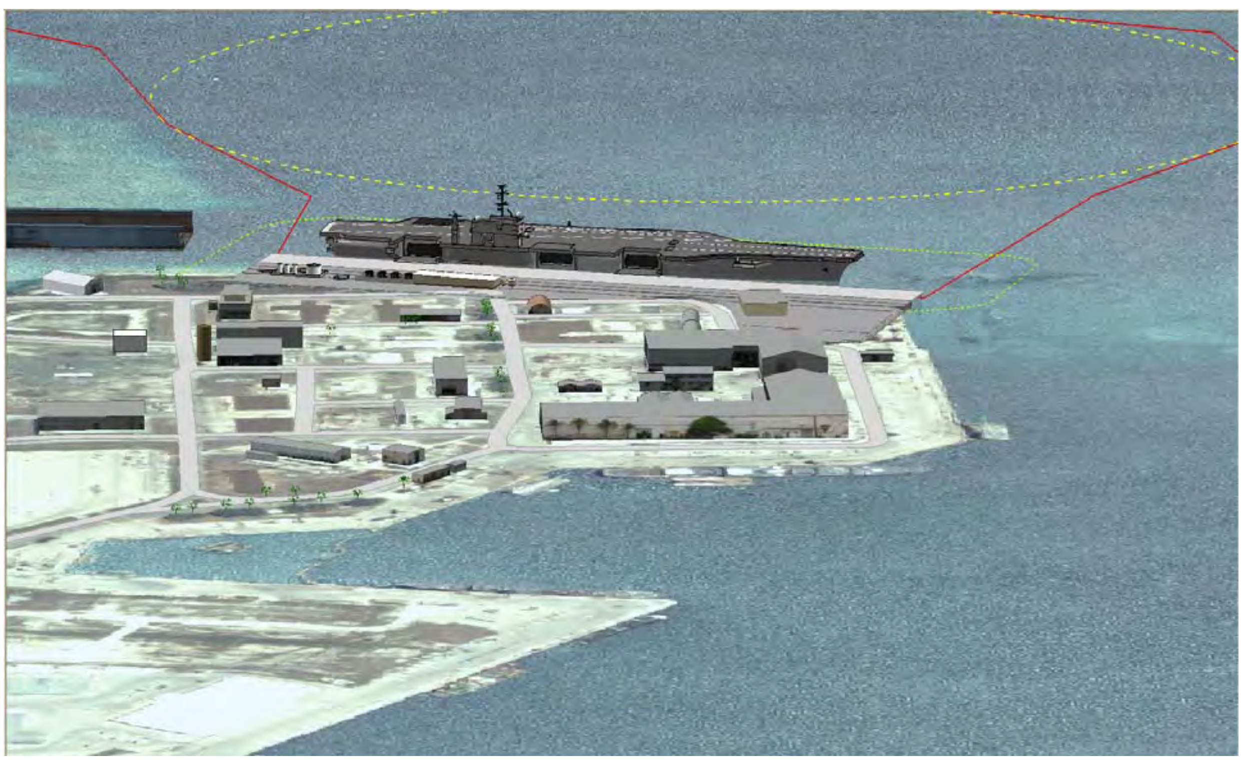

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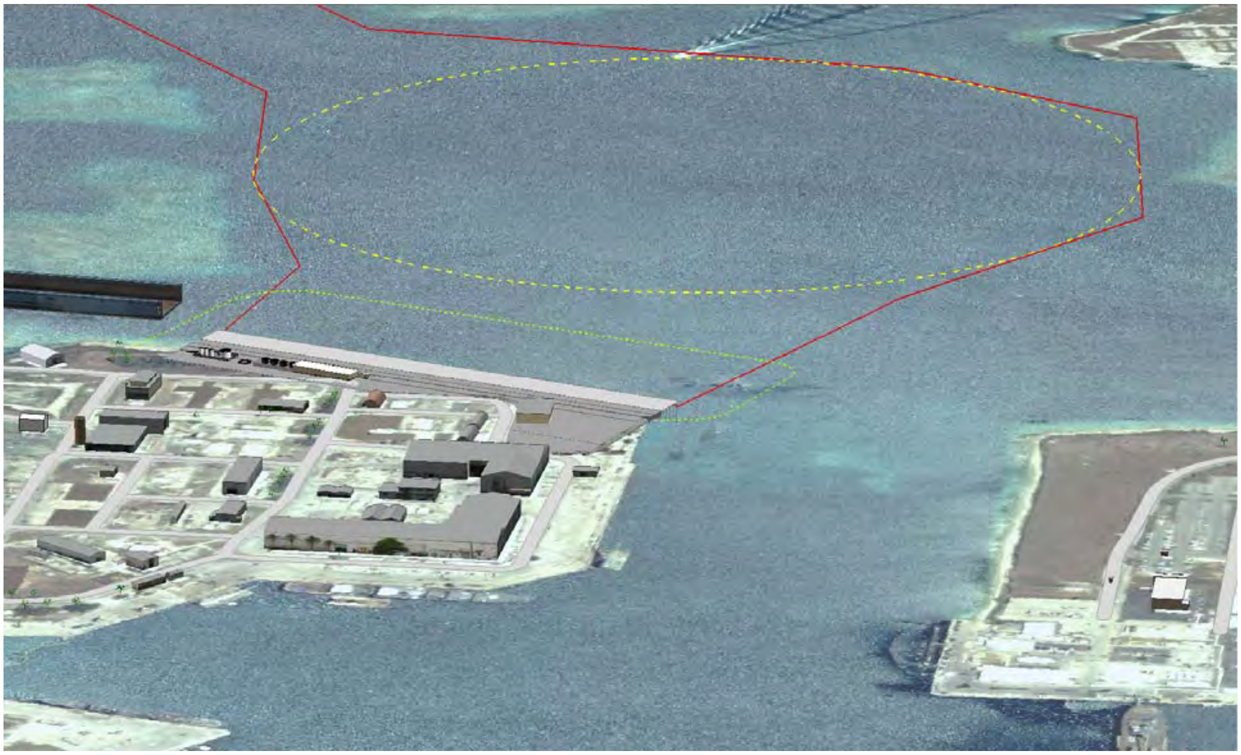
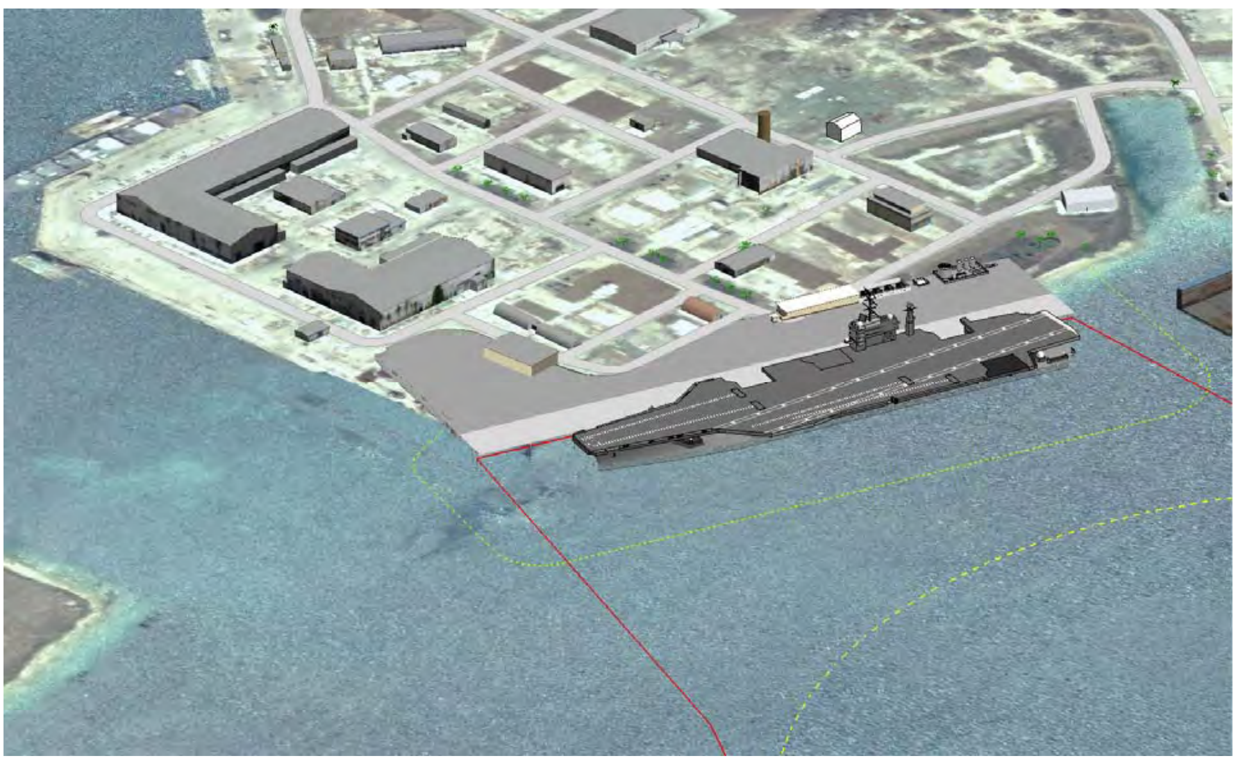
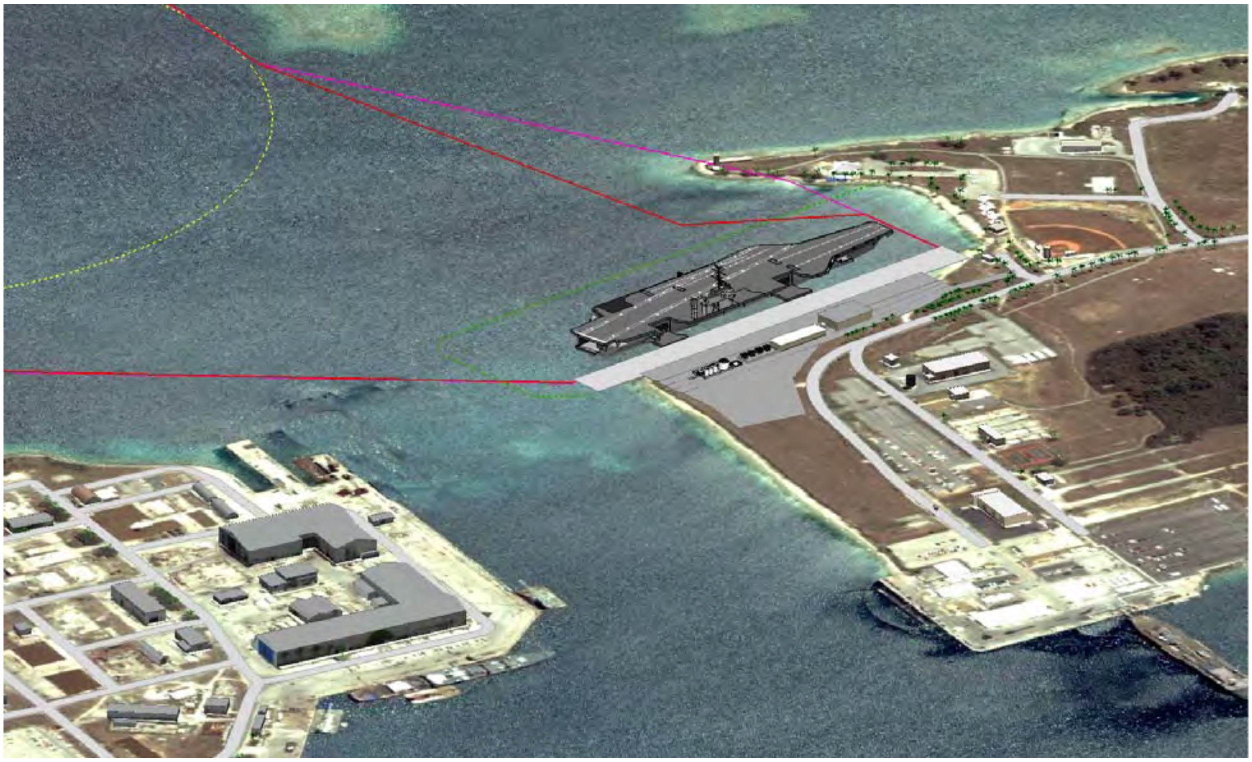

Alternative 1 – Image 5


Alternative 1 – Image 6

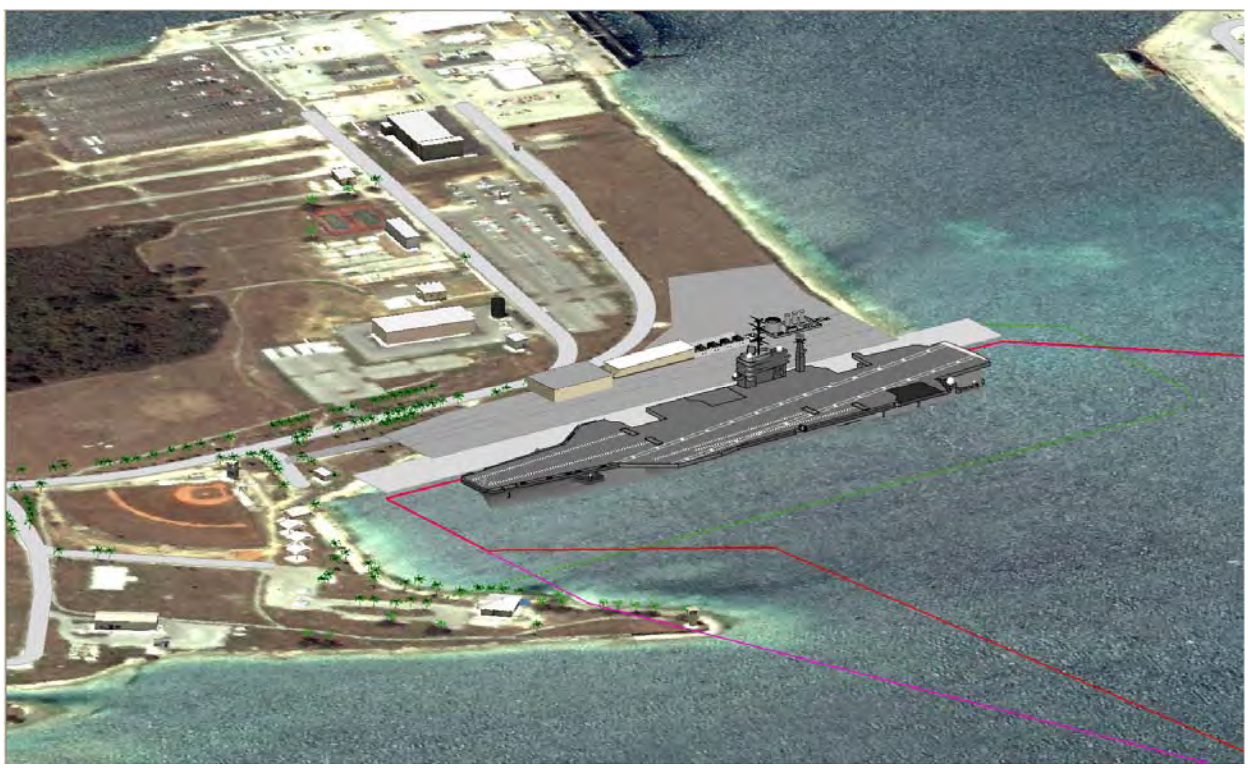
Alternative 2 – Polaris Point Parallel to Shore

Alternative 2 – Image 1

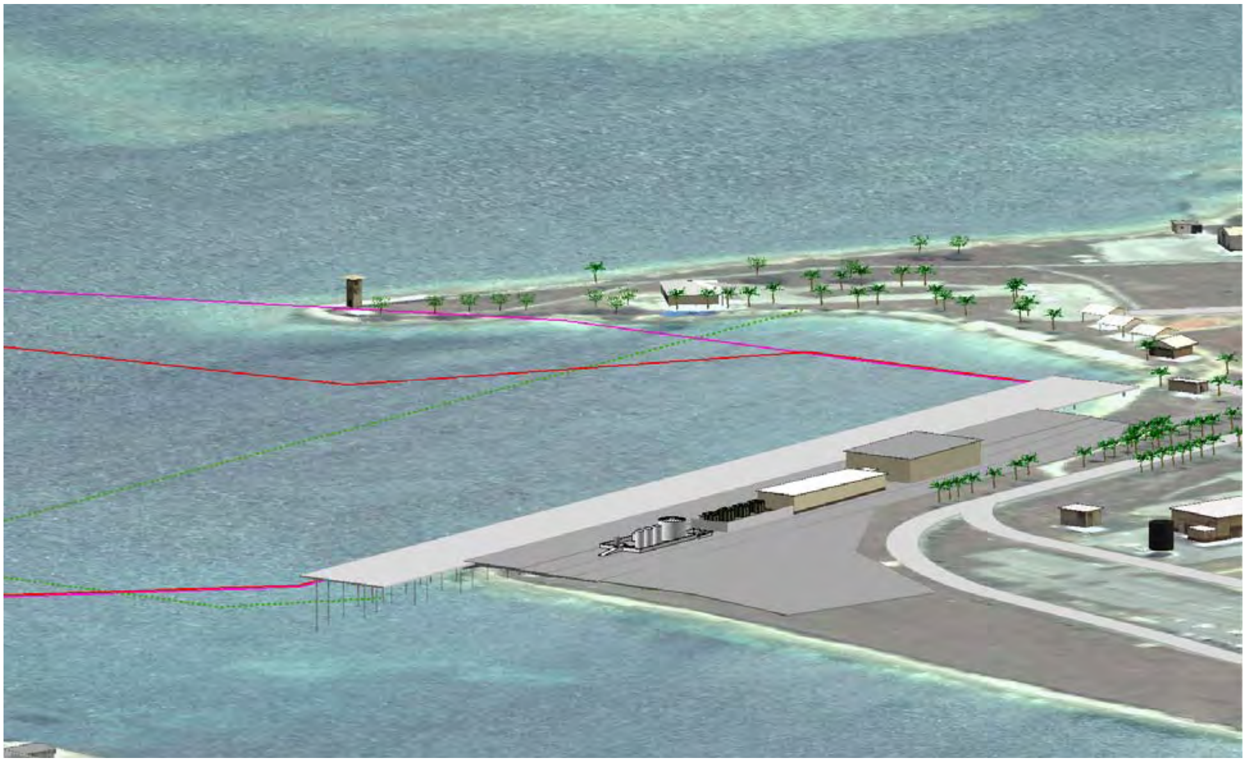
Alternative 2 – Image 2

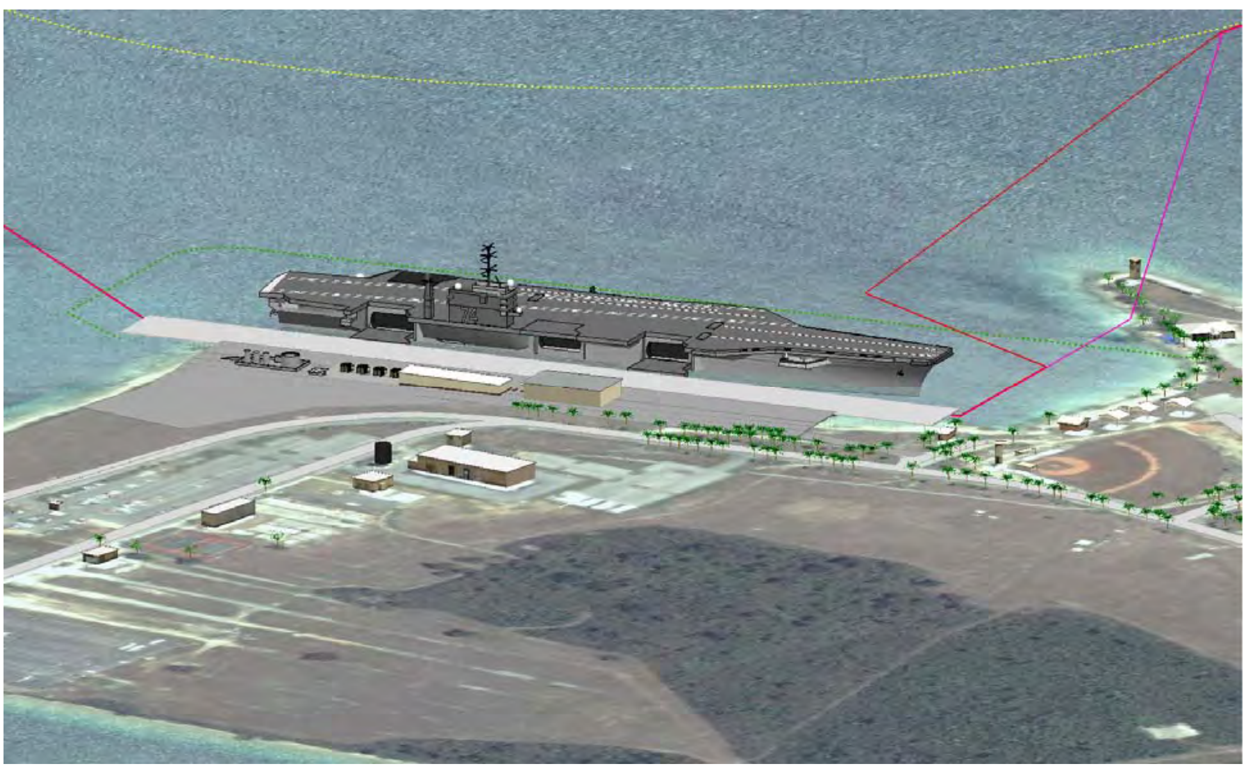


Alternative 2 – Image 3



Alternative 2 – Image 4

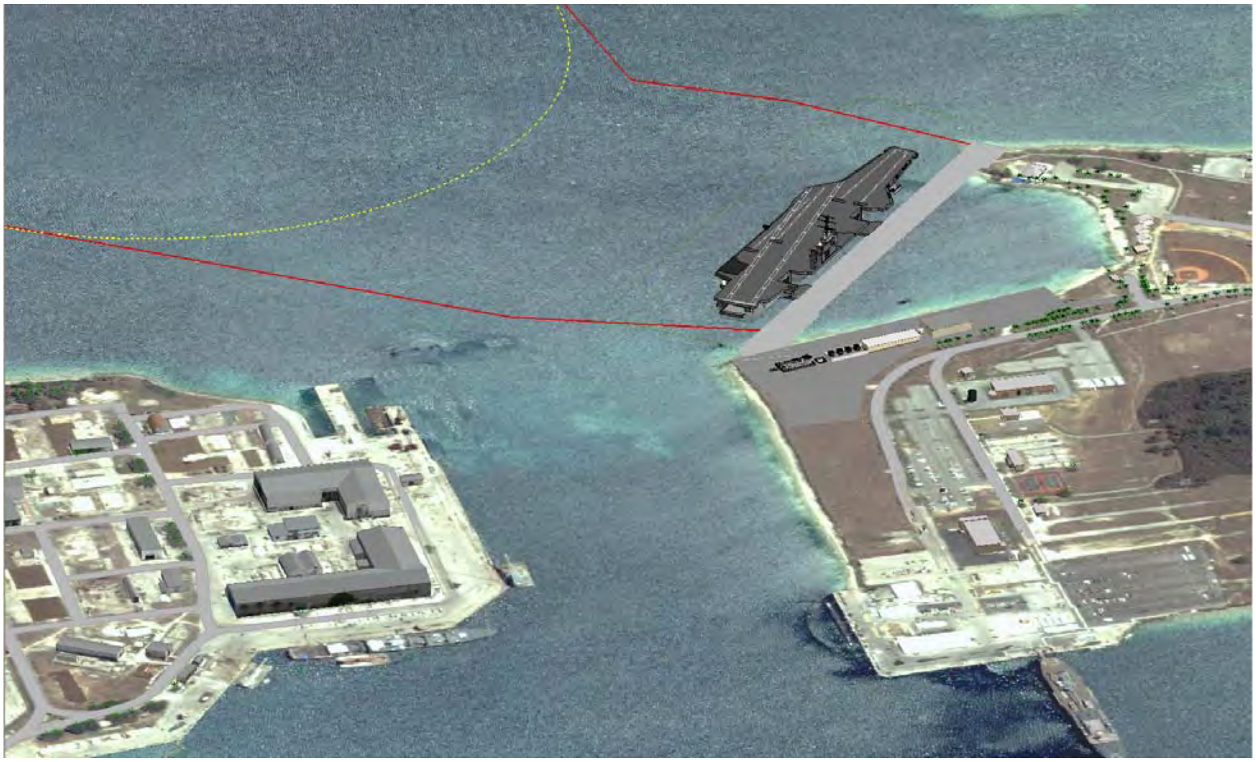

Alternative 2 – Image 5


Alternative 2 – Image 6

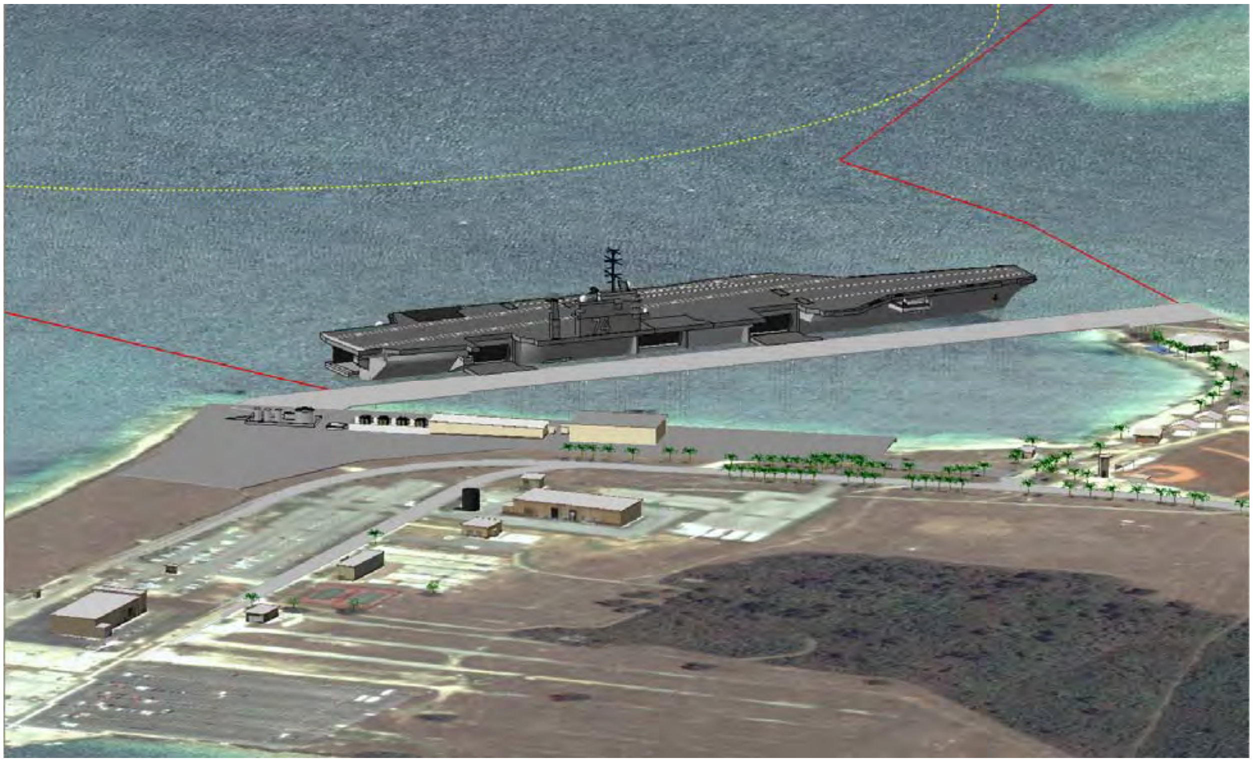
Alternative 3 – Polaris Point Diagonal Offshore


Alternative 3 – Image 1

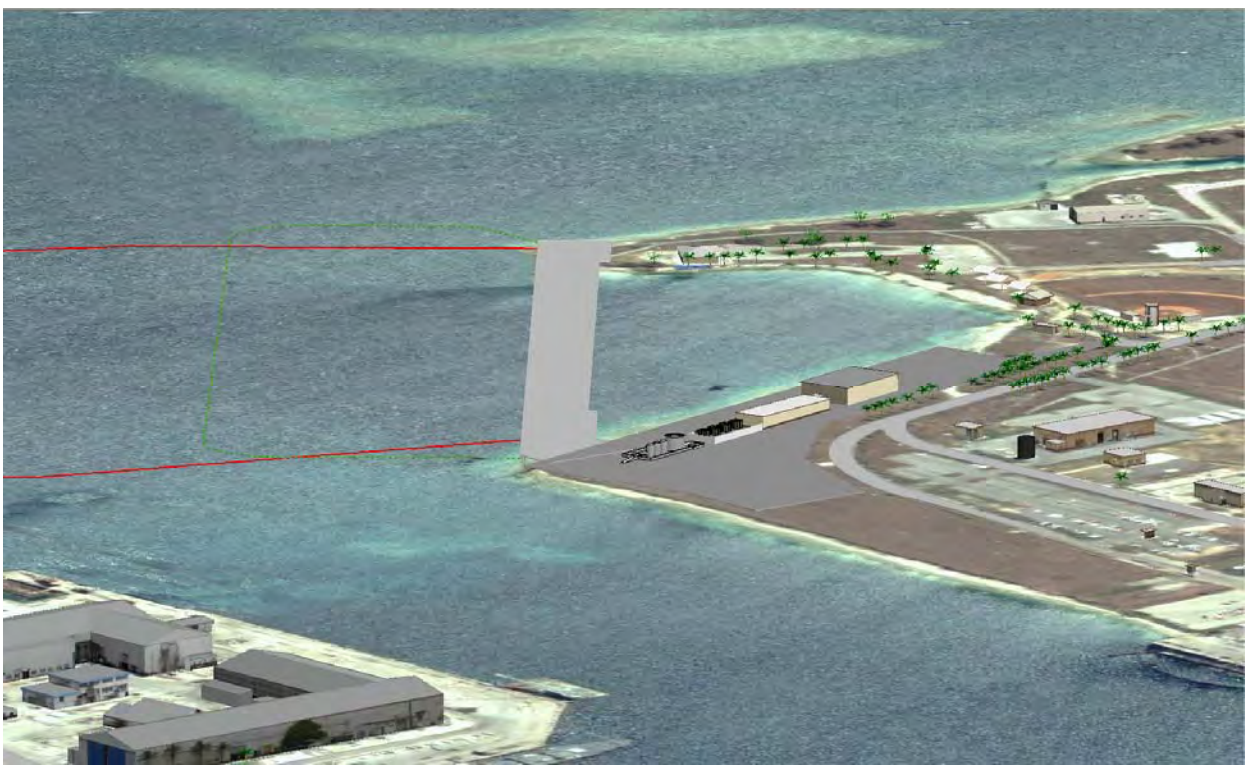

Alternative 3 – Image 2


Alternative 3 – Image 3


Alternative 3 – Image 4



Alternative 3 – Image 5



Alternative 3 – Image 6

APPENDIX B

COST ESTIMATES

APPENDIX B

Alternative 1 - Former SRF

COST ESTIMATE

Description	Qty	Unit	Unit Cost	Costs
Alternate #1: Former SRF Facility				
Project General Conditions				
Construction General Conditions				
General Conditions	1	ls	16,381,286	16,381,286
Construction General Conditions	**1**	**ls**		**16,381,286**
Mobilization / Demobilization / Housing				
Mobilization / Demobilization	1	ls	9,307,549	9,307,549
Contractor Workforce Housing and Per Diem Costs				
Mobilization / Demobilization / Housing	**1**	**ls**		**9,307,549**
Dredging				
Dredging - SRF Channel Option #1				
Dredge Mobilization	1	ls	9,208,320	9,208,320
Dredging 342,200		cu yd	20.26	6,932,392
Overdredge 136,700		cu yd	20.26	2,769,310
Dredge Disposal - uplands	478,900	cu yd	40.52	19,403,404
Aids to Navigation	1	ls	2,025,830	2,025,830
Rip Rap Removal	-	cu yd		
Land Filling Material Handling	-	cu yd		
Dredging - SRF Channel Option #1	**478,900**	**cu yd**	**84**	**40,339,256**
Wharf Struture				
Steel Pipe Piles at Main Pier Structure				
Material - Pipe - 24" diameter - .62" wall - 156 #/lf	33,060	lf	663	21,919,860
Material - Rebar Cage	248,713	lbs	1.81	450,946
Material - Fill Concrete	1,082	cu yd	608	657,585
Installation - Piles	410	ea	39,909	16,362,632
Installation - Rebar	248,713	lbs	1.09	271,298
Installation - Concrete	1,082	cu yd	85.02	91,995
Steel Pipe Piles at Main Pier Structure	**410**	**ea**	**96,962**	**39,754,316**

Description	Qty	Unit	Unit Cost	Costs
Cast In Place Concrete at Deck				
Concrete Material - 126,750 sf Deck	10,000	cu yd	608	6,077,491
Rebar	2,500	Tns	3,626	9,065,591
Formwork	143,000	sf	46.14	6,598,499
Installation -rebar	2,500	Tns	2,182	5,454,042
Installation - concrete	10,000	cu yd	143	1,432,388
Cast In Place Concrete at Deck	**10,000**	**cu yd**	**2,863**	**28,628,012**
CVN Camel / Fender Structure				
Piles	18,000	lf	193	3,480,745
Camels - (steel load transfer float)	3	unit	2,092,800	6,278,400
6 lf Diameter Foam Filled Fenders	12	ea	184,166	2,209,997
Pile Installation	120	ea	5,157	618,799
Camel / Fender Assembly	12	ea	36,612	439,347
Brows	3	ea	920,832	2,762,496
CVN Camel / Fender Structure	**1**	**ls**		**15,789,784**
Miscellaneous Metals				
Materials	66,250	lbs	10.13	671,056
Installation	66,250	lbs	10.13	671,056
Miscellaneous Metals	**66,250**	**lbs**	**20.26**	**1,342,113**
100 Ton Bollards				
Materials	13	ea	141,808	1,843,506
Installation	13	ea	40,517	526,716
100 Ton Bollards	**13**	**ea**	**182,325**	**2,370,222**
200 Ton Storm Bollards				
Materials	8	ea	202,583	1,620,664
Installation	8	ea	40,517	324,133
200 Ton Storm Bollards	**8**	**ea**	**243,100**	**1,944,797**
Cathodic Protection and Special Coatings				
Berth	1	ls	3,038,746	3,038,746
Cathodic Protection and Special Coatings	**1**	**ls**		**3,038,746**

Description	Qty	Unit	Unit Cost	Costs
Marine Revetment				
Wharf Revetment				
Quarry Stone Fill Procurment and Transportation	41,961	cu yd	81.03	3,400,235
Quarry Stone Fill Placement	41,961	cu yd	60.77	2,550,176
Riprap Stone Procurment and Transportation	19,815	cu yd	153.96	3,050,779
Riprap Stone Placement	19,815	cu yd	60.77	1,204,255
Wharf Revetment	**61,776**	**cu yd**	**165**	**10,205,445**
Sitework				
Site Work				
PCC Cut-Off Wall Extension	27	cu yd	2,076.88	56,076
Demolish and Remove Aspahlt Concrete Pavement	634	cu yd	79.62	50,476
Disposal of Pavement Material	634	cu yd	40.52	25,688
Demolish and Remove Watchtower	75	cu yd	750.01	56,251
Demolish and Remove One Story Building	720	sf	178.27	128,357
Disposal of Building Demolition Material + fees	275	cu yd	202.58	55,710
Scarify and Recompact Site	204,160	sf	13.13	2,680,086
Hydroseed 2:1 Slope	2,031	sy	1.50	3,036
Armor Stone - 3' thick, 500 lbss. Size	335	cu yd	182.32	61,079
Armor Stone - Placement	335	cu yd	81.03	27,146
Fill Material Importation (dredge disposal)	52,040	cu yd	20.26	1,054,242
Grading - Fill, Placeent and Compact	52,040	cu yd	102.10	5,313,380
Pavement - 3" Aspahlt Concrete, 10" Base	28,600	sy	111.66	3,193,584
Pavement Material - Aspahlt Concrete	4,542	ton	130.97	594,906
Pavement Material - Base	8,294	cu yd	83.61	693,508
Road Stripe - 4" Width	53	lf	1.13	60
Traffic Control Signs	2	ea	3,687.01	7,374
Catch Basins - 2' x 2'	7	ea	13,208.41	92,459
Side Inlet - 4' Length	1	ea	16,773.88	16,774
Aspahlt Concrete Curb - 6" Height	7	ton	1,359.69	9,518
Pre-Cast Concrete Curb, 6" with 18" Gutter	18	lf	501.96	9,035
Pre-Cast Concrete Sidewalk - 4" Thick	12	cu yd	2,390.48	28,686
Pre-Cast Concrete Swale - 4' Width, 4" Thick	6,020	sf	46.99	282,853
Reinforced Concrete Pipe Storm Drain - 12" Dia.	-	lf		-
Reinforced Concrete Pipe Storm Drain - 18" Dia.	511	lf	381.87	195,135
Reinforced Concrete Pipe Storm Drain - 21" Dia.	306	lf	405.66	124,133
Reinforced Concrete Pipe Storm Drain - 24" Dia.	434	lf	429.48	186,393
Reinforced Concrete Pipe Storm Drain - 27" Dia.	295	lf	460.21	135,761
Reinforced Concrete Pipe Storm Drain - 30" Dia.	-	lf		-
Reinforced Concrete Pipe Storm Drain - 33" Dia.	-	lf		-
Reinforced Concrete Pipe Storm Drain - 36" Dia.	-	lf		-
CDS Inline PMSU 40 / 30 Separator	2	ea	27,470.26	54,941
CDS Inline PMSU 30 / 30 Separator	-	ea		-
CDS Inline PMSU 40 / 40 Separator	-	ea		-

Description	Qty	Unit	Unit Cost	Costs
Pre-Cast Concrete Outfall Structure	1	ea	6,361.11	6,361
Hardened Security Fencing	1,495	lf	343.27	513,190
Security Chain Link Fence	115	lf	345.20	39,698
Pedestrian Gate	1	ea	1,256.01	1,256
Swing Gate - Double, 20-foot Opening	1	ea	20,825.54	20,826
Retractable Bollards - 4 Units	1	set	124,953.22	124,953
Traffic Spikes	1	set	16,773.88	16,774
Floating Barriers for FPCON Charlie/Delta	2,900	lf	542.92	1,574,475
Floating Barrier Sea Anchorage	7	ea	359,698.34	2,517,888
Land Anchors for Floating Barriers	-	ea		-
Wharf Anchorage for Floating Barriers	-	ea		-
MWR Improvements	4	ac	1,012,915.20	4,051,661
Site Work	**1**	**ls**		**24,003,729**
Buildings				
Guard Booth				
Guard Booth	1	ea	287,760	287,760
Guard Booth	**1**	**ls**		**287,760**
Security Watch Tower				
Security Watch Tower - 20' x 20 'x 50' Height	2	ea	500,702	1,001,405
Security Watch Tower	**2**	**ea**		**1,001,405**
Transit Shed				
Transit Shed	10,000	sf	432	4,316,400
Transit Shed	**1**	**ls**		**4,316,400**
Air compressor shed				
Air compressor Shed	1,200	sf	863	1,035,936
Air compressor shed	**1**	**ls**		**1,035,936**
Water Treatment Building				
Water Treatment Building	1,250	sf	863	1,079,100
Water Treatment Building	**1**	**ls**		**1,079,100**
Boiler House				
Boiler House	2,116	sq ft	863	1,826,700
Boiler House	**1**	**ls**		**1,826,700**

Description	Qty	Unit	Unit Cost	Costs
Mechanical				
Steam Generation				
312 HP 150psi Scotch Marine	2	ea	517,802	1,035,605
Low Nox Burner	2	ea	65,637	131,274
10,500 MBH 150 psi Deaerator	1	ea	287,668	287,668
w/ feedwater pumpset & controls	1	ea	34,115	34,115
Flash Tank HP condensate	1	ea	18,232	18,232
Flash Tank IP condensate	1	ea	18,232	18,232
Flash Tank LP condensate	1	ea	18,232	18,232
Condensate forwarding system	1	lot	24,472	24,472
Boiler Stack and Breeching	2	ea	22,284	44,568
Metering Station	1	ea	18,783	18,783
Boiler Stack 24" diam	50	lf	658	32,920
Barometric damper	2	ea	2,299	4,599
Steam Piping 6"	1,200	lf	232	278,155
Steam Piping 8"	200	lf	327	65,329
Steam Piping 4" and smaller	500	lf	139	69,608
Condensate piping 2"	100	lf	86	8,630
8" 150# gate valve	2	ea	12,661	25,323
8" 150# Check valve	2	ea	12,256	24,513
6" 150# gate valve	4	ea	8,549	34,196
4" 150# gate valve	3	ea	5,531	16,592
Pressure reducing station	2	lot	34,642	69,283
8" and 6" fitting allowance	1	lot	116,708	116,708
4" and smaller allowance	1	lot	23,186	23,186
6" Concrete Pads	15	cu yd	1,145	17,171
Pipe excavation & backfill	200	lf	12	2,423
Pipe Bedding 6" pipe	200	lf	4	802
Steam Generation	**1**	**sys**		**2,420,619**
Fuel Train				
2gpm fuel pumpset	1	ea	3,841	3,841
2500 gal Day Tank w/level cntrls	1	ea	27,369	27,369
Fuel Oil Storage Tank	1	ea	121,226	121,226
2" A106 Piping	300	lf	86	25,890
Fittings allowance	1	lot	18,147	18,147
Fuel Oil Specialties allowance	1	lot	15,437	15,437
Fuel Train	**1**	**ls**		**211,911**
Compressed Air				
2400 scfm (125psi) dplx compressor	3	ea	457,838	1,373,513
Dessicant Dryer skid	1	ea	429,476	429,476
Air Receiver skid	1	ea	130,869	130,869
6" concrete pads	7	cu yd	1,145	8,013
6" welded steel piping	1,200	lf	232	278,155
4" welded steel piping	50	lf	139	6,961
2" and smaller SW steel pipe	500	lf	74	36,789
6" piping fitting allowance	1	lot	94,444	94,444

Description	Qty	Unit	Unit Cost	Costs
4" piping fitting allowance	1	lot	2,319	2,319
2" and smaller fitting allowance	1	lot	12,160	12,160
Pipe excavation & backfill	200	lf	12	2,423
Pipe Bedding 6" pipe	200	lf	4	802
Compressed Air	**1**	**ls**		**2,375,923**
Water Treatment				
Packaged Water Treatment	20,000	gpd	235	4,708,840
Water Treatment	**1**	**ls**		**4,708,840**
Exterior Piping				
6" Ductile Iron Pipe	1,200	lf	118	141,241
10" Ductile Iron Pipe	250	lf	171	42,694
Pipe excavation & backfill	250	lf	12	3,029
Pipe Bedding 10" pipe	250	lf	10	2,472
Pipe Bedding 6" pipe	200	lf	4	859
Exterior Piping	**1**	**ls**		**190,294**
Boiler Room DDC System	1	lot	121,550	121,550
Work Station	1	ea	34,488	34,488
Application software	1	lot	17,390	17,390
Boiler Room DDC System	**1**	**ls**		**173,427**
Alternate #1: Former SRF Facility				**$ 212,733,569**

COST ESTIMATE - ELECTRICAL

DD1391 - CVN BERTHING STUDY
NAVBASE
AGANA, GUAM

DECEMBER 2007
HHMI CORPORATION
MELVIN H. YOKOTA

ITEM DESCRIPTION	QUANTITY		MATERIAL COST		LABOR COST		ENGINEERING ESTIMATE	
	NO.	UNIT	UNIT	TOTAL	UNIT	TOTAL	UNIT	TOTAL
ELECTRICAL COST SUMMARY - SRF								
GPA PITI 34.5 KV SWITCHING STATION UPGRADE								100,000
GPA UPGRADE PITI X20 LINE								1,500,000
34.5 KV FDR (PITI TO POLARIS POINT ROAD)								9,597,872
34.5 KV FDR (POLARIS ROAD TO OROTE SS)								13,523,810
34.5 KV CONDUCTORS (OROTE SS TO SRF SS)								3,900,618
34.5 KV EXT FROM SRF BERTH TO SRF SS								6,078,431
OROTE SUBSTATION ADDITION								380,000
SRF SUBSTATION ADDITION								760,000
BERTH SUBSTATION								15,712,000
MWR SERVICE								75,000
BERTH COMMUNICATIONS								1,182,533
BERTH POWER DISTRIBUTION								300,000
SITE LIGHTING AND EMERGENCY POWER								750,000
GENERAL CONDITIONS								1,000,000
TOTAL ELECTRICAL COST								**54,860,263**
ESCALATION TO OCTOBER 2011 (1.0867)								**59,616,648**
FROM OTHER APPROPRIATIONS								
IDS								25,000

COST ESTIMATE - ELECTRICAL

DD1391 - CVN BERTHING STUDY
NAVBASE
AGANA, GUAM

DECEMBER 2007
HHMI CORPORATION
MELVIN H. YOKOTA

ITEM DESCRIPTION	QUANTITY		MATERIAL COST		LABOR COST		ENGINEERING ESTIMATE	
	NO.	UNIT	UNIT	TOTAL	UNIT	TOTAL	UNIT	TOTAL
GPA PITI 34.5 KV SWITCHING STATION UPGRADE							100000	100,000
SUBTOTAL GPA PITI 34.5 KV SWITCHING STATION UPGRADE								100,000
GPA UPGRADE PITI X20 LINE							1500000	1,500,000
SUBTOTAL GPA UPGRADE PITI X20 LINE								1,500,000
34.5 KV FDR (PITI TO POLARIS POINT ROAD)								
Sawcut	6012	M					10	60,962
Trench and Haul	2098	CM					69	144,930
152 Sch 40 PVC	6012	M					44	266,031
Concrete (Thermal)	412	CM					344	141,773
Backfill (Thermal)	1553	CM					316	490,919
Thermal Testing	16	EA					1000	16,000
Restore pavement	1698	SM					43	73,388
Manhole	13	EA					42000	546,000
Conductor. 750 kcmil, 38 kV EPR	19840	M					320	6,348,800
Conductor. #4/0 SDBC	3306	M					26	85,956
MV Splice	39	EA					1068	41,652
MV Termination	6	EA					1488	8,928
Traffic Management	1	LS					500000	500,000
Misc Tape, Fasteners, Hardware	1	LS					872534	872,534
SUBTOTAL 34.5 KV FDR (PITI TO POLARIS POINT ROAD)								9,597,872
34.5 KV FDR (POLARIS ROAD TO OROTE SS)								
Sawcut	9020	M					10	91,463
Trench and Haul	3148	CM					69	217,464
152 Sch 40 PVC	9020	M					44	399,135
Concrete (Thermal)	617	CM					344	212,316
Backfill (Thermal)	2330	CM					316	736,536
Thermal Testing	24	EA					1000	24,000
Restore pavement	2548	SM					43	110,125
Manhole	19	EA					42000	798,000
Conductor. 750 kcmil, 38 kV EPR	29770	LM					320	9,526,400
Conductor. #4/0 SDBC	4961	LM					26	128,986
MV Splice	15	EA					1068	16,020
MV Termination	6	EA					1488	8,928
Traffic Management	1	LS					25000	25,000
Misc Tape, Fasteners, Hardware	1	LS					1229437	1,229,437
SUBTOTAL 34.5 KV FDR (POLARIS ROAD TO OROTE SS)								13,523,810
34.5 KV CONDUCTORS (OROTE SS TO SRF SS)								
Conductor. 750 kcmil, 38 kV EPR	10692	M					320	3,421,440
Conductor. #4/0 SDBC	3240	M					26	84,240
MV Splice	6	EA					1068	6,408
MV Termination	6	EA					1488	8,928
Traffic Management	1	LS					25000	25,000
Misc Tape, Fasteners, Hardware	1	LS					354602	354,602
SUBTOTAL 34.5 KV CONDUCTORS (OROTE SS TO SRF SS)								3,900,618
34.5 KV EXT FROM SRF BERTH TO SRF SS								
Sawcut	2200	M					10	22,308
Trench and Haul	923	CM					69	63,761
6" Sch 40 PVC	4400	M					44	194,700
Concrete (Thermal)	253	CM					344	87,060
Backfill (Thermal)	569	CM					316	179,867
Thermal Testing	7	EA					1000	7,000
Restore pavement	622	SM					43	26,883

COST ESTIMATE - ELECTRICAL

DD1391 - CVN BERTHING STUDY
NAVBASE
AGANA, GUAM

DECEMBER 2007
HHMI CORPORATION
MELVIN H. YOKOTA

ITEM DESCRIPTION	QUANTITY		MATERIAL COST		LABOR COST		ENGINEERING ESTIMATE	
	NO.	UNIT	UNIT	TOTAL	UNIT	TOTAL	UNIT	TOTAL
Manhole	5	EA					42000	210,000
Conductor. 750 kcmil, 38 kV EPR	14520	M					320	4,646,400
Conductor. #4/0 SDBC	2420	M					26	62,920
MV Splice	15	EA					1068	16,020
MV Termination	6	EA					1488	8,928
Misc Tape, Fasteners, Hardware	1	LS					552585	552,585
SUBTOTAL 34.5 KV EXT FROM SRF BERTH TO SRF SS								6,078,431
OROTE SUBSTATION ADDITION								
34.5 kV Bus Tie Breaker Section	1	EA					190000	190,000
34.5 kV Express Feeder Section	1	EA					190000	190,000
SUBTOTAL SRF SUBSTATION ADDITION								380,000
SRF SUBSTATION ADDITION								
34.5 kV Bus Tie Breaker Section	1	EA					190000	190,000
34.5 kV Express Feeder Section	3	EA					190000	570,000
SUBTOTAL SRF SUBSTATION ADDITION								760,000
BERTH SUBSTATION								
34.5 kV Vacuum Switchgear	2	EA					2380000	4,760,000
34.5 kV Grounding Transformer	1	EA					260000	260,000
34.5 kV Station Service	1	EA					50000	50,000
Substation Building	1	EA					1300000	1,300,000
SCADA	1	EA					100000	100,000
20/26/33 MVA Transformer	2	EA					2000000	4,000,000
13.8 kV Vacuum Switchgear	2	EA					546000	1,092,000
12/16/20 MVA Transformer	2	EA					1500000	3,000,000
4.16 kV Switchgear	2	EA					325000	650,000
Industrial Power	1	EA					300000	300,000
480V Switchgear	1	EA					200000	200,000
SUBTOTAL BERTH SUBSTATION								15,712,000
MWR SERVICE							75000	75,000
SUBTOTAL MWR SERVICE								75,000
BERTH COMMUNICATIONS								
103 Sch 40 PVC	7600	M					30	228,000
Innerduct	3800	M					10	38,000
Trench and Backfill	1520	CM					147	223,440
Concrete	385	CM					334	128,590
NCTS Cabling Costs	1	LS					400000	400,000
Communications Handhole	24	EA					500	12,000
Communications Mound	3	EA					15000	45,000
Misc Tape, Fasteners, Hardware	1	LS					107503	107,503
SUBTOTAL BERTH COMMUNICATIONS								1,182,533
BERTH POWER DISTRIBUTION								
POWER MOUND AND CONNECTION	4	EA					75000	300,000
SUBTOTAL BERTH POWER DISTRIBUTION								300,000
SITE LIGHTING AND EMERGENCY POWER							750000	750,000
SUBTOTAL SITE LIGHTING AND EMERGENCY POWER								750,000
GENERAL CONDITIONS							1000000	1,000,000

COST ESTIMATE - ELECTRICAL

DD1391 - CVN BERTHING STUDY
NAVBASE
AGANA, GUAM

DECEMBER 2007
HHMI CORPORATION
MELVIN H. YOKOTA

ITEM DESCRIPTION	QUANTITY		MATERIAL COST		LABOR COST		ENGINEERING ESTIMATE	
	NO.	UNIT	UNIT	TOTAL	UNIT	TOTAL	UNIT	TOTAL
SUBTOTAL GENERAL CONDITIONS								1,000,000

BUDGET ESTIMATE SUMMARY SHEET

TITLE:	CVN BERTHING FEASIBILITY STUDY - SEWER & BILGE OILY WASTE SYSTEM UPGRADES (FORMER SRF FACILITY)	DATE:	FEBRUARY 2008
INSTALLATION:	U.S. NAVBASE, GUAM	DATE ESCALATED TO:	OCTOBER 2011
LOCATION:	AGANA, GUAM	DESIGN STATUS:	FEASIBILITY STUDY
		ESCALATION FACTOR:	1.0867
PREPARED BY:	Engineering Concepts, Inc.	AREA COST FACTOR:	---

DESCRIPTION	UNIT	QUANTITY	UNIT COST (OCT 2007)	TOTAL COST (OCT 2007)	2011 COST TRANSFERRED TO 1391 Sum (Rnd, 10K)
NEW BILGE OILY WASTE COLLECTION SYSTEM & TREATMENT FACILITY				4,213,000	4,580
Bilge Oily Waste Collection Ashore	LS	1	767,000	(767,000)	
Bilge Oily Waste Pump Station	LS	1	766,000	(766,000)	
Bilge Oily Waste Treatment System	LS	1	2,530,000	(2,530,000)	
Technical Operating Manuals	LS	1	150,000	(150,000)	
WASTEWATER COLLECTION SYSTEM IMPROVEMENTS				17,942,420	19,500
Ship Wastewater Collection Ashore	LS	1	646,000	(646,000)	
Submersible Pump Station A	LS	1	2,576,000	(2,576,000)	
10-inch Force Main A	M	30	820	(24,600)	
15-inch Gravity Sewer Line A	M	274	4,590	(1,257,660)	
Submersible Pump Station B	LS	1	2,576,000	(2,576,000)	
10-inch Force Main B	M	1,067	820	(874,940)	
15-inch Gravity Sewer Line B	M	244	4,590	(1,119,960)	
Submersible Pump Station C	LS	1	2,576,000	(2,576,000)	
10-inch Force Main C	M	945	820	(774,900)	
15-inch Relief Sewer Line along Marine Drive	M	139	4,590	(638,010)	
18-inch Relief Sewer Line along Marine Drive	M	575	6,230	(3,582,250)	
24-inch Relief Sewer Line along Marine Drive	M	110	9,510	(1,046,100)	
Technical Operating Manuals	LS	1	250,000	(250,000)	
WATER SYSTEM IMPROVEMENTS				512,250	560
Supply Lateral to Pier (8-inch)	M	35	750	(26,250)	
Pierside Water Lines & Outlets (8 and 6 inch lines)	LS	1	486,000	(486,000)	
SUPPORTING FACILITIES				300,000	330
Electrical Utilities	LS	1	300,000	(300,000)	
SUBTOTAL*					**24,970**
* Includes Overhead, Profit, Bond & Insurance, GRT, & Prime Mark-up on subcontract					

APPENDIX B

Alternative 2 - Polaris Point Parallel to Shore

Description	Qty	Unit	Unit Cost	Costs
Alternate #2: Polaris Point Parallel to Shore				
Project General Conditions				
Construction General Conditions				
General Conditions	1	ls	17,838,846	17,838,846
Construction General Conditions	**1**	**ls**		**17,838,846**
Mobilization				
Mobilization / Demobilization	1	ls	10,135,708	10,135,708
Contractor Workforce Housing and Per Diem Costs	1	ls	-	-
Mobilization	**1**	**ls**		**10,135,708**
Dredging - Alternative 2A				
Dreging - Polaris Marginal Wharf - Reduced Impact				
Dredge Mobilization	1	ls	9,208,320	9,208,320
Dredging 587,700		cu yd	20.26	11,905,805
Overdredge 170,300		cu yd	20.26	3,449,989
Dredge Disposal - uplands	758,000	cu yd	40.52	30,711,589
Aids to Navigation	1	ls	2,025,830	2,025,830
Rip Rap Removal	-	cu yd		-
Land Filling Material Handling	-	cu yd		-
Dreging - Polaris Marginal Wharf - Reduced Impact	**758,000**	**cu yd**	**76**	**57,301,534**
Wharf Struture				
Steel Pipe Piles at Main Pier Structure				
Material - Pipe - 24" diameter - .62" wall - 156 #/lf	33,060	lf	663	21,919,860
Material - Rebar Cage	248,713	lbs	1.81	450,946
Material - Fill Concrete	1,082	cu yd	608	657,585
Installation - Piles	410	ea	39,909	16,362,632
Installation - Rebar	248,713	lbs	1.09	271,298
Installation - Concrete	1,082	cu yd	85.02	91,995
Steel Pipe Piles at Main Pier Structure	**410**	**ea**	**96,962**	**39,754,316**

Description	Qty	Unit	Unit Cost	Costs
Cast In Place Concrete at Deck				
Concrete Material - 126,750 sf Deck	10,000	cu yd	608	6,077,491
Rebar	2,500	Tns	3,626	9,065,591
Formwork	143,000	sf	46.14	6,598,499
Installation -rebar	2,500	Tns	2,182	5,454,042
Installation - concrete	10,000	cu yd	143	1,432,388
Cast In Place Concrete at Deck	**10,000**	**cu yd**	**2,863**	**28,628,012**
CVN Camel / Fender Structure				
Piles	18,000	lf	193	3,480,745
Camels - (steel load transfer float)	3	unit	2,092,800	6,278,400
6 lf Diameter Foam Filled Fenders	12	ea	184,166	2,209,997
Pile Installation	120	ea	5,157	618,799
Camel / Fender Assembly	12	ea	36,612	439,347
Brows	3	ea	920,832	2,762,496
CVN Camel / Fender Structure	**1**	**ls**		**15,789,784**
Miscellaneous Metals				
Materials	66,250	lbs	10.13	671,056
Installation	66,250	lbs	10.13	671,056
Miscellaneous Metals	**66,250**	**lbs**	**20.26**	**1,342,113**
100 Ton Bollards				
Materials	13	ea	141,808	1,843,506
Installation	13	ea	40,517	526,716
100 Ton Bollards	**13**	**ea**	**182,325**	**2,370,222**
200 Ton Storm Bollards				
Materials	8	ea	202,583	1,620,664
Installation	8	ea	40,517	324,133
200 Ton Storm Bollards	**8**	**ea**	**243,100**	**1,944,797**
Cathodic Protection and Special Coatings				
Berth	1	ls	3,038,746	3,038,746
Cathodic Protection and Special Coatings	**1**	**ls**		**3,038,746**

Description	Qty	Unit	Unit Cost	Costs
Marine Revetment				
Wharf Revetment				
Quarry Stone Fill Procurment and Transportation	41,961	cu yd	81.03	3,400,235
Quarry Stone Fill Placement	41,961	cu yd	60.77	2,550,176
Riprap Stone Procurment and Transportation	19,815	cu yd	153.96	3,050,779
Riprap Stone Placement	19,815	cu yd	60.77	1,204,255
Wharf Revetment	**61,776**	**cu yd**	**165**	**10,205,445**
Sitework				
Site Work				
PCC Cut-Off Wall Extension	-	cu yd		-
Demolish and Remove Aspahlt Concrete Pavement	3,570	cu yd	79.62	284,226
Disposal of Pavement Material	3,570	cu yd	40.52	144,644
Demolish and Remove Watchtower	-	cu yd		-
Demolish and Remove One Story Building	1,200	sf	178.27	213,928
Disposal of Building Demolition Material	310	cu yd	202.58	62,801
Scarify and Recompact Site	304,000	sf	13.13	3,990,724
Hydroseed 2:1 Slope	2,717	sy	1.50	4,062
Armor Stone - 3' thick, 500 lbss. Size	1,385	cu yd	182.32	252,520
Armor Stone - Placement	1,385	cu yd	81.03	112,231
Fill Material Importation (dredge disposal)	62,475	cu yd	20.26	1,265,638
Grading - Fill, Placeent and Compact	62,475	cu yd	102.10	6,378,813
Pavement - 3" Aspahlt Concrete, 10" Base	29,295	sy	111.66	3,271,190
Pavement Material - Aspahlt Concrete	4,440	ton	130.97	581,503
Pavement Material - Base	8,110	cu yd	83.61	678,097
Road Stripe - 4" Width	207	lf	1.13	235
Traffic Control Signs	4	ea	3,687.01	14,748
Catch Basins - 2' x 2'	5	ea	13,208.41	66,042
Side Inlet - 4' Length	1	ea	16,773.88	16,774
Aspahlt Concrete Curb - 6" Hieght	20	ton	1,359.69	27,194
Pre-Cast Concrete Curb, 6" with 18" Gutter	189	lf	501.96	94,870
Pre-Cast Concrete Sidewalk - 4" Thick	11	cu yd	2,390.48	26,295
Pre-Cast Concrete Swale - 4' Width, 4" Thick	4,028	sf	46.99	189,258
Reinforced Concrete Pipe Storm Drain - 12" Dia.	-	lf		-
Reinforced Concrete Pipe Storm Drain - 18" Dia.	339	lf	381.87	129,454
Reinforced Concrete Pipe Storm Drain - 21" Dia.	210	lf	405.66	85,189
Reinforced Concrete Pipe Storm Drain - 24" Dia.	210	lf	429.48	90,190
Reinforced Concrete Pipe Storm Drain - 27" Dia.	210	lf	460.21	96,644
Reinforced Concrete Pipe Storm Drain - 30" Dia.	271	lf	490.98	133,056
Reinforced Concrete Pipe Storm Drain - 33" Dia.	-	lf		-
Reinforced Concrete Pipe Storm Drain - 36" Dia.	-	lf		-
CDS Inline PMSU 40 / 30 Separator	-	ea		-
CDS Inline PMSU 30 / 30 Separator	1	ea	27,470.26	27,470
CDS Inline PMSU 40 / 40 Separator	-	ea		-

CVN-Capable Berthing, Guam
COST ESTIMATE

Description	Qty	Unit	Unit Cost	Costs
Pre-Cast Concrete Outfall Structure	1	ea	6,361.11	6,361
Hardened Security Fencing	1,872	lf	343.27	642,604
Security Chain Link Fence	134	lf	345.20	46,257
Pedestrian Gate	1	ea	1,256.01	1,256
Swing Gate - Double, 20-foot Opening	1	ea	20,825.54	20,826
Retractable Bollards - 4 Units	1	ea	124,953.22	124,953
Traffic Spikes	1	ea	16,773.88	16,774
Floating Barriers for FPCON Charlie/Delta	2,916	lf	542.92	1,583,162
Floating Barrier Sea Anchorage	5	ea	359,698.34	1,798,492
Land Anchors for Floating Barriers	-	ea		-
Wharf Anchorage for Floating Barriers	-	ea		-
MWR Improvements	2.4	ac	1,012,915.20	2,430,996
Site Work	**1**	**ls**		**24,909,474**
Buildings				
Guard Booth				
Guard Booth	1	ea	287,760	287,760
Guard Booth	**1**	**ls**		**287,760**
Security Watch Tower				
Security Watch Tower - 20' x 20 'x 50' Height	2	ea	500,702	1,001,405
Security Watch Tower	**2**	**ea**		**1,001,405**
Transit Shed				
Transit Shed	10,000	sf	432	4,316,400
Transit Shed	**1**	**ls**		**4,316,400**
Air compressor shed				
Air compressor shed	1,200	sf	863	1,035,936
Air compressor shed	**1**	**ls**		**1,035,936**
Water Treatment Building				
Water Treatment Building	1,250	sf	863	1,079,100
Water Treatment Building	**1**	**ls**		**1,079,100**
Boiler House				
Boiler House	2,116	sq ft	863	1,826,700
Boiler House	**1**	**ls**		**1,826,700**

Description	Qty	Unit	Unit Cost	Costs
Mechanical				
Steam Generation				
312 HP 150psi Scotch Marine	2	ea	517,802	1,035,605
Low Nox Burner	2	ea	65,637	131,274
10,500 MBH 150 psi Deaerator	1	ea	287,668	287,668
w/ feedwater pumpset & controls	1	ea	34,115	34,115
Flash Tank HP condensate	1	ea	18,232	18,232
Flash Tank IP condensate	1	ea	18,232	18,232
Flash Tank LP condensate	1	ea	18,232	18,232
Condensate forwarding system	1	lot	24,472	24,472
Boiler Stack and Breeching	2	ea	22,284	44,568
Metering Station	1	ea	18,783	18,783
Boiler Stack 24" diam	50	lf	658	32,920
Barometric damper	2	ea	2,299	4,599
Steam Piping 6"	1,200	lf	232	278,155
Steam Piping 8"	200	lf	327	65,329
Steam Piping 4" and smaller	500	lf	139	69,608
Condensate piping 2"	100	lf	86	8,630
8" 150# gate valve	2	ea	12,661	25,323
8" 150# Check valve	2	ea	12,256	24,513
6" 150# gate valve	4	ea	8,549	34,196
4" 150# gate valve	3	ea	5,531	16,592
Pressure reducing station	2	lot	34,642	69,283
8" and 6" fitting allowance	1	lot	116,708	116,708
4" and smaller allowance	1	lot	23,186	23,186
6" Concrete Pads	15	cu yd	1,145	17,171
Pipe excavation & backfill	200	lf	12	2,423
Pipe Bedding 6" pipe	200	lf	4	802
Steam Generation	**1**	**sys**		**2,420,619**
Fuel Train				
2gpm fuel pumpset	1	ea	3,841	3,841
2500 gal Day Tank w/level cntrls	1	ea	27,369	27,369
Fuel Oil Storage Tank	1	ea	121,226	121,226
2" A106 Piping	300	lf	86	25,890
Fittings allowance	1	lot	18,147	18,147
Fuel Oil Specialties allowance	1	lot	15,437	15,437
Fuel Train	**1**	**ls**		**211,911**
Compressed Air				
2400 scfm (125psi) dplx compressor	3	ea	457,838	1,373,513
Dessicant Dryer skid	1	ea	607,749	607,749
Air Receiver skid	1	ea	130,869	130,869
6" concrete pads	7	cu yd	1,145	8,013
6" welded steel piping	1,200	lf	232	278,155
4" welded steel piping	50	lf	139	6,961
2" and smaller SW steel pipe	500	lf	74	36,789
6" piping fitting allowance	1	lot	94,444	94,444

Description	Qty	Unit	Unit Cost	Costs
4" piping fitting allowance	1	lot	2,319	2,319
2" and smaller fitting allowance	1	lot	12,160	12,160
Pipe excavation & backfill	200	lf	12	2,423
Pipe Bedding 6" pipe	200	lf	4	802
Compressed Air	**1**	**ls**		**2,554,196**
Water Treatment				
Packaged Water Treatment	20,000	gpd	235	4,708,840
4" welded steel piping	**1**	**ls**		**4,708,840**
Exterior Piping				
6" Ductile Iron Pipe	1,200	lf	118	141,241
10" Ductile Iron Pipe	250	lf	171	42,694
Pipe excavation & backfill	250	lf	12	3,029
Pipe Bedding 10" pipe	250	lf	9	2,299
Pipe Bedding 6" pipe	200	lf	4	802
Exterior Piping	**1**	**ls**		**190,065**
Boiler Room DDC System	1	lot	121,550	121,550
Work Station	1	ea	34,488	34,488
Application software	1	lot	17,390	17,390
Boiler Room DDC System	**1**	**ls**		**173,427**
Alternate #2A: Polaris Point Parallel to Shore				**$ 233,065,355**
Dredging Alternative 2				
Dreging - Polaris Marginal Wharf				
Dredge Mobilization	1	ls	9,208,320	9,208,320
Dredging 803,700		cu yd	20.26	16,281,599
Overdredge 189,500		cu yd	20.26	3,838,949
Dredge Disposal - uplands	993,200	cu yd	40.52	40,241,095
Aids to Navigation	1	ls	2,025,830	2,025,830
Rip Rap Removal	-	cu yd		-
Land Filling Material Handling	-	cu yd		-
Dreging - Polaris Marginal Wharf	**993,200**	**cu yd**	**72**	**71,595,793**
Alternate #2: Polaris Point Parallel to Shore				**$ 247,359,615**

COST ESTIMATE - ELECTRICAL

DD1391 - CVN BERTHING STUDY
NAVBASE
AGANA, GUAM

FEBRUARY 2008
HHMI CORPORATION
MELVIN H. YOKOTA

ITEM DESCRIPTION	QUANTITY		MATERIAL COST		LABOR COST		ENGINEERING ESTIMATE	
	NO.	UNIT	UNIT	TOTAL	UNIT	TOTAL	UNIT	TOTAL
ELECTRICAL COST SUMMARY - POLARIS POINT								
GPA PITI 34.5 KV SWITCHING STATION UPGRADE								100,000
34.5 KV FDR (PITI TO POLARIS POINT ROAD)								9,597,872
34.5 KV FDR (MARINE CORP DR TO POLARIS SS)								6,795,268
BERTH SUBSTATION								15,712,000
MWR SERVICE								75,000
BERTH COMMUNICATIONS								914,386
BERTH POWER DISTRIBUTION								300,000
SITE LIGHTING AND EMERGENCY POWER								750,000
GENERAL CONDITIONS								1,000,000
TOTAL ELECTRICAL COST								**35,244,526**
ESCALATION TO OCTOBER 2011 (1.0867)								**38,300,226**
FROM OTHER APPROPRIATIONS								
IDS								25,000

COST ESTIMATE - ELECTRICAL

DD1391 - CVN BERTHING STUDY FEBRUARY 2008
NAVBASE HHMI CORPORATION
AGANA, GUAM MELVIN H. YOKOTA

ITEM DESCRIPTION	QUANTITY		MATERIAL COST		LABOR COST		ENGINEERING ESTIMATE	
	NO.	UNIT	UNIT	TOTAL	UNIT	TOTAL	UNIT	TOTAL
GPA PITI 34.5 KV SWITCHING STATION UPGRADE							100000	100,000
SUBTOTAL GPA PITI 34.5 KV SWITCHING STATION UPGRADE								100,000
34.5 KV FDR (PITI TO POLARIS POINT ROAD)								
Sawcut	6012	M					10	60,962
Trench and Haul	2098	CM					69	144,930
152 Sch 40 PVC	6012	M					44	266,031
Concrete (Thermal)	412	CM					344	141,773
Backfill (Thermal)	1553	CM					316	490,919
Thermal Testing	16	EA					1000	16,000
Restore pavement	1698	SM					43	73,388
Manhole	13	EA					42000	546,000
Conductor. 750 kcmil, 38 kV EPR	19840	M					320	6,348,800
Conductor. #4/0 SDBC	3306	M					26	85,956
MV Splice	39	EA					1068	41,652
MV Termination	6	EA					1488	8,928
Traffic Management	1	LS					500000	500,000
Misc Tape, Fasteners, Hardware	1	LS					872534	872,534
SUBTOTAL 34.5 KV FDR (PITI TO POLARIS POINT ROAD)								9,597,872
34.5 KV FDR (MARINE CORP DR TO POLARIS SS)								
Sawcut	2460	M					10	24,944
Trench and Haul	1032	CM					69	71,291
152 Sch 40 PVC	4920	M					44	217,710
Concrete (Thermal)	283	CM					344	97,383
Backfill (Thermal)	636	CM					316	201,046
Thermal Testing	8	EA					1000	8,000
Restore pavement	695	SM					43	30,038
Manhole	5	EA					42000	210,000
Conductor. 750 kcmil, 38 kV EPR	16240	M					320	5,196,800
Conductor. #4/0 SDBC	2706	M					26	70,356
MV Splice	15	EA					1068	16,020
MV Termination	6	EA					1488	8,928
Traffic Management	1	LS					25000	25,000
Misc Tape, Fasteners, Hardware	1	LS					617752	617,752
SUBTOTAL 34.5 KV FDR (PITI TO POLARIS POINT ROAD)								6,795,268
BERTH SUBSTATION								
34.5 kV Vacuum Switchgear	2	EA					2380000	4,760,000
34.5 kV Grounding Transformer	1	EA					260000	260,000
34.5 kV Station Service	1	EA					50000	50,000
Substation Building	1	EA					1300000	1,300,000
SCADA	1	EA					100000	100,000
20/36/33 MVA Transformer	2	EA					2000000	4,000,000
13.8 kV Vacuum Switchgear	2	EA					546000	1,092,000
12/16/20 MVA Transformer	2	EA					1500000	3,000,000
4.16 kV Switchgear	2	EA					325000	650,000
Industrial Power	1	EA					300000	300,000
480V Switchgear	1	EA					200000	200,000
SUBTOTAL BERTH SUBSTATION								15,712,000
MWR SERVICE							75000	75,000
SUBTOTAL MWR SERVICE								75,000
BERTH COMMUNICATIONS								
103 Sch 40 PVC	600	M					30	18,000
Innerduct	300	M					10	3,000

COST ESTIMATE - ELECTRICAL

DD1391 - CVN BERTHING STUDY
NAVBASE
AGANA, GUAM

FEBRUARY 2008
HHMI CORPORATION
MELVIN H. YOKOTA

ITEM DESCRIPTION	QUANTITY		MATERIAL COST		LABOR COST		ENGINEERING ESTIMATE	
	NO.	UNIT	UNIT	TOTAL	UNIT	TOTAL	UNIT	TOTAL
Trench and Backfill	120	CM					147	17,640
Concrete	30	CM					334	10,020
NCTS Cabling Costs	1	LS					250000	250,000
Communications Handhole	4	EA					400	1,600
Communications Mound	3	EA					15000	45,000
B4434-Marine Drive Connection	1350	M					360	486,000
Misc Tape, Fasteners, Hardware	1	LS					83126	83,126
SUBTOTAL BERTH COMMUNICATIONS								914,386
BERTH POWER DISTRIBUTION								
POWER MOUND AND CONNECTION	4	EA					75000	300,000
SUBTOTAL BERTH POWER DISTRIBUTION								300,000
SITE LIGHTING AND EMERGENCY POWER							750000	750,000
SUBTOTAL SITE LIGHTING AND EMERGENCY POWER								750,000
GENERAL CONDITIONS							1000000	1,000,000
SUBTOTAL GENERAL CONDITIONS								1,000,000

BUDGET ESTIMATE SUMMARY SHEET

TITLE:	CVN BERTHING FEASIBILITY STUDY - SEWER & BILGE OILY WASTE SYSTEM UPGRADES (POLARIS POINT PARALLEL & DIAGONAL CONFIGURATIONS)	DATE:	FEBRUARY 2008
INSTALLATION:	U.S. NAVBASE, GUAM	DATE ESCALATED TO:	OCTOBER 2011
LOCATION:	AGANA, GUAM	DESIGN STATUS:	FEASIBILITY STUDY
		ESCALATION FACTOR:	1.0867
PREPARED BY:	Engineering Concepts, Inc.	AREA COST FACTOR:	---

DESCRIPTION	UNIT	QUANTITY	UNIT COST	TOTAL COST	COST TRANSFERRED TO 1391 Sum (Rnd, 10K)
NEW BILGE OILY WASTE COLLECTION SYSTEM & TREATMENT FACILITY				4,213,000	4,580
Bilge Oily Waste Collection Ashore	LS	1	767,000	(767,000)	
Bilge Oily Waste Pump Station	LS	1	766,000	(766,000)	
Bilge Oily Waste Treatment System	LS	1	2,530,000	(2,530,000)	
Technical Operating Manuals	LS	1	150,000	(150,000)	
WASTEWATER COLLECTION SYSTEM IMPROVEMENTS				22,685,050	24,660
Ship Wastewater Collection Ashore	LS	1	607,000	(607,000)	
Submersible Pump Station	LS	1	2,576,000	(2,576,000)	
10-inch Force Main	M	396	820	(324,720)	
15-inch Gravity Sewer Line	M	159	4,590	(729,810)	
Dry Pit / Wet Well Type Pump Station	LS	1	6,669,000	(6,669,000)	
12-inch Force Main	M	4,130	980	(4,047,400)	
8-inch Relief Sewer Line along Marine Drive	M	92	2,930	(269,560)	
12-inch Relief Sewer Line along Marine Drive	M	234	3,950	(924,300)	
15-inch Relief Sewer Line along Marine Drive	M	304	4,590	(1,395,360)	
21-inch Relief Sewer Line along Marine Drive	M	710	6,890	(4,891,900)	
Technical Operating Manuals	LS	1	250,000	(250,000)	
WATER SYSTEM IMPROVEMENTS				552,750	610
Supply Lateral to Pier (8-inch)	M	89	750	(66,750)	
Pierside Water Lines & Outlets (8 and 6 inch lines)	LS	1	486,000	(486,000)	
SUPPORTING FACILITIES				250,000	280
Electrical Utilities	LS	1	250,000	(250,000)	
SUBTOTAL*					**30,130**
* Includes Overhead, Profit, Bond & Insurance, GRT, & Prime Mark-up on subcontract					

APPENDIX B

Alternative 3 - Polaris Point Diagonal Offshore

Description	Qty	Unit	Unit Cost	Costs
Alternate #3: Polaris Point Diagonal Offshore				
Project General Conditions				
Construction General Conditions				
General Conditions	1	ls	21,030,245	21,030,245
Construction General Conditions	**1**	**ls**		**21,030,245**
Mobilization				
Mobilization / Demobilization	1	ls	11,949,003	11,949,003
Contractor Workforce Housing and Per Diem Costs	1	ls		-
Mobilization	**1**	**ls**		**11,949,003**
Dredging				
Dredging - Polaris Point Offshore Berth				
Dredge Mobilization	1	ls	9,208,320	9,208,320
Dredging 503,700		cu yd	20.26	10,204,108
Overdredge 168,700		cu yd	20.26	3,417,576
Dredge Disposal - uplands	672,400	cu yd	40.52	27,243,367
Aids to Navigation	1	ls	2,025,830	2,025,830
Rip Rap Removal	-	cu yd		-
Land Filling Material Handling	-	cu yd		-
Dredging - Polaris Point Offshore Berth	**672,400**	**cu yd**	**77**	**52,099,201**
Wharf Struture				
Steel Pipe Piles at Main Pier Structure				
Material - Pipe - 30" diameter - .62" wall - 196 #/lf	41,278	lf	832	34,353,823
Material - Rebar Cage	267,440	lbs	1.81	484,900
Material - Fill Concrete	1,145	cu yd	608	695,873
Installation - Piles	457	ea	53,212	24,317,798
Installation - Rebar	267,440	lbs	1.09	291,726
Installation - Concrete	1,145	cu yd	85.02	97,351
Steel Pipe Piles at Main Pier Structure	**457**	**ea**	**131,819**	**60,241,471**

Description	Qty	Unit	Unit Cost	Costs
Cast In Place Concrete Deck				
Concrete Material - 144,000 Deck Area	12,600	cu yd	608	7,657,639
Rebar	3,150	Tns	3,626	11,422,645
Formwork	163,248	sf	46.14	7,532,810
Installation -rebar	3,150	Tns	2,182	6,872,093
Installation - concrete	12,600	cu yd	143	1,804,809
Cast In Place Concrete Deck	**12,600**	**cu yd**	**2,801**	**35,289,995**
CVN Camel / Fender Structure				
Piles	18,000	lf	193	3,480,745
Camels	3	unit	2,092,800	6,278,400
6 lf Diameter Foam Filled Fenders	12	ea	184,166	2,209,997
Pile Installation	120	ea	5,157	618,799
Camel / Fender Assembly	12	ea	36,612	439,347
Brows	3	ea	920,832	2,762,496
CVN Camel / Fender Structure	**1**	**ls**		**15,789,784**
Miscellaneous Metals				
Materials	66,250	lbs	10.13	671,056
Installation	66,250	lbs	10.13	671,056
Miscellaneous Metals	**66,250**	**lbs**	**20.26**	**1,342,113**
100 Ton Bollards				
Materials	13	ea	141,808	1,843,506
Installation	13	ea	40,517	526,716
100 Ton Bollards	**13**	**ea**	**182,325**	**2,370,222**
200 Ton Storm Bollards @ Land Structure				
Materials	8	ea	202,583	1,620,664
Installation	8	ton	40,517	324,133
200 Ton Storm Bollards @ Land Structure	**8**	**ea**		**1,944,797**
Cathodic Protection and Special Coatings				
Berth	1	ls	4,051,661	4,051,661
Cathodic Protection and Special Coatings	**1**	**ls**		**4,051,661**

COST ESTIMATE

Description	Qty	Unit	Unit Cost	Costs
Landside Abutment Piling - Both Land Connections				
Material - Pipe - 48" diameter - .75" wall - 385 #/lf - 39 ea @ 50 lf	1,950	lf	1,333.71	2,600,726
Material - Rebar Cage	22,823	lbs	1.81	41,381
Material - Fill Concrete	852	cu yd	607.75	517,802
Installation - Piles	39	ea	8,616.53	336,045
Installation - Rebar	22,823	lbs	1.09	24,896
Installation - Concrete	852	cu yd	85.02	72,440
Landside Abutment Piling - Both Land Connections	**1**	**ls**		**3,593,289**
Landside Transition Deck				
Deck Area	20,480	sf		-
30" Diameter Piling	10,780	lf	996.26	10,739,665
Deck, Cap and Piling Concrete	4,000	cu yd	3,241.33	12,965,315
Landside Transition Deck	**1**	**ls**		**23,704,980**
Marine Revetment				
Wharf Revetment				
Quarry Stone Fill Procurment and Transportation	9,169	cu yd	81.03	743,014
Quarry Stone Fill Placement	9,169	cu yd	60.77	557,261
Riprap Stone Procurment and Transportation	4,330	cu yd	153.96	666,652
Riprap Stone Placement	4,330	cu yd	60.77	263,152
Wharf Revetment	**13,499**	**cu yd**	**165**	**2,230,079**
Sitework				
Site Work				
PCC Cut-Off Wall Extension	-	cu yd		-
Demolish and Remove Aspahlt Concrete Pavement	892	cu yd	79.62	71,017
Disposal of Pavement Material	892	cu yd	40.52	36,141
Demolish and Remove Watchtower	-	cu yd		-
Demolish and Remove One Story Building	-	sf		-
Disposal of Building Demolition Material + fees	225	cu yd	202.58	45,581
Scarify and Recompact Site	303,447	sf	13.13	3,983,464
Hydroseed 2:1 Slope	1,568	sy	1.50	2,344
Armor Stone - 3' thick, 500 lbss. Size	1,482	cu yd	182.32	270,205
Armor Stone - Placement	2,902	cu yd	81.03	235,173
Fill Material Importation (dredge disposal)	40,002	cu yd	20.26	810,379
Grading - Fill, Placeent and Compact	24,698	cu yd	102.10	2,521,712
Pavement - 3" Aspahlt Concrete, 10" Base	29,295	sy	111.66	3,271,190
Pavement Material - Aspahlt Concrete	4,542	ton	130.97	594,906
Pavement Material - Base	8,294	cu yd	83.61	693,508
Road Stripe - 4" Width	262	lf	1.13	297
Traffic Control Signs	8	ea	3,687.01	29,496
Catch Basins - 2' x 2'	4	ea	13,208.41	52,834
Side Inlet - 4' Length	1	ea	16,773.88	16,774
Aspahlt Concrete Curb - 6" Height	26	ton	1,359.69	35,352

Description	Qty	Unit	Unit Cost	Costs
Pre-Cast Concrete Curb, 6" with 18" Gutter	189	lf	501.96	94,870
Pre-Cast Concrete Sidewalk - 4" Thick	13	cu yd	2,390.48	31,076
Pre-Cast Concrete Swale - 4' Width, 4" Thick	4,080	sf	46.99	191,701
Reinforced Concrete Pipe Storm Drain - 12" Dia.	339	lf	334.26	113,315
Reinforced Concrete Pipe Storm Drain - 18" Dia.	361	lf	381.87	137,855
Reinforced Concrete Pipe Storm Drain - 21" Dia.	-	lf		-
Reinforced Concrete Pipe Storm Drain - 24" Dia.	231	lf	429.48	99,209
Reinforced Concrete Pipe Storm Drain - 27" Dia.	279	lf	460.21	128,398
Reinforced Concrete Pipe Storm Drain - 30" Dia.	248	lf	490.98	121,763
Reinforced Concrete Pipe Storm Drain - 33" Dia.	-	lf		-
Reinforced Concrete Pipe Storm Drain - 36" Dia.	-	lf		-
CDS Inline PMSU 40 / 30 Separator	-	ea		-
CDS Inline PMSU 30 / 30 Separator	1	ea	27,470.26	27,470
CDS Inline PMSU 40 / 40 Separator	-	ea		-
Pre-Cast Concrete Outfall Structure	1	ea	6,361.11	6,361
Hardened Security Fencing	2,323	lf	343.27	797,419
Security Chain Link Fence	973	lf	345.20	335,881
Pedestrian Gate	1	ea	1,256.01	1,256
Swing Gate - Double, 20-foot Opening	2	ea	20,825.54	41,651
Retractable Bollards - 4 Units	2	ea	124,953.22	249,906
Traffic Spikes	2	ea	16,773.88	33,548
Floating Barriers for FPCON Charlie/Delta	3,494	lf	542.92	1,896,971
Floating Barrier Sea Anchorage	8	ea	359,698.34	2,877,587
Land Anchors for Floating Barriers	-	ea		-
Wharf Anchorage for Floating Barriers		ea		-
MWR Improvements	2.4	ac	1,012,915.20	2,430,996
Site Work	**1**	**ls**		**22,287,606**
Buildings				
Guard Booth				
Guard Booth	2	ea	287,760	575,520
Guard Booth	**1**	**ls**		**575,520**
Security Watch Tower				
Security Watch Tower - 20' x 20 'x 50' Height	2	ea	500,702	1,001,405
Security Watch Tower	**2**	**ea**		**1,001,405**
Transfer Shed				
Transfer Shed	10,000	sf	432	4,316,400
Transfer Shed	**1**	**ls**		**4,316,400**
Air compressor shed				
Air compressor shed	1,200	sf	863	1,035,936
Air compressor shed	**1**	**ls**		**1,035,936**

Description	Qty	Unit	Unit Cost	Costs
Water Treatment Building				
Water Treatment Building	1,250	sf	863	1,079,100
Water Treatment Building	**1**	**ls**		**1,079,100**
Boiler House				
Boiler House	2,116	sq ft	863	1,826,700
Boiler House	**1**	**ls**		**1,826,700**
Mechanical				
Steam Generation				
312 HP 150psi Scotch Marine	2	ea	517,802	1,035,605
Low Nox Burner	2	ea	65,637	131,274
10,500 MBH 150 psi Deaerator	1	ea	287,668	287,668
w/ feedwater pumpset & controls	1	ea	34,115	34,115
Flash Tank HP condensate	1	ea	18,232	18,232
Flash Tank IP condensate	1	ea	18,232	18,232
Flash Tank LP condensate	1	ea	18,232	18,232
Condensate forwarding system	1	lot	24,472	24,472
Boiler Stack and Breeching	2	ea	22,284	44,568
Metering Station	1	ea	18,783	18,783
Boiler Stack 24" diam	50	lf	658	32,920
Barometric damper	2	ea	2,299	4,599
Steam Piping 6"	1,200	lf	232	278,155
Steam Piping 8"	200	lf	327	65,329
Steam Piping 4" and smaller	500	lf	139	69,608
Condensate piping 2"	100	lf	86	8,630
8" 150# gate valve	2	ea	12,661	25,323
8" 150# Check valve	2	ea	12,256	24,513
6" 150# gate valve	4	ea	8,549	34,196
4" 150# gate valve	3	ea	5,531	16,592
Pressure reducing station	2	lot	34,642	69,283
8" and 6" fitting allowance	1	lot	116,708	116,708
4" and smaller allowance	1	lot	23,186	23,186
6" Concrete Pads	15	cu yd	1,145	17,171
Pipe excavation & backfill	200	lf	12	2,423
Pipe Bedding 6" pipe	200	lf	4	802
Steam Generation	**1**	**sys**		**2,420,619**
Fuel Train				
2gpm fuel pumpset	1	ea	3,841	3,841
2500 gal Day Tank w/level cntrls	1	ea	27,369	27,369
Fuel Oil Storage Tank	1	ea	121,226	121,226

Description	Qty	Unit	Unit Cost	Costs
2" A106 Piping	300	lf	86	25,890
Fittings allowance	1	lot	18,147	18,147
Fuel Oil Specialties allowance	1	lot	15,437	15,437
Fuel Train	**1**	**sys 211,911**		
Compressed Air				
2400 scfm (125psi) dplx compressor	3	ea	457,838	1,373,513
Dessicant Dryer skid	1	ea	607,749	607,749
Air Receiver skid	1	ea	130,869	130,869
6" concrete pads	7	cu yd	1,145	8,013
6" welded steel piping	1,200	lf	232	278,155
4" welded steel piping	50	lf	139	6,961
2" and smaller SW steel pipe	500	lf	74	36,789
6" piping fitting allowance	1	lot	94,444	94,444
4" piping fitting allowance	1	lot	2,319	2,319
2" and smaller fitting allowance	1	lot	12,160	12,160
Pipe excavation & backfill	200	lf	12	2,423
Pipe Bedding 6" pipe	200	lf	4	802
Compressed Air	**1**	**sys 2,554,196**		
Water Treatment				
Packaged Water Treatment	20,000	gpd	235	4,708,840
Water Treatment	**1**	**sys 4,708,840**		
Exterior Piping				
6" Ductile Iron Pipe	1,200	lf	118	141,241
10" Ductile Iron Pipe	250	lf	171	42,694
Pipe excavation & backfill	250	lf	12	3,029
Pipe Bedding 10" pipe	250	lf	9	2,299
Pipe Bedding 6" pipe	200	lf	4	802
Exterior Piping	**1**	**ls**		**190,065**
Boiler Room DDC System				
Boiler Room DDC System	1	lot	121,550	121,550
Work Station	1	ea	34,488	34,488
Application software	1	lot	17,390	17,390
Boiler Room DDC System	**1**	**ls**		**173,427**
Alternate #3: Polaris Point Diagonal Offshore				**$ 278,018,566**

COST ESTIMATE - ELECTRICAL

DD1391 - CVN BERTHING STUDY
NAVBASE
AGANA, GUAM

FEBRUARY 2008
HHMI CORPORATION
MELVIN H. YOKOTA

ITEM DESCRIPTION	QUANTITY		MATERIAL COST		LABOR COST		ENGINEERING ESTIMATE	
	NO.	UNIT	UNIT	TOTAL	UNIT	TOTAL	UNIT	TOTAL
ELECTRICAL COST SUMMARY - POLARIS POINT								
GPA PITI 34.5 KV SWITCHING STATION UPGRADE								100,000
34.5 KV FDR (PITI TO POLARIS POINT ROAD)								9,597,872
34.5 KV FDR (MARINE CORP DR TO POLARIS SS)								6,795,268
BERTH SUBSTATION								15,712,000
MWR SERVICE								75,000
BERTH COMMUNICATIONS								914,386
BERTH POWER DISTRIBUTION								300,000
SITE LIGHTING AND EMERGENCY POWER								750,000
GENERAL CONDITIONS								1,000,000
TOTAL ELECTRICAL COST								**35,244,526**
ESCALATION TO OCTOBER 2011 (1.0867)								**38,300,226**
FROM OTHER APPROPRIATIONS								
IDS								25,000

COST ESTIMATE - ELECTRICAL

DD1391 - CVN BERTHING STUDY FEBRUARY 2008
NAVBASE HHMI CORPORATION
AGANA, GUAM MELVIN H. YOKOTA

ITEM DESCRIPTION	QUANTITY		MATERIAL COST		LABOR COST		ENGINEERING ESTIMATE	
	NO.	UNIT	UNIT	TOTAL	UNIT	TOTAL	UNIT	TOTAL
GPA PITI 34.5 KV SWITCHING STATION UPGRADE							100000	100,000
SUBTOTAL GPA PITI 34.5 KV SWITCHING STATION UPGRADE								100,000
34.5 KV FDR (PITI TO POLARIS POINT ROAD)								
Sawcut	6012	M					10	60,962
Trench and Haul	2098	CM					69	144,930
152 Sch 40 PVC	6012	M					44	266,031
Concrete (Thermal)	412	CM					344	141,773
Backfill (Thermal)	1553	CM					316	490,919
Thermal Testing	16	EA					1000	16,000
Restore pavement	1698	SM					43	73,388
Manhole	13	EA					42000	546,000
Conductor. 750 kcmil, 38 kV EPR	19840	M					320	6,348,800
Conductor. #4/0 SDBC	3306	M					26	85,956
MV Splice	39	EA					1068	41,652
MV Termination	6	EA					1488	8,928
Traffic Management	1	LS					500000	500,000
Misc Tape, Fasteners, Hardware	1	LS					872534	872,534
SUBTOTAL 34.5 KV FDR (PITI TO POLARIS POINT ROAD)								9,597,872
34.5 KV FDR (MARINE CORP DR TO POLARIS SS)								
Sawcut	2460	M					10	24,944
Trench and Haul	1032	CM					69	71,291
152 Sch 40 PVC	4920	M					44	217,710
Concrete (Thermal)	283	CM					344	97,383
Backfill (Thermal)	636	CM					316	201,046
Thermal Testing	8	EA					1000	8,000
Restore pavement	695	SM					43	30,038
Manhole	5	EA					42000	210,000
Conductor. 750 kcmil, 38 kV EPR	16240	M					320	5,196,800
Conductor. #4/0 SDBC	2706	M					26	70,356
MV Splice	15	EA					1068	16,020
MV Termination	6	EA					1488	8,928
Traffic Management	1	LS					25000	25,000
Misc Tape, Fasteners, Hardware	1	LS					617752	617,752
SUBTOTAL 34.5 KV FDR (PITI TO POLARIS POINT ROAD)								6,795,268
BERTH SUBSTATION								
34.5 kV Vacuum Switchgear	2	EA					2380000	4,760,000
34.5 kV Grounding Transformer	1	EA					260000	260,000
34.5 kV Station Service	1	EA					50000	50,000
Substation Building	1	EA					1300000	1,300,000
SCADA	1	EA					100000	100,000
20/36/33 MVA Transformer	2	EA					2000000	4,000,000
13.8 kV Vacuum Switchgear	2	EA					546000	1,092,000
12/16/20 MVA Transformer	2	EA					1500000	3,000,000
4.16 kV Switchgear	2	EA					325000	650,000
Industrial Power	1	EA					300000	300,000
480V Switchgear	1	EA					200000	200,000
SUBTOTAL BERTH SUBSTATION								15,712,000
MWR SERVICE							75000	75,000
SUBTOTAL MWR SERVICE								75,000
BERTH COMMUNICATIONS								
103 Sch 40 PVC	600	M					30	18,000
Innerduct	300	M					10	3,000

COST ESTIMATE - ELECTRICAL

DD1391 - CVN BERTHING STUDY
NAVBASE
AGANA, GUAM

FEBRUARY 2008
HHMI CORPORATION
MELVIN H. YOKOTA

ITEM DESCRIPTION	QUANTITY		MATERIAL COST		LABOR COST		ENGINEERING ESTIMATE	
	NO.	UNIT	UNIT	TOTAL	UNIT	TOTAL	UNIT	TOTAL
Trench and Backfill	120	CM					147	17,640
Concrete	30	CM					334	10,020
NCTS Cabling Costs	1	LS					250000	250,000
Communications Handhole	4	EA					400	1,600
Communications Mound	3	EA					15000	45,000
B4434-Marine Drive Connection	1350	M					360	486,000
Misc Tape, Fasteners, Hardware	1	LS					83126	83,126
SUBTOTAL BERTH COMMUNICATIONS								914,386
BERTH POWER DISTRIBUTION								
POWER MOUND AND CONNECTION	4	EA					75000	300,000
SUBTOTAL BERTH POWER DISTRIBUTION								300,000
SITE LIGHTING AND EMERGENCY POWER							750000	750,000
SUBTOTAL SITE LIGHTING AND EMERGENCY POWER								750,000
GENERAL CONDITIONS							1000000	1,000,000
SUBTOTAL GENERAL CONDITIONS								1,000,000

BUDGET ESTIMATE SUMMARY SHEET

TITLE:	CVN BERTHING FEASIBILITY STUDY - SEWER & BILGE OILY WASTE SYSTEM UPGRADES (POLARIS POINT PARALLEL & DIAGONAL CONFIGURATIONS)	DATE:	FEBRUARY 2008
INSTALLATION:	U.S. NAVBASE, GUAM	DATE ESCALATED TO:	OCTOBER 2011
LOCATION:	AGANA, GUAM	DESIGN STATUS:	FEASIBILITY STUDY
		ESCALATION FACTOR:	1.0867
PREPARED BY:	Engineering Concepts, Inc.	AREA COST FACTOR:	---

DESCRIPTION	UNIT	QUANTITY	UNIT COST	TOTAL COST	COST TRANSFERRED TO 1391 Sum (Rnd, 10K)
NEW BILGE OILY WASTE COLLECTION SYSTEM & TREATMENT FACILITY				4,213,000	4,580
Bilge Oily Waste Collection Ashore	LS	1	767,000	(767,000)	
Bilge Oily Waste Pump Station	LS	1	766,000	(766,000)	
Bilge Oily Waste Treatment System	LS	1	2,530,000	(2,530,000)	
Technical Operating Manuals	LS	1	150,000	(150,000)	
WASTEWATER COLLECTION SYSTEM IMPROVEMENTS				22,685,050	24,660
Ship Wastewater Collection Ashore	LS	1	607,000	(607,000)	
Submersible Pump Station	LS	1	2,576,000	(2,576,000)	
10-inch Force Main	M	396	820	(324,720)	
15-inch Gravity Sewer Line	M	159	4,590	(729,810)	
Dry Pit / Wet Well Type Pump Station	LS	1	6,669,000	(6,669,000)	
12-inch Force Main	M	4,130	980	(4,047,400)	
8-inch Relief Sewer Line along Marine Drive	M	92	2,930	(269,560)	
12-inch Relief Sewer Line along Marine Drive	M	234	3,950	(924,300)	
15-inch Relief Sewer Line along Marine Drive	M	304	4,590	(1,395,360)	
21-inch Relief Sewer Line along Marine Drive	M	710	6,890	(4,891,900)	
Technical Operating Manuals	LS	1	250,000	(250,000)	
WATER SYSTEM IMPROVEMENTS				552,750	610
Supply Lateral to Pier (8-inch)	M	89	750	(66,750)	
Pierside Water Lines & Outlets (8 and 6 inch lines)	LS	1	486,000	(486,000)	
SUPPORTING FACILITIES				250,000	280
Electrical Utilities	LS	1	250,000	(250,000)	
SUBTOTAL*					**30,130**
* Includes Overhead, Profit, Bond & Insurance, GRT, & Prime Mark-up on subcontract					

APPENDIX C

Reference Project Criteria and Guidance Materials

CVN UTILITY REQUIREMENTS GUIDANCE

Exerpt 24 Sept. 07 Email

Douglas, Greg J.

From: Fukuda, Kalani M CIV NAVFAC PAC [kalani.fukuda@navy.mil]
Sent: Monday, September 24, 2007 10:48 AM
To: Sanehira, Todd S CIV NAVFAC PAC
Cc: Fukuda, Kalani M CIV NAVFAC PAC
Subject: RE: CVN Utility Requirements

Todd,

Just to keep track of things. Item 11 is resolved. Item 11, OWWO rate is 90 gpm.

Awaiting feedback on Item #1, Steam.

v/r,
Kalani

-----Original Message-----
From: Fukuda, Kalani M CIV NAVFAC PAC
Sent: Tuesday, September 18, 2007 14:33
To: Sanehira, Todd S CIV NAVFAC PAC
Cc: Fukuda, Kalani M CIV NAVFAC PAC
Subject: FW: CVN Utility Requirements

Todd,

As requested the attached Word file contains the utility demand requirements for the CVN 68 and 78. Below are comments on the various utilities.

1. STEAM: The steam is still undecided. I thought I got something on this from Frank Cole or Chris Fair, but I can't find an email. The CVN
78 is not normally required, but not sure if that is the case for the CVN 68. I just sent an email to Frank Cole on status of steam info.

2. POTABLE WATER: See Vic's email, "RE: CVN Utility Requirements"

3. PURE WATER: Study to recommend course of action.

4. FIRE FIGHTING WATER: Not required.

5. COOLING/FLUSHING WATER: Not required.

6. COMPRESSED AIR: Not required.

7. SHORE POWER: See attached "CVN 68 UTILITY RQMTS with CVN 78 NOTES FOR GUAM 21 Aug 07" document.

8. SANITARY SEWER (CHT) DISCHARGE: See attached "CVN 68 UTILITY RQMTS with CVN 78 NOTES FOR GUAM 21 Aug 07" document.

9. TELEPHONE: See attached "CVN 68 UTILITY RQMTS with CVN 78 NOTES FOR GUAM 21 Aug 07" document. Consultant should be coordinating with NCTS and SPAWAR Guam.

10. TELECOMMUNICATIONS: IT21 or C4SIR requirements. Consultant should be coordinating with NCTS and SPAWAR Guam.

11. OILY WASTE/WASTE OIL (OWWO) DISCHARGE: See attached "CVN 68 UTILITY RQMTS with CVN 78 NOTES FOR GUAM 21 Aug 07" document. Checking with Frank Cole on whether to provide lines for 90 or 180 gpm.

v/r,
Kalani

-----Original Message-----
From: Cole, Frank B CIV NAVFAC Lant
Sent: Tuesday, September 04, 2007 2:51
To: Fukuda, Kalani M CIV NAVFAC PAC
Subject: FW: CVN Utility Requirements

info

-----Original Message-----
From: Pfarrer, Mark D CTR NAVFACHQ, BDD
Sent: Friday, August 31, 2007 13:10
To: Cole, Frank B CIV NAVFAC Lant
Subject: RE: CVN Utility Requirements

Frank,
Regarding #11. The OWWO rates were based on information provided to me during one of my utility meetings at the NGNN design reviews in Newport News. The OWWO system has two pumps, each 90 gpm. The system can operate, as required, with one or both, hence 90-180 gpm range. The NIMITZ Class ITG says 200 gpm. I suppose, though, that the CVN 78 could limit itself to 90 gpm if the shore installation requested it. I will ask PMS 378 if they can live with only 90 gpm in the FPC, and let you know what I find out. -- Mark

-----Original Message-----
From: Cole, Frank B CIV NAVFAC Lant
Sent: Thursday, August 23, 2007 11:20
To: Pfarrer, Mark D CTR NAVFACHQ, BDD; Ebmeier, David A CIV NAVFAC Lant
Cc: Fukuda, Kalani M CIV NAVFAC PAC
Subject: FW: CVN Utility Requirements

Mark,
Could you look at my comments on items 2 & 11 below?
Dave,
Could you look at my comment 7 below?
Frank

-----Original Message-----
From: Cole, Frank B CIV NAVFAC Lant
Sent: Thursday, August 23, 2007 11:06
To: Fukuda, Kalani M CIV NAVFAC PAC
Cc: Yao, Victor K CIV NAVFAC PAC ; Suganuma, Francis M. CIV (N01CE31); Sanden, Clifford R CIV (CPF N43); Burke, Francis J CIV COMNAVAIRPAC, N43; Ishikawa, John K CIV NAVFAC PAC ; Lee, Eric K CIV NAVFAC PAC ; Rios, Jorge P (Pat) CAPT COMPACFLT; Hung, Benjamin C CIV NAVFAC PAC ; Sanehira, Todd S CIV NAVFAC PAC ; 'Caplan, Faith R.'; Wong, Dominic W CIV NAVFAC PAC ; Seelig, William N CIV (NFESCDET); Yamashita, Byrnes K CIV NAVFAC PAC ; Mun, Thomas J CIV NAVFAC PAC
Subject: FW: CVN Utility Requirements

Kalani,
Comments:
1. Steam - need direction from NAVSEA05/PMS312. Have they been tasked?

2. Potable Water - not sure why 235,000 gpd vs 185,000 gpd. I'll check with NAVFAC HQ BD ILS who prepared CVN78 FPC (they are in frequent contact with PMS378) 3. Pure Water - concur 4. Firefighting Water - concur 5. Cooling/Flushing Water - concur 6. Compressed Air - concur 7. Shore Power - I'll forward to Dave Ebmeier NAVFAC LANT for review/comment 8. CHT - concur 9. Telephone - concur 10. IT/COMM - concur 11. OWWO - 90-180 gpm is too much of a range. I'll check with NAVFAC HQ BD ILS who prepared CVN78 FPC (they are in frequent contact with PMS378) 12. HP Air - concur R/ Frank

-----Original Message-----
From: Fukuda, Kalani M CIV NAVFAC PAC
Sent: Tuesday, August 21, 2007 22:28
To: Yao, Victor K CIV NAVFAC PAC ; Suganuma, Francis M. CIV (N01CE31); Sanden, Clifford R CIV (CPF N43); Burke, Francis J CIV COMNAVAIRPAC, N43; Cole, Frank B CIV NAVFAC Lant
Cc: Ishikawa, John K CIV NAVFAC PAC ; Lee, Eric K CIV NAVFAC PAC ; Rios, Jorge P (Pat) CAPT COMPACFLT; Hung, Benjamin C CIV NAVFAC PAC ; Sanehira, Todd S CIV NAVFAC PAC ; 'Caplan, Faith R.'; Wong, Dominic W CIV NAVFAC PAC ; Seelig, William N CIV (NFESCDET); Yamashita, Byrnes K CIV NAVFAC PAC ; Mun, Thomas J CIV NAVFAC PAC ; Fukuda, Kalani M CIV NAVFAC PAC
Subject: RE: CVN Utility Requirements

To All:

Went through the utility requirements list with the notes from the 13 Aug 07 teleconference and added in the CVN 78 requirements as I see it from the DRAFT Facility Planning, Rev 1, Jul 07. Also added in notes.

1. Steam needs further research as noted.

Victor,

Could you please review the water and wastewater requirements and let us know whether you agree with my recommendations.

Cliff/Francis Burke/Francis Suganuma/Frank Cole,

Any comments?

Thanks.

v/r,
Kalani

-----Original Message-----
From: Fukuda, Kalani M CIV NAVFAC PAC
Sent: Tuesday, August 21, 2007 11:54
To: Suganuma, Francis M. CIV (N01CE31); Sanden, Clifford R CIV (CPF N43)
Cc: Ishikawa, John K CIV NAVFAC PAC ; Lee, Eric K CIV NAVFAC PAC ; Rios, Jorge P (Pat) CAPT COMPACFLT; Yao, Victor K CIV NAVFAC PAC ; Hung, Benjamin C CIV NAVFAC PAC ; Sanehira, Todd S CIV NAVFAC PAC ; 'Caplan, Faith R.'; Wong, Dominic W CIV NAVFAC PAC ; Seelig, William N CIV (NFESCDET); Yamashita, Byrnes K CIV NAVFAC PAC ; Mun, Thomas J CIV NAVFAC PAC ; Fukuda, Kalani M CIV NAVFAC PAC
Subject: RE:

Francis/Cliff,

I agree with you, Francis, that we should plan for the CVN 78 along with the CVN 68 and other 480V vessels. Basically boils down to bringing in 30MVA power from GPA side of the house transform down to 13.8kV at Polaris Point/SRF area and then further stepping down to 4,160 V and 480 V. I am not sure whether GPA's current 34.5 kV lines running down Marine Corp Drive has the capacity to support the additional 30 MVA or even 21 MVA, if not then would have to look further upstream. Note the consultant would have to coordinate and work with GPA via NAVFAC Marianas in obtaining the 34.5kV, 30MVA power. Also I believe there will be stand-by power charges imposed by GPA for having the 30MVA power capacity available in their system. This will be a future operational cost. Obviously providing power to SRF area would be more costly than at Polaris Point.

v/r,
Kalani

-----Original Message-----
From: Lee, Eric K CIV NAVFAC PAC
Sent: Tuesday, August 21, 2007 10:49
To: Fukuda, Kalani M CIV NAVFAC PAC
Cc: Ishikawa, John K CIV NAVFAC PAC ; Rios, Jorge P (Pat) CAPT COMPACFLT; Yao, Victor K CIV NAVFAC PAC ; Hung, Benjamin C CIV NAVFAC PAC ; Sanehira, Todd S CIV NAVFAC PAC ; Suganuma, Francis M. CIV (N01CE31); Sanden, Clifford R CIV (CPF N43); Caplan, Faith R.; Wong, Dominic W CIV NAVFAC PAC ; Seelig, William N CIV (NFESCDET); Yamashita, Byrnes K CIV NAVFAC PAC
Subject:

Kalani,
Francis' short answer is that the Guam CVN Wharf should be designed to meet the requirements of the next class of CVN (CVN-78, "Ford" Class).
Pls re-engage CPF N43 to see if/how the requirements change.

Shucks, I thought we had a pretty good idea of the requirements to pass to the AE, but looks like we need to iterate. Not sure how much is really known, at this early stage, but it sounds like we'll need to provide 13.8kV, 4,150V, and 480V service (not simultaneously).

Others,
FYI, preliminary Facility Planning Criteria (FPC) document for CVN-78.

Eric

-----Original Message-----
From: Suganuma, Francis M. CIV (N01CE31)
Sent: Tuesday, August 21, 2007 10:05
To: Lee, Eric K CIV NAVFAC PAC ; Sanehira, Todd S CIV NAVFAC PAC ; Fukuda, Kalani M CIV NAVFAC PAC
Cc: Ishikawa, John K CIV NAVFAC PAC ; Rios, Jorge P (Pat) CAPT COMPACFLT
Subject: RE: CVN-78 OFFICER'S BROW MEETING - NAVSTA NORFOLK 15 AUG 07

thanks Eric for bringing this up... I meant to earlier on but failed to up to now. Yes, we should plan for CVN 78 Class. Regardless of homeport assignment (PAC vs. LANT) Guam will need to be able to support transient visits by all operational CVNs.

V/R, francis
****
Francis M. Suganuma
Commander, U.S. Pacific Fleet
Theater Assessment & Strategic Studies / BRAC Coordinator (N01CE31)
(808) 474-6460 / Cellular: (808) 478-7419 francis.suganuma@navy.mil
francis.suganuma@navy.smil.mil (SIPRNET)

-----Original Message-----
From: Lee, Eric K CIV NAVFAC PAC
Sent: Monday, August 20, 2007 16:08
To: Sanehira, Todd S CIV NAVFAC PAC ; Fukuda, Kalani M CIV NAVFAC PAC
Cc: Ishikawa, John K CIV NAVFAC PAC ; Suganuma, Francis M. CIV (N01CE31)
Subject: FW: CVN-78 OFFICER'S BROW MEETING - NAVSTA NORFOLK 15 AUG 07

Kalani,
CVN 78 projected to require 50% more shore power, at 13.8 kV - up to 30 MW with airwing onboard. I know that CVN 78 is a long way from being built, but pls confirm w/CPF wrt/the electrical requirement we need to satisfy at the Guam CVN wharf.

Eric

-----Original Message-----
From: Ching, Gary M CIV NAVFAC PAC On Behalf Of Ishizu, Wesley W CIV NAVFAC PAC
Sent: Monday, August 20, 2007 13:03
To: Lee, Eric K CIV NAVFAC PAC ; Lucero, Bernard M CIV NAVFAC PAC
Cc: Ishizu, Wesley W CIV NAVFAC PAC
Subject: FW: CVN-78 OFFICER'S BROW MEETING - NAVSTA NORFOLK 15 AUG 07

fyi

-----Original Message-----
From: Hansen, Dean LCDR (NAVFACMAR)
[mailto:Dean.Hansen@navfacmar.navy.mil]
Sent: Monday, August 20, 2007 12:09
To: Ishizu, Wesley W CIV NAVFAC PAC; Gamez, Joshua J LT NAVFAC PAC, OP; Wakabayashi, Marvan R CIV NAVFAC PAC
Subject: FW: CVN-78 OFFICER'S BROW MEETING - NAVSTA NORFOLK 15 AUG 07

Gents,
This was passed to me today...not sure whether this will impact the design criteria for the CVN wharf or not, but I thought I'd pass it along in case you haven't seen it yet.

vr/
DLH

-----Original Message-----
From: Suess, Matthew E. CDR (NAVFACMAR)
Sent: Tuesday, August 21, 2007 7:56 AM
To: Turner, Benjamin H. LT (NAVFACMAR)
Cc: Petersen, Michael C. (NAVFACMAR); Hawn, Eric J LCDR; Hansen, Dean LCDR (NAVFACMAR); Tomiak, Robert B. CDR (NAVFACMAR); Fuligni, Paul T.
CAPT (NAVFACMAR); Amato, Paul R. (NAVFACMAR)

Subject: FW: CVN-78 OFFICER'S BROW MEETING - NAVSTA NORFOLK 15 AUG 07

LT Turner,

Please forward this to the PWO when he returns and clears some space in his email inbox. No action required yet.

All,

Some interesting info on the new "Ford" class CVN. The issue of concern is how one installs a 40' brow with the flight deck almost directly above the lift point. More interesting are some of the specs on the ship (including 50% more shore power rqmt than a Nimitz-class). For that info, see the last document (CVN 78 FPC Jul0.pdf)

VR,

CDR Matt Suess
NAVFAC Marianas Ops
671-339-4260

-----Original Message-----
From: Cole, Frank B (NAVFAC LANT)
Sent: Monday, August 20, 2007 10:05 PM
To: Jackson, Mark W (NAVFAC SE); Washington, Julius C (NAVFAC SW); Bernotas, Scott A (NAVFAC NW); Worden, Rodney O (NAVFAC HI); Sommer, John T CDR NAVFACFE; Suess, Matthew E. CDR (NAVFACMAR); KurganCM@eu.navfac.navy.mil

Cc: Worcester, James A (NAVFAC LANT); Bolton, Philip N (NAVFAC LANT); Pfarrer, Mark D CTR NAVFACHQ, BDD
Subject: FW: CVN-78 OFFICER'S BROW MEETING - NAVSTA NORFOLK 15 AUG 07
Importance: High

OPS Officers,
I am assisting NAVFAC HQ BD with a tasker to look at officer's brow installation on new generation aircraft carrier, CVN-78.

Expectation is that PMS378 will come to NAVFAC formally, by letter in the near future requesting our disposition on this issue.

Please forward this to your PWO's who have purview over the following installations: Mayport, San Diego (North Island), Everett, Bremerton, Puget Sound Naval Shipyard, Pearl Harbor, Guam, Yokosuka, Busan (Korea), Changi (Singapore), Rota (Spain), and Jebel Ali (UAE). Also request that PWO's advise me of receipt of this information.

This is more of a "heads up" at this time. As I receive input this week from local players and setup our next local meeting, I will keep PWO's in the loop. May need to solicit their input as well.

R/FBC
Frank B. Cole, Jr., PE
Spec Asst for Waterfront & Harbors
NAVFAC Atlantic
Code CIENG
757-322-4203
frank.cole@navy.mil

-----Original Message-----
From: Cole, Frank B CIV NAVFAC Lant
Sent: Wednesday, August 15, 2007 12:22
To: Stewart, Janet K CIV NAVFAC Lant; Aguiar, Joseph R CIV Navy Crane Center, 07; Washbourne, David M CIV 710, C710; Watters, Timothy D CIV NNSY, C740; Langlois, Jim LT NAVFAC MidLant, 250; Theisz, Eddy L CIV ENG SEWELLS PT/YRKTWN DESIGN; Kelly, Howard D CIV NAVFAC Lant; Hawkinson, Sandra L CIV NS Norfolk Port OPS; Soto, Leticia LT Navfac MidLant, OPS; Allen,

Eric J CIV NAVFAC MIDLANT; Bell, Carl A CIV; Schindler, Ron E CIV; Jones, Joseph F Jr CIV; Macias, Kail S CIV (NAVFACHQ); Pfarrer, Mark D CTR NAVFACHQ, BDD; Dean, Clay CONT (NAVFACHQ); Jones, Leonard R CIV SEA 04L

Cc: Iselin, Steven R SES NAVFACHQ; Gott, Joseph E CIV (NAVFACHQ)
Subject: CVN-78 OFFICER'S BROW MEETING - NAVSTA NORFOLK 15 AUG 07

All,
Meeting was held today to discuss potential problems with (Lead Design Yard) LDY proposed method of installing officer's brow on CVN-78.
List of attendees is attached. Slide presentations are attached.
Latest draft of CVN-78 Facilities Planning Criteria is attached.

Key points from meeting:

* By this email, I am requesting comments on LDY proposed method. Specifically, detail issues/concerns, follow-on questions, and alternative solutions. As discussed, Joe Aquiar will consolidate comments from crane community and forward to me. Need to have this input back by 22 Aug 07.

* Joe Aquiar mentioned that additional organizations from NNSY should be aware of this, and that he would forward information
* LT Soto will provide me list of PWO's so that I can forward this

information and have them develop positions, similar to exercise we are going through here at Norfolk. When I transmit this information to them, I will solicit typical pier sections.

* I will work with NAVFAC HQ to setup our next meeting, which we expect to include representatives from LDY.

R/FBC
Frank B. Cole, Jr., PE
Spec Asst for Waterfront & Harbors
NAVFAC Atlantic
Code CIENG
757-322-4203
frank.cole@navy.mil

<<CVN78_MTG.PDF>> <<19 Jul 07_Final Officer's Gang Way Summary.ppt>> <<CVN-78_OFFICER'S BROW.ppt>> <<CVN 78 FPC Jul07.pdf>>

CVN POWER REQUIREMENTS GUIDANCE

Exerpt CPF Email Guidance 21 Nov. 07

Douglas, Greg J.

From: Koemmpel, Kenneth J CIV PSNS/IMF, Code 312SP [kenneth.koemmpel@navy.mil]
Sent: Wednesday, November 21, 2007 10:59 AM
To: Suganuma, Francis M. CIV (N01CE31)
Cc: Burke, Francis J CIV COMNAVAIRPAC, 312; Gist, Walter J SES CIV NAVSEA 08 NR; Nix, Bruce L PSNS/IMF, NRRO; Morris, Andrew T CIV NAVSEA 08P; Gray, William W CIV Code 2340; Fogelson, Leslie A CIV Code 2340, Code 2340; Angell, Mark E CIV Code 2340, Code 2340
Subject: Power Requirements for a CVN at Guam

Francis,

I have not seen your e-mail with the Guam CVN power requirements question "What redundant power source is required for a CVN Transit berth at Guam?"

A single line source will be acceptable. The requirement for a double transformer with 21MVA capability for each tramsformer is required. The transformers will need to be larger than 21MVA to address heat loads etc. At Yokosuka we are installing 25 MVA transformers. Because of the tranient nature of the conops for the Guam CVN berth onboard backup power will povide the necessary redundant power just like it does when the ship is at sea. Please let me know if you have additional questions.

Ken Koemmpel

CORAL MITIGATION GUIDANCE

Resource Agency Response to NAVFAC Information Requests Made at the CVN Briefing Meeting.

25 March 08

Resource Agency Response to NAVFAC Information Requests Made at the CVN Briefing Meeting
March 25, 2008

1. Mitigation Cost Estimate

Without additional information, we believe that a worst-case scenario must be used to determine mitigation requirements. It may be possible to relax the worst-case scenario with additional appropriate data and adequate time to conduct appropriate analyses.

We have used the Kilo Wharf project as a basis for estimating the CVN mitigation. This project is similar in that it is a large dredging project in Apra Harbor that has undergone mitigation developed through the cooperative efforts of the Navy and Federal and Territorial resource agencies.

Using a worst case scenario for the proposed CVN project and estimates from Kilo Wharf we derive the following:

Kilo Wharf cost/acre

Estimated full cost of Mitigation[1] =	$8.2 Million
Area of direct damage from dredging =	4.7 acres
Cost per acre for mitigation[2] =	$1.74 Million/acre

[1]Cost used is for the total cost of the mitigation project (as estimated by the resource agencies) and not the funded cost. In the view of the resource agencies, the Kilo Wharf mitigation project is under-funded.
[2]This cost figure accounts for the ~20 acres of reef indirectly impacted by the Kilo Wharf project.

Worst Case Estimates for CVN project

Two estimates were derived for the CVN project. The first estimate is derived from the alternative with the largest potential environmental impact (Polaris Point Parallel – full width). The second estimate is derived from the preferred alternative identified at the March 25, 2008 meeting (Polaris Point Parallel – reduced impact).

Total dredged area (Polaris Point Parallel – full width) = 251,800 m-sq = 62.22 acres
Cost for Mitigation = $1.74 Million/acre * 62.22 acres = $108.26 Million

Total dredge area (Polaris Point Parallel – reduced impact) = 238,400 m-sq = 58.91 acres
Cost for Mitigation = $1.74 Million/acre * 58.91 acres = $102.5 Million

These estimates were made with the following caveats:

1. This is a worst case estimate that assumes all dredge area will be coral reef and all area is permanently lost.
2. These estimates are only for the CVN pier project and do not take into account losses associated with Inner Apra Harbor projects, such as the amphibious landing ramps and other inner harbor dredging. Information on the acreage to be dredged for these projects was not available.

3. Monitoring for the success of the mitigation is required under Army Corps regulation and should be included in the up-front cost of the mitigation project. An appropriate coral reef mitigation project will most likely have a long time line and the determination of success may take a decade or more. The resource agencies wish to ensure that appropriate funding to conduct this essential part of the mitigation project is appropriately allocated.

Finally, we believe it is imperative that the mitigation funding come from a source that will allow it to be used for the actions for which it is intended. Limitations of use associated with MILCON funding created difficulties during the Kilo Wharf project, and efforts should be made to ensure that appropriate funding sources are used. Additionally, an effort must be made to ensure that sufficient funding to complete the mitigation project is available at the start of the project; no additional funding for the mitigation project should need to be requested in out years.

2. Additional Survey Needs

In order to meet individual agency mandates, the resource agencies believe it is important to be involved in the data collection for projects of this size and scope. The work at Kilo Wharf, with lessons learned, should serve as a model for this cooperative effort.

It is critical that the resource agencies view the site. Having first hand experience will improve the cooperative effort. The resource agencies will be able to provide more timely and accurate information/recommendations.

To meet these goals, we would request assistance from the Dept of Navy that would enable us to participate as a full partner in the field. Assistance with any issues that would facilitate the completion of field work in timely manner, especially issues associated with funding, site access, and inclusion of Navy personnel as part of the survey effort.

Some additional data needs include, but may not be limited to:

1. Detailed size-frequency information for corals
2. Data on coral reef functional groups
3. An index of coral health
4. Comprehensive macro-invertebrate and algal inventory data
5. Sediment characterization, including at minimum size, composition, biologically-relevant chemistry (e.g., pore water nutrients), and toxicity.

We request that these specific data needs be developed and collected through a cooperative effort between the Navy and the federal and territorial resource agencies.

3. Information Necessary to reduce worst-case estimate

Information needed to reduce the worst case scenario would include, but may not be limited to:

1. Design plans that have a stable footprint. We acknowledge that plans change, but every time the footprint of the plan is shifted, it becomes difficult to reduce the area of impact to the "actual" foot print. (The worst case scenario tires to account for all possible damage in the project area). Additional, a detailed description of how dredging and construction/fill activities will be conducted (e.g., number of anchors, types of lines deployed, if anchors will be moved and how frequently, mitigation measures for anchors and sediments, etc.) is necessary.
2. Estimated recovery potential for the coral reef environment. Mitigation is for both acres lost and the duration for which it is lost. Recovery potential for reefs that are not permanently removed needs to be determined. This requires a greater understanding of ecosystem function/processes including information such as the potential for new recruitment and juvenile survival to adulthood. This information must be collected based on the project design in order to adequately assess the impact in a scientifically sound manner (see #1).
3. Accurate oceanographic information, examining all levels of the water column, is needed. Any sediment impact analysis needs to account for varying sediment particle size (smaller particles tend to have longer suspension times and a larger adverse ecological effect). If Kilo Wharf is any indication, the acreage of reef indirectly affected will be larger than the acreage directly affected. If these areas can be identified, the impacts determined, and the recovery potential estimated, the worst case scenario can be reduced.
4. A clear and realistic description of the anticipated impacts from activities. This should be based on data where possible or supporting literature from a tropical reefs systems when directly applicable data for Apra Harbor is not available (e.g., sediment mortality rates from different sized particles)

4. Participants for the CVN working group

We recommend the following individuals/agencies be part of this group:

Michael Molina, Dwayne Minton (USFWS)
Gerry Davis, Steve Kolinski (NMFS)
Wendy Wiltse (USEPA)
Paul Bassler, Tino Augon, Jay Guttierez (Guam Dept Ag.)
Guam Bureau of Statistics and Plans (Vanie Lujan(?))
Guam EPA (Mike Gawel (?))
Local Navy Contact (Guam)
Appropriate NAVFAC and other Navy personnel

CVN UTILITIES GUIDANCE

CVN 68 UTILITY RQMTS with CVN 78 NOTES FOR GUAM

21 Aug 07

<u>CVN 68 UTILITY REQUIREMENTS WITH CVN 78 NOTES FOR GUAM</u>
<u>Results of 13 Aug phoncon between PSNS, CNAF N43, CPF N43, CNAF N8, NAVFAC PAC</u>

ASSUMPTIONS:

- Guam visits vary in length between short 1-2 day visits up to 21 days.
- For visits less than 7 days, it is likely that one reactor would remain operating and the ship would stay on its own power. However, the ship would still connect to pier potable water, shore steam and CHT.
- For visits less than 7 days, the embarked air wing would stay aboard.
- Only emergent/voyage repairs will be conducted in Guam.
- For visits of longer duration (up to 21 days), a portion of the air wing may move ashore. However, a large portion will remain onboard the CVN.
- In the absence of a CVN, other ships/submarines may tie up at the CVN capable berth.

1. STEAM.
Constant Load: 7,000 lb/hr
Quality: Certified Pure, 150 psi

Comment [f1]: Need to understand how this is derived. ITG indicates 50,000 pph at 10 deg Celsius which includes steam heating requirements. Need to understand the basis for that and ensure that it reflects that the air wing is embarked.

CVN 78: Normally not required.

NOTE: Per Frank Cole, NAVFAC Lant, 14 Aug 07 email:

```
Summary
*     Values in TN-1702 and subsequently published in Mil-Hdbk 1025/2 are the
only ones we really have a basis for as they were metered
*     Beginning in 1994 and to present, we have stuck with the 50,000 pph
total as directed by AIRPAC/NAVSEA/PMS312
*     50,000 pph seems excessive; might be worth revisiting with
NAVSEA/PMS312 to see if number could be reduced
```

Recommendation: 50,000 pph does seem to be excessive and believe that most of it is for space heating. Guam will not get to the point of requiring space heating. Recommend NAVSEA/PMS312 be consulted on requirement.

****

2. POTABLE WATER.
Normal Requirement with ships Compliment: ~~100,000~~ 185,000 gpd
Station Location (ft): 300 S, 540 S
Station Height (ft): 36
EPA Approved, 40 psi (residual)

Comment [f2]: Agreed that the "air wing embarked" value of 185,000 gpd should be used. For Guam, need to know is this a question of creating additional capacity/infrastructure or running pipe to the selected berth?

CVN 78: Normally 225 gpm @ 30-40 psi; 235,000 gpd

NOTE: Unless directed otherwise, provide potable requirement for 235,000 gpd.

RECOMMENDATION: Provide for potable water demands per CVN 78 requirements.

CVN 68 UTILITY REQUIREMENTS WITH CVN 78 NOTES FOR GUAM
Results of 13 Aug phoncon between PSNS, CNAF N43, CPF N43, CNAF N8, NAVFAC PAC

****
3. PURE WATER.
Quality: Certified Pure
150 gpm and 20,000 gpd

CVN 78: Per DRAFT CVN 78 FPC, pure water provided via tanker truck. Controlled pure water: 100 gpm up to 20,000 gpd. Grade A pure water: two connection 28-56 gpm per connection.

RECOMMENDATION: Study should provide recommendation on course of action.

Comment [f3]: Permanent facility not required and given the assumptions regarding maintenance, the requirement will not likely be more than ½ of this value. PSNS action to review history for CVNs tied up at Pier L/M at NASNI and Evertt and Pier D in PSNS to define anticipated requirement. It is anticipated that the result can be met by temporary means and the study should identify both the anticipated requirement as well as identification of how it will be met. If the selected berth is at Polaris Point, it may be worth checking to see if there is justification for pursuing a permanent facility that supports both submarines and the CVN.

****
4. FIRE FIGHTING WATER.
Not required. Per UFC 4-150-02 for active berths fire fighting water to be provided by ships own pumps, unless directed otherwise. Shore-side fire fighting water is required at shipyard/repair piers.

CVN 78: None required.

Comment [f4]: Concur. No requirement.

****
5. COOLING/FLUSHING WATER.
Not required. Per UFC 4-150-02 for active berths cooling/flushing water to be provided by ships own pumps, unless directed otherwise. Shore-side cooling/flushing water is required at shipyard/repair piers.

CVN 78: None required.

Comment [f5]: Concur. No requirement.

****
6. COMPRESSED AIR.
Quality: ~~125 psig~~ None required. Provided with portable units as required.
Pressure: ~~2,400 scfm~~
Minimum Branch Size: ~~4 in~~
Minimum Outlet Risers per Berth: ~~5~~

CVN 78: LP provided by portable unit.

Comment [f6]: No requirement anticipated. Level of maintenance can either be supported from ship's air or in infrequent cases where that cannot be supported, shipyard will lease or buy portable units. Should only be considered for inclusion at the berth if capacity already exists and the requirement only results in piping to the berth.

****

CVN 68 UTILITY REQUIREMENTS WITH CVN 78 NOTES FOR GUAM
Results of 13 Aug phoncon between PSNS, CNAF N43, CPF N43, CNAF N8, NAVFAC PAC

7. SHORE POWER.

Comment [f7]: 480V shore power not required for the CVN. However, CPF indicated a desire that the requirements reflect the potential for berthing an LHA/LHD. Should be called out as a non-CVN requirement. Should be built to support transition later to 13.8KV requirement of CVN 78 and beyond—ie whatever can be included now to support that additional requirement later at as low a cost as possible. CNAF will id the anticipated 13.8 kv requirement for consideration.

No. of Stations	Station Location (ft)	Station Height (ft)	Voltage Am	pacity Per Station	Remarks
1 5	48 S	30	4,160	1,440	CVN Pwr
1 7	04 S	30	4,160	1,440	CVN Pwr
2	296 S	30	480	4,000	Per ITG 480 V power for other vessels
2	1016 S	40	480	4,000	Per ITG 480 V power for other vessels

CVN 78: 30MW @ 13.8 kV (Two 15 MW stations) with air wing.

RECOMMENDATION: Provide 13.8 kV power for the CVN 78, 4,160 V power for CVN 68 and 480 V power for other vessels.

****

8. SANITARY SEWER (CHT) DISCHARGE.

Comment [f8]: Should be shown as 1200 gpm (3 CHT pumps at 400 gpm max)

PUMP STATION	PUMP PUMP	RATING	DISCHARGE CONNECTION SIZE
1 1A		400 gpm	4”
1B		400 gpm	
2 2A		400 gpm	
2B		400 gpm	

CVN 78: Forward, stbd side: 250 gpm; Aft, stbd side: 500 gpm.

RECOMMENDATION: Provide CHT requirements for CVN 68, which has a larger output of 1,200 gpm.

****

9. TELEPHONE.

Comment [f9]: Concur

Active Lines: 60 pr
Cable Size at Berth: 200 pr
(Coordinate with NCTS Guam N2, Karl Bruner.)

CVN 78: 60 pr min, 100 pr max.

RECOMMENDATION: Provide telephone requirements per CVN 68, which has the largest requirement.

CVN 68 UTILITY REQUIREMENTS WITH CVN 78 NOTES FOR GUAM
Results of 13 Aug phoncon between PSNS, CNAF N43, CPF N43, CNAF N8, NAVFAC PAC

****
10. TELECOMMUNICATIONS – IT21 or C4SIR requirements.
Coordinate with SPAWARS Guam and NCTS Guam.

CVN 78: Digital T-1/ISDN, 2 lines.

RECOMMENDATION: Coordinate with SPAWARS Guam and NCTS Guam.

****
11. OILY WASTE/WASTE OIL (OWWO) DISCHARGE.

PUMP STATION	PUMP	PUMP RATING, GPM	PEAK GPD	AVE GPD	DISCHARGE CONNECION SIZE
1 1A		90	80,000	35,000	2.5 in
1B		90			

Comment [f10]: Concur

CVN 78: 90 – 180 gpm.

RECOMMENDATION: Provide per CVN 78 requirements.
****
12. HIGH PRESSURE AIR.
Quality: Chapter 9490 NSTM
Average Demand: 3,000 – 4,500 psi

Comment [f11]: No requirement anticipated. Level of maintenance can either be supported from ship's HP air or in infrequent cases where that cannot be supported, shipyard will lease or buy portable units. Should only be considered for inclusion at the berth if capacity already exists and the requirement only results in piping to the berth.

CVN 78: HP none required.

EHSS GUIDANCE

Email Correspondence

Randy Girdwood (SPAWAR) to Eric Lee (NAVFAC PAC). 30 Jan 08

Randy Girdwood (SPAWAR) to Eric Lee (NAVFAC PAC). 02 Apr 08

Richard Cofer (NAVFAC Lant) to Joseph Condin (NAVFAC PAC), with attachments. 17 Mar 08

From: Randy Girdwood [randy@spawar.navy.mil]
Sent: Wednesday, January 30, 2008 2:34 PM
To: Lee, Eric K CIV NAVFAC PAC ; Douglas, Greg J.
Cc: Lucas, Jolie C.; Omiya, Laurie M CIV NAVFAC PAC
Subject: RE: 2008-01-03 Waterside Security System Bi-Weekly Report

Eric,

I concur with your statement / breakout.

R/Randy Girdwood
SPAWARSYSCEN San Diego
619-553-5033

-----Original Message-----
From: Lee, Eric K CIV NAVFAC PAC [mailto:eric.k.lee@navy.mil]
Sent: Tuesday, January 29, 2008 6:14 PM
To: Douglas, Greg J.
Cc: Lucas, Jolie C.; Randy Girdwood; Omiya, Laurie M CIV NAVFAC PAC
Subject: FW: 2008-01-03 Waterside Security System Bi-Weekly Report

Greg,
Just confirming that we will incorporate EHSS costs into the appropriate cost categories on the 1391. I believe that the $200K infrastructure costs should be part of the MCON costs, $300K + $250K for equipment procurement, design, and installation should be OPN equipment costs.

Randy/Laurie,
Pls confirm proper fund sources.

Thanks,
Eric

-----Original Message-----
From: Randy Girdwood [mailto:randy@spawar.navy.mil]
Sent: Monday, January 14, 2008 8:41
To: Lee, Eric K CIV NAVFAC PAC
Cc: 'Douglas, Greg J.'; Omiya, Laurie M CIV NAVFAC PAC ;
randy@spawar.navy.mil
Subject: RE: 2008-01-03 Waterside Security System Bi-Weekly Report

Eric,

Thanks for the pics.

Comments inserted below.

R/Randy Girdwood
SPAWARSYSCEN San Diego
619-553-5033

-----Original Message-----
From: Lee, Eric K CIV NAVFAC PAC [mailto:eric.k.lee@navy.mil]
Sent: Wednesday, January 09, 2008 12:29 PM
To: Randy Girdwood
Cc: Douglas, Greg J.; Omiya, Laurie M CIV NAVFAC PAC
Subject: RE: 2008-01-03 Waterside Security System Bi-Weekly Report

Randy,
Providing figures, fyi.

Sounds like a $750K figure would be reasonable, since the MCON just needs to provide for the additional coverage required, not an initial EHSS that covers all of Guam's needs. I assume that the procurement and installation is done via SPAWAR Contract?

RG: The procurement and installation is done by a mix of SPAWAR and Contractor Personnel. We'll work with the local FEC for the infrastructure / minor construction.

1. Could you give an approximate breakdown - infrastructure vs. equipment&installation, and the funding source?

RG: Approximate breakdown: $200k infrastructure; 300k equipment; 250k engineering/installation.

-If all infrastructure/equipment/installation would be provided from central funding, then we don't need a breakdown. We just need to identify the total system and the cost (on the 1391) as "from other appropriations."

RG: Typically, everything is covered under centralized funding. However, we can work with other methods.

-If the MCON needs to provide just the infrastructure, then we need to know the breakdown to increase the construction portion of the MCON, and identify the remaining cost from other appropriations.

RG: The rough breakout is provided, just in case.

2. If, by some miracle, the CVN Wharf was funded ahead of the primary EHSS installation, could you accelerate Guam's EHSS installation?

RG: The decision is at the CNIC / NAVFAC level - and it all comes done to funding. We can execute in about 18 months after funds receipt.

Eric

-----Original Message-----
From: Randy Girdwood [mailto:randy@spawar.navy.mil]
Sent: Wednesday, January 09, 2008 7:21
To: Lee, Eric K CIV NAVFAC PAC
Cc: 'Douglas, Greg J.'; randy@spawar.navy.mil
Subject: RE: 2008-01-03 Waterside Security System Bi-Weekly Report

Eric,

During our site visit, we'll take the eventual carrier pier into consideration for the site layout. If an additional remote sensor site is required (for adequate coverage) on the carrier pier as part of MCON effort, a reasonable SWAG is $750k for the infrastructure, equipment, and installation.

R/Randy Girdwood
SPAWARSYSCEN San Diego
619-553-5033

-----Original Message-----
From: Lee, Eric K CIV NAVFAC PAC [mailto:eric.k.lee@navy.mil]
Sent: Tuesday, January 08, 2008 6:29 PM
To: Randy Girdwood; Douglas, Greg J.
Cc: Douglas, Greg J.
Subject: RE: 2008-01-03 Waterside Security System Bi-Weekly Report

Randy,
Thanks for reply.

I'm asking about an EHSS, which would be required as part of an MCON, so it's possible the MCON should include the infrastructure costs. The proposed MCON is for a CVN-capable wharf in Guam, and I understand that
policies require and EHSS for CVN wharves.

Operators would like the project in FY11/12, but at over $400mil, it might not be funded, soon. It's possible that you may actually install an Apra Harbor EHSS, before the MCON is completed.

The proposed wharf sites are to either side of the channel to the inner harbor. If you did install a EHSS, don't know if these areas would be covered. If not we'd have to install an additional system as part of the MCON.

Should we just add the EHSS infrastructure costs to the MCON, to be conservative? I guess we need to identify the EHSS equipment costs, as well.

Let me know what you think/recommend.

Eric Lee
Base Development
NAVFAC Pacific
808-472-1170

-----Original Message-----
From: Randy Girdwood [mailto:randy@spawar.navy.mil]
Sent: Tuesday, January 08, 2008 7:33
To: Lee, Eric K CIV NAVFAC PAC
Cc: 'Douglas, Greg J.'; Condlin, Joseph R CIV NAVFAC PAC ; Omiya, Laurie M CIV NAVFAC PAC ; Seelig, William N CIV (NFESCDET); randy@spawar.navy.mil
Subject: RE: 2008-01-03 Waterside Security System Bi-Weekly Report

Eric,

The notional budget for the Guam installation is $2.5M. This is for a turn-key installation, from design through system turnover. Typically, the infrastructure costs (foundations, power, telemetry) are much less than the MILCON threshold - and is covered by the $2.5M. However, if there is new construction planned, we can provide input on what is needed to support the system.

Note that the EHSS project has received seed funding under the ATFP Ashore Program to develop a Base Electronics System Engineering Plan (BESEP) to protrect Apra Harbor. I have loosely scheduled a site visit in 2008 to initiate the planning phase.

Kind regards,

Randy Girdwood
SPAWARSYSCEN San Diego
619-553-5033

-----Original Message-----
From: Lee, Eric K CIV NAVFAC PAC [mailto:eric.k.lee@navy.mil]
Sent: Monday, January 07, 2008 8:00 PM
To: Randy@spawar.navy.mil
Cc: Douglas, Greg J.; Condlin, Joseph R CIV NAVFAC PAC ; Omiya, Laurie M CIV NAVFAC PAC
Subject: FW: 2008-01-03 Waterside Security System Bi-Weekly Report

Randy,
Can you help us with a budget estimate for an EHSS?

We are writing a 1391 for a CVN-capable wharf in Guam. I understand that EHSS is a requirement for a CVN wharf. We need to include the cost in the 1391.

I have copied Greg Douglas, who represents our consultant who is doing the study and preparing the 1391.

Greg,
Pls contact Randy, unless you already have a reliable estimate.

Joe/Laurie,
Should this EHSS be considered MCON cost, or Collateral Equipment?

Thanks,
Eric Lee
Base Development
NAVFAC Pacific

-----Original Message-----
From: Lefebvre, Paul (NAVFAC ESC)
Sent: Monday, January 07, 2008 7:37
To: Lee, Eric K CIV NAVFAC PAC
Cc: Nixon, Chip (NFESC)
Subject: RE: 2008-01-03 Waterside Security System Bi-Weekly Report

Hi Eric!

Happy New Year to you, too.

Recommend contacting Randy Girdwood at SPAWAR:

ELECTRONIC HARBOR SECURITY
SYSTEM (EHSS) - SPAWAR
Randy@spawar.navy.mil 619-553-5033
Baxter@spawar.navy.mil 619-553-6697

Please let me know if you have further questions on port security or other topics. Plan to be your way late this month.

Paul

Paul F. Lefebvre
Regional Operations Coordinator
NAVFAC Engineering Service Center
805-982-3548
805-340-8288 cell

-----Original Message-----
From: Lee, Eric K CIV NAVFAC PAC
Sent: Monday, January 07, 2008 9:27
To: Lefebvre, Paul (NAVFAC ESC)
Subject: FW: 2008-01-03 Waterside Security System Bi-Weekly Report

Happy New Year, Paul!
Do you have an NFESC POC for EHSS? Pg 12 mentions that a system is

being evaluated. We are doing a 1391 for a CVN Wharf in Guam and I believe EHSS is a requirement. Would like to discuss the requirement and estimated cost w/an expert.

Eric

-----Original Message-----
From: Kamimoto, Clyde H CIV NAVFAC PAC
Sent: Sunday, January 06, 2008 9:03
To: Ishizu, Wesley W CIV NAVFAC PAC; Yamashita, Byrnes K CIV NAVFAC PAC ; Simpkins, Vanessa F CIV NAVFAC PAC; Len, Peter C CIV NAVFAC PAC; Lucero, Bernard M CIV NAVFAC PAC ; Lee, Eric K CIV NAVFAC PAC ; Ching, Gary M CIV NAVFAC PAC; Wakabayashi, Marvan R CIV NAVFAC PAC ; Ching, Clayton Y CIV NAVFAC PAC ; Yamagata, Jocelyn C CIV NAVFAC PAC; Shimabukuro, Mark T CIV NAVFAC PAC ; Nakamoto, Wayne S CIV NAVFAC PAC ; Andre Lee (E-mail); Bill Neville (NFM) (william.neville@navfacmar.navy.mil); Neville, Bill CIV NAVFAC SE; Cheryl Milligan; Curtis Wong (curtis.wong@navfacfe.navy.mil); Fukawa, Janice A CIV NAVFAC HI, BD; Hansen, Dean LCDR (NAVFACMAR); Karsten Koch (karsten.koch@navfacfe.navy.mil); Karthik Bharat (karthik.bharat@navfacfe.navy.mil); Kotoshirodo, Carrie L CIV NAVFAC HI, OPHBD2; LCDR Eric Hawn (eric.hawn@navfacmar.navy.mil); Tanaka, Lynn K. T., NAVFAC Hawaii, ARE2; Miyashiro, Glenn M CIV NAVFAC HI, OPHBD1; Rey; Johnston, Steven K CIV NAVFAC HI, BD; Brunner Matthew D LTJG (Sasebo); 'Capili, Cesar Jose (NSFDG N5)'; Clements, John J CIV NAVFACFE; dmkreag@atsugi.navy.mil; Lenny Kim; LT Troy Brown (troy.brown@fe.navy.mil); Mike Lavielle; rosario.alba@cfao.navy.mil; Yuko Ebina; Zenger, Scott A CIV NAVFAC HI, PRB
Subject: FW: 2008-01-03 Waterside Security System Bi-Weekly Report

-----Original Message-----
From: Fauber, Sally L CTR NAVFACHQ ATFP
Sent: Thursday, January 03, 2008 8:02
To: Baldwin, Charles L CIV NAVFAC EURSWA; Bernard, Mike CIV SPAWARSYSCEN Charleston SC J633; Brawun, Charles; Butters, Robert L CIV NF Planning Dept; Castro, Ernesto LT (SPSC); Cohen, Robert M LCDR NAVFAC MIDLANT; Daniels, Vernon CIV SPAWAR, J742; Dellalibera, Frank (NFESC); Dominy, Russell O CIV NAVFAC SW, PRTH; Edwards, Brian CIV ,SPAWARSYSCEN; Edwards, Dennis E CDR NAVFAC SE; Evans, Gary L SPAWAR; Glimme, Todd S CIV SPAWAR,SSC SD; Goddeau, Nicholas; Guthmuller, Harry L CIV NSWC PC; Hawkinson, Sandra L CIV NS Norfolk Port OPS; Huneycutt, Ralph K CIV Spawar; Ickes, Warren L CIV NAVSTA Pearl Harbor, N9; Iuvale, Andrew B. CIV N01AT; Jackson, Glen P LCDR COMSUBFOR, N9FP; johnnysn@spawar.navy.mil; kaness@spawar.navy.mil; Kinsey, Chris CMDR ESC09; Kurgan, Christopher M CDR NAVFAC Europe; Lederer, Cliff (NFESC); Lefebvre, Paul (NAVFAC ESC); Lines, Cliffton J LCDR COMSUBFOR, N9FP; Mahlie, Rick Spawar; Mauk, Michael CIV NWSCHS 091; Messock, Richard (NFESC); Morgan, Allan SPAWAR; mwong@spawar.navy.mil; Peeples, David CIV SPAWARSYSCEN Charleston SC J742; randy@spawar.navy.mil; Reed, William E SPAWAR, 543WR; Rourk, Rodney R. CIV (742); Rusek, Ronald M CTR NAVFAC MW, OPS; Senter, Eli; Shebaro,

Ziad; Shebaro, Ziad; Smith, John W CIV Spawar, 742; Walter, Paul G. CIV SPAWARSYSCEN; Ward, Carlene; Zielinski, Greg CAPT, NFESC CO; Aguilera, Susanah CIV NAVFAC SW; All, JC CIV NAVFAC SE; Breen, Amanda A CIV NAVFACHQ; Anderson, Victor (NFESC); Andvik, Brian K CIV NAVFAC NW; Tjoumas, Angelo G CIV HQ Engineer Ops Center; Barcus, Richard S CAPT CNRMA, N9; Bautista, Emmanuel CDR NAVFAC NW, Ops; Brion, Voltaire H CDR NSSC Commanding Officer; Steven Brooks; Brown, Edward W CAPT NAVFAC SE, Executive Officer; Bryan, Mike CIV NAVFAC HQ, BDD; Carmichael, Ronald B CIV NAVSEA; Carr, Scott; Cavileer, D; Clarke, Michael T CIV (NFESCDET); Cole, Frank B CIV NAVFAC Lant; Conroy, Raymond B CIV NNSY, C1120; Cooperman, Mitchell B CIV NAVFAC MIDLANT BD BLC; coopers@nsa.naples.navy.mil; Danis, Kurt D CTR USA USNORTHCOM HQs J34; Kim, Darrell M CIV NAVFAC; Krejdovsky, Dave S CIV NSWCDD, Z23; Day, John S CAPT PEO LMW; DiNobile, Steven J CAPT Naval Station Norfolk, Commanding Officer; Duke, Russell NDW; Eckstrom, Reed A CAPT CNIC HQ, N15; Edwards, Henry B CDR USFF, N3-AT5S; Erickson, Martin CIV USFF, N803; erik.karlson@me.navy.mil; Fauber, Sally L CTR NAVFACHQ ATFP; Foskett, David CIV COMNAVREGNW Port Operations N3; Griffin, Terry CIV Commander Navy Region SE; Grimes, Jeff J CIV CNRNE, 912; Gross, R D CIV (BANG); Hayhurst, Jeffrey K CDR NAVSTA Norfolk, N32; hidehiko.akashi.ja@navfacfe.navy.mil;
Howard, Albert CDR (CNATRA); Ishizu, Wesley W CIV NAVFAC PAC; McConnell, Joseph J CIV NAVFACHQ ; Joyner, Selinda C CIV NAVFACHQ Acquisition, ACQ; Kamimoto, Clyde H CIV NAVFAC PAC ; Kelly, David J CDR Base Support, 100B; Korn, Chris; Draper, Kraig P. USNCIV NAVFACHQ; Lambert, Eugene H CIV NAVSTA Norfolk; Lawrence.Garcia@me.navy.mil; Lehman, Larry CIV CNRNW, Public Safety; Levy, Will CIV NDW; Lister, Scott R CAPT NAVFACHQ OFP, OF; Fleischmann, Lori CIV (NAVFACHQ); Lynch, John J CIV NAVFAC Lant; Macias, Kail S CIV (NAVFACHQ); Maki; Marion, Dennis S LT NAVSTA Norfolk, N93; mark.scott@me.navy.mil; Markey, Jeff H CIV NAVFAC MW PWD GL FMD; Schenck, Marshall H CIV HQ Engineer Ops Center; Martin, Steve W SPAWAR; Fields, Mike D CIV NAVFACHQ, ATFP; Essoglou, Milon CIV (NAVFACHQ); Murdock, Tracey E CAPT; Murley, Steve P CTR CNIC HQ, N7; Nelson, Lasandra CIV CNIC HQ, N3; nishimurag@eu.navfac.navy.mil; Oakley, Harold O CTR NAVFACHQ, ATFP; Orzell, Michael S CDR USFF, N3-AT5P; Jay, Otis C CIV HQ Engineer Ops Center; Perez, Manuel (NFESC); peter.novick@fe.navy.mil; Petro, George CAPT USFF, N803; phillipsa@eu.navfac.navy.mil; Pine, Pam G CIV USFF, N3-AT3R; Pregel, Tony A CAPT NAVFAC Lant; Pyle, Loyd E JR CAPT; Reid, Michael Anthony CIV HQ 00, ATFP; Robishaw, Richard W CIV NAVFACHQ; richard.w.neely@eu.navy.mil; Rodriguez, Jose J CDR NSA Norfolk, N142; Saum, Mike CDR PWD Norfolk; Schelfhout, Stephen J CIV NSWC PC; Shaw, Claude B CIV CNRH, N3; Smith, Eric CTR CNIC; Sontag, Charles R CIV NBK Bangor, N93; Soto, Leticia LT Navfac MidLant, OPS; steven.chan@me.navy.mil; Iselin, Steven SES NAVFACHQ, ED; steven.koepsell@navfacfe.navy.mil; Thompson, Wil L LCDR USFF, N3-AT3O; Toth, Bruce CIV Commander Navy Region SE; Valle, Timothy W CIV NRMW/NAVSTA EMO N37; Van de Voorde, Jim R CTR NAVFACHQ, ATFP; Vesterman, John E CDR USFF, N3-AT3; Keip, Vincent J CIV HQ Engineer Ops Center; Whitehouse, John CIV CNRH, N37; Whitteker Sam CIV; Ennis, Wilson E CIV HQ Engineer Ops Center; Wright, O CIV USFF, N3-ATB; Albright, Deborah Civ NAVFAC; Arkwright, Michele G CIV PEO LMW; Ayling, Michael CTR CNIC HQ, N3; Bailey, Mark E CIV NSWCDL, Z11;

baxter@spawar.navy.mil; Cherepon, Glen J CIV NAVFAC SW; Clanahan, Chuck CIV CNIC HQ, N3AT; Cofer, Richard J CIV NAVFAC Lant; Coker, Christine L CIV NAVBASE Kitsap, N9; Coleman, Joseph W CIV NAVSEA HQ, SEA 05; Condlin, Joseph R CIV NAVFAC PAC ; Croson, Matthew Franklin LT; Crouch, David A (NFESC); Cullen, William P CAPT CNIC HQ, N3; Davis, Jackie M CIV USFF, N3/N5C1; Davis, Jim W CIV USFF, N3-AT5; DeVisser, Alexandra (NFESC); Douvres, Matthew A CIV CNRSW; Duong, Anh N CIV CNO N3AT13; Ermovick, Tony CAPT NAVFAC MIDLANT; Fontan, Will C CIV NSWCDD, Z23; Funn, John V CDR NAVSEA, PMS480; Galloway, John P SES PEO LMW; Gauthier, Ron SPAWAR; Gibson, Jack R CIV NAVFAC SW; Goodin, Glenn CIV NSWCDL, Z23; Goldberg, Barbara M CTR NS Newport, N424; Golie, Carl CIV CNIC HQ, N3AT; Grower, Jason P. LT CNO N3AT3; Hagen, Mark D LTJG NAVFAC MIDLANT; Haseltine, David K CIV CNRSE, N3AT; Hellman, David H CAPT OASN (I&E) BRAC PMO; Hulse, Richard L CIV CNO, N3AT; Huskey, Jeffrey CIV CNIC HQ, N6; Jones, Pat CIV CNIC HQ, N3; Larson, Jonathan CTR CNIC HQ, N57; Leigh, Lori CIV NFESC; Lester, Frank CIV Force Protection Program Manager; Lutz, Marjorie CIV CNIC HQ, N3; Macinski, Michael J CAPT CNO, N3AT; McIntyre, Owen CIV CNIC HQ, N3; Meyers, Michael J CIV, N8S&T; Morrissey, Shawn B. CIV CNRH, N3; Mueller, Tim CIV (CPF N34); Naiser, Donald CDR CNIC HQ, N3; Newton, Rick P CDR CNIC HQ, N3; Nixon, Chip (NFESC); Nolan, Richard J CIV CNIC HQ, N3; Oboyle, Thomas J CIV (NFESCDET); Peterson, Leila K CTR CNIC, N3; Phillips, Jon R LT NSSC NORFOLK; Piepgrass, Dan J CIV CNIC HQ, N3; Pittman, John R CIV (NFESCDET); Powell, Chris S CDR USFF, N3-AT5; Reid, Michael Anthony CIV HQ 00, ATFP; Risley, Jim CIV CNIC HQ; Schuler, Al CIV LMW; Seelig, William N CIV (NFESCDET); Shultz, Daniel CDR, Commanding Officer; Siegel, Jonathan B CIV NAVFAC MIDLANT; Sinder, Mark CTR CNIC HQ, OPS; Spruill, John SPAWAR; Stark, Stephen E CTR CNI HQ, Public Safety; Tausig, Wayne (NFESC); Thomsen, James E SES PEO LMW; Tullos, Rex CDR CNIC; Viggiano, Mike (NFESC) NAVFAC; Vitale, Philip CIV (NAVFAC); Wagner, William John GS13 CNRMA; Whittier, Kim CIV NAVFAC; Wyckoff, Russell CDR CNRMA, N3; Yoshikawa, Stacie A CIV 250, 2523; Zahorbenski, Theodore S CIV SPAWAR Old Towne; Armstrong, Ayana D. OPR NAVFACWASH; Bastinelli, Peter CIV NAVFAC Lant; Bernotas, Scott CDR NAVFAC NW, BANG; Blankenship, Art CIV NSWCDL, Z06; Bowling, Gina CTR CNIC N3, Emergency Management; Carter, Dareyl
CWO3 NAVSTA Mayport N32; Charters, Tom CIV SPAWARSYSCEN SAN DIEGO 2838; Cooper, Ted J CONT NSWC, PC; Cunha, Jim CAPT CNO, N3AT; Finnegan, Joseph T CTR CNIC HQ, N3; Fitzgibbon, Steven W CIV NSWC PC; Flotten, Brandy C NAVAIR; Fung, Daniel S CIV NAVFAC SW; Gilmore, Charles OPERATIONS, PDPS; Hartmann, Beth L CDR NAVFAC MW, XO; Horning, Spencer H CIV NAVFAC NW; Johnson, Henry D CIV SPAWAR; Laderer, David A LCDR CNRMA; Lee, Robert E CIV; Lillard, John D SPAWAR; Little, Maureen (NFESC); Londergan, Diana CIV Spawar 742DL; Lustig, Edward A Jr CIV NAVSURFWARCENDIV, E314; Lynch, Richard D CIV NAVFAC SE; McCracken, Alicia G CTR PEO LMW; McGraw, Jennifer CIV NAVSEA PEO LMW; Miller, Allen CIV NFESC; Mitchell, John CIV SPAWAR, OT11 1852E; Moorefield, Carlton; Mule, Leonard W CIV NF CIVIL STRUC BRANCH SP/YT; Palmer, Stephen E CTR USFF, N3-AT5P4; Robb, Jeffrey A CIV NAVFAC SE; Searight, Jonathan CIV SPAWARSYSCEN Charleston SC J63C; Seiter, Scott; Sergienko, Eric CDR; Smith, David M CDR NAVFAC Southeast, RE Staff; Sparks, Stevenson L CIV NAVFAC NW; Summers, Doug CIV NAVSURFWARCENDIV, CRANE Code 8056; Tate, Ann E SES NSWCDL, C92; Torres, Luis A CIV

NAVFAC; Troffer, Michael A CIV EODTECHDIV; Varnava, Andrew (NFESC); Yingling, Theresa L CIV NAVSEA PEO LMW; Zeller, Charles A CIV NAVSURFWARCENDIV Crane, Code JXNF
Subject: 2008-01-03 Waterside Security System Bi-Weekly Report

>V/r,
>Sally Fauber
>Anti-Terrorism/Force Protection (AT/FP)
>Phone: 202-685-9356
DSN: 325-9356
>Email: sally.fauber.ctr@navy.mil

From: Randy Girdwood [randy@spawar.navy.mil]
Sent: Wednesday, April 02, 2008 6:32 PM
To: Lee, Eric K CIV NAVFAC PAC
Subject: RE: Guam CVN - clarifications

Eric,

My apology for the delay. A brief, written description of EHSS follows.

"The Electronic Harbor Security System (EHSS) is designed to protect Navy ships in port from waterborne attacks. The EHSS is part of the Commander, Navy Installation Command / Naval Facilities Engineering Command Anti-terrorism Force Protection Ashore program under the Waterfront Protection capability area. EHSS is designed to work with waterfront barriers as part of a layered defense to protect U.S. Navy ships in port against waterborne attacks. The principal function of the EHSS is to aid existing security personnel with the tasks of detecting, classifying, assessing, and responding to waterborne threats. The EHSS is an integrated system composed of Commercial-Off-The-Shelf (COTS) and Government-Off-The-Shelf equipment."

I'm not clear what additional information is required for the CVN project, at this point. Most of the EHSS work will be completed outside the MILCON effort. After our upcoming site visit, we can provide much better information on site selections that include coverage of the carrier pier. If the preferred location is on the pier, we can provide additional details.
The main requirement for a pier installation will be power and fiber-optics / conduits. During a similar installation, we had to run a separate conduit runs down the length of the pier since the existing capacity was completely used. Ideally, that could be incorporated into the design. The tower and generator will require some footprint, but these shouldn't negatively impact the pier design.

Break-break, new subject:

Earlier, I spoke with Mr. Roy Kinsey from SPAWARSYSCEN Charleston. Reportedly, he received year-end funding from CNIC last year that was placed on contract. Those funds are targeted to install a wireless network and possibly some cameras on the waterfront. His group has meetings scheduled with the N6 during the week of 14 April 2008. I'm considering moving our site visit for EHSS to overlap - it looks like there may be some synergy between the two projects.

Questions:
1. Do you see any issues with an EHSS site visit during the week of 14 Apr?
2. Can you provide the contact information for the NAVBASE Guam SECO?
3. Can you provide the contact information for the Public Works

Officer?

Thanking you in advance.

Randy Girdwood
SPAWARSYSCEN San Diego
619-553-5033

-----Original Message-----
From: Lee, Eric K CIV NAVFAC PAC [mailto:eric.k.lee@navy.mil]
Sent: Monday, March 24, 2008 6:10 PM
To: randy@spawar.navy.mil; Baxter@spawar.navy.mil
Cc: Douglas, Greg J.
Subject: RE: Guam CVN - clarifications

Randy,
Have not heard back from you. Left a phone message, too. Could you privide
a little bit of general info on ehss, so we can include in our report. We
will be stating that EHSS is required for the CVN wharf, and provide cost
estimates as previously discussed. We need to include a paragraph or so to
describe what we might be talking about wrt EHSS.

Thanks,
Eric

-----Original Message-----
From: Lee, Eric K CIV NAVFAC PAC
Sent: Thursday, March 13, 2008 9:33
To: randy@spawar.navy.mil
Cc: Douglas, Greg J.
Subject: FW: Guam CVN - clarifications

Randy,

Can you provide some general info on EHSS, and the kind of system that might
be employed at a Guam CVN Wharf?

Pls see questions b. and c., below.

To refresh your memory, even assuming an EHSS for the Inner Apra Harbor, due
to the location of the CVN wharves (outside the channel to Inner Apra Harbor)

Thanks,
Eric Lee

-----Original Message-----
From: Douglas, Greg J. [mailto:GJDouglas@tecinc.com]
Sent: Tuesday, March 11, 2008 10:39
To: Lee, Eric K CIV NAVFAC PAC
Cc: Muslin, Dan; Stewart, Warren; Lucas, Jolie C.
Subject: Guam CVN - clarifications

Eric,

One outstanding issue came up today:

1. We spoke at length with Warren Stuart this morning, and they (Halcrow) did not get clear direction regarding the use of electronic surveillance equipment. They have included the floating barriers (PSB's), but have thus far left out the EHSS. You provided us with direction to include EHSS costs in the 1391, and I had (incorrectly) assumed this came down from work Halcrow had been engaged in. The attached email is the final correspondence we had on the EHSS system. This was direction for TEC to include costs in the 1391, but no direction with regard to the narrative, description of the EHSS, etc.

a. What is the final determination regarding EHSS?

b. What should Halcrow include in the narrative for the EHSS system?

c. What type of system do the costs noted in the attached email cover?

d. Were the "fund sources" confirmed by Randy/Laurie as noted in the email?

Re: Steam:

We discussed the steam issue at length today as well. Warren and his team are reviewing the email string now.

I believe we are still in favor of leaving the costs in as they are now, particularly at this programmatic level, to ensure adequate funds are available. There is more inherent risk with retrofitting old equipment to

new uses, and costs can be unpredictable. My concern is with 1b and 1c
below (excerpt from email string). The existing equipment at SRF needs to
be repaired and upgraded.

Can you provide further, clear direction on this item?

"

Please help us to ensure we understand clearly, by verifying the following:

1a. Are both boilers going to be 250 HP (after the Kilo wharf boiler is
moved)? YES, PLEASE SEE ITEM 1.

1b. Are both boilers going to be fully operational, prior to the CVN wharf
(earliest completion would be 2013)? YES, PLEASE PREPARE DD1391 FOR PROJECT
TO REPAIR/UPGRADE EXSISTING BOILER PLANT AT SRF.

1c. Is (will) all associated equipment complete and in good operating
condition? ASSOCIATED EQUIPMENT FROM KILO WHARF BOILER PLANT IS IN GOOD
OPERATING CONDITIONS. THE EXISTING ASSOCIATED EQUIPMENT AT SRF NEEDED TO BE
REPAIR.

1d. Have (will) the existing SRF steam lines been replaced since 2004?
STEAM LINE WAS REPLACED FROM LIMA TO ROMEO IN 2003.

If the answers to 1a., 1b., 1c., 1d. are all "yes," then we can remove all
steam-related costs.

"

Thanks.

Best Regards,

Greg Douglas

TEC Inc.

514 Via De La Valle, Suite 308

Solana Beach, CA 92075

Ph. (858) 509-3157

Fax (858) 509-3157

Cell (858) 829-6096

Email: gjdouglas@tecinc.com

From: Cofer, Richard J CIV NAVFAC Lant [richard.cofer@navy.mil]
Sent: Monday, March 17, 2008 5:07 AM
To: Condlin, Joseph R CIV NAVFAC PAC
Cc: Lee, Eric K CIV NAVFAC PAC ; Lynch, John J CIV NAVFAC Lant
Subject: RE: 2008-01-03 Waterside Security System Bi-Weekly Report
Signed By: There are problems with the signature. Click the signature button for details.

Follow Up Flag: Follow up
Flag Status: Flagged

Attachments: OPNAVINST 5530 14D (30 JAN 07) - Final.pdf; UFC 4-025-01 Waterfront Security Ver A.pdf

OPNAVINST) 14D (30 JAN 0 UFC 4-025-01 Waterfront Securi

Joe,

Requirements for protection of waterfront assets are not dictated by Unified Facility Criteria, it is rooted in DoD and Navy Policy/Regulations. See OPNAVINST 5530.14D Table VIII-1, Security of Waterfront Assets Matrix in U.S. Navy Controlled Ports. The 5530 14D is attached.

CVN is classified as a "Priority B" asset. Priority B assets require electronic water/waterside security system (CCTV, associated alarms, surface craft or swimmer detection, underwater detection). Water barriers are required to prevent direct unchallenged access from small boat attacks.

Attached is the current Draft of the Waterfront Security UFC. You have a copy of the old one.

Regards,

Richard Cofer, P.E.
NAVFAC Atlantic, ATFP
6506 Hampton Blvd
Norfolk, VA 23508-1278
757-322-4447
http://www.wbdg.org/references/pa_dod_eico.php

entity to whom they are addressed. If you have received this e-mail in
error please notify the sender by return e-mail and delete this message from
your system immediately. Any unauthorized use or dissemination of this
message and the attachments, without the full consent of the sender, in
whole or in part is strictly prohibited.

-----Original Message-----
From: Condlin, Joseph R CIV NAVFAC PAC
Sent: Friday, March 14, 2008 17:32
To: Lynch, John J CIV NAVFAC Lant; Cofer, Richard J CIV NAVFAC Lant
Cc: Lee, Eric K CIV NAVFAC PAC
Subject: FW: 2008-01-03 Waterside Security System Bi-Weekly Report
Importance: High

I'm working with planners for the Guam DPRI build-up. I need to get a copy
of any upcoming UFC drafts for electronic harbor security, water barriers,
waterfront security, i.e., UFC 4-012-18. If you have any draft UFCs coming
out please forward a copy via e-mail.

DPRI is sensitive. Please keep "close hold".

Regards,
Joe Condlin

-----Original Message-----
From: Lee, Eric K CIV NAVFAC PAC
Sent: Tuesday, March 11, 2008 11:23
To: Condlin, Joseph R CIV NAVFAC PAC
Subject: FW: 2008-01-03 Waterside Security System Bi-Weekly Report

Joe,
As we discussed, thanks for the help.

Just want to be sure I'm not adding nice-to-haves, vs. requirements.

Thanks,
Eric

-----Original Message-----
From: Randy Girdwood [mailto:randy@spawar.navy.mil]
Sent: Thursday, January 31, 2008 8:04
To: Lee, Eric K CIV NAVFAC PAC
Cc: randy@spawar.navy.mil
Subject: RE: 2008-01-03 Waterside Security System Bi-Weekly Report

Eric,

I can't say definitively. I believe the UFC (at least the draft version from
a few years ago) required waterfront protection (barriers and EHSS) for
Priority B assets. Regrettably, I can't cite chapter and verse.

Hope that helps.

R/Randy Girdwood
SPAWARSYSCEN San Diego
619-553-5033

-----Original Message-----
From: Lee, Eric K CIV NAVFAC PAC [mailto:eric.k.lee@navy.mil]
Sent: Wednesday, January 30, 2008 8:17 PM
To: Randy Girdwood
Subject: RE: 2008-01-03 Waterside Security System Bi-Weekly Report

Randy,
I was assuming that an EHSS is required, for a CVN berth. Is this truly a
requirement, and if so, what is the reference criteria?

Thanks,
Eric

-----Original Message-----
From: Randy Girdwood [mailto:randy@spawar.navy.mil]
Sent: Wednesday, January 30, 2008 12:34
To: Lee, Eric K CIV NAVFAC PAC ; 'Douglas, Greg J.'
Cc: 'Lucas, Jolie C.'; Omiya, Laurie M CIV NAVFAC PAC
Subject: RE: 2008-01-03 Waterside Security System Bi-Weekly Report

Eric,

I concur with your statement / breakout.

R/Randy Girdwood
SPAWARSYSCEN San Diego
619-553-5033

-----Original Message-----
From: Lee, Eric K CIV NAVFAC PAC [mailto:eric.k.lee@navy.mil]
Sent: Tuesday, January 29, 2008 6:14 PM
To: Douglas, Greg J.
Cc: Lucas, Jolie C.; Randy Girdwood; Omiya, Laurie M CIV NAVFAC PAC
Subject: FW: 2008-01-03 Waterside Security System Bi-Weekly Report

Greg,
Just confirming that we will incorporate EHSS costs into the appropriate
cost categories on the 1391. I believe that the $200K infrastructure costs
should be part of the MCON costs, $300K + $250K for equipment procurement,
design, and installation should be OPN equipment costs.

Randy/Laurie,
Pls confirm proper fund sources.

Thanks,
Eric

-----Original Message-----
From: Randy Girdwood [mailto:randy@spawar.navy.mil]
Sent: Monday, January 14, 2008 8:41
To: Lee, Eric K CIV NAVFAC PAC
Cc: 'Douglas, Greg J.'; Omiya, Laurie M CIV NAVFAC PAC ; randy@spawar.navy.mil
Subject: RE: 2008-01-03 Waterside Security System Bi-Weekly Report

Eric,

Thanks for the pics.

Comments inserted below.

R/Randy Girdwood
SPAWARSYSCEN San Diego
619-553-5033

-----Original Message-----
From: Lee, Eric K CIV NAVFAC PAC [mailto:eric.k.lee@navy.mil]
Sent: Wednesday, January 09, 2008 12:29 PM
To: Randy Girdwood
Cc: Douglas, Greg J.; Omiya, Laurie M CIV NAVFAC PAC
Subject: RE: 2008-01-03 Waterside Security System Bi-Weekly Report

Randy,
Providing figures, fyi.

Sounds like a $750K figure would be reasonable, since the MCON just needs to
provide for the additional coverage required, not an initial EHSS that
covers all of Guam's needs. I assume that the procurement and installation

is done via SPAWAR Contract?

RG: The procurement and installation is done by a mix of SPAWAR and Contractor Personnel. We'll work with the local FEC for the infrastructure /
minor construction.

1. Could you give an approximate breakdown - infrastructure vs. equipment&installation, and the funding source?

RG: Approximate breakdown: $200k infrastructure; 300k equipment; 250k engineering/installation.

-If all infrastructure/equipment/installation would be provided from central
funding, then we don't need a breakdown. We just need to identify the total
system and the cost (on the 1391) as "from other appropriations."

RG: Typically, everything is covered under centralized funding. However, we
can work with other methods.

-If the MCON needs to provide just the infrastructure, then we need to know
the breakdown to increase the construction portion of the MCON, and identify
the remaining cost from other appropriations.

RG: The rough breakout is provided, just in case.

2. If, by some miracle, the CVN Wharf was funded ahead of the primary EHSS
installation, could you accelerate Guam's EHSS installation?

RG: The decision is at the CNIC / NAVFAC level - and it all comes done to
funding. We can execute in about 18 months after funds receipt.

Eric

-----Original Message-----
From: Randy Girdwood [mailto:randy@spawar.navy.mil]
Sent: Wednesday, January 09, 2008 7:21
To: Lee, Eric K CIV NAVFAC PAC
Cc: 'Douglas, Greg J.'; randy@spawar.navy.mil
Subject: RE: 2008-01-03 Waterside Security System Bi-Weekly Report

Eric,

During our site visit, we'll take the eventual carrier pier into consideration for the site layout. If an additional remote sensor site is
required (for adequate coverage) on the carrier pier as part of MCON effort,
a reasonable SWAG is $750k for the infrastructure, equipment, and installation.

R/Randy Girdwood
SPAWARSYSCEN San Diego
619-553-5033

-----Original Message-----
From: Lee, Eric K CIV NAVFAC PAC [mailto:eric.k.lee@navy.mil]
Sent: Tuesday, January 08, 2008 6:29 PM
To: Randy Girdwood; Douglas, Greg J.
Cc: Douglas, Greg J.
Subject: RE: 2008-01-03 Waterside Security System Bi-Weekly Report

Randy,
Thanks for reply.

I'm asking about an EHSS, which would be required as part of an MCON, so
it's possible the MCON should include the infrastructure costs. The proposed MCON is for a CVN-capable wharf in Guam, and I understand that
policies require and EHSS for CVN wharves.

Operators would like the project in FY11/12, but at over $400mil, it might
not be funded, soon. It's possible that you may actually install an Apra
Harbor EHSS, before the MCON is completed.

The proposed wharf sites are to either side of the channel to the inner
harbor. If you did install a EHSS, don't know if these areas would be covered. If not we'd have to install an additional system as part of the
MCON.

Should we just add the EHSS infrastructure costs to the MCON, to be conservative? I guess we need to identify the EHSS equipment costs, as
well.

Let me know what you think/recommend.

Eric Lee
Base Development
NAVFAC Pacific

808-472-1170

-----Original Message-----
From: Randy Girdwood [mailto:randy@spawar.navy.mil]
Sent: Tuesday, January 08, 2008 7:33
To: Lee, Eric K CIV NAVFAC PAC
Cc: 'Douglas, Greg J.'; Condlin, Joseph R CIV NAVFAC PAC ; Omiya, Laurie M
CIV NAVFAC PAC ; Seelig, William N CIV (NFESCDET);
randy@spawar.navy.mil
Subject: RE: 2008-01-03 Waterside Security System Bi-Weekly Report

Eric,

The notional budget for the Guam installation is $2.5M. This is for a turn-key installation, from design through system turnover. Typically, the
infrastructure costs (foundations, power, telemetry) are much less than the
MILCON threshold - and is covered by the $2.5M. However, if there is new
construction planned, we can provide input on what is needed to support the
system.

Note that the EHSS project has received seed funding under the ATFP Ashore
Program to develop a Base Electronics System Engineering Plan
(BESEP) to protrect Apra Harbor. I have loosely scheduled a site visit in
2008 to initiate the planning phase.

Kind regards,

Randy Girdwood
SPAWARSYSCEN San Diego
619-553-5033

-----Original Message-----
From: Lee, Eric K CIV NAVFAC PAC [mailto:eric.k.lee@navy.mil]
Sent: Monday, January 07, 2008 8:00 PM
To: Randy@spawar.navy.mil
Cc: Douglas, Greg J.; Condlin, Joseph R CIV NAVFAC PAC ; Omiya, Laurie M CIV
NAVFAC PAC
Subject: FW: 2008-01-03 Waterside Security System Bi-Weekly Report

Randy,
Can you help us with a budget estimate for an EHSS?

We are writing a 1391 for a CVN-capable wharf in Guam. I understand

that
EHSS is a requirement for a CVN wharf. We need to include the cost in the
1391.

I have copied Greg Douglas, who represents our consultant who is doing the
study and preparing the 1391.

Greg,
Pls contact Randy, unless you already have a reliable estimate.

Joe/Laurie,
Should this EHSS be considered MCON cost, or Collateral Equipment?

Thanks,
Eric Lee
Base Development
NAVFAC Pacific

-----Original Message-----
From: Lefebvre, Paul (NAVFAC ESC)
Sent: Monday, January 07, 2008 7:37
To: Lee, Eric K CIV NAVFAC PAC
Cc: Nixon, Chip (NFESC)
Subject: RE: 2008-01-03 Waterside Security System Bi-Weekly Report

Hi Eric!

Happy New Year to you, too.

Recommend contacting Randy Girdwood at SPAWAR:

ELECTRONIC HARBOR SECURITY
SYSTEM (EHSS) - SPAWAR
Randy@spawar.navy.mil 619-553-5033
Baxter@spawar.navy.mil 619-553-6697

Please let me know if you have further questions on port security or other
topics. Plan to be your way late this month.

Paul

Paul F. Lefebvre
Regional Operations Coordinator
NAVFAC Engineering Service Center
805-982-3548
805-340-8288 cell

-----Original Message-----

From: Lee, Eric K CIV NAVFAC PAC
Sent: Monday, January 07, 2008 9:27
To: Lefebvre, Paul (NAVFAC ESC)
Subject: FW: 2008-01-03 Waterside Security System Bi-Weekly Report

Happy New Year, Paul!
Do you have an NFESC POC for EHSS? Pg 12 mentions that a system is being
evaluated. We are doing a 1391 for a CVN Wharf in Guam and I believe EHSS
is a requirement. Would like to discuss the requirement and estimated cost
w/an expert.

Eric

-----Original Message-----
From: Kamimoto, Clyde H CIV NAVFAC PAC
Sent: Sunday, January 06, 2008 9:03
To: Ishizu, Wesley W CIV NAVFAC PAC; Yamashita, Byrnes K CIV NAVFAC PAC ;
Simpkins, Vanessa F CIV NAVFAC PAC; Len, Peter C CIV NAVFAC PAC; Lucero,
Bernard M CIV NAVFAC PAC ; Lee, Eric K CIV NAVFAC PAC ; Ching, Gary M CIV
NAVFAC PAC; Wakabayashi, Marvan R CIV NAVFAC PAC ; Ching, Clayton Y CIV
NAVFAC PAC ; Yamagata, Jocelyn C CIV NAVFAC PAC; Shimabukuro, Mark T CIV
NAVFAC PAC ; Nakamoto, Wayne S CIV NAVFAC PAC ; Andre Lee (E-mail); Bill
Neville (NFM) (william.neville@navfacmar.navy.mil); Neville, Bill CIV NAVFAC
SE; Cheryl Milligan; Curtis Wong (curtis.wong@navfacfe.navy.mil); Fukawa,
Janice A CIV NAVFAC HI, BD; Hansen, Dean LCDR (NAVFACMAR); Karsten Koch
(karsten.koch@navfacfe.navy.mil); Karthik Bharat
(karthik.bharat@navfacfe.navy.mil); Kotoshirodo, Carrie L CIV NAVFAC HI,
OPHBD2; LCDR Eric Hawn (eric.hawn@navfacmar.navy.mil); Tanaka, Lynn K. T.,
NAVFAC Hawaii, ARE2; Miyashiro, Glenn M CIV NAVFAC HI, OPHBD1; Rey;
Johnston, Steven K CIV NAVFAC HI, BD; Brunner Matthew D LTJG (Sasebo);
'Capili, Cesar Jose (NSFDG N5)'; Clements, John J CIV NAVFACFE;
dmkreag@atsugi.navy.mil; Lenny Kim; LT Troy Brown
(troy.brown@fe.navy.mil);
Mike Lavielle; rosario.alba@cfao.navy.mil; Yuko Ebina; Zenger, Scott A CIV
NAVFAC HI, PRB
Subject: FW: 2008-01-03 Waterside Security System Bi-Weekly Report

-----Original Message-----
From: Fauber, Sally L CTR NAVFACHQ ATFP
Sent: Thursday, January 03, 2008 8:02
To: Baldwin, Charles L CIV NAVFAC EURSWA; Bernard, Mike CIV SPAWARSYSCEN
Charleston SC J633; Brawun, Charles; Butters, Robert L CIV NF Planning Dept;
Castro, Ernesto LT (SPSC); Cohen, Robert M LCDR NAVFAC MIDLANT; Daniels,
Vernon CIV SPAWAR, J742; Dellalibera, Frank (NFESC); Dominy, Russell O CIV
NAVFAC SW, PRTH; Edwards, Brian CIV ,SPAWARSYSCEN; Edwards, Dennis E CDR
NAVFAC SE; Evans, Gary L SPAWAR; Glimme, Todd S CIV SPAWAR,SSC SD; Goddeau,
Nicholas; Guthmuller, Harry L CIV NSWC PC; Hawkinson, Sandra L CIV NS
Norfolk Port OPS; Huneycutt, Ralph K CIV Spawar; Ickes, Warren L CIV NAVSTA
Pearl Harbor, N9; Iuvale, Andrew B. CIV N01AT; Jackson, Glen P LCDR
COMSUBFOR, N9FP; johnnysn@spawar.navy.mil; kaness@spawar.navy.mil; Kinsey,
Chris CMDR ESC09; Kurgan, Christopher M CDR NAVFAC Europe; Lederer, Cliff
(NFESC); Lefebvre, Paul (NAVFAC ESC); Lines, Cliffton J LCDR COMSUBFOR,
N9FP; Mahlie, Rick Spawar; Mauk, Michael CIV NWSCHS 091; Messock, Richard
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Appendix K

Additional Reports - Noise

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FINAL

Wyle Report

WR 08-01

Aircraft Noise Study for Andersen Air Force Base, Guam

Subcontract No. 07S-10875-HI16
Job No. T54676

August 2008

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1.0 Introduction

The Naval Facilities Engineering Command (NAVFACENGCOM) conducts aircraft surveys at various Naval and Marine Corps facilities throughout the United States and overseas. The noise exposure contours developed during these studies are incorporated into Air Installations Compatible Use Zones (AICUZ), Range Air Installation Compatible Use Zones (RAICUZ) or other environmental documents such as Environmental Impact Statements (EIS). These documents are used to promote the compatibility of Navy and Marine Corps activities with neighboring land uses.

This noise analysis was conducted in conjunction with the Joint Guam Program Office EIS for proposed activity at Andersen Air Force Base (AFB) including the Guam Joint Military Master Plan (GJMMP). The data are based on a 2003 noise study by the Air Force Center for Engineering and the Environment[1] (AFCEE) initially intended to provide input to an AICUZ update for the installation; however, no AICUZ study was ever produced or released using the data. Data for the analysis herein was also based on Alternative A of the 2006 EIS for the establishment of a intelligence, surveillance, reconnaissance and strike capability (ISR/Strike EIS) and interviews with Andersen AFB personnel (AFCEE, 2003; DAF, 2006; Andersen AFB, 2007b; Andersen AFB 2007c). The current noise study includes analyses of a Baseline scenario, defined as Calendar Year (CY) 2006 tempo of operations; a No Action scenario, defined as CY2014 projected tempo of operations; and a Proposed Action scenario based on proposed operations for CY2014.

The No Action Scenario includes CY2006 operations plus the following changes:

- Transfer of ISR/Strike-related operations for transient B-1, B-2, B-52, F-15, F-22, KC-135R, and RQ-4 Global Hawk aircraft;
- Increased use of Andersen AFB for special exercises, resulting in up to four-fold operations increase of transient F-15A, F-16C, KC-10, KC-135 aircraft;
- Increase in Air Mobility Command (AMC) deployment-related cargo and air carrier service;
- One-for-one replacement of all aircraft carrier (CVN) airwing EA-6B "Prowler" operations with EA-18G "Growler" operations; and
- One-for-one replacement of Multimission Maritime Aircraft (MMA) P-3A operations with P-8A operations.

[1] Formerly known as Air Force Center for Environmental Excellence

The Prospective scenario includes a range of potential actions the Navy could take in addition to the actions listed above. For Andersen AFB in particular, the Navy anticipates the following changes:

- Transfer of four CH-53E, six AH-1Z, and three UH-1N aircraft in support of the USMC relocation to Guam;;
- Transfer of a Marine F/A-18D squadron in support of the USMC relocation to Guam;
- Addition of a new based MV-22 squadron; and
- Increased visits by CVN airwings to Andersen AFB, resulting in a four-fold increase of transient CVN F/A-18C, F/A-18F, SH-60B/F, EA-18G, and E-2C airfield operations.

This report has six sections followed by four appendices. Section 2.0 describes the noise metrics and technical tools used to conduct the analyses. Section 3 describes Andersen AFB. The CY2006 operations data and noise exposure are presented in Section 4. Section 5 presents the modeled operations data and noise exposure of the CY2014 No Action scenario. Section 6 presents the modeled operations data and noise exposure of the CY2014 Proposed Scenario.

Appendix A provides an in-depth discussion of noise, noise metrics, and the effect of noise on communities and the environment. Appendix B contains tables of runway and flight track utilization for all modeled aircraft. Appendix C includes representative flight profiles modeled for proposed based aircraft: CH-53, AH-1, UH-1, MV-22, and F/A-18D. Appendix D lists the maintenance run-up profiles for all modeled aircraft.

2.0 Noise Metrics, Zones and Analysis Tools

2.1 Noise Metrics

As used in environmental noise analyses, a noise metric refers to the unit that quantitatively measures the effect of noise on the environment. Although the primary noise metric for this study is a cumulative daily metric, it is built upon single-event noise metrics. Pertinent single-event and cumulative metrics and their uses are described below and in greater detail in Appendix A.

2.1.1 Maximum Sound Level (L_{max})

The highest A-weighted[2] integrated sound level measured during a single event in which the sound level changes value with time (e.g., an aircraft overflight) is called the maximum A-weighted sound level or maximum sound level (L_{max}). L_{max} is given in units of A-weighted decibels (dBA).

During an aircraft overflight, the noise level starts at the ambient or background noise level, rises to the maximum level as the aircraft flies closest to the observer, and returns to the background level as the aircraft recedes into the distance. L_{max} indicates the maximum sound level occurring for a fraction of a second. For aircraft noise, the "fraction of a second" over which the maximum level occurs is one-eighth second (ANSI, 1988). The maximum sound level is important in judging the interference caused by a noise event with conversation, TV or radio listening, sleep, or other common activities. Although it provides some measure of the intrusiveness of the event, it does not completely describe the total event because it does not account for the length of time that the sound is heard.

2.1.2 Sound Exposure Level (SEL)

SEL is a composite metric that represents both the intensity of a sound and its duration. Individual time-varying noise events (e.g., aircraft overflights) have two main characteristics: a sound level that changes throughout the event and a period of time over which the event is heard. SEL provides a measure of the net impact of the entire acoustic event, but it does not directly represent the sound level heard at any given instant. During an aircraft flyover, SEL would include both the maximum noise level and the lower noise levels produced during onset and recess periods of the overflight.

SEL is a logarithmic measure of the total acoustic energy transmitted to the listener during the event. Mathematically, it represents the A-weighted sound level of a constant sound that would, in one second, generate the same acoustic energy as the actual time-varying noise event. For sound from aircraft overflights, which typically last more than one second, the SEL is usually greater than the L_{max} because an individual overflight takes seconds and the L_{max} occurs instantaneously. SEL is considered the best metric to compare noise levels from overflights.

[2] A-weighting refers to adjustments made to the measured or computed sound pressure level at different frequencies in order to approximate the frequency response of the human ear.

2.1.3 Day-Night Average Sound Level (DNL)

Day-Night Average Sound Level is the noise measure used for federal assessment of aircraft noise exposures in communities in the vicinity of airfields/airports. Day-Night Average Sound Level is abbreviated DNL or L_{dn} and is given in dBA. DNL is an average A-weighted sound level generated by all aviation-related operations during an average or busy 24-hour period, with sound levels of nighttime noise events emphasized by adding an additional 10 dB to their measured levels. Nighttime is defined as the period from 10 p.m. (2200) to 7:00 a.m. (0700) the following morning. The 10 dB weighting accounts for the generally lower background sound levels and greater community sensitivity to noise during nighttime hours. As explained in Appendix A, DNL has been found to provide the best measure of long-term community reaction to transportation noises, especially aircraft noise.

For consistency with Air Force standard practice, DNL was based on annual average flying day (AFD) operations. The number of AFD operations is calculated for each aircraft type by dividing the annual number of operations of that aircraft type by the number of days in the year that that aircraft was active.

2.2 Clear Zones and Accident Potential Zones

Inhabited areas around airports are exposed to the possibility of aircraft accidents even with well-maintained aircraft and highly trained crews. Despite stringent maintenance requirements and countless hours of training, past history makes it clear that accidents will occur. The risk of people on the ground being injured or killed by aircraft accidents is small. However, an aircraft accident is a high consequence event and when a crash does occur, the results are often catastrophic. Because of this, the Air Force does not attempt to base its safety standards on accident probabilities. Instead, the Air Force approaches this safety issue from a planning perspective.

In support of the Air Installation Compatible Use Zone (AICUZ) program, the Air Force completed a study in 1973 that analyzed accidents that occurred within 10 nautical miles of military airfields. The study found that accidents clustered around the extended runway centerline. Three zones were based on the crash distribution: the Clear Zone (CZ), Accident Potential Zone (APZ) I, and Accident Potential Zone II. All zones are 3,000 feet wide and centered on the runway centerline. The Clear Zone has the highest accident potential of the three zones. It begins at the end of the runway and extents 3,000 feet. No structures except navigational aids and airfield lighting are allowed in the Clear Zone. APZ I is an area of reduced accident potential beginning at the end of the clear zone and extending 5,000 feet. Various industrial, manufacturing, and agricultural land uses are acceptable within APZ I. APZ II extends from the end of APZ I an additional 7,000 feet. The accident potential in APZ II is low enough that low-density housing and commercial uses are compatible with flight operations. (US Air Force, 1999)

2.3 Analysis Tools

This section describes the analysis tools used to calculate the noise levels in this report: the NOISEMAP and Rotorcraft Noise Model (RNM) computer programs.

The programs described below are most accurate and useful for comparing "before-and-after" noise levels that would result from alternative scenarios when calculations are made in a consistent manner. The programs allow noise exposure prediction of such proposed actions without actual implementation or noise monitoring of those actions. The programs also have the capability of calculating sound levels at specified points on the ground, allowing the analysis of noise-sensitive receptors.

2.3.1 NOISEMAP and RNM

Analyses of aircraft noise exposure and compatible land uses around DoD facilities are normally accomplished using a group of computer-based programs, collectively called NOISEMAP (Czech and Plotkin, 1998; Wasmer Consulting, 2006a; Page, et. al., 2007; Wasmer Consulting, 2006b). The NOISEMAP suite of computer programs was primarily developed by the Air Force, which serves as the lead DoD agency for aircraft noise modeling. The NOISEMAP suite of computer programs includes BaseOps, OMEGA10, OMEGA11, NOISEMAP, RNM and NMPlot. The suite also includes the NOISEFILE and NCFiles databases.

The BaseOps program allows entry of runway coordinates, airfield information, flight tracks, flight profiles (engine thrust settings, altitudes, and speeds) along each flight track for each aircraft, numbers of daily flight operations, run-up coordinates, run-up profiles, and run-up operations. At this stage, closed-pattern operations, which are counted by Air Traffic Control (ATC) as two operations (one departure and one arrival), are entered in the program as one noise event (one departure followed by one arrival with the aircraft remaining in the vicinity of the airfield). The OMEGA10 program then calculates the SEL for each model of aircraft from the NOISEFILE database, taking into consideration the specified speeds, engine thrust settings, and environmental conditions appropriate to each type of flight operation. The OMEGA11 program calculates maximum A-weighted sound levels from the NOISEFILE database for each model of aircraft taking into consideration the engine thrust settings and environmental conditions appropriate to run-up operations. The core NMAP program incorporates the number of daytime and nighttime flight and run-up events, the flight paths, and flight/run-up profiles of each aircraft and calculates the resulting sound level at points on the ground in the facility's vicinity. NMPlot calculates contours of equal sound level, and is used to visualize and output the modeling results. In this study, NOISEMAP Version 7.2 was used to analyze fixed-wing aircraft operations.

RNM is a computer program developed by Wyle Laboratories, Inc. for the National Aeronautics and Space Administration (NASA)-Langley Research Center (LaRC). RNM, as part of LaRC's Tilt Rotor Aeroacoustic Code (TRAC) suite of computer programs, is aimed at the prediction of far-field sound levels from tilt rotor aircraft and helicopters. DoD and the North Atlantic Treaty Organization (NATO) have adopted RNM for the environmental impact assessment of rotorcraft noise (NATO, 2000).

RNM simulates vehicle flight along a prescribed flight track, and the sound is analytically propagated through the atmosphere to specified receiver locations. RNM accounts for spherical spreading, atmospheric absorption, ground reflection and attenuation, Doppler shifts, the difference in phase between direct and reflected rays, varying terrain and ground impedance between the vehicle and the receiver. Although not utilized for this study, RNM has the ability to account for horizontally stratified atmospheres with winds and curved ray paths. RNM's acoustic algorithms are more robust than NOISEMAP's algorithms, partially due to RNM's more detailed noise database (NCFiles), consisting of one-third octave band sound hemispheres for each vehicle in its inventory. In addition to altitude and speed, RNM accounts for roll, pitch, yaw, and nacelle angles, if applicable, along each flight track for each aircraft. In this report, RNM Version 7 was used to analyze most rotary-wing aircraft/operations.

2.3.2 Topography and Noise Contours

NOISEMAP Version 7.2 and RNM Version 7 have been expanded to include atmospheric sound propagation effects over varying terrain, including hills and mountainous regions, as well as regions of varying acoustical impedance—for example, water around coastal regions. Even for flat terrain, the terrain propagation algorithms are more robust than for excluding terrain. This feature was used for computing the noise levels presented in this analysis. Elevation grid files with a grid point spacing of 500 feet were created from the National Elevation Dataset (NED) one arcsecond data (USGS, 2008). Impedance grid files were created from geographic information systems (GIS) data provided by Andersen AFB (Andersen AFB, 2007a). Because the majority of the off-base land is undeveloped jungle, the island of Guam was modeled as acoustically "soft" with a flow resistivity of 200 cgs-rayls.

Each of the noise computation programs can incorporate the number of day and night operations, flight paths, and profiles of the aircraft to calculate DNL at many points on the ground around the facility. This process results in a "grid" file containing noise levels at different points of a user specified rectangular area. The grid point spacing used to compute the noise grids for this study was 500 feet. The NMPlot program uses the grid file to draw contours of equal DNL for overlay onto maps. The NMPlot program is also capable of adding multiple grid files logarithmically and arithmetically subtracting grids.

Each program can also compute DNL for specific points of interest, e.g., noise-sensitive receptors and determine the primary contributors to the overall DNL at each point. No points of interest were modeled in this study.

3.0 Andersen Air Force Base

The following sections discuss the history, region, and vicinity of Andersen AFB, as well as the aviation users, climatic conditions, data collection efforts and historical flight operations.

3.1 Regional and Local Setting

As shown in Figure 3-1, Andersen AFB is located on the north end of the island of Guam. Guam is one of the Mariana Islands and lies approximately 3,800 statute miles southwest of Hawaii and 1,500 miles east of the Philippines. The land use on Guam is 36 percent agricultural and 47 percent undeveloped forest. (UN, 2007) The largest metropolitan area, Hagatna, is located approximately 20 miles southwest of the base.

Andersen AFB is approximately 150 miles south of the Farallon de Medinilla Island naval bombing range. In addition, nearby Air Traffic Control Assigned Airspaces provide numerous training opportunities. Northwest Field, an unlit auxiliary airfield, is approximately five miles northwest of the center of the Andersen airfield. The only other major aviation use on the island is A.B. Won Pat International Airport (Guam International Airport.)

The Andersen airfield has two parallel runways. Runway 06L/24R is 11,185 feet long and 200 feet wide. Runway 06R/24L is 10,558 feet long and 200 feet wide. Based helicopters generally depart and arrive on Pad N1 or Pad N19 on the north side of the airfield, but perform closed patterns on the runways. Field elevation is 627 feet above Mean Sea Level (MSL) (DAFIF, 2003), and the magnetic declination is 1.5 degrees East (NGA, 2006). All maps in this report depict a north arrow pointing to true north.

3.2 Historical Context

Andersen Air Force Base opened as North Field in 1944, part of an Army Air Forces plan to prevent the need for a full-scale invasion of Japan. It was primarily used as a B-29 staging base in the Pacific during WWII, when daily bombing missions over Japan were launched from North Field. When the Air Force became a separate branch of service in 1947, North Field was renamed North Guam AFB. In 1949, it was renamed Andersen AFB in honor of Brigadier General James Roy Andersen.

During the years between World War II and the Korean War, Guam was a consolidation and disposal point for surplus war materials that had accumulated in the Pacific Theater. During the Korean War, Andersen served in an administrative and logistical capacity, operating ammunition dumps and providing maintenance services to transient aircraft. After the war, Andersen began supporting bomber and aerial refueling units on rotational deployments from the United States.

Figure 3-1.
Regional Map of Guam

Andersen's role in the Vietnam conflict is legendary. In 1964, KC-135 Stratotankers assigned to the Andersen Tanker Task Force were used for the first time to support combat operations. From early 1972, Andersen AFB was the site of one of the most massive buildups of air power in history. Over 150 B-52s used all available space on the flight line, and the influx of bombers, crews, and support personnel pushed Andersen's military population past 15,000.

In 1989, control of Andersen AFB passed from Strategic Air Command to Pacific Air Forces. The 633rd Air Base Wing, a Pacific Air Forces organization aligned under Thirteenth Air Force, was activated on Andersen AFB and became the host unit, providing support services for various transient and tenant organizations. The base continues to support strategic operations in the region and serves as a staging base for activities in Asia and the South Pacific, as well as providing forward support to bomber crews deploying overseas in Europe, Southwest Asia and in the Pacific. (Andersen AFB, 2008a)

3.3 Aviation Users

Andersen AFB is an important forward-based logistics support center for contingency forces deploying in the Pacific and Indian oceans. Andersen is home to the 36th Wing, Air Mobility Command's 734th Air Mobility Support Squadron, naval unit Helicopter Sea Combat Squadron Twenty Five (HSC-25) and several other tenant organizations. The 36th Wing of the Pacific Air Forces is host unit to USAF Active, Reserve, National Guard and US Naval forces, and provides peacetime and wartime support to project global power and reach from its strategic location in the Pacific. Andersen's clear flying conditions, relatively unlimited airspace, nearby air-to-ground range, and unlit auxiliary fields make this an ideal and active training area for the U.S. military and militaries of nearby countries.

Based aircraft include the MH-60S of the Navy HSC-25 Squadron. The MH-60S Knighthawk is a four-bladed single rotor helicopter that combines the fuselage of the US Army Blackhawk with the engine, rotor system, and dynamic components of the Navy SH-60 Seahawk. MH-60S aircraft perform aerial resupply of seaborne vessels, evacuation, day/night amphibious search and rescue, and airborne mine countermeasures services.

As described in Section 4, the balance of the airfield's flight operations is by transient units. Transient fixed-wing aircraft types include B-1, B-2, and B-52 bombers, KC-135 tankers, and F-15, F-16, and F-18 fighters, among others. Regular transit and cargo aircraft include C-5, C-17, and KC-10, as well as civilian-type B747.

3.4 Climate

Guam has a tropical marine climate with high humidity and nearly constant warm temperatures. There is little seasonal or daily variation in temperature or humidity. Rain falls throughout the year, with approximately 5 inches of precipitation per month during the dry season (January to June) and frequent squalls totaling 15 inches per month in the rainy season (July through December). The island experiences moderate northeast trade winds, and infrequent typhoon activity occurs during the rainy season.

Because weather is an important factor in the propagation of noise, the computer model requires input of the average daily temperatures in degrees Fahrenheit (°F), percent relative humidity (% RH) and station pressure in inches of mercury (inHg) for each month of a year. NOISEMAP's BaseOps program computes absorption coefficients for each month and selects the median coefficient to use in the noise exposure modeling (US Air Force, 1992). Monthly average climatic data was provided by Andersen AFB. Average monthly temperature and relative humidity are plotted in Figure 3-2. Temperatures for summer months (May to September) and winter months (October to April) averaged 85 °F and 83 °F, respectively. Relative humidity for the same periods averaged 76 percent during summer months and 75 percent during winter months. The station pressure averaged 29.22 inHg. The modeled conditions selected by the BaseOps program correspond to the month of November with a temperature of 84 °F and a relative humidity of 78 percent.

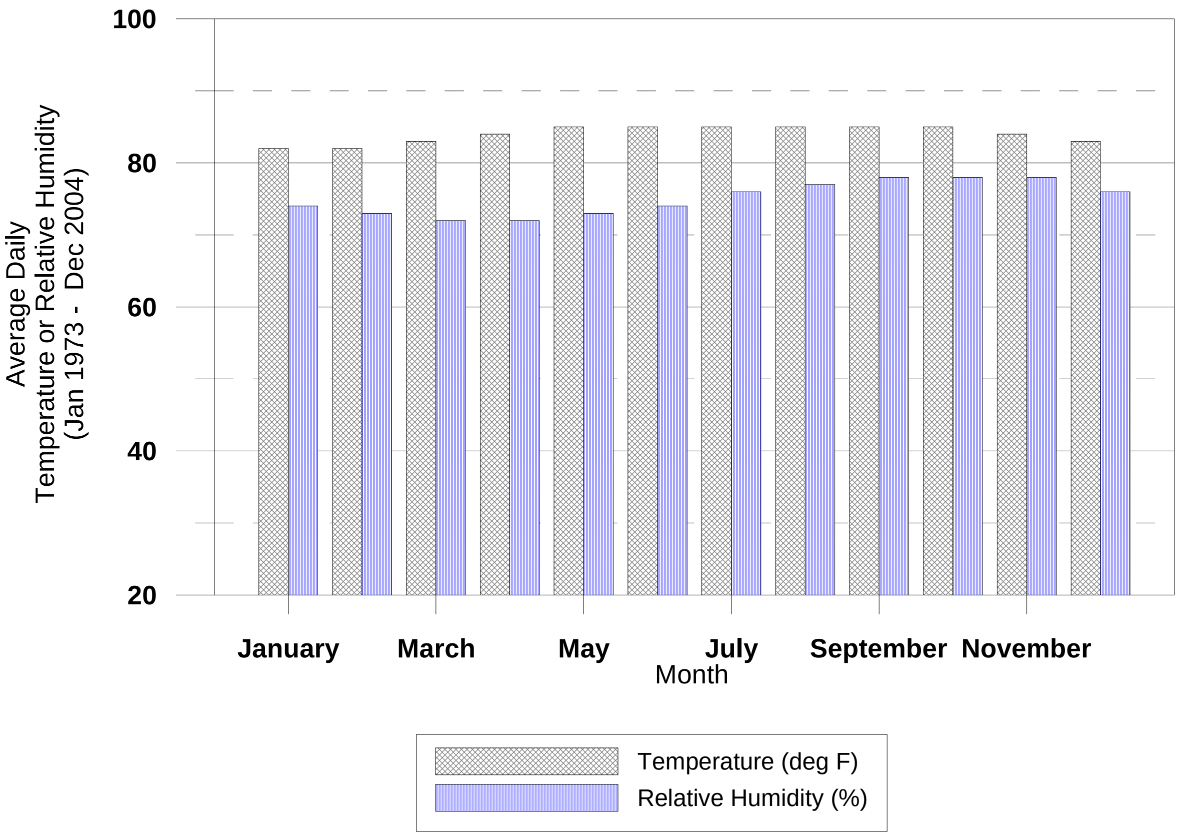

Figure 3-2. Average Daily Temperature and Relative Humidity at Andersen AFB

3.5 Noise Study Data Collection

The primary purpose of this noise study is to support the Guam Joint Military Master Plan and to estimate noise exposure due to the relocation of Marine aircraft to Andersen AFB. In May of 2007, Wyle began the data collection phase and prepared a set of data collection packages based on previous modeling of Andersen AFB. Wyle supplied the data package in electronic format to Andersen AFB and Navy personnel. These packages were used to gather and/or confirm airfield information (weather data, geographic coordinates of navigational aids, runways, etc.), points of interest and noise-sensitive receptors, numbers of existing flight operations, flight tracks, runway and flight track utilization, run-up and operations.

In June of 2007, Wyle personnel traveled to Andersen AFB to review the contents of the data packages. Wyle engineers met with the contacts listed in Table 3-1 (Andersen AFB, 2007b).

Table 3-1. Contacts for Andersen AFB GJMMP Aircraft Noise Study

Name	Title/Function	Organization	Phone	E-Mail
Bob Henderson	Program Manager	NAVFAC Southwest	619-532-1622	robert.k.henderson @navy.mil
Fang Yang	Project Manager	Earth Tech	212-778-8605	fang.yang @earthtech.com
Rachel Romond	Acoustical Engineer	Wyle Labs	310-322-1763	rachel.romond @wyle.com
Geral Long	Project Manager Alternate	Wyle Labs	703-415-4550	geral.long @wyle.com
Jun H. Abaya	Architect/Planner	36 CES	671-366-2075	jun.abaya @andersen.af.mil
LCDR Jonathan Kline	Maint. Officer	HSC-25	671-366-2218	jonathan.kline @hsc25.navy.mil
SMSgt Fred Erolin	Chief Controller	36 OSS/OSAT (ATC/Tower)	671-366-3416	fred.erolin @andersen.af.mil
TSgt Danielle Gresser	TERPS	36 OSS/OSAT (ATC)	671-366-4306	danielle.gresser @andersen.af.mil
Pat Larson	Air Terminal Manager	734 AMS/TR (AMC)	671-366-7220	patrick.larson @andersen.af.mil
CMsgt Al Irwin	AMC Maintenance Superintendent	734 AMS/MX (AMC)	671-366-7346	alvin.irwin @andersen.af.mil
Capt. Allen Neyland	36 MSX OpsO	36 MSX (Maint. Sqn)	671-366-6121	allen.neyland @andersen.af.mil
Maj Rob Puckett	36 OSS / ADO	36 OSS (Base Ops)	671-366-1016	robert.puckett @andersen.af.mil
Capt Paul Lee	Weather Flight Commander	36 OSS/OSW (Weather)	671-366-3176	paul.lee @andersen.af.mil
SMSgt Darron Williams	Airfield Manager	36 OSS/OSAM	671-366-1196	darron.williams @andersen.af.mil
Rich Storaci	FAA Airspace	FAA Guam ARTCC	671-473-1234	richard.storaci @FAA.gov
Michael D. Lynn	QAE Transient Alert	36 MXS	671-688-7107	michael.lynn @andersen.af.mil

As a result of the June 2007 site visit, significant changes were made to the flight tracks, aircraft mix, and operations of the previous modeling. After the results of the June site visit were integrated into the model, Wyle prepared data verification packages. The Navy program manager returned to Andersen AFB and confirmed the remainder of information needed to estimate noise exposure (Andersen AFB, 2007c).

3.6 Historical Flight Operations

For the purposes of Air Traffic Control (ATC), a flight operation is defined as a takeoff or landing of one aircraft, with closed patterns counted as two operations. The counts in this and subsequent sections of this report do not include operations at Northwest Field (except for interfacility flights by Andersen based aircraft), Guam International Airport, nor transitions through the airspace above Andersen AFB.

Table 3-2 and Figure 3-3 show historical aircraft operations at Andersen AFB for CY2001 through CY2006 from Air Traffic Activity Reports (ATARs). Over the past six years, operational tempo has been fairly constant. The peak operation was reached during CY2005 with 30,642 aircraft operations, of which 29,102 were by Air Force or other military aircraft. The year with the least amount of activity over the past six years is CY2004 with 29,623 operations, of which 27,998 were Air Force or other military aircraft. As depicted in Table 3-2 and Figure 3-3, military aircraft account for approximately 95 percent of the flight operations.

Table 3-2. Historical Annual Flight Operations from Air Traffic Activity Reports

Annual Operations from ATARs				
		Civil		
Calendar Year	Military	Air Carrier	General Aviation	Total
2006	28,903	623	929	30,455
2005	29,102	605	935	30,642
2004	27,998	620	1,005	29,623
2003	28,705	635	1,000	30,340
2002	28,705	635	1,000	30,340
2001	28,705	635	1,000	30,340

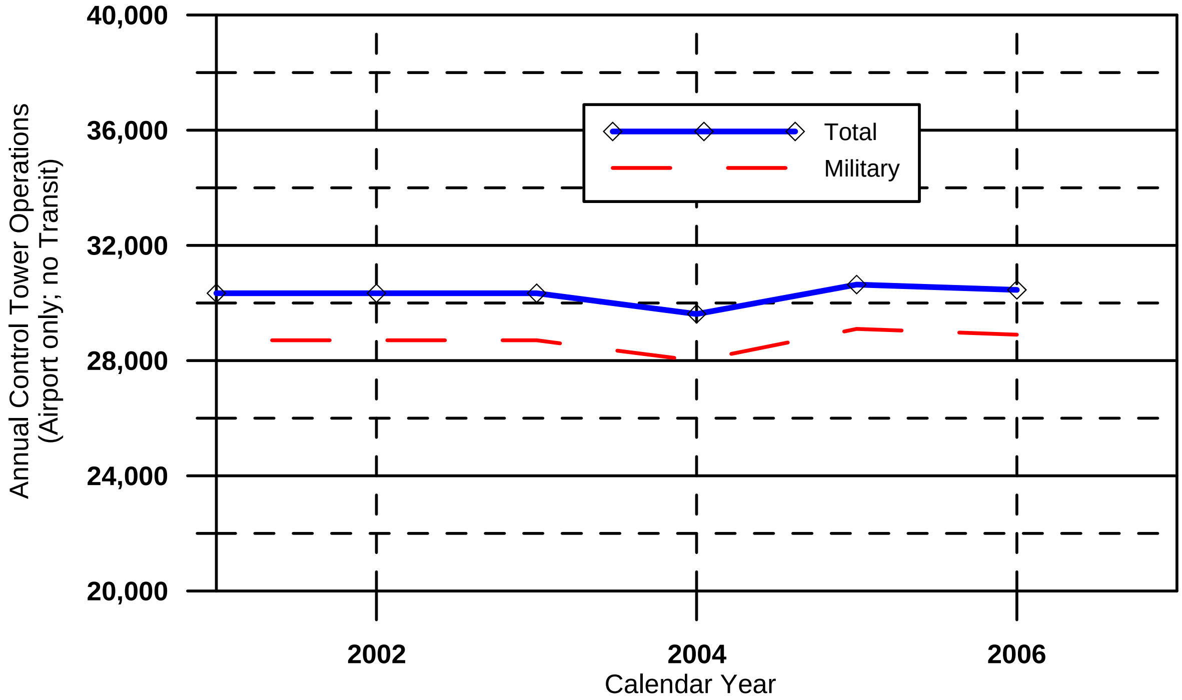

Figure 3-3. Annual Flight Operations at Andersen AFB

3.7 Clear Zones and Accident Potential Zones

Clear Zones and Accident Potential Zones for Andersen AFB are shown in Figure 3-4. They were determined using the standard Air Force geometry described in Section 2.

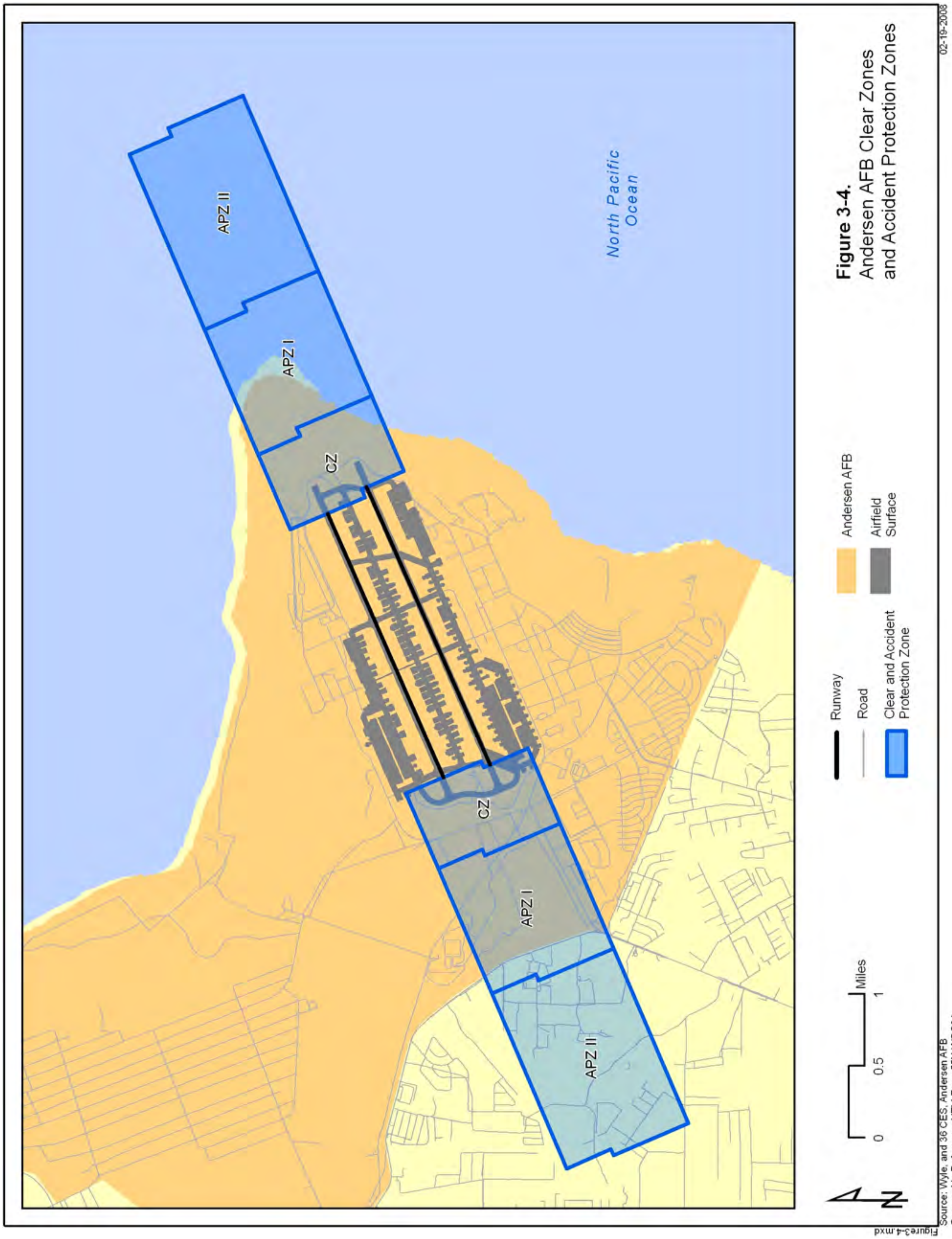

Figure 3-4.
Andersen AFB Clear Zones and Accident Protection Zones

4.0 Baseline (CY2006) Scenario

The Baseline scenario for Andersen AFB is defined as airfield operations during CY2006. Northwest Field is considered a separate airfield, and operations other than based aircraft interfacility flights are not included in this analysis. Section 4.1 discusses flight operations by aircraft type. Section 4.2 discusses runway/helipad utilization, flight track utilization, flight profiles and daily operations by aircraft type. Section 4.3 describes maintenance run-up operations, and Section 4.4 discusses the calculated DNL contours.

4.1 Flight Operations

The first step in the noise analysis process is to determine the number of annual flight operations for the year studied. The computer noise model requires input of the annual operations by aircraft type, operation type, and temporal period (acoustical daytime hours of 0700-2200 and nighttime hours of 2200-0700). Upon inspection by Andersen AFB staff, the aircraft mix and flight operations numbers from the 2003 noise study were found to be out of date. As the military ATARs counts were fairly constant from 2001 through 2006, the total number of annual flight operations for the Baseline scenario was based on the 2006 ATAR count. Operations by aircraft type were based on interviews with Andersen AFB staff from Base Operations, Tower, Air Mobility Command (AMC), Maintenance, and HSC-25 (Andersen AFB, 2007b; Andersen AFB, 2007c). The Baseline scenario includes operations by deployed transport and AMC aircraft, Coronet West, Valiant Shield, Cope North and SOCPAC exercises, and visiting CVN airwings.

Table 4-1 shows the resultant numbers of operations by aircraft group, modeled aircraft type, and period of day for the Baseline scenario. Annual based and transient military flight operations and civilian Air Carrier total 29,524, which is two less than what would be derived from Table 3-2 due to rounding. General Aviation (GA) operations were not modeled and their contribution to the overall aircraft noise environment would likely be insignificant relative to the contribution of the military and air carrier aircraft.

Operation types include departures, straight-in (nonbreak) arrivals, overhead break arrivals, touch-and-go patterns, and ground controlled approach (GCA) patterns. According to Andersen AFB Tower personnel, less than seven field carrier landing practice (FCLP) operations were performed at Andersen AFB between January and December 2007, so FCLP operations were not modeled for any aircraft. Due to lack of flight profile input, C-130 and E-2 overhead breaks were modeled as non-breaks and C-130 touch-and-go and GCA Box pattern operations were not modeled.

Because much of Andersen AFB flight activity is by deployed or transient aircraft, the fleet mix for the Baseline scenario includes many aircraft types. The top users of the airfield are the MH-60S Knighthawks in HSC-25 (modeled as SH-60B aircraft in RNM), with 66 percent of the total military operations. Jet tankers (modeled as KC-135R) are the next most frequent users of the airfield, with approximately 10 percent of the total operations. F/A-18E/F and T-45 comprise eight percent of the total operations. The next most frequent users are transient F-15s, with approximately seven percent of the total operations. Based HSC-25 aircraft perform approximately 6 percent of their operations during the acoustical nighttime (10pm – 7am) period, and transient aircraft perform an average of 14 percent of their operations during the same period.

Table 4-1 Baseline (CY2006) Annual Flight Operations for Andersen AFB

Mission Group	Assumed Type	Modeled Aircraft Type	Departure			Nonbreak Arrival			Overhead Break Arrival			Touch and Go[1]			GCA Box[1]			Total		
			Day	Night	Total	Day	Night	Total	Day	Night	Total	Day	Night	Total	Day	Night	Total	Day	Night	Total
HSC-25	OM Helo	SH60B	2,966	91	3,057	2,598	459	3,057	-	-	-	11,738	489	12,227	585	25	610	17,887	1,064	18,951
Local & Transient	Jet	B-1	80	9	89	80	9	89	-	-	-	322	36	358	161	18	179	643	72	715
	Jet	B-2	49	6	55	49	6	55	-	-	-	198	22	220	99	11	110	395	45	440
	Jet	B-52H	95	10	105	95	10	105	-	-	-	322	36	358	161	18	179	673	74	747
	Jet	C-9A	14	3	17	14	3	17	-	-	-	-	-	-	-	-	-	28	6	34
	Jet	KC-10A[2]	60	50	110	101	9	110	-	-	-	124	14	138	62	7	69	347	80	427
	Jet	C-21A[4]	24	6	30	24	6	30	-	-	-	-	-	-	-	-	-	48	12	60
	Prop	C-130H&N&P[3,5]	43	-	43	22	-	22	22	-	22	172	-	172	86	-	86	345	-	345
	Jet	KC-135R	388	41	429	388	41	429	-	-	-	1,240	138	1,378	620	69	689	2,636	289	2,925
	Jet	F-15A	598	-	598	11	-	11	588	-	588	964	-	964	-	-	-	2,161	-	2,161
	Jet	F-16C	9	-	9	-	-	-	9	-	9	-	-	-	-	-	-	18	-	18
Transient[7]	VM Helo	CH-46E[6]	19	-	19	19	-	19	-	-	-	-	-	-	-	-	-	38	-	38
	VM Helo	CH53E	6	16	22	6	16	22	-	-	-	-	-	-	-	-	-	12	32	44
	Jet	C-5A	46	186	232	209	23	232	-	-	-	-	-	-	-	-	-	255	209	464
	Jet	C-17	58	232	290	262	29	291	-	-	-	-	-	-	-	-	-	320	261	581
	Jet	C-20	2	-	2	2	-	2	-	-	-	-	-	-	-	-	-	4	-	4
	Prop	C-12[6]	19	-	19	19	-	19	-	-	-	-	-	-	-	-	-	38	-	38
Transient CVN Wing	VM Jet	EA-6B	17	-	17	1	-	1	16	-	16	-	-	-	-	-	-	34	-	34
	VM Jet	F-18A/C	121	-	121	12	-	12	110	-	110	-	-	-	-	-	-	243	-	243
	VM Jet	F-18E/F	146	-	146	14	-	14	131	-	131	-	-	-	-	-	-	291	-	291
	VM Jet	C-21A[4]	17	-	17	17	-	17	-	-	-	-	-	-	-	-	-	34	-	34
	VM Prop	E-2C[5]	26	-	26	3	-	3	23	-	23	-	-	-	-	-	-	52	-	52
	VM Helo	SK70 (UH-60A) BLACKH[6]	37	2	39	37	2	39	-	-	-	-	-	-	-	-	-	74	4	78
Transient MMA	VM Prop	P-3A	78	11	89	78	11	89	-	-	-	-	-	-	-	-	-	156	22	178
Civilian (Transient)	Civilian	B-747-SP (N)	104	166	270	104	166	270	-	-	-	-	-	-	-	-	-	208	332	540
	Civilian	B-757-200-RR	33	8	41	33	8	41	-	-	-	-	-	-	-	-	-	66	16	82
Based Total			2,966	91	3,057	2,598	459	3,057	-	-	-	11,738	489	12,227	585	25	610	17,887	1,064	18,951
Military Transient Total			1,952	572	2,524	1,463	165	1,628	899	-	899	3,342	246	3,588	1,189	123	1,312	8,845	1,106	9,951
Civilian (Transient) Total			137	174	311	137	174	311	-	-	-	-	-	-	-	-	-	274	348	622
Grand Total			5,055	837	5,892	4,198	798	4,996	899	-	899	15,080	735	15,815	1,774	148	1,922	27,006	2,518	29,524

Day = 0700-2159 local; Night = 2200-0659 Local

Notes: (1) Each Closed Pattern event (Touch and Go, GCA Box) is counted here as 2 operations (1 landing + 1 departure)
(2) KC-10A Closed Pattern Operations (Touch and Go, GCA Box) modeled as KC-135R
(3) C-130H&N&P Closed Pattern Operations (Touch and go, GCA Box) not modeled
(4) C-21A Local& Transient Operations modeled as C-21A Transient CVN Wing
(5) Overhead Break Arrivals Modeled as Nonbreak Arrivals
(6) Ops from AFCEE's Modeling of Baseline for 2003
(7) Obtained for CVW-5 data from NAVAIR

Source: AAFB (Wyle and NAVFAC site visits)

4.2 Runway and Flight Track Utilization, Flight Profiles, and Average Flying Day Events

The next step in the noise modeling process is assignment of the flight operations to runways via runway utilization percentages for each aircraft type, operation type and DNL time period. This data was extracted directly from the 2003 noise study.

Appendix B presents the runway utilization for the modeled aircraft types. As confirmed by the 2003 noise study and interviews with Andersen AFB Tower and Base Operations personnel, fixed-wing aircraft at Andersen AFB primarily use Runway 06 because of the direction of the prevailing winds. For most aircraft, Runway 24 for used approximately three percent of the operations.

As runway usage can differ during different periods of the day, specific percentages of operations during the DNL time periods of day and night are also shown in the tables. Note the percentages are not percentages of total operations but percentages for each period and operation type – they sum vertically to 100 percent for each operation type. As listed in Appendix B, Based MH-60S (SH-60B) rotary-wing aircraft only use Pad N1 or Pad N19 for departure and arrival operations, but use the main runways for pattern work.

The next step in the noise modeling process is assignment of runway operations to flight tracks via flight track utilization percentages for each aircraft type, operation type, and DNL time period. Figures 4-1 through 4-7 depict the modeled flight tracks. The track IDs generally follow a naming convention of runway/pad ID, operation type (D for departure, U for departure from the runway underrun, A for arrival, T for touch-and-go, G for GCA Box), and sequence number or letter. Tracks for based rotary-wing aircraft follow a slightly different convention: "RW", operation type (D for departure or A for arrival) and sequence number. The letter P is appended to the ID of tracks in the proposed scenario. The tracks were initially extracted from the 2003 noise study and reviewed by ATC and Andersen AFB Tower personnel. Modifications, additions, and/or deletions were based on squadron input and a second review by ATC and Andersen Tower (Andersen AFB, 2007a; Andersen AFB, 2007b).

Overhead break patterns measure approximately 1.5 nautical miles (NM) abeam and 2.5 NM end to end. The overhead break altitude is 2,100 feet MSL, or 1,473 feet above ground level (AGL). The pattern altitude for fixed-wing touch-and-go flight tracks is 1,600 feet MSL (973 feet AGL). The touch-and-go pattern for most fixed-wing aircraft is approximately 1 NM abeam and 4.5 NM end to end, while the touch-and-go pattern for large fixed-wing aircraft is 3 NM abeam and 7.5 NM long. Rotary-wing and tiltrotor aircraft use a smaller touch-and-go pattern that is approximately 0.25 NM abeam and 1 NM long. The rotary-wing pattern altitude is 1,100 feet MSL (473 feet AGL). Each runway has a single Ground Controlled Approach (GCA) box pattern that is used by all aircraft regardless of type. The GCA box is approximately 6 NM abeam and 17 NM end-to-end. The final approach leg is 10 NM on runway heading. The GCA box altitude is 2,200 feet MSL.

Figure 4-1. Modeled Departure Flight Tracks on Runways 06L and 06R

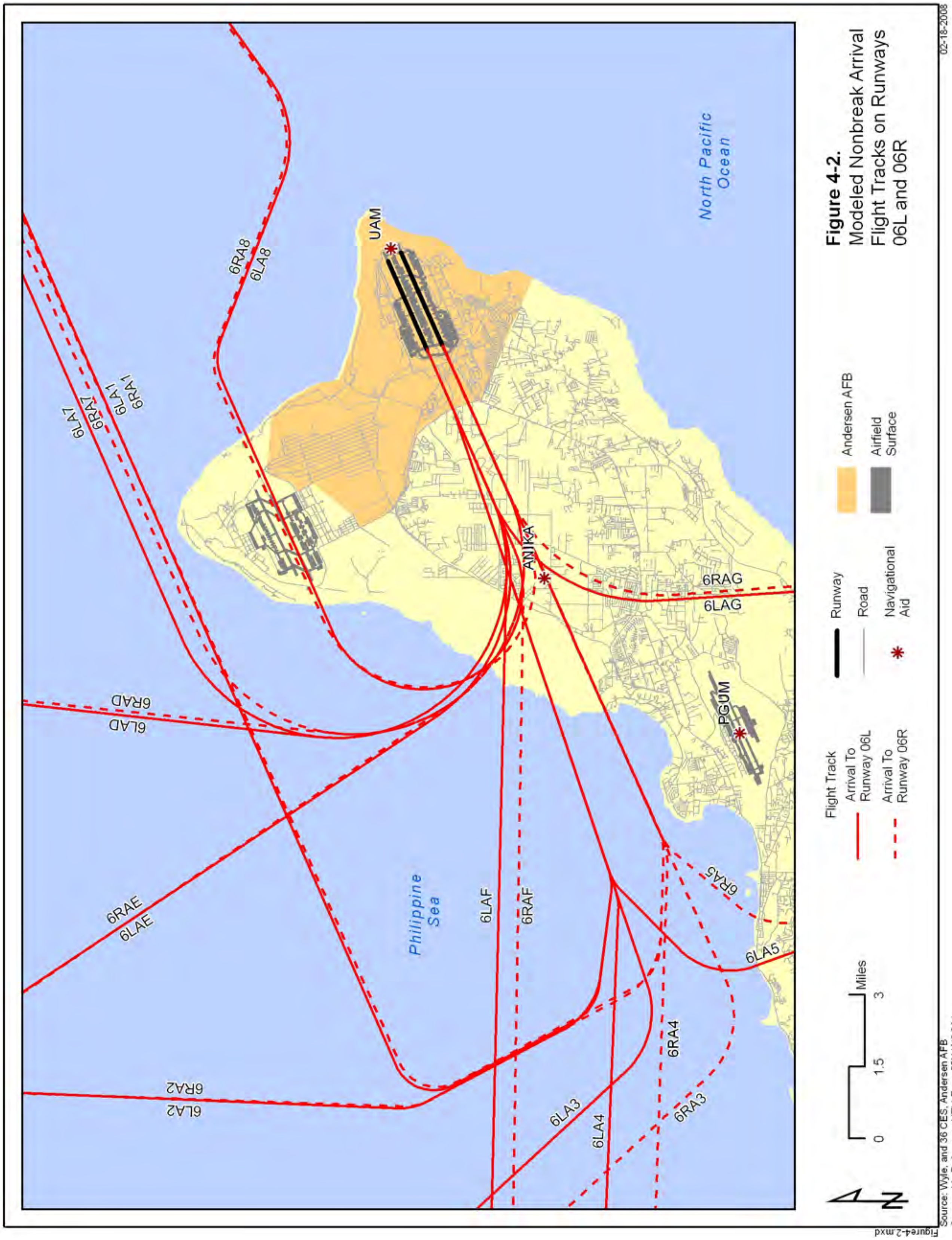

Figure 4-2. Modeled Nonbreak Arrival Flight Tracks on Runways 06L and 06R

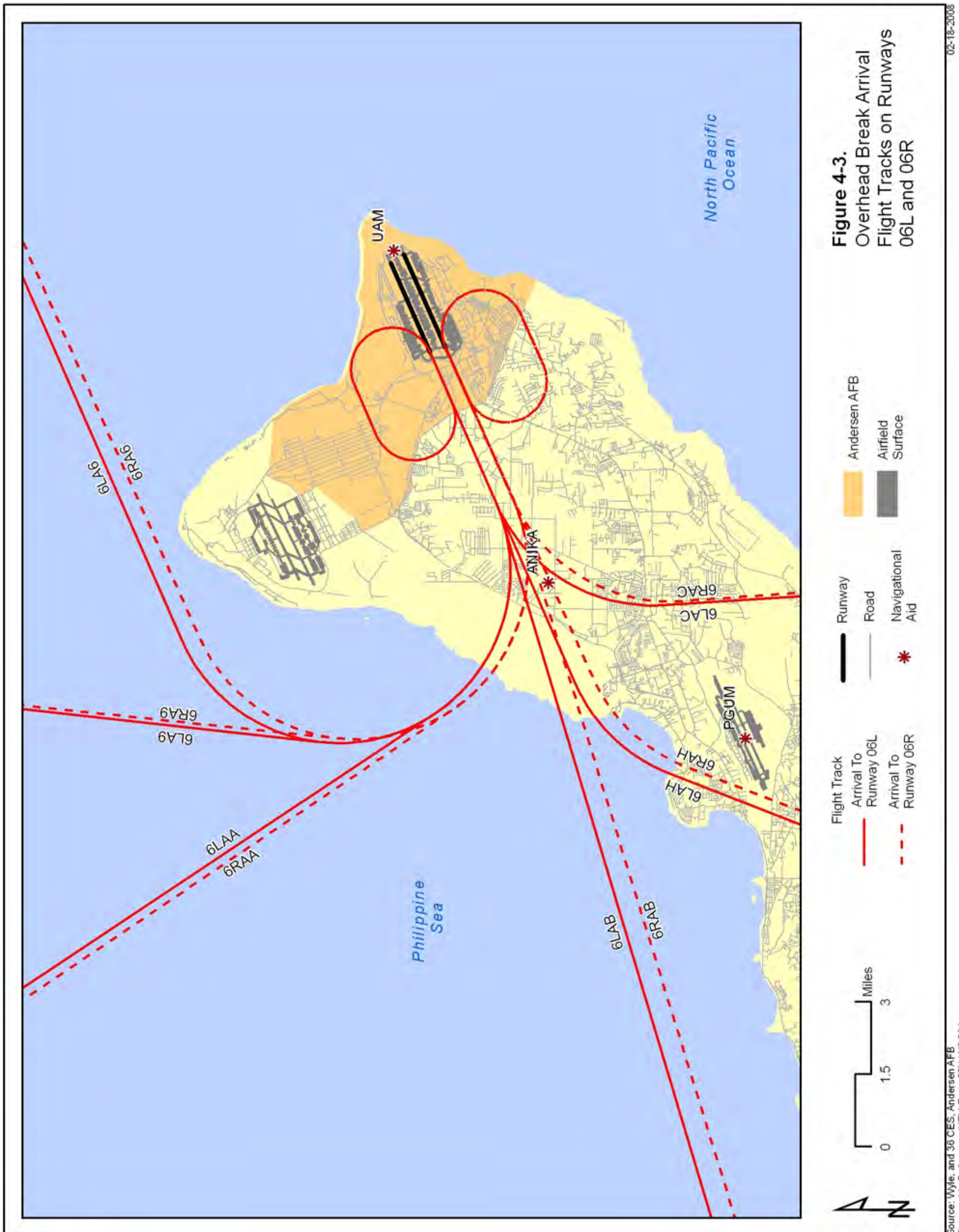

Figure 4-3. Overhead Break Arrival Flight Tracks on Runways 06L and 06R

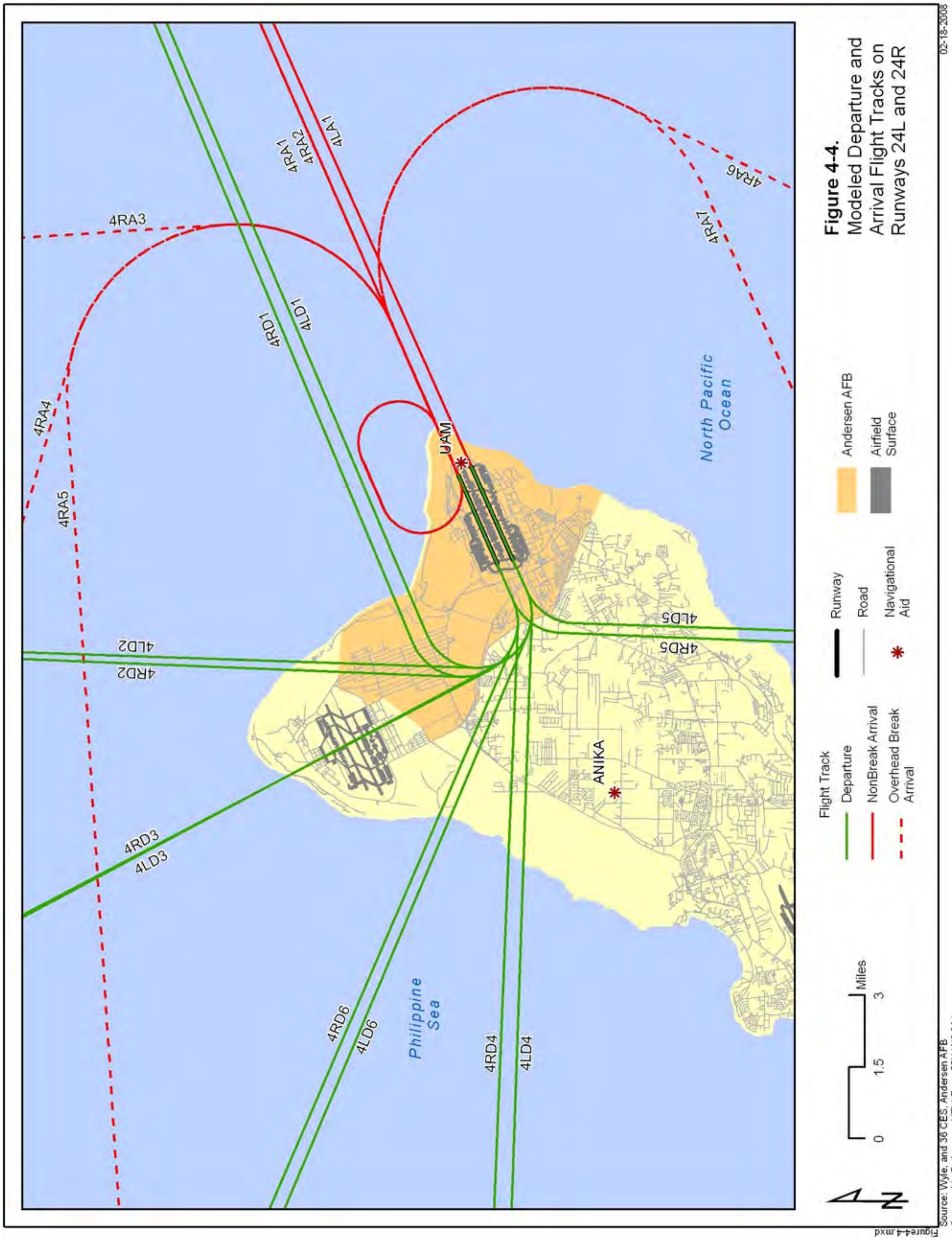

Figure 4-4. Modeled Departure and Arrival Flight Tracks on Runways 24L and 24R

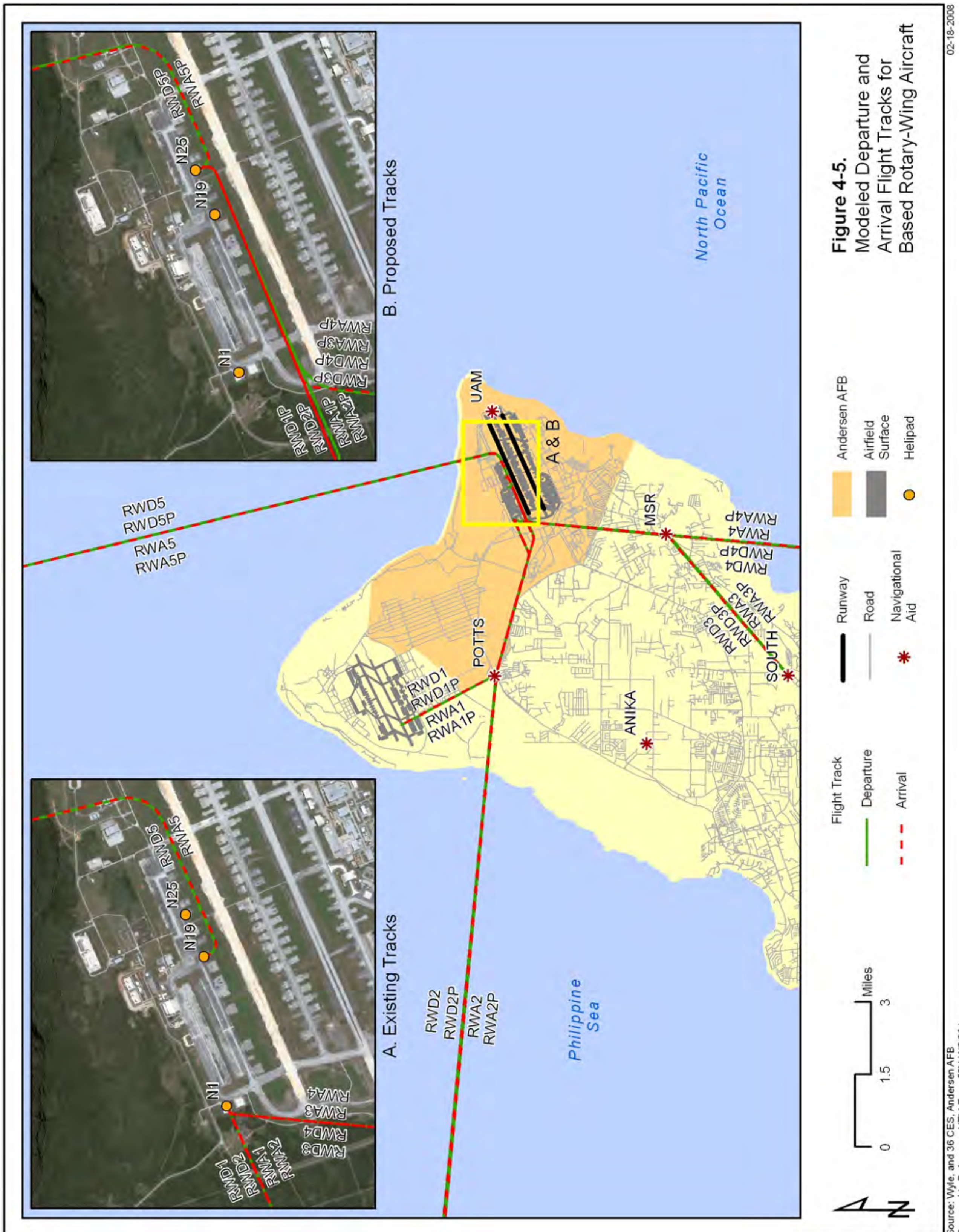

Figure 4-5. Modeled Departure and Arrival Flight Tracks for Based Rotary-Wing Aircraft

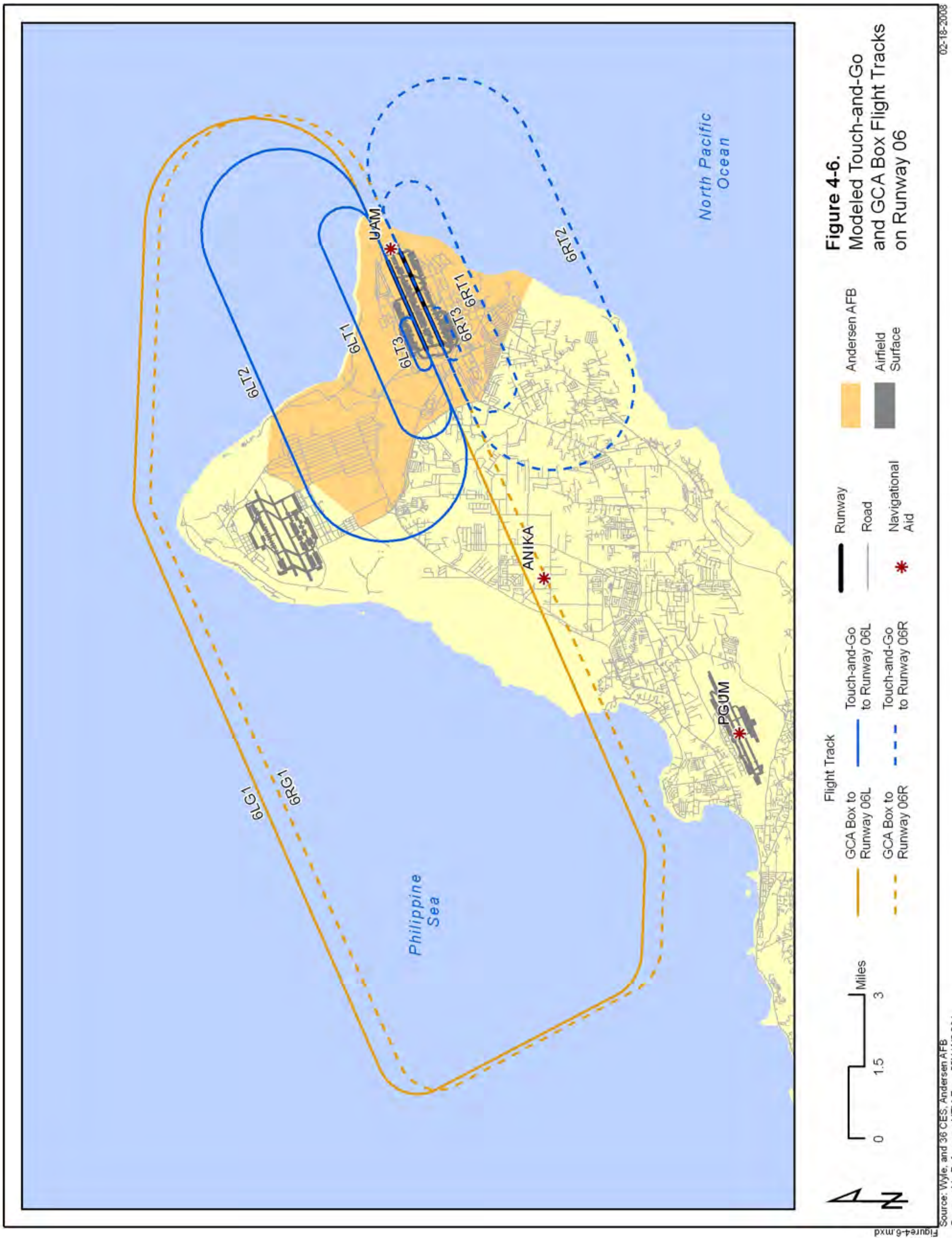

Figure 4-6. Modeled Touch-and-Go and GCA Box Flight Tracks on Runway 06

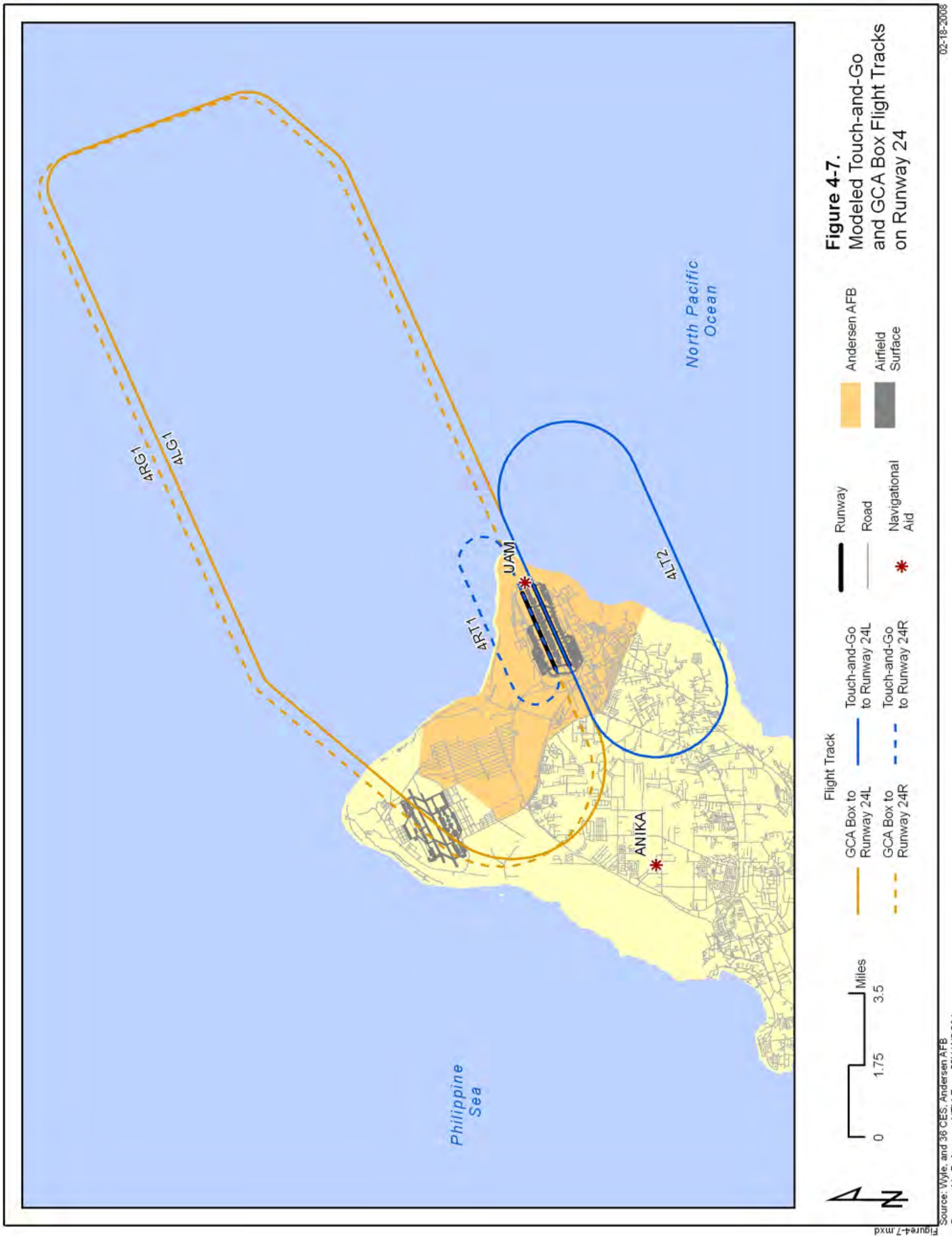

Figure 4-7. Modeled Touch-and-Go and GCA Box Flight Tracks on Runway 24

The tables in Appendix B show the modeled flight track utilization percentages for each modeled aircraft type. This data was extracted directly from the 2003 noise study and modified per changes to flight tracks. Note the percentages for each period sum vertically to 100 for each runway and operation type combination.

Fixed-wing flight profiles consist of power settings, airspeeds and altitudes at a series of points along each modeled flight track. Rotary-wing flight profiles consist of a combination of airspeeds, altitudes and attitude along each modeled flight track. Attitude consists of roll, pitch and yaw angles (and nacelle angle for tilt rotor aircraft). This data defines the vertical profile (altitude) and performance profile (power setting and/or airspeed) and orientation for each modeled aircraft.

Where applicable, flight profiles for this study were initially extracted from the 2003 noise study. Flight personnel from HSC-25 modified the profiles to be modeled for the MH-60S. Representative flight profiles for based HSC-25 aircraft are shown in Appendix C. All other flight profiles were checked for consistency with course rules, resulting in some updates to overhead break and pattern altitudes. Because of the wide array of origins for the modeled aircraft, the other aspects of the flight profiles taken from the 2003 noise study were assumed to be accurate. KC-10 closed patterns were modeled with a KC-135R surrogate due to lack of flight profile input.

Fixed-wing departure profiles can also be automatically modeled with a pre-flight run-up, conducted at the runway threshold prior to brake release. As in the 2003 noise study, nearly all fixed-wing aircraft were modeled with a five-second run-up at the takeoff power setting for that aircraft. The exceptions were B-2As, whose departure profiles included a 15-second pre-flight run-up. If an aircraft's departure profile used afterburner power, then the pre-flight run-up was modeled with afterburner power. Pre-flight run-ups were not modeled for rotary-wing or tiltrotor aircraft.

The next step in the noise modeling process is the computation of the daytime and nighttime events in an annual average flying day (AFD) for each aircraft's flight profile on each modeled track. This is accomplished by dividing the track operations by the number of annual flying days for the given aircraft and dividing closed-pattern operations (e.g., touch-and-go, FCLP and GCA Box) by 2[3]. As in the 2003 noise study, the based MH-60Ss and all transient aircraft were modeled with 356 flying days per year. The resultant daily numbers of events are presented in Table 4-2 There are approximately 56 events per average flying day, 34 of which are based aircraft, 20 are other military transient aircraft, and 2 are civilian transient aircraft.

[3] The closed pattern operations are divided by two for noise modeling purposes only. ATC counts closed patterns as two distinct operations: one departure and one arrival. In NOISEMAP and RNM, the departure and arrival are represented by one event because both operations are connected on a single flight track.

Table 4-2 Baseline (CY2006) Modeled Average Flying Day Flight Events for Andersen AFB

Mission Group	Assumed Type	Modeled Aircraft Type	Departure			Nonbreak Arrival			Overhead Break Arrival			Touch and Go[1]			GCA Box[1]			Total		
			Day	Night	Total	Day	Night	Total	Day	Night	Total	Day	Night	Total	Day	Night	Total	Day	Night	Total
HSC-25	OM Helo	SH60B	8.13	0.25	8.38	7.12	1.26	8.38	-	-	-	16.08	0.67	16.75	0.80	0.04	0.84	32.13	2.22	34.35
Local & Transient	Jet	B-1	0.22	0.02	0.24	0.22	0.02	0.24	-	-	-	0.44	0.05	0.49	0.22	0.03	0.25	1.10	0.12	1.22
	Jet	B-2	0.13	0.02	0.15	0.13	0.02	0.15	-	-	-	0.27	0.03	0.30	0.14	0.02	0.15	0.67	0.09	0.75
	Jet	B-52H	0.26	0.03	0.29	0.26	0.03	0.29	-	-	-	0.44	0.05	0.49	0.22	0.03	0.25	1.18	0.14	1.32
	Jet	C-9A	0.04	0.01	0.05	0.04	0.01	0.05	-	-	-	-	-	-	-	-	-	0.08	0.02	0.10
	Jet	KC-10A[2]	0.16	0.14	0.30	0.28	0.02	0.30	-	-	-	-	-	-	-	-	-	0.44	0.16	0.60
	Jet	C-21A[4]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Prop	C-130H&N&P[3,5]	0.12	-	0.12	0.12	-	0.12	-	-	-	-	-	-	-	-	-	0.24	-	0.24
	Jet	KC-135R	1.06	0.11	1.17	1.06	0.11	1.17	-	-	-	1.87	0.21	2.08	0.94	0.11	1.04	4.93	0.54	5.46
	Jet	F-15A	1.64	-	1.64	0.03	-	0.03	1.61	-	1.61	1.32	-	1.32	-	-	-	4.60	-	4.60
	Jet	F-16C	0.02	-	0.02	-	-	-	0.02	-	0.02	-	-	-	-	-	-	0.04	-	0.04
Transient	VM Helo	CH-46E[6]	0.05	-	0.05	0.05	-	0.05	-	-	-	-	-	-	-	-	-	0.10	-	0.10
	VM Helo	CH53E	0.02	0.04	0.06	0.02	0.04	0.06	-	-	-	-	-	-	-	-	-	0.04	0.08	0.12
	Jet	C-5A	0.13	0.51	0.64	0.57	0.06	0.63	-	-	-	-	-	-	-	-	-	0.70	0.57	1.27
	Jet	C-17	0.16	0.64	0.80	0.72	0.08	0.80	-	-	-	-	-	-	-	-	-	0.88	0.72	1.60
	Jet	C-20	0.01	-	0.01	0.01	-	0.01	-	-	-	-	-	-	-	-	-	0.02	-	0.02
	Prop	C-12[6]	0.05	-	0.05	0.05	-	0.05	-	-	-	-	-	-	-	-	-	0.10	-	0.10
Transient CVN Wing[7]	VM Jet	EA-6B	0.05	-	0.05	-	-	-	0.04	-	0.04	-	-	-	-	-	-	0.09	-	0.09
	VM Jet	F-18A/C	0.33	-	0.33	0.03	-	0.03	0.30	-	0.30	-	-	-	-	-	-	0.66	-	0.66
	VM Jet	F-18E/F	0.40	-	0.40	0.04	-	0.04	0.36	-	0.36	-	-	-	-	-	-	0.80	-	0.80
	VM Jet	C-21A[4]	0.11	0.02	0.13	0.11	0.02	0.13	-	-	-	-	-	-	-	-	-	0.22	0.04	0.26
	VM Prop	E-2C[5]	0.07	-	0.07	0.01	-	0.01	0.06	-	0.06	-	-	-	-	-	-	0.14	-	0.14
	VM Helo	SK70 (UH-60A) BLACKH[6]	0.10	0.01	0.11	0.10	0.01	0.11	-	-	-	-	-	-	-	-	-	0.20	0.02	0.22
Transient MMA	VM Prop	P-3A	0.21	0.03	0.24	0.21	0.03	0.24	-	-	-	-	-	-	-	-	-	0.42	0.06	0.48
Civilian (Transient)	Civilian	B-747-SP (N)	0.28	0.45	0.73	0.28	0.45	0.73	-	-	-	-	-	-	-	-	-	0.56	0.90	1.46
	Civilian	B-757-200-RR	0.09	0.02	0.11	0.09	0.02	0.11	-	-	-	-	-	-	-	-	-	0.18	0.04	0.22
Based Total			8.13	0.25	8.38	7.12	1.26	8.38	-	-	-	16.08	0.67	16.75	0.80	0.04	0.84	32.13	2.22	34.35
Military Transient Total			5.34	1.58	6.92	4.06	0.45	4.51	2.39	-	2.39	4.34	0.34	4.68	1.51	0.17	1.68	17.64	2.54	20.18
Civilian (Transient) Total			0.37	0.47	0.84	0.37	0.47	0.84	-	-	-	-	-	-	-	-	-	0.74	0.94	1.68
Grand Total			13.84	2.30	16.14	11.55	2.18	13.73	2.39	-	2.39	20.42	1.01	21.43	2.31	0.21	2.52	50.51	5.70	56.21

Day = 0700-2159 local; Night = 2200-0659 local

Notes: (1) Each Closed Pattern Event (Touch and go, GCA Box) is counted here as 1 event

(2) KC-10A Closed Pattern Operation (touch and Go, GCA Box) modeled as KC-135R

(3) C-130 H&N&P Closed Pattern Operations (Touch and Go, GCA Box) not modeled

(4) C-21A Local & Transient Operations modeled as C-21A Transient CVN Wing

(5) Overhead Break Arrivals Modeled as Nonbreak Arrivals

(6) Ops from AFCEE's modeling of Baseline for 2003

(7) Obtained for CVW-5 data from NAVAIR

Source: AAFB (Wyle and NAVFAC site visits)

4.3 Maintenance Run-up Operations

Maintenance run-up operations are performed by both based and transient aircraft. Run-up modeling from the 2003 noise study was reviewed by Andersen AFB maintenance personnel for run-up location, aircraft type, and event frequency. Based MH-60S run-up data was verified by HSC-25 maintenance personnel. Because most maintenance is performed on transient aircraft, Andersen Maintenance personnel were not able to verify all run-up power profiles for fixed-wing aircraft. After removing profiles for retired aircraft and verifying the frequency, type, and duration of run-ups, remaining profiles were assumed to be accurate. Figure 4-8 shows the modeled run-up locations. Not all locations in the figure are used for the Baseline scenario. Modeled run-up operations, profiles, and locations for all scenarios are shown in Appendix D.

4.4 Baseline Scenario Noise Exposure

Using the data described in Sections 4.1 through 4.3, NOISEMAP Version 7.2, RNM Version 7.0 were used to calculate and plot the 60 dB through 85 dB DNL contours for the AFD operations for Andersen AFB, as shown in Figure 4-9.

The off-base overland portion of the 60 dB DNL contour extends along runway heading approximately five statute miles southwest of the base boundary. The off-base overland portion of the 65 dB DNL contour extends approximately 2.5 miles southwest of the AFB boundary. The main contributors to off-base overland noise exposure are the approaches to Runway 06R and pattern work on Runway 06R. The highest off-base overland DNL exposure outside Andersen AFB property is between 75 dB and 80 dB DNL evidenced by the 75 dB DNL contour extending approximately 600 feet past the southwest base boundary.

Figure 4-8. Modeled Run-Up Locations

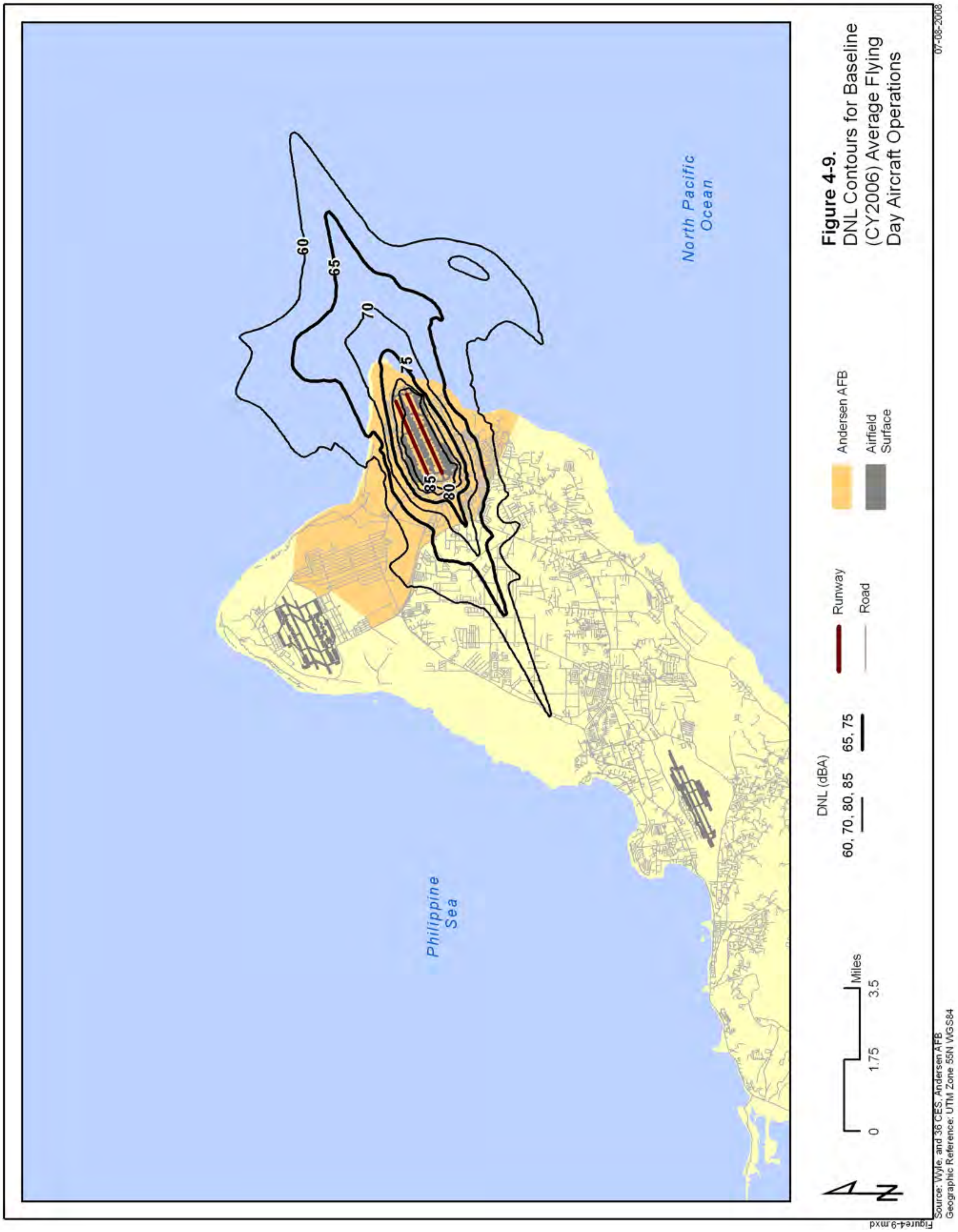

Figure 4-9. DNL Contours for Baseline (CY2006) Average Flying Day Aircraft Operations

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5.0 No Action (CY2014) Scenario

The No Action scenario models projected Andersen AFB airfield operations during CY2014. Northwest Field is considered a separate airfield. Except for based aircraft interfacility flights, operations at Northwest Field are not included in this analysis. Section 5.1 discusses flight operations by aircraft type. Section 5.2 discusses runway/helipad utilization, flight track utilization, flight profiles and daily operations by aircraft type. Section 5.3 describes maintenance run-up operations, and Section 5.4 discusses the calculated DNL contours.

5.1 Flight Operations

Calendar Year 2014 No Action operations are based on the Baseline CY2007 operations, with increases in mission- or exercise-specific aircraft provided by Andersen AFB personnel. These additions include:

- Addition of ISR/Strike-related operations for transient B-1, B-2, B-52, F-15E, F-22, KC-135R, and RQ-4 Global Hawk aircraft. 2014 will be during Phase 1 of ISR/Strike deployment, and the additional operations were calculated by scaling Phase 4 operations by the ratio of Phase 1 and Phase 4 aircraft loading;
- Increased use of Andersen AFB for special exercises, resulting in three times the number of operations for transient heavies (modeled as KC-10A and KC-135R) and four times the number of operations for transient fighters (modeled as F-15A and F-16C);
- Increased Air Mobility Command (AMC) deployment-related cargo and air carrier sorties by MD-11 (modeled as KC-10A) and C-17 aircraft;
- One-for-one replacement of all CVN airwing EA-6B “Prowler” operations with EA-18G “Growler” operations; and
- One-for-one replacement of Multimission Maritime Aircraft (MMA) P-3A operations with P-8A operations.

HSC-25 and civilian transient operations would remain the same as in the Baseline scenario, and no FCLPs are modeled. Table 5-1 shows the resultant numbers of operations by aircraft group, modeled aircraft type, and period of day for the Baseline scenario. Annual based and transient military flight operations would total 67,517. Addition of civilian and air carrier operations would bring the total to 68,139.

The top users of the airfield would still be the MH-60S Knighthawks in HSC-25 (modeled as SH-60B aircraft in RNM), with 28 percent of the total military operations. ISR/Strike F-22s would be the next most frequent users, with 17 percent of the total military operations. KC-135Rs and F-15As would each account for 13 percent of the total airfield operations. The based HSC-25 aircraft would remain at 6 percent nighttime (i.e., between 2200 and 0700) and transient aircraft would reduce their nighttime operations percentage from 14 to 8.

Table 5-1. No Action (CY2014) Annual Flight Operations for Andersen AFB

Mission Group	Assumed Type	Modeled Aircraft Type	Departure			Nonbreak Arrival			Overhead Break Arrival			Touch and Go(1)			GCA Box(1)			Total		
			Day	Night	Total	Day	Night	Total	Day	Night	Total	Day	Night	Total	Day	Night	Total	Day	Night	Total
Based	HSC-25 Sqn	SH60B	2,966	91	3,057	2,598	459	3,057	-	-	-	11,738	489	12,227	585	25	610	17,887	1,064	18,951
Transient ISR Strike	Jet	**B-1**	188	28	216	188	28	216	-	-	-	376	56	432	376	56	432	1,128	168	1,296
	Jet	**B-2A**	42	6	48	42	6	48	-	-	-	84	12	96	84	12	96	252	36	288
	Jet	**B-52H**	188	28	216	188	28	216	-	-	-	376	56	432	376	56	432	1,128	168	1,296
	Jet	**F-15E**	341	5	346	102	2	104	239	4	242	1,736	27	1,763	307	5	311	2,724	41	2,765
	Jet	**F-22(7)**	1,362	21	1,383	408	6	414	953	15	968	6,945	106	7,050	1,226	19	1,244	10,892	166	11,058
	Jet	**KC-135R**	835	125	960	835	125	960	-	-	-	2,506	374	2,880	2,506	374	2,880	6,682	998	7,680
	Jet	**Global Hawk (modeled as T-45)**	187	33	220	187	33	220	-	-	-	187	33	220	-	-	-	561	99	660
Local & Transient	Jet	B-1	80	9	89	80	9	89	-	-	-	322	36	358	161	18	179	643	72	715
	Jet	B-2	49	6	55	49	6	55	-	-	-	198	22	220	99	11	110	395	45	440
	Jet	B-52H	95	10	105	95	10	105	-	-	-	322	36	358	161	18	179	673	74	747
	Jet	C-9A	14	3	17	14	3	17	-	-	-	-	-	-	-	-	-	28	6	34
	Jet	**KC-10A(2,7)**	201	235	436	324	112	436	-	-	-	372	42	414	186	21	207	1,083	410	1,493
	Jet	C-21A(4)	24	6	30	24	6	30	-	-	-	-	-	-	-	-	-	48	12	60
	Prop	C-130H&N&P(3,5)	43	-	43	22	-	22	22	-	22	172	-	172	86	-	86	345	-	345
	Jet	KC-135R	1,164	123	1,287	1,164	123	1,287	-	-	-	3,720	414	4,134	1,860	207	2,067	7,908	867	8,775
	Jet	**F-15A**	2,392	-	2,392	44	-	44	2,352	-	2,352	3,856	-	3,856	-	-	-	8,644	-	8,644
	Jet	**F-16C**	36	-	36	-	-	-	36	-	36	-	-	-	-	-	-	72	-	72
Transient	VM Helo	CH-46E(6)	19	-	19	19	-	19	-	-	-	-	-	-	-	-	-	38	-	38
	VM Helo	CH-53E	6	16	22	6	16	22	-	-	-	-	-	-	-	-	-	12	32	44
	Jet	C-5A	46	186	232	209	23	232	-	-	-	-	-	-	-	-	-	255	209	464
	Jet	**C-17(7)**	112	238	350	274	77	351	-	-	-	-	-	-	-	-	-	386	315	701
	Jet	C-20	2	-	2	2	-	2	-	-	-	-	-	-	-	-	-	4	-	4
	Prop	C-12(6)	19	-	19	19	-	19	-	-	-	-	-	-	-	-	-	38	-	38
Transient CVN Wing(8)	VM Jet	**EA-18G (as F/A-18E/F)**	17	-	17	1	-	1	16	-	16	-	-	-	-	-	-	34	-	34
	VM Jet	F-18A/C	121	-	121	12	-	12	110	-	110	-	-	-	-	-	-	243	-	243
	VM Jet	F-18E/F	146	-	146	14	-	14	131	-	131	-	-	-	-	-	-	291	-	291
	VM Jet	C-21A(4)	17	-	17	17	-	17	-	-	-	-	-	-	-	-	-	34	-	34
	VM Prop	E-2C(5)	26	-	26	3	-	3	23	-	23	-	-	-	-	-	-	52	-	52
	VM Helo	SK70 (UH-60A) BLACKH(6)	37	2	39	37	2	39	-	-	-	-	-	-	-	-	-	74	4	78
Transient MMA	VM Jet	P-8A (modeled as B 737-700)	78	11	89	78	11	89	-	-	-	-	-	-	-	-	-	156	22	178
Civilian (Transient)	Civilian	B-747-SP (N)	104	166	270	104	166	270	-	-	-	-	-	-	-	-	-	208	332	540
	Civilian	B-757-200-RR	33	8	41	33	8	41	-	-	-	-	-	-	-	-	-	66	16	82
Based Total			2,966	91	3,057	2,598	459	3,057	-	-	-	11,738	489	12,227	585	25	610	17,887	1,064	18,951
Military Transient Total			7,886	1,091	8,977	4,457	626	5,082	3,882	18	3,900	21,172	1,213	22,385	7,427	796	8,223	44,823	3,744	48,566
Civilian (Transient) Total			137	174	311	137	174	311	-	-	-	-	-	-	-	-	-	274	348	622
Grand Total			10,989	1,356	12,345	7,192	1,259	8,450	3,882	18	3,900	32,910	1,702	34,612	8,012	821	8,833	62,984	5,156	68,139

Day = 0700-2159 local; Night = 2200-0659 local

Notes: (1) Each Closed Pattern Event (Touch and go, GCA Box) is counted here as 2 operations (1 landing + 1 departure)

(2) KC-10A Closed Pattern Operations (Touch and Go, GCA Box) modeled as KC-135R

(3)C-130H&N&P Closed Pattern Operations (Touch and go, GGCA Box) not modeled

(4) C-21A Local & Transient Operations Modeled as C-21A Transient CVN Wing

(5) Overhead Break Arrivals Modeled as Nonbreak Arrivals

(6) Ops from AFCEE's modeling of Baseline for 2003

(7) Include add'l Transient ops per AMC & Base Ops

(8) Obtained for CVW-5 data from NAVAIR

(9) **BOLD = changes from Baseline**

Source: AAFB (Wyle and NAVFAC site visits)

5.2 Runway and Flight Track Utilization, Flight Profiles, and Average Flying Day Events

Runways, flight tracks, runway/flight track utilization and flight profiles for the aircraft present in the Baseline case would remain the same as in the No Action case. Flight profiles and flight track utilization for the ISR/Strike aircraft were taken from the modeling files for the ISR/Strike EIS. EA-18G flight profiles were taken from a 2004 analysis of EA-18Gs at NAS Whidbey Island, modeled with the F/A-18E/F aircraft type. P-8 flight profiles were taken from an MMA study at MCBH Kaneohe Bay and modeled with the civilian-style B737-700 aircraft type. All new flight profiles were checked for consistency with current Andersen AFB course rules. The CVN wing EA-18 would use the same runway and flight track utilization as the Baseline EA-6B, and the P-8A would use the same runway and flight track utilization as the Baseline P-3. Runway and flight track utilization tables for all modeled aircraft are shown in Appendix C.

Average flying day operations were calculated in the same manner as for the Baseline case. The annual operations for each aircraft type and track were divided by the number of flying days for the aircraft. Based and transient aircraft would have 365 flying days per year All ISR/Strike aircraft except the Global Hawk would have 240 flying days per year, and the Global Hawk would have 220 flying days. The resultant AFD events for each aircraft are shown on Table 5-2. There would be approximately 150 events in an average flying day, of which 34 would be based aircraft, 114 would be other military transient aircraft, and 2 would be civilian transient aircraft.

Table 5-2. Modeled Average Flying Day Flight Events for No Action (CY2014) Scenario

Mission Group	Assumed Type	Modeled Aircraft Type	Departure			Nonbreak Arrival			Overhead Break Arrival			Touch and Go[1]			GCA Box[1]			Total		
			Day	Night	Total	Day	Night	Total	Day	Night	Total	Day	Night	Total	Day	Night	Total	Day	Night	Total
Based	HSC-25 Sqn	SH60B	8.13	0.25	8.38	7.12	1.26	8.38	-	-	-	16.08	0.67	16.75	0.80	0.04	0.84	32.13	2.22	34.35
Transient ISR Strike	Jet	**B-1**	0.78	0.12	0.90	0.78	0.12	0.90	-	-	-	0.79	0.12	0.90	0.79	0.12	0.90	3.13	0.47	3.60
	Jet	**B-2A**	0.18	0.03	0.21	0.18	0.03	0.21	-	-	-	0.18	0.03	0.20	0.18	0.03	0.20	0.71	0.11	0.82
	Jet	**B-52H**	0.78	0.12	0.90	0.78	0.12	0.90	-	-	-	0.79	0.12	0.90	0.79	0.12	0.90	3.13	0.47	3.60
	Jet	**F-15E**	1.42	0.02	1.44	0.43	0.01	0.44	0.99	0.01	1.00	3.62	0.06	3.67	0.64	0.01	0.65	7.10	0.11	7.20
	Jet	**F-22**[7]	5.67	0.09	5.76	1.70	0.03	1.73	3.97	0.06	4.03	14.47	0.22	14.69	2.56	0.04	2.60	28.37	0.44	28.81
	Jet	**KC-135R**	3.48	0.52	4.00	3.48	0.52	4.00	-	-	-	5.22	0.78	6.00	5.22	0.78	6.00	17.40	2.60	20.00
	Jet	**Global Hawk (modeled as T-45)**	0.85	0.15	1.00	0.85	0.15	1.00	-	-	-	0.43	0.08	0.50	-	-	-	2.13	0.38	2.50
Local & Transient	Jet	B-1	0.22	0.02	0.24	0.22	0.02	0.24	-	-	-	0.44	0.05	0.49	0.22	0.03	0.25	1.10	0.12	1.22
	Jet	B-2	0.13	0.02	0.15	0.13	0.02	0.15	-	-	-	0.27	0.03	0.30	0.14	0.02	0.15	0.67	0.09	0.75
	Jet	B-52H	0.26	0.03	0.29	0.26	0.03	0.29	-	-	-	0.44	0.05	0.49	0.22	0.03	0.25	1.18	0.14	1.32
	Jet	C-9A	0.04	0.01	0.05	0.04	0.01	0.05	-	-	-	-	-	-	-	-	-	0.08	0.02	0.10
	Jet	**KC-10A**[2,7]	0.55	0.64	1.19	0.89	0.31	1.20	-	-	-	-	-	-	-	-	-	1.44	0.95	2.39
	Jet	C-21A[4]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Prop	C-130H&N&P[3,5]	0.12	-	0.12	0.12	-	0.12	-	-	-	-	-	-	-	-	-	0.24	-	0.24
	Jet	KC-135R	3.19	0.34	3.53	3.19	0.34	3.53	-	-	-	5.61	0.63	6.23	2.81	0.31	3.12	14.79	1.62	16.41
	Jet	**F-15A**	6.55	-	6.55	0.12	-	0.12	6.44	-	6.44	5.28	-	5.28	-	-	-	18.39	-	18.39
	Jet	**F-16C**	0.10	-	0.10	-	-	-	0.10	-	0.10	-	-	-	-	-	-	0.20	-	0.20
Transient	VM Helo	CH-46E[6]	0.05	-	0.05	0.05	-	0.05	-	-	-	-	-	-	-	-	-	0.10	-	0.10
	VM Helo	CH-53E	0.02	0.04	0.06	0.02	0.04	0.06	-	-	-	-	-	-	-	-	-	0.04	0.08	0.12
	Jet	C-5A	0.13	0.51	0.64	0.57	0.06	0.63	-	-	-	-	-	-	-	-	-	0.70	0.57	1.27
	Jet	**C-17**[7]	0.31	0.65	0.96	0.75	0.21	0.96	-	-	-	-	-	-	-	-	-	1.06	0.86	1.92
	Jet	C-20	0.01	-	0.01	0.01	-	0.01	-	-	-	-	-	-	-	-	-	0.02	-	0.02
	Prop	C-12[6]	0.05	-	0.05	0.05	-	0.05	-	-	-	-	-	-	-	-	-	0.10	-	0.10
Transient CVN Wing[8]	VM Jet	**EA-18G (as F/A-18E/F)**	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	VM Jet	F-18A/C	0.33	-	0.33	0.03	-	0.03	0.30	-	0.30	-	-	-	-	-	-	0.66	-	0.66
	VM Jet	F-18E/F	0.45	-	0.45	0.04	-	0.04	0.40	-	0.40	-	-	-	-	-	-	0.89	-	0.89
	VM Jet	C-21A[4]	0.11	0.02	0.13	0.11	0.02	0.13	-	-	-	-	-	-	-	-	-	0.22	0.04	0.26
	VM Prop	E-2C[5]	0.07	-	0.07	0.07	-	0.07	-	-	-	-	-	-	-	-	-	0.14	-	0.14
	VM Helo	SK70 (UH-60A) BLACKH[6]	0.10	0.01	0.11	0.10	0.01	0.11	-	-	-	-	-	-	-	-	-	0.20	0.02	0.22
Transient MMA	VM Jet	P-8A (modeled as B-737-700)	0.21	0.03	0.24	0.21	0.03	0.24	-	-	-	-	-	-	-	-	-	0.42	0.06	0.48
Civilian (Transient)	Civilian	B-747-SP (N)	0.28	0.45	0.73	0.28	0.45	0.73	-	-	-	-	-	-	-	-	-	0.56	0.90	1.46
	Civilian	B-757-200-RR	0.09	0.02	0.11	0.09	0.02	0.11	-	-	-	-	-	-	-	-	-	0.18	0.04	0.22
Based Total			8.13	0.25	8.38	7.12	1.26	8.38	-	-	-	16.08	0.67	16.75	0.80	0.04	0.84	32.13	2.22	34.35
Military Transient Total			26.16	3.37	29.53	15.18	2.08	17.26	12.20	0.07	12.27	37.51	2.14	39.65	13.54	1.46	15.00	104.59	9.12	113.71
Civilian (Transient) Total			0.37	0.47	0.84	0.37	0.47	0.84	-	-	-	-	-	-	-	-	-	0.74	0.94	1.68
Grand Total			34.66	4.09	38.75	22.67	3.81	26.48	12.20	0.07	12.27	53.59	2.81	56.40	14.34	1.50	15.84	137.46	12.28	149.74

Day = 0700-2159 local; Night = 2200-0659 local

Note: (1) Each Closed Pattern Event (Touch and Go, GCA Box) is counted here as 1 event

(2) KC-10A Closed Pattern Operations (Touch and Go, GCA Box) modeled as KC135R

(3) C-130H&N&P Closed Pattern Operation (Touch and go, GCA Box) not modeled

(4) C-21A Local & Transient Operations Modeled a C21A Transient CVN Wing

(5) Overhead Break Arrivals modeled as Nonbreak Arrivals

(6) Ops from AFCEE's modeling of Baseline for 2003

(7) Include add'l Transient ops per AMC & Base Ops

(8) Obtained for CVW-5 data from NAVAIR

(9) **BOLD = changes from Baseline**

Source: AAFB (Wyle and NAVFAC site visits

5.3 Maintenance Run-up Operations

The location, frequency, and profiles of maintenance run-up operations for based and transient aircraft present in the Baseline scenario would be the same in the No Action scenario. Run-up profiles for ISR/Strike F-15E and F-22 were taken from the ISR/Strike EIS and moved from the EIS modeled location to Pad S27 and Pad S35 because the EIS modeled location would not exist. No run-up profiles existed in the source files for the EA-18G or P-8A, so run-ups for those aircraft were omitted from the study. Modeled run-up operations, profiles, and locations for all scenarios are shown in Appendix D.

5.4 No Action Scenario Noise Exposure

Using the data described in Sections 5.1 through 5.3, NOISEMAP Version 7.2, RNM Version 7.0 were used to calculate and plot the 60 dB through 85 dB DNL contours for the AFD operations for the No Action Scenario for Andersen AFB, as shown in Figure 5-1.

The off-base overland portion of the 60 dB DNL contour would extend along runway heading approximately seven statute miles southwest of the base boundary to the western shoreline of the island. The 60 dB DNL contour over the water to the northwest would be due to GCA box operations on 06L/06R. The 60 dB DNL contour would have a ‘hook’ to the southeast due to large-aircraft touch-and-go operations on Runway 06R/24L.

The off-base overland portion of the 65 dB DNL contour would extend approximately 3.5 miles southwest of the AFB boundary. The main lobes would follow the approach paths to Runways 06L/06R. The highest off-base overland DNL exposure outside Andersen AFB property would be between 75 dB and 80 dB evidenced by the 75 dB DNL contour extending approximately an average of 1,700 feet past the southwest base boundary.

Figure 5-2 compares the No Action DNL contours to the Baseline DNL contours. The influence of the growth in GCA pattern operations and large aircraft touch-and-goes is evident in the 60 DNL No Action contour lobes over water to the northwest and in the ‘hook’ to the southeast. The increase in overall operations, especially in approaches to Runways 06L/R, would cause the approximately two-mile growth in the 60 and 65 dB DNL contours along the extended centerlines of Runways 06L/R southwest of the AFB.

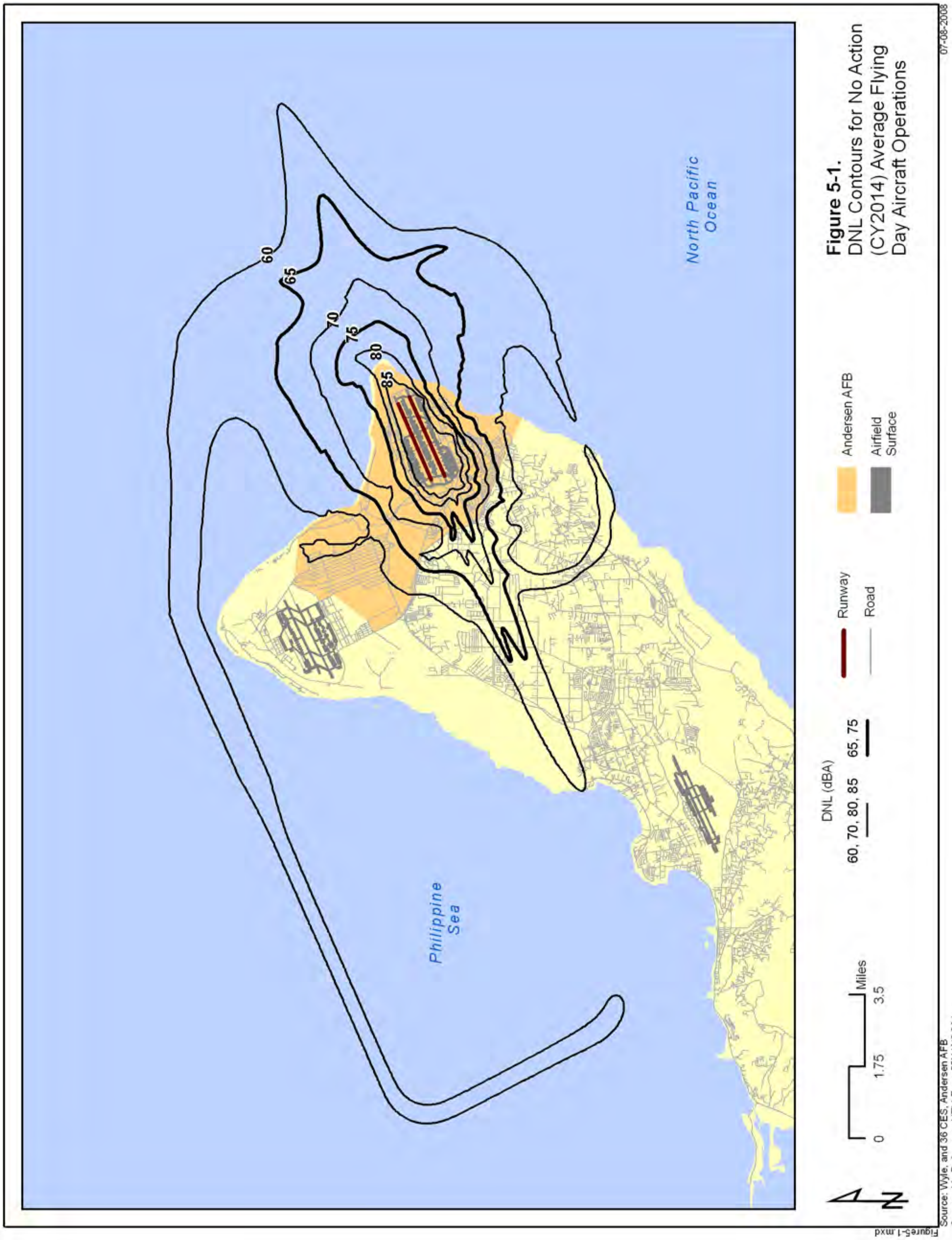

Figure 5-1. DNL Contours for No Action (CY2014) Average Flying Day Aircraft Operations

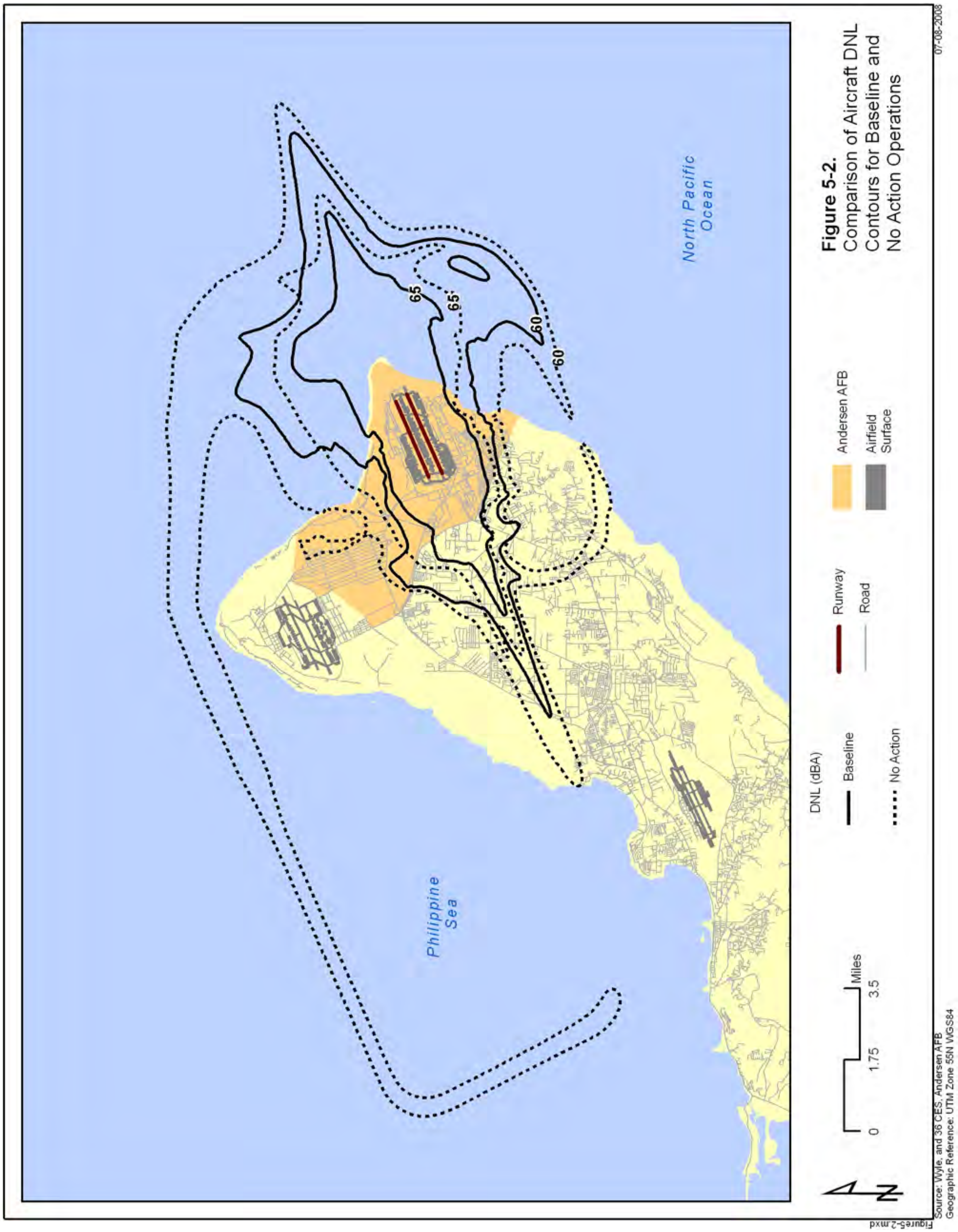

Figure 5-2. Comparison of Aircraft DNL Contours for Baseline and No Action Operations

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6.0 Proposed (CY2014) Scenario

The Proposed scenario models proposed Andersen AFB airfield operations during CY2014. Northwest Field is considered a separate airfield. Except for based aircraft interfacility flights, operations at Northwest Field are not included in this analysis. Section 6.1 discusses flight operations by aircraft type. Section 6.2 discusses runway/helipad utilization, flight track utilization, flight profiles and daily operations by aircraft type. Section 6.3 describes maintenance run-up operations, and Section 6.4 discusses the calculated DNL contours.

6.1 Flight Operations

Calendar Year 2014 Proposed operations are based on the Baseline CY2007 operations with the increases and replacements described in Section 5.1, plus the following changes:

- Transfer of four CH-53E, six AH-1Z, and three UH-1N aircraft in support of the USMC relocation to Guam;
- Transfer of a Marine F/A-18D Squadron in support of the USMC relocation to Guam;
- Transfer of a new based MV-22 squadron; and
- Increased visits of CVN airwings from one per year to four per year, resulting in an increase of transient CVN F/A-18C, F/A-18F, SH-60B/F, EA-18G, and E-2C airfield operations.

HSC-25 and civilian transient operations would remain the same as in the Baseline scenario, and no FCLPs are modeled. Table 6-1 shows the resultant numbers of operations by aircraft group, modeled aircraft type, and period of day for the Proposed scenario. Annual based and transient military flight operations would total 93,037. Addition of civilian and air carrier operations would bring the total to 93,649.

The top users of the airfield would still be the MH-60S Knighthawks in HSC-25 (modeled as SH-60B aircraft in RNM), now with 20 percent of the total military operations. ISR/Strike F-22s would be the next most frequent users, with 12 percent of the total military operations. Based AH-1s, F-15As, Transient ISR Strike KC-135Rs and Local Transient KC-135Rs would each account for 8 to 10 percent of the total airfield operations. Overall, seven percent of the based aircraft operations would be flown at night (i.e., between 2200 and 0700), and nine percent of the transient operations would be flown during the same period.

Table 6-1. Proposed Action (CY2014) Annual Flight Operations for Andersen AFB

Mission Group	Assumed Type	Modeled Aircraft Type	Departure			Nonbreak Arrival			Overhead Break Arrival			Touch and Go[1]			GCA Box[1]			Total		
			Day	Night	Total	Day	Night	Total	Day	Night	Total	Day	Night	Total	Day	Night	Total	Day	Night	Total
Based Additions	VM Helo	**CH-53E[8]**	432	18	450	383	68	451	-	-	-	540	60	600	108	12	120	1,463	158	1,621
	VM Helo	**AH-1N[9]**	2,250	-	2,250	2,250	-	2,250	-	-	-	3,000	-	3,000	1,500	-	1,500	9,000	-	9,000
	VM Helo	**UH-1N[9]**	750	-	750	750	-	750	-	-	-	1,000	-	1,000	500	-	500	3,000	-	3,000
	VM Rotary	**MV-22B[9]**	1,244	735	1,979	124	74	198	1,119	662	1,781	566	-	566	707	-	707	3,760	1,471	5,231
	VM Jet	**F/A-18D**	1,147	23	1,170	168	8	176	985	10	995	1,752	73	1,825	374	24	398	4,426	138	4,564
Based (HSC-25)	OM Helo	SH60B	2,966	91	3,057	2,598	459	3,057	-	-	-	11,738	489	12,227	585	25	610	17,887	1,064	18,951
Transient ISR Strike	Jet	**B-1**	188	28	216	188	28	216	-	-	-	376	56	432	376	56	432	1,128	168	1,296
	Jet	**B-2A**	42	6	48	42	6	48	-	-	-	84	12	96	84	12	96	252	36	288
	Jet	**B-52H**	188	28	216	188	28	216	-	-	-	376	56	432	376	56	432	1,128	168	1,296
	Jet	**F-15E**	341	5	346	102	2	104	239	4	242	1,736	27	1,763	307	5	311	2,724	41	2,765
	Jet	**F-22[7]**	1,362	21	1,383	408	6	414	953	15	968	6,945	106	7,050	1,226	19	1,244	10,892	166	11,058
	Jet	**KC-135R**	835	125	960	835	125	960	-	-	-	2,506	374	2,880	2,506	374	2,880	6,682	998	7,680
	Jet	**Global Hawk (modeled as T-45)**	187	33	220	187	33	220	-	-	-	187	33	220	-	-	-	561	99	660
Local & Transient	Jet	B-1	80	9	89	80	9	89	-	-	-	322	36	358	161	18	179	643	72	715
	Jet	B-2	49	6	55	49	6	55	-	-	-	198	22	220	99	11	110	395	45	440
	Jet	B-52H	95	10	105	95	10	105	-	-	-	322	36	358	161	18	179	673	74	747
	Jet	C-9A	14	3	17	14	3	17	-	-	-	-	-	-	-	-	-	28	6	34
	Jet	**KC-10A[2,7]**	201	235	436	324	112	436	-	-	-	372	42	414	186	21	207	1,083	410	1,493
	Jet	C-21A[4]	24	6	30	24	6	30	-	-	-	-	-	-	-	-	-	48	12	60
	Prop	C-130H&N&P[3,5]	43	-	43	22	-	22	22	-	22	172	-	172	86	-	86	345	-	345
	Jet	KC-135R	1,164	123	1,287	1,164	123	1,287	-	-	-	3,720	414	4,134	1,860	207	2,067	7,908	867	8,775
	Jet	**F-15A**	2,392	-	2,392	44	-	44	2,352	-	2,352	3,856	-	3,856	-	-	-	8,644	-	8,644
	Jet	**F-16C**	36	-	36	-	-	-	36	-	36	-	-	-	-	-	-	72	-	72
Transient	VM Helo	CH-46E[6]	19	-	19	19	-	19	-	-	-	-	-	-	-	-	-	38	-	38
	VM Helo	CH-53E	6	16	22	6	16	22	-	-	-	-	-	-	-	-	-	12	32	44
	Jet	C-5A	46	186	232	209	23	232	-	-	-	-	-	-	-	-	-	255	209	464
	Jet	**C-17[7]**	112	238	350	274	77	351	-	-	-	-	-	-	-	-	-	386	315	701
	Jet	C-20	2	-	2	2	-	2	-	-	-	-	-	-	-	-	-	4	-	4
	Prop	C-12[6]	19	-	19	19	-	19	-	-	-	-	-	-	-	-	-	38	-	38
Transient CVN Wing[10]	VM Jet	**EA-18G (as F/A-18E/F)**	68	-	68	4	-	4	64	-	64	-	-	-	-	-	-	136	-	136
	VM Jet	**F-18A/C**	484	-	484	48	-	48	440	-	440	-	-	-	-	-	-	972	-	972
	VM Jet	**F-18E/F**	584	-	584	56	-	56	524	-	524	-	-	-	-	-	-	1,164	-	1,164
	VM Jet	C-21A[4]	17	-	17	17	-	17	-	-	-	-	-	-	-	-	-	34	-	34
	VM Prop	**E-2C[5]**	104	-	104	12	-	12	92	-	92	-	-	-	-	-	-	208	-	208
	VM Helo	**SK70 (UH-60A) BLACKH[6]**	148	8	156	148	8	156	-	-	-	-	-	-	-	-	-	296	16	312
Transient MMA	VM Jet	**P-8A (modeled as B-737-700)**	78	11	89	78	11	89	-	-	-	-	-	-	-	-	-	156	22	178
Civilian (Transient)	Civilian	B-747-SP (N)	104	166	270	104	166	270	-	-	-	-	-	-	-	-	-	208	332	540
	Civilian	B-757-200-RR	33	8	41	33	8	41	-	-	-	-	-	-	-	-	-	66	16	82
Based Total			8,789	867	9,656	6,273	609	6,882	2,104	672	2,776	18,596	622	19,218	3,774	61	3,835	39,536	2,831	42,367
Military Transient Total			8,927	1,097	10,024	4,658	632	5,289	4,722	18	4,740	21,172	1,213	22,385	7,427	796	8,223	46,905	3,756	50,660
Civilian (Transient) Total			137	174	311	137	174	311	-	-	-	-	-	-	-	-	-	274	348	622
Grand Total			17,853	2,138	19,991	11,068	1,415	12,482	6,826	690	7,516	39,768	1,835	41,603	11,201	857	12,058	86,715	6,935	93,649

Day=0700-2159 local; Night = 2200-0659 local

Notes: (1) Each Closed Pattern Event (Touch and go, GCA Box) is counted here as 2 operations (1 landing + 1 departure)
(2) KC-10A Closed Pattern Operations (Touch and go, GCA box) modeled as KC-135R
(3) C-130H&N&P Closed Pattern Operations (Touch and Go, GCA Box) not modeled
(4) C-21A Local & Transient Operations modeled as C-21A Transient CVN Wing
(5) Overhead Break Arrivals modeled as Nonbreak Ariivals
(6) Ops from AFCEE's modeling of Baseline for 1993
(7) Include add'l transient ops per AMC & Base Ops
(8) Excludes LHA T&G from FRF Camp Schwab
(9) Excludes LHA T&G from FRF Camp Schwab
(10) Obtained for CVW-5 data from NAVAIR
(11) **BOLD = changes from Baseline**

Source: AAFB (Wyle and NAVFAC site visits)

6.2 Runway and Flight Track Utilization, Flight Profiles, and Average Flying Day Events

With the exception of the based MH-60S, runways, flight tracks, runway/flight track utilization and flight profiles for the aircraft in the No Action case would remain the same for corresponding aircraft in the Proposed case. Flight profiles and flight track utilization for the proposed rotary wing aircraft were taken from a draft noise study for the Futenma Replacement Facility (FRF) at Camp Schwab, Okinawa (Wyle, 2008). Flight profiles for the Marine F/A-18D were extracted from the 2003 noise study. MV-22 flight profiles were taken from the West Coast MV-22 beddown EIS currently in progress. All new flight profiles were checked for consistency with current Andersen AFB course rules. All proposed based rotary wing aircraft would have the same flight track utilization as the existing HSC-25 aircraft, except departure and arrival flight tracks would originate and terminate at pad N25 rather than pads N1 and N19. The MH-60S departure and arrival flight tracks would move to pad N25, and proposed MH-60S flight profiles would be applied to the new tracks. Marine F/A-18D flight track utilization would be the same as modeled in the 2003 noise study, but the runway utilization would be modified to favor Runway 06L because the proposed hangar would be on the north side of the airfield. MV-22 aircraft would use the same flight tracks and pads as HSC-25 aircraft, with additional departures and overhead break arrivals to the main runways. Runway and flight track utilization tables for all modeled aircraft are shown in Appendix C.

Average flying day operations were calculated in the same manner as for the Baseline and No Action cases. The annual operations for each aircraft type and track were divided by the number of flying days for the aircraft. All based and transient (including proposed aircraft) aircraft would have 365 flying days per year All ISR/Strike aircraft except the Global Hawk would have 240 flying days per year, and the Global Hawk would have 220 flying days. The resultant AFD operations for each aircraft are shown on Table 6-2. There would be approximately 206 events in an average flying day, of which 85 would be based aircraft, 119 would be other military transient aircraft, and 2 would be civilian transient aircraft.

Table 6-2. Modeled Average Flying Day Flight Events for Proposed (CY2014) Scenario

Mission Group	Assumed Type	Modeled Aircraft Type	Departure			Nonbreak Arrival			Overhead Break Arrival			Touch and Go[1]			GCA Box[1]			Total		
			Day	Night	Total	Day	Night	Total	Day	Night	Total	Day	Night	Total	Day	Night	Total	Day	Night	Total
Based Additions	VM Helo	**CH-53E**[8]	1.18	0.05	1.23	1.05	0.19	1.24	-	-	-	0.74	0.08	0.82	0.15	0.02	0.17	3.12	0.34	3.46
	VM Helo	**AH-1N**[9]	6.16	-	6.16	6.16	-	6.16	-	-	-	4.11	-	4.11	2.06	-	2.06	18.49	-	18.49
	VM Helo	**UH-1N**[9]	2.05	-	2.05	2.05	-	2.05	-	-	-	1.37	-	1.37	0.69	-	0.69	6.16	-	6.16
	VM Rotary	**MV-22B**[9]	3.41	2.01	5.42	0.34	0.20	0.54	3.07	1.81	4.88	0.78	-	0.78	0.97	-	0.97	8.57	4.02	12.59
	VM Jet	**F/A-18D**	3.14	0.06	3.20	0.46	0.02	0.48	2.70	0.03	2.73	2.40	0.10	2.50	0.51	0.04	0.55	9.21	0.25	9.46
Based (HSC-25)	OM Helo	SH60B	8.13	0.25	8.38	7.12	1.26	8.38	-	-	-	16.08	0.67	16.75	0.80	0.04	0.84	32.13	2.22	34.35
Transient ISR Strike	Jet	**B-1**	0.78	0.12	0.90	0.78	0.12	0.90	-	-	-	0.79	0.12	0.90	0.79	0.12	0.90	3.13	0.47	3.60
	Jet	**B-2A**	0.18	0.03	0.21	0.18	0.03	0.21	-	-	-	0.18	0.03	0.20	0.18	0.03	0.20	0.71	0.11	0.82
	Jet	**B-52H**	0.78	0.12	0.90	0.78	0.12	0.90	-	-	-	0.79	0.12	0.90	0.79	0.12	0.90	3.13	0.47	3.60
	Jet	**F-15E**	1.42	0.02	1.44	0.43	0.01	0.44	0.99	0.01	1.00	3.62	0.06	3.67	0.64	0.01	0.65	7.10	0.11	7.20
	Jet	**F-22**[7]	5.67	0.09	5.76	1.70	0.03	1.73	3.97	0.06	4.03	14.47	0.22	14.69	2.56	0.04	2.60	28.37	0.44	28.81
	Jet	**KC-135R**	3.48	0.52	4.00	3.48	0.52	4.00	-	-	-	5.22	0.78	6.00	5.22	0.78	6.00	17.40	2.60	20.00
	Jet	**Global Hawk (modeled as T-45)**	0.85	0.15	1.00	0.85	0.15	1.00	-	-	-	0.43	0.08	0.50	-	-	-	2.13	0.38	2.50
Local & Transient	Jet	B-1	0.22	0.02	0.24	0.22	0.02	0.24	-	-	-	0.44	0.05	0.49	0.22	0.03	0.25	1.10	0.12	1.22
	Jet	B-2	0.13	0.02	0.15	0.13	0.02	0.15	-	-	-	0.27	0.03	0.30	0.14	0.02	0.15	0.67	0.09	0.75
	Jet	B-52H	0.26	0.03	0.29	0.26	0.03	0.29	-	-	-	0.44	0.05	0.49	0.22	0.03	0.25	1.18	0.14	1.32
	Jet	C-9A	0.04	0.01	0.05	0.04	0.01	0.05	-	-	-	-	-	-	-	-	-	0.08	0.02	0.10
	Jet	**KC-10A**[2,7]	0.55	0.64	1.19	0.89	0.31	1.20	-	-	-	-	-	-	-	-	-	1.44	0.95	2.39
	Jet	C-21A[4]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Prop	C-130H&N&P[3,5]	0.12	-	0.12	0.12	-	0.12	-	-	-	-	-	-	-	-	-	0.24	-	0.24
	Jet	KC-135R	3.19	0.34	3.53	3.19	0.34	3.53	-	-	-	5.61	0.63	6.23	2.81	0.31	3.12	14.79	1.62	16.41
	Jet	**F-15A**	6.55	-	6.55	0.12	-	0.12	6.44	-	6.44	5.28	-	5.28	-	-	-	18.39	-	18.39
	Jet	**F-16C**	0.10	-	0.10	-	-	-	0.10	-	0.10	-	-	-	-	-	-	0.20	-	0.20
Transient	VM Helo	CH-46E[6]	0.05	-	0.05	0.05	-	0.05	-	-	-	-	-	-	-	-	-	0.10	-	0.10
	VM Helo	CH-53E	0.02	0.04	0.06	0.02	0.04	0.06	-	-	-	-	-	-	-	-	-	0.04	0.08	0.12
	Jet	C-5A	0.13	0.51	0.64	0.57	0.06	0.63	-	-	-	-	-	-	-	-	-	0.70	0.57	1.27
	Jet	**C-17**[7]	0.31	0.65	0.96	0.75	0.21	0.96	-	-	-	-	-	-	-	-	-	1.06	0.86	1.92
	Jet	C-20	0.01	-	0.01	0.01	-	0.01	-	-	-	-	-	-	-	-	-	0.02	-	0.02
	Prop	C-12[6]	0.05	-	0.05	0.05	-	0.05	-	-	-	-	-	-	-	-	-	0.10	-	0.10
Transient CVN Wing[10]	VM Jet	**EA-18G (as F/A-18E/F)**	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	VM Jet	**F-18A/C**	1.33	-	1.33	0.13	-	0.13	1.21	-	1.21	-	-	-	-	-	-	2.67	-	2.67
	VM Jet	**F-18E/F**	1.79	-	1.79	0.16	-	0.16	1.61	-	1.61	-	-	-	-	-	-	3.56	-	3.56
	VM Jet	C-21A[4]	0.11	0.02	0.13	0.11	0.02	0.13	-	-	-	-	-	-	-	-	-	0.22	0.04	0.26
	VM Prop	**E-2C**[5]	0.28	-	0.28	0.28	-	0.28	-	-	-	-	-	-	-	-	-	0.56	-	0.56
	VM Helo	**SK70 (UH-60A) BLACKH**[6]	0.41	0.02	0.43	0.41	0.02	0.43	-	-	-	-	-	-	-	-	-	0.82	0.04	0.86
Transient MMA	VM Jet	**P-8A (modeled as B-737-700)**	0.21	0.03	0.24	0.21	0.03	0.24	-	-	-	-	-	-	-	-	-	0.42	0.06	0.48
Civilian (Transient)	Civilian	B-747-SP (N)	0.28	0.45	0.73	0.28	0.45	0.73	-	-	-	-	-	-	-	-	-	0.56	0.90	1.46
	Civilian	B-757-200-RR	0.09	0.02	0.11	0.09	0.02	0.11	-	-	-	-	-	-	-	-	-	0.18	0.04	0.22
Based Total			24.07	2.37	26.44	17.18	1.67	18.85	5.77	1.84	7.61	25.48	0.85	26.33	5.17	0.09	5.26	77.67	6.82	84.48
Military Transient Total			29.02	3.38	32.40	15.92	2.09	18.01	14.32	0.07	14.39	37.51	2.14	39.65	13.54	1.46	15.00	110.31	9.14	119.45
Civilian (Transient) Total			0.37	0.47	0.84	0.37	0.47	0.84	-	-	-	-	-	-	-	-	-	0.74	0.94	1.68
Grand Total			53.46	6.22	59.68	33.47	4.23	37.70	20.09	1.91	22.00	62.99	2.99	65.98	18.71	1.55	20.26	188.72	16.90	205.61

Day = 0700-2159 local; Night = 2200-0659 local

Notes: (1) Each Closed Pattern Event (Touch and Go, GCA Box) is counted here as 1 event
(2) KC-10A Closed Pattern Operations (Touch and Go, GCA Box) modeled as KC-135R
(3) C-130H&N&P Closed Pattern Operation (Touch and Go, GCA Box) not modeled
(4) C-21A Local & Transient Operations modeled as C-21A Transient CVN Wing
(5) Overhead Break Arrivals modeled as Nonbreak Arrivals
(6) Ops from AFCEE's modeling of Baseline for 2003
(7) Include add'l transient ops per AMC & Base Ops
(8) Excludes LHA T&G and CLA T&G from FRF Camp Schwab
(9) Excludes LHA T&G from FRF Camp Schwab
(10) Obtained for CVW-5 data from NAVAIR
(11) **BOLD = changes from Baseline**

Source: AAFB (Wyle and NAVFAC site visits)

6.3 Maintenance Run-up Operations

The location, frequency, and profiles of maintenance run-up operations for based and transient aircraft present in the No Action scenario would be the same in the Proposed scenario. Run-up profiles for ISR/Strike F-15E and F-22 were taken from the ISR/Strike EIS and moved from the EIS modeled location to Pad S27 and Pad S35 because the EIS modeled location would not exist. No run-up profiles existed in the source files for the EA-18G or P-8A, so run-ups for those aircraft were omitted from the study. Run-up profiles for the proposed based rotary wing and MV-22 aircraft were taken from the draft FRF Camp Schwab study, and their operations were scaled by the ratio of aircraft loading at Andersen AFB to the loading at Camp Schwab. Run-up profiles for the proposed Marine F/A-18D aircraft were taken from a draft noise study for NAS Lemoore (Wyle, 2008b), and their operations were scaled by the aircraft loading ratio as well.

Because the facility for the proposed based aircraft would be on the north side of the airfield, all run-up operations that were modeled on pads N19 through N42 in the Baseline scenario would be moved to pads S4 through S45 for the proposed scenario. Maintenance run-ups by proposed rotary-wing aircraft and HSC-25 aircraft would be performed at a dedicated hover check pad at the new facility. See Figure 4-8 for the location of the hover check pad. Maintenance run-ups by proposed fixed-wing aircraft would be performed at Pad N1 or Pad N2. Modeled run-up operations, profiles, and locations for all scenarios are shown in Appendix D.

Although a maintenance test cell or hush house is anticipated, the presence of these capabilities is yet to be determined as aircraft engine production may be supported from site(s) in US or Japan depending on the airframe mix and future logistics practices. For conservative noise exposure computations, all run-ups were modeled to be outdoors.

6.4 Proposed Scenario Noise Exposure

Using the data described in Sections 6.1 through 6.3, NOISEMAP Version 7.2, RNM Version 7.0 were used to calculate and plot the 60 dB through 85 dB DNL contours for the AFD operations for the Proposed CY2014 Scenario at Andersen AFB, as shown in Figure 6-1.

The off-base overland portion of the 60 dB DNL contour would extend along runway heading approximately 7.5 statute miles southwest of the base boundary to the western shoreline of the island. The 60 dB DNL contour over the water to the northwest would be due to GCA box operations on 06L/06R. The 60 dB DNL contour would have a 'hook' to the southeast due to large-aircraft touch-and-go operations on Runway 06R/24L and a 'hook' to Northwest Field due to GCA box operations on Runways 24L/R.

The off-base overland portion of the 65 dB DNL contour would extend approximately four miles southwest of the AFB boundary. The main lobes would follow the approach paths to Runways 06L/06R with an 'offshoot' to the northwest due to GCA Box pattern operations on Runway 24R. The highest off-base overland DNL exposure outside Andersen AFB property would be between 75 dB and 80 dB evidenced by the 75 dB DNL contour extending approximately an average of 4,000 feet past the southwest base boundary.

Figure 6-2 compares the Proposed Action DNL contours to the No Action DNL contours. The primary difference between the two sets of contours is the 60 dB DNL Proposed Action contour 'hook' extending to Northwest Field which would be due to the growth in GCA pattern operations on Runways 24L/R. Minor differences (increases) in the 70 and 75 dB DNL contours in proximity to the AFB are noticeable and would be due to the increase in overall operations that are primarily a result of increased visits of the CVN Wing.

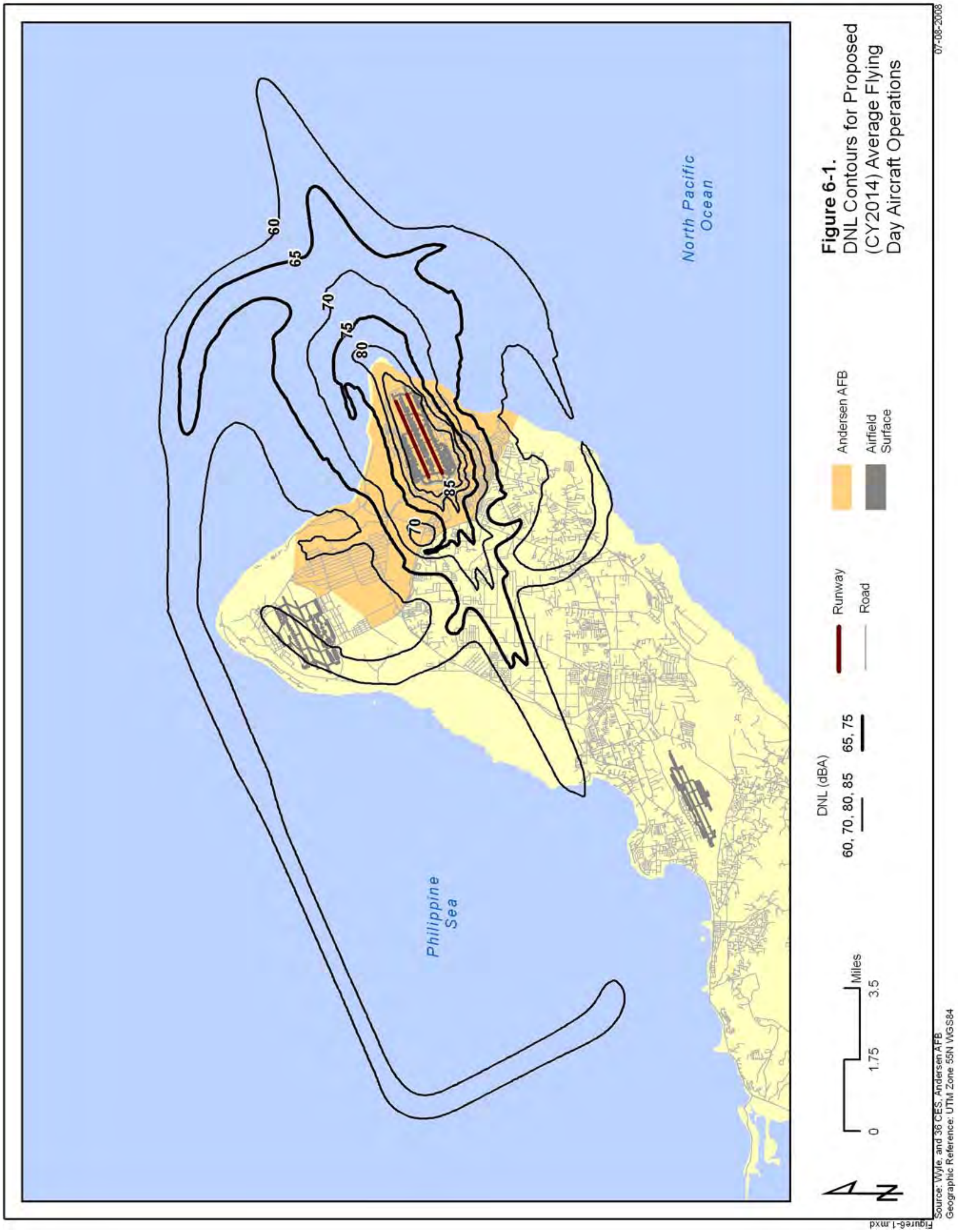

Figure 6-1. DNL Contours for Proposed (CY2014) Average Flying Day Aircraft Operations

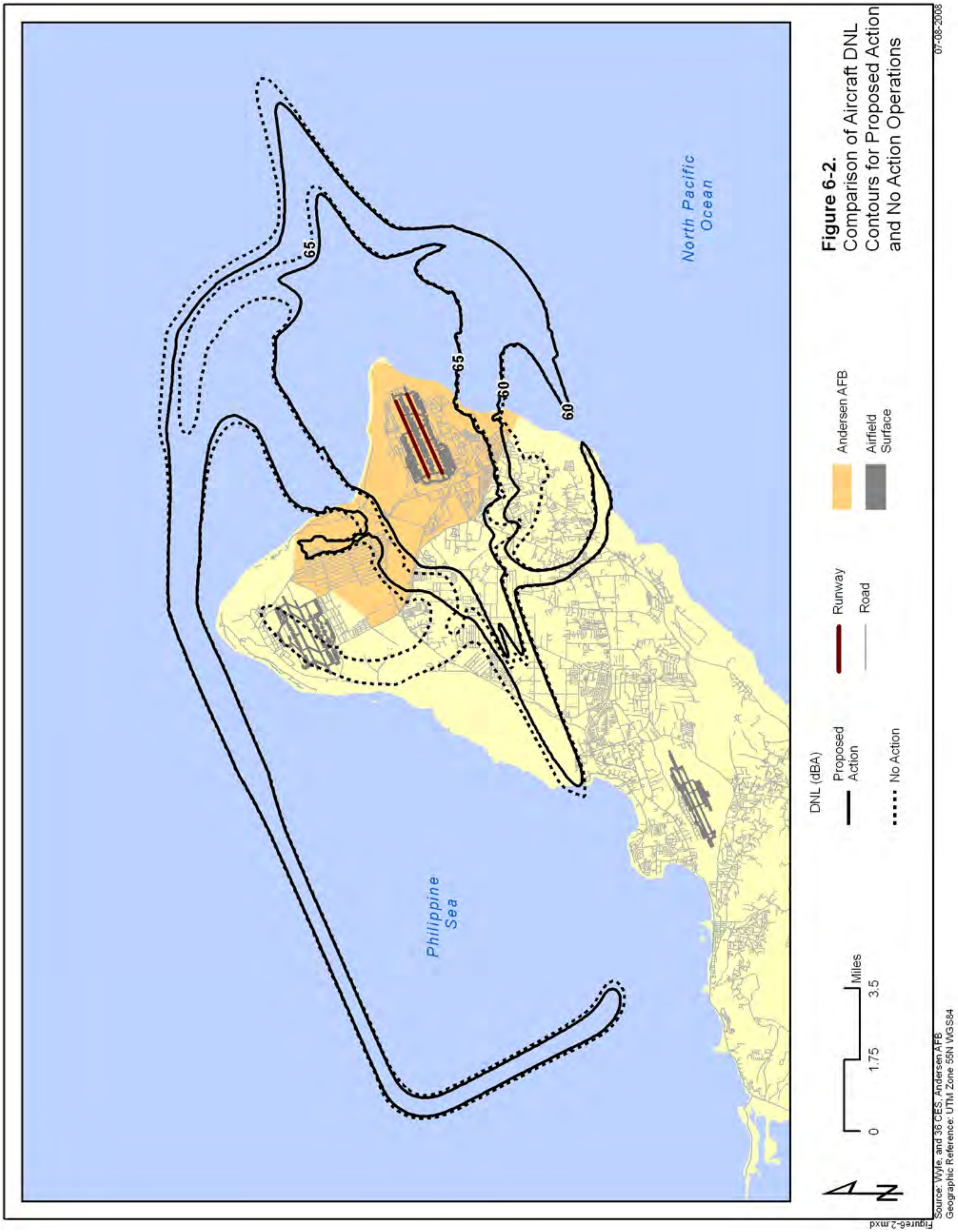

Figure 6-2. Comparison of Aircraft DNL Contours for Proposed Action and No Action Operations

DEPARTMENT OF THE ARMY
US ARMY CENTER FOR HEALTH PROMOTION AND PREVENTIVE MEDICINE
5158 BLACKHAWK ROAD
ABERDEEN PROVING GROUND MD 21010-5403

MCHB-TS-EON

26 AUG 2009

MEMORANDUM FOR Navy Facilities Engineering Command, Pacific (Environmental Planning Branch/Mr. Kyle Fujimoto), 258 Makalapa Drive, Suite 100, Pearl Harbor, HI 96860

SUBJECT: Operational Noise Consultation, No. 52-EN-0BVU-09, Operational Noise Contours for Proposed Range Development at Guam and Tinian, August 2009.

1. We are enclosing 2 copies of the consultation.

2. Please contact us if this consultation or any of our services did not meet your needs or expectations.

3. The point of contact is Ms. Kristy Broska, Environmental Protection Specialist or Ms. Catherine Stewart, Program Manager, Operational Noise, USACHPPM, at DSN 584-3829, Commercial (410) 436-3829, or email: kristy.broska@us.army.mil or catherine.stewart@us.army.mil.

FOR THE COMMANDER:

Encl

DONALD F. ARCHIBALD
COL, MS
Director, Environmental Health Engineering

U.S. Army Center for Health Promotion and Preventive Medicine

USACHPPM

OPERATIONAL NOISE CONSULTATION
NO. 52-EN-0BVU-09
OPERATIONAL NOISE CONTOURS
PROPOSED RANGE DEVELOPMENT
GUAM AND TINIAN
AUGUST 2009

Distribution authorized to U.S. Government agencies only; protection of privileged information evaluating another command; August 09. Other requests for this document shall be referred to Navy Facilities Engineering Command, Pacific (Environmental Planning Branch/Mr. Kyle Fujimoto), 258 Makalapa Drive, Suite 100, Pearl Harbor, HI 96860

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EXECUTIVE SUMMARY
OPERATIONAL NOISE CONSULTATION
NO. 52-EN-0BVU-09
OPERATIONAL NOISE CONTOURS
PROPOSED RANGE DEVELOPMENT
GUAM AND TINIAN
AUGUST 2009

1. PURPOSE. To provide the Navy Facilities Engineering Command, Pacific (NAVFAC PAC) noise contours for proposed range development at Guam and Tinian.

2. CONCLUSIONS.

a. Guam Training Ranges.

(1) Northwest Field Weapons. The existing and projected "busy day" C-weighted average sound Day Night Level (CDNL) Noise Zone II (62 decibels (dB) CDNL) and Noise Zone III (70 dB CDNL) contours do not extend beyond the Andersen Air Force Base (AFB) boundary. The contours remaining on base indicate that annual average noise levels from the demolition activity are compatible with the surrounding environment. Yet, there is potential for individual events to cause annoyance and possibly generate noise complaints.

(2) Andersen South.

(a) Breacher Facility and Hand Grenade Range Alternative 1. Under the Breacher Facility and the Hand Grenade Alternative 1 location, the "busy day" CDNL Noise Zone II (62 dB CDNL) extends into a small portion of the non-military land between Andersen South and the Route 15 Land. Based upon the available aerial image, there appears to be no noise sensitive land uses in this area. The Noise Zone III (70 dB CDNL) contour does not extend beyond the Andersen South boundary. The contours remaining on base indicate that annual average noise levels from the demolition activity are compatible with the surrounding environment. Yet, there is potential for individual events to cause annoyance and possibly generate noise complaints.

(b) Breacher Facility and Hand Grenade Range Alternative 2. Under the Breacher Facility and the Hand Grenade Alternative 2 location, multiple residential areas exist within the "busy day" Noise Zone II (62 dB CDNL) contour. The Noise Zone III (70 dB CDNL) contour extends into the non-military land between Andersen South and the Route 15 Land. There may be a small number of residences within the Noise Zone III (70 dB CDNL) contour.

(c) Small Caliber Weapons Activity. The proposed Route 15 Alternatives would generate PK15(met) Noise Zone II (87 dB) and Zone III (104 dB) contours that extend beyond the Andersen South boundary and the Route 15 Land. Under the Route 15 Alternatives, existing residential areas would fall within the Noise Zone II (87 dB PK15[met]) contour. There may be scattered residences within the Noise Zone III (104 dB PK15[met]) contour.

(d) Grenade Launcher Activity. The proposed grenade launcher activity would be audible at the boundary but unlikely loud enough to generate complaints.

(e) Mitigation Potential. Small Arms Noise Zones are based on peak levels and computed using the loudest weapon fired at each location. Since the .50 caliber is significantly louder than the other rounds used for the assessment, though the contours would remain the same size, limiting the hours or number of days the .50 caliber is fired would lessen the noise impact on surrounding communities. Additionally, further modeling could be run to investigate if incorporating barriers into the range designs would lessen the number of noise sensitive receptors within the Noise Zones.

b. Tinian Training Ranges. The proposed small caliber weapon activity alternatives would generate PK15(met) Noise Zone II (87 dB) and Noise Zone III (104 dB) contours that extend beyond the Tinian Training Range boundary. However, there are no noise sensitive land uses within the noise contours.

3. RECOMMENDATIONS.

a. Include the information from this consultation in the appropriate National Environmental Policy Act documentation.

b. Although no Federal Law prohibits the Department of Defense training and testing activities from making noise, the Services have always tried to be good neighbors. To reduce the risk of noise complaints from the proposed activity, the NAVFAC PAC should use the U.S. Army's Operational Noise Management Program guidance in conjunction with the Air Force's Air Installation Compatible Use Zone program to address the impulsive noise events.

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OPERATIONAL NOISE CONSULTATION
NO. 52-EN-0BVU-09
OPERATIONAL NOISE CONTOURS
PROPOSED RANGE DEVELOPMENT
GUAM AND TINIAN
AUGUST 2009

1. REFERENCES. A list of the references used in this consultation is in Appendix A. A glossary of terms and abbreviations used are in Appendix B. Appendix C contains the Noise Zone Descriptions and Land Use Guidelines used in this consultation.

2. AUTHORITY. The Navy Facilities Engineering Command, Pacific (NAVFAC PAC) funded this consultation.

3. PURPOSE. To provide the NAVFAC PAC noise contours for the proposed range development for use in the appropriate Guam and Tinian National Environmental Policy Act (NEPA) documentation.

4. NOISE CONTOURING PROCEDURES.

a. Demolition Activity.

(1) The noise simulation program used to assess the demolition, explosive, and hand grenade noise is the Blast Noise Impact Assessment (BNOISE2) program (U.S. Army 2003a). The BNOISE2 program requires operational data concerning the location of the range, the quantity and type explosives and hand grenades utilized. Due to the limited number of operational days per year, the C-weighted average sound Day Night Level (CDNL) noise contours were developed based upon a “busy day” scenario. The use of a “busy day” scenario is twofold, it provides an up tempo training scenario and ensures the calculated noise levels are not diluted by periods of low or non-existent activity.

(2) To predict the risk of complaints for the demolition and hand grenade operations, PK15(met) contours were developed. The complaint risk contours are based on peak levels rather than a cumulative or average level, therefore the size of the contours will not change if the number of detonations increases or decreases.

b. Small Caliber Activity. The noise simulation program used to assess small caliber weapons (.50 caliber and below) noise is the Small Arms Range Noise Assessment Model (SARNAM) (U.S. Army 2003b). The SARNAM program requires operational data concerning types of weapons and range layout. The contours for small arms operations were created using PK15(met) as prescribed in Army Regulation (AR) 200-1 (U.S. Army 2007). The contours show the predicted peak levels for individual rounds (metric term is PK15(met)). Since the contours are based on peak levels rather than a cumulative or average level, the size of the contours will not change if the number of rounds fired increases.

5. GUAM TRAINING RANGES – NORTHWEST FIELD WEAPONS (NFW).

a. General. The NFW is a field exercise training area located in the northern area of Andersen Air Force Base (AFB). Appendix D shows the location of the Guam Training Ranges.

b. Existing Demolition Activity. Table 1 lists the ammunition expenditure utilized to develop the CDNL noise contours at NFW. The facility is utilized during daytime hours (0700 – 2200) approximately 25 days per year.

TABLE 1. NORTHWEST FIELD WEAPONS – EXISTING DEMOLITION EXPENDITURE.

Explosive Type and Weight	**“Busy Day” Expenditure**	**Annual Expenditure**
	0700 – 2200 hours	0700 – 2200 hours
Ammonium Nitrate (40 pounds)	1	25

(1) Figure 1 contains the CDNL noise contours for the existing activity at the NFW. The Land Use Planning Zone (LUPZ) (57 decibel (dB) CDNL), Zone II (62 dB CDNL) and Zone III (70 dB CDNL) noise contours do not extend beyond the Andersen AFB boundary.

(2) Figure 2 contains the complaint risk noise contours for the NFW demolition activity. The moderate risk of complaint (115 dB PK15[met]) area extends approximately 1,300 meters beyond the Andersen AFB boundary into a residential area. The high risk of complaint (130 dB PK15[met]) area does not extend beyond the boundary.

c. Projected Demolition Activity. Table 2 lists the ammunition expenditure utilized to develop the projected CDNL noise contours at the NFW. The facility is utilized during daytime hours (0700 – 2200). Under the projected operating environment, the number of operational days would vary between 2 – 48 days per year dependant upon the unit and the type of training being conducted.

(1) Figure 3 contains the CDNL noise contours for the existing and projected activity at the NFW. The LUPZ (57 dB CDNL) noise contour extends slightly into the Naval Computer and Telecommunications Station (NCTS) Finegayan. The Zone II (62 dB CDNL) and Zone III (70 dB CDNL) noise contours do not extend beyond the Andersen AFB boundary.

(2) The projected operating environment complaint risk contours are identical to the existing operating environment as the largest explosive charge is the same (Figure 2).

TABLE 2. NORTHWEST FIELD WEAPONS – PROJECTED DEMOLITION EXPENDITURE.

Explosive Type and Weight	"Busy Day" Expenditure 0700 – 2200 hours	Annual Expenditure 0700 – 2200 hours
Ammonium Nitrate (40 pounds) [1]	0	25
Ammonium Nitrate (40 pounds) [2]	3	6
TNT (7 pounds) [3]	6	288
C-4 (0.5 pounds) [4]	6	288
Other (20 pounds TNT equivalent)	2	96

Note: TNT = Trinitrotoluene

[1] Existing cratering charge expenditure (1 per day, 25 days per year). Due to unit specific training, the existing cratering charges would not be conducted on the same day as the proposed cratering charges.

