Appendix E
Habitat Equivalency Analysis (HEA)

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Appendix E - Habitat Equivalency Analysis (HEA)

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Habitat Equivalency Analysis and Supporting