[2] Proposed expenditure (3 per day, 2 days per year).

[3] Estimated TNT charges (less than 20 pounds, average weight of 7 pounds per charge, 48 days per year).

[4] Estimated C-4 charges (0.5 pounds per soldier, 48 days per year).

d. Land Use Compatibility.

(1) Per AR 200-1, noise sensitive land uses, such as housing, schools, and medical facilities are acceptable within the Noise Zone I, normally not recommended in Noise Zone II, and not recommended in Noise Zone III (U.S. Army 2007). Based upon the available aerial images in Appendix D, land use near Andersen AFB is primarily residential.

(2) The "busy day" CDNL Noise Zone II and Noise Zone III contours do not extend beyond the Andersen AFB boundary. The contours remaining on base indicate that annual average noise levels from the demolition activity are compatible with the surrounding environment. Yet, there is potential for individual events to cause annoyance and possibly generate noise complaints.

e. Complaint Risk. The complaint risk guidelines indicate a moderate probability of receiving noise complaints from the NFW demolition activity.

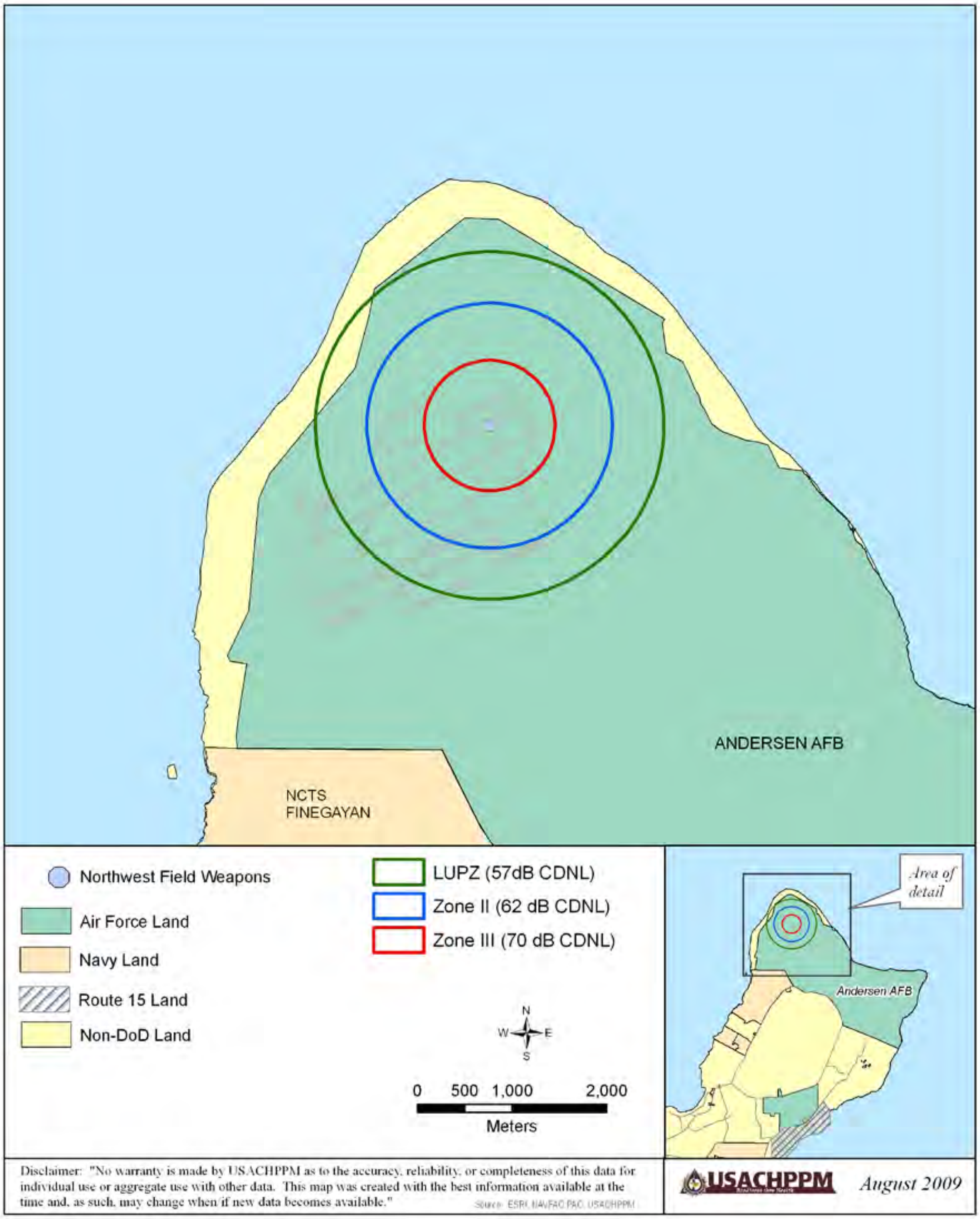

FIGURE 1. GUAM TRAINING RANGE – NORTHWEST FIELD WEAPONS EXISTING DEMOLITION OPERATIONAL NOISE CONTOURS

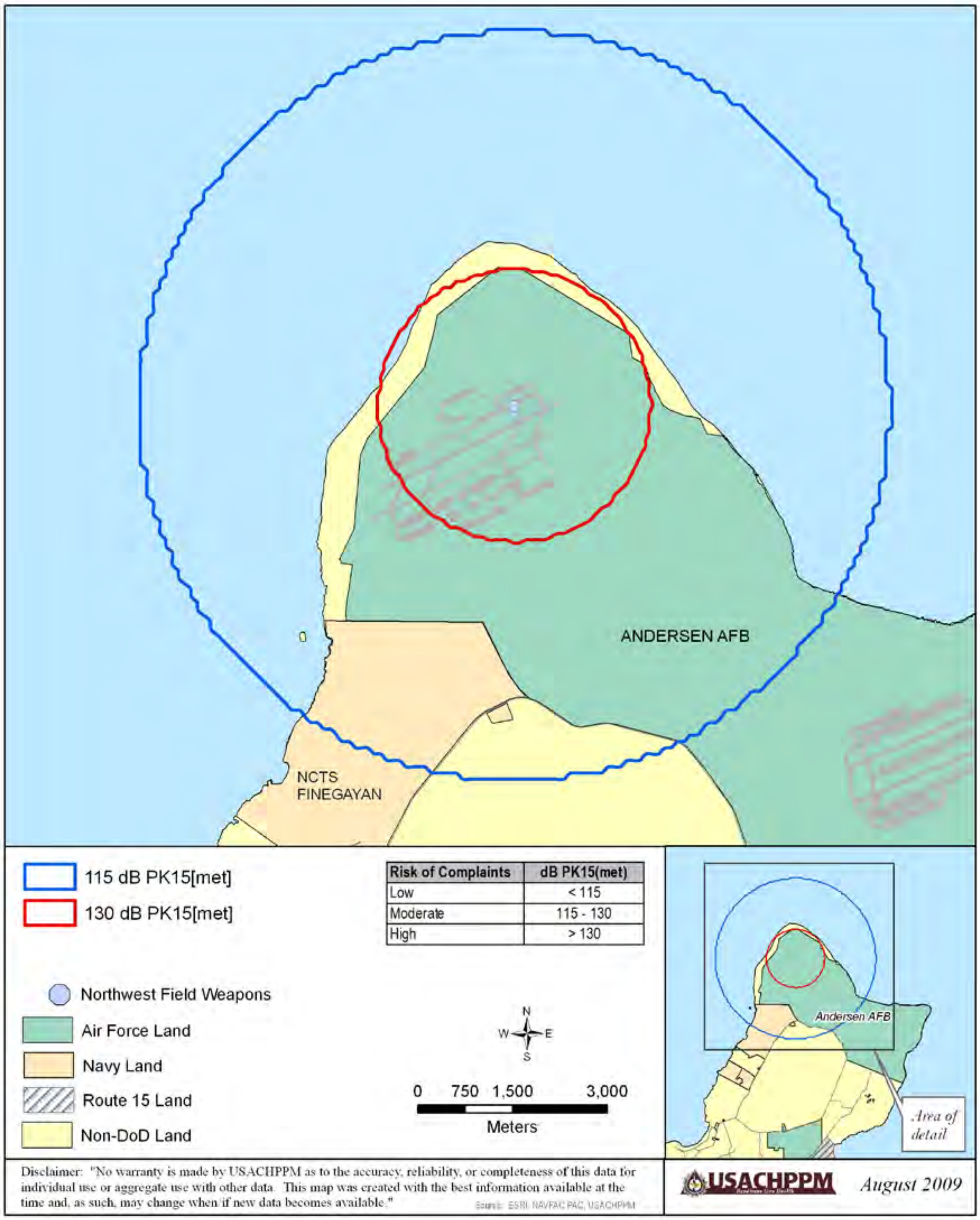

FIGURE 2. GUAM TRAINING RANGE - NORTHWEST FIELD WEAPONS COMPLAINT RISK CONTOURS

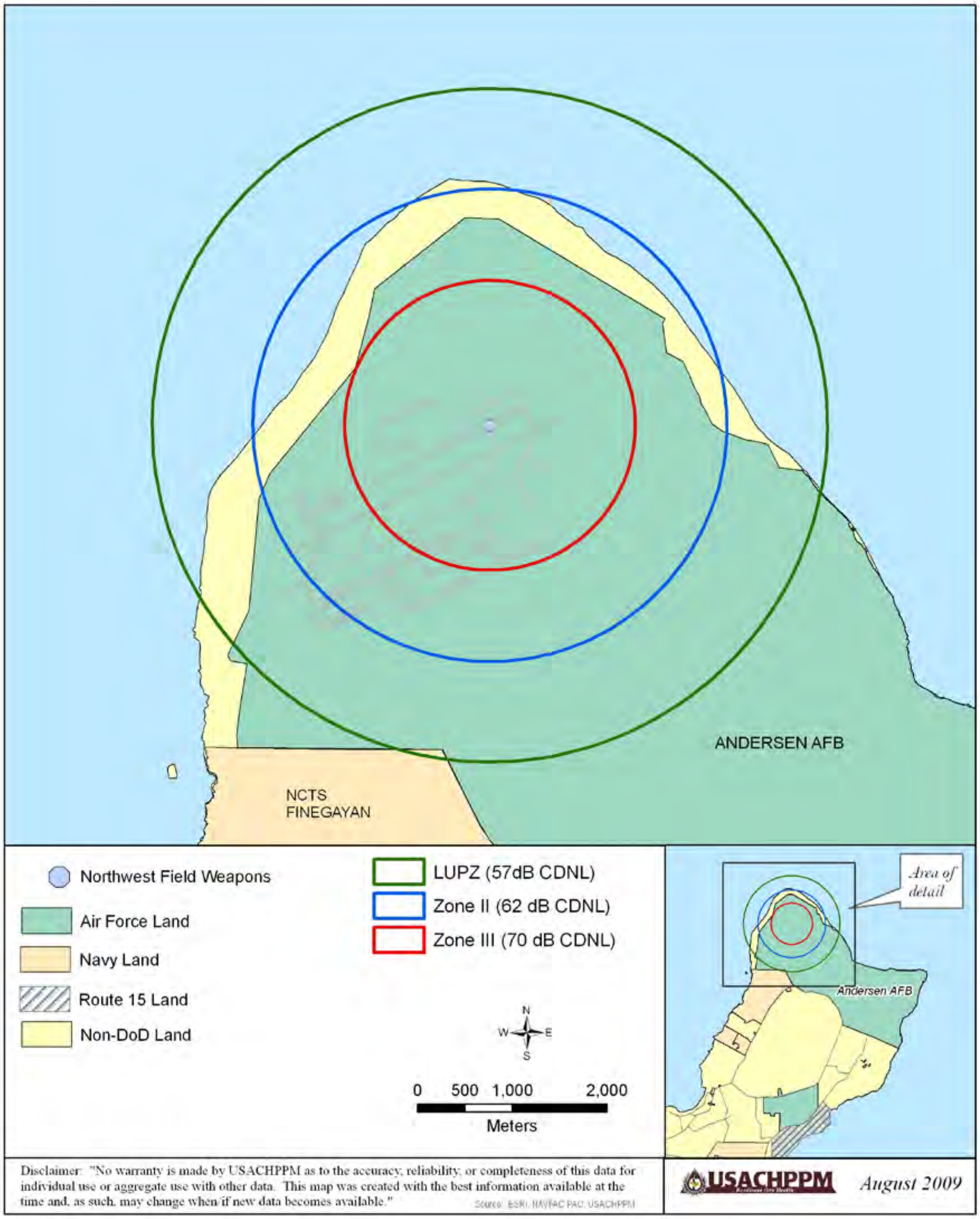

FIGURE 3. GUAM TRAINING RANGE – NORTHWEST FIELD WEAPONS PROJECTED DEMOLITION OPERATIONAL NOISE CONTOURS

6. GUAM TRAINING RANGES – ANDERSEN SOUTH TRAINING AREA.

a. Breacher Facility and Hand Grenade Range Noise Contour Results.

(1) General.

(a) The proposed Breacher Facility would consist of multiple existing structures. These structures would be utilized as a Military Operations in Urbanized Terrain (MOUT) training environment. The proposed activity is estimated at 36 days of utilization per year.

(b) The Hand Grenade Range consists of a hand grenade familiarization range and a hand grenade house with shock absorbing concrete walls. The proposed activity is estimated at 70 days of utilization per year with an average of 80 hand grenades per day.

(c) Table 3 lists the ammunition expenditure utilized to develop the CDNL noise contours. The facilities will be utilized during daytime hours (0700 – 2200).

TABLE 3. ANDERSEN SOUTH PROJECTED BREACHER FACILITY AND HAND GRENADE EXPENDITURE.

Facility	**Weapon**	**"Busy Day" Expenditure** 0700 – 2200 hours	**Annual Expenditure** 0700 – 2200 hours
Breacher Facility	TNT (0.25 pounds)	2	72
Familiarization Range	Hand Grenade, M67	54	3,780
Grenade House	Hand Grenade, M67	26	1,820

(2) Alternative 1 Layout.

(a) Figure 4 contains the noise contours for the projected activity for the Breacher Facility and the Hand Grenade Range Alternative 1 layout. The LUPZ (57 dB CDNL) noise contour extends beyond the Andersen South boundary in all directions. The Zone II (62 dB CDNL) extends into a small area of non-military land between the Andersen South boundary and the Route 15 Land. The Zone III (70 dB CDNL) noise contour extends into the Route 15 Land.

(b) Figure 5 contains the complaint risk noise contours for the Breacher Facility and the Hand Grenade Range Alternative 1 layout. The moderate risk of complaint (115 dB PK15[met]) area extends beyond the boundary in all directions. Land use within the moderate risk of complaint (115 dB PK15[met]) area varies, containing both undeveloped and residential areas. The high risk of complaint (130 dB PK15[met]) area extends into the Route 15 Land.

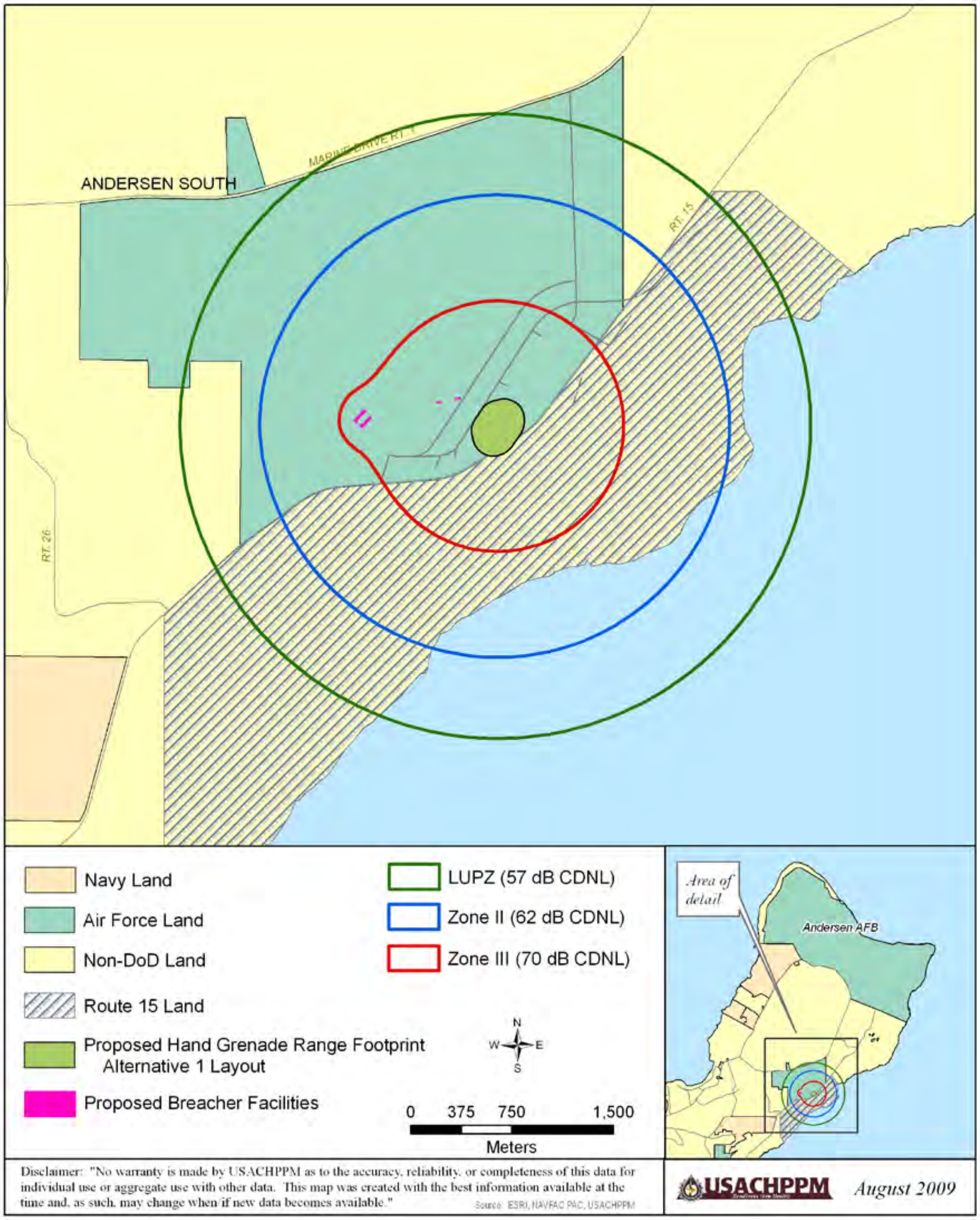

FIGURE 4. GUAM TRAINING RANGE - ANDERSEN SOUTH
BREACHER FACILITY AND HAND GRENADE RANGE ALTERNATIVE 1 LAYOUT
OPERATIONAL NOISE CONTOURS

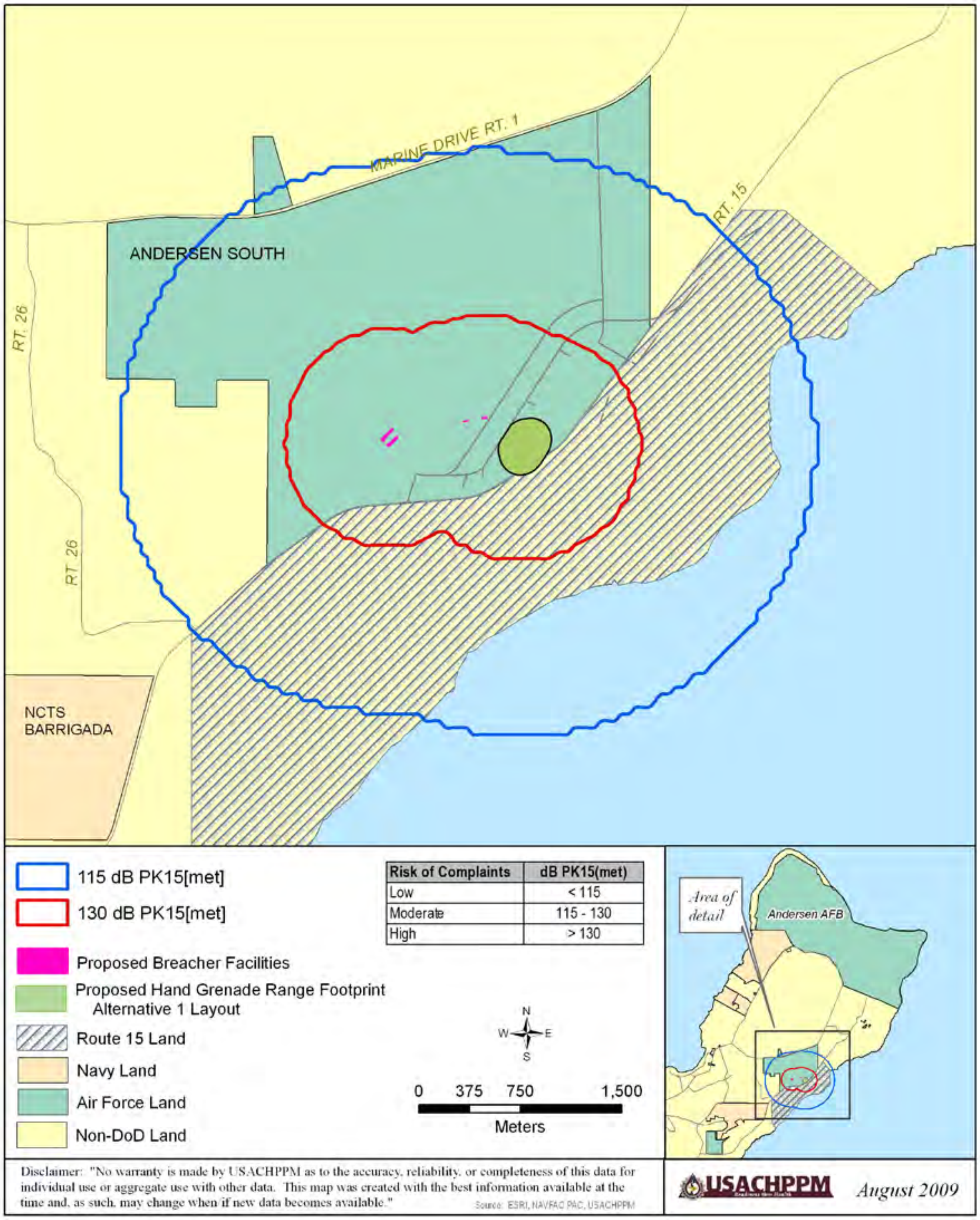

FIGURE 5. GUAM TRAINING RANGE - ANDERSEN SOUTH
BREACHER FACILITY AND HAND GRENADE RANGE ALTERNATIVE 1 LAYOUT
COMPLAINT RISK CONTOURS

(3) Alternative 2 Layout.

(a) Figure 6 contains the noise contours for the projected activity for the Breacher Facility and the Hand Grenade Range Alternative 2 layout. The LUPZ (57 dB CDNL) noise contour extends beyond the boundary in all directions. The Zone II (62 dB CDNL) noise contour extends approximately 1,000 meters beyond the eastern boundary, crossing Route 15 and less than 600 meters beyond the northern boundary. The Zone III (70 dB CDNL) noise contour extends into the non-military land between Andersen South and the Route 15 Land.

(b) Figure 7 contains the complaint risk noise contours for the Breacher Facility and the Hand Grenade Range Alternative 2 layout. The moderate risk of complaint (115 dB PK15[met]) area extends beyond the boundary in all directions. Land use within the moderate risk of complaint (115 dB PK15[met]) area varies, containing both undeveloped and residential areas. The high risk of complaint (130 dB PK15[met]) area extends into the non-military land between Andersen South and the Route 15 Land. Based upon the available aerial image land use within the high risk of complaint (130 dB PK15[met]) area is undeveloped.

(4) Land Use Compatibility.

(a) Per AR 200-1, noise sensitive land uses, such as housing, schools, and medical facilities are acceptable within the Noise Zone I, normally not recommended in Noise Zone II, and not recommended in Noise Zone III (U.S. Army 2007). Based upon the available aerial image shown in Appendix D, land use surrounding Andersen South area varies from undeveloped to residential.

(b) Under the Breacher Facility and the Hand Grenade Alternative 1 location, the "busy day" CDNL Noise Zone II (62 dB CDNL) extends into a small portion of non-military land between Andersen South and the Route 15 Land. Based upon the available aerial image there appears to be no noise sensitive land uses in this area. The Noise Zone III (70 dB CDNL) contours do not extend beyond the Andersen South boundary.

(c) Under the Breacher Facility and the Hand Grenade Alternative 2 location, multiple residential areas exist within the "busy day" Noise Zone II (62 dB CDNL) contour. The Noise Zone III (70 dB CDNL) contour extends into the non-military land between Andersen South and the Route 15 Land. There may be a small number of residences within the Noise Zone III (70 dB CDNL) contour.

(5) Complaint Risk. The complaint risk guidelines indicate a moderate probability of receiving noise complaints from the breacher facility activity. The complaint risk guidelines indicate a moderate probability of receiving noise complaints for the hand grenade activity from the Alternative 1 location. The complaint risk guidelines indicate a moderate to high probability of receiving noise complaints for the hand grenade activity from the Alternative 2 location.

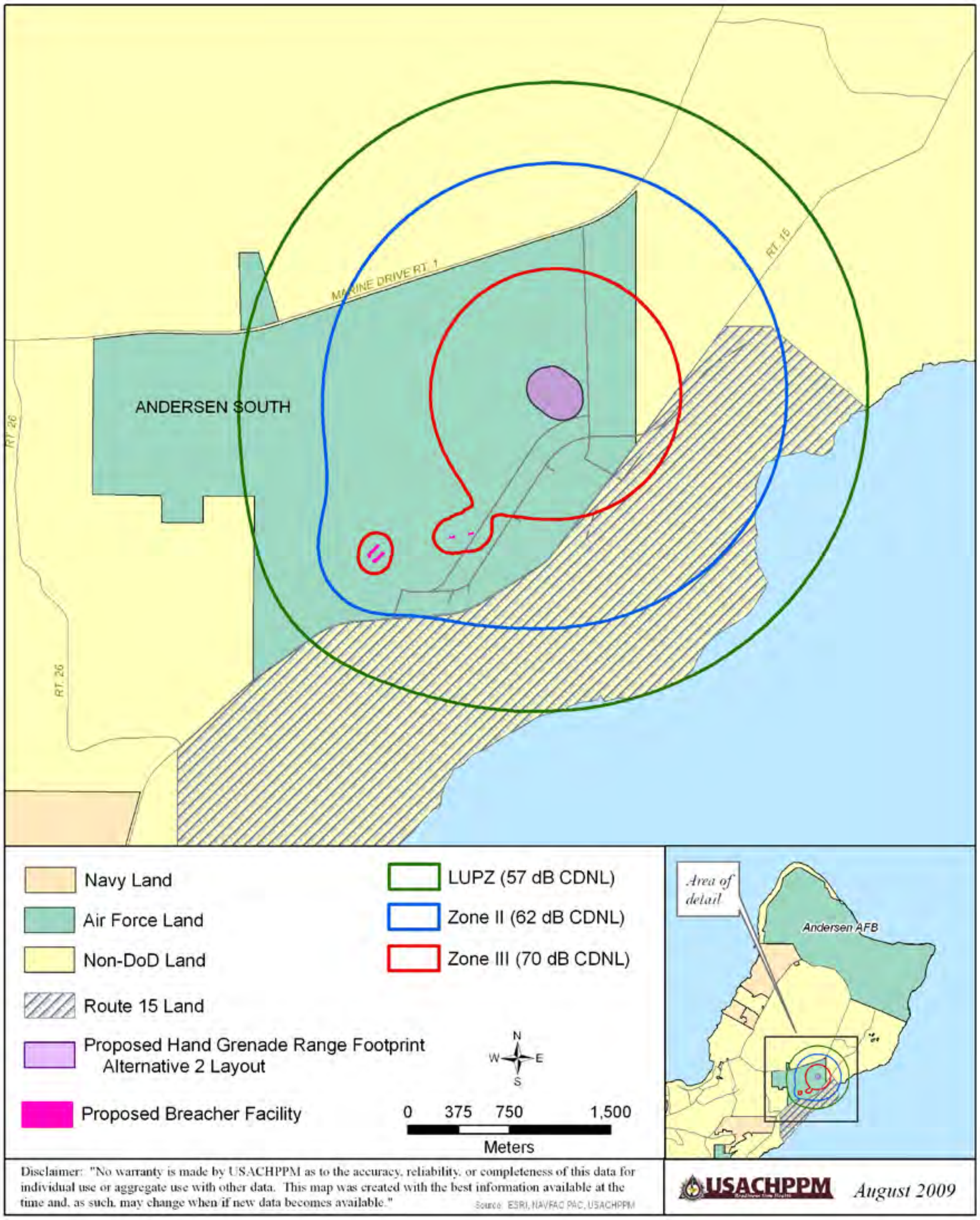

FIGURE 6. GUAM TRAINING RANGE - ANDERSEN SOUTH
BREACHER FACILITY AND HAND GRENADE RANGE ALTERNATIVE 2 LAYOUT
OPERATIONAL NOISE CONTOURS

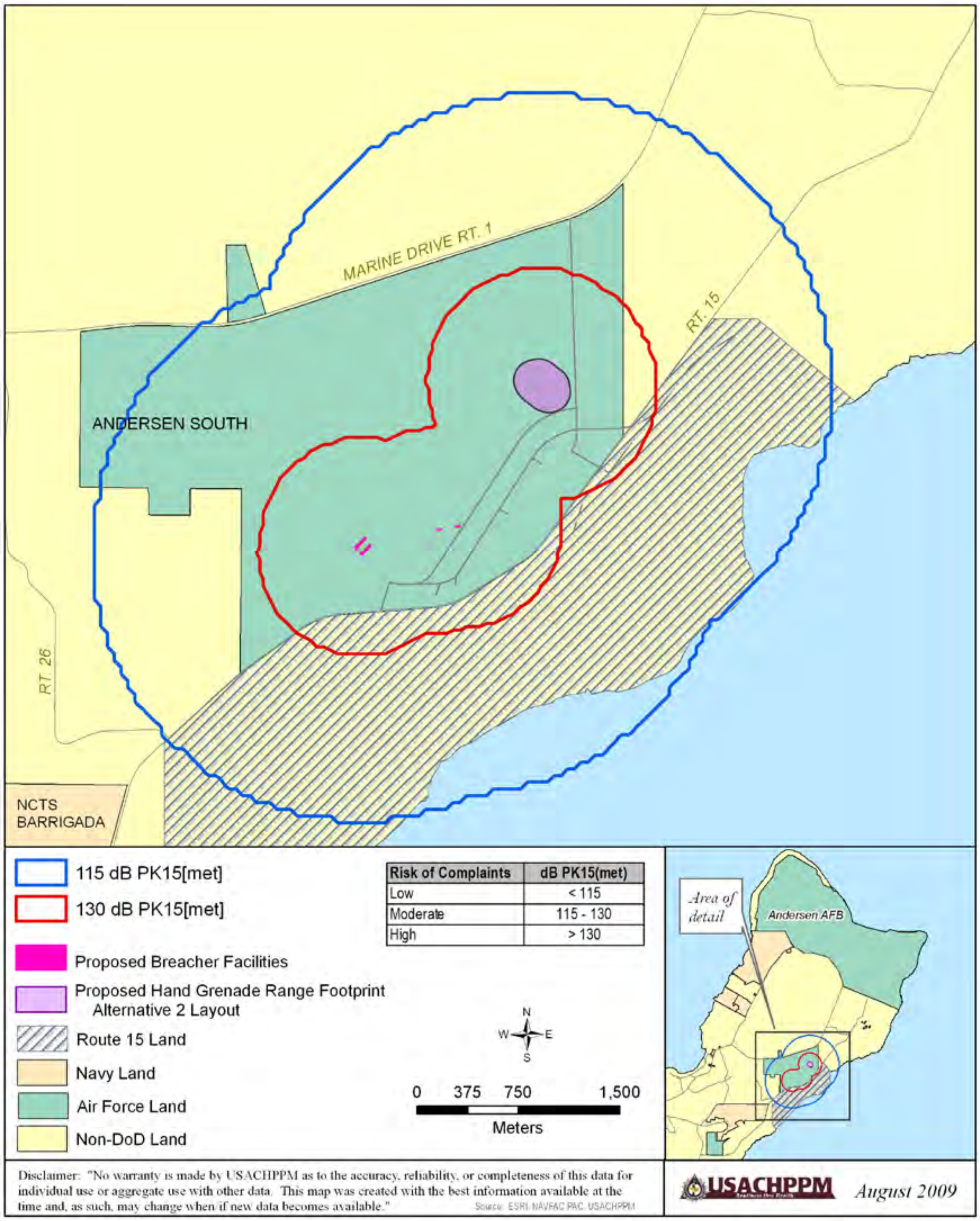

FIGURE 7. GUAM TRAINING RANGE - ANDERSEN SOUTH
BREACHER FACILITY AND HAND GRENADE RANGE ALTERNATIVE 2 LAYOUT
COMPLAINT RISK CONTOURS

b. Small Caliber Weapons Noise Contour Results.

(1) General. Table 4 lists the ranges and types of weapons utilized to create the projected small caliber weapons operational noise contours at the Andersen South training area.

TABLE 4. ANDERSEN SOUTH – PROJECTED SMALL CALIBER RANGE UTILIZATION.

	KD	MPMG	PISTOL	SQUARE BAY	UNKNOWN DISTANCE
PISTOL, 9mm			√	√	
PISTOL, .45 cal			√	√	
RIFLE, 5.56mm	√			√	√
MACHINE GUN, 7.62mm		√			
MACHINE GUN, .50 cal		√			

Note: cal = caliber, KD = Known Distance, mm = millimeter, MPMG = Multi-Purpose Machine Gun

(2) Route 15 Alternative A Layout. Figure 8 contains the small caliber weapons contours for the projected activity listed in Table 4 under the Route 15 Alternative A range layout. The Alternative A layout would generate a Zone II [PK15(met) 87 dB] noise contour that extends up to 4,000 meters beyond the eastern boundary of Andersen South and the Route 15 Land. The Zone III [PK15(met) 104 dB] noise contour extends approximately 100 meters beyond the eastern boundary of Andersen South and the Route 15 Land.

(3) Route 15 Alternative B Layout. Figure 9 contains the small caliber weapons contours for the projected activity listed in Table 4 under the Route 15 Alternative B range layout. The Alternative B layout would generate a Zone II [PK15(met) 87 dB] noise contour that extends 600 – 1,200 meters beyond the eastern boundary of Andersen South and the Route 15 Land. The Zone II [PK15(met) 87 dB] noise contour extends up to 1,400 meters beyond the western boundary of Andersen South and the Route 15 Land. The Zone III [PK15(met) 104 dB] noise contour extends less than 100 meters beyond the eastern boundary of Andersen South and the Route 15 Land. The Zone III [PK15(met) 104 dB] noise contour extends less than 70 meters beyond the western boundary of Andersen South and the Route 15 Land.

(4) Land Use Compatibility. Per AR 200-1, noise sensitive land uses, such as housing, schools, and medical facilities are acceptable within the Noise Zone I, normally not recommended in Noise Zone II, and not recommended in Noise Zone III (U.S. Army 2007). Based upon the available aerial image shown in Appendix D, residential areas would fall within the Noise Zone II [PK15(met) 87 dB] contour. There may be scattered residences within the Noise Zone III [PK15(met) 104 dB] contour.

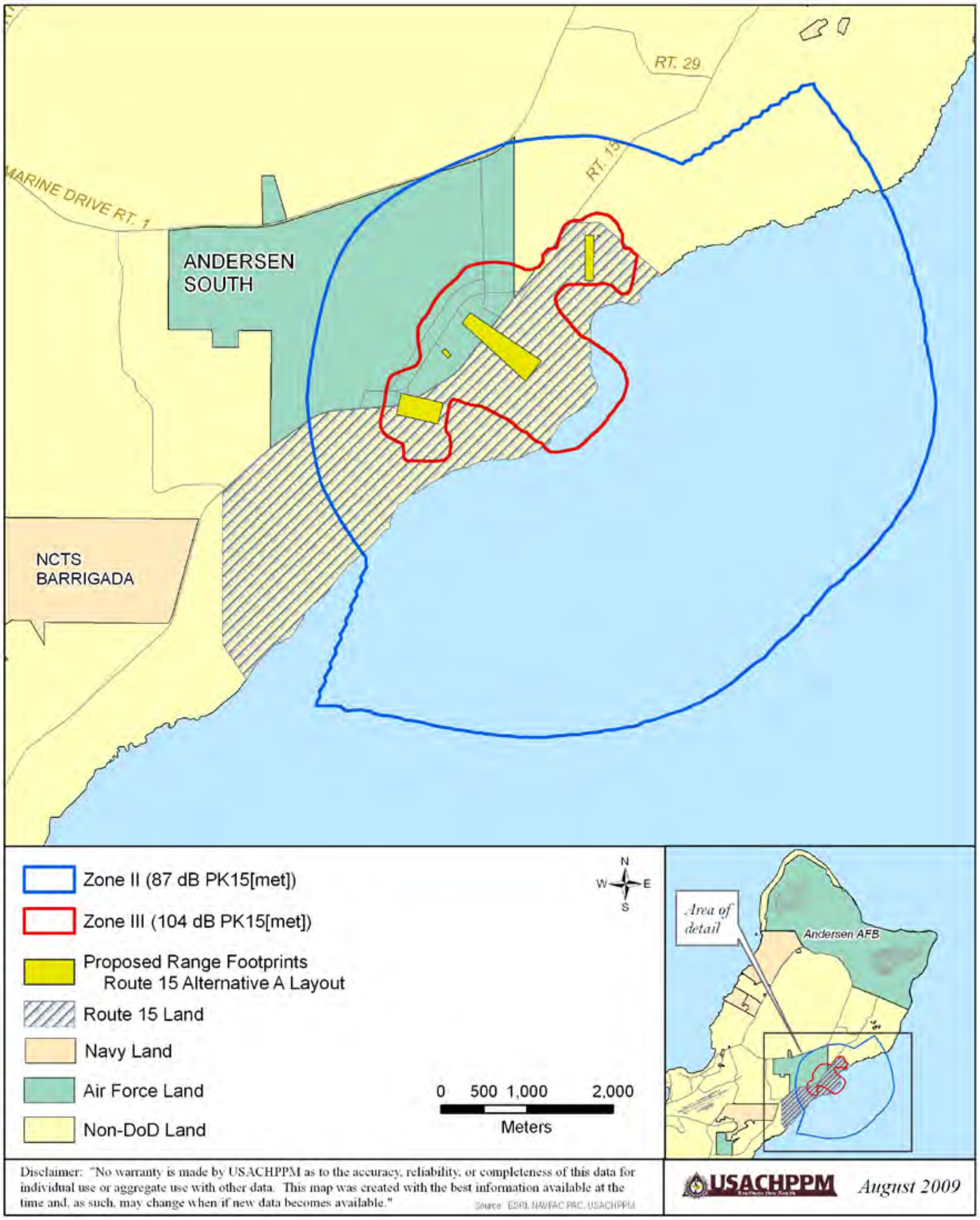

FIGURE 8. GUAM TRAINING RANGES - ROUTE 15 ALTERNATIVE A
PROJECTED SMALL CALIBER OPERATIONAL NOISE CONTOURS

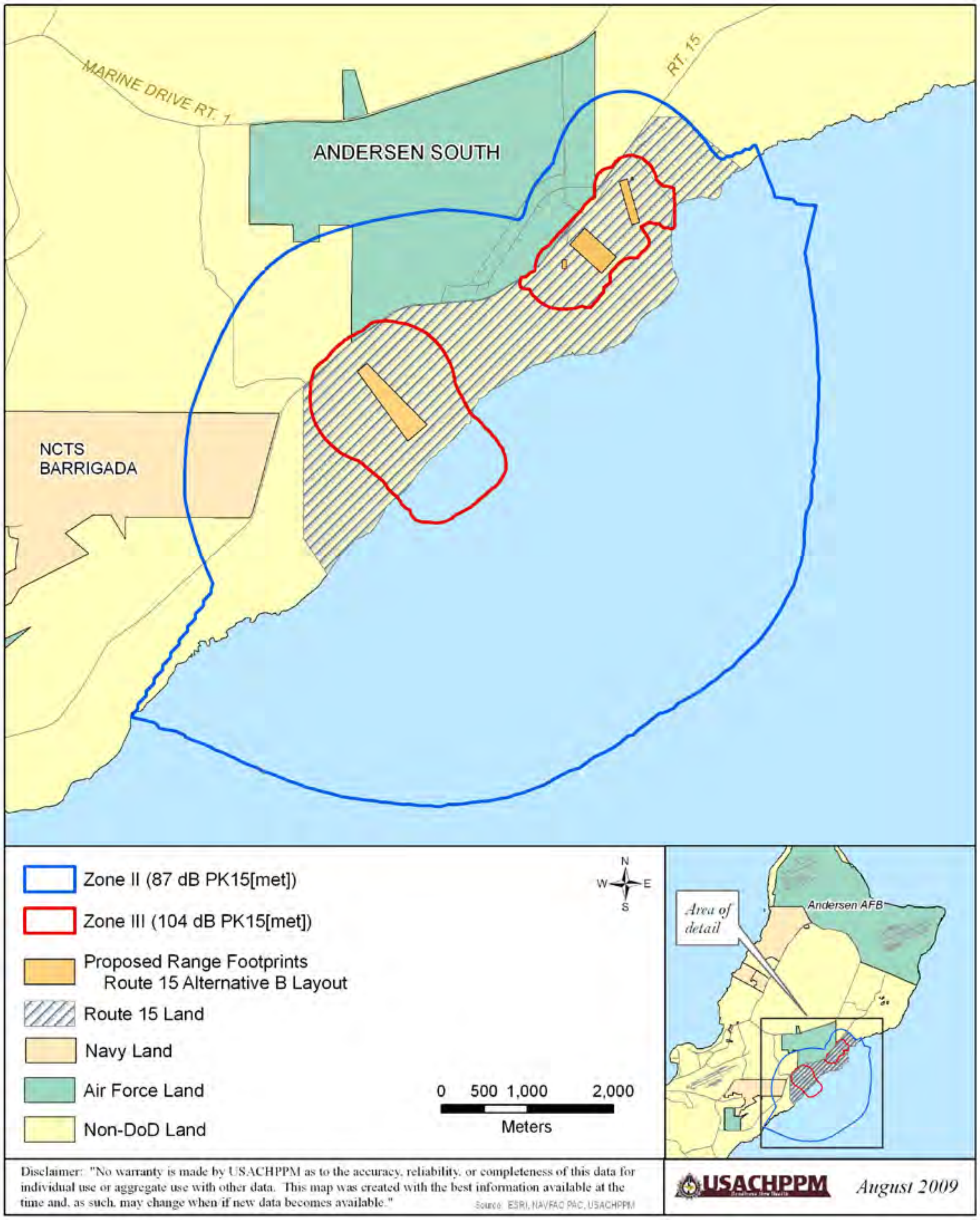

FIGURE 9. GUAM TRAINING RANGES - ROUTE 15 ALTERNATIVE B PROJECTED SMALL CALIBER OPERATIONAL NOISE CONTOURS

c. Shoot House Small Caliber Weapons Noise. The structures utilized in the Breacher Facility would also be utilized as Shoot Houses in the MOUT training environment. The proposed shoot houses are more than 850 meters from the boundary. The proposed weapon utilization would consist of the 12 gauge shot gun and 5.56mm rifle.

(1) To generate contours using SARNAM, specific firing point and target point locations must be entered into the computer. At a MOUT facility, there are no set firing point or target point locations; firing can occur at multiple locations and in multiple directions of fire. Therefore, noise contours for MOUT activity can not be modeled using SARNAM. However, by looking at the predicted peak levels for an 5.56mm blank round in Table 5, we can see that noise approaching Zone II levels [PK15(met) 87 dB] would extend out approximately 200 meters. Table 6 contains the predicted peak levels for a 12 gauge shotgun. We can see that noise approaching Zone II levels [PK15(met) 87 dB] would extend out approximately 800 meters.

TABLE 5. PREDICTED PEAK FOR 5.56mm BLANK ROUND.

	Predicted Level, dBP Azimuth		
Distance, meters	**0°**	**90°**	**180°**
100	87-97	86-96	87-97
200	80-90	79-89	80-90
400	69-79	68-78	69-79

Note: the 0° is directly in front of the weapon and the 180° azimuth is directly behind the weapon.

TABLE 6. PREDICTED PEAK FOR 12 GAUGE SHOTGUN.

	Predicted Level, dBP Azimuth		
Distance, meters	**0°**	**90°**	**180°**
100	117-127	105-115	106-116
200	110-120	98-108	100-110
400	99-109	88-98	90-100
800	90-100	79-89	82-92

Note: the 0° is directly in front of the weapon and the 180° azimuth is directly behind the weapon.

(2) Based upon the location of the Shoot Houses, the areas that could be exposed to Zone II levels from the small caliber operations do not extend beyond the Andersen South boundary.

7. MITIGATION TECHNIQUES TO REDUCE SMALL CALIBER WEAPONS NOISE LEVELS.

a. General. Small caliber PK15(met) contours are modeled to depict noise levels from individual weapons using weather conditions or wind direction that favors sound propagation. Gunshots are impulsive in nature and occur over a very short period in time, only a few thousandths of a second. The peak sound pressure level, PK, is defined as the level, expressed in decibels, of the highest instantaneous sound pressure that occurs during a given time period. Unlike topographic contours, noise contours are not intended to be precise representations of the noise zones. Meteorology and the receiver's perception of the source, etc. can influence the impact of noise. Noise contours do not clearly divide noise zones with one side of the line compatible and the other side incompatible.

b. Mitigation Potential- Operational.

(1) Small Arms Noise Zones are based on peak levels and computed using the loudest weapon fired at each location. Since the .50 caliber is significantly louder than the other rounds used for the assessment, though the contours would remain the same size, limiting the hours or number of days the .50 caliber is fired would lessen the noise impact on surrounding communities.

(2) Investigate the possibility of using the .50 caliber plastic bullet in place of the .50 caliber ball round. The acoustical energy “noise” from the .50 caliber plastic bullet is similar to the 7.62mm round. Although the Noise Zone II contour using the .50 caliber plastic bullet would still extend into the residential areas, the size of the Noise Zone II contour would be smaller.

c. Mitigation Potential- Physical Barrier.

(1) Barriers can be effective for small caliber weapons noise. The height of an effective noise reduction barrier must be considerably larger than the predominant wavelength, but the required height also depends on the barrier location relative to the source and the receiver, and on the amount of sound reduction that is needed to achieve the desired sound level. To be effective, barrier dimensions must be larger compared to the noise wavelength of the small caliber weapons utilized. The predominate frequency of the muzzle blast energy for the .50 caliber ball round is around 350 Hertz (Hz); wave length is about 1 meter (3 feet) high. The predominate frequency of muzzle blast energy for the 7.62mm and 5.56mm ball rounds is around 1000 Hz; wave length is about 1/3 meter (1 foot) high.

(2) The utility of constructing noise barriers in the vicinity of the MPMG, CPQC and KD ranges was investigated. The objective of this effort was to study the effectiveness of a barrier to reduce noise levels as well as to identify its dimensions. The SARNAM model (U.S. Army 2003b) was used to estimate the noise reduction that could be achieved with the placement of an earthen berm between the ranges and the residential areas. The SARNAM model is an analytical approximation of experimental data; the results provided by the formulation are consistent with the results of optical diffraction theory. Three sound diffraction paths are considered in the SARNAM: over the barrier, around the left side of the barrier, and around the right side of the barrier.

(3) As an indicator to the potential effectiveness of a barrier in noise reduction, one barrier design was analyzed for the CPQC and KD ranges and one barrier design for the MPMG ranges. Further modeling could be run to investigate if incorporating other barrier designs into the range would lessen the number of noise sensitive receptors within the Noise Zones.

(a) CPQC and KD Range Barrier Design. Based upon the location of the proposed ranges and the residential areas, a 3 meter high earthen berm would need to be constructed 3 meters behind the firing line; the berm would need to be the full width (uninterrupted) of the CPQC and KD range footprints, and extending 5 meters to either side of the range footprint (Figure 10). Although the layout for Alt A is shown in the figure, the barrier design would be the same for the CPQC and KD range locations in Alt B. Based upon the projected CPQC and KD range activity and location, a barrier of this design has the potential to provide up to 15 dB noise reduction.

(b) MPMG Range Barrier Design. Based upon the location of the proposed ranges and the residential areas, two earthen berms 3 meters high would need to be constructed for the MPMG range. One berm would be needed 3 meters behind the firing line and extending the full width (uninterrupted) of the MPMG range and extending 5 meters past the range footprint. A second berm would be needed along side of the range between the range footprint and the residential area. This side berm would need to join the berm behind the firing line and be 500 meters long (Figure 11). Although the layout for Alt B is shown in the figure, the barrier design would be the similar for the Alt A layout, with the side berm being constructed to the left side of the range (from the firing line point of view). Based upon the projected MPMG range activity and location, a barrier of this design has the potential to provide up to 10 dB noise reduction.

(c) Summary. The barrier designs presented have the potential to provide approximately a 10 -15 dB noise reduction dependant upon the weapon. However, construction barriers of this size may be cost prohibitive. Additionally, construction of a berm along side of the MPMG range may be limited in size or prohibited from a safety stand point.

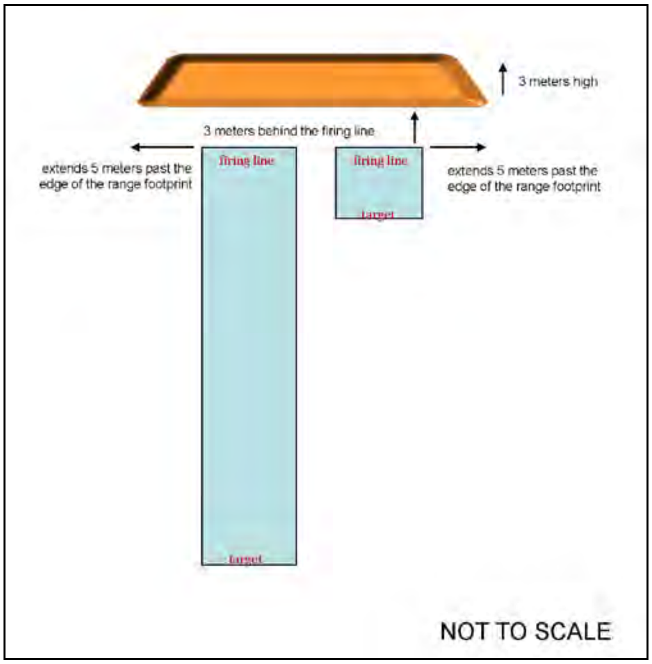

FIGURE 10. POTENTIAL BARRIER DESIGN FOR THE CPQC AND KD RANGES.

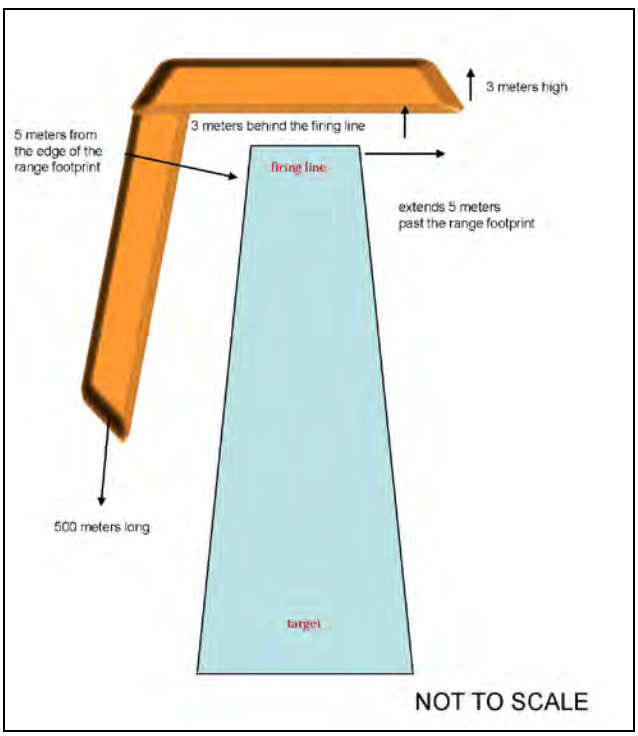

FIGURE 11. POTENTIAL BARRIER DESIGN FOR THE MPMG RANGES.

8. TINIAN TRAINING RANGES.

a. General. Appendix E shows the location of the proposed Tinian Training Ranges. The 90th Street Option 1 is referred to as Alternative 1; the 90th Street Option 2 is referred to as Alternative 2; and the West Field Option is referred to as Alternative 3. Table 7 lists the ranges and types of weapons utilized to create the projected activity operational noise contours at the Tinian Training Ranges.

TABLE 7. TINIAN – PROJECTED SMALL CALIBER RANGE UTILIZATION.

	CPQC	FIELD FIRE	KD	IPBC
PISTOLS, 9mm, .45 caliber	√			
RIFLE, 5.56mm		√	√	√

Note: CPQC = Combat Pistol Qualification Course, KD = Known Distance,
IPBC = Infantry Platoon Battle Course, mm = millimeter

b. Small Caliber Weapons Noise Contour Results.

(1) Alternative 1 Layout. Figure 12 contains the small caliber weapons contours for the projected activity under the Alternative 1 layout and the weapon utilization listed in Table 7. The Alternative 1 layout would generate a Zone II [PK15(met) 87 dB] noise contour that extends approximately 200 meters into the San Jose Airport property. The Zone III [PK15(met) 104 dB] noise contour does not extend beyond the Tinian Training Range area.

(2) Alternative 2 Layout. Figure 13 contains the small caliber weapons contours for the projected activity under the Alternative 2 layout and the weapon utilization listed in Table 7. The Alternative 2 layout generates a Zone II [PK15(met) 87 dB] noise contour that extends approximately 150 meters into the San Jose Airport property. The Zone III [PK15(met) 104 dB] noise contour does not extend beyond the Tinian Training Range area.

(3) Alternative 3 Layout. Figure 14 contains the small caliber weapons contours for the projected activity under the Alternative 3 layout and the weapon utilization listed in Table 7. The Alternative 3 layout generates a Zone II [PK15(met) 87 dB] noise contour that extends approximately 950 meters into the San Jose Airport property. The Zone III [PK15(met) 104 dB] noise contour extends approximately 200 meters into the San Jose Airport property.

c. Land Use Compatibility. Per AR 200-1, noise sensitive land uses, such as housing, schools, and medical facilities are acceptable within the Noise Zone I, normally not recommended in Noise Zone II, and not recommended in Noise Zone III (U.S. Army 2007). Under the Tinian alternatives, there are no noise sensitive land uses within the noise contours.

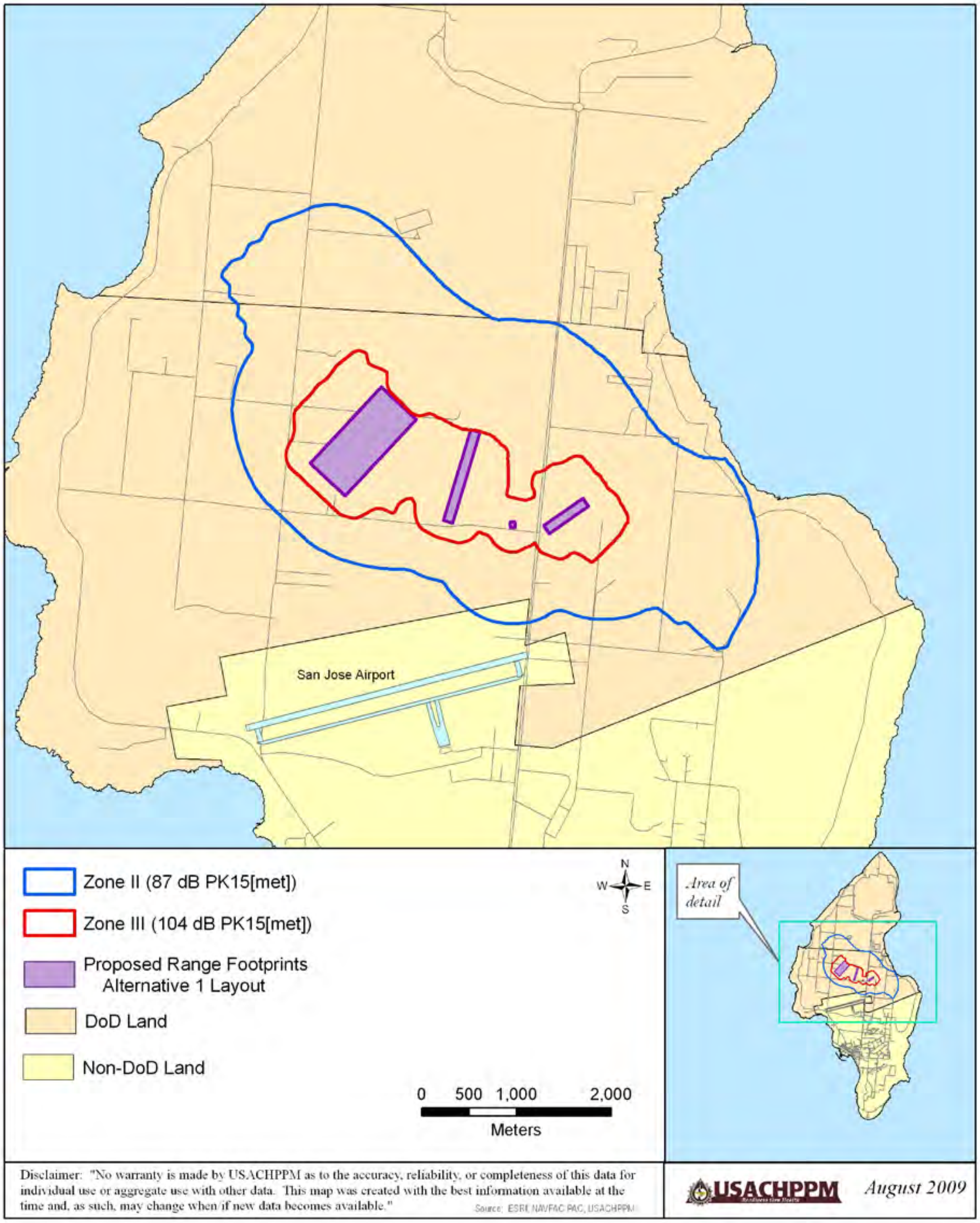

FIGURE 12. TINIAN TRAINING RANGE - ALTERNATIVE 1
PROJECTED SMALL CALIBER OPERATIONAL NOISE CONTOURS

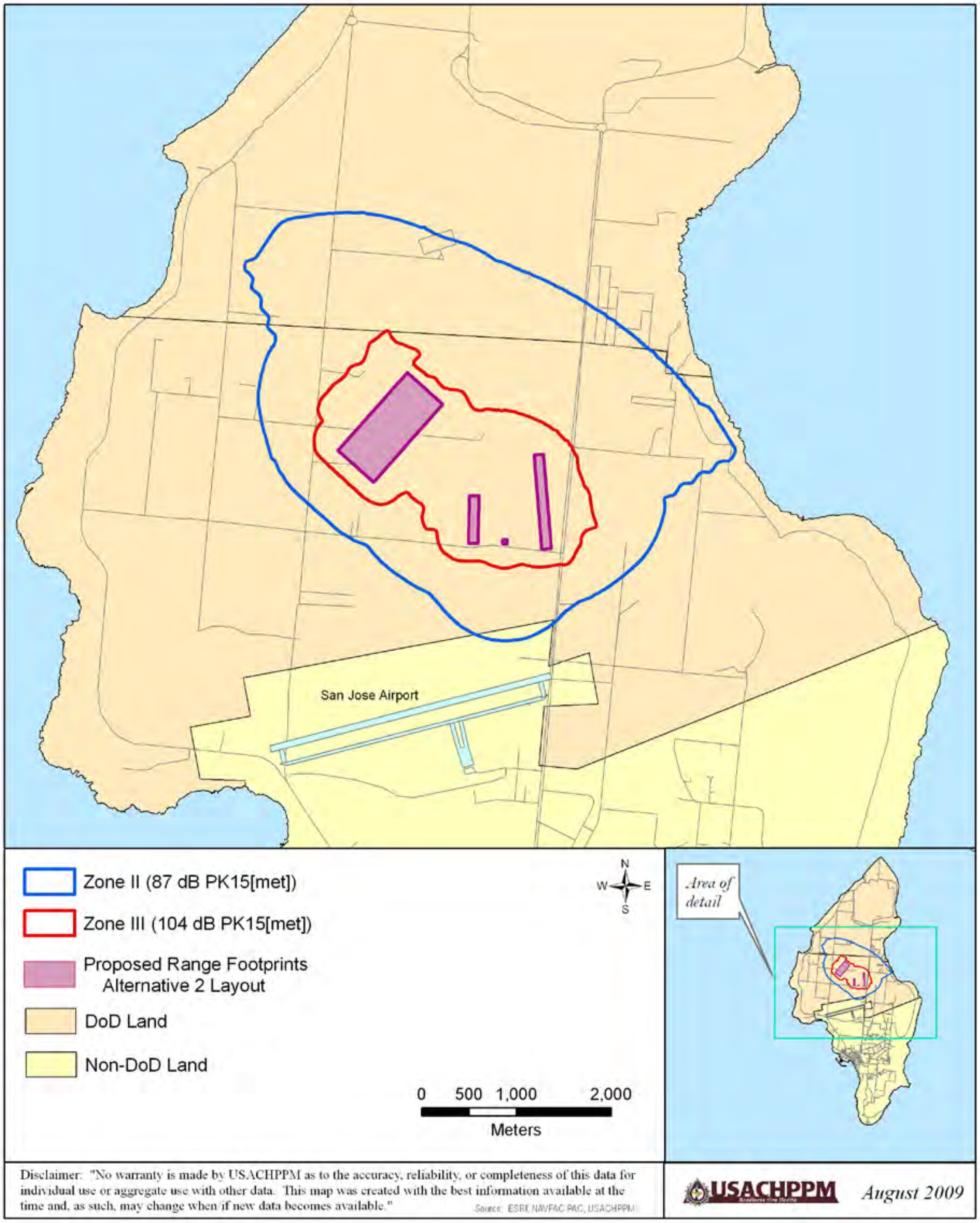

FIGURE 13. TINIAN TRAINING RANGE - ALTERNATIVE 2
PROJECTED SMALL CALIBER OPERATIONAL NOISE CONTOURS

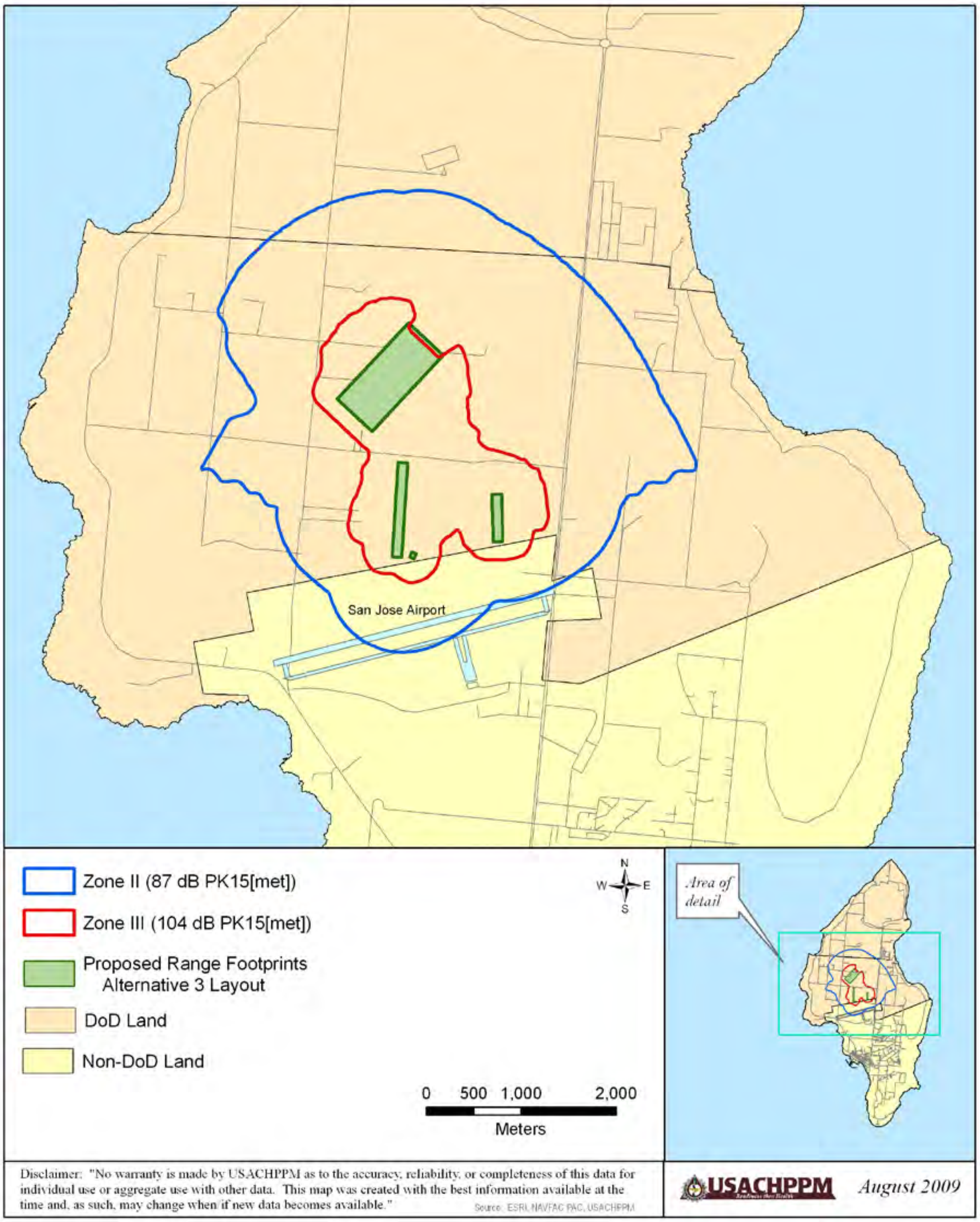

FIGURE 14. TINIAN TRAINING RANGE - ALTERNATIVE 3
PROJECTED SMALL CALIBER OPERATIONAL NOISE CONTOURS

9. GRENADE LAUNCHER.

a. Tables 8 and 9 contain the complaint risk criterion for the launch noise of the 40mm grenade launchers. The distances and levels listed represent a conservative approach and were calculated based upon hearing conservation criteria (U.S. Army 1999) and a known measurement (U.S. Army 1984). This data represents the best available scientific quantification for assessing the complaint risk for the launch noise of the 40mm grenade launcher until a detailed noise measurement study is completed.

TABLE 8. Complaint Risk to the Side of the 40mm Grenade Launcher, Inert* Round.

Risk of Complaints	Distance from Grenade Launcher	Noise Level PK15(met)
Low	> 300 meters^	< 115 dB
Moderate	65 - 300 meters^	115 dB
High	< 65 meters^	>130 dB
Risk of hearing damage for unprotected ears	< 19 meters+	>140 dB

** -- Inert is defined as any round that does not make noise upon impact, such as smoke, illum, TP*
^ – Calculated value
+ – Known value, hearing conservation criteria.

TABLE 9. Complaint Risk to the Rear of the 40mm Grenade Launcher, Inert* Round.

Risk of Complaints	Distance from Grenade Launcher	Noise Level PK15(met)
Low	> 110 meters^	< 115 dB
Moderate	25 - 110 meters^	115 dB
High	< 25 meters^	>130 dB
Risk of hearing damage for unprotected ears	< 7 meters+	>140 dB

** -- Inert is defined as any round that does not make noise upon impact, such as smoke, illum, TP*
^– Calculated value
+– Known value, hearing conservation criteria.

b. The proposed MPMG range activity may also include a 40mm grenade launcher. The proposed MPMG range locations at the Route 15 area are located such that the noise from the grenade launcher would be audible at the boundary. Both Route 15 alternative range locations are more than 300 meters from the rear of the grenade launcher to the boundary and 600 meters from the side of the grenade launcher to the boundary. The risk of complaints from the grenade launcher activity at the Route 15 Land area would be low.

10. CONCLUSIONS.

a. Guam Training Ranges.

(1) Northwest Field Weapons. The existing and projected "busy day" CDNL Noise Zone II (62 dB CDNL) and Noise Zone III (70 dB CDNL) contours do not extend beyond the Andersen AFB boundary. The contours remaining on base indicate that annual average noise levels from the demolition activity are compatible with the surrounding environment. Yet, there is potential for individual events to cause annoyance and possibly generate noise complaints.

(2) Andersen South.

(a) Breacher Facility and Hand Grenade Range Alternative 1. Under the Breacher Facility and the Hand Grenade Alternative 1 location, the "busy day" CDNL Noise Zone II (62 dB CDNL) extends into a small portion of non-military land between Andersen South and the Route 15 Land. Based upon the available aerial image there appears to be no noise sensitive land uses in this area. The Noise Zone III (70 dB CDNL) contours do not extend beyond the Andersen South boundary. The contours remaining on base indicate that annual average noise levels from the demolition activity are compatible with the surrounding environment. Yet, there is potential for individual events to cause annoyance and possibly generate noise complaints.

(b) Breacher Facility and Hand Grenade Range Alternative 2. Under the Breacher Facility and the Hand Grenade Alternative 2 location, multiple residential areas exist within the "busy day" Noise Zone II (62 dB CDNL) contour. The Noise Zone III (70 dB CDNL) contour extends into the non-military land between Andersen South and the Route 15 Land. There may be a small number of residences within the Noise Zone III (70 dB CDNL) contour.

(c) Small Caliber Weapons Activity. The proposed Route 15 Alternatives would generate PK15(met) Noise Zone II (87 dB) and Zone III (104 dB) contours that extend beyond the Andersen South boundary and the Route 15 Land. Under the Route 15 Alternatives, existing residential areas would fall within the Noise Zone II (87 dB PK15[met]) contour. There may be scattered residences within the Noise Zone III (104 dB PK15[met]) contour.

(d) Grenade Launcher Activity. The proposed grenade launcher activity would be audible at the boundary but unlikely to generate complaints.

(e) Mitigation Potential. Small Arms Noise Zones are based on peak levels and computed using the loudest weapon fired at each location. Since the .50 caliber is significantly louder than the other rounds used for the assessment, though the contours would remain the same size, limiting the hours or number of days the .50 caliber is fired would lessen the noise impact on surrounding communities. Additionally, further modeling could be run to investigate if incorporating barriers into the range designs would lessen the number of noise sensitive receptors within the Noise Zones.

b. Tinian Training Ranges. The proposed small caliber weapon activity alternatives would generate a PK15(met) Noise Zone II (87 dB) and Noise Zone III (104 dB) contours that extend beyond the Tinian Training Range boundary. However, there are no noise sensitive land uses within the noise contours.

11. RECOMMENDATIONS.

a. Include the information from this consultation in the appropriate NEPA documentation.

b. Although no Federal Law prohibits the Department of Defense training and testing activities from making noise, the Services have always tried to be good neighbors. To reduce the risk of noise complaints from the proposed activity, the NAVFAC PAC should use the U.S. Army's Operational Noise Management Program guidance in conjunction with the Air Force's Air Installation Compatible Use Zone program to address the impulsive noise events. (Appendix F).

Kristy Broska

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Environmental Protection Specialist
Operational Noise

APPROVED:

For: CATHERINE STEWART
Program Manager
Operational Noise

APPENDIX A

REFERENCES

1. U.S. Army, 2003a, U.S. Army Construction Engineering Research Laboratories, BNOISE2 Computer Model, Version 1.3.2003-07-03.

2. The U.S. Army, 2003b, U.S. Army Construction Engineering Research Laboratories, SARNAM Computer Model, Version 2.6.2003-06-06.

3. The U.S. Army, 2007, Army Regulation 200-1, Environmental Protection and Enhancement, Chapter 14 Operational Noise.

APPENDIX B

GLOSSARY OF TERMS, ACRONYMS & ABBREVIATIONS

B-1. GLOSSARY OF TERMS.

Average Sound Level - the mean-squared sound exposure level of all events occurring in a stated time interval, plus ten times the common logarithm of the quotient formed by the number of events in the time interval, divided by the duration of the time interval in seconds.

C-Weighted Sound Level - a quantity, in decibels, read from a standard sound level meter with C-weighting circuitry. The C-scale incorporates slight de-emphasis of the low and high portion of the audible frequency spectrum.

Day-Night Average Sound Level (DNL) - the 24-hour average frequency-weighted sound level, in decibels, from midnight to midnight, obtained after addition of 10 decibels to sound levels in the night from midnight up to 7 a.m. and from 10 p.m. to midnight (0000 up to 0700 and 2200 up to 2400 hours).

Decibels (dB) – a logarithmic sound pressure unit of measure.

Land Use Planning Zone (LUPZ) - DNL noise contours represent an annual average that separates the Noise Zone II from the Noise Zone I.

Noise – any sound without value.

PK15(met) - the maximum value of the instantaneous sound pressure for each unique sound source, and applying the 15 percentile rule accounting for meteorological variation.

B-2. GLOSSARY OF ACRONYMS AND ABBREVIATIONS.

AFB	Air Force Base
BNOISE2	Blast Noise Impact Assessment
cal	caliber
CPQC	Combat Pistol Qualification Course
dB	Decibels
CDNL	C-weight Day Night Level
IPBC	Infantry Platoon Battle Course
KD	Known Distance
mm	millimeter
MPMG	Multi-Purpose Machine Gun
NAVFAC PAC	Navy Facilities Engineering Command, Pacific
NCTS	Naval Computer and Telecommunications Station
NEPA	National Environmental Policy Act
NFW	Northwest Field Weapons
PK15(met)	Unweighted Peak, 15% Metric
SARNAM	Small Arms Range Noise Assessment Model
TNT	Trinitrotoluene

APPENDIX C

NOISE ZONE DESCRIPTIONS

C-1. REFERENCE. The U.S. Army, 2007, Army Regulation 200-1, Environmental Protection and Enhancement, Chapter 14 Operational Noise. The Air Force and the Navy uses the Army regulation in regards to noise from weapon activity.

C-2. For a detailed explanation of Noise Zone Descriptions and Land Use Guidelines see Army Regulation 200-1, Chapter 14 (U.S. Army 2007).

C-3. Day Night Level (DNL). The DNL is used to describe the cumulative or total noise exposure during a prescribed time period. The DNL is the energy average noise level calculated with a 10 decibel penalty for operations occurring between 2200 and 0700.

C-4. PK15(met) Noise Contour Description. The PK15(met) is the peak sound level, factoring in the statistical variations caused by weather, that is likely to be exceeded only 15 percent of the time (i.e., 85 percent certainty that sound will be within this range). This "85 percent solution" gives the installation and the community a means to consider the areas impacted by training noise without putting stipulations on land that would only receive high sound levels under infrequent weather conditions that greatly favor sound propagation. The PK15(met) does not take the duration or the number of events into consideration, so the size of the contours will remain the same regardless of the number of events.

C-5. Land Use Guidelines.

a. The Noise Zone III consists of the area around the noise source in which the level is greater than 70 decibels (dB) C-weighted day-night average sound level (CDNL) for large caliber weapons or greater than 104 dB PK15(met) for small caliber weapons. Noise-sensitive land uses (such as housing, schools, and medical facilities) are not recommended within Noise Zone III.

b. The Noise Zone II consists of an area where the DNL is between 62 and 70 dB CDNL for large caliber weapons or between 87 and 104 dB PK15(met) for small caliber weapons. Land within Noise Zone II should normally be limited to activities such as industrial, manufacturing, transportation, and resource production. However, if the community determines that land in Noise Zone II (attributable to small arms or aviation) areas must be used for residential purposes, then noise level reduction (NLR) features of 25 to 30 decibels should be incorporated into the design and construction of *new* buildings to mitigate noise levels. For large caliber weapons, NLR features can not adequately mitigate the low-frequency component of large caliber weapons noise.

c. The Noise Zone I includes all areas around a noise source in which the day-night sound level is less than 62 dB CDNL for large caliber weapons and less than 87 PK15(met) for small arms weapons. This area is usually acceptable for all types of land use activities.

d. The Land Use Planning Zone (LUPZ) DNL noise contours (57 dB CDNL) represent an annual average that separates the Noise Zone II from the Noise Zone I. Taking all operations that occur over the year and dividing by the number of training days generates the contours. But, the noise environment varies daily and seasonally because operations are not consistent through all 365 days of the year. In addition, the Federal Interagency Committee on Urban Noise document states "Localities, when evaluating the application of these guidelines to specific situations, may have different concerns or goals to consider." For residential land uses, depending on attitudes and other factors, a 57 CDNL may be considered by the public as an impact on the community environment. In order to provide a planning tool that could be used to account for days of higher than average operations and possible annoyance, the LUPZ contour is being included on the noise contour maps.

e. See Table C-1 for land use guidelines.

Table C-1. LAND USE PLANNING GUIDELINES.

Noise Zones	Large-Caliber Weapons dB CDNL	Small Arms dB PK15(met)
LUPZ	57 – 62	n/a
I	< 62	<87
II	62 - 70	87-104
III	> 70	>104

C-6. Complaint Risk Guidelines for Demolition Activity and Large Caliber Weapons.

a. A peak contour is based upon the expected level that one could get on a sound level meter when a weapon was fired. Since weather conditions can cause noise levels to vary significantly from day to day (even from hour to hour) the programs calculate a range of peak levels. By plotting the PK15(met) contour, events would be expected to fall within the contours 85 percent of the time. This metric represents the best available scientific quantification for assessing the complaint risk of large caliber weapons ranges. The complaint risk areas for PK15(met) noise contours are defined as follows:

(1) The high risk of complaint consists of the area around the noise source in which PK15(met) is greater than 130 dB for large caliber weapons.

(2) The moderate risk of complaint area consists of where the PK15(met) noise contour is between 115 dB and 130 dB for large caliber weapons.

(3) The low risk of complaint area is where the PK15(met) noise level is less than 115 dB for large caliber weapons.

b. See Table C-2 for complaint risk guidelines.

Table C-2. COMPLAINT RISK GUIDELINES.

Risk of Complaints	**Large Caliber Weapons PK15(met) dB Noise Contour**
Low	< 115
Moderate	115 - 130
High	> 130

APPENDIX D

GUAM TRAINING RANGE AREA MAPS

FIGURE D-1. GUAM TRAINING RANGES VICINITY MAP

FIGURE D-2. ANDERSEN AIR FORCE BASE – NORTHWEST FIELD WEAPONS VICINITY MAP

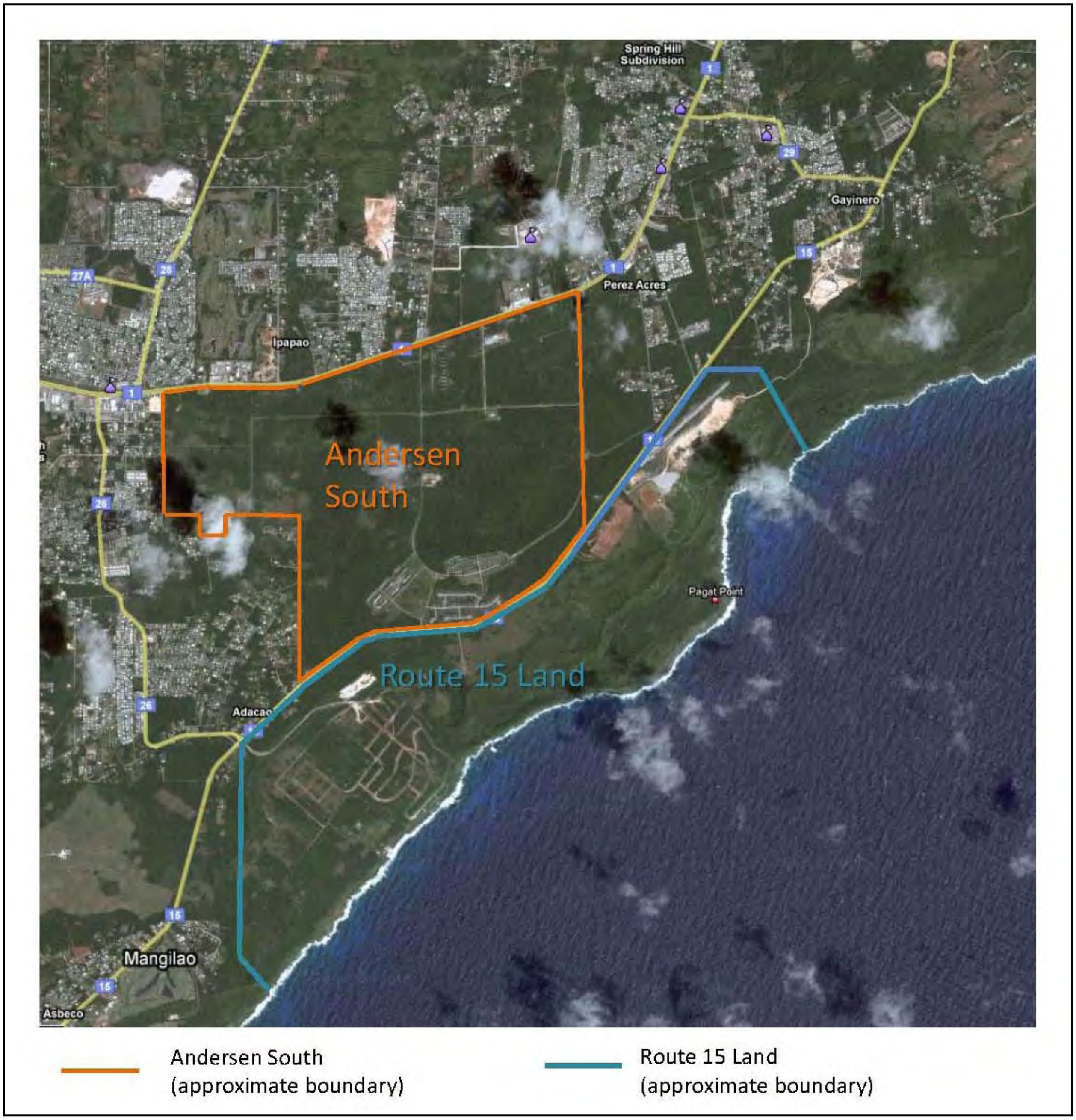

FIGURE D-3. ANDERSEN SOUTH AND ROUTE 15 LAND VICINITY MAP

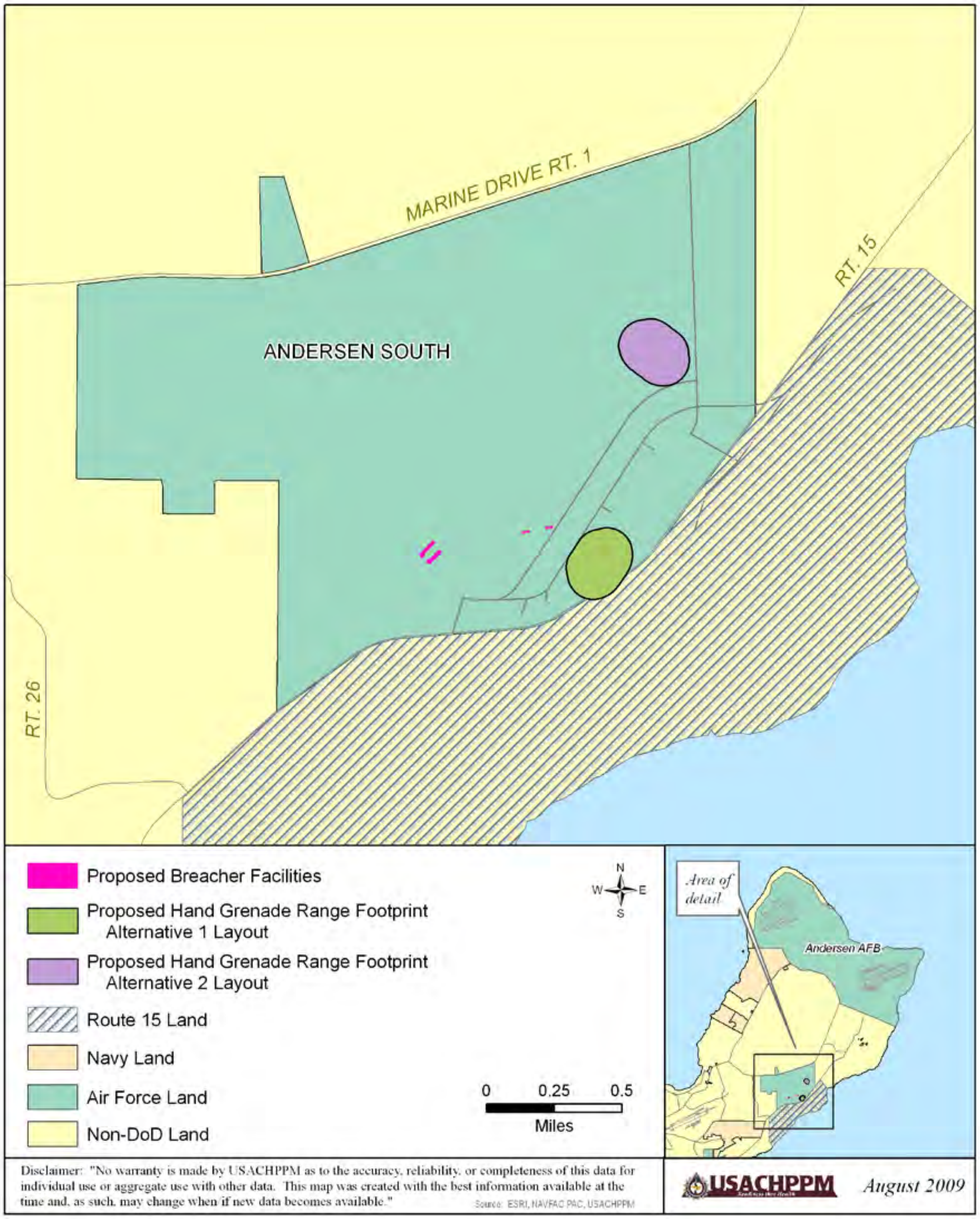

FIGURE D-4. GUAM TRAINING RANGES – ROUTE 15
PROPOSED BREACHER FACILITIES
PROPOSED HAND GRENADE RANGE ALTERNATIVES

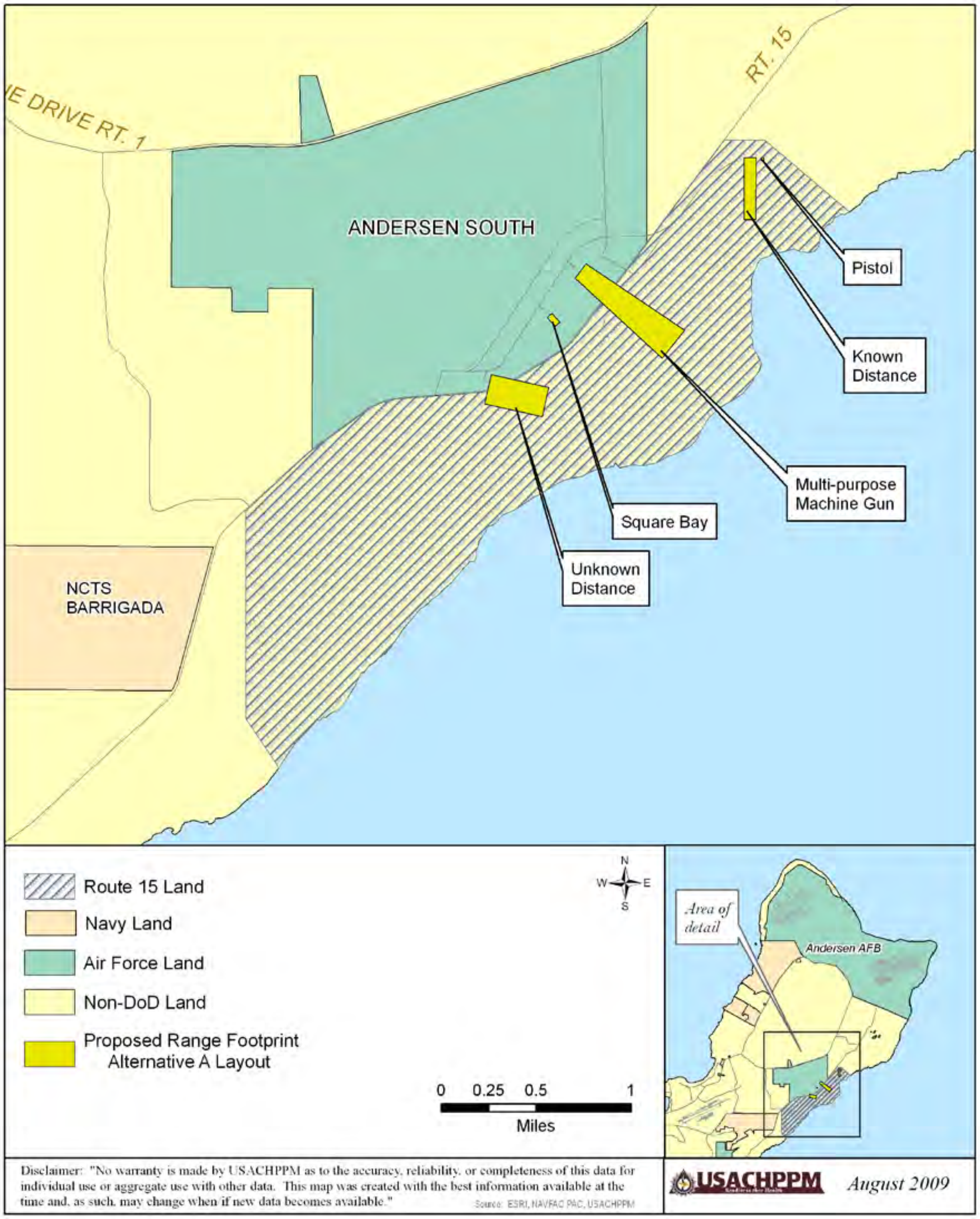

FIGURE D-5. GUAM TRAINING RANGES - ROUTE 15 ALTERNATIVE A LAYOUT

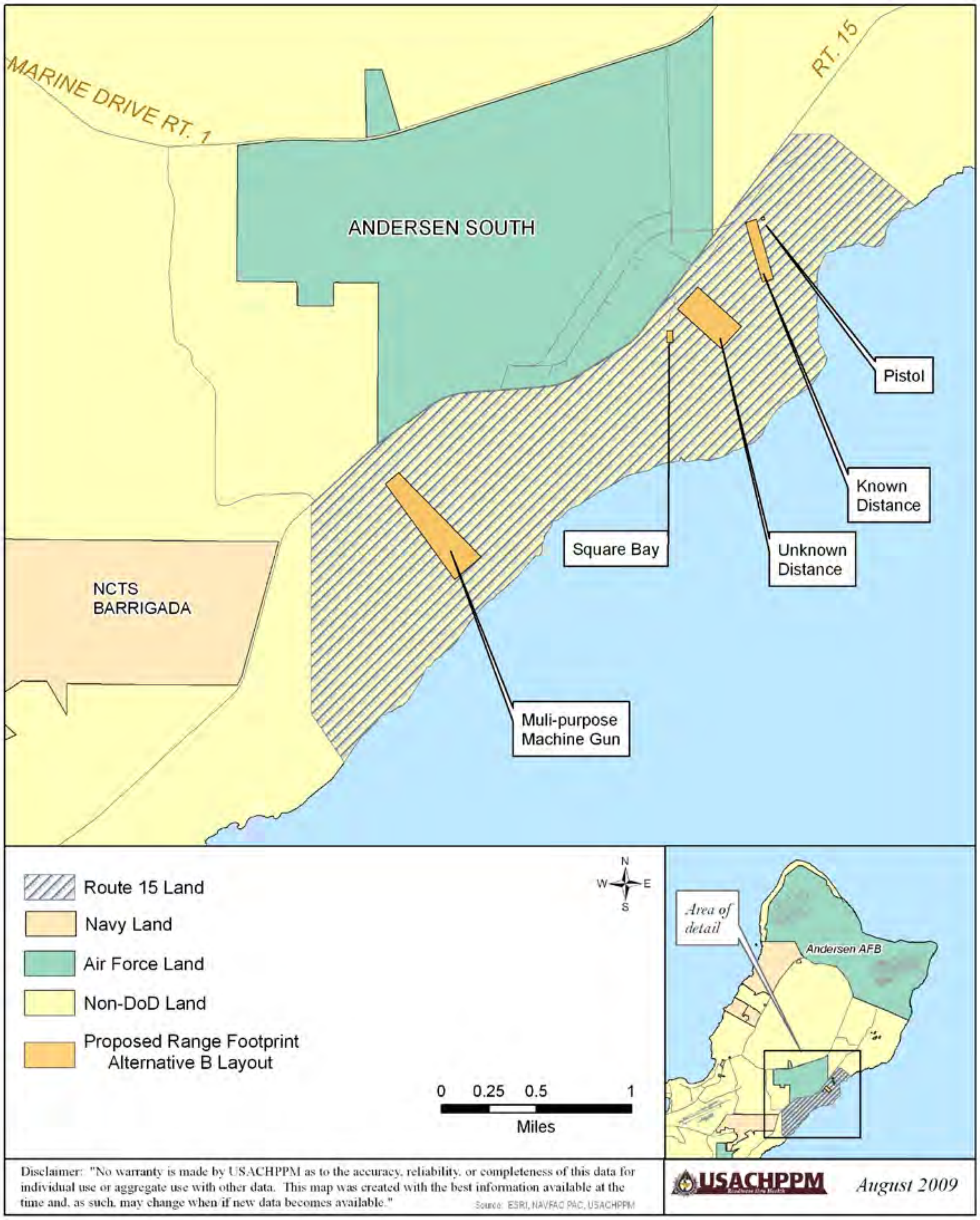

FIGURE D-6. GUAM TRAINING RANGES - ROUTE 15 ALTERNATIVE B LAYOUT

APPENDIX E

TINIAN TRAINING RANGES AREA MAPS

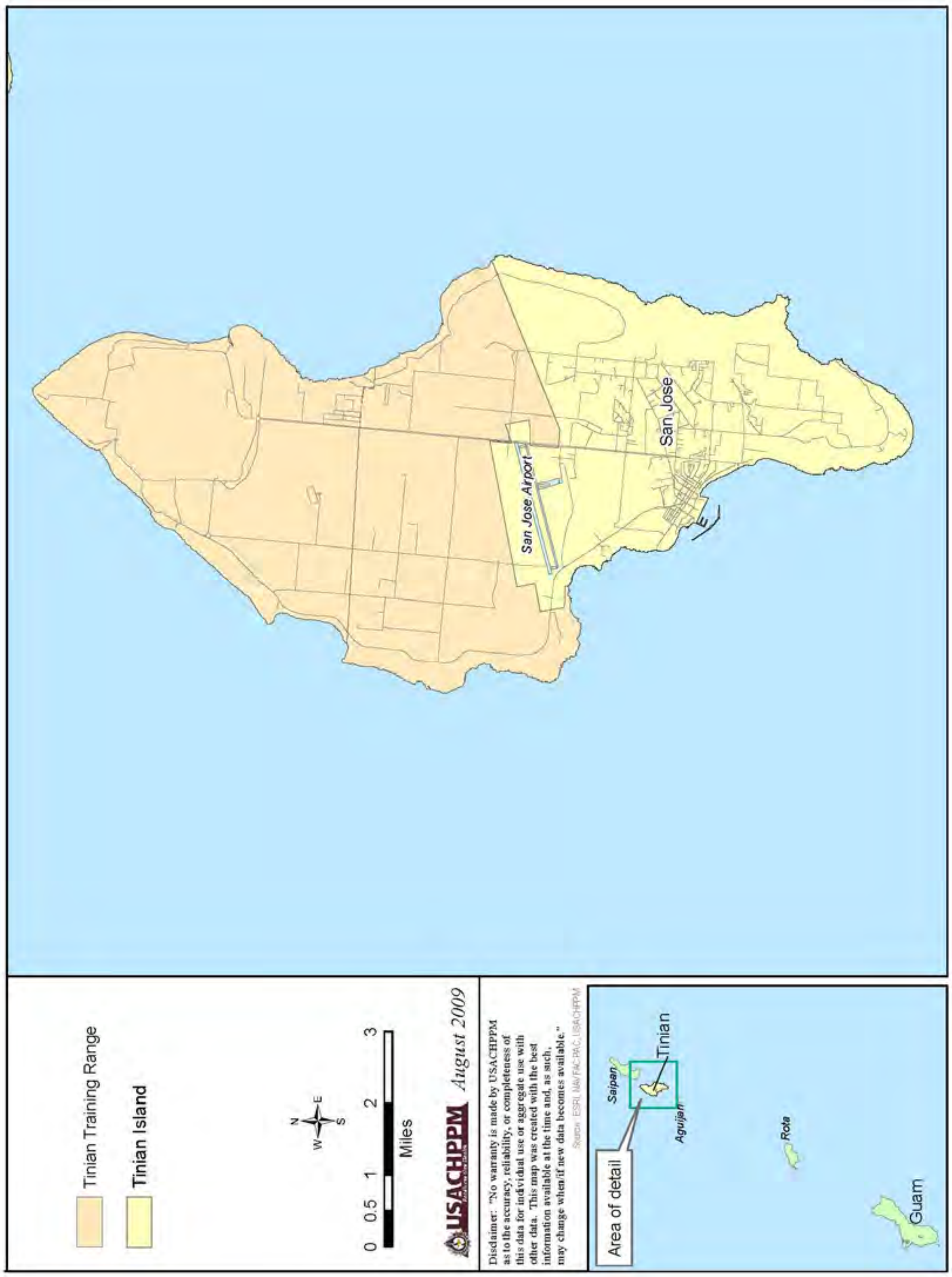

FIGURE E-1. TINIAN TRAINING RANGES VICINITY MAP

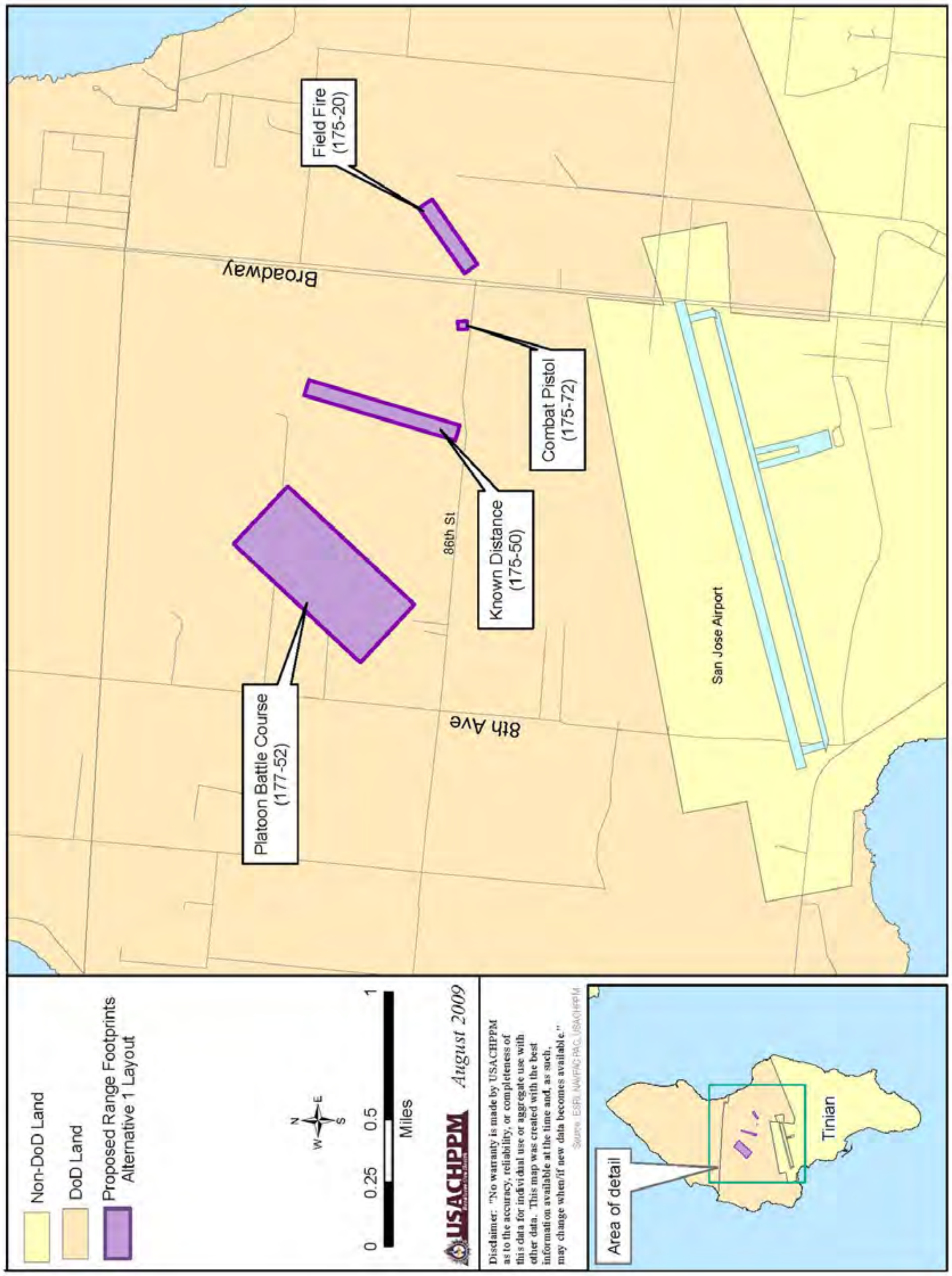

FIGURE E-2. TINIAN TRAINING RANGES ALTERNATIVE 1 LAYOUT

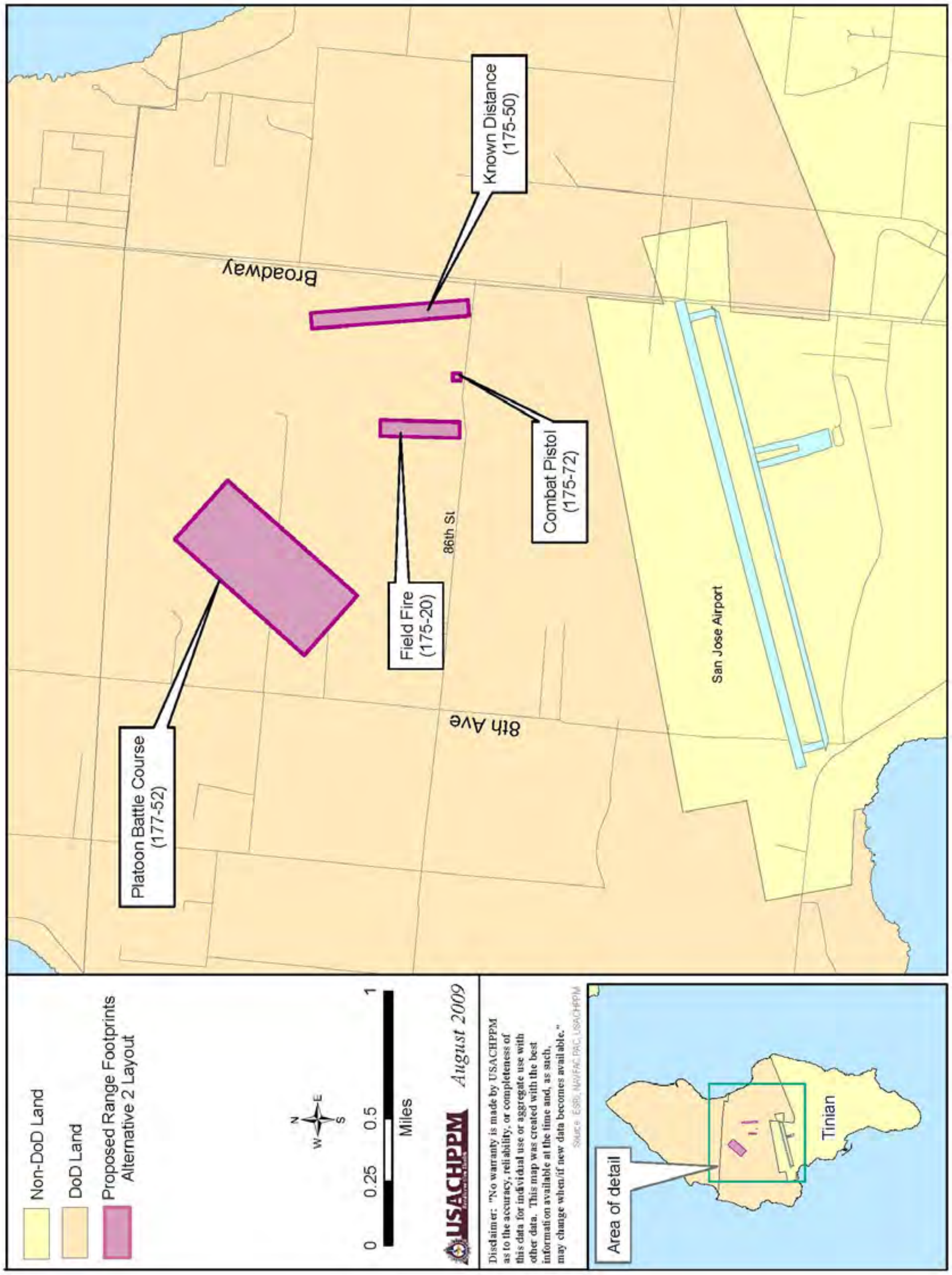

FIGURE E-3. TINIAN TRAINING RANGES ALTERNATIVE 2 LAYOUT

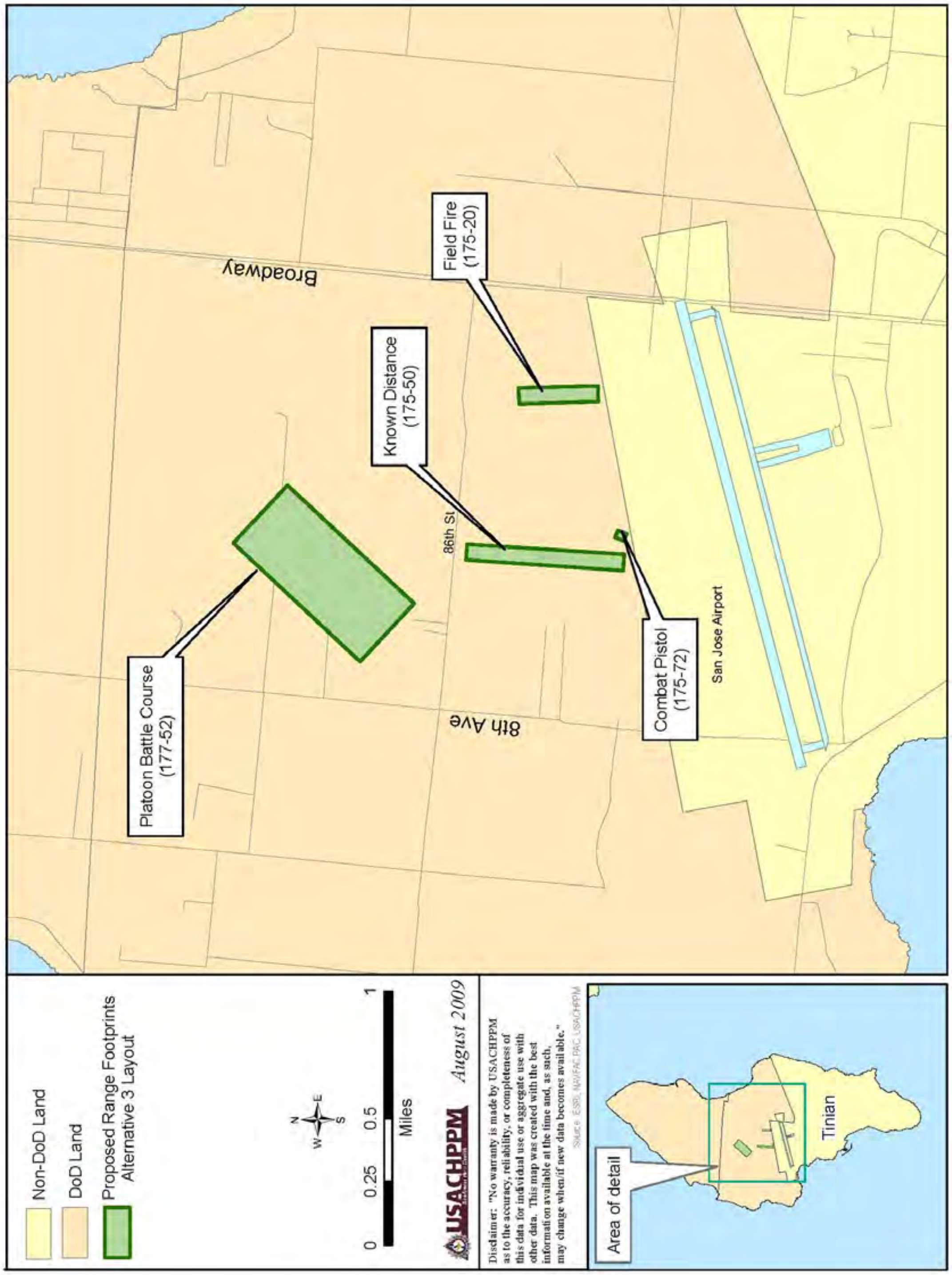

FIGURE E-4. TINIAN TRAINING RANGES ALTERNATIVE 3 LAYOUT

APPENDIX F

OPERATIONAL NOISE MANAGEMENT PROGRAM

F-1. REFERENCE. The U.S. Army, 2007, Army Regulation 200-1, Environmental Protection and Enhancement, Chapter 14 Operational Noise.

F-2. The Army developed the Operational Noise Management Program (ONMP) as method for the installation commanders to establish and maintain active programs to achieve the maximum feasible compatibility between the noise environment and noise-sensitive land uses, both on and off the installation. The program requires that all appropriate governmental bodies and citizens be fully informed whenever ONMP or other planning matters affecting the installation are under consideration. This includes a positive and continuous effort designed to:

a. Provide information, criteria, and guidelines to Federal, State, regional, and local planning bodies, civic associations, and similar groups.

b. Inform such groups of the requirements of the operational activity, noise exposure, aircraft accident potential, explosive testing, artillery firing, etc...

c. Describe the noise reduction measures, which are being or could be used.

d. Ensure that all reasonable, economical, and practical measures are taken to reduce or control the impact of noise-producing or hazardous activities so as to minimize the exposure of populated areas. This must be done without jeopardizing the safety or effectiveness of military operations.

e. Establishing a noise complaint management program.

F-3. Use the ONMP guidance in conjunction with the Air Installation Compatible Use Zone program to address the impulsive noise events at the proposed Guam and Tinian Training Ranges.

F-4. For further details regarding the ONMP contact the Operational Noise Program at the U.S. Army Center for Health Promotion and Preventive Medicine and Army Regulation 200-1, Chapter 14 (U.S. Army 2007).

Appendix K

Additional Reports - Utilities

Interim Report

NORTHERN DISTRICT WASTEWATER TREATMENT PLANT OUTFALL ASSESSMENT

-PHASE 2-

TANGUISSON POINT, GUAM

Prepared for:

Department of the Navy
Naval Facilities Engineering Command, Pacific
Pearl Harbor, Hawaii 96860-7300

Prepared by:

Engineering Concepts, Inc.
1150 S. King Street, Suite 700
Honolulu, Hawaii 96814

September 2009

Interim Report

NORTHERN DISTRICT WASTEWATER TREATMENT PLANT OUTFALL ASSESSMENT

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September 2009

EXECUTIVE SUMMARY

Note*: *This interim report presents the preliminary findings based on the initial field work conducted between August 2008 and March 2009. Additional field visits, data collection, and water quality sampling are scheduled and will be presented in subsequent reports.

This assessment of the discharge from a proposed Department of Defence (DoD) ocean outfall on the marine water environment was prepared in accordance with the Naval Facilities Engineering Command, Pacific (NAVFAC Pacific), Contract No. N62742-08-D-1920. The objective of this investigation was to evaluate the impacts to the receiving marine environment resulting from the consolidated treatment and disposal of DoD wastewater, including additional wastewater loadings associated with the relocation of the U.S. Marine Corps (USMC) from Okinawa to Guam. The results of this study are documented in this report.

The purpose of this study is to support the environmental impact statement (EIS) that will be prepared for the USMC relocation from Okinawa to Guam. According to planning documents, USMC personnel may be relocated to the Naval Computer and Telecommunications Station (NCTS) Finegayan, South Finegayan Housing area, Andersen Air Force Base (AAFB), AAFB Northwest Field, and AAFB South. These areas currently discharge wastewater to the Northern District Wastewater Treatment Plant (NDWWTP), which is owned and operated by the Guam Waterworks Authority (GWA). An assessment of the wastewater treatment and disposal options to support the USMC relocation was provided in the report, *"Guam Wastewater Utility Study Report for Proposed USMC Relocation,"* July 2008, by Earth Tech, Inc. and TEC Inc. Joint Venture (hereafter referred to as July 2008 study).

The July 2008 study evaluated nine wastewater treatment and disposal options. Three of the nine options utilized the NDWWTP outfall as the means for effluent disposal. Impacts to the receiving marine waters associated with these options were addressed in Phase 1 of this investigation. The preliminary results of these options are summarized in a report titled "Northern District Wastewater Treatment Plant Outfall Assessment, Tanguisson Point, Guam" (hereafter referred to as Phase 1 Report). This Phase 2 study evaluates the option to build a new secondary treatment plant dedicated to treat all DoD wastewater flow generated in the north, including the additional flow associated with the USMC relocation. This option is identified in the July 2008 study as Option 2. Effluent from the proposed DoD secondary treatment plant will discharge into M-2 waters through a new ocean outfall that will be located north of the new NDWWTP outfall and south of the M-1/M-2 boundary.

The results of the nearfield and farfield plume modeling performed by EKNA Services are used to assess the water quality associated with the treatment and disposal method proposed in Option 2. The environmental and biological impact assessments were performed by AECOS, Inc. This interim report contains their preliminary findings based on the initial field work conducted between August 2008 and March 2009. Parameters used to assess the environmental impacts on the receiving marine waters include:

- Comparison with the Guam Water Quality Standards (GWQS) and
- Effects to the ecological life and environment of the receiving marine waters.

Comparison with the GWQS

Initial dilution (nearfield) and farfield modeling performed in the Phase 1 study indicated that the discharge of 12 MGD of primary treated effluent from the new NDWWTP outfall will impact the receiving water quality in the vicinity of the proposed DoD outfall. For this Phase 2 study, these plume models were updated with additional ocean and wind data collected through subsequent field visits and used to develop the theoretical ambient receiving water conditions near the proposed DoD outfall. The updated initial dilution factor for the new NDWWTP outfall is 300. The resulting ambient water quality conditions at the proposed DoD outfall are summarized in **Table ES-1**.

TABLE ES-1
CALCULATED AMBIENT WATER QUALITY CONDITIONS
AT THE PROPOSED DOD OUTFALL

Water Quality Constituent	Unit	Background Concentration	NDWWTP Primary Treated Effluent Concentration	Calculated Ambient Concentration at Proposed DoD Outfall	GWQS (M-2 Waters)
Enterococci	#/100mL	0	240,000	400	104
Orthophosphate (as P)	μg P/L	5	2,620	9.4	50
Nitrate-Nitrite	μg N/L	1.1	9	1.1	200
TSS	mg/L	5.6	80	5.7	20
Turbidity	NTU	0.25	59	0.3	1
Priority Toxic Pollutants					
Lead	μg/L	0	4.94	0	8.1
Copper	μg/L	0	68.3	0.1	3.1
Zinc	μg/L	0	276	0.5	86
Additional Toxic Pollutants					
Ammonia (as N)	μg N/L	0	18,400	30.7	20
Total Sulfide	μg/L	0	140	0.2	5
Non-Regulated Constituents					
Total Nitrogen	μg N/L	151	47,600	230.1	---
Total Phosphorus	μg P/L	13	3,850	19.4	---

** Calculated ambient receiving water quality concentrations greater than the GWQS are highlighted in yellow.*

The results indicate that enterococci and ammonia in the receiving waters near the proposed DoD outfall will likely exceed the GWQS due to the primary effluent discharge plume from the NDWWTP.

The conceptual design of the proposed DoD outfall evaluated in this Phase 2 study consists of a single port outfall (no diffuser) at a depth of 150 feet. The nearfield plume model indicates that the proposed DoD outfall will be capable of providing an average initial dilution of 251 at a design flow of 5 MGD and current speed and direction of 10 cm/sec and 15 deg true north. The plume surfaces for all runs and does not travel far horizontally before surfacing.

Utilizing the ambient water quality conditions near the proposed DoD outfall calculated in **Table ES-1**, the anticipated constituent concentrations of the discharge of secondary treated effluent from the proposed DoD outfall after initial dilution is achieved are summarized in **Table ES-2**.

TABLE ES-2
CALCULATED CONSTITUENT CONCENTRATION AFTER INITIAL DILUTION OF 251 IS ACHIEVED AT THE PROPOSED DOD OUTFALL

Water Quality Constituent	Unit	Calculated Ambient Concentration at Proposed DoD Outfall	DoD Secondary Treated Effluent Concentration	Calculated Constituent Concentration After Initial Dilution	GWQS (M-2 Waters)
Enterococci	#/100mL	400	15	398.5	104
Orthophosphate (as P)	μg P/L	9.4	1,640	15.9	50
Nitrate-Nitrite	μg N/L	1.1	14,900	60.5	200
TSS	mg/L	5.7	9	5.7	20
Turbidity	NTU	0.3	16	0.4	1
Priority Toxic Pollutants					
Lead	μg/L	0	4.43	0	8.1
Copper	μg/L	0.1	54.6	0.3	3.1
Zinc	μg/L	0.5	72.6	0.8	86
Additional Toxic Pollutants					
Ammonia (as N)	μg N/L	30.7	3,500	44.5	20
Total Sulfide	μg/L	0.2	140	0.8	5
Non-Regulated Constituents					
Total Nitrogen	μg N/L	230.1	23,950	324.6	---
Total Phosphorus	μg P/L	19.4	3,760	34.3	---

** Calculated ambient receiving water quality concentrations greater than the GWQS are highlighted in yellow.*

Due to the high levels of enterococci and ammonia in the primary effluent discharged from the new NDWWTP outfall, the resulting ambient receiving water quality in the vicinity of the proposed DoD outfall exceeds the GWQS. Although the end of pipe enterococci level present in the secondary treated discharge from the proposed DoD outfall is below the GWQS, the resulting concentration after mixing with the ambient receiving water exceeds the GWQS.

By upgrading the NDWWTP to provide secondary treatment, the reduction of pollutants in the discharge will result in the ambient receiving waters near the proposed DoD outfall to comply with the GWQS as indicated in **Table ES-3**. The anticipated constituent concentrations resulting from the discharge of secondary treated effluent from the proposed DoD outfall after initial dilution will also meet the GWQS as indicated in **Table ES-4**.

TABLE ES-3
CALCULATED AMBIENT WATER QUALITY CONDITIONS
AT THE PROPOSED DOD OUTFALL

Water Quality Constituent	Unit	Background Concentration	NDWWTP Secondary Treated Effluent Concentration	Calculated Ambient Concentration at Proposed DoD Outfall	GWQS (M-2 Waters)
Enterococci	#/100mL	0	15	0	104
Orthophosphate (as P)	μg P/L	5	1,640	7.7	50
Nitrate-Nitrite	μg N/L	1.1	14,900	25.9	200
TSS	mg/L	5.6	9	5.6	20
Turbidity	NTU	0.25	16	0.3	1
Priority Toxic Pollutants					
Lead	μg/L	0	4.43	0	8.1
Copper	μg/L	0	54.6	0.1	3.1
Zinc	μg/L	0	72.6	0.1	86
Additional Toxic Pollutants					
Ammonia (as N)	μg N/L	0	3,500	5.8	20
Total Sulfide	μg/L	0	140	0.2	5
Non-Regulated Constituents					
Total Nitrogen	μg N/L	151	23,950	190.7	---
Total Phosphorus	μg P/L	13	3,760	19.2	---

TABLE ES-4
CALCULATED CONSTITUENT CONCENTRATION AFTER INITIAL DILUTION OF 251 IS ACHIEVED AT THE PROPOSED DOD OUTFALL
(Secondary Treated Effluent Discharged from NDWWTP)

Water Quality Constituent	Unit	Calculated Ambient Concentration at Proposed DoD Outfall	DoD Secondary Treated Effluent Concentration	Calculated Constituent Concentration After Initial Dilution	GWQS (M-2 Waters)
Enterococci	#/100mL	0	15	0	104
Orthophosphate (as P)	μg P/L	7.7	1,640	14.2	50
Nitrate-Nitrite	μg N/L	25.9	14,900	85.2	200
TSS	mg/L	5.6	9	5.6	20
Turbidity	NTU	0.3	16	0.3	1
Priority Toxic Pollutants					
Lead	μg/L	0	4.43	0	8.1
Copper	μg/L	0.1	54.6	0.3	3.1
Zinc	μg/L	0.1	72.6	0.4	86
Additional Toxic Pollutants					
Ammonia (as N)	μg N/L	5.8	3,500	19.8	20
Total Sulfide	μg/L	0.2	140	0.8	5
Non-Regulated Constituents					
Total Nitrogen	μg N/L	190.7	23,950	285.3	---
Total Phosphorus	μg P/L	19.2	3,760	34.1	---

Effects to the Ecological Life and Environment of the Receiving Marine Waters

The three components of sewage effluent found to be most detrimental to marine life and coral reefs are nutrients, sediments, and toxic substances. Tropical ocean waters are typically characterized as low in nutrients and particulates. Therefore, the discharge of high levels of nutrients and particulates may have detrimental impacts to the receiving marine waters.

The following assessment is derived from a review of existing studies performed by others in the vicinity of the proposed DoD outfall, supplemented by investigations performed at other marine outfalls located in Guam and Hawaii.

Water Column Impacts

The nearfield plume analysis indicates that the discharge from the diffuser rises quickly, with minimal horizontal dispersion before reaching the surface. The elapsed time for this initial mixing and rise of the fluids is short, occurring in minutes. Therefore, there is minimum interaction with the extant assemblage of organisms in the water column.

Phytoplankton may assimilate some nutrients present in the farfield plume. Since phytoplankton requires several days to replicate and the plume will likely disperse over a wide area in a matter of hours, however, the increase in biomass is not likely to be a concern. The low phytoplankton biomass (based on the low level of chlorophyll α) also suggests that any increase resulting from phytoplankton productivity will be rapidly grazed by herbivorous zooplankters. Therefore, detectable changes in phytoplankton or herbivorous zooplankton biomass are not anticipated.

Enterococcus and ammonia in the surfacing plume will exceed the GWQS. These exceedances are attributed to the ambient receiving water quality condition resulting from the primary effluent discharged from the new NDWWTP outfall. These anticipated constituent concentrations are based on the modeling results by EKNA Services and do not take into account the degradation of constituents, die-off of organisms, or uptake of the pollutants by existing aquatic life.

Enterococcus in the discharge plume will eventually be diluted to near zero. Unfavorable conditions provided by the marine environment will likely destroy these bacteria and most others from the wastewater. Factors such as pH, temperature, solar (UV) radiation, predation, osmotic stress, nutrient deficiencies, particulate levels, turbidity, oxygen concentrations, and microbial community composition affect bacteria inactivation.

The toxicity of ammonia is dependent on pH. Dissolved in water, ammonia will react with hydrogen ions (H^+) to form non-toxic ammonium ions (NH_4^-). When mixed with the higher pH level of the receiving marine water, ammonia present in the wastewater discharge will increase in toxicity. Toxicity is still a function of concentration and, since the initial dilution of ammonia in the rising plume is around 45 μgN/L, this value is nearly two orders of magnitude (or about 1/100) of the concentration found to be toxic to most fishes (EPA, 1972).

Benthic Impacts

Benthic impacts are associated with the sedimentation of particulates entrained in the discharge plume. Sources of the particulates in the wastewater discharge plume include particulates in the effluent, particulates produced in the environment from nutrient enrichment, and natural seston.

Based on several studies performed on deep ocean outfalls off Oahu in the Hawaiian Islands, no significant impacts have been reported on the benthic faunal. Impacts to polychaete assemblage and the crustacean and soft bottom communities were found to be limited. Since the conditions off Tanguisson Point are similar to those off the Oahu deep ocean outfalls, adverse impacts to the receiving marine waters are not anticipated with the discharge of secondary treated effluent from the proposed DoD outfall.

Sewage Impacts on Coral Reef Ecosystems

The Guam nearshore environment is characterized by extensive coral bottom and coral reef areas. In the vicinity between Tanguisson Point and Falcona Beach, high coral cover and diversity exist.

Detrimental impacts to the coral reef ecosystem associated with excessive nutrient-loading, bacteria, and sediment abrasion have been documented in other studies. These impacts, however, are dependent on the flushing properties of the receiving waters and characteristics of the sediment. A 1985 report by Pastorok and Bilyard studied the impact of sewage effluent on the coral reef ecosystem. The study concluded that the discharge of sewage had little or no impact on the coral reef ecosystem in well-flushed water along open coasts.

In general, coral species located along the seaward margin of the reef are less tolerant to high sediment loadings than species found on the inner reef. However, the physical condition of the seaward margin of the reef typically prevents the accumulation of sediments. The wastewater plume models for this investigation also indicated that the plume rises to the surface quickly and then spreads out, broadening the area subject to the dissolved and particulate substances in the effluent, thus reducing the concentration of the constituents that will arrive at the reef.

The coral reef off Tanguisson Point, at its closest point, is located approximately 360 feet from the outfall. This is approximately 1,100 feet from the shoreline and roughly 820 feet from the reef margin. The results of the farfield plume analysis indicate that the average dilution along the face of the reef will be on the order of 1,000 to 2,000. Without the influence of primary treated effluent discharged through the new NDWWTP outfall, the proposed DoD discharge of secondary treated effluent will meet GWQS as the discharge plume surfaces. With the primary treated effluent discharge from the NDWWTP, the average dilution factor for the mixed plume as it surfaces and spreads to the nearby reef front is expected to be on the order of 10, reducing the ammonia concentration well below the GWQS of 20 μg N/L. The 24-hour visitation frequency for the reef area is on the order of 5 to 10 percent.

The results of the farfield plume analysis and water quality assessment indicate some impact on the nearshore reef ecosystem associated with the discharge of 12 MGD of primary treated effluent through the new NDWWTP outfall. Due to the prevailing ocean current and wind conditions, mixing and flushing capabilities, and distance from the shore, however, the biological impacts are anticipated to be inconsequential and very limited in area. This potential impact may be mitigated by improving the treatment provided at the NDWWTP to secondary levels. The addition of 5 MGD of secondary treated effluent through the proposed DoD outfall should not alter this assessment, with the exception that detectable ammonia levels (below the GWQS limits) may impinge on the reef margin.

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CHAPTER 1
INTRODUCTION

This assessment of the impacts of the discharge from a proposed Department of Defence (DoD) ocean outfall on the marine water environment was prepared in accordance with the Naval Facilities Engineering Command, Pacific (NAVFAC Pacific), Contract No. N62742-08-D-1920. The objective of this investigation was to evaluate the impacts to the receiving marine environment resulting from the consolidated treatment and disposal of DoD wastewater, including additional wastewater loadings associated with the U.S. Marine Corps (USMC) relocation from Okinawa to Guam. The results of this study are documented in this report.

1.1 Purpose of Study and Background Information

The purpose of this study is to support the environmental impact statement (EIS) that will be prepared for the relocation of the USMC from Okinawa to Guam. According to planning documents, potential locations for the relocated personnel in Guam include the Naval Computer and Telecommunications Station (NCTS) Finegayan, South Finegayan Housing area, Andersen Air Force Base (AAFB), AAFB Northwest Field, and AAFB South. These areas currently discharge their wastewater to the Northern District Wastewater Treatment Plant (NDWWTP), which is owned and operated by the Guam Waterworks Authority (GWA). An assessment of the wastewater treatment and disposal options to support the USMC relocation was provided in the report, *"Guam Wastewater Utility Study Report for Proposed USMC Relocation"* dated July 2008 prepared by Earth Tech, Inc. and TEC Inc. Joint Venture (hereafter referred to as July 2008 study).

The July 2008 study evaluated nine wastewater treatment and disposal options. Three of the nine options presented in the July 2008 study utilized the existing NDWWTP outfall as the means for effluent disposal. The impact of these three options on the marine environment was investigated in Phase 1 of this project, and the results of the study are presented in the report, "Northern District Wastewater Treatment Plant Outfall Assessment, Tanguisson Point, Guam" (hereafter referred to as Phase 1 report).

This Phase 2 investigation evaluates the option to build a new secondary treatment plant dedicated to treat all of DoD's wastewater flows generated in the north, including the additional flow associated with the USMC relocation. This option is identified in the July 2008 study as Option 2. The new treatment plant will be constructed on DoD land near the proposed USMC Finegayan development, north of the NDWWTP. A new ocean outfall will be constructed to dispose treated secondary effluent from this facility. The outfall will be located north of the existing NDWWTP outfall.

Due to the relatively close proximity of the existing and proposed outfalls, effluent discharged from the existing NDWWTP outfall will likely impact water quality of the receiving waters in the vicinity of the proposed DoD outfall. Although water quality monitoring is being performed to establish baseline values of the receiving waters, the magnitude of the current discharge from the NDWWTP is less than half the ultimate design capacity of the treatment plant. Therefore, as a conservative measure, the results of the nearfield and farfield plume analysis performed for the Phase 1 report were utilized in this investigation to predict the maximum water quality impacts associated with the ultimate design discharge from the existing NDWWTP outfall. This information was used to develop the theoretical ambient receiving water conditions for the proposed DoD outfall discharge.

1.2 Scope of Work

The scope of work for this Phase 2 investigation is to assess the environmental impacts of a new point discharge from the proposed DoD secondary treatment plant on the receiving marine waters. The proposed DoD secondary treatment plant and outfall will be located north of the existing NDWWTP and outfall.

Parameters used to assess the environmental impacts on the receiving marine waters include the following:

- Comparison with the Guam Water Quality Standards (GWQS)
- Effects to the ecological life and environment of the receiving marine waters

To conduct this assessment, a conceptual design of the proposed DoD outfall was developed. The conceptual outfall design considered the bathymetry in the area, boundaries of the M-1 and M-2 waters delineated in the GWQS, and the anticipated quality and quantity of effluent discharged from the proposed DoD secondary treatment plant. This investigation is not intended to replace an engineering report. The conceptual DoD outfall design presented in this investigation will require a follow-up detailed engineering report.

Specific tasks required for this investigation include:

- Collection of site specific data on the receiving waters
  - ⇒ Ocean current dynamics
  - ⇒ Conductivity-Temperature-Depth (CTD) and water quality data from the water column utilizing an array of stations
- Wastewater characterization of secondary treated effluent
- Analysis of the proposed DoD outfall
  - ⇒ Perform nearfield (initial dilution) plume analysis using the most recent U.S. Environmental Protection Agency (USEPA) models
  - ⇒ Perform farfield plume analysis based on industry standard practices acceptable to USEPA
- Updating the nearfield and farfield plume analysis results from the Phase I investigation to develop the theoretical ambient receiving water conditions in the vicinity of the proposed DoD outfall
- Evaluation of the impacts to ecological life and environment of the receiving marine waters based on the results of the outfall analysis performed above and anticipated fate of the effluent constituents

Field investigations for benthic ecosystem, coral, phytoplankton, fishes, and other marine life were not included in this study. Previous studies by others performed in the vicinity of the DoD outfall were used, if available, and supplemented by investigations of other marine outfalls located in Guam and Hawaii.

The scope of work is included in **Appendix 1A** for reference.

1.3 Report Organization

A project team was assembled for this study with the expertise necessary to complete the various tasks associated with this investigation. The team members and involvement in this project are as follows:

Engineering Concepts, Inc. (Project Coordinator) – Civil and Environmental/Sanitary Engineers

- Establish the basis of analysis for this investigation
- Develop future wastewater flows and characteristics used in the assessment of the DoD outfall
- Develop criteria to evaluate compliance with the GWQS

EKNA Services, Inc. – Coastal and Ocean Engineers

- Characterize existing ocean current dynamics
- Develop the conceptual design of the proposed DoD outfall
- Perform nearfield and farfield plume analysis of the DoD outfall
- Assess the dilution and concentration of the mixed effluent constituents from the NDWWTP outfall and the DoD outfall

AECOS, Inc. – Aquatic Biology and Water Quality Scientists

- Characterize baseline and theoretical "pristine" background conditions of the receiving marine waters in the vicinity of the DoD outfall
- Assess impacts on the offshore benthic and water column ecosystems under the various treatment options

A variety of information is contained in this report. To simplify the presentation of technical information, the main body of the report contains general information regarding the project, basis of developing the preliminary design of the proposed DoD outfall, and impacts to the receiving marine waters. Results of the nearfield and farfield analysis of the proposed DoD outfall and environmental and ecological impacts to the marine waters are also summarized in the main body of the report. Detailed technical information is provided in the appendices and consists of complete reports prepared by EKNA Services, Inc. and AECOS, Inc.

This report is organized in the following manner:

Chapter 1 **Introduction** presents the purpose, scope of work, and overview of this study.

Chapter 2 **Criteria and Methodology** summarizes the applicable regulatory drivers, basis of analysis, and methodology employed in this investigation to assess the potential impacts of the discharge from the proposed DoD outfall on the receiving waters. Also included in this chapter is a description of the field investigation and data collection required to obtain the information used in this assessment.

Chapter 3 **Receiving Water Conditions** establishes the physical oceanographic and water quality conditions that were used as the basis for the assessment performed in this investigation. This chapter also includes the results of the Phase 1 report and evaluates the impact of the discharge from the existing NDWWTP outfall on the receiving water quality in the vicinity of the DoD outfall.

Chapter 4 **Assessment of the Discharge from the Proposed DoD Outfall** describes the anticipated characteristics of the effluent discharged from the proposed DoD secondary treatment plant, conceptual design of the proposed DoD outfall, and the impacts on the receiving waters. This chapter includes the results of the nearfield and farfield plume analysis performed by EKNA Services and the environmental impact assessment of the receiving water performed by AECOS, Inc.

Appendices Pertinent information and data referenced in the report are presented in appendices, whose numbers correspond to the chapter for which it contains supporting information.

1.4 ACKNOWLEDGMENT

We wish to thank the following people for their support during the course of this study:

- Gerald Akai – NAVFAC Pacific, Environmental
- Jack Brown, Rolfe Banes, Brian Hess, Joseph Anderson – COMNAVMAR

CHAPTER 2
CRITERIA AND METHODOLOGY

The purpose of this study is to assess the impacts of a new point discharge from the proposed DoD outfall on the marine water environment. Prior to discharge, the wastewater will be treated at a proposed DoD secondary treatment plant located north of the existing NDWWTP. This DoD facility will be designed to treat all DoD wastewater flows generated in the north, including additional wastewater flows associated with the USMC relocation. This wastewater treatment and disposal option was presented in the July 2008 study as Option 2.

This chapter outlines the criteria and methodology used to assess the environmental and ecological effects to the receiving waters associated with the discharge from the proposed DoD outfall.

2.1 REQUIREMENTS AND POLICIES

The following sections summarize the applicable regulatory requirements concerning point discharges and the environmental protection standards that apply to the receiving water quality.

2.1.1 Federal Water Pollution Control Act

The Federal Water Pollution Control Act (FWPCA) and subsequent amendments, commonly referred to as the Clean Water Act (CWA), authorized the USEPA, individual states, and local governments to establish programs that would control pollution and restore and maintain the chemical, physical, and biological integrity of the nation's water. The goal of the CWA is to restore the quality of the nation's water by regulating the discharge of point sources.

The CWA considers all discharges to the nation's water unlawful, unless specifically authorized by a permit that would require the discharge to attain technology-based effluent quality limits. The National Pollutant Discharge Elimination System (NPDES) permit program was established in 1972 under the CWA. The USEPA administers the NPDES program and mandates that dischargers of point source pollutants obtain an NPDES permit. By definition, a "pollutant" includes solid waste, sewage, or sewage sludge.

Pollutants discharged to U.S. waters are federally regulated by the USEPA through the NPDES permit process prescribed in 40 CFR Part 122. EPA-approved permitting programs may be promulgated by a state or territory in lieu of the federal program. While state programs must meet the standards of the federal program, they are typically more stringent than the federal regulations. Currently, the Territory of Guam does not have an approved permitting system and relies on the federal program to regulate the discharge of pollutants to its marine waters. Guam is under the administrative jurisdiction of USEPA Region IX. Therefore, NPDES permits are issued by USEPA Region IX, while the Guam Environmental Protection Agency (GEPA), the local regulatory agency, provides input regarding the receiving water quality standards, pursuant to Section 401 of the CWA.

2.1.2 Revised Guam Water Quality Standards

The GEPA adopted standards to protect the quality of Guam's territorial waters. The intent of these standards is to eliminate the degradation of receiving waters due to point source pollution.

These water quality standards are entitled, “Guam Water Quality Standards 2001 Revision" (GWQS). A copy of the GWQS is included in **Appendix 2A** for reference.

The numeric water quality standards for each criteria regulated under the GWQS differ based on the classification of the receiving waters. Coastal waters off-shore from the mean high water mark subject to ebb and tidal flows are classified in the GWQS under three major marine water categories: M-1, M-2, and M-3. These categories are defined in the GWQS as follows:

> *M-1 marine waters* - *“Water in this category must be of high enough quality to protect for whole body contact recreation, and to ensure the preservation and protection of marine life, including corals and reef-dwelling organisms, fish and related fisheries resources, and enable the pursuit of marine scientific research as well as aesthetic enjoyment. This category of water shall remain substantially free from pollution attributed to domestic, commercial and industrial discharges, shipping and boating, or mariculture, construction and other activities which can reduce the waters’ quality.”*

> *M-2 marine waters* - *“Water in this category must be of sufficient quality to allow for the propagation and survival of marine organisms, particularly shellfish and other similarly harvested aquatic organisms, corals and other reef-related resources, and whole body contact recreation. Other important and intended uses include mariculture activities, aesthetic enjoyment and related activities.”*

> *M-3 marine waters* - *“Water in this category is intended for general, commercial and industrial use, while allowing for protection of aquatic life, aesthetic enjoyment and compatible recreation with limited body contact. Specific intended uses include the following: shipping, boating and berthing, industrial cooling water, and marinas.”*

The classification of Guam’s marine waters is illustrated on **Figure 2.1-1**. According to the GWQS, any new point source discharge into M-1 waters is prohibited. The proposed location of the DoD outfall will be situated in M-2 marine waters, south of the M-1/M-2 boundary as shown on **Figure 2.1-2**. The existing NDWWTP outfall is located south of the proposed DoD outfall.

In order for marine waters to meet the water quality criteria, effluent limitations are placed on discharging sources. Water quality criteria for M-2 marine waters and effluent limitations imposed by the GWQS are applicable for the proposed DoD outfall and are discussed in the following sections. Due to the close proximity of the M-1/M-2 boundary, water quality criteria for M-1 marine waters are also presented in the following sections.

2.1.2.1 Regulatory Definitions

GEPA defines the following criteria as applicable to meeting the GWQS.

- *Discharge.* The direct or indirect outflow of liquid waste or wastewater from any domestic, commercial, industrial, agricultural, or any other source onto land or into waters of Guam. The term “discharge” includes either the discharge of a single pollutant or the discharge of multiple pollutants.

- *Effluent.* The liquid waste that is discharged directly or indirectly into a waterbody, storm drain, or sewage system.

- *Industrial Waste.* Any discharge containing gaseous, solid, dissolved, or suspended material resulting from any process of industry, manufacturing, trade, or business or from the processing of any natural resource, together with such sewage as may be present which may pollute the waters of Guam.

- *Mixing Zone.* The area or volume of a waterbody within which effluent(s) shall become physically mixed with the receiving waters through initial dilution. Initial dilution is the process through which the wastewater immediately mixes with the receiving water due to the momentum of the waste discharge, and the difference in density between the discharge and the receiving water.

- *Point Source.* Any discernible, confined, and discrete conveyance including, but not limited to, any pipe, ditch, channel, tunnel, conduit, well, discrete fissure, container rolling stock, concentrated animal feeding operation, or vessel or other floating craft from which pollutants are, or may be, discharged. This term does not include flows from irrigated agriculture, or agricultural, storm water runoff.

- *Pollutant.* Means dredged spoil, solid waste, incinerator residue, sewage, garbage, sewage sludge, munitions, chemical wastes, biological materials, radioactive materials, heat, wrecked, or discarded equipment, rock, sand, cellar dirt and industrial, municipal, and agricultural waste discharged into water.

2.1.2.2 Regulatory Standards

GEPA has adopted standards to conserve, protect, maintain, and improve the quality of Guam's waters for human consumption (drinking, fish and shellfish harvesting, and food processing); for the growth and propagation of aquatic life; for marine research; for the preservation of coral reefs and wilderness areas; and for domestic, agricultural, commercial, industrial, recreational, and other legitimate uses. All waters are required to meet acceptable aesthetic qualifications, be capable of supporting desirable aquatic life, and be free from substances, conditions or combinations thereof attributable to domestic, commercial, and industrial discharges or agricultural, construction and land-use practices, or other human activities that cause visible floating material, produces turbidity or deposits, result in objectionable color, odor or taste, is toxic or harmful, or induces growth of undesirable aquatic life.

The GWQS provides specific water quality criteria based on the marine water classification. Water quality criteria applicable to M-2 and M-1 waters are presented in **Table 2.1-1**.

TABLE 2.1-1
GUAM WATER QUALITY STANDARDS

Parameter	Guam Water Quality Standards	
	M-2	M-1
Enterococci	35 enterococci/100 mL (geometric mean of 5 sequential samples over a 30-day period); 104 enterococcci/100 mL (instantaneous reading)	
pH[1]	6.5 - 8.5	
Orthophosphate	0.05 mg/L	0.025 mg/L
Nitrate-Nitrogen	0.20 mg/L	0.10 mg/L
Dissolved Oxygen[2]	75% saturation (minimum)	
Salinity	<u><</u>10% increase over ambient (except due to natural conditions)	
Total Non-Filterable Suspended Solids	20 mg/L (except due to natural conditions); and <u><</u>10% increase over ambient	5 mg/L (except due to natural conditions)
Turbidity[3]	<u><</u>1.0 NTU over ambient (except due to natural conditions)	<u><</u>0.5 NTU over ambient (except due to natural conditions)
Radioactive	strictly prohibited	
Temperature	<u><</u>1.8 degrees F variation from ambient	
Oil and Petroleum Products	visible film, or sheen, or surface discoloration with corresponding oil or petroleum product odor is unacceptable; damage to fish, invertebrates or drinking water quality is unacceptable; formation of oil deposits on shore or bottom is unacceptable	
Pesticides	reference U.S. Water Quality Criteria Guidance “Blue Book” (NAS/NAE, 1973) (US-GPO #5501-00520), “Red Book” (USEPA, 1976), “Green Book” (FWPCA, 1968) and “Gold Book” (USEPA, 1986a), which is updated periodically	
Toxic Substances	see Table 2.1-2	
Aluminum	0.20 mg/L	
Ammonia	0.02 mg/L	
Barium	0.50 mg/L	
Boron	5.00 mg/L	
Bromine	0.10 mg/L (free); 100.00 mg/L (as Bromate)	
Chlorine (total)	0.0075 mg/L	
Fluoride	1.50 mg/L	
Iron	0.05 mg/L	
Manganese	0.02 mg/L	
Molybdenum	--	
Sulfide	0.005 mg/L	
Tributyltin	0.010 µg/L (chronic); 0.356 µg/L (acute)	
Uranium[4]	0.00 mg/L	

Reference: Guam Water Quality Standards (2001 Revision)

(1)For open ocean water where the depth is substantially greater than the euphotic zone, the pH should not be changed more than 0.2 units from the naturally occurring variation, or in any case outside the range of 6.5-8.5.
(2)Where natural conditions cause lower dissolved oxygen levels, controllable water quality factors shall not cause further reductions.
(3)Marine waters exhibiting debris, rapidly settling particles, and/or true color are required to be measured by secchi disc. Secchi disc visibility shall not decrease by more than 5 meters from ambient conditions except when due to natural conditions.
(4)Naturally occurring uranium has been reported in concentrations of 0.003 mg/L, 0.00004 mg/L (river water).

In addition to receiving water quality criteria presented in **Table 2.1-1**, general effluent limitations provided in the GWQS include:

- Dilution is not acceptable as the sole means of treatment.
- All point source discharges to Guam's waters will be controlled through the federal NPDES or local GEPA permit programs.
- All sewage, including industrial waters and other wastes, shall be treated to the degree required to achieve standards of water quality prior to discharge to the waters of Guam.
- Pretreatment of toxic and hard-to-treat substances is required at the source if pass-through, interference with treatment processes, or sludge contamination results at the municipal treatment plant.
- No effluent shall, alone or in combination with other sources, cause a violation of any water quality standard.
- Measurement of pollutant concentrations to determine compliance with effluent limitations shall be made at the point immediately following final treatment before mixing with other wastes.
- Operating reports shall be submitted to GEPA.
- New and existing permitted point source discharges will promptly comply with any new or more restrictive water quality-based effluent limitations based upon adopted water quality criteria.

For secondary treatment, the GWQS provides the following minimum levels for effluent quality:

- Biochemical Oxygen Demand (5 day)
  - The arithmetic mean of the concentration for samples collected over a period of 30 consecutive days shall not exceed 30 mg/L.
  - The arithmetic mean of the concentration for samples collected over a period of 7 consecutive days shall not exceed 45 mg/L.
  - The arithmetic mean of the concentration of the effluent samples collected over a period of 30 consecutive days shall not exceed 15 percent of the arithmetic mean of the concentration of the influent samples collected over the same period (85 percent removal rate).
- Suspended Solids
  - The arithmetic mean of the concentration for samples collected over a period of 30 consecutive days shall not exceed 30 mg/L.
  - The arithmetic mean of the concentration for samples collected over a period of 7 consecutive days shall not exceed 45 mg/L.
  - The arithmetic mean of the concentration of the effluent samples collected over a period of 30 consecutive days shall not exceed 15 percent of the arithmetic mean of the concentration of the influent samples collected over the same period (85 percent removal rate).

- Microbiology
  - The appropriate GEPA microbiological indicator and standard for receiving waters classification will apply to the effluent and/or;
  - The arithmetic mean of the fecal coliform values for samples collected over a period of 30 consecutive days shall not exceed 200 per 100 mL.
  - The arithmetic mean of the fecal coliform values for samples collected over a period of 7 consecutive days shall not exceed 400 per 100 mL.

- pH
  - Effluent values for pH shall remain within the limits of 6.0 to 9.0.

Mixing zones are also regulated under the GWQS. Water quality criteria are required to be met at every boundary point of the mixing zone. In summary, the designated uses or water quality of the waters shall not be affected by the presence of the mixing zone.

2.1.3 Quality Criteria for the Receiving Water

The CWA Amendments required that USEPA establish ambient water quality criteria for pollutants expected to cause adverse effects on aquatic, marine, or human life. Not regulatory driven but based on the latest scientific research, these water quality criteria are published in “Quality Criteria for Water, 1986", also referred to as the “Gold Book”. However, certain water quality standards have been revised since 1986. The pollutants and the thresholds expected to cause observable effects on marine life and human health (carcinogens) are listed in **Table 2.1-2**, as reported in the GWQS 2001 revision.

TABLE 2.1-2
GUAM WATER QUALITY STANDARDS
NUMERICAL CRITERIA FOR PRIORITY TOXIC POLLUTANTS

CONSTITUENT	CAS NO. (11)	SALTWATER		HUMAN HEALTH (10^{-6} risk for carcinogens) FOR CONSUMPTION OF ORGANISMS ONLY (µg/L)
		CRITERION MAXIMUM CONCENTRATION (1) (µg/L)	CRITERION CONTINUOUS CONCENTRATION (2) (µg/L)	
Antimony	7440360			4,300 (3)
Arsenic	7440382	69	36	
Beryllium	7440417			(5)
Cadmium	7440439	42	9.3	(5)
Chromium (III)	16065831			(5)
Chromium (VI)	8540299	1100	50	(5)
Copper	7440508	4.8	3.1	
Lead	7439921	210	8.1	(5)
Mercury	7439976	2.1	0.025	0.051(3)
Nickel	7440020	74	8.2	4,600 (3)
Selenium	7782492	290	71	(5)
Silver	7440224	2.3		
Thallium	7440280			6.3 (3)
Zinc	7440666	95	86	69,000
Cyanide	57125	1	1	200,000 (3,6)
Asbestos	1332214			7,000,000 fibers/L (7)
2,3,7,8-TCDD (Dioxin)	1746016			0.000000014 (4)
Acrolein	107028			780
Acrylonitrile	107131			0.66 (3,4)
Benzene	71432			71 (3,4)
Bromoform	75252			360 (3,4)
Carbon Tetrachloride	56235			4.4 (3,4)
Chlorobenzene	108907			21,000 (3,6)
Chlorodibromomethane	124481			34 (3,4)
Chloroethane	75003			
2-Chloroethylvinyl Ether	110758			
Chloroform	67663			470 (3,4)

TABLE 2.1-2 (Continued)

CONSTITUENT	CAS NO. [11]	SALTWATER		HUMAN HEALTH (10^{-6} risk for carcinogens) FOR CONSUMPTION OF ORGANISMS ONLY (µg/L)
		CRITERION MAXIMUM CONCENTRATION [1] (µg/L)	CRITERION CONTINUOUS CONCENTRATION [2] (µg/L)	
Dichlorobromomethane	75274			46 [3,4]
1,1-Dichloroethane	75343			
1,2-Dichloroethane	107062			99 [3,4]
1,1-Dichloroethylene	75354			3.2 [3,4]
1,2-Dichloropropane	78875			39 [3]
1,3-Dichloropropylene	542756			1,700 [3]
Ethylbenzene	100414			29,000 [3]
Methyl Bromide	74839			4,000 [3]
Methyl Chloride	74873			[5]
Methylene Chloride	75092			1,600 [3,4]
1,1,2,2-Tetrachloroethane	79345			11 [3,4]
Tetrachloroethylene	127184			8.85 [4]
Toluene	108883			200,0000 [3]
1,2-Trans-Dichloroethylene	156605			140,000 [3]
1,1,1-Trichloroethane	71556			[5]
1,1,2-Trichloroethane	79005			42 [3,4]
Trichloroethylene	79016			81 [4]
Vinyl Chloride	75014			525 [4]
2-Chlorophenol	95578			400 [3]
2,4-Dichlorophenol	120832			790 [3]
2,4-Dimethylphenol	105679			2,300 [3]
2-Methyl-4,6-Dinitrophenol	534521			765
2,4-Dinitrophenol	51285			14,000 [3]
2-Nitrophenol	88755			
4-Nitrophenol	100027			
3-Methyl-4-Chlorophenol	59507			

TABLE 2.1-2 (Continued)

CONSTITUENT	CAS NO. (11)	SALTWATER		HUMAN HEALTH (10^{-6} risk for carcinogens) FOR CONSUMPTION OF ORGANISMS ONLY (µg/L)
		CRITERION MAXIMUM CONCENTRATION (1) (µg/L)	CRITERION CONTINUOUS CONCENTRATION (2) (µg/L)	
Pentachlorophenol	87865	13	7.9	8.2 (3,4,6)
Phenol	108952			4,600,000 (3,6)
2,4,6-Trichlorophenol	88062			6.5 (3,4)
Acenaphthene	83329			2,700 (3)
Acenaphthylene	208968			
Anthracene	120127			110,000 (3)
Benzidene	92875			0.00054 (3,4)
Benzo(a)Anthracene	56553			0.049 (3,4)
Benzo(a)Pyrene	50328			0.049 (3,4)
Benzo(b)Fluoranthene	205992			0.049 (3,4)
Benzo(ghi)Perylene	191242			
Benzo(k)Fluoranthene	207089			0.049 (3,4)
Bis(2-Chloroethoxy) Methane	111911			1.4 (3,4)
Bis(2-Chloroethyl)Ether	111444			
Bis(2-Chloroisopropyl) Ether	108601			170,000 (3)
Bis(2-Ethylhexyl) Phthalate	117817			5.9 (3,4)
4-Bromophenyl Phenyl Ether	101553			
Butylbenzyl Phthalate	85687			5,200 (3)
2-Chloronaphthalene	91587			4,300 (3)
4-Chlorophenyl Phenyl Ether	7005723			
Chrysene	218019			0.049 (3,4)
Dibenzo(a,h)Anthracene	53703			0.049 (3,4)
1,2-Dichlorobenzene	95501			17,000 (3)
1,3-Dichlorobenzene	541731			2,600
1,4-Dichlorobenzene	106467			2,600

TABLE 2.1-2 (Continued)

CONSTITUENT	CAS NO. (11)	SALTWATER		HUMAN HEALTH (10^{-6} risk for carcinogens) FOR CONSUMPTION OF ORGANISMS ONLY (µg/L)
		CRITERION MAXIMUM CONCENTRATION (1) (µg/L)	CRITERION CONTINUOUS CONCENTRATION (2) (µg/L)	
3,3-Dichlorobenzidine	91941			0.077 (3,4)
Diethyl Phthalate	84662			120,000 (3)
Dimethyl Phthalate	131113			2,900,000
Di-n-Butyl Phthalate	84742			12,000 (3)
2,4-Dinitrotoluene	121142			9.1 (4)
2,6-Dinitrotoluene	606202			
Di-n-Octyl Phthalate	117840			
1,2-Diphenylhydrazine	122667			0.54 (3,4)
Fluoranthene	206440			370 (3)
Fluorene	86737			14,000 (3)
Hexachlorobenzene	118741			0.00077 (3,4)
Hexachlorobutadiene	87683			50 (3,4)
Hexachlorocyclopentadiene	77474			17,000 (3,6)
Hexachloroethane	67721			8.9 (3,4)
Indeno(1,2,3-cd)Pyrene	193395			0.049 (3,4)
Isophorone	78591			2,600 (4)
Naphthalene	91203			
Nitrobenzene	98953			1,900 (3,6)
N-Nitrosodimethylamine	62759			8.1 (3,4)
N-Nitrosodi-n-Propylamine	621647			1.4 (3,4) 5
N-Nitrosodiphenylamine	86306			16 (3,4)
Phenanthrene	85018			11,000 (3)
Pyrene	129000			
1,2,4-Trichlorobenzene	120821			940
Aldrin	309002	1.3 (8)		0.00014 (3,4)
alpha-BHC	319846			0.013 (3,4)
beta-BHC	319857			0.046 (3,4)

TABLE 2.1-2 (Continued)

CONSTITUENT	CAS NO. [11]	SALTWATER		HUMAN HEALTH (10^{-6} risk for carcinogens) FOR CONSUMPTION OF ORGANISMS ONLY (µg/L)
		CRITERION MAXIMUM CONCENTRATION [1] (µg/L)	CRITERION CONTINUOUS CONCENTRATION [2] (µg/L)	
gamma-BHC	58899	0.16 [8]		0.063 [4]
delta-BHC	319869			
Chlordane	57749	0.09 [8]	0.004 [8]	0.0022 [3,4]
4,4'-DDT	50293	0.13 [8]	0.001 [8]	0.00059 [3,4]
4,4'-DDE	72559			0.00059 [3,4]
4,4'-DDD	72548			0.00084 [3,4]
Dieldrin	60571	0.71 [8]	0.0019 [8]	0.00014 [3,4]
alpha-Endosulfan	959988	0.034 [8]	0.0087 [8]	240 [3]
beta-Endosulfan	33213659	0.034 [8]	0.0087 [8]	240 [3]
Endosulfan Sulfate	1031078			240 [3]
Endrin	72208	0.037[8]	0.0023 [8]	0.81 [3,6]
Endrin Aldehyde	7421934			0.81 [3,6]
Heptachlor	76448	0.053 [8]	0.0036 [8]	0.00021 [3,4]
Heptachlor Epoxide	1024573	0.053 [8]	0.0036 [8]	0.00011 [3,4]
PCBs	1336363		0.03 [8,10]	0.000171 [3,4]
Toxaphene	8001352	0.21	0.0002	0.00075 [3,4]

Reference: Guam Water Quality Standards (10 August 2001)

Notes:

(1) Criteria Maximum Concentration (CMC) is an acute concentration. It is the one (1) hour average concentration in ambient waters that should not be exceeded once every 3 years on average.

(2) Criteria Continuous Concentration (CCC) is a chronic concentration. It is the four (4) day average concentration of a pollutant in ambient water that should not be exceeded more than once every 3 years on average.

(3) Criteria revised to reflect the USEPA q_1* or RfD, as contained in the Integrated Risk Information System (IRIS) as of 1 October 1996. The fish tissue bioconcentration factor (BCF) from the 1980 documents was retained in each case.

(4) These criteria are based upon carcinogenicity of 10^{-6} risk.

(5) The Agency is not promulgating human health criteria for these contaminants. However, permit authorities should address these contaminants in NPDES permit actions using Guam's existing narrative criteria for toxics.

(6) No criteria for protection of human health from consumption of aquatic organisms (excluding water) were presented in the 1980 criteria document, or in the 1986 Quality Criteria for Water. Nevertheless, sufficient information was presented in the 1980 document to allow a calculation of a criterion, even though the results of such a calculation were not shown in the document.

(7) The criterion for asbestos is the MCL (40 CFR 141.62).

(8) Aquatic life criteria for these compounds were issued by the USEPA in 1980 utilizing the 1980 Guidelines for criteria development. The acute values shown are final acute values (FAV), which by the 1980 Guidelines are instantaneous values as contrasted with a CMC which is a short-term average.

(9) This criterion applies to total PCBs or cogener or isomer analyses.

(10) PCBs are a class of chemicals which include aroclors 1242, 1254, 1221, 1232, 1248, 1260, and 1016, CAS numbers 53469219, 11097691, 11104282, 11141165, 12672296, 11096825, and 12674112, respectively. The aquatic life criteria apply to this set of PCBs.

(11) Chemical Abstracts Service "CAS" registry number.

2.2 SUMMARY OF APPROACH

The purpose of this study is to support the EIS that will be prepared for the USMC relocation from Okinawa to Guam. An EIS is a document required under the National Environmental Policy Act to ensure that federal agencies have addressed the environmental concerns associated with their actions. The EIS identifies the environmental effects associated with a proposed action as well as the effects of other reasonable alternatives to this action.

2.2.1 Study Methodology

The proposed USMC relocation from Okinawa to Guam will increase population in the northern portion of the island. Phase 1 of this project investigated the environmental impacts to the receiving waters associated with options to treat the additional wastewater flows at the existing NDWWTP and discharge the treated effluent through the plant's outfall. The construction of a new outfall for the NDWWTP was recently completed and placed into operation on 23 January 2009. The new NDWWTP outfall replaces the old outfall that discharged seaward of the shallow reef flat. The new outfall was designed to discharge into deeper water at a 140-foot depth and to accommodate design average and peak flows of 12.0 MGD and 28.6 MGD, respectively. The diffuser system for the new outfall as shown in the original design documents has yet to be installed. For the purpose of the Phase 1 investigation, however, it was assumed that the diffuser system was installed according to the original design documents to achieve the dispersion of effluent intended. Preliminary results of the Phase 1 investigation are documented in a separate interim report dated February 2009 titled *Northern District Wastewater Treatment Plant Outfall Assessment*, hereafter referred to as the Phase 1 Report.

This Phase 2 study addresses the environmental impacts to the receiving waters associated with the option of treating all DoD wastewater flows generated in the northern district of Guam, including the additional flows associated with the USMC relocation, at a new DoD secondary treatment facility. This proposed DoD facility will be located north of the existing NDWWTP and will discharge secondary treated effluent to the Philippine Sea through a new DoD outfall. The proposed DoD outfall will be located north of both the old and new NDWWTP outfalls. The results of the Phase 1 investigation indicate that the plume from the new NDWWTP outfall generally migrates toward the north and west, in the direction of the proposed DoD outfall. This will impact the environment and ecology of the receiving waters in the vicinity of the proposed DoD outfall associated with the discharge from the new NDWWTP outfall.

The purpose of this Phase 2 investigation is to focus on the additional environmental impacts to the receiving waters associated with the proposed discharge from the DoD outfall. The primary criterion used to assess environmental impact is compliance with the GWQS. If the constituents in the treated effluent from the proposed DoD secondary treatment plant meet GWQS without dilution, then no further analysis is required. Otherwise, further evaluation is necessary to assess initial dilution and farfield transport of the constituents in the receiving waters and their biological impacts to the marine life, benthic faunal, and the coral reef ecosystems.

Assessment of the environmental and ecological impacts associated with the discharge from the proposed DoD outfall is further complicated by the following:

- There are no preliminary design plans for the proposed DoD outfall.
- The current discharge from the new NDWWTP outfall creates an altered ambient receiving water environment in the vicinity of the proposed DoD outfall, making it difficult to ascertain pristine water quality conditions without the influence of the NDWWTP discharge plume.
- The current discharge from the NDWWTP was determined to be approximately 5.1 MGD, which is less than half the design capacity of the new outfall of 12.0 MGD. The NDWWTP may utilize the entire capacity of its new outfall in the future due to civilian growth and development in the area. Therefore, current water quality sampling preformed for this investigation may not be appropriate to predict the influence of the discharge from the NDWWTP on future ambient receiving water conditions in the vicinity of the proposed DoD outfall.

To address these challenges, the following approach was undertaken in this investigation.

2.2.1.1 Conceptual DoD Outfall Design

Conceptual design of the proposed DoD outfall was performed for this investigation. The following criteria were used as the basis for the design of the proposed DoD outfall:

- Discharge an average flow of 5.0 MGD of secondary treated effluent.
- Locate within the M-2 water quality boundaries.
- Configuration to consider the existing bathymetry in the area.
- Performance based on achieving GWQS.

As presented in the Phase 1 Report, the results of the farfield plume analysis indicate that the GWQS for enterococcus and ammonia cannot be achieved in the vicinity of the proposed DoD outfall due to the primary treated effluent discharged from the new NDWWTP outfall. These constituent exceedances cannot be addressed by the proposed DoD outfall and must be corrected at the NDWWTP. Therefore, the conceptual design of the proposed DoD outfall was based on achieving the water quality levels presented in the GWQS, assuming secondary treatment will be provided at the NDWWTP to reduce the pollutants discharged.

2.2.1.2 Future Receiving Water Quality Development

Phase 2 of the investigation assessed the environmental and ecological impacts to the receiving waters associated with a new point discharge from the proposed DoD outfall. Since the discharge plume from the new NDWWTP outfall will likely migrate toward the DoD outfall, there will be preexisting environmental and ecological impacts to the receiving waters that are not associated with the proposed DoD outfall discharge. Therefore, this investigation will determine the impacts associated with the new NDWWTP outfall discharge to the receiving waters in the vicinity of the proposed DoD outfall location as well as the compounded impacts associated with the addition of a new point discharge from the proposed DoD outfall.

As a conservative approach, the future ambient water quality condition anticipated in the vicinity of the proposed DoD outfall was based on the NDWWTP discharging primary treated effluent at the full design capacity of its new outfall of 12.0 MGD. Since the current discharge from the NDWWTP is approximately 5.1 MGD, water quality sampling in the vicinity of the proposed DoD outfall cannot be used to project the modified ambient water quality of the receiving waters resulting from the discharge of 12.0 MGD from the new NDWWTP outfall. Initial dilution analysis and farfield plume modeling performed for the new NDWWTP outfall in the Phase 1 investigation was updated in this study to estimate the future ambient water quality condition resulting from the discharge of 12.0 MGD of primary treated effluent from the new NDWWTP outfall. The methodology used for this Phase 2 investigation is summarized on **Figure 2.2-1**.

2.2.2 Outfall and Plume Modeling

Initial dilutions for the new NDWWTP and proposed DoD outfalls were developed by EKNA Services, Inc. for this investigation using the USEPA approved dilution model *Visual Plumes*. This modeling program was used to predict the initial dilution that can be achieved with various outfall configurations. The new NDWWTP outfall model was originally developed for the Phase 1 portion of this investigation and is documented in the Phase 1 Report. The proposed DoD outfall was developed for this Phase 2 investigation.

Farfield plume modeling was also performed by EKNA Services, Inc. to determine the fate of the plume beyond the diffuser location, after initial dilution has taken place. The results of this model were used to determine the environmental and ecological impacts to the areas adjacent to the outfall.

To accurately simulate the nearfield and farfield plumes, the physical characteristics of the outfall configuration, design flow, and CTD, ocean current and wind rose data were input into the computer model.

2.3 DATA COLLECTION AND GENERATION

Data collected in Phase 1 were also utilized in this Phase 2 study. This included gathering and reviewing existing information pertinent to this investigation and available from NAVFAC Pacific and GWA, such as previous design and planning reports, record drawings of the NDWWTP and outfall, laboratory analysis of the wastewater characteristics, and flow data from the plant. Assistance from NAVFAC Pacific, COMNAVMAR, and GWA in providing this information contributed substantially to this investigation.

Additional information specific to the proposed DoD outfall location was collected for this second phase of the investigation. AECOS, Inc. researched and collected data from existing reports and studies performed by others on the marine life and environment in the vicinity of the proposed DoD outfall. Supplemental information was provided through a review of reports and investigations performed on other marine outfalls located in Guam and Hawaii.

Field work for this phase of the investigation included the installation of data collecting instruments and water quality sampling in the vicinity of the proposed DoD outfall. A summary of the field instruments installed and the water quality sampling results follows.

2.3.1 Ocean Current Recorders

Site specific data on the dynamics of ocean currents are necessary for the development of nearfield and farfield plume models. The ocean current meter measurement program implemented for this investigation included a 9-month in-situ deployment of two current meters.

An illustration of the current meter mooring is presented on **Figure 2.3-1**. Two separately moored InterOcean S4 electromagnetic current meters were installed at the locations shown on **Figure 2.3-2**. This instrument measures and records current speed and direction, water depth, and water temperature. Data are continuously stored in the instrument at preset intervals to match the expected length of deployment.

This Phase 2 report is based on the first four months of data (14 August 2008 to 9 December 2008) consisting of two deployments. Deployment 1 collected ocean current data from 14 August 2008 to 7 October 2008 at stations CM1 and CM2. The data collection period for the second deployment was from 8 October 2008 to 9 December 2008. A summary of these results is presented in Chapter 3.

2.3.2 Receiving Water Quality Data

This investigation implemented a one-year water quality monitoring program to gather baseline information on current ambient conditions of the receiving waters. The water quality constituents monitored for this investigation were limited to those regulated under the GWQS and were likely to be present in the wastewater discharge in quantities that may result in a detrimental impact to the receiving marine waters. This was determined through a review of existing data provided by GWA on the NDWWTP effluent characteristics and data from other primary and secondary wastewater treatment plants located in Guam and Hawaii. In addition to the select GWQS constituents, total nitrogen, total phosphorus, and chlorophyll α were included in the limited water quality monitoring program. Total nitrogen and phosphorus represent the total nutrient source available for breakdown by phytoplankton and benthic algae, and chlorophyll α is an indicator of phytoplankton biomass in the marine water.

Water quality sampling was performed for both Phases 1 and 2 of this investigation. The Phase 1 water quality monitoring plan consisted of four sampling events that took place over the course of one year. The water quality monitoring program consisted of an array of ten sampling stations located in and around the new NDWWTP outfall, with samples collected at three depths (near surface, near bottom, and mid-depth). The Phase 2 water quality monitoring plan consisted of three sampling events that took place over a nine-month period. Eight sampling stations in and around the proposed DoD outfall were established. Preliminary results from the Phase 1 study indicated a lack of a thermocline through the water column. Samples were therefore collected only at the near surface and near bottom depths for each of the eight sampling locations in Phase 2.

The location of the sampling stations for both phases is summarized in **Table 2.3-1** and shown previously on **Figure 2.3-2**.

TABLE 2.3-1
RECEIVING WATER SAMPLING STATIONS

Phase	Station No.	Latitude (N) Deg Dec Min	Longitude (E) Deg Dec Min	Depth* Meters
1	1	13 33.21678	144 48.46404	19 / 38
	2	13 33.14590	144 48.44342	22.5 / 45
	3	13 33.11463	144 48.43620	20 / 40
	4	13 33.08166	144 48.42806	19 / 38
	5	13 33.03607	144 48.39470	19.5 / 39
	6	13 32.93168	144 48.37360	23.5 / 47
	7	13 33.12751	144 48.38585	29.5 / 59
	8	13 33.12218	144 48.40900	26 / 52
	9	13 33.10841	144 48.46130	19 / 38
	10	13 33.10339	144 48.48598	17 / 34
2	A	13 33.358	144 48.468	28
	B	13 33.358	144 48.468	40
	C	13 33.257	144 48.477	36
	D	13 33.290	144 48.430	54
	E	13 33.288	144 48.454	43
	G	13 32.285	144 48.504	30
	H	13 33.284	144 48.527	6
	J	13 33.181	144 48.453	38

**Depth of sample: Phase 1 – mid-depth and bottom, Phase 2 – bottom.*

The analysis of the samples collected is presented in **Table 2.3-2** and was conducted in accordance with standard oceanographic or EPA methods with detection limits less than the values specified in the Guam Water Quality Standards.

TABLE 2.3-2
WATER QUALITY MONITORING PROGRAM

Analyses	Hold Time	Preservation Method
pH	15 minutes	none
Dissolved Oxygen	Immediate	none
Temperature	Immediate	none
Salinity (field)	Immediate (needed for DO)	none
Salinity (by salinometer)	28 days	none
Turbidity	48 hrs	chill on ice to 4ºC
Total Suspended Solids	7 days	chill on ice to 4ºC
Nitrate + Nitrite Nitrogen	28 days	chill on ice to 4ºC , freeze
Ammonia Nitrogen	28 days	chill on ice to 4ºC , freeze
Total Nitrogen	28 days	chill on ice to 4ºC , freeze
Ortho-Phosphate	48 hrs	chill on ice to 4ºC
Total Phosphorus	28 days	chill on ice to 4ºC , freeze
Chlorophyll	---	Chill sample on ice, filter and extract as soon as possible; store frozen in dark
Enterococcus	6-8 hrs	chill on ice to 4ºC

In addition to the analyses presented in the table above, a vertical profile of conductivity, temperature, and depth (CTD) of each sampling station was collected using the Sea-Bird Electronics Seacat Profiler SBE 19.

Limited toxic substances were analyzed as part of the Phase 1 water quality monitoring program and included total sulfide, copper, lead, and zinc. Four samples were collected at each of the four sampling events (sixteen samples total).

This Phase 2 report is primarily based on the water quality results of the samples collected near the proposed DoD outfall location identified under the Phase 2 monitoring program. These results are comprised of the first two scheduled sampling events; one during 10-11 November 2008 and one during 23-24 March 2009. The old NDWWTP outfall was still in operation during the November 2008 sampling event. Discharge through the old NDWWTP outfall was discontinued in January 2009, when the new NDWWTP outfall was completed. The March 2009 water quality sampling results reflect this.

2.3.3 NDWWTP Effluent Wastewater Quality Data

The quality of the primary treated effluent discharged through the new NDWWTP outfall was previously evaluated in the Phase 1 Report. This information is still relevant for this Phase 2 study due to the influence of this discharge plume on ambient water quality of the receiving water in the vicinity of the proposed DoD outfall.

Data collected and used in the Phase 1 evaluation of the NDWWTP discharge included available discharge monitoring reports (DMR) and additional analytical testing performed by GWA on the NDWWTP influent and effluent wastewater. To supplement this information, grab samples of influent and effluent were taken at the NDWWTP on 13 October 2008 for the Phase 1 investigation and analyzed for the same water quality parameters included in the monitoring program for the receiving waters (see **Table 2.3-2**) with the exception of chlorophyll. Total sulfide, copper, lead, and zinc were also included in the analyses.

CHAPTER 3
RECEIVING WATER CONDITIONS

Primary treated wastewater currently discharges through the new NDWWTP ocean outfall at an average daily flow rate of 5.1 MGD. Phase 1 of this investigation addressed the impacts associated with the discharge of additional DoD flows through this new NDWWTP outfall. Results of the farfield plume analysis in Phase 1 indicated that the discharge from the new NDWWTP outfall will migrate in a northwesterly direction toward the proposed DoD outfall and will likely alter the marine environment in this area to less than pristine conditions.

As discussed in Chapter 2, the initial dilution analysis and farfield plume modeling results for the new NDWWTP outfall performed during Phase 1 of this investigation were updated for this Phase 2 study to predict water quality conditions of the receiving waters in the vicinity of the proposed DoD outfall. As shown schematically on Figure 2.2-1 in Chapter 2, information required to perform this task included the following:

- Discharge quantity and quality from the NDWWTP (assessed in Phase 1 study)
- Ocean current data (collected for both Phases 1 and 2 of this investigation)
- Pristine receiving water quality conditions without the influence of any wastewater discharges (utilizing results from the Phase 1 and 2 water quality monitoring plans)

This chapter presents the information utilized to form the basis for developing anticipated receiving water quality conditions in the vicinity of the proposed DoD outfall resulting from the influence of the new NDWWTP outfall discharge.

To minimize confusion in the discussions presented in the subsequent sections of this chapter and Chapter 4, the following terminology is used with respect to describing the receiving water quality conditions:

> **Baseline** water quality refers to the results of all sampling effort in the project location. This is the current (actual) receiving water quality of the waters off Tanguisson Point and includes the influence of the existing discharge from the new NDWWTP outfall (approximate average discharge of 5.1 MGD).
>
> **Background** water quality is used to characterize the water quality conditions that would exist in the absence of a wastewater discharge. In an attempt to derive average background water quality values in the waters off Tanguisson Point not influenced by the NDWWTP discharge, analytical results for select stations monitored in Phases 1 and 2 were used. Where local field measurements are either absent or not considered representative of the background water quality, historical data on similar open coastal environments were used to estimate background concentrations.
>
> **Ambient** water quality is the theoretical water quality condition in the vicinity of the proposed DoD outfall determined using the initial dilution analysis and farfield plume modeling results for the new NDWWTP outfall during Phase 1 of the investigation. Although “ambient” is used in a similar sense in the GWQS, the standards consider ambient to be actual conditions, not the theoretical values determined in this Phase 2 study.

3.1 NDWWTP PRIMARY EFFLUENT QUANTITY AND QUALITY

The NDWWTP was commissioned in 1980 and was designed to provide primary treatment for an average daily flow of 12 MGD and a peak hourly flow of 28.6 MGD. Currently, all DoD wastewater flow in the north is treated at the NDWWTP. This Phase 2 study evaluates the option to construct a separate DoD treatment facility for all DoD wastewater flow in the north, including the additional wastewater loading associated with the relocation of the U.S. Marine Corps from Okinawa to Guam. Although wastewater from DoD facilities would no longer be treated at the NDWWTP under this option, this Phase 2 study assumes the entire capacity of the new outfall of 12 MGD will be utilized by future growth and development of the civilian population. Therefore, the discharge from the new NDWWTP outfall that will influence water quality conditions in the vicinity of the proposed DoD outfall is 12 MGD.

Primary treated effluent quality discharged from the NDWWTP was previously evaluated in Phase 1 of this investigation. The following discussions are excerpts from the Phase 1 Report and are used to establish effluent quality discharged from the new NDWWTP outfall.

3.1.1 GMP's 1998 Analytical Results

The *"Basis of Design for the Northern District Treatment Plant Outfall Extension"* was prepared by GMP Associates, Inc. in September 2001 for GWA and the Department of Public Works, hereafter referred to as the 2001 BOD Report. This document contained the effluent wastewater concentrations used to design the new NDWWTP outfall. Included in the 2001 BOD Report was a priority toxic pollutant scan. Of the 126 priority pollutants, five were detected, including lead, p-Dichlorobenzene, toluene, copper, and zinc. The 2001 BOD Report indicated that the concentration of lead of 2,900 μg/L was likely to be an aberration. The concentration of lead measured at other treatment plants in Guam and Hawaii was used to support this conclusion. Therefore, lead was not included in the required dilution analysis in the 2001 BOD Report. Effluent concentrations used in the 2001 BOD Report for the design of the new NDWWTP outfall are presented in **Table 3.1-1**, along with the required dilution determined in the 2001 BOD Report.

As indicated in the 2001 BOD Report, the dilution required for the new NDWWTP outfall was determined to be 200. This is based on the effluent total suspended solids (TSS) concentration of 190 mg/L relative to the ambient concentration found in the receiving waters. The required dilution for TSS was the second highest value. Enterococci required the largest dilution of 8,000. The 2001 BOD Report indicated that this dilution could not be practicably achieved by a diffuser constructed at a reasonable cost. Therefore, the new NDWWTP outfall was designed to attain the required dilution of 200.

TABLE 3.1-1

NDWWTP EFFLUENT CONCENTRATIONS AND REQUIRED DILUTION PRESENTED IN 2001 BOD REPORT

Constituent Regulated by Guam Water Quality Standards	Unit	Water Quality Standard	Effluent Concentration	Required Dilution
Enterococci	#/100mL	104	830,000*	7,981
pH		6.5 – 8.5	7.2	10
Orthophosphate	μg/L	50	4,240*	85
Nitrate-Nitrogen	μg/L	200	29	0
Dissolved Oxygen	mg/L	4.6	0	6
Salinity	ppt	+/- 10% ambient	0.8	0
Total Suspended Solids	μg/L	20,000	190,000	170
Turbidity	NTU	1 + ambient	---	---
Temperature	°C	1 + ambient	30	0
Priority Toxic Pollutants				
p-Dichlorobenzene	μg/L	2,600	1.1	0
Toluene	μg/L	5,000	1.9	0
Copper	μg/L	3.1	53	17
Zinc	μg/L	86	2,110	2
Additional Toxic Pollutants				
Ammonia	μg/L	20	1,045*	52
Sulfide	μg/L	5	110*	22
Non-regulated Chemical Constituents				
Acetone	μg/L	---	86	n/a
4-Methylphenol	μg/L	---	45	n/a

Notes:

- *Values identified with "*" are estimated from analyses of primary effluent from Oahu wastewater treatment plants.*
- *Ammonia and orthophosphate are averaged from grab samples.*
- *Application factor of 0.05 applied to total NH_3 concentration of 20.9 mg/L.*
- *Sulfide concentration is from an in-plant survey at Sand Island WWTP.*
- *Enterococci is from a five plant survey of primary effluent.*
- *Effluent total suspended solids concentration is the maximum average value recorded from January 1997 to September 1998.*
- *Required dilution for dissolved oxygen assumes 3 mg/L immediate demand.*

3.1.2 GWA's 2007-2008 Analytical Results

GWA provided DMRs for the NDWWTP for the period October 2006 to June 2007. In accordance with the NPDES permit requirements, 5-day biochemical oxygen demand (BOD_5), TSS, settleable solids, oil and grease, and pH are monitored in the effluent. BOD_5 and TSS are also monitored in the influent entering the plant. Both monthly average and daily maximum values are recorded for all parameters except pH, for which minimum and maximum values are reported. A summary of the results contained in the DMR is provided in **Table 3.1-2**.

TABLE 3.1-2
DMR SUMMARY
(October 2006 to June 2007)

Parameter	Statistical Analysis	Influent		Effluent			
		Monthly Average	Daily Maximum	Monthly Average	Monthly Average Discharge Limit	Daily Maximum	Daily Maximum Discharge Limit
BOD_5 (mg/L)	Geometric Mean	112	163	78	85	95	170
	Minimum	65	104	46		57	
	Maximum	195	274	113		141	
	90% Analysis*	153	222	101		117	
TSS (mg/L)	Geometric Mean	104	182	66	50	105	100
	Minimum	59	59	33		35	
	Maximum	428	1,332	276		844	
	90% Analysis*	141	304	85		128	
Settleable Solids (mL/L)	Geometric Mean	NA	NA	0.68	1	1.74	2
	Minimum	NA	NA	0.2		0.3	
	Maximum	NA	NA	4		20	
	90% Analysis*	NA	NA	1.6		5.4	
Oil and Grease (kg/day)	Geometric Mean	NA	NA	859	---	859	---
	Minimum	NA	NA	498		498	
	Maximum	NA	NA	1,692		1,692	
	90% Analysis*	NA	NA	1,524		1,524	
pH (Minimum and Maximum)	Geometric Mean	NA	NA	7.24	7.0	7.75	9.0
	Minimum	NA	NA	6.82		7.06	
	Maximum	NA	NA	7.65		8.32	
	90% Analysis*	NA	NA	6.9		8.1	

**Statistical analysis used to develop a value that is exceeded only 10 percent of the time.*

As indicated in the table above, the NPDES permit discharge limits for all parameters monitored were exceeded at least once during the period October 2006 to June 2007. The monthly average and daily maximum geometric mean for TSS of 66 mg/L and 105 mg/L, respectively, indicate that this parameter frequently exceeded the discharge limits. The DMR indicated that primary treatment provided at the NDWWTP can achieve approximately 40 percent removal of BOD_5 and 39 percent removal of TSS.

GWA also provided supplemental influent and effluent wastewater quality data from January 2008 to May 2008. Daily samples were collected at the NDWWTP and analyzed at GWA's Hagatna Wastewater Treatment Plant. BOD_5, TSS, settleable solids, and pH were analyzed in both the influent and effluent samples from the NDWWTP. A summary of these results is provided in **Table 3.1-3**.

TABLE 3.1-3
SUMMARY OF HAGATNA LABORATORY RESULTS
(January 2008 to May 2008)

Parameter	Statistical Analysis	Influent (Daily Samples)	Effluent (Daily Samples)	Daily Maximum Discharge Limit	Average Percent Removal
BOD_5 (mg/L)	Geometric Mean	133.14	96.33	170	22%
	Minimum	58.00	66.30		
	Maximum	207.48	141.00		
	90% Analysis*	182.8	123.7		
TSS (mg/L)	Geometric Mean	127.08	66.53	100	44%
	Minimum	57.00	34.51		
	Maximum	346.00	110.00		
	90% Analysis*	168.2	93.1		
Settleable Solids (mL/L)	Geometric Mean	4.62	0.44	2	89%
	Minimum	0.80	0.00		
	Maximum	13.00	2.00		
	90% Analysis*	7.0	1.0		
pH (Minimum and Maximum)	Geometric Mean	7.08	6.98	7 - 9	pH reduction of 2%
	Minimum	5.99	5.96		
	Maximum	7.73	7.51		
	90% Analysis*	7.5	7.4		

**Statistical analysis used to develop a value that is exceeded only 10 percent of the time.*

The maximum TSS concentration observed between January 2008 and May 2008 was 110 mg/L, which exceeds the NPDES daily maximum discharge limit of 100 mg/L. **Table 3.1-3** also indicates that the pH level dropped below 7 during this monitoring period.

3.1.3 2008 Grab Sample Results and Temperature Monitoring

An influent and effluent wastewater grab sample was taken on 13 October 2008 from the NDWWTP to verify the wastewater characterization provided in the 2001 BOD Report. The results are summarized in **Table 3.1-4**.

TABLE 3.1-4
NDWWTP INFLUENT AND EFFLUENT GRAB SAMPLE RESULTS
(13 October 2008)

Constituent Regulated by Guam Water Quality Standards	Unit	Influent Concentration	Effluent Concentration	% Removal
Enterococci	#/100mL	> 240,000	> 240,000	---
Total Phosphorus	μg/L	4,700	3,850	18%
Orthophosphate (as P)	μg/L	2,940	2,620	11%
Total Nitrogen	μg/L	47,900	47,600	1%
Nitrate+Nitrite (as N)	μg/L	8	9	-13%
TSS	mg/L	201	80	60%
Turbidity	NTU	111	59.0	47%
Temperature	°C	28.6	29.8	-4%
Priority Toxic Pollutants				
Lead	mg/L	0.00443	0.00494	-12%
Copper	mg/L	0.0800	0.0683	15%
Zinc	mg/L	0.245	0.276	-13%
Additional Toxic Pollutants				
Ammonia (as N)	μg/L	18,400	18,400	---
Total Sulfide	mg/L	0.51	0.14	73%

A majority of the grab sample concentrations were less than those reported in the 2001 BOD Report, which was used to develop the dilution criterion for the deeper NDWWTP outfall. Considerable disparity was found with enterococci, orthophosphate, TSS, and lead.

The enterococci and orthophosphate concentrations reported in the 2001 BOD Report were 830,000 #/100 mL and 4,240 μg/L, respectively, which is significantly higher than the grab sample taken on 13 October 2008. This may be attributed to different sampling methods. The 2001 BOD Report did not elaborate on the source of the data with respect to sampling and analytical method or number of samples that comprise the values presented in the report. In addition, the enterococci and orthophosphate concentrations in the 2001 BOD Report were not taken from the NDWWTP but were extrapolated from data collected from other treatment plants on Oahu.

The TSS concentration reported in the 2001 BOD Report was 190 mg/L. This constituent was used to establish the dilution criterion of 200 for the new NDWWTP outfall. The grab sample taken on 13 October 2008 indicated a much lower concentration of 80 mg/L. Based on the DMRs and analytical tests performed by GWA (see section 3.1.2), the daily maximum concentration is approximately 110 mg/L. Based on this information, the TSS value of 190 mg/L in the 2001 BOD Report appears to be high.

As stated in the 2001 BOD Report, the lead concentration of 2,900 μg/L was likely to be an aberration and was excluded from consideration in the development of the new NDWWTP outfall design (see section 3.1.1).

3.1.4 Effluent Wastewater Characterization Summary

After reviewing the available analytical wastewater characteristic data for the NDWWTP discharge, it appears the grab sample collected on 13 October 2008 is consistent with effluent characteristics defined in the 2001 BOD Report, with the exception of enterococci, orthophosphate, TSS, and lead. The enterococci and orthophosphate concentrations presented in the 2001 BOD Report were developed from data collected at other WWTPs and may not necessarily reflect the concentrations found in the discharge from the NDWWTP. Therefore, this investigation applied the results of the 13 October 2008 grab sample instead of the 2001 BOD Report for these constituents. As previously discussed in section 3.1.3, the concentrations of TSS and lead presented in the 2001 BOD Report appeared to be high. The TSS concentration found in the grab sample is more consistent with typically effluent values and was therefore used in this investigation.

Table 3.1-5 summarizes the wastewater characteristics for the primary treated effluent discharged through the new NDWWTP outfall.

TABLE 3.1-5
PRIMARY TREATED EFFLUENT WASTEWATER CHARACTERISTICS

Constituent Regulated by Guam Water Quality Standards	Unit	Effluent Concentration
Enterococci	#/100mL	> 240,000
pH	---	7.0
Orthophosphate (as P)	μg/L	2,620
Nitrate-Nitrogen	μg/L	9
Dissolved Oxygen	mg/L	0
Salinity	ppt	0.8
TSS	μg/L	80,000
Turbidity	NTU	59.0
Temperature	°C	29.8
Priority Toxic Pollutants		
p-Dichlorobenzene	μg/L	1.1
Toluene	μg/L	1.9
Lead	μg/L	4.94
Copper	μg/L	68.3
Zinc	μg/L	276
Additional Toxic Pollutants		
Ammonia (as N)	μg/L	18,400
Total Sulfide	μg/L	140

3.2 NEW NDWWTP OUTFALL DESIGN (2005 CONSTRUCTION PLANS)

The new NDWWTP outfall was placed into operation on 23 January 2009. The diffuser system shown in the original design documents was not installed. For the purpose of both Phases 1 and 2 of this investigation, however, the initial dilution analysis and farfield plume modeling assumed the diffuser system will be installed in the future. The following discussions are excerpts from the Phase 1 Report and are used to establish the physical parameters of the new NDWWTP outfall used in the nearfield and farfield model development.

As a result of EPA's tentative denial of the renewal application for the NDWWTP, GWA decided to extend the ocean outfall into deeper waters and revised the permit application accordingly. The basis of design report (2001 BOD Report) for the new NDWWTP outfall extension was prepared by GMP Associates, Inc. in September 2001 under the Department of Public Works' Tumon Bay Infrastructure and Beautification Project. Construction plans for this new outfall were also prepared by GMP Associates, Inc. in 2005 (hereafter referred to as the 2005 Construction Plans). A copy of these construction plans is provided in **Appendix 3A**.

The new NDWWTP outfall extends approximately 1,700 feet into the ocean as measured from the shoreline, with the diffuser section discharging into deeper marine waters as shown on **Figure 3.2-1**. The diffuser section will be situated along the (-)140-foot elevation contour and will be comprised of 400 linear feet of 34-, 28-, 22-, and 20-inch piping. The design criteria for this new NDWWTP outfall are summarized in **Table 3.2-1**. The 2005 Construction Plans indicate that the resulting mixing zone is a 700-foot by 300-foot area, as shown on **Figure 3.2-2**.

Concerns regarding the design of the new NDWWTP outfall diffuser system, as shown in the 2005 Construction Plans, were identified through discussions with GWA and a preliminary hydraulic analysis performed on the system. These issues are summarized below:

- Based on a preliminary review of the 2005 Construction Plans, the tideflex check valve located at the terminus of the diffuser section will likely result in a disproportionate distribution of flow through the diffuser system. A preliminary hydraulic analysis performed by EKNA Services indicated that approximately 20 percent of the flow will be discharged through the terminus tideflex check valve. This will result in an imbalanced discharge through the diffuser system, making it difficult to attain the required dilution intended in the 2001 BOD Report for the new deeper outfall extension.

- GWA's discussions with GEPA indicated that GEPA will not allow a credit for dilution; thus requiring the discharge to meet GWQS at the end of pipe. As a result, GWA decided not to install the diffuser system until this issue is resolved.

Construction of the new deeper ocean outfall extension was recently completed without the diffuser section and placed in operation on 23 January 2009. As presented in the 2001 BOD Report, the diffuser system was designed to achieve a dilution factor of 200. However, this initial dilution cannot be attained with the open end pipe as constructed. EKNA Services determined that initial dilution from a single port outfall is 115.

Figure 3.2-1

New NDWWTP Outfall

Table 3.2-1

New NDWWTP Outfall Design Criteria*

Parameter	Criteria
Peak Hourly Flow:	28.6 MGD
Initial Dilution Ratio:	200:1
Discharge Depth:	140 feet below MLLW
Head Loss at Peak Hourly Flow at High Tide:	51 feet
Diffuser Length and Outside Diameter:	100 feet 34 inches 100 feet 28 inches 100 feet 22 inches 100 feet 20 inches
Number of Ports and Spacing:	40 at 10 feet on centers
Port:	6 inch series 35-D Tideflex Check Valve
Horizontal Direction Drilling Parameters:	
Entry Angle:	12 Degrees
Radius of Curvature:	3,400 feet
Exit Angle:	6 Degrees
Pipeline:	High Density Polyethelene 34-inch outside diameter with SR = 17

- *As presented in the construction drawings for the Tumon Infrastructure and Beautification Northern District Sewer Outfall Extension, prepared by GMP Associates, Inc., 2005.*

Figure 3.2-2

New Deeper NDWWTP Ocean Outfall Extension

For the purpose of this investigation, it was assumed that GWA will install the diffuser system. To achieve the design intent of the diffuser system as documented in the 2001 BOD Report, it was also assumed that the terminus tideflex check valve will not be installed. This modification of the outfall and diffuser system will hereafter be referred to as the "Modified Diffuser Design".

3.3 RECEIVING WATER CONDITIONS

Physical oceanographic conditions and receiving water quality were determined for both Phases 1 and 2 of this investigation. For this Phase 2 study, both baseline and background water quality characteristics were evaluated. The primary purpose for determining baseline water quality characteristics is to assess the current impact of the discharge from the new NDWWTP outfall (i.e., discharge of 5.1 MGD). Establishing background water quality characteristics in the absence of a wastewater discharge is necessary when modeling the effects of the farfield plume created by the new NDWWTP outfall operating at full capacity (i.e., discharge of 12 MGD). Interim results from Phases 1 and 2 are summarized below.

3.3.1 Physical Oceanographic Conditions

The characteristics of the discharge plume from an outfall are dependent on the site-specific dynamics of ocean currents and density of the receiving waters. EKNA Services performed the field work necessary to obtain this information to develop subsequent hydraulic plume models for the new NDWWTP and proposed DoD outfall. EKNA Services Interim Report is provided in **Appendix 3B**. A summary of the results follows.

3.3.1.1 Ocean Current Meter Measurements

Two single point moored current meters were deployed near the vicinity of the new NDWWTP outfall and the proposed DoD outfall (refer to Figure 2.3-2 in Chapter 2). The results of the initial 2-month ocean current meter deployment (14 August to 7 October 2008) conducted for Phase 1 indicated that the currents recorded from both meters were similar in speed and direction. The current direction is oriented parallel to the bathymetry contours, with a dominant northerly direction (0 to 30 ° True). The tidal currents are reversing currents; however, there is a mean net drift toward the north. The mean ocean current speed is 10 cm/sec, with a maximum speed of 50 cm/sec. The maximum ocean current speed typically lasted for one hour.

The results of the second 2-month ocean current deployment (8 October to 9 December 2008) were similar to the first deployment with respect to speed and direction. The mean current for the entire four-month period was about 10 cm/sec, with a maximum speed of 50 cm/sec. The current is typically oriented parallel to the bathymetry contours, with a dominant flow direction toward the north.

3.3.1.2 Density Profile Measurements

The nearfield effluent plume is affected by the density of the ocean waters. Ocean water density is determined by water temperature and salinity. A large density gradient through the water column can prevent the plume from reaching the surface, thereby decreasing initial dilution. Ten sampling stations around the new NDWWTP outfall and eight sampling stations around the proposed DoD outfall were sampled using a conductivity-temperature-depth (CTD) profiler. The location of these sampling stations was previously shown on Figure 2.3-2 in Chapter 2.

The results of the CTD sampling indicate that there is little variability of density throughout the water column. This may be attributed to the relatively shallow water depth and nearshore circulation, resulting in good mixing of the ocean waters at this location. There was more variability in the density profiles collected on 7 October 2008 compared to the profiles collected on 15 August 2008 and 28 January 2009, which may have been attributed to the high rainfall events during this time. The greatest variability of density occurred at stations closest to the recently decommissioned NDWWTP diffuser, which was operational prior to the January 2009 data collection period.

Due to the relative uniformity of the density of the water column, effluent discharged through the deep ocean outfall can be expected to rise rapidly to the surface. The relatively shallow water depth and nearshore circulation at this location will result in good mixing of the ocean waters.

3.3.2 Receiving Water Quality

Receiving water quality in the vicinity of the proposed DoD outfall is summarized below. Detailed analysis and results are presented in the AECOS, Inc. Interim Report provided in **Appendix 3C**.

AECOS, Inc. developed a water quality monitoring program and subsequent water quality and biology impact assessment for both Phases 1 and 2 of this investigation. The limited water quality monitoring program consisted of the analyses of 13 GWQS constituents (refer to Table 2.3-2 in Chapter 2) from samples collected at various depths. Four toxic substances (sulfide, copper, lead, and zinc) were sampled only in Phase 1 to determine their presence in the NDWWTP discharge. The water quality monitoring plan for Phase 1 consisted of ten sampling stations (refer to Figure 2.3-2 in Chapter 2) around the new NDWWTP outfall. Samples were collected at three depths (near surface, near bottom, and mid-depth). The Phase 2 water quality monitoring plan consisted of eight sampling stations around the proposed DoD outfall. Preliminary results in Phase 1 indicated that samples collected at two depths (near surface and near bottom) would be adequate.

Water quality data from Phases 1 and 2 for select stations and depths were utilized to establish the background water quality of the receiving waters around the proposed DoD outfall. Where local field measurements were either absent or not considered representative of the background water quality, historical data from similar open coastal environments were used to estimate background concentrations. The background concentrations for the receiving waters in the vicinity of the proposed DoD outfall were determined by AECOS, Inc. and are presented in **Table 3.3-1**.

TABLE 3.3-1

BACKGROUND WATER QUALITY CHARACTERISTICS OF THE RECEIVING WATERS

Water Quality Constituent	Unit	GWQS Limit	Background Concentration
Enterococci	#/100mL	104	none
Orthophosphate (as P)	μg P/L	50	5
Nitrate-Nitrite	μg N/L	200	1
TSS	mg/L	20	5.6
Turbidity	NTU	1	0.25
Priority Toxic Pollutants			
Lead	μg/L	8.1	none
Copper	μg/L	3.1	none
Zinc	μg/L	86	none
Additional Toxic Pollutants			
Ammonia (as N)	μg N/L	20	<1
Total Sulfide	μg/L	5	none
Non-Regulated Constituents			
Total Nitrogen	μg N/L	---	151
Total Phosphorus	μg P/L	---	13

The baseline water quality monitoring results for Phase 2 conducted on 10 and 11 November 2008 (old NDWWTP outfall in operation) and 23 and 24 March 2009 (new NDWWTP outfall in operation) are summarized below.

3.3.2.1 Baseline Temperature

In conjunction with salinity, temperature determines the density of the ocean water. There was little to no change in temperature with depth for samples collected in both November 2008 and March 2009. The baseline temperature measured for all samples collected at various depths during the November 2008 and March 2009 sampling events ranged from 29.5 to 29.8 °C and 28.1 to 28.5 °C, respectively. The baseline temperature did not exceed the 1.0 °C deviation stipulated in the GWQS for each sampling period.

3.3.2.2 Baseline Salinity

In conjunction with temperature, salinity determines the density of the ocean water. Like the results for temperature, there was little change in salinity across the water column. Salinity increased slightly with depth, ranging from 34.645 ppt at the surface to 34.701 ppt near the ocean bottom during the November 2008 sampling period and 35.467 ppt (surface) to 35.539 ppt (bottom) during the March 2009 sampling period. The maximum deviation of all eight sampling stations from the median concentration was less than 2 percent, which is well within the GWQS of 10 percent of the naturally occurring condition.

3.3.2.3 Baseline Dissolved Oxygen

Dissolved oxygen (DO) in marine waters is a factor of wind action at the air-sea interface, primary productivity (phytoplankton and benthic algae), and respiration. The maximum DO concentration in marine waters is a function of temperature and salinity. Similar to the temperature and salinity results, there was little change of DO saturation with depth, ranging from 91 percent to 99 percent at all stations and depths. These baseline DO saturation levels are above the GWQS minimum level of 75 percent.

3.3.2.4 Baseline pH

pH levels in marine waters may be influenced by surface water runoff, intrusion of groundwater, wastewater discharges, and excessive plant (phytoplankton and/or benthic algae) productivity. There was little variation in pH levels through the water column, indicating a well mixed environment. High pH levels are anticipated in marine surface waters as a result of higher phytoplankton productivity in this zone. However, the low presence of chlorophyll α (see section 3.3.2.12) and/or freshwater input from surface runoff may have attributed to the lower pH levels observed. At all eight sampling locations and depths, the baseline pH levels ranged from a high of 8.18 to a low of 7.95, which is within the GWQS range of 6.5 to 8.5.

3.3.2.5 Baseline Turbidity

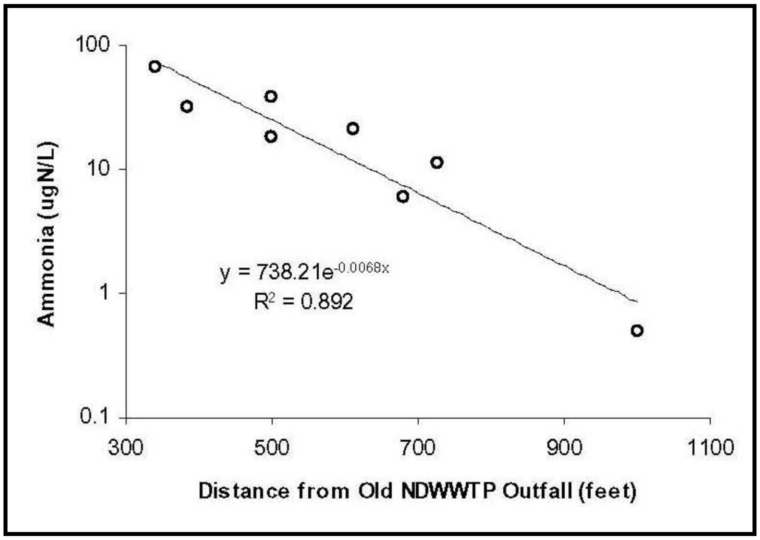
Turbidity in marine waters is influenced by surface water runoff, suspension of bottom sediments in shallow nearshore waters resulting from wave and wind action, and microscopic life naturally occurring in water. With the exception of one sample with high turbidity attributed to bottom sediment disturbance during sampling, low baseline turbidity less than 1 NTU was measured at all remaining stations and depths. This indicates a marine water environment with low levels of particulates. The GWQS stipulates that turbidity shall not increase by more than 1 NTU from ambient conditions, except under natural conditions.

3.3.2.6 Baseline TSS

Like turbidity, TSS in marine waters is influenced by surface water runoff, suspension of bottom sediments due to wave and wind action, and microscopic life naturally occurring in water. Baseline TSS levels measured during the November 2008 sampling period were nearly double those of the March 2009 sampling period. The mean surface and bottom TSS concentrations measured in November 2008 were 8.3 mg/L and 7.1 mg/L respectively. The mean surface and bottom TSS concentrations measured in March 2009 were 4.6 mg/L and 3.2 mg/L respectively. These baseline TSS concentrations are below the GWQS of 20 mg/L.

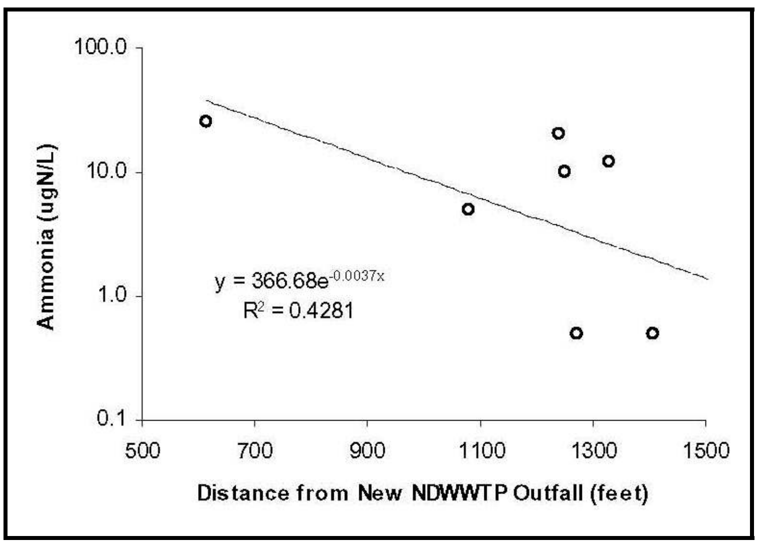
3.3.2.7 Baseline Ammonia

Ammonia is one of three major inorganic nitrogen moieties (ammonia, nitrite, and nitrate) utilized by marine phytoplankton and benthic algal populations. Ammonia is preferred over nitrite and nitrate and is typically found in very low concentrations in marine waters. Baseline ammonia levels at the stations sampled in November 2008 and March 2009 can be attributed to the discharge from the old and new NDWWTP outfalls, as shown on **Figures 3.3-1** and **3.3-2**, respectively.



SURFACE WATER AMMONIA CONCENTRATION VERSUS DISTANCE TO OLD NDWWTP OUTFALL (NOVEMBER 2008 SAMPLING EVENT)

FIGURE 3.3-1



SURFACE WATER AMMONIA CONCENTRATION VERSUS DISTANCE TO NEW NDWWTP OUTFALL (MARCH 2009 SAMPLING EVENT)

FIGURE 3.3-2

Results of the November 2008 sampling event indicated that the surface water ammonia concentration increased with proximity to the old NDWWTP outfall, which was operational at the time of sampling. Although there is less correlation with the March 2009 water samples, primarily due to proximity of the sampling stations with respect to the location of the new NDWWTP outfall, the elevated surface water ammonia levels present indicate some contribution of ammonia from the discharge of effluent through the new NDWWTP outfall.

The mean ammonia concentration measured in the November 2008 water samples is higher than the March 2009 water samples. This may be attributed to the proximity of the sampling stations with respect to the NDWWTP outfall discharge points. The mean baseline ammonia concentration present in the surface water samples collected in November 2008 was 24 μg N/L, while the mean baseline concentration present in the March 2009 samples was 1 μg N/L. It is likely that, in the absence of the NDWWTP discharge, the ammonia concentration in both the surface and bottom water samples would be undetectable in the vicinity of the proposed DoD outfall. The mean baseline ammonia concentration for both sampling events is less than the GWQS limit of 0.02 mg N/L for marine waters.

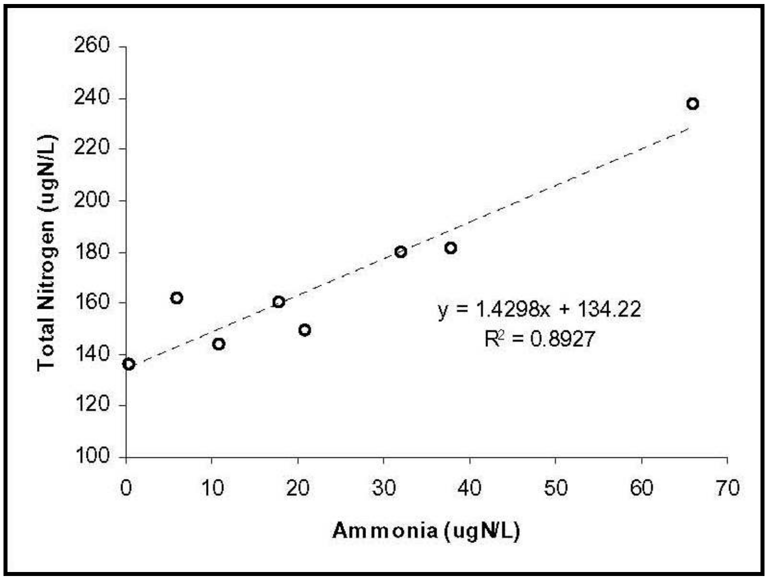
3.3.2.8 Baseline Nitrate + Nitrite

Nitrate and nitrite are two of the three major inorganic nitrogen moieties (ammonia is the third) utilized by marine phytoplankton and benthic algal populations. Due to the typically low concentration of ammonia in marine waters, this nitrogen fraction is the primary source for phytoplankton and benthic algae productivity. The baseline concentration of nitrate-nitrite present in both surface and bottom samples and both sampling events was relatively low. Like ammonia, high concentrations were present in the November 2008 samples, which may be attributed to the close proximity to the old NDWWTP discharge point. The mean baseline nitrate + nitrite concentration present in the surface water samples collected in November 2008 was 3 μg N/L, while the mean baseline concentration present in the March 2009 samples was 1 μg N/L. The GWQS stipulates that the nitrate concentration in marine water should not exceed 0.20 mg N/L. The baseline nitrate + nitrite concentration is well below this limit.

3.3.2.9 Baseline Total Nitrogen

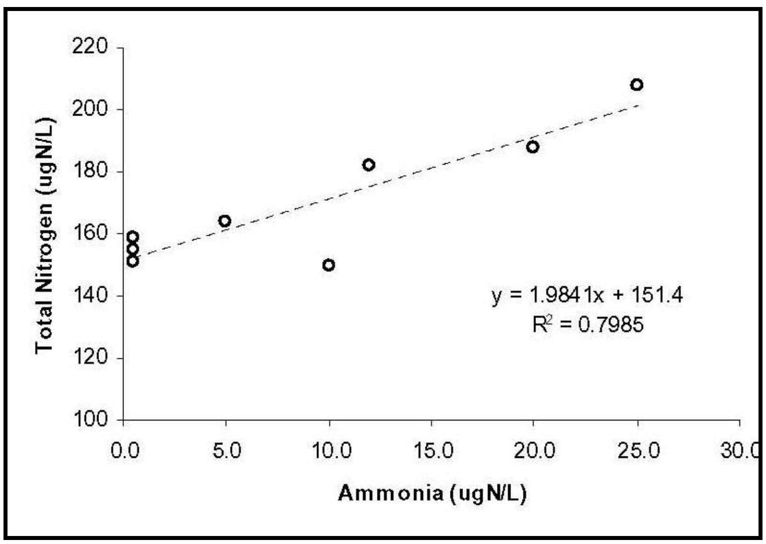
Total nitrogen represents the total quantity available for breakdown by phytoplankton and benthic algae productivity. Although no limit was established for total nitrogen in the GWQS, this parameter was monitored in this investigation to understand the fate of inorganic + organic nitrogen present in the discharge from the outfall.

The mean total nitrogen concentration present in the water samples collected for both sampling events was similar; 169 μg N/L and 170 μg N/L for the November 2008 and March 2009 samples, respectively. The corresponding mean bottom water concentration was 136 μg N/L and 144 μg N/L respectively. Sampling stations with high baseline concentrations of total nitrogen typically correlated with high baseline concentrations of ammonia in the samples. **Figures 3.3-3** and **3.3-4** show total baseline nitrogen concentration present in the surface water samples as a function of baseline ammonia concentrations for the November 2008 and March 2009 sampling events, respectively.



SURFACE WATER TOTAL NITROGEN CONCENTRATION AS A FUNCTION OF AMMONIA (NOVEMBER 2008 SAMPLING EVENT)

FIGURE 3.3-3



SURFACE WATER TOTAL NITROGEN CONCENTRATION AS A FUNCTION OF AMMONIA (MARCH 2009 SAMPLING EVENT)

FIGURE 3.3-4

The November 2008 and March 2009 sampling results indicate that the NDWWTP effluent discharge plumes from both the old and new outfalls impact nitrogen in surface water. As indicated by regression lines on **Figures 3.3-3** and **3.3-4**, in the absence of ammonia in the NDWWTP effluent discharge, background total nitrogen in the November 2008 and March 2009 samples were 136 µg N/L and 155 µg N/L, respectively. These values are similar to the mean baseline nitrogen concentration present in the bottom water samples.

3.3.2.10 Baseline Total Phosphorus

Total phosphorus represents the total quantity available for breakdown by phytoplankton and benthic algae productivity. Some total phosphorus is refractile and cannot be broken down into inorganic fractions and will not be available to primary production. Like total nitrogen, no limit for total phosphorus was established in the GWQS. This parameter was nevertheless monitored in this investigation to understand the fate of inorganic + organic phosphorus present in the discharge from the outfall.

The mean total phosphorus concentration present in the November 2008 sample indicated higher levels present in the surface (24 µg P/L) compared to the bottom (19 µg P/L), indicating the influence by surface and/or groundwater input from the island and the discharge of effluent from the NDWWTP. The March 2009 mean surface and bottom water concentrations for total phosphorus were both 16 µg P/L.

3.3.2.11 Baseline Orthophosphate

Orthophosphate is the primary inorganic form of phosphorus utilized by phytoplankton and benthic algae productivity. Orthophosphate concentrations are typically low, but detectable, in tropical marine coastal waters. Like the nitrogen moieties, a somewhat higher concentration of orthophosphate was present in the surface water samples compared to the bottom water samples. This may indicate an influence by surface and/or groundwater input from the island. The surface and bottom mean orthophosphate concentrations in the November 2008 samples were 9 µg P/L and 6 µg P/L, respectively, and 8 µg P/L and 7 µg P/L, respectively, in the March 2009 samples. The GWQS limits orthophosphate concentration in marine water to no more than 0.05 mg P/L (50 µg P/L). The baseline orthophosphate concentration is well below this limit.

3.3.2.12 Baseline Chlorophyll α

Chlorophyll α is an indicator of phytoplankton biomass in the marine water. Although no limit for chlorophyll α was established in the GWQS, this parameter was measured for this investigation to determine the potential impacts associated with the addition of elevated nitrogen and phosphorus in the wastewater discharge.

There was little variability across the water column and among the eight sampling sites for both the November 2008 and March 2009 sampling events. This indicates that phytoplankton in the water column is not being influenced by the nutrients present in the discharge from the NDWWTP. The mean baseline surface water concentration of chlorophyll α measured in November 2008 and March 2009 was 0.12 µg /L and 0.18 µg/L, respectively. The mean baseline bottom water concentration for both sampling events was 0.15 µg/L.

3.3.2.13 Baseline Enterococci

Enterococcus bacteria is found in avian and mammalian fecal matter and is an indicator of sewage contamination of the marine waters. Both the November 2008 and March 2009 samples exhibited high levels of enterococci in the surface water samples, with all but one sample collected during both sampling events exceeding the GWQS instantaneous limit for enterococci of 104 enterococci/100 mL. Enterococci were present in lower concentrations in the samples collected near the bottom.

There is a strong correlation between enterococci concentration and ammonia level at each sampling station shown on **Figures 3.3-5** and **3.3-6**, indicating that the discharge plumes from the old and new NDWWTP outfall impact water quality in the vicinity of the proposed DoD outfall. Due to the proximity of the sampling stations and the old and new NDWWTP outfalls, the mean baseline surface water concentration for enterococci was higher during the November 2008 sampling event (703 enterococci/100 mL, old NDWWTP outfall active) compared to the March 2009 sampling event (472 enterococci/100 mL, new NDWWTP outfall active).

3.3.2.14 Toxic Substances

Total sulfide, copper, lead, and zinc were analyzed in Phase 1 at a few preselected sampling sites. These constituents were analyzed in the August 2008 sampling event from samples collected at mid-depth for stations 1, 6, and 10, and near bottom depth for station 2. The concentrations found in all samples were below the detectable limits.

3.4 DIFFUSER SYSTEM PLUME ANALYSIS – NEW NDWWTP OUTFALL

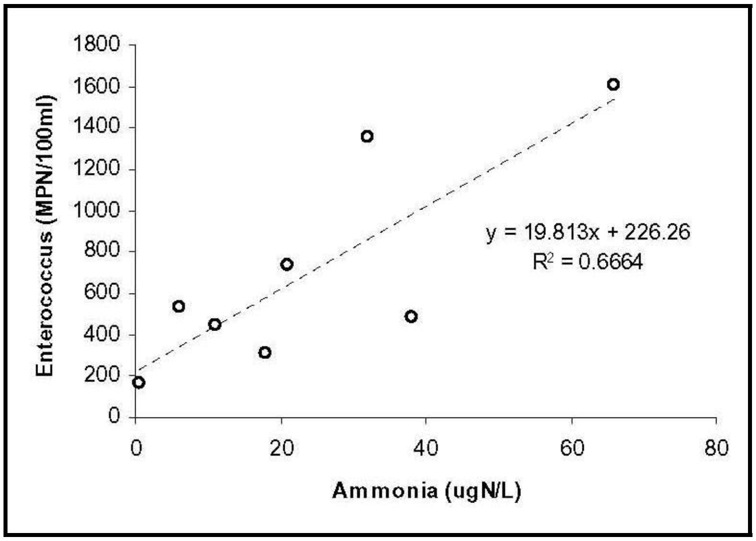
The “Modified Diffuser Design” described in section 3.2 was modeled by EKNA Services to determine the initial dilution (nearfield) and farfield plumes of the new NDWWTP outfall that will likely influence ambient receiving water quality conditions in the vicinity of the proposed DoD outfall. The following conditions were incorporated in the nearfield and farfield plume models:

Discharge Quantity: Design Average Flow = 12 MGD

Discharge Quality: Primary Treated Effluent (refer to **Table 3.1-5**)

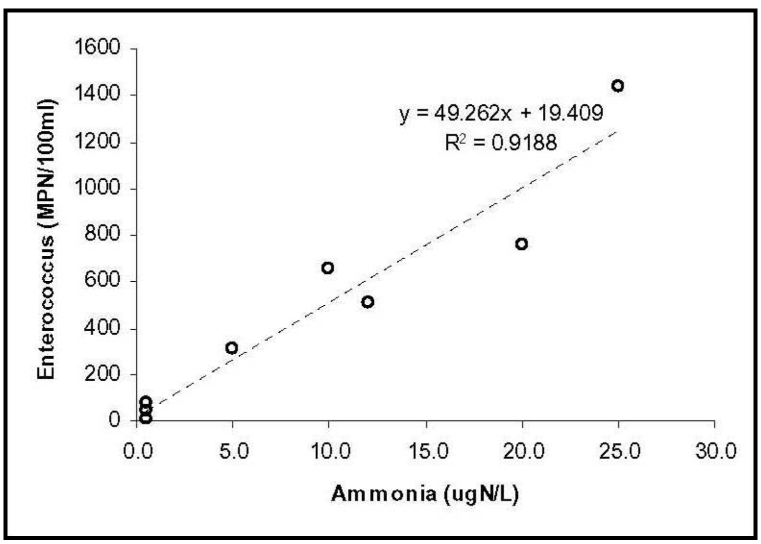
Outfall and Diffuser System Design:
“Baseline Modified Diffuser Design” (see section 3.2)
Four sections of high density polyethylene pipe (HDPE)
Each section 100 feet in length
Diameter of each section: 34”, 28”, 22”, and 20”
40 vertical ports located 10 feet on center
Each port fitted with a 6-inch Tideflex valve

A summary of the nearfield and farfield results for the new NDWWTP outfall are presented in the following sections. Refer to EKNA Services Interim Report in **Appendix 3B** for a detailed analysis.



SURFACE WATER ENTEROCOCCUS CONCENTRATION AS A FUNCTION OF AMMONIA (NOVEMBER 2008 SAMPLING EVENT)

FIGURE 3.3-5



SURFACE WATER ENTEROCOCCUS CONCENTRATION AS A FUNCTION OF AMMONIA (MARCH 2009 SAMPLING EVENT)

FIGURE 3.3-6

3.4.1 Nearfield (Initial Dilution) Plume Modeling

The USEPA-approved dilution model, *Visual Plumes* (VP), was used to determine the initial dilutions provided under various effluent discharge flow scenarios presented in this investigation. The three-dimensional Updated Merge (UM3) model was used to simulate single and multi-port submerged discharges.

Ocean current data collected from the first four months of the monitoring period (14 August to 9 December 2008) indicate a mean current speed of 10 cm/sec at a dominant direction of 15 degrees true north. In addition to this information, CTD profiles obtained on 15 August 2008, 7 October 2008, and 28 January 2009 were used in this Phase 2 interim model run for the new NDWWTP outfall. All CTD profiles, with the exception of five inshore stations (stations 1, 2, 10, A, and H), were modeled (27 runs) and averaged to yield an average dilution value considered to be representative of the initial dilution for the given design discharge flow and current speed. CTD profiles for the five inshore stations were not used because of the likely influence of the existing NDWWTP discharge on the salinity readings at these stations.

The average dilution obtained for the new NDWWTP outfall at the design average flow of 12 MGD is 300. The plume surfaces for all runs and does not travel far horizontally before surfacing.

3.4.2 Farfield Plume Modeling

Following initial dilution, the nearfield plume remains relatively passive and is subsequently transported away from the diffuser by ocean currents. The fate of the plume beyond the diffuser is generally termed the farfield plume. To develop the farfield plume, the methodology was to utilize all the continuous time-series of ocean current measurements obtained in the field to model the transport process. Therefore, the resulting farfield plume is a cumulative representation of all plume events, providing an envelope of visitation probability of a tracer particle released into the plume after initial dilution has occurred. The probability envelope is developed by spatially tracking a tracer particle for a specified period of time. The receiving ocean water is depicted by a grid system; each grid square representing a 200 meter by 200 meter area. As a tracer particle is released into the plume after initial dilution has occurred, the incidence and time of incidence of the particle entering a grid square are recorded. The progression of the tracer particle is tracked through the grid system until the specified period of time has elapsed. Another tracer particle is released and tracked in the same manner. This analysis is performed over many thousands of trials to develop an expected visitation frequency or impact probability for each grid square. The resulting value assigned to each grid square is then used to develop the probability envelopes or contours.

In addition to determining the visitation probability of a tracer particle (representing a constituent in the wastewater) in the grid system (representing the receiving marine water), the concentration of particles associated with the visitation occurrence is of particular interest with respect to the water quality aspects of this investigation. After initial dilution, the plume is further diluted through the transport of ocean currents and entrainment of ambient ocean water. This subsequent dilution is primarily time dependent. The methodology used to extend the visitation probability analysis to include estimates of the concentration and dilution probabilities is provided in the EKNA Services Interim Report (see **Appendix 3B**).

For farfield plume modeling, initial dilution provided under average flow conditions is applicable because it represents a relatively consistent discharge flow through the outfall. Peak flow occurs intermittently and typically coincides with a rainfall event. In general, peak flows last for a period of a few hours, subsiding after the rainfall event has ended. A portion of the increased flow under this condition is also attributed to inflow and infiltration of rain water into the wastewater collection system. This addition of non-wastewater flow will dilute the concentration of constituents in the effluent prior to discharge through the outfall, reducing the dilution requirement of the diffuser system under this peak flow condition.

As indicated in the initial dilution results, the probability of the plume surfacing is 100 percent. As a result, wind patterns in conjunction with ambient ocean current will affect the fate of the farfield plume. Wind data at Guam International Airport were obtained from the National Oceanic and Atmospheric Administration (NOAA). The wind data were adjusted to reflect the lower elevation of the ocean surface with respect to the source of the data and reduced easterly (offshore) winds resulting from the sheltering effects of the cliffs.

3.4.2.1 24-Hour Visitation Frequency

The 24-hour visitation frequency was analyzed using the farfield plume model. This analysis was performed to determine the percent visitation occurrence of a tracer particle released into the plume after initial dilution had taken place, regardless of time. **Figure 3.4-1** shows the combined effect of winds and currents on the 24-hour visitation frequency of the surface plume. Due to the offshore winds and the ocean current in the predominantly northern direction, the transport of the surface plume is likely to occur in the northwesterly direction, away from Tumon Bay. As shown on **Figure 3.4-1**, the probability of the plume entering Tumon Bay is less than one percent of the time. Due to the close proximity of the new NDWWTP outfall and the proposed DoD outfall, this farfield plume analysis is applicable to both outfalls.

3.4.2.2 Farfield Dilution Factors

Average farfield dilution factors (F_{ave}) were developed in this Phase 2 study to simplify the calculation of the total dilution of any constituent based on an assumed initial dilution. Contour plots of the F_{ave} for the new NDWWTP outfall are presented on **Figure 3.4-2**. The following equation can be used to calculate total dilution based on an assumed initial dilution value:

$$S_{ave} = S_0 F_{ave}$$

where:
- S_{ave} = total farfield dilution for the outfall
- S_0 = initial dilution for the outfall
- F_{ave} = average farfield dilution factor for the outfall

Based on **Figure 3.4-2**, F_{ave} for the new NDWWTP outfall at the location of the proposed DoD outfall is about 2. Using the above equation and an initial dilution factor of 300 for the new NDWWTP outfall as determined in section 3.4.1, the total farfield dilution (S_{ave}) applied to the primary effluent discharge from the NDWWTP is 600.

Figure 3.4-1

24-Hour Visitation Frequency Impact Analysis – Surface Plume

Figure 3.4-2

Fave for New NDWWTP Outfall

3.4.2.3 Ambient Receiving Water Quality Conditions Near the Proposed DoD Outfall

The dilution required to meet a water quality standard can be calculated using the following expression (EPA Amended Section 301(h) Technical Support Document dated September 1994):

$$S_a = (C_e – C_a) / (C_s – C_a)$$

where:
S_a = dilution
C_e = effluent concentration
C_s = water quality standard
C_a = receiving water concentration

The above equation can be rearranged to solve for the resulting ambient receiving water quality parameters using the total farfield dilution for the outfall as determined in section 3.4.2.2.

C_s = C_F = "chronic" concentration of a constituent in the receiving water
S_a = S_{ave} = total farfield dilution for the outfall

$$C_F = C_a + (C_e – C_a) / S_{ave}$$

Ambient receiving water quality conditions in the vicinity of the proposed DoD outfall resulting from the influence of the discharge plume from the new NDWWTP outfall can be calculated using the following equation:

$$C1_F = C_a + (C1_e – C_a) / S1_{ave}$$

where:
$C1_F$ = "chronic" concentration of a constituent in the receiving water
C_a = background concentration of the constituent of interest in the receiving water
$C1_e$ = concentration of the constituent of interest in the primary treated effluent discharged from the new NDWWTP outfall
$S1_{ave}$ = total farfield dilution for the new NDWWTP outfall
= 600 (see section 3.4.2.2)

The ambient concentration of constituents in the receiving waters at the propose DoD outfall is summarized in **Table 3.4-1**.

TABLE 3.4-1

CALCULATED AMBIENT WATER QUALITY CONDITIONS AT THE PROPOSED DOD OUTFALL ($S1_{ave}$ = 600)

Water Quality Constituent	Unit	Background Concentration (C_a)	NDWWTP Primary Treated Effluent Concentration ($C1_e$)	Calculated Ambient Concentration at Proposed DoD Outfall ($C1_F$)	GWQS (M-2 Waters)
Enterococci	#/100mL	0	240,000	400	104
Orthophosphate (as P)	μg P/L	5	2,620	9.4	50
Nitrate-Nitrite	μg N/L	1.1	9	1.1	200
TSS	mg/L	5.6	80	5.7	20
Turbidity	NTU	0.25	59	0.3	1
Priority Toxic Pollutants					
Lead	μg/L	0	4.94	0	8.1
Copper	μg/L	0	68.3	0.1	3.1
Zinc	μg/L	0	276	0.5	86
Additional Toxic Pollutants					
Ammonia (as N)	μg N/L	0	18,400	30.7	20
Total Sulfide	μg/L	0	140	0.2	5
Non-Regulated Constituents					
Total Nitrogen	μg N/L	151	47,600	230.1	---
Total Phosphorus	μg P/L	13	3,850	19.4	---

** Calculated ambient receiving water quality concentrations greater than the GWQS are highlighted in yellow.*

CHAPTER 4
ASSESSMENT OF THE DISCHARGE FROM THE PROPOSED DOD OUTFALL

Phase 2 of the study assesses the environmental and ecological impacts to the receiving waters associated with a new point discharge from the proposed DoD outfall, which is described as Option 2 in the July 2008 study. This chapter contains information on the development of the discharge quantity and quality from the proposed DoD secondary treatment plant and the conceptual design and performance of the proposed DoD outfall. Based on this information, the resulting impacts to the receiving marine waters were evaluated and summarized in this chapter.

4.1 PROPOSED DOD SECONDARY TREATMENT PLANT EFFLUENT QUANTITY AND QUALITY

As presented in the July 2008 study, the design average and peak wastewater flows for Option 2 are 4.51 and 10.92 MGD, respectively. These design flows account for all of the DoD wastewater generated in the northern district of Guam, including the additional flows associated with the relocation of the USMC.

In order to develop wastewater characteristics for secondary treated effluent, actual raw wastewater of the influent entering the NDWWTP was utilized, and typical industry standard removal efficiencies for the conventional activated sludge process were applied. The resulting constituent concentration was compared to typical secondary treated effluent wastewater concentrations found in textbooks and concentrations from existing secondary treatment facilities in Guam and Hawaii.

Table 4.1-1 summarizes the treated effluent wastewater characteristics for the discharge from the proposed DoD secondary treatment plant. DMRs for secondary treatment facilities in Guam and Hawaii were obtained for the period July 2007 to June 2008 and were reviewed for comparative purposes. This information is summarized in **Table 4.1-2**.

4.2 CONCEPTUAL DESIGN AND HYDRAULIC ANALYSIS OF THE PROPOSED DOD OUTFALL

The intent of discharging wastewater through an outfall and diffuser system is to minimize the detrimental impacts of the discharge by providing adequate dilution, dispersion, and transport of the pollutants released into the receiving marine waters. Compliance with the GWQS is one criterion used to minimize environmental and ecological impacts to the receiving waters and was used in this study as the basis for the conceptual design of the proposed DoD outfall.

TABLE 4.1-1

TREATED EFFLUENT WASTEWATER CHARACTERISTICS OF THE PROPOSED DOD SECONDARY TREATMENT PLANT

Constituent Regulated by Guam Water Quality Standards	Unit	Influent Conc.	Effluent Conc.	Comments*
Enterococci	#/100mL	> 240,000	15	Assume disinfection prior to discharge. Similar to the Apra Harbor WWTP.
pH	---	7.0	7.0	Assume no change.
Orthophosphate (as P)	μg/L	2,940	1,640	Apply textbook removal efficiency of 44%.
Nitrate-Nitrogen	μg/L	8	14,900	Calculated based on ammonia reduction (conversion of ammonia to nitrate). Comparable to Hawaii Secondary WWTPs.
Dissolved Oxygen	mg/L	---	2.0	Assume minimum DO of 2 mg/L is maintained in the activated sludge process.
Salinity	ppt	---	0.8	Assume same as Primary. No change with Secondary Treatment.
TSS	μg/L	201,000	9,000	Apply textbook removal efficiency of 96%. Comparable to the Apra Harbor WWTP with similar low TSS entering the plant.
Turbidity	NTU	111	16	Apply textbook removal efficiency of 86%. Higher than Hawaii Secondary WWTPs.
Temperature	°C	28.6	29.8	Assume same as Primary. No change with Secondary Treatment.
Priority Toxic Pollutants				
Lead	μg/L	4.43	4.43	No additional removal based on textbook information.
Copper	μg/L	80	54.6	Apply textbook removal efficiency of 32%. Higher than Guam and Oahu Secondary WWTPs.
Zinc	μg/L	245	72.6	Apply textbook removal efficiency of 70%. Higher than Guam and Oahu Secondary WWTPs.
Additional Toxic Pollutants				
Ammonia (as N)	μg/L	18,400	3,500	Apply average ammonia concentration from Hawaii Secondary WWTPs.
Total Sulfide	μg/L	510	140	Assume same as Primary. No change with Secondary Treatment.

**Note: Textbook value refers to Metcalf & Eddy, Wastewater Engineering Treatment and Reuse, Fourth Edition.*

Table 4.1-2

Summary of DMRs from Secondary WWTPs in Guam and Hawaii

Initial dilution required to meet the GWQS may be calculated using the following expression (EPA Amended Section 301(h) Technical Support Document dated September 1994):

$$Sa = \frac{(Ce - Ca)}{(Cs - Ca)}$$

Where Ce = Effluent Concentration
Cs = Water Quality Standard (GWQS)
Ca = Receiving Water Concentration
Sa = Dilution

Table 4.2-1 summarizes the required dilution to meet the GWQS for each constituent regulated. The ambient receiving water quality in the vicinity of the proposed DoD outfall will be influenced by the discharge from the new NDWWTP outfall. The resulting ambient concentrations of the constituents in the receiving waters (Ca) were previously determined in Table 3.4-1 of Chapter 3 and are used in the calculations below. The effluent concentration (Ce) anticipated with the proposed DoD secondary treatment plant was previously presented in **Table 4.1-1**.

TABLE 4.2-1
REQUIRED DILUTION FOR THE PROPOSED DOD OUTFALL

Constituent Regulated by GWQS	Unit	GWQS M-2 Water (Cs)	Ambient Receiving Water Quality ($Ca = C1_F$)	Effluent Conc. (Ce)	Required Dilution (Sa)
Enterococci	#/100mL	104	400	15	0
Orthophosphate (as P)	μg/L	50	9.4	1,640	40
Nitrate-Nitrogen	μg/L	200	1.1	14,900	75
TSS	μg/L	20,000	5,700	9,000	0
Turbidity	NTU	1	0.3	16	22
Priority Toxic Pollutants					
Lead	μg/L	8.1	0	4.43	0
Copper	μg/L	3.1	0.1	54.6	18
Zinc	μg/L	86	0.5	72.6	0
Additional Toxic Pollutants					
Ammonia (as N)	μg/L	20	30.7	3,500	**NA**
Total Sulfide	μg/L	5	0.2	140	29

Constituents that exceed the M-2 limit in the GWQS are highlighted in yellow.

As indicated in **Table 4.2-1** above, the ambient concentrations for enterococci and ammonia in the vicinity of the proposed DoD outfall are greater than the GWQS due to the influence of primary treated effluent discharged from the new NDWWTP outfall. Therefore, no amount of dilution can be provided by the proposed DoD outfall to achieve compliance with the GWQS. Improvements to the effluent discharged from the new NDWWTP outfall are necessary to reduce the ambient enterococci and ammonia concentration in the receiving water within the GWQS limits. By providing secondary treatment at the NDWWTP, ammonia concentrations may be reduced to 3,500 μg/L, resulting in an ambient concentration of 5.8 μg/L near the proposed DoD outfall. The dilution required by the proposed DoD outfall for ammonia is 246.

Based on this information, the performance goal for the conceptual design of the proposed DoD outfall was to achieve a dilution factor of 250. Conceptual designs were developed by EKNA Services to determine whether the dilution factor of 250 can be achieved by the proposed DoD outfall based on the physical constraints of the bathymetry in the area.

Detailed description and hydraulic analysis performed for the conceptual design of the proposed DoD outfall are contained in EKNA Services Interim Report (**Appendix 3B**). The results of the nearfield and farfield plume modeling for the proposed DoD outfall are summarized below.

Four conceptual designs of the proposed DoD outfall were analyzed using the UM3 model and incorporated an open pipe outlet at varying depths without a diffuser. All CTD profiles obtained on 15 August 2008, 7 October 2008, and 28 January 2009, with the exception of five inshore stations, were used for the plume analysis. The initial dilution results for the four conceptual DoD outfall designs discharging 5 MGD are summarized in **Table 4.2-2**.

TABLE 4.2-2

INITIAL DILUTION FOR THE PROPOSED DOD OUTFALL

(Design Flow of 5 MGD, Current Speed and Direction of 10 cm/sec and 15 degT)

Conceptual Design of DoD Outfall	Range of Initial Dilution[1]	Average Initial Dilution[2]	Surfaced Plume?	Average Horizontal Distance[3]	Average Plume Diameter[4]
Single Port Outfall – 140 ft Depth	213 – 234	231	100% Yes	34 feet	61 feet
Single Port Outfall – 150 ft Depth	224 – 255	251	100% Yes	33 feet	65 feet
Dual Port Outfall – 140 ft Depth	173 – 235	229	100% Yes	47 feet	128 feet
Dual Port Outfall – 150 ft Depth	175 – 255	244	100% Yes	48 feet	132 feet

Notes: (1) Run performed for all CTD profiles conducted on 8/15/2008, 10/7/2008, and 1/28/2009, except at stations 1, 2, 10, A, H.
(2) Average initial dilution for all runs.
(3) Average horizontal excursion distance for plume (centerline) for all runs.
(4) Average diameter of the plume at the surface for all runs.
(5) Highlighted in yellow is the conceptual design scenario that met the minimum initial dilution factor of 250.

The nearfield results indicate that the initial dilution factor of 250 can be achieved with a single port outfall at a depth of 150 feet. The plume surfaces for all runs and does not travel far horizontally before surfacing.

Farfield plume modeling was performed to assess the fate of the plume beyond the diffuser location. Interim ocean current data collected for both Phases 1 and 2 of this investigation were utilized in the farfield model. As indicated in the initial dilution results, the probability of the plume surfacing is 100 percent. As a result, wind patterns in conjunction with ambient ocean current will affect the fate of the farfield plume. Wind data at Guam International Airport were obtained from the National Oceanic and Atmospheric Administration (NOAA). The data were adjusted to reflect the lower elevation of the ocean surface with respect to the source of the data and reduced easterly (offshore) winds resulting from the sheltering effects of the cliffs.

Like the analysis of the new NDWWTP outfall (see section 3.4.2.2 of Chapter 3), average farfield dilution factors (F_{ave}) were developed for the proposed DoD outfall. Contour plots of the F_{ave} values for the proposed DoD outfall are presented on **Figure 4.2-1**.

Due to the influence of the primary effluent discharged from the new NDWWTP outfall on the ambient receiving water quality conditions in the vicinity of the proposed DoD outfall, the resulting time averaged concentration of a constituent anticipated in the receiving water may be calculated using the following equation:

$$C2_F = C1_F + (C2_e - C1_F) / S2_{ave}$$

where:

- $C2_F$ = "chronic" concentration of a constituent in the receiving water due to the proposed DoD outfall discharge
- $C1_F$ = ambient receiving water quality resulting from the new NDWWTP outfall discharge of 12 MGD of primary treated effluent (see Chapter 3, section 3.4.2.2)
- $C2_e$ = concentration of the constituent of interest in the secondary treated effluent discharged from the propose DoD outfall
- $S2_{ave}$ = total farfield dilution for the proposed DoD outfall
  = $S2_0F2_{ave}$ where $S2_0$ is the initial dilution for the proposed DoD outfall and $F2_{ave}$ is the average farfield dilution factor for the proposed DoD outfall

The above equation may also be used to specify the concentration of a constituent at the proposed DoD outfall after initial dilution by setting the average farfield dilution factor ($F2_{ave}$) to 1 as follows:

$$C2_i = C1_F + (C2_e - C1_F) / S2_0$$

Using the $C1_F$ values at the proposed DoD outfall location calculated in Table 3.4-1 of Chapter 3, the constituent concentrations resulting from the initial dilution ($C2_i$) provided by the proposed DoD outfall are summarized in **Table 4.2-3**.

Figure 4.2-1

TABLE 4.2-3

CALCULATED CONSTITUENT CONCENTRATION AFTER INITIAL DILUTION PROVIDED BY THE PROPOSED DOD OUTFALL ($S2_0$ = 251)

Water Quality Constituent	Unit	Calculated Ambient Concentration at Proposed DoD Outfall ($C1_F$)	DoD Secondary Treated Effluent Concentration ($C2_e$)	Calculated Constituent Concentration After Initial Dilution ($C2_i$)	GWQS (M-2 Waters)
Enterococci	#/100mL	400	15	398.5	104
Orthophosphate (as P)	μg P/L	9.4	1,640	15.9	50
Nitrate-Nitrite	μg N/L	1.1	14,900	60.5	200
TSS	mg/L	5.7	9	5.7	20
Turbidity	NTU	0.3	16	0.4	1
Priority Toxic Pollutants					
Lead	μg/L	0	4.43	0	8.1
Copper	μg/L	0.1	54.6	0.3	3.1
Zinc	μg/L	0.5	72.6	0.8	86
Additional Toxic Pollutants					
Ammonia (as N)	μg N/L	30.7	3,500	44.5	20
Total Sulfide	μg/L	0.2	140	0.8	5
Non-Regulated Constituents					
Total Nitrogen	μg N/L	230.1	23,950	324.6	---
Total Phosphorus	μg P/L	19.4	3,760	34.3	---

** Calculated ambient receiving water quality concentrations greater than the GWQS are highlighted in yellow.*

Due to the high level of enterococci and ammonia in the primary effluent discharged from the new NDWWTP outfall, the resulting ambient receiving water quality in the vicinity of the proposed DoD outfall exceeds the GWQS. Although the enterococci level at the end of the pipe in the secondary treated discharge from the proposed DoD outfall is below the GWQS, the concentration that results after mixing with the ambient receiving water exceeds the GWQS.

As indicated in **Table 4.2-4**, the constituent concentration that results after initial dilution is provided by the proposed DoD outfall ($C2_i$) will be able to meet the GWQS if the NDWWTP is upgraded to provide secondary treatment similar to that at the proposed DoD facility.

Constituent concentrations at the M-1 water boundary are calculated in **Table 4.2-5**. The results indicate that the GWQS can be achieved for M-1 waters for all constituents except enterococci with the secondary discharge from the proposed DoD outfall and primary discharge from the new NDWWTP outfall. Disinfection of the discharge from the NDWWTP is required to reduce enterococci in the discharge to comply with M-1 water quality.

4.3 ENVIRONMENTAL IMPACTS TO THE RECEIVING WATER

The results of the nearfield and farfield plume modeling by EKNA Services were used to assess the water quality and biological impacts on the receiving marine waters associated with a new point discharge from a proposed DoD outfall identified as Option 2 in the July 2008 study. This assessment included the effects of the modeled design discharge of 12 MGD from the new NDWWTP outfall as it mixes with the secondary treated effluent that will be discharged from the proposed DoD outfall at a design flow of 5 MGD. The water quality and biological impact assessments were performed by AECOS, Inc. This interim report contains their preliminary findings based on field work conducted for Phases 1 and 2 of this investigation.

Field investigation of benthic ecosystem, coral, phytoplankton, fishes, and other marine life was not included in the scope of this investigation. AECOS, Inc. researched and reviewed previous studies performed by others in the vicinity of the proposed DoD outfall to assess the existing benthic infaunal assemblages and coral reef ecosystem in the vicinity of Tanguisson Point and the anticipated impacts associated with the discharge of sewage effluent from an outfall. Studies on other marine outfalls located in Guam and Hawaii were also reviewed for supplemental information used in the analysis.

The results of the work performed by AECOS, Inc. are summarized below. A detailed report is provided in **Appendix 3C**.

4.3.1 Water Quality Impact Assessment

The three components of wastewater found to be most detrimental to marine life and coral reefs are nutrients, sediments, and toxic substances. Therefore, these constituents will be the focus of the following analyses. Although enterococcus is not usually considered a pathogenic organism, its presence in marine water is important since this organism is used as an indicator of wastewater contamination in recreational waters.

Constituents that may be present in the receiving water after initial dilution has been achieved were previously presented in **Table 4.2-3**. When the farfield plume from the new NDWWTP outfall (discharging primary treated effluent at 12 MGD) is mixed with the nearfield plume from the proposed DoD outfall (discharging secondary treated effluent at 5 MGD), all constituents

Table 4.2-4

Calculated Constituent Concentrations after Initial Dilution

Table 4.2-5

Calculated Constituent Concentrations at M-1 Boundary meet the GWQS limits, with the exception of enterococcus and ammonia. Based on an analysis of the farfield plume, the GWQS will be achieved for all water quality parameters in the combined NDWWTP and DoD effluent plume within approximately 1,000 feet (for ammonia) to 1,650 feet (for enterococcus) north of the proposed DoD outfall.

4.3.2 Biological Impact Assessment

Tropical ocean waters are typically characterized as low in nutrients and particulates. The discharge of high levels of nutrients and particulates may therefore have a detrimental impact on the receiving marine water.

To minimize this impact, wastewater is treated prior to discharge to reduce the particulates present in the effluent. Secondary treatment may be utilized to further reduce the oxygen demand of the pollutants present in the discharge. Advance treatment is also available to reduce the nutrient level in the discharge. Reduction of toxic substances is best handled at the source by enforcing pretreatment and best management practices.

The following assessment is based on a review of existing studies performed by others in the vicinity of the proposed DoD outfall, supplemented by investigations performed on other marine outfalls located in Guam and Hawaii.

4.3.2.1 Water Column Impacts

As flow is discharged through an outfall, either through a diffuser or an open end pipe, wastewater and the receiving marine waters are mixed, providing the opportunity for biological substances present in the receiving water to interact with the chemical and physical properties of the discharge. The nearfield plume analysis performed by EKNA Services indicated that the discharge from the diffuser rises quickly, with minimal horizontal dispersion before reaching the surface. This initial mixing and rise of the fluids is short, occurring in minutes. Therefore, there is minimum interaction with the extant assemblage of organisms in the water column. In the immediate vicinity of the discharge, particulate organic matter (POM) can attract fishes.

Both physical mixing and uptake by marine organisms will reduce the concentration of biologically active substances in the water column. Phytoplankton may assimilate with some of the nutrients present in the farfield plume. Since phytoplankton requires several days to replicate and the plume will likely disperse over a wide area in a matter of hours, however, the increase in biomass is not likely to be a concern. The low phytoplankton biomass (based on the low level of chlorophyll α) suggests that any increase resulting from phytoplankton productivity will be rapidly grazed by herbivorous zooplankters. Therefore, detectable changes in phytoplankton or herbivorous zooplankton biomass are not anticipated.

As discussed in section 4.3.1, enterococcus and ammonia levels in the surfacing plume will exceed the GWQS. These exceedances are attributed to the ambient receiving water quality condition resulting from the primary effluent discharge from the new NDWWTP outfall. These anticipated constituent concentrations are based on the modeling results by EKNA Services and do not take into account the degradation of constituents, die-off of organisms, or uptake of the pollutants by existing aquatic life.

Enterococcus in the discharge plume will eventually be diluted to near zero. Unfavorable conditions provided by the marine environment will likely destroy these bacteria and most others from the wastewater. Factors such as pH, temperature, solar (UV) radiation, predation, osmotic stress, nutrient deficiencies, particulate levels, turbidity, oxygen concentrations, and microbial community composition affect bacteria inactivation.

The toxicity of ammonia is dependent on pH. Dissolved in water, ammonia will react with hydrogen ions (H^+) to form non-toxic ammonium ions (NH_4^-). When mixed with the higher pH level in the receiving marine water, ammonia present in the wastewater discharge will increase in toxicity. At a pH of 7.2 and a temperature of 30 °C (undiluted wastewater), 1.3 percent of the ammonia present is toxic. As pH approaches 8.2 (marine water), toxic ammonia will comprise approximately 88.6 percent of the total concentration. Toxicity is still a function of concentration and, since the initial dilution of ammonia in the rising plume is around 45 μgN/L, this value is nearly two orders of magnitude (or about 1/100) of the concentration found to be toxic to most fishes (EPA, 1972).

4.3.2.2 Benthic Impacts

Benthic impacts are associated with the sedimentation of particulates entrained in the discharge plume. Sources of particulates in the wastewater discharge plume include particulates in the effluent, particulates produced in the environment from nutrient enrichment, and natural seston (natural, very minute living and non-living particulates in water).

Based on a study performed by Bailey-Brock and Krause (2007), the benthic community in the vicinity of the NDWWTP outfall can be characterized by diverse invertebrate and polychaete assemblages, with high abundance of some taxa, typical of communities found in carbonate sand. The benthic environment at the proposed DoD outfall is anticipated to be similar.

Based on several studies performed on deep ocean outfalls off Oahu in the Hawaiian Islands, no significant impacts have been reported on the benthic faunal. Impacts to polychaete assemblages and the crustacean and soft bottom communities were found to be limited. Since the conditions off Tanguisson Point are similar to those off the Oahu deep ocean outfalls, adverse impacts to the receiving marine waters are not anticipated with the discharge of secondary treated effluent from the proposed DoD outfall.

4.3.2.3 Sewage Impacts on Coral Reef Ecosystem

The Guam nearshore environment is characterized by extensive coral bottom and coral reef areas. In the vicinity between Tanguisson Point and Falcona Beach, high coral cover and diversity exists.

Detrimental impacts to the coral reef ecosystem associated with excessive nutrient-loading, bacteria, and sediment abrasion have been documented in other studies. These impacts, however, are dependent on the flushing properties of the receiving waters and the characteristics of the sediment. A 1985 report by Pastorok and Bilyard studied the impact of sewage effluent on the coral reef ecosystem. The study concluded that the discharge of sewage had little or no impact on the coral reef ecosystem in well-flushed water along open coasts.

Increased nutrient levels tend to favor algal growth and filter-feeding invertebrates (Birkeland, 1977). A study by Smith and Smith (2006) indicated that an increase in nutrient concentration may lead to a "phase shift" in the nature of the benthic algal community from one dominated by zooxanthellae (coral symbionts) to one dominated by fleshy macro-algae.

Documented impacts of sedimentation on coral reef systems include impeded growth due to unnecessary energy expenditure used to actively reject particles that settle on them, surface abrasion due to the re-suspension of sediments, decreased light availability, and toxic effects associated with the decomposition of organic matter. In general, coral species located along the seaward margin of the reef are less tolerant to high sediment loadings than species found on the inner reef. However, the physical condition of the seaward margin of the reef typically prevents the accumulation of sediments. The wastewater plume models for this investigation also indicated that the plume rises to the surface quickly and then spreads out, broadening the area subject to the dissolved and particulate substances in the effluent, thus reducing the concentration of the constituents that will arrive at the reef.

The coral reef off Tanguisson Point, at its closest point, is located approximately 360 feet from the outfall. This is approximately 1,100 feet from the shoreline and roughly 820 feet from the reef margin. The results of the farfield plume analysis indicate that the average dilution along the face of the reef will be on the order of 1,000 to 2,000. Without the influence of primary treated effluent discharged through the new NDWWTP outfall, the proposed DoD discharge of secondary treated effluent will meet GWQS as the discharge plume surfaces. With the primary treated effluent discharge from the NDWWTP, the average dilution factor for the mixed plume as it surfaces and spreads to the nearby reef front is expected to be on the order of 10, reducing the ammonia concentration well below the GWQS of 20 μg N/L. The 24-hour visitation frequency for the reef area is on the order of 5 to 10 percent.

The results of the farfield plume analysis and water quality assessment indicate some impact on the nearshore reef ecosystem associated with the discharge of 12 MGD of primary treated effluent through the new NDWWTP outfall. Due to the prevailing ocean current and wind conditions, mixing and flushing capabilities, and distance from the shore, however, the biological impacts are anticipated to be inconsequential and very limited in area. This potential impact may be mitigated by improving the treatment provided at the NDWWTP to secondary levels. The addition of 5 MGD of secondary treated effluent through the proposed DoD outfall should not alter this assessment, with the exception that detectable ammonia levels (below the GWQS limits) may impinge on the reef margin.

TABLE 4.1-2
SUMMARY OF DMRs FROM SECONDARY WWTPs IN GUAM AND HAWAII

Parameter	Secondary Treatment							
	Apra Harbor		Waianae		Kailua Regional		Wahiawa	
	Geometric Mean	90%*	Geometric Mean	90%*	Geometric Mean	90%*	Geometric Mean	90%*
Flow (ft^3/sec)	3.5	3.8	3.3	3.4	11.8	13.2	1.9	1.8
pH	7.2 to 7.5	7.2 to 7.6	7.2 to 7.5	7.0 to 7.6	6.8 to 7.1	6.7 to 7.2	7.1 to 7.3	7.0 to 7.4
BOD5 (mg/L) - Influent	76	93	189	199	169	186	---	---
BOD5 (mg/L) - Effluent	12	17	17	18	15	18	8	11
% BOD Removal	83%		91%		91%		---	
TSS (mg/L) - Influent	177	330	153	157	237	258	---	---
TSS (mg/L) - Effluent	10	14	12	13	18	21	10	14
% TSS Removal	93%		92%		92%		---	
Turbidity (NTU)			7.4	9	9	11.5		
Enterococci (MPN/100 mL)	3.9	11.6	56,219	130,399	20,039	35,900		
Coliform, fecal general (CFU/100 mL)	4.3	14.2					3	7
Nitrogen, Total (as N) (mg/L) - Max			22.8	27.8	17	18.4	23.4	25.8
Nitrite Plus Nitrate, Total (as N) (mg/L) - Max			14.8	16.5	9.6	11.7		
Nitrogen, Ammonia (as N) (mg/L) - Max			4.7	10.6	3.9	9.3		
Ammonia & Ammonium, Total (μg/L)	37.3	156						
Phosphorus, Total (as P) (mg/L) - Max			3.8	4.4	2.8	3.4	2.1	2.9
Nickel, Total Recoverable (μg/L)	12.8	14.8						
Zinc, Total Recoverable (μg/L)	25.1	42.1						
Aluminum, Total Recoverable (μg/L)	206	361						
Copper, Total Recoverable (μg/L)	7.6	10.7						
Oil and Grease (mg/L) - Influent	---	---						
Oil and Grease (mg/L) - Effluent	1.3	2						
Chlorine, Total Residual (μg/L)	4.4	9.8					0.02	0.02
TUC STAT 1Hr Chr. Tripneustes Gratilla - Max			93.6	452.4	65.5	185.2		
TUC STAT RE 7Day Chr. Ceriodaphnia Dubia - Max			33	29.4	46.3	46.3		
% Survival Tilapia Mossambica							75	0

Statistical analysis used to develop a value that is exceeded only 10 percent of the time.

TABLE 4.2-4
CALCULATED CONSTITUENT CONCENTRATIONS AFTER INITIAL DILUTION ASSUMING SECONDARY TREATED EFFLUENT DISCHARGED FROM THE NDWWTP

Water Quality Constituents	Unit	Background Concentrations (C_a)	NDWWTP Secondary Treated Effluent Concentration ($C1_e$)	Initial Dilution Provided by New NDWWTP Outfall ($S1_0$)	Average Farfield Dilution Factor For the New NDWWTP Outfall at Proposed DoD Outfall Location ($F1_{ave}$)	Calculated Ambient Concentrations at Proposed DoD Outfall ($C1_F$)	DoD Secondary Treated Effluent Concentration ($C2_e$)	Initial Dilution Provided by Proposed DoD Outfall ($S2_0$)	Average Farfield Dilution Factor For the Proposed DoD Outfall Location ($F2_{ave}$)	Calculated Constituent Concentration After Initial Dilution ($C2_i$)	GWQS (M-2 Waters)
Enterococci	#/100mL	0	15	300	2	0	15	251	1	0	104
Orthophosphate (as P)	µg P/L	5	1,640	300	2	7.7	1,640	251	1	14.2	50
Nitrate-Nitrite	µg N/L	1.1	14,900	300	2	25.9	14,900	251	1	85.2	200
TSS	mg/L	5.6	9	300	2	5.6	9	251	1	5.6	20
Turbidity	NTU	0.25	16	300	2	0.3	16	251	1	0.3	1
Priority Toxic Pollutants											
Lead	µg/L	0	4.43	300	2	0	4.43	251	1	0	8.1
Copper	µg/L	0	54.6	300	2	0.1	54.6	251	1	0.3	3.1
Zinc	µg/L	0	72.6	300	2	0.1	72.6	251	1	0.4	86
Additional Toxic Pollutants											
Ammonia (as N)	µg N/L	0	3,500	300	2	5.8	3,500	251	1	19.8	20
Total Sulfide	µg/L	0	140	300	2	0.2	140	251	1	0.8	5
Non-Regulated Constituents											
Total Nitrogen	µg N/L	151	23,950	300	2	190.7	23,950	251	1	285.3	---
Total Phosphorus	µg P/L	13	3,760	300	2	19.2	3,760	251	1	34.1	---

TABLE 4.2-5

CALCULATED CONSTITUENT CONCENTRATIONS AT M-1 BOUNDARY WITH INFLUENCE OF PRIMARY EFFLUENT DISCHARGED FROM THE NDWWTP

Water Quality Constituents	Unit	Background Concentrations* (C_a)	NDWWTP Primary Treated Effluent Concentration ($C1_e$)	Initial Dilution Provided by New NDWWTP Outfall ($S1_0$)	Average Farfield Dilution Factor For the New NDWWTP Outfall at M-1 Boundary ($F1_{ave}$)	Calculated Ambient Concentrations at M-1 Boundary ($C1_F$)	DoD Secondary Treated Effluent Concentration ($C2_e$)	Initial Dilution Provided by Proposed DoD Outfall ($S2_0$)	Average Farfield Dilution Factor For the Proposed DoD Outfall at the M-1 Boundary ($F2_{ave}$)	Calculated Constituent Concentration at M-1 Boundary ($C2_F$)	GWQS (M-1 Waters)
Enterococci	#/100mL	0	240,000	300	4	200	15	251	5	200	104
Orthophosphate (as P)	μg P/L	5	2,620	300	4	7.2	1,640	251	5	8.5	25
Nitrate-Nitrite	μg N/L	1.1	9	300	4	1.1	14,900	251	5	13.0	100
TSS	mg/L	5	80	300	4	5.1	9	251	5	5	5
Turbidity	NTU	0.25	59	300	4	0.3	16	251	5	0.3	0.5
Priority Toxic Pollutants											
Lead	μg/L	0	4.43	300	4	0	4.43	251	5	0	8.1
Copper	μg/L	0	68.3	300	4	0.1	54.6	251	5	0.1	3.1
Zinc	μg/L	0	276	300	4	0.2	72.6	251	5	0.3	86
Additional Toxic Pollutants											
Ammonia (as N)	μg N/L	0	18,400	300	4	15.3	3,500	251	5	18.1	20
Total Sulfide	μg/L	0	140	300	4	0.1	140	251	5	0.2	5
Non-Regulated Constituents											
Total Nitrogen	μg N/L	151	47,600	300	4	190.5	23,950	251	5	209.5	---
Total Phosphorus	μg P/L	13	3,850	300	4	16.2	3,760	251	5	19.2	---

**Background concentration of TSS reduced from 5.4 mg/L to 5 mg/L to match GWQS for M-1 waters.*

Note: Constituents that exceed the M-1 limit in the GWQS are highlighted in yellow.

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Power Supplementary Analysis Letter Report

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Power Supplementary Analysis Letter Report

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TABLES

ACRONYMS AND ABBREVIATIONS

CT	combustion turbine
CVN	carrier vessel nuclear
DoD	Department of Defense
DEIS	draft Environmental Impact Statement
ESG	Expeditionary Strike Group
GPA	Guam Power Authority
IWPS	Island-Wide Power System
LEED	Leadership in Energy and Environmental Design
MW	megawatt
NAVFAC	Naval Facilities Engineering Command
OEIS	Overseas Environmental Impact Statement
UFC	United Facility Code
USMC	United States Marine Corps

1. Purpose

This letter report discusses the differences between the power demand estimates presented in the *Guam Power Generation Study Report for Proposed U.S. Marine Corps Relocation* (NAVFAC Pacific 2008a) and the draft *Guam and CNMI Military Relocation Environmental Impact Statement/Overseas Environmental Impact Statement* (NAVFAC Pacific2009) (herein referred to as Power Study and DEIS/OEIS, respectively) to determine whether the conclusions made in the Power Study are still valid regarding projected Department of Defense (DoD) power demands. This letter report also assesses construction workforce power demand and explains how the projected power demand associated with the induced civilian population growth was determined in the EIS. The analysis and recommendations provided in the Power Study are based on prior preliminary population estimates. The analysis and recommendations presented in the DEIS/OEIS and included here are based on data presented in the Power Study and revised to reflect the current population data presented in Volume 1, Table 2.1-2 of the EIS; elimination of the Unified Facility Criteria (UFC) growth factor of 25% during the interim period; updated reduced power demand data for the aircraft carrier group; and increased power supply from Guam Power Authority (GPA). Thus, this letter report will do the following:

- Show the current population forecasts used in the EIS
- Briefly explain the new power demand estimates based on current population forecasts inclusive of buildup construction workforce and induced civilian growth from the socio-economic study in the DEIS/OEIS and the elimination of the UFC growth factor
- Explain the assessment of increased supply from GPA
- Discuss any revisions to the power generation recommendations between the Power Study and the EIS

2. Revised Power Demand Increases and Totals and Power Supply Increases from Guam Power Authority

The proposed military buildup on Guam would increase the demand for power. To assist with utilities planning to support the proposed military relocation, the Navy conducted a utility study for power. This study sought to: (1) quantify the increased DoD demand that would result from the military buildup and (2) identify utility solutions to meet those projected demands. In general, the Power Study accounted for projected power demand increases for new DoD facilities, which provides for DoD personnel, increases in the on-base civilian workforce required to support the military buildup, and construction workers working on base.

The utility Power Study assumed that the construction workers would reside off base and would be served by Guam public utilities at their place of residence. The impact on power demand from these construction workers was not evaluated in the Power Study because the focus of that study was on-base demand only. The DEIS/OEIS considers the impact of the construction workforce housing by making assumptions on the per capita demand. The DEIS/OEIS also estimates the increased power demand for the induced civilian growth. With the new total power demand, the DEIS/OEIS evaluates increased power needs for the islandwide GPA power system.

The Power Study identified anticipated loads and determined the need and options for additional power generation in Guam to support the DoD buildup. The load estimates reflected planned facilities that would support the various service branches based on preliminary load projections and UFC guidelines for planning. Those guidelines were further evaluated against current DoD facility requirements and goals for the program, which resulted in reevaluation of projected loads to address anticipated Leadership in Energy and Environmental Design (LEED) goals and remove the 25% growth factor during the buildup period. For long-term power generation planning, this growth factor would be used.

The LEED goals identify an approach to project design that would result in more efficient facilities than proscribed by the UFC guidelines. The expected impact on building loads would be an estimated reduction of power demand between 25 and 35 percent. It was decided to use a conservative reduction associated with the LEED approach of 10 percent, and the projected load demand would be 10 percent less than UFC for the new Marine base. The 25% growth factor originally in the demand calculations was used to establish capacity for new generation planning, whereas the DEIS/OEIS interim impacts address the facility demand and would not include spare capacity for unknown use.

A socioeconomic analysis performed in support of the DEIS/OEIS projected that, in addition to direct increases in DoD personnel, the on-base civilian workforce, and a temporary construction workforce, the proposed military buildup would result in induced civilian population growth. The population loading assumptions developed by the socioeconomics team and assumed for analysis in the DEIS/OEIS are summarized in Table 1. The assumptions regarding direct DoD personnel, the on-base civilian workforce, and the construction workforce vary somewhat from what was assumed in the Power Study. However, because power demand is based on constructed facilities more than population, it has minimal impact on the estimated power demand for the new DoD facilities. The population increases that do affect estimated power demand are the construction workforce and induced civilian growth. The additional power demand for these categories was estimated using a per capita basis.

The socioeconomic analysis projected that induced civilian growth as a result of the military buildup could increase the islandwide population of Guam by up to 40,000 in the peak year of 2014. The increased demand associated with this induced civilian growth was calculated by extrapolating the results and methodology used in the utility studies. The per capita power demand for the induced civilian growth was estimated at two-thirds of that for a current resident. The reduced amount is based on the expectation that a full proportional amount of new infrastructure would not be necessary for incremental growth, thus resulting in a reduced power demand per capita growth.

This new population forecast information provides the basis for revised electrical power demand projections for the Island-Wide Power System (IWPS), which are presented in Table 12, and shows current IWPS expected demand growth without the DoD buildup growth per the *Guam Power Authority Integrated Resource Plan* (NAVFAC Pacific 2008b). The load per construction worker was assessed at one-third that for a current permanent resident in Guam because facility and electrical requirements would be significantly less for the transient workforce. The workforce housing is anticipated to be work camp/dormitory style housing with reduced amounts of appliances; exterior amenities; and use of shared facilities, such as kitchens and entertainment areas.

DoD electrical demand increases related to military population growth are based on planned facilities, as previously noted, with facility requirements determined by the master plan for the DoD in Guam. The facility electrical demand loads have been calculated based on UFC guidelines as modified to address the anticipated LEED impact (a 10-percent savings) and do not reflect the 25-percent UFC growth factor for long-term generation planning. The Power Study included loads for the aircraft carrier vessel nuclear (CVN) (without escort ships) and Expeditionary Strike Group (ESG) vessels. These loads were not considered when determining interim period base load demand because they are not planned to require land-based electrical services until 2015. When that occurs, they would be served by peaking generation capacity related to the projected schedule of three times per year that the CVN or ESG may be in port (each, and not simultaneously).

Table 1 shows the current population projections, including the results of the socioeconomic study performed for the EIS.

Table 1: Projected Guam Population Growth Associated with the Projected DoD Buildup

Summary Table	Base-line	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	Total at 2019 (including baseline)
DoD (all inclusive, Marine Corps arrivals complete in 2014)												
Active	33	510	1,220	1,220	1,220	8,602	9,182	9,182	9,182	9,182	9,182	9,215
Dependents	52	537	1,231	1,231	1,231	9,000	9,950	9,950	9,950	9,950	9,950	10,002
Transient	0	0	400	400	400	2,000	9,222	9,222	9,222	9,222	9,222	9,222
Civilian Work Force (on base)	12	102	244	244	244	1,720	1,836	1,836	1,836	1,836	1,836	1,848
		1,149	3,095	3,095	3,095	21,322	30,190	30,190	30,190	30,190	30,190	
Non-Military												
Construction Jobs (direct, on-site)	0	3,238	8,202	14,217	17,834	18,374	12,140	3,785	0	0	0	0
Full-Time Equivalent Jobs (direct, from purchases)	0	1,640	4,029	6,659	8,074	9,657	7,538	3,889	2,254	2,254	2,356	2,356
Full-Time Equivalent Jobs (indirect and induced)	0	1,126	3,009	5,114	6,003	7,330	5,402	2,457	2,092	2,092	2,126	2,126
Dependents	0	3,886	9,500	15,216	17,569	22,494	16,869	8,820	6,116	6,116	6,157	6,157
Project-Related Subtotal	97	11,038	27,835	44,301	52,575	79,178	72,140	49,141	40,653	40,653	40,830	40,927
Non-Project Related												
DoD												
Active	6,635	80	80	80	130	170	250	250	250	250	450	7,085
Dependents	8,360	118	118	118	148	240	290	290	290	290	290	8,650
Transient	0	900	900	1,256	1,256	1,256	1,256	1,256	1,256	1,256	1,780	1,780
Civilian Work Force (on base)	2,489	17	17	17	27	35	38	38	38	38	45	2,534
Non-Project Related Subtotal	17,484	1,115	1,115	1,471	1,561	1,701	1,834	1,834	1,834	1,834	2,565	20,049
Grand Total Population Total (Op.'s + Construction)	17,581	12,153	28,950	45,772	54,136	80,879	73,974	50,975	42,487	42,487	43,395	60,976
Guam Population (general)		180,692	183,081	185,435	187,754	190,042	192,302	194,541	196,757	198,942	201,095	201,095
Guam Population Increase (general)			2,389	4,743	7,062	9,350	11,610	13,849	16,065	18,250	20,403	
ISLAND POPULATION TOTAL (Op.'s + Construction + Guam Pop.)		192,845	212,031	231,207	241,890	270,921	266,276	245,516	239,244	241,429	244,490	244,490

Table 2 shows the forecast power demand and supply and the sources for those items, incorporating the factors discussed above. The supply forecast is based on implementation of the preferred interim alternative of reconditioning up to four existing combustion turbines (CTs) owned by GPA. These

CTs would be operated within their current permit conditions. Additional GPA generating resources may be used to meet the new demand, but all would be operated within current permit limits.

Table 2: Electrical Power Demand and Supply Projections for DoD Buildup

	Demand (MW)									
	Interim Period without 25% Growth Factor					Long-Term without 25% Growth Factor				
GPA Power System	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Islandwide, including DoD and GPA baseline projected growth										
Existing Guam	281	287	294	299	303	306	309	312	315	318
Guam-Induced Civilian Increase (induced growth caused by military increase)	4.93	12.25	19.99	23.44	29.24	22.08	11.23	7.75	7.75	7.88
Construction Worker Increase	1.18	2.99	5.19	6.51	6.70	4.43	1.38	0.00	0.00	0.00
DoD Increase (less 39.8 MW load from transient aircraft carriers)	1.83	2.18	5.04	11.35	17.99	33.31	35.29	35.29	35.29	36.26
Total Demand	288.94	304.42	324.21	340.29	356.93	365.82	356.90	355.03	358.03	362.14
Total Available Supply	490.00	490.00	550.00	550.00	550.00	630.00	630.00	630.00	630.00	630.00
Future Supply Accounting for 1.52 Reliability Factor	322.37	322.37	361.84	361.84	361.84					
Future Supply Accounting for 1.52 Reliability Factor						414.47	414.47	414.47	414.47	414.47
Supply – Demand (net excess or shortfall without transient loads)	33.43	17.95	37.63	21.55	4.91	48.66	57.58	59.44	56.44	52.33
Transient Load Highest requirement with CVN group)						39.82	39.82	39.82	39.82	39.82
Supply – Demand (net excess or shortfall with transient loads)	33.43	17.95	37.63	21.55	4.91	8.84	17.76	19.62	16.62	12.51

MW megawatts.
Source: NAVFAC Pacific 2008b for existing Guam growth projections.

The power supply assessment of the GPA IWPS was revised based on new information from GPA. The first revision was related to the realization that the GPA report of power supply status may show a generating facility at zero production. That was misinterpreted in the Power Study to mean that this facility was not capable of generation. The reality is that such facilities may be able to generate power but were not generating power because they were not required. The second revision to power supply reflects the fact that GPA recently completed reconditioning Dededo CT #2, making it available for power generation and thus increasing available power supply.

The total load projections were evaluated against planned interim and long-term power generation plans to determine supply adequacy. This information is used in the DEIS/OEIS to refine plans for facilities and establish mitigation requirements so that the power system capacity would not be exceeded at any point during the planned buildup. This comparison is also presented in Table 2.

3. Revised Recommendations Presented in the DEIS/OEIS

The basic power generation conclusions and recommendations reached in the Power Study are essentially correct. The construction workforce and the induced civilian growth added power demand, but this increase in demand was partially offset by the estimated LEED reductions and deletion of the 25-percent UFC growth factor. In addition, the available power supply from GPA was reassessed to be higher than shown in the Power Study. The resulting alternatives discussed in the DEIS/OEIS are similar to those presented in the Power Study.

4. Conclusion

Because electrical power demand is a function primarily of constructed facilities, the original Power Study demand for DoD-only loads (on base) were not significantly affected by the revised on-base population forecasts. The additional induced civilian population growth and construction workforce would increase the estimated required demand by approximately 35.9 megawatts (MW) at the peak in 2014 before falling to less than 8 MW in 2017. This increased interim demand would be offset by demand reductions from LEED design (which would reduce the estimated demand for new DoD facilities by 10 percent compared with the UFC), deletion of the 25-percent growth factor on new DoD demand proscribed in the UFC for interim conditions, and an increase in the available power supply from GPA. Thus, the power-generating alternatives presented in the DEIS/OEIS are similar to those recommended in the original Power Study.

5. References

Naval Facilities Engineering Command, Pacific (NAVFAC Pacific). 2008a. *Guam Power Generation Study Report for Proposed U.S. Marine Corps Relocation*. July.

———. 2008b. *Guam Power Authority Integrated Resource Planning.*

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Revised Final Report

Guam Solid Waste Utility Study for Proposed USMC Relocation

Prepared For:

Naval Facilities Engineering Command Pacific
Pearl Harbor, Hawaii

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Executive Summary

Background

The Guam Integrated Military Development Plan (GIMDP), formerly the Joint Guam Military Master Plan (JGMMP), provides for the planned increase in military population on Guam. The Northern Guam bases, NCTS Finegayan, South Finegayan Housing area, Andersen Air Force Base (AAFB), AAFB Northwest Field, and AAFB South will experience most of the military personnel increase. Solid waste disposal facilities for these installations and all other Department of Defense (DoD) installations on Guam are currently provided by separate Navy and Air Force landfills.

This study evaluates long-term solid waste disposal facility alternatives for the DoD to service its current and proposed future United States Marine Corps (USMC) solid waste disposal needs and to meet future regulatory requirements. Although solid waste systems typically benefit from economies of scale, this study focuses on developing facilities that will only dispose solid waste generated from DoD activities. It includes planning for projects that represent the best value alternative solid waste disposal facilities that will enable the DoD on Guam to meet the defined future DoD requirements.

Solid Waste Quantities

The military personnel and dependent population on Guam is projected to increase from the current baseline population of about 15,080 persons to about 40,000 persons in the year 2016 when the proposed USMC relocation to Guam is scheduled to be complete. The total projected additional military and dependent population associated with the proposed USMC relocation to Guam is about 17,552 persons. The total projected additional military and dependent population associated with other services is about 9,912 persons. Solid waste quantities are correspondingly projected to increase from current design capacity levels of approximately 16,230 tons per year to approximately 53,320 tons per year in the year 2019. The projected solid waste quantity associated with the proposed USMC relocation is approximately 23,710 tons per year.

Regulations Applicable to Solid Waste

The Guam Environmental Protection Agency (GEPA) developed a State program and was granted primacy for enforcing the requirements of 40 CFR Part 258 Criteria for Municipal Solid Waste Landfills. The Rules and Regulations for GEPA, Title 22, Division 4, Chapter 23 Solid Waste Disposal include the 40 CFR Part 258 requirements as a minimum and are applicable to DoD solid waste activities on Guam.

Guam does not have total primacy for implementation and enforcement of the Clean Air Act Amendments, since GEPA has not prepared a “State Implementation Plan” for incorporating these regulations into its requirements.

Therefore, the requirements of 40 CFR Part 60 Subpart AAAA New Source Performance Standards for Small Municipal Waste Combustion Units would be applicable to DoD solid waste activities involving solid waste incineration or waste to energy alternatives.

Guam laws and regulations pertaining to solid waste handling and disposal are codified in the Guam Code Annotated, Title 10, Chapter 33 Solid Waste, Chapter 51 Solid Waste Management and Litter Control, and Chapter 73 Fire Prevention. Chapter 73 contains a provision that prohibits the construction and operation of municipal solid waste incinerators and waste to energy (WTE) facilities on Guam. These laws and regulations are not all directly applicable to DoD solid waste activities located within DoD property on Guam.

Solid Waste Disposal Alternatives

Based on a preliminary review of the available solid waste disposal alternatives for DoD on Guam, the following alternatives were identified for evaluation:

(1) Install liner and other improvements at existing Navy Sanitary Landfill at Apra Harbor.

(2) Use new landfill constructed by GovGuam

(3) Construct new landfill in Central Guam.

(4) Incinerator/Waste-to-Energy

(5) Barge Waste off island.

(6) Status Quo, continue to use unlined Apra Harbor Navy Landfill.

(7) Construct new landfill in Northern Guam.

(8) Utilize existing landfill at Andersen Air Force Base.

(9) Expand existing landfill at Andersen Air Force Base.

(10) Use potential new private waste-to-energy facility with landfill at Guatali

The focus of this study is final disposal of solid waste. Therefore, methodologies such as materials recovery, waste diversion, waste minimization, and source reduction were not incorporated into the analysis. These methodologies would generally reduce the volume of solid waste requiring final disposal. However, for this study, they would not significantly affect the selection of a particular disposal technology.

A preliminary screening analysis was conducted. The technical aspects of the alternatives were developed to a conceptual level to allow evaluation of the relative viability of the ten identified alternatives. The alternatives were screened on the basis of environmental and regulatory issues, implementation and policy issues, and potential scheduling issues. Based on the screening analysis, Alternatives 5 through 10 were judged as nonviable and were eliminated from further consideration, as summarized below.

Alternative 5 – Barging solid waste to an off-island landfill or other solid waste disposal facility was judged as nonviable because of the very high costs and potential socio-political as well as environmental concerns.

Alternative 6 – Pursuing the status quo by operating the Apra Harbor Navy Sanitary Landfill without installation of a liner system was judged as nonviable because it is believed that GEPA will not allow significant additional disposal without installation of a liner system.

Alternative 7 – Navy/DoD construction of a new landfill in northern Guam was judged as nonviable because it would be placed over the Northern Guam Lens Aquifer (NGLA), an environmentally sensitive groundwater protection zone providing the only significant potable groundwater source and almost 80 percent of the drinking water for the island. The NGLA area had been ruled out as a suitable area for siting a new landfill during an EIS process conducted by GovGuam. GEPA may be unlikely to approve a new landfill over the NGLA given less-sensitive available locations on the inland.

Alternative 8 – Using the existing landfill at Andersen Air Force Base (AAFB) was judged as nonviable because it has very limited site life remaining. A 2-acre lined expansion recently pursued would only provide capacity for an estimated two to four additional years.

Alternative 9 – Expansion of the landfill at AAFB was judged as nonviable because it would be located over the NGLA. Similar to Alternative 7, it may not be advisable or possible to pursue permitting a significant new landfill footprint located above the NGLA.

Alternative 10 – The potential new private WTE facility with a landfill at Guatali has yet to obtain permits for construction of either the landfill or WTE facility. This process could be long and contentious given the litigious history of the project. Funding for the project is still uncertain. Given these factors, Alternative 10 was judged as non-viable.

Alternatives 1 through 4 were developed in more detail for evaluation. The evaluation included environmental issues, regulatory issues, implementation and policy issues, economics and net present value life cycle cost analysis, and schedule. Because Guam is a relatively small island with limited land availability, a long term solid waste solution is needed. Therefore the analysis period for the life cycle cost analysis was set at 50 years. The net present value life cycle cost analysis under military construction funding is summarized in Table ES-1, which is included at the end of this section. The net present value life cycle cost analysis under private sector financing is summarized in Table ES-2, which is included at the end of this section. The results of the comparative evaluation are summarized in Table ES-3, which is also included at the end of this section.

Summary of Findings

The major findings of the study are summarized below.

- Continued use of the existing Navy Landfill at the Apra Harbor Naval Complex is necessary to provide sufficient time to implement planning and construction of new solid waste disposal facilities.
- GEPA has regulatory primacy for enforcing USEPA solid waste regulations on Guam. It is anticipated that soon after the new GovGuam lined landfill becomes operational, GEPA would require all landfills on Guam to be lined or to close. This would have a direct impact on the existing unlined Navy Landfill at Apra Harbor. It would be prudent to begin programming a project that would include a liner for the inactive portion of the existing landfill and a separation liner for the active portion of the existing landfill.
- A landfill is needed for essentially any alternative considered. Materials that cannot be handled by a particular process and the residual material generated by a process will require landfill disposal.
- Continued use of the existing Navy Landfill at the Apra Harbor Naval Complex would not provide 50 years of service unless the DoD is willing to fill to elevations higher than 100 feet mean sea level (MSL). Based on current design criteria for constructing landfills, the existing landfill could be filled to elevation 140 feet MSL.
- Construction of a new DoD landfill on DoD property in central Guam is the most cost-effective and reliable alternative on a 50-year life cycle cost basis under both military construction and private funding. Because the landfill would be a DoD landfill, the DoD would control the waste allowed to be disposed in the landfill. Certain waste streams could be diverted to other available solid waste facilities, such as the GovGuam landfill, to extend the life of the DoD landfill.
- Use of the GovGuam Layon Landfill has a 50-year life cycle cost comparable to construction of a new DoD landfill. However, the Layon Landfill has not yet begun construction and it is uncertain when the landfill would become operational. In addition, under this alternative, the DoD would be entirely dependent on the Layon Landfill. If the capacity is reached earlier than anticipated and GovGuam again has difficulties in constructing a replacement landfill, the DoD will be significantly impacted.
- Construction and operation of a waste to energy (WTE) facility has the highest 50-year life cycle cost. However, a WTE facility has potential for extending the life of the existing Navy Landfill at the Apra Harbor Naval Complex well beyond the 50-year service life considered for this study.

Summary of Recommendations

Based on the results of the analysis and evaluations performed for this study, the recommendations below are offered.

- Establish a planned final fill plan for the existing Navy Landfill at the Apra Harbor Naval Complex corresponding to the alternative final fill plan for elevation 100 feet mean sea level. Retain the option to fill to elevation 140 feet mean sea level if the need arises in the future.
- Revise landfill operation practices as recommended in the Sanitary Landfill Management Plan. The revised practices include utilizing a systematic daily cell construction method with a single application of daily cover material, and obtaining heavier landfill operating equipment, such as a Caterpillar D8 or equivalent, outfitted for landfill service.
- Implement improvements to the existing Navy Landfill including the construction of a liner for the inactive area and a separation liner for the active area. The project can be phased to allow flexibility to make adjustments if construction of a Waste-to-Energy Facility moves forward. The liner should be designed to accommodate filling to elevation 140 feet mean sea level. This would provide DoD the flexibility to fill to that elevation if it became necessary to do so.
- Conduct a study to develop a long-term strategy for managing potential releases from the unlined active portion of the existing Navy Landfill. The study should include assessment of mitigation measures that might be needed if a separation liner is constructed over the existing active portion of the landfill.
- Develop a project to construct a new Navy Landfill within the Apra Harbor Naval Complex Ordnance Annex. This landfill will be needed in the foreseeable future, particularly if a Waste-to-Energy Facility does not move forward.
- Track status of construction of the new GovGuam landfill and continue to evaluate its potential for disposal of DoD solid waste, particularly residential solid waste generated from housing areas, in the future.

Table ES-1
Summary of Present Value Analysis – Military Construction Funding

Alternative	PV Analysis 25 - Year	PV Analysis 50 - Year
Alternative 1-1 Apra Harbor Landfill - 54 ft MSL See Note b	Inadequate Service Life	Inadequate Service Life
Alternative 1-2 Apra Harbor Landfill - 100 ft MSL See Note c	56,000,000	Inadequate Service Life
Alternative 2 GovGuam landfill See Note d,e	123,000,000	189,000,000
Alternative 3 New Navy Landfill See Note f	149,000,000	174,000,000
Alternative 4a Modular WTE Facility See Note g	179,000,000	270,000,000
Alternative 4b Field-Erected WTE Facility See Note g	210,000,000	277,000,000

Notes:

a Present Value Analysis uses a real discount rate of 2.8 percent in accordance with OMB Circular No. A-94, Appendix C, Rev January 2008.

b Estimated service life is limited to the year 2023 and would be exhausted prior to the end of the 25-year and 50-year analysis periods.

c Estimated service life is limited to the year 2036 and would be exhausted prior to the end of the 50-year analysis period.

d Assumed tip fee at the GovGuam landfill is $95/ton over the analysis period.

e Costs include an estimated 40 percent increase in collection driver/truck costs to use GovGuam landfill as compared to the current system. After the proposed relocation of Marines is completed, 80 percent of the DoD solid waste stream will be generated in Northern Guam.

f Costs include an estimated 15 percent increase in collection driver/truck costs to use new Navy landfill in Central Guam as compared to the current system. After the proposed relocation of Marines is completed, 80 percent of the DoD solid waste stream will be generated in Northern Guam.

g It is assumed that WTE would extend service life of the Apra Harbor Landfill to 65 years for landfilling of incombustible waste and residual ash.

Table ES-2
Summary of Present Value Analysis – Private Entity Funding

Alternative	PV Analysis 25 - Year	PV Analysis 50 - Year
Alternative 1-1 Apra Harbor Landfill - 54 ft MSL See Note b	Inadequate Service Life	Inadequate Service Life
Alternative 1-2 Apra Harbor Landfill - 100 ft MSL See Note c	60,000,000	Inadequate Service Life
Alternative 2 GovGuam Landfill See Notes d,e	123,000,000	189,000,000
Alternative 3 New Navy Landfill See Note f	153,000,000	176,000,000
Alternative 4a Modular WTE Facility See Note g	184,000,000	270,000,000
Alternative 4b Field-Erected WTE Facility See Note g	217,000,000	283,000,000

Notes:

a Present Value Analysis uses a real discount rate of 2.8 percent in accordance with OMB Circular No. A-94, Appendix C, Rev January 2008.

b Estimated service life is limited to the year 2023 and would be exhausted prior to the end of the 25-year and 50-year analysis periods.

c Estimated service life is limited to the year 2036 and would be exhausted prior to the end of the 50-year analysis period.

d Assumed tip fee at the GovGuam landfill is $95/ton over the analysis period, which is discounted over the analysis period.

e Costs include an estimated 40% collection driver/truck cost increase to use GovGuam landfill as compared to the current system. After proposed USMC relocation is completed, 80% of the DoD solid waste stream will be generated in Northern Guam.

f Costs include an estimated 15% collection driver/truck cost increase to use new Navy landfill in Central Guam as compared to the current system. After proposed USMC relocation is completed, 80% of the DoD solid waste stream will be generated in Northern Guam.

g It is assumed that WTE would extend service life of the Apra Harbor Landfill to 65 years for landfilling of incombustible waste and residual ash.

h. Capital projects over the study period were assumed to be financed or funded through a sinking fund, except for Alternative 2, which utilizes planned GovGuam Landfill costs.

i. Capital projects financing assumed 20-year periods except for Alternative 1-1, which used a 15-year period based on projected service life.

j. Capital projects financing assumed Japanese bank financing with an amortized origination fee of 1.00 percent and an interest rate of 2.5 percent.

k. Capital project sinking funds used various accumulation periods based on cash flow requirements and assumed earned interest at an annual percentage rate of 1.0%.

l. Equal annual landfill closure fund deposits were accumulated over the alternative landfill life including earned interest at an annual percentage rate of 1.0%.

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TABLE ES-3
SUMMARY MATRIX OF COMPARATIVE PROS AND CONS (P= Pro; C= Con)

Alt.	Option/Issue	Environmental	Regulatory	Implementation/Policy	Economics	Schedule
1	Improve Existing Navy Landfill at Apra Harbor (AHNLF)	C- May increase extent/duration of VOC migration C- Slightly greater degree of GHG emissions compared to adding WTE and/or MRF C- Separation liner (Alt 1-2) has potential to fail due to differential settlement.	C- GEPA likely to request separation liner over active area (assumed for Alternative 1-2 but not Alternative 1-1). C- Would use AHNLF up to 27 years by filling to elevation 100 MSL (Alt. 1-2). The GEPA may not approve a permit for continued use of the landfill for this long of a period.	C- GovGuam and GEPA prefer regional landfill for entire island	P/C – Alternative 1-1 does not provide comparison to other alternatives for 25 and 50-year periods; however, can be used as less costly interim alternative to Alternatives 2 through 4. C- Significant capital cost required for liner and LCRS system under Alternative without providing long-term strategy.	P- Although not providing a long-term strategy, provides more than adequate flex time for decisions and implementing other alternatives (Alt. 1-1= 2015 with current fill practices; Alt. 1-2=2036, with revised filling practices).
2	Use New Landfill Constructed by GovGuam	P- Entire new GovGuam landfill would be lined with base liner on native soil (compared to separation liner over waste for Alt 1-2)	P- If available soon (assumed expedited by 2010), $11M for site improvements and liner for inactive area of AHNLF would not be required. P- Based on letter communication GEPA appears to favor DoD use of the proposed GovGuam Landfill and closure of the AHNLF as soon as possible.	C- Historical and current lack of stable garbage fee collection is impediment to obtaining financing of proposed new GovGuam Landfill. C- Navy would be at risk if GovGuam cannot implement proposed new landfill when needed to replace AHNLF. C- Navy would be dependent on the GovGuam landfill; with less control if funding, environmental control, operational or other problems occur with the landfill.	C- Present Value analysis indicates $123M and $189M for 25 and 50 year analysis, respectively, at an assumed $95/ton tip fee. The 50 year analysis indicates that this alternativeis nine percent higher than Alternative 3. C- Increase in collection costs from AAFB, the proposed USMC relocation and Navy Base to new GovGuam landfill in south (Estimated 40 percent increase in truck and driver cost compared to AHNLF location). P- New large liner capital investment by DOD not required C- Lack of enforceable fee collection system by GovGuam could negatively affect reliable economics for DoD.	P- There is adequate capacity at the AHNLF provided that GovGuam can resolve all Consent Decree and permitting issues to allow Navy disposal. The AHNLF has a range of 7 to 12 years with current operating conditions and up to 14 to 27 years with recommended operational improvements; depending up whether AHNLF can be filled to elevation 54MSL or 100MSL. C – The timing for resolution of permitting issues for the proposed GovGuam landfill is not clear at this time.
3	Construct New Navy Landfill in Central Guam	P- Lined Landfill should reduce degree/term of VOC migration from existing AHNLF if closed sooner	C- Appears that GEPA wants the DOD to use the planned GovGuam landfill near Layon (letter).	P- New landfill would provide 50 years of service and operational flexibility to the DoD. C- Historic asset mitigation required at preliminary site. C- Potential impact to Santa Rita Spring must be determined. C- Permit from GEPA required	P- Present Value analysis indicates $149M and $174M for 25 and 50 year analysis including capital, landfill operations, and collection driver and truck costs under MCON funding. Under private funding this alternative has a PV of $153M and $176M for 25 and 50 yr analysis, respectively. C- Slightly less collection economics (Estimated 15 percent increase in truck and driver cost) compared to current system using AHNLF	P- Siting and constructing a new MSWLF typically can take at least 4 years. Given that Alternative 1-1 provides 7 years of capacity without operational improvements (heavier equipment and operational improvements may increase this to 14 years); scheduling for developing the new landfill is judged as viable.
4	Incinerator/Waste-to-Energy	P- Less GHG emissions than landfill for combustible fraction of waste stream; also would provide an energy offset C- Landfill still required for significant portion (46 percent) of the waste stream	C- Significant air quality permitting. C- Would use AHNLF in long term for disposal of non-combustible waste and ash. The GEPA may not approve the continued use of the landfill for >50 years given existing portion of unlined waste. C- Guam PL 25-175 Amended 10 GCA Chapter 73, Fire Prevention to prohibit municipal solid waste incinerators. A determination must be made regarding the applicability of 10 GCA Chapter 73 to DoD.	C- Significant initial financing is required: $46M and $98 capital cost, respectively, for Modular (4a) or Field Erected (4b) facilities.	C - Present Value analysis for Modular (4a) facility indicates $179M and $270M for 25 and 50 year analysis, respectively under MCON funding. Under private funding this alternative has a PV of $184M and $270M for 25 and 50 yr analysis, respectively. C - Present Value analysis for Modular (4b) facility indicates $210M and $277M for 25 and 50 year analysis, respectively under MCON funding. Under private funding this alternative has a PV of $217M and $283M for 25 and 50 yr analysis, respectively.	C- Expedited earliest schedule is assumed to allow phased construction in 2012 and 2013 at the soonest.

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ACRONYMS

°C	degree Celsius
°F	degree Fahrenheit
AAFB	Andersen Air Force Base
ac-ft	acre foot
Cd	Cadmium
CI	Activated Carbon Injection
COC	Constituents of Concern
CY	cubic yards
DoD	Department of Defense
DPW	Department of Public Works
DPW	Department of Public Works, Government of Guam
EIS	Environmental Impact Analysis
EPA	Environmental Protection Agency, United States
FAA	Federal Aviation Agency
FF	Fabric Filter
ft	feet or foot
ft/day	feet per day
GCMP	Guam Coastal Management Program
GDAWR	Guam Department of Agriculture - Division of Aquatic & Wildlife Resources
GEPA	Guam Environmental Protection Agency
GIMDP	Guam Integrated Military Development Plan (GIMDP)
GLUP	Guam Land Use Plan
GovGuam	Government of Guam
GWUDI	Groundwater under the direct influence of surface water
HDPE	High density polyethylene
HCl	Hydrochloric Acid
Hg	Mercury
JGMMP	Joint Guam Military Master Plan JGMMP
LCRS	Leachate collection and removal system
LLDPE	linear low-density polyethylene
MALS	Marine Air Logistics Squadron
MCON	Military Construction

MCY	million cubic yards
MG	Megagrams
mg/L	milligrams per liter
MLG	Marine Logistic Group
MLLW	mean lower low water
Mm	millimeter
MSL	mean sea level
NAVFAC	Naval Facilities Engineering Command
NAVMAG	Naval Magazine
NGLA	Northern Guam Lens Aquifer
NGLS	Northern Guam Lens Study
NOx	Nitrogen Oxides
NPDES	National Pollution Discharge Elimination System
O&M	Operation and maintenance
Pb	Lead
PM	Particulate
psi	pounds per square inch
SDA	Spray Dryer Absorber
SNCR	Selective Non-Catalytic Reduction
SO2	Sulfur Dioxide
SOF	Special Operations Forces
SPE	Special Purpose Entity
SWDRR	Solid Waste Disposal Rules and Regulations (government of Guam)
tpd	tons per day
tpy	tons per year
U.S.	United States
USGS	United States Geological Survey
USMC	United States Marine Corps
VOC	volatile organic compound
WWTP	Wastewater treatment plant
WTE	Waste-to-Energy

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1.0 Introduction

1.1 Purpose

The Guam Integrated Military Development Plan (GIMDP), formerly the Joint Guam Military Master Plan (JGMMP), describes the planned increase in military population on Guam. NCTS Finegayan, South Finegayan Housing area, Andersen Air Force Base (AAFB), AAFB Northwest Field, and AAFB South will experience most of the military personnel increase on Guam. Solid waste disposal facilities for these installations and all other Department of Defense (DoD) installations on Guam are currently provided by separate Navy and Air Force landfills.

The United States of America (U.S.) and Japan agreement involves in part the Special Purpose Entity (SPE), which was conceived as a business venture to allow Japan to provide family housing and utilities for the proposed United States Marine Corps (USMC) relocation to Guam. Like a public-private venture, the SPE would recoup its investments and expenditures through housing leases and utilities service charges. Although few details are known about the SPE, all solid waste disposal alternatives on DoD property are being considered by the SPE.

The purpose of this study is to identify reasonable alternatives for solid waste disposal facility improvements to support the proposed USMC relocation on Guam as well as supporting other existing and known future DoD requirements

1.2 Background Information

The island of Guam is part of the Marianas Island chain. Guam is a U.S. territory and is located approximately 3,800 miles west of Hawaii and 1,500 miles south of Japan. The island is approximately 30 miles long and ranges from 4 to 11 miles wide. The total land area is approximately 212 square miles. The 2007 population of Guam is estimated at approximately 171,000.

The solid waste management system on Guam includes the Navy Sanitary Landfill located at Apra Harbor, the landfill and recycling center located at Andersen Air Force Base, and the Ordot Dump owned and operated by the Government of Guam (GovGuam). The Navy and Air Force disposal sites are operated by the DoD and provide service to military personnel and residents of the bases as well as commercial waste streams from base activities. The remaining waste stream of Guam is serviced by GovGuam using the Ordot Dump and citizen drop-off transfer stations.

The Guam Department of Public Works (DPW) was operating the Ordot Dump, which is now under federal receivership. Under a Consent Decree with the United States Environmental Protection Agency (USEPA) the Ordot Dump was directed to achieve complete closure by October 23, 2007. In response to this requirement, the DPW advertised Requests for Letters of Interest for these projects in January 2006 and prepared procurement packages for the design and construction for closure of the Ordot Dump, the design, construction and operation of a new landfill at Layon, and the design, construction and operation of other solid waste operations and activities. However, the construction of the planned new landfill has been delayed for a number of reasons including local opposition and the inability to secure adequate funding for the landfill construction and closure activities.

This Study evaluates solid waste disposal facility alternatives for the DoD to service its current and proposed future Marine Corps solid waste disposal needs and to meet future regulatory requirements. Although solid waste systems typically benefit from economies of scale, this study focuses on developing facilities that will only dispose solid waste generated from DoD activities. It includes planning for projects that represent the best value alternative solid waste disposal facilities that will enable the DoD on Guam to meet the defined future DoD requirements. This study also provides a basis for the SPE to plan, design and execute recommended solid waste projects.

1.3 Proposed U.S. Marine Corps Relocation and Other DoD Growth

The DoD is planning to increase the military population on the island of Guam. The official military loading is expected to increase by approximately 12,569 military personnel over the current baseline population of 7,653 military personnel. This includes military personnel from the Air Force, Army, Coast Guard, Marines, and Navy. The number of additional dependents associated with accompanied personnel is expected to be about 11,833. The total population increase is expected to be approximately 24,402 personnel, close to 15 percent of the current population of Guam. Of the total DoD population increase, about 17,552 military personnel and dependents are associated with the proposed USMC relocation from Okinawa to Guam.

1.4 Solid Waste Disposal Alternatives

Based on a preliminary review of the available disposal alternatives for DoD on Guam, the following alternatives were identified for evaluation:

(1) Provide liner and other improvements at the existing Navy Landfill.

(2) Use new landfill constructed by GovGuam

(3) Construct new landfill in Central Guam.

(4) Incinerator/Waste-to-Energy

(5) Barge Waste off island.

(6) Status Quo, Navy to continue to use unlined Apra Harbor landfill.

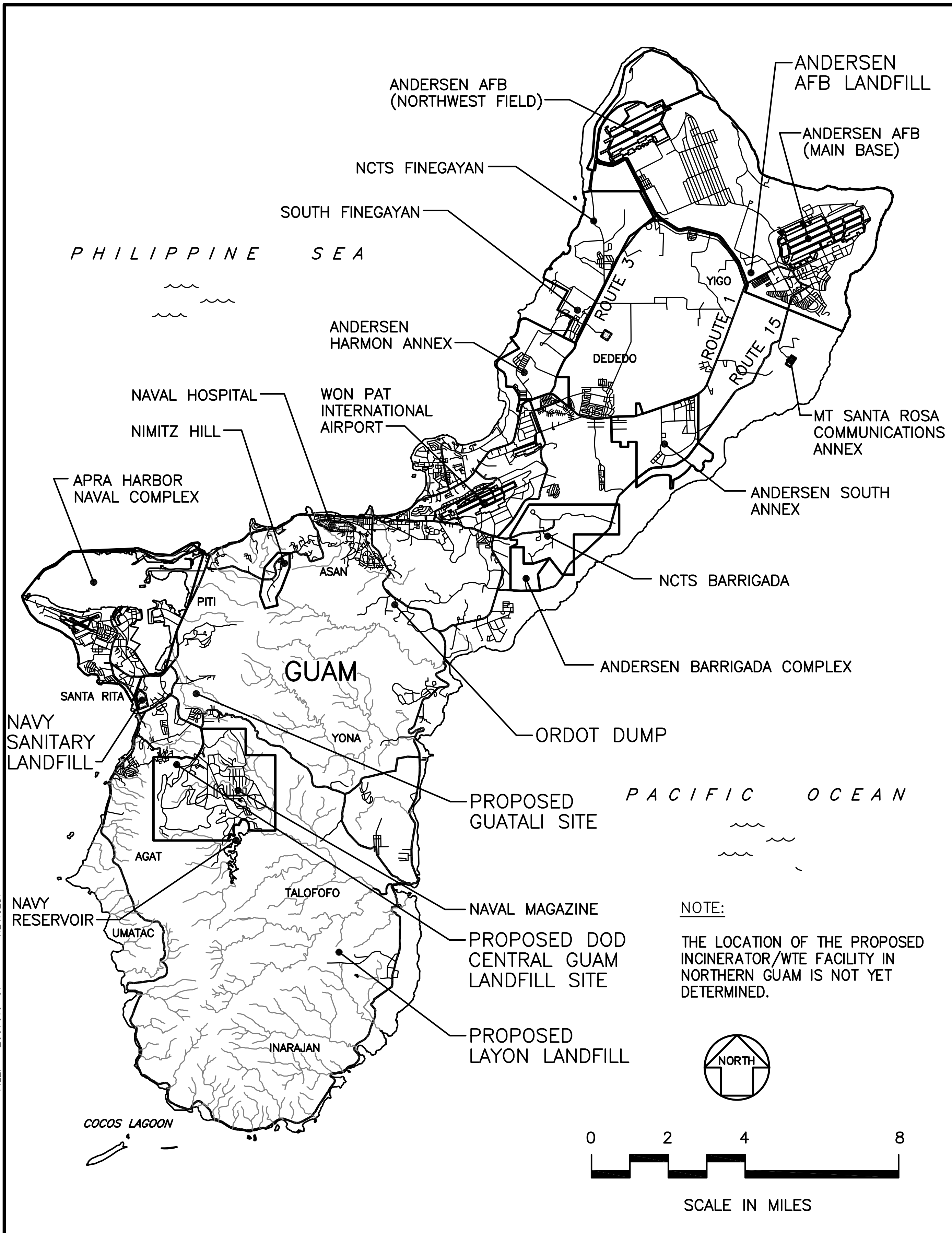
(7) Construct new landfill in Northern Guam.

(8) Utilize existing landfill at Andersen Air Force Base.

(9) Expand existing landfill at Andersen Air Force Base.

(10) Use proposed new private waste-to-energy facility with landfill at Guatali

The general locations of the alternatives are shown on Figure 1-1. In addition to these disposal alternatives, the DoD could utilize waste diversion programs, including recycling and composting programs. However, these programs will only extend the life of these disposal alternatives; not replace the need for them.



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Hawaii Pacific Engineers, Inc.	GUAM SOLID WASTE UTILITY STUDY FOR PROPOSED USMC RELOCATION	VICINITY MAP	FIGURE 1-1

2.0 Solid Waste Generation and Disposal Conditions

2.1 Existing Conditions

2.1.1 Waste Collection System

The Navy Sanitary Landfill receives all of the non-hazardous solid wastes generated on the Navy installations. This section presents a brief overview of the solid waste generation and then focuses on the existing solid waste stream entering the landfill. Field investigations and review of landfill records were conducted to quantify and characterize the solid waste stream entering the landfill. Projected base loadings were then used to develop future quantities and characteristics of the solid waste stream entering the landfill.

Solid wastes generated by the Navy installations and their tenants were categorized into four general source categories for this study:

- Family housing;
- Commercial and industrial activities;
- Construction activities; and
- Other wastes.

Housing waste is collected in 90-gallon refuse containers emptied by 40-cubic yard capacity, side-loading, compacting refuse trucks. Commercial and industrial waste is collected in 3-, 6- and 8-cubic yard "front loader" containers placed near various facilities at the Naval installations. The containers are emptied by 40-cubic yard capacity, front-loading, compacting refuse collection trucks. Selected Naval facilities have 20- and 40-cubic yard "dinosaur" containers that are collected by roll-on/roll-off, rear-loading tractors. Refuse from ships is collected in special containers located along the ship's berthing pier. The containers are picked up from the pier and transported to the steam sterilization facility for decontamination of the ship refuse. After the ship refuse is decontaminated, the steam-sterilized waste is transported to the Navy Sanitary Landfill for disposal.

The landfill accepts various waste debris from construction projects such as excess soil, wood, concrete, and construction and demolition debris. Asbestos waste is accepted on a case-by-case basis. The asbestos contractor places the asbestos waste and covers the waste with at least six inches of soil cover. The landfill operator is required to observe the process and ensure that the landfill remains in compliance with its permit.

2.1.2 Assessment of Existing Waste Generation

Field investigations and data collection were performed to assess the quantity of solid waste entering the Navy Sanitary Landfill; to develop projected solid waste stream quantities and characteristics, and to allow subsequent analysis of remaining landfill life and potential future disposal alternatives. Field investigations were conducted between 11 December 2006 and 18 December 2006. Data was analyzed for the landfill airspace volume utilization using topographic mapping and related to the volume of material added to the landfill.

The following parameters were estimated based on volumetric calculations and visual observations of the landfilling operations:

- The annual landfilling rate was calculated to be 49,580 cubic yards per year, based on a total landfill volume change of 529,000 cubic yards between February 1996 and October 2006.
- An observed in-place density of 625 pounds per cubic yard and in-place solid waste to cover material ratio of 1:1 were used to calculate a daily solid waste generation rate of 21 tons per day.
- Based on a present Navy population of 7,000, the unit solid waste generation rate was calculated to be 6.1 pounds per capita per day. A previous study [Guam Water Quality Management Plan, 1979] indicated a military per capita generation rate of 7.4 pounds per day.

Annual solid waste volumes for 2006 were estimated based on the reported volumes, refuse collection schedule, trip tickets and disposal logs.

- The total solid waste generated based on the reported volumes to GEPA was calculated to be 309,400 cubic yards. It should be noted that the volume of the housing waste appears to be a compacted volume.
- The calculated annual solid waste generated based on the refuse collection schedule is 187,300 cubic yards. It should be noted that this value includes only the waste from commercial and industrial activities collected in the 3-, 6-, 8-, 20- and 40-cubic yard containers and assumes that the refuse container is full.
- The estimated solid waste volume generated based on the trip tickets is 134,300 cubic yards. It should be noted that this total includes only commercial and industrial waste. Housing and customer-hauled waste is not included. It was also assumed that the containers were full.
- The total solid waste volume generated based on the disposal logs was calculated to be 135,600 cubic yards. It should be noted that the volumes recorded for housing and some of the commercial and industrial waste volumes appears to be a compacted volume.

It appeared that the solid waste volumes recorded on the reports to GEPA and disposal logs were overestimated. Because the estimated volumes based on the solid waste records did not appear to be sufficiently accurate, the calculated change in landfill volume based on the available topographic survey maps and information and observations of landfill placement practices were used to develop the basic solid waste data to project quantities of future solid waste stream entering the landfill.

Basic solid waste data for the existing solid waste stream based on the analyses and investigations described above and per capita parameters used for projection of solid waste quantities are presented in Table 2-1.

Table 2-1

Basic Solid Waste Stream Data

Parameter	Value	Unit
Total landfilled volume, solid waste and cover material	49,580	cy/yr
Cover material to solid waste ratio	1.0	
In-place solid waste volume	24,790	cy/yr
Cover material volume	24,790	cy/yr
In-place solid waste density	625	lbs/cy
Total solid waste entering landfill	21	tons/day
Current population served by landfill	7,000	
Per capita unit waste generation investigation	6.1	lbs/day
Per capita unit waste generation used for this report	7.4	lbs/day

2.2 Projected Conditions

Activity at the DoD installations is expected to increase due to planned development of additional facilities for DoD operations and the proposed relocation of USMC operations. The proposed USMC relocation is anticipated to start in 2012 and be completed by 2016. Furthermore, the existing Andersen Air Force Base Landfill is currently near capacity. The current Government of Guam Ordot Dump is scheduled to be closed due to violations of EPA regulations. The new Government of Guam landfill is behind schedule and the completion date is uncertain. There is a potential for disposing solid waste from the Air Force facilities in the Navy Sanitary Landfill until the Government of Guam opens their new landfill. Updated projected population data was obtained and is summarized in Table 2-2.

The solid waste alternatives included in this study were developed to serve the entire DoD population on Guam. Therefore, the proportional share of the solid waste stream and the associated costs of the facilities and operations attributable to the proposed USMC relocation corresponds to the population associated with the proposed USMC relocation relative to the total planned DoD population on Guam.

Table 2-2

Military Population

Year	USMC	Air Force	Navy	Army	USCG	SOF	Total
2008	5	4,597	7,016	80	320	0	12,018
2009	5	5,095	9,580	80	320	0	15,080
2010	305	6,745	9,910	80	320	0	17,360
2011	305	6,745	9,910	130	320	50	17,460
2012	905	7,451	9,910	130	320	50	18,766
2013	5,900	7,451	9,910	130	504	50	23,945
2014	10,895	7,451	10,130	130	504	50	29,160
2015	15,890	7,451	10,930	1,660	504	980	37,415
2016	17,557	7,451	10,930	1,660	504	980	39,082
2017	17,557	7,451	10,930	1,660	504	980	39,082
2018	17,557	7,451	10,930	1,660	504	980	39,082
2019	17,557	7,851	10,930	1,660	504	980	39,482
2020	17,557	7,851	10,930	1,660	504	980	39,482
Percent of Total	44.5%	19.9%	27.7%	4.2%	1.3%	2.5%	100.0

The basic solid waste data was combined with projected base loading for all military installations on Guam to derive the projected quantities of the future solid waste stream entering the landfill. The estimated solid waste quantity breakdown between the Navy, Air Force and the proposed USMC relocation for year 2014 is as follows:

	Solid Waste Quantity at 6.1 lbs/cpd	Solid Waste Quantity at 7.4 lbs/cpd
Navy	12,168 tons/year	14,761 tons/year
Air Force	7,740 tons/year	10,603 tons/year
USMC	19,545 tons/year	23,711 tons/year
Army	1,848 tons/year	2,242 tons/year
USCG	561 tons/year	681 tons/year
SOF	1,091 tons/year	1,323 tons/year
Total	43,953 tons/year	53,320 tons/year

The estimated quantities for the solid waste stream entering the Navy Sanitary Landfill are summarized in Table 2-3. As shown, this includes projected generation at 6.1 lbs/cpd and 7.4 lbs/cpd.

Table 2-3

Projected Solid Waste Quantities

Year	Population	Projected Solid Waste at 6.1 lbs/cpd (tons/year)	Projected Solid Waste at 7.4 lbs/cpd (tons/year)	Remarks
2008	12,018	13,379	16,230	
2009	15,080	16,788	20,366	Baseline
2010	17,360	19,326	23,445	
2011	17,460	19,437	23,580	
2012	18,766	20,891	25,343	Proposed USMC relocation begins
2013	23,945	26,657	32,338	
2014	29,160	32,462	39,381	
2015	37,415	41,652	50,529	
2016	39,082	43,508	52,780	Proposed USMC relocation complete
2017	39,082	43,508	52,780	
2018	39,082	43,508	52,780	
2019	39,482	43,953	53,320	
2020	39,482	43,953	53,320	
2021	39,482	43,953	53,320	
2022	39,482	43,953	53,320	

A solid waste characterization analysis was not conducted as a part of this study. A solid waste characterization study was conducted for the Marine Corps Base Hawaii, Kaneohe Bay (MCBH-KB). Solid waste generation activities for military installations on Guam and MCBH-KB are similar. Both military installations on Guam and MCBH-KB have similar facilities including maintenance shops, administrative offices, commissary and exchange facilities, fast-food establishments, club operations, family housing and unaccompanied personnel housing. Furthermore, both military installations on Guam and MCBH-KB are located in an island environment with similar climate and weather conditions. Due to the lack of solid waste characterization data for military installations on

Guam, it was assumed that the solid waste characterization for MCBH-KB would best represent the solid waste characteristics for military installations on Guam.

For purposes of this study it was assumed that the residential and commercial/ industrial per capita solid waste generation for military installations on Guam would be 7.4 lbs/day based on the 1979 Guam Water Quality Management Plan. This is higher than the calculated present per capita solid waste generation for Naval facilities on Guam. However, it is judged as a prudent conservative assumption for planning purposes.

The projected average daily solid waste quantities and composition for military installations on Guam are summarized in Table 2-4. Table 2-5 summarizes the projected solid waste quantities and composition for the solid waste management alternatives evaluated in this report. The column titled “No Waste Diversion” shows the waste generated that it is assumed would have to be disposed, absent any increase in diversion activities over current conditions. This is the landfill quantity assumed for all alternatives except Alternatives 4, 5, and 10. The right column of Table 2-5 shows the assumed residual ash volume that would need to be land filled at a Navy facility under Alternative 4 after processing of waste at a Navy WTE facility. Alternative 5 assumes that the total solid waste quantity would be barged off-island. Alternative 10 assumes use of a proposed private WTE and landfill facility at Guatali. Table 2-6 shows the projected solid waste stream quantities by source category.

Table 2-4

Projected Average Daily Solid Waste Quantities and Composition

	Residential		Commercial/ Industrial		Composite	
Per Capita Waste Generation (lbs/day)						7.4
Current Military Population						12,018
Total Current Weight (lbs/day)						88,933
Baseline Military Population						15,080
Total Baseline Weight (lbs/day)						111,592
Projected Military Population						39,482
Total Projected Weight (lbs/day)						292,167
Residential/Commercial/Industrial Waste						
Percent of Total		19.7		42.6		
Total Current Computed Weight (lbs/day)		17,520		37,886		55,406
Total Projected Weight (lbs/day)		57,557		124,463		182,020
Composition	percent	lbs/day	percent	lbs/day	percent	lbs/day
Aluminum Cans	3.4	1,956.9	1.2	1,493.6	1.9	3,450.5
Glass (Brown)	4.0	2,302.3	0.5	622.3	1.6	2,924.6
Glass (Clear)	3.0	1,726.7	1.8	2,240.3	2.2	3,967.0
Glass (Green)	0.8	460.5	0.2	248.9	0.4	709.4
Ferrous Metals	0.8	460.5	5.0	6,223.2	3.7	6,683.7
Non-Ferrous Metals	1.4	805.8	1.4	1,742.5	1.4	2,548.3
Newspaper	1.3	748.2	0.9	1,120.2	1.0	1,868.4
Mixed Paper	1.9	1,093.6	4.0	4,978.5	3.3	6,072.1
Office Paper	0.3	172.7	3.0	3,733.9	2.1	3,906.6
Cardboard	6.6	3,798.8	2.3	2,862.6	3.7	6,661.4
Plastics	1.7	978.5	1.2	1,493.6	1.4	2,472.1
Compostable Material	6.2	3,568.5	15.7	19,540.7	12.7	23,109.2
Miscellaneous Waste	68.6	39,484.1	62.8	78,162.8	64.6	117,646.9
Total Collected Waste	100.0	57,557.1	100.0	124,463.1	100.0	182,020.2
Construction Waste						
Percent of Total						37.7
Total Current Computed Weight (lbs/day)						33,528
Total Projected Weight (lbs/day)						110,147

Table 2-5

Projected Solid Waste Quantities and Composition for Waste Diversion Alternatives

Composition	No Waste Diversion (lbs/day)	Materials Recovery (lbs/day)	Waste-to-Energy (lbs/day)
Aluminum Cans	3,451	0	3,451
Glass (Brown)	2,925	0	2,925
Glass (Clear)	3,967	0	3,967
Glass (Green)	709	0	709
Ferrous Metals	6,684	0	6,684
Non-Ferrous Metals	2,548	0	2,548
Newspaper	1,868	0	0
Mixed Paper	6,072	0	0
Office Paper	3,907	0	0
Cardboard	6,661	0	0
Plastics	2,472	0	0
Compostable Material (See Note 1)	23,109	23,109	0
Miscellaneous Waste (See Note 2)	117,647	117,647	11,765
Total Collected Waste	182,020	140,756	32,048
Total Self-Hauled Waste (See Note 3)	110,147	110,147	110,147
Total Projected Weight to Landfill	292,167	250,903	142,195

Notes:
1. Compostable material includes food waste and green waste.
2. Miscellaneous waste includes discarded items, such as clothing, shoes, small appliances, small furniture and carpet. It was assumed that 10 percent of the miscellaneous waste was non-combustible.
3. Self-hauled waste includes construction and demolition debris.

Table 2-6

Projected Average Daily Solid Waste Quantities by Source Category

	Residential	Commercial/ Industrial	Construction	Total
Per Capita Waste Generation (lbs/day)				7.4
Current Military Population				12,018
Total Current Weight (lbs/day)				88,933
Baseline Military Population				15,080
Total Baseline Weight (lbs/day)				111,592
Projected Military Population				39,482
Total Projected Weight (lbs/day)	57,557	124,463	110,147	292,167

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3.0 Regulatory Involvement for Solid Waste Disposal Alternatives

3.1 Regulations Overview

This section summarizes the regulations applicable to the Navy Sanitary Landfill, a new landfill on Guam, and a WTE facility on Guam.

3.1.1 Landfill Regulations

The Federal regulations pertinent to landfills on Guam are contained in Title 40 of the Code of Federal Regulations (CFR), Part 258. Local regulations are included in the Guam Environmental Protection Agency (GEPA) Rules and Regulations for Solid Waste Disposal. The GEPA Rules and Regulations for Solid Waste Disposal are based on the Federal regulations contained in 40 CFR Part 258.

3.1.1.1 Federal Regulations

The Federal regulations governing the operation of municipal solid waste landfills are contained in 40 CFR Part 258. The Federal regulations contain guidance and policies on the purpose, scope and applicability of the regulations, location restrictions, operating criteria, design criteria, groundwater monitoring and corrective actions, closure and post-closure care, and financial assurance criteria.

The purpose of the regulations is to establish minimum standards for all municipal solid waste landfills to ensure the protection of human health and the environment. The regulations apply to all new municipal solid waste (MSW) landfills, existing MSW landfills and lateral expansions of existing landfills.

The location restrictions of the regulations include criteria related to airport safety, floodplains, wetlands, fault areas, seismic impact zones, and unstable areas such as landslides, mudslides or sinkholes. The operating criteria in the regulations establishes requirements for excluding hazardous waste, applying cover material, controlling disease vectors, controlling explosive gases, controlling air emissions, restricting access, controlling storm water run-on and run-off, protecting surface waters, restricting liquids, and recordkeeping. The design criteria in the regulations apply to new landfills and lateral expansions of existing landfills. New and landfill expansions must be constructed with a composite liner and a leachate collection system, which has been approved by the GEPA. The liner and leachate collection system should be designed for groundwater protection by ensuring that levels of contaminants do not exceed the Federal limits for safe drinking water. The groundwater monitoring and corrective action criteria established in the regulations apply to all municipal solid waste landfills unless the owner/operator can demonstrate that there is no potential for migration of hazardous constituents from the landfill to the uppermost aquifer. The regulations establish criteria for groundwater monitoring systems, sampling and analysis programs, and corrective actions for the protection of human health.

The closure and post-closure care criteria established in the regulations are intended to reduce potential difficulties in the future. Upon closure of the landfill, the owner/operator must notify GEPA prior to closure, prepare a closure plan, install a final cover designed to minimize infiltration and erosion, and record a notation on the deed of the property that the land has been used as a landfill facility and that future use is restricted. Following closure of the landfill, the owner/operator must maintain the integrity of the final cover, maintain the leachate collection system, monitor the groundwater in accordance with the criteria established, and maintain the gas monitoring system for a period of 30 years. The length of the post-closure care period may be increased or decreased at the discretion of GEPA.

The financial assurance criteria established in the regulations apply to all owners and operators of municipal solid waste landfills except owners or operators who are Federal government entities. The owner/operators must demonstrate the ability to cover expenses for site closure, post-closure maintenance, and corrective actions for known releases. The owner/operator may demonstrate financial assurance through the following mechanisms: trust fund, surety bond, letter of credit, insurance, corporate financial test, local government financial test, corporate guarantee, local government guarantee, state approved mechanism, state assumption of responsibility or a combination of these mechanisms.

3.1.1.2 GEPA Landfill Rules

The GEPA Rules and Regulations for Solid Waste Disposal; Title 22, Division 4, Chapter 23 establishes minimum standards governing the design, construction, installation, operation and maintenance of solid waste disposal facilities on Guam. The GEPA requirements for a landfill permit are similar to the Federal regulations except for a few differences:

- Permit requirements for the operation of a solid waste management facility, including landfill are included.
- List of solid wastes that are prohibited for disposal at the landfill is included. These wastes include waste oil, regulated hazardous wastes, whole or partially whole vehicles, vehicle parts, tires, batteries, septic tank pumping, appliances, sewage sludge, and other petroleum based products and oil based paints.
- Health and safety requirements for the protection of all personnel associated with the operation of the landfill disposal site are included.

The GEPA Rules and Regulations for Solid Waste Disposal; Title 22, Division 4, Chapter 23 is included as Appendix A.

3.1.2 WTE Requirements

Since the GEPA has not received approval of a State Implementation Plan relating to the Clean Air Act Amendments regulations for municipal waste combustors (MWC), the federal rules would apply. The federal WTE facility emission guidelines for small municipal waste combustion (MWC) units (*i.e.*, units with a design combustion capacity of 35 to 250 tons per day of municipal waste) located in areas not covered by an approved State or tribal plan, must comply with Subpart AAAA of 40 CFR Part 60 (New Source Performance Standards for Small Municipal Waste Combustion Units) which were issued in final form on January 31, 2003.

In addition, ash residue from MWCs was determined by the US Supreme Court to be not exempt from regulation as a hazardous waste treatment, storage, or disposal facility under Subtitle C of the Resource Conservation and Recovery Act (RCRA), even though MWCs that burn household waste alone or in combination with non-hazardous wastes from industrial and commercial sources are exempt. On April 12, 1995, EPA issued its Revised Implementation Strategy for MWC ash. The revised strategy requires MWCs that burn household and non-hazardous commercial wastes to have programs in place that determine whether the ash generated is considered hazardous based on certain leachate toxicity criteria. Waste not meeting the criteria must be disposed as a hazardous waste in full compliance with RCRA Subtitle C. The strategy specifies that the hazardous waste determination sampling must be conducted following the combustion and air pollution control processes at the point where the ash exits the combustion building.

Pursuant to the Supreme Court Rulings and EPA regulations, any WTE facility would be required to conduct tests of the ash residue generated to determine whether it meets the requirements for disposal in a Subtitle D landfill. These tests would be required to comply with the draft “Sampling and Analysis of Municipal Refuse Incinerator Ash” published by the Office of Solid Waste, EPA; Chapter 9, Sampling Plan, of SW 846-Test Methods For Evaluating Solid Waste,

3.2 Regulatory Involvement

3.2.1 GEPA

The GEPA was created in March 1973 and is responsible for establishing and maintaining the quality of the air, land and water of Guam. In December 1998, Public Law 24-304 created the Solid Waste Management Program. The Program is responsible for permitting solid waste collection and treatment, storage, and disposal facilities. In addition, the Program is responsible for inspection, compliance monitoring, enforcement, and corrective action on all solid waste-related activities. Other activities include beverage container inspections, public education, and pollution prevention incentives.

In 1996, the Solid Waste Management and Litter Control Act was revised giving Guam EPA authority to impose administrative penalties for solid and hazardous waste management violations and defined civil versus criminal penalties. The revised Act provided provisions for citizen suits, established permit fees for certain solid waste activities, and created a Solid Waste Management Fund to support activities to effectuate the Act, which includes paying for full-time employees and related expenses. Aside from the Fund, the Program's activities are supported by the Litter Revolving Fund which was created to be used primarily for anti-littering campaigns. At its meeting on September 27, 2006, the Guam EPA Board of Directors approved the *Guam 2006 Integrated Solid Waste Management Plan*, which updated the previous *Guam 2000 Integrated Solid Waste Management Plan* (2006 ISWMP) as required by Chapter 51, of Title 10 Guam Code Annotated.

The ISWMP includes the following principal provisions:

- Controlled privatization of solid waste management operations
- Assignment of the oversight on the privatized solid waste operations to the CCU
- Inclusion of all federal facilities in the operations and use of the landfill
- Requirement of a Waste Composition and Characterization study
- Exclusion of recyclable and compostable materials from the landfill
- Development of solid waste transfer stations for accepting of waste and recyclables and for transfer of waste to large carriers to haul it to the landfill
- Improved public information on solid waste management
- Satisfaction of the Consent Decree calling for opening and privately operating a legally conforming landfill by October 2007 and closing Ordot Dump before October 2007.

3.2.2 USEPA Region 9

USEPA's Region 9 office headquartered in San Francisco provides public health and environmental oversight for the southwestern United States (Arizona, California, Nevada, Hawaii, U.S. territories of Guam and American Samoa, the Commonwealth of the Northern Mariana Islands, and other unincorporated U.S. Pacific possessions). EPA Region 9 also works with 147 federally recognized tribes in the Pacific Southwest. In addition, Region 9 has a field office in Hawaii to better serve the Pacific Islands.

Although GEPA has been designated as the administrator for solid waste disposal issues, the USEPA is working closely with the 42 staff personnel at Guam EPA and other organizations within Guam to address certain specific environmental issues on the island, two of which include:

- Guam has a fragile drinking water infrastructure which is chronically at risk of contamination from wastewater. Until recently, Guam had extensive wastewater problems, with more than 500 million gallons of raw sewage spills between 1999 and 2002. Almost 8 percent of residents do not have access to adequate plumbing, 6.5 times the national average of 1.2 percent. All residents have experienced boil-water notices within the last several years.
- The Ordot municipal dump is an unlined, uncontrolled dump that was initially used as a disposal area during World War II. It has reached its capacity and was scheduled for closure by October 2007 under an EPA consent decree. The EPA consent decree arose due to the historic and continuing discharge of pollutants to the Lonfit River. The dump has also experienced operational difficulties during its history, including fires.

3.2.3 Guam Department of Public Works (DPW)

DPW is one of several agencies of the Government of Guam and consists of several divisions including the Solid Waste Management Division (SWMD). The operation of the DPW is supported by the revenues derived from the services that it renders, fines and penalties that it collects, grants, and appropriations from the Guam General Fund (General Fund).

The Guam DPW and other non-DoD entities must comply with the Guam laws and regulations as codified under the Guam Code Annotated. Although all of the Guam laws and regulations are not directly applicable to DoD solid waste activities that involve only DoD installations, they can have an indirect impact. The most notable indirect impact is the non-compliant status of the Ordot Dump and the delayed construction of the new GovGuam landfill. The Guam laws and regulations would also be applicable to any facilities, such as regional facilities, that handle both DoD and non-DoD solid waste. The Guam laws and regulations relevant to solid waste handling and disposal are included in Appendix B.

The SWMD currently has five sections: administration, customer service, residential solid waste collection, transfer station drop-off locations and landfill operations. Support for SWMD's operations comes from revenues derived from solid waste services charges and occasional cash infusions from the Federal grants, Compact Impact funds and the General Fund. Until recently, there was no separate monthly financial reporting for SWMD's operations. DPW is responsible for complying with the tasks and deadlines mandated by the EPA Consent Decree.

Due to the delays in meeting the Consent Decree deadlines for the closure of the Ordot Dump and completion of the new landfill, the US District Court has placed the SWMD in federal receivership.

3.2.4 Public Utility Commission (PUC)

The PUC is comprised of a seven member board appointed by the Governor and confirmed by the Legislature. Pursuant to the recent enactment of Public Law 28-56, the PUC is responsible for establishing tipping and user fees including business and governmental tipping fees and a variable residential tipping fee, which were previously set by the DPW. These fees are intended to provide the principal funding source for the Project and all SWMD operations.

In September, 2005, after the DPW filed its first formal rate increase petition, a rate increase of 25 percent was awarded by the PUC. The rate increase became effective on April 10, 2006. The DPW is preparing a petition to the PUC for a series of increases which are intended to ensure that the SWMD would continue to be able to meet the debt service covenants of its borrowing obligations and to provide sufficient ongoing equity in the Solid Waste System.

4.0 Assessment of Solid Waste Disposal Alternatives

4.1 Alternative 1 – Improve Navy Sanitary Landfill – Apra Harbor

4.1.1 Description

4.1.1.1 Existing Landfill Conditions

The Navy Sanitary Landfill is currently operating under an expired Waste Management Facility Permit (Permit Number 95-1009, dated 26 December 1995), issued by the Guam Environmental Protection Agency (GEPA). The Navy Sanitary Landfill at the Apra Harbor Naval Complex is located in the southeastern portion of the Naval Complex. The landfill is located on U.S. Navy property and is exempt from local zoning requirements. The existing landfill is shown on Figure 4-1. The landfill boundary information was obtained from the Naval Station boundary coordinate data indicated on a previous topographic survey map, NAVFAC Drawing Number 73139263, completed under Project Number PWC 15161. The active waste placement area is in the southeast corner of the landfill site. Other designated areas of the landfill site include asbestos, hardfill, wood waste and sewage sludge disposal areas.

The Navy Sanitary Landfill is operated by the Base Operations Support (BOS) contractor, DZSP-21 and used as a disposal site for non-hazardous solid wastes generated from all Naval activities on Guam, including Apra Harbor Naval Complex, Ordnance Annex (Naval Magazine), Nimitz Hill, Naval Hospital, Naval Computer and Telecommunication Station (NCTS) Barrigada, South Finegayan and NCTS Finegayan.

Naval activities on Guam generate approximately 21 tons of solid waste daily. The Navy Sanitary Landfill currently accepts waste from housing, commercial and industrial activities, hardfill from on-base construction projects, sterilized waste from ships, asbestos waste, and wastewater treatment sludge that has passed the paint filter test.

An office located at the landfill entrance is the only on-site structure. There is no scale house on-site. No particular waste placement method is indicated in the permit. The area waste disposal method of landfill operation is generally employed at the landfill site. In this method, the waste that enters the landfill is spread out on the current active waste placement area and compacted by a bulldozer. The soil for covering the wastes comes from stockpiled soils brought into the landfill from landscapers and on-base construction projects. Additional soils, when other soil sources are not available, could be excavated from two locations on site; the northwest corner or an area near the center of the landfill. Soil is spread and compacted over the solid waste after each load.

There are two up-gradient groundwater wells located to the east and northeast of the landfill boundary, two down-gradient groundwater wells located to the west of the landfill boundary and west of Route 2, and four groundwater monitoring wells

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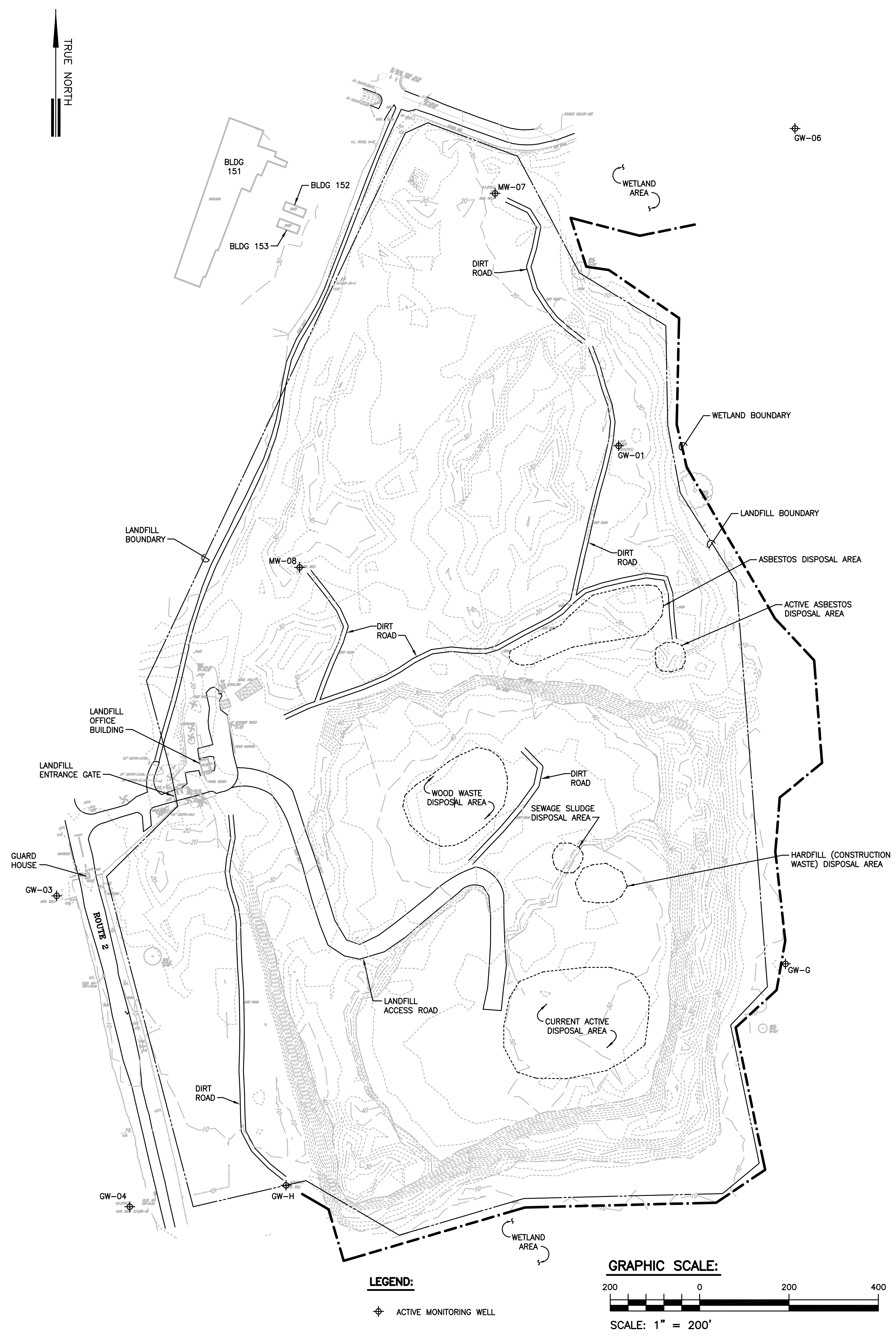

LEGEND:

⌖ ACTIVE MONITORING WELL

GRAPHIC SCALE:

200 0 200 400

SCALE: 1" = 200'

HDR HPE Hawaii Pacific Engineers, Inc.	GUAM SOLID WASTE UTILITY STUDY FOR PROPOSED USMC RELOCATION	EXISTING NAVY SANITARY LANDFILL PLAN	FIGURE 4-1

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located within the landfill boundary. The 1995 permit states that a total of eight groundwater wells are monitored semi-annually. The permit also states that the site is monitored for the presence of landfill gas, on a quarterly basis. Groundwater and methane monitoring reports are provided as part of the semi-annual Solid Waste Reports to GEPA.

4.1.1.2 Liner and Other Improvements

Preliminary recommendations regarding liner and other improvements for the existing Navy Sanitary Landfill include the following:

- Reduce the quantity of daily soil cover and revise the soil cover placement frequency to once each day.
- Purchase a larger dozer or equivalent equipment and use the larger dozer for all waste compacting and cell construction activities wherever possible.
- Install a truck scale at the Navy Sanitary Landfill for use in self-hauled industrial/commercial wastes and the refuse collection trucks
- Construct a new landfill control building and paved access road. The facility would include an office, storage area, electrical room and restroom with a total area of approximately 600 square feet.
- Provide a Subtitle D liner system and leachate collection systems for the existing inactive area within the landfill boundary. Consider an expansion separation liner for the existing active landfill area.
- Develop a new lined sanitary landfill. A potentially suitable site within the Ordnance Annex has been identified with possible future access via public roadways. Areas within the Ordnance Annex are encumbered and opportunities for beneficial use of those areas are limited. (Section 4.2 discusses this further).
- Consider disposal of residential solid waste in the new Government of Guam landfill when the landfill becomes operational.
- Explore the possibility to provide a materials recovery facility (MRF) to reduce waste generation by diverting materials for recycling and recovery.

This alternative assumes that the recommendations listed above will be implemented except for the last item. Although it may be advisable to implement an MRF for DoD waste, it is not assumed as a condition for any of the alternatives in this report. This is discussed further in Section 5.

4.1.1.3 Landfill Geometry and Volume

Several approaches to maximizing the useable life of the Navy Sanitary Landfill were evaluated. Alternatives considered include looking at the potential for increasing waste disposal capacity through landfill design alterations and possible airspace savings achievable through operational changes described in 4.1.1.2. Three alternative final fill plans were first evaluated based on comparison of their relative non-monetary advantages and disadvantages. A final fill plan is selected based on the considerations discussed, below.

Remaining Usable Landfill Capacity

The Navy Sanitary Landfill does not appear to be filled to any particular final filling plan. A grading plan was developed under a previous study "Vertical Landfill Expansion Evaluation" by GMP Associates, Inc. dated September 1996. However, the grading plan was not adopted for landfill operations, and it was observed that the landfill was not being filled to conform to any specific landfill grading plan.

Calculations for the 1996 study estimated a remaining landfill airspace volume of 1,724,900 cubic yards based on utilizing the entire area within the existing landfill boundaries and a final fill height of 48 feet mean sea level. The 1996 study projected a landfill life extending through the year 2045 based on receiving 77,000 cubic yards of uncompacted waste annually, an uncompacted specific weight of 717 pounds per cubic yard, a compacted specific weight of 1864 pounds per cubic yard, and a waste to cover ratio of 5 to 1. The change in landfill volume from 1996 to 2006 would have been about 355,000 cubic yards. The projected annual waste volume did not include construction generated waste.

The 1996 study estimated that as much as 69,600 additional cubic yards of construction related materials could be generated annually for a total of 146,600 cubic yards annually. The 1996 study projected that at this accelerated rate of solid waste generation, the landfill life would extend 25 years through the year 2021. The projection was based on receiving 146,600 cubic yards of un-compacted waste annually, an un-compacted specific weight of 717 pounds per cubic yard, a compacted specific weight of 1864 pounds per cubic yard, and a waste to cover ratio of 5 to 1. The change in landfill volume would have been about 677,000 cubic yards.

Calculations carried out for this study indicated that from the condition shown on the 1996 topographic map to the landfill topographic survey conducted in October 2006, the landfill had received a total of approximately 529,000 cubic yards of material.

Alternative Final Fill Plans

Although a filling plan was developed under the 1996 GMP study, based on the current landfilling operations, based on site observations the current landfill operations do not follow the proposed grading plan. The 1996 GMP landfill filling plan is characterized by vertical elevation changes of six feet, separated by 15-foot wide benches, and 4Horizontal:1Vertical (4H:1V) side slopes. The 1996 GMP final grading plan proposed a maximum elevation of 48 feet mean sea level (MSL). However, certain areas of the landfill have been filled higher than the proposed maximum elevation of 48 feet MSL. Based on the topographic survey completed in October 2006, the highest elevation within the landfill boundary was approximately 52 feet MSL.

Typical current landfill practices utilize vertical elevation changes of 50 feet with side slopes of 3H:1V, separated by 15-foot wide benches. Therefore, an increase in remaining available landfill volume can be achieved under a revised final fill plan utilizing updated landfill design and operational practices.

The basic landfill grading criteria established for developing alternative final fill plans for the Navy Sanitary Landfill are summarized in Table 4-1 below.

Table 4-1

Landfill Design Criteria

Maximum final landfill side-slope surface grade, post-settlement	3H:1V
All-weather access road	
Width, including shoulder	25 feet
Maximum gradient	8 percent
Minimum cross-slope	2 percent
Perimeter road and buffer zone minimum width	50 feet
Design storm for run-on storm water	25-year 24-hour storm
Design storm for run-on site facilities for contact water only	100-year 24-hour storm
Waste density, typical industry standard with D8 dozer	1200 lbs/cy
Refuse to Soil Cover Ratio, typical for well run landfill	3:1

Three alternative final fill plans based on different final maximum elevations were developed and evaluated for additional landfill airspace achievable. In each case, a volumetric computation was performed to estimate the total volume of fill space (airspace) remaining in the landfill. The remaining airspace volume is the difference between the final grades developed for each alternative and the grades shown on the October 2006 topographic map. This airspace would be displaced by refuse and daily, intermediate and final cover. The airspace volumes provided by each alternative grading configuration were then compared to assess their relative difference.

The final fill plan alternatives encompass a footprint of approximately 60 acres and considered side slopes graded at a ratio of 3Horizontal:1Vertical (3H:1V).

These are shown as Figures 4-2 through 4-4 and termed alternative final fill plans 1 through 3, respectively.

Each alternative is based on landfilling of both the active and “inactive” areas of the landfill. They each include a refuse vehicle access road alignment from the landfill entrance to the top of the proposed fill area, an operations area consisting of a truck scale and a new landfill control building, a 50-foot wide perimeter road, a vegetative buffer zone on the north side of the landfill, and an area for a future run-off control system.

Table 4-2 summarizes the remaining landfill life that would be available under the three alternative final fill plans. It lists the estimated available remaining volume and site life with and without the operational improvements at waste generation rates of 6.1 and 7.4 lbs./capita/day. Operational improvements are discussed in more detail in Section 5.1.

Alternative Final Fill Plan 3, shown on Figure 4-4, shows an approach to maximizing the remaining landfill capacity, filling to a potential maximum final landfill height of 140 feet above MSL. A constraint on the maximum landfill height was not identified in any regulation or land use document, however, there may be a practical maximum height based on maintaining minimal aesthetic impacts of surrounding areas. Alternative Final Fill Plan 3 was considered to determine, from a technical standpoint, how much additional airspace could be realized while retaining adequate area for operations.

The greatest amount of landfill airspace gain is provided by Alternative Final Fill Plan 3. However, the visual impact of this alternative may not be desirable. It is therefore not considered further in this study.

Alternative Final Fill Plan 1 is judged a very conservative approach given that the maximum elevation is 54 MSL and the landfill has already been filled to elevation 52 MSL, based on 2006 topographic mapping. Alternative Final Fill Plan 2 is judged as a compromise between optimizing landfill capacity and visual aesthetics and is therefore selected along with the Alternative 1 grading plan as a potential final fill plan for the Navy Sanitary Landfill under Alternative 1 of this study.

The active waste placement area is currently limited to the southern portion of the landfill site. The northern portion of the landfill site, consisting of approximately 14 acres, is believed to have been used for limited waste placement in the distant past.

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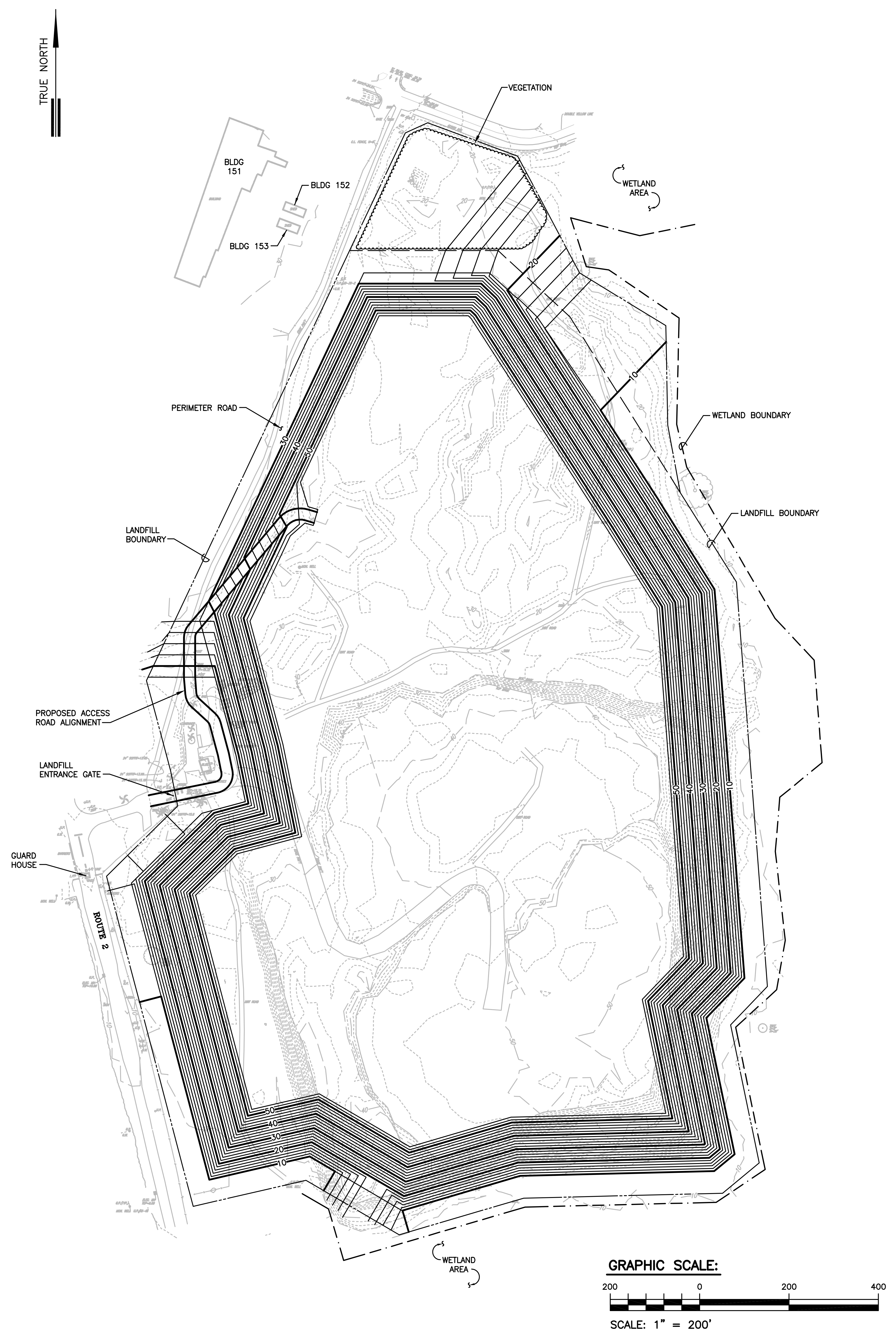

HDR HPE Hawaii Pacific Engineers, Inc.	GUAM SOLID WASTE UTILITY STUDY FOR PROPOSED USMC RELOCATION	ALTERNATIVE FINAL FILL PLAN 1 MAXIMUM ELEVATION = 54 FEET	FIGURE 4–2

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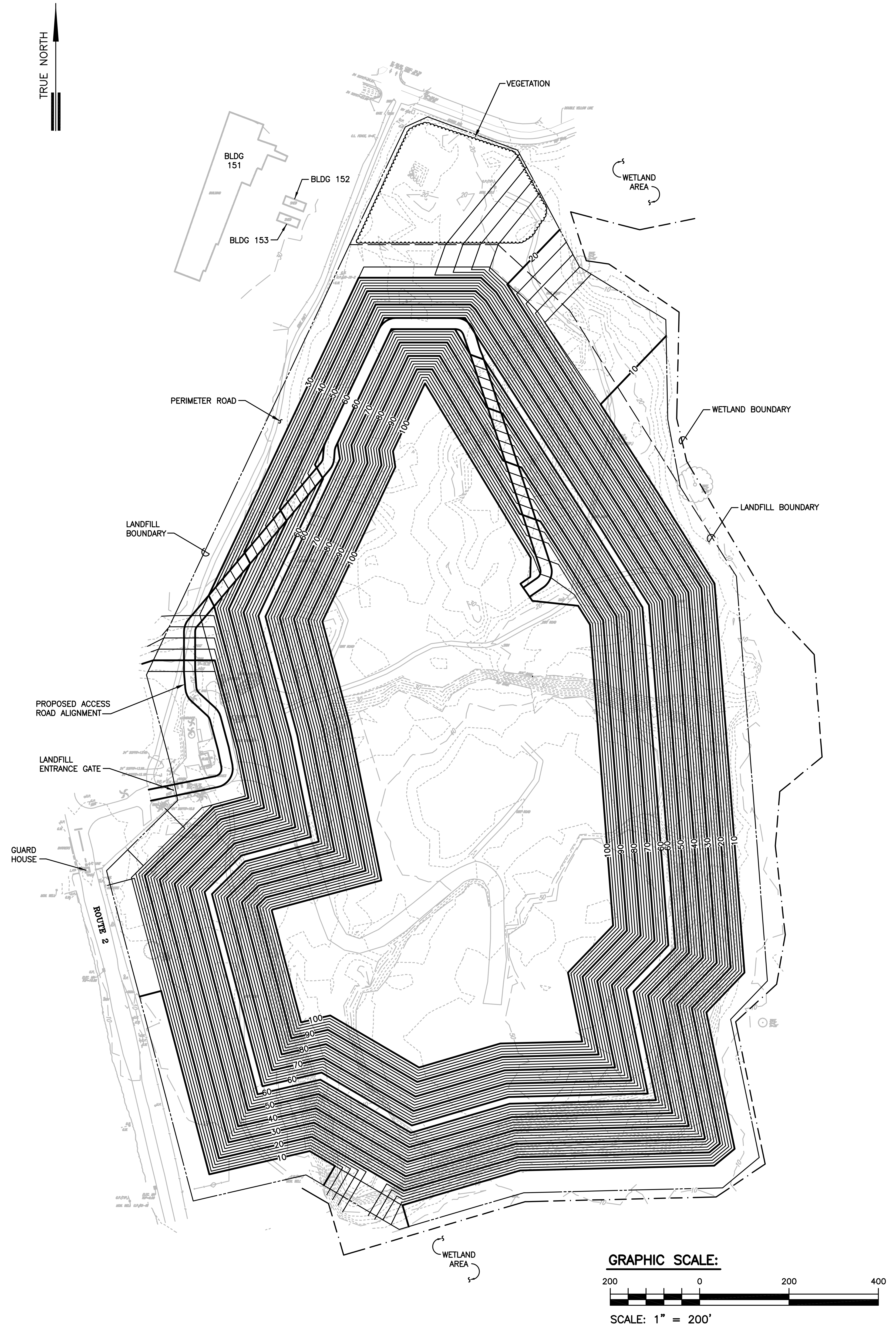

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GUAM SOLID WASTE UTILITY STUDY FOR PROPOSED USMC RELOCATION

ALTERNATIVE FINAL FILL PLAN 2
MAXIMUM ELEVATION = 100 FEET

FIGURE 4–3

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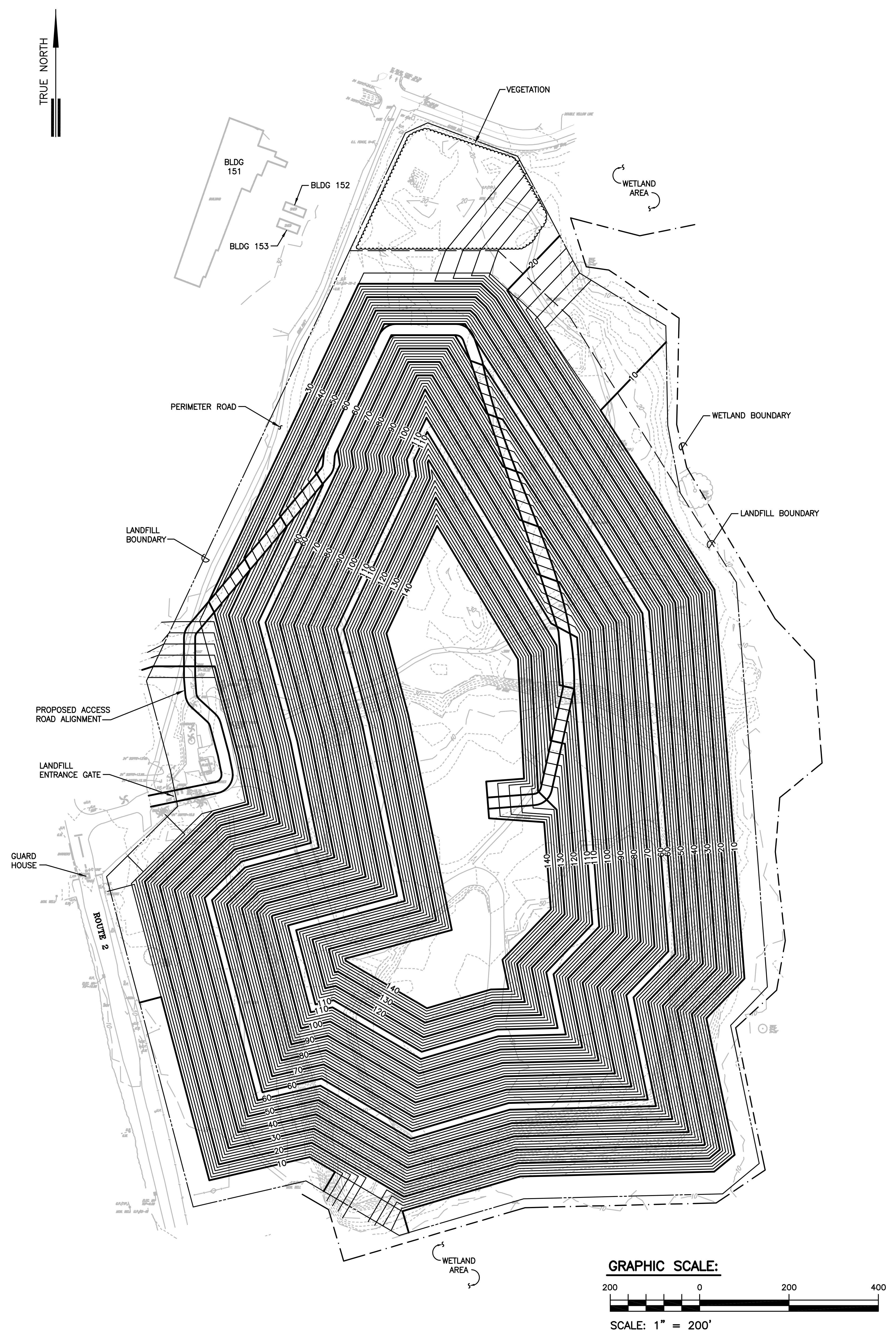

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GUAM SOLID WASTE UTILITY STUDY FOR PROPOSED USMC RELOCATION

ALTERNATIVE FINAL FILL PLAN 3
MAXIMUM ELEVATION = 140 FEET

FIGURE 4–4

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Table 4-2

Projected Remaining Landfill Life Under Various Conditions, Years

	Alternative Final Fill Plan 1		Alternative Final Fill Plan 2		Alternative Final Fill Plan 3	
Estimated Available Remaining Volume, cy	1,200,000		2,900,000		3,500,000	
Waste Generation Rate, lbs/capita/day	6.10	7.40	6.10	7.40	6.10	7.40
Lighter compacting equipment[1]						
Current waste composition	8	**7**	14	**12**	16	**14**
Current waste composition Revise filling practices[2]	10	**9**	19	**16**	22	**19**
Current waste composition Use ADC tarp[3]	11	**10**	21	**18**	25	**21**
Current, heavier compacting equipment[4]						
Current waste composition[5]	12	**10**	23	**20**	27	**23**
Current waste composition Revise filling practices[2]	16	**14**	32	**27**	38	**32**
Current waste composition, Revise filling practices[2] Divert Housing Waste in 5 years[6]	18	**16**	39	**33**	46	**39**
Current waste composition Use ADC tarp[3]	18	**15**	38	**32**	45	**38**
Heavier compacting equipment and revise filling practices						
Implement materials recovery[7]	19	**16**	41	**34**	49	**41**
Implement materials recovery Use ADC tarp[3]	21	**18**	46	**39**	55	**46**
Implement waste-to-energy[8]	29	**25**	65	**55**	78	**65**
Implement waste-to-energy Use ADC tarp[3]	24	**28**	74	**57**	89	**74**

Table Footnotes

1 In-place unit weight achieved = 625 lbs./cy.
2 In-place solid waste to cover material ratio of 3:1 used for revised filling practices (Except ADC Tarp)
3 Use of ADC tarp assumes a cover material ratio of 8:1 with only periodic cover material placement
4 Heavier equipment assumes an in-place unit weight achieved = 1,200 lbs./cy
5 In-place solid waste to cover material ratio of 1:1 used for current filling practices
6 Assumes diversion of housing waste = 19.7 percent of cy landfilled
7 Assumes diversion as a result of recovery = 23 percent of cy landfilled
8 Assumes diversion from WTE facility = 54 percent of cy landfilled

The least cost approach to utilizing the remaining life of the existing landfill would be to continue to utilize the existing area as an unlined landfill. However, lining a portion or all of the landfill area may become necessary as a result of local regulatory changes or other considerations. Therefore, it is assumed that for all Alternative Final Fill Plans that a Subtitle D liner system would be provided for the existing inactive area within the landfill boundary. Because the existing Navy Sanitary Landfill was in operation before the Subtitle D liner system requirement became effective, the Navy is not categorically required to incorporate a liner system for the active area. However, providing a liner system for the existing inactive landfill area would indicate the Navy's initiative to comply with the intent of the current Environmental Protection Agency (EPA) regulations and could be viewed favorably by Guam Environmental Protection Agency (GEPA) for any future landfill permit applications. Although under current EPA regulations a liner system is not required for the Navy Sanitary Landfill, GEPA has the regulatory authority for permitting and enforcement. The Navy must comply with the GEPA regulations, which are at least stringent as EPA regulations.

To effectively manage the entire existing landfill site, it is assumed under Alternative Final Fill Plan 1 that the Navy could continue filling operations in the active portion of the landfill site to the proposed maximum elevation of approximately 54 feet MSL. At that point, the Navy would line the "inactive" 14-acre northern area; complete filling of this area, and then complete capping and closure of the entire landfill. Under Alternative Final Fill Plan 2, it is assumed that a separation liner would be installed in the active portion of the landfill. Under this scenario, filling would take place in the active area to appropriate grades for constructing the separation liner and this configuration would be allowed to stabilize until lining and filling of the 14-acre inactive area was completed to a point requiring extending the fill over the active area. At that point, a separation liner would be installed over the active area to allow filling of the entire landfill to final grades and then capping and closure. This phasing of operations will allow some settlement of the active area prior to placement of the separation liner. Even under these conditions, the separation liner design should consider use of materials such as LLDPE, which will better withstand differential settlement than HDPE materials typically used for base liner systems. Slope stability analysis will also be needed to verify the adequacy of the separation liner grading configuration and separation liner materials.

For purposes of this study it is assumed that the separation liner over the active area must be approved by the GEPA Administrator, but not necessarily the level of a prescriptive composite liner required under Subtitle D. We have assumed that the separation liner would consist of a textured (both sides given that slope stability has not been performed) 80 mils linear low-density polyethylene (LLDPE) membrane that can deform much more than a typical base liner HDPE material. It is not clear that a composite liner will be required given that the landfill was in operation before Subtitle D became effective. However, it is assumed that the liner design for the inactive area would be a composite liner using 80-mils LLDPE with a lower component consisting of a minimum 2-foot thick compacted soil layer with a maximum hydraulic conductivity of 1.0 x 10-7 cm/sec. This will meet the performance requirements of Subtitle D given the inactive area may not have waste placed in all areas and yet be more flexible than typical HDPE for potential differential settlement that could occur from decomposition of irregular areas of old waste that may have been placed.

4.1.2 Viability

4.1.2.1 Environmental / Regulatory Issues

Two main environmental issues were identified for consideration when comparing this alternative to other alternatives. The existing Navy Sanitary Landfill is unlined and has experienced an apparent groundwater release of low level VOCs and thallium, which could have varying impacts depending on the alternatives selected. Closure of the Navy Landfill would eventually be required for all alternatives of this study and would involve closure of both the inactive and active areas of the landfill as described in the previous section. However, this will vary somewhat if this landfill operation is combined with Alternative 6, which would require capping and closure of the active area and only minimal action regarding the inactive area.

As discussed above, it is expected that GEPA will request that the inactive area be lined and the active area be equipped with a separation liner between the existing unlined landfill and vertical expansion. It is also expected that GEPA will require that a LFG control system be installed for the additional horizontal and vertical landfilling that would occur at the Navy Landfill under Alternative 1.

<u>Apparent Releases from the Navy Sanitary Landfill</u>

Due to the apparent releases from the Navy Sanitary Landfill, the Site Operations Plan indicates that quarterly groundwater monitoring is required. DZSP-21 SOP for groundwater monitoring requires compliance with 40 CFR Part 141 G, sets procedures for sampling, analysis of samples, and contaminant level requiring additional assessment.

Based on the DZSP-21 monitoring program, “statistically significant” concentrations of the pesticide chlordane and five volatile organic compounds (VOCs) were detected in the down-gradient wells in 2006. The constituents were detected at statistically significant concentrations, but the concentrations did not exceed action levels for those constituents. The VOCs detected at “statistically significant” concentrations are listed below.

- Toluene;
- 1,4-dichlorobenzene;
- 2-hexanone;
- Chlorobenzene; and

- Trichloroethene (TCE).

There is some uncertainty regarding the spatial distribution on VOCs from the Navy Landfill. However, regardless of the spatial distribution, the presence of low level VOC in groundwater wells is a concern because these are manmade compounds believed to be migrating from the unlined Navy Landfill. It is not unusual for unlined landfills to release low level VOC to groundwater as this typically occurs from migration of LFG or leachate from the landfill.

When constituents are detected at statistically significant levels, the landfill groundwater monitoring plan calls for additional assessment monitoring. The assessment monitoring program includes groundwater monitoring two times per year and includes an expanded list of analytical parameters. During the second assessment monitoring round, thallium was detected and confirmed to be present in one monitoring well at levels requiring agency notification and follow-up action. The required notifications were made, and follow-up actions are in progress.

When comparing the alternatives of this study it should be noted that even if the Navy closed the landfill as soon as possible to implement another alterative, the release of VOCs would likely persist and require remedial action such as capping of the landfill or additional measures if capping does not show a decreasing trend in VOC levels detected in the monitoring wells. Adding the liner for the inactive area and separation liner for the active area would minimize potential release from waste placed in the inactive area and above the separation liner but the VOC releases from unlined waste in the active area would persist. The installation of a LFG control system, both above and below the separation liner, can be expected to help reduce the level of VOC release. However, continued use of the space above the separation liner could increase the difficulty of implementing measures to mitigate continued release of constituents from areas below the liner if determined to be necessary in the future.

<u>Greenhouse Gas Emissions</u>

Public and governmental interest in climate change has increased dramatically over the past ten years. State and local governments have taken the lead in developing regulations and mandates related to reducing greenhouse gas emissions (GHG). Recently, momentum has been building in the United States (US) Congress to pass some type of national climate change legislation. Politicians are being pressured by concerned citizens who would like to reduce GHG emissions and by private companies who would like to replace the uneven policy environment with a uniform federal regulation. Methane emissions from landfills have been identified as a significant source of GHG emissions and are between 21 and 23 times as potent as carbon dioxide in terms of a GHG impact.

Installation of a LFG collection system at the Navy Landfill will decrease the level of GHG emissions compared to current conditions. GHG emissions from future DoD waste disposal using other landfill alternatives (2, 3, 5, 7, 8, and 9) can be expected to be similar as it is assumed these other landfills will also be equipped with LFG control systems. However, GHG emissions using WTE alternatives (4 and 10) would result in a comparative decrease in GHG emissions. Studies have indicated that a WTE facility could reduce GHG emissions from fossil fuel energy offsets by as much as 40 percent when compared to landfill disposal and as much as 60 percent if landfill gas collection and flaring is not part of the landfill option.

Alternative 6, continuing the status quo, would involve continued landfilling without a LFG control system. It is not clear if this is even viable from a regulatory view from a groundwater protection standpoint, but Alternative 1 providing a LFG control system would significantly reduce GHG emissions compared to Alternative 6 because a LFG control system can be expected to be 75 percent to 90 percent efficient in collecting and destroying LFG.

4.1.2.2 Implementation or Policy Issues

There does not appear to be implementation flaws with the Navy pursuing the improvement and continued use of its landfill at Apra Harbor considering the approach would be to line the remaining portion of the landfill and install a LFG control system for the landfill meets and exceed applicable regulations.

Improvement and continued use of the Navy Landfill at Apra Harbor assumes it would be used for all DoD waste on Guam over the planning period described in Section 3 and that other non DoD waste would be disposed at a new landfill constructed by GovGuam. GovGuam and the GEPA have proposed a policy that a regional approach to landfilling should be undertaken using the proposed GovGuam landfill near Layon (Alternative 2) due in part to the economies of scale of using a regional/island-wide approach. The potential economy of scale for a regional landfill for the island is valid at the relatively limited tonnage generated on the island. However, there are implementation concerns with the DoD relying on the proposed GovGuam landfill due to problems GovGuam has experienced with collection of solid waste fees. This lack of a reliable fee collection and funding source has been one of several issues delaying the proposed GovGuam landfill. The implementation problems and concerns related to the proposed GovGuam landfill are discussed further in 4.2. A separate DoD landfill would not be subject to many of the delays and issues associated with the implementation of the new GovGuam landfill.

4.2 Alternative 2 – Use New Landfill Constructed by GOVGUAM

The DPW has developed detailed plans for the construction of a new landfill to replace the Ordot Dump in the south central part of the island.

4.2.1 Description

The site selected for the Layon Landfill is approximately 176 acres in size and is located near the village of Inarajan. The Layon Landfill location is shown on

Figure 4-5. Layon is located in the higher badland (highly eroded rocky) areas on the west side of the Dandan parcel, southwest of the former NASA tracking station. The landfill site will be accessed from Route 4 by approximately 3.3 miles of reconstructed and new road consisting of two segments, which would be constructed under the Phase 1 construction project:

- Approximately 1.3 miles of existing Dandan Road that will be reconstructed to provide safe and suitable access for heavy trucks; and
- Approximately 2.0 miles of new road.

The Phase 1 will also include bulk excavation needed prior to the construction of the Landfill. The Phase 2 construction will complete the Landfill construction and the support facilities. DPW has determined requirements for capacity and life of the Layon Landfill. Based on studies of future waste disposal requirements, DPW has established a minimum design capacity of the site at 14 million cubic yards as an estimate of the volume required to manage Guam's municipal solid waste for a 30-year period, including DoD waste. The total size of the landfill refuse footprint is based on alternatives evaluated in the Supplemental Environmental Impact Statement ("SEIS"). The recommended design in the SEIS indicates a refuse footprint of 141 acres.

4.2.2 Design Criteria

The Landfill IFB design criteria and specifications are based on the February 5, 2006 Design Specification documents. The proposed cell construction phases are shown on Figure 4-6.

4.2.2.1 Cell Construction

The Layon Landfill is designed for the disposal of municipal solid waste according to the requirements of the GEPA as set forth in its Solid Waste Disposal Rules and Regulations (SWDRR) under 10 GCA Chapter 51: Solid Waste Management and Litter Control Act. The fundamental design criteria for municipal solid waste landfills are generally set forth in SWDRR §23401, consisting of:

- The landfill must have a liner system approved by the GEPA Administrator, or a prescriptive composite liner consisting of an upper component and a lower component. The proposed liner design consists of an upper component that is a flexible membrane liner of at least 30 mils (0.030 inch) thickness, or 60 mils if composed of HDPE. The lower component is to be minimum 2-feet thick compacted soil layer with a maximum hydraulic conductivity of 1.0 x 10-7 cm/sec. Sub-drains are placed below the liner to manage shallow groundwater and maintain separation between the groundwater surface and the liner system.

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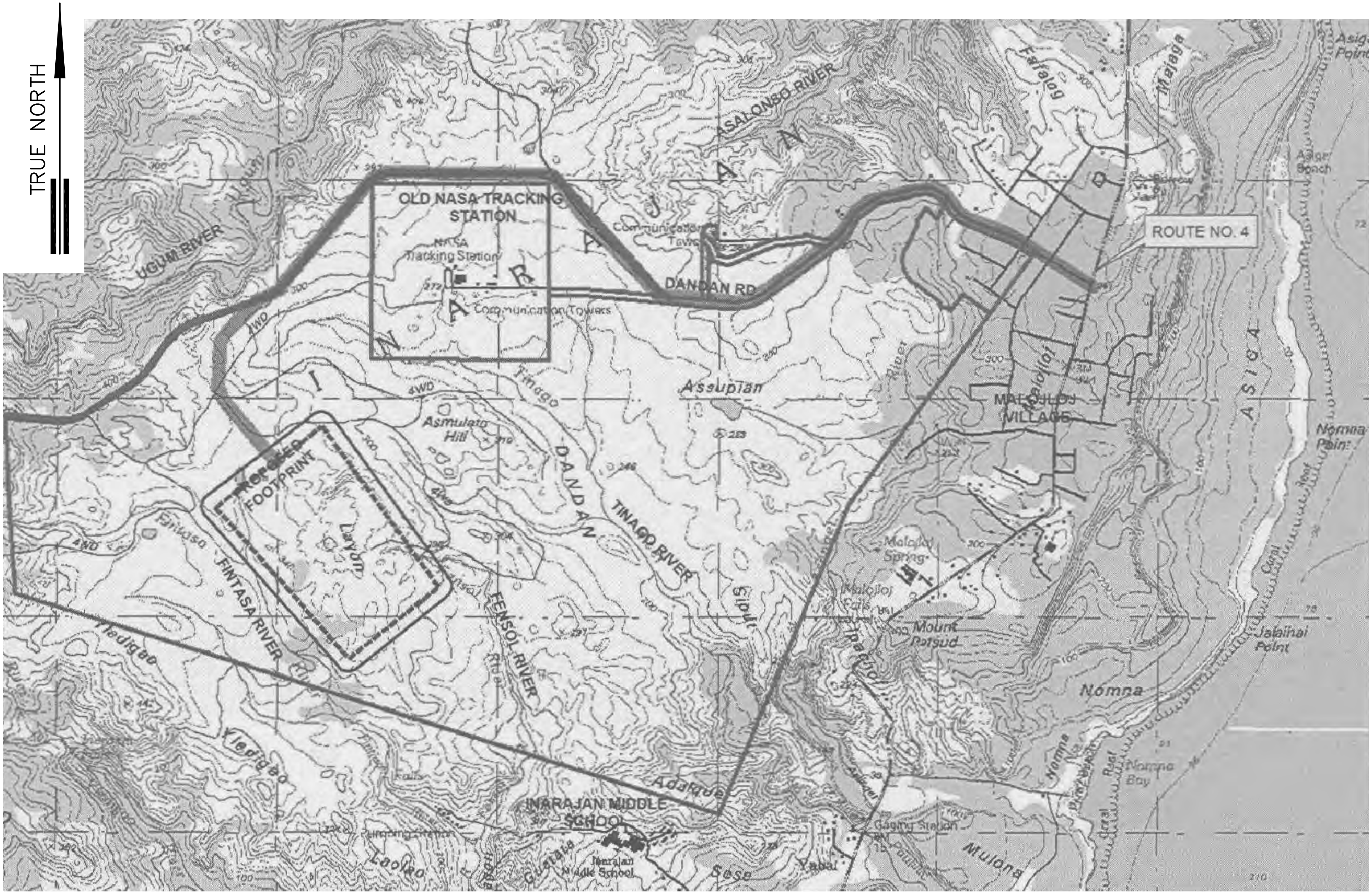

Hawaii Pacific Engineers, Inc.

GUAM SOLID WASTE UTILITY STUDY
FOR PROPOSED USMC RELOCATION

LAYON LANDFILL LOCATION

FIGURE 4-5

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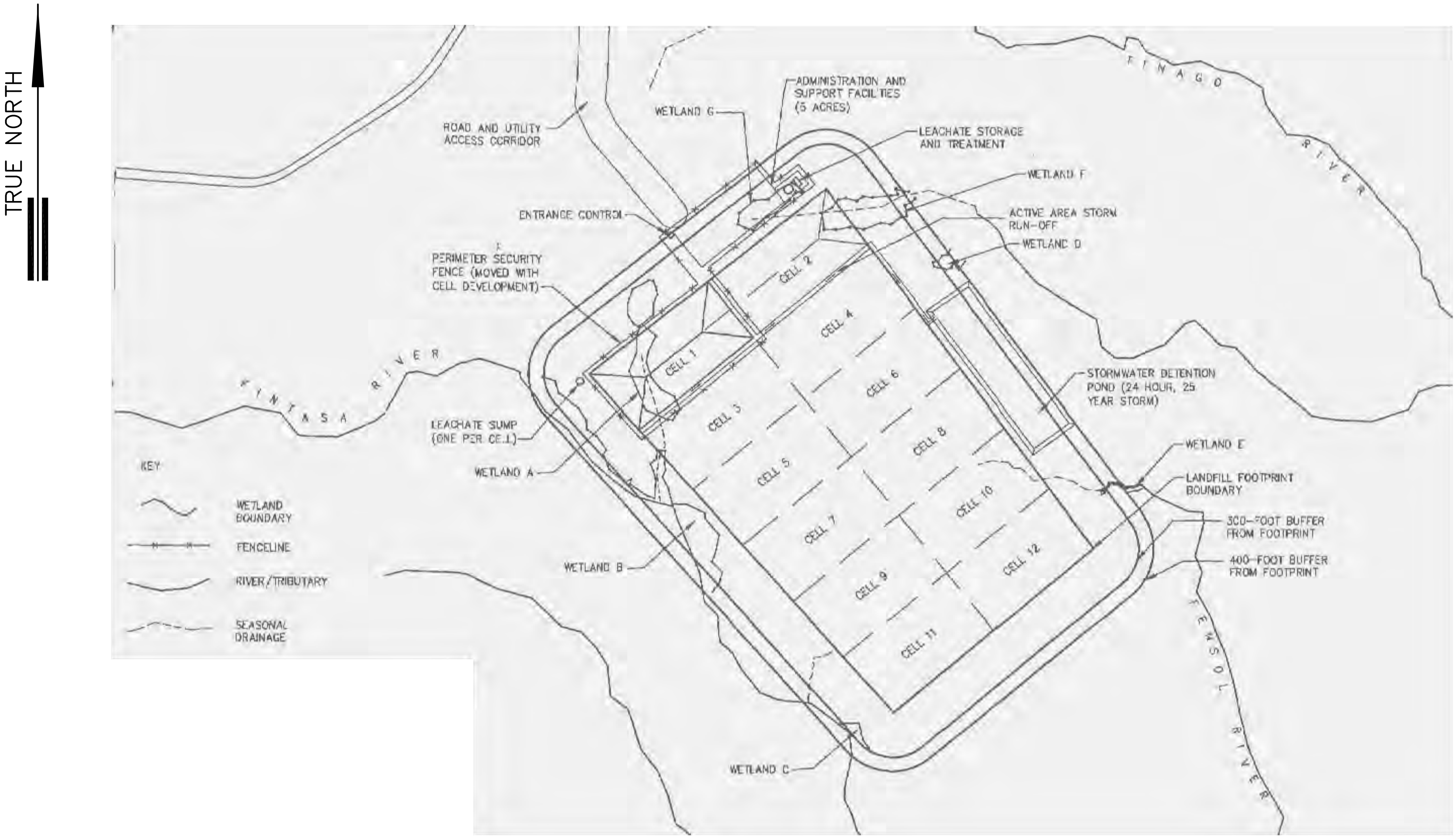

NOT TO SCALE

Hawaii Pacific Engineers, Inc.

GUAM SOLID WASTE UTILITY STUDY FOR PROPOSED USMC RELOCATION

LAYON LANDFILL CELL CONSTRUCTION PHASES

FIGURE 4–6

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- The landfill is designed to have a leachate collection and removal system ("LCRS") consisting of a 12-inch granular drainage layer on the floor of each cell, which is sloped to a central gravel-filled trench within which a thick-walled perforated HDPE collection pipe is installed and designed and constructed to maintain a maximum of 30 centimeters (approximately 12 inches) of leachate above the liner system.
- Gas is designed to be managed by installation of horizontal collectors and vertical wells within the refuse, developing a main loop header system, and delivering gas to a central blower and flare station located in the entrance area. Subject to demonstration of economic feasibility, an energy recovery facility is likely to be added in the future.

4.2.2.2 Leachate Management

Layon Landfill will be designed and operated to manage leachate primarily by recirculation to the waste mass. Leachate will be pumped from the temporary holding tanks and reintroduced to the landfill by several different methods including any or all of the following:

- During dry weather periods, leachate may be pumped directly to sprinkler systems for spreading over the surface of the landfill top deck.
- Leachate may be pumped to a site water truck and delivered to the working face for spreading over the refuse before it is covered with daily cover soil.
- Leachate may be pumped or delivered by tanker truck to horizontal trenches or vertical infiltration wells for subsurface reintroduction to the refuse mass.

Specific means and methods of leachate reintroduction will be detailed in the site's operations plan prior to beginning disposal operations.

Recirculation of leachate is generally known to increase the rate of biological activity within the waste mass, thereby advancing decomposition, settlement and consolidation of the waste mass and enhancing the generation of landfill gas.

During initial operation of the site, it is likely that leachate will be generated before sufficient refuse has been placed in Cell 1 to make leachate reintroduction practical. During this interim period, any leachate generated will be transported to the nearest public wastewater treatment facility using conventional tanker trucks.

4.2.2.3 Support Facilities

The Layon Landfill Project includes three buildings to facilitate the operation of the landfill.

- *An Administration Building:* The facility is a single story 2,358 square foot building which will house the administrative staff. The building is located adjacent to the scales and the staff will interact with the vehicles entering the site. The facility has a break room with cooking facilities and restroom with a shower for extended stays during times of natural disasters.
- *A Maintenance Building:* The 6,734 square foot building will handle the maintenance of the landfill equipment. The maintenance bays are high-bay story and are equipped with compressed air connections and overhead reels for engine oil, grease, gear oil, hydraulic oil, and transmission oil. The two-story portion of the facility houses an office area, men and women's locker rooms, break room, and storage areas.
- *Generator Building:* A 798 square foot single story building which contains the main electrical room for the site, emergency generator, and pumps for the water system

In addition, a new 10-inch diameter waterline will be installed to service the Access Road and the Layon Landfill, connecting to the existing system at Kumati Road. Therefore, the existing 6-inch waterline that currently extends to the Tracking Station will be replaced when the new road is constructed. Underground utilities will be brought to the site, including power and telephone, and provisions for telemetry and cable TV. The existing overhead power lines currently installed from Route 4 to the new service road origination point will be converted to underground lines. All existing customers currently connected to overhead power lines being removed will be connected to the new underground lines. The storm-water conveyance systems will be designed to maintain peak discharges from the landfill site at flow volumes estimated for existing (pre-development) conditions.

4.2.3 Viability

4.2.3.1 Environmental / Regulatory Issues

The DPW is currently using the Ordot Dump for disposal of its solid waste and has not met the Consent Decree deadlines for closure of the Ordot Dump and the construction of the new landfill. The Guam Legislature has not acted to pass legislation necessary to finance and begin construction of the Layon Landfill. As a result on December 14, 2007 the United States District Court for the Territory of Guam imposed a fine on GovGuam that was due on January 24, 2008. New deadlines are being negotiated for compliance with the Consent Decree.

The DPW has submitted all the required permit applications for the development of the landfill site to the GEPA and there are no apparent regulatory impediments to the construction of the landfill.

4.2.3.2 Implementation or Policy Issues

The disposal charges at the new landfill facility would likely be set by the PUC. However, it is difficult to accurately predict when the facility might be available and what the cost for disposal might be.

The US District Court administering the Consent Decree has placed the Guam solid waste management program into receivership and will be administered by a third party reporting directly to the court. It is not clear at this time how this might impact the project development.

4.2.3.3 Schedule Issues

The schedule for implementation of the Layon Landfill Project established under the Consent Decree has not been met. This issue is now before the U.S. District Court for resolution.

Table 4-3

Original Consent Decree Implementation Schedule

Key Milestones	Consent Decree Compliance Date	Status
Consent Decree	02/11/04	Complete
List of New Landfill sites	03/12/04	Complete
Draft Closure Plan & EIS	12/07/04	Complete
Ordot Permit Application	12/07/06	Under Revision
90% Draft Closure/Post Closure Plan	05/06/05	Complete
New Landfill Draft Plan	08/04/05	Complete
Final Closure/Post closure Plan	09/03/05	Under Revision
90% Ordot wetland Mitigation Plan	09/03/05	Ongoing
Ordot Interim Permit Issued	12/02/05	Complete
Ordot Bid Advertisement	01/11/06	Delayed
90% Draft landfill Design Plan/Permit Application	02/05/06	Complete
90% :amdfill Wetland Mitigation Plan	02/05/06	Not Required
Award Closure Contract	04/21/06	Delayed
100% Landfill Design Plan	06/05/06	Under Revision
Landfill Invitation for Bid Issued	06/05/06	Delayed
Landfill Permit Approved	09/03/06	Delayed
Landfill Contract Award	10/13/06	Delayed
Landfill Construction Complete/Operations Begin	09/23/07	Delayed
Ordot Closure Complete/All Discharges Cease	10/23/07	Delayed

Table 4-4

Original Consent Decree Penalties

§	Task	Consent Decree Deadline	Requested Revised Deadline	Total Stipulated Penalties
Ordot Dump Closure				
8.f.	Advertise for Construction IFB	1/11/06	3/8/06	$20,500
8.g.	Award Closure Contract	4/21/06	6/21/06	$47,000
8.h	Complete Ordot Closure	10/23/07	4/24/09	$2,535,000
8.i	Cease All Discharges	10/23/07	4/24/09	$2,535,000
Layon Landfill				
9.h	Award New Construction Contract	10/13/06	11/30/06	$33,000
9.i.	Begin Operations	9/23/07	9/19/08	1,600,000
17	SEP	2/11/08	5/21/09	Not Determined
				$6,770,500

4.3 Alternative 3 – Construct New Landfill in Central Guam

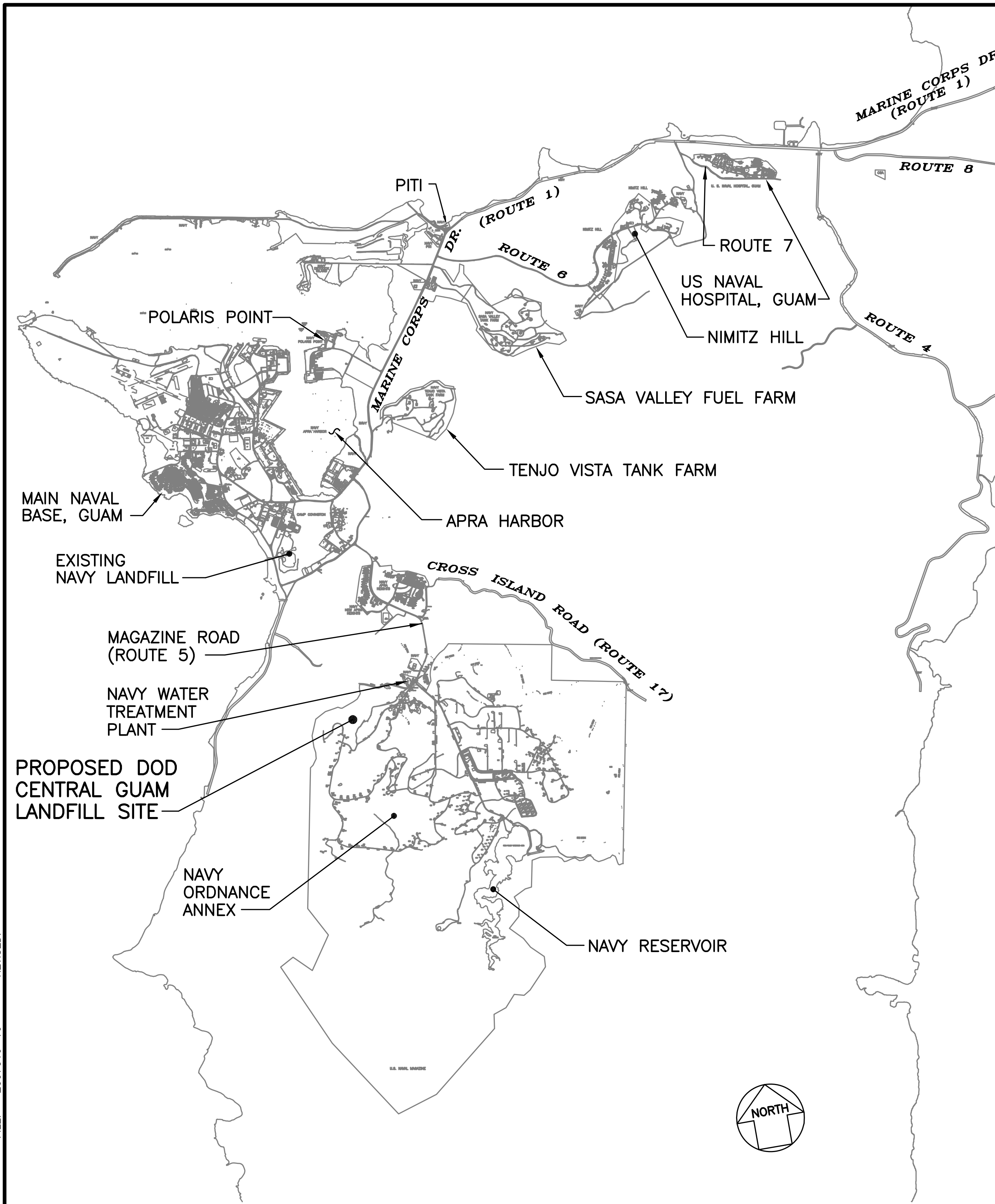
4.3.1 Description

The Navy has not performed a siting study for a replacement facility for the existing landfill at Apra Harbor. However, initial planning has focused on potential locations in central Guam that would provide favorable collection economics, and in particular have included a potential 50 acre site in the northwest portion of the Ordnance Annex. Although the site has not been evaluated in detail, it provides a potential site for comparison to other alternatives in this report. The general location of the site is shown on Figure 4-7.

4.3.1.1 Overview

The site assumed for a new Navy Landfill in central Guam would provide approximately a 40-acre to 50 -acre landfill footprint as shown on Figure 4-8. The site is located within a former quarry area and the terrain is steep. The existing topography of the site ranges from about 400 feet MSL to approximately 600 feet MSL. The landfill site could be accessed from Route 5 by a new road.

A conceptual base and final grading configuration was developed for this report. Based on preliminary calculations this configuration could provide a design capacity of 6.35 million cubic yards, or about 2.86 million tons at a waste density of 1,200 lbs/CY and a waste to cover material ratio of 3:1. Given the projected annual solid waste stream of 53,320 tons beginning in 2019 after the proposed USMC relocation and other planned operations is completed, the estimated capacity would provide a service life of about 50 years.



GENERAL ISLAND LOCATION MAP

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GRAPHIC SCALE:

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HDR Hawaii Pacific Engineers, Inc.	GUAM SOLID WASTE UTILITY STUDY FOR PROPOSED USMC RELOCATION	PROPOSED DOD LANDFILL LOCATION MAP	FIGURE 4-7

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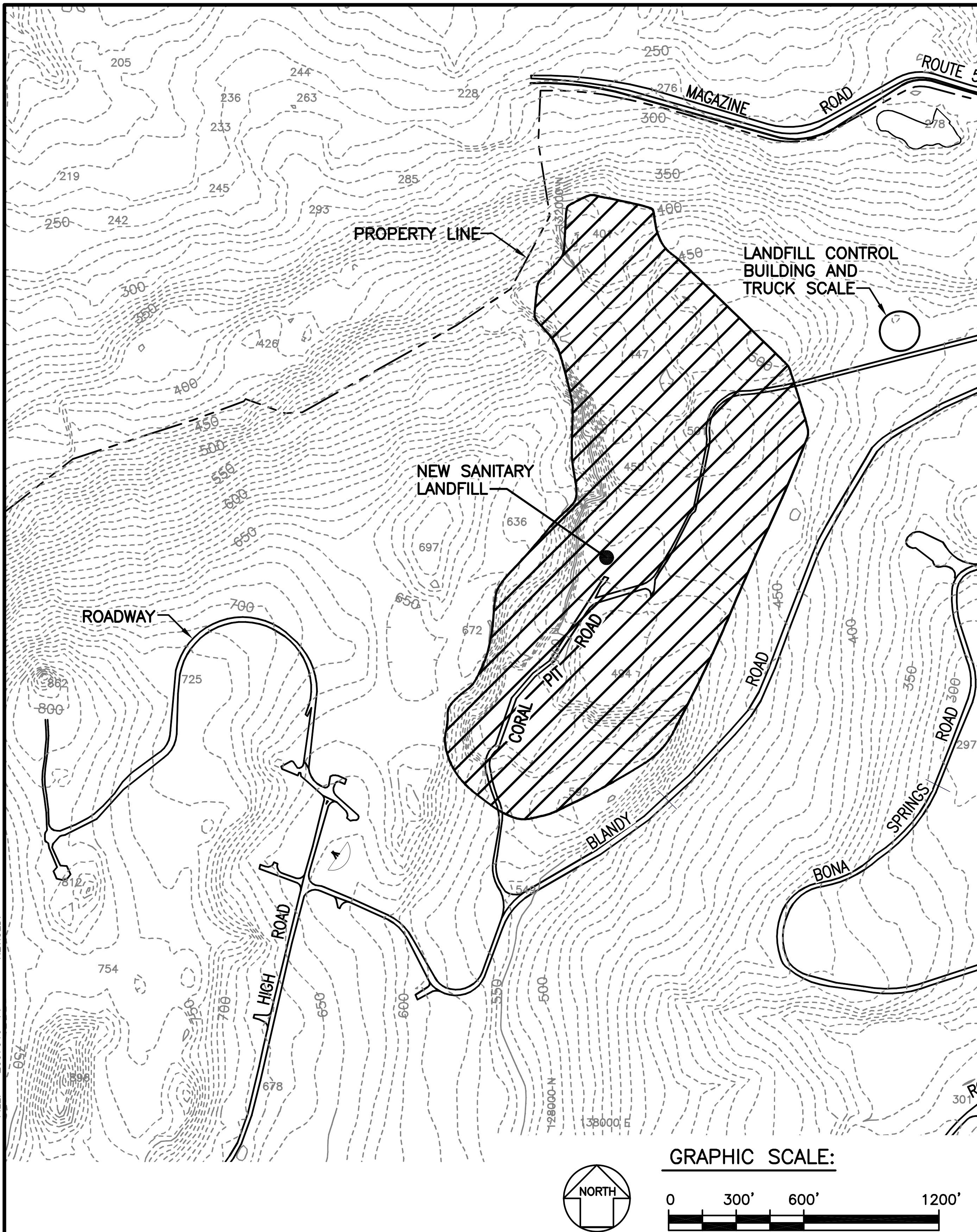

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HDR | HPE Hawaii Pacific Engineers, Inc.	GUAM SOLID WASTE UTILITY STUDY FOR PROPOSED USMC RELOCATION	PROPOSED DOD LANDFILL LOCATION PLAN	FIGURE 4–8

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4.3.1.2 Cell Construction

The new landfill would be designed for the disposal of municipal solid waste according to the requirements of the GEPA as set forth in its Solid Waste Disposal Rules and Regulations (SWDRR) under 10 GCA Chapter 51: Solid Waste Management and Litter Control Act. The fundamental design criteria for municipal solid waste landfills were previously discussed in Section 4.2, describing the planned GovGuam Landfill near Layon. A new Navy Landfill in central Guam would be required to meet the same requirements, and would include a Subtitle D composite liner system, leachate collection system and LFG control system. According to new source performance standard requirements, the LFG control system would need to be installed prior to a predicted annual nonmethane organic compounds emission rate of 50 MG.

4.3.1.3 Leachate Management

The new Navy Landfill could be designed and operated to manage leachate primarily by recirculation to the waste mass. Leachate would be pumped from the temporary holding tanks and reintroduced to the landfill. Recirculation of leachate is generally known to increase the rate of biological activity within the waste mass, thereby advancing decomposition, settlement and consolidation of the waste mass and enhancing the generation of landfill gas.

During initial operation of the site, it is likely that leachate will be generated before sufficient refuse has been placed in the first cell to make leachate reintroduction practical. During this interim period, leachate generated would be transported to the nearest public wastewater treatment facility using conventional tanker trucks.

4.3.1.4 Support Facilities and Utilities

It is assumed that development for the new Navy Landfill facility will include a 600 square foot landfill control building located near a truck scale. Mechanical and electrical systems would have to be provided for the scale facility and leachate collection and removal/recirculation system. In the future when the LFG collection system would be installed, the flare and associated electrical and mechanical systems would have to be installed.

Additional utilities will be brought to the site, including power and telephone, potable water, sewage collection and provisions for communications. The landfill storm-water conveyance systems will be designed to maintain peak discharges from the landfill site to control ponding of rain water and to minimize erosion.

4.3.2 Viability

4.3.2.1 Environmental / Regulatory Issues

The new Navy Landfill site has several remnants of World War II structures that are of historic significance. Section 106 consultation with the Guam Historic Preservation Office would be needed and mitigation measures may be required.

Santa Rita spring is located near the proposed site, and a study to determine the potential impact to the spring may be required.

4.3.2.2 Implementation or Policy Issues

As noted above historic preservation and potential impact to an existing spring would need to be addressed and resolved as determined to be necessary.

4.3.2.3 Schedule Issues

It is generally believed that permitting and construction of the initial module of a new landfill takes from 4 to 5 years, given no significant impediments or challenges. This does not include time for an alternative site evaluation and siting process, which has yet to be performed.

4.4 Alternative 4 – Construct an Incinerator/ Waste-to-Energy facility

A waste incineration or WTE facility could be constructed to dispose of the combustible portion of the DoD waste stream and reduce the volume of landfilled material. This WTE facility would process only the DoD waste stream. A private WTE facility on Guam has been proposed, but has not yet been developed due to a variety of legal and environmental issues. In the year 2000, after the private WTE facility was proposed, Public Law 25-175 prohibiting municipal solid waste incinerators and waste-to-energy facilities was passed by the Guam Legislature. PL 25-175 is included in Appendix C. The Supreme Court of Guam is expected to issue a decision that may determine the fate of the proposed private WTE facility. A DoD WTE facility located on federal government property and processing only DoD solid waste may be able to proceed through construction and implementation if it is a separate, independent facility.

WTE facilities have been installed to process municipal solid waste and various other types of non-hazardous wastes in many locations in the U.S. and are widely used in Europe, Japan, Korea, Taiwan, and other areas for waste disposal. An incinerator does not recover energy whereas a WTE facility includes a waste heat boiler to capture much of the energy from the hot flue gases to produce steam and electricity. The technology can be used in an integrated manner with recycling, composting or other means of handling portions of the waste stream. Not all waste components are applicable to WTE and thus the waste management system still requires a landfill or other disposal means for certain components. For instance large bulky items, large quantities of non-combustible items, and certain construction and demolition materials, are not processible. An ash residue also remains after processing that needs to be addressed. The following discussion addresses what the WTE facility might entail in this application.

4.4.1 Description

The WTE facility size is assumed to be 120 to 150 tpd or approximately 38,000 to 47,000 tpy of waste processed depending on the number of processing trains installed. This size was selected to allow processing of the assumed total combustible waste based upon 7.4 lb per capita per day on the military installations. The total average assumed daily waste generation is just over 150 tpd. Daily and seasonal waste generation variations are not known. For waste storage calculations, it is assumed that waste collection would occur over an 8 to 16 hour period 5 – 5 ½ days per week.

Not all the waste would be processible in WTE facilities. A portion of the waste stream cannot be processed by a WTE including construction and demolition rubble, bulky metal items, and large white goods that are not combustible, too large to feed into the units, or not combustion compatible. When possible, full truckloads of non-processible material would be directed to proceed directly to the landfill to avoid double handling at the facility. Waste received on the tipping floor would be sorted to remove any non-processible material. This material would be re-loaded on a roll-off or other truck and transported to the landfill.

The facility could consist of multiple (2 or 3) units in sizes ranging from about 40 tons per day (tpd) or a single field-erected unit of 130 - 150 tpd. All of these unit sizes would be classified as Small Municipal Waste Combustor for EPA regulatory purposes. Maintenance requirements normally require approximately 15 percent downtime for each unit. Therefore, the modular units provide more flexibility in operations and would allow operation even when only one unit would be out of service. During periods of reduced operation or high waste generation, excess waste could be more readily stored until it can be processed within certain limits.

Field erected units would be expected to be about 100 tpd in size or larger and thus only a single field erected unit may be possible. If a single unit is installed, the waste storage would need to be oversized for storage of all of the waste until it can be processed. To account for this extra waste storage and to ensure capacity will be available, it is assumed a single processing train would need to be oversized or have about 130 - 150 tpd processing capacity. Field-erected units generally have a better performance record, higher availability and longer life but tend to have higher capital costs.

An incinerator or WTE facility could be located near industrial locations that require steam or electrical power or located at one of the existing landfill sites. In this manner it may be possible to utilize some existing infrastructure such as landfill roadways, truck scales and support facilities for the WTE facility. The ash could also be disposed in the landfill or used for alternate daily cover at the landfill or roadway construction, if ash testing shows the material does not exhibit any hazardous characteristics. Waste that needs to be bypassed from the WTE facility and waste that cannot be processed at the facility would be diverted to the landfill.

Depending on the arrangement, a facility of this size should be able to be located in a 4 to 8 acre location with limited on-site roadways and queuing space. It is best if the site is generally flat or gently sloped with access to major roadways and water for boilers, condensers and ash quench.

Packer trucks and roll-off vehicles would be able to utilize the tipping floor. Refuse trucks would enter the site from the access road and normally are weighed for accounting purposes before proceeding to the tipping floor. An enclosed maneuvering area is typically provided with a clear span and 30 foot roof height that would allow packers and roll-offs unloading. The concrete floor surface is made from high strength concrete to maximize surface life. Facilities with field-erected units generally have a large pit for storage of waste. Waste may be deposited directly into the pit or pushed in by front-end loader. Redundant cranes are used to mix the waste and charge the combustor hopper. Modular units however generally utilize floor storage and small bobcat to mid-size front-end loaders for waste handling and storage. The pit and crane system is generally more expensive but provides more efficient waste storage. The floor storage arrangement requires a very large storage floor for peak deliveries such as over holiday weekends.

Waste may be charged to the combustion units by means of the same bobcat or small front-end loader used for storage or the cranes. Material would be fed into a feed hopper and fall by gravity through a chute onto a ram feeder where it will be pushed into the combustion chamber. This waste will also help maintain an air seal to provide a more stable control of the combustion air. Some systems have a sliding door that opens for charging and closes afterwards to help maintain combustion air control. Waste in the hopper will be maintained within a determined range to allow for steady operation and must be charged periodically 24-hours per day seven days per week.

The ram feeder will push the waste into the combustion chamber. Smaller modular units are typically equipped with refractory lined furnaces while larger field erected units may have a waterwall refractory lined enclosure. Modular units generally have several grate steps or downward inclined stages or rams that serve as the grate. As the wastes are pushed forward through the furnace it tumbles down the steps helping to mix the waste and complete combustion. Field-erected units have a more sophisticated grate system consisting of grate bars and grate sections with more steps and better combustion air mixing to improve burnout.

Primary combustion air is provided to combust the waste. Most modular units utilize a two chamber combustion approach where the waste is partially volatilized in the primary chamber and the gases driven off the waste to complete combustion in a smaller secondary chamber. Auxiliary fuel may need to be provided to complete combustion periodically in the second chamber when the gas is not rich enough to fully combust the volatile gases. Larger field erected units generally have an upper furnace area where additional secondary air is introduced to complete combustion. Startup auxiliary fuel burners are provided to warm up the unit and also help maintain proper combustion conditions during shutdowns and occasional upset conditions.

For modular units often the bottom ash drops into a submerged drag chain conveyor. The water extinguishes any remaining embers and cools the ash. The drag chain conveyor pushes the ash up an inclined slope for dewatering. Field erected units may use an ash extractor for the same application. The ash falls off the end of the grate into a quench basin. An ash extractor pushes the ash up an inclined slope for dewatering. Waste burnout is usually less efficient in a modular combustor and thus ash quantities generally are higher than for a field erected unit. In addition ash extractors can usually remove more water from the ash than a drag chain conveyor. Some fines and ash will fall through the grate system and must be collected. This material is usually combined with the bottom ash.

Combustion controls are provided for stable operation. Control of primary and secondary combustion air, refuse feed rate, and grate movement are used to control the thermal release and burnout of the waste. Feedback from instrumentation informs the operator how the unit is performing.

An incinerator would pass the hot flue gas from the combustion chamber to the air pollution control systems through refractory lined ducts. Incinerators without heat recovery are not commonly used today. For a facility with energy recovery the flue gas passes through a boiler where steam is generated. In a modular combustor, the boiler is generally a waste heat boiler connected to the unit by a short duct. For a field-erected unit the boiler is integral with the combustion chamber. Tube bundles suspended in the ductwork generate steam. Since fly ash can cause tube erosion and collect on tube surfaces, tube bundles normally consist of in-line tubes with large clearances. Usually modular units generate saturated steam at about 200 – 250 pounds per square inch (psig). Field erected units usually are equipped with a waterwall boiler and superheaters and may generate steam at much higher temperatures and pressures, typically 650 psig and 750^{o}F. An economizer increases efficiency. The lower pressure steam is not as efficient for electrical production but can be very useful if steam can be used on base or for other process applications. The higher pressure steam can also be extracted for steam uses.

The fly ash will accumulate in the boiler tube bundles and must be removed. The most common method is to use soot-blowers. Rappers may also be used in some cases. The fly ash drops into hoppers and is removed from the boiler. The fly ash is generally combined with the bottom ash for disposal.

A turbine generator is used to produce electricity. If no steam sales are possible a condensing unit is used and either an air cooled condenser or condenser and cooling tower is used to condense the steam to condensate. Condensate pumps are used to pump the water to a deaerator and boiler feed pumps deliver the water to the boiler economizer. A condenser and cooling tower is more efficient than an air cooled condenser, however the system requires more water for condensing the steam. In the event the turbine generator must be taken out of service, it is advisable to include a bypass condenser so that waste can continue to be processed. A water treatment system consisting of reverse osmosis (RO) units and/or a demineralizer is used to produce high quality water for boiler makeup.

A number of air pollution control devices are required. Modular units generally have low NOx emissions and control may not be required. Field erected units in the U.S. generally use selective non-catalytic reduction (SNCR) for control of NOx. This technology injects ammonia or urea reagent into a temperature zone on the boiler where the reagent reacts with the nitrogen compounds turning them into nitrogen gas. More than 50 percent reduction is possible in most cases. Where more control is required certain additional steps can be taken to enhance the performance of the SNCR system.

A spray dryer absorber (SDA) sometimes called a semi-dry scrubber or dry injection of lime is generally used for acid gas control. Dry injection is less effective but lower cost. The lime reacts with sulfur dioxide (SO_2), hydrochloric acid (HCl) and other acid gases in the flue gas stream minimizing their emission. The scrubber residue is captured in a fabric filter (FF) or baghouse along with other particulate. Activated carbon injection (CI) is used for mercury (Hg) control. The activated carbon is injected in the ductwork upstream of the FF or SDA. Dioxins and furans (Dioxins) and other organics are controlled by good combustion controls and any remaining dioxins are further controlled by CI. The FF captures the particulate (PM). The PM contains most of the other metals that were volatilized in the combustion chamber. The clean flue gas is then discharged from a stack. A continuous emission monitoring system (CEMS) is used to demonstrate continuous air emission environmental performance. It is used to measure carbon monoxide (CO) SO_2, NOx, oxygen (O_2) and certain boiler and APC readings to demonstrate compliance.

Boiler flyash, scrubber residue, and particulate are all collected and conveyed to the ash storage area. This material is mixed with the bottom and both are disposed as combined ash. Testing is required to demonstrate the ash achieves the EPA Toxicity Characteristic Leaching Procedure (TCLP) before it can be disposed of in a landfill. Ferrous metal may be recovered from the ash. The ash may be used for cover material if regulatory approvals are achieved.

4.4.2 Viability

While this option is potentially viable, there are a number of issues that would need to be addressed.

4.4.2.1 Environmental / Regulatory Issues

A WTE facility or incinerator would be required to comply with EPA's regulations for New Small Municipal Waste Combustors as provided in 40 CRF Part 60 Subpart AAAA. These requirements are further discussed in Section 5. This facility would be less than 250 tpd and thus would be a Class II facility. The regulations stipulate requirements for materials separation and public hearings that must be completed to address this plan. A siting analysis and hearings are also required. Operating requirements, emission limits, emission monitoring requirements, stack testing and other monitoring and recordkeeping requirements are contained in the rules. However, GEPA could impose additional requirements increasing the stringency for the facility as have been done in some of the other state regulations.

To achieve the emissions requirements, air pollution control equipment would be required to address the various pollutants. Several reagents may be required to reduce emissions below required limits. Lime or sodium bicarbonate would be needed for acid gas control, depending on which might be easiest to obtain on island. Lime as either calcium oxide or calcium hydroxide is usually less expensive than sodium bicarbonate but sodium bicarbonate is sometimes used due to it higher reactivity. Aqueous ammonia, anhydrous ammonia or urea would be needed for NOx control on field erected units. Modular units usually have lower NOx emissions; however it may be difficult if not impossible to install additional controls to lower NOx emissions. Anhydrous ammonia has certain handling requirements and thus is not normally used. Activated carbon would be required for mercury control. All of these reagents would need to be imported to the island.

The ash residue would be required to meet the TCLP requirements. Generally the excess lime used for emissions control conditions the ash as well minimizing leaching of metals. If sodium bicarbonate is used for acid gas control, it may be more difficult for the ash to achieve compliance with the TCLP test criteria as compared with use of a lime-based control technology.

4.4.2.2 Implementation or Policy Issues

The economics of a facility is improved if energy recovery occurs. Electric rates on the island are high due to the cost of importing fuel for power generation. The current avoided fuel cost for electricity is approximately $0.11 per kWh. The viability would be better if consistent steam customers could be identified that are close enough to the facility to justify installing a steam line. An extraction turbine could be used to produce electrical power with extractions ports for steam at the desired market conditions.

Currently wastes from incoming ships and planes are autoclaved to destroy any pathogens prior to disposal in a landfill. With proper approval and operator training, this waste could be brought to the WTE facility and combusted for assured destruction. The cost savings for not having to autoclave the waste could be used to help offset the cost of the facility. There may also be other combustible high security sensitive wastes that require special handling that could be processed for a higher fee. Examples include bank notes, expired pharmaceuticals, confidential documents or contraband.

An extended time period is required for permitting and construction of a WTE facility. Generally about three (3) to five (5) years is adequate to get a WTE facility to commercial operation.

In the interim period waste would need to continue to be disposed in a landfill. After the facility is on line, the ash residue remaining is approximately 30 percent of the incoming waste by weight and 10 to 12 percent of the incoming waste by volume. With proper approval, the ash could be used for alternate daily cover material at a landfill reducing soil needs. In some cases the residue may be used for road construction, drainage layers, or other landfill uses. Development of other residue reuse applications is in progress and may be viable in the future.

Public Law 25-175 added a provision to Chapter 73, Fire Prevention, Division 3 of Title 10 of the Guam Annotated Code that prohibits construction or operation of a municipal solid waste incinerator or waste to energy facility. Although the DoD is generally not subject to Guam laws and regulations, the DoD must comply with certain U.S. federal laws that are administered by the Government of Guam. The GEPA has primacy for enforcement of 40 CFR Part 258, Criteria for Municipal Solid Waste Landfills, which is applicable to the DoD on Guam.

4.5 Alternative 5 – Barge Waste Off-Island

An alternative to disposing solid waste on Guam is to ship solid waste to a location outside Guam for disposal. A majority of the materials that result in waste generation on the island are brought to Guam in cargo containers, resulting in an excess capacity of shipping containers that are sent back empty. These excess containers could be used to back-ship the waste off the island. However, shipment of DoD's solid waste would be subject to the availability of excess containers. Therefore, this alternative included scheduled barge service dedicated to the movement of DoD solid waste to a location outside Guam.

4.5.1 Description

Based on a similar option evaluated in Hawaii, the DoD waste would be compressed into double-plastic-wrapped MSW bales and barged to a continental landfill for disposal. Under the Hawaii alternative, the waste would be barged to Oregon where it would be disposed in the Roosevelt Regional Landfill near Roosevelt, Washington.

Although the acceptability or associated cost of waste receipt and disposal could not be confirmed, the relative costs for waste transport to possible landfills in closer than the continental US were evaluated. Specifically, two landfills; the Tai Chung landfill in Taipei and the Carmona landfill in the Philippines were identified as possible disposal sites. It should be noted that while each of these major metropolitan communities (Taipei and Manila) have appropriate barge receipt infrastructure, these communities appear to be struggling with waste management issues. Similar to much of Southeast Asia, many of these communities lack environmentally adequate landfills that are constructed and operated in a manner comparable to US standards. Reports of illegal waste disposal due to the lack of adequate sanitary landfill capacity are prominent in the news. While the specific tip fee costs of waste receipt and disposal at these locations are unknown, the primary benefit of these sites is that the estimated time in transit is only 10 and 12 days respectively. As compared to the estimated 71 days in transit to Oregon, these two landfills offer a notably closer and therefore less costly transit cost.

The technology required would consist of a shredding and baling facility sized to handle the tonnage throughput. The bales would be hauled on flat bed trucks to the port for loading on to barges by the barge operators. Deployment schedules would be dependent on the bale configuration and size, "backhaul cargo" opportunities and port "turn-around" times. For instance, the bales could be loaded in cargo shipping containers which would normally be shipped back empty. "Turn-around" times would be dependent on stevedoring activity, cargo availability, equipment maintenance and weather. Based on the projected annual waste from DoD facilities of approximately 53,320 tons means the system would have to be sized to handle approximately 210 tons per working day.

A single-tow ocean-barge could handle approximately 6,500 tons of waste. A double-tow ocean barge could handle approximately 10,000 tons of waste. Based on the DoD waste quantity, transporting waste off-island would require approximately 6 double-tow barge loads per year. The estimated ocean transit time is approximately 71 days plus approximately 5 days of port time. Barge loading/unloading would require a staging area at the port for the baled waste which is assumed to be delivered as approximately 1.9 ton bales (i.e., about 3,600 bales; about 16 square feet per bale). Based on stacking the bales three high, the area required would be approximately 20,000 square feet.

Operators would load the bales on flatbed shuttle trucks with forklifts with lift arms or paddles for delivery to the barges. Each flatbed truck could handle approximately thirteen bales. Shore cranes would lift the bale from the flatbed trucks on to the barge. A similar off-loading operation is expected at the continental port. Hawaii looked at existing port infrastructure in the Pacific Northwest and identified three possible candidate ports: Longview, Washington; Vancouver, Washington and Portland, Oregon. To minimize the truck hauling distance to the Roosevelt Landfill, the Port of Portland was selected as the most economical. The one-way driving distance to the landfill is approximately 140 miles and would take approximately 3 hours. Since most of the other waste delivered to the Roosevelt Landfill is delivered in containers or semi-trailers and not baled, the bales would require special handling at the landfill.

4.5.2 Viability

Preliminary assessment indicates that the life-cycle costs associated with this alternative are very high. In addition, there is a high probability for cargo handling inefficiencies, truck driver unavailability and transit delays that would further increase costs and risks for this alternative. Therefore, this alternative is not considered to be viable.

The option of barging wastes to landfills located in Southeast Asia could potentially reduce transit and shipping costs. However, the lack of appropriate sanitary landfills equipped with US equivalent protection standards makes this option non viable for the purposes of this study.

4.5.2.1 Environmental / Regulatory Issues

Under 7 CFR 330.400 and 9 CFR 94.5, the Animal and Plant Health Inspection Service (APHIS), a division of U.S. Department of Agriculture regulates the importation and interstate movement of garbage that may pose a risk of introducing or disseminating animal or plant pests or diseases that are new to or not widely distributed within the United States.

In response to a request by business interests and public officials in Hawaii, APHIS prepared a draft pest risk assessment (PRA), titled ``The Risk of Introduction of Pests to the Continental United States via Plastic-Baled Municipal Solid Waste from Hawaii `` (March 2006) to evaluate the interstate movement of garbage from Hawaii to the mainland of the United States. The objective of the PRA was to evaluate whether a baling technology that would bundle, wrap, and seal the MSW into airtight bales would effectively mitigate potential plant pest risks associated with MSW from Hawaii. The PRA focused on the planned use of the baling technology because airtight enclosure from creation to burial would mitigate the risks of establishment by any plant pests. The PRA addressed the following three issues:

- The ability of the baling technology to provide a strong, airtight barrier;
- The examination of the occurrence of ruptures or punctures; and
- The examination of general pathway procedures to reduce pest incidence in the bales and the chances of escape in the event of accidental ruptures or punctures.

The PRA concluded that transporting MSW from Hawaii to the continental United States in airtight bales poses a low risk of pest introduction and dissemination because the baling technology mitigates the risk from all types of plant pests. Pest mitigation processes such as the baling technology itself or features of the proposed pathway, including the waste type, and how bales are staged, handled, transported, and buried, are added safeguards that would prevent the introduction and dissemination of exotic pests. As a complement to the baling technology, the PRA recommended proper staging of bales and certification that the bales are mollusk-free to mitigate against contaminating pests. The PRA also recommended diversion of yard and agricultural waste, prompt shipment of bales, monitoring and inspection of bales, and thorough cleanup of any ruptures that do occur.

Therefore, APHIS adopted a rule change published in the Federal Register on August 23, 2006 that allows the barging of double-plastic-wrapped MSW bales to the continental U.S, which became effective on September 22, 2006. However, the rules restrict the baling of any fruit products to incidental quantities. Similar regulatory approvals will likely be required in order to transport DoD waste from Guam to any other country.

4.5.2.2 Implementation or Policy Issues

Implementation of this alternative would require a receiving facility willing to accept the solid waste. The receiving facility would also need to be capable of handling and disposing the solid waste in an environmentally sound manner. The facilities identified as meeting the above criteria are located on the west coast of the continental United States. As noted above, there may be solid waste handling and disposal facilities located closer to Guam. However, no contact has been made with either the Taipei or Philippines landfills to determine the technical viability and cost of waste receipt and disposal. .

4.6 Alternative 6 – Use Existing Unlined Landfill – Apra Harbor

4.6.1 Description

The existing Navy Sanitary Landfill conditions are described in Section 4.1.1.1. Alternative 1 assumed that a number of landfill site and operational improvements including upgraded equipment purchases would take place, including construction of a liner for the landfill. This Alternative 6 assumes that the Navy would continue to landfill at the Apra Harbor site but would not install a liner system. Similar to Alternative 1, a passive landfill gas venting system would be installed.

The basic final grading criteria would be the same as Alternative 1 as described in Section 4.1.1.3. It is assumed that the Navy would implement either Alternative Final Filling Plan 1 or 2 as previously described for Alternative 1 with the estimated resulting site lives as shown in Table 4-5. This would be less costly than Alternative 1 because the Navy would not install the liner over the inactive area using Alternative Final Filling Plan 1 (54 MSL) or a separation liner if Final Filling Plan 2 (100 MSL) were implemented. The table below shows the difference in capital costs for Alternative 6 compared to Alternative 1 for the two alternative final filling plans. The preliminary capital costs shown in Table 4-5 include estimated closure cap costs.

Table 4-5

Preliminary Capital Cost Comparison – Alternative 6 Versus Alternative 1

Alternative 6 (Max. 54 MSL or 100 MSL)	Alternative 1 (Max. 54 MSL)	Alternative 1 (Max. 100 MSL)
$8,400,000	$18,900,000	$30,600,000

4.6.2 Viability

As indicated in Section 4.1 it is expected that GEPA will request that the inactive area of the Navy Sanitary Landfill be equipped with a liner and that if significant additional filling in the active area is implemented, that a separation liner be installed. Although not categorically required by USEPA regulations, GEPA has regulatory primacy and has expressed a desire that future landfilling on the island of Guam at a minimum be performed on a Subtitle D compliance liner system. GEPA and other GovGuam personnel have proposed that the Navy and Air Force both consider use of the GovGuam landfill planned near Layon as would be implemented described in Alternative 2. Furthermore, a letter by GEPA, dated April 17, 2006 to the Air Force indicated that “Guam EPA will address the Navy Landfill in the very near future. The ideal compliance scenario would have the Air Force transition directly to the new Layon Landfill and concurrently have the Navy Landfill in the process of regulatory closure.”

This would appear to indicate that the continuation of the status quo where the Navy would continue unlined landfill operations would not be viable in view of the GEPA position. It also might not be an environmentally proactive position for the Navy to pursue given the VOCs detected in groundwater monitoring wells. GEPA has regulatory primacy for enforcing the USEPA municipal solid waste regulations and can impose more stringent requirements for landfills within their jurisdiction. It is anticipated that soon after the new GovGuam lined landfill becomes operational, GEPA would enact and implement a requirement that all operating landfills have a liner system or close within a specified period.

Given the difficulties with implementing the planned new GovGuam landfill as previously discussed in Section 4.2, the GEPA may not be in a position to force the Navy to use that facility. However, it seems unlikely that GEPA will continue to allow unlined operations at the Navy Sanitary Landfill to continue into the long-term future, particularly after the GovGuam new lined landfill becomes operational. Therefore, this alternative is not viewed as viable and is not considered further in Section 5.

4.7 Alternative 7 – Construct New Landfill in Northern Guam

4.7.1 Description

This alternative would have the Navy construct a new lined landfill somewhere in northern Guam. A siting study nor preliminary assessment of a specific location have not been performed or analyzed to this point.

An advantage of this approach would be that it could be located closer to the larger DoD waste generator, which would be Northern Guam, where the proposed relocation of the Marines is focused. However, a significant risk and drawback to this approach would be that it would be located over the Northern Guam Lens Aquifer (NGLA), a sole source aquifer providing nearly 80 percent of all drinking water on Guam.

4.7.2 Viability

4.7.2.1 Environmental / Regulatory Issues

Given the high environmental sensitivity of the NGLA, it would be difficult for the Navy to site a new landfill in Northern Guam given some of the other alternatives in this study that would not pose a long term risk to contamination of such an important aquifer. Even though a modern Subtitle D landfill liner greatly mitigates this risk, it cannot entirely remove it.

If the Navy did undertake a siting study for a new landfill in Northern Guam this would likely create significant public opposition due to the NGLA as well as regulatory scrutiny by the GEPA. At present, water drawn from the Northern Guam Lens is not considered to be groundwater under the influence of surface water, limiting required treatment to disinfection only. However, indications of contamination from onsite wastewater disposal systems are occurring on a more frequent and consistent basis. GEPA and EPA have initiated public discussions to notify water purveyors that full compliance with the surface water treatment rule will be required. The increased military population in northern Guam, and the civilian population increase that will likely also occur, would increase the importance of the Northern Guam Lens, and the need to protect it to the fullest extent possible. As an example, during the GovGuam EIS siting study, Guam's *Groundwater Protection Zone* and other potential groundwater producing areas were eliminated from consideration for a landfill. Any siting study performed by the Navy would need to provide similar consideration for the Groundwater Protection Zone.

Given the above environmental policy and technical considerations and regulatory issues this alternative is not viewed as viable and is not considered further in Section 5.

4.8 Alternative 8 – Use Existing Andersen Air Force Base Landfill

4.8.1 Description

The existing landfill operations at Andersen Air Force Base include a municipal solid waste landfill area and a construction and demolition debris disposal area. The AAFB municipal solid waste landfill is a vertical expansion constructed over an unlined landfill area. The AAFB landfill began operation in late 1998 with a design capacity of 172,000 cubic yards and expected life of ten years. The landfill was planned to have sufficient capacity to handle AAFB solid waste only until the opening of the new GovGuam landfill. At the time of permitting for the AAFB landfill, the GovGuam landfill was scheduled to be operational by the year 2008. When it became apparent that the GovGuam landfill would not be ready for use as originally anticipated, AAFB planned a further incremental expansion of their lined expanded landfill to provide a limited amount of additional volume.

A recycling center is operated at AAFB by a contractor. The recycling center primarily serves as an accumulation point for cardboard, paper, plastic bottles, aluminum cans and glass. Covered storage area is very limited, and the majority of the accumulated materials are stored in uncovered open areas at the recycling center site. The recycling center operator and AAFB usually arrange for transport of the materials off AAFB on an annual basis by a recycler. Because of the small quantities involved, and the poor condition of the cardboard materials, the recycling operation generally does not generate any offsetting revenue.

This alternative assumes that the AAFB Landfill will run out of space in the recently implemented 2-acre expansion as early as 2009. Alternative 9 is based on a larger expansion of the AAFB Landfill.

4.8.2 Viability

4.8.2.1 Environmental / Regulatory Issues

Because the AAFB Landfill is above the NGLA, it will receive the same scrutiny as any proposed landfill in northern Guam. In addition, the existing AAFB landfill is located upgradient from several freshwater subzones that lie within the AAFB boundary. Monitoring wells installed under the Base Installation Restoration Program have not detected significant levels of contaminants in the downstream groundwater. However, because the coralline structure of northern Guam is characterized by highly variable porosity, fractures and voids, there is concern about the location of water supply wells relative to the landfill location. These concerns placed substantial constraints on the location of water supply wells recently constructed in the Northwest Field area. Further expansion of the AAFB landfill would heighten concerns for protection of the water supplies within DoD property.

4.8.2.2 Implementation or Policy Issues

Based on planning for the AAFB, the Air Force intended to use the planned new GovGuam Landfill near Layon for disposal when the AAFB Landfill existing active area runs out of capacity. The current active area capacity is exhausted. Because the new GovGuam Layon landfill is not operational, the AAFB has initiated a separate project that will expand the existing permitted landfill by 2 acres and extend the lifespan of the landfill to at least 2009. If the GovGuam landfill does not become available at that time, the Air Force would need to further expand the landfill to serve beyond 2009 or use another landfill such as the Navy Sanitary Landfill.

The 2-acre lined landfill expansion being implemented by the AAFB is an interim measure. It does not provide adequate capacity for the longer term DoD waste steam described in Section 3 that must be serviced to satisfy the goal of this study; therefore, Alternative 8 is not considered viable and is not considered further in Section 5.

4.9 Alternative 9 – Expand Existing Andersen Air Force Base Landfill

4.9.1 Description

As described in Section 4.8, the AAFB Landfill is implementing a 2-acre expansion planned to extend capacity until the GovGuam Landfill becomes operational. It is located over the NGLA, a sensitive environmental area that provides almost 80 percent of the drinking water for the island. This alternative would involve expansion of the AAFB Landfill to serve the future disposal needs of the DoD described in Section 3. No detailed planning or design work has been performed for this alternative as there are planning level environmental and regulatory concerns for expansion of the landfill that are discussed further, below.

4.9.2 Viability

4.9.2.1 Environmental / Regulatory Issues

Similar to discussion of environmental/regulatory and implementation and policy issues facing Alternative 7, it will be difficult for the AAFB to expand the landfill as part of a long term strategy to serve the DoD solid waste future disposal needs described in Section 3. The landfill is located over the NGLA and a significant expansion would likely receive as much scrutiny as a new landfill. As noted for Alternative 7, a previous landfill siting process by GovGuam has ruled out the NGLA area. It is likely that GEPA would not be in favor of a landfill expansion in northern Guam given the predisposition to having future landfilling occur at the planned GovGuam Layon Landfill, in part because it is not located above the NGLA.

Given the above environmental and regulatory issues, this alternative is not viewed as viable and is not considered further in Section 5.

4.10 Alternative 10 – Proposed WTE Facility /Landfill – Guatali

4.10.1 Description

A private developer is planning to develop a WTE facility to serve the entire island which could potentially provide disposal services to DoD as well. In 1982 the Government of Guam issued an exclusive license to build an incinerator to a company called International Energy Enterprises Inc. In 1989 the island's master plan included an incinerator, but Energy Enterprises sold its license to G Power, who teamed up with Wheelabrator Technologies and formed a partnership with a local company called GMP and Associates, which created a company called Guam Resource Recovery Partners or GRRP.

In 1991 the Guam Economic Development Authority agreed to sell $75 million in bonds to fund the incinerator project and in July 1996, signed a contract with GRRP. However in August 25, 2000, the Guam legislature passed a law (Public Law 24-57) blocking public funding for a WTE project. In addition, the legislature passed a law (Public Law 25-175) which prohibits the construction and operation of a "municipal solid waste incinerator or a waste–to-energy facility" on the island. This project has been the subject of numerous litigation battles in the Guam Superior and Supreme Courts regarding whether the WTE license and funding agreement are still valid.

On December 13, 2007, GRRP held a ceremonial groundbreaking at the Guatali site for the development of the landfill. According to GRRP estimates based upon the projected municipal solid waste generation for Guam, the proposed landfill site with the addition of a waste-to-energy facility would accommodate landfill operations for 19 to 21 years. Without the waste-to-energy facility, the proposed site would accommodate landfill operations for approximately 12 years, according to GRRP.

4.10.2 Viability

4.10.2.1 Environmental / Regulatory Issues

A Draft Environmental Impact Statement – Solid waste Management Facility for the Island of Guam conducted a screening process for a potential landfill site but ruled out the Guatali, Piti site based on slope and geological exclusionary criterion. Deficiencies in the screening process were identified during the Ordot Consent Decree negotiation, which mandated that a new landfill siting process be initiated. This process resulted in the selection of the Layon Landfill site as discussed in Alternative 2.

4.10.2.2 Implementation or Policy Issues

GRRP has not yet obtained permits for the construction of either the landfill or the WTE facility. This process could be long and contentious given the litigious history of the project.

Given these major implementation and policy impediments, this alternative is not considered as a viable option at this time.

4.11 Summary of Screening of Nonviable Alternatives

As discussed above, Alternatives 5 through 10 were judged as nonviable for further consideration, summarized as follows:

Alternative 5 – Barging solid waste to an off-island landfill or other solid waste disposal facility was judged as nonviable because of the very high costs and potential socio-political as well as environmental concerns.

Alternative 6 – Pursuing the status quo by operating the Apra Harbor Navy Sanitary Landfill without installation of a liner system is judged as nonviable because it is believed that GEPA will not allow significant additional disposal without installation of a liner system.

Alternative 7 – Navy/DoD construction of a new landfill in northern Guam is judged as nonviable because it would be placed over the NGLA, an environmentally sensitive groundwater protection zone providing the only significant potable groundwater source and almost 80 percent of the drinking water for the island. The NGLA has been ruled out as a suitable area for siting a new landfill during an EIS process conducted by GovGuam and GEPA may be unlikely to approve a new landfill over the NGLA given less-sensitive available locations on the island.

Alternative 8 – Using the existing landfill at the AAFB is judged as nonviable because it has very limited site life remaining. A 2-acre lined expansion recently pursued would only provide capacity for an estimated two to four additional years.

Alternative 9 – Expansion of the landfill at the AAFB is judged as nonviable because it would be located over the NGLA. Similar to Alternative 7, it may not be advisable or possible to pursue permitting significant new landfill footprint located above the NGLA.

Alternative 10 – The potential new private WTE facility with a landfill at Guatali has yet to obtain permits for construction of either the landfill or WTE facility. This process could be long and contentious given the litigious history of the project and it is not clear how funding for the project will occur. Given these factors, Alternative 10 is judged as non-viable.

It should be noted that the judgments above are based on a relative comparison of the alternatives. The reasons these alternatives are dropped from further consideration may not be categorical fatal flaws, but they are considered to be significant impediments to successful implementation as compared to Alternatives 1 through 4. Based on this preliminary comparative assessment, Alternatives 1 through 4 are analyzed in more detail in Section 5.

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5.0 Viable Solid Waste Disposal Alternatives

5.1 Alternative 1 – Improve Navy Sanitary Landfill – Apra Harbor

5.1.1 Analysis

5.1.1.1 Site Life under Varying Conditions

As discussed in Section 4, landfill design configurations can provide a range of site lives using various operational improvements or landfill diversion strategies. Alternative final fill plans 1 and 2 shown in the table are identified as viable possibilities as discussed in Section 4.1.1. At the assumed waste generation rate of 7.4 lbs/cy assumed for this study, the range of site lives for these alternative final plans ranges from 7 to 28 years under the lowest Alternative 1 Final Fill Plan (54MSL) compared to 12 to 57 years under the Alternative 2 Final Fill Plan (100MSL), under a range of operating conditions.

The Alternative Final Fill Plan 1 is a minimal approach and is viewed as a transition phase to the Navy pursuing one of the other alternatives in the long term after closure of the Apra Harbor site. The projected site life of 7 years is a very conservative approach based on continuing the status quo in terms of operations. With the recommended heavier compaction equipment, the site life filling only to elevation 54 MSL would provide 10 to 14 years of capacity combined with revised filling practices. The Sanitary Landfill Management Plan contains a description of the recommended heavier dozer and improved filling practices. In addition to use of heavier equipment, the improved filling practices would primarily involve systematic construction of daily cells and application of a single soil cover layer at the end of the day.

Alternative final fill plan 2 optimizes the remaining capacity of the landfill by extending the fill height only to elevation 100 MLS out of consideration of visual impacts, even though technically it could be extended to elevation 140 MSL. As noted in Table 4-2, this will generally more than double the site life compared to only filling to elevation 54 MSL.

Other strategies to extending the site life of the landfill evaluated, as summarized in Table 4-2, include use of ADC tarps, which is expected to provide roughly a 15 percent increase in site life. This is shown in combination with various filling practices. The performance from using ADC tarps assumes that soil or other cover material would have to be used periodically.

The next tier of landfill space conservation shown on the bottom portion of Table 4-2 portrays diversion using a materials recovery facility or WTE facility. The materials recovery facility is assumed to divert 54 percent of the volume of the landfill. The MRF strategy combined with recommended landfill operational improvements is expected to extend the site life from 27 years to 34 years. If employing ADC tarps could provide a waste to soil ratio of 8:1, the site life would be increased to 39 years.

Pursuing a WTE facility is included as Alternative 4 of this study, below. The expectation is that a WTE would divert 54 percent of the landfill volume. Under this scenario, the landfill life would be extended from 27 to 55 years. If employing ADC tarps could provide a waste to soil ratio of 8:1, the site life with WTE would be increased to 57 years.

5.1.1.2 Environmental Considerations

As indicated in Section 4.1.2.1, landfilling of additional waste has the potential to increase the degree and extent of duration of VOC releases from the landfill. Under the limited Alternative Final Fill Plan 1 to maximum elevation 54 feet MSL, the portion of the estimated additional 1,200,000 cy of landfill volume above the active area would not be lined and could contribute to continuing VOC releases. Installation of an active LFG control system is expected to help reduce the VOC emissions to soil and groundwater to some degree.

Under the proposed Alternative Final Fill Plan 2 utilizing a maximum elevation of 100 MLS a separation liner would be installed which would minimize the level of VOC release to groundwater from material placed above the separation liner. Due to expected differential settlement of waste beneath the separation liner there is a risk that the liner could fail. Although methods could be undertaken to consolidate waste prior to liner construction there will be differential settlement as the decomposable waste fraction in the fill breaks down.

Two important factors should be noted when comparing the potential groundwater impacts of continuing to use the Apra Harbor Landfill to other viable alternatives (1 through 4). First, the Navy would still be required to minimize and remediate the release of VOCs from the existing unlined landfill. Secondly, the Navy would still be required to landfill a majority of the waste stream at another landfill site on Guam or an off-shore landfill if barging of waste were pursued. Placing a base liner in the inactive area of the Navy Landfill at Apra Harbor prior to waste placement will result in performance similar to other options because a Subtitle D liner system will be employed. The additional waste placed above a separation liner would have similar containment as provided with other landfill alternatives. Because much of the waste beneath the separation liner would have been placed with light compaction equipment and significant cover soil, differential settlement that could compromise the integrity of the liner system is a significant risk compared to other landfill options.

Groundwater monitoring is required by the Rules and Regulations for the Guam Environmental Protection Agency (GEPA) Solid Waste Disposal, Title 22, Division 4, Chapter 23, Article 5. This would continue over the operational lives of the landfill and the post closure maintenance period and potentially longer if landfill releases to the environment are occurring and the GEPA determines that the facility poses a contamination threat to the environment.

As indicated in Section 4.1.2.1, installation of a LFG collection system at the Navy Landfill will decrease the level of GHG emissions compared to current conditions. GHG emissions from future DoD waste disposal using other landfill alternatives (2, 3, 5, 7, 8, and 9) can be expected to be similar as it is assumed these other landfills will also be equipped with LFG control systems. However, GHG emissions using WTE Alternative 4 would result in a comparative decrease in GHG emissions. Studies have indicated that a WTE facility could reduce GHG emissions from fossil fuel energy offsets by as much as 40 percent when compared to landfill disposal and as much as 60 percent if landfill gas collection and flaring is not part of the landfill option.

5.1.2 Costs

The costs vary between Alternative Final Fill Plan 1 and 2, because of the difference in the amount of landfill liner that would be required. Following is a description of the major cost components for this alternative, including the final fill plan sub-alternatives. Because these options are the easiest to implement, they can provide interim solutions to allow proper planning and development of some of the other longer term alternatives. Therefore, these cost factors below are also applied transitionally to the other alternatives in the comparative analysis discussion in Section 5.5.

Estimated capital dollar costs for Final Filling Plan 1 (termed Alternative 1-1) include a landfill control building, truck scale facility, site work, liner and leachate collection system, leachate treatment system, landfill gas control system, and closure cap for a total of $20.5M. This includes cost for a closure cap for 60 acres including both the inactive and active landfill area. For Alternative 1-1, it is assumed that 14 acres of the "inactive" area of the Navy Landfill would be lined and equipped with a LCRS; however, the active area would not be lined. The costs assume that a LFG control system would be installed on 60 acres to include a flare. This is not categorically required under the new source performance standards, but it was assumed that it would be installed based on requirements or option of the GEPA or Navy as discussed in Section 4.1. It is assumed that the construction of all items except the LFG control system and closure cap would occur in 2009. For the private financing model, it is assumed that these initial landfill costs would finance and amortized for anticipated landfill life of 15 years. For the economic analysis, installation of the LFG control system is conservatively assumed to occur in 2013 to allow time for filling on the inactive area to appropriate grades. Closure capping would occur when the entire landfill reaches final grades.

The estimated capital costs for Alternative 1-2 total $32.2M. The main difference is that the liner and LCRS system would include a separation liner over the active landfill area.

The estimated annual operational costs for Alternative 1 are shown below and include costs for the current troop levels and the estimated costs after completion of the proposed Marine relocation.

Landfill Operation Cost - Current

Description	Qty	Hrs /Day	Hourly Wage	Hourly Equipt	Daily Cost	Annual Cost
Personnel						
Manager/Supervisor	1	8	25.00		200	50,400
Operator/Equipment Operator Onsite	1	8	16.12		129	32,503
Equipment Operator Onsite	1	8	16.12		129	32,503
Drivers/Operators Refuse Collection	8	8	9.50		608	153,216
Laborers	3	8	10.29		247	62,225
Environmental Specialist	1	2	21.10		42	10,634
Equipment						
Dozer Operation	1	4		66.77	267	67,304
Refuse Truck Operation	8	6		25.55	1,226	309,017
Totals					2,848	717,802
Collection Drivers and Trucks Only						462,233

Note: Refuse truck operation based on Apra Harbor Landfill location

Landfill Operation Cost - Projected

Description	Qty	Hrs /Day	Hourly Wage	Hourly Equipt	Daily Cost	Annual Cost
Personnel						
Manager/Supervisor	1	8	25.00		200	50,400
Operator/Equipment Operator Onsite	1	8	16.12		129	32,503
Equipment Operator Onsite	1	8	16.12		129	32,503
Drivers/Operators Refuse Collection	29	8	9.50		2,128	555,408
Laborers	5	8	10.29		412	103,708
Environmental Specialist	1	2	21.10		84	21,269
Equipment						
Dozer Operation	1	8		66.77	534	134,608
Refuse Truck Operation	29	6		25.55	4,292	1,120,185
Totals					8,137	2,050,584
Collection Drivers and Trucks Only						1,675,593

Note: Refuse truck operation based on Apra Harbor Landfill location

These include the collection and costs and landfill operations costs, as denoted. The expected increase in operating staff hours is in part due to tonnage increase and also due to additional duties related to operating a landfill with a LFG control system.

The economic analysis in Section 5.5 assumes that these costs will grow in relation to the waste stream tonnage between the two scenarios shown. It also includes estimated annual sums for operations and maintenance of LFG control system during operations and in the post closure maintenance period.

5.1.3 Issues

The principal issue with this alternative is that neither sub-alternative will provide the desired 50 year economic service life.

5.2 Alternative 2 – Use New Landfill Constructed by GOVGUAM

5.2.1 Analysis

The permitting for the Layon Landfill is virtually complete and DPW ready to issue a two-phase construction bid package. Construction was expected to be completed in 24 months. In 2006, the DPW developed a financing plan for closure of Ordot and the construction of the new Layon Landfill that included approximately $13 million in DPW reimbursement costs for planning, design development and permitting activities, approximately $23.4 million in Ordot closure costs, $62.5 million for the development of new landfill and approximately $2 million transfer station improvements through the issuance of approximately $118 million in revenue bonds. However, the legislative approval and PUC rate increase approvals necessary for providing the revenue assurance to the financing community has delayed the revenue bond financing. This delay in closure of Ordot as required under the Consent Decree has resulted in DPW being fined. In addition, the US District Court has placed the Guam Solid Waste Management program in receivership for not complying with the Consent Decree.

5.2.2 Costs

Expense estimates for operations, which are subject to certain economies of scale, will vary based on the quantity of waste delivered to the Layon Landfill. The rate of delivery will also affect the actual timing for the required future cell expansions.

The DPW will incur expenses from the Layon Landfill operations which will include:

- Layon Contractor landfill operating fee
- DPW scale facility operations

Preliminary operating cost estimates were prepared for the financing of Layon Landfill assumed a September 2008 start of operations in accordance with the Consent Decree schedule. At that time, it was estimated that the Layon Contractor operating fee will be approximately $16 per ton (in 2007 dollars), based on the projected tonnage delivery quantities. These rates are assumed to escalate at an annual rate of 3 percent per year.

In addition, debt service costs for revenue bonds for the entire financing were estimated at that time to be approximately $8.8 million per year. Approximately 65 percent of these estimated capital costs were directly related to the Layon Landfill development. However, the project implementation delays have likely increased these costs.

The DPW plans to manage the scale facility operations which will require at least two full-time personnel as well as a part-time person to cover periods of vacation and sick leave. The operating expenses associated for the scale house are anticipated to be approximately $105,500 per year, escalated at 3 percent per annum.

There are also significant future costs that would be incurred for landfill cell expansions, landfill closure and post-closure care that were not included in the original financing package. In order to cover these future capital costs, the DPW had planned on establishing a sinking fund surcharge. The plan was to ramp up these surcharges to minimize the initial “rate shock” on the residential population. Therefore, the early 2007 projection for the 2009 tipping fee at the landfill was approximately $95 per ton.

This rate assumed that the DPW improved residential bill collection efficiency for solid waste collection services to reduce the delinquent accounts, which was more than 50 percent. The revenue shortfall from these delinquent accounts has historically resulted in funding shortfalls for equipment maintenance and unsatisfactory service quality.

5.2.3 Schedule

As discussed in Section 4, GovGuam has not met the deadlines established by the EPA Consent Decree for opening of their new landfill and closure of the Ordot Dump. At this time, the landfill design documents are reported to be under revision, and a definite implementation schedule for construction and operation of the new landfill has not yet been established.

5.2.4 Issues

As discussed in Section 4 above, there are conflicting opinions in the legislature regarding the landfill location, project financing approvals, private versus public solid waste services and waste disposal options. Therefore, while a GovGuam option could eventually be implemented, the final costs and schedule for availability are uncertain. Therefore, the DoD would need an alternative that assures that viable waste disposal will be available.

5.3 Alternative 3 – Construct New Landfill in Central Guam

5.3.1 Analysis

The preliminary site assumed for a new DoD landfill in Central Guam is located in the Ordnance Annex. The site assumed for a new Navy Landfill in central Guam would provide approximately a 60-acre landfill footprint. The existing topography of the site ranges from about 400 feet MSL at the north along Route 5, to approximately 650 feet MSL at the southwestern edge. The landfill site would be accessed from Route 5 by a new road.

A conceptual base and final grading configuration was developed for this report, and would have a maximum elevation of approximately 680 feet MSL. Based on preliminary calculations this configuration would provide a design capacity of 6.35 million cubic yards, or about 2.86 million tons at a waste density of 1,200 lbs/cy and a waste to cover material ratio of 3:1. At the projected annual solid waste stream of 53,320 tons beginning in 2019 after the proposed USMC relocation is completed, the estimated capacity would provide a service life of about 50 years.

The new Navy Landfill would require a permit from the GEPA. There are also remnants of World War II structures that are of historic significance. Section 106 consultation with the Guam Historic Preservation Office would be needed, and mitigation measures may be required. Santa Rita spring is located near the proposed site, and a study to determine the potential impact to the spring may be required.

5.3.2 Costs

Estimated capital dollar costs for initial landfill development under Alternative 3 are shown below for a total of $97,000,000. This includes initial construction for a 60-acre facility with a liner and LCRS. The private financing model assumes that the initial site development and construction of the first two landfill modules would be financed and amortized for 20 years. The remaining eight landfill modules would be funded by scheduled sinking funds (see Appendix D.2). The economic analysis in Section 5.5 assumes this facility would be available in 2012.

ALTERNATIVE 3 NEW LANDFILL	
Landfill Control Building	$687,000
Truck Scale Facility	$140,400
Leachate Treatment System	$2,328,560
Site Work	$65,057,200
Liner and Leachate Collection System	$28,379,520
	$96,593,120

This landfill cost summary does not include costs for a closure cap or LFG control system, which will occur as the site develops. The economic analysis in Section 5.5 is based on a 50 year period for cost comparison of the alternatives (to 2058). During this period the following additional capital costs are assumed to be required, which would be funded using a sinking fund approach.

- 2032 – Construction of the initial phase of the LFG control system over 20 acres and an associated flare. Estimated current dollars cost is $600,000.
- 2038 – Half of the closure cap, involving the estimated landfill capacity of 50 years, is accounted in the analysis based on a current dollars cost of $3,800,000.
- 2045 – It is assumed that the LFG control system will be extended 15 acres (for a total of 35 acres) at an estimated current dollars cost of $450,000.
- 2058 – at the end of the 50-year alternative cost effectiveness comparison in Section 5.5 the estimated current dollars cost of $300,000 for extending the LFG control system an additional 10 acres (total system of 45 acres at that time) is applied. A prorated portion of remaining portion of the landfill final cover cap (20 of 25 years) is also applied in the year 2058. This is estimated to be $3,000,000. (The landfill life would extend to 2063).

The estimated annual operational costs for the Apra Harbor landfill staff and collections operations in 2013 were previously itemized in Section 5.1.2. In the economic comparison in Section 5.5, it is assumed that collection costs under Alternative 3 will increase by 15 percent based on the additional off-route truck time compared to use of the Apra Harbor Landfill (basis of that estimated figure is included in Section 5.5).

5.3.3 Issues

The principal issues regarding this option include verifying the site, performing environmental studies, developing historic asset mitigation measures and obtaining the required permit from the GEPA.

5.4 Alternative 4 – Construct an Incinerator/ Waste-to-Energy facility

DoD has implemented WTE facilities at other base locations to provide steam and electrical energy for its facilities. Therefore this option was considered potentially viable considering the high cost of energy production on Guam.

5.4.1 Analysis

Both a multi-unit modular mass burn facility and a single-unit field-erected waste-to-energy facility were evaluated. Each of these technologies has certain advantages and limitations, but either could be used to manage the combustible portion of the waste stream. The non-combustible components of the waste stream and items such as metal lawn chairs, bicycles, tree trunks, sludge materials, and other materials normally would not be received or would be sorted on the tipping floor and not processed. Pallets may be broken up on the floor or by the crane or loader and then may be charged. Green waste could be taken to a composting operation or may be processed other than large limbs and tree trunks. The retention time in the combustion chamber is not long enough to fully combust such large items and will show up in the ash, which could cause a pluggage in the ash handling system. Recyclable materials could be removed from the waste stream prior to delivery to the WTE facility to minimize the size of the combustion unit. Ash and residue from the modular facility may have a slightly higher residual combustible content and moisture content, but the difference is usually small.

Because some materials cannot be processed and due to the ash residue a landfill is still required if a WTE facility is used. The landfill would also serve as a backup, if the WTE facility is down for maintenance and not capable of processing some or all of the combustible waste. Waste reduction is about ninety percent by volume for the material processed, greatly increasing landfill life. For this analysis it is assumed that about 54 percent reduction can be expected in the volume of material required to be landfilled. It may be possible to find reuses for some or the entire ash residue. Research is underway and applications as a replacement for aggregate material may be possible in the future. In Europe, the bottom ash material is often used in the sub-base of roadways and similar projects. Bottom ash constitutes about 70 to 80 percent of the total ash residue material, thus significant reduction may occur. However, management of the remaining fly ash may require special treatment. Therefore, for this study, ash reuse has not been considered.

Ferrous (magnetic) metal is often recovered from WTE facility ash. It is anticipated that much of the ferrous metal would be removed prior to the waste being sent to the WTE facility and that insufficient ferrous metal will remain to warrant installation of a ferrous recovery system. A reassessment of this assumption could be completed after a facility has been installed and a ferrous recovery system could be added later. Ferrous recovery could offer another potential revenue stream for the facility.

The processing unit(s) requires periodic maintenance. Modular units likely will require short planned outages at least quarterly and possibly as frequently as monthly. Glass material may need to be removed from the primary chamber and other repairs may be required. Field-erected units can achieve longer run cycles. Generally outages are scheduled every six months. Unplanned outages also will occur generally due to equipment failures and material handling issues. The overall capacity factor for the facility however is expected to be 85 percent for modular units and possibly slightly higher (88 percent) for field-erected units.

This analysis assumes energy recovery will be completed. The value of electrical power helps to justify the addition of a turbine generator for the facility. No suitable steam uses have been identified at this time. Use of steam for process applications can greatly increase the economics of the facility by offsetting fossil fuel currently used to generate the steam. This could be a possible upside potential for a facility if a significant steam user is identified.

Air emissions requirements from the facility can be achieved with existing technology. Highly restrictive requirements for larger facilities have been in place for many years and much experience has been demonstrated with field-erected facilities. Somewhat less data is available documenting experience with modular units, however a number of facilities exist and have achieved the requirements. Modular units may have lower emissions for certain pollutants such as NOx; however some of the control technologies used on larger field erected units can greatly reduce this pollutant. Not all of these control technologies may be as effective on modular units.

WTE facilities do require significant consumption of water. The water may be used for boiler makeup, steam cooling, ash quenching, flue gas cooling, and other uses. In an area where water is limited, this may be a concern. Not all water used by the facility is required to be potable or even fresh water. Some facilities use wastewater treatment tertiary water for certain applications. The specific demand for any facility would need to be evaluated. A preliminary site for the WTE facility could be at the south end of South Finegayan adjacent to the proposed location of a possible DoD wastewater treatment plant.

5.4.2 Costs

Capital and operating costs for WTE were developed for both a modular mass burn WTE facility as well as a field-erected mass burn WTE facility. Because energy revenues are significant, a case for an incinerator without energy recovery was not considered. In both cases, it was assumed electricity would be produced and no steam sales would occur. The modular facility is less capital intensive; however the life of the facility is shorter and is less efficient at energy recovery. The field-erected unit is more expensive, but is more durable and part of the extra cost is offset by higher revenue generation.

Because a specific site has not been definitively selected, site development costs are based on a generic site and could vary depending on the site characteristics. It is assumed however that site roadway, utilities, and other improvements are required. No assumption regarding demolition of existing structures was included. It is assumed that water would be obtained from existing nearby supply systems and wells are not needed. Scales and a scale house are included in the estimate.

Since the location of the landfill relative to the combustion facility is not definitively known, for purposes of this analysis it is assumed that the landfill is relatively close and a typical haul cost and disposal fee is included. The actual values will depend upon the final facility arrangement. Overhead and profit for a contract operator is included for both alternatives. No revenues from recovery of ferrous metal were included.

The capital cost for a modular facility is estimated to be about $48 million for the equipment and facility. It is assumed that these initial capital costs would be financed and amortized over 20 years. This includes design engineering, permitting construction, start-up and testing, and other costs to bring the facility to the point of commercial operation. The modular boilers are expected to arrive in a series of shipping crates. The components are partially preassembled minimizing field erection time and costs. Additional equipment such as ash handling and water treatment would be added around the combustion units. The single stage steam turbine would be located in a separate building along with other waterside equipment. Administration and locker areas are also included. Nearly all equipment and operations will be located indoors with waste received and stored on a tipping floor. The waste will be handled with a front-end loader

Annual operating costs are projected to be about $6 million dollars. A large portion of this cost is for labor. It is assumed that about 23 people would be required to operate the facility. Shifts will be maintained around the clock, seven days a week with three people required to operate the facility. During the daytime, additional personnel will be on site to complete administrative tasks, maintenance work, general housekeeping, operate the scales, transport ash and similar tasks. As needed, maintenance and operational help would be called in for other shifts.

Both planned and forced outages will occur for the facility. Planned outages are expected to be required about every two months for each combustor to complete some basic tuning and repairs. Generally these will be short outages just long enough to cool the unit down, inspect the unit and complete the work required. Two to four times per year extra time for additional tasks will be required. Forced outages will also occur. Issues may include boiler tube failures, issues with air pollution control equipment or combustor components. The repairs will be completed and the unit returned to service. The most common system upset is caused by charging something that is too large to process that gets hung up in the ash system or feed system. These issues may be addressed on-line or may require a short outage. It is expected that about 80 to 85 percent availability will be possible.

Electrical revenues are estimated for the modular facility to produce about $490,000 of income for the project. It is assumed that 11 cents per kilowatt can be obtained for the power produced. No steam sales revenue is included in the analysis but would offer potential additional revenue stream if a steam customer is identified.

Life extension measures are required to keep the facility operating through the term of evaluation period. These measures are needed for the comparative analysis with other long-term options for waste disposal. Various components of the facility require ongoing repair and replacement but some component systems eventually wear out and require more significant replacement. For instance, the refractory inside the combustor will crack and need to be replaced as part of the general maintenance for the unit. Over time, however, the entire combustor shell will need to be replaced due to the temperatures and operating conditions encountered. Although the estimated operating costs includes typical maintenance reserves for operating over a typical twenty year contract period, additional capital investment would likely be required to maintain the facility over a 50-year analysis period. The timing of these capital investments is difficult to predict for any particular facility, but based on available data the net present value of these capital investments is expected to be nearly $30 million for the modular WTE facility. Under the private financing model, it is assumed that the majority of these capital costs would be financed and amortized over 20 years, except for smaller costs for minor facility rehabilitation, which would be funded using sinking funds.

The capital cost for a field-erected facility is estimated to be more than twice the cost of a modular facility at about $98 million dollars for the equipment and facility. It is assumed that these initial capital costs would be financed and amortized over 20 years. This includes design engineering, permitting construction, start-up and testing, and other costs to bring the facility to the point of commercial operation. The field-erected boiler has a higher cost for a number of reasons including the extra cost of construction at the site. Since a single unit is provided the nominal size of the facility is larger to provide some additional margin to process accumulated waste after facility outages. Field erection results in a more durable unit. Additional equipment such as ash handling and water treatment would be added around the combustion units. The condensing steam turbine would be located in a separate building along with other waterside equipment. Administration and locker areas are also included. Nearly all equipment and operations will be located indoors with waste received and stored in a concrete bunker. The waste will be mixed and charged using refuse cranes.

Annual operating costs are projected to be about $7 million dollars. Labor required for the field-erected unit is assumed to be similar to that required for the modular facility. It is assumed that about 23 personnel would be required to operate the facility. Shifts will be maintained around the clock seven days a week with three personnel required to operate the facility. During the daytime additional personnel will be on site to complete administrative tasks, maintenance work, general housekeeping, operate the scales, transport ash and similar tasks. Maintenance and operational help would be called in for other shifts as needed.

Both planned and forced outages will occur for the facility. Planned outages are expected to be required about every six months to complete some basic tuning and repairs. Generally these will last several days to allow for inspection of the unit and completion of the work required. Forced outages will also occur. The most common problems include boiler tube failures, issues with air pollution control equipment or combustor components. The repairs will be completed and the unit returned to service. Short term outages or upsets may result from charging something that is too large to process or gets hung up in the ash system. It is expected that about 85 to 88 percent availability will be possible.

Electrical revenues are estimated for the modular facility to produce about $1,700,000 of income for the project. It is assumed that 11 cents per kilowatt can be obtained for the power produced. No steam sales revenue is included in the analysis but would offer potential additional revenue stream if a steam customer is identified.

Life extension measures are required to keep the facility operating through the term of evaluation period. These measures are needed for the comparative analysis with other options for waste disposal. Various components of the facility require ongoing repair and replacement but some component systems eventually wear out and require more significant replacement. Although the estimated operating costs includes typical maintenance reserves for operating over a typical twenty year contract period, additional capital investment would likely be required to maintain the facility over a 50-year analysis period. Over the life of this extended evaluation period, it is assumed that a fund with $5.3 million would be required for the field erected WTE facility. It is assumed that the majority of these capital costs would be financed and amortized over 20 years, except for smaller minor facility rehabilitation costs, which would be funded using sinking funds.

5.4.3 Schedule

Development, permitting, and construction of a WTE facility must be completed prior to commercial operation of the facility. It is estimated that five years is required to complete these steps. Implementation of a project can be achieved prior to 2014 when it is anticipated that the facility would be required. Progress would however need to begin soon and no major roadblocks occur for it to be in place by that time. A landfill will still be required at that time for ash disposal and for disposal of non-combustible waste and bypass waste.

5.5 Alternative Comparisons

5.5.1 Implementation and Scheduling Issues

Table 5-1 describes the major scheduling assumptions for this report. As shown, these are what are judged the most optimistic or aggressive scheduling assumptions also used in the cost comparison in the following section.

The first row shows the assumed implementation actions for the Navy Landfill at Apra Harbor. For Alternative 1, including both final fill configurations, 1-1 and 1-2 it is assumed that the Navy would install a liner on all or part of the permitted landfill area footprint in 2009 to allow additional landfilling.

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TABLE 5-1

Scheduling Assumptions

Alternative	1-1	1-2	2	3	4
Description	Apra Harbor Landfill (54 MSL)	Apra Harbor Landfill (100 MSL)	GovGuam Landfill near Layon	New Navy Landfill in Central Guam	Waste-to-Energy
Major Implementation Actions at Apra Harbor Landfill	2009 Landfill improvements and line inactive area only 2013 LFG control system and flare	2009 Landfill improvements and line entire footprint 2013 LFG control system and flare	2010 Construct closure cap and LFG venting system (active area only - no liner)	2009 Landfill improvements and line inactive area 2013 Closure cap and LFG control system installation	2009 Landfill improvements and line entire footprint 2013 LFG control system and flare
Alternative Implementation			2010 Begin landfilling at GovGuam Landfill (pending resolution of issues)	2012 Construction of initial module and site ancillary facilities needed for operation.	2012/13 Construct WTE Facility
Assumed Life of Alternative Implementation Measures	14 years (2023) (7.4 ppp/d and revised operations)	27 years (2036) (7.4 ppp/d and revised operations)	>50 years (>2058)	>50 years (>2058)	>50 years (>2058)
Major Projects Over Life or 50 years	2023 Assumed closure cap	2036 Assumed closure cap		2038 Assumed incremental closure of ½ of landfill	2029, 2039, 2049 Minor life extension measures 2034, 2054 Minor life extension measures

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For Alternative 2, it is assumed that GovGuam would resolve permitting and implementation issues and the new landfill near Layon would be available for landfilling in 2010. In this case, it is assumed that the Navy would not need to provide the investment of lining the inactive area of the Navy Landfill and would perform limited filling of the active area prior to performing closure in 2010.

Alternative 3 assumed that it will take three years for the Navy to perform site selection, design and permitting of a landfill in Central Guam. Construction of the initial lined module and ancillary facilities would occur in 2012 to allow filling operations to begin at the new site and closure of the Apra Harbor Landfill in 2013.

The implementation of Alternative 4 is assumed to require construction of a WTE facility in 2012 and 2013.

A major difference between Alternative 1 and the other alternatives implementing new strategies or facilities is that Alternative 1 does not provide service for the 50 year period analyzed in the cost effectiveness analysis in the following section. The site lives for the two final fill configurations used for Alternative 1 are estimated to extend to 2023 and 2036, respectively. One of the other alternatives would have to be implemented to provide a long term strategy of 50 years to the year 2058. Under these scenarios minor and major rehabilitation of the WTE facility would have to occur for Alternative 4.

Given its considerable size, out of operational considerations it is assumed that the Navy will consider developing the new Landfill in Central Guam in modules. Constructing the new landfill sequentially in modules is recommended to reduce the exposure of unused liner to degradation from ultraviolet rays and to storm-water that must be managed separate from the LCRS flows. Constructing an entire liner for 50 years of landfill area is not preferred because exposure to the elements, in particular sunlight ultraviolet rays would compromise the liner. However, the entire landfill liner and development cost is discounted in a lump sum in 2012, the initial year of liner construction.

As discussed previously, the schedule allowing the Navy to use the GovGuam facility is a significant uncertainty at this time. However, even if it is delayed longer than the assumed year of availability of 2010 it is unlikely that it would be delayed beyond 2013 when the other alternatives would become operational unless there is a fatal flaw and the GovGuam landfill cannot become operational as proposed by GovGuam. In this case it would not be a viable alternative.

5.5.2 Cost Comparison

The total net present value costs based on 25-year and 50-year periods under military construction funding for the detailed evaluation of solid waste alternatives are summarized in Table 5-2. The total net present value costs based on 25-year and 50-year periods under private funding for the detailed evaluation of solid waste alternatives are summarized in Table 5-3. Appendix D contains the spreadsheet tables that show the annual current dollars and present value analysis for the capital, operating and revenues (WTE Alternative) for the alternatives under both military construction funding and private funding. Appendix D also contains the detailed cost assumptions and calculations used for the analysis.

Following are major findings regarding the cost and economic analysis:

- Continued use of the existing Navy Landfill at Apra Harbor with lining of the inactive portion of the landfill and a separation liner over the active portion of the landfill is the most cost-effective alternative when considering only a 25-year planning period. This alternative would not provide 50-years of service unless the Navy was willing to exceed the anticipated target elevation of 100 feet MSL.
- Navy implementation of a new landfill in Central Guam (Alternative 3) at the assumed location provides the most cost effective alternative over the 50-year analysis period, assuming a $95/ton tip fee for use of the proposed GovGuam Landfill near Layon (Alternative 2). The long term 50-year analysis shows the present value of Alternative 3 as approximately nine percent lower given the economic assumptions.
- Although the Apra Harbor Landfill does not provide 50 years of service without implementing another alternative strategy; utilizing the existing Apra Harbor Landfill to the capacity provided by Alternative 1-2 prior to implementing a new landfill in Central Guam would provide the most cost effective strategy. This is demonstrated by the result that the net present value cost of Alternative 1-2 is less than Alternative 3 for the 25-year analysis.
- The WTE alternatives are roughly 1.5 times the estimated present value of a new Central Guam Landfill due to retention of the landfill costs for non-burnable waste and ash plus the higher operating costs for a WTE facility.

Table 5-2
Summary of Present Value Analysis – Military Construction Funding

Alternative	PV Analysis 25 - Year	PV Analysis 50 - Year
Alternative 1-1 Apra Harbor Landfill - 54 ft MSL See Note b	Inadequate Service Life	Inadequate Service Life
Alternative 1-2 Apra Harbor Landfill - 100 ft MSL See Note c	56,000,000	Inadequate Service Life
Alternative 2 GovGuam landfill See Note d,e	123,000,000	189,000,000
Alternative 3 New Navy Landfill See Note f	149,000,000	174,000,000
Alternative 4a Modular WTE Facility See Note g	179,000,000	270,000,000
Alternative 4b Field-Erected WTE Facility See Note g	210,000,000	277,000,000

Notes:

a Present Value Analysis uses a real discount rate of 2.8 percent in accordance with OMB Circular No. A-94, Appendix C, Rev January 2008.

b Estimated service life is limited to the year 2023 and would be exhausted prior to the end of the 25-year and 50-year analysis periods.

c Estimated service life is limited to the year 2036 and would be exhausted prior to the end of the 50-year analysis period.

d Assumed tip fee at the GovGuam landfill is $95/ton over the analysis period.

e Costs include an estimated 40 percent increase in collection driver/truck costs to use GovGuam landfill as compared to the current system. After the proposed relocation of Marines is completed, 80 percent of the DoD solid waste stream will be generated in Northern Guam.

f Costs include an estimated 15 percent increase in collection driver/truck costs to use new Navy landfill in Central Guam as compared to the current system. After the proposed relocation of Marines is completed, 80 percent of the DoD solid waste stream will be generated in Northern Guam.

g It is assumed that WTE would extend service life of the Apra Harbor Landfill to 65 years for landfilling of incombustible waste and residual ash.

Table 5-3
Summary of Present Value Analysis – Private Entity Funding

Alternative	PV Analysis 25 - Year	PV Analysis 50 - Year
Alternative 1-1 Apra Harbor Landfill - 54 ft MSL See Note b	Inadequate Service Life	Inadequate Service Life
Alternative 1-2 Apra Harbor Landfill - 100 ft MSL See Note c	60,000,000	Inadequate Service Life
Alternative 2 GovGuam Landfill See Notes d,e	123,000,000	189,000,000
Alternative 3 New Navy Landfill See Note f	153,000,000	176,000,000
Alternative 4a Modular WTE Facility See Note g	184,000,000	270,000,000
Alternative 4b Field-Erected WTE Facility See Note g	217,000,000	283,000,000

Notes:

a Present Value Analysis uses a real discount rate of 2.8 percent in accordance with OMB Circular No. A-94, Appendix C, Rev January 2008.

b Estimated service life is limited to the year 2023 and would be exhausted prior to the end of the 25-year and 50-year analysis periods.

c Estimated service life is limited to the year 2036 and would be exhausted prior to the end of the 50-year analysis period.

d Assumed tip fee at the GovGuam landfill is $95/ton over the analysis period, which is discounted over the analysis period.

e Costs include an estimated 40% collection driver/truck cost increase to use GovGuam landfill as compared to the current system. After proposed USMC relocation is completed, 80% of the DoD solid waste stream will be generated in Northern Guam.

f Costs include an estimated 15% collection driver/truck cost increase to use new Navy landfill in Central Guam as compared to the current system. After proposed USMC relocation is completed, 80% of the DoD solid waste stream will be generated in Northern Guam.

g It is assumed that WTE would extend service life of the Apra Harbor Landfill to 65 years for landfilling of incombustible waste and residual ash.

h. Capital projects over the study period were assumed to be financed or funded through a sinking fund, except for Alternative 2, which utilizes planned GovGuam Landfill costs.

i. Capital projects financing assumed 20-year periods except for Alternative 1-1, which used a 15-year period based on projected service life.

j. Capital projects financing assumed Japanese bank financing with an amortized origination fee of 1.00 percent and an interest rate of 2.5 percent.

k. Capital project sinking funds used various accumulation periods based on cash flow requirements and assumed earned interest at an annual percentage rate of 1.0%.

l. Equal annual landfill closure fund deposits were accumulated over the alternative landfill life including earned interest at an annual percentage rate of 1.0%.

5.5.3 Pros and Cons

Table 5-4 is a matrix of the four viable alternatives analyzed in this section after alternatives 5 through 10 were judged non-viable as described in Section 4. The table lists the pros and cons of the alternatives in terms of environmental, regulatory, implementation/policy, economics and scheduling issues.

Although Alternative 1 presents the most economical approach, it is limited in service life for Alternative 1-1 (7 to 14 year site life depending on operations) and does not present a comparable 50-year economic life for Alternative 1-2. Although with improved equipment and operational practices at the Apra Harbor Navy Landfill it is estimated that an additional 27 years of site life would remain. There may be some concerns about a separation liner above waste being compromised in the long term by differential settlement, or the affects of significant waste overburden on the existing unlined portion of the landfill that may be releasing low levels of VOCs. Based on this evaluation, Alternative 1 appears to provide an interim approach to implementing one of the other alternatives in the long term.

Alternative 2, use of the planned GovGuam landfill, provides an economical approach. Based on the projected $95/ton tip fee, use of the proposed GovGuam landfill was shown to be comparable in cost-effectiveness to construction of a new Navy Landfill. However, given the level of uncertainty and difficulties experienced by GovGuam in implementing the new landfill, the proposed GovGuam landfill does not appear to be as reliable as implementing a new Navy Landfill in Central Guam.

Alternative 3, a new Navy landfill in Central Guam, provides an economical approach based on the present value analysis over both 25 and 50 year periods. A drawback to this approach appears to be that the GEPA has indicated a preference that the Navy and DoD use Alternative 2, the planned GovGuam Landfill near Layon.

Alternative 4 is significantly more costly than use of the proposed GovGuam landfill and a new Navy Landfill in Central Guam. A WTE facility at the relatively small scale required has poor economics which are even more costly as a strategy given that a landfill operation would also need to continue for non-burnable waste and residual ash. However, a WTE facility also provides for continued solid waste disposal capacity well beyond 50-year period utilized for this study. Because of the very limited availability of land on Guam, WTE should continue to be considered as part of a "very-long-term" strategy for handling and disposal of DoD solid waste on Guam.

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TABLE 5-4
SUMMARY MATRIX OF COMPARATIVE PROS AND CONS (P= Pro; C= Con)

Alt.	Option/Issue	Environmental	Regulatory	Implementation/Policy	Economics	Schedule
1	Improve Existing Navy Landfill at Apra Harbor (AHNLF)	C- May increase extent/duration of VOC migration C- Slightly greater degree of GHG emissions compared to adding WTE and/or MRF C- Separation liner (Alt 1-2) has potential to fail due to differential settlement.	C- GEPA likely to require separation liner over active area (assumed for Alternative 1-2 but not Alternative 1-1). C- Would use AHNLF up to 27 years by filling to elevation 100 MSL (Alt. 1-2). The GEPA may not approve a permit for continued use of the landfill for this long of a period.	C- GovGuam and GEPA prefer regional landfill for entire island	P/C – Alternative 1-1 does not provide comparison to other alternatives for 25 and 50-year periods; however, can be used as less costly interim alternative to Alternatives 2 through 4. C- Significant capital cost required for liner and LCRS system under Alternative without providing long-term strategy.	P- Although not providing a long-term strategy, provides more than adequate flex time for decisions and implementing other alternatives (Alt. 1-1= 2015 with current fill practices; Alt. 1-2=2036, with revised filling practices).
2	Use New Landfill Constructed by GovGuam	P- Entire new GovGuam landfill would be lined with base liner on native soil (compared to separation liner over waste for Alt 1-2)	P- If available soon (assumed expedited by 2010), $11M for site improvements and liner for inactive area of AHNLF would not be required. P- Based on letter communication GEPA appears to favor DoD use of the proposed GovGuam Landfill and closure of the AHNLF as soon as possible.	C- Historical and current lack of stable garbage fee collection is impediment to obtaining financing of proposed new GovGuam Landfill. C- Navy would be at risk if GovGuam cannot implement proposed new landfill when needed to replace AHNLF. C- Navy would be dependent on the GovGuam landfill; with less control if funding, environmental control, operational or other problems occur with the landfill.	C- Present Value analysis indicates $123M and $189M for 25 and 50 year analysis, respectively, at an assumed $95/ton tip fee. The 50 year analysis indicates that this alternative is nine percent higher than Alternative 3. C- Increase in collection costs from AAFB, the proposed USMC relocation and Navy Base to new GovGuam landfill in south (Estimated 40 percent increase in truck and driver cost compared to AHNLF location). P- New large liner capital investment by DOD not required C- Lack of enforceable fee collection system by GovGuam could negatively affect reliable economics for DoD.	P- There is adequate capacity at the AHNLF provided that GovGuam can resolve all Consent Decree and permitting issues to allow Navy disposal. The AHNLF has a range of 7 to 12 years with current operating conditions and up to 14 to 27 years with recommended operational improvements; depending up whether AHNLF can be filled to elevation 54MSL or 100MSL. C – The timing for resolution of permitting issues for the proposed GovGuam landfill is not clear at this time.
3	Construct New Navy Landfill in Central Guam	P- Lined Landfill should reduce degree/term of VOC migration from existing AHNLF if closed sooner	C- Appears that GEPA wants the DOD to use the planned GovGuam landfill near Layon (letter).	P- New landfill would provide 50 years of service and operational flexibility to the DoD. C- Historic asset mitigation required at preliminary site. C- Potential impact to Santa Rita Spring must be determined. C- Permit form GEPA required	P- Present Value analysis indicates $149M and $174M for 25 and 50 year analysis including capital, landfill operations, and collection driver and truck costs under MCON funding. Under private funding this alternative has a PV of $153M and $176M for 25 and 50 yr analysis, respectively. C- Slightly less collection economics (Estimated 15 percent increase in truck and driver cost) compared to current system using AHNLF	P- Siting and constructing a new MSWLF typically can take at least 4 years. Given that Alternative 1-1 provides 7 years of capacity without operational improvements (heavier equipment and operational improvements may increase this to 14 years); scheduling for developing the new landfill is judged as viable.
4	Incinerator/Waste-to-Energy	P- Less GHG emissions than landfill for combustible fraction of waste stream; also would provide an energy offset C- Landfill still required for significant portion (46 percent) of the waste stream	C- Significant air quality permitting. C- Would use AHNLF in long term for disposal of non-combustible waste and ash. The GEPA may not approve the continued use of the landfill for >50 years given existing portion of unlined waste. C- Guam PL 25-175 Amended 10 GCA Chapter 73, Fire Prevention to prohibit municipal solid waste incinerators. A determination must be made regarding the applicability of 10 GCA Chapter 73 to DoD.	C- Significant initial financing is required: $46M and $98 capital cost, respectively, for Modular (4a) or Field Erected (4b) facilities.	C - Present Value analysis for Modular (4a) facility indicates $179M and $270M for 25 and 50 year analysis, respectively under MCON funding. Under private funding this alternative has a PV of $184M and $270M for 25 and 50 yr analysis, respectively. C - Present Value analysis for Modular (4b) facility indicates $210M and $277M for 25 and 50 year analysis, respectively under MCON funding. Under private funding this alternative has a PV of $217M and $283M for 25 and 50 yr analysis, respectively.	C- Expedited earliest schedule is assumed to allow phased construction in 2012 and 2013 at the soonest.

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6.0 Limitations

6.1 Waste Diversion Potential

The focus of this study is the final disposal of solid waste. Therefore, methodologies such as materials recovery, waste diversion, waste minimization, and source reduction were not incorporated into the analysis. These methodologies would generally reduce the volume of solid waste requiring final disposal. However, for this study, they would not significantly affect the selection of a particular disposal technology. When final selection of a disposal facility is selected, however, waste diversion potential should be reevaluated.

6.2 Additional Development Studies

Additional development studies will be needed and include the following:

- Conduct a site engineering investigation for improvements to the existing Navy Landfill at the Apra Harbor Naval Complex. Prepare a landfill operation and implementation manual with grading plans to facilitate filling to the target final landfill elevation.
- Conduct a site engineering investigation of the proposed site for a new Navy Landfill in the Apra Harbor Naval Complex Ordnance Annex.
- Conduct environmental investigations for the proposed site for a new Navy Landfill in the Apra Harbor Naval Complex Ordnance Annex. The environmental investigations would more definitively identify the potential impacts and mitigative measures that may be required.
- Conduct a preliminary engineering study for development of a DoD Waste-to-Energy Facility.
- Conduct an engineering study to investigate the feasibility of a solid waste transfer station and materials recovery facility on DoD property in northern Guam.

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7.0 Recommendations

The major findings of the study are summarized below.

- Continued use of the existing Navy Landfill at the Apra Harbor Naval Complex is necessary to provide sufficient time to implement planning and construction of new solid waste disposal facilities.
- GEPA has regulatory primacy for enforcing USEPA solid waste regulations on Guam. It is anticipated that soon after the new GovGuam lined landfill becomes operational, GEPA would require all landfills on Guam to be lined or to be closed. This would have a direct impact on the existing unlined Navy Landfill at Apra Harbor. It would be prudent to begin programming a project that would include a liner for the inactive portion of the existing landfill and a separation liner for the active portion of the existing landfill.
- A landfill is needed for essentially any alternative considered. Materials that cannot be handled by a particular process and the residual material generated by a process will require landfill disposal.
- Continued use of the existing Navy Landfill at the Apra Harbor Naval Complex would not provide 50 years of service unless the DoD is willing to fill to elevations higher than 100 feet mean sea level (MSL). Based on current design criteria for constructing landfills, the existing landfill could be filled to elevation 140 feet MSL.
- Construction of a new DoD landfill on DoD property in central Guam is the most cost-effective and reliable alternative on a 50-year life cycle cost basis under both military construction and private sector funding. Because the landfill would be a DoD landfill, the DoD would control the waste allowed to be disposed in the landfill. Certain waste streams could be diverted to other available solid waste facilities, such as the GovGuam landfill, to extend the life of the DoD landfill.
- Use of the GovGuam Layon Landfill has a 50-year life cycle cost that is slightly higher but essentially comparable to construction of a new DoD landfill. However, the Layon Landfill has not yet begun construction and it is uncertain when the landfill would become operational. In addition, under this alternative, the DoD would be entirely dependent on the Layon Landfill. If the capacity is reached earlier than anticipated and GovGuam again has difficulties in constructing a replacement landfill, the DoD will be significantly impacted.

- Construction and operation of a waste to energy (WTE) facility has the highest 50-year life cycle cost. However, a WTE facility has potential for extending the life of the existing Navy Landfill at the Apra Harbor Naval Complex well beyond the 50-year service life considered for this study.

Based on the results of the analysis and evaluations performed for this study, the recommendations below are offered.

- Establish a planned final fill plan for the existing Navy Landfill at the Apra Harbor Naval Complex corresponding to the alternative final fill plan for elevation 100 feet mean sea level. Retain the option to fill to elevation 140 feet mean sea level if the need arises in the future.
- Revise landfill operation practices as recommended in the Sanitary Landfill Management Plan. The revised practices include utilizing a systematic daily cell construction method with a single application of daily cover material, and obtaining heavier landfill operating equipment, such as a Caterpillar D8 or equivalent, outfitted for landfill service.
- Implement improvements to the existing Navy Landfill including the construction of a liner for the inactive area and a separation liner for the active area. The project can be phased to allow flexibility to make adjustments if construction of a Waste-to-Energy Facility moves forward. The liner should be designed to accommodate filling to elevation 140 feet mean sea level. This would provide DoD the flexibility to fill to that elevation if it became necessary to do so.
- Conduct a study to develop a long-term strategy for managing potential releases from the unlined active portion of the existing Navy Landfill. The study should include assessment of mitigation measures that might be needed if a separation liner is constructed over the existing active portion of the landfill.
- Develop a project to construct a new Navy Landfill within the Apra Harbor Naval Complex Ordnance Annex. This landfill will be needed in the foreseeable future, particularly if a Waste-to-Energy Facility does not move forward.
- Track status of construction of the new GovGuam landfill and continue to evaluate its potential for disposal of DoD solid waste, particularly residential solid waste generated from housing areas, in the future.

8.0 References

U.S. EPA, Title 40 CFR Chapter 1 Part 258, Criteria for Municipal Solid Waste Landfills, 1 July 1996.

U.S. EPA, Title 40 CFR Chapter 1 Part 60, Subpart AAAA, New Source Performance Standards for Small Municipal Waste Combustion Units, 31 January, 2003

Subtitle C of the Resource Conservation and Recovery Act (RCRA),

GEPA, Rules and Regulations for the Guam Environmental Protection Agency – Solid Waste Disposal, Title 22, Division 4, Chapter 23.

Guam 2006 Integrated Solid Waste Management Plan

U.S. Navy Public Works Center, Guam, Sanitary Landfill Closure Plan and Post Closure Plan, September 1999.

Barrett Consulting Group, Inc., Hydrogeologic Investigation of the Naval Station Landfill, Guam, Mariana Islands, 1 February 1988.

GMP Associates, Landfill Vertical Expansion Evaluation, PWC Guam Landfill, U.S. Naval Public Works Center, Guam, Marianas Islands, September 1996.

A Draft Environmental Impact Statement – – Layon Landfill Location (1995, J.C. Tenorio and Associates, Inc., Consulting Engineers

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Appendices

Appendix A

GEPA Rules and Regulations for Solid Waste Disposal

RULES AND REGULATIONS FOR THE GUAM ENVIRONMENTAL PROTECTION AGENCY (GEPA) SOLID WASTE DISPOSAL

Title 22

Division 4

Chapter 23

Article 1

General regulations

Article 2

Location restrictions

Article 3

Operating criteria

Article 4

Design criteria

Addendum A

Schedule of permit fees for all other solid waste management facilities.

Addendum B

Duration of permit fees for all other solid waste management facilities.

Addendum C

Administrative penalties.

Appendix I

Constituents for detection monitoring.

Appendix II

List for hazardous and organic constituents.

Article 1

General regulations

§23101. Purpose, scope, and applicability. (a) The purpose of this Chapter is to establish the Guam's minimum criteria for all Municipal Solid Waste Landfill (MSWLF) units and other solid waste management facilities. These minimum criteria are intended to ensure the protection of human health and the environment.

(b) These rules and regulations apply to owners and operators of new Municipal Solid Waste Landfill units, existing Municipal Solid Waste Landfill units, and lateral expansions, except as otherwise specifically provided in this Chapter. All other solid waste management facilities and practices that are not regulated under Subtitle C of Resource Conservation and Recovery Act ('RCRA'), 42 U.S.C. §6941, as amended, are subject to the criteria contained in 40 CFR, Part 257.

(c) These criteria do not apply to Municipal Solid Waste Landfill units that do not receive waste after October 9, 1991.

(d) Municipal Solid Waste Landfill units that receive waste after October 9, 1991 but stop receiving waste before October 9, 1993 are exempt from all the requirements of this Chapter, except the final cover requirement specified in Article 6, §23601 'Closure criteria' of this Chapter. The final cover must be installed within Six (6) months of last receipt of wastes. Owners or operators of Municipal Solid Waste Landfill units described in this paragraph that fail to complete cover installation within this Six (6) month period will be subject to all the requirements of this Chapter unless otherwise specified.

(e) All Municipal Solid Waste Landfill units that receive waste on or after October 9, 1993 must comply with all requirements of this Chapter unless otherwise specified.

(f) Municipal Solid Waste Landfill units failing to satisfy these criteria are considered open dumps for purposes of Guam solid waste management planning under RCRA.

(g) Municipal Solid Waste Landfill units failing to satisfy these criteria constitute open dumps, which are prohibited under §4005 of the RCRA.

(h) Municipal Solid Waste Landfill units containing sewage sludge and failing to satisfy these criteria violate §§309 and 405(e) of the Clean Water Act of 1977, 33 U.S.C. 1251, as amended.

(i) This Part shall be effective immediately.

§23102. Definitions. (a) Unless otherwise noted, all terms contained in this Section are defined by their plain meaning. This Section contains definitions for terms that appear throughout this Chapter; additional definitions appear in the specific sections to which they apply.

(1) 'Active area' shall mean that portion of a facility where solid waste recycling, treatment, storage, or disposal operations are being conducted, designed to be, or have been conducted. Buffer zones shall not be considered part of the active area of a facility.

(2) 'Active life' means the period of operation beginning with the initial receipt of solid waste and ending at completion of closure activities in accordance with Article 6, §23601 'Closure criteria' of this Chapter.

(3) 'Active portion' means that part of a facility or unit that has received or is receiving wastes and that has not been closed in accordance with Article 6, §23601 'Closure criteria' of this Chapter.

(4) 'Administrator' shall mean the Administrator of the Guam Environmental Protection Agency or his designee.

(5) 'Agency' shall mean the Guam Environmental Protection Agency.

(6) 'Agricultural waste' shall mean wastes on farms resulting from the production of agricultural products including, but not limited to manures and carcasses of dead animals.

(7) 'Air quality standard' shall mean a standard set for maximum allowable contamination in ambient air as set forth in Guam's Air Pollution Control Standards and Regulations.

(8) 'Alternate Boundary' shall mean a boundary line that may be used in lieu of the disposal facility's property line, subject to the Administrator's approval.

(9) 'Aquifer' means a geological formation, group of formations, or portion of a formation capable of yielding significant quantities of ground-water to wells or springs.

(10) 'Ashes' shall mean the residue including any air pollution flue dusts from combustion or incineration of material including solid wastes.

(11) 'Base Flood' shall mean a flood that has a One Percent (1%) or greater chance of occurring in any year or a flood of a magnitude equalled or exceeded once in One Hundred (100) years.

(12) 'Bioremediation' shall mean the process by which organic materials (e.g. petroleum products) are biologically degraded, usually to innocuous materials such as carbon dioxide, methane, water, inorganic salts, biomass, and by-products that are less complex than the parent compound.

(13) 'Board' shall mean the Board of Directors of the Guam Environmental Protection Agency.

(14) 'Buffer zone' shall mean that part of a facility that lies between the active area and

the property boundary.

(15) 'Bulky waste' shall mean large items of refuse, such as appliances, furniture, automobiles, and other oversize wastes which would typically not fit into reusable or disposable containers.

(16) 'Cell' shall mean compacted solid wastes that are enclosed by natural soil or cover material in a sanitary landfill.

(17) 'Clean Water Act' shall mean the Clean Water Act of 1977 which amended the Federal Water Pollution Control Act of 1972, codified as 33 U.S.C. §1251, as amended.

(18) 'Closure' shall mean those actions taken by the owner or operator of a solid waste site or facility to cease operations and to ensure that all such facilities are closed in conformance with applicable regulations at the time of such closures and to prepare the site for the post-closure period.

(19) 'Collecting agency' shall mean any agency, business or service operated by a person with a Solid Waste Collection Permit for the collection of solid waste.

(20) 'Commercial solid waste' means all types of solid waste generated by stores, offices, restaurants, warehouses, multiple dwellings of five or more units, hotels, motels, bunkhouses, ranger stations, crew quarters, campgrounds, picnic areas, and day-use recreation areas and other non-manufacturing activities, excluding residential and industrial wastes.

(21) 'Compliance schedule' shall mean a written schedule of required measures in a permit including an enforcement sequence leading to compliance with this Chapter.

(22) 'Composting' shall mean the controlled degradation of organic solid waste.

(23) 'Container' shall mean a device used for the collection, storage, or transportation

of solid waste including but not limited to reusable containers, disposable containers and tanks, fixed or detachable.

(24) 'Cover material' shall mean soil or other approved suitable material that is used to cover compacted solid wastes in a land disposal site.

(25) 'Daily cover' shall mean cover material that is spread and compacted on the top and side slopes of a solid waste cell at the end of each operating day or after a period of Twenty-four (24) hours in order to control vectors, fire, moisture and erosion, and to assure aesthetic appearance.

(26) 'Demolition waste' shall mean solid waste, largely inert waste, resulting from the demolition or razing of buildings, roads and other man-made structures. Demolition wastes consists of, but is not limited to, concrete brick, bituminous concrete, wood and masonry, roofing material, steel, and minor amounts of other metals like copper. All these materials can be used as hardfill materials. Plaster or any other material that is likely to produce gases or a leachate during the decomposition process are not considered to be demolition waste for the purposes of this Chapter. Asbestos waste is also not considered to be demolition waste for the purpose of this Chapter.

(27) 'Detachable containers' shall mean reusable containers that are mechanically loaded or handled such as a 'dumpster' or drop box.

(28) 'Disposal containers' shall mean containers that are used once to handle solid waste such as plastic bags, cardboard boxes, and paper bags.

(29) 'Disposal' shall mean the discharge, deposit, injection, dumping, spilling, leaking or placing of any solid waste or hazardous waste into or on any land or water so that such solid

waste or hazardous waste or any constituent thereof may enter the environment or be emitted into the air or discharged into any waters including ground-water.

(30) 'Disposal site' shall mean the location where any treatment, utilization, processing, or deposition of solid waste occurs. See also the definition of interim solid waste facility.

(31) 'Endangered or threatened species' shall mean any species listed as such pursuant to the Endangered Species Act of Guam, §63201 of Title 5, Guam Code Annotated or the United States Endangered Species Act of 1973, as amended.

(32) 'Energy recovery' shall mean the recovery of energy in a usable form from mass burning or refuse derived fuel incineration, pyrolysis of any other means of using the heat of combustion of solid waste that involves high temperature processing.

(33) 'Existing facility' shall mean a facility which is owned or leased, and in operation, or for which construction has begun, on or before the effective date of this Chapter and the owner or operator has obtained permits or approvals necessary under Federal and Guam statutes, regulations and ordinances. A facility has commenced construction if either:

(A) on-site physical construction program has begun; or

(B) the owner or operator has entered into contractual obligations which cannot be cancelled or modified without substantial loss for physical construction of the facility to be completed within a reasonable time frame.

(34) 'Existing municipal solid waste landfill unit' shall mean any municipal solid waste landfill unit that is receiving solid waste as of October 9, 1993. Waste placement in existing units must be consistent with past operating practices or modified practices to ensure good management.

(35) 'Expanded facility' shall mean a facility adjacent to an existing facility for which

the land is purchased and approved by GEPA after the effective date of this Chapter. A vertical expansion approved and permitted by GEPA after the effective date of this Chapter shall also be considered an expanded facility.

(36) 'Facility' shall mean all contiguous land and structures, other appurtenances, and improvements on the land used for the disposal, transfer, storage, treatment, and processing, of solid waste.

(37) 'Facility structures' shall mean buildings, sheds, utility lines, and drainage pipes on the facility.

(38) 'Final cover' shall mean a cover system designed and constructed to:

(A) have permeability less than or equal to the permeability of any bottom liner system or natural subsoils present of a permeability no greater than 1 x 10^{-5} cm/sec, which ever is less, and

(B) minimize infiltration through the closed Municipal Solid Waste Landfill unit by the use of an infiltration layer that contains a minimum of Eighteen (18) inches of an earthen material, and

(C) minimize erosion of the final cover by the use of an erosion layer that contains a minimum Six (6) inches of earthen material that is capable of sustaining native plant growth.

(39) 'Final treatment' shall mean the act of processing or preparing solid waste for disposal, utilization reclamation or other approved method of use.

(40) 'Free-liquids' shall mean any sludge which produces measurable liquids when the Paint Filter Liquids Test, Method 9095 of Environmental Protection Agency Publication Number

SW-846, is performed.

(41) 'Free moisture' shall mean liquid that will drain freely by gravity from solid materials.

(42) 'Garbage' shall mean discarded animal and vegetable wastes, and animal and vegetable wastes resulting from the handling, preparation, cooking and serving of foods, including cans, bottles and cartons, in which it was received and wrapping in which it may have been placed for disposal, swill and carcasses of dead animals of such a character and proportion as to be capable of attracting or providing food for vectors. This does not include raw sewage or sludge related to wastewater processes.

(43) 'Ground-water' shall mean water below the land surface in a zone of saturation.

(44) 'Hardfill' shall mean a method of compaction and earth cover of solid waste, other than those containing garbage or other putrescible (putrescent) waste, including, but not limited to, demolition waste and like waste not constituting a health or nuisance hazard, where cover need not be applied on a per day used basis.

(45) 'Hazardous waste' shall mean any material or substance which, by reason of its composition or characteristics,

(A) is hazardous waste as defined in the Solid Waste Disposal Act, 42 USC §6901, et seq., as amended, replaced or superseded and the regulations implementing same,

(B) is a hazardous substance as defined by the Comprehensive Environmental Response, Compensation and Liability Act of 1980, 42 USC §9601, et seq.,

(C) is material the disposal of which is regulated by the Toxic Substances Control

Act, 15 USC §2601, et seq., as amended, replaced, or superseded, and the regulations implementing same,

(D) is special nuclear or by-products material within the meaning of the Atomic Energy Act of 1954,

(E) is pathological, infectious or biological waste,

(F) is treated as hazardous waste or as a hazardous substance under applicable law, or

(G) requires a hazardous waste or similar permit for its storage, treatment, incineration of disposal.

(46) 'Household waste' shall mean any solid waste (including garbage, trash, and sanitary waste in septic tanks) derived from households (of single and multiple residences of up to four units).

(47) 'Incineration' shall mean reducing the volume of solid wastes by use of an enclosed device using controlled flame combustion.

(48) 'Incinerator' shall mean an enclosed device using controlled flame combustion, the primary purpose of which, is to thermally break down solid waste.

(49) 'Industrial solid waste' shall mean solid waste generated by manufacturing or industrial processes that is not a hazardous waste regulated under Subtitle C of the Resource Conservation and Recovery Act (RCRA) or Guam's Hazardous Waste Management Regulations. Such waste may include, but is not limited to, waste resulting from the following manufacturing processes/operations: electric power generation; fertilizer/agricultural chemicals; food and related products/by-products; inorganic chemicals; iron and steel manufacturing; leather and leather

products; nonferrous metals manufacturing/foundries; organic chemicals; plastics and resins manufacturing; pulp and paper industry; rubber and miscellaneous plastic products; stone, glass, clay, and concrete products; textile manufacturing; transportation equipment; and water treatment. This term does not include mining waste or oil and gas waste.

(50) 'Inert wastes' shall mean non-combustible waste that will not cause any leachate or cause any environmental concern that are likely to retain their physical and chemical structure under expected conditions of disposal, including resistance to biological attack and chemical attack from acidic rainwater.

(51) 'Infectious waste' shall mean:

(A) equipment, instruments, utensils and fomites of a disposed nature used in the treatment of patients or animals who are suspected by a medical professional to have or have been diagnosed as having a communicable disease and must therefore, be isolated as required by public-health agencies; or

(B) laboratory wastes, including pathological specimens (i.e., all tissues, specimens of blood elements, excreta, and excretion obtained from patients or laboratory animals) and disposal fomites attendant thereto and similar disposal materials from outpatient areas and emergency rooms; or

(C) carcass of any animal that has died from a communicable disease.

(52) 'Interim solid waste handling facilities' shall mean interim treatment, utilization or processing site engaged in solid waste handling which is not the final site of disposal. Transfer stations, composting, source separation centers, and treatment centers are considered as some of the interim solid waste handling facilities.

(53) 'Intermediate cover' shall mean cover material that serves the same function as daily cover, but must resist erosion for a longer time, because it is applied on areas where additional cells will not be constructed for extended periods of time.

(54) 'Landspreading disposal facility' shall mean a facility that applies sludge or other solid wastes onto or incorporates solid waste into the soil surface at a greater than vegetative utilization and soil conditioners/immobilization rates.

(55) 'Lateral expansion' shall mean a horizontal expansion of the waste boundaries of an existing Municipal Solid Waste Landfill unit.

(56) 'Leachate' shall mean a liquid that has passed through or emerged from solid waste and contains soluble, suspended, or miscible materials removed from such waste.

(58) 'Lower explosive limit' shall mean the lowest percent by volume of a mixture of explosive gases which will propagate a flame in air at 25 degrees centigrade and atmospheric pressure.

(59) 'Material resource recovery facility' shall mean a facility where recyclable materials such as scrap metal, aluminum, newspaper, and paper are accepted for recycling.

(60) 'Medical waste' shall mean any solid waste which is generated in the diagnosis, treatment, or immunization of human beings or animals, in research pertaining thereto, or in the production or testing of biologicals. Such terms does not include any hazardous or household waste identified, listed, or defined under 10 Guam Code Annotated Chapter 51 or regulations promulgated under this Chapter.

(61) 'Municipal solid waste landfill unit' shall mean a discrete area of land or an excavation that receives household waste, and that is not a land application unit, surface

impoundment, injection well, or waste pile, as those terms are defined under the Code of Federal Regulations 40 Part §257.2. A Municipal Solid Waste Landfill unit also may receive other types of RCRA Subtitle D wastes, such as commercial solid waste, nonhazardous sludge, small quantity generator waste and industrial solid waste. Such a landfill may be publicly or privately owned. A Municipal Solid Waste Landfill unit may be a new Municipal Solid Waste Landfill unit, an existing Municipal Solid Waste Landfill unit or a lateral expansion.

(62) 'New municipal solid waste landfill unit' shall mean any municipal solid waste landfill unit that has not received waste prior to October 9, 1993.

(63) 'Open burning' shall mean the combustion of solid waste without:

(A) Control of combustion air to maintain adequate temperature for efficient combustion,

(B) Containment of the combustion reaction in an enclosed device to provide sufficient residence time and mixing for complete combustion, and

(C) Control of the emission of the combustion products.

(64) 'Open dump' shall mean a land disposal site which does not meet standards set forth in this Chapter and where solid wastes are disposed in a manner that does not protect the environment, is susceptible to open burning, and is exposed to the elements, vectors and scavengers.

(65) 'Operator' shall mean any person who accepts solid waste from a collector for transfer, storage, recycling, combustion, processing or disposal.

(66) 'Owner' shall mean the person(s) who owns a facility or part of a facility.

(67) 'Performance standards' shall mean the criteria for the performance of solid waste

handling facilities.

(68) 'Permeability' shall mean the ease with which a porous material allows liquid or gaseous fluids to flow through it. For water, this is usually expressed in units of centimeters per second and termed hydraulic conductivity.

(69) 'Permit' shall mean an authorization issued by the Guam Environmental Protection Agency which allows a person to perform solid waste management activities at a specific location and which includes specific conditions for such facility operations.

(70) 'Person' shall mean any individual, partnership, co-partnership, firm, company, corporation, association, joint stock company, trust, estate, or any agency, department, or instrumentality of the Federal or local government, or any other legal representatives, agents or assigns.

(71) 'Pile' shall mean any non-containerized accumulation of solid waste that is used for treatment or storage.

(72) 'Plans' shall mean reports and drawings, including a narrative operating description, prepared to describe the land disposal site and its proposed operation.

(73) 'Point of compliance' shall mean that part of ground-water that lies beneath the perimeter of a solid waste facility's active area as that active area would exist at closure of the facility.

(74) 'Post-closure' shall mean the requirements placed upon disposal sites after closure to ensure their environmental safety for at least a twenty-year period or until the site becomes stabilized (i.e., little or no settlement, gas production or leachate generation).

(75) 'Premises' shall mean a tract or parcel of land with or without habitable buildings.

(76) 'Processing' shall mean any method, system, or other treatment designed to change the physical, chemical or biological character or composition of any solid waste. This includes the neutralization of any hazardous waste; rendering of any hazardous waste non-hazardous, safer for transport, amenable for recovery, amenable for storage, or reduced in volume; or any other activity or processing designed to change the physical form or chemical composition of hazardous waste so as to render it non-hazardous.

(77) 'Putrescible waste' shall mean solid waste which contains material capable of being decomposed by micro-organisms, producing a foul-smelling matter.

(78) 'Pyrolysis' shall mean the process in which solid wastes are heated in an enclosed device in the absence of oxygen to vaporization, producing a hydrocarbon-rich gas capable of being burned for recovery of energy.

(79) 'Reclamation site' shall mean a location used for the processing or the storage of recyclable waste.

(80) 'Refuse' shall mean anything that is discarded as worthless and useless.

(81) 'Remediation' shall mean a permitted process by which the concentration of contamination is reduced to acceptable Guam Environmental Protection Agency levels.

(82) 'Reserved' shall mean a section having no requirements and which is set aside for future possible rule-making as a note to the regulated community.

(83) 'Residential waste' see household waste.

(84) 'Residue' shall mean all the materials that remain after completion of thermal processing, including bottom ash, fly ash and grate shifting.

(85) 'Resource Conservation and Recovery Act' (RCRA) shall mean the Resource

Conservation and Recovery Act (42 U.S.C. §6941) as amended.

(86) 'Reusable containers' shall mean containers that are used more than once to handle solid waste such as garbage cans.

(87) 'Rubbish' shall mean nonputrescible solid waste, including ashes, consisting of both combustible and noncombustible waste such as paper, cardboard, cans, yard clippings, wood, glass, bedding, crockery and broken or rejected matter or litter of any kind.

(88) 'Run-off' shall mean any rainwater, leachate, or other liquid that drains over land from any part of a facility.

(89) 'Run-on' shall mean any rainwater, leachate, or other liquid that drains over land onto any part of a facility.

(90) 'Salvaging' shall mean the controlled removal of waste materials for utilization.

(91) 'Saturated zone' shall mean that part of the earth's crust in which all voids are filled with water.

(92) 'Scavenging' shall mean uncontrolled and unauthorized removal of solid waste materials from a municipal solid waste storage or disposal site(s).

(93) 'Septage' shall mean a semi-solid consisting of settled sewage solids combined with varying amounts of water and dissolved materials generated from a septic tank system.

(94) 'Sludge' shall mean any solid, semi-solid, or liquid waste generated from a municipal, commercial, or industrial wastewater treatment plant, water supply treatment plant, or air pollution control facility or any other such waste having similar characteristics and effects exclusive of the treated effluent from a wastewater treatment plant.

(95) 'Sole source aquifer' shall mean an aquifer designated by the Environmental

Protection Agency pursuant to Section 1424e of the Safe Drinking Water Act (PL 93-523).

(96) 'Solid waste' shall mean any garbage, rubbish, refuse, or sludge from a wastewater treatment plant, water supply treatment plant, or air pollution control facility and other discarded or spilled material(s), including solid, liquid, semisolid, or contained gaseous material resulting from industrial, commercial, mining, and agricultural operations, and from community activities, but does not include solid or dissolved material in domestic sewage, or solid or dissolved materials in irrigation return flows or industrial discharges which are point sources subject to permits under Section 402 of the Federal Water Pollution Control Act, as amended (86 Stat. 880), or source, special nuclear, or byproduct material as defined by the Atomic Energy Act of 1954, as amended (68 Stat. 923).

(97) 'Solid waste handling' shall mean the management, storage, collection, transportation, treatment, utilization, processing or final disposal of solid wastes, including the recovery and recycling of materials from solid wastes, the recovery of energy resources from such wastes or the conversion of the energy in such wastes to more useful forms or combinations thereof.

(98) 'Solid waste management' shall mean the purposeful systematic control of the generation, storage, collection, transportation, separation, processing, recovery and disposal of solid waste.

(99) 'State' shall mean any of the states of the United States of America, the District of Columbia, the Commonwealth of Puerto Rico, the Virgin Islands, Guam, American Samoa, and the Commonwealth of the Northern Marianas Islands.

(100) 'Storage' shall mean the interim containment of solid waste in accordance with

Federal and local regulations.

(101) 'Surface impoundment' shall mean a facility or part of a facility which is a natural topographic depression, man-made excavation or diked area formed primarily of earthen materials (although it may be lined with man-made materials), and which is designed to hold an accumulation of liquids or sludge. The term includes holding, storage, settling and aeration pits, ponds or lagoons, but does not include injection wells.

(102) 'Surface water' shall mean all lakes, rivers, ponds, streams, inland waters and all other water and water courses.

(103) 'Transfer station' shall mean any intermediate waste facility in which solid waste collected from any source is temporarily deposited and stored while awaiting transportation to another solid waste management facility.

(104) 'Treatment' shall mean the physical, chemical or biological processing of solid waste to make such solid wastes safer for storage or disposal, amendable for energy or material resource recovery or reduced in volume.

(105) 'Uppermost aquifer' shall mean the geologic formation nearest the natural ground surface that is an aquifer, as well as, lower aquifers that are hydraulically interconnected with this aquifer within the facility's property boundary.

(106) 'Utilization' shall mean consuming, expending or exhausting by use, solid waste materials.

(107) 'Vector' shall mean any insect or other arthropod, rodent or other animal capable of transmitting the causative agents of human disease, or disrupting the normal enjoyment of life by adversely affecting the public health and well-being.

(108) 'Vertical expansion' shall mean the disposal of solid waste within the footprint of an existing Municipal Solid Waste Landfill following the proper engineering procedures.

(109) 'Waste management unit boundary' shall mean a vertical surface located at the hydraulically downgradient limit of the unit. This vertical surface extends down into the uppermost aquifer.

(110) 'Waste recycling' shall mean reusing waste materials and extracting valuable materials from a waste stream.

(111) 'Waste reduction' shall mean reducing the amount or type of waste generated.

(112) 'Water quality standard' shall mean the Guam Water Quality Standards, as amended.

(113) 'Water table' shall mean the upper most aquifer.

(114) 'Working face' shall mean that portion of the sanitary landfill where solid wastes are discharged and are spread and compacted prior to the placement of cover material.

§23103. Consideration of other federal laws. The owner or operator of municipal solid waste landfill units and other facilities must comply with other applicable Federal rules, laws, regulations, and or other requirements.

§23104. Solid waste management permit system. (a) Permits Required. It shall be unlawful for any person to initiate construction of, establish or operate any solid waste management facility or modify an existing solid waste management facility without a permit issued in accordance with the provisions of this Chapter. All permitted solid waste management facilities shall be operated in accordance with the provisions of Chapter 51 of Title 10, Guam Code Annotated, and this Chapter. For the purposes of these regulations, the following are considered solid waste management facilities:

(1) municipal solid waste landfill facility;

(2) industrial solid waste landfill facility (reserved);

(3) solid waste transfer facility;

(4) solid waste hardfill facility;

(5) solid waste storage facility;

(6) solid waste processing facility:

(A) solid waste composting facility;

(B) solid waste material resource recovery facility;

(C) solid waste remediation facility:

(1) bioremediation;

(2) all other remediation;

(D) solid waste incinerator facility;

(E) solid waste-to-energy recovery facility;

(F) other processing facility.

(b) Application for permit.

(1) Application for a permit shall be completed on forms furnished by the Administrator and shall include the following information:

(A) detailed plans and specifications of the facility and a brief description of the type of facility; a map showing the location of the proposed facility;

(B) certification of compliance with zoning requirements and local ordinances by the Department of Land Management, Department of Public Health and Social Services, Department of Public Works, and the Guam Environmental

Protection Agency;

(C) an operations plan detailing such items as, the proposed method and length of operation; population and area to be served; the characteristics, quantity and source of material to be disposed; the type of equipment to be used; the number and responsibilities of site personnel; source and type of cover material; emergency operating procedures; and the proposed ultimate use of the disposal site. In those cases where only landfilling with demolition debris will take place, certain items may be excluded from the application form by the Administrator;

(D) the Administrator may require any additional information necessary to adequately assess the environmental impact of the proposed solid waste management facility, and prevent injury to the public health, welfare or environment of Guam.

(2) A proof of performance bond obtained from a bonding company authorized to do business in Guam may be required by the Administrator. The bond shall be payable to the government of Guam and conditioned on the fulfillment by the holder of the requirements of this Chapter.

(3) Each application shall be signed by the owner or his authorized representative, and shall constitute an agreement that the owner will assume responsibility for the construction or modification and operation of the facility in accordance with this Chapter. If the owner is a partnership or group other than a corporation, the application shall be signed by One (1) individual who is a member of the group. If the owner is a corporation, the application shall be signed by an officer of the corporation or general

manager of the facility.

(4) All new applications or renewal applications for a permit for a municipal solid waste landfill shall be accompanied by a non-refundable application fee of Ten thousand Dollars ($10,000.00) payable to the Treasurer of Guam and deposited into the Solid Waste Management Fund pursuant to Section 51117 of Public Law 23-64. New applications or renewal applications for permits for all other solid waste management facilities shall be accompanied by a non-refundable application fee payable to the Treasurer of Guam in the amount indicated on the attached schedule of fees as listed on Addendum A. These non-refundable application fees shall be deposited into the Solid Waste Management Fund.

(5) The Administrator shall approve an application for permit if the application and supporting information clearly show that the issuance, thereof, does not pose a threat to the environment, public health or welfare, and that the solid waste disposal facility is designed, built, and equipped in accordance with the best practicable technology so as to operate without causing a violation of applicable rules and regulations.

(6) The Administrator may issue to the applicant a conditional approval. Under such an approval the Administrator may:

(A) require the applicant to provide for sampling and testing to determine the degree of pollution from the solid waste management facility, if necessary;

(b) specify conditions which will bring the operation of the solid waste management facility described in the application within the requirements of this

Chapter.

(7) Written acceptance of any and all permit conditions by the applicant shall be necessary prior to any construction for which a permit is required.

(8) Unless otherwise provided for in §23104 of this Chapter, the Administrator may hold a public hearing to solicit public reaction and recommendations on a proposed permit application or permit renewal if the Administrator determines there is a significant degree of public interest in the proposed permit.

(c) Municipal Solid Waste Landfill permits.

(1) All owners of existing municipal solid waste landfill facilities shall file immediately an application for permit to continue to operate.

(2) The Administrator shall, within a reasonable time, not to exceed One hundred and twenty (120) days from the date the application is received with payment of the application fee, notify the applicant in writing if the application has been filled out properly and contains all the necessary information.

If additional information is requested by the Agency, then the request stops the One hundred and twenty (120) day time period and the remaining days left shall resume on the day after the supplementary information is received.

(3) Before issuing a permit for a municipal solid waste landfill facility, the Administrator shall cause to be published notice of Agency's intention to issue such a permit and that the public has Forty-five (45) days to summit written comments on the proposed action; The contents of the public notice shall include at least the following:

(A) name, address, and phone number of Agency issuing the public notice;

(B) name and address of each applicant;

(C) brief description of each applicant's activities or operations which result in the disposal or other activities described in the application;

(D) a short description of the location of each disposal or activity indicating whether such disposal or activity is new or existing; and

(E) address and phone number of agency premises at which interested persons may obtain further information and inspect a copy of the variance applications and supporting and related documents.

(4) If within Forty-five (45) days after publication and broadcast, the Agency receives written notice of opposition to the Agency's intention to issue such a permit and a request for a hearing is made by a substantially affected party, then the Agency shall provide for a hearing in accordance with the Administrative Adjudication Law, Chapter 9 of Title 5, Guam Code Annotated.

(A) A request for a hearing shall be in writing and shall state the nature of the issues proposed to be raised in the hearing and the basis for being the proper party to request a hearing.

(B) The Board shall affirm, modify, or revoke the proposed action to be taken by the Agency. The Board may delay making a decision if it determines that the application was incomplete or public comments have not been adequately addressed.

(5) Written comments to GEPA with all supporting evidence, along with a copy

for the applicant, must be received or postmarked within the Forty-five (45) day comment period to be considered by the Agency.

(6) All comments received during the comment period shall be considered in making a decision and the Administrator will prepare a written response to all significant comments, as determined by the Administrator, that were received during the public comment period or raised during an Agency hearing. The response to comments shall be made available to the public upon request.

(d) Permits for facilities other than MSWLF.

(1) The Administrator shall, within a reasonable time, not to exceed One hundred twenty (120) days from the date the application is received, notify the applicant in writing, if the application has been filled out properly and contains all the necessary information. If the Administrator has not acted (i.e., approved, denied, or requested for additional information) within the One hundred twenty (120) day period from the day the application is received, the application shall be deemed to have been approved. The request for additional information stops the One hundred twenty (120) day period and the remaining days out of this period shall resume on the day the supplementary information is received.

(2) The applicant may submit questions and comments, in duplicate, in response to the Administrator's action on the application.

(3) The Administrator shall consider the applicant's questions and comments, and shall notify the applicant, in writing, of his final approval or denial of the application.

(4) Before issuing a permit for the processing, storage or disposal of solid

waste, the Administrator shall:

(A) cause to be published in a major local newspaper or newspaper of general circulation, and broadcast over a local radio station or stations, notice of the Agency's intention to issue such a permit;

(B) if, within Forty-five (45) days after publication and broadcast, the Agency receives written notice of opposition to the Agency's intention to issue such permit and a request for a hearing is made, provide for a hearing in accordance with the Administrative Adjudication Law, Chapter 9 of Title 5, Guam Code Annotated, if requested by a substantially affected party;

(C) allow interested persons to submit written significant comments during the Forty-five (45) day period.

(5) Composting waste generated from no more than Three (3) households for personal use is exempted from permit requirements.

(e) Effect of the permit. The general and special conditions of the permit become the standards and guide for the facility.

(1) The owner or operator must notify the Agency that the construction has been completed in accordance with the approved plans and specifications.

(2) An inspection of the facility will be conducted by the Agency to confirm that the facility is ready to accept solid wastes.

(3) The conditions will specify that the facility operate in accordance with the approved Operation Manual.

(4) Additional conditions specify type, frequency and data required for

monitoring and record keeping.

(f) Permit denial. If a permit is denied, the applicant shall have the opportunity to appeal the decision at a hearing by the Board of Directors of GEPA in accordance with the Administrative Adjudication Law, Chapter 9 of Title 5, Guam Code Annotated. Such hearing shall be held not more than Sixty (60) days after the Board receives this notice of intent to appeal.

(g) Duration of Permit. The Administrator shall grant a permit for Five (5) years for all municipal solid waste landfills following the date of issuance. The duration of permit for all other solid waste management facilities are listed on the attached Addendum B.

(h) Modification to existing permits. The Administrator may, on his own motion or the application of any person, modify a permit if, after affording the applicant an opportunity for a hearing, the Administrator determines that:

(1) any condition of the permit has been violated or due to a change in any condition requiring either a temporary or permanent reduction or elimination of the permitted disposal;

(2) there is a change in applicable laws or regulations governing solid waste management; or

(3) such action is in the public interest.

The Agency will develop a schedule to revisit and reissue all existing permits affected by the change in the law or regulations at the time of the change. Modification of the permit shall become final Ten (10) days after service of notice of the final decision to modify the permit on the holder of the permit.

(i) Suspension of permit. The Administrator may, on his own motion or the application of any person, suspend a permit if, after affording the applicant an opportunity for a hearing, the Administrator determines that:

(1) any condition of the permit has been violated or any regulations of the agency has been violated; or

(2) such action is in the public interest.

The permit shall be suspended until all conditions of the permit are met or all violations have been properly corrected. Suspension of a permit shall become final Ten (10) days after service of notice of the final decision to suspend on the holder of the permit.

(j) Revocation of permits. The Administrator may, on his own motion or the application of any person, revoke any permit if, after affording the applicant an opportunity for a hearing, the Administrator determines that:

(1) there is a violation of any condition of the permit;

(2) the permit was obtained by misrepresentation, or failure to disclose fully all relevant facts;

(3) there is a change in any condition that requires either a temporary or permanent reduction or elimination of the permitted disposal; or

(4) such is in the public interest.

Revocation of a permit shall become final Ten (10) days after service of notice of the final decision to revoke on the holder of the permit.

(k) Permit renewal. Each permittee must apply for a renewal of the permit Sixty (60) days before the permit expires. At the time of renewal of a solid waste management permit, the facility is reevaluated and the permit conditions updated to reflect changes and the current operational procedures.

(l) Transfer of permit. A permit shall not be transferable, whether by operation of law or otherwise, either from one location to another, from one solid waste disposal facility to another or from one person to another, without the written approval of the Administrator.

(m) Reporting termination. Sixty (60) days prior to closure any person issued a permit shall report the permanent termination of a solid waste processing or disposal facility for which the permit has been issued to the Administrator and within the Thirty (30) days after closure shall surrender the permit to the Administrator, unless otherwise noted in this Chapter. The Administrator may approve immediate closure of any solid waste management facility if the facility poses major threat to human health and the environment.

(n) Posting of permit. Upon granting an approval for a permit, the Administrator shall issue to the applicant a permit which shall be posted in a conspicuous place at or near the operation site for which the permit was issued.

(o) Falsifying or altering permit. No person shall knowingly deface, alter, forge, counterfeit or falsify a permit. Any such activity shall bring about immediate revocation of the permit.

Article 2

Location restrictions

§23201. **Airport safety.** (a) Owners or operators of new MSWLF units, existing MSWLF units, and lateral expansions that are located within Ten thousand feet (10,000') (Three thousand forty-eight (3,048) meters) of any airport runway end used by turbojet aircraft or within Five thousand feet (5,000') (One thousand five hundred and twenty-four (1,524) meters) of any airport runway end used by only piston-type aircraft must demonstrate that the units are designed and operated so that the MSWLF unit does not pose a bird hazard to aircraft. Components of such demonstrations are identified in Chapter 2, Subpart B, of the EPA Solid Waste Disposal Facility Criteria, Technical Manual, published in November 1993 or as updated.

(b) Owners or operators proposing to site new MSWLF units and lateral expansions located within a five-mile radius of any airport runway end used by turbojet or piston-type aircraft must notify the affected airport and the Federal Aviation Administration (FAA).

(c) The owner or operator must place the demonstration in Subsection (a) of this §23201 in the operating record and notify the Administrator that it has been placed in the operating record.

(d) Additional definitions, for the purposes of this Article 2:

(1) 'Airport' means public-use airport open to the public without prior permission and without restrictions within the physical capacities of available facilities.

(2) 'Bird hazard' means an increase in the likelihood of bird/aircraft collisions that may cause damage to the aircraft or injury to its occupants.

§23202. Floodplains. (a) Owners or operators of new MSWLF units, existing MSWLF units, and lateral expansions located in One hundred (100) year floodplains must demonstrate that the unit will not restrict the flow of the One hundred (100) year flood, reduce the temporary water storage capacity of the floodplain, or result in washout of solid waste so as to pose a hazard to human health and the environment. The owner or operator must place the demonstration in the operating record and notify the Administrator that it has been placed in the operating record. Components of such demonstrations are identified in Chapter 2, Subpart B, of the EPA Solid Waste Disposal Facility Criteria, Technical Manual, published in November 1993 or as updated.

(b) For the purposes of this Chapter:

(1) 'Floodplain' means the lowland and relatively flat areas adjoining inland and coastal waters, including flood-prone areas of offshore islands, that are inundated by the One hundred (100) year flood.

(2) 'One hundred (100) year flood' means a flood that has a One Percent (1%) or greater chance of recurring in any given year or a flood of a magnitude equalled or exceeded once in One Hundred (100) years on the average over a significantly long period.

(3) 'Washout' means the carrying away of solid waste by waters of the base flood.

§23203. Wetlands. (a) New MSWLF units and lateral expansions shall not be located in wetlands, unless the owner or operator can make the following demonstrations to the Administrator:

(1) Where applicable, under §404 of the Clean Water Act or applicable Territorial wetlands laws, the presumption that a practicable alternative to the proposed landfill is available which does not involve wetlands is clearly rebutted;

(2) The construction and operation of the MSWLF unit will not:

(A) cause or contribute to violations of any applicable Territorial water quality standard;

(B) violate any applicable toxic effluent standard or prohibition under Section 307 of the Clean Water Act;

(C) jeopardize the continued existence of endangered or threatened species or result in the destruction or adverse modification of a critical habitat, protected under the Endangered Species Act of 1973 or the Endangered Species Act of Guam, as amended; and

(D) violate any requirement under the Marine Protection, Research, and Sanctuaries Act of 1972, for the protection of a marine sanctuary;

(3) The MSWLF unit will not cause or contribute to significant degradation of wetlands. The owner or operator must demonstrate the integrity of the MSWLF unit and its ability to protect ecological resources by addressing the following factors:

(A) erosion, stability, and migration potential of native wetland soils, mud, and deposits used to support the MSWLF unit;

(B) erosion, stability, and migration potential of dredged and fill materials used to support the MSWLF unit;

(C) the volume and chemical nature of the waste managed in the MSWLF unit;

(D) impacts on fish, wildlife, and other aquatic resources and their habitat from release of the solid waste;

(E) the potential effects of catastrophic release of waste to the wetland and the resulting impacts on the environment; and

(F) any additional factors, as necessary, to demonstrate that ecological resources in the wetland are sufficiently protected;

(4) to the extent required under §404 of the Clean Water Act or applicable

territorial wetlands laws, steps have been taken to attempt to achieve no net loss of wetlands (as defined by acreage and function) by first avoiding impacts to wetlands to the maximum extent practicable as required by paragraph A. 1 of this section, then minimizing unavoidable impacts to the maximum extent practicable, and finally offsetting remaining unavoidable wetland impacts through all appropriate and practicable compensatory mitigation actions (e.g., restoration of existing degraded wetlands or creation of man-made wetlands); and

(5) sufficient information is available to make a reasonable determination with respect to these demonstrations.

(b) For the purposes of this section, 'wetlands' means those areas that are inundated by surface or ground-water with a frequency sufficient to support and under normal circumstances does or would support a prevalence of vegetative or aquatic life that requires saturated or seasonally saturated soil conditions for growth and reproduction. Wetlands generally include swamps, marshes, mangroves, natural ponds, surface springs, estuaries and similar such areas.

§23204. Fault areas. (a) New MSWLF units and lateral expansions shall not be located within Two hundred (200) feet (Sixty (60) meters) of a fault that has had displacement in Holocene time unless the owner or operator demonstrates to the Administrator that an alternative setback distance of less than Two hundred (200) feet (Sixty (60) meters) will prevent damage to the structural integrity of the MSWLF unit and will be protective of human health and the environment. Components of such demonstrations are identified in Chapter 2, Subpart B, of the EPA Solid Waste Disposal Facility Criteria, Technical Manual, published in November 1993 or as updated.

(b) For the purposes of this Article:

(1) 'Fault' means a fracture or a zone of fractures in any material along which strata on One (1) side have been displaced with respect to that on the other side.

(2) 'Displacement' means the relative movement of any Two (2) sides of a fault measured in any direction.

(3) 'Holocene' means the most recent epoch of the Quaternary period, extending from the end of the Pleistocene Epoch to the present.

§23205. **Seismic impact zones.** (a) New MSWLF units and lateral expansions shall not be located in seismic impact zones, unless the owner or operator demonstrates to the Administrator that all containment structures, including liners, leachate collection systems, and surface water control systems, are designed to resist the maximum horizontal acceleration in lithified earth material for the site. The owner or operator must place the demonstration in the operating record and notify the Administrator that it has been placed in the operating record. Components of such demonstrations are identified in Chapter 2, Subpart B, of the EPA Solid Waste Disposal Facility Criteria, Technical Manual, published in November 1993 or as updated.

(b) For the purposes of this Article:

(1) 'Seismic impact zone' means an area with a Ten Percent (10%) or greater probability that the maximum horizontal acceleration in lithified earth material, expressed as a percentage of the earth's gravitational pull (g), will exceed 0.10g in Two hundred and fifty (250) years.

(2) 'Maximum horizontal acceleration in lithified earth material' means the maximum expected horizontal acceleration depicted on a seismic hazard map, with a

Ninety Percent (90%) or greater probability that the acceleration will not be exceeded in Two hundred and fifty (250) years, or the maximum expected horizontal acceleration based on a site-specific seismic risk assessment.

(3) 'Lithified earth material' means all rock, including all naturally occurring and naturally formed aggregates or masses of minerals or small particles of older rock that formed by crystallization of magma or by induration of loose sediments. This term does not include man-made materials, such as fill, concrete, and asphalt, or unconsolidated earth materials, soil, or regolith lying at or near the earth surface.

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§23206. Unstable Areas. (a) Owners or operators of new MSWLF units, existing MSWLF units, and lateral expansions located in an unstable area must demonstrate that engineering measures have been incorporated into the MSWLF unit's design to ensure that the integrity of the structural components of the MSWLF unit will not be disrupted. The owner or operator must place the demonstration in the operating record and notify the Administrator that it has been placed in the operating record. Components of such demonstrations are identified in Chapter 2, Subpart B, of the EPA Solid Waste Disposal Facility Criteria, Technical Manual, published in November 1993 or as updated. The owner or operator must consider the following factors, at a minimum, when determining whether an area is unstable:

(1) on-site or local soil conditions that may result in significant differential settling;

(2) on-site or local geologic or geomorphologic features; and

(3) on-site or local human-made features or events (both surface and

subsurface).

(b) For the purposes of this Article:

(1) 'Unstable area' means a location that is susceptible to natural or human-induced events or forces capable of impairing the integrity of some or all of the landfill structural components responsible for preventing releases from a landfill. Unstable areas can include poor foundation conditions, areas susceptible to mass movements, and Karst terrains.

(2) 'Structural components' means liners, leachate collection systems, final covers, run-on/run-off systems, and any other component used in the construction and operation of the MSWLF that is necessary for protection of human health and the environment.

(3) 'Poor foundation conditions' means those areas where features exist which indicate that a natural or man-induced event may result in inadequate foundation support for the structural components of a MSWLF unit.

(4) 'Areas susceptible to mass movement' means those areas of influence (i.e., areas characterized as having an active or substantial possibility of mass movement) where the movement of earth material at, beneath, or adjacent to the MSWLF unit, because of natural or man-induced events, results in the downslope transport of soil and rock material by means of gravitational influence. Areas of mass movement include, but are not limited to, landslides, avalanches, debris slides and flows, soil fluction, block sliding, and rock fall.

(5) 'Karst terrains' means areas where karst topography, with its characteristic

surface and subterranean features, is developed as the result of dissolution of limestone, dolomite, or other soluble rock. Characteristic physiographic features present in karst terrains include, but are not limited to, sinkhole, sinking streams, caves, large springs, and blind valleys.

§23207. **Closure of existing municipal solid waste landfill units.** (a) Existing MSWLF units that cannot make the demonstration specified in §§23201, 23202, and 23206 of this Article 2, must close immediately, in accordance with §23601 and conduct post-closure activities in accordance with §23602, all of this Chapter.

(b) The deadline for closure required by Subsection (a) of this §23207 may be extended up to Two (2) years if the owner or operator demonstrates to the Administrator that:

(1) there is no available alternative disposal capacity; and

(2) there is no immediate threat to human health and the environment.

Article 3

Operating criteria

§23301. **Solid waste accepted.** (a) As a part of the permit application, the owner/operator shall report what wastes shall be accepted and identify any special handling required. Only wastes for which the facility has been permitted shall be accepted.

(b) The permit application shall specify procedures for wastes requiring special handling. Wastes approved for acceptance at each are:

(1) Municipal Solid Waste Landfill Facility:

(A) residential waste;

(B) commercial waste;

(C) animal carcasses, body parts, etc. (to be disposed of only in the approved area as designated in the permit)

(2) Industrial Solid Waste Landfill Facility (Reserved)

(3) Solid Waste Transfer Facility:

(A) residential waste;

(B) yard waste.

(4) Solid Waste Hardfill Facility:

(A) demolition and construction debris (bricks, concrete, stones, masonry materials, rocks, asphalt, rebar, corrugated steel, scrap metal, paving materials, and undecayed wood materials attached to the construction debris);

(B) packaging and rubble resulting from construction, remodeling, repair, or demolition operations on pavements, houses, commercial buildings, and other structures, excluding asbestos containing materials;

(c) clay, limestone, coral, broken glass and pottery.

(5) Solid Waste Storage Facility:

(A) vehicles, vehicle parts, appliances, and metals still having worth and use.

Salvaged materials, such as automobile bodies, metals, and appliances may be salvaged in a controlled manner only by the permit holder. These materials must be drained of any free liquids and hazardous waste; the liquids and hazardous waste must be transferred to a solid waste processing facility for final disposal or processing. Chlorofluorocarbons (CFCs) must be properly removed for recycling at the processing facility or CFC recovery center, as approved by the Guam Air Pollution Control Program.

(6) Solid Waste Processing Facility

(A) Solid Waste Composting Facility:

(1) yard waste such as grass clippings, tree branches, leaves, and other organic waste;

(2) paper waste;

(3) vegetative waste.

(B) Solid Waste Material Resource Recovery Facility:

(1) scrap metal, aluminum, and batteries;

(2) newspapers, paper, magazines, cardboard, glass, and plastics;

(3) tires, oil, and CFCs.

(C) Solid Waste Remediation Facility:

(1) bioremediation

(A) petroleum contaminated waste;

(2) all other remediation.

(D) Solid Waste Incinerator Facility:

(1) residential waste;

(2) construction waste.

(E) Solid Waste-to-Energy Recovery Facility:

(1) residential waste;

(2) construction waste.

(F) Other Processing Facility:

(1) vehicles and vehicle parts;

(2) appliances.

§23302. Solid waste excluded. (a) Using information indicated on the permit application, the Administrator determines specific wastes to be excluded and the permittee shall identify them in the plans. The generator of excluded wastes and hazardous material shall report these wastes to the Administrator prior to disposal and consult with the Administrator in determining method of disposal. The criteria used in this Chapter shall determine what types of waste shall be excluded.

(b) Regular users of the land disposal site shall be provided with a list of excluded waste. The list shall be displayed prominently at the site entrance.

(c) Wastes excluded from solid waste management facilities shall include but not limited to the following:

(1) Municipal Solid Waste Landfill Facility:

(A) waste oil and regulated hazardous waste;

(B) whole or partially whole vehicles, vehicle parts, tires, batteries, appliances, septic tank pumping, sewage sludge and other petroleum products and oil based paints.

(2) Industrial Solid Waste Landfill Facility (Reserved)

(3) Solid Waste Transfer Facility:

(A) commercial, government and military solid wastes (unless approved by the administrator);

(B) inert material or waste;

(C) biological waste, pathological wastes, radioactive wastes, medical wastes, infectious waste, free liquids, asbestos, animal carcasses and offal, ashes, putrescible animal waste, sewage sludge, other sludge and other petroleum products;

(D) all wastes excluded from MSWLFs are also excluded from Solid Waste Transfer Facilities.

(4) Solid Waste Hardfill Facility:

(A) hazardous waste, infectious waste, biological waste, radioactive waste, medical waste, liquid waste, asbestos, animal carcasses and offal, ashes composting material, decayed matter, putrescible animal and vegetable waste;

(B) lawn and yard clippings, grass and leaves, and other organic waste;

(C) paper products, cardboard, cans, whole or partially whole vehicles, vehicle parts, tires and other rubber and synthetic products, or automobile batteries;

(D) residential waste, plastic products, mattresses and box springs, clothing, cloth and bedding, appliances and furniture, septic tank pumping, sewer sludge and other sludges, waste oil and other petroleum products, and miscellaneous trash and litter.

(5) Solid Waste Storage Facility:

(A) hazardous waste;

(B) residential waste.

(6) Solid Waste Processing Facility:

(A) Solid Waste Composting Facility:

(1) hazardous waste;

(2) residential waste.

(B) Solid Waste Material Resource Recovery Facility:

(1) hazardous waste.

(C) Solid Waste Remediation Facility:

(1) bioremediation

(a) hazardous waste

(2) all other remediation

(a) hazardous waste

(D) Solid Waste Incinerator Facility:

(1) hazardous waste.

(E) Solid Waste Energy Recovery Facility:

(1) hazardous waste.

(F) Other processing facility:

(1) hazardous waste;

(2) residential waste;

(3) yard waste.

§23303. Procedures for excluding the receipt of hazardous waste.

(a) Owners or operators of all MSWLF units must implement a program at the facility for detecting and preventing the disposal of regulated hazardous wastes as defined in Guam's Hazardous Waste Management Regulations and polychlorinated biphenyl (PCB) wastes as defined in 40 CFR Part 761. This program must include, at a minimum:

(1) random inspections of incoming loads;

(2) records of any inspections;

(3) training of facility personnel to recognize regulated hazardous waste and PCB wastes; and

(4) notification of Administrator if a regulated hazardous waste or PCB waste is discovered at the facility.

(b) For purposes of this section, 'regulated hazardous waste' means a solid waste that is a hazardous waste or was not generated by a conditionally exempt small quantity generator as defined in Guam's Hazardous Waste Management Regulations.

§23304. Cover material requirements. (a) Except as provided in Subsection (b) of this §23304, the owners or operators of all MSWLF units must cover disposed solid waste with Six (6) inches of earthen material at the end of each operating day, or at more frequent intervals if necessary, to control disease vectors, fires, odors, blowing litter, and scavenging.

(b) Alternative materials of an alternative thickness (other than at least Six (6) inches of earthen material) may be approved by the Administrator if the owner or operator demonstrates that the alternative material and thickness control disease vectors, fires, odors, blowing litter, and scavenging without presenting a threat to human health and the environment.

(c) In order to conserve land disposal site capacity, thereby preserving land resources, and to minimize moisture infiltration and settlement, solid waste and cover material shall be compacted to the smallest practicable volume. Solid wastes may be reduced in volume by using balers, shredders, or other reducing devices before placement in cells.

(d) The Administrator may grant a temporary waiver from the requirement of Subsections (a) and (b) of this §23304, if the owner or operator demonstrates that there are extreme short term climatic conditions that make meeting such requirements impractical.

§23305. Disease vector control. (a) Owners or operators of all MSWLF units must prevent or control on-site populations of disease vectors using techniques appropriate for the protection of human health and the environment.

(b) For purposes of this Section, 'disease vectors' means any rodents, flies, mosquitoes, or other animals, including insects, capable of transmitting disease to humans.

§23306. Explosive gases control. (a) Owners or operators of all MSWLF units must ensure that:

(1) the concentration of methane gas generated by the facility does not exceed Twenty-five Percent (25%) of the lower explosive limit for methane in facility structures (excluding gas control or recovery system components); and

(2) the concentration of methane gas does not exceed the lower explosive limit for methane at the facility property boundary.

(b) Owners or operators of all MSWLF units must implement a routine methane monitoring program to ensure that the standards of Subsection (a) of this §23306 are met.

(1) The type and frequency of monitoring must be determined based on the following factors:

(A) soil conditions;

(B) the hydrogeologic conditions surrounding the facility;

(C) the hydraulic conditions surrounding the facility; and

(D) the location of facility structures and property boundaries.

(2) The minimum frequency of monitoring shall be quarterly.

(c) If methane gas levels exceeding the limits specified in Subsection (a) of this §23306 are detected, the owner or operator must:

(1) immediately take all necessary steps to ensure protection of human health and notify the Administrator;

(2) within Seven (7) days of detection, place in the operating record the methane gas levels detected and a description of the steps taken to protect human health; and

(3) within Sixty (60) days of detection, implement a remediation plan for the methane gas releases, place a copy of the plan in the operating record, and notify the Administrator that the plan has been implemented; the plan shall describe the nature and extent of the problem and the proposed remedy;

(4) the Administrator may establish alternative schedules for demonstrating compliance with Items (2) and (3) of Subsection (c) of this §23306.

(d) For purposes of this Section, 'lower explosive limit' means the lowest percent by volume of a mixture of explosive gases in air that will propagate a flame at Twenty-five Degrees Celsius (25°C) and atmospheric pressure.

§23307. Air criteria. (a) Owners or operators of all MSWLFs must ensure that the units do not violate any applicable requirements developed under a State Implementation Plan

(SIP) approved or promulgated by the United States Environmental Protection Agency (USEPA) Administrator pursuant to Section 110 of the Clean Air Act, as amended, or any additional requirements of the Guam Air Pollution Control rules, regulations, or laws.

(b) Open burning of solid waste, except for the infrequent burning of agricultural wastes, silvicultural wastes, landclearing debris, diseased trees, or debris from emergency clean-up operations, is prohibited at all MSWLF units.

§23308. Access requirements. (a) Owners or operators of all MSWLF units must control public access and prevent unauthorized vehicular traffic and illegal dumping of wastes by using artificial barriers, natural barriers, or both, as appropriate to protect human health and the environment.

(b) Characteristics of on-site soil shall be evaluated with respect to their effects on site operations, such as vehicle maneuverability and their use as cover material shall be included in the design of the facility.

(c) The site shall be accessible to vehicles for which the site is designed by all weather roads leading from the public road system; temporary roads maintained in a passable condition shall be provided as needed to deliver wastes to the working face.

§23309. Run-on/run-off control systems. (a) Owners or operators of all MSWLF units must design, construct, and maintain:

(1) a run-on control system to prevent flow onto the active portion of the landfill during the peak discharge from a Twenty-five (25) year storm;

(2) a run-off control system from the active portion of the landfill to collect and control at least the water volume resulting from a Twenty-four (24) hour, Twenty-five (25)

year storm.

(b) Run-off from the active portion of the landfill unit must be handled in accordance with §233010 'Surface water requirements' of this Chapter.

§23310. Surface water requirements. MSWLF units shall not cause a discharge of pollutants into waters of the United States, including wetlands, that violates any requirements of the Clean Water Act, including, but not limited to, the National Pollutant Discharge Elimination System (NPDES) requirements, pursuant to Section 402, or cause the discharge of a nonpoint source of pollution to waters of the United States, including wetlands, that violates any requirement of an area-wide or territorial-wide water quality management plan that has been approved under Section 208 or 319 of the Clean Water Act, as amended.

§23311. Liquid restrictions. (a) Bulk or non-containerized liquid waste may not be placed in MSWLF units unless:

(1) the waste is household waste other than septic waste; or

(2) the waste is leachate or gas condensate derived from the MSWLF unit and the MSWLF unit, whether it is a new or existing MSWLF or lateral expansion, is designed with a composite liner and leachate collection system as described in Item (2) of Subsection (a), §23401 of this Chapter. The owner or operator must place the demonstration in the operating record and notify the Administrator that it has been placed in the operating record.

(b) Containers holding liquid waste may not be placed in a MSWLF unit unless:

(1) the container is a small container similar in size to that normally found in household waste;

(2) the container is designed to hold liquids for use other than storage; or

(3) the waste is household waste;

(4) the oil filters are drained for at least Twenty-four(24) hours or crushed and are not regulated as hazardous waste.

(c) For the purposes of this Section:

(1) 'Liquid waste' means any waste material that is determined to contain 'free liquids' as defined by Method 9095 (Paint Filter Liquids Test), as described in 'Test Methods for Evaluating Solid Wastes, Physical/Chemical Methods' (EPA Pub. No. SW-846).

(2) 'Gas condensate' means the liquid generated as a result of gas recovery process(es) at the MSWLF unit.

§23312. Recordkeeping requirements. (a) The owner or operator of a MSWLF unit must record and retain near the facility in an operating record or in an alternative location approved by the Administrator, the following information as it becomes available:

(1) any location restriction demonstration required under Article 2 of this Chapter;

(2) inspection records, training procedures, and notification procedures required in Subsection (a) of §23303 of this Chapter;

(3) gas monitoring results from monitoring and any remediation plans required by §23306 of this Chapter;

(4) any MSWLF unit design documentation for placement of leachate or gas condensate in a MSWLF unit as required under Item (2) of Subsection (a), §233011 of this

Chapter;

(5) any demonstration, certification, finding, monitoring, testing, or analytical data required by Article 5 of these this Chapter;

(6) closure and post-closure care plans and any monitoring, testing, or analytical data as required by Article 6 of this Chapter;

(7) any cost estimates and financial assurance documentation required by Article 7 of this Chapter;

(8) description of solid waste materials received, identified by source of materials; and the license plate number of the vehicle transporting them for disposal; these records shall be maintained on a daily basis and summarized monthly as to the number of tons received, number of vehicles by type, and kinds of waste materials received;

(9) operation problems, complaints or difficulties;

(10) air quality and litter control efforts;

(11) vector control efforts.

(b) The owner/operator must notify the Administrator when the documents from Subsection (a) of this §23312 have been placed or added to the operating record, and all information contained in the operating record must be furnished upon request to the Administrator or be made available at all reasonable times for inspection by the Administrator.

(c) The Administrator may set alternative schedules for recordkeeping and notification requirements as specified in Subsections (a) and (b) of this §23312, except for the notification requirements in Subsection (b) of §23201 and Item (3) of Subsection (g), §23506 of this Chapter.

§23313. Safety. (a) The land disposal site shall be designed, constructed, and operated in such a manner as to protect the health and safety of personnel associated with the operation and meet all appropriate federal and local Occupational Safety and Health Act requirements.

(b) The operating manual shall describe safety precautions and procedures to be employed at the site during the working day. In addition, the following safety measures are required:

(1) personal safety devices such as hard hats, gloves, and footwear shall be worn by all facility employees while on the site;

(2) safety devices, including but not limited to such items as rollover protective structures, seat-belts, and audible reverse warning devices shall be provided on all equipment used to spread and compact solid wastes or cover material at the facility; fire extinguisher shall be provided and be located within the immediate vicinity of the working face;

(3) provisions shall be made to extinguish any fires in wastes being delivered to the site or which occur at the working face or within equipment or personnel facilities;

(4) communications equipment shall be available on-site for emergency situations;

(5) scavenging shall be prohibited at all times to avoid injury and to prevent interference with site operations;

(6) access to the disposal site shall be controlled and shall be by established roadways only. The site shall be accessible only when operating personnel are on duty. Large volume containers may be placed at the site entrance so that users can conveniently

deposit waste after hours. The containers and the areas around them shall be maintained in a sanitary and litter-free condition. Containers shall be emptied daily unless an alternate schedule is approved by the Administrator;

(7) traffic signs, markers or site personnel shall be provided to promote an orderly traffic pattern to and from the discharge area, maintain efficient operating conditions, and, if necessary, restrict access to hazardous areas. Drivers of manually discharging vehicles shall not hinder operation of mechanically discharging vehicles. Vehicles shall not be left unattended at the working face or along traffic routes. If a regular user persistently poses a safety hazard, he may be barred from the site and reported to the Agency.

Article 4

Design criteria

§23401. Design criteria for Municipal Solid Waste Landfills.

(a) New MSWLF units and lateral expansions shall be constructed:

(1) in accordance with a design approved by the Administrator. The design must ensure that the concentration values listed in §23403 of this Chapter will not be exceeded in the uppermost aquifer at the relevant point of compliance, as specified by the Administrator under Subsection (d) of this §23401, or

(2) with a composite liner, as defined in Subsection (b) of this §23401 and a leachate collection system that is designed and constructed to maintain less than a Thirty centimeter (30cm) (Twelve inches (12")) depth of leachate over the liner.

(3) So as not to cause or contribute to the taking of any endangered or

threatened species of plant, fish or wildlife, and not cause the destruction of critical habitat of endangered or threatened species.

(b) For purposes of this section, 'composite liner' means a system consisting of two components; the upper component must consist of a minimum 30-mil flexible membrane liner (FML), and the lower component must consist of at least a two-foot layer of compacted soil with a hydraulic conductivity of no more than 1 x 10^{-7} cm/sec. FML components consisting of High Density Polyethylene (HDPE) shall be at least 60-mil thick. The FML component must be installed in direct and uniform contact with the compacted soil component.

(c) When approving a design that complies with Item (1) of Subsection (a) of this §23401, the Administrator shall consider at least the following factors:

(1) The hydrogeologic characteristics of the facility and surrounding land;

(2) The climatic factors of the area;

(3) The volume and physical and chemical characteristics of the leachate;

(4) The types and quantities of solid waste expected to be disposed of at the facility. Survey methods and results shall be incorporated in the design of the facility;

(5) Land use and zoning within one-quarter mile of the site including location of all residences, buildings, wells, water courses, historical sites, recreational areas and roads;

(6) Facilities for employee convenience and equipment maintenance;

(7) Litter control program proposed by applicant; and

(8) Site operation and maintenance plan.

(d) The relevant point of compliance specified by the Administrator shall be no more than 150 meters from the waste management unit boundary and shall be located on land owned by the owner of the MSWLF unit. In determining the relevant point of compliance, the Administrator shall consider at least the following factors:

(1) the hydrogeologic characteristics of the facility and surrounding land;

(2) the volume and physical and chemical characteristics of the leachate;

(3) the quantity, quality, and detection, of flow of ground-water;

(4) the proximity and withdrawal rate of the ground-water users;

(5) the availability of alternative drinking water supplies;

(6) the existing quality of the ground-water, including other sources of contamination and their cumulative impacts on the ground-water and whether ground-water is currently used or reasonably expected to be used for drinking water;

(7) public health, safety, and welfare effects; and

(8) practicable capability of the owner or operator.

§23402. Design criteria for Solid Waste Management Facilities other than MSWLF. (a) Plans for the design, construction, and operation of solid waste management sites or modifications to existing sites shall be prepared or approved by a professional engineer and submitted to the Administrator for approval.

(b) The types and quantities of all solid wastes expected to be at the facility should be determined by survey and analysis to form a basis for design. The survey methods and results shall be incorporated with the application for a permit for the facility.

(c) Site development plans shall include the following design factors:

(1) initial and final topographies at contour intervals of Ten (10) feet or less;

(2) land use and zoning within One-quarter (1/4) mile of the site including location of all residences, buildings, wells, water courses, historical sites, recreational areas and roads. All airports within Two (2) miles of the site shall be identified to aid in assessing the potential hazard of birds to aircraft;

(3) location of all utilities within Five Hundred (500) feet of the site;

(4) facilities for employee convenience and equipment maintenance;

(5) narrative description, with associated drawings, indicating site development and operation procedures.

(d) The construction operation of a solid waste management facility other than a MSWLF shall not cause or contribute to the taking of any endangered or threatened species of plant, fish, or wildlife and shall not cause the destruction of the critical habitat of endangered or threatened species.

(e) The design, construction, and operation of a solid waste management facility other than a MSWLF shall not restrict the flow of the base flood, reduce the temporary water storage capacity of the floodplain, or result in a washout of solid waste so as to pose a hazard to human life, wildlife, or land or water resources.

(f) The solid waste management facility, other than a MSWLF, shall not be located, constructed, or operated so that birds attracted to the facility pose a hazard to aircraft approaching or leaving any airport.

§23403. Table of maximum contaminant levels (MCL) for constituents at the relevant point of compliance.

<u>Chemical</u>	<u>MCL (mg/l)</u>

Arsenic	0.05
Barium	1.0
Benzene	0.005
Cadmium	0.01
Carbon tetrachloride	0.005
Chromium (hexavalent)	0.05
2,4-Dichlorophenoxy acetic acid	0.1
1,4-Dichlorobenzene	0.075
1,2-Dichloroethane	0.005
1,1-Dichloroethylene	0.007
Endrin	0.0002
Fluoride	4.0
Lindane	0.004
Lead	0.05
Mercury	0.002
Methoxychlor	0.1
Nitrate	10.0
Selenium	0.01
Silver	0.05
Toxaphene	0.005
1,1,1-Trichloromethane	0.2
Trichloroethylene	0.005

2,4,5-Trichlorophenoxy acetic acid	0.01
Vinyl Chloride	0.002

Article 5

Ground-water monitoring and corrective action

§23501. Applicability. (a) The requirements in this part apply to MSWLF units, except as provided in Subsection (b) of this §23501.

(b) Ground-water monitoring requirements under §§23502 through 506 of this Chapter may be suspended by the Administrator for a MSWLF unit if the owner or operator can demonstrate that there is no potential for migration of hazardous constituents from that MSWLF unit to the uppermost aquifer (as defined in §23102 of this Chapter) during the active life of the unit and the post-closure care period. This demonstration must be certified by a qualified ground-water scientist and approved by the Administrator, and must be based upon:

(1) site-specific field collected measurements, sampling, and analysis of physical, chemical, and biological processes affecting contaminant fate and transport; and

(2) contaminant fate and transport predictions that maximize contaminant migration and consider impacts on human health and environment.

(c) Owners and operators of MSWLF units must comply with the ground-water monitoring requirements of this Chapter according to the following schedule unless an alternative schedule is specified as discussed in Article 6 of this Chapter.

(1) Existing MSWLF units and lateral expansions less than One (1) mile from a drinking water intake (surface or subsurface) must be in compliance with the ground-

water monitoring requirements specified in §§23502 through 23506 of this Chapter;

(2) Existing MSWLF units and lateral expansions greater than one mile but less than Two (2) miles from a drinking water intake (surface or subsurface) must be in compliance with the ground-water monitoring requirements specified in §§23502 through 23506 of this Chapter;

(3) Existing MSWLF units and lateral expansions greater than Two (2) miles from a drinking water intake (surface or subsurface) must be in compliance with the ground-water monitoring requirements specified in §§23502 through 23506 of this Chapter.

(4) New MSWLF units must be in compliance with the ground-water monitoring requirements specified in §§23502 through 23506 of this Chapter before waste can be placed in the unit.

(d) Once established at a MSWLF unit, ground-water monitoring shall be conducted throughout the active life and post-closure care period of that MSWLF unit as specified in §23602 of this Chapter.

(e) For the purposes of Article 5 of this Chapter, a 'qualified ground-water scientist' is a scientist or engineer who has received a baccalaureate or post-graduate degree in the natural sciences or engineering and has sufficient training and experience in ground-water hydrology and related fields as may be demonstrated by state or territorial registration, professional certifications, or completion of accredited university programs that enable that individual to make sound professional judgements regarding ground-water monitoring, contaminant fate and transport, and corrective-action.

(f) The Administrator may establish alternative schedules for demonstrating compliance with Item (2) of Subsection (d), §23502, pertaining to notification of placement of certification in operating record; Item (1) of Subsection (c), §23505, pertaining to notification that statistically significant increase (SSI) notice is in operating record; Items (2) and (3) of Subsection (c), §23506, pertaining to an assessment monitoring program; Subsection (b) of §23506, pertaining to sampling and analyzing Appendix II constituents; Item (1) of Subsection (d), §23506, pertaining to placement of notice (Appendix II constituents detected) in record and notification of notice in record; Item (2) of Subsection (d), §23506, pertaining to sampling for Appendix I and II; Item (2) of Subsection (g) of §23506, pertaining to notification (and placement of notice in record) of SSI above ground-water protection standard; Item (4) of Subsection (g), §23506 and Subsection (a) of §23507 pertaining to assessment of corrective measures; Subsection (a) of §23508, pertaining to selection of remedy and notification of placement in record; Item (4) of Subsection (c), §23509, pertaining to notification of placement in record (alternative corrective action measures); and Subsection (f) of §23509, pertaining to notification of placement in record (certification of remedy completed), all of this Chapter.

§23502. **Ground-water monitoring systems.** (a) A ground-water monitoring system must be installed that consists of a sufficient number of wells, installed at appropriate locations and depths, to yield ground-water samples from the uppermost aquifer (as defined in §23102 of this Chapter) that:

(1) represent the quality of background ground-water that has not been affected by leakage from a unit. A determination of background quality may include sampling of wells that are not hydraulically upgradient of the waste management area

where:

(A) hydrogeologic conditions do not allow the owner or operator to determine what wells are hydraulically upgradient; or

(B) sampling at other wells will provide an indication of background ground-water quality that is as representative or more representative than that provided by the upgradient wells; and

(2) represent the quality of ground-water passing the relevant point of compliance specified by the Administrator under Subsection (d) of §23401 of this Chapter. The downgradient monitoring system must be installed at the relevant point of compliance specified by the Administrator under Subsection (d) of §23401 that ensures detection of ground-water contamination in the uppermost aquifer. When physical obstacles preclude installation of ground-water monitoring wells at the relevant point of compliance at existing units, the down-gradient monitoring system may be installed at the closest practicable distance hydraulically down-gradient from the relevant point of compliance specified by the Administrator under §23401 of this Chapter that ensure detection of groundwater contamination in the uppermost aquifer.

(b) The Administrator may approve a multi-unit ground-water monitoring system instead of separate ground-water monitoring systems for each MSWLF unit when the facility has several units, provided the multi-unit ground-water monitoring system meets the requirement of Subsection (a) of §23502 of this Chapter and will be as protective of human health and the environment as individual monitoring systems for each MSWLF unit, based on the following factors:

(1) number, spacing, and orientation of the MSWLF units;

(2) hydrogeologic setting;

(3) site history;

(4) engineering design of the MSWLF units; and

(5) type of waste accepted at the MSWLF units.

(c) Monitoring wells must be cased in a manner that maintains the integrity of the monitoring well bore hole. This casing must be screened or perforated and packed with gravel or sand, where necessary, to enable collection of ground-water samples. The annular space (i.e., the space between the bore hole and well casing) above the sampling depth must be sealed to prevent contamination of samples and the ground-water.

(1) The owner or operator must notify the Administrator that the design, installation, development, and decommission of any monitoring wells, piezometers and other measurement, sampling, and analytical devices documentation has been placed in the operating record; and

(2) The monitoring wells, piezometers, and other measurement, sampling, and analytical devices must be operated and maintained so that they perform to design specifications throughout the life of the monitoring program.

(d) The number, spacing, and depths of monitoring systems shall be:

(1) determined based upon site-specific technical information that must include thorough characterization of:

(A) aquifer thickness, ground-water flow rate, ground-water flow direction including seasonal and temporal fluctuations in ground-water flow; and

(B) saturated and unsaturated geologic units and fill materials overlying the uppermost aquifer, materials comprising the uppermost aquifer, and materials comprising the confining unit defining the lower boundary of the uppermost aquifer; including, but not limited to thicknesses, stratigraphy, lithology, hydraulic conductivities, porosities, and effective porosities.

(2) certified by a qualified ground-water scientist or approved by the Administrator. Within Fourteen (14) days of this certification, the owner or operator must notify the Administrator that the certification has been placed in the operating record.

§23503. (Reserved)

§23504. Ground-water sampling and analysis requirements. (a) The ground-water monitoring program must include consistent sampling and analysis procedures that are designed to ensure monitoring results that provide an accurate representation of ground-water quality at the background and downgradient wells installed in compliance with Subsection (a) of §23502 of this Chapter. The owner or operator must notify the Administrator that the sampling and analysis program documentation has been placed in the operating record and the program must include procedures and techniques for:

(1) sample collection;

(2) sample preservation and shipment;

(3) analytical procedures;

(4) chain of custody control; and

(5) quality assurance and quality control.

(b) The ground-water monitoring program must include sampling and analytical methods that are appropriate for ground-water sampling and that accurately measure hazardous constituents and other monitoring parameters in ground-water samples. Ground-water samples shall not be field-filtered prior to laboratory analysis.

(c) The sampling procedures and frequency must be protective of human health and the environment.

(d) Ground-water elevations must be measured in each well immediately prior to purging, each time ground-water is sampled. The owner or operator must determine the rate and direction of ground-water flow each time ground-water is sampled. Ground-water elevations in wells which monitor the same waste management area must be measured within a period of time short enough to avoid temporal variations in ground-water flow which could preclude accurate determination of ground-water flow rate and direction.

(e) The owner or operator must establish background ground-water quality in a hydraulically upgradient or background wells for each of the monitoring parameters or constituents required in the particular ground-water monitoring program that applies to the MSWLF unit, as determined under Subsection (a) of §23505 or Subsection (a) of §23506 of this Chapter. Background ground-water quality may be established at wells that are not located hydraulically upgradient from the MSWLF unit if it meets the requirements of Item (1) of Subsection (a), §23502 of this Chapter.

(f) The number of samples collected to establish groundwater quality data must be consistent with the appropriate statistical procedures determined pursuant to Subsection (g) of this §23504. The sampling procedures shall be those specified under Subsection (b) of §23505 for detection monitoring, Subsections (b) and (d) of §23506 for assessment monitoring, and Subsection (b) of §23507 for corrective action, all of this Chapter.

(g) The owner or operator must specify in the operating record one of the following statistical methods to be used in evaluating ground-water monitoring data for each hazardous constituent. The statistical test chosen shall be conducted separately for each hazardous constituent in each well.

(1) A parametric analysis of variance (ANOVA) followed by multiple comparisons procedures to identify statistically significant evidence of contamination. The method must include estimation and testing of the contrasts between each compliance well's mean and the background mean levels for each constituent.

(2) An analysis of variance (ANOVA) based on ranks followed by multiple comparisons procedures to identify statistically significant evidence of contamination. The method must include estimation and testing of the contrasts between each compliance well's median and the background median levels for each constituent.

(3) A tolerance or prediction interval procedure in which an interval for each constituent is established from the distribution of the background data, and the level of each constituent in each compliance well is compared to the upper tolerance or prediction limit.

(4) A control chart approach that gives control limits for each constituent.

(5) Another statistical test method that meets the performance standards of Subsection (h) of this §23504. The owner or operator must place a justification for this alternative in the operating record and notify the Administrator of the use of this

alternative test. The justification must demonstrate that the alternative method meets the performance standards of Subsection (h) of this §23504. Components of such demonstrations are identified in Chapter 5, Subpart E, of the EPA Solid Waste Disposal Facility Criteria, Technical Manual, published in November 1993 or as updated.

(h) Any statistical method chosen under Subsection (g) of this §23504 shall comply with the following performance standards, as appropriate.

(1) The statistical method used to evaluate ground-water monitoring data shall be appropriate for the distribution of chemical parameters or hazardous constituents. If the distribution of the chemical parameters or hazardous constituents is shown by the owner or operator to be inappropriate for a normal theory test, then the data should be transformed or a distribution-free theory test should be used. If the distributions for the constituents differ, more than one statistical method may be needed.

(2) If an individual well comparison procedure is used to compare an individual compliance well constituent concentration with background constituent concentrations or a ground-water protection standard, the test shall be done at a Type I error level no less than 0.01 for each testing period. If a multiple comparisons procedure is used, the Type I experiment wise error rate for each testing period shall be no less than 0.05; however, the Type I error of no less than 0.01 for individual well comparisons must be maintained. This performance standard does not apply to tolerance intervals, prediction intervals, or control charts.

(3) If a control chart approach is used to evaluate ground-water monitoring data, the specific type of control chart and its associated parameter values shall be

protective of human health and the environment. The parameters shall be determined after considering the number of samples in the background data base, the data distribution, and the range of the concentration values for each constituent of concern.

(4) If a tolerance interval or a predictional interval is used to evaluate ground-water monitoring data, the levels of confidence and, for tolerance intervals, the percentage of the population that the interval must contain, shall be protective of human health and the environment. These parameters shall be determined after considering the number of samples in the background data base, the data distribution, and the range of the concentration values for each constituent of concern.

(5) The statistical method shall account for data below the limit of detection with One (1) or more statistical procedures that are protective of human health and the environment. Any practical quantitative limit (pql) that is used in the statistical method shall be the lowest concentration level that can be reliably achieved within specified limits of precision and accuracy during routine laboratory operating conditions that are available to the facility.

(6) If necessary, the statistical method shall include procedures to control or correct for seasonal and spatial variability as well as temporal correlation in the data.

(i) The owner or operator must determine whether or not there is a statistically significant increase over background values for each parameter or constituent required in the particular ground-water monitoring program that applies to the MSWLF unit, as determined under Subsection (a) of §23505 or Subsection (a) of §23506, all of this Chapter.

(1) In determining whether a statistically significant increase has occurred,

the owner or operator must compare the ground-water quality of each parameter or constituent at each monitoring well designated pursuant to Item (2) of Subsection (a) of §23502 of this Chapter, to the background value of that constituent, according to the statistical procedures and performance standards specified under Subsections (g) and (h) of this §23504.

(2) Within a reasonable period of time after completing sampling and analysis, the owner or operator must determine whether there has been a statistically significant increase over background at each monitoring well.

§23505. Detection monitoring program. (a) Detection monitoring is required at MSWLF units at all ground-water monitoring wells defined under Items (1) and (2) of Subsection (a), §23502 of this Chapter. At a minimum, a detection monitoring program must include the monitoring for the constituents listed in Appendix I of this Chapter.

(1) The Administrator may delete any of the Appendix I monitoring parameters for a MSWLF unit if it can be shown that the removed constituents are not reasonably expected to be contained in or derived from the waste contained in the unit.

(2) The Administrator may establish an alternative list of inorganic indicator parameters for a MSWLF unit, in lieu of some or all of the heavy metals (constituents 1-15 in Appendix I of this Chapter), if the alternative parameters provide a reliable indication of inorganic releases from the MSWLF unit to the ground-water. In determining alternative parameters, the Administrator shall consider the following factors:

(A) the types, quantities, and concentrations of constituents in waste managed at the MSWLF unit;

(B) the mobility, stability, and persistence of waste constituents or their reaction products in the unsaturated zone beneath the MSWLF unit;

(C) the detectability of indicator parameters, waste constituents, and reaction products in the ground-water; and

(D) the concentration or values and coefficients of variation of monitoring parameters or constituents in the ground-water background.

(b) The monitoring frequency for all constituents listed in Appendix I of this Chapter, or in the alternative list approved in accordance with Item (2) of Subsection (a) of this §23505, shall be at least semi-annual during the active life of the facility (including closure) and the post-closure period. A minimum of Four (4) independent samples from each well (background and downgradient) must be collected and analyzed for the Appendix I constituents, or the alternative list approved in accordance with Item (2) of Subsection (a) of this §23505, during the first semiannual sampling event. At least One (1) sample from each well (background and downgradient) must be collected and analyzed during subsequent semiannual sampling events. The Administrator may specify an appropriate alternative frequency for repeated sampling and analysis for Appendix I constituents, or the alternative list approved in accordance with Item (2) of Subsection (a) of this §23505, during the active life (including closure) and the post-closure care period. The alternative frequency during the active life (including closure) shall be no less than annual. The alternative frequency shall be based on consideration of the following factors:

(1) lithology of the aquifer and unsaturated zone;

(2) hydraulic conductivity of the aquifer and unsaturated zone;

(3) ground-water flow rates;

(4) minimum distance between upgradient edge of the MSWLF unit and downgradient monitoring well screen (minimum distance of travel); and

(5) resource value of the aquifer.

(c) If the owner or operator determines, pursuant to Subsection (g) of §23504, that there is a statistically significant increase over background for One (1) or more of the constituents listed in Appendix I of this Chapter, or in the alternative list approved in accordance with Item (2) of Subsection (a) of this §23505, at any monitoring well at the boundary specified under Item (2) of Subsection (a) of §23502, the owner or operator:

(1) must within Fourteen (14) days of this finding place a notice in the operating record indicating which constituents have shown statistically significant changes from background levels, and notify the Administrator that this notice was placed in the operating record; and

(2) must establish an assessment monitoring program meeting the requirements of §23506 within Ninety (90) days except as provided for in Item (3) of Subsection (c) of this §23505.

(3) may demonstrate that a source other than a MSWLF unit caused the contamination or that the statistically significant increase resulted from error in sampling, analysis, statistical evaluation, or natural variation in ground-water quality. Components of such demonstrations are identified in Chapter 5, Subpart E, of the EPA Solid Waste Disposal Facility Criteria, Technical Manual, published in November 1993

or as updated. A report documenting this demonstration must be certified by a qualified ground-water scientist or approved by the Administrator and be placed in the operating record. If a successful demonstration is made and documented, the owner or operator may continue detection monitoring as specified in this section. If, after Ninety (90) days, a successful demonstration is not made, the owner or operator must initiate an assessment monitoring program as required in §23506 of this Chapter.

§23506. Assessment monitoring program. (a) Assessment monitoring is required whenever a statistically significant increase over background has been detected for one or more of the constituents listed in Appendix I or in the alternative list approved in accordance with Item (2) of Subsection (a) of §23505.

(b) Within Ninety (90) days of triggering an assessment monitoring program, and annually thereafter, the owner or operator must sample and analyze the ground-water for all constituents identified in Appendix II of this Chapter. A minimum of One (1) sample from each downgradient well must be collected and analyzed during each sampling event. For any constituent detected in the downgradient wells as the result of the complete Appendix II analysis, a minimum of Four (4) independent samples from each well (background and downgradient) must be collected and analyzed to establish background for the new constituents. The Administrator may specify an appropriate subset of wells to be sampled and analyzed for Appendix II constituents during assessment monitoring. The Administrator may delete any of the Appendix II monitoring parameters for a MSWLF unit if it can be shown that the removed constituents are not reasonably expected to be in or derived from the waste contained in the unit.

(c) The Administrator may specify an appropriate alternate frequency for repeated sampling and analysis for the full set of Appendix II constituents required by Subsection (b) of §23506, during the active life (including closure) and post-closure care of the unit considering the following factors:

(1) lithology of the aquifer and unsaturated zone;

(2) hydraulic conductivity of the aquifer and unsaturated zone;

(3) ground-water flow rates;

(4) minimum distance between upgradient edge of the MSWLF unit and downgradient monitoring well screen (minimum distance of travel);

(5) resource value of the aquifer; and

(6) nature (fate and transport) of any constituents detected in response to this §23506.

(d) After obtaining the results from the initial or subsequent sampling events required in Subsection (b) of this §23506, the owner or operator must:

(1) within Twenty-four (24) hours, place a notice in the operating record identifying the Appendix II constituents that have been detected and notify the Administrator that this notice has been placed in the operating record;

(2) within Ninety (90) days, and on at least a semi-annual basis thereafter, resample all wells specified by Subsection (a) of §23502, conduct analyses for all constituents in Appendix I of this Chapter or in the alternative list approved in accordance with Item (2) of Subsection (a) of §23505, and for those constituents in Appendix II of these regulations that are detected in response to Subsection (b) of this

§23506, and record their concentrations in the facility operating record. At least One (1) sample from each well (background and downgradient) must be collected and analyzed during these sampling events.

The Administrator may specify an alternative monitoring frequency during the active life (including closure) and the post closure period for the constituents referred to in this paragraph. The alternative frequency for Appendix I constituents, or the alternative list approved in accordance with Item (2) of Subsection (a) of §23505, during the active life (including closure) shall be no less than annual. The alternative frequency shall be based on consideration of the factors specified in Subsection (c) of this §23506;

(3) establish background concentrations for any constituents detected pursuant to Subsection (b) or Item (2) of Subsection (d), all of this §23506; and

(4) establish ground-water protection standards for all constituents detected pursuant to Subsections (b) and (d) of this §23506. The ground-water protection standards shall be established in accordance with Subsections (h) or (i) of this §23506.

(e) If the concentrations of all Appendix II constituents are shown to be at or below background values, using the statistical procedures in Subsection (g) of §23504, for Two (2) consecutive sampling events, the owner or operator must notify the Administrator of this finding and may return to detection monitoring.

(f) If the concentrations of any Appendix II constituents are above background values, but all concentrations are below the ground-water protection standard established under Subsections (h) or (i) of this §23506, using the statistical procedures in Subsections (g) of §23504, the owner or operator must continue assessment monitoring in accordance with this

§23506.

(g) If One (1) or more Appendix II constituents are detected at statistically significant levels above the ground-water protection standard established under Subsections (h) or (i) of this §23506, in any sampling event, the owner or operator must, within Fourteen (14) days of this finding, place a notice in the operating record identifying the Appendix II constituents that have exceeded the ground-water protection standard and notify the Administrator and all appropriate local government officials that the notice has been placed in the operating record. The owner or operator also:

(1) must characterize the nature and extent of the release by installing additional monitoring wells as necessary;

(2) must install at least One (1) additional monitoring well at the facility boundary in the direction of contaminant migration and sample this well in accordance with Item (2) of Subsection (d) of this §23506;

(3) must notify all persons who own the land or reside on the land that directly overlies any part of the plume of contamination if contaminants have migrated off-site if indicated by sampling of wells in accordance with Item (1) of Subsection (g) of this §23506; and

(4) must initiate an assessment of corrective measures as required by §23507 of this Chapter within Ninety (90) days; or

(5) may demonstrate that a source other than a MSWLF unit caused the contamination, or that the SSI resulted from error in sampling, analysis, statistical evaluation, or natural variation in ground-water quality. Components of such

demonstrations are identified in Chapter 5, Subpart E, of the EPA Solid Waste Disposal Facility Criteria, Technical Manual, published in November 1993 or as updated. A report documenting this demonstration must be certified by a qualified ground-water scientist or approved by the Administrator and placed in the operating record. If a successful demonstration is made, the owner or operator must continue monitoring in accordance with the assessment monitoring program pursuant to this §23506, and may return to detection monitoring if the Appendix II constituents are at or below background as specified in Subsection (e) of this §23506. Until a successful demonstration is made, the owner or operator must comply with Subsection (g) of this §23506, including initiating an assessment of corrective measures.

(h) The owner or operator must establish a ground-water protection standard for each Appendix II constituent detected in the ground-water. The ground-water protection standard shall be:

(1) for constituents for which a maximum contaminant level (MCL) has been promulgated under Section 1412 of the Safe Drinking Water Act (42 U.S.C. §300g) and under 40 CFR Part 141, the MCL for that constituent;

(2) for constituents for which MCLs have not been promulgated, the background concentration for the constituent established from wells in accordance with Item (1) of Subsection (a) of §23502; or

(3) For constituents for which the background level is higher than the MCL identified under Item (1) of Subsection (h) of this §23506 or health based levels identified under Item (1) of Subsection (i) of this §23506, the background concentration.

(i) The Administrator may establish an alternative ground-water protection standard for constituents for which MCLs have not been established. These ground-water protection standards shall be appropriate health based levels that satisfy the following criteria:

(1) the level is derived in a manner consistent with USEPA guidelines for assessing the health risks of environmental pollutants (51 FR 33992, 34006, 34014, 34028, September 24, 1986);

(2) the level is based on scientifically valid studies conducted in accordance with the Toxic Substances Control Act Good Laboratory Practice Standards (40 CFR Part 792) or equivalent;

(3) for carcinogens, the level represents a concentration associated with an excess lifetime cancer risk level (due to continuous lifetime exposure) with the 1×10^{-4} to 1×10^{-6} range; and

(4) for systemic toxicant, the level represents a concentration to which the human population (including sensitive subgroups) could be exposed to on a daily basis that is likely to be without appreciable risk of deleterious effects during a lifetime. For purposes of this Subsection (i) of this §23506, systemic toxicant includes toxic chemicals that cause effects other than cancer or mutation.

(j) In establishing ground-water protection standards under Subsection (i) of this §23506, the Administrator may consider the following:

(1) multiple contaminants in the ground-water;

(2) exposure threats to sensitive environmental receptors; and

(3) other site-specific exposure or potential exposure to ground-water.

§23507. Assessment of corrective measures. (a) Within Ninety (90) days of finding that any of the constituents listed in Appendix II have been detected at a statistically significant level exceeding the ground-water protection standards defined under Subsections (h) or (i) of §23506 of this Chapter, the owner or operator must initiate an assessment of corrective measures. Such an assessment must be completed within a reasonable period of time.

(b) The owner or operator must continue to monitor in accordance with the assessment monitoring program as specified in §23506 of this Chapter.

(c) The assessment shall include an analysis of the effectiveness of potential corrective measures in meeting all of the requirements and objectives of the remedy as described under §23508 of this Chapter, addressing at least the following:

(1) the performance, reliability, ease of implementation, and potential impacts of appropriate potential remedies, including safety impacts, cross-media impacts, and control of exposure to any residual contamination;

(2) the time required to begin and complete the remedy;

(3) the costs of remedy implementation; and

(4) The institutional requirements such as territorial or local permit requirements or other environmental or public health requirements that may substantially affect implementation of the remedy.

(d) The owner or operator must discuss the results of the corrective measures assessment, prior to the selection of remedy, in a public meeting with interested and affected parties.

§23508. Selection of remedy. (a) Based on the results of the corrective measures assessment conducted under §23507 of this Chapter, the owner or operator must select a remedy that, at a minimum, meets the standards listed in Suybsection (b) of this §23508. The owner or operator must notify the Administrator, within Fourteen (14) days of selecting a remedy, a report describing the selected remedy has been placed in the operating record and how it meets the standards in Subsection (b) of this §23508.

(b) Remedies must:

(1) be protective of human health and the environment;

(2) attain the ground-water protection standard as specified pursuant to Subsections (h) or (i) of §23506 of this Chapter;

(3) control the source(s) of releases so as to reduce or eliminate, to the maximum extent practicable, further releases of Appendix II constituents into the environment that may pose a threat to human health or the environment; and

(4) comply with standards for management of wastes as specified in Subsection (d) of §23509 of this Chapter.

(c) In selecting a remedy that meets the standards of Subsection (b) of this §23508, the owner or operator shall consider the following evaluation factors:

(1) The long-term and short-term effectiveness and protectiveness of the potential remedy(ies), along with the degree of certainty that the remedy will prove successful based on consideration of the following:

(A) magnitude of reduction of existing risks;

(B) magnitude of residual risks in terms of likelihood of further releases due to waste remaining following implementation of a remedy;

(C) the type and degree of long-term management required, including monitoring, operation, and maintenance;

(D) short-term risks that might be posed to the community, workers, or the environment during implementation of such a remedy, including potential threats to human health and the environment associated with excavation, transportation, and redisposal or containment;

(E) time until full protection is achieved;

(F) potential for exposure of humans and environmental receptors to remaining wastes, considering the potential threat to human health and the environment associated with excavation, transportation, redisposal, or containment;

(G) long-term reliability of the engineering and institutional controls; and

(H) potential need for replacement of the remedy.

(2) The effectiveness of the remedy in controlling the source to reduce further releases based on consideration of the following factors:

(A) the extent to which containment practices will reduce further releases;

(B) the extent to which treatment technologies may be used.

(3) The ease or difficulty of implementing a potential remedy(ies) based on consideration of the following types of factors:

(A) degree of difficulty associated with constructing the technology;

(B) expected operational reliability of the technologies;

(C) need to coordinate with and obtain necessary approvals and permits from other agencies;

(D) availability of necessary equipment and specialists; and

(E) available capacity and location of needed treatment, storage, and disposal services.

(4) Practicable capability of the owner or operator, including a consideration of the technical and economic capability.

(5) The degree to which community concerns are addressed by a potential remedy(ies).

(d) The owner or operator shall specify as part of the selected remedy a schedule(s) for initiating and completing remedial activities. Such a schedule must require the initiation of remedial activities within a reasonable period of time taking into consideration the factors set forth in Items (1) through (8) of Subsection (d) of this §23508. The owner or operator must consider the following factors in determining the schedule of remedial activities:

(1) extent and nature of contamination;

(2) practical capabilities of remedial technologies in achieving compliance with ground-water protection standards established under Subsections (g) or (h) of §23506 of this Chapter and other objectives of the remedy;

(3) availability of treatment or disposal capacity for wastes managed during implementation of the remedy;

(4) desirability of utilizing technologies that are not currently available, but

which may offer significant advantages over already available technologies in terms of effectiveness, reliability, safety, or ability to achieve remedial objectives;

(5) potential risks to human health and the environment from exposure to contamination prior to completion of the remedy;

(6) resource value of the aquifer including:

(A) current and future uses;

(B) proximity and withdrawal rate of users;

(C) ground-water quantity and quality;

(D) the potential damage to wildlife, crops, vegetation, and physical structures caused by exposure to waste constituent;

(E) the hydrogeologic characteristic of the facility and surrounding land;

(F) ground-water removal and treatment costs; and

(G) the cost and availability of alternative water supplies.

(7) practicable capability of the owner or operator;

(8) other relevant factors.

(e) The Administrator may determine that remediation of a release of an Appendix II constituent from a MSWLF unit is not necessary if the owner or operator demonstrates to the Administrator that:

(1) the ground-water is additionally contaminated by substances that have originated from a source other than a MSWLF unit and those substances are present in concentrations such that cleanup of the release from the MSWLF unit would provide no

significant reduction in risk to actual or potential receptors; or

(2) the constituent(s) is present in ground-water that:

(A) is not currently or reasonably expected to be a source of drinking water; and

(B) is not hydraulically connected with waters to which the hazardous constituents are migrating or are likely to migrate in a concentration(s) that would exceed the ground-water protection standards established under Subsections (h) or (i) of §23506; or

(3) remediation of the release(s) is technically impracticable; or

(4) remediation results in unacceptable cross-media impacts.

(f) A determination by the Administrator pursuant to Subsection (e) of §23508 shall not affect the authority of Guam to require the owner or operator to undertake source control measures or other measures that may be necessary to eliminate or minimize further releases to the ground-water, to prevent exposure to the ground-water, or to remediate the ground-water to concentrations that are technically practicable and significantly reduce threats to human health or the environment.

§23509. Implementation of the corrective action program. (a) Based on the schedule established under Subsection (d) of §23508 of this Chapter, for initiation and completion of remedial activities the owner or operator must:

(1) establish and implement a corrective action ground-water monitoring program that:

(A) at a minimum, meet the requirements of an assessment monitoring program under §23506 of this Chapter;

(B) indicate the effectiveness of the corrective action remedy; and

(C) demonstrate compliance with ground-water protection standard pursuant to Subsection (e) of this §23509. Components of such demonstrations are identified in Chapter 5, Subpart E, of the EPA Solid Waste Disposal Facility Criteria, Technical Manual, published in November 1993 or as updated.

(2) implement the corrective action remedy selected under §23508 of this Chapter; and

(3) take any interim measures necessary to ensure the protection of human health and the environment. Interim measures should, to the greatest extent practicable, be consistent with the objectives of, and contribute to, the performance of any remedy that may be required pursuant to §23508 of this Chapter. The following factors must be considered by an owner or operator in determining whether interim measures are necessary:

(A) time required to develop and implement a final remedy;

(B) actual or potential exposure of nearby populations or environmental receptors to hazardous constituents;

(C) actual or potential contamination of drinking water supplies or sensitive ecosystems;

(D) further degradation of the ground-water that may occur if remedial action is not initiated expeditiously;

(E) weather conditions that may cause hazardous constituents to migrate or be released;

(F) risks of fire or explosion, or potential for exposure to hazardous constituents as a result of an accident or failure of a container or handling system; and

(G) other situations that may pose threats to human health and the environment.

(b) An owner or operator may determine, based on information developed after implementation of the remedy has begun or other information, that compliance with requirements of Subsection (b) of §23508 of this Chapter are not being achieved through the remedy selected. In such cases, the owner or operator must implement other methods or techniques that could practicably achieve compliance with the requirements, unless the owner or operator makes the determination under Subsection (c) of this §23509.

(c) If the owner or operator determines that compliance with requirements under Subsection (b) of §23508 cannot be practically achieved with any currently available methods, the owner or operator must:

(1) obtain certification of a qualified ground-water scientist or approval by the Administrator that compliance with requirements under Subsection (b) of §23508 cannot be practically achieved with any currently available methods;

(2) implement alternate measures to control exposure of humans or the environment to residual contamination, as necessary to protect human health and the environment; and

(3) implement alternate measures for control of the sources of contamination,

or for removal or decontamination of equipment, units, devices, or structures that are:

(A) technically practicable; and

(B) consistent with the overall objective of the remedy.

(4) notify the Administrator within Fourteen (14) days that a report justifying the alternative measures prior to implementing the alternative measures has been placed in the operating record.

(d) All solid wastes that are managed pursuant to a remedy required under §23508 of this Chapter, or an interim measure required under Item (3) of Subsection (a) of this §23509, shall be managed in a manner;

(1) that is protective of human health and the environment; and

(2) that complies with applicable RCRA requirements.

(e) Remedies selected pursuant to §23508 of this Chapter, shall be considered complete when:

(1) the owner or operator complies with the ground-water protection standards established under Subsections (h) or (i) of §23506 at all points within the plume of contamination that lie beyond the ground-water monitoring well system established under Subsection (a) of §23502;

(2) compliance with the ground-water protection standards established under Subsections (h) or (i) of §23506 has been achieved by demonstrating that concentrations of Appendix II constituents have not exceeded the ground-water protection standard(s) for a period of Three (3) consecutive years using the statistical procedures and performance standards in Subsections (g) or (h) of §23504. Components of such

demonstrations are identified in Chapter 5, Subpart E, of the EPA Solid Waste Disposal Facility Criteria, Technical Manual, published in November 1993 or as updated. The Administrator may specify an alternative length of time during which the owner or operator must demonstrate that concentrations of Appendix II constituents have not exceeded the ground-water protection standard(s) taking into consideration:

(A) extent and concentration of the release(s);

(B) behavior characteristics of the hazardous constituents in the ground-water;

(C) accuracy of monitoring or modeling techniques, including any seasonal, meteorological, or other environmental variabilities that may affect the accuracy; and

(D) characteristics of the ground-water;

(3) all actions required to complete the remedy have been satisfied.

(f) Upon completion of the remedy, the owner or operator must notify the Administrator within Fourteen (14) days that a certification that the remedy has been completed in compliance with the requirements of Subsection (e) of this §23509 has been placed in the operating record. The certification must be signed by the owner or operator and by a qualified ground-water scientist or approved by the Administrator.

(g) When, upon completion of the certification, the owner or operator determines that the corrective action remedy has been completed in accordance with the requirements under Subsection (e) of this §23509, the owner or operator shall be released from the requirements for financial assurance for corrective action under §23704.

Article 6

Closure and post-closure care

§23601. Closure criteria. (a) Owners or operators of all MSWLF units must install a final cover system that is designed to minimize infiltration and erosion. The final cover system must be comprised of an erosion layer underlain by an infiltration layer as follows:

(1) the infiltration layer must be comprised of a minimum of Eighteen (18) inches of earthen material that has a permeability less than or equal to the permeability of any bottom liner system or natural subsoils present, or a permeability no greater than 1×10^{-5} cm/sec, whichever is less, and

(2) the erosion layer must consist of a minimum Six (6) inches of earthen material that is capable of sustaining native plant growth.

(b) The Administrator may approve an alternative final cover design that includes:

(1) an infiltration layer that achieves an equivalent reduction in infiltration as the infiltration layer specified in Item (1) of Subsection (a) of this §23601; and

(2) an erosion layer that provides equivalent protection from wind and water erosion as the erosion layer specified in Item (2) of Subsection (a) of this §23601.

(c) The owner or operator must prepare a written closure plan that describes the steps necessary to close all MSWLF units at any point during its active life in accordance with the cover design requirements in Subsections (a) or (b) of this §23601, as applicable. This plan must be approved by Guam EPA prior to the initiation of closure activities. The closure plan, at a minimum, must include the following information:

(1) a description of the final cover, designed in accordance with Subsections

(a) of this §23601 and the methods and procedures to be used to install the cover;

(2) an estimate of the largest area of the MSWLF unit ever requiring a final cover as required under Subsections (a) of this §23601 at any time during the active life;

(3) an estimate of the maximum inventory of wastes ever on-site over the active life of the landfill facility; and

(4) a schedule for completing all activities necessary to satisfy the closure criteria in this §23601.

(d) The owner or operator must notify the Administrator that a closure plan has been prepared and placed in the operating record immediately or by the initial receipt of waste, whichever is later.

(e) Prior to beginning closure of each MSWLF unit as specified in Subsections (f) of this §23601, an owner or operator must notify the Administrator that a notice of the intent to close the unit has been placed in the operating record.

(f) The owner or operator must begin closure activities of each MSWLF unit no later than Thirty (30) days after the date on which the MSWLF unit receives the known final receipt of wastes or, if the MSWLF unit has remaining capacity and there is a reasonable likelihood that the MSWLF unit will receive additional wastes, no later than One (1) year after the most recent receipt of wastes. Extensions beyond the One (1) year deadline for beginning closure may be granted by the Administrator if the owner or operator demonstrates that the MSWLF unit has the capacity to receive additional wastes and the owner or operator has taken and will continue to take all steps necessary to prevent threats to human health and the environment from the unclosed MSWLF unit.

(g) The owner or operator of all MSWLF units must complete closure activities of each MSWLF unit in accordance with the closure plan within One hundred and eighty (180) days following the beginning of closure as specified in Subsection (f) of this §23601. Extensions of the closure period may be granted by the Administrator if the owner or operator demonstrates that closure will, of necessity, take longer than One hundred and eighty (180) days and he has taken and will continue to take all steps to prevent threats to human health and the environment from the unclosed MSWLF unit.

(h) Following closure of each MSWLF unit, the owner or operator must notify the Administrator that a certification, signed by an independent registered professional engineer and approved by the Administrator, verifying that closure has been completed in accordance with the closure plan, has been placed in the operating record.

(i) Following closure of all MSWLF units, the owner or operator must record a notation on the deed to the landfill facility property, or some other instrument that is normally examined during title search, and notify the Administrator that the notation has been recorded and a copy has been placed in the operating record.

(j) The notation on the deed must in perpetuity notify any potential purchaser of the property that:

(1) the land has been used as a landfill facility; and

(2) its use is restricted under Item (3) of Subsection (c) of this §23602.

(k) The owner or operator may request permission from the Administrator to remove the notation from the deed if all wastes are removed from the facility.

§23602. Post-closure care requirements. (a) Following closure of each

MSWLF unit, the owner or operator must conduct post-closure care. Post-closure care must be conducted for Thirty (30) years, except as provided under Subsection (b) of this §23602, and consist of at least the following:

(1) maintaining the integrity and effectiveness of any final cover, including making repairs to the cover as necessary to correct the effects of settlement, subsidence, erosion, or other events, and preventing run-on and run-off from eroding or otherwise damaging the final cover;

(2) maintaining and operating the leachate collection system in accordance with the requirements in §23401 of this Chapter. The Administrator may allow the owner or operator to stop managing leachate if the owner or operator demonstrates that leachate no longer poses a threat to human health and the environment;

(3) monitoring the ground-water in accordance with the requirements of Article 5 of this Chapter and maintaining the ground-water monitoring system, if applicable; and

(4) Maintaining and operating the gas monitoring system in accordance with the requirements of §23306.

(b) The length of the post-closure care period may be:

(1) decreased by the Administrator if the owner or operator demonstrates that the reduced period is sufficient to protect human health and the environment and this demonstration is approved by the Administrator; or

(2) increased by the Administrator, if the Administrator determines that the lengthened period is necessary to protect human health and the environment.

(c) The owner or operator of all MSWLF units must prepare a written post-closure plan that includes, at a minimum, the following information:

(1) a description of the monitoring and maintenance activities required in Subsection (a) of this §23602, for each MSWLF unit, and the frequency at which these activities will be performed;

(2) name, address, and telephone number of the person or office to contact about the facility during the post-closure period; and

(3) a description of the planned uses of the property during the post-closure period. Post-closure use of the property shall not disturb the integrity of the final cover, liner(s), or any other components of the containment system, or the function of the monitoring systems unless necessary to comply with the requirements in this Chapter.

The Administrator may approve any other disturbance if the owner or operator demonstrates that disturbance of the final cover, liner or other component of the containment system, including any removal of waste, will not increase the potential threat to human health or the environment.

(d) The owner or operator must notify the Administrator that a post-closure plan has been prepared and placed in the operating record immediately or by the initial receipt of waste, whichever is later.

(e) Following completion of the post-closure care period for each MSWLF unit, the owner or operator must notify the Administrator that a certification, signed by an independent registered professional engineer and approved by the Administrator, verifying that post-closure care has been completed in accordance with the post-closure plan, has been placed in the operating record.

Article 7

Financial assurance criteria

§23701. **Applicability and effective date.** (a) The requirements of this Article 7 apply to owners and operators of all MSWLF units, except owners or operators who are local or federal government entities whose debts and liabilities are the debts and liabilities of Guam or the United States.

(b) The requirements of this Article shall be effective immediately.

§23702. **Financial assurance for closure.** (a) The owner or operator must have a detailed written estimate, in current dollars, of the cost of hiring a third party to close the largest area of all MSWLF units ever requiring a final cover as required under §23601 of this Chapter at any time during the active life in accordance with the closure plan. The owner or operator must notify the Administrator that the estimate has been placed in the operating record.

(1) The cost estimate must equal the cost of closing the largest area of all MSWLF units ever requiring a final cover at any time during the active life when the extent and manner of its operation would make closure the most expensive, as indicated by its closure plan (see Item (2) of Subsection (c), §23601 of this Chapter).

(2) During the active life of the MSWLF unit, the owner or operator must annually adjust the closure cost estimate for inflation.

(3) The owner or operator must increase the closure cost estimate and the amount of financial assurance if changes to the closure plan or MSWLF unit conditions increase the maximum cost of closure at any time during the remaining active life.

(4) The owner or operator may reduce the closure cost estimate and the amount of financial assurance if the cost estimate exceeds the maximum cost of closure at any time during the remaining life of the MSWLF unit. The owner or operator must notify the Administrator that the justification for the reduction of the closure cost estimate and the amount of financial assurance has been placed in the operating record.

(b) The owner or operator of each MSWLF unit must establish financial assurance for closure of the MSWLF unit in compliance with §23705 of this Chapter. The owner or operator must provide continuous coverage for closure until released from financial assurance requirements by demonstrating compliance with Subsections (h), (i), and (j) of §23601 of this Chapter.

§23703. Financial assurance for post-closure care. (a) The owner or operator must have a detailed written estimate, in current dollars, of the cost of hiring a third party to conduct post-closure care for the MSWLF unit in compliance with the post-closure plan developed under §23602 of this Chapter. The post-closure cost estimate used to demonstrate financial assurance in Subsection (b) of this §23703 must account for the total costs of conducting post-closure care, including annual and periodic costs as described in the post-closure plan over the entire post-closure care period. The owner or operator must notify the Administrator that the estimate has been placed in the operating record.

(1) The cost estimate for post-closure care must be based on the most expensive costs of post-closure care during the post-closure care period.

(2) During the active life of the MSWLF unit and during the post- closure care period, the owner or operator must annually adjust the post-closure cost estimate

for inflation.

(3) The owner or operator must increase the post-closure care cost estimate and the amount of financial assurance provided under Subsection (b) of this §23703 if changes in the post-closure plan or MSWLF unit conditions increase the maximum costs of post-closure care.

(4) The owner or operator may reduce the post-closure cost estimate and the amount of financial assurance provided under Subsection (b) of this §23703 if the cost estimate exceeds the maximum costs of post-closure care remaining over the post-closure care period. The owner or operator must notify the Administrator that the justification for the reduction of the post-closure cost estimate and the amount of financial assurance has been placed in the operating record.

(b) The owner or operator of each MSWLF unit must establish, in a manner in accordance with §23705, financial assurance for the costs of post-closure care as required under §23602 of this Chapter. The owner or operator must provide continuous coverage for post-closure care until released from financial assurance requirements for post-closure care by demonstrating compliance with Subsection (e) of §23602 of this Chapter.

§23704. **Financial assurance for corrective action.** (a) An owner or operator of a MSWLF unit required to undertake a corrective action program under §23509 of this Chapter must have a detailed written estimate, in current dollars, of the cost of hiring a third party to perform the corrective action in accordance with the program required under that Section. The corrective action cost estimate must account for the total costs of corrective action activities as described in the corrective action plan for the entire corrective action period. The owner or operator must notify the Administrator that the estimate has been placed in the operating record.

(1) The owner or operator must annually adjust the estimate for inflation until the corrective action program is completed in accordance with Subsection (f) of §23509 of this Chapter.

(2) The owner or operator must increase the corrective action cost estimate and the amount of financial assurance provided under Subsection (b) of this §23704 if changes in the corrective action program or MSWLF unit conditions increase the maximum costs of corrective action.

(3) The owner or operator may reduce the amount of the corrective action cost estimate and the amount of financial assurance provided under Subsection (b) of this §23704 if the cost estimate exceeds the maximum remaining costs of corrective action. The owner or operator must notify the Administrator that the justification for the reduction of the corrective action cost estimate and the amount of financial assurance has been placed in the operating record.

(b) The owner or operator of each MSWLF unit required to undertake a corrective action program under §23509 of this Chapter must establish, in a manner in accordance with §23705 of this Chapter, financial assurance for the most recent corrective action program. The owner or operator must provide continuous coverage for corrective action until released from financial assurance requirements for corrective action by demonstrating compliance with Subsections (f) and (g) of §23509 of this Chapter.

§23705. Allowable mechanisms. The mechanisms used to demonstrate financial assurance under this section must ensure that the funds necessary to meet the costs of closure, post-closure care, and corrective action for known releases will be available whenever they are needed. Owners and operators must choose from the options specified in Subsections (a) through (f) of this §23705.

(a) Trust fund.

(1) An owner or operator may satisfy the requirements of this §23705 by establishing a trust fund which conforms to the requirements of Subsection (a) of this §23705. The trustee must be an entity which has the authority to act as a trustee and whose trust operations are regulated and examined by a federal or local agency. A copy of the trust agreement must be placed in the facility's operating record. The owner or operator must notify the Administrator that a copy of the trust fund agreement has been placed in the facility's operating record.

(2) Payments into the trust fund must be made annually by the owner or operator over the term of the initial permit or over the remaining life of the MSWLF unit, whichever is shorter, in the case of a trust fund for closure or post-closure care, or over One-half (1/2) of the estimated length of the corrective action program in the case of corrective action for known releases. This period is referred to as the pay-in period.

(3) For a trust fund used to demonstrate financial assurance for closure and post-closure care, the first payment into the fund must be at least equal to the current cost estimate for closure or post-closure care, divided by the number of years in the pay-in period as defined in Item (2) of Subsection (a) of this §23705. The amount of

subsequent payments must be determined by the following formula:

(A) Next payment = (CE - CV)/Y.

(B) CE is the current cost estimate for closure or post-closure care (updated for inflation or other changes), CV is the current value of the trust fund, and Y is the number of years remaining in the pay-in period.

(4) For a trust fund used to demonstrate financial assurance for corrective action, the first payment into the trust fund must be at least equal to One-half (1/2) of the current cost estimate for corrective action, divided by the number of years in the corrective action pay-in period as defined in Item (2) of Subsection (a) of this §23705. The amount of subsequent payments must be determined by the following formula:

(A) Next payment = (RB - CV)/Y.

(B) RB is the most recent estimate of the required trust fund balance for corrective action (i.e., the total costs that will be incurred during the second half of the corrective action period), CV is the current value of the trust fund, and Y is the number of years remaining on the pay-in period.

(5) The initial payment into the trust fund must be made immediately or before the initial receipt of waste, whichever is later, in the case of closure and post-closure care, or no later than One hundred twenty (120) days after the corrective action remedy has been selected in accordance with the requirements of §23509 of this Chapter.

(6) If the owner or operator establishes a trust fund after having used One (1) or more alternate mechanisms specified in this Article, the initial payment into the trust

fund must be at least the amount that the fund would contain if the trust fund were established initially and annual payments made according to the specifications of Subsection (a) of this §23705, as applicable.

(7) The owner or operator, or other person authorized to conduct closure, post-closure care, or corrective action activities may request reimbursement from the trustee for these expenditures. Requests for reimbursement will be granted by the trustee only if sufficient funds are remaining in the trust fund to cover the remaining costs of closure, post-closure care, or corrective action, and if justification and documentation of the cost is placed in the operating record. The owner or operator must notify the Administrator that the documentation of the justification for reimbursement has been placed in the operating record and that reimbursement has been received.

(8) The trust fund may be terminated by the owner or operator only if the owner or operator substitutes alternate financial assurance as specified in this section or if he is no longer required to demonstrate financial responsibility in accordance with the requirements of Subsection (b) of §23703 or Subsection (b) of §23704, all of this Chapter.

(b) Surety bond guaranteeing payment or performance.

(1) An owner or operator may demonstrate financial assurance for closure or post-closure care by obtaining a payment or performance surety bond which conforms to the requirements of this Item (1) of Subsection (b) of this §23705. An owner or operator may demonstrate financial assurance for corrective action by obtaining a performance bond which conforms to the requirements of this paragraph. The bond must

be effective immediately or before the initial receipt of waste, whichever is later, in the case of closure and post-closure care, or no later than One hundred twenty (120) days after the corrective action remedy has been selected in accordance with the requirements of §23509. The owner or operator must notify the Administrator that a copy of the bond has been placed in the operating record. The surety company issuing the bond must, at a minimum, be among those listed as acceptable sureties on federal bonds in Circular 570 of the U.S. Department of the Treasury.

(2) The penal sum of the bond must be in an amount at least equal to the current closure, post-closure care or corrective action cost estimate, whichever is applicable, except as provided in Subsection (g) of §23705.

(3) Under the terms of the bond, the surety will become liable on the bond obligation when the owner or operator fails to perform as guaranteed by the bond.

(4) The owner or operator must establish a standby trust fund. The standby trust fund must meet the requirements of Subsection (a) of §23705, except the requirements for initial payment and subsequent annual payments specified in Items (2), (3), (4), and (5) of Subsection (a) of this §23705.

(5) Payments made under the terms of the bond will be deposited by the surety directly into the standby trust fund. Payments from the trust fund must be approved by the trustee.

(6) Under the terms of the bond, the surety may cancel the bond by sending notice of cancellation by certified mail to the owner and operator and to the Administrator One hundred and twenty (120) days in advance of cancellation. If the

surety cancels the bond, the owner or operator must obtain alternate financial assurance as specified in this Article 7.

(7) The owner or operator may cancel the bond only if alternate financial assurance is substituted as specified in this section or if the owner or operator is no longer required to demonstrate financial responsibility in accordance with Subsection (b) of §23702, Subsection (b) of §23703, or Subsection (b) of §23704, all of this Chapter.

(c) Letter of credit.

(1) An owner or operator may satisfy the requirements of this Article 7 by obtaining an irrevocable standby letter of credit which conforms to the requirements of this Subsection (c). The letter of credit must be effective immediately or before the initial receipt of waste, whichever is later, in the case of closure and post-closure care, or no later than One hundred and twenty (120) days after the corrective action remedy has been selected in accordance with the requirements of §23509 of this Chapter. The owner or operator must notify the Administrator that a copy of the letter of credit has been placed in the operating record. The issuing institution must be an entity which has the authority to issue letters of credit and whose letter-of-credit operations are regulated and examined by a federal or local agency.

(2) A letter from the owner or operator referring to the letter of credit by number, issuing institution, and date, and providing the following information: name, and address of the facility, and the amount of funds assured, must be included with the letter of credit in the operating record.

(3) The letter of credit must be irrevocable and issued for a period of at least

One (1) year in an amount at least equal to the current cost estimate for closure, post-closure care or corrective action, whichever is applicable, except as provided in Subsection (a) of §23705. The letter of credit must provide that the expiration date will be automatically extended for a period of at least One (1) year unless the issuing institution has cancelled the letter of credit by sending notice of cancellation by certified mail to the owner and operator and to the Administrator One hundred and twenty (120) days in advance of cancellation. If the letter of credit is cancelled by the issuing institution, the owner or operator must obtain alternate financial assurance.

(4) The owner or operator may cancel the letter of credit only if alternate financial assurance is substituted as specified in this §23705 or if the owner or operator is released from the requirements of this section in accordance with Subsection (b) of §23702, Subsection (b) of §23703, or Subsection (b) of §23704, all of this Chapter.

(d) Insurance.

(1) An owner or operator may demonstrate financial assurance for closure and post-closure care by obtaining insurance which conforms to the requirements of this paragraph. The insurance must be effective immediately or before the initial receipt of waste, whichever is later. At a minimum, the insurer must be licensed to transact the business of insurance, or eligible to provide insurance as an excess or surplus lines insurer, in Guam or One (1) or more States. The owner or operator must notify the Administrator that a copy of the insurance policy has been placed in the operating record.

(2) The closure or post-closure care insurance policy must guarantee that

funds will be available to close the MSWLF unit whenever final closure occurs or to provide post-closure care for the MSWLF unit whenever the post-closure care period begins, whichever is applicable. The policy must also guarantee that once closure or post-closure care begins, the insurer will be responsible for the paying out of funds to the owner or operator or other person authorized to conduct closure or post-closure care, up to an amount equal to the face amount of the policy.

(3) The insurance policy must be issued for a face amount at least equal to the current cost estimate for closure or post-closure care, whichever is applicable, except as provided in Subsection (a) of this §23705. The term 'face amount' means the total amount the insurer is obligated to pay under the policy. Actual payments by the insurer will not change the face amount, although the insurer's future liability will be lowered by the amount of the payments.

(4) An owner or operator, or any other person authorized to conduct closure or post-closure care, may receive reimbursements for closure or post-closure expenditures, whichever is applicable. Requests for reimbursement will be granted by the insurer only if the remaining value of the policy is sufficient to cover the remaining costs of closure or post-closure care, and if justification and documentation of the cost is placed in the operating record. The owner or operator must notify the Administrator that the documentation of the justification for reimbursement has been placed in the operating record and that reimbursement has been received.

(5) Each policy must contain a provision allowing assignment of the policy to a successor owner or operator. Such assignment may be conditional upon consent of

the insurer, provided that such consent is not unreasonably refused.

(6) The insurance policy must provide that the insurer may not cancel, terminate or fail to renew the policy except for failure to pay the premium. The automatic renewal of the policy must, at a minimum, provide the insured with the option of renewal at the face amount of the expiring policy. If there is a failure to pay the premium, the insurer may cancel the policy by sending notice of cancellation by certified mail to the owner and operator and to the Administrator One hundred and twenty (120) days in advance of cancellation. If the insurer cancels the policy, the owner or operator must obtain alternate financial assurance as specified in this section.

(7) For insurance policies providing coverage for post-closure care, commencing on the date that liability to make payments pursuant to the policy accrues, the insurer will thereafter annually increase the face amount of the policy. Such increase must be equivalent to the face amount of the policy, less any payments made, multiplied by an amount equivalent to Eighty-five Percent (85) of the most recent investment rate or of the equivalent coupon-issue yield announced by the U.S. Treasury for Twenty-six (26) week Treasury securities.

(8) The owner or operator may cancel the insurance policy only if alternate financial assurance is substituted as specified in this section or if the owner or operator is no longer required to demonstrate financial responsibility in accordance with the requirements of Subsection (b) of §23702, Subsection (b) of §23703, or Subsection (b) of §23704, all of this Chapter.

(e) Local approved mechanism. An owner or operator may satisfy the requirements of this section by obtaining any other mechanism that meets the criteria specified in Subsection (h) of this §23705, and that is approved by the Administrator.

(f) Local assumption of responsibility. If the Administrator either assumes legal responsibility for an owner or operator's compliance with the closure, post-closure care or corrective action requirements of this Article 7, or assures that the funds will be available from local sources to cover the requirements, the owner or operator will be in compliance with the requirements of this section. Any local assumption of responsibility must meet the criteria specified in Subsection (h) of this §23705.

(g) Use of multiple financial mechanisms. An owner or operator may satisfy the requirements of this Article 7 by establishing more than One (1) financial mechanism per facility. The mechanisms must be as specified in Subsections (a) through (f) of this §23705, except that it is the combination of mechanisms, rather than the single mechanism, which must provide financial assurance for an amount at least equal to the current cost estimate for closure, post-closure care or corrective action, whichever is applicable. The financial test and a guarantee provided by a corporate parent, sibling, or grandparent may not be combined if the financial statements of the Two (2) firms are consolidated.

(h) Criteria for language of financial assurance mechanisms. The language of the mechanisms listed in Subsections (a) through (g) of this §23705, must satisfy the following criteria:

(1) the financial assurance mechanisms must ensure that the amount of funds assured is sufficient to cover the costs of closure, post-closure care, and corrective action for known releases when needed;

(2) the financial assurance mechanisms must ensure that funds will be available in a timely fashion when needed;

(3) the financial assurance mechanisms must be obtained by the owner or operator immediately or prior to the initial receipt of solid waste, whichever is later, in the case of closure and post-closure care, and no later than One hundred and twenty (120) days after the corrective action remedy has been selected in accordance with the requirements of §23509 of this Chapter, until the owner or operator is released from the financial assurance requirements under §§23702, 23703, and 23704 of this Chapter;

(4) the financial assurance mechanisms must be legally valid, binding, and enforceable under federal and local law;

(5) the financial assurance mechanism required by this Chapter may not be canceled by the guarantor unless the Administrator has received written notice thereof and there has been a lapse of One hundred and twenty (120) days between receipt of notice and cancellation date.

Addendum A

Fee schedule for all other solid waste management facilities.

1.	Solid Waste Transfer Facility	$500.00
2.	Industrial Solid Waste Landfill Facility	(Reserved)
3.	Solid Waste Hardfill Facility	$500.00
4.	Solid Waste Storage Facility	$500.00
5.	Solid Waste Processing Facility	
a.	Solid Waste Composting Facility	$100.00
b.	Solid Waste Material Resource Recovery Facility	$200.00
c.	Solid Waste Remediation Facility	
(1)	Bioremediation	
(a)	Temporary Site Specific	$200.00
(b)	Permanent	$500.00
(2)	All other remediation	$500.00
d.	Solid Waste Incinerator Facility	$500.00
e.	Solid Waste-to-Energy Recovery Facility	$10,000.00
f.	Other Processing Facility	$200.00

Addendum B The following is the duration of permit for all other solid waste management facilities.

1.	Solid Waste Transfer Facility			5 years
2.	Industrial Solid Waste Landfill Facility			(Reserved)
3.	Solid Waste Hardfill Facility			2 years
4.	Solid Waste Storage Facility			2 years
5.	Solid Waste Processing Facility			
	a.	Solid Waste Composting Facility		5 years
	b.	Solid Waste Material Resource Recovery Facility		5 years
	c.	Solid Waste Remediation Facility		
		(1)	Bioremediation	
			(a) Temporary Site Specific	2 years
			(b) Permanent	5 years
		(2)	All other remediation	2 years
	d.	Solid Waste Incinerator Facility		5 years
	e.	Solid Waste-to-Energy Recovery Facility		5 years
	f.	Other Processing Facility		2 years

Addendum C **Administrative Penalties.** After following the procedures as outlined in Subsection (e) of §51115 of Public Law 23-64, the Administrator may impose the following administrative penalties up to the listed amount per day for each violation. The violations are including but not limited to the following:

1.	Acceptance of Prohibited Solid Wastes	$1,000.00
2.	Procedures for Excluding Receipt of Hazardous Waste	$1,000.00
3.	Failure to Meet Cover Material Requirements	$1,000.00
4.	Failure to Provide Disease Vector Control	$500.00
5.	Failure to Provide Explosive Gases Control	$800.00
6.	Failure to Meet Air Criteria	$500.00
7.	Failure to Meet Access Requirements	$500.00
8.	Lack of Run-on/Run-off Control Systems	$1,000.00
9.	Failure to Meet Surface Water Requirements	$1,000.00
10.	Acceptance of Liquid Wastes	$1,000.00
11.	Failure to Meet Recordkeeping Requirements	$500.00
12.	Failure to Provide Safety Equipment	
a.	Appropriate Hard Hats	$500.00
b.	Appropriate Respirators/Breathing Equipment	$500.00
c.	Appropriate Safety Shoes	$500.00
d.	Ear Protection	$500.00
e.	Appropriate Work Gloves	$500.00
f.	Appropriate Fire Extinguisher(s)	$1,000.00

g.	First Aid	$1,000.00
h.	Communication Equipment	$500.00
i.	Rollover Protective Structures	$500.00
j.	Seat Belts	$500.00

Appendix B

Guam Code Annotated - Laws Relevant to Solid Waste

Appendix B.1

10GCA Chapter 33 Solid Waste

CHAPTER 33
SOLID WASTE

ARTICLE 1
SOLID WASTE

§ 33101. Definitions.

As used in this Chapter:

(a) *Garbage* means the solid or semi-solid but reusable animal and vegetable waste resulting from the handling, preparation, cooking and serving of foods, including cans, bottles and cartons, in which it was received and wrapping in which it may have been placed for disposal;

(b) *Rubbish* means nonputrescible solid waste, including ashes, consisting of both combustible and noncombustible waste such as paper, cardboard, tin cans, yard clippings, wood, glass, bedding, crockery and broken or rejected matter or litter of any kind;

(c) *Dump* means any area, whether on public or private property, where garbage, trash, refuse, junk, debris or other broken and rejected material is deposited, other than in legal trash or garbage receptacles or other authorized disposal sites; and

(d) *Premises* means any vacant lot or any private property on which is located one (1) or more of the following: home, apartment, hotel or commercial or manufacturing establishment but does not include a dump.

SOURCE: GC § 9630.

§ 33102. Prohibition.

No person shall have on his premises any garbage or rubbish except as provided in this Chapter.

SOURCE: GC § 9630.1.

§ 33103. Storage.

All garbage and rubbish shall be stored and maintained in durable receptacles which shall have close fitting covers, unless otherwise prescribed in the rules and regulations promulgated under this Chapter.

SOURCE: GC § 9630.2.

§ 33104. Residence.

Each person shall provide adequate containers for the storage of all garbage and rubbish prior to collection on the premises where he resides except that where there are multiple dwelling units confined to one (1) property and consisting of five (5) or more units, the owner shall provide adequate containers for all tenants.

SOURCE: GC § 9630.3.

§ 33105. Commercial Establishments.

The owner or operator of any business establishments or commercial operation shall provide adequate containers for the storage of garbage or rubbish that is generated in the course of operating his business or commercial enterprise.

SOURCE: GC § 9630.4.

§ 33106. Removal.

Garbage and rubbish shall be removed from all premises at regular intervals as may be established by regulation, but under no circumstances shall garbage or rubbish accumulate for a period exceeding seven (7) days.

SOURCE: GC § 9630.5.

§ 33107. Dumps.

No person shall maintain or permit the establishment of a dump on their premises unless as otherwise permitted by law.

SOURCE: GC § 9630.6.

§ 33108. Edible Garbage.

The Director is authorized to prescribe by regulation such processing and limitations with respect to the use of garbage as animal feed or other use as he may deem necessary for the public health. No garbage shall be sold or disposed of as food for human consumption.

SOURCE: GC § 9630.7.

§ 33109. Vehicles.

Vehicles used for conveying garbage or rubbish shall not be used for the transportation or conveyance of any food or drink that will or may be used for human consumption.

SOURCE: GC § 9630.8.

ARTICLE 2
SWMF HEALTH MONITORING AND COMPENSATION.

SOURCE: This article was added by P.L. 24-181:1.

§ 33201. Legislative Finding and Intent.

Solid Waste Management Facilities ('SWMF') have byproducts that if exposed repeatedly, or consumed in finite amount, can be detrimental to good health. The community where the SWMF is processing municipal solid waste should be compensated for accepting a facility (incinerator, landfill, WTEF, combustion, plasma, processing) which is essential for the Islands' health and welfare, but inherently exposes that village with not only noxious and eyesore surroundings, but perhaps imposes respiratory disease, infection disorders, cancer ailments and other disorders more than the expected distribution for such illnesses. It is therefore imperative that the monitoring of people, since the facilities and the environment are being monitored already by the Guam Environmental Protection Agency ('GEPA') and the Department of Public Health and Social Services ('DPHSS'), be established and also logically that we should compensate villages.

Recognizing the critical need to establish a Municipal SWMF, it is the intent of the Guam Legislature to provide for the monitoring and compensation of the environmental impact of the Municipal SWMF on the health and welfare of residents in the neighborhood.

§ 33202. Title.

This Article may be cited or referred to as the, "*SWMF Health Monitoring and Compensation Act of 1998.*"

§ 33203. Additional Definitions to this Chapter.

In addition to the words and phrases defined herein, all definitions contained in §51102 of Chapter 51, Part 2, Division 2 of Title 10 of the Guam Code Annotated are applicable, unless specifically defined for in this Chapter:

(1) *Department* means the Department of Public Health and Social Services ('DPHSS').

(2) *Director* means the Director of DPHSS.

(3) *Division* means the Division of Environmental Health of DPHSS.

(4) *DISID* means the Department of Integrated Services for Individuals with Disabilities.

(5) *Base Line Study* shall mean a collection of information and/or test results for the following, but not limited to: laboratory studies, radiology, tissue and specimen samples, etc.

(6) *GEPA* shall mean the Guam Environmental Protection Agency.

(7) *DOAg* shall mean the Department of Agriculture.

§ 33204. Monitoring.

All efforts toward the opening, maintenance, operation and closure of solid waste management facilities, including dump sites, landfills, incinerators and the like, shall be taken with utmost caution, taking into consideration the environmental impact of such municipal solid waste management programs upon the lives and health of the families residing in the neighborhood of such facilities. Specifically, the following related tasks are assigned:

(a) Monitoring Authority. All SWMF that are involved in the following: landfill, waste to energy facility, incineration, plasma torch or flame technology and other SWMF that the Director of DPHSS or

Administrator of GEPA designates shall be monitored. The Environmental Health Division of DPHSS shall conduct an initial base-line study of the people, vectors and other animals around the solid waste management facility within a radius of one (1) mile from the perimeter of the SWMF and may be extended to cover an area up to five (5) miles at the discretion of the Director of DPHSS. The GEPA and DOAg shall provide assistance to DPHSS, not limited to technical support, training, collaboration of data, etc. The base-line data shall be established and should at least include relevant data of the best indicators determining whether the prevalence of allergies, respiratory disorders, infectious diseases, cancer ailments and other diseases are more than the expected distribution than that of a national standard or an established local standard. The summary report of such findings shall be reported to the Governor, the Speaker of the Guam Legislature, and the Director of DISID for the Division of Health Planning. The follow-up analysis shall be no less than every two (2) years and may be as frequent as authorized by the Director of DPHSS. The Director of DPHSS may hire the assistance of no more than three (3) consultants, such that one (1) must be a certified epidemiologist and one (1) must be a licensed physician. The Director may also contract the project to a qualified company with a certified epidemiologist and a licensed physician staff according to the Procurement Laws, Chapter 5 of Title 5 of the Guam Code Annotated.

(b) Source of Funding. Any person operating a Solid Waste Management Facility(ies) shall be levied one percent (1%) of all tipping fees, as defined in § 51118 of Part 2, Division 2 of Title 10 of the Guam Code Annotated. The collected amount by DPW shall be deposited to the SWMF Medical Monitoring Fund ('SWMF-MMF').

(c) Distribution of Funds. There shall be a quarterly disbursement of funds from the SWMF-MMF by the Director of DPHSS for the amount collected in Paragraph (b) above as follows:

(1) For Landfill Closure. The village(s) where the landfill facility is to be closed shall receive twenty-five percent (25%) of the levied amount from Subsection (b), Source of Funding, up to five (5) years after the date of closure declared by DPW. The monetary amount shall be appropriated from the SWMF-MMF to the respective village(s) Mayor's operational account for community health care needs or community health programs. After the fifth (5^{th}) year, the amount set aside for this Paragraph shall be appropriated equally to Paragraphs

(2) and (3) below. The Village of Ordot/Chalan Pago Landfill closure shall be the first recipient of this Provision.

(2) For other village(s) with a Solid Waste Management Facility(ies), the sum of twenty-five percent (25%) of the levied amount from Paragraph (b), Source of Funding, shall be appropriated from the SWMF-MMF to the respective village Mayor's operational account for community health care needs or community health programs.

(3) The Department of Public Health and Social Services shall receive fifty percent (50%) of the levied amount from Paragraph (b), Source of Funding, for the purpose of this Act. GEPA and DOAg shall be compensated for all expenses relative to the enforcement of this Act from the SWMF-MMF by the Director of DPHSS.

(4) Administrative Responsibility and Accountability. The respective recipient mayor(s), Director of DPHSS, GEPA and DOAg are hereby authorized to use their share of the SWMF-MMF for the purposes intended in this Act and shall prepare a financial summary report to the Governor and the Speaker of the Guam Legislature on an annual basis, or as per request by the Governor or Speaker of the Guam Legislature.

(5) Creation of SWMF-MMF. There is hereby created, separate and apart from other funds within the Department, a fund to be known as the Solid Waste Management Facilities - Medical Monitoring Fund ('SWMF-MMF'). The SWMF-MMF shall not be commingled with the General Fund or any other funds of the government of Guam, and it shall be maintained in a separate bank account as required under this Article and may be deposited in an interest bearing account.

(6) Promulgating Rules and Regulations. DPHSS shall promulgate rules and regulations within sixty (60) days after enactment of this Act through the Administrative Adjudication Law. The rules and regulations shall include revising and creating forms, maintaining the confidentiality of records, summary reports appropriate for public disclosure, other documents as are necessary in accordance with the management of confidentiality of patient records, provisions for violation or breech of information management and any other provision to falsify the intent and the enforcement of this Act.

(7) The lack of rules and regulations shall not impede the enforcement of Paragraphs (1), (2) and (3) above.

§ 33205. Standing to Sue, Injunction.

The Director of DPHSS shall have standing to bring a lawsuit in the Superior Court of Guam for public nuisance in order to enjoin the operation of a SWMF.

Appendix B.2

10GCA Chapter 51 Solid Waste Management and Litter Control

CHAPTER 51
SOLID WASTE MANAGEMENT AND LITTER CONTROL

ARTICLE 1
SOLID WASTE MANAGEMENT

SOURCE: GC § 57170 et seq. (1974 GC Supplement). Repealed and reenacted by P.L. 14-37:1 (June 18, 1977); P.L. 17-87 (Jan. 18, 1985); and P.L. 23-64 (Dec. 5, 1995). Further amended as indicated herein.

NOTE: This Article was amended in part by P.L. 24-139 (Feb. 7, 1998) and P.L. 24-272 (Oct. 2, 1998), which were found by the Guam Supreme Court in *Pangelinan v. Gutierrez*, 2000 Guam 11 (Mar. 10, 2000) and 2004 Guam 16 (Sept. 9, 2004), to be invalid. **Thus, the amendments by P.L.s 24-139 and 24-272 are void and of no effect**. However, notwithstanding the aforementioned court holdings and without consideration thereof, parts of this Article were amended or added by P.L. 24-309 (Dec. 18, 1998); P.L. 25-70 (July 15, 1999); P.L. 25-93 (Dec. 29, 1999); P.L. 25-175 (Dec. 14, 2000); P.L. 26-35 (Oct. 1, 2001); P.L. 28-11 (Mar. 9, 2005); and P.L. 28-56 (June 30, 2005). Therefore, until this Article is corrected by the legislature, it is presented here in the form repealed and reenacted by P.L. 24-272 and amended by subsequent laws as indicted in SOURCE comments. **However, reference must be made to the Article as it existed prior to P.L. 24-139**. Thus, the Article, as repealed and reenacted by P.L. 23-64, is included in its entirety in a NOTE at the end of this Article.

§ 51101. Legislative Findings.

(a) The Guam Legislature finds:

(1) the Ordot Landfill is a threat to the health and safety of the residents of Guam, and specifically for the residents of Ordot-Chalan Pago, Yona and the villages down river and downwind;

(2) solid waste collection and disposal on Guam does not adequately eliminate the threat that improperly disposed solid waste poses to the health, safety, and welfare of Guam residents;

(3) under the Government of Guam Property Act, the Ordot Landfill shall be converted to a public park after it is closed in accordance with applicable U.S. E.P.A. and government of Guam regulations. In order to protect the health and welfare of the residents of Chalan Pago-Ordot and the people of Guam, the Agency shall monitor the landfill on an on-going basis for compliance with this Section and take proper measures to mitigate environmental damage;

(4) the Ordot Landfill reached its capacity in the 1990's, and the closure of the dump is necessary in order to eliminate this existing serious environmental hazard. The dump should be converted to a public park;

(5) even with closure of the Ordot Landfill and construction of a new landfill at the same or any other site, landfilling cannot continue as the sole method of waste disposal for Guam due to the shortage of land on Guam, and the general aversion of any community to the location of a landfill within their proximity;

(6) it is in the best interest of the government to privatize through free and fair competition, the solid waste management operations of the Island, from collection to disposal, without jeopardizing the job

security for the employees of the Solid Waste Management Division of the Department of Public Works as well as the private businesses currently engaged in solid waste collection, recycling and other solid waste management operations;

(7) it is in the best interest of the government to establish a funding procedure or financial arrangement which will pay for operations and meet the requirements for a totally funded program for solid waste management;

(8) Guam contains approximately 215 square miles of landmass. Over half of that mass is located over the northern Guam Lens, a pure groundwater resource that requires protection. Thus, any landfill more likely should be located in southern Guam, south of a line running approximately from Cabras Island to Pago Bay. With the pristine south already imposed upon by this geological and environmental constraint, and in order to protect the cultural traditional nature of the villages in the south and the unique environments there, a source and waste disposal reduction policy shall be implemented to minimize the requirement for landfilling;

(9) source reduction shall include a conservation and recycling program. It shall also consider the disposal of green waste through mulching or composting, or the recovery of resources through recycling of the green waste. Construction or demolition waste and metallic debris shall be addressed alternately, and the alternate plan should include hardfilling or quarrying, recycling or disposal other than at the landfill. Rubber tires, rubber products, and batteries shall be addressed and recycled, recovered or disposed of at alternate sites;

(10) a solid waste management plan for Guam shall address typhoon and other disaster recovery; it is estimated that Super Typhoon Paka produced over 750,000 cubic yards of waste, which should be recycled or disposed of; Guam is in: the typhoon belt; in an active volcanic range; and, an active seismic zone so disasters will happen on a regular basis;

(11) the Guam Legislature further finds that while other communities with alternative sites for landfilling enjoy the option of not paying for source reduction and resource recovery, we must establish a Guam site-specific solid waste management policy,

because we have very limited alternative acceptable sites for future disposal requirements;

(12) in 1983, the Guam Environmental Protection Agency ('GEPA') adopted a Solid Waste Management Plan for Guam and also adopted regulations for solid waste collection and disposal;

(13) the government must now establish an updated Solid Waste Management Plan ('SWMP' *or* the 'Plan') , which shall include the closure and beneficial use of the Ordot Landfill, the privatization of the complete solid waste program, including landfill operations and provisions for job protection for the employees of the Solid Waste Division, source reduction, recycling, composting, resource recovery, waste reduction and regulated landfill disposal in an integrated program for solid waste collection and disposal, and the funding for the Plan. The SWMP shall also address construction debris or demolition waste; metallic debris; tires; waste oil; household hazardous waste; abandoned vehicles and other bulky metallic waste; white goods, such as washers, dryers and refrigerators; and green waste, which may be useful in some form, but unnecessarily contribute to landfill volume;

(14) the Department of Public Works shall implement the updated Solid Waste Management Plan, as approved by the Guam Legislature, regulated by GEPA;

(15) any and all solid waste handling and disposal contemplated by and authorized under this Act shall obtain and operate under any and all permits required by laws, rules and regulations applicable to Guam; and

(16) The government of Guam shall not direct or regulate existing permitted private entities actively engaged in solid waste collection or recycling beyond the scope and extent of Federal statutory and regulatory requirements. The standings of such private businesses permitted to actively engage in solid waste collection shall be given maximum protection and support under this Act to promote their viability and longevity under a free enterprise system.

(b) The purposes of this Chapter are to:

(1) plan for and regulate the storage, collection, transportation, separation, processing and disposal of solid waste to protect the public

safety, health and welfare, and to enhance the environment of the people of Guam;

(2) provide the authority and resources, including funding to plan for, establish, finance, operate and maintain efficient, environmentally acceptable solid waste management systems, privatized, but administered by the Department of Public Works and regulated by GEPA;

(3) privatize Guam's Solid Waste Management System ('SWMS') subject to all applicable laws and Public Law Number 24-06;

(4) establish the SWMS to be operated by private ventures, entities or individuals, to promote land conservation by limiting landfilling requirements consistent with the SWMP, and to establish as a limit the reusing, recycling and composting of no less than twenty percent (20%) of the total solid waste generated on Guam from all sources within the time frame established by the Plan and a comprehensive solid waste disposal and resource recovery program that ultimately will minimize Guam's need for additional landfills beyond replacing the Ordot Landfill; quantitative factors to meet such an objective shall be specified and substantiated in the SWMP;

(5) continue authority to regulate solid waste storage practices within the Department of Public Health and Social Services pursuant to Chapter 33 of this Title and, where applicable, establish such authority in the Department of Public Works to insure that such practices do not constitute a danger to human health, safety and welfare;

(6) continue authority in GEPA to review the design of and to issue permits for the operation of solid waste collection, transport, processing and disposal activities;

(7) continue authority in GEPA to undertake a comprehensive investigation of and set minimum standards for the transportation, processing, storage, treatment, and disposal of hazardous waste, and conduct surveys for special disposal facilities for hazardous waste, to protect public health, other living organisms and the environment through an effective and efficient hazardous waste management system;

(8) continue authority in GEPA to establish and implement an enforcement system to prevent the improper disposal of solid waste;

(9) promote the application of a Solid Waste Management System which preserves and enhances the quality of air, water and land resources;

(10) promote and assist in the development of markets for recovered and recycled materials;

(11) support and encourage the rapid and efficient removal, recycling, processing, or disposal of abandoned vehicles and other bulky waste, and to assure that the recovery of resources is facilitated;

(12) authorize the closure and beneficial use of the Ordot Landfill site, and promote, assist and support the construction and operation of a privatized sanitary landfill, resource recovery and other solid waste management facilities;

(13) require consideration and evaluation of treatment of bottom and fly ash generated from resource recovery facilities that any municipal solid waste incinerator company which operates a facility which generates bottom and fly ash or waste ash shall be responsible for the collection and disposal thereof and cost of the collection and disposal thereof; and

(14) authorize GEPA to establish such advisory committees as are necessary to carry out its planning and solid waste management responsibilities; the committees shall include but limited to representatives of GEPA, DPW, the Department of Public Health and Social Services, collectors, operators, applicable Federal agencies, educational/environmental groups and the public at large.

SOURCE: Repealed and reenacted by P.L. 24-139:2. Repealed and reenacted by P.L. 24-272:1.

§ 51102. Definitions.

For the purpose of this Chapter, the following words and phrases shall have the meanings given herein, unless their use in the text of the Chapter clearly demonstrates a different meaning.

(1) *Administrator* means the Administrator of GEPA or his designee.

(2) *Agency* means GEPA.

(3) *Best public interest* means any activity which: lessens the demand for landfill sites, conserves land resources and serves to insure proper, cost

effective and environmentally sound disposal of solid waste; and, does not pose health risks to human life or endanger plant and animal life.

(4) *Board* means the Board of Directors of GEPA.

(5) *Business* means and includes any activity or conduct, whether proprietary, partnerships, corporate or whatever form, engaged in, or caused to be engaged in, with the object of gain or economic benefit, either direct or indirect, but shall not include casual sales, personal service contracts, fundraising activities by political candidates or the activities of non-profit associations.

(6) *Collection* or *Collect* means the act of removing solid waste from a generator.

(7) *Collector* means any individual, governmental organization or business which has received a permit to collect and transport waste in accordance with applicable laws and regulations.

(8) *Combustion* means to thermally break down certain types of solid waste in an enclosed device using controlled temperatures.

(9) *Composting* means the controlled degradation of organic solid waste.

(10) *Department* means the Department of Public Works ('DPW') .

(11) *Director* means the Director of DPW.

(12) *Disposal* means the discharge, deposit, injection, dumping, spilling, leaking, or placing of any solid waste or hazardous waste into or on any land or water so that such solid waste or hazardous waste or any constituent thereof may enter the environment or be emitted into the air or discharged into any waters, including ground water.

(13) *Division* means the Division of Solid Waste Management of the DPW.

(14) *Dump* means a land site where solid waste is disposed without a valid permit or a landfill that has historically been in regulatory noncompliance.

(15) *Dwelling* means a building or portion thereof designed exclusively for residential occupancy by one (1) family for living and sleeping purposes and not to exceed two (2) dwelling units.

(16) *Dwelling unit* means one (1) or more rooms and a single kitchen in a dwelling, designed as a unit for occupancy by one (1) family for living and sleeping purposes.

(17) *Financial assurance* means a financial guarantee assuring that funds are available to pay for the design, construction, operation and closure of a solid waste landfill facility, for rendering post-closure at a solid waste landfill facility, for corrective action and to compensate third parties for bodily injury and property damage caused by sudden and non-sudden accidents related to the operation of a solid waste landfill facility.

(18) *Generator* means any person that generates or produces solid waste.

(19) *Government* means the government of Guam, all of its agencies, whether line or autonomous, and all public corporations.

(20) *Hardfill* shall mean a method of compaction and earth cover of solid wastes other than those containing garbage or other putrescible (putrescent) waste, including, *but not limited to*, demolition material, and like materials not constituting a health or nuisance hazard, where cover need not be applied on a per day used basis. No combustible materials shall be deposited in a hardfill.

(i) *Combustible Materials* shall mean any solid or liquid that may be ignited.

(a) *Combustible Solids*, as defined in Title 49 of the Code of Federal Regulations, Chapter 1, Subtitle B, Part 173.124, are those capable of igniting and burning.

(b) *Combustible Liquids*, as defined in Title 29 of the Code of Federal Regulations, Chapter 17, Subtitle B, Part 1910.106, shall mean any materials having a flash point at or above 100 degrees Fahrenheit (37.8 degrees Celsius) , but below 200 degrees Fahrenheit (93.3 degrees Celsius) , except any mixture having components with flashpoints of 200 degrees Fahrenheit (93.3 degrees Celsius) , or higher, the total volume of which make up ninety-nine percent (99%) or more of the total volume of the mixture.

(21) *Hazardous Waste* means any material or substance which, by reason of its composition or characteristics,

(i) is hazardous waste as defined in the Solid Waste Disposal Act, 42 USC §6901, et seq., as amended, replaced or superseded and the regulations implementing same,

(ii) is a hazardous substance as defined by the Comprehensive Environmental Response, Compensation and Liability Act of 1980, 42 USC § 9601, et seq.,

(iii) is material the disposal of which is regulated by the Toxic Substances Control Act, 15 USC § 2601, et seq., as amended, replaced or superseded, and the regulations implementing same,

(iv) is special nuclear or by-products material within the meaning of the Atomic Energy Act of 1954,

(v) is pathological, infectious or biological waste,

(vi) is treated as hazardous waste or as a hazardous substance under applicable law,

(vii) requires a hazardous waste or similar permit for its storage, treatment, incineration of disposal,

(viii) may cause or significantly contribute to an increase in mortality or an increase in serious irreversible, or incapacitating reversible illness, or

(ix) may pose a substantial present or potential hazard to human health or the environment when improperly treated, stored, transported or disposed of, or otherwise damaged.

(22) *Highway* means the entire width between the boundary lines of every right-of-way or publicly maintained travel ways when any part thereof is open to the use of the public for purposes of vehicular travel.

(23) *Incinerator* means an enclosed device using controlled flame combustion, the primary purpose of which is to thermally break down solid waste.

(24) *Multi-family dwelling* means a building containing three (3) or more dwellings.

(25) *Office* means the Office of Recycling of the Division.

(26) *Operator* means any person who accepts solid waste from a collector for transfer, storage, recycling, combustion, processing or disposal.

(27) *Performance bond* means a security for financial loss caused by the act or default performance of a person or by uncontrollable conditions.

(28) *Person* means any individual, partnership, co-partnership, firm, company, corporation, association, joint stock company, trust, estate, or any agency, department, or instrumentality of the Federal or local government, or any other legal representatives, agents or assigns.

(29) *Plan* means the interim or final Solid Waste Management Plan (‘SWMP’) to be prepared and adopted by the Agency in accordance with the Administrative Adjudication Law.

(30) *Plasma torch heating technology* means converting electrical energy into heat energy producing clean fuel gas and recyclable slag.

(31) *Plasma Remediation In-Situ Materials* ('PRISM') means a plasma torch technology process that melts down and converts landfill material into slag and fuel gas.

(32) *Pollution* means the condition caused by the presence in the environment of substances of such character and in such quantities that the quality of the environment is impaired or rendered offensive to life.

(33) *Processing* means any method, system or other treatment designed to change the physical, chemical or biological character or composition of any solid waste. This includes the neutralization of any hazardous waste; the rendering of any hazardous waste non-hazardous, safer for transport, amenable for recovery, amenable for storage or reduced in volume; or any other activity or processing designed to change the physical form or chemical composition of hazardous waste so as to render it non-hazardous.

(34) *Recyclable materials* includes the following materials discarded from households, businesses, commercial and industrial establishments, hotels, government, agricultural, landscaping, yard maintenance and military operations which may be reused or for which a market exists:

(i) *aluminum* means any product manufactured of aluminum or aluminum alloy;

(ii) *battery* means any lead acid battery or dry cell battery discarded on Guam, independent of intended use;

(iii) *biomass* means any large biomass source, such as trees, wood, grass, hedge cuttings, jungle growth, yard waste and sewage sludge;

(iv) *construction debris* means the materials from building construction;

(v) *corrugated cardboard* means kraft, jute or test liner pulp which is made by combining two (2) or more webs of paper and formed or shaped into wrinkles or folds or into alternate ridges and grooves;

(vi) *demolition waste* means the materials obtained from the demolishment or razing of buildings;

(vii) *glass* means any product manufactured from a mixture of silicates, borates or phosphates;

(viii) *metal scrap* means any metal, in whole or in parts, from buildings, equipment, machinery or vehicles;

(ix) newspaper means a publication which is distributed and contains news articles, opinions, features, and advertising and is printed on impermanent wood pulp materials;

(x) *office paper* means computer paper and white and colored ledger paper;

(xi) *used oil* means any petroleum-based, mineral, or synthetic oil which through use, storage or handling has become unsuitable for its original purpose due to the presence of impurities or loss of original properties; and

(xii) such other materials which the Department determines, from time to time, may be recycled.

(35) *Recycle* or *Recycling* means the method by which recovered resources are converted for use as raw material or feedstock to make new products.

(36) *Recycling Officer* means the head of the Office of Recycling.

(37) *Resource recovery* means the process of recovering recyclable materials or the recovery of energy from solid waste.

(38) *Resource Recovery Facility* ('RRF') is a facility which recovers for sale or reuse of recyclable materials.

(39) *Reusing* means the reintroduction of a commodity in the economic stream without any changes.

(40) *Sanitary landfill* means an approved site where solid waste and ash are disposed using modern sanitary landfilling techniques in accordance with Federal and local regulations.

(41) *Sanitary landfilling* means an engineered method of disposing of solid waste on land in accordance with Federal and local regulations in a manner that protects the environment by spreading the waste in thin layers, compacting it to the smallest practical volume, and covering it with approved material at the end of each working day.

(42) *Separation* means the systematic division of solid waste into designated components.

(43) *Solid waste* means any garbage, refuse or sludge from a waste treatment plant, water supply treatment plant, or air pollution control facility and other discarded and/or spilled materials, including solid, liquid, semisolid or contained gaseous material resulting from industrial, mining, commercial, and agriculture operations, and from community activities, but does not include solid or dissolved material in domestic sewage, or solid or dissolved materials in irrigation return flows or industrial discharges which are point sources subject to permits under §402 of the Federal Water Pollution Control Act, as amended (68 Stat. 880) , or source, special nuclear, or by-product material as defined by the Atomic Energy Act of 1954, as amended (68 Stat. 923) .

(44) *Solid waste management* means the purposeful, systematic control of the generation, storage, collection, transportation, separation, processing and disposal of solid waste.

(45) *Solid waste management facilities* means any facility, or any machinery, equipment, vehicles, structures or any part of accessories thereof installed or acquired for the primary purpose of: collection, transportation, storage, recycling, processing or disposal of solid waste, and shall include sanitary landfills, resource recovery facilities, or plasma torch.

(46) *Solid Waste Management Plan* means a comprehensive plan and all amendments and revisions thereto for provisions of solid waste management throughout Guam.

(47) *Solid waste management practices* means the actions to effectuate the generation, storage, collection, transportation, processing, recycling, incineration, plasma torch or resource recovery or disposal of solid waste.

(48) *Solid Waste Management System* ('SWMS') means the entire system covered in the SWMP and designated by the Director for the storage, collection, generation, transportation, processing, recycling, incineration, plasma torch and disposal of solid waste within Guam.

(49) *Source separated waste* means recyclable materials which are set aside by the generator for segregated collection and transport to solid waste management facilities.

(50) *Storage* means the interim containment of solid waste in accordance with Federal and local regulations.

(51) *Transfer station* shall mean any intermediate waste facility in which solid waste collected from any source is temporarily deposited and stored while awaiting transportation to another solid waste management facility.

(52) *Duplex* means a residential building containing two (2) separate dwelling units either side by side or one above the other.

(53) *Single Family Residence* means a detached building designed for and/or occupied exclusively by one (1) family, or one (1) of two (2) dwelling units on a duplex.

SOURCE: Repealed and reenacted by P.L. 24-139:3. Repealed and reenacted by P.L. 24-272:1. Subsection (17) repealed and reenacted by P.L. 24-309:2. Subsection (52) added by P.L. 25-93:12. Subsection (53) added by P.L. 25-93:13. Subsection (20) repealed and reenacted ny P.L. 28-11:2 and subsection 20(i) added by P.L. 28-11:3.

§ 51103. Powers and Duties of the Agency and the Department.

(a) The Agency shall have the authority under this Act and other laws of Guam, pursuant to the Administrative Adjudication Law, to:

(1) prepare and adopt in accordance with the Administrative Adjudication Law an interim Solid Waste Management Plan, consistent with the provisions of this Act, within one hundred eighty (180) days of the effective date of this Act;

(2) prepare and adopt in accordance with the Administrative Adjudication Law a final Solid Waste Management Plan, consistent with the provisions of this Act, within three hundred (300) days of the effective date of this Act. The Plan shall be revised at least every five (5) years, or sooner as needed;

(3) administer Guam's Solid Waste Management Program pursuant to provisions of this Chapter;

(4) prepare, adopt, promulgate, modify, update, and repeal rules and regulations in cooperation with appropriate government agencies, industries and private parties, for the collection, transportation, storage and disposal of hazardous waste;

(5) prepare, adopt, promulgate, modify, update, repeal, and enforce rules and regulations setting environmental standards for collection, transportation, separation, processing, recycling, materials and resource recovery, incineration, plasma torch and disposal of solid waste in order to conserve the air, water, and land resources of Guam, protect the public health, prevent environmental pollution and public nuisances, and enable it and the Department to carry out the purposes and provisions of this Chapter and the Plan;

(6) establish the procedures for review and issuance of permits governing the design, operation, closure, and post-closure of solid waste management facilities, which procedures shall be consistent with the procedures used by the United States Environmental Protection Agency in the issuance of similar permits;

(7) enforce compliance with any of its rules and regulations issued pursuant to this Chapter and require the taking of such remedial measures for solid waste management or solid waste management practices as may be necessary or appropriate to implement or effectuate its responsibilities under this Chapter;

(8) prepare, adopt, promulgate, modify, update, repeal, and enforce such other rules and regulations as may be necessary to establish a hazardous waste program which meets the requirements of Section 3006 of the Federal Resource Conservation and Recovery Act (42 U.S.C. 6926, et seq.) and regulations promulgated pursuant thereto;

(9) prepare, issue, modify, remove and enforce orders for compliance with any of the provisions of this Chapter or of any rules and regulations issued pursuant thereto and requiring the taking of such remedial measures for solid waste management as may be necessary or appropriate to implement or effectuate the provisions and purposes of this Chapter;

(10) impose and collect penalties against any person for the violation of any of its rules, regulations or compliance orders issued under this Chapter;

(11) require a financial guarantee assuring that funds are available to pay for the design, construction, operation and closure of a solid waste landfill facility, for rendering post-closure at a solid waste landfill facility, for corrective action and to compensate third parties for bodily injury and property damage caused by sudden and non-sudden accidents related to the operation of solid waste landfill facility.

(12) serve as the official government of Guam representative for all purposes of the Federal Solid Waste Disposal Act, (P.L. No. 91-512), or as subsequently amended, and for the purpose of such other local or Federal legislation as has been or may hereafter be enacted to assist in the management of solid waste;

(13) provide technical assistance to local and Federal agencies, and other persons, and cooperate with appropriate local agencies and private organizations in carrying out the duties under this Chapter;

(14) encourage and recommend procedures for private financing to develop, design, construct and operate solid waste management system in accomplishing the desired objectives of this Chapter; and

(15) insure that the interest of existing permitted private entities actively engaged in solid waste management operations are duly and lawfully protected and are not unfairly jeopardized or removed.

(16) determine the applicability, type and sum required for posting a performance bond on solid waste management facilities that are not municipal solid waste landfills.

(b) The Department shall have the following powers and duties pursuant to the Administrative Adjudication Law to:

(1) adopt and enforce rules, regulations and other procedures for the implementation of the solid waste management system created by the Plan and such other rules and regulations as are necessary to fulfill the Department's powers and duties under this Act;

(2) privatize all other solid waste management facilities and operations not addressed above in Subsection (2) and within the policy guidelines of the Solid Waste Management Plan, including the closure and beneficial use of the Ordot Landfill site, source reduction, recycling, composting, resource recovery, waste reduction, new landfill and transfer stations. This responsibility shall also address

construction debris or demolition waste, metallic debris, white goods, tires and green waste; contracts with private entities shall fully encompass development, financing, construction and operation of any such facilities;

(3) fulfill any of its duties under this Act and consistent with the SWMP by entering into contracts with private entities; all such new contracts shall be entered into according to the procedures of the Guam Procurement Law, Chapter 5, Division 1 of Title 5 of the Guam Code Annotated, and other applicable laws of Guam;

(4) establish administrative procedures for the dissemination of rates and fee schedules and the collection of fees and charges authorized and duly adopted or set under this Act for the collection, processing, resources recovery or disposal of solid waste within Guam, including, but not limited to, fees assessed to owners of dwellings, fees assessed to any other generators or collectors, and fees assessed for solid waste received at designated solid waste management facility within Guam;

(5) administer, supervise and fulfill the responsibilities of the government in any contract entered into pursuant to provisions of the Guam Procurement Law (5 GCA Chapter 5) for the development, construction, operation or closure of landfills, RRF or any other solid waste management facility contracted or prescribed in the Plan and legally established under Guam and Federal laws, rules and regulations;

(6) organize, plan for, secure and manage resources and promote the implementation of the Plan;

(7) evaluate and promote capital improvements and maintenance programs to the solid waste management system;

(8) address the necessity for a facility for the shredding of tires for recycling or for use as rubberized asphalt;

(9) address the necessity for a facility for the recycling of glass, including its use as glassphalt;

(10) address the necessity for a facility for the recycling of scrap metals, including discarded vehicles, appliances and equipment, including shredding for containerization or other shipment;

(11) require the preparation of any necessary environmental impact assessments or environmental impact reports;

(12) mandate the inspection and monitoring of all solid waste management facilities to assure compliance with this Act, the Plan, other law, rules and regulations applicable to Guam; and

(13) apply for all grants-in-aid requests and administration of any such programs or funds, except those established for recycling.

(c) There is established within the Division of Solid Waste of the Department, the Office of Recycling and the position of Recycling Officer who shall head the Office. The Office shall be responsible for the following:

(1) establishing and managing in conjunction with the Plan a promotional program for recycling, composting and the recovery of resources, including recommendations on the size, character, location and ownership of any RRF or composting facility;

(2) evaluating and insuring adequate capacities within the solid waste management system for recycling;

(3) plan, organize, coordinate and pursue the following objectives:

(i) publish and disseminate guidebooks, newsletters and instruction manuals to promote recycling;

(ii) in conjunction with the Mayors Council of Guam, conduct public outreach activities to promote recycling;

(iii) establish a recycling demonstration project in at least six (6) selected villages throughout Guam, wherein compartmentalized containers will be located and serve as recycling drop-off centers for the community; the Department shall contract for the supply of the containers and their hauling for recycling or other disposal; all revenues generated by the sale of recyclable materials shall be paid to the Mayors and be used by the Mayors to support programs which further encourage recycling; moreover, individual accounts shall be established for each Mayor to record all costs and revenues in order to evidence the commercial feasibility, or lack thereof, of recycling;

(iv) develop a recommended program for composting of biomass on government property;

(v) formulate and recommend other recycling demonstration projects and initiatives;

(vi) identify economically priced products manufactured of recycled material which are usable by the government in the place of products manufactured of virgin material;

(vii) study recycling techniques to determine the most cost-effective manner of collecting, processing, storing, marketing, transporting or reusing recyclable materials;

(viii) establish a recycling telephone hotline serving to take inquiries and disseminate information on recycling;

(ix) recommend the establishment or revision of administrative or procurement practices which will promote recycling;

(x) determine and report through the Director to the Guam Legislature the costs and benefits of establishing a system for source separated waste;

(xi) recommend new legislation to facilitate recycling through planning, market research, source separated waste, surcharges, fees, operational subsidies, tax incentives and other similar means;

(xii) identify and promote businesses reusing or converting recyclable materials;

(xiii) advise and assist collectors on efficient techniques for recycling; and

(xiv) conduct media advertising, public opinion surveys, seminars, workshops and community relations campaigns to promote public awareness of the benefits and methods of recycling.

SOURCE: Repealed and reenacted by P.L. 24-139:4. Repealed and reenacted by P.L. 24-272:1. Subsection (a) (11) repealed and reenacted by P.L. 24-309:3. Subsection (a) (16) added by P.L. 24-309:4.

§ 51104. Permits.

(a) The Administrator is authorized and directed to issue permits for all collectors, operators and solid waste management facilities, their design, operation, maintenance, substantial alteration, modification or enlargement. All such permits shall be non-transferable and conditioned upon the observance of the laws of Guam and rules, compliance orders or regulations authorized in this Chapter. All such permits shall include provisions to hold the permittee liable during the duration of the permit and twenty-five (25) years after the expiration of the permit for all costs related to health and environmental restoration attributed to the operation of the facility.

(b) Each permit holder shall apply for the renewal of each permit held, upon forms provided by the Agency, not less than sixty (60) days prior to the expiration date of such solid waste management permit to be renewed, or not less than one hundred eighty (180) days prior to the expiration date of each hazardous waste management permit to be renewed.

(c) Each permit application and each permit renewal application shall be submitted with proof of financial assurance, of a type and in a sum established by the Administrator conditioned on the fulfillment by the permit holder of the requirements of this Chapter and the rules and regulations authorized therein. No financial assurance mechanism required under this Chapter may be canceled by the guarantor unless the Administrator has received written notice thereof and there has been a lapse of one hundred twenty (120) days between receipt of notice and cancellation date.

(d) Before issuing a solid waste management permit to any person with respect to any facility for the processing, storage or disposal of solid waste, the Administrator shall:

(1) Cause to be published in a major local newspaper or newspaper of general circulation, and broadcast over a local radio station or stations, notice of the Agency's intention to issue such a permit.

(2) If, within forty-five (45) days after publication and broadcast, the Agency receives written notice of opposition to the Agency's intention to issue such permit and a request for a hearing is made, the Agency shall provide for a hearing in accordance with the Administrative Adjudication Law, if requested by a substantially affected party or an informal public meeting if requested by any other person.

(e) Before issuing a hazardous waste management permit to any person with respect to any facility for the processing, storage or disposal of hazardous waste, the Administrator shall:

(1) cause to be published in a major local newspaper or newspaper of general circulation, and broadcast over a local radio station or stations, notice of the Agency's intention to issue such a permit; and

(2) if, within forty-five (45) days after publication and broadcast, the Agency receives written notice of opposition to the Agency's intention to issue such permit and a request for a hearing is made, the Agency shall provide for a hearing in accordance with the Administrative Adjudication Law, if requested by a substantially affected party or an informal public meeting if requested by any other person.

(f) The Administrator is authorized and directed to suspend, revoke, condition, modify or terminate any permit issued under Subsection (a) of this Section for non-compliance with any of the rules, compliance orders, regulations or permit conditions authorized in this Chapter.

(g) The Administrator shall determine the applicability for requiring a performance bond for permit applications and permit renewal applications for solid waste management facilities that are not landfills. Upon the determination that a performance bond is required, that Administrator will decide the type and sum required to ensure fulfillment by the permit holder of the requirements of this Chapter and the rules and regulations authorized therein.

SOURCE: Repealed and reenacted by P.L. 24-139:5. Repealed and reenacted by P.L. 24-272:1. Subsection (g) added by P.L. 24-309:5.

§ 51105. Permit Fees.

Each application for a permit, or renewal application, shall be accompanied by a certified check or money order in the amount prescribed by regulations. All fees required by the section shall be non-returnable and shall be placed in the revolving fund established under Section 51117 of this Chapter.

§ 51106. Inspections.

(a) The Agency is hereby authorized to inspect all solid waste and hazardous waste management facilities at all reasonable times to insure compliance with the laws of Guam, the provisions of this Chapter and the rules and regulations authorized herein. This authority shall include access to and authority to copy all records relating to solid or hazardous waste, as well as the authority to obtain samples, or require monitoring or testing to ensure that the owner or operator is in compliance.

(b) The Agency is authorized to have the power to enter at reasonable times upon any private or public property for the purpose of inspecting and investigating conditions relating to solid or hazardous waste on Guam.

(c) It shall be a misdemeanor for any person to interfere with such inspections or investigations.

(d) Administrative Inspection Warrants.

(i) The Agency, by its duly authorized representatives, shall have the power to enter and inspect any property, premises or place for the purpose of determining the compliance or noncompliance with any provision of this Chapter, any rule and regulations promulgated thereto, or any order or permit or term or condition thereof, issued pursuant to this Chapter rule and regulation promulgated thereto.

(ii) *Unless* an emergency exists or the Agency has reason to believe that any unlawful activity is being conducted, or will be conducted, the Agency shall provide prior notification of such inspection, and the inspection shall be during normal business hours. If such entry or inspection is denied or *not* consented to *and* no emergency exists, the Agency is empowered to and shall obtain from the appropriate court a warrant to enter and conduct an inspection. The courts on Guam are empowered to issue such warrants upon a showing that such entry and inspection is required to verify that the purposes of the Act are being carried out. *If* samples are taken, the owner and operator of the premises for which such samples are taken shall be entitled to a receipt for such samples and, upon request, a sufficient portion to perform an analysis equivalent to that which the Agency may perform.

(iii) In the event of an emergency which presents an immediate and substantial threat to the public health and safety or the environment, the Agency shall have the authority to issue such orders as may be appropriate to protect the public health and safety or the environment, including emergency authorization for procurement.

(iv) Any person against whom an emergency order is issued shall be entitled to a hearing within twenty-four (24) hours. The GEPA Board shall affirm, modify or set aside the order of the Agency.

SOURCE: Repealed and reenacted by P.L. 24-309:6.

§ 51106.1. Criminal Search Warrants.

A search warrant relating to offenses of environmental laws may be served at any time of the day or night *if* the judge or magistrate issuing the warrant is satisfied that there is probable cause to believe that grounds exist for the warrant.

SOURCE: Added by P.L. 24-309:7.

§ 51107. Inspection Fees.

The Agency is hereby authorized to include as part of permit fees under § 51105, fees for inspections conducted of all solid waste management facilities, hazardous waste treatment, storage and disposal facilities, hazardous waste transporters, generators of hazardous waste, waste oil generators, recyclers, marketers, brokers and all other waste oil facilities including boilers and industrial furnaces as well as waste to energy facilities.

§ 51108. Notice.

Any notice, order or other official correspondence affecting the rights of any person under this Chapter shall be delivered by personal service or sent by registered or certified mail with a return receipt to the address of such person as shown by the records of the Agency. The return receipt, signed by the addressee, or his agent, shall be conclusive proof of delivery.

§ 51109. Hearings.

(a) Any person who received an order from the Administrator as authorized by this Chapter and any person whose permit application is disapproved by the Administrator may, within fifteen (15) days of the date of receipt of such order or disapproval, file a Notice of Intent to appeal with the Board, setting forth in such Notice a verified petition outlining the legal and factual basis for such appeal.

(b) The Board of Directors shall, not more than sixty (60) days after receipt of such Notice of Appeal, hold a public hearing at which time the person appealing may appear and present evidence in person or through counsel in support of this petition.

(c) The Agency is hereby authorized to administer oaths, examine witnesses and issue subpoenas to compel the attendance of witnesses and the production of evidence relevant to the matter involved in the hearing.

(d) The Board shall affirm, modify or revoke any action which is appealed and shall notify the appellant of its decision not more than thirty (30) days after the conclusion of the hearing. Such notice shall be in writing and shall state the reasons for the decision.

(e) Any person may appeal such decision to the Superior Court of Guam by filing with the Agency a written notice of such intent to appeal within ten (10) days of the notice in subsection (d) of this Section and shall have a transcript of the proceedings upon request.

§ 51110. Prohibited Solid Waste Activities.

(a) It shall be unlawful for any person to:

(1) Violate any provision of this Chapter or any rule, regulation, standard, or order issued pursuant to this Chapter;

(2) Own, operate or use a dump for the disposal of solid waste;

(3) Place, or allow to be placed, any solid waste upon the highways, public or private property contrary to the provisions of this Chapter;

(4) Manage solid waste facilities without a permit issued pursuant to this Chapter;

(5) Store, collect, transport, process, or dispose of solid waste in such a manner as to degrade the environment, create a public nuisance, create a health or safety hazard, or violate any provisions of this Chapter;

(6) Transport any solid waste in any vehicle in any street or highway unless adequate precautions are taken to prevent such solid waste from falling or from being dislodged from such vehicle upon any street, highway, or any other public or private property;

(7) Not immediately pick up and remove waste which has fallen off the vehicle they are operating during the course of transportation upon any street, highway or any other public or private property;

(8) No person shall destroy or attempt to destroy by burning, except as authorized by 10 GCA §73113, any garbage, dead animals or other offensive substances, the burning of which may give off foul and

noisome odor. Nothing in this Section shall preclude the burning of trees, brush, grass and other vegetable matter authorized by the Administrator.

(9) Improperly manage or operate a solid waste management facility.

(10) Improperly manage or operate a hazardous waste management facility.

(b) Each day of continued violation of this section or the provisions of this Chapter or rules and regulations authorized herein shall be deemed a separate offense or violation.

SOURCE: Subsection (a) (8) repealed and reenacted by P.L. 24-139:6; P.L. 25-175:6. Subsection (a) (9) added by P.L. 24-139:7. Subsection (a) (8) repealed and reenacted by P.L. 24-272:1. Subsection (a) (9) repealed and reenacted by P.L. 24-272:1. Subsection (a) (10) repealed and reenacted by P.L. 24-272:1.

§ 51111. Prohibited Hazardous Waste Activities.

(a) It shall be unlawful for any person to:

(1) Violate any provision of this Chapter or any rule, regulation, standard, or order issued pursuant to this Chapter;

(2) Own, operate or use a dump for the disposal of hazardous waste;

(3) Place, or allow to be placed, any hazardous waste upon the highways, public or private property contrary to the provisions of this Chapter;

(4) Manage hazardous waste facilities without a permit issued pursuant to this Chapter;

(5) Store, collect, transport, process or dispose of hazardous waste in such a manner as to degrade the environment, create a public nuisance, create a health or safety hazard as determined by the Director of the Department of Public Health and Social Services or the Administrator or violate any provision of this Chapter;

(6) Knowingly make any false statement or representation in any hazardous waste application, label, manifest, record, report, permit or other document filed, maintained, or used for purposes of compliance with the provisions of this Chapter.

(7) Improperly manage or operate a hazardous waste management facility.

(b) Each day of continued violation of this section or the provisions of this Chapter or rules and regulations authorized herein shall be deemed a separate offense or violation.

SOURCE: Subsection (a) (7) added by P.L. 24-139:8.

§ 51112. Injunction.

The Agency shall maintain an action to restrain any violation or threatened violation of the provisions of this Chapter or the rules and regulations authorized herein. Such right to injunctive relief is in addition to any other powers or penalties conferred by this Chapter.

§ 51113. Plats.

All persons operating a sanitary landfill, hardfill, or other approved disposal site under permits issued pursuant to this Chapter shall, upon completion of the sanitary landfill or hardfill, file with the Department of Land Management and the Building Permit Section of the Department of Public Works, a plat of each site, together with a description of the waste placed therein and in conformance with rules and regulations adopted pursuant to § 51103(a) (8) of this Chapter.

§ 51114. Applicability to Government Agencies.

Government agencies shall comply with all provisions of this Chapter including planning, review, and permit requirements, with the exception of § 51104(c) . Government agencies may contract with any person to carry out their responsibilities under this Chapter. Such contractors shall also comply with the provisions of this Chapter.

§ 51115. Penalties.

(a) Solid Waste-Criminal Penalties. Any person who knowingly violates any solid waste management provision of this Chapter, or any valid solid waste management rule or regulation promulgated under this Chapter, or who refuses or neglects to comply with any lawful order issued by the Administrator in carrying out the provisions of this Chapter shall, upon conviction, be imprisoned for a term of not more than one (1) year, and/or be fined not more than $1,000 per day for each violation or noncompliance, and shall make restitution.

(b) Solid Waste-Civil Penalties. Any person who violates any solid waste management provision of this Chapter, or any valid solid waste management rule or regulation promulgated under this Chapter, or who refuses or neglects to comply with any lawful order issued by the Administrator in carrying out the provisions of this Chapter shall, in addition to clean-up costs and other damages, forfeit and pay a civil penalty of not more than $1,000 per day for each violation or noncompliance.

(c) Hazardous Waste-Criminal Penalties. Any person who knowingly violates any hazardous waste management provisions of this Chapter, or any valid hazardous waste management rule or regulation promulgated under this Chapter, or who refuses or neglects to comply with any lawful order issued by the Administrator in carrying out the provisions of this Chapter shall be guilty upon conviction of a felony of the third degree, and be fined not less than $10,000 per day for each violation and/or noncompliance, and shall make restitution.

(d) Hazardous Waste-Civil Penalties. Any person who violates any hazardous waste management provision of this Chapter, or any valid hazardous waste management rule or regulation promulgated under this Chapter, or who refuses or neglects to comply with any lawful order issued by the Administrator in carrying out the provisions of this Chapter shall, in addition to clean-up costs and other damages, forfeit and pay a civil penalty of not less than $10,000 per day for each violation or noncompliance.

(e) Administrative Penalties. In addition to any other administrative or judicial remedy provided by this Chapter, or by rules adopted under this Chapter, the Administrator is authorized to impose by order the penalties specified in § 51115(b) and (d) respectively. Factors to be considered in imposing an administrative penalty include the nature and history of the violation and of any prior violations, and the opportunity, difficulty, and history of corrective action. It is presumed that the violator's economic and financial conditions allow payment of the penalty, and the burden of proof to the contrary is on the violator. In any proceeding to recover the civil penalty imposed, the Administrator need only show that notice was given, a hearing was held or the time granted for requesting a hearing has expired without such a request, the civil penalty was imposed, and that the penalty remains unpaid.

§ 51116. Citizen's Suits.

(a) Any person may commence a civil action on his behalf:

(1) Against any person (including the United States, and any other governmental instrumentality or agency, to the extent permitted by law) who is alleged to be in violation of any permit, standard, regulation, condition, requirement, prohibition, or order which has become effective pursuant to this Chapter; or

(2) Against any person, including the United States, and any other governmental instrumentality or agency, to the extent permitted by law, and including any past or present generator, past or present transporter, or past or present owner or operator of a treatment, storage, or disposal facility, who has contributed or who is contributing to the past or present handling, storage, treatment, transportation, or disposal of any solid or hazardous waste which may present an imminent and substantial endangerment to health or the environment; or

(3) Against the Administrator where there is alleged a failure of the Administrator to perform any duty under this Chapter which is not discretionary with the Administrator.

Any action under paragraph (a) (1) , (a) (2) , or (a) (3) of this Section shall be brought in the Superior Court of Guam. The Superior Court shall have jurisdiction, without regard to the amount in controversy or the citizenship of the parties, to enforce the permit, standard, regulation, condition, requirement, prohibition, or order referred to in paragraph (a) (1) , to restrain any person who has contributed or is contributing to the past or present handling, storage, treatment, transportation, or disposal of any solid or hazardous waste referred to in paragraph (a) (2) , to order such person to take such further action as may be necessary, or both, or to order the Administrator to perform the act or duty referred to in paragraph (a) (3), as the case may be, and to apply any appropriate civil penalties under § 51115(b) and (d) . No bond shall be required for issuance of an injunction or temporary injunction after a duly noticed hearing.

(b) Except for injunctive relief, no action may be commenced under subsection (a) (1) or (a) (2) of this Section:

(1) Prior to ninety (90) days after the plaintiff has given notice of the violation or endangerment to (i) the Administrator; (ii) the government of Guam; and (iii) to any alleged violator of such permit, standard, regulation, condition, requirement, prohibition, or order

referred in subsection (a) (1) of this Section if applicable or to any person alleged to have contributed or to be contributing to the past or present handling, storage, treatment, transportation, or disposal of any solid or hazardous waste referred to in subsection (a) (2) of this Section if applicable.

(2) Except for injunctive relief, if the Administrator or government of Guam has commenced and is diligently prosecuting a civil or criminal action to require compliance with such permit, standard, regulation, condition, requirement, prohibition, or order pursuant to subsection (a) (1) of this Section or if the Administrator or government of Guam, in order to restrain or abate acts or conditions which may have contributed or are contributing to the activities which may present the alleged endangerment under subsection (a) (2) of this Section has commenced and is diligently prosecuting an action under local law or under the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) or is actually engaging in a removal action under CERCLA or has incurred cost to initiate a remedial Investigation and Feasibility Study under CERCLA and is diligently proceeding with a remedial action.

(c) Except for injunctive relief, no action may be commenced under subsection (a) (3) of this Section prior to sixty (60) days after the plaintiff has given notice to the Administrator and the government of Guam in which the failure has occurred that he will commence such action.

§ 51117. Solid Waste Management Fund.

There is established a non lapsing, revolving fund, hereafter referred to as the "Solid Waste Management Fund" which shall be maintained separate and apart from any other funds of the Government of Guam, and shall be administered by the Administrator. Independent records and accounts shall be maintained in connection therewith. All fees, reimbursements, assessments, fines, bail forfeitures, and other funds collected or received pursuant to this Article shall be deposited in this Fund and used for the administration and implementation of this Article, including purchase of equipment and payment of personnel costs of the Agency.

§ 51118. Tipping/User Fees and Solid Waste Operations Fund.

(a) Legislative Intent. Tipping and user fees shall provide a financing source for government of Guam costs and expenses directly related to the closure of the Ordot landfill, the development, design, construction, operation and final closure of a new sanitary landfill and the Ordot Landfill, as well as other solid waste management facilities that are contracted or may be established by this Act and in accordance with the plan and annual fiscal year appropriation for the Division of Solid Waste Management of DPW.

(1) Tipping/user fees will vary depending on the nature of collection, privatized contract for residential dwellings or hired commercial collectors for other municipal solid wastes outlets.

(2) For residential or dwelling, the charge is a user fee which includes the collection fee with the disposal tipping fee.

(3) For commercial, including multi-family dwellings and government agencies, the charge is a disposal tipping fee and does not include collection fees independently charged by commercial waste haulers.

(b) Effective Date of Charging Tipping Fees. The commercial and residential tipping fees established in this § 51118 are charged beginning the first day of the month following the adoption of supporting rules and regulations by DPW under the Administrative Adjudication Law.

(c) Business and Governmental Tipping Fees. A tipping fee of Four Dollars ($4.00) per cubic yard, uncompacted, is hereby established for business and government generators. For compacted trash, a tipping fee of Four Dollars ($4.00) per cubic yard multiplied by the compaction ratio of any vehicle or container with compaction equipment, is hereby established for business and government generators. Commercial and government collectors shall provide the Department of Public Works the compaction ratios of all equipment used to haul solid waste to the landfill to insure the accurate assessment of tipping fees for compacted trash. This fee does *not* include collection charges that are independently set by licensed commercial collectors.

(d) Residential Tipping Fees. A residential tipping fee, which includes collection charges, is hereby established for residential generators in the amount of Eight Dollars ($8.00) per dwelling per month.

(e) PUC Rate-making. The Public Utilities Commission of Guam ['PUC'] is hereby authorized to establish and amend commercial, government and residential tipping and user fees [including without limitation a self-drop fee, a variable residential tipping fee and a targeted lifeline rate for residential tipping fee, *collectively referred to as 'tipping* *fees'],* which when established shall replace those previously created by law or by the Department of Public Works ['DPW']. Tipping fees established by PUC shall be based on volume and on an actuarial analysis of costs of service. Rate-making authority, which was previously given to the DPW under this Section, is hereby *revoked.* PUC is empowered to undertake a focused management audit of the existing operations of the DPW Division of Solid Waste Management. In performing its duties under this Section, PUC shall have the full authority and powers conferred upon it by its enabling legislation, 12 GCA 12000 *et. sec.,* including the audit power conferred upon it by Public Laws 25-05:12 and 26-78:2.

(f) Solid Waste Operations Fund. All tipping, user and other fees authorized under this Section and collected based on duly established rules and regulations or on a PUC rate order shall be deposited in a special fund designated and hereby established as the Solid Waste Operations Fund. All tipping/user fees in the Fund shall be used *solely* for solid waste management practices and, pursuant to PUC order, for the payment of regulatory costs and expenses as may be incurred by PUC in performing its regulatory duties under Subsection (e).

(g) Notification to Department of Interior. Within thirty (30) days of the enactment of this Act, the Governor shall notify the Department of Interior of the establishment of tipping fees, for the purpose of releasing Federal funds available to resolve environmental issues relative to the Ordot Landfill. Unless otherwise restricted by any conditions, Federal-funding will be allocated between the Ordot Landfill compliance mitigation work and closure.

(h) DPW to Develop Variable Residential Tipping Fees In recognition of the fact that the initial residential tipping fee established by Public Law Number 24-272 is a flat fee, which discourages trash reduction, penalizes smaller families and subsidizes large residential generators of waste, the Department of Public Works shall develop a plan to institute a sliding scale of residential tipping fees. The sliding scale shall, at a minimum, charge residential generators based on the amount of waste produced and picked up by the department. The plan shall also address the methodology for billing individual residential customers based on the revised variable tipping fee. The plan shall be submitted to *I Liheslaturan Guåhan* within four (4) months of enactment of this Act.

(h) (1) Lifeline Rates for Tipping Fees. Notwithstanding any other provision of law, the Department of Public Works shall, through the development of rules and regulations pursuant to the Administrative Adjudication Law, establish and modify from time to time, Targeted Lifeline Rates for Residential Tipping Fees covering pick-up and delivery of residential trash *only* that are consistent with and meeting the low income eligibility criteria, requirement, policies or procedures established by the Guam Housing and Urban Renewal Authority ('GHURA') applicable to their Low Income Public Housing Program.

(i) Self-Drop Fee Established. Any person or entity that is *not* a business or government generator shall be billed Two Dollars ($2.00) per vehicle load of solid waste delivered to a landfill operated by the Department or its contractor; provided, that the vehicle load capacity is one (1) ton or less. Vehicles in excess of said load capacity shall be billed a rate that is based on an established formula developed by the Department.

(j) Temporary Exemption from Tipping Fees for Municipal Waste Collection. For a period of one (1) year commencing the date of the enactment of this Act, all waste collected by any Mayor or Vice-Mayor in the performance of their official duties, and transported to a landfill operated by the Department or its contractor, shall be exempt from all tipping fees. The Department of Public Works shall monitor and record the amount of solid waste delivered by Mayors and Vice-Mayors under this Section. This information shall be provided on a quarterly basis to the Mayors Council, *I Maga'lahen Guåhan, and I Liheslaturan Guahån* for the purpose of determining an appropriate budget for each municipality following the end of the exemption.

(k) 'Good Citizen' Exemption Established. Any individual, registered non-profit organization, or other person who intends to volunteer their resources for the purpose of cleaning up and collecting trash and litter from public places or facilities may be granted a temporary exemption from the fees established herein by securing a written exemption from the Department of Public Works in advance of their planned collection activities. The Department of Public Works shall determine the manner, time limit and procedure by which such an exemption may be granted and honored.

(l) Temporary Exemption of Tipping Fees Following a Force Majeure. Following a force majeure, *I Maga'lahen Guåhan* shall be authorized to suspend tipping fees for all solid waste collected and transported to a landfill that is operated by the Department or its contractor for a period *not to exceed* sixty (60) days.

(m) Exemption from Tipping Fees for Municipal Waste Collection. All Mayors or Vice-Mayors who collect waste in the performance of their official duties shall be allowed to dump the waste at the Ordot landfill, the Agat transfer station and any other landfill or transfer station operated by the Department of Public Works ('DPW') , or its contractor. The Mayors or Vice-Mayors shall be exempt from all tipping fees when dumping the waste collected in their official capacity.

SOURCE: Added by P.L. 24-139:9. Repealed and reenacted by P.L. 24-272:1. Subsection (c) amended by P.L. 25-70:2 & P.L. 25-93:1. Subsection (d) amended by P.L. 25-93:2. Subsection (e) amended by P.L. 25-70:3; repealed and reenacted by P.L. 28-56:1 (June 30, 2005). Subsection (f) amended by P.L. 28-56:2 (June 30, 2005). Subsection (h) added by P.L. 25-93:3. Subsection (i) added by P.L. 25-93:4. Subsection (j) added by P.L. 25-93:5. Subsection (k) added by P.L. 25-93:6. Subsection (l) added by P.L. 25-93:7. Subsection (m) added by P.L. 26-35:III:23(c) .

§ 51119. The Solid Waste Management Plan.

(a) The Plan to be adopted by the Agency shall address a solid waste management system for Guam which shall include, but not be limited to, source reduction, recycling, composting, resource recovery and sanitary landfilling, with the objective of reducing the amount of solid waste to be processed, landfilled or otherwise legally disposed of. It shall also require the application of plasma torch or flame technology, if permitted and cost effective, to stabilize materials at the Ordot Landfill. It shall also include:

(1) a program for the privatization of all solid waste management and operations within the authorized frameworks as enacted by this Article; the Agency shall submit a privatization plan to the Guam Legislature. The Guam Legislature shall have up to ninety (90) calendar days after official receipt to review and amend the plan as appropriate, and approve or disapprove the plan;

(2) an inventory of current residential, business, military and other institutional solid waste generation;

(3) an inventory of existing publicly available solid waste management facilities and an inventory of existing collection systems and routes;

(4) projections of residential, business, military and other institutional solid waste that will be generated within Guam during the five (5) and ten (10) year periods following the effective date of this Section;

(5) projections for decrease in solid waste disposal as a result of source reduction, recycling and solid waste management facilities;

(6) an identification of potential sites for future sanitary landfills;

(7) projections for potential requirements for monofills at future sanitary landfill for special wastes, such as asbestos or ash;

(8) provide for and incorporate recycling activities required in Item (3) of Subsection (b) of § 51120 of this Article;

(9) provide guidelines for the orderly collection, transportation, storage, separation, processing, recycling, combustion and disposal of all solid waste;

(10) provide programs for the educational training of collectors, operators and other solid waste management professionals;

(11) provide for a public education program encouraging recycling and source reduction and explaining the Plan;

(12) suggest new legislation to improve solid waste management;

(13) evaluate and determine markets for recycled materials;

(14) investigate and recommend new technologies for source reduction, recycling, composting, sanitary landfill and other solid waste disposal; and

(15) provide guidelines, including timeline for converting the Ordot Landfill to beneficial use.

(b) The Plan shall be revised and updated by the Agency every five (5) years.

SOURCE: Added by P.L. 24-139:10. Repealed and reenacted P.L. 24-272:1.

NOTE: As stated above, because P.L.s 24-179 and 25-272 were found to be invalid by the Supreme Court of Guam, Article 1 repealed and reenacted by P.L. 23-64, is presented herein:

ARTICLE 1
SOLID WASTE MANAGEMENT

§ 51101. Findings of Necessity and Declaration of Purposes.

(a) The people of this Territory find:

(1) Continuing technological changes in methods of packaging and marketing of consumer products, together with the economic and population growth of the Territory, the rising affluence of its citizens, and its expanding industrial activity have created new and ever mounting problems involving disposal of garbage, refuse, and solid waste materials resulting from domestic, commercial, agricultural, institutional and industrial activities.

(2) Traditional methods of disposing of solid waste in the Territory are no longer adequate to meet the ever-increasing problem. Improper methods and practices of handling and disposal of solid wastes pollute our land, air and water resources, blight our countryside, adversely affect land values and damage the overall quality of our environment.

(b) It is hereby declared to be the purpose of this Chapter to:

(1) Plan for and regulate the storage, collection, transport, separation, processing and disposal of solid waste in order to protect the public safety, health and welfare and to enhance the environment of the people of the Territory;

(2) Continue authority to regulate solid waste storage practices within the Department of Public Health and Social Services pursuant to Chapter 33 of this Title to ensure that such practices do not constitute a danger to human health and welfare;

(3) Provide the authority and resources to operate and maintain efficient, environmentally acceptable solid waste management systems within the Department of Public Works;

(4) Establish permanent responsibility for long range solid waste management planning with the Guam Environmental Protection Agency. Operational planning necessary for daily activities of the Solid Waste Division shall remain the responsibility of the Department of Public Works. The Guam Environmental Protection Agency shall be responsible to provide technical assistance in solid waste management and shall have

the authority to establish such advisory committees as are necessary to carry out the planning and assistance functions. Such committees should be composed of representatives from concerned government agencies, private solid waste operators, educational groups, federal agencies when applicable, and the public at large;

(5) Require review of the design and the issuance of permits for the operation of solid waste collection, transport, transport-related, processing, and disposal activities by the Guam Environmental Protection Agency;

(6) Promote the application of resource recovery systems which preserve and enhance the quality of air, water and land resources;

(7) Promote and assist in the development of markets for recovered and recycled materials;

(8) Support and encourage the rapid and efficient removal of abandoned vehicles and bulky waste from public and private premises to assure that related resource recovery is facilitated, and for other purposes;

(9) Undertake a comprehensive investigation of and set minimum standards for the generation, transportation, processing, storage, treatment and disposal of hazardous waste; conduct surveys for special disposal facilities, to protect public health, other living organisms and the environment through an effective and efficient hazardous waste management system;

(10) Establish an effective enforcement system to prevent the improper disposal of solid wastes.

§ 51102. Definitions.

For the purpose of this Chapter, the following words and phrases shall have the meaning given herein unless their use in the text of the Chapter clearly demonstrates a different meaning.

(1) Administrator shall mean the Administrator of the Guam Environmental Protection Agency or his designee.

(2) Agency shall mean the Guam Environmental Protection Agency.

(3) Board shall mean the Board of Directors of the Guam Environmental Protection Agency.

(4) Collection shall mean the act of removing solid waste from the central storage point of the source of generation.

(5) Disposal shall mean the discharge, deposit, injection, dumping, spilling, leaking or placing of any solid waste or hazardous waste into or on any land or water so that such solid waste or hazardous waste or any constituent thereof may enter the environment or be emitted into the air or discharged into any waters, including ground water.

(6) Dump shall mean a land site where solid waste is disposed without a valid permit.

(7) Financial Assurance shall mean a financial guarantee assuring that funds are available to pay for closure of a solid waste management facility, rendering post-closure at a solid waste management facility, and to compensate third parties for bodily injury and property damage caused by sudden and non-sudden accidents related to the operation of a solid waste management facility.

(8) Government shall mean the government of Guam.

(9) Hardfill shall mean a method of compaction and earth cover of solid wastes other than those containing garbage or other putrescible (putrescent) waste, including, but not limited to, tree limbs and stumps, demolition material, and like materials not constituting a health or nuisance hazard, where cover need not be applied on a per day used basis.

(10) Hazardous Waste shall mean a solid waste, or combination of solid wastes, which because of its quantity, concentration, or physical, chemical, or infectious characteristics may:

(a) cause or significantly contribute to an increase in mortality or an increase in serious irreversible, or incapacitating reversible, illness; or

(b) pose a substantial present or potential hazard to human health or the environment when improperly treated, stored, transported or disposed of, or otherwise damaged.

(11) Highway means the entire width between the boundary lines of every right-of-way or publicly maintained travel ways when any part thereof is opened to the use of the public for purposes of vehicular travel.

(12) Incinerator shall mean an enclosed device using controlled flame combustion, the primary purpose of which is to thermally break down solid waste.

(13) Person shall mean any individual, partnership, co-partnership, firm, company, trust, estate, or any agency, department of instrumentality of the Federal Government or Government of Guam, or any other legal representative, agent or assigns.

(14) Pollution shall mean the condition caused by the presence in the environment of substances of such character and in such quantities that the quality of the environment is impaired or rendered offensive to life.

(15) Public Nuisance shall anything which is dangerous to life, injurious to health, or renders soil, or water or food impure or unwholesome.

(16) Processing shall mean any method, system, or other treatment designed to change the physical, chemical or biological character or composition of any solid waste. This includes the neutralization of any

hazardous waste; the rendering of any hazardous waste non-hazardous, safer for transport, amenable for recovery, amenable for storage, or reduced in volume; or any other activity or processing designed to change the physical form or chemical composition of hazardous waste so as to render it non-hazardous.

(17) Resource Recovery shall mean the act of recycling or reusing materials which still have useful physical or chemical properties after serving a specific purpose for the same or other purposes.

(18) Recycling shall mean the process by which recovered resources are transformed into new products in such a manner that products lose their identity.

(19) Reusing shall mean the reintroduction of a commodity in the economic stream without any change.

(20) Sanitary Landfill shall mean an approved site where solid waste is disposed using sanitary landfilling techniques.

(21) Sanitary Landfilling shall mean an engineered method of disposing of solid waste on land in an approved manner that protects the environment by spreading the waste in thin layers, compacting it to the smallest practical volume, and covering it with soil by the end of each working day.

(22) Separation shall mean the systematic division of solid waste into designated components.

(23) Solid Waste shall mean any garbage, refuse, sludge from a waste treatment plant, water supply treatment plant, or air pollution control facility and other discarded and/or spilled materials, including solid, liquid, semisolid, or contained gaseous material resulting from industrial, commercial, mining, and agricultural operations, and from community activities, but does not include solid or dissolved material in domestic sewage, or solid or dissolved materials in irrigation return flows or industrial discharges which are point sources subject to permits under Section 402 of the Federal Water Pollution Control Act, as amended (86 Stat. 880), or source, special nuclear, or byproduct materials as defined by the Atomic Energy Act of 1954, as amended (68 Stat. 923).

(24) Solid Waste Management shall mean the purposeful, systematic control of the generation, storage, collection, transportation, separation, processing, recovery and disposal of solid waste.

(25) Solid Waste Management Facilities shall mean machinery, equipment, vehicles, structures or any part of accessories thereof installed or acquired for primary purpose of collecting, transporting, storage, processing or disposing of solid waste.

(26) Solid Waste Management Practices shall mean the actions to effectuate the generation, storage, collection, transportation, processing or

the ultimate disposal of solid waste.

(27) Solid Waste Management System shall mean the entire process of storage, collection, transportation, processing and disposal of solid waste by any person engaging in such process as a business or any government agency.

(28) Storage shall mean the interim containment of solid waste in approved manner.

(29) Territorial Solid Waste Management Plan shall mean a comprehensive plan and all amendments and revisions thereto for provisions of solid waste management throughout the Territory.

(30) Transfer Station shall mean any intermediate waste facility in which solid waste collected from any source is temporarily deposited and stored while awaiting transportation to another solid waste management facility.

§ 51103. Power and Duties.

(a) The Agency shall have the responsibility to:

(1) Administer the territorial solid waste management program pursuant to provisions of this Chapter;

(2) Provide technical assistance to local and federal agencies, and other persons, and cooperate with appropriate local agencies and private organizations in carrying out the duties under this Chapter;

(3) Encourage and recommend procedures for the utilization of self-financing solid waste management systems and agencies in accomplishing the desired objectives of this Chapter;

(4) Promote the planning and application of resource recovery to preserve and enhance the quality of air, water and land resources;

(5) Serve as the official territorial representative for all purposes of the Federal Solid Waste Disposal Act, (Public Law 91-512), or as subsequently amended, and for the purpose of such other territorial or federal legislation as has been or may hereafter be enacted to assist in the management of solid waste;

(6) Survey the solid waste management practices within the territory and prepare a solid waste management plan; such plan to include but not necessarily be limited to the development, investigation and research, including the preparation of legislative action as may be required for new disposal sites, processes, recycling facilities or methods. The plan shall be revised at least every five (5) years, or sooner as needed;

(7) Develop regulations in cooperation with appropriate

government agencies, industrial and private parties, for the generation, collection, transportation, storage, processing and disposal of hazardous waste, in accordance with the Administrative Adjudication Act;

(8) Prepare, adopt, promulgate, modify, update, repeal, and enforce rules and regulations governing solid waste collection, transport, separation, processing, and disposal in order to conserve the air, water, and land resources of the Territory, protect the public health, prevent environmental pollution and public nuisances, and enable it to carry out the purposes and provisions of this Chapter and the adopted Territorial Solid Waste Management Plan;

(9) Establish the procedures for review and issuance for permit application, governing the design, operation, closure and post-closure of solid waste management facilities;

(10) Prepare, issue, modify, remove and enforce orders for compliance with any of the provisions of this Chapter or of any rules and regulations issued pursuant thereto and requiring the taking of such remedial measures for solid waste management as may be necessary or appropriate to implement or effectuate the provisions and purposes of this Chapter;

(11) Prepare, adopt, promulgate, modify, update, repeal, and enforce such other rules and regulations as may be necessary to establish a hazardous waste program which may be at least equivalent to or more stringent, or broader in scope than the requirements of Section 3006 of the Federal Resource Conservation and Recovery Act (42 U.S.C. 6926, et seq.) and regulations promulgated pursuant thereto.

(b) The Department of Public Works shall be responsible for:

(1) Public solid waste collection, transport and disposal. Such collection and disposal services shall be furnished to all villages and urban areas, and may be extended to further areas by administrative action. The Director of Public Works may by regulation prescribe requirements with regards to solid waste containers, and collection of solid and bulky waste. Public sanitary landfills, hardfills, transfer stations, processing or recycling plants as currently exist or may be established will be operated and maintained by the Department of Public Works. The Director of Public Works, with the approval of the Governor, may execute a contract after public bid with a private party or firm for the collection and disposal of any solid or bulky waste, or other offensive substances, or separate items thereof including the operation of any sanitary landfill, hardfill, transfer station, processing, recycling, or storage plant which is publicly owned provided that any employee whose job is adversely affected by any such contract shall be given first preference for any other job for

which he qualifies in the Government of Guam.

(2) Operational and logistic planning for solid and bulky waste management to include collection, routing equipment, material and equipment procurement disposal, transfer and storage site operations, processing and recycling plant operations and maintenance, and engineering functions related thereto. The Director of Public Works is authorized to negotiate for and approve contracts for recycling and composting at the Order Landfill, or at any other site approved by the Guam Environmental Protection Agency, under the following procedures: The Director, after duly advertising for a request for proposals for the removal or composting of recyclable materials from the landfill, shall enter into a contract with any interested business organization, either local or off island, to collect and recycle or compost such materials.

The successful bidder or bidders shall not be charged for the materials. The Department may assist successful bidders in collecting storage batteries and waste oil which are to be found in the various villages of Guam.

§ 51104. Permits.

(a) The Administrator is hereby authorized and directed to issue permits for solid waste management facilities and hazardous waste management facilities, including design, operation, maintenance, substantial alteration, modification or enlargement. All such permits shall be non-transferable and conditioned upon the observance of the laws of the territory and rules and regulations authorized herein.

(b) Each permit holder shall apply for the renewal of each permit held, upon forms provided by the Agency, not less than sixty (60) days prior to the expiration date of such solid waste management permit to be renewed, or not less than one hundred eighty (180) days prior to the expiration date of each hazardous waste management permit to be renewed.

(c) Each permit application and each permit renewal application shall be submitted with proof of financial assurance, of a type and in a sum established by the Administrator conditioned on the fulfillment by the permit holder of the requirements of this Chapter and the rules and regulations authorized therein. No financial assurance mechanism required under this Chapter may be canceled by the guarantor unless the Administrator has received written notice thereof and there has been a lapse of one hundred twenty (120) days between receipt of notice and cancellation date.

(d) Before issuing a solid waste management permit to any person with respect to any facility for the incineration, recycling, or disposal of solid waste, the Administrator shall:

(1) Cause to be published in a major local newspaper or

newspaper of general circulation, and broadcast over a local radio station or stations, notice of the Agency's intention to issue such a permit.

(2) If, within forty-five (45) days after publication and broadcast, the Agency receives written notice of opposition to the Agency's intention to issue such permit and a request for a hearing is made, the Agency shall provide for a hearing in accordance with the Administrative Adjudication Act if requested by a substantially affected party.

(e) Before issuing a hazardous waste management permit to any person with respect to any facility for the processing, storage, or disposal of hazardous waste, the Administrator shall:

(1) Cause to be published in a major local newspaper or newspaper of general circulation, and broadcast over a local radio station or stations, notice of the Agency's intention to issue such a permit.

(2) If, within forty-five (45) days after publication and broadcast, the Agency receives written notice of opposition to the Agency's intention to issue such permit and a request for a hearing is made, the Agency shall provide for a hearing in accordance with the Administrative Adjudication Act if requested by a substantially affected party or an informal public meeting if requested by any other person.

§ 51105. Permit Fees.

Each application for a permit, or renewal application, shall be accompanied by a certified check or money order in the amount prescribed by regulations. All fees required by the section shall be non-returnable and shall be placed in the revolving fund established under Section 51117 of this Chapter.

§ 51106. Inspections.

The Agency is hereby authorized to inspect all solid waste management facilities and hazardous waste management facilities at all reasonable times to insure compliance with the laws of the Territory, the provisions of this Chapter and the rules and regulations authorized herein. This authority shall include access to and authority to copy all records relating to hazardous waste, as well as the authority to obtain samples of any waste handled in the facilities. It shall be a misdemeanor for any person to interfere with such inspections. It shall also constitute a violation of Prohibited Solid Waste Activities and Prohibited Hazardous Waste Activities and shall carry the Solid Waste Civil Penalties and Hazardous Waste Civil Penalties as set forth respectively in § 51114(b) and § 51114(d) below.

§ 51107. Inspection Fees.

The Agency is hereby authorized to include as part of permit fees under § 51105, fees for inspections conducted of all solid waste management facilities, hazardous waste treatment, storage and disposal facilities, hazardous waste transporters, generators of hazardous waste, waste oil generators, recyclers, marketers, brokers and all other waste oil facilities including boilers and industrial furnaces as well as waste to energy facilities.

§ 51108. Notice.

Any notice, order or other official correspondence affecting the rights of any person under this Chapter shall be delivered by personal service or sent by registered or certified mail with a return receipt to the address of such person as shown by the records of the Agency. The return receipt, signed by the addressee, or his agent, shall be conclusive proof of delivery.

§ 51109. Hearings.

(a) Any person who received an order from the Administrator as authorized by this Chapter and any person whose permit application is disapproved by the Administrator may, within fifteen (15) days of the date of receipt of such order or disapproval, file a Notice of Intent to appeal with the Board, setting forth in such Notice a verified petition outlining the legal and factual basis for such appeal.

(b) The Board of Directors shall, not more than sixty (60) days after receipt of such Notice of Appeal, hold a public hearing at which time the person appealing may appear and present evidence in person or through counsel in support of this petition.

(c) The Agency is hereby authorized to administer oaths, examine witnesses and issue subpoenas to compel the attendance of witnesses and the production of evidence relevant to the matter involved in the hearing.

(d) The Board shall affirm, modify or revoke any action which is appealed and shall notify the appellant of its decision not more than thirty (30) days after the conclusion of the hearing. Such notice shall be in writing and shall state the reasons for the decision.

(e) Any person may appeal such decision to the Superior Court of Guam by filing with the Agency a written notice of such intent to appeal within ten (10) days of the notice in subsection (d) of this Section and shall have a transcript of the proceedings upon request.

§ 51110. Prohibited Solid Waste Activities.

(a) It shall be unlawful for any person to:

(1) Violate any provision of this Chapter or any rule, regulation, standard, or order issued pursuant to this Chapter;

(2) Own, operate or use a dump for the disposal of solid

waste;

(3) Place, or allow to be placed, any solid waste upon the highways, public or private property contrary to the provisions of this Chapter;

(4) Manage solid waste facilities without a permit issued pursuant to this Chapter;

(5) Store, collect, transport, process, or dispose of solid waste in such a manner as to degrade the environment, create a public nuisance, create a health or safety hazard, or violate any provisions of this Chapter;

(6) Transport any solid waste in any vehicle in any street or highway unless adequate precautions are taken to prevent such solid waste from falling or from being dislodged from such vehicle upon any street, highway, or any other public or private property;

(7) Not immediately pick up and remove waste which has fallen off the vehicle they are operating during the course of transportation upon any street, highway or any other public or private property;

(8) No person shall destroy or attempt to destroy by burning, except in an incinerator the construction and operation of which is approved by the Administrator, or as may otherwise be authorized by the Administrator, any garbage, dead animals, or other offensive substances, the burning of which may give off foul and noisome odor. Nothing in this Section shall preclude the burning of trees, brush, grass and other vegetable matter authorized by the Administrator.

(b) Each day of continued violation of this section or the provisions of this Chapter or rules and regulations authorized herein shall be deemed a separate offense or violation.

§ 51111. Prohibited Hazardous Waste Activities.

(a) It shall be unlawful for any person to:

(1) Violate any provision of this Chapter or any rule, regulation, standard, or order issued pursuant to this Chapter;

(2) Own, operate or use a dump for the disposal of hazardous waste;

(3) Place, or allow to be placed, any hazardous waste upon the highways, public or private property contrary to the provisions of this Chapter;

(4) Manage hazardous waste facilities without a permit issued pursuant to this Chapter;

(5) Store, collect, transport, process or dispose of hazardous waste in such a manner as to degrade the environment, create a public nuisance, create a health or safety hazard as determined by the Director of the Department of Public Health and Social Services or the Administrator or violate any provision of this Chapter;

(6) Knowingly make any false statement or representation in any hazardous waste application, label, manifest, record, report, permit or other document filed, maintained, or used for purposes of compliance with the provisions of this Chapter.

(b) Each day of continued violation of this section or the provisions of this Chapter or rules and regulations authorized herein shall be deemed a separate offense or violation.

§ 51112. Injunction.

The Agency shall maintain an action to restrain any violation or threatened violation of the provisions of this Chapter or the rules and regulations authorized herein. Such right to injunctive relief is in addition to any other powers or penalties conferred by this Chapter.

§ 51113. Plats.

All persons operating a sanitary landfill, hardfill, or other approved disposal site under permits issued pursuant to this Chapter shall, upon completion of the sanitary landfill or hardfill, file with the Department of Land Management and the Building Permit Section of the Department of Public Works, a plat of each site, together with a description of the waste placed therein and in conformance with rules and regulations adopted pursuant to § 51103(a)(8) of this Chapter.

§ 51114. Applicability to Government Agencies.

Government agencies shall comply with all provisions of this Chapter including planning, review, and permit requirements, with the exception of § 51104(c). Government agencies may contract with any person to carry out their responsibilities under this Chapter. Such contractors shall also comply with the provisions of this Chapter.

§ 51115. Penalties.

(a) Solid Waste-Criminal Penalties. Any person who knowingly violates any solid waste management provision of this Chapter, or any valid solid waste management rule or regulation promulgated under this Chapter, or who refuses or neglects to comply with any lawful order issued by the Administrator in carrying out the provisions of this Chapter shall, upon conviction, be imprisoned for a term of not more than one (1) year, and/or be fined not more than $1,000 per day for each violation or noncompliance, and shall make restitution.

(b) Solid Waste-Civil Penalties. Any person who violates any solid waste management provision of this Chapter, or any valid solid waste management rule or regulation promulgated under this Chapter, or who refuses or neglects to comply with any lawful order issued by the Administrator in carrying out the provisions of this Chapter shall, in addition to clean-up costs and other damages, forfeit and pay a civil penalty of not more than $1,000 per day for each violation or noncompliance.

(c) Hazardous Waste-Criminal Penalties. Any person who knowingly violates any hazardous waste management provisions of this Chapter, or any valid hazardous waste management rule or regulation promulgated under this Chapter, or who refuses or neglects to comply with any lawful order issued by the Administrator in carrying out the provisions of this Chapter shall be guilty upon conviction of a felony of the third degree, and be fined not less than $10,000 per day for each violation and/or noncompliance, and shall make restitution.

(d) Hazardous Waste-Civil Penalties. Any person who violates any hazardous waste management provision of this Chapter, or any valid hazardous waste management rule or regulation promulgated under this Chapter, or who refuses or neglects to comply with any lawful order issued by the Administrator in carrying out the provisions of this Chapter shall, in addition to clean-up costs and other damages, forfeit and pay a civil penalty of not less than $10,000 per day for each violation or noncompliance.

(e) Administrative Penalties. In addition to any other administrative or judicial remedy provided by this Chapter, or by rules adopted under this Chapter, the Administrator is authorized to impose by order the penalties specified in § 51115(b) and (d) respectively. Factors to be considered in imposing an administrative penalty include the nature and history of the violation and of any prior violations, and the opportunity, difficulty, and history of corrective action. It is presumed that the violator's economic and financial conditions allow payment of the penalty, and the burden of proof to the contrary is on the violator. In any proceeding to recover the civil penalty imposed, the Administrator need only show that notice was given, a hearing was held or the time granted for requesting a hearing has expired without such a request, the civil penalty was imposed, and that the penalty remains unpaid.

§ 51116. Citizen's Suits.

(a) Any person may commence a civil action on his behalf:

(1) Against any person (including the United States, and any other governmental instrumentality or agency, to the extent permitted by law) who is alleged to be in violation of any permit, standard, regulation, condition, requirement, prohibition, or order which has become effective pursuant to this Chapter; or

(2) Against any person, including the United States, and any other governmental instrumentality or agency, to the extent

permitted by law, and including any past or present generator, past or present transporter, or past or present owner or operator of a treatment, storage, or disposal facility, who has contributed or who is contributing to the past or present handling, storage, treatment, transportation, or disposal of any solid or hazardous waste which may present an imminent and substantial endangerment to health or the environment; or

(3) Against the Administrator where there is alleged a failure of the Administrator to perform any duty under this Chapter which is not discretionary with the Administrator.

Any action under paragraph (a)(1), (a)(2), or (a)(3) of this Section shall be brought in the Superior Court of Guam. The Superior Court shall have jurisdiction, without regard to the amount in controversy or the citizenship of the parties, to enforce the permit, standard, regulation, condition, requirement, prohibition, or order referred to in paragraph (a)(1), to restrain any person who has contributed or is contributing to the past or present handling, storage, treatment, transportation, or disposal of any solid or hazardous waste referred to in paragraph (a)(2), to order such person to take such further action as may be necessary, or both, or to order the Administrator to perform the act or duty referred to in paragraph (a)(3), as the case may be, and to apply any appropriate civil penalties under § 51115(b) and (d). No bond shall be required for issuance of an injunction or temporary injunction after a duly noticed hearing.

(b) Except for injunctive relief, no action may be commenced under subsection (a)(1) or (a)(2) of this Section:

(1) Prior to ninety (90) days after the plaintiff has given notice of the violation or endangerment to (i) the Administrator; (ii) the government of Guam; and (iii) to any alleged violator of such permit, standard, regulation, condition, requirement, prohibition, or order referred in subsection (a)(1) of this Section if applicable or to any person alleged to have contributed or to be contributing to the past or present handling, storage, treatment, transportation, or disposal of any solid or hazardous waste referred to in subsection (a)(2) of this Section if applicable.

(2) Except for injunctive relief, if the Administrator or government of Guam has commenced and is diligently prosecuting a civil or criminal action to require compliance with such permit, standard, regulation, condition, requirement, prohibition, or order pursuant to subsection (a)(1) of this Section or if the Administrator or government of Guam, in order to restrain or abate acts or conditions which may have contributed or are contributing to the activities which may present the alleged endangerment under subsection (a)(2) of this Section has commenced and is diligently prosecuting an action under local law or under the Comprehensive Environmental Response, Compensation and Liability Act

(CERCLA) or is actually engaging in a removal action under CERCLA or has incurred cost to initiate a remedial Investigation and Feasibility Study under CERCLA and is diligently proceeding with a remedial action.

(c) Except for injunctive relief, no action may be commenced under subsection (a)(3) of this Section prior to sixty (60) days after the plaintiff has given notice to the Administrator and the government of Guam in which the failure has occurred that he will commence such action.

§ 51117. Solid Waste Management Fund.

There is established a non lapsing, revolving fund, hereafter referred to as the "Solid Waste Management Fund" which shall be maintained separate and apart from any other funds of the Government of Guam, and shall be administered by the Administrator. Independent records and accounts shall be maintained in connection therewith. All fees, reimbursements, assessments, fines, bail forfeitures, and other funds collected or received pursuant to this Article shall be deposited in this Fund and used for the administration and implementation of this Article, including purchase of equipment and payment of personnel costs of the Agency.

ARTICLE 2
LITTER CONTROL

SOURCE: Added by P.L. 14-37:1 (June 18, 1977). Repealed and reenacted by P.L. 17-87 (Jan. 18, 1985) and P.L. 23-64 (Dec. 5, 1995). Further amended as indicated herein.

§ 51201. Declaration of Purpose.

It is hereby declared to be the purpose of this Article to define and prescribe procedures pertaining to littering, and to provide authority for the regulation of littering in order to enhance the environment for the people of Guam.

§ 51202. Definitions.

For the purpose of this Article, the following words shall have the meaning given herein unless their use in the text clearly demonstrates a different meaning:

(a) *Apprehending Officers* shall mean any designated individual with the Department of Parks and Recreation, the Department of Agriculture, the Guam Environmental Protection Agency, the Department of Public Health and Social Services, the Department of Public Works, all village mayors and assistant mayors, and any peace officer in the Guam Police Department.

(b) *Litter* shall mean discarded, used or leftover solid materials, including but not limited to garbage, trash, rubbish, refuse, paper, containers, bulky metallic waste, packing or construction materials or carcasses of dead animals.

(c) *Littering* shall mean willful or negligent throwing, dropping, placing, depositing, or sweeping, allowing or causing such acts, of any litter on land or water, in other than appropriate storage containers or areas designated for such purpose.

(d) *Vehicle* shall mean a device in, upon or by which any person or property may be propelled, moved, or drawn upon a highway, except a device moved by human or animal power.

(e) *Watercraft* shall mean any boat, ship, vessel, barge or other floating craft.

§ 51203. Power and Duties.

(a) The Administrator of the Guam Environmental Protection Agency, in consultation with the Attorney General's Office, is empowered to prescribe and amend such rules and procedures as are necessary for the efficient implementation of this Article.

(b) Violations of this Article will be recorded on forms approved by and prosecuted within the Traffic Division of the Superior Court of Guam.

(c) Apprehending officers, as defined herein, shall have the power to apprehend persons violating this Article and issue citations for such violation.

§ 51204. Litter Control Revolving Fund.

There is established a fund to be known as the Litter Control Revolving Fund which shall be maintained separate and apart from any other fund of the Government of Guam and shall be administered by the Administrator. Independent records and accounts shall be maintained in connection therewith. Except as provided in §40115 of Title 5, Guam Code Annotated, 50 percent (50%) of all assessments, fines, bail forfeitures and other funds collected or received pursuant to this Article shall be deposited in the Litter Control Revolving Fund and used for the administration and implementation of this Article; for education programs and advertisement promotions aimed at increasing awareness of litter and defacement problems; for the placement of anti-litter and anti-graffiti signs around the island; and for the cleanup of litter and defacement from public highways, streets, alleys, roads, bridges, buildings, signs, restrooms, public recreational areas or other public lands that are most visible to the public, and 50 percent (50%) shall be deposited in the Guam Beautification Fund as provided in 21 GCA §77114.1.

§ 51205. Prohibited Activities.

(a) It shall be unlawful for any person to willfully or negligently dump, deposit, throw, leave or abandon any litter upon any public highway, street, alley or road, upon public parks or recreation areas or upon any other public property except as designated for such use, or upon property owned by another person without written permission of the owner, or into any bay, channel, harbor, river, creek, stream, reservoir, coastal waters, or other waters of the Territory.

(b) Apprehension of Violation. Apprehension for violation of prohibitions may be initiated by an apprehending officer who witnessed an offense or discovered an article bearing a person's name on the property of another, or any public property except as designated for such use, or by any private citizen, who witnessed an offense or discovered incriminating evidence, who is willing to make the initial charge and testify for the Government.

(c) Any person who shall witness the throwing, dumping, or depositing of litter from a vehicle or water craft which is in violation of prohibitions may report the date, time of day and location of the littering and the license registration number to apprehending officers. The registration number as recorded shall constitute prima facie evidence that the littering was done by the person to whom such vehicle or water craft is registered. Nothing in this Section shall be construed to modify or change the burden of the Government to prove the defendant guilty beyond a reasonable doubt.

(d) Any person who violates this section while occupying a motor vehicle which is moving, or located on public property or a public right of way, shall be deemed to have committed a violation no only of this section, but of 16 GCA Chapter (Rules of the Road) , and shall be guilty of a petty misdemeanor.

SOURCE: Subsection (d) added by P.L. 25-170:4.

§ 51206. Enforcement.

Any person apprehended for violation of any of the above prohibitions shall be served by the apprehending officer with a citation and an order to appear at the Traffic Court Division of the Superior Court of Guam for prosecution. Parents or legal guardians will assume all responsibility for any violations of this Chapter committed by any minors under their care.

§ 51207. Penalties.

(a) Littering shall be punishable by a fine of *not less than* One Hundred Dollars ($100.00) , nor more than One Thousand Dollars ($1,000.00) . Any person convicted of a second or subsequent litter offense shall be required by the Court to pick up and remove litter from a public place under the supervision of the Superior Court of Guam's Probation Office, or its designee, or as the Court shall otherwise provide, for a period of *not less than* eight (8) hours for each offense.

Any person convicted of any litter offense may also be required by the Court to pay the cost of removing the litter they caused. The Superior Court of Guam shall transfer all money collected to pay fines imposed under this Section to the Guam Environmental Protection Agency for use in the Litter and Defacement Control Revolving Fund established by § 51204 of Title 10 of the Guam Code Annotated. Any peace officer, as that term is defined by 8 GCA § 5.55, may issue a citation for a litter offense.

(b) A person charged with a first violation may avoid a court hearing by posting bail in the amount of the minimum fine or paying such prescribed fine as the Traffic Court Division of the Superior Court shall prescribe.

SOURCE: Subsection (a) amended by P.L. 25-170:5.

§ 51208. Severability Clause.

The provisions of this Chapter are severable and if any provision or part thereof shall be held invalid or unconstitutional or inapplicable to any person or circumstances, such invalidity, unconstitutionality or inapplicability shall not affect or impair the remaining provisions of this Chapter.

ARTICLE 3
ANNUAL CONTRACT FOR SCRAP REMOVAL

SOURCE: Added by P.L. 23-64 (Dec. 5, 1995). Further amended as indicated herein.

§ 51301. Contract to Remove Scrap.

The Director of Public Works, after duly advertising for a request for proposals for the removal of scrap metal, shall enter into a contract with any interested business organization, either local or off-island, to collect and remove from Guam scrap metal. The successful offeror may not be charged for the scrap metal but may post a one hundred thousand dollars ($100,000) performance bond to assure its completion of the removal project within twelve (12) months from receiving from the Director a Notice to Proceed. "Scrap Metal" for the purpose of this Article means abandoned vehicles and other abandoned metal implements of which the Department of Public Works has jurisdiction and the right to dispose. In so disposing of such scrap metal, the Director shall not charge any fees to the owner of the same.

§ 51302. Annual Contract.

The Director shall advertise for and execute such a contract each year with any qualified party on the same terms as are set out in § 51301 of this Article.

§ 51303. Environmental Impact Study.

The Guam Environmental Protection Agency (GEPA) shall annually cause an environmental impact study to be undertaken by the successful offeror to ensure that there are no potential adverse ecological damage to aquifers caused by the annual scrap removal contract.

§ 51304. Conformity to Waste Removal Regulations.

The successful offeror shall perform all work under this Article in compliance with applicable rules and regulations of GEPA on the removal of scrap metal and hazardous waste. As a minimum, the Department of Public Works Director shall ensure that all successful offerors include as part of their processing, an intake system to screen and remove batteries and other potentially hazardous residual material including, engine oil, hydraulic fluids and coolant and Freon from air conditioning units.

ARTICLE 4
CONTRACT FOR COLLECTION OF RECYCLABLE PAPER.

SOURCE: Added by P.L. 24-246:3. (Aug. 14, 1998) except for § 51404 and any following.

§ 51401. Contract to Accept and Collect Recyclable Paper.

The Director of Public Works, in accordance with the applicable procurement laws, and after advertising for a request for proposals ('RFP') for the collection of recyclable paper, shall enter into a two (2) - year contract with any qualified local interested business or nonprofit organization, to accept and collect recyclable paper to include newsprint, office paper and magazines from the public, and to implement a plan to prevent them from entering Guam's waste stream. The qualified local business or nonprofit organization shall have active recycling experience and knowledge in Guam. The RFP shall include the requirement that the prospective contractor accepts and pays for all recyclable paper, to include newsprint, office paper and magazines offered by the public. The successful offeror shall be one who bids the highest amount per pound to be paid to the public for the recyclable paper for the duration of the contract term. The contractor shall be granted One Hundred Fifty Thousand Dollars ($150,000.00) per annum, to be appropriated from the Solid Waste Operations Fund established in this Chapter, to supplement its operations in accordance with the terms and conditions negotiated between the successful offeror and the Department of Public Works. No part of the contract shall require the government to grant more than the annual sum granted at the beginning of the contract period.

§ 51402. Biennial Contract.

The Director shall advertise for and execute such a contract every two (2) years with any qualified party on the same terms as are set out in § 51401 of this Article.

§ 51403. Conformity to All Laws and Rules and Regulations.

The successful offeror shall perform all work under this Article incompliance with all applicable laws, including those of this Chapter, and rules and regulations of GEPA as may be established. As a minimum, the Department of Public Works Director shall ensure that all offerors include as part of their processing, a plan to remove the collected paper from Guam's waste stream.

§ 51404. Report.

Each successful bidder shall file a report on a quarterly basis with I Maga'lahen Guåhan [the Governor] and I Liheslaturan Guåhan [the Legislature], outlining the following:

(a) total type and amount of paper recycled;

(b) cost comparison of the cost of the paper-recycling program versus landfill disposal of paper, or any less-than-conventional methods of paper waste reduction; and

(c) recommendations for permanent implementation and improvements to the recycling program.

SOURCE: Added by P.L. 26-147:3.

ARTICLE 5
RECYCLING REVOLVING FUND

SOURCE: Added by P.L. 27-38:2 (Nov. 13, 2003). This Article was repealed and reenacted in its entirety by P.L. 28-171:2 (Jan. 29, 2007).

§ 51501. Definitions.

As used in this Article, and except as otherwise provided, the following words and phrases shall mean:

(a) 'Administrator' shall mean the Administrator of the Guam Environmental Protection Agency, or his designee.

(b) 'DPW' shall mean the Department of Public Works.

(c) 'Director' shall mean the Director of the Department of Public Works.

(d) 'Enameled white goods' shall mean appliances for home or commercial use including, but *not limited to,* refrigerators, water heaters, air conditioners, washers, dryers, and stoves.

(e) 'GEPA' shall mean the Guam Environmental Protection Agency.

(f) 'Gross Vehicle Weight' or 'Gross Vehicle Weight Rating' means the value specified by the manufacturer as the loaded weight of a single vehicle.

(g) 'Heavy Equipment' shall mean any equipment, motor vehicle or motor carrier, or non-road motor vehicle with a gross weight or gross vehicle weight of five (5) tons or more.

(h) 'Junk Vehicle' means a motor vehicle, regardless of operating condition, that the registered owner has declared to have no value or no use, or that is abandoned by being placed, discarded, or disposed of on public or private property without approval by owners of said property for more than seven (7) calendar days, or that is no longer registered in accordance with Chapter 7 of Title 16 GCA.

(i) 'Motor Vehicle' or 'motorized vehicle' shall mean automobiles, automobile trucks, automobile wagons, buses, trucks, motorcycles or other self propelled wheeled conveyances that are primarily for use on Guam's public streets, roads, and highways that are required to be registered with the Motor Vehicles Division, Department of Revenue and Taxation, Government of Guam.

(j) 'Municipal Solid Waste' is a subset of solid waste and is defined as durable goods (e.g., appliance, batteries, tires), nondurable goods (e.g., newspapers, books, magazines), containers and packaging, food wastes, yard trimmings, and miscellaneous organic wastes from residential, commercial, and industrial non-process sources.

(k) 'Recyclable materials' means materials which still have useful physical or chemical properties after serving a specific purpose for the same or other purpose. Recyclable materials are as follows:

(1) batteries (i.e., lead-acid, portable computer batteries, nickel-cadmium, sealed types for power backup);

(2) automobiles, buses, and trucks or any motor vehicle;

(3) tires (passenger/commercial);

(4) enameled white goods;

(5) home appliances (other small appliances that are not considered enameled white goods);

(6) glass and plastic bottles;

(7) foam padding;

(8) lead;

(9) metals (ferrous/non-ferrous);

(10) organic material (i.e., tree trimmings, palm fronds, grass, food waste, soiled cardboard);

(11) paper products;

(12) wood pallets and scrap wood;

(13) construction and demolition debris (‘C&D’);

(14) x-ray film;

(15) automobile oil and fluids;

(16) freon and other refrigerant gases;

(17) electronic waste (i.e., computers, circuit boards, televisions, and portable phones);

(18) heavy equipment; and

(19) other recyclable materials deemed recyclable by GEPA pursuant to its rules and regulations.

(l) ‘Recycle or Recycling’ means a method by which recovered resources are converted for use as raw materials or feedstock to make new products, as defined in § 51102 (35) of Chapter 51 of Title 10 GCA.

(m) ‘Recycling Company’ shall mean any business licensed by the Department of Revenue and Taxation, and permitted, as required in § 51104 of Chapter 51 of Title 10 GCA, by the Guam Environmental Protection Agency to conduct business on Guam.

(n) ‘Recycling Facility’ shall mean all contiguous land, structures, and other appurtenances, and improvements on land used for the collection, separation, recovery, and sale or reuse of recovered resources that would otherwise be disposed of as municipal solid waste, and is an integral part of a manufacturing process aimed at producing a marketable product made of post consumer material.

(o) ‘Recycling fee’ shall mean an annual fee levied upon the registered owner of a motor vehicle to assist in the recycling and disposal of motor vehicles and other recyclable materials in accordance with this Article.

§ 51502. Recycling Revolving Fund.

There is hereby created the Recycling Revolving Fund ('Fund'), which shall be maintained separate and apart from any other funds, including the General Fund of the government of Guam, and independent records and accounts shall be maintained thereof. All revenue generated from recycling fees collected pursuant to this Article, including interest earned, shall be deposited into the 'Recycling Revolving Fund', hereinafter in this Article referred to as the 'Fund'.

§ 51503. Continuing Appropriation

(a) All revenues from the Recycling Revolving Fund are hereby appropriated to the Department of Public Works to fund the costs of the administration and implementation of this Article.

(b) In Fiscal Year 2007, the Director of Public Works *shall* expend monies from the Recycling Revolving Fund to pay current obligations of the Department of Public Works arising from the ongoing Island-Wide Collection and Off-Island Disposal of Abandoned Vehicles, White Goods, Tires, and Batteries program pursuant to GSA Bid No. 038-05.

SOURCE: P.L. 28-171:2 (Jan. 29, 2007). Amended by P.L. 29-002:VI:11 (May 18, 2007).

§ 51504. Administration of the Recycling Revolving Fund.

The Director of Public Works shall administer the Fund and shall encumber all amounts available in the Fund as expeditiously as possible for the purposes of assisting and encouraging recycling of recyclable materials. The Director shall administer the Fund in accordance with this Article to cause the following material/waste to be recycled or otherwise disposed according to the following priority:

(a) First Priority - junk vehicles, tires, batteries, waste oil, white goods/appliances,

(b) Second Priority - paper, cardboard, plastic, and glass,

(c) Third Priority - other recyclable materials as determined by the Director.

(d) *Not more than* one (1) FTE employee at Guam Environmental Protection Agency to administer this Article.

The Director of Public Works, *no later than* ten (10) days after the end of each fiscal year, shall transfer from the Recycling Revolving Fund three percent (3%) of the total amount collected during that fiscal year to fund one (1) FTE employee at the Guam Environmental Protection Agency. The Fund shall be subject to audits by the Public Auditor.

§ 51505. Levy and Collection of Recycling Fees.

The Director of Revenue and Taxation is hereby authorized to levy a Recycling Fee on individuals who are renewing their annual motor vehicle registration with the Department of Revenue and Taxation Division of Motor Vehicles, through the vehicle registration system. The Director of Revenue and Taxation shall collect the Recycling Fees mandated by this Article and transmit the fees to the Director of DPW for deposit in the Recycling Revolving Fund.

§ 51506. Recycling Fees.

The Recycling Fees authorized in § 51505 are hereby imposed as follows:

(a) *Twenty Five Dollars ($25.00)* annually for each automobile, bus and truck registered by the Department of Revenue and Taxation through the annual vehicle registration system.

(b) *Three Dollars ($3.00)* for each motorcycle and trailer registered by the Department of Revenue and Taxation through the annual vehicle registration system.

(c) *Thirty Dollars ($30.00)* for each piece of heavy equipment registered by the Department of Revenue and Taxation through the annual vehicle registration system.

§ 51507. Authorization for DPW to Contract with Recycling Companies.

(a) DPW is authorized, in accordance with the applicable procurement laws, to enter into contracts with recycling companies for the collection, recycling, disposal, and processing, or any combination thereof, of automobiles, buses, heavy equipment, trucks, batteries, tires, white goods, and other recyclable materials, and as required by, or in accordance with, Articles 3 and 4 of Title 10 GCA, Chapter 51. The Director of DPW shall submit any proposed Requests for Proposals to *I Liheslaturan Guahan* within three (3) months of the enactment hereof.

(b) At a minimum, the Director of Department of Public Works shall require that all offerors include, as part of their written offers, proof of current approved permits, certification of compliance with Title 10 GCA Chapter 51 from GEP A and a plan to remove collected recyclable materials, including abandoned vehicles, from Guam's waste stream. Contractors employed under this Section shall perform all work under this Article in compliance with all applicable laws, including those of this Chapter, and the applicable Rules and Regulations of GEP A and DPW.

(c) DPW shall promulgate the necessary rules and regulations, in accordance with the Administrative Adjudication Law, to properly implement this Article.

§ 51508. Adjustment of Recycling Fees.

The Director shall review the fee authorized by § 51506, supra, every twenty four (24) months and is authorized to adjust the fee by *not more than* twenty-five percent (25%) in accordance with the Administrative Adjudication Law.

ARTICLE 6
MUNICIPAL RECYCLING PROGRAM

SOURCE: Added by P.L. 27-37:2 (Nov. 14, 2003).

§ 51601. Definitions.

For purposes of this Article, except as otherwise provided, the following words and phrases, together with all of the common derivatives thereof, shall have the meaning ascribed to them as follows:

(a) 'GEPA' shall mean the Guam Environmental Protection Agency.

(b) 'Recycling' means the process by which recovered resources are transformed into new products in such a manner that products lose their initial identity, as defined in § 51102 (18) of Chapter 51 of Title 10 of the Guam Code Annotated.

(c) 'Recyclable materials' means materials which still have useful physical or chemical properties after serving a specific purpose for the same or other purpose. Recyclable materials are as follows:

(1) batteries (i.e., lead-acid, portable computer batteries, nickel-cadmium, sealed types for power backup);

(2) automobiles, buses, and trucks or any form of motorized vehicle;

(3) tires (passenger/commercial);

(4) enameled white goods;

(5) home appliances (other small appliances that are not considered enameled white goods);

(6) glass and plastic bottles;

(7) foam padding;

(8) lead;

(9) metals (ferrous/non-ferrous);

(10) organic material (i.e., tree trimmings, palm fronds, grass, food waste, soiled cardboard);

(11) paper products;

(12) wood pallets and scrap wood;

(13) construction and demolition debris ('C&D');

(14) x-ray film;

(15) automobile oil and fluids;

(16) Freon and other refrigerant gases;

(17) electronic waste (i.e., computers, circuit boards, televisions, and portable phones);

(18) heavy equipment; and

(19) other recyclable materials deemed recyclable by GEPA pursuant to the Rules and Regulations.

(d) 'Recycling company' means any business licensed by the Department of Revenue and Taxation, and issued a permit, as required in § 51104 of Chapter 51 of Title 10 of the Guam Code Annotated, from the Guam Environmental Protection Agency to conduct business on Guam.

(e) 'DPW' means the Department of Public Works.

SOURCE: Added by P.L. 27-37:2 as section 61601 and renumbered by Compiler to section 51601 to fit within the appropriate chapter and article.

§ 51602. Creation of Municipal Recycling Proceeds Fund for Each Village.

There is hereby established a Municipal Recycling Proceeds Fund for each municipality which shall be maintained separate and apart from any other funds, including the General Fund of the government of Guam, and independent records and accounts shall be maintained in connection therewith. The proceeds from the sale of recyclable materials collected, in accordance with the Municipal Recycling Program, from each village shall be deposited in the respective Municipal Recycling Proceeds Fund. All revenue deposited in each Municipal Recycling Proceeds Fund shall not be commingled with General Fund monies and shall be kept in a separate bank account. All proceeds from fees collected in accordance with §61603 of this Article shall be deposited in the Municipal Recycling Proceeds Fund for the respective village and used exclusively for the purposes authorized in §61604 of this Article. The Municipal Planning Council of each municipality shall administer the Municipal Recycling Proceeds Fund for its municipality which shall be subject to audits by the Public Auditor.

SOURCE: Added by P.L. 27-37:2 as section 61602 and renumbered by Compiler to section 51602 to fit within the appropriate chapter and article.

§ 51603. Creation of the Municipal Recycling Program.

There is hereby created a Municipal Recycling Program within the Recycling Office of the Department of Public Works to promote recycling on the municipal level in partnership with the village mayors. The program shall incorporate the following components:

(1) Recycling Drop-Off Bins. DPW shall solicit drop-off bins from recycling companies that would be made available to each mayor participating in the Municipal Recycling Program. The recycling drop-off bins shall be rust-proof, and located at a suitable site within the respective villages so that the residents will have a repository to which they can bring recyclable materials in accordance with guidelines established by DPW.

The mayors of each village participating in the program will be responsible for the security and cleaning of the bins and the supervision of their use for recycling purposes.

(2) Village Education Program. In coordination with the village mayors, DPW and GEPA shall create educational programs to promote recycling and the use of the recycling drop-off bins within each village.

(3) Sale of Recyclable Materials. In partnership with the village mayors, DPW shall arrange for the sale of recyclable materials, collected at the Recycling Drop-off Bins in each village, to recycling companies. The proceeds from the sale of recyclable materials shall be deposited into the respective Municipal Recycling Proceeds Fund of the village from which the recyclable materials were collected.

(4) The Program shall first begin with pilot programs at three (3) villages; one (1) each from northern, central, and southern Guam. The selection of the three (3) villages shall be made by DPW in concert with the village mayors.

SOURCE: Added by P.L. 27-37:2 as section 61603 and renumbered by Compiler to section 51603 to fit within the appropriate chapter and article.

§ 51604. Authorization for Municipal Planning Councils to Use the Proceeds from the Sale of Recyclable Materials for Village Needs.

The proceeds from the sale of recyclable materials from a village site shall be retained for use by the municipal government of that village in its Municipal Recycling Proceeds Fund. Expenditures from a village's Municipal Recycling Proceeds Fund shall be exclusively for the needs of that village as determined by the respective Municipal Planning Council through adoption of a resolution.

SOURCE: Added by P.L. 27-37:2 as section 61604 and renumbered by Compiler to section 51604 to fit within the appropriate chapter and article.

ARTICLE 7
RECYCLING ENTERPRISE ZONE

SOURCE: Added by P.L. 28-92 (Dec. 12, 2005), An Act to Create a Recycling Enterprise Zone at the Jose D. Leon Guerrero Commercial Port," as an uncodified permanent law. Codified here as Article 7 of this Chapter by the Compiler of Laws.

§ 51701. Definitions.

§ 51701. Definitions.

For purposes of this Act, and except as otherwise provided, the following words and phrases, together with all of the common derivatives thereof, shall have the meaning ascribed to them as follows:

(a) 'JLGCP' shall mean the Jose D. Leon Guerrero Commercial Port.

(b) 'Recycle' or 'Recycling' means the method by which recovered resources are converted for use as raw material or feedstock to make new products, as defined in §51102 (35) of Chapter 51, Title 10 of the Guam Code Annotated.

(c) 'Recycling company' means any business licensed by the Department of Revenue and Taxation, and has been issued a permit as required in §51104 of Chapter 51, Title 10 of the Guam Code Annotated by the Guam Environmental Protection Agency ('GEPA') to conduct business on Guam and that specifically commits eighty percent (80%) of its operations to recycling.

(d) 'Transshipment' shall mean to transfer for further transportation from one (1) ship or conveyance to another.

(e) 'Recyclable materials' means materials that still have useful physical or chemical properties after serving a specific purpose for the same or other purpose. Recyclable materials are as follows:

(1) batteries (i.e., lead-acid, portable computer batteries, nickel-cadmium, sealed types for power backup);

(2) automobiles, buses, and trucks or any form of motorized vehicle;

(3) tires (passenger/commercial);

(4) enameled white goods;

(5) home appliances (other small appliances that are not considered enameled white goods);

(6) glass and plastic bottles;

(7) foam padding;

(8) lead;

(9) metals (ferrous/non-ferrous);

(10) organic material (i.e., tree trimmings, palm fronds, grass, food waste, soiled cardboard);

(11) paper products;

(12) wood pallets and scrap wood;

(13) construction and demolition debris (‘C&D’);

(14) x-ray film;

(15) automobile oil and fluids;

(16) freon and other refrigerant gases;

(17) electronic waste (i.e., computers, circuit boards, televisions, and portable phones);

(18) heavy equipment; and

(19) other recyclable materials deemed recyclable by GEPA pursuant to the Rules and Regulations.

§ 51702. Establishment of Recycling Enterprise Zone.

There is established a “Recycling Enterprise Zone” at the Jose D. Leon Guerrero Commercial Port for use by recycling companies for the processing of automobiles, trucks, and tires for recycling purposes and the transshipment of recyclable materials. The size of the zone and its site on the JLGCP property shall be designated by the Board of Directors of the Port Authority of Guam and guided by the provisions of Section 7.10.4 of the Integrated Solid Waste Management Plan. Such designation shall be made within sixty (60) days of the enactment hereof and the site shall be made available for lease to recycling companies eligible under Section 4 of this Act. The Board of Directors of the Port Authority of Guam shall determine and charge a reasonable rate for the lease of said property.

§ 51703. Eligibility of Recycling Companies for use of the Recycling Enterprise Zone.

Lease space in the Recycling Enterprise Zone shall only be available to companies that qualify for Qualifying Certificates as recycling companies under guidelines established by the Guam Economic Development and Commerce Authority.

Appendix B.3

10GCA Chapter 73 Fire Prevention

CHAPTER 73
FIRE PREVENTION

§ 73101. Theaters: Prohibition.

No manager or other person shall use, or assist in, or countenance the use of, any theater, hall or other building for theatrical purposes, or for public entertainment of any kind where stage scenery and apparatus are employed, without a certificate in writing by the Fire Chief to the effect that the provisions of all existing regulations for the prevention of fires have been complied with to his satisfaction.

SOURCE: Added by P.L. 17-78.

§ 73102. Same: Fire Equipment.

Every manger or other person using any such building shall keep and maintain in good condition therein such fire fighting equipment as the Fire Chief, by regulation, shall prescribe.

SOURCE: Added by P.L. 17-78.

§ 73103. Same: Freedom from Obstruction.

Every manager or other person using any such building shall, at all times during performances, or when such building is open to the public, keep every aisle, passageway, exit, entrance, and stairway open and clear of temporary seats or other obstructions and all doors and gates in or of every such aisle, passageway, exit, entrance and stairway, unlocked and fastened so that they will open freely, and no person shall stand or remain in any such aisle, passageway, exit, entrance, or stairway during performances, or while such building is open.

SOURCE: Added by P.L. 17-78.

§ 73104. Same: Admission of Fire Department.

Every manager or person using any such building shall at all times freely admit a detail from the Guam Fire Department in every building used as a theater or place of public amusement, whenever the same shall be necessary in the discretion of the Fire Chief for the purposes of assisting in case of fire or in enforcing the provisions of this Chapter.

SOURCE: Added by P.L. 17-78.

§ 73105. Fire Equipment: Woodworking Establishments.

Sawmills, carpenter shops and other places where wood is sawed, planed or worked in such manner as to cause accumulations of sawdust or shavings, shall maintain in good condition therein such fire fighting equipment as the Fire Chief, by regulation, shall prescribe.

SOURCE: Added by P.L. 17-78.

§ 73106. Woodworking Establishments: Fire Prevention.

Before a sawmill or woodworking shop is closed for the day, the floors and machinery of the same shall be swept clean of accumulations of wood, dust and shavings, which shall be placed outside the building in trash cans or in a place approved by the Fire Chief for storage of such materials.

No furnace or anvil shall be used or placed nearer than twenty-five (25) feet from any saw, plane, or woodworking machine.

Lumber shall be stored so as not to constitute a fire hazard.

The Fire Chief or his agents may inspect any sawmill or woodworking shop at any time.

SOURCE: Added by P.L. 17-78.

§ 73107. Fire Equipment: Garages.

Every space maintained as a garage for taxis or for commercial repairing, cleaning, upkeep, or storage of automobiles, trucks or gasoline engines, shall maintain in good condition therein such fire fighting equipment as the Fire Chief, by regulation, shall prescribe.

SOURCE: Added by P.L. 17-78.

§ 73108. Prohibition.

It shall be unlawful for any person to remove the gasoline tank cover of any vehicle in the vicinity of a gasoline pump, while the motor of such vehicle is running.

SOURCE: Added by P.L. 17-78.

§ 73109. Fire Hydrant Inspection.

The Fire Chief shall have all fire hydrants inspected quarterly to see that they are maintained in good working order.

SOURCE: Added by P.L. 17-78.

§ 73110. Penalty.

Violation of any provision of this Chapter is a misdemeanor.

SOURCE: Added by P.L. 17-78.

§ 73111. Uniform Fire Code.

Inspection of premises and areas and relative to the prevention of fires or the spread thereof, shall be in accordance with the Uniform Fire Code issued by the International Conference of Building Officials and the Western Fire Chief's Association. Standards and requirements for fire prevention enforcement as set out in the Uniform Fire Code and its appendices, and in the standards published by the International Conference of Building Officials and by the Western Fire Chiefs' Association shall apply in Guam in the absence of any specific provisions on the subject matter of such standards in this Chapter.

SOURCE: Added by P.L. 17-78; amended by P.L. 20-135:1; further amended by P.L. 22-82:1.

§ 73112. Updating of Uniform Fire Code.

The Uniform Fire Code, along with its appendices, shall automatically be adopted in Guam as such code and its appendices are updated every three (3) years by the International Conference of Building Officials and by the Western Fire Chiefs' Association. The Guam Fire Department (the A**GFD**@) shall transmit copies of such code and its appendices as updated every three (3) years to the Department of Public Works, to the Public Utility Agency of Guam, to the Guam Environmental Protection Agency, to the Guam Contractors Association, and to the Guam Chapter of the American Institute of Architects. The GFD shall develop and promulgate, pursuant to the Administrative Adjudication Law, rules setting forth grace periods within which parties in violation of the Uniform Fire Code may bring their premises up to code. None of the provisions of such code shall be enforced so as to prevent the issuance of building or occupancy permits until such rules have been duly promulgated, and no building built prior to promulgation of such rules which is not in compliance with such code shall be condemned for such violation; provided, however, that as such building is renovated or rebuilt, it shall be brought into compliance with such code. The GFD and the other government agencies together with the associations to which copies of such code are transmitted shall work together on a voluntary basis to plan how construction in Guam can be brought into compliance with such code, which plan shall be incorporated into the rules to be promulgated by the GFD; provided, however, that such plan shall be completed and such rules submitted to the Legislature pursuant to the Administrative Adjudication Law within one (1) year of the enactment of this section.

SOURCE: Added by P.L. 22-82:2.

§ 73113. Municipal Solid Waster Incinerators Prohibited.

Notwithstanding any other provision of law, it shall be unlawful for any person to construct or operate on Guam a municipal solid waste incinerator or waste-to-energy facility, as defined by the rules and regulations of the United States Environmental Protection Agency or laws of the United States of America. Nothing in this section shall be construed as prohibiting the construction or operation of hazardous waste incinerators or biomedical incinerators as defined by the rules and regulations of the U.S. Environmental Protection Agency or the laws of the United States of America.

SOURCE: Added by P.L. 25-175:5.

Appendix C

Selected Guam Public Laws

Public Law 25-175

MINA'BENTE SINGKO NA LIHESLATURAN GUÅHAN
2000 (SECOND) Regular Session

Bill No. 478 (LS)
As substituted by the Committee
on Natural Resources and amended on
the Floor.

Introduced by:

J. M.S. Brown
F. B. Aguon, Jr.
E. C. Bermudes
A. C. Blaz
E. B. Calvo
M. G. Camacho
Mark Forbes
L. F. Kasperbauer
A. C. Lamorena, V
C. A. Leon Guerrero
K. S. Moylan
V. C. Pangelinan
J. C. Salas
S. A. Sanchez, II
A. R. Unpingco

AN ACT TO APPROVE AND AMEND THE INTEGRATED SOLID WASTE MANAGEMENT PLAN.

BE IT ENACTED BY THE PEOPLE OF GUAM:

Section 1. Legislative Findings and Intent. Public Law Number 24-272 required that the Guam Environmental Protection Agency, pursuant to the Administrative Adjudication Law, create a Solid Waste Management Plan for Guam and submit said Plan to *I Liheslaturan Guåhan*. *I Maga'lahen Guåhan* submitted the Integrated Solid Waste Management Plan for the Island of Guam on August 25, 2000. Said Plan consists of three (3) parts, Phase I, Phase II and Part III consisting of Attachments created by the Guam Planning Council which are affixed thereto. *I Mina'Bente Singko Na Liheslaturan Guåhan* wants to approve said Plan with certain deletions. Said Plan recommends the implementation of a purported contract between the government of Guam and Guam Resource Recovery Partners, which *I Liheslaturan Guåhan* has already disapproved of and refused to fund. *I Liheslaturan Guåhan* wants to maintain and continue government of Guam policy against the use of municipal waste incinerators for trash disposal.

The Plan calls for the creation of a separate government agency to deal with waste management, a function which is adequately performed by the Department of Public Works, and *I Liheslaturan Guåhan* believes the creation of such an agency would result in unnecessary expense and duplication of effort within the Executive Branch of government. The Committee on Natural Resources of this *Liheslatura* conducted a public hearing on this Plan on September 19, 2000 and October 12, 2000 at which public comments were received, much of it unfavorable to the concept of an incinerator and the aforementioned contract with Guam Resource Recovery Partners. A copy of said Plan is attached hereto. Phase I, Phase II, and the Attachments are denominated Exhibits A, and B, respectively.

Section 2. *Except* as provided herein, the Integrated Solid Waste Management Plan for the Island of Guam is hereby adopted, recognized and established as the sole governing Plan on the subject, and shall supercede any Integrated Solid Waste Management Plan which the Executive Branch may, or may not, legally have in place. Said Plan may be modified by the Guam Environmental Protection Agency in accordance with the provisions of the Administrative Adjudication Law and Public Law Number 24-272, but *only* in a manner consistent with this Act. No officer or agency of the government of Guam shall implement or expend funds, or commit resources to implement any portion of the Integrated Solid Waste Management Plan for the Island of Guam which is disapproved or deleted by this Act or any waste-to-energy facility, or any incineration project aimed at reduction of municipal solid waste. It is against government of Guam policy to create an incinerator for the disposal of municipal solid waste or the disposal of any waste other than biologically hazardous waste.

Section 3. Any tables, photographs, graphs, statistics or the like, in the Plan, which are inconsistent with the language herein or the attachments, or which support the creation of an incinerator or waste-to-energy facility are deemed deleted.

Section 4. This Act shall take effect immediately.

Section 5. Section 73113 is hereby *added* to Chapter 73, Division 3 of Title 10 of the Guam Code Annotated to read as follows:

"Section 73113. Municipal Solid Waste Incinerators Prohibited.

Notwithstanding any other provision of law, it shall be unlawful for any person to construct or operate on Guam a municipal solid waste incinerator or a waste-to-energy facility, as defined by the rules and regulations of the United States Environmental Protection Agency or the laws of the United States of America. Nothing in this Section shall be construed as prohibiting the construction or operation of hazardous waste incinerators or biomedical incinerators, as defined by the rules and regulations of the United States Environmental Protection Agency or the laws of the United States of America."

Section 6. Section 51110(a)(8) of Article 1, Chapter 51, Part 2 of Title 10 of the Guam Code Annotated is hereby *repealed and reenacted* to read as follows:

"(8) No person shall destroy or attempt to destroy by burning, *except* as authorized by §73113 of Chapter 73, Division 3 of Title 10 of the Guam Code Annotated, any garbage, dead animals or other offensive substances, the burning of which may give off foul and noisome odor. Nothing in this Section shall preclude the burning of trees, brush, grass and other vegetable matter authorized by the Administrator."

Section 7. Severability. *If* any provision of this Section or its application to any person or circumstance is found to be invalid or contrary to law, such invalidity shall *not* affect other provisions or applications of this Section which can be given effect without the invalid provisions or applicat ions, and to this end the provisions of this Section are severable.

Appendix D

Cost Data

Appendix D.1

Cost Data – Military Construction Funding

Appendix D.1

Cost Data – Military Construction Funding

PV Analysis	Alternative 1-1[b] Apra Harbor LF (54MSL)	Alternative 1-2[c] Apra Harbor LF (100MSL)	Alternative 2[d,e] GovGuam Landfill	Alternative 3[f] New Navy Landfill	Alternative 4a[g] Modular WTE Facility	Alternative 4b[g] Erected WTE Facility
25 -Year	Inadequate Service Life	56,000,000	123,000,000	149,000,000	179,000,000	210,000,000
		38%	83%	100%	120%	141%
50 - Year	Inadequate Service Life	Inadequate Service Life	189,000,000	174,000,000	270,000,000	277,000,000
			109%	100%	155%	159%

Notes

a Present Value Analysis uses a real discount rate of 2.8 percent, with inflation premium removed per OMB Circular No. A-94; Appendix C, rev January 2008

b Estimated service life is limited to the year 2023 and would be exhausted prior to 25 and 50 year analysis periods.

c Estimated service life is limited to the year 2036 and would be exhausted prior to 50 year analysis periods.

d Assumed a tip fee at the Gov Guam landfill of $95/ton over the analysis period, which is discounted over the analysis period.

e Includes estimated 40% increase in collection driver/truck costs to use GovGuam LF vs current system (80 % waste from northern Guam after troop relocation).

f Includes estimated 15% increase in collection driver/truck costs to use Central Guam LF vs current system (80 % waste from northern Guam after troop relocation).

g Assumes WTE would extend Apra Harbor Landfill site life to 65 years for landfilling of unburnable waste and residual ash.

CURRENT DOLLARS ANALYSIS

	Alternative 1-1 (54 MSL)		Alternative 1-2 (100 MSL)		Alternative 2		Alternative 3		Alternative 4a			Alternative 4b		
	Apra Harbor Landfill		Apra Harbor Landfill		Gov Guam Landfill		New Navy Landfill		Modular Waste-to-Energy Facility			Erected Waste-to-Energy Facility		
Year	Capital	Operating	Capital	Operating	Capital	Operating	Capital	Operating	Capital	Operating	Revenue	Capital	Operating	Revenue
2008														
2009	$ 11,133,317	$ 873,908	$ 22,825,361	$ 873,908		$ 1,228,470	$ 11,133,317	$ 873,908	$ 22,825,361	$ 873,908		$ 22,825,361	$ 873,908	
2010		$ 994,824		$ 994,824	$ 7,198,973	$ 3,159,235		$ 994,824		$ 994,824			$ 994,824	
2011		$ 1,003,782		$ 1,003,782		$ 3,771,600		$ 1,003,782	$ 2,629,000	$ 1,003,782		$ 5,047,000	$ 1,003,782	
2012		$ 1,066,791		$ 1,066,791		$ 4,009,271	$ 95,927,520	$ 1,066,791	$ 17,284,000	$ 1,066,791		$ 37,142,000	$ 1,066,791	
2013	$ 1,790,609	$ 1,331,541	$ 1,790,609	$ 1,331,541		$ 4,951,764	$ 9,389,965	$ 2,245,264	$ 27,866,609	$ 1,331,541		$ 57,825,609	$ 1,371,541	
2014		$ 1,557,676		$ 1,557,676		$ 5,900,808		$ 2,475,092		$ 8,460,586	$ (489,000)		$ 8,810,586	$ (1,733,000)
2015		$ 1,900,734		$ 1,900,734		$ 7,403,083		$ 2,838,896		$ 8,460,586	$ (489,000)		$ 8,810,586	$ (1,733,000)
2016		$ 2,090,584		$ 2,090,584		$ 7,706,450		$ 2,912,362		$ 8,460,586	$ (489,000)		$ 8,810,586	$ (1,733,000)
2017		$ 2,090,584		$ 2,090,584		$ 7,706,450		$ 2,912,362		$ 8,460,586	$ (489,000)		$ 8,810,586	$ (1,733,000)
2018		$ 2,090,584		$ 2,090,584		$ 7,706,450		$ 2,912,362		$ 8,460,586	$ (489,000)		$ 8,810,586	$ (1,733,000)
2019		$ 2,090,584		$ 2,090,584		$ 7,779,243		$ 2,929,990		$ 8,460,586	$ (489,000)		$ 8,810,586	$ (1,733,000)
2020		$ 2,090,584		$ 2,090,584		$ 7,779,243		$ 2,929,990		$ 8,460,586	$ (489,000)		$ 8,810,586	$ (1,733,000)
2021		$ 2,090,584		$ 2,090,584		$ 7,779,243		$ 2,929,990		$ 8,460,586	$ (489,000)		$ 8,810,586	$ (1,733,000)
2022		$ 2,090,584		$ 2,090,584		$ 7,779,243		$ 2,929,990		$ 8,460,586	$ (489,000)		$ 8,810,586	$ (1,733,000)
2023	$ 7,599,356	$ 2,090,584		$ 2,090,584		$ 7,779,243		$ 2,929,990		$ 8,460,586	$ (489,000)		$ 8,810,586	$ (1,733,000)
2024				$ 2,090,584		$ 7,779,243		$ 2,929,990		$ 8,460,586	$ (489,000)		$ 8,810,586	$ (1,733,000)
2025				$ 2,090,584		$ 7,779,243		$ 2,929,990		$ 8,460,586	$ (489,000)		$ 8,810,586	$ (1,733,000)
2026				$ 2,090,584		$ 7,779,243		$ 2,929,990		$ 8,460,586	$ (489,000)		$ 8,810,586	$ (1,733,000)
2027				$ 2,090,584		$ 7,779,243		$ 2,929,990		$ 8,460,586	$ (489,000)		$ 8,810,586	$ (1,733,000)
2028				$ 2,090,584		$ 7,779,243		$ 2,929,990		$ 8,460,586	$ (489,000)		$ 8,810,586	$ (1,733,000)
2029				$ 2,090,584		$ 7,779,243		$ 2,929,990	$ 8,079,000	$ 8,460,586	$ (489,000)	$ 1,312,500	$ 8,810,586	$ (1,733,000)
2030				$ 2,090,584		$ 7,779,243		$ 2,929,990		$ 8,460,586	$ (489,000)		$ 8,810,586	$ (1,733,000)
2031				$ 2,090,584		$ 7,779,243		$ 2,929,990		$ 8,460,586	$ (489,000)		$ 8,810,586	$ (1,733,000)
2032				$ 2,090,584		$ 7,779,243	$ 596,870	$ 2,929,990		$ 8,460,586	$ (489,000)		$ 8,810,586	$ (1,733,000)
2033				$ 2,090,584		$ 7,779,243		$ 2,929,990		$ 8,460,586	$ (489,000)		$ 8,810,586	$ (1,733,000)
2034				$ 2,090,584		$ 7,779,243		$ 2,929,990	$ 16,158,000	$ 8,460,586	$ (489,000)	$ 2,625,000	$ 8,810,586	$ (1,733,000)
2035				$ 2,090,584		$ 7,779,243		$ 2,929,990		$ 8,460,586	$ (489,000)		$ 8,810,586	$ (1,733,000)
2036			$ 7,599,356	$ 2,090,584		$ 7,779,243		$ 2,929,990		$ 8,460,586	$ (489,000)		$ 8,810,586	$ (1,733,000)
2037						$ 7,779,243		$ 2,929,990		$ 8,460,586	$ (489,000)		$ 8,810,586	$ (1,733,000)
2038						$ 7,779,243	$ 3,799,678	$ 2,929,990		$ 8,460,586	$ (489,000)		$ 8,810,586	$ (1,733,000)
2039						$ 7,779,243		$ 2,929,990	$ 8,079,000	$ 8,460,586	$ (489,000)	$ 1,312,500	$ 8,810,586	$ (1,733,000)
2040						$ 7,779,243	$ -	$ 2,929,990		$ 8,460,586	$ (489,000)		$ 8,810,586	$ (1,733,000)
2041						$ 7,779,243		$ 2,929,990		$ 8,460,586	$ (489,000)		$ 8,810,586	$ (1,733,000)
2042						$ 7,185,076		$ 2,929,990		$ 8,460,586	$ (489,000)		$ 8,810,586	$ (1,733,000)
2043						$ 7,185,076		$ 2,929,990		$ 8,460,586	$ (489,000)		$ 8,810,586	$ (1,733,000)
2044						$ 7,185,076		$ 2,114,990		$ 8,460,586	$ (489,000)		$ 8,810,586	$ (1,733,000)
2045						$ 7,185,076	$ 447,652	$ 2,114,990		$ 8,460,586	$ (489,000)		$ 8,810,586	$ (1,733,000)
2046						$ 7,185,076		$ 2,114,990		$ 8,460,586	$ (489,000)		$ 8,810,586	$ (1,733,000)
2047						$ 7,185,076		$ 2,114,990	$ 8,079,000	$ 8,460,586	$ (489,000)		$ 8,810,586	$ (1,733,000)
2048						$ 7,185,076		$ 2,114,990		$ 8,460,586	$ (489,000)		$ 8,810,586	$ (1,733,000)
2049						$ 7,185,076		$ 2,114,990		$ 8,460,586	$ (489,000)	$ 1,312,500	$ 8,810,586	$ (1,733,000)
2050						$ 7,185,076		$ 2,114,990		$ 8,460,586	$ (489,000)		$ 8,810,586	$ (1,733,000)
2051						$ 7,185,076		$ 2,114,990		$ 8,460,586	$ (489,000)		$ 8,810,586	$ (1,733,000)
2052						$ 7,185,076	$ -	$ 2,114,990		$ 8,460,586	$ (489,000)		$ 8,810,586	$ (1,733,000)
2053						$ 7,185,076		$ 2,114,990		$ 8,460,586	$ (489,000)		$ 8,810,586	$ (1,733,000)
2054						$ 7,185,076		$ 2,114,990	$ 16,158,000	$ 8,460,586	$ (489,000)	$ 2,625,000	$ 8,810,586	$ (1,733,000)
2055						$ 7,185,076		$ 2,114,990		$ 8,460,586	$ (489,000)		$ 8,810,586	$ (1,733,000)
2056						$ 7,185,076		$ 2,114,990		$ 8,460,586	$ (489,000)		$ 8,810,586	$ (1,733,000)
2057						$ 7,185,076		$ 2,114,990		$ 8,460,586	$ (489,000)		$ 8,810,586	$ (1,733,000)
2058						$ 7,185,076	$ 3,338,177	$ 2,114,990	$ 5,845,658	$ 8,460,586	$ (489,000)	$ 5,845,658	$ 8,810,586	$ (1,733,000)
	$ 20,523,281		$ 32,215,325		$ 7,198,973		$ 124,633,178		$ 133,003,628			$ 137,873,128		

PRESENT VALUE ANALYSIS

	Alternative 1-1 (54 MSL) Apra Harbor Landfill		Alternative 1-2 (100 MSL) Apra Harbor Landfill		Alternative 2 Gov Guam Landfill		Alternative 3 New Navy Landfill		Alternative 4a Modular Waste-to-Energy Facility			Alternative 4b Erected Waste-to-Energy Facility		
Year	Capital	Operating	Capital	Operating	Capital	Operating	Capital	Operating	Capital	Operating	Revenue	Capital	Operating	Revenue
2009	$ 10,830,075	$ 850,105	$ 22,203,658	$ 850,105	$ -	$ 1,195,009	$ 10,830,075	$ 850,105	$ 22,203,658	$ 850,105	$ -	$ 22,203,658	$ 850,105	$ -
2010	$ -	$ 941,370	$ -	$ 941,370	$ 6,812,152	$ 2,989,481	$ -	$ 941,370	$ -	$ 941,370	$ -	$ -	$ 941,370	$ -
2011	$ -	$ 923,975	$ -	$ 923,975	$ -	$ 3,471,733	$ -	$ 923,975	$ 2,419,977	$ 923,975	$ -	$ 4,645,730	$ 923,975	$ -
2012	$ -	$ 955,228	$ -	$ 955,228	$ -	$ 3,589,988	$ 85,895,568	$ 955,228	$ 15,476,466	$ 955,228	$ -	$ 33,257,747	$ 955,228	$ -
2013	$ 1,559,679	$ 1,159,816	$ 1,559,679	$ 1,159,816	$ -	$ 4,313,148	$ 8,178,966	$ 1,955,698	$ 24,272,726	$ 1,159,816	$ -	$ 50,367,992	$ 1,194,657	$ -
2014	$ -	$ 1,319,831	$ -	$ 1,319,831	$ -	$ 4,999,802	$ -	$ 2,097,166	$ -	$ 7,168,722	$ (414,334)	$ -	$ 7,465,280	$ (1,468,385)
2015	$ -	$ 1,566,641	$ -	$ 1,566,641	$ -	$ 6,101,840	$ -	$ 2,339,902	$ -	$ 6,973,465	$ (403,048)	$ -	$ 7,261,946	$ (1,428,390)
2016	$ -	$ 1,676,188	$ -	$ 1,676,188	$ -	$ 6,178,875	$ -	$ 2,335,073	$ -	$ 6,783,527	$ (392,070)	$ -	$ 7,064,149	$ (1,389,484)
2017	$ -	$ 1,630,533	$ -	$ 1,630,533	$ -	$ 6,010,579	$ -	$ 2,271,471	$ -	$ 6,598,761	$ (381,391)	$ -	$ 6,871,741	$ (1,351,638)
2018	$ -	$ 1,586,122	$ -	$ 1,586,122	$ -	$ 5,846,867	$ -	$ 2,209,603	$ -	$ 6,419,028	$ (371,003)	$ -	$ 6,684,573	$ (1,314,823)
2019	$ -	$ 1,542,920	$ -	$ 1,542,920	$ -	$ 5,741,338	$ -	$ 2,162,429	$ -	$ 6,244,191	$ (360,898)	$ -	$ 6,502,503	$ (1,279,011)
2020	$ -	$ 1,500,895	$ -	$ 1,500,895	$ -	$ 5,584,959	$ -	$ 2,103,530	$ -	$ 6,074,116	$ (351,068)	$ -	$ 6,325,392	$ (1,244,174)
2021	$ -	$ 1,460,015	$ -	$ 1,460,015	$ -	$ 5,432,839	$ -	$ 2,046,236	$ -	$ 5,908,673	$ (341,506)	$ -	$ 6,153,105	$ (1,210,286)
2022	$ -	$ 1,420,248	$ -	$ 1,420,248	$ -	$ 5,284,863	$ -	$ 1,990,502	$ -	$ 5,747,736	$ (332,204)	$ -	$ 5,985,510	$ (1,177,321)
2023	$ 5,022,039	$ 1,381,564	$ -	$ 1,381,564	$ -	$ 5,140,917	$ -	$ 1,936,286	$ -	$ 5,591,183	$ (323,156)	$ -	$ 5,822,481	$ (1,145,254)
2024	$ -	#VALUE!	$ -	$ 1,343,934	$ -	$ 5,000,892	$ -	$ 1,883,546	$ -	$ 5,438,894	$ (314,354)	$ -	$ 5,663,892	$ (1,114,060)
2025	$ -	#VALUE!	$ -	$ 1,307,329	$ -	$ 4,864,681	$ -	$ 1,832,243	$ -	$ 5,290,753	$ (305,792)	$ -	$ 5,509,623	$ (1,083,716)
2026	$ -	#VALUE!	$ -	$ 1,271,720	$ -	$ 4,732,180	$ -	$ 1,782,338	$ -	$ 5,146,647	$ (297,463)	$ -	$ 5,359,555	$ (1,054,199)
2027	$ -	#VALUE!	$ -	$ 1,237,082	$ -	$ 4,603,288	$ -	$ 1,733,792	$ -	$ 5,006,466	$ (289,361)	$ -	$ 5,213,575	$ (1,025,485)
2028	$ -	#VALUE!	$ -	$ 1,203,387	$ -	$ 4,477,907	$ -	$ 1,686,568	$ -	$ 4,870,103	$ (281,479)	$ -	$ 5,071,571	$ (997,554)
2029	$ -	#VALUE!	$ -	$ 1,170,610	$ -	$ 4,355,940	$ -	$ 1,640,630	$ 4,523,788	$ 4,737,454	$ (273,813)	$ 734,926	$ 4,933,435	$ (970,383)
2030	$ -	#VALUE!	$ -	$ 1,138,726	$ -	$ 4,237,296	$ -	$ 1,595,944	$ -	$ 4,608,419	$ (266,355)	$ -	$ 4,799,061	$ (943,952)
2031	$ -	#VALUE!	$ -	$ 1,107,710	$ -	$ 4,121,883	$ -	$ 1,552,475	$ -	$ 4,482,897	$ (259,100)	$ -	$ 4,668,347	$ (918,242)
2032	$ -	#VALUE!	$ -	$ 1,077,539	$ -	$ 4,009,614	$ 307,641	$ 1,510,189	$ -	$ 4,360,795	$ (252,043)	$ -	$ 4,541,194	$ (893,231)
2033	$ -	#VALUE!	$ -	$ 1,048,190	$ -	$ 3,900,403	$ -	$ 1,469,056	$ -	$ 4,242,019	$ (245,178)	$ -	$ 4,417,504	$ (868,902)
2034	$ -	#VALUE!	$ -	$ 1,019,640	$ -	$ 3,794,166	$ -	$ 1,429,043	$ 7,880,733	$ 4,126,477	$ (238,500)	$ 1,280,290	$ 4,297,183	$ (845,235)
2035	$ -	#VALUE!	$ -	$ 991,867	$ -	$ 3,690,823	$ -	$ 1,390,119	$ -	$ 4,014,083	$ (232,004)	$ -	$ 4,180,139	$ (822,213)
2036	$ -	#VALUE!	$ 3,507,273	$ 964,851	$ -	$ 3,590,295	$ -	$ 1,352,256	$ -	$ 3,904,750	$ (225,684)	$ -	$ 4,066,283	$ (799,818)
2037	$ -	#VALUE!	$ -	#VALUE!	$ -	$ 3,492,505	$ -	$ 1,315,424	$ -	$ 3,798,395	$ (219,537)	$ -	$ 3,955,528	$ (778,033)
2038	$ -	#VALUE!	$ -	#VALUE!	$ -	$ 3,397,378	$ 1,659,409	$ 1,279,595	$ -	$ 3,694,937	$ (213,558)	$ -	$ 3,847,790	$ (756,842)
2039	$ -	#VALUE!	$ -	#VALUE!	$ -	$ 3,304,843	$ -	$ 1,244,743	$ 3,432,188	$ 3,594,296	$ (207,741)	$ 557,587	$ 3,742,986	$ (736,227)
2040	$ -	#VALUE!	$ -	#VALUE!	$ -	$ 3,214,828	$ -	$ 1,210,839	$ -	$ 3,496,397	$ (202,083)	$ -	$ 3,641,037	$ (716,175)
2041	$ -	#VALUE!	$ -	#VALUE!	$ -	$ 3,127,264	$ -	$ 1,177,859	$ -	$ 3,401,165	$ (196,579)	$ -	$ 3,541,865	$ (696,668)
2042	$ -	#VALUE!	$ -	#VALUE!	$ -	$ 2,809,736	$ -	$ 1,145,777	$ -	$ 3,308,526	$ (191,224)	$ -	$ 3,445,394	$ (677,692)
2043	$ -	#VALUE!	$ -	#VALUE!	$ -	$ 2,733,206	$ -	$ 1,114,569	$ -	$ 3,218,410	$ (186,016)	$ -	$ 3,351,551	$ (659,234)
2044	$ -	#VALUE!	$ -	#VALUE!	$ -	$ 2,658,761	$ -	$ 782,629	$ -	$ 3,130,749	$ (180,949)	$ -	$ 3,260,263	$ (641,278)
2045	$ -	#VALUE!	$ -	#VALUE!	$ -	$ 2,586,343	$ 161,137	$ 761,313	$ -	$ 3,045,476	$ (176,021)	$ -	$ 3,171,462	$ (623,811)
2046	$ -	#VALUE!	$ -	#VALUE!	$ -	$ 2,515,898	$ -	$ 740,577	$ -	$ 2,962,525	$ (171,226)	$ -	$ 3,085,080	$ (606,820)
2047	$ -	#VALUE!	$ -	#VALUE!	$ -	$ 2,447,372	$ -	$ 720,405	$ 2,751,859	$ 2,881,834	$ (166,563)	$ -	$ 3,001,051	$ (590,292)
2048	$ -	#VALUE!	$ -	#VALUE!	$ -	$ 2,380,712	$ -	$ 700,783	$ -	$ 2,803,341	$ (162,026)	$ -	$ 2,919,310	$ (574,214)
2049	$ -	#VALUE!	$ -	#VALUE!	$ -	$ 2,315,867	$ -	$ 681,696	$ -	$ 2,726,985	$ (157,613)	$ 423,040	$ 2,839,796	$ (558,574)
2050	$ -	#VALUE!	$ -	#VALUE!	$ -	$ 2,252,789	$ -	$ 663,128	$ -	$ 2,652,709	$ (153,320)	$ -	$ 2,762,447	$ (543,360)
2051	$ -	#VALUE!	$ -	#VALUE!	$ -	$ 2,191,429	$ -	$ 645,066	$ -	$ 2,580,456	$ (149,144)	$ -	$ 2,687,205	$ (528,560)
2052	$ -	#VALUE!	$ -	#VALUE!	$ -	$ 2,131,741	$ -	$ 627,496	$ -	$ 2,510,172	$ (145,081)	$ -	$ 2,614,013	$ (514,164)
2053	$ -	#VALUE!	$ -	#VALUE!	$ -	$ 2,073,678	$ -	$ 610,405	$ -	$ 2,441,801	$ (141,130)	$ -	$ 2,542,814	$ (500,159)
2054	$ -	#VALUE!	$ -	#VALUE!	$ -	$ 2,017,196	$ -	$ 593,779	$ 4,536,327	$ 2,375,293	$ (137,286)	$ 736,964	$ 2,473,555	$ (486,536)
2055	$ -	#VALUE!	$ -	#VALUE!	$ -	$ 1,962,253	$ -	$ 577,606	$ -	$ 2,310,596	$ (133,546)	$ -	$ 2,406,182	$ (473,284)
2056	$ -	#VALUE!	$ -	#VALUE!	$ -	$ 1,908,806	$ -	$ 561,874	$ -	$ 2,247,662	$ (129,909)	$ -	$ 2,340,644	$ (460,393)
2057	$ -	#VALUE!	$ -	#VALUE!	$ -	$ 1,856,816	$ -	$ 546,570	$ -	$ 2,186,441	$ (126,371)	$ -	$ 2,276,891	$ (447,853)
2058	$ -	#VALUE!	$ -	#VALUE!	$ -	$ 1,806,241	$ 839,177	$ 531,683	$ 1,469,527	$ 2,126,888	$ (122,929)	$ 1,469,527	$ 2,214,874	$ (435,655)
Sum 25 Year	$ 17,411,792	#VALUE!	$ 23,763,337	$ 31,821,676	$ 6,812,152	$ 116,186,325	$ 105,212,250	$ 43,805,353	$ 68,896,614	$ 116,524,344	$ (6,455,616)	$ 111,210,054	$ 121,179,769	$ (22,878,491)
25 Year PV	#VALUE!		55,585,013		122,998,477		149,017,603		178,965,342			209,511,331.54		
Sum 50 Year	$ 17,411,792	#VALUE!	$ 27,270,610	#VALUE!	$ 6,812,152	$ 182,447,271	$ 107,871,973	$ 66,210,589	$ 88,967,248	$ 192,064,710	$ (10,821,654)	$ 115,677,462	$ 199,845,111	$ (38,351,587)
50 Year PV	#VALUE!		#VALUE!		189,259,422		174,082,562		270,210,304			277,170,986		

COST ESTIMATING AND ECONOMIC ASSUMPTIONS

General Cost factors

Costs shown below have been adjusted for Guam in detail sheets or use the following factors, applied as noted in line item description.

For Construction projects - PAX Newsletter No 3.2.1, 30 April 2007 - Area Cost Factors (ACF) - (See example factors used)

1.15	California
2.64	Guam
2.296	Use Factor

For Primarily Labor or O&M Projects

May 2006 State Occupational Employment and Wage Estimates

Installation, Maintenance and Repair Occupations - 49-0000

Guam	49-0000	$	27,970	
California	49-0000	$	42,760	
Labor	Conversion		0.65	Guam/CA

Given that material factor in Means is 1.4 use below:

0.8	Use Factor

ALTERNATIVE 1-1: Landfill Improvements and Liner "Untouched Area" in 2009; LFG Control in 2013; Closure in 2024

Capital Costs			
2009	$	11,133,317	Scale, Control Building, Line Untouched, LCRS, Site Work
2013	$	1,790,609	LFG Control System and Flare for 60 Acres @$10k/acre & $150,000 Flare + tax- (x Guam/CA ACF)
2023	$	7,599,356	Closure Cap (assumes 7.4ppd and revised filling practices yielding 14 years site life)
Oper Costs			
Reference	$	717,802	Annual Landfill Operating and Collection Cost 2007 (Includes Refuse Trucks and Drivers - tonnage prorated to 2012)
	$	2,050,584	Annual Landfill Operating Cost 2016 - future tonnage (Includes Refuse Trucks and Drivers)
2013	$	40,000	Additional Annual LFG Control Operating Cost - $50,000 (Guam/CA O&M Factor, above)
	$	775,000	Annual PC Care w/o LFG/GW items
	$	*40,000*	*Additional O&M for LFG in PCM period - $50,000 X O&M Guam factor*
2024 to 2054	*$*	*815,000*	*Total Annual PCM Costs; 30 years (does not in include GW monitoring Assumed needed under All).*

ALTERNATIVE 1-2: Landfill Improvements and Liner in 2009; LFG Control in 2013; Closure in 2036

Capital Costs			
2009	$	22,825,361	Scale, Control Building, Line entire acreage, LCRS, Site Work
2013	$	1,790,609	LFG Control System and Flare for 60 Acres @$10k/acre & $150,000 Flare- (x Guam/CA ACF)
2036	$	7,599,356	Closure Cap (assumes 7.4ppd and revised filling practices yielding 27 years site life)
Oper Costs			
Reference	$	717,802	Reference Annual Landfill Operating & Collection Cost 2007 (Includes Refuse Trucks and Drivers - prorated to 2016)
2016 to future	$	2,050,584	Annual Landfill Operating Cost 2016 - future tonnage (Includes Refuse Trucks and Drivers)
2013 to future	$	40,000	Additional Annual LFG Control Operating Cost - $50,000 (Guam/CA O&M Factor, above)
2036	$	775,000	Annual PC Care w/o LFG/GW items (grass cutting high?)
	$	*40,000*	*Additional O&M for LFG in PCM period - $50,000 X O&M Guam factor*
2036 to 2066	*$*	*815,000*	*Total Annual PCM Costs; 30 years (does not in include GW monitoring Assumed needed under All).*

ALTERNATIVE 2: GovGuam Landfill Operational in 2010; tip fee (shown as annual "operating" cost) as shown.

2010 to future	$	95.00	Assumed Tip Fee for use of GovGuam Landfill
2010 to future		140%	Comparative Collection Cost over Alternative 1 due to greater off-route collection costs
			Includes Closure costs for 46 acres (assumed untouched area not included) below:
2010	$	7,198,973	Closure (Cap and LFG venting) of 46 acres (prorated from 60 acres); NO LINER
2011 to 2041	$	594,167	Total Annual PCM Costs (46 acres); 30 years; LFG venting, no LFG control system (not including GW monitoring).

ALTERNATIVE 3: AHLF (line untouched only) to 2013; Close AHLF in 2013; Construct new LF 2012; Operations 2013.

<u>Apra Harbor Landfill in interim</u>

Capital Costs (Apra Harbor interim)			
2009	$	11,133,317	Scale, Control Building, Site Work (Liner for untouched area only - 14 acres)
2013	$	1,790,609	LFG Control System and Flare for 60 Acres @$10k/acre & $150,000 Flare- (x Guam/CA ACF)
2013	$	7,599,356	Closure Cap for 60 acres
Oper Costs			
to 2016	$	717,802	Reference Annual Landfill Operating & Collection Cost 2007 (Includes Refuse Trucks and Drivers - prorated to 2016)
	$	775,000	Annual PC Care w/o LFG/GW items
	$	40,000	Additional O&M for LFG in PCM period - $50,000 X O&M Guam factor
2013 to 2043	*$*	*815,000*	*Total Annual PCM Costs; 30 years (does not in include GW monitoring Assumed needed under All).*

<u>New Navy Landfill In Central Guam</u>

2012		95,927,520	Scale, Control Building, Liner, LCRS, Site Work (Includes all of earthwork per MCON Accounting Funding)
2032	$	596,870	Initial Portion [20 year] of LFG Control and Flare for 20 Acres @$10k/acre & $150,000 Flare- (x Guam/CA ACF)
2045	$	447,652	Add to LFG Control System 15 Acres ($10k/acre CA x factor adjust to Guam)
2058	$	298,435	Add to LFG Control System 10 Acres (15 acres to be completed at closure beyond 2058)
Reference	$	7,599,356	Closure Cap -60 acres (Apply in 2038 [25 year of life] and prorated in 2058 for 20/25 years of remaining life)
2038	$	3,799,678	1/2 of closure cap cost prorated for first 25 years of site life
2058	$	3,039,742	remainder of closure cap cost prorated for year-26 to year 2058; or 20 years out of remaining site life
2013	$	374,991	New Landfill Operating Cost - Minus Collection Costs
Oper Costs			
2013 to 2063		115%	Apply Comparative Collection Cost over Alternative 1 due to greater off-route collection costs

ALTERNATIVE 4a: Modular WTE Facility

2011	$	2,629,000	Permitting, survey, and 70% engineering work
2012	$	17,284,000	40% of Total Construction Cost less Start up, permitting, survey, 70% of engineering costs
2013	$	26,076,000	60% of Total Construction Cost plus Startup; less permitting, survey and engineering
2014 to Future	$	6,445,000	Annual Operating Cost
2014 to Future	$	489,000	Annual Electrical Sales Revenue
2029	$	8,079,000	Minor Life Extension Measures (replacement of system components)
2034	$	16,158,000	Major Life Extension Measures (replacement of combustion units and major boiler components)
2039	$	8,079,000	Minor Life Extension Measures (replacement of system components)
2049	$	8,079,000	Minor Life Extension Measures (replacement of system components)
2054	$	16,158,000	Major Life Extension Measures (replacement of combustion units and major boiler components)
<u>Residual Waste and Ash Landfill Costs (46% of waste stream - Based on adjustments of Alt 1-2 landfill costs)</u>			
2009	$	22,825,361	Scale, Control Building, Line entire acreage, LCRS, Site Work
2013	$	1,790,609	LFG Control System and Flare for 60 Acres @$10k/acre & $150,000 Flare- (x Guam/CA ACF)
2058	$	5,845,658	Prorate closure cap to end of 50 year period (50 of 65 year site life [See Table 4-1])
Oper Costs			
Ref to 2014	$	717,802	Reference Annual Landfill Operating & Collection Cost 2007 (Includes Refuse Trucks and Drivers - prorated to 2016)
2014 to future	$	299,993	Annual Landfill Operating Cost 2014 - 80% of landfill only cost for **Alt 1-2**)
2014 to future	$	1,675,593	Collection Cost for Refuse trucks and Drivers
2013 to future	$	40,000	Additional Annual LFG Control Operating Cost - $50,000 (Guam/CA O&M Factor, above)

ALTERNATIVE 4b - Field Erected WTE

2011	$	5,047,000	Permitting, survey, and 70% engineering work
2012	$	37,142,000	40% of Total Construction Cost less Start up, permitting, survey, 70% of engineering costs
2013	$	56,035,000	60% of Total Construction Cost plus Startup; less permitting, survey and engineering
2014 to future	$	6,795,000	Annual Operating Cost
2014 to future	$	1,733,000	Annual Electrical Sales Revenue
2029	$	1,312,500	Minor Life Extension Measures (replacement of system components)
2034	$	2,625,000	Major Life Extension Measures (replacement of combustion units and major boiler components)
2039	$	1,312,500	Minor Life Extension Measures (replacement of system components)
2049	$	1,312,500	Minor Life Extension Measures (replacement of system components)
2054	$	2,625,000	Major Life Extension Measures (replacement of combustion units and major boiler components)
<u>Residual Waste and Ash Landfill Costs (46% of waste stream - Based on adjustments of Alt 1-2 landfill costs)</u>			
2009	$	22,825,361	Scale, Control Building, Line entire acreage, LCRS, Site Work
2013	$	1,790,609	LFG Control System and Flare for 60 Acres @$10k/acre & $150,000 Flare- (x Guam/CA ACF)
2058	$	5,845,658	Prorate closure cap to end of 50 year period (50 of 65 year site life [See Table 4-1])
Oper Costs			
Ref to 2014	$	717,802	Reference Annual Landfill Operating & Collection Cost 2007 (Includes Refuse Trucks and Drivers - prorated to 2016)
2014 to future	$	299,993	Annual Landfill Operating Cost 2014 - 80% of landfill only cost for Alt 1-2)
2014 to future	$	1,675,593	Collection Cost for Refuse trucks and Drivers
2013 to future	$	40,000	Additional Annual LFG Control Operating Cost - $50,000 (Guam/CA O&M Factor, above)

COMPARISON OF COLLECTION COST INCREASE USING VARIOUS ALTERNATIVE LANDFILLS
(ASSUMED AFTER FULL TROOP RELOCATION - 80% GENERATED IN NORTHERN GUAM)
Cost factor of 100% set for Apra harbor landfill based on 2 full load basis, below - variables in bold

ALT 1,4,6 ASSUMED EXISTING CASE USING APRA HARBOR LANDFILL

	Route time assumptions		Collection cycle		Cumul min	Cum hrs.
	15	yard to route	15	yard to route	15	0.25
	120	Assumed on-route	120	On route first load	135	2.25
Note 1	**40**	Route to LF or back	40	Route to LF	175	2.92
	15	Unload at LF	15	Unload at LF	190	3.17
	40	Break time/day	40	LF to Route	230	3.83
	40	LF to yard	120	On-route second	350	5.83
			15	Route to LF	365	6.08
			15	Unload at LF	380	6.33
			40	LF to yard	420	7.00
			40	Breaks	460	*7.67*

Notes:

1 Assumes 80 percent of waste from AF and Marines located in north - 20 miles one way
100% % full last load using minutes deduction to get 8 hours total
100% Total Daily Efficiency prorated over 2 loads
100% Cost Factor

ALT 2 ASSUMED USING NEW GOV GUAM LANDFILL

	Route time assumptions		Collection cycle		Cumul min	Cum hrs.
	15	yard to route	15	yard to route	15	0.25
	120	Assumed on-route	120	On route first load	135	2.25
Note 2	**70**	Route to LF or back	70	Route to LF	205	3.42
	15	Unload at LF	15	Unload at LF	220	3.67
	40	Break time/day	70	LF to Route	290	4.83
	40	LF to yard	**25**	On-route second	315	5.25
			70	Route to LF	385	6.42
			15	Unload at LF	400	6.67
			40	LF to yard	440	7.33
			40	Breaks	480	*8.00*

Notes:

2 Assumes 80 percent of waste from AF and Marines located in north - 35 miles one way
21% % full last load using minutes deduction to get 8 hours total
60% Total Daily Efficiency prorated over 2 loads
140% Increase Cost Factor

ALT 3 ASSUMED USING NEW NAVY CENTRAL GUAM LANDFILL

	Route time assumptions		Collection cycle		Cumul min	Cum hrs.
	15	yard to route	15	yard to route	15	0.25
	120	Assumed on-route	120	On route first load	135	2.25
Note 3	**50**	Route to LF or back	50	Route to LF	185	3.08
	15	Unload at LF	15	Unload at LF	200	3.33
	40	Break time/day	50	LF to Route	250	4.17
	40	LF to yard	**85**	On-route second	335	5.58
			50	Route to LF	385	6.42
			15	Unload at LF	400	6.67
			40	LF to yard	440	7.33
			40	Breaks	480	*8.00*

Notes:

3 Assumes 80 percent of waste from AF and Marines located in north - 25 miles one way
71% % full last load using minutes deduction to get 8 hours total
85% Total Daily Efficiency prorated over 2 loads
115% Increase Cost Factor

LANDFILL OPERATION COST (current) - Refuse Trucks for Apra Harbor Landfill Location

Description	Quantity	Hours/Day	Wage $/Hour	Equipment Cost, $/Hour	Daily Cost $	Annual Cost $
Personnel						
Manager/Supervisor	1	8	$ 25.00	-	$ 200	$ 50,400
Operator/Equipment Operator (On-site)	1	8	$ 16.12	-	$ 129	$ 32,503
Equipment Operator (On-site)	1	8	$ 16.12	-	$ 129	$ 32,503
Drivers/Operators for Refuse Collection Trucks	8	8	$ 9.50	-	$ 608	$ 153,216
Laborers	3	8	$ 10.29	-	$ 247	$ 62,225
Environmental Specialist	1	2	$ 21.10	-	$ 42	$ 10,634
Equipment						
Dozer Operation	1	4	-	$ 66.77	$ 267	$ 67,304
Refuse Trucks Operation	8	6	-	$ 25.55	$ 1,226	$ 309,017
TOTALS					$ 2,848	$ 717,802
Collection Drivers and Trucks Only						$ 462,233

LANDFILL OPERATION COST (2016 and beyond @ approx 55,000 TPY) - Refuse Trucks (Apra Harbor Landfill Location)

Description	Quantity	Hours/Day	Wage $/Hour	Equipment Cost, $/Hour	Daily Cost, $	Annual Cost, $
Personnel						
Manager/Supervisor	1	8	$ 25.00	-	$ 200	$ 50,400
Operator/Equipment Operator (On-site)	1	8	$ 16.12	-	$ 129	$ 32,503
Equipment Operator (On-site)	1	8	$ 16.12	-	$ 129	$ 32,503
Drivers/Operators for Refuse Collection Trucks	**29**	8	$ 9.50	-	$ 2,204	$ 555,408
Laborers	**5**	8	$ 10.29	-	$ 412	$ 103,708
Environmental Specialist	1	**4**	$ 21.10	-	$ 84	$ 21,269
Equipment						
Dozer Operation	1	**8**	-	$ 66.77	$ 534	$ 134,608
Refuse Trucks Operation	**29**	6	-	$ 25.55	$ 4,445	$ 1,120,185
TOTALS					$ 8,137	$ 2,050,584
Collection Drivers and Trucks Only						$ 1,675,593

ALTERNATIVE 1-1 - LINE INACTIVE AREA OF LANDFILL

	ITEMS OF WORK	QUANTITIES		LABOR COST		TOTAL COST	
	REVISED	NO OF UNITS	UN-IT	UNIT COST	COST	UNIT COST	COST
001	**Landfill Control Building**						
	Landfill Control Building	600	SF	725	435,000	725	435,000
	SUBTOTAL						435,000
	TAX					4%	17,400
	TOTAL						452,400
002	**Truck Scale Facility**						
	Truck Scale Structure	780	CF	25	19,500	25	19,500
	Truck Scale	1	EA	70,000	70,000	70,000	70,000
	SUBTOTAL						89,500
	TAX					4%	3,580
	TOTAL						93,080
003	**Closure Cap**						
	Closure Cap (60 Acres)	1	LS	7,307,073	7,307,073	7,307,073	7,307,073
	SUBTOTAL						7,307,073
	TAX					4%	292,283
	TOTAL						7,599,356
004	**Landfill Gas Control System**						
	LFG Control System (60 Acres)	1	LS	1,721,739	1,721,739	1,721,739	1,721,739
	SUBTOTAL						1,721,739
	TAX					4%	68,870
	TOTAL						1,790,609
005	**Leachate Treatment System**						
	Leachate Treatment System (14.4 Acres)	1	LS	719,924	719,924	719,924	719,924
	Mechanical for Leachate Treatment System (14.4 Acres)	1	LS	15,566	15,566	15,566	15,566
	Electrical for Leachate Pumps (14.4 Acres)	1	LS	31,132	31,132	31,132	31,132
	SUBTOTAL						766,622
	TAX					4%	30,665
	TOTAL						797,287
006	**Site Work**						
	Chain Link Fence	1100	LF	64	70,683	64	70,683
	Gate	1	EA	3,753	3,753	3,753	3,753
	SUBTOTAL						74,436
	TAX					4%	2,977
	TOTAL						77,414
007	**Liner and Leachate Collection System**						
	Liner and Leachate Collection System (14.4 Acres)	1	LS	9,339,554	9,339,554	9,339,554	9,339,554
	SUBTOTAL						9,339,554
	TAX					4%	373,582
	TOTAL						9,713,136

COST MODEL SUMMARY SHEET

PROJECT TITLE				CONTRACT NO.
ACTIVITY Apra Harbor Naval Complex		LOCATION Guam		AMENDMENT NO.
PREPARED BY (Name)	TITLE OR ORGANIZATION HDR|Hawaii Pacific Engineers, Inc.		DATE	TYPE OF ESTIMATE
ACF	FY	FER	CATEGORY CODE	COST ESCALATED TO

	$/SYS	SYS QUAN (UM)	TOTAL	BUILDING	BUILT-IN EQUIPMENT
ALTERNATIVE 1-1 - LINE INACTIVE AREA OF LANDFILL					
PRIMARY FACILITIES					
001 Landfill Control Building	$ 452,400	1	$ 452,400.0		
002 Truck Scale Facility	$ 93,080	1	$ 93,080.0		
003 Closure Cap	$ 7,599,356	1	$ 7,599,355.9		
004 LFG Control System (60 Acres)	$ 1,790,609	1	$ 1,790,609		
005 Leachate Treatment System	$ 797,287	1	$ 797,286.9		
006 Site Work	$ 77,414	1	$ 77,413.6		
007 Liner and Leachate Collection System	$ 9,713,136	1	$ 9,713,136.2		
			$ 20,523,281.2		

ALTERNATIVE 1-2 - LINE EXIST AND INACTIVE AREA OF LANDFILL							
ITEMS OF WORK	QUANTITIES		LABOR COST		TOTAL COST		
REVISED	NO OF UNITS	UN-IT	UNIT COST	COST	UNIT COST	COST	
001 Landfill Control Building							
Landfill Control Building	600	SF	725	435,000	725	435,000	
SUBTOTAL						435,000	
TAX					4%	17,400	
TOTAL						452,400	
002 Truck Scale Facility							
Truck Scale Structure	780	CF	25	19,500	25	19,500	
Truck Scale	1	EA	70,000	70,000	70,000	70,000	
SUBTOTAL						89,500	
TAX					4%	3,580	
TOTAL						93,080	
003 Closure Cap							
Closure Cap (60 Acres)	1	LS	7,307,073	7,307,073	7,307,073	7,307,073	
SUBTOTAL						7,307,073	
TAX					4%	292,283	
TOTAL						7,599,356	
004 Landfill Control System							
LFG Control System (60 Acres)	1	LS	1,721,739	1,721,739	1,721,739	1,721,739	
SUBTOTAL						1,721,739	
TAX					4%	68,870	
TOTAL						1,790,609	
005 Leachate Treatment System							
Leachate Treatment System (60 Acres)	1	LS	1,520,784	1,520,784	1,520,784	1,520,784	
Mechanical for Leachate Treatment System (60 Acres)	1	LS	32,882	32,882	32,882	32,882	
Electrical for Leachate Pumps (60 Acres)	1	LS	65,764	65,764	65,764	65,764	
SUBTOTAL						1,619,430	
TAX					4%	64,777	
TOTAL						1,684,207	
006 Site Work							
Chain Link Fence	1100	LF	64	70,683	64	70,683	
Gate	1	EA	3,753	3,753	3,753	3,753	
SUBTOTAL						74,436	
TAX					4%	2,977	
TOTAL						77,414	
006 Liner and Leachate Collection System							
Liner and Leachate Collection System (60 Acres)	1	LS	19,729,096	19,729,096	19,729,096	19,729,096	
SUBTOTAL						19,729,096	
TAX					4%	789,164	
TOTAL						20,518,260	

COST MODEL SUMMARY SHEET

PROJECT TITLE				CONTRACT NO. N62742-06-D-1881
ACTIVITY Apra Harbor Naval Complex		LOCATION Guam		AMENDMENT NO.
PREPARED BY (Name)	TITLE OR ORGANIZATION HDR|Hawaii Pacific Engineers, Inc.		DATE	TYPE OF ESTIMATE
ACF	FY	FER	CATEGORY CODE	COST ESCALATED TO

	$/SYS	SYS QUAN (UM)	TOTAL	BUILDING	BUILT-IN EQUIPMENT
ALTERNATIVE 1-2 - LINE EXIST AND INACTIVE AREA OF LANDFILL					
PRIMARY FACILITIES					
001 Landfill Control Building	$ 452,400	1	$ 452,400		
002 Truck Scale Facility	$ 93,080	1	$ 93,080		
003 Closure Cap	$ 7,599,356	1	$ 7,599,356		
004 Landfill Control System	$ 1,790,609	1	$ 1,790,609		
005 Leachate Treatment System	$ 1,684,207	1	$ 1,684,207		
006 Site Work	$ 77,414	1	$ 77,414		
007 Liner and Leachate Collection System	$20,518,260	1	$ 20,518,260		
			$ 32,215,325		

ALTERNATIVE 2 - USE GOVGUAM LANDFILL CLOSE EXISTING LANDFILL								
	ITEMS OF WORK	QUANTITIES		COST		TOTAL COST	
	REVISED	NO OF UNITS	UN-IT	UNIT COST	COST	UNIT COST	COST
001	**Closure Cap**						
	Closure Cap (60 Acres)	1	LS	7,307,073	7,307,073	7,307,073	7,307,073
	SUBTOTAL						7,307,073
	TAX					4%	292,283
	TOTAL						7,599,356
002	**Landfill Gas Venting System**						
	LFG Venting System (60 Acres)	1	LS	1,721,739	1,721,739	1,721,739	1,721,739
	SUBTOTAL						1,721,739
	TAX					4%	68,870
	TOTAL						1,790,609

COST MODEL SUMMARY SHEET

PROJECT TITLE				CONTRACT NO. N62742-06-D-1881
ACTIVITY Apra Harbor Naval Complex		LOCATION Guam		AMENDMENT NO.
PREPARED BY (Name)	TITLE OR ORGANIZATION HDR|Hawaii Pacific Engineers, Inc.		DATE	TYPE OF ESTIMATE
ACF	FY	FER	CATEGORY CODE	COST ESCALATED TO

	$/SYS	SYS QUAN (UM)	TOTAL	BUILDING	BUILT-IN EQUIPMENT
ALTERNATIVE 2 - USE GOVGUAM LANDFILL CLOSE EXISTING LANDFILL					
PRIMARY FACILITIES					
001 Closure Cap	7,599,356	1	7,599,356		
002 Landfill Gas Venting System	1,790,609	1	1,790,609		
			9,389,964		

ALTERNATIVE 3 - NEW LANDFILL							
ITEMS OF WORK	QUANTITIES		LABOR COST		TOTAL COST		
REVISED	NO OF UNITS	UN-IT	UNIT COST	COST	UNIT COST	COST	
001 Landfill Control Building						
Landfill Control Building	600	SF			1,102	661,000
SUBTOTAL						661,000
TAX					4%	26,440
TOTAL						687,440
002 Truck Scale Facility						
Truck Scale Structure	780	CF			37	29,000
Truck Scale	1	EA			106,000	106,000
SUBTOTAL						135,000
TAX					4%	5,400
TOTAL						140,400
003 Leachate Treatment System						
Leachate Treatment System (60 Acres)	1	LS			2,103,000	2,103,000
Mechanical for Leachate Treatment System (60 Acres)	1	LS			45,000	45,000
Electrical for Leachate Pumps (60 Acres)	1	LS			91,000	91,000
SUBTOTAL						2,239,000
TAX					4%	89,560
TOTAL						2,328,560
004 Site Work						
Clearing and Grubbing	1	LS			101,000	101,000
Chain Link Fence	6000	LF			97	583,000
Gate	1	EA			6,000	6,000
Earthwork	1200000	CY			10	12,000,000
Gunite Lining, fiber reinforced, 4-in thick	2000000	SF			23	46,000,000
Potable Water	1	LS			21,000	21,000
Septic Tank and Subsurface Disposal	1	LS			168,000	168,000
Groundwater Monitoring Wells	1	LS			1,885,000	1,885,000
Electrical	1	LS			402,000	402,000
Mechanical	1	LS			749,000	749,000
SUBTOTAL						61,915,000
TAX					4%	2,476,600
TOTAL						64,391,600
005 Liner and Leachate Collection System						
Liner and Leachate Collection System (60 Acres)	1	LS			27,288,000	27,288,000
SUBTOTAL						27,288,000
TAX					4%	1,091,520
TOTAL						28,379,520

COST MODEL SUMMARY SHEET

PROJECT TITLE			CONTRACT NO. N62742-06-D-1881
ACTIVITY Apra Harbor Naval Complex	LOCATION Guam		AMENDMENT NO.
PREPARED BY (Name)	TITLE OR ORGANIZATION HDR|Hawaii Pacific Engineers, Inc.	DATE	TYPE OF ESTIMATE
ACF / FY	FER	CATEGORY CODE	COST ESCALATED TO

	$/SYS	SYS QUAN (UM)	TOTAL	BUILDING	BUILT-IN EQUIPMENT
ALTERNATIVE 3 - NEW LANDFILL					
PRIMARY FACILITIES					
001 Landfill Control Building	$ 687,440	1	$ 687,440		
002 Truck Scale Facility	$ 140,400	1	$ 140,400		
003 Leachate Treatment System	$ 2,328,560	1	$ 2,328,560		
004 Site Work	$ 64,391,600	1	$ 64,391,600		
005 Liner and Leachate Collection System	$ 28,379,520	1	$ 28,379,520		
			$ 95,927,520		

Project:	**Guam Modular WTE Feasibility Study**
Technology:	**Modular Mass Burn Facility 120 tpd-7 days per week**
Date:	**02/12/08**
Estimate Basis:	**Conceptual Layout (Average 120tpd)**
Costs:	**2008$**
Location:	**Guam**

ALTERNATIVE 4a

COST SUMMARY[(1)]

MODULAR MASS BURN FACILITY

Conceptual Layout (Average 120tpd)

TOTAL CAPITAL COST	$41,390,000	to	$50,588,000
ANNUAL OPERATION & MAINTENANCE COST	$6,445,154	to	$7,090,000
ANNUAL COST	$10,661,154	to	$12,242,000
YEAR 2008 ANNUAL TONNAGE	37,230	Short tons	
COST PER TON (Before Energy Revenues)	$286	to	$329

Notes
(1) All costs are presented in 2008 Dollars

Project:	**Guam Modular WTE Feasibility Study**	
Technology:	**Modular Mass Burn Facility**	**120 tpd-7 days per week**
Date:	**02/12/08**	
Estimate Basis:	**Conceptual Layout (Average 120tpd)**	
Costs:	**2008$**	
Location:	**Guam**	

ALTERNATIVE 4a
MODULAR MASS BURN FACILITY
CAPITAL COST SUMMARY [(1)]
Conceptual Layout (Average 120tpd)

			Estimated Costs[(2)]
I.	SITE AQUISITION		$ -
II.	SITE DEVELOPMENT		$ 2,739,400
III.	SCALE HOUSE AND SCALES		$ 247,101
IV.	BUILDINGS		$ 6,456,100
V.	PROCESSING EQUIPMENT		$ -
VI.	MOBILE EQUIPMENT		$ 699,900
VII.	POWER BLOCK EQUIPMENT		$ 19,916,224
	SUBTOTAL CONSTRUCTION AND EQUIPMENT		$ 30,058,726
	CONTINGENCY	25%	$ 7,514,700
	SALES TAX	4%	$ 1,502,900
	DESIGN/ENGINEERING	8%	$ 3,005,900
	PERMITTING		$ 450,000
	SURVEYING AND SOILS REPORT		$ 75,000
	CONSTRUCTION INSPECTION	5%	$ 1,878,700
	START UP AND TESTING	4%	$ 1,502,900
	TOTAL CAPITAL COST (FACILITY IMPLEMENTATION)		$ 45,988,826

Project:	**Guam Modular WTE Feasibility Study**	
Technology:	**Modular Mass Burn Facility**	**120 tpd-7 days per week**
Date:	**02/12/08**	
Estimate Basis:	**Conceptual Layout (Average 120tpd)**	
Costs:	**2008$**	
Location:	**Guam**	

NOTES:
(1) All costs rounded to 1000's
(2) All costs in 2008 $.

I. SITE AQUISITION

Subtotal I	$0

II. SITE DEVELOPMENT

Item	Quantity	Units	Unit Price	Item Cost		Total
Site Preparation					$	367,400
Excavation - foundations(1)	9,400	cy	$17	$159,300		
General Earthwork (2)	15,100	cy	$14	$204,700		
Finishing Grassing & Grading	1	acres	$3,390	$3,400		
Demolition	0	cy material	$339	$0		
Site Improvements					$	1,312,700
Approach /Roadways Concrete (3)	4,000	sy	$102	$406,800		
Asphalt Roadways & Parking	5,000	sy	$68	$339,000		
Retaining Walls	400	cy	$847	$339,000		
Site Drainage	1	L.S.	$127,110	$127,100		
Fencing(4)	2,000	lf	$25	$50,800		
Landscaping (Minimal)	1	L.S.	$50,000	$50,000		
Site Utilities (5)					$	1,059,300
Fire Protection	2,000	lf	$42	$84,700		
Water Supply	1,500	lf	$42	$63,600		
Well Field	0	LS	$50,000	$0		
Sewer System	1,500	lf	$42	$63,600		
Electrical Substation	1	L.S.	$847,399	$847,400		
Subtotal II					$	2,739,400

Notes:
(1) Based on estimated building square footages. Demolition calculated separately below
(2) General Earthwork includes moving soil, backfill, embankment, loadout tunnel excav, etc.
(3) Roadway unit price includes curbs, gutters, etc.
(4) Assumes perimeter fencing at 6' (w/ barbed wire) with gates and litter fencing around maneuvering area of 15' height.
(5) Utilities unit price includes excavation, bedding material, piping installed, backfill, etc.

III. SCALE HOUSE AND SCALES

Item	**Quantity**	**Units**	**Unit Price**	**Item Cost**	**Total**
Metal Building (1)	400	sf	$153	$61,013	
Concrete Slabwork(2)	15	cy	$339	$5,084	
Concrete Footings	10	cy	$678	$6,779	
Interior Treatments(3)	400	sf	$85	$33,896	
Motor Truck Scales & Foundations	2	LS	$93,214	$186,428	
Mechanical(4)	400	sf	$17	$6,779	
Electrical(5)	400	sf	$20	$8,135	
Subtotal III					$247,101

Notes:
(1) No additional facilities for waste delivery truck drivers or admintration activities areas, are included.
(2) Assumes stable soil with good load bearing capacity. Slab floor is 6" reinforced concrete.
(3) Includes tile, painting, window covers and funiture
(4) Building mechanical includes drains, plumbing, air handling, fire protection, etc.
(5) Electrical includes lighting, power, communications, etc.

Project:	**Guam Modular WTE Feasibility Study**	
Technology:	**Modular Mass Burn Facility**	**120 tpd-7 days per week**
Date:	**02/12/08**	
Estimate Basis:	**Conceptual Layout (Average 120tpd)**	
Costs:	**2008$**	
Location:	**Guam**	

IV. BUILDINGS

Item	Quantity	Units	Unit Price	Item Cost	Total
Metal Buildings - Preengineered (1) (2)	13,000	sf	$ 153	$1,982,900	
Ash Concrete Push Walls(3)	100	cy	$ 678	$67,800	
Metal Buildings - Engineered	672,000	cf	$ 6	$3,986,200	
Concrete Pit (3)	0	cy	$ 400	$0	
Overhead Doors	4	ea	$ 16,948	$67,800	
Admin. Area	1,728	sf	$ 203	$351,400	
Subtotal IV					$6,456,100

Notes:

(1) Metal bldg. includes structural steel, column free bldg. (long span), 30 ft. clear height, & 20 yr roofing warranty with mechanical and electrical.

(2) Assumes stable soil with good load bearing capacity. Slab floor is 10" reinforced concrete on grade; 12" on structural slabs

(3) 4 ft thick wall with 10 ft thick mat

V. PROCESSING EQUIPMENT

Item	Quantity	Type	Units	Unit Price	Item Cost	Total
Overhead Cranes NOT USED		Hydraulic Grapple	0	$ 259,560	$ -	
Subtotal V						$0

Notes:

VI. MOBILE EQUIPMENT

Item	Quantity	Units	Unit Price	Item Cost	Total
Ash Trucks and Trailers	1	ea	$211,850	$211,800	
Loader	1	ea	$254,220	$254,200	
Back up Loader	1	ea	$200,000	$200,000	
Pick-up/Utility Truck	1	ea	$33,896	$33,900	
Subtotal VI					$699,900

Notes:

(1) Loader used for fuel handling

Project:	**Guam Modular WTE Feasibility Study**	
Technology:	**Modular Mass Burn Facility**	**120 tpd-7 days per week**
Date:	**02/12/08**	
Estimate Basis:	**Conceptual Layout (Average 120tpd)**	
Costs:	**2008$**	
Location:	**Guam**	

VII. POWER BLOCK EQUIPMENT

Item	Quantity	Unit	Unit Price	Item Cost	Total
Modular Mass Burn Incinerator (1)	3	ls	$956,712	$2,870,100	
Heat Recovery Boiler(1)	3	ls	$260,073	$780,200	
SNCR (NOx Control)	0	ls	$89,598	$0	
Air Pollution Control Equipment(1)	3	ls	$673,425	$2,020,300	
Continuous Emissions Monitoring	3	ls	$288,541	$865,624	
Bottom Ash Quench(1)	3	ls	$54,048	$162,100	
Bottom Ash Conveying	1	ls	$400,000	$400,000	
Flyash Handling/Conditioning	3	ls	$299,799	$899,400	
Aux Cooling Water System	1	ls	$46,448	$46,400	
Condensate System	1	ls	$160,456	$160,500	
Chem Feed	1	ls	$87,265	$87,300	
Circulating Water System	1	ls	$137,232	$137,200	
Waste Water System	1	ls	$161,863	$161,900	
Water Treatment	1	ls	$157,641	$157,600	
Fire Protection	1	ls	$135,825	$135,800	
Feedwater System(1)	1	ls	$125,370	$125,400	
Compressed Air System	1	ls	$34,484	$34,500	
Service Water System	1	ls	$33,076	$33,100	
Steam Piping	1	ls	$46,448	$46,400	
Steam Turbine (2)	1	ls	$557,200	$557,200	
Electrical System	1	ls	$2,060,591	$2,060,600	
Equipment Subtotal					$11,741,624
Boiler Erection (Labor)	1	ls	$2,835,300	$2,835,300	
Steam Turbine Installation(2)	1	ls	$390,040	$390,000	
Mechanical Systems Installation (Labor)	1	ls	$2,375,906	$2,375,900	
Electrical Installation (Labor)	1	ls	$1,556,783	$1,556,800	
Ocean Freight	3	ls	$200,000	$600,000	
Installation Subtotal					$7,758,000
Shop Tools & Equip.	1	Allowance	$122,531	$122,500	
Control Room Furnishings	1	Allowance	$49,012	$49,000	
Spare Parts	1	Allowance	$245,061	$245,100	
Miscellaneous Items					$416,600
Subtotal VII					**$19,916,224**

Notes:

(1) Based on equipment quote from Pennram

(2) Based on equipment qoute and installation estimate from Turbosteam

Subtotal I through VII	**$30,058,726**

Project:	**Guam Modular WTE Feasibility Study**	
Technology:	**Modular Mass Burn Facility**	**120 tpd-7 days per week**
Date:	**02/12/08**	
Estimate Basis:	**Conceptual Layout (Average 120tpd)**	
Costs:	**2008$**	
Location:	**Guam**	

ALTERNATIVE 4a
MODULAR MASS BURN FACILITY
OPERATIONS AND MAINTENANCE COST SUMMARY [1]
Conceptual Layout (Average 120tpd)

				Estimated Costs[2]
I.	LABOR		$	1,778,000
II.	FACILITY MAINTENANCE		$	844,000
III.	UTILITIES		$	932,928
IV.	PROCESS RESIDUE HAUL & DISPOSAL		$	419,226
V.	ROLLING STOCK O&M COSTS		$	126,900
VI.	MISCELLANEOUS COSTS		$	91,100
	SUBTOTAL OPERATION & MAINTENANCE		$	4,192,154
	CONTINGENCY	25%	$	1,048,000
	OVERHEAD AND PROFIT	15%	$	786,000
	ACCOUNTING, SUPPLIES, MISC.	5%	$	262,000
	ADMINISTRATION	3%	$	157,000
TOTAL ANNUAL OPERATION & MAINTENANCE COST			$	6,445,154
VII.	MINUS	SALES REVENUES[3]	$	489,194
NET ANNUAL OPERATION & MAINTENANCE COST			$	5,955,960

NOTES:
(1) All costs rounded to 1000
(2) All costs in 2008$
(3) Doesn't include ferrous revenues

Project:	**Guam Modular WTE Feasibility Study**	
Technology:	**Modular Mass Burn Facility**	**120 tpd-7 days per week**
Date:	**02/12/08**	
Estimate Basis:	**Conceptual Layout (Average 120tpd)**	
Costs:	**2008$**	
Location:	**Guam**	

I. LABOR

Job Classification	Personnel(1)	$/hr(2)	hrs/yr (3)	Over-time Hrs	Annual Cost	% OT	Total
Facility Manager	1	$54	2,080	0	$112,000	0%	
Operating Engineer	1	$47	2,080	0	$98,000	0%	
Administrative/Clerical	1	$20	2,080	208	$48,000	10%	
Scale Attendant	2	$24	2,080	208	$116,000	10%	
Lead Equipment Operator	4	$41	2,080	312	$413,000	15%	
Equipment Operators	8	$30	2,080	312	$605,000	15%	
Mechanic	1	$34	2,080	208	$81,000	10%	
Electrician/Electronics Specialis	1	$34	2,080	208	$81,000	10%	
Welders	1	$34	2,080	208	$81,000	10%	
Helper	0	$20	2,080	208	$0	10%	
Residue Disposal Drivers	1	$27	2,080	208	$65,000	10%	
Spotters/Laborers	2	$16	2,080	208	$78,000	10%	
Subtotal	23						$1,778,000

Notes:

(1) Based on a 24-hour, seven day per week operation.

(2) Includes fringe benefits (retirement, ss, workers comp, health & life insurance, vacation/sick leave) at 35%
and overtime rate is at 1.5 times straight time

(3) Assumes standard working shift hours 5 Days/Wk 8 Hr/Day

II. FACILITY MAINTENANCE

Item	% of Capital Value	Quantity	Unit	Unit Price	Annual Cost	Total
Site Maintenance(1)	1.5%	1	Lump	$ 35,580	$35,580	
Building Repair & Replacement	3.3%	1	Lump	$ 221,000	$221,000	
Equipment Maintenance (3)	2.0%	1	Lump	$ 234,832	$234,832	
Equipment Replacement (4)	3.0%	1	Lump	$ 352,249	$352,249	
Subtotal						$ 844,000

Notes:

(1) Percentage of capital value is based on empirical data from operating plants in the U.S.

(2) Site maintenance is estimated as % capital construction cost for site improvements and site utilities.

(3) Buidling repair base on a 30 year depreciation of the original capital cost with escalation.

(4) Equipment maintenance (annual needs) and replacement (periodic needs) estimated based on assumed 20 life.

Project:	Guam Modular WTE Feasibility Study		
Technology:	Modular Mass Burn Facility	120	tpd-7 days per week
Date:	02/12/08		
Estimate Basis:	Conceptual Layout (Average 120tpd)		
Costs:	2008$		
Location:	Guam		

III. UTILITIES

Item	Quantity	Unit	Unit Price	Annual Cost	Total
Electricity Purchase (1)	127	MWh/yr	$ 200	$ 25,316	
Propane(2)	308	Gal/Yr	$ 3.39	$ 1,043	
Diesel (3)	206,361	Gal/Yr	$ 3.75	$ 773,852	
Telephone (Mobile/Fixed) (4)	20	Phones	$ 480	$ 9,600	
Water	32,830,965	Gal/Yr	$ 0.003	$ 98,493	
Sewer (5)	8,207,741	Gal/Yr	$ 0.003	$ 24,623	
Subtotal					$ 932,928

Notes:

(1) Electricity purchase accounts for energy use during downtimes only; inhouse power provided by the system otherwise.

(2) Propane used for burner ignition 2008 price ratioed according with diesel prices plus 10%

(3) Diesel used for start-up and shutdown and to maintain "good combustion control" in secondary chamber

(4) Based on mobile phones for entire staff except drivers, helpers and laborers.

(5) Sewer use based on 25% of water use; evaporation and ash quench account for rest.

IV. PROCESS RESIDUE HAUL & DISPOSAL

Item	Cost /Load(1)	Quantity	Unit	Unit Price	Annual Cost	Total
Process Residue Haul	$ 75	503	Tons	$ 3.75	$ 1,886	
Ash Haul	$ 75	14,079	Tons	$ 3.75	$ 52,796	
Landfill Disposal Fees		14,582	Tons	$ 25.00	$ 364,545	
Subtotal						$ 419,226

Notes:

(1) Cost assumes truck operating costs per 20-ton load

V. ROLLING STOCK O&M COSTS

Fuel	Weeks	Unit Rate	Units	Unit Price	Annual Cost	Total
Loader	52	200	gal/wk	$ 3.75	$39,000	
Back up Loader	52	100	gal/wk	$ 3.75	$19,500	
Pick-up Truck	52	30	gal/wk	$ 3.75	$5,900	
Maintenance	**# Vehicles**	**Quantity**	**Units**	**Unit Price**	**Annual Cost**	**Total**
Loader	1	1	L.S.	$13,982	$14,000	
Pick-up Truck	1	12,000	Miles/Yr	$0.50	$6,000	
General O&M		1	L.S.	$42,500	$42,500	
Subtotal						$126,900

Notes:

(1) Based on Owning and Operationg Cost Methodology in the Catepillar Performance Handbook.

Project:	**Guam Modular WTE Feasibility Study**	
Technology:	**Modular Mass Burn Facility**	**120 tpd-7 days per week**
Date:	**02/12/08**	
Estimate Basis:	**Conceptual Layout (Average 120tpd)**	
Costs:	**2008$**	
Location:	**Guam**	

VI. MISCELLANEOUS COSTS

Item	Useage (1)	Quantity	Unit	Unit Price	Annual Cost	Total
Property Insurance (2)	1	0.3%			$88,100	
Flood Insurance (2)	0	1.2%			$0	
Property Taxes (3)	1	3,252	m2	$0.78	$3,000	
Subtotal						$ 91,100

Notes:

(1) Multiplier used to adjust costs for various potential sites. Zero means expense not appicalbe to this site.

(2) Based on % of capital construction costs.

(3) Based on area of developed property.

Subtotal I through VI	$4,192,154

VII. SALES REVENUES(3)

Material	Units	Unit	Unit Value	Annual Revenues	Total
Net Electric Generation	4,447	MWh	$110	$489,194	Addressed in Pro Forma
Net Steam Generation	176,843	Mlbs.	$0	$0	Addressed in Pro Forma
Aluminum	-	Tons	$800	$0	No recovery provided
Ferrous Metals	-	Tons	$25	$0	
Subtotal VII					$489,194

Water Usage Estimates — 120 TPD

		Conversion factor =	3.785412
Domestic	**Assumptions**	**Gallons/Yr**	**Liters/Year**
Average People/Day	5.48		
gpd/person	25		
gallons per day	137		
days/week	7		
weeks/year	52		
gallons per year		49,833	188,640
Blowdown/Spray Dryer	4%	947,482	
Spray Dryer(Lb/hr Water/tpd Fuel)	212.00	2,950,564	
Ash Quench(15% moisture)	5.80	423,529	
Cooling Tower (blowdown 20% evap.)		28,424,448	
Washdown		35,100	132,868
Total Water Usage		32,830,957	124,278,698
Evaporation/Ash Quench	75%	24,623,218	93,209,023
Total Sewer Usage		8,207,739	31,069,674

Reagent Usage Estimates

	Qty/Ton
Lime (Lbs/Ton)	20
Ammonia (lbs/Ton)	NA
Carbon (Lbs/Ton)	0.66

Energy Generation Assumptions

	Gross Generation Amount/Ton	**In-House Power Amount/Ton**	**Net Generation Amount/Ton**		**Net Annual Generation**	
Steam Production (mlb)	5.41	0.66	4.75	=	176,843	Mlbs.
Electricity Production (kWh)	136	16.55	119	=	4,447	MWh
Single stage condensing turbine	0.68	MW at	27,040	lbs/hr	0%	Margin

Energy Consumption Assumptions

Item	**mmBtu/Ton**	**Btu/Gal**	**MMBTU**	**Gal/yr**
Propane (mmBtu)	0.000757	91600	28	308
Diesel (mmBtu)	0.776	140000	28,890	206,361

Item	**Qty/Ton**	**hp**	**load factor**	**kw**	**hrs/year**	**kwh/yr**
Power Purchase Req. (kWh/Ton)	3.4					126,582
Total Purchase						126,582

MSW Quanitites and Characteristics

Waste Quantity	40,000	tpy		
Daily Delivery	110	tpd - 7 days per weeks		
Capacity Factor	85%			
Delivery Capacity	129	tpd - 5 days per week		
Annual Throughput	37,230	tpy		
MSW HHV (B&W)	5,200	Btu/lb		
Boiler Efficiency (B&W)	65%			
Fuel Feed Rate (B&W)	10,000	Lbs/Hr at	120	tons/day
Gross Steam Production (B&W)	27,040	Lb/Hr	5408	lbs(steam)/ton

MSW Storage Calculations

Floor Storage Days	3	Days		
Floor Storage Tons	387	tons		
MSW Density	17	lb/cf		
MSW Volume Capacity	46,414	cu. ft.		
Pit Area - NOT USED	900	SF	35	ft deep plus 50% of vol. up to charging level
Pit length - NOT USED	26	ft at	35	feet wide

Residue Disposal

Assumes 5% unburned and combined fly ash and bottom ash with scrubber residue.

Residue Disposal	1.5%	2 tpd5	0.1	Truckloads/Day5
Ash Disposal	30%	38.7 tpd7	2	Truckloads/Day7
Truck Payload (Tons)	20		2.0	Truckloads/Day
		28 HRS/week	4	HRs/day
			2	Round Trip Haul

Basic Conceptual Layout Dimensions

		Length	Span	Area	Height	Number of Stories	Size Adjustment
Conversion Factor	**M to Ft**	**3.28084**	**3.28084**	**10.76391111**	**3.28084**		
Exterior Maneuvering	Feet	150.0	60.0	9,000			
	Meters	45.7	18.3	836			
MSW Tipping Floor	Feet	75.0	150.0	11,250	40.0	1.0	
	Meters	22.9	45.7	1,045	12.2		
Boiler Bldg	Feet	35.0	150.0	5,250	115.0	1.0	
	Meters	10.7	45.7	488	35.1		
Turbine Building	Feet	50.0	45.0	4,500	15.0	2.0	
	Meters	15.2	13.7	209	4.6		
Maintenance/Storage	Feet	48.0	36.0	1,728	16.4	1.0	0.8
	Meters	14.6	11.0	161	5		
Admin/ Control Room	Feet	48.0	36.0	1,728	16.4	1.0	0.8
	Meters	14.6	11.0	161	5		
Refuse Storage Bldg (Pit)	Feet		35.0	-	115.0	1.0	
	Meters	0.0	10.7	-	31		
Ash Storage Bldg	Feet	35.0	30.0	1,050	30.0	1.0	0.75
	Meters	10.7	9.1	98	9.1		
Site Development	Feet	350.0	100.0	35,000			
	Meters	106.7	30.5	3,252			
		Total Bldg Floor Area		14,256			

Modular Mass Burn Facility

Capital Cost	$	45,989,000	
Life Extension Measures	$	32,315,424	Capital cost less site work, scalehouse and scales, buildings, mobile equipment, engineering, permitting, survey
Operating Cost	$	6,445,000	
Energy Revenue	$	489,000	

2008 Dollars

Capital Cost Breakdown			
Year 0	$	2,629,000	Permitting, survey, and 70% engineering work
Year 1	$	17,284,000	40% of total less start up, permitting, survey, 70% of engineering
Year 2	$	26,076,000	60% of total plus startup less permitting, survey and engineering
Total	$	45,989,000	

Life Extension			
Year 15	$	8,079,000	25%
Year 20	$	16,158,000	50%
Year 25	$	8,079,000	25%

Project:	**Guam Field Erected WTE Feasibility Study**	
Technology:	**Mass Burn Facility**	**150 tpd-7 days per week**
Date:	**04/09/08**	
Estimate Basis:	**Conceptual Layout (Average 150tpd)**	
Costs:	**2008$**	
Location:	**Guam**	

ALTERNATIVE 4b
COST SUMMARY(1)
MASS BURN FACILITY
Conceptual Layout (Average 150tpd)

TOTAL CAPITAL COST	$88,401,000	to	$108,046,000
ANNUAL OPERATION & MAINTENANCE COST	$6,795,174	to	$7,475,000
ANNUAL COST	$15,799,174	to	$18,480,000
YEAR 2003 ANNUAL TONNAGE	37,230	Short tons	
COST PER TON (Before Energy Revenues)	$424	to	$496

Notes
(1) All costs are presented in 2008 Dollars

Project:	**Guam Field Erected WTE Feasibility Study**	
Technology:	**Mass Burn Facility**	**150 tpd-7 days per week**
Date:	**04/09/08**	
Estimate Basis:	**Conceptual Layout (Average 150tpd)**	
Costs:	**2008$**	
Location:	**Guam**	

ALTERNATIVE 4b
MASS BURN FACILITY
CAPITAL COST SUMMARY [1]
Conceptual Layout (Average 150tpd)

			Estimated Costs[2]
I.	SITE AQUISITION		$ -
II.	SITE DEVELOPMENT		$ 2,491,900.00
III.	SCALE HOUSE AND SCALES		$ 247,101
IV.	BUILDINGS		$ 6,320,500
V.	PROCESSING EQUIPMENT		$ 879,803
VI.	MOBILE EQUIPMENT		$ 499,900
VII.	POWER BLOCK EQUIPMENT		$ 54,155,041
	SUBTOTAL CONSTRUCTION AND EQUIPMENT		$ 64,594,246
	CONTINGENCY	25%	$ 16,148,600
	SALES TAX	4%	$ 3,229,700
	DESIGN/ENGINEERING	8%	$ 6,459,400
	PERMITTING		$ 450,000
	SURVEYING AND SOILS REPORT		$ 75,000
	CONSTRUCTION INSPECTION	5%	$ 4,037,100
	START UP AND TESTING	4%	$ 3,229,700
	TOTAL CAPITAL COST (FACILITY IMPLEMENTATION)		$ 98,223,746

NOTES:

(1) All costs rounded to 1000's

(2) All costs in 2008 $.

Project:	**Guam Field Erected WTE Feasibility Study**		
Technology:	**Mass Burn Facility**	**150**	**tpd-7 days per week**
Date:	**04/09/08**		
Estimate Basis:	**Conceptual Layout (Average 150tpd)**		
Costs:	**2008$**		
Location:	**Guam**		

I. SITE AQUISITION

Subtotal I	$0

II. SITE DEVELOPMENT

Item	Quantity	Units	Unit Price	Item Cost		Total
Site Preparation					$	194,600
Excavation - foundations(1)	7,600	cy	$17	$128,800		
General Earthwork (2)	4,600	cy	$14	$62,400		
Finishing Grassing & Grading	1	acres	$3,390	$3,400		
Demolition	0	cy material	$339	$0		
Site Improvements					$	1,238,000
Approach /Roadways Concrete (3)	3,500	sy	$102	$355,900		
Asphalt Roadways & Parking	3,400	sy	$68	$230,500		
Retaining Walls	500	cy	$847	$423,700		
Site Drainage	1	L.S.	$127,110	$127,100		
Fencing(4)	2,000	lf	$25	$50,800		
Landscaping (Minimal)	1	L.S.	$50,000	$50,000		
Site Utilities (5)					$	1,059,300
Fire Protection	2,000	lf	$42	$84,700		
Water Supply	1,500	lf	$42	$63,600		
Well Field	0	LS	$50,000	$0		
Sewer System	1,500	lf	$42	$63,600		
Electrical Substation	1	L.S.	$847,399	$847,400		
Subtotal II					$	2,491,900

Notes:

(1) Based on estimated building square footages. Demolition calculated separately below

(2) General Earthwork includes moving soil, backfill, embankment, loadout tunnel excav, etc.

(3) Roadway unit price includes curbs, gutters, etc.

(4) Assumes perimeter fencing at 6' (w/ barbed wire) with gates and litter fencing around maneuvering area of 15' height.

(5) Utilities unit price includes excavation, bedding material, piping installed, backfill, etc.

III. SCALE HOUSE AND SCALES

Item	Quantity	Units	Unit Price	Item Cost	Total
Metal Building (1)	400	sf	$153	$61,013	
Concrete Slabwork(2)	15	cy	$339	$5,084	
Concrete Footings	10	cy	$678	$6,779	
Interior Treatments(3)	400	sf	$85	$33,896	
Motor Truck Scales & Foundations	2	LS	$93,214	$186,428	
Mechanical(4)	400	sf	$17	$6,779	
Electrical(5)	400	sf	$20	$8,135	
Subtotal III					$247,101

Notes:

(1) No additional facilities for waste delivery truck drivers or admintration activities areas, are included.

(2) Assumes stable soil with good load bearing capacity. Slab floor is 6" reinforced concrete.

(3) Includes tile, painting, window covers and funiture

(4) Building mechanical includes drains, plumbing, air handling, fire protection, etc.

(5) Electrical includes lighting, power, communications, etc.

Project:	**Guam Field Erected WTE Feasibility Study**	
Technology:	**Mass Burn Facility**	**150 tpd-7 days per week**
Date:	**04/09/08**	
Estimate Basis:	**Conceptual Layout (Average 150tpd)**	
Costs:	**2008$**	
Location:	**Guam**	

IV. BUILDINGS

Item	Quantity	Units	Unit Price	Item Cost	Total
Metal Buildings - Preengineered (1) (2)	3,000	sf	$ 153	$457,600	
Ash Concrete Push Walls(3)	100	cy	$ 678	$67,800	
Metal Buildings - Engineered	792,000	cf	$ 6	$4,698,000	
Concrete Pit (3)	1,000	cy	$ 678	$677,900	
Overhead Doors	4	ea	$ 16,948	$67,800	
Admin. Area	1,728	sf	$ 203	$351,400	
Subtotal IV					$6,320,500

Notes:

(1) Metal bldg. includes structural steel, column free bldg. (long span), 30 ft. clear height, & 20 yr roofing warranty with mechanical and electrical.

(2) Assumes stable soil with good load bearing capacity. Slab floor is 10" reinforced concrete on grade;
12" on structural slabs

(3) 4 ft thick wall with 10 ft thick mat

V. PROCESSING EQUIPMENT

Item	Quantity	Type	Units	Unit Price	Item Cost	Total
Overhead Cranes		Hydraulic Grapple	2	$ 439,902	$ 879,803	
Subtotal V						$879,803

Notes:

VI. MOBILE EQUIPMENT

Item	Quantity	Units	Unit Price	Item Cost	Total
Ash Trucks and Trailers	1	ea	$211,850	$211,800	
Loader	1	ea	$254,220	$254,200	
Pick-up/Utility Truck	1	ea	$33,896	$33,900	
Subtotal VI					$499,900

Notes:

(1) Loader used for ash loading and general maintenance activities

Project:	**Guam Field Erected WTE Feasibility Study**		
Technology:	**Mass Burn Facility**	**150**	**tpd-7 days per week**
Date:	**04/09/08**		
Estimate Basis:	**Conceptual Layout (Average 150tpd)**		
Costs:	**2008$**		
Location:	**Guam**		

VII. POWER BLOCK EQUIPMENT

Item	Quantity	Unit	Unit Price	Item Cost	Total
Mass Burn Boiler (1)	1	ls	$19,921,027	$19,921,000	
SNCR (NOx Control)	1	ls	$264,388	$264,400	
Continuous Emissions Monitoring	1	ls	$288,541	$288,541	
Bottom Ash Handling	1	ls	$377,742	$377,700	
Flyash Handling/Conditioning	1	ls	$358,392	$358,400	
Aux Cooling Water System	1	ls	$55,526	$55,500	
Condensate System	1	ls	$191,815	$191,800	
Chem Feed	1	ls	$104,321	$104,300	
Circulating Water System	1	ls	$164,053	$164,100	
Waste Water System	1	ls	$193,498	$193,500	
Water Treatment	1	ls	$188,450	$188,500	
Fire Protection	1	ls	$162,370	$162,400	
Feedwater System	1	ls	$147,227	$147,200	
Compressed Air System	1	ls	$41,224	$41,200	
Service Water System	1	ls	$39,541	$39,500	
Steam Piping	1	ls	$55,526	$55,500	
Steam Turbine	1	ls	$2,563,367	$2,563,400	
Electrical System	1	ls	$2,463,315	$2,463,300	
Equipment Subtotal					$27,580,241
Boiler Erection (Labor)	1	ls	$17,928,924	$17,928,900	
Steam Turbine Installation	1	ls	$1,794,357	$1,794,400	
Mechanical Systems Installation (Labor)	1	ls	$3,250,136	$3,250,100	
Electrical Installation (Labor)	1	ls	$1,724,320	$1,724,300	
Ocean Freight	1	ls	$1,379,012	$1,379,000	
Installation Subtotal					$24,697,700
Shop Tools & Equip.	1	Allowance	$146,478	$146,500	
Control Room Furnishings	1	Allowance	$58,591	$58,600	
Spare Parts	1	Allowance	$292,956	$293,000	
Miscellaneous Items					$498,100
Subtotal VII					**$54,155,041**

Notes:

(1) Based on equipment quote from Babcock and Wilcox

Subtotal I through VII	**$64,594,246**

Project:	**Guam Field Erected WTE Feasibility Study**	
Technology:	**Mass Burn Facility**	**150 tpd-7 days per week**
Date:	**04/09/08**	
Estimate Basis:	**Conceptual Layout (Average 150tpd)**	
Costs:	**2008$**	
Location:	**Guam**	

ALTERNATIVE 4b
MASS BURN FACILITY
OPERATIONS AND MAINTENANCE COST SUMMARY [1]
Conceptual Layout (Average 150tpd)

			Estimated Costs[2]
I. LABOR			$ 1,778,000
II. FACILITY MAINTENANCE			$ 1,674,000
III. UTILITIES			$ 295,426
IV. PROCESS RESIDUE HAUL & DISPOSAL			$ 369,048
V. ROLLING STOCK O&M COSTS			$ 107,400
VI. MISCELLANEOUS COSTS			$ 195,300
	SUBTOTAL OPERATION & MAINTENANCE		$ 4,419,174
	CONTINGENCY	25%	$ 1,105,000
	OVERHEAD AND PROFIT	15%	$ 829,000
	ACCOUNTING, SUPPLIES, MISC.	5%	$ 276,000
	ADMINISTRATION	3%	$ 166,000
TOTAL ANNUAL OPERATION & MAINTENANCE COST			$ 6,795,174
VII.	MINUS	SALES REVENUES[3]	$ 1,732,627
NET ANNUAL OPERATION & MAINTENANCE COST			$ 5,062,547

NOTES:
(1) All costs rounded to 1000
(2) All costs in 2008$
(3) Doesn't include ferrous revenues

Project:	**Guam Field Erected WTE Feasibility Study**
Technology:	**Mass Burn Facility** **150 tpd-7 days per week**
Date:	**04/09/08**
Estimate Basis:	**Conceptual Layout (Average 150tpd)**
Costs:	**2008$**
Location:	**Guam**

I. LABOR

Job Classification	Personnel(1)	$/hr(2)	hrs/yr (3)	Over-time Hrs	Annual Cost	% OT	Total
Facility Manager	1	$54	2,080	0	$112,000	0%	
Operating Engineer	1	$47	2,080	0	$98,000	0%	
Administrative/Clerical	1	$20	2,080	208	$48,000	10%	
Scale Attendant	2	$24	2,080	208	$116,000	10%	
Lead Equipment Operator	4	$41	2,080	312	$413,000	15%	
Equipment Operators	8	$30	2,080	312	$605,000	15%	
Mechanic	1	$34	2,080	208	$81,000	10%	
Electrician/Electronics Specialist	1	$34	2,080	208	$81,000	10%	
Welders	1	$34	2,080	208	$81,000	10%	
Helper	0	$20	2,080	208	$0	10%	
Residue Disposal Drivers	1	$27	2,080	208	$65,000	10%	
Spotters/Laborers	2	$16	2,080	208	$78,000	10%	
Subtotal	23						$1,778,000

Notes:

(1) Based on a 24-hour, seven day per week operation.

(2) Includes fringe benefits (retirement, ss, workers comp, health & life insurance, vacation/sick leave 35%
and overtime rate is at 1.5 times straight time

(3) Assumes standard working shift hours 5 Days/Wk 8 Hr/Day

II. FACILITY MAINTENANCE

Item	% of Capital Value	Quantity	Unit	Unit Price	Annual Cost	Total
Site Maintenance (1) (2)	1.5%	1	Lump	$ 34,460	$34,460	
Building Repair & Replacement (2)	3.3%	1	Lump	$ 217,000	$217,000	
Equipment Maintenance (3)	2.0%	1	Lump	$ 569,201	$569,201	
Equipment Replacement (4)	3.0%	1	Lump	$ 853,801	$853,801	
Subtotal						$ 1,674,000

Notes:

(1) Percentage of capital value is based on empirical data from operating plants in the U.S.

(2) Site maintenance is estimated as % capital construction cost for site improvements and site utilities.

(3) Buidling repair based on a 30 year depreciation of the original capital cost with escalation.

(4) Equipment maintenance (annual needs) and replacement (periodic needs) estimated based on assumed 20 year life.

III. UTILITIES

Item	Quantity	Unit	Unit Price	Annual Cost	Total
Electricity Purchase (1)	139	MWh/yr	$ 200.00	$ 27,796	
Diesel (2)	26,593	Gal/Yr	$ 3.75	$ 99,723	
Telephone (Mobile/Fixed) (3)	20	Phones	$ 480	$ 9,600	
Water	42,215,078	Gal/Yr	$ 0.003	$ 126,645	
Sewer (4)	10,553,770	Gal/Yr	$ 0.003	$ 31,661	
Subtotal					$ 295,426

Notes:

(1) Electricity purchase accounts for energy use during downtimes only; inhouse power provided by the system otherwise.

(2) Diesel used for start-up and shutdown only to maintain "good combustion control"

(3) Based on mobile phones for entire staff except drivers, helpers and laborers.

(4) Sewer use based on 25% of water use; evaporation and ash quench account for rest.

Project:	**Guam Field Erected WTE Feasibility Study**		
Technology:	**Mass Burn Facility**	**150**	**tpd-7 days per week**
Date:	**04/09/08**		
Estimate Basis:	**Conceptual Layout (Average 150tpd)**		
Costs:	**2008$**		
Location:	**Guam**		

IV. PROCESS RESIDUE HAUL & DISPOSAL

Item	Cost /Load(1)	Quantity	Unit	Unit Price	Annual Cost	Total
Process Residue Haul	$ 75	503	Tons	$ 3.75	$ 1,886	
Ash Haul	$ 75	13,140	Tons	$ 3.75	$ 49,276	
Landfill Disposal Fees		13,643	Tons	$ 23.30	$ 317,886	
Subtotal						$ 369,048

Notes:

(1) Cost assumes truck operating costs per 20-ton load

V. ROLLING STOCK O&M COSTS

Fuel	Weeks	Unit Rate	Units	Unit Price	Annual Cost	Total
Loader	52	200	gal/wk	$ 3.75	$39,000	
Pick-up Truck	52	30	gal/wk	$ 3.75	$5,900	
Maintenance	**# Vehicles**	**Quantity**	**Units**	**Unit Price**	**Annual Cost**	**Total**
Loader	1	1	L.S.	$13,982	$14,000	
Pick-up Truck	1	12,000	Miles/Yr	$0.50	$6,000	
General O&M		1	L.S.	$42,500	$42,500	
Subtotal						$107,400

Notes:

(1) Based on Owning and Operationg Cost Methodology in the Catepillar Performance Handbook.

VI. MISCELLANEOUS COSTS

Item	Useage (1)	Quantity	Unit	Unit Price	Annual Cost	Total
Property Insurance (2)	1	0.3%			$192,300	
Flood Insurance (2)	0	1.2%			$0	
Property Taxes (3)	1	3,252	m2	$0.78	$3,000	
Subtotal						$ 195,300

Notes:

(1) Multiplier used to adjust costs for various potential sites. Zero means expense not appicalbe to this site.

(2) Based on % of capital construction costs.

(3) Based on area of developed property.

Subtotal I through VI	$4,419,174

VII. SALES REVENUES(3)

Material	Units	Unit	Unit Value	Annual Revenues	Total
Net Electric Generation	15,751	MWh	$110	$1,732,627	Addressed in Pro Forma
Net Steam Generation	223,380	Mlbs.	$0	$0	Addressed in Pro Forma
Aluminum	-	Tons	$800	$0	No recovery provided
Ferrous Metals	-	Tons	$25	$0	
Subtotal VII					$1,732,627

Water Usage Estimates — 150 TPD

	Conversion factor =		3.785412
Domestic	**Assumptions**	**Gallons/Yr**	**Liters/Year**
Average People/Day	5.48		
gpd/person	25		
gallons per day	137		
days/week	7		
weeks/year	52		
gallons per year		49,833	188,640
Blowdown/Spray Dryer	4%	1,226,400	
Spray Dryer(Lb/hr Water/tpd Fuel)	212.00	3,688,206	
Ash Quench(15% moisture)	5.80	423,529	
Cooling Tower (blowdown 20% evap.)		36,792,000	
Washdown		35,100	132,868
Total Water Usage		42,215,068	159,801,426
Evaporation/Ash Quench	75%	31,661,301	119,851,070
Total Sewer Usage		10,553,767	39,950,357

Reagent Usage Estimates

	Qty/Ton
Lime (Lbs/Ton)	20
Ammonia (lbs/Ton)	7.5
Carbon (Lbs/Ton)	0.66

Energy Generation Assumptions

	Gross Generation Amount/Ton	**In-House Power Amount/Ton**	**Net Generation Amount/Ton**		**Net Annual Generation**	
Steam Production (mlb)	7.00	1.00	6	=	223,380	Mlbs.
Electricity Production (kWh)	494	70.51	423	=	15,751	MWh
Assumes condensing turbine	2.75	MW at	39,000	lbs/hr	0%	Margin

Energy Consumption Assumptions

Item	**mmBtu/Ton**	**Btu/Gal**	**MMBTU**	**Gal/yr**
Diesel (mmBtu)	0.1	140000	3,723	26,593

Item	**Qty/Ton**	**hp**	**load factor**	**kw**	**hrs/year**	**kwh/yr**
Power Purchase Req. (kWh/Ton)	3.73					138,981
Total Purchase						138,981

MSW Quanitites and Characteristics

Waste Quantity	40,000	tpy		Note system is slightly derated to allow for outages		
Daily Delivery	110	tpd - 7 days per weeks				
Capacity Factor	85%					
Delivery Capacity	129	tpd - 5 days per week				
Annual Throughput	37,230	tpy				
MSW HHV (B&W)	5,200	Btu/lb				
Boiler Efficiency (B&W)	71%					
Fuel Feed Rate (B&W)	10,000	Lbs/Hr at	120	tons/day	650degF/650psig	
Gross Steam Production (B&W)	35,000	Lb/Hr	7000	lbs(steam)/ton	3.5	lbstm/lb MSW

MSW Storage Calculations

Pit Storage	5	Days		
Pit Storage	645	tons		
MSW Density	20	lb/cf		
MSW Pit Capacity	63,292	cu. ft.		
Pit Area	1,300	SF	30	ft deep plus 50% of vol. up to charging level
Pit length	33	ft at	40	feet wide

Residue Disposal

Assumes cofiring RDF w/ coal and disposing both residues

Residue Disposal	1.5%	2 tpd5	0	Truckloads/Day5
Ash Disposal	28%	36.1 tpd7	2	Truckloads/Day7
Truck Payload (Tons)	20		2.0	Truckloads/Day
		24 HRS/week	4	HRs/day
			2	Round Trip Haul

Basic Conceptual Layout Dimensions

		Length	Span	Area	Height	Number of Stories	Size Adjustment
Conversion Factor	**M to Ft**	**3.28084**	**3.28084**	**10.7639111**	**3.28084**		
Exterior Maneuvering	Feet	55.0	60.0	3,300			
	Meters	16.8	18.3	307			
MSW Tipping Floor	Feet	55.0	35.0	1,925	40.0	1.0	
	Meters	16.8	10.7	179	12.2		
Boiler Bldg	Feet	60.0	85.0	5,100	115.0	1.0	
	Meters	18.3	25.9	474	35.1		
Turbine Building	Feet	50.0	45.0	4,500	15.0	2.0	
	Meters	15.2	13.7	209	4.6		
Maintenance/Storage	Feet	48.0	36.0	1,728	16.4	1.0	0.8
	Meters	14.6	11.0	161	5		
Admin/ Control Room	Feet	48.0	36.0	1,728	16.4	1.0	0.8
	Meters	14.6	11.0	161	5		
Refuse Storage Bldg (Pit)	Feet	30.0	40.0	1,200	115.0	1.0	
	Meters	9.1	12.2	111	31		
Ash Storage Bldg	Feet	35.0	30.0	1,050	30.0	1.0	0.75
	Meters	10.7	9.1	98	9.1		
Site Development	Feet	350.0	100.0	35,000			
	Meters	106.7	30.5	3,252			
		Total Bldg Floor Area		15,306			

Mass Burn Facility

Capital Cost	$	98,224,000
Life Extension Measures	$	5,250,000
Operating Cost	$	6,795,000
Energy Revenue	$	1,733,000

2008 Dollars

Capital Cost Breakdown			
Year 0	$	5,047,000	Permitting, survey, and 70% engineering work
Year 1	$	37,142,000	40% of total less start up, permitting, survey, 70% of engineering
Year 2	$	56,035,000	60% of total plus startup less permitting, survey and engineering
Total	$	98,224,000	

Life Extension			
Year 15	$	1,312,500	25%
Year 20	$	2,625,000	50%
Year 25	$	1,312,500	25%

Appendix D.2

Cost Data – Private Entity Funding

PV Analysis	Alternative 1-1[b] Apra Harbor LF (54MSL)	Alternative 1-2[c] Apra Harbor LF (100MSL)	Alternative 2[d,e] GovGuam Landfill	Alternative 3[f] New Navy Landfill	Alternative 4a[g] Modular WTE Facility	Alternative 4b[g] Erected WTE Facility
25 -Year	Inadequate Service Life	60,000,000	123,000,000	153,000,000	184,000,000	217,000,000
		39%	80%	100%	120%	142%
50 - Year	Inadequate Service Life	Inadequate Service Life	189,000,000	176,000,000	270,000,000	283,000,000
			107%	100%	153%	161%

Notes

General
1. Capital projects over the study period were assumed to be financed or funded through a sinking fund, except for Alternative 2, planned GovGuam Landfill costs.
2. Capital projects financings assumed were for 20-year periods except for Alternative 1-1 which used a 15 year period.
3. Capital project financings assumed origination fees of 1.00% and an interest rate of 2.5%.
3. Capital project sinking funds were for varied periods in consideration of cash flow and included earned interest at an annual percentage rate of 1.0%.
4. Equal annual landfill closure fund deposits were considered over the alternative landfill life including earned interest at an annual percentage rate of 1.0%.

a Present Value Analysis uses a real discount rate of 2.8 percent, with inflation premium removed per OMB Circular No. A-94; Appendix C, rev January 2008

b Estimated service life is limited to the year 2023 and would be exhausted prior to 25 and 50 year analysis periods.

c Estimated service life is limited to the year 2036 and would be exhausted prior to 50 year analysis periods.

d Assumed a tip fee at the Gov Guam landfill of $95/ton over the analysis period, which is discounted over the analysis period.

e Includes estimated 40% increase in collection driver/truck costs to use GovGuam LF Vs current system (80 % waste from northern Guam after troop relocation).

f Includes estimated 15% increase in collection driver/truck costs to use Central Guam LF Vs current system (80 % waste from northern Guam after troop relocation).

g Assumes WTE would extend Apra Harbor Landfill site life to 65 years for landfilling of unburnable waste and residual ash.

CURRENT DOLLARS ANALYSIS

	Alternative 1-1 (54 MSL)		Alternative 1-2 (100 MSL)		Alternative 2		Alternative 3		Alternative 4a			Alternative 4b		
	Apra Harbor Landfill		Apra Harbor Landfill		Gov Guam Landfill		New Navy Landfill		Modular Waste-to-Energy Facility			Erected Waste-to-Energy Facility		
Year	Capital/*Finance*	Operating	Capital/*Finance*	Operating	AHLF Closure	Service Fee	Capital/*Finance*	Operating	Capital/*Finance*	Operating	Revenue	Capital/*Finance*	Operating	Revenue
2008														
2009	$ 1,562,664	$ 873,908	$ 1,841,399	$ 873,908		$ 1,228,470	$ 1,437,281	$ 873,908	$ 1,687,866	$ 873,908		$ 1,687,866	$ 873,908	
2010	$ 1,562,664	$ 994,824	$ 1,841,399	$ 994,824	$ 466,411	$ 3,159,235	$ 1,437,281	$ 994,824	$ 1,687,866	$ 994,824		$ 1,687,866	$ 994,824	
2011	$ 1,562,664	$ 1,003,782	$ 1,841,399	$ 1,003,782	$ 466,411	$ 3,771,600	$ 1,437,281	$ 1,003,782	$ 4,909,114	$ 1,003,782		$ 8,118,576	$ 1,003,782	
2012	$ 1,562,664	$ 1,066,791	$ 1,841,399	$ 1,066,791	$ 466,411	$ 4,009,271	$ 5,901,739	$ 1,066,791	$ 4,909,114	$ 1,066,791		$ 8,118,576	$ 1,066,791	
2013	$ 1,562,664	$ 1,331,541	$ 1,841,399	$ 1,331,541	$ 466,411	$ 4,951,764	$ 5,901,739	$ 2,245,264	$ 4,909,114	$ 1,331,541		$ 8,118,576	$ 1,371,541	
2014	$ 1,562,664	$ 1,557,676	$ 1,841,399	$ 1,557,676	$ 466,411	$ 5,900,808	$ 5,901,739	$ 2,475,092	$ 4,909,114	$ 8,460,586	$ (489,000)	$ 8,118,576	$ 8,810,586	$ (1,733,000)
2015	$ 1,562,664	$ 1,900,734	$ 1,841,399	$ 1,900,734	$ 466,411	$ 7,403,083	$ 5,901,739	$ 2,838,896	$ 4,909,114	$ 8,460,586	$ (489,000)	$ 8,118,576	$ 8,810,586	$ (1,733,000)
2016	$ 1,562,664	$ 2,090,584	$ 1,841,399	$ 2,090,584	$ 466,411	$ 7,706,450	$ 5,901,739	$ 2,912,362	$ 4,909,114	$ 8,460,586	$ (489,000)	$ 8,118,576	$ 8,810,586	$ (1,733,000)
2017	$ 1,562,664	$ 2,090,584	$ 1,841,399	$ 2,090,584	$ 466,411	$ 7,706,450	$ 6,572,186	$ 2,912,362	$ 4,909,114	$ 8,460,586	$ (489,000)	$ 8,118,576	$ 8,810,586	$ (1,733,000)
2018	$ 1,562,664	$ 2,090,584	$ 1,841,399	$ 2,090,584	$ 466,411	$ 7,706,450	$ 6,572,186	$ 2,912,362	$ 4,909,114	$ 8,460,586	$ (489,000)	$ 8,118,576	$ 8,810,586	$ (1,733,000)
2019	$ 1,562,664	$ 2,090,584	$ 1,841,399	$ 2,090,584	$ 466,411	$ 7,779,243	$ 6,572,186	$ 2,929,990	$ 4,909,114	$ 8,460,586	$ (489,000)	$ 8,118,576	$ 8,810,586	$ (1,733,000)
2020	$ 1,562,664	$ 2,090,584	$ 1,841,399	$ 2,090,584	$ 466,411	$ 7,779,243	$ 6,572,186	$ 2,929,990	$ 4,909,114	$ 8,460,586	$ (489,000)	$ 8,118,576	$ 8,810,586	$ (1,733,000)
2021	$ 1,562,664	$ 2,090,584	$ 1,841,399	$ 2,090,584	$ 466,411	$ 7,779,243	$ 6,572,186	$ 2,929,990	$ 4,909,114	$ 8,460,586	$ (489,000)	$ 8,118,576	$ 8,810,586	$ (1,733,000)
2022	$ 1,562,664	$ 2,090,584	$ 1,841,399	$ 2,090,584	$ 466,411	$ 7,779,243	$ 6,186,230	$ 2,929,990	$ 4,909,114	$ 8,460,586	$ (489,000)	$ 8,118,576	$ 8,810,586	$ (1,733,000)
2023	$ 1,562,664	$ 2,090,584	$ 1,841,399	$ 2,090,584	$ 466,411	$ 7,779,243	$ 6,507,860	$ 2,929,990	$ 4,909,114	$ 8,460,586	$ (489,000)	$ 8,118,576	$ 8,810,586	$ (1,733,000)
2024			$ 1,841,399	$ 2,090,584	$ 466,411	$ 7,779,243	$ 6,507,860	$ 2,929,990	$ 4,909,114	$ 8,460,586	$ (489,000)	$ 8,118,576	$ 8,810,586	$ (1,733,000)
2025			$ 1,841,399	$ 2,090,584	$ 466,411	$ 7,779,243	$ 6,507,860	$ 2,929,990	$ 4,909,114	$ 8,460,586	$ (489,000)	$ 8,118,576	$ 8,810,586	$ (1,733,000)
2026			$ 1,841,399	$ 2,090,584	$ 466,411	$ 7,779,243	$ 6,507,860	$ 2,929,990	$ 4,909,114	$ 8,460,586	$ (489,000)	$ 8,118,576	$ 8,810,586	$ (1,733,000)
2027			$ 1,841,399	$ 2,090,584	$ 466,411	$ 7,779,243	$ 6,186,230	$ 2,929,990	$ 4,909,114	$ 8,460,586	$ (489,000)	$ 8,118,576	$ 8,810,586	$ (1,733,000)
2028			$ 1,841,399	$ 2,090,584	$ 466,411	$ 7,779,243	$ 6,186,230	$ 2,929,990	$ 4,909,114	$ 8,460,586	$ (489,000)	$ 8,118,576	$ 8,810,586	$ (1,733,000)
2029			$ 246,565	$ 2,090,584	$ 466,411	$ 7,779,243	$ 5,375,166	$ 2,929,990	$ 3,674,604	$ 8,460,586	$ (489,000)	$ 6,582,279	$ 8,810,586	$ (1,733,000)
2030			$ 246,565	$ 2,090,584		$ 7,779,243	$ 5,375,166	$ 2,929,990	$ 3,674,604	$ 8,460,586	$ (489,000)	$ 6,582,279	$ 8,810,586	$ (1,733,000)
2031			$ 246,565	$ 2,090,584		$ 7,779,243	$ 5,375,166	$ 2,929,990	$ 865,240	$ 8,460,586	$ (489,000)	$ 218,484	$ 8,810,586	$ (1,733,000)
2032			$ 246,565	$ 2,090,584		$ 7,779,243	$ 1,132,101	$ 2,929,990	$ 865,240	$ 8,460,586	$ (489,000)	$ 218,484	$ 8,810,586	$ (1,733,000)
2033			$ 246,565	$ 2,090,584		$ 7,779,243	$ 810,471	$ 2,929,990	$ 865,240	$ 8,460,586	$ (489,000)	$ 218,484	$ 8,810,586	$ (1,733,000)
2034			$ 246,565	$ 2,090,584		$ 7,779,243	$ 810,471	$ 2,929,990	$ 1,912,094	$ 8,460,586	$ (489,000)	$ 388,554	$ 8,810,586	$ (1,733,000)
2035			$ 246,565	$ 2,090,584		$ 7,779,243	$ 810,471	$ 2,929,990	$ 1,912,094	$ 8,460,586	$ (489,000)	$ 388,554	$ 8,810,586	$ (1,733,000)
2036			$ -	$ 2,090,584		$ 7,779,243	$ 1,132,101	$ 2,929,990	$ 1,912,094	$ 8,460,586	$ (489,000)	$ 388,554	$ 8,810,586	$ (1,733,000)
2037						$ 7,779,243	$ 783,283	$ 2,929,990	$ 1,912,094	$ 8,460,586	$ (489,000)	$ 388,554	$ 8,810,586	$ (1,733,000)
2038						$ 7,779,243	$ 721,504	$ 2,929,990	$ 1,912,094	$ 8,460,586	$ (489,000)	$ 388,554	$ 8,810,586	$ (1,733,000)
2039						$ 7,779,243	$ 399,874	$ 2,929,990	$ 1,912,094	$ 8,460,586	$ (489,000)	$ 388,554	$ 8,810,586	$ (1,733,000)
2040						$ 7,779,243	$ 721,504	$ 2,929,990	$ 1,912,094	$ 8,460,586	$ (489,000)	$ 388,554	$ 8,810,586	$ (1,733,000)
2041						$ 7,779,243	$ 721,504	$ 2,929,990	$ 1,912,094	$ 8,460,586	$ (489,000)	$ 388,554	$ 8,810,586	$ (1,733,000)
2042						$ 7,185,076	$ 721,504	$ 2,929,990	$ 1,912,094	$ 8,460,586	$ (489,000)	$ 388,554	$ 8,810,586	$ (1,733,000)
2043						$ 7,185,076	$ 721,504	$ 2,929,990	$ 1,912,094	$ 8,460,586	$ (489,000)	$ 388,554	$ 8,810,586	$ (1,733,000)
2044						$ 7,185,076	$ 1,043,134	$ 2,114,990	$ 1,912,094	$ 8,460,586	$ (489,000)	$ 388,554	$ 8,810,586	$ (1,733,000)
2045						$ 7,185,076	$ 1,010,718	$ 2,114,990	$ 1,912,094	$ 8,460,586	$ (489,000)	$ 388,554	$ 8,810,586	$ (1,733,000)
2046						$ 7,185,076	$ 689,088	$ 2,114,990	$ 1,912,094	$ 8,460,586	$ (489,000)	$ 388,554	$ 8,810,586	$ (1,733,000)
2047						$ 7,185,076	$ 1,010,718	$ 2,114,990	$ 1,912,094	$ 8,460,586	$ (489,000)	$ 388,554	$ 8,810,586	$ (1,733,000)
2048						$ 7,185,076	$ 1,010,718	$ 2,114,990	$ 1,912,094	$ 8,460,586	$ (489,000)	$ 388,554	$ 8,810,586	$ (1,733,000)
2049						$ 7,185,076	$ 1,010,718	$ 2,114,990	$ 1,139,886	$ 8,460,586	$ (489,000)	$ 263,102	$ 8,810,586	$ (1,733,000)
2050						$ 7,185,076	$ 689,088	$ 2,114,990	$ 1,139,886	$ 8,460,586	$ (489,000)	$ 263,102	$ 8,810,586	$ (1,733,000)
2051						$ 7,185,076	$ 689,088	$ 2,114,990	$ 1,139,886	$ 8,460,586	$ (489,000)	$ 263,102	$ 8,810,586	$ (1,733,000)
2052						$ 7,185,076	$ 689,088	$ 2,114,990	$ 1,139,886	$ 8,460,586	$ (489,000)	$ 263,102	$ 8,810,586	$ (1,733,000)
2053						$ 7,185,076	$ 689,088	$ 2,114,990	$ 1,139,886	$ 8,460,586	$ (489,000)	$ 263,102	$ 8,810,586	$ (1,733,000)
2054						$ 7,185,076	$ 440,957	$ 2,114,990	$ 1,139,886	$ 8,460,586	$ (489,000)	$ 263,102	$ 8,810,586	$ (1,733,000)
2055						$ 7,185,076	$ 440,957	$ 2,114,990	$ 1,139,886	$ 8,460,586	$ (489,000)	$ 263,102	$ 8,810,586	$ (1,733,000)
2056						$ 7,185,076	$ 440,957	$ 2,114,990	$ 1,139,886	$ 8,460,586	$ (489,000)	$ 263,102	$ 8,810,586	$ (1,733,000)
2057						$ 7,185,076	$ 440,957	$ 2,114,990	$ 1,139,886	$ 8,460,586	$ (489,000)	$ 263,102	$ 8,810,586	$ (1,733,000)
2058						$ 7,185,076		$ 2,114,990	$ 1,139,886	$ 8,460,586	$ (489,000)	$ 263,102	$ 8,810,586	$ (1,733,000)
					$ 9,328,227	$ 354,612,474	$ 147,178,660	$ 125,210,242	$ 141,764,988	$ 385,997,217		$ 171,789,431	$ 401,787,217	
ste volume, cy						$ 363,940,701		$ 272,388,902		$ 527,762,205			$ 573,576,648	

PRESENT VALUE ANALYSIS

	Alternative 1-1 (54 MSL) Apra Harbor Landfill		Alternative 1-2 (100 MSL) Apra Harbor Landfill		Alternative 2 Gov Guam Landfill		Alternative 3 New Navy Landfill		Alternative 4a Modular Waste-to-Energy Facility			Alternative 4b Erected Waste-to-Energy Facility		
Year	Capital/Finance	Operating	Capital/Finance	Operating	AHLF Closure	Service Fee	Capital/Finance	Operating	Capital/Finance	Operating	Revenue	Capital/Finance	Operating	Revenue
2009	$ 1,520,101	$ 248,609	$ 1,791,244	$ 850,105	$ -	$ 1,195,009	$ 1,398,134	$ 850,105	$ 1,641,893	$ 850,105	$ -	$ 1,641,893	$ 850,105	$ -
2010	$ 1,478,697	$ 941,370	$ 1,742,456	$ 941,370	$ 441,350	$ 2,989,481	$ 1,360,052	$ 941,370	$ 1,597,172	$ 941,370	$ -	$ 1,597,172	$ 941,370	$ -
2011	$ 1,438,422	$ 923,975	$ 1,694,996	$ 923,975	$ 429,329	$ 3,471,733	$ 1,323,008	$ 923,975	$ 4,518,807	$ 923,975	$ -	$ 7,473,095	$ 923,975	$ -
2012	$ 1,399,243	$ 955,228	$ 1,648,829	$ 955,228	$ 417,635	$ 3,589,988	$ 6,852,026	$ 955,228	$ 4,395,727	$ 955,228	$ -	$ 7,269,548	$ 955,228	$ -
2013	$ 1,361,131	$ 1,159,816	$ 1,603,919	$ 1,159,816	$ 406,260	$ 4,313,148	$ 6,665,395	$ 1,955,698	$ 4,275,999	$ 1,159,816	$ -	$ 7,071,544	$ 1,194,657	$ -
2014	$ 1,324,057	$ 1,319,831	$ 1,560,232	$ 1,319,831	$ 395,194	$ 4,999,802	$ 6,483,848	$ 2,097,166	$ 4,159,532	$ 7,168,722	$ (414,334)	$ 6,878,934	$ 7,465,280	$ (1,468,385)
2015	$ 1,287,994	$ 1,566,641	$ 1,517,736	$ 1,566,641	$ 384,430	$ 6,101,840	$ 6,307,245	$ 2,339,902	$ 4,046,237	$ 6,973,465	$ (403,048)	$ 6,691,570	$ 7,261,946	$ (1,428,390)
2016	$ 1,252,912	$ 1,676,188	$ 1,476,397	$ 1,676,188	$ 373,959	$ 6,178,875	$ 6,135,452	$ 2,335,073	$ 3,936,028	$ 6,783,527	$ (392,070)	$ 6,509,310	$ 7,064,149	$ (1,389,484)
2017	$ 1,218,786	$ 1,630,533	$ 1,436,184	$ 1,630,533	$ 363,774	$ 6,010,579	$ 5,968,339	$ 2,271,471	$ 3,828,821	$ 6,598,761	$ (381,391)	$ 6,332,013	$ 6,871,741	$ (1,351,638)
2018	$ 1,185,590	$ 1,586,122	$ 1,397,066	$ 1,586,122	$ 353,865	$ 5,846,867	$ 5,805,777	$ 2,209,603	$ 3,724,534	$ 6,419,028	$ (371,003)	$ 6,159,546	$ 6,684,573	$ (1,314,823)
2019	$ 1,153,297	$ 1,542,920	$ 1,359,013	$ 1,542,920	$ 344,227	$ 5,741,338	$ 5,647,643	$ 2,162,429	$ 3,623,088	$ 6,244,191	$ (360,898)	$ 5,991,776	$ 6,502,503	$ (1,279,011)
2020	$ 1,121,884	$ 1,500,895	$ 1,321,997	$ 1,500,895	$ 334,851	$ 5,584,959	$ 5,493,816	$ 2,103,530	$ 3,524,405	$ 6,074,116	$ (351,068)	$ 5,828,576	$ 6,325,392	$ (1,244,174)
2021	$ 1,091,327	$ 1,460,015	$ 1,285,990	$ 1,460,015	$ 325,731	$ 5,432,839	$ 5,344,179	$ 2,046,236	$ 3,428,409	$ 5,908,673	$ (341,506)	$ 5,669,821	$ 6,153,105	$ (1,210,286)
2022	$ 1,061,602	$ 1,420,248	$ 1,250,963	$ 1,420,248	$ 316,859	$ 5,284,863	$ 5,198,618	$ 1,990,502	$ 3,335,028	$ 5,747,736	$ (332,204)	$ 5,515,390	$ 5,985,510	$ (1,177,321)
2023	$ 1,032,687	$ 1,381,564	$ 1,216,890	$ 1,381,564	$ 308,228	$ 5,140,917	$ 5,057,021	$ 1,936,286	$ 3,244,191	$ 5,591,183	$ (323,156)	$ 5,365,166	$ 5,822,481	$ (1,145,254)
2024	$ -	#VALUE!	$ 1,183,745	$ 1,343,934	$ 299,833	$ 5,000,892	$ 4,919,281	$ 1,883,546	$ 3,155,828	$ 5,438,894	$ (314,354)	$ 5,219,033	$ 5,663,892	$ (1,114,060)
2025	$ -	#VALUE!	$ 1,151,503	$ 1,307,329	$ 291,666	$ 4,864,681	$ 4,785,293	$ 1,832,243	$ 3,069,871	$ 5,290,753	$ (305,792)	$ 5,076,880	$ 5,509,623	$ (1,083,716)
2026	$ -	#VALUE!	$ 1,120,139	$ 1,271,720	$ 283,722	$ 4,732,180	$ 4,654,954	$ 1,782,338	$ 2,986,256	$ 5,146,647	$ (297,463)	$ 4,938,599	$ 5,359,555	$ (1,054,199)
2027	$ -	#VALUE!	$ 1,089,629	$ 1,237,082	$ 275,994	$ 4,603,288	$ 4,528,166	$ 1,733,792	$ 2,904,919	$ 5,006,466	$ (289,361)	$ 4,804,085	$ 5,213,575	$ (1,025,485)
2028	$ -	#VALUE!	$ 1,059,951	$ 1,203,387	$ 268,477	$ 4,477,907	$ 4,404,830	$ 1,686,568	$ 2,825,796	$ 4,870,103	$ (281,479)	$ 4,673,234	$ 5,071,571	$ (997,554)
2029	$ -	#VALUE!	$ 138,063	$ 1,170,610	$ 261,164	$ 4,355,940	$ 3,540,311	$ 1,640,630	$ 2,057,572	$ 4,737,454	$ (273,813)	$ 3,685,708	$ 4,933,435	$ (970,383)
2030	$ -	#VALUE!	$ 134,302	$ 1,138,726	$ -	$ 4,237,296	$ 3,443,882	$ 1,595,944	$ 2,001,529	$ 4,608,419	$ (266,355)	$ 3,585,319	$ 4,799,061	$ (943,952)
2031	$ -	#VALUE!	$ 130,644	$ 1,107,710	$ -	$ 4,121,883	$ 3,350,080	$ 1,552,475	$ 458,453	$ 4,482,897	$ (259,100)	$ 115,765	$ 4,668,347	$ (918,242)
2032	$ -	#VALUE!	$ 127,086	$ 1,077,539	$ -	$ 4,009,614	$ 55,463	$ 1,510,189	$ 445,966	$ 4,360,795	$ (252,043)	$ 112,612	$ 4,541,194	$ (893,231)
2033	$ -	#VALUE!	$ 123,624	$ 1,048,190	$ -	$ 3,900,403	$ 53,952	$ 1,469,056	$ 433,819	$ 4,242,019	$ (245,178)	$ 109,545	$ 4,417,504	$ (868,902)
2034	$ -	#VALUE!	$ 120,257	$ 1,019,640	$ -	$ 3,794,166	$ 52,483	$ 1,429,043	$ 932,585	$ 4,126,477	$ (238,500)	$ 189,509	$ 4,297,183	$ (845,235)
2035	$ -	#VALUE!	$ 116,982	$ 991,867	$ -	$ 3,690,823	$ 51,053	$ 1,390,119	$ 907,183	$ 4,014,083	$ (232,004)	$ 184,347	$ 4,180,139	$ (822,213)
2036	$ -	#VALUE!	$ -	$ 964,851	$ -	$ 3,590,295	$ 49,663	$ 1,352,256	$ 882,474	$ 3,904,750	$ (225,684)	$ 179,326	$ 4,066,283	$ (799,818)
2037	$ -	#VALUE!	$ -	#VALUE!	$ -	$ 3,492,505	$ 48,310	$ 1,315,424	$ 858,438	$ 3,798,395	$ (219,537)	$ 174,442	$ 3,955,528	$ (778,033)
2038	$ -	#VALUE!	$ -	#VALUE!	$ -	$ 3,397,378	$ 20,014	$ 1,279,595	$ 835,056	$ 3,694,937	$ (213,558)	$ 169,691	$ 3,847,790	$ (756,842)
2039	$ -	#VALUE!	$ -	#VALUE!	$ -	$ 3,304,843	$ 19,469	$ 1,244,743	$ 812,312	$ 3,594,296	$ (207,741)	$ 165,069	$ 3,742,986	$ (736,227)
2040	$ -	#VALUE!	$ -	#VALUE!	$ -	$ 3,214,828	$ 18,939	$ 1,210,839	$ 790,186	$ 3,496,397	$ (202,083)	$ 160,573	$ 3,641,037	$ (716,175)
2041	$ -	#VALUE!	$ -	#VALUE!	$ -	$ 3,127,264	$ 18,423	$ 1,177,859	$ 768,664	$ 3,401,165	$ (196,579)	$ 156,199	$ 3,541,865	$ (696,668)
2042	$ -	#VALUE!	$ -	#VALUE!	$ -	$ 2,809,736	$ 17,921	$ 1,145,777	$ 747,727	$ 3,308,526	$ (191,224)	$ 151,945	$ 3,445,394	$ (677,692)
2043	$ -	#VALUE!	$ -	#VALUE!	$ -	$ 2,733,206	$ 17,433	$ 1,114,569	$ 727,361	$ 3,218,410	$ (186,016)	$ 147,806	$ 3,351,551	$ (659,234)
2044	$ -	#VALUE!	$ -	#VALUE!	$ -	$ 2,658,761	$ 16,958	$ 782,629	$ 707,550	$ 3,130,749	$ (180,949)	$ 143,780	$ 3,260,263	$ (641,278)
2045	$ -	#VALUE!	$ -	#VALUE!	$ -	$ 2,586,343	$ 16,496	$ 761,313	$ 688,278	$ 3,045,476	$ (176,021)	$ 139,864	$ 3,171,462	$ (623,811)
2046	$ -	#VALUE!	$ -	#VALUE!	$ -	$ 2,515,898	$ 16,047	$ 740,577	$ 669,531	$ 2,962,525	$ (171,226)	$ 136,054	$ 3,085,080	$ (606,820)
2047	$ -	#VALUE!	$ -	#VALUE!	$ -	$ 2,447,372	$ 15,610	$ 720,405	$ 651,295	$ 2,881,834	$ (166,563)	$ 132,349	$ 3,001,051	$ (590,292)
2048	$ -	#VALUE!	$ -	#VALUE!	$ -	$ 2,380,712	$ 15,185	$ 700,783	$ 633,555	$ 2,803,341	$ (162,026)	$ 128,744	$ 2,919,310	$ (574,214)
2049	$ -	#VALUE!	$ -	#VALUE!	$ -	$ 2,315,867	$ 14,771	$ 681,696	$ 367,404	$ 2,726,985	$ (157,613)	$ 84,802	$ 2,839,796	$ (558,574)
2050	$ -	#VALUE!	$ -	#VALUE!	$ -	$ 2,252,789	$ 14,369	$ 663,128	$ 357,397	$ 2,652,709	$ (153,320)	$ 82,492	$ 2,762,447	$ (543,360)
2051	$ -	#VALUE!	$ -	#VALUE!	$ -	$ 2,191,429	$ 13,977	$ 645,066	$ 347,662	$ 2,580,456	$ (149,144)	$ 80,245	$ 2,687,205	$ (528,560)
2052	$ -	#VALUE!	$ -	#VALUE!	$ -	$ 2,131,741	$ 13,597	$ 627,496	$ 338,193	$ 2,510,172	$ (145,081)	$ 78,060	$ 2,614,013	$ (514,164)
2053	$ -	#VALUE!	$ -	#VALUE!	$ -	$ 2,073,678	$ 13,226	$ 610,405	$ 328,981	$ 2,441,801	$ (141,130)	$ 75,934	$ 2,542,814	$ (500,159)
2054	$ -	#VALUE!	$ -	#VALUE!	$ -	$ 2,017,196	$ 12,866	$ 593,779	$ 320,021	$ 2,375,293	$ (137,286)	$ 73,865	$ 2,473,555	$ (486,536)
2055	$ -	#VALUE!	$ -	#VALUE!	$ -	$ 1,962,253	$ 12,516	$ 577,606	$ 311,304	$ 2,310,596	$ (133,546)	$ 71,854	$ 2,406,182	$ (473,284)
2056	$ -	#VALUE!	$ -	#VALUE!	$ -	$ 1,908,806	$ 12,175	$ 561,874	$ 302,825	$ 2,247,662	$ (129,909)	$ 69,896	$ 2,340,644	$ (460,393)
2057	$ -	#VALUE!	$ -	#VALUE!	$ -	$ 1,856,816	$ 11,843	$ 546,570	$ 294,577	$ 2,186,441	$ (126,371)	$ 67,993	$ 2,276,891	$ (447,853)
2058	$ -	#VALUE!	$ -	#VALUE!	$ -	$ 1,806,241	$ 11,521	$ 531,683	$ 286,554	$ 2,126,888	$ (122,929)	$ 66,141	$ 2,214,874	$ (435,655)
Sum 25 Year	$ 18,927,731	#VALUE!	$ 28,562,597	$ 31,821,676	$ 6,876,547	$ 116,186,325	$ 108,776,765	$ 43,805,353	$ 73,619,883	$ 116,524,344	$ (6,455,616)	$ 118,316,134	$ 121,179,769	$ (22,878,491)
25 Year PV	#VALUE!		60,384,272		123,062,872		152,582,118		183,688,611			216,617,411		
Sum 50 Year	$ 18,927,731	#VALUE!	$ 28,799,835	#VALUE!	$ 6,876,547	$ 182,447,271	$ 109,301,630	$ 66,210,589	$ 88,486,998	$ 192,064,710	$ (10,821,654)	$ 121,427,113	$ 199,845,111	$ (38,351,587)
50 Year PV	#VALUE!		#VALUE!		189,323,818		175,512,219		269,730,054			282,920,637		

COST ESTIMATING AND ECONOMIC ASSUMPTIONS

General Cost factors

Costs shown below have been adjusted for Guam in detail sheets or use the following factors, applied as noted in line item description.

For Construction projects - PAX Newsletter No 3.2.1, 30 April 2007 - Area Cost Factors (ACF) - (See example factors used)

1.15	California
2.64	Guam
2.296	Use Factor

For Primarily Labor or O&M Projects

May 2006 State Occupational Employment and Wage Estimates
Installation, Maintenance and Repair Occupations - 49-0000

Guam	49-0000	$	27,970	
California	49-0000	$	42,760	
Labor	Conversion		0.65	Guam/CA

Given that material factor in Means is 1.4 use below:
0.8 Use Factor

Financing and Interest Earned Assumptions		
Bank Financing		
	Interest Rate	**Amortization Period***
BOJ Bank Rate	2.50%	20 yrs
OriginationFees	1.00%	Capitalized
* Deviations for other terms are noted		
Interest Earned- Sinking/Closure Fund		
	Interest Rate	**Amortization Period**
	1.00%	varies

ALTERNATIVE 1-1: Landfill Improvements and Liner "Untouched Area" in 2009; LFG Control in 2013; Closure in 2024

Capital Costs			
2009	$	11,133,317	Scale, Control Building, Line Untouched, LCRS, Site Work
2013	$	1,790,609	LFG Control System and Flare for 60 Acres @$10k/acre & $150,000 Flare + tax- (x Guam/CA ACF)
Finance	$	1,054,258	Annual pmt for financing of above 2 items (2023-2009/approx use 15 years finance period assumed)
2023	$	7,599,356	Closure Cap (assumes 7.4ppd and revised filling practices yielding 14 years site life)
Fund		$508,405.81	Annual closure fund contribution (2009 to year shown- includes fund interest)
Oper Costs			
Reference	$	717,802	Annual Landfill Operating and Collection Cost 2007 (Includes Refuse Trucks and Drivers - tonnage prorated to 2012)
	$	2,050,584	Annual Landfill Operating Cost 2015 - future tonnage (Includes Refuse Trucks and Drivers)
2013	$	40,000	Additional Annual LFG Control Operating Cost - $50,000 (Guam/CA O&M Factor, above)
	$	775,000	Annual PC Care w/o LFG/GW items (Rounded $765,230 from Pre-final Landfill Management Plan, November 2007)
	$	*40,000*	*Additional O&M for LFG in PCM period - $50,000 X O&M Guam factor*
2024 to 2054	*$*	*815,000*	*Total Annual PCM Costs; 30 years (does not in include GW monitoring Assumed needed under All).*

ALTERNATIVE 1-2: Landfill Improvements and Liner in 2009; LFG Control in 2013; Closure in 2036

Capital Costs			
2009	$	22,825,361	Scale, Control Building, Line entire acreage, LCRS, Site Work
2013	$	1,790,609	LFG Control System and Flare for 60 Acres @$10k/acre & $150,000 Flare- (x Guam/CA ACF)
Finance	$	1,594,834	Annual pmt for financing of above 2 items
2036	$	7,599,356	Closure Cap (assumes 7.4ppd and revised filling practices yielding 27 years site life)
Fund		$246,565	Annual closure fund contribution (2009 up to closure year shown- includes fund interest)
Oper Costs			
Reference	$	717,802	Reference Annual Landfill Operating & Collection Cost 2007 (Includes Refuse Trucks and Drivers - prorated to 2015)
2015 to future	$	2,050,584	Annual Landfill Operating Cost 2015 - future tonnage (Includes Refuse Trucks and Drivers)
2015 to future	$	40,000	Additional Annual LFG Control Operating Cost - $50,000 (Guam/CA O&M Factor, above)
2036	$	775,000	Annual PC Care w/o LFG/GW items (Rounded $765,230 from Pre-final Landfill Management Plan, November 2007)
	$	*40,000*	*Additional O&M for LFG in PCM period - $50,000 X O&M Guam factor*
2036 to 2066	*$*	*815,000*	*Total Annual PCM Costs; 30 years (does not in include GW monitoring Assumed needed under All).*

ALTERNATIVE 2: GovGuam Landfill Operational in 2010; tip fee (shown as annual "operating" cost) as shown.

2010 to future	$	95.00	Assumed Tip Fee for use of GovGuam Landfill
2010 to future		140%	Comparative Collection Cost over Alternative 1 due to greater off-route collection costs
Capital Cost			Includes Closure costs for 46 acres (assumed untouched area not included) below:
2010	$	7,198,973	Closure (Cap and LFG venting) of 46 acres (prorated from 60 acres); NO LINER
Finance	$	466,411	Annual pmt for financing of above item
2011 to 2041	$	594,167	Total Annual PCM Costs (46 acres); 30 years; LFG venting, no LFG control system (not including GW monitoring).

ALTERNATIVE 3: AHLF/New Navy LF (line untouched only) to 2013; Close AHLF in 2013; Construct new LF 2012; Operations 2013.

Apra Harbor Landfill in interim

Capital Costs (Apra Harbor interim)			
2009	$	11,133,317	Scale, Control Building, Site Work (Liner for untouched area only - 14 acres)
2013	$	1,790,609	LFG Control System and Flare for 60 Acres @$10k/acre & $150,000 Flare- (x Guam/CA ACF)
2013	$	7,599,356	Closure Cap for 60 acres
Finance	$	1,329,675	Annual pmt for financing of above 3 items
Oper Costs			
to 2015	$	717,802	Reference Annual Landfill Operating & Collection Cost 2007 (Includes Refuse Trucks and Drivers - prorated to 2015)
	$	775,000	Annual PC Care w/o LFG/GW items (Rounded $765,230 from Pre-final Landfill Management Plan, November 2007)
	$	40,000	Additional O&M for LFG in PCM period - $50,000 X O&M Guam factor
2013 to 2043	*$*	*815,000*	*Total Annual PCM Costs; 30 years (does not in include GW monitoring Assumed needed under All).*

New Navy Landfill In Central Guam

Capital Costs

$			28,379,520	Total Liner and LCRS
$			12,000,000	Total Landfill Earthwork (included in phased module financings, below)
$			55,548,000	Other Initial Site Capital Development Costs minus total earthwork
$			95,927,520	Total site Development Costs
	2012		62,950,912	Initial Site Development and Module 1
	Finance	$	4,078,501	Annual pmt for financing of above item
	2017	$	5,383,936	Liner/LCRS Module 2
	Finance	$	348,818	Annual pmt for financing of above item
	2022	$	4,037,952	Liner/LCRS Module 3
	Fund		$385,956	Sinking Fund Annual payment (2012 to year shown)
	2027	$	3,364,960	Liner/LCRS Module 4
	Fund		$321,630	Sinking Fund Annual payment (2017 to year shown)
	2033	$	3,364,960	Liner/LCRS Module 5
	Fund		$321,630	Sinking Fund Annual payment (2023 to year shown)
	2039	$	3,364,960	Liner/LCRS Module 6
	Fund		$321,630	Sinking Fund Annual payment (2029 to year shown)
	2046	$	3,364,960	Liner/LCRS Module 7
	Fund		$321,630	Sinking Fund Annual payment (2036 to year shown)
	2050	$	3,364,960	Liner/LCRS Module 8
	Fund		$321,630	Sinking Fund Annual payment (2040 to year shown)
	2054	$	3,364,960	Liner/LCRS Module 9
	Fund		$321,630	Sinking Fund Annual payment (2044 to year shown)
	2057	$	3,364,960	Liner/LCRS Module 10
	Fund		$321,630	Sinking Fund Annual payment (2047 to year shown)
CHECK			95,927,520	Total Liner and LCRS Capital Cost
	2032	$	596,870	Initial Portion [20 year] of LFG Control and Flare for 20 Acres @$10k/acre & $150,000 Flare- (x Guam/CA ACF)
	Fund		$196,980	Sinking Fund Annual payment (2029 to year shown)
	2045	$	447,652	Add to LFG Control System 15 Acres ($10k/acre CA x factor adjust to Guam)
	Fund		$32,417	Sinking Fund Annual payment (2032 to year shown)
	2058	$	298,435	Add to LFG Control System 10 Acres (15 acres to be completed at closure beyond 2058)
	Fund		$73,499	Sinking Fund Annual payment (2054 to year shown)
Reference		$	7,198,973	Closure Cap -60 acres (Apply in 2038 [25 year of life] and prorated in 2058 for 20/25 years of remaining life)
	2038	$	3,599,486	1/2 of closure cap cost prorated for first 25 years of site life
	Fund		$107,607	Annual closure fund contribution (2009 to closure year shown- includes fund interest)
	2058	$	2,879,589	portion of closure cap cost prorated for years 26 to year 2058; or 20 years
	Fund		$45,828	Annual closure fund contribution (2038 to year shown- includes fund interest)

Oper Costs

2015	$	374,991	New Landfill Operating Cost - Minus Collection Costs
2015 to 2063		115%	Apply Comparative Collection Cost over Alternative 1 due to greater off-route collection costs

ALTERNATIVE 4a: Modular WTE Facility

Capital Costs

2011	$	2,629,000	Permitting, survey, and 70% engineering work
2012	$	17,284,000	40% of Total Construction Cost less Start up, permitting, survey, 70% of engineering costs
2013	$	26,076,000	60% of Total Construction Cost plus Startup; less permitting, survey and engineering
Finance	$	2,809,364	Annual pmt for financing of above 3 items
2029	$	8,079,000	Minor Life Extension Measures (replacement of system components)
Fund		$411,884	Sinking Fund Annual payment (2011 to year shown)
2034	$	16,158,000	Major Life Extension Measures (replacement of combustion units and major boiler components)
Finance	$	1,046,854	Annual pmt for financing of above item)
2039	$	8,079,000	Minor Life Extension Measures (replacement of system components)
Fund		$772,208	Sinking Fund Annual payment (2029 to year shown)
2049	$	8,079,000	Minor Life Extension Measures (replacement of system components)
Fund		$772,208	Sinking Fund Annual payment (2039 to year shown)
2054	$	16,158,000	Major Life Extension Measures (replacement of combustion units and major boiler components)
Finance	$	1,046,854	Annual pmt for financing of above item (Assumed sinking fund not used since near end of study period)

WTE Operating Costs

2014 to Future	$	6,445,000	Annual Operating Cost
2014 to Future	$	489,000	Annual Electrical Sales Revenue

Residual Waste and Ash Landfill Costs (46% of waste stream - Based on adjustments of Alt 1-2 landfill costs)

Capital Costs

2009	$	22,825,361	Scale, Control Building, Line entire acreage, LCRS, Site Work
2013	$	1,790,609	LFG Control System and Flare for 60 Acres @$10k/acre & $150,000 Flare- (x Guam/CA ACF)
Finance	$	1,594,834	Annual pmt for financing of above 2 items (PMT(rate,nper,pv,fv,type))
2058	$	5,845,658	Prorate closure cap to end of 50 year period (50 of 65 year site life [See Table 4-1])
Fund		$93,032	Annual closure fund contribution (2009 to year shown- includes fund interest)

LF Oper Costs

Ref to 2014	$	717,802	Reference Annual Landfill Operating & Collection Cost 2007 (Includes Refuse Trucks and Drivers - prorated to 2015)
2014 to future	$	299,993	Annual Landfill Operating Cost 2014 - 80% of landfill only cost for Alt 1-2)
2014 to future	$	1,675,593	Collection Cost for Refuse trucks and Drivers
2015 to future	$	40,000	Additional Annual LFG Control Operating Cost - $50,000 (Guam/CA O&M Factor, above)

ALTERNATIVE 4b - Field Erected WTE

2011	$	5,047,000	Permitting, survey, and 70% engineering work
2012	$	37,142,000	40% of Total Construction Cost less Start up, permitting, survey, 70% of engineering costs
2013	$	56,035,000	60% of Total Construction Cost plus Startup; less permitting, survey and engineering
Finance	$	6,363,795	Annual pmt for financing of above 3 items (PMT(rate,nper,pv,fv,type))
2029	$	1,312,500	Minor Life Extension Measures (replacement of system components)
Fund		$66,914	Sinking Fund Annual payment (2011 to year shown)
2034	$	2,625,000	Major Life Extension Measures (replacement of combustion units and major boiler components)
Finance	$	170,070	Annual pmt for financing of above item
2039	$	1,312,500	Minor Life Extension Measures (replacement of system components)
Fund		$125,451	Sinking Fund Annual payment (2029 to year shown)
2049	$	1,312,500	Minor Life Extension Measures (replacement of system components)
Fund		$125,451	Sinking Fund Annual payment (2039 to year shown)
2054	$	2,625,000	Major Life Extension Measures (replacement of combustion units and major boiler components)
Finance	$	170,070	Annual pmt for financing of above item

WTE Operating Costs

2014 to future	$	6,795,000	Annual Operating Cost
2014 to future	$	1,733,000	Annual Electrical Sales Revenue

Residual Waste and Ash Landfill Costs (46% of waste stream - Based on adjustments of Alt 1-2 landfill costs)

2009	$	22,825,361	Scale, Control Building, Line entire acreage, LCRS, Site Work
2013	$	1,790,609	LFG Control System and Flare for 60 Acres @$10k/acre & $150,000 Flare- (x Guam/CA ACF)
Finance	$	1,594,834	Annual pmt for financing of above 2 items (PMT(rate,nper,pv,fv,type))
2058	$	5,845,658	Prorate closure cap to end of 50 year period (50 of 65 y
Fund		$93,032	Annual closure fund contribution (2009 to year shown- includes fund interest)

LF Oper Costs

Ref to 2014	$	717,802	Reference Annual Landfill Operating & Collection Cost
2014 to future	$	299,993	Annual Landfill Operating Cost 2014 - 80% of landfill only cost for Alt 1-2)
2014 to future	$	1,675,593	Collection Cost for Refuse trucks and Drivers
2015 to future	$	40,000	Additional Annual LFG Control Operating Cost - $50,000 (Guam/CA O&M Factor, above)

COMPARISON OF COLLECTION COST INCREASE USING VARIOUS ALTERNATIVE LANDFILLS
(ASSUMED AFTER FULL TROOP RELOCATION - 80% GENERATED IN NORTHERN GUAM)
Cost factor of 100% set for Apra harbor landfill based on 2 full load basis, below - variables in bold

ALT 1,4,6 ASSUMED EXISTING CASE USING APRA HARBOR LANDFILL

	Route time assumptions		Collection cycle		Cumul min	Cum hrs.
	15	yard to route	15	yard to route	15	0.25
	120	Assumed on-route	120	On route first load	135	2.25
Note 1	**40**	Route to LF or back	40	Route to LF	175	2.92
	15	Unload at LF	15	Unload at LF	190	3.17
	40	Break time/day	40	LF to Route	230	3.83
	40	LF to yard	120	On-route second	350	5.83
			15	Route to LF	365	6.08
			15	Unload at LF	380	6.33
			40	LF to yard	420	7.00
			40	Breaks	460	*7.67*

Notes:

1	Assumes 80 percent of waste from AF and Marines located in north - 20 miles one way
100%	% full last load using minutes deduction to get 8 hours total
100%	Total Daily Efficiency prorated over 2 loads
100%	Cost Factor

ALT 2 ASSUMED USING NEW GOV GUAM LANDFILL

	Route time assumptions		Collection cycle		Cumul min	Cum hrs.
	15	yard to route	15	yard to route	15	0.25
	120	Assumed on-route	120	On route first load	135	2.25
Note 2	**70**	Route to LF or back	70	Route to LF	205	3.42
	15	Unload at LF	15	Unload at LF	220	3.67
	40	Break time/day	70	LF to Route	290	4.83
	40	LF to yard	**25**	On-route second	315	5.25
			70	Route to LF	385	6.42
			15	Unload at LF	400	6.67
			40	LF to yard	440	7.33
			40	Breaks	480	*8.00*

Notes:

2	Assumes 80 percent of waste from AF and Marines located in north - 35 miles one way
21%	% full last load using minutes deduction to get 8 hours total
60%	Total Daily Efficiency prorated over 2 loads
140%	Increase Cost Factor

ALT 3 ASSUMED USING NEW NAVY CENTRAL GUAM LANDFILL

	Route time assumptions		Collection cycle		Cumul min	Cum hrs.
	15	yard to route	15	yard to route	15	0.25
	120	Assumed on-route	120	On route first load	135	2.25
Note 3	**50**	Route to LF or back	50	Route to LF	185	3.08
	15	Unload at LF	15	Unload at LF	200	3.33
	40	Break time/day	50	LF to Route	250	4.17
	40	LF to yard	**85**	On-route second	335	5.58
			50	Route to LF	385	6.42
			15	Unload at LF	400	6.67
			40	LF to yard	440	7.33
			40	Breaks	480	*8.00*

Notes:

3	Assumes 80 percent of waste from AF and Marines located in north - 25 miles one way
71%	% full last load using minutes deduction to get 8 hours total
85%	Total Daily Efficiency prorated over 2 loads
115%	Increase Cost Factor

LANDFILL OPERATION COST (current) - Refuse Trucks for Apra Harbor Landfill Location

Description	Quantity	Hours/Day	Wage $/Hour	Equipment Cost, $/Hour	Daily Cost $	Annual Cost $
Personnel						
Manager/Supervisor	1	8	$ 25.00	-	$ 200	$ 50,400
Operator/Equipment Operator (On-site)	1	8	$ 16.12	-	$ 129	$ 32,503
Equipment Operator (On-site)	1	8	$ 16.12	-	$ 129	$ 32,503
Drivers/Operators for Refuse Collection Trucks	8	8	$ 9.50	-	$ 608	$ 153,216
Laborers	3	8	$ 10.29	-	$ 247	$ 62,225
Environmental Specialist	1	2	$ 21.10	-	$ 42	$ 10,634
Equipment						
Dozer Operation	1	4	-	$ 66.77	$ 267	$ 67,304
Refuse Trucks Operation	8	6	-	$ 25.55	$ 1,226	$ 309,017
TOTALS					$ 2,848	$ 717,802
Collection Drivers and Trucks Only						$ 462,233

LANDFILL OPERATION COST (2015 and beyond @ approx 55,000 TPY) - Refuse Trucks (Apra Harbor Landfill Location)

Description	Quantity	Hours/Day	Wage $/Hour	Equipment Cost, $/Hour	Daily Cost, $	Annual Cost, $
Personnel						
Manager/Supervisor	1	8	$ 25.00	-	$ 200	$ 50,400
Operator/Equipment Operator (On-site)	1	8	$ 16.12	-	$ 129	$ 32,503
Equipment Operator (On-site)	1	8	$ 16.12	-	$ 129	$ 32,503
Drivers/Operators for Refuse Collection Trucks	**29**	8	$ 9.50	-	$ 2,204	$ 555,408
Laborers	**5**	8	$ 10.29	-	$ 412	$ 103,708
Environmental Specialist	1	**4**	$ 21.10	-	$ 84	$ 21,269
Equipment						
Dozer Operation	1	**8**	-	$ 66.77	$ 534	$ 134,608
Refuse Trucks Operation	**29**	6	-	$ 25.55	$ 4,445	$ 1,120,185
TOTALS					$ 8,137	$ 2,050,584
Collection Drivers and Trucks Only						$ 1,675,593

ALTERNATIVE 1-1 - LINE INACTIVE AREA OF LANDFILL							
ITEMS OF WORK	QUANTITIES		LABOR COST		TOTAL COST		
	NO OF UNITS	UN-IT	UNIT COST	COST	UNIT COST	COST	
REVISED							

	NO OF UNITS	UNIT	LABOR UNIT COST	LABOR COST	TOTAL UNIT COST	TOTAL COST
001 Landfill Control Building						
Landfill Control Building	600	SF	725	435,000	725	435,000
SUBTOTAL						435,000
TAX					4%	17,400
TOTAL						452,400
002 Truck Scale Facility						
Truck Scale Structure	780	CF	25	19,500	25	19,500
Truck Scale	1	EA	70,000	70,000	70,000	70,000
SUBTOTAL						89,500
TAX					4%	3,580
TOTAL						93,080
003 Closure Cap						
Closure Cap (60 Acres)	1	LS	7,307,073	7,307,073	7,307,073	7,307,073
SUBTOTAL						7,307,073
TAX					4%	292,283
TOTAL						7,599,356
004 Landfill Gas Control System						
LFG Control System (60 Acres)	1	LS	1,721,739	1,721,739	1,721,739	1,721,739
SUBTOTAL						1,721,739
TAX					4%	68,870
TOTAL						1,790,609
005 Leachate Treatment System						
Leachate Treatment System (14.4 Acres)	1	LS	719,924	719,924	719,924	719,924
Mechanical for Leachate Treatment System (14.4 Acres)	1	LS	15,566	15,566	15,566	15,566
Electrical for Leachate Pumps (14.4 Acres)	1	LS	31,132	31,132	31,132	31,132
SUBTOTAL						766,622
TAX					4%	30,665
TOTAL						797,287
006 Site Work						
Chain Link Fence	1100	LF	64	70,683	64	70,683
Gate	1	EA	3,753	3,753	3,753	3,753
SUBTOTAL						74,436
TAX					4%	2,977
TOTAL						77,414
007 Liner and Leachate Collection System						
Liner and Leachate Collection System (14.4 Acres)	1	LS	9,339,554	9,339,554	9,339,554	9,339,554
SUBTOTAL						9,339,554
TAX					4%	373,582
TOTAL						9,713,136

COST MODEL SUMMARY SHEET

PROJECT TITLE			CONTRACT NO. N62742-06-D-1881
ACTIVITY Apra Harbor Naval Complex	LOCATION Guam		AMENDMENT NO.
PREPARED BY (Name)	TITLE OR ORGANIZATION HDR|Hawaii Pacific Engineers, Inc.	DATE	TYPE OF ESTIMATE
ACF / FY	FER	CATEGORY CODE	COST ESCALATED TO

	$/SYS	SYS QUAN (UM)	TOTAL	BUILDING	BUILT-IN EQUIPMENT
ALTERNATIVE 1-1 - LINE INACTIVE AREA OF LANDFILL					
PRIMARY FACILITIES					
001 Landfill Control Building	$ 452,400	1	$ 452,400.0		
002 Truck Scale Facility	$ 93,080	1	$ 93,080.0		
003 Closure Cap	$ 7,599,356	1	$ 7,599,355.9		
004 LFG Control System (60 Acres)	$ 1,790,609	1	$ 1,790,609		
005 Leachate Treatment System	$ 797,287	1	$ 797,286.9		
006 Site Work	$ 77,414	1	$ 77,413.6		
007 Liner and Leachate Collection System	$ 9,713,136	1	$ 9,713,136.2		
			$ 20,523,281.2		

ALTERNATIVE 1-2 - LINE EXIST AND INACTIVE AREA OF LANDFILL								
	ITEMS OF WORK	QUANTITIES		LABOR COST		TOTAL COST		
	REVISED	NO OF UNITS	UN-IT	UNIT COST	COST	UNIT COST	COST	
001	**Landfill Control Building**							
	Landfill Control Building	600	SF	725	435,000	725	435,000	
	SUBTOTAL						435,000	
	TAX					4%	17,400	
	TOTAL						452,400	
002	**Truck Scale Facility**							
	Truck Scale Structure	780	CF	25	19,500	25	19,500	
	Truck Scale	1	EA	70,000	70,000	70,000	70,000	
	SUBTOTAL						89,500	
	TAX					4%	3,580	
	TOTAL						93,080	
003	**Closure Cap**							
	Closure Cap (60 Acres)	1	LS	7,307,073	7,307,073	7,307,073	7,307,073	
	SUBTOTAL						7,307,073	
	TAX					4%	292,283	
	TOTAL						7,599,356	
004	**Landfill Control System**							
	LFG Control System (60 Acres)	1	LS	1,721,739	1,721,739	1,721,739	1,721,739	
	SUBTOTAL						1,721,739	
	TAX					4%	68,870	
	TOTAL						1,790,609	
005	**Leachate Treatment System**							
	Leachate Treatment System (60 Acres)	1	LS	1,520,784	1,520,784	1,520,784	1,520,784	
	Mechanical for Leachate Treatment System (60 Acres)	1	LS	32,882	32,882	32,882	32,882	
	Electrical for Leachate Pumps (60 Acres)	1	LS	65,764	65,764	65,764	65,764	
	SUBTOTAL						1,619,430	
	TAX					4%	64,777	
	TOTAL						1,684,207	
006	**Site Work**							
	Chain Link Fence	1100	LF	64	70,683	64	70,683	
	Gate	1	EA	3,753	3,753	3,753	3,753	
	SUBTOTAL						74,436	
	TAX					4%	2,977	
	TOTAL						77,414	
006	**Liner and Leachate Collection System**							
	Liner and Leachate Collection System (60 Acres)	1	LS	19,729,096	19,729,096	19,729,096	19,729,096	
	SUBTOTAL						19,729,096	
	TAX					4%	789,164	
	TOTAL						20,518,260	

COST MODEL SUMMARY SHEET

PROJECT TITLE				CONTRACT NO. N62742-06-D-1881
ACTIVITY Apra Harbor Naval Complex		LOCATION Guam		AMENDMENT NO.
PREPARED BY (Name)	TITLE OR ORGANIZATION HDR|Hawaii Pacific Engineers, Inc.		DATE	TYPE OF ESTIMATE
ACF	FY	FER	CATEGORY CODE	COST ESCALATED TO

	$/SYS	SYS QUAN (UM)	TOTAL	BUILDING	BUILT-IN EQUIPMENT
ALTERNATIVE 1-2 - LINE EXIST AND INACTIVE AREA OF LANDFILL					
PRIMARY FACILITIES					
001 Landfill Control Building	$ 452,400	1	$ 452,400		
002 Truck Scale Facility	$ 93,080	1	$ 93,080		
003 Closure Cap	$ 7,599,356	1	$ 7,599,356		
004 Landfill Control System	$ 1,790,609	1	$ 1,790,609		
005 Leachate Treatment System	$ 1,684,207	1	$ 1,684,207		
006 Site Work	$ 77,414	1	$ 77,414		
007 Liner and Leachate Collection System	$20,518,260	1	$ 20,518,260		
			$ 32,215,325		

ALTERNATIVE 2 - USE GOVGUAM LANDFILL CLOSE EXISTING UNLINED LANDFILL							
	ITEMS OF WORK	QUANTITIES		COST		TOTAL COST	
	REVISED	NO OF UNITS	UN-IT	UNIT COST	COST	UNIT COST	COST
001	**Landfill Control Building**						
	Landfill Control Building	600	SF	725	435,000	725	435,000
	SUBTOTAL						435,000
	TAX					4%	17,400
	TOTAL						452,400
002	**Truck Scale Facility**						
	Truck Scale Structure	780	CF	25	19,500	25	19,500
	Truck Scale	1	EA	70,000	70,000	70,000	70,000
	SUBTOTAL						89,500
	TAX					4%	3,580
	TOTAL						93,080
003	**Closure Cap**						
	Closure Cap (60 Acres)	1	LS	7,307,073	7,307,073	7,307,073	7,307,073
	SUBTOTAL						7,307,073
	TAX					4%	292,283
	TOTAL						7,599,356
004	**Landfill Gas Venting System**						
	LFG Venting System (60 Acres)	1	LS	182,677	182,677	182,677	182,677
	SUBTOTAL						182,677
	TAX					4%	7,307
	TOTAL						189,984
005	**Site Work**						
	Chain Link Fence	1100	LF	64	70,683	64	70,683
	Gate	1	EA	3,753	3,753	3,753	3,753
	SUBTOTAL						74,436
	TAX					4%	2,977
	TOTAL						77,414

COST MODEL SUMMARY SHEET

PROJECT TITLE						CONTRACT NO. N62742-06-D-1881
ACTIVITY Apra Harbor Naval Complex			LOCATION Guam			AMENDMENT NO.
PREPARED BY (Name)		TITLE OR ORGANIZATION HDR|Hawaii Pacific Engineers, Inc.		DATE		TYPE OF ESTIMATE
ACF	FY		FER	CATEGORY CODE		COST ESCALATED TO

	$/SYS	SYS QUAN (UM)	TOTAL	BUILDING	BUILT-IN EQUIPMENT
ALTERNATIVE 2 - USE GOVGUAM LANDFILL CLOSE UNLINED LANDFILL					
PRIMARY FACILITIES					
001 Landfill Control Building	452,400	1	452,400		
002 Truck Scale Facility	93,080	1	93,080		
003 Closure Cap	7,599,356	1	7,599,356		
004 Landfill Gas Venting System	189,984	1	189,984		
005 Site Work	77,414	1	77,414		
			8,412,234		

ALTERNATIVE 3 - NEW LANDFILL						
ITEMS OF WORK	QUANTITIES		LABOR COST		TOTAL COST	
REVISED	NO OF UNITS	UN-IT	UNIT COST	COST	UNIT COST	COST
001 Landfill Control Building						
Landfill Control Building	600	SF			1,102	661,000
SUBTOTAL						661,000
TAX					4%	26,440
TOTAL						687,440
002 Truck Scale Facility						
Truck Scale Structure	780	CF			37	29,000
Truck Scale	1	EA			106,000	106,000
SUBTOTAL						135,000
TAX					4%	5,400
TOTAL						140,400
003 Leachate Treatment System						
Leachate Treatment System (60 Acres)	1	LS			2,103,000	2,103,000
Mechanical for Leachate Treatment System (60 Acres)	1	LS			45,000	45,000
Electrical for Leachate Pumps (60 Acres)	1	LS			91,000	91,000
SUBTOTAL						2,239,000
TAX					4%	89,560
TOTAL						2,328,560
004 Site Work						
Clearing and Grubbing	1	LS			101,000	101,000
Chain Link Fence	6000	LF			97	583,000
Gate	1	EA			6,000	6,000
Earthwork	1200000	CY			10	12,000,000
Gunite Lining, fiber reinforced, 4-in thick	2000000	SF			23	46,000,000
Potable Water	1	LS			21,000	21,000
Septic Tank and Subsurface Disposal	1	LS			168,000	168,000
Groundwater Monitoring Wells	1	LS			1,885,000	1,885,000
Electrical	1	LS			402,000	402,000
Mechanical	1	LS			749,000	749,000
SUBTOTAL						61,915,000
TAX					4%	2,476,600
TOTAL						64,391,600
005 Liner and Leachate Collection System						
Liner and Leachate Collection System (60 Acres)	1	LS			27,288,000	27,288,000
SUBTOTAL						27,288,000
TAX					4%	1,091,520
TOTAL						28,379,520

COST MODEL SUMMARY SHEET

PROJECT TITLE				CONTRACT NO. N62742-06-D-1881
ACTIVITY Apra Harbor Naval Complex		LOCATION Guam		AMENDMENT NO.
PREPARED BY (Name)	TITLE OR ORGANIZATION HDR|Hawaii Pacific Engineers, Inc.		DATE	TYPE OF ESTIMATE
ACF	FY	FER	CATEGORY CODE	COST ESCALATED TO

	$/SYS	SYS QUAN (UM)	TOTAL	BUILDING	BUILT-IN EQUIPMENT
ALTERNATIVE 3 - NEW LANDFILL					
PRIMARY FACILITIES					
001 Landfill Control Building	$ 687,440	1	$ 687,440		
002 Truck Scale Facility	$ 140,400	1	$ 140,400		
003 Leachate Treatment System	$ 2,328,560	1	$ 2,328,560		
004 Site Work	$ 64,391,600	1	$ 64,391,600		
005 Liner and Leachate Collection System	$ 28,379,520	1	$ 28,379,520		
			$ 95,927,520		

Project:	**Guam Modular WTE Feasibility Study**
Technology:	**Modular Mass Burn Facility 120 tpd-7 days per week**
Date:	**02/12/08**
Estimate Basis:	**Conceptual Layout (Average 120tpd)**
Costs:	**2008$**
Location:	**Guam**

ALTERNATIVE 4a

COST SUMMARY[1]

MODULAR MASS BURN FACILITY

Conceptual Layout (Average 120tpd)

TOTAL CAPITAL COST	$41,390,000	to	$50,588,000
ANNUAL OPERATION & MAINTENANCE COST	$6,445,154	to	$7,090,000
ANNUAL COST	$10,661,154	to	$12,242,000
YEAR 2008 ANNUAL TONNAGE	37,230	Short tons	
COST PER TON (Before Energy Revenues)	$286	to	$329

Notes
(1) All costs are presented in 2008 Dollars

Project:	**Guam Modular WTE Feasibility Study**	
Technology:	**Modular Mass Burn Facility**	**120 tpd-7 days per week**
Date:	**02/12/08**	
Estimate Basis:	**Conceptual Layout (Average 120tpd)**	
Costs:	**2008$**	
Location:	**Guam**	

ALTERNATIVE 4a
MODULAR MASS BURN FACILITY
CAPITAL COST SUMMARY [1]
Conceptual Layout (Average 120tpd)

			Estimated Costs[2]
I.	SITE AQUISITION		$ -
II.	SITE DEVELOPMENT		$ 2,739,400
III.	SCALE HOUSE AND SCALES		$ 247,101
IV.	BUILDINGS		$ 6,456,100
V.	PROCESSING EQUIPMENT		$ -
VI.	MOBILE EQUIPMENT		$ 699,900
VII.	POWER BLOCK EQUIPMENT		$ 19,916,224
	SUBTOTAL CONSTRUCTION AND EQUIPMENT		$ 30,058,726
	CONTINGENCY	25%	$ 7,514,700
	SALES TAX	4%	$ 1,502,900
	DESIGN/ENGINEERING	8%	$ 3,005,900
	PERMITTING		$ 450,000
	SURVEYING AND SOILS REPORT		$ 75,000
	CONSTRUCTION INSPECTION	5%	$ 1,878,700
	START UP AND TESTING	4%	$ 1,502,900
	TOTAL CAPITAL COST (FACILITY IMPLEMENTATION)		$ 45,988,826

Project:	**Guam Modular WTE Feasibility Study**	
Technology:	**Modular Mass Burn Facility**	**120 tpd-7 days per week**
Date:	**02/12/08**	
Estimate Basis:	**Conceptual Layout (Average 120tpd)**	
Costs:	**2008$**	
Location:	**Guam**	

NOTES:

(1) All costs rounded to 1000's

(2) All costs in 2008 $.

I. SITE AQUISITION

Subtotal I	$0

II. SITE DEVELOPMENT

Item	Quantity	Units	Unit Price	Item Cost		Total
Site Preparation					$	367,400
Excavation - foundations(1)	9,400	cy	$17	$159,300		
General Earthwork (2)	15,100	cy	$14	$204,700		
Finishing Grassing & Grading	1	acres	$3,390	$3,400		
Demolition	0	cy material	$339	$0		
Site Improvements					$	1,312,700
Approach /Roadways Concrete (3)	4,000	sy	$102	$406,800		
Asphalt Roadways & Parking	5,000	sy	$68	$339,000		
Retaining Walls	400	cy	$847	$339,000		
Site Drainage	1	L.S.	$127,110	$127,100		
Fencing(4)	2,000	lf	$25	$50,800		
Landscaping (Minimal)	1	L.S.	$50,000	$50,000		
Site Utilities (5)					$	1,059,300
Fire Protection	2,000	lf	$42	$84,700		
Water Supply	1,500	lf	$42	$63,600		
Well Field	0	LS	$50,000	$0		
Sewer System	1,500	lf	$42	$63,600		
Electrical Substation	1	L.S.	$847,399	$847,400		
Subtotal II					$	2,739,400

Notes:

(1) Based on estimated building square footages. Demolition calculated separately below

(2) General Earthwork includes moving soil, backfill, embankment, loadout tunnel excav, etc.

(3) Roadway unit price includes curbs, gutters, etc.

(4) Assumes perimeter fencing at 6' (w/ barbed wire) with gates and litter fencing around maneuvering area of 15' height.

(5) Utilities unit price includes excavation, bedding material, piping installed, backfill, etc.

III. SCALE HOUSE AND SCALES

Item	**Quantity**	**Units**	**Unit Price**	**Item Cost**	**Total**
Metal Building (1)	400	sf	$153	$61,013	
Concrete Slabwork(2)	15	cy	$339	$5,084	
Concrete Footings	10	cy	$678	$6,779	
Interior Treatments(3)	400	sf	$85	$33,896	
Motor Truck Scales & Foundations	2	LS	$93,214	$186,428	
Mechanical(4)	400	sf	$17	$6,779	
Electrical(5)	400	sf	$20	$8,135	
Subtotal III					$247,101

Notes:

(1) No additional facilities for waste delivery truck drivers or admintration activities areas, are included.

(2) Assumes stable soil with good load bearing capacity. Slab floor is 6" reinforced concrete.

(3) Includes tile, painting, window covers and funiture

(4) Building mechanical includes drains, plumbing, air handling, fire protection, etc.

(5) Electrical includes lighting, power, communications, etc.

Project:	**Guam Modular WTE Feasibility Study**	
Technology:	**Modular Mass Burn Facility**	**120 tpd-7 days per week**
Date:	**02/12/08**	
Estimate Basis:	**Conceptual Layout (Average 120tpd)**	
Costs:	**2008$**	
Location:	**Guam**	

IV. BUILDINGS

Item	Quantity	Units	Unit Price	Item Cost	Total
Metal Buildings - Preengineered (1) (2)	13,000	sf	$ 153	$1,982,900	
Ash Concrete Push Walls(3)	100	cy	$ 678	$67,800	
Metal Buildings - Engineered	672,000	cf	$ 6	$3,986,200	
Concrete Pit (3)	0	cy	$ 400	$0	
Overhead Doors	4	ea	$ 16,948	$67,800	
Admin. Area	1,728	sf	$ 203	$351,400	
Subtotal IV					$6,456,100

Notes:

(1) Metal bldg. includes structural steel, column free bldg. (long span), 30 ft. clear height, & 20 yr roofing warranty with mechanical and electrical.

(2) Assumes stable soil with good load bearing capacity. Slab floor is 10" reinforced concrete on grade;
12" on structural slabs

(3) 4 ft thick wall with 10 ft thick mat

V. PROCESSING EQUIPMENT

Item	Quantity	Type	Units	Unit Price	Item Cost	Total
Overhead Cranes NOT USED		Hydraulic Grapple	0	$ 259,560	$ -	
Subtotal V						$0

Notes:

VI. MOBILE EQUIPMENT

Item	Quantity	Units	Unit Price	Item Cost	Total
Ash Trucks and Trailers	1	ea	$211,850	$211,800	
Loader	1	ea	$254,220	$254,200	
Back up Loader	1	ea	$200,000	$200,000	
Pick-up/Utility Truck	1	ea	$33,896	$33,900	
Subtotal VI					$699,900

Notes:

(1) Loader used for fuel handling

Project:	**Guam Modular WTE Feasibility Study**		
Technology:	**Modular Mass Burn Facility**	**120**	**tpd-7 days per week**
Date:	**02/12/08**		
Estimate Basis:	**Conceptual Layout (Average 120tpd)**		
Costs:	**2008$**		
Location:	**Guam**		

VII. POWER BLOCK EQUIPMENT

Item	Quantity	Unit	Unit Price	Item Cost	Total
Modular Mass Burn Incinerator (1)	3	ls	$956,712	$2,870,100	
Heat Recovery Boiler(1)	3	ls	$260,073	$780,200	
SNCR (NOx Control)	0	ls	$89,598	$0	
Air Pollution Control Equipment(1)	3	ls	$673,425	$2,020,300	
Continuous Emissions Monitoring	3	ls	$288,541	$865,624	
Bottom Ash Quench(1)	3	ls	$54,048	$162,100	
Bottom Ash Conveying	1	ls	$400,000	$400,000	
Flyash Handling/Conditioning	3	ls	$299,799	$899,400	
Aux Cooling Water System	1	ls	$46,448	$46,400	
Condensate System	1	ls	$160,456	$160,500	
Chem Feed	1	ls	$87,265	$87,300	
Circulating Water System	1	ls	$137,232	$137,200	
Waste Water System	1	ls	$161,863	$161,900	
Water Treatment	1	ls	$157,641	$157,600	
Fire Protection	1	ls	$135,825	$135,800	
Feedwater System(1)	1	ls	$125,370	$125,400	
Compressed Air System	1	ls	$34,484	$34,500	
Service Water System	1	ls	$33,076	$33,100	
Steam Piping	1	ls	$46,448	$46,400	
Steam Turbine (2)	1	ls	$557,200	$557,200	
Electrical System	1	ls	$2,060,591	$2,060,600	
Equipment Subtotal					$11,741,624
Boiler Erection (Labor)	1	ls	$2,835,300	$2,835,300	
Steam Turbine Installation(2)	1	ls	$390,040	$390,000	
Mechanical Systems Installation (Labor)	1	ls	$2,375,906	$2,375,900	
Electrical Installation (Labor)	1	ls	$1,556,783	$1,556,800	
Ocean Freight	3	ls	$200,000	$600,000	
Installation Subtotal					$7,758,000
Shop Tools & Equip.	1	Allowance	$122,531	$122,500	
Control Room Furnishings	1	Allowance	$49,012	$49,000	
Spare Parts	1	Allowance	$245,061	$245,100	
Miscellaneous Items					$416,600
Subtotal VII					**$19,916,224**

Notes:

(1) Based on equipment quote from Pennram

(2) Based on equipment qoute and installation estimate from Turbosteam

Subtotal I through VII	**$30,058,726**

Project:	**Guam Modular WTE Feasibility Study**	
Technology:	**Modular Mass Burn Facility**	**120 tpd-7 days per week**
Date:	**02/12/08**	
Estimate Basis:	**Conceptual Layout (Average 120tpd)**	
Costs:	**2008$**	
Location:	**Guam**	

ALTERNATIVE 4a
MODULAR MASS BURN FACILITY
OPERATIONS AND MAINTENANCE COST SUMMARY (1)
Conceptual Layout (Average 120tpd)

			Estimated Costs(2)
I.	LABOR		$ 1,778,000
II.	FACILITY MAINTENANCE		$ 844,000
III.	UTILITIES		$ 932,928
IV.	PROCESS RESIDUE HAUL & DISPOSAL		$ 419,226
V.	ROLLING STOCK O&M COSTS		$ 126,900
VI.	MISCELLANEOUS COSTS		$ 91,100
	SUBTOTAL OPERATION & MAINTENANCE		$ 4,192,154
	CONTINGENCY	25%	$ 1,048,000
	OVERHEAD AND PROFIT	15%	$ 786,000
	ACCOUNTING, SUPPLIES, MISC.	5%	$ 262,000
	ADMINISTRATION	3%	$ 157,000
TOTAL ANNUAL OPERATION & MAINTENANCE COST			$ 6,445,154
VII.	MINUS	SALES REVENUES(3)	$ 489,194
NET ANNUAL OPERATION & MAINTENANCE COST			$ 5,955,960

NOTES:
(1) All costs rounded to 1000
(2) All costs in 2008$
(3) Doesn't include ferrous revenues

Project:	**Guam Modular WTE Feasibility Study**	
Technology:	**Modular Mass Burn Facility**	**120 tpd-7 days per week**
Date:	**02/12/08**	
Estimate Basis:	**Conceptual Layout (Average 120tpd)**	
Costs:	**2008$**	
Location:	**Guam**	

I. LABOR

Job Classification	Personnel(1)	$/hr(2)	hrs/yr (3)	Over-time Hrs	Annual Cost	% OT	Total
Facility Manager	1	$54	2,080	0	$112,000	0%	
Operating Engineer	1	$47	2,080	0	$98,000	0%	
Administrative/Clerical	1	$20	2,080	208	$48,000	10%	
Scale Attendant	2	$24	2,080	208	$116,000	10%	
Lead Equipment Operator	4	$41	2,080	312	$413,000	15%	
Equipment Operators	8	$30	2,080	312	$605,000	15%	
Mechanic	1	$34	2,080	208	$81,000	10%	
Electrician/Electronics Specialis	1	$34	2,080	208	$81,000	10%	
Welders	1	$34	2,080	208	$81,000	10%	
Helper	0	$20	2,080	208	$0	10%	
Residue Disposal Drivers	1	$27	2,080	208	$65,000	10%	
Spotters/Laborers	2	$16	2,080	208	$78,000	10%	
Subtotal	23						$1,778,000

Notes:

(1) Based on a 24-hour, seven day per week operation.

(2) Includes fringe benefits (retirement, ss, workers comp, health & life insurance, vacation/sick leave) at 35%
and overtime rate is at 1.5 times straight time

(3) Assumes standard working shift hours 5 Days/Wk 8 Hr/Day

II. FACILITY MAINTENANCE

Item	% of Capital Value	Quantity	Unit	Unit Price	Annual Cost	Total
Site Maintenance(1)	1.5%	1	Lump	$ 35,580	$35,580	
Building Repair & Replacement	3.3%	1	Lump	$ 221,000	$221,000	
Equipment Maintenance (3)	2.0%	1	Lump	$ 234,832	$234,832	
Equipment Replacement (4)	3.0%	1	Lump	$ 352,249	$352,249	
Subtotal						$ 844,000

Notes:

(1) Percentage of capital value is based on empirical data from operating plants in the U.S.

(2) Site maintenance is estimated as % capital construction cost for site improvements and site utilities.

(3) Buidling repair base on a 30 year depreciation of the original capital cost with escalation.

(4) Equipment maintenance (annual needs) and replacement (periodic needs) estimated based on assumed 20 life.

Project:	Guam Modular WTE Feasibility Study		
Technology:	Modular Mass Burn Facility	120	tpd-7 days per week
Date:	02/12/08		
Estimate Basis:	Conceptual Layout (Average 120tpd)		
Costs:	2008$		
Location:	Guam		

III. UTILITIES

Item	Quantity	Unit	Unit Price	Annual Cost	Total
Electricity Purchase (1)	127	MWh/yr	$ 200	$ 25,316	
Propane(2)	308	Gal/Yr	$ 3.39	$ 1,043	
Diesel (3)	206,361	Gal/Yr	$ 3.75	$ 773,852	
Telephone (Mobile/Fixed) (4)	20	Phones	$ 480	$ 9,600	
Water	32,830,965	Gal/Yr	$ 0.003	$ 98,493	
Sewer (5)	8,207,741	Gal/Yr	$ 0.003	$ 24,623	
Subtotal					$ 932,928

Notes:

(1) Electricity purchase accounts for energy use during downtimes only; inhouse power provided by the system otherwise.

(2) Propane used for burner ignition 2008 price ratioed according with diesel prices plus 10%

(3) Diesel used for start-up and shutdown and to maintain "good combustion control" in secondary chamber

(4) Based on mobile phones for entire staff except drivers, helpers and laborers.

(5) Sewer use based on 25% of water use; evaporation and ash quench account for rest.

IV. PROCESS RESIDUE HAUL & DISPOSAL

Item	Cost /Load(1)	Quantity	Unit	Unit Price	Annual Cost	Total
Process Residue Haul	$ 75	503	Tons	$ 3.75	$ 1,886	
Ash Haul	$ 75	14,079	Tons	$ 3.75	$ 52,796	
Landfill Disposal Fees		14,582	Tons	$ 25.00	$ 364,545	
Subtotal						$ 419,226

Notes:

(1) Cost assumes truck operating costs per 20-ton load

V. ROLLING STOCK O&M COSTS

Fuel	Weeks	Unit Rate	Units	Unit Price	Annual Cost	Total
Loader	52	200	gal/wk	$ 3.75	$39,000	
Back up Loader	52	100	gal/wk	$ 3.75	$19,500	
Pick-up Truck	52	30	gal/wk	$ 3.75	$5,900	
Maintenance	**# Vehicles**	**Quantity**	**Units**	**Unit Price**	**Annual Cost**	**Total**
Loader	1	1	L.S.	$13,982	$14,000	
Pick-up Truck	1	12,000	Miles/Yr	$0.50	$6,000	
General O&M		1	L.S.	$42,500	$42,500	
Subtotal						$126,900

Notes:

(1) Based on Owning and Operationg Cost Methodology in the Catepillar Performance Handbook.

Project:	**Guam Modular WTE Feasibility Study**	
Technology:	**Modular Mass Burn Facility**	**120 tpd-7 days per week**
Date:	**02/12/08**	
Estimate Basis:	**Conceptual Layout (Average 120tpd)**	
Costs:	**2008$**	
Location:	**Guam**	

VI. MISCELLANEOUS COSTS

Item	Useage (1)	Quantity	Unit	Unit Price	Annual Cost	Total
Property Insurance (2)	1	0.3%			$88,100	
Flood Insurance (2)	0	1.2%			$0	
Property Taxes (3)	1	3,252	m2	$0.78	$3,000	
Subtotal						$ 91,100

Notes:

(1) Multiplier used to adjust costs for various potential sites. Zero means expense not appicalbe to this site.

(2) Based on % of capital construction costs.

(3) Based on area of developed property.

Subtotal I through VI	$4,192,154

VII. SALES REVENUES(3)

Material	Units	Unit	Unit Value	Annual Revenues	Total
Net Electric Generation	4,447	MWh	$110	$489,194	Addressed in Pro Forma
Net Steam Generation	176,843	Mlbs.	$0	$0	Addressed in Pro Forma
Aluminum	-	Tons	$800	$0	No recovery provided
Ferrous Metals	-	Tons	$25	$0	
Subtotal VII					$489,194

Water Usage Estimates — 120 TPD

		Conversion factor =	3.785412
Domestic	**Assumptions**	**Gallons/Yr**	**Liters/Year**
Average People/Day	5.48		
gpd/person	25		
gallons per day	137		
days/week	7		
weeks/year	52		
gallons per year		49,833	188,640
Blowdown/Spray Dryer	4%	947,482	
Spray Dryer(Lb/hr Water/tpd Fuel)	212.00	2,950,564	
Ash Quench(15% moisture)	5.80	423,529	
Cooling Tower (blowdown 20% evap.)		28,424,448	
Washdown		35,100	132,868
Total Water Usage		32,830,957	124,278,698
Evaporation/Ash Quench	75%	24,623,218	93,209,023
Total Sewer Usage		8,207,739	31,069,674

Reagent Usage Estimates

	Qty/Ton
Lime (Lbs/Ton)	20
Ammonia (lbs/Ton)	NA
Carbon (Lbs/Ton)	0.66

Energy Generation Assumptions

	Gross Generation Amount/Ton	**In-House Power Amount/Ton**	**Net Generation Amount/Ton**		**Net Annual Generation**	
Steam Production (mlb)	5.41	0.66	4.75	=	176,843	Mlbs.
Electricity Production (kWh)	136	16.55	119	=	4,447	MWh
Single stage condensing turbine	0.68	MW at	27,040	lbs/hr	0%	Margin

Energy Consumption Assumptions

Item	**mmBtu/Ton**	**Btu/Gal**	**MMBTU**	**Gal/yr**
Propane (mmBtu)	0.000757	91600	28	308
Diesel (mmBtu)	0.776	140000	28,890	206,361

Item	**Qty/Ton**	**hp**	**load factor**	**kw**	**hrs/year**	**kwh/yr**
Power Purchase Req. (kWh/Ton)	3.4					126,582
Total Purchase						126,582

MSW Quanitites and Characteristics

Waste Quantity	40,000	tpy		
Daily Delivery	110	tpd - 7 days per weeks		
Capacity Factor	85%			
Delivery Capacity	129	tpd - 5 days per week		
Annual Throughput	37,230	tpy		
MSW HHV (B&W)	5,200	Btu/lb		
Boiler Efficiency (B&W)	65%			
Fuel Feed Rate (B&W)	10,000	Lbs/Hr at	120	tons/day
Gross Steam Production (B&W)	27,040	Lb/Hr	5408	lbs(steam)/ton

MSW Storage Calculations

Floor Storage Days	3	Days		
Floor Storage Tons	387	tons		
MSW Density	17	lb/cf		
MSW Volume Capacity	46,414	cu. ft.		
Pit Area - NOT USED	900	SF	35	ft deep plus 50% of vol. up to charging level
Pit length - NOT USED	26	ft at	35	feet wide

Residue Disposal

Assumes 5% unburned and combined fly ash and bottom ash with scrubber residue.

Residue Disposal	1.5%	2	tpd5	0.1	Truckloads/Day5
Ash Disposal	30%	38.7	tpd7	2	Truckloads/Day7
Truck Payload (Tons)	20			2.0	Truckloads/Day
		28	HRS/week	4	HRs/day
				2	Round Trip Haul

Basic Conceptual Layout Dimensions

		Length	Span	Area	Height	Number of Stories	Size
Conversion Factor	**M to Ft**	**3.28084**	**3.28084**	**10.76391111**	**3.28084**		**Adjustment**
Exterior Maneuvering	Feet	150.0	60.0	9,000			
	Meters	45.7	18.3	836			
MSW Tipping Floor	Feet	75.0	150.0	11,250	40.0	1.0	
	Meters	22.9	45.7	1,045	12.2		
Boiler Bldg	Feet	35.0	150.0	5,250	115.0	1.0	
	Meters	10.7	45.7	488	35.1		
Turbine Building	Feet	50.0	45.0	4,500	15.0	2.0	
	Meters	15.2	13.7	209	4.6		
Maintenance/Storage	Feet	48.0	36.0	1,728	16.4	1.0	0.8
	Meters	14.6	11.0	161	5		
Admin/ Control Room	Feet	48.0	36.0	1,728	16.4	1.0	0.8
	Meters	14.6	11.0	161	5		
Refuse Storage Bldg (Pit)	Feet		35.0	-	115.0	1.0	
	Meters	0.0	10.7	-	31		
Ash Storage Bldg	Feet	35.0	30.0	1,050	30.0	1.0	0.75
	Meters	10.7	9.1	98	9.1		
Site Development	Feet	350.0	100.0	35,000			
	Meters	106.7	30.5	3,252			
		Total Bldg Floor Area		14,256			

Modular Mass Burn Facility

Capital Cost	$	45,989,000	
Life Extension Measures	$	32,315,424	Capital cost less site work, scalehouse and scales, buildings, mobile equipment, engineering, permitting, survey
Operating Cost	$	6,445,000	
Energy Revenue	$	489,000	

2008 Dollars

Capital Cost Breakdown			
Year 0	$	2,629,000	Permitting, survey, and 70% engineering work
Year 1	$	17,284,000	40% of total less start up, permitting, survey, 70% of engineering
Year 2	$	26,076,000	60% of total plus startup less permitting, survey and engineering
Total	$	45,989,000	

Life Extension			
Year 15	$	8,079,000	25%
Year 20	$	16,158,000	50%
Year 25	$	8,079,000	25%

Project:	**Guam Field Erected WTE Feasibility Study**	
Technology:	**Mass Burn Facility**	**150 tpd-7 days per week**
Date:	**04/09/08**	
Estimate Basis:	**Conceptual Layout (Average 150tpd)**	
Costs:	**2008$**	
Location:	**Guam**	

ALTERNATIVE 4b
COST SUMMARY[(1)]
MASS BURN FACILITY
Conceptual Layout (Average 150tpd)

TOTAL CAPITAL COST	$88,401,000	to	$108,046,000
ANNUAL OPERATION & MAINTENANCE COST	$6,795,174	to	$7,475,000
ANNUAL COST	$15,799,174	to	$18,480,000
YEAR 2003 ANNUAL TONNAGE	37,230	Short tons	
COST PER TON (Before Energy Revenues)	$424	to	$496

Notes
(1) All costs are presented in 2008 Dollars

Project:	**Guam Field Erected WTE Feasibility Study**	
Technology:	**Mass Burn Facility**	**150 tpd-7 days per week**
Date:	**04/09/08**	
Estimate Basis:	**Conceptual Layout (Average 150tpd)**	
Costs:	**2008$**	
Location:	**Guam**	

ALTERNATIVE 4b
MASS BURN FACILITY
CAPITAL COST SUMMARY [1]
Conceptual Layout (Average 150tpd)

				Estimated Costs[2]
I.	SITE AQUISITION		$	-
II.	SITE DEVELOPMENT		$	2,491,900.00
III.	SCALE HOUSE AND SCALES		$	247,101
IV.	BUILDINGS		$	6,320,500
V.	PROCESSING EQUIPMENT		$	879,803
VI.	MOBILE EQUIPMENT		$	499,900
VII.	POWER BLOCK EQUIPMENT		$	54,155,041
	SUBTOTAL CONSTRUCTION AND EQUIPMENT		$	64,594,246
	CONTINGENCY	25%	$	16,148,600
	SALES TAX	4%	$	3,229,700
	DESIGN/ENGINEERING	8%	$	6,459,400
	PERMITTING		$	450,000
	SURVEYING AND SOILS REPORT		$	75,000
	CONSTRUCTION INSPECTION	5%	$	4,037,100
	START UP AND TESTING	4%	$	3,229,700
	TOTAL CAPITAL COST (FACILITY IMPLEMENTATION)		$	98,223,746

NOTES:
(1) All costs rounded to 1000's
(2) All costs in 2008 $.

Project:	**Guam Field Erected WTE Feasibility Study**	
Technology:	**Mass Burn Facility**	**150 tpd-7 days per week**
Date:	**04/09/08**	
Estimate Basis:	**Conceptual Layout (Average 150tpd)**	
Costs:	**2008$**	
Location:	**Guam**	

I. SITE AQUISITION

Subtotal I	$0

II. SITE DEVELOPMENT

Item	Quantity	Units	Unit Price	Item Cost	Total
Site Preparation					$ 194,600
Excavation - foundations(1)	7,600	cy	$17	$128,800	
General Earthwork (2)	4,600	cy	$14	$62,400	
Finishing Grassing & Grading	1	acres	$3,390	$3,400	
Demolition	0	cy material	$339	$0	
Site Improvements					$ 1,238,000
Approach /Roadways Concrete (3)	3,500	sy	$102	$355,900	
Asphalt Roadways & Parking	3,400	sy	$68	$230,500	
Retaining Walls	500	cy	$847	$423,700	
Site Drainage	1	L.S.	$127,110	$127,100	
Fencing(4)	2,000	lf	$25	$50,800	
Landscaping (Minimal)	1	L.S.	$50,000	$50,000	
Site Utilities (5)					$ 1,059,300
Fire Protection	2,000	lf	$42	$84,700	
Water Supply	1,500	lf	$42	$63,600	
Well Field	0	LS	$50,000	$0	
Sewer System	1,500	lf	$42	$63,600	
Electrical Substation	1	L.S.	$847,399	$847,400	
Subtotal II					$ 2,491,900

Notes:

(1) Based on estimated building square footages. Demolition calculated separately below

(2) General Earthwork includes moving soil, backfill, embankment, loadout tunnel excav, etc.

(3) Roadway unit price includes curbs, gutters, etc.

(4) Assumes perimeter fencing at 6' (w/ barbed wire) with gates and litter fencing around maneuvering area of 15' height.

(5) Utilities unit price includes excavation, bedding material, piping installed, backfill, etc.

III. SCALE HOUSE AND SCALES

Item	Quantity	Units	Unit Price	Item Cost	Total
Metal Building (1)	400	sf	$153	$61,013	
Concrete Slabwork(2)	15	cy	$339	$5,084	
Concrete Footings	10	cy	$678	$6,779	
Interior Treatments(3)	400	sf	$85	$33,896	
Motor Truck Scales & Foundations	2	LS	$93,214	$186,428	
Mechanical(4)	400	sf	$17	$6,779	
Electrical(5)	400	sf	$20	$8,135	
Subtotal III					$247,101

Notes:

(1) No additional facilities for waste delivery truck drivers or admintration activities areas, are included.

(2) Assumes stable soil with good load bearing capacity. Slab floor is 6" reinforced concrete.

(3) Includes tile, painting, window covers and funiture

(4) Building mechanical includes drains, plumbing, air handling, fire protection, etc.

(5) Electrical includes lighting, power, communications, etc.

Project:	**Guam Field Erected WTE Feasibility Study**		
Technology:	**Mass Burn Facility**	**150**	**tpd-7 days per week**
Date:	**04/09/08**		
Estimate Basis:	**Conceptual Layout (Average 150tpd)**		
Costs:	**2008$**		
Location:	**Guam**		

IV. BUILDINGS

Item	Quantity	Units	Unit Price	Item Cost	Total
Metal Buildings - Preengineered (1) (2)	3,000	sf	$ 153	$457,600	
Ash Concrete Push Walls(3)	100	cy	$ 678	$67,800	
Metal Buildings - Engineered	792,000	cf	$ 6	$4,698,000	
Concrete Pit (3)	1,000	cy	$ 678	$677,900	
Overhead Doors	4	ea	$ 16,948	$67,800	
Admin. Area	1,728	sf	$ 203	$351,400	
Subtotal IV					$6,320,500

Notes:

(1) Metal bldg. includes structural steel, column free bldg. (long span), 30 ft. clear height, & 20 yr roofing warranty with mechanical and electrical.

(2) Assumes stable soil with good load bearing capacity. Slab floor is 10" reinforced concrete on grade;
12" on structural slabs

(3) 4 ft thick wall with 10 ft thick mat

V. PROCESSING EQUIPMENT

Item	Quantity	Type	Units	Unit Price	Item Cost	Total
Overhead Cranes		Hydraulic Grapple	2	$ 439,902	$ 879,803	
Subtotal V						$879,803

Notes:

VI. MOBILE EQUIPMENT

Item	Quantity	Units	Unit Price	Item Cost	Total
Ash Trucks and Trailers	1	ea	$211,850	$211,800	
Loader	1	ea	$254,220	$254,200	
Pick-up/Utility Truck	1	ea	$33,896	$33,900	
Subtotal VI					$499,900

Notes:

(1) Loader used for ash loading and general maintenance activities

Project:	Guam Field Erected WTE Feasibility Study		
Technology:	Mass Burn Facility	150	tpd-7 days per week
Date:	04/09/08		
Estimate Basis:	Conceptual Layout (Average 150tpd)		
Costs:	2008$		
Location:	Guam		

VII. POWER BLOCK EQUIPMENT

Item	Quantity	Unit	Unit Price	Item Cost	Total
Mass Burn Boiler (1)	1	ls	$19,921,027	$19,921,000	
SNCR (NOx Control)	1	ls	$264,388	$264,400	
Continuous Emissions Monitoring	1	ls	$288,541	$288,541	
Bottom Ash Handling	1	ls	$377,742	$377,700	
Flyash Handling/Conditioning	1	ls	$358,392	$358,400	
Aux Cooling Water System	1	ls	$55,526	$55,500	
Condensate System	1	ls	$191,815	$191,800	
Chem Feed	1	ls	$104,321	$104,300	
Circulating Water System	1	ls	$164,053	$164,100	
Waste Water System	1	ls	$193,498	$193,500	
Water Treatment	1	ls	$188,450	$188,500	
Fire Protection	1	ls	$162,370	$162,400	
Feedwater System	1	ls	$147,227	$147,200	
Compressed Air System	1	ls	$41,224	$41,200	
Service Water System	1	ls	$39,541	$39,500	
Steam Piping	1	ls	$55,526	$55,500	
Steam Turbine	1	ls	$2,563,367	$2,563,400	
Electrical System	1	ls	$2,463,315	$2,463,300	
Equipment Subtotal					$27,580,241
Boiler Erection (Labor)	1	ls	$17,928,924	$17,928,900	
Steam Turbine Installation	1	ls	$1,794,357	$1,794,400	
Mechanical Systems Installation (Labor)	1	ls	$3,250,136	$3,250,100	
Electrical Installation (Labor)	1	ls	$1,724,320	$1,724,300	
Ocean Freight	1	ls	$1,379,012	$1,379,000	
Installation Subtotal					$24,697,700
Shop Tools & Equip.	1	Allowance	$146,478	$146,500	
Control Room Furnishings	1	Allowance	$58,591	$58,600	
Spare Parts	1	Allowance	$292,956	$293,000	
Miscellaneous Items					$498,100
Subtotal VII					**$54,155,041**

Notes:

(1) Based on equipment quote from Babcock and Wilcox

Subtotal I through VII	**$64,594,246**

Project:	**Guam Field Erected WTE Feasibility Study**	
Technology:	**Mass Burn Facility**	**150 tpd-7 days per week**
Date:	**04/09/08**	
Estimate Basis:	**Conceptual Layout (Average 150tpd)**	
Costs:	**2008$**	
Location:	**Guam**	

ALTERNATIVE 4b
MASS BURN FACILITY
OPERATIONS AND MAINTENANCE COST SUMMARY [1]
Conceptual Layout (Average 150tpd)

				Estimated Costs[2]
I.	LABOR			$ 1,778,000
II.	FACILITY MAINTENANCE			$ 1,674,000
III.	UTILITIES			$ 295,426
IV.	PROCESS RESIDUE HAUL & DISPOSAL			$ 369,048
V.	ROLLING STOCK O&M COSTS			$ 107,400
VI.	MISCELLANEOUS COSTS			$ 195,300
		SUBTOTAL OPERATION & MAINTENANCE		$ 4,419,174
		CONTINGENCY	25%	$ 1,105,000
		OVERHEAD AND PROFIT	15%	$ 829,000
		ACCOUNTING, SUPPLIES, MISC.	5%	$ 276,000
		ADMINISTRATION	3%	$ 166,000
TOTAL ANNUAL OPERATION & MAINTENANCE COST				$ 6,795,174
VII.	MINUS	SALES REVENUES[3]		$ 1,732,627
NET ANNUAL OPERATION & MAINTENANCE COST				$ 5,062,547

NOTES:
(1) All costs rounded to 1000
(2) All costs in 2008$
(3) Doesn't include ferrous revenues

Project:	**Guam Field Erected WTE Feasibility Study**
Technology:	**Mass Burn Facility** **150 tpd-7 days per week**
Date:	**04/09/08**
Estimate Basis:	**Conceptual Layout (Average 150tpd)**
Costs:	**2008$**
Location:	**Guam**

I. LABOR

Job Classification	Personnel(1)	$/hr(2)	hrs/yr (3)	Over-time Hrs	Annual Cost	% OT	Total
Facility Manager	1	$54	2,080	0	$112,000	0%	
Operating Engineer	1	$47	2,080	0	$98,000	0%	
Administrative/Clerical	1	$20	2,080	208	$48,000	10%	
Scale Attendant	2	$24	2,080	208	$116,000	10%	
Lead Equipment Operator	4	$41	2,080	312	$413,000	15%	
Equipment Operators	8	$30	2,080	312	$605,000	15%	
Mechanic	1	$34	2,080	208	$81,000	10%	
Electrician/Electronics Specialist	1	$34	2,080	208	$81,000	10%	
Welders	1	$34	2,080	208	$81,000	10%	
Helper	0	$20	2,080	208	$0	10%	
Residue Disposal Drivers	1	$27	2,080	208	$65,000	10%	
Spotters/Laborers	2	$16	2,080	208	$78,000	10%	
Subtotal	23						$1,778,000

Notes:

(1) Based on a 24-hour, seven day per week operation.

(2) Includes fringe benefits (retirement, ss, workers comp, health & life insurance, vacation/sick leave 35%

and overtime rate is at 1.5 times straight time

(3) Assumes standard working shift hours 5 Days/Wk 8 Hr/Day

II. FACILITY MAINTENANCE

Item	% of Capital Value	Quantity	Unit	Unit Price	Annual Cost	Total
Site Maintenance (1) (2)	1.5%	1	Lump	$ 34,460	$34,460	
Building Repair & Replacement (2)	3.3%	1	Lump	$ 217,000	$217,000	
Equipment Maintenance (3)	2.0%	1	Lump	$ 569,201	$569,201	
Equipment Replacement (4)	3.0%	1	Lump	$ 853,801	$853,801	
Subtotal						$ 1,674,000

Notes:

(1) Percentage of capital value is based on empirical data from operating plants in the U.S.

(2) Site maintenance is estimated as % capital construction cost for site improvements and site utilities.

(3) Buidling repair based on a 30 year depreciation of the original capital cost with escalation.

(4) Equipment maintenance (annual needs) and replacement (periodic needs) estimated based on assumed 20 year life.

III. UTILITIES

Item	Quantity	Unit	Unit Price	Annual Cost	Total
Electricity Purchase (1)	139	MWh/yr	$ 200.00	$ 27,796	
Diesel (2)	26,593	Gal/Yr	$ 3.75	$ 99,723	
Telephone (Mobile/Fixed) (3)	20	Phones	$ 480	$ 9,600	
Water	42,215,078	Gal/Yr	$ 0.003	$ 126,645	
Sewer (4)	10,553,770	Gal/Yr	$ 0.003	$ 31,661	
Subtotal					$ 295,426

Notes:

(1) Electricity purchase accounts for energy use during downtimes only; inhouse power provided by the system otherwise.

(2) Diesel used for start-up and shutdown only to maintain "good combustion control"

(3) Based on mobile phones for entire staff except drivers, helpers and laborers.

(4) Sewer use based on 25% of water use; evaporation and ash quench account for rest.

Project:	**Guam Field Erected WTE Feasibility Study**	
Technology:	**Mass Burn Facility**	**150 tpd-7 days per week**
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Location:	**Guam**	

IV. PROCESS RESIDUE HAUL & DISPOSAL

Item	Cost /Load(1)	Quantity	Unit	Unit Price	Annual Cost	Total
Process Residue Haul	$ 75	503	Tons	$ 3.75	$ 1,886	
Ash Haul	$ 75	13,140	Tons	$ 3.75	$ 49,276	
Landfill Disposal Fees		13,643	Tons	$ 23.30	$ 317,886	
Subtotal						$ 369,048

Notes:

(1) Cost assumes truck operating costs per 20-ton load

V. ROLLING STOCK O&M COSTS

Fuel	Weeks	Unit Rate	Units	Unit Price	Annual Cost	Total
Loader	52	200	gal/wk	$ 3.75	$39,000	
Pick-up Truck	52	30	gal/wk	$ 3.75	$5,900	
Maintenance	**# Vehicles**	**Quantity**	**Units**	**Unit Price**	**Annual Cost**	**Total**
Loader	1	1	L.S.	$13,982	$14,000	
Pick-up Truck	1	12,000	Miles/Yr	$0.50	$6,000	
General O&M		1	L.S.	$42,500	$42,500	
Subtotal						$107,400

Notes:

(1) Based on Owning and Operationg Cost Methodology in the Catepillar Performance Handbook.

VI. MISCELLANEOUS COSTS

Item	Useage (1)	Quantity	Unit	Unit Price	Annual Cost	Total
Property Insurance (2)	1	0.3%			$192,300	
Flood Insurance (2)	0	1.2%			$0	
Property Taxes (3)	1	3,252	m2	$0.78	$3,000	
Subtotal						$ 195,300

Notes:

(1) Multiplier used to adjust costs for various potential sites. Zero means expense not appicalbe to this site.

(2) Based on % of capital construction costs.

(3) Based on area of developed property.

Subtotal I through VI	$4,419,174

VII. SALES REVENUES(3)

Material	Units	Unit	Unit Value	Annual Revenues	Total
Net Electric Generation	15,751	MWh	$110	$1,732,627	Addressed in Pro Forma
Net Steam Generation	223,380	Mlbs.	$0	$0	Addressed in Pro Forma
Aluminum	-	Tons	$800	$0	No recovery provided
Ferrous Metals	-	Tons	$25	$0	
Subtotal VII					$1,732,627

Water Usage Estimates — 150 TPD

			Conversion factor =	3.785412
Domestic	**Assumptions**	**Gallons/Yr**	**Liters/Year**	
Average People/Day	5.48			
gpd/person	25			
gallons per day	137			
days/week	7			
weeks/year	52			
gallons per year		49,833	188,640	
Blowdown/Spray Dryer	4%	1,226,400		
Spray Dryer(Lb/hr Water/tpd Fuel)	212.00	3,688,206		
Ash Quench(15% moisture)	5.80	423,529		
Cooling Tower (blowdown 20% evap.)		36,792,000		
Washdown		35,100	132,868	
Total Water Usage		42,215,068	159,801,426	
Evaporation/Ash Quench	75%	31,661,301	119,851,070	
Total Sewer Usage		10,553,767	39,950,357	

Reagent Usage Estimates

	Qty/Ton
Lime (Lbs/Ton)	20
Ammonia (lbs/Ton)	7.5
Carbon (Lbs/Ton)	0.66

Energy Generation Assumptions

	Gross Generation Amount/Ton	**In-House Power Amount/Ton**	**Net Generation Amount/Ton**		**Net Annual Generation**	
Steam Production (mlb)	7.00	1.00	6	=	223,380	Mlbs.
Electricity Production (kWh)	494	70.51	423	=	15,751	MWh
Assumes condensing turbine	2.75	MW at	39,000	lbs/hr	0%	Margin

Energy Consumption Assumptions

Item	**mmBtu/Ton**	**Btu/Gal**	**MMBTU**	**Gal/yr**
Diesel (mmBtu)	0.1	140000	3,723	26,593

Item	**Qty/Ton**	**hp**	**load factor**	**kw**	**hrs/year**	**kwh/yr**
Power Purchase Req. (kWh/Ton)	3.73					138,981
Total Purchase						138,981

MSW Quanitites and Characteristics

Waste Quantity	40,000	tpy		Note system is slightly derated to allow for outages		
Daily Delivery	110	tpd - 7 days per weeks				
Capacity Factor	85%					
Delivery Capacity	129	tpd - 5 days per week				
Annual Throughput	37,230	tpy				
MSW HHV (B&W)	5,200	Btu/lb				
Boiler Efficiency (B&W)	71%					
Fuel Feed Rate (B&W)	10,000	Lbs/Hr at	120	tons/day	650degF/650psig	
Gross Steam Production (B&W)	35,000	Lb/Hr	7000	lbs(steam)/ton	3.5	lbstm/lb MSW

MSW Storage Calculations

Pit Storage	5	Days		
Pit Storage	645	tons		
MSW Density	20	lb/cf		
MSW Pit Capacity	63,292	cu. ft.		
Pit Area	1,300	SF	30	ft deep plus 50% of vol. up to charging level
Pit length	33	ft at	40	feet wide

Residue Disposal

Assumes cofiring RDF w/ coal and disposing both residues

Residue Disposal	1.5%	2 tpd5	0	Truckloads/Day5
Ash Disposal	28%	36.1 tpd7	2	Truckloads/Day7
Truck Payload (Tons)	20		2.0	Truckloads/Day
		24 HRS/week	4	HRs/day
			2	Round Trip Haul

Basic Conceptual Layout Dimensions

		Length	Span	Area	Height	Number of Stories	Size Adjustment
Conversion Factor	**M to Ft**	**3.28084**	**3.28084**	**10.7639111**	**3.28084**		
Exterior Maneuvering	Feet	55.0	60.0	3,300			
	Meters	16.8	18.3	307			
MSW Tipping Floor	Feet	55.0	35.0	1,925	40.0	1.0	
	Meters	16.8	10.7	179	12.2		
Boiler Bldg	Feet	60.0	85.0	5,100	115.0	1.0	
	Meters	18.3	25.9	474	35.1		
Turbine Building	Feet	50.0	45.0	4,500	15.0	2.0	
	Meters	15.2	13.7	209	4.6		
Maintenance/Storage	Feet	48.0	36.0	1,728	16.4	1.0	0.8
	Meters	14.6	11.0	161	5		
Admin/ Control Room	Feet	48.0	36.0	1,728	16.4	1.0	0.8
	Meters	14.6	11.0	161	5		
Refuse Storage Bldg (Pit)	Feet	30.0	40.0	1,200	115.0	1.0	
	Meters	9.1	12.2	111	31		
Ash Storage Bldg	Feet	35.0	30.0	1,050	30.0	1.0	0.75
	Meters	10.7	9.1	98	9.1		
Site Development	Feet	350.0	100.0	35,000			
	Meters	106.7	30.5	3,252			
		Total Bldg Floor Area		15,306			

Mass Burn Facility

Capital Cost	$	98,224,000
Life Extension Measures	$	5,250,000
Operating Cost	$	6,795,000
Energy Revenue	$	1,733,000

2008 Dollars

Capital Cost Breakdown			
Year 0	$	5,047,000	Permitting, survey, and 70% engineering work
Year 1	$	37,142,000	40% of total less start up, permitting, survey, 70% of engineering
Year 2	$	56,035,000	60% of total plus startup less permitting, survey and engineering
Total	$	98,224,000	

Life Extension			
Year 15	$	1,312,500	25%
Year 20	$	2,625,000	50%
Year 25	$	1,312,500	25%

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Guam Power Generation Study Report for Proposed USMC Relocation

July 2008, Revision 1

Department of the Navy
Naval Facilities Engineering Command, Pacific
258 Makalapa Drive, Suite 100
Pearl Harbor, HI 96860-3134

Naval Facilities Engineering Command
NAVFAC PACIFIC

Contract Number N62742-06-D-1870/TO 0018

Guam Power Generation Study Report for Proposed USMC Relocation

July 2008, Revision 1

Prepared for:

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Contract Number N62742-06-D-1870/TO 0018

EXECUTIVE SUMMARY

The purpose of this study is to evaluate the increase in electrical load to the Island-Wide Power System (IWPS) required to support the proposed United States Marine Corps (USMC) relocation to Guam, hereafter referred to as "USMC relocation," and study the interconnection to the IWPS and options available for power generation in Guam. The outcome of this study needs to provide sufficiently detailed information to support the Environmental Impact Statement process. In September 2007, the Naval Facilities Engineering Command, Pacific (NAVFAC Pacific), under Master Contract No. N62742-06-D-1870 issued a Task Order to TEC JV to prepare a Guam Power Generation Study Report that evaluates the impact resulting from the USMC relocation and identify viable options for power generation technologies and evaluate interconnection options for the power generation system. Earth Tech visited Naval Base Guam Pacific facilities in Guam between 1 October and 12 October 2007, and met with respective decision makers within NAVFAC Marianas and several other agencies in Guam to understand the regulatory requirements, siting conditions, and design features required for this project. This report presents the findings of our evaluations based on the information gathered during the field study, information provided by NAVFAC Pacific, and subsequent detailed analysis of the Guam power generation options.

The first step for evaluating the power needs related to the USMC relocation to Guam and future Department of Defense (DoD) loads associated with the military buildup involves determining what new preliminary loads would be added to the island. A summary of those preliminary loads is included in Table ES-1.

Table ES-1 lists the anticipated preliminary loads for each component of the military buildup and results in an anticipated demand load of 47.53 megawatts (MW) attributed to USMC activities and 160.53 MW of demand with all anticipated preliminary DoD loads (existing and future). Each of the load values in Table ES-1 also includes 25 percent capacity for future loads and is based on a demand factor of 0.27 applied to the anticipated connected loads to arrive at the demand load.

Load projections provided by NAVFAC support a preliminary total DoD future planned demand load of 160.53 MW (Table ES-1) which includes 47.7 MW of other planned DoD loads at Apra Harbor and a total of 47.53 MW of future loads associated with the USMC relocation. A major portion of the Apra Harbor load is associated with the transient CVN berthing. This is the preliminary basis for recommending the potential base load demand of 60 MW with peaking generation for the remaining 40 MW of total future DoD load. The majority of the peaking load is associated with the CVN berthing expected to occur three times per year for approximately 3 weeks each time. The result is 100 MW (not including reliability reserve of 60 percent) of additional generation demand to meet the preliminary loads associated with USMC and other DoD facilities planned for Guam (included in the last line of Table ES-1).

The majority of the USMC relocation is expected to complete construction between 2013 and 2015. The military buildup in Guam also coincides with Guam Power Authority (GPA) exceeding their 1 day in 4.5 years reserve capacity to meet reliability goals. In general, the capacity GPA uses to meet the 1 day in 4.5 years represents 1.6 times the demand capacity required. That is to say that 1.6 MW of capacity is required for every 1.0 MW of demand load.

As indicated in GPA's demand forecast, the reserve capacity is exceeded in 2016 based on the GPA load projections for the IWPS. GPA's demand forecast is based on an installed generation capacity of 550 MW. Review of one year of GPA's actual generation capacity indicates an average daily generation capacity of 455 MW or nearly 20 percent less than their stated capacity. This is largely related to units out of service for extended periods of time and units simply not available to be scheduled into the generation capacity for the daily report.

Consideration of GPA's published daily available capacity (455 MW), demand forecast and indicated reserve capacity to maintain a 1 day in 4.5 years reserve indicates that GPA will exceed their reserve capacity in 2008 (or regardless of the projected loads required by the USMC or Apra Harbor. The lower actual generation capacity is the primary basis for suggesting the need for additional generation in the near future. However, as stated elsewhere in this report, the decision to add generation to the IWPS is GPA's responsibility as regulated by the Public Utilities Commission.

Table ES-1: Current and Preliminary Future Military Electrical Loads for Guam in MW

Load Description	Existing Demand Load (MW)	MILCON Preliminary Planned Demand (MW)	USMC Notional Increase Demand (MW)	Preliminary Total DoD Future Planned Demand (MW)
Existing Navy electrical demand for 19 service locations (based on peak demand data in GIMDP report dated July 2006 [HHF 2006])	47.55	na	na	na
AAFB	18.1	10.80	0.57	29.47
Northwest Field	0.5	1.35	0.00	1.80
Andy South – MARBO	1.0	0.00	0.00	1.00
NCTS (North) – Finegayan plus utilities	1.2	3.53	20.10	24.83
South Finegayan Housing Area	1.5	0.00	8.15	9.65
Barrigada	1.3	0.00	0.00	1.3
Naval Hospital	3.2	2.07	0.00	5.27
Apra Harbor (NAVBASE Guam)	20.75	47.70	18.71	87.16
Total Electrical Loads (MW)	47.55	65.45	47.53	160.53

AAFB	Andersen Air Force Base
MILCON	military construction
MW	megawatt
MARBO	Marianas Bonins Command
na	not applicable
NAVBASE	Naval Base
NCTS	Naval Computer and Telecommunications Station

POWER GENERATION/INTERCONNECTION ALTERNATIVES

The following four power generation alternatives are considered for this Project:

- *Option 1*: Recapitalize, modernize, and modify the GPA system to support the added base load to the GPA grid. The added generation will be provided by GPA.
- *Option 2A:* Construct a new Special Purpose Entity (SPE) owned/operated base load power plant on DoD-provided land and specifically to meet load requirements for the facilities associated with the USMC relocation. The facility would have the ability to provide excess power to the GPA grid. Also, the GPA grid would be used for back-up power in the event the SPE Plant is out of service.
- *Option 2B:* Construct a new SPE owned/operated base load power plant on DoD or other provided land. The normal operation of this base load plant will be to provide power to the GPA grid at the best available location as an Independent Power Producer (IPP). The new Marine loads would be connected to the IWPS but not at the point of the new SPE facility.
- *Option 3:* Construct a new SPE owned/operated base load power plant for load on N. Finegayan with no connection to GPA. This option would require spare capacity to provide necessary generation with one unit out of service and failure of the largest unit (if units are not the same size).

SUMMARY OF FINDINGS

The report evaluates three main issues and will require that each be considered separately in the final approach. The three main issues evaluated were as follows:

- Power requirements for additional military loads associated with relocating Marines to Guam plus planned DoD loads.
- Power interconnection options to meet anticipated future military loads in Guam.
- Power generation alternatives for both conventional and alternatives sources of power.

The power requirements are anticipated to be 160.53 MW peak demand and include all known existing and future DoD requirements for the various branches and the transient CVN load at Apra Harbor. The base load increase attributed to the USMC relocation is approximately 47 MW. Preliminary DoD demand loads estimated by the Guam Integrated Military Development Plan (GIMDP) (HHF 2006) were presented in October 2007 to the GPA for preliminary analysis and planning for the IWPS. Current load projections are based on the loading plans provided by the U.S. Navy and are presented in Table ES-1 in units of MW in Table ES-1.

The recommendation supported by the load analysis is to provide generation that meets the load requirements and includes capacity that supports the system reliability needs (1.6 times base load provides a level of generation that includes capacity to meet reliability expectations). The generation would be made up of 60 percent base load and 40 percent peaking generation capacity. This generation mix is based on recommendations included in the business case analysis for planned DoD loads. This will require 75 MW (45 MW base load and 30 MW peaking generation) for USMC projected loads and 104 MW (62.4 MW base load and 41.6 MW peaking generation) for other DoD loads anticipated in Guam. Each of these values includes 60 percent capacity to support system reliability requirements.

The detailed results of GPA's load flow analysis and anticipated IWPS improvements required to support those loads are presented elsewhere in this report and summarized below:

- The IWPS will require upgrades to existing transmission lines and facilities to alleviate line overloading and unacceptable voltages. The results of the analysis are presented in

  Appendix A Guam Power Authority Load Flow Analysis Data

  Appendix B Customer Service Agreement

  Appendix C Navy-Provided Outage Data

  Appendix D Detailed Cost Tables for IWPS Improvements

- There is a need to add generation within the next 5–7 years to meet system requirements.
- The responsibility for system improvements and additional generation lies with GPA (reference current Customer Service Agreement Article 1, pages I-1 through 3 between Navy and GPA, which is included in Appendix B).

Option 3 is not considered viable for the following primary reason:

- The facilities required for an independent power system that approaches the level of quality and reliability required by DoD are not considered cost effective

The evaluation of power source options also included review of both conventional sources of fuel or energy and alternative sources of fuel or energy. The summary of that analysis is that conventional fuel alternatives would include coal, liquefied natural gas (LNG), heavy fuel oil (No. 6), and No. 2 diesel fuel. Each of these options is summarized below:

- Coal would require a substantial investment in handling facilities but potentially offers a more stable future cost basis that adds stability in the future cost of electricity by diversifying fuel sources used in Guam.
- LNG does not appear to offer a reasonable option for a new facility based on preliminary evaluation of terminal facilities cost and potential difficulty in permitting the necessary facilities. There is no infrastructure in place and will require the generating facility to be located near the fuel offloading and storage facility.
- Both fuel oil options are currently in use in Guam and offer a variety of fuel supply options and potential sites with fuel available that requires minimal infrastructure improvements.

The alternative energy analysis resulted in several options that should be considered in future plans for energy in Guam. Alternative energy options will not be considered as a base load generation source due to the inability to be dispatched (scheduled) under all conditions regardless of the availability of sun, wind, ocean wave or geothermal at the time. The alternative energy options identified with anticipated energy costs at or below the current cost of electricity in Guam (January 2008) are listed below:

- Wind energy
- Simple or combined cycle biofuel plant (Biodiesel fuel)
- Geothermal (potentially viable)
- Solar thermal electric (somewhat higher cost per kWhr than current GPA rates)
- Distributed solar photovoltaic systems with the facilities construction
- Ocean Thermal Energy Conversion (OTEC)
- Wave energy as a technology to watch as it matures. While not considered commercially viable at this time, the technology may likely become more cost competitive in the future

A common conclusion associated with these options is that any generation solution that meets future power needs for the planned DoD facilities will require significant upgrades to existing transmission and distribution systems. Future energy plans could include wind energy, biofuel/biodiesel, geothermal (if additional evaluation proved viable), OTEC, wave energy and possibly solar thermal (based on land requirements, state of technology and limitations related to potential typhoons). These options are not considered further for base load generation as they do not meet the reliability expectations for base load generation. It is expected that alternative energy could make up as much as 50 percent of the anticipated new energy consumption (not base load generation) if suitable locations can be found for wind turbines and solar thermal proves out in a more detailed evaluation.

Providing 50 percent of the new energy consumption would equate to approximately 25 percent of the DoD energy needs. This would allow the DoD to comply with the Energy Policy Act of 2005 and the DoD's goal of 25 percent alternative energy use by 2025. This will not adequately address the base load generation needs, but would provide a renewable source of energy and meet a valuable need in Guam for non-oil based power.

Anticipated energy production cost for some alternative energy sources are projected at less than current GPA retail rates. GPA anticipates additional rate increases in February 2008 and October 2008 with the exception that rates will likely increase further if oil prices continue to rise.

CONTENTS

APPENDICES

DRAWINGS (POCKET INSERTS AFTER APPENDICES)

FIGURES

TABLES

ACRONYMS AND ABBREVIATIONS

°F degree	Fahrenheit
AAFB	Andersen Air Force Base
AC alternating	current
ANSI	American National Standards Institute
BTU	British Thermal Unit
COMNAVMARIANAS	Commander, Naval Forces Marianas
CSA	Customer Service Agreement
CVN	nuclear-powered aircraft carrier
DC direct	current
DoD	Department of Defense
EAF	Equivalent Availability Factor
EFOR	Equivalent Forced Outage Rate
EIA	Energy Information Administration
EIS	environmental impact statement
ft^2	square foot
GIMDP	Guam Integrated Military Development Plan
GJMMP	Guam Joint Military Master Plan
GovGuam	Government of Guam
GPA	Guam Power Authority
gpm	gallons per minute
Hz	hertz
IPP	Independent Power Producer
IRP	Integrated Resource Plan
IWPS	Island Wide Power System
JGMMP	Joint Guam Military Master Plan
JGPO	Joint Guam Program Office
kV	kilovolt
kW kilowatt	
kW/yr	kilowatt of generation capacity per year
kWh	kilowatt hour
LNG	liquefied natural gas
LOLP	loss of load probability
MARBO	Marianas Bonins Command
m^2 square	meter
mph	mile per hour
MVA megavolt	ampere
MVAR	megavolt ampere reactive
MW	megawatt
MWh	megawatt hour
na not	applicable
N/A not	available
NAVFAC Pacific	Naval Facilities Engineering Command, Pacific
NCTS	U.S. Naval Computer and Telecommunications Station
NELHA	National Energy Laboratory Hawaii
NO_x	generic abbreviation for mono-nitrogen oxides
O&M	Operation and Maintenance
OTEC	Ocean Thermal Energy Conversion

PUC	Public Utilities Commission
SAIDI	System Average Interruption Duration Index
SAIFI	System Average Interruption Frequency Index
SPE	Special Purpose Entity
SWAC	Sea Water Air Conditioning
Therm	Term that equals 100,000 BTUs
U.S.	United States
USMC	United States Marine Corps
V volt	

1. Introduction

1.1 PURPOSE

The purpose of this study is to evaluate power requirements for proposed facilities and establish generation capacity needs, evaluate interconnection options with Guam Power Authority (GPA), and to evaluate alternative energy options that are viable on Guam. The power required for proposed facilities will consider the United States Marine Corps (USMC) relocation, hereafter referred to as the "USMC relocation," nuclear-powered aircraft carrier (CVN) berthing and related power needs identified in earlier reports for the future military impacts to electrical system on Guam.

There are 4 interconnection options identified in the project definition as described below:

- *Option 1:* Recapitalize, modernize and modify the GPA system to support the added base load to the GPA grid. The added generation will be provided by GPA.
- *Option 2A:* Construct a new Special Purpose Entity (SPE) owned/operated base load power plant on Department of Defense (DoD)-provided land specifically to meet load requirements for the facilities associated with the USMC relocation. The facility would have the ability to provide excess power to the GPA grid. Also, the GPA grid would be used for back-up power in the event the SPE Plant is out of service.
- *Option 2B:* Construct a new SPE owned/operated base load power plant on DoD or other provided land. The normal operation of this base load plant will be to provide power to the GPA grid at the best available location as an Independent Power Producer (IPP). The new Marine loads would be connected to the island wide power system (IWPS) but not at the point of the new SPE facility.
- *Option 3:* Construct a new SPE owned/operated base load power plant for load on N. Finegayan with no connection to GPA. This option would require spare capacity to provide necessary generation with one unit out of service and failure of the largest unit (if units are not the same size).

These options will be described in more detail in Section 3 of the report. Results and supplemental information are provided in the following appendixes to this report:

Appendix A Guam Power Authority Load Flow Analysis Data

Appendix B Customer Service Agreement

Appendix C Navy-Provided Outage Data

Appendix D Detailed Cost Tables for IWPS Improvements

This study will evaluate a list of alternative energy options to determine whether each option is viable in Guam. The general requirements for each option will be described and reviewed against the limitations of Guam as related to natural resources, land use, interconnection with the existing grid and other issues identified for each alternative energy option. The sources of alternative energy that are evaluated in the study are listed below:

- Ocean thermal energy conversion (OTEC)
- Wind power generation
- Solar energy conversion

- Biofuel power generation
- Waste-to-energy generation
- Fuel cell power generation
- Wave energy conversion
- Geothermal

1.2 BACKGROUND INFORMATION

Guam is the southernmost and largest of the Mariana Islands, a group of 15 islands located approximately 3,600 miles west of Hawaii and 1,400 miles south of Japan. The island is a territory of the United States (U.S.). The main axis of the island runs NE–SW for a total length of 30 miles and the varies from 8 miles wide at its northern tip, to 4 miles wide near the center to 11.5 miles in the south. The total area of the island is 212 square miles. The current population of Guam is approximately 171,000.

The Guam Integrated Military Development Plan (GIMDP) (HHF 2006), formerly the Joint Guam Military Master Plan (JGMMP), identified a potential military build-up on Guam. The GIMDP was initiated by the U.S. Pacific Command (USPACOM). As of this writing, Naval Facilities Engineering Command, Pacific (NAVFAC Pacific) is conducting the Guam Joint Military Master Plan (GJMMP), which is the master plan for future build-up of Guam with detailed plans for the USMC relocation to Guam. Naval Computer and Telecommunications Station (NCTS) Finegayan, South Finegayan Housing area, Andersen Air Force Base (AAFB), AAFB Northwest Field, and Andersen South will provide locations for most of the facilities associated USMC relocation to Guam and result in the electrical load increase to the IWPS. Electrical service for DoD facilities is currently provided through the GPA and 19 service locations throughout the island. These service locations are governed by a customer service agreement (CSA) between the Navy and GPA. The electrical rates are based on information contained in Schedule N as referenced in the CSA.

Based on the findings presented in the GIMDP, NAVFAC Pacific has made the decision to perform an electrical power generation study to identify all reasonable alternatives for power generation to support the USMC relocation to Guam. The study will address all reasonable alternatives with sufficient and detailed information to support the Environmental Impact Statement (EIS) process. The study will evaluate and recommend power generation, transmission and distribution improvements anticipated to support the proposed USMC relocation to Guam.

1.2.1 GPA Background

The GPA provides power to all military facilities on Guam through a CSA. This agreement establishes the electrical rates paid to GPA and is in force until 2012. A recent review of the CSA identified a number of concerns. A copy of the CSA is included in Appendix B. Those concerns described in that document and also of importance to this report are listed below:

- Navy has not generated power for the IWPS nor furnished fuel to GPA for at least three fiscal years, FY04–FY06. (Article 3)
- The CSA requires Navy to notify GPA of anticipated DoD–Guam load increases. (Article 8)
- CSA can only be amended by written agreement between both parties—thus prohibiting either party from unilaterally amending the CSA for any reason. (Article 15)
- GPA's service rules and regulations must be considered in the planning of future DoD–Guam facilities and infrastructure improvements—particularly with regard to parallel

operations and line extensions. The Navy is responsible for selecting and installing protective relaying devices and setting parameters for the relays to coordinate with GPA's protective devices to avoid unnecessary service interruptions. (Article 28)

- GPA will construct, own, operate and maintain electric lines and equipment only under, along, upon and over public streets, roads and highways where it has the legal right to do so, and on public lands and private property across which it has otherwise obtained rights-of-way or other necessary rights satisfactory to GPA. (Article 28)
- A cursory examination based on available DoD project data determined that at least 7 Navy joint-use transmission facility items of the 26 listed in CSA Table 3 will potentially be affected.

1.2.1.1 GENERATION SYSTEM

The existing generation system consists of units operated by the Navy, units operated by GPA and units operated by IPPs. A list of installed generation units is included in Table 1-1. This table lists all available units, fuel used, entity responsible for operation, and whether the unit is considered base load, peaking or backup capacity.

Table 1-1: Existing Generation System Resources

Plants	Capacity MW	Technology	Year Installed	Fuel	Type	Owner	Operator
NCTS Finegayan	7.5	N/A	N/A	N/A	Back-up	DOD	DOD
Radio Barrigada	4	N/A	N/A	N/A	Back-up	DOD	DOD
Orote	19.8	N/A	N/A	N/A	Back-up	DOD	DOD
NavHosp.	2	N/A	N/A	N/A	Back-up	DOD	DOD
*Cabras #1	66	Steam Turbine	1974	RFO No. 6	Base Load	GPA	GPA
*Cabras #2	66	Steam Turbine	1975	RFO No. 6	Base Load	GPA	GPA
*Cabras #3	40	Slow Speed Turbine	1996	RFO No. 6	Base Load	GPA	GPA
*Cabras #4	40	Slow Speed Turbine	1996	RFO No. 6	Base Load	GPA	GPA
*Tanguisson #1	26.5	Steam Turbine	1976	RFO No. 6	Base Load	GPA	IPP
*Tanguisson #2	26.5	Steam Turbine	1976	RFO No. 6	Base Load	GPA	IPP
*Temes	40	Combustion Turbine	1997	Diesel No. 2	Peaking Load	GPA	IPP
*PITI #8 (MEC)	44	Slow Speed Diesel	1999	RFO No. 6	Base Load	GPA	IPP
*PITI #9 (MEC)	44	Slow Speed Diesel	1999	RFO No. 6	Base Load	GPA	IPP
Manengon 1 & 2	8.8	Medium Speed Diesel	1993	Diesel No. 2	Peaking Load	GPA	GPA
Dededo CT #1	23	Combustion Turbine	1992	Diesel No. 2	Peaking Load	GPA	GPA
Dededo CT #2	23	Combustion Turbine	1994	Diesel No. 2	Peaking Load	GPA	GPA
Dededo (D) #1, 2, 3, 4	10	Combustion Turbine	1972	Diesel No. 2	Peaking Load	GPA	GPA
Macheche	21	Combustion Turbine	1993	Diesel No. 2	Peaking Load	GPA	GPA
Yigo (CT)	21	Combustion Turbine	1993	Diesel No. 2	Peaking Load	GPA	GPA
Talafofo #1 & 2	10	Medium Speed Diesel	1994	Diesel No. 2	Peaking Load	GPA	GPA
Mt. Tenjo	26.4	Medium Speed Diesel	1994	Diesel No. 2	Peaking Load	GPA	GPA

Plants	Capacity MW	Technology	Year Installed	Fuel	Type	Owner	Operator
Marbo CT	14	Combustion Turbine	1993	Diesel No. 2	Peaking Load	GPA	GPA

*Denotes unit managed by independent power producer (IPP) or private management contract (PMC).
N/A not available

Capacity (Base Load/Peak)

The GPA operates and has agreements for purchasing power from units as listed in Table 1-1. There are basically two types of units listed. The larger units operated from heavy fuel oil (No. 6) are typically base load capacity units and have limited operating ranges that favor operation at or near rated capacity. The other type of units are considered peaking units and can be started and placed on line quickly, are more distributed, rated at lower capacity per unit/engine and typically more costly to operate. The peaking units are typically operated for short periods of time, and not intended to meet daily demands from the IWPS loads.

Quality/Reliability

There are two general characteristics of delivered power that were reviewed in this report. One is the power quality and can be described in terms of voltage level, alternating current (AC) frequency of the power delivered, disturbances on the system such as voltage sags, voltage spikes and harmonics in the system that impact sensitive equipment connected to the power system.

The other main characteristic is the power reliability. This refers to events that interrupt the power supply to the customer and is typically measured in outage rate and outage duration. Power utility measurements for these aspects use two main parameters to evaluate reliability performance.

- System Average Interruption Frequency Index (SAIFI)
- System Average Interruption Duration Index (SAIDI)

Each of these parameters is tracked for all customers (average interruption duration or SAIDI in minutes of outages per customer per year and average frequency of interruptions is outages per customer per year). These parameters are evaluated by most utilities and are used in reviewing performance improvements from year to year and to establish goals for utilities to achieve. A graph of recent data from the GPA is included for reference (Figure 1-1) (the units for SAIDI are average total minutes of outage per customer and for SAIF I are the average number of outage events per customer with both values calculated on a yearly basis).

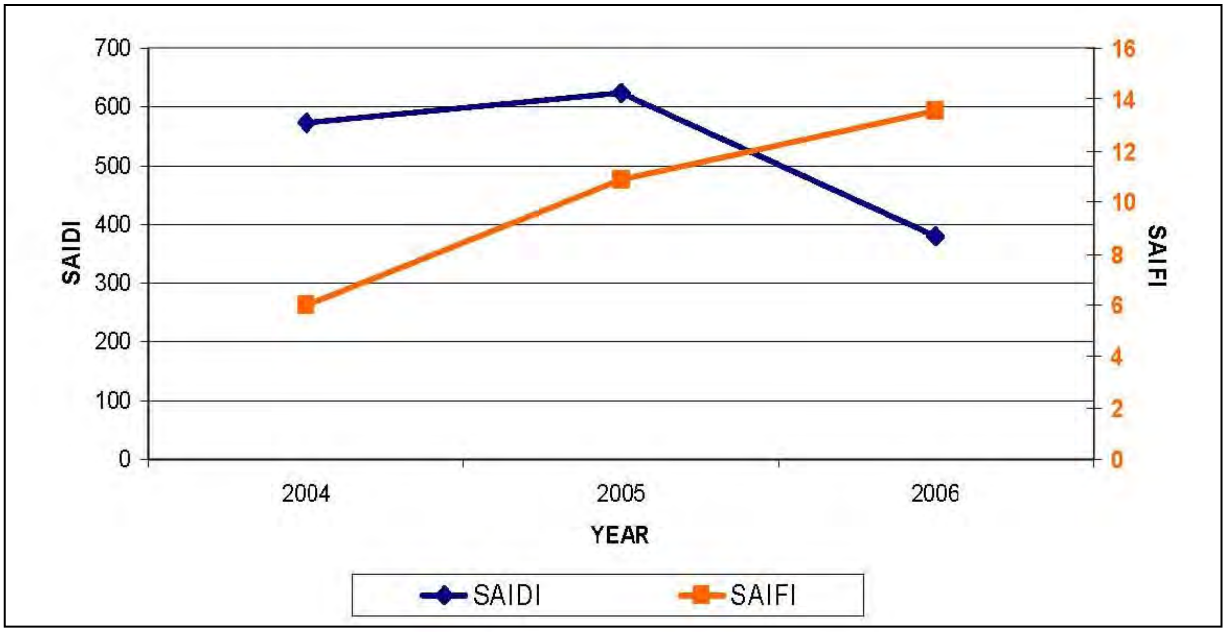

Figure 1-1: Recent SAIDI/SAIFI Data from GPA

NAVFAC Pacific has been working to establish expected performance characteristics for each of the parameters that have been presented to this point and they are included here for information purposes. It should be noted that the requirements have not been finalized and should be considered preliminary at this time.

Table 1-2: Expected Performance Characteristics for each Parameter

Parameter	CSA Agreement Levels	Requirements
Voltage	Voltage delivery should be within 5% of the prescribed voltage.	Voltage Range for 13.8 kV nominal voltage - minimum 13,460V (-2 1/2%) to maximum 14,490V (+ 5%), Reference ANSI C84.1-1995 (ANSI 2005)
Frequency	Alternating service of approximately 60 Hz will be regularly supplied. (Direct current will not be supplied).	Frequency Range for 13.8kV nominal voltage: 59.5Hz – 60.5 Hz. Reference based on IEEE STD 446 (Orange Book) (IEEE 1996)
Generation Reliability Standards	LOLP of 1 day in 10 years and operating reliability of 4 days in 10 years. Equivalent forced outage rate of 15% and average forced outage rate of 8% calculated as a four year rolling average. Equivalent availability factor of 85 %.	LOLP, Planning Reliability Purposes - 1 day in 10 years LOLP, Operating Reliability Purposes - 4 days in 10 years EFOR - 9% National Industry Performance EAF - 85% National Industry Performance
Distribution Reliability Standards	Substation and transmission outages should contribute no more than 0.10 days (144 minutes) per year to loss of load incidence. Distribution outages should contribute no more than 0.30 days (432 minutes) per year No overloaded circuits in a normally configured system (calculated by comparing monthly peak load with circuit rating)	SAFI : 1.10 interruptions/year/customer SAIDI: 1.50 hours/year/customer (90 minutes)

ANSI American National Standards Institute
EAF Equivalent Availability Factor
EFOR Equivalent Forced Outage Rate
Hz hertz
kV kilovolt
LOLP loss of load probability
V volt

1.2.2 Renewable Alternative Energy

The GPA has been evaluating alternative energy as part of their Integrated Resource Plan (IRP). They have been working with the firm of R. W. Beck, Inc. to identify costs and impacts of several fuel options that include alternative energy as well as conventional fuel sources for power generation. GPA has not completed the process but did provide a copy of a document prepared by R. W. Beck, Inc. to indicate what they have been investigating relative to Guam's future power needs.

1.2.3 Operations and Maintenance

GPA has the responsibility of meeting requirements for system operation and maintenance (O&M) as defined in the current CSA with the Navy.

1.3 20-YEAR PLAN

The loads associated with the military buildup in Guam represent the major loads anticipated over the next 10 years and impact GPA planning for facilities over the next 20 years. NAVFAC provided best available information to GPA in October 2007 (GIMDP demand load projections) to allow them to begin this planning process with preliminary loads and general load locations. It is anticipated that this information will be incorporated into the 20-year plan for GPA.

1.3.1 Alternative Energy

GPA has incorporated alternative energy into its plans for future energy needs in Guam. The main options considered by GPA to date include wind turbines, biomass, and ocean thermal. GPA has a report that considers the opportunity of installing an ocean thermal facility to provide energy for cooling systems to the major consumers in Tamun and Tamuning Bays in Guam. There have been no specific plans made to implement such a project at this time.

1.3.2 Reliability/Power Quality

The system performance will continue to be an important issue with GPA in planning for system improvements. The GPA has been conducting stake holder meetings as part of their Strategic Planning and Operations Research Department (SPORD) planning process. This planning will continue into 2008.

The CSA requirements for reliability and power quality are established under the current CSA and have been determined as being met by an independent auditor as defined in the CSA. The result of GPA meeting the requirements was that facility control was turned over to them for complete responsibility to operate and manage the IWPS.

1.4 MILITARY BACKGROUND

The significance of the history for this study primarily relates to the CSA established between the Navy and GPA. This document dates back to 1989 and was extended for a 10-year period that will end in 2012. A new agreement will need to be established prior to expiration of the current CSA.

1.4.1 Build-Up Loads

There were several sources of data available that included data for planned electrical loads in Guam. Initial load projections that were provided to GPA for system analysis were obtained from the GIMDP (HHF 2006). These loads are summarized in Table 1-3 as MW values.

Table 1-3: Current and Preliminary Future Military Electrical Loads for Guam in MW

Load Description	Existing Demand Load (MW)	MILCON Preliminary Planned Demand (MW)	USMC Preliminary Future Planned Demand (MW)	Preliminary Total DoD Future Planned Demand (MW)
Existing Navy electrical demand for 19 service locations (based on peak demand data in GIMDP report dated July 2006 [HHF 2006])	47.55	na	na	na
AAFB	18.1	10.80	0.57	29.87
Northwest Field	0.5	1.35	0.0	1.80
Andy South – MARBO		0.00	0.00	0.00
NCTS (North) – Finegayan	1.2	3.53	20.10	24.83
South Finegayan Housing Area	1.5	0.00	8.15	9.65
Barrigada	1.3	0.00	0.00	1.3
Naval Hospital	3.2	2.07	0.00	5.27
Apra Harbor (NAVBASE Guam)	20.75	47.70	18.71	87.16
Total Electrical Loads (MW)	47.55	65.45	47.53	160.53

na not applicable
MILCON military construction
MW megawatt
MARBO Marianas Bonins Command
NAVBASE Naval Base
NCTS Naval Computer and Telecommunications Station

1.4.2 Schedule

The major portion of these loads is expected to add about 50 megawatts (MW) to the power system between 2010 and 2015 with the remaining loads added in the following 5–10 years. A more specific schedule for adding loads can be created as the master planning is concluded.

1.4.3 DoD Loads

The preliminary load list for DoD planned facilities included all military loads for master planning and included loads associated with the transient CVN in Apra Harbor.

1.4.4 GIMDP Loads

The loads identified in GIMDP were essentially developed based on facility planning associated with a potential military build-up developed by the services. The GJMMP will provide better facility planning information when the study is completed and may be used to determine electrical demand loads that will impact the IWPS.

2. Evaluation of Power Generation Sources

2.1 CONVENTIONAL POWER GENERAL

Conventional power generation refers to the use of carbon-based fuels for this report. Those fuels considered are liquefied natural gas (LNG), coal, diesel No. 2, and heavy fuel oil No. 6 (also referred to as bunker oil). These fuel sources were considered as potentially suitable for Guam, given the current world energy market and resources available to Guam.

In general, facility costs and cost per megawatt hour (MWh) are based on a report conducted by GPA in 2006 (IRP) with fuel costs based on average energy costs for 2006 (latest available from Energy Information Administration). The average costs of energy ($/MWh) were calculated from heat rates indicated in the GPA IRP and fuel costs from the EIA data that considers all types of fuel for a given category (coal costs include prices paid for various types of fuel for all sources tracked by the Energy Information Administration).

2.1.1 Liquefied Natural Gas

LNG is one of many fuel types that are used for power generation in various parts of the world. While LNG has a long history of safe use in the United State, it is not without a long list of issues associated with the infrastructure required to utilize the fuel as a significant source of electrical power for Guam. One of the most difficult issues to evaluate for any generating station will continue to be cost of fuel. World use of LNG appears to be increasing and would indicate the potential for continued rising of fuel costs. This study has not attempted to evaluate the long-term fuel costs for a LNG-based facility.

LNG is a hazardous fuel frequently shipped in tankers from various parts of the world to destinations with ports suitable for offloading the fuel. LNG is not currently available in quantities large enough to support power generation in Guam and would require new facilities for import and handling to support this need. LNG infrastructure is highly visible and easily identified; it can also be vulnerable to terrorist attack due to the highly visible nature of the facilities (tanks and related facilities are exposed and unique in configuration). Nonetheless, public concerns about LNG risks continue to raise questions about LNG security. While LNG has historically made up a small part of power generation (this percentage varies depending on local resources and power needs), variability in worldwide fuel costs and rising natural gas prices in various areas in the world will impact the worldwide cost of LNG due to worldwide increasing LNG demand.

2.1.1.1 FUEL DELIVERY/STORAGE

The fuel delivery infrastructure for LNG requires three major facility elements: tanker ships, marine terminals, and storage facilities.

LNG Tanker Ships

LNG is transported in very large (generally 150,000–270,000 cubic meters), specially designed tanker ships. LNG tankers are double-hulled, containing several massive refrigerated tanks, each sealed and insulated to maintain a safe LNG temperature and prevent leakage during transit. Approximately 200 tankers are in service around the world, with a combined cargo capacity of over 16 million cubic meters of LNG, equivalent to over five times the average daily U.S. natural gas consumption in 2001. Another 125 tankers with 22 million cubic meters of capacity are on order.

LNG Marine Terminals

LNG tankers unload their cargo at dedicated marine terminals which store and re-gasify the LNG for distribution to local markets. These terminals consist of docks, LNG handling equipment, storage tanks, and interconnections to regional gas transmission pipelines. Guam does not currently have facilities for off-loading, storing, re-gasifying (if provided to natural gas pipelines), or distributing LNG. It is anticipated that LNG facilities in Guam would require transport of LNG to the power generating facility for re-gasification and use. This is due to the lack of a natural gas infrastructure in Guam and the prohibitive costs associated with this infrastructure.

The LNG industry is often described as a "LNG chain." This is in reference to the fact that LNG systems require that large interdependent investments that must be closely coordinated to be successful. All links of the chain must work together for natural gas to be produced, liquefied and exported, transported, imported, re-gasified and sold as natural gas to consumers. LNG projects require significant fuel reserves and must produce substantial volumes. Overall systems may require end-to-end investments of 2 to 5 billion dollars and consumption volumes of up to 1.0 billion cubic feet per day to be profitable. The large initial capital investment results in an extended pay back period, and corresponding financial risk, which means that most of the world's LNG is sold under long-term contracts (typically 20–25 years). There are, however some short-term and medium-term markets and, occasionally, there are sales of individual cargoes.

This generally indicates that LNG is not reasonably feasible for Guam due to the extensive infrastructure required, the high cost of infrastructure and the large volumes of consumption required to make LNG facilities cost-effective. Table 2-1, presented at the end of this section, compares fuel alternatives for a 50 MW generating facility.

2.1.1.2 Operation and Maintenance

Operation and maintenance costs for LNG-based generation facilities will generally be less than those costs for oil-fueled or coal-fueled facilities. It is anticipated that scheduled maintenance will require less than 4 weeks of downtime each year or about 7 percent of the year. Fixed operating cost for a new facility could be approximately $60 per kilowatt of generation capacity per year (kW/yr) with additional variable operating costs of $2.5 per MWh produced.

2.1.1.3 Construction Time/Schedule

As with any capital project of this nature, the time schedule requires permitting, engineering and construction as the main components of the project. The anticipated implementation of a LNG facility will require additional time associated with the offloading facilities for LNG. The anticipated time for the LNG facilities is indicated below:

- Permitting at 30 months
- Start of Engineering to Closeout at 28 months
- Total duration (accounting for overlap) 48 months

It should be noted that the anticipated schedule duration is general and does not account for any special siting or permitting issues that may apply to an actual project.

2.1.1.4 Cost per MW (Capital) Cost per Megawatt Hour (Production)

Capital costs anticipated for this report do not account for land acquisition but do account for the cost of shore delivery facilities due to the variability in cost. Costs for capital facilities and energy production from LNG are listed below:

- Cost per MW installed capacity (60 MW facility)—$5 million per MW
- Cost per MWh production (based on cost of $11/MMBtu)—$55.87 per MWh

2.1.1.5 SITE (REQUIREMENTS LAND AREA)

The site requirement for a 60 MW facility is anticipated to be 15–30 acres and would include both the offloading facilities and the power station collocated at the same site. Space requirements and logistics will be different if the generation station is located some distance from the offloading facilities.

2.1.1.6 POWER QUALITY– RELIABILITY

The power quality for any of the generation options is expected to meet all government service requirements that are affected by the power generating station. Reliability requirements that are a function of the overall IWPS are impacted by a proposed facility but do not rely solely on the proposed power facility. As a result, the reliability impact of the proposed generating facility cannot be evaluated separately. A proposed LNG facility would be expected to have a maximum capacity factor (availability of the generation facility) of 90 percent.

2.1.1.7 BASE LOAD, PEAKING LOAD

LNG fuel is used to supply both base-load and peaking facilities for power generation. The power needs for Guam would dictate a base-load facility. The existing diesel-fueled engines would continue to provide necessary peaking load capacity for the IWPS.

2.1.1.8 DESIGN LIFE

The expected design life for a LNG facility is 30 years.

2.1.1.9 ENVIRONMENTAL – EMISSION, WATER, REMEDIATION

The environmental issues related to a LNG facility are complex and vary by selected site. This paragraph will present general issues associated with environmental impacts related to an LNG facility.

Environmental studies covered in an EIS for a proposed LNG terminal include impacts on air quality, biological resources (aquatic and terrestrial), water resources, cultural resources, land use, coastal zone management, transportation (on-shore traffic and marine navigation), socioeconomics, visual resources, waste management, noise, geology and soils, recreation, public health and safety, and environmental justice. State agencies are invited to comment and may play a role in permitting. LNG terminal applicants must obtain permit for air emissions, coastal zone management, water discharge, and land use.

Construction of a LNG terminal facility affects relatively large areas of land and water resources. A recent LNG terminal application described the required land and water area as approximately 188 acres, of which 68 acres would be utilized for temporary construction facilities. Construction typically requires the use of diesel-powered heavy construction equipment to dredge ship channels, drive pilings for pier construction, clear vegetation, and construct LNG storage tanks, ancillary buildings, and service facilities. The most significant impacts will arise from dredging and material handling.

The most significant impacts occurring during the operational phase of an LNG terminal include impacts to air and water quality and the visual impact of the facility. These will be long-term impacts, as LNG terminals are typically designed to operate for at least 25 to 30 years. Impacts to air and water resources are cumulative and mitigation measures are designed and implemented accordingly.

Ultimately, LNG plants will face decommissioning. The most significant impacts resulting from the decommissioning phase of an LNG terminal are associated with demolition and disposal of wastes.

Air quality impacts are generated by demolition equipment and truck transport of demolition wastes. Some components of the facility such as buried pipelines can be safely abandoned in place after being flushed and capped. Site characterization studies may be required by regulatory agencies to determine the extent of (possible or potential) soil or groundwater contamination that may have occurred at the facility during the operational phase. In the event that contaminants are discovered, appropriate remediation plans may need to be developed and implemented.

2.1.1.10 WATER REQUIREMENTS

Water requirements are expected to be nominal at 225 gallons per minute (gpm) of fresh water for a 60 MW facility.

2.1.2 Coal

Coal represents about 36 percent of the world production of electricity (based on Report #DOE/EIA-0484 (2007) [DOE 2007b]) and about 26 percent of the world energy consumption. Coal is generally available from locations in the region near Guam. Australia, China, Vietnam, and Africa are all exporters of coal.

2.1.2.1 FUEL DELIVERY STORAGE

Coal delivery and storage facilities do not exist in Guam at the level required for commercial power production. These facilities would need to be developed in advance of any coal-fueled generating station for Guam. The potential for a coal facility in Guam was discussed with the GPA, Government of Guam (GovGuam), and a local business. Each organization expressed an interest in the diversity that coal-based power generation could provide on Guam, the potential for a more stable fuel source for electricity production and that a suitable facility could be sited in Guam if the proper support were available at all levels of industry and government.

It was anticipated in a report prepared for the GPA that the port facilities for coal handling may cost $25 million. There has been no detailed analysis of site location for Guam.

2.1.2.2 O&M

Operation and maintenance requirements for a coal-based facility are higher than for many other fuel options (such as natural gas, No. 6 fuel oil, and diesel) due to the type of fuel, emissions, and complexity of the facility. These costs are typically higher than similar costs for LNG, diesel and fuel oil based systems. Scheduled maintenance duration each year is anticipated at just over 5 weeks or about 10 percent of each year. Fixed operating cost for a new facility could be approximately $80/kW/yr with additional variable operating costs of $4.5 per MWh produced.

2.1.2.3 CONSTRUCTION TIME/SCHEDULE

Coal facilities have long implementation schedules. This is partly due to permitting requirements and the complexity of construction for coal handling facilities and generation plant. The plant schedule for a coal facility is expected to be as follows:

- Permitting at 30 months
- Start of Engineering to Closeout at 36 months
- Total duration (accounting for overlap) 56 months

It should be noted that the anticipated schedule duration is general and does not account for any special siting or permitting issues that may apply to an actual project.

2.1.2.4 COST PER MW (CAPITAL) COST PER MW (PRODUCTION)

Capital costs anticipated for this report do not account for land acquisition but do account for a $25 million cost for coal handling facilities. Costs for capital facilities and energy production from coal are listed below:

- Cost per MW installed capacity (60 MW facility)—$4.4 million per MW
- Cost per MWh production—$17.75 per MWh

2.1.2.5 SITE (REQUIREMENTS/LAND AREA)

The site requirement for a 60 MW facility is anticipated to be 200–300 acres (largest site requirements of all fuel sources reviewed) and would include both the coal handling facilities and the power station collocated at the same site. Space requirements and logistics will be different if the generation station is located any distance from the offloading facilities.

2.1.2.6 QUALITY POWER/RELIABILITY

The power quality for any of the generation options is expected to meet all government service requirements that are affected by the power generating station. Reliability requirements that are a function of the overall IWPS are impacted by a proposed facility but do not rely solely on the proposed power facility. As a result, the reliability impact of the proposed generating facility cannot be evaluated separately. A proposed coal-fueled generating facility would be expected to have a maximum capacity factor of 85 percent.

2.1.2.7 BASE LOAD, PEAKING LOAD

Coal-based generation is used as to meet base-load power generation. The power needs for Guam would dictate a base-load facility. The existing diesel-fueled engines would continue to provide necessary peaking load capacity for the IWPS.

2.1.2.8 DESIGN LIFE

The expected design life for a coal fueled facility is 30 years.

2.1.2.9 ENVIRONMENTAL – EMISSION, WATER, REMEDIATION

Fossil fuel power contributes to acid rain, global warming, and air pollution (electricity generation is responsible for 39 percent of U.S. carbon dioxide emissions). Acid rain is caused by the emission of nitrogen oxides and sulfur dioxide into the air. These compounds may be only mildly acidic, yet when they react with the atmosphere; they create acidic compounds such as sulfurous acid, nitric acid and sulfuric acid that fall as rain, hence the term acid rain. In Europe and the U.S., stricter emission laws have reduced the environmental hazards associated with this problem.

Another danger related to coal combustion is the emission of fly ash, tiny solid particles that are dangerous for public health. (Natural gas plants emit virtually no fly ash) These can be filtered out of the stack gas, although this does not happen everywhere. All coal burning power plants emit carbon dioxide. Research has shown that increased concentration of carbon dioxide in the atmosphere is positively correlated with a rise in mean global temperature, also known as climate change.

Coal also contains low levels of uranium, thorium, and other naturally occurring radioactive isotopes whose release into the environment leads to radioactive contamination. While these substances are present as very small trace impurities, enough coal is burned that significant amounts of these substances are released. A 1,000 MW coal-burning power plant (much larger than the 60 MW facility being considered for Guam) could release as much as 5.2 tons/year of uranium (containing

74 pounds of uranium-235) and 12.8 tons/year of thorium. The radioactive emission from this coal power plant is 100 times greater than a comparable nuclear power plant with the same electrical output; including processing output, the coal power plant's radiation output is over 3 times greater.

Trace amounts of mercury exist in coal and other fossil fuels. When these fuels burn, toxic mercury is released and can accumulate in food chains, which is especially harmful to aquatic ecosystems. According to the U.S. Department of Energy, the worldwide emission of mercury from both natural and human sources was 5,500 tons in 1995, of which coal-fired plants in the U.S.A release an estimated 48 tons annually or less than 1 percent of the worldwide emissions. The Environmental Working Group (a privately funded environmental advocacy organization) alleges that coal-fired power plants are the largest emitters of mercury in the United States.

2.1.2.10 Water Requirements

A 60 MW coal fueled facility is expected to require approximately 1000 gpm of water for various processes (primarily makeup water for the steam process and cooling water).

2.1.3 Diesel No. 2

Number (No.) 2 diesel fuel is one of the most common fuel source for standby power generation and often used for peak power generation under some conditions. The basic issues related to the use of No. 2 diesel as a peaking source are listed below:

- High cost of fuel as compared to other generally available fuels such as natural gas heavy fuel oil or coal
- High maintenance costs for reciprocating engines as compared to combined cycle technology
- Overall efficiency of the installation is approximately 40 percent without a viable use for waste heat from the engines (which would increase efficiency to approximately 80 percent but require the system to operate continuously)
- Units are typically limited by engine size (typically less than 2.5 MW per engine with limited availability of larger units)

These issues are typically over-ridden by the low cost of installation, ability to bring on-line in a short time and the high reliability as a peaking source for electrical power generation for relatively small installation (10 MW or less).

2.1.3.1 Fuel Delivery Storage

No. 2 diesel is available in large quantity and is a widely used source of fuel in Guam. Both military and civilian organizations use the fuel for a variety of applications in Guam. The result is a developed infrastructure for fuel delivery from tankers, fuel storage, and distribution through various pipelines in Guam. The availability of fuel will vary depending on location of facility.

2.1.3.2 O&M

Operation and maintenance requirements for a No. 2 diesel-fueled facility generally consist of relatively short outages for limited service requirement and extended outages associated with engine overhaul. Scheduled maintenance duration each year is anticipated at approximately 5.5 weeks per year or about 10 percent of the available hours each year. Fixed operating cost for a new facility could be approximately $40/kW/yr with additional variable operating costs of $4.5 per MWh produced.

2.1.3.3 Construction Time/Schedule

Diesel-fueled facilities would be expected to have the following general schedule for implementation:

- Permitting at 24 months
- Start of Engineering to Closeout at 18 months
- Total duration (accounting for overlap) 30 months

It should be noted that the anticipated schedule duration is general and does not account for any special siting or permitting issues that may apply to an actual project.

2.1.3.4 Cost per MW (Capital) Cost per MW (Production)

Capital costs anticipated for this report do not account for land acquisition. Costs for capital facilities and energy production from No. 2 diesel are listed below:

- Cost per MW installed capacity (60 MW facility)—$1.7 million per MW
- Cost per MWh production—$52.96 per MWh

2.1.3.5 Site (Requirements/Land Area)

The site requirement for a 40 MW facility is anticipated to be 10–25 acres. Space requirements and logistics will vary with the specific location and fuel availability and storage requirements.

2.1.3.6 Quality Power/Reliability

The power quality for any of the generation options based on conventional fuels is expected to meet all government service requirements that are affected by the power generating station. Reliability requirements that are a function of the overall IWPS are impacted by a proposed facility but do not rely solely on the proposed power facility. As a result, the reliability impact of the proposed generating facility cannot be evaluated separately. A proposed No. 2 diesel facility would be expected to have a maximum capacity factor near 85 percent.

2.1.3.7 Base Load, Peaking Load

Number 2 diesel-based generation (with reciprocating engines) can be used as to meet base-load power generation but is not a widely used application for base load capacity. The power needs for Guam would dictate a base-load facility. The existing diesel-fueled engines would continue to provide necessary peaking load capacity for the IWPS.

2.1.3.8 Design Life

The expected design life for a diesel-fueled facility is 30 years.

2.1.3.9 Environmental – Emission, Water, Remediation

Fossil fuel power contributes to acid rain, global warming, and air pollution. Acid rain is caused by the emission of nitrogen oxides and sulfur dioxide into the air. These compounds may be only mildly acidic, yet when they react with the atmosphere; they create acidic compounds such as sulfurous acid, nitric acid and sulfuric acid that fall as rain, hence the term acid rain. In Europe and the U.S., stricter emission laws have reduced the environmental hazards associated with this problem.

2.1.3.10 WATER REQUIREMENTS

A 40 MW No. 2 diesel-fueled facility is expected to require less than 50 gpm of water for various processes.

2.1.4 Heavy Fuel Oil (No. 6)

No. 6 fuel oil is used to fuel a major portion of the installed generation capacity in Guam. The basic issues associated with the use of No. 6 fuel oil as a fuel source are listed below:

- Cost of fuel is lower than No. 2 diesel
- Lower maintenance cost for combustion turbine technology when compared against maintenance costs for reciprocating engines.
- Overall efficiency of the installation is approximately 40–45 percent without a viable use for waste heat from the engines (which would increase efficiency to approximately 80 percent but require the system to operate continuously and a system to recover and receive beneficial use of the waste heat from the generation system)
- Units are typically limited by engine size (typically less than 2.5 MW per engine with limited availability of larger units up to 10–20 MW rating)

These issues are typically over-ridden by the availability of fuel and the lack of readily available alternative fuel sources.

2.1.4.1 FUEL DELIVERY STORAGE

No. 6 fuel oil is available in large quantity and is a widely used fuel to provide electricity in Guam. Both military and civilian organizations use the fuel for a variety of applications in Guam. The result is a developed infrastructure for fuel delivery from tankers, fuel storage, and fuel distribution through various pipelines in Guam. The specific availability of fuel will vary depending on actual facility location.

2.1.4.2 O&M

Operation and maintenance requirements for a No. 6 fuel oil fueled facility generally consist of relatively short outages for limited service requirement and extended outages associated with engine overhaul. Scheduled maintenance duration each year is anticipated at approximately 3.5 weeks per year or about 7 percent of the available hours each year. Fixed operating cost for a new facility could be approximately $40/kW/yr with additional variable operating costs of $4.5 per MWh produced.

2.1.4.3 CONSTRUCTION TIME/SCHEDULE

No. 6 fuel oil fueled facilities would be expected to have the following general schedule for implementation:

- Permitting at 24 months
- Start of Engineering to Closeout at 18 months
- Total duration (accounting for overlap) 30 months

It should be noted that the anticipated schedule duration is general and does not account for any special siting or permitting issues that may apply to an actual project. Also, this anticipated schedule is based on information provided by GPA as related to re-powering (replacing) an existing generation unit located in an existing facility.

2.1.4.4 Cost per MW (Capital) Cost per MW (Production)

Capital costs anticipated for this report do not account for land acquisition. Costs for capital facilities and energy production from No. 6 fuel oil are listed below:

- Cost per MW installed capacity (60 MW facility)—$0.6 million per MW (based on information provided by GPA and re-powering an existing unit, located at the Piti site, to provide 60 MW of capacity)
- Cost per MWh production—$50.46 per MWh

2.1.4.5 Site (Requirements/Land Area)

The site requirement for a 60 MW facility is anticipated to be 10–25 acres. The space requirements for re-powering an existing unit within GPA facilities would require less space (5–15 acres) and be significantly more cost-effective for an equivalent facility separately located elsewhere in Guam. Space requirements and logistics will vary with the specific location and fuel availability and storage requirements.

2.1.4.6 Quality Power/Reliability

The power quality for any of the generation options based on conventional fuels is expected to meet all government service requirements that are affected by the power generating station. Reliability requirements that are a function of the overall IWPS are impacted by a proposed facility but do not rely solely on the proposed power facility. As a result, the reliability impact of the proposed generating facility cannot be evaluated separately. A proposed heavy fuel oil based facility would be expected to have a maximum capacity factor near 91 percent.

2.1.4.7 Base Load, Peaking Load

No. 6 fuel oil based generation (with a combined cycle turbine) can be used as to meet base-load power generation. The existing diesel-fueled engines would continue to provide necessary peaking load capacity for the IWPS.

2.1.4.8 Design Life

The expected design life for a heavy fuel oil fueled facility is 30 years.

2.1.4.9 Environmental – Emission, Water, Remediation

Fossil fuel power contributes to acid rain, global warming, and air pollution. Acid rain is caused by the emission of nitrogen oxides and sulfur dioxide into the air. These compounds may be only mildly acidic, yet when they react with the atmosphere; they create acidic compounds such as sulfurous acid, nitric acid and sulfuric acid that fall as rain, hence the term acid rain. In Europe and the U.S., stricter emission laws have reduced the environmental hazards associated with this problem.

2.1.4.10 Water Requirements

A 60 MW No. 6 fuel oil fueled facility is expected to require approximately 300 gpm of water for the various processes.

2.1.5 Summary

The conventional fuel sources were evaluated to provide a basis for any decision related to power generation facilities and identifying a rough cost basis for capital facilities and energy costs. It should be noted that the fuel costs may differ significantly from those presented in this report, given the current volatility of fuels. Basic alternative comparisons are presented in Table 2-1 below.

Table 2-1: Conventional Fuel Source Comparison

Fuel Type	Capital Cost Per MW of Installed Capacity (60 MW Facility) $U.S. million	Production Cost per MWh (Based on Cost of $11/MMBtu) $U.S.	Water Usage Gallons per Minute (60 MW Facility)	Land Requirements in Acres (60 MW Facility)
Liquefied natural gas	5.0	55.87	225	15–30
Coal	4.4	17.75	1,000	200–300
Diesel Fuel No. 2	1.7	52.96	50	10–25 [a]
Heavy Fuel Oil (No. 6)	1.7[b]	50.46	300	10–25

[a] Based on 40 MW facility. Larger space will be required for a 60 MW facility.
[b] Based on new facilities, renovation of existing unit could be implemented for approximately $0.6 million per MW up to a 60 MW facility.

General information has been presented regarding environmental impact from the conventional power generation fuel options. While there is variability in emissions for each type of fuel and different grades of fuel, some data were evaluated for small generating stations (100 –150 MW) based on data in a report conducted by the Commission for Environmental Cooperation for 2002. Please refer to emission data that indicate average kg/MWh for the number of plants in the data set and between 100 and 150 MW (Table 2-2).

Table 2-2: Power Plant Average Emissions

Fuel Type	No. of Plants	2002 EPA SO_2 kg/MWh	2002 EPA CO_2 kg/MWh	2002 EPA NO_x kg/MWh
Oil	3	3.136	855.453	1.286
Gas	56	0.120	987.834	0.811
Coal	23	8.857	1188.331	2.677

Source: Commission for Environmental Cooperation of North America. (2002). *North Power Plan Air Emissions*

2.2 ALTERNATIVE ENERGY SOURCES

Guam is a fairly attractive location for alternative energy development due to its geographical features and location in the western North Pacific. Possible renewable energy sources that can be utilized include ocean thermal, wind, solar, wave, and geothermal energy. In addition, biomass, waste-to-energy, fuel cells, and other technologies are also appropriate for consideration given the size of its population and the island's agricultural and industrial base.

Guam is the southernmost island in the Marianas archipelago, and is situated at 13 N latitude and 144 E longitude (Figure 2-1). It is approximately 30 miles long and between 4 to 12 miles wide, with a total land area of 212 square miles. The island is comprised of two inactive volcanoes: the central and northern portions are primarily limestone, and the southern portion is largely volcanic. The highest point on the island is Mount Lamlam with an elevation of 1,332 feet.

Due to its location in the western north Pacific near the equator, the ocean currents are heavily influenced by the North Pacific Equatorial current which moves westward across the Pacific. Winds are predominantly trade winds that come from the northeast. These conditions contribute to the tropical climate on Guam, which averages between 86 to 76 degrees Fahrenheit (°F) dry bulb, and between 84 percent and 66 percent relative humidity. While the island is outside of the most active tropical cyclone activity area, it is frequently impacted by cyclones during the wet season that extends from July through November.

Guam is situated just to the east of the Mariana Trench, which has the deepest ocean depths in the world, and is the subduction zone between the Philippine and Pacific plates. This adjacency makes the Marianas islands a volcanically active area with the potential for large earthquakes.

The population on Guam as of 2006 is approximately 174,000, with approximately 20 percent of the residents in active U.S. military service or dependants. The total power demand on the island peaks near 250 MW, and the average electrical energy production is around 2,000,000 MWh/year. All of the electricity on the island is produced by the GPA. The utility lists a total generating capacity of 550 MW, with the all of its generation capacity supplied from fossil fuel fired plants.

Figure 2-1: Map of Guam

The U.S. military currently purchases all of its power from the GPA under a customer service agreement and rate schedule N. While power is drawn from the grid at 20 separate locations, all of the military's electricity is billed as if it were drawn from a single meter based on the concurrent peak demands and aggregate energy consumption. Currently, the United States (U.S.) military's total peak demand averages about 47 MW per month with 330,000 MWh per year in electrical energy consumption. Based on the present fuel oil charges, the average cost for electricity for the U.S. military is $.20 per kilowatt hour (kWh).

2.2.1 Ocean Thermal Energy Conversion

OTEC systems utilize the temperature gradient between warm surface ocean waters and cold deep ocean waters to drive either an ammonia closed cycle, an open cycle, or a combined cycle power plant. While none of these systems are in commercial production, the technology has been proven several times. In 1979, a 50 kW demonstration plant was operated at the National Energy Laboratory of Hawaii Authority (NELHA). This plant generated a 50 kW of gross power and a net power of 10 kW with about 40 kW required for pumping. Although this plant is not currently operating, the U.S. Navy is examining a barge-mounted OTEC facility for its Diego Garcia base, and a 1 MW net power output production plant is being built at the NELHA.

Guam is an ideal location for OTEC since its western coastline fringes on cold deep ocean water from the Marianas Trench. In fact, a 40-degree difference can be found between sea level and 1,000 meters below sea level at a location less than 1 kilometer from Guam's shore. [1] This cold ocean water, in conjunction with Guam's warm coastal surface waters, can provide a renewable and sustainable energy source that is non-polluting. Cold water pumped from the deep ocean can also be used for aquaculture, as a direct cooling source for central chilled water air conditioning systems, and as a source of fresh water that is generated as a by-product in open OTEC cycles. Since the supply of the deep cold water and warm surface water is always available diurnally throughout the year, OTEC systems could provide a reliable source of power that could either serve as continuous duty, or even as a back-up or supplemental power generation power plants.

Because the thermal gradient between cold ocean water at 40°F and warm surface water at 80°F is relatively low, the overall thermodynamic efficiency of these systems is only on the order of 2 to 3 percent. A 5 MW power plant will need a cold water pipeline approximately 12 feet in diameter for a flow rate of around 160,000 gpm. The pipeline costs and parasitic pumping power losses for these systems are large and need to be accounted for in the design.

2.2.1.1 Quantification of Resource:

Given the large magnitude of the ocean thermal gradient resource, the amount of power that can be generated from OTEC technology is significantly larger than the 50 MW of generating capacity required to support the load growth. However, the cost and economics for this resource will be impacted by the high cost for the construction of the cold water pipeline, the materials that need to be utilized for the heat exchangers and pumps in the power plant due to the corrosive sea water environment, and the cost for research and development of the system which has not yet been put into commercial production.

2.2.1.2 O&M

Since the technology has not been commercially developed, the cost for operation and maintenance of OTEC systems cannot be readily quantified. However, the power plant cycle will require full time

[1] NREL. Markets for OTEC. http://www.nrel.gov/otec/markets.html

24 hour staffed plant operators. Upkeep and annual maintenance and inspection of the cold water pipe line will be required. The heat exchangers, pumps, and other components exposed to seawater will also require annual cleaning of biofouling deposits and other maintenance. The power plant equipment, including the turbine, generator, switchgear, and other components will also require annual maintenance and repair.

2.2.1.3 Construction Time/Schedule

Due to the lack of commercial development, the timeline for the implementation of an OTEC plant is expected to be between 5 to 10 years at best. Oceanographic studies to determine the best location for the cold water intake and routing of the pipeline to the shoreline will take 2 to 3 years. An EIS will also be required for the pipeline, the disposal of the cold water influent, and for the power plant facility. Construction of the facility after the necessary studies and environmental assessment is completed will take another 3 to 5 years.

2.2.1.4 Cost per MW (Capital) Cost per MW (Production)

Based on very preliminary numbers, the cost for a 50 MW OTEC power plant is estimated at approximately $10,000-$15,000 per kW.[2] [3] A continuous duty 50 MW OTEC plant will generate approximately 394,000 MWh per year assuming 90 percent availability. Based on a design life of 20 years, the average cost per kWh not including O&M costs, and transmission/distribution costs is estimated at approximately 12 to 18 cents per kWh.

2.2.1.5 Site (Requirements Land Area)

The land area for a 50 MW OTEC power plant is estimated at approximately 2 acres, or approximately the same land area as for a conventional plant. However, the facility will also require an easement and shoreline access for the cold water pipeline and warm water intake and discharges. As an alternative, a sea-based off-shore OTEC platform could also be utilized in lieu of a land based facility. However, the rights for an ocean platform and the undersea electric cable that would need to be installed may prolong the time for a sea-based system to be placed on line.

2.2.1.6 Quality Power/Reliability

Since the OTEC power plant operates on the ocean thermal temperature differential which remains fairly constant independent of the time of day and season, the power plant should be able to operate as a continuous duty power generation facility.

2.2.1.7 Base Load, Peaking Load

Due to the large capital investment that would be required for an OTEC power plant, operation of the plant as a base loaded unit is recommended. However, the plant can be controlled to operate as a load following unit if needed. Operation of the OTEC system as a peaking unit is not recommended.

2.2.1.8 Design Life

The design life of an OTEC power plant is anticipated to be between 20 to 30 years with proper operation and maintenance. The pipelines and electrical generation, distribution, and transmission equipment should have even longer lives.

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[2] Energy Unit, South Pacific Applied Geosciences Commission. "Ocean Thermal Energy Conversion and the Pacific Islands." March 2001.

[3] Guam Power Authority. A Technical and Economic Feasibility Assessment of a Deep Sea Water Cooling System at Tumon Bay, Guam. January 2006

2.2.1.9 ENVIRONMENTAL – EMISSION, WATER, REMEDIATION

OTEC systems will have very little environmental impact, other than the potential thermal pollution caused by the discharge of cold ocean water which is warmed, and the warm surface that is cooled, as they provide the heat sink and heat source for the cycle. The system may also require chlorination or other measures to prevent biofouling of equipment such as the heat exchangers and pumps.

2.2.1.10 WATER REQUIREMENTS

OTEC systems do not require potable or other sources of fresh water to operate. Fresh water may be generated as a by-product if an open cycle OTEC plant is utilized.

2.2.1.11 SPECIAL USES – AC FOR HOTELS, ETC.

Another potential use for the cold ocean water is to use it for cooling of central chilled water systems. This would be of tremendous benefit to Guam's hotel and resort areas, and to large Navy facilities that utilize central chilled water systems. The benefit of utilizing deep ocean water for cooling has a potential thermal efficiency of 30 per cent if it is used to displace cooling that would otherwise be cooled by electric chillers versus 2 to 3 percent if it is used to generate power through an OTEC cycle. However, the cost for the piping to the resort areas, and for large district cooling chilled water systems that would need to be provided on the military bases to take advantage of this technology will add to the cost and complexity of the systems.

2.2.1.12 STATE OF TECHNOLOGY

The only OTEC power plant in operation is a demonstration plant at NELHA in Kailua Kona, Hawaii. The Navy is currently developing an OTEC plant for Diego Garcia, and a new 1 MW production OTEC system is also being designed and installed at NELHA. GPA also contracted with Makai Engineering to conduct a feasibility study for the application of a Sea Water Air Conditioning system for Tumon Bay. It was found that SWAC is a technically feasible means of providing up to 16,000 tons of air conditioning to the Tumon Bay area and financially feasible for loads that exceed 8,100 tons. Energy usage could be reduced by 8.4 MW. [4]

2.2.1.13 SUMMARY VIABLE/NON-VIABLE TECH FOR ISLAND

Based on this analysis, while OTEC technology appears to be economically viable and feasible for Guam, it is too far out in terms of delivery schedule to be constructed in time to meet the planned expansion deadlines.

2.2.2 Wind Power Generation

Wind turbines for electrical generation are commercially available in sizes from 25 kW to 3,000 kW. Based on our review of the available wind studies for Guam, the best areas for wind development for the military include AAFB for the Air Force, which is located on the northeastern tip of the island, and the ridgeline at the Navy Munitions Site and Orote Peninsula on the Main Base (Figure 2-2) for the Navy that are located along the central portion of the island. While long-term historic wind data are not available for AAFB, data were gathered for the Guam Airport and the winds at these locations are estimated to average around 11 miles per hour (mph) at 50 meters above ground or a Class 2 rating. Based on current capital costs, the use of wind energy is generally considered to be marginally cost effective on sites that have at least a Class 3 wind speed rating with average wind speeds of approximately 15 mph. This is based on a wind speed rating scale that ranges from a Class

[4] Guam Power Authority. A Technical and Economic Feasibility Assessment of a Deep Sea Water Cooling System at Tumon Bay, Guam. January 2006

1 rating for the least favorable sites to a Class 7 rating for the most favorable sites. Since power varies with the cube of the wind speed, a 12 mph wind site will have only one-half the potential wind power output of a 15 mph wind speed site. However, since the electrical costs for Guam are much higher than the U.S. average costs, the 12 mph wind speeds may be adequate to make this wind development viable. This fact must also be weighed against Guam's construction cost which is also much higher than average U.S. construction costs.

Wind energy provides the benefit of being a renewable and sustainable energy source that is non-polluting. However, aesthetics and the large land area required for the siting of the wind turbines are major considerations. In additional, this energy source is intermittent depending on the actual wind speeds present at the site, and cannot be used as a reliable means of power generation to serve as a continuous duty, or even as a back-up source of power.

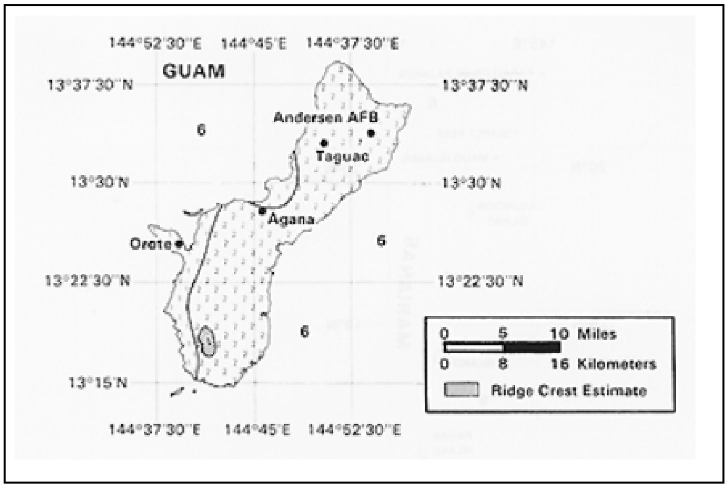

Figure 2-2: Average Wind Velocity

2.2.2.1 Quantification of Wind Resource:

Average anticipated wind speeds around 11 mph on Guam appear to be less than ideal for wind energy development. Typical nominal 3 MW wind turbines designed for 15 mph winds will only generate 1.5 MW at 12 mph.[5] Approximately 30 to 40, 3 MW nominal wind turbines will thus be needed to generate 50 MW of electrical power. The previous studies for the development of wind power on Guam have identified approximately 16 MW of wind development potential for the Navy sites at the ridgeline at the Navy Munitions Site and Orote Peninsula. The potential yield for AAFB has yet to be quantified.

2.2.2.2 O&M

Based on data from wind turbine farms that are already in commercial development, the cost for operation and maintenance of wind power systems averages between 2 and 3 cents per kWh.[6] Full-time 24-hour staffed plant operators are not required for wind farms. However, upkeep and annual maintenance and inspection of the turbines, generators, inverters, switchgear, and other components will be required.

[5] General Electric. GE Wind Energy. gewindenergy.com

[6] U.S. Department of Energy Efficiency and Renewable Energy DOE 2007a

2.2.2.3 Construction Time/Schedule

Since wind turbines are readily available in the commercial market, the timeline for the implementation of a wind farm development is between 3 to 5 years, not accounting for interconnect to existing grid requirements. Wind studies to determine the best location for the wind farms will take 1 to 2 years. An EIS will also be required for each wind farm development. Construction of the facilities after the necessary studies and environmental assessment is completed will take another 1 to 2 years.

2.2.2.4 Cost per MW (Capital) Cost per MW (Production)

Based on previous wind farm developments, the cost for wind farm developments is estimated at approximately $3,000 per kW for ideal wind sites. Based on a capacity factor of 26[7] percent assumed in the previous wind studies for Guam, wind farm developments with a total capacity of 50 MW will generate approximately 45,900-61,200 MWh per year. Based on a design life of 20 years, the average cost per kWh not including O&M costs, and transmission/distribution costs is estimated at approximately 23 cents per kWh.

2.2.2.5 Site (Requirements Land Area)

The land area for a single 2.5 to 3.6 MW wind turbine with a 280 to 340 foot diameter rotor is approximately 2 acres. A 50 MW wind farm development with 30 to 40 turbines will require a land area of between 60 to 80 acres.

2.2.2.6 Quality Power/Reliability

Since the wind farm developments are totally reliant on the strength of the winds, power production is not very consistent and reliable. The power is typically converted and stored as direct current (DC), and then inverted to AC power to maintain 60 Hz power regardless of wind speed and load.

2.2.2.7 Base Load, Peaking Load

Due to the intermittent nature of wind power, it cannot be used for base loaded or peaking operation. However, it can provide a significant portion of the electricity that would otherwise need to be generated using fossil fuels.

2.2.2.8 Design Life

The design life of wind turbines is anticipated to be between 20 and 30 years with proper operation and maintenance. The supporting electrical generation, distribution, and transmission equipment should have similar life spans. However, the life of the storage batteries is significantly lower and will need to be replaced every 2 to 3 years. Modern turbines are designed to generate power in winds up to 25 mph. Beyond this wind speed, they are designed to shut down but maintain their orientation to the prevailing winds to minimize potential wind load damage. In this configuration, they are able to withstand gusts up to 156 mph. Since 50-year typhoon 2-second interval wind gusts on Guam are predicted to exceed 170 mph, there is some potential for a severe typhoon to damage the wind turbines. Additional research and possible design enhancements are needed to mitigate the potential for wind damage.

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[7] Global Energy Concepts. Preliminary Assessment of Wind Energy Development Potential for Guam Naval Facilities. October 2007

2.2.2.9 ENVIRONMENTAL – EMISSION, WATER, REMEDIATION

Wind power systems will have some environmental impact, including the potential noise from the turbines, aesthetic concerns on how the turbines may impact the surrounding landscape, potential harmful impact on flying birds and bats, and interference with radar and other electro magnetic frequency signals.

2.2.2.10 WATER REQUIREMENTS

Wind farms do not require potable or other sources of fresh water to operate.

2.2.2.11 SPECIAL USES – AC FOR HOTELS, ETC.

Not applicable.

2.2.2.12 STATE OF TECHNOLOGY

Wind turbine technology is in widespread use. There are over 74,000 MW of wind turbines that have already been installed and operating worldwide as of 2006. The most recent improvements have been in the turbine design to reduce noise and increase efficiency, and in the power generation and control of the system.

2.2.2.13 SUMMARY VIABLE/NON-VIABLE TECH FOR ISLAND

Based on this analysis, wind farm development appears to be economically viable and feasible for Guam, and a plant can be constructed in time to meet the planned expansion deadlines. However, wind energy cannot be used as a reliable source of power for base loaded or peak shaving operation and the implementation of a large wind farm will require considerable land area.

2.2.3 Solar Energy Generation

The majority of photovoltaic panels for electrical generation are commercially available in crystalline, poly-crystalline, and amorphous silicon panels. Typical systems are in the range of 2 kW for residential systems, and 50 kW or larger in commercial application. Inverters are used to convert the DC power output from the panels into AC power. Most of these systems are installed at the house or building level, and supply the power at 120V or 220V. Large land or large roof top areas are required for panel installation.

Based on the available solar insolation data for Guam made available by National Renewable Energy Laboratory, a majority of the U.S. military lands in Guam are in areas with an average of 5.08 $kWh/m^2/day$[8] (Figure 2-3), which makes the use of photovoltaics attractive. Additional radiation data was collected at the Guam International Airport providing an average of 5.03 $kWh/m^2/day$. However, large land or large roof top areas are required for panel installation. As a rule of thumb, 1 kW of power output will require 100 square feet (ft^2) of roof area. A 5 MW system will thus require 500,000 ft^2 of area, and a 50 MW system will require 5,000,000 ft^2 of area.

Based on current capital costs, the use of photovoltaics (PV) will be marginally cost effective at current electrical rates, but the economics are improving, especially when tax credits and incentives are considered. While there are no known incentives from the GPA at this time. PV systems also have the benefit of being a renewable and sustainable energy source that is non-polluting. However, this energy source is available only during sunlight hours, and is also intermittent depending on the

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[8] Global Energy Concepts. Preliminary Assessment of Wind Energy Development Potential for Guam Naval Facilities. October 2007

weather. Consequently, PV cannot be used as a reliable means of power generation to serve as a continuous duty, or even as a back-up source of power.

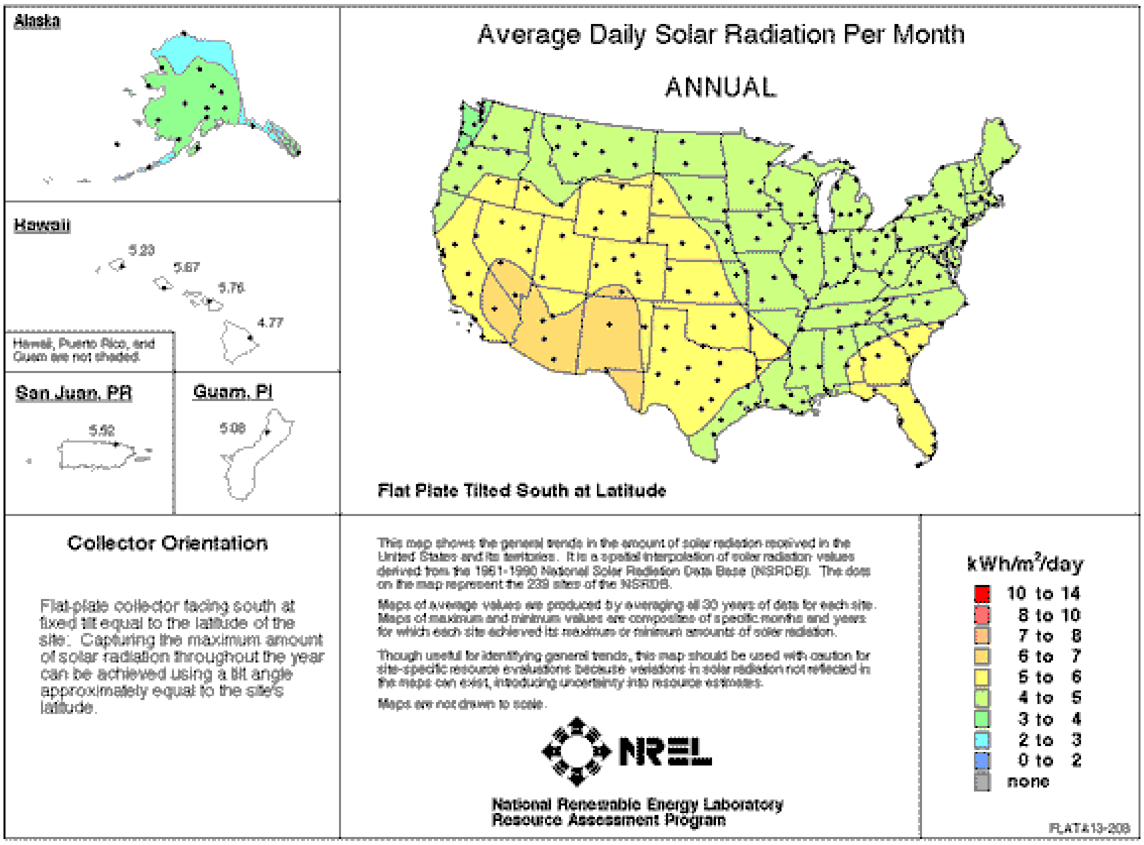

Figure 2-3: Average Daily Solar Radiation per Month

2.2.3.1 QUANTIFICATION OF SOLAR ENERGY RESOURCE

Average solar insolation values for Guam are favorable for PV and other forms of solar energy development. Based on typical sizing of 1 kW per 100 ft^2, 5,000,000 ft^2 of roof area is required to support the development of a 50 MW system. The most practical means to achieve this level of PV development is to place smaller distributed systems on the roofs of the planned facilities. The preliminary facilities planning indicates that total roof area available is over 5,000,000 ft^2. The area offers the potential to provide up to 50 MW of PV power generation capacity during peak sun periods.

2.2.3.2 O&M

PV systems are very passive and require very little active maintenance or system monitoring. The cost for operation and maintenance of PV systems is minimal and averages less than 1 cent per kWh for annual panel cleaning and maintenance checks of the inverter system and electrical system interface.

2.2.3.3 CONSTRUCTION TIME/SCHEDULE

Since PV systems are readily available in the commercial market, the timeline for the implementation of a PV power system is between 1 to 2 years. No additional studies or an EIS will be required. Construction of the PV systems can be phased to coincide with the development of the family housing units.

2.2.3.4 COST PER MW (CAPITAL) COST PER MW (PRODUCTION)

Based on previous PV installations, the cost for photovoltaic system development is estimated at approximately $8,000 per kW. Assuming an average of 5.03 kW h/m^2/day of solar insolation and a 15 percent efficiency[9], the PV development will generate approximately 76,000 MWh per year. Based on a design life of 20 years, the average cost per kWh not including O&M costs, and transmission/distribution costs is estimated at approximately 45 cents per kWh.

2.2.3.5 SITE (REQUIREMENTS LAND AREA)

The land area for PV is not required as long as they are located on the roofs of the new buildings that will be a part of the housing expansion on the island for the military.

2.2.3.6 QUALITY POWER/RELIABILITY

Since PV systems are totally reliant on the sun, they are only operational during the daytime hours and will be impacted by inclement weather. The power is typically converted and stored as DC current, and then inverted to AC power to maintain 60 Hz power.

2.2.3.7 BASE LOAD, PEAKING LOAD

Due to the intermittent nature of solar energy, it cannot be used for base loaded or peaking operation. However, it can provide a significant portion of the electricity that would otherwise need to be generated using fossil fuels.

2.2.3.8 DESIGN LIFE

The design life of PV systems is anticipated to be between 20 to 30 years with proper operation and maintenance. The supporting electrical generation, distribution, and transmission equipment should have similar life spans. Flat panel collectors with properly designed structural supports can withstand the high wind speeds from typhoons. However, they are still susceptible to impact damage unless they are protected by parapets or other devices to shield them from flying projectiles. Another solution would be to utilize amorphous silica panels that are direct mounted on the roofs of the buildings.

2.2.3.9 ENVIRONMENTAL – EMISSION, WATER, REMEDIATION

PV systems will have very little environmental impact. They should also have very little aesthetic concerns since the PV panels would be integrated into the roof forms of the buildings.

2.2.3.10 WATER REQUIREMENTS

PV systems do not require potable or other sources of fresh water to operate

2.2.3.11 SPECIAL USES – AC FOR HOTELS, ETC.

Not applicable

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[9] Electric Power Research Institute. "Renewables: A Promising Coalition of Many" Journal EPRI, Summer 2007.

2.2.3.12 State of Technology

PV technology is in widespread use. There are over 5,000 MW[10] of PV systems that have already been installed and operating over the past 20 years. The most recent improvements have been in the types of materials used for the PV panels that increase efficiency and reduce production and manufacturing costs, and in the power generation and control of the system.

2.2.3.13 Summary Viable/Non-Viable Tech for Island

Based on this analysis, PV systems, although more expensive than competing renewable technologies, appear to be economically viable and feasible for Guam. A significant number of distributed PV systems can be constructed in time to meet the planned expansion deadlines. While solar energy cannot be used as a reliable source of power for base loaded or peak shaving operation, it can displace a significant portion of the electrical load that would otherwise need to be generated using fossil fuels.

2.2.4 Biofuel (Biodiesel) Power Generation

Biofuels can utilize either simple or combined Brayton cycle combustion turbines that were originally developed for aircraft jet engine technology, or reciprocating gas or diesel engine technology. These turbines and engines principally use fossil fuel for power generation; however, they can also burn other fuels such as biofuels, ethanol, and hydrogen, if and when those fuels become available. Combustion turbines can operate on either ethanol or biodiesel. Gas engines can operate on ethanol, while diesel engines would be used to operate on biodiesel fuels. Air emissions from biofuel power plants will be lower than for power plants that utilize conventional fossils fuels. Improvements in air emission control technology such as low NO_x control burners will also help to further reduce NO_x emissions. Further reduction in air emissions is possible with the use of water or steam injection, or with the use of selective catalytic reduction (SCR) technology. However, these additional emission controls add a significant capital and operational maintenance costs.

Currently, there is no agricultural business on Guam that is developing crops for the biofuel market, and there are no producers of biofuel on the island. Currently, 20 percent of the land on Guam is used for agriculture, and another 15 percent used for pasture land. While there is some potential for further development, the implementation of biofuels on a sustainable basis is not realistic at this time. It thus appears that biofuels will need to be imported to the island if they are utilized within the immediate future.

2.2.4.1 Quantification of Biofuel Energy Resource

Given the lack of biofuel production facilities on Guam, all of the fuel must be imported for the immediate future. Based on a 35 percent efficiency plant, a 50 MW power plant operating on biofuels will require a tank farm with approximately 500,000 gallons per month of storage capacity if it is operated as a base-loaded, continuous duty plant. The storage and handling requirements for this fuel will be similar to the requirements for conventional fuels discussed in the previous sections.

2.2.4.2 O&M

A continuous duty biofuel power plant will require full time 24 hour staffed plant operators. Upkeep and annual maintenance and inspection of the generating units and ancillary systems, including the emission control system, fuel system, switchgear, controls, and switchgear will also be required. If a

[10] Electric Power Research Institute. "Renewables: A Promising Coalition of Many" Journal EPRI, Summer 2007.

combined cycle system is utilized, than additional maintenance on the boilers, condenser water system, heat exchangers, pumps, and other components will also be required.

2.2.4.3 Construction Time/Schedule

Since biofuel power plants would utilize standard conventional generating equipment, the timeline for the implementation of a biofuel power plant is between 2 to 3 years. The EIS and air permits for biofuel power plant will require approximately 1 year. Construction of the facility after the necessary studies and environmental assessment is completed will take another 1 to 2 years.

2.2.4.4 Cost per MW (Capital) Cost per MW (Production)

The cost for a biofuel power facility is estimated at approximately $1,500 per kW for the use of simple cycle combustion turbines, or reciprocating gas or diesel engine generators. The cost for a combined cycle combustion turbine or reciprocating engine plant with heat recovery boilers and steam turbine generators is estimated at $2,500 per kW. Another $500 per kW will be needed for additional air emission control devices if the units are operated as base loaded or continuous duty units. A 50 MW system could produce up to approximately 394,000 MWh per year if it is operated as base-loaded generators assuming a 90 percent availability factor. Based on an design life of 20 years, the average cost per kWh not including O&M costs, and transmission/distribution costs is estimated at approximately 22 cents per kWh for simple cycle turbines and reciprocating gas or diesel engines, or 17 cents per kWh for combined cycle power systems assuming that the biofuels are purchased at the equivalent cost per therm as oil at $100 per barrel.

2.2.4.5 Site (Requirements Land Area)

The land area for a 50 MW biofuel power plant is estimated at approximately 2 to 3 acres, including the fuel storage tanks and electrical substation. Additional easements and shoreline access may also be required for condenser water intake and discharge piping if direct ocean cooling is allowed, and for the electrical transmission lines from the substation back to the gird.

2.2.4.6 Quality Power/Reliability

Biofuel power generation facilities can provide continuous, reliable power as long as the fuel supplies are adequate and can either operate continuously or intermittently to support the gird.

2.2.4.7 Base Load, Peaking Load

Biofuel power plants can operate as either base-loaded, load following, or peaking units. Combined cycle plants should be utilized for continuous base loaded duty due to their higher efficiency. However, additional heat recovery equipment, air emission controls, and additional maintenance will be required if a combined cycle plant is provided for continuous duty operation.

2.2.4.8 Design Life

The design life of a biofuel power plant is anticipated to be between 20 to 30 years with proper operation and maintenance. The fuel storage system and electrical generation, distribution, and transmission equipment should have even lower lives.

2.2.4.9 Environmental – Emission, Water, Remediation

Biofuel power plants will have a significant environmental impact, including noise and air emissions from the turbines or engines, and aesthetic concerns on how the plant may impact the surrounding landscape. In addition, a source of water for combined cycle operation will also need to be developed.

2.2.4.10 WATER REQUIREMENTS

Combined cycle systems will require water for condenser cooling. This will most likely require an on-site well for brackish water if it is available or the use of ocean water for direct cooling. The discharge of the condenser water can create some thermal pollution if it is discharged back into the ocean.

2.2.4.11 SPECIAL USES – AC FOR HOTELS, ETC.

Not applicable

2.2.4.12 STATE OF TECHNOLOGY

Biofuel power plants are commercially in production and are an adaptation of conventional power plants. Additional technology to adapt standard engines to operate more efficiently on biofuels is being developed, including development of better NO_x controls and burner technology that is tailored to these fuels.

2.2.4.13 SUMMARY VIABLE/NON-VIABLE TECH FOR ISLAND

Biofuel power plants are viable and readily available for implementation on Guam for use as reliable base loaded power units as well as intermittent peaking operation units. However, all of the biofuel supplies must be imported as Guam does not have the agricultural base to support the production of local biofuels at this time.

2.2.5 Waste-to-Energy (Biomass) Generation

Biomass power plants typically consist of steam power plants that burn bagasse from sugar processing or other agricultural by-products such as wood chips or hay. Since the biomass must be burned to generate steam, air emissions are a primary issue. Combustion air emission controls, and scrubbing of the waste exhaust air stream are normally required, which add to the complexity and operating costs for the system.

Similar to biofuels, there are no agricultural businesses on Guam that is developing crops for the biomass market. Currently, 20 percent of the land on Guam is used for agriculture, and another 15 percent used for pasture land. While there is some potential for further development, the implementation of biomass on a sustainable basis is not realistic at this time

2.2.5.1 QUANTIFICATION OF BIOMASS ENERGY RESOURCE

There is a lack of large scale biomass agriculture and biomass processing facilities on Guam. Due to the bulk and weight of biomass, it is not practical to import biomass for fuel into Guam. Based on current land use, the 15 percent of pasture land can be used for some biomass crop development. Approximately 80,000 – 230,000 acres will be needed for a 50 MW power plant to sustain its use.[11] This would require significantly more land area than the amount currently in use for agricultural and pasture land. Since it is not practical to develop agricultural biomass crops on military lands, and biomass facility would have to be developed in conjunction with the public or private sectors.

2.2.5.2 O&M

A continuous duty biomass power plant will require full time 24 hour staffed plant operators. Upkeep and annual maintenance and inspection of the boilers, condenser water system, heat

[11] State Energy Conservation Office. Energy Crops for Fuel. http://www.seco.cpa.state.tx.us/re_biomass-crops.htm

exchangers, pumps, generating units, and ancillary systems, including the emission control system, fuel system, switchgear, controls, and switchgear will also be required.

2.2.5.3 CONSTRUCTION TIME/SCHEDULE

Since biomass power plants would utilize standard conventional generating equipment, the timeline for the implementation of a biomass power plant is between 2 to 3 years. The EIS and air permits for a biomass power plant will require approximately 1 year. Construction of the facility after the necessary studies and environmental assessment is completed will take another 1 to 2 years. The main concern on the construction of a biomass facility is the time it would take to develop sustainable levels of biomass crops.

2.2.5.4 COST PER MW (CAPITAL) COST PER MW (PRODUCTION)

The cost for a biomass power facility is estimated at approximately $3,000–$5,000 per kW.[12] Another $500 per kW will be needed for additional air emission control devices if the units are operated as base loaded or continuous duty units. A 50 MW system could produce up to 394,000 MWh per year if it is operated as base-loaded generators assuming a 90 percent availability factor. Based on an design life of 20 years, the average cost per kWh not including O&M costs, and transmission/distribution costs is estimated at approximately 25 cents per kWh for simple cycle turbines and reciprocating gas or diesel engines, or 19 cents per kWh for combined cycle power systems assuming that the biomass is purchased at the equivalent cost per therm as oil at $100 per barrel.

2.2.5.5 SITE (REQUIREMENTS LAND AREA)

The land area for a 50 MW biomass power plant is estimated at approximately 2 to 3 acres, including the biomass processing area and electrical substation. Additional easements and shoreline access may also be required for condenser water intake and discharge piping, and for the electrical transmission lines from the substation back to the gird

2.2.5.6 QUALITY POWER/RELIABILITY

Biomass power generation facilities can provide continuous, reliable power as long as the fuel supplies are adequate and can either operate continuously or intermittently to support the gird. Base Load, Peaking Load

Biomass power plants can operate as either base-loaded, load following, or peaking units. Base loaded plants should be designed with additional heat recovery to boost their efficiency. However, additional heat recovery equipment, air emission controls, and additional maintenance will be required for continuous duty operation.

2.2.5.7 DESIGN LIFE

The design life of a biofuel power plant is anticipated to be between 20 to 30 years with proper operation and maintenance. The fuel storage system and electrical generation, distribution, and transmission equipment should have even longer lives.

2.2.5.8 ENVIRONMENTAL – EMISSION, WATER, REMEDIATION

Biomass power plants will have a significant environmental impact, including noise and air emissions from the boilers and turbines, and aesthetic concerns on how the plant may impact the

[12] IEA Energy Technology Essentials http://www.iea.org/Textbase/techno/essentials.ntm

surrounding landscape. In addition, a source of water for the turbine condenser will also need to be developed.

2.2.5.9 *Water Requirements*

A biomass power plant will require water for condenser cooling. This will most likely require an on-site well for brackish water if it is available or the use of ocean water for direct cooling. The discharge of the condenser water can create some thermal pollution if it is discharged back into the ocean. One possible solution would be to use on-site injection wells to discharge the effluent.

2.2.5.10 *Special Uses – AC for Hotels, Etc.*

Not applicable

2.2.5.11 *State of Technology*

Biomass power plants are commercially in production and are an adaptation of conventional power plants. Additional technology to operate boilers more efficiently on biofuels is being developed, including development of better NO_x controls and burner technology that is tailored to these fuels. Additional air emission control technology will also be required to support the operation of biomass plants.

2.2.5.12 *Summary Viable/Non-Viable Tech for Island*

Biomass power plants are viable and readily available for implementation on Guam for use as reliable base loaded power units as well as intermittent peaking operation units. However, Guam does not have the agricultural base to support the production of biomass at this time. The development of sustainable supplies of biomass crops is needed to support the implementation of this technology, and will require the development of additional lands in the public or private sector outside of the military.

2.2.6 Fuel Cell Power Generation

Fuel cells operate on the chemical reaction between hydrogen and oxygen which produces electricity, and water as a by-product. Although there are a few installations in operation, it is still in commercial development. While the technology is also non-polluting, it relies on hydrogen as its fuel source.

Hydrogen is not commercially available as a fuel source, and the extraction of hydrogen from water and/or the reduction of gas or other fuels into hydrogen currently still require additional equipment in the process. Natural gas is often utilized as a fuel stock for the fuel cells. However, Guam lacks natural gas resources, so the natural gas must be imported if it is utilized. Because this technology is not commercially available, and because sustainable sources for the production of hydrogen fuel have not yet been developed, the use of fuel cell generators is not recommended at this time. Since natural gas or propane must currently be used to operate the fuel cells, this technology is not considered a renewable and an alternate energy technology and is not evaluated in further detail at this time.

2.2.6.1 *Fuel Delivery Storage*

Not applicable

2.2.6.2 *O&M*

Not applicable

2.2.6.3 Construction Time/Schedule

Not applicable

2.2.6.4 Cost per MW (Capital) Cost per MW (Production)

Not applicable

2.2.6.5 Site (Requirements Land Area)

Not applicable

2.2.6.6 Quality Power/Reliability

Not applicable

2.2.6.7 Base Load, Peaking Load

Not applicable

2.2.6.8 Design Life

Not applicable

2.2.6.9 Environmental – Emission, Water, Remediation

Not applicable

2.2.6.10 Water Requirements

Not applicable

2.2.6.11 Special Uses – AC for Hotels, Etc.

Not applicable

2.2.6.12 State of Technology

Not applicable

2.2.6.13 Summary Viable/Non-Viable Tech for Island

Not applicable

2.2.7 Waste-to-Energy Conversion/Generation

Waste-to-energy power plants have conventionally been steam power plants that sort and burn solid wastes. Since the wastes are normally burned to generate steam, air emissions are a primary issue. Combustion air emission controls, and scrubbing of the waste exhaust air stream are normally required, which add to the complexity and operating costs for the system.

Alternative technologies to conventional waste-to-energy steam power plants include gasification, smelting, and plasma-arc technologies. However, none of these competing technologies are available yet in the commercial market.

Based on rule of thumb estimates, the population on Guam can support a 10 to 20 MW waste-to-energy power plant. Since the military will comprises approximately 30 percent of the island's population after the relocation, a waste energy plant sized only for the military would be between 5 to 10 MW.

2.2.7.1 QUANTIFICATION OF WASTE ENERGY RESOURCE

Based on the military's resident population on Guam and the projected load growth, the total waste stream available for a waste-to-energy power plant is approximately 10 to 20 MW. A waste storage and processing center for this waste stream will also be needed to support this facility.

2.2.7.2 O&M

A continuous duty waste-to-energy power plant will require full time 24 hour staffed plant operators. The sorting and processing of the waste stream will require a full time crew. Upkeep and annual maintenance and inspection of the waste processing equipment, boilers, condenser water system, heat exchangers, pumps, generating units and ancillary systems, including the emission control system, fuel system, switchgear, controls, and switchgear will also be required.

2.2.7.3 CONSTRUCTION TIME/SCHEDULE

Since the waste-to-energy power plant would utilize standard conventional generating equipment, the timeline for the implementation of waste-to-energy power plant is between 3 to 5 years. The EIS and air permits for a waste-to-energy power plant, and to develop a waste stream collection and sorting plan will require approximately 2 years. Construction of the facility after the necessary studies and environmental assessment is completed will take another 2 to 3 years.

2.2.7.4 COST PER MW (CAPITAL) COST PER MW (PRODUCTION)

The cost for a waste-to-energy power facility is estimated at approximately $3,000 per kW. Another $500 per kW will be needed for additional air emission control devices if the units are operated as base loaded or continuous duty units. A 10 to 20 MW system could produce up to approximately 79,000 to 158,000 MWh per year if it is operated as base-loaded generators assuming a 90 percent availability factor. Based on a design life of 20 years, the average cost per kWh not including O&M costs, and transmission/distribution costs is estimated at approximately 22 cents per kWh assuming that the tipping fees are credited to the facility at $20 per ton, and that disposal and landfill costs are ignored.

2.2.7.5 SITE (REQUIREMENTS LAND AREA)

The land area for a 10 to 20 MW biomass power plant is estimated at approximately 4 acres, including the waste processing and sorting area and electrical substation. Additional easements and shoreline access may also be required for condenser water intake and discharge piping, and for the electrical transmission lines from the substation back to the grid.

2.2.7.6 QUALITY POWER/RELIABILITY

Waste-to-energy power generation facilities can provide continuous, reliable power as long as the fuel supplies are adequate and can either operate continuously or intermittently to support the gird.

2.2.7.7 BASE LOAD, PEAKING LOAD

Waste-to-energy power plants are normally operated as base-loaded units to maximize the return on the initial higher cost for the equipment. This will normally also require the plant to be designed with additional heat recovery to boost their efficiency, and air emission controls, and additional maintenance for continuous duty operation.

2.2.7.8 DESIGN LIFE

The design life of a waste-to-energy power plant is anticipated to be between 20 to 30 years with proper operation and maintenance. The electrical generation, distribution, and transmission equipment should have even lower lives. However, the processing and sorting equipment will typically need to be replaced more frequently.

2.2.7.9 *Environmental – Emission, Water, Remediation*

Waste-to-energy power plants will have a significant environmental impact, including the processing and treatment of the waste and sludge disposal, noise and air emissions from the boilers and turbines, and aesthetic concerns on how the plant may impact the surrounding landscape. In addition, a source of water for the turbine condenser will also need to be developed.

2.2.7.10 *Water Requirements*

A waste-to-energy power plant will require water for condenser cooling. This will most likely require an on-site well for brackish water if it is available or the use of ocean water for direct cooling. The discharge of the condenser water can create some thermal pollution if it is discharged back into the ocean. One possible solution would be to use on-site injection wells to discharge the effluent.

2.2.7.11 *Special Uses – AC for Hotels, Etc.*

Not applicable

2.2.7.12 *State of Technology*

Pre-engineering waste-to-energy or custom designed waste-to-energy power plants are commercially available and utilize of conventional power plant technology. Additional technology to operate boilers more efficiently and to lower emissions is being developed. Additional air emission control technology will also be required to support the operation of waste-to-energy plants. Competing technologies including gasification, smelting, and plasma-arc technologies are currently under development but are not in commercial production at this time.

2.2.7.13 *Summary Viable/Non-Viable Tech for Island*

Waste-to-energy power plants are suitable as base loaded power units. This technology may be viable if Guam were to change existing restrictions to incineration.

2.2.8 Geothermal Power Generation

Guam is situated several miles east of the southern projection of historically active line of volcanoes that comprise the Mariana volcanic arc (Figure 2-4). The area is still subject to volcanic activity, with the nearest known active volcanism being an underwater eruption that occurred 100 miles north just south of Saipan. Since the Marianas island chain is at the edge of the subduction zone between the Philippine and Pacific plates, Guam is subject to frequent earthquakes and tectonic plate movements that make the island a likely candidate for subterranean volcanic activity and possible geothermal development.

However, there are no known detailed studies or assessment of the geothermal potential for Guam other than a report from the Colorado School of Mines published in 1975 that provided a general overview of the potential for geothermal energy in the pacific region. Additional geological studies and drilling is needed to quantify and determine the extent of the potential for geothermal development on Guam.

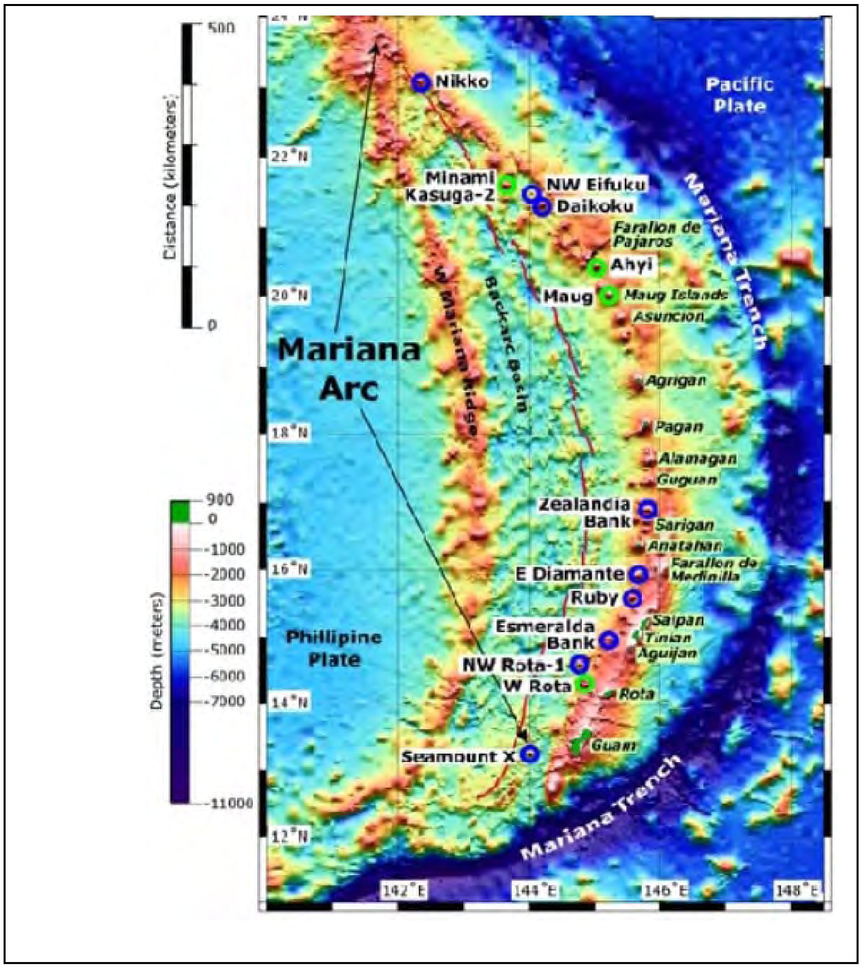

Figure 2-4: Mariana Arc

2.2.8.1 QUANTIFICATION OF GEOTHERMAL ENERGY RESOURCE

It is difficult to quantify the potential yield for geothermal energy without further studies and geological exploration for this resource. However, if there are active geothermal heat sources within the area, a geothermal power plant in the range of 30 to 50 MW should be feasible as long as an adequate number and size of geothermal wells are provided for sustained operation.

2.2.8.2 O&M

A geothermal power plant will require full time 24 hour manned plant operators. Upkeep and annual maintenance and inspection of the wells heat exchangers, condenser water system, pumps, generating units, and ancillary systems, including the emission control system, fuel system, switchgear, controls, and switchgear will also be required.

2.2.8.3 CONSTRUCTION TIME/SCHEDULE

Due to the lack of geological research, the time line for the implementation of a geothermal power plant is between 4 to 6 years. Geology and drilling studies to characterize the potential for geothermal energy and to determine the best location for drilling to support this resource will take 2 to 3 years. An EIS will also be required for the geothermal wells and venting issues, and for the power plant facility. Construction of the facility after the necessary studies and environmental assessment is completed will take another 2 to 3 years.

2.2.8.4 COST PER MW (CAPITAL) COST PER MW (PRODUCTION)

The cost for a geothermal power facility is estimated at approximately $2,000 per kW, plus the cost to develop the geothermal well resource. A 30 to 50 MW system could produce up to approximately 237,000 MWh to 394,000 MWh per year when operated as base-loaded generators assuming 90 percent availability. Based on a design life of 20 years, the average cost per kWh not including O&M costs, and transmission/distribution costs is estimated at approximately 3 cents per kWh.

2.2.8.5 SITE (REQUIREMENTS LAND AREA)

The land area for a 30 to 50 MW geothermal power plant is estimated at approximately 2 to 3 acres, including the well, power plant, and electrical substation. Additional easements and shoreline access may also be required for condenser water intake and discharge piping, and for the electrical transmission lines from the substation back to the gird

2.2.8.6 QUALITY POWER/RELIABILITY

Geothermal power generation facilities can provide continuous, reliable power as long as the wells sustain their projected yields and can either operate continuously or intermittently to support the gird.

2.2.8.7 BASE LOAD, PEAKING LOAD

Geothermal energy power plants are normally operated as base-loaded units to maximize the return on the initial higher cost for the equipment. The use of geothermal power for peaking duty is not recommended.

2.2.8.8 DESIGN LIFE

The design life of a geothermal energy power plant is anticipated to be between 20 to 30 years with proper operation and maintenance. The source wells, electrical generation, distribution, and transmission equipment should have even longer lives.

2.2.8.9 ENVIRONMENTAL – EMISSION, WATER, REMEDIATION

Geothermal power plants will have a significant environmental impact, including the drilling for geothermal energy, disposal of the effluent, venting of gases from the well, noise and air emissions from the turbines, and aesthetic concerns on how the plant may impact the surrounding landscape. In addition, a source of water for the turbine condenser will also need to be developed.

2.2.8.10 WATER REQUIREMENTS

A geothermal power plant will require water for condenser cooling. This will most likely require an on-site well for brackish water if it is available or the use of ocean water for direct cooling. The discharge of the condenser water can create some thermal pollution if it is discharged back into the ocean. One possible solution would be to use on-site injection wells to discharge the effluent.

2.2.8.11 SPECIAL USES – AC FOR HOTELS, ETC.

Not applicable

2.2.8.12 STATE OF TECHNOLOGY

Geothermal power plants are in widespread use throughout the world in areas with active geothermal resources and are an adaptation of conventional power plants. The technology to utilize geothermal energy is time tested and widely available. The Big Island of Hawaii currently has a 30 MW geothermal power plant that has been in operation for the past 15 years and has recently expanded in production from 30 to 50 MW.

2.2.8.13 SUMMARY VIABLE/NON-VIABLE TECH FOR ISLAND

Geothermal power systems are proven and time tested. However, the potential yield for a geothermal system in Guam requires additional geological survey and exploration to quantify the potential for this resource.

2.2.9 Solar Thermal Electric

Solar thermal electric systems utilize large collecting mirror arrays to concentrate or focus solar radiation to heat water or to generate steam for heating or to drive a power plant. Most of these systems are not yet available commercially, but the projected implementation costs for these technologies show promise in significantly reducing costs over photovoltaic systems. Solar Thermal Electric systems are ideal for high solar intensity insolation areas with clear near cloudless skies. Based on the solar insolation data, a majority of the U.S. military lands in Guam are in areas with an average of 5.03 $kWh/m^2/day$, which makes the use of solar thermal electric systems, in addition to photovoltaics, marginally attractive. These systems do have the benefit of being a renewable and sustainable energy source that is non-polluting. However, these systems will only operate during sunlight hours and are intermittent depending on the weather.

Large land areas are required for the collecting mirror array installation. A 10 MW system will require approximately 60 acres of land area. Solar thermal systems cannot be used as a reliable means of power generation to serve as a continuous duty, or even as a back-up source of power without the use of supplemental fuel-fired burners to generate steam when solar energy is unavailable. However, they can provide supplemental energy to the grid to reduce the overall energy use.

2.2.9.1 QUANTIFICATION OF SOLAR ENERGY RESOURCE

Based on the available solar insolation data, a majority of the U.S. military lands in Guam are in areas with an average of 5.03 $kWh/m^2/day$, which makes the use of solar thermal electric systems viable. These systems can be scaled to fit within the available space. While power generation from solar energy appears feasible, it is limited in that the energy is only available during daytime hours and is affected by weather.

2.2.9.2 O&M

Solar thermal electric systems are fairly passive, but do require active monitoring and maintenance since the steam produced from the solar concentrations is used to drive an active steam turbine and require very little active maintenance or system monitoring. Upkeep and annual maintenance and inspection of the collector arrays, steam concentrator, turbine, condenser water system, pumps, controls, and switchgear will also be required.

2.2.9.3 CONSTRUCTION TIME/SCHEDULE

The timeline for the implementation of a solar thermal electric plant is between 2 to 3 years. Approximately 1 year will be needed to prepare an EIS for the collection system, power plant facility, and water use. Construction of the facility after the necessary studies and environmental assessment is completed will take another 1 to 2 years.

2.2.9.4 COST PER MW (CAPITAL) COST PER MW (PRODUCTION)

Based on previous installations, the cost for solar thermal electric system development is estimated at approximately $5000 per kW. Assuming an average of 5.03 $kWh/m^2/day$ of solar insolation and a 15 percent efficiency[13], the PV development will generate approximately 76,000 MWh per year. Based on a design life of 20 years, the average cost per kWh not including O&M costs, and transmission/distribution costs is estimated at approximately 31 cents per kWh.

2.2.9.5 SITE (REQUIREMENTS LAND AREA)

Based on rule of thumb guidelines, a 50 MW power plant will require approximately 300 acres in land area. This includes the space requirements for the collectors, steam power plant, and substation.

2.2.9.6 QUALITY POWER/RELIABILITY

Since solar thermal electric systems are totally reliant on the sun, they are only operational during the daytime hours and will be impacted by inclement weather. The power output from the turbine will thus vary throughout the day depending on the actual weather conditions.

2.2.9.7 BASE LOAD, PEAKING LOAD

Due to the intermittent nature of solar energy, it cannot be used for base loaded or peaking operation. However, it can provide a significant portion of the electricity that would otherwise need to be generated using fossil fuels.

2.2.9.8 DESIGN LIFE

The design life of solar thermal electric systems is anticipated to be between 20 to 30 years with proper operation and maintenance. The supporting electrical generation, distribution, and transmission equipment should have similar life spans.

2.2.9.9 ENVIRONMENTAL – EMISSION, WATER, REMEDIATION

Solar thermal electric systems will have some environmental impact. Aesthetic concerns could be raised since the collectors would be highly visible. In addition, a source of water for the turbine condenser will also need to be developed.

2.2.9.10 WATER REQUIREMENTS

The solar thermal electric power plant will require water for condenser cooling. This will most likely require an on-site well for brackish water if it is available or the use of ocean water for direct cooling. The discharge of the condenser water can create some thermal pollution if it is discharged back into the ocean.

2.2.9.11 SPECIAL USES – AC FOR HOTELS, ETC.

Not applicable

2.2.9.12 STATE OF TECHNOLOGY

The use of solar thermal electric is gaining in popularity since it has the potential for significantly lower construction costs over PV technology. The most recent improvements have been in the design of the collectors, the steam power plant equipment selection, and in the control of the system. Hawaii Electric Light Company on the Big Island of Hawaii is commissioning a solar thermal electric system under contract to Sopogy. Sopogy is also proposing a similar solar thermal electric system to

[13] Electric Power Research Institute. "Renewables: A Promising Coalition of Many" Journal EPRI, Summer 2007.

the GPA. Pacific Gas and Electric has contracted with Solel to buy power from a 553 MW solar thermal electric plant that will cover 9 square miles in the Mojave Desert.

2.2.9.13 SUMMARY VIABLE/NON-VIABLE TECH FOR ISLAND

Based on this analysis, solar thermal electric systems appear to be economically viable and feasible for Guam. In addition, the technology has developed enough so that it can be integrated in time to support the planned expansion. While solar energy cannot be used as a reliable source of power for base loaded or peak shaving operation, it can displace a significant portion of the electrical load that would otherwise need to be generated using fossil fuels.

2.2.10 Wave Energy Generation

Wave energy generators take advantage of the energy carried in the waves that flow across the coastline to exact energy primarily using mechanical action generators. There are no wave energy generators that are commercially available, however, there is wave energy demonstration project sponsored by the Department of Defense that is being constructed offshore of Marine Corps Base Hawaii. While wave energy generators are non-polluting and renewable, the amount of power extracted from these units will be intermittent and dependent on the strength of the ocean waves. These units cannot be used to provide a reliable means of power for continuous duty, peak shaving, or for emergency power.

2.2.10.1 QUANTIFICATION OF WAVE ENERGY RESOURCE

Information on the average wave energy yields along the coastal areas on Guam is not readily available. However, typical wave energy yields in similar areas such as Hawaii are in the range of 4.6 kW per lf[14]. Typical wave generator designs are in the 1 to 1.5 MW per unit range. The number of wave energy generators can be scaled up to provide the target of 50 MW of electrical power.

2.2.10.2 O&M

Since the technology has not been commercially developed, the cost for operation and maintenance of wave generator systems cannot be readily quantified. However, the equipment does not require full time 24 hour manned plant operators. Mechanical pumps, housings, controls, and other components exposed to seawater will also require annual cleaning of biofouling deposits and corrosion, and other maintenance. The power plant equipment, including the generator, switchgear, and other components will also require annual maintenance and repair.

2.2.10.3 CONSTRUCTION TIME/SCHEDULE

Due to the lack of commercial development, the timeline for the implementation of an wave generators is between 3 to 5 years. Wave energy studies to determine the best location for the generating units will take 2 to 3 years. An EIS will also be required for the impact of the generators on coastal wave action and the shoreline, and for the power plant facility. Construction of the facility after the necessary studies and environmental assessment is completed will take another 1 to 2 years.

2.2.10.4 COST PER MW (CAPITAL) COST PER MW (PRODUCTION)

Based on very preliminary numbers, the cost for a 50 MW wave energy farm is estimated at approximately $3,000 to $4,000 per kW. Assuming that the wave generators will operate at design output 40 percent of the time, they will generate approximately 175,200,000 kWh per year. Based on

[14] U.S. Department of the Interior. Wave Energy Potential on the U.S. Outer Continental Shelf. http://ocsenergy.anl.gov

a design life of 20 years, the average cost per kWh not including O&M costs, and transmission/distribution costs can range from 8 to 10 cents per kWh depending on the amount of wave energy available.

2.2.10.5 SITE (REQUIREMENTS LAND AREA)

Most of the wave generation equipment will most likely be placed out in the ocean. However, a shore facility with a substation to intercept and distribute the power will be required. The land area for this facility is estimated at approximately 1 acre.

2.2.10.6 QUALITY POWER/RELIABILITY

Since the wave farm development is totally reliant on the strength of the waves, power production is not very consistent and reliable. The power is typically converted and stored as DC current, and then inverted to AC power to maintain 60 Hz power regardless of wave speed and load.

2.2.10.7 BASE LOAD, PEAKING LOAD

Due to the intermittent nature of the wave energy, it cannot be used for base loaded or peaking operation. However, it can provide a significant portion of the electricity that would otherwise need to be generated using fossil fuels.

2.2.10.8 DESIGN LIFE

The design life of wave generators is anticipated to be between 20 to 30 years with proper operation and maintenance. The supporting electrical generation, distribution, and transmission equipment should have similar life spans. However, the life of the storage batteries is significantly lower and will need to be replaced every 2 to 3 years.

2.2.10.9 ENVIRONMENTAL – EMISSION, WATER, REMEDIATION

Wave energy systems will have some impact on the ocean environment and shoreline, and on aesthetic concerns on how the turbines may impact the surrounding seascape.

2.2.10.10 WATER REQUIREMENTS

Wave generators do not require potable or other sources of fresh water to operate.

2.2.10.11 SPECIAL USES – AC FOR HOTELS, ETC.

Not applicable

2.2.10.12 STATE OF TECHNOLOGY

Wave energy generators are still in the developmental stage. There are numerous competing designs, none that have been issued for production. The Navy is testing a 1 MW output unit at Marine Corps Base Hawaii.

2.2.10.13 SUMMARY VIABLE/NON-VIABLE TECH FOR ISLAND

Based on this analysis, wave energy systems appear to be economically viable and feasible for Guam. However, the technology has not developed enough so that it can be integrated in time to support the planned expansion. While wave energy cannot be used as a reliable source of power for base loaded or peak shaving operation, it can displace a significant portion of the electrical load that would otherwise need to be generated using fossil fuels.

2.2.11 Description of GPA Present and Future Alt. Energy Projects Summary – Viable/Non-Viable for GUAM

2.2.12 Summary and Recommendations for Alternative Energy Development on Guam

Based on this analysis, a summary of the alternative energy technologies for Guam are summarized in Table 2-3.

This assessment would suggest that alternate energy resources have the potential to generate a significant portion of the military's electrical energy consumption of Guam which currently averages 330,000 MWh per year. Energy use by the military will also increase significantly due to the planned expansion. The most viable alternative energy technologies that should be considered to supplement the power generated from conventional power plants are the following:

- OTEC has the potential to provide a continuous, reliable source of electrical power. However, the time frame for its development is 5 to 10 years out.
- Wind energy development should be explored, provided that the military has the satisfactory land area to accommodate the wind farm developments.
- Biofuel
- Installation of distributed photovoltaics should be considered to supplement the power drawn from the grid, possibly through third party power contracts.
- The installation of a solar thermal electric system using a third party power producer should be considered. However, the land area required for a solar thermal system will be significantly greater than for the other technologies.
- Geothermal (potentially viable)

A combination of the implementation of several renewable technologies, for example, some wind and distributed solar energy development for the near term, supplemented by OTEC and solar thermal electric in the future, could be considered a viable option for the military's energy strategy on Guam.

Table 2-3: Summary Assessment of Alternative Energy Technologies for Guam

Alternative Energy Technology	Mode of Operation	Size (MW per unit)	Capital Cost Per kW	Area Required for 50 MW Power Plant	Cost for 50 MW Power Plant (If applicable)	Annual MWh Output for 50 MW Plant	Approximate Cost per kWh	Commercially Available Technology	Site Specific	Renewable	Construction Time Frame	Life Expectancy
OTEC	Base load	10 to 100	$10,000 to $15,000	2 to 3 acres	$500 Mil to $750 Mil	394,200	$0.12 to $0.18	NO	YES - On Coastline	YES	5–10 years	25 years
Wind Energy	As Available 12.5 mph average	0.6 to 3 (wind turbine) 10 (Farm typ.)	$3,000	60 to 80 acres	$150 Mil	113,880	$0.14 to $0.15	YES	YES - Min. Class 3–4 site	YES	2–3 years	25 years
Photovoltaics	As Available 5.03[a] kWh/m^2/day	0.004 to 0.050	$8,000	5,000,000 ft^2	$400 Mil	76,000[b]	$0.45	YES	YES Rooftops	YES	1–2 years	25 years
Simple Cycle Biofuel Plant	Peaking or Base Load	10 to 20	$1,500	2 to 3 acres	$75 Mil	394,000	$0.17 to $0.22	YES	NO	YES, but no biofuels on island	2–3 years	25 years
Combined Cycle Biofuel Plant	Peaking or Base Load	10 to 20	$2,500	2 to 3 acres	$150 Mil	394,000	$0.17 to $0.22	YES	NO	YES, but no biofuels on island	2–3 years	25 years
Biomass Plant	Base Load	10 to 20	$1,000	80,000 to 230,000	$150 Mil to $275 Mil	394,000	$0.19 to $0.25	YES	NO	YES, but no biomass on island	2–3 years	25 years
Fuel Cells	Base Load	0.1 to 0.25	$8,000	Not Recommended	Not Recommended	Not Recommended	$0.08 to $0.12	NO	NO	Depends on fuel source	na	25 years
Waste to Energy Plant	Base Load	10 to 20	$1,000	4 acres	$175 Mil	394,000	$0.19 to $0.22	YES	NO	NO	2–3 years	25 years
Geothermal	Base Load	10 to 20	$1,000	2 to 3 acres	$100 Mil	394,000	$0.02	YES	YES	YES	3–5 years	25 years
Solar Thermal Electric	As Available 5.03[a] kWh/m^2/day	1.2 to 200	$5,000	300 acres	$250 Mil	76,000[b]	$0.31	YES	YES	YES	2–3 years	25 years
Wave Energy	As Available	1	$5,000	1 acre	$150 Mil to $250 Mil	175,200	$0.08 to $0.11	NO	YES - On Coastline	YES	3–5 years	25 years

Mil million
na not applicable
[a] Based on actual radiation data taken at Guam International Airport
[b] The analysis was conducted using PV Solar Design Pro, which uses the historical daily solar radiation data from Guam International Airport to determine the system yield

3. Analysis of Power Generation Options

Four options were identified as possible approaches to meet future power requirements for the USMC relocation. Each option is presented in this section with advantages and disadvantages associated with the option.

3.1 OPTION 1

This option is based on recapitalizing, modernizing, and modifying the existing GPA system to support the proposed base load from the GPA Grid. The added generation will be provided by GPA.

3.1.1 Load Impact to Existing System

The preliminary additional loads anticipated for the military buildup are listed in Table 3-1. The loads are distributed throughout the island as indicated by the map depicted in Figure 3-1. The map shows the major facility locations. These general locations were provided to GPA to allow a preliminary analysis of load impacts due to the proposed loads.

Table 3-1: Current and Preliminary Future Military Electrical Loads for Guam

Load Description	Existing Demand Load (MW)	USMC Notional Increase (MW)	Future Planned Demand (MW)
Existing Navy electrical demand for 19 service locations (based on peak demand data in GIMDP report dated July 2006 [HHF 2006]) and broken down as follows:	47.55		
Andersen Air Force Base	18.1	0.57	29.47
Northwest Field	0.5	0	1.80
Andy South – MARBO	1.0	0	1.0
NCTS (North) – Finegayan	1.2	20.10	24.83
South Finegayan Housing Area	1.5	8.15	9.65
Barrigada	1.3	0	1.3
Naval Hospital	3.2	0	5.27
Apra Harbor (NAVBASE)	20.75	18.71	87.16
Total Electrical Loads (Includes 25 percent spare capacity on new loads)	47.55	47.53	160.53

MARBO Marianas Bonins Command
NAVBASE Naval Base
NCTS Naval Computer and Telecommunications Station
MVA megavolt ampere
MW megawatt

Table 3-2: Current and Future Military Populations in Guam

Service	Active Duty	Dependents	On-base Civilian	Total
Baseline (FY06)				
USMC	3	2	1	6
Air Force	2145	2950	805	5900
Navy	39	66	1481	1586
Army	30	50	11	91
USCG	0	0	0	0
SOF	0	0	0	0
Notional Increase				
USMC	8552	9000	3207	20759
Air Force	1656	1100	244	3000
Navy	1300	50	487	1837
Army	630	950	236	1816
USCG	81	103	30	214
SOF	350	630	131	1111
Total Future Loading				
USMC	8555	9002	3208	20765
Air Force	3801	4050	1049	8900
Navy	1330	116	1968	3423
Army	660	1000	247	1907
USCG	81	103	30	214
SOF	350	630	131	1111

The GPA performed a load analysis to evaluate system voltage and line capacity based on the proposed loads. The results of this analysis are included in Appendix A – Guam Power Authority Load Flow Analysis Data. This analysis resulted in a series of recommended line and equipment upgrades to the IWPS. These are detailed in Table 3-5 and Table 3-6. The upgrades described in the tables will be required for any generation solution that locates the additional generation near existing Piti and Cabras.

3.1.2 Sites

Generating facility sites were not considered as part of this option as the responsibility for additional generation is under GPA's control and responsibility.

These loads are based on anticipated electrical demand to support personnel loading presented in Table 3-2 and include USMC Notional Increase and planned total future loads.

3.1.3 Costs Related to Power Generation, Transmission and Distribution

Load requirements are to be provided to the GPA for planning purposes to accommodate the future loads. Costs associated with any requirements over and above normal transmission service from GPA are to be calculated based on the CSA and paid by the Navy. Article 18 of the CSA defines the responsibility of GPA to provide service to new facilities as follows:

> *"28.17 Line Extensions. Extensions of 1ines necessary to furnish permanent 34.5 kV service to the Navy will be made by modifications to this Agreement in accordance with the following provisions:*

28.17.1 General

28-17.1.1 Ownership, Operation and Maintenance. GPA will construct, own, operate and maintain electric lines and equipment only under, along, upon and over public streets, roads and highways where it has the legal right to do so, and on public lands and private property across which it has otherwise obtained rights-of-way or other necessary rights satisfactory to GPA.

28-17.1.2 Special Facilities. GPA will install only those facilities which it deems necessary to render service in accordance with GPA's standard facilities for 34.5 kV service. If the Navy requests facilities which are acceptable to GPA but are in addition to, or in substitution for, the standard facilities which GPA normally would install, the Navy shall make a contribution to cover the extra cost thereof."

The current CSA also includes Article 19 which indicates that a rate study is to be conducted to determine the allocation of costs associated with Navy services. It appears that the costs associated with improvements required by the Navy would be similarly allocated and evaluated based on the current CSA (in force until 2012).

3.1.4 Plant Production Capacity vs. Reliability

The system reliability requirements are impacted by the availability and capacity of generating units in service or available for service within the IWPS. The additional loads will impact the IWPS reliability by utilizing system capacity and reducing the available capacity in both spinning reserve and peaking units available for service. While evaluation of this option does not address specific generation requirements, it should be noted that the future reliability of the IWPS relies on the system analysis that provides adequate reserve capacity to allow units to be out of service for regular maintenance and out of service due to unexpected failures.

3.1.5 Existing Generation System Description

The existing GPA generation system consists of generation units owned by GPA, generation contracted to GPA and Navy owned generation units that are available to GPA for dispatch based on conditions in the CSA. The list of generation units is included in an example of the GPA generation status report prepared daily and submitted to the Navy's Utility Group. This example is indicated in Table 3-3 and represents installed capacity (553.4 MW) and units available for use (429.8 MW).

Figure 3-1: Guam Facility Location Map

Table 3-3: Example of a Generation Status Report

Plants	Rated Capacity	Actual Capacity	Capacity Used	First Year to Service	Remarks
DoD Diesels					
NCTS Finegayan	7.5	7.5	0	Unknown	
Radio Barrigada	4	4	0	Unknown	
Orote	19.8	19.8	0	Unknown	
NavHosp.	2	2	0	Unknown	
DoD Total	**33.3**	**33.3**	**0**		
GPA Steam					
Cabras #1	66	66	52	1974	
Cabras #2	66	66	47	1975	
Cabras #3	40	39	37	1996	
Cabras #4	40	39	37	1996	
Tanguisson #1	26.5	26.5	15	1976	
Tanguisson #2	26.5	26.5	15	1976	
Temes	40	40	0	1997	
Enron #8	44	0	0	1999	9/27/07 0745HRS: Tagged out for overhaul
Enron #9	44	44	42	1999	
GPA Diesels					
Manengon	10	8.8	0	Unknown	
Dededo CT #1	23	21	0	1992	
Dededo CT #2	23	0	0	1994	
Dededo (D)	10	5	0	1972	
Macheche	22	20	0	1993	
Yigo (CT)	22	0	0	1993	
Talafofo	10	4	0	1993	
Mt. Tenjo	26.4	24	0	1993	
Marbo CT	14	0	0		
GPA Total	**553.4**	**429.8**			**System Power Factor - 0.900**
System Total	**586.7**	**463.1**			
Peak Load Total			245		

3.1.5.1 CONDITION

The condition of the IWPS is an extremely complicated issue to evaluate in great detail. We can review the performance of the system based on a number of performance criteria. Some of this has been presented in Section 1.2.1 of this report.

3.1.5.2 SYSTEM DEFICIENCIES

General concerns with the IWPS revolve around power quality and reliability. Interviews with various agencies indicate that power quality (frequency, voltage level, harmonics) meets expectations. However, power outages (system reliability) have historically been more frequent than is acceptable to customers.

The GPA authority has made changes and improvements within the IWPS to reduce the power outages. Part of the system evaluation included a stability study GPA performed to determine what system improvements would have the most impact on the IWPS. The study was completed in July 2005. The summary of recommended capital improvements to the IWPS address the major recommendations in the report to improve the stability of the system and reduce unnecessary outages.

This report will not provide a detailed analysis of historical outages or improvements in performance since GPA changed load shedding scheme in early 2007. This report does provide information related to data provided by the Navy as it relates to outages in recent years. A summary of outage reports from October 2005 to July 2006 is included in Appendix C. The summary indicates the following as related to system outages:

- There were 214 outages during the period indicated.
- GPA system failures accounted for 39 of those outages which further break down to 10 generation outages and 29 transmission and distribution system outages.
- The Navy system accounts for 175 of the outages.

This summary covers a relatively short period of time and is not intended to provide a comprehensive evaluation of the IWPS performance or to detail outages down to specific circuits or devices. The summary does show that nearly 85 percent of the outages in a 9-month period were beyond the GPA system. A more detailed evaluation of the outage data should be able to identify specific system components (lines, breakers, switch gear, transformers or similar components) that represent a larger portion of the outages and suggest upgrades that will have the greatest impact to system performance.

3.1.5.3 AGE

The age of generation units within the IWPS varies from over 30 years old to less than 10 years old. A summary of the base load generation units and their therm of efficiency is listed in Table 3-4.

3.1.5.4 FUEL EFFICIENCIES CONDITION CAPACITY

Basic information regarding fuel efficiency of base load generation units was evaluated to determine level of efficiency being maintained by the GPA system. This information is presented in Table 3-4.

Table 3-4: Fuel Efficiency of Base Load Generation Units

Power Plant	Generation (MWh)	% to Total	Specific FOC (lit/Kwh)	Thermal Efficiency (%)
Cabras #1	156,953	16.41	0.259	34.35
Cabras #2	138,191	14.45	0.260	34.13
Cabras #3	131,124	13.71	0.211	42.18
Cabras #4	137,732	14.40	0.2178	40.84
Tanguisson #1	47,140	4.92	0.3361	26.46
Tanguisson #2	39,123	4.09	0.3517	25.29
Enron IPP Plt #8	160,932	16.83	0.2073	42.91

Power Plant	Generation (MWh)	% to Total	Specific FOC (lit/Kwh)	Thermal Efficiency (%)
Enron IPP Plt #9	144,994	15.16	0.2078	42.78
Total	956,189	100		

Specific FOC and Thermal Efficiency data provided by GPA.

The information presented in Table 3-4 confirms that while there are units in operation that perform at a relatively low efficiency, those units provide a relatively low percentage of total power delivered. That number would change as the system loads increase due to the USMC relocation. It is anticipated that any new projected loads given to the GPA will result in a revised capital improvement plan to address the system efficiency and capacity.

3.1.5.5 QUALITY/RELIABILITY

The basic requirements established by the CSA were evaluated independently and determined to have been met by the GPA as a condition to transfer the facilities to GPA control.

3.1.6 Transmission and Distribution

The transmission and distribution systems are the responsibility of the GPA. This stipulation is outlined in the current CSA is force until 2012.

3.1.6.1 SYSTEM DESCRIPTION

The GPA distributes power to the Navy at transmission level voltage and consists of 19 service locations. Each of these locations is metered as described in the CSA.

3.1.6.2 RELIABILITY

The information reviewed in preparation of this report included outage data from the Navy utilities staff, data from GPA and references to unscheduled outages in GIMDP. The results of this review are that the existing transmission system has greatly improved reliability in recent years and that recent (2007) changes in load shedding strategies has reduced unscheduled outages to Navy service locations. The NAVFAC Marianas staff has indicated in meetings that the vast majority of power outages experienced by their customers are the result of an aging infrastructure and the difficult environment in which the equipment operates.

3.1.6.3 CONDITION

The general condition of the transmission and distribution system throughout Guam is in good repair. There are some areas still affected by damage related to the most recent typhoon but the IWPS continues to be improved and planned projects will both maintain and improve the performance of the power system.

3.2 OPTION 2A

This option would construct a new SPE owned/operated base load power plant on DoD-provided land specifically to meet load requirements for the facilities associated with the USMC relocation. The facility would have the ability to provide excess power to the GPA grid. Also, the GPA grid would be used for back-up power in the event the SPE Plant is out of service. There are potential alternatives to this option that would address different generation capacities, and location of generation facilities near the major loads projected for the USMC relocation.

This interconnection option also anticipates that the SPE would contract with GPA for backup capacity to allow units to be taken out of service for maintenance or provide capacity through peaking units in the event a unit trips from the grid. This would require GPA to initiate a project and establish the project criteria under current Guam Public Utilities Commission (PUC) rules.

For the purpose of this evaluation, the option will be based on a 60 MW base load generation facility potentially located near the major load at North Finegayan (location for a majority of the housing and base loads for the Marine facilities and represents approximately 80 percent of the anticipated demand load for proposed facilities when the Apra Harbor loads are not included). The 60 MW base load is less than the projected demand load because only a portion of the planned loads are located to allow distribution from the power facility.

3.2.1 Loads

The preliminary GIMDP Study describes additional loads anticipated for the military buildup that are listed in Table 3-1. The loads are distributed throughout the island as indicated by the map depicted in Figure 3-1. The map shows the major facility locations. These general locations were provided to GPA to allow an analysis of load impacts due to the proposed loads. In general, these loads, and the load and transmission system analysis apply to all options in Section 3.

GPA performed a preliminary load analysis to evaluate system voltage and line capacity based on the proposed loads. The results of this analysis are included in Appendix A. This analysis resulted in a GPA recommendation of improvements to alleviate the overloading of lines and reduced voltage due to the military loads projected by 2014. This list of proposed upgrades would improve several transmission lines and install facilities as described in Table 3-5 below. Detailed backup for costs presented in Table 3-5 appear in Appendix D. These costs are based on 2008 dollars.

Table 3-5: Anticipated GPA Improvements to Meet Military Load Increases, Part I

Project Description	Project List	System Overhead/Underground	Voltage	Project Cost ($M)	See Figure
Upgrade Piti X20 to Orote X35 line	A	Overhead	34.5kV	$1.8	A
Upgrade Harmon X87 to Andersen X73 line	A	Overhead	34.5kV	$3.1	A
Upgrade Piti X21 to Orote X31line Double Circuit	A	Overhead	34.5kV	$3.5	A
Dededo CT X150/ !55 to Andersen X71line Double Circuit	A	Overhead	34.5kV	$7.6	A
Upgrade Harmon X88 to Dededo X151/154 line Double Circuit	A	Overhead	34.5kv	$5.8	A
Upgrade Harmon X82 to Yigo X160 line	A	Overhead	34.5kv	$3.9	A
New 24 MVAR Capacitor Bank at Orote 13.8kV	A	N/A	13.8kv	$0.8	A
New 3 MVAR Capacitor Bank at SRF 13.8kV	A	N/A	13.8kV	$0.3	A
New 24 MVAR Capacitor Bank at Andersen 13.8kV	A	N/A	13.8kV	$0.8	A
New 18 MVAR Capacitor Bank at NCS	A	N/A	13.8kV	$0.6	A
Total Costs	A			$28.2	

Information developed from Guam Power Authority/Consolidated Commission on Utilities (CCU) *Mission Critical Infrastructure: A Partnership Presentation*. Figure A located at end of report.
MVAR megavolt ampere reactive

This option list is based on upgrades to lines and additional capacitor installations and does not upgrade voltage level for any lines. This approach is a minimal approach and does not completely alleviate the adverse impacts of proposed loads. A more complete upgrade would involve the proposed project list described in Table 3-6 below. Detailed backup for costs presented in Table 3-6 appears in Appendix D.

Table 3-6: Anticipated GPA Improvements to Meet Military Load Increases, Part II

Project Description	Project List	System Overhead/Underground	Voltage	Project Cost ($M)	See Figure
New Harmon to Andersen line	B	Overhead	115kV	$8.2	B
New Andersen Substation With 112 MVA Power Transformer	B	Overhead	115kV	$9.6	B
New Piti Orote line	B	Overhead	115kV	$2.8	B
New Orote Substation With 112 MVA Power Transformer	B	Overhead	115kV	$9.6	B
Upgrade Harmon X87 to Andersen X73	B	Overhead	115kV	$4.7	B
Piti X20 to Orote X35 line	B	Overhead	115kV	$4.9	B
New 24 MVAR Capacitor Bank at Orote 13.8kV	B	N/A	13.8kv	$0.8	B
New 3 MVAR Capacitor Bank at SRF 13.8kV	B	N/A	13.8kV	$0.3	B
New 24 MVAR Capacitor Bank at Andersen 13.8kV	B	N/A	13.8kV	$0.8	B
New 18 MVAR Capacitor Bank at NCS	B	N/A	13.8kV	$0.6	B
Total Costs Option B	B			$42.3	

Information developed from Guam Power Authority/Consolidated Commission on Utilities (CCU) Mission Critical Infrastructure: A Partnership Presentation. Figure B located at end of report.
MVAR megavolt ampere reactive

The main difference between the two solutions is that rather than adding an additional parallel transmission line to existing facilities, the approach increases the transmission line voltage and upgrades the affected substation transformers. This solution results in an improvement over the Option A approach. The Line analysis data are included in Appendix A.

3.2.2 Sites

This paragraph provides an overview of potential power generation facility sites that have been considered in Guam by several organizations and issues associated with each site. It should be noted that no site has been eliminated as a result of this study but simply identified, relative considerations discussed and potential interconnect with GPA identified near the site in order to provide a starting point for future consideration.

North Guam

North Finegayan

- Results in an industrial facility located within an area of predominantly operational type facilities
- Places the generation near a major portion of the load
- Significant issue associated with permitting a facility in that area of the island due to prevailing winds and proximity to commercial and residential development
- Current land allocation does not provide sufficient space required for anticipated facilities (allocation based on limited information available at time planning document was issued)
- Will require extending power distribution network to anticipated location of power facilities

Potts Junction

- Existing fuel pipeline that currently carries JP-8 fuel runs along edge of property (capacity for fuel delivery was not available)
- Location allows reasonably simple access to IWPS transmission and distribution network
- Residential development located near the site identified for this use may impact permitting

South Guam

Existing GPA Facility at Piti

- Lower capital cost for new generation
- Simpler EPA permitting due to existing land use
- Industrial site with limited commercial and no residential development near the location

Existing infrastructure for power distribution

- Land available near Shell Oil site
- Rural location near an existing fuel storage tank farm
- Relatively close to distribution interconnect
- EPA permitting likely to be easier in southern Guam due to land use and environmental differences

3.2.3 Costs – Capital, Power Gen/T&D

Costs associated with system improvements could not be included due to the timing of information acquired to base the costs on.

3.2.4 Plant Production (MW)

Power plant production capability will be based on projected load requirements and coordination with GPA as the organization responsible for the IWPS. General capacity has been established at 60 MW for planning purposes.

3.2.5 Existing Generation System Description

The existing generation system is described in Section 3.1.5.

3.2.6 Transmission and Distribution

The existing transmission and distribution system is described in Section 3.1.6.

3.3 OPTION 2B

This option would construct a new SPE owned/operated base load power plant on DoD or other provided land. The normal operation of this base load plant will be to provide power to the GPA grid at the best available location as an Independent Power Producer (IPP). The new Marine loads would be connected to the IWPS but not necessarily at the point of the new SPE facility. The main difference between this option and option 2A is that this option allows much more flexibility in locating the generation facility. Option 2A is intended to locate the power generation facility near the major loads. Option 2A would primarily provide power to the proposed loads with an ability to sell excess power to the GPA through an interconnection with GPA.

This interconnection would also allow the SPE to contract with GPA for backup capacity to allow units to be taken out of service for maintenance or provide capacity through peaking units in the event a unit trips from the grid.

3.3.1 Loads

The preliminary additional loads anticipated for the military buildup are listed in Table 3-1. The loads are distributed throughout the island as indicated by the map depicted in Figure 3-1. The map shows the major facility locations. These general locations were provided to GPA to allow an analysis of load impacts due to the proposed loads.

The GPA performed a preliminary load analysis to evaluate system voltage and line capacity based on the proposed loads. The results of this analysis are included in Appendix A. This solution results in an improvement over the Option A approach. The Line analysis data are included in Appendix A.

3.3.2 Sites

Basic site options identified are listed in Section 3.2.2.

3.3.3 Costs

Costs associated with transmission system improvements required to support additional generation requirements are summarized in Table 3-5 and Table 3-6 and detailed in Appendix D.

3.3.4 Plant Production MW, Base Load/Military Requirements/Base Load with Unit Out/1 Unit Maintained

Power plant production capability will be based on projected load requirements and coordination with GPA as the organization responsible for the IWPS. General capacity has been established at 60 MW for planning purposes. It should be noted that system generation requirements will be based on a business case analysis that reflects both base load generation and peaking generation requirements.

3.3.5 Existing Generation System Description

The existing generation system is described in Section 3.1.5.

3.3.6 Transmission and Distribution

The existing transmission and distribution system is described in Section 3.1.6.

3.4 OPTION 3

This option would establish a separate grid system for planned loads. One of the main issues associated with this approach is backup power and reliability of the system. In general, a power facility with a firm capacity of 60 MW (e.g. 3–20 MW units) would require an additional two units to be installed to provide the ability to remove one unit from service, have a unit fail and still provide the ability to meet the 60 MW firm capacity rating. The system reliability would also be affected by the distribution system design. Most distribution systems provide multiple paths to provide power to a location. The number of paths would depend on the voltage level and type of equipment located at the point in question.

Either of these two issues (generation and distribution) will have a tremendous effect on the installed cost for this option. The generation impact could require twice the firm capacity to be installed to meet reliability expectations and the distribution system would need to be designed such that alternate feeders were available given failure of one feeder to maintain an equivalent level of redundancy that currently exists within the existing GPA transmission system.

It should be anticipated that backup power may be required for all facilities with a moderate to high level of mission critical rating. The requirement for local standby generators and the associated space and cost would need to be considered in the master planning if the level of reliability was not met with the proposed generation and distribution system for this option.

3.4.1 Loads

The loads anticipated for the military buildup are listed in Table 3-1. The loads are distributed throughout the island as indicated by the map depicted in Figure 3-1. The map shows the major facility locations. These general locations were provided to GPA in October 2007 to allow an analysis of load impacts due to the proposed loads.

The GPA performed a load analysis to evaluate system voltage and line capacity based on the proposed loads. The results of this analysis are included in Appendix A. The analysis resulted in two improvement options for the transmission systems (Option A and Option B). Option B represents a higher cost associated with the 115 kV or high voltage approach but also provides a better long term solution over Option A and better system performance based on the data available.

3.4.2 Sites

The site options are generally those discussed for the Northern portion of Guam. Much of the central portion of Guam is commercial and residential and limits the availability of a site for power generation.

3.4.3 Costs – Capital, Power Gen/T&D

Costs associated with system improvements were not able to be included due to the timing of information acquired to base the costs on.

3.4.4 Plant Production (MW)

Power plant production capability will be based on projected load requirements and coordination with GPA as the organization responsible for the IWPS. General capacity has been established at 60 MW for planning purposes. The capacity for this option will require additional study and evaluation due to the costs associated with an independent power distribution system. It is not clear that this option can be considered viable with the current CSA agreement between the Navy and GPA.

3.4.5 Existing Generation System Description

The existing generation system is described in Section 3.1.5.

3.4.6 Transmission and Distribution

The existing transmission and distribution system is described in Section 3.1.6. The proposed transmission and distribution for this option would require an independent power system with no GPA interconnect.

3.4.6.1 System Description

This system approach will require a robust distribution (transmission system for remote locations) to meet the reliability and quality requirements described in Section 1, Introduction. The system would need to provide the demand capacity with specific segment failures. This report does not provide any detailed level of design for this approach.

3.4.6.2 Reliability

The system reliability will need to meet the requirements described in Table 1-2. These requirements establish the minimum system criteria for the detailed design of the electrical system.

3.5 General Power Generation Considerations

The existing IWPS relies solely on fossil fuels for power generation in Guam. System planning and future power requirements must incorporate a diverse portfolio of power generation to reduce the impact on the economy from any one source of energy. GPA has conducted evaluations of alternative power generation and has ongoing plans that continue to evaluate alternative sources of energy for Guam. Their integrated resource plan has been updated several times in the past and will continue to include alternative energy options in evaluating the future of GPA generation plans.

3.5.1 Alternative Energy Options

Alternative energy does not typically provide a reliable source of power to the electrical grid. There are exceptions to this statement, such as waste-to-energy, ocean thermal, geothermal and to a lesser extent, wave technology. Alternative energy sources such as wind, solar, and biomass are all less reliable than the aforementioned technologies.

Alternative energy can offer a relatively reliable and renewable source of energy. It is the renewable aspect that is not provided by any significant source in Guam at this time. The alternative technologies continue to change and their cost/benefit ratios change with the ever-increasing cost of energy throughout the world. Sources of energy such as heavy fuel oil and No. 2 diesel are expected to increase in cost and the higher costs will have a substantial effect on the economy of Guam.

It is for these reasons that any future plans for additional power generation capacity in Guam should include a portion of that energy produced from alternative sources.

3.5.2 Military CSA

A customer service agreement (CSA) is in force between the Navy and GPA. Portions of the CSA are included in Appendix B, Customer Service Agreement. The significant aspects of the agreement that are relevant to this study are listed below:

- The CSA established performance metrics that the Navy expects to be met at the service points throughout the system.
- The CSA provides limited authority to the Navy for reselling power to other customers.
- The Navy is responsible for providing information to the GPA for planning purposes to allow them the opportunity to make system improvements to meet anticipated load increases in a timely manner.

3.5.3 Backup

There are no specific backup requirements to be provided by GPA. The GPA is responsible for meeting basic requirements for the number of minutes of service interruption during a year and for meeting availability requirements for loss of generation probability.

This means that any facility that cannot tolerate a minimum level of power outages and duration of outages in minutes to hours will require a backup power supply. This backup supply may include a standby generation that can restore power within seconds and operate for hours to day, an uninterruptible power supply (UPS) system that provides uninterrupted service for several minutes to a few hours or a combination of both systems. A combination of both UPS and standby generator is capable of providing uninterrupted service for a period of hours or days and would be limited be fuel supply and permitted operating limitations.

3.5.4 IPP Involvement

Use of the terms independent power producer (IPP) and special purpose entity (SPE) are similar and only separated to differentiate between an organization that is specifically defined to represent a company contracted to meet requirements of the USMC relocation (the SPE) and a more generic term (IPP) that simply represents an organization that has a long-term agreement with GPA to provide electricity at a specific quality and quantity within a minimum and maximum range of production rate.

The GPA has the sole responsibility to provide power through the IWPS and currently has long-term agreements with long established IPPs. Any new IPP agreements or increase in power requirements to existing agreements are expected to be initiated by GPA.

3.5.5 SPE Involvement, GOJ

The capital improvements required to provide additional power generation are anticipated to be provided by an SPE that recovers the capital investment through the sale of energy over the contracted period. The details of the capital facilities are not defined in this report. This report identifies anticipated load requirements, describes interconnection options for the power generation needs, and evaluates potentially viable alternative energy options for Guam.

4. Recommendations

This section summarizes each of the options discussed above and provides a general description of recommended direction supported by this study.

4.1 INTERCONNECTION OPTIONS

The four interconnection options introduced in Section 1 represent the alternatives identified in the basis of this study. These options are repeated again below for reference:

- *Option 1:* Recapitalize, modernize and modify the GPA system to support the added base load to the GPA grid. The added generation will be provided by GPA.
- *Option 2A:* Construct a new SPE owned/operated base load power plant on DoD-provided land specifically to meet load requirements for the facilities associated with the USMC relocation. The facility would have the ability to provide excess power to the GPA grid. Also, the GPA grid would be used for back-up power in the event the SPE Plant is out of service.
- *Option 2B:* Construct a new SPE owned/operated base load power plant on DoD or other provided land. The normal operation of this base load plant will be to provide power to the GPA grid at the best available location as an IPP. The new USMC loads would be connected to the IWPS but not at the point of the new SPE facility.
- *Option 3:* Construct a new SPE owned/operated base load power plant for load on North Finegayan with no connection to GPA. This option would require spare capacity to provide necessary generation with one unit out of service and failure of the largest unit (if units are not the same size).

Additional alternatives were discussed but do not offer substantial differences that warrant identifying additional options for evaluation. These options identify variations for interconnection of new generation to the system that would support the anticipated future loads.

4.1.1 Option 1

This option would keep GPA as the provider for all energy requirements for the Navy. The future load requirements would be met by additional generation capacity that meets the reliability and quality levels identified in the CSA. Specific levels that are to be met by GPA are listed in Table 1-2.

The existing system was reviewed to determine GPA's ability to meet the substantial increase in loads between 2010 and 2014. There are essentially two major considerations with the system's ability to meet these future load requirements. The first is the ability of the transmission and distribution systems to support the additional loads on the circuits that interconnect the power system. The second is the generation capacity of the system and the ability to meet future load increases.

NAVFAC provided a list of preliminary load locations and demand levels to GPA as a first step for a system analysis. GPA evaluated these loads to determine the impacts to the existing IPWS. The data that illustrate the system impacts are included in Appendix A. These impacts were further evaluated by GPA and resulted in two approaches that were considered by GPA to alleviate these effects.

The first approach is to simply increase the line capacity at each of the overloaded lines and add capacitor banks at several locations to address unacceptable voltage conditions at several other locations in the distribution system. The improvements are listed in Table 3-5 and indicated in the drawing titled Figure A, located in a pocket at the back of this report. While these improvements address the immediate needs of the system, they do not provide much additional benefit for future growth in the system and are somewhat short-term solutions to the system impacts.

The second approach, described in Table 3-6, is based on replacing and increasing the voltage rating to four transmission lines. This approach will provide a longer range solution to the anticipated increase in demand to the IWPS. The improvements associated with this approach are indicated in the drawing titled Figure B, located in a pocket at the back of this report. The proposed lines increase the system transmission capacity to meet the increased load demand at the northern end of Guam and in Apra Harbor. These are the two main load concentrations that impact the IWPS.

Table 1-2 indicates expectations included in the current CSA. The CSA's agreement expires in 2012. A recent review of the CSA resulted in a recommendation that the Navy begins in 2009 to develop a replacement agreement.

4.1.2 Option 2A

This option anticipates that an SPE would construct a new power generating facility (on DoD provided land) to meet the anticipated load requirements for the USMC relocation to Guam. This facility would be configured primarily to provide energy to support DoD loads and includes the ability to sell excess power to GPA. The facility would rely on GPA for backup power requirements.

The concept of selling excess power to GPA presumes that GPA needs the additional power, that GPA will contract to provide backup capacity for the SPE and that the existing regulations allow the approach to be carried out. This option will likely require improvements to the IWPS in addition to the power generation facility. The type of improvements will vary substantially with the site location for the additional generation.

The load analysis performed in this study would indicate that projected continuous/average load increases are in the range of 50–60 MW, with an additional capacity requirement of approximately 60 MW for transient loads in Apra Harbor (these loads are primarily associated with a planned CVN berthing in Apra Harbor). Additional analysis is required to determine the optimum generation capacity for the planned loads. Load planning will need to be developed with GPA to evaluate the system performance, maintain an adequate spinning reserve, and have sufficient spare capacity to allow maintenance cycles on operating units and respond to the unexpected unit failure.

4.1.3 Option 2B

This option is essentially the same as Option 2A except for the generating facility location. This option would open consideration for locations outside of DoD property, would primarily interconnect with GPA at a location that works for the generation station and rely on system improvements to address the transmission requirements.

4.1.4 Option 3

This option would establish a separate power generation and distribution system. There are several other major considerations make this option undesirable. The major items are listed below:

- A separate system would require the power producer to provide the necessary system backup and spinning reserve capacity to meet system demands and reliability requirements.
- The system would require privately owned transmission lines to deliver power to remote load locations for loads associated with the USMC relocation and require the associated rights-of-way for these transmission line routes.

- The facility design requirements may require additional standby generation units to address reliability requirements that may not be provided by an isolated power system.

These issues will result in a cost basis that cannot be supported with a competitive cost for electricity to the new customers associated with the USMC relocation.

4.2 ALTERNATIVE ENERGY

A series of alternative energy options were identified and evaluated for use in Guam. The alternative energy technologies evaluated are listed below:

- OTEC
- Wind energy
- Photovoltaics
- Simple cycle biofuel plant (combined cycle biofuel plant)
- Biomass plant
- Fuel cells
- Waste-to-energy plant
- Geothermal
- Solar thermal electric
- Wave energy

4.2.1 Viable Options

These options were evaluated to determine which are viable in Guam. The aspects evaluated to determine viability are summarized in Table 2-1. The viable options were selected as those that could provide a reliable source of energy and an acceptable (relatively close to current energy costs) and could be supported with current infrastructure in Guam. Those alternative energy sources identified as viable are listed below:

- Wind energy
- Simple cycle biofuel plant (combined cycle biofuel plant)
- Solar thermal electric (this option is marginally viable based on preliminary evaluation and could warrant additional review to determine if the technology is viable in some form)
- Distributed solar photovoltaic systems installed as part of the facility construction
- Geothermal (potentially viable)
- Wave (although not currently available at commercial levels similar to Guam, it should be re-evaluated in 5-10 years as technology matures)

Each of these sources indicates that the source of energy is available in sufficient quantities to support a commercial installation and produce energy at or near the current market price for electricity and provide a payback.

4.2.2 Non-Viable Options

These alternative energy options were identified and non-viable due to a lack of natural resources to support the facility, excessive costs of energy for the resulting facility or a technology that is not commercially available to support a facility.

- Ocean thermal energy conversion (OTEC)
- Photovoltaics
- Biomass plant
- Fuel cells
- Wave energy

A detailed evaluation of each alternative energy source is included in Section 2.

4.3 CONVENTIONAL POWER GENERATION

For the purposes of this report, power generation refers to the use of fossil fuels to produce electricity. This report considered four fuel options to produce power for Guam. Those options are coal, liquefied natural gas (LNG), heavy fuel oil (No. 6) and No. 2 diesel. While each of these fuels are in wide use throughout the world, fuel availability and cost vary for each location and greatly impact the viability of the fuel for each application.

The greatest mitigating factor to consider for the future generation plans in Guam is related to diversification of energy sources. The current generation system in Guam relies on heavy fuel oil and No. 2 diesel as the sources of energy to produce electricity. This results in a highly volatile environment when considering the future cost of electricity in Guam. Any future plans for energy in Guam should heavily consider diversification to mitigate the impact from a single fuel source on the cost of energy in Guam.

4.3.1 Viable Options

Viable options are those that appear to be supportable with supply and distribution systems within Guam or those where new handling facilities could be constructed in such a manner that the lower cost of energy would pay for the facilities. Existing distribution networks for fuel oil and diesel make them readily available with limited additions to infrastructure (the additions will vary depending on the actual facility location). There are currently no facilities for handling large volumes of coal or LNG in Guam.

Coal handling facilities were considered for Guam. A potentially viable site from a technical engineering standpoint was identified near existing generation facilities in Piti. There appear to be nearly 200 acres of land controlled by GPA and the Government of Guam in that area. However, this site would be in a non-attainment area. Additional analysis is needed to determine the viability of a facility at this location.

4.3.2 Non-Viable Options

The infrastructure required for LNG results in a substantial impact to implement. The tankers, storage, re-gasification and generation facilities result in the highest cost of construction for any of the fuel alternatives. Growing world demand for LNG is likely to increase pressure on prices and increase the cost on energy produced with this fuel. This fuel source is not considered viable at this time without additional investigation into the specific facilities and infrastructure required to support the system.

4.4 RECOMMENDATIONS

This report evaluated the anticipated energy needs associated with the USMC relocation and other DoD loads and the interconnection options associated with planned generation facilities and alternative energy options for Guam. Each of these issues can be complicated and is affected by other items. As such, these recommendations are based on the main issues described for each recommendation.

4.4.1 Power Generation

The loads presented in Table 1-3 reflect USMC and DoD facility requirements to meet future facility plans. The table summary reflects total loads in MW without future capacity requirements for 25 percent capacity. These load values represent the basic demand load requirements that reflect connected loads multiplied by 0.27 to obtain a demand load value. The 0.27 was calculated from similar facilities in operation.

The power generation demand requirements for the USMC facilities are 40 MW with an additional 60 MW from other DoD loads that include a transient CVN berthing requirement at Apra Harbor. It is anticipated that these loads will be supplied by a combination of base load facilities that operate essentially continuously and peaking facilities that operate as needed daily or seasonally. Initial business case analysis has recommended a mix of 60 percent base load capacity and 40 percent peaking load capacity for the planned loads.

A summary of this mix of capacity (base load and peaking) in presented in Table 4-1. This table establishes the recommended generation required to support USMC and other DoD loads expected to be added by 2019 (USMC relocation expected to occur by 2014).

Table 4-1: Recommended Generation Levels/Costs

	Load (MW)		Generation[a] (MW)		Total USMC+Other DoD Generation Costs
	USMC	Other DoD	USMC	Other DoD	
Recommended Generation Levels					
Generation Type					
Base load	28.3	52.3	45.28	84	na
Peaking	18.89	34.86	30.224	56	na
Generation Facility Costs ($M)					
Baseload Generation					
Heavy Fuel Oil	na	na	$77	$142	na
Coal	na	na	$199	$245	na
LNG	na	na	$226	$279	na
Peaking Generation Costs					
Diesel	na	na	$36	$67	na
Total Generation Cost (base load plus peaking)					
Heavy Fuel Oil Base Load	na	na	$113	$209	$322
Coal Base Load	na	na	$236	$312	$548
LNG Base Load	na	na	$263	$346	$608

na not applicable
[a] - Generation includes additional capacity to meet system reliability requirements.

The power generation evaluation also included review of conventional generation fuel alternatives. These alternatives consisted of oil (No. 2 diesel and heavy fuel oil), LNG, and coal. Each of these fuels was evaluated with regard to Guam's ability to support with existing infrastructure or requirement for new infrastructure, availability of the fuel and facility requirements (e.g., space, O&M, water, environmental impact). The general conclusions were that coal and LNG would require significant infrastructure improvements to accommodate a new generation facility with that fuel source.

Of those two, coal appears to be more technically feasible due to simpler fuel handling facilities (LNG facilities can be extremely difficult to permit due to the nature of the fuel), and more stable fuel costs. However, the potential for carbon emission penalties would adversely impact the use of coal and favor LNG. The long-term costs associated with LNG appear to trend upward more than coal but historical information is no indication of future changes based on recent world energy markets.

4.4.2 Generation Interconnection

Four options for system interconnection were evaluated for power generation. Three of the options have the potential for overlap depending on the funding mechanism and purchased power agreement that meets the requirements for additional loads. These options are 1, 2A and 2B. Option 3 would result in a separate power generation and transmission system for some or all of the planned loads and is not considered a viable option due to costs associated with an entirely new system and the need for installed standby/backup capacity to meet reliability requirements.

Options 1, 2A, and 2B are all considered viable and will depend on the business case analysis conclusions as well as GPA and the direction they will take in procuring additional generation capacity for the IWPS. It is anticipated that the generation location will be determined by final site analysis but likely be located near existing industrial zoned areas due to noise and emission impacts.

4.4.3 Alternative Energy

Alternative energy options evaluated resulted in several technologies that are considered viable based on current energy costs, maturity of the technology, and available information related to Guam for wind, geothermal, solar and related resource data. The options considered viable are listed below for reference.

- OTEC has the potential to provide a continuous, reliable source of electrical power. However, the time frame for its development is 5 to 10 years out.
- Wind energy development should be explored, provided that the military has the satisfactory land area to accommodate the wind farm developments.
- Biofuel
- Installation of distributed photovoltaics should be considered to supplement the power drawn from the grid, possibly through third party power contracts.
- The installation of a solar thermal electric system using a third party power producer should be considered. However, the land area required for a solar thermal system will be significantly greater than for most of the other technologies.
- Geothermal (potentially viable). The main limitation at this point is the lack of geothermal data. The data available to the study was general and does not include specific site data.

Current energy policy (EPAct 2005) commits to a 25 percent level of energy from renewable energy sources by 2025. The decisions related to power generation in Guam should consider this commitment to renewable energy by planning to include as much as 50 percent of the long-term planned generation to renewable energy sources.

5. References

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Appendix A
Guam Power Authority Load Flow Analysis Data

Voltage Limit Report

Name	kV	Outage	Existing 2007 Load	New DOD Loads	Line Upgrades w/ No 115 kV	Line Upgrades Including 115 kV	Outage description
Pagat 34	34.5	line_38	0.9115	0.8987	0.9213	0.9434	Line Harmon 3 34.5 to Macheche 34.5 Circuit 1
Pulantat	34.5	line_22	0.8724	0.8815	0.9106	0.956	Line Pulantat 34.5 to Barrigad 34.5 Circuit 1
Tamuning	34.5	line_67	0.9148	0.8761	0.9362	0.9566	Line Agana 34 34.5 to Tamuning 34.5 Circuit 1 and Tamuning T600
Tamuning	115	line_5	0.966	0.847	0.9571	0.9575	Line Agana115 115.0 to Tamuning 115.0 Circuit 1
San Vito	34.5	line_67	0.9167	0.8792	0.9391	0.9594	Line Agana 34 34.5 to Tamuning 34.5 Circuit 1 and Tamuning T600
Harmn115	115	line_5	0.9688	0.8527	0.9606	0.9604	Line Agana115 115.0 to Tamuning 115.0 Circuit 1
Harmn115	115	line_61	0.9619	0.8498	0.9616	0.9609	Line Piti 115 115.0 to Harmn115 115.0 and Agana T400
Harmn115	115	line_62	0.9664	0.8662	0.9636	0.9612	Line Piti 115 115.0 to Harmn115 115.0 and Piti T700
Harmn115	115	line_63	0.9641	0.8476	0.9623	0.9619	Line Piti 115 115.0 to Harmn115 115.0 and Tamuning T600
Pagat 34	34.5	line_63	0.9263	0.8916	0.944	0.9626	Line Piti 115 115.0 to Harmn115 115.0 and Tamuning T600
Pagat 34	34.5	line_61	0.9188	0.8963	0.9442	0.9626	Line Piti 115 115.0 to Harmn115 115.0 and Agana T400
Harmn115	115	line_65	0.9696	0.8552	0.9637	0.9627	Line Tamuning 115.0 to Harmn115 115.0 and Tamuning T600
Harmn115	115	line_64	0.9698	0.8555	0.9639	0.9627	Line Agana115 115.0 to Tamuning 115.0 Circuit 1 and Tamuning T600
Tamuning	115	line_64	0.9699	0.8555	0.9639	0.9628	Line Agana115 115.0 to Tamuning 115.0 Circuit 1 and Tamuning T600
Tumon 34	34.5	line_67	0.9234	0.8836	0.9431	0.9633	Line Agana 34 34.5 to Tamuning 34.5 Circuit 1 and Tamuning T600
Harmn115	115	line_4	0.9694	0.8606	0.9637	0.9638	Line Piti 115 115.0 to Harmn115 115.0 Circuit 1
Harmn115	115	line_54	0.9785	0.8618	0.9713	0.9651	Line Cabr 115 115.0 to Piti 115 115.0 Circuit 1 and Line Cabr 115 115.0 to Agana
NCS Fine	34.5	line_37	0.9373	na	0.8791	0.967	Line Harmon 1 34.5 to NCS Fine 34.5 Circuit 1
Pagat 34	34.5	line_67	0.9313	0.892	0.9465	0.9677	Line Agana 34 34.5 to Tamuning 34.5 Circuit 1 and Tamuning T600
Harmn115	115	line_6	0.9799	0.8772	0.9717	0.9709	Line Tamuning 115.0 to Harmn115 115.0 Circuit 1
Harmn115	115	line_55	0.9805	0.8772	0.972	0.9713	Line Tamuning 115.0 to Harmn115 115.0 and Line Giattap 34.5 to Harmon 1 34.5
Tamuning	115	line_54	0.9817	0.869	0.9755	0.9715	Line Cabr 115 115.0 to Piti 115 115.0 Circuit 1 and Line Cabr 115 115.0 to Agana
Potts Jc	34.5	line_37	0.9381	na	0.8844	0.9719	Line Harmon 1 34.5 to NCS Fine 34.5 Circuit 1
Harmn115	115	line_59	0.9788	0.8818	0.9745	0.972	Line Cabr 115 115.0 to Agana115 115.0 Circuit 1 and Piti T700
Harmn115	115	line_58	0.9847	0.8767	0.9783	0.9726	Line Cabr 115 to Piti 115 and Agana T400
Harmn115	115	line_57	0.979	0.8745	0.9735	0.9728	Line Cabr 115 115.0 to Agana115 115.0 Circuit 1 and Agana T400
Tamuning	115	line_62	0.9792	0.8812	0.9756	0.9736	Line Piti 115 115.0 to Harmn115 115.0 and Piti T700
Harmn115	115	line_2	0.9806	0.8764	0.9737	0.9741	Line Cabr 115 115.0 to Agana115 115.0 Circuit 1
Harmn115	115	line_3	0.9806	0.8764	0.9737	0.9741	Line Cabr 115 115.0 to Agana115 115.0 Circuit 2
Tamuning	115	line_61	0.9785	0.8684	0.9753	0.9748	Line Piti 115 115.0 to Harmn115 115.0 and Agana T400
Tamuning	115	line_59	0.9809	0.8833	0.9767	0.9752	Line Cabr 115 115.0 to Agana115 115.0 Circuit 1 and Piti T700
Harmn115	115	line_66	0.9835	0.8767	0.9761	0.9756	Line Piti 345 34.5 to Anigua 3 34.5 Circuit 1 and Agana T400
Talofofo	34.5	line_22	0.8946	0.903	0.9314	0.9757	Line Pulantat 34.5 to Barrigad 34.5 Circuit 1
Tamuning	115	line_4	0.9819	0.8749	0.9752	0.976	Line Piti 115 115.0 to Harmn115 115.0 Circuit 1
Harmn115	115	line_67	0.9804	0.8634	0.975	0.9761	Line Agana 34 34.5 to Tamuning 34.5 Circuit 1 and Tamuning T600
Agana115	115	line_54	0.9854	0.8765	0.9802	0.9769	Line Cabr 115 115.0 to Piti 115 115.0 Circuit 1 and Line Cabr 115 115.0 to Agana
Tamuning	115	line_63	0.9799	0.8679	0.977	0.977	Line Piti 115 115.0 to Harmn115 115.0 and Tamuning T600
Tamuning	115	line_2	0.9829	0.8783	0.9762	0.9775	Line Cabr 115 115.0 to Agana115 115.0 Circuit 1
Tamuning	115	line_3	0.9829	0.8783	0.9762	0.9775	Line Cabr 115 115.0 to Agana115 115.0 Circuit 2
Tamuning	115	line_57	0.9846	0.8797	0.978	0.9779	Line Cabr 115 115.0 to Agana115 115.0 Circuit 1 and Agana T400
Yigo_345	34.5	line_61	0.9187	0.8569	0.9441	0.9787	Line Piti 115 115.0 to Harmn115 115.0 and Agana T400
Harmn115	115	line_34	0.9877	0.8806	0.9777	0.9788	Line Tanguiss 34.5 to Harmon 3 34.5 Circuit 2
Harmn115	115	tran_50	0.9859	0.8843	0.979	0.9788	Tran Agana 34 34.50 to Agana115 115.00 Circuit 1
Harmn115	115	line_1	0.9888	0.881	0.9801	0.9788	Line Cabr 115 115.0 to Piti 115 115.0 Circuit 1
Harmn115	115	line_9	0.9873	0.8922	0.9817	0.9788	Line Cabrs345 34.5 to Piti 345 34.5 Circuit 1
Harmn115	115	tran_48	0.9873	0.8922	0.9817	0.9788	Tran Cabrs345 34.50 to Cabr 115 115.00 Circuit 1
Yigo_345	34.5	line_63	0.9252	0.8518	0.944	0.9791	Line Piti 115 115.0 to Harmn115 115.0 and Tamuning T600
Harmn115	115	line_60	0.9882	0.894	0.982	0.9791	Line Cabr 115 to Piti 115 and Piti T700
Harmn115	115	line_23	0.9868	0.8833	0.9786	0.9792	Line Agana 34 34.5 to Barrigad 34.5 Circuit 1
Agana115	115	line_59	0.9841	0.8883	0.9806	0.9792	Line Cabr 115 115.0 to Agana115 115.0 Circuit 1 and Piti T700
Harmn115	115	line_17	0.9885	0.8761	0.9779	0.9793	Line Apra 34. 34.5 to Tenjotap 34.5 Circuit 1
Harmn115	115	line_14	0.9879	0.8846	0.9792	0.9794	Line Talofofo 34.5 to Apra 34. 34.5 Circuit 1
Harmn115	115	line_38	0.9883	0.884	0.9794	0.9794	Line Harmon 3 34.5 to Macheche 34.5 Circuit 1

Voltage Limit Report

Name	kV	Outage	Existing 2007 Load	New DOD Loads	Line Upgrades w/ No 115 kV	Line Upgrades Including 115 kV	Outage description
Harmn115	115	tran_49	0.9878	0.8912	0.9816	0.9794	Tran Piti 345 34.50 to Piti 115 115.00 Circuit 1
Harmn115	115	line_33	0.9887	0.8765	0.9773	0.9795	Line Tanguiss 34.5 to Harmon 1 34.5 Circuit 1
Harmn115	115	tran_51	0.9867	0.8838	0.9792	0.9796	Tran Tamuning 34.50 to Tamuning 115.00 Circuit 1
Harmn115	115	line_13	0.9886	0.884	0.979	0.9797	Line Piti 345 34.5 to Anigua 3 34.5 Circuit 1
Yigo_345	34.5	line_5	0.9354	0.8713	0.9469	0.98	Line Agana115 115.0 to Tamuning 115.0 Circuit 1
Harmn115	115	line_35	0.9875	0.8776	0.978	0.9801	Line Harmon 3 34.5 to Dededo 3 34.5 Circuit 1
Harmn115	115	line_19	0.9887	0.8825	0.9789	0.9801	Line Piti 345 34.5 to Cld Stor 34.5 Circuit 1
Harmn115	115	line_12	0.989	0.8847	0.9795	0.9802	Line Piti 345 34.5 to Agana 34 34.5 Circuit 1
Harmn115	115	line_39	0.988	0.8818	0.9791	0.9803	Line Harmon 1 34.5 to Yigo_345 34.5 Circuit 1
Harmn115	115	line_25	0.9881	0.8847	0.9796	0.9803	Line Agana 34 34.5 to Tamuning 34.5 Circuit 1
Yigo_345	34.5	line_62	0.9331	0.8873	0.9491	0.9804	Line Piti 115 115.0 to Harmn115 115.0 and Piti T700
Harmn115	115	line_28	0.9881	0.885	0.9795	0.9804	Line Tamuning 34.5 to Tumon 34 34.5 Circuit 1
Yigo_345	34.5	line_64	0.9327	0.8651	0.9465	0.9805	Line Agana115 115.0 to Tamuning 115.0 Circuit 1 and Tamuning T600
Harmn115	115	line_11	na	0.882	0.9794	0.9805	Line Piti 345 34.5 to Orote 34 34.5 Circuit 1
Harmn115	115	line_24	0.9883	0.8845	0.9794	0.9805	Line Agana 34 34.5 to Radio Ba 34.5 Circuit 1
Harmn115	115	line_21	0.989	0.8857	0.9799	0.9805	Line Pulantat 34.5 to Talofofo 34.5 Circuit 1
Yigo_345	34.5	line_65	0.9326	0.8649	0.9464	0.9806	Line Tamuning 115.0 to Harmn115 115.0 and Tamuning T600
Harmn115	115	line_31	0.9896	0.8857	0.9802	0.9806	Line Anigua 3 34.5 to Agana 34 34.5 Circuit 1
Harmn115	115	line_10	0.9885	0.8888	0.9813	0.9806	Line Piti 345 34.5 to Tenjotap 34.5 Circuit 1
Harmn115	115	line_27	0.9885	0.8848	0.9797	0.9807	Line Radio Ba 34.5 to Marbo 34 34.5 Circuit 1
Harmn115	115	line_40	0.9885	0.8848	0.9797	0.9807	Line Dededo 3 34.5 to Marbo 34 34.5 Circuit 1
Harmn115	115	line_29	0.9883	0.8853	0.9798	0.9807	Line Tamuning 34.5 to San Vito 34.5 Circuit 1
Harmn115	115	line_26	0.9891	0.8855	0.9802	0.9808	Line Barrigad 34.5 to GAA 34.5 34.5 Circuit 1
Harmn115	115	line_15	0.989	0.8824	0.98	0.9809	Line Apra 34. 34.5 to Orote 34 34.5 Circuit 1
Harmn115	115	line_18	0.9889	0.8854	0.98	0.9809	Line Orote 34 34.5 to Cld Stor 34.5 Circuit 1
Harmn115	115	line_44	0.9889	0.8858	0.9802	0.9809	Line Macheche 34.5 to GAA 34.5 34.5 Circuit 1
Harmn115	115	base	0.989	0.8859	0.9803	0.9809	Base system (n-0)
Harmn115	115	line_30	0.9892	0.8859	0.9803	0.9809	Line Tumon 34 34.5 to Harmon 3 34.5 Circuit 1
Harmn115	115	line_47	0.989	0.8857	0.9804	0.9809	Line GIAT 34.5 to Harmon 1 34.5 Circuit 1
Harmn115	115	line_22	0.9894	0.887	0.9811	0.9809	Line Pulantat 34.5 to Barrigad 34.5 Circuit 1
Harmn115	115	line_32	0.9892	0.886	0.9803	0.981	Line San Vito 34.5 to Harmon 3 34.5 Circuit 1
Harmn115	115	line_46	0.9891	0.8858	0.9804	0.981	Line GAA 34.5 34.5 to GIAT 34.5 Circuit 1
Harmn115	115	line_41	0.9888	0.8855	0.9803	0.9811	Line NCS Fine 34.5 to Potts Jc 34.5 Circuit 1
Harmn115	115	line_42	0.9888	0.8855	0.9803	0.9811	Line Potts Jc 34.5 to Andersen 34.5 Circuit 1
Harmn115	115	line_45	0.989	0.8858	0.9803	0.9811	Line Yigo_345 34.5 to Andersen 34.5 Circuit 1
Agana115	115	line_2	0.9861	0.8833	0.9801	0.9815	Line Cabr 115 115.0 to Agana115 115.0 Circuit 1
Agana115	115	line_3	0.9861	0.8833	0.9801	0.9815	Line Cabr 115 115.0 to Agana115 115.0 Circuit 2
Harmn115	115	line_16	0.9898	0.887	0.981	0.9819	Line Apra 34. 34.5 to Umatac34 34.5 Circuit 1
Agana115	115	line_62	0.9877	0.8928	0.9843	0.9821	Line Piti 115 115.0 to Harmn115 115.0 and Piti T700
NCS Fine	34.5	line_61	0.9403	0.8202	0.9545	0.9825	Line Piti 115 115.0 to Harmn115 115.0 and Agana T400
NCS Fine	34.5	line_63	0.9459	0.8151	0.9545	0.9829	Line Piti 115 115.0 to Harmn115 115.0 and Tamuning T600
Tamuning	115	line_58	0.9935	0.8897	0.9865	0.9829	Line Cabr 115 to Piti 115 and Agana T400
Tamuning	115	line_66	0.9914	0.885	0.9829	0.983	Line Piti 345 34.5 to Anigua 3 34.5 Circuit 1 and Agana T400
Harmn115	115	tran_53	na	0.8787	0.9834	0.9831	Tran Harmon 1 34.50 to Harmn115 115.00 Circuit 2
Yigo_345	34.5	line_4	0.9368	0.8818	0.9499	0.9833	Line Piti 115 115.0 to Harmn115 115.0 Circuit 1
Potts Jc	34.5	line_61	0.935	0.8255	0.9524	0.9834	Line Piti 115 115.0 to Harmn115 115.0 and Agana T400
Agana115	115	line_57	0.9908	0.8877	0.9838	0.9834	Line Cabr 115 115.0 to Agana115 115.0 Circuit 1 and Agana T400
Harmn115	115	line_68	0.9888	0.88	0.9835	0.9835	Line Tamuning 34.5 to Tumon 34 34.5 Circuit 1 and Harmon T500
Yigo_345	34.5	line_54	0.9428	0.8799	0.9549	0.9836	Line Cabr 115 115.0 to Piti 115 115.0 Circuit 1 and Line Cabr 115 115.0 to Agana
Potts Jc	34.5	line_63	0.941	0.8204	0.9524	0.9837	Line Piti 115 115.0 to Harmn115 115.0 and Tamuning T600
Harmn115	115	tran_52	0.992	0.8883	0.9838	0.9837	Tran Harmon 3 34.50 to Harmn115 115.00 Circuit 1
Pagat 34	34.5	base	0.9548	0.9443	0.9645	0.9838	Base system (n-0)
NCS Fine	34.5	line_5	0.9551	0.834	0.9568	0.9839	Line Agana115 115.0 to Tamuning 115.0 Circuit 1

Voltage Limit Report

Name	kV	Outage	Existing 2007 Load	New DOD Loads	Line Upgrades w/ No 115 kV	Line Upgrades Including 115 kV	Outage description
Marbo 34	34.5	line_61	0.9287	0.898	0.9584	0.984	Line Piti 115 115.0 to Harmn115 115.0 and Agana T400
Agana115	115	line_63	0.9872	0.8773	0.9839	0.984	Line Piti 115 115.0 to Harmn115 115.0 and Tamuning T600
NCS Fine	34.5	line_62	0.9529	0.8509	0.959	0.9842	Line Piti 115 115.0 to Harmn115 115.0 and Piti T700
Dededo 3	34.5	line_61	0.9285	0.8931	0.9583	0.9843	Line Piti 115 115.0 to Harmn115 115.0 and Agana T400
Agana115	115	line_4	0.9901	0.8859	0.9835	0.9843	Line Piti 115 115.0 to Harmn115 115.0 Circuit 1
NCS Fine	34.5	line_65	0.9529	0.8284	0.9566	0.9844	Line Tamuning 115.0 to Harmn115 115.0 and Tamuning T600
NCS Fine	34.5	line_64	0.953	0.8286	0.9567	0.9844	Line Agana115 115.0 to Tamuning 115.0 Circuit 1 and Tamuning T600
Dededo 3	34.5	line_63	0.9359	0.8883	0.9581	0.9844	Line Piti 115 115.0 to Harmn115 115.0 and Tamuning T600
Tamuning	115	line_34	0.9924	0.8856	0.9825	0.9844	Line Tanguiss 34.5 to Harmon 3 34.5 Circuit 2
Tamuning	115	line_9	0.9922	0.8975	0.9866	0.9844	Line Cabrs345 34.5 to Piti 345 34.5 Circuit 1
Tamuning	115	tran_48	0.9922	0.8975	0.9866	0.9844	Tran Cabrs345 34.50 to Cabr 115 115.00 Circuit 1
Potts Jc	34.5	line_5	0.9504	0.8397	0.9549	0.9847	Line Agana115 115.0 to Tamuning 115.0 Circuit 1
Tamuning	115	line_38	0.9929	0.8888	0.984	0.9847	Line Harmon 3 34.5 to Macheche 34.5 Circuit 1
Tamuning	115	line_17	0.9933	0.8811	0.9827	0.9848	Line Apra 34. 34.5 to Tenjotap 34.5 Circuit 1
Agana115	115	line_61	0.9903	0.8833	0.9858	0.9849	Line Piti 115 115.0 to Harmn115 115.0 and Agana T400
Tamuning	115	tran_49	0.9925	0.8962	0.9863	0.9849	Tran Piti 345 34.50 to Piti 115 115.00 Circuit 1
Tamuning	115	line_14	0.9928	0.8896	0.9841	0.985	Line Talofofo 34.5 to Apra 34. 34.5 Circuit 1
Potts Jc	34.5	line_62	0.9482	0.8563	0.9571	0.9851	Line Piti 115 115.0 to Harmn115 115.0 and Piti T700
Tamuning	115	line_13	0.9935	0.8889	0.9838	0.9851	Line Piti 345 34.5 to Anigua 3 34.5 Circuit 1
Potts Jc	34.5	line_65	0.948	0.8337	0.9546	0.9852	Line Tamuning 115.0 to Harmn115 115.0 and Tamuning T600
Piti 115	115	line_54	1.0094	0.8866	0.9968	0.9852	Line Cabr 115 115.0 to Piti 115 115.0 Circuit 1 and Line Cabr 115 115.0 to Agana
Potts Jc	34.5	line_64	0.9482	0.8339	0.9547	0.9853	Line Agana115 115.0 to Tamuning 115.0 Circuit 1 and Tamuning T600
Tamuning	115	line_33	0.9936	0.8828	0.9826	0.9853	Line Tanguiss 34.5 to Harmon 1 34.5 Circuit 1
Tamuning	115	line_60	0.9923	0.8972	0.985	0.9855	Line Cabr 115 to Piti 115 and Piti T700
Marbo 34	34.5	line_63	0.939	0.8959	0.9597	0.9856	Line Piti 115 115.0 to Harmn115 115.0 and Tamuning T600
Tamuning	115	line_19	0.9936	0.8875	0.9838	0.9856	Line Piti 345 34.5 to Cld Stor 34.5 Circuit 1
Tamuning	115	line_12	0.9939	0.8897	0.9843	0.9856	Line Piti 345 34.5 to Agana 34 34.5 Circuit 1
Tamuning	115	line_35	0.9923	0.8829	0.9829	0.9857	Line Harmon 3 34.5 to Dededo 3 34.5 Circuit 1
Harmn115	115	line_43	0.9933	0.8923	0.9849	0.9857	Line Macheche 34.5 to Pagat 34 34.5 Circuit 1
Tamuning	115	line_25	0.993	0.8898	0.9844	0.9858	Line Agana 34 34.5 to Tamuning 34.5 Circuit 1
Tamuning	115	line_23	0.9929	0.89	0.9846	0.9858	Line Agana 34 34.5 to Barrigad 34.5 Circuit 1
Tamuning	115	tran_50	0.9937	0.8922	0.9856	0.9858	Tran Agana 34 34.50 to Agana115 115.00 Circuit 1
Tamuning	115	line_39	0.9928	0.8867	0.984	0.986	Line Harmon 1 34.5 to Yigo_345 34.5 Circuit 1
Tamuning	115	line_11	na	0.8871	0.9842	0.986	Line Piti 345 34.5 to Orote 34 34.5 Circuit 1
Tamuning	115	line_30	0.9934	0.891	0.9848	0.986	Line Tumon 34 34.5 to Harmon 3 34.5 Circuit 1
Tamuning	115	line_21	0.9938	0.8907	0.9848	0.9861	Line Pulantat 34.5 to Talofofo 34.5 Circuit 1
Tamuning	115	line_47	0.9934	0.8906	0.9849	0.9861	Line GIAT 34.5 to Harmon 1 34.5 Circuit 1
Tamuning	115	line_31	0.9944	0.8907	0.985	0.9861	Line Anigua 3 34.5 to Agana 34 34.5 Circuit 1
Tamuning	115	line_10	0.9933	0.894	0.9862	0.9862	Line Piti 345 34.5 to Tenjotap 34.5 Circuit 1
Tamuning	115	line_24	0.9935	0.8902	0.9846	0.9863	Line Agana 34 34.5 to Radio Ba 34.5 Circuit 1
Tamuning	115	line_46	0.9936	0.8908	0.985	0.9863	Line GAA 34.5 34.5 to GIAT 34.5 Circuit 1
Tamuning	115	line_27	0.9936	0.8905	0.9847	0.9864	Line Radio Ba 34.5 to Marbo 34 34.5 Circuit 1
Tamuning	115	line_40	0.9936	0.8905	0.9847	0.9864	Line Dededo 3 34.5 to Marbo 34 34.5 Circuit 1
Tamuning	115	line_15	0.9938	0.8873	0.9848	0.9864	Line Apra 34. 34.5 to Orote 34 34.5 Circuit 1
Tamuning	115	line_67	0.9905	0.8771	0.9849	0.9864	Line Agana 34 34.5 to Tamuning 34.5 Circuit 1 and Tamuning T600
Tamuning	115	line_32	0.9936	0.8913	0.9849	0.9864	Line San Vito 34.5 to Harmon 3 34.5 Circuit 1
Tamuning	115	line_1	0.9938	0.8897	0.9858	0.9864	Line Cabr 115 115.0 to Piti 115 115.0 Circuit 1
Tamuning	115	line_22	0.9941	0.8919	0.9858	0.9864	Line Pulantat 34.5 to Barrigad 34.5 Circuit 1
Andersen	34.5	line_61	0.9165	0.8445	0.9451	0.9865	Line Piti 115 115.0 to Harmn115 115.0 and Agana T400
Tamuning	115	line_18	0.9938	0.8904	0.9848	0.9865	Line Orote 34 34.5 to Cld Stor 34.5 Circuit 1
Tamuning	115	line_26	0.9938	0.8909	0.985	0.9865	Line Barrigad 34.5 to GAA 34.5 34.5 Circuit 1
Tamuning	115	line_44	0.9938	0.8909	0.9851	0.9865	Line Macheche 34.5 to GAA 34.5 34.5 Circuit 1
Tamuning	115	base	0.9939	0.8909	0.9851	0.9865	Base system (n-0)

Voltage Limit Report

Name	kV	Outage	Existing 2007 Load	New DOD Loads	Line Upgrades w/ No 115 kV	Line Upgrades Including 115 kV	Outage description
Harmn115	115	line_20	0.9905	0.8946	0.9861	0.9865	Line Cld Stor 34.5 to Cold Sto 34.5 Circuit 1
Tamuning	115	line_41	0.9935	0.8907	0.985	0.9866	Line NCS Fine 34.5 to Potts Jc 34.5 Circuit 1
Tamuning	115	line_42	0.9935	0.8907	0.985	0.9866	Line Potts Jc 34.5 to Andersen 34.5 Circuit 1
Tamuning	115	line_45	0.9938	0.8906	0.9851	0.9866	Line Yigo_345 34.5 to Andersen 34.5 Circuit 1
Andersen	34.5	line_63	0.9235	0.8393	0.9449	0.9868	Line Piti 115 115.0 to Harmn115 115.0 and Tamuning T600
Tamuning	115	line_28	0.9937	0.8914	0.9853	0.9869	Line Tamuning 34.5 to Tumon 34 34.5 Circuit 1
Tamuning	115	line_29	0.9939	0.8915	0.9853	0.9869	Line Tamuning 34.5 to San Vito 34.5 Circuit 1
NCS Fine	34.5	line_4	0.9564	0.845	0.9598	0.9873	Line Piti 115 115.0 to Harmn115 115.0 Circuit 1
Tamuning	115	tran_52	0.993	0.8903	0.9857	0.9873	Tran Harmon 3 34.50 to Harmn115 115.00 Circuit 1
Tamuning	115	line_16	0.9946	0.8921	0.9858	0.9874	Line Apra 34. 34.5 to Umatac34 34.5 Circuit 1
Tamuning	115	tran_53	na	0.8809	0.9859	0.9874	Tran Harmon 1 34.50 to Harmn115 115.00 Circuit 2
NCS Fine	34.5	line_54	0.9626	0.8434	0.9651	0.9875	Line Cabr 115 115.0 to Piti 115 115.0 Circuit 1 and Line Cabr 115 115.0 to Agana
Andersen	34.5	line_5	0.9342	0.8602	0.9483	0.9877	Line Agana115 115.0 to Tamuning 115.0 Circuit 1
Tamuning	115	tran_51	0.994	0.8933	0.9869	0.9879	Tran Tamuning 34.50 to Tamuning 115.00 Circuit 1
Andersen	34.5	line_62	0.9319	0.876	0.9504	0.9881	Line Piti 115 115.0 to Harmn115 115.0 and Piti T700
Potts Jc	34.5	line_4	0.9518	0.8506	0.9579	0.9881	Line Piti 115 115.0 to Harmn115 115.0 Circuit 1
Tamuning	115	line_68	0.991	0.8837	0.9864	0.9881	Line Tamuning 34.5 to Tumon 34 34.5 Circuit 1 and Harmon T500
Piti 115	115	line_58	1.01	0.8949	0.9996	0.9881	Line Cabr 115 to Piti 115 and Agana T400
Andersen	34.5	line_65	0.9309	0.8527	0.9474	0.9883	Line Tamuning 115.0 to Harmn115 115.0 and Tamuning T600
Andersen	34.5	line_64	0.9311	0.8529	0.9475	0.9883	Line Agana115 115.0 to Tamuning 115.0 Circuit 1 and Tamuning T600
Potts Jc	34.5	line_54	0.9579	0.8488	0.9631	0.9884	Line Cabr 115 115.0 to Piti 115 115.0 Circuit 1 and Line Cabr 115 115.0 to Agana
Yigo_345	34.5	line_58	0.9405	0.8892	0.9575	0.9891	Line Cabr 115 to Piti 115 and Agana T400
Yigo_345	34.5	tran_53	na	0.8475	0.936	0.9894	Tran Harmon 1 34.50 to Harmn115 115.00 Circuit 2
Yigo_345	34.5	line_57	0.9347	0.8855	0.9532	0.9894	Line Cabr 115 115.0 to Agana115 115.0 Circuit 1 and Agana T400
NCS Fine	34.5	tran_53	na	0.8031	0.9435	0.9895	Tran Harmon 1 34.50 to Harmn115 115.00 Circuit 2
Agana115	115	line_34	0.997	0.8924	0.9877	0.9896	Line Tanguiss 34.5 to Harmon 3 34.5 Circuit 2
Agana115	115	line_38	0.9972	0.8952	0.9888	0.9896	Line Harmon 3 34.5 to Macheche 34.5 Circuit 1
Umatac34	34.5	line_56	na	na	0.8841	0.9897	Line Piti 345 34.5 to Orote 34 34.5 and Piti to Apra w/ Tenjo Tap 34.5
Pulantat	34.5	base	0.9455	0.9448	0.9619	0.9898	Base system (n-0)
Yigo_345	34.5	line_67	0.9333	0.8564	0.9495	0.99	Line Agana 34 34.5 to Tamuning 34.5 Circuit 1 and Tamuning T600
Agana115	115	line_17	0.9979	0.8878	0.9878	0.99	Line Apra 34. 34.5 to Tenjotap 34.5 Circuit 1
Agana115	115	line_14	0.9974	0.8962	0.9892	0.9902	Line Talofofo 34.5 to Apra 34. 34.5 Circuit 1
Agana115	115	line_13	0.998	0.8956	0.9889	0.9903	Line Piti 345 34.5 to Anigua 3 34.5 Circuit 1
Agana115	115	line_66	0.9994	0.8954	0.9904	0.9903	Line Piti 345 34.5 to Anigua 3 34.5 Circuit 1 and Agana T400
Agana115	115	line_33	0.9981	0.8899	0.9879	0.9905	Line Tanguiss 34.5 to Harmon 1 34.5 Circuit 1
Yigo_345	34.5	line_39	0.9158	0.8396	0.9381	0.9906	Line Harmon 1 34.5 to Yigo_345 34.5 Circuit 1
Agana115	115	line_19	0.9981	0.8942	0.9889	0.9907	Line Piti 345 34.5 to Cld Stor 34.5 Circuit 1
Tamuning	115	line_43	0.9977	0.897	0.9893	0.9908	Line Macheche 34.5 to Pagat 34 34.5 Circuit 1
Agana115	115	line_12	0.9984	0.8963	0.9894	0.9908	Line Piti 345 34.5 to Agana 34 34.5 Circuit 1
Agana115	115	line_35	0.9967	0.8894	0.988	0.9909	Line Harmon 3 34.5 to Dededo 3 34.5 Circuit 1
Andersen	34.5	line_4	0.9357	0.8707	0.9514	0.9911	Line Piti 115 115.0 to Harmn115 115.0 Circuit 1
Agana115	115	line_39	0.9973	0.8934	0.9891	0.9911	Line Harmon 1 34.5 to Yigo_345 34.5 Circuit 1
Tamuning	115	line_55	0.9977	0.8955	0.9892	0.9911	Line Tamuning 115.0 to Harmn115 115.0 and Line Giattap 34.5 to Harmon 1 34.5
Agana115	115	line_11	na	0.8937	0.9893	0.9911	Line Piti 345 34.5 to Orote 34 34.5 Circuit 1
Dededo 3	34.5	line_67	0.9409	0.889	0.9609	0.9912	Line Agana 34 34.5 to Tamuning 34.5 Circuit 1 and Tamuning T600
Agana115	115	line_67	0.995	0.8834	0.9894	0.9912	Line Agana 34 34.5 to Tamuning 34.5 Circuit 1 and Tamuning T600
Agana115	115	line_47	0.9979	0.8971	0.9899	0.9912	Line GIAT 34.5 to Harmon 1 34.5 Circuit 1
Agana115	115	line_30	0.998	0.8975	0.9899	0.9912	Line Tumon 34 34.5 to Harmon 3 34.5 Circuit 1
Yigo_345	34.5	line_66	0.9376	0.8844	0.9539	0.9913	Line Piti 345 34.5 to Anigua 3 34.5 Circuit 1 and Agana T400
Agana115	115	line_21	0.9983	0.8973	0.9899	0.9913	Line Pulantat 34.5 to Talofofo 34.5 Circuit 1
Agana115	115	line_31	0.9988	0.8973	0.9901	0.9913	Line Anigua 3 34.5 to Agana 34 34.5 Circuit 1
Agana115	115	line_25	0.9981	0.8968	0.9898	0.9914	Line Agana 34 34.5 to Tamuning 34.5 Circuit 1
Agana115	115	line_46	0.9981	0.8974	0.9901	0.9914	Line GAA 34.5 34.5 to GIAT 34.5 Circuit 1

Voltage Limit Report

Name	kV	Outage	Existing 2007 Load	New DOD Loads	Line Upgrades w/ No 115 kV	Line Upgrades Including 115 kV	Outage description
Agana115	115	line_23	0.9979	0.8973	0.9902	0.9914	Line Agana 34 34.5 to Barrigad 34.5 Circuit 1
Agana115	115	line_22	0.9984	0.8983	0.9907	0.9914	Line Pulantat 34.5 to Barrigad 34.5 Circuit 1
Andersen	34.5	line_54	0.9412	0.8684	0.9562	0.9915	Line Cabr 115 115.0 to Piti 115 115.0 Circuit 1 and Line Cabr 115 115.0 to Agana
Agana115	115	line_15	0.9983	0.8938	0.9898	0.9915	Line Apra 34. 34.5 to Orote 34 34.5 Circuit 1
Agana115	115	line_27	0.9983	0.8973	0.9899	0.9915	Line Radio Ba 34.5 to Marbo 34 34.5 Circuit 1
Agana115	115	line_40	0.9983	0.8973	0.9899	0.9915	Line Dededo 3 34.5 to Marbo 34 34.5 Circuit 1
Agana115	115	line_32	0.9981	0.8978	0.99	0.9915	Line San Vito 34.5 to Harmon 3 34.5 Circuit 1
Tamuning	115	line_6	0.9984	0.8958	0.9898	0.9916	Line Tamuning 115.0 to Harmn115 115.0 Circuit 1
Agana115	115	line_24	0.9982	0.8971	0.9898	0.9916	Line Agana 34 34.5 to Radio Ba 34.5 Circuit 1
Agana115	115	line_18	0.9983	0.897	0.9899	0.9916	Line Orote 34 34.5 to Cld Stor 34.5 Circuit 1
Agana115	115	base	0.9983	0.8975	0.9901	0.9916	Base system (n-0)
Agana115	115	line_44	0.9983	0.8975	0.9901	0.9916	Line Macheche 34.5 to GAA 34.5 34.5 Circuit 1
Agana115	115	line_26	0.9983	0.8977	0.9901	0.9916	Line Barrigad 34.5 to GAA 34.5 34.5 Circuit 1
Agana115	115	tran_51	0.9974	0.8976	0.9905	0.9916	Tran Tamuning 34.50 to Tamuning 115.00 Circuit 1
Agana115	115	line_41	0.998	0.8974	0.99	0.9917	Line NCS Fine 34.5 to Potts Jc 34.5 Circuit 1
Agana115	115	line_42	0.998	0.8974	0.99	0.9917	Line Potts Jc 34.5 to Andersen 34.5 Circuit 1
Agana115	115	line_45	0.9983	0.8972	0.9902	0.9917	Line Yigo_345 34.5 to Andersen 34.5 Circuit 1
Agana115	115	line_28	0.9982	0.898	0.9903	0.992	Line Tamuning 34.5 to Tumon 34 34.5 Circuit 1
Agana115	115	line_29	0.9984	0.898	0.9903	0.992	Line Tamuning 34.5 to San Vito 34.5 Circuit 1
Potts Jc	34.5	tran_53	na	0.8117	0.9428	0.9921	Tran Harmon 1 34.50 to Harmn115 115.00 Circuit 2
Agana115	115	tran_52	0.997	0.8964	0.9903	0.9921	Tran Harmon 3 34.50 to Harmn115 115.00 Circuit 1
Tamuning	115	line_20	0.9953	0.8998	0.991	0.9922	Line Cld Stor 34.5 to Cold Sto 34.5 Circuit 1
Agana115	115	tran_53	na	0.8873	0.9905	0.9923	Tran Harmon 1 34.50 to Harmn115 115.00 Circuit 2
Yigo_345	34.5	line_2	0.9448	0.8966	0.957	0.9925	Line Cabr 115 115.0 to Agana115 115.0 Circuit 1
Yigo_345	34.5	line_3	0.9448	0.8966	0.957	0.9925	Line Cabr 115 115.0 to Agana115 115.0 Circuit 2
Agana115	115	line_16	0.9991	0.8987	0.9909	0.9926	Line Apra 34. 34.5 to Umatac34 34.5 Circuit 1
Agana115	115	line_1	0.9984	0.898	0.9913	0.9926	Line Cabr 115 115.0 to Piti 115 115.0 Circuit 1
Talofofo	34.5	line_17	0.9331	0.8993	0.9497	0.9927	Line Apra 34. 34.5 to Tenjotap 34.5 Circuit 1
Agana115	115	line_68	0.9952	0.89	0.9909	0.9928	Line Tamuning 34.5 to Tumon 34 34.5 Circuit 1 and Harmon T500
NCS Fine	34.5	line_58	0.9616	0.8542	0.9681	0.9929	Line Cabr 115 to Piti 115 and Agana T400
NCS Fine	34.5	line_57	0.9559	0.8505	0.9637	0.9932	Line Cabr 115 115.0 to Agana115 115.0 Circuit 1 and Agana T400
Umatac34	34.5	line_17	0.9317	0.8733	0.9374	0.9934	Line Apra 34. 34.5 to Tenjotap 34.5 Circuit 1
Marbo 34	34.5	line_67	0.9454	0.8988	0.9636	0.9934	Line Agana 34 34.5 to Tamuning 34.5 Circuit 1 and Tamuning T600
Dededo 3	34.5	line_68	0.9248	0.8978	0.9564	0.9935	Line Tamuning 34.5 to Tumon 34 34.5 Circuit 1 and Harmon T500
NCS Fine	34.5	line_67	0.9548	0.8214	0.9605	0.9937	Line Agana 34 34.5 to Tamuning 34.5 Circuit 1 and Tamuning T600
NCS Fine	34.5	line_59	0.9624	0.8653	0.967	0.9937	Line Cabr 115 115.0 to Agana115 115.0 Circuit 1 and Piti T700
Potts Jc	34.5	line_58	0.9562	0.8591	0.966	0.9939	Line Cabr 115 to Piti 115 and Agana T400
Potts Jc	34.5	line_57	0.9506	0.8553	0.9615	0.9941	Line Cabr 115 115.0 to Agana115 115.0 Circuit 1 and Agana T400
Dededo 3	34.5	line_35	0.9051	0.8394	0.9373	0.9945	Line Harmon 3 34.5 to Dededo 3 34.5 Circuit 1
Ded CT#1	13.8	line_35	0.9051	0.8994	0.9374	0.9945	Line Harmon 3 34.5 to Dededo 3 34.5 Circuit 1
Yigo_345	34.5	line_68	0.9219	0.8684	0.9485	0.9946	Line Tamuning 34.5 to Tumon 34 34.5 Circuit 1 and Harmon T500
Potts Jc	34.5	line_59	0.9576	0.8704	0.9649	0.9946	Line Cabr 115 115.0 to Agana115 115.0 Circuit 1 and Piti T700
Potts Jc	34.5	line_67	0.9493	0.826	0.9581	0.9947	Line Agana 34 34.5 to Tamuning 34.5 Circuit 1 and Tamuning T600
Harmon 1	34.5	tran_53	na	0.8971	0.9602	0.9949	Tran Harmon 1 34.50 to Harmn115 115.00 Circuit 2
NCS Fine	34.5	line_6	0.9669	0.8662	0.9679	0.9949	Line Tamuning 115.0 to Harmn115 115.0 Circuit 1
NCS Fine	34.5	line_66	0.959	0.8498	0.9645	0.995	Line Piti 345 34.5 to Anigua 3 34.5 Circuit 1 and Agana T400
Yigo_345	34.5	tran_50	0.9416	0.8973	0.958	0.9953	Tran Agana 34 34.50 to Agana115 115.00 Circuit 1
Yigo_345	34.5	tran_51	0.9463	0.8956	0.9574	0.9957	Tran Tamuning 34.50 to Tamuning 115.00 Circuit 1
Potts Jc	34.5	line_6	0.9624	0.8717	0.9661	0.9958	Line Tamuning 115.0 to Harmn115 115.0 Circuit 1
Potts Jc	34.5	line_66	0.9536	0.8544	0.9623	0.996	Line Piti 345 34.5 to Anigua 3 34.5 Circuit 1 and Agana T400
Cold Storage	34.5	line_19	0.9494	0.8633	0.9142	0.9962	Line Piti 345 34.5 to Cld Stor 34.5 Circuit 1
NCS Fine	34.5	line_2	0.9646	0.8609	0.9672	0.9963	Line Cabr 115 115.0 to Agana115 115.0 Circuit 1
NCS Fine	34.5	line_3	0.9646	0.8609	0.9672	0.9963	Line Cabr 115 115.0 to Agana115 115.0 Circuit 2

Voltage Limit Report

Name	kV	Outage	Existing 2007 Load	New DOD Loads	Line Upgrades w/ No 115 kV	Line Upgrades Including 115 kV	Outage description
Marbo 34	34.5	line_35	0.9143	0.8571	0.9425	0.9964	Line Harmon 3 34.5 to Dededo 3 34.5 Circuit 1
Yigo_345	34.5	line_35	0.9197	0.841	0.9433	0.9965	Line Harmon 3 34.5 to Dededo 3 34.5 Circuit 1
NCS Fine	34.5	line_55	0.9691	0.8664	0.9696	0.9967	Line Tamuning 115.0 to Harmn115 115.0 and Line Giattap 34.5 to Harmon 1 34.5
Agana115	115	line_64	1.0013	0.897	0.996	0.9968	Line Agana115 115.0 to Tamuning 115.0 Circuit 1 and Tamuning T600
Yigo_345	34.5	line_33	0.9526	0.8892	0.9563	0.9969	Line Tanguiss 34.5 to Harmon 1 34.5 Circuit 1
Agana115	115	line_65	1.0014	0.8971	0.9961	0.9969	Line Tamuning 115.0 to Harmn115 115.0 and Tamuning T600
Tamuning	115	line_65	1.0014	0.8971	0.9961	0.9969	Line Tamuning 115.0 to Harmn115 115.0 and Tamuning T600
Andersen	34.5	line_58	0.9376	0.8765	0.9584	0.9972	Line Cabr 115 to Piti 115 and Agana T400
Potts Jc	34.5	line_2	0.9598	0.8661	0.9652	0.9972	Line Cabr 115 115.0 to Agana115 115.0 Circuit 1
Potts Jc	34.5	line_3	0.9598	0.8661	0.9652	0.9972	Line Cabr 115 115.0 to Agana115 115.0 Circuit 2
Yigo_345	34.5	tran_52	0.9352	0.8935	0.9542	0.9973	Tran Harmon 3 34.50 to Harmn115 115.00 Circuit 1
Potts Jc	34.5	line_55	0.9643	0.8719	0.9675	0.9974	Line Tamuning 115.0 to Harmn115 115.0 and Line Giattap 34.5 to Harmon 1 34.5
Andersen	34.5	line_57	0.9318	0.8727	0.954	0.9975	Line Cabr 115 115.0 to Agana115 115.0 Circuit 1 and Agana T400
Andersen	34.5	line_59	0.9407	0.8887	0.9578	0.9979	Line Cabr 115 115.0 to Agana115 115.0 Circuit 1 and Piti T700
Yigo_345	34.5	line_17	0.9526	0.8952	0.9607	0.9979	Line Apra 34. 34.5 to Tenjotap 34.5 Circuit 1
Andersen	34.5	line_67	0.9302	0.8423	0.9497	0.9982	Line Agana 34 34.5 to Tamuning 34.5 Circuit 1 and Tamuning T600
NCS Fine	34.5	line_68	0.9461	0.8349	0.9603	0.9982	Line Tamuning 34.5 to Tumon 34 34.5 Circuit 1 and Harmon T500
Yigo_345	34.5	line_24	0.949	0.8989	0.9602	0.9984	Line Agana 34 34.5 to Radio Ba 34.5 Circuit 1
Talofofo	34.5	base	0.9444	0.9451	0.9658	0.9989	Base system (n-0)
Andersen	34.5	line_6	0.9466	0.8913	0.9596	0.999	Line Tamuning 115.0 to Harmn115 115.0 Circuit 1
NCS Fine	34.5	line_41	0.9873	0.8518	0.9822	0.999	Line NCS Fine 34.5 to Potts Jc 34.5 Circuit 1
NCS Fine	34.5	line_42	0.9873	0.8518	0.9822	0.999	Line Potts Jc 34.5 to Andersen 34.5 Circuit 1
Potts Jc	34.5	line_42	0.9873	0.8518	0.9822	0.999	Line Potts Jc 34.5 to Andersen 34.5 Circuit 1
NCS Fine	34.5	tran_50	0.9626	0.8627	0.9687	0.9991	Tran Agana 34 34.50 to Agana115 115.00 Circuit 1
Potts Jc	34.5	line_68	0.9395	0.8389	0.9575	0.9992	Line Tamuning 34.5 to Tumon 34 34.5 Circuit 1 and Harmon T500
NCS Fine	34.5	line_23	0.9672	0.8643	0.9688	0.9992	Line Agana 34 34.5 to Barrigad 34.5 Circuit 1
NCS Fine	34.5	tran_51	0.9666	0.861	0.9681	0.9994	Tran Tamuning 34.50 to Tamuning 115.00 Circuit 1
Andersen	34.5	line_66	0.9345	0.8711	0.9545	0.9995	Line Piti 345 34.5 to Anigua 3 34.5 Circuit 1 and Agana T400
NCS Fine	34.5	line_38	0.9704	0.8679	0.9703	0.9995	Line Harmon 3 34.5 to Macheche 34.5 Circuit 1
Yigo_345	34.5	base	0.9534	0.9081	0.9635	0.9996	Base system (n-0)
Andersen	34.5	line_55	0.9473	0.8914	0.9603	0.9998	Line Tamuning 115.0 to Harmn115 115.0 and Line Giattap 34.5 to Harmon 1 34.5
Potts Jc	34.5	tran_50	0.9573	0.8675	0.9665	1.0001	Tran Agana 34 34.50 to Agana115 115.00 Circuit 1
NCS Fine	34.5	line_33	0.9718	0.8498	0.9657	1.0004	Line Tanguiss 34.5 to Harmon 1 34.5 Circuit 1
Potts Jc	34.5	tran_51	0.9616	0.8657	0.9659	1.0004	Tran Tamuning 34.50 to Tamuning 115.00 Circuit 1
Potts Jc	34.5	line_23	0.9627	0.8698	0.9669	1.0004	Line Agana 34 34.5 to Barrigad 34.5 Circuit 1
Andersen	34.5	line_2	0.9431	0.8849	0.9582	1.0006	Line Cabr 115 115.0 to Agana115 115.0 Circuit 1
Andersen	34.5	line_3	0.9431	0.8849	0.9582	1.0006	Line Cabr 115 115.0 to Agana115 115.0 Circuit 2
NCS Fine	34.5	line_9	0.971	0.8774	0.974	1.0006	Line Cabrs345 34.5 to Piti 345 34.5 Circuit 1
NCS Fine	34.5	tran_48	0.971	0.8774	0.974	1.0006	Tran Cabrs345 34.50 to Cabr 115 115.00 Circuit 1
Potts Jc	34.5	line_38	0.9664	0.8739	0.9688	1.0009	Line Harmon 3 34.5 to Macheche 34.5 Circuit 1
NCS Fine	34.5	line_35	0.9512	0.8225	0.9584	1.001	Line Harmon 3 34.5 to Dededo 3 34.5 Circuit 1
NCS Fine	34.5	tran_52	0.9578	0.8597	0.9656	1.001	Tran Harmon 3 34.50 to Harmn115 115.00 Circuit 1
NCS Fine	34.5	line_60	0.9717	0.8793	0.974	1.0011	Line Cabr 115 to Piti 115 and Piti T700
NCS Fine	34.5	line_1	0.9728	0.8683	0.9737	1.0014	Line Cabr 115 115.0 to Piti 115 115.0 Circuit 1
NCS Fine	34.5	tran_49	0.9715	0.8768	0.9741	1.0014	Tran Piti 345 34.50 to Piti 115 115.00 Circuit 1
Potts Jc	34.5	line_33	0.9673	0.8566	0.9641	1.0015	Line Tanguiss 34.5 to Harmon 1 34.5 Circuit 1
Andersen	34.5	tran_53	na	0.8426	0.9401	1.0016	Tran Harmon 1 34.50 to Harmn115 115.00 Circuit 2
NCS Fine	34.5	line_17	0.9722	0.8595	0.9709	1.0016	Line Apra 34. 34.5 to Tenjotap 34.5 Circuit 1
Potts Jc	34.5	line_9	0.9663	0.8825	0.972	1.0016	Line Cabrs345 34.5 to Piti 345 34.5 Circuit 1
Potts Jc	34.5	tran_48	0.9663	0.8825	0.972	1.0016	Tran Cabrs345 34.50 to Cabr 115 115.00 Circuit 1
NCS Fine	34.5	line_14	0.9713	0.871	0.9724	1.0016	Line Talofofo 34.5 to Apra 34. 34.5 Circuit 1
Potts Jc	34.5	line_35	0.9412	0.8197	0.9541	1.0017	Line Harmon 3 34.5 to Dededo 3 34.5 Circuit 1
NCS Fine	34.5	line_34	0.973	0.8674	0.9722	1.0018	Line Tanguiss 34.5 to Harmon 3 34.5 Circuit 2

Voltage Limit Report

Name	kV	Outage	Existing 2007 Load	New DOD Loads	Line Upgrades w/ No 115 kV	Line Upgrades Including 115 kV	Outage description
NCS Fine	34.5	line_28	0.9707	0.8686	0.9714	1.0019	Line Tamuning 34.5 to Tumon 34 34.5 Circuit 1
NCS Fine	34.5	line_13	0.9728	0.87	0.9722	1.0019	Line Piti 345 34.5 to Anigua 3 34.5 Circuit 1
Apra 34.	34.5	line_56	na	na	0.8979	1.002	Line Piti 345 34.5 to Orote 34 34.5 and Piti to Apra w/ Tenjo Tap 34.5
Potts Jc	34.5	tran_52	0.9518	0.8641	0.963	1.002	Tran Harmon 3 34.50 to Harmn115 115.00 Circuit 1
Potts Jc	34.5	line_60	0.967	0.8843	0.972	1.0021	Line Cabr 115 to Piti 115 and Piti T700
NCS Fine	34.5	line_39	0.9656	0.8555	0.9684	1.0023	Line Harmon 1 34.5 to Yigo_345 34.5 Circuit 1
NCS Fine	34.5	line_24	0.9697	0.8653	0.971	1.0023	Line Agana 34 34.5 to Radio Ba 34.5 Circuit 1
Potts Jc	34.5	line_1	0.9681	0.8736	0.9718	1.0023	Line Cabr 115 115.0 to Piti 115 115.0 Circuit 1
NCS Fine	34.5	line_29	0.9707	0.8696	0.972	1.0024	Line Tamuning 34.5 to San Vito 34.5 Circuit 1
Potts Jc	34.5	tran_49	0.9668	0.8819	0.9721	1.0024	Tran Piti 345 34.50 to Piti 115 115.00 Circuit 1
NCS Fine	34.5	line_19	0.9726	0.8682	0.9721	1.0025	Line Piti 345 34.5 to Cld Stor 34.5 Circuit 1
NCS Fine	34.5	line_12	0.9733	0.871	0.9729	1.0025	Line Piti 345 34.5 to Agana 34 34.5 Circuit 1
Potts Jc	34.5	line_17	0.9675	0.8647	0.9689	1.0026	Line Apra 34. 34.5 to Tenjotap 34.5 Circuit 1
Potts Jc	34.5	line_14	0.9666	0.8763	0.9704	1.0026	Line Talofofo 34.5 to Apra 34. 34.5 Circuit 1
Umatac34	34.5	line_11	na	0.8974	0.9491	1.0027	Line Piti 345 34.5 to Orote 34 34.5 Circuit 1
Potts Jc	34.5	line_34	0.9678	0.872	0.97	1.0027	Line Tanguiss 34.5 to Harmon 3 34.5 Circuit 2
NCS Fine	34.5	line_21	0.9729	0.8724	0.9732	1.0027	Line Pulantat 34.5 to Talofofo 34.5 Circuit 1
NCS Fine	34.5	line_25	0.9719	0.8712	0.9731	1.0028	Line Agana 34 34.5 to Tamuning 34.5 Circuit 1
Potts Jc	34.5	line_28	0.9659	0.8737	0.9693	1.0029	Line Tamuning 34.5 to Tumon 34 34.5 Circuit 1
Potts Jc	34.5	line_13	0.9681	0.8752	0.9702	1.0029	Line Piti 345 34.5 to Anigua 3 34.5 Circuit 1
NCS Fine	34.5	line_11	na	0.8674	0.9726	1.0029	Line Piti 345 34.5 to Orote 34 34.5 Circuit 1
NCS Fine	34.5	line_10	0.9722	0.8759	0.9747	1.0029	Line Piti 345 34.5 to Tenjotap 34.5 Circuit 1
Andersen	34.5	line_68	0.9165	0.8533	0.9478	1.003	Line Tamuning 34.5 to Tumon 34 34.5 Circuit 1 and Harmon T500
Potts Jc	34.5	line_39	0.9583	0.8564	0.9652	1.003	Line Harmon 1 34.5 to Yigo_345 34.5 Circuit 1
NCS Fine	34.5	line_27	0.971	0.8671	0.9722	1.003	Line Radio Ba 34.5 to Marbo 34 34.5 Circuit 1
NCS Fine	34.5	line_40	0.971	0.8671	0.9722	1.003	Line Dededo 3 34.5 to Marbo 34 34.5 Circuit 1
NCS Fine	34.5	line_31	0.974	0.8724	0.9738	1.003	Line Anigua 3 34.5 to Agana 34 34.5 Circuit 1
NCS Fine	34.5	line_26	0.9734	0.871	0.9737	1.0031	Line Barrigad 34.5 to GAA 34.5 34.5 Circuit 1
Potts Jc	34.5	line_24	0.9645	0.8696	0.9687	1.0032	Line Agana 34 34.5 to Radio Ba 34.5 Circuit 1
NCS Fine	34.5	line_15	0.9729	0.8688	0.9735	1.0032	Line Apra 34. 34.5 to Orote 34 34.5 Circuit 1
NCS Fine	34.5	line_18	0.9728	0.8719	0.9734	1.0033	Line Orote 34 34.5 to Cld Stor 34.5 Circuit 1
Cabras_4	13.8	base	1.007	0.9236	1.0027	1.0033	Base system (n-0)
Potts Jc	34.5	line_29	0.9659	0.8747	0.97	1.0034	Line Tamuning 34.5 to San Vito 34.5 Circuit 1
Potts Jc	34.5	line_19	0.9679	0.8734	0.9701	1.0034	Line Piti 345 34.5 to Cld Stor 34.5 Circuit 1
NCS Fine	34.5	base	0.9729	0.8726	0.9737	1.0034	Base system (n-0)
Potts Jc	34.5	line_12	0.9687	0.8763	0.9709	1.0035	Line Piti 345 34.5 to Agana 34 34.5 Circuit 1
NCS Fine	34.5	line_44	0.9729	0.8726	0.9737	1.0035	Line Macheche 34.5 to GAA 34.5 34.5 Circuit 1
NCS Fine	34.5	line_32	0.9739	0.8721	0.974	1.0035	Line San Vito 34.5 to Harmon 3 34.5 Circuit 1
Andersen	34.5	tran_50	0.9386	0.8846	0.9589	1.0036	Tran Agana 34 34.50 to Agana115 115.00 Circuit 1
NCS Fine	34.5	line_45	0.9728	0.8696	0.9741	1.0036	Line Yigo_345 34.5 to Andersen 34.5 Circuit 1
NCS Fine	34.5	line_22	0.9742	0.8749	0.9753	1.0036	Line Pulantat 34.5 to Barrigad 34.5 Circuit 1
Cabras_2	13.8	base	1.007	0.9236	1.0031	1.0036	Base system (n-0)
Potts Jc	34.5	line_25	0.9672	0.8764	0.9711	1.0037	Line Agana 34 34.5 to Tamuning 34.5 Circuit 1
Potts Jc	34.5	line_21	0.9683	0.8776	0.9712	1.0037	Line Pulantat 34.5 to Talofofo 34.5 Circuit 1
NCS Fine	34.5	line_30	0.9741	0.8723	0.9744	1.0037	Line Tumon 34 34.5 to Harmon 3 34.5 Circuit 1
Potts Jc	34.5	line_11	na	0.8727	0.9706	1.0039	Line Piti 345 34.5 to Orote 34 34.5 Circuit 1
Potts Jc	34.5	line_10	0.9675	0.8812	0.9728	1.0039	Line Piti 345 34.5 to Tenjotap 34.5 Circuit 1
Andersen	34.5	line_35	0.9062	0.8097	0.9395	1.004	Line Harmon 3 34.5 to Dededo 3 34.5 Circuit 1
Andersen	34.5	tran_51	0.944	0.8827	0.9581	1.004	Tran Tamuning 34.50 to Tamuning 115.00 Circuit 1
Potts Jc	34.5	line_27	0.966	0.8716	0.9702	1.004	Line Radio Ba 34.5 to Marbo 34 34.5 Circuit 1
Potts Jc	34.5	line_40	0.966	0.8716	0.9702	1.004	Line Dededo 3 34.5 to Marbo 34 34.5 Circuit 1
Potts Jc	34.5	line_31	0.9694	0.8777	0.9718	1.004	Line Anigua 3 34.5 to Agana 34 34.5 Circuit 1
Potts Jc	34.5	line_26	0.9687	0.8763	0.9717	1.0041	Line Barrigad 34.5 to GAA 34.5 34.5 Circuit 1

Voltage Limit Report

Name	kV	Outage	Existing 2007 Load	New DOD Loads	Line Upgrades w/ No 115 kV	Line Upgrades Including 115 kV	Outage description
Potts Jc	34.5	line_15	0.9683	0.8741	0.9715	1.0042	Line Apra 34. 34.5 to Orote 34 34.5 Circuit 1
Potts Jc	34.5	line_18	0.9682	0.8771	0.9714	1.0043	Line Orote 34 34.5 to Cld Stor 34.5 Circuit 1
NCS Fine	34.5	line_46	0.9743	0.8722	0.975	1.0043	Line GAA 34.5 34.5 to GIAT 34.5 Circuit 1
Potts Jc	34.5	line_44	0.9682	0.8778	0.9717	1.0044	Line Macheche 34.5 to GAA 34.5 34.5 Circuit 1
Potts Jc	34.5	base	0.9683	0.8779	0.9718	1.0044	Base system (n-0)
NCS Fine	34.5	line_16	0.9738	0.8741	0.9745	1.0044	Line Apra 34. 34.5 to Umatac34 34.5 Circuit 1
Potts Jc	34.5	line_32	0.9694	0.8773	0.9721	1.0045	Line San Vito 34.5 to Harmon 3 34.5 Circuit 1
Andersen	34.5	line_23	0.9467	0.8895	0.9604	1.0046	Line Agana 34 34.5 to Barrigad 34.5 Circuit 1
Potts Jc	34.5	line_30	0.9695	0.8775	0.9724	1.0046	Line Tumon 34 34.5 to Harmon 3 34.5 Circuit 1
Potts Jc	34.5	line_22	0.9695	0.8802	0.9733	1.0046	Line Pulantat 34.5 to Barrigad 34.5 Circuit 1
Potts Jc	34.5	line_45	0.9679	0.8733	0.9722	1.005	Line Yigo_345 34.5 to Andersen 34.5 Circuit 1
NCS Fine	34.5	line_47	0.975	0.873	0.9759	1.005	Line GIAT 34.5 to Harmon 1 34.5 Circuit 1
Potts Jc	34.5	line_46	0.9694	0.8775	0.9729	1.0051	Line GAA 34.5 34.5 to GIAT 34.5 Circuit 1
Andersen	34.5	line_33	0.9514	0.8811	0.9583	1.0054	Line Tanguiss 34.5 to Harmon 1 34.5 Circuit 1
Potts Jc	34.5	line_16	0.9692	0.8793	0.9726	1.0054	Line Apra 34. 34.5 to Umatac34 34.5 Circuit 1
Andersen	34.5	line_39	0.9328	0.8596	0.954	1.0055	Line Harmon 1 34.5 to Yigo_345 34.5 Circuit 1
Apra 34.	34.5	line_17	0.9448	0.8873	0.9504	1.0056	Line Apra 34. 34.5 to Tenjotap 34.5 Circuit 1
Andersen	34.5	tran_52	0.9307	0.8799	0.954	1.0057	Tran Harmon 3 34.50 to Harmn115 115.00 Circuit 1
Umatac34	34.5	base	0.95	0.9406	0.9652	1.0057	Base system (n-0)
Potts Jc	34.5	line_47	0.9699	0.8781	0.9737	1.0057	Line GIAT 34.5 to Harmon 1 34.5 Circuit 1
Andersen	34.5	line_34	0.9496	0.8886	0.9622	1.0058	Line Tanguiss 34.5 to Harmon 3 34.5 Circuit 2
Andersen	34.5	line_1	0.9517	0.8926	0.9648	1.0058	Line Cabr 115 115.0 to Piti 115 115.0 Circuit 1
Piti 115	115	base	1.0163	0.9187	1.0056	1.0058	Base system (n-0)
Andersen	34.5	line_38	0.9522	0.8952	0.9633	1.0059	Line Harmon 3 34.5 to Macheche 34.5 Circuit 1
Dededo 3	34.5	base	0.9644	0.9426	0.9785	1.0059	Base system (n-0)
Andersen	34.5	line_17	0.9511	0.8835	0.9619	1.0061	Line Apra 34. 34.5 to Tenjotap 34.5 Circuit 1
Andersen	34.5	line_14	0.9502	0.895	0.9634	1.0061	Line Talofofo 34.5 to Apra 34. 34.5 Circuit 1
SRF	34.5	line_9	na	0.8997	0.9507	1.0062	Line Cabrs345 34.5 to Piti 345 34.5 Circuit 1
SRF	34.5	tran_48	na	0.8997	0.9507	1.0062	Tran Cabrs345 34.50 to Cabr 115 115.00 Circuit 1
SRF	34.5	line_62	na	0.8997	0.9513	1.0064	Line Piti 115 115.0 to Harmn115 115.0 and Piti T700
Andersen	34.5	line_24	0.9462	0.8851	0.9609	1.0064	Line Agana 34 34.5 to Radio Ba 34.5 Circuit 1
Andersen	34.5	line_13	0.9518	0.8939	0.9632	1.0064	Line Piti 345 34.5 to Anigua 3 34.5 Circuit 1
Andersen	34.5	line_28	0.9492	0.8918	0.962	1.0065	Line Tamuning 34.5 to Tumon 34 34.5 Circuit 1
Cabr 115	115	base	1.0163	0.9195	1.0058	1.0065	Base system (n-0)
Marbo 34	34.5	base	0.9667	0.9486	0.9798	1.0067	Base system (n-0)
Andersen	34.5	line_29	0.9491	0.8929	0.9628	1.0069	Line Tamuning 34.5 to San Vito 34.5 Circuit 1
Andersen	34.5	line_19	0.9515	0.8922	0.9631	1.0069	Line Piti 345 34.5 to Cld Stor 34.5 Circuit 1
Andersen	34.5	line_12	0.9524	0.895	0.9639	1.007	Line Piti 345 34.5 to Agana 34 34.5 Circuit 1
Cabras_3	13.8	base	1.007	0.9289	1.007	1.007	Base system (n-0)
MEC 8	13.8	base	1.007	0.9338	1.007	1.007	Base system (n-0)
MEC 9	13.8	base	1.007	0.9366	1.007	1.007	Base system (n-0)
Andersen	34.5	line_21	0.9519	0.8964	0.9642	1.0072	Line Pulantat 34.5 to Talofofo 34.5 Circuit 1
Andersen	34.5	line_25	0.9508	0.8952	0.9642	1.0073	Line Agana 34 34.5 to Tamuning 34.5 Circuit 1
Andersen	34.5	line_11	na	0.8914	0.9636	1.0074	Line Piti 345 34.5 to Orote 34 34.5 Circuit 1
Andersen	34.5	line_27	0.9486	0.8879	0.9629	1.0075	Line Radio Ba 34.5 to Marbo 34 34.5 Circuit 1
Andersen	34.5	line_40	0.9486	0.8879	0.9629	1.0075	Line Dededo 3 34.5 to Marbo 34 34.5 Circuit 1
Andersen	34.5	line_31	0.9532	0.8964	0.9649	1.0075	Line Anigua 3 34.5 to Agana 34 34.5 Circuit 1
Andersen	34.5	line_10	0.9511	0.8999	0.9659	1.0075	Line Piti 345 34.5 to Tenjotap 34.5 Circuit 1
Andersen	34.5	line_15	0.9519	0.8928	0.9646	1.0077	Line Apra 34. 34.5 to Orote 34 34.5 Circuit 1
Andersen	34.5	line_26	0.9522	0.8953	0.9647	1.0077	Line Barrigad 34.5 to GAA 34.5 34.5 Circuit 1
Andersen	34.5	line_18	0.9518	0.8959	0.9644	1.0078	Line Orote 34 34.5 to Cld Stor 34.5 Circuit 1
SRF	34.5	line_19	na	0.8687	0.927	1.0079	Line Piti 345 34.5 to Cld Stor 34.5 Circuit 1
Andersen	34.5	line_44	0.9518	0.8966	0.9648	1.0079	Line Macheche 34.5 to GAA 34.5 34.5 Circuit 1

Voltage Limit Report

Name	kV	Outage	Existing 2007 Load	New DOD Loads	Line Upgrades w/ No 115 kV	Line Upgrades Including 115 kV	Outage description
Andersen	34.5	base	0.9519	0.8966	0.9648	1.0079	Base system (n-0)
Andersen	34.5	line_32	0.9532	0.8959	0.9652	1.008	Line San Vito 34.5 to Harmon 3 34.5 Circuit 1
Andersen	34.5	line_22	0.9532	0.8989	0.9665	1.0081	Line Pulantat 34.5 to Barrigad 34.5 Circuit 1
Andersen	34.5	line_30	0.9534	0.8962	0.9656	1.0082	Line Tumon 34 34.5 to Harmon 3 34.5 Circuit 1
Andersen	34.5	line_46	0.9522	0.8965	0.9656	1.0082	Line GAA 34.5 34.5 to GIAT 34.5 Circuit 1
Andersen	34.5	line_47	0.9522	0.8966	0.9661	1.0084	Line GIAT 34.5 to Harmon 1 34.5 Circuit 1
SRF	34.5	line_56	na	na	0.8946	1.0087	Line Piti 345 34.5 to Orote 34 34.5 and Piti to Apra w/ Tenjo Tap 34.5
Andersen	34.5	line_16	0.9528	0.8981	0.9657	1.0089	Line Apra 34. 34.5 to Umatac34 34.5 Circuit 1
NCS Fine	34.5	line_43	0.9789	0.8821	0.9802	1.0089	Line Macheche 34.5 to Pagat 34 34.5 Circuit 1
NCS Fine	34.5	line_20	0.9745	0.8832	0.9802	1.009	Line Cld Stor 34.5 to Cold Sto 34.5 Circuit 1
Orote 34	34.5	line_19	0.9516	0.8714	0.929	1.0098	Line Piti 345 34.5 to Cld Stor 34.5 Circuit 1
Potts Jc	34.5	line_43	0.9744	0.8873	0.9783	1.01	Line Macheche 34.5 to Pagat 34 34.5 Circuit 1
Potts Jc	34.5	line_20	0.9699	0.8884	0.9783	1.01	Line Cld Stor 34.5 to Cold Sto 34.5 Circuit 1
Andersen	34.5	line_45	0.9509	0.8864	0.9657	1.0102	Line Yigo_345 34.5 to Andersen 34.5 Circuit 1
Orote 34	34.5	line_56	na	na	0.8967	1.0105	Line Piti 345 34.5 to Orote 34 34.5 and Piti to Apra w/ Tenjo Tap 34.5
SRF	34.5	line_61	na	0.9	0.9589	1.0106	Line Piti 115 115.0 to Harmn115 115.0 and Agana T400
SRF T1	13.8	line_11	na	0.884	1.0142	1.0108	Line Piti 345 34.5 to Orote 34 34.5 Circuit 1
Cold Storage	34.5	line_17	0.955	0.8899	0.962	1.011	Line Apra 34. 34.5 to Tenjotap 34.5 Circuit 1
Cold Storage	34.5	line_11	na	0.855	0.9525	1.0116	Line Piti 345 34.5 to Orote 34 34.5 Circuit 1
SRF T2	13.8	line_11	na	0.884	0.9941	1.0122	Line Piti 345 34.5 to Orote 34 34.5 Circuit 1
SRF	34.5	line_11	na	0.8441	0.9375	1.0125	Line Piti 345 34.5 to Orote 34 34.5 Circuit 1
SRF	34.5	line_17	na	0.8838	0.9532	1.013	Line Apra 34. 34.5 to Tenjotap 34.5 Circuit 1
OroteT13	13.8	line_11	na	0.8873	0.9964	1.0142	Line Piti 345 34.5 to Orote 34 34.5 Circuit 1
OroteT99	13.8	line_11	na	0.8873	0.9964	1.0142	Line Piti 345 34.5 to Orote 34 34.5 Circuit 1
Orote 34	34.5	line_11	na	0.8469	0.9395	1.0144	Line Piti 345 34.5 to Orote 34 34.5 Circuit 1
Orote 34	34.5	line_17	0.954	0.8864	0.9552	1.0148	Line Apra 34. 34.5 to Tenjotap 34.5 Circuit 1
Cold Storage	34.5	base	0.9622	0.9265	0.9723	1.0149	Base system (n-0)
Cold Storage	34.5	line_15	0.9622	0.8985	0.9671	1.0153	Line Apra 34. 34.5 to Orote 34 34.5 Circuit 1
SRF	34.5	base	na	0.9228	0.9667	1.0178	Base system (n-0)
SRF	34.5	line_15	na	0.8926	0.9595	1.0185	Line Apra 34. 34.5 to Orote 34 34.5 Circuit 1
Orote 34	34.5	base	0.9621	0.9253	0.9686	1.0196	Base system (n-0)
Orote 34	34.5	line_15	0.9621	0.8952	0.9614	1.0203	Line Apra 34. 34.5 to Orote 34 34.5 Circuit 1
Marbo CT	13.8	line_35	0.9377	0.8791	0.9667	1.022	Line Harmon 3 34.5 to Dededo 3 34.5 Circuit 1
AnderT16	13.8	line_35	1.0138	0.8717	1.0163	1.0318	Line Harmon 3 34.5 to Dededo 3 34.5 Circuit 1
AnderT15	13.8	line_35	0.9951	0.8718	1.0163	1.0318	Line Harmon 3 34.5 to Dededo 3 34.5 Circuit 1
OroteT11	13.8	line_11	na	0.8874	1.0119	1.0411	Line Piti 345 34.5 to Orote 34 34.5 Circuit 1
OroteT12	13.8	line_11	na	0.8864	1.0124	1.0417	Line Piti 345 34.5 to Orote 34 34.5 Circuit 1
Cabrs345	34.5	line_9	0.9902	1.0766	1.0473	1.0574	Line Cabrs345 34.5 to Piti 345 34.5 Circuit 1

Overload Report

Name	kV	Name	kV	Type	Rated Mva	Outage	Existing 2007 Load	New DOD Loads	Line Upgrades w/ No 115 kV	Line Upgrades Including 115 kV	Outage description
Piti 345	34.5	Cld Stor	34.5	Line	59	line_11	na	238.60%	47.80%	44.50%	Line Piti 345 34.5 to Orote 34 34.5 Circuit 1
Harmon 1	34.5	NCS Fine	34.5	Line	59	line_35	58.60%	188.00%	50.20%	53.30%	Line Harmon 3 34.5 to Dededo 3 34.5 Circuit 1
Piti 345	34.5	Cld Stor	34.5	Line	59	line_17	58.80%	179.10%	40.10%	45.10%	Line Apra 34. 34.5 to Tenjotap 34.5 Circuit 1
Orote 34	34.5	Cld Stor	34.5	Line	59	line_11	na	168.80%	33.00%	20.00%	Line Piti 345 34.5 to Orote 34 34.5 Circuit 1
Harmon 1	34.5	NCS Fine	34.5	Line	59	line_41	3.90%	165.60%	27.50%	54.10%	Line NCS Fine 34.5 to Potts Jc 34.5 Circuit 1
Harmon 1	34.5	NCS Fine	34.5	Line	59	line_42	3.90%	165.60%	27.50%	54.10%	Line Potts Jc 34.5 to Andersen 34.5 Circuit 1
Piti 345	34.5	Cld Stor	34.5	Line	59	line_15	36.10%	164.70%	35.20%	36.30%	Line Apra 34. 34.5 to Orote 34 34.5 Circuit 1
Harmon 1	34.5	NCS Fine	34.5	Line	59	line_39	45.90%	164.50%	43.40%	52.50%	Line Harmon 1 34.5 to Yigo_345 34.5 Circuit 1
Cabr 115	115	Cabras_1	13.8	Tran	80	line_67	83.60%	162.80%	85.30%	82.50%	Line Agana 34 34.5 to Tamuning 34.5 Circuit 1 and Tamuning T600
Cabr 115	115	Cabras_1	13.8	Tran	80	line_63	83.50%	160.00%	84.80%	83.00%	Line Piti 115 115.0 to Harmn115 115.0 and Tamuning T600
Cabr 115	115	Cabras_1	13.8	Tran	80	line_17	79.70%	157.50%	84.50%	81.30%	Line Apra 34. 34.5 to Tenjotap 34.5 Circuit 1
Cabr 115	115	Cabras_1	13.8	Tran	80	tran_53	na	157.40%	83.40%	79.80%	Tran Harmon 1 34.50 to Harmn115 115.00 Circuit 2
Cabr 115	115	Cabras_1	13.8	Tran	80	line_61	82.90%	156.50%	84.00%	82.80%	Line Piti 115 115.0 to Harmn115 115.0 and Agana T400
Cabr 115	115	Cabras_1	13.8	Tran	80	line_65	82.40%	156.20%	84.20%	82.20%	Line Tamuning 115.0 to Harmn115 115.0 and Tamuning T600
Cabr 115	115	Cabras_1	13.8	Tran	80	line_64	82.30%	156.10%	84.20%	82.20%	Line Agana115 115.0 to Tamuning 115.0 Circuit 1 and Tamuning T600
Cabr 115	115	Cabras_1	13.8	Tran	80	line_35	81.50%	156.00%	84.60%	80.60%	Line Harmon 3 34.5 to Dededo 3 34.5 Circuit 1
Harmon 1	34.5	NCS Fine	34.5	Line	59	line_67	35.90%	155.40%	39.10%	47.30%	Line Agana 34 34.5 to Tamuning 34.5 Circuit 1 and Tamuning T600
Cabr 115	115	Cabras_1	13.8	Tran	80	line_68	83.10%	155.30%	83.80%	80.30%	Line Tamuning 34.5 to Tumon 34 34.5 Circuit 1 and Harmon T500
Harmon 1	34.5	NCS Fine	34.5	Line	59	line_68	40.80%	155.10%	40.70%	47.10%	Line Tamuning 34.5 to Tumon 34 34.5 Circuit 1 and Harmon T500
Cabr 115	115	Cabras_1	13.8	Tran	80	line_33	79.40%	154.70%	83.90%	80.70%	Line Tanguiss 34.5 to Harmon 1 34.5 Circuit 1
Dededo 3	34.5	Andersen	34.5	Line	42	line_39	60.60%	154.50%	31.30%	16.70%	Line Harmon 1 34.5 to Yigo_345 34.5 Circuit 1
Cabr 115	115	Cabras_1	13.8	Tran	80	line_5	81.30%	153.60%	83.70%	81.60%	Line Agana115 115.0 to Tamuning 115.0 Circuit 1
Harmon 1	34.5	NCS Fine	34.5	Line	59	line_63	32.90%	153.00%	37.80%	48.50%	Line Piti 115 115.0 to Harmn115 115.0 and Tamuning T600
Cabr 115	115	Cabras_1	13.8	Tran	80	line_66	81.40%	152.60%	84.00%	82.40%	Line Piti 345 34.5 to Anigua 3 34.5 Circuit 1 and Agana T400
Cabr 115	115	Cabras_1	13.8	Tran	80	line_11	na	152.60%	83.40%	80.30%	Line Piti 345 34.5 to Orote 34 34.5 Circuit 1
Cabr 115	115	Cabras_1	13.8	Tran	80	line_34	79.80%	152.10%	83.60%	81.20%	Line Tanguiss 34.5 to Harmon 3 34.5 Circuit 2
Cabr 115	115	Cabras_1	13.8	Tran	80	line_39	80.40%	152.00%	83.40%	80.30%	Line Harmon 1 34.5 to Yigo_345 34.5 Circuit 1
Harmon 1	34.5	NCS Fine	34.5	Line	59	line_61	34.00%	152.00%	37.90%	48.70%	Line Piti 115 115.0 to Harmn115 115.0 and Agana T400
Cabr 115	115	Cabras_1	13.8	Tran	80	line_15	79.30%	151.80%	82.70%	80.00%	Line Apra 34. 34.5 to Orote 34 34.5 Circuit 1
Cabr 115	115	Cabras_1	13.8	Tran	80	line_19	79.40%	151.00%	84.10%	80.70%	Line Piti 345 34.5 to Cld Stor 34.5 Circuit 1
Cabr 115	115	Cabras_1	13.8	Tran	80	line_4	80.90%	150.90%	83.50%	81.60%	Line Piti 115 115.0 to Harmn115 115.0 Circuit 1
Cabr 115	115	Cabras_1	13.8	Tran	80	line_38	80.80%	150.20%	84.00%	81.90%	Line Harmon 3 34.5 to Macheche 34.5 Circuit 1
Harmon 1	34.5	NCS Fine	34.5	Line	59	line_65	32.00%	149.70%	37.40%	48.40%	Line Tamuning 115.0 to Harmn115 115.0 and Tamuning T600
Cabr 115	115	Cabras_1	13.8	Tran	80	line_57	81.10%	149.60%	83.20%	81.80%	Line Cabr 115 115.0 to Agana115 115.0 Circuit 1 and Agana T400
Harmon 1	34.5	NCS Fine	34.5	Line	59	line_64	32.00%	149.60%	37.40%	48.40%	Line Agana115 115.0 to Tamuning 115.0 Circuit 1 and Tamuning T600
Cabr 115	115	Cabras_1	13.8	Tran	80	tran_51	81.10%	149.30%	83.50%	81.20%	Tran Tamuning 34.50 to Tamuning 115.00 Circuit 1
Cabr 115	115	Cabras_1	13.8	Tran	80	line_13	79.60%	148.90%	82.90%	80.40%	Line Piti 345 34.5 to Anigua 3 34.5 Circuit 1
Harmon 1	34.5	NCS Fine	34.5	Line	59	line_66	35.80%	148.90%	38.70%	47.90%	Line Piti 345 34.5 to Anigua 3 34.5 Circuit 1 and Agana T400
Cabr 115	115	Cabras_1	13.8	Tran	80	tran_52	81.00%	148.80%	83.00%	80.00%	Tran Harmon 3 34.50 to Harmn115 115.00 Circuit 1
Cabr 115	115	Cabras_1	13.8	Tran	80	line_14	79.80%	148.70%	83.00%	80.90%	Line Talofofo 34.5 to Apra 34. 34.5 Circuit 1
Cabr 115	115	Cabras_1	13.8	Tran	80	line_23	80.40%	148.50%	83.20%	80.80%	Line Agana 34 34.5 to Barrigad 34.5 Circuit 1
Cabr 115	115	Cabras_1	13.8	Tran	80	line_12	79.40%	148.30%	82.60%	80.20%	Line Piti 345 34.5 to Agana 34 34.5 Circuit 1
Cabr 115	115	Cabras_1	13.8	Tran	80	line_2	80.20%	148.20%	82.90%	80.90%	Line Cabr 115 115.0 to Agana115 115.0 Circuit 1
Cabr 115	115	Cabras_1	13.8	Tran	80	line_3	80.20%	148.20%	82.90%	80.90%	Line Cabr 115 115.0 to Agana115 115.0 Circuit 2

Overload Report

Name	kV	Name	kV	Type	Rated Mva	Outage	Existing 2007 Load	New DOD Loads	Line Upgrades w/ No 115 kV	Line Upgrades Including 115 kV	Outage description
Cabr 115	115	Cabras_1	13.8	Tran	80	line_24	79.50%	148.00%	82.50%	80.00%	Line Agana 34 34.5 to Radio Ba 34.5 Circuit 1
Cabr 115	115	Cabras_1	13.8	Tran	80	line_25	79.30%	148.00%	82.40%	79.90%	Line Agana 34 34.5 to Tamuning 34.5 Circuit 1
Cabr 115	115	Cabras_1	13.8	Tran	80	line_18	79.30%	147.90%	82.60%	79.90%	Line Orote 34 34.5 to Cld Stor 34.5 Circuit 1
Cabr 115	115	Cabras_1	13.8	Tran	80	line_47	79.50%	147.90%	82.40%	80.20%	Line GIAT 34.5 to Harmon 1 34.5 Circuit 1
Cabr 115	115	Cabras_1	13.8	Tran	80	line_45	79.30%	147.90%	82.20%	80.00%	Line Yigo_345 34.5 to Andersen 34.5 Circuit 1
Harmon 1	34.5	NCS Fine	34.5	Line	59	tran_52	37.80%	147.90%	39.40%	47.10%	Tran Harmon 3 34.50 to Harmn115 115.00 Circuit 1
Cabr 115	115	Cabras_1	13.8	Tran	80	line_41	79.60%	147.80%	82.70%	79.80%	Line NCS Fine 34.5 to Potts Jc 34.5 Circuit 1
Cabr 115	115	Cabras_1	13.8	Tran	80	line_42	79.60%	147.80%	82.70%	79.80%	Line Potts Jc 34.5 to Andersen 34.5 Circuit 1
Cabr 115	115	Cabras_1	13.8	Tran	80	line_27	79.40%	147.80%	82.40%	80.00%	Line Radio Ba 34.5 to Marbo 34 34.5 Circuit 1
Cabr 115	115	Cabras_1	13.8	Tran	80	line_40	79.40%	147.80%	82.40%	80.00%	Line Dededo 3 34.5 to Marbo 34 34.5 Circuit 1
Cabr 115	115	Cabras_1	13.8	Tran	80	line_21	79.20%	147.70%	82.40%	79.90%	Line Pulantat 34.5 to Talofofo 34.5 Circuit 1
Cabr 115	115	Cabras_1	13.8	Tran	80	line_31	79.20%	147.70%	82.30%	80.00%	Line Anigua 3 34.5 to Agana 34 34.5 Circuit 1
Cabr 115	115	Cabras_1	13.8	Tran	80	line_55	79.70%	147.60%	82.60%	80.40%	Line Tamuning 115.0 to Harmn115 115.0 and Line Giattap 34.5 to Harmon 1 34.5
Cabr 115	115	Cabras_1	13.8	Tran	80	line_46	79.40%	147.60%	82.30%	80.00%	Line GAA 34.5 34.5 to GIAT 34.5 Circuit 1
Cabr 115	115	Cabras_1	13.8	Tran	80	base	79.30%	147.60%	82.30%	79.90%	Base system (n-0)
Cabr 115	115	Cabras_1	13.8	Tran	80	line_44	79.20%	147.60%	82.20%	79.90%	Line Macheche 34.5 to GAA 34.5 34.5 Circuit 1
Cabr 115	115	Cabras_1	13.8	Tran	80	tran_50	80.30%	147.50%	82.70%	81.00%	Tran Agana 34 34.50 to Agana115 115.00 Circuit 1
Cabr 115	115	Cabras_1	13.8	Tran	80	line_22	80.00%	147.50%	82.50%	80.40%	Line Pulantat 34.5 to Barrigad 34.5 Circuit 1
Cabr 115	115	Cabras_1	13.8	Tran	80	line_28	79.70%	147.50%	82.50%	80.00%	Line Tamuning 34.5 to Tumon 34 34.5 Circuit 1
Cabr 115	115	Cabras_1	13.8	Tran	80	line_30	79.40%	147.50%	82.40%	80.10%	Line Tumon 34 34.5 to Harmon 3 34.5 Circuit 1
Harmon 1	34.5	NCS Fine	34.5	Line	59	line_57	34.60%	147.50%	38.10%	48.00%	Line Cabr 115 115.0 to Agana115 115.0 Circuit 1 and Agana T400
Cabr 115	115	Cabras_1	13.8	Tran	80	line_29	79.60%	147.40%	82.50%	79.90%	Line Tamuning 34.5 to San Vito 34.5 Circuit 1
Cabr 115	115	Cabras_1	13.8	Tran	80	line_6	79.50%	147.40%	82.40%	80.20%	Line Tamuning 115.0 to Harmn115 115.0 Circuit 1
Cabr 115	115	Cabras_1	13.8	Tran	80	line_26	79.30%	147.40%	82.30%	79.90%	Line Barrigad 34.5 to GAA 34.5 34.5 Circuit 1
Cabr 115	115	Cabras_1	13.8	Tran	80	line_32	79.30%	147.30%	82.30%	79.90%	Line San Vito 34.5 to Harmon 3 34.5 Circuit 1
Dededo 3	34.5	Andersen	34.5	Line	42	tran_53	na	147.00%	37.00%	13.60%	Tran Harmon 1 34.50 to Harmn115 115.00 Circuit 2
Harmon 1	34.5	NCS Fine	34.5	Line	59	line_24	34.50%	146.80%	38.40%	48.60%	Line Agana 34 34.5 to Radio Ba 34.5 Circuit 1
Harmon 1	34.5	NCS Fine	34.5	Line	59	line_34	34.10%	146.70%	39.00%	52.90%	Line Tanguiss 34.5 to Harmon 3 34.5 Circuit 2
Harmon 1	34.5	NCS Fine	34.5	Line	59	line_58	34.50%	146.70%	37.90%	48.00%	Line Cabr 115 to Piti 115 and Agana T400
Harmon 1	34.5	NCS Fine	34.5	Line	59	line_5	30.00%	146.20%	36.40%	48.50%	Line Agana115 115.0 to Tamuning 115.0 Circuit 1
Harmon 1	34.5	NCS Fine	34.5	Line	59	line_54	31.10%	145.70%	36.70%	48.20%	Line Cabr 115 115.0 to Piti 115 115.0 Circuit 1 and Line Cabr 115 115.0 to Agana
Harmon 1	34.5	NCS Fine	34.5	Line	59	line_45	29.90%	145.70%	36.30%	43.30%	Line Yigo_345 34.5 to Andersen 34.5 Circuit 1
Harmon 1	34.5	NCS Fine	34.5	Line	59	line_27	33.80%	145.60%	38.10%	48.30%	Line Radio Ba 34.5 to Marbo 34 34.5 Circuit 1
Harmon 1	34.5	NCS Fine	34.5	Line	59	line_40	33.80%	145.60%	38.10%	48.30%	Line Dededo 3 34.5 to Marbo 34 34.5 Circuit 1
Harmon 1	34.5	NCS Fine	34.5	Line	59	tran_51	33.50%	145.60%	37.90%	47.40%	Tran Tamuning 34.50 to Tamuning 115.00 Circuit 1
Harmon 1	34.5	NCS Fine	34.5	Line	59	tran_50	34.50%	145.30%	37.90%	47.60%	Tran Agana 34 34.50 to Agana115 115.00 Circuit 1
Cabr 115	115	Cabras_1	13.8	Tran	80	line_16	75.10%	145.00%	78.30%	75.90%	Line Apra 34. 34.5 to Umatac34 34.5 Circuit 1
Cabr 115	115	Cabras_1	13.8	Tran	80	line_10	79.70%	144.50%	81.60%	80.10%	Line Piti 345 34.5 to Tenjotap 34.5 Circuit 1
Harmon 1	34.5	NCS Fine	34.5	Line	59	line_4	30.00%	144.30%	36.30%	48.30%	Line Piti 115 115.0 to Harmn115 115.0 Circuit 1
Cabr 115	115	Cabras_1	13.8	Tran	80	line_54	79.50%	144.20%	80.70%	79.80%	Line Cabr 115 115.0 to Piti 115 115.0 Circuit 1 and Line Cabr 115 115.0 to Agana
Harmon 1	34.5	NCS Fine	34.5	Line	59	line_62	30.50%	143.70%	36.60%	48.50%	Line Piti 115 115.0 to Harmn115 115.0 and Piti T700
Cabr 115	115	Cabras_1	13.8	Tran	80	line_1	79.20%	143.40%	81.00%	78.00%	Line Cabr 115 115.0 to Piti 115 115.0 Circuit 1
Harmon 1	34.5	NCS Fine	34.5	Line	59	line_17	30.80%	143.20%	36.60%	47.20%	Line Apra 34. 34.5 to Tenjotap 34.5 Circuit 1
Piti 345	34.5	Cld Stor	34.5	Line	59	line_10	58.90%	143.10%	32.30%	35.50%	Line Piti 345 34.5 to Tenjotap 34.5 Circuit 1

Overload Report

Name	kV	Name	kV	Type	Rated Mva	Outage	Existing 2007 Load	New DOD Loads	Line Upgrades w/ No 115 kV	Line Upgrades Including 115 kV	Outage description
Harmon 1	34.5	NCS Fine	34.5	Line	59	line_2	31.20%	142.90%	36.70%	47.70%	Line Cabr 115 115.0 to Agana115 115.0 Circuit 1
Harmon 1	34.5	NCS Fine	34.5	Line	59	line_3	31.20%	142.90%	36.70%	47.70%	Line Cabr 115 115.0 to Agana115 115.0 Circuit 2
Harmon 1	34.5	NCS Fine	34.5	Line	59	line_59	31.70%	142.80%	37.00%	47.80%	Line Cabr 115 115.0 to Agana115 115.0 Circuit 1 and Piti T700
Cabr 115	115	Cabras_1	13.8	Tran	80	line_58	79.60%	142.70%	80.80%	80.00%	Line Cabr 115 to Piti 115 and Agana T400
Harmon 1	34.5	NCS Fine	34.5	Line	59	line_28	31.60%	142.20%	36.90%	47.20%	Line Tamuning 34.5 to Tumon 34 34.5 Circuit 1
Harmon 1	34.5	NCS Fine	34.5	Line	59	line_47	33.70%	141.80%	37.30%	49.50%	Line GIAT 34.5 to Harmon 1 34.5 Circuit 1
Harmon 1	34.5	NCS Fine	34.5	Line	59	line_29	31.40%	141.80%	36.70%	47.30%	Line Tamuning 34.5 to San Vito 34.5 Circuit 1
Cabr 115	115	Cabras_1	13.8	Tran	80	line_60	80.60%	141.70%	83.30%	79.20%	Line Cabr 115 to Piti 115 and Piti T700
Harmon 1	34.5	NCS Fine	34.5	Line	59	line_11	na	141.70%	36.50%	47.30%	Line Piti 345 34.5 to Orote 34 34.5 Circuit 1
Cabr 115	115	Cabras_1	13.8	Tran	80	line_62	81.90%	141.50%	82.30%	82.30%	Line Piti 115 115.0 to Harmn115 115.0 and Piti T700
Harmon 1	34.5	NCS Fine	34.5	Line	59	line_19	30.80%	141.50%	36.50%	47.30%	Line Piti 345 34.5 to Cld Stor 34.5 Circuit 1
Harmon 1	34.5	NCS Fine	34.5	Line	59	line_13	31.10%	141.40%	36.70%	47.40%	Line Piti 345 34.5 to Anigua 3 34.5 Circuit 1
Harmon 1	34.5	NCS Fine	34.5	Line	59	line_15	30.80%	141.40%	36.40%	47.30%	Line Apra 34. 34.5 to Orote 34 34.5 Circuit 1
Harmon 1	34.5	NCS Fine	34.5	Line	59	line_55	32.10%	141.30%	36.60%	49.40%	Line Tamuning 115.0 to Harmn115 115.0 and Line Giattap 34.5 to Harmon 1 34.5
Harmon 1	34.5	NCS Fine	34.5	Line	59	line_1	30.70%	141.20%	36.40%	47.40%	Line Cabr 115 115.0 to Piti 115 115.0 Circuit 1
Harmon 1	34.5	NCS Fine	34.5	Line	59	line_46	32.90%	141.10%	37.00%	48.70%	Line GAA 34.5 34.5 to GIAT 34.5 Circuit 1
Harmon 1	34.5	NCS Fine	34.5	Line	59	line_12	30.90%	141.10%	36.60%	47.30%	Line Piti 345 34.5 to Agana 34 34.5 Circuit 1
Harmon 1	34.5	NCS Fine	34.5	Line	59	line_25	30.90%	140.90%	36.50%	47.20%	Line Agana 34 34.5 to Tamuning 34.5 Circuit 1
Harmon 1	34.5	NCS Fine	34.5	Line	59	line_14	30.90%	140.90%	36.50%	47.00%	Line Talofofo 34.5 to Apra 34. 34.5 Circuit 1
Harmon 1	34.5	NCS Fine	34.5	Line	59	line_44	31.30%	140.80%	36.60%	47.60%	Line Macheche 34.5 to GAA 34.5 34.5 Circuit 1
Harmon 1	34.5	NCS Fine	34.5	Line	59	line_32	30.60%	140.80%	36.40%	47.30%	Line San Vito 34.5 to Harmon 3 34.5 Circuit 1
Harmon 1	34.5	NCS Fine	34.5	Line	59	line_18	30.80%	140.80%	36.40%	47.20%	Line Orote 34 34.5 to Cld Stor 34.5 Circuit 1
Harmon 1	34.5	NCS Fine	34.5	Line	59	line_31	30.70%	140.70%	36.50%	47.30%	Line Anigua 3 34.5 to Agana 34 34.5 Circuit 1
Harmon 1	34.5	NCS Fine	34.5	Line	59	line_21	30.80%	140.70%	36.40%	47.10%	Line Pulantat 34.5 to Talofofo 34.5 Circuit 1
Harmon 1	34.5	NCS Fine	34.5	Line	59	base	30.80%	140.60%	36.40%	47.20%	Base system (n-0)
Harmon 1	34.5	NCS Fine	34.5	Line	59	line_30	30.40%	140.60%	36.30%	47.30%	Line Tumon 34 34.5 to Harmon 3 34.5 Circuit 1
Harmon 1	34.5	NCS Fine	34.5	Line	59	line_26	30.70%	140.60%	36.30%	46.80%	Line Barrigad 34.5 to GAA 34.5 34.5 Circuit 1
Harmon 1	34.5	NCS Fine	34.5	Line	59	line_23	29.70%	140.60%	36.00%	45.50%	Line Agana 34 34.5 to Barrigad 34.5 Circuit 1
Harmon 1	34.5	NCS Fine	34.5	Line	59	line_9	31.30%	140.50%	36.70%	47.40%	Line Cabrs345 34.5 to Piti 345 34.5 Circuit 1
Harmon 1	34.5	NCS Fine	34.5	Line	59	tran_48	31.30%	140.50%	36.70%	47.40%	Tran Cabrs345 34.50 to Cabr 115 115.00 Circuit 1
Harmon 1	34.5	NCS Fine	34.5	Line	59	tran_49	31.20%	140.40%	36.60%	47.40%	Tran Piti 345 34.50 to Piti 115 115.00 Circuit 1
Harmon 1	34.5	NCS Fine	34.5	Line	59	line_6	29.50%	140.40%	35.90%	47.80%	Line Tamuning 115.0 to Harmn115 115.0 Circuit 1
Harmon 1	34.5	NCS Fine	34.5	Line	59	line_60	31.50%	140.30%	36.70%	47.40%	Line Cabr 115 to Piti 115 and Piti T700
Harmon 1	34.5	NCS Fine	34.5	Line	59	line_16	30.70%	140.30%	36.40%	47.20%	Line Apra 34. 34.5 to Umatac34 34.5 Circuit 1
Cabr 115	115	Cabras_1	13.8	Tran	80	tran_49	79.90%	140.20%	81.00%	80.50%	Tran Piti 345 34.50 to Piti 115 115.00 Circuit 1
Harmon 1	34.5	NCS Fine	34.5	Line	59	line_22	30.70%	140.20%	36.30%	47.40%	Line Pulantat 34.5 to Barrigad 34.5 Circuit 1
Cabr 115	115	Cabras_1	13.8	Tran	80	line_59	80.90%	140.00%	81.60%	81.60%	Line Cabr 115 115.0 to Agana115 115.0 Circuit 1 and Piti T700
Harmon 1	34.5	NCS Fine	34.5	Line	59	line_10	30.80%	139.90%	36.30%	47.30%	Line Piti 345 34.5 to Tenjotap 34.5 Circuit 1
Harmon 1	34.5	NCS Fine	34.5	Line	59	line_43	30.20%	138.60%	36.00%	47.50%	Line Macheche 34.5 to Pagat 34 34.5 Circuit 1
Harmon 1	34.5	NCS Fine	34.5	Line	59	line_20	30.70%	138.50%	36.00%	47.00%	Line Cld Stor 34.5 to Cold Sto 34.5 Circuit 1
Harmon 1	34.5	NCS Fine	34.5	Line	59	tran_53	na	138.30%	29.70%	32.40%	Tran Harmon 1 34.50 to Harmn115 115.00 Circuit 2
Piti 345	34.5	Cld Stor	34.5	Line	59	line_22	50.30%	138.00%	31.80%	35.50%	Line Pulantat 34.5 to Barrigad 34.5 Circuit 1
Cabr 115	115	Cabras_1	13.8	Tran	80	line_43	63.00%	137.70%	66.80%	64.50%	Line Macheche 34.5 to Pagat 34 34.5 Circuit 1
Cabr 115	115	Cabras_1	13.8	Tran	80	line_9	79.90%	137.50%	80.20%	80.40%	Line Cabrs345 34.5 to Piti 345 34.5 Circuit 1

Overload Report

Name	kV	Name	kV	Type	Rated Mva	Outage	Existing 2007 Load	New DOD Loads	Line Upgrades w/ No 115 kV	Line Upgrades Including 115 kV	Outage description
Cabr 115	115	Cabras_1	13.8	Tran	80	tran_48	79.90%	137.50%	80.20%	80.40%	Tran Cabrs345 34.50 to Cabr 115 115.00 Circuit 1
Harmon 1	34.5	NCS Fine	34.5	Line	59	line_38	26.90%	137.50%	34.60%	44.00%	Line Harmon 3 34.5 to Macheche 34.5 Circuit 1
Harmon 1	34.5	NCS Fine	34.5	Line	59	line_33	31.00%	137.50%	34.10%	42.40%	Line Tanguiss 34.5 to Harmon 1 34.5 Circuit 1
Piti 345	34.5	Cld Stor	34.5	Line	59	line_61	45.70%	135.60%	30.80%	31.70%	Line Piti 115 115.0 to Harmn115 115.0 and Agana T400
Piti 345	34.5	Cld Stor	34.5	Line	59	line_23	46.30%	135.20%	31.20%	35.80%	Line Agana 34 34.5 to Barrigad 34.5 Circuit 1
Piti 345	34.5	Cld Stor	34.5	Line	59	line_66	45.60%	134.70%	30.90%	35.10%	Line Piti 345 34.5 to Anigua 3 34.5 Circuit 1 and Agana T400
Piti 345	34.5	Cld Stor	34.5	Line	59	line_63	44.40%	134.70%	30.60%	32.80%	Line Piti 115 115.0 to Harmn115 115.0 and Tamuning T600
Cabr 115	115	Cabras_1	13.8	Tran	80	line_20	73.50%	133.70%	64.80%	62.80%	Line Cld Stor 34.5 to Cold Sto 34.5 Circuit 1
Piti 345	34.5	Cld Stor	34.5	Line	59	line_57	44.80%	133.70%	30.60%	32.40%	Line Cabr 115 115.0 to Agana115 115.0 Circuit 1 and Agana T400
Piti 345	34.5	Cld Stor	34.5	Line	59	line_58	44.30%	133.50%	30.50%	37.10%	Line Cabr 115 to Piti 115 and Agana T400
Piti 345	34.5	Cld Stor	34.5	Line	59	line_64	43.80%	133.50%	30.50%	33.80%	Line Agana115 115.0 to Tamuning 115.0 Circuit 1 and Tamuning T600
Piti 345	34.5	Cld Stor	34.5	Line	59	line_65	43.80%	133.50%	30.50%	33.80%	Line Tamuning 115.0 to Harmn115 115.0 and Tamuning T600
Piti 345	34.5	Cld Stor	34.5	Line	59	line_67	43.30%	133.50%	30.40%	34.60%	Line Agana 34 34.5 to Tamuning 34.5 Circuit 1 and Tamuning T600
Piti 345	34.5	Cld Stor	34.5	Line	59	tran_53	na	133.40%	30.50%	34.10%	Tran Harmon 1 34.50 to Harmn115 115.00 Circuit 2
Piti 345	34.5	Cld Stor	34.5	Line	59	tran_50	44.30%	132.80%	30.50%	32.70%	Tran Agana 34 34.50 to Agana115 115.00 Circuit 1
Piti 345	34.5	Cld Stor	34.5	Line	59	line_68	44.00%	132.80%	30.40%	34.10%	Line Tamuning 34.5 to Tumon 34 34.5 Circuit 1 and Harmon T500
Piti 345	34.5	Cld Stor	34.5	Line	59	line_54	43.10%	132.80%	30.30%	39.50%	Line Cabr 115 115.0 to Piti 115 115.0 Circuit 1 and Line Cabr 115 115.0 to Agana
Piti 345	34.5	Cld Stor	34.5	Line	59	line_5	43.40%	132.70%	30.40%	34.10%	Line Agana115 115.0 to Tamuning 115.0 Circuit 1
Piti 345	34.5	Cld Stor	34.5	Line	59	line_62	42.90%	132.50%	30.40%	29.90%	Line Piti 115 115.0 to Harmn115 115.0 and Piti T700
Piti 345	34.5	Cld Stor	34.5	Line	59	line_4	43.40%	132.30%	30.40%	33.40%	Line Piti 115 115.0 to Harmn115 115.0 Circuit 1
Piti 345	34.5	Cld Stor	34.5	Line	59	line_38	43.60%	132.20%	30.50%	34.50%	Line Harmon 3 34.5 to Macheche 34.5 Circuit 1
Piti 345	34.5	Cld Stor	34.5	Line	59	line_59	42.50%	132.00%	30.30%	30.50%	Line Cabr 115 115.0 to Agana115 115.0 Circuit 1 and Piti T700
Piti 345	34.5	Cld Stor	34.5	Line	59	tran_51	43.10%	131.80%	30.40%	33.70%	Tran Tamuning 34.50 to Tamuning 115.00 Circuit 1
Piti 345	34.5	Cld Stor	34.5	Line	59	tran_52	43.50%	131.60%	30.30%	34.00%	Tran Harmon 3 34.50 to Harmn115 115.00 Circuit 1
Piti 345	34.5	Cld Stor	34.5	Line	59	line_2	43.10%	131.60%	30.30%	33.80%	Line Cabr 115 115.0 to Agana115 115.0 Circuit 1
Piti 345	34.5	Cld Stor	34.5	Line	59	line_3	43.10%	131.60%	30.30%	33.80%	Line Cabr 115 115.0 to Agana115 115.0 Circuit 2
Piti 345	34.5	Cld Stor	34.5	Line	59	line_35	42.50%	131.60%	30.20%	34.20%	Line Harmon 3 34.5 to Dededo 3 34.5 Circuit 1
Piti 345	34.5	Cld Stor	34.5	Line	59	line_33	42.40%	131.50%	30.20%	34.30%	Line Tanguiss 34.5 to Harmon 1 34.5 Circuit 1
Piti 345	34.5	Cld Stor	34.5	Line	59	line_13	42.80%	131.30%	30.30%	36.00%	Line Piti 345 34.5 to Anigua 3 34.5 Circuit 1
Piti 345	34.5	Cld Stor	34.5	Line	59	line_34	42.50%	131.20%	30.20%	34.30%	Line Tanguiss 34.5 to Harmon 3 34.5 Circuit 2
Piti 345	34.5	Cld Stor	34.5	Line	59	line_12	42.60%	131.10%	30.20%	35.60%	Line Piti 345 34.5 to Agana 34 34.5 Circuit 1
Piti 345	34.5	Cld Stor	34.5	Line	59	line_39	42.40%	131.10%	30.10%	34.30%	Line Harmon 1 34.5 to Yigo_345 34.5 Circuit 1
Piti 345	34.5	Cld Stor	34.5	Line	59	line_9	41.60%	131.00%	30.10%	30.30%	Line Cabrs345 34.5 to Piti 345 34.5 Circuit 1
Piti 345	34.5	Cld Stor	34.5	Line	59	tran_48	41.60%	131.00%	30.10%	30.30%	Tran Cabrs345 34.50 to Cabr 115 115.00 Circuit 1
Piti 345	34.5	Cld Stor	34.5	Line	59	line_55	43.00%	130.90%	30.20%	34.40%	Line Tamuning 115.0 to Harmn115 115.0 and Line Giattap 34.5 to Harmon 1 34.5
Piti 345	34.5	Cld Stor	34.5	Line	59	line_47	42.90%	130.90%	30.20%	34.30%	Line GIAT 34.5 to Harmon 1 34.5 Circuit 1
Piti 345	34.5	Cld Stor	34.5	Line	59	line_1	42.30%	130.90%	30.10%	37.40%	Line Cabr 115 115.0 to Piti 115 115.0 Circuit 1
Piti 345	34.5	Cld Stor	34.5	Line	59	tran_49	41.80%	130.90%	30.10%	31.40%	Tran Piti 345 34.50 to Piti 115 115.00 Circuit 1
Piti 345	34.5	Cld Stor	34.5	Line	59	line_31	42.40%	130.80%	30.20%	34.90%	Line Anigua 3 34.5 to Agana 34 34.5 Circuit 1
Piti 345	34.5	Cld Stor	34.5	Line	59	line_6	42.60%	130.80%	30.20%	34.40%	Line Tamuning 115.0 to Harmn115 115.0 Circuit 1
Piti 345	34.5	Cld Stor	34.5	Line	59	line_46	42.70%	130.70%	30.20%	34.30%	Line GAA 34.5 34.5 to GIAT 34.5 Circuit 1
Piti 345	34.5	Cld Stor	34.5	Line	59	line_60	41.70%	130.70%	30.10%	34.40%	Line Cabr 115 to Piti 115 and Piti T700
Piti 345	34.5	Cld Stor	34.5	Line	59	line_28	42.40%	130.60%	30.10%	34.40%	Line Tamuning 34.5 to Tumon 34 34.5 Circuit 1
Piti 345	34.5	Cld Stor	34.5	Line	59	line_24	42.30%	130.60%	30.10%	34.40%	Line Agana 34 34.5 to Radio Ba 34.5 Circuit 1

Overload Report

Name	kV	Name	kV	Type	Rated Mva	Outage	Existing 2007 Load	New DOD Loads	Line Upgrades w/ No 115 kV	Line Upgrades Including 115 kV	Outage description
Piti 345	34.5	Cld Stor	34.5	Line	59	line_27	42.30%	130.60%	30.10%	34.40%	Line Radio Ba 34.5 to Marbo 34 34.5 Circuit 1
Piti 345	34.5	Cld Stor	34.5	Line	59	line_40	42.30%	130.60%	30.10%	34.40%	Line Dededo 3 34.5 to Marbo 34 34.5 Circuit 1
Piti 345	34.5	Cld Stor	34.5	Line	59	line_29	42.40%	130.60%	30.10%	34.30%	Line Tamuning 34.5 to San Vito 34.5 Circuit 1
Piti 345	34.5	Cld Stor	34.5	Line	59	line_41	42.40%	130.60%	30.10%	34.20%	Line NCS Fine 34.5 to Potts Jc 34.5 Circuit 1
Piti 345	34.5	Cld Stor	34.5	Line	59	line_42	42.40%	130.60%	30.10%	34.20%	Line Potts Jc 34.5 to Andersen 34.5 Circuit 1
Piti 345	34.5	Cld Stor	34.5	Line	59	base	42.30%	130.60%	30.10%	34.20%	Base system (n-0)
Piti 345	34.5	Cld Stor	34.5	Line	59	line_45	42.30%	130.60%	30.10%	34.20%	Line Yigo_345 34.5 to Andersen 34.5 Circuit 1
Piti 345	34.5	Cld Stor	34.5	Line	59	line_25	42.20%	130.50%	30.10%	34.70%	Line Agana 34 34.5 to Tamuning 34.5 Circuit 1
Piti 345	34.5	Cld Stor	34.5	Line	59	line_30	42.30%	130.50%	30.10%	34.20%	Line Tumon 34 34.5 to Harmon 3 34.5 Circuit 1
Piti 345	34.5	Cld Stor	34.5	Line	59	line_32	42.30%	130.50%	30.10%	34.20%	Line San Vito 34.5 to Harmon 3 34.5 Circuit 1
Piti 345	34.5	Cld Stor	34.5	Line	59	line_44	42.20%	130.50%	30.10%	34.20%	Line Macheche 34.5 to GAA 34.5 34.5 Circuit 1
Piti 345	34.5	Cld Stor	34.5	Line	59	line_26	42.20%	130.00%	30.00%	34.20%	Line Barrigad 34.5 to GAA 34.5 34.5 Circuit 1
Piti 345	34.5	Cld Stor	34.5	Line	59	line_43	41.80%	129.60%	29.90%	34.20%	Line Macheche 34.5 to Pagat 34 34.5 Circuit 1
Piti 345	34.5	Orote 34	34.5	Line	54	line_19	na	129.20%	46.60%	42.70%	Line Piti 345 34.5 to Cld Stor 34.5 Circuit 1
Piti 345	34.5	Cld Stor	34.5	Line	59	line_21	40.80%	129.00%	29.40%	33.00%	Line Pulantat 34.5 to Talofofo 34.5 Circuit 1
Piti 345	34.5	Cld Stor	34.5	Line	59	line_16	39.60%	127.90%	29.40%	33.60%	Line Apra 34. 34.5 to Umatac34 34.5 Circuit 1
Dededo 3	34.5	Andersen	34.5	Line	42	line_33	33.40%	127.40%	27.60%	19.70%	Line Tanguiss 34.5 to Harmon 1 34.5 Circuit 1
Piti 345	34.5	Cld Stor	34.5	Line	59	line_14	35.00%	125.90%	28.30%	31.80%	Line Talofofo 34.5 to Apra 34. 34.5 Circuit 1
Dededo 3	34.5	Andersen	34.5	Line	42	line_5	36.30%	122.30%	24.70%	15.70%	Line Agana115 115.0 to Tamuning 115.0 Circuit 1
Dededo 3	34.5	Andersen	34.5	Line	42	line_45	32.20%	122.30%	22.90%	11.90%	Line Yigo_345 34.5 to Andersen 34.5 Circuit 1
Dededo 3	34.5	Andersen	34.5	Line	42	line_63	33.10%	121.30%	22.50%	10.90%	Line Piti 115 115.0 to Harmn115 115.0 and Tamuning T600
Dededo 3	34.5	Andersen	34.5	Line	42	line_38	39.20%	120.50%	26.10%	16.20%	Line Harmon 3 34.5 to Macheche 34.5 Circuit 1
Piti 345	34.5	Agana 34	34.5	Line	29	line_66	98.60%	120.40%	110.50%	110.40%	Line Piti 345 34.5 to Anigua 3 34.5 Circuit 1 and Agana T400
Dededo 3	34.5	Andersen	34.5	Line	42	line_4	36.10%	120.30%	24.40%	14.90%	Line Piti 115 115.0 to Harmn115 115.0 Circuit 1
Dededo 3	34.5	Andersen	34.5	Line	42	line_61	32.10%	120.30%	22.40%	10.60%	Line Piti 115 115.0 to Harmn115 115.0 and Agana T400
Dededo 3	34.5	Andersen	34.5	Line	42	line_65	33.60%	120.00%	23.10%	12.40%	Line Tamuning 115.0 to Harmn115 115.0 and Tamuning T600
Dededo 3	34.5	Andersen	34.5	Line	42	line_64	33.60%	119.90%	23.10%	12.40%	Line Agana115 115.0 to Tamuning 115.0 Circuit 1 and Tamuning T600
Dededo 3	34.5	Andersen	34.5	Line	42	line_54	34.00%	118.90%	23.30%	12.10%	Line Cabr 115 115.0 to Piti 115 115.0 Circuit 1 and Line Cabr 115 115.0 to Agana
Dededo 3	34.5	Andersen	34.5	Line	42	line_62	35.80%	118.60%	24.10%	14.30%	Line Piti 115 115.0 to Harmn115 115.0 and Piti T700
Dededo 3	34.5	Andersen	34.5	Line	42	line_23	35.60%	117.50%	24.20%	12.90%	Line Agana 34 34.5 to Barrigad 34.5 Circuit 1
Dededo 3	34.5	Andersen	34.5	Line	42	line_6	35.90%	117.00%	24.40%	16.80%	Line Tamuning 115.0 to Harmn115 115.0 Circuit 1
Dededo 3	34.5	Andersen	34.5	Line	42	line_17	33.50%	115.90%	23.00%	12.30%	Line Apra 34. 34.5 to Tenjotap 34.5 Circuit 1
Dededo 3	34.5	Andersen	34.5	Line	42	line_2	33.60%	115.70%	23.00%	11.90%	Line Cabr 115 115.0 to Agana115 115.0 Circuit 1
Dededo 3	34.5	Andersen	34.5	Line	42	line_3	33.60%	115.70%	23.00%	11.90%	Line Cabr 115 115.0 to Agana115 115.0 Circuit 2
Dededo 3	34.5	Andersen	34.5	Line	42	line_55	32.00%	115.50%	23.00%	15.00%	Line Tamuning 115.0 to Harmn115 115.0 and Line Giattap 34.5 to Harmon 1 34.5
Dededo 3	34.5	Andersen	34.5	Line	42	line_67	28.10%	115.30%	20.00%	17.10%	Line Agana 34 34.5 to Tamuning 34.5 Circuit 1 and Tamuning T600
San Vito	34.5	Harmon 3	34.5	Line	29	line_67	114.90%	115.20%	106.70%	104.50%	Line Agana 34 34.5 to Tamuning 34.5 Circuit 1 and Tamuning T600
Dededo 3	34.5	Andersen	34.5	Line	42	line_1	33.60%	115.10%	23.00%	12.60%	Line Cabr 115 115.0 to Piti 115 115.0 Circuit 1
Dededo 3	34.5	Andersen	34.5	Line	42	line_26	33.60%	114.90%	23.10%	12.50%	Line Barrigad 34.5 to GAA 34.5 34.5 Circuit 1
Dededo 3	34.5	Andersen	34.5	Line	42	line_11	na	114.80%	23.00%	12.50%	Line Piti 345 34.5 to Orote 34 34.5 Circuit 1
Dededo 3	34.5	Andersen	34.5	Line	42	line_19	33.50%	114.80%	23.00%	12.50%	Line Piti 345 34.5 to Cld Stor 34.5 Circuit 1
Dededo 3	34.5	Andersen	34.5	Line	42	line_15	33.50%	114.70%	22.90%	12.50%	Line Apra 34. 34.5 to Orote 34 34.5 Circuit 1
Dededo 3	34.5	Andersen	34.5	Line	42	line_30	33.90%	114.40%	23.10%	12.90%	Line Tumon 34 34.5 to Harmon 3 34.5 Circuit 1
Dededo 3	34.5	Andersen	34.5	Line	42	line_14	33.50%	114.40%	22.90%	11.80%	Line Talofofo 34.5 to Apra 34. 34.5 Circuit 1

Overload Report

Name	kV	Name	kV	Type	Rated Mva	Outage	Existing 2007 Load	New DOD Loads	Line Upgrades w/ No 115 kV	Line Upgrades Including 115 kV	Outage description
Dededo 3	34.5	Andersen	34.5	Line	42	line_18	33.50%	114.30%	22.90%	12.50%	Line Orote 34 34.5 to Cld Stor 34.5 Circuit 1
Dededo 3	34.5	Andersen	34.5	Line	42	line_21	33.50%	114.30%	22.90%	12.30%	Line Pulantat 34.5 to Talofofo 34.5 Circuit 1
Dededo 3	34.5	Andersen	34.5	Line	42	line_25	33.50%	114.30%	22.90%	12.00%	Line Agana 34 34.5 to Tamuning 34.5 Circuit 1
Dededo 3	34.5	Andersen	34.5	Line	42	line_32	33.70%	114.20%	23.00%	12.60%	Line San Vito 34.5 to Harmon 3 34.5 Circuit 1
Dededo 3	34.5	Andersen	34.5	Line	42	base	33.50%	114.20%	22.90%	12.40%	Base system (n-0)
Dededo 3	34.5	Andersen	34.5	Line	42	line_31	33.60%	114.20%	22.80%	12.00%	Line Anigua 3 34.5 to Agana 34 34.5 Circuit 1
Dededo 3	34.5	Andersen	34.5	Line	42	line_59	33.20%	114.20%	22.60%	11.70%	Line Cabr 115 115.0 to Agana115 115.0 Circuit 1 and Piti T700
Dededo 3	34.5	Andersen	34.5	Line	42	line_16	33.50%	114.10%	22.90%	12.50%	Line Apra 34. 34.5 to Umatac34 34.5 Circuit 1
Dededo 3	34.5	Andersen	34.5	Line	42	line_12	33.30%	114.10%	22.70%	11.60%	Line Piti 345 34.5 to Agana 34 34.5 Circuit 1
Dededo 3	34.5	Andersen	34.5	Line	42	line_13	33.20%	114.10%	22.60%	11.40%	Line Piti 345 34.5 to Anigua 3 34.5 Circuit 1
Dededo 3	34.5	Andersen	34.5	Line	42	line_22	33.50%	114.00%	22.90%	12.50%	Line Pulantat 34.5 to Barrigad 34.5 Circuit 1
Dededo 3	34.5	Andersen	34.5	Line	42	line_10	33.50%	113.90%	22.90%	12.40%	Line Piti 345 34.5 to Tenjotap 34.5 Circuit 1
Dededo 3	34.5	Andersen	34.5	Line	42	line_44	32.80%	113.90%	22.60%	12.00%	Line Macheche 34.5 to GAA 34.5 34.5 Circuit 1
Dededo 3	34.5	Andersen	34.5	Line	42	line_29	32.80%	113.80%	22.60%	12.30%	Line Tamuning 34.5 to San Vito 34.5 Circuit 1
Dededo 3	34.5	Andersen	34.5	Line	42	line_28	32.60%	113.70%	22.40%	12.10%	Line Tamuning 34.5 to Tumon 34 34.5 Circuit 1
Dededo 3	34.5	Andersen	34.5	Line	42	line_57	29.60%	113.70%	21.20%	11.60%	Line Cabr 115 115.0 to Agana115 115.0 Circuit 1 and Agana T400
Dededo 3	34.5	Andersen	34.5	Line	42	line_46	30.50%	113.60%	21.90%	11.70%	Line GAA 34.5 34.5 to GIAT 34.5 Circuit 1
Orote 34	34.5	Cld Stor	34.5	Line	59	line_17	40.60%	113.50%	26.00%	21.90%	Line Apra 34. 34.5 to Tenjotap 34.5 Circuit 1
Dededo 3	34.5	Andersen	34.5	Line	42	line_43	33.80%	113.40%	23.00%	13.40%	Line Macheche 34.5 to Pagat 34 34.5 Circuit 1
Dededo 3	34.5	Andersen	34.5	Line	42	line_58	29.30%	113.20%	21.10%	11.60%	Line Cabr 115 to Piti 115 and Agana T400
Dededo 3	34.5	Andersen	34.5	Line	42	line_20	33.50%	113.10%	22.90%	12.80%	Line Cld Stor 34.5 to Cold Sto 34.5 Circuit 1
Dededo 3	34.5	Andersen	34.5	Line	42	tran_49	33.10%	112.90%	22.60%	12.30%	Tran Piti 345 34.50 to Piti 115 115.00 Circuit 1
Harmon 1	34.5	Yigo_345	34.5	Line	29	line_35	82.20%	112.80%	38.90%	35.70%	Line Harmon 3 34.5 to Dededo 3 34.5 Circuit 1
Dededo 3	34.5	Andersen	34.5	Line	42	line_9	33.00%	112.60%	22.50%	12.20%	Line Cabrs345 34.5 to Piti 345 34.5 Circuit 1
Dededo 3	34.5	Andersen	34.5	Line	42	tran_48	33.00%	112.60%	22.50%	12.20%	Tran Cabrs345 34.50 to Cabr 115 115.00 Circuit 1
Dededo 3	34.5	Andersen	34.5	Line	42	line_47	29.30%	112.30%	21.30%	12.00%	Line GIAT 34.5 to Harmon 1 34.5 Circuit 1
Dededo 3	34.5	Andersen	34.5	Line	42	line_60	32.70%	112.10%	22.40%	12.70%	Line Cabr 115 to Piti 115 and Piti T700
Dededo 3	34.5	Andersen	34.5	Line	42	tran_51	30.30%	112.00%	21.10%	13.10%	Tran Tamuning 34.50 to Tamuning 115.00 Circuit 1
Dededo 3	34.5	Andersen	34.5	Line	42	line_66	27.80%	111.90%	20.00%	14.00%	Line Piti 345 34.5 to Anigua 3 34.5 Circuit 1 and Agana T400
Dededo 3	34.5	Andersen	34.5	Line	42	tran_50	29.20%	111.70%	21.00%	12.20%	Tran Agana 34 34.50 to Agana115 115.00 Circuit 1
Agana115	115	Tamuning	115	Line	181	line_61	98.40%	110.90%	99.40%	96.50%	Line Piti 115 115.0 to Harmn115 115.0 and Agana T400
Dededo 3	34.5	Andersen	34.5	Line	42	line_68	21.90%	110.00%	17.60%	23.00%	Line Tamuning 34.5 to Tumon 34 34.5 Circuit 1 and Harmon T500
Dededo 3	34.5	Andersen	34.5	Line	42	line_27	29.60%	109.60%	20.10%	10.20%	Line Radio Ba 34.5 to Marbo 34 34.5 Circuit 1
Dededo 3	34.5	Andersen	34.5	Line	42	line_40	29.60%	109.60%	20.10%	10.20%	Line Dededo 3 34.5 to Marbo 34 34.5 Circuit 1
Dededo 3	34.5	Andersen	34.5	Line	42	tran_52	24.90%	109.40%	19.00%	17.70%	Tran Harmon 3 34.50 to Harmn115 115.00 Circuit 1
Dededo 3	34.5	Andersen	34.5	Line	42	line_24	28.60%	108.80%	19.80%	11.90%	Line Agana 34 34.5 to Radio Ba 34.5 Circuit 1
Dededo 3	34.5	Andersen	34.5	Line	42	line_34	28.90%	107.90%	18.60%	10.20%	Line Tanguiss 34.5 to Harmon 3 34.5 Circuit 2
Piti 345	34.5	Orote 34	34.5	Line	54	line_17	na	105.70%	34.90%	39.10%	Line Apra 34. 34.5 to Tenjotap 34.5 Circuit 1
Dededo 3	34.5	Andersen	34.5	Line	42	line_41	46.80%	103.60%	29.80%	12.80%	Line NCS Fine 34.5 to Potts Jc 34.5 Circuit 1
Dededo 3	34.5	Andersen	34.5	Line	42	line_42	46.80%	103.60%	29.80%	12.80%	Line Potts Jc 34.5 to Andersen 34.5 Circuit 1
Piti 345	34.5	Orote 34	34.5	Line	54	line_18	na	101.30%	35.60%	30.40%	Line Orote 34 34.5 to Cld Stor 34.5 Circuit 1
Orote 34	34.5	Cld Stor	34.5	Line	59	line_20	34.00%	100.90%	20.70%	21.10%	Line Cld Stor 34.5 to Cold Sto 34.5 Circuit 1
Piti 345	34.5	Cld Stor	34.5	Line	59	line_20	34.00%	100.90%	20.70%	21.10%	Line Cld Stor 34.5 to Cold Sto 34.5 Circuit 1
Tanguiss	34.5	Harmon 1	34.5	Line	54	tran_53	na	100.70%	90.40%	60.80%	Tran Harmon 1 34.50 to Harmn115 115.00 Circuit 2

Overload Report

Name	kV	Name	kV	Type	Rated Mva	Outage	Existing 2007 Load	New DOD Loads	Line Upgrades w/ No 115 kV	Line Upgrades Including 115 kV	Outage description
GIAT	34.5	Harmon 1	34.5	Line	29	line_38	101.00%	87.70%	89.90%	88.20%	Line Harmon 3 34.5 to Macheche 34.5 Circuit 1

134.97%

Appendix B
Customer Service Agreement

GUAM POWER AUTHORITY
UTILITY SERVICE CONTRACT

GUAM POWER AUTHORITY

PART I - CUSTOMER SERVICE AGREEMENT

Tables

Appendixes

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CUSTOMER AGREEMENT

The United States of America, hereinafter called "Navy," and the Guam Power Authority, hereinafter called "GPA," agree as follows:

ARTICLE 1

Recitals

1.1 This Agreement describes the terms, conditions and rate setting procedures and service rules and regulations applicable to energy and capacity sold and delivered by GPA to Navy, the services Navy will provide to GPA during the interim period and Navy's compensation thereof and services other than electric service that GPA will provide to Navy and compensation thereof. Nothing in this Agreement is intended to be determinative of the issue of ownership of Navy electrical production, transmission and distribution facilities on Guam.

1.2 Navy operates electrical production, transmission and certain distribution facilities which are used jointly for the supply of electricity to Department of Defense (DOD) installations on Guam and to GPA for retail distribution to GPA's customers.

1.3 GPA operates electric production, transmission and distribution facilities which are used for the supply of electricity for retail distribution to GPA's customers and to Department of Defense installations on Guam.

1.4 The Island-Wide Power System is dispatched and controlled by GPA from the GPA Dispatch Control Center.

1.5 GPA and Navy agree to terminate the Power Pool Agreement and amendments thereto which now exist between the parties as of the effective date of this Agreement.

1.6 GPA and Navy desire to establish a relationship whereby Navy and other Department of Defense facilities on Guam become a firm service customer of GPA.

1.7 Navy will operate and maintain their assets during the interim period to allow time for GPA to achieve defined performance standards. Navy pledges the output and use of the joint use Navy generation and transmission assets to GPA during the interim period except in emergency situations as defined in Article 17.

1.8 GPA desires the output and use of the joint use Navy generation and transmission assets and the related services Navy will provide during the interim period.

1.9 Navy and GPA desire to continue to have GPA operate and maintain Tanguisson Unit No. 1.

1.10 Navy and GPA desire transfer of responsibility for the Island-Wide Power System to GPA when the conditions described in Article 7.4 have been met.

1.11 Any disputes will be resolved in accordance with the disputes resolution procedures contained in Article 26.

ARTICLE 3

Services Navy Will Provide and Assets Navy Will Make Available During the Interim Period

3.1 During the interim period, the Navy will provide certain services to GPA in support of the IWPS and will make certain Navy joint use generation, transmission assets and other mutually agreed assets available to the IWPS. GPA agrees to accept the services offered by Navy during the interim period and the use of Navy joint use generation and transmission assets. For the services described in Article 3.5 below, Navy has and will continue to offer GPA the option of assuming responsibility to provide the service with proper notification to Navy of GPA's intent to assume such responsibility.

3.2 At the termination of the interim period, Navy will discontinue provision of all interim period services to the IWPS as described under this Article.

3.3 At the termination of the interim period, the Navy joint use generation, transmission and other mutually agreed assets and associated real estate as listed in Table 3 will be made available to GPA for use in the IWPS.

3.4 Navy will provide personnel, materials and support to operate and maintain the Navy joint use generation, transmission and other mutually agreed assets and facilities except that GPA will continue to operate and maintain Tanguisson No. 1 in accordance with the terms and conditions of Appendix B. The assets and facilities contemplated for Navy to operate and maintain are listed in Table 3 and Table 4. At Navy's option, with GPA's written concurrence, Navy may transfer responsibility for operation and maintenance of specific Navy assets or facilities to GPA during the interim period.

3.5 In addition to providing personnel, materials, subcontractors and other requirements to operate and maintain the Navy's joint use generation and transmission system, the Navy will continue provision of the following services during the interim period:

3.5.1 Navy will operate, maintain and make available the use of telephone circuits used in the dispatch and control of the IWPS during the interim period. At its option and with six (6) months notice, GPA can elect to provide through ownership or contract, all or part of the telecommunications requirements for dispatch and control of the IWPS. In this event, Navy retains the right to leave its facilities in place including operation and maintenance thereof during the interim period, but Navy would not be compensated by GPA for facilities no longer required for the IWPS.

3.5.2 Navy will continue to supply fresh water to the power generation facilities installed on Guam from the effective date of this contract through the interim period. During the interim period, Navy will supply fresh water for other requirements or new facilities under supplemental agreements on a best efforts basis. At its option, with six (6) months notice, GPA can elect to provide some or all of the fresh water requirements including transportation thereof for the IWPS.

3.5.3 Navy will continue to purchase, store and make low sulphur fuel oil available to the IWPS during the interim period. Navy will continue to transport low sulphur fuel oil through Navy's pipeline facilities and otherwise transport such fuel for use in the IWPS during the interim period. At its option, with six (6) months prior notice, GPA can assume responsibility for supply and/or transportation of low-sulphur fuel oil during the interim period provided that GPA meets all EPA environmental requirements and the Navy is released from any responsibility to provide such fuel under agreements between the parties to this Agreement and EPA.

3.5.4 Navy will continue to allow GPA pole attachments to Navy joint use poles during the interim period. Navy will be advised in writing with two (2) week advance notice of proposed GPA attachments prior to their installation. Navy may reject a proposed GPA pole attachment prior to the scheduled attachment date if the attachment may impair the structural integrity or stability of the pole or the proposed attachment impairs the integrity of the Navy system to operate on a stand-alone basis.

3.5.5 Navy may allow GPA pole attachments to Navy non-joint use poles.

3.5.6 Navy will continue to provide certain engineering services of the Pacific Division, Naval Facilities Engineering Command through the interim period. GPA may request and Pacific Division will supply such services on an as available basis. These services have and will continue to be generally limited to relay coordination and power system analysis.

3.5.7 Navy will continue to provide transportation of distilled water between power plants and transportation of fuel oil to the Tanguisson power plant when required.

3.5.8 Navy will continue to provide input to the planning of IWPS generation and transmission facilities. Navy will continue to design and execute facilities changes in the Navy joint use generation, transmission and other mutually agreed facilities. GPA shall be given an opportunity to review and provide written input to proposed Navy changes to joint use assets.

3.5.9 Navy may provide assistance as GPA may request on GPA's or Navy's joint use system.

3.5.10 Navy will continue to make certain Navy buildings that house Navy and GPA joint use generation and transmission facilities available during the interim period. GPA will request Navy approval of all modifications or expansion of GPA facilities in Navy buildings in writing with necessary plans and drawings and cannot begin modifications without written Navy authorization. The criteria Navy will use to evaluate whether to approve the building use include the following:

--The use proposed by GPA will not interfere with existing or proposed Navy facilities

--There are no other suitable buildings available to GPA for the same or similar use

--The space requested in the building is the minimum space required to accomplish GPA's facilities plans

Navy's approval will not be unreasonably withheld or unnecessarily delayed.

3.6 Navy personnel providing services to the IWPS shall be properly trained and supervised. Navy facilities shall be operated, maintained and improved in accordance with good and generally accepted utility standards and Navy operation and maintenance standards. Navy will provide services in a safe, efficient and cost-effective manner.

3.7 Existing land use permits granted to GPA by Navy will be continued through the interim period or until such time as such land use permits are converted into easements. Requests by GPA for use of Navy land or easements after the effective date of this Agreement will be a request for an easement on Navy land or assignment of an interest in a Navy easement if such interest is assignable. The Navy will not be responsible for acquisition of additional real estate interests from private parties for the benefit of GPA. Navy shall grant such easements in accordance with its regulations and applicable federal law. Navy shall grant easements in perpetuity subject to the following conditions:

--GPA's attainment of the standards or otherwise assuming full responsibility for the IWPS

--Use by GPA is restricted to a specific use, e.g., 34.5 kV substation or 115 kV line

--Navy may request return of all or any portion of the easement to the extent necessary to eliminate undue interference with its activities; provided that, unless Navy determines that relocation is not feasible, it will convey without charge a substitute easement permitting GPA to relocate its easement facilities elsewhere on Navy land at GPA's sole cost and expense except for easements covering Navy-designated utility corridor areas for which relocation costs will be shared on a 50-50 basis, the Navy share to be included as a cost item in any Navy project requiring such easement relocation. The Navy-designated utility corridor areas will be established when the easements are granted

--Use by GPA is limited to IWPS facilities

--Easements may be revoked if conditions for use are not met

GPA will file an application for easement with the Navy which will include a drawing and legal description of the proposed easement area together with an explanation of the purpose for which the land is to be used. The criteria Navy will use to evaluate whether to grant an easement include the following:

--The land use proposed by GPA will not interfere with existing or proposed Navy use of the land

--There is no other available land that could reasonably be used for the purpose proposed by GPA

--The land requested under easement is the minimum land needed to accomplish GPA's facility plans

Navy approval of an easement will not be unreasonably withheld or unnecessarily delayed.

3.8 The services Navy is to provide during the interim period described in Article 3.5 terminate at the end of the interim period. Navy has no continuing obligation to provide such services under this Agreement after the termination of the interim period.

3.9 Both parties recognize the desirability of maintaining a highly trained and experienced work force to operate the IWPS electrical facilities. Appropriate federal procedures will be used at the end of the interim period to disestablish the associated units of the Power Division of the Utilities Department and Maintenance Department of the Navy PWC Guam. The Navy and GPA agree to cooperate fully to ensure that the Navy can continue to successfully recruit personnel during the interim period and to ensure that GPA can recruit qualified Navy PWC Guam personnel for the turnover.

3.9.1 Navy will provide GPA information as allowed by federal privacy, freedom of information, and personnel management laws and regulations to apprise GPA of the dedicated full-time staffing required to operate the facilities. Navy will allow a reasonable amount of duty time for personnel of such positions for employment interviews with GPA. Navy will provide its personnel with assistance in obtaining private information required by GPA to allow GPA to devise incentives to recruit Navy PWC Guam personnel.

3.9.2 GPA will provide Navy information relevant to its employee benefits to assist in maintaining adequate Navy staffing during the interim period. GPA offers right of first refusal to all Navy PWC Guam personnel assigned to work centers of the Power Division of the Utilities Department and Maintenance Department of the Navy PWC Guam who are dedicated full-time to those facilities to be transferred to

GPA. Navy PWC Guam personnel must exercise right of first refusal not later than three months before the end of the interim period to allow outside recruitment if needed.

3.9.3 Details of the transition of personnel at the completion of the interim period will be included in a transition plan developed in accordance with Appendix C.

3.10 As Navy facilities listed in Table 3, or their maintenance and operation, are transferred to GPA, the special tools, equipment, supplies and transportation equipment associated with these facilities will be made available to GPA at no cost, as permitted by U.S. Public Law 100-202. The details of the transfer of special tools, equipment, supplies and transportation equipment will be included in a transition plan developed in accordance with Appendix C. The determination of the quantity to be transferred will be in accordance with Appendix D.

3.11 Navy will continue to make capital improvements to the Navy joint use generation and transmission facilities during the interim period. GPA shall be given an opportunity to review and provide written input to proposed changes to Navy joint use assets. Navy will pay for such capital improvements and they shall become part of the Navy's joint use generation and transmission facilities. In the event that Navy offers and GPA accepts an early termination of the interim period, with respect to part or all of the Navy facilities, GPA will forthwith assume responsibility for planning, executing and funding capital improvements to such facilities.

3.12 Navy will obtain for a finite number of GPA emergency service workers the required security clearances to allow them access to DOD-secured facilities which contain those portions of the electrical equipment necessary for GPA to perform its IWPS dispatch, operation and maintenance responsibilities. GPA emergency service workers proposed for security clearances must meet applicable clearance criteria as defined by DOD directives. These clearances will be prearranged for the emergency service workers so that they can access transmission and substation equipment for the purpose of diagnosing the cause of trouble and making that cause of trouble safe. The repair crews necessary to complete permanent repairs would require additional clearances which would be arranged at the time that such repair crews required access to on-base facilities.

ARTICLE 8

Forecasts of Reimbursable Costs

8.1 Under the terms of this Agreement GPA and Navy may incur costs that are reimbursable in whole or part by the other party. The reimbursement of such cost is subject to the terms of this Agreement. To assist both parties in the planning, budgeting and control of their respective organizations, GPA and Navy will provide certain forecast data to the other party.

8.2 Forecast cost data will be provided in good faith in accordance with the terms of this Agreement. The forecasts will not be binding on the supplier of the forecast. To facilitate exchange of information about costs incurred on behalf of the other party, budget review meetings will be held quarterly to discuss budget/actual status and revised budget expectations.

8.3 GPA shall annually provide to Navy a monthly budget for a two (2) year period of operation and maintenance expenses for Tanguisson No. 1 and other services it provides to Navy and a separate five (5) year annual forecast of capital expenditures for Tanguisson No. 1. The monthly two (2) year budget and the annual five (5) year forecast will be provided in the format of the monthly service billing/cost summary by July 31 of each year.

8.4 Navy shall annually provide to GPA a monthly budget for a two (2) year period of operation and maintenance expenses to be incurred on Navy joint use assets and in providing other services to GPA. The budget shall reflect not only expenses to be incurred but also the amounts Navy anticipates GPA will reimburse under the terms of this Agreement. Navy shall provide a five (5) year annual forecast of capital expenditures that Navy will be reimbursed by GPA based upon GPA's request for assistance. Budgets and forecasts will be provided in the format of the monthly service billing/cost summary by July 31 of each year.

8.5 In addition to budgets and forecasts of reimbursable costs described above, GPA and Navy will exchange budget and forecast information, including load forecasts, on their respective operations as such information becomes available.

8.6 Navy shall notify GPA promptly of any anticipated change in Navy operations or maintenance activities which would significantly affect Navy's load characteristics or resource capabilities, to the extent such changes are not reflected in information already submitted to GPA.

ARTICLE 15

Miscellaneous Provisions

15.1 This Agreement, including tables, appendices and attachments, can be amended only by written agreement between both of the parties.

15.2 The failure of GPA or Navy to insist in any one or more instances upon strict performance of any provisions of this Agreement or to take advantage of any rights hereunder, shall not be construed as a waiver of any provisions or rights, which shall remain in full force and effect.

15.3 This Agreement is intended by the parties as the final expression of their agreement and is intended also as a complete and exclusive expression of the terms of their agreement. All prior written or oral understandings, offers or other communications pertaining to this Agreement are abrogated and withdrawn.

15.4 If the incremental energy cost of a party is used in determining compensation for a particular transaction, supporting documentation on all components of such cost will be provided upon request of the other party.

ARTICLE 18

Rates and Regulation

18.1 The PUC is acknowledged to be an eligible regulatory body in accordance with the Armed Services Procurement Regulation, Supplement 5. Accordingly, the Navy agrees, for the purpose of this Agreement, as a matter of comity rather than law, to comply with the current regulations, practices and decisions of the PUC concerning accounting practices, allowability of costs, pricing and rates, subject to appeal to the Guam Superior Court and continuing through normal judicial channels.

18.2 Both parties agree, subject to the approval of the PUC, to have a fixed cost of service and rate structure methodology to determine the cost associated with serving the Navy and non-Navy loads and to develop Navy's rates in accordance with Article 19 for a five (5) year period to provide for stability and predictability in setting rates.

18.3 Navy and GPA agree to the methodology for establishing initial rates to be paid by Navy, as set forth in Article 19. Rates to be charged Navy at the effective date of this Agreement shall be established in accordance with this methodology and will become a part of this Agreement. (Article 19.6 specifies the procedures and guidelines for implementing these initial rates.) Navy and GPA agree to support the use of this methodology for future rate adjustments unless changes in IWPS operations and/or system conditions cause this methodology to produce a result that is no longer reflective of the cost (including return as described in Articles 19.6 and 19.7 of this Agreement) of serving the Navy and non-Navy customer classes.

18.4 No changes will be made in the cost of service and rate structure methodology for a period of five (5) years from the effective date of this Agreement, if the PUC, in approving this Agreement, orders GPA to utilize this cost of service and rate structure methodology for a five (5) year period to determine the costs associated with serving Navy and non-Navy loads and to develop Navy's rates in accordance with Article 19. If the PUC does not issue such an order in approving this Agreement, this Agreement shall not be effective.

Further, if GPA and Navy mutually agree that there is a significant change in IWPS operations and/or system conditions that cause this methodology to produce a result that is no longer reflective of the cost (including return as described in Articles 19.6 and 19.7 of this Agreement) of serving the Navy and non-Navy customer classes, GPA may propose and Navy will support a change in the cost of service and rate structure methodology in GPA's next general rate filing.

18.5 After the period specified in Articles 18.2 and 18.4, if changes in cost of service and rate structure methodology are sought, the procedures specified in this Article shall be followed.

18.5.1 If GPA or PUC determines it is necessary to seek a change in the methodology in effect for setting rates, GPA shall give Navy forty-five (45) days notice of its desire together with the recommended changes. If Navy agrees to the change in methodology, GPA will submit such modifications to the PUC for its approval or other action.

18.5.2 If Navy determines it is necessary to seek a change in the methodology in effect for setting rates, Navy shall give GPA forty-five (45) days notice of its desire together with Navy's recommended changes. If GPA agrees to the change in methodology, GPA will submit such modifications to the PUC for its approval or other action.

18.5.3 If GPA and Navy are unable to reach an agreement as to any matter relating to methodology within an additional forty-five (45) days of one party's notice to the other, GPA will then submit its position to the PUC pursuant to the rules and regulations of the PUC. Navy shall have the right to submit its position to the PUC, and no changes may be made until the PUC has conducted a hearing to consider both parties' positions and has rendered its decision. Pending a decision of the PUC, GPA agrees to continue to furnish electric service to the Navy at the rates then applicable.

18.6 If changes in rate levels are sought, the procedures specified below will be followed:

18.6.1 If GPA seeks an increase in the level of rates applicable to the Navy, the procedures specified in Article 19.7 shall be followed.

18.6.2 If GPA seeks a decrease in the level of the rates applicable to the Navy, GPA may either follow the procedures set forth in Article 19.7, or the procedures set forth in Articles 18.5.1 and 18.5.3.

18.6.3 If Navy determines to seek a decrease in the level of rates which it is paying, it may, at any time, enter into negotiations with GPA respecting such rate levels. In such instance, the procedures specified in Articles 18.5.2 and 18.5.3 will be followed.

ARTICLE 28

Service Rules and Regulations

28.1 Characteristics of Service

28.1.1 Alternating current service of approximate sixty (60) hertz will be regularly supplied. (Direct current will not be supplied.)

28.1.2 Voltages referred to herein are cited at nominal levels as normally intended to be delivered. Actual levels may vary within acceptable industry limits as defined in American National Standard C84.

28.2 Phase and Voltage Specification. Services will be provided at 34.5 kV three phase, three wire, except as noted in Table 1.

28.3 Equipment Protection

28.3.1 Protection of Navy's Facilities. The Navy is responsible for furnishing, calibrating, installing, inspecting and keeping in good and safe condition at its own risk and expense, all appropriate protection devices of any kind or character, which may be required to properly protect the Navy's facilities. GPA will not be responsible for any loss or damage caused by the negligence or wrongful act of the Navy or Navy's agents, employees or licensees in omitting, installing, maintaining, using, operating or interfering with any such protective devices.

28.3.2 Protection from Service Interruptions. The Navy is responsible for selecting and installing the protective devices as necessary to coordinate properly with GPA's protective devices to avoid exposing other customers to unnecessary service interruptions.

28.4 Interference with Service

28.4.1 Voltage. If the Navy operates equipment which causes detrimental voltage fluctuations, Navy must reasonably limit those fluctuations. The Navy will be required to provide whatever corrective measures are necessary.

28.4.2 Current. If the Navy superimposes a current of any frequency upon any part of its electric system, other than the current supplied by GPA, Navy shall, at its expense, prevent the transmission of such current beyond its electrical system.

28.5 Other Conditions of Service. The Navy's loads shall be balanced on the three phases in accordance with good engineering practice.

28.6 Billings for Electric Utility Service

28.6.1 Navy is required to pay the charges assessed in accordance with GPA's established rates and billing cycle for the electric utility services provided.

28.6.2 Billing Period. Electric utility services will be billed monthly.

28.6.3 Metered Service. Bills for metered service will be based on meter registration. Meters will be read as required for the preparation of regular bills.

28.6.4 Estimated Bills. If, because of unusual conditions or for reasons beyond its control, GPA is unable to read the Navy's meters on the scheduled reading date, GPA may bill the Navy for estimated demand and consumption during the billing period, and make any necessary corrections when a reading is obtained. Estimated demand and consumption for this purpose will be calculated considering the Navy's prior usage. Adjustments for any under or overestimate of a Navy's demand and consumption will be reflected on the next regularly scheduled billing based on an actual reading following the period of inaccessibility.

28.6.5 Conjunctive Billing. The Navy's billing will be on a conjunctive basis.

28.7 Payment of Bills. Payment will be made in accordance to the Prompt Payment Act of 1982 and Article 4.

28.8 Meter Test

28.8.1 GPA will conduct meter testing to ensure accurate meter registration.

28.8.2 National Standards

28.8.2.1 Meters and associated metering devices will be tested and adjusted by GPA personnel in conformity with the standards of the American National Standards Institute Code for Electricity Metering (ANSI) C12-1975, or latest edition.

28.8.2.2 GPA will test meters individually. No meter will be placed in service or allowed to remain in service which is found to have more than a two percent (2%) registration error under normal operating conditions.

28.8.2.3 When tested, all meters and/or associated devices will be adjusted by GPA personnel as close to the condition of zero error as possible. All tolerances are to be interpreted as maximum permissible variations from the condition of zero error. When making adjustments, the prescribed tolerance limits shall not be taken advantage of.

28.8.2.4 GPA will not install a meter which is known to be defective. The capacity of the meter and the index mechanism shall be consistent with the Navy electric power requirements.

28.8.3 Testing Removed Meters

28.8.3.1 When deemed necessary, meters and/or associated devices will be tested after they are removed from service. These tests will be done before the meters and/or associated devices are adjusted, repaired or retired. No meter will be allowed to remain in service which is found to have an error in registration in excess of the prescribed tolerance limit.

28.8.4 Navy Requested Test. Navy may request GPA to test their electric meter at no charge once every six (6) months. The cost of any additional tests will be borne by the Navy if the percentage of error is found to be no more than two percent (2%). Tests will be conducted within ten (10) working days of receipt of request.

28.8.5 Test Report. The Navy will have the right to witness GPA's test of the meter or, if it desires, have the presence of an expert or other representative appointed by the Navy. A report giving the results of the test will be provided to the Navy within ten (10) working days of the test. A copy of the report, together with a complete record of each test, will be kept on file by GPA for at least three (3) years.

28.9 Adjustment of Bills

28.9.1 For Meter Error

28.9.1.1 If, after testing, any meter is found to be registering more than two percent (2%) fast, GPA will refund or credit to the Navy the overcharge based on corrected meter readings for the period in which the meter was in use, not to exceed one hundred eighty (180) days, unless it can be shown that the error was due to a particular cause, the date of which can be reliably established or computed back to but not beyond that date, and in no case beyond twelve (12) months.

28.9.1.2 If, after testing, a meter is found to register more than two percent (2%) slow, GPA's billing adjustment will be for electric energy consumed up to one hundred eighty (180) days prior to date of test. If the actual period of error has been determined to exceed one hundred eighty (180) days, the adjustment will cover that total period, but in no case beyond twelve (12) months.

28.9.2 For Billing Error

28.9.2.1 If the Navy is overcharged as a result of incorrect reading of the meter, incorrect application of the rate schedule, incorrect connection of the meter, incorrect multiplier or other similar reasons, the amount of the overcharge will be adjusted, refunded or credited to the Navy based on corrected billing for the preceding one hundred eighty (180) days, subject to the provisions of Article 28.9.2.3 below.

28.9.2.2 If the Navy is undercharged as a result of incorrect reading of the meter, incorrect application of the rate schedule, incorrect connection of the meter, incorrect multiplier or other similar reasons, the undercharge will be billed to the Navy based on corrected billing for the preceding one hundred eighty (180) days, subject to the provisions of Article 28.9.2.3 below.

28.9.2.3 When it is found that a billing error has been made, the date of which can be reliably established, the overcharge or undercharge will be computed back to but not beyond that date, and not beyond twelve (12) months.

28.10 Service Connections and Facilities on Navy's Premises

28.10.1 All meters will be installed by GPA at approved locations on Navy's premises and will be placed so they are easily accessible for inspections, reading and testing.

28.10.2 The Navy will, at its expense, provide an alternate and approved location for all meters in order to comply with the foregoing whenever the existing meter or meters becomes inaccessible for inspection, reading or testing by reason of any changes made by the Navy.

28.10.3 All GPA meters and related metering equipment will be sealed by GPA and no seal will be tampered with or broken except by a duly authorized representative of GPA.

28.11 No Unauthorized Work. Only a duly authorized representative of GPA or a Navy employee under the direction of the IWPS power dispatcher may connect or disconnect the Navy's conductors to or from GPA's conductors.

28.12 Responsibility for Navy Electrical Facilities

28.12.1 Good and Safe Condition. The Navy will, at its sole risk and expense, furnish, install, inspect and keep in good and safe condition all electrical facilities beyond the point of delivery required for receiving electric energy, including any necessary protective devices, regardless of the location of the transformers, meters or other GPA equipment.

28.12.2 Navy Side (Point of Delivery). The Navy will be solely responsible for the delivery of all electric energy on its side of the point of delivery.

28.12.3 Adjusting Protective Equipment. Whenever GPA determines coordination is required between the Navy's protective equipment and that of the GPA, GPA will review and, if it approves, will agree to the arrangement and setting of the Navy's protective equipment. In the interest of service reliability to the Navy and other customers, GPA may from time to time require the Navy to submit evidence that the agreed upon coordination is maintained.

28.12.4 Navy Responsibility for Actions. GPA will not be responsible for loss or damage caused by the negligence, lack of proper care or the wrongful act of the Navy, its agents, employees, or licensees in installing lines, machinery, apparatus or equipment.

28.13 Access to Premises. GPA shall have access to any premises served at all reasonable times during the continuance of this Agreement and at its termination for the purposes of installing, repairing and removing GPA's equipment, and for any other proper purpose hereunder provided, however, that Navy may limit or restrict such right of access in any manner considered by the Navy to be necessary or advisable.

28.14 Shortage of Electric Supply and Interruption of Delivery

28.14.1 Shortage and Interruption. GPA will exercise reasonable diligence and care to furnish and deliver a continuous and sufficient supply of electric energy to the Navy. However, it does not guarantee continuity or sufficiency of supply since electric service is inherently subject to interruption, suspension, curtailment and fluctuation.

28.14.2 Temporary Suspension for Repairs. Whenever temporary suspension is necessary for the purpose of making repairs or improvements, GPA will notify and coordinate with the Navy and proceed as rapidly as possible to avoid Navy inconvenience.

28.15 Resale of Electric Energy. It is expressly understood and agreed that Navy has the right to resell electric utility services to its customers as defined in Article 2.3.

28.16 Parallel Operations. The operation of Navy generating facilities in parallel with the IWPS will be planned and coordinated with and approved by the IWPS power dispatcher.

28.17 Line Extensions. Extensions of lines necessary to furnish permanent 34.5 kV service to the Navy will be made by modifications to this Agreement in accordance with the following provisions:

28.17.1 General

28.17.1.1 Ownership, Operation and Maintenance. GPA will construct, own, operate and maintain electric lines and equipment only under, along, upon and over public streets, roads and highways where it has the legal right to do so, and on public lands and private property across which it has otherwise obtained rights-of-way or other necessary rights satisfactory to GPA.

28.17.1.2 Special Facilities. GPA will install only those facilities which it deems necessary to render service in accordance with GPA's standard facilities for 34.5 kV service. If the Navy requests facilities which are acceptable to GPA but are in addition to, or in substitution for, the standard facilities which GPA normally would install, the Navy shall make a contribution to cover the extra cost thereof.

28.17.1.3 Refunds. GPA will have the right to connect subsequent customers to all Navy line extensions. If these are permanent connections and are made within five (5) years of the date the line extension is energized, subsequent customers connected will be treated for purposes of extension allowance and charges as if they were included among the customers for whom the extension was originally constructed. Reallocation of these charges among the customers will be made on the same basis. Refunds, if any, to the Navy will also be made on the same basis. The line extension allowance will be calculated from a permanent customer's point of delivery toward the source of supply. No refund will be made on any contribution to GPA for any cost of line extension beyond the free length if the Navy should terminate its original request less than thirty (30) months of the date permanent power was installed.

28.17.2 Overhead Extensions

28.17.2.1 Extension Allowance. Overhead line extensions will be made by GPA at its expense provided the cost of the line required does not exceed thirty (30) months' estimated revenue derived from the line. GPA will install, own, operate and maintain the necessary meters and switching and protective equipment at its expense, except where the Navy requests special facilities as covered by Article 28.17.1.2 above.

28.17.2.2 Extensions Beyond Allowance. For overhead line extensions whose estimated cost exceeds the thirty (30) months' estimated revenue to be derived from the line, the Navy shall make a contribution equal to the difference between the estimated line cost and the thirty (30) months' estimated revenue. The estimated line cost will exclude meters, switching and protective equipment, and will be based on the route determined by GPA. When a line extension is to be installed on Navy property, the route of any portion on Navy property must be mutually agreed to by Navy and GPA.

28.17.3 Underground Extensions

28.17.3.1 General. GPA will install underground line extensions only when the Navy makes a contribution of the estimated difference between the cost of the underground system and the cost to the Navy of an equivalent overhead system in accordance with Article 28.17.2 or when, for engineering and operating reasons, GPA may install the system underground at its own expense. The type of underground system that will be installed under this rule shall meet engineering construction standards of GPA. When an underground line extension is to be installed on Navy property, the Navy will normally provide necessary supporting structures (ducts, manholes, etc.) and appropriate rights-of-way. GPA will install, own, operate and maintain the underground facilities outside of Navy property.

28.17.3.2 Replacement of Overhead with Underground Facilities. When mutually-agreed upon by the Navy and GPA, overhead facilities will be replaced with underground facilities, provided the Navy makes a contribution of the estimated cost installed of the underground facilities less the estimated net salvage of the overhead facilities removed.

28.18 Discontinuance of Service. GPA will not provide service to electrical equipment which, when operated, will be detrimental to GPA's or another customer's equipment. GPA will discontinue service to a Navy delivery point if the Navy continues to operate the equipment at that delivery point after being notified in writing by GPA to discontinue the operation. Discontinuance of service to any Navy delivery point will in no way affect service at other Navy delivery points.

28.19 Ability to Serve Other Customers From Facilities on Navy Property. All facilities installed by GPA at its expense on Navy's premises for the purpose of delivering electric energy to the Navy will continue to be the property of GPA and will be removed at the termination of service. These facilities may also be used to supply other customers whether or not on the same premises, provided the proper easement agreements have been obtained.

28.20 Navy Responsibility for GPA's Property. In the event of loss or damage to GPA's property on the Navy's premises caused by the Navy's tenants, agents or employees, either intentionally or arising from negligence, carelessness or misuse, the cost of repairs or replacements will be at the Navy's expense.

28.21 Unsafe Equipment or Condition

28.21.1 Service Refusal. GPA will have the right to refuse or discontinue service to a GPA point of delivery to Navy if Navy wiring or other equipment at that delivery point, or the use thereof, GPA has determined is unsafe or in violation of applicable laws, ordinances, rules or regulations of any public authority. GPA can also refuse service at a GPA point of delivery to Navy if it finds that any condition on the Navy's premises at that delivery point could endanger GPA's service facilities. Refusal or discontinuance of service to any Navy delivery point will in no way affect service at other Navy delivery points.

28.21.2 Service Discontinued. GPA may discontinue service to a Navy delivery point immediately and without notice if GPA determines a hazardous condition exists or if the Navy threatens to create a hazardous condition at that delivery point. Service will not be restored until GPA is satisfied changes have been made to eliminate the hazardous condition. Discontinuance of service to any Navy delivery point will in no way affect service at other Navy delivery points.

28.21.3 Navy Notification of Defect. GPA does not assume any responsibility to inspect or repair the Navy's electrical system, other equipment or any part thereof. In the event the Navy has knowledge that its service is in any way defective, it is its responsibility to notify GPA at once. GPA will not be liable or responsible for any electrical system, appliances, facilities, or other equipment beyond the point of delivery which it does not own or maintain in accordance with these rules except for damage where GPA's characteristics of service do not meet acceptable industry limits per Article 28.1.

Appendix C
Navy-Provided Outage Data

Total of 214 unscheduled power outages documented for the period October 2005 to July 2006. Breakdown is as follows:

GPA System Failure – 39

Generators tripping off-line – 10
Transmission and Distribution system fault - 29

3 outages affected all of Naval Station, Naval Magazine, Camp Covington, Apra Housing areas, Cold Storage and Polaris Point.
4 outages affected all of Naval Hospital.
5 outages affected all housing areas, barracks, and administrative facilities at NCTS Finagayan and Air Force Det. 5 facilities at Northwest Field.
13 outages affected AAFB housing areas and Marbo water wells.
9 outages affected Naval Magazine, Camp Covington and Apra Housing areas.

Navy System Failure – 175

124 – Equipment failure
25 – Snakes, rodents, birds, etc.
14 - Unknown
4 - Lightning
3 – Vegetation
2 – Contactor
2 – False report
1 – Vehicular accident

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DOCUMENT TRANSMITTAL FORM

Page 1 of 5

CUSTOMER: Raytheon Technical Services Guam, Inc. (RTSG)
FACILITY: Annex 8
LOCATION: Guam Naval Facilities

LOG #: 2347
SET Contract No: Sub-000002
ISSUE CODE:
DATE: Nov. 04, 2005

TO: DZSP 21
P.O. Box GH
Agana, Guam 96932
ATTENTION: Mr. Wally Toma, Subcontract Administrator

We are sending you: X Attached __Under Separate Cover via:______________the: __Shop Drawings

__Prints __Samples __Specifications __Reports __Inspections __Test Schedules __Copy of Letter

__Change Order __Constr.Progress Chart/Schedule __Payment Estimate X As Stated ______________

Copies	Reference No.	Category Type	Description and Purpose
1	Annex 1602	CDRL No. F-1602000-F	Power System Dispatcher's Unscheduled and Scheduled Outage Report (4 pages)

Name of: Subcontractor, Supplier/Manufacturer ______________

__For Approval __Approved as Submitted __Resubmit __copies for approval X For Your Use

__Approved as Noted __Submit __copies for distribution X As Requested __Returned for Corrections

__Return __corrected prints __For Review and Comment __Other: ______________

I certify that the attached information is ready for execution and that the attached information complies with the requirements of the contract documents.

By: [signature] 11-04-05
T.J. Jacot, Senior Vice-President

S.E.T. – Pacific, Inc.

ELECTRIC DISTRIBUTION LOG (UNSCHEDULED OUTAGES)

SEQUENTIAL LOG FOR 4.16, 13.8, 34.5 KV — RELAY TARGETS ACTION — MONTH: SEP 28 TO OCT 31 YEAR: 2005

UO#	DATE	TIME: LOSS (TRIP)	TIME: RETURN (CLOSE)	TIME: ELAPSED HOURS	LOCATION: BASE / SUBSTATION	LOCATION: CIRCUIT BREAKER	LOCATION: AREA CUT-OFF OR AFFECTED	LOAD KV	OVER CURRENT: KF	OVER CURRENT: A	OVER CURRENT: B	OVER CURRENT: C	OVER CURRENT: GRD	XFMER DIFF	OUTAGE CAUSE*	SPECIFIC CAUSE OF OUTAGE / COMMENTS
206	09/29/05 – 09/30/05	0905	0913	1 DAY :08	POLARIS PT.	ON P-2	RECREATION CABANA AREA	SEC.							D2	SECONDARY PANEL DAMAGED BY VEHICLE.
207	09/30/05	0840	1125	2:45	AAFB	P-91	HOUSIN AREA: CAPEHART/PARTIAL OF FLEMING HTS.	13.8		I			I		D7	P-91-16P SWITCHGEAR FLASHED OVER.
208	09/30/05	1119	1220	1:01	OROTE	P-129	SECURITY/COAST GUARD/NAVFAC ADMIN AREAS, LOCKWOOD/SOUTH TIP HSG, CHAPEL, CDC, GYM, THEATER, OROTE TELEX	13.8			T				B2	PRIMARY LINES FELL ON POLES NT-16/NT-17/NT-18/NT-18-3.
208	09/30/05	1119	1657	5:38	CNM	ON P-129	NORTH TIP. HSG	13.8							B2	PRIMARY LINES FELL ON POLES NT-16/NT-17/NT-18/NT-18-3.
209	09/30/05	1827	2120	2:53	CNM	ON P-129	BLDG 2016 SWIMMING POOL	SEC.							C1	BROKEN SECONDARY CONNECTION.
01	10/02/05	0535	0612	:37	ANIGUA	P-281	NRMC AREA: NAVHOSP BLR ON GENERATOR	13.8							D6	GPA P-281 BREAKER TRIPPED/FAULT ON GPA CIRCUIT.
02	10/06/05	0101	0526	4:25	MARBO	ON P-51	AIR FORCE WELLS #5, 6, 7, 8	13.8							D3	FUSE BLEW ON POLE # MB-2-1/HEAVY RAIN IN THE AREA.
03	10/06/05	0535	0602	:27	POTTS JCT	T-110	COAST/GEODETIC SURVEY HSG, DET-T, MMS-1 COMPOUND, GTA, FAME OFFICE	13.8				1			D3	NO FINDINGS/HEAVY RAIN IN THE AREA.
04	10/06/05	0728	1206	4:38	AAFB	ON P-68	PARTIAL OF FLEMING HTS HSG: ST-9/10/11/12/13/15/16/17 AND BLDG 28125	13.8							D7	FL-3 SWITCHGEAR FLASHED OVER/HEAVY RAIN IN THE AREA.
05	10/06/05	1520	1755	2:35	OROTE/OLD STORAGE	T-11/T-12/T-13/T-132	OLD/NEW APRA HSG; ALL OF CNM AND NAVMAG AREA	13.8							D6	GPA X-20/X-35, X-31, X-36 BREAKERS TRIPPED.
05	10/06/05	1520	1609	:49	OROTE	P-129	SECURITY/COAST GUARD/NAVFAC ADMIN COMPOUND, NORTH/SOUTH TIP/LOCKWOOD HSG, CHAPEL, CDC, GYM, OROTE TELEX AND DRMO	13.8							D6	GPA X-20/X-35, X-31, X-36 BREAKERS TRIPPED.
05	10/06/05	1520	1609	:49	OROTE	P-16	COMMISSARY, NEX COMPLEX/BLDGS	13.8							D6	GPA X-20/X-35, X-31, X-36 BREAKERS TRIPPED.

*LEGEND: A1: LOAD SHEDDING; A2: GENERATOR TRIP; B1: STORM; B2: LIGHTNING; B3: EARTHQUAKE; C1: LINE; C2: TRANSFORMER; C3: RELAY; C4: BREAKER; D1: HUMAN ERROR; D2: VEHICLE ACCIDENT; D3: UNKNOWN; D4: TREE; D5: SNAKE; D6: GPA POWER SURGE; D7: OTHER

S.E.T. – Pacific, Inc.

ELECTRIC DISTRIBUTION LOG (UNSCHEDULED OUTAGES)

SEQUENTIAL LOG FOR 4.16, 13.8, 34.5 KV — RELAY TARGETS ACTION — MONTH: SEP 28 TO OCT 31 YEAR: 2005

UO#	DATE	TIME LOSS (TRIP)	TIME RETURN (CLOSE)	TIME ELAPSED HOURS	LOCATION BASE / SUBSTATION	LOCATION CIRCUIT BREAKER	LOCATION AREA CUT-OFF OR AFFECTED	LOAD KV	OVER CURRENT KF	OVER CURRENT A	OVER CURRENT B	OVER CURRENT C	OVER CURRENT GRD	XFMER DIFF	OUTAGE CAUSE*	SPECIFIC CAUSE OF OUTAGE / COMMENTS
05	10/06/05	1520	1611	:51	OROTE	T-17	WWTP, BARRACKS COMPLEX, CLUB RUMORS, SUMAY MARINA, PORT OPGS, DZSP MAINT COMPOUND, CSS-15, SLS-16, GSY, BLDG 2116	4.16							D6	GPA X-20/X-35, X-31, X-36 BREAKERS TRIPPED.
05	10/06/05	1520	1612	:52	OROTE	P-128	HARBOR/BAYVIEW HSG	13.8							D6	GPA X-20/X-35, X-31, X-36 BREAKERS TRIPPED.
05	10/06/05	1520	1612	:52	OROTE	P-14	VICTOR #2 SUB, MSC/MSF/SEALS COMPOUND, GSY, KILO PIER AND DENTAL CLINIC	13.8							D6	GPA X-20/X-35, X-31, X-36 BREAKERS TRIPPED.
05	10/06/05	1520	1616	:56	OROTE	P-25	ALPHA/BRAVO PIER: USS CITY OF CORPUS CHRISTI	13.8							D6	GPA X-20/X-35, X-31, X-36 BREAKERS TRIPPED.
05	10/06/05	1520	1754	2:34	COLD STORAGE	P-134	CAMP COVINGTON, OLD/NEW APRA HSG, DODEA, NAVMAG AREA	13.8							D6	GPA X-20/X-35, X-31, X-36 BREAKERS TRIPPED.
05	10/06/05	1520	1755	2:35	COLD STORAGE	P-133	COLD STORAGE COMPOUND	13.8							D6	GPA X-20/X-35, X-31, X-36 BREAKERS TRIPPED.
06	10/08/05 – 10/09/05	2352	0012	:20	CNM	ON P-129	QTRS. #17/19 HUTCHINS, QTRS. #26/28 OROTE PT. LOCKWOOD	13.8							C1	DEFECTIVE CUT-OUT ASSEMBLY ON POLE # JB-49-16.
07	10/12/05	0823	1032	2:09	AAFB	P-91	CAPEHART HSG AND PARTIAL OF ROBERTS TERRACE HSG	13.8		I	I	I			D7	FLASHOVER/MOISTURE AT CL-5.
08	10/12/05	1527	1555	:28	AAFB	ON P-94	BLDG 14540 SEWER LIFT STA.	13.8							D5	BLOWN FUSE ON POLE #NB-35-1 CAUSED BY SNAKE.
09	10/13/05	0809	0938	1:23	MARBO	ON P-51	WATER BOOSTER #3 STATION	13.8							C1	DEFECTIVE CUT-OUT ASSEMBLY ON POLE # MB-29.
10	10/13/05	0913	1046	1:33	AAFB	P-82	CONTROL TOWER, MATS TERMINAL, 3RD DIV. HDQTRS, BX, AIR COMM	13.8		I	I	I		13.8	D7	FLASHOVER AT MH-119 (P-81 SIDE).
11	10/15/05	0149	0517	3:28	MARBO	ON P-51	AIR FORCE WELLS # 5/6/7/8	13.8							D6	GPA SURGE/FUSE BLEW ON POLE MA-2-1.
12	10/18/05	1027	1611	5:44	POLARIS PT.	ON P-2	BLDG 4445 QTR DECK	SEC.							D7	BURNT KWH METER BASE.

*LEGEND: A1: LOAD SHEDDING; A2: GENERATOR TRIP; B1: STORM; B2: LIGHTNING; B3: EARTHQUAKE; C1: LINE; C2: TRANSFORMER; C3: RELAY; C4: BREAKER; D1: HUMAN ERROR; D2: VEHICLE ACCIDENT; D3: UNKNOWN; D4: TREE; D5: SNAKE; D6: GPA POWER SURGE; D7: OTHER

ELECTRIC DISTRIBUTION LOG (UNSCHEDULED OUTAGES)

SEQUENTIAL LOG FOR 4.16, 13.8, 34.5 KV									RELAY TARGETS ACTION							MONTH: SEP 28 TO OCT 31 YEAR: 2005
UO#	DATE	TIME			LOCATION			LOAD	OVER CURRENT					XFMER DIFF	OUTAGE CAUSE*	SPECIFIC CAUSE OF OUTAGE / COMMENTS
		LOSS (TRIP)	RETURN (CLOSE)	ELAPSED HOURS	BASE / SUBSTATION	CIRCUIT BREAKER	AREA CUT-OFF OR AFFECTED	KV	KF	A	B	C	GRD			
13	10/20/05	0840	1110	2:30	MARBO	ON P-51	AIR FORCE WELLS #5/6/7/8	13.8							C1	DEFECTIVE CUT-OUT ASSEMLY ON POLE # MA-2-1.
14	10/21/05	1348	1400	:12	ROMEO CNM	ON P-130	USS PASADENA	.48							D1	SUBMARINERS OVERLOADED R-3C/3D/3E/3F BREAKERS.
15	10/22/05	0804	1149	3:45	AAFB	P-91	CAPEHART HSG AND PARTIAL OF ROBERTS TERRACE HSG.	13.8		I	I	I	I		D7	CL-7 SWITCHGEAR FLASHED OVER/MOISTURE.
16	10/22/05	0937	0941	:04	AAFB	P-93	PARTIAL OF ROBERTS TERRACE	13.8					I		D6	GPA POWER SURGE.
17	10/22/05	0947	1006	:19	COLD STORAGE	P-134	OLD/NEW APRA HSG, NAVMAG AREA, PARTIAL OF CAMP COVINGTON	13.8					I		D6	GPA POWER SURGE.
18	10/22/05	1616	1805	1:49	AAFB	ON P-93	PARTIAL OF FLEMING HTS. HSG	13.8							D7	MH-205/MH-206 FLASHED OVER/MOISTURE.
19	10/24/05	0018	0243	2:25	ROMEO CNM	ON P-130	USS PASADENA	.48							D1	SUBMARINERS OVERLOADED R-3C/3D/3E/3F BREAKERS.
	10/24/05	0132	0402	2:30	HARMON/ AAFB	ON X-87/ X-73	NCTS 4 KV (F-2/F-3/F-4) AND POTTS JCT SUBSTATIONS	4.16 13.8							D6	GPA X-87/X-73 LINE TRIPPED.
20	10/28/05	2117	2314	1:57	MARBO	ON P-51	AIR FORCE WELLS #7/8	13.8							D3	FUSE BLEW ON POLE # MB-2-1.
21	10/29/05	1052	1124	:32	AAFB	P-91	CAPEHART HSG AND PARTIAL OF ROBERTS TERRACE	13.8							D6	GPA X-42/X-80 LINE TRIPPED.

*LEGEND: A1: LOAD SHEDDING A2: GENERATOR TRIP B1: STORM B2: LIGHTNING B3: EARTHQUAKE C1: LINE C2: TRANSFORMER C3: RELAY
C4: BREAKER D1: HUMAN ERROR D2: VEHICLE ACCIDENT D3: UNKNOWN D4: TREE D5: SNAKE D6: GPA POWER SURGE D7: OTHER

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S.E.T. – Pacific, Inc.

DOCUMENT TRANSMITTAL FORM

Page 1 of 5

CUSTOMER: Raytheon Technical Services Guam, Inc. (RTSG)
FACILITY: Annex 8
LOCATION: Guam Naval Facilities

LOG #: 2347
SET Contract No: Sub-000002
ISSUE CODE:
DATE: Nov. 04, 2005

TO: DZSP 21
P.O. Box GH
Agana, Guam 96932
ATTENTION: Mr. Wally Toma, Subcontract Administrator

We are sending you: X Attached __Under Separate Cover via:______________the: __Shop Drawings

__Prints __Samples __Specifications __Reports __Inspections __Test Schedules __Copy of Letter

__Change Order __Constr.Progress Chart/Schedule __Payment Estimate X As Stated ______________

Copies	Reference No.	Category Type	Description and Purpose
1	Annex 1602	CDRL No. F-1602000-F	Power System Dispatcher's Unscheduled and Scheduled Outage Report (4 pages)

Name of: Subcontractor, Supplier/Manufacturer ______________________________

__For Approval __Approved as Submitted __Resubmit __copies for approval X For Your Use

__Approved as Noted __Submit __copies for distribution X As Requested __Returned for Corrections

__Return __corrected prints __For Review and Comment __Other: ______________

I certify that the attached information is ready for execution and that the attached information complies with the requirements of the contract documents.

By: ______________________________ 11-04-05
T.J. Jacot, Senior Vice-President

S.E.T. – Pacific, Inc.

ELECTRIC DISTRIBUTION LOG (UNSCHEDULED OUTAGES)

SEQUENTIAL LOG FOR 4.16, 13.8, 34.5 KV | RELAY TARGETS ACTION | MONTH: SEP 28 TO OCT 31 YEAR: 2005

UO#	DATE	TIME LOSS (TRIP)	TIME RETURN (CLOSE)	TIME ELAPSED HOURS	LOCATION BASE / SUBSTATION	LOCATION CIRCUIT BREAKER	LOCATION AREA CUT-OFF OR AFFECTED	LOAD KV	OVER CURRENT KF	OVER CURRENT A	OVER CURRENT B	OVER CURRENT C	OVER CURRENT GRD	XFMER DIFF	OUTAGE CAUSE*	SPECIFIC CAUSE OF OUTAGE / COMMENTS
206	09/29/05 – 09/30/05	0905	0913	1 DAY :08	POLARIS PT.	ON P-2	RECREATION CABANA AREA	SEC.							D2	SECONDARY PANEL DAMAGED BY VEHICLE.
207	09/30/05	0840	1125	2:45	AAFB	P-91	HOUSIN AREA: CAPEHART/PARTIAL OF FLEMING HTS.	13.8		I			I		D7	P-91-16P SWITCHGEAR FLASHED OVER.
208	09/30/05	1119	1220	1:01	OROTE	P-129	SECURITY/COAST GUARD/NAVFAC ADMIN AREAS, LOCKWOOD/SOUTH TIP HSG, CHAPEL, CDC, GYM, THEATER, OROTE TELEX	13.8			T				B2	PRIMARY LINES FELL ON POLES NT-16/NT-17/NT-18/NT-18-3.
208	09/30/05	1119	1657	5:38	CNM	ON P-129	NORTH TIP. HSG	13.8							B2	PRIMARY LINES FELL ON POLES NT-16/NT-17/NT-18/NT-18-3.
209	09/30/05	1827	2120	2:53	CNM	ON P-129	BLDG 2016 SWIMMING POOL	SEC.							C1	BROKEN SECONDARY CONNECTION.
01	10/02/05	0535	0612	:37	ANIGUA	P-281	NRMC AREA: NAVHOSP BLR ON GENERATOR	13.8							D6	GPA P-281 BREAKER TRIPPED/FAULT ON GPA CIRCUIT.
02	10/06/05	0101	0526	4:25	MARBO	ON P-51	AIR FORCE WELLS #5, 6, 7, 8	13.8							D3	FUSE BLEW ON POLE # MB-2-1/HEAVY RAIN IN THE AREA.
03	10/06/05	0535	0602	:27	POTTS JCT	T-110	COAST/GEODETIC SURVEY HSG, DET-T, MMS-1 COMPOUND, GTA, FAME OFFICE	13.8				I			D3	NO FINDINGS/HEAVY RAIN IN THE AREA.
04	10/06/05	0728	1206	4:38	AAFB	ON P-68	PARTIAL OF FLEMING HTS HSG: ST-9/10/11/12/13/15/16/17 AND BLDG 28125	13.8							D7	FL-3 SWITCHGEAR FLASHED OVER/HEAVY RAIN IN THE AREA.
05	10/06/05	1520	1755	2:35	OROTE/OLD STORAGE	T-11/T-12/T-13/T-132	OLD/NEW APRA HSG; ALL OF CNM AND NAVMAG AREA	13.8							D6	GPA X-20/X-35, X-31, X-36 BREAKERS TRIPPED.
05	10/06/05	1520	1609	:49	OROTE	P-129	SECURITY/COAST GUARD/NAVFAC ADMIN COMPOUND, NORTH/SOUTH TIP/LOCKWOOD HSG, CHAPEL, CDC, GYM, OROTE TELEX AND DRMO	13.8							D6	GPA X-20/X-35, X-31, X-36 BREAKERS TRIPPED.
05	10/06/05	1520	1609	:49	OROTE	P-16	COMMISSARY, NEX COMPLEX/BLDGS	13.8							D6	GPA X-20/X-35, X-31, X-36 BREAKERS TRIPPED.

*LEGEND: A1: LOAD SHEDDING; A2: GENERATOR TRIP; B1: STORM; B2: LIGHTNING; B3: EARTHQUAKE; C1: LINE; C2: TRANSFORMER; C3: RELAY; C4: BREAKER; D1: HUMAN ERROR; D2: VEHICLE ACCIDENT; D3: UNKNOWN; D4: TREE; D5: SNAKE; D6: GPA POWER SURGE; D7: OTHER

S.E.T. – Pacific, Inc.

ELECTRIC DISTRIBUTION LOG (UNSCHEDULED OUTAGES)

SEQUENTIAL LOG FOR 4.16, 13.8, 34.5 KV — RELAY TARGETS ACTION — MONTH: Sep 28 to Oct 31 YEAR: 2005

UO#	DATE	TIME: LOSS (TRIP)	TIME: RETURN (CLOSE)	TIME: ELAPSED HOURS	LOCATION: BASE / SUBSTATION	LOCATION: CIRCUIT BREAKER	LOCATION: AREA CUT-OFF OR AFFECTED	LOAD KV	OVER CURRENT: KF	OVER CURRENT: A	OVER CURRENT: B	OVER CURRENT: C	OVER CURRENT: GRD	XFMER DIFF	OUTAGE CAUSE*	SPECIFIC CAUSE OF OUTAGE / COMMENTS
05	10/06/05	1520	1611	:51	OROTE	T-17	WWTP, BARRACKS COMPLEX, CLUB RUMORS, SUMAY MARINA, PORT OPGS, DZSP MAINT COMPOUND, CSS-15, SLS-16, GSY, BLDG 2116	4.16							D6	GPA X-20/X-35, X-31, X-36 BREAKERS TRIPPED.
05	10/06/05	1520	1612	:52	OROTE	P-128	HARBOR/BAYVIEW HSG	13.8							D6	GPA X-20/X-35, X-31, X-36 BREAKERS TRIPPED.
05	10/06/05	1520	1612	:52	OROTE	P-14	VICTOR #2 SUB, MSC/MSF/SEALS COMPOUND, GSY, KILO PIER AND DENTAL CLINIC	13.8							D6	GPA X-20/X-35, X-31, X-36 BREAKERS TRIPPED.
05	10/06/05	1520	1616	:56	OROTE	P-25	ALPHA/BRAVO PIER: USS CITY OF CORPUS CHRISTI	13.8							D6	GPA X-20/X-35, X-31, X-36 BREAKERS TRIPPED.
05	10/06/05	1520	1754	2:34	COLD STORAGE	P-134	CAMP COVINGTON, OLD/NEW APRA HSG, DODEA, NAVMAG AREA	13.8							D6	GPA X-20/X-35, X-31, X-36 BREAKERS TRIPPED.
05	10/06/05	1520	1755	2:35	COLD STORAGE	P-133	COLD STORAGE COMPOUND	13.8							D6	GPA X-20/X-35, X-31, X-36 BREAKERS TRIPPED.
06	10/08/05 – 10/09/05	2352	0012	:20	CNM	ON P-129	QTRS. #17/19 HUTCHINS, QTRS. #26/28 OROTE PT. LOCKWOOD	13.8							C1	DEFECTIVE CUT-OUT ASSEMBLY ON POLE # JB-49-16.
07	10/12/05	0823	1032	2:09	AAFB	P-91	CAPEHART HSG AND PARTIAL OF ROBERTS TERRACE HSG	13.8		I	I	I			D7	FLASHOVER/MOISTURE AT CL-5.
08	10/12/05	1527	1555	:28	AAFB	ON P-94	BLDG 14540 SEWER LIFT STA.	13.8							D5	BLOWN FUSE ON POLE #NB-35-1 CAUSED BY SNAKE.
09	10/13/05	0809	0938	1:23	MARBO	ON P-51	WATER BOOSTER #3 STATION	13.8							C1	DEFECTIVE CUT-OUT ASSEMBLY ON POLE # MB-29.
10	10/13/05	0913	1046	1:33	AAFB	P-82	CONTROL TOWER, MATS TERMINAL, 3RD DIV. HDQTRS, BX, AIR COMM	13.8		I	I	I		13.8	D7	FLASHOVER AT MH-119 (P-81 SIDE).
11	10/15/05	0149	0517	3:28	MARBO	ON P-51	AIR FORCE WELLS # 5/6/7/8	13.8							D6	GPA SURGE/FUSE BLEW ON POLE MA-2-1.
12	10/18/05	1027	1611	5:44	POLARIS PT.	ON P-2	BLDG 4445 QTR DECK	SEC.							D7	BURNT KWH METER BASE.

*LEGEND: A1: LOAD SHEDDING; A2: GENERATOR TRIP; B1: STORM; B2: LIGHTNING; B3: EARTHQUAKE; C1: LINE; C2: TRANSFORMER; C3: RELAY; C4: BREAKER; D1: HUMAN ERROR; D2: VEHICLE ACCIDENT; D3: UNKNOWN; D4: TREE; D5: SNAKE; D6: GPA POWER SURGE; D7: OTHER

S.E.T. – Pacific, Inc.

ELECTRIC DISTRIBUTION LOG (UNSCHEDULED OUTAGES)

SEQUENTIAL LOG FOR 4.16, 13.8, 34.5 KV — RELAY TARGETS ACTION — MONTH: Sep 28 to Oct 31 YEAR: 2005

UO#	DATE	TIME: LOSS (TRIP)	TIME: RETURN (CLOSE)	TIME: ELAPSED HOURS	LOCATION: BASE / SUBSTATION	LOCATION: CIRCUIT BREAKER	LOCATION: AREA CUT-OFF OR AFFECTED	LOAD KV	OVER CURRENT: KF	OVER CURRENT: A	OVER CURRENT: B	OVER CURRENT: C	OVER CURRENT: GRD	XFMER DIFF	OUTAGE CAUSE*	SPECIFIC CAUSE OF OUTAGE / COMMENTS
13	10/20/05	0840	1110	2:30	MARBO	ON P-51	AIR FORCE WELLS #5/6/7/8	13.8							C1	DEFECTIVE CUT-OUT ASSEMLY ON POLE # MA-2-1.
14	10/21/05	1348	1400	:12	ROMEO CNM	ON P-130	USS PASADENA	.48							D1	SUBMARINERS OVERLOADED R-3C/3D/3E/3F BREAKERS.
15	10/22/05	0804	1149	3:45	AAFB	P-91	CAPEHART HSG AND PARTIAL OF ROBERTS TERRACE HSG.	13.8		I	I	I	I		D7	CL-7 SWITCHGEAR FLASHED OVER/MOISTURE.
16	10/22/05	0937	0941	:04	AAFB	P-93	PARTIAL OF ROBERTS TERRACE	13.8					I		D6	GPA POWER SURGE.
17	10/22/05	0947	1006	:19	COLD STORAGE	P-134	OLD/NEW APRA HSG, NAVMAG AREA, PARTIAL OF CAMP COVINGTON	13.8					I		D6	GPA POWER SURGE.
18	10/22/05	1616	1805	1:49	AAFB	ON P-93	PARTIAL OF FLEMING HTS. HSG	13.8							D7	MH-205/MH-206 FLASHED OVER/MOISTURE.
19	10/24/05	0018	0243	2:25	ROMEO CNM	ON P-130	USS PASADENA	.48							D1	SUBMARINERS OVERLOADED R-3C/3D/3E/3F BREAKERS.
	10/24/05	0132	0402	2:30	HARMON/ AAFB	ON X-87/ X-73	NCTS 4 KV (F-2/F-3/F-4) AND POTTS JCT SUBSTATIONS	4.16 13.8							D6	GPA X-87/X-73 LINE TRIPPED.
20	10/28/05	2117	2314	1:57	MARBO	ON P-51	AIR FORCE WELLS #7/8	13.8							D3	FUSE BLEW ON POLE # MB-2-1.
21	10/29/05	1052	1124	:32	AAFB	P-91	CAPEHART HSG AND PARTIAL OF ROBERTS TERRACE	13.8							D6	GPA X-42/X-80 LINE TRIPPED.

*LEGEND: A1: LOAD SHEDDING; A2: GENERATOR TRIP; B1: STORM; B2: LIGHTNING; B3: EARTHQUAKE; C1: LINE; C2: TRANSFORMER; C3: RELAY; C4: BREAKER; D1: HUMAN ERROR; D2: VEHICLE ACCIDENT; D3: UNKNOWN; D4: TREE; D5: SNAKE; D6: GPA POWER SURGE; D7: OTHER

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DOCUMENT TRANSMITTAL FORM

CUSTOMER: DZSP21
FACILITY: Electrical, Steam, Hot Water & Demineralized Water
LOCATION: Guam Naval Facilities

LOG #: **2390**
SET Contract No. SUB-000002
ISSUE CODE:
DATE: 02 December 2005

TO: DZSP21
P.O. Box GH
Hagatna, Guam 96932
ATTENTION: Wally Toma, Subcontract Administrator

We are sending you: XX Attached __Under Separate Cover via:__________the: __Shop Drawings

__Prints __Samples __Specifications __Reports __Inspections __Test Schedules __Copy of Letter

__Change Order __Constr.Progress Chart/Schedule __Payment Estimate __As Stated __________

Copies	Reference No.	Category Type	Description and Purpose
1	**Annex 1602**	**CDRL F-1602000-F**	**Power System Dispatcher's Unscheduled and Scheduled Outage Report – November 2005 (5 pages)**

Name of: Subcontractor, Supplier/Manufacturer __________

__For Approval __Approved as Submitted __Resubmit __Copies for approval XX For Your Use

__Approved as Noted __Submit __Copies for distribution __As Requested __Returned for Corrections

__Return __corrected prints __For Review and Comment __Other: __________

I certify that the attached information is ready for execution and that the attached information complies with the requirements of the contract documents.

By: [signature] Jay D. Miller, President 12 / 02 / 05

cc:

Received By: __________ Date: __________

Systems,
Energy &
Technologies, Inc.

S.E.T. – Pacific, Inc.

POWER SYSTEM DISPATCHER'S UNSCHEDULED AND SCHEDULED OUTAGE REPORT			
CDRL No: F-1602000-F	Prepared By: Connie Judicpa	Month/Year: November 2005	No. of Page(s): 6
FREQUENCY: Monthly.			

- **Unscheduled Outage Report**
  - See attached (4 pages)
- **Scheduled Outage Report**
  - See attached (1 page)

ELECTRIC DISTRIBUTION LOG (UNSCHEDULED OUTAGES)

SEQUENTIAL LOG FOR 4.16, 13.8, 34.5 KV									RELAY TARGETS ACTION							MONTH: NOVEMBER YEAR: 2005
		TIME			LOCATION			LOAD	OVER CURRENT							
UO#	DATE	LOSS (TRIP)	RETURN (CLOSE)	ELAPSED HOURS	BASE / SUBSTATION	CIRCUIT BREAKER	AREA CUT-OFF OR AFFECTED	KV	KF	A	B	C	GRD	XFMER DIFF	OUTAGE CAUSE*	SPECIFIC CAUSE OF OUTAGE / COMMENTS
22	11/01/05	0801	1319	5:18	CNM	ON P-14	BLDG 5545 KILO PIER	SEC							C4	LOOSE CONNECTION ON A 100 AMP BREAKER AT BLDG 5545.
23	11/03/05	0042	0501	4:19	CNM	ON P-14	BLDGS 3000/3001/3002 SEALS COMPOUND	13.8							D3	BLOWN IN-LINE FUSE ON POLE JC-27.
24	11/04/05	0944	1006	:22	AAFB	P-93	ROBERTS TERRACE HSG AND PARTIAL OF CAPEHART HSG.	13.8	√						A2	GPA MEC GENERATOR #9 TRIPPED.
24	11/04/05	0944	1028	:44	MARBO	P-51	AIR FORCE WELLS #5-9 AND BOOSTER PUMP STATION	13.8	√						A2	GPA MEC GENERATOR #9 TRIPPED.
25	11/04/05	1344	1408	:24	OROTE	P-129	SECURITY/COAST GUARD COMPOUND, SLS – 14/23, NAVFACMAR ADMIN COMPLEX, TRANSPORTATION AND VICTOR BOWTS	13.8					T		C1	DEFECTIVE TERMINATOR ON P-15 RISER POLE.
25	11/04/05	1344	1701	3:17	OROTE	P-129	NORTH/SOUTH TIP AND LOCKWOOD HSG, CDC GYM, THEATER, USDA, CHAPEL, BOQ, BEQ, OROTE TELEX AND SLS-17	13.8					I		C1	DEFECTIVE TERMINATOR ON P-15 RISER POLE.
26	11/04/05	1515	1541	:26	OROTE	T-11	P-14/P-16/T-17/P-115	13.8						LO	C1	GPA X-31 PRIMARY JUMPER BURNT.
26	11/04/05	1515	1537	:22	OROTE	P-11S	BARRACKS #14 AND #15	13.8							C1	GPA X-31 PRIMARY JUMPER BURNT.
26	11/04/05	1515	1539	:24	OROTE	P-16	NEX COMPLEX/BLDGS AND COMMISSARY AND McDONALDS	13.8							C1	GPA X-31 PRIMARY JUMPER BURNT.
26	11/04/05	1515	1539	:24	OROTE	T-17	WWTP, BARRACKS COMPLEX, CLUB RUMORS, LAUNDROMAT, SUMAY COVE, FIRE STA, GSY, DZSP-21 MAINT COMPOUND, SLS-16, CSS-15	13.8							C1	GPA X-31 PRIMARY JUMPER BURNT.

*LEGEND: A1: LOAD SHEDDING; A2: GENERATOR TRIP; B1: STORM; B2: LIGHTNING; B3: EARTHQUAKE; C1: LINE; C2: TRANSFORMER; C3: RELAY; C4: BREAKER; D1: HUMAN ERROR; D2: VEHICLE ACCIDENT; D3: UNKNOWN; D4: TREE; D5: SNAKE; D6: GPA POWER SURGE; D7: OTHER

ELECTRIC DISTRIBUTION LOG (UNSCHEDULED OUTAGES)

SEQUENTIAL LOG FOR 4.16, 13.8, 34.5 KV — RELAY TARGETS ACTION — MONTH: NOVEMBER YEAR: 2005

UO#	DATE	TIME: LOSS (TRIP)	TIME: RETURN (CLOSE)	TIME: ELAPSED HOURS	LOCATION: BASE / SUBSTATION	LOCATION: CIRCUIT BREAKER	LOCATION: AREA CUT-OFF OR AFFECTED	LOAD: KV	OVER CURRENT: KF	OVER CURRENT: A	OVER CURRENT: B	OVER CURRENT: C	OVER CURRENT: GRD	XFMER DIFF	OUTAGE CAUSE*	SPECIFIC CAUSE OF OUTAGE / COMMENTS
26	11/04/05	1515	1541	:26	OROTE	P-14	VICTOR PIER #2, SEALS/MSC/MFC/EOD COMPOUNDS, BLDGS 3179, 3180, 2118, KILO PIER, DENTAL CLINIC, GYS, SLS-21/22	13.8							C1	GPA X-31 PRIMARY JUMPER BURNT.
27	11/05/05	2008	2130	1:22	AAFB	P-93	ROBERTS TERRACE HSG AND PARTIAL OF CAPEHART HSG.	13.8	√						A2	GPA MEC GENERATOR #9 TRIPPED.
27	11/05/05	2008	2232	2:24	MARBO	P-51	AIR FORCE WELLS #5-9 AND BOOSTER PUMP STATION.	13.8	√						A2	GPA MEC GENERATOR #9 TRIPPED.
28	11/07/05	0653	0958	3:05	AAFB	P-94	EXCHANGE GAS STA, POL, LOX PLANT, ILS STROBE LIGHT, MSA-1/TARAGUE AREA	13.8		T	T				B2	PRIMARY JUMPER BURNT ON POLE #NB-20.
29	11/08/05	1013	1159	1:46	AAFB	P-95	SUBSTATIONS "D"/"F"/20-MEG: ALL INDUSTRIAL AREAS	13.8		T		T			D3	P-95 BREAKER TRIPPED.
30	11/09/05	1022	1159	1:37	AAFB	P-95	SUBSTATIONS "D"/"F"/20-MEG: ALL INDUSTRIAL AREAS	13.8		T		T			D7	P-95 BREAKER TRIPPED.
30	11/09/05	1337	1405	:28	AAFB	P-95	SUBSTATIONS "D"/"F"/20-MEG: ALL INDUSTRIAL AREAS	13.8		T					D7	P-95 BREAKER TRIPPED.
31	11/10/05	1625	1654	:29	CNM	ON P-14	SEALS COMPOUND: BLDGS #3000/3001/3002	13.8							C1	DEFECTIVE IN-LINE CUT-OUT ASSEMBLY.
32	11/11/05	0921	1219	2:58	NAVMAG	ON P-134	BLDGS #402/405/406/879/1005/1014	13.8							D5	FUSES BLEW ON POLE JG-104-10-2/JG-104-10-2-8.
33	11/11/05 – 11/12/05	2219	0105	2:46	NAVMAG	ON P-134	BLDG 407 FIRE STATION	SEC.							D7	SECONDARY DOUBLE THROW SWITCH BURNT.
34	11/13/05	1711	2044	3:33	AAFB	P-91	CAPEHART HSG AND PARTIAL OF ROBERTS TERRACE HSG.	13.8			T	T	1		D7	CL-33 SWITCHGEAR FLASHED OVER DUE TO MOISTURE.

*LEGEND: A1: LOAD SHEDDING; C4: BREAKER; A2: GENERATOR TRIP; D1: HUMAN ERROR; B1: STORM; D2: VEHICLE ACCIDENT; B2: LIGHTNING; D3: UNKNOWN; B3: EARTHQUAKE; D4: TREE; C1: LINE; D5: SNAKE; C2: TRANSFORMER; D6: GPA POWER SURGE; C3: RELAY; D7: OTHER

Electric Distribution Log (Unscheduled Outages)

SEQUENTIAL LOG FOR 4.16, 13.8, 34.5 KV — RELAY TARGETS ACTION — MONTH: November YEAR: 2005

UO#	Date	Time: Loss (Trip)	Time: Return (Close)	Time: Elapsed Hours	Location: Base / Substation	Location: Circuit Breaker	Location: Area Cut-off or Affected	Load: KV	Over Current: KF	Over Current: A	Over Current: B	Over Current: C	Over Current: GRD	XFMER Diff	Outage Cause*	Specific Cause of Outage / Comments
35	11/13/05 – 11/14/05	2336	0715	7:39	AAFB	P-93	FLEMING HTS AND PARTIAL OF ROBERTS TERRACE HSG.	13.8		I	I	I			D5	SNAKE CAUSED A SHORT AT MH-212.
36	11/14/05	0746	1217	4:31	COLD STORAGE	P-134	OLD/NEW APRA HSG, DODEA, NAVMAG, PARTIAL OF CAMP COVINGTON	13.8					T		C1	DEAD-END BELL DEFECTIVE ON POLE AH-12-10-5-5.
37	11/14/05	0841	1040	1:59	CNM	ON P-129	MAIN GATE/SENTRY POST #1	13.8							D5	SNAKE CAUSED FUSE TO BLOW ON H-FRAME STRUCTURE.
38	11/23/05	1118	-	-	CNM	ON P-14	VICTOR #2 PIER OLD POLISHING TRAILER OUTLET	13.8							C2	DEFECTIVE 25KVA TRANSFORMER ON POLE #JC-2-10.
39	11/27/05	1020	1241	2:21	AAFB	P-62	HSG MAINT, POL, PASS/ID OFFICE, MAIN GATE, RECYCLE/CONTRACTOR'S OFFICE	13.8					T		D7	GPA 34.5 KV GUY WIRE BROKE COMING IN CONTACT WITH THE PRIMARY LINE ON POLE #NE-49.
40	11/28/05	1325	1449	1:24	CAMP COVINGTON	ON P-134	BLDG 526 NEX BEE-QUICK	13.8							C1	TRANSFORMER SECONDARY WIRE CAME OFF.
41	11/29/05	0921	1000	:56	MARBO	ON P-51	BLDG 1301 STATION POWER	13.8							D5	SNAKE CAUSED FUSE TO BLOW ON POLE #MB-1-1A.
42	11/30/05	0045	0319	2:34	OROTE/COLD STORAGE	T-11/T-12, T-13 AND T-132	OROTE AND COLD STORAGE SUBSTATIONS	13.8							C4	GPA X-20/X-21/X-35/X-36 BREAKERS TRIPPED.
42	11/30/05	0045	0254	2:09	OROTE	P-25	USS FRANK CABLE AND USS HOUSTON	13.8							C4	GPA X-20/X-21/X-35/X-36 BREAKERS TRIPPED.
42	11/30/05	0045	0255	2:10	OROTE	P-129	SECURITY/COAST GUARD COMPOUND, SLS – 14/23, NAVFACMAR ADMIN COMPLEX, TRANSPORTATION AND VICTOR BOWTS. NORTH/SOUTH TIP AND LOCKWOOD HSG, CDC GYM, THEATER, USDA, CHAPEL, BOQ, BEQ, OROTE TELEX AND SLS-17	13.8							C4	GPA X-20/X-21/X-35/X-36 BREAKERS TRIPPED.

*LEGEND: A1: LOAD SHEDDING; A2: GENERATOR TRIP; B1: STORM; B2: LIGHTNING; B3: EARTHQUAKE; C1: LINE; C2: TRANSFORMER; C3: RELAY; C4: BREAKER; D1: HUMAN ERROR; D2: VEHICLE ACCIDENT; D3: UNKNOWN; D4: TREE; D5: SNAKE; D6: GPA POWER SURGE; D7: OTHER

ELECTRIC DISTRIBUTION LOG (UNSCHEDULED OUTAGES)

SEQUENTIAL LOG FOR 4.16, 13.8, 34.5 KV — RELAY TARGETS ACTION — MONTH: NOVEMBER YEAR: 2005

UO#	DATE	TIME: LOSS (TRIP)	TIME: RETURN (CLOSE)	TIME: ELAPSED HOURS	LOCATION: BASE / SUBSTATION	LOCATION: CIRCUIT BREAKER	LOCATION: AREA CUT-OFF OR AFFECTED	LOAD KV	OVER CURRENT: KF	OVER CURRENT: A	OVER CURRENT: B	OVER CURRENT: C	OVER CURRENT: GRD	XFMER DIFF	OUTAGE CAUSE*	SPECIFIC CAUSE OF OUTAGE / COMMENTS
42	11/30/05	0045	0256	2:11	OROTE	P-128	HARBOR/BAYVIEW HSG	13.8							C4	GPA X-20/X-21/X-35/X-36 BREAKERS TRIPPED.
42	11/30/05	0045	0256	2:11	OROTE	P-130	BLGS #3190/3191, SIERRA AND ROMEO PIERS	13.8							C4	GPA X-20/X-21/X-35/X-36 BREAKERS TRIPPED.
42	11/30/05	0045	0257	2:12	OROTE	P-16	NEX COMPLEX/BLDGS AND COMMISSARY AND McDONALDS	13.8							C4	GPA X-20/X-21/X-35/X-36 BREAKERS TRIPPED.
42	11/30/05	0045	0258	2:13	OROTE	P-11S	BARRACKS #14 AND #15	13.8							C4	GPA X-20/X-21/X-35/X-36 BREAKERS TRIPPED.
42	11/30/05	0045	0258	2:13	OROTE	T-17	WWTP, BARRACKS COMPLEX, CLUB RUMORS, LAUNDROMAT, SUMAY COVE, FIRE STA, GSY, DZSP-21 MAINT COMPOUND, SLS-16, CSS-15	13.8							C4	GPA X-20/X-21/X-35/X-36 BREAKERS TRIPPED.
42	11/30/05	0045	0259	2:14	OROTE	P-14	VICTOR PIER #2, SEALS/MSC/MFC/EOD COMPOUNDS, BLDGS 3179, 3180, 2118, KILO PIER, DENTAL CLINIC, GYS, SLS-21/22	13.8							C4	GPA X-20/X-21/X-35/X-36 BREAKERS TRIPPED.
42	11/30/05	0045	0316	2:31	COLD STORAGE	P-133	BLDGD 3202 WAREHOUSE #6, COLD STORAGE PLANT, BATTERY LOCKER	13.8							C4	GPA X-20/X-21/X-35/X-36 BREAKERS TRIPPED.
42	11/30/05	0045	0319	2:34	COLD STORAGE	P-134	OLD/NEW APRA HSG, NAVMAG, DODEA MIDDLE SCHOOL, PARTIAL CAMP COVINGTON	13.8							C4	GPA X-20/X-21/X-35/X-36 BREAKERS TRIPPED.
43	11/30/05	0700	0750	:50	AAFB	P-82	HANGARS/DOCKS, AUTOMATION BLDG, COLD STORAGE, SUPPLY BLDGS.	13.8		T	T	T			D7	SWITCH P-82-31 BURNT AT MH-131.
43	11/30/05	0700	1339	6:39	AAFB	ON P-82	BLDGS 19017/19028/20016/20025	13.8							D7	SWITCH P-82-31 BURNT AT MH-131.
44	11/30/05 – 12/01/05	2122	0030	3:08	AAFB	ON P-81	BLDGS 23002/23003	13.8							C1	TRANSFORMER PRIMARY JUMPER BURNT.

*LEGEND: A1: LOAD SHEDDING; C4: BREAKER; A2: GENERATOR TRIP; D1: HUMAN ERROR; B1: STORM; D2: VEHICLE ACCIDENT; B2: LIGHTNING; D3: UNKNOWN; B3: EARTHQUAKE; D4: TREE; C1: LINE; D5: SNAKE; C2: TRANSFORMER; D6: GPA POWER SURGE; C3: RELAY; D7: OTHER

SET®

S.E.T. – Pacific, Inc.

DOCUMENT TRANSMITTAL FORM

CUSTOMER: DZSP21
FACILITY: Electrical, Steam, Hot Water & Demineralized Water
LOCATION: Guam Naval Facilities

LOG #: 2390
SET Contract No. SUB-000002
ISSUE CODE:
DATE: 02 December 2005

TO: DZSP21
P.O. Box GH
Hagatna, Guam 96932
ATTENTION: Wally Toma, Subcontract Administrator

We are sending you: XX Attached __Under Separate Cover via:______________the: __Shop Drawings

__Prints __Samples __Specifications __Reports __Inspections __Test Schedules __Copy of Letter

__Change Order __Constr.Progress Chart/Schedule __Payment Estimate __As Stated ______________

Copies	Reference No.	Category Type	Description and Purpose
1	Annex 1602	CDRL F-1602000-F	Power System Dispatcher's Unscheduled and Scheduled Outage Report – November 2005 (5 pages)

Name of: Subcontractor, Supplier/Manufacturer ______________________________

__For Approval __Approved as Submitted __Resubmit __Copies for approval XX For Your Use

__Approved as Noted __Submit __Copies for distribution __As Requested __Returned for Corrections

__Return __corrected prints __For Review and Comment __Other: ______________

I certify that the attached information is ready for execution and that the attached information complies with the requirements of the contract documents.

By: ______________________ 12 / 02 / 05
Jay D. Miller, President

cc:

Received By: ______________________ Date: ____________

Systems,
Energy &
Technologies, Inc.

S.E.T. – Pacific, Inc.

POWER SYSTEM DISPATCHER'S UNSCHEDULED AND SCHEDULED OUTAGE REPORT			
CDRL No: F-1602000-F	Prepared By: Connie Judicpa	Month/Year: November 2005	No. of Page(s): 6
FREQUENCY: Monthly.			

- **Unscheduled Outage Report**
  - See attached (4 pages)

- **Scheduled Outage Report**
  - See attached (1 page)

ELECTRIC DISTRIBUTION LOG (UNSCHEDULED OUTAGES)

SEQUENTIAL LOG FOR 4.16, 13.8, 34.5 KV									RELAY TARGETS ACTION							MONTH: NOVEMBER YEAR: 2005
UO#	DATE	TIME			LOCATION			LOAD	OVER CURRENT					XFMER DIFF	OUTAGE CAUSE*	SPECIFIC CAUSE OF OUTAGE / COMMENTS
		LOSS (TRIP)	RETURN (CLOSE)	ELAPSED HOURS	BASE / SUBSTATION	CIRCUIT BREAKER	AREA CUT-OFF OR AFFECTED	KV	KF	A	B	C	GRD			
22	11/01/05	0801	1319	5:18	CNM	ON P-14	BLDG 5545 KILO PIER	SEC							C4	LOOSE CONNECTION ON A 100 AMP BREAKER AT BLDG 5545.
23	11/03/05	0042	0501	4:19	CNM	ON P-14	BLDGS 3000/3001/3002 SEALS COMPOUND	13.8							D3	BLOWN IN-LINE FUSE ON POLE JC-27.
24	11/04/05	0944	1006	:22	AAFB	P-93	ROBERTS TERRACE HSG AND PARTIAL OF CAPEHART HSG.	13.8	√						A2	GPA MEC GENERATOR #9 TRIPPED.
24	11/04/05	0944	1028	:44	MARBO	P-51	AIR FORCE WELLS #5-9 AND BOOSTER PUMP STATION	13.8	√						A2	GPA MEC GENERATOR #9 TRIPPED.
25	11/04/05	1344	1408	:24	OROTE	P-129	SECURITY/COAST GUARD COMPOUND, SLS – 14/23, NAVFACMAR ADMIN COMPLEX, TRANSPORTATION AND VICTOR BOWTS	13.8					T		C1	DEFECTIVE TERMINATOR ON P-15 RISER POLE.
25	11/04/05	1344	1701	3:17	OROTE	P-129	NORTH/SOUTH TIP AND LOCKWOOD HSG, CDC GYM, THEATER, USDA, CHAPEL, BOQ, BEQ, OROTE TELEX AND SLS-17	13.8					I		C1	DEFECTIVE TERMINATOR ON P-15 RISER POLE.
26	11/04/05	1515	1541	:26	OROTE	T-11	P-14/P-16/T-17/P-115	13.8						LO	C1	GPA X-31 PRIMARY JUMPER BURNT.
26	11/04/05	1515	1537	:22	OROTE	P-11S	BARRACKS #14 AND #15	13.8							C1	GPA X-31 PRIMARY JUMPER BURNT.
26	11/04/05	1515	1539	:24	OROTE	P-16	NEX COMPLEX/BLDGS AND COMMISSARY AND McDONALDS	13.8							C1	GPA X-31 PRIMARY JUMPER BURNT.
26	11/04/05	1515	1539	:24	OROTE	T-17	WWTP, BARRACKS COMPLEX, CLUB RUMORS, LAUNDROMAT, SUMAY COVE, FIRE STA, GSY, DZSP-21 MAINT COMPOUND, SLS-16, CSS-15	13.8							C1	GPA X-31 PRIMARY JUMPER BURNT.

*LEGEND: A1: LOAD SHEDDING; C4: BREAKER; A2: GENERATOR TRIP; D1: HUMAN ERROR; B1: STORM; D2: VEHICLE ACCIDENT; B2: LIGHTNING; D3: UNKNOWN; B3: EARTHQUAKE; D4: TREE; C1: LINE; D5: SNAKE; C2: TRANSFORMER; D6: GPA POWER SURGE; C3: RELAY; D7: OTHER

ELECTRIC DISTRIBUTION LOG (UNSCHEDULED OUTAGES)

SEQUENTIAL LOG FOR 4.16, 13.8, 34.5 KV — RELAY TARGETS ACTION — MONTH: NOVEMBER YEAR: 2005

UO#	DATE	TIME: LOSS (TRIP)	TIME: RETURN (CLOSE)	TIME: ELAPSED HOURS	LOCATION: BASE / SUBSTATION	LOCATION: CIRCUIT BREAKER	LOCATION: AREA CUT-OFF OR AFFECTED	LOAD: KV	OVER CURRENT: KF	OVER CURRENT: A	OVER CURRENT: B	OVER CURRENT: C	OVER CURRENT: GRD	XFMER DIFF	OUTAGE CAUSE*	SPECIFIC CAUSE OF OUTAGE / COMMENTS
26	11/04/05	1515	1541	:26	OROTE	P-14	VICTOR PIER #2, SEALS/MSC/MFC/EOD COMPOUNDS, BLDGS 3179, 3180, 2118, KILO PIER, DENTAL CLINIC, GYS, SLS-21/22	13.8							C1	GPA X-31 PRIMARY JUMPER BURNT.
27	11/05/05	2008	2130	1:22	AAFB	P-93	ROBERTS TERRACE HSG AND PARTIAL OF CAPEHART HSG.	13.8	√						A2	GPA MEC GENERATOR #9 TRIPPED.
27	11/05/05	2008	2232	2:24	MARBO	P-51	AIR FORCE WELLS #5-9 AND BOOSTER PUMP STATION.	13.8	√						A2	GPA MEC GENERATOR #9 TRIPPED.
28	11/07/05	0653	0958	3:05	AAFB	P-94	EXCHANGE GAS STA, POL, LOX PLANT, ILS STROBE LIGHT, MSA-1/TARAGUE AREA	13.8		T	T				B2	PRIMARY JUMPER BURNT ON POLE #NB-20.
29	11/08/05	1013	1159	1:46	AAFB	P-95	SUBSTATIONS "D"/"F"/20-MEG: ALL INDUSTRIAL AREAS	13.8		T		T			D3	P-95 BREAKER TRIPPED.
30	11/09/05	1022	1159	1:37	AAFB	P-95	SUBSTATIONS "D"/"F"/20-MEG: ALL INDUSTRIAL AREAS	13.8		T		T			D7	P-95 BREAKER TRIPPED.
30	11/09/05	1337	1405	:28	AAFB	P-95	SUBSTATIONS "D"/"F"/20-MEG: ALL INDUSTRIAL AREAS	13.8		T					D7	P-95 BREAKER TRIPPED.
31	11/10/05	1625	1654	:29	CNM	ON P-14	SEALS COMPOUND: BLDGS #3000/3001/3002	13.8							C1	DEFECTIVE IN-LINE CUT-OUT ASSEMBLY.
32	11/11/05	0921	1219	2:58	NAVMAG	ON P-134	BLDGS #402/405/406/879/1005/1014	13.8							D5	FUSES BLEW ON POLE JG-104-10-2/JG-104-10-2-8.
33	11/11/05 – 11/12/05	2219	0105	2:46	NAVMAG	ON P-134	BLDG 407 FIRE STATION	SEC.							D7	SECONDARY DOUBLE THROW SWITCH BURNT.
34	11/13/05	1711	2044	3:33	AAFB	P-91	CAPEHART HSG AND PARTIAL OF ROBERTS TERRACE HSG.	13.8			T	T	1		D7	CL-33 SWITCHGEAR FLASHED OVER DUE TO MOISTURE.

*LEGEND: A1: LOAD SHEDDING; A2: GENERATOR TRIP; B1: STORM; B2: LIGHTNING; B3: EARTHQUAKE; C1: LINE; C2: TRANSFORMER; C3: RELAY; C4: BREAKER; D1: HUMAN ERROR; D2: VEHICLE ACCIDENT; D3: UNKNOWN; D4: TREE; D5: SNAKE; D6: GPA POWER SURGE; D7: OTHER

Electric Distribution Log (Unscheduled Outages)

SEQUENTIAL LOG FOR 4.16, 13.8, 34.5 KV									RELAY TARGETS ACTION							MONTH: NOVEMBER YEAR: 2005
UO#	DATE	TIME			LOCATION			LOAD	OVER CURRENT					XFMER DIFF	OUTAGE CAUSE*	SPECIFIC CAUSE OF OUTAGE / COMMENTS
		LOSS (TRIP)	RETURN (CLOSE)	ELAPSED HOURS	BASE / SUBSTATION	CIRCUIT BREAKER	AREA CUT-OFF OR AFFECTED	KV	KF	A	B	C	GRD			
35	11/13/05 – 11/14/05	2336	0715	7:39	AAFB	P-93	FLEMING HTS AND PARTIAL OF ROBERTS TERRACE HSG.	13.8		I	I	I			D5	SNAKE CAUSED A SHORT AT MH-212.
36	11/14/05	0746	1217	4:31	COLD STORAGE	P-134	OLD/NEW APRA HSG, DODEA, NAVMAG, PARTIAL OF CAMP COVINGTON	13.8					T		C1	DEAD-END BELL DEFECTIVE ON POLE AH-12-10-5-5.
37	11/14/05	0841	1040	1:59	CNM	ON P-129	MAIN GATE/SENTRY POST #1	13.8							D5	SNAKE CAUSED FUSE TO BLOW ON H-FRAME STRUCTURE.
38	11/23/05	1118	-	-	CNM	ON P-14	VICTOR #2 PIER OLD POLISHING TRAILER OUTLET	13.8							C2	DEFECTIVE 25KVA TRANSFORMER ON POLE #JC-2-10.
39	11/27/05	1020	1241	2:21	AAFB	P-62	HSG MAINT, POL, PASS/ID OFFICE, MAIN GATE, RECYCLE/CONTRACTOR'S OFFICE	13.8					T		D7	GPA 34.5 KV GUY WIRE BROKE COMING IN CONTACT WITH THE PRIMARY LINE ON POLE #NE-49.
40	11/28/05	1325	1449	1:24	CAMP COVINGTON	ON P-134	BLDG 526 NEX BEE-QUICK	13.8							C1	TRANSFORMER SECONDARY WIRE CAME OFF.
41	11/29/05	0921	1000	:56	MARBO	ON P-51	BLDG 1301 STATION POWER	13.8							D5	SNAKE CAUSED FUSE TO BLOW ON POLE #MB-1-1A.
42	11/30/05	0045	0319	2:34	OROTE/COLD STORAGE	T-11/T-12, T-13 AND T-132	OROTE AND COLD STORAGE SUBSTATIONS	13.8							C4	GPA X-20/X-21/X-35/X-36 BREAKERS TRIPPED.
42	11/30/05	0045	0254	2:09	OROTE	P-25	USS FRANK CABLE AND USS HOUSTON	13.8							C4	GPA X-20/X-21/X-35/X-36 BREAKERS TRIPPED.
42	11/30/05	0045	0255	2:10	OROTE	P-129	SECURITY/COAST GUARD COMPOUND, SLS – 14/23, NAVFACMAR ADMIN COMPLEX, TRANSPORTATION AND VICTOR BOWTS. NORTH/SOUTH TIP AND LOCKWOOD HSG, CDC GYM, THEATER, USDA, CHAPEL, BOQ, BEQ, OROTE TELEX AND SLS-17	13.8							C4	GPA X-20/X-21/X-35/X-36 BREAKERS TRIPPED.

*LEGEND: A1: LOAD SHEDDING; A2: GENERATOR TRIP; B1: STORM; B2: LIGHTNING; B3: EARTHQUAKE; C1: LINE; C2: TRANSFORMER; C3: RELAY; C4: BREAKER; D1: HUMAN ERROR; D2: VEHICLE ACCIDENT; D3: UNKNOWN; D4: TREE; D5: SNAKE; D6: GPA POWER SURGE; D7: OTHER

ELECTRIC DISTRIBUTION LOG (UNSCHEDULED OUTAGES)

SEQUENTIAL LOG FOR 4.16, 13.8, 34.5 KV — RELAY TARGETS ACTION — MONTH: NOVEMBER YEAR: 2005

UO#	DATE	TIME: LOSS (TRIP)	TIME: RETURN (CLOSE)	TIME: ELAPSED HOURS	LOCATION: BASE / SUBSTATION	LOCATION: CIRCUIT BREAKER	LOCATION: AREA CUT-OFF OR AFFECTED	LOAD: KV	KF	OVER CURRENT: A	OVER CURRENT: B	OVER CURRENT: C	GRD	XFMER DIFF	OUTAGE CAUSE*	SPECIFIC CAUSE OF OUTAGE / COMMENTS
42	11/30/05	0045	0256	2:11	OROTE	P-128	HARBOR/BAYVIEW HSG	13.8							C4	GPA X-20/X-21/X-35/X-36 BREAKERS TRIPPED.
42	11/30/05	0045	0256	2:11	OROTE	P-130	BLGS #3190/3191, SIERRA AND ROMEO PIERS	13.8							C4	GPA X-20/X-21/X-35/X-36 BREAKERS TRIPPED.
42	11/30/05	0045	0257	2:12	OROTE	P-16	NEX COMPLEX/BLDGS AND COMMISSARY AND MCDONALDS	13.8							C4	GPA X-20/X-21/X-35/X-36 BREAKERS TRIPPED.
42	11/30/05	0045	0258	2:13	OROTE	P-11S	BARRACKS #14 AND #15	13.8							C4	GPA X-20/X-21/X-35/X-36 BREAKERS TRIPPED.
42	11/30/05	0045	0258	2:13	OROTE	T-17	WWTP, BARRACKS COMPLEX, CLUB RUMORS, LAUNDROMAT, SUMAY COVE, FIRE STA, GSY, DZSP-21 MAINT COMPOUND, SLS-16, CSS-15	13.8							C4	GPA X-20/X-21/X-35/X-36 BREAKERS TRIPPED.
42	11/30/05	0045	0259	2:14	OROTE	P-14	VICTOR PIER #2, SEALS/MSC/MFC/EOD COMPOUNDS, BLDGS 3179, 3180, 2118, KILO PIER, DENTAL CLINIC, GYS, SLS-21/22	13.8							C4	GPA X-20/X-21/X-35/X-36 BREAKERS TRIPPED.
42	11/30/05	0045	0316	2:31	COLD STORAGE	P-133	BLDGD 3202 WAREHOUSE #6, COLD STORAGE PLANT, BATTERY LOCKER	13.8							C4	GPA X-20/X-21/X-35/X-36 BREAKERS TRIPPED.
42	11/30/05	0045	0319	2:34	COLD STORAGE	P-134	OLD/NEW APRA HSG, NAVMAG, DODEA MIDDLE SCHOOL, PARTIAL CAMP COVINGTON	13.8							C4	GPA X-20/X-21/X-35/X-36 BREAKERS TRIPPED.
43	11/30/05	0700	0750	:50	AAFB	P-82	HANGARS/DOCKS, AUTOMATION BLDG, COLD STORAGE, SUPPLY BLDGS.	13.8		T	T	T			D7	SWITCH P-82-31 BURNT AT MH-131.
43	11/30/05	0700	1339	6:39	AAFB	ON P-82	BLDGS 19017/19028/20016/20025	13.8							D7	SWITCH P-82-31 BURNT AT MH-131.
44	11/30/05 – 12/01/05	2122	0030	3:08	AAFB	ON P-81	BLDGS 23002/23003	13.8							C1	TRANSFORMER PRIMARY JUMPER BURNT.

*LEGEND: A1: LOAD SHEDDING; A2: GENERATOR TRIP; B1: STORM; B2: LIGHTNING; B3: EARTHQUAKE; C1: LINE; C2: TRANSFORMER; C3: RELAY; C4: BREAKER; D1: HUMAN ERROR; D2: VEHICLE ACCIDENT; D3: UNKNOWN; D4: TREE; D5: SNAKE; D6: GPA POWER SURGE; D7: OTHER

S.E.T. – Pacific, Inc.

DOCUMENT TRANSMITTAL FORM

CUSTOMER: DZSP 21
FACILITY: Electrical, Steam, Hot Water & Demin Water
LOCATION: Guam Naval Facilities

LOG #: **2432**
SET Contract No: SUB-000002
ISSUE CODE:
DATE: January 3, 2006

TO: DZSP 21
P.O. Box GH
Agana, Guam 96932
ATTENTION: Mr. Wally Toma, Subcontract Administrator

We are sending you: X Attached _Under Separate Cover via:__________the: __Shop Drawings

__Prints __Samples __Specifications __Reports __Inspections __Test Schedules __Copy of Letter

_Change Order __Constr.Progress Chart/Schedule __Payment Estimate X As Stated __________

Copies	Reference No.	Category Type	Description and Purpose
1	Annex 1602	CDRL No. F-1602000-F	Power System Dispatcher's Unscheduled and Scheduled Outage Reports (5 pages)

Name of: Subcontractor, Supplier/Manufacturer __________

__For Approval __Approved as Submitted __Resubmit __copies for approval X For Your Use

__Approved as Noted __Submit __copies for distribution X As Requested __Returned for Corrections

__Return __corrected prints __For Review and Comment __Other: __________

I certify that the attached information is ready for execution and that the attached information complies with the requirements of the contract documents.

By: [signature] 01/03/06
T. J. Jacot, Senior Vice-President

Systems,
Energy &
Technologies, Inc.

S.E.T. – Pacific, Inc.

POWER SYSTEM DISPATCHER'S UNSCHEDULED AND SCHEDULED OUTAGE REPORT			
CDRL No: F-1602000-F	Prepared By: Peter Blas	Month/Year: December 2005	No. of Pages: 4
FREQUENCY: Monthly.			

- **Unscheduled Outage Report**
  - See attached (2 pages)
- **Scheduled Outage Report**
  - See attached (2 pages)

S.E.T. – Pacific, Inc.
CDRL F-1602000-F

ELECTRIC DISTRIBUTION LOG (UNSCHEDULED OUTAGES)

SEQUENTIAL LOG FOR 4.16, 13.8, 34.5 KV									RELAY TARGETS ACTION							MONTH: DECEMBER YEAR: 2005
		TIME			LOCATION			LOAD	OVER CURRENT							
UO#	DATE	LOSS (TRIP)	RETURN (CLOSE)	ELAPSED HOURS	BASE / SUBSTATION	CIRCUIT BREAKER	AREA CUT-OFF OR AFFECTED	KV	KF	A	B	C	GRD	XFMER DIFF	OUTAGE CAUSE*	SPECIFIC CAUSE OF OUTAGE / COMMENTS
45	12/08/05	1015	1110	:55	PAD-5	P-25/A2	USS FRANK CABLE AND USS HOUSTON AT ALPHA PIER	13.8							D1	UNKNOWN PARTY TRIPPED A2 PRIMARY BREAKER.
46	12/08/05	1840	2016	1:36	AAFB	P-93	FLEMING HEIGHTS AND PARTIAL OF ROBERTS TERRACE HSG.	13.8							C4	P-93 TRIPPED ON OVER CURRENT.
47	12/11/05 – 12/12/05	1330	1215	22:45	AAFB	ON P-94	SIRENA AND PATI POINT BEACHES, FIRING RANGE AND WELL/SPRINGS	13.8							D7	IGUANA ON POLE NB-105-24-8.
48	12/12/05	1318	1657	3:39	PITI	P-6	VHF REPEATER STA, FAA VORTAC STA, NIMITZ HILL AREA, NRMC NEX COMPLEX, DZSP21 MAINT. OFFICE	13.8							D2	GARBAGE TRUCK HIT STEEL POLE.
49	12/14/05	1434	1449	:15	AAFB	P-93	FLEMING HEIGHTS AND PARTIAL OF ROBERTS TERRACE HSG.	13.8							C4	P-93 TRIPPED ON OVER CURRENT.
50	12/14/05	1809	2000	1:51	AAFB	ON P-93	ROBERTS TERRACE QTRS. 1040, 1043, 1047, 1049 ROTA	13.8							D7	FORMICA BOARD FLASHED OVER AT STNB TRANSFORMER SWITCHGEAR.
51	12/16/05	1856	2004	1:08	COLD STORAGE	P-134	OLD/NEW APRA HSG, DODEA MIDDLE SCHOOL, NAVMAG AREA, PARTIAL OF CAMP COVINGTON	13.8					I		C4	P-134 TRIPPED ON OVER CURRENT.
52	12/17/05	0303	0424	1:21	CNM	ON P-129	SOUTH TIP HSG.	13.8							C1	DOWNED PRIMARY LINE BETWEEN POLES #JG-37-74-17 AND JG-37-74-18.
53	12/17/05	2120	2320	2:00	MARBO	ON P-51	MARBO WELLS #8/#9	13.8							D3	FUSE BLEW ON POLE # MB-2-2-2; CAUSE UNKNOWN; NO FINDINGS.
54	12/19/05	1342	1459	1:17	CNM	ON P-16	NEX BOOKSTORE BLDG 258	13.8							D7	TWO FUSES BLEW ON POLE JD-32-2 CAUSED BY BIRDS.
55	12/19/05	1536 1536	1855 1548	3:19 :12	OROTE	P-129	SOUTH TIP HSG, BACK GATE, LANDFILL AND PARTIAL OF CAMP COVINGTON, SECURITY/COAST GUARD/NAVFAC COMPOUND/PASS/ID, LOCKWOOD, NORTH TIP HSG, CDC, CHAPEL, GYM, THEATER, BEQ/BOQ	13.8							D7	DEFECTIVE POLE TOP SWITCH 13-06.

*LEGEND: A1: LOAD SHEDDING; A2: GENERATOR TRIP; B1: STORM; B2: LIGHTNING; B3: EARTHQUAKE; C1: LINE; C2: TRANSFORMER; C3: RELAY; C4: BREAKER; D1: HUMAN ERROR; D2: VEHICLE ACCIDENT; D3: UNKNOWN; D4: TREE; D5: SNAKE; D6: GPA POWER SURGE; D7: OTHER

ELECTRIC DISTRIBUTION LOG (UNSCHEDULED OUTAGES)

SEQUENTIAL LOG FOR 4.16, 13.8, 34.5 KV — RELAY TARGETS ACTION — MONTH: DECEMBER YEAR: 2005

UO#	DATE	TIME: LOSS (TRIP)	TIME: RETURN (CLOSE)	TIME: ELAPSED HOURS	LOCATION: BASE / SUBSTATION	LOCATION: CIRCUIT BREAKER	LOCATION: AREA CUT-OFF OR AFFECTED	LOAD KV	OVER CURRENT: KF	OVER CURRENT: A	OVER CURRENT: B	OVER CURRENT: C	OVER CURRENT: GRD	XFMER DIFF	OUTAGE CAUSE*	SPECIFIC CAUSE OF OUTAGE / COMMENTS
56	12/22/05	1007	1053	:46	CNM	ON P-14	BLDGS 18803/5545 KILO WHARF	.480							C4	BREAKER TRIPPED ON OVERLOAD.
57	12/22/05	1639 1639	1831 1654	1:52 :15	AAFB AAFB	P-91 P-93	CAPEHART AND PARTIAL OF ROBERTS TERRACE AND FLEMING HTS AND PARTIAL OF ROBERTS TERRACE	13.8 13.8			I		I I		D7	FLASHED OVER AT CL-14.
58	12/23/05	1212	-	-	CNM	ON P-130	USS HOUSTON AT ROMEO PIER.	.480							C4	BREAKERS TRIPPED ON OVERLOAD.
59	12/26/05 – 12/27/05	2041	0249	6:08	CNM	ON P-129	QTRS. #27/28/30/32/33/34 GILMORE LOCKWOOD HSG	13.8							C2	DEFECTIVE 75 KVA TRANSFORMER ON POLE JB-49-47.
60	12/27/05	0800	0856	:56	CNM	ON P-14	BLDGS 18803/5545 KILO	.480							C2	DEFECTIVE DRY-TYPE TRANSFORMER.
61	12/30/05	1137	1502	3:25	CNM	ON P-134	SOUTH TIP HSG 601 A/B & 602A/B LEARY ST.	13.8							C2	DEFECTIVE 50 KVA TRANSFORMER ON POLE #JG-37-74-29.

*LEGEND:
A1: LOAD SHEDDING; A2: GENERATOR TRIP; B1: STORM; B2: LIGHTNING; B3: EARTHQUAKE; C1: LINE; C2: TRANSFORMER; C3: RELAY
C4: BREAKER; D1: HUMAN ERROR; D2: VEHICLE ACCIDENT; D3: UNKNOWN; D4: TREE; D5: SNAKE; D6: GPA POWER SURGE; D7: OTHER

SET®

S.E.T. – Pacific, Inc.

DOCUMENT TRANSMITTAL FORM

CUSTOMER: DZSP 21
FACILITY: Electrical, Steam, Hot Water & Demin Water
LOCATION: Guam Naval Facilities

LOG #: **2490**
SET Contract No: SUB-000002
ISSUE CODE:
DATE: February 01, 2006

TO: DZSP 21
P.O. Box GH
Agana, Guam 96932
ATTENTION: Mr. Wally Toma, Subcontract Administrator

We are sending you: X Attached _Under Separate Cover via:__________ the: __Shop Drawings

__Prints __Samples __Specifications __Reports __Inspections __Test Schedules __Copy of Letter

_Change Order __Constr.Progress Chart/Schedule __Payment Estimate X As Stated __________

Copies	Reference No.	Category Type	Description and Purpose
1	**Annex 1602**	**CDRL No. F-1602000-F**	**Power System Dispatcher's Unscheduled and Scheduled Outage Reports – Jan. 2006 (6 pages)**

Name of: Subcontractor, Supplier/Manufacturer __________

__For Approval __Approved as Submitted __Resubmit __copies for approval X For Your Use

__Approved as Noted __Submit __copies for distribution X As Requested __Returned for Corrections

__Return __corrected prints __For Review and Comment __Other: __________

I certify that the attached information is ready for execution and that the attached information complies with the requirements of the contract documents.

By: [signature] Feb. 01, 2006
Jay D. Miller, President

Systems,
Energy &
Technologies, Inc.

S.E.T. – Pacific, Inc.

POWER SYSTEM DISPATCHER'S UNSCHEDULED AND SCHEDULED OUTAGE REPORT			
CDRL No: F-1602000-F	Prepared By: Peter Blas	Month/Year: Jan. 2006	No. of Pages: 5
FREQUENCY: Monthly.			

- **Unscheduled Outage Report**
  - See attached (4 pages)

- **Scheduled Outage Report**
  - See attached (1 page)

ELECTRIC DISTRIBUTION LOG (UNSCHEDULED OUTAGES)

SEQUENTIAL LOG FOR 4.16, 13.8, 34.5 KV									RELAY TARGETS ACTION							MONTH: JANUARY YEAR: 2006
UO#	DATE	TIME			LOCATION			LOAD	OVER CURRENT					XFMER DIFF	OUTAGE CAUSE*	SPECIFIC CAUSE OF OUTAGE / COMMENTS
		LOSS (TRIP)	RETURN (CLOSE)	ELAPSED HOURS	BASE / SUBSTATION	CIRCUIT BREAKER	AREA CUT-OFF OR AFFECTED	KV	KF	A	B	C	GRD			
01	01/03/06	1301	1326	:25	CNM	ON P-14	BLDGS 1803/5545 AT KILO	.480							C4	480V BREAKER TRIPPED ON OVERCURRENT.
02	01/04/06	1022	1141	1:19	CNM	ON P-14	BLDGS 1803/5545 AT KILO	.480							C4	480V BREAKER TRIPPED ON OVERCURRENT.
03	01/07/06	1318	1649	3:31	AAFB	ON P-91	CT-77/CT-78 CAPEHART HSG	13.8							D7	P-91-16P SWITCH FLASHED OVER AT CL-7.
04	01/07/06	1915	2159	2:44	CNM	ON P-134	#25/27/29/31 FERN ST, SOUTH TIP. HSG	13.8							C1	DEFECTIVE CUT-OUT ASSEMBLY ON POLE J6-37-74-6
05	01/08/06	0858	0952	:54	AAFB	P-91	CAPEHART HSG AND PARTIAL OF ROBERTS TERRACE HSG	13.8							D7	BUSS FLASHED OVER AT CL-7 SWITCHGEAR.
	01/08/06	0858	1655	6:57	AAFB	ON P-91	CT-77/CT-78 CAPEHART HSG.	13.8							D7	BUSS FLASHED OVER AT CL-7 SWITCHGEAR.
06	01/08/06	1534	1750	2:16	CNM	ON P-134	BLDG 529 CAMP COVINGTON	13.8							D5	SNAKE CAUSED FUSES TO BLOW ON POLE #JG-26-2.
07	01/09/06	1103	1515	4:12	CNM	ON P-134	#1, 3, 5, 7 JASMIN AND #2, 4, 6, 8 CARNATION, SOUTH TIP HSG	13.8							C1	TRANSFORMER SECONDARY WIRE BURNT ON POLE #JG-37-74-9-1.
08	01/10/06	1954	2215	2:21	CNM	ON P-129	#15/17/19/21/23/25 NORTH COLUMBUS, NORTH TIP.	13.8							C1	BLOWN FUSE ON POLE NT-29-2.
	01/11/06	1000	1044	:44	AAFB	ON P-67	BLDG 1625 CDC	13.8							D7	BLOWN FUSES AT SWITCHGEAR.
09	01/12/06	1634	2003	3:29	SOUTH FIN	ON P-87	#21/22/23 ORCHID LANE	13.8							C1	SECONDARY TERMINAL BLOCK BURNT.
10	01/14/06	0210	0318	1:08	AAFB	P-91	CAPEHART AND PARTIAL OF ROBERTS TERRACE HSG	13.8							A2	GPA MEC GENS #8/9 TRIPPED.
10	01/14/06	0210	0320	1:10	AAFB	P-93	PARTIAL OF ROBERTS TERRACE HSG	13.8							A2	GPA MEC GENS #8/9 TRIPPED.
10	01/14/06	0210	0343	1:33	COLD STORAGE	P-134	OLD/NEW APRA HSG, APRA DODEA AND CAMP COVINGTON	13.8							A2	GPA MEC GENS #8/9 TRIPPED.

*LEGEND: A1: LOAD SHEDDING; A2: GENERATOR TRIP; B1: STORM; B2: LIGHTNING; B3: EARTHQUAKE; C1: LINE; C2: TRANSFORMER; C3: RELAY; C4: BREAKER; D1: HUMAN ERROR; D2: VEHICLE ACCIDENT; D3: UNKNOWN; D4: TREE; D5: SNAKE; D6: GPA POWER SURGE; D7: OTHER

ELECTRIC DISTRIBUTION LOG (UNSCHEDULED OUTAGES)

SEQUENTIAL LOG FOR 4.16, 13.8, 34.5 KV | RELAY TARGETS ACTION | MONTH: JANUARY YEAR: 2006

UO#	DATE	TIME LOSS (TRIP)	TIME RETURN (CLOSE)	TIME ELAPSED HOURS	LOCATION BASE / SUBSTATION	LOCATION CIRCUIT BREAKER	LOCATION AREA CUT-OFF OR AFFECTED	LOAD KV	OVER CURRENT KF	OVER CURRENT A	OVER CURRENT B	OVER CURRENT C	OVER CURRENT GRD	XFMER DIFF	OUTAGE CAUSE*	SPECIFIC CAUSE OF OUTAGE / COMMENTS
11	01/14/06	2013	2306	2:51	OROTE/COLD STORAGE	T-11 T-12 T-13 T-132	OROTE AND COLD STORAGE SUBSTATIONS	13.8							C4	GPA X-20/X-21/X-36 BREAKERS TRIPPED.
11	01/14/06	2013	2231	2:18	OROTE	P-25	USS CORPUS CHRISTI AND USS FRANK CABLE	13.8							C4	GPA X-20/X21/X-36 BREAKERS TRIPPED.
11	01/14/06	2013	2232	2:19	OROTE	P-128	HARBOR/BAYVIEW HSG	13.8							C4	GPA X-20/X21/X-36 BREAKERS TRIPPED.
11	01/14/06	2013	2233	2:20	OROTE	P-130	BLDGS. 3190/3191 AND SIERRA #1/2/ROMEO PIERS	13.8							C4	GPA X-20/X21/X-36 BREAKERS TRIPPED.
11	01/14/06	2013	2234	2:21	OROTE	P-17	SEWAGE TREATMENT PLT/BARRACKS COMPLEX, CLUB RUMORS, BOWLING, SLS-16, MAINT. COMP, SUMAY MARINA, PORT OPS AND GSY	4.16							C4	GPA X-20/X21/X-36 BREAKERS TRIPPED.
11	01/14/06	2013	2235	2:22	OROTE	P-115	BARRACKS #14/15	13.8							C4	GPA X-20/X21/X-36 BREAKERS TRIPPED.
11	01/14/06	2013	2236	2:23	OROTE	P-14	VICTOR #2 SUB, BLDGS 3179/3180/2118, SEALS/MSC/MSF/EOD COMPOUNDS, GSY, SLS-21, DENTAL CLINIC AND KILO PIER	13.8							C4	GPA X-20/X21/X-36 BREAKERS TRIPPED.
11	01/14/06	2013	2237	2:24	OROTE	P-16	McDONALDS, NEX AUTOPORT, GARAGE, NEX COMPLEX AND COMMISSARY	13.8							C4	GPA X-20/X21/X-36 BREAKERS TRIPPED.
11	01/14/06	2013	2254	2:41	OROTE	P-129	COAST GUARD/SECURITY/NAVFAC ADMIN COMPOUND, PASS/ID, MAIN GATE, LOCKWOOD/NORTH TIP HSG, CHAPEL, CDC, GYM, THEATER, OROTE TELEX, USDA, BOQ/BEQ, SLS-14/17/23, DRMO AND TRANSPORTATION	13.8							C4	GPA X-20/X21/X-36 BREAKERS TRIPPED.

*LEGEND: A1: LOAD SHEDDING; A2: GENERATOR TRIP; B1: STORM; B2: LIGHTNING; B3: EARTHQUAKE; C1: LINE; C2: TRANSFORMER; C3: RELAY; C4: BREAKER; D1: HUMAN ERROR; D2: VEHICLE ACCIDENT; D3: UNKNOWN; D4: TREE; D5: SNAKE; D6: GPA POWER SURGE; D7: OTHER

ELECTRIC DISTRIBUTION LOG (UNSCHEDULED OUTAGES)

SEQUENTIAL LOG FOR 4.16, 13.8, 34.5 KV — RELAY TARGETS ACTION — MONTH: JANUARY YEAR: 2006

UO#	DATE	TIME: LOSS (TRIP)	TIME: RETURN (CLOSE)	TIME: ELAPSED HOURS	LOCATION: BASE / SUBSTATION	LOCATION: CIRCUIT BREAKER	LOCATION: AREA CUT-OFF OR AFFECTED	LOAD KV	OVER CURRENT: KF	OVER CURRENT: A	OVER CURRENT: B	OVER CURRENT: C	OVER CURRENT: GRD	XFMER DIFF	OUTAGE CAUSE*	SPECIFIC CAUSE OF OUTAGE / COMMENTS
11	01/14/06	2013	2300	2:47	OROTE	X-34	US COAST GUARD SHIPS	34.5							C4	GPA X-20/X-21/X-36 BREAKERS TRIPPED.
11	01/14/06	2013	2300	2:47	COLD STORAGE	P-133	WHSE #6 BLDG 3202, COLD STORAGE PLANT/BATTERY LOCKER	13.8							C4	GPA X-20/X-21/X-36 BREAKERS TRIPPED.
11	01/14/06	2013	2306	2:51	COLD STORAGE	P-134	CAMP COVINGTON, SOUTH TIP HSG, OLD/NEW APRA HSG AND APRA DODEA	13.8							C4	GPA X-20/X-21/X-36 BREAKERS TRIPPED.
12	01/16/06	1515	1715	2:00	CNM	ON P-16	BLDG 701 NEX AUTO-PORT	13.8							C1	DEFECTIVE CUT-OUT ASSEMBLY ON POLE JH-18-17-1.
13	01/17/06	0724	0831	1:07	CNM	ON F-5	DZSP21 MAINT. COMPOUND	4.16							C1	SECONDARY LINE SHORTED OUT AT BLDG 1767.
14	01/17/06	1448	1539	:51	NIMITZ HILL	ON P-137	SEWER LIFT STA #4	13.8							D5	SNAKE ON POLE KC-21-5A.
15	01/17/06	2236	0104	2:28	ANIGUA	P-282	NRMC AREA EXCEPT NEX BLDGS. NAVHOSP/BLR ON GENERATOR POWER	13.8							D6	GPA ANIGUA SUBSTATION TRIPPED.
16	01/18/06	1304	1332	:18	COLD STORAGE	P-134	CAMP COVINGTON, SOUTH TIP HSG, OLD/NEW APRA HSG AND APRA DODEA	13.8							A2	GPA CABRAS GENERATOR #3 TRIPPED.
16	01/18/06	1304	1336	:32	AAFB	P-91	CAPEHART HSG AND PARTIAL OF ROBERTS TERRACE HSG	13.8							A2	GPA CABRAS GENERATOR #3 TRIPPED.
17	01/18/06	1934	2132	1:58	NCTS	F-3	WATER SOFTENER PLANT/ELEVATED TANK, NEX BLDGS, BARRACKS, CHAPEL AND PARTIAL HSG	4.16							C1	FOUND LOOSE PRIMARY JUMPER ON POLE # F5-11.
18	01/19/06	1316	1347	:31	NIMITZ HILL	P-136	DODEA HIGH SCHOOL ON GENERATOR POWER	13.8							D4	COCONUT LEAVES STRUCK POWER LINE.
19	01/19/06	1712	1933	2:21	NCTS	F-3	WATER SOFTENER PLANT/ELEVATED TANK, NEX BLDGS, BARRACKS, CHAPEL AND PARTIAL HSG	4.16					T		C1	DEFECTIVE CUT-OUT ASSEMBLY ON H-FRAME.
20	01/21/06	1139	1310	1:31	MARBO	ON P-51	AIR FORCE WELLS #7/8	13.8							C1	DEFECTIVE CUT-OUT ASSEMBLY ON POLES #MA-2-1/MA-6.

*LEGEND: A1: LOAD SHEDDING; A2: GENERATOR TRIP; B1: STORM; B2: LIGHTNING; B3: EARTHQUAKE; C1: LINE; C2: TRANSFORMER; C3: RELAY; C4: BREAKER; D1: HUMAN ERROR; D2: VEHICLE ACCIDENT; D3: UNKNOWN; D4: TREE; D5: SNAKE; D6: GPA POWER SURGE; D7: OTHER

ELECTRIC DISTRIBUTION LOG (UNSCHEDULED OUTAGES)

SEQUENTIAL LOG FOR 4.16, 13.8, 34.5 KV									RELAY TARGETS ACTION							MONTH: JANUARY YEAR: 2006
UO#	DATE	TIME			LOCATION			LOAD	OVER CURRENT					XFMER DIFF	OUTAGE CAUSE*	SPECIFIC CAUSE OF OUTAGE / COMMENTS
		LOSS (TRIP)	RETURN (CLOSE)	ELAPSED HOURS	BASE / SUBSTATION	CIRCUIT BREAKER	AREA CUT-OFF OR AFFECTED	KV	KF	A	B	C	GRD			
21	01/21/06	1637	1845	2:08	AAFB	P-91	CAPEHART HSG AND PARTIAL OF ROBERTS TERRACE HSG	13.8					T		D7	CL-14 FLASHED OVER.
22	01/24/06	0928	1304	3:36	NCTS	ON F-3	NEX BLDGS 206/207	4.16							C1	DEFECTIVE INSULATORS ON POLES FS-9-FS-93.
23	01/24/06	1438	1613	1:35	AAFB	ON P-68	BLDG 21001 POST OFFICE	13.8							C1	BLOWN FUSE IN MH-168-1/P-65-45.
24	01/25/06	0946	1115	1:29	NCTS	ON F-2	McDONALDS BLDGS 111/492/134/338	4.16							C1	DEFECTIVE CUT-OUT ASSEMBLY ON H-FRAME.
25	01/28/06	1218	1740	5:22	AAFB	ON P-65	BLDG 25014 CHILLER PLANT	13.8							D7	CAT CAUSED THE TRANSFORMER SWITCHGEAR TO FLASH OVER.
26	1/30/06	1714	1905	1:51	COLD STORAGE	T-132	COLD STORAGE SUB.	13.8							C1	GPA X-20/X-35 LINE TRIPPED.
26	1/30/06	1714	1909	1:55	COLD STORAGE	P-134	CAMP COVINGTON, OLD/NEW APRA, SOUTH TIP HSG, APRA DODEA, CNM BACK GATE, LANDFILL	13.8							C1	GPA X-20/X-35 LINE TRIPPED.
26	1/30/06	1714	1911	1:57	COLD STORAGE	P-133	BLDG. 3202 WHSE #6, COLD STORAGE PLANT/BATTERY LOCKER	13.8							C1	GPA X-20/X-35 LINE TRIPPED.

*LEGEND: A1: LOAD SHEDDING; A2: GENERATOR TRIP; B1: STORM; B2: LIGHTNING; B3: EARTHQUAKE; C1: LINE; C2: TRANSFORMER; C3: RELAY; C4: BREAKER; D1: HUMAN ERROR; D2: VEHICLE ACCIDENT; D3: UNKNOWN; D4: TREE; D5: SNAKE; D6: GPA POWER SURGE; D7: OTHER

SET®

S.E.T. – Pacific, Inc.

DOCUMENT TRANSMITTAL FORM

CUSTOMER: DZSP 21
FACILITY: Electrical, Steam, Hot Water & Demin Water
LOCATION: Guam Naval Facilities

LOG #: 2565
SET Contract No: SUB-000002
ISSUE CODE:
DATE: March 02, 2006

TO: DZSP 21
P.O. Box GH
Agana, Guam 96932
ATTENTION: Mr. Wally Toma, Subcontract Administrator

We are sending you: X Attached __Under Separate Cover via:______________the: __Shop Drawings

__Prints __Samples __Specifications __Reports __Inspections __Test Schedules __Copy of Letter

__Change Order __Constr.Progress Chart/Schedule __Payment Estimate X As Stated ______________

Copies	Reference No.	Category Type	Description and Purpose
1	Annex 1602	CDRL No. F-1602000-F	Power System Dispatcher's Unscheduled and Scheduled Outage Reports – Feb. 2006 (5 pages)

Name of: Subcontractor, Supplier/Manufacturer ______________________________

__For Approval __Approved as Submitted __Resubmit __copies for approval X For Your Use

__Approved as Noted __Submit __copies for distribution X As Requested __Returned for Corrections

__Return __corrected prints __For Review and Comment __Other: ______________________

I certify that the attached information is ready for execution and that the attached information complies with the requirements of the contract documents.

By: Jay D. Miller [signature] Mar. 02, 2006
Jay D. Miller, President

Systems,
Energy &
Technologies, Inc.

S.E.T. – Pacific, Inc.

POWER SYSTEM DISPATCHER'S UNSCHEDULED AND SCHEDULED OUTAGE REPORT			
CDRL No: F-1602000-F	Prepared By: Peter Blas	Month/Year Feb. 2006	No. of Pages: 4
FREQUENCY: Monthly.			

- **Unscheduled Outage Report**
  - See attached (3 pages)
- **Scheduled Outage Report**
  - See attached (1 page)

S.E.T. – Pacific, Inc.
CDRL F-1602000-F

ELECTRIC DISTRIBUTION LOG (UNSCHEDULED OUTAGES)

SEQUENTIAL LOG FOR 4.16, 13.8, 34.5 KV									RELAY TARGETS ACTION							MONTH: FEBRUARY YEAR: 2006
UO#	DATE	TIME			LOCATION			LOAD	OVER CURRENT					XFMER DIFF	OUTAGE CAUSE*	SPECIFIC CAUSE OF OUTAGE / COMMENTS
		LOSS (TRIP)	RETURN (CLOSE)	ELAPSED HOURS	BASE / SUBSTATION	CIRCUIT BREAKER	AREA CUT-OFF OR AFFECTED	KV	KF	A	B	C	GRD			
27	02/02/06	1008	1300	2:52	AAFB	ON P-82	BLDG 19009 WATER TREATMENT PLANT	13.8							C2	DEFECTIVE 25 KVA PAD-MOUNTED TRANSFORMER TO BLDG. 19006.
27	02/02/06 – 02/07/06	1008	1543	5 DAYS 5:35	AAFB	ON P-82	BLDG 19008 WATER TOWER	13.8							C2	DEFECTIVE 25 KVA PAD-MOUNTED TRANSFORMER TO BLDG. 19006.
28	02/02/06 – 02/03/06	2346	0135	1:49	COLD STORAGE	T-132	COLD STORAGE PLANT, WHSE#5, APRA DODEA/MINI-MART, LANDFILL, BACK GATE, CAMP COVINGTON, OLD/NEW APRA AND SOUTH TIP. HSG.	13.8							C1	GPA X-20/X-35 LINE TRIPPED.
29	02/03/06	0412	0609	1:57	COLD STORAGE	T-132	COLD STORAGE PLANT, WHSE#5, APRA DODEA/MINI-MART, LANDFILL, BACK GATE, CAMP COVINGTON, OLD/	13.8							C1	GPA X-20/X-35 LINE TRIPPED.
30	02/04/06	0051	0254	2:03	RADIO BARR/MARBO	P-142/T-14	RADIO BARR. GOLF COURSE, WELLS 3/4/8, ARMY RESERVE, MARBO WELLS/BOOSTER PUMPS, AIR FORCE WHSE	13.8							C1	DOWNED PRIMARY LINE ON GPA P-213 CIRCUIT.
31	02/06/06	0806	1039	2:33	NCTS 4 KV	T-47	McDONALDS, MAIN GATE, ADMIN, GYM, NEX BLDGS, CHAPEL, HOUSING/BARRACKS, WATER TOWER/SOFTENER PLANT	4.16							C1	GPA X-87/X-73 CIRCUIT BREAKER TRIPPED DUE TO A DEFECTIVE 34.5 KV CONNECTION.
32	02/07/06	0830	1615	7:45	AAFB	ON P-94	BLDG 9034 MSA-1	13.8							C1	DEFECTIVE LIGHTNING ARRESTOR ON POLE NB-133.
33	02/07/06 – 02/09/06	1310	1754	1 DAY 4:44	CNM	ON P-14	BLDG 6010 MSC MEDICAL SUPPLY BLDG	SEC.							D1	J.L. BAKER & SONS TRACTOR TRAILER DAMAGED THE SECONDARY LINE FEEDING BLDG 6010.
34	02/07/06 – 02/08/06	1816	2149	3:33	AAFB	ON P-94	BLDG 9008 MSA-1	13.8							C1	BLOWN LIGHTNING ARRESTOR ON POLE NB-123.
35	02/10/06	0401	0625	2:24	COLD STORAGE	P-134	CAMP COVINGTON, OLD/NEW APRA AND LANDFILL, CNM BACK GATE, SOUTH TIP HS, APRA DODEA/MINI-MART	13.8					T		D4	TREE BRANCHES TOUCHED PRIMARY LINE DURING HIGH WINDS AT QTRS. 34/38 CABRAS, OLD APRA HSG.

*LEGEND: A1: LOAD SHEDDING A2: GENERATOR TRIP B1: STORM B2: LIGHTNING B3: EARTHQUAKE C1: LINE C2: TRANSFORMER C3: RELAY
C4: BREAKER D1: HUMAN ERROR D2: VEHICLE ACCIDENT B3: UNKNOWN D4: TREE D5: SNAKE D6: GPA POWER SURGE D7: OTHER

Electric Distribution Log (Unscheduled Outages)

SEQUENTIAL LOG FOR 4.16, 13.8, 34.5 KV — RELAY TARGETS ACTION — MONTH: FEBRUARY YEAR: 2006

UO#	Date	Time			Location			Load	Over Current					XFMER DIFF	Outage Cause*	Specific Cause of Outage / Comments
		Loss (Trip)	Return (Close)	Elapsed Hours	Base / Substation	Circuit Breaker	Area Cut-Off or Affected	KV	KF	A	B	C	GRD			
35	02/10/06	0401	1020	6:19	CAMP COVINGTON	ON P-134	BLDGS 542/546/548	13.8							C1	BLOWN FUSE ON POLE JG-37-8-1-2.
36	02/10/06	1031	1049	:18	AAFB	P-91	CAPEHART HSG AND PARTIAL OF ROBERTS TERRACE HSG	13.8	√						A2	GPA MEC GEN. #8 TRIPPED.
36	02/10/06	1031	1051	:20	COLD STORAGE	P-134	CAMP COVINGTON, OLD/NEW APRA AND LANDFILL, CNM BACK GATE, SOUTH TIP HS, APRA DODEA/MINI-MART	13.8	√						A2	GPA MEC GEN. #8 TRIPPED.
37	02/11/06	0943	1034	:51	POTTS JCT	P-110	AIR FORCE MMS AREA, GTA, GAME OFFICE, DET-5, COAST/GEODETIC SURVEY	13.8			I	I			D1	BUCKET TRUCK BOOM MADE CONTACT WITH 2 PRIMARY LINES.
38	02/16/06 – 02/17/06	2253	0122	2:29	CNM	ON P-129	SOUTH TIP HSG	13.8							C1	DOWNED PRIMARY LINE CAUSED BY BURNT SADDLE (ALUMINUM/COPPER CONNECTOR).
39	02/17/06	0938	1030	:52	POLARIS PT	ON P-2	CONCESSION GROUNDS SITE 3	SEC.							C1	DEFECTIVE CONNECTION ON SECONDARY SPLIT BOLT AT TRANSFORMER.
40	02/17/06	1917	2207	2:50	CNM	ON P-129	BLDG 2016 SWIMMING POOL	SEC.							D1	THE MOTOR VOLTAGE RATING THAT WAS INSTALLED DID NOT MATCH THE POWER SOURCE.
41	02/17/06	-	-	-	POLARIS PT	ON P-25	ARCHING ON POLE KD-58-40	13.8							D7	SALT SPRAY CAUSED THE OUTAGE.
42	02/17/05	2207	2245	:38	POLARIS PT	ON P-25	USS CITY OF CORPUS CHRISTI	.480							C1	GPA X-21/X-31 LINE TRIPPED.
43	02/18/06	1632	1751	1:19	NIMITZ HILL	P-137	TOP O'THE MAR, LIFT STA. #4, BOQ, FLAG CIRCLE, TURNER/SHERMAN HSG, ADELUP RESERVOIR AND DODEA GYM	13.8		T	T				C1	BROKEN DEAD END BELL ON POLE KC-15.
44	02/20/06	2135	2348	2:13	AAFB	P-91	CAPEHART HSG AND PARTIAL OF ROBERTS TERRACE HSG	13.8	√						A2	GPA CABRAS GENERATOR #2 TRIPPED.

*LEGEND: A1: LOAD SHEDDING; C4: BREAKER; A2: GENERATOR TRIP; D1: HUMAN ERROR; B1: STORM; D2: VEHICLE ACCIDENT; B2: LIGHTNING; D3: UNKNOWN; B3: EARTHQUAKE; D4: TREE; C1: LINE; D5: SNAKE; C2: TRANSFORMER; D6: GPA POWER SURGE; C3: RELAY; D7: OTHER

Form SET-063 R0
Rev. 03/01/02

ELECTRIC DISTRIBUTION LOG (UNSCHEDULED OUTAGES)

SEQUENTIAL LOG FOR 4.16, 13.8, 34.5 KV									RELAY TARGETS ACTION								MONTH: FEBRUARY YEAR: 2006
		TIME			LOCATION			LOAD	OVER CURRENT								
UO#	DATE	LOSS (TRIP)	RETURN (CLOSE)	ELAPSED HOURS	BASE / SUBSTATION	CIRCUIT BREAKER	AREA CUT-OFF OR AFFECTED	KV	KF	A	B	C	GRD	XFMER DIFF	OUTAGE CAUSE*		SPECIFIC CAUSE OF OUTAGE / COMMENTS
44	02/20/06	2135	2314	1:39	COLD STORAGE	P-134	OLD/NEW APRA HSG, NAVMAG AREA, APRA DODEA/MINI-MART, PARTIAL OF CAMP COVINGTON	13.8	√						A2		GPA CABRAS GENERATOR #2 TRIPPED.
45	02/21/06	1600	1707	1:07	AAFB	P-65	CLINIC/MEDICAL BLDG, COMMISSARY, BARRACKS, CHILLER PLANT, EXCHANGE GLDGS, TROPICANA CLUB, GALLEY AND GYM	13.8			T				C1		DEFECTIVE UNDERGROUND SPLICE AT MH-148 WAS DONE BY BLACK CONSTRUCTION CO.
46	02/23/06	0740	1410	6:30	AAFB	ON P-94	SIRENA/PATI POINT BEACHES	13.8							C1		BROKEN DEAD END BELLS ON POLE NB-105-24.
47	02/24/06	2217	2337	1:20	MARBO	ON P-51	AIR FORCE WELLS #7/8	13.8							C1		BLOWN FUSE ON POLE MB-2-1.
48	02/25/06 – 02/26/06	2240	1044	12:04	AAFB	ON P-91	QTRS #1863/1865/1922/1924 DUPLEX PACIFICO, CAPEHART HSG	13.8							C2		DEFECTIVE 100 KVA PAD-MOUNTED TRANSFORMER CT-47 (LEAKING).
49	02/27/06	1224	1350	1:26	PITI	P-2	DELTA/ECHO, OSIR, LOWER/UPPER SASA, POLARIS PT, TENJO VISTA, REEFER VANS, OLD ARMY RESERVE, ATM AND GPA	13.8					T		D5		SNAKE AT POLE TOP SWITCH 13-29 LOWER SASA CAUSED THE OUTAGE.

*LEGEND: A1: LOAD SHEDDING; A2: GENERATOR TRIP; B1: STORM; B2: LIGHTNING; B3: EARTHQUAKE; C1: LINE; C2: TRANSFORMER; C3: RELAY; C4: BREAKER; D1: HUMAN ERROR; D2: VEHICLE ACCIDENT; D3: UNKNOWN; D4: TREE; D5: SNAKE; D6: GPA POWER SURGE; D7: OTHER

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S.E.T. – Pacific, Inc.

DOCUMENT TRANSMITTAL FORM

CUSTOMER: DZSP 21
FACILITY: Electrical, Steam, Hot Water & Demin Water
LOCATION: Guam Naval Facilities

LOG #: **2638**
SET Contract No: SUB-000002
ISSUE CODE:
DATE: April 03, 2006

TO: DZSP 21
P.O. Box GH
Agana, Guam 96932
ATTENTION: Mr. Wally Toma, Subcontract Administrator

We are sending you: X Attached _Under Separate Cover via:__________ the: __Shop Drawings

__Prints __Samples __Specifications __Reports __Inspections __Test Schedules __Copy of Letter

_Change Order __Constr.Progress Chart/Schedule __Payment Estimate X As Stated __________

Copies	Reference No.	Category Type	Description and Purpose
1	**Annex 1602**	**CDRL No. F-1602000-F**	**Unscheduled and Scheduled Outage Reports – Mar. 2006 (5 pages)**

Name of: Subcontractor, Supplier/Manufacturer __________

__For Approval __Approved as Submitted __Resubmit __copies for approval X For Your Use

__Approved as Noted __Submit __copies for distribution X As Requested __Returned for Corrections

__Return __corrected prints __For Review and Comment __Other: __________

I certify that the attached information is ready for execution and that the attached information complies with the requirements of the contract documents.

By: [signature] Apr. 03, 2006
Jay D. Miller, President

Systems,
Energy &
Technologies, Inc.

S.E.T. – Pacific, Inc.

UNSCHEDULED AND SCHEDULED OUTAGE REPORT			
CDRL No: F-1602000-F	Prepared By: Peter Blas	Month/Year: Mar. 2006	No. of Pages: 4
FREQUENCY: Monthly.			

- **Unscheduled Outage Report**
  - See attached (2 pages)

- **Scheduled Outage Report**
  - See attached (2 page)

Electric Distribution Log (Unscheduled Outages)

SEQUENTIAL LOG FOR 4.16, 13.8, 34.5 KV									RELAY TARGETS ACTION							MONTH: MARCH YEAR: 2006
UO#	Date	Time			Location			Load	Over Current					XFMER DIFF	Outage Cause*	Specific Cause of Outage / Comments
		Loss (Trip)	Return (Close)	Elapsed Hours	Base / Substation	Circuit Breaker	Area Cut-Off or Affected	KV	KF	A	B	C	GRD			
	03/04/06 – 03/05/06	2334	0016	:42	NCTS 4KV	T-47	McDONALD'S, MAIN GATE, ADMIN, HOUSING, BARRACKS, CHAPEL, NEX BLDGS, MESS, WATER SOFTENING PLT, GYM & CDC	4.16							C1	GPA "HOT SPOT" REPAIRS ON X-87/SW 34-63.
50	03/05/06	1504	1754	2:50	AAFB	P-93	PARTIAL OF CAPEHART AND ROBERTS TERRACE HSG.	13.8		I	I	I			D7	FLASHED OVER AT MH-214.
50	03/05/06	1504	2131	6:27	MH-214 AAFB	ON P-93	STATION TRANSFORMERS 7B & 8A	13.8							D7	FLASHED OVER AT MH-214.
51	03/10/06	0552	1727	1135	CAMP COVINGTON	ON P-134	BLDGS 556A-B, BLDG. 560	13.8							C1	SECONDARY AT TRANSFORMER GOING TO BLDG 560 WAS BURNED DUE TO OVERLOAD.
52	03/11/06	0010	0250	2:40	MARBO	ON P-51	AIR FORCE WELLS #7/8	13.8							C1	FUSE ON POLE #MA-2-1 WAS BLOWN.
53	03/11/06	0552	1829	12:37	MARBO	ON P-51	AIR FORCE WELLS #7/8	13.8							D7	TERMITES DAMAGED UNDERGROUND CABLE/SPLICE AT MH-1.
54	03/11/06	-	-	-	MARBO	ON P-51	AIR FORCE WELL #6	SEC.							D7	SECONDARY RELAY TRIPPED ON OVERLOAD.
	03/13/06	0216 0216	0452 0300	2:36 :44	POTTS JCT NCTS 4KV	T-110 T-47	POTTS JCT SUB (P-110) NCTS 4 KV SUB (F-2/F-3/F-4)	13.8 4KV							C1	GPA X-87/X-73 LINE TRIPPED.
	03/13/06	1308	1344	36	NCTS 4KV	T-47	NCTS 4KV SUB (F-2/F-3/F-4)	4KV							C1	X-87 WAS DE-ENERGIZED DUE TO DEFECTIVE POLE TOP SWITCH.
55	03/16/06	-	-	-	POTTS JCT	ON P-110	NONE	13.8							C1	DITCH TRENCHER HIT/DAMAGED OLD 15 KV UNDERGROUND CABLE (NOT IN USE).
56	03/17/06	1527	2147	6:20	PITI	ON P-2	ECHO PIER	13.8							C2	DEFECTIVE 100KVA TRANSFORMER ON POLE KD-13-49-1.
57	03/20/06	0148	0430	2:42	OROTE	ON P-16	BLDG 257 COMMISSARY	SEC.							C4	1700-AMP MAIN SECONDARY BREAKER TRIPPED.

*LEGEND: A1: LOAD SHEDDING; A2: GENERATOR TRIP; B1: STORM; B2: LIGHTNING; B3: EARTHQUAKE; C1: LINE; C2: TRANSFORMER; C3: RELAY; C4: BREAKER; D1: HUMAN ERROR; D2: VEHICLE ACCIDENT; D3: UNKNOWN; D4: TREE; D5: SNAKE; D6: GPA POWER SURGE; D7: OTHER

ELECTRIC DISTRIBUTION LOG (UNSCHEDULED OUTAGES)

SEQUENTIAL LOG FOR 4.16, 13.8, 34.5 KV									RELAY TARGETS ACTION							MONTH: MARCH YEAR: 2006
UO#	DATE	TIME			LOCATION			LOAD	OVER CURRENT					XFMER DIFF	OUTAGE CAUSE*	SPECIFIC CAUSE OF OUTAGE / COMMENTS
		LOSS (TRIP)	RETURN (CLOSE)	ELAPSED HOURS	BASE / SUBSTATION	CIRCUIT BREAKER	AREA CUT-OFF OR AFFECTED	KV	KF	A	B	C	GRD			
58	03/24/06	1058	1108	:10	COLD STORAGE	P-134	OLD/NEW APRA HSG, APRA DODEA/MINI-MART & PARTIAL OF CAMP COVINGTON	13.8	√						C4	THERE WERE PROBLEMS WITH GPA CABRAS GENERATORS #3/4.
59	03/24/06 – 03/25/06	1925	0402	8:37	AAFB	ON P-68	QTRS. #28132 TO 28135 FLEMING HTS.	13.8							C2	75KVA PAD-MOUNTED TRANSFORMER AT STA #16 WAS DEFECTIVE.
60	03/26/06	1315	1518	2:03	CNM	ON P-130	USS CHOSIN AT ROMEO	SEC.							C4	CIRCUIT BREAKERS #R-2A/R-2B/R-3C WOULD NOT CLOSE.
61	03/27/06	1543	1752	2:09	MARBO	ON P-51	AIR FORCE WELL #9	SEC.							C4	MAIN SECONDARY BREAKER TRIPPED.
62	03/29/06	0923			UPPER SASA	ON P-2	BLDG 1714	2.4							C2	POTENTIAL TRANSFORMER WAS DEFECTIVE.

*LEGEND: A1: LOAD SHEDDING; A2: GENERATOR TRIP; B1: STORM; B2: LIGHTNING; B3: EARTHQUAKE; C1: LINE; C2: TRANSFORMER; C3: RELAY; C4: BREAKER; D1: HUMAN ERROR; D2: VEHICLE ACCIDENT; D3: UNKNOWN; D4: TREE; D5: SNAKE; D6: GPA POWER SURGE; D7: OTHER

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S.E.T. – Pacific, Inc.

DOCUMENT TRANSMITTAL FORM

CUSTOMER: DZSP| 21
FACILITY: Bldg 104
LOCATION: Guam Naval Facilities

LOG #: **2713**
SET Contract No: SUB-000002
ISSUE CODE:
DATE: May 01, 2006

TO: DZSP 21
P.O. Box GH
Agana, Guam 96932
ATTENTION: Mr. Wally Toma, Subcontract Administrator

We are sending you: X Attached __Under Separate Cover via:______________the: __Shop Drawings

__Prints __Samples __Specifications __Reports __Inspections __Test Schedules __Copy of Letter

__Change Order __Constr.Progress Chart/Schedule __Payment Estimate X As Stated ________________

Copies	Reference No.	Category Type	Description and Purpose
1	**Annex 1602**	**CDRL No. F-1602000-F**	**Unscheduled and Scheduled Outage Reports – Apr. 2006 (6 pages)**

Name of: Subcontractor, Supplier/Manufacturer ____

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__Approved as Noted __Submit __copies for distribution X As Requested __Returned for Corrections

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I certify that the attached information is ready for execution and that the attached information complies with the requirements of the contract documents.

By: [signature] May 01, 2006
Jay D. Miller, President

Systems,
Energy &
Technologies, Inc.

S.E.T. – Pacific, Inc.

UNSCHEDULED AND SCHEDULED OUTAGE REPORT			
CDRL No: F-1602000-F	Prepared By: Peter Blas	Month/Year: Apr. 2006	No. of Pages: 5
FREQUENCY: Monthly.			

- **Unscheduled Outage Report**
  - See attached (3 pages)

- **Scheduled Outage Report**
  - See attached (2 pages)

ELECTRIC DISTRIBUTION LOG (UNSCHEDULED OUTAGES)

SEQUENTIAL LOG FOR 4.16, 13.8, 34.5 KV									RELAY TARGETS ACTION							MONTH: APRIL YEAR: 2006
UO#	DATE	TIME			LOCATION			LOAD	OVER CURRENT					XFMER DIFF	OUTAGE CAUSE*	SPECIFIC CAUSE OF OUTAGE / COMMENTS
		LOSS (TRIP)	RETURN (CLOSE)	ELAPSED HOURS	BASE / SUBSTATION	CIRCUIT BREAKER	AREA CUT-OFF OR AFFECTED	KV	KF	A	B	C	GRD			
63	04/01/06	0530	0758	2:28	COLD STORAGE	T-132	COLD STORAGE PLANT/WHSE, OLD/NEW APRA HSG, NAVMAG AREA, APRA DODEA/MINI-MART, PARTIAL OF CAMP COVINGTON	13.8							C2	GPA'S 34.5 KV PTS BURNT/X-22/X-37 LINE AND X-20 TO X-35 LINE TRIPPED.
64	04/03/06	1136	1438	3:02	RADIO BARR/MARBO	ON P-213	BLDGS 49/50/54/55/58/59, GOLF COURSE WELLS 3/4/8 AND MARBO WELLS	13.8							C1	GPA'S IN-LINE FUSE BLEW/CORRODED FUSE BARREL ON POLE LS-1-1.
65	04/06/06 – 04/07/06	1637	0155	9:18	AAFB	ON P-91	QTRS. #1954/1955 CAPEHART HSG.	13.8							C2	DEFECTIVE 50 KVA PAD-MOUNTED TRANSFORMER (CT-51).
66	04/06/06 – 04/07-06	2345	0130	1:45	ANIGUA	P-282	NRMC AREA (EXCEPT NEX BLDGS) HOSPITAL/BLR PLT ON GENERATOR	13.8							D7	BIRD ON POLE #KG-60 TRIPPED P-282 BREAKER AND BLEW 2 FUSES TO GATE BARRICADES.
67	04/08/06	0946	1010	:24	PITI	P-2	DELTA/ECHO PIERS, OSIR, LOWER/UPPER SASA, POLARIS PT., ALPHA/BRAVO PIERS, TENJO VISTA, ATM, REEFER VANS, OLD ARMY RESERVE	13.8							D7	BIRD ON POLE #KD-58-39 TRIPPED P-2 BREAKER.
68	04/10/06	2215	2259	:44	COLD STORAGE	P-134	OLD/NEW APRA HSG, APRA DODEA/MINI-MART, NAVMAG, PARTIAL CAMP COVINGTON	13.8	√						C1	GPA 115KV LINE (CABRAS TO AGANA) TRIPPED.
68	04/10/06 – 04/11/06	2215	0039	2:24	AAFB	P-91	CAPEHART HSG AND PARTIAL OF ROBERTS TERRACE HSG.	13.8	√						C1	GPA 115KV LINE (CABRAS TO AGANA) TRIPPED.
69	04/12/06	2024	2231	2:07	AAFB	ON P-93	QTRS. AT PONAPE/PARADISE LANE ON STA. #8 ROBERTS TERRACE HSG	13.8							D7	FLASH-OVER AT MH-214/STA #8.
70	04/19/06 – 04/21/06	1634	1727	2 DAYS :53	AAFB	P-98	MSA II/TACAN AREA	13.8							C1	DEFECTIVE Y-SPLICE AT MH-23.
71	04/19/06	1728	-	-	MARBO	ON P-51	AIR FORCE WELLS #5-9	SEC.							C2	HIGH VOLTAGE ON GPA T-55 TRANSFORMER AT DEDEDO.

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ELECTRIC DISTRIBUTION LOG (UNSCHEDULED OUTAGES)

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		LOSS (TRIP)	RETURN (CLOSE)	ELAPSED HOURS	BASE / SUBSTATION	CIRCUIT BREAKER	AREA CUT-OFF OR AFFECTED	KV	KF	A	B	C	GRD			
72	04/19/06	2204	2347	1:43	POTTS JCT	P-110	COAST/GEODETIC SURVEY, DET-5, GTA, GAME OFFICE, MMS-1 COMPOUND	13.8							D3	NO VISIBLE CAUSE FOUND.
73	04/20/06	0613	0654	:41	AAFB	P-91	CAPEHART HSG AND PARTIAL OF ROBERTS	13.8	√						A2	GPA CABRAS GENERATOR #3 TRIPPED.
73	04/20/06	0613	0717	1:04	COLD STORAGE	P-134	OLD/NEW APRA HSG, DODEA, NAVMAG PARTIAL OF CAMP COVINGTON	13.8	√						A2	GPA CABRAS GENERATOR #3 TRIPPED.
74	04/20/06	0739	1010	2:31	CNM	ON P-14	BLDG 267	13.8							C1	LOOSE PRIMARY JUMPERS ON POLE # FE-7.
75	04/23/06	0850	1000	1:10	ANIGUA	P-282	CHAPEL, CDC, WELLS #1-2-3, HSG, SLS-3, POOL, FAMILY CENTER, GYM, NAVHOSP, NURSES QTRS., MAIN GATE	13.8							C4	GPA P-282/P-283 BREAKERS TRIPPED.
	04/25/06	1942	2354	3:12	HARMON/AAFB	X-87/X-73	4KV NCTS SUBSTATION POTTS-JCT SUBSTA.	4.16 13.8							C1	DEFECTIVE DEAD-END BELL ON GPA X-87/X-73 LINE.
	04/25/06	2225	2302	:37	AAFB	P-94	GTA, CIV GAS STA, POL, LOX PLANT, HC-5/MSA-1/MSA-2/TARAGUE AREA	13.8							C1	DEFECTIVE DEAD-END BELL ON GPA X-87/X-73 LINE.
	04/27/06	1116	1617	5:01	DEDEDO	P-87	SOUTH FIN HSG AREA	13.8							C1	DEFECTIVE UG ON GPA P-87 CIRCUIT.
76	04/28/06	1054	1327	2:33	NCTS	F-3	NEX BLDGS, CHAPEL, BARRACKS, CDC, WATER SOFTENING PLT, PARTIAL OF HSG	4.16					T		D3	NO VISIBLE CAUSE FOUND.
77	04/28/06	1102	1116	:14	COLD STORAGE	P-134	OLD/NEW APRA HSG, APRA DODEA/MINI-MART, NAVMAG, PARTIAL CAMP COVINGTON	13.8	√						A2	GPA DEDEDO GAS TURBINE TRIPPED.
78	04/30/06	0926	1648	7:22	CNM	ON P-129	QTRS. #2246A OROTE PT RD, LOCKWOOD HSG	SEC.							C4	DEFECTIVE MAIN SECONDARY BREAKER.

*LEGEND: A1: LOAD SHEDDING A2: GENERATOR TRIP B1: STORM B2: LIGHTNING B3: EARTHQUAKE C1: LINE C2: TRANSFORMER C3: RELAY
C4: BREAKER D1: HUMAN ERROR D2: VEHICLE ACCIDENT D3: UNKNOWN D4: TREE D5: SNAKE D6: GPA POWER SURGE D7: OTHER

ELECTRIC DISTRIBUTION LOG (UNSCHEDULED OUTAGES)

SEQUENTIAL LOG FOR 4.16, 13.8, 34.5 KV — RELAY TARGETS ACTION — MONTH: APRIL YEAR: 2006

UO#	DATE	TIME			LOCATION			LOAD	OVER CURRENT					XFMER DIFF	OUTAGE CAUSE*	SPECIFIC CAUSE OF OUTAGE / COMMENTS
		LOSS (TRIP)	RETURN (CLOSE)	ELAPSED HOURS	BASE / SUBSTATION	CIRCUIT BREAKER	AREA CUT-OFF OR AFFECTED	KV	KF	A	B	C	GRD			
79	04/30/06 – 05/01/06	2330	0144	2:14	POTTS JCT	P-110	COAST/GEODETIC SURVEY, DET-5, GTA, GAME OFFICE, MMS-1 COMPOUND	13.8				I			C1	BROKEN DEAD-END BELLS ON POLES NG-72-3/72-4.

*LEGEND: A1: LOAD SHEDDING; A2: GENERATOR TRIP; B1: STORM; B2: LIGHTNING; B3: EARTHQUAKE; C1: LINE; C2: TRANSFORMER; C3: RELAY; C4: BREAKER; D1: HUMAN ERROR; D2: VEHICLE ACCIDENT; D3: UNKNOWN; D4: TREE; D5: SNAKE; D6: GPA POWER SURGE; D7: OTHER

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S.E.T. – Pacific, Inc.

DOCUMENT TRANSMITTAL FORM

CUSTOMER: DZSP| 21
FACILITY: Bldg 104
LOCATION: Guam Naval Facilities

LOG #: **2792**
SET Contract No: SUB-000002
ISSUE CODE:
DATE: June 05, 2006

TO: DZSP 21
P.O. Box GH
Agana, Guam 96932
ATTENTION: Mr. Wally Toma, Subcontract Administrator

We are sending you: X Attached __Under Separate Cover via:__________the: __Shop Drawings

__Prints __Samples __Specifications __Reports __Inspections __Test Schedules __Copy of Letter

__Change Order __Constr.Progress Chart/Schedule __Payment Estimate X As Stated __________

Copies	Reference No.	Category Type	Description and Purpose
1	**Annex 1602**	**CDRL No. F-1602000-F**	**Unscheduled and Scheduled Outage Reports – May. 2006 (5 pages)**

Name of: Subcontractor, Supplier/Manufacturer __________

__For Approval __Approved as Submitted __Resubmit __copies for approval X For Your Use

__Approved as Noted __Submit __copies for distribution X As Requested __Returned for Corrections

__Return __corrected prints __For Review and Comment __Other: __________

I certify that the attached information is ready for execution and that the attached information complies with the requirements of the contract documents.

By: [signature] June 05, 2006
Jay D. Miller, President

Systems,
Energy &
Technologies, Inc.

S.E.T. – Pacific, Inc.

UNSCHEDULED AND SCHEDULED OUTAGE REPORT			
CDRL No: F-1602000-F	Prepared By: Peter Blas	Month/Year: May 2006	No. of Pages: 4
FREQUENCY: Monthly.			

- **Unscheduled Outage Report**
  - See attached (2 pages)

- **Scheduled Outage Report**
  - See attached (2 pages)

ELECTRIC DISTRIBUTION LOG (UNSCHEDULED OUTAGES)

SEQUENTIAL LOG FOR 4.16, 13.8, 34.5 KV									RELAY TARGETS ACTION							MONTH: MAY YEAR: 2006
UO#	DATE	TIME			LOCATION			LOAD	OVER CURRENT					XFMER DIFF	OUTAGE CAUSE*	SPECIFIC CAUSE OF OUTAGE / COMMENTS
		LOSS (TRIP)	RETURN (CLOSE)	ELAPSED HOURS	BASE / SUBSTATION	CIRCUIT BREAKER	AREA CUT-OFF OR AFFECTED	KV	KF	A	B	C	GRD			
80	05/02/06	1842	1938	:51	NCTS	ON F-3	BLDG 303 AUTO-PORT	SEC.							D1	FALSE REPORT; FOUND BLDG STILL HAS POWER.
81	05/02/06	1419	1438	:19	COLD STORAGE	P-134	OLD/NEW APRA HSG, APRA DODEA/MINI-MART, NAVMAG, PARTIAL CAMP COVINGTON	13.8	√						A2	GPA MEC GENERATOR #8 TRIPPED.
	05/02/06	1450	-	-	DEDEDO	P-87	SOUTH FIN. HSG.	13.8							D6	GPA DEDEDO SUBSTATION LOST POWER.
	05/02/06	1450	-	-	DEDEDO	P-89	AIR FORCE WELLS 1-2-3-5-6-7-8-9, BOOSTER PUMPS 1-2-3	13.8							D6	GPA DEDEDO SUBSTATION LOST POWER.
	05/02/06	1909	-	-	DEDEDO	P-89	AIR FORCE WELLS 1-2-3-5-6-7-8-9, BOOSTER PUMPS 1-2-3	13.8							C4	GPA P-89 BREAKER TRIPPED.
	05/02/06	2029	-	-	HARMON/DEDEDO	X-88/X-151/154	USNS SUMNER AT SIERRA 2	SEC.							D6	GPA X-88 TO X-151/154 LINE TRIPPED.
82	05/02/06	1842	2000	1:18	NCTS	ON F-3	BLDG 303 AUTO-PORT	SEC.							D1	FALSE REPORT; FOUND BLDG STILL HAS POWER.
83	05/06/06	1805	2048	2:43	AAFB	ON P-93	QTRS AT PARADISE/PONAPE AVE. ROBERTS TERRACE HSG	13.8							D7	FLASHOVER AT MH-214/STN. #8.
84	05/09/06	0950	1159	2:09	AAFB	ON P-93	QTRS AT PARADISE/PONAPE AVE. ROBERTS TERRACE HSG	13.8							D7	DEFECTIVE TERMINATOR AT MH-2H/STN #8.
85	05/11/06	0600	1557	9:57	HARMON	T-22	P-48: WELLS A, 2, 5, TEL HUT P-114: NCTS BLDG 309 ON GEN.	13.8							D7	RAT SHORTED OUT T-22 BREAKER.
86	05/13/06	1434	1621	1:48	ALPHA PIER	ON P-25	USS FRANK CABLE	SEC.							D1	CUSTOMER OVERLOADED A2-2 BREAKER.
87	05/16/06	0120	0750	6:30	SOUTH FIN.	ON P-87	PARTIAL OF SOUTH FIN HSG	13.8							C1	DEFECTIVE PRIMARY UG CABLE (T-8A/T-11A).
88	05/16/06	1511	1538	:27	AAFB	P-93	PARTIAL OF ROBERTS TERRACE HSG.	13.8	√						C1	GPA X-87/X-73 LINE TRIPPED.
89	05/16/06	2050	2228	1:38	AAFB	ON P-93	QTRS AT PARADISE/PONAPE AVE. ROBERTS TERRACE HSG	13.8							D3	BLOWN FUSE AT MH-214/STN #7B; FOUND NO VISIBLE CAUSE.

*LEGEND: A1: LOAD SHEDDING; A2: GENERATOR TRIP; B1: STORM; B2: LIGHTNING; B3: EARTHQUAKE; C1: LINE; C2: TRANSFORMER; C3: RELAY; C4: BREAKER; D1: HUMAN ERROR; D2: VEHICLE ACCIDENT; D3: UNKNOWN; D4: TREE; D5: SNAKE; D6: GPA POWER SURGE; D7: OTHER

ELECTRIC DISTRIBUTION LOG (UNSCHEDULED OUTAGES)

SEQUENTIAL LOG FOR 4.16, 13.8, 34.5 KV									RELAY TARGETS ACTION							MONTH: MAY YEAR: 2006
UO#	DATE	TIME			LOCATION			LOAD	OVER CURRENT					XFMER DIFF	OUTAGE CAUSE*	SPECIFIC CAUSE OF OUTAGE / COMMENTS
		LOSS (TRIP)	RETURN (CLOSE)	ELAPSED HOURS	BASE / SUBSTATION	CIRCUIT BREAKER	AREA CUT-OFF OR AFFECTED	KV	KF	A	B	C	GRD			
90	05/19/06	0627	1340	7:13	CNM	ON P-128	QTRS. AT KELP/JETTY COVE.	13.8							C2	DEFECTIVE 250 KVA PAD-MOUNTED TRANSFORMER.
91	05/21/06	1735	2032	2:57	CNM	ON P-129	BLDG 71 ARMORY, CNM	13.8							C1	BLOWN FUSE; FOUND NO VISIBLE CAUSE.
92	05/22/06	0448	0756	3:08	HARMON/ AAFB	T-47/ T-110	NCTS 4 KV SUBSTATION AND POTTS JCT. SUBSTATION	4:16 13.8							C1	GPA X-87/X-73 LINE TRIPPED.
93	05/22/06	1840	2045	2:05	AAFB	P-93	PARTIAL OF ROBERTS TERRACE HSG.	13.8					I/ T		D7	TOADS SHORTED OUT STN #8 AT MH-214.
94	05/23/06	0339	0522	1:43	AAFB	P-91	CAPEHART HSG AND PARTIAL OF ROBERTS TERRACE HSG	13.8							C1	GPA X-87/X-73 LINE TRIPPED.
94	05/23/06	0339	0532	1:53	HARMON/ AAFB	T-47/ T-110	NCTS 4 KV SUBSTATION AND POTTS JCT. SUBSTATION	4.16 13.8							C1	GPA X-87/X-73 LINE TRIPPED.
	05/24/06	1909	1926	:17	DEDEDO	P-87	SOUTH FIN HSG.	13.8							C4	GPA P-87 BREAKER TRIPPED ON OVERLOAD.
95	05/28/06	0700	0735	:35	NRMC	ON P-138	NAVHOSP/BOILER/FIRE STATION	13.8							C1	DEFECTIVE FUSE HOLDER.
96	05/31/06	1416	-	-	LOWER SASA	ON P-2	PUMPS #1 TO #6	4.16							D7	FAULT ON MOTOR CIRCUIT.
97	05/31/06	1830	2056	2:26	AAFB	ON P-82	BLDG 22021 COMMISSARY	13.8							C2	BLOWN TRANSFORMER INTERNAL FUSE; FOUND NO VISIBLE CAUSE.

*LEGEND: A1: LOAD SHEDDING; A2: GENERATOR TRIP; B1: STORM; B2: LIGHTNING; B3: EARTHQUAKE; C1: LINE; C2: TRANSFORMER; C3: RELAY; C4: BREAKER; D1: HUMAN ERROR; D2: VEHICLE ACCIDENT; D3: UNKNOWN; D4: TREE; D5: SNAKE; D6: GPA POWER SURGE; D7: OTHER

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DOCUMENT TRANSMITTAL FORM

CUSTOMER: DZSP| 2I
FACILITY: Bldg I04
LOCATION: Guam Naval Facilities

LOG #: **2860**
SET Contract No: SUB-000002
ISSUE CODE:
DATE: July 03, 2006

TO: DZSP 21
P.O. Box GH
Agana, Guam 96932
ATTENTION: Mr. Wally Toma, Subcontract Administrator

We are sending you: X Attached __Under Separate Cover via:________________the: __Shop Drawings

__Prints __Samples __Specifications __Reports __Inspections __Test Schedules __Copy of Letter

__Change Order __Constr.Progress Chart/Schedule __Payment Estimate X As Stated ____________________

Copies	Reference No.	Category Type	Description and Purpose
1	**Annex 1602**	**CDRL No. F-1602000-F**	**Unscheduled and Scheduled Outage Reports – Jun. 2006 (5 pages)**

Name of: Subcontractor, Supplier/Manufacturer ____

__For Approval __Approved as Submitted __Resubmit __copies for approval X For Your Use

__Approved as Noted __Submit __copies for distribution X As Requested __Returned for Corrections

__Return __corrected prints __For Review and Comment __Other: ________________________

I certify that the attached information is ready for execution and that the attached information complies with the requirements of the contract documents.

By: Chris Stewart for Ty Jacot July 03, 2006
Ty J. Jacot, Senior Vice-President

Systems,
Energy &
Technologies, Inc.

S.E.T. – Pacific, Inc.

UNSCHEDULED AND SCHEDULED OUTAGE REPORT			
CDRL No: F-1602000-F	Prepared By: Peter Blas	Month/Year: Jun 2006	No. of Pages: 4
FREQUENCY: Monthly.			

- **Unscheduled Outage Report**
  - See attached (2 pages)

- **Scheduled Outage Report**
  - See attached (2 pages)

ELECTRIC DISTRIBUTION LOG (UNSCHEDULED OUTAGES)

SEQUENTIAL LOG FOR 4.16, 13.8, 34.5 KV									RELAY TARGETS ACTION							MONTH: JUN YEAR: 2006
UO#	DATE	TIME			LOCATION			LOAD	OVER CURRENT					XFMER DIFF	OUTAGE CAUSE*	SPECIFIC CAUSE OF OUTAGE / COMMENTS
		LOSS (TRIP)	RETURN (CLOSE)	ELAPSED HOURS	BASE / SUBSTATION	CIRCUIT BREAKER	AREA CUT-OFF OR AFFECTED	KV	KF	A	B	C	GRD			
98	06/02/06	1116	1151	:35	OROTE	P-16	McDONALD, COMMISSARY, NEX AUTO PORT/GARAGE, AUTO SALES OFFICE, HOME GALLERY MAIN NEX BLDG 258	13.8					T		C1	DEFECTIVE LIGHTNING ARRESTOR ON POLE JH-48-9-1.
98	06/02/06	1116	1555	4:39	CNM	ON P-16	BLDG 700 NEX II	13.8							C1	DEFECTIVE LIGHTNING ARRESTOR ON POLE JH-48-9-1.
99	06/02/06 – 06/10/06	1216	1100	8 DAYS 22:44	MH-130-1 AAFB	ON P-82	BLDGS #18027, 18030, 19013 AND 19021 (WASHRACK/HANGER AREA)	13.8							D1	DICK PACIFIC SUBCONTRACTOR "SG5" HIT/DAMAGED UNDERGROUND LINE WHILE EXCAVATING AT MH-130-1/P-82-2B CIRCUIT.
100	06/02/06	0826	0919	:53	AAFB	P-66	SUBSTATIONS "D" AND "F": INDUSTRIAL AREAS	13.8							D3	NO VISIBLE CAUSE FOUND.
101	06/02/06	0928	1420	4:52	AAFB	P-94	CIV GAS STATION/GARAGE, POL, LOX PLANT, LANDFILL/MSA-1 AND TARAGUE AREA, HC-5 LIFT STA AND ILS	13.8					T		C1	DEFECTIVE UNDERGROUND CABLE AT MH-7 TO MH-8.
102	06/04/06	1044	1352	2:25	AAFB	P-93	PARTIAL OF ROBERTS TERRACE HSG.	13.8		I	I		I		D7	TOADS SHORTED-OUT STN #8 AT MH-214.
102	06/04/06	1044	1533	4:49	AAFB	ON P-93	STN #7/STN #8 AT MH-214.	13.8							D7	TOADS SHORTED-OUT STN #8 AT MH-214.
103	06/05/06	0804	0952	1:48	AAFB	ON P-94	BLDG 14529 WHSE.	13.8							D5	SNAKE ON POLE #NE-34-1.
104	06/06/06	1823	2145	3:22	AAFB	P-68	WING HDQTRS , BARRACKS, COMMISSARY, AIR NAIONAL GUARD, GYM/BOWLING/CAR SALES, FLEMING HEIGHTS HSG & MESS	13.8			T		T		C1	BLOWN SPLICE AT MH-141.
104	06/06/06	1823	2221	3:58	AAFB	ON P-93	STN #7/STN #8 AT MH-214.	13.8							D7	TOADS SHORTED OUT STN #7 AT MH-214.
105	06/07/06	0953	1120	1:27	HARMON/NCT S	P-48/P-58	TELEPHONE HUT, WELLS #2/5/A NCTS BLDG 309	13.8			√		T		D3	NO VISIBLE CAUSE FOUND.
106	06/08/06	2141	2345	2:04	AAFB	ON P-94	ILS STROBE LIGHTS	13.8							D5	SNAKE ON POLE #NB-44.

*LEGEND: A1: LOAD SHEDDING; A2: GENERATOR TRIP; B1: STORM; B2: LIGHTNING; B3: EARTHQUAKE; C1: LINE; C2: TRANSFORMER; C3: RELAY; C4: BREAKER; D1: HUMAN ERROR; D2: VEHICLE ACCIDENT; D3: UNKNOWN; D4: TREE; D5: SNAKE; D6: GPA POWER SURGE; D7: OTHER

ELECTRIC DISTRIBUTION LOG (UNSCHEDULED OUTAGES)

SEQUENTIAL LOG FOR 4.16, 13.8, 34.5 KV									RELAY TARGETS ACTION							MONTH: JUNE YEAR: 2006
UO#	DATE	TIME			LOCATION			LOAD	OVER CURRENT					XFMER DIFF	OUTAGE CAUSE*	SPECIFIC CAUSE OF OUTAGE / COMMENTS
		LOSS (TRIP)	RETURN (CLOSE)	ELAPSED HOURS	BASE / SUBSTATION	CIRCUIT BREAKER	AREA CUT-OFF OR AFFECTED	KV	KF	A	B	C	GRD			
107	06/11/06	0559	0815	2:16	AAFB	P-94	CIV GAS STATION/GARAGE, POL, LOX PLANT, LANDFILL/MSA-1 AND TARAGUE AREA, HC-5 LIFT STA AND ILS	13.8				T			C1	BROKEN DEAD-END BELLS ON POLE #NB-33-4.
107	06/11/06	0559	1047	4:48	AAFB	ON P-94	CATHODIC PROTECTION.	13.8							C1	BROKEN DEAD-END BELLS ON POLE #NB-33-4.
108	06/12/06	1121	1135	:14	AAFB	ON P-93	PARTIAL OF FLEMING HTS HSG.	13.8	√						A2	GPA CABRAS GENERATOR #3 TRIPPED.
109	06/13/06 - 06/14/06	1428	1321	22:53	NRMC	ON P-138	DICK PACIFIC FIELD OFFICE	SEC.							D7	CONTRACTOR'S DEFECTIVE KWH METER SOCKET.
110	06/15/06	1140	1430	2:50	NAVMAG	ON P-134	BLDG 859/860 (BEQ/BLR)	13.8							B3	NO VISIBLE CAUSE FOUND.
111	06/16/06	0940	1345	4:05	RADIO BARRIGADA	ON P-213	BLDGS #54/55/56, OLD/NEW ARMY RESERVE CENTERS	13.8							D5	SNAKE ON POLE #LS-1-4-2/BLOWN FUSE ON LS-1-4/LS-1-4-2.
112	06/23/06	0337	0818	4:41	NAVMAG	ON P-134	ALL OF NAVMAG AREA	13.8							C1	BROKEN DEAD-END BELLS ON POLE #JG-146-1
113	06/26/06	1308	1423	1:15	CAMP COVINGTON	ON P-129	BLDGS 542/546/548	13.8							D7	BIRD ON POLE #JG-37-8-1-2.

*LEGEND: A1: LOAD SHEDDING; A2: GENERATOR TRIP; B1: STORM; B2: LIGHTNING; B3: EARTHQUAKE; C1: LINE; C2: TRANSFORMER; C3: RELAY; C4: BREAKER; D1: HUMAN ERROR; D2: VEHICLE ACCIDENT; D3: UNKNOWN; D4: TREE; D5: SNAKE; D6: GPA POWER SURGE; D7: OTHER

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S.E.T. – Pacific, Inc.

DOCUMENT TRANSMITTAL FORM

CUSTOMER: DZSP| 21
FACILITY: Bldg 104
LOCATION: Guam Naval Facilities

LOG #: **2936**
SET Contract No: SUB-000002
ISSUE CODE
DATE: August 01, 2006

TO: DZSP 21
P.O. Box GH
Agana, Guam 96932
ATTENTION: Mr. Wally Toma, Subcontract Administrator

We are sending you: X Attached __Under Separate Cover via:__________the: __Shop Drawings

__Prints __Samples __Specifications __Reports __Inspections __Test Schedules __Copy of Letter

__Change Order __Constr.Progress Chart/Schedule __Payment Estimate X As Stated __________

Copies	Reference No.	Category Type	Description and Purpose
1	Annex 1602	CDRL No. F-1602000-F	Unscheduled and Scheduled Outage Reports – Jul. 2006 (7 pages)

Name of: Subcontractor, Supplier/Manufacturer __________

__For Approval __Approved as Submitted __Resubmit __copies for approval X For Your Use

__Approved as Noted __Submit __copies for distribution X As Requested __Returned for Corrections

__Return __corrected prints __For Review and Comment __Other: __________

I certify that the attached information is ready for execution and that the attached information complies with the requirements of the contract documents.

By: Jay D. Miller, President Aug. 01, 2006

Systems,
Energy &
Technologies, Inc.

S.E.T. – Pacific, Inc.

UNSCHEDULED AND SCHEDULED OUTAGE REPORT			
CDRL No: F-1602000-F	Prepared By: Peter Blas	Month/Year: Jul 2006	No. of Pages: 6
FREQUENCY: Monthly.			

- **Unscheduled Outage Report**
  - See attached (4 pages)
- **Scheduled Outage Report**
  - See attached (2 pages)

ELECTRIC DISTRIBUTION LOG (UNSCHEDULED OUTAGES)

SEQUENTIAL LOG FOR 4.16, 13.8, 34.5 KV									RELAY TARGETS ACTION							MONTH: JUL YEAR: 2006
UO#	DATE	TIME			LOCATION			LOAD	OVER CURRENT					XFMER DIFF	OUTAGE CAUSE*	SPECIFIC CAUSE OF OUTAGE / COMMENTS
		LOSS (TRIP)	RETURN (CLOSE)	ELAPSED HOURS	BASE / SUBSTATION	CIRCUIT BREAKER	AREA CUT-OFF OR AFFECTED	KV	KF	A	B	C	GRD			
114	07/01/06	1804	1904	:60	AAFB	P-91	CAPEHART HSG AND PARTIAL OF ROBERTS TERRACE	13.8					T		D6	GPA X-161 TO X-70 LINE TRIPPED.
115	07/03/06	0830	2030	12:00	HARMON/ NCTS	P-114/ P-59	UNDERGROUND LINE TO NCTS BLDG 309	13.8		T	T T	T T			D7	DEFECTIVE SWITCHGEAR #5/INSULATOR BACKET SHORTED OUT.
116	07/03/06	1228	1401	1:33	HARMON/ NCTS	P-48/ P-58	TEL HUT, WELLS #2/5/"A" AND NCTS BLDG 309	13.8					T		D3	NO VISIBLE CAUSE FOUND.
117	07/06/06	0047	0148	1:01	ANIGUA	P-282	NRMC: MAIN GATE, SLS-3, CHAPEL, CDC, GYM, POOLL, HSG, DODEA OFFICE, NURSES QTRS, WELLS #1-2-3	13.8				T	T		D6	GPA X-23/X-43 AND P-282 TRIPPED.
118	07/07/06	0745	0950	2:05	MARBO	P-53	AIR FORCE WELLS #1-9/BOOSTER PUMPS #1-3, APPLIANCE WAREHOUSE AND GPA	13.8				I	I		D5	SNAKE ON POLE AT AIR FORCE WELL #1/BOOSTER #2.
118	07/07/06	0745	1119	3:34	MARBO	P-52	GPA CUSTOMERS	13.8		I	I		I		D3	NO VISIBLE CAUSE FOUND.
119	07/07/06	0825	0924	:59	NRMC	ON P-138	DICK PACIFIC FIELD OFFICE	13.8							D3	NO VISIBLE CAUSE FOUND.
120	07/07/06	1225	1433	2:08	OROTE	P-14	VICTOR #2 PIER, WHSE #3/4, B2118, KILO PIER, SLS-21, GABGAB BEACH, SIERRA/ROMEO SEALS/EOD/MSC/MSF COMPOUND AND GSY	13.8					I		D5	SNAKE ON POLE JB-61-36.
121	07/08/06	1239	1640	4:01	AAFB	P-91	CAPEHART HOUSING AND PARTIAL OF ROBERT TERRACE HSG	13.8		I	I	I	I		D7	FLASHED-OVER AT CL-25 SWITCHGEAR.
	07/08/06	1734	1738	:04	ANIGUA	P-282	NRMC AREA: HOUSING, CDC, CHAPEL, WELLS #1-2-3, MAIN GATE, SLS-3, BLDG 100, GYM, POOL AND NURSES QTRS.	13.8							D6	GPA P-282 BREAKER TRIPPED.
122	07/08/06 – 07/09/06	1734	0008	6:34	NRMC	ON P-282	NRMC AREA: HOUSING, CDC, CHAPEL, WELLS #1-2-3, MAIN GATE, SLS-3, BLDG 100, GYM, POOL AND NURSES QTRS.	13.8							D4	VEGETATION ON PRIMARY LINE ON POLES K6-59-13/15.
123	07/09/06	0202	1018	8:16	NRMC	ON P-282	WELL #3	13.8							C2	DEFECTIVE 15 KVA TRANSFORMER.

*LEGEND: A1: LOAD SHEDDING; A2: GENERATOR TRIP; B1: STORM; B2: LIGHTNING; B3: EARTHQUAKE; C1: LINE; C2: TRANSFORMER; C3: RELAY; C4: BREAKER; D1: HUMAN ERROR; D2: VEHICLE ACCIDENT; D3: UNKNOWN; D4: TREE; D5: SNAKE; D6: GPA POWER SURGE; D7: OTHER

ELECTRIC DISTRIBUTION LOG (UNSCHEDULED OUTAGES)

SEQUENTIAL LOG FOR 4.16, 13.8, 34.5 KV									RELAY TARGETS ACTION							MONTH: JULY YEAR: 2006
UO#	DATE	TIME			LOCATION			LOAD	OVER CURRENT					XFMER DIFF	OUTAGE CAUSE*	SPECIFIC CAUSE OF OUTAGE / COMMENTS
		LOSS (TRIP)	RETURN (CLOSE)	ELAPSED HOURS	BASE / SUBSTATION	CIRCUIT BREAKER	AREA CUT-OFF OR AFFECTED	KV	KF	A	B	C	GRD			
124	07/09/06 – 07/10/06	2311	0819	9:08	AAFB	P-93	PARTIAL OF ROBERT TERRACE HSG.	13.8					I		D7	BURNT INSULATORS ON P-67-54 SWITCH AT MH-207A.
125	07/10/06	1358	1625	2:27	ASAN	ON P-1	ASAN BOOSTER PUMP	13.8							D5	SNAKE ON POLE #KF-50.
126	07/12/06	0912	1307	3:55	AAFB	ON P-67	BLDG 1625 CDC	13.8							D6	OLD SWITCHGEAR AT MH-C6 SHORTED OUT.
127	07/12/06 – 07/13/06	1650	2335	1 DAY 6:45	AAFB	P-98	MSA-III AREA	13.8			T				D6	BURNT SPLICES AT MH-20.
127	07/12/06	1857	1936	:39	AAFB	P-97	20 MEG SUBSTATION	13.8			T				D6	BURNT SPLICES AT MH-20.
127	07/12/06	1857	1942	:45	AAFB	P-95	USDA, CATHODIC/POL, FIRE TRNG, BASECOM, DOG KENNEL AND HC-5	13.8							D6	BURNT SPLICES AT MH-20.
128	07/13/06	0312	0523	2:11	MARBO	ON P-51	AIR FORCE BOOSTER PUMP #3	13.8							D3	NOVISIBLE CAUSE FOUND.
129	07/13/06	1245	1334	:49	NRMC	ON P-138	DICK PACIFIC FIELD OFFICE	13.8							D6	BIRD ON POLE #NH-2-1
130	07/13/06	2138	2251	1:13	OROTE	P-16	NEX COMPLEX/AUTO PORT/NEX II, MCDONALDS, AND COMMISSARY	13.8					T		C1	BLOWN LIGHTNING ARRESTOR.
131	07/14/06 – 07/18/06	1425	1705	4 DAYS 2:40	NRMC	ON P-282	WELL #3	13.8							D6	BURNT MOTOR, KWH METER/SOCKET/WIRE.
132	07/15/06	1258	2127	2:05	AAFB	P-93	ROBERT TERRACE HSG	13.8					I		D6	BLOWN SPLICES AT CL-43 SWITCHGEAR.
133	07/25/06	2157	2210	:13	PAD-5	ON P-14	USS LAJOLLA AT ALPHA PIER	.480							D1	CUSTOMER OVERLOADED A3-4 CIRCUIT BREAKER.
134	07/17/06	0926	1236	3:10	PITI	ON P-2	TENJO VISTA FUEL FARM, VALVE PIT	.480							D4	VEGETATION ON SECONDARY LINES.
135	07/17/06	0929	1015	:46	AAFB	ON P-62	BLDG 2408 RECYCLE CENTER	13.8							D3	NO VISIBLE CAUSE FOUND.

*LEGEND: A1: LOAD SHEDDING; A2: GENERATOR TRIP; B1: STORM; B2: LIGHTNING; B3: EARTHQUAKE; C1: LINE; C2: TRANSFORMER; C3: RELAY; C4: BREAKER; D1: HUMAN ERROR; D2: VEHICLE ACCIDENT; D3: UNKNOWN; D4: TREE; D5: SNAKE; D6: GPA POWER SURGE; D7: OTHER

ELECTRIC DISTRIBUTION LOG (UNSCHEDULED OUTAGES)

SEQUENTIAL LOG FOR 4.16, 13.8, 34.5 KV | RELAY TARGETS ACTION | MONTH: JUL YEAR: 2006

UO#	DATE	TIME			LOCATION			LOAD	OVER CURRENT					XFMER DIFF	OUTAGE CAUSE*	SPECIFIC CAUSE OF OUTAGE / COMMENTS
		LOSS (TRIP)	RETURN (CLOSE)	ELAPSED HOURS	BASE / SUBSTATION	CIRCUIT BREAKER	AREA CUT-OFF OR AFFECTED	KV	KF	A	B	C	GRD			
136	07/18/06	1352	1712	3:20	CNM	ON P-16	BLDG 257 HOME GALLEY/LAUNDROMAT	13.8							D5	SNAKE ON POLE #JD-23-6.
137	07/19/06	1133	1608	4:35	RADIO BARRIGADA	ON P-213	BLDGS #50/55/56 AND THE OLD/NEW ARMY RESERVE CENTER	13.8							B2	LIGHTNING/DOWNED POLE #LS-1-6 PRIMARY LINE; DEFECTIVE DEADEND BELLS.
138	07/19/06	2114	2219	1:05	AAFB	P-94	CIVILIAN GAS STATION, POL, LOX PLANT, ILS, CATHODIC PROTECTION, LANDFILL, MSA-I/TARAGUE AREA	13.8				T/I			C1	BLOWN LIGHTNING ARRETOR ON POLE #NB-13.
139	07/19/06	2135	2201	:26	AAFB	P-91	CAPEHART HSG AND PARTIAL OF ROBERT TERRACE HSG	13.8		I	I	I	I		D3	NO VISIBLE CAUSE FOUND.
140	07/21/06	0757	0800	:03	ANIGUA	P-282	NRMC AREA: HOUSING, CDC, CHAPEL, NURSES QTRS, BLDG 13, GYM, DODEA OFFICE, POOL, SLS-3 AND GATE	13.8							D6	BIRD ON POLE #KG-59.
141	07/21/06	1612	1648	:36	OROTE	P-14	VICTOR #2 PIER, WHSE #3/4, B2118, KILO PIER, SLS-21, GABGAB BEACH, EOD/MSC/MSF COMPOUND AND GSY	13.8					I		D6	BIRD ON POLE #JC-27.
141	07/21/06	1612	1837	2:25	CNM	ON P-14	SEALD COMDPOUND BLDGS 3000-3002	13.8							D6	BIRD ON POLE #JC-27.
142	07/22/06	1750	2307	5:17	AAFB	ON P-91	CT-42/CT-43/CT-44 QTRS AT CAPEHART HSG.	13.8							D6	BLOWN TERMINATOR AT CL-14 SWITCHGEAR.
143	07/26/06	0816	1830	10:14	NAVMAG	ON P-134	BLDGS 401, 403, 769, 400, 734 AND 879 GYM	13.8							B2	LIGHTNING; BURNT POLE/ACCESSORIES. DEFECTIVE DEAD END BELLS ON POLE #JG-104-10-7-3 AND POLE JG-104-10-2.
144	07/26/06	1447	1714	2:27	AAFB	P-98	BLDGS #2800/2820 TACAN AND MSA-II AREA	13.8		T		T			D3	NO VISIBLE CAUSE FOUND.
145	07/29/06-07/30/06	1713	0042	7:29	CNM	ON P-129	QTRS #14/16/18/20 GILMORE AND 2228A/B MCMILLAN LOCKWOOD	13.8							B2	LIGHTNING/DEFECTIVE T-14 75 KVA PAD-MOUNTED TRANSFORMER.
146	07/29/06-07/30/06	2241	0159	3:18	AAFB	ON P-62	BLDGS #9000/9001/9002	13.8							D5	SNAKE ON POLE #NB-113.

*LEGEND: A1: LOAD SHEDDING; A2: GENERATOR TRIP; B1: STORM; B2: LIGHTNING; B3: EARTHQUAKE; C1: LINE; C2: TRANSFORMER; C3: RELAY; C4: BREAKER; D1: HUMAN ERROR; D2: VEHICLE ACCIDENT; D3: UNKNOWN; D4: TREE; D5: SNAKE; D6: GPA POWER SURGE; D7: OTHER

ELECTRIC DISTRIBUTION LOG (UNSCHEDULED OUTAGES)

SEQUENTIAL LOG FOR 4.16, 13.8, 34.5 KV — RELAY TARGETS ACTION — MONTH: JUL YEAR: 2006

UO#	DATE	TIME			LOCATION			LOAD	OVER CURRENT					XFMER DIFF	OUTAGE CAUSE*	SPECIFIC CAUSE OF OUTAGE / COMMENTS
		LOSS (TRIP)	RETURN (CLOSE)	ELAPSED HOURS	BASE / SUBSTATION	CIRCUIT BREAKER	AREA CUT-OFF OR AFFECTED	KV	KF	A	B	C	GRD			
147	07/30/06	0107	0127	:20	NEW APRA	ON P-134	GUARDHOUSE NEW APRA HSG	SEC							D3	NO VISIBLE CAUSE FOUND.
148	07/30/06	0542	0854	3:12	MARBO	P-51	AIR FORCE BOOSTER PUMP #3, WELLS #5-9	13.8				I	I		D3	NO VISIBLE CAUSE FOUND.
149	07/31/06	1215	1710	4:55	OROTE	T-12	P-128/P-129/P-130		UNDERVOLTAGE AND LOCKOUT 786B.						D6	A PHASE DIFFERENTIAL RELAY SHORTED OUT; WATER WAS INSIDE THE RELAY BOX.
149	07/31/06	1215	1407	1:52	OROTE	P-129	COAST GUARD/SECURITY/NFM COMPOUND, TRANSPORTATION, CDC, CHAPEL, GYM, NORTH/SOUTH TIP/LOCKWOOD HSG AND DRMO	13.8							D6	A PHASE DIFFERENTIAL RELAY SHORTED OUT; WATER WAS INSIDE THE RELAY BOX.
149	07/31/06	1215	1710	4:55	OROTE	P-128	HARBOR/BAYVIEW HSG	13.8							D6	A PHASE DIFFERENTIAL RELAY SHORTED OUT; WATER WAS INSIDE THE RELAY BOX.
149	07/31/06	1215	1711	4:56	OROTE	P-130	BLDGS #3190/3191	13.8							D6	A PHASE DIFFERENTIAL RELAY SHORTED OUT; WATER WAS INSIDE THE RELAY BOX.

*LEGEND: A1: LOAD SHEDDING; A2: GENERATOR TRIP; B1: STORM; B2: LIGHTNING; B3: EARTHQUAKE; C1: LINE; C2: TRANSFORMER; C3: RELAY; C4: BREAKER; D1: HUMAN ERROR; D2: VEHICLE ACCIDENT; D3: UNKNOWN; D4: TREE; D5: SNAKE; D6: GPA POWER SURGE; D7: OTHER

Appendix D
Detailed Cost Tables for IWPS Improvements

Project Description: **Upgrade Piti X20 to Orote X35 34.5kV Line** **Project List: A (1)**

Description	Unit	Unit Cost	Quantity	Cost	References	Remarks
336 ACSR Conductor	WMile	$37,800	20	$756,000.00	RSMeans	Includes cable sag length factor .01
1/0 ACSR Ground Wire	WMile	$37,800	2.5	$94,500.00	RSMeans	Includes cable sag length factor .01
Conductor Pulley Setups	Mile	$600	88	$52,800.00	RSMeans	
Pulling Conductors	WMile	$9,600	20	$192,000.00	RSMeans	
Insulators 34.5kV	Ea	$270	792	$213,840.00	RSMeans	
Insulators 115kV	Ea	$300		$0.00		
Concrete Pole w/ Crossarm	Ea	$60,000		$0.00		
Circuit Breaker 115kV, Gas, Outdoor	Ea	$943,500		$0.00		
Circuit Breaker 34.5kV, Outdoor	Ea	$153,000	2	$306,000.00	RSMeans	
112 MVA Station Type Transformer	MVA	$48,000		$0.00		
115kV Substation Gravel Base	Cu Yd	$156		$0.00		
115kV Substation Grounding	Sq Ft	$60		$0.00		
115kV Substation Fence	Ln Ft	$300		$0.00		
115kV Substation Switchgear Bldg	Sq Ft	$1,032		$0.00		
115kV Substation HV Equip. Structure	Ea	$300,000		$0.00		
Concrete Equipment Pad	Ea	$7,500	2	$15,000.00	Engineer Jugement/RSMeans	
Substation Bus Connection	Ea	$45,000	2	$90,000.00	Engineer Jugement/RSMeans	
Gang Switch 115kV	Ea	$105,000		$0.00		
34.5 kV Switchgear	Bay	$120,000		$0.00		

Total Construction Materials and Labor	**$1,720,140.00**
Contingencies 10%	**$172,014.00**
TOTAL	**$1,892,154.00**

Project Description: **Upgrade Harmon X87 to Andersen X73 34.5kV Line** **Project List: A (2)**

Description	Unit	Unit Cost	Quantity	Cost	References	Remarks
336 ACSR Conductor	WMile	$37,800	40.6	$1,534,680.00	RSMeans	Includes cable sag length factor .01
1/0 ACSR Ground Wire	WMile	$37,800	5.1	$192,780.00	RSMeans	Includes cable sag length factor .01
Conductor Pulley Setups	Mile	$600	176	$105,600.00	RSMeans	
Pulling Conductors	WMile	$9,600	40.6	$389,760.00	RSMeans	
Insulators 34.5kV	Ea	$270	1408	$380,160.00	RSMeans	
Insulators 115kV	Ea	$300		$0.00		
Concrete Pole w/ Crossarm	Ea	$60,000		$0.00		
Circuit Breaker 115kV, Gas, Outdoor	Ea	$943,500		$0.00		
Circuit Breaker 34.5kV, Outdoor	Ea	$153,000	2	$306,000.00	RSMeans	
112 MVA Station Type Transformer	MVA	$48,000		$0.00		
115kV Substation Gravel Base	Cu Yd	$156		$0.00		
115kV Substation Grounding	Sq Ft	$60		$0.00		
115kV Substation Fence	Ln Ft	$300		$0.00		
115kV Substation Switchgear Bldg	Sq Ft	$1,032		$0.00		
115kV Substation HV Equip. Structure	Ea	$300,000		$0.00		
Concrete Equipment Pad	Ea	$7,500	2	$15,000.00	Engineer Judgement/RSMeans	
Substation Bus Connection	Ea	$45,000	2	$90,000.00	Engineer Judgement/RSMeans	
Gang Switch 115kV	Ea	$105,000		$0.00		
34.5 kV Switchgear	Bay	$120,000		$0.00		

Total Construction Materials and Labor	**$2,820,000.00**
Contingencies 10%	**$282,000.00**
TOTAL	**$3,102,000.00**

Project Description: **Upgrade Piti X21 to Orote X31 Double Circuit 34.5kV Line** **Project List: A (3)**

Description	Unit	Unit Cost	Quantity	Cost	References	Remarks
336 ACSR Conductor	WMile	$37,800	40	$1,512,000.00	RSMeans	Includes cable sag length factor .01
1/0 ACSR Ground Wire	WMile	$37,800	2.5	$94,500.00	RSMeans	Includes cable sag length factor .01
Conductor Pulley Setups	Mile	$600	174	$104,400.00	RSMeans	
Pulling Conductors	WMile	$9,600	40	$384,000.00	RSMeans	
Insulators 34.5kV	Ea	$270	2784	$751,680.00	RSMeans	
Insulators 115kV	Ea	$300		$0.00		
Concrete Pole w/ Crossarm	Ea	$60,000		$0.00		
Circuit Breaker 115kV, Gas, Outdoor	Ea	$943,500		$0.00		
Circuit Breaker 34.5kV, Outdoor	Ea	$153,000	2	$306,000.00	RSMeans	
112 MVA Station Type Transformer	MVA	$48,000		$0.00		
115kV Substation Gravel Base	Cu Yd	$156		$0.00		
115kV Substation Grounding	Sq Ft	$60		$0.00		
115kV Substation Fence	Ln Ft	$300		$0.00		
115kV Substation Switchgear Bldg	Sq Ft	$1,032		$0.00		
115kV Substation HV Equip. Structure	Ea	$300,000		$0.00		
Concrete Equipment Pad	Ea	$7,500	2	$15,000.00	Engneer Judgement/RSMeans	
Substation Bus Connection	Ea	$45,000	2	$90,000.00	Engneer Judgement/RSMeans	
Gang Switch 115kV	Ea	$105,000		$0.00		
34.5 kV Switchgear	Bay	$120,000		$0.00		

Total Construction Materials and Labor	**$3,160,000.00**
Contingencies 10%	**$316,000.00**
TOTAL	**$3,476,000.00**

Project Description: Dededo CT X150/X155 to Andersen X71 Double Circuit 34.5kV Line Project List: A (4)

Description	Unit	Unit Cost	Quantity	Cost	References	Remarks
336 ACSR Conductor	WMile	$37,800	117	$4,422,600.00	RSMeans	Includes cable sag length factor .01
1/0 ACSR Ground Wire	WMile	$37,800	7.3	$275,940.00	RSMeans	Includes cable sag length factor .01
Conductor Pulley Setups	Mile	$600	255	$153,000.00	RSMeans	
Pulling Conductors	WMile	$9,600	117	$1,123,200.00	RSMeans	
Insulators 34.5kV	Ea	$270	2040	$550,800.00	RSMeans	
Insulators 115kV	Ea	$300		$0.00		
Concrete Pole w/ Crossarm	Ea	$60,000		$0.00		
Circuit Breaker 115kV, Gas, Outdoor	Ea	$943,500		$0.00		
Circuit Breaker 34.5kV, Outdoor	Ea	$153,000	3	$459,000.00	RSMeans	
112 MVA Station Type Transformer	MVA	$48,000		$0.00		
115kV Substation Gravel Base	Cu Yd	$156		$0.00		
115kV Substation Grounding	Sq Ft	$60		$0.00		
115kV Substation Fence	Ln Ft	$300		$0.00		
115kV Substation Switchgear Bldg	Sq Ft	$1,032		$0.00		
115kV Substation HV Equip. Structure	Ea	$300,000		$0.00		
Concrete Equipment Pad	Ea	$7,500	3	$22,500.00	Engineer Judgement/RSMeans	
Substation Bus Connection	Ea	$45,000	3	$135,000.00	Engineer Judgement/RSMeans	
Gang Switch 115kV	Ea	$105,000		$0.00		
34.5 kV Switchgear	Bay	$120,000		$0.00		
Total Construction Materials and Labor				**$6,870,000.00**		
Contingencies 10%				**$687,000.00**		
TOTAL				**$7,557,000.00**		

Project Description: **Upgrade harmon X88 to Dededo X151/154 Double Circuit 34.5kV Line** **Project List: A (5)**

Description	Unit	Unit Cost	Quantity	Cost	References	Remarks
336 ACSR Conductor	WMile	$37,800	83	$3,137,400.00	RSMeans	Includes cable sag length factor .01
1/0 ACSR Ground Wire	WMile	$37,800	2.6	$98,280.00	RSMeans	Includes cable sag length factor .01
Conductor Pulley Setups	Mile	$600	182	$109,200.00	RSMeans	
Pulling Conductors	WMile	$9,600	83	$796,800.00	RSMeans	
Insulators 34.5kV	Ea	$270	2184	$589,680.00	RSMeans	
Insulators 115kV	Ea	$300		$0.00		
Concrete Pole w/ Crossarm	Ea	$60,000		$0.00		
Circuit Breaker 115kV, Gas, Outdoor	Ea	$943,500		$0.00		
Circuit Breaker 34.5kV, Outdoor	Ea	$153,000	3	$459,000.00	RSMeans	
112 MVA Station Type Transformer	MVA	$48,000		$0.00		
115kV Substation Gravel Base	Cu Yd	$156		$0.00		
115kV Substation Grounding	Sq Ft	$60		$0.00		
115kV Substation Fence	Ln Ft	$300		$0.00		
115kV Substation Switchgear Bldg	Sq Ft	$1,032		$0.00		
115kV Substation HV Equip. Structure	Ea	$300,000		$0.00		
Concrete Equipment Pad	Ea	$7,500	3	$22,500.00	Engineer Judgement/RSMeans	
Substation Bus Connection	Ea	$45,000	3	$135,000.00	Engineer Judgement/RSMeans	
Gang Switch 115kV	Ea	$105,000		$0.00		
34.5 kV Switchgear	Bay	$120,000		$0.00		

Total Construction Materials and Labor	**$5,250,000.00**
Contingencies 10%	**$525,000.00**
TOTAL	**$5,775,000.00**

Project Description: **Upgrade HarmonX82 to Yigo X160 34.5kV Line** **Project List: A (6)**

Description	Unit	Unit Cost	Quantity	Cost	References	Remarks
336 ACSR Conductor	WMile	$37,800	52	$1,965,600.00	RSMeans	Includes cable sag length factor .01
1/0 ACSR Ground Wire	WMile	$37,800	6.5	$245,700.00	RSMeans	Includes cable sag length factor .01
Conductor Pulley Setups	Mile	$600	228	$136,800.00	RSMeans	
Pulling Conductors	WMile	$9,600	52	$499,200.00	RSMeans	
Insulators 34.5kV	Ea	$270	1824	$492,480.00	RSMeans	
Insulators 115kV	Ea	$300		$0.00		
Concrete Pole w/ Crossarm	Ea	$60,000		$0.00		
Circuit Breaker 115kV, Gas, Outdoor	Ea	$943,500		$0.00		
Circuit Breaker 34.5kV, Outdoor	Ea	$153,000	2	$306,000.00	RSMeans	
112 MVA Station Type Transformer	MVA	$48,000		$0.00		
115kV Substation Gravel Base	Cu Yd	$156		$0.00		
115kV Substation Grounding	Sq Ft	$60		$0.00		
115kV Substation Fence	Ln Ft	$300		$0.00		
115kV Substation Switchgear Bldg	Sq Ft	$1,032		$0.00		
115kV Substation HV Equip. Structure	Ea	$300,000		$0.00		
Concrete Equipment Pad	Ea	$7,500	2	$15,000.00	Engineer Judgement/RSMeans	
Substation Bus Connection	Ea	$45,000	2	$90,000.00	Engineer Judgement/RSMeans	
Gang Switch 115kV	Ea	$105,000		$0.00		
34.5 kV Switchgear	Bay	$120,000		$0.00		
Total Construction Materials and Labor				**$3,510,000.00**		
Contingencies 10%				**$351,000.00**		
TOTAL				**$3,861,000.00**		

Project Description: **New Capacitor Bank at Orote Substation 13.8kV** **Project List: A (7)**

Description	Unit	Unit Cost	Quantity	Cost	References	Remarks
Capacitor Bank	Mvars	$21,975	24	$527,400.00	RSMeans	
Concrete Equipment Pad	LS	$7,500	1	$7,500.00	Engineer Judgement/RSMeans	
Outdoor Air Circuit Breaker 13.8 kV	Ea	$160,275	1	$160,275.00	RSMeans	

Total Construction Materials and Labor	**$700,000.00**
Contingencies 10%	**$70,000.00**
TOTAL	**$770,000.00**

Project Description: **New Capacitor Bank at SRF Substation 13.8kV** **Project List: A (8)**

Description	Unit	Unit Cost	Quantity	Cost	References	Remarks
Capacitor Bank	Mvars	$21,975	3	$65,925.00	RSMeans	
Concrete Equipment Pad	LS	$7,500	1	$7,500.00	Engineer Judgement/RSMeans	
Outdoor Air Circuit Breaker 13.8 kV	Ea	$160,275	1	$160,275.00	RSMeans	

Total Construction Materials and Labor	**$230,000.00**
Contingencies 10%	**$23,000.00**
TOTAL	**$253,000.00**

Project Description: **New Capacitor Bank at Andersen Substation 13.8kV** **Project List: A (9)**

Description	Unit	Unit Cost	Quantity	Cost	References	Remarks
Capacitor Bank	Mvars	$21,975	24	$527,400.00	RSMeans	
Concrete Equipment Pad	LS	$7,500	1	$7,500.00	Engineer Judgement/RSMeans	
Outdoor Air Circuit Breaker 13.8 kV	Ea	$160,275	1	$160,275.00	RSMeans	

Total Construction Materials and Labor	**$700,000.00**
Contingencies 10%	**$70,000.00**
TOTAL	**$770,000.00**

Project Description: **New Capacitor Bank at NCS Substation 13.8kV** **Project List: A (10)**

Description	Unit	Unit Cost	Quantity	Cost	References	Remarks
Capacitor Bank	Mvars	$21,975	18	$395,550.00	RSMeans	
Concrete Equipment Pad	LS	$7,500	1	$7,500.00	Engineeer Judgement/RSMeans	
Outdoor Air Circuit Breaker 13.8 kV	Ea	$160,275	1	$160,275.00	RSMeans	

Total Construction Materials and Labor	**$560,000.00**
Contingencies 10%	**$56,000.00**
TOTAL	**$616,000.00**

Project Description: **New Harmon to Andersen 115kV Line** **Project List: B (1)**

Description	Unit	Unit Cost	Quantity	Cost	References	Remarks
336 ACSR Conductor	WMile	$37,800	40.6	$1,534,680.00	RSMeans	Includes cable sag length factor .01
1/0 ACSR Ground Wire	WMile	$37,800	5.1	$192,780.00	RSMeans	Includes cable sag length factor .01
Conductor Pulley Setups	Mile	$600	106	$63,600.00	RSMeans	Length/pole spc x 2
Pulling Conductors	WMile	$9,600	40.6	$389,760.00	RSMeans	
Insulators 34.5kV	Ea	$270		$0.00		
Insulators 115kV	Ea	$300	265	$79,500.00	RSMeans	
Concrete Pole w/ Crossarm	Ea	$60,000	53	$3,180,000.00	Engineer Judgement/RSMeans	
Circuit Breaker 115kV, Gas, Outdoor	Ea	$943,500	2	$1,887,000.00	RSMeans	
Circuit Breaker 34.5kV, Outdoor	Ea	$153,000		$0.00		
112 MVA Station Type Transformer	MVA	$48,000		$0.00		
115kV Substation Gravel Base	Cu Yd	$156		$0.00		
115kV Substation Grounding	Sq Ft	$60		$0.00		
115kV Substation Fence	Ln Ft	$300		$0.00		
115kV Substation Switchgear Bldg	Sq Ft	$1,032		$0.00		
115kV Substation HV Equip. Structure	Ea	$300,000		$0.00		
Concrete Equipment Pad	Ea	$7,500	2	$15,000.00	Engineer Judgement/RSMeans	
Substation Bus Connection	Ea	$45,000		$0.00		
Gang Switch 115kV	Ea	$105,000	2	$210,000.00	RSMeans	
34.5 kV Switchgear	Bay	$120,000		$0.00		

Total Construction Materials and Labor	**$7,360,000.00**
Contingencies 10%	**$736,000.00**
TOTAL	**$8,096,000.00**

Project Description: **New Andersen Substation with 112MVA Power Transformer** **Project List: B (2)**

Description	Unit	Unit Cost	Quantity	Cost	References	Remarks
336 ACSR Conductor	WMile	$37,800		$0.00		
1/0 ACSR Ground Wire	WMile	$37,800		$0.00		
Conductor Pulley Setups	Mile	$600		$0.00		
Pulling Conductors	WMile	$9,600		$0.00		
Insulators 34.5kV	Ea	$270		$0.00		
Insulators 115kV	Ea	$300		$0.00		
Concrete Pole w/ Crossarm	Ea	$60,000		$0.00		
Circuit Breaker 115kV, Gas, Outdoor	Ea	$943,500	1	$943,500.00	RSMeans	
Circuit Breaker 34.5kV, Outdoor	Ea	$153,000		$0.00		
112 MVA Station Type Transformer	MVA	$48,000	112	$5,376,000.00	RSMeans	
115kV Substation Gravel Base	Cu Yd	$156	50	$7,800.00	Engineer Judgement	
115kV Substation Grounding	Sq Ft	$60	43,560	$2,613,600.00	Engineer Judgement	
115kV Substation Fence	Ln Ft	$300	833	$249,900.00	Engineer Judgement	
115kV Substation Switchgear Bldg	Sq Ft	$1,032	800	$825,600.00	Engineer Judgement	Land Provided by DOD
115kV Substation HV Equip. Structure	Ea	$300,000	1	$300,000.00	Engineer Judgement	
Concrete Equipment Pad	Ea	$7,500	2	$15,000.00	Engineer Judgement/RSMeans	
Substation Bus Connection	Ea	$45,000	1	$45,000.00	Engineer Judgement/RSMeans	
Gang Switch 115kV	Ea	$105,000		$0.00		
34.5 kV Switchgear	Bay	$120,000	6	$720,000.00	Engineer Judgement/RSMeans	

Total Construction Materials and Labor	**$11,100,000.00**
Contingencies 10%	**$1,110,000.00**
TOTAL	**$12,210,000.00**

Project Description: **New Piti to Orote 115kV Line** **Project List: B (3)**

Description	Unit	Unit Cost	Quantity	Cost	References	Remarks
336 ACSR Conductor	WMile	$37,800	10.1	$381,780.00	RSMeans	Includes cable sag length factor .01
1/0 ACSR Ground Wire	WMile	$37,800	2.5	$94,500.00	RSMeans	Includes cable sag length factor .01
Conductor Pulley Setups	Mile	$600	27	$16,200.00	RSMeans	Length/pole spc x 2
Pulling Conductors	WMile	$9,600	10.1	$96,960.00	RSMeans	
Insulators 34.5kV	Ea	$270		$0.00		
Insulators 115kV	Ea	$300	135	$40,500.00	RSMeans	
Concrete Pole w/ Crossarm	Ea	$60,000	27	$1,620,000.00	Engineer Judgement/RSMeans	
Circuit Breaker 115kV, Gas, Outdoor	Ea	$943,500		$0.00		
Circuit Breaker 34.5kV, Outdoor	Ea	$153,000		$0.00		
112 MVA Station Type Transformer	MVA	$48,000		$0.00		
115kV Substation Gravel Base	Cu Yd	$156		$0.00		
115kV Substation Grounding	Sq Ft	$60		$0.00		
115kV Substation Fence	Ln Ft	$300		$0.00		
115kV Substation Switchgear Bldg	Sq Ft	$1,032		$0.00		
115kV Substation HV Equip. Structure	Ea	$300,000		$0.00		
Concrete Equipment Pad	Ea	$7,500	2	$15,000.00	Engineer Judgement/RSMeans	
Substation Bus Connection	Ea	$45,000		$0.00		
Gang Switch 115kV	Ea	$105,000	2	$210,000.00	RSMeans	
34.5kV Switchgear	Bay	$120,000				

Total Construction Materials and Labor **$2,470,000.00**

Contingencies 10% **$247,000.00**

TOTAL **$2,717,000.00**

Project Description: **New Orote Substation with 112MVA Power Transformer** **Project List: B (4)**

Description	Unit	Unit Cost	Quantity	Cost	References	Remarks
336 ACSR Conductor	WMile	$37,800		$0.00		
1/0 ACSR Ground Wire	WMile	$37,800		$0.00		
Conductor Pulley Setups	Mile	$600		$0.00		
Pulling Conductors	WMile	$9,600		$0.00		
Insulators 34.5kV	Ea	$270		$0.00		
Insulators 115kV	Ea	$300		$0.00		
Concrete Pole w/ Crossarm	Ea	$60,000		$0.00		
Circuit Breaker 115kV, Gas, Outdoor	Ea	$943,500	1	$943,500.00	RSMeans	
Circuit Breaker 34.5kV, Outdoor	Ea	$153,000		$0.00		
112 MVA Station Type Transformer	MVA	$48,000	112	$5,376,000.00	RSMeans	
115kV Substation Gravel Base	Cu Yd	$156	50	$7,800.00	Enigineer Judgement	
115kV Substation Grounding	Sq Ft	$60	43,560	$2,613,600.00	Enigineer Judgement	
115kV Substation Fence	Ln Ft	$300	833	$249,900.00	Enigineer Judgement	
115kV Substation Switchgear Bldg	Sq Ft	$1,032	800	$825,600.00	Enigineer Judgement	Land Provided by DOD
115kV Substation HV Equip. Structure	Ea	$300,000	1	$300,000.00	Enigineer Judgement	
Concrete Equipment Pad	Ea	$7,500	2	$15,000.00	Engineer Judgement/RSMeans	
Substation Bus Connection	Ea	$45,000	1	$45,000.00	Engineer Judgement/RSMeans	
Gang Switch 115kV	Ea	$105,000		$0.00		
34.5 kV Switchgear	Bay	$120,000	6	$720,000.00	Engineer Judgement/RSMeans	

Total Construction Materials and Labor **$11,100,000.00**

Contingencies 10% **$1,110,000.00**

TOTAL **$12,210,000.00**

Project Description: **Upgrade Harmon X87 to Andersen X73 115kV Line** **Project List: B (5)**

Description	Unit	Unit Cost	Quantity	Cost	References	Remarks
336 ACSR Conductor	WMile	$37,800	40.6	$1,534,680.00	RSMeans	Includes cable sag length factor .01
1/0 ACSR Ground Wire	WMile	$37,800	5.1	$192,780.00	RSMeans	Includes cable sag length factor .01
Conductor Pulley Setups	Mile	$600	53	$31,800.00	RSMeans	Length/pole spc x 2
Pulling Conductors	WMile	$9,600	40.6	$389,760.00	RSMeans	
Insulators 34.5kV	Ea	$270		$0.00		
Insulators 115kV	Ea	$300	265	$79,500.00	RSMeans	
Concrete Pole w/ Crossarm	Ea	$60,000		$0.00		
Circuit Breaker 115kV, Gas, Outdoor	Ea	$943,500	2	$1,887,000.00	RSMeans	
Circuit Breaker 34.5kV, Outdoor	Ea	$153,000		$0.00		
112 MVA Station Type Transformer	MVA	$48,000		$0.00		
115kV Substation Gravel Base	Cu Yd	$156		$0.00		
115kV Substation Grounding	Sq Ft	$60		$0.00		
115kV Substation Fence	Ln Ft	$300		$0.00		
115kV Substation Switchgear Bldg	Sq Ft	$1,032		$0.00		
115kV Substation HV Equip. Structure	Ea	$300,000		$0.00		
Concrete Equipment Pad	Ea	$7,500	2	$15,000.00	Engineer Judgement/RSMeans	
Substation Bus Connection	Ea	$45,000	2	$90,000.00	Engineer Judgement/RSMeans	
Gang Switch 115kV	Ea	$105,000		$0.00		
		$120,000				

Total Construction Materials and Labor	**$4,220,000.00**
Contingencies 10%	**$422,000.00**
TOTAL	**$4,642,000.00**

Project Description: **New Piti X20 to Orote X35 115kV Line** **Project List: B (6)**

Description	Unit	Unit Cost	Quantity	Cost	References	Remarks
336 ACSR Conductor	WMile	$37,800	10.1	$381,780.00	RSMeans	Includes cable sag length factor .01
1/0 ACSR Ground Wire	WMile	$37,800	2.5	$94,500.00	RSMeans	Includes cable sag length factor .01
Conductor Pulley Setups	Mile	$600	27	$16,200.00	RSMeans	Length/pole spc x 2
Pulling Conductors	WMile	$9,600	10.1	$96,960.00	RSMeans	
Insulators 34.5kV	Ea	$270		$0.00		
Insulators 115kV	Ea	$300	135	$40,500.00	RSMeans	
Concrete Pole w/ Crossarm	Ea	$60,000	27	$1,620,000.00	Engineer Judgement/RSMeans	
Circuit Breaker 115kV, Gas, Outdoor	Ea	$943,500	2	$1,887,000.00	RSMeans	
Circuit Breaker 34.5kV, Outdoor	Ea	$153,000		$0.00		
112 MVA Station Type Transformer	MVA	$48,000		$0.00		
115kV Substation Gravel Base	Cu Yd	$156		$0.00		
115kV Substation Grounding	Sq Ft	$60		$0.00		
115kV Substation Fence	Ln Ft	$300		$0.00		
115kV Substation Switchgear Bldg	Sq Ft	$1,032		$0.00		
115kV Substation HV Equip. Structure	Ea	$300,000		$0.00		
Concrete Equipment Pad	Ea	$7,500	2	$15,000.00	Engineer Judgement/RSMeans	
Substation Bus Connection	Ea	$45,000	2	$90,000.00	Engineer Judgement/RSMeans	
Gang Switch 115kV	Ea	$105,000		$0.00		
Connection at Intermediate Substat	Ea	$120,000	2	$240,000.00	Engineer Judgement/RSMeans	

Total Construction Materials and Labor **$4,480,000.00**

Contingencies 10% **$448,000.00**

TOTAL **$4,928,000.00**

Project Description: **New Capacitor Bank at Orote Substation 13.8kV** **Project List: B (7)**

Description	Unit	Unit Cost	Quantity	Cost	References	Remarks
Capacitor Bank	Mvars	$21,975	24	$527,400.00	RSMeans	
Concrete Equipment Pad	LS	$7,500	1	$7,500.00	Engineer Judgement/RSMeans	
Outdoor Air Circuit Breaker 13.8 kV	Ea	$160,275	1	$160,275.00	RSMeans	

Total Construction Materials and Labor	**$700,000.00**
Contingencies 10%	**$70,000.00**
TOTAL	**$770,000.00**

Project Description: **New Capacitor Bank at SRF Substation 13.8kV** **Project List: B (8)**

Description	Unit	Unit Cost	Quantity	Cost	References	Remarks
Capacitor Bank	Mvars	$21,975	3	$65,925.00	RSMeans	
Concrete Equipment Pad	LS	$7,500	1	$7,500.00	engineer Judgement/RSMeans	
Outdoor Air Circuit Breaker 13.8 kV	Ea	$160,275	1	$160,275.00	RSMeans	

Total Construction Materials and Labor	**$230,000.00**
Contingencies 10%	**$23,000.00**
TOTAL	**$253,000.00**

Project Description: **New Capacitor Bank at Andersen Substation 13.8kV** **Project List: B (9)**

Description	Unit	Unit Cost	Quantity	Cost	References	Remarks
Capacitor Bank	Mvars	$21,975	24	$527,400.00	RSMeans	
Concrete Equipment Pad	LS	$7,500	1	$7,500.00	Engineer Judgement/RSMeans	
Outdoor Air Circuit Breaker 13.8 kV	Ea	$160,275	1	$160,275.00	RSMeans	

Total Construction Materials and Labor	**$700,000.00**
Contingencies 10%	**$70,000.00**
TOTAL	**$770,000.00**

Project Description: **New Capacitor Bank at NCS Substation 13.8kV** **Project List: B (10)**

Description	Unit	Unit Cost	Quantity	Cost	References	Remarks
Capacitor Bank	Mvars	$21,975	18	$395,550.00	RSMeans	
Concrete Equipment Pad	LS	$7,500	1	$7,500.00	Engineer Judgement/RSMeans	
Outdoor Air Circuit Breaker 13.8 kV	Ea	$160,275	1	$160,275.00	RSMeans	

Total Construction Materials and Labor **$560,000.00**

Contingencies 10% **$56,000.00**

TOTAL **$616,000.00**

Ocean Thermal Energy Conversion

Electricity Generation			Construction/Operating Cost		
Nominal Size	50	MW	Initial Cost Low	10000	$/kW
Availability Factor	90	%	Initial Cost High	15000	$/kW
Operating Days	365	days	Operating Cost Low	0.02	$/kWh
Operaating Time	24	hrs/day	Operating Cost High	0.03	$/kWh
Design Life	20	yrs			
Electricity Generated	394,200,000	kWh/yr	Total Cost Low	$500,000,000	initial cost
			Total Cost High	$750,000,000	initial cost
Cost/kWh					
Interest Rate	7	%			
Cost/kWh - Low	**$0.12**	**/kwh**	**no O & M cost**		
Cost/kWh - High	**$0.18**	**/kwh**	**no O & M cost**		
Cost/kWh - Low	$0.14	/kwh	with O & M cost		
Cost/kWh - High	$0.21	/kwh	with O & M cost		

Resources

http://www.nrel.gov/otec/markets.html

Guam Power Authority. A Technical and Economic Feasibility Assessment of a Deep Sea Water District Cooling System at Tumon Bay, Guam. January 2006

Wind Farm

Electricity Generation			Construction/Operating Cost			113880000
Nominal Size	50	MW	Initial Cost Low	3000	$/kW	
Capacity Factor	26	%	Initial Cost High	3000	$/kW	
Operating Days	365	days	Operating Cost Low	0.02	$/kWh	
Operaating Time	24	hrs/day	Operating Cost High	0.03	$/kWh	
Design Life	20	yrs				
Electricity Generated	61,200,000	kWh/yr	Total Cost Low	$150,000,000	initial cost	
			Total Cost High	$150,000,000	initial cost	
Cost/kWh						
Interest Rate	7	%				
Cost/kWh - Low	**$0.23**	**/kwh**	**no O & M cost**			
Cost/kWh - High	$0.23	/kwh	no O & M cost			
Cost/kWh - Low	$0.25	/kwh	with O & M cost			
Cost/kWh - High	$0.26	/kwh	with O & M cost			

Resources

Lawrence Berkely National Laboratory. Annual Report on U.S. Wind Power Installation, Cost and Performance Trends: 2006.
GE Energy http://www.gepower.com/prod_serv/products/wind_turbines/en/index.htm

Photovoltaics

Electricity Generation			Construction/Operating Cost			
Solar Insolation	5.88	kWh/m^2/Day	Initial Cost Low	8000	$/kW	145158672
Area	5,000,000	ft^2	Initial Cost High	8000	$/kW	
Operating Days	365	days	Operating Cost Low	0	$/kWh	
Efficiency	15	%	Operating Cost High	0	$/kWh	
Design Life	25	yrs				
Electricity Generated	76,549,474	kWh/yr	Total Cost Low	$400,000,000	initial cost	
			Total Cost High	$400,000,000	initial cost	
Cost/kWh						
Interest Rate	7	%				
Cost/kWh - Low	**$0.45**	**/kwh**	**no O & M cost**			
Cost/kWh - High	$0.45	/kwh	no O & M cost			
Cost/kWh - Low	$0.45	/kwh	with O & M cost			
Cost/kWh - High	$0.45	/kwh	with O & M cost			

Biodiesel

Electricity Generation			Construction/Operating Cost		
Nominal Size	50	MW	Initial Cost Low	1500	$/kW
Availability Factor	90	%	Initial Cost High	3000	$/kW
Operating Days	365	days	Operating Cost Low	0.15	$/kWh
Operaating Time	24	hrs/day	Operating Cost High	0.18	$/kWh
Design Life	20	yrs			
Electricity Generated	394,200,000	kWh/yr	Total Cost Low	$75,000,000	initial cost
			Total Cost High	$150,000,000	initial cost
Cost/kWh					
Interest Rate	7	%			
Cost/kWh - Low	$0.02	/kwh	no O & M cost		
Cost/kWh - High	$0.04	/kwh	no O & M cost		
Cost/kWh - Low	**$0.17**	**/kwh**	**with O & M cost**		
Cost/kWh - High	**$0.22**	**/kwh**	**with O & M cost**		

Waste to Energy - Biomass

Electricity Generation			Construction/Operating Cost		
Nominal Size	50	MW	Initial Cost Low	3000	$/kW
Availability Factor	90	%	Initial Cost High	5500	$/kW
Operating Days	365	days	Operating Cost Low	0.15	$/kWh
Operaating Time	24	hrs/day	Operating Cost High	0.18	$/kWh
Design Life	20	yrs			
Electricity Generated	394,200,000	kWh/yr	Total Cost Low	$150,000,000	initial cost
			Total Cost High	$275,000,000	initial cost

Cost/kWh			
Interest Rate	7	%	
Cost/kWh - Low	$0.04	/kwh	no O & M cost
Cost/kWh - High	$0.07	/kwh	no O & M cost
Cost/kWh - Low	**$0.19**	**/kwh**	**with O & M cost**
Cost/kWh - High	**$0.25**	**/kwh**	**with O & M cost**

Area Required			
Ethanol Production			
Sorghum - Low	172	gallons/acre	http://www.seco.cpa.state.tx.us/re_biomass-crops.htm
Sugarcane - High	500	gallons/acre	
Energy Content of Ethanol	84000	Btu/gallon	http://bioenergy.ornl.gov/papers/misc/energy_conv.html
	24.61177849	kWh/gallon	
Efficiecny	40	%	
For a 50-MW Plant	40041803.57	gallons/yr	
Area Required Low	80,084	acres	
Area Required High	232,801	acres	

Waste to Energy - Conversion

Electricity Generation			Construction/Operating Cost		
Nominal Size	50	MW	Initial Cost Low	3500	$/kW
Availability Factor	90	%	Initial Cost High	3500	$/kW
Operating Days	365	days	Operating Cost Low	0.15	$/kWh
Operaating Time	24	hrs/day	Operating Cost High	0.18	$/kWh
Design Life	20	yrs			
Electricity Generated	394,200,000	kWh/yr	Total Cost Low	$175,000,000	initial cost
			Total Cost High	$175,000,000	initial cost
Cost/kWh					
Interest Rate	7	%			
Cost/kWh - Low	$0.04	/kwh	no O & M cost		
Cost/kWh - High	$0.04	/kwh	no O & M cost		
Cost/kWh - Low	**$0.19**	**/kwh**	**with O & M cost**		
Cost/kWh - High	**$0.22**	**/kwh**	**with O & M cost**		

Geothermal

Electricity Generation				Construction/Operating Cost			
Nominal Size		50	MW	Initial Cost Low		2000	$/kW
Availability Factor		90	%	Initial Cost High	N/A		$/kW
Operating Days		365	days	Operating Cost Low		0	$/kWh
Operaating Time		24	hrs/day	Operating Cost High		0	$/kWh
Design Life		20	yrs				
Electricity Generated		394,200,000	kWh/yr	Total Cost Low		$100,000,000	initial cost
				Total Cost High	N/A		initial cost
Cost/kWh							
Interest Rate		7	%				
Cost/kWh - Low		$0.02	/kwh	no O & M cost			
Cost/kWh - High	N/A		/kwh	no O & M cost			

Solar Thermal Electric

Electricity Generation			Construction/Operating Cost			96772448
Solar Insolation	5.88	kWh/m^2/Day	Initial Cost Low	5000	$/kW	
Area	5,000,000	ft^2	Initial Cost High	5000	$/kW	
Operating Days	365	days	Operating Cost Low	0	$/kWh	
Efficiency	15	%	Operating Cost High	0	$/kWh	
Design Life	20	yrs				
Electricity Generated	76,549,474	kWh/yr	Total Cost Low	$250,000,000	initial cost	
			Total Cost High	$250,000,000	initial cost	
Cost/kWh						
Interest Rate	7	%				
Cost/kWh - Low	**$0.31**	**/kwh**	**no O & M cost**			
Cost/kWh - High	$0.31	/kwh	no O & M cost			
Cost/kWh - Low	$0.31	/kwh	with O & M cost			
Cost/kWh - High	$0.31	/kwh	with O & M cost			

Resources

U.S. Department of Energy Energy Efficiency and Renewable Energy. Parabolic Trough Solar thermal Electric Power Plants. July 2006

Wave Energy

Electricity Generation			Construction/Operating Cost		
Nominal Size	50	MW	Initial Cost Low	3000	$/kW
Availability Factor	40	%	Initial Cost High	4000	$/kW
Operating Days	365	days			
Operaating Time	24	hrs/day			
Design Life	20	yrs			
Electricity Generated	175,200,000	kWh/yr	Total Cost Low	$150,000,000	initial cost
			Total Cost High	$200,000,000	initial cost
Cost/kWh					
Interest Rate	7	%			
Cost/kWh - Low	$0.08	/kwh	no O & M cost		
Cost/kWh - High	$0.11	/kwh	no O & M cost		

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EarthTech
A Tyco International Ltd. Company

FIGURE A
ANTICIPATED GPA IMPROVEMENTS TO MEET MILITARY LOAD INCREASES 34.5kV TRANSMISSION ONE-LINE DIAGRAM

102079

EarthTech
A Tyco International Ltd. Company

FIGURE B

ANTICIPATED GPA IMPROVEMENTS TO MEET MILITARY LOAD INCREASES
115kV TRANSMISSION
ONE-LINE DIAGRAM

102079

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Guam Wastewater Utility Study Report for Proposed USMC Relocation

July 2008, Revision 1

Department of the Navy
Naval Facilities Engineering Command, Pacific
258 Makalapa Drive, Suite 100
Pearl Harbor, HI 96860-3134

Naval Facilities Engineering Command
NAVFAC PACIFIC

Contract Number N62742-06-D-1870/TO 0011

Guam Wastewater Utility Study Report for Proposed USMC Relocation

July 2008, Revision 1

Prepared for:

Department of the Navy
Naval Facilities Engineering Command, Pacific
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TEC Inc. Joint Venture
A Joint Venture of TEC Inc., Earth Tech, Inc., and EDAW, Inc.

Contract Number N62742-06-D-1870/TO 0011

EXECUTIVE SUMMARY

The Guam Integrated Military Development Plan (GIMDP), formerly the Joint Guam Military Master Plan, identified a planned increase in military population on Guam. Naval Computer and Telecommunications Station Finegayan, South Finegayan Housing area, Andersen Air Force Base (AAFB), AAFB Northwest Field, and AAFB South provide potential locations for most of the proposed United States Marine Corps (USMC) relocation to Guam. Sewage from these locations is currently conveyed to the Guam Northern District Wastewater Treatment Plant (NDWWTP) for treatment and disposal. The NDWWTP is owned and operated by Guam Waterworks Authority (GWA).

The Naval Facilities Engineering Command, Pacific, under Master Contract Number (No.) N62742-06-D-1870 issued a Task Order to the TEC JV to prepare Wastewater Utility Study Report and Planning Documents for the review of collection mains, pump stations, treatment and disposal system alternatives. This report includes evaluation of reasonable wastewater treatment alternatives to support the USMC relocation to Guam and provide sufficient and detailed information to support the environmental impact study process.

This report presents the findings of our evaluations conducted based on the information gathered during the field study; correspondence with the Guam Environmental Protection Agency, GWA, and United States Environmental Protection Agency (EPA) Region 9; search of plan files for previous studies, as-built drawings, planned sewer improvement projects, National Pollutant Discharge Elimination System, records on GWA, Air Force/Navy sewer systems; and detailed analysis of the recommended wastewater treatment options.

The following wastewater treatment alternatives are reviewed:

- **Option 1A** – Expand and upgrade existing primary treatment system at the Government of Guam (GovGuam) NDWWTP to accept the additional flow and load
- **Option 1B** – Expand and upgrade the GovGuam NDWWTP to secondary treatment
- **Option 2** – Build new secondary treatment plant near the proposed development on Department of Defense (DoD) land and construct new outfall
- **Option 3** – Build new separate secondary treatment plant at GovGuam NDWWTP site to treat DoD load only
- **Option 4** – Build a new tertiary treatment plant near the proposed development on DoD land and send effluent to a new water treatment plant (or existing water treatment Plant)
- **Option 5** – Build a new secondary treatment plant and construct new outfall on eastern coastline
- **Option 6** – Build a new tertiary treatment plant near proposed development and reuse the effluent, send the residual to the GWA outfall
- **Option 7** – Build a new tertiary treatment plant near proposed development on DoD land and install injection wells
- **Option 8** – Install pretreatment for DoD industrial flows in conjunction with the upgrade and expansion of the GovGuam NDWWTP.

Earth Tech developed a ranking system to identify four most favorable alternatives. The ranking system used a relative factor for regulatory agency involvement and cost of construction. The system used a factor 1 for low involvement or relative cost, 2 for medium involvement or relative cost and 3 for high involvement or relative cost. Table 5-3 in Section 5 of this report provides the total overall score and relative ranking of each alternative and Table 5-4 in Section 5 summarizes reasons for eliminating some of the alternatives. Based on the relative rankings, Earth Tech considered the following four alternatives for detailed analysis:

1. Expand and upgrade existing primary treatment system at the GovGuam NDWWTP to accept the additional flow and load
2. Expand and upgrade the GovGuam NDWWTP to secondary treatment
3. Build new secondary treatment plant near the proposed development on Department of Defense (DoD) land and construct new outfall
4. Build new separate secondary treatment plant at GovGuam NDWWTP site to treat DoD load only

The military buildup populations in Guam including USMC relocation for the study are provided in Table ES-1. Table ES-2, provides current and future military populations in Northern Guam where GIMDP identified as the major area for future USMC relocation.

Table ES-1: Current and Future Military Populations in Guam

Service	Active Duty	Dependants	On-base Civilian	Total
Baseline (FY06)				
USMC	3	2	1	6
Air Force	2,145	2,950	805	5,900
Navy	4,350	5,230	1,631	11,211
Army	30	50	11	91
USCG	140	180	53	373
SOF	0	0	0	0
Notional Increase				
USMC	8,552	9,000	3,207	20,759
Air Force	1,656	1,100	244	3,000
Navy	1,300	50	487	1,837
Army	630	950	236	1,816
USCG	81	103	30	214
SOF	350	630	131	1,111
Total Future Loading				
USMC	8,555	9,002	3,208	20,765
Air Force	3,801	4,050	1,049	8,900
Navy	5,650	5,280	2,118	13,048
Army	660	1,000	247	1,907
USCG	221	283	83	587
SOF	350	630	131	1,111

Note: Data from Navy's email dated 6/20/08 (14 September 2006 memorandum)
SOF Special Operation Force
USCG United States Coast Guard

Table ES-2: Current and Future Military Populations in Northern Guam

Service	Active Duty	Dependants	On-base Civilian	Total
Baseline (FY06)				
USMC	3	2	1	6
Air Force	2,145	2,950	805	5,900
Navy	39	66	1,481	1,586
Army	30	50	11	91
USCG	0	0	0	0
SOF	0	0	0	0
Notional Increase				
USMC	8,552	9,000	3,207	20,759
Air Force	1,656	1,100	244	3,000
Navy	0	0	0	0
Army	630	950	236	1,816
USCG	0	0	0	0
SOF	350	630	131	1,111
Total Future Loading				
USMC	8,555	9,002	3,208	20,765
Air Force	3,801	4,050	1,049	8,900
Navy	39	66	1,481	1,586
Army	660	1,000	247	1,907
USCG	0	0	0	0
SOF	350	630	131	1,111

Notes: 1. Assumed current USMC and Army reside in Northern Guam region.
2. All increased USMC, and Army and SOF live in Finegayan.
3. All increased AF live in AAFB.
4. Navy baseline population at NCTS Finegayan from GIMDP, 6/14/06.
5. Assumed no Navy and USCG population increase in Northern Guam.

USCG United States Coast Guard

For detailed analysis, the projected DoD waste water flows and existing wastewater flows to NDWWTP from both Civilian and Military flows are considered. Military wastewater flow includes domestic wastewater flow and industrial wastewater flow. The domestic wastewater flow is generated mainly from sanitary and general purposes and normally estimated from a residential population, while the industrial wastewater flow is generated from industrial operation processes. The following Table ES-3 provides current and future wastewater flows in Northern Guam Region. Detailed flow analysis is provided in Section 3 of this report.

Table ES-3: Current and Future Civilian and DoD Flows in Northern Guam Region

Type of Flow	Current Wastewater Flow (Y2006) (mgd)	Projected Wastewater Flow (mgd)	Total Projected Future Wastewater Flow (Y2025) (mgd)
Civilian	7.29	5.83	13.12
Military	1.23	3.28	4.51
USMC	–	2.52	2.52
Air Force	1.10	0.44	1.54
Navy	0.12	–	0.12
Army	0.01	0.20	0.21
SOF	–	0.12	0.12

Type of Flow	Current Wastewater Flow (Y2006) (mgd)	Projected Wastewater Flow (mgd)	Total Projected Future Wastewater Flow (Y2025) (mgd)
Total flow	8.52	9.11	17.63

mgd million gallons per day

Total planned wastewater flow generated from military facilities in Northern Guam is 3.28 million gallons per day (mgd), thus the average daily flow to NDWWTP is 17.63 mgd in the future. An average future daily flow of 17.63 mgd and peak flow of 40.44 mgd is considered for evaluating the following two viable alternatives:

- Expand and upgrade existing primary treatment system at the GovGuam NDWWTP to accept the additional flow and load
- Expand and upgrade the GovGuam NDWWTP to secondary treatment

A breakdown of average and future wastewater flows to NDWWTP and DoD plant are provided in Table ES-2. As shown in Table ES-2, the average future daily flow from military facilities is 4.51 mgd, and the peak future flow is 10.92 mgd. These flows are considered for evaluating the following two viable alternatives:

- Build new secondary treatment plant near the proposed development on Department of Defense (DoD) land and construct new outfall
- Build new separate secondary treatment plant at GovGuam NDWWTP site to treat DoD load only

Table ES-4: Average and Peak Wastewater Flows Considered for Viable Alternatives

Wastewater Treatment Alternative	Average Daily Flow (mgd)	Peak Daily Flow (mgd)
Option 1A: Expand & Upgrade NDWWTP Primary Treatment	17.63	40.44
Option 1B: Expand & Upgrade NDWWTP to Secondary Treatment	17.63	40.44
Option 2: DoD Secondary Treatment on DoD Land	4.51	10.92
Option 3: Separate Secondary Treatment at NDWWTP Site to Treat DoD Load Only	4.51	10.92

The detailed analysis of the four viable alternatives is provided in Section 6 of this report. The following Table ES-5 provides total present capital costs and annual life cycle costs of the four viable alternatives based on year 2008 cost, and Table ES-6 provides year 2010 capital costs estimated as the costs when construction starts and year 2013 capital costs estimated as mid-point costs of the construction.

Table ES-5: Cost Summary on Viable Alternatives

Option:	Option 1A: Expand & Upgrade NDWWTP Primary Treatment	Option 1B: Expand & Upgrade NDWWTP to Secondary Treatment	Option 2: DoD Secondary Treatment on DoD Land	Option 3: Separate Secondary Treatment at NDWWTP Site to Treat DoD Load Only
Capital Costs				
Total Capital Cost	$53,038,000	$175,533,000	$172,375,000	$161,250,000
Amortized Capital Cost	$3,903,000	$12,916,000	$12,684,000	$11,865,000

Option:	Option 1A: Expand & Upgrade NDWWTP Primary Treatment	Option 1B: Expand & Upgrade NDWWTP to Secondary Treatment	Option 2: DoD Secondary Treatment on DoD Land	Option 3: Separate Secondary Treatment at NDWWTP Site to Treat DoD Load Only
O&M Costs				
Total Annual Cost	$769,000	$3,089,000	$1,540,000	$1,541,000
Annual Life Cycle Costs	$4,672,000	$16,005,000	$14,224,000	$13,406,000
USMC Capital Cost	*$31,692,000*	*$62,408,000*	*$96,317,000*	*$90,101,000*

O&M Operations and Maintenance

Table ES-6: Cost Summary on Viable Alternatives at Y2010 and Y2013

Option:	Option 1A: Expand & Upgrade NDWWTP Primary Treatment	Option 1B: Expand & Upgrade NDWWTP to Secondary Treatment	Option 2: DoD Secondary Treatment on DoD Land	Option 3: Separate Secondary Treatment at NDWWTP Site to Treat DoD Load Only
Total Capital Costs				
Y2010 Cost	$55,450,000	$183,520,000	$180,220,000	$168,590,000
Y2013 Cost	$58,910,000	$194,940,000	$191,450,000	$179,080,000
USMC Costs				
Y2010 Cost	$33,130	$65,250,000	$100,700,000	$94,200,000
Y2013 Cost	$35,200	$69,310,000	$106,970,000	$100,070,000

In Table ES-5, Both the annual life cycle cost of $4,672,000, including amortized construction cost and estimated annual Operations and Maintenance cost, and total construction cost of $53,038,000 for Option 1A, (which would expand and upgrade existing primary treatment system at GovGuam NDWWTP to accept the additional flow and load), are the lowest compared to the other three alternatives. The USMC's capital cost share ($31,692,000) based on wastewater flow contribution is also the lowest for Option 1A. However, we recommend a secondary treatment alternative because the EPA Region 9 indicated that the increased discharge from DoD activities in the Northern Guam region would have an impact on the existing NPDES permit requirements, water quality standards and NPDES requirements for current and any future effluent discharge would be based on EPA secondary treatment technology based requirements. Among the three secondary treatment alternatives, Option 3 – Build New Separate Secondary Treatment Plant at GovGuam NDWWTP Site to treat DoD only has lowest capital cost ($161,250,000) and annual life cycle cost ($13,406,000). Based on capital cost allocations, Option 1B-Expand and Upgrade the GovGuam NDWWTP to secondary treatment options is beneficial to Navy as USMC share will be $62,408,000. However, in this option GWA share will be $88,702,000 and GWA does not want to upgrade the treatment plant to secondary as it will increase the sewer charges and puts hardship on Northern Guam civilian population. Hence GWA would like to operate the plant under 301(h) waiver and may upgrade the NDWWTP to secondary treatment within its current planning horizon of 20 years. Earth Tech team feels that the DoD should consider building New Separate Secondary Treatment Plant at GovGuam NDWWTP Site to treat DoD load only. The study and recommended alternatives work for the assumed military buildup population loading concentrated at the Finegayan area, and that significant population shifts to other locations will require further analysis to identify the further collection system, and treatment plant requirements and associated construction cost. A brief summary of the recommended alternative and the other three viable alternatives in the order of preference is presented below:

THE RECOMMENDED ALTERNATIVE:

Option 3 – Build new separate secondary treatment plant at GovGuam NDWWTP site to treat DoD load only

The recommended alternative will build a separate secondary treatment train to treat DoD loads only at the existing NDWWTP. The treatment train includes secondary treatment facilities to enhance removal of biodegradable organic matter (in solution or suspension) and suspended solids found in wastewater. The following new process components are required at the NDWWTP for this alternative:

- Headworks (two screens and two aerated grit chambers with odor control)
- Three primary clarifiers
- Three trickling filters
- Three secondary clarifiers
- Two chlorine contact tanks
- Three anaerobic digesters
- Two centrifuge solids dewatering systems with odor control
- Effluent monitoring and measurement
- Outfall diffuser capacity expansion

The detailed sizes of new process components required at the NDWWTP for providing secondary treatment for DoD flows (Option 3) are listed in Table ES-7.

Table ES-7: Components for Constructing Separate Secondary Treatment Plant at GovGuam NDWWTP to Treat DoD Load Only

Construction Components	Unit	Dimensions/Description
Headwork	1	Two mechanical fine screens and Two (2) aerated grit chambers, each 45 ft long x 12 ft wide x 7 ft SWD
Primary clarifier	3	60 ft diameter x 10 ft SWD
Trickling filter pumping station	1	40 ft long x 25 ft wide x 16 ft high
Trickling filter	3	65 ft diameter x 24 ft SWD
Secondary clarifier	3	80 ft diameter x 13 ft SWD
Chlorine contact tank	2	55 ft long x 25 ft wide x 14 ft SWD
Effluent measurement	1	Automatic sampler
Ocean outfall capacity expansion	1	Multiport diffusers
Anaerobic digesters	3	80 ft diameter x 18 ft SWD
Solids dewatering centrifuges	2	125 gpm each

ft feet
gpm gallons per minute
SWD side water depth

A new 24-inch, 33,300 feet of sewer and 30-inch, 12,600 feet of sewer are required to convey flow from AAFB and Finegayan to the new DoD constructed plant at the NDWWTP site. The outfall diffuser capacity needs to be expanded to discharge peak flows. The estimated project cost for constructing a new separate secondary treatment facility at the NDWWTP site to treat DoD load only is $161,250,000**.** A summary of preliminary construction cost for the recommended alternative (Option 3) is shown in Table ES-8.

Table ES-8: Preliminary Construction Cost for Recommended Alternative– Build New Separate Secondary Treatment Plant at GovGuam NDWWTP Site to Treat DoD Load Only

Construction Categories	Cost Opinion
Headwork Expansion	$4,313,000
Primary Clarifier Expansion	$8,724,000
Pumping Station	$2,281,000
Trickling Filters	$10,994,000
Secondary Clarifiers	$13,242,000
Chlorine Contact Tanks	$4,296,000
Anaerobic Digesters	$30,797,000
Influent and Effluent Samplers	$159,000
Solids Dewatering Building	$10,518,000
Site Work and Utilities	$5,973,000
Relief Sewer	$27,525,000
Outfall Diffuser Capacity Expansion	$621,000
TREATMENT SUBTOTAL COST	$91,298,000
SEWER SUBTOTAL COST	$28,147,000
TOTAL COST	$119,444,000
PROJECT SERVICES	$41,806,000
TOTAL ESTIMATED COST	$161,250,000
TOTAL ESTIMATED PROJECT COST (ROUNDED)	**$161,250,000**
TOTAL ESTIMATED PROJECT COST FOR USMC	**$90,101,000**

OTHER VIABLE ALTERNATIVES IN THE ORDER OF PREFERENCE:

Option 1B – Expand and Upgrade GovGuam NDWWTP to Secondary Treatment

In this alternative the NDWWTP will be upgraded to include secondary treatment facilities to enhance removal of biodegradable organic matters (in solution or suspension) and suspended solids found in wastewater. The following new process components and upgrades are required at the NDWWTP for this alternative:

- Headworks expansion and odor control
- One primary clarifier (same size as existing ones)
- Three trickling filters
- Four secondary clarifiers
- One chlorine contact tank
- Three anaerobic digesters (same size as existing ones)
- Two centrifuge solids dewatering systems and odor control
- Effluent monitoring and measurement expansion
- Outfall diffuser capacity expansion

A summary of the new process components and upgrades required at the NDW WTP for expanding and upgrading to secondary treatment (Option 1B) are listed in Table ES-9.

Table ES-9: Major Process Components for Expanding and Upgrading GovGuam NDWWTP to Secondary Treatment

Construction Components	Expand (E)/Upgrade (U)/NEW (N)	Unit	Dimensions/Description
Headworks	U/N	2	Two fine screens
Primary clarifier	N	1	130 ft diameter x 7 ft SWD
Trickling filter pumping station	N	1	40 ft long x 25 ft wide x 16 ft high
Trickling filter	N	3	120 ft diameter x 24 ft SWD
Secondary clarifier	N	4	125 ft diameter x 16 ft SWD
Chlorine contact tank	N	1	70 ft x 40 ft x 14 SWD
Effluent measurement	E	1	Automatic sampler
Odor control system	N	1	Locate at Headworks and Solids Dewatering
Anaerobic digester	U N	2 3	80 ft diameter x 18 ft SWD 80 ft diameter x 18 ft SWD
Solids dewatering centrifuges	N	2	225 gpm each
Outfall capacity expansion	N	1	400 ft long multiport diffusers

in inch
SWD side water depth

A summary of preliminary construction cost for the Option 1B alternative is shown in Table ES-10.

Table ES-10: Preliminary Construction Cost for Viable Alternative– Expand and Upgrade GovGuam NDWWTP to Secondary Treatment

Construction Categories	Cost Opinion
Headwork	$1,529,000
Primary Clarifiers	$6,465,000
Pumping Station	$2,759,000
Trickling Filters	$26,783,000
Secondary Clarifiers	$34,728,000
Chlorine Contact Tanks	$2,596,000
Anaerobic Digesters	$30,797,000
Influent and Effluent Samplers	$159,000
Solids Dewatering Building	$11,214,000
Site Work and Utilities	$8,192,000
Sewer Interceptors	$4,181,000
Ocean Outfall & Piping	$621,000
TREATMENT SUBTOTAL COST	$125,223,000
SEWER SUBTOTAL COST	$4,802,000
TOTAL COST	$130,026,000
PROJECT SERVICES	$45,509,000
TOTAL ESTIMATED PROJECT COST	$175,535,000
TOTAL ESTIMATED PROJECT COST (ROUNDED)	**$175,540,000**
TOTAL ESTIMATED PROJECT COST FOR USMC	**$62,408,000**

Option 2 – Build New Secondary Treatment Plant Near the Proposed Development on DoD Land and Construct New Outfall

This alternative considers construction of a secondary treatment plant that will be owned and operated by DoD. A newly constructed independent sewer main is required to convey all military generated wastewater in the Northern Guam region to a DoD secondary treatment plant near the proposed USMC Finegayan development on DoD land.

The following new process components are required for this alternative:

- Headworks (two screens and two aerated grit chambers with odor control)
- Three primary clarifiers
- Three trickling filters
- Three secondary clarifiers
- Two chlorine contact tanks
- Three anaerobic digesters
- Two centrifuge solids dewatering systems with odor control
- Effluent monitoring and measurement
- Ocean outfall

A summary of the major process components for Option 2 – Secondary Treatment Plant Near the Proposed Development on DoD Land and Construct New Outfall is provided in Table ES-11.

Table ES-11: Major Process Components for Building New Secondary Treatment Plant Near the Proposed Development on DoD Land and Construct New Outfall

Construction Components	Unit	Dimensions/Description
Headwork	1	Two mechanical fine screens and Two (2) aerated grit chambers, each 45 ft long × 12 ft wide × 7 ft SWD
Primary clarifier	3	60 ft diameter × 10 ft SWD
Trickling filter pumping station	1	40 ft long × 25 ft wide × 16 ft high
Trickling filter	3	65 ft diameter × 24 ft SWD
Secondary clarifier	3	80 ft diameter × 13 ft SWD
Chlorine contact tank	2	55 ft long × 25 ft wide × 14 SWD
Effluent measurement	1	Automatic sampler
Ocean outfall & effluent transmission piping	1	30 in diameter, 7,400 ft long
Anaerobic digesters	3	80 ft diameter × 18 ft SWD
Solids dewatering centrifuges	2	125 gpm each

lbs pounds
SWD side water depth

A summary of preliminary construction cost for the Option 2 alternative is shown in Table ES-12.

Table ES-12: Preliminary Construction Cost for Viable Alternative– Build New Secondary Treatment Plant Near the Proposed Development on DoD Land and Construct New Outfall

Construction Categories	Cost Opinion
Headwork	$4,313,000
Primary Clarifiers	$8,724,000
Pumping Station	$2,281,000
Trickling Filters	$10,994,000
Secondary Clarifiers	$13,242,000
Chlorine Contact Tanks	$4,296,000
Anaerobic Digesters	$30,797,000
Influent and Effluent Samplers	$159,000
Solids Dewatering Building	$10,518,000
Site Work and Utilities	$5,973,000
Sewer Interceptors	$24,339,000
Ocean Outfall & Piping	$12,048,000
TREATMENT SUBTOTAL COST	$91,298,000
SEWER SUBTOTAL COST	$36,388,000
TOTAL COST	$127,685,000
PROJECT SERVICES	$44,690,000
TOTAL ESTIMATED PROJECT COST	$172,375,000
TOTAL ESTIMATED PROJECT COST (ROUNDED)	**$172,380,000**
TOTAL ESTIMATED PROJECT COST FOR USMC	**$96,317,000**

Option 1A- Expand and Upgrade Existing Primary Treatment System at the GovGuam NDWWTP to Accept the Additional Flow and Load

This alternative will expand and upgrade the existing primary treatment facilities at the NDWWTP to accept the additional wastewater from USMC relocation and other future military build up in the Northern Guam region. The NDWWTP will have to add the following new process capacities to meet the requirement:

- Headworks expansion with odor control
- One primary clarifier (same size as existing ones)
- One anaerobic digester (same size as existing ones)
- Two centrifuge solids dewatering systems with odor control
- One chlorine contact tank (same size as existing ones)
- Effluent monitoring upgrade
- Outfall diffuser capacity expansion

The preliminary sizes of the NDWWTP expansion facilities are listed in Table ES-13.

Table ES-13: Major Components for Expanding and Upgrading Existing Primary Treatment System at the NDWWTP to Accept the Additional Load

Construction Components	Expand (E)/ Upgrade (U)/ NEW (N)	Unit	Dimensions/Description
Headworks	U/N	2	Two fine screens
Primary clarifier	N	1	130 ft diameter x 7 ft SWD
Chlorine contact tank	N	1	70 ft x 40 ft x 14 ft SWD
Effluent measurement	U		Automatic sampler
Odor control system	N	1	Locate at Headworks and Solids Handling
Anaerobic digester	U N	2 1	80 ft diameter x 18 ft SWD 80 ft diameter x 18 ft SWD
Solids dewatering centrifuges	N	2	225 gpm each
Outfall capacity expansion	N	1	400 ft long multiport diffusers

SWD side water depth

A new gravity 24-inch, 7,500-foot relief sewer will be constructed to convey flow USMC Finegayan area to the headworks of the NDWW TP. The outfa ll diffuser capacity needs to be expanded to discharge peak flows. A summary of preli minary construction cost for the Option 1A altern ative is shown in Table ES-14.

Table ES-14: Preliminary Construction Cost for Viable Alternative – Expand and Upgrade Existing Primary Treatment System at the GovGuam NDWWTP to Accept the Additional Flow and Load

Construction Categories	Cost Opinion
Headwork Expansion	$1,529,000
Primary Clarifier Expansion	$6,465,000
Chlorine Contact Tanks	$2,596,000
Anaerobic Digesters	$10,266,000
Influent and Effluent Samplers	$159,000
Solids Dewatering Building	$11,214,000
Site Work and Utilities	$2,256,000
Relief Sewer	$4,181,000
Outfall Diffuser Capacity Expansion	$621,000
TREATMENT SUBTOTAL COST	$34,486,000
SEWER SUBTOTAL COST	$4,802,000
TOTAL COST	$39,288,000
PROJECT SERVICES	$13,751,000
TOTAL ESTIMATED COST	$53,039,000
TOTAL ESTIMATED PROJECT COST (ROUNDED)	**$53,040,000**
TOTAL ESTIMATED PROJECT COST FOR USMC	**$31,692,000**

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FIGURES

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ACRONYMS AND ABBREVIATIONS

AAFB	Andersen Air Force Base
AOP	advanced oxidation process
BOD_5	5-day, biochemical oxygen demand
CFR	Code of Federal Regulations
CIP	Capital Improvement Program
CY cubic	yard
DO dissolved	oxygen
DoD	Department of Defense
DPW	Department of Public Works, Government of Guam
EIS	Environmental Impact Study
EPA	Environmental Protection Agency, United States
ft feet	
ft/sec	feet per second
ft^2 square	foot
ft^3 cubic	foot
ft^3/min	cubic feet per minute
GBSPO	Guam Bureau of Statistics and Planning Office
GBT Gravity	Belt Thickener
GDAWR	Guam Department of Aquatic and Wildlife Resources
GDOA	Guam Department of Agriculture
GEPA	Guam Environmental Protection Agency
GIMDP	Guam Integrated Military Development Plan
GovGuam	Government of Guam
GOJ	Government of Japan
gpd	gallons per day
gpd/ft^2	gallons per day per square foot
gpm	gallons per minute
GWA	Guam Waterworks Authority
HP horsepower	
IGPBS	Integrated Global Presence and Basing Strategy
in inch	
ISR	United States Air Force Global Intelligence, Surveillance Reconnaissance
lb poun	d
lb/day	pounds per day
lb/day/ft^2	pounds per day per square foot
MBR me	mbrane bioreactor
mg/L	milligrams per liter
mgd	million gallons per day
MILCON Military	Construction
ml/L	milliliters per liter
MWSS	Marine Wing Support Squadron
NAVFAC	Naval Facilities Engineering Command
NCTS	Naval Computer and Telecommunications Station
NDMA N-nitrosodimethy	amine
NDWWTP	North District Wastewater Treatment Plant
NPDES	National Pollution Disposal Elimination System
NTU	nephelometric turbidity unit

No.	number
O&M	Operation and Maintenance
ppt	part per trillion
QOL	Quality of Life
RO	Reverse Osmosis
SOF	Special Operation Force
SWD	side water depth
TDH	total dynamic head
TDS	total dissolved solids
TOC	total organic carbon
TSS	total suspended solids
U.S.	United States
USAF	United States Air Force
USCG	United Stated Coast Guard
USG	United Stated Government
USMC	United States Marine Corps
UV	ultraviolet
WQS	Guam Water Quality Standards
WWTP	wastewater treatment plant

1. Introduction

1.1 PURPOSE

The purpose of this study is to identify all reasonable wastewater treatment alternatives to support the United States Marine Corps (USMC) relocation to Guam and provide sufficient and detailed information to support the environmental impact statement (EIS) process. The Naval Facilities Engineering Command (NAVFAC), Pacific, under Master Contract Number (No.) N62742-06-D-1870 issued a Task Order to the TEC JV to prepare Wastewater Utility Study Report and Planning Documents for the review of collection mains, pump stations, treatment and disposal system alternatives. During the week of 23 July and 30 July, Earth Tech visited NAVFAC Marianas facilities in Guam, and met with NAVFAC staff and several other regulatory agencies in Guam to gather information regarding the regulatory requirements and existing wastewater infrastructure for this project.

This report presents the findings of our evaluations conducted based on the information gathered during the field study; correspondence with Guam Environmental Protection Agency (GEPA), Guam Waterworks Authority (GWA), and United States (U.S.) Environmental Protection Agency (EPA) Region 9; search of plan files for previous studies, as-built drawings, planned sewer improvement projects, National Pollutant Discharge Elimination System (NPDES), records on GWA, Air Force/Navy sewer systems; and detailed analysis of the recommended wastewater treatment options.

1.2 BACKGROUND INFORMATION

The island of Guam is part of the Marianas chain. Guam is a territory of the U.S. and is located approximately 3,800 miles west of Honolulu, Hawaii and 1,400 miles south of Tokyo, Japan. The island is approximately 30 miles long, ranging from 4 to 11 miles wide. The total land area is approximately 212 square miles. The current population of Guam is approximately 171,000.

The Guam Integrated Military Development Plan (GIMDP), formerly the Joint Guam Military Master Plan, identified a planned increase in military population on Guam. Naval Computer and Telecommunications Station (NCTS) Finegayan, South Finegayan Housing area, Andersen Air Force Base (AAFB), AAFB Northwest Field, and AAFB South provide potential locations for most of the proposed USMC relocation to Guam. Sewage from these locations is currently conveyed to the Guam Northern District Wastewater Treatment Plant (NDWWTP) for treatment and disposal. The NDWWTP is owned and operated by the GWA.

Based on the findings presented in the GIMDP, NAVFAC has made the decision to perform wastewater utility study to identify all reasonable alternatives for sewerage improvements to support the USMC relocation to Guam. The study addresses all reasonable wastewater treatment alternatives with sufficient and detailed information to support the EIS process. The study determines wastewater collection, treatment, and disposal requirements for the Department of Defense (DoD) in Northern Guam. The study identifies and develops alternatives to support the existing and proposed DoD development. The study provides a comparative analysis and recommendations for collection, treatment, and disposal of wastewater. The study provides environmental impact analysis (for use in the EIS) on the most feasible treatment and disposal alternatives. The effluent disposal options include utilizing existing GWA outfall, constructing new outfall, irrigation, injecting into the ground water, and further treatment as potable water. The study identifies and develops planning documents for projects that represent the recommended alternative for the wastewater system.

1.3 SCOPE OF WORK

This study encompasses AAFB, AAFB Northwest Field, AAFB South, NCTS Finegayan, and South Finegayan. This study provides assessment of wastewater treatment options available in Northern

Guam Region, and covers the interceptor conveyance of sewage exiting these bases and their treatment and disposal system(s).

Based on the original scope of work and information gathered during initial field investigations, the following nine wastewater treatment alternatives are reviewed. The detailed analyses of the options are provided in the following sections of this report.

- **Option 1A** – Expand and upgrade existing primary treatment system at the Government of Guam (GovGuam) NDWWTP to accept the additional flow and load
- **Option 1B** – Expand and upgrade the GovGuam NDWWTP to secondary treatment
- **Option 2** – Build new secondary treatment plant near the proposed development on DoD land and construct new outfall
- **Option 3** – Build new separate secondary treatment plant at GovGuam NDWWTP site to treat DoD load only
- **Option 4** – Build a new tertiary treatment plant near the proposed development on DoD land and send effluent to a new water treatment plant (or existing water treatment Plant)
- **Option 5** – Build a new secondary treatment plant and construct new outfall on eastern coastline
- **Option 6** – Build a new tertiary treatment plant near proposed development and reuse the effluent, send the residual to the GWA outfall
- **Option 7** – Build a new tertiary treatment plant near proposed development on DoD land and install injection wells
- **Option 8** – Install pretreatment for DoD industrial flows in conjunction with the upgrade and expansion of the GovGuam NDWWTP.

2. Existing Wastewater Treatment in Northern Guam Region

The waste water treatment in Northern Guam is provided by the GWA. The GWA NDWWTP is located in the Tanguisson Point area in Northern Guam. The Plant is a 12.0 million gallons per day (mgd) primary treatment plant with an ocean outfall. Military wastewater flow from AAFB and Finegayan area currently is conveyed to NDWWTP. The following sections provide brief description of wastewater system in AAFB, NCTS Finegayan, and details of NDWWTP.

2.1 ANDERSEN AIR FORCE BASE

The existing AAFB wastewater collection system consists of a network of gravity sewers, four major pump stations, and force mains located on the south side of the airfield. Two small sewage pump stations collect wastewater generated from facilities located on the north side of the airfield and convey the wastewater via force main to the gravity collection system on the south side of the airfield. The system also collects wastewater generated by the industrial and residential areas on the base and discharge wastewater off-base into the GWA sewage collection system at a sewer manhole located near the AAFB main gate. The wastewater is treated at the GWA NDWWTP.

2.2 NCTS FINEGAYAN

The wastewater system at NCTS Finegayan is primarily a gravity sewer system consisting of two main trunk lines. The wastewater is conveyed to NDWWTP via GWA wastewater collection system. At South Finegayan, the waste water collection system is a gravity sewer connected to the GWA wastewater collection system. The wastewater is conveyed to NDWWTP. The average wastewater flow generated by NCTS Finegayan is approximately 0.12 mgd.

2.3 DOD FLOWS AND LOADS

The NDWWTP provides wastewater treatment for AAFB under an agreement with the U.S. Air Force. The historical average wastewater flow generated by AAFB is approximately 1.1 mgd.

The AAFB wastewater collection system consists of a network of gravity sewers and four major sewage pump stations and force mains located on the south side of the airfield. Existing sewer system is discussed in Table 2-1 below.

Table 2-1: Existing Sewer System

Facility 1295 Sewage Pump Station	
Area Served	Residential area bounded by Palau Loop
Type	Submersible Pump
Size (HP) and Flow (gpm)	40, Flow capacity not available
Number	3
Standby generator system	Yes
Size of the Force Main (inches)	10
Length of the Force Main (ft)	Discharges into gravity sewage collection
Facility 24101 Sewage Pump Station	
Area Served	Area bound by B-52 Static display, Chicago Avenue and Arc Light Boulevard. The pump station also serves the facilities located along Arc Light Boulevard to the AMC Terminal.
Type	Horizontal Pump
Size (HP) and flow (gpm)	7.5 & 140
Head (ft)	45
Number	2

Standby generator system	Yes
Facility 24101 Sewage Pump Station (Continued)	
Wet well (ft × ft)	5 × 5
Size of the Force Main (inches)	8 inches
Length of the Force Main (ft)	1,350 [a]
Facility 1098 Sewage Pump Station	
Area Served	Serves entire main base area
Type	Vertical dry Pit Sewage Pump
Size (HP) and Flow (gpm)	150 & 2,450
Head (ft)	170
Number	3
Standby generator system	Yes
Size of the Force Main (inches)	18
Length of the Force Main (ft)	12,800 [b]
Facility 1881 Sewage Pump Station	
Area Served	Serves entire main base area
Size (HP) and Flow (gpm)	150 & 2,450 (three pumps) 150 & 3000 (one pump)
Head (ft)	170 (3 pumps), 130 (one pump)
Number	4
Standby generator system	Yes
Size of the Force Main (inches)	20
Length of the Force Main (ft)	6,300 [c]

ft feet
gpm gallons per minute
HP horsepower
Head total dynamic head (TDH)
[a] Discharges to a sewer manhole located along Davis Avenue
[b] Discharges into wet well of the Facility 1881 Sewage Pump Station
[c] Discharges into GWA sewage collection system manhole near AAFB main gate
(Source: Volume II Civil Utility Systems Report for Utility Study For Construction Program Projects, AAFB, Guam, May 2006))

2.4 NDWWTP FLOWS AND LOADS

The design capacity for NDWWTP is 12 mgd. However, its current permit limit is 6 mgd (GWA 2007). The monthly average flows during the years 2004 and 2005 ranged from 9 mgd to 9.50 mgd with an overall average value of 9.30 mgd. The monthly average total suspended solids (TSS) loads during the years 2004 and 2005 ranged from 7,500 pounds per day (lb/day) to 22,500 lb/day with an average of 8,220 lb/day. The monthly average 5-day biochemical oxygen demand (BOD_5) loads during the years 2004 and 2005 ranged from 10,000 lb/day to 22,500 lb/day with an average value of 16,600 lb/day. Using the maximum monthly values, the flows during the years 2004 and 2005 exceeded the permit limit of 6 mgd. Effluent BOD_5 concentration limits, effluent BOD_5 loadings, and effluent suspended solids concentration also exceeded permit limits on a number of instances during the period of January 2004 to March 2005.

2.5 NDWWTP DESIGN CRITERIA

The NDWWTP was commissioned in 1979 and is designated Class III Wastewater Treatment Plant (WWTP). The plant is a primary treatment plant located on the northwestern coast of Guam. Location of the treatment plant is shown in Figure 2-1. NDWWTP provides services to Andersen Air Force Base along with the local population. The WWTP contains the following unit processes:

Figure 2-1
Location of
Northern District WWTP

- Comminutor
- Grit Removal
- Primary Clarifiers
- Chlorine Contact Tank
- Anaerobic Digesters
- Centrifuges
- Air Drying Bed for Solids Dewatering and Stabilization

The NDWWTP is designed for the following flows:

- Average flow 12.0 mgd
- Peak flow capacity 27.0 mgd

The NDWWTP discharges treated effluent through a 30-inch outfall into Philippines Sea. The design criteria of NDWWTP are provided in Table 2-2. The current effluent permit limitations are discussed in Section 2.8.

Table 2-2: Existing Plant Design Summary

Item	Design Value
Comminutor	
Type	Chicago Pump
Number	1
Diameter(ft)	Not Available
Power (HP)	3
Back Up Manual Bar Screen	
Bar screen width (inch)	72
Bar Spacing (inch)	2
Number	1
Influent Metering	
Type	Parshall Flume
Number	1
Size (inch)	36
Preaeration Tanks	
Number	2
Length (ft) × Width (ft) × Depth (ft)	4,350
Capacity (mgd)	6.2
Air blower Capacity (ft^3/min)	800
Grit Removal	
Number	2
Width (ft)	22
Length (ft)	54.3
Hydraulic retention time (min)	3
Capacity, (mgd)	12.0
Primary Clarifiers	
Type	Circular
Number	2
Diameter(ft)	130
Side water depth (ft)	7
Surface Area (ft^2)	13,266
Weir length (feet)	471
Average Design Surface Overflow Rate (gpd/ft^2/day)	900

Item	Design Value
Peak Surface Overflow Rate (gpd/ft^2)	2,000
Effluent Metering	
Type	Parshall Flume
Number	1
Disinfection	
Type	Chlorine Contact Unit
Number	2
Surface Dimension (ft × ft)	70 × 40
Total Volume (ft^3)	39,572
Design Detention Time at peak flow (min)	16
Submersible Pumps to Send Scum and Sludge from Chlorine Contact Tank to Primary Digesters	
Type	Centrifugal Pumps
Number	2
Capacity (gpm)	n/a
Head (ft)	n/a
Primary clarifier sludge pumps equipped with upstream grinders	
Type	Air Operated Diaphragm pump
Number	4
Capacity (gpm)	n/a
Head (ft)	n/a
Sludge recirculation pumps	
Type	Centrifugal
Number	2
Capacity (gpm)	450
Head (ft)	10
Primary Scum Pumps	
Type	Centrifugal Pumps
Number	2
Capacity (gpm)	450
Head (ft)	10
Primary Anaerobic Digester	
Type	Coated concrete tank with floating steel cover
Number	1
Diameter (ft)	80
Sidewall depth (ft)	21
Center depth (ft)	18
Total Active volume (ft^3)	287,327
Detention Time (days)	19
Design volatile solid loading (lb/ft^3)	0.13
Secondary Anaerobic Digester	
Type	
Number	1
Diameter (ft)	80
Sidewall depth (ft)	21
Center depth (ft)	18
Total Active volume (ft^3)	287,327
Detention Time (days)	19
Design volatile solid loading (lb/ft^3)	0.13
Heater	
Manufacturer	Cyclotherm
Capacity(Btu/hr)	500,000
Digester Sludge Recirculation Pump	
Type	Centrifugal Pump
Number	1
Capacity (gpm)	100

Item	Design Value
Head (ft)	22
Digester Sludge Transfer Pumps	
Type	Progressive Cavity Pump
Number	2
Capacity (gpm)	232
Head (ft)	10
Mechanical Dewatering	
Type	Centrifuge (Inoperative)
Number	2
Motor (HP)	75
Centrifuge Feed Pump	
Type	Progressive Cavity Pump
Number	2
Capacity (gpm)	110
Head (ft)	10
Centrifuge Polymer Feed Pumps	
Type	
Number	2
Capacity (gpm)	n/a
Head (ft)	n/a
Sludge Drying Beds	
Type	Sand
Number	8
Size – length x width (ft)	30 × 105
Total Sludge Bed Capacity (lb/day)	1,864
Outfall to Philippine Sea	
Pipeline Size, each (inches)	30
Peak Hour Capacity	27 mgd
Length of the outfall from the shore	2,100 ft
Depth at which wastewater is discharged	150 ft

ft feet
ft^3 cubic foot
ft^3/min cubic feet per minute
gpd/ft^2 gallons per day per square foot
lb/day/ft^2 pounds per day per square foot
n/a not available

2.6 EVALUATION OF MAJOR UNIT PROCESSES

2.6.1 Wastewater Flow

Raw wastewater influent enters the NDWWTP via a 42 inch diameter gravity line and via a 27-inch diameter forcemain from GWA's Southern Link Pump Station.

2.6.2 Preliminary Treatment

A communitor is used to grind debris in the influent. There is one communitor and the manufacturer is Chicago Pump. This is driven by a 3 horsepower (HP) pump. Currently the communitor is not in service and bar screen is used to remove debris. The screen is 72 inches wide with bar spacing of 2 inches. The screen is cleaned manually. The influent flow is measured using a Parshall flume. The Parshall flume is 36 inches wide. The flume is equipped with an ultrasonic level sensor for the flow measurement. This is currently not operational.

The flow from the Parshall flume enters two aerated grit basins. Each tank is 4,350 square feet (ft^2) equipped with an air blower with a capacity of 800 cubic feet per minute.

The influent enters flow splitter box prior to primary clarifiers. There are two clarifiers each diameter of 130 feet, side water depth of 7 feet and weir length of 471 feet. Surface area of each clarifier is 13,266 ft^2. One clarifier has a peak flow capacity of 27 mgd using a surface overflow rate of 2,000 gpd/ft^2. An aerial view of the treatment plant is shown in Figure 2-2.

2.7 SLUDGE HANDLING AND DISPOSAL

Four chopper pumps are installed as primary pumps to transfer the primary clarifier sludge to the primary anaerobic digester. Scum from the chlorine contact tanks is also pumped to the primary anaerobic digester. The stabilized sludge flows into a secondary anaerobic digester tank for thickening. These digesters are equipped with sludge heaters and gas and sludge recirculation systems. The sludge is designed to be pumped to two centrifuges for dewatering. The digesters and centrifuges are currently inoperative. The sludge from the primary clarifiers is transported to Hagatna WWTP where it is stabilized using aerobic digesters and dewatered using centrifuges.

2.8 REGULATORY AND EFFLUENT PERMIT REQUIREMENTS

NDWWTP is considered as a Class III facility according to the GEPA. NDWWTP disposes of primary treated effluent into the Philippine Sea through an outfall.

Effluent limitations for the NDWWTP effluent are contained in NPDES Permit No. GU0020141 issued on 30 June 1986 by the EPA. The NDWWTP is currently operating under 301(h) that allows discharge of primary treated effluent. This permit expired on 30 June 1991 and application for renewal has been submitted and is under review by the EPA. The original renewal received tentative denial from the EPA because of impacts to water quality and coral reef environment. The GWA revised the permit application to include a decision to extend the ocean outfall. Design of the outfall is completed and GWA is in the process of proceeding with the construction project. Table 2-3 summarizes the key effluent limits and monitoring requirements outlined in the current NPDES permit.

Table 2-3: NDWWTP NPDES Permit Requirements

Effluent Characteristic	Discharge Limitations				Monitoring Requirements	
	lb/day		Other Units (specify)			
	Average Monthly	Daily Max	Average Monthly	Daily Max	Measurement Frequency	Sample type
Flow (mgd)				6	Continuous	—
BOD_5[a]	4,256	8,512	85 mg/L	170 mg/L	Once/week	Composite
Suspended Solids [a]	2,504	5,008	50 mg/L	100 mg/L	Once/week	Composite
Settleable Solids	—	—	1 ml/L	2 ml/L	Once/week	Discrete
Oil and Grease [b]	—	—	—	—	Once/month	Discrete
pH[c]	Not less than 7.0 standard units nor greater than 9.0 standard units					

mg/L milligram per liter
ml/L milliliter per liter
[a] Both the influent and effluent shall be monitored.
[b] Oil and grease shall be monitored in the effluent on a monthly basis over as month period since many toxic organic pollutants partition into this fraction. If the level of oil and grease is found to be unacceptable, this permit shall be modified to include an effluent limitation and monitoring requirement for this parameter.
[c] The discharge shall not cause the pH of the receiving water to deviate more than 0.5 pH units of that which would occur naturally.

Figure 2-2
Aerial Northern District WWTP

C:\Projects\Guam\ArcGIS\figure6-7 small.mxd

2.9 RECENT FLOWS AND LOADINGS

During 2004 and 2005 the monthly average and daily maximum flow rate ranged from 8.9 to 9.6 mgd and from 9.4 to 9.8 mgd, respectively. Based on the permit limit of 6 mgd, the influent flow rates reported during this period are consistently above the permit limit.

The monthly average and daily maximum reported flow rate, BOD_5, TSS, settleable solids, and pH are listed in Table 2-4. The permit's mass effluent rates are based on 6 mgd flow.

Table 2-4: Northern District WWTP Influent and Effluent Wastewater Characteristics

Parameter	Average	Range
Flow (mgd)	9.3	8.9-9.6
Influent BOD_5 (mg/L)	221.1	130-306
Effluent BOD_5 (mg/L)	85.6	60-126
BOD_5 Removal Rate (%)	60.3	25.4-69.4
Influent BOD_5 (lb/day)	17,024.6	10,388-23,540
Effluent BOD_5 (lb/day)	6,722.0	5,053-9,877
Influent Suspended Solids (mg/L)	105.4	63-278
Effluent Suspended Solids (mg/L)	61.2	32-125
TSS Removal Rate (%)	38.7	100-66
Influent Suspended Solids (lb/day)	8,139.3	4,923-22,124
Effluent Suspended Solids (lb/day)	4,734.3	2,439-10,068
Effluent Settleable Solids (ml/L)	0.8	0.3-1.7
Effluent pH	7.5	6.8-8.1
Flow (mgd)	9.6	9.4-9.8
Influent BOD_5 (mg/L)	270.3	161-521
Effluent BOD_5 (mg/L)	101.9	69-178
Influent BOD_5 (lb/day)	20,610.1	12,716-40,429
Effluent BOD_5 (lb/day)	7,887.7	5,340-13,755
Influent Suspended Solids (mg/L)	159.3	80-672
Effluent Suspended Solids (mg/L)	80.5	46-170
Effluent Suspended Solids (lb/day)	12,368.9	3,491-13,044
Effluent Settleable Solids (ml/L)	1.6	0.3-5.0

2.10 POTENTIAL FUTURE PERMIT LIMITS AND REQUIREMENTS

The existing NPDES permit is based on a flow of 6 mgd. Since both current and future flows exceed this limit, an increased flow limit must be established. The design capacity of NDWWTP is 12.0 mgd, with one primary clarifier out of service. The current estimated flow is 9.3 mgd and the projected future flow by 2025 is 13.12 mgd not including any DoD flow from the proposed USMC relocation. Neither of these flows exceeds the original design capacity; however, both exceed the capacity if redundancy is considered.

Currently, the GWA is planning on extending the ocean outfall as part of the permit renewal and rehabilitation of the influent grit removal system.

2.11 NEW OCEAN OUTFALL UNDER CONSTRUCTION AT THE NDWWTP

The GWA is in the process of constructing a new ocean outfall at the NDWWTP to comply with stipulated order and to bring the NDWWTP into regulatory compliance. The new outfall is designed with a peak hour capacity of 27 mgd and the limiting factor is the diffuser on the end. The outfall consists of a 34 inch diameter high density polyethylene pipe 1,960 linear feet in length with a 400-foot long multiport diffuser, and extends about 2,100 feet from shore line to 150 feet depth in the ocean. The diffuser will be anchored with 36 two-piece concrete pedestal weights seated on the bottom substrate. The total construction cost of the new outfall is $9,650,000.

3. Projected Future Conditions

3.1 GUAM INTEGRATED MILITARY DEVELOPMENT

During recent years, as global events have influenced the U.S. foreign policy, the DoD has placed greater focus on stationing forces in the Pacific Region. In response to the global situation, the U.S. Pacific Command began an initiative known as Integrated Global Presence and Basing Strategy (IGPBS). A key component of this initiative is a proposed buildup of USMC, U.S. Navy, USAF, and U.S. Army elements in Guam. During the planning timeframe of GIMDP, the U.S. government was conducting negotiations with Government of Japan to realign U.S. forces within the country as well as relocate significant portion of USMC units in Okinawa to Guam.

The principal elements of IGPBS considered for wastewater study include:

- Relocation of USMC ground and air assets to Guam from various locations
- Development of USAF Global Intelligence, Surveillance, and Reconnaissance (ISR) and Strike hub
- Associated infrastructure, housing, and quality of life (QOL) improvements.

EDAW Inc. is developing a master plan to identify the land use and facility requirements for Marine relocation. NCTS Finegayan, South Finegayan Housing area, AAFB, AAFB Northwest Field, and AAFB South will bear the brunt of the military personnel increase on Guam. The master plan group developed several site plan concepts for the Main Base at Navy NCTS Finegayan. At this time Alternative Option 8 is the preferred alternative. Figure 3-1 provides proposed facilities to support the Marine Relocation. Table 3-1 provides the proposed facilities as identified in Figure 3-1.

Table 3-1: NCTS Finegayan Development Alternative Option 8 Proposed Building List

Map Label No.	Map Label Color Code	BFR ID	BFR ID List	Description
1	MAW	3	3, 4, 5, 6, 7, 8, 9, 10, 911	MAW ARMORY
2	Division Admin/Ops	11	11, 12, 13, 14, 15, 16, 17, 365, 575	DIV ARMORY
3	III MEF Admin/Ops	18	18, 21, 22, 19	MEF ARMORY
4	HQ Group	23	23, 24, 25, 26, 27, 28, 29, 30, 31, 686	MLG ARMORY
5	MAW	32	32, 34, 52, 53	MACG HAZ / FLAM STORAGE
6	Division Admin/Ops	35	35, 36, 511, 606	DIV HAZ / FLAM STORAGE
7	Play Fields	362	362	OUTDOOR PLAYING FIELDS HOUSING & MAIN BASE
8	III MEF Admin/Ops	37	37, 38	HAZ / FLAM STORAGE
9	MLG	40	687, 688, 40, 47, 48, 41, 545, 546	HAZ / FLAM STORAGE MLG
10	Community Support	56	56	BAND BUILDING
11	Division/III MEF HQ	57	57	OPERATIONAL TRAINER / TECG
12	Division Admin/Ops	58	58	PARACHUTE LOFT
13	MAW	70	70, 72, 73, 74	MAW AUTO MAINTENANCE SHOP
14	Division Admin/Ops	76	76, 77, 857	MOTOR TRANSPORT MAINTENANCE, H&S, RECON
15	Division Admin/Ops	78	78, 576, 577	MOTOR TRANSPORT MAINTENANCE, 12MAR / ARTY
16	III MEF Admin/Ops	79	79, 81, 82	AUTOMOTIVE MAINTENANCE
17	MLG	86	87, 694, 62, 86, 40	MT MAINTENANCE CLR-37 / 3D MED BN

Map Label No.	Map Label Color Code	BFR ID	BFR ID List	Description
18	MLG	89	89, 68, 47	ENGINEERING MAINT. SUPPORT CO CLB-5
19	MLG	90	90, 69, 48, 61, 67, 643	MT MAINTENANCE / MT CO CLR 5
20	Division Admin/Ops	146	146, 580	ARTILLERY HEAVY GUN SHOP
21	MAW	148	148, 150, 151	MACG ELECTRONIC MAINTENANCE
22	Division Admin/Ops	153	153, 154	COMM MAINTENANCE, HQ BN, RECON
23	III MEF Admin/Ops	156	156, 158, 159	COMM ELECT MAINTENANCE
24	MLG	162	162	H&S CO ELECTRONIC MAINTENANCE CLR-5
25	MLG	165	165	LS CO PARACHUTE FIELD MAINTENANCE SHOP
26	MAW	166	166, 169, 171	MACG ORGANIC STORAGE
27	MAW	167	167, 170, 51	ORGANIC STORAGE, MWHS, MWSG
28	Division Admin/Ops	173	172, 173	ORGANIC UNIT STORAGE, HQ, RECON, FAST
29	Division Admin/Ops	174	174, 581	ORGANIC UNIT STORAGE, HQ, 12 MAR
30	III MEF Admin/Ops	175	175	MHG SUPPLY WAREHOUSE
31	III MEF Admin/Ops	176	179, 176, 178, 367	ORGANIC STORAGE MEF
32	MLG	181	181, 189	ORGANIC UNIT STORAGE, MED BN
33	MLG	182	182, 695, 696, 697	ORGANIC UNIT STORAGE, CLR 37
34	MLG	183	183	ORGANIC UNIT STORAGE, CLR 35
35	MLG	186	186	ORGANIC UNIT STORAGE, CLB 5
36	MLG	188	188	SUPPLY CO, SUPPLY BN, CLR 35
37	MLG	190	190	CONTROLLED HUMIDITY WAREHOUSE CLR 35
38	MLG	191	191	CONTROLLED HUMIDITY WAREHOUSE LS CO
39	MLG	192	192	MAGTF DISTRIBUTION CENTER
40	MAW	195	195, 208	MAW HQ / MWHS OFFICE
41	Division/III MEF HQ	196	196	DIVISION HQ
42	Division/III MEF HQ	197	197	MEF HQ
43	HQ Group	198	198	MLG HQ
44	MAW	199	199	MWSG-17 HQ
45	MAW	200	200	MACG-18 HQ
46	Division/III MEF HQ	201	201	12TH MARINES RGT HQ
47	Division/III MEF HQ	202	202	MHG HQ
48	HQ Group	203	203, 257, 260, 261	CLR 37 HQ
49	MAW	204	204, 206	MWCS / MASS HQ
50	MAW	207	207, 218, 219, 209	MACS / MTACS HQ
51	Division Admin/Ops	210	513, 210	HQ / RECON BN HQ

Map Label No.	Map Label Color Code	BFR ID	BFR ID List	Description
52	III MEF Admin/Ops	211	211, 213	BN HQ, 7TH COMM, 3D INTEL
53	HQ Group	215	215, 216, 240, 243	SUPPLY BN / MAINTENANCE BN DET HQ, CLR 35
54	HQ Group	217	217, 248, 249, 250, 251, 645	CLR 5 HQ
55	Division/III MEF HQ	220	220, 221, 222, 514, 223, 224	HQ BN COMPANY OFFICES
56	Division Admin/Ops	225	225, 155	HQ BTRY, COM PLT, CNTRBTRYRAD
57	III MEF Admin/Ops	226	226, 227, 228	CO HQ / OPERATIONS, 3D INTEL
58	III MEF Admin/Ops	232	232, 233, 234, 235	CO HQ / OPERATIONS, 7TH COMM
59	III MEF Admin/Ops	236	236, 366	5TH ANGLICO / FAST CO HQ
60	HQ Group	238	237, 238, 792	3D MED BN / SURGICAL CO HQ
61	MLG	241	241, 184	MATERIAL READINESS CO, SUPPLY BN
62	MLG	242	185, 242, 42	MED LOG CO, SUPPLY BN
63	MLG	244	43, 64, 91, 244	ENGINEER MAINTENANCE CO, CLR 35
64	MLG	245	245, 44, 163	ELECTRONIC MAINTENANCE CO, CLR 35
65	MLG	246	65, 92, 246, 45	MOTOR TRANSPORT MAINT CO, CLR 35
66	MLG	247	46, 66, 93, 247	GENERAL SUPPORT MAINTENANCE, CLR 35
67	Community Support	252	252, 254, 194, 705, 164, 49	DEN HQ, CLR 35
68	HQ Group	256	256, 565, 566, 567, 568, 563, 564	9TH ESB COMPANY HQ
69	Community Support	258	258	DISBURSING OFFICE, CLR 37 / MEF
70	MLG	259	259, 147, 687, 688	COMMUNICATIONS CO DET, CLR 37
71	MLG	264	264	FUEL READY STORAGE
72	Fire/Police/Emergency Services	266	266	ALERT FORCE BUILDING
73	Community Support	270	270, 346, 341	AUDITORIUM / TRAVEL OFFICE
74	Community Support	319	319	EXCHANGE CENTRAL ADMIN
75	MLG	284	284, 288, 268.1	AUTO MAINTENANCE / MHE
76	MLG	285	285	VEHICLE HOLDING SHED
77	MLG	290	289, 290	PWC SHOP / WAREHOUSE
78	MLG	292	292	GENERAL STORAGE SHED
79	Quality of Life	294	294	MEDICAL CLINIC
80	Community Support	295.3	295.3	FACILITIES ENGINEER / ENVIRONMENTAL OFFICE

Map Label No.	Map Label Color Code	BFR ID	BFR ID List	Description
81	BEQ/BOQ	298	296, 368, 297, 369, 839, 840, 500, 515, 526, 584, 590, 596, 622, 623, 624, 625, 726, 741, 746, 501, 516, 527, 585, 591, 597, 626, 627, 628, 629, 727, 742, 747, 573, 650, 656, 677, 684, 699, 710, 796, 572, 649, 657, 676, 683, 700, 709, 795, 521, 532, 538, 711, 798, 522, 533, 539, 712, 799, 752, 757, 758, 759, 781, 786, 804, 808, 816, 819, 824, 753, 760, 761, 762, 782, 787, 805, 809, 817, 820, 825	BEQ (E1 - E3, E4 - E5)
82	Community Support	300	300, 291	DINING HALL
83	Fire/Police/Emergency Services	303	303	FIRE STATION
84	Quality of Life	304	304	ISSUE UNIFORM CENTER
85	Fire/Police/Emergency Services	305	305	BRIG
86	Fire/Police/Emergency Services	306	306, 268.2	POLICE / PMO STATION
87	Fire/Police/Emergency Services	312	312	PMO KENNEL
88	Community Support	313	313	REHABILITATION CENTER
89	MLG	314	314	RECYCLING CENTER
90	Quality of Life	315	315	RELIGIOUS MINISTRY FACILITY
91	Quality of Life	316	316	POST OFFICE
92	Quality of Life	317	317, 324, 325, 320, 323, 337	MAIN EXCHANGE
93	MLG	321.2	321.2	EXCHANGE SNACK SHOP
94	MLG	326	326	EXCHANGE MAINTENANCE SHOP
95	Quality of Life	327	327, 328	BANK / CREDIT UNION
96	Quality of Life	328	327, 328	BANK / CREDIT UNION
97	Quality of Life	329	329	TEMPORARY LODGING
98	Quality of Life	330	330, 331	COMMISARY
99	Community Support	332	332	FAMILY SERVICES CENTER
100	Quality of Life	334	334, 336, 322	EXCHANGE MAIN SERVICES STATION
101	Quality of Life	337	317, 324, 325, 320, 323, 337	MAIN EXCHANGE
102	Quality of Life	338	348, 338, 339	REC CENTER / HOBBY SHOP / EQUIP ROOM
103	Community Support	339	348, 338, 339	REC CENTER / HOBBY SHOP / EQUIP ROOM
104	Quality of Life	340	340	AUTO HOBBY SHOP
105	Quality of Life	342	342, 333	BOWLING ALLEY / AMUSEMENT CENTER
106	Quality of Life	345	345	SKATING RINK
107	Recreation	348	348, 338, 339	REC CENTER / HOBBY SHOP / EQUIP ROOM
108	Education/Community Services	349	349	YOUTH CENTER
109	Community Support	350	350	COMMISSIONED OFFICERS OPEN MESS
110	Community Support	351	351	ENLISTED CLUB

Map Label No.	Map Label Color Code	BFR ID	BFR ID List	Description
111	Quality of Life	354	354, 318.1	PACKAGE STORE / LOCATION EXCHANGE MAIN BASE
112	Education/Community Services	355	355	CHILD DEVELOPMENT CENTER
113	Quality of Life	356	356, 359	LIBRARY / EDUCATION SERVICES
114	Park - Picnic Area	357	357	RECREATION PAVILLION
115	MLG	358	358	EXCHANGE WAREHOUSE
116	Education/Community Services	359	356, 359	LIBRARY / EDUCATION SERVICES
117	Play Courts	361	361	PLAYING COURTS HOUSING & MAIN BASE
118	Quality of Life	432	432	THEATER
119	BEQ/BOQ	502	301, 302, 570, 647, 659, 674, 681, 702, 707, 793, 569, 646, 660, 673, 680, 703, 706, 855, 524, 535, 541, 714, 801, 525, 536, 542, 715, 802, 503, 518, 529, 587, 593, 599, 634, 635, 636, 637, 729, 744, 749, 504, 519, 530, 588, 594, 600, 638, 639, 640, 641, 730, 745, 750, 755, 766, 767, 768, 784, 789, 811, 822, 827, 853, 756, 785, 812, 823, 854, 842, 843	BOQ
120	Division/III MEF HQ	512	512	OPERATIONAL TRAINER FACILITY
121	MLG	544	544	GARAGE 9TH ESB
122	MLG	547	547, 548, 560, 561	9TH ESB BN WAREHOUSE
123	MLG	549	549, 558, 559, 187, 50	9TH ESB, EOD STORAGE
124	HQ Group	550	550, 791	OPERATIONAL TRAINER FACILITY
125	MLG	551	551	WOODWORKING HOP
126	MLG	553	553, 554, 552	ENGINEER / MT EQUIP MAINT SHOP 9TH ESB
127	MLG	557	557	COMM MAINTENANCE SHOP 9TH ESB
128	HQ Group	563	256, 565, 566, 567, 568, 563, 564	9TH ESB COMPANY HQ
129	Division Admin/Ops	582	582, 583	ARTILLERY BN HQ DET / CO HQ
130	Division Admin/Ops	609	609, 610, 611	CAB VEHICLE MAINTENANCE
131	Division Admin/Ops	614	614, 615	CAB COMM MAINTENANCE
132	Division Admin/Ops	616	616	CAB ORGANIC UNIT STORAGE
133	Division Admin/Ops	618	618, 619, 620, 621, 617	CAB HQ
134	MLG	644	644	MT OPEN STORAGE
135	MLG	654	654	ELECTRIC MAINT CO CLR 35
136	MLG	655	652, 653, 655	ORDNANCE MAINT CO CLR 35
137	MLG	665	88, 63, 41, 664, 665	ORGANIC MT MAINTENANCE CLR-35
138	HQ Group	679	679	CLR 35 HQ
139	MLG	690	690	CARGO STAGING AREA
140	MLG	691	691	CONTAINER OPS BUILDING
141	HQ Group	698	698, 851	LEGAL SERVICES FACILITY

Map Label No.	Map Label Color Code	BFR ID	BFR ID List	Description
142	Division Admin/Ops	717	717, 732, 602, 603, 604, 605	ARMORIES
143	Division Admin/Ops	718	718, 733	HAZ / FLAM STORAGE
144	Division Admin/Ops	719	719, 734	VEHICLE MAINTENANCE
145	Division Admin/Ops	722	722, 737	COMMUNICATION MAINTENANCE
146	Division Admin/Ops	723	723	ORGANIC STORAGE
147	Division Admin/Ops	724	724	BN HQ
148	Division Admin/Ops	725	725	CO HQ
149	Division Admin/Ops	738	738	ORGANIC STORAGE
150	Division Admin/Ops	739	739	BATTALION / SQUADRON HQ
151	Division Admin/Ops	740	740	COMPANY / BATTERY HQ
152	Division Admin/Ops	830	830	ARMORY
153	Division Admin/Ops	831	831, 836	OPERATIONAL STORAGE
154	Division Admin/Ops	832	832	AUTO SHOP
155	Division Admin/Ops	835	835	ELEC / COMM MAINTENANCE SHOP
156	Division Admin/Ops	837	837, 838	JSDF HQ
157	Community Support	845	845	PHOTOGRAPHIC BUILDING
158	Community Support	847	847	PMO ISMT
159	MLG	850	850	DSSA WAREHOUSE
160	Community Support	851	698, 851	LEGAL SERVICES FACILITY
161	MLG	901	901	CORROSION CONTROL FACILITY
162	MLG	907	907, 908	TMP / PPP
163	Community Support	909	909	PASS / ID OFFICE
164	MLG	913	913	JEMS WAREHOUSE
165	Community Support	997		
166	Quality of Life	999		
167	Existing Facility - Retained	1000		
168	MLG	29301		
169	Quality of Life	31802		
170	Quality of Life	31803		
171	Recreation	34401		
172	Quality of Life	34403		
173	Recreation	36302		
174	Elementary School			
175	Middle School			
176	High School			
177	Water / Wastewater			
178	IRP SITE			
179	BEQ/BOQ		298, 370, 571, 648, 658, 675, 682, 701, 708, 794, 523, 534, 540, 713, 800, 502, 517, 528, 586, 592, 598, 630, 631, 632, 633, 728, 743, 748, 754, 763, 764, 765, 783, 788, 806, 810, 818, 821, 826, 841	BEQ NCO (E6 - E9)

Source: EDAW Inc

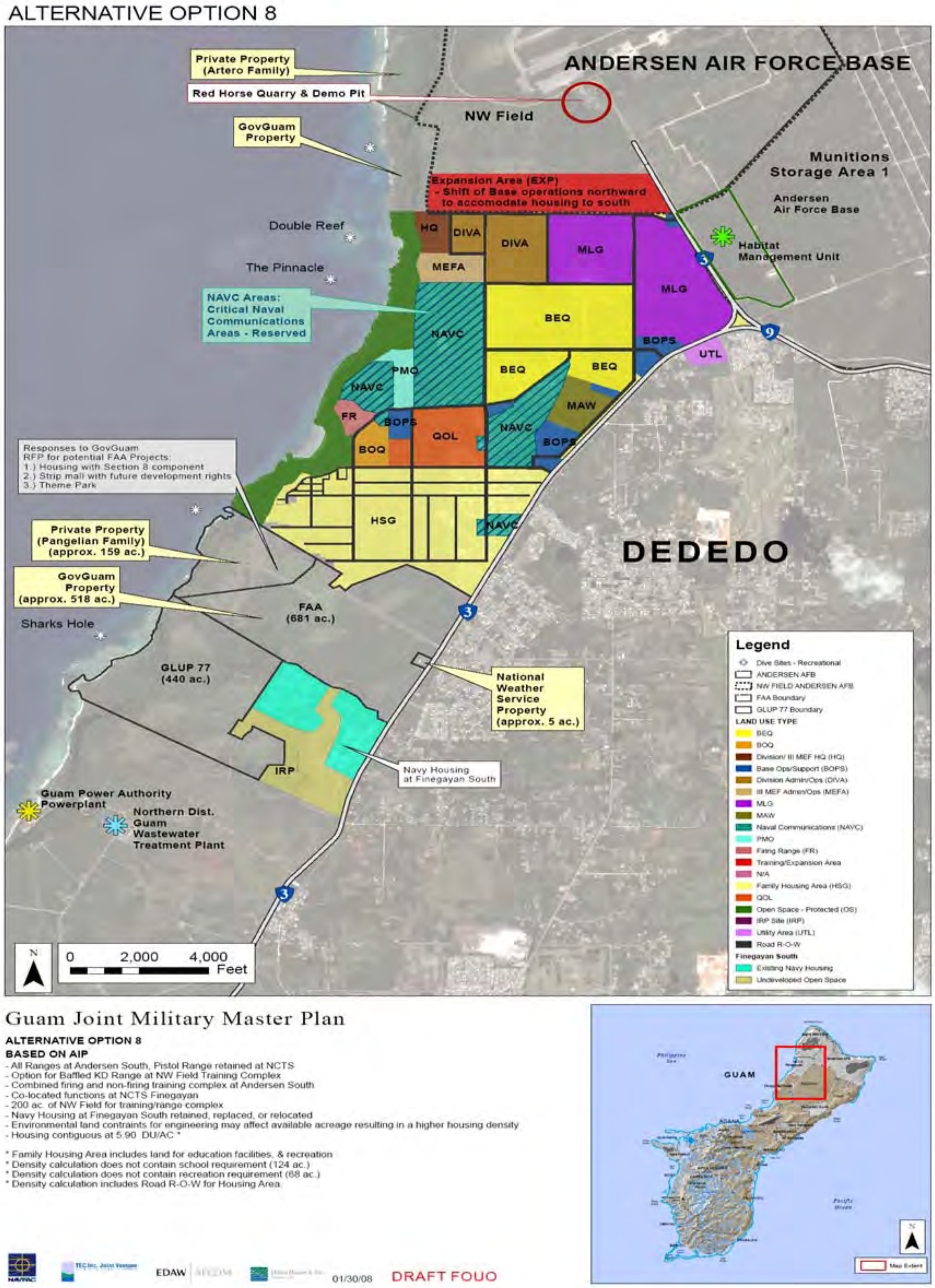

Figure 3-1
NCTS Finegayan Proposed Facilities

3.1.1 Andersen Air Force Base (AAFB)

The 2001 Quadrennial Defense Review directed the Air Force to expand basing in the Pacific region with a rationally tailored, multifaceted force able to respond quickly to defeat an adversary's military and political objectives. In response, the Air Force proposes to locate ISR, strike, and aerial refueling aircraft and personnel in the western Pacific as part of the U.S. Pacific Command's ISR/strike capability (ISR/Strike). AAFB, Guam was identified as the installation to host the ISR/Strike. EDAW Inc. is preparing a master plan to identify the facility requirements for ISR/Strike project. Several alternatives are under consideration. Alternative A is the preferred alternative. The alternative would establish the ISR/Strike capability by basing as many as 12 KC-135 aerial refueling aircraft and four Global Hawk RQ-4 unmanned aerial vehicles (Global Hawk) and support personnel at AAFB. The Base population would increase by as many as 3,000 personnel when combining the additional military, Air Force civilian, contractor, and dependant personnel. Facility construction, addition, and alteration projects, including 190 family housing units and associated family housing support facilities, would be constructed.

The following new mission hangars and facilities will be constructed along the South Ramp and North Ramp at AAFB.

South Ramp Facilities:

- Global Hawk Maintenance Hangar
- Air and Space Expeditionary Force (AEF) Support Hangar
- Fire Station
- Corrosion Control Hangar (Tanker)
- Renovated Wash Rack Hangar (Tanker, Bomber)
- General Purpose Maintenance Hangar and Aircraft Maintenance Unit (Tanker, Bomber Occasionally)
- Fuel Cell Hangar (Tanker, Bomber)

North Ramp Facilities:

- Transient Assault Echelon Fighter Hangar
- Marine Aviation Logistics Squadron Hangar
- AH-1W Hangar
- CH-53E Hangar
- HSC-25 Hangar
- Marine Aircraft Group Headquarters
- Marine Wing Support Squadron (MWSS) Headquarters
- Base Support Dining Hall
- Auto Maintenance Shop
- MWSS Organic Storage

3.1.2 NCTS Finegayan

The NCTS Finegay an parcel is the proposed locatio n for the m ajority of USMC base development . The principal Marine Com plex w ould be developed within the general NCTS Finegay an area. The South Fineg ayan Fam ily Housing would be redeveloped, and two adjacent federal parcels are considered for variety of uses. The site provides approximately 2,420 acres of land, and a shoreline over 2 miles in length. Most of the land along the cl iff line is considered pr ime limestone habitat that provides habitat for endangered plant and animal species. As a result development in NCTS Finegayan is restricted to 1,9 00 t o 2 ,000 acres. The NCTS Finegayan area is used for industrial/commercial facilities. Some of the major future proposed facilities at NCTS include electronic maintenance shops, engineering maintenance com panies, storage, warehouses, container operations buildings, cargo staging area, vehicle maintenance area, and administrative buildings. Table A-1 provided in Appendix A provides li st of facilities that support operational and training r equirements for Marine Relocation. As identified in the Tabl e A-1, the adm inistrative buildings cum ulatively occupy approxim ately 134,000 ft^2, vehicle maintenance shops occupy 5 66,000 ft^2, w eapon maintenance shops occupy 81,000 ft^2, and electronics and communication maintenance shops occupy 190,000 ft^2.

3.1.3 South Finegayan

The South is proposed pr imarily for fam ily housin g and related QOL use. A total of 290 acres is proposed f or fam ily housing and QOL facilities. Th e proposed facilities include fam ily housing, bachelors housing, transient acco mmodation, schools, parks, fire, police, post office, library, church, child development center, auditoriums, dining facilities, play fields, and swimming pools.

The South Finegay an is proposed prim arily for fam ily housing and related QOL use for both Marine relocation and Arm y deploy ment. The Arm y's m ajor operation facilities will be located at NCTS Barrigada, but their housing and QOL facilities will be constructed at Finegayan to minimize the need for additional comm unity support facili ties. The So uth Finega yan area will acco mmodate a total of 17,552 people that will be relocated from Japan. Of 17,552 personnel 8,552 ar e active duty personnel and 9,000 are dependants. The South Fi negayan also accommodates a total of 1,500 Army personnel and a total of 980 Special Operation Force (SOF) pe rsonnel that will be deploy ed. As per the GIMDP report, elementary school-going children are 21 percent of dependant populatio n, and middle and high school num bers ar e approxim ately 6 percent of de pendant population. Based on that projection, elementary school attending children are anticipated to be 1,890, and middle and high school children are anticipated to be 540 each. The following Table 3-2 provides current and future military population in Guam and Table 3-3 provides current and future military populations in Northern Guam.

Table 3-2: Current and Future Military Populations in Guam

Service	Active Duty	Dependants	On-base Civilian	Total
Baseline (FY06)				
USMC	3	2	1	6
Air Force	2,145	2,950	805	5,900
Navy	4,350	5,230	1,631	11,211
Army	30	50	11	91
USCG	140	180	53	373
SOF	0	0	0	0
Notional Increase				
USMC	8,552	9,000	3,207	20,759
Air Force	1,656	1,100	244	3,000
Navy	1,300	50	487	1,837

Service	Active Duty	Dependants	On-base Civilian	Total
Army	630	950	236	1,816
USCG	81	103	30	214
SOF	350	630	131	1,111
Total Future Loading				
USMC	8,555	9,002	3,208	20,765
Air Force	3,801	4,050	1,049	8,900
Navy	5,650	5,280	2,118	13,048
Army	660	1,000	247	1,907
USCG	221	283	83	587
SOF	350	630	131	1,111

Notes:
1. Data from Navy's email dated 6/20/08 (14 September 2006 memorandum)

Table 3-3: Current and Future Military Populations in Northern Guam

Service	Active Duty	Dependants	On-base Civilian	Total
Baseline (FY06)				
USMC	3	2	1	6
Air Force	2,145	2,950	805	5,900
Navy	39	66	1,481	1,586
Army	30	50	11	91
USCG	0	0	0	0
SOF	0	0	0	0
Notional Increase				
USMC	8,552	9,000	3,207	20,759
Air Force	1,656	1,100	244	3,000
Navy	0	0	0	0
Army	630	950	236	1,816
USCG	0	0	0	0
SOF	350	630	131	1,111
Total Future Loading				
USMC	8,555	9,002	3,208	20,765
Air Force	3,801	4,050	1,049	8,900
Navy	39	66	1,481	1,586
Army	660	1,000	247	1,907
USCG	0	0	0	0
SOF	350	630	131	1,111

Notes:
1. Assumed current USMC and Army reside in Northern Guam region.
2. All Increased USMC, and Army and SOF live in Finegayan.
3. All Increased AF live in AAFB.
4. Navy baseline population at NCTS Finegayan from GIMDP, 6/14/06.
5. Assumed no Navy and USCG population increase in Northern Guam.

3.2 DoD AND NDWWTP WASTEWATER FLOWS

The following section presents the wastewater flow estimation for the proposed facilities for the Marine relocation and improvement to the existing DoD facilities (AAFB Base). Total wastewater flow contributions from domestic, and industrial users are considered for this study. The domestic wastewater flow for the USMC relocation was calculated using unit flow information provided in Unified Facilities Criteria UFC 3-240-02N, Wastewater Treatment Systems Augmenting Handbook, 16 January 2004. Industrial flows were calculated using unit flow information provided in Water Pollution Control Federation Manual of Practice No. FD-5. Table 3-4 lists the unit flow values used in estimating wastewater flows.

Table 3-4: Wastewater Flow Estimating Unit Values

Category	Value
Resident Population	120 gpcd
Non-Resident Population	35 gpcd
Industrial Users	15,500 gpd/acre

gpcd gallons per capita per day
gpd gallons per day
Resident population includes active duty and dependent personnel
Non-Resident population includes on-base civilian personnel

The current and future average daily wastewater flows from DoD facilities and off-base civilian population are summarized in Table 3-5. A total of 837,000 square feet consisting of vehicle maintenance shops, weapon maintenance shops, and electronics and communication maintenance shops are considered for industrial flow estimation. The existing and future anticipated flows from civilian population located in Northern Guam contribute to Northern District Wastewater Treatment Plant (NDWWTP), which was provided by GWA.

Table 3-5: Current and Future Average Wastewater Flows in Northern Guam

Service	Active Duty	Dependants	On-base Civilian	Domestic Flow (mgd)	Industrial Flow (mgd)	Total Flow (mgd)
Baseline (FY06)						
Off-base Civilian						**7.29**
Military	2,217	3,068	2,298	0.71	0.52	**1.23**
Finegayan:	72	118	1,493	0.08	0.06	**0.14**
USMC	3	2	1	0.00	0.00	0.00
Navy	39	66	1,481	0.06	0.06	0.12
Army	30	50	11	0.01	0.00	0.01
SOF	0	0	0	0.00	0.00	0.00
AAFB:	2,145	2,950	805	0.64	0.46	**1.10**
Air Force	2,145	2,950	805	0.64	0.46	1.10
Total Northern Guam Flow						**8.52**
Notional Increase						
Off-base Civilian						**5.83**
Military	11,188	11,680	3,818	2.88	0.40	**3.28**
Finegayan:	9,532	10,580	3,574	2.54	0.30	**2.84**
USMC	8,552	9,000	3,207	2.22	0.30	2.52
Navy	0	0	0	0.00	0.00	0.00
Army	630	950	236	0.20	0.00	0.20
SOF	350	630	131	0.12	0.00	0.12

Service	Active Duty	Dependants	On-base Civilian	Domestic Flow (mgd)	Industrial Flow (mgd)	Total Flow (mgd)
AAFB:	1,656	1,100	244	0.34	0.10	**0.44**
Air Force	1,656	1,100	244	0.34	0.10	0.44
Total Northern Guam Flow						**9.11**
Total Future Loading						
Off-base Civilian						**13.12**
Military	13,405	14,748	6,116	3.59	0.92	**4.51**
Finegayan:	9,604	10,698	5,067	2.61	0.36	**2.97**
USMC	8,555	9,002	3,208	2.22	0.30	2.52
Navy	39	66	1,481	0.06	0.06	0.12
Army	660	1,000	247	0.21	0.00	0.21
SOF	350	630	131	0.12	0.00	0.12
AAFB:	3,801	4,050	1,049	0.98	0.56	**1.54**
Air Force	3,801	4,050	1,049	0.98	0.56	1.54
Total Northern Guam Flow						**17.63**

Notes:
1. AAFB and Navy industrial flows are from GIMDP, 6/14/06
2. Existing off-base civilian flow from Table 4-3, Guam Wastewater Master Plan, 2007. Calculated by subtracting AAFB & NCTAMS flows (7.8-0.45-0.06=7.29 mgd)
3. Future off-base civilian flow (FY2025) calculated per GWA's direction
4. Assumed Army and SOF live in Future Finegayan main base

Peak factor for DoD flows was determined using the Babbit's curve in Water Pollution Control Federation Manual of Practice No. FD-5. Peak factor for off–base civilian population was based on the design criteria provided in Guam Wastewater Master Plan. The following Table 3-6 provides future peak flows in Northern Guam.

Table 3-6: Future Peak Wastewater Flows in Northern Guam

Type of Flows	Domestic Flow (mgd)	Industrial Flow (mgd)	Peak Flow Factor	Total Peak Flow (mgd)
Total Future Loading				
Off-base Civilian Flow	13.12		2.25	**29.52**
Military Flow	3.59	0.92		**10.92**
Finegayan:	2.61	0.36	2.62	**7.20**
USMC	2.22	0.30		
Navy	0.06	0.06		
Army	0.21	0.00		
SOF	0.12	0.00		
AAFB:	0.98	0.56	3.23	**3.72**
USAF	0.98	0.56		
Total Northern Guam Flow				**40.44**

4. Regulatory Involvement for Wastewater Treatment Alternatives

The regulatory requirements for the proposed wastewater treatment alternatives were discussed with the following regulatory agencies during the field investigations.

- Bureau of Statistics and Planning (Coastal Management)
- GEPA
- EPA Region 9
- Guam Department of Aquatic and Wildlife Resources (GDAWR)
- Department of Parks and Recreation (Historic Preservation)
- Department of Public Works
- GWA

4.1 BUREAU OF STATISTICS AND PLANNING (COASTAL MANAGEMENT)

The Guam Coastal Management Program was developed on Guam as a core component within the Bureau of Statistics and Plans, a staff agency within the Office of the Governor. It coordinates all the use, protection, and development of land and ocean resources within Guam's coastal zone.

The Bureau of Statistics and Planning was contacted by Earth Tech to understand the regulatory requirements for the viable wastewater alternatives that are discussed in detail in Section 6. The following is the summary of the discussion

- Joint Use of Existing GWA Outfall would have the least impact, since it already exists.
- Reef system impacts are a concern for the new DoD outfall option. The Department of Fish and Wildlife should be consulted to obtain potential mitigation requirements.
- A Habitat Equivalency Model may need to be performed as part of the planning process for a new outfall.
- Reforestation, reducing sediments, and non-point source (storm water) pollution reduction should also be considered.
- Improving the habitat for native species should also be investigated.

4.2 GUAM ENVIRONMENTAL PROTECTION AGENCY (GEPA)

GEPA is responsible for the implementation of specific local and federal statutes and regulations on environmental protection. It oversees the management and protection of Guam's drinking water, groundwater, surface and marine water resources for public water supplies and other beneficial uses. It manages and protects Guam's principal source aquifer from pollution and overdraws. It is responsible for administering a program that provides sewage treatment and related facilities for Guam, and controlling pollution from domestic wastewater. It also handles the administration of the Federal Sewer Construction Grants Program, the NPDES Program, Spill Prevention Control and Countermeasure Program, Nonpoint Source Management Program, Individual Wastewater Program, implementation and enforcement of the Guam Water Quality Standards, Guam Soil Erosion and Sediment Control Regulations, Feedlot Waste Management Regulations, Connection to Public Sewer Regulations, and Air Pollution Control.

GEPA was contacted by Earth Tech to understand the regulatory requirements for the viable wastewater alternatives that are discussed in detail in Section 6. Following is a summary of our correspondence with GEPA staff.

Earth Tech contacted GEPA staff regarding the regulatory requirements for injecting effluent from the tertiary treatment plant into the groundwater. Our initial research identified that the Underground Injection Control regulations provided by GEPA categorize sewage treatment effluent recharge wells as Class V wells. Current GEPA regulations prohibit Class V injection wells. The wells could only be installed with a GEPA waiver to the regulations. GEPA has mentioned that it will review the design and documents before approving the groundwater injection of treated effluent.

4.3 EPA Region 9

EPA Region 9 is located in San Francisco. It has environmental protection responsibility in the southwestern U.S. (Arizona, California, Nevada, and the Pacific Region including Hawaii). The EPA also has direct role in environmental protection for the U.S. territories of Guam and American Samoa, the Commonwealth of the Northern Marian a Islands, and other unincorporated U.S. Pacific possessions around southwest Pacific Ocean. The Pacific Islands Office in EPA Region 9 manages the EPA's involvement and activities in the Pacific Insular areas including Guam. It regulates Guam's treated wastewater ocean outfall discharge through NPDES permit. It also guides Guam's sewage sludge disposal practice.

EPA Region 9 was contacted by Earth Tech to understand the regulator requirements for the viable wastewater alternatives that are discussed in detail in Section 6. Following is summary of our correspondence with EPA Region 9 staff.

- NPDES requirements for current and any future effluent discharge would be based on EPA secondary treatment technology based requirements and Guam Water Quality Standards (WQS). Mixing zones may be allowed per the Guam WQS and would be subject to the approval of GEPA with concurrence from the EPA. Although the NDWWTP currently has a waiver from meeting secondary treatment requirements, waivers for newly constructed treatment plants are no longer allowed. Permittees with an existing waiver are still allowed an opportunity to seek renewal of their waiver. However, EPA Region 9 cannot predict what future permitting requirements may be; 301(h) waivers are certainly not guaranteed in the future; and changes to WQS may result in additional permitting requirements as well.
- With respect to the current NPDES permit for the NDWWTP, it is currently administratively extended until EPA issues a new permit for the facility. EPA is continuing to review information.
- EPA Region 9 envisions that if the DoD has its own treatment plant and discharges through the NDWWTP outfall that each facility would have its own NPDES permit and effluent limitations. With a joint outfall there would be shared responsibilities for receiving water impacts that could affect the NDWWTP permit conditions/requirements.
- Should DoD discharge into the NDWWTP, there is a good chance that there would be associated impacts with the increased discharge that could have an impact on the continuance of the GWA's waiver for the NDWWTP.
- As mentioned above, continuance of 301(h) waivers are uncertain and DoD may want to consider taking advantage of this opportunity (military buildup) to develop a comprehensive solution to the area's infrastructure needs with GWA which could result in cost savings for both the DoD and the GWA.

4.4 DIVISION OF AQUATIC AND WILDLIFE

GDAWR in the Guam Department of Agriculture (GDOA) is a GovGuam agency to restore, conserve, manage, and enhance the aquatic resources in and about Guam and to provide for the public use of and benefits from these resources. It is responsible for endangered species recovery and conservation. It regulates, monitors, or studies the wildlife resources on and around Guam.

The Earth Tech team met with the GDAWR staff during the field work to understand the regulatory requirements for the viable wastewater treatment alternatives that are discussed in Section 6 of this report. Following are the concerns from the Department:

- The key concerns related to installation of water and sewer facilities are options that include marine construction (such as a new outfall). These include construction impacts to coral reefs and the aquatic habitat in the area of coral reefs. Also, the long term impact of the treated effluent on the coral reef habitat is a concern.
- The water intake and brine discharge outfall for a water desalination facility will have considerations similar to the wastewater effluent outfall.
- Construction on the land is also a concern in forested or preservation areas that are populated by native species of animals and vegetation. Vacant lots that are overgrown with grass and other vegetation are not as sensitive as forested areas.
- Development in the Finegayan or NCTS area is of major concern, since it is in the vicinity of the Haputo Ecological Preserve. There may also be archaeological impacts in these areas.
- Dredging and excavation in coral reefs should be avoided. If coral reefs are disturbed then habitat restoration plan must be developed. Tunneling or directional drilling below the coral layer may be necessary for outfall construction.
- The Pati Point Marine Preserve (Federal Listed) is located to the east of AAFB. This area should be avoided as a site for an ocean outfall.
- The recent Navy Kilo Wharf Renovation in Apra Harbor required habitat restoration. Some of the restoration was actually provided in the Cetti Bay area. This project can be reviewed as an example for some potential habitat restoration alternatives.
- "Two for one" restoration is sometimes required where larger, older native plant species are removed. This is an attempt to compensate for the age and size of the habitat that is removed.
- Bringing invasive foreign species onto the island with construction materials from other regions is a big concern. Methods must be provided to verify that invasive plant and animal species are not being transported to the island with each delivery.
- Mitigation and restoration costs should be separately shown in the cost estimates.
- The GDOA and the National Oceanic Atmospheric Administration have a habitat equivalence model for identifying coral reef mitigation costs.
- Prefer to implement "direct" mitigations, not the swapping unrelated mitigations (example: planting trees as mitigation for coral that is destroyed).
- Prefer to implement "natural" mitigation, not use "fixed infrastructure" improvements as a form of mitigation.

4.5 DEPARTMENT OF PARKS AND RECREATION (HISTORIC PRESERVATION)

Historic Resources Division of Guam Department of Parks and Recreation is responsible for the Guam historic preservation program that works to help keep in place Guam's long and colorful history, and its people's heritage. It reviews new construction plans to avoid potential impact on historic sensitive area.

The Earth Tech team met with the Department of Parks and Recreation staff during the field work to understand the regulatory requirements for the viable wastewater alternatives that are discussed in detail in Section 6. Following is a summary of our correspondence with Department staff:

- The land adjacent to the existing plant was at one time covered with Quonset huts and then subsequently, thoroughly bladed when they were abandoned. Guam's Territorial Archaeologist is certain that there are no resources that are of concern.
- Department of Parks and Recreation will attach no requirements for historic resources investigations of the area involved in the expansion of the plant, or the construction of a tertiary-treatment plant with injection wells. However, as it is a federally funded project the Department needs to receive a letter of consultation from whichever DOD-entity owns the land or is the project initiator. The consultation letter will state "no historic properties affected" and the Department will concur with this.
- The Guam Department of Parks and Recreation houses the Historic Resources Division, State Historic Preservation Office. It is, therefore, the review agency for compliance with Federal historic resources laws for all Federal undertakings on Guam.
- This project will most likely require the participation of an archaeologist, to first survey the route, and then to conduct any testing warranted by the survey findings. If plant construction and pipeline construction are part of the same permit application then the DoD would have to place the preceding conditions on it.

4.6 DEPARTMENT OF PUBLIC WORKS

Guam Department of Public Works (DPW) is responsible for all new construction permit review and approval, highway and transportation maintenance and construction, public bus operations, and solid waste management on Guam.

The Earth Tech team met with the DPW staff during the field work to understand the regulatory requirements for the viable wastewater alternatives that are discussed in detail in Section 6. Following is a summary of the meeting:

- Construction in public right of way will require contractor to provide a performance bond to cover surface preparation, compaction, and surface restoration.
- Backfill of trenches within the road prism will require placement of flowable fill rather than compaction of native soil.
- Construction within the traveled way will be restricted to evenings.
- Ground penetrating radar should be used for utility investigations during design. Record drawings for many utilities do not exist.
- Work within the shoulder of the road can be performed during the day. However, the closure will be restricted to one lane with proper barricades and traffic control.
- The DPW may require full width overlay paving for trench cuts within roads, particularly for newer roads.

- The DPW has standard pavement restoration and trenching details that should be included in the Project Manual
- The DPW now enforces minimum separation requirements between adjacent utilities.
- Mid-America Traffic Center (MATC) guidelines are used for traffic control.
- Design submittals are reviewed by the DPW, Historical Preservation, GPA, and GEPA.
- Permit fees are based on tables in 1997 edition of Uniform Building Code
- Erosion, dust, sediment, vehicle traffic, and storm water controls are part of the permitting process. GEPA guidelines must be observed.

4.7 GUAM WATERWORKS AUTHORITY

GWA was established by the Guam Legislature, and it is a semi autonomous, self-supporting agency. The GWA administers Guam water utility service including water treatment and distribution, sewage conveyance, treatment, and disposal. An elected, non-partisan Consolidated Commission on Utilities oversees the operations of the GWA and regulates its rates.

GWA was contacted by Earth Tech to understand the regulatory requirements for the viable wastewater alternatives that are discussed in detail in Section 6. Following is a summary of our correspondence with GWA staff.

- GWA's typical wastewater charges for Navy are based on rate structure for government entities.
- GWA believes that the rate charged to the military is based on a 1980 vintage agreement. This agreement is in need of an update. GWA also anticipates that this agreement would be updated as part of this development process and that it would specify a rate per 1,000 gallons that would be charged for wastewater discharged to the GWA system. The rates mentioned above can be used anticipated guideline for estimating what the rate charged to the military will be.
- If on the other hand, the U.S. military is considering an option that would construct a wastewater treatment plant rather than discharge to the GWA system, then for planning purposes it can be anticipated that the GWA outfall will not be available for use due to implications related to its capacity and water quality impacts in the area surrounding the discharge. In this case, GWA would also expect a direct compensation for the impact of lost revenues resulting from the disconnection of NCTS and Air Force discharges into the GWA system.
- GWA has designed a new outfall and is under construction. The peak hour capacity of the outfall is 27 mgd. The limiting factor is the diffuser on the end. The outfall extends about 2100 feet from shore line to a depth of 150 feet. The bid cost for NDWWTP outfall is $9.6 million.
- The EPA and GEPA have not committed to allowing a mixing zone. The GWA has pursued but received no formal response from the EPA regarding 301(h) waiver and/or requirement for secondary treatment. However, the EPA has verbally communicated this past December that 301(h) waivers may not be granted for current permit renewal regardless of any additional flows. The GWA expects to upgrade to secondary treatment within their current planning horizon of 20 years in any event.

5. Review of Wastewater Treatment Alternatives

As discussed in Section 1, the following eight alternatives are evaluated in this stduy:

- **Option 1A** – Expand and upgrade existing primary treatment system at the Government of Guam (GovGuam) NDWWTP to accept the additional flow and load
- **Option 1B** – Expand and upgrade the GovGuam NDWWTP to secondary treatment
- **Option 2** – Build new secondary treatment plant near the proposed development on Department of Defense (DoD) land and construct new outfall
- **Option 3** – Build new separate secondary treatment plant at GovGuam NDWWTP site to treat DoD load only
- **Option 4** – Build a new tertiary treatment plant near the proposed development on DoD land and send effluent to a new water treatment plant (or existing water treatment Plant)
- **Option 5** – Build a new secondary treatment plant and construct new outfall on eastern coastline
- **Option 6** – Build a new tertiary treatment plant near proposed development and reuse the effluent, send the residual to the GWA outfall
- **Option 7** – Build a new tertiary treatment plant near proposed development on DoD land and install injection wells
- **Option 8** – Install pretreatment for DoD industrial flows in conjunction with the upgrade and expansion of the GovGuam NDWWTP.

This section provides brief description of each alternative and their advantages and disadvanatges in reference to regulartory requirements and considerations, public perception, technology capability, system reliability, engineering constructability, project construction cost, project execution time, and the DoD's influence over system Operation and Maintenance (O&M). This section describes methodology used to identify most viable alternatives that are evaluated in detail in Section 6.

5.1 Expand and Upgrade Existing Primary Treatment System at GovGuam NDWWTP to Accept the Additional Flow and Load

This alternative will expand and upgrade the existing primary treatment facilities at the NDWWTP to accept the additional wastewater from USMC relocation and other future military build up in the Northern Guam region. The projected year 2025 flow for the NDWWTP including civilian and military population increase will be 17.63 mgd and excess its designed treatment capacity of the plant (12 mgd). To accommodate the additional flow of 9.11 mgd from the military build up and civilian population growth in the Northern Guam area estimated in Table 3-4, the plant will need to expend its primary treatment capacity and apply a new discharge permit from the EPA. The effluent discharge requirements and required level of treatment will be re-evaluated by the EPA in conjunction with the request for increased flow.

This alternative will also involve sharing the cost for expanding the NDWWTP with the GWA, and coordinating with the GWA on ongoing and planned Capital Improvement Program (CIP) projects to achieve the future required treatment capacity to accept the additional load.

The GWA sewer capacity will reach its capacity with the additional flow from anticipated civilian customers increase and future Air Force projects at AAFB. As such, an independent relief sewer will be required to convey wastewater generated from USMC relocation at Finegayan region to the NDWWTP.

The GWA require pretreatment of industrial flows discharged from AAFB and future USMC operation, which mainly come out from vehicle, aircraft washing and painting, and other workshops that will have an impact on operation of the NDWWTP.

There are some potential odor issues at the NDWWTP, and the interconnecting interceptors. Presently the remote location of the current facility helps with the mitigation of these issues. However, there is a proposal to develop large scale hotels in the area adjacent to Two Lovers Point near the NDWWTP. This could have an impact on future expansion of the facility, and odor control improvements should be considered during the expansion of the plant.

5.2 EXPAND AND UPGRADE GOVGUAM NDWWTP TO SECONDARY TREATMENT

This alternative will expand and upgrade the NDWWTP facility to provide a secondary treatment for civilian flow and additional wastewater generated from USMC relocation, and Army and Air Force build up. Treated effluent is still discharged via existing outfall to the Philippine Sea and the NDWWTP discharge permit needs to be modified with new flow limits; however it is anticipated that a secondary discharge permit should be easier to be approved by EPA for ocean disposal. The GWA sewer rates for existing non-DoD users will be increased due to the plant upgrading to the secondary treatment for non-DoD portion of the flow and the additional electrical power and sludge produced by the secondary treatment system.

This alternative would also involve coordinating with GWA on its ongoing and planned CIP projects for the NDWWTP. As discussed in Section 5.1, an independent sewer interceptor will be required to convey wastewater generated from USMC and Army relocation at Finegayan region to the NDWWTP.

As discussed in the previous section, the GWA require pretreatment of industrial flows discharged from its military users in the Northern Guam region that will have impact on the NDWWTP.

As discussed in Section 5.1, there are some potential odor issues at the NDWWTP and odor control improvements should be considered during the expansion of the plant.

5.3 BUILD NEW SECONDARY TREATMENT PLANT NEAR THE PROPOSED DEVELOPMENT ON DEPARTMENT OF DEFENSE (DOD) LAND AND CONSTRUCT NEW OUTFALL

This alternative would build a new secondary treatment plant adjacent to the NDWWTP on DoD-owned land, and treat only the DoD wastewater from existing sources and proposed future military build up, including the USMC relocation in the Northern Guam area. The final effluent from the secondary treatment plant will be discharged into Philippine Sea via a newly constructed ocean outfall and a new NPDES permit will be required for the disposal.

The existing GWA's trunk sewer conveys both AAFB and civilian flow to the NDWWTP. Since it is not feasible to separate military flow from the trunk sewer or at the diversion structure upstream of the headworks, a new interceptor connecting directly to the AAFB collection system will be required to convey wastewater from AAFB to the new DoD WWTP. Same as in Section 5.1 and 5.2, an independent interceptor will be required as well to convey the DoD generated wastewater from Finegayan region to the new DoD WWTP. The cost of interceptor sewer from AAFB is additional cost compared to the two previous options discussed in Section 5.1 and 5.2.

Although the DoD will operate the treatment plant, industrial flows generated at the DoD facilities are required to be pretreated before entering the sewer. As discussed in Section 5.1, there are some potential odor issues near the NDWWTP site and odor control improvements should be considered during the construction of DoD plant. The plant biosolids treatment and disposal would be managed by the DoD and shall comply with EPA's Code of Federal Regulations (CFR) 503.

5.4 BUILD NEW SEPARATE SECONDARY TREATMENT PLANT AT GOVGUAM NDWWTP SITE TO TREAT DOD LOAD ONLY

This alternative would build a new secondary treatment plant at the NDWWTP site, and treat the DoD wastewater from existing sources and proposed military build up in the Northern Guam region including USMC relocation. The existing NDWWTP will have two separate treatment process trains. The existing primary treatment will continue to treat flow from civilian population in Northern Guam. The new process train will have a separate headworks, primary treatment, secondary treatment, and sludge handling facilities to treat DoD load only. It will require jointly utilizing the existing NDWWTP ocean outfall for its treated effluent disposal. Other constraints and considerations are similar to the alternative discussed in Section 5.2. This alternative also requires new NPDES permit application.

As discussed in Section 5.3, diverting existing DoD wastewater from GWA to NDWWTP is required and will result in additional cost of constructing a new DoD owned sewer interceptor from AAFB comparing to the two previous options discussed in Sections 5.1 and 5.2. Since new secondary treatment train will be constructed adjacent to the original treatment process at the NDWWTP site about one mile south from NCTS Finegayan area, the alternative will require construction of a longer sewer interceptor for military Finegayan activities comparing to the Option discussed in Section 5.3.

Industrial flows generated at the DoD facilities are required to be pretreated before entering the sewer. As discussed in Section 5.1, there are some potential odor issues at the NDWWTP, and odor control improvements should be considered during the construction of plant. The plant biosolids treatment and disposal would be managed by GWA and shall comply with EPA's CFR 503 regulations.

5.5 BUILD A NEW TERTIARY TREATMENT PLANT NEAR THE PROPOSED DEVELOPMENT ON DOD LAND AND SEND EFFLUENT TO A NEW WATER TREATMENT PLANT (OR EXISTING WATER TREATMENT PLANT)

This alternative would build a new tertiary treatment plant, which includes primary treatment, secondary biological treatment and advanced tertiary treatment, near the proposed development on DoD land. It will treat the DoD wastewater from existing sources and proposed future expansions in Northern Guam region including USMC relocation, and inject treated effluent directly into the raw water supply immediately upstream of a new water treatment plant built in the Northern Guam region.

This kind of treatment application falls in a category of direct potable reuse of reclaimed water, and its normal treatment practice consists of primary settlement, submersible membrane bioreactor, disinfection, Reverse Osmosis (RO) and advance oxidation.

While this discharge eliminates the option of building an outfall, the approach to discharge treated wastewater directly to a potable water treatment plant does not have a proven track record. Only few direct potable reuse applications have been reported worldwide (Metcalf & Eddy 2007). Even without factoring in its extremely high capital investment cost and abnormal sophisticated process operation, it might be difficult to gain regulatory acceptance of this approach, and it is likely that community acceptance of this approach cannot be achieved. Currently there are no direct potable reuse applications in the United States. All reclaimed water that is treated by wastewater treatment plants has been used as potable water in an indirect way which includes a temporal or spatial separation such as natural buffers, either a stretch of river or a ground water aquifer, between the reclaimed water introduction and its distribution to the potable water treatment plant.

In addition, brine generated from RO operation requires some kind of discharge arrangements. Typical brine disposal routes include evaporation, crystallization, deep underground injection, ocean or sewer discharge. From economic standpoint, only the last two may be feasible for our study, and they require permission from either the EPA or the GWA. Since there are no regulations available on the reclaimed water potable reuse application, the process of establishing treatment requirements and performance monitoring standards for this option will add time and cost to the project.

In addition to the construction of a new sewer interceptor to convey wastewater from NCTS Finegayan area, a new DoD-owned interceptor system as described in Section 5.3 should be constructed to convey wastewater flow from AAF B. A new effluent discharge pipe should be constructed to convey the effluent to the proposed or existing water treatment facility.

The plant bio solids treatment and disposal would be managed by the DoD and shall comply with EPA's CFR 503 regulations.

5.6 BUILD A NEW SECONDARY TREATMENT PLANT AND CONSTRUCT NEW OUTFALL ON EASTERN COASTLINE

This alternative would build a new secondary treatment plant on the eastern side of the island to treat DoD wastewater from existing sources and future military build up in Northern Guam region including USMC proposed relocation and construct new outfall on the eastern coastline. It is feasible only when majority of USMC relocation occurs in the east side of Northern Guam, and it also requires routing and diverting all existing and future USMC relocation wastewater flow to the new treatment plant. The construction of new outfall will have an adverse impact on coral reef and will likely require mitigation activities to satisfy both Guam Bureau of Statistics and Planning Office (GBSPO) and GDAWR. The entire northeast coastline around the AAFB is designated as Federal Listed Pati Point Marine Preserve that will restrict this area as a site for an ocean outfall.

Guam Department of Parks and Recreation Historical Preservation also noted that there are potential historical artifacts in the area a new ocean outfall. Many of the historical sites and burial grounds are located along the coast, on the lower plateau.

NPDES permit for new outfall from the EPA will require water quality studies to identify the impact of the new outfall in the receiving water. These studies will add time and costs to the project. The DoD would be responsible for the treatment, effluent refuse, and disposal of biosolids.

Construction of the plant on a site that is located in forested or preservation areas that are populated by native species of animals and vegetation and may require mitigation activities to satisfy the GDAWR.

5.7 BUILD A NEW TERTIARY TREATMENT PLANT NEAR PROPOSED DEVELOPMENT AND REUSE THE EFFLUENT, SEND THE RESIDUAL TO THE GWA OUTFALL

This alternative would build a new tertiary treatment plant near the proposed development on DoD land, and treat DoD wastewater from both existing sources and future proposed military build up in the Northern Guam region including USMC relocation. It will reuse the treated effluent from tertiary system for toilet flushing, wash water for vehicles and aircrafts, landscape irrigation, cooling water for building climate control and probably potential non-DoD end users. Excess effluent that is produced would be discharged to the existing NDWWTP outfall. A NPDES permit is required to accommodate additional flow to the outfall. To achieve treatment requirement for the above mentioned reuse practice, it requires installing a wastewater treatment process consisting of primary treatment, membrane bioreactor, disinfection, and color removal. The DoD would be responsible for the treatment, effluent reuse and biosolids disposal with this alternative.

The total estimated reclaimed water produced by this alternative is 3.6 mgd; however, the Finegayan area lacks sustainable and reliable reclaimed water reuse demand. A study to assess the demand for reclaimed water usage and identify a sustainable reuse water rate structure is required. In addition, a separate water distribution and dual plumbing system will be required, and a cross connection risk has to be addressed for this option. This will add time and cost to the project. The installation of dual plumbing system for existing buildings may not be economically feasible. The GWA also indicated that the current sewer rate structure would be impacted since the outfall capacity is consumed without receiving the revenue from the DoD for sewage treatment.

Similar to all alternatives with the construction of the DoD wastewater treatment plant on the west side of Northern Guam, a new DoD-owned interceptor system should be constructed to convey wastewater to the treatment plant. For this alternative a new transmission line should be constructed to discharge excess reclaimed water to the NDWWTP outfall.

5.8 BUILD A NEW TERTIARY TREATMENT PLANT NEAR PROPOSED DEVELOPMENT ON DOD LAND AND INSTALL INJECTION WELLS

This alternative would build a new tertiary treatment plant near the proposed development on DoD land. It will treat DoD wastewater from existing sources and future proposed military build up in the Northern Guam region including USMC relocation. Treated effluent would be injected into the underground aquifer for groundwater replenishment and will increase groundwater sustainability of the Northern Guam Aquifer. The DoD would be responsible for treatment, groundwater monitoring, and biosolids disposal.

Guam's Northern Lens is its sole source aquifer, and it is directly underneath the Northern Guam region. As northern Guam sets on a karst limestone plateau with high water conductivity, it results in a low retention time between injection wells and withdraw wells and a minimum soil aquifer treatment. Under these conditions, a very high degree of treatment normally beyond EPA primary drinking water standards has to be achieved. In practice, even if the treatment presented in Section 5.4 is applied for this kind of indirect potable reuse of reclaimed water, the same kind of scrutiny will be anticipated from regulatory agencies and communities. Since there are no regulations available in Guam on the application of indirect potable reuse of reclaimed water, the process of establishing treatment requirements and performance monitoring standards for this option will consume time and increase cost to the project.

In addition to the construction of a new separate DoD-owned sewer interceptor system, a new transmission line will be required to convey reclaimed water to the injection wells. The cost of the transmission line and its operation will depend on topographical condition of piping route and locations of the injection wells that are determined by underground geological structure and required set back distance between injection wells and withdraw wells.

5.9 INSTALL PRETREATMENT FOR DOD INDUSTRIAL FLOWS IN CONJUNCTION WITH THE UPGRADE AND EXPANSION OF THE GWA NDWWTP

This is not an alternative but requires installing pretreatment for DoD industrial flows in conjunction with upgrades and expansions of the NDWWTP as described in both Sections 5.1 and 5.2. The DoD industrial flows occur mainly from on base vehicle and aircraft washing and painting operations.

Even though this option is essential for normal operation of NDWWTP, currently there are no pretreatment units installed at DoD facilities besides a few existing obsolete oil water separators in AAFB. Wastewater characteristics from each industrial stream will need to be evaluated to develop the pretreatment processes as required. GWA had indicated that Industrial Pretreatment Standards will be imposed on all industrial users on the island. Earth Tech will coordinate with the DoD to obtain industrial wastewater stream characteristics for various industrial facilities.

The DoD will be responsible for pretreatment, solids disposal, and discharge of treated effluent into GWA sewer. The DoD may have to file an Industrial Discharge permit identifying discharge quality agreement between the military and the GWA. The permit may require the DoD to monitor sewage for compliance with pretreatment discharge limits.

In practice, this option has to be implemented and combined into all previous discussed alternatives. To guarantee a proper treatment operation of every above reviewed alternative, this option has to be carried out first.

5.10 ADVANTAGES AND DISADVANTAGES OF TREATMENT ALTERNATIVES

The major advantages and disadvantages of each wastewater treatment alternative for this application are provided in Table 5-1.

5.11 AGENCY INVOLVEMENT FOR TREATMENT OPTIONS

The regulatory requirements and their involvement for each wastewater treatment alternative are evaluated. Table 5-2 provides summary of regulatory and agency considerations for each alternative

5.12 RECOMMENDED VIABLE WASTEWATER TREATMENT ALTERNATIVES

Earth Tech developed a ranking system to identify four most favorable alternatives. The ranking system uses a relative factor for regulatory agency involvement and cost of construction. The system uses a factor 1 for low involvement or relative cost, 2 for medium involvement or relative cost and 3 for high involvement or relative cost. Table 5-3 provides the total overall score and relative ranking of each alternative. Based on the relative rankings, Earth Tech recommends that the four most favorable wastewater treatment alternatives outlined in Table 5-3 should be considered for further evaluation. Table 5-4 provides the reasons for eliminating the other five alternatives for further evaluation. The four recommended alternatives considered for detailed analysis are:

- Expand and upgrade existing primary treatment system at the GovGuam NDWWTP to accept the additional flow and load
- Expand and upgrade the GovGuam NDWWTP to secondary treatment
- Build new secondary treatment plant near the proposed development on DoD land and construct new outfall
- Build new separate secondary treatment plant at GovGuam NDWWTP site to treat DoD load only

Table 5-1: Advantages and Disadvantages of Treatment Options

Wastewater Treatment Alternatives	Advantages	Disadvantages
Option 1A – Expand and upgrade existing primary treatment system at GovGuam NDWWTP to accept the additional flow and load	• GWA is responsible for treatment and disposal • GWA is responsible for NPDES permit • Standard construction schedule • Lower construction cost compared to all other treatment options	• Wastewater capacity must be acquired • Need to share odor control facility cost • NDWWTP permit needs to be modified with new flow limits • Contingent on extension or re-issuance of GWA 301(h) waiver from the EPA
Option 1B – Expand and Upgrade GovGuam's NDWWTP to secondary treatment	• GWA is responsible for treatment and disposal • GWA is responsible for NPDES permit • Standard construction schedule • Lower construction cost compared to other secondary treatment options (Option 2, Option 3, and Option 5)	• Wastewater capacity must be acquired • Need to share odor control facility cost • NDWWTP permit needs to be re-issued with new discharge limits • Sewer rated for DoD and non-DoD users will increase
Option 2 – Build new secondary treatment plant near the proposed development on DoD land and construct new outfall	• The DoD provides wastewater capacity • Standard construction schedule	• Require modifications to the GWA's NPDES Permit • Require GWA's outfall • Diverting existing DoD wastewater from GWA to new DoD WWTP is required and will require additional costs compared to Option 1A and Option 1B • GDAWR mitigation requirements • High construction cost compared to other secondary treatment options (Option 1B, and Option 3)
Option 3 –Build new separate secondary treatment plant at GovGuam NDWWTP site to treat DoD load only	• DoD provides wastewater capacity • Standard construction schedule	• Require modifications to GWA's NPDES Permit • Require GWA's outfall • Require partnership with GWA to share treatment plant site. Would result in legal issues that may delay to the project • Guam Department of Aquatic and Wildlife Resources (GDAWR) mitigation requirements • Diverting existing DoD wastewater from GWA to new DoD WWTP is required and will require additional costs compared to Option 1A and Option 1B
Option 4 – Build a new tertiary treatment plant near the proposed development on DoD land and send effluent to a new water treatment plant (or existing water treatment Plant)	• DoD provides wastewater capacity • New outfall construction is not required • Increases potable water capacity	• Diverting existing DoD wastewater from GWA to new DoD WWTP is required and will incur additional cost • Conveying the effluent to new water or existing water treatment plant is required and will incur additional cost • GDAWR mitigation requirements • Require RO brine disposal arrangement • Unproven track record • Public opinion against directly consuming reclaimed water • Longer planning effort and longer construction schedule

Wastewater Treatment Alternatives	Advantages	Disadvantages
Option 5 – Build a new secondary treatment plant and construct new outfall on eastern coastline	• DoD provides wastewater capacity	• Require new NPDES Permit. Require additional studies for outfall construction. • Diverting existing DoD wastewater from GWA to new DoD WWTP is required and will require additional cost • GDAWR and GBSPO mitigation requirements • Department of Parks and Recreation Historical Preservation mitigation requirements • Longer planning effort and longer construction schedule • Additional cost and time for water quality studies to identify the impact of new outfall on receiving water • High construction cost compared to other secondary treatment options (Option 1B, Option 2 and Option 3)
Option 6 – Build a new tertiary treatment plant near proposed development and reuse the effluent, send the residual to the GWA outfall	• DoD provides wastewater capacity • New outfall construction is not required • Reuse of effluent	• Require modifications to GWA's NPDES Permit • Requires partnership with GWA to utilize GWA's outfall • Diverting existing DoD wastewater from GWA to new DoD WWTP is required and will require additional cost • GDAWR mitigation requirements • Complicated permit process for treated water reuse • Longer planning effort and longer construction schedule • Limited applications for reuse water • Additional cost for construction of effluent reuse distribution system and pipe to GWA outfall to send the residual
Option 7 – Build a new tertiary treatment plant near proposed development on DoD land and install injection wells	• Increase yield of underground aquifer • Control over the availability of wastewater capacity • New outfall construction is not required	• Diverting existing DoD wastewater from GWA to new DoD WWTP is required and will require additional cost • GDAWR) mitigation requirements • Groundwater discharge permit required • Longer planning effort and longer construction schedule • Additional cost for construction and maintenance of injection wells and monitoring wells • Injection over the northern aquifer is not allowed
Option 8 – Install pretreatment for DoD industrial flows in conjunction with the upgrade and expansion of the GWA NDWWTP	• Protects downstream wastewater treatment facilities from process upsets • Reduces quantities of toxic materials in effluent and biosolids produced at WWTP	• None

Table 5-2: Summary of Regulatory Agency Considerations

Regulatory Agency	Relative Involvement	List of Potential Considerations
Option 1A – Expand and upgrade existing primary treatment system at GovGuam Northern District WWTP to accept the additional flow and load		
Bureau of Statistics and Planning (Coastal Management)	Low-1	Off-shore construction is not required and GWA outfall exists
GEPA	Low-1	GEPA does not regulate discharges to ocean
EPA Region 9	Moderate-2	EPA has regulatory authority to set discharge limits. Permit for 301(h) waiver already exists
GDAWR	Moderate-2	Off-shore construction is not required and GWA outfall exists Long term impact of the primary effluent on the aquatic habitat is a concern
Department of Parks and Recreation (Historic Preservation)	Low-1	No construction on undeveloped land
Department of Public Works	Moderate-2	Possible public traffic disruption for relief interceptor construction
GWA	Moderate-2	GWA operates NDWWTP Sharing construction and operation costs Coordination with on going CIP projects
Option 1B – Expand and upgrade GovGuam NDWWTP to secondary treatment		
Bureau of Statistics and Planning (Coastal Management)	Low-1	Off-shore construction is not required and GWA outfall exists
GEPA	Low-1	GEPA does not regulate discharges to ocean
EPA Region 9	High-3	EPA has regulatory authority to set discharge limits Existing permit needs updating for secondary treatment limits
GDAWR	Moderate-2	Off-shore construction is not required and GWA outfall exists Long term impact of the secondary effluent on the aquatic habitat is a concern
Department of Parks and Recreation (Historic Preservation)	Low-1	No construction on undeveloped land
Department of Public Works	Moderate-2	Possible public traffic disruption for relief interceptor construction
GWA	High-3	GWA operates NDWWTP Sharing construction and operation costs Coordination with on going CIP projects
Option 2 – Build new secondary treatment plant near the proposed development on DoD land and construct new outfall		
Bureau of Statistics and Planning (Coastal Management)	Low-1	Off-shore construction is not required and GWA outfall exists
GEPA	Low-1	GEPA does not regulate discharges to ocean
EPA Region 9	High-3	EPA has regulatory authority to set discharge limits
GDAWR	High-3	Construction on undeveloped land may be required causing habitat disruption Long term impact of the treated effluent on the coral reef habitat is a concern
Department of Parks and Recreation (Historic Preservation)	High-3	Construction site may contain historical artifacts
Department of Public Works	High-3	New sewer line construction is required for diverting DoD wastewater
Guam Waterworks Authority (GWA)	Low -1	GWA treatment revenue is reduced

Regulatory Agency	Relative Involvement	List of Potential Considerations
Option 3 – Build new separate secondary treatment plant at GovGuam NDWWTP site to treat DoD load only		
Bureau of Statistics and Planning (Coastal Management)	Low-1	Off-shore construction is not required and GWA outfall exists
GEPA	Low-1	GEPA does not regulate discharges to ocean
EPA Region 9	High-3	EPA has regulatory authority to set discharge limits Existing permit will require updating for revised limits
GDAWR	Moderate -2	Off shore construction is not required and GWA outfall exists Long term impact of the blended primary and secondary effluent on the aquatic habitat is a concern
Department of Parks and Recreation (Historic Preservation)	Low -1	No construction on undeveloped land
Department of Public Works	Low - 1	No construction on undeveloped land
GWA	High-3	GWA owns outfall GWA Operates NDWWTP GWA treatment revenue is reduced
Option 4 – Build a new tertiary treatment plant near the proposed development on DoD land and send effluent to a new water treatment plant (or existing water treatment Plant)		
Bureau of Statistics and Planning (Coastal Management)	Low-1	Off-shore construction is not required
GEPA	High-3	GEPA regulates potable water supplies
EPA Region 9	High-3	EPA sets safe drinking water limits for local agencies
GDAWR	High-3	Construction on undeveloped land may be required causing habitat disruption
Department of Parks and Recreation (Historic Preservation)	High-3	Construction site may contain historical artifacts
Department of Public Works	High-3	New sewer line construction is required for diverting DoD wastewater Construction of new water line connection is required
GWA	High-3	GWA purchases water from DoD system, and monitoring requirements will be more stringent than current condition
Option 5 – Build a new secondary treatment plant and construct new outfall on eastern coastline		
Bureau of Statistics and Planning (Coastal Management)	High-3	Off-shore construction is required
GEPA	Low-1	GEPA does not regulate discharges to ocean
EPA Region 9	High-3	EPA has regulatory authority to set discharge limits
GDAWR	High-3	Construction on undeveloped land may be required causing habitat disruption New discharge causes concern for long term impact of secondary effluent on aquatic habitat
Department of Parks and Recreation (Historic Preservation)	High-3	Construction site may contain historical artifacts
Department of Public Works	High-3	New sewer line construction is required for diverting DoD wastewater
GWA	Low-1	GWA treatment revenue is reduced

Regulatory Agency	Relative Involvement	List of Potential Considerations
Option 6 – Build a new tertiary treatment plant near proposed development and reuse the effluent, send the residual to the GWA outfall		
Bureau of Statistics and Planning (Coastal Management)	Low-1	Off-shore construction is not required and GWA outfall exists
GEPA	High-3	GEPA would regulate reclaimed water Existing permit requires updating for revised limits
EPA Region 9	High-3	EPA has regulatory authority to set outfall discharge limits
GDAWR	High-3	Construction on undeveloped land may be required causing habitat disruption Long-term impact of the blended primary and tertiary effluent on the aquatic habitat is a concern
Department of Parks and Recreation (Historic Preservation)	High-3	Construction site may contain historical artifacts
Department of Public Works	High-3	New sewer line construction is required for diverting DoD wastewater Construction of new reused water line is required
GWA	High-3	GWA owns outfall GWA treatment revenue is reduced
Option 7 – Build a new tertiary treatment plant near proposed development on DoD land and install injection wells		
Bureau of Statistics and Planning (Coastal Management)	Low-1	Off-shore construction is not required
GEPA	High-3	GEPA has regulatory authority on groundwater recharge
EPA Region 9	High -3	EPA has regulatory authority to set outfall discharge limits
GDAWR	High-3	Construction on undeveloped land may be required causing habitat disruption Long term impact of the treated effluent on the coral reef habitat is a concern
Department of Parks and Recreation (Historic Preservation)	High-3	Construction site may contain historical artifacts
Department of Public Works	High-3	New sewer line construction is required for diverting DoD wastewater
GWA	High-3	GWA potable water supply is from same aquifer GWA treatment revenue is reduced
Option 8 – Install pretreatment for DoD industrial flows in conjunction with the upgrade and expansion of the GWA NDWWTP		
Bureau of Statistics and Planning (Coastal Management)	Low-1	Off-shore construction is not required
GEPA	Low-1	GEPA does not regulate industrial discharge to sewer
EPA Region 9	Low-1	EPA does not regulate industrial discharge to sewer
GDAWR	Low-1	Construction is on the base and adjacent to the operation facility
Department of Parks and Recreation (Historic Preservation)	Low-1	Construction is on the base and adjacent to the operation facility
Department of Public Works	Low-1	Construction does not affect traffic
GWA	High-3	GWA requires pretreatment of industrial discharges GWA has indicated that DoD should consider immediate implementation of pretreatment regardless of the future wastewater alternatives selected

Table 5-3: Relative Ranking of Alternatives

Wastewater Treatment Alternatives	Relative Score								Total Score (a)	Relative Ranking	Recommendation
	Bureau of Statistics and Planning	Guam EPA	EPA Region 9	Department of Aquatic and Wildlife	Department of Parks and Recreation	Department of Public Works	Guam Waterworks Authority	Construction Cost			
Option 1A – Expand and upgrade existing primary treatment system at GovGuam NDWWTP to accept the additional flow and load	Low-1	Low-1	Moderate-2	Moderate-2	Low-1	Moderate-2	Moderate-2	Low-1	12	1	Considered for Detailed Evaluation
Option 1B – Expand and upgrade GovGuam NDWWTP to secondary treatment	Low-1	Low-1	High-3	Moderate-2	Low-1	Moderate-2	High-3	Moderate-2	15	3	Considered for Detailed Evaluation
Option 2 – Build new secondary treatment plant near the proposed development on DoD land and construct new outfall	Low-1	Low-1	High-3	High-3	High-3	High-3	Low-1	High-3	18	4	Considered for Detailed Evaluation
Option 3 – Build new separate secondary treatment plant at GovGuam NDWWTP site to treat DoD load only	Low-1	Low-1	High-3	Moderate 2	Low - 1	Low -1	High-3	Moderate - 2	14	2	Considered for Detailed Evaluation
Option 4 – Build a new tertiary treatment plant near the proposed development on DoD land and send effluent to a new water treatment plant (or existing water treatment Plant)	Low-1	High-3	High-3	High-3	High-3	High-3	High-3	High-3	22	6	Eliminated
Option 5 – Build a new secondary treatment plant and construct new outfall on eastern coastline	High-3	Low-1	High-3	High-3	High-3	High-3	Low-1	High-3	20	5	Eliminated
Option 6 – Build a new tertiary treatment plant near proposed development and reuse the effluent, send the residual to the GWA outfall	Low-1	High-3	High-3	High-3	High-3	High-3	High-3	High-3	22	6	Eliminated
Option 7 – Build a new tertiary treatment plant near proposed development on DoD land and install injection wells	Low-1	High-3	High -3	High -3	High -3	High-3	High-3	High -3	22	6	Eliminated
Option 8 – Install pretreatment for DoD industrial flows in conjunction with the upgrade and expansion of the GWA NDWWTP	Low-1	Low-1	Low-1	Low-1	Low-1	Low-1	High-3	Low-1	9	NA	Project requirement for all options

Table 5-4: Factors for Elimination

Wastewater Treatment Alternatives	Recommended Option	Factors for Eliminating Alternatives
Option 1A – Expand and upgrade existing primary treatment system at GovGuam NDWWTP to accept the additional flow and load	Yes	NA
Option 1B – Expand and Upgrade GovGuam's NDWWTP to secondary treatment	Yes	NA
Option 2 – Build new secondary treatment plant near the proposed development on DoD land and construct new outfall	Yes	NA
Option 3 – Build new separate secondary treatment plant at GovGuam NDWWTP site to treat DoD load only	Yes	NA
Option 4 – Build a new tertiary treatment plant near the proposed development on DoD land and send effluent to a new water treatment plant (or existing water treatment Plant)	No	• Conveyance facilities for diverting existing DoD wastewater from GWA to new DoD WWTP • Incur additional cost for conveying the effluent to new water or existing water treatment plant • GDAWR mitigation requirements may cause project delays and additional costs to DoD • Establishing new water quality monitoring requirements may result in longer planning effort and longer construction schedule
Option 5 – Build a new secondary treatment plant and construct new outfall on eastern coastline	No	• Require new NPDES Permit. Require additional studies for outfall construction. • New outfall is required • Conveyance facilities for diverting existing DoD wastewater from GWA to new DoD WWTP • DAWR and GBSPO mitigation requirements may add time and cost to project • Guam Department of Parks and Recreation Historical Preservation indicates that historical sites and burial grounds may be located along the coast on the lower plateau • Longer planning effort and longer construction schedule
Option 6 – Build a new tertiary treatment plant near proposed development and reuse the effluent, send the residual to the GWA outfall	No	• Conveyance facilities for diverting existing DoD wastewater from GWA to new DoD WWTP • GDAWR and GBSPO mitigation requirements may add time and cost to project • Complicated permit process for treated water reuse may add time and cost to the project • Construction of reclaimed water distribution network and dual plumbing systems is required

Wastewater Treatment Alternatives	Recommended Option	Factors for Eliminating Alternatives
Option 7 – Build a new tertiary treatment plant near proposed development on DoD land and install injection wells	No	• Diverting existing DoD wastewater from GWA to new DoD WWTP is required and will require additional cost • GDAWR mitigation requirements • Groundwater discharge permit required • Longer planning effort and longer construction schedule • Additional cost for construction and maintenance of injection wells and monitoring wells • Injection over the northern aquifer is not allowed • Requires construction of outfall or diversion to GWA sewer in case Injection wells are not available
Option 8 – Install pretreatment for DoD industrial flows in conjunction with the upgrade and expansion of the GWA NDWWTP	Yes	Recommended for all options

6. Viable Wastewater Treatment Alternatives

The Earth Tech Guam Wastewater Utility Study Letter Report submitted to the NAVFAC on 31 August 2007 recommended four viable wastewater treatment alternatives for further evaluation. The four recommended viable alternatives are:

- **Option 1A** – Expand and upgrade existing primary treatment system at GovGuam Northern District WWTP to accept the additional flow and load
- **Option 1B** – Expand and upgrade GovGuam NDWWTP to secondary treatment
- **Option 2** – Build new secondary treatment plant near the proposed development on DoD land and construct new outfall
- **Option 3** – Build new separate secondary treatment plant at GovGuam NDWWTP site to treat DoD load only

In this section, all four viable wastewater treatment alternatives are discussed in detail and their associated collection system modification issues are also evaluated. Based on the preliminary life cycle cost estimation combined with evaluation of institutional constrains and public concerns for each viable alternative, this study recommends preferred alternatives of the viable wastewater treatment ones for further Environmental Impact Study on USMC relocation to Guam initiative. In addition to the above identified viable alternatives, another alternative Option 7 – Build a New Tertiary Treatment Plant near Proposed Development and Install Injection Wells was evaluated initially. With further discussions with GEPA staff regarding the regulatory requirements for injecting effluent from the tertiary treatment plant into the groundwater, our team identified that the Underground Injection Control regulations provided by GEPA categorize sewage treatment effluent recharge wells as Class V wells. Current GEPA regulations prohibit Class V injection wells. The wells could only be installed with a GEPA waiver to the regulations. However GEPA has indicated that it may approve the option upon reviewing the design and documents. As there is an ambiguity in the approval process and concerns that there is not enough detention time in the aquifer this option was dropped from the viable alternative list. However the detailed analysis and preliminary construction cost of this alternative is provided in Appendix C.

6.1 Description of Viable Alternatives

Among four viable alternatives, Option 1A and Option 1B are both to expand and upgrade existing GovGuam

NDWWTP and assumed that Navy will coordinate with the GWA on the schedule of implementing its planned Capital Improvement Program (CIP) to make sure the existing treatment facility will be at its designed capacity by the time expansion and upgrade is completed.

6.1.1 Expand and Upgrade Existing Primary Treatment System at GovGuam NDWWTP to Accept the Additional Flow and Load

As described in Section 2, the NDWWTP is the only wastewater treatment facility in the northern region on the island of Guam, and it is a primary treatment facility with comminutor and aerated grit chamber for preliminary treatment, and primary clarifiers mainly for removal of settleable organics, and suspended solids.

Wastewater preliminary treatment removes rags, floatables, grit, and grease that may cause maintenance or operational problems to the subsequent treatment processes. For municipal applications, it normally consists of treatment such as screening or shredding, grit removal, flow equalization, and neutralization.

Wastewater primary treatment removes a portion of the suspended solids and associated organic matter from wastewater by settling and skimming. A primary clarifier enhances solid liquid separation utilizing gravitational settling to remove suspended solids, and it normally removes 60 percent suspended solids as TSS and 30 percent organic matter presented as BOD_5 from municipal wastewater.

The NDWWTP is a primary treatment facility. It was designed for a treating an average daily flow of 12.0 mgd and a peak flow of 27.0 mgd. Recent flow, averaging approximately from 8.9 to 9.6 mgd from 2004 and 2005 are presented in the GWA *Water Resources Master Plan* dated January 2007 (GWA 2007), which includes a daily wastewater flow of 1.4 mgd generated from AAFB and NCTS Finegayan in Northern Guam. Projected 2025 flow based on land use planning and recent population growth trend in the tributary without consideration of any future military expansion is 13.12 mgd as discussed in Section 3. This will burden the designed treatment capacity of the NDWWTP, and plant expansion will be required if any additional wastewater flows result from future military buildup in the region to be treated.

In the year 2025, if all military wastewater generated in the Northern Guam is still treated by the NDWWTP, the total flow of 1.54 mgd from AAFB, with present flow of 1.1 mgd, and future flow of 0.44 mgd from the Air Force bed down MILCON projects will all be conveyed through the existing GWA main to the NDWWTP. The GWA sewer main has adequate capacity to carry the extra flow, however, wastewater flow of 2.97 mgd generated by USMC, Army, and SOF relocation at Finegayan area have to be carried by a newly constructed relief sewer to the NDWWTP (as shown in Figure 6-1).

As described in Section 3, total planned wastewater flow generated from USMC relocation, Air Force bed down MILCON and other military buildup in Northern Guam area is 3.28 mgd. If it all conveys to the NDWWTP, the future required treatment flow at the NDWWTP treated will be 17.63 mgd. Based on peak factors calculated using Babbit's curve in Water Pollution Control Federation Manual of Practice No. FD-5, the peak flow of the NDWWTP in the future will reach 40.44 mgd. Using the estimates in Section 3, future influent flow and its characteristics and loadings of the NDWWTP are presented in Table 6-1. For this evaluation, Earth Tech assumed that the future civilian and military wastewater flow will have characteristics similar to the wastewater flow discharging to the existing NDWWTP.

Table 6-1: Estimated NDWWTP Influent Flow and Loading in 2025

Flows	Flow rate (mgd)
Average daily flow	17.63
Peak wet weather flow	40.44

Parameters	Concentration (mg/L)	Loading (lbs/day)
BOD_5	217	31,877
Suspended solids	131	19,227

lbs pounds

The NDWWTP primary treatment facility is currently operating with the effluent concentration requirement as presented in Table 6-2.

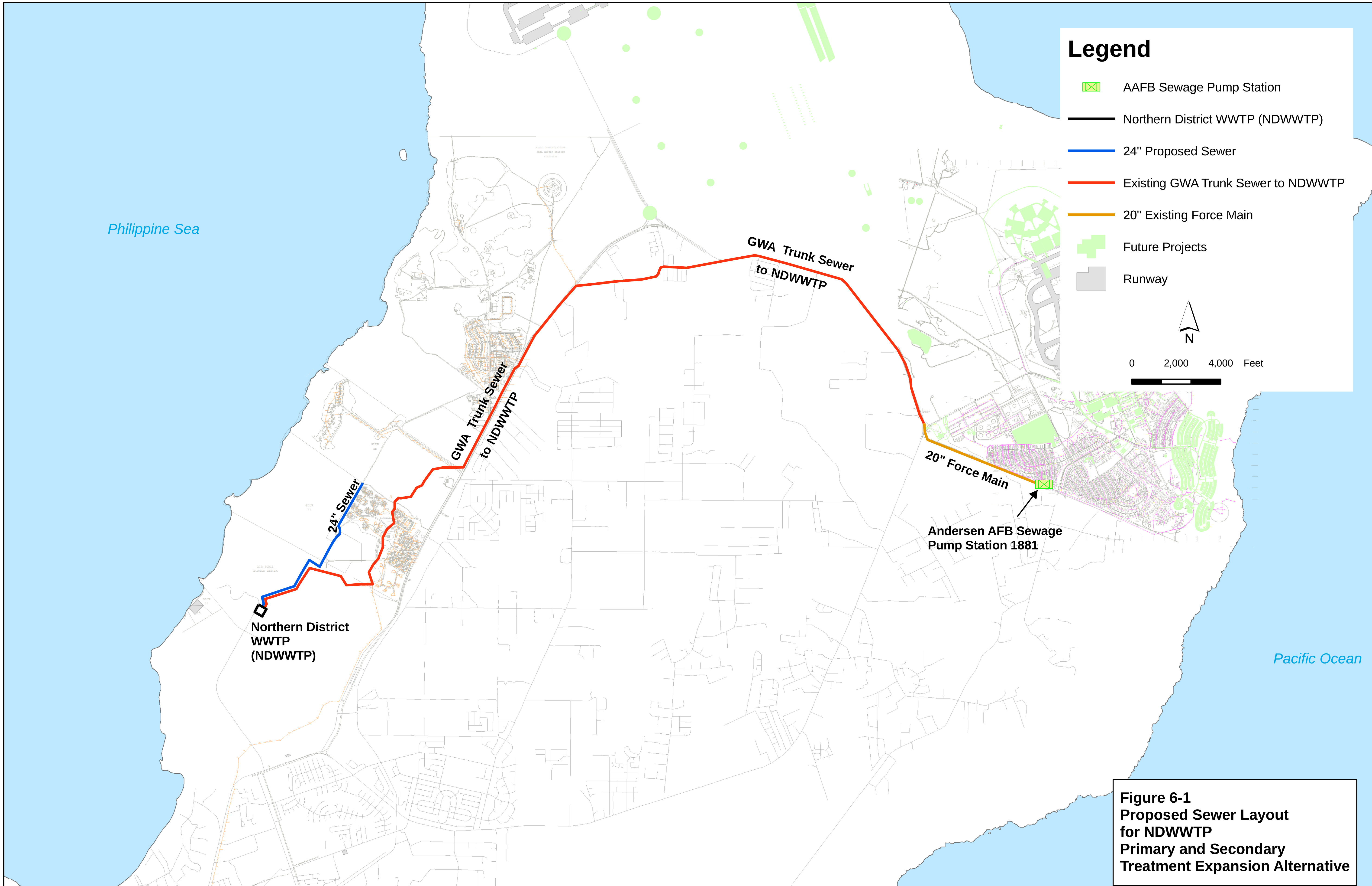

Figure 6-1
Proposed Sewer Layout for NDWWTP Primary and Secondary Treatment Expansion Alternative

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Table 6-2: Current NDWWTP Effluent Pollutant Concentration Requirement

Characteristic of discharge	Unit of measurement	Daily maximum concentration	Average monthly concentration
BOD_5	mg/L	170	85
Suspended solids	mg/L	100	50
Settleable solids	ml/L	2	1
Hydrogen-ion	pH	7.0 – 9.0	

Source: GWA 2007

Based on the current plant process capacity that was evaluated in Section 2.3, in order to accommodate future anticipated flow and loadings while still achieving the existing effluent discharge requirement as presented in Table 6-2, the NDWWTP will have to add the following new process capacities as shown on Figure 6-2:

- Headworks expansion with odor control
- One primary clarifier (same size as existing ones)
- One anaerobic digester (same size as existing ones)
- Two centrifuge solids dewatering systems with odor control
- One chlorine contact tank (same size as existing ones)
- Effluent monitoring upgrade
- Outfall diffuser capacity expansion

The preliminary sizes of the NDWWTP expansion facilities are listed in Table 6-3.

Table 6-3: Major Components for Expanding and Upgrading Existing Primary Treatment System at the NDWWTP to Accept the Additional Flow and Load

Construction Components	Expand (E)/ Upgrade (U)/ NEW (N)	Unit	Dimensions/Description
Headworks	U/N	2	Two fine screens
Primary clarifier	N	1	130 ft diameter x 7 ft SWD
Chlorine contact tank	N	1	70 ft long x 40 ft wide x 14 ft SWD
Effluent measurement	U		Automatic sampler
Odor control system	N	1	Locate at headworks and solids handling
Anaerobic digester	U N	2 1	80 ft diameter x 18 ft SWD 80 ft diameter x 18 ft SWD
Solids dewatering centrifuges	N	2	225 gpm each
Outfall capacity expansion	N	1	400 ft long multiport diffusers

As described above, one wastewater stream comes into the treatment plant from the existing GWA sewer and the other from the USMC Finegayan relief sewer. Subsequently two wastewater streams are combined and flow through the existing NDWWTP headworks upgraded with new fine screens followed by existing rectangular aerated grit chambers into an upgraded diversion box. Grit and screenings are disposed of in a sanitary landfill. The diversion box distributes flow evenly into one new and two existing circular primary clarifiers. After removal of solids within the tanks, effluent from each primary clarifier is then combined and flows into an upgraded chlorine disinfection system for treated flow disinfection. The upgraded disinfection system with chlorination and dechlorination includes three chlorine contact tanks with one new constructed tank. Dechlorination is provided because residual chlorine from chlorination disinfection has adverse effects on aquatic organisms in the receiving water. The chlorine disinfected effluent flows into a transmission line that leads to the 34-inch ocean outfall. The existing NDWWTP ocean outfall needs to be upgraded to include additional multiport diffusers to accept additional flow. Primary sludge that settled at the bottom of the primary clarifier collected by a scraper blade, and scum that floated at the top of the primary clarifier skimmed by surface skimming, are both pumped out into an upgraded anaerobic digestion system for sludge stabilization. Digested solids are then pumped by solids transfer pumps to a centrifuge dewatering system for further solids volume reduction. The cake produced by sludge dewatering is finally hauled out of the plant as Class B solids for disposal.

The existing grit removal chamber has enough capacity to treat future anticipated flow; headworks upgrading is still required. Two new mechanical fine screens and other associated equipment such as a washer and a compacting are recommended.

Two existing primary clarifiers, 130-foot diameter and 7-foot side water depth, were originally designed to treat an average flow of 12 mgd, while one clarifier is out of service for routine maintenance. To accommodate additional 3.28 mgd wastewater flow generated from future military buildup and 5.83 mgd from off-base civilian growth, one additional clarifier, the same size as the existing ones is required to be constructed adjacent to the existing primary clarifiers for this alternative. After expansion, the three clarifier system will provide a capacity that allows one clarifier to be offline for maintenance without compromising effluent discharge standards.

One additional concrete chlorine contact tank is required to be constructed using common wall of two existing chlorine contact tanks. The new tank will have same dimensions as the existing tank 70 feet long and 40 feet wide and 14 feet side water depth. After expansion, the chlorine disinfection system will provide a capacity that allows one tank to be offline for maintenance.

The capacity of the existing outfall is limited by its end diffusers, as the result one 400-foot long multiport diffuser branch will be installed with a precast concrete junction box connected to the existing outfall pipe to increase the discharge capacity of the outfall in this alternative.

Settled solids that are generated within the primary clarifiers will be treated by an anaerobic digestion system at the NDWWTP for pathogen control and solids reduction. The existing system is a 2-stage high rate anaerobic digestion facility; each stage consists of one anaerobic digester with a diameter of 80 feet and an average side water depth of 18 feet. The first digester will be designed to provide solids stabilization, while the second digester will provide solid liquid separation and some short-term storage for digested sludge. The existing anaerobic digestion system has not been functioning and is currently out of service, while sludge at the NDWWTP is currently being transported to the GWA Hagatna WWTP in central Guam for required treatment. In this alternative, upgrading the solids treatment system includes upgrading the existing digesters to increase their treatment capacity. The digesters will be designed for a hydraulic detention time over 15 days to meet EPA Class B standards. To meet operation reliability requirements, one new digester tank is needed so that the digestion system can handle planned future sludge loadings with one digester out of service for maintenance.

At present, the solids dewatering system at the NDWWTP is not operational. The alternative requires adding a centrifuge system for dewatering anaerobic digested solids and reducing the volume for disposal. Two centrifuges each rated for a flow of 225 gpm are required. Two centrifuges provide enough treatment capacity to allow one unit to be offline for maintenance.

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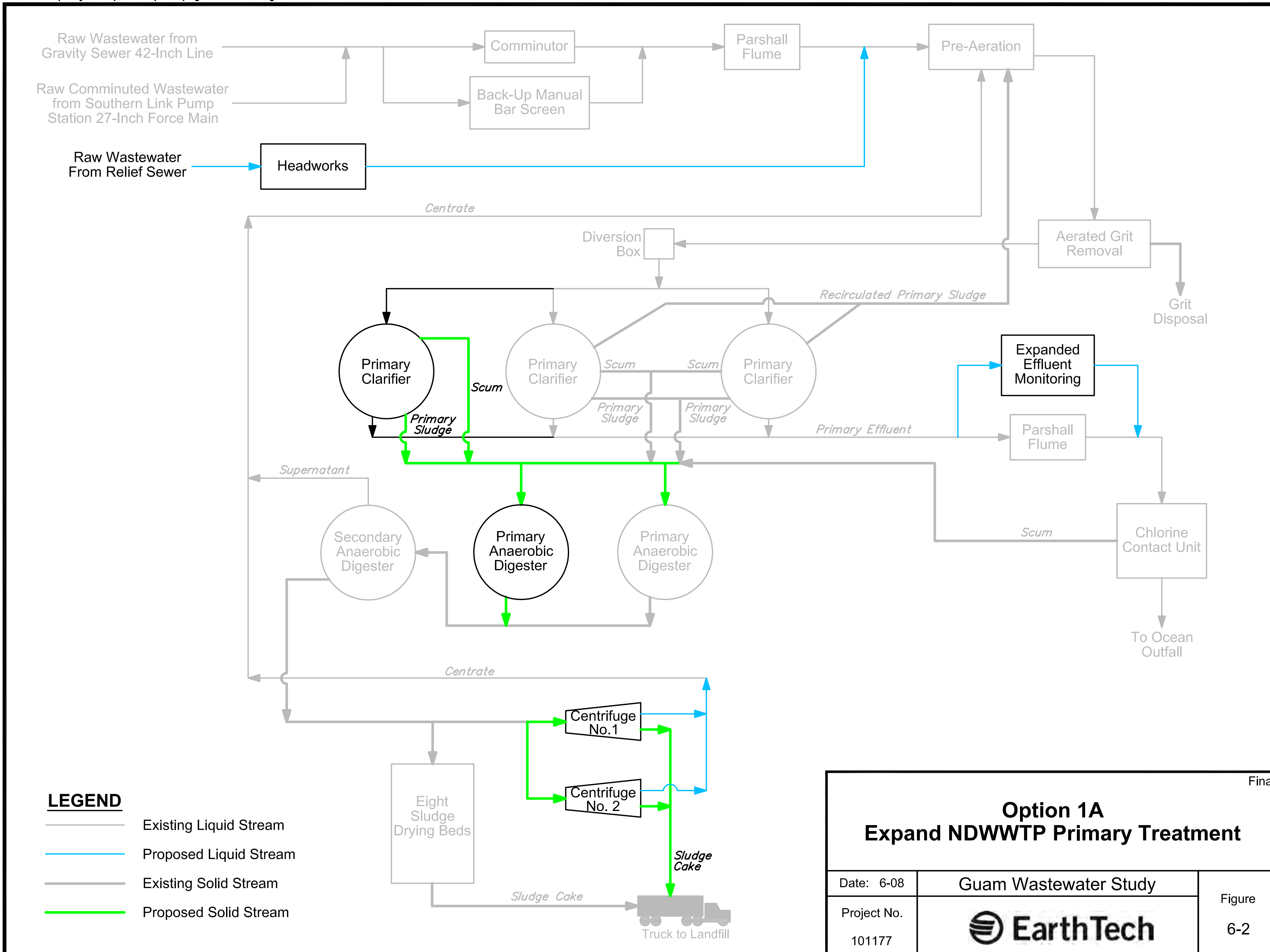

Final

Option 1A
Expand NDWWTP Primary Treatment

Date: 6-08	Guam Wastewater Study	Figure
Project No. 101177	EarthTech	6-2

6.1.2 Expand and Upgrade GovGuam NDWWTP to Secondary Treatment

In addition to suspended solids removal by primary treatment, a wastewater treatment facility can utilize secondary treatment to enhance removal of biodegradable organic matter (in solution or suspension) and suspended solids. Secondary treatment normally refers to a biological treatment process that utilizes microorganisms to consume organic pollutants. It can be either a suspended growth activated sludge treatment or an aerobic attached growth treatment system (such as trickling filter).

During this study, the EPA indicated that secondary treatment will be required for flow and loadings for the new DoD development. The national minimum secondary treatment requirements are presented in Table 6-4. In order to meet anticipated increased stringent EPA ocean outfall discharge requirements to Guam municipal wastewater treatment facilities, the existing primary treatment facility at the NDWWTP needs to be upgraded to provide secondary treatment. The object of this alternative is to expand and upgrade the existing primary treatment system at the NDWWTP to secondary treatment, and to treat current wastewater flow, as well as additional flow from both civilian and military sources.

Table 6-4: Minimum National Standards for Secondary Treatment

Characteristic of discharge	Unit of measurement	Average 30-day concentration	Average 7-day concentration
BOD_5	mg/L	30	45
Suspended solids	mg/L	30	45
Hydrogen-ion	pH	6.0 – 9.0	

By expanding and upgrading the existing primary system, the NDWWTP can be converted to a new secondary treatment process as shown in the schematic process diagram on Figure 6-3. A trickling filter system was selected as the secondary treatment process not only because of its lower power requirement and less sludge production compared with a suspended growth system (such as Activated Sludge System) but also because of its simple and reliable operational characteristics. It is desirable to have a simple process to minimize future operation and maintenance requirements on the island of Guam.

The influent wastewater flow and loadings described in Section 6.1.1 also apply to this alternative. This alternative requires construction of a new relief sewer from the NCTS Finegayan to the NDWWTP and its sewer layout is shown on Figure 6-1.

Two wastewater streams then combine and flow through the NDWWTP upgraded headworks with new fine screens followed by existing rectangular aerated grit chambers into an upgraded diversion box. Grit and screenings are disposed in a sanitary landfill. Subsequently, the diversion box distributes flow evenly into one new and two existing circular primary clarifiers, while clarified primary effluent is combined and pumped to the top of the three new circular trickling filters for secondary biological treatment. Trickling filter flow is conveyed into four new circular secondary clarifiers for solid liquid separation. Clarified final effluent then flows through the effluent Parshall flume flow measurement system, and subsequently into an upgraded chlorine disinfection system for treated flow disinfection. The upgraded disinfection system with chlorination and dechlorination includes three chlorine contact tanks with one newly constructed tank. Dechlorination is provided because residual chlorine from chlorination disinfection has adverse effects on aquatic organisms in the receiving water. The chlorine disinfected effluent flows into the 34-inch ocean outfall for final disposal. The existing NDWWTP ocean outfall needs to be upgraded with additional multiport discharge diffusers to accept additional flow. The sludge from both primary clarifiers and secondary clarifiers is collected via sludge transfer pumps to an anaerobic digestion system for pathogen control and solids reduction. Digested solids are pumped to a centrifuge dewatering system for volume reduction. Dewatered cake is hauled as Class B solids for offsite disposal.

The following new process components and upgrades are required at the NDWWTP for this alternative:

- Headworks expansion and odor control
- One primary clarifier (same size as existing ones)
- Three trickling filters
- Four secondary clarifiers
- One chlorine contact tank
- Three new anaerobic digesters (same size as existing ones)
- Two centrifuge solids dewatering systems and odor control
- Effluent monitoring and measurement expansion
- Outfall diffuser capacity expansion

The sizes of the new process components and upgrades required at the NDWWTP for expanding and upgrading to secondary treatment are listed in Table 6-5.

Table 6-5: Components for Expanding and Upgrading the NDWWTP to Secondary Treatment

Construction Components	Expand (E)/Upgrade (U)/NEW (N)	Unit	Dimensions/Description
Headworks	U/N	2	Two fine screens
Primary clarifier	N	1	130 ft diameter x 7 ft SWD
Trickling filter pumping station	N	1	40 ft long x 25 ft wide x 16 ft high
Trickling filter	N	3	120 ft diameter x 24 ft SWD
Secondary clarifier	N	4	125 ft diameter x 16 ft SWD
Chlorine contact tank	N	1	70 ft long x 40 ft wide x 14 ft SWD
Effluent measurement	E	1	Automatic sampler
Odor control system	N	1	Locate at headworks and solids dewatering
Anaerobic digester	U N	2 3	80 ft diameter x 18 ft SWD 80 ft diameter x 18 ft SWD
Solids dewatering centrifuges	N	2	225 gpm each
Outfall capacity expansion	N	1	400 ft long multiport diffusers

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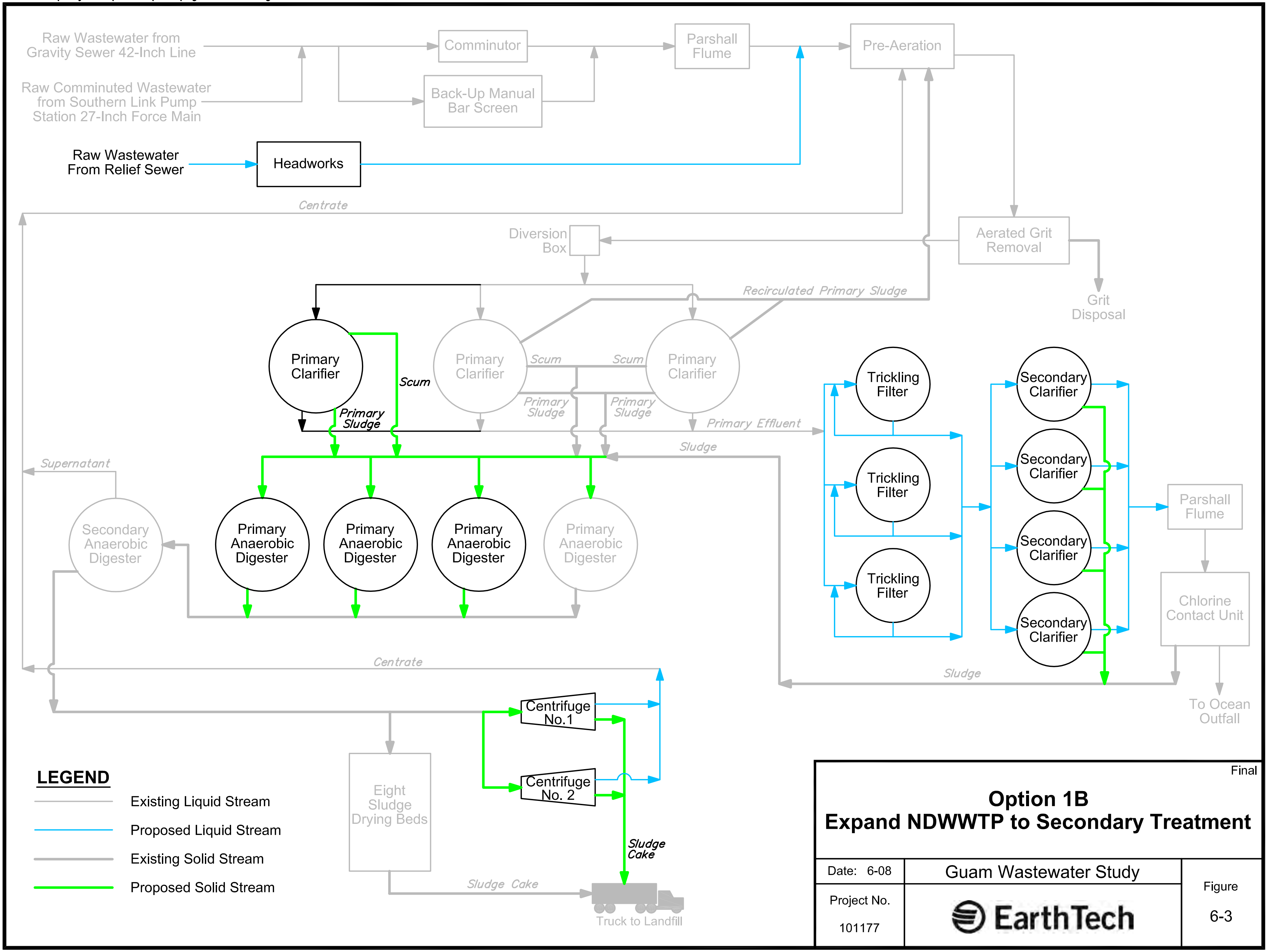

Final

Option 1B
Expand NDWWTP to Secondary Treatment

Date: 6-08	Guam Wastewater Study	Figure
Project No. 101177	EarthTech	6-3

Figure 6-3 shows a process flow diagram of the upgraded NDWWTP secondary treatment. In this alternative, the preliminary and primary treatment expansion and upgrade features of the plant are exactly the same as the ones discussed in the first alternative discussed in Section 6.1.1. The primary effluent from three primary clarifiers, each 130-foot diameter and 7-foot water depth, is then pumped via a newly constructed trickling filter pump station to the top of the three new circular trickling filters for secondary biological treatment. Secondary biological treatment system includes three trickling filters and four secondary clarifiers. Each circular trickling filter is 120-foot in diameter and 24-foot water depth. Each secondary clarifier is 125-foot in diameter and 16-foot water depth. Secondary treated effluent coming out of secondary clarifier then flows through a flow measurement Parshall flume into a chlorine disinfection system. The chlorine disinfection system has two existing chlorine contact tanks and one newly constructed concrete chlorine contact tank built with common wall adjacent to the existing tanks. The new tank will have the same dimensions as the existing ones: 70 feet long and 40 feet wide with 14-foot side water depth. After expansion, the chlorine disinfection system will provide a capacity that allows one tank to be offline for maintenance. The capacity of the existing outfall is limited by its end diffusers; as the result, in this alternative, one 400-foot long multiport diffuser branch will be installed with a precast concrete junction box connected to the existing outfall pipe to increase the discharge capacity of the outfall.

Primary sludge produced by primary clarifiers and secondary biological sludge produced by secondary clarifiers are all pumped into plant solids treatment facility for sludge digestion and subsequent dewatering. Solids treatment includes five anaerobic digesters and two solids dewatering centrifuges. Each digester is 80-foot in diameter and 18-foot liquid depth. Three first-stage anaerobic digesters are operated for stabilization, and two second-stage anaerobic digesters provide liquid solids separation and thickening. The digesters are designed for a hydraulic detention time over 15 days to meet EPA Class B standards, and will operate to handle planned future sludge loadings with one digester out of service for maintenance. An aerobic digested sludge is then pumped to two centrifuges with a capacity of 225 gpm each for the solids dewatering to reduce the volume of final disposed sludge. Dewatered cake is hauled as Class B solids for offsite disposal.

6.1.3 Build New Secondary Treatment Plant near the Proposed Development on DoD Land and Construct New Outfall

This alternative considers construction of a secondary treatment plant that will be owned and operated by DoD, rather than upgrading the existing treatment plant (NDWWTP, which is owned by GWA) to secondary treatment. In this alternative, a newly constructed independent sewer main is required to convey all military generated wastewater in the Northern Guam region to a DoD secondary treatment plant near the proposed USMC Finegayan development on DoD land (as shown on Figure 6-4). The new sewer main carries a total average daily wastewater flow of 4.51 mgd. This includes current NCTS Finegayan daily wastewater flow of 0.14 mgd, current AAFB daily flow of 1.1 mgd, future Air Force bed down MILCON wastewater flow of 0.44 mgd, plus future USMC, Army and SOF wastewater flow of 2.97 mgd in the NCTS Finegayan area as indicated in Table 3-4. The treated effluent from this secondary wastewater treatment plant will be discharged via a new DoD ocean outfall into Philippine Sea. The future peak flow for the DoD secondary plant is estimated to be 10.92 mgd in Table 3-4 and its peak factor is estimated based on the served population from Babbit's curve in Water Pollution Control Federation Manual of Practice No. FD-5. Earth Tech assumed that the future military wastewater flow will have characteristics similar to the wastewater flow discharging to the NDWWTP. Future influent wastewater flow and its characteristics and loadings to the DoD secondary plant are presented in Table 6-6.

Table 6-6: Estimated Influent Flow and Loading in 2025 for DoD Secondary Wastewater Treatment

Flows	Flow rate (mgd)	
Average daily flow	4.51	
Peak wet weather flow	10.92	
Parameters	Concentration (mg/L)	Loading (lbs/day)
BOD_5	204	7,677
Suspended solids	205	7,707

The independent sewer that connects the AAFB collection system at its main gate lift station, runs along the Route 3 and combines the flow generated by the relocated USMC from the Finegayan will carry wastewater into the proposed DoD secondary treatment facility at the southern end of Finegayan.

The new secondary wastewater treatment plant will consist of following components:

- Headworks (two screens and two aerated grit chambers with odor control)
- Three primary clarifiers
- Three trickling filters
- Four secondary clarifiers
- Two chlorine contact tanks
- Three anaerobic digesters
- Two centrifuge solids dewatering systems with odor control
- Effluent monitoring and measurement
- Ocean outfall

Figure 6-5 shows a process flow diagram of the new DoD secondary treatment. Preliminary treatment for this alternative includes bar racks and 3/8-inch to 1/2-inch mechanical fine screens at the headworks structure, followed by two aerated grit removal chambers. Each chamber has a 45-foot length and 12-foot width and 7-foot water depth. Grit and screenings removed are disposed in a sanitary landfill.

Primary treatment includes three primary clarifiers, each 60-foot diameter and 10-foot water depth. Secondary treatment system includes three trickling filters and three secondary clarifiers. Each circular trickling filter is 65-feet in diameter and 24-foot water depth. Each secondary clarifier is 80-feet in diameter and 13-foot water depth. Subsequently a disinfection system with two chlorine contact tanks, each 55-feet long by 25-feet wide with water depth of 14-feet, provides chlorination and dechlorination to the secondary clarifier effluent, and its effluent flows into the 30-inch ocean outfall for final discharge at Philippine Sea, west of the plant. A new ocean outfall about 5,000 feet long 30-inch effluent transmission pipe and 2,400 feet long 30-inch outfall is required for the treated effluent disposal in this alternative.

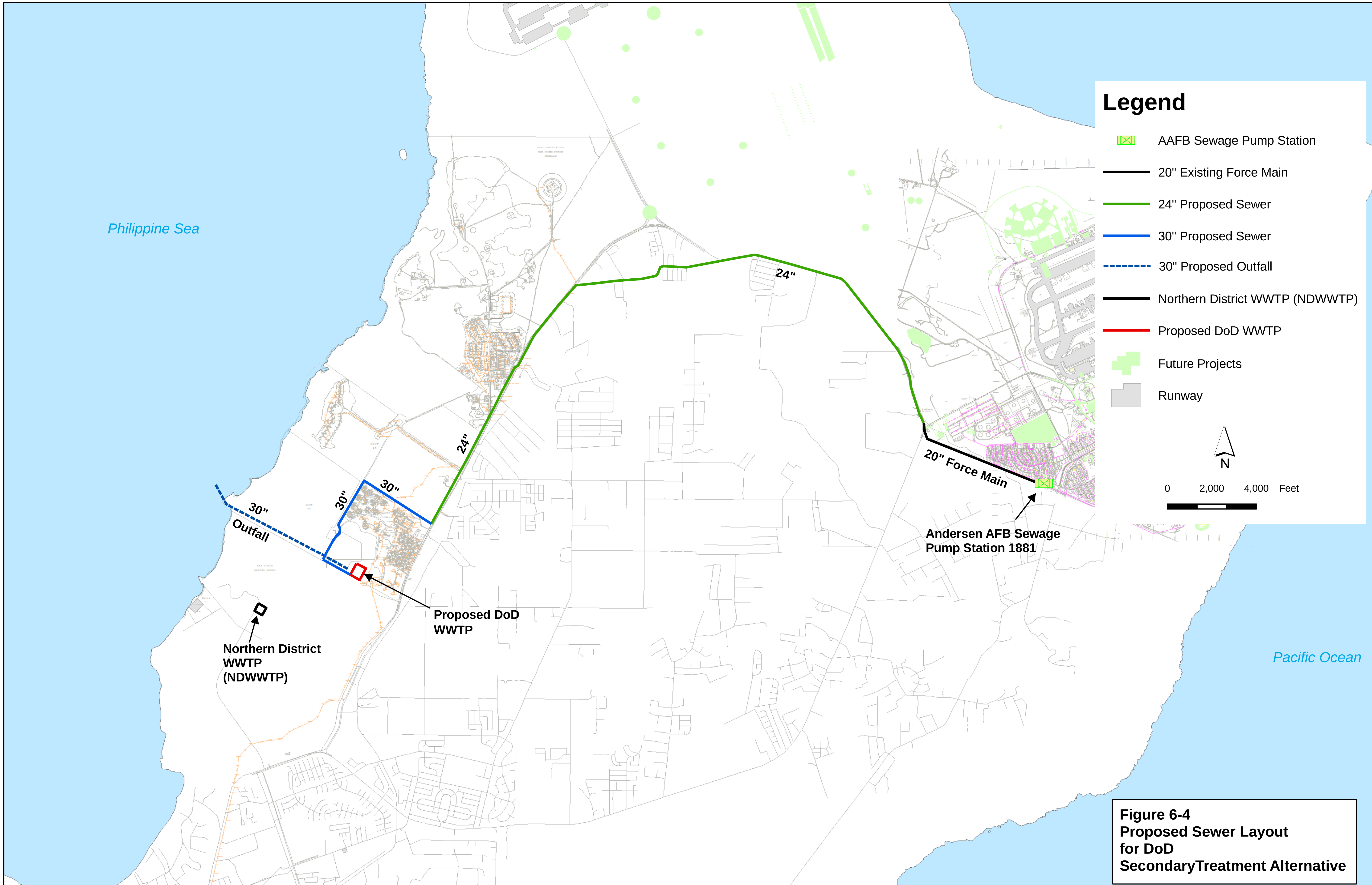

Figure 6-4
Proposed Sewer Layout for DoD SecondaryTreatment Alternative

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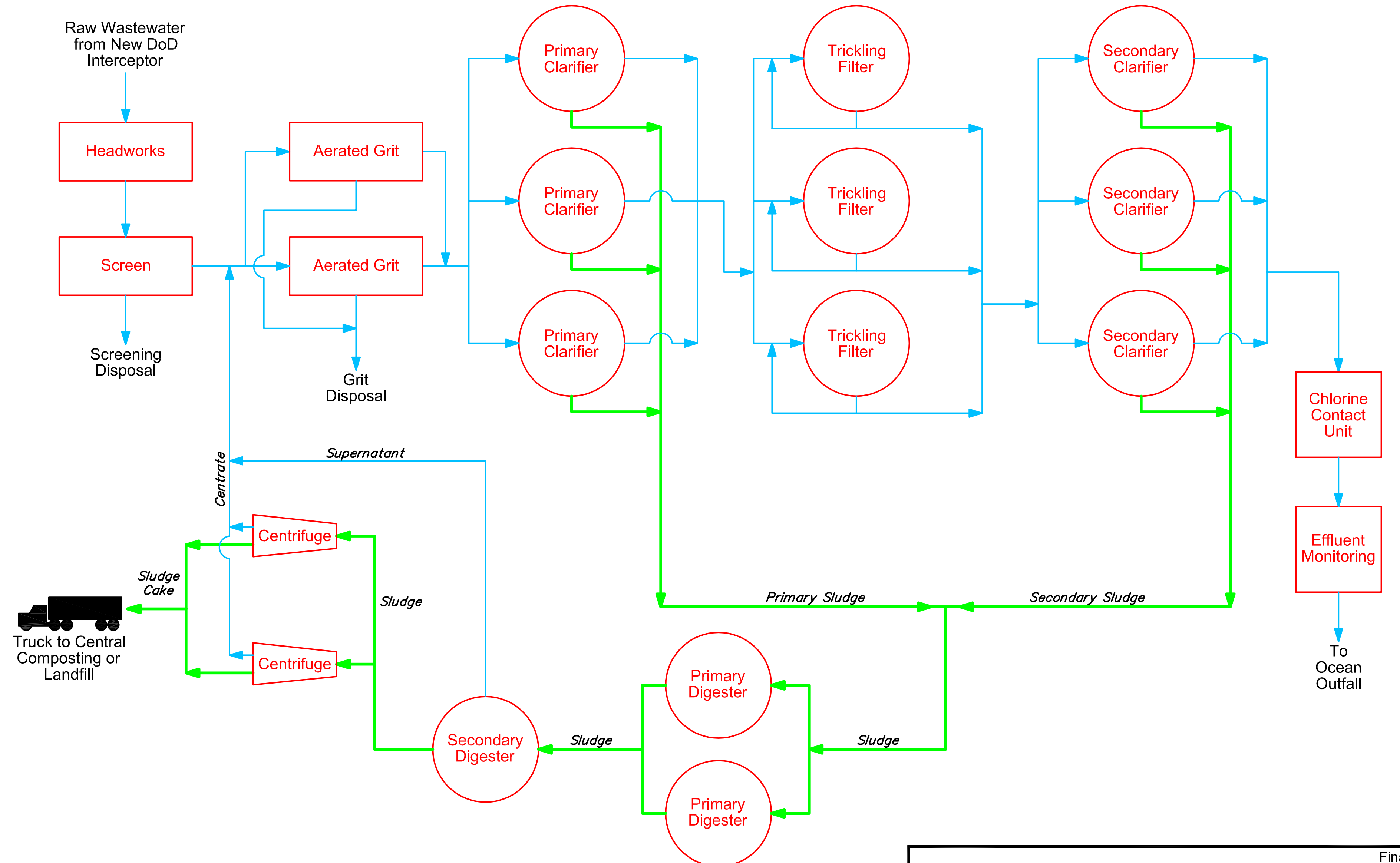

LEGEND

- Existing Liquid Stream
- Proposed Liquid Stream
- Existing Solid Stream
- Proposed Solid Stream

Final

Option 2:
Build New DoD Secondary Treatment Facility on DoD Land

Date: 6-08	Guam Wastewater Study	Figure
Project No. 101177	EarthTech	6-5

Solids treatment for both primary sludge and secondary sludge includes three anaerobic digesters and two solids dewatering centrifuges for sludge digestion and dewatering. Each digester is 80-feet in diameter and 18-foot liquid depth. Two first stage anaerobic digesters are operated for stabilization, and one second stage anaerobic digester provides liquid solids separation and thickening. The digesters are designed for a hydraulic detention time over 15 days to meet EPA Class B standards, and will operate to handle planned future sludge loadings with one digester out of service for maintenance. Anaerobic digested sludge is then pumped to two centrifuges with a capacity of 125 gpm each for the solids dewatering to reduce the volume of final disposed sludge. Dewatered cake is hauled as Class B solids for offsite disposal.

A summary of the major process components for a new DoD secondary treatment plant adjacent to the NDWWTP and a new outfall are listed in Table 6-7.

Table 6-7: Major Process Components for Building a New DoD Secondary Treatment Plant Near the Proposed Development on DoD Land and Constructing a New Outfall

Construction Components	Unit	Dimensions/Description
Headwork	1	Two mechanical fine screens and Two (2) aerated grit chambers, each 45 ft long x 12 ft wide x 7 ft SWD
Primary clarifier	3	60 ft diameter x 10 ft SWD
Trickling filter pumping station	1	40 ft long x 25 ft wide x 16 ft high
Trickling filter	3	65 ft diameter x 24 ft SWD
Secondary clarifier	3	80 ft diameter x 13 ft SWD
Chlorine contact tank	2	55 ft long x 25 ft wide x 14 ft SWD
Effluent measurement	1	Automatic sampler
Odor control system	1	Locate at headworks and solids handling
Ocean outfall & effluent transmission piping	1	30 in diameter, 7,400 ft long
Anaerobic digesters	3	80 ft diameter x 18 ft SWD
Solids dewatering centrifuges	2	125 gpm each

in inch

6.1.4 Build New Separate Secondary Treatment Plant at GovGuam NDWWTP Site to Treat DoD Load Only

This alternative would build a new secondary treatment plant at the NDWWTP site, and treat the DoD wastewater from the DoD facilities and proposed military buildup in the Northern Guam region including USMC relocation. The existing NDWWTP will upgrade to have two separate and independent treatment process trains. The existing primary treatment will continue to treat flow from civilian population in Northern Guam. The new process train consists of primary and secondary treatment all the way to chlorine disinfection. The new treatment plant will have separate headworks, primary treatment, secondary treatment, chlorine disinfection, and sludge handling facilities to treat the load from DoD facilities in Northern Guam area. The new process train, including both liquid treatment and solids treatment, is a self-contained and complete secondary treatment system from the start to the end, and it will require jointly utilizing the existing NDWWTP ocean outfall for its secondary treated effluent disposal. This alternative requires constructing a new independent sewer main to convey all military generated wastewater in the Northern Guam region to the NDWWTP site as shown on Figure 6-6. The independent sewer connects the AAFB collection system at its main gate lift station, runs along the Route 3 and combines the flow generated by the military buildup from the Finegayan area, and carries wastewater into the newly constructed secondary treatment plant located inside the NDWWTP fence about 0.8 miles south of the Southern Finegayan. The influent wastewater flow and loadings of Table 6-7 in Section 6.1.3 also apply to this alternative.

The new secondary wastewater treatment plant will consist of following components:

- Headworks (two screens and two aerated grit chambers with odor control)
- Three primary clarifiers
- Three trickling filters
- Three secondary clarifiers
- Two chlorine contact tanks
- Three anaerobic digesters
- Two centrifuge solids dewatering systems with odor control
- Effluent monitoring and measurement
- Outfall diffuser capacity expansion

Figure 6-7 shows a process flow diagram of the new secondary treatment plant inside NDWWTP site. Preliminary treatment for this alternative includes bar racks and 3/8-inch to 1/2-inch mechanical fine screens at the headworks structure, followed by two aerated grit removal chambers. Each chamber has a 45-foot length and 12-foot width and 7-foot water depth. Grit and screenings removed are disposed in a sanitary landfill. Primary treatment includes three primary clarifiers, each 60-foot diameter and 10-foot water depth.

Secondary treatment system includes three trickling filters and three secondary clarifiers. Each circular trickling filter is 65-foot in diameter and 24-foot water depth. Each secondary clarifier is 80-foot in diameter and 13-foot water depth. Subsequently a disinfection system with two chlorine contact tanks, each 55 feet long by 25 feet wide with water depth of 14 feet, provides chlorination and dechlorination to the secondary clarifier effluent, and its effluent flows into the NDWWTP existing 34-inch ocean outfall for final discharge at Philippine Sea, west of the plant. The capacity of the existing outfall is limited by its end diffusers; as the result, a new ocean outfall multiport diffuser branch will be installed with a precast concrete junction box connected to the existing outfall pipe to increase the discharge capacity of the outfall in this alternative.

Solids treatment for both primary sludge and secondary sludge includes three anaerobic digesters and two solids dewatering centrifuges for sludge digestion and dewatering. Each digester is 80-foot in diameter and 18-foot liquid depth. Two first stage anaerobic digesters are operated for stabilization, and one second stage anaerobic digester provides liquid solids separation and thickening. The digesters are designed for a hydraulic detention time over 15 days to meet EPA Class B standards, and will operate to handle planned future sludge loadings with one digester out of service for maintenance. Anaerobic digested sludge is then pumped to two centrifuges with a capacity of 225 gpm each for the solids dewatering to reduce the volume of final disposed sludge. Dewatered cake is hauled as Class B solids for offsite disposal.

All the above described treatment facilities are sized for secondarily treating DoD load only. A summary of the major process components for a new secondary treatment plant at NDWWTP site to treat DoD load only are listed in Table 6-8.

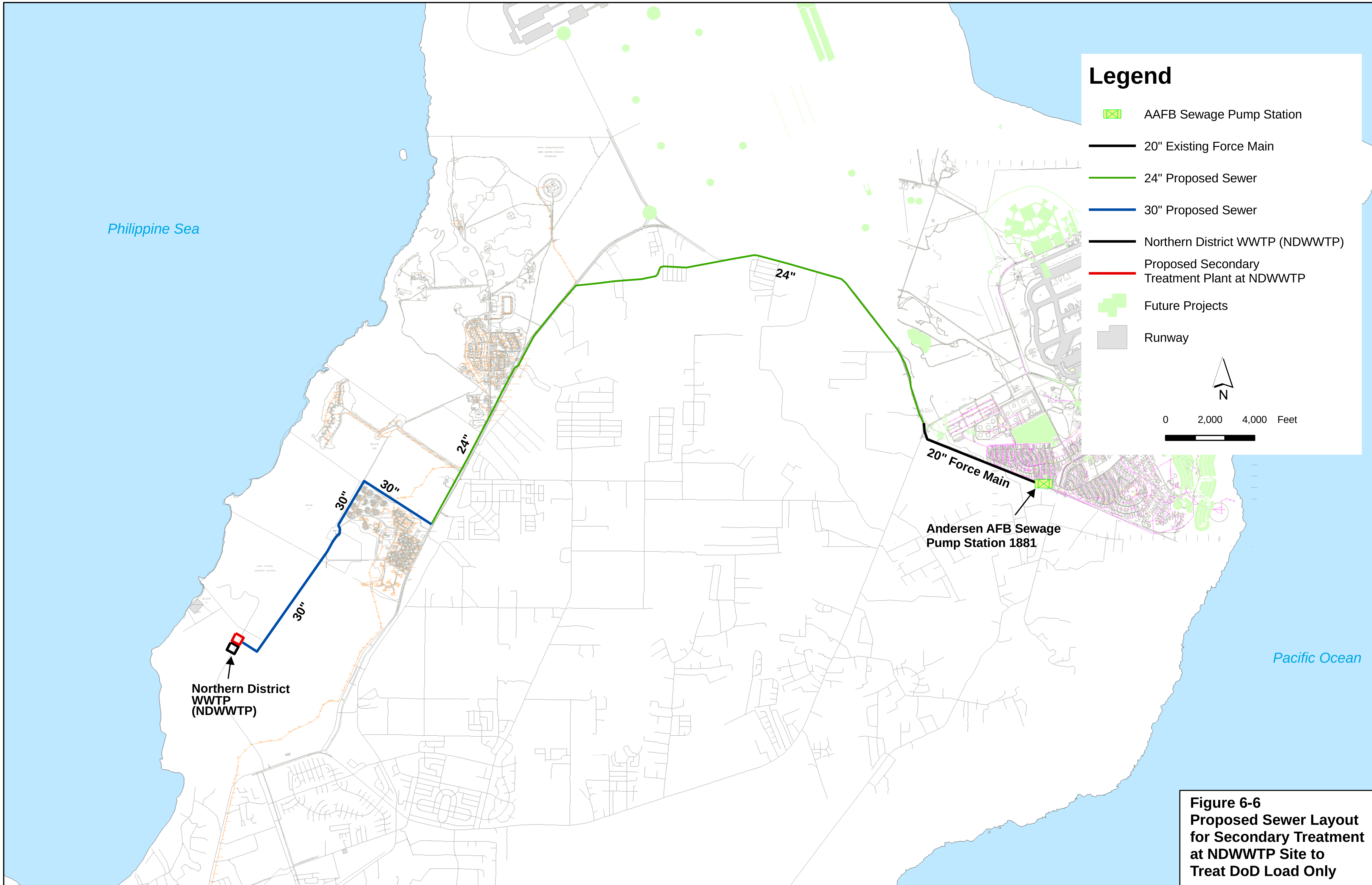

Figure 6-6
Proposed Sewer Layout for Secondary Treatment at NDWWTP Site to Treat DoD Load Only

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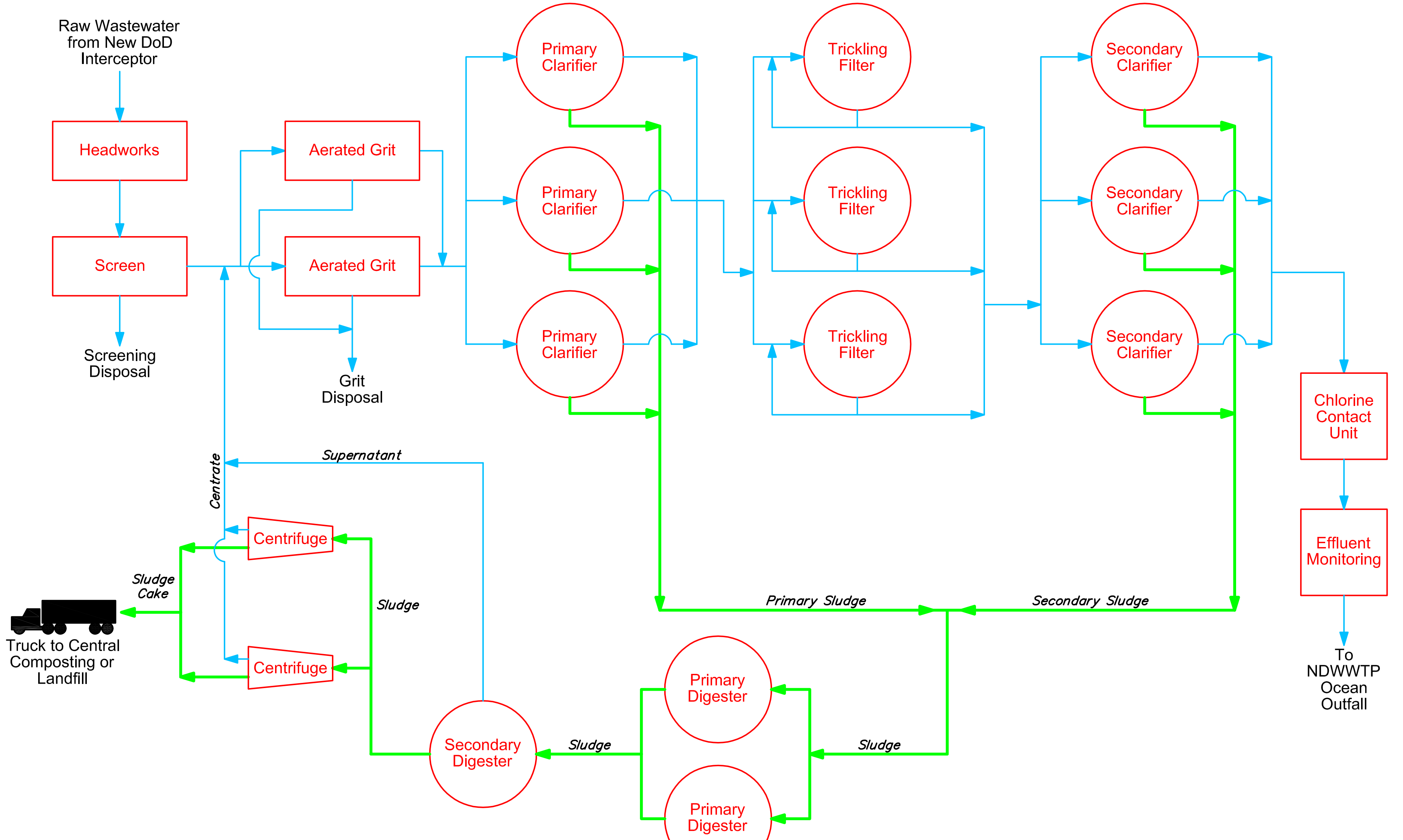

LEGEND

Existing Liquid Stream
Proposed Liquid Stream
Existing Solid Stream
Proposed Solid Stream

Final

Option 3:
Build New DoD Secondary Treatment Facility at NDWWTP Site to Treat DoD Load Only

Date: 6-08	Guam Wastewater Study	Figure
Project No. 101177	EarthTech	6-7

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Table 6-8: Major Process Components for Building a New Secondary Treatment Plant at the NDWWTP Site to Treat DoD Load Only

Construction Components	Unit	Dimensions/Description
Headwork	1	Two mechanical fine screens and Two (2) aerated grit chambers, each 45 ft long x 12 ft wide x 7 ft SWD
Primary clarifier	3	60 ft diameter x 10 ft SWD
Trickling filter pumping station	1	40 ft long x 25 ft wide x 16 ft high
Trickling filter	3	65 ft diameter x 24 ft SWD
Secondary clarifier	3	80 ft diameter x 13 ft SWD
Chlorine contact tank	2	55 ft long x 25 ft wide x 14 ft SWD
Effluent measurement	1	Automatic sampler
Anaerobic digesters	3	80 ft diameter x 18 ft SWD
Solids dewatering centrifuges	2	125 gpm each
Outfall capacity expansion	1	Multiport diffusers

in inch

6.2 DESCRIPTION OF COLLECTION SYSTEM MODIFICATIONS

The existing sewer maps and topography maps were examined to determine how discharges from proposed facilities, identified in Section 3, will be delivered to the NDWWTP. Based on the flows identified in Section 3, the GWA's collection system connecting the AAFB will have enough capacity to convey flows from AAFB. However, a relief sewer is needed south of Finegayan area where flows from the proposed USMC development will be discharged.

Using projected flows identified in Section 3, a sewer collection system was developed that will convey discharges from the proposed facilities to NDWWTP. The recommended collection system is sized based on the following criteria:

- Minimum pipe size 8-inches
- At peak dry weather flow, pipe flow not to exceed 75 percent
- Minimum flow velocity 2 feet per second
- Pipe diameter determined using Manning's pipe friction formula
- Coefficient of roughness "n" equal to 0.013

Option 1A and Option 1B require the same set of collection system modifications, and Option 2 and Option 3 require another similar set of collection system modifications. However, Option 2 has the wastewater treatment facility located within DoD land at the southeast corner of the USMC Finegayan area, while Option 3 has the wastewater treatment facility located at NDWWTP site.

Option 1A and Option 1B modifications are based on all military generated wastewater, either from the AAFB or from the USMC relocation will still be carried over to the NDWWTP for treatment. All current and future military buildup at the AAFB is still conveyed through the existing GWA sewer to the NDWWTP, while wastewater flow generated from the USMC relocation at Finegayan will be conveyed via a new relief sewer line to the NDWWTP.

Option 2 modifications are based on all military generated wastewater including both the AAFB and the Finegayan, and will be conveyed via an independently separated sewer interceptor to the new DoD wastewater treatment facility located inside DoD land at the southeast corner of the USMC Finegayan area for treatment in the future.

Option 3 modifications are based on all military generated wastewater, including both the AAFB and the Finegayan, and will be conveyed via an independently separated sewer interceptor to the new secondary wastewater treatment facility located at the NDWWTP site for treatment. The location of the secondary wastewater treatment facility in this set of modifications is different from Option 2, and it is about 0.8-mile south. .

6.2.1 Construct a New Relief Sewer to Accommodate USMC Relocation Wastewater Flow

As discussed in the previous sections, after expansion and upgrading it is anticipated that the NDWWTP will treat a total average daily flow of 17.63 mgd and peak flow of 40.44 mgd. This includes military flow generated from the AAFB about 1.54 mgd (1.1 mgd existing flow and 0.44 mgd from future Air Force bed down MILCON projects), and flow of 2.97 mgd generated by the military buildup at the Finegayan area. The wastewater flow generated by the USMC relocation at the Finegayan area (that has a peak flow of 7.2 mgd) is required to be carried via the newly constructed relief sewer to the NDWWTP as shown on Figure 6-1.

A new gravity relief sewer will be connected from the collection system of the USMC Finegayan area on the west side of the planned USMC Finegayan development to the headworks of the NDWWTP.

As shown on Figure 6-1, a 24-inch, 7,500 foot sewer will be required to convey flow from the Finegayan area to the NDWWTP.

6.2.2 Construct a New Separate Sewer for All Military Activities in Northern Guam Region to DoD Secondary Treatment Facility Inside DoD Land

In this alternative, a newly constructed DoD-owned wastewater facility located at the southwest corner of the USMC Finegayan area requires the DoD to construct its own independent sewage interceptor to collect wastewater generated from military activities at both the AAFB and the Finegayan areas. The interceptor will connect AAFB collection system at its main gate lift station and will run west along Route 3, then will combine the flow generated by the USMC and Army from the Finegayan into the proposed DoD secondary treatment plant located at the southwest corner of the DoD Finegayan development (as shown on Figure 6-4). The interceptor will be designed to have a capacity for 3.72 mgd peak flow from the AAFB to the beginning of the NCTS Finegayan, then 10.92 mgd peak flow from the NCTS boundary to the new DoD treatment plant.

As shown on Figure 6-4, 33,300 feet of 24-inch sewer and 8,700 feet of 30-inch sewer are required to convey flow from the AAFB and the Finegayan areas to the new DoD plant.

This option will also require construction of 5,000 feet of 30-inch effluent transmission line and 2,400 feet of 30-inch outfall to discharge effluent to the Philippine Sea.

6.2.3 Construct a New Separate Sewer for All Military Activities in Northern Guam Region to Secondary Treatment Facility at the NDWWTP Site to Treat DoD Load Only

In this alternative, a DoD constructed secondary wastewater facility is planned at the NDWWTP site to treat northern Guam DoD load only. An independent sewage interceptor to collect wastewater generated from military activities both at the AAFB and the Finegayan areas is required for this alternative. The interceptor connects the AAFB collection system at its main gate lift station and runs along Route 3, then combines the flow from Finegayan generated by the USMC and Army to the new DoD constructed secondary treatment plant at the NDWWTP site (as shown on Figure 6-6). The interceptor prior to the connection of NCTS Finegayan is designed to have a capacity for 3.72 mgd peak flow, and the subsequent section of the interceptor all the way to the new treatment facility is required to have a capacity of 10.92 mgd.

As shown on Figure 6-6, 33,300 feet of 24-inch sewer and 13,500 feet of 30-inch sewer are required to convey flow from AAFB and Finegayan to the new secondary treatment plant at the NDWWTP site.

6.3 PRELIMINARY OPINION OF PROBABLE CONSTRUCTION COST

A summary of the preliminary opinion of probable construction cost (the construction cost estimate) is outlined in this section. The quantities shown are estimates based on descriptions in this study and vendor proposals. The estimates are intended to be as comprehensive as possible at the study stage where much of the work is still at a conceptual level.

The quantities for all work items shall be reviewed and updated during the Detailed Design. A project level allowance of 35 percent is added to the estimated construction cost for project services to establish the total estimated project cost. Project services include the following:

- Environmental Impact Report/Other Documents
- Design Engineering
- Construction Engineering and Contract Administration
- General and Administrative Expenses
- Contingencies

The current construction cost estimate is based on June 2007 prices (ENR_{LA} = 8,900). A summary of the preliminary construction cost for each alternative is shown in Table 6-9 through Table 6-12. An escalation index value of 4.55 percent is used to estimate January 2010 cost from January 2008. The escalation index data is obtained from Earth Tech's cost estimating software *RACER* 2008. The data was provided to Earth Tech by Air Force Civil Engineering Support Agency and were obtained from the Secretary of the Air Force/Financial Management and Controller. The construction cost portion of the USMC relocation for each alternative is listed in the cost tables. A detailed construction cost allocation among the GWA, the USMC and other relevant DoD units is presented in Table 6-14. The cost allocation is determined based on the flow contribution from the GWA, USMC, and other DoD units. A detailed cost spreadsheet is provided in Appendix B.

As shown in Table 6-14, Option 1A that expands & upgrades existing primary treatment system at the NDWWTP to accept the additional flow and load has the lowest construction cost. Among the three secondary treatment options, preliminary construction cost for Option 2 and Option 3 that treat DoD load only is lower than Option 1B that treats both off-base civilian load and DoD load in Northern Guam region. Even though Option 2 and Option 3 treat an average daily flow of 4.51 mgd compared to 17.63 mgd in Option 1B, preliminary construction cost for Option 1B is only 3 million dollars more than Option 2 and about 14 million dollars more than Option 3. This is because in Option 1B, existing 12 mgd treatment capacity is available for primary treatment, disinfection and sludge digestion, only requires expanding existing primary, disinfection and sludge treatment capacity to treat 5.63 mgd additional load and upgrade secondary treatment for all 17.63 mgd, while Option 2 and Option 3 have to treat 4.51 mgd load through primary, secondary, disinfection and sludge digestion processes. The construction cost difference between Option 2 and 3 is because of construction of the outfall.

An estimate of the O&M costs for viable alternatives has been developed and a detailed cost spreadsheet is provided in Appendix B. The assumptions and criteria that form the basis for this estimate are presented below:

- Staffing of two expansion and upgrade alternatives (Options 1A and 1B) at the NDWWTP would be by the GWA.
- Staffing of two expansion and upgrade alternatives (Options 1A and 1B) at the NDWWTP will be similar (in terms of shift and time of day coverage by operators and sharing of maintenance with other facilities) to the current staffing at the existing NDWWTP.
- Staffing of DoD operating alternative (Options 2) would be by the DoD.
- Staffing of treating DoD load only alternative (Options 3) at the NDWWTP site will be negotiated between the GWA and DoD, but assumed similar (in terms of shift and time of day coverage by operators and sharing of maintenance with other facilities) to the DoD operating alternative (Option 2) for conservative estimation.
- Staff labor of manager at $75,000 per year including fringe benefits, operator/mechanic at $45,000 per year including fringe benefits, and administrative assistant at $30,000 per year including fringe benefits.
- Flow based on projected future value of 17.63 mgd for two expansion and upgrade alternatives (Options 1A and 1B) at the NDWWTP.
- Flow based on projected future value of 4.51 mgd for two DoD load only alternatives.
- Power cost based on $0.20 per kilowatt hour.
- Polymer cost based on $3.00 per pound.
- Sodium hypochlorite cost based on $0.85 per gallon.
- Citric acid cost based on $6.50 per gallon.
- General repair and maintenance based on $0.15 percent of estimated construction costs.
- Sewer line maintenance based on 0.15 per foot.
- Solids hauling and disposal based on $25 per cubic yard (cy) processing/land application fee and $285 per 20 cy truck trip for transportation.

The above viable alternatives will require a life cycle comparison for a recommended selection. An annual 4 percent interest was used to compare 20-year net present worth for each alternative. Table 6-13 presents an outline of annual costs for each alternative. Revenues form sewer connection fee and sale of reuse water are not included in the annual costs analysis. In addition, Earth Tech also prepared a separate O&M cost estimate showing distribution of O&M costs between the DoD and the GWA for Option 1A and Option 1B. The costs are distributed in proportion to the flow contribution to the NDWWTP, which is 4.51 mgd of 17.63 mgd for the DoD and 13.12 mgd of 17.63 mgd for the GWA.

Table 6-15 and Table 6-16 present total O&M cost and respective cost distribution to the GWA and the DoD for Option 1A and Option 1B.

Table 6-9: Preliminary Construction Cost for Option 1A– Expand and Upgrade Existing Primary Treatment System at the GovGuam NDWWTP to Accept the Additional Flow and Load

1. Component xxx	Guam Wastewater Utility Study		2. Date June 2008
3. Installation and Location Marine Relocation, Guam	4. Project Title Guam Wastewater Utility Study		
5. Program Element	6. Category Code	7. Project Number	8. Project Cost ($000) 55,450

9. Cost Estimates

Item	U/M	Quantity	Unit Cost	Cost ($000)
Headworks Expansion				
6mm Fine Screen Equipment	1	2	$637,168	1,274
Instrumentation/SCADA	LS	1	$63,717	64
Electrical	LS	1	$191,150	191
Primary Clarifier				
Reinforced Concrete	CY	1,300	$2,124	2,761
Earthwork	CY	6,300	$106	669
Sludge and Scum Collector Equipment	EA	1	$876,106	876
Miscellaneous Metals	LS	1	$215,310	215
Frap Weirs	LS	1	$129,186	129
Protective Coatings	LS	1	$350,442	350
Piping and Valves	LS	1	$129,186	129
Instrumentation/SCADA	LS	1	$172,248	172
Electrical	LS	1	$430,619	431
Sludge Pump Station Improvements	LS	1	$732,053	732
Chlorine Contact Tanks				
Reinforced Concrete	CY	600	$2,124	1,274
Earthwork	CY	3,600	$106	382
Chemical Feed and Mixing Equipment	LS	1	$318,584	319
Miscellaneous Metals	LS	1	$98,761	99
Slide Gates and Weirs	LS	1	$59,257	59
Protective Coatings	LS	1	$127,434	127
Piping and Valves	LS	1	$59,257	59
Instrumentation/SCADA	LS	1	$79,009	79
Electrical	LS	1	$197,522	198
Anaerobic Digesters				
Reinforced Concrete	CY	1,000	$2,124	2,124
Earthwork	CY	1,400	$106	149
Digester Mixing and Heating Equipment	EA	1	$2,123,894	2,124
Miscellaneous Metals	LS	1	$263,788	264
Roofing and Insulation	LS	1	$241,805	242
Protective Coatings	LS	1	$659,469	659
Piping and Valves	LS	1	$1,538,761	1,539
Instrumentation/SCADA	LS	1	$307,752	308
Electrical	LS	1	$659,469	659
New Sludge Pump Station	LS	1	$2,198,230	2,198

Item	U/M	Quantity	Unit Cost	Cost ($000)
Solids Dewatering Building				
Reinforced Concrete	CY	1200	$2,124	2,549
Earthwork	CY	3200	$106	340
Masonry Interior Walls	LS	1	$375,504	376
Miscellaneous Metals	LS	1	$346,619	347
Frap Weirs	LS	1	$86,655	87
Roofing and Insulation	LS	1	$404,389	404
4Doors and Windows	LS	1	$72,212	72
Protective Coatings	LS	1	$173,310	173
Building Specialties	LS	1	$28,885	29
Sludge Grinders	EA	2	$63,717	127
Sludge Feed Pumps	EA	2	$79,646	159
Polymer Feed System	EA	2	$238,938	478
Polymer Feed Pumps	EA	2	$21,239	42
Odor Control System	EA	1	$477,876	478
Centrifuges	EA	2	$1,274,336	2,549
Process Piping and Valves	LS	1	$519,929	520
HVAC	LS	1	$433,274	433
Plumbing	LS	1	$288,850	289
Electrical	LS	1	$1,444,248	1,444
Instrumentation/SCADA	LS	1	$317,735	318
Influent and Effluent Samplers	EA	2	$79,646	159
Site Work and Utilities	LS	1	$2,256,076	2,256
Relief Sewer, 24"D	FT	7500	$558	4,181
Outfall Diffuser Capacity Expansion	FT	400		621
Treatment Cost				34,486
Sewer Cost				4,802
Sub Total				39,288
Project Services 35.00%				13,751
Total Contract Cost				53,039
Total Request				53,039
Total Request (Rounded)				53,040
Total Escalated 2010 Request (Rounded)				55,450
Total Escalated 2013 Mid-Point Construction Cost (Rounded)				58,910
Total Request for USMC (Rounded)				31,690
Total Escalated 2010 Request for USMC (Rounded)				33,130
Total Escalated 2013 Mid-Point Construction Cost for USMC (Rounded)				35,200

10. Description of Proposed Construction:

1. New Headworks are constructed for relief sewer and this extra sewage will be mixed with GWA sewer at the grit chamber.
2. One new Primary Clarifier is added for the extra flow.
3. One primary anaerobic digester is added.
4. Two Centrifuges are added for solid dewatering.
5. Solids dewatering building will be added.
6. One chlorine contact tank is added.
7. Outfall capacity is added.

Table 6-10: Preliminary Construction Cost for Option 1B– Expand and Upgrade the GovGuam NDWWTP to Secondary Treatment

1. Component xxx	Guam Wastewater Utility Study		2. Date June 2008
3. Installation and Location Marine Relocation, Guam	4. Project Title Guam Wastewater Utility Study		
5. Program Element	6. Category Code	7. Project Number	8. Project Cost ($000) 183,520

9. COST ESTIMATES

Item	U/M	Quantity	Unit Cost	Cost ($000)
Headworks Expansion				
6mm Fine Screen Equipment	1	2	$637,168	1,274
Instrumentation/SCADA	LS	1	$63,717	64
Electrical	LS	1	$191,150	191
Primary Clarifier				
Reinforced Concrete	CY	1,300	$2,124	2,761
Earthwork	CY	6,300	$106	669
Sludge and Scum Collector Equipment	EA	1	$876,106	876
Miscellaneous Metals	LS	1	$215,310	215
Frap Weirs	LS	1	$129,186	129
Protective Coatings	LS	1	$350,442	350
Piping and Valves	LS	1	$129,186	129
Instrumentation/SCADA	LS	1	$172,248	172
Electrical	LS	1	$430,619	431
Sludge Pump Station Improvements	LS	1	$732,053	732
Trickling Filter Pumping Station				
Reinforced Concrete	CY	400	$2,124	850
Earthwork	CY	1,600	$106	170
Trickling Filter Influent Pump Equipment	EA	3	$238,938	717
Miscellaneous Metals	LS	1	$86,814	87
Protective Coatings	LS	1	$501,770	502
Piping and Valves	LS	1	$52,088	52
Instrumentation/SCADA	LS	1	$121,540	122
Electrical	LS	1	$260,442	260
Trickling Filters				
Reinforced Concrete	CY	5,700	$2,124	12,106
Earthwork	CY	6,600	$106	701
Trickling Filter Plastic Media	CY	30,300	$319	9,653
Trickling Filter Influent Pump Equipment	EA	3	$477,876	1,434
Rotary Distribution Equipment	LS	1	$589,381	589
Miscellaneous Metals	LS	1	$353,628	354
Protective Coatings	LS	1	$1,003,540	1,004
Piping and Valves	LS	1	$353,628	354
Instrumentation/SCADA	LS	1	$117,876	118
Electrical	LS	1	$471,504	472
Secondary Clarifier				
Reinforced Concrete	CY	7200	$2,124	15,292
Earthwork	CY	44000	$106	4,673
Sludge and Scum Collector Equipment	EA	4	$876,106	3,504
Miscellaneous Metals	LS	1	$1,173,451	1,173
Frap Weirs	LS	1	$704,071	704
Protective Coatings	LS	1	$1,401,770	1,402
Piping and Valves	LS	1	$704,071	704
Instrumentation/SCADA	LS	1	$938,761	939
Electrical	LS	1	$2,346,903	2,347
Sludge Pump Station Improvements	LS	1	$3,989,735	3,990

Item	U/M	Quantity	Unit Cost	Cost ($000)
Chlorine Contact Tanks				
Reinforced Concrete	CY	600	$2,124	1,274
Earthwork	CY	3,600	$106	382
Chemical Feed and Mixing Equipment	LS	1	$318,584	319
Miscellaneous Metals	LS	1	$98,761	99
Slide Gates and Weirs	LS	1	$59,257	59
Protective Coatings	LS	1	$127,434	127
Piping and Valves	LS	1	$59,257	59
Instrumentation/SCADA	LS	1	$79,009	79
Electrical	LS	1	$197,522	198
Anaerobic Digesters				
Reinforced Concrete	CY	600	$2,124	1,274
Earthwork	CY	3,600	$106	382
Digester Mixing and Heating Equipment	LS	1	$318,584	319
Miscellaneous Metals	LS	1	$98,761	99
Roofing and Insulation	LS	1	$59,257	59
Protective Coatings	LS	1	$127,434	127
Piping and Valves	LS	1	$59,257	59
Instrumentation/SCADA	LS	1	$79,009	79
Electrical	LS	1	$197,522	198
New Sludge Pump Station	CY	600	$2,124	1,274
Solids Dewatering Building				
Reinforced Concrete	CY	1,200	$2,124	2,549
Earthwork	CY	3,200	$106	340
Masonry Interior Walls	LS	1	$375,504	376
Miscellaneous Metals	LS	1	$346,619	347
Frap Weirs	LS	1	$86,655	87
Roofing and Insulation	LS	1	$404,389	404
Doors and Windows	LS	1	$72,212	72
Protective Coatings	LS	1	$173,310	173
Building Specialties	LS	1	$28,885	29
Sludge Grinders	EA	2	$63,717	127
Sludge Feed Pumps	EA	2	$79,646	159
Polymer Feed System	EA	2	$238,938	478
Polymer Feed Pumps	EA	2	$21,239	42
Odor Control System	EA	1	$477,876	478
Centrifuges	EA	2	$1,274,336	2,549
Process Piping and Valves	LS	1	$519,929	520
HVAC	LS	1	$433,274	433
Plumbing	LS	1	$288,850	289
Electrical	LS	1	$1,444,248	1,444
Instrumentation/SCADA	LS	1	$317,735	318
Influent and Effluent Samplers	EA	2	$79,646	159
Site Work and Utilities	LS	1	$8,192,185	8,192
Relief Sewer, 24"D	FT	7500	$558	4,181
Ocean Outfall Expansion	FT	400		621
Treatment Cost				125,223
Sewer Cost				4,802
Sub Total				130,026
Project Services 35.00%				45,509
Total Contract Cost				175,535
Total Request				175,535
Total Request (Rounded)				175,530
Total Escalated 2010 Request (Rounded)				183,520
Total Escalated 2013 Mid-Point Construction Cost (Rounded)				194,940
Total Request for USMC (Rounded)				62,410

Item	U/M	Quantity	Unit Cost	Cost ($000)
Total Escalated 2010 Request for USMC (Rounded)				65,250
Total Escalated 2013 Mid-Point Construction Cost for USMC (Rounded)				69,310

10. Description of Proposed Construction:

1. New Headworks are constructed for relief sewer and this extra sewage will be mixed with GWA sewer at the grit chamber.
2. One new Primary Clarifier is added for the extra flow.
3. Three trickling filters are added for secondary treatment.
4. Four secondary clarifiers are added for secondary treatment
5. Two primary anaerobic digesters are added.
6. One secondary anaerobic digester is added.
7. Two Centrifuges are added for solid dewatering.
8. Solids dewatering building will be added.
9. One chlorine contact tank is added.
10. Outfall capacity is added.

Table 6-11 Preliminary Construction Cost for Option 2– Build New Secondary Treatment Plant Near the Proposed Development on DoD Land and Construct New Outfall

1. Component xxx	Guam Wastewater Utility Study		2. Date June 2008
3. Installation and Location Marine Relocation	4. Project Title Guam Wastewater Utility Study		
5. Program Element	6. Category Code	7. Project Number	8. Project Cost ($000) 182,610

9. COST ESTIMATES

Item	U/M	Quantity	Unit Cost	Cost ($000)
Headworks Expansion				
Reinforced Concrete	CY	400	$2,124	850
Earthwork	CY	1400	$106	149
Fine Screenings Equipment	EA	2	$238,938	478
Grit Chamber Equipment	EA	2	$106,195	212
Grit Pumps Equipment	EA	2	$58,407	117
Grit Washer Equipment	EA	2	$185,841	372
Miscellaneous Metals	LS	1	$108,850	109
Frap Weirs	LS	1	$65,310	65
Protective Coatings	LS	1	$176,814	177
Piping and Valves	LS	1	$544,248	544
Instrumentation/SCADA	LS	1	$152,389	152
Electrical	LS	1	$326,549	327
Grit & Screenings Building	LS	1	$761,947	762
Primary Clarifier				
Reinforced Concrete	CY	1500	$2,124	3,186
Earthwork	CY	2200	$106	234
Sludge and Scum Collector Equipment	EA	3	$424,779	1,274
Miscellaneous Metals	LS	1	$234,690	235
Frap Weirs	LS	1	$140,814	141
Protective Coatings	LS	1	$509,735	510
Piping and Valves	LS	1	$140,814	141
Instrumentation/SCADA	LS	1	$187,752	188
Electrical	LS	1	$469,381	469
Sludge Pump Station Improvements	LS	1	$2,346,903	2,347
Trickling Filter Pumping Station				
Reinforced Concrete	CY	400	$2,124	850
Earthwork	CY	1600	$106	170
Trickling Filter Influent Pump Equipment	EA	3	$159,292	478
Miscellaneous Metals	LS	1	$74,867	75
Protective Coatings	LS	1	$334,513	335
Piping and Valves	LS	1	$44,920	45
Instrumentation/SCADA	LS	1	$104,814	105
Electrical	LS	1	$224,602	225
Trickling Filters				
Reinforced Concrete	CY	2700	$2,124	5,735
Earthwork	CY	2400	$106	255
Trickling Filter Plastic Media	CY	9000	$319	2,867
Trickling Filter Influent Pump Equipment	EA	3	$265,487	796
Rotary Distribution Equipment	LS	1	$195,929	196
Miscellaneous Metals	LS	1	$117,558	118
Protective Coatings	LS	1	$557,522	558
Piping and Valves	LS	1	$274,301	274
Instrumentation/SCADA	LS	1	$39,186	39
Electrical	LS	1	$156,743	157

Item	U/M	Quantity	Unit Cost	Cost ($000)
Secondary Clarifier				
Reinforced Concrete	CY	2400	$2,124	5,097
Earthwork	CY	12900	$106	1,370
Sludge and Scum Collector Equipment	EA	4	$557,522	2,230
Miscellaneous Metals	LS	1	$434,867	435
Frap Weirs	LS	1	$260,920	261
Protective Coatings	LS	1	$892,035	892
Piping and Valves	LS	1	$260,920	261
Instrumentation/SCADA	LS	1	$347,894	348
Electrical	LS	1	$869,735	870
Sludge Pump Station Improvements	LS	1	$1,478,549	1,479
Chlorine Contact Tanks				
Reinforced Concrete	CY	1200	$2,124	2,549
Earthwork	CY	4400	$106	467
Chemical Feed and Mixing Equipment	LS	1	$318,584	319
Miscellaneous Metals	LS	1	$166,726	167
Slide Gates and Weirs	LS	1	$100,035	100
Protective Coatings	LS	1	$127,434	127
Piping and Valves	LS	1	$100,035	100
Instrumentation/SCADA	LS	1	$133,381	133
Electrical	LS	1	$333,451	333
Anaerobic Digesters				
Reinforced Concrete	CY	3000	$2,124	6,372
Earthwork	CY	4200	$106	446
Digester Mixing and Heating Equipment	EA	3	$2,123,894	6,372
Miscellaneous Metals	LS	1	$791,363	791
Roofing and Insulation	LS	1	$725,416	725
Protective Coatings	LS	1	$1,978,407	1,978
Piping and Valves	LS	1	$4,616,283	4,616
Instrumentation/SCADA	LS	1	$923,257	923
Electrical	LS	1	$1,978,407	1,978
New Sludge Pump Station	LS	1	$6,594,690	6,595
Solids Dewatering Building				
Reinforced Concrete	CY	1200	$2,124	2,549
Earthwork	CY	3200	$106	340
Masonry Interior Walls	LS	1	$375,504	376
Miscellaneous Metals	LS	1	$346,619	347
Frap Weirs	LS	1	$86,655	87
Roofing and Insulation	LS	1	$404,389	404
Doors and Windows	LS	1	$72,212	72
Protective Coatings	LS	1	$173,310	173
Building Specialties	LS	1	$28,885	29
Sludge Grinders	EA	2	$53,097	106
Sludge Feed Pumps	EA	2	$66,372	133
Polymer Feed System	EA	2	$238,938	478
Polymer Feed Pumps	EA	2	$15,929	32
Odor Control System	EA	1	$477,876	478
Centrifuges	EA	2	$955,752	1,912
Process Piping and Valves	LS	1	$519,929	520
HVAC	LS	1	$433,274	433
Plumbing	LS	1	$288,850	289
Electrical	LS	1	$1,444,248	1,444
Instrumentation/SCADA	LS	1	$317,735	318

Item	U/M	Quantity	Unit Cost	Cost ($000)
Influent and Effluent Samplers				
Automatic Samplers	EA	2	$79,646	159
Site Work and Utilities				
Paving, Grading, and Yard Piping	LS	1	$5,972,742	5,973
Sewer Interceptor I, 24"D	FT	33300	$558	18,565
Sewer Interceptor II, 30"D	FT	8700	$664	5,774
Effluent Transmission Line, 30"D	FT	5000	$664	3,319
Ocean Outfall, 30"	FT	2400	$3,637	8,729
Treatment Cost				91,298
Sewer Cost				36,388
Sub Total				127,685
Project Services 35.00%				44,690
Total Contract Cost				172,375
Total Request				172,375
Total Request (Rounded)				172,380
Total Escalated 2010 Request (Rounded)				180,220
Total Escalated 2013 Mid-Point Construction Cost (Rounded)				191,450
Total Request for USMC (Rounded)				96,320
Total Escalated 2010 Request for USMC (Rounded)				100,700
Total Escalated 2013 Mid-Point Construction Cost for USMC (Rounded)				106,970

10. Description of Proposed Construction:

DoD will be constructing a new secondary treatment plant which includes:

1. Two sewer interceptors
2. Head works: Fine screening and Grit chamber
3. Primary treatment: Three primary Clarifiers
4. Secondary treatment: Three trickling Filters and Three secondary Clarifiers
5. Solid Stabilization: Two Primary Anaerobic Digesters and One Secondary Anaerobic Digester
6. Solids Dewatering: Two Centrifuges and solids dewatering building
7. Disinfection: Two Chlorine Contact Tanks
8. Ocean Outfall

Table 6-12: Preliminary Construction Cost for Option 3 – Build a New Separate Secondary Treatment Plant at GovGuam NDWWTP site to Treat DoD Load Only

1. Component xxx	Guam Wastewater Utility Study		2. Date June 2008
3. Installation and Location Marine Relocation	4. Project Title Guam Wastewater Utility Study		
5. Program Element	6. Category Code	7. Project Number	8. Project Cost ($000) 168,590

9. COST ESTIMATES

Item	U/M	Quantity	Unit Cost	Cost ($000)
Headworks Expansion				
Reinforced Concrete	CY	400	$2,124	$850
Earthwork	CY	1400	$106	$149
Fine Screenings Equipment	EA	2	$238,938	$478
Grit Chamber Equipment	EA	2	$106,195	$212
Grit Pumps Equipment	EA	2	$58,407	$117
Grit Washer Equipment	EA	2	$185,841	$372
Miscellaneous Metals	LS	1	$108,850	$109
Frap Weirs	LS	1	$65,310	$65
Protective Coatings	LS	1	$176,814	$177
Piping and Valves	LS	1	$544,248	$544
Instrumentation/SCADA	LS	1	$152,389	$152
Electrical	LS	1	$326,549	$327
Grit & Screenings Building	LS	1	$761,947	$762
Primary Clarifier				
Reinforced Concrete	CY	1500	$2,124	$3,186
Earthwork	CY	2200	$106	$234
Sludge and Scum Collector Equipment	EA	3	$424,779	$1,274
Miscellaneous Metals	LS	1	$234,690	$235
Fro Weirs	LS	1	$140,814	$141
Protective Coatings	LS	1	$509,735	$510
Piping and Valves	LS	1	$140,814	$141
Instrumentation/SCADA	LS	1	$187,752	$188
Electrical	LS	1	$469,381	$469
Sludge Pump Station Improvements	LS	1	$2,346,903	$2,347
Trickling Filter Pumping Station				
Reinforced Concrete	CY	400	$2,124	$850
Earthwork	CY	1600	$106	$170
Trickling Filter Influent Pump Equipment	EA	3	$159,292	$478
Miscellaneous Metals	LS	1	$74,867	$75
Protective Coatings	LS	1	$334,513	$335
Piping and Valves	LS	1	$44,920	$45
Instrumentation/SCADA	LS	1	$104,814	$105
Electrical	LS	1	$224,602	$225
Trickling Filters				
Reinforced Concrete	CY	2700	$2,124	$5,735
Earthwork	CY	2400	$106	$255
Trickling Filter Plastic Media	CY	9000	$319	$2,867
Rotary Distribution Equipment	EA	3	$265,487	$796
Miscellaneous Metals	LS	1	$195,929	$196
FRP Weirs	LS	1	$117,558	$118
Protective Coatings	LS	1	$557,522	$558
Piping and Valves	LS	1	$274,301	$274
Instrumentation/SCADA	LS	1	$39,186	$39

Item	U/M	Quantity	Unit Cost	Cost ($000)
Secondary Clarifier				
Reinforced Concrete	CY	2400	$2,124	$5,097
Earthwork	CY	12900	$106	$1,370
Sludge and Scum Collector Equipment	EA	4	$557,522	$2,230
Miscellaneous Metals	LS	1	$434,867	$435
FRP Weirs	LS	1	$260,920	$261
Protective Coatings	LS	1	$892,035	$892
Piping and Valves	LS	1	$260,920	$261
Instrumentation/SCADA	LS	1	$347,894	$348
Electrical	LS	1	$869,735	$870
New Sludge Pump Station	LS	1	$1,478,549	$1,479
Secondary Clarifier				
Chlorine Contact Tank				
Reinforced Concrete	CY	1200	$2,124	$2,549
Earthwork	CY	4400	$106	$467
Chemical Feed Mixing Equipment	LS	1	$318,584	$319
Miscellaneous Metals	LS	1	$166,726	$167
Weirs	LS	1	$100,035	$100
Protective Coatings	LS	1	$127,434	$127
Piping and Valves	LS	1	$100,035	$100
Instrumentation/SCADA	LS	1	$133,381	$133
Electrical	LS	1	$333,451	$333
Anaerobic Digesters				
Reinforced Concrete	CY	3000	$2,124	$6,372
Earthwork	CY	4200	$106	$446
Digester Mixing and Heating Equipment	EA	3	$2,123,894	$6,372
Miscellaneous Metals	LS	1	$791,363	$791
Roofing and Insulation	LS	1	$725,416	$725
Protective Coatings	LS	1	$1,978,407	$1,978
Piping and Valves	LS	1	$4,616,283	$4,616
Instrumentation/SCADA	LS	1	$923,257	$923
Electrical	LS	1	$1,978,407	$1,978
New Sludge Pump Station	LS	1	$6,594,690	$6,595
Solids Dewatering Building				
Reinforced Concrete	CY	1200	$2,124	$2,549
Earthwork	CY	3200	$106	$340
Masonry Interior Walls	LS	1	$375,504	$376
Miscellaneous Metals	LS	1	$346,619	$347
FRP Grating	LS	1	$86,655	$87
Roofing and Insulation	LS	1	$404,389	$404
Doors and Windows	LS	1	$72,212	$72
Protective Coatings	LS	1	$173,310	$173
Building Specialties	LS	1	$28,885	$29
Sludge Grinders	EA	2	$53,097	$106
Sludge Feed Pumps	EA	2	$66,372	$133
Polymer Feed System	EA	2	$238,938	$478
Polymer Feed Pumps	EA	2	$15,929	$32
Odor Control System	EA	1	$477,876	$478
Centrifuges -125 gpm	EA	2	$955,752	$1,912
Process Piping and Valves	LS	1	$519,929	$520
HVAC	LS	1	$433,274	$433
Plumbing	LS	1	$288,850	$289
Electrical	LS	1	$1,444,248	$1,444
Influent and Effluent Samplers				
Automatic Samplers	EA	2	$79,646	$159
Site Work and Utilities				
Paving, Grading, and Yard Piping	LS	1	$5,972,742	$5,973

Item	U/M	Quantity	Unit Cost	Cost ($000)
Sewer Interceptor I, 24"D	FT	33300	$558	$18,565
Sewer Interceptor II, 30"D	FT	13500	$664	$8,960
Outfall Diffusers Expansion	FT	400		$621
Treatment Cost				$91,298
Sewer Cost				$28,147
Sub Total				119,444
Project Services 35.00%				41,806
Total Contract Cost				161,250
Total Request				161,250
Total Request (Rounded)				161,250
Total Escalated 2010 Request Rounded)				168,590
Total Escalated 2013 Mid-Point Construction Cost (Rounded)				179,080
Total Request for USMC (Rounded)				90,100
Total Escalated 2010 Request for USMC (Rounded)				94,200
Total Escalated 2013 Mid-Point Construction Cost for USMC (Rounded)				100,070

10. Description of Proposed Construction:

DoD will be constructing a new secondary treatment plant which includes

1. Two sewer interceptors
2. Head works: Fine screening and Grit chamber
3. Primary treatment: Three primary Clarifiers
4. Secondary treatment: Three trickling Filters and Three secondary Clarifiers
5. Solid Stabilization: Two Primary Anaerobic Digesters and One Secondary Anaerobic Digester
6. Solids Dewatering: Two Centrifuges and solids dewatering building
7. Disinfection: Two Chlorine Contact Tanks
8. Ocean Outfall Capacity Expansion

Table 6-13: Life Cycle Cost Comparison of Wastewater Treatment Options

Item	Description	Option 1a: Expand & Upgrade NDWWTP Primary Treatment	Option 1b: Expand & Upgrade NDWWTP to Secondary Treatment	Option 2: DoD Secondary Treatment on DoD Land	Option 3: Separate Secondary Treatment at NDWWTP Site to Treat DoD Load Only
A.	**Estimated Capital Cost**				
1	Headworks	$1,529,000	$1,529,000	$4,313,000	$4,313,000
2	Primary Clarifiers	$6,465,000	$6,465,000	$8,724,000	$8,724,000
3	Pumping Stations	-	$2,759,000	$2,281,000	$2,281,000
4	Trickling Filters	-	$26,783,000	$10,994,000	$10,994,000
5	Secondary Clarifiers	-	$34,728,000	$13,242,000	$13,242,000
6	Chlorine Contact Tanks	$2,596,000	$2,596,000	$4,296,000	$4,296,000
7	Anaerobic Digesters	$10,266,000	$30,797,000	$30,797,000	$30,797,000
8	Sludge Thickening & Dewatering System	$11,214,000	$11,214,000	$10,518,000	$10,518,000
9	Influent & Effluent Samplers	$159,000	$159,000	$159,000	$159,000
10	Site Work & Utilities	$2,256,000	$8,192,000	$5,973,000	$5,973,000
11	Sewer Interceptors	$4,181,000	$4,181,000	$24,340,000	$27,526,000
12	Effluent Transmission Line	-	-	$3,319,000	-
13	Ocean Out Fall & Piping	$621,000	$621,000	$8,729,000	$621,000
14	Project Services	$13,751,000	$45,509,000	$44,690,000	$41,806,000
	TOTAL	**$53,038,000**	**$175,533,000**	**$172,375,000**	**$161,250,000**
B.	**Estimated Annual O&M Cost**				
1	Labor & Benefits	$45,000	$135,000	$465,000	$465,000
2	Chemicals	$216,000	$201,000	$62,000	$62,000
3	Collection	$1,000	$1,000	$8,000	$9,000
4	Contract Services	$261,000	$622,000	$260,000	$260,000
5	Maintenance	$53,000	$200,000	$251,000	$251,000
6	Utilities	$193,000	$1,930,000	$494,000	$494,000
	TOTAL	**$769,000**	**$3,089,000**	**$1,540,000**	**$1,541,000**
C.	**Annual Costs**				
1	Amortized Capital Cost	$3,903,000	$12,916,000	$12,684,000	$11,865,000
2	Estimated Annual O&M Cost	$769,000	$3,089,000	$1,540,000	$1,541,000
	TOTAL	**$4,672,000**	**$16,005,000**	**$14,224,000**	**$13,406,000**

Table 6-14: Capital Cost Allocations between USMC and Other Relevant DoD Units

Cost Allocation	Option 1A: Expand & Upgrade NDWWTP Primary Treatment	Option 1B: Expand & Upgrade NDWWTP to Secondary Treatment	Option 2: DoD Secondary Treatment on DoD Land	Option 3: Separate Secondary Treatment at NDWWTP Site to Treat DoD Load Only
GWA	$12,436,000	$88,702,000	—	—
USMC	$31,692,000	$62,408,000	$96,317,000	$90,101,000
Other DoD Units	$8,910,000	$24,425,000	$76,058,000	$71,149,000
Total Cost	**$53,038,000**	**$175,535,000**	**$172,375,000**	**$161,250,000**

Table 6-15: Annual O&M Cost and Cost Distribution between GWA and DoD for Option 1A– Expand and Upgrade Existing Primary Treatment System at the GovGuam NDWWTP to Accept the Additional Flow and Load

Cost Categories	Quantity	O& M Cost	GWA's O&M Cost Share	DoD's O&M Cost Share
Labor & Benefits	LS	$45,000	$33,000	$12,000
Chemicals	LS	$216,000	$161,000	$55,000
Collection	LS	$1,000	—	$1000
Contract Services	LS	$261,000	$194,000	$67,000
Maintenance	LS	$53,000	$39,000	$14,000
Utilities	LS	$193,000	$144,000	$49,000
Total Annual Operation Cost		$769,000	$571,000	$198,000

Table 6-16: Annual O&M Cost and Cost Distribution between GWA and DoD for Option 1B– Expand and Upgrade the GovGuam NDWWTP to Secondary Treatment

Cost Categories	Quantity	O& M Cost	GWA's O&M Cost Share	DoD's O&M Cost Share
Labor & Benefits	LS	$135,000	$100,000	$35,000
Chemicals	LS	$201,000	$150,000	$51,000
Collection	LS	$1,000	-	$1000
Contract Services	LS	$622,000	$463,000	$159,000
Maintenance	LS	$200,000	$149,000	$51,000
Utilities	LS	$1,930,000	$1,436,000	$494,000
Total Annual Operation Cost		**$3,089,000**	**$2,298,000**	**$791,000**

7. Recommended Wastewater Treatment Alternative

Based on the cost analysis discussed in Section 6, the total present capital costs and annual life cycle costs of the four viable alternatives are presented in Table 7-1.

Table 7-1: Cost Summary of Viable Alternatives

Option:	Option 1A: Expand & Upgrade NDWWTP Primary Treatment	Option 1B: Expand & Upgrade NDWWTP to Secondary Treatment	Option 2: DoD Secondary Treatment on DoD Land	Option 3: Separate Secondary Treatment at NDWWTP Site to Treat DoD Load Only
Capital Costs				
Total Capital Cost	$53,038,000	$175,533,000	$172,375,000	$161,250,000
Amortized Capital Cost	$3,903,000	$12,916,000	$12,684,000	$11,865,000
O&M Costs				
Total Annual Cost	$769,000	$3,089,000	$1,540,000	$1,541,000
Annual Life Cycle Costs	$4,672,000	$16,005,000	$14,224,000	$13,406,000
USMC Capital Cost	*$31,692,000*	*$62,408,000*	*$96,317,000*	*$90,101,000*

Both the annual life cycle cost of $4,672,000, including amortized construction cost and estimated annual O&M cost, and total construction cost of $53,038,000 for Option 1A – Expand and upgrade existing primary treatment system at GovGuam NDWWTP to accept the additional flow and load, are the lowest compared to other three alternatives. The USMC's capital cost share ($31,692,000) based on wastewater flow contribution is also the lowest for Option 1A. However, we recommend a secondary treatment alternative because the EPA Region 9 indicated that the increased discharge from DoD activities in the Northern Guam region would have an impact on the existing NPDES permit requirements, water quality standards, and NPDES requirements for current and any future effluent discharge would be based on EPA secondary treatment technology based requirements. Among the three secondary treatment alternatives, Option 3 – Build New Separate Secondary Treatment Plant at GovGuam NDWWTP Site to treat DoD only has lowest capital cost ($161,250,000) and annual life cycle cost ($13,406,000). Based on capital cost allocations, Option 1B – Expand and Upgrade the GovGuam NDWWTP to secondary treatment options is beneficial to Navy as USMC share will be $62,408,000. However, in this option GWA share will be $88,702,000 and GWA does not want to upgrade the treatment plant to secondary as it will increase the sewer charges and puts hardship on Northern Guam civilian population. Hence GWA would like to operate the plant under 301(h) waiver and may upgrade the NDWWTP to secondary treatment within its current planning horizon of 20 years. Earth Tech team feels that the DoD should consider building a new separate secondary treatment plant at GovGuam NDWWTP Site to treat DoD load only. The study and recommended alternatives work for the assumed military buildup population loading concentrated at the Finegayan area, and that significant population shifts to other locations will require further analysis to identify the further collection system, and treatment plant requirements and associated construction cost.

7.1 Description of Recommended Alternative

In this alternative, a separate secondary treatment train will be built at NDWWTP facility to treat DoD loads only. The secondary treatment train will include facilities to enhance removal of biodegradable organic matters (in solution or suspension) and suspended solids found in wastewater. Figure 7-1 shows the schematic process diagram of the recommended alternative. The following new process components and expansion are required at the NDWWTP site for this alternative:

- Headworks (two screens and two aerated grit chambers with odor control)
- Three primary clarifiers
- Three trickling filters
- Three secondary clarifiers
- Two chlorine contact tanks
- Three anaerobic digesters
- Two centrifuge solids dewatering systems with odor control
- Effluent monitoring and measurement
- Outfall diffuser capacity expansion

The detail sizes of new process components and upgrades required at a new secondary treatment plant at NDWWTP site to treat DoD load only are listed in Table 7-2.

Table 7-2: Components for Constructing Separate Secondary Treatment Plant at GovGuam NDWWTP to Treat DoD Load Only

Construction Components	Unit	Dimensions/Description
Headwork	1	Two mechanical fine screens and Two (2) aerated grit chambers, each 45 ft long x 12 ft wide x 7 ft SWD
Primary clarifier	3	60 ft diameter x 10 ft SWD
Trickling filter pumping station	1	40 ft long x 25 ft wide x 16 ft high
Trickling filter	3	65 ft diameter x 24 ft SWD
Secondary clarifier	3	80 ft diameter x 13 ft SWD
Chlorine contact tank	2	55 ft long x 25 ft wide x 14 ft SWD
Effluent measurement	1	Automatic sampler
Ocean outfall capacity expansion	1	Multiport diffusers
Anaerobic digesters	3	80 ft diameter x 18 ft SWD
Solids dewatering centrifuges	2	125 gpm each

7.2 DESCRIPTION OF COLLECTION SYSTEM MODIFICATIONS

An independent sewage interceptor to collect wastewater generated from military activities both at the AAFB and the Finegayan areas is required for this alternative. The interceptor connects the AAFB collection system at its main gate lift station and runs along Route 3, then combines the flow from Finegayan generated by the USMC and Army to the new DoD constructed secondary treatment plant at the NDWWTP site (as shown on Figure 6-6). The interceptor prior to the connection of NCTS Finegayan is designed to have a capacity for 3.72 mgd peak flow, and the subsequent section of the interceptor all the way to the new treatment facility is required to have a capacity of 10.92 mgd.

As shown on Figure 6-6, 33,300 feet of 24-inch sewer and 12,600 feet of 30-inch sewer are required to convey flow from AAFB and Finegayan to the new DoD-constructed plant at the NDWWTP site. The normal process of acquiring a sewer easement is required where necessary. The U.S. Government and Government of Japan shall determine who is responsible for obtaining the easements.

7.3 PRELIMINARY CONSTRUCTION COST

The estimated project cost for constructing a new separate secondary treatment facility at the NDWWTP site to treat DoD load only is $161,250,000. A summary of preliminary project cost for the recommended alternative is shown in Table 7-3.

Table 7-3: Preliminary Construction Cost for Recommended Alternative– Build New Separate Secondary Treatment Plant at GovGuam NDWWTP Site to Treat DoD Load Only

Construction Categories	Cost Opinion
Headwork Expansion	$4,313,000
Primary Clarifier Expansion	$8,724,000
Pumping Station	$2,281,000
Trickling Filters	$10,994,000
Secondary Clarifiers	$13,242,000
Chlorine Contact Tanks	$4,296,000
Anaerobic Digesters	$30,797,000
Influent and Effluent Samplers	$159,000
Solids Dewatering Building	$10,518,000
Site Work and Utilities	$5,973,000
Relief Sewer	$27,525,000
Outfall Diffuser Capacity Expansion	$621,000
TREATMENT SUBTOTAL COST	$91,298,000
SEWER SUBTOTAL COST	$28,147,000
TOTAL COST	$119,444,000
PROJECT SERVICES	$41,806,000
TOTAL ESTIMATED COST	$161,250,000
TOTAL ESTIMATED PROJECT COST (ROUNDED)	**$161,250,000**
TOTAL ESTIMATED PROJECT COST FOR USMC	**$90,101,000**

7.4 PRELIMINARY CONSTRUCTION SCHEDULE

Earth Tech anticipates that for Option 3, constructing secondary treatment and expanding existing outfall capacity would require about 12 to 18 months to design, 5 to 6 months to bid and award, and 25 to 30 months to construct the wastewater collection and treatment facilities. We assumed that the wastewater treatment regulatory agency permitting work will be done concurrently with the design. Therefore, a total time required is 3.5 to 4.5 years. The schedule may be compressed by 6 months to one year if "design build" or "fast track" construction methodologies are used.

7.5 OTHER VIABLE ALTERNATIVES IN THE ORDER OF PREFERENCE

A brief summary of the other three viable alternatives in the order of preference is presented below:

7.5.1 Option 1B – Expand and Upgrade GovGuam NDWWTP to Secondary Treatment

In this alternative the NDWWTP will be upgraded to include secondary treatment facilities to enhance removal of biodegradable organic matters (in solution or suspension) and suspended solids found in wastewater. The following new process components and upgrades are required at the NDWWTP for this alternative:

- Headworks expansion and odor control
- One primary clarifier (same size as existing ones)

- Three trickling filters
- Four secondary clarifiers
- One chlorine contact tank
- Three anaerobic digesters (same size as existing ones)
- Two centrifuge solids dewatering systems and odor control
- Effluent monitoring and measurement expansion
- Outfall diffuser capacity expansion

A summary of the new process components and upgrades required at the NDW WTP for expanding and upgrading to secondary treatment are listed in Table 7-4.

Table 7-4: Major Process Components for Expanding and Upgrading GovGuam NDWWTP to Secondary Treatment

Construction Components	Expand (E)/Upgrade (U)/NEW (N)	Unit	Dimensions/Description
Headworks	U/N	2	Two fine screens
Primary clarifier	N	1	130 ft diameter x 7 ft SWD
Trickling filter pumping station	N	1	40 ft long x 25 ft wide x 16 ft high
Trickling filter	N	3	120 ft diameter x 24 ft SWD
Secondary clarifier	N	4	125 ft diameter x 16 ft SWD
Chlorine contact tank	N	1	70 ft x 40 ft x 14 SWD
Effluent measurement	E	1	Automatic sampler
Odor control system	N	1	Locate at Headworks and Solids Dewatering
Anaerobic digester	U N	2 3	80 ft diameter x 18 ft SWD 80 ft diameter x 18 ft SWD
Solids dewatering centrifuges	N	2	225 gpm each
Outfall capacity expansion	N	1	400 ft long multiport diffusers

A new gravity 24-inch, 7,500-foot relief sewer will be constructed to convey flow from the USMC Finegayan area to the headworks of the NDWWTP. The outfall diffuser needs to be expanded to discharge additional peak flows.

A summary of preliminary construction cost of this alternative is shown in Table 7-5.

Table 7-5: Preliminary Construction Cost for Viable Alternative– Expand and Upgrade GovGuam NDWWTP to Secondary Treatment

Construction Categories	Cost Opinion
Headwork	$1,529,000
Primary Clarifiers	$6,465,000
Pumping Station	$2,759,000
Trickling Filters	$26,783,000
Secondary Clarifiers	$34,728,000
Chlorine Contact Tanks	$2,596,000
Anaerobic Digesters	$30,797,000
Influent and Effluent Samplers	$159,000
Solids Dewatering Building	$11,214,000

Construction Categories	Cost Opinion
Site Work and Utilities	$8,192,000
Sewer Interceptors	$4,181,000
Ocean Outfall & Piping	$621,000
TREATMENT SUBTOTAL COST	$125,223,000
SEWER SUBTOTAL COST	$4,802,000
TOTAL COST	$130,026,000
PROJECT SERVICES	$45,509,000
TOTAL ESTIMATED PROJECT COST	$175,535,000
TOTAL ESTIMATED PROJECT COST (ROUNDED)	**$175,540,000**
TOTAL ESTIMATED PROJECT COST FOR USMC	**$62,408,000**

7.5.2 Option 2 – Build New Secondary Treatment Plant Near the Proposed Development on DoD Land and Construct New Outfall

This alternative considers construction of a secondary treatment plant that will be owned and operated by DoD. A newly constructed independent sewer main is required to convey all military generated wastewater in the Northern Guam region to a DoD secondary treatment plant near the proposed USMC Finegayan development on DoD land.

The following new process components are required for this alternative:

- Headworks (two screens and two aerated grit chambers with odor control)
- Three primary clarifiers
- Three trickling filters
- Three secondary clarifiers
- Two chlorine contact tanks
- Three anaerobic digesters
- Two centrifuge solids dewatering systems with odor control
- Effluent monitoring and measurement
- Ocean outfall

A summary of the major process components for building a new secondary treatment plant near the proposed development on DoD land and constructing new outfall are listed in Table 7-6.

Table 7-6: Major Process Components for Building New Secondary Treatment Plant Near the Proposed Development on DoD Land and Constructing New Outfall

Construction Components	Unit	Dimensions/Description
Headwork	1	Two mechanical fine screens and Two (2) aerated grit chambers, each 45 ft long x 12 ft wide x 7 ft SWD
Primary clarifier	3	60 ft diameter x 10 ft SWD
Trickling filter pumping station	1	40 ft long x 25 ft wide x 16 ft high
Trickling filter	3	65 ft diameter x 24 ft SWD
Secondary clarifier	3	80 ft diameter x 13 ft SWD
Chlorine contact tank	2	55 ft long x 25 ft wide x 14 SWD

Construction Components	Unit	Dimensions/Description
Effluent measurement	1	Automatic sampler
Ocean outfall & effluent transmission piping	1	30 in diameter, 7,400 ft long
Anaerobic digesters	3	80 ft diameter x 18 ft SWD
Solids dewatering centrifuges	2	125 gpm each

A new 24-inch, 33,300-foot sewer and 30-inch, 8,700-foot sewer will be constructed to convey flow from the AAFB and the Finegayan areas to the new DoD plant. This option will also require construction of 5,000 feet of 30-inch effluent transmission line and 2,400 feet of 30-inch outfall to discharge effluent to the Philippine Sea.

A summary of preliminary construction cost of this alternative is shown in Table 7-7.

Table 7-7: Preliminary Construction Cost for Viable Alternative – Build New Secondary Treatment Plant Near the Proposed Development on DoD Land and Construct New Outfall

Construction Categories	Cost Opinion
Headwork	$4,313,000
Primary Clarifiers	$8,724,000
Pumping Station	$2,281,000
Trickling Filters	$10,994,000
Secondary Clarifiers	$13,242,000
Chlorine Contact Tanks	$4,296,000
Anaerobic Digesters	$30,797,000
Influent and Effluent Samplers	$159,000
Solids Dewatering Building	$10,518,000
Site Work and Utilities	$5,973,000
Sewer Interceptors	$24,339,000
Ocean Outfall & Piping	$12,048,000
TREATMENT SUBTOTAL COST	$91,298,000
SEWER SUBTOTAL COST	$36,388,000
TOTAL COST	$127,685,000
PROJECT SERVICES	$44,690,000
TOTAL ESTIMATED PROJECT COST	$172,375,000
TOTAL ESTIMATED PROJECT COST (ROUNDED)	**$172,380,000**
TOTAL ESTIMATED PROJECT COST FOR USMC	**$96,317,000**

7.5.3 Option 1A – Expand and Upgrade Existing Primary Treatment System at the GovGuam NDWWTP to Accept the Additional Flow and Load

This alternative will expand and upgrade the existing primary treatment facilities at the NDWWTP to accept the additional wastewater from USMC relocation and other future military build up in the Northern Guam region. The NDWWTP will have to add the following new process capacities to meet the requirement:

- Headworks expansion with odor control
- One primary clarifier (same size as existing ones)
- One anaerobic digester (same size as existing ones)

- Two centrifuge solids dewatering systems with odor control
- One chlorine contact tank (same size as existing ones)
- Effluent monitoring upgrade
- Outfall diffuser capacity expansion

The preliminary sizes of the NDWWTP expansion facilities are listed in Table 7-8.

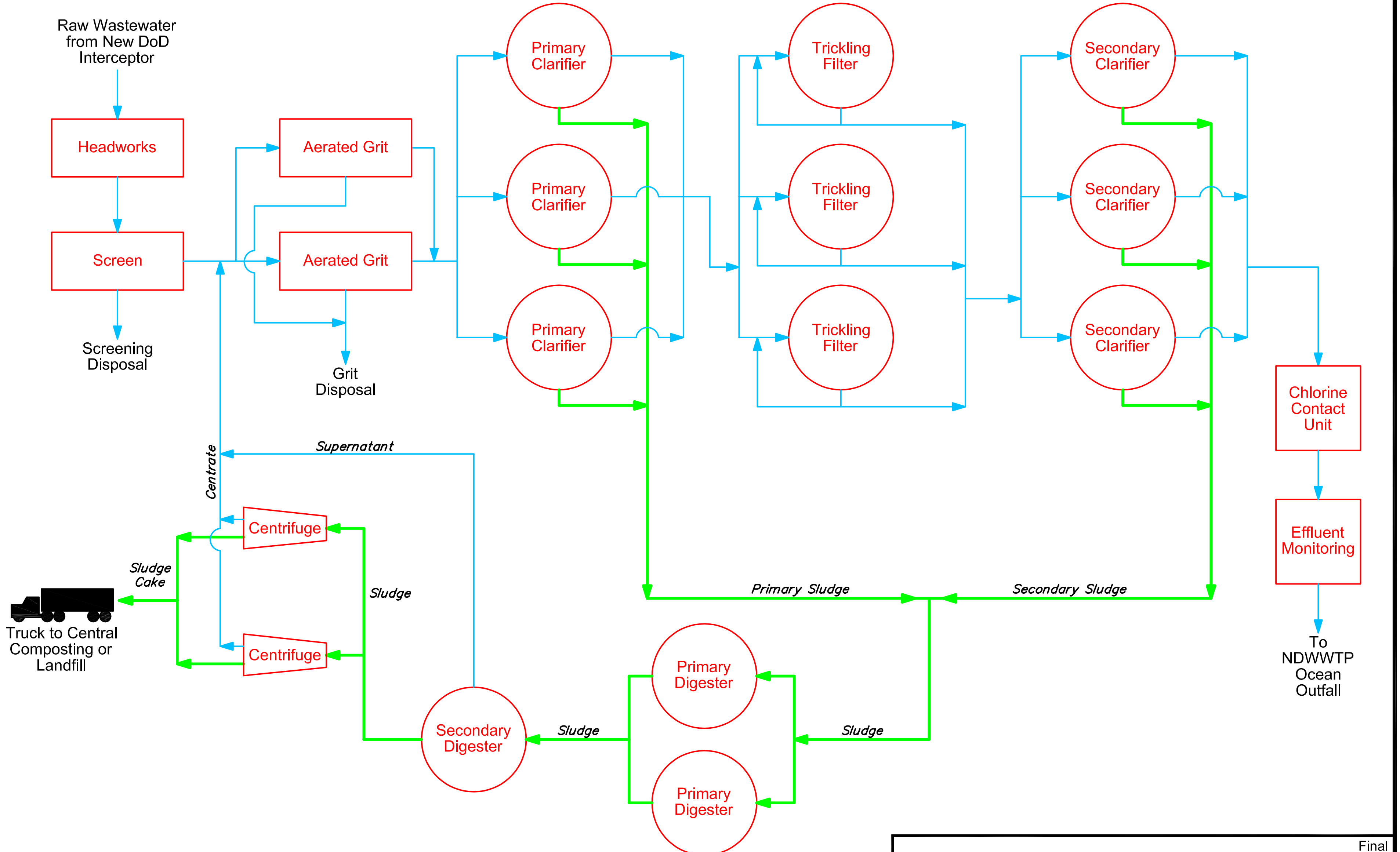
Table 7-8: Major Components for Expanding and Upgrading Existing Primary Treatment System at the NDWWTP to Accept the Additional Flow and Load

Construction Components	Expand (E)/ Upgrade (U)/ NEW (N)	Unit	Dimensions/Description
Headworks	U/N	2	Two fine screens
Primary clarifier	N	1	130 ft diameter x 7 ft SWD
Chlorine contact tank	N	1	70 ft x 40 ft x 14 ft SWD
Effluent measurement	U		Automatic sampler
Odor control system	N	1	Locate at Headworks and Solids Handling
Anaerobic digester	U N	2 1	80 ft diameter x 18 ft SWD 80 ft diameter x 18 ft SWD
Solids dewatering centrifuges	N	2	225 gpm each
Outfall capacity expansion	N	1	400 ft long multiport diffusers

A new gravity 24 inch, 7,500 foot relief sewer will be constructed to convey flow from the USMC Finegayan area to the headworks of the NDWWTP. The outfall diffuser needs to be expanded to discharge peak flows. A summary of preliminary construction cost of this alternative is shown in Table 7-9.

Table 7-9: Preliminary Construction Cost for Viable Alternative – Expand and Upgrade Existing Primary Treatment System at the GovGuam NDWWTP to Accept the Additional Flow and Load

Construction Categories	Cost Opinion
Headwork Expansion	$1,529,000
Primary Clarifier Expansion	$6,465,000
Chlorine Contact Tanks	$2,596,000
Anaerobic Digesters	$10,266,000
Influent and Effluent Samplers	$159,000
Solids Dewatering Building	$11,214,000
Site Work and Utilities	$2,256,000
Relief Sewer	$4,181,000
Outfall Diffuser Capacity Expansion	$621,000
TREATMENT SUBTOTAL COST	$34,486,000
SEWER SUBTOTAL COST	$4,802,000
TOTAL COST	$39,288,000
PROJECT SERVICES	$13,751,000
TOTAL ESTIMATED COST	$53,039,000
TOTAL ESTIMATED PROJECT COST (ROUNDED)	**$53,040,000**
TOTAL ESTIMATED PROJECT COST FOR USMC	**$31,692,000**



LEGEND

- Existing Liquid Stream
- Proposed Liquid Stream
- Existing Solid Stream
- Proposed Solid Stream

Final

Option 3:
Build New DoD Secondary Treatment Facility at NDWWTP Site to Treat DoD Load Only

Date: 6-08	Guam Wastewater Study	Figure
Project No. 101177	EarthTech	7-1

8. References

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Appendix A
List of Facilities to Support Operational and Training Requirements for Marine Relocation

Borry

DEPARTMENT OF THE NAVY
HEADQUARTERS UNITED STATES MARINE CORPS
3000 MARINE CORPS PENTAGON
WASHINGTON, DC 20350-3000

IN REPLY REFER TO:
11000
LFL
SEP 14 2006

MEMORANDUM FOR ASSISTANT SECRETARY OF THE NAVY (INSTALLATIONS AND ENVIRONMENT)

Subj: REQUIREMENTS FOR NATIONAL ENVIRONMENTAL POLICY ACT (NEPA) ANAYLSIS OF MARINE CORPS RELOCATION FROM OKINAWA TO GUAM

Ref: (a) ASN (I&E) memo of 17 Aug 06

Encl: (1) Personnel and Units Identified for Relocation
(2) Facilities to Support Operational and Training Requirements
(3) Facilities to Support Quality of Life and Housing Requirements
(4) Training Range Requirements and Land Use Issues
(5) Development Costs

1. As requested in the reference, enclosures (1) through (4) provide estimated requirements for the 1 May 2006 Agreed Implementation Plan laydown of Marines and dependents relocating from Okinawa to Guam. The relocation effort is estimated to cost $10.27 B as outlined in enclosure (5).

2. This detail provides a solid foundation for the required National Environmental Policy Act (NEPA) analysis. However, it should be noted that as we further refine our requirements analysis, changes are inevitable. Therefore, we recommend that the NEPA analysis scope be flexible enough to support changes as they are approved. The elements normally addressed within a NEPA analysis such as environmental and socio-economic impacts should cover all relevant issues.

3. The Marine Corps looks forward to providing our input on the NEPA analysis scope of work and are also available to assist the Naval Facilities Engineering Command in its development if desired.

R. Magnus

R. MAGNUS
Assistant Commandant
of the Marine Corps

PERSONNEL AND UNITS IDENTIFIED FOR RELOCATION

Under the 1 May Agreed Implementation Plans (AIPs), the following units will be relocated to Guam:

I. Command Element (3,046 PN)
- III Marine Expeditionary Force (MEF) Command Element and MEF Headquarters Group (MHG)
- 7th Communications Battalion
- 3d Intelligence Battalion
- III Material Handling Group (MHG)
- The MEF Band
- 5th Air Naval Gunfire Liaison Company (ANGLICO)
- Force Reconnaissance elements
- Marines assigned to the Joint Base

II. Ground Combat Element (1,100 PN)
- 3d Marine Division Headquarters
- HQ Battalion
- 12 Marine Artillery Regiment Headquarters

III. Aviation Combat Element (1,856 PN)
- 1st Marine Aircraft Wing Headquarters
- Marine Wing Headquarters Squadron-1
- Helicopter Marine Heavy (HMH) Squadron
- Marine Air Control Group (MACG) -18 HQ
- Marine Wing Communications Squadron (MWCS)-18
- Marine Air Control Squadron(MACS)-4
- Marine Air Support Squadron(MASS)-2
- Marine Tactical Air Control Squadron (MTACS)-18
- 1st Stinger Battery
- Marine Wing Support Group (MWSG)-17 Headquarters
- Marine Wing Support Squadron (MWSS) detachment

IV. Combat Service Support (2,550 PN)
- 3rd Marine Logistics Group (MLG) Headquarters
- Combat Logistics Regiment Headquarters
- Communications (Comm) Co
- Military Police (MP) Co
- Food Service Co
- 3d Material Readiness Battalion (MRB) (-)
- 3d Medical Bn (-)

ENCLOSURE(1)

- 3d Medical Bn (-)
- 3d Dental Bn (-)
- 9th Engineer Support (ESB) Bn (-)
- Transportation Det
- Combat Logistics Regiment-3 Headquarters Company (Direct Support)
- Headquarters Company

Total Personnel: 8,552 PN
Dependents: 9,000 PN

V. Transients

- 1 Infantry Battalion (Approx 800 PN)
- 1 Artillery Battery (Approx 150 PN)
- 1 Aviation Squadron (Approx 250 PN)

Beyond the above transients, there will be visiting units from USMC, DoD, and Allied countries that will train at Bi-Lateral Training area.

FACILITIES TO SUPPORT OPERATIONAL AND TRAINING REQUIREMENTS

The assigned units will require operational, maintenance, and training spaces. Facilities requirements are provided in the table below:

Unit	FAC	Description	UM	Requirement
12 Marine HQ	1164	Miscellaneous Pavement	SY	500
12 Marine HQ	2141	Vehicle Maintenance Shop	SF	25,700
12 Marine HQ	2145	Vehicle Maintenance Facility	EA	8
12 Marine HQ	2152	Weapon Maintenance Shop, Depot	SF	11,900
12 Marine HQ	2171	Electronics & Comm Maintenance Shop	SF	28,900
12 Marine HQ	4421	Covered Storage Building, Installation	SF	25,900
12 Marine HQ	6100	General Administrative Building	SF	15,700
1st Stinger Bty	2141	Vehicle Maintenance Shop	SF	5,800
1st Stinger Bty	2171	Electronics & Comm Maintenance Shop	SF	2,600
1st Stinger Bty	4421	Covered Storage Building, Installation	SF	7,900
1st Stinger Bty	6100	General Administrative Building	SF	6,700
3D Mar Div HQ	2134	Marine Maintenance Support Facility	SF	5,700
3D Mar Div HQ	2141	Vehicle Maintenance Shop	SF	9,300
3D Mar Div HQ	2152	Weapon Maintenance Shop, Depot	SF	6,600
3D Mar Div HQ	6100	General Administrative Building	SF	73,500
ANGLICO	6100	General Administrative Building	SF	26,000
Arty Bn HQ	1164	Miscellaneous Pavement	SY	200
Arty Bn HQ	2141	Vehicle Maintenance Shop	SF	8,600
Arty Bn HQ	2145	Vehicle Maintenance Facility	EA	3
Arty Bn HQ	2152	Weapon Maintenance Shop, Depot	SF	4,000
Arty Bn HQ	2171	Electronics & Comm Maintenance Shop	SF	9,700
Arty Bn HQ	4421	Covered Storage Building, Installation	SF	8,700
Arty Bn HQ	6100	General Administrative Building	SF	5,300
Base Support	1164	Miscellaneous Pavement	SY	2,200
Base Support	1231	Vehicle Fueling Facility	OL	23
Base Support	1241	Operating Fuel Storage	GA	1,581,700
Base Support	1311	Communications Building	SF	38,300
Base Support	1441	Photo Building	SF	17,100
Base Support	1442	Operations Support Lab	SF	1,400
Base Support	1443	Operations Supply Building	SF	14,200
Base Support	1444	Misc. Operations Support Building	SF	1,500
Base Support	1444	Misc. Operations Support Building	SF	2,000
Base Support	1444	Misc. Operations Support Building	SF	2,400
Base Support	1498	Security Support Facility	SF	3,100
Base Support	2141	Vehicle Maintenance Shop	SF	126,700
Base Support	2145	Vehicle Maintenance Facility	EA	36
Base Support	2171	Electronics & Comm Maintenance Shop	SF	43,400
Base Support	2191	Facility Engineer Maintenance Shop	SF	266,000
Base Support	4211	Ammunition Storage, Depot & Arsenal	SF	5,600
Base Support	4421	Covered Storage Building, Installation	SF	945,200

Base Support	4427	Small Arms Storage, Installation	SF	17,700
Base Support	6100	General Administrative Building	SF	637,300
Base Support	7220	Dining Facility	SF	52,000
Base Support	7311	Fire Station Facility	SF	61,200
Base Support	7312	Prison/Confinement Facility	SF	73,000
Base Support	7313	Police Station	SF	65,200
Base Support	7344	Postal Facility	SF	49,900
Base Support	7351	Education Center	SF	69,700
Base Support	7352	Dependent School	SF	201,125
Base Support	7361	Religious Ministry Facilities	SF	94,100
Base Support	7421	Indoor Physical Fitness Facility	SF	90,469
Base Support	7431	Auditorium & Theater Facility	SF	55,700
Base Support	7512	Outdoor Swimming Pool	EA	5
Base Support	7522	Athletic Field	EA	12
Comm Bn	1164	Miscellaneous Pavement	SY	400
Comm Bn	1443	Operations Supply Building	SF	8,100
Comm Bn	1444	Misc. Operations Support Building	SF	1,600
Comm Bn	2141	Vehicle Maintenance Shop	SF	27,800
Comm Bn	2171	Electronics & Comm Maintenance Shop	SF	66,700
Comm Bn	4421	Covered Storage Building, Installation	SF	27,800
Comm Bn	4427	Small Arms Storage, Installation	SF	6,800
Comm Bn	6100	General Administrative Building	SF	48,200
Gen Sup Det	1164	Miscellaneous Pavement	SY	1,100
Gen Sup Det	1231	Vehicle Fueling Facility	OL	3
Gen Sup Det	1443	Operations Supply Building	SF	6,700
Gen Sup Det	1444	Misc. Operations Support Building	SF	16,600
Gen Sup Det	1444	Misc. Operations Support Building	SF	30,000
Gen Sup Det	2141	Vehicle Maintenance Shop	SF	266,800
Gen Sup Det	2145	Vehicle Maintenance Facility	EA	17
Gen Sup Det	2151	Weapon Maintenance Shop	SF	15,430
Gen Sup Det	2162	Ammunition Maintenance Shop, Depot	SF	5,000
Gen Sup Det	2171	Electronics & Comm Maintenance Shop	SF	33,300
Gen Sup Det	2182	Installation Support Equipment Maint Shop	SF	21,100
Gen Sup Det	2184	Parachute & Dingy Maintenance Shop	SF	27,500
Gen Sup Det	4121	Bulk Liquid Storage, Other Than Fuel	GA	1,000
Gen Sup Det	4211	Ammunition Storage, Depot & Arsenal	SF	74,300
Gen Sup Det	4251	Open Ammunition Storage	SY	2,400
Gen Sup Det	4421	Covered Storage Building, Installation	SF	922,200
Gen Sup Det	4427	Small Arms Storage, Installation	SF	22,400
Gen Sup Det	4521	Open Storage, Installation	SY	600
Gen Sup Det	6100	General Administrative Building	SF	116,400
Intel Bn	1164	Miscellaneous Pavement	SY	300
Intel Bn	1311	Communications Building	SF	8,400
Intel Bn	2171	Electronics & Comm Maintenance Shop	SF	3,100
Intel Bn	4421	Covered Storage Building, Installation	SF	7,000
Intel Bn	6100	General Administrative Building	SF	46,400
MACG-18 HQ	2141	Vehicle Maintenance Shop	SF	14,700

MACG-18 HQ	2171	Electronics & Comm Maintenance Shop	SF	2,400
MACG-18 HQ	4421	Covered Storage Building, Installation	SF	4,300
MACG-18 HQ	4427	Small Arms Storage, Installation	SF	6,400
MACG-18 HQ	6100	General Administrative Building	SF	12,100
MACS-4	2141	Vehicle Maintenance Shop	SF	5,700
MACS-4	2171	Electronics & Comm Maintenance Shop	SF	9,300
MACS-4	4421	Covered Storage Building, Installation	SF	21,600
MACS-4	6100	General Administrative Building	SF	12,500
MACS-4	8526	Miscellaneous Paved Area	SY	5,000
MASS-2	2171	Electronics & Comm Maintenance Shop	SF	14,400
MASS-2	4421	Covered Storage Building, Installation	SF	19,300
MASS-2	6100	General Administrative Building	SF	13,100
MEF CE	1311	Communications Building	SF	5,400
MEF CE	4421	Covered Storage Building, Installation	SF	26,900
MEF CE	6100	General Administrative Building	SF	97,000
MEF CE	8526	Miscellaneous Paved Area	SY	400
MHG	1443	Operations Supply Building	SF	6,500
MHG	2141	Vehicle Maintenance Shop	SF	29,000
MHG	4421	Covered Storage Building, Installation	SF	86,800
MHG	4427	Small Arms Storage, Installation	SF	6,400
MHG	6100	General Administrative Building	SF	55,900
MHG	8526	Miscellaneous Paved Area	SY	9,500
MLG HQ	2141	Vehicle Maintenance Shop	SF	293
MLG HQ	2171	Electronics & Comm Maintenance Shop	SF	300
MLG HQ	4421	Covered Storage Building, Installation	SF	2,400
MLG HQ	4427	Small Arms Storage, Installation	SF	400
MLG HQ	6100	General Administrative Building	SF	4,100
MTACS-18	1164	Miscellaneous Pavement	SY	1,300
MTACS-18	2171	Electronics & Comm Maintenance Shop	SF	800
MTACS-18	4421	Covered Storage Building, Installation	SF	16,300
MTACS-18	6100	General Administrative Building	SF	25,800
MWCS-18	2141	Vehicle Maintenance Shop	SF	21,600
MWCS-18	2171	Electronics & Comm Maintenance Shop	SF	9,500
MWCS-18	4421	Covered Storage Building, Installation	SF	22,200
MWCS-18	4427	Small Arms Storage, Installation	SF	600
MWCS-18	6100	General Administrative Building	SF	9,100
MWCS-18	8928	Loading Platform/Ramp	EA	1
MWHS-1	2171	Electronics & Comm Maintenance Shop	SF	15,000
MWHS-1	4421	Covered Storage Building, Installation	SF	21,900
MWHS-1	4427	Small Arms Storage, Installation	SF	600
MWHS-1	6100	General Administrative Building	SF	48,800
MWSG-17 HQ	6100	General Administrative Building	SF	12,800
MWSS	1241	Operating Fuel Storage	GA	2,500
MWSS	1444	Misc. Operations Support Building	SF	1,900
MWSS	2141	Vehicle Maintenance Shop	SF	3,500
MWSS	2145	Vehicle Maintenance Facility	EA	1
MWSS	2152	Weapon Maintenance Shop, Depot	SF	2,500
MWSS	2171	Electronics & Comm Maintenance Shop	SF	600

MWSS	4111	Bulk Liquid Fuel Storage	BL	1
MWSS	4421	Covered Storage Building, Installation	SF	15,100
MWSS	4427	Small Arms Storage, Installation	SF	400
MWSS	4521	Open Storage, Installation	SY	4,400
MWSS	6100	General Administrative Building	SF	4,200
Navy		AAV Access	LS	
Navy		Wharf Improvements	LS	
Navy		Lay down/ Staging	LS	
Navy		Navy Training	LS	
Navy		"Other Impacts"	LS	
Navy		Road/Transportation Improvements	LS	
Navy		Utilities	LS	
Navy		Contingency	LS	
Recon Co	2133	Marine Maintenance Shop	SF	9,600
Recon Co	2141	Vehicle Maintenance Shop	SF	2,000
Recon Co	2171	Electronics & Comm Maintenance Shop	SF	3,400
Recon Co	2182	Installation Support Equipment Maint Shop	SF	2,900
Recon Co	2184	Parachute & Dingy Maintenance Shop	SF	3,900
Recon Co	4421	Covered Storage Building, Installation	SF	1,400
Recon Co	4427	Small Arms Storage, Installation	SF	1,000
Recon Co	6100	General Administrative Building	SF	10,000
Trnst Arty Bty	2141	Vehicle Maintenance Shop	SF	14,300
Trnst Arty Bty	4421	Covered Storage Building, Installation	SF	3,600
Trnst Arty Bty	4427	Small Arms Storage, Installation	SF	11,600
Trnst Arty Bty	6100	General Administrative Building	SF	18,200
Trnst Inf Bn	2141	Vehicle Maintenance Shop	SF	4,400
Trnst Inf Bn	2171	Electronics & Comm Maintenance Shop	SF	5,000
Trnst Inf Bn	4421	Covered Storage Building, Installation	SF	13,000
Trnst Inf Bn	6100	General Administrative Building	SF	36,800

Training Building requirements:

3D Mar Div HQ	1711	General Purpose Instruction Building	SF	11,700
Base Support	1711	General Purpose Instruction Building	SF	38,500
Comm Bn	1711	General Purpose Instruction Building	SF	1,600
Gen Sup Det	1711	General Purpose Instruction Building	SF	3,300
Intel Bn	1711	General Purpose Instruction Building	SF	600
MACG-18 HQ	1711	General Purpose Instruction Building	SF	4,700
MHG	1711	General Purpose Instruction Building	SF	25,900
MWHS-1	1711	General Purpose Instruction Building	SF	6,500
12 Marine HQ	1712	Applied Instruction Building	SF	1,600
Arty Bn HQ	1712	Applied Instruction Building	SF	600
Band	1712	Applied Instruction Building	SF	18,100
MEF CE	1712	Applied Instruction Building	SF	37,400
Trnst Inf Bn	1712	Applied Instruction Building	SF	1,800
MACS-4	1721	Flight Simulator Facility	SF	1,700
MHG	1721	Flight Simulator Facility	SF	21,000
MLG HQ	1721	Flight Simulator Facility	SF	260

Base Support	1732	Training Aids Support Building	SF	36,600
Base Support	1790	Miscellaneous Training Facility	EA	26
Base Support	7431	Auditorium & Theater Facility	SF	29,300

Training Support near a Runway:

MLG HQ	1112	Rotary Wing Landing Area, Surfaced	SY	1,100
Helo Training Sup	1131	Aircraft Apron, Surfaced	SY	37,200
MACS-4	1412	Aviation Operations Building	SF	7,400
Helo Training Sup	1444	Misc. Ops Support Building (02 space in Hangar)	SF	12,000
Helo Training Sup	2111	Aircraft Maintenance Hangar	SF	53,600
Helo Training Sup	2112	Aircraft Maintenance Shop (01 space in Hangar)	SF	12,050
Helo Training Sup (HMH)	2111	Aircraft Maintenance Hangar	SF	53,600
Helo Training Sup (HMH)	1444	Misc. Ops Support Building (02 space in Hangar)	SF	12,000
Helo Training Sup (HMH)	2112	Aircraft Maintenance Shop (01 space in Hangar)	SF	12,050

Infrastructure to support above facilities, training, and all development will include new and expansion of existing utility systems, roads, and waste facilities. These improvements are included in the total construction at a scope to be determined upon completion of additional studies.

FACILITIES TO SUPPORT QUALITY OF LIFE AND HOUSING REQUIREMENTS

The following requirements will be necessary to support family housing on Guam:

Total housing negotiated at 44% of 8,000 = 3,520 units. The anticipated split is approximately:

2,958 Units Enlisted Housing
558 Units Officer Housing
4 Units General Officer Quarters
3,520 Units

Bachelor housing Requirements:

I. Permanent Party

- Approximately 3,400 Rooms Bachelor Housing (USMC 2x0)
- Approximately 400 Bachelor Officer Rooms (1+1 Enhanced)

II. Transient Quarters to accommodate:

- 1 Infantry Battalion (800 PN)
- 1 Artillery Battery (150 PN)
- 1 Helicopter Squadron w/ 250 PN
- Visiting Officer's Quarters (100 Rooms)
- Temporary Lodging Facility (TLF w/ 70 Rooms)

Quality of Life facilities include the following:

Base Support	7314	Community Counseling Center	SF	12,700
Base Support	7333	Open Mess & Club Facility	SF	77,800
Base Support	7346	Exchange Sales Facility	SF	135,330
Base Support	7346	Exchange Sales Facility	SF	12,930
Base Support	7346	Exchange Sales Facility	SF	20,000
Base Support	7371	Nursery & Child Care Facility	SF	61,000
Base Support	7372	Family-Services-Center	SF	8,753
Base Support	7385	Public Restroom/Shower	SF	39,800
Base Support	7411	Hobby & Craft Center	SF	25,500
Base Support	7412	Automobile Craft Center	SF	33,800
Base Support	7415	Bowling Center	SF	70,200
Base Support	7416	Library	SF	55,400
Base Support	7417	Recreation Center	SF	31,200
Base Support	7417	Recreation Center	SF	32,200
Base Support	7441	Transient Lodging	SF	93,000
Base Support	7447	Miscellaneous MWR Facility	SF	30,300
Base Support	7447	Miscellaneous MWR Facility	SF	2,900
Base Support	7521	Outdoor Playing Courts	EA	42

TRAINING RANGE REQUIREMENTS AND LAND USE ISSUES

Training Requirements on Guam:

Planned Training - Facility Use	Notional location	Frequency of Use	Area Required (Size)	Land Use Issues
Guam (Notional)				
Individual combat skills (Gas chamber, land nav, survival skills, MCMAP, first aid, obstacle course, repelling course, leadership reaction course, etc.)	NCTS Finegayan	Daily, monthly, quarterly, per exercise	20 acres	Facilities, Environmental, Real Estate, Bird Migration
Small arms (9MM, M-16, 240G, 0.50 Cal, M203)	NCTS Finegayan	Daily	2 KD Small Arms ranges at 50 Firing points ea, Pistol Range at 30 Firing Points, MG range. SDZ includes over-water areas.	Facilities, Environmental, Real Estate, Bird Migration. Protection of SDZ may require closing shore and water areas during firing, by base security personnel.
Communications	NCTS Finegayan	Weekly	1 acre tract	None
Small unit patrolling and maneuver	Guam/NAV MAG	Weekly	20 acres	Environmental, Real Estate, Bird Migration
Crew Served Weapons (240G, .50 Cal)	Guam/NAV MAG	Monthly	20 acres	Clear range
MOUT	Andersen South	Quarterly	5 City blocks with roads	None
Convoy Ops	Andersen South	Monthly	7 Mile road march	Environmental mitigation
Demolition Ops	Finegayan/ Andersen South	Monthly	30ft x 30ft (bldg); range 150ft max depth of water, 400ft x 400ft	Environmental, Real Estate, Bird Migration
Equipment Operator Training/Practice	Guam	Daily	30ft x 30ft pad	None
Obstacles/Breaching	Guam	Daily	15ft x 15ft block house	None

ENCLOSURE(4)

Bridging	Guam for small bridging	Quarterly	40ft x 40ft	None
Landing beach	Guam	Quarterly	100m x 500m beach front	None
NSWU-1 CQC/Breacher House	Existing Breacher House	Weekly	On site of existing Breacher House	None

Potential Off-Island Training Requirements:

Planned Training - Facility Use	Notional location	Frequency of Use	Area Required (Size)	Land Use Issues
Tinian (Notional)				
Maneuver and tactical ops (Bn size)	Northern 2/3 of Island	Weekly	15 – 20 Sq Mi maneuver range	**Environmental issue:** NEPA applies; coral reef will require mitigation, sea turtles will require mitigation, potential archeological sites, Micronesian Megapod and Tinian Monarch may be issues, endangered wetland, R/W is Nat Historical Landmark; will be quarantine issues. **Land Issues:** Upper 2/3 of island leased from CNMI by DOD; can't buy land, have to lease from CNMI or private citizens of CNMI;
Mechanized ground (tanks, AAV/EFV)	Northern 2/3 of Island	Weekly	15 – 20 Sq Mi maneuver range	

ENCLOSURE(4)

				Other issues: Water is brackish therefore may need water treatment; power needs upgrading; airport expansion is in the works; port facilities lacking; UXO cleanup will be required.
Aguian (Notional)				
Artillery Live fire	Tinian to Goat Island	Monthly	25 Sq Mi impact area with clear live fire zones	**Aguijan**: Several environ issues; Megapods, fruit bats, swiftlets, migratory seabirds. Current enviro mitigation in progress removing goats that damage foliage birds like. **Legal/land**: Tinian Mayor controls Aguijan. Concerned entities will be CNMI, Tinian Mayor, Dept of Public lands and Federal Agencies, therefore may have to negotiate with several offices. **Additional Notes**: Will require UXO clean up; people on Tinian use Aguijan to hunt; Expect this issue to be politically and environmentally challenging.
Saipan (Notional)				
MOUT facility	Saipan	Monthly	5 city blocks	None
Aviation landing practice including NVG	Suitable expedition airfield	Daily when aviation squadrons onboard	8,000 ft airstrip	No major environmental issues. More populated. May be open to economic benefits. Infrastructure not well maintained.

FDM (Notional)				
Inert ordnance	Scored Air-Ground Target	Weekly when aviation squadrons onboard	2 acres	None
EW (portable) staging site	Northern "No-Drop" Zone	Quarterly	30ft x 30ft pad	None

SARIGAN (Notional)				
EW (portable) staging site	TBD	Quarterly	30ft x 30ft pad	None
"No Drop" Air-to-Ground range	Sarigan	Daily when aviation squadrons onboard	Navy RCD specifies two 20x20 nm land areas; airspace surface to 50,000 feet	None
Rota (Notional)				
Aviation landing practice including NVG	Suitable airfield	Daily when aviation squadrons onboard	8,000 ft strip	No significant environmental issues. May be noise issues since more highly populated. Infrastructure not well maintained.
PAGAN (Notional)				
EW (portable) staging site	Andersen, Northwest Field	Quarterly	30ft x 30ft pad	None
STOM Sea, Land, Subsurface Areas	Pagan	Monthly when MAGTF units onboard	USMC RCD specifies 739 sq nm land area; dedicated beachfront (see Landing Beach above); airspace of 50x80 nm, surface to 50,000 feet.	Environmental issues: Megapods, fruit bats, sea birds. Some cultural resources. Environmental group called "Pagan Watch" will likely oppose and use of Pagan.
Combined arms	Pagan	Weekly when MAGTF units onboard	See above	Legal/Land: Approx 20 people live in Pagan intermittently. Some families still claim land ownership. Lease price may be high due to presence of Pozolan Ash -- has mining potential.

Amphibious Assault (AAV or EFV)	Pagan	Weekly when MAGTF units onboard	See above	Other issues:Due to eruption, island has large amount of Pozolan Ash used in cement mfgr. Valued in the $Bs; Pozolan mining may become an issue.
Airspace (Notional)				
Restricted Areas (over land air-to-air)	Guam, Tinian, Saipan, FDM, Sarigan, Pagan	Daily when aviation squadrons onboard	1200 sq miles	Requires coordination with FAA; FACSFAC HI
Warning Areas (over water air-to-air)	Guam, Tinian, Saipan, FDM, Sarigan, Pagan	Daily when aviation squadrons onboard	4000 sq miles	Requires coordination with FAA; FACSFAC HI
Establish Area Control Guam	Guam, Tinian, Saipan, FDM, Sarigan, Pagan	Daily when aviation squadrons onboard	10,000 sq miles	Requires coordination with FAA; FACSFAC HI
General				
Data Backbone	Guam, Tinian, Saipan, FDM, Sarigan, Pagan	Monthly	TBD	Remote construction sites, security

* Training ranges requirement reduced when training available in deployed locations (e.g., Australia, Philippines, etc.). Deployment frequency contingent upon TEEP, sea lift, and availability of exercise related funding.

Agreed U.S.-Japan Sharing of Development Costs for USMC Relocation to Guam

All Figures: U.S. $1.0B

Priority	Description	Est. Dev. Cost	GOJ Share	USG share
I	Total op. facilities - Facilities - Assoc. Utilities - Other assoc. on-base infrastructure	4.60 3.70 0.74 0.16	Total 2.03 (44%) - Cash 1.29 - Recoverable 0.74	2.57 (56%)
II	Housing	2.55	Total 2.55 (100%) - Recoverable 2.10*	0* (0%)
III	Barracks/QOL	1.87	1.51 (81%)	0.36 (19%)
IV	Off-Base Infrastructure	0.25	0 (0%)	0.25 (100%)
V	Expeditionary Road	1.0	0 (0%)	1.0 (100%)
	Grand Total	**10.27**	**6.09 (59%) ****	**4.18 (41%)**

*Japan will finance $2.1B ($1.5B equity + .6B loan to project owner) to fund and develop 3,520 units of housing, valued at $2.55B by DOD. U.S. will provide overseas housing allowance (OHA) to USMC service members on Guam.

**Shows GOJ percentage of total development cost estimate, combining direct contributions and equity/loans to recoverable-cost projects.

ENCLOSURE (5)

Appendix B
Detailed Cost Spreadsheet

Cost Estimate

The cost estimate approaches of this report are described below.

I. Capital Cost

Capital costs are defined as the cost incurred to construct and install a new infrastructure facility or refurbish and rehabilitate an existing facility. Capital costs are incurred on the project services, purchase of land, buildings, equipment, construction, and pre-operating costs. Unlike operating and maintenance (O&M) costs, capital costs are one-time expenses.

1. Construction/Installation Costs

The construction costs are broken down in the detailed cost sheets in Appendix B. The cost estimates for each component were provided in 2008 dollars.

2. Project Services Cost

As indicated in Section 6.3, project services include the following:

- Environmental Impact Report/Other Documents
- Design Engineering
- Construction Engineering and Contract Administration
- General and Administrative Expenses
- Contingencies

A project level allowance of 35 percent is added to the estimated construction cost for project services to establish the total estimated project capital cost.

3. Escalation of Capital Costs

Escalation of Capital Costs to 2010

The capital cost of year 2010 is estimated when construction starts. An escalation index value of 4.55 percent was used to estimate January 2010 cost from January 2008. The escalation index data is obtained from Earth Tech's cost estimating software *RACER* 2008. The data was provided to Earth Tech by Air Force Civil Engineering Support Agency and were obtained from the Secretary of the Air Force/Financial Management and Controller.

Cost in 2010 = Cost in 2008 × Escalation Factor (4.55%)

Escalation of Capital Costs to Mid-Point of Construction (2013)

The capital cost of year 2013 is estimated as a mid-point cost of the construction. An escalation index value of 11.06 percent was used to estimate January 2013 cost from January 2008 from Earth *RACER* 2008.

Cost in 2013 = Cost in 2008 × Escalation Factor (11.06%)

4. Total Capital Cost Amortized to Annual Capital Cost during Project Life Cycle

To compare project life cycle cost, the total capital cost (lump-sum) of the project is distributed into equal amount of annual capital cost for the duration of project life cycle time. An annual 4 percent interest and 20-year project life cycle were assumed in the study.

The general formula used is:

$$\text{Annual Cost} = \text{Total Cost} \times i \cdot \frac{(1+i)^n}{(1+i)^n - 1}$$

where:

i is the interest rate and,

n is the number of years

II. Operation and Maintenance Costs

Operation and maintenance (O&M) costs include the costs of labor and benefits, energy/power, chemicals, and facility/equipment repair and maintenance. The assumptions of O&M cost were described in Section 6.3.

III. Cost Allocation among the Stakeholders

For each alternative, USMC will share capital costs among all beneficial parties of the project. It will share the costs with Guam Waterworks Authority (GWA), Navy, Air Force, Army and Special Operation Force (SOF) in Alternative 1A and 1B, while share with Navy, Air Force, Army and SOF in Alternative 2 and 3. The cost allocation was calculated based on a ratio of each beneficiary wastewater flow treated by the capital investment.

1. Cost Allocations for Option 1A and 1B

The flow ratios among the stakeholders for expanding and upgrading North District Wastewater Treatment Plant (NDWWTP) are shown in Table B-1.

Table B-1: Flow ratio among the stakeholders in the GovGuam NDWWTP

Type of Flow	Current Flow (mgd)	Increased Future Flow for Primary Treatment (mgd)	Total Future Flow (mgd)	Future Primary Treatment Percentage	Secondary Treatment Percentage
GWA flow	7.29	1.12	13.12	25.5%	74.4%
USMC flow	0	2.52	2.52	57.3%	14.3%
Navy flow	0.12	0	0.12	0.0%	0.7%
Air Force flow	1.10	0.44	1.54	10.0%	8.7%
Army flow	0.01	0.2	0.21	4.5%	1.2%
SOF	0	0.12	0.12	2.7%	0.7%
Total flow	8.52	4.4	17.63	100.0%	100.0%

mgd million gallons per day

The existing treatment capacity of NDWWTP is 12 million gallons per day (mgd). The plant is designed to provide primary treatment for incoming wastewater flow. For Alternatives 1A and 1B, the increased primary treatment capacity treats all the future flows generated by military buildup in Northern Guam and Northern Guam's civilian flow in excess of 12 mgd. Columns 3 and 5 of Table B-1 show the flows and the respective percentages for future primary treatment in Alternative 1A and 1B. The current Air Force flow of 1.10 mgd from AAFB, Navy flow of 0.12 mgd from NCTS Finegayan, and GWA flow of 7.29 plus the NDWWTP's remained capacity of 3.48 mgd (12 mgd minus 8.52 mgd) was not considered in the cost sharing of primary treatment expansion. The cost of secondary treatment in alternative 1B was distributed within the stakeholders based on total future flow ratios shown in columns 4 and 6 of Table B-1. The capital cost of 1A has only primary treatment cost, while the capital cost of 1B includes the cost to expand existing primary treatment from 12 mgd to 17.63 mgd and the cost for upgrading to secondary treatment for total flow of 17.63 mgd.

2. Cost Allocations for Option 2 and 3

The costs of Option 2 and 3 will be shared within different DoD units based on their future total flow ratios as shown in Table B-2

Table B-2: Flow ratio among the DoD units in Northern Guam Region

Type of Flow	Current Flow (mgd)	Projected future Flow Increase (mgd)	Total Projected Future Flow (mgd)	Future Total Flow Percentage
USMC flow	0	2.52	2.52	55.9%
Navy flow	0.12	0	0.12	2.7%
Air Force flow	1.1	0.44	1.54	34.1%
Army flow	0.01	0.2	0.21	4.7%
SOF	0	0.12	0.12	2.7%
Total flow	1.23	3.28	4.51	100.0%

PROJECT COMPUTATION SHEET

Client: NAVFEC
Project: Final Report for Utility Study on MC Relocation to Guam
Design Calculations
File Name: 101177 preliminary_cost
Latest Revision: 10-Jul-08

Subject: Cost Estimation

Project No.:101177.06.02
Prepared By: YM
Date: July-2008
Reviewed By: RBS

OPTION 1A: EXPAND & UPGRADE NDWWTP PRIMARY TREATMENT

Table 1: Line Item Costs

Construction Categories	Item Description	Quantity	Unit	Unit Cost	Cost Opinion	Sub. Toal Cost
Headworks Expasion	6mm Fine Screen Equipment	2	1	$637,168	$1,274,336	$1,529,204
	Instrumentation/SCADA	1	LS	$63,717	$63,717	
	Electrical	1	LS	$191,150	$191,150	
Primary Clarifier	Reinforced Concrete	1300	CY	$2,124	$2,761,062	$6,465,239
	Earthwork	6300	CY	$106	$669,027	
	Sludge and Scum Collector Equipment	1	EA	$876,106	$876,106	
	Miscellaneous Metals	1	LS	$215,310	$215,310	
	Frp Weirs	1	LS	$129,186	$129,186	
	Protective Coatings	1	LS	$350,442	$350,442	
	Piping and Valves	1	LS	$129,186	$129,186	
	Instrumentation/SCADA	1	LS	$172,248	$172,248	
	Electrical	1	LS	$430,619	$430,619	
	Sludge Pump Station Improvements	1	LS	$732,053	$732,053	
Chlorine Contact Tank	Reinforced Concrete	600	CY	$2,124	$1,274,336	$2,596,460
	Earthwork	3600	CY	$106	$382,301	
	Chemical Feed and Mixing Equipment	1	LS	$318,584	$318,584	
	Miscellaneous Metals	1	LS	$98,761	$98,761	
	Slide Gates and Weirs	1	LS	$59,257	$59,257	
	Protective Coatings	1	LS	$127,434	$127,434	
	Piping and Valves	1	LS	$59,257	$59,257	
	Instrumentation/SCADA	1	LS	$79,009	$79,009	
	Electrical	1	LS	$197,522	$197,522	
Anaerobic Digesters (New)	Reinforced Concrete	1000	CY	$2,124	$2,123,894	$10,265,735
	Earthwork	1400	CY	$106	$148,673	
	Digester Mixing and Heating Equipment	1	EA	$2,123,894	$2,123,894	
	Miscellaneous Metals	1	LS	$263,788	$263,788	
	Roofing and Insulation	1	LS	$241,805	$241,805	
	Protective Coatings	1	LS	$659,469	$659,469	
	Piping and Valves	1	LS	$1,538,761	$1,538,761	
	Instrumentation/SCADA	1	LS	$307,752	$307,752	
	Electrical	1	LS	$659,469	$659,469	
	New Sludge Pump Station	1	LS	$2,198,230	$2,198,230	

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Project No.:101177.06.02
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Date: July-2008
Reviewed By: RBS

OPTION 1A: EXPAND & UPGRADE NDWWTP PRIMARY TREATMENT

Table 1: Line Item Costs

Construction Categories	Item Description	Quantity	Unit	Unit Cost	Cost Opinion	Sub. Toal Cost
Solids Dewatering Building	Reinforced Concrete	1200	CY	$2,124	$2,548,673	$11,213,735
	Earthwork	3200	CY	$106	$339,823	
	Masonry Interior Walls	1	LS	$375,504	$375,504	
	Miscellaneous Metals	1	LS	$346,619	$346,619	
	Frp Grating	1	LS	$86,655	$86,655	
	Roofing and Insulation	1	LS	$404,389	$404,389	
	Doors and Windows	1	LS	$72,212	$72,212	
	Protective Coatings	1	LS	$173,310	$173,310	
	Building Specialties	1	LS	$28,885	$28,885	
	Sludge Grinders	2	EA	$63,717	$127,434	
	Sludge Feed Pumps	2	EA	$79,646	$159,292	
	Polymer Feed System	2	EA	$238,938	$477,876	
	Polymer Feed Pumps	2	EA	$21,239	$42,478	
	Odor Control System	1	EA	$477,876	$477,876	
	Centrifuges -225 gpm	2	EA	$1,274,336	$2,548,673	
	Process Piping and Valves	1	LS	$519,929	$519,929	
	HVAC	1	LS	$433,274	$433,274	
	Plumbing	1	LS	$288,850	$288,850	
	Electrical	1	LS	$1,444,248	$1,444,248	
	Instrumentation/SCADA	1	LS	$317,735	$317,735	
Influent and Effluent Samplers	Automatic Samplers	2	EA	$79,646	$159,292	$159,292
Site Work and Utilities	Paving, Grading, and Yard Piping	1	LS	$2,256,076	$2,256,076	$2,256,076
Relief Sewer, 24"D	Lump Sum	7500	FT	$558	$4,181,416	$4,181,416
Outfall Diffusers Expansion	Lump Sum	400	FT		$621,000	$621,000
TOTAL COST						$39,288,156

PROJECT COMPUTATION SHEET

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Design Calculations
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OPTION 1B: EXPAND & UPGRADE NDWWTP TO SECONDARY TREATMENT

Table 1: Line Item Costs

Construction Categories	Item Description	Quantity	Unit	Unit Cost	Cost Opinion	Sub. Toal Cost
Headworks Expasion	6mm Fine Screen Equipment	2	1	$637,168	$1,274,336	$1,529,204
	Instrumentation/SCADA	1	LS	$63,717	$63,717	
	Electrical	1	LS	$191,150	$191,150	
Primary Clarifiers	Reinforced Concrete	1300	CY	$2,124	$2,761,062	$6,465,239
	Earthwork	6300	CY	$106	$669,027	
	Sludge and Scum Collector Equipment	1	EA	$876,106	$876,106	
	Miscellaneous Metals	1	LS	$215,310	$215,310	
	Frp Weirs	1	LS	$129,186	$129,186	
	Protective Coatings	1	LS	$350,442	$350,442	
	Piping and Valves	1	LS	$129,186	$129,186	
	Instrumentation/SCADA	1	LS	$172,248	$172,248	
	Electrical	1	LS	$430,619	$430,619	
	Sludge Pump Station Improvements	1	LS	$732,053	$732,053	
Trickling Filter Pumping Station	Reinforced Concrete	400	CY	$2,124	$849,558	$2,758,938
	Earthwork	1600	CY	$106	$169,912	
	Trickling Filter Influent Pump Equipment	3	EA	$238,938	$716,814	
	Miscellaneous Metals	1	LS	$86,814	$86,814	
	Protective Coatings	1	LS	$501,770	$501,770	
	Piping and Valves	1	LS	$52,088	$52,088	
	Instrumentation/SCADA	1	LS	$121,540	$121,540	
	Electrical	1	LS	$260,442	$260,442	
Trickling Filters	Reinforced Concrete	5700	CY	$2,124	$12,106,195	$26,783,363
	Earthwork	6600	CY	$106	$700,885	
	Trickling Filter Plastic Media	30300	CY	$319	$9,653,097	
	Rotary Distribtution Equipment	3	EA	$477,876	$1,433,628	
	Miscellaneous Metals	1	LS	$589,381	$589,381	
	Frp Weirs	1	LS	$353,628	$353,628	
	Protective Coatings	1	LS	$1,003,540	$1,003,540	
	Piping and Valves	1	LS	$353,628	$353,628	
	Instrumentation/SCADA	1	LS	$117,876	$117,876	
	Electrical	1	LS	$471,504	$471,504	

PROJECT COMPUTATION SHEET

Client: NAVFEC
Project: Final Report for Utility Study on MC Relocation to Guam
Design Calculations
File Name: 101177 preliminary_cost
Latest Revision: 10-Jul-08

Subject: Cost Estimation

Project No.:101177.06.02
Prepared By: YM
Date: July-2008
Reviewed By: RBS

OPTION 1B: EXPAND & UPGRADE NDWWTP TO SECONDARY TREATMENT

Table 1: Line Item Costs

Construction Categories	Item Description	Quantity	Unit	Unit Cost	Cost Opinion	Sub. Toal Cost
Secondary Clarifiers	Reinforced Concrete	7200	CY	$2,124	$15,292,035	$34,727,788
	Earthwork	44000	CY	$106	$4,672,566	
	Sludge and Scum Collector Equipment	4	EA	$876,106	$3,504,425	
	Miscellaneous Metals	1	LS	$1,173,451	$1,173,451	
	Frp Weirs	1	LS	$704,071	$704,071	
	Protective Coatings	1	LS	$1,401,770	$1,401,770	
	Piping and Valves	1	LS	$704,071	$704,071	
	Instrumentation/SCADA	1	LS	$938,761	$938,761	
	Electrical	1	LS	$2,346,903	$2,346,903	
	New Sludge Pump Station	1	LS	$3,989,735	$3,989,735	
Chlorine Contact Tank	Reinforced Concrete	600	CY	$2,124	$1,274,336	$2,596,460
	Earthwork	3600	CY	$106	$382,301	
	Chemical Feed and Mixing Equipment	1	LS	$318,584	$318,584	
	Miscellaneous Metals	1	LS	$98,761	$98,761	
	Slide Gate and Weirs	1	LS	$59,257	$59,257	
	Protective Coatings	1	LS	$127,434	$127,434	
	Piping and Valves	1	LS	$59,257	$59,257	
	Instrumentation/SCADA	1	LS	$79,009	$79,009	
	Electrical	1	LS	$197,522	$197,522	
Anaerobic Digesters (New)	Reinforced Concrete	3000	CY	$2,124	$6,371,681	$30,797,204
	Earthwork	4200	CY	$106	$446,018	
	Digester Mixing and Heating Equipment	3	EA	$2,123,894	$6,371,681	
	Miscellaneous Metals	1	LS	$791,363	$791,363	
	Roofing and Insulation	1	LS	$725,416	$725,416	
	Protective Coatings	1	LS	$1,978,407	$1,978,407	
	Piping and Valves	1	LS	$4,616,283	$4,616,283	
	Instrumentation/SCADA	1	LS	$923,257	$923,257	
	Electrical	1	LS	$1,978,407	$1,978,407	
	New Sludge Pump Station	1	LS	$6,594,690	$6,594,690	

PROJECT COMPUTATION SHEET

Client: NAVFEC
Project: Final Report for Utility Study on MC Relocation to Guam
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File Name: 101177 preliminary_cost
Latest Revision: 10-Jul-08

Subject: Cost Estimation

Project No.:101177.06.02
Prepared By: YM
Date: July-2008
Reviewed By: RBS

OPTION 1B: EXPAND & UPGRADE NDWWTP TO SECONDARY TREATMENT

Table 1: Line Item Costs

Construction Categories	Item Description	Quantity	Unit	Unit Cost	Cost Opinion	Sub. Toal Cost
Solids Dewatering Building	Reinforced Concrete	1200	CY	$2,124	$2,548,673	$11,213,735
	Earthwork	3200	CY	$106	$339,823	
	Masonry Interior Walls	1	LS	$375,504	$375,504	
	Miscellaneous Metals	1	LS	$346,619	$346,619	
	Frp Grating	1	LS	$86,655	$86,655	
	Roofing and Insulation	1	LS	$404,389	$404,389	
	Doors and Windows	1	LS	$72,212	$72,212	
	Protective Coatings	1	LS	$173,310	$173,310	
	Building Specialties	1	LS	$28,885	$28,885	
	Sludge Grinders	2	EA	$63,717	$127,434	
	Sludge Feed Pumps	2	EA	$79,646	$159,292	
	Polymer Feed System	2	EA	$238,938	$477,876	
	Polymer Feed Pumps	2	EA	$21,239	$42,478	
	Odor Control System	1	EA	$477,876	$477,876	
	Centrifuges -225 gpm	2	EA	$1,274,336	$2,548,673	
	Process Piping and Valves	1	LS	$519,929	$519,929	
	HVAC	1	LS	$433,274	$433,274	
	Plumbing	1	LS	$288,850	$288,850	
	Electrical	1	LS	$1,444,248	$1,444,248	
	Instrumentation/SCADA	1	LS	$317,735	$317,735	
Influent and Effluent Samplers	Automatic Samplers	2	EA	$79,646	$159,292	$159,292
Site Work and Utilities	Paving, Grading, and Yard Piping	1	LS	$8,192,185	$8,192,185	$8,192,185
Relief Sewer, 24"D	Lump Sum	7500	FT	$558	$4,181,416	$4,181,416
Outfall Diffusers Expansion	Lump Sum	400	FT		$621,000	$621,000
TOTAL COST						$130,025,823

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PROJECT COMPUTATION SHEET

Project No.:101177.06.02
Client: NAVFEC
Prepared By: YM
Project: Final Report for Utility Study on MC Relocation to Guam
Subject: Cost Estimation
Date: July-2008
Design Calculations
Reviewed By: RBS
File Name: 101177 preliminary_cost
Latest Revision: 10-Jul-08

OPTION 2: DoD SECONDARY TREATMENT

Table 1: Line Item Costs

Construction Categories	Item Description	Quantity	Unit	Unit Cost	Cost Opinion	Sub. Toal Cost
DoD Headworks	Reinforced Concrete	400	CY	$2,124	$849,558	$4,313,097
	Earthwork	1400	CY	$106	$148,673	
	Fine Screenings Equipment	2	EA	$238,938	$477,876	
	Grit Chamber Equipment	2	EA	$106,195	$212,389	
	Grit Pumps Equipment	2	EA	$58,407	$116,814	
	Grit Washer Equipment	2	EA	$185,841	$371,681	
	Miscellaneous Metals	1	LS	$108,850	$108,850	
	Frp Weirs	1	LS	$65,310	$65,310	
	Protective Coatings	1	LS	$176,814	$176,814	
	Piping and Valves	1	LS	$544,248	$544,248	
	Instrumentation/SCADA	1	LS	$152,389	$152,389	
	Electrical	1	LS	$326,549	$326,549	
	Grit & Screenings Building	1	LS	$761,947	$761,947	
Primary Clarifier	Reinforced Concrete	1500	CY	$2,124	$3,185,841	$8,723,894
	Earthwork	2200	CY	$106	$233,628	
	Sludge and Scum Collector Equipment	3	EA	$424,779	$1,274,336	
	Miscellaneous Metals	1	LS	$234,690	$234,690	
	Frp Weirs	1	LS	$140,814	$140,814	
	Protective Coatings	1	LS	$509,735	$509,735	
	Piping and Valves	1	LS	$140,814	$140,814	
	Instrumentation/SCADA	1	LS	$187,752	$187,752	
	Electrical	1	LS	$469,381	$469,381	
	New Sludge Pump Station	1	LS	$2,346,903	$2,346,903	
Trickling Filter Pumping Station	Reinforced Concrete	400	CY	$2,124	$849,558	$2,281,062
	Earthwork	1600	CY	$106	$169,912	
	Trickling Filter Influent Pump Equipment	3	EA	$159,292	$477,876	
	Miscellaneous Metals	1	LS	$74,867	$74,867	
	Protective Coatings	1	LS	$334,513	$334,513	
	Piping and Valves	1	LS	$44,920	$44,920	
	Instrumentation/SCADA	1	LS	$104,814	$104,814	
	Electrical	1	LS	$224,602	$224,602	

PROJECT COMPUTATION SHEET

Client: NAVFEC
Project: Final Report for Utility Study on MC Relocation to Guam
Design Calculations
File Name: 101177 preliminary_cost
Latest Revision: 10-Jul-08

Subject: Cost Estimation

Project No.:101177.06.02
Prepared By: YM
Date: July-2008
Reviewed By: RBS

OPTION 2: DoD SECONDARY TREATMENT

Table 1: Line Item Costs

Construction Categories	Item Description	Quantity	Unit	Unit Cost	Cost Opinion	Sub. Toal Cost
Trickling Filters	Reinforced Concrete	2700	CY	$2,124	$5,734,513	$10,994,336
	Earthwork	2400	CY	$106	$254,867	
	Trickling Filter Plastic Media	9000	CY	$319	$2,867,257	
	Rotary Distribtution Equipment	3	EA	$265,487	$796,460	
	Miscellaneous Metals	1	LS	$195,929	$195,929	
	Frp Weirs	1	LS	$117,558	$117,558	
	Protective Coatings	1	LS	$557,522	$557,522	
	Piping and Valves	1	LS	$274,301	$274,301	
	Instrumentation/SCADA	1	LS	$39,186	$39,186	
	Electrical	1	LS	$156,743	$156,743	
Secondary Clarifiers	Reinforced Concrete	2400	CY	$2,124	$5,097,345	$13,242,265
	Earthwork	12900	CY	$106	$1,369,912	
	Sludge and Scum Collector Equipment	4	EA	$557,522	$2,230,088	
	Miscellaneous Metals	1	LS	$434,867	$434,867	
	Frp Weirs	1	LS	$260,920	$260,920	
	Protective Coatings	1	LS	$892,035	$892,035	
	Piping and Valves	1	LS	$260,920	$260,920	
	Instrumentation/SCADA	1	LS	$347,894	$347,894	
	Electrical	1	LS	$869,735	$869,735	
	New Sludge Pump Station	1	LS	$1,478,549	$1,478,549	
Chlorine Contact Tanks	Reinforced Concrete	1200	CY	$2,124	$2,548,673	$4,295,575
	Earthwork	4400	CY	$106	$467,257	
	Chemical Feed and Mixing Equipment	1	LS	$318,584	$318,584	
	Miscellaneous Metals	1	LS	$166,726	$166,726	
	Slide Gates and Weirs	1	LS	$100,035	$100,035	
	Protective Coatings	1	LS	$127,434	$127,434	
	Piping and Valves	1	LS	$100,035	$100,035	
	Instrumentation/SCADA	1	LS	$133,381	$133,381	
	Electrical	1	LS	$333,451	$333,451	
Anaerobic Digesters (New)	Reinforced Concrete	3000	CY	$2,124	$6,371,681	$30,797,204
	Earthwork	4200	CY	$106	$446,018	
	Digester Mixing and Heating Equipment	3	EA	$2,123,894	$6,371,681	
	Miscellaneous Metals	1	LS	$791,363	$791,363	
	Roofing and Insulation	1	LS	$725,416	$725,416	
	Protective Coatings	1	LS	$1,978,407	$1,978,407	
	Piping and Valves	1	LS	$4,616,283	$4,616,283	
	Instrumentation/SCADA	1	LS	$923,257	$923,257	
	Electrical	1	LS	$1,978,407	$1,978,407	
	New Sludge Pump Station	1	LS	$6,594,690	$6,594,690	

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PROJECT COMPUTATION SHEET

Client: NAVFEC
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File Name: 101177 preliminary_cost
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Subject: Cost Estimation

Project No.:101177.06.02
Prepared By: YM
Date: July-2008
Reviewed By: RBS

OPTION 2: DoD SECONDARY TREATMENT

Table 1: Line Item Costs

Construction Categories	Item Description	Quantity	Unit	Unit Cost	Cost Opinion	Sub. Toal Cost
Solids Dewatering Building	Reinforced Concrete	1200	CY	$2,124	$2,548,673	$10,518,159
	Earthwork	3200	CY	$106	$339,823	
	Masonry Interior Walls	1	LS	$375,504	$375,504	
	Miscellaneous Metals	1	LS	$346,619	$346,619	
	Frp Grating	1	LS	$86,655	$86,655	
	Roofing and Insulation	1	LS	$404,389	$404,389	
	Doors and Windows	1	LS	$72,212	$72,212	
	Protective Coatings	1	LS	$173,310	$173,310	
	Building Specialties	1	LS	$28,885	$28,885	
	Sludge Grinders	2	EA	$53,097	$106,195	
	Sludge Feed Pumps	2	EA	$66,372	$132,743	
	Polymer Feed System	2	EA	$238,938	$477,876	
	Polymer Feed Pumps	2	EA	$15,929	$31,858	
	Odor Control System	1	EA	$477,876	$477,876	
	Centrifuges -125 gpm	2	EA	$955,752	$1,911,504	
	Process Piping and Valves	1	LS	$519,929	$519,929	
	HVAC	1	LS	$433,274	$433,274	
	Plumbing	1	LS	$288,850	$288,850	
	Electrical	1	LS	$1,444,248	$1,444,248	
	Instrumentation/SCADA	1	LS	$317,735	$317,735	
Influent and Effluent Samplers	Automatic Samplers	2	EA	$79,646	$159,292	$159,292
Site Work and Utilities	Paving, Grading, and Yard Piping	1	LS	$5,972,742	$5,972,742	$5,972,742
Sewer Interceptor I, 24"D	Lump Sum	33300	FT	$558	$18,565,487	$18,565,487
Sewer Interceptor II, 30"D	Lump Sum	8700	FT	$664	$5,774,336	$5,774,336
Effluent Transmission Line, 30"D	Lump Sum	5,000	FT	$664	$3,318,584	$3,318,584
Ocean Out Fall, 30"	Lump Sum	2400	FT	$3,637	$8,729,204	$8,729,204
TOTAL COST						$127,685,238

PROJECT COMPUTATION SHEET

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File Name: 101177 preliminary_cost
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Subject: Cost Estimation

Project No.:101177.06.02
Prepared By: YM
Date: July-2008
Reviewed By: RBS

OPTION 3: DoD SECONDARY TREATMENT at NDWWTP to Treat DoD Load Only

Table 1: Line Item Costs

Construction Categories	Item Description	Quantity	Unit	Unit Cost	Cost Opinion	Sub. Toal Cost
DoD Headworks	Reinforced Concrete	400	CY	$2,124	$849,558	$4,313,097
	Earthwork	1400	CY	$106	$148,673	
	Fine Screenings Equipment	2	EA	$238,938	$477,876	
	Grit Chamber Equipment	2	EA	$106,195	$212,389	
	Grit Pumps Equipment	2	EA	$58,407	$116,814	
	Grit Washer Equipment	2	EA	$185,841	$371,681	
	Miscellaneous Metals	1	LS	$108,850	$108,850	
	Frp Weirs	1	LS	$65,310	$65,310	
	Protective Coatings	1	LS	$176,814	$176,814	
	Piping and Valves	1	LS	$544,248	$544,248	
	Instrumentation/SCADA	1	LS	$152,389	$152,389	
	Electrical	1	LS	$326,549	$326,549	
	Grit & Screenings Building	1	LS	$761,947	$761,947	
Primary Clarifier	Reinforced Concrete	1500	CY	$2,124	$3,185,841	$8,723,894
	Earthwork	2200	CY	$106	$233,628	
	Sludge and Scum Collector Equipment	3	EA	$424,779	$1,274,336	
	Miscellaneous Metals	1	LS	$234,690	$234,690	
	Frp Weirs	1	LS	$140,814	$140,814	
	Protective Coatings	1	LS	$509,735	$509,735	
	Piping and Valves	1	LS	$140,814	$140,814	
	Instrumentation/SCADA	1	LS	$187,752	$187,752	
	Electrical	1	LS	$469,381	$469,381	
	New Sludge Pump Station	1	LS	$2,346,903	$2,346,903	
Trickling Filter Pumping Station	Reinforced Concrete	400	CY	$2,124	$849,558	$2,281,062
	Earthwork	1600	CY	$106	$169,912	
	Trickling Filter Influent Pump Equipment	3	EA	$159,292	$477,876	
	Miscellaneous Metals	1	LS	$74,867	$74,867	
	Protective Coatings	1	LS	$334,513	$334,513	
	Piping and Valves	1	LS	$44,920	$44,920	
	Instrumentation/SCADA	1	LS	$104,814	$104,814	
	Electrical	1	LS	$224,602	$224,602	

PROJECT COMPUTATION SHEET

Client: NAVFEC
Project: Final Report for Utility Study on MC Relocation to Guam
Design Calculations
File Name: 101177 preliminary_cost
Latest Revision: 10-Jul-08

Subject: Cost Estimation

Project No.:101177.06.02
Prepared By: YM
Date: July-2008
Reviewed By: RBS

OPTION 3: DoD SECONDARY TREATMENT at NDWWTP to Treat DoD Load Only

Table 1: Line Item Costs

Construction Categories	Item Description	Quantity	Unit	Unit Cost	Cost Opinion	Sub. Toal Cost
Trickling Filters	Reinforced Concrete	2700	CY	$2,124	$5,734,513	$10,994,336
	Earthwork	2400	CY	$106	$254,867	
	Trickling Filter Plastic Media	9000	CY	$319	$2,867,257	
	Rotary Distribtution Equipment	3	EA	$265,487	$796,460	
	Miscellaneous Metals	1	LS	$195,929	$195,929	
	Frp Weirs	1	LS	$117,558	$117,558	
	Protective Coatings	1	LS	$557,522	$557,522	
	Piping and Valves	1	LS	$274,301	$274,301	
	Instrumentation/SCADA	1	LS	$39,186	$39,186	
	Electrical	1	LS	$156,743	$156,743	
Secondary Clarifiers	Reinforced Concrete	2400	CY	$2,124	$5,097,345	$13,242,265
	Earthwork	12900	CY	$106	$1,369,912	
	Sludge and Scum Collector Equipment	4	EA	$557,522	$2,230,088	
	Miscellaneous Metals	1	LS	$434,867	$434,867	
	Frp Weirs	1	LS	$260,920	$260,920	
	Protective Coatings	1	LS	$892,035	$892,035	
	Piping and Valves	1	LS	$260,920	$260,920	
	Instrumentation/SCADA	1	LS	$347,894	$347,894	
	Electrical	1	LS	$869,735	$869,735	
	New Sludge Pump Station	1	LS	$1,478,549	$1,478,549	
Chlorine Contact Tank	Reinforced Concrete	1200	CY	$2,124	$2,548,673	$4,295,575
	Earthwork	4400	CY	$106	$467,257	
	Chemical Feed and Mixing Equipment	1	LS	$318,584	$318,584	
	Miscellaneous Metals	1	LS	$166,726	$166,726	
	Weirs	1	LS	$100,035	$100,035	
	Protective Coatings	1	LS	$127,434	$127,434	
	Piping and Valves	1	LS	$100,035	$100,035	
	Instrumentation/SCADA	1	LS	$133,381	$133,381	
	Electrical	1	LS	$333,451	$333,451	
Anaerobic Digesters (New)	Reinforced Concrete	3000	CY	$2,124	$6,371,681	$30,797,204
	Earthwork	4200	CY	$106	$446,018	
	Digester Mixing and Heating Equipment	3	EA	$2,123,894	$6,371,681	
	Miscellaneous Metals	1	LS	$791,363	$791,363	
	Roofing and Insulation	1	LS	$725,416	$725,416	
	Protective Coatings	1	LS	$1,978,407	$1,978,407	
	Piping and Valves	1	LS	$4,616,283	$4,616,283	
	Instrumentation/SCADA	1	LS	$923,257	$923,257	
	Electrical	1	LS	$1,978,407	$1,978,407	
	New Sludge Pump Station	1	LS	$6,594,690	$6,594,690	

PROJECT COMPUTATION SHEET

Client: NAVFEC
Project: Final Report for Utility Study on MC Relocation to Guam
Design Calculations
File Name: 101177 preliminary_cost
Latest Revision: 10-Jul-08

Subject: Cost Estimation

Project No.:101177.06.02
Prepared By: YM
Date: July-2008
Reviewed By: RBS

OPTION 3: DoD SECONDARY TREATMENT at NDWWTP to Treat DoD Load Only

Table 1: Line Item Costs

Construction Categories	Item Description	Quantity	Unit	Unit Cost	Cost Opinion	Sub. Toal Cost
Solids Dewatering Building	Reinforced Concrete	1200	CY	$2,124	$2,548,673	$10,518,159
	Earthwork	3200	CY	$106	$339,823	
	Masonry Interior Walls	1	LS	$375,504	$375,504	
	Miscellaneous Metals	1	LS	$346,619	$346,619	
	Frp Grating	1	LS	$86,655	$86,655	
	Roofing and Insulation	1	LS	$404,389	$404,389	
	Doors and Windows	1	LS	$72,212	$72,212	
	Protective Coatings	1	LS	$173,310	$173,310	
	Building Specialties	1	LS	$28,885	$28,885	
	Sludge Grinders	2	EA	$53,097	$106,195	
	Sludge Feed Pumps	2	EA	$66,372	$132,743	
	Polymer Feed System	2	EA	$238,938	$477,876	
	Polymer Feed Pumps	2	EA	$15,929	$31,858	
	Odor Control System	1	EA	$477,876	$477,876	
	Centrifuges -125 gpm	2	EA	$955,752	$1,911,504	
	Process Piping and Valves	1	LS	$519,929	$519,929	
	HVAC	1	LS	$433,274	$433,274	
	Plumbing	1	LS	$288,850	$288,850	
	Electrical	1	LS	$1,444,248	$1,444,248	
	Instrumentation/SCADA	1	LS	$317,735	$317,735	
Influent and Effluent Samplers	Automatic Samplers	2	EA	$79,646	$159,292	$159,292
Site Work and Utilities	Paving, Grading, and Yard Piping	1	LS	$5,972,742	$5,972,742	$5,972,742
Sewer Interceptor I, 24"D	Lump Sum	33300	FT	$558	$18,565,487	$18,565,487
Sewer Interceptor II, 30"D	Lump Sum	13500	FT	$664	$8,960,177	$8,960,177
Outfall Diffusers Expansion	Lump Sum	400	FT		$621,000	$621,000
TOTAL COST						$119,444,291

EarthTech
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PROJECT COMPUTATION SHEET

Client: NAVFEC
Project: Final Report for Utility Study on MC Relocation to Guam
Design Calculations
File Name: 101177 preliminary_cost
Latest Revision: 30-Jun-08

Subject: Annual O&M Cost Estimation

Cost Categories	Quantity	Cost Est.	GWA Cost Est.	DoD Cost Est.
Labor & Benefits	LS	$45,000	$33,000	$12,000
Capital Improvements	LS	$0	$0	$0
Chemicals	LS	$216,000	$161,000	$55,000
Collection	LS	$1,000	$0	$1,000
Contract Services	LS	$261,000	$194,000	$67,000
Maintenance	LS	$53,000	$39,000	$14,000
Supplies	LS	$0	$0	$0
Utilities	LS	$193,000	$144,000	$49,000
TOTAL ANNUAL OPERATION COST		$769,000	$571,000	$198,000

OPTION 1B: EXPAND & UPGRADE NDWWTP TO SECONDARY TREATMENT

Cost Categories	Quantity	Cost Est.	GWA Cost Est.	DoD Cost Est.
Labor & Benefits	LS	135,000	100,000	35,000
Capital Improvements	LS	0	0	0
Chemicals	LS	201,000	150,000	51,000
Collection	LS	1,000	0	1,000
Contract Services	LS	622,000	463,000	159,000
Maintenance	LS	200,000	149,000	51,000
Supplies	LS	0	0	0
Utilities	LS	1,930,000	1,436,000	494,000
TOTAL ANNUAL OPERATION COST		3,089,000	2,298,000	791,000

PROJECT COMPUTATION SHEET

EarthTech
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Client: NAVFEC
Project: Final Report for Utility Study on MC Relocation to Guam
Design Calculations
File Name: 101177 preliminary_cost
Latest Revision: 30-Jun-08

Subject: Annual O&M Cost Estimation

OPTION 2: DOD SECONDARY TREATMENT ON DoD LAND

Cost Categories	Quantity	Cost Est.	DoD Cost Est.
Labor & Benefits	LS	465,000	465,000
Capital Improvements	LS	0	0
Chemicals	LS	62,000	62,000
Collection	LS	8,000	8,000
Contract Services	LS	260,000	260,000
Maintenance	LS	251,000	251,000
Supplies	LS	0	0
Utilities	LS	494,000	494,000
TOTAL ANNUAL OPERATION COST		1,540,000	1,540,000

OPTION 3: SECONDARY TREATMENT AT NDWWTP SITE TO TREAT DoD LOAD ONLY

Cost Categories	Quantity	Cost Est.	DoD Cost Est.
Labor & Benefits	LS	465,000	465,000
Capital Improvements	LS	0	0
Chemicals	LS	62,000	62,000
Collection	LS	9,000	9,000
Contract Services	LS	260,000	260,000
Maintenance	LS	251,000	251,000
Supplies	LS	0	0
Utilities	LS	494,000	494,000
TOTAL ANNUAL OPERATION COST		1,541,000	1,541,000

Project Life (yrs) 20
Interest Rate (%) 4

LIFE CYCLE COST COMPARISON

ITEM	DESCRIPTION	OPTION 1A	OPTION 1B	OPTION 2	OPTION 3
		Expand & Upgrade NDWWTP Primary Treatment	Expand & Upgrade NDWWTP to Secondary Treatment	DoD Secondary Treatment Facility on DoD Land	Separate Secondary Treatment Facility at NDWWTP to Treat DoD Load Only
A.	**Estimated Capital Cost**				
1	Headworks	$1,529,000	$1,529,000	$4,313,000	$4,313,000
2	Primary Clarifiers	$6,465,000	$6,465,000	$8,724,000	$8,724,000
3	Pumping Stations	-	$2,759,000	$2,281,000	$2,281,000
4	Trickling Filters	-	$26,783,000	$10,994,000	$10,994,000
5	Secondary Clarifiers	-	$34,728,000	$13,242,000	$13,242,000
6	Chlorine Contact Tanks	$2,596,000	$2,596,000	$4,296,000	$4,296,000
7	Anaerobic Digesters	$10,266,000	$30,797,000	$30,797,000	$30,797,000
8	Sludge Thickening & Dewatering System	$11,214,000	$11,214,000	$10,518,000	$10,518,000
9	Influent & Effluent Samplers	$159,000	$159,000	$159,000	$159,000
10	Site Work & Utilities	$2,256,000	$8,192,000	$5,973,000	$5,973,000
11	Sewer Interceptors	$4,181,000	$4,181,000	$24,340,000	$27,526,000
12	Effluent Transmission Line	-	-	$3,319,000	-
13	Ocean Out Fall & Piping	$621,000	$621,000	$8,729,000	$621,000
14	Project Services	$13,751,000	$45,509,000	$44,690,000	$41,806,000
	TOTAL	**$53,038,000**	**$175,533,000**	**$172,375,000**	**$161,250,000**
B.	**Estimated Annual O&M Cost**				
1	Labor & Benefits	$45,000	$135,000	$465,000	$465,000
2	Chemicals	$216,000	$201,000	$62,000	$62,000
3	Collection	$1,000	$1,000	$8,000	$9,000
4	Contract Services	$261,000	$622,000	$260,000	$260,000
5	Maintenance	$53,000	$200,000	$251,000	$251,000
6	Utilities	$193,000	$1,930,000	$494,000	$494,000
	TOTAL	**$769,000**	**$3,089,000**	**$1,540,000**	**$1,541,000**
C. Annual	**Costs**				
1	Amortized Capital Cost	$3,903,000	$12,916,000	$12,684,000	$11,865,000
2	Estimated Annual O&M Cost	$769,000	$3,089,000	$1,540,000	$1,541,000
	TOTAL	**$4,672,000**	**$16,005,000**	**$14,224,000**	**$13,406,000**

Appendix C
Detailed Analysis for Option 7 - Build a New Tertiary Treatment Plant near Proposed Development on DoD LAND and Install Injection Wells

Build a New Tertiary Treatment Plant near Proposed Development and Install Injection Wells

Tertiary treatment in municipal wastewater treatment practice normally refers the technologies that remove residual suspended solids, and potentially dissolved solids and trace constituents after secondary treatment, as required for specific water reuse application. For residual suspended solids removal, medium filtration, surface filtration, or membrane technology can be used. Total dissolved solids are normally removed by Reverse Osmosis (RO), and trace constituents by advanced oxidation.

This alternative includes the proposed DoD owned tertiary wastewater treatment plant at the southern end of proposed future USMC relocation site in the Finegayan area. It provides tertiary treatment for all the wastewater generated by military activities in the Northern Guam area, and treated effluent would be injected into the underground aquifer for groundwater replenishment and will increase groundwater sustainability of the Northern Guam Aquifer. With the Northern Guam Lens aquifer being designated by the EPA as a Sole Source Aquifer under the Safe Drinking Water Act, any planned groundwater recharge with reclaimed water is anticipated to be required to treat and achieve the relevant regulatory standards for indirect potable reuse, since later on it will be pumped out for potable water supply. Indirect potable reuse was defined by Metcalf & Eddy (2007) as *"The planned incorporation of reclaimed water into a raw water supply, such as in potable water storage reservoir or a groundwater aquifer, resulting in mixing, dilution, and assimilation, thus providing an environmental buffer."*

The planned DoD tertiary plant will treat the same influent flow and loading as presented in Table 6-6 of Section 6.1.3.

An independent sewer that connects the AAFB collection system at its main gate Lift Station 1881, runs along the Route 3, and combines the flow generated by USMC from Finegayan, will carry wastewater into the proposed DoD tertiary treatment plant at the southern end of Finegayan as shown on Figure C-1 attached at the end of the Appendix.

At present, there are no Federal regulations that specifically address indirect or direct potable reuse of reclaimed water. The EPA developed Guidelines for Water Reuse in 2004 and suggested the quality standard for treated municipal wastewater injection into underground potable aquifer as listed in the following Table C-1.

Table C-1: EPA Guidelines of Water Reuse for Groundwater Recharge by Injection into Potable Aquifers

Types of Reuse	Treatment	Reclaimed Water Quality	Reclaimed Water Monitoring	Setback Distances	Comments
Groundwater recharge by injection into potable aquifers	Secondary Filtration Disinfection Advanced wastewater treatment	Includes, but not limited to, the following: pH = 6.5 – 8.5 <= 2 NTU No detectable total coli/100 ml 1mg/l Cl_2 residual (minimum) <= 3 mg/L TOC <= 0.2 mg/L total toxics Nitrate N < 10 mg/L Meet drinking water standards	Includes, but not limited to the following: pH - daily Turbidity – continuous Total coliform – daily Cl_2 Residual – continuous Drinking water standards – quarterly Other – depends on constituent	2000 ft to extraction wells. May vary depending on site-specific conditions.	The reclaimed water should be retained underground for at least 9 months prior to withdrawal. Monitoring wells are necessary to detect the influence of the recharge operation on the groundwater. Recommended quality limits should be met at the point of injection. The reclaimed water should not contain measurable levels of viable pathogens after percolation through the vadose zone. A higher chlorine residual and/or a longer contact time may be necessary to assure virus and protozoa inactivation.

Source: EPA 2004
NTU nephelometric turbidity unit
TOC total organic carbon

California, Florida, and a few other stat es are in the forefront of developing discrete criteria relating to planned i ndirect potab le reuse of reclaimed water. California has prepare d draft criteria for groundwater recharge (the most recent being in 2004), and are shown in the Table C-2.

Table C-2: California Draft Groundwater Injection Regulations

Parameter	Requirement
Turbidity	0.2 NTU
Total nitrogen	5 mg/L
Total coliforms	2.2 total coliform/100 mL
TOC	0.5 mg/L
Set back distance	2,000 ft
Retention time underground	12 month
Drinking water standards	Meet all drinking water maximum contaminant levels (except nitrogen and new federal and state regulations as they are adopted)

Source: *Draft groundwater Recharge Regulations*, California Department of Health Services

With concerns on reliability of som e unregulated trace constituents rem oval, and consideration of source water that meets all drinking water standards, it does not necessarily indicate that the water is safe. The above California drafted groundwater injection regulation reflects the mitigations necessary to address these concerns. In present prac tice, reclai med injection into an underground potable aquifer norm ally has a multiple barrier protection sy stem (such as RO and ad vanced oxidation process) for advanced treatment to avoid unknown potential health risks.

The northern part of Guam is set on a karst limestone hig h pl ateau, where highl y por ous and channelized li mestone sub surface media with a high hydraulic conductivit y exist. From ground surface to groundwater surface is approxim ately 200 feet to 350 feet. This geology provi des little reliable opportunit y f or soil aquifer tr eatment, wh ich offers additional treatment as wat er passes through the soil vadose zone to an underlying aquifer. Due to limited surface area contact, flow through fractured limestone media may offer inefficient soil aquifer treatment.

Since groundwater under direct influence from surface water in the Northern Guam area has already been a concern to the GEPA, to gain public confidence on the practice of injecting reclaimed water directly into potable aquifer in a karst limestone region, the treatment processes train similar to California practice is used for this study. Groundwater recharge with reclaimed water in the Orange County Groundwater Replenishment Project, which treats secondary effluent from Orange County Sanitation District Plant # 1, employs a process including microfiltration, RO, advanced oxidation with ultraviolet (UV), and hydrogen peroxide.

A treatment process schematic flow diagram of the DoD tertiary waste water treatment plant (WWTP) is shown on Figure C-2 attached at the end of the Appendix.

Influent sewage flow will enter the treatment plant through two rotary drum fine screens at the headworks and pass through two aerated grit removal chambers. Each chamber will be approximately 45 feet long and 12 feet wide with a 7-foot water depth. Grit and screenings are disposed of in a sanitary landfill.

Primary treatment includes three primary clarifiers, each 60 feet in diameter with a 10-foot side water depth. Primary treated effluent is pumped into a flow distribution box and subsequently distributed into four rectangular membrane bioreactors each 80 feet long, 45 feet wide and 20 feet deep. Each membrane bioreactor (MBR) consists of four sections (pre-anoxic, aeration, membrane, and post-anoxic). The pre- and post-anoxic sections are used for denitrification. The aeration section degrades organic material and performs nitrification, and the membrane section provides solid and liquid separation. An inline pre-chlorination injection, followed by an inline dechlorination system destroys residual biological matter within the MBR effluent preventing biological fouling and chlorine oxidation within the RO system. Disinfected water is then fed by pumps into a RO system. The RO membranes remove a substantial portion of dissolved organic and inorganic components as well as viruses, producing permeate with low total dissolved solids (TDS) and total organic carbon (TOC) levels. RO permeate will be treated by an advanced oxidation process (AOP) with UV/hydrogen peroxide to destroy trace constituents such as synthetic organic chemicals. The purity of the permeate stream results in a water that is moderately corrosive. To stabilize the product water prior to underground injection, AOP treated water will be treated by decarbonation and lime addition. Reclaimed water is pumped out through a transmission pipeline to injection wells and recharged into the underground aquifer. The rejection water from the RO process is concentrated with constitutes such as salts and other dissolved solids. It can be discharged via a new ocean outfall or into the GWA sewer for disposal.

Membrane Bioreactor

The MBR combines biological treatment with an integrated membrane system. It can provide enhanced organics and suspended solids removal for the wastewater treatment plant. MBR achieves biological treatment to organic matter using conventional suspended growth activated sludge treatment in a bioreactor, and subsequently uses a membrane for separating treated wastewater from the active biomass in a suspended growth system. By coupling a biological reactor with a membrane system, conventional treatment operation such as gravity sedimentation and media filtration can be eliminated and it will produce an equivalent tertiary treatment effluent. The MBR requires less overall space. In this alternative, the MBR was utilized as a single one step process unit to achieve the required tertiary treatment for removing suspended and colloidal solids, including bacteria and protozoa, prior to RO treatment.

There are several types of MBRs. Figure C-3 (attached at the end of this Appendix) shows the types of MBRs available. They can be either internally immersed in the bioreactor or external to the bioreactors, including:

Flat Plate: The flat plate membrane is a submerged unit with the following operating characteristics:

- Operates with the pre-aeration basins at low dissolved oxygen (DO) concentration in the range of 0.2 milligrams per liter (mg/L) to 0.8 mg/L.
- Speed of the blowers is controlled by the measured residual DO.
- Air is cycled to maintain mixed liquor DO between 0.2 mg/L and 0.6 mg/L.
- Flat plate membranes reduce the potential for fouling.
- Reduces cleaning cycles.
- 6-log removal of bacteria and 4-log removal of viruses.
- Chemical clean in-place every 6 months with bleach.

External: External membranes are tubular membranes located on skids outside the oxidation ditch.

- Requires fine screen of 1.0 millimeter.
- External membrane skids located on a concrete slab next to the bioreactors.
- Tubular membranes, installed inside protective polyvinyl chloride vessels.

Hollow Fiber: Hollow fiber membranes are strands assembled together in a unitary rack.

- Immersed in the aeration tank.
- Available with reinforced and unreinforced membrane design.

All MBR designs offer the following advantages:

- Pretreatment requirements for subsequent reverse osmosis system for TDS control are provided.
- Secondary clarifiers and Return Activated Sludge pumping is not required.
- California Title 22 requirements, which have stringent requirements on suspended solids, bacteria and protozoa removal, are met by this process.
- Ability to remove nitrogen and phosphorus.
- Washout of solids and sludge bulking are not an issue.
- Reduced disinfection requirements

RO System

The RO system can separate a solvent, such as water, from a saline solution by using a semi-permeable membrane and hydraulic pressure. The RO membranes will remove a substantial portion of dissolved organic and inorganic components, producing permeate with low TDS and TOC.

Within the RO system, the pretreated feed will be separated into a purified permeate stream and concentrated brine stream. Based on the design water quality analyses, the RO system is normally designed for product water recoveries between 80 percent and 90 percent.

The RO membrane is a key treatment process for this integrated membrane reclaimed water plant. In practice, the selection of RO semi-permeable membranes will require pilot tests to determine the optimum continuing recovery rate and the latest low fouling membranes from various manufacturers.

The RO system will be comprised of discrete modular membrane trains housing the pressure vessels and spiral wound RO membrane elements. Wound depth type cartridge filters will be employed upstream of the RO membrane trains to protect against incidental particulate matter, which may enter the system and could potentially foul the RO membrane elements.

Each RO train will be equipped with a single, non-redundant high pressure membrane feed pump. For the selected RO train capacity, vertical turbine canned pumps will be used. Figure C-4 attached at the end of the Appendix shows a typical RO membrane system.

Advance Oxidation Process (AOP)

For reclaimed water indirect potable reuse, AOP may be used to destroy trace constituents including a variety of natural and synthetic organic carcinogens such as dioxane and N-nitrosodimethyamine (NDMA) that cannot be removed or destroyed by tertiary treatment and conventional oxidants to protect public health and the environment.

The AOP in the plant will provide an additional barrier beyond MBR/RO for the inactivation of bacteria and viruses in water reclaimed for groundwater aquifer injection.

The UV system design is based on treating 4.5 mgd of RO product water on a continuous basis for groundwater injection. Four logs of virus inactivation are required for normal operation of the UV system. Overall the MF/RO/UV treatment system will provide multiple barriers and a total of six-logs of virus removal. The UV design basis for destruction of NDMA assumes treatment of an inlet concentration of up to 150 parts per trillion (ppt) to an outlet concentration of 10 ppt. Figure C-4 attached at the end of the Appendix shows a typical UV system.

Wasted sludge from the MBR process is pumped to a Gravity Belt Thickener (GBT) system for reducing sludge water content, and two, 125 gpm GBT are included. Thickened sludge combined with primary sludge generated by primary clarifiers is pumped into a 2-stage anaerobic digestion system, which has two first-stage anaerobic digesters and one secondary anaerobic digester. Each digester has a 80-foot diameter and 18-foot side water depth. Digested sludge is subsequently dewatered by two centrifuges with a capacity of 125 gpm each. Finally, dewatered cake is hauled out as Class B solids for offsite disposal.

A summary of the major process components for a new DoD tertiary treatment plant near the proposed development and installation of injection wells are listed in Table C-3.

Table C-3: Major Process Components for Building a New DoD Tertiary Treatment Plant near Finegayan Development and Constructing New Groundwater Injection Wells

Construction Components	Unit	Dimensions/Description
Headwork	1	2 Rotary drum fine screens 2 Aerated grit chambers, each 45 ft long x 12 ft wide x 7 ft SWD
Primary clarifier	3	60 ft diameter x 10 ft SWD

Construction Components	Unit	Dimensions/Description
Membrane bioreactor	4	80 ft long x 45 ft wide x 20 ft SWD
Prechlorination / Dechlorination	1	Two 500 lbs/day chlorinators
RO system	1	75 modules each 120 gpm
Advance oxidization system	1	Two 4,500 gpm modules
Anaerobic digester	3	80 ft diameter x 18 ft SWD
Sludge gravity belt thickener	2	125 gpm each
Sludge dewatering centrifuges	2	125 gpm each
RO brine disposal line	1	30 in diameter, 7,500 ft long
Effluent transmission line	1	Approx. 7.5 miles
Injection wells	2	36 in casings
Monitoring wells	3	6 in casings

Reclaimed Water Transmission Line and Underground Injection Wells

Maximum wastewater production resulting from transfer of DoD assets to Guam is estimated at 4.1 mgd. Groundwater injection is one potential means of disposal of wastewater effluent. This option would use the highly treated wastewater effluent to recharge the freshwater lens at a location that would support the proposed new production wells on the AAFB property. Physical locations and the proposed layout of recharge wells for this scenario are shown on Figure C-1 attached at the end of the Appendix.

Under the disposal option, four recharge wells would be located parallel to Marine Drive on the southern boundary of the AAFB. The injection wells are arrayed in a line conforming to a ridge in the volcanic basement below the water bearing limestone. The ridge was chosen because the proposed production wells for the DoD expansion on Guam will be located on either side of the volcanic basement ridge allowing the injected effluent to directly recharge the portions of the aquifer that will be heavily pumped to supply water for new military and support personnel arriving on Guam. There are two injection wells proposed with approximately 1,000 feet of spacing between them. Each well would be capable of a recharge rate of approximately 1,600 gpm yielding a maximum combined injection rate of 3,200 gpm. Under non-peak loads, one to two wells would be operated allowing distribution of effluent recharge across a 2,000-foot front while enabling at least one well to be removed from service for maintenance and upkeep. The Water Utility Study provides details of the design and construction of the water injection wells.

Under this recharge option highly treated effluent is pumped from the proposed DoD WWTP facility to the injection wells. The proposed effluent pipeline runs along Route 3 (a light duty all weather road) and Marine Drive. The proposed line crosses Salisbury junction at 616 feet, just before the recharge wells. The proposed 18-inch force main is approximately 40,000 feet long.

The effluent pump station will have three vertical turbine pumps, where two pumps are in operation and one is standby. It is estimated that each pump needs to pump 1,500 gpm with a total dynamic head of 388 feet. The recommended pump is a 5-stage 15H at 1,770 revolutions per minute with a 250 HP motor. The pumps should be provided with variable frequency drives and automated controls.

Emergency Bypass or Alternative Disposal of Effl uent in Case of Non-Avai lability of In jection Wells

In case of plant failure or when effluent can not meet the groundwater inject ion standards due to process proble ms, two alt ernatives are e valuated. Th e first one is to discharge through a 30" ocean outfall. The second option is to discharge to GW A sewer. The constriction cost estimate include d cost for these two options.

A summary of preliminary construction cost estimates for this option is provided in Table C-4.

Table C-4: Preliminary Construction Cost for Option 7 – Build a New Tertiary Treatment Plant Near Proposed Development and Install Injection Wells

1. Component xxx		Guam Wastewater Utility Study		2. Date July, 2008
3. Installation and Location Marine Relocation	4. Project Title Guam Wastewater Utility Study			
5. Program Element	6. Category Code	7. Project Number	8. Project Cost ($000) 294,400,	
9. COST ESTIMATES				
Item	**U/M**	**Quantity**	**Unit Cost**	**Cost ($000)**
Headworks Expansion				
Reinforced Concrete	CY	400	$2,124	850
Earthwork	CY	1,400	$106	149
Fine Screenings Equipment	EA	2	$292,035	584
Grit Chamber Equipment	EA	2	$106,195	212
Grit Pumps Equipment	EA	2	$58,407	117
Grit Washer Equipment	EA	2	$185,841	372
Miscellaneous Metals	LS	1	$114,159	114
Frap Weirs	LS	1	$68,496	68
Protective Coatings	LS	1	$192,743	193
Piping and Valves	LS	1	$570,796	571
Instrumentation/SCADA	LS	1	$159,823	160
Electrical	LS	1	$342,478	342
Grit & Screenings Building	LS	1	$799,115	799
Primary Clarifier				
Reinforced Concrete	CY	1,500	$2,124	3,186
Earthwork	CY	2,200	$106	234
Sludge and Scum Collector Equipment	EA	3	$424,779	1,274
Miscellaneous Metals	LS	1	$234,690	235
Fro Weirs	LS	1	$140,814	141
Protective Coatings	LS	1	$509,735	510
Piping and Valves	LS	1	$140,814	141
Instrumentation/SCADA	LS	1	$187,752	188
Electrical	LS	1	$469,381	469
Sludge Pump Station Improvements	LS	1	$2,346,903	2,347
Membrane Bioreactors				
Reinforced Concrete	CY	4,800	$2,124	10,195
Earthwork	CY	4,400	$106	467
MBR System Equipment	EA	4	$5,575,221	22,301
Miscellaneous Metals	LS	1	$1,648,142	1,648
Fro Weirs and Gates	LS	1	$329,628	330
Protective Coatings	LS	1	$1,599,292	1,599
Piping and Valves	LS	1	$5,274,053	5,274
Instrumentation/SCADA	LS	1	$2,307,398	2,307
Electrical	LS	1	$4,944,425	4,944
MBR Pump and Blower Building	LS	1	$6,104,071	6,104

Item	U/M	Quantity	Unit Cost	Cost ($000)
Reverse Osmosis				
Reinforced Concrete	CY	500	$2,124	1,062
Earthwork	CY	600	$106	64
Reverse Osmosis System	LS	1	$13,008,850	13,009
Miscellaneous Metals	LS	1	$706,726	707
Roofing and Insulation	LS	1	$424,035	424
Protective Coatings	LS	1	$168,850	169
Piping and Valves	LS	1	$424,035	424
Instrumentation/SCADA	LS	1	$989,416	989
Electrical	LS	1	$2,120,177	2,120
Reverse Osmosis Building	LS	1	$2,402,867	2,403
Advanced Oxidation Process				
Reinforced Concrete	CY	400	$2,124	850
Earthwork	CY	600	$106	64
Ultraviolet and Peroxide Feed System	LS	1	$2,867,257	2,867
Miscellaneous Metals	LS	1	$226,832	227
Protective Coatings	LS	1	$136,991	137
Piping and Valves	LS	1	$1,323,186	1,323
Instrumentation/SCADA	LS	1	$264,637	265
Electrical	LS	1	$567,080	567
Anaerobic Digesters				
Reinforced Concrete	CY	3,000	$2,124	6,372
Earthwork	CY	4,200	$106	446
Digester Mixing and Heating Equipment	EA	3	$2,123,894	6,372
Miscellaneous Metals	LS	1	$791,363	791
Roofing and Insulation	LS	1	$725,416	725
Protective Coatings	LS	1	$1,978,407	1,978
Piping and Valves	LS	1	$4,616,283	4,616
Instrumentation/SCADA	LS	1	$923,257	923
Electrical	LS	1	$1,978,407	1,978
New Sludge Pump Station	LS	1	$6,594,690	6,595
Thickening and Dewatering Building				
Reinforced Concrete	CY	1,500	$2,124	3,186
Earthwork	CY	4,000	$106	425
Masonry Interior Walls	LS	1	$469,381	469
Miscellaneous Metals	LS	1	$433,274	433
Fro Grating	LS	1	$108,319	108
Roofing and Insulation	LS	1	$505,487	505
Doors and Windows	LS	1	$90,265	90
Protective Coatings	LS	1	$216,637	217
Building Specialties	LS	1	$36,106	36
Thickener Feed Pump	EA	2	$79,646	159
Thickener Polymer Feed System	EA	2	$238,938	478
Thickener Polymer Feed Pump	EA	2	$21,239	42
3.0 Meter Gravity Belt Thickener	EA	2	$477,876	956
Thickened Sludge Pump	EA	2	$79,646	159
Sludge Grinders	EA	2	$63,717	127
Sludge Feed Pumps	EA	2	$79,646	159
Polymer Feed System	EA	2	$238,938	478
Polymer Feed Pumps	EA	2	$21,239	42
Odor Control System	EA	1	$477,876	478
Centrifuges	EA	2	$1,274,336	2,549
Process Piping and Valves	LS	1	$649,912	650
HVAC	LS	1	$541,593	542
Plumbing	LS	1	$361,062	361
Electrical	LS	1	$1,805,310	1,805
Instrumentation/SCADA	LS	1	$397,168	397

Item	U/M	Quantity	Unit Cost	Cost ($000)
Influent and Effluent Samplers				
Automatic Samplers	EA	2	$79,646	159
Site Work and Utilities				
Paving, Grading, and Yard Piping	LS	1	$9,933,305	9,933
Sewer Interceptor (I), 24" D	FT	33,300	$558	18,565
Sewer Interceptor (II), 30" D	FT	8,700	$664	5,774
RO Brine Disposal Out Fall Line	FT	2,400	$3,637	8,729
Effluent Pumping Station	LS	1	$2,920,354	2,920
Effluent Transmission Line	FT	40,000	$478	19,115
Injection Well Heads	EA	2	$584,071	1,168
Monitoring Wells	EA	3	$159,292	478
Treatment Cost				156,404
Sewer Cost				52,184
Sub Total				208,588
Project Services 35.00%				73,006
Total Contract Cost				342,818
Total Request				342,818
Total Contract Cost				281,594
Total Request				281,594
Total Request (Rounded)				281,590
Total Escalated 2010 Request (Rounded)				294,400
Total Escalated 2013 Mid-Point Construction Cost (Rounded)				312,740
Total Request for USMC (Rounded)				157,410
Total Escalated 2010 Request for USMC (Rounded)				164,570
Total Escalated 2013 Mid-Point Construction Cost for USMC (Rounded)				174,820

10. Description of Proposed Construction:

DoD will be constructing a new tertiary treatment plant which includes

1. Two sewer interceptors
2. Head works: Fine screening and Grit chamber
3. Primary treatment: Three primary Clarifiers
4. Tertiary treatment: Four MBRs, one Reverse Osmosis, and One Advanced Oxidation Unit
5. Solid Stabilization: Two Gravity Belt Thickeners, Two Primary Anaerobic Digesters and One Secondary Anaerobic Digester
6. Solids Dewatering: Two Centrifuges and solids dewatering building
7. Effluent Transmission line to recharge wells
8. Four injection wells and three monitoring wells.

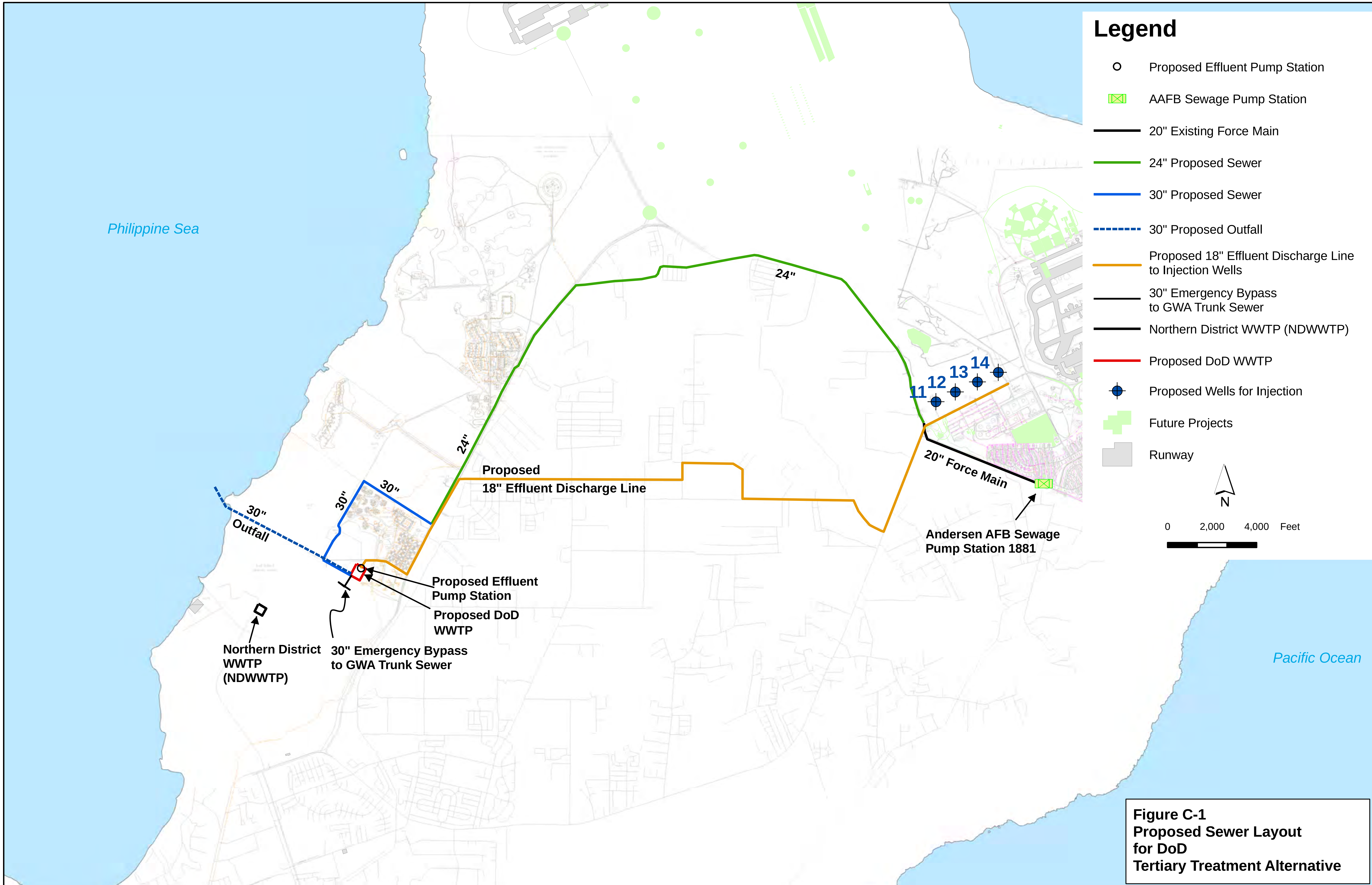

Figure C-1
Proposed Sewer Layout for DoD Tertiary Treatment Alternative

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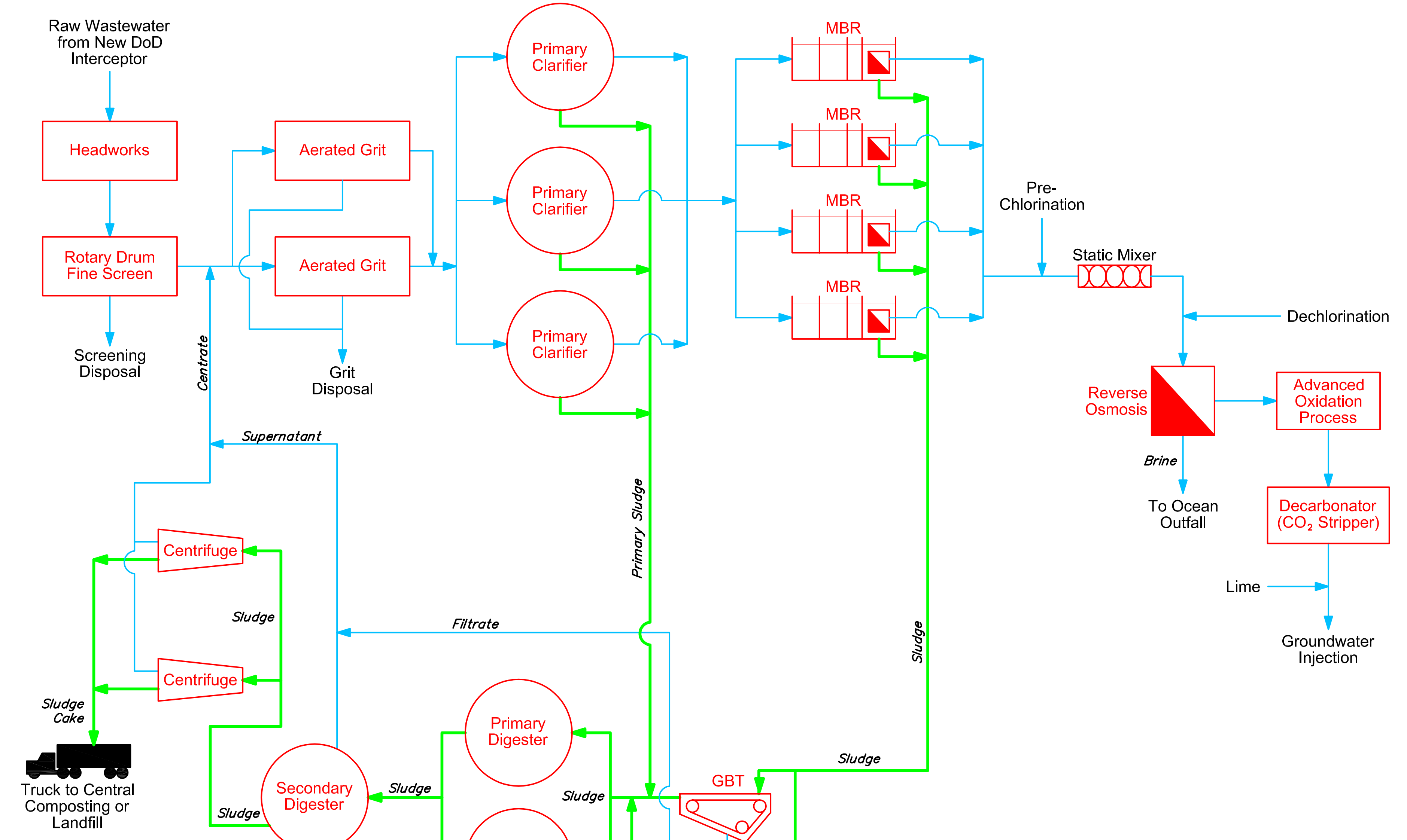

LEGEND

Existing Liquid Stream

Proposed Liquid Stream

Existing Solid Stream

Proposed Solid Stream

GBT Gravity Belt Thickener

MBR Membrane Bio Reactor

Final

Option 7: Build New DoD Tertiary Treatment Facility for Groundwater Recharge

Date: 6-08	Guam Wastewater Study	Figure
Project No. 101177	EarthTech	C-2

Flat Plate
Source: Enviroquip Inc.

External
Source: Parkson Inc

Hollow Fiber
Source: GE-Zenon

Figure C-3
Types of MBRs

Reverse Osmosis Membrane

In-Line UV System

Figure C-4
Typical RO Membrane and UV System

Guam Water Utility Study Report for Proposed USMC Relocation

July 2008, Revision 1

Department of the Navy
Naval Facilities Engineering Command, Pacific
258 Makalapa Drive, Suite 100
Pearl Harbor, HI 96860-3134

NAVFAC
Naval Facilities Engineering Command
NAVFAC PACIFIC

Contract Number N62742-06-D-1870/TO 0015

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Prepared for:

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Naval Facilities Engineering Command, Pacific
258 Makalapa Drive, Suite 100
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A Joint Venture of TEC Inc., Earth Tech, Inc., and EDAW, Inc.

Contract Number N62742-06-D-1870/TO 0015

EXECUTIVE SUMMARY

The purpose of this study is to identify all reasonable alternatives for potable water supply to support the proposed United States Marine Corps (USMC) relocation to Guam (hereafter referred to as the USMC Relocation) and provide sufficient and detailed information to support the Environmental Impact Statement process. In July 2007, the Naval Facilities Engineering Command, Pacific (NAVFAC Pacific), under Master Contract No. N62742-06-D-1870, issued a Task Order to TEC Joint Venture (JV) to prepare Water Utility Study Report and Planning Documents for the evaluation of potable water system improvements to support the USMC relocation. During the weeks of July 23rd and July 30th, Earth Tech visited NAVFAC Pacific facilities in Guam, and met with respective decision makers within NAVFAC and several other agencies in Guam to understand the regulatory requirements and design features for this project. This report presents the findings of the evaluations conducted based on the information gathered during the field study, and subsequent detailed analysis of the recommended water supply options.

WATER SUPPLY ALTERNATIVES

The following nine water resource alternatives are considered for this project:

- **Option 1** – Optimize groundwater resource development within Department of Defense (DoD) property while considering the potential impact to neighboring wells, the estimated remaining sustainable yield, the maximum safe pumping rate from individual wells to avoid salt water intrusion and excessive drawdown and the quality of the groundwater.
- **Option 2** – Determine the requirements for rehabilitation, treatment of well water, or replacement of existing wells not currently in production due to contamination, structural, and/or mechanical problems.
- **Option 3** – Purchase water from GWA. Establish the quantity of potable water that GWA would be agreeable to selling to DoD. This quantity will determine the amount of water needed from other resource alternatives.
- **Option 4** – Sediment dredging at Navy reservoir.
- **Option 5** – Expand Naval reservoir storage capacity by raising the dam crest.
- **Option 6** – Potable water reclamation through effluent reuse. If selected as a wastewater alternative, it would reduce requirements from groundwater resources.
- **Option 7** – Non-potable water reclamation through effluent reuse. If selected as a wastewater alternative, it would reduce requirements from groundwater resources.
- **Option 8** – Desalination.
- **Option 9 –** Develop a new surface water source.

SUMMARY OF FINDINGS

The current supply and future water demands for the USMC relocation and other DoD facilities are shown in Table E-1. The USMC Finegayan Base Complex will require a total of 12.1 million gallons per day (MGD) to meet the maximum daily demand. The water resource options were evaluated to identify a cost-effective means of addressing this water demand.

Table E-1: DoD Water Demands and Current Water Supplies

Units: MGD	USMC Finegayan (USMC+ other DoD	USMC Finegayan (USMC Only)	AAFB	Navy [c,d,e]
Current Supply	**2.3**	**2.3**	**4.7**	**11.4**
Current Supply Locations	Wells on-site / Navy Island-wide System	Wells on-site / Navy Island-wide System	Wells in South Annex/ Five Wells on AAFB	Navy Reservoir / Wells at Naval Hospital
Current Maximum Daily Demand	0.4	0.003	3.4	10.7
Future Maximum Daily Demand	12.1	10.7	5.2	12.0
Approximate Supply Allotted to GWA	-		-	4.0
Total Supply Needed [a]	**12.8**	**11.4**	**5.9**	**16.0**
Additional Supply Needed [b]	**10.5**	**9.1**	**1.2**	**4.5**

average daily demand - average daily domestic demand + industrial demand + unaccounted for water
maximum daily demand - maximum daily domestic demand + industrial demand + unaccounted for water
[a] Maximum Daily Demand + the size of the large well where the supply is based on wells.
[b] Total Supply Needed - Current Supply
[c] The Navy current and future demands are based on calculations according to *Unified Facilities Criteria (UFC) Water Supply Systems*. UFC 3-230-19n, DoD (2005)
[d] The Navy totals include Apra Harbor, the Ordnance Area, the Naval Hospital, Nimitz Hill and Barrigada.
[e] The Navy current supply is based on information provided in Engineering Concepts (2005).

A summary of the findings for the alternative review is provided in Table E-2.

Table E-2: Summary of Option Evaluation

Water System Alternative	Description of Option	Evaluation Considerations	Recommendation
Option 1 – Optimize Groundwater Resource Development within DoD Property	Development of new groundwater wells in the Northern Guam Lens Aquifer. Volume: dependent on sustainable yield and demand	• Salt water intrusion/ Excessive aquifer draw down. • Managed fully by DoD/ Reliable and secure. • Integrated System with GWA. • Sustainable yield/ GWUDI considerations.	Retained for detailed evaluation
Option 2 – Determine the Requirements for Rehabilitation, Treatment of Well Water, or Replacement of Existing Wells	Rehabilitation or replacement of under performing wells in the Northern Guam Lens Aquifer. Volume: 3.8 MGD (capacity of inactive wells; See Section 5.1)	• Salt water intrusion/ Excessive aquifer draw down. • Reduced stress on aquifer from installation of new wells. • Managed fully by DoD/ Reliable and secure. • Integrated system with GWA. • Sustainable yield/ GWUDI considerations.	Retained for detailed evaluation
Option 3 – Purchase Water from GWA	Purchase water from GWA . Volume: subject to availability	• New connections with DoD water systems. • Upgrading systems/ energy savings.	Retained for detailed evaluation

Water System Alternative	Description of Option	Evaluation Considerations	Recommendation
Option 4 – Sediment Dredging at Navy Reservoir	Dredge accumulated sediments in the Navy Reservoir thereby increasing capacity. Volume: 2.5 MGD (the additional capacity needed to return the Navy Reservoir to design capacity)	• Current storage capacity reduced due to sedimentation. • Need to dredge to sustain long-term supply • Managed fully by DoD.	Potentially viable. Additional analysis is necessary to fully evaluate.
Option 5 – Expand Naval Reservoir Storage Capacity by Raising Dam Crest	Raise the Navy Reservoir dam crest to increase capacity. Volume: 4 MGD (based on Barrett [1994])	• Technical complexity of design and implementation • Relative advantages compared to other viable alternatives • Overall cost	Eliminated
Option 6 – Potable Water Reclamation through Effluent Reuse	Wastewater treatment plant effluent is reused for human consumption. Volume: 8.8 MGD (Final Wastewater Utility Study)	• Negative connotations/ public perception. • Tied to wastewater study. • Relative advantages compared to other viable alternatives	Eliminated
Option 7 – Non-Potable Water Reclamation through Effluent Reuse	Wastewater treatment plant effluent is reused for non-potable uses Volume: 8.8 MGD (Final Wastewater Utility Study)	• Require separate distribution system. • Tied to Wastewater study. • Relative advantages compared to other viable alternatives	Eliminated
Option 8 – Desalination	Ocean water or brackish water is desalinated in order to obtain fresh water suitable for human consumption. Volume: Design to meet demand	• Construction of desalination plant/Effluent discharge. • High energy demands • Overall cost	Retained for detailed evaluation
Option 9 – Develop a New Surface Water Source	Identify surface water source, design, construct and operate source, treatment, transmission and distribution system Volume: 9.2 MGD (based on Barrett [1994] & SWCA/Tom Nance Water Resource Engineering [2007])	• Complexity in identification, design and implementation • Relative advantages compared to other viable alternatives • Overall cost	Eliminated; Implementation of the Lost River plan described in SWCG (2007) might provide additional supply if needed in the future.

A detailed review was conducted for the following options:

- **Option 1** – Optimize groundwater resource development within DoD property.
- **Option 2** – Determine the requirements for rehabilitation, treatment of well water, or replacement of existing wells not currently in production due to contamination, structural and/or mechanical problems.
- **Option 3** – Purchase water from GWA.
- **Option 8** – Desalination.

Options 4 and Option 9 (Lost River) are improvements to the Navy Reservoir. Additional study is needed to fully evaluate these options.

SUMMARY OF RECOMMENDATIONS

The recommended water system for the USMC relocation includes all elements of Option 1 with supplementary water supply from Option 3. Additional water supply to Naval facilities in southern

Guam is addressed by Option 2. A summary of the recommended future water supply is shown in Table E-3. The recommended water supply addresses the water demands in the north and has the flexibility to supply water to south Guam (Barrigada and other naval facilities). There is excess water of 2.5 MGD at USMC Finegayan and a deficit of 1.4 MGD for the Navy Island-wide System. The excess water from USMC Finegayan can supply the additional water to the Navy Island-wide System, if required.

Table E-3: DoD Water Supplies Including the Recommended Water System

Units: MGD	USMC Finegayan (USMC+ other DoD	USMC Finegayan (USMC Only)	AAFB	Navy
Supply				
Current	2.3	2.3	4.7	11.4
Option 1	13.0	10.0		
Option 2				0.5
Option 3 [a]	TBD	TBD		
Option 4 [b]				*2.5*
AAFB 5 On-Site Wells			1.7	
Planned Supply	**15.2**	**12.3**	**6.5**	**14.5**
Future Supply Locations	Wells on-site and on AAFB / Desalination	Wells on-site and on AAFB / Desalination	Wells on-site and on South Annex	Navy Reservoir / Wells at Naval Hospital
Potential Emergency Supply	Navy Island-wide System / AAFB / GWA	Navy Island-wide System / AAFB / GWA	USMC Finegayan	USMC Finegayan
Total Supply Needed [b]	**12.8**	**11.4**	**5.9**	**16.0**
Excess Water	**2.5**	**0.9**	**0.6**	**-1.4**

Note:
[a] Option 3 is not included in the Total Future Supply because it is not certain that the substantive modifications to the existing GWA system needed to provide water to DoD will be implemented.
[b] Option 4 will require further evaluation.

Figure E-1 and Figure E-2 show the elements of the recommended water system. The components of this water system include:

Water Resource Development

- 21 water supply wells plus one contingency well on AAFB (Option 1)
- Continued use of existing Navy wells on Finegayan (Option 1)
- Rehabilitation of NRMC #3 (Option 2)
- Monitoring wells on AAFB (10), Finegayan (2), South Andersen Annex (5), Naval Hospital (2) (Options 1 and 2)
- Installation of the five wells planned by AAFB (Option 2)

Water Treatment

- One 14 MGD water treatment plant on AAFB (Option 1)
- One 3.3 MGD water treatment plant on South Andersen Annex (Option 2)

- One 3.3 MGD water treatment plant on AAFB (10 planned wells) (Option 2)
- One 0.88 MGD water treatment plant at the Naval Hospital (Option 2)

Distribution

- Waterlines to transport the water from the wells to the treatment plant (Options 1 and 2)
- Waterlines to transport the treated water to storage (Options 1 and 2)
- Waterlines to distribute water throughout the Finegayan Base Complex (Option 1)
- An interconnect with AAFB water system for raw water (Option 1)
- A connection from the USMC WTP to with AAFB Santa Rosa treated water storage tank (Option 1)
- An interconnect with the Navy Island-wide water system (Option 1)
- Improvements to allow water to flow from the USMC system to the Andersen South Annex and Air Force Barrigada (Option 1)
- Improvements to the Navy Island-wide water system (Options 1 and 2)
  - Size pipes appropriately
  - Replace corroded pipes
  - Transport water to the south as well as north
- A connection to the GWA water system (Option 3)
- Pumping stations (Options 1 and 2)
- Elevated storage tanks on Finegayan Base Complex, Andersen South Annex and AF Barrigada (Options 1 and 2)
- Standby power (Option 1)

Costs for Basic Scenario 1, which is for the USMC only, are presented in Table E-4. These are the costs for Option 1 and Option 3, but assume the Finegayan Base Complex will only be used by relocated USMC personnel. The total present worth capital cost is $566M. The total present worth O&M cost is $108M assuming a 25 year life. The total present worth of life cycle costs for the recommended water system is $674M.

Table E-4 Cost Summary for Basic Scenario 1 (USMC Only)

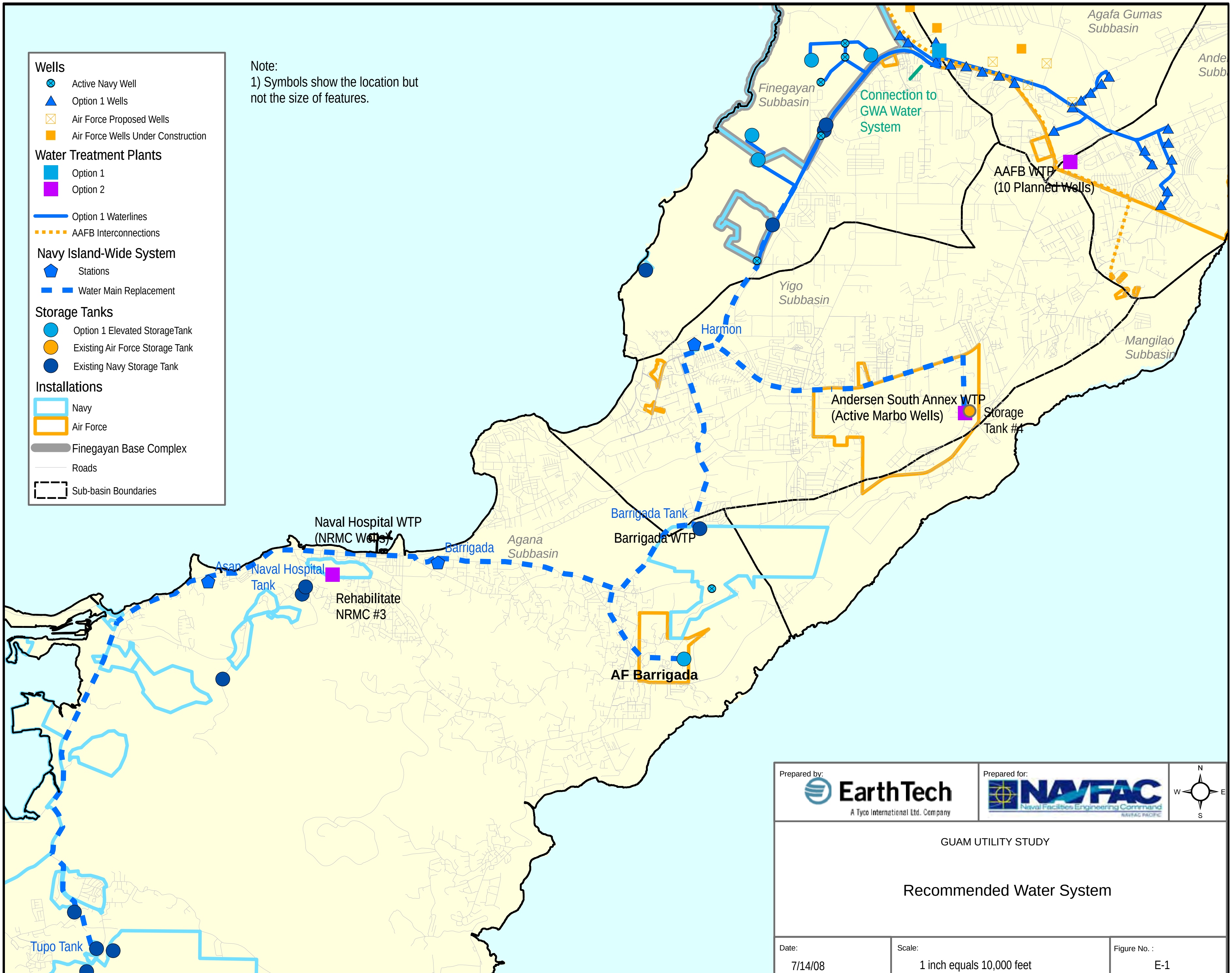
CAPITAL COSTS ($000)	Basic Scenario 1
Total Capital Cost	**$555,264**
Present Worth Guam Capital Costs	**$566,205**
O&M COSTS ($000)	
Total Annual O&M Cost	**$4,534**
Present Worth of O&M Costs (25 year life)	**$108,205**
Present Worth of Life Cycle Costs ($000)	**$674,410**

Costs for Basic Scenario 2, which includes all DoD loads, are presented in Table E-5. These costs are for USMC and other DoD populations combined. The total present worth capital cost of the Option 1, 2 and 3 is $708M. The total present worth O&M cost is $202M assuming a 25-year life. The total present worth of life cycle costs for the recommended water system is $910M.

Table E-5 Cost Summary for Basic Scenario 2 (All DoD Loads)

Option:	Recommended Alternative
CAPITAL COSTS ($000)	
Present Worth Guam Capital Costs	**$707,628**
O&M COSTS ($000)	
Total Annual O&M Cost	**$8,483**
Present Worth of O&M Costs (25 year life)	**$202,461**
Present Worth of Life Cycle Costs ($000)	**$910,088**

Note:
The cost for the recommended alternative is the sum of the costs for Option 1, 2 and 3 minus the cost of improvements to the Navy Island-wide System between Barrigada and the Tupo Tank which is included in the cost of Option 1 and Option 2.



Prepared by: EarthTech A Tyco International Ltd. Company

Prepared for: NAVFAC Naval Facilities Engineering Command NAVFAC PACIFIC

GUAM UTILITY STUDY

Recommended Water System

Date:	Scale:	Figure No.:
7/14/08	1 inch equals 10,000 feet	E-1

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FIGURES

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ACRONYMS AND ABBREVIATIONS

°C	degree Celsius
°F	degree Fahrenheit
AAFB	Andersen Air Force Base
AF	Air Force
ac-ft	acre-foot
BSP	Bureau of Statistics and Planning
CFR	Code of Federal Regulations
cy	cubic yard
DC	direct current
DoD	Department of Defense
DO	dissolved oxygen
DPW	Department of Public Works
EDR	electrodialysis reversal
EIS	Environmental Impact Statement
EPA	Environmental Protection Agency, United States
ESQD	explosives safe quantity distance
FAA	Federal Aviation Agency
ft	feet or foot
ft/day	feet per day
fps	feet per second
ft^2	square feet
ft^3	cubic feet
FY	fiscal year
GA	gallon
GCMP	Guam Coastal Management Program
GDAWR	Guam Department of Agriculture - Division of Aquatic & Wildlife Resources
GEPA	Guam Environmental Protection Agency
GIMDP	Guam Integrated Military Development Plan
GovGuam	Government of Guam
gpcd	gallons per capita per day
gpd	gallons per day
gph	gallons per hour
gpm	gallons per minute
GWA	Guam Waterworks Authority
GWUDI	Groundwater under the direct influence of surface water
HQ	Headquarters
JGMMP	Joint Guam Military Master Plan
JV	joint venture
LF	linear foot
MARBO	Marianas Bonins Command
MCB	Marine Corps Base
MCL	maximum contaminant level
MDD	maximum daily demand
MEU	Marine Expeditionary Unit
MCY	million cubic yards
MG	million gallons

mg/L	milligram(s) per liter
mgd	million gallons per day
mi^2	square miles
MLG	Marine Logistic Group
MLLW	mean lower low water
mm	millimeter
msl	mean sea level
NAS	Naval Air Station
NAVFAC	Naval Facilities Engineering Command
NAVMAG	Naval Magazine
NCO	Non-Commissioned Officer
NCTAMS	Naval Computer and Telecommunications Area Master Station
NCTS	Naval Computer and Telecommunications Station
NGLA	Northern Guam Lens Aquifer
NGLS	Northern Guam Lens Study
NPDES	National Pollution Discharge Elimination System
NWF	Northwest Field
NRMC	Navy Regional Medical Clinic
NTU	nephelometric turbidity unit
O&M	operation and maintenance
psi	pounds per square inch
PWL	pumping water level
Q	discharge pumping rate
Q/s	specific capacity
QOL	Quality of Life
RO	reverse osmosis
s	drawdown
SDWA	Safe Drinking Water Act
SOF	Special Forces
SOP	standard operating procedure
SY	sustainable yield; square yard
TBD	to be determined
TOC	total organic carbon
SWL	static water level
U.S.	United States
UFC	Unified Facilities Criteria
UFW	unaccounted for water
USCG	United States Coast Guard
USFWS	United States Fish & Wildlife Service
UIC	underground injection control
USGS	United States Geological Survey
USMC	United States Marine Corps
UV	ultraviolet
VOC	volatile organic compound
WRMP	Water Resources Master Plan
WTP	water treatment plant
WWTP	wastewater treatment plant

1. Introduction

1.1 PURPOSE

The purpose of this study is to identify all reasonable alternatives for potable water supply to support the proposed United States Marine Corps (USMC) relocation to Guam (hereafter referred to as the USMC Relocation) and provide sufficient and detailed information to support the Environmental Impact Statement (EIS) process. In July 2007, the Naval Facilities Engineering Command, Pacific (NAVFAC Pacific), under Master Contract No. N62742-06-D-1870 issued a Task Order to TEC Joint Venture (JV) to prepare a Water Utility Study Report and Planning Documents for the evaluation of potable water system improvements to support the USMC relocation. During the weeks of 23 July and 30 July, Earth Tech visited NAVFAC Pacific facilities in Guam, and met with respective decision makers within NAVFAC and several other agencies in Guam to understand the regulatory requirements and design features for this project. This report presents the findings of the evaluations conducted based on the information gathered during the field study, and subsequent detailed analysis of the recommended water supply options.

1.2 BACKGROUND INFORMATION

Guam is the southernmost and largest of the Mariana Islands, a group of 15 islands located approximately 3,600 miles west of Hawaii and 1,400 miles south of Japan. The island is a territory of the United States (U.S.). The main axis of the island runs NE-SW for a total length of 30 miles and the width varies from 8 miles wide at its northern tip, to 4 miles wide near the center to 11.5 miles in the south. The total area of the island is 212 square miles (mi^2). The current population of Guam is approximately 168,564 (2005 U.S. Census).

The Guam Integrated Military Development Plan (GIMDP), formerly the Joint Guam Military Master Plan (JGMMP), identified the planned increase in military population on Guam. Naval Computer and Telecommunications Station (NCTS) Finegayan, South Finegayan Housing area, Andersen Air Force Base (AAFB), AAFB Northwest Field, and Andersen South will provide locations for most of the planned USMC relocation to Guam. Potable water for the Apra Harbor Naval Reservation, AAFB, and other related Department of Defense (DoD) facilities are provided by separate Navy and Air Force systems. The Navy is providing water to Guam Waterworks Authority (GWA) from its surface water reservoir for a limited number of civilians in the southern part of the island.

Based on the findings presented in the GIMDP, NAVFAC has made the decision to perform a water utility study to identify all reasonable alternatives for potable water supply to support the USMC relocation to Guam. The study will address all reasonable alternatives with sufficient and detailed information to support the EIS process. The study will evaluate and recommend water resource, water distribution, storage, and treatment system improvements to Navy and Air Force water systems to meet future DoD requirements. The study will identify and develop alternatives to support the existing and planned DoD development. The study will provide environmental impact analysis (for use in the EIS) on the most feasible water system improvement alternatives. The study will identify and develop planning documents for projects that represent the best value alternative for the water system.

1.3 WATER SUPPLY ALTERNATIVES

As specified in the scope of work the following nine water resource alternatives are considered for this Project:

- **Option 1** – Optimize groundwater resource development within DoD property while considering the potential impact to neighboring wells, the estimated remaining sustainable yield, the maximum safe pumping rate from individual wells to avoid salt water intrusion and excessive drawdown, and the quality of the groundwater.

- **Option 2** – Determine the requirements for rehabilitation, treatment of well water, or replacement of existing wells not currently in production due to contamination, structural, or mechanical problems.
- **Option 3** – Purchase water from GWA. Establish the quantity of potable water that GWA would be agreeable to selling to DoD. This quantity will determine the amount of water needed from other resource alternatives.
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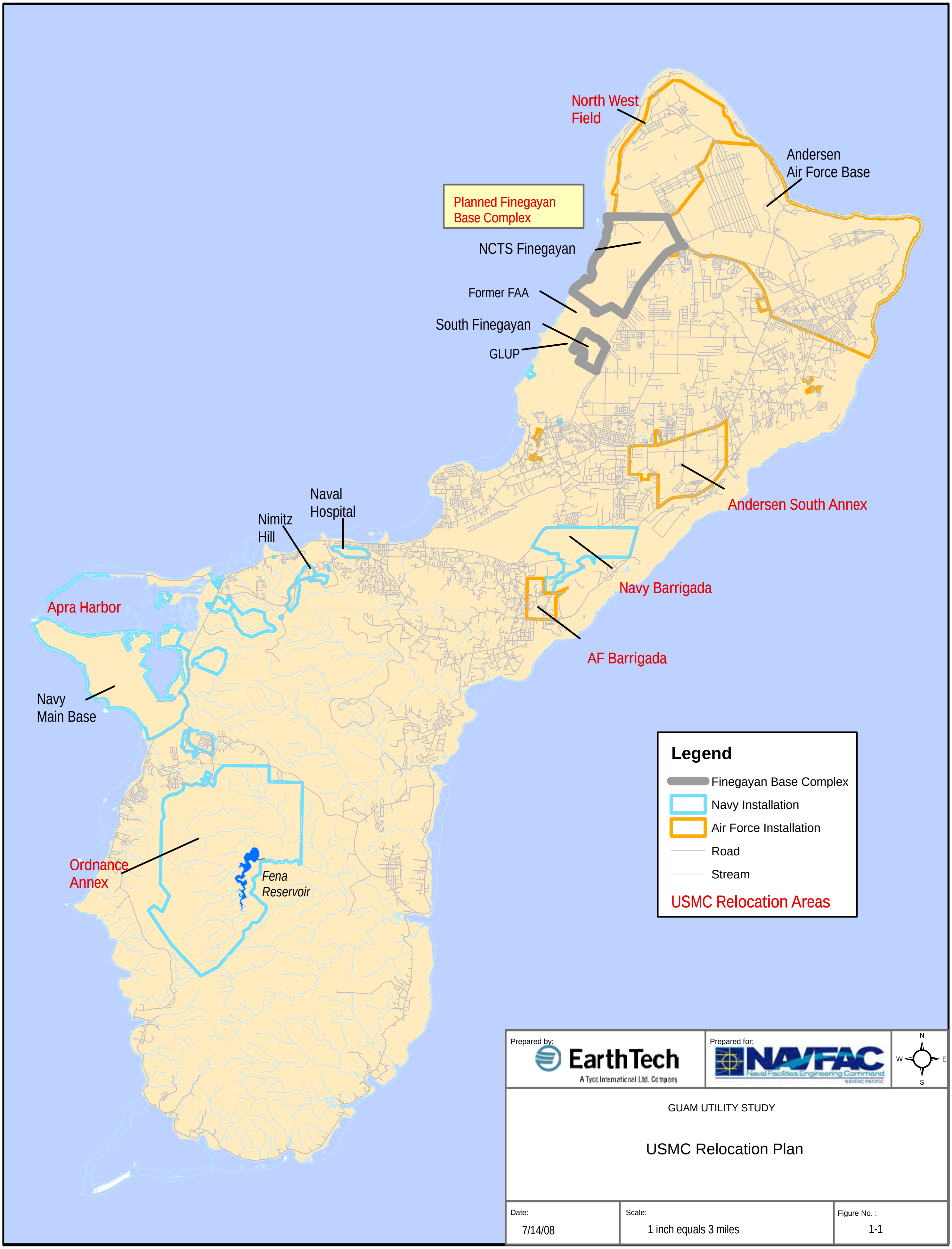
- **Option 7** – Non-potable water reclamation through effluent reuse. If selected as a wastewater alternative, it would reduce requirements from groundwater resources.
- **Option 8** – Desalination.
- **Option 9 –** Develop a new surface water source.

The Scope of Work is provided in Appendix A.

1.4 PLANNED USMC FACILITIES

The Master Plan for the planned USMC relocation is currently in development and the planning information available to date has been used for the purposes of this study. The assumed DoD future water supply requirements are based on Alternative 1 of the Final Report of Water, Wastewater, and Solid Waste Management Impact Assessment for JGMMP (HPE 2006) supplemented with the latest available detailed information from the TEC JV planners and a USMC planning document (HHF 2007). The areas which will have a future Marine Corp presence are identified in Figure 1-1 according to Alternative C of the Master Plan currently in development. Note that the details of the plan are still under development. The information in the HHF (2007) is used in this document to evaluate water supply needs, but the final plan may differ from those used in this document. In Alternative C, housing for the USMC relocation is limited to the Finegayan Base Complex. The recommended water system will have some flexibility to cover alternative USMC housing arrangements in the Andersen South Annex and Air Force Barrigada. The water demand estimates do not include the added demand from non-resident military workers such as USMC staff who will work on AAFB, but the design will connect the water systems to allow the demands to be met as needed on the bases. Current and future military populations assumed for this study are presented in Table 1-1. For this study, the army is assumed to be housed at the Finegayan Base Complex.

A list of facilities required for the USMC relocation is presented in Table 1-2.



Prepared by: EarthTech A Tyco International Ltd. Company

Prepared for: NAVFAC Naval Facilities Engineering Command NAVFAC PACIFIC

GUAM UTILITY STUDY

USMC Relocation Plan

Date:	Scale:	Figure No. :
7/14/08	1 inch equals 3 miles	1-1

Table 1-1: Current and Future Military Populations

Service	Active Duty	Dependents	On-Base Civilian	Total
Baseline (FY05)				
USMC	3	2	1	6
Air Force	2,145	2,950	805	5,900
Navy	4,350	5,230	1,631	11,211
Army	30	50	11	91
USCG	140	180	53	373
SOF	-	-	-	-
Notional Increase				
USMC	8,552	9,000	3,207	20,759
Air Force	1,656	1,100	244	3,000
Navy	1,300	50	487	1,837
Army	630	950	236	1,816
USCG	81	103	30	214
SOF	350	630	131	1,111
Total Future Loading				
USMC	8,555	9,002	3,208	20,765
Air Force	3,801	4,050	1,049	8,900
Navy	5,650	5,280	2,118	13,048
Army	660	1,000	247	1,907
USCG	221	283	83	587
SOF	350	630	131	1,111

Table 1-2: USMC Facility Requirements

Description	Size	Description	Size	Description	Size
Helicopter Landing Pad	1111 SY	Maintenance Hangar OH Space	130720 ft²	Dependent School, 1 through 6	420850 ft²
Taxiway	9100 SY	Maintenance Hangar 01 Space	61110 ft²	Dependent School, High	262500 ft²
Aircraft Parking-Apron	172065 SY	Maintenance Hangar 02 Space	63706 ft²	Personnel Weather Shelter	15300 ft²
Aircraft Access Apron	9833 SY	Aviation Armaments Shop	5000 ft²	Kennel	450 ft²
Aircraft Washrack-Pavement	2250 SY	Parachute/Survival Equipment Shop	16344 ft²	Rehab Center	45000 ft²
Aircraft Rinse Facility	1200 SY	Engine Test Cell	2 EA	Recycling Center	1 EA
Aircraft Compass-Calibration Pad	2000 SY	Power Check Pad	1 EA	Religious Ministry Facilities	40172 ft²
Arming-Dearming Pad	3910 SY	Boat Shop	8050 ft²	Post Office	10701 ft²
Line Vehicle Parking	200 SY	Amphibian Vehicle Maintenance Shop	176430 ft²	Exchange Retail Store	37950 ft²
Ordnance Handling Pad	2064 SY	Refueler Vehicle Shop	3230 ft²	Location Exchange	22575 ft²
Combat Aircraft Ordnance Loading Area	2405 SY	Vehicle Holding Shed	13440 ft²	Exchange Central Administration	16900 ft²
Fire & Rescue Vehicle Alert Pad	175 SY	Auto Organizational Shop	225482 ft²	Exchange Cafeteria	24300 ft²
Tactical Support Van Pad	2444 SY	Field Maintenance Shop	159910 ft²	Exchange Snack Stands	1900 ft²
Filling Station	---	Vehicle Wash Platform	65 EA	Exchange Auto Parts Store	10750 ft²
Filling Station Building	65 SF	Grease Rack	39 EA	Exchange Food Store	3300 ft²
Vehicle Ready Fuel Storage	138000 GA	Heavy Gun Shop	11340 ft²	Exchange Service Outlet	28715 ft²
Communications Center	41680 SF	Electronic/Comm Maint Shop	319437 ft²	Exchange Dry Cleaning Shop	15050 ft²
Visual Approach Slope Indicator	2 EA	Field Maintenance Shop, Comm/Elex	41650 ft²	Exchange Maint Shop	2419 ft²
Wind Direction Indicator	2 EA	Construction Weight Handling Equip Shop	5600 ft²	Bank	6860 ft²
Parking&Service Area Lighting	2022 LF	Battery Shop	197 EA	Credit Union	14200 ft²
Simulated Carrier Deck Lighting	1 EA	Aviation GSE Maintenance Shop	8515 ft²	Temporary Lodging	73188 ft²

Description	Size	Description	Size	Description	Size
Taxiway Lighting	5800 LF	Aviation GSE Holding Shed	6232 ft^2	Commissary	45000 ft^2
Heliport Pad Lighting	400 LF	Dental Equipment Repair Shop	3350 ft^2	Comm Cold Storage Det	27000 ft^2
Aircraft Fire& Rescue Station	1700 ft^2	Field Maintenance Shop (Parachute)	37510 ft^2	Family Services Center	10500 ft^2
Aircraft Line Operations Building	240 ft^2	Public Works Shop	28300 ft^2	Amusement Center	6560 ft^2
Aircraft Operations Building	9760 ft^2	Public Works Storage	16000 ft^2	Exchange Service Station	6710 ft^2
Control Tower	2956 ft^2	High Explosive Magazine	30000 ft^2	Exchange Gas Station	1290 ft^2
LOX Pad	5596 ft^2	Inert Storage Building	3000 ft^2	Exchange Customer Op. Car Wash	2300 ft^2
Ordnance Operations Building	15100 ft^2	Ordnance Assembly Area	1111 SY	Thrift Shop	4300 ft^2
Armory	56968 ft^2	Cold Storage Warehouse	9200 ft^2	Hobby Shop--Arts/Crafts	17740 ft^2
Marine Barracks	4215 ft^2	Organic Unit Storage	794037 ft^2	MWR Supply/Support Facility	10080 ft^2
Alert Force Building	6000 ft^2	Specific Purpose Warehouse	242000 ft^2	Hobby Shop--Automotive	14790 ft^2
POL Operation/Sampling Building	4300 ft^2	Controlled Humidity Warehouse	88590 ft^2	Entertainment Center	10050 ft^2
Operational Haz/Flam Storage	30167 ft^2	General Storage Shed	18200 ft^2	Bowling Alley	15260 ft^2
Expeditionary Air Control Site	2 EA	Integrated Log. Overhaul & Outfitting	151120 ft^2	Gymnasium	63000 ft^2
Cargo Staging Area	72600 SY	Open Storage (Vehicle/Equip Parking)	124406 SY	Indoor Fitness Facility	61900 ft^2
Waterfront Transit Shed	10000 ft^2	Dental Clinic	22160 ft^2	Skating Rink	16100 ft^2
Waterfront Operations Building	6000 ft^2	Medical Clinic	47030 ft^2	Information Ticket and Travel Office	1210 ft^2
Landing Craft Ramp	2 EA	Administrative Office	106886 ft^2	Contracted Leisure Travel Agency	900 ft^2
Academic Instruction Building	630 ft^2	Division/Wing Headquarters	272410 ft^2	Recreation Center	6000 ft^2
Applied Instruction Facility	16720 ft^2	Regimental/Group HQ	64730 ft^2	Youth Center	29291 ft^2
General Purpose Auditorium	6000 ft^2	Battalion/Squadron HQ	222936 ft^2	Commissioned Officers Open Mess	25000 ft^2
Operational Trainer Facility	70230 ft^2	Company/Battery HQ	141080 ft^2	Enlisted Personnel Club	59400 ft^2
Indoor Arms Range	20 FP	Bachelor Enlisted Quarters E1-E3	725913 ft^2	Staff NCO Club	25000 ft^2
Maneuver/Training Area (Light)	---	Bachelor Enlisted Quarters E4-E5	498154 ft^2	Consolidated Officers/EP Open Mess	54700 ft^2
Battle Sight Zero Range	---	Bachelor Enlisted Quarters E6-E9	102935 ft^2	Package Store	10800 ft^2
Rifle Known Distance Range	---	Transient Personnel Unit Quarters E5-E6	5850 ft^2	Child Development Center	42600 ft^2
Machine Gun Field Fire Range	---	Enlisted Dining Facility	47145 ft^2	Library	20000 ft^2
Mortar Range	1 EA	Bachelor Officer Quarters, W1-O2	74745 ft^2	Recreation Pavilion	4000 ft^2
Fire and Movement Range	---	Bachelor Officer Quarters, O3 & above	30225 ft^2	Exchange Warehouse	22091 ft^2
Hand Grenade Range	8 FP	Fire Station	30170 ft^2	Educational Services Office	23100 ft^2
Engineer Range	8 FP	Issue-Uniform Center	7203 ft^2	Bathhouse	14500 ft^2
Training Course	6 EA	Brig Confinement	23220 ft^2	Playing Courts	19 EA
Combat Training Pool/Tank	65 EA	Police Station	15620 ft^2	Outdoor Playing Fields	12 EA
MOUT (Large)	1 EA	Gate/Sentry House	248 ft^2	Outdoor Swimming Pool - Installation	3 EA
Corrosion Control Hangar	13284 ft^2	Dependent School-Kindergarten	50160 ft^2		

Source: HHF 2007

EA	each	GA	gallon
LF	linear foot	ft^2	square foot
SY	square yard		

More details of the primary areas which will be occupied by the Marine Corps are provided below assuming Alternative C is selected.

1.4.1 Finegayan Base Complex

The planned development at the Finegayan Base Complex may include:

- Family housing; and,
- Operations (including Bachelor Quarters and main-side Quality of Life [QOL] facilities).

Water demand associated with the USMC relocation at the Finegayan Base Complex is assumed to be the industrial and fire demands associated with the planned structures, and the domestic demand associated with the relocated Marines and their dependents, civilian support, and transients. Some members of the SOF, US Army and their dependents may be housed at the MCB.

1.4.2 North Ramp Aviation Facilities

The concept for aviation operations is to develop the North Ramp of AAFB to provide a rotary wing facility, as proposed in the GIMDP. Facilities planned for the North Ramp are those directly related to aviation operations in compliance with the AAFB zoning plan. The remaining elements of the Marine Aircraft Wing would be located at NCTS Finegayan.

Operations and facilities at the North Ramp include:

- Facilities for fixed wing aircraft on the main apron;
- Separate rotary wing facilities;
- Maintenance areas; and
- Facilities for transient squadrons to be sized for full time presence.

Water demand associated with the USMC relocation at the North Ramp Aviation Facilities is assumed to be the industrial and fire demands associated with the planned structures.

1.4.3 Naval Base Development

Naval Base Guam, headquartered in Apra Harbor, is the only location on Guam capable of providing for USMC embarkation operations training and contingency operations.

Principal program concepts include:

- Facilities need to include administrative space, support space (e.g., bunk room, mess facilities, showers, and computer connectivity), a transit warehouse for temporary covered storage of materials and troop muster, an organizational maintenance building for equipment and vehicle repair, a wash rack, and snake inspection area.
- Approximately seven to eight acres of open storage area for cargo and equipment staging.

Water demand associated with the USMC relocation is assumed to be primarily the industrial and fire demands associated with the planned structures. It is assumed that the base will house the Navy and USCG.

1.4.4 Ordnance Annex Development

GIMDP initiatives impact the Ordnance Annex as a result of the increased USMC ground elements requirement for ammunition storage, and by the need for an indirect fire training range which cannot be met elsewhere on Guam.

Major elements of the plan include:

- Construct 53,000 square feet (ft^2) of replacement magazine space in the central portion of the Annex to allow appropriate Public Traffic Route clearance for roads and areas to be developed as part of the firing range.
- Construct 25,000 ft^2 of new magazine capacity.
- Construct a mortar and 40 millimeter Training Projectile training range.

Water demand associated with the USMC relocation at the Ordnance Annex is assumed to be industrial and fire demands associated with the planned structures.

1.4.5 Maneuver Training Areas

Andersen South provides the location for a company-sized maneuver training area. It is anticipated that a Military Operations in Urban Terrain facility for which a basic requirement has been identified, would be located here along with an engineer equipment training area, a motor transport driver training area, and some facilities (if required) to support Division Schools. A range management facility with parking, storage for range vehicles, communications, internal roadways, and covered instructional areas would also be needed.

It is assumed that the facilities to be used by the Marines currently exist and the industrial and fire protection water demands and storage requirements are met by the existing supply.

Other maneuver training will take place at different areas for different sized maneuver elements. It is anticipated that squad and platoon level training will largely occur in open lands about the Finegayan base, and within walking distance at Northwest Field, just to the north of Finegayan.

No additional water demand is assumed for maneuver training.

1.5 PHYSICAL ENVIRONMENT

Relevant aspects of the physical environment important for the purposes of this study are described below. This section describes the northern Guam topography, climate, geology and hydrogeology to support the general design for a water supply system. Specific information on the water budget for the Northern Guam Lens Aquifer (NGLA), which is critical to a comprehensive analysis and a thorough analysis of the alternatives is provided in Section 6.1 of this report.

1.5.1 Topography

The island is sharply divided into two distinct physiographic provinces by a NW-SE trending fault near the island's center. To the north of the fault is a low-relief limestone plateau that rises in elevation towards the northeast, with coastal cliffs standing from 200 to 600 ft above mean sea level (msl). The limestone is so permeable that normal stream drainage patterns have not been able to form; instead a gentle karst topography has developed and drainage takes place directly into the ground or through sinkholes. South of the fault is a rolling to sharply dissected terrain that consists of extrusive and pyroclastic volcanic rocks that are fringed in the east by an uplifted fossil reef limestones, which are contemporaneous with limestones in the north. A narrow band of limestone also caps the highest mountain range which lies several miles inland and parallel to the western coast of the island. The highest peak, Mt. Lamlam, reaches 1,332 ft above msl. Two distinct drainage patterns have developed in the south: west of the high mountains drainage is by steeply sloping parallel streams; while to the east the drainage pattern is generally dendritic with some modifications imposed by faulting and other structural features. Limestone areas in the south have no distinct drainage features. Water resources in the south are predominantly from streams and a surface water reservoir, while groundwater from the limestone is the source of potable water in the north.

1.5.2 Climate

The climate on Guam is warm and humid throughout the year. Average temperatures range from 85 to 89 degrees Fahrenheit (°F) in the afternoon and 70 to 75°F in the evening. The relative humidity is 65 to 75 percent in the afternoon, and 85 to 100 percent in the evening.

The constant northeasterly trade winds result in a well-defined dry season that runs from January through May, which is broken by an occasional shower. July to November is the wet season during which trade winds are frequently interrupted by tropical storms with heavy rain. The months of June and December separate the two seasons and are transitional in nature.

The average annual rainfall on Guam is 80 to 90 inches, but is locally variable. Near Apra on the western coast the mean is 85 inches, while it averages 115 inches in the southern mountains. On the northern limestone plateau, rainfall averages between 85 and 105 inches annually. About 68 to 73 percent of the annual precipitation occurs during the wet season and 15 to 20 percent during the dry season. The remainder occurs during the transitional months.

1.5.3 Geology

The sharp division of Guam into the two distinct geologic provinces of approximate equal size is by the NE-SW trending Pago-Adelup fault. North of the fault lies a limestone plateau, while a dissected volcanic upland lies south of the fault. Volcanic units preceded limestone deposition north of the fault and the volcanic surface had been eroded before limestone emplacement such that gross unconformities separate the rock types.

The oldest rocks are Late Middle Eocene pillow basalts and basalt flows and came from a volcano located west of Guam. These rocks are overlain by Late Eocene to Early Oligocene tuffaceous shale and sandstone which is interbedded with breccia and lava flows. A second volcanic center developed to the southwest and produced extensive lavas and pyroclastic deposits until its final collapse in the Early Oligocene. Volcaniclastic sedimentation continued through the Late Oligocene to the Early Miocene, when massive reef and lagoonal limestone formation began over the volcanics.

The Miocene Bonya Limestone and the Miocene-Pliocene Alifan Limestone are found directly on top of the volcanic units in the interior highlands of southern Guam. The Alifan Limestone is also found in the northwest corner of the southern province and on the flanks of Mt. Santa Rosa in the north. The Alifan Limestone was succeeded by deposition of detrital Miocene Pliocene Barrigada Limestone, which is an extensive unit exposed in the interior of the northern plateau. This unit is a principal aquifer in that province and extends well above and below the position of the fresh-water lens. The Barrigada Limestone grades laterally and upward into the Pliocene-Pleistocene Mariana Limestone, a reef and lagoonal deposit that dominates the northern plateau. The high cliffs north of the Pago-Adelup fault are exposures of the Mariana limestone, as are the cliffs of the Orote Peninsula to the south of Apra Harbor.

The Mariana Limestone has been interpreted as a shallow-water fringing and barrier reef deposit that is thickest along the periphery of the northern peninsula. The Mariana contains large openings, voids and caverns, which are typical of massive coral growth. Inland, a lagoonal facies of the Mariana Limestone grades into the Barrigada Limestone, which is interpreted as a deep-water limestone of bank and off-reef detrital deposits. These deposits are heterogeneous and are often cemented and filled with fine calcareous mud. The Barrigada Limestone dominates the interior of the northern plateau and accounts for the greatest volume of the fresh-water lens aquifer. Most of the limestone bedrock of Guam has undergone extensive fresh-water diagenesis, resulting in significant changes in primary porosity most notably modification by karst processes. In northern Guam, infiltrating rainwater dissolves the limestone creating karst features such as sinkholes, caves, and dissolution-widening fissures. Generally, the result is an increased hydraulic conductivity. In southern Guam, karst processes have resulted in caves and spring development.

1.5.4 Hydrogeology

Nearly all of Guam can be described in terms of two rocks types: limestone and volcanics. Generally speaking, the volcanics can be considered aquicludes when they are associated with limestone. In a strict sense, both the limestone and the volcanics are aquifers; however, aquifer properties of the limestone make it favorable for use as an exploitable fresh water source. In southern Guam, the lack of extensive limestone deposits and the unfavorable hydraulic properties of the volcanic rock typically preclude the exploitation of groundwater as a fresh water source. The primary water supply in the south is surface water in the form of the Navy Reservoir, which is supplemented to a minor degree by springs (Barrett 1994). In northern Guam, the sole water source is a limestone aquifer which contains a freshwater body within the Mariana Limestone and the Barrigada Limestone called the Northern Guam Lens Aquifer (NGLA) (Mink 1976; CDM 1982).

Hydraulic characteristics of the limestone aquifer are highly variable in both a horizontal and vertical direction. Mink (1976) suggested that the hydraulic conductivity of limestone units, particularly the Barrigada Limestone, is "profoundly affected by the quantity of clay mixed with the limestone components" and further implied that local hydraulic properties are skewed to lower values, due to specific conditions surrounding a specific location (e.g., well, infiltration gallery), whereas regional hydraulic properties are generally higher, as they represent an average between impermeable rock and open caverns (e.g., fractures and karst features). Mink classified argillaceous limestones as those containing up to 10 percent clay content and having a local hydraulic conductivity as low as 20 ft per day (ft/day). This compares to a "clean" limestone, having low clay content and having a local conductivity of about 200 ft/day. Regional hydraulic conductivities are lowest in the more argillaceous southern portion of the NGLA, ranging from 500 to 1,500 ft/day, whereas clean limestones to the north can reach as high as 15,000 to 20,000 ft/day (CDM 1982). An average regional hydraulic conductivity of 2,000 ft/day was proposed by Mink (1976); however, modeling studies suggest that best fit simulations require a regional hydraulic conductivity of around 20,000 ft/day (Contractor 1983; Jocson et al. 2002). Based upon these early studies, preliminary estimates of average hydraulic conductivity in the limestone were proposed for well productivity purposes (Mink 1976; CDM 1982):

- Clean limestone: 190 ft/day
- Probable limestone: 120 ft/day
- Argillaceous limestone: 52 ft/day
- Very argillaceous limestone: 26 ft/day

The NGLA is generally lens-shaped in cross-section and is underlain by denser seawater; however, the base is modified where it contacts the relatively impermeable basement volcanic rock. Mink (1976) proposed the term *basal zone* where the lens is underlain by seawater, and *para-basal zone* where the base of the lens is volcanic rock. Typical steady state hydraulic head in the basal zone is approximately a meter above msl; in the para-basal zone it can range from two to five meters above msl, depending upon local hydraulic conductivity. Lens geometry in the para-basal zone is dependent upon freshwater recharge rates, basement elevations, basement slopes, and hydraulic conductivity.

Based upon basement volcanic contours the NGLA was divided into a series of six sub-basins (CDM 1982). The sub-basins boundaries reflect the basement topography forming hydrological divides in the subsurface. Sub-basin boundaries were subsequently revised by McDonald and Jensen (2003) on the basis of updated basement contours. The *Northern Guam Lens Study* (NGLS) (1982) proposed guidelines that prescribed appropriate well depths and pumping rates for basal and para-basal zones of the NGLA:

Groundwater Area	Maximum Capacity (gallons per minute [gpm])	Minimum Spacing	Preferred Depth (ft)	Maximum Depth (ft below msl)
Basal				
Groundwater head <4 ft above msl	200	300	≤25	40
Groundwater head >4 ft above msl	350	300	≤35	50
Para-basal				
Southern Agana sub-basin	200[a]	300	- -	50
Upper Yigo-Tumon sub-basin	750	300	- -	50-60
Other para-basal areas	500	300	- -	50

[a] *350 gpm under special conditions*

The Guam Environmental Protection Agency (GEPA) currently uses these guidelines and bases other local regulations on the 1982 NGLS.

2. Existing Water Systems in Northern Guam

2.1 SERVICE AREAS AND WATER SYSTEMS

The existing water supply in Guam is comprised of the following three separate, but partially interconnected water systems.

- AAFB Water System
- Navy Water System
- GWA Water System

The first two of the above systems are the DoD systems, while the GWA system is the primary source of water to the general public in Guam. The locations of the service areas for each system including the distribution lines are shown on Figure 2-1 and Figure 2-2. Active supply wells are listed in Table 2-1.

Andersen Air Force Base Water System

AAFB is located in northern Guam and covers approximately 24.5 mi^2. The base consists of two major areas and several smaller areas called annexes. The major areas collectively known as the "main base" are North Field containing the base's active operations and Northwest Field (NWF) containing abandoned runways and landing fields. The annexes are scattered throughout northern Guam and contain base housing, communications services, and water and petroleum storage facilities. The two largest annexes are the Marianas Bonins Command (MARBO) Annex (also known as Andersen South) and the Harmon Annex. The MARBO Annex lies about 4 miles south of the main base and covers approximately 3.8 mi^2. The Harmon Annex, 4 miles south of NWF, covers about 2.8 mi^2 in Western Guam.

The AAFB water system supplies water to Andersen NWF and Andersen South, and include an off-base water supply, treatment, storage and transmission systems and an on-base water distribution system. The off-base water supply and transmission system includes nine water production wells, two booster pump stations, three reservoirs, chlorination facilities, a fluoridation facility, and approximately 80,000 ft of water lines. The existing on-base water distribution system includes a pump station, three water storage tanks, and approximately 700,000 ft of water lines.

Water is currently supplied from wells located in the MARBO Annex, stored, disinfected and fluoridated, then pumped to the main base. The nine off-base production wells are located at Andersen South Annex and the Tumon area and draw water from the Northern Guam Lens Aquifer. Water is currently supplied to AAFB from seven of the nine off-base water production wells. Two wells, Marbo Well No. 2 and Tumon Maui Well, are currently not operational due to the detection of volatile organic compounds (VOCs) in the groundwater at concentrations which exceed U.S. Environmental Protection Agency (EPA) Maximum Contaminant Levels (MCLs) for drinking water. Five wells have been installed in the NWF, and five more wells have been planned.

Table 2-1: Active Supply Wells

Well	Capacity (gpm)
Air Force	
Marbo #1	170
Marbo #3	210
Marbo #5	180
Marbo #6	480
Marbo #7	255
Marbo #8	490
Marbo #9	400
Wells 3a, 5, 6 ,7 8	1100
Navy	
Navy Reservoir	6260
Almagosa Spgs	928
Bona Springs	426
NCTS A	180
NCTS B1	200
NCTS #5	100
NCTS #6	125
NCTS #7	235
NCTS #9	200
NCTS #10	180
NCTS #11	180
NCTS #12	180
NRMC #1	234
NRMC #2	200
GWA	
A-01	264
A-02	240
A-03	265
A-04	310
A-05	253
A-06	315
A-08	253
A-09	318
A-10	310
A-12	177
A-13	313
A-14	301
A-15	318
A-17	292
A-18	304
A-19	206
A-21	294
A-23	344
A-25	347
A-26	71
GWA (cont.)	
A-30	788
A-31	350
A-32	240
AG-02	600
D-01	114
D-02	216
D-04	285
D-05	155
D-06	235
D-07	229
D-08	195
D-09	257
D-10	252
D-11	249
D-12	208
D-13	196
D-14	269
D-15	242
D-16	235
D-19	205
D-20	227
D-21	238
D-25	339
D-27	320
D-28	0
EX-05	410
EX-11	221
F-01	144
F-02	154
F-03	157
F-04	142
F-06	220
F-07	0
F-09	199
F-10	204
F-11	189
F-12	160
F-13	0
F-15	238
F-16	340
F-17	239
F-18	352
F-19	219
GWA (cont.)	
F-20	254
G-501	133
H-01	286
HGC-02	582
M-01	244
M-02	209
M-03	225
M-04	216
M-05	225
M-06	229
M-07	242
M-08	237
M-09	148
M-15	253
M-17B	316
M-18	291
M-20A	228
M-21	343
M-23	257
St Rita Sprg	165
Y-01	240
Y-02	238
Y-03	221
Y-04A	240
Y-05	157
Y-06	240
Y-09	599
Y-10	274
Y-12	312
Y-15	520
Y-16	319
Y-17	320
Y-18	484
Y-19	404
Y-20	379
Y-21A	251
Y-22	296
Y-23	318

References:

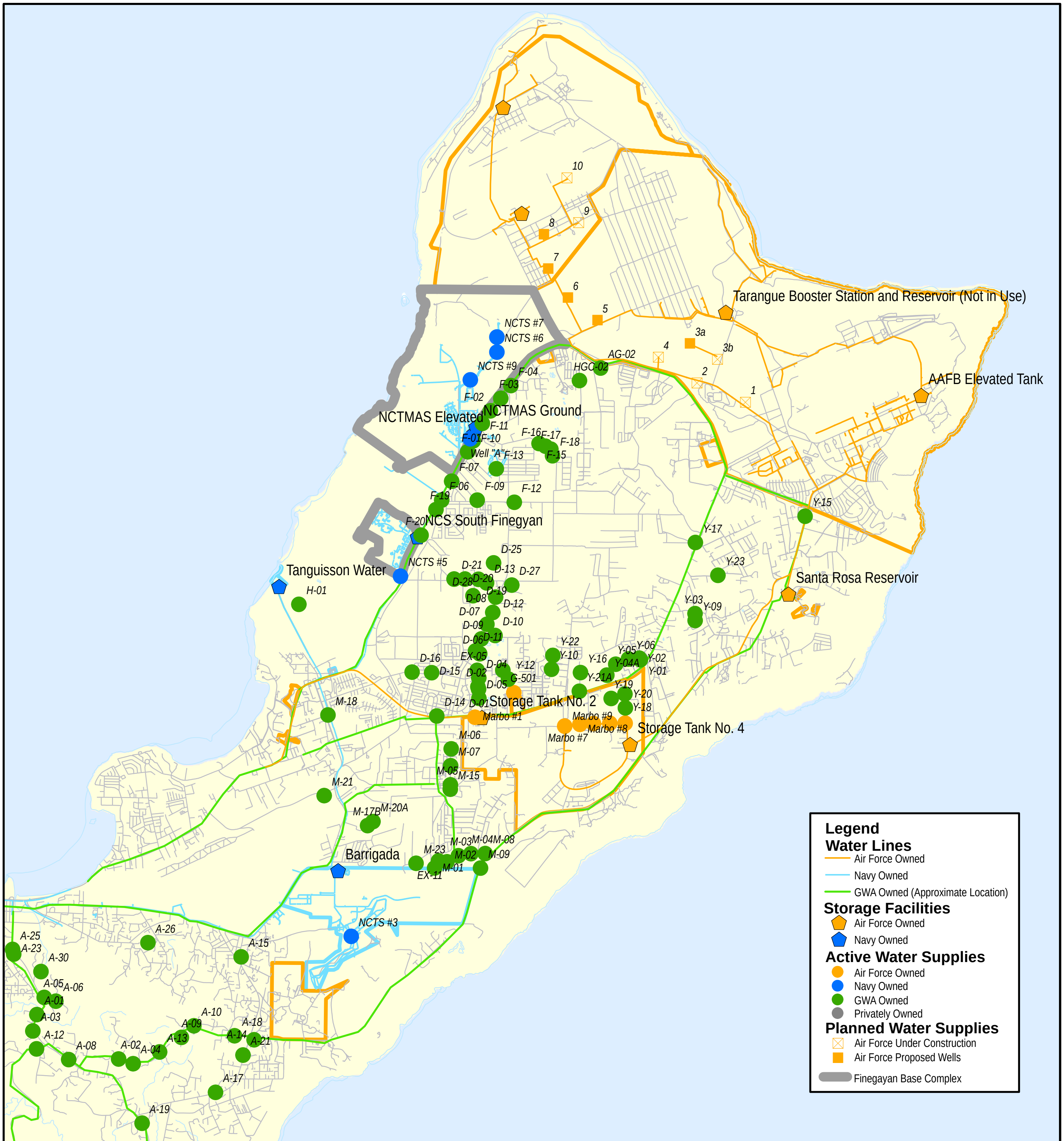
Navy– measured or calculated values from Navy Utility Report, 2005 and guidance from the Navy;

Air Force – measured values from AAFB Utility Report, May 2006

GWA - 30-Day Average Rates from GWA WRMP

Notes:

1. NRMC #2 is operational but production is limited.
2. The production rates for NCTS #10, 11 and 12 are assumed to be 180 gpm.
3. Wells 3a, 5, 6, 7, and 8 have been constructed but are not yet active.



Note:
1) The proposed location are shown for the AAFB wells currently under construction.
2) Two additional Navy wells are operational (NCTS #12 and NCTS "B1"), but coordinates were not available.
3) Symbols indicate the approximate location, but not the size of features.

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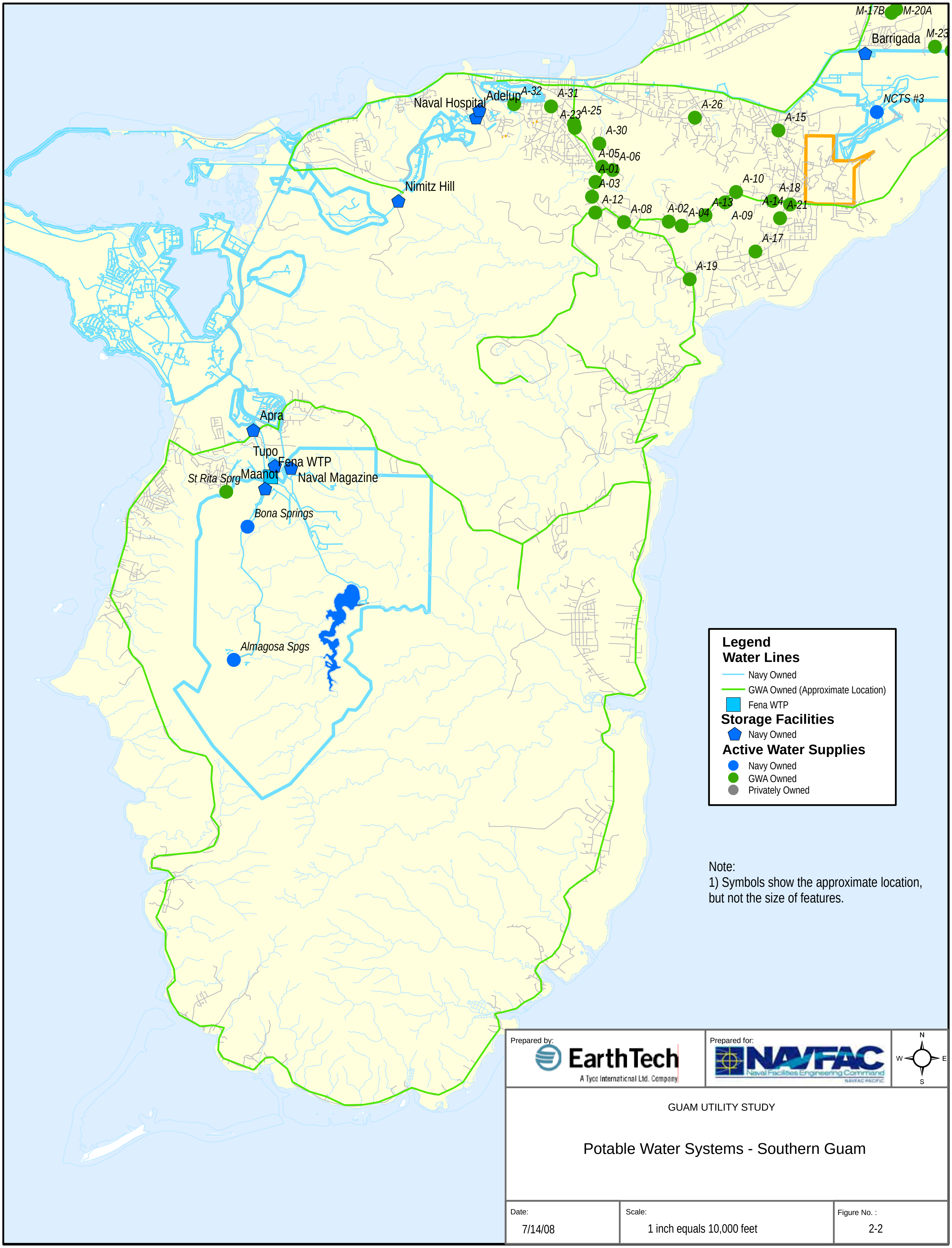
Prepared for: NAVFAC — Naval Facilities Engineering Command — NAVFAC PACIFIC

GUAM UTILITY STUDY

Potable Water Systems - Northern Guam

Date:	Scale:	Figure No. :
7/14/08	1 inch equals 10,000 feet	2-1



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Prepared for: NAVFAC Naval Facilities Engineering Command NAVFAC PACIFIC

GUAM UTILITY STUDY

Potable Water Systems - Southern Guam

Date:	Scale:	Figure No. :
7/14/08	1 inch equals 10,000 feet	2-2

Navy Water System

The Navy system and service areas are NCTS Finegayan, South Finegayan, NCTS Barrigada, Nimitz Hill, Naval Hospital, Ordnance Annex, and the Apra Harbor Complex.

The NCTS Finegayan is situated on the northwest coast of Guam, about 9 miles north of the capital city of Hagatna, and occupies approximately 3,000 acres. The Site is bounded by the AAFB to the north, Route 3 to the east, and the FAA parcel to the south. The Site includes residential units for family and unaccompanied personnel, community service facilities, administrative buildings, medical and dental clinics, support communication facilities, and mechanical shops.

South Finegayan is located on the northwest coast of Guam, approximately 8 miles northeast of Hagatna and occupies approximately 270 acres. The Site is bounded by NCTS Finegayan to the north and the Philippine Sea to the west. The area is comprised of family housing, an unaccompanied personnel housing unit, and a youth center.

NCTS Barrigada is located to the east central part of Guam, approximately 3 miles east of Hagatna and occupies approximately 1,850 acres. The Site is bound by the former Naval Air Station (NAS) Hagatna to the west, Mount Barrigada to the north and AAFB Communication Annex to the south.

Nimitz Hill is located along the west central coast of Guam, approximately 1.5 miles south of Hagatna. It occupies about 95 acres and is bounded by Naval Hospital to the northeast and by Piti Village to the west. Naval Hospital is located northeast of Nimitz Hill along the west central coast of Guam, directly east of Hagatna. Facilities at Nimitz Hill include operations facilities, officers club, thrift shop, a federal fire station, and a high school. The main facility at Naval Hospital is a 57-bed hospital at Hagatna Heights. Other facilities include family and unaccompanied personnel housing, medical facilities, fire station, convenience stores, recreational facilities, utility plants, and a chapel.

The Apra Harbor Naval Base Complex is located on the west-central coast of Guam, approximately eight miles southwest of Hagatna. The site encompasses a land area of 4,500 acres and a harbor of 650 acres. The Ordnance Annex is located approximately 2.5 miles southeast of Apra Harbor Naval Base Complex and encompasses approximately 8,840 acres of land most of which is used as buffer land or as watershed for the Navy Reservoir. The Apra Harbor Naval Base Complex and additional Navy areas include Orote Peninsula, Guam Economic Development Authority, Camp Covington, both new and old Apra Heights Housing Areas, Tenjo Vista, Sasa Valley, and Dry Dock Island. The Ordnance Annex has an ammunition wharf at Orote Peninsula with headquarters in the highlands above Apra Harbor Naval Base Complex along Route 5.

The existing Navy water system is an island-wide system extending from the Navy Reservoir in Southern Guam to NCTS Finegayan near the northern tip of Guam. Water for the system is primarily supplied from the Navy Water Treatment Plant (WTP). Water is distributed from the treatment plant to reservoirs designed to serve different service zones and transfer water to other Navy installations across the island. Most of the transmission mains from the reservoirs to the distribution systems are 24-inch pipelines. The Navy system is interconnected to supply water to GWA and for emergency service capability. The connection with the AAFB system is out of service.

In most of the service areas, water is supplied either from on-site groundwater wells or through the Navy island-wide water system or by interconnection with the GWA. The Island-wide water system consists of three primary sources, which are located at the southern region of Guam; Almagosa Springs, Bona Springs, and the Navy Reservoir surface water impoundment. Water from the above three sources are treated at the Navy WTP and distributed through a network of reservoirs, transmission mains and booster pump stations. A brief description of the water supply sources in each of the Navy service areas is provided below.

- At NCTS Finegayan, water is primarily supplied by groundwater wells located on-site and at South Finegayan. If necessary, water can also be supplied by interconnections with the GWA system or the Navy island-wide system. Groundwater wells are the primary source of potable water for this area.
- At the South Finegayan Housing area, water is primarily supplied by the groundwater wells on-site and at NCTS Finegayan. If necessary, water can be supplied by interconnections with the GWA system or the Navy island-wide system.
- At NCTS Barrigada, water is primarily supplied by groundwater wells. As a backup, the water storage system is connected to the Navy island-wide systems.
- At Naval Hospital, water can be provided from either the Navy island-wide water system or from on-site groundwater wells. Currently, two wells are operational and one well is inactive due to high chloride levels. The 2005 UTS reported that the three wells had tested positive for total coliform and two wells had tested positive for E. coli. Improvements were recommended to improve disinfection of the well water.
- At Apra Harbor Naval Base Complex and other Navy areas south of the Piti Power Plant, potable water is supplied entirely by the Navy WTP.

GWA Water System

The GWA water system consists of three public water systems known as the Northern, Central, and Southern Public Water Systems, serving the respective areas of the island with some overlaps. The Northern and Central systems are designated as ‘Large’ and the Southern System is designated as ‘Small’.

The Northern Public Water System is bounded on the north by AAFB and includes the remaining northern half of Guam and extends southwards towards Tamuning and Barrigada and along the east side to Route 17 to Yona. The Northern System overlaps the Southern System in the Windward Hills and Talofofo area along Routes 14, 4, and 4A.

The Central Public Water System extends along the west side of Guam from Mongmong-Toto-Maite south to Agat. The system extends inland to Sinjana and roughly follows the western borders of Chalan Pago and Yona to Route 17 and then the western border of Tolofofo to Agat. The main source of water for this area is the Navy WTP.

The Southern Public Water Systems roughly extends south of Route 17, around the southern tip of Guam to Umatac.

The Northern Public Water System is the largest system serving all public areas in the north and central parts of the island south of AAFB and serves an approximate population of 146,050. This system consists of 119 groundwater wells, 14 reservoirs (11 in use) and 10 booster pump stations (9 in use). The Central Public Water System consists of one spring, 8 reservoirs (5 in use) and 9 booster stations (6 in use). The main source of water for this system is the Navy Water System and water is purchased through 54 metered interconnections, of which 15 are reported to be inactive. Water from the Northern System can also be fed to the Central System in the areas of Mongmong-Toto-Maite, Sinjana, Hagatna Heights, Asan, and parts of Piti. Northern water can also be supplied to Apra Heights, Santa Rita and Agat through water mains that run along Routes 17, 5, 12, and 2.

The Southern Public Water System supplying the southern and southeastern parts of the island consists of 2 groundwater wells, 4 springs, 14 reservoirs, 16 booster stations (14 in use), and the Ugum Water Treatment Plant. It is the GWA Northern Public Water System that is of importance with respect to the USMC relocation due to its proximity to the relocation areas and since this system is primarily supplied by the same Guam Northern Lens source aquifer that serves the DoD systems.

2.2 DoD Storage Facilities

The location of the DoD storage facilities for each system is shown on Figure 2-1. The capacity of the storage facilities are listed in Table 2-2. The storage capacity by area is shown in Table 2-3.

Table 2-2: DoD Storage Facilities

Tank	Capacity (Gallons)	Capacity (MGD)	Owner	Location	Type
Water Storage Tank	150,000	0.15	AAFB	AAFB, Northwest Field	At-Grade, Steel
Water Storage Tank	150,000	0.15	AAFB	AAFB, Northwest Field	Steel
Storage Tank No. 2	250,000	0.25	AAFB	Andersen South	Partially buried concrete
Storage Tank No. 4	480,000	0.48	AAFB	Andersen South	Partially buried concrete
Santa Rosa Reservoir	2,000,000	2.00	AAFB	Andersen South	Buried concrete
Facility 19008	250,000	0.25	AAFB	AAFB Main Base	Ground Level concrete
Tarangue Reservoir (Not in Use)	1,000,000	1.00	AAFB	AAFB Main Base	
NCS South Finegayan South	250,000	0.25	Navy	South Finegayan	Elevated
NCTMAS Elevated	250,000	0.25	Navy	North Finegayan	Elevated
NCTMAS Ground (inoperative in 2005)	200,000	0.20	Navy	North Finegayan	Ground
Barrigada	3,000,000	3.00	Navy	NCTAMS Barrigada	Reinforced Concrete covered by earth
Naval Hospital	1,000,000	1.00	Navy	Navy Hospital	Reinforced Concrete covered by earth
Nimitz Hill	1,000,000	1.00	Navy	Nimitz Hill	Reinforced Concrete covered by earth
Adelup	3,000,000	3.00	Navy	Navy Hospital/Nimitz Hill	Reinforced Concrete covered by earth
Maanot	500,000	0.50	Navy	Apra Harbor/ Ordnance Area	Reinforced Concrete at Grade
Tupo	5,000,000	5.00	Navy	Apra Harbor/ Ordnance Area	Reinforced Concrete covered by earth
Naval Magazine	700,000	0.70	Navy	Apra Harbor/ Ordnance Area	Reinforced Concrete covered by earth
Apra Heights Tank	5,000,000	5.00	Navy	Apra Harbor/ Ordnance Area	Reinforced Concrete covered by earth

Table 2-3: DoD Storage Capacity by Area

Area	Total Existing Capacity (MG)
South Finegayan	0.25
North Finegayan	0.25
Andersen NW Field	0.30
Andersen Main Base	0.25
Andersen South	2.73
Apra Harbor/Ordnance Area	11.2
Barrigada	3.0
Navy Hospital/Nimitz Hill	5.0

MG million gallons

Andersen Air Force Base

At AAFB there are three on-base water storage tanks in use: a 150,000-gallon tank in the Northwest Field, a 150,000-gallon tank further north near Ritidian Point, and a 250,000-gallon tank and booster pump station at the east end of the AAFB main base area. The 150,000-gallon tank in the Northwest Field area is a steel, at-grade storage tank. A 150,000-gallon water storage tank, Facility 825, is located north of AAFB Northwest Field. Facility 825 is owned by the Navy and formerly the Naval Communications facility at Ritidian Point. The U.S. Fish and Wildlife Service (USFWS) has since taken over the land and uses the tank. Although water is supplied to the tank by AAFB water system, the Air Force does not draw water from the tank and does not maintain the tank. The 250,000-gallon ground level concrete storage tank was constructed around 1985 and replaced a former elevated storage tank. Water is supplied to the storage tank through a 12-inch cast iron main along Arc Light Boulevard, while the outflow is through a separate 12-inch pipeline.

The off-base reservoir includes Storage Tank No. 2, Storage Tank No. 4, and Santa Rosa Reservoir. The booster pump stations are used to transfer water from the wells to Santa Rosa Reservoir, which is AAFB's primary potable water storage tank. Santa Rosa Reservoir is located on Mt. Santa Rosa approximately 1.5 miles south of AAFB Santa Rosa gate. The reservoir is a buried concrete reservoir and has two 1.0 million gallon (MG) compartments for a total storage capacity of 2.0 MG. The inflow pipeline to Santa Rosa Reservoir is a 30-inch pipeline and the outflow is a separate 16-inch pipeline.

Navy Water System

At the Naval Computer and Telecommunications Area Master Station (NCTAMS), storage of potable water is provided by ground reservoir and the NCTAMS North Finegayan elevated tank. The ground reservoir provides storage of the treated water from the water softening plant and also acts as a holding tank for the booster pump that supplies water to the elevated tank. The elevated tank delivers water and maintains a near-constant pressure in the water distribution systems for the NCTAMS system. The elevated tank also provides sufficient head to transport water to the South Finegayan Housing area through a 10-inch main along Route 3. Storage in South Finegayan Housing is provided by a 0.25 MG elevated steel tank that is adjacent to Route 3 and Royal Palm Drive. Water in the storage tank is provided either through groundwater wells or through the Navy WTP. The Barrigada Tank is the storage facility for the NCTS Barrigada Service Area and is situated off Route 16, within and adjacent to the northern NCTAMS Barrigada boundary. The Adelup Tank serves both the Nimitz Hill and the Naval Hospital service area. Each area has a dedicated reservoir - the Nimitz Hill Tank and the Naval Hospital Tank. Booster pumps at the Adelup Tank Complex convey water from these two tanks and also serve the distribution system. The Adelup Tank has a capacity of 3.0 MG and an 18-inch influent line. Two sets of booster pumps (total of 5 pumps) are installed at the site of Adelup Tank. The first set of three booster pumps serves the Nimitz Hill area, while the second set of two pumps serves the Naval Hospital.

Potable water to the Apra Harbor Naval Base Complex and other Navy areas south of the Piti Power Plant is supplied entirely by the Navy WTP. The Apra Heights Tank serves a majority of Apra Harbor Naval Base Complex, while the Tupo Tank serves the X-Ray wharf portion of Apra Harbor Naval Base Complex and area north of complex. The Maanot tank is used to supply water to the upper portion of the old Apra Heights Housing Area. The Navy WTP also supplies water to the Ordnance Annex from the Naval Magazine (NAVMAG) tank. The Navy WTP treats raw water from three primary sources: Almagosa Springs, Bona Spring, and the Navy Reservoir surface water impoundment. The Navy WTP supplies water to four main reservoirs: Apra Heights and Tupo Tanks via gravity, and NAVMAG and Maanot tanks via pumps located at the Navy WTP clearwell. The 5.0 MG Apra Heights Tank serves most of the Apra Harbor Naval Base Complex, including the nearby New Apra Heights housing and the lower portion of the Old Apra Heights Housing.

Water stored in the 5.0 MG Tupo tank is primarily transported north of the main base that includes Nimitz Hill, Naval Hospital, NCTS Barrigada, NCTS South Finegayan Housing, and NCTS Finegayan. Water for the Ordnance Annex is stored and distributed through the 0.7 MG NAVMAG tank through a 10-inch transmission main.

2.3 GROUNDWATER QUALITY

Some issues with the water quality from the DoD wells are:

- Groundwater from the Northern Guam Lens is typically hard, containing calcium and magnesium carbonate.
- Tumon Maui and Marbo #2 are not in service due to volatile organic contamination.
- Routine bacteriological testing at wells in the Finegayan area and Naval Hospital area has identified the presence of total coliform and E. coli.
- Chloride levels rose to unacceptable levels (i.e., greater than 250 milligrams per liter [mg/L]) in some wells.

Historical water quality data are presented in Table 2-4. The Air Force regularly monitors the water quality at the AAFB and South Andersen Annex. A summary of data collected from the Tumon Maui and Marbo wells is provided in Table 2-5 through Table 2-8. Data characterizing biological contamination in the groundwater is not available for this study.

Table 2-4: Historical Water Quality

Constituent	Wells					
	A Series	A-9	D Series	Y Series	H-1	M1-1
pH	7.0	7.0	7.2	7.3	7.3	7.1
Residue on evap.	360	600	370	275	450	350
Total Hardness	**292**	**360**	**226**	**242**	**265**	**380**
Calcium (Ca)	113	130	78	85	88	98
Ca as CaCO3	**283**	**325**	**195**	**213**	**220**	**245**
Magnesium (Mg)	2	10	6	7	10	8
Mg as CaCO3	**8**	**41**	**25**	**29**	**41**	**33**
Chloride	16	140	50	17	95	30
NO3	9	9	9.5	9.3	9	4
SO4	2.5	13	8.0	2.0	20	4.5
Iron (Fe)	0.01	0.01	0.02	0.02	0.02	0.03

Source: Mink (1976)
Units: mg/L, except pH

Table 2-5: Harmon and Tumon Sampling Points Downgradient of MARBO Annex OU

Analyte	Units	MCL	Samples Taken 1978-2007		
			Min.	Max.	Meeting or Exceeding EPA Threshold
VOCs					
Tetrachloroethene (PCE)	µg/L	5	0.2 (est.)	22.4	5 (9/89), 9 (8/90), 8.3 (4/91), 6.1 (6/91), 7.6 (3/94), 14.6 (12/94), 11.6 (3/95), 11.6 (4/95), 12.9 (5/95), 13.1 (5/95), 13.4 (9/95), 9.4 (9/95), 11 (12/96), 11.2 (2/97), 18.2 (2/97), 19.9 (2/97), 19.5 (2/97), 22.4 (2/97), 5.2 (6/01), 5.4 (8/01), 5.0 (8/01)
Trichloroethene (TCE)	µg/L	5	0.2	5.2	5.4 (6/01)
Water Quality Parameters					
Alkalinity, Bicarbonate	mg/L	N/A	154	160	
Chloride	mg/L	N/A	0.19	9200	

EPA Environmental Protection Agency, United States
VOC volatile organic compounds
MCL Maximum Contaminant Level

Table 2-6: Tumon Maui Well Groundwater Field Quality Parameters 2003-2007

Parameter	Units	Min.	Max.
pH		6.7	7.46
Specific Conductivity	µmhos/cm	0.756	980
Temperature	ºC	27.01	28.96
Turbidity	NTU	0	9.5
DO	mg/L	3.46	16.23
Redox	mV	86	508
Chloride	mg/L	75.3	119

Table 2-7: Production Well MW-2 Groundwater Analytical Results, MARBO Annex

Analyte	Units	MCL	Samples Taken 1996-2006		
			Min.	Max.	Meeting or Exceeding EPA Threshold
VOCs					
Tetrachloroethene (PCE)	µg/L	5	>0.1	0.2	
Trichloroethene (TCE)	µg/L	5	0.4	5.8	5 (10/96), 5.4 (10/00), 5.8 (10/01), 5.7 (5/02), 6 (10/02)
Water Quality Parameters					
Alkalinity, Bicarbonate	mg/L	N/A	210	216	
Chloride	mg/L	N/A	13.8	67.2	

Table 2-8: MW-2 Groundwater Field Quality Parameters, 1996-2006

Parameter	Units	Min.	Max.
pH		6.44	8.31
Specific Conductivity	µmhos/cm	398	686
Temperature	ºC	26.61	30.11
Turbidity	NTU	0	271
DO	mg/L	0.32	9.41
Redox	mV	-175	3932
Chloride	mg/L	6.28	74.7

3. Projected Future Water System Conditions

3.1 WATER SYSTEM DEMANDS

The following section presents the water demand calculation for the proposed facilities for the Marine relocation and improvement to the existing DoD facilities (AAFB and the Naval Base). The demand calculations presented in Final Report Water, Wastewater, and Solid Waste Management Impact Assessment for JGMMP, Guam (HPE 2006) for Alternative 1 is the basis for the calculation with modifications as necessary from the Facilities Requirement and Initial Concept Plan, Helber Hastert & Fee, Planners (2007) and military population estimates from the Navy presented in Table 1-1.

The water demand for the USMC relocation was calculated using the Unified Facilities Criteria (UFC) 3-230-19N "Design: Water Supply Systems." Total requirements are calculated for domestic, industrial, fire protection and unaccounted for water (UFW) demands.

3.1.1 Domestic Uses

Domestic uses include drinking water, household uses, and household lawn irrigation.

Per Capita Requirements are shown in Table 3-1 for permanent and temporary installation in the tropics.

Table 3-1: Average Potable Domestic Water Requirements Gallons Per Capita Per Day

Use Category	Tropic (gpcd)
Unaccompanied Personnel Housing	155
Family Housing	180
Workers (per shift)	45

Source: DoD 2005
gpcd gallons per capita per day

The average demand for each use category shown in Table 3-3, in gallons per day (gpd), is calculated by Equation 1:

Equation 1

Average daily domestic demand in gpd = gpcd x design population x growth factor

The following growth factors are used in Equation 1:

a) Large systems (5,000 population or greater), 1.25.

b) Small systems (populations less than 5,000), 1.50.

Total average demand is the sum of averages for unaccompanied personnel housing, family housing and workers.

Other controlling demands are calculated by Equation (2):

Equation 2

Maximum Daily Domestic Demand = average daily domestic demand in gpd x K

Using the following data for the coefficient, K:

Table 3-2: Controlling Demand Coefficients

Demand	Units of Demand	Coefficient K	
		Population <5,000	Population >5,000
Maximum Day Flow	gpd	2.25	2
Maximum Hour Flow	gpm	4.0/1,440	3.5/1,440
Instantaneous Peak Flow	gpm	5.0/1,440	4.5/1,440

Source: DoD 2005
gpd = gallons per day

Table 3-3 presents the domestic demand for the USMC relocation. Details of the demand calculation are presented in Appendix B.

Table 3-3: Domestic Demand at the Finegayan Base Complex

Population	
Accompanied Personnel	4,255
Dependents	10,632
Unaccompanied Personnel	5,310
Civilian Support Workers	3,586
Total Population	23,783
Daily Demand	
UFC Growth Factor	1.25
Average Daily Domestic Demand (MGD)	**4.6**
UFC Coefficient K	2.00
Maximum Daily Domestic Demand (MGD)	**9.2**

3.1.2 Industrial Uses

Industrial uses include air conditioning, irrigation, swimming pools, shops, laundries, dining, processing, flushing, air conditioning, and boiler makeup water. The planned facilities for the USMC relocation are presented in Table 1-2. Demands were assigned according to the values in Table 4-4 of UFC 3-230-19N (DoD 2005).

Table 3-4: Industrial Water Requirements Potable Water - Permanent Installations

Use	Unit	Requirements		
		Min	Avg	Max
Air conditioning:	gpm/ton	—	0.05	0.10
Laundries	gal/lb	3	—	6
Irrigation				
Motor vehicles	Gpd/car	30	—	50
Restaurants	Gal/Meal	0.5	—	4.0

From UFC 3-230-19N

Additionally, UFC 3-230-19N (DoD 2005) requires that water demand data from other activities having uses similar to those anticipated will be used. The industrial demands for the facilities not covered by Table 4-2 in DoD (2005) were assigned a demand based on the measured demands for similar to facilities within the existing Navy bases. The average daily industrial use is 1.4 MGD at the Finegayan Base Complex. This demand includes 400 gpm for use in a power generation. Details of the demand calculation are presented in Appendix B.

3.1.3 Fire Protection Demands

Fire protection demand includes water required for maintaining the fire protection system within the facility and is designed based on the criteria outlined under MIL HDBK 1008C. Requirements for fire protection water storage are based on the assumption that there will be only one fire at a time. The quantity of water required is equal to the product of the fire protection water demand and the required duration, and must be available at all times. Water supply for the domestic, industrial, and other demands is added to these requirements to determine the total amount of water required in the facility. The fire flow requirements under the Military Handbook Fire Protection for Facilities Engineering, Design, and Construction (MIL-HDBK 1008C [DoD 1994]) vary greatly based on hazard classification of the activity in the facility.

The 2007 conceptual plan for relocation indicates four commands and 19 permanently based organizations including facilities such as family housing, aviation operation (including hangars, maintenance shops, training facilities), command centers (including administrative offices) and facilities housing various base support operations. The fire flow requirement for each facility is determined by the hazard classification for each facility structure and operation. For the current design a maximum fire flow demand of 3,750 gpm for a minimum duration of 150 minutes is assumed. This value is referenced from Table C-1, in Unified Facilities Criteria Fire Protection Engineering for Facilities (UFC 3-600-01 [DoD 2006]), and classifies the facility as “extra hazard”, which includes facilities such as hangars, ordnance plants and warehouses. While some of the facilities listed in the 2007 plan would fall under light or ordinary hazard category, the “extra hazard” designation is selected for the conceptual fire protection demand, assuming all the facilities listed in the relocation plan to be a single unit. Details of the calculation are presented in Appendix B.

Fire demands estimated per area are presented in Table 3-5. Most of the facilities listed in Table 1-2 are assumed to be on the Finegayan Base Complex. Facilities for the Aviation Facilities at AAFB North Ramp are assumed to be located at the Northern Ramp Aviation Facility. Facilities for the Embark Operations at Apra Harbor/Ordnance Annex, Fleet Anti-Terrorism Security Team Company, and MEU are assumed to be at the Embark Operation at Apra Harbor/Ordnance Area.

Table 3-5: USMC Relocation Fire Demands by Area

Facility	Peak Fire Protection Demand (gpd)
Northern Ramp Aviation Facility	562,500
Embark Operation at Apra Harbor/ Ordnance Area	202,500
Finegayan Base	562,500
Andersen South	0

Note: The fire demand calculation by area will need to be adjusted if housing is located in Andersen South Annex or AF Barrigada.

3.1.4 Unaccounted for Water

UFW is water that is not metered (such as that lost in leaks in unmetered mains) and is not accounted for in billing by the water utility. UFW is derived by subtracting the amount of water measured by meters and billed to customers, from the water that is produced from the treatment plants and wells, and also accounting for net changes in water storage tank inventories. The current UFW for the Navy is calculated to be approximately 15 percent according to 20 Code of Federal Regulations (CFR) 05 utility technical study report (Engineering Concepts 2005). It is assumed that the current AAFB UFW will be the same because the age of the pipes and maintenance level is similar. Based on state standards summarized in the 2005 utility technical study report (Engineering Concepts 2005), a UFW of 15 percent is assumed for the current design. The estimated UFW for each area is shown in Table 3-6 with the summary of the DoD demands.

3.1.5 Summary of Calculated Demands

The DoD future average and maximum daily demands are summarized in Table 3-6. The average and maximum daily demands are calculated as the sum of the domestic, industrial, and unaccounted for water demands.

Table 3-6: DoD Future Water Demands

Units: MGD	USMC Finegayan	USMC Only Finegayan	AAFB	Navy Island-wide System
Total Population	23,783	20,765	8,900	13,635
Industrial/Commercial Demand	1.4	1.4	1.0	4.0
Average Daily Demand				
Average Daily Domestic Demand	4.6	4.0	1.8	2.8
Average Daily UFW	0.9	0.8	0.4	2.1
Average Daily Demand	6.9	6.2	3.2	8.9
Maximum Daily Demand				
UFC Coefficient K	2	2	2	2 / 2.25
Maximum Daily Domestic Demand	9.2	8.0	3.5	5.7
Maximum Daily UFW	1.6	1.4	0.7	2.2
Maximum Daily Demand	12.1	10.7	5.2	12.0

Average Daily Demand = Average Domestic Demand + Industrial Demand + Unaccounted for Water
Maximum Daily Demand = Maximum Domestic Demand + Industrial Demand + Unaccounted for Water
Unless a UFW demand was provided in the JGMMP a loss rate of 15% was assumed to calculate the UFW demand.

3.2 DESIGN CAPACITY OF SYSTEM COMPONENTS FOR THE USMC RELOCATION

3.2.1 Water Supply Sources

The source will be designed to meet the Military activity's quantity demands. Where there is inadequate storage between the source and the treatment plant or distribution system, the supply will provide maximum day domestic demand plus industrial use demand.

For options with supply wells, sufficient capacity will be included to meet the maximum day domestic demand plus industrial use demand, with the largest well out of service.

Potential water supply sources are evaluated in Sections 5 and 6 of this report.

3.2.2 Treatment Plant

The design capacity of treatment plants will meet the maximum day domestic demand plus industrial use demand assuming adequate equalizing storage following treatment.

Groundwater extracted from the NGLA will be assumed to be under the influence of surface water and treated to meet drinking water standards. This is a worst case scenario for planning. The primary treatments will be direct filtration and disinfection. The water will not be softened.

3.2.3 Transmission Mains

Where the distribution is pumped from storage, transmission mains will have capacities equal to the maximum-daily demand plus industrial use demand.

3.2.4 Distribution System

The minimum capacity of the distribution system will be sufficient to meet these conditions:

- Instantaneous peak domestic and industrial flows combined
- Maximum fire demands, plus 50 percent of average domestic demands, plus industrial demands which cannot be restricted during the fire
- Replenishment of normal storage volume within 24 hours of average demand after a fire.

3.2.5 Storage Facilities

Reservoir capacity for the USMC relocation will be adequate to satisfy the total of the following requirements:

- Peak fire flow demand
- 50 percent of average daily consumption (domestic and industrial).
- Minimum working volume of one hour at average demand (domestic and industrial) for scheduling of treatment plant equipment and service pumps maintenance.

The storage capacity for the facility is referenced from Section 2.3.5 of MIL HDBK 1005/7A and is based on Equation 3:

Equation 3

Storage = Peak Fire Flow Demand + 50% Average Daily Use + 1 hour of Average Daily Use (3)

In the above equation, the average daily use includes both domestic and industrial. Table 3-6 shows the water demands for the proposed Marine Relocation for Guam. Additional storage will be required for the Finegayan Base Complex (Table 3-7). The condition of the current storage facilities at Finegayan will need to be assessed. It is assumed that these storage facilities may need to be replaced. Details of the storage capacity calculations are presented in Appendix B.

Table 3-7: DoD Storage Capacity Future Requirements and Existing Capacity

Units: MG	Future Minimum Storage Requirements	Existing Storage Capacity
USMC Finegayan	4.8	0.5
AAFB	4.5	3.28
Apra Harbor/ Ordnance Annex	6.4	19.2

Note:
1. Additional storage capacity will be required at Andersen South Annex and AF Barrigada if housing for the USMC relocation is placed at these locations.
References:
Engineering Concepts, Inc. 2005;
HHMI Corporation, Hawaii Pacific Engineers, and ECS, Inc. 2006

4. Regulatory Involvement for Water Systems Alternatives

The regulatory requirements for the proposed water treatment alternatives were discussed with the following regulatory agencies during the field investigations:

- GEPA
- U.S. Environmental Protection Agency (EPA) Region 9
- GWA
- Department of Public Works
- Department of Parks and Recreation (Historic Preservation)
- Guam Division of Aquatic and Wildlife Resources
- Bureau of Statistics and Planning (Coastal Management)

4.1 GEPA

The GEPA is responsible for the implementation of specific local and federal statutes and regulations on environmental protection. It oversees the management and protection of Guam's drinking water, groundwater, surface and marine water resources for public water supplies and other beneficial uses. It manages and protects Guam's principal source aquifer from pollution and overdraws.

Regulations: In 1983, the EPA granted GEPA primary enforcement responsibility or primacy of the Safe Drinking Water Program. The Program's main goals are to undertake planning activities, and to develop, implement, and enforce Guam's Primary and Secondary Safe Drinking Water Regulations, as authorized by the Guam Safe Drinking Water Act (SDWA) and the Federal SDWA. GEPA's prescribed regulations incorporate by reference the relevant sections of the CFR, making EPA regulations applicable to Guam. The Guam SDWA provides for GEPA Administrator review of plans and specifications for the construction or substantial alteration of a public water system.

Groundwater under the direct influence of surface water (GWUDI): GWUDI is a regulatory designation of a groundwater source that may be contaminated by untreated surface water due to inadequate filtration by the overlying soil and rock formations. In northern Guam, the presence of fractures in the limestone aquifers make the groundwater susceptible to surface water contamination. GWUDI may contain protozoa, such as Giardia and Cryptosporidium, which may pose a risk to public health. GWUDI is a significant issue on Guam. If Guam's Northern Aquifer is determined to be to any extent GWUDI, additional treatment will be required for public water supply. Studies will be completed through the ongoing efforts of EPA, GWA, DoD, and others to conduct GWUDI analysis of the Northern Guam Lens Aquifer.

Reactivation of Wells: GEPA prefers that water system owners reactivate and treat contaminated wells before considering the development of new wells. GEPA representatives prefer an integrated water supply system, including that which would serve the DoD expansion, to be managed and operated by GWA. GEPA expressed no opposition to potable or non-potable water reclamation through effluent reuse. GEPA indicated a preference for dredging the Navy Reservoir, but they do not strongly favor expanding the Navy reservoir storage capacity by dredging, or implementing a desalination process. However, GEPA supports studying desalination as an alternative, considering the limited water resources in Guam.

Aquifer Recharge via Injection Wells. The Guam SDWA empowered the GEPA to establish an underground injection control (UIC) program, setting standards for contaminants, permits, inspection, monitoring, record keeping and report, all of which conform to federal statute and regulations. These regulations apply only to Class V injection wells. GEPA will regulate any discharge of effluent to the aquifer, according to GEPA water quality guidelines. GEPA would be amenable to injection of tertiary effluent into the aquifer. GEPA representatives indicated a preference for an injection location toward the middle of the aquifer, rather than along the edge where the water would be lost into the ocean.

4.2 EPA REGION 9

EPA Region 9 works with California, Hawaii, Nevada, Arizona, and the Pacific trust territories, including Guam, to establish water quality standards for the protection of aquatic life and human health. GEPA's Safe Drinking Water Program has primary enforcement responsibility or primacy of the Safe Drinking Water Program.

- The SDWA authorizes three ground water protection activities: the UIC regulatory program, the Sole Source Aquifer designation program, and the Source Water Assessment and Protection program, which includes Wellhead Protection.
- The National Pollution Discharge Elimination System (NPDES) Compliance and Enforcement Program of the Clean Water Act regulates point source discharges to the nation's waters. NPDES permits can be issued to individual dischargers or can be issued for a group of dischargers (i.e., general permits). Both individual and general permits contain requirements for controlling pollutant dischargers, monitoring discharges, and reporting compliance. EPA administers and is the permitting authority for this program in Guam.
- The EPA has provided guidelines for the reuse of recycled water in *Guidelines for Water Reuse* (EPA 2004).

4.3 GUAM WATERWORKS AUTHORITY

The GWA was established by the Guam Legislature, and is a semi autonomous, self-supporting agency. It administers Guam water utility service including water treatment and distribution. An elected, non-partisan Consolidated Commission on Utilities oversees the operations of GWA and regulates its rates.

Most of the key potable water regulations with which GWA must comply are administered by GEPA under the Safe Drinking Water Program. GWA views ensuring adequate disinfection, under the EPA's Stage 2 Disinfection Byproduct Rule, and the determination of the extent that the Northern Lens is considered GWUDI, as significant current challenges.

GWA's Water Resources Management Program plays a key role in managing and protecting Guam's principal source aquifer from pollution and overpumping. The program is responsible for implementing the Water Resources Development and Operating Regulations, UIC Regulations, Wellhead Protection and Water Quality Standards. These guidelines define, among other things, design considerations, source development, treatment, storage, and distribution.

- GWA representatives expressed a preference for an integrated water supply system, including that serving the DoD expansion, to be managed and operated by GWA. Coordination with GWA is important in the development of new production wells in the DoD areas to avoid negative impacts due to overpumping of the aquifer. GWA does not object to dredging the Navy Reservoir, expanding the Navy Reservoir storage capacity by dredging, or implementing a desalination process. GWA supports studying desalination as an alternative, considering the limited water resources in Guam, but questions whether the desalination will be economically not viable compared to other available options.

- GWA prefers recapturing the water lost through leaking water mains, estimated by them at 40-50 percent, to developing new water supply wells.
- GWA representatives would also like to have reliability and security issues defined and joint mitigation plans developed in providing water supply for new DoD facilities.
- If the groundwater supply is determined to be under the influence of surface water, GWA prefers a consolidated treatment system to solve this problem.
- GWA recommends that GEPA establish regulations for recycled water reuse similar to those of Hawaii and California. Hawaii uses three categories and California four, each based on treatment standards and beneficial uses.
- GWA is exploring the siting of an estimated 16 new wells. There may be some conflict with DoD wells planned in the Agafa-Gumas sub-basin.

4.4 DEPARTMENT OF PUBLIC WORKS

Among the responsibilities of the Guam Department of Public Works (DPW) are construction quality control of facilities and highways, traffic engineering, building permits and inspection, contracts administration, and design and analysis. Maintenance responsibilities include facilities maintenance and transportation maintenance, as well as highway maintenance and construction.

DPW representatives have provided requirements, including:

- Contractor performance bond for construction in public right of way
- Backfill of utility trenches in roadways with flowable fill
- Inclusion of standard pavement restoration and trenching details in the Project Manual of DPW
- Daytime construction limited to work on the shoulder of the road, closing only one lane, with traffic control and proper barricades.
- Minimum separation requirements between adjacent utilities.
- Full width overlay paving for trench cuts within some roads, particularly newer roads.
- Review of design submissions by DPW, as well as Historic Preservation, Guam Power Authority and GEPA
- Permit fees for work, as found in the latest edition of the Uniform Building Code
- Control of erosion, dust, sediment, vehicle traffic, and stormwater per GEPA guidelines, as part of the permitting process

The DPW representatives indicated a preference for an integrated water supply system managed and operated by GWA. DPW indicated a preference for dredging the Navy Reservoir, but does not strongly favor developing a new surface water alternative, expanding the Navy Reservoir storage capacity by dredging, or implementing a desalination process. However, DPW supports studying desalination as an alternative, considering the limited water resources in Guam.

4.5 DEPARTMENT OF PARKS AND RECREATION

The Guam Historic Resources Division of the Department of Parks and Recreation carries out territorial and federal law preservation mandates and, for purposes of the National Historic Preservation Act, acts as the State Historic Preservation Office for Guam. A certificate of approval must be issued by the Guam Historic Preservation Officer before any action affecting potential historic sites or objects is undertaken. Each organization planning any public construction or improvement is responsible for review to determine if any historic site is present.

The Department of Parks and Recreation will review and comment on the design and implementation of alternatives.

4.6 DIVISION OF AQUATIC & WILDLIFE RESOURCES

The Guam Department of Agriculture's Division of Aquatic & Wildlife Resources (GDAWR) is a GovGuam agency to restore, conserve, manage, and enhance the aquatic resources in and about Guam and to provide for the public use of and benefits from these resources. It is responsible for endangered species recovery and conservation. It regulates, monitors, and studies the wildlife resources on and around Guam. The GDAWR has identified land-based sources of pollution as one of the five most important threats to Guam's coral reefs.

The GDAWR will review and comment on the design and implementation of alternatives which may have impact on natural resources.

4.7 BUREAU OF STATISTICS AND PLANNING (COASTAL MANAGEMENT)

The Guam Coastal Management Program (GCMP) was developed on Guam as a core component within the Bureau of Statistics and Planning (BSP), a staff agency within the Office of the Governor. It coordinates all the use, protection, and development of land and ocean resources within Guam's coastal zone.

The BSP will review and comment on the design and implementation of alternatives which may have impact on the coastal zone. The BSP reviews Federal Activities for consistency with GCMP policies. Federal Activities are those conducted by the Federal government that are in the coastal zone or directly affect the coastal zone. The Procedures Guide for Achieving Federal Consistency with the GCMP provides instructions for preparing an assessment, and a list of federal licenses and permits subject to certification for consistency, and National Coastal Zone Management Act and federal regulations governing federal consistency with approved coastal management programs citations.

5. Review of Water System Alternatives

5.1 OPTION 1 - OPTIMIZE GROUNDWATER RESOURCE DEVELOPMENT WITHIN DOD PROPERTY

5.1.1 Description

Option 1 includes the development of groundwater wells drawing water from the Guam Northern Lens Aquifer in the Navy water system and the AAFB water system. Since all the three water systems in the northern part of Guam draw water from the same aquifer with a limited sustainable yield, the development of this alternative to include new production wells must consider the impacts from wells pumping in adjacent areas and proposed additional well production from GWA. The impacts include potential salt water intrusion problems, excessive drawdown in the aquifer, and other related water quality problems. This alternative includes use of the existing Navy wells at Finegayan which produce up to 1.5 MGD (see Table 2-1). The USMC water system will be connected with both the Air Force and Navy Island-wide system to allow flexibility to meet water demands on the DoD bases in Northern Guam if housing is shifted away from the Finegayan Base Complex and in emergencies.

At present, GEPA, GWA, Water and Environmental Research Institute of the Western Pacific University of Guam, the University of North Carolina, and the DoD are negotiating a long-term study on the aquifer to determine susceptibility of the aquifer to surface water contamination. For this study, all water extracted from the Northern Lens Aquifer will be considered GWUDI, with the groundwater consolidated and treated to meet drinking water standards.

The increased water supply from implementation of Option 1 will primarily support the USMC relocation. However, Army service members will be housed at the Finegayan Base Complex, requiring approximately 9 percent of the total demand.

5.1.2 Viability

The development and implementation of this alternative can be managed by DoD, avoiding uncertainties in timely implementation through direct management. GWA currently operates 119 wells tapping the same aquifer. Coordination with GWA is important in the development of new productions wells in the DoD areas to avoid negative impacts due to over-pumping of the aquifer. Also, GWA is considering installing wells adjacent to the AAFB which could draw water away from proposed wells on DoD property.

The freshwater lens aquifer is segregated into six distinct and hydrologically separate sub-basins on the northern portion of the island. The primary sub-basin used for groundwater extraction by the Navy, Finegayan Sub-basin, is near its maximum sustainable yield. As such, water supplies for the USMC relocation would have to come from another source. Alternatively, the sub-basin being tapped by AAFB still appears to have sustainable yield available before reaching capacity. The AAFB has recently drilled five new wells in the northwest field, which are not yet on line due to problems in the construction of the water reservoir. These wells will have a positive impact on DoD water supply, once the system is operational. Based on review of the sustainable yield and current pumping capacity for existing wells, the water supply obtained from within DoD properties can meet the projected USMC demand.

5.2 OPTION 2 - DETERMINE THE REQUIREMENTS FOR REHABILITATION, TREATMENT OF WELL WATER OR REPLACEMENT OF EXISTING WELLS NOT CURRENTLY IN OPERATION

5.2.1 Description

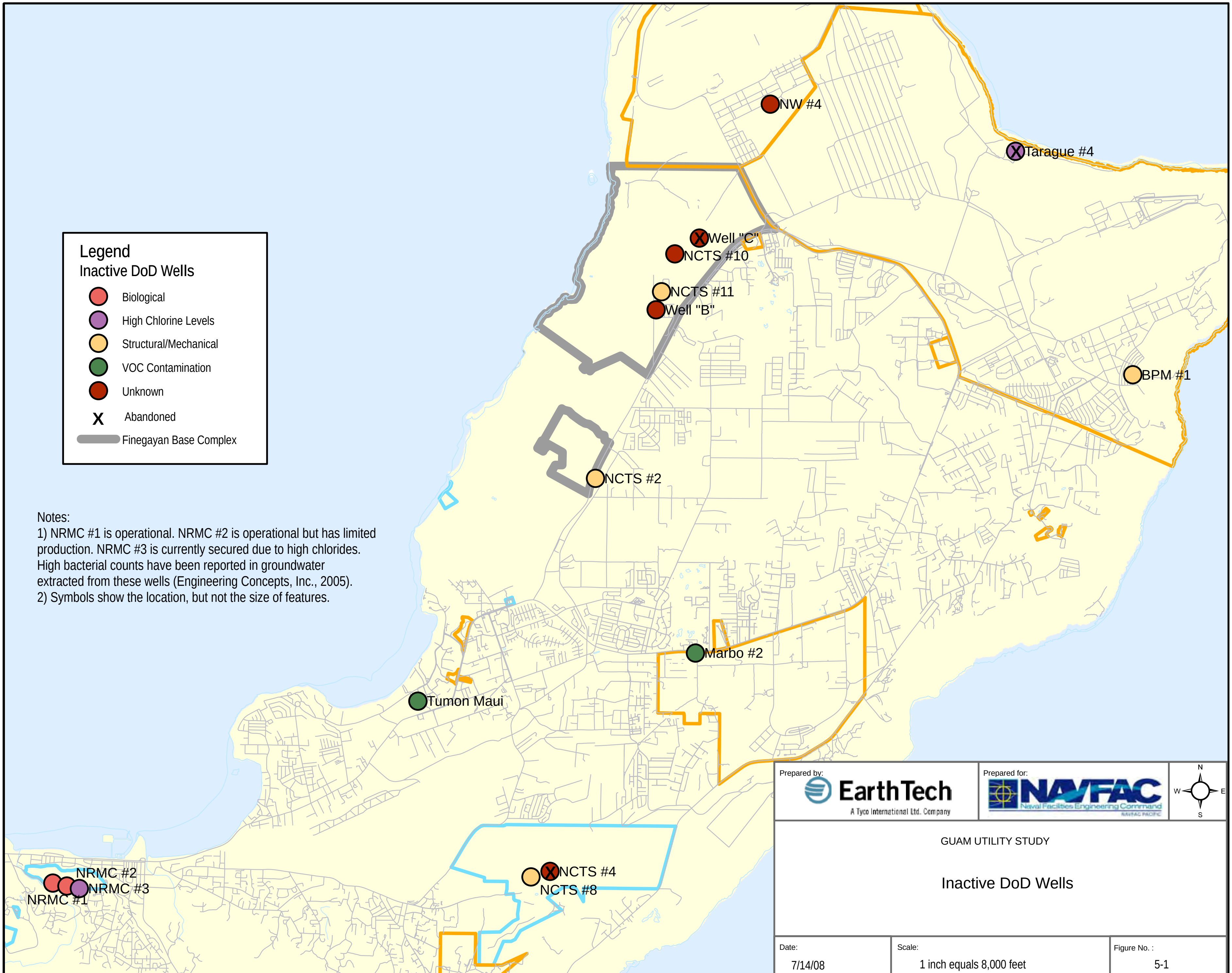
Option 2 includes the development of non-operational and underperforming existing groundwater wells drawing water from the Northern Guam Lens Aquifer in the Navy water system and the AAFB water system. Since all the three water systems in the northern part of Guam draw water from the same aquifer with a limited sustainable yield, similar to the first alternative, the development of this alternative to include rehabilitation or replacement of existing production wells also considers the impacts from wells pumping in adjacent areas. These impacts would include potential salt water intrusion problems, excessive drawdown in the aquifer and other related water quality problems. Table 5-1 provides a list of the inactive DoD wells (see also Figure 5-1). Successful rehabilitation or replacement of the inactive wells would result in approximately an additional 4 MGD if there is adequate available yield in the aquifers.

It is anticipated that the water supply from implementation of Option 1 will meet the demands of the USMC relocation. Implementation of Option 2 will provide additional supply for other DoD requirements.

Table 5-1: Inactive DoD Wells

Owner	Well	Pumping Rate (gpm)[a]	Note
VOC Contamination			
Air Force	Marbo #2	320	The pumping rate was not provided. For this assessment, the highest pumping rate from the active Marbo Wells was assumed.
Air Force	Tumon Maui	900	
Biological Contamination			
Navy	NRMC #1	234	Fully operational. According to the 2005 UTS, well has been turned off at times due to biological contamination.
Navy	NRMC #2	200	Operational but production is limited. According to the 2005 UTS, the well has been turned off at times due to biological contamination.
High Chloride Levels			
Navy	NRMC #3	178	Secured due to high chlorides. According to the 2005 UTS, the well has also been turned off at times due to biological contamination.
Structural/Mechanical			
Navy	NCTS #2	225	Not operational due to collapsed screens
Navy	NCTS #8	200	Not operational due to collapsed screens
Permanently Inactive			
Air Force	Tarague #4	NA	High chloride, not in use since 1977.
Air Force	BPM #1	NA	Well not discussed in the 2006 Civil Utility Report.
Air Force	NW #4	NA	AF drawing identified the well as abandoned.
Navy	NCTS #4	~200	These wells are identified in the Navy CADD drawing but are not discussed in the 2005 UTS study. Assumed to be abandoned.
Navy	Well C	~200	

Notes:
NA not applicable
[a] Navy pumping rates are measured or calculated values from Navy Utility Report, 2005 and the Air Force rates are measured values from AAFB Utility Report, May 2006 and Hawaii Pacific Engineers (HPE) 2003.



Prepared by: EarthTech A Tyco International Ltd. Company

Prepared for: NAVFAC Naval Facilities Engineering Command

GUAM UTILITY STUDY

Inactive DoD Wells

Date:	Scale:	Figure No. :
7/14/08	1 inch equals 8,000 feet	5-1

5.2.2 Viability

This alternative has the potential to add to the reliability of a DoD water supply. The development and implementation of this alternative could be managed by DoD avoiding uncertainties in timely implementation through direct and proper management. Coordination with GWA is important in the development of new productions wells in the DoD areas to avoid negative impacts due to over-pumping. As discussed in Section 4.1, GWUDI will be considered to be applicable for this alternative and future planning efforts need to assume that treatment of extracted groundwater will be required.

This option is examined in detail in Section 6.3 of this report.

5.3 OPTION 3 - PURCHASE WATER FROM GWA

5.3.1 Description

This alternative includes obtaining water from GWA either by purchasing water or through exchanging water through metered interconnections between GWA and DoD water systems. There are several existing connections between the GWA and Navy water systems, although given the information currently available, none of these connections will be sufficient to supply a significant portion of the demand in the northern region without construction. The implementation of this alternative would include establishing or upgrading metered connections between the GWA and DoD water systems.

The increased water supply from implementation of Option 3 would support the USMC relocation and other DoD requirements.

5.3.2 Viability

Since the Northern Public Water System operated by GWA has an elaborate water supply system in Northern Guam with 119 well drawing water from the Guam Northern Lens Aquifer, this alternative could be considered to supplement Options 1 and 2. Additionally, this alternative could potentially result in energy cost savings by reducing the cross-island pumping of large quantities of water through the existing parallel water mains running from the north to the south.

5.4 OPTION 4 – SEDIMENT DREDGING AT THE NAVY RESERVOIR

The Navy Reservoir, located in the southern portion of Guam, is a primary source of potable water for the island and was created through impoundment of the Fena River valley by a dam. The Navy Reservoir Dam, constructed by the Navy and completed in 1951, is a zoned earth and rockfill embankment with a maximum height of 85 ft above original grade. The entire watershed impounded by the dam covers an area of 5.88 mi^2 of moderately to steeply sloped lands, and soil within the watershed is predominantly clay of volcanic origin. The slopes and soil type both contribute to rapid runoff rates and significant erosion, particularly in areas where the native vegetation has been removed. Eroded soil is ultimately transported to the reservoir itself by the runoff, and contributes to ongoing reduction of reservoir capacity due to sedimentation.

5.4.1 Description

Relevant studies investigating the reservoir in depth include “Utility Technical Study of the Potable Water Systems, PWC Guam” (Engineering Concepts, Inc. 2005) and “Maintenance Dredging Study” (Engineering Management & Planning Services Corporation [EMPSCO] 2006). The information presented for this option is primarily based on these two studies.

The utility technical study evaluated the water supply system for Guam's naval installations as a whole, and included investigations of the condition and capacity of all potable water sources, and treatment and distribution systems for naval facilities. As such, it was not focused solely on the Navy Reservoir, and did not include a specific investigation of the reservoir itself. Instead, it relied on surveys conducted by others to evaluate conditions in the reservoir.

The maintenance dredging study was focused solely on the Navy Reservoir and included reviews of prior surveys of the reservoir, as well as a new bathymetric survey conducted in 2005 for the study. Specifically, the maintenance dredging study references the pre-construction survey conducted 1949, as well as other surveys conducted in 1973, 1979, and 1990. For the new survey conducted specifically for the maintenance dredging study, the survey area was limited to a 60-acre area near the dam.

The controlling hydraulic structures that establish the maximum water elevation and minimum usable water elevations in the reservoir are the spillway and outlet structures. The spillway, which establishes the maximum water elevation in the reservoir, is a curved 179-ft long flat-crested sill at an elevation of 111.35 ft above mean lower low water (MLLW). The outlet, which establishes the lowest elevation of usable storage, consists of an intake structure at an elevation of 66.02 ft MLLW (Engineering Concepts 2005).

At full stage (i.e., a water elevation in the reservoir of 111.35 ft MLLW), the reservoir covers an area of 197 acres (roughly 0.31 mi^2) and impounds approximately 7,180 ac-ft of water, according to bathymetry collected in 1990. Approximately 6,400 ac-ft of the total impoundment is usable capacity (i.e., water stored above the outlet structure). However, both the total impoundment and usable capacity are constantly being reduced due to sedimentation within the reservoir, and the current storage capacities are not explicitly known.

5.4.1.1 *Analysis of Available Bathymetric Data*

In its summary of prior surveys, the maintenance dredging study notes that the anticipated total impoundment of the reservoir, based on the 1949 pre-construction survey, was 8,300 ac-ft. No estimate of the usable capacity of the reservoir was presented. The 1973 survey reported a total capacity of 7,500 ac-ft, with no estimate of the usable storage presented. The 1979 survey purportedly shows a total capacity of 7,860 ac-ft. No usable capacity estimate from the 1979 survey is identified, and the maintenance dredging study indicates that unrevised stage-capacity curves from the 1949 and 1973 surveys are presented in the report for the 1979 survey. The 1990 survey is reported to show a total capacity of about 7,180 ac-ft, of which 6,400 ac-ft is usable capacity. The storage capacity identified in the 1973 survey appears anomalous when compared to the 1979 and 1990 survey results. According to the maintenance dredging study, the 1973 survey used updated aerial photography and 500 depth soundings to determine bathymetry. Considering that this represents a sounding density on the order of 2.5 soundings per acre of water surface, the accuracy of this survey is questionable; consequently, this survey is excluded from further use in this analysis.

The 2005 survey did not cover the entire reservoir, and focuses only a 60-acre area immediately near the dam itself; as such, direct comparisons of this survey to the prior surveys to establish rates of sedimentation are not possible. Calculations comparing the 1949 and 2005 surveys indicate that approximately 800 ac-ft of sedimentation has occurred since 1949 within the 60-acre area of the 2005 survey. The estimated loss of total capacity in the reservoir between 1949 and 1990 is 1,120 ac-ft. If the rate of sedimentation is assumed to be linear, the total loss of reservoir capacity would be in excess of 1,300 ac-ft as of 2005.

5.4.1.2 *DREDGING OPTIONS*

The maintenance dredging study presented two distinct options for restoration of storage volume through dredging. “Level 1” dredging would restore the Navy Reservoir bathymetry to that identified in the 1949 pre-construction survey, and would require approximately 1.29 million cubic yards (MCY), or 800 ac-ft, of dredging. “Level 2” dredging would remove sediments that have accumulated since 1949 above an elevation 1 ft below the elevation of the outlet structure (66 ft MLLW; thus, sediments accumulated above 65 ft MLLW would be removed). This option entails dredging 0.29 MCY (180 ac-ft) of sediment.

5.4.2 Costs

Generally, costs for a dredging project are divided into a mobilization/demobilization fee and the dredging cost. For the Navy Reservoir dredging project, the maintenance dredging study estimated a unit dredging cost of $24/cubic yard (CY), and a handling and disposal cost of $6/CY, for a total dredging unit cost of $30/CY. As this price is reflective primarily of labor, fuel and equipment costs for workers and material actually onsite during the actual dredging work only, the location of the work in Guam is not likely to materially alter the unit price of the dredging work itself. Dredging costs are therefore estimated at $38,580,000 for Level 1 dredging, and $8,733,600 for Level 2 dredging.

The mobilization/demobilization cost, however, will reflect the difficulties of working in a relatively remote location in the form of a higher base cost. The maintenance dredging study estimated the mobilization and demobilization cost as $500,000. In light of the potential difficulties likely to be encountered in contracting for a dredge, which may increase the distance across which a dredge must be mobilized by at least a factor of 2 (as the study assumed a dredge mobilized from within 2,000 miles), this estimate is similarly scaled by a factor of 2, to a total of $1,000,000, for the life-cycle costs. Furthermore, while a mobilization for Level 1 dredging would likely entail the movement of a larger dredge to Guam than Level 2 (based on the significant difference in targeted dredge volume), it is assumed that mobilization and demobilization costs would essentially be equal, as the bulk of the cost is expected to be associated with the large distance across the equipment is being mobilized, and in the disassembly and reconstruction of the plant in Guam for overland transportation. Consequently, Level 2 dredging would be negatively impacted by elevated mobilization costs.

Based on the costing rationale described above, and assuming the remaining “incidental” items estimated in the maintenance dredging study have not changed appreciably since 2005, the total the Level 1 dredging project would remove approximately 1.29 MCY of material from Navy Reservoir at a cost of $40,580,000, while the Level 2 project would remove approximately 0.29 MCY at a cost of $10,733,600. Assuming a constant rate of sedimentation of 27.3 ac-ft per year (44,100 cy/year) based on the comparison of the 1990 and 1949 surveys, the life cycles of the Level 1 and 2 projects are approximately 29 and 6.5 years, respectively.

The increased water supply from implementation of Option 4 would serve DoD demands in south Guam. Provided water is supplied from the Northern Aquifer near the Finegayan Base Complex, water supply from implementation of this option would not support the USMC relocation, but would provide additional supply in the south that could be transported to north Guam if necessary.

5.4.3 Viability

Potential benefits of the proposed dredging alternatives are several. First, the proposed work is relatively simple in its execution, and does not present a great demand for skilled labor trades that may be difficult to procure from the limited labor pool on Guam. Secondly, the dredging alternatives do not result in the creation of new capital structures which must be operated and maintained on an indefinite basis. The dredging alternatives also maintain the existing hydrology of the reservoir system, and do not require inundation of additional land. Finally, these alternatives do not require changes to the existing water distribution network, in that the existing discharge and bypass points are maintained in place.

Potential obstacles and drawbacks exist, as well. In particular, the potential difficulties in mobilizing a dredge to project site due to its remote location and the large mobilization distances to dredges will cause uncertainty in actual project costs. In addition, there are significant logistics difficulties in managing dredged material on Guam, as noted in the maintenance dredging study (EMPSCO 2006). While that study assumed equal dredged material management unit costs for both dredging alternatives, the lack of sufficient land area may complicate implementation of the Level 1 alternative. Dredging in the 60-acre area near the dam also does not address upland causes of decreasing reservoir capacity. Without implementation of a comprehensive watershed management plan, the rate of sedimentation will continue unabated, and may increase as climatic conditions and land development increase runoff, and therefore erosion.

Although Option 4 is a viable alternative, it cannot be sustained as a stand-alone alternative for USMC relocation. Water supplied by this option would require transportation to the north to supply the primary USMC relocation water demands, but would provide additional supply for the DoD facilities in southern Guam. It is recommended that this alternative be retained as a means of increasing the DoD water supply.

5.5 OPTION 5 - EXPAND NAVAL RESERVOIR STORAGE CAPACITY BY RAISING DAM CREST

5.5.1 Description

Option 5 involves raising the dam crest of the Navy Reservoir to increase capacity. Structural requirements for dam improvements will need to be assessed, designed and implemented building on the Surface Water Development Study (Barrett, 1994) and subsequent investigations by the Navy.

5.5.1.1 ADDITIONAL YIELD

Based on a review of topographic maps depicting the immediate vicinity of the Navy Reservoir, the topography is such that raising the elevation of the dam crest by 20 ft would not significantly change the surface area of the reservoir, which is currently 197 acres at full stage. Consequently, for the purpose of this analysis, it is assumed that a 20-ft increase in the dam crest would yield a 3,940 ac-ft, or 55 percent, increase in total reservoir capacity. The assumption that increases in surface area with rising elevation are negligible is a conservative assumption from the standpoints of estimating both safe yield (as the total impounded volume is somewhat underestimated) and capital cost per unit of water delivered (as the cost is assessed against a lower capacity, and is thus an overestimate).

The entire increase in volume would be usable storage, and would represent roughly a 62 percent increase in usable storage over the last known usable storage volume estimate of 6,400 ac-ft (based on the stage-capacity curves determined from the 1990 survey). Assuming that the watershed generates sufficient runoff to ensure reliability of this supply, the safe yield of the reservoir would therefore increase from 11.4 to 15.4 MGD (Barrett 1994), an increase of 4.0 MGD, or 35 percent. This option requires further study to determine whether the safe yield is sustainable in dryer weather.

5.5.1.2 CONCEPTUAL DESIGN FOR CAPTURING WATER

Preliminary designs for raising the dam called for a rather conventional technique involving placement of additional fill on both the upstream and downstream faces of the dam, thereby raising the crest. A significant drawback of this conventional approach, however, is the volume of fill material required. Further investigation of the existing dam’s stability found that impounding additional water using a reinforced soil system cap along the existing dam crest would be feasible (Barrett 1994).

The reinforced soil system consists of modular concrete facing panels retaining a compacted earth fill reinforced with metal strips or geogrids. Effectively, this alternative builds an extension of the dam crest in the form of a wall. The proposed construction is similar to that often used to create retained fills or reinforced embankments on highway and land development projects, and is often generically referred to as “reinforced earth.” Although this alternative requires the construction of a significant quantity of new structural elements, the volume of fill required is substantially reduced, resulting in significant reductions in cost and length of construction. The actual feasibility of this alternative, however, is dependent upon additional geotechnical and structural analyses of the dam.

5.5.2 Costs

5.5.2.1 Construction Cost

Based on the estimate provided in Barrett (1994), the present worth construction cost for the reinforced earth alternative is estimated at $4,300,000, not including costs for expansion and improvement of the existing water treatment facility and distribution system. Also not included in this estimate are any operation and maintenance costs that would be associated with this alternative. While operations costs, as such, could be minimal, maintenance costs will be determined by the extent of the maintenance program, which has yet to be developed. In particular, they will be driven by the labor and material costs to perform routine inspections, as well as “typical” non-capital type repairs. These ongoing costs have not yet been established. Further analysis is necessary to validate the assessment and costing provided in Barrett (1994).

The increased water supply from implementation of Option 5 would serve DoD demands in south Guam, provided water is supplied from the Northern Aquifer near the Finegayan Base Complex.

5.5.3 Viability

The primary benefit of this alternative is that it provides a significant increase in usable storage capacity at a relatively low cost, especially as compared to other in-reservoir options (i.e., dredging). Provided that the existing watershed generates sufficient runoff to reliably supply an expanded Navy Reservoir (an assumption which must be confirmed by a detailed hydrologic analysis), this option provides increased storage and daily use capacity without altering other waterways in ways that may affect downstream ecosystems. This option can also be implemented entirely on lands currently owned by the military, and would therefore not require acquisition of privately-owned lands or displacement of existing residential or commercial land uses.

There are potential drawbacks to the expanded reservoir option, as well. As noted in Barrett (1994), fringe wetlands around the perimeter of the reservoir would be inundated as a result of raising the dam crest, and would be considered as a “fill” by the US Army Corps of Engineers. As a result of the inundation of fringe wetlands, this option would also disturb nesting areas for the moorhen, an endangered species. The swiftlet, fruit bat, giant fern, and starling are other endangered species known or suspected to exist within the project area (Barrett 1994), though it is not clear how or if implementation of this option would affect these species. Further review and analysis is necessary to determine the implementability of this option, e.g., whether this option is reasonable and safe; whether the reservoir can be used while construction is ongoing; and what modifications to the spillway might be necessary.

This alternative has the advantages of improving the DoD water supply by increasing its storage capacity in the Navy Reservoir. However, the disadvantages and uncertainties are significant and include:

- Technical complexity of design and implementation;
- Potential adverse environmental impacts;
- Uncertainties with respect to relative advantages compared to other viable alternatives;
- Studies (hydraulic, geotechnical, seismic) required;
- Potential difficulties during construction limiting use of the reservoir; and
- Overall cost may be greater than estimated.

The viability of this option is less certain than Options 1 and 2. Therefore, it is recommended that this alternative be eliminated from further evaluation.

5.6 OPTION 6 - POTABLE WATER RECLAMATION THROUGH EFFLUENT REUSE

5.6.1 Description

Wastewater collected from the Finegayan base complex is subject to tertiary treatment as described in the pre-Final Draft Wastewater Utility Study (Earth Tech 2007). The treated, potable water is returned to the main water supply for reuse. An estimated average daily flow of 8.8 MGD treated wastewater from the DoD will be available for potable water use.

While much research has been conducted in the direct potable reuse of reclaimed water, this is not a current practice within the US. However, indirect potable reuse through groundwater reinjection is developed through wastewater treatment plant (WWTP) effluent being combined with well water prior to injection. The perception of effluent reuse is an issue to be dealt with since such an option is likely to be met with significant public opposition. This indirect potable reuse alternative has a psychological advantage in that the injection of the treated effluent into groundwater reduces the perception of reclaimed water (treated effluent) used as potable water.

This alternative includes construction of a new tertiary treatment plant, providing primary treatment, secondary biological treatment, and advanced tertiary treatment, near the proposed development on DoD land. It will treat the DoD wastewater from existing sources and proposed future expansions in Northern Guam region including USMC relocation to drinking water standards.

This treatment application is categorized as direct potable reuse of reclaimed water, and normal treatment practice consists of primary settlement, submersible membrane bioreactor, disinfection, reverse osmosis (RO), and advanced oxidation.

While this discharge eliminates the option of building an outfall, discharging treated wastewater directly to a potable water treatment plant does not have a proven track record. Only few direct potable reuse applications have been reported worldwide (Metcalf & Eddy, 2007). Even without factoring in its extremely high capital investment cost and sophisticated process operation, it might be difficult to gain regulatory acceptance of this approach, and it is not likely that community acceptance of this approach can be achieved. Currently there are no direct potable reuse applications in the United States. All reclaimed water that is treated by wastewater treatment plants has been used as potable water in an indirect way which includes a temporal or spatial separation such as natural buffers, either a stretch of river or a ground water aquifer, between the reclaimed water introduction and its distribution to the potable water treatment plant.

In addition, brine generated from RO operation will need to be managed. Typical brine disposal routes include evaporation, crystallization, deep underground injection, ocean or sewer discharge. From an economic standpoint, only the last two may be feasible, and will require permission from either the EPA or the GWA. Since there are no regulations on the reclaimed water potable reuse application, the process of establishing treatment requirements and performance monitoring standards for this option will also add time and cost to the project.

A new interceptor system would be constructed to convey wastewater flow from AAFB. A new effluent discharge pipe would be constructed to convey the effluent to the proposed or existing water treatment facility.

The plant biosolids treatment and disposal would be managed by the DoD and comply with EPA's 40 CFR Part 503 regulations.

Construction of the plant on a site that is located in forested or preservation areas that are populated by native species of animals and vegetation may require mitigation activities to satisfy the GDAWR.

The water supply provided by implementation of Option 6 would support the USMC relocation.

5.6.2 Viability

Studies have shown treated wastewater can consistently meet potable water standards, but as listed in EPA (2004), this practice is unlikely to be adopted in the U.S. because:

- Opinion surveys show the public will accept many types of nonpotable reuse but are reluctant to accept potable reuse.
- Indirect potable reuse is more acceptable to the public than direct potable reuse.
- Direct potable reuse is not often necessary.

Other disadvantages include:

- Construction of a WWTP is required.
- Conveying the effluent to new or existing water treatment plant
- GDAWR mitigation requirements
- Longer planning effort and longer construction schedule

This alternative remains viable; however, using treated effluent as potable water has certain negative connotations. It might be more acceptable if potable water supplies were less readily available. This alternative is tied directly to decisions made in the wastewater study and has been rejected as a viable alternative.

In discussions with GEPA, no opposition to this alternative was expressed. However, concern was raised about public perception on effluent reuse for potable water needs and it was noted that it was unlikely that such an option would be acceptable to the public given other viable options for water supplies.

Although this is a viable alternative, it cannot be sustained as a stand-alone alternative. The availability of other viable options doesn't justify consideration of this alternative given the potential hurdles in implementation and the likely negative public response. Therefore, it is recommended that this alternative be eliminated from further evaluation.

5.7 OPTION 7 - NON-POTABLE WATER RECLAMATION THROUGH EFFLUENT REUSE

5.7.1 Description

Non-potable water reclaimed from effluent reuse can be used to recharge the aquifer. This section addresses use of the reclaimed water to supplement the water supply. Wastewater collected from the MCB is subject to tertiary treatment as described in the Wastewater Utility Study (Earth Tech 2007). Based on the Pre-Final Draft Wastewater Utility Study, an estimated average daily flow of 8.8 MGD of treated wastewater will be available for non-potable water use during peak conditions.

Use of water reclamation for industrial uses is not considered in this section because industrial water demand consists of only 6 percent of the total water and does not justify the added complication of a dual water system.

This alternative includes construction of a new tertiary treatment plant near the proposed development on DoD land. It will treat the DoD wastewater from existing sources and future proposed military buildup in the Northern Guam region, including USMC relocation. Treated effluent would be injected into underground aquifer for groundwater recharge or to limit salt water intrusion. The DoD would be responsible for treatment, groundwater monitoring, and biosolids disposal. A separate sewer interceptor and a transmission line would be constructed to convey reclaimed water to the injection wells. The cost of the transmission line and its operation will depend on topographical condition of piping route and locations of the injection wells that are determined by underground geological structure and required set back distance between injection wells and withdraw wells.

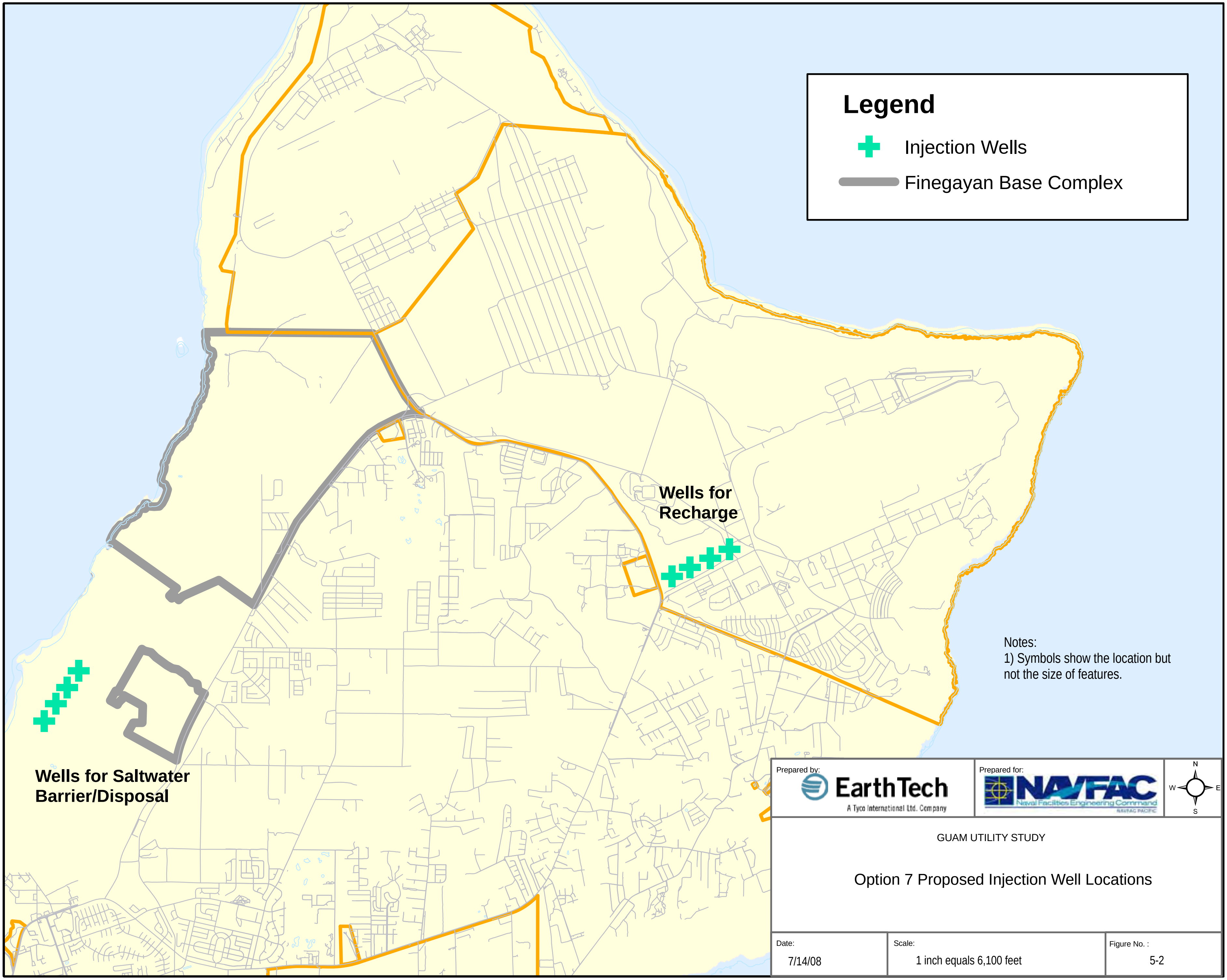
Construction of the plant on a site that is located in forested or preservation areas that are populated by native species of animals and vegetation and may require mitigation activities to satisfy the GDAWR.

The water supply provided by implementation of Option 7 would support the USMC relocation.

5.7.1.1 INJECTION OF TREATED WASTEWATER EFFLUENT

Wastewater production resulting from transfer of DoD assets to Guam is estimated at 8.8 MGD average daily flow. Groundwater injection is one potential means of disposal of wastewater effluent. Two possible injection scenarios were considered. The first is disposal by injection of treated effluent in wells approximately 1,500 to 2,000 ft inland at a location near the proposed WWTP. In this option, treated effluent is disposed in the ocean by leakage from freshwater lens underlying northern Guam, but the placement of the discharge could result in a barrier to saltwater intrusion. In the second option, the highly treated wastewater effluent is used to recharge the freshwater lens at a location that would support the proposed new production wells at AAFB. Physical locations and potential layout of injection wells for both scenarios are shown in Figure 5-2.

Under the disposal option, four injection wells would be located east of Tanguisson Point in a line approximately parallel with the coast with a separation distance between wells of approximately 1,000 ft. Each well would be capable of an injection rate of approximately 1,600 gpm yielding a maximum combined injection rate of 6,400 gpm. Under non-peak loads, two to three wells would be operated allowing distribution of effluent injection across a 4,000-ft front while enabling at least one well to be removed from service for maintenance and upkeep.



GUAM UTILITY STUDY

Option 7 Proposed Injection Well Locations

Date:	Scale:	Figure No. :
7/14/08	1 inch equals 6,100 feet	5-2

The aquifer recharge option would also include four 1,600-gpm wells with a 1,000-ft spacing. This option would allow one or more wells to be down for maintenance and upkeep during non-peak operations. The recharge option has the wells located in a 4,000-ft line parallel and to the north of Marine Drive on the southern boundary of AAFB. The injection wells are arrayed in a line conforming to a ridge in the volcanic basement below the water bearing limestone. The ridge was chosen because proposed production wells for DoD expansion on Guam are located on either side of the volcanic basement ridge allowing the injected effluent to directly recharge the portions of the aquifer that will be heavily pumped to supply water for new military and support personnel arriving on Guam.

The disposal option utilizes the freshwater lens as the receiving water for the treated wastewater effluent. Injection of the wastewater would elevate the water table surface in the disposal zone. This could have a positive effect on the potable production wells in the Finegayan sub-basin directly upgradient from the injection area. If the doming effect of the injection zone extended inland sufficiently, this could result in slightly higher capacities from the potable production wells in the affected area. However, preliminary calculations tend to indicate no increase as a result of effluent injection (see Appendix G).

Two major issues are associated with the aquifer recharge option. The first issue is transferring the treated effluent across the island to the injection point, a distance of 6 to 8 miles (depending on route) and an increase of elevation of 300 ft. The second issue is acceptance of highly treated wastewater effluent as recharge for potable production wells. This issue has two components: public perception, and technical requirements. The public may perceive that treated wastewater is used as drinking water and therefore reject the concept of aquifer recharge with treated effluent. The technical difficulty is that at the selected injection point, the recommended 9 to 12 month effluent detention time in the aquifer prior to removal could not be met.

The conceptual designs for injection wells to be used for treated wastewater effluent disposal or aquifer recharge are included in Appendix G. The injection wells are assumed to be 12-inch diameter, which readily accommodate an 8-inch conductor pipe and couplings.

At present, there are no Federal regulations that specifically address indirect or direct potable reuse of reclaimed water. The EPA developed Guidelines for Water Reuse in 2004 and suggested the quality standard for treated municipal wastewater injection into underground potable aquifer as listed in Table 5-2.

California, Florida, and a few other states are in the forefront of developing discrete criteria relating to planned indirect potable reuse of reclaimed water. California has prepared draft criteria for groundwater recharge (the most recent being in 2004), and are shown in Table 5-3.

With concerns on reliability of some unregulated trace constituents removal, and consideration of source water that meets all drinking water standards, it does not necessarily indicate that the water is safe. The California draft groundwater recharge regulations reflect the mitigation necessary to address these concerns. In present practice reclaimed injection into underground potable aquifer normally has multiple barrier protection system (such as RO and advanced oxidation process) for advanced treatment to avoid unknown potential health risks.

Table 5-2: EPA Guidelines of Water Reuse for Groundwater Recharge by Injection into Potable Aquifers

Types of Reuse	Treatment	Reclaimed Water Quality	Reclaimed Water Monitoring	Setback Distances	Comments
Groundwater recharge by injection into potable aquifers	Secondary Filtration Disinfection Advanced wastewater treatment	Includes, but not limited to, the following: pH = 6.5 – 8.5 <= 2 NTU No detectable total coli/100 ml 1mg/l chlorine residual (minimum) <= 3 mg/L total organic carbon (TOC) <= 0.2 mg/L total toxics Nitrate N < 10 mg/L Meet drinking water standards	Includes, but not limited to the following: pH - daily Turbidity – continuous Total coliform – daily chlorine residual – continuous Drinking water standards – quarterly Other – depends on constituent	2,000 ft to extraction wells. May vary depending on site-specific conditions.	The reclaimed water should be retained underground for at least 9 months prior to withdrawal. Monitoring wells are necessary to detect the influence of the recharge operation on the groundwater. Recommended quality limits should be met at the point of injection. The reclaimed water should not contain measurable levels of viable pathogens after percolation through the vadose zone. A higher chlorine residual and/or a longer contact time may be necessary to assure virus and protozoa inactivation.

Table 5-3: California Draft Groundwater Injection Regulations

Parameter	Requirement
Turbidity	0.2 NTU
Total nitrogen	5 mg/L
Total coliform	2.2 total coliform/100 mL
Total Organic Carbon	0.5 mg/L
Set back distance	2,000 ft
Retention time underground	12 month
Drinking water standards	Meet all drinking water maximum contaminant levels (except nitrogen and new federal and state regulations as they are adopted)

Source: Draft Groundwater Recharge Regulations, California Department of Health Services

The northern part of Guam is set on a karst limestone high plateau, where highly porous and channelized limestone subsurface media with a high hydraulic conductivity exist. From ground surface to groundwater surface is approximately 200 to 350 ft. This geology provides little reliable opportunity for soil aquifer treatment which offers additional treatment as water passes through the soil vadose zone to an underlying aquifer. Due to limited surface area contact, flow through fractured limestone media may offer inefficient soil aquifer treatment.

Since GWUDI in the Northern Guam area has already been a concern to the GEPA, to gain public confidence on the practice of injecting reclaimed water directly into potable aquifer in a karst limestone region, a treatment processes train similar to California practice is used for this study. Groundwater recharge with reclaimed water in the Orange County Groundwater Replenishment Project, which treats secondary effluent from Orange County Sanitation District Plant #1, employs a process including microfiltration, RO, advanced oxidation with ultraviolet (UV), and hydrogen peroxide.

5.7.1.2 HYDRAULIC FEASIBILITY OF INJECTION WELLS

When water is discharged into a well, a cone develops above the potentiometric surface in much the same way as a cone develops below the potentiometric surface when water is pumped from a well. When water is injected, the cone is reversed. In other words, it becomes a cone of impression or recharge rather than a cone of depression or discharge. This cone of impression surrounds the pumping well and can be analyzed mathematically in a very similar way as the cone of depression.

The amount of water introduced into the aquifer depends on the rate of injection, hydraulic conductivity, type of well, and potentiometric levels. However, the most important factor in any injection system is proper design of injection wells. A properly designed injection well will operate more efficiently requiring less hydraulic pressure with reduced probabilities of incrustation, thus resulting in longer well life and decreased overall operating costs.

To calculate injection pressures and water build-up in the injection wells, it was assumed that each injection well will receive 1,600 gpm continuous flow. This flow rate is well below the legally permissible injection rates under the EPA UIC regulations of 3.5 MGD (2,430 gpm) and velocity restriction of 8 fps.

It is important to determine injection pressures to ensure that there are no concerns from the engineering, economic, and regulatory points of view. Flow and pressure restrictions are imposed to protect the receiving formation from potential fracturing pressures. Fracturing pressures for limestones are approximately 600 pounds per square inch (psi). It is prudent to maintain a safety factor and maintain injection pressures in the limestone at less than 200 ft of water or below 87 psi.

Estimates of water level build-up and injection pressures were made using the Theis equation and hydraulic conductivities of 50 ft/day, 100 ft/day and 200 ft/day. Assuming a hydraulic conductivity of 200 ft/day, the head in the injection well above the top of the aquifer would be approximately 21 ft and the injection pressure head will be about 9 psi. If hydraulic conductivity is 100 ft/day, the head in the injection well above the top of the aquifer would be approximately 39 ft and the injection pressure head will be 17 psi. At the lowest hydraulic conductivity of 50 ft/day, the head in the injection well above the top of the aquifer would be approximately 74 ft and the injection pressure head will be 32 psi.

The calculated injection pressures are low and appear to have adequate safety factor for potential adverse aquifer affects that may reduce flow. The equations used are based on assumptions of perfect aquifer hydraulics and ideal water quality conditions in the aquifer; including (for example) homogeneous formation, isotropic aquifer characteristics, fully penetrating wells, and laterally extensive aquifers. Over time, injection pressure will increase as a result of screen plugging from incrustation and biological fouling. It would be important to clean and maintain the wells every few years.

5.7.2 Viability

This option will not be considered further because:

- Use of treated wastewater to recharge the aquifer is not considered a viable option because the residence time is far smaller than the EPA-recommended time of 9 months.
- Use of treated wastewater to act as a barrier to saltwater intrusion is not considered viable because calculations show the disposal of the treated water to be an ineffective barrier.

Additionally, this option may not meet regulatory approval. GEPA UIC regulations categorize sewage treatment effluent recharge wells as Class V wells. GEPA does not specify the treatment standards and criteria for underground injecting the sewage treatment effluent to recharge the aquifer. GEPA will review the design and documents before approving the groundwater injection of treated effluent.

Additional disadvantages include:

- Existing DoD wastewater diverted from GWA to a new DoD WWTP
- WWTP construction
- GDAWR mitigation requirements
- Groundwater discharge permit
- Longer planning effort and longer construction schedule leading to increased costs

5.8 OPTION 8 – DESALINATION

Desalination is a process that removes dissolved minerals from seawater, brackish water, or treated wastewater. The water supply provided by implementation of Option 8 would support the USMC relocation.

A number of technologies have been developed for desalination, including reverse osmosis (RO), electrodialysis reversal (EDR), and distillation. In RO, feedwater is pumped at high pressure through permeable membranes, separating salts from the water. In EDR, ions are transferred through the membranes by means of direct current (DC) voltage and are removed from the feed water as the current drives the ions through the membranes. In the distillation process, feedwater is heated and then evaporated to separate out dissolved minerals.

Operating Parameters for Desalination

Desalination Process	Total Dissolved Solids (TDS) Range (mg/L)	Temperature Range (°C)
Distillation	30,000 – 500,000	35 – 120
RO	500 – 50,000	0 – 40
EDR	500 – 3,000	0 – 65

Source: CDTF 2003

It is assumed that brackish water with TDS levels ranging from about 3,000 mg/L to 4,000 mg/L will be supplied. Within this TDS range, RO is preferred. Brackish water generally requires less energy to desalinate than seawater due to its lower concentration of dissolved solids. Therefore, the desalination of brackish water is generally less expensive than desalination of seawater.

Energy costs represent about one-third to one-half of the cost of desalination, and as a result, desalination costs are relatively sensitive to the cost of energy. In addition to the energy required for the desalination process, energy is also needed to transport water to end users.

5.8.1 Description

For this option, the lowest salinity water available outside of the NGLS will be considered. Brackish water wells will be located within 1,000 ft of the shoreline to avoid impacts to the NGLS and existing wells. Sufficient brackish water will be collected from a series of wells to generate 12 MGD of potable water. Freshwater from the existing Navy wells will be sent to the same facility for water treatment assuming GWUDI. The desalination plant will be located near the Finegayan Base Complex on AAFB to be close to the location of the source and the demand. The plant includes units for pretreatment (filtration and disinfection), desalination, and post-treatment (corrosion control, remineralization and disinfection) resulting in a product of drinking water quality with TDS less than

500 mg/L. If desalination of brackish water is implemented, untreated brackish water may be used to meet fire demands requiring a separate set of non-potable waterlines and storage.

It is assumed that the brackish water will have a TDS level ranging from 3,000 mg/L to 4,000 mg/L and an oil and grease level less than 10 mg/L. In this case, RO is the preferred process. Advantages of RO plants over distillation include:

- RO plants usually have lower energy requirements;
- RO plants take up less surface area than distillation plants for the same amount of water production;
- RO plants tend to have higher recovery rates – up to about 50% for seawater;
- RO plant feedwater generally does not require heating, and the thermal impacts of discharges are lower;
- RO plants have fewer problems with corrosion.

Desalination plants produce liquid wastes that may contain some or all of the following constituents: high salt concentrations, chemicals used during defouling of plant equipment, and pretreatment residues. Liquid wastes may be discharged directly into the ocean, combined with other discharges (e.g., power plant cooling water or sewage treatment plant effluent) before ocean discharge, discharged into a sewer for treatment in a sewage treatment plant, or dried and disposed in a landfill. Combining the brine discharge with discharges from other plants serves to dilute the high salt concentrations and minimize adverse impacts associated with desalination discharges. In addition, combining with power plant cooling water helps to lower the temperature of the cooling water. Desalination plants also produce a small amount of solid waste (e.g., spent pretreatment filters and solid particles that are filtered out in the pretreatment process [California Coastal Commission 1993]).

Land disposal is not an option that is considered here, since it requires a significant amount of land and land disposal often requires the lining of evaporation ponds to minimize the effects on the surrounding aquifers (Barrett 1994). Since rainfall exceeds evaporation in Guam, the evaporation ponds would increase rather than decrease in volume. The preferred option would be to combine the discharges with those of neighboring power plant or treatment plants. Membranes that are destroyed during use will be disposed in a landfill.

5.8.2 Costs

Desalination would include similar requirements for resource development (well installation), water treatment (disinfection and filtration), and distribution (infrastructure, pumping, storage). The cost for desalination capital and O&M are additional.

5.8.3 Viability

Desalination is a viable option that results in very pure water, excellent pathogen removal, and flexible operations. The costs for this option are likely to be high relative to the water supplied by Options 1 and 2. The high power demand for desalination will need to be considered in the utility planning for electricity. The cost for desalination will also be sensitive to the level of TDS in the brackish water supply. This option is carried forward for detailed analysis because of the limited supply of freshwater in the NGLS. If water demands eventually exceed the capacity of the freshwater aquifer in the north, desalination could potentially provide a source of potable water for the DoD.

5.9 OPTION 9 - DEVELOP A NEW SURFACE WATER SOURCE

5.9.1 Description

Development of a new surface water source on Guam would require identifying a new water source, conceptualizing and designing the water source area, treatment, transmission and distribution infrastructure, and constructing the complete system to supplement the existing water systems. Such a system preferably would have to be sited within DoD lands and finding an alternate surface water source with significant capacity would likely be a major and costly initiative.

Barrett (1994) presents a detailed analysis of 30 potential surface water source alternatives in southern Guam. The analysis included estimates of the yield and reliability of the source, impacts to endangered species, habitats, and the ecosystem. Conceptual designs and screening level construction costs are included in the report. A summary of the analyses is presented in Table 5-4.

Table 5-4: Surface Water Source Development Summary Alternatives

Rank	Alt. #	Alternative	Water Quantity Diverted (MGD)[a]
1	26	Ylig Treatment Rehab.	2.00
2	18	Talofofo Diversion	2.00
3	22	Tolaeyuus Div./Lost River	0.90 (1.7-5.6[b])
4	9	Inarajan Diversion	2.00
5	7	Geus Treat. Upgrade	0.15
6	30	Tarzan Diversion	1.00
7	27	Ylig Reservoir	11.40
8	3	Navy Res. Modif. (Option 5)	4.00
9	14	Lonfit Reservoir	3.30

[a] Information from Barrett (1994)
[b] Estimate from SWCA (2007)

The Proposed Supplemental Water Supply for the Fena Reservoir System, Naval Magazine, Guam (SWCA, June 2007) report reviews five alternatives and selected pumping from the Lost River at its mouth below the Navy Reservoir as a viable alternative. Based on an extensive U.S. Geological Survey (USGS) data set, SWCA estimated that the supplemental supply from this source would have ranged from 1.7 to 5.6 MGD during the 1998 to 2001 period.

5.9.2 Costs

A summary of the screening level capital costs and yields estimated in Barrett (1994) are provided in Table 5-5. Additional study is necessary to validate these costs.

Table 5-5: Screening Level Capital Costs for Surface Water Alternatives

Alt. #	Alternative	Capital Cost Estimate- Guam (2008) $M
18	Talofofo Diversion	16
22	Tolaeyuus Div./Lost River	2
9	Inarajan Diversion	14
30	Tarzan Diversion	11
14	Lonfit Reservoir	56

Note: Costs are from Barrett (1994)

The estimated cost for supplemental water supply from the Lost River is $2,750,000 based on a SWCA (2007) conceptual plan.

The increased water supply from implementation of Option 9 would serve DoD demands in south Guam. Provided water is supplied from the Northern Aquifer near the Finegayan Base Complex, water supply from implementation of this alternative would not support the USMC relocation.

5.9.3 Viability

Additional study is necessary to fully evaluate and provide updated information on the alternatives identified in Barrett (1994). The top-ranked surface water sources are all in southern Guam, requiring significant transportation costs to meet the demand at the Finegayan Base Complex. This alternative will add more cost without having any meaningful benefits to meet the USMC relocation water needs. This option would increase the water supply to DoD facilities in southern Guam, but, with the exception of the Lost River, additional study is needed to assess the implementability and cost of the surface water sources. This option is eliminated from further consideration in this water study. However, it may be beneficial to carry forward the preliminary engineering analysis for capture of the Lost River as a means of supplementing supply to DoD in southern Guam.

5.10 SUMMARY OF OPTIONS

A summary of the options is provided in Table 5-6. Earth Tech recommends that the following options be considered for further evaluation.

- **Option 1** – Optimize groundwater resource development within DoD property.
- **Option 2** – Determine the requirements for rehabilitation, treatment of well water, or replacement of existing wells not currently in production due to contamination, structural and/or mechanical problems.
- **Option 3** – Purchase water from GWA.
- **Option 8** – Desalination.

Table 5-6: Summary of Option Evaluation

Water System Alternative	Description of Option	Evaluation Considerations	Recommendation
Option 1 – Optimize Groundwater Resource Development within DoD Property	Development of new groundwater wells in the Northern Lens Aquifer. Volume: dependent on sustainable yield and demand	• Salt water intrusion/ Excessive aquifer draw down. • Managed fully by DoD/ Reliable and secure. • Integrated System with GWA. • Sustainable yield/ GWUDI considerations.	Retained for Evaluation in Section 6

Water System Alternative	Description of Option	Evaluation Considerations	Recommendation
Option 2 – Determine the Requirements for Rehabilitation, Treatment of Well Water, or Replacement of Existing Wells	Rehabilitation or replacement of under performing wells in the Northern Lens Aquifer. Volume: 3.8 MGD (capacity of inactive wells; See Section 5.1)	• Salt water intrusion/ Excessive aquifer draw down. • Reduced stress on aquifer from installation of new wells. • Managed fully by DoD/ Reliable and secure. • Integrated system with GWA. • Sustainable yield/ GWUDI considerations.	Retained for Evaluation in Section 6
Option 3 – Purchase Water from GWA	Purchase water from GWA. Volume: subject to availability	• New connections with DoD water systems. • Upgrading systems/ energy savings.	Retained for Evaluation in Section 6
Option 4 – Sediment Dredging at Navy Reservoir	Dredge accumulated sediments Navy Reservoir thereby increasing capacity. Volume: 2.5 MGD (the additional capacity needed to return the Navy Reservoir to design capacity)	• Current storage capacity reduced due to sedimentation. • Need to dredge to sustain long-term supply • Managed fully by DoD.	Potentially viable. Additional analysis is necessary to fully evaluate.
Option 5 – Expand Naval Reservoir Storage Capacity by Raising Dam Crest	Raise the Navy Reservoir dam crest to increase capacity. Volume: 4 MGD (based on Barrett [1994])	• Technical complexity of design and implementation • Relative advantages compared to other viable alternatives • Overall cost	Eliminated
Option 6 – Potable Water Reclamation through Effluent Reuse	Wastewater treatment plant effluent is reused for human consumption. Volume: 8.8 MGD [Final Wastewater Utility Study])	• Negative connotations/ public perception. • Tied to wastewater study. • Relative advantages compared to other viable alternatives	Eliminated
Option 7 – Non-Potable Water Reclamation through Effluent Reuse	Wastewater treatment plant effluent is reused for non-potable uses Volume: 8.8 MGD [Final Wastewater Utility Study])	• Require separate distribution system. • Tied to Wastewater study. • Relative advantages compared to other viable alternatives	Eliminated
Option 8 – Desalination	Sea water or brackish water is desalinated in order to obtain fresh water suitable for human consumption. Volume: Design to meet demand	• Construction of desalination plant/Effluent discharge. • High energy demands • Overall cost.	Retained for Evaluation in Section 6

Water System Alternative	Description of Option	Evaluation Considerations	Recommendation
Option 9 – Develop a New Surface Water Source	Identify surface water source, design, construct and operate source, treatment, transmission and distribution system Volume: 9.2 MGD (based on Barrett [1994] & SWCA/Tom Nance Water Resource Engineering [2007])	• Complexity in identification, design and implementation • Relative advantages compared to other viable alternatives • Overall cost	Eliminated; Implementation of the Lost River plan described in SWCA (2007) might provide additional supply if needed in the future.

Option 4 and Option 9 (Lost River plan) are improvements to the Navy Reservoir. Development of these options may be necessary to meet the DoD-wide water needs, but additional study is needed to fully evaluate these options.

6. Viable Water System Alternatives

6.1 OVERVIEW

This section provides a summary of the sustainable and available yield estimates for the NGLA, the required supply to meet the USMC relocation water demand and other DoD requirements, the current DoD supply and the planned supply for Option 1 and Option 2.

6.1.1 Sustainable Yield

Sustainable yield is defined as the rate at which groundwater can be continuously withdrawn from an aquifer without impairing the quality or the quantity of the pumped water. In order to achieve the hypothetically available sustainable yield, the means of water withdrawal has to be optimized, which is usually not the case. Therefore, the full capacity of the aquifer is not available. Additionally, sustainable yield is not equal to recharge. In the case of the NGLA, leakage at the edges of the lens along the coastline must be taken into account.

There have been two published estimates of the NGLA: one by NGLS (CDM 1982), and one by Barrett Consulting with John Mink (cited herein as Barrett 1991). The NGLS estimates were based on a steady-state condition and relied on conservative assumptions such that future development and groundwater management programs could be easily implemented. The NGLS was the first to divide the aquifer into a series of six sub-basins and 47 management zones. The sub-basin division is based primarily on topographic expression of basement topography forming effective hydrological divides in the subsurface. Based on the position of the freshwater lens, the sub-basins can be either basal (freshwater lens floating on top of salt water), or para-basal (freshwater lens bottom in contact with basement rock, where the basement surface rises above the freshwater-saltwater interface). Management zones are a construct to optimally manage well fields within the basin.

The second estimate of sustainable yield was prepared by Barrett (1991), which revised the simulation to a transient system rather than steady-state. Barrett argued that the NGLA is best described as a transient system, as the majority of the recharge comes during the wet season and that transient conditions best represent seasonal variations in recharge. The revised estimate of using transient conditions increased sustainable yield to approximately 70 to 80 MGD. Table 6-1 compares sustainable yield estimates of the NGLS (1982) and Barrett (1991) reports for each sub-basin. Current estimates of well production and available yield are presented in Table 6-1. The majority of the Andersen and Agafa-Gumas sub-basins lie beneath existing DoD property (Andersen AFB and North West Field). Additionally, a significant portion of the Finegayan sub-basin lies below the Naval Communication Station property abutting the NW Field to the south. The yield estimates presented herein utilize the Barrett (1991) yield estimates as the basis for determining available yield (Dr. Jensen (WERI), pers. comm., October 1991). The management zones identified in the 1982 NGLS do not match the sub-basin boundaries which are based on the 1991 volcanic basement contours. As a result of this discrepancy, the study presented herein does not rely on the 1982 NGLS management zones. Additionally, the NGLS management zones were a constructed used as a means of managing well fields. With the changes to the number and location of wells since the early 1980s, the 1982 NGLS zones appear to be outdated.

Barrett (1991) argued that the increased estimate is supported by increased withdrawals in the past decade along with the relative stability of the basal portions of the aquifer, especially in heavily exploited Yigo and Finegayan sub-basins. However, McDonald and Jensen (2003) suggest that there has been a distinct chloride increase over time, which they interpreted as being indicative of over-pumping.

Table 6-1: Sustainable Yield Estimates

Sub-basin	Well Production	1982 NGLS		1991 Barrett et al	
		Sustainable Yield	Available Yield	Sustainable Yield	Available Yield
Agana	10.9	13.13	2.23	20.5	9.60
Mangilao	2.5	3.90	1.37	6.6	4.07
Andersen	0.7	6.24	5.49	9.8	9.05
Agafa-Gumas	0.0	10.09	10.09	12	12.0
Finegayan	8.2	6.39	-1.84	11.6	3.36
Yigo-Tumon	21.3	19.08	-2.25	20	-1.33
TOTALS	**43.7**	**58.85**	**15.10**	**80.5**	**36.75**

Production references:
Navy– measured or calculated values from Navy Utility Report, 2005
Air Force – measured values from AAFB Utility Report, May 2006
GWA - 30-Day Average Rates from GWA WRMP

The 2007 GWA Water Resources Master Plan (WRMP) (GWA, 2007) discusses significant system losses as an explanation for the apparent lack of stress being shown in the basal aquifer. Based on a population of 168,564 (2005 U.S. Census) and an assumed per capita usage of 125 gpcd (gallons per capita per day), total consumption should be approximately 26 to 31 MGD. In fact, current production is approaching 60 MGD; 44 MGD from the northern aquifer, 11 MGD from the Navy Reservoir, and 2 MGD from the Ugum diversion in the south. The discrepancy is likely due to leakage within the distribution networks. Based on these numbers, the GWA water system loss may be as high as nearly 50 percent, while other estimates of loss are in the 34 to 40 percent range. While it is probable that the majority of the lost water ultimately returns to the aquifer, upconing from below as indicated by increasing chloride content is likely a result of over-pumping.

Updated production estimates from the six sub-basins from 1996 are: Agana – 11 MGD, Mangilao – 2.5 MGD, Yigo – 21 MGD, Finegayan - 8 MGD, Andersen - 1 MGD, and Agafa-Gumas – <1 MGD, for a total production of 44 MGD. This is an 8 MGD increase over the estimate provided in the 1991 Barrett report. The total estimated production from the year 2003 (McDonald 2003; GWA 2007) is approximately 46 MGD, another increase of greater than 8 MGD over a 6-year interval. This trend clearly demonstrates the demand on the freshwater lens as a potable water source

Based on these data and estimates, it is clear that the groundwater resources within the Andersen or the Agafa-Gumas sub-basins are under-developed, compared to the southern sub-basins. Both the Andersen and Agafa-Gumas sub-basins are predominated by para-basal zones, meaning that they have the potential for increased production rates. These sub-basins also have the benefit of not creating a significant impact on groundwater production for civilian purposes, as the majority of these sub-basins lie under DOD property and are therefore generally unavailable for civilian exploitation. An additional factor related to the selection of these two sub-basins is that the Agafa-Gumas sub-basin is near the proposed development area for the Marine relocation. However, GWA plans to install additional wells near the AAFB property in the Agafa-Gumas sub-basin. The GWA wells could reduce the amount of freshwater that is available on the DoD property.

6.1.2 Water Supply to Meet USMC Relocation and Other DoD Requirements

The future maximum daily demand and future required supply for the USMC relocation and other DoD requirements is presented in Table 6-2. Future required supply is calculated according to the description in Section 3.2.1 for water supplies dependent on groundwater to meet the maximum daily demand with the largest well out of service. Other DoD requirements include an allotment of approximately 4 MGD to the Government of Guam (GovGuam) documented in a Memorandum of Understanding from 1991.

Table 6-2: Required Water Supply

Units (MGD)	Future Maximum Daily Demand	Largest Well	Future Required Supply
USMC Finegayan Base Complex	12.1	0.6	12.8
Andersen AFB	5.2	0.7	5.9
Navy			
Naval Hospital	0.7		
Apra	9.8		
Ordnance Annex	0.3		
Barrigada	0.8		
Nimitz Hill	0.4		
GWA Allotment	4.0		
Total Navy Sites	16.0	NA	16.0

The current DoD water supply is described in Table 6-3. The Navy Reservoir, Almagosa Springs & Bona Springs provide the supply to naval facilities in addition to the current supply from wells. The Navy supply is currently sufficient to meet the Navy demand and the GWA allotment. Additional supply is required for AAFB, the naval facilities, and the USMC Finegayan Base Complex to meet future DoD demands.

Table 6-3: Current Water Supply and Additional Supply Required to Meet Future DoD Demands

Site	Future Required Supply	Current Supply	Current Supply Description	Additional Required Supply
USMC Finegayan Base Complex	12.8	2.3	Navy Wells on Finegayan Bases	10.5
Andersen AFB	5.9	4.7	Marbo Wells in Andersen South Annex / Five Wells on AAFB	1.2
Navy				
Naval Hospital	0.7	0.3	Navy WTP; Navy Wells	
Apra	9.8		Navy WTP	
Ordnance Annex	0.3		Navy WTP	
Barrigada	0.8	0.1	Navy WTP; Navy Wells	
Nimitz Hill	0.4		Navy WTP	
Navy Reservoir, Almagosa Spgs & Bona Springs		11.0		
GWA Allotment	4.0		Navy WTP	
Total Navy Sites	16.0	11.4		4.5

Units (MGD)

Planned additional DoD supply is presented in Table 6-4. The planned additional supply is based on groundwater development with the exception of options supporting the Navy Reservoir – dredging the reservoir to increase capacity and development of the Lost River as a surface water source.

Table 6-4: Planned Additional Supply

Site	Planned Additional Supply	Future Supply Description
USMC Finegayan Base Complex	13.0	Wells on AAFB (Option 1)
Andersen AFB	1.7	Five proposed wells
Navy		
Naval Hospital	0.5	Rehabilitation or replacement of well NRMC #3 (Option 2)
Navy Reservoir	2.5	Dredging the Navy Reservoir to the original capacity (Option 4) Continue design analysis of Lost River surface water development (Option 9 – [SWCA, 2007]) – supply uncertain, not included in Planned Supply[1]
Total Navy Sites	3.1	

Units are in MGD
Note: As an alternative, replacement of inactive Navy wells, relocating wells to Barrigada (Option 2) may be considered to provide additional supply to the Navy Island Wide System. This option is discussed in detail in Section 6.3.

Well production estimates by sub-basin, including the planned groundwater supplies, are shown in Table 6-5. The planned supplies do not exceed the sustainable yield of the aquifer based on the 1991 estimates. Note that the Yigo sub-basin already exceeds the estimate of sustainable yield. For this reason, rehabilitation of the Tumon Maui well and Marbo #2 well is not planned. Although the USMC Finegayan Base Complex is located on the Finegayan sub-basin, the majority of the groundwater supply will be taken from Agafa-Gumas and Andersen sub-basins because the Finegayan sub-basin is near capacity.

Table 6-5: Well Production and Yield Estimates by Subbasin

Subbasin Units (MGD)	Agafa-Gumas	Agana	Andersen	Finegayan	Mangilao	Yigo	Total
Well Production							
GWA Active Wells		10	0.7	6.7	2.5	18	38
DoD Active Wells	0.0	0.8		1.5		3.1	5.4
GWA Expansion	2.9	2.7					5.6
GWA Well Rehabilitation		0.5		0.5		2.8	3.8
Air Force Planned Wells	***1.3***			***0.4***			***1.7***
Air Force Wells *Under Construction*	***0.7***			***0.9***			***1.6***
Option 1	***7.1***		***4.5***	***1.4***			***13***
Option 2		***0.5***					***0.5***
Total Well Production	12	15	5	11	2.5	24	70
Yield							
1991 Sustainable Yield Estimate	12	21	10	12	6.6	20	81
Available Yield	0.0	5.9	4.5	0.2	4.1	-4.2	11

Note: GWA estimates a total well rehabilitation capacity of 3.8MGD. The EPA permitted capacities for the inactive wells were used to estimate the well production by sub-basin which may differ from the measured capacity of the GWA wells.
Production references:
Navy– measured or calculated values from Navy Utility Report, 2005 and Navy guidance
Air Force – measured values from AAFB Utility Report, May 2006
GWA - 30-Day Average Rates from GWA WRMP

Based on the available information, the existing well production is 43.4 MGD. The expansion and rehabilitation estimates for GWA are 9.4 MGD. The planned wells for AAFB are 3.3 MGD.

Including the planned well production for the DoD, the total well production (DoD and GWA) is 70 MGD. The total sustainable yield estimate for the NGLS is 81 MGD. Therefore, the planned water supply for USMC is consistent with the sustainable yield estimates.

For this report, the maximum daily demand is used to determine the additional supply requirements and assess the available yield. Although theoretically it is appropriate to compare the average daily demand to the sustainable yield estimates, the comparison in the Final Water Utility Study is made between the sustainable yield and the GWA demand plus DoD maximum daily demand (MDD). This comparison is conservative, since the NGLS is a significant resource; the duration of time spent at the MDD is not known; and the resulting potential impact to the NGLS has not been quantified. Because this conservative assumption has been made, on average, there will be additional available yield in the sub-basins over the estimates presented in Table 6-9 if well production increased to meet the estimated DoD water demands.

The expansion and rehabilitation estimates identified by GWA in the GWA WRMP are included in the water resources planning. GWA's proposed locations for 16 new wells will need to be reviewed during the design stage to determine whether the DoD well locations should be adjusted. Installation of wells at Navy Barrigada may be a reasonable alternative to meet some of the USMC water demand. Excess water supply, assuming the planned increases to water supplies are fully implemented, is shown in Table 6-6. The total excess supply is 2.5 MGD at the USMC Finegayan Base Complex, 0.6 MGD at AAFB and -1.4 MGD at the naval facilities. The additional demand for the Navy will be met through the excess supply at USMC Finegayan, through connection with the Navy Island Wide System. Additional supply may be provided by Option 2 if replacement wells are located on Navy Barrigada (about 3.5 MGD) or by Option 3 – Purchase from GWA, but that quantity is subject to availability and therefore not included in this total.

Table 6-6: Excess Supply

	Current Supply	Planned Additional Supply	Total Future Supply (Current + Planned Additional)	Excess Supply (Total Future Supply -Required Supply)
USMC Finegayan Base Complex	2.3	13.0	15.2	2.5
Andersen AFB	4.7	1.7	6.5	0.6
Navy				
Naval Hospital	0.3	0.5	0.9	
Apra				
Ordnance Annex				
Barrigada	0.1		0.1	
Nimitz Hill				
Navy Supply	11.0	2.5	13.5	
GWA Allotment				
Total Navy Sites	11.4	3.1	14.5	-1.4 (Demand met by USMC Excess Supply through the connection to the Navy Island-wide System)

Units in MGD

6.2 OPTION 1 - OPTIMIZE GROUNDWATER RESOURCE DEVELOPMENT WITHIN DOD PROPERTY

This section provides the rationale for potential new supply well locations, well construction and O&M recommendations, and the water supply system components.

6.2.1 Potential Well Locations

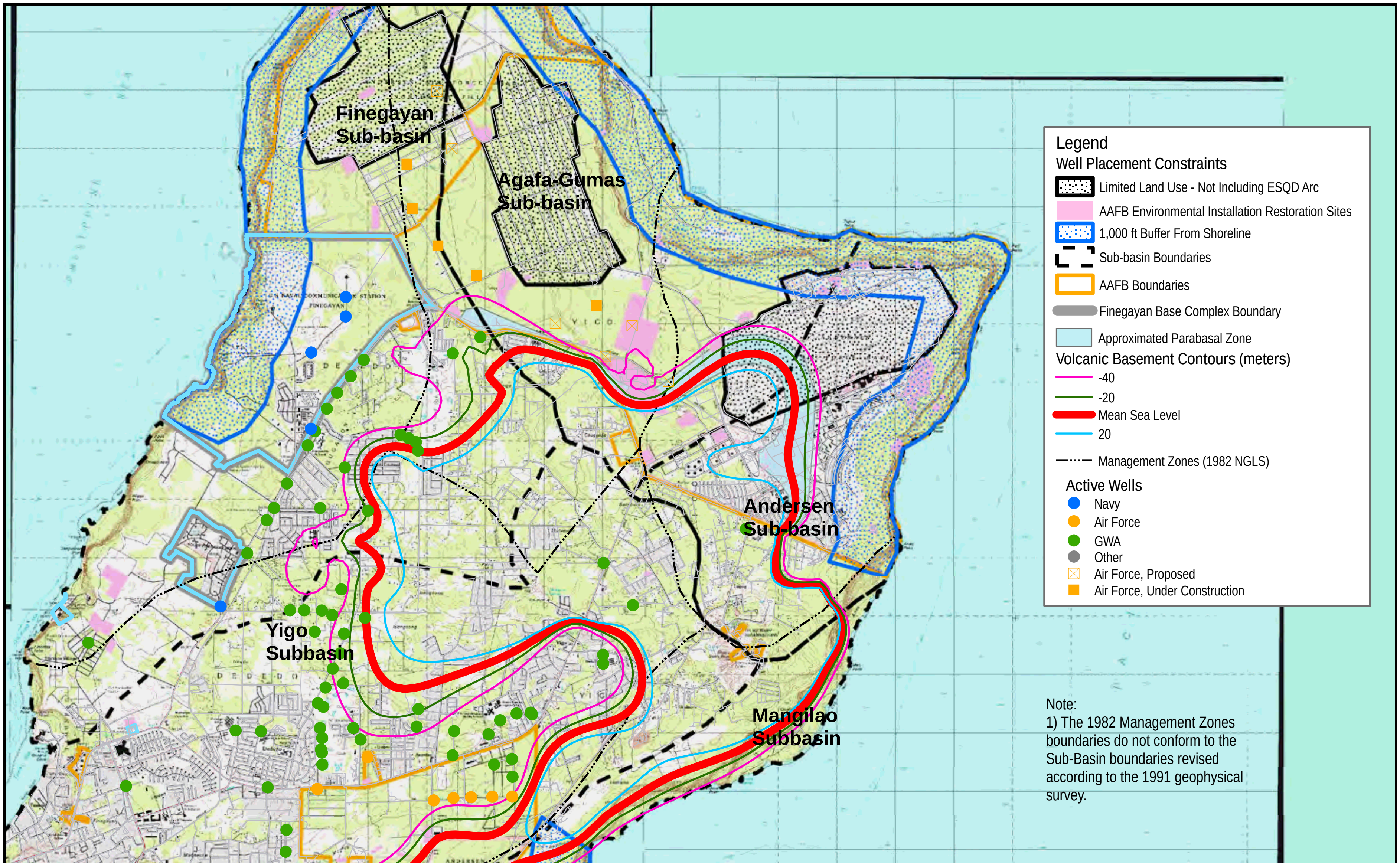
Using the 1991 estimates of sustainable yield, it appears there is sufficient groundwater available within military reservation boundaries to meet the new required supply resulting from the transfer of Marine Corps and other assets to Guam. Potential well locations are selected with consideration of the following constraints:

- Limiting well locations to DoD property;
- Limiting well production within sub-basins limited by the sustainable yield considering demands from GWA;
- Preferentially locating wells in para-basal zones to achieve higher yield with lower chloride levels, a lower number of wells and associated costs;
- Maintaining a 1,000-ft distance from the shoreline to avoid saltwater intrusion;
- Maintaining approximately a 800 to 1,000-ft distance from other supply wells;
- Maintaining a distance from environmental Installation Restoration sites (e.g., landfills); and
- Locating wells away from areas used by AAFB (e.g., airfields, munition storage).

Figure 6-1 presents the location of these constraints. The areas that are excluded from use due to AAFB land use are underestimates, and do not include a buffer to account for the explosive arcs. Due to the spatial limitations, some proposed well locations are near or within residential zones. The para-basal zones are roughly drawn on this figure. It is assumed that the para-basal zone extends seaward to a point where the top of the impermeable volcanic basement underlies the limestone aquifer at depth of approximately 40 meters below msl. A transitional para-basal/basal zone is assumed to exist in the area where the top of the impermeable volcanic basement underlies the limestone aquifer at depths between 40 and 60 meters below msl. These assumptions are based on existing GWA well locations described as para-basal or transitional that appear to meet these characteristics according to available volcanic basement contour maps.

The potential well locations and capacities are presented in Figure 6-2. Some considerations for the proposed locations include:

- Based on the Barrett (1991) volcanic bedrock contour mapping, a significant portion of the available potential high yield para-basal zone exists on or near the military reservation boundary.
- Additionally, wells located along the boundary are less secure. To compensate for this, the wells will have added security: provided with pitless adaptors, and located within a locked structure.
- If the para-basal zone yields less than the proposed well production, some of the wells may need to be relocated to the basal zone on DoD property, farther from the DoD boundary, and additional wells installed. This alternative layout is not presented in this utility report due to the uncertainty of land use by AAFB nearer to the active facilities.



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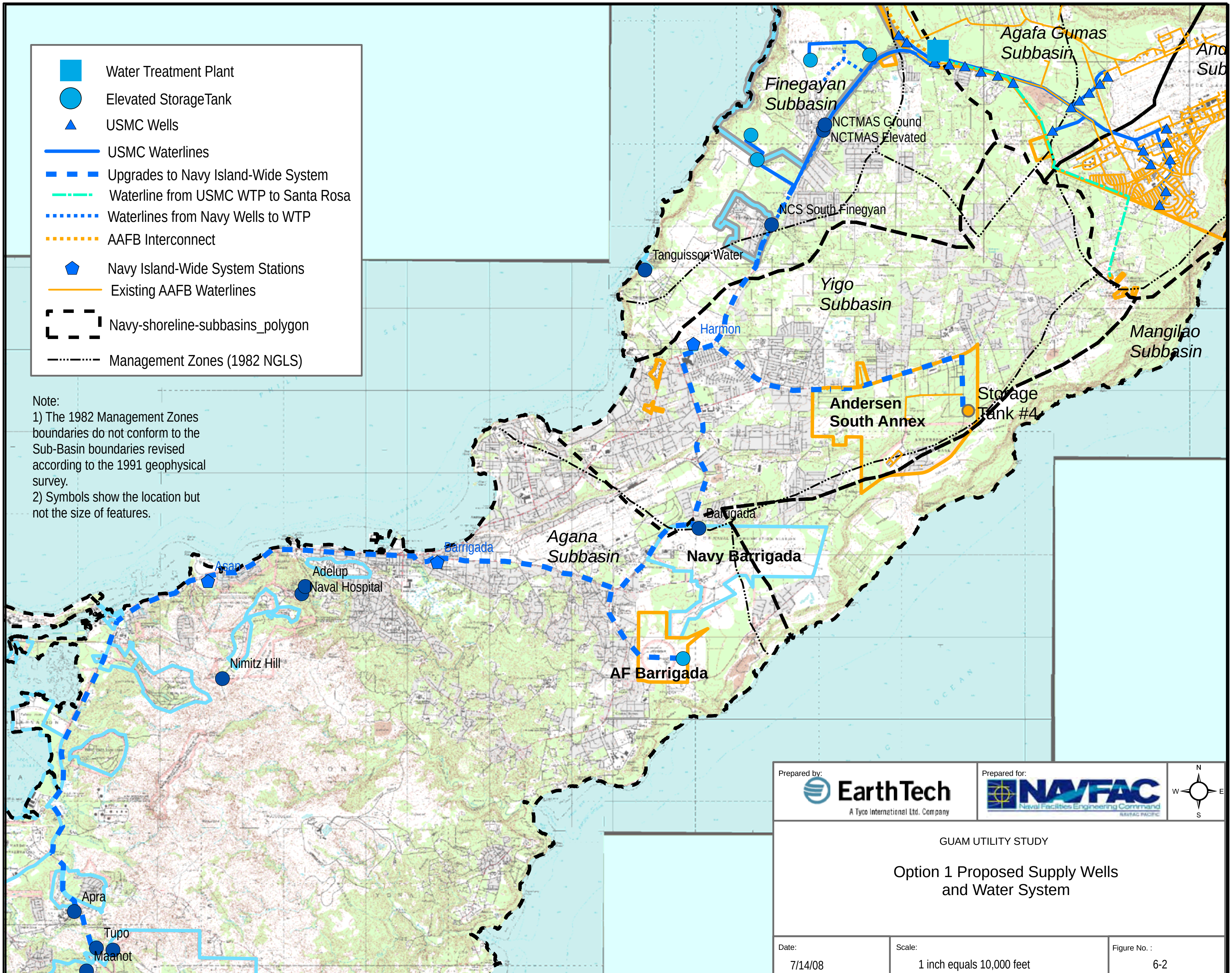
Well Placement Constraints

Date:	Scale:	Figure No. :
7/14/08	1 inch equals 8,000 feet	6-1



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Option 1 Proposed Supply Wells and Water System

Date:	Scale:	Figure No. :
7/14/08	1 inch equals 10,000 feet	6-2

Assuming that a para-basal well production capacity of 450 gpm and transitional well capacities ranging from 250 to 300 gpm can be achieved, it is estimated that a minimum of 22 wells will be needed to the meet required supply. These limits are consistent with the recommendations for supply wells presented in the 1982 NGLS. Prior to installation of any production wells, a geophysical survey should be completed to accurately establish the volcanic basement rock contours below the AAFB property, and multiple test wells will be necessary to confirm the desired pumping capacities can be achieved. One additional para-basal a well locations was added in this preliminary plan to provide back-up capacity in accordance with the Water Supply Systems UFC (3-230-19N) (DoD 2005). However, it is assumed that this well will not be routinely used, or if used, other wells nearby would be idled during use of the back-up wells.

Alternate well locations can be selected in areas of AAFB that are outside of the constraints shown on Figure 6-1 and the ESQD arc or other limitations to be specified by the base. Outside of the para-basal zone, a higher number of low capacity wells will be required to meet the required supply for the Finegayan Base Complex.

6.2.2 Water System Components

The water system components are described in this section. The main components are the wells, water treatment plant (assuming the NGLA will receive a GWUDI determination), and distribution system. The distribution system will include the water lines connecting the wells to the water treatment plant, water lines to distribution water to the Finegayan Base Complex, distribution within the base, storage and standby generators. In addition, the water lines connecting the existing Navy wells at Finegayan will be replaced and extended for treatment at the USMC water treatment plant. The USMC water lines will be connected to the Navy Island-wide system and the AAFB water system for added security in the event of emergencies. The Navy Island-wide system between Finegayan and Barrigada will be upgraded to allow water to flow from north to south, accommodating alternative arrangements which may house a significant portion of the USMC staff on Air Force Barrigada or Andersen South Annex. If alternative housing is selected, the anticipated water demands are approximately:

- 10.3 MGD at Andersen South Annex (75 percent of USMC housing) or
- 4.1 MGD at Air Force Barrigada (30 percent of USMC housing).

To add flexibility to meet water demands if alternate housing arrangements are selected, the following modifications are proposed:

- The Navy Island-wide system will be extended to Andersen South Annex to accommodate alternative housing arrangements;
- The water mains between Barrigada and Finegayan will be replaced;
- The Navy Island-wide system will be adjusted to allow 7 MGD to flow from the USMC treated waterlines to the facilities in south Guam or from south Guam to the north; and,
- A water main will be installed between the USMC WTP and Santa Rosa.

6.2.2.1 WELLS

Well Construction. Based on information in the report by McDonald and Jensen (2003) it was assumed that all wells will be constructed in limestone and a portion of the saturated interval will be screened below mean sea level. For wells in the para-basal zone, it was assumed the well would be terminated approximately 50 ft below msl and for wells in the basal/transitional zones, well termination was assumed to be 30 ft below msl. Well construction cost estimates assume a 500 gpm well drilled in the para-basal area to a total depth of 577 ft and a 300 gpm well drilled in the transitional area to a depth of 512 ft. Well construction details and calculations of "per foot" cost for each type of well are presented in Appendix E.

Because no previous Guam well construction information is available from which to make estimates, actual costs could differ significantly from those shown. In addition, since few wells exist in the projected production areas, it is not known if the proposed well locations would be able to produce the desired yields. Thus it is strongly recommended that a geophysical survey be commissioned to establish correct well placement based on accurate basement contours, and investigatory wells be drilled prior to installation of each production well.

Table 6-7 presents the well capacity and sub-basin location for potential wells needed to meet new demands resulting from transfer of DoD assets to Guam.

Table 6-7: Option 1 Proposed Well Details

Well Number	Proposed Capacity (gpm)	Sub-Basin
1	450	Agafa-Gumas
2	450	Andersen
3	250	Finegayan
4	450	Agafa-Gumas
5	450	Agafa-Gumas
6	450	Agafa-Gumas
7	450	Agafa-Gumas
8	450	Finegayan
9	450	Agafa-Gumas
10	450	Andersen
11	450	Andersen
12	450	Agafa-Gumas
13	450	Andersen
14	450	Agafa-Gumas
15	250	Agafa-Gumas
16	250	Finegayan
17	450	Andersen
18	450	Andersen
19	450	Agafa-Gumas
20	300	Agafa-Gumas
21	450	Andersen
22	300	Agafa-Gumas

Well Placement Studies. A number of geophysical tools exist which may be used to more accurately define the depth to volcanic basement rock at potential supply well locations. Seismic reflection, if successful, would provide the highest definition of the basement contours. However, seismic reflection is significantly more expensive than electromagnetic, or time and domain resistivity surveys. Based on the need to accurately define basement contours for proper well placement, the higher definition afforded by seismic methods is recommended. Seismic reflection costs approximately $10,000 to $20,000 per mile. Assuming approximately one-half mile of seismic work would be necessary for each well site and using the higher end of the price range, geophysical exploration at each supply well site would cost approximately $10,000. The total cost for 22 well sites would be approximately $220,000, based on costs in the mainland United States. This estimate does not include mobilization costs for seismic equipment, which could be significant in Guam.

Aquifer Monitoring: Periodic monitoring of the aquifer following implementation of Option 1 is recommended to optimize the system and adjust pumping rates if chloride levels are shown to be increasing. The monitoring program should be coordinated with GWA.

Well Operation and Maintenance. Proper O&M of the supply wells is necessary so that the wells consistently meet the design capacity and achieve the design life span. Deterioration of the well system starts as soon as the well is constructed and generally occurs slowly. Given time, a critical point is reached and deterioration accelerates, resulting in substantially decreased yield, or worse yet, total failure.

The proper operation of any well includes maintaining current and accurate records, from construction and throughout the life of the well. Regular monitoring provides information for gauging how the well is doing and allows the operator to:

- Detect system problems before failure occurs.
- Schedule maintenance or repairs.
- Predict future performance problems.
- Evaluate solutions to performance problems.
- Perform rehabilitation before irreparable damage is done.

Well system performance depends on three primary components: the aquifer; the well; and the pump. These components are interactive and interrelated. Thus, it is often difficult to separate the effects manifested by an inefficient pump from the effects of an inefficient well or a low-yield aquifer. Each component is susceptible to common performance problems.

Aquifers are susceptible to drought, over-pumping, and regional or local dewatering. Wells commonly experience screen or side wall plugging, fill or sloughing, and physical failure. Pumps are susceptible to corrosion, mechanical wear, erosion, and mechanical failure. Accurate and frequent monitoring and plotting of some easily obtained parameters will help the water system operator keep abreast of a wells performance and diagnose potential problems. These parameters are static water level (SWL), pumping water level (PWL), pumping rate, and specific capacity (Q/s).

The water level in a non-pumping well is known as the SWL or non-pumping water level. The water level in a pumping well is known as the PWL. Drawdown is the difference between PWL and SWL. SWLs and PWLs are affected by many other factors, including:

- Rate and duration of pumping.
- Accuracy of water level measurements.
- Rate and duration of pumping from other nearby wells (interference drawdown).
- Rate of aquifer recharge and other seasonal effects.
- Barometric pressure changes.

It is recommended that SWLs and PWLs be measured in all wells at least monthly, and preferably more frequently. SWL is a primary indicator of aquifer performance. A decline in SWL may indicate aquifer dewatering is occurring. PWL is an indicator of well and aquifer performance. A decline in PWL may indicate a decrease in well efficiency, regional water-level decline, or well interference.

Well pumping rates should be determined from flow meters located at the wells or from rate and run-time totalizers at pumping stations. Pumping rates and times should be recorded daily. It is important that pumping rate and PWL be measured at the same time. Pumping rate is primary indicator of pump performance. However, changes in pumping rate will also occur as a result of well or aquifer performance problems. If other parameters are relatively unchanged, a decline in pumping rate may indicate a decrease in pump performance.

The Q/s of a well is defined as the discharge (pumping) rate (Q) per unit drawdown (s), and is a measure of the well efficiency. The measurement unit for specific capacity is gallons per minute per foot of drawdown. A comparison of specific capacity values for a given well over time provides a means for evaluating changes in well performance. A decline in specific capacity may indicate a drop in well efficiency, assuming other parameters are relatively unchanged. A change in specific capacity implies that either drawdown or pumping rate (well yield) or both have changed. Changes in drawdown or yield can be real, or apparent, due inaccurate yield or water level measurements.

Long-term well performance data should be plotted to analyze trends or changes in performance. It is also important to collect and plot other data, such as precipitation, that may affect well performance, to help analyze long and short term water level trends.

Some examples of well system performance responses that may be observed in the local wells and possible causes include:

- Unchanged SWL, with declining PWL and pumping rate, may be due to a drop in well efficiency from plugging of the well screen and migration of fines into formation surrounding the well screen as a result of over-pumping the well. Pumping a well too hard, and exceeding the recommended entrance velocity, can cause migration of fine materials toward the screen and plugging of the filter pack.
- Unchanged SWL, with nearly identical declining trends in PWL, pumping rate and specific capacity, may be due to incrustation and biofouling of the borehole.
- Unchanged SWL, PWL and specific capacity, with a significant drop in pumping rate may be due to a hole in the pump column.
- Relatively unchanged SWL, PWL and specific capacity, with a steady decline in pumping rate, may be due to sand wear of the pump.
- Decline in both SWL and PWL may be due to aquifer dewatering.

It is recommended that inspection and maintenance of wells and pumps be performed at least every 10 years. Monitoring, plotting, and review of well and pump performance data described above (water levels, pumping rate, and specific capacity) will indicate if a maintenance interval more frequent than every 10 years is necessary.

After pumps are removed, wells should be televised (video inspected) to observe the integrity of the well and the current depth. The video inspection will help determine whether or not treatment is needed and the appropriate mechanical or chemical treatment to be performed, if any.

6.2.2.2 Central Water Treatment System

Well water extracted from the proposed 22 new wells will be collected and treated for water supply to the end user. This section presents design basis for water treatment, treatment technologies and processes, equipment layout, and construction and O&M costs. The plant is designed for a peak treatment capacity of 14 MGD.

All 22 new wells will be located within a single geographic area. Because the treatment system must include disinfection and filtration, it is more cost-effective to combine all well waters and treat the combined water in a central location.

The treatment plant location is shown on Figure 6-2. This location was chosen due to its proximity to the highway and the planned USMC base, has sufficient space to accommodate the treatment plant and an aboveground storage tank, and there are significant elevation changes in the region.

Evaluation Basis and Regulatory Requirements

The extracted groundwater in the area may be GWUDI. As such, the extracted groundwater will need to be disinfected and filtered. To achieve these objectives, the following evaluation basis is established:

Flow: 14 million gallons per day (MGD)

Influent and Treatment Objectives:

Parameter	Well Water	Treatment Objectives
Coliform	500 counts/100 ml	Zero counts/100 ml
E. coli	500 counts/100 ml	Zero counts/100 ml
Turbidity	1 NTU	0.3 NTU
Residual chlorine		0.5 mg/l

Because the groundwater may be determined to be under the influence of surface water, the water treatment system must meet the EPA GWUDI requirements. This is a worst case assumption for planning purposes. The regulations require chlorination and filtration in the water treatment process. Turbidity will be addressed through direct filtration. During design, alternative technologies to address turbidity should be considered, and compared to direct filtration based on cost and land requirements.

Treatment Processes and Schemes

Figure 6-3 presents a water treatment process flow block diagram. As presented in the diagram, the following is major water treatment process units:

- Equalization Tank
- Rapid Mix Tank
- Flocculation Tank
- Anthracite/sand
- Filter
- Thickener

- Filter Press
- Clearwell
- Treated Water Reservoir

Well water will be extracted from the 22 wells and transported to a central water treatment plant via a common pipeline. Chlorine will be injected in the common well water pipeline at a predetermined rate and the chlorinated water will be collected in an equalization tank that will also serve as a feed tank to the downstream treatment units. The equalized well water will be pumped into a rapid mix tank where alum will be added. The chemically reacted water will flow into a flocculation tank where polymer will be added and flocculation will occur. The flocculated water will flow to filters where suspended solids will be captured and removed. Chlorine will be added into the filtrate before it is collected in a clear well. The treated water will be transported to the distribution system.

The sludge (floc) generated from alum and polymer addition will be washed out by the backwash of the filters and it will be collected in a backwash water settling tank. The settled sludge then will be transported to a raw sludge holding tank and in turn to a thickener. The thickened sludge will be collected in a thickened sludge holding tank that will serve as a feed tank to filter presses. The clear water from the filter backwash water settling tank, the thickener supernatant, and the filter press filtrate will be returned to the equalization tank. The thickened sludge will be pumped into the filter presses for dewatering. The filter cake will be disposed at an offsite location.

Equipment Sizing and Redundancy

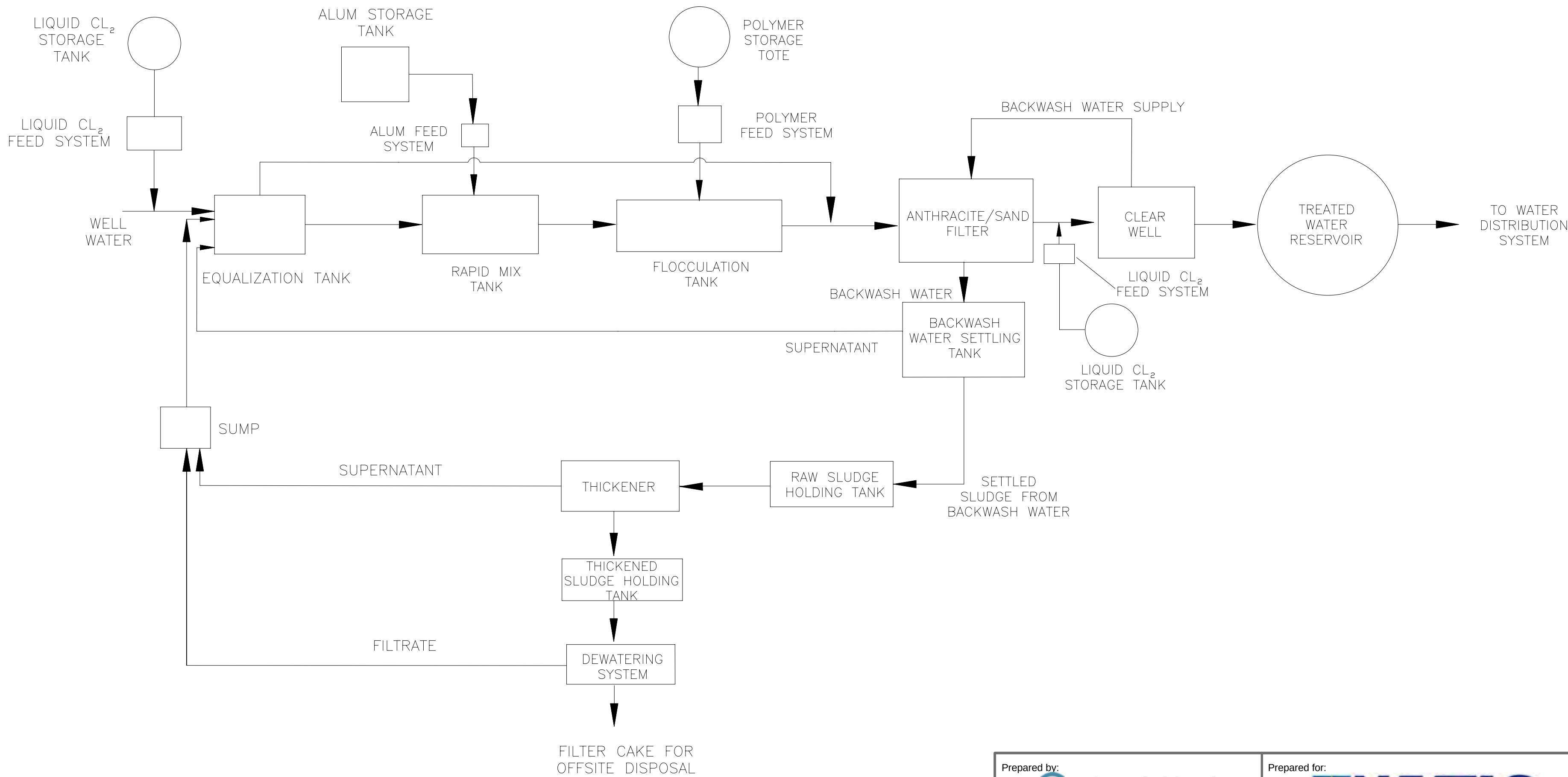
Key process equipment items, chemical feed systems, and buildings are identified and their information presented below.

Major Equipment Units:

Equipment Item	Quantity	Dimension	Notes/Comments
Equalization Tank	3	585,000 Gallons	
Rapid Mix Tank	2	20,000 Gallons	1 unit is an extra unit for redundancy.
Flocculation Tank	2	300,000 gallons	
Filter	6	Working Surface Area: 4,800 ft^2	
Raw Sludge Holding Tank	2	1,400 Gallons	
Thickener	2	Diameter: 7 ft.	
Thickened Sludge Holding Tank	2	Working Volume: 5,000 Gallons	
Filter Backwash Water Settling Tank	3	550,000 Gallons	
Filter Press	2	Filter Volume per Filter Press: 8 ft^3	
Treated Water Reservoir	1	3,000,000 Gallons	

Chemical Feed Storage/ Feed Systems:

Equipment Item	Quantity	Capacity	Notes/Comments
Liquid Chlorine Storage Tank	2	1,000 Gallons	
Liquid Chlorine Feed	4 with 2 in operation	Prechlorination: 5 gph Postchlorination: 10 gph	1 unit for each stage is an extra unit for redundancy.
Alum Storage Tank	2	10,000 Gallons	
Alum Feed System	2	5 gph	1 unit is an extra unit for redundancy.
Polymer Storage Tote	2	525 Gallon Tote	
Polymer Feed System	2	Neat Polymer: 4 gph Diluted Polymer: 60 gph	1 unit is an extra unit for redundancy.



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Option 1 Water Treatment Process Flow Block Diagram

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7/14/08	Not to scale	6-3

Buildings:

Building	Quantity	Size	Notes/Comments
Administration/Control Building	1	25’ Width x 40’ Length	Office and control room will be located.
Chemical Building	1	40’ Width x 40’ Length	Chemicals and chemical feed systems will be housed.
Filter Building	1	75’ Width x 100’ Length	Filters and local controls will be housed.
Filter Press Dewatering Building	1	70’ Width x 70’ Length	Filter presses, conveyors, dumpsters will be housed.

Redundancy is provided in the water treatment system to avoid or minimize shutdowns due to equipment failure. All process equipment units, water pumps, and chemical feed pumps are provided with redundancy.

Treatment Plant Operation and Maintenance

The water treatment systems will require the operator’s attention. Anticipated O&M requirements are presented below.

Routine Operation Activities:

- Prepare operation daily log sheets and record daily operation activities.
- Check the amount of the chemicals remaining in the storage tanks and order them in advance. There should be a sufficient inventory of the chemicals for water treatment.
- Dewater the sludge periodically and handle the filter cake for storage at a designated location. It is anticipated that sludge will be dewatered four times a day, each cycle taking about two hours. The operator should verify that filter cake drops properly and must follow the manufacturer’s operation instructions.
- Respond properly in a timely fashion when and alarm goes off, in accordance with standard operating procedures (SOPs).
- Follow the equipment manufacturers’ operation recommendations.

Routine Maintenance:

- Prepare maintenance log sheets and record maintenance activities. Frequent maintenance is not anticipated but the moving parts of the equipment items will need periodic maintenance.
- Follow the equipment manufacturers’ maintenance recommendations.
- In addition, the operator should avoid any direct contact with the chemicals and must follow the health and safety plan.

Equipment Layout

Figure 6-4 presents an equipment layout. The area required for installation of the proposed process units and support systems is estimated to be approximately 225,100 ft^2.

6.2.2.3 DISTRIBUTION SYSTEM

Pumps at each well station will pump water from the wells through raw water transmission mains to the central water treatment plant. Water will flow by gravity through the water treatment plant to a clearwell (or ground storage reservoir) on the water treatment plant site. High lift pumping equipment will pump treated water from the clearwell into treated water transmission mains which will bring water to the distribution system and to the elevated water storage tanks.

Due to variations in topography in the Finegayan service area, the water distribution system will be separated into two pressure zones. The high level zone will serve the northern portion of the Finegayan service area and the low level zone will serve the southern portion of the Finegayan service area.

The low level zone will serve areas with ground elevations from approximately 300 ft above msl to 400 ft above msl. The water tower will have a high water level of approximately 497 ft above msl.

The high level zone will serve areas with ground elevations from approximately 400 ft above msl to 490 ft above msl. The water tower will have a high water level of approximately 586 ft above msl.

Provisions for transferring water between the two pressure zones will be included in the high lift pump station. Additional pressure reducing and or booster pumping stations could be located at the interface between the two pressure zones.

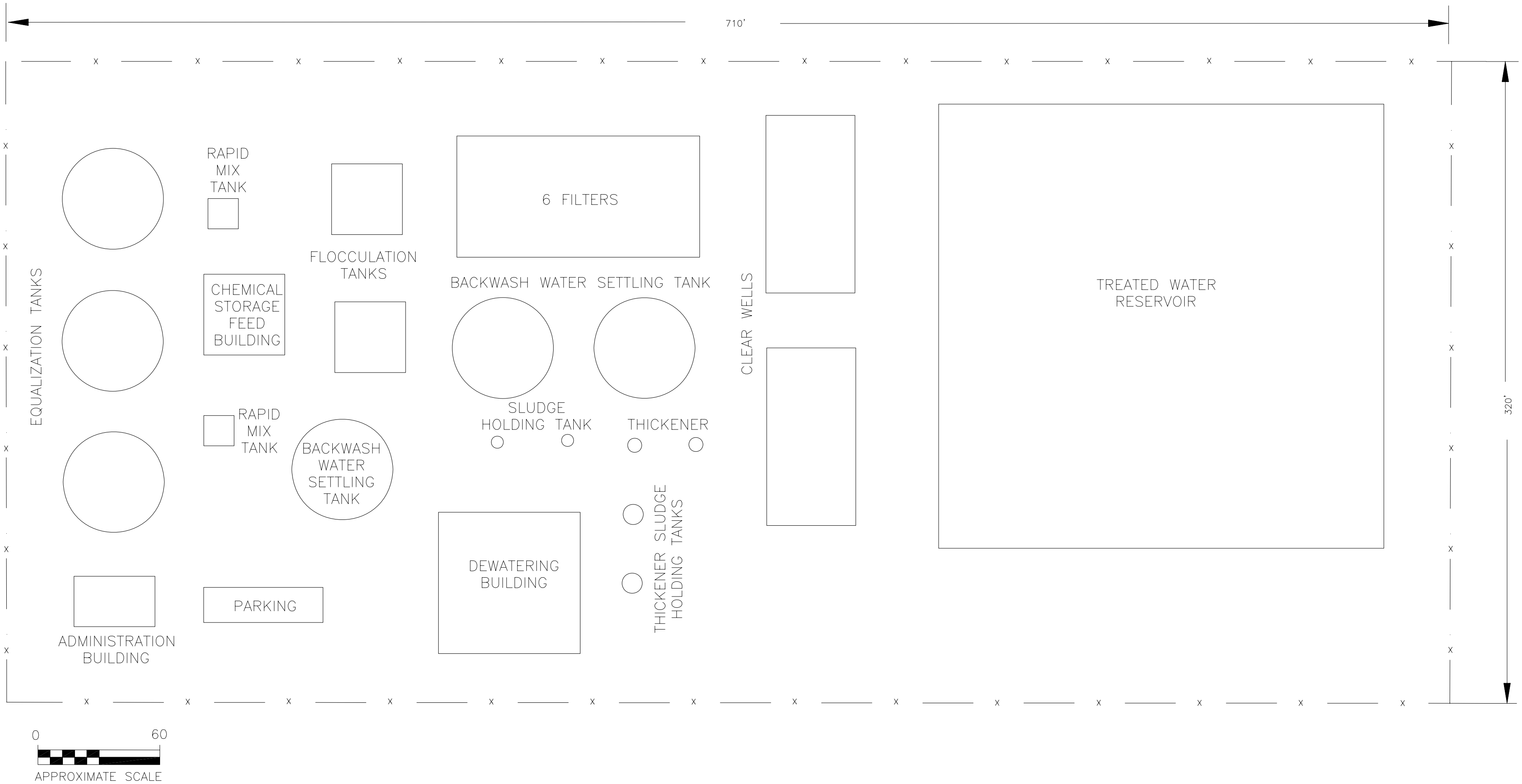
The proposed wells and water treatment plant are discussed earlier in this section of the report. Other water system components include:

- Well pumps
- Well pump discharge pipes at each well head
- Well house
- Raw water transmission mains
- High lift pumping equipment
- Treated water transmission mains
- Water distribution system
- Water storage
- Connection to the Navy's Island-wide water system
- Connections to the Andersen Air Force Base Water System
- Connections to the Guam Water Authority system
- Upgrades to the Navy's Island-wide water system

Well Pumping Stations

Each well station will include a submersible well pump. Each well pump will have an above ground discharge pipe, which will need to be protected. The discharge pipe will have an air/vacuum relief valve, check valve, surge relief valve, and a flow meter. No chemicals will be added at the well stations. The well houses will be constructed with decorative concrete block walls and wood truss supported roof with asphalt shingles. There will be one room at each well house.

Standby generators will be provided at 11 well houses to provide power to pump average day demands during power outages. The standby generators will be installed outside the well houses.



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Option 1 Water Treatment Plant Layout

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7/14/08	As shown	6-4

Raw Water Transmission Mains

The raw water transmission mains will convey water from the wells to the water treatment plant. The mains range from 8 to 30 inches in diameter, and are sized to provide velocities less than 6 fps to minimize friction head losses.

High Lift Pumping Equipment

A high lift pumping station will be constructed at the clearwell at the water treatment plant. The pump station will have equipment for pumping water from the clearwell to the distribution system. Pumps will be dedicated to the high level pressure zone and low level pressure zone. Flow control valves will allow water to be diverted from the high level zone to the low level zone. Pump operation will be automatically controlled based on water levels in the water towers.

A standby generator at the water treatment plant will provide power to pump average day water demands during power outages.

Treated Water Transmission Mains

Two treated water transmission mains will convey water from the water treatment plant to the Finegayan distribution system. Each transmission main will be dedicated to a pressure zone. The treated water is distributed throughout the Finegayan Base Complex through 8 inch and 12 inch water mains with valves and hydrants spaced at approximately 500 ft intervals.

Interconnections with AAFB will permit transfer of water between the DoD water systems.

Water Distribution System

A network of water distribution pipes will be constructed in the Finegayan service area. For planning purposes it is assumed the pipes will follow the preliminary street layout, and pipe diameters will range between 8 and 12 inches. The size and locations of distribution piping will need to be coordinated with expected land uses, estimated domestic demands and fire flow requirements for the structures that will be constructed on the base. The distribution system will be separated into the two separate pressure zones.

Water Storage

Approximately 5 MG of elevated storage are needed in the distribution system. One MG of treated water storage is provided in the clearwell at the water treatment plant. Additional storage is required in the distribution system. The elevated storage will be split between the two pressure zones. For planning purposes, it is assumed that the storage requirements will be 2.5 MG in each pressure zone. Two tanks will be installed in each pressure zone, to allow continuous operation when a tower is out of service for maintenance or repairs. The actual storage requirements in each zone may vary depending on the location of the divide between the two zones. For the purpose of this study, it was assumed that two 1.25 MG tanks will be constructed in each pressure zone.

Typical designs for water towers of this size include three alternative styles of tanks: fluted column steel tank, elevated spheroid steel tank, or composite (reinforced concrete pedestal with a steel tank). It will be important to construct large diameter distribution mains near the water tower locations.

Andersen South Developments

The paragraphs above describe water system improvements needed with all of the proposed USMC development at the Finegayan service area. If 75 percent of the proposed housing is moved to Andersen South (Alternative E), approximately 10.3 MGD water needs to be transferred to the Andersen South area. To achieve this, a 30-inch water transmission main will be extended from the proposed Finegayan 30 inch treated water transmission main to a new water storage facility in the vicinity of the existing water Storage Tank 4 at Andersen South. Additional storage and distribution system improvements will be needed to serve the housing. For preliminary planning purposes, it is assumed that the costs for the additional storage and distribution system improvements at Andersen South are offset by storage and distribution system piping that would not be needed on the Finegayan complex.

If housing is planned for the Andersen South area, additional water system planning and modeling will be needed to verify that the water can be transferred, stored, and distributed as needed for the housing water requirements. Due to variations in topography in the Andersen South area, the water distribution system for the proposed housing area would need to be split into two pressure zones. Based on a preliminary evaluation, the pressure zones could be at the same hydraulic grade lines as the AAFB Storage Tank 4 pressure zone and the Santa Rosa Reservoir pressure zone.

Navy Island-wide Water System Connections and Improvements

The US Navy Island-wide water system provides water to much of the island. The Navy's water system currently provides water to the limited existing developments in the Finegayan area by bringing water from the southern portions of its service area northward through a system of transmission mains, pumping stations, and reservoirs. Connecting the proposed MCB Finegayan water system to the Navy Island-wide system can provide greater flexibility in distributing drinking water around the island. To facilitate moving approximately 7 MGD of water from the proposed MCB Finegayan system southward to the Navy Island-wide system, a 24-inch main should be constructed from the Finegayan system to the Barrigada tank.

Additionally, extending the new transmission main from the Barrigada tank to the Tupo tank provides greater flexibility in moving water around the island. The new 24 inch and 30 inch water main would replace smaller diameter transmission mains, many of which were constructed of asbestos cement and are documented to be in deteriorating condition. Additional improvements, including replacing the Barrigada Pumping Station and Harmon Pumping Station with higher capacity pumps with variable frequency drives, will allow greater flexibility in transporting water throughout the island. Based on a review of documentation of the pumping station in the 2005 Water Study, it appears the Asan Pumping Station is not used and not needed, and should be abandoned.

Prior to constructing these additional mains, additional study and hydraulic modeling is needed to confirm the feasibility and operating conditions. Improvements to the Navy's water system can be implemented over time.

6.2.3 Costs

Details of the cost estimate are provided in Appendix C and Appendix E.

The capital costs for Option 1 are:

Capital Costs	$000
1) Water Resources Development	$21,257
2) Water Treatment	$75,857
3) Distribution	$336,274
Total Construction Cost without contingency	$433,388
Contingencies (20%)	$86,678
Engineering (15%)	$65,008
Total Capital Cost (with contingency and engineering)	**$585,074**
Present Worth Guam Capital Costs	**$589,663**

The O&M costs for Option 1 are:

O&M Costs	$000
1) Water Resources Development	$309
2) Water Treatment	$1,766
3) Distribution	$2,134
Total Annual O&M Cost without contingency	$4,209
Contingency (20%)	$842
Total Annual O&M Cost	**$5,051**
Present Worth of O&M Costs (25 year life)	$120,546

The total present worth of life cycle costs for Option 1 is $710M.

The costs for Option 1 are primarily to accommodate the USMC relocation. However, the Finegayan Base Complex is expected to also house staff from the army and continue to be the location of the Navy communication facilities. The Basic Scenario 1 (USMC only) costs are presented in Section 7.

6.2.4 Discussion

The best and most current information available (Barrett 1991) strongly suggests there is sufficient sustainable yield available in the aquifers underlying DoD property to meet the increased water demand resulting from the influx of Marine Corps and other military assets to Guam. However, because well development on the AAFB property has been limited, available data are scarce with regard to where and how to extract that resource. As such, potential production well locations were selected assuming:

- Para-basal zone well yields could range from 500 to 750 gpm
- Available volcanic basement contour mapping correctly and accurately reflects actual basement rock elevations and position below the limestone aquifer
- Location of the potential production wells in the para-basal zones would optimize production capacity while minimizing saltwater intrusion.

Potential well sites have not been ground verified and thus may need to be relocated due to nearby contaminant sources or other obstructions/exclusions. Concurrently, no active wells exist near most of the proposed high yielding well locations. As such, siting adjustments may be required for many if not all of the proposed wells based on more detailed hydrogeologic investigations prior to well construction and on-site evaluation of drilling exclusion areas. If the well capacities assumed for this study are not attained, additional wells will be installed to provide adequate water supply generated by Option 1 wells. Additionally, wells may be installed on Navy Barrigada, if there is not sufficient capacity. As discussed for Option 2 in Section 6.3, it is estimated that approximately 3.5 MGD may be produced from wells on Navy Barrigada.

Finally, a significant portion of the para-basal water in the Agafa-Gumas sub-basin is outside of the DoD-controlled property. GWA could choose to exploit that resource which could significantly impact the ability to extract large quantities of para-basal water on AAFB property. Coordination with the GWA will be essential if optimal well placement and extraction capacities are to be realized on DoD property.

Given these factors, the following steps should be taken prior to selecting this option as the main potable water source for expanded military demands on Guam:

- Obtain updated mapping of the volcanic basement rock contours and accurately map para-basal, basal, and transitional aquifer production zones for the entire AAFB property
- Adjust potential high yield well locations based on updated contour information
- Identify all current (and known future) well drilling exclusion zones as confirmed by AAFB personnel
- Modify potential well sites to conform with drilling exclusion zones, and determine if remaining sustainable yield is sufficient to meet demand requirements
- If remaining sustainable yield appears to be sufficient, complete a thorough geophysical survey of remaining potential production well siting areas to accurately identify volcanic basement contours in most likely potable well production areas
- Once precise basement contours have been determined, drill test wells in remaining potential high yield areas to verify capacity of production wells
- If production capacity is verified, coordinate production well location information with GWA so that future capacity of DoD production wells will not be impacted by future GWA production wells

6.3 OPTION 2 - DETERMINE THE REQUIREMENTS FOR REHABILITATION, TREATMENT OF WELL WATER, OR REPLACEMENT OF EXISTING WELLS

6.3.1 Analysis

This section provides the recommended approach for each inactive well, potential locations for replacement wells, and the proposed treatment to satisfy the requirements of a GWUDI determination.

6.3.1.1 INACTIVE DOD WATER SUPPLY WELLS

Construction, maintenance, and operation records are not available for the Navy and Air Force water supply wells on Guam; however, several DoD wells are reported to be inactive although the reason for idling wells is not always known. Some wells have been inactivated due to a structural or mechanical failure but the specific nature of the failure is unknown. Table 6-8 lists known inactive DoD wells and the problem causing inactivation (if known).

Table 6-8: Inactive DoD Wells Status, Problem, and Recommendation

Well Name	Well Owner	Well Status	Identified Problem
Well C	Navy	Inactive	Unknown
NCTS #2	Navy	Inactive	Structural/ Mechanical
NCTS #4	Navy	Inactive	Unknown
NCTS #8	Navy	Inactive	Structural/ Mechanical
NRMC #1	Navy	Operational	Microbial Contamination[a]
NRMC #2	Navy	Operational, but unreliable	Microbial Contamination[a]
NRMC #3	Navy	Inactive	Saline, Microbial Contamination
Marbo #2	Air Force	Inactive	VOC Contamination
Tumon Maui	Air Force	Inactive	VOC Contamination
Taraque #4	Air Force	Permanently Inactive	Saline
BPM #1	Air Force	Permanently Inactive	Structural/ Mechanical
NW #4	Air Force	Abandoned	Unknown

[a] NRMC #1 and NRMC #2 are operational; however, according to Navy Utility Report (2005), these wells have been turned off at times due to contamination

General Recommendations

When the status of the well is permanently inactive, the well should be properly abandoned and replaced with a well of equal or greater capacity if possible. In cases where the well is pumping saline water, the standard recommendation is to reduce pumping capacity to the point where salinity is reduced to an acceptable level. When the well is contaminated, but its capacity is not diminished, the recommendation is to add the appropriate treatment to the well to remove or inactivate contaminants and continue to use the well to its design capacity. Finally, when well inactivation was a result of structural or mechanical problems, the recommendation is to investigate and identify the specific problem and determine whether or not well rehabilitation is technically feasible and economically justified.

Structural/mechanical problems may be a result of numerous factors including, but not limited to, biological, chemical, or sediment fouling of aquifer formation, filter pack, or well screen; mechanical failure of well casing and/or screen as a result of corrosion or erosion; and collapse of the borehole as a result of seismic activity or caving formation. Regardless of the cause, the first step in rehabilitation is to remove the well pump and examine the well. After pumps are removed, wells should be televised (video inspected) to observe the integrity of the well and the current depth. The video inspection will help determine the appropriate mechanical or chemical treatment to be performed.

Wells containing sediment should be bailed, then developed by pumping and surging using the well contractor’s pump. If a well is fouled with iron bacteria, the well and pumping equipment should be cleaned and sanitized using both mechanical and chemical methods. The cleaning method should include a series of chemical treatments chosen to be most effective for the type of incrustation and/or iron bacteria found in the well and/or on the pumping equipment. If a well shows evidence of biofouling, it should be rehabilitated using well cleaners and super-chlorination. Jetting and high pressure air bursts are effective methods for uniform placement of cleaner and chlorine in a well.

If a well shows evidence of plugging from carbonate incrustation, it should be brushed and washed with an acid solution. Inhibitors and antifoam agents should be used; the work should be performed by trained contractors. Solutions pumped from the well should be neutralized prior to disposal. If a well has a collapsed screen, it may be possible to extract the old inner casing and well screen and install new inner casing and screen, depending on the original construction of the well. If an open borehole has collapsed, it may be possible to re-drill and develop the borehole. Each well must be evaluated on a case-by-case basis to decide the best course of action.

Specific Recommendations

Given the limited available yield in the Finegayan Sub-basin, no wells will be rehabilitated or replaced in this area. To provide additional supply to the Navy Island-wide system, replacement wells could be located on Navy Barrigada. If Option 1 is fully implemented, the DoD would have adequate supply. If there is additional water demand over the estimate provided herein, wells could be installed at Navy Barrigada for an estimated 3.5 MGD production. The groundwater from these wells will be treated on Barrigada and distributed to the Navy Island-wide system. The Navy Island-wide system will be upgraded to allow the water to flow from Barrigada to the naval facilities in the south. Water mains will be replaced due to the age and condition of the pipes. Reactivation and treatment is not recommended for Marbo #2 and Tumon Maui because there is no available yield remaining in the Yigo sub-basin based on the 1991 sustainable yield estimates. NRMC #3 at the Naval Hospital should be studied to reduce chloride levels using the general recommendations provided above. The five remaining planned wells at AAFB should be installed (HPE 2003).

Other DoD water system improvements that will be necessary if the NGLA is determined to be GWUDI are: a water treatment plant for the Marbo Wells on Andersen South Annex, a water treatment plant for the ten AAFB wells that are under construction or proposed, and a water treatment plant for the three NRMC wells at the Naval Hospital. These improvements are included in Option 2.

6.3.1.2 Potential Replacement Well Siting

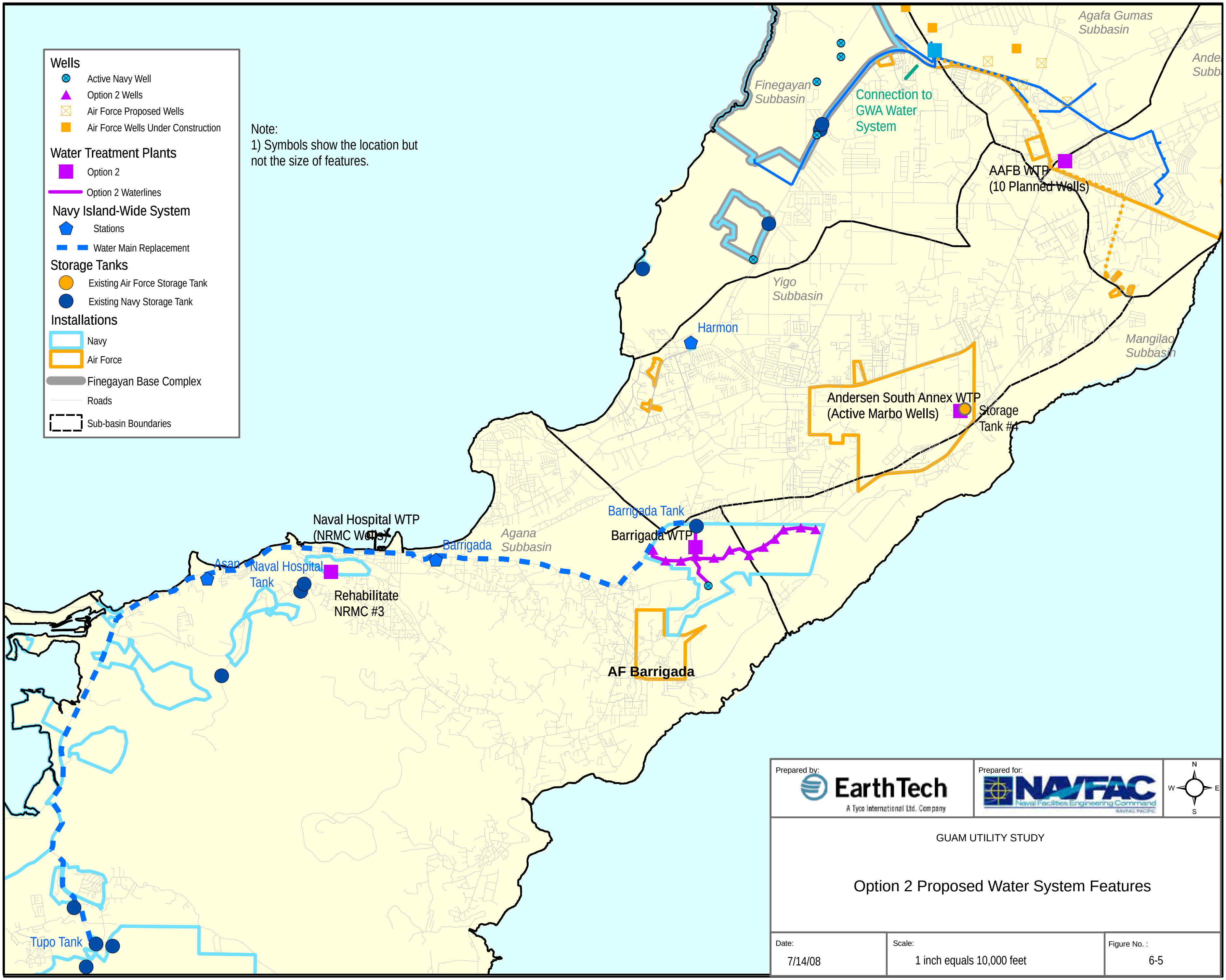
Figure 6-5 shows the proposed location of the replacement wells, treatment plants and additional waterlines. The wells on Barrigada are located in the para-basal zone running across the DoD property maintaining a 1,000 ft separation between the supply wells.

6.3.2 Water System Components

The water system components are described in this section. The main components are the wells, water treatment plants assuming the NGLA will receive a GWUDI determination and distribution system. The distribution system will include the water lines connecting the wells to the water treatment plant on Barrigada, a connection to the Navy Island-wide system and improvements to the Navy Island-wide system to allow treated water to be transported south. The Navy Island-wide system between Barrigada and Tupo will be upgraded to allow water to flow from north to south.

6.3.2.1 Water Treatment for the Marbo Wells #1, 3, 5, 6, 7, 8, and 9

Water extracted from the Marbo wells will be collected and treated for water supply to the end user. The groundwater from Marbo Wells #1, 3, 5, 6, 7, 8, and 9 will be treated by disinfection and filtration. The treatment plant is designed for a peak capacity of 3.32 MGD. This section presents design basis for water treatment, treatment technologies and processes, and equipment layout.


Wells
Active Navy Well
Option 2 Wells
Air Force Proposed Wells
Air Force Wells Under Construction
Water Treatment Plants
Option 2
Option 2 Waterlines
Navy Island-Wide System
Stations
Water Main Replacement
Storage Tanks
Existing Air Force Storage Tank
Existing Navy Storage Tank
Installations
Navy
Air Force
Finegayan Base Complex
Roads
Sub-basin Boundaries
Note:
1) Symbols show the location but not the size of features.
Agafa Gumas Subbasin
Finegayan Subbasin
Connection to GWA Water System
AAFB WTP (10 Planned Wells)
Yigo Subbasin
Harmon
Mangilao Subbasin
Andersen South Annex WTP (Active Marbo Wells)
Storage Tank #4
Barrigada Tank
Barrigada WTP
Naval Hospital WTP (NRMC Wells)
Barrigada
Agana Subbasin
Asan
Naval Hospital Tank
Rehabilitate NRMC #3
AF Barrigada
Tupo Tank
Prepared by:
EarthTech
A Tyco International Ltd. Company
Prepared for:
NAVFAC
Naval Facilities Engineering Command
N
W
E
S
GUAM UTILITY STUDY
Option 2 Proposed Water System Features
Date:
7/14/08
Scale:
1 inch equals 10,000 feet
Figure No. :
6-5

Evaluation Basis and Regulatory Requirements

Evaluation Basis:

Flow: 3.32 million gallons per day (MGD)

Influent Characteristics and Treatment Objectives:

Parameter	Well Water	Treatment Objectives
Coliform	500 counts/100 ml	Zero counts/100 ml
E. coli	500 counts/100 ml	Zero counts/100 ml
Turbidity	1 NTU	0.3 NTU
Residual chlorine		0.5 mg/l

There are no water quality data available for the specific wells. The well water quality for coliform and E. coli has been assumed as presented above. The turbidity available from the reviewed literature is used for evaluation.

Regulatory Requirements:

Because the groundwater may be under the influence of surface water, the water treatment system must meet EPA GWUDI requirements. This is a worst case assumption for planning purposes. The regulations require disinfection and filtration in the water treatment process.

Treatment Processes and Schemes

There are various water treatment technologies and processes for disinfection and filtration. Disinfection can be achieved by chlorination, ozonation, and/or UV, and filtration by sand or membrane filtration. For this evaluation, the following approach is taken for water treatment:

- Chlorination for disinfection
- Anthracite/Sand filtration for filtration

Figure 6-6 presents a water treatment process flow block diagram. As shown on Figure 6-6, the major water treatment process units include:

- Equalization Tank
- Rapid Mix Tank
- Flocculation Tank
- Anthracite/Sand Filter
- Thickener
- Filter Press

Alternative filtration technologies should be considered during design. Water from Marbo Wells 1, 3, 5, 6, 7, 8, and 9 will be collected in an equalization tank and treated for turbidity by coagulation/flocculation and filtration prior to entering Storage Tank No. 4. The filtered water will be collected in Storage Tank No. 4.

The sludge generated from the water treatment processes will be processed through thickener and filter press dewatering. Filter cake will be disposed off-site.

Equipment Sizing and Redundancy

Key process equipment items, chemical feed systems, and buildings are identified and their information presented below.

Major Equipment Units:

Equipment Item	Quantity	Approximate Capacity	Notes/Comments
Equalization Tank	2	280,000 Gallons	
Rapid Mix Tank	2	4,650 Gallons	
Flocculation Tank	2	70,000 gallons	1 unit is an extra unit for redundancy.
Filter	3	Working Surface Area: 1,176 ft^2	
Raw Sludge Holding Tank	2	350 Gallons	
Thickener	2	Diameter: 4 ft.	
Thickened Sludge Holding Tank	2	Working Volume: 1,200 Gallons	
Filter Backwash Water Settling Tank	2	275,000 Gallons	
Filter Press	2	Filter Volume per Filter Press: 8 ft^3	

<u>Chemical Feed Storage/ Feed Systems:</u>

Equipment Item	Quantity	Approximate Capacity	Notes/Comments
Liquid Chlorine Storage Tank	2	125 Gallons tote	
Liquid Chlorine Feed System	4	Prechlorination: 1gph	1 unit for each stage is an extra unit for redundancy.
Alum Storage Tank	2	2,500 Gallons	
Alum Feed System	2	2 gph	1 unit is an extra unit for redundancy.
Polymer Storage Tote	2	125 Gallon tote	
Polymer Feed System	2	Neat Polymer: 0.5 gph Diluted Polymer: 20 gph	1 unit is an extra unit for redundancy.

<u>Buildings:</u>

Building	Quantity	Size	Notes/Comments
Administration/Control Building	1	25 ft Width × 40 ft Length	Office and control room will be located.
Chemical Building	1	30 ft Width × 40 ft Length	Chemicals and chemical feed systems will be housed.
Filter Building	1	50 ft Width × 50 ft Length	Filters and local controls will be housed.
Dewatering Building	1	60 ft Width × 60 ft Length	Filter presses, conveyors, dumpsters will be housed.

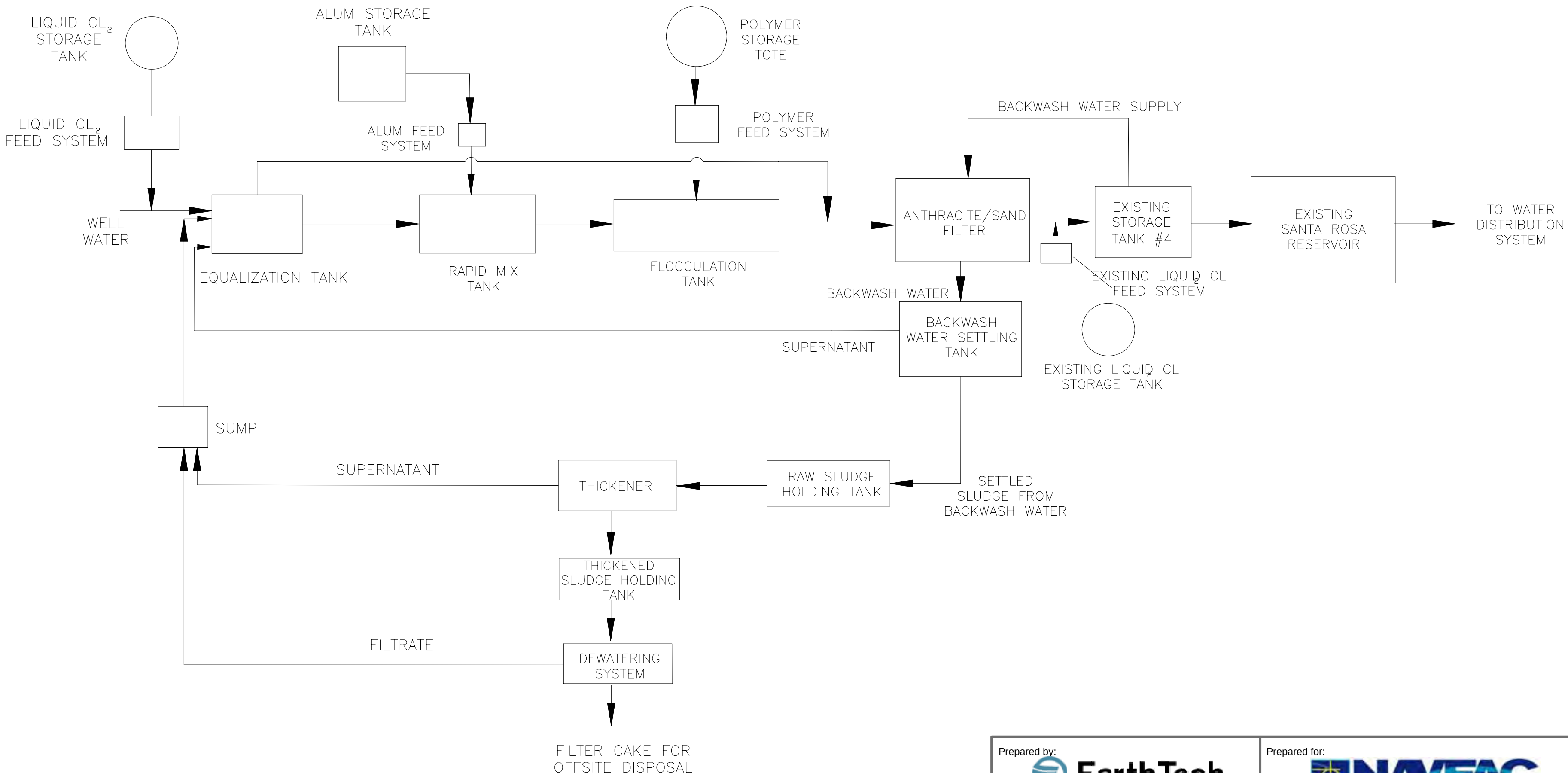
Redundancy is provided in the water treatment system to avoid or minimize shutdowns due to equipment failures. All process equipment units, pumps and chemical feed pumps are provided with redundancy.

Operation and Maintenance

The water treatment systems will require the operator's attention. Anticipated O&M requirements are presented below.

Routine Operation Activities:

- Preparation of operation daily log sheets and record daily operation activities.



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Prepared for: NAVFAC Naval Facilities Engineering Command NAVFAC PACIFIC

GUAM UTILITY STUDY

Option 2 Water Treatment Process
Flow Block Diagram
Andersen South Annex

Date:	Scale:	Figure No. :
7/14/08	Not to scale	6-6

- Check the amount of the chemicals remaining in the storage tanks and order them in advance. There should not be a shortage of water treatment chemicals.
- Dewater the sludge periodically and handle the filter cake for storage at a designated location. It is anticipated that sludge will be dewatered once a day, taking about two hours. The operator should verify that filter cake drops properly and must follow the manufacturer's operation instructions.
- Respond properly in a timely fashion when alarm goes off, in accordance with the SOPs.
- Follow the equipment manufacturers' operation recommendations.

Routine Maintenance:

- Prepare maintenance log sheets and record maintenance activities. Frequent maintenance is not anticipated but the moving parts of the equipment items will need periodic maintenance.
- Follow the equipment manufacturers' maintenance recommendations.
- In addition, the operator should avoid any direct contact with the chemicals and must follow the health and safety plan.

Equipment Layout

Figure 6-7 presents an equipment layout. The area required for installation of the proposed process units and support systems is estimated to be approximately 90,000 ft^2.

6.3.2.2 WATER TREATMENT FOR THE AAFB 10 NEW WELLS

Well water extracted from the AAFB 10 new wells will be collected and treated for water supply to the end user. The treatment plant is designed for a peak capacity of 3.31 MGD. This section presents design basis for water treatment, treatment technologies and processes, and equipment layout.

Evaluation Basis and Regulatory Requirements

Evaluation Basis:

Flow: 3.31 million gallons per day (MGD)

Influent Characteristics and Treatment Objectives:

Parameter	Well Water	Treatment Objectives
Coliform	500 counts/100 ml	Zero counts/100 ml
E. coli	500 counts/100 ml	Zero counts/100 ml
Turbidity	1 NTU	0.3 NTU
Residual chlorine		0.5 mg/l

There are no water quality data available for the specific wells. The well water quality for coliform and E. coli has been assumed as presented above. The turbidity level is assumed to be 1 NTU based on guidance from the Navy.

Regulatory Requirements:

Because the groundwater may be under the influence of surface water, the water treatment system must meet EPA GWUDI requirements. The regulations require disinfection and filtration in the water treatment process.

Treatment Processes and Schemes

There are various water treatment technologies and processes for disinfection and filtration. Disinfection can be achieved by chlorination, ozonation and/or UV, and filtration by sand or membrane filtration. For this evaluation, the following approach is taken for water treatment:

- Chlorination for disinfection
- Anthracite/Sand filtration for filtration

Figure 6-8 presents a water treatment process flow block diagram. As shown on Figure 6-8, the major water treatment process units include:

- Equalization Tank
- Rapid Mix Tank
- Flocculation Tank
- Anthracite/Sand Filter
- Thickener
- Filter Press
- Clearwell
- Treated Water Reservoir

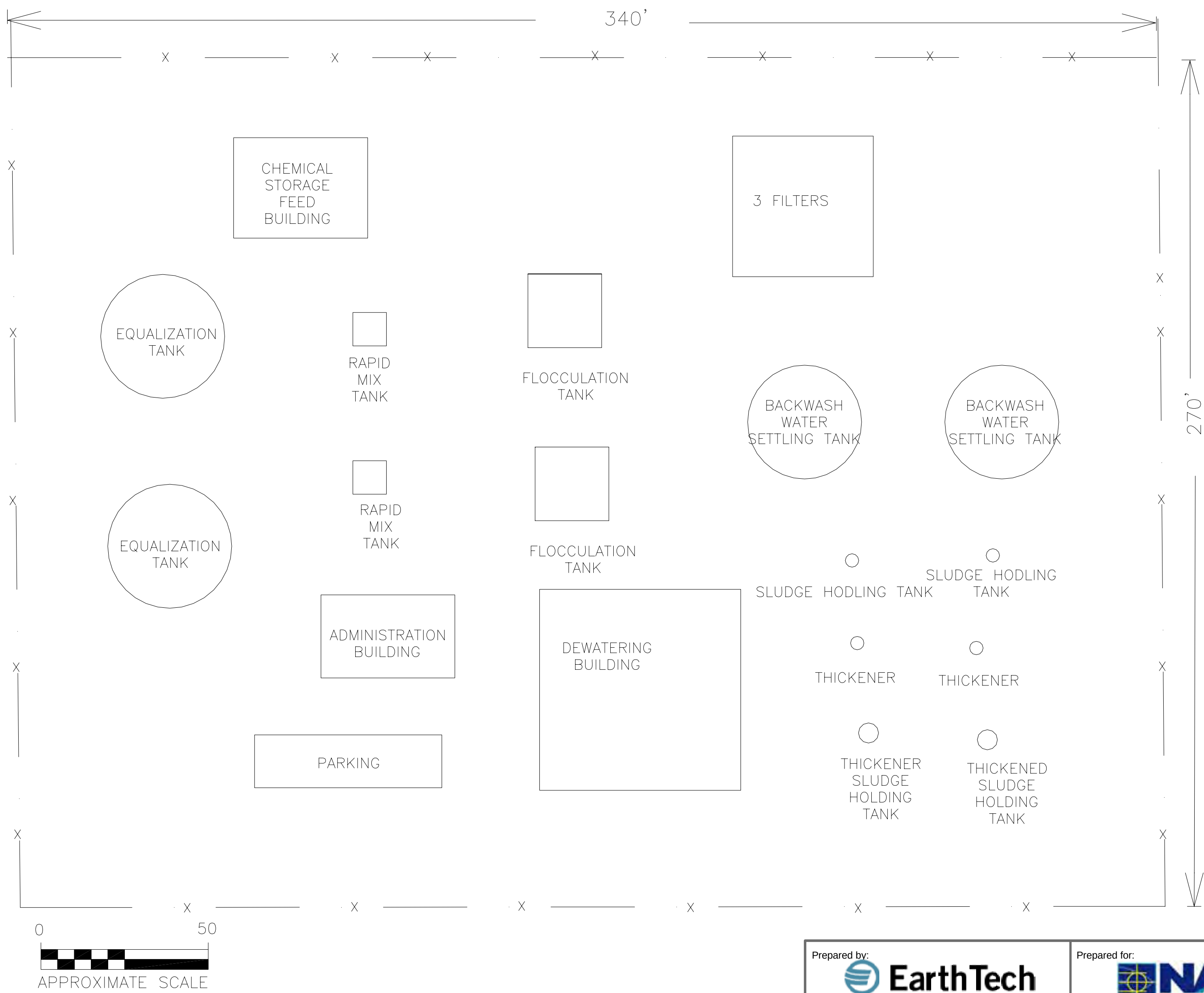
As shown in Figure 6-8, the well waters will be disinfected with chlorine, coagulated/flocculated, and filtered prior to entering the water distribution system. The sludge generated from the water treatment processes will be processed through thickener and filter press dewatering. Filter cake will be disposed off-site.

Equipment Sizing and Redundancy

Key process equipment items, chemical feed systems, and buildings are identified and their information presented below.

Major Equipment Units:

Equipment Item	Quantity	Approximate Capacity	Notes/Comments
Equalization Tank	2	280,000 Gallons	
Rapid Mix Tank	2	4,650 Gallons	1 unit is an extra unit for redundancy.
Flocculation Tank	2	70,000 gallons	
Filter	3	Working Surface Area: 1,176 ft^2	
Raw Sludge Holding Tank	2	350 Gallons	
Thickener	2	Diameter: 4 ft.	
Thickened Sludge Holding Tank	2	Working Volume: 1,200 Gallons	
Filter Backwash Water Settling Tank	2	275,000 Gallons	
Filter Press	2	Filter Volume per Filter Press: 8 ft^3	
Treated Water Reservoir	1	1,000,000 Gallons	



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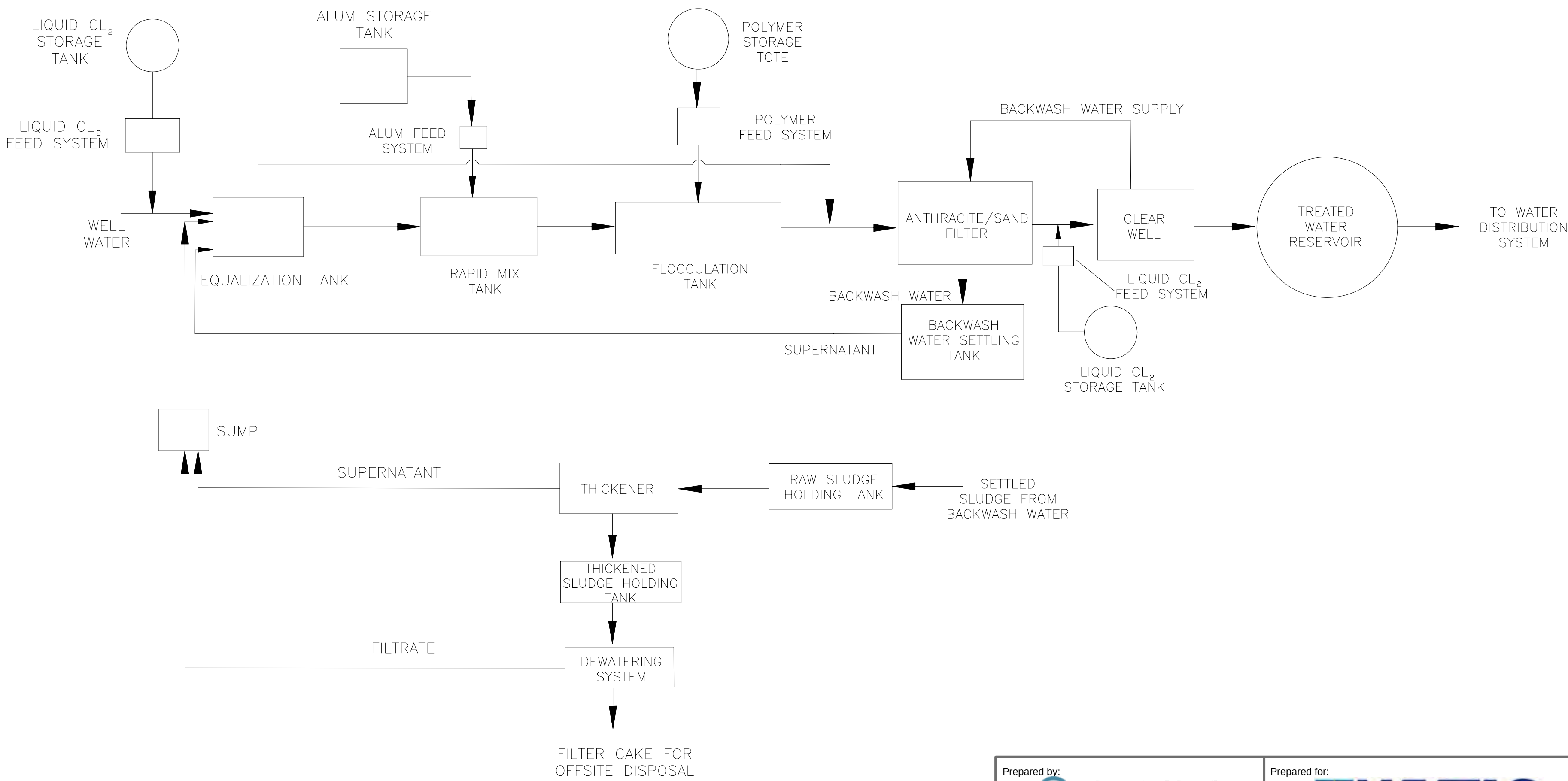
Option 2 Water Treatment Plant Layout Andersen South Annex

Date:	Scale:	Figure No. :
7/14/08	As shown	6-7



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GUAM UTILITY STUDY

Option 2 Water Treatment Process Flow Block Diagram AAFB (10 Wells)

Date:	Scale:	Figure No. :
7/14/08	Not to scale	6-8

Chemical Feed Storage/ Feed Systems:

Equipment Item	Quantity	Approximate Capacity	Notes/Comments
Liquid Chlorine Storage Tank	2	125 Gallons tote	
Liquid Chlorine Feed System	4	Prechlorination: 1 gph	1 unit for each stage is an extra unit for redundancy.
Alum Storage Tank	2	2,500 Gallons	
Alum Feed System	2	2 gph	1 unit is an extra unit for redundancy.
Polymer Storage Tote	2	125 Gallon tote	
Polymer Feed System	2	Neat Polymer: 0.5 gph Diluted Polymer: 20 gph	1 unit is an extra unit for redundancy.

The cost of a treated water storage tank is not included in this estimate because it is assumed that AAFB is constructing a tank as part of the on-site well development.

Buildings:

Building	Quantity	Size	Notes/Comments
Administration/Control Building	1	25 ft Width × 40 ft Length	Office and control room will be located.
Chemical Building	1	30 ft Width × 40 ft Length	Chemicals and chemical feed systems will be housed.
Filter Building	1	50 ft Width × 50 ft Length	Filters and local controls will be housed.
Dewatering Building	1	60 ft Width × 60 ft Length	Filter presses, conveyors, dumpsters will be housed.

Redundancy is provided in the water treatment system to avoid or minimize shutdowns due to equipment failures. All process equipment units, pumps and chemical feed pumps are provided with redundancy.

Operation and Maintenance

The water treatment systems will require the operator's attention. Anticipated O&M requirements are presented below.

Routine Operation Activities:

- Preparation of operation daily log sheets and record daily operation activities.
- Check the amount of the chemicals remaining in the storage tanks and order them in advance. There should not be shortage of the chemicals for water treatment.
- Dewater the sludge periodically and handle the filter cake for storage at a designated location. It is anticipated that sludge would be dewatered once a day, taking about two hours. The operator should verify that filter cake drops properly and must follow the manufacturer's operation instructions.
- Respond properly in a timely fashion when alarm goes off, in accordance with the SOP.
- Follow the equipment manufacturers' operation recommendations.

Routine Maintenance:

- Prepare maintenance log sheets and record maintenance activities. Frequent maintenance is not anticipated but the moving parts of the equipment items will need periodic maintenance.
- Follow the equipment manufacturers' maintenance recommendations.

- In addition, the operator should avoid any direct contact with the chemicals and must follow the proper health and safety plan.

Equipment Layout

Figure 6-9 presents an equipment layout. The area required for installation of the proposed process units and support systems is estimated to be approximately 120,000 ft^2.

6.3.2.3 BARRIGADA WELL WATER TREATMENT

The total capacity of the 11 water supply wells, excluding the one 250 gpm well is 3.3 MGD. In the absence of location specific water quality data, the conceptual design and costs for the AAFB 10 new wells from Section 6.3.2.2 will be assumed for the Barrigada water treatment plant.

6.3.2.4 NRMC #1, #2 AND #3 WELL WATER TREATMENT

NRMC #1, #2, and #3 well waters are biologically contaminated and will be treated with disinfection. Coliform or other undesired microorganisms can be controlled effectively by chlorination, ozonation, and/or UV. In this evaluation, chlorine is used for disinfection. Under the GWUDI rules, the well waters need to be treated by filtration in addition to disinfection. The treatment plant is designed for a peak capacity of 0.88 MGD. The biologically contaminated wells are summarized below.

Evaluation Basis and Regulatory Requirements

Wells	Capacity		Reasons for Being Inactive
NRMC #1	234 GPM	Calculated	High bacteria
NRMC #2	200 GPM	On permit	High bacteria
NRMC #3	178 GPM	Calculated	High bacteria
	612 GPM		
Total	0.881 MGD		

Influent Characteristics and Treatment Objectives

Parameter	Well Water	Treatment Objectives
Coliform	500 counts/100 ml	Zero counts/100 ml
E. coli	500 counts/100 ml	Zero counts/100 ml
Turbidity	1 NTU	0.3 NTU
Residual chlorine		0.5 mg/l

Treatment Processes and Schemes

NRMC #1, #2, and #3 are located close to each other. Therefore, it will be cost-effective to combine the well water and treat the combined well water in a single water treatment system. These wells are remote from other wells that also require treatment. For that reason, it will be more cost-effective to treat the combined NRMC well water separately rather of combining it with other well water from other areas.

As shown in Figure 6-10, the well waters will be disinfected with chlorine, coagulated/flocculated, and filtered prior to entering the water distribution system.

Equipment Sizing and Redundancy

Key process equipment items, chemical feed systems, and buildings are identified and their information presented below.

Major Equipment Units:

Equipment Item	Quantity	Approximate Capacity	Notes/Comments
Equalization Tank	2	75,000 Gallons	
Rapid Mix Tank	2	15,000 Gallons	
Flocculation Tank	2	18,500 gallons	1 unit is an extra unit for
Filter	2	Working Surface Area: 300 ft^2	redundancy.
Raw Sludge Holding Tank	2	150 Gallons	
Thickener	2	Diameter: 2 ft.	
Thickened Sludge Holding Tank	2	Working Volume: 300 Gallons	
Filter Backwash Water Settling Tank	2	70,000 Gallons	
Filter Press	2	Filter Volume per Filter Press: 5 ft^3	
Clearwell	2	75,000 Gallons	
Treated Water Reservoir	1	500,000 Gallons	

Chemical Feed Storage/ Feed Systems:

Equipment Item	Quantity	Capacity	Notes/Comments
Liquid Chlorine Storage Tank	2	40 Gallons	
Liquid Chlorine Feed	4	Prechlorination: 0.5 gph Postchlorination: 1 gph	1 unit for each stage is an extra unit for redundancy.
Alum Storage Tank	2	650 Gallons	
Alum Feed System	2	0.5 gph	1 unit is an extra unit for redundancy.
Polymer Storage Tote	2	50 Gallon Tote	
Polymer Feed System	2	Neat Polymer: 0.1 gph Diluted Polymer: 5 ph	1 unit is an extra unit for redundancy.

Buildings:

Building	Quantity	Size	Notes/Comments
Administration/Control Building	1	20 ft Width × 40 ft Length	Office and control room will be located.
Chemical Building	1	25 ft Width × 30 ft Length	Chemicals and chemical feed systems will be housed.
Filter Building	1	40 ft Width × 50 ft Length	Filters and local controls will be housed.
Filter Press Building	1	50 ft Width × 60 ft Length	Filter presses, conveyors, dumpsters will be housed.

Redundancy is provided in the water treatment system to avoid or minimize shutdowns due to equipment failures. All process equipment units, pumps, and chemical feed pumps are provided with redundancy.

Operation and Maintenance

The water treatment systems will require the operator’s attention. Anticipated O&M requirements are presented below.

Routine Operation Activities:

- Preparation of operation daily log sheets and record daily operation activities.

- Check the amount of the chemicals remaining in the storage tanks and order them in advance. There should not be shortage of the chemicals for water treatment.
- Dewater the sludge periodically and handle the filter cake for storage at a designated location. It is anticipated that sludge would be dewatered once a day, taking about two hours. The operator should verify that filter cake drops properly and must follow the manufacturer's operation instructions.
- Respond properly in a timely fashion when alarm goes off, in accordance with the standard operations procedure.
- Follow the equipment manufacturers' operation recommendations.

Routine Maintenance:

- Prepare maintenance log sheets and record maintenance activities. Frequent maintenance is not anticipated but the moving parts of the equipment items will need periodic maintenance.
- Follow the equipment manufacturers' maintenance recommendations.
- In addition, the operator should avoid any direct contact with the chemicals and must follow the proper health and safety plan.

Equipment Layout

Figure 6-11 presents an equipment layout. The area required for installation of the proposed process units and support systems is estimated to be approximately 56,550 ft^2.

6.3.2.5 SUMMARY FOR WATER TREATMENT

The water treatment evaluation presented above is preliminary. This evaluation will need to be fine-tuned based on site-specific information. The following is suggested for further evaluation:

- Collect and analyze the well water for the parameters of concern to supplement the existing data. The parameters should include actual counts of coliform and E. coli, total and individual hardness, total and individual alkalinity, turbidity, pH, VOCs and other constituents that can cause fouling such as iron and manganese.
- Based on the analytical data, establish a sound evaluation basis.
- Assess the availability of the chemicals to be used for water treatment. Also assess whether the sludge to be generated from water treatment can be cost-effectively disposed at a local disposal site. If some chemicals and waste disposal are not readily available, the approaches to water treatment will need to be modified accordingly.
- Evaluate different treatment technologies and processes and approaches and select one that fits the site conditions best.

6.3.2.6 DISTRIBUTION SYSTEM

For this analysis, Option 2 includes constructing 12 new wells near the U.S. Naval Communication center. Water from the 12 new wells and the existing nearby well will be pumped through new raw water transmission mains to a new Barrigada Water Treatment Plant. Water will flow by gravity through the plant to a clearwell. The treated water will then be pumped from the clearwell to the existing Barrigada storage tank with a new treated water transmission main.

Navy Island-wide Water System Connections and Improvements

The U.S. Navy Island-wide water system provides water to much of the island. The Navy's water system currently provides water to the limited existing developments in the Navy Barrigada area by bringing water from the southern portions of its service area northward through a system of transmission mains, pumping stations, and reservoirs. Connecting the proposed Barrigada water system to the Navy Island-wide system can provide additional supply to naval facilities in south Guam. Extending the new transmission main from the Barrigada tank to the Tupo tank provides greater flexibility in moving water around the island. Water main replacement is consistent with the recommendations of the Engineering Concepts (2005) to, "Consider systematically replacing water mains that have a history of failure, in particular those lines that are prone to breakage in areas of corrosive soil." Replacement of the water mains can be phased in as necessary based on the latest information on leakage and failures within the Navy Island-Wide System. Please see Section 6.2.2.3 for more details on improvements to the Navy Island-wide Water System.

Prior to constructing these additional mains, additional study and hydraulic modeling is needed to confirm the feasibility and operating conditions.

6.3.3 Costs

Details of the cost estimate are provided in Appendix C and Appendix E.

The capital costs for Option 2 are:

Capital Costs	$000
1) Water Resources Development	$15,851
2) Water Treatment	$80,973
3) Distribution	$91,511
Total Construction Cost without contingency	$188,335
Contingencies (20%)	$37,667
Engineering (15%)	$28,250
Total Capital Cost	**$254,252**
Present Worth Guam Capital Costs	$256,246

The O&M costs for Option 2 are:

O&M Costs	$000
1) Water Resources Development	$236
2) Water Treatment	$3,034
3) Distribution	$1,105
Total Annual O&M Cost without contingency	$4,375
Contingency (20%)	$875
Total Annual O&M Cost	**$5,250**
Present Worth of O&M Costs (25 year life)	$125,304

The total present worth of life cycle costs for Option 2 is $382M.

If the Navy Barrigada wells and improvements to the Navy Island-wide System are excluded from Option 2, the revised costs are:

The capital costs for Option 2 are:

Capital Costs	$000
1) Water Resources Development	$7,231
2) Water Treatment	$57,721
3) Distribution	$20,107
Total Construction Cost without contingency	$85,059
Contingencies (20%)	$17,012
Engineering (15%)	$12,759
Total Capital Cost	**$114,829**
Present Worth Guam Capital Costs	$115,730

The O&M costs for Option 2 are:

O&M Costs	$000
1) Water Resources Development	$226
2) Water Treatment	$2,210
3) Distribution	$425
Total Annual O&M Cost without contingency	$2,860
Contingency (20%)	$572
Total Annual O&M Cost	**$3,432**
Present Worth of O&M Costs (25 year life)	$81,914

The total present worth of life cycle costs for Option 2 excluding the Navy Barrigada wells and improvements to the Navy Island-wide System is $198M.

Option 2 is primarily meant to meet other DoD requirements for water supply. The Basic Scenario 2 (other DoD requirements) costs are presented in Section 7.

6.4 OPTION 3 – PURCHASE WATER FROM GWA

This alternative includes obtaining water with GWA either by purchasing water or through exchanging water through metered interconnections between GWA and DoD water systems. There are several existing connections between the GWA and Navy water systems. The implementation of this alternative would include establishing new metered connections between the GWA and the USMC water systems.

Since the Northern Public Water System operated by GWA has an elaborate water supply system in Northern Guam with 119 wells drawing water from the NGLA, considering this alternative to supplement Options 1 and 2 is preferable. Additionally, this alternative could result in energy cost savings by reducing the cross-island pumping of large quantities of water through the existing parallel water mains running from the north to the south.

The Navy currently sells water from its reservoir to GWA for civilian consumers in the southern part of the island; there are no connections between AAFB and GWA in the northern part of the island. According to the GWA Master Plan, currently there are 54 connections between the Navy WTP water supply and GWA's system, of which 39 are active. All of the connections are located in the Central system. Preliminary analysis of this study suggests that there is no need to interconnect with

GWA for a water supply; however, if the Navy continues to provide water to GWA for residents in the south, there is potential for increasing this contribution while reducing the northern demands through water from GWA wells in the north. This would reduce the need for cross-island pumping. It is assumed that this option would require long-term augmentation of the reservoir.

6.4.1 Analysis

This section evaluates the amount of water GWA will have available to supply the USMC relocation based on the information provided in GWA's 2007 Master Plan. The GWA supply and demand for water in the North, South and Central regions were determined based on the GWA Master Plan (GWA 2007). Figure 6-12 from the GWA *Water Resources Master Plan* (WRMP) shows the boundaries of each system. The GWA WRMP includes a brief discussion of the military expansion in Volume 1 Chapter 17. However, the intent of Chapter 17 was to "provide a sense of the potential growth impact" and the expansion was not included in cost estimates contained in the rest of the WRMP.

6.4.1.1 GWA Sources

Table 6-9 provides the production rates for the current GWA sources. Potable water is mainly supplied to the Northern system by 119 deep wells. Collectively these wells have a daily average production rate of approximately 38 MGD. The current production rates are approximately equal to the design and permitted rates, indicating that the wells are running at full capacity. The GWA WRMP also assumed that the active wells were running 24 hours per day. Based on the EPA permitted rates and design actual rates of the inactive GWA wells listed in the GWA WRMP, reactivation of wells selected GWA wells would increase the production rate by 3.8 MGD. In addition to the deep wells, the northern system also receives approximately 3.6 MGD from the Navy WTP.

The GWA WRMP discusses options for expanding the well system in the Agana sub-basin to produce an additional 2.7 MGD and Agafa-Gumas sub-basin to produce an additional 2.9 MGD. These expansions are identified as being in areas that are outside of DoD boundaries and available to the GWA.

Table 6-9: GWA Owned Water Supplies

	Current Production Rate[a,b] (MGD)	Well Reactivation (MGD)	Future Expansions (MGD)[c]	Total
North				
Deep Wells	38	3.8	5.6	**47.7**
South				
Ugum Water Treatment Plant	2.2		1.8	
Santa Rita Spring	0.2			
Non-potable Deep Wells	0.1			**4.3**

Notes:
[a] Based on Table 6-2 of GWA WRMP.
[b] According to the GWA Master Plan, the Ugum WTP was designed to provide 4.0 MGD.
[c] Future sources include the expansion of the northern well system, and upgrades to Ugum to meet design.

There are no sources of potable water within the Central System. This area mainly relies on potable water from the Navy WTP, but in some areas can also receive water from the Northern wells. According to the GWA WRMP, from October 1, 2003 to September 30, 2004, GWA received on average 4.3 MGD of Navy water with a monthly average peak of approximately 6.7 MGD. The amount of water provided by the Navy to GWA has since been reduced to less than 3.5 MGD.

The southern system has three sources of water: the Ugum Water Treatment Plant, four springs, and two deep water wells. Only one of the four springs, the Santa Rita Spring, is active, and neither of the two deep water wells supplies potable water. The Ugum WTP was designed to provide 4.0 MGD. However, this value is exceeded approximately 75 percent of the time. According to the GWA WRMP, from March to July, the production rate exceeds 4.0 MGD 80 percent of the time and from April to June it is exceeded 20 to 50 percent of the time. In order for the Ugum WTP to reliably withdraw 4.0 MGD, year-round raw water storage is required. The Santa Rita Spring provides approximately 0.2 MGD of potable water and the two deep wells in the south provide approximately 0.1 MGD of non-potable water. A summary of the GWA sources is provided in Table 6-9.

6.4.1.2 GWA DEMAND

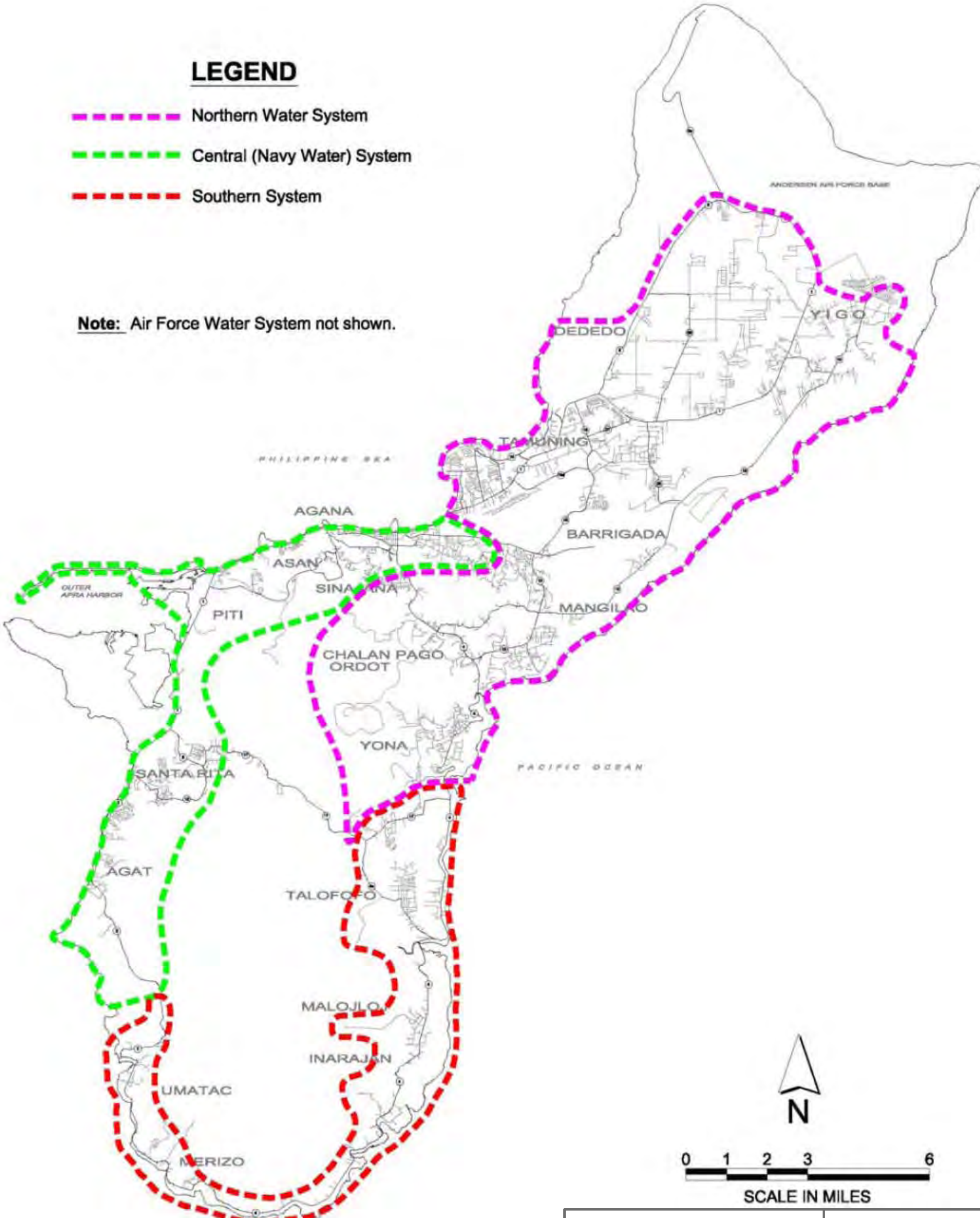
The GWA WRMP estimated the current (2005) and future demands (2025) as part of the Capital Improvement Program. The modeling results were not directly used since the current GWA estimates assume improvements to the GWA system which have not yet been implemented. In addition to assumptions of extensive improvements, the future demand calculations do not account for the effects of military increases and the GWA WRMP only provided an island-wide total.

The current demand for GWA water was estimated using the assumptions outlined in the GWA WRMP. Based on U.S. Census Bureau data (2005), Guam has an estimated population of 168,564. Assuming a per capita usage of 125 gallons per capita per day with an additional 10 MGD for miscellaneous purposes, and a loss of 50 percent, the total demand is approximately 47.5 MGD. The estimate of current demand is shown in Table 6-10. This value agrees with the demand calculations in Chapter 6 of the GWA WRMP of the modeling which place the overall average daily demand at 42 MGD and the maximum daily demand at 56.6 MGD. A comparison of the estimates is provided in Table 6-11.

Table 6-10: GWA Demands

System	Population Served[a]	Baseline Demand[b] (MGD)	Miscellaneous Used[c] (MGD)	Total plus 15% loss (MGD)[d]	Total plus 50% Loss (MGD)[c]	GWA Supply (MGD)
Current						
Northern	146,050	18.3	8.4	30.7	40.0	38.3
Central	22,000	2.8	1.3	4.6	6.0	-
Southern	5,504	0.7	0.3	1.2	1.5	2.5
Total	173,554	21.7	10.0	36.4	47.5	40.8
Future[e,f]						
Northern	198,563	24.8	8.5	38.3	50.0	47.7
Central	27,500	3.4	1.2	5.3	6.9	-
Southern	6,880	0.9	0.3	1.3	1.7	4.3
Total	232,943	29.1	10.0	45.0	58.7	52

Notes:
[a] Current populations based on Table 1-1 of GWA Master Plan.
[b] Assumption of 125 gallons per capita per day based on GWA Master Plan.
[c] Assumption of 10 MGD for miscellaneous uses based on GWA Master Plan.
[d] GWA Master Plan cites percent loss at approximately 55 percent.
[e] Assumes that the population served by the GWA water system will grow (without military expansion considerations) approximately 25% as outlined in the GWA Master Plan
[f] Assumes a population increase equal to 60% of the military expansion will occur off base based on the Point Paper meeting notes representing an increase of approximately 16,000.



From 2007 GWA Master Plan Volume 2 Figure 1-1

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Option 3 GWA Water System Boundaries

Date:	Scale:	Figure No. :
7/14/08	As shown	6-12

Table 6-11: GWA Demands Estimates Compared to CIP Modeling

System	Total plus 15% loss (MGD)	Total plus 50% Loss (MGD)	GWA Modeling	GWA Supply (MGD)
Current				
Northern	30.7	40.0	36.2 - 48.8	38.3
Central	4.6	6.0	3.9 - 5.2	—
Southern	1.2	1.5	1.9 - 2.6	2.5
Total	36.4	47.5	42 - 56.6	40.8
Future				
Northern	38.3	50.0		47.7
Central	5.3	6.9		—
Southern	1.3	1.7		4.3
Total	45.0	58.7	46.5	52

The future demand estimates assumed that the population served by the GWA water system will grow without military expansion considerations by approximately 25 percent as outlined in the GWA WRMP. In addition, according to meeting notes collected during Earth Tech's site visit in 2007, a population increase equal to 60 percent of the military expansion will occur off base. This additional population increase of approximately 16,000 was applied to the Northern system demand. If a loss rate of 50 percent is applied to the demand, the future demand will total approximately 59 MGD. This is an increase of 11 MGD. If improvements are made to the current system to reduce the loss rate to an acceptable level of 15 percent, no increase from current water supply will be required to meet future demand. The estimate of future demand is shown in Table 6-10. These values are in agreement with the CIP 2025 modeled estimate of 46.5 MGD, which does not include any increase arising from the military expansions. A comparison of these numbers is shown in Table 6-11.

6.4.1.3 WATER AVAILABLE IN THE NORTH FOR PURCHASE

Based on the information available in the GWA WRMP, there is currently no water available from GWA to provide to the Navy in the North. GWA currently requires approximately 3.6 MGD of water from the Navy to meet the current demand in the North. If improvements are not made to the system to reduce the loss rate, it is also expected that there will be no water available for GWA to provide to the Navy in the 2025. However, water may become available if the following improvements are made to the GWA northern system:

- Reduce the loss rate to an acceptable level of 15 percent
- Reactivation of deep wells currently out of service
- Expansion of the northern well system to produce 5.6 MGD (as assumed in Chapter 6).

With these improvements, the GWA could have water available to provide to the DoD.

6.4.1.4 WATER SYSTEM IMPROVEMENTS

With this option to supplement military base water with water from the GWA system, a connection to the GWA system is made near the proposed water treatment plant. The GWA water would be routed to the treated water mains near the Finegayan Base Complex. Data on the GWA system is available in the GWA 2007 Master Plan, but this information is not specific to pipe segments. For the purpose of this alternative evaluation, it is assumed that the capacity of the GWA system piping and pressure is sufficient to accommodate this option.

A connection will be made to the GWA system, just south of the proposed water treatment plant. A separate pipeline will convey water from the GWA system into the proposed plant, where the GWA water will discharge into the clearwell and mix with the treated water from the plant. A flow meter installed in the water treatment plant or in a vault near the connection to the GWA system will measure flow to the system for billing purposes. An air gap will be provided to prevent backflow into the GWA system. The high lift pumps, treated water transmission mains, and water storage are the same as described in Option 1. It is assumed that the additional supply from GWA would be in place of water supply developed by the DoD. Therefore, the DoD storage capacity would not need to increase to meet the supply provided by GWA.

6.4.2 Costs

Details of the cost estimate are provided in Appendix C.

Since GWA already is capable of buying substantial amounts of water from the Navy, no new connections would be needed to send water from the Navy water system to the GWA system. A new connection is required to provide water in the north from the GWA network of wells to the Finegayan Base Complex distribution system.

Capital Costs	$000
1) Water Resources Development	$0
2) Water Treatment	$0
3) Distribution	$1,642
Total Construction Cost without contingency	$1,642
Contingencies (20%)	$328
Engineering (15%)	$246
Total Capital Cost	**$2,217**
Present Worth Guam Capital Costs	$2,235

There are no O&M costs for Option 3.

The total present worth of life cycle costs for Option 3 is $2.2M.

The costs for Option 3 are primarily to accommodate the USMC relocation. However, the Finegayan Base Complex is expected to also house staff from the army and continue to be the location of the Navy communication facilities. The Basic Scenario 1 (USMC only) costs are presented in Section 7.

Discussion

There is little or no water available for purchase from the GWA in the north that is not already required for GWA customers in that region. In the future water, the purchase option may become available if the GWA system is improved to reduce the loss rate, and if expansion of the GWA northern well systems is implemented.

6.5 Option 8 – Desalination (Brackish Water)

This section provides the rationale for potential new brackish water supply system components. Like Option 1, this option will provide sufficient water to meet the USMC relocation and other additional DoD water demands.

6.5.1 Potential Well Locations

Brackish water wells will be planned which supply the treatment plant with enough water to produce a total of 14 MGD of potable water. The plant will accept the 2.3 MGD of freshwater from the existing Navy wells on the Finegayan Base Complex. To supply the remaining approximately 12 MGD of potable water, it is assumed that 18 MGD of brackish water (3,000 to 4,000 mg/L TDS) will be required. The brackish water supply wells will be designed with a higher capacity, 450 gpm, since these wells will be drawing saline water. This limit is consistent with the recommendations for supply wells presented in the 1982 NGLS. To meet the supply, 28 supply wells are required. Consistent with the constraints for the freshwater wells, the brackish water supply wells will be separated by a distance of at least 1,000 ft to avoid interference and upconing. To avoid influencing existing freshwater wells, the supply wells are placed within 1,000 ft of the shoreline. Figure 6-13 shows a schematic of the subsurface. The brackish water wells will be screened within the brackish water zone.

Proposed brackish water supply well locations are shown on Figure 6-14. Most of the wells located near the northwest shoreline are within the fenced area of the military reservation. The wells located outside of the fenced area might be relocated for security. The wells along the northern shoreline are located in a limestone forest. These wells may need to be relocated due to habitat considerations. Most of the area around the Northwest Field is considered important habitat by the regulatory agencies. This area is home to the last known nesting area of the endangered Mariana Fruit Bat on the island. The area to the northeast is prime limestone forest which is important habitat for many species. It may be necessary to identify alternate well locations in areas of AAFB that are outside of the AAFB constraints shown on Figure 6-1 or other limitations to be specified by the base.

The final placement of supply wells will require additional information. The proposed locations are selected primarily in locations which are expected to produce sufficient supply to the treatment plant without harming the aquifer or influencing existing wells. Prior to installing wells, it is recommended that a pre-design study including a seismic survey, pump tests, and development of a multi-layer groundwater model be conducted to support design. The study will provide data to optimize the well locations and design parameters to avoid impacts to existing wells and the aquifer.

6.5.2 Water System Components

The water system components are described in this section. The main components are the wells, water treatment plant for desalination and disinfection, and distribution system. The main components are consistent with the description provided in Section 6.2.2 for Option 1, with the exception of the desalination treatment and the location of wells and raw water lines. Option 8 includes the modifications to the existing Navy Island-wide system to add flexibility to meet water demands if alternate housing arrangements are selected.

6.5.2.1 Wells

Well Construction. It is assumed that the well construction for the brackish water wells will be similar to the freshwater wells described in Section 6.2.2.1, but the wells will be screened in the brackish water zone.

Pre-Design Studies. Seismic studies and test borings should be conducted at each well site as described in Sections 6.2.1 and 6.2.2.1 for the freshwater wells. It may be necessary to evaluate areas other than the notional areas shown in Figure 6-14. Given the potential for saltwater intrusion caused by the brackish water wells, it is recommended that a multi-layer groundwater model be prepared to aide in well placement and design and avert impacts to water quality in existing wells. The model will provide information to assess whether the approximately 1,000-ft spacing is adequate; to determine if there will be significant upcoming; and to identify operating parameters. Pump tests and aquifer monitoring will be needed to support the model. For planning, it is assumed that pump tests will be conducted at 10 locations and 20 monitoring wells will be installed.

Aquifer Monitoring: Long-term monitoring of the aquifer following implementation of Option 8 is recommended. TDS levels will be measured periodically from monitoring wells. If TDS levels are shown to be increasing, pumping rates may be adjusted.

6.5.2.2 Central Water Treatment System

Well water extracted from the proposed 28 new wells will be collected, desalinated and treated for water supply to the end user. This section presents a design basis for desalination, water treatment, treatment technologies and processes, and costs. The plant is designed for a peak treatment capacity of 14 MGD. Prior to design, the water quality of the brackish water should be tested to determine the optimal treatment processes. This report provides a general estimate of the approach and cost for desalination for comparison to other water utility alternatives. If desalination is selected, it is recommended that a pilot study be implemented.

The treatment plant location is shown on Figure 6-14. This location was chosen due to its proximity to the highway and the planned USMC base, and because it has sufficient space to accommodate the treatment plant and an aboveground storage tank for finished water.

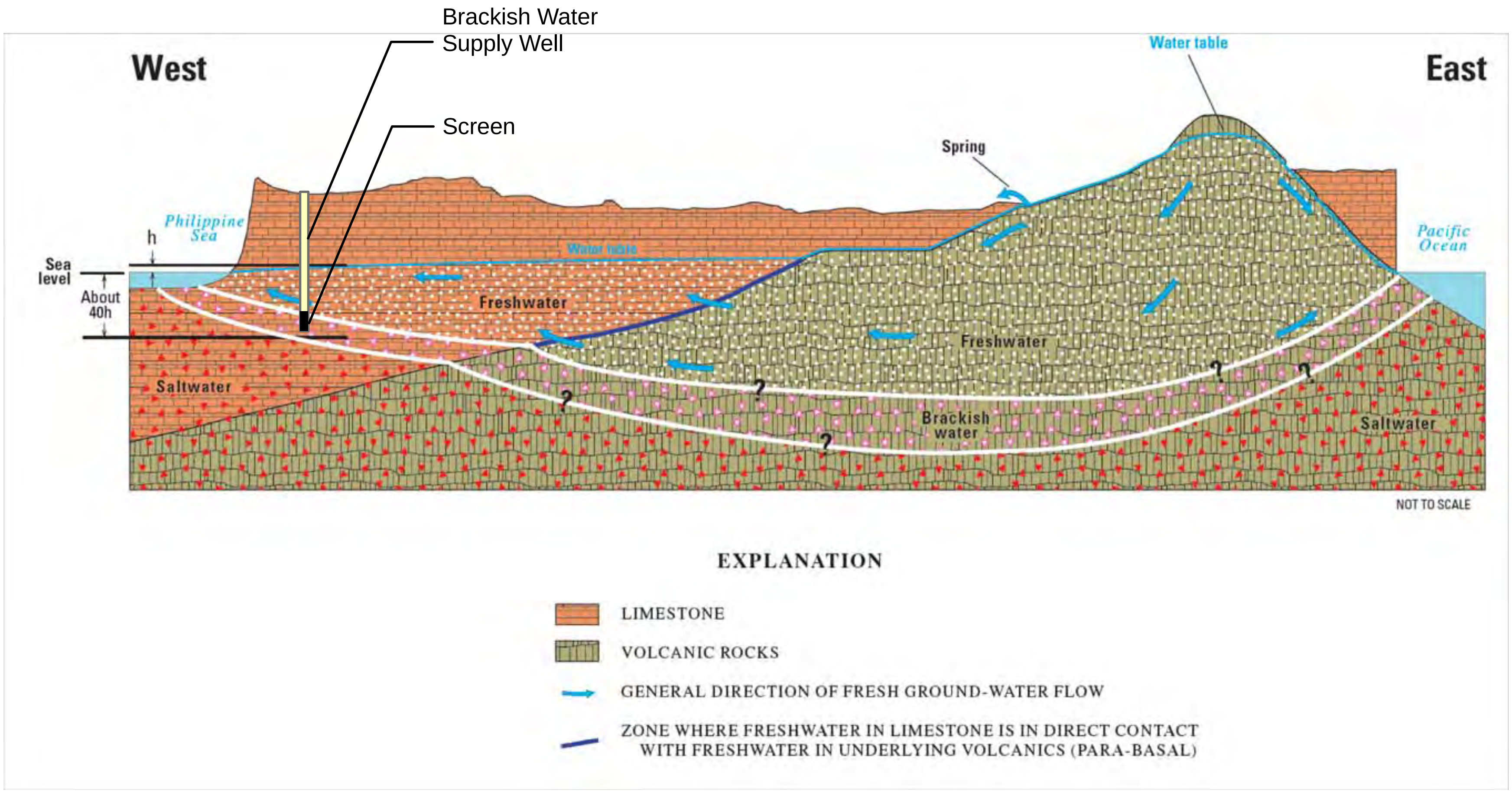
Evaluation Basis and Regulatory Requirements

It is assumed that the extracted brackish groundwater in the area will have a TDS level from 3,000 to 4,000 mg/L. A RO membrane system with appropriate pretreatment will be employed to treat the brackish water. In order to maintain total residual chlorine in the distribution system, the desalinated water will need to be disinfected in the plant. To achieve these objectives, the following evaluation basis is established:

Water demand: 14 million gallons per day (MGD)

Influent and Treatment Objectives:

Parameter	Brackish Water	Treatment Objectives
TDS	3000 to 4000 mg/l	<500 mg/l
Coliform	500 counts/100 ml	Zero counts/100 ml
E. Coli	500 counts/100 ml	Zero counts/100 ml
Turbidity	1 NTU	≤0.5 NTU
Residual chlorine	NA	0.5 mg/l



Note: Figure taken from USGS (2003).

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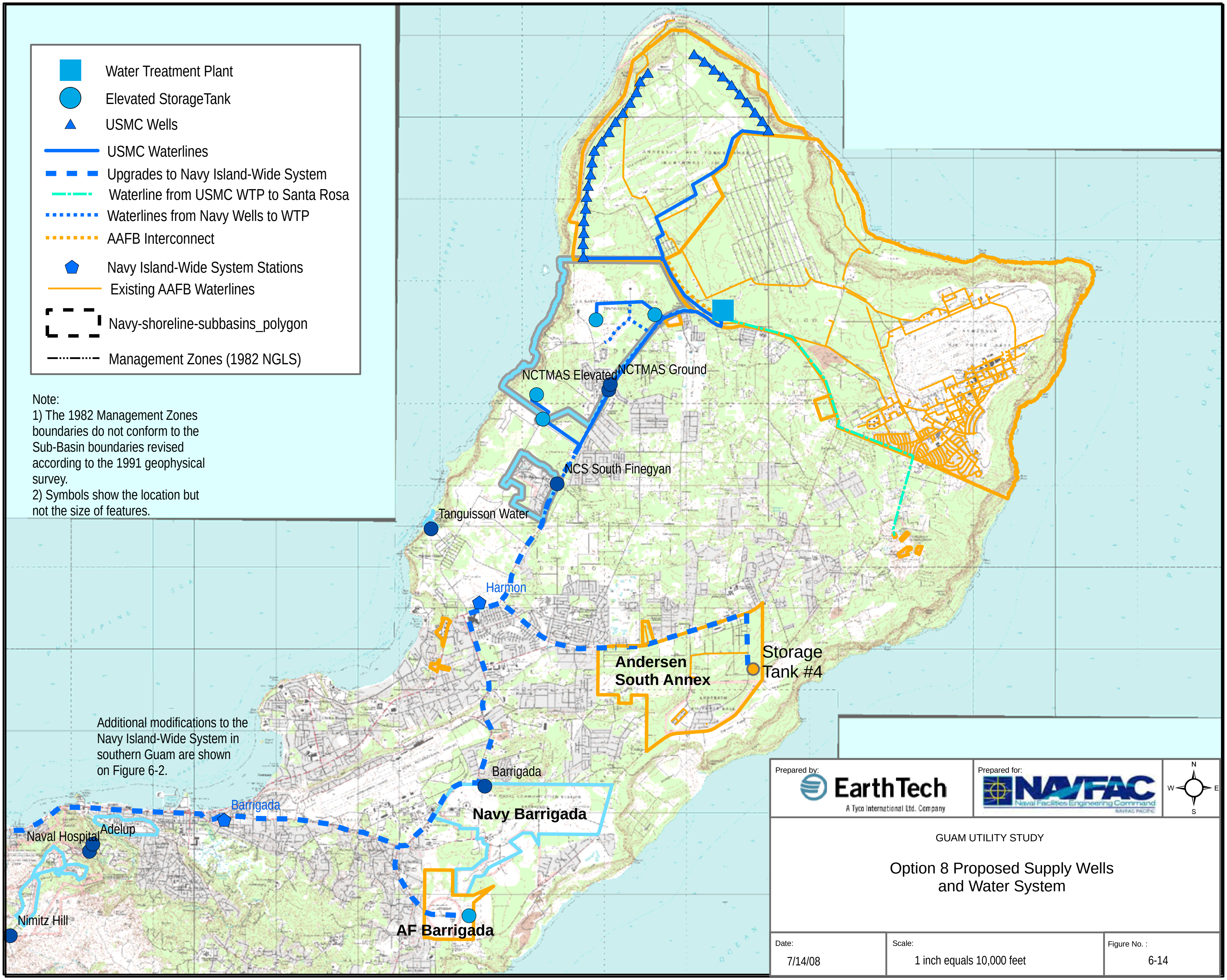
Option 8 Proposed Supply Wells
Location Constraints

Date:	Scale:	Figure No. :
7/14/08	not to scale	6-13


Water Treatment Plant
Elevated StorageTank
USMC Wells
USMC Waterlines
Upgrades to Navy Island-Wide System
Waterline from USMC WTP to Santa Rosa
Waterlines from Navy Wells to WTP
AAFB Interconnect
Navy Island-Wide System Stations
Existing AAFB Waterlines
Navy-shoreline-subbasins_polygon
Management Zones (1982 NGLS)
Note:
1) The 1982 Management Zones boundaries do not conform to the Sub-Basin boundaries revised according to the 1991 geophysical survey.
2) Symbols show the location but not the size of features.
NCTMAS Elevated
NCTMAS Ground
NCS South Finegyan
Tanguisson Water
Harmon
Andersen South Annex
Storage Tank #4
Additional modifications to the Navy Island-Wide System in southern Guam are shown on Figure 6-2.
Barrigada
Navy Barrigada
Barrigada
Adelup
Naval Hospital
Nimitz Hill
AF Barrigada
Prepared by:
EarthTech
A Tyco International Ltd. Company
Prepared for:
NAVFAC
Naval Facilities Engineering Command
N
W
E
S
GUAM UTILITY STUDY
Option 8 Proposed Supply Wells and Water System
Date:
7/14/08
Scale:
1 inch equals 10,000 feet
Figure No. :
6-14

Treatment Processes

The following are the major water treatment process units:

- Surge Tanks
- Desalination pretreatment unit(s)
- RO membrane units
- Wastewater Holding tanks
- Ground storage tank for finished water

Brackish well water will be extracted from the wells and transported to the desalination water treatment plant via a common pipeline and then collected in a surge tank that will also serve as a feed tank to the downstream treatment units. The treatment will provide 14 MGD (net) of potable water of which the existing Navy wells provide 2.3 MGD freshwater. For simplicity, the freshwater will be treated in the same facility. In order to obtain the remaining 12 MGD potable water, the system will treat about 18 MGD. The well water will be pumped into the pretreatment system first. If the brackish water quality is relatively good, the pretreatment process can be multimedia sand filtration followed by cartridge filtration. If the brackish water has elevated hardness, turbidity, and organics, the pretreatment process can be microfiltration (MF) or ultrafiltration (UF). After the pretreatment system, antiscalant, biocide, and acid will be added to condition the pretreated water to reduce fouling/scaling of the RO membrane. Then the conditioned water will pumped into the RO membrane system. The RO membrane unit can be one stage or two stages based on the design by the vendor and the influent water quality. The RO membrane units will remove colloids, ionic species, bacteria, and viruses and produce high quality water. The treated water will be collected and disinfected before pumping to the distribution system. A block diagram is shown in Figure 6-15.

The wastewater produced by the desalination plant will be collected in a wastewater holding tank and discharged either into an outfall to the ocean (which would require a permit) or to the GWA sewer under the appropriate discharge permits.

Equipment Sizing and Redundancy

Key process equipment items, chemical feed systems, and buildings are identified and their information presented below. Conceptual level information on the desalination system is provided herein. Specifics of the desalination system equipment will be developed during design.

Major Equipment Units:

Equipment Item	Quantity	Capacity	Notes/Comments
Surge Tank	2	460,000 Gallons	An extra unit is provided for redundancy.
Wastewater Holding Tank	2	80,000 Gallons	
Water Storage Tank	1	1.25 Million Gallons	

Chemical Feed Storage/ Feed Systems:

Equipment Item	Quantity	Capacity	Notes/Comments
Liquid Chlorine Storage Tank	2	2,000 Gallons	An extra unit is provided for redundancy.
Liquid Chlorine Feed (Pump)	2	Chlorination: 10 gph	

Buildings:

Building	Quantity	Size	Notes/Comments
Administration/Control Building	1	25' Width x 40' Length	Office and control room
Chemical Building	1	25' Width x 40' Length	Chemicals and chemical feed systems
Desalination System	1	60' Width x 100' Length	Pretreatment and RO system

Redundancy is provided in the water treatment system to avoid or minimize shutdowns due to equipment failures. All process equipment units, pumps, and chemical feed pumps are provided with redundancy.

Treatment Plant Operation and Maintenance

The water treatment systems will require the operator's attention. Anticipated O&M activities are summarized below.

Routine Operation Activities:

- Prepare operation daily log sheets and record daily operation activities.
- Check the amount of the chemicals remaining in the storage tanks and order them in advance. There should be a sufficient inventory of the chemicals for water treatment.
- Respond properly in a timely fashion when alarm goes off, in accordance with the standard operations procedure.
- Follow the equipment manufacturers' operation recommendations.

Routine Maintenance:

- Prepare maintenance log sheets and record maintenance activities. Frequent maintenance is not anticipated but the moving parts of the equipment items will need periodic maintenance.
- Follow the equipment manufacturers' maintenance recommendations.

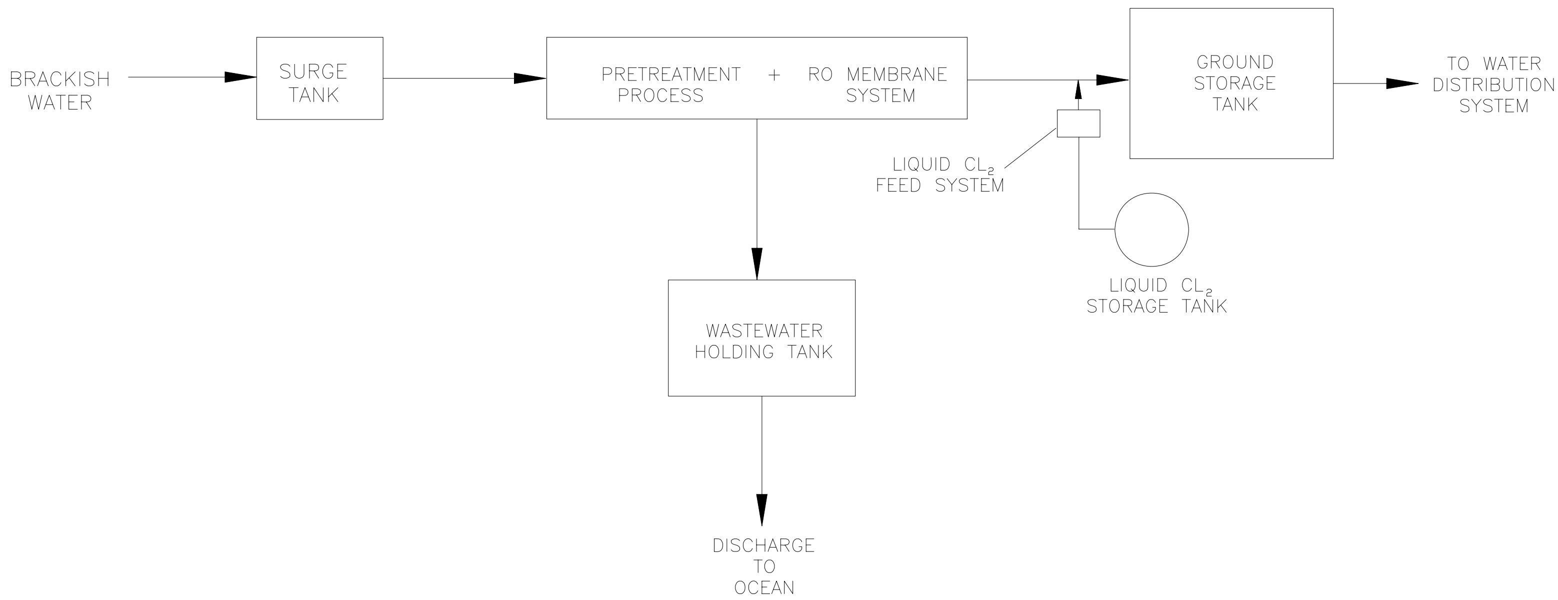
In addition, the operator should avoid any direct contact with the chemicals and must follow the health and safety plan.

The area required for installation of the proposed process units and support systems is expected to be similar to the area required for the Option 1 water treatment plant, 225,100 ft^2.

6.5.2.3 DISTRIBUTION SYSTEM

Distribution system components are incorporated into the water system using the approach discussed in Section 6.2.2.3.

- Raw Water Transmission Mains
- Well Pumping Stations
- High Lift Pumping Equipment
- Water Distribution System on the MCB



Note: Freshwater from the existing Navy wells is combined with the water from the brackish water supply wells.

Prepared by: EarthTech A Tyco International Ltd. Company

Prepared for: NAVFAC Naval Facilities Engineering Command NAVFAC PACIFIC

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Option 8 Water Treatment Process Flow Block Diagram

Date:	Scale:	Figure No. :
7/14/08	Not to scale	6-15

- Treated Water Transmission Mains
- Water Storage
- Andersen South Developments
- Navy Island-wide Water System Connections and Improvements

6.5.3 Costs

Details of the cost estimate are provided in Appendix C.

The capital costs for Option 8 are:

Capital Costs	$000
1) Water Resources Development	$34,133
2) Water Treatment	$125,360
3) Distribution	$350,434
Total Construction Cost without contingency	$509,927
Contingencies (20%)	$101,985
Engineering (15%)	$76,489
Total Capital Cost (with contingency and engineering)	**$688,401**
Present Worth Guam Capital Costs	**$693,800**

The O&M costs for Option 8 are:

O&M Costs	$000
1) Water Resources Development	$427
2) Water Treatment	$12,689
3) Distribution	$3,239
Total Annual O&M Cost without contingency	$16,355
Contingency (20%)	$3,271
Total Annual O&M Cost	**$19,626**
Present Worth of O&M Costs (25 year life)	$468,383

The total present worth of life cycle costs for Option 8 is $1.2B.

6.5.4 Discussion

Desalination is technically feasible, but is more costly than use of freshwater (Option 1) and has a significant power demand. A detailed study including data collection and modeling would be necessary to identify the location of wells to minimize upcoming and influence on freshwater wells. The preferred location of the brackish water supply wells, is within 1,000 ft of shore, placing the wells in areas that may be identified as environmentally sensitive or in areas designated for future military operations. A pilot study for the desalination should be implemented prior to optimize the process and determine the best performance in terms of cost, system reliability, and water quality. Desalination is not recommended for further consideration, because the available information indicates that installation of freshwater supply wells will more cost-effectively meet the additional DoD water demands in the north with less risk to the aquifer, and there are adequate groundwater resources to meet the anticipated demand from DoD and GWA.

7. Recommended Water System

To accommodate the USMC relocation and meet other DoD requirements, the recommended water system includes all elements of Option 1, with supplementary water supply from Option 2 and Option 3.

Based on the analysis presented in Section 6, Option 1 alone provides sufficient water to meet the USMC relocation water demands without interfering with GWA plans for well rehabilitation and expansion in the NGLA. This option also includes improvements to the Navy Island-wide water system to provide the flexibility to locate USMC housing in Andersen South Annex or Air Force Barrigada according to Alternative A (30 percent of USMC housing at Navy Barrigada) and Alternative E (75 percent of USMC housing at Andersen South Annex). Excess water provided by Option 1, meets the additional demand estimated for the Navy facilities through connection to the Navy Island-wide water system.

Option 2 provides water supply to meet the estimated water demand for other DoD requirements. This option is recommended because implementation will provide additional supply to the naval facilities, provides water that is compliant with a GWUDI determination and provides a reliable supply of water to the Naval Hospital. For the recommended alternative, Option 2 does not include installation of wells on Navy Barrigada, since the additional supply from these wells is not required to meet the anticipated water demand. These wells might be installed if sufficient water is not provided from the Agafa-Gumas and Andersen sub-basins for Option 1.

Option 3 is recommended because it provides additional water supply for the USMC relocation, if there are significant improvements to GWA's water system. This option is included in the event that these improvements are made to provide insurance that the USMC relocation water demands can be met. Alternatively, the approximately 4 MGD provided to GWA by the Navy may be distributed from the proposed DoD water supply in the north, possibly reducing distribution costs. Water provided from GWA would be in place of water supplied by DoD wells. Therefore, it is not necessary to increase storage capacity to meet the supply provided by GWA.

The cost of dredging the Navy Reservoir (Option 4) is not included in this summary, although the additional supply is necessary to meet DoD requirements in south Guam. Supply wells on Navy Barrigada might be considered as an alternative to modifications to the Navy Reservoir (Option 2). Additional study is necessary to provide a cost estimate for Option 4.

The recommended water system includes all elements of Option 1, with supplementary water supply from Option 2 and Option 3. The components of this water system include:

Water Resource Development

- 21 water supply wells plus one contingency well on AAFB (Option 1)
- Continued use of existing Navy wells on Finegayan (Option 1)
- Rehabilitation of NRMC #3 (Option 2)
- Monitoring wells on AAFB (10), Finegayan (2), South Andersen Annex (5), Naval Hospital (2) (Options 1 and 2)
- Installation of the five wells planned by AAFB (Option 2)

Water Treatment

- One 14 MGD water treatment plant on AAFB (Option 1)

- One 3.3 MGD water treatment plant on South Andersen Annex (Option 2)
- One 3.3 MGD water treatment plant on AAFB (10 planned wells) (Option 2)
- One 0.88 MGD water treatment plant at the Naval Hospital (Option 2)

Distribution

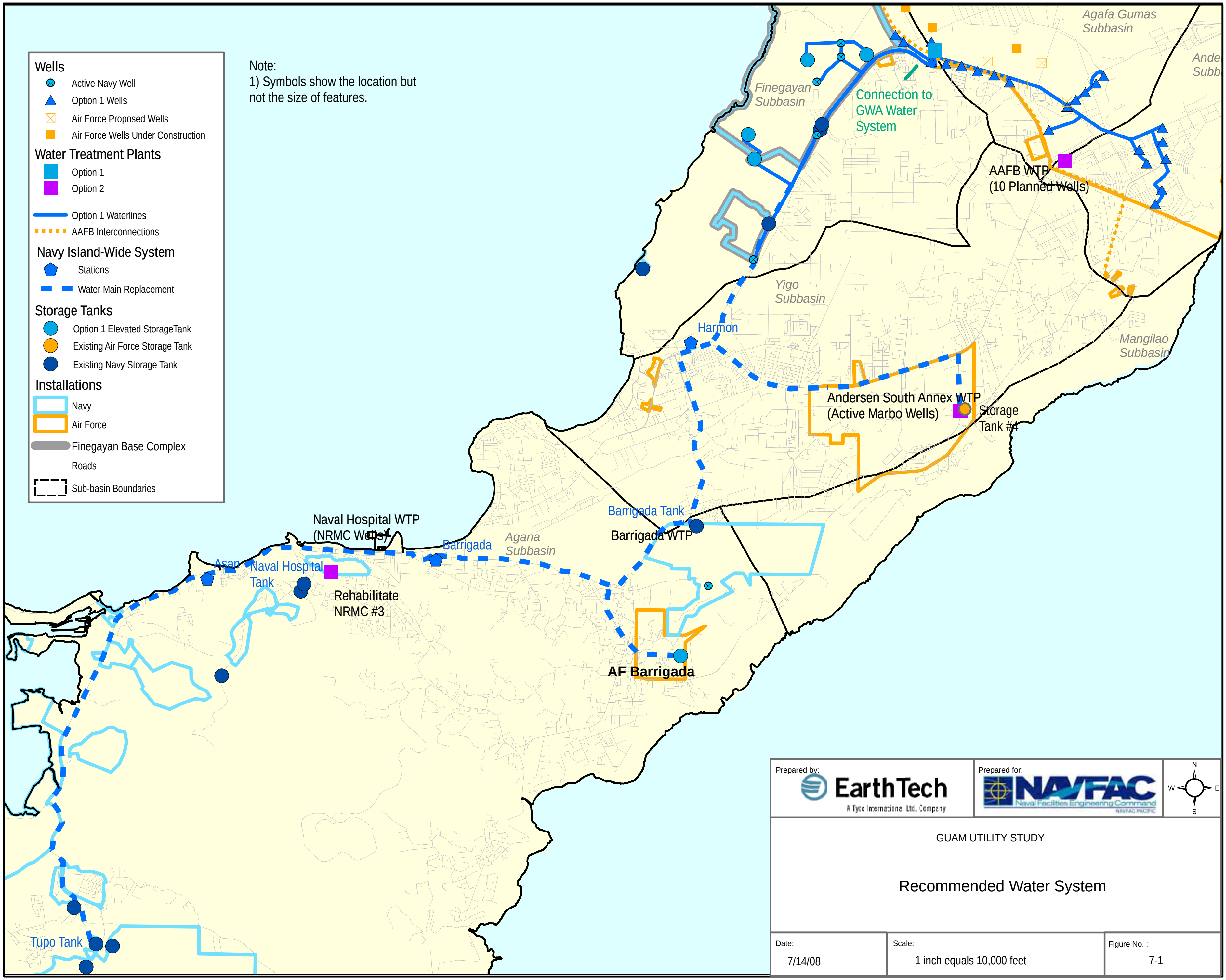
- Waterlines to transport the water from the wells to the treatment plant (Options 1 and 2)
- Waterlines to transport the treated water to storage (Options 1 and 2)
- Waterlines to distribute water throughout the Finegayan Base Complex (Option 1)
- An interconnect with AAFB water system for raw water (Option 1)
- A connection from the USMC WTP to with AAFB Santa Rosa treated water storage tank (Option 1)
- An interconnect with the Navy Island-wide water system (Option 1)
- Improvements to allow water to flow from the USMC system to the Andersen South Annex and Air Force Barrigada (Option 1)
- Improvements to the Navy Island-wide water system (Options 1 and 2)
  - Size pipes appropriately
  - Replace corroded pipes
  - Transport water to the south as well as north
- A connection to the GWA water system (Option 3)
- Pumping stations (Options 1 and 2)
- Elevated storage tanks on Finegayan Base Complex, Andersen South Annex and AF Barrigada (Options 1 and 2)
- Standby power (Option 1)

Figure 7-1 shows the elements of the recommended alternative.

Costs for Basic Scenario 1 which is for the USMC only, are presented in Table 7-1. These are the costs for Option 1 and Option 3, but assumes the Finegayan Base Complex will only be used by relocated USMC personnel. The total present worth capital cost is $566M. The total present worth O&M cost is $108M assuming a 25 year life. The total present worth of life cycle costs for the recommended water system is $674M.Details of the calculation are provided in Appendix F.

Table 7-1: Cost Summary for Basic Scenario 1 (USMC Only)

CAPITAL COSTS ($000)	Basic Scenario 1
Total Capital Cost	**$555,264**
Present Worth Guam Capital Costs	**$566,205**
O&M COSTS ($000)	
Total Annual O&M Cost	**$4,534**
Present Worth of O&M Costs (25 year life)	**$108,205**
Present Worth of Life Cycle Costs ($000)	**$674,410**



GUAM UTILITY STUDY

Recommended Water System

Date:	Scale:	Figure No.:
7/14/08	1 inch equals 10,000 feet	7-1

Costs for Basic Scenario 2 which includes all DoD loads are presented in Table 7-2. These costs are for USMC and other DoD populations combined. The total present worth capital cost of the Option 1, 2 and 3 is $708M. The total present worth O&M cost is $202M assuming a 25 year life. The total present worth of life cycle costs for the recommended water system is $910M.

Table 7-2: Cost Summary for Basic Scenario 2 (All DoD Loads)

Option:	Recommended Alternative
CAPITAL COSTS ($000)	
Present Worth Guam Capital Costs	**$707,628**
O&M COSTS ($000)	
Total Annual O&M Cost	**$8,483**
Present Worth of O&M Costs (25 year life)	**$202,461**
Present Worth of Life Cycle Costs ($000)	**$910,088**

The preliminary cost estimates presented in Table 7-1 and Table 7-2 are developed with the assumption that the NGLA is identified as GWUDI. If the NGLA is not identified as GWUDI, water treatment will be limited to disinfection. Revised costs for Basic Scenario 1 and Basic Scenario 2 are presented in Table 7-3, assuming the NGLA is not identified as GWUDI. The total present worth capital cost is $539M. The total present worth O&M cost is $191M assuming a 25-year life. The total present worth of life cycle costs for the recommended water system is $729M.

Table 7-3: Cost Summary for Basic Scenario 2 Assuming NGLA Groundwater is not GWUDI

Option:	Recommended Alternative (GWUDI Not Assumed)
CAPITAL COSTS ($000)	
Total Capital Cost	$528,759
Present Worth Guam Capital Costs	$538,655
O&M COSTS ($000)	
Total Annual O&M Cost	$6,164
Present Worth of O&M Costs (25 year life)	$190,757
Present Worth of Life Cycle Costs ($000)	$729,412

7.1 PRELIMINARY CONSTRUCTION SCHEDULE

Earth Tech anticipates that to implement the recommended water system would require about 12 to 18 months to design, 5 to 6 months to bid and award, and 25 to 30 months to construct the water supply facilities. It is assumed that the regulatory agency permitting work will be done concurrently with the design. Therefore, the total time required is approximately five years.

The water system consist of several major components including the wells and pumping stations, raw water transmission mains, water treatment plant(s), water storage tanks, treated water transmission mains, water distribution system, connections to the Navy Island-wide water system, connections to the Andersen Air Force Base water system, connections to the Guam Water Authority water system, and replacement of water mains in the Navy and Air Force water systems to improve flow of drinking water throughout the Island.

Scheduling and planning the water system improvements will be important so drinking water and fire protection water will be available when and where it is needed.

Prior to constructing any water system improvements, detailed water system master planning and hydraulic modeling will be necessary. Master planning and modeling will assure that the water improvements are in the right location and of the right size for the proposed developments.

The longest lead items will be the water treatment plant(s) and the wells.

Wells and Well Pumping Stations

General areas have been identified for the well sites. However, before the wells can be constructed, specific sites need to be identified and approved. Each site will need to be reviewed and evaluated for code requirements for separation distances from potential contamination sources. Each well will be designed for the geology at the site. GEPA will review and approve the well site and well specifications. The well will be bid, constructed and tested. After the water quantity and quality are confirmed, the well pump station will be designed, reviewed by the Guam EPA, bid, and constructed.

Prior to placing the well on-line, a wellhead protection plan needs to be completed and approved by the GEPA.

It is anticipated that the time required from selection of the well site to placing the well in operation is approximately two years.

It will be important to develop an implementation plan for well site selection, design and construction to group wells for regulatory approval process for optimizing the overall schedule.

Raw Water Transmission Mains

The general locations of raw water transmission mains have been identified. However, the final locations of the mains cannot be determined until the well sites have been selected. Due to the number of water transmission mains already believed to be in existing road rights-of-way, careful selection of the final route is necessary. Topographic surveys, including field locating of existing utilities will be needed before the water mains can be designed and constructed. The water main designs will need to be reviewed and approved by the GEPA before they can be constructed. The time to go from route selection to construction could be three years or longer.

Water Treatment Plants

The locations of the water treatment plants need to be finalized, then final facility planning and design can proceed. Water quality has been estimated based on data from the many existing wells on the Island. Final decisions will need to be made regarding the treatment processes to be used and the methods of procuring the treatment equipment need to be determined. GEPA will need to review and approve the treatment design before the plant can be constructed. The time to plan, design, bid and construct the water treatment plants is approximately five years.

Water Storage Tanks

Two types of water storage tanks are included. It is expected that the treated water storage tanks at the water treatment plants will be cast in place concrete tanks, constructed at or below grade. The schedule for design, regulatory approvals, bidding, and construction of the ground storage tanks would be approximately two years. The design of the ground storage tanks needs to be closely coordinated with the design of the adjacent water treatment plants because it is anticipated that water will flow by gravity from the water treatment plant into the reservoir.

The elevated tank site locations need to be coordinated with the design of the water distribution systems and the surrounding land uses and ground elevations. The time to select the locations and style of tank, design, obtain regulatory approval, bid, and construct an elevated tank is approximately two years.

It will be important to prioritize the tank construction sequence with the areas that will develop first.

Treated Water Transmission Mains to Finegayan MCB

Two transmission mains are proposed to transport water from the high lift pump station at the water treatment plant to each water pressure zone. The locations of the transmission mains will need to be coordinated with the existing water transmission mains in the rights of way, and with the water tower locations. Implementation of the Treated Water Transmission Main could take up to two years.

Water Distribution System at Finegayan MCB

The water distribution system layout and sizes will need to be closely coordinated with the developments planned for the base. Fire flow requirements can vary significantly based on the type of building construction and building use that can be expected. Master planning and hydraulic modeling will be used to locate and size the water mains. It will be important to phase the design and construction. It is estimated that the planning, design, bidding, regulatory approvals, and construction of the distribution system will take approximately four to five years.

Water Distribution System within the Navy Island-wide System

Improvements to the Navy's water system can be implemented over time. Extensions of the water mains can be prioritized if USMC housing is located on AF Barrigada or Andersen South Annex.

7.2 SUMMARY OF INFORMATION TO SUPPORT THE EIS

The estimated size and coordinates of the primary water supply structures is provided in Table 7-4. The locations were reviewed against the footprint of Installation Restoration sites on AAFB and USGS topographic maps showing significant features of the bases. Locations may need to be adjusted to conform to land use requirements of the bases. With the exception of the waterlines, all water supply structures are located on DoD bases. Easements may need to be acquired for waterlines extending outside of the DoD property.

Table 7-4: Water Supply Structure Size and Locations

Feature	Area Required (ft)	Approximate Northing [a]	Approximate Easting [a]	Elevation (ft)
Option 1 Well 1	200x200; 100x100 min.	1,502,493	271,728	—
Option 1 Well 2	200x200; 100x100 min.	1,501,036	275,462	—
Option 1 Well 3	200x200; 100x100 min.	1,503,483	269,141	—
Option 1 Well 4	200x200; 100x100 min.	1,502,252	273,574	—
Option 1 Well 5	200x200; 100x100 min.	1,502,469	273,837	—
Option 1 Well 6	200x200; 100x100 min.	1,502,898	270,554	—
Option 1 Well 7	200x200; 100x100 min.	1,502,767	270,946	—
Option 1 Well 8	200x200; 100x100 min.	1,503,004	269,817	—
Option 1 Well 9	200x200; 100x100 min.	1,502,064	273,339	—
Option 1 Well 10	200x200; 100x100 min.	1,499,522	275,279	—
Option 1 Well 11	200x200; 100x100 min.	1,500,514	275,068	—

Feature	Area Required (ft)	Approximate Northing [a]	Approximate Easting [a]	Elevation (ft)
Option 1 Well 12	200x200; 100x100 min.	1,501,328	272,683	—
Option 1 Well 13	200x200; 100x100 min.	1,500,847	274,887	—
Option 1 Well 14	200x200; 100x100 min.	1,501,899	273,133	—
Option 1 Well 15	200x200; 100x100 min.	1,503,490	269,818	—
Option 1 Well 16	200x200; 100x100 min.	1,503,657	268,942	—
Option 1 Well 17	200x200; 100x100 min.	1,501,381	275,453	—
Option 1 Well 18	200x200; 100x100 min.	1,500,630	275,543	—
Option 1 Well 19	200x200; 100x100 min.	1,502,645	274,017	—
Option 1 Well 20	200x200; 100x100 min.	1,502,667	271,354	—
Option 1 Well 21	200x200; 100x100 min.	1,499,858	275,439	—
Option 1 Well 22	200x200; 100x100 min.	1,502,942	270,176	—
Option 1 USMC WTP	225,100 ft^2	1,503,278	269,903	—
Option 1 Elevated Storage at USMC Finegayan Base Complex	200x200	1,500,621	265,507	Low Zone 497 ft.
	200x200	1,503,170	268,239	High Zone 586 ft.
	200x200	1,503,043	266,801	High Zone 586 ft.
	200x200	1,501,218	265,353	Low Zone 497 ft.
Option 1 AF Barrigada Storage Tank	200x200	1,488,478	263,705	413 ft.
Option 2 AAFB WTP	119,665 ft^2			—
Option 2 Andersen South WTP	90,000 ft^2	1,494,461	270,527	—
Option 2 NRMC Wells WTP	56,550 ft^2	TBD	TBD	—

[a] Coordinates are in WGS 1984 UTM Zone 55N Transverse Mercator (Meter)

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Barrigada Utility Study to Support USMC Off-Base Housing Facilities Requirements

September 2009

Department of the Navy
Naval Facilities Engineering Command, Pacific
258 Makalapa Drive, Suite 100
Pearl Harbor, HI 96860-3134

Contract Number N62742-06-D-1870, CTO 0035

Barrigada Utility Study to Support USMC Off-Base Housing Facilities Requirements

September 2009

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A Joint Venture of TEC Inc., AECOM TS Inc., and EDAW, Inc.

Contract Number N62742-06-D-1870, CTO 0035

EXECUTIVE SUMMARY

The Guam Joint Military Master Plan (GJMMP) identifies a planned increase in military population and activity on Guam. The Environmental Impact Statement (EIS) for this action presents several EIS Cantonment alternatives for the United States Marine Corps (USMC). Potential sites for EIS Cantonment Alternative 3 and 8 include Department of Defense (DoD) land at Barrigada, Guam, specifically Navy Barrigada and Air Force (AF) Barrigada.

The Naval Facilities Engineering Command, Pacific, under Master Contract Number (No.) N62742-06-D-1870 issued Contract Task Order No. 35 to the TEC, Inc. Joint Venture to study the electrical power, potable water, and wastewater utilities for EIS Cantonment Alternatives 3 and 8 at Barrigada, Guam. The Barrigada Utility Study will support the preparation of the EIS for the USMC relocation to Guam with sufficient and detailed information for EIS Cantonment Alternatives 3 and 8, including the interim and long-term alternatives for each of the three utilities; the study includes site plans, cost estimates, and schedule schemes. The status of existing utilities will be considered in preparing the required alternatives. The EIS Cantonment Alternatives 3 and 8 from the May 2009 in-progress EIS were used for this analysis.

The Barrigada Utility Study uses the projected military buildup populations provided from the Navy on 9 February 2009 (NAVFAC Pacific 2009) that are consistent with the populations used in the in-progress EIS for Guam. Housing locations for construction workers and increased civilian population on Guam required certain assumptions in order to assess the impact on existing utilities. An overview of the population data assumptions used in this study is provided below:

- Assumptions for distribution of the military, dependents, and civilian transient worker populations are derived from the Parsons Brinckerhoff Inc. model assumptions report (PB 2008) and are the same as used in the 28 January 2009 Traffic Analysis.
- Assumptions for family housing in Navy Barrigada (33 percent) and in AF Barrigada (33 percent) are derived from the Parsons Brinckerhoff Inc. model assumptions report (PB 2008) and the same as used in the 28 January 2009 Traffic Analysis.
- Assumptions for the on-base civilian work force are 40 percent of the active duty military population with 33 percent living in Navy Barrigada, 33 percent in AF Barrigada, and 33 percent in Finegayan.

An overview of the utility findings and options that would be required to support EIS Cantonment Alternatives 3 and 8 are presented below. Because the impacted areas for Cantonment Alternative 3 are larger than and inclusive of Alternative 8, Alternative 3 will be analyzed as representative of both alternatives. This approach will present the alternative with the maximum potential adverse effect and is consistent with the approach used in the 28 January 2009 Traffic Analysis.

Electrical Power Utility Overview

In the Guam Power Generation Study (Earth Tech 2008a), electrical generation and distribution system improvements were recommended to serve the Finegayan Base (for EIS Cantonment Alternatives 1 and 2). The Guam Power Authority generation system will require additional power generation capacity to serve the USMC relocation and other DoD planned loads. The power generation requirements for Cantonment Alternative 3 will be similar to the Cantonment Alternatives 1 and 2, but the transmission and distribution requirements will be different.

EIS Cantonment Alternative 3 differs from the previously considered EIS Cantonment Alternatives 1 and 2 in that a portion of the accompanied service members is housed on Navy Barrigada and AF Barrigada. It is assumed that the overall conclusions documented in the Guam Power Generation Study (Earth Tech 2008a) will be the same for EIS Cantonment Alternative 3. Therefore, this report provides a detailed analysis of power distribution options to support Navy Barrigada and AF Barrigada facilities.

The electrical systems in both Navy and AF Barrigada areas will require extensive upgrades due to existing electrical distribution systems being inadequate to support requirements for the proposed housing. Those upgrades would include the following major components:

- New substation at AF Barrigada (Eagle Field area)
- Upgraded distribution between Highway 16 and the new AF Barrigada substation
- Upgrades to existing Navy Barrigada substation
- Upgrades to distribution between Highway 16 and Navy Barrigada substation

The upgrades would support the planned housing developments at Navy and AF Barrigada based on information available. Table ES-1 provides a summary of the options considered for upgrades to the electrical system.

Table ES-1: Cost Summary of Electrical Options Considered

Option	Option 1: Replace existing substation with new serving all loads	Option 2: Install new substation for each of two areas	Option 3: Upgrade existing Navy Barrigada substation and install new AF Barrigada substation	Option 4: Upgrade existing Navy Barrigada substation and feed AF Barrigada from GPA substation at 13.8kV
Capital Costs				
Total Capital Cost	$36,500,000	$45,000,000	$38,341,000	$33,000,000
Amortized Capital Cost	$2,686,000	$3,311,000	$2,821,000	$2,428,000
O&M Costs				
Total Annual Cost	$557,000	$686,000	$585,000	$503,000
Annual Life Cycle Costs	$3,243,000	$3,997,000	$3,406,000	$2,931,000
Estimated Construction Duration	*2.0 to 2.5 years*	*2.5 to 3.0 years*	*2.0 to 2.5 years*	*2.5 to 3.0 years*

The options considered do not have widely varying costs; however, they do offer higher or lower reliability and have less direct impacts to long-term operation of each option. Option 3 was selected as the option that provides the best balance between reliability (reasonable circuit lengths) and costs. While Options 1 and 4 offer lower cost, they also have lower reliability due to long circuit lengths to serve Navy and AF Barrigada areas from locations that are further from the facilities. Option 2 has the highest cost but also provides new substations for each new housing area while not providing additional reliability or significant benefits to justify the higher cost.

Potable Water Utility Overview

In the Guam Water Utility Study (Earth Tech 2008b), development of groundwater resources was recommended as the primary source to serve the Finegayan Base (Alternatives 1 and 2). The supply from rehabilitated wells and purchase of water from Guam Waterworks Authority (GWA) are not sufficient to meet USMC relocation water demand. Review of the available yield indicates that the water supply from the Northern Guam Lens Aquifer is sufficient to meet the projected demand based on the 1991 sustainable yield estimates.

EIS Cantonment Alternative 3 differs from the previously considered EIS Cantonment Alternatives 1 and 2 in that a portion of the accompanied service members is housed on Navy Barrigada and AF Barrigada. It is assumed that the overall conclusions documented in the Guam Water Utility Study (Earth Tech 2008b) will be the same for EIS Cantonment Alternative 3. Therefore, this report provides a detailed analysis of groundwater resource development as the primary source for Navy Barrigada and AF Barrigada.

Summary of Findings for Potable Water. The current and future water demands for the USMC relocation areas are shown in Table ES-2.

For EIS Cantonment Alternative 3, it was determined that the USMC Finegayan Base Complex water supply will have capacity to serve Navy Barrigada demand. It is estimated that the wells installed on Navy Barrigada will be sufficient to supply AF Barrigada. The capacities for water system components, sized according to the Unified Facilities Criteria guidance, are presented in Table ES-3. Twenty (20) wells on Andersen Air Force Base (AFB) will meet the supply requirements for the Finegayan water system. Eleven (11) wells on Navy Barrigada will meet the supply for AF Barrigada. Groundwater will be collected and treated at two central water treatment plants, one on Andersen AFB and one on Navy Barrigada. Additional storage capacity is required at Finegayan and AF Barrigada. Partial replacement of the Navy island-wide water system mains is included in this option to transport water from Finegayan to the facilities in Barrigada. This study included the raw and treated transmission mains, excluding distribution from water storage to users. Figure ES- 1 shows a schematic of the planned DoD water supplies.

Life cycle costs for EIS Cantonment Alternative 3 are shown in Table ES-4. Costs are based on year 2008 dollars and escalated to the mid-point year of construction to permit comparison with the costs presented in the Guam Water Utility Study. The costs of the alternatives presented in this study do not include components for DoD that do not relate to the USMC relocation (e.g., water treatment plants for the Andersen AFB water system). The present worth cost is $520 million (M).

The USMC-only cost estimate (assuming the non-USMC population is 10 percent of the total) is provided in Table ES-5. The present worth cost for is $459M.

Table ES-2: DoD Water Demands in USMC Relocation Areas

	USMC Relocation Areas		
	Finegayan Base Complex	Navy Barrigada	AF Barrigada
Current			
Average Daily Demand (mgd)	0.1	1.0	None
Maximum Daily Demand (mgd)	0.2	1.0	None
Future			
Average Daily Demand (mgd)	4.5	1.4 [a]	1.5
Maximum Daily Demand (mgd)	7.3	3.2 [a]	3.3

mgd million gallons per day
[a] The demand for Navy Barrigada excludes demands unrelated to the USMC Relocation.

Table ES-3: Facility Capacities for Water

	USMC Relocation Areas		
Water Supply (mgd)	**Finegayan and Navy Barrigada**		**AF Barrigada**
Existing Navy Supply	2.3		0.4
Additional Required	11.1		3.2
Total Future Capacity	13.4		3.6
Treatment Capacity (mgd)	**Finegayan and Navy Barrigada**		**AF Barrigada**
Existing Treatment Capacity	0		0
Total Future Capacity	14.0		3.3
Storage Capacity (mg)	**Finegayan**	**Navy Barrigada**	**AF Barrigada**
Existing Supply	0 [b]	3.0	0
Total Future Capacity	3.6	3.0	1.0

— not applicable
[b] It is assumed that all existing storage facilities on Finegayan will be demolished.

Table ES-4: Cantonment Alternative 3 Life Cycle Costs

Capital Costs	Cost ($000)
Total Construction Cost	$277,105
Contingencies (20%)	$55,421
Engineering (15%)	$41,566
Total Capital Cost	**$374,092**
Present Worth Guam Capital Costs	**$377,026**
Annual O&M Costs	
Total Annual O&M Cost	$4,992
Contingency (20%)	$998
Total Annual O&M Cost	**$5,990**
Present Worth of O&M Costs (25 year life)	**$142,951**
Present Worth of Total Costs	**$519,977**

Table ES-5: Cantonment Alternative 3 Life Cycle Costs for Water - USMC Only

Capital Costs	Cost ($000)
Total Construction Cost	$246,972
Contingencies (20%)	$49,394
Engineering (15%)	$37,046
Total Capital Cost	**$333,413**
Present Worth Guam Capital Costs	**$336,028**
Annual O&M Costs	
Total Annual O&M Cost	$4,288
Contingency (20%)	$858
Total Annual O&M Cost	**$5,146**
Present Worth of O&M Costs (25 year life)	**$122,801**
Present Worth of Total Costs	**$458,828**

Figure ES- 1: Diagram of Sources and Demand

Wastewater Utility Overview

To identify reasonable wastewater treatment options to support the potential EIS Cantonment alternatives, four wastewater options were analyzed in detail in this study:

- Expand and upgrade existing primary treatment system at the Government of Guam (GovGuam) Hagatna Wastewater Treatment Plant (WWTP) to accept the additional flow and load.
- Expand and upgrade the GovGuam Hagatna WWTP to secondary treatment.
- Build new secondary treatment plant near the proposed development on DoD land and construct new outfall.
- Build new separate secondary treatment plant at GovGuam Hagatna WWTP site to treat DoD load only.

The current and projected increased average daily wastewater flows in the central Guam wastewater basin related to the Barrigada housing alternatives of USMC relocation to Guam are summarized in Table ES-6. Military flow is generated from the military activities in Navy Barrigada and AF Barrigada, while outside base civilian flow includes the flows generated from Guam population and its natural growth, and induced population due to military buildup in the region.

Table ES-6: Current and Future Average Wastewater Flow in Central Guam for USMC Relocation Main Cantonment Alternative 3

Projected Wastewater Flows	Baseline (Y2009)	Estimated Increase (Y2019)	Total Future Loading (Y2019)
Outside-base Civilian, mgd	4.38	1.44	5.82
Military, mgd	0.34	1.25	1.59
Total Central Guam Flow, mgd	**4.72**	**3.11**	**7.40**

Assumptions:
1. No Navy, AF, Coast Guard, and Guam National Guard population increase in Barrigada area.
2. # of USMC and Army personnel and dependents in Barrigada obtained from Guam Traffic Analysis Data spreadsheet (01-28-09).
3. Navy Barrigada existing flow (Y2009) estimated 80% of water demand data (total - irrigation) supplied by Jack Brown of NAFM.
4. Off-base civilian existing flow (2009) estimated by deducting DoD flow from Hagatna WWTP flow data provided by GWA.
5. Off-base civilian future flow (Y2019) calculated by 30% island wide civilian natural population growth data from US Census Bureau, International Data Base (IBD), and 15 Dec 2008: http://www.census.gov/ipc/www/ibd/.

Table ES-7 presents total present capital costs and annual life cycle costs of the four viable options based on year 2009 cost.

Table ES-7: Cost Summary of Wastewater Viable Options

Option	Option 1: Expand & Upgrade Hagatna WWTP Primary Treatment	Option 2: Expand & Upgrade Hagatna WWTP to Secondary Treatment	Option 3: DoD Secondary Treatment on DoD Land	Option 4: Separate Secondary Treatment at Hagatna WWTP Site to Treat DoD Load Only
Capital Costs				
Total Capital Cost	$20,795,000	$90,319,000	$161,008,000	$65,237,000
Amortized Capital Cost	$1,530,000	$6,646,000	$11,847,000	$4,800,000

Option	Option 1: Expand & Upgrade Hagatna WWTP Primary Treatment	Option 2: Expand & Upgrade Hagatna WWTP to Secondary Treatment	Option 3: DoD Secondary Treatment on DoD Land	Option 4: Separate Secondary Treatment at Hagatna WWTP Site to Treat DoD Load Only
O&M Costs				
Total Annual Cost	$607,000	$2,722,000	$1,396,000	$995,000
Annual Life Cycle Costs	$2,137,000	$9,368,000	$13,243,000	$5,795,000
USMC Barrigada Housing Related Treatment Capital Cost	*$10,706,000*	*$28,043,000*	*$82,147,000*	*$44,312,000*
Estimated Construction Duration	*2.0 to 3.0 years*	*3.5 to 4.5 years*	*4.0 to 5.5 years*	*4.0 to 5.5 years*

Both the annual life cycle cost of $2,137,000, including amortized construction cost and estimated annual operations and maintenance cost, and total construction cost of $20,795,000 for Option 1 – *Expand and upgrade existing primary treatment system at GovGuam Hagatna WWTP to accept the additional flow and load*, are the lowest compared to the other three options. The USMC's capital cost share ($10,706,000) based on wastewater flow contribution is also the lowest for Option 1. However, we recommend a secondary treatment option because the increased discharge from DoD activities on the island of Guam would have an impact on the existing National Pollutant Discharge Elimination System (NPDES) permit requirements, water quality standards, and NPDES requirements for current and any future effluent discharge (based on secondary treatment technology-based requirements established by the EPA).

Among the three secondary treatment options (i.e., Options 2, 3, and 4 for wastewater treatment), Option 4 – *Build new separate secondary treatment plant at GovGuam Hagatna WWTP site to treat DoD load only* has the lowest capital cost ($65,237,000) and annual life cycle cost ($5,795,000). However, Option 2 – *Expand and upgrade the GovGuam Hagatna WWTP to secondary treatment* is beneficial to Guam as it assists them in meeting EPA desired and likely mandated secondary treatment levels. The proposed upgrades in Option 2 could be implemented in phased construction. By refurbishing existing effluent pumping station and building a new ultraviolet (UV) disinfection system in the Hagatna WWTP, the plant is able to handle additional wastewater generated from construction workforce and the proposed project induced population in central Guam area during interim period with primary treatment. After the rest of the proposed upgrades are completed, the Hagatna WWTP could treat proposed future flow from both civilian population and Barrigada military activities with secondary biological treatment to fulfill EPA requirements. In conclusion, Option 2 – *Expand and upgrade the GovGuam Hagatna WWTP to secondary treatment* is recommended to support USMC off-base housing facilities requirements.

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ACRONYMS AND ABBREVIATIONS

$	United States dollar
ACP	asbestos cement pipes
AF	Air Force
AFB	Air Force Base
AMD	Air and Missile Defense
amp	ampere
BOD	biochemical oxygen demand
CFR	Code of Federal Regulations
DoD	Department of Defense
EIS	Environmental Impact Statement
EPA	Environmental Protection Agency, United States
ESQD	Explosive Safety Quantity Distance
ft/sec	feet per second
gal	gallon
GEPA	Guam Environmental Protection Agency
GJMMP	Guam Joint Military Master Plan
GovGuam	Government of Guam
GPA	Guam Power Authority
gpcd	gallons per capita per day
gpd	gallons per day
gpm	gallons per minute
GWA	Guam Waterworks Authority
GWRMP	Guam Water Resources Master Plan
GWUDI	groundwater under the direct influence of surface water
HDBK	handbook
HP	horsepower
IBD	inhabited building distance
IWPS	island-wide power system
kV	kilovolt
kVa	kilovolt-ampere
kW	kilowatt
M	million
MARBO	Marianas Bonins Command
MCB	Marine Corps Base
MDD	minimum daily demand
MG	million gallons
mgd	million gallons per day
mg/L	milligram per liter
MIL	military
msl	mean sea level
MVA	million volt-ampere
MW	megawatt
NAS	Naval Air Station
NAVCOMM	Naval Communications
NAVFAC	Naval Facilities Engineering Command
NCTS	Naval Computer and Telecommunications Station
NEXRAD	Next Generation Radar

NGLA	Northern Guam Lens Aquifer
NIW	Navy Island-Wide
No.	number
NPDES	National Pollutant Discharge Elimination System
NWF	Northwest Field
O&M	operations and maintenance
PVC	polyvinyl chloride
SPS	sewage pump station
T&D	transmission and distribution
TSS	total suspended solids
U.S.	United States
UFC	Unified Facilities Criteria
UFW	unaccounted for water
USCG	United States Coast Guard
USGS	United States Geological Survey
USMC	United States Marine Corps
UV	ultra violet
VCP	vitrified clay pipes
WERI	Water and Environmental Research Institute
WWTP	wastewater treatment plant

1. Introduction

The Guam Joint Military Master Plan (GJMMP) identifies a planned increase in military population and activity on Guam. The Environmental Impact Statement (EIS) for this action presents several EIS Cantonment alternatives for the United States Marine Corps (USMC). Potential sites for EIS Cantonment Alternatives 3 and 8 include Department of Defense (DoD) land at Barrigada, Guam, specifically Navy Barrigada and Air Force (AF) Barrigada.

The Naval Facilities Engineering Command, Pacific, under Master Contract Number (No.) N62742-06-D-1870 issued Contract Task Order No. 35 to the TEC, Inc Joint Venture to study the electrical power, potable water, and wastewater utilities for EIS Cantonment Alternatives 3 and 8 at Barrigada, Guam. The Barrigada Utility Study will support the preparation of the EIS for the USMC relocation to Guam with sufficient and detailed information for EIS Cantonment Alternatives 3 and 8, including the interim and long-term alternatives for each of the three utilities; the study includes site plans, cost estimates, and schedule schemes. The status of existing utilities will be considered in preparing the required alternatives. The EIS Cantonment Alternatives 3 and 8 from the May 2009 in-progress EIS are shown on Figure 1-1 and Figure 1-2.

The Barrigada Utility Study uses the military buildup populations presented in Table 1-1 through Table 1-6, which are the projected populations provided from the Navy on 9 February 2009 (NAVFAC Pacific 2009) and are consistent with the populations used in the in-progress EIS for Guam. Housing locations for construction workers and increased civilian population on Guam required certain assumptions in order to assess the impact on existing utilities. An overview of the population data assumptions used in this study is provided below:

- Assumptions for distribution of the military, dependents, and civilian transient worker populations are derived from the Parsons Brinckerhoff Inc. model assumptions report (PB 2008) and are the same as used in the 28 January 2009 Traffic Analysis.
- Assumptions for family housing in Navy Barrigada (33 percent) and in AF Barrigada (33 percent) are derived from the Parsons Brinckerhoff Inc. model assumptions report (PB 2008) and the same as used in the 28 January 2009 Traffic Analysis.
- Assumptions for the on-base civilian work force is 40 percent of the active duty military population with 33 percent living in Navy Barrigada, 33 percent in AF Barrigada, and 33 percent in Finegayan.

Because the impacted areas for Cantonment Alternative 3 are larger than and inclusive of Alternative 8, Alternative 3 will be analyzed as representative of both alternatives. This approach will present the alternative with the maximum potential adverse effect and is consistent with the approach used in the Traffic Analysis (01-28-09). The following sections will cover each of the three utilities studied for EIS Cantonment Alternatives 3 at DoD land at Barrigada.

- Section 2: Electrical Power
- Section 3: Potable Water
- Section 4: Wastewater

Figure 1-1: USMC Main Cantonment Alternative 3

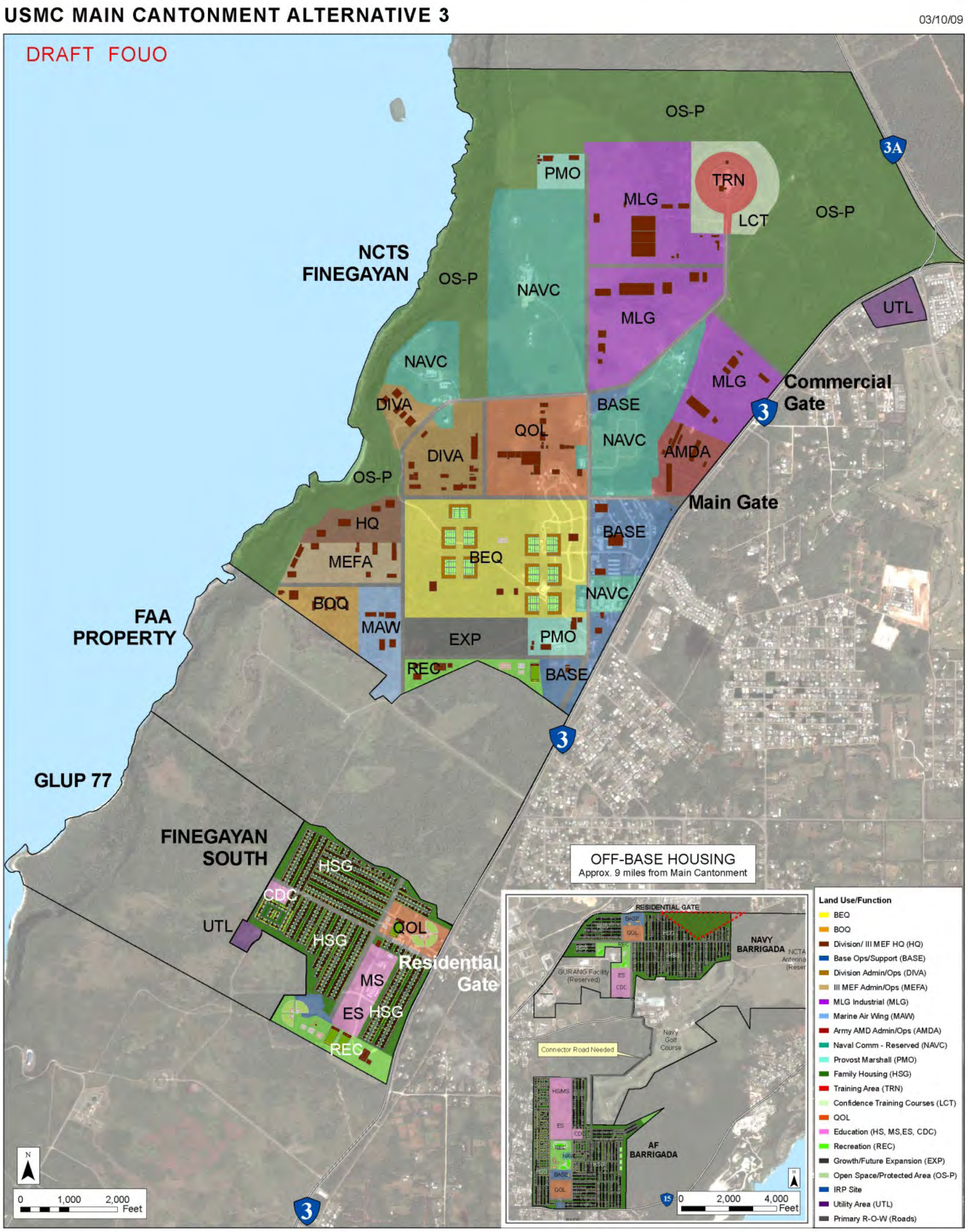

Figure 1-2: USMC Main Cantonment Alternative 8

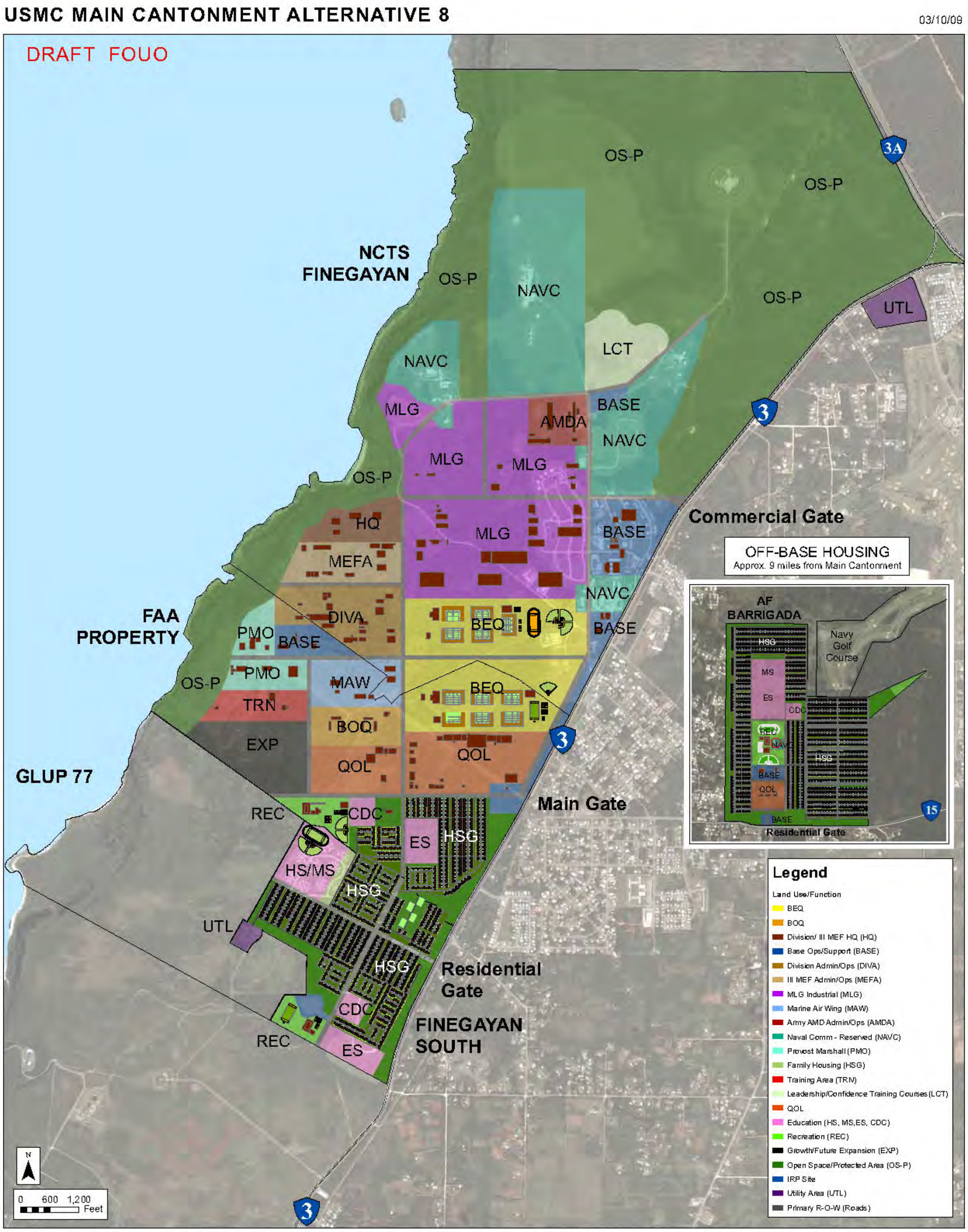

Table 1-1: Projected Population Associated with the Proposed Military Relocation Project on Guam

Table 1-2: Project-Related Population Distribution Associated with the Proposed Military Relocation Project on Guam in 2019 (Alternative 3)

Table 1-3: Projected Population Associated with the Proposed Military Relocation Project in Barrigada Area (Alternative 3)

Table 1-4: Projected Population Associated with the Proposed Military Relocation Project in Northern Guam (Alternative 3)

Table 1-5: Projected Population Associated with the Proposed Military Relocation Project in Apra Harbor (Alternative 3)

Table 1-6: Projected Off-Base Non-Military Population Associated with the Proposed Military Relocation Projection Guam (Alternative 3)

2. Electrical Power Utility

The military buildup populations projected in the EIS for Guam that were used as a basis for this utility study are presented in Table 1-1 through Table 1-6. Certain assumptions were required regarding the housing locations for construction workers and increased civilian population of Guam in order to assess the impact on existing utilities operated by the Government of Guam (GovGuam). The assumptions are footnoted in the population worksheets.

This study provides conceptual level planning for power distribution to the Navy and Air Force Barrigada area. This planning information identifies impacts to substation and electrical lines to facilitate assessment of impacts in the EIS.

2.1 ANALYSIS OF ELECTRICAL POWER DEMAND – CURRENT AND FUTURE

The existing conditions were evaluated with input from Naval Facilities Engineering Command (NAVFAC) Marianas staff to establish existing demands in the area. Guam Power Authority (GPA) provided additional input regarding impacts to the island-wide power system (IWPS) transmission (see Appendix B), distribution, and substation systems. Areas considered in this report are Navy Barrigada and Air Force (AF) Barrigada. Navy Barrigada is somewhat developed in that there are existing electrical distribution facilities and a substation that serve the area. AF Barrigada is less developed and the limited power needs in the area are served by the substation located at Navy Barrigada.

The Navy and GPA terms used for the area are described to clarify terms used in this report. GPA refers to a substation that serves the general area as "Barrigada Substation," whereas "Radio Barrigada" is used in referring to the Navy substation located near the golf course, which is also referred to as "Navy Barrigada." This report will refer to the Radio Barrigada area as Navy Barrigada and the area to the south (Barrigada Substation) as AF Barrigada.

The existing Navy Barrigada substation is located near the entrance to the golf course and is rated at 9.375 million volt-ampere (MVA) (two transformers connected to provide redundancy for the substation). The existing substation transformers are being rebuilt under a contract that is under construction. Existing demand loads on this substation amount to approximately 3.5 megawatts (MW) of peak demand or about 40 percent of the substation capacity. This information was provided by the Navy from historical electrical demand information for the substation. The existing GPA Barrigada substation has a capacity of 22 MVA and is currently loaded to 12.4 MW based on information provided by GPA and summarized in Table 2-1.

Table 2-1: Existing Loads

Area	Substation	Existing Load	Planned Load
Navy Barrigada	Transformer 23/24	3.5MW	16.27MW
Air Force Barrigada	Existing served from Navy Barrigada	0.5MW included in Navy Barrigada	12.52MW
GPA Barrigada	22MVA (19.8MW) GPA Substation	12.4MW	13.02MW (Air Force Barrigada)

The additional load at AF Barrigada will exceed the capacity of the GPA substation if connected to the GPA Barrigada Substation. Discussions with Navy and GPA staff indicated that a new substation (Navy/GPA) should be located near the planned AF Barrigada housing under EIS Cantonment Alternative 3 to serve those loads. This option would allow a joint facility to be built near the housing area at AF Barrigada (South housing area) and provide the ability to use the substation to house the Navy switchgear and GPA service equipment.

Planned future demand is expected to be 16.3 MW at Navy Barrigada and 12.5 MW at AF Barrigada. Each of these load increases will require expansion or upgrade of the existing distribution system.

The basis for power demand at the EIS Cantonment Alternative 3 housing areas is the facilities list provided with the planning layouts for facilities. The demand calculations can be found in Appendix B.2.

Both housing areas planned in EIS Cantonment Alternative 3 results in approximately 29 MW of additional demand to the Barrigada area.

2.2 EVALUATION OF EXISTING CONDITIONS AND FUTURE REQUIREMENTS

2.2.1 Existing Conditions

The existing DoD loads in the Barrigada area affected by planned housing under EIS Cantonment Alternative 3 are currently served through the Navy Barrigada substation. This substation had operational problems that necessitated a project to repair/rebuild these units in place. While this will restore the transformers to reliable service, the capacity of this substation is not sufficient to provide power to the planned housing and existing loads.

The Navy Barrigada substation supplies power to DoD facilities nearby as well as south to the area surrounding the golf course (near AF Barrigada). Addition of the substantial housing planned for the AF Barrigada area would overload the existing distribution and require major portions to be replaced. Minimal distribution exists in the AF Barrigada area (Southern portion of the planned housing for EIS Cantonment Alternative 3) to support the radio facilities in that area (Transmitter building 81 and United States Coast Guard (USCG) LORAN building based on Navy electrical distribution system maps). This distribution is also insufficient and would require replacement if the new housing were served from Navy Barrigada.

The proposed option will need to re-connect existing loads to provide power from any of the options. The existing circuits will need to be picked up near the existing Navy Barrigada Substation to cause minimal disruption in service and limit that amount of work required to serve the existing loads.

There is no known reliability or regulatory issue in the area relative to electrical distribution. Some conditions exist in the high power antenna areas (Navy Barrigada) that may impact facility planning to maintain minimum separation from radio equipment.

2.3 ELECTRICAL POWER OPTIONS

2.3.1 Interim Options Considered

The interim options available are limited due to the location of the planned facilities and existing infrastructure. Options considered are based on using two substation transformers that provide redundant capacity should one circuit or transformer fail. The remaining transformer would be capable of supporting the facility load. This configuration provides an economical level of redundancy with limited complexity.

Additional options could involve adding a transformer to the existing Navy Barrigada Substation to provide additional capacity. This arrangement does not provide the additional capacity that the switchgear requires, adds complexity to the switching required for the added transformer, and does not provide redundancy simply by adding a transformer as the existing transformers are not sized to support the planned loads. These reasons limited options to the more conventional two transformer arrangement that provides an economical level of redundancy for the substation.

The existing GPA distribution must be upgraded at the same time that the Navy and AF Barrigada Substations are installed to provide the necessary load capacity for the planned facilities. This is because the existing circuits are not capable of reliably handling the additional loads, and a partial upgrade would not be cost effective and may result in spending nearly double the cost of upgrading the circuits to the required capacity with the other interim projects. The options considered are listed below:

- Option 1 – *Replace existing Navy Barrigada substation with new substation sized to support planned Cantonment Alternative 3 facilities in both areas.*
- Option 2 – *Install new substation at each planned housing area.*
- Option 3 – *Upgrade existing Navy Barrigada substation and install new substation for the AF Barrigada housing area* (GPA refers to this area as Eagle Field).
- Option 4 – *Upgrade existing Navy Barrigada substation to support nearby planned housing and feed AF Barrigada housing from the existing GPA substation* (would require upgrading due to inadequate capacity).

The options were evaluated and ranked based on cost, increase or decrease in reliability to the system, and implementation difficulty as described in Table 2-2. The results are presented below in descending order by rank:

1. Option 3. This option takes advantage of as much existing distribution as possible from the substation and upgrades existing facilities to provide improved reliability. While upgrading the existing substation will require outage to implement, they should be reasonable and existing facilities have standby generators where deemed necessary. Installing a new substation at the AF Barrigada area will require minimal interruptions to existing systems.
2. Option 2. While this option will be the simplest to implement (no existing facilities to work around), it does not use the opportunity to improve the existing substation or switchgear by upgrading for additional capacity and is potentially more costly than Option 3.
3. Options 1 and 4. These options are similar in that each proposes to upgrade the existing Navy Barrigada substation and serve the AF Barrigada from some distance away. This option avoids the cost of a substation for the southern housing area but would require extensive underground distribution from either the existing Navy Barrigada location or the GPA Barrigada substation. The long distances present voltage drop challenges at the lower distribution voltage (13.8 kilovolts [kV] versus 34.5 kV) and would be a concern for reliability.

Table 2-2: Electrical Power Option Analysis

Option	Cost	Implementation	Reliability Impact
1. Replace existing substation and serve all planned facilities	Lowest	Difficult due to long distance between Navy and AF Barrigada and upgrading existing substation	Lowest
2. Install new substation and new distribution for all planned facilities. Existing substation to remain.	Highest	Simple due to all new construction but higher cost to re-feed existing facility circuits and coordination required	Medium
3. Install new substation at AF Barrigada and upgrade existing Navy Barrigada substation	Medium	Medium due to upgrade of existing substation work	Highest
4. Upgrade existing Navy Barrigada substation and GPA substation in Barrigada for AF Barrigada area.	Medium	Medium to difficult due to need to upgrade existing GPA substation and distance to new housing	Medium

It should be noted that distribution and substation improvements to meet interim requirements and long-term power requirements are the same for Cantonment Alternative 3. The housing construction is anticipated by 2015 and is before the long-term generation is anticipated to be available. No additional identified system improvements are required during the long-term period of 2015 and later.

2.3.2 Recommendation

The recommended option is Option 3 – *Upgrade the existing Barrigada Substation and install a new substation near the planned housing in AF Barrigada* (GPA Eagle Field substation). The option would also require new distribution feeders from GPA substations (Barrigada and Pulantat substations) to serve the AF Barrigada Switchgear. This option is recommended to avoid placing all of the new facilities on one substation, running excessively long distribution loops from the Navy area to the AF area, and reworking existing distribution at Navy Barrigada by upgrading the existing substation rather than installing a new substation. This option also improves reliability by distributing substation facilities and avoiding overly long distribution lines.

The Option 3 modifications and additional loads in the Navy and AF Barrigada areas require additional GPA transmission and distribution (T&D) improvements to support the additional load and provide two sources of power for reliability. These improvements require the following upgrades to the T&D system:

- AF Barrigada (Eagle Field) Substation located at AF Barrigada
- Barrigada to AF Barrigada (Eagle Field) 34.5 kV Line
- AF Barrigada (Eagle Field) to Pulantat 34.5 kV Line (essentially re-routing Barrigada to Pulantat 34.5 kV line to go through Eagle Field Substation first)
- Apra to Talofofo 34.5 kV Line
- 12 MVAR capacitor bank at AF Barrigada (Eagle Field) for voltage support.
- 6 MVAR capacitor bank at Navy Barrigada for voltage support.

These improvements are in addition to the distribution inside DoD property to support the additional facilities.

Each of the planned housing areas will require a substation that is connected to 34.5 kV lines from GPA and provides distribution voltage at 13.8 kV. The sizing of those units will need to support existing, planned and possible future loads for the area. The substation sizes are selected based on the load requirements described in Table 2-1 and below in Table 2-3.

Table 2-3: Navy and AF Barrigada Substation

Load Description	Load (MW)	Notes
Navy Barrigada Existing	3.0 MW	0.5 MW will be transferred to AF Barrigada loads
Navy Barrigada Planned Loads	16.3 MW	
Navy Barrigada Substation	19.3 MW (24 MVA using 0.8 power factor for demand load)	Represents anticipated coincident demand load
AF Barrigada Existing	0.5 MW	
AF Barrigada Planned Loads	12 MW	
AF Barrigada Substation	12.5 MW (15.6 MVA using 0.8 power factor for demand load)	Represents anticipated coincident demand load

The substation capacity for Navy Barrigada should be planned for 30 MVA. This provides for the anticipated 24 MVA of load with the next largest substation size. The substation capacity for AF Barrigada should be planned for 20 MVA. This supports the anticipated 15.6 MVA of load and uses the next largest substation size.

3. Potable Water Utility

The military buildup populations projected in the EIS for Guam that were used as a basis for this utility study are presented in Table 1-1 through Table 1-6. Certain assumptions were required regarding the housing locations for construction workers and increased civilian population of Guam in order to assess the impact on existing utilities operated by the GovGuam. The military buildup populations were provided by the Navy on 9 February 2009 (NAVFAC Pacific 2009). The population distribution ratios for military personnel and dependents are the same as the Traffic Analysis. The on-base civilian population is 50 percent of 40 percent active duty to be consistent with the February 9, 2009 population estimate. The project related population for Finegayan Base Complex includes the USMC and Army AMD. The family housing in the Barrigada area will be 66 percent of the total family housing. It is assumed that the 2000 USMC transients are housed on Finegayan Base. It is assumed that the construction workers will be housed off base and that all construction related water will be provided by the contractor through GWA.

This study provides conceptual level planning for potable water supply to Navy Barrigada and AF Barrigada areas. The planning information identifies impacts to water storage, future additional water supply wells, water treatment, and distribution systems to facilitate assessment of impacts in the EIS. In this study, the water supply for Finegayan Base Complex will be from new proposed wells located primarily on the Andersen Air Force Base (AFB). Water will be supplied to Navy Barrigada and AF Barrigada partially from wells located on Navy Barrigada and from the Finegayan Base Complex water system through upgrades to the Navy Island-Wide (NIW) system water mains.

3.1 Analysis of Water System Demands – Current and Future

3.1.1 Water System Demands

The following section presents the water demand calculation for the proposed facilities for the Marine relocation and improvement to the existing DoD facilities (Andersen AFB and the Naval Base). The water demand for the USMC relocation was calculated using the Unified Facilities Criteria (UFC) 3-230-19N "Design: Water Supply Systems." Total requirements are calculated for domestic, industrial, fire protection and unaccounted for water (UFW) demands.

The DoD population data presented in Section 1 is the basis for the domestic demand. The *Final Report Water, Wastewater, and Solid Waste Management Impact Assessment for JGMMP, Guam* (HPE 2006) for Alternative 1 and the *Final U.S. Marine Corps Facility Requirements and Initial Concept Plan* (HHF 2007) provides the basis for the measured water losses and the industrial demands. All DoD water demands are considered, because (1) water may be supplied to the Barrigada bases from either the Navy or the planned Finegayan water supply; and (2) the availability of water from the Northern Guam Lens Aquifer (NGLA) will be assessed considering all DoD and Guam Waterworks Authority (GWA) wells current and planned.

3.1.1.1 Domestic Uses

Domestic uses include drinking water, household uses, and household lawn irrigation.

Per capita requirements are shown in Table 3-1 for permanent and temporary installation in the tropics.

Table 3-1: Average Potable Domestic Water Requirements Gallons Per Capita Per Day

Use Category	Tropic (gpcd)
Unaccompanied Personnel Housing	155
Family Housing	180
Workers (per shift)	45

Source: DoD 2005
gpcd gallons per capita per day

The average demand for each use category shown Table 3-1, in gallons per day (gpd), is calculated by Equation 1:

Equation 1

$$\text{Average daily domestic demand in gpd} = \text{gpcd} \times \text{design population} \times \text{growth factor}$$

The following growth factors are used in Equation 1:

a) Large systems (5,000 population or greater), 1.25.

b) Small systems (populations less than 5,000), 1.50.

Total average demand is the sum of averages for unaccompanied personnel housing, family housing and workers.

Other controlling demands are calculated by Equation (2):

Equation 2

$$\text{Maximum Daily Domestic Demand (MDD)} = \text{average daily domestic demand in gpd} \times K$$

Table 3-2 provides the data for the coefficient, K.

Table 3-2: Controlling Demand Coefficients for Water

Demand	Units of Demand	Coefficient K	
		Population <5,000	Population >5,000
Maximum Day Flow	gpd	2.25	2
Maximum Hour Flow	gpm	4.0/1,440	3.5/1,440
Instantaneous Peak Flow	gpm	5.0/1,440	4.5/1,440

Source: DoD 2005
gpd = gallons per day

Table 3-3 presents the future DoD populations and domestic demand. The number of accompanied service members was estimated assuming 2.5 dependents per accompanied service member. It is assumed that the active service members housed at Navy Barrigada and AF Barrigada will travel to Finegayan for work each day. Transients are counted under non resident military workers with a consumption rate of 45 gallons per capita per day (gpcd). Although the transients are housed on base, it is assumed that their water consumption will be relatively low compared to residents. The transients are expected to spend a significant portion of the time off-island on training bases. When on-base, the transients will be housed in officers or enlisted quarters which will not require all of the water demands of a home, e.g. household lawn irrigation.

The USMC relocation-related MDDs are 4.9 mgd for the Finegayan Base Complex, 2.8 mgd for Navy Barrigada and 2.8 mgd for AF Barrigada. For existing bases, the MDDs are 4.7 mgd for the remaining Navy Bases (not including Navy Barrigada) and 2.5 mgd for Andersen AFB.

Table 3-3: DoD Future Population and Domestic Demand for Water

	USMC Relocation Areas				
	Finegayan Base Complex	**Navy Barrigada**	**AF Barrigada**	**Remaining Navy Bases**	**AAFB**
Accompanied Personnel	1,327	1,262	1,262	2,067	1,180
Dependents	3,369	3,317	3,317	5,173	2,950
Unaccompanied Personnel	5,365	0	0	2,290	965
Non Resident Military Workers	4,524	0	0	0	1,780
Civilians on base	1,665	92	92	1,331	805
Total Population	16,250	4,671	4,671	10,861	7,680
Average Daily Domestic Demand (mgd)	2.4	1.2	1.2	2.3	1.3
Maximum Daily Domestic Demand (mgd)	4.9	2.8	2.8	4.7	2.5

AAFB Andersen AFB

3.1.1.2 Industrial Uses

Industrial uses include air conditioning, irrigation, swimming pools, shops, laundries, dining, processing, flushing, and boiler makeup water. Demands were assigned according to the values in Table 4-4 of UFC 3-230-19N (DoD 2005).

Table 3-4: Industrial Water Requirements Potable Water - Permanent Installations

		Requirements		
	Unit	Min	Avg	Max
Air conditioning:	gpm/ton	—	0.05	0.10
Laundries	gal/lb	3	—	6
Irrigation				
Motor vehicles	gpd/car	30	—	50
Restaurants	gal/meal	0.5	—	4.0

From UFC 3-230-19N

Additionally, UFC 3-230-19N (DoD 2005) requires that water demand data from other activities having uses similar to those anticipated be used. The industrial demands for the facilities not covered by Table 4-2 in DoD (2005) were assigned a demand based on the measured demands for similar facilities within the existing Navy bases. The average daily industrial use is 1.4 million gallons per day (mgd) at the Finegayan Base Complex. This demand includes 400 gallons per minute (gpm) for use in a power generation. Details of the demand calculation are present in Appendix C.2. The Finegayan Base facility list is from the Facilities Requirement and Initial Concept Plan (HHF 2007). The industrial facilities planned for Navy Barrigada and AF Barrigada are from the TEC, Inc. descriptions for Alternative 3. The future DoD industrial demands are listed in Table 3-5. The current industrial demand estimate was not included in the future industrial demand estimate for Finegayan in the Guam Water Utility Study (Earth Tech 2008b) because it was assumed that the changes to the base would eliminate and replace most sources of industrial demand. To be conservative, the future demand in Table 3-5 for Finegayan includes the 100,000 gpd estimate for current industrial use, which is from UTS 2008.

The USMC relocation-related industrial demands are 1.43 mgd for the Finegayan Base Complex, 1.17 mgd for Navy Barrigada and 0.05 mgd for AF Barrigada. For existing bases, the industrial demands are 3.38 mgd for the remaining Navy Bases (not including Navy Barrigada) and 1.00 mgd for Andersen AFB. There is an additional water demand on the Navy bases of 0.14 mgd from the CVN.

Table 3-5: Future DoD Industrial Demands for Water

mgd	USMC Relocation Areas				
Daily Industrial Demands (mgd)	**Finegayan Base Complex**	**Navy Barrigada**	**AF Barrigada**	**Remaining Navy Bases**	**AAFB**
GJMMP Report					
Existing	0.10	0.89	0.00	2.91	0.76
Additional from Projects In Progress	0	0.28	0.00	0.45	0.17
Estimated from May 2007 Report					
USMC Relocation	0.75	0.002	0.05	0.02	0.07
400 gpm for power in north Guam	0.58				
Total Industrial/Commercial	1.43	1.17	0.05	3.38	1.00
Additional Demand For CVN				0.14	

AAFB Andersen AFB

Note: The industrial demand for Navy Barrigada (1.17 mgd) includes the current Navy industrial/commercial demands.

3.1.1.3 Fire Protection Demands

Fire protection demand includes water required for maintaining the fire protection system within the facility and is designed based on the criteria outlined under the Military Handbook Fire Protection for Facilities Engineering, Design, and Construction (MIL HDBK 1008C [DoD 1994]). Requirements for fire protection water storage are based on the assumption that there will be only one fire at a time. The quantity of water required is equal to the product of the fire protection water demand and the required duration, and must be available at all times. Water supply for the domestic, industrial, and other demands is added to these requirements to determine the total amount of water required in the facility. The fire flow requirements under MIL HDBK 1008C (DoD 1994) vary greatly based on hazard classification of the activity in the facility.

The 2007 conceptual plan for relocation indicates four commands and 19 permanently based organizations, which include facilities such as family housing, aviation operation (including hangars, maintenance shops, training facilities), command centers (including administrative offices) and facilities housing various base support operations. The fire flow requirement for each facility is determined by the hazard classification for each facility structure and operation. For the current design, a maximum fire flow demand of 7,500 gpm for a minimum duration of 150 minutes is assumed. This value is referenced from Table C-1, in UFC Fire Protection Engineering for Facilities (UFC 3-600-01 [DoD 2006]), and classifies the facility as "extra hazard," which includes facilities such as hangars, ordnance plants, and warehouses. While some of the facilities listed in the 2007 plan would fall under light or ordinary hazard category, the "extra hazard" designation is selected for the conceptual fire protection demand, assuming all the facilities listed in the relocation plan are a single unit. For Navy Barrigada and AF Barrigada, the facilities are assumed to be light hazard with a maximum fire demand of 0.1 mgd. Details of the calculation are presented in Appendix C.2.

3.1.1.4 Unaccounted for Water

UFW is water that is not metered (such as that lost in leaks in unmetered mains) and is not accounted for in billing by the water utility. UFW is derived by subtracting the amount of water measured by meters and billed to customers, from the water that is produced from the treatment plants and wells, and also accounting for net changes in water storage tank inventories. The current UFW for the Navy is calculated to be approximately 15 percent according to the utility technical study report (Engineering Concepts 2005). It is assumed that the current Andersen AFB UFW will be the same because the age of the pipes and maintenance level is similar. Based on state standards summarized in the 2005 utility technical study report (Engineering Concepts 2005), a UFW of 15 percent is assumed for the current design. The estimated UFW for each area is shown in the Table 3-6 with the summary of the DoD demands.

Table 3-6: Future DoD UFW

	USMC Relocation Areas		
	Finegayan Base Complex	Navy Barrigada (USMC Only)	AF Barrigada
Average Daily UFW (mgd)	0.6	0.1	0.2
Maximum Daily UFW (mgd)	0.9	0.4	0.4

Note: The water demands for Navy Barrigada 3 exclude the demand not related to USMC Relocation.

3.1.1.5 Summary of Calculated Demands

The DoD future average and maximum daily demands are summarized in Table 3-7. The average and maximum daily demands are calculated as the sum of the domestic, industrial, and unaccounted for water demands. Current demands are presented in Table 3-8. The current Finegayan Base Complex water demand of 0.1 mgd is based on the daily demand for the existing population and the industrial demand from UTS 2005. The current demand is included in the total future water demand for the Finegayan Base Complex.

The USMC relocation-related future maximum daily demands are 7.3 mgd for the Finegayan Base Complex, 3.2 mgd for Navy Barrigada, and 3.3 mgd for AF Barrigada. For existing bases, the future MDDs are 11.3 mgd for the remaining Navy Bases (not including Navy Barrigada) and 4.0 mgd for Andersen AFB.

Table 3-7: DoD Future Daily Demands for Water

	USMC Relocation Areas				
	Finegayan Base Complex	Navy Barrigada (USMC Only)	AF Barrigada	Remaining Navy Bases	AAFB
Average Daily Demand (mgd)	4.5	1.4	1.5	8.9	2.6
Maximum Daily Demand (mgd)	7.3	3.2	3.3	11.3	4.0

Note: The MDD for Navy Barrigada excludes the demand not related to USMC Relocation. These demands are included in the remaining Navy demands

AAFB Andersen AFB

Table 3-8: DoD Current Daily Demands for Water

	USMC Relocation Areas				
	Finegayan Base Complex	Navy Barrigada	AF Barrigada	Remaining Navy Bases	AAFB
Average Daily Demand (mgd)	0.1	1.0	None	7.3	2.2
Maximum Daily Demand (mgd)	0.2	1.0	None	9.8	3.5

AAFB Andersen AFB

3.2 EVALUATION OF EXISTING CONDITIONS/CAPACITY & PROJECTED FUTURE REQUIRED CAPACITY

3.2.1 Service Areas and Water Systems Overview

The existing water supply in Guam is comprised of the following three separate, but partially interconnected water systems:

- Navy Water System
- Andersen AFB Water System
- GWA Water System

The first two of the above systems are the DoD systems, while the GWA system is the primary source of water to the general public in Guam.

Navy Water System. The Navy system and service areas are Naval Computer and Telecommunications Station (NCTS) Finegayan, South Finegayan, Navy (NCTS) Barrigada, Nimitz Hill, Naval Hospital, Ordnance Annex, and the Apra Harbor Complex.

The NCTS Finegayan is situated on the northwest coast of Guam, about 9 miles north of the capital city of Hagatna, and occupies approximately 3,000 acres. NCTS Finegayan is bounded by the Andersen AFB to the north, Route 3 to the east, and the FAA parcel to the south. NCTS Finegayan includes residential units for family and unaccompanied personnel, community service facilities, administrative buildings, medical and dental clinics, support communication facilities, and mechanical shops.

South Finegayan is located on the northwest coast of Guam, approximately 8 miles northeast of Hagatna and occupies approximately 270 acres. South Finegayan is bounded by NCTS Finegayan to the north and the Philippine Sea to the west. The area comprises family housing, an unaccompanied personnel housing unit, and a youth center.

Navy Barrigada is located to the east central part of Guam, approximately 3 miles east of Hagatna and occupies approximately 1,850 acres. Navy Barrigada is bounded by the former Naval Air Station (NAS) Hagatna to the west, Mount Barrigada to the north and Andersen AFB Communication Annex to the south. Photos of the existing water system components are provided in Appendix C.4.

Nimitz Hill is located along the west central coast of Guam, approximately 1.5 miles south of Hagatna. It occupies about 95 acres and is bounded by Naval Hospital to the northeast and by Piti Village to the west. Naval Hospital is located northeast of Nimitz Hill along the west central coast of Guam, directly east of Hagatna. Facilities at Nimitz Hill include operations facilities, officers club, thrift shop, a federal fire station, and a high school. The main facility at Naval Hospital is a 57-bed hospital at Hagatna Heights. Other facilities include family and unaccompanied personnel housing, medical facilities, fire station, convenience stores, recreational facilities, utility plants, and a chapel.

The Apra Harbor Naval Base Complex is located on the west-central coast of Guam, approximately eight miles southwest of Hagatna. The site encompasses a land area of 4,500 acres and a harbor of 650 acres. The Ordnance Annex is located approximately 2.5 miles southeast of Apra Harbor Naval Base Complex and encompasses approximately 8,840 acres of land most of which is used as buffer land or as watershed for the Navy Reservoir. The Apra Harbor Naval Base Complex and additional Navy areas include Orote Peninsula, Guam Economic Development Authority, Camp Covington, both new and old Apra Heights Housing Areas, Tenjo Vista, Sasa Valley, and Dry Dock Island. The

Ordnance Annex has an ammunition wharf at Orote Peninsula with headquarters in the highlands above Apra Harbor Naval Base Complex along Route 5.

The existing Navy water system is an island-wide system extending from the Navy Reservoir in Southern Guam to NCTS Finegayan near the northern tip of Guam. Water for the system is primarily supplied from the Navy Water Treatment Plant (WTP). Water is distributed from the treatment plant to reservoirs designed to serve different service zones and transfer water to other Navy installations across the island. Most of the transmission mains from the reservoirs to the distribution systems are 24-inch pipelines. The Navy system is interconnected to supply water to GWA and for emergency service capability. The connection with the Andersen AFB system is out of service.

In most of the service areas, water is supplied either from onsite groundwater wells or through the NIW water system or by interconnection with the GWA. The NIW water system comprises three primary sources, which are located at the southern region of Guam: Almagosa Springs, Bona Springs, and the Navy Reservoir surface water impoundment. Water from the above three sources are treated at the Navy WTP and distributed through a network of reservoirs, transmission mains and booster pump stations. A brief description of the water supply sources in each of the Navy service areas is provided below.

- At NCTS Finegayan, water is primarily supplied by groundwater wells located on site and at South Finegayan. If necessary, water can also be supplied by interconnections with the GWA system or the Navy island-wide system. Groundwater wells are the primary source of potable water for this area.
- At the South Finegayan Housing area, water is primarily supplied by the groundwater wells on site and at NCTS Finegayan. If necessary, water can be supplied by interconnections with the GWA system or the Navy island-wide system.
- At Navy Barrigada, water is primarily supplied by groundwater wells. As a backup, the water storage system is connected to the Navy island-wide systems.
- At Naval Hospital, water can be provided from either the Navy island-wide water system or from onsite groundwater wells. Currently, two wells are operational and one well is inactive due to high chloride levels. The three wells had tested positive for total coliform and two wells had tested positive for E. coli (Engineering Concepts 2005). Improvements were recommended to improve disinfection of the well water.
- At Apra Harbor Naval Base Complex and other Navy areas south of the Piti Power Plant, potable water is supplied entirely by the Navy WTP.

Andersen AFB Water System. Andersen AFB is located in northern Guam and covers approximately 24.5 square miles. The base consists of two major areas and several smaller areas called annexes. The major areas collectively known as the “main base” are North Field containing the base’s active operations and Northwest Field (NWF) containing abandoned runways and landing fields. The annexes are scattered throughout northern Guam and contain base housing, communications services, and water and petroleum storage facilities. The annexes include the Marianas Bonins Command (MARBO) Annex (also known as Andersen South), the Harmon Annex, and AF Barrigada.

The Andersen AFB water system includes an off-base water supply, treatment, storage and transmission systems, and an on-base water distribution system. The off-base water supply and transmission system includes nine water production wells, two booster pump stations, three reservoirs, chlorination facilities, a fluoridation facility, and approximately 80,000 feet of water lines. The existing on-base water distribution system includes a pump station, three water storage tanks, and approximately 700,000 feet of water lines.

Water is currently supplied from wells located in the MARBO Annex, stored, disinfected and fluoridated, and then pumped to the main base. The 9 off-base production wells are located at Andersen South Annex and the Tumon area and draw water from the NGLA. Water is currently supplied to Andersen AFB from 7 of the 9 off-base water production wells. Andersen AFB plans on installing 10 wells with a total capacity of 3.3 mgd on the NW Field. To date, 5 of the wells have been installed and activated.

There are no known existing water supply facilities on AF Barrigada. It is assumed that the existing and planned Andersen AFB water system will serve Air Force water demands only.

GWA Water System. The GWA water system comprises three public water systems known as the Northern, Central, and Southern Public Water Systems, serving the respective areas of the island with some overlaps. The Northern and Central systems are designated as 'Large' and the Southern System is designated as 'Small.' A schematic of the GWA water system is provided in Figure 3-1.

The Northern Public Water System is the largest system serving all public areas in the north and central parts of the island south of Andersen AFB and serves an approximate population of 146,050. This system consists of 119 groundwater wells, 14 reservoirs (11 in use) and 10 booster pump stations (9 in use). It is the GWA Northern Public Water System that is of importance with respect to the USMC relocation due to its proximity to the relocation areas and since this system is primarily supplied by the same aquifer that serves the DoD systems.

The Central Public Water System consists of one spring, 8 reservoirs (5 in use) and 9 booster stations (6 in use). The main source of water for this system is the Navy Water System and water is purchased through 54 metered interconnections, of which 15 are reported to be inactive. Water from the Northern System can also be fed to the Central System in the areas of Mongmong-Toto-Maite, Sinjana, Hagatna Heights, Asan, and parts of Piti. Northern water can also be supplied to Apra Heights, Santa Rita, and Agat through water mains that run along Routes 17, 5, 12, and 2.

The Southern Public Water System supplying the southern and southeastern parts of the island consists of 2 groundwater wells, 4 springs, 14 reservoirs, 16 booster stations (14 in use), and the Ugum WTP.

3.2.2 Design Capacity of System Components for the USMC Relocation

3.2.2.1 Water Supply Sources

The water supply source will be designed to meet the military activity's quantity demands. Where there is inadequate storage between the source and the treatment plant or distribution system, the supply will provide maximum day domestic demand plus industrial use demand.

For supply wells, sufficient capacity will be included to meet the maximum day domestic demand plus industrial use demand, with the largest well out of service.

Figure 3-1: GWA Water System

Figure 3-1

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Figure 3-1

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Figure 3-1

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Figure 3-1

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Existing or planned rehabilitation water supplies in Finegayan and Navy Barrigada are listed in Table 3-9. There is no existing water supply at AF Barrigada. The Navy has nine active wells at Finegayan with a total capacity of 2.3 mgd, and two wells at Navy Barrigada that are currently out of service but are being rehabilitated by the Navy. Well NCTS #5 on Finegayan Base is currently down hard due to a collapsed well screen. The Navy plans to replace this well at a different location since the current location has rising chloride levels. Other Navy water supplies having a total capacity of 11 mgd are listed in Table 3-10. The Naval Hospital well rehabilitation and dredging of Fena Reservoir and/or rehabilitation of the Lost River cofferdam were included in the recommended alternative presented in the Guam Water Utility Study (Earth Tech 2008b). Water supply from the existing Navy wells can also be accessible by the Navy through the NIW system.

Table 3-9: DoD Water Supplies Current or Planned Rehabilitation in USMC Relocation Areas

	Capacity (gpm)	Planned (gpm)	Total (mgd)
Navy Wells on Finegayan	**1,480**	**100**	**2.3**
NCTS #5		100	
NCTS #6	125		
NCTS #7	235		
NCTS #9	200		
NCTS #10	180		
NCTS #11	180		
NCTS #12	180		
NCTS A	180		
NCTS B1	200		
Navy Wells on Barrigada	**0**	**300**	**0.43**
NCTS #3		100	
NCTS #8		200	

[a] There are no existing wells on AF Barrigada.

Table 3-10: Other Navy Water Supplies in Navy Island-Wide Water System

	Capacity (gpm)	Planned (gpm)	Total (mgd)
Navy S. Guam	**7,614**	**1,736**	**13.5**
Almagosa Spring	928		
Bona Spring	426		
Fena Reservoir	6,260		
Lost River/Fena Sediment Dredging		1,736	2.5
Naval Hospital Supply	**234**	**378**	**0.88**
NRMC #1	234		
NRMC #2 Rehabilitation		200	
NRMC #3 Rehabilitation		178	

The required future water supply for the DoD facilities is shown in Table 3-11 using the UFC requirements described in Section 3.1.1. It is assumed that the supply for Navy Barrigada will be met by the Finegayan water supply transported through the NIW water main. The supply required for AF Barrigada is 3.6 mgd for Alternative 3. The supply necessary for the Finegayan base to meet the demand at Finegayan base and Navy Barrigada is 11.1 mgd for Alternative 3. This supply does not address the demand from Navy industrial facilities on Navy Barrigada, which will be met through the NIW system. The 2.3 mgd from existing wells is included in the total supply for Finegayan, but not used to address the USMC relocation demand. The supply from the existing wells could partially address the 3.5 mgd additional supply required for Navy Bases through the NIW system. There is an excess 1.65 mgd supply at Andersen AFB, but it is assumed that additional programs may be planned for the AF bases which are not reflected in the current population estimate.

The USMC relocation-related required water supplies are 13.4 MG for the Finegayan Base Complex (including Navy Barrigada) and 3.6 MG for AF Barrigada. For existing bases, the required water supplies are 13.0 MG for the remaining Navy Bases (not including Navy Barrigada) and 6.5 mgd for Andersen AFB.

Table 3-11: Required Water Supply (mgd)

	USMC Relocation Areas				
	Finegayan Base Complex	Navy Barrigada (USMC Only)	AF Barrigada	Remaining Navy Bases	AAFB
Minimum Required (MDD+largest well)	7.9	3.2	3.6	11.3	4.8
GWA Allotment				4.0	
Total Supply Required (Sum Minimum Required and GWA Allotment)	**7.9**	**3.2**	**3.6**	**15.3**	**4.8**
Existing Supply	2.3		0.4	11.8	4.7
Additional Required	11.1		3.2	3.5	0.1
Additional Planned Capacity (Notes 2, 3, and 5)	11.1		3.2	1.2	1.7
Total Future Capacity	13.4		3.6	13.0	6.5

Note 1: The MDD for Navy Barrigada excludes the demand not related to USMC Relocation. These demands are included in the remaining Navy demands.
2: The MDD for Finegayan and Navy Barrigada are combined to estimate the water system capacities.
3. A "Largest Well" size is not included for the remaining Navy bases since the primary water source is Fena Reservoir.
4. The existing supply is not subtracted from the "Additional Required" for Finegayan since it required for other navy activities.
5. The future water supply for the USMC relocation does not include the supply from existing Navy wells on base. The supply from these wells will be used by the Navy through the Navy Island Wide system.

An estimate of the future available yield is presented in Table 3-12. Current and future well production estimates are summed for GWA and DoD. It is assumed that all DoD wells will be put in production at a rate which will supply the average daily demand to the water systems. It is assumed that the DoD wells will rarely supply water at full capacity. Based on the GWA WRMP, the GWA water supply does not include a controlling demand coefficient for maximum daily demand. Therefore, the full capacity of the GWA water supply wells is included in the estimate. GWA planned well capacities are based on a recent communication with the Navy which identified 29 proposed well locations. For the NGLA, the total future well production is 67 mgd. The total well production is subtracted from the 1991 sustainable yield estimates by sub-basin to estimate the available yield, 14 mgd. As shown in Table 3-12, the NGLA has adequate available yield to accommodate the full capacity of the current, planned, and required future supply to meet DoD demand for Cantonment Alternative 3. The estimated future available yield in the Yigo sub-basin is -8.2 mgd. No proposed DoD wells are located in this sub-basin due to this shortfall.

The accuracy of the available yield estimates is dependent on the accuracy of the well capacities and sustainable yield estimates. Well capacities were compiled from the various sources including DoD documents (e.g., UTS 2005), shapefiles of the sub-basin boundaries and well locations with capacity estimates from Water and Environmental Research Institute (WERI), and information in the GWA WRMP.

Sustainable yield is defined as the rate at which groundwater can be continuously withdrawn from an aquifer without impairing the quality or the quantity of the pumped water. In order to achieve the hypothetically available sustainable yield, the means of water withdrawal has to be optimized, which is usually not the case. Therefore, the full capacity of the aquifer is not available. Additionally, sustainable yield is not equal to recharge. In the case of the NGLA, leakage at the edges of the lens along the coastline must be taken into account.

There have been two published estimates of the NGLA: one by Camp Dresser & McKee Inc. (CDM) (CDM 1982), and one by Barrett Consulting with John Mink (cited herein as Barrett 1991). The CDM estimates were based on a steady-state condition and relied on conservative assumptions such that future development and groundwater management programs could be easily implemented. The CDM was the first to divide the aquifer into a series of six sub-basins and 47 management zones. The sub-basin division is based primarily on topographic expression of basement topography forming effective hydrological divides in the subsurface. Based on the position of the freshwater lens, the sub-basins can be either basal (freshwater lens floating on top of salt water), or para-basal (freshwater lens bottom in contact with basement rock, where the basement surface rises above the freshwater-saltwater interface). Management zones are a construct to optimally manage well fields within the basin.

The second estimate of sustainable yield was prepared by Barrett (1991), which revised the simulation to a transient system rather than steady-state. Barrett argued that the NGLA is best described as a transient system, as the majority of the recharge comes during the wet season and that transient conditions best represent seasonal variations in recharge. The revised estimate of using transient conditions increased sustainable yield to approximately 70 to 80 MGD. The majority of the Andersen and Agafa-Gumas sub-basins lie beneath existing DoD property (Andersen AFB and North West Field). Additionally, a significant portion of the Finegayan sub-basin lies below the Naval Communication Station property abutting the NW Field to the south. The yield estimates presented herein utilize the Barrett (1991) yield estimates as the basis for determining available yield (Dr. Jensen (WERI), pers. comm., October 1991). The management zones identified in the CDM study (1982) do not match the sub-basin boundaries which are based on the 1991 volcanic basement contours. As a result of this discrepancy, the study presented herein does not rely on the management zones as presented in the 1982 NGLA study by CDM. Additionally, the management zones from the 1982 NGLA study were used as a means of managing well fields. With the changes to the number and location of wells since the early 1980s, the 1982 zones appear to be outdated. Barrett (1991) argued that the increased estimate is supported by increased withdrawals in the past decade along with the relative stability of the basal portions of the aquifer, especially in heavily exploited Yigo and Finegayan sub-basins.

Table 3-12: Future Available Yield Estimate Based on Total Well Production (mgd)

Subbasin (MGD)	Agafa-Gumas	Agana	Andersen	Finegayan	Mangilao	Yigo	Total
Well Production							
GWA Current Wells		10.0	0.7	6.7	2.5	18.0	37.9
GWA Future Wells	2.6	3.5	1.3	1.3	1.2	7.0	16.9
DoD Future Average Daily Demand	3.7	2.7	2.0	0.7	1.4	1.3	11.8
Total Well Production	6.3	16.2	4.0	8.7	5.1	26.3	66.6
Yield							
1991 Sustainable Yield Estimate	12.0	20.5	9.8	11.6	6.6	20.0	80.5
Available Yield	5.7	4.3	5.8	2.9	1.5	-6.3	13.9

Table 3-12 includes the GWA current and planned water supply totaling 54.9 mgd which meets the anticipated demand from construction workers and induced population. Average daily demand estimates for GWA are shown in Table 3-13. GWA water supply capacity meets the average daily demand requirements, not the maximum daily demand, unlike the UFC requirements followed by DoD. The demand peaks in 2014 at 60 mgd. The estimated current water demand currently exceeds the current GWA water supply. GWA plans to expand the water system to exceed the estimated demand projection. However, it is recommended that GWA reduce leakage from the system to make more efficient use of the existing GWA well supply.

Table 3-13: GWA Water Demand Including Construction Workers and Induced Population

	Population Served by GWA Wells (North & Central)				Demand
Year	**Baseline**	**Construction Workers**	**Induced**	**Total**	**mgd**
2010	175,271	3,238	6,651	185,161	49.3
2011	177,589	8,202	16,538	202,328	52.5
2012	179,872	14,217	26,989	221,078	56.0
2013	182,121	17,834	31,646	231,601	58.0
2014	184,341	18,374	39,481	242,196	60.0
2015	186,533	12,140	29,809	228,482	57.4
2016	188,705	3,785	15,165	207,655	53.5
2017	190,854	0	10,462	201,317	52.3
2018	192,974	0	10,462	203,436	52.7
2019	195,062	0	10,639	205,701	53.1
Demand Assumptions					
Rate:		125	gpcd		
Industrial Demand North and Central Guam:		9.7	mgd		
UFW:		50%			

47.7 total active + planned wells mgd
16.3 amount to meet add in 2014 recommend additional supply plus actions to reduce water loss

3.2.2.2 Treatment Plant

The design capacity of treatment plants will meet the maximum day domestic demand plus industrial use demand assuming adequate equalizing storage following treatment. The treatment capacity requirements are shown in Table 3-14. The WTP capacity for AF Barrigada is 3.3 mgd. The Finegayan WTP capacity is 14 mgd . The WTP capacity includes the supply from the existing Navy wells in order to be consistent with the WTP sizing in the Guam Water Utility Study (Earth Tech 2008b), which included existing supply for use by the Navy through the NIW system.

Table 3-14: Water Treatment Capacity in USMC Relocation Areas (mgd)

	USMC Relocation Areas		
	Finegayan Base Complex	Navy Barrigada (USMC Only) [a]	AF Barrigada
Minimum Required (MDD)	7.3	3.2	3.3
Existing Treatment Capacity	0		0
Additional Required [b]	10.4		3.3
Additional Capacity to Treat Navy Wells	2.3		0.0
Future Planned Capacity	14.0		3.3
Total Future Capacity	14.0		3.3

[a] The values shown for Navy Barrigada do not include demands unrelated to the USMC relocation.
[b] The MDD for the Finegayan Base Complex and Navy Barrigada (USMC Only) are combined to estimate the water system capacities.

Groundwater extracted from the NGLA will be assumed to be under the influence of surface water and treated to meet drinking water standards; for planning, this scenario presents the maximum potential adverse effect. The primary treatments will be direct filtration and disinfection. The water from the NGLA is hard, but can be used without softening. There is a water softening plant on Finegayan Base, but the system is not always on line. GWA water is not softened. For this study, it is assumed the water will not be softened.

3.2.2.3 Transmission Mains

Where the distribution is pumped from storage, transmission mains will have capacities equal to the maximum-daily demand plus industrial use demand.

The NIW system will transport a portion of the water required to meet the demand at Navy Barrigada from the Finegayan Base Complex water supply. Given the age of the water mains in the Navy Island Wide System, it is assumed that the water mains will require replacement between the Finegayan Base Complex and a point on the existing main near AF Barrigada. An extension will be required between the existing water main and AF Barrigada.

3.2.2.4 Distribution System

The distribution system within the facility is not included in the conceptual design.

3.2.2.5 Storage Facilities

Reservoir capacity for the USMC relocation will be adequate to satisfy the total of the following requirements:

- Peak fire flow demand
- 50 percent of average daily consumption (domestic and industrial)
- Minimum working volume of 1 hour at average demand (domestic and industrial) for scheduling of treatment plant equipment and service pumps maintenance

The storage capacity for the facility is referenced from Section 2.3.5 of MIL HDBK 1005/7A and is based on Equation 3:

Equation 3

Storage = Peak Fire Flow Demand + 50% Average Daily Use + 1 hour of Average Daily Use (3)

In the above equation, the average daily use includes both domestic and industrial.

The minimum required storage capacity for the USMC relocation areas is shown in Table 3-15. It is assumed that all Navy existing reservoirs on Finegayan will be demolished. No storage facilities are currently present on AF Barrigada. New storage facilities will be required for Finegayan and AF Barrigada. An existing 3-million gallon (MG) concrete reinforced Navy reservoir can address the required storage requirements at Navy Barrigada. The reservoir is leaking. The extent of the damage is not known. It is assumed that the tank will require inspection and repair.

Table 3-15: Water Storage Capacity in USMC Relocation Areas (mgd)

	USMC Relocation Areas		
	Finegayan Base Complex [a]	**Navy Barrigada (USMC Only)**	**AF Barrigada**
Minimum Required	3.54	1.6	0.9
Existing Supply	0	3.0	0
Additional Required	3.54	0.0	0.9
Future Planned Capacity	3.6	0.0	1.0
Total Future Capacity	3.6	3.0	1.0

— not applicable
[a] It is assumed that all existing storage facilities on Finegayan will be demolished.

3.2.3 Regulatory Involvement for Water Systems Options

The regulatory requirements for the proposed water treatment options were discussed with the following regulatory agencies during the field investigations:

- Guam Environmental Protection Agency (GEPA)
- U.S. Environmental Protection Agency (EPA) Region 9
- GWA
- Department of Public Works
- Department of Parks and Recreation (Historic Preservation)
- Guam Division of Aquatic and Wildlife Resources
- Bureau of Statistics and Planning (Coastal Management)

A summary of the regulatory involvement is provided in the Guam Water Utility Study (Earth Tech 2008b). In June 2009, ATS met with representatives of GEPA and GWA. Minutes of these meetings are provided in Appendix C.3. Guam recently passed legislation that gives additional authority over water resources to Guam regulatory agencies. According to GEPA, well permits will not be reviewed by GEPA until GWA has approved the location of the wells. During the meeting with GWA, the GWA representative for water supply acknowledged the separate water supply wells for the DoD and expressed concern over placement of the DoD wells and sharing of the NGLA resource. At the time of the meeting, GWA had not considered placement of additional GWA wells to meet the requirements of the construction workers and induced population.

GEPA representatives also informed ATS that the groundwater under direct influence of surface water (GWUDI) determination for the NGLA has not been completed. GEPA assumes that all wells are GWUDI unless data is provided to show otherwise.

GEPA noted that the area of influence for a well is considered to be 1,000 feet. Wells should be separated by 2,000 feet, but GEPA will consider well specific data to allow closer spacing. Wells should also be 1,000 feet from possible contaminant sources such as sewers, but GEPA will consider closer spacing if the water is treated at a WTP.

During the June 2009 meeting, GEPA discussed permit approval for three wells on the Guam Airport which are located in the Yigo sub-basin. According to the available information on existing well capacity, the available yield for the Yigo sub-basin is negative (a shortfall) assuming either the 1982 or 1991 sustainable yield estimates. Based on this information and GEPA's emphasis on evaluating site specific information during the permit process, it appears that GEPA does not issue permits based strictly on either 1982 or 1991 sustainable yield estimates.

3.2.3.1 GEPA Permitting Requirements

A list of the well requirements for GEPA permitting is provided in Table 3-16 with information on due dates and regulatory response times. Additional permit requirements for system construction are provided in Table 3-17. The Navy and GEPA have established a liaison position staffed by a Navy service member who is the contact for all USMC relocation permitting inquiries going forward.

The permit required for drilling, exploratory drilling, pump testing and water quality testing is the "Application for Well Drilling Permit". (The GEPA "Test Boring Application" is only applicable for test boring, test pitting, percolation testing or simply, for geotechnical investigations only.) The well drilling permit application will be reviewed by GWA prior to submittal to GEPA. Once the exploratory wells are ready for development, detailed well construction plans that are approved and signed by the owner (DoD) are submitted for agency review. GEPA will review and approve the plans with comments to be incorporated with the final drawings. Response times are listed in Table 3-16. However, GEPA may require at least one month to review and approve permit applications. GEPA will conduct a site visit before issuance of permits. A notice to proceed will be issued by GEPA to proceed with the well development. No separate permit will be issued during this time.

After the wells are fully developed, the "Application for Well Operating Permit" will be filed with GEPA by the owner to run the wells. The well coordinates and elevations are surveyed after construction. Coordinates and elevations are not needed during the exploratory phase.

Table 3-16: Well Permitting Requirements for Water

Well	Submittal Requirements	Due Date	Response Time
Well drilling permit application	Submit complete application package to GEPA Administrator cc: Water Resources Program Manager	At least 15 days prior to drilling operations	Permit issuance within 15 days following complete submittal of well drilling permit application package
Application fee	Remit payment for application fee ($250 per well) by check or electronic transfer documents	Due with permit application	No GEPA action
Inspection of proposed site	GEPA must schedule the inspection of proposed site	At least 24 hrs prior to desired inspection date	Within 15 day review and approval period
Performance bond	Submit copy of performance bond for each well to Administrator cc: Water Resources Program	Due with permit application	No GEPA Action

Well	Submittal Requirements	Due Date	Response Time
Maximum pumping capacity - not to exceed pumping rates identified in Northern Guam Lens Study	Provide information on permit application	Due with permit application	GEPA comments / RFI within 1 week application submittal
Notification prior to drilling and after drilling complete	Submit written notification advising Administrator of anticipated drilling start and completion dates cc: Water Resources Program. Provide verbal and email notification to Water Resources program prior to initiating drilling and following completion of drilling work, installation of well casing, and installation of equipment or appurtenances in well. University of Guam Water & Energy Research Institute must be notified before well drilling takes place.	Written notification at least 2 weeks prior to anticipated drilling start date. Verbal and email notification 48 hours prior to and following completion of work	
Preliminary report	Submit preliminary report with drilling permit application to Administrator cc: Water Resource Program	Due with permit application	GEPA comments / RFI within 1 week application submittal

The following information is also required:
Physical / chemical analysis
- Well blow-off line
- if provided, slope downward and terminate at a point not subject to flooding

Secured facility
- provide perimeter fence and lockable gates or enclosed ventilated lockable well house

All weather access road proper drainage
- fine grade well site in such a manner to assure proper surface water drainage away from well

Drilling information
- drilling operation records
- well driller's log
- representative samples of rock materials penetrated during drilling
- results of pumping tests conducted
- map showing location of test site, pumped well, piezometers, recharge and impervious boundaries
- lithological cross-section of the pumping test site

Yield and drawdown report
- yield and drawdown report
- water samples, pump tests for each well and where well(s) are located less than 1,000 feet away from the new well
- yield and drawdown report during long-term and recovery tests simultaneously

Table 3-17: System Installation Permitting Requirements for Water

Requirement Description (What is it?)	Submittal Requirements	Due Date	GEPA Response Time
Siting approval Seek approval from GEPA notifying of intent to initiate construction of PWS or to increase capacity of existing PWS	Submit letter to Water Division providing • narrative project description, e.g. purpose, population served, estimated cost, raw source water data (surface water only) • location map • applicant responsible for setting up meeting to present proposed project (Groundwater - Water Resources Program, Surface Water - Safe Drinking Water Program)		Water Division approval within 2 weeks of Siting meeting with GEPA, EPA (if needed) and military staff, additional time may be needed to address issues

Requirement Description (What is it?)	Submittal Requirements	Due Date	GEPA Response Time
Construction design approval Seek approval to initiate construction	Submit 2 sets of plan documents (paper or electronic) of proposed construction to GEPA Administrator cc: Safe Drinking Water/Water Resource Program Managers. Plan documents will include: • engineering plans and specifications, i.e. schedule of materials and equipment, • proposed treatment process, and • permit application for well drilling (see well requirements sheet). A meeting and presentation will be required for 30% design submittal.	At 30-60-90% design completion prior to proceeding with next design stage and At 100% design completion prior to commencement of construction	Administrator signature of approval at 100% design stage. At 30-60-90%, Water Division written approval (i.e. approval of meeting proceedings) to proceed to next design stage within 30 days of construction design review meetings at 30%, and 15 days at each 60% and 90% designs.
Inspections during construction GEPA will inspect to verify that construction conforms with approved plans and specifications before system is put into operation.	GEPA may request specific documentation prior to an inspection that includes but is not limited to: procedure for proper disinfection and sanitation of the plumbing system and a timeline for these activities to take place, MSDSs, chemical product data, specifications of drinking water plumbing materials, etc.	Before system is put into operation.	Written inspection results due within 5 business days of inspection.
Operations approval Seek approval to place system into operation	Submit letter to GEPA Administrator cc: Safe Drinking Water Program Manager requesting approval and providing proposed operation date. Submittal requirements vary from system to system and are specified in the approved construction design. They can include but are not limited to: • equipment O&M manuals • as-built plans • manufacturer required operator training • SOPs • emergency shutdown and startup • treatment-specific SOPs • water quality testing results • hydrostatic testing results	At least 30 days prior to operating new or altered water system	GEPA shall provide operations approval or comments and request for more information within 2 weeks from receiving letter requesting operations approval.

3.3 WATER SYSTEM OPTIONS

3.3.1 Review of Technical Options

A summary of the options reviewed for the Guam Water Utility Study (Earth Tech 2008b) is provided in Table 3-18. ATS provided a detailed review of the following four options:

- **Option 1** – Optimize groundwater resource development within DoD property.
- **Option 2** – Determine the requirements for rehabilitation, treatment of well water, or replacement of existing wells not currently in production due to contamination, structural and/or mechanical problems.
- **Option 3** – Purchase water from GWA.
- **Option 8** – Desalination.

For EIS Cantonment Alternatives 1 and 2, ATS recommended development of groundwater resources (Option 1) as the primary source to serve the Finegayan Base. The supply from rehabilitated wells (Option 2) and purchase of water from GWA (Option 3) are not sufficient to meet USMC relocation water demand. Desalination (Option 8) is a viable means of meeting the USMC demand, but is significantly more costly and energy intensive. Implementation of this option is recommended if freshwater resources are insufficient to meet the combined DoD and GWA water demand. However, review of the available yield, indicates that the water supply from the NGLA is sufficient to meet the peak projected demand.

Cantonment Alternative 3 differs from the previously considered Cantonment Alternatives 1 and 2 in that a portion of the accompanied service members is housed on Navy Barrigada or AF Barrigada. It is assumed that the conclusions documented in the Guam Water Utility Study (Earth Tech 2008b) will be the same for Alternative 3. Therefore, this report will provide a detailed analysis of groundwater resource development as the primary source for Navy Barrigada and AF Barrigada.

Table 3-18: Summary of Option Evaluation for Water

Water System Alternative	Evaluation Considerations	Recommendation
Option 1 – Optimize Groundwater Resource Development within DoD Property	• Salt water intrusion/ Excessive aquifer draw down. • Managed fully by DoD/ Reliable and secure. • Integrated System with GWA. • Sustainable yield/ GWUDI considerations.	Detailed review. Included in DoD recommended alternative.
Option 2 – Determine the Requirements for Rehabilitation, Treatment of Well Water, or Replacement of Existing Wells	• Salt water intrusion/ Excessive aquifer draw down. • Reduced stress on aquifer from installation of new wells. • Managed fully by DoD/ Reliable and secure. • Integrated system with GWA. • Sustainable yield/ GWUDI considerations.	Detailed review. Included in DoD recommended alternative. Insufficient supply from rehabilitated wells to meet full demand from USMC Relocation.
Option 3 – Purchase Water from GWA	• New connections with DoD water systems. • Upgrading systems/ energy savings. • No excess supply available for DoD.	Detailed review. Included in DoD recommended alternative.
Option 4 – Sediment Dredging at Navy Reservoir	• Current storage capacity reduced due to sedimentation. • Need to dredge to sustain long-term supply • Managed fully by DoD.	Potentially viable. Additional analysis is necessary to fully evaluate.
Option 5 – Expand Naval Reservoir Storage Capacity by Raising Dam Crest	• Technical complexity of design and implementation • Relative advantages compared to other viable alternatives • Overall cost	Eliminated
Option 6 – Potable Water Reclamation through Effluent Reuse	• Negative connotations/ public perception. • Tied to wastewater study. • Relative advantages compared to other viable alternatives	Eliminated
Option 7 – Non-Potable Water Reclamation through Effluent Reuse	• Require separate distribution system. • Tied to Wastewater study. • Relative advantages compared to other viable alternatives	Eliminated
Option 8 – Desalination	• Construction of desalination plant/Effluent discharge. • High energy demands • Overall cost.	Detailed review. Viable if freshwater resources are not sufficiently abundant to meet demand
Option 9 – Develop a New Surface Water Source	• Complexity in identification, design and implementation • Relative advantages compared to other viable alternatives • Overall cost.	Reviewed in October 2008 letter report to meet DoD demand in southern Guam.

3.3.2 Long-term Options

This section provides a description of the water supply system components. The main components are the wells, WTP (assuming the NGLA will receive a GWUDI determination), distribution system, and storage. For Alternative 3, it is assumed that the water will be supplied from the Finegayan water system and wells installed on Navy Barrigada. Improvements to the Navy or Andersen AFB water systems are not considered, except to the extent the components will be used to support Alternative 3.

3.3.2.1 Water Resources

Well locations are identified on the Andersen AFB and Navy Barrigada to support Alternative 3. Wells were not located on AF Barrigada because there is no para-basal zone in the area and the Agana sub-basins can contain dirty limestone (containing clay) that limits production. Using the 1991 estimates of sustainable yield, sufficient groundwater is available within military reservation boundaries to meet the new required supply resulting from the transfer of USMC and other assets to Guam. Potential well locations are selected with consideration of the following constraints:

- Limiting well locations to DoD property;
- Limiting well production within sub-basins limited by the sustainable yield (1991) considering demands from GWA;
- Preferentially locating wells in para-basal zones to achieve higher yield with lower chloride levels, a lower number of wells and associated costs;
- Maintaining a 1,000-foot distance from the shoreline to avoid saltwater intrusion;
- Maintaining approximately a 800 to 1,000-foot distance from other supply wells;
- Locating wells outside of environmental Installation Restoration sites (e.g., landfills); and
- Locating wells away from areas used by Andersen AFB (e.g., airfields, munition storage).

Figure 3-2 presents the location of these constraints. The para-basal zone is shown in light-blue on Figure 3-2.The areas that are excluded from use due to Andersen AFB land use are underestimates, and do not include a buffer to account for the explosive arcs. Due to the spatial limitations, some proposed well locations are near or within residential zones where dry wells and sewer lines have been identified. Wells within a solvent plume in the eastern portion of the site is identified on Figure 3-2. The proposed wells are upgradient from the plume. On Navy Barrigada, the exact well locations may need to be adjusted in the design stage based on current communication site use in the eastern portion of the base (e.g., for underground utilities), but there are no specific restrictions on site use in this area. Additional constraints may alter the location of the wells including future DoD construction, underground utilities, biological habitat restrictions, historical/cultural resource restrictions and restrictions on noise/visual impacts during construction.

Well installation was not considered on Andersen South because wells in this area are in the Yigo sub-basin. Comparing the current well capacity in the Yigo sub-basin to the 1991 sustainable yield estimates, there is no available yield remaining in this sub-basin.

The para-basal zones are roughly drawn on Figure 3-2. It is assumed that the para-basal zone extends seaward to a point where the top of the impermeable volcanic basement underlies the limestone aquifer at a depth of approximately 40 meters below mean sea level (msl). A transitional para-basal/basal zone is assumed to exist in the area where the top of the impermeable volcanic basement underlies the limestone aquifer at depths between 40 and 60 meters below msl. These assumptions are based on existing GWA well locations described as para-basal or transitional that appear to meet these characteristics according to available volcanic basement contour maps.

The potential well locations and capacities are presented in Figure 3-3. Some considerations for the proposed locations include the following:

- A significant portion of the available potential high yield para-basal zone exists on or near the military reservation boundary.
- Wells located along the boundary are less secure. To compensate for this, the wells will have added security, be provided with pitless adaptors, and be located within a locked structure.
- If the para-basal zone yields less than the proposed well production, some of the wells may need to be relocated to the basal zone on DoD property, farther from the DoD boundary, and additional wells installed.
- Wells near the approach to runways may need to be frangible or flush mounted. Wells located near the main base will be constructed to minimize noise and visual impact.

Wells were sited on Andersen AFB along the para-basal zone avoiding the installation restoration sites and Andersen AFB facilities. Wells are placed in and near the main base housing in order to supply water from the Andersen sub-basin. This area may be subject to impacts from the sewer lines or dry wells. The water will be collected for disinfection at a central water treatment plant. All but three wells are outside of all Explosive Safety Quantity Distance (ESQD) arcs. Spacing between wells is approximately 1,000 ft.

Wells were sited on Navy Barrigada are placed along the para-basal zone avoiding existing Navy structures, including the communication towers on the eastern side of the base. The wells follow the existing roadways. Several GWA are located immediately to the northeast of the site. The GWA wells are approximately 1,000 ft from the nearest planned well and should not impact production from the planned wells.

Well production rates were assigned assuming up to 450 gpm for para-basal wells and 100–300 gpm for transitional wells. Based on these assumptions, a minimum of 31 additional wells will be needed to meet the required supply for Cantonment Alternative 3 (20 wells on Andersen AFB and 11 wells on Navy Barrigada including the required contingency wells). These limits are consistent with the recommendations for supply wells presented in the 1982 NGLA study (CDM 1982). (The sustainable yield estimates presented in the 1991 report (Barrett 1991) are included in this study for an assessment of well capacities by sub-basin. These values are an update to the analysis presented in the 1982 NGLA study. However, the 1982 study included recommendations on the installation of supply wells that were not updated in the 1991 report.) The Navy is currently implementing a study consisting of installing test wells on Andersen AFB and Barrigada to confirm the desired pumping capacities can be achieved.

If the well production rate is significantly lower than estimated from the para-basal zone on Andersen AFB and Finegayan Base Complex, the number of wells could approximately double (e.g., 48 wells in the Finegayan Base Complex water system). A notional figure assuming seven 450 gpm wells are replaced with 21 lower capacity wells is provided in Appendix C.2. A lower well capacity was assigned to the Navy Barrigada wells (200 mgd). The well capacity for these wells is not expected to vary significantly from this estimate. Production from existing Navy wells on Barrigada is consistent with the estimate.

Alternate well locations can be selected in areas of Andersen AFB and Navy Barrigada that are outside of the constraints shown on Figure 3-2 or other limitations to be specified by the base. Outside of the para-basal zone, a higher number of low capacity wells will be required to meet the required supply for the Finegayan water system. A figure showing the ESQD arcs on Andersen AFB is included in Appendix C.2. Three of the proposed well locations fall within the inhabited building distance (IBD) ESQD arc. Planned Andersen AFB wells are located within the IBD EQSD arc.

Table 3-19 presents the well capacity and sub-basin location for potential wells needed to meet new demands resulting from transfer of DoD assets to Guam.

Table 3-19. Proposed Well Details

Well Number	Proposed Capacity (gpm)	Sub-Basin
Located on AAFB	7,708 gpm (11.1 mgd)	
1	450	Agafa-Gumas
2	450	Andersen
3	150	Andersen
4	450	Agafa-Gumas
5	450	Agafa-Gumas
6	450	Agafa-Gumas
7	450	Agafa-Gumas
8	270	Finegayan
9	450	Agafa-Gumas
10	450	Andersen
11	450	Andersen
12	450	Agafa-Gumas
13	450	Andersen
14	450	Agafa-Gumas
15	288	Agafa-Gumas
16	150	Andersen
17	450	Andersen
18	450	Andersen
19	450	Agafa-Gumas
20	100	Agafa-Gumas
Located on Navy Barrigada	2,500 gpm (3.6 mgd)	
1	200	Mangilao
2	200	Mangilao
3	200	Mangilao
4	200	Mangilao
5	200	Mangilao
6	200	Agana
7	200	Agana
8	200	Agana
9	200	Agana
10	200	Agana
11	200	Agana
NCTS #3 *(existing)*	100	Agana
NCTS #8 *(existing)*	200	Agana

The existing two Navy wells on Navy Barrigada, which are being rehabilitated by the Navy, will also be included in the water supply for Alternative 3. The Navy wells on Finegayan are not included in the water supply allotted for the USMC relocation. These wells are periodically down because of high chloride levels, the presence of coliform, or structural problems.

Periodic monitoring of the aquifer following implementation of the water supply wells is recommended to optimize the system and adjust pumping rates if chloride levels are shown to be increasing. The monitoring program should be coordinated with GWA.

Proper operations and maintenance (O&M) of the supply wells is necessary so that the wells consistently meet the design capacity and achieve the design life span. Deterioration of the well system starts as soon as the well is constructed and generally occurs slowly. Given time, a critical point is reached and deterioration accelerates, resulting in substantially decreased yield, or worse yet, total failure. A description of well O&M requirements is provided in the Guam Water Utility Study (Earth Tech 2008b).

3.3.2.2 Water Treatment

Well water extracted from the wells will be collected and treated for water supply to the end user. Because the treatment system must include disinfection and filtration, it is more cost-effective to combine all well waters and treat the combined water in a central location. Two plants will be required for Alternative 3, one on Navy Barrigada and one on Andersen AFB. The plant on Navy Barrigada is designed for a peak treatment capacity of 3.3 mgd. The WTP on Andersen AFB is designed for a peak treatment capacity of 14 mgd. The treatment plant locations for Alternative 3 are shown on Figure 3-3.

The extracted groundwater in the area may be GWUDI. As such, the extracted groundwater will need to be disinfected and filtered. The WTPs are evaluated on the basis of the plant peak flow rates. Because the groundwater may be determined to be under the influence of surface water, the water treatment system must meet the EPA GWUDI requirements. This assumption allows planning for the scenario presenting the maximum potential adverse effect. The regulations require chlorination and filtration in the water treatment process. Turbidity will be addressed through direct filtration. During design, alternative technologies to address turbidity should be considered and compared to direct filtration based on cost and land requirements. Details of the treatment process are provided in Appendix C.2 for the Andersen AFB and Navy Barrigada WTPs with process diagrams and equipment layout.

3.3.2.3 Water Storage

For Navy Barrigada, it is assumed that the existing 3-MG Barrigada reservoir can be used to meet the 1.6-MG minimum required storage for Alternative 3. Some expense for inspection and repair to the leaking structure will be required.

For AF Barrigada, a 1-MG tank is planned to meet the 0.95-MG minimum required storage for both Alternative 3. There is no existing storage in this area.

For Finegayan, the minimum storage required is 3.54-MG for Alternative 3 (three 1-MG and one 0.6-MG tank).

The new storage for Alternative 3 is assumed to be elevated tanks. However, the Navy has expressed their preference for concrete ground level tanks instead. A comparison of the costs between elevated tanks and ground level tanks is provided in Section 3.3.2.5.

Figure 3-2: Constraints for Well Placement

Figure 3-3: Proposed Supply Wells and Water System

3.3.2.4 DISTRIBUTION SYSTEM

Pumps at each well station will pump water from the wells through raw water transmission mains to the central water treatment plant on Andersen AFB or Navy Barrigada. Water will flow through the water treatment plant to a clearwell (or ground storage reservoir) on the water treatment plant site. High lift pumping equipment will pump treated water from the clearwell into treated water transmission mains, which will bring water to the distribution system and to the water storage tanks.

For Alternative 3, the well supply from Navy Barrigada wells is sufficient to meet the demand at AF Barrigada. The water from these wells is transported from the WTP and reservoir on Navy Barrigada to AF Barrigada through the NIW (30-inch main) and a planned connection from the NIW to a planned reservoir on AF Barrigada (24-inch main). The cost includes replacement of the NIW water main in sections, which are planned for use in Alternative 3 since the water mains are over 50 years old and significant water loss is expected in these water lines from leakage. The 4.5 mgd minimum required water demand at Navy Barrigada from the USMC relocation is supplied through the NIW 24-inch water main from the Finegayan water system to the Navy Barrigada reservoir.

Pumping Stations. Each well station will include a submersible well pump. Each well pump will have an above ground discharge pipe, which will need to be protected. The discharge pipe will have an air/vacuum relief valve, check valve, surge relief valve, and a flow meter. No chemicals will be added at the well stations. The well houses will be constructed with decorative concrete block walls and wood truss supported roof with asphalt shingles. The final design for structures will meet Guam building codes for typhoon requirements. There will be one room at each well house.

Standby generators will be provided at 11 well houses on Andersen AFB and 5 well houses on Navy Barrigada to provide power to pump average day demands during power outages. The standby generators will be installed outside the well houses.

Raw Water Transmission Mains. The raw water transmission mains will convey water from the wells to the water treatment plant. The mains range from 8 to 30 inches in diameter, and are sized to provide velocities less than 6 fps to minimize friction head losses. There is a water interconnection from Andersen AFB wells on Northwest Field to the Marine Corps Base (MCB) WTP on Andersen AFB. Water mains are included to transport water from the existing Navy wells on the Finegayan Base Complex to the Andersen AFB WTP.

High Lift Pumping Equipment.A high lift pumping station will be constructed at the clearwell at the water treatment plant. The pump station will have equipment for pumping water from the clearwell to the distribution system. Pumps will be dedicated to the high level pressure zone and low level pressure zone at Finegayan Base Complex. Flow control valves will allow water to be diverted from the high level zone to the low level zone. Pump operation will be automatically controlled based on water levels in the water towers.

A high lift pumping station will be constructed at the clearwell at the Navy Barrigada WTP. The pump station will have equipment for pumping water to the pressure zone served by the existing Navy Barrigada ground storage tank. Pumps will operate based on water level in the existing Navy Barrigada ground storage tank.

AF Barrigada will receive water from the existing Barrigada ground storage tank. A 1-MG elevated storage tank will be constructed at AF Barrigada. It is assumed that a pump station will not be needed.

A standby generator will provide power to the high lift pumps during power outages.

Treated Water Transmission Mains. Two treated water transmission mains will convey water from the water treatment plant to storage. For Alternative 3, replacement NIW mains are planned. Distribution of treated water to users within the bases is not included in this plan.

Prior to constructing these additional mains, additional study and hydraulic modeling is needed to confirm the feasibility and operating conditions. Improvements to the Navy's water system can be implemented over time.

3.3.2.5 COSTS

The costs estimated for Alternative 3 are provided in Table 3-20. Costs are based on year 2008 dollars and escalated to the mid-point year of construction to permit immediate comparison with the costs presented in the Guam Water Utility Study (Earth Tech 2008b). Details of the cost estimate are provided in Appendix C.1. The present worth cost is $520 million (M).

Table 3-20: Cantonment Alternative 3 Life Cycle Costs for Water

Capital Costs	Cantonment Alternate 3 COST ($000)
1) Water Resources Development	$28,993
2) Water Treatment	$99,109
3) Distribution	$149,003
Total Construction Cost	$277,105
Contingencies (20%)	$55,421
Engineering (15%)	$41,566
Total Capital Cost	**$374,092**
Present Worth Guam Capital Costs	**$377,026**
1) Water Resources Development	$535
2) Water Treatment	$2,590
3) Distribution	$1,866
Total Annual O&M Cost	$4,992
Contingency (20%)	$998
Total Annual O&M Cost	**$5,990**
Present Worth of O&M Costs (25 year life)	**$142,951**
Present Worth of Total Costs	**$519,977**

The portion of non-USMC service members and dependents on Finegayan, Navy Barrigada, and AF Barrigada is not included in the population estimate, which is the basis for these utility studies. The USMC-only cost estimates will be based on the assumption that the non-USMC population is 10 percent of the total, consistent with the population estimates used for the Guam Water Utility Study (Earth Tech 2008b). USMC-only costs are provided in Table 3-21. The present worth cost is $459M .

Table 3-21: Cantonment Alternative 3 Life Cycle Costs for Water - USMC Only

Capital Costs	COST ($000)
1) Water Resources Development	$27,732
2) Water Treatment	$73,643
3) Distribution	$145,598

Capital Costs	COST ($000)
Total Construction Cost	$246,972
Contingencies (20%)	$49,394
Engineering (15%)	$37,046
Total Capital Cost	**$333,413**
Present Worth Guam Capital Costs	**$336,028**
1) Water Resources Development	$511
2) Water Treatment	$2,008
3) Distribution	$1,770
Total Annual O&M Cost	$4,288
Contingency (20%)	$858
Total Annual O&M Cost	**$5,146**
Present Worth of O&M Costs (25 year life)	**$122,801**
Present Worth of Total Costs	**$458,828**

If the water is not GWUDI, the costs without treatment at central WTPs are provided in Table 3-22. The present worth cost is $311M. The cost of water treatment is approximately 40 percent of the total life cycle costs.

Table 3-22: Cantonment Alternative 3 Life Cycle Costs for Water - No GWUDI

Capital Costs	COST ($000)
1) Water Resources Development	$28,993
2) Water Treatment	$0
3) Distribution	$149,003
Total Construction Cost	$177,996
Contingencies (20%)	$35,599
Engineering (15%)	$26,699
Total Capital Cost	**$240,295**
Present Worth Guam Capital Costs	**$242,180**
1) Water Resources Development	$535
2) Water Treatment	$0
3) Distribution	$1,866
Total Annual O&M Cost	$2,401
Contingency (20%)	$480
Total Annual O&M Cost	**$2,881**
Present Worth of O&M Costs (25 year life)	**$68,765**
Present Worth of Total Costs	**$310,944**

The cost estimates provided above assume that additional water storage will consist of elevated tanks. The capital cost of concrete ground level tanks is greater than the cost of elevated tanks, but O&M costs are less. Table 3-23 compares the cost of 5 mg of concrete reservoir and elevated tank storage. The capital cost of the concrete reservoir storage is $6.7M more than elevated tank storage. The O&M cost of the concrete reservoir storage is $19,000 less per year than elevated tank storage. Assuming concrete reservoir storage, costs will increase for pumping (including a high lift pump station at AF Barrigada) and for increased water main diameter for distribution through the NIW system south to Barrigada.

Table 3-23: Cost Comparison for Elevated Tanks and Ground Reservoirs

	Unit	Unit Rate	Qty	$000
Reinforce concrete reservoir - 2 MG	ea	$8,192,000	2	$16,384
Telemetry	ea	$51,200	2	$102
Site work	ea	$128,000	2	$256
Electrical service to site	ea	$12,800	2	$26
Reinforce concrete reservoir - 1 MG	ea	$4,096,000	1	$4,096
Telemetry	ea	$51,200	1	$51
Site work	ea	$128,000	1	$128
Electrical service to site	ea	$12,800	1	$13
Elevated Water Tower - 1 MG	ea	$2,764,800	5	$13,824
Telemetry	ea	$51,200	5	$256
Site work	ea	$51,200	5	$256
Electrical service to site	ea	$12,800	5	$64
Total Construction Cost Ground Reservoirs 5 MG				$21,056
Total Construction Cost Elevated Tanks 5 MG				$14,400
Difference				$6,656
Yearly O&M Concrete Reservoirs	ea	$10,000	1	$10
Yearly O&M Elevated Tanks	ea	$28,750	1	$29
Difference				-$19

ea each
qty quantity

3.3.2.6 *Preliminary Construction Schedule*

ATS anticipates that implementation of the recommended water system would require about 12 to 18 months to design, 5 to 6 months to bid and award, and 25 to 30 months to construct the water supply facilities. It is assumed that the regulatory agency permitting work will be done concurrently with the design. Therefore, the total time required is approximately 5 years.

The water system comprises several major components, including the wells and pumping stations, raw water transmission mains, water treatment plant(s), water storage tanks, treated water transmission mains, and the water distribution system. Scheduling and planning the water system improvements will be important so drinking water and fire protection water will be available when and where it is needed.

Prior to constructing any water system improvements, detailed water system master planning and hydraulic modeling will be necessary. Master planning and modeling will assure that the water improvements are in the right location and of the right size for the proposed developments.

The longest lead items will be the water treatment plant(s) and the wells.

Wells and Well Pumping Stations. General areas have been identified for the well sites. However, before the wells can be constructed, specific sites need to be identified and approved. Each site will need to be reviewed and evaluated for code requirements for separation distances from potential contamination sources. Each well will be designed for the geology at the site. GEPA will review and approve the well site and well specifications. The well will be bid, constructed, and tested. After the water quantity and quality are confirmed, the well pump station will be designed, reviewed by the GEPA, bid, and constructed.

Prior to placing the well on-line, a wellhead protection plan needs to be completed and approved by the GEPA.

It is anticipated that the time required from selection of the well site to placing the well in operation is approximately 2 years.

It will be important to develop an implementation plan for well site selection, design and construction to group wells for regulatory approval process for optimizing the overall schedule.

Raw Water Transmission Mains. The general locations of raw water transmission mains have been identified. However, the final locations of the mains cannot be determined until the well sites have been selected. Due to the number of water transmission mains already believed to be in existing road rights-of-way, careful selection of the final route is necessary. Topographic surveys (including field locating of existing utilities) will be needed before the water mains can be designed and constructed. The water main designs will need to be reviewed and approved by the GEPA before they can be constructed. The time to go from route selection to construction could be 3 years or longer.

Water Treatment Plants. The locations of the water treatment plants need to be finalized before final facility planning and design can proceed. Water quality has been estimated based on data from the many existing wells on the island. Final decisions will need to be made regarding the treatment processes to be used and the methods of procuring the treatment equipment need to be determined. GEPA will need to review and approve the treatment design before the plant can be constructed. The time to plan, design, bid and construct the water treatment plants is approximately 5 years.

Water Storage Tanks. Two types of water storage tanks are included. It is expected that the treated water storage tanks at the water treatment plants will be cast-in-place concrete tanks, constructed at or below grade. The schedule for design, regulatory approvals, bidding, and construction of the ground storage tanks would be approximately 2 years. The design of the ground storage tanks needs to be closely coordinated with the design of the adjacent water treatment plants because it is anticipated that water will flow by gravity from the water treatment plant into the reservoir.

The elevated tank site locations need to be coordinated with the design of the water distribution systems and the surrounding land uses and ground elevations. Approximately 2 years time is required to select the locations and style of tank, design, obtain regulatory approval, bid, and construct an elevated tank.

It will be important to prioritize the tank construction sequence with the areas that will develop first.

Transmission Mains. The locations of the transmission mains will need to be coordinated with the existing water transmission mains in the rights of way, and with the water tower locations. Implementation of the Treated Water Transmission Main could take up to 2 years.

3.3.2.7 SUMMARY OF INFORMATION TO SUPPORT THE EIS

The estimated size and coordinates of the primary water supply structures is provided in Appendix C.2. The locations were reviewed against the footprint of United States Geological Survey

(USGS) topographic maps and USGS showing significant features of the bases. Locations may need to be adjusted to conform to land use requirements of the bases and planned future use layout. With the exception of the waterlines, all water supply structures are located on DoD bases. Easements may need to be acquired for waterlines extending outside of the DoD property.

3.3.3 Interim Alternative

For potable water, no distinction is made between interim and long-term alternatives. It is assumed that 10 wells on Andersen AFB would be installed to meet the interim DoD demand with housing on the Finegayan Base Complex only. The water treatment plant would be designed with modular components, which will meet the interim demand, and then be expanded to meet full design capacity.

4. Wastewater Utility

The military buildup populations projected in the EIS for Guam that were used as a basis for this utility study are presented in Table 1-1 through Table 1-6. Certain assumptions were required regarding the housing locations for construction workers and increased civilian population of Guam in order to assess the impact on existing utilities operated by the GovGuam. The assumptions are footnoted in the population worksheets.

This study provides conceptual level planning for wastewater flow and treatment from the Navy and Air Force Barrigada area. This planning information identifies impacts to wastewater treatment and collection systems to facilitate assessment of impacts in the EIS.

4.1 Analysis of Wastewater Flows and Treatment Capacity Requirements

4.1.1 Basis of Wastewater Flows and Treatment Capacity Requirements Calculations

In order to identify wastewater treatment capacity requirements for USMC relocation, it is essential to determine the quantity and source of wastewater flow. Wastewater normally consists of domestic sanitary sewage and industrial wastewater. The sanitary sewage could be estimated by population and the industrial wastewater could be determined based on type of industry and its activities. This study addresses wastewater generated in Barrigada area of Guam for EIS Cantonment Alternative 3.

In EIS Cantonment Alternative 3, relocated USMC personnel will have a main base at Finegayan area in Northern Guam and an off-base housing area for family housing and associated base operations, educational facilities, and recreation and quality of life in DoD properties at Barrigada. Military personnel living at Barrigada area would commute to Finegayan main base for day activities. As a result, wastewater generated from USMC relocation activities at Barrigada is assumed to be sanitary sewage that can be estimated by number of USMC personnel.

Population growth related to the Barrigada housing alternatives for Marine relocation to Guam included accompanied military personnel, their dependents and on-base civilian workforce and off-base civilian workforce; construction workforce; induced population growth, and Guam local civilian natural growth in the region. Based on assumptions of the alternatives, only accompanied military personnel from both Marine and Army would be located at Barrigada, while unaccompanied personnel and transient personnel would be located at Finegayan main base. Based on the Traffic Analysis assumptions, the proposed family housing would equally split among Finegayan main base, Navy Barrigada and Air Force Barrigada. As a result, two thirds of accompanied military personnel, their dependents, and on-base civilians would live at Barrigada area. The USMC relocation related population increases in Barrigada DoD properties by 2019 are shown in Table 4-1.

Table 4-1: Proposed On-Base Population Distribution for USMC Relocation to Guam Alternative 3

Projected Related Population Category	Island-wide	Finegayan (NCTS+South)	Navy Barrigada	AF Barrigada
Alternative 3				
Active-Duty	9,182			
Transient	2,000			
Military personnel subtotal	11,182	8,659	1,262	1,261
Dependents	9,950	3,317	3,317	3,316
Civilian Work Force (on base)	1,836	612	612	612

According to the draft GJMMP, Army AMD housing will be located in AF Barrigada, with a total 342 units. The study assumed that a total of 342 Army personnel and 950 dependents will stay in AF Barrigada.

Barrigada area is located inside of central Guam wastewater basin defined by GWA in GWRMP. The off-base central Guam civilian population growths are considered for evaluating wastewater treatment options that utilize GWA treatment facilities.

Off-base population growths such as USMC relocation project construction workforce, USMC relocation project induced population, and Guam local civilian population are estimated only for central Guam region in this study. It is assumed that the Guam natural population growth, project induced population are evenly distributed on the island, one third in north, one third in central, and one third in south. Two thirds of the project related construction workforce will be located in the northern Guam area and the rest in the central Guam. The projected Barrigada on-base and off-base populations associated with the proposed military relocation project in Guam are presented in Table 1-3.

4.1.2 Wastewater Flows and Treatment Capacity Requirements Calculations

Domestic wastewater flow generated from Marine relocation was calculated per Unified Facilities Criteria UFC 3-240-02N, Wastewater Treatment Systems Augmenting Handbook, 16 January 2004. The following unit flow information is considered for the wastewater flow generation

120 gpcd for resident personnel
35 gpcd per for transient personnel

Marine relocation related population increase consists of accompanied military personnel, and their dependents. The on-base civilian workforce who live on the base were counted as resident personnel, while transient population included military personnel who come to the island for training and civilian personnel working in housing area but living outside were counted as non-resident personnel. Based on GJMMP, Marine relocation related military transient population were planned to use Finegayan Main base and will not contribute wastewater flow in Barrigada. As discussed earlier the Barrigada study area will not contribute industrial wastewater hence only domestic wastewater was considered for the analysis.

A unit value of 120 gpcd is considered for estimating wastewater flow generated by off-base non-military population that includes local Guam population, project related construction workforce and induced population.

4.1.3 Barrigada Projected Wastewater Flow Requirements

Total wastewater flow generated from Barrigada base is summary of current baseline flow and future Marine relocation generated flow.

The planned on-base housing will be located in Navy and Air Force Barrigada. The current wastewater flow from Navy Barrigada discharges to GWA sewer for treatment at Hagatna Wastewater Treatment Plant (WWTP). Currently there is no wastewater flow from Air Force Barrigada. There is no sewer flow data available for Navy Barrigada area. Neither Navy nor GWA has wastewater flow records. The water consumption data from May 2008 through May 2009 was provided by NAVFAC Marianas. As recommended by NAVFAC Marianas, our analysis considered 80 percent water consumption as wastewater flow. Based on this analysis the current wastewater flow from Navy Barrigada is 0.34 mgd.

Based on the wastewater flow data from March 2008 through March 2009, the current average flow at Hagatna WWTP is 4.72 mgd. Current and projected increased average daily wastewater flow in central Guam wastewater basin related to the Barrigada housing alternatives of Marine relocation to Guam was summarized in Table 4-2. As presented from the table, military flow is generated from the military activities in Navy Barrigada and AF Barrigada, while outside base civilian flow includes the flows generated from Guam population and its natural growth, and induced population due to military buildup in the region.

Table 4-2: Current and Future Average Wastewater Flow in Central Guam for USMC Relocation Alternative 3

Scenario	Service	DoD Active Duty	DoD Dependents	On-base Civilian	Total Population	Unit Flow (gpcpd)	Total Flow (mgd)
Baseline (Y2009)	**Outside-base Civilian**						**4.38**
	Military at Brrigada	-	-	-	-	-	**0.34**
	USMC	0	0	0	0	120	0.00
	Navy	-	-	-	-	-	0.34
	Army	0	0	0	0	120	0.00
	Total Central Guam Flow						**4.72**
Notional Increase (Y2019)	**Outside-base Civilian**				11967	120	**1.44**
	Guam Natural Growth				8421	120	1.01
	Induced Population				3546	120	0.43
	Military at Barrigada	2523	6633	1224	10380	120	**1.25**
	USMC	2181	5683	1058	8922	120	1.07
	Army	342	950	166	1458	120	0.17
	Total Central Guam Flow						**3.11**
Total Future Loading (Y2019)	**Outside-base Civilian**				**-**	**-**	**5.82**
	Guam Civilian Population				-	-	5.39
	Induced Population				3546	120	0.43
	Military at Barrigada	2523	6633	1224	-	-	**1.59**
	USMC	2181	5683	1058	8922	120	1.07
	Navy	-	-	-	-	-	034
	Army	342	950	166	1458	120	0.17
	Total Central Guam Flow						**7.40**

Notes:
1. No Navy, AF, Coast Guard, and Guam National Guard population increase in Barrigada area.
2. Assume Cantonment Alt. 3 and Alt. 8 with same population distribution in Barrigada.
3. Assume Army stays in AF Barrigada and army active duty with family # from GJMMP April 2008.
4. # of USMC and Army personnel and dependents in Barrigada obtained from Guam Traffic Analysis Data spreadsheet (01-28-09).
5. No industrial flow in Barrigada residential base.
6. Navy Barrigada existing flow (Y2009) estimated 80% of water demand data (total - irrigation) supplied by Jack Brown of NAFM.
7. Off-base civilian existing flow (2009) estimated by deducting DoD flow from Hagatna WWTP flow data provided in Julie Shane's email.
8. Off-base civilian future flow (Y2019) calculated by 30% island wide civilian natural population growth data from US Census Bureau, International Data Base (IBD), and 15 Dec 2008: http://www.census.gov/ipc/www/ibd/.
9. Current baseline year: 2009; Planning future year: 2019.

From the above Table 4-2, the projected 2019 average daily wastewater flow generated from DoD Barrigada properties is 1.59 mgd. The peak factor was calculated using Babbit's curve in Water

Pollution Control Federation Manual of Practice No. FD-5. The peak flow as presented in Table 4-3 from DoD Barrigada area in 2019 will be 4.97 mgd.

Table 4-3: Projected Y2019 Wastewater Flow Generated from DoD Barrigada Properties

Flows	Flow rate (mgd)
Average daily flow	1.59
Peak wet weather flow	4.97

From Table 4-2, the projected wastewater flow at the Hagatna WWTP by year 2019 from regional Guam natural population growth, USMC future expansion and associated induced population is 7.40 mgd. In this evaluation, it was assumed that the future combined civilian and military wastewater flow will have peak characteristics similar to the wastewater flow discharging to the existing Hagatna WWTP. Hence the same peaking factor of 1.75 was used in the evaluation. The wastewater flows to Hagatna WWTP in year 2019 are presented in the Table 4-4.

Table 4-4: Projected Wastewater Treatment Flow at Hagatna WWTP in 2019

Flows	Flow rate (mgd)
Average daily flow	7.40
Peak wet weather flow	12.95

4.2 EXISTING WASTEWATER SYSTEM FOR BARRIGADA AREA

Two of the four cantonments alternatives proposed for relocation of the USMC to Guam are included in Barrigada area in Central Guam. The proposed housing associated base operations, educational facilities, and recreation and quality of life facilities will be located in Navy and AF Barrigada areas.

Navy land (approximately 300 acres) at Barrigada is located east of Route 16, west of Route 15, and north of Route 8. The eastern portion of the property contains the electronic antenna farm for Naval Communications (NAVCOMM) emitters and receivers. The west portion includes Navy Fleet Hospital Facility, Guam National Guard Facility, and Navy Golf Course.

Air Force land (approximately 445 acres) at Barrigada is located south of Route 8, north of Route 15, and east of Route 10. It is currently used only for Air Force Next Generation Radar (NEXRAD) weather satellite receiver.

Currently, only Navy Barrigada has sewer service that conveys wastewater to GWA central sewer basin with treatment at GWA Hagatna WWTP at the coast of Hagatna, Guam. Air Force NEXRAD weather satellite receiver in Air Force Barrigada does not generate wastewater flow.

4.2.1 Existing Sewer System in Navy Barrigada

Current sewer collection system in Navy Barrigada is comprised of approximately 13,000 feet gravity sewer lines with size ranging from 6 to 8 inches in diameter. Most of the lines were built in the 1950s, 1960s and 1980s with vitrified clay pipes (VCP) and asbestos cement pipes (ACP). The collection system connects buildings of Fleet Hospital Facility, Guam National Guard Facility, and Navy Reserves Facilities at west part of the property, flowing from north down into an 8 inch sewer trunk along Route 8 at south. The sewer trunk, built in 1982, conveys wastewater in a southwest direction and connects to a GWA manhole just before the intersection of Route 8 and Route 16. Figure 4-1 shows the existing sewer system in Navy Barrigada.

In addition, isolated areas such as Navy Golf Course Clubhouse and NAVCOMM operation facility in the east of the property are served by septic tanks and leaching fields.

There are no generated sewer flow data available for Navy Barrigada area. Neither Navy nor GWA has measurements on this part of wastewater flow. Based on current water consumption (May 2008 – May 2009) provided by NAVFAC Marianas, and assuming 80 percent of water is converted to wastewater (per recommendation by NAVFAC Marianas), current wastewater flow from Navy Barrigada is estimated at 0.34 mgd.

4.2.2 Existing GWA Wastewater System Associated to Navy Barrigada Property

Navy Barrigada property is located inside GWA central wastewater basin and currently wastewater generated from the property is conveyed though the central GWA sewage system to GWA Hagatna WWTP for treatment and disposal to the Philippine Sea.

4.2.2.1 Existing GWA Sewer Line from Navy Barrigada to Hagatna WWTP

Wastewater generated from Navy Barrigada discharges into GWA central sewer basin system at intersection of Route 8 and Route 16. The trunk sewer runs along Route 16 toward the west, and then connects to trunk sewer that runs under Route 1 Marine Corps Drive flowing west to GWA Agana Main Sewer Pump Station (SPS).The main SPS pumps sewage to Hagatna WWTP for treatment. All the sewers from northeast under Marine Corps Drive for the area as far as west part of Tumon Bay, from southeast under Route 8 from Barrigada, from south under Route 4, and from west under Marine Corps Drive for Asan Piti area in the central Guam discharges to the Agana Main SPS.

The sewer trunk from Navy Barrigada to the treatment plant consists of sewer lines with diameter ranging from 8-inch to 38-inch of VCP, ACP, and polyvinyl chloride (PVC) pipes. Most of the trunks were built between 1975 and 1990; some were even built in 1950s. GWA does not have as-built sewer information available for this segment of the sewer trunk. There are no records available on flow rates or sewer conditions for this section of sewer line. Figure 4-2 shows the existing GWA sewer system.

4.2.2.2 Existing GWA Hagatna WWTP

Hagatna WWTP was built on a man-made island located in the west of Hagatna Bay and treats wastewater flows from all central Guam. It was commissioned in 1979 and has a designed capacity of 12 mgd average flow and 21 mgd peak flow for a primary treatment level. The plant was refurbished in 2007 in order to restore its operation by refurbishing or replacing its major unit processes and components with upgraded and more modern equipment and facilities.

The plant liquid process stream includes a flow division structure, and a Parshall flume followed by three rectangular primary clarifiers, and treated effluent discharged into Philippine Sea though a newly extended 1,200-foot ocean outlet. Its solid process stream consists of four square aerobic digesters and a centrifuge dewatering system with solid handling capability of 9,800 to 15,300 pounds per day, and dewatered solid is disposed of to a Guam sanitary landfill. The primary clarifiers remove suspended solids from the raw wastewater and aerobic digesters stabilize the solids removed by the primary clarifiers. The design criteria of Hagatna WWTP in GWRMP are provided in Table 4-5.

Table 4-5: Existing WWTP Design Summary

Item	Design Value
Influent Metering	
Type	Parshall Flume
Number	1
Primary Clarifiers	
Type	Rectangular
Number	3
Length (ft)	120
Width (ft)	34
Side water depth (ft) (shallowest)	11.6
Side water depth (ft) (deepest)	12
Surface area (ft^2)	4,080
Weir length (feet)	204
Total surface area (ft^2)	12,240
Total volume (ft^3)	122,400
Total design flow (mgd)	12
Design surface overflow rate (gpd/ft^2)	980
Design weir overflow rate (gpd/ft^2)	58,824
Primary sludge inline grinders	
Type	Inline Grinder
Number	4
Capacity (gpm)	80-500
Primary sludge cavity pumps	
Type	Progressive Cavity Pump
Number	4
Capacity (gpm)	100
Head (ft)	40
Scum pit scum removal pumps	
Type	Chopper Pumps
Number	2
Capacity (gpm)	200
Head (ft)	40
Pump gallery sump pumps	
Type	Submersible/Non-clog
Number	2
Capacity (gpm)	60
Head (ft)	20
Pump gallery booster pumps	
Type	Submersible/Non-clog
Number	2
Capacity (gpm)	60
Head (ft)	20
Aerobic Digester	
Type	Coated Concrete Square Tank
Number	4
Length (ft)	32
Width (ft)	32

Item	Design Value
Water depth (ft)	18
Active sludge waste depth (ft)	15
Total Active volume (ft^3)	61,440
Aerators	
Type	Low Speed Surface Aerator
Number	4
Output Speed (RPM)	37
Motor (HP)	40
Sludge Decant Tank	
Type	Coated Concrete Rectangular Tank
Number	1
Length (ft)	32
Width (ft)	9
Side water depth (ft)	11.5
Digester dewatering pumps	
Type	Torque Flow Pump
Number	2
Capacity (gpm)	700
Head (ft)	35
Centrifuge sludge Feed Pumps	
Type	Progressive Cavity Pump
Number	2
Capacity (gpm)	120
Head (ft)	150
Centrifuges	
Type	Centrifuge
Number	2
Capacity (gpm)	150
T Motor (HP)	60
Outfall to Philippine Sea	
Pipeline Size, each (inches)	30
Peak Hour Capacity	27 mgd
Length of the outfall from the shore	2,100 ft
Depth at which wastewater is discharged	150 ft

ft feet
ft^3 cubic foot
ft^3/min cubic feet per minute
gpd/ft^2 gallons per day per square foot
gpm gallons per minute
HP horse power
lb/day/ft^2 pounds per day per square foot
n/a not available
RPM revolutions per minute

Based on the discussion with GWA personnel during the field visit, the plant is in compliance with all requirements of current National Pollutant Discharge Elimination System (NPDES) discharge permit. However when treated effluent is over 6 mgd, there is potential for backflow occurrence during high tide period with existing gravity ocean outfall design. GWA personnel recommended an upgrade with an effluent pumping station for discharging treated flow.

The treated effluent discharge to the ocean is regulated under NPDES Permit No. GU0020087 issued June 30, 1986 with 301 (h) waiver that exempts the plant from full secondary treatment requirements. The NPDES permit requirements on effluent of Hagatna WWTP are listed in Table 4-6. The permit has not been renewed since it expired in 1991, and in January 2009 EPA

Region 9 tentatively denied a renewal of 301 (h) exemption and required Hagatna WWTP upgraded to secondary treatment. GovGuam is asking the EPA to delay its decision until GWA completes additional studies to test the performance capability of the newly installed outfall.

Table 4-6: Hagatna WWTP NPDES Permit Requirements

	Discharge Limitations				Monitoring Requirements	
	lb/day		Other Units (specify)			
Effluent Characteristic	Average Monthly	Daily Max	Average Monthly	Daily Max	Measurement Frequency	Sample type
Flow (mgd)	—	—	—	12	Continuous	—
BOD_5[a]	8,011	16,022	80 mg/L	160 mg/L	Once/week	Composite
Suspended Solids [a]	6,008	12,016	60 mg/L	120 mg/L	Once/week	Composite
Settleable Solids	—	—	1 ml/L	2 ml/L	Once/week	Discrete
Oil and Grease [b]	—	—	—	—	Once/month	Discrete
pH[c]	Not less than 7.0 standard units nor greater than 9.0 standard units				Once/month	Discrete

BOD biochemical oxygen demand
mg/L milligram per liter
ml/L milliliter per liter
[a] Both the influent and effluent shall be monitored.
[b] Oil and grease shall be monitored in the effluent on a monthly basis over a six-month period since toxic organic pollutants partition into this fraction. If the level of oil and grease is found to be unacceptable, this permit shall be modified to include an effluent limitation and monitoring requirement for this parameter.
[c] The discharge shall not cause the pH of the receiving water to deviate more than 0.5 pH units of that which would occur naturally.

4.2.2.3 GWA Moratorium Sewer Improvement Project

Central Guam sewer collection system that conveys sewage to Hagatna WWTP has several limitations, which, because the system are all interconnected, created overflows during high flow conditions. To alleviate the problems, GWA proposed a design build finance project, the Moratorium Project, to improve central Guam sewer system to allow it in its entirety and to operate satisfactorily. Besides upgrading, the project proposed to include:

- Blocking connection between northern and central sewage systems at Route 16 SPS;
- A new 24-inch force main from Tamuning SPS directly to Hagatna WWTP;
- A new 24-inch pressure line from New Chaot SPS directly down to Hagatna WWTP;
- Refurbishing Agana Main SPS to support the proposed modification to the sewerage system;
- A new vortex grit removal system in Hagatna WWTP for reducing sedimentation and FOG going to the plant.

Figure 4-1: Navy Sewer System

Figure 4-2: GWA Sewer System

Agana Main SPS would be refurbished to a design normal operation flow of 12 mgd and peak flow of 27.11 mgd. With proposed relief sewer lines from Tamuning and Chaot running directly to the treatment plant, Agana Main SPS would have an attenuated flow and improved pumping efficiency.

With the improvement project, a new vortex grit removal system at Hagatna WWTP and a new grit removal system at Tamuning SPS would be installed to provide preliminary treatment for all influent wastewater to the Hagatna WWTP. The project was expected to bid in September 2009 and scheduled to complete in 24 months.

4.3 EVALUATION OF WASTEWATER TREATMENT OPTIONS

Construction of Marine Corps and the Army AMD housing at DoD Barrigada properties would increase wastewater flows to the Hagatna WWTP. The wastewater flow from Barrigada is currently conveyed to the Hagatna WWTP in central Guam for treatment and disposal. Projected wastewater flows to the Hagatna WWTP as if military Barrigada wastewater still goes to the plant are summarized in Table 4-4.

As a result of the proposed military buildup, the average daily flow to the Hagatna WWTP from military sources is projected to increase to 1.59 mgd by year 2019 and the total flow from military and civilian sources would increase to 7.40 mgd by year 2019.

A socio-economic analysis of the proposed military build-up has estimated that induced civilian growth as a result of the military build-up could increase the island-wide population on Guam by up to 40,000 in year 2014. The total wastewater flow to Hagatna WWTP would reach its peak in year 2014 due to the construction workforce and induced population growth. Table 4-7 summarizes existing Guam civilian and DoD flows, projected increases in Guam civilian flows due to natural population growth, projected DoD increases associated with the military build-up, increases associated with the imported construction workforce, and civilian increases that would result from induced growth.

Table 4-7: Projected Interim Wastewater Flows to the Hagatna WWTP

	Year									
Source of Wastewater Flow	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Existing Guam Civilian	4.38	4.38	4.38	4.38	4.38	4.38	4.38	4.38	4.38	4.38
Existing DoD	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34
Guam Civilian Increase	0.19	0.29	0.38	0.48	0.57	0.66	0.75	0.84	0.92	1.01
DoD Increase	0.07	0.16	0.16	0.16	1.14	1.25	1.25	1.25	1.25	1.25
Construction Workforce	0.13	0.33	0.57	0.71	0.73	0.49	0.15	0.00	0.00	0.00
Subtotal Direct DoD and Guam Civilian	**5.12**	**5.50**	**5.83**	**6.07**	**7.17**	**7.11**	**6.87**	**6.81**	**6.89**	**6.98**
Induced Civilian Increase	0.27	0.66	1.08	1.27	1.58	1.19	0.61	0.42	0.42	0.43
Total Flow –all sources	**5.38**	**6.16**	**6.91**	**7.34**	**8.75**	**8.31**	**7.48**	**7.22**	**7.31**	**7.40**

Notes: all units are mgd

The total average daily flow in year 2019 and the interim peak average daily flow in year 2014 are less than the plant design capacity of 12 mgd. **The projected peak daily flow of 15.3 mgd in year 2014 and 13.0 mgd in year 2019 exceed the current EPA permitted maximum daily flow of 12 mgd for the plant based on the plant peak flow calculation using originally designed peak to average flow ratio. As a result, the existing permit limit is required to be modified to reflect the plant maximum daily treatment capacity of 21 mgd.**

Both interim and long-term wastewater treatment options are considered to meet the increased demand of the proposed military buildup in Barrigada area of central Guam. The interim options are developed to meet projected interim wastewater demands and long-term options are developed to meet the wastewater flows in year 2019.

4.3.1 Interim Option

Interim Option would refurbish and upgrade the primary treatment facilities of the Hagatna WWTP to accept the additional DoD and its buildup related flows. The existing NPDES permit of the Hagatna WWTP is based on maximum daily flow of 12 mgd. The projected average daily and peak daily flow to the WWTP during interim period will be 8.75 mgd and 15.3 mgd respectively. **The existing permit limit will require modification to reflect the plant maximum daily treatment capacity of 21 mgd.**

The GWA plant personnel indicated that during high tide periods the plant has backflow problem with its gravity ocean when treated effluent is over 6 mgd. In order to accommodate interim anticipated flow and loadings, the Hagatna WWTP would have to be refurbished and upgraded the following existing facilities:

- **Refurbishing existing effluent pumping station with new pumps**
- **Modifying sewer(s) based on the induced and construction population distribution in central Guam.**

Significant upgrades and improvements to the current condition of the plant and associated central Guam collection system are being performed. The interim option solution should be reevalauted at the time of impelementation as the plant and collection systeme being upgraded by the end of the year. **For incorportaing the interim option, the Navy would need to coordinate with GWA for modifying the NPDES permit to increase the effluent discharge limitation from 12.0 mgd to 21.0 mgd.**

4.3.2 Long-Term Options

Four long-term viable wastewater treatment conceptual options were reviewed:

1. Expand and upgrade existing primary treatment system at the GovGuam Hagatna WWTP to accept the additional flow and load
2. Expand and upgrade the GovGuam Hagatna WWTP to secondary treatment
3. Build new secondary treatment plant near the proposed development to DoD land and construct new outfall
4. Build new separate secondary treatment plant at GovGuam Hagatna WWTP site to treat DoD load only

4.3.2.1 Expand and Upgrade Existing Primary Treatment System at GovGuam Hagatna WWTP to Accept the Additional Flow and Load

As described in Section 4.2, the Hagatna WWTP is a major wastewater treatment facility in the central region on the island of Guam. Hagatna WWTP is a primary treatment facility with primary clarifiers mainly for removal of settleable organics and suspended solids. The plant has aerobic digesters and a sludge dewatering system for stabilizing primary sludge and reducing its volume before landfill disposal.

Primary treatment of wastewater removes a portion of the suspended solids and associated organic matter from wastewater by settling and skimming. A primary clarifier enhances solid liquid separation utilizing gravitational settling to remove suspended solids, and it normally removes 60 percent suspended solids as total suspended solids (TSS) and 30 percent organic matter presented as biochemical oxygen demand (BOD_5) from municipal wastewater.

The Hagatna WWTP is a primary treatment facility. It was designed for a treating an average daily flow of 12.0 mgd and a peak flow of 21.0 mgd. The projected 2019 wastewater flow to Hagatna WWTP due to Guam natural population growth, USMC future expansion and associated induced population growth is 7.4 mgd. In this evaluation, it was assumed that the future civilian and military wastewater flow will have characteristics similar to the wastewater flow discharging to the existing Hagatna WWTP. A new relief sewer from Navy Barrigada to the Hagatna WWTP needs to be constructed and the proposed sewer layout is shown on Figure 4-3. As a result, Hagatna WWTP influent flow and loading are presented in Table 4-8.

Table 4-8: Projected Hagatna WWTP Influent Flow and Loading in 2019

Flows	Flow rate (mgd)
Average daily flow	7.40
Peak wet weather flow	12.95

Parameters	Concentration (mg/L)	Loading (lbs/day)
BOD_5	184	18,400
Suspended solids	207	20,700

lbs pounds

The average daily and peak daily design capacity of Hagatna WWTP is 12.0 mgd and 21.0 mgd respectively. The projected Hagatna WWTP influent average flow of 7.40 mgd and peak daily flow of 12.95 mgd in 2019 are about 62 percent of the Hagatna WWTP's designed treatment capacity. The plant is not required to be expanded to meet the future flows. However, the projected 2019 peak daily flow of 12.95 mgd exceeds the current EPA permit flow of 12 mgd for the plant. Hence, the NPDES permit of the plant has to be updated.

Based on the existing plant process capacity that was evaluated in Section 4.2.2.2 and recommendations from GWA, in order to accommodate future anticipated flow and loadings while still achieving the existing effluent discharge requirement as presented in Table 4-6, the Hagatna WWTP will have to add the following new process facilities. The proposed facilities are shown on Figure 4-4:

- One effluent Ultraviolet disinfection system
- Refurbishing effluent pumping station

An ultra violet (UV) system was chosen for effluent disinfection because it does not require using chemicals and hence reduces O&M costs. The preliminary sizes of the Hagatna WWTP upgrade facilities are listed in Table 4-9.

Table 4-9: Major Components for Upgrading Existing Primary Treatment System at the Hagatna WWTP to Accept the Additional Flow and Load

Construction Components	NEW (N)/Refurbishing (R)	Unit	Dimensions/Description
UV disinfection system	N	1	30 ft long x 12 ft wide channels 56 ft long x 14 ft wide outlet weirs
Effluent pumping station	R	1	3 x 60 HP pumps

With the plant upgrades, primary treated flows into a new three channel UV system for disinfection, each 30 feet long, 2.5 feet wide, and 6 feet deep. At the end of channels, it has an outlet weir structure for serpentine weir control 56 feet long, 14 feet wide, and 6 feet deep. The UV disinfected effluent is then pumped by newly refurbished effluent pumps into a transmission line that leads to the 30-inch ocean outfall for final discharge.

4.3.2.2 Expand and Upgrade GovGuam Hagatna WWTP to Secondary Treatment

In addition to suspended solids removal by primary treatment, a wastewater treatment facility can utilize secondary treatment to enhance removal of biodegradable organic matter (in solution or suspension) and suspended solids. Secondary treatment normally refers to a biological treatment process that utilizes microorganisms to consume organic pollutants. It can be either a suspended growth activated sludge treatment or an aerobic attached growth treatment system (such as trickling filter).

During this study, the EPA tentatively indicated that secondary treatment will be required for the Hagatna WWTP. The national minimum secondary treatment requirements are presented in Table 4-10. In order to meet anticipated increased stringent EPA ocean outfall discharge requirements to Guam municipal wastewater treatment facilities, the existing primary treatment facility at the Hagatna WWTP needs to be upgraded to provide secondary treatment. The objective of this option is to expand and upgrade the existing primary treatment system at the Hagatna WWTP to secondary treatment, and to treat current wastewater flow, as well as additional flow from both civilian and military sources.

Figure 4-3: Long-Term Alternative Option 1 (Proposed Sewer Layout)

Figure 4-4: Long-Term Option 1 (Process Diagram for Upgrading the Primary Treatment at Hagatna WWTP)

Table 4-10: Minimum National Standards for Secondary Wastewater Treatment

Characteristic of discharge	Unit of measurement	Average 30-day concentration	Average 7-day concentration
BOD_5	mg/L	30	45
Suspended solids	mg/L	30	45
pH	pH	6.0 – 9.0	

By expanding and upgrading the existing primary system, the Hagatna WWTP can be converted to a new secondary treatment process as shown in the schematic process diagram on Figure 4-5. A trickling filter system was selected as the secondary treatment process not only because of its lower power requirement and less sludge production compared with a suspended growth system (such as Activated Sludge System) but also because of its simple and reliable operational nature. It is desirable to have a simple process to minimize future operation and maintenance requirements on the island of Guam.

The influent wastewater flows and loadings described in Table 4-8 of Section 4.3.2.1 also apply to this option. This option requires construction of a new relief sewer from Navy Barrigada to the Hagatna WWTP and its sewer layout is same as long-term Wastewater Option 1 shown on Figure 4-3.

The existing Hagatna WWTP is built on a man-made coral island and has limited space for future expansion. In order to utilize the available land at the plant more efficiently, chemicals will be added to existing primary clarifiers to enhance coagulation and flocculation process and improve precipitation to remove more solids and organic matter from the influent wastewater. It is proposed that 0.75 milligram per liter (mg/L) polymer and 20 mg/L Ferric Chloride will be added to the primary clarifiers and improve removal rate of BOD to 45 percent, and TSS to 80 percent. As a result, less solids and organic matter requires treatment by the new secondary process and hence less space required for the secondary treatment facility components. After preliminary and primary treatments, the primary effluent is pumped to the top of the three new circular trickling filters for secondary biological treatment. Trickling filter flow is conveyed into three new rectangular secondary clarifiers for solid liquid separation. Each circular trickling filter is 85-foot in diameter and 24-foot water depth. Each secondary clarifier is 220-foot long, 60-foot wide and 18-foot water depth. Clarified final effluent then flows into a UV disinfection system for treated flow disinfection. The UV disinfection system has three contact channels each with two UV banks. The UV system has an overall tee shape with one tee containing channels of 30-foot long, 12-foot wide and 6-foot depth and an outlet weir structure of 14-foot long, 56-foot wide and 6-foot depth. After all, the refurbished effluent pumping station pumps UV disinfected effluent through the plant 30-inch ocean outfall into to the Philippine for final disposal.

The secondary clarifiers generated humus sludge are collected and pumped back to the primary clarifiers for co-settling and producing a thicker settled sludge. The co-settled sludge of the primary clarifiers is then pumped by sludge transfer pumps to an aerobic digestion system for sludge stabilization. Aerobic digestion system includes four existing aerobic digesters with surface aerators and five new ones with air diffuser aeration. Air diffuser aeration is recommended for the new digesters due to its capability of operating in a deeper tank, and reduces total foot print of the structure. Each new digester is 44-foot long, 23-foot wide and 21-foot liquid depth, and blower room will be constructed on the top of the digesters to reduce foot print of the structure. Digested solids are pumped to the existing centrifuge dewatering system for volume reduction. Dewatered cake is then hauled out as Class B solids for offsite disposal.

The following new process components and upgrades are required at the Hagatna WWTP for this option:

- Three trickling filters
- Three rectangular secondary clarifiers
- One UV disinfection system
- Five new rectangular aerobic digesters
- Refurbishing effluent pumping station

The sizes of the new process components and upgrades required at the Hagatna WWTP for expanding and upgrading to secondary treatment are listed in Table 4-11.

Table 4-11: Components for Expanding and Upgrading the Hagatna WWTP to Secondary Treatment

Construction Components	Expand (E)/Upgrade (U)/NEW (N)	Unit	Dimensions/Description
Chemical enhanced precipitation system	N	1	Chemical storage tanks, dosing pumps and control
Trickling filter pumping station	N	1	40 ft long x 25 ft wide x 16 ft high
Trickling filter	N	3	85 ft diameter x 24 ft SWD
Secondary clarifier	N	3	220 ft long x 60 ft wide x 12 ft SWD
UV disinfection system	N	1	Three UV channels of 30' L x 12' W, one outlet weir structure 56' L x 14' W
Effluent pumping station	R	1	3 x 60 HP pumps
Aerobic digester	N	5	44 ft long x 18 ft wide x 21 ft SWD

4.3.2.3 Build New Secondary Treatment Plant near the Proposed Development on DoD Land and Construct New Outfall

This option considers construction of a secondary treatment plant that will be owned and operated by DoD for the relocated USMC, rather than upgrading the existing GWA owned treatment plants to secondary treatment. In this option, newly constructed independent sewer mains are required to convey all military generated wastewater in the Northern Guam region and Barrigada housing area to a DoD secondary treatment plant near the proposed USMC Finegayan development on DoD land (as shown on Figure 4-6). A new sewer main and two new pump stations carrying a total average daily wastewater flow of 1.59 mgd from Barrigada housing bases to the proposed new DoD treatment facility at South Finegayan is required to be constructed for this option. The proposed DoD treatment facility is designed to treat total of 3.08 mgd average daily flow generated from planned Finegayan main base (1.49 mgd) and Barrigada housings (1.59 mgd). The treated effluent from this secondary wastewater treatment plant will be discharged via a new DoD ocean outfall into Philippine Sea. The future peak flow for the DoD secondary plant is estimated to be 7.48 mgd and its peak factor is estimated based on the served population from Babbit's curve in Water Pollution Control Federation Manual of Practice No. FD-5. It is assumed that the future military wastewater flow will have characteristics similar to the wastewater flow discharging to the nearby North District WWTP. Future influent wastewater flow and its characteristics and loadings to the DoD secondary plant are presented in Table 4-12.

Figure 4-5: Long-Term Option 2 (Expanded Hagatna WWTP to Secondary Treatment)

Figure 4-6: Proposed Sewer Layout for DoD Secondary Treatment Option

Table 4-12: Projected Influent Flow and Loading in 2019 for DoD Secondary Wastewater Treatment on DoD Land

Flows	Flow rate (mgd)	
Average daily flow	3.08	
Peak wet weather flow	7.48	
Parameters	Concentration (mg/L)	Loading (lbs/day)
BOD_5	206	5,292
Suspended solids	202	5,189

The new DoD secondary wastewater treatment plant will consist of following components:

- Headworks (two screens and two aerated grit chambers with odor control)
- Three primary clarifiers
- Three trickling filters
- Three secondary clarifiers
- Two chlorine contact tanks
- Three anaerobic digesters
- Two centrifuge solids dewatering systems with odor control
- Effluent monitoring and measurement
- Ocean outfall

Figure 4-7 shows a process flow diagram of the new DoD secondary treatment. Preliminary treatment for this option includes bar racks and 3/8-inch to 1/2-inch mechanical fine screens at the headworks structure, followed by two aerated grit removal chambers. Each chamber has a 40-foot length and 12-foot width and 7-foot water depth. Grit and screenings removed are disposed of in a sanitary landfill.

Primary treatment includes three primary clarifiers, each 55-foot diameter and 10-foot water depth. Secondary treatment system includes three trickling filters and three secondary clarifiers. Each circular trickling filter is 60 feet in diameter and 24-foot water depth. Each secondary clarifier is 75 feet in diameter and 13-foot water depth. Subsequently a disinfection system with two chlorine contact tanks, each 50 feet long by 20 feet wide with water depth of 14 feet, provides chlorination and dechlorination to the secondary clarifier effluent, and its effluent flows into the 30-inch ocean outfall for final discharge at Philippine Sea, west of the plant. A new ocean outfall about 5,000 feet long 30-inch effluent transmission pipe and 2,400-foot long 30-inch outfall is required for the treated effluent disposal in this option.

Solids treatment for both primary sludge and secondary sludge includes three anaerobic digesters and two solids dewatering centrifuges for sludge digestion and dewatering. Each digester is 65 feet in diameter and 18-foot liquid depth. Two first stage anaerobic digesters are operated for stabilization, and one second stage anaerobic digester provides liquid solids separation and thickening. The digesters are designed for a hydraulic detention time over 15 days to meet EPA Class B standards, and will operate to handle planned future sludge loadings with one digester out of service for maintenance. Anaerobic digested sludge is then pumped to two centrifuges with a capacity of 125 gpm each for the solids dewatering to reduce the volume of final disposed sludge. Dewatered cake is hauled as Class B solids for offsite disposal.

4.3.2.4 BUILD NEW SECONDARY TREATMENT PLANT AT GOVGUAM HAGATNA WWTP SITE TO TREAT DOD LOAD ONLY

This option would build a new secondary treatment plant at the Hagatna WWTP site, and treat the DoD wastewater from the DoD Barrigada properties including proposed USMC housings. The existing Hagatna WWTP will be upgraded to have two separate and independent treatment process trains. The existing primary treatment will continue to treat flow from civilian population in Central Guam. The new process train consists of primary and secondary treatment, as well as UV disinfection, and solids treatment. The new treatment plant will have separate headworks, primary treatment, secondary treatment, UV disinfection, and sludge handling facilities to treat the load from DoD Barrigada properties. The new process train, including both liquid treatment and solids treatment, is a self-contained and complete secondary treatment system from the start to the end, and it will require jointly utilizing the existing Hagatna WWTP ocean outfall for its secondary treated effluent disposal. This alternative requires constructing a new independent sewer main to convey all military generated wastewater in the DoD Barrigada properties to the Hagatna WWTP site as shown on Figure 4-8. The independent sewer connects the proposed Barrigada housing collection system near Navy Barrigada main gate, runs west along the Route 8 then Route 16, and carries wastewater into the newly constructed secondary treatment plant located inside the Hagatna WWTP fence at Agana Bay. Projected wastewater flow from Barrigada area is presented in Table 4-3. The projected wastewater loadings are estimated based on 0.20 lb/cap/d of BOD and 0.23 lb/cap/d of TSS with the served population in WEF Manual of Practice 8 (MOP8). The projected influent wastewater flow and its characteristics and loadings to the DoD secondary plant at the Hagatna WWTP site are presented in Table 4-13.

Table 4-13: Projected Influent Flow and Loading in 2019 for DoD Secondary Wastewater Treatment at Hagatna WWTP site

Flows	Flow rate (mgd)	
Average daily flow	1.59	
Peak wet weather flow	4.97	
Parameters	Concentration (mg/L)	Loading (lbs/day)
BOD_5	200	2,652
Suspended solids	230	3,050

The new secondary wastewater treatment plant will consist of following components:

- Headworks (two screens and two aerated grit chambers with odor control)
- Three primary clarifiers
- Three trickling filters
- Three rectangular secondary clarifiers
- One UV disinfection system
- Three anaerobic digesters
- Two centrifuge solids dewatering systems with odor control
- Effluent monitoring and measurement

Figure 4-9 shows a process flow diagram of the new secondary treatment plant inside the Hagatna WWTP site. Preliminary treatment for this option includes bar racks and 3/8-inch to 1/2-inch mechanical fine screens at the headworks structure, followed by two vortex grit removal chambers.

Figure 4-7: Long-Term Option 3 (Building New DoD Secondary Treatment Facility on DoD Land)

Figure 4-8: Proposed Sewer Layout for Separate Secondary Treatment Plant at GovGuam Hagatna WWTP Site to Treat DoD Load Only

Figure 4-9: Option 4 (Build New DoD Secondary Treatment Facility at Hagatna WWTP Site to Treat DoD Load Only)

Grit and screenings removed are disposed of in a sanitary landfill. Primary treatment includes three rectangular primary clarifiers, each 60-foot long by 20-foot wide with 12-foot water depth. Chemical enhanced precipitation is incorporated into the primary settlement design to reduce the size of proposed subsequent secondary treatment process. It is proposed that 0.75 mg/L polymer and 20 mg/L Ferric Chloride will be added to the proposed primary clarifiers to improve removal rate of BOD to 45 percent, and TSS to 80 percent.

Secondary treatment system includes three trickling filters and three secondary clarifiers. Each circular trickling filter is 35-foot in diameter and 24-foot water depth. Each secondary clarifier is 100-foot long by 20-foot wide with 12-foot water depth. Subsequently a disinfection system with two UV channels, each 20 feet long by 2.5 feet wide with water depth of 3 feet, containing two banks of UV lamps provides disinfection to the secondary clarifier effluent, and its effluent flows into the Hagatna WWTP existing 30-inch ocean outfall for final discharge at Philippine Sea, west of the plant.

The secondary clarifiers generate humus sludge that are collected and pumped back to the primary clarifiers for co-settling and producing a thicker settled sludge. The co-settled sludge of the primary clarifiers is then pumped by sludge transfer pumps to an aerobic digestion system for sludge stabilization. The sludge digestion system includes two anaerobic digesters and two solids dewatering centrifuges for sludge digestion and dewatering. Each digester is 30-feet in diameter and 30-foot liquid depth. One anaerobic digester is operated for stabilization, and another provides liquid solids separation and thickening. When one digester is offline for cleaning, another digester operates for stabilization and liquid solids separation. The anaerobic digesters are designed for a hydraulic detention time over 15 days to meet EPA Class B standards. Anaerobic digested sludge is then pumped to two centrifuges with a capacity of 60 gpm each for the solids dewatering to reduce the volume of final disposed sludge. Dewatered cake is hauled as Class B solids for offsite disposal.

All the above described treatment facilities are sized for treating DoD load only. A summary of the major process components for a new secondary treatment plant at Hagatna WWTP site to treat DoD load only are listed in Table 4-14.

Table 4-14: Major Process Components for Building a New Secondary Treatment Plant at the Hagatna WWTP Site to Treat DoD Load Only

Construction Components	Unit	Dimensions/Description
Headwork	1	Two mechanical fine screens and Two (2) vortex grit chambers, each 14 ft long x 2 ft wide straight channel and 7 ft diameter chamber
Primary clarifier	3	60 ft long x 20 ft wide x 12 ft SWD
Trickling filter pumping station	1	25 ft long x 25 ft wide x 16 ft high
Trickling filter	3	35 ft diameter x 24 ft SWD
Secondary clarifier	3	100 ft long x 20 ft wide x 12 ft SWD
UV disinfection channel	2	20 ft long x 2.5 ft wide channel and 14 ft long x 12 ft wide weir
Effluent pumping station	1	3 x 60 HP pumps
Effluent measurement	1	Automatic sampler
Anaerobic digesters	2	30 ft diameter x 30 ft SWD
Solids dewatering centrifuges	2	60 gpm each

in inch

4.3.2.5 DESCRIPTION OF COLLECTION SYSTEM MODIFICATIONS

The existing sewer maps and topography maps were examined to convey wastewater from proposed facilities, identified in Section 4.2, to the Hagatna WWTP. Wastewater generated in Navy Barrigada discharges to GWA central sewer basin system at intersection of Route 8 and Route 16. First the sewer trunk is followed along Route 16 toward west, and then connected to trunk runs under Route 1 Marine Corps Drive flowing west to GWA Agana Main Sewer Pump Station (SPS). After that, the main SPS pumps wastewater to Hagatna WWTP for treatment. There is no sewer service to Air Force Barrigada. Based on our discussions with GWA, it was recognized that sewer records are not available for sewer from Barrigada to the Agana Main SPS. Some segments of the sewer were constructed with VCP and may be as old as 40 to 50 years. The sewer has not been surveyed and does not have flow meters either. As a result, a relief sewer is recommended in this study to collect wastewater generated from proposed USMC housing at both Navy and AF Barrigada and other military activities in the area, and convey to the proposed treatment facilities.

The recommended relief sewer is sized based on the following criteria:

- Minimum pipe size 8 inches
- At peak dry weather flow, maximum flow depth over diameter (d/D) is less than 0.8
- Minimum flow velocity 2.5 feet per second for gravity sewer pipe
- Maximum flow velocity is 5 feet per second for force mains
- Pipe diameter determined using Manning’s pipe friction formula
- Coefficient of roughness “n” equal to 0.013

It is sized to carry projected flow at DoD Barrigada properties that is described in Table 4-3. Following natural grade, sewage generated in Navy Barrigada is drained towards south and finally collected at southwest corner of the property near the exiting base gate. Sewage generated from proposed AF Barrigada housing area is drained down towards north and finally intersect Navy Barrigada sewer trunk near Navy Barrigada base gate.

Option 1, 2 and 4 require the almost same set of collection system modifications, and Option 3 require another set of collection system modifications. Option 1, 2 and 4 propose carrying the wastewater generated from the DoD Barrigada properties to the Hagatna WWTP site for treatment, while Option 3 requires conveying the wastewater to the proposed new secondary treatment facility located within DoD land at the southeast corner of the proposed USMC Finegayan main base.

Construct a New Relief Sewer to Accommodate USMC Relocation Wastewater Flow Generated from Barrigada Area to the Hagatna WWTP. As discussed in the previous sections, proposed Option 1 and 2 would treat all wastewater flows generated within the central Guam wastewater basin including both civilian flow and proposed USMC housing at Barrigada. The total projected wastewater will be treated by either primary process as proposed in Option 1 or secondary process as proposed in Option 2. The DoD wastewater flows generated in Barrigada area will be conveyed through a new gravity relief sewer from Navy Barrigada gate first along Route 8 and then along Route 16 west all the way down to the GWA Agana main SPS.

As shown on Figure 4-3, the proposed relief sewer consisting of 15,300-foot 18-inch sewer, 1,500-foot 21-inch sewer, and 6,900-foot 24-inch sewer will be required to convey flow from the Barrigada area to the GWA Agana main SPS. The relief sewer is sized with average flow and peak daily flow provided in Table 4-3.

Construct a New Separate Sewer for All Military Activities in Barrigada Area to DoD Secondary Treatment Facility Inside DoD Land. In this option, a newly constructed DoD-owned wastewater facility located at the southwest corner of the USMC Finegayan area requires the DoD to construct its own independent sewage interceptor to collect wastewater generated from proposed USMC housing at Barrigada area. The interceptor will connect proposed Barrigada housing collection system at proposed sewage pumping station at Navy Barrigada gate. The proposed pump station will have three 125 HP dry pit pumps, two duty and one standby. Wastewater will be pumped north up to Route 16 to the west of Barrigada Hill and then run down along Route 16 north until intersecting Route 3. Another new proposed SPS has three 75 HP pumps—two duty and one standby—that pump wastewater northeast to the new proposed DoD treatment plant at south Finegayan.

As shown on Figure 4-6, the proposed sewer consisting of 18,710-foot 18-inch force main, 3,650-foot 15-inch gravity sewer, and 4,700-foot 24-inch gravity sewer will be required to convey flow from the Barrigada area to the new proposed DoD plant at south Finegayan. The sewer is designed to have capacity for conveying 5 mgd flow as indicated in Table 4-3.

This option will also require construction of 5,000 feet of 30-inch effluent transmission line and 2,400 feet of 30-inch outfall to discharge effluent to the Philippine Sea.

Construct a New Separate Sewer for All Military Activities in Barrigada Area to Secondary Treatment Facility at the Hagatna WWTP Site to Treat DoD Load Only. In Option 4, a DoD constructed secondary wastewater facility is proposed at the Hagatna WWTP site to treat Barrigada DoD load only. The sewer layout is similar to the one for Option 1 and 2 except a proposed sewage pumping station by the Marine Drive in front of the Hagatna WWTP to pump wastewater flow to the proposed DoD secondary treatment plant (as shown on Figure 4-9). The proposed new sewage pump station has three 25 HP pumps, two on duty and one on standby. The sewer is designed to have capacity for conveying 5 mgd flow as indicated in Table 4-3.

As shown on Figure 4-8, the proposed relief sewer consisting of 3,500-foot 18-inch force main, 15,300-foot 18-inch sewer, and 6,900-foot 24-inch sewer will be required to convey flow from the Barrigada area to the proposed DoD secondary treatment tactility at the Hagatna WWTP site.

4.3.3 Preliminary Opinion of Probable Construction Cost

A summary of the preliminary opinion of probable construction cost (the construction cost estimate) is outlined in this section. The quantities shown are estimates based on descriptions in this study and vendor proposals. The estimates are intended to be as comprehensive as possible at the study stage where much of the work is still at a conceptual level.

The quantities for all work items shall be reviewed and updated during the Detailed Design. A project level allowance of 35 percent is added to the estimated construction cost for project services to establish the total estimated project cost. Project services include the following:

- Environmental Impact Report/Other Documents
- Design Engineering
- Construction Engineering and Contract Administration
- General and Administrative Expenses
- Contingencies

The current construction cost estimate is based on July 2008 prices (ENR_{LA} = 9,335). A summary of the preliminary construction cost for each option is shown in Appendix D.1. A detailed construction cost allocation among the GWA, the USMC and other project related partners is presented in Table

4-15. The cost allocation is determined based on the flow contribution from the GWA, USMC, and other DoD units.

Table 4-15: Capital Cost Allocations between USMC and Other Project Related Partners

Cost Allocation	Option 1: Expand & Upgrade Hagatna WWTP Primary Treatment	Option 2: Expand & Upgrade Hagatna WWTP to Secondary Treatment	Option 3: DoD Secondary Treatment on DoD Land	Option 4: Separate Secondary Treatment at Hagatna WWTP Site to Treat DoD Load Only
GWA	$5,033,000	$49,034,000	—	—
USMC Housing	$10,706,000	$28,043,000	$82,147,000	$44,312,000
USMC Main Base	—	—	$50,636,000	—
Other DoD Units	$5,056,000	$13,242,000	$29,201,000	$20,925,000
Total Cost	**$20,795,000**			

As shown in Table 4-15 **Capital Cost Allocation**, shown above, Option 1, which expands and upgrades the existing primary treatment system at the Hagatna WWTP to accept the additional flow and load, has the lowest construction cost. Among the three secondary treatment options, the preliminary construction cost for Option 4, which treats DoD load only, is the lowest construction cost, while Option 3, which treats USMC loads from both proposed Finegayan Main Base and Barrigada housing area, has highest estimated construction cost. The high capital cost of Option 3 includes proposed sewer line and pumping stations to convey USMC generated wastewater from its Barrigada housing to the proposed DoD treatment facility at south Finegayan. If only comparing the capital costs, then treating only USMC Barrigada housing generated wastewater (i.e., Option 2, expand and upgrade the Hagatna WWTP to secondary treatment) is the lowest among three secondary options.

An estimate of the O&M costs for viable options has been developed and a detailed cost spreadsheet is provided in Appendix D.1. The assumptions and criteria that form the basis for this estimate are presented below:

- Staffing of two expansion and upgrade options (Options 1 and 2) at the Hagatna WWTP would be by the GWA.
- Staffing of two expansion and upgrade options (Options 1 and 2) at the Hagatna WWTP will be similar (in terms of shift and time of day coverage by operators and sharing of maintenance with other facilities) to the current staffing at the existing Hagatna WWTP.
- Staffing of DoD operating option (Option 3) would be by the DoD.
- Staffing of treating DoD load only option (Option 4) at the Hagatna WWTP site will be negotiated between the GWA and DoD, but assumed similar (in terms of shift and time of day coverage by operators and sharing of maintenance with other facilities) to the DoD operating option (Option 3) for conservative estimation.
- Staff labor of manager at $75,000 per year including fringe benefits, operator/mechanic at $45,000 per year including fringe benefits, and administrative assistant at $30,000 per year including fringe benefits.
- Flow based on projected future value of 7.4 mgd for two expansion and upgrade options (Options 1 and 2) at the Hagatna WWTP.
- Flow based on projected future value of 3.08 mgd for Option 3 USMC loads at both proposed Finegayan and Barrigada areas only.

- Flow based on projected future value of 1.59 mgd for Option 4 DoD Barrigada load only.
- Power cost based on $0.20 per kilowatt hour.
- Polymer cost based on $3.00 per pound.
- Sodium hypochlorite cost based on $0.85 per gallon.
- Citric acid cost based on $6.50 per gallon.
- Ferric Chloride cost based on $14.0 per gallon.
- General repair and maintenance based on $0.15 percent of estimated construction costs.
- Sewer line maintenance based on 0.15 per foot.
- Solids hauling and disposal based on $25 per cubic yard (cy) processing/land application fee and $285 per 20 cy truck trip for transportation.

The above viable options will require a life cycle comparison for a recommended selection. An annual 4 percent interest was used to compare 20-year net present worth for each option. Table 4-16 presents an outline of annual costs for each option. Revenues from sewer connection fee and sale of reuse water are not included in the annual costs analysis.

In addition, the study also provided a separate O&M cost estimate showing distribution of O&M costs between the DoD and the GWA for Option 1 and Option 2. The costs are distributed in proportion to the flow contribution to the Hagatna WWTP, which is 1.59 mgd of 7.4 mgd for the DoD and 5.81 mgd of 7.4 mgd for the GWA. Table 4-17 and Table 4-18 present total O&M cost and respective cost distribution to the GWA and the DoD for Option 1 and Option 2.

Table 4-16: Life Cycle Cost Comparison of Wastewater Treatment Options

Item	Description	Option 1: Expand & Upgrade Hagatna WWTP Primary Treatment	Option 2: Expand & Upgrade Hagatna WWTP to Secondary Treatment	Option 3: DoD Secondary Treatment on DoD Land	Option 4: Separate Secondary Treatment at Hagatna WWTP Site to Treat DoD Load Only
A.	**Estimated Capital Cost**				
1	Headworks	—	—	$3,458,000	$2,812,000
2	Primary Clarifiers	—	—	$6,098,000	$4,465,000
3	Chemical Enhanced Settlement System	—	$323,000	—	$118,000
4	Pumping Stations	—	$2,025,000	$1,687,000	$1,404,000
5	Trickling Filters	—	$14,793,000	$8,380,000	$4,014,000
6	Secondary Clarifiers	—	$22,079,000	$10,458,000	$5,459,000
7	Effluent Pump Station	$3,992,000	$2,856,000	$2,729,000	$925,000
8	Disinfection System	$470,000	$488,000	$2,788,000	$585,000
9	Sludge Digesters	—	$10,002,000	$23,247,000	$4,287,000
10	Sludge Thickening & Dewatering System	—	—	$10,518,000	$10,093,000
11	Influent & Effluent Samplers	—	—	$159,000	—
12	Site Work & Utilities	$285,000	$3,680,000	$4,671,000	$2,392,000
13	Sewer System	$10,657,000	$10,657,000	$35,998,000	$11,770,000
14	Effluent Transmission Line	—	—	$2,788,000	—
15	Ocean Out Fall & Piping	—	—	$7,009,000	—
16	Project Services	**$5,391,000**	**$23,416,000**	**$41,020,000**	**$16,913,000**
	TOTAL	**$20,795,000$**	**$90,319,000$**	**$161,008,000$**	**$65,237,000$**

Item	Description	Option 1: Expand & Upgrade Hagatna WWTP Primary Treatment	Option 2: Expand & Upgrade Hagatna WWTP to Secondary Treatment	Option 3: DoD Secondary Treatment on DoD Land	Option 4: Separate Secondary Treatment at Hagatna WWTP Site to Treat DoD Load Only
B.	**Estimated Annual O&M Cost**				
1	Labor & Benefits	$45,000	$135,000	$465,000	$375,000
2	Chemicals	$144,000	$975,000	$51,000	$37,000
3	Collection	$4,000	$4,000	$8,000	$3,000
4	Contract Services	$280,000	$598,000	$227,000	$155,000
5	Maintenance	$53,000	$200,000	$251,000	$251,000
6	Utilities	$81,000	$810,000	$394,000	$174,000
	TOTAL	**$607,000**	**$2,722,000**	**$1,396,000**	**$995,000**
C.	**Annual Costs**				
1	Amortized Capital Cost	$1,530,000	$6,646,000	$11,847,000	$4,800,000
2	Estimated Annual O&M Cost	$607,000	$2,722,000	$1,396,000	$995,000
	TOTAL	**$2,137,000**	**$9,368,000**	**$13,243,000**	**$5,795,000**

Table 4-17: Annual O&M Cost and Cost Distribution between GWA and DoD for Option 1 – Expand and Upgrade Existing Primary Treatment System at the GovGuam Hagatna WWTP to Accept the Additional Flow and Load

Cost Categories	Quantity	O& M Cost	GWA's O&M Cost Share	DoD's O&M Cost Share
Labor & Benefits	LS	$45,000	$35,000	$10,000
Chemicals	LS	$144,000	$113,000	$31,000
Collection	LS	$4,000	—	$4,000
Contract Services	LS	$280,000	$220,000	$60,000
Maintenance	LS	$53,000	$42,000	$11,000
Utilities	LS	$81,000	$64,000	$17,000
Total Annual Operation Cost		**$607,000**	**$474,000**	**$133,000**

Table 4-18: Annual O&M Cost and Cost Distribution between GWA and DoD for Option 2 – Expand and Upgrade the GovGuam Hagatna WWTP to Secondary Treatment

Cost Categories	Quantity	O& M Cost	GWA's O&M Cost Share	DoD's O&M Cost Share
Labor & Benefits	LS	$135,000	$106,000	$29,000
Chemicals	LS	$975,000	$766,000	$209,000
Collection	LS	$4,000	$0	$4,000
Contract Services	LS	$598,000	$470,000	$128,000
Maintenance	LS	$200,000	$157,000	$43,000
Utilities	LS	$810,000	$636,000	$174,000
Total Annual Operation Cost		**$2,722,000**	**$2,135,000**	**$587,000**

4.3.4 Preliminary Construction Schedule

It is anticipated that for Option 1, upgrading existing primary treatment would require about 6 to 10 months to design, 1 to 2 months to bid and award, and 12 to 18 months to construct the wastewater collection and treatment facilities. We assumed that the wastewater treatment regulatory agency permitting work will be done concurrently with the design. **Therefore, a total time required is 2.0 to 3.0 years**.

For Option 2, constructing secondary treatment and upgrading existing primary treatment would require about 12 to 18 months to design, 5 to 6 months to bid and award, and 25 to 30 months to construct the wastewater collection and treatment facilities. We assumed that the wastewater treatment regulatory agency permitting work will be done concurrently with the design. **Therefore, a total time required is 3.5 to 4.5 years**.

For Option 3 and 4, constructing secondary treatment plant at DoD land or GovGuam Hagatna WWTP site would require about 18 to 24 months to design, 5 to 6 months to bid and award, and 30 to 36 months to construct the wastewater collection and treatment facilities. We assumed that the wastewater treatment regulatory agency permitting work will be done concurrently with the design. **Therefore, a total time required is 4.0 to 5.5 years**.

4.4 RECOMMENDED WASTEWATER TREATMENT OPTION

Based on the cost analysis discussed in Section 4.3.3, the total present capital costs and annual life cycle costs of the four viable options are presented in Table 4-19.

Table 4-19: Cost Summary of Viable Options for Wastewater

Option:	Option 1: Expand & Upgrade Hagatna WWTP Primary Treatment	Option 2: Expand & Upgrade Hagatna WWTP to Secondary Treatment	Option 3: DoD Secondary Treatment on DoD Land	Option 4: Separate Secondary Treatment at Hagatna WWTP Site to Treat DoD Load Only
Capital Costs				
Total Capital Cost	$20,795,000	$90,319,000	$161,008,000	$65,237,000
Amortized Capital Cost	$1,530,000	$6,646,000	$11,847,000	$4,800,000
O&M Costs				
Total Annual Cost	$607,000	$2,722,000	$1,396,000	$995,000
Annual Life Cycle Costs	$2,137,000	$9,368,000	$13,243,000	$5,795,000
USMC Barrigada Housing Related Treatment Capital Cost	*$10,706,000*	*$28,043,000*	*$82,147,000*	*$44,312,000*

Both the annual life cycle cost of $2,137,000, including amortized construction cost and estimated annual O&M cost, and total construction cost of $20,795,000 for Option 1 – *Expand and upgrade existing primary treatment system at GovGuam Hagatna WWTP to accept the additional flow and load*, are the lowest compared to other three options. The USMC's capital cost share ($10,706,000) based on wastewater flow contribution is also the lowest for Option 1**. However, we recommend a secondary treatment option because the EPA Region 9 indicated that the increased discharge from DoD activities on the island Guam would have an impact on the existing NPDES permit requirements, water quality standards, and NPDES requirements for current and any future effluent discharge would be based on EPA secondary treatment technology based requirements.** Among the three secondary treatment options, Option 4 – *Build new separate secondary treatment plant at GovGuam Hagatna WWTP site to treat DoD load only* has lowest capital cost ($65,237,000) and annual life cycle cost ($5,795,000). However, based on capital cost allocations, Option 2 – *Expand and upgrade the GovGuam Hagatna WWTP to secondary treatment* is beneficial to Navy as USMC share will be lowest at $28,043,000 in all three of proposed secondary treatment options. The proposed upgrades in Option 2 could be implemented in phased construction. With refurbishing existing effluent pumping station and building a new UV disinfection system in the Hagatna WWTP, the plant is able to handle additional wastewater generated from the construction workforce and the proposed project induced population in central Guam area during the interim period for primary treatment. After the remaining proposed upgrades are complete, the Hagatna WWTP could treat proposed future flow from both civilian population and Barrigada military activities with secondary biological treatment to fulfill EPA requirements.

4.4.1 Description of Recommended Option

In this option, Hagatna WWTP facility will be expanded and upgraded to secondary treatment plant. The secondary treatment train will include facilities to enhance removal of biodegradable organic matters (in solution or suspension) and suspended solids found in wastewater. Figure 4-10 shows the schematic process diagram of the recommended option. The following new process components and expansion are required at the Hagatna WWTP site for this option:

The following new process components and upgrades are required at the Hagatna WWTP for this option:

- Three trickling filters
- Three rectangular secondary clarifiers
- One UV disinfection system
- Five new rectangular aerobic digesters
- Refurbishing effluent pumping station

The sizes of the new process components and upgrades required at the Hagatna WWTP for expanding and upgrading to secondary treatment are listed in Table 4-20.

Table 4-20: Components for Recommended Option - Expanding and Upgrading the Hagatna WWTP to Secondary Treatment

Construction Components	Expand (E)/Upgrade (U)/NEW (N)	Unit	Dimensions/Description
Chemical enhanced precipitation system	N	1	Chemical storage tanks, dosing pumps and control
Trickling filter pumping station	N	1	40 ft long x 25 ft wide x 16 ft high
Trickling filter	N	3	85 ft diameter x 24 ft SWD
Secondary clarifier	N	3	220 ft long x 60 ft wide x 12 ft SWD
UV disinfection system	N	1	Three UV channels of 30' L x 12' W, one outlet weir structure 56' L x 14' W
Effluent pumping station	R	1	3 x 60 HP pumps
Aerobic digester	N	5	44 ft long x 18 ft wide x 21 ft SWD

4.4.2 Description of Collection System Modifications

Recommended option (Option 2) would treat all wastewater flows generated within the central Guam wastewater basin including both civilian flow and proposed USMC housing in Barrigada at the Hagatna WWTP. The DoD wastewater flows generated in Barrigada area will be conveyed through a new gravity relief sewer from Navy Barrigada gate first along Route 8 and then along Route 16 west all the way down to the GWA Agana main SPS. The relief sewer is sized with average flow of 1.59 mgd and peak daily flow of 4.97 mgd.

As shown on Figure 4-3, the proposed relief sewer consisting of 15,300 foot 18-inch sewer, 1,500-foot 21-inch sewer, and 6,900-foot 24-inch sewer will be required to convey flow from the Barrigada area to the GWA Agana main SPS. The normal process of acquiring a sewer easement is required where necessary. The U.S. Government and Government of Japan shall determine who is responsible for obtaining the easements.

4.4.3 Preliminary Construction Cost

The estimated project cost for expanding and upgrading the Hagatna WWTP to secondary treatment is $90,319,000. A summary of preliminary project cost for the recommended option is shown in Table 4-21.

Table 4-21: Preliminary Construction Cost for Recommended Option– Expanding and Upgrading the Hagatna WWTP to Secondary Treatment

Construction Categories	Cost Opinion
Chemical Enhanced Settlement System	$323,000
Pumping Stations	$2,025,000
Trickling Filters	$14,793,000
Secondary Clarifiers	$22,079,000
Effluent Pump Station	$2,856,000
Disinfection System	$488,000
Sludge Digester Expansion	$10,002,000
Site Work & Utilities	$3,680,000
Sewer System	$10,657,000
TREATMENT SUBTOTAL COST	$56,247,000
SEWER SUBTOTAL COST	$10,657,000
TOTAL COST	$66,904,000
PROJECT SERVICES	$23,416,000
TOTAL ESTIMATED COST	
TOTAL ESTIMATED PROJECT COST (ROUNDED)	**$90,300,000**
TOTAL ESTIMATED PROJECT COST FOR USMC	**$28,043,000**

4.4.4 Preliminary Construction Schedule

It is anticipated that for Option 2, constructing secondary treatment and upgrading existing primary treatment would require about 12 to 18 months to design, 5 to 6 months to bid and award, and 25 to 30 months to construct the wastewater collection and treatment facilities. We assumed that the wastewater treatment regulatory agency permitting work will be done concurrently with the design. **Therefore, a total time required is 3.5 to 4.5 years**. The schedule may be compressed by 6 months to 1 year if “design build” or “fast track” construction methodologies are used.

Figure 4-10: Recommended Option: Expand and Upgrade Hagatna WWTP to Secondary Treatment

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Wastewater Supplementary Analysis Letter Report

October 2009

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Naval Facilities Engineering Command, Pacific
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Pearl Harbor, HI 96860-3134

NAVFAC
Naval Facilities Engineering Command
NAVFAC PACIFIC

Contract Number N62742-06-D-1870/CTO 7

Wastewater Supplementary Analysis Letter Report

October 2009

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ACRONYMS AND ABBREVIATIONS

AFB	Air Force Base
BMD	Ballistic Missile Defense (now referred to as the Air and Missile Defense Task Force)
CVN	carrier vessel nuclear
DoD	Department of Defense
EIS	environmental impact statement
DEIS	Draft Environmental Impact Statement
GIMDP	Guam Integrated Military Development Plan
GWA	Guam Waterworks Authority
JGMMP	Joint Guam Military Master Plan
NDWWTP	Northern District Wastewater Treatment Plant
OEIS	Overseas Environmental Impact Statement
UFC	Unified Facilities Criteria
USMC	United States Marine Corps
WWTP	wastewater treatment plant

1. Purpose

This letter report discusses the wastewater utility differences between the data presented in the *Guam Wastewater Utility Study Report for Proposed U.S. Marine Corps Relocation* (NAVFAC Pacific 2008), and the draft *Guam and CNMI Military Relocation Environmental Impact Statement/Overseas Environmental Impact Statement* (DEIS/OEIS) (NAVFAC Pacific 2009a) to determine whether the conclusions made in the original wastewater utility study (*Guam Wastewater Utility Study Report for Proposed U.S. Marine Corps Relocation*, July 2008, Revision 1 [NAVFAC Pacific 2008]) are still valid for the DEIS. The analysis and recommendations presented in the wastewater study are based on population data that did not include the construction workforce or induced civilian growth. The analysis and recommendations presented in the DEIS being prepared for a November 2009 issue are based on data in the wastewater study, revised Guam Waterworks Association (GWA) baseline wastewater flows, and modified data presented in the DEIS for the additional demands from the population data presented in Volume 1, Table 2.1-2 of the DEIS.

This letter report also discusses validity of wastewater treatment alternatives discussed in *Barrigada Utility Study to Support USMC Off-Base Housing Facilities Requirements*, September 2009 (NAVFAC Pacific 2009b) and *Guam Wastewater Utility Study Report for Proposed U.S. Marine Corps Relocation*, July 2008, Revision 1 (NAVFAC Pacific 2008) and proposes a collective project-specific and long-term programmatic alternative to address wastewater flows from proposed Department of Defense (DoD) facilities in Barrigada and the northern Guam area at the Northern District Wastewater Treatment Plant (NDWWTP). The analysis and recommendations provided in this report are based on February 2009 population data.

Thus, this letter report will do the following:

- Revise the estimated wastewater demand increases for the current population forecasts
- Revise the wastewater demand totals to reflect new current demand data provided by GWA
- Explain why DEIS recommendations may differ from the recommendations in the two utility studies (NAVPAC Pacific 2008, 2009b)

2. Revised Wastewater Demand Increases and Totals

The *Joint Guam Military Master Plan* (JGMMP) (NAVFAC Pacific 2009c), formerly the *Guam Integrated Military Development Plan* (GIMDP) (NAVFAC Pacific 2006), identifies a planned increase in military population and activity on Guam. The environmental impact statement (EIS) prepared for this action presents several EIS cantonment alternatives for the United States Marine Corps (USMC). The JGMMP identified a planned increase in the military population on Guam. Naval Computer and Telecommunications Station Finegayan, South Finegayan Housing Area, Andersen Air Force Base (AFB), Andersen AFB Northwest Field, and Andersen AFB South provide potential locations for most of the planned USMC relocation to Guam as proposed Cantonment Alternatives 1 and 2. Sewage from these locations is currently conveyed to the NDWWTP for treatment and disposal. The NDWWTP is owned and operated by GWA.

Potential sites for EIS Cantonment Alternatives 3 and 8 include DoD land at Barrigada, Guam—specifically, Navy Barrigada and Air Force Barrigada. Sewage from these locations is currently conveyed to the Guam Hagatna Wastewater Treatment Plant (WWTP) for treatment and disposal. The Hagatna WWTP is owned by GWA.

The proposed military buildup on Guam would increase the demand on existing wastewater utilities. To assist with utilities planning to support the proposed military relocation, the Navy conducted the following two wastewater utility studies:

- *Guam Wastewater Utility Study Report for Proposed U.S. Marine Corps Relocation*, July 2008, Revision 1 (NAVFAC Pacific 2008)
- *Barrigada Utility Study Report to Support USMC Off-Base Housing Facilities Requirements*, September 2009 (NAVFAC Pacific 2009b)

The utility studies sought to: (1) quantify the increased DoD demand that would result from the military buildup and (2) develop utility solutions to meet those projected demands. The population that the utility studies were based on is summarized in the individual wastewater studies. However, in general, the studies accounted for projected increases in DoD personnel and increases in the on-base civilian workforce required to support the military buildup but did not consider the construction workforce or induced and normal civilian growth.

A socioeconomic analysis performed in support of the DEIS projected that in addition to direct increases in DoD personnel, the on-base civilian workforce, and a temporary construction workforce, the proposed military buildup would likely induce civilian population growth. The population loadings developed by the socioeconomics team and assumed for analysis in the DEIS are summarized in Volume 1, Table 2.1-2. The population loading assumptions for direct DoD personnel, the on-base civilian workforce, and the construction workforce vary somewhat from what was assumed in the original utility reports. Specifically, the following differences are noted:

- Personnel by service changed (fewer permanent Air Force and Navy personnel)
- Transient personnel not previously identified were added (Navy personnel and Marines)
- Slight increase in the construction workforce numbers
- A large induced civilian growth

A qualitative assessment of the population changes determined that increases in the Marine transient personnel would be offset by reductions in the number of permanent Air Force and Navy personnel. All Navy transient personnel would be housed on ships, and these ships would not require hotel services during the interim period (i.e., would not initially contribute to demands on public utilities). Considering these additions and reductions, a determination was made that the on-base demand for the population described in Volume 1, Table 2.1-2, of the DEIS would not be significantly different from the demand calculated in the original utility study (*Guam Wastewater Utility Study Report for Proposed U.S. Marine Corps Relocation*, July 2008, Revision 1) and that the general conclusions and recommendations made in the original utility study would still be valid for the current population being considered in the DEIS.

The utility study (*Guam Wastewater Utility Study Report for Proposed U.S. Marine Corps Relocation*, July 2008, Revision 1) did not consider the potential impact of induced civilian growth. The socioeconomic analysis projected that induced civilian growth as a result of the military buildup could increase the islandwide population of Guam by up to 40,000 in the peak year of 2014. The increased demand associated with this induced civilian growth was determined and included in this letter report. The *Barrigada Utility Study Report to Support USMC Off-Base Housing Facilities Requirements*, September 2009 (NAVFAC Pacific 2009b), considered the impact of both induced population growth and the construction workforce. The current forecast population is shown in Table 1.

Table 1: Projected Guam Population Growth Associated with the Projected DoD Buildup

Summary Table	Base-line	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	Total at 2019 (incl. baseline)
DoD (all Marine Corps personnel would arrive by 2014)												
Active	33	510	1,220	1,220	1,220	8,602	9,182	9,182	9,182	9,182	9,182	9,215
Dependents	52	537	1,231	1,231	1,231	9,000	9,950	9,950	9,950	9,950	9,950	10,002
Transient	0	0	400	400	400	2,000	9,222	9,222	9,222	9,222	9,222	9,222
Civilian Work Force (on base)	12	102	244	244	244	1,720	1,836	1,836	1,836	1,836	1,836	1,848
		1,149	3,095	3,095	3,095	21,322	30,190	30,190	30,190	30,190	30,190	
Non-Military												
Construction Jobs (direct, on-site)	0	3,238	8,202	14,217	17,834	18,374	12,140	3,785	0	0	0	0
Full-Time Equivalent Jobs (direct, from purchases)	0	1,640	4,029	6,659	8,074	9,657	7,538	3,889	2,254	2,254	2,356	2,356
Full-Time Equivalent Jobs (indirect and induced)	0	1,126	3,009	5,114	6,003	7,330	5,402	2,457	2,092	2,092	2,126	2,126
Dependents	0	3,886	9,500	15,216	17,569	22,494	16,869	8,820	6,116	6,116	6,157	6,157
Non-Military Subtotal		9,890	24,739	41,206	49,480	57,855	41,949	18,950	10,462	10,462	10,639	
Project-Related Subtotal	97	11,038	27,835	44,301	52,575	79,178	72,140	49,141	40,653	40,653	40,830	40,927
Non-Project Related												
DoD												
Active	6,635	80	80	80	130	170	250	250	250	250	450	7,085
Dependents	8,360	118	118	118	148	240	290	290	290	290	290	8,650
Transient	0	900	900	1,256	1,256	1,256	1,256	1,256	1,256	1,256	1,780	1,780
Civilian Work Force (on base)	2,489	17	17	17	27	35	38	38	38	38	45	2,534
Non-Project Related Subtotal	17,484	1,115	1,115	1,471	1,561	1,701	1,834	1,834	1,834	1,834	2,565	20,049
Grand Total Population Total (Op.'s + Construction)	17,581	12,153	28,950	45,772	54,136	80,879	73,974	50,975	42,487	42,487	43,395	60,976
Guam Population (general)		180,692	183,081	185,435	187,754	190,042	192,302	194,541	196,757	198,942	201,095	201,095
Guam Population Increase (general)			2,389	4,743	7,062	9,350	11,610	13,849	16,065	18,250	20,403	
ISLAND POPULATION TOTAL (Op.'s + Construction + Guam Pop.)		192,845	212,031	231,207	241,890	270,921	266,276	245,516	239,244	241,429	244,490	244,490

The revised wastewater demand for the NDWWTP based on the population projections provided in Table 1 and the Unified Facilities Criteria (UFC) are provided in Table 2. For a discussion on the UFC, please see the original utility reports.

Table 2: Projected Wastewater Demand at Northern District Wastewater Treatment Plant Using February 2009 Population Data

	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
North District Wastewater Treatment Plant										
Existing Guam Civilian	5.20	5.20	5.20	5.20	5.20	5.20	5.20	5.20	5.20	5.20
Existing DoD	0.53	0.53	0.53	0.53	0.53	0.53	0.53	0.53	0.53	0.53
Guam Civilian Increase	0.42	0.64	0.85	1.06	1.26	1.47	1.67	1.87	2.07	2.26
DoD Increase	0.24	0.48	0.53	0.57	2.71	2.95	2.99	3.03	3.07	3.12
Construction Workforce	0.26	0.66	1.14	1.43	1.47	0.97	0.30	0.00	0.00	0.00
Subtotal Direct DoD and Guam Civilian	**6.65**	**7.50**	**8.25**	**8.79**	**11.17**	**11.11**	**10.69**	**10.62**	**10.86**	11.11
Indirect/Induced Increase	0.27	0.66	1.08	1.27	1.58	1.19	0.61	0.42	0.42	0.43
Total Average Daily Flow – all sources	**6.92**	**8.16**	**9.33**	**10.05**	**12.75**	**12.31**	**11.29**	**11.04**	**11.28**	**11.54**
Total Peak Daily Flow – all sources	**15.56**	**18.37**	**20.99**	**22.62**	**28.69**	**27.69**	**25.41**	**24.85**	**25.38**	**25.96**

These revised wastewater treatment demand numbers are significantly less than those in the *Guam Wastewater Utility Study Report for Proposed U.S. Marine Corps Relocation*, July 2008, Revision 1 because of the reduction in current demand reported by GWA and Andersen AFB (approximately 3 million gallons per day lower), in spite of the increased demand from the construction workforce and induced civilian growth.

The revised wastewater treatment demand is depicted in Figure 1 and shows the source of the demand.

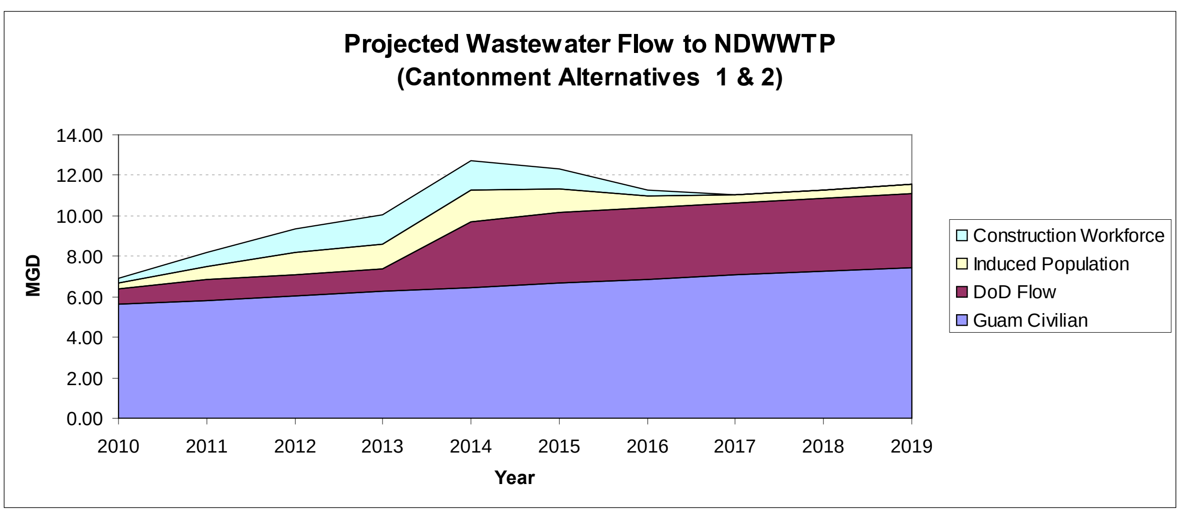

Figure 1: Projected Phased Wastewater Flows to the NDWWTP Based on New Population Loading Data

3. Revised Recommendations Presented in the DEIS

3.1 REVISED RECOMMENDATIONS IN SUPPORT OF MAIN CANTONMENT ALTERNATIVES 1 AND 2

The original utility study (NAVFACPAC 2008) recommended expansion of the NDWWTP because of the higher current wastewater flow reported at that time and the subsequent higher forecasts with new DoD population. Because the revised wastewater flow is lower, it is feasible that the NDWWTP primary treatment system could be refurbished to handle most of the future wastewater flow under either Main Cantonment Alternative 1 or 2. There is a short time when the wastewater flow forecast presented in Table 2 exceeds the design capacity of the NDWWTP, but that excess flow can be adequately handled by using chemical additions and increasing the surface overflow rate within the normal design range. Thus, the DEIS proposes in the short term to upgrade the primary treatment at the NDWWTP.

There has also been a recent regulatory ruling by the U.S. Environmental Protection Agency denying secondary treatment waiver. This event has led to the further revision of the recommended alternative to include upgrading the NDWWTP to secondary treatment in the near future.

3.2 REVISED RECOMMENDATIONS IN SUPPORT OF MAIN CANTONMENT ALTERNATIVES 3 AND 8

If Main Cantonment Alternative 3 or 8 is chosen, DoD facilities will be constructed at Finegayan, Navy Barrigada, and/or Air Force Barrigada. The Barrigada area is serviced by the Hagatna WWTP. For this reason, the original wastewater study for the Barrigada alternatives considered using only Hagatna WWTP for wastewater treatment or a stand-alone DoD WWTP at Finegayan. Using the Hagatna WWTP was discarded in the DEIS for the following reasons:

- Most of the improvements related to Marine relocation to Guam would be located in northern Guam, where wastewater is routed to the NDWWTP. Collection of all DoD flows at one WWTP allows for efficient management of the wastewater treatment.
- Concentrating WWTP improvements associated with DoD wastewater at one plant owned by GWA would help to ensure efficient use of GWA's limited Capital Improvements Plan (CIP) budget resources. This approach also relieves the logistical burden of upgrading two WWTPs in the same period.
- The ocean outfall for the Hagatna WWTP does not have a diffuser installed and is located in a heavily populated area of Guam. The NDWWTP has a newly installed ocean outfall with a diffuser system that is undergoing design evaluation based on future flow forecasts and the effluent discharges in a relatively remote area of the island. It is preferable to route the wastewater flows to the NDWWTP to minimize the environmental impacts related to effluent discharge.

Thus, the recommended alternative for wastewater in support of Main Cantonment Alternatives 3 and 8 presented in the DEIS is the same as for Main Cantonment Alternatives 1 and 2, with the added requirement that wastewater from Barrigada be conveyed to the NDWWTP via force main.

3.3 RETAINED RECOMMENDATION FOR POTENTIAL LONG-TERM WASTEWATER ALTERNATIVE

One long-term alternative considered in both of the wastewater utility reports has been retained in the DEIS. That long-term alternative would be to construct a stand-alone DoD-only WWTP with secondary treatment capability and a new outfall. This new WWTP would be constructed on DoD land at Finegayan. Under this scenario, the NDWWTP primary treatment would be upgraded for the near term, but the secondary treatment capability at the NDWWTP would not be implemented. This long-term alternative is retained since it is not known at this time whether or not GWA would commit to upgrading the NDWWTP to secondary treatment. Thus, the near-term wastewater flow would be handled by the refurbished primary treatment process at NDWWTP, and the new DoD WWTP would treat all DoD wastewater in the future.

This alternative would require revisions to the sewage collection system to convey all DoD wastewater to the NDWWTP, including the flow from Barrigada if either Main Cantonment Alternative 3 or 8 is chosen.

4. Conclusions

Because of revisions in current wastewater flows into the NDWWTP from the original wastewater utility study (NAVFAC Pacific 2008) and the official U.S. Environmental Protection Agency denial for a secondary treatment waiver application by GWA, the recommended alternatives for wastewater to accommodate the DoD buildup have been revised. These revised alternatives are presented in the DEIS and would be able to handle the revised wastewater demand forecast for the new population forecast. The DEIS presents details showing how the new demand for wastewater was calculated for the construction workforce and the induced civilian growth.

5. References

Guam Waterworks Authority (GWA). 2007. *Water Resources Master Plan*. January.

Naval Facilities Engineering Command, Pacific (NAVFAC Pacific). 2006. *Guam Integrated Military Development Plan*.

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Potable Water Supplementary Analysis Letter Report

October 2009

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Potable Water Supplementary Analysis Letter Report, Guam

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ACRONYMS AND ABBREVIATIONS

AFB	Air Force Base
ATS	AECOM Technical Services
DoD	Department of Defense
DEIS	Draft Environmental Impact Statement
gpm	gallons per minute
GWA	Guam Waterworks Authority
LEED	Leadership in Energy and Environmental Design
MGd	million gallons per day
mld	million liters per day
NAVFAC Pacific	Naval Facilities Engineering Command, Pacific
NGLA	Northern Guam Lens Aquifer
OEIS	Overseas Environmental Impact Statement
UFC	Unified Facilities Criteria
UFW	unaccounted for water
USC	United States Code
USMC	United States Marine Corps

1. Purpose

This letter report discusses the differences between the *Guam Water Utility Study Report for Proposed U.S. Marine Corps Relocation* (NAVFAC Pacific 2008) (herein referred to as the Water Study) and the draft *Guam and CNMI Military Relocation Environmental Impact Statement/Overseas Environmental Impact Statement (DEIS/OEIS)* (NAVFAC Pacific 2009a). The results and conclusions of the Water Study were based on estimated population data, which has been superceeded by the current population forecast presented in Volume 1, Table 2.1 -2 of the DEIS/OEIS. The current population forecast includes substantial induced growth in the Guam civilian population related to the Department of Defense (DoD) buildup forecast by a socioeconomic study performed in support of the DEIS/OEIS. The Unified Facilities Criteria (UFC) proscribed growth factor was also removed from the estimated interim water demands because a growth factor is not applicable during buildup.

The *Barrigada Utility Study to Support USMC Off-Base Housing Facilities Requirements*, September 2009 (NAVFAC Pacific 2009b) (herein referred to as the Barrigada Study) provided additional information in support of Main Cantonment Alternatives 3 and 8 as presented in the DEIS/OEIS. This additional information was added to the DEIS/OEIS to support those main cantonment alternatives and is based on the current population forecast.

Potable water demand presented in the DEIS/OEIS reflects the impacts of complying with executive orders regarding conservation of water and using Leadership in Energy and Environmental Design (LEED) approaches to reduce water demand.

Lastly, adjustments in potable water demand and the recent report *University of Guam – Water Engineering Research Center Review of Northern Guam Lens Aquifer Sustainable Yield, Guam Water Utility Study for Proposed USMC Relocation,* 7 September 2009 (NAVFAC Pacific 2009c) (herein referred to as the NGLA Sustainable Yield Review), provide additional information regarding aquifer sustainable yield and forecast demand on the aquifer. That information is presented in the DEIS/OEIS and summarized herein.

Thus this letter report will accomplish the following:

- Show the current population forecasts used in the DEIS/OEIS
- Briefly explain the new potable water demand estimates based on current population forecasts inclusive of buildup construction workforce and induced civilian growth from the socioeconomic study in the DEIS/OEIS, elimination of the UFC growth factor, and compliance with executive orders on water conservation and LEED initiatives
- Present a brief summary on the sustainable yield of the Northern Guam Lens Aquifer and its capacity to provide the forecast additional water
- Discuss any differences in the potable water recommendations in the Water Study and the DEIS/OEIS

2. Revised Potable Water Demand and Supply

The proposed military buildup on Guam would increase the demand on the potable water utilities. To assist with utilities planning to support the proposed military relocation, the Navy conducted a potable water utility study. The Water Study sought to: (1) quantify the increased DoD demand that would result from the military buildup and (2) develop water system solutions to meet the projected demand. The study accounted for projected increases in DoD personnel and dependents and increases in the on-base civilian workforce required to support the military buildup. The population estimates used for these analyses were preliminary.

The Water Study assumed that the construction workers would reside off base and would be served by Guam public utilities at their place of residence. An estimate was made to identify when demand would exceed supply. Because the current population forecast is now available, that estimate is no longer valid and was revised in the DEIS/OEIS.

A socioeconomic analysis performed in support of the DEIS/OEIS projected that in addition to direct increases in DoD personnel, the on-base civilian workforce, and a temporary construction workforce, the proposed military buildup would likely induce civilian population growth. This population estimate was finalized in February 2009. The population loading assumptions for direct DoD personnel, the on-base civilian workforce, and the construction workforce vary somewhat from what was assumed in the original utility reports. Specifically, the following differences are noted:

- Personnel by service changed (fewer permanent Air Force and Navy personnel)
- Transient personnel not previously identified were added (Navy personnel and Marines)
- Slight increase in the construction workforce numbers
- A large induced civilian growth

A qualitative assessment of the population changes determined that increases in the number of Marine transient personnel would be offset by reductions in the number of permanent Air Force and Navy personnel. All Navy transient personnel would be ship-board, and ship personnel would not require water services during the interim period (i.e., would not initially contribute to demands on potable water). Considering these additions and reductions, a determination was made that the on-base interim period demand in support of the February 2009 population estimate would not be significantly different from the demand calculated in the original utility studies, except for the deletion of the UFC growth factor, and that the general conclusions and recommendations made in the original Water Study for the DoD water system would still be valid for the current on-base population being considered in the DEIS/OEIS.

The Water Study did not consider the potential impact of induced civilian growth. The socioeconomic analysis projected that induced civilian growth as a result of the military buildup could increase the islandwide population of Guam by up to 40,000 in the peak year of 2014. The increased demand associated with this induced civilian growth was determined and included in this letter report. The Barrigada Study (NAVFAC Pacific 2009b) considered the impact of both induced population growth and the construction workforce. The current forecast population is shown in Table 1.

Table 1: Projected Guam Population Growth Associated with the Projected DoD Buildup

Summary Table	Baseline	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	Total at 2019 (incl. baseline)
DoD (all Marine Corps personnel would arrive by 2014)												
Active	33	510	1,220	1,220	1,220	8,602	9,182	9,182	9,182	9,182	9,182	9,215
Dependents	52	537	1,231	1,231	1,231	9,000	9,950	9,950	9,950	9,950	9,950	10,002
Transient	0	0	400	400	400	2,000	9,222	9,222	9,222	9,222	9,222	9,222
Civilian Work Force (on base)	12	102	244	244	244	1,720	1,836	1,836	1,836	1,836	1,836	1,848
		1,149	3,095	3,095	3,095	21,322	30,190	30,190	30,190	30,190	30,190	
Non-Military												

Summary Table	Baseline	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	Total at 2019 (incl. baseline)
Construction Jobs (direct, on-site)	0	3,238	8,202	14,217	17,834	18,374	12,140	3,785	0	0	0	0
Full-Time Equivalent Jobs (direct, from purchases)	0	1,640	4,029	6,659	8,074	9,657	7,538	3,889	2,254	2,254	2,356	2,356
Full-Time Equivalent Jobs (indirect and induced)	0	1,126	3,009	5,114	6,003	7,330	5,402	2,457	2,092	2,092	2,126	2,126
Dependents	0	3,886	9,500	15,216	17,569	22,494	16,869	8,820	6,116	6,116	6,157	6,157
Non-Military Subtotal		9,890	24,739	41,206	49,480	57,855	41,949	18,950	10,462	10,462	10,639	
Project-Related Subtotal	97	11,038	27,835	44,301	52,575	79,178	72,140	49,141	40,653	40,653	40,830	40,927
Non-Project Related												
DoD												
Active	6,635	80	80	80	130	170	250	250	250	250	450	7,085
Dependents	8,360	118	118	118	148	240	290	290	290	290	290	8,650
Transient	0	900	900	1,256	1,256	1,256	1,256	1,256	1,256	1,256	1,780	1,780
Civilian Work Force (on base)	2,489	17	17	17	27	35	38	38	38	38	45	2,534
Non-Project Related Subtotal	17,484	1,115	1,115	1,471	1,561	1,701	1,834	1,834	1,834	1,834	2,565	20,049
Grand Total Population Total (Op.'s + Construction)	17,581	12,153	28,950	45,772	54,136	80,879	73,974	50,975	42,487	42,487	43,395	60,976
Guam Population (general)		180,692	183,081	185,435	187,754	190,042	192,302	194,541	196,757	198,942	201,095	201,095
Guam Population Increase (general)			2,389	4,743	7,062	9,350	11,610	13,849	16,065	18,250	20,403	
ISLAND POPULATION TOTAL (Op.'s + Construction + Guam Pop.)		192,845	212,031	231,207	241,890	270,921	266,276	245,516	239,244	241,429	244,490	244,490

Executive order compliance and LEED initiatives are forecast to reduce the increase in average and maximum daily water demand from the DoD buildup on the DoD system by 22 percent and 40 percent, respectively, compared to the UFC. A large part of the demand reduction would result from using native landscaping, which would remove the need for exterior irrigation. The DEIS/OEIS has a full discussion of the executive orders and LEED initiatives that would be followed. The following list identifies some of the directives and guidance documents addressed in the DEIS/OEIS:

- Executive Order 12902, "Energy Efficiency and Water Conservation at Federal Facilities"
- Executive Order 13423, "Strengthening Federal Environmental, Energy, and Transportation Management"
- Energy Policy Act of 2005

- Energy Independence and Security Act of 2007
- 10 United States Code (USC) 2866, " Water Conservation at Military Installations"
- 10 USC 2915, "New Construction: Use of Renewable Forms of Energy and Energy Efficient Products"
- Military Handbook 1165, *Water Conservation*, Mil-HDBK-1165 (1996)
- *Navy Water Conservation Guide For Shore Activities*
- Executive Order 13514, "Federal Leadership In Environmental, Energy, and Economic Performance" (5 October 2009)

Executive Order 13423, for example, requires that all existing Navy and Air Force Bases reduce their water use by 16 percent by 2015. This percent reduction is included in the modified potable water demand estimates for the existing DoD Guam facilities presented in the DEIS/OEIS.

The revised water demand applicable to Main Cantonment Alternatives 1 and 2, and identified in Table 2, is based on the population projections provided in Table 1, adherence to UFC guidelines, elimination of the UFC growth factor during the buildup years, and demand reductions from water conservation efforts. The forecasts for Main Cantonment Alternatives 3 and 8 are essentially the same. For reference, a discussion on the UFC is provided in the original utility report.

Table 2: DoD Water Supply and Demand Estimates with Compliance to Executive Orders and Sustainability Factor at End State

Water Supply Source	Marine Corps Finegayan	Andersen AFB	Navy	Total
Cantonment Alternatives 1 and 2				
Current Surface Water Supply			11	11
Current Groundwater Supply		4.7	3.1	7.8
Development of New Water Supply Wells	6.9			6.9
Rehabilitation of Existing Navy Well			0.5	0.5
GWA Transfer Projected Need in 2019			-3.3	-3.3
Supply for Cantonment Alternatives 1 and 2	**6.9**	**4.7**	**11.3**	**22.9**
Maximum Daily Demand Using Revised UFC and Sustainability Principles	**6.3**	**2.8**	**10.1**	**19.2**
Projected Excess (Supply – Demand)	0.6	1.9	1.2	**3.7**

Legend: AFB = Air Force Base; DoD = Department of Defense; GWA = Guam Waterworks Authority; UFC = Unified Facilities Criteria.

As shown in Table 2, the revised forecast in DoD system demand and proposed increased supply of up to 22 new wells for the proposed USMC base at Finegayan area results in an excess maximum daily supply capacity of approximately 3.7 MGd.

During analysis of the Guam Waterworks Authority (GWA) potable water system, the increased civilian demand was estimated based on GWA guidelines and 50 percent unaccounted for water (UFW). For the population primarily served by GWA, there are significant increases in the buildup-related population between 2010 and 2019, with the peak year being 2014. The buildup-related population is higher in the February 2009 estimate by up to 40,732 people in 2014 primarily due to the forecast induced civilian growth. At the end of the construction phase, the civilian population estimate is 4,355 higher than prior estimates. The GWA system estimated demand and supply forecasts are presented in Table 3.

Table 3: Projected Water Supply and Demand on the GWA Water System

GWA Water System	*Year*									
	2010	*2011*	*2012*	*2013*	*2014*	*2015*	*2016*	*2017*	*2018*	*2019*
Potable Water Demand[a]										
Existing Guam Civilian[b]	48.9	49.3	49.8	50.2	50.6	51.1	51.5	51.9	52.3	52.7
Construction Workforce	0.6	1.5	2.7	3.3	3.4	2.3	0.7	0.0	0.0	0.0
Induced Civilian Increase	1.2	3.1	5.1	5.9	7.4	5.6	2.8	2.0	2.0	2.0
Total Projected Demand	50.7	54.0	57.5	59.5	61.5	58.9	55.0	53.9	54.3	54.7
Potable Water Supply										
Existing GWA Supply[c]	48.4	48.4	48.4	48.4	48.4	48.4	48.4	48.4	48.4	48.4
Projected Excess before Expansion (Supply-Demand)	-2.3	-5.6	-9.1	-11.1	-13.1	-10.5	-6.6	-5.5	-5.9	-6.3
GWA Planned Expansion[d]	0	0	7	7	7	7	7	7	7	7
Total Planned Supply	48.4	48.4	55.4	55.4	55.4	55.4	55.4	55.4	55.4	55.4
Projected Excess after Expansion (Supply-Demand)	-2.3	-5.6	-2.1	-4.1	-6.1	-3.5	0.4	1.5	1.1	0.7

Notes: All units are MGd. This table does not include GWA's effort to detect and fix leaks, UFW.
[a] Demand is based on a 50% UFW rate and population estimates provided in Volume 6, Table 2.2-3
[b] Includes projected increases in civilian demand related to natural population growth.
[c] Includes 4 MGd transferred from Navy to GWA.
[d] GWA Draft Capital Improvement Plan 2010-2014
Source: GWA 2007.

As summarized in Table 3, the total civilian demand on the GWA water system (including demand associated with the construction workforce and induced civilian growth) is projected to reach 61.5 MGd (233 million liters per day [mld]) in 2014. The GWA water system currently has the capacity to supply 48.4 MGd (183 mld) of potable water. Planned GWA expansions would increase that capacity to 55.4 MGd (210 mld). According to GWA's 2010–2014 Capital Improvement Plan, GWA plans to install 16 potable wells with a combined capacity of 7 MGd (26 mld). There are shortfalls during the buildup even with GWA's planned expansion. The existing shortfall of 2.3 MGd (8.7 mld) in 2010 increases to a maximum of 6.1 MGd (23 mld) in 2014. To address this shortfall, DoD is willing to transfer excess water production capacity to GWA if requested. Alternately, GWA could install more potable water wells, or adaptive management practices could be implemented by DoD, such as slowing the construction tempo. More information on adaptive management is provided in Volume 7 of the DEIS/OEIS. Other mitigation might be available, such as accelerating the GWA leak detection and repair program currently under way, reconditioning existing GWA problem wells, and implementing water-saving initiatives. The impact on the GWA water system is a large concern.

3. Northern Guam Lens Aquifer

To compare the estimated available yield of the Northern Guam Lens Aquifer (NGLA) with the demand at full buildout, Table 4 presents the approximate DoD and civilian well production, assuming average daily demand at the United States Marine Corps (USMC) base and off base. Because sustainable yield defines the rate at which groundwater can be *continuously* withdrawn from an aquifer without impairing the quality or the quantity of the pumped water, it is more appropriate to consider the average daily demand instead of the maximum daily demand when assessing potential impacts on the aquifer. Total average well demand from the NGLA of 63.5 MGd (240 mld) is below the 1991 sustainable yield estimate of 80.5 MGd (305.7 mld) but exceeds the 1982 sustainable yield estimate of 58.9 MGd (217 mld). Note that the 1991 report made a minor adjustment to the sustainable yield estimate contained in the 1982 report from 58.8 mgd (223 mld). The 1991 estimate is considered a more accurate estimate of the sustainable yield, however, because it was determined using a dynamic model of the aquifer. The 1982 estimate was determined using a static model. In addition, the NGLA Sustainable Yield Review (NAVFAC Pacific 2009c), confirmed that the current situation on Guam does not alter the results of the 1991 sustainable yield assessment.

Table 4: Total Well Production and Yield Estimates Projected for 2014 (Peak Year)

Wells	Total
GWA Maximum Average Daily Demand on Groundwater Resources	56
Cantonment Alternatives 1 and 2	
DoD Additional Average Daily Demand on Groundwater Resources based on UFC (Finegayan, Andersen AFB, and Navy Hospital)	7.5
Total Required Well Production	63.5
DoD Additional Average Daily Demand based on Sustainability Estimates	6.5
Total Required Well Production with DoD Sustainability Initiatives	**62.4**

Legend: AFB = Air Force Base; DoD = Department of Defense; GWA = Guam Waterworks Authority; UFC = Unified Facilities Criteria.

A sensitivity analysis was performed to determine the effect of using the average DoD daily demand estimates and various GWA UFW loss rates on the available yield of the NGLA. Figure 1 graphically represents the effect of reducing GWA's UFW loss rate, with DoD and GWA wells producing enough water to meet the average daily demand. With adequate well water production to meet the DoD and GWA average daily demands, peak well production would occur in 2014, with well production rates ranging between 64 MGd (242 mld) and 50 MGd (189 mld), depending on the UFW loss rate assumed for GWA. Note that DoD plans to support an updated sustainable yield study to be completed by the U.S. Geological Survey.

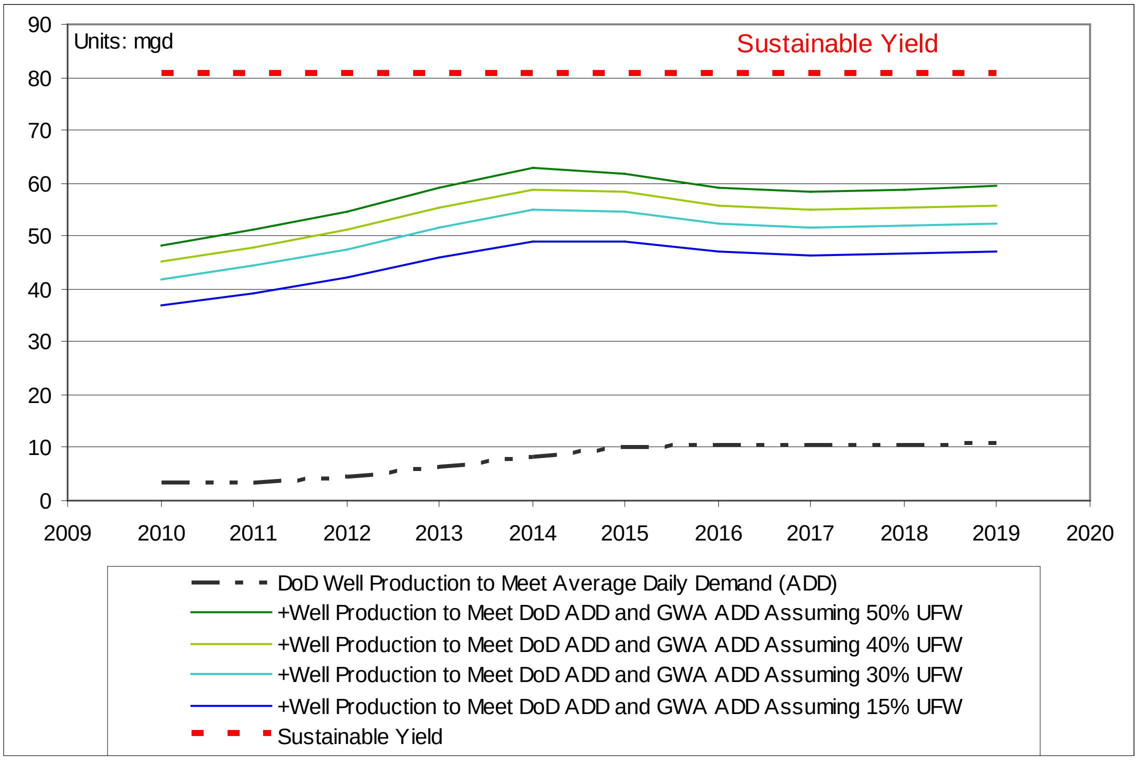

Figure 1. Well Production to Meet DoD Average Daily Demand and GWA Average Daily Demand (15–50 Percent UFW for GWA)

4. Revised Recommendations Presented in the DEIS/OEIS

The recommended alternative for the DoD on-base water system was revised to reduce the capacity of the water supply in order to accommodate the reduced water demand estimate based on the factors presented above. In the Water Study, the capacity of the proposed new wells totals 9,000 gallons per minute (gpm) to address Main Cantonment Alternatives 1 and 2. In the DEIS/OEIS, the capacity of the proposed new wells is reduced to approximately 7,750 gpm to be consistent with the adjusted water demand discussed above. No modifications were made in the DEIS/OEIS to the water supply proposed to address Main Cantonment Alternatives 3 and 8 except that the location of some of the wells would be in Navy Barrigada and the number of wells would be higher because of lower expected capacity at those locations.

No recommendations for the off-base water supply were made in the Water Study. The GWA water system was evaluated in the Water Study only to determine whether excess water was available in the off-base system for purchase by DoD and to evaluate the combined impact of the DoD and GWA water systems on the NGLA. Recommendations are presented in the DEIS/OEIS and briefly discussed above to address shortfalls in the off-base GWA water system.

5. Conclusions

Water demands presented in the DEIS/OEIS have been revised primarily for consistency with the February 2009 population estimate for the buildup, including the construction workforce and induced civilian growth, the compliance with executive orders affecting water demand, and the LEED initiatives. The revised estimates were compared to the water demands and water supply recommendations presented in the Water Study. The following conclusions were drawn from this comparison:

- On base, the revised water demands are lower than the water demands presented in the Water Study, which were based on rough population estimates. The water supply for Main Cantonment Alternatives 1 and 2 presented in the DEIS/OEIS has been adjusted to be consistent with the revised projected water demand. No other modifications to recommendations for the DoD water supply have been made in the DEIS/OEIS.
- Off base, the revised water demands are higher than previously estimated because of the induced civilian growth forecast. The DEIS/OEIS presents recommendations to address the shortfalls. No recommendations were made for the off-base water system in previous reports.

6. References

Guam Waterworks Authority (GWA). 2007. *Water Resources Master Plan*. January.

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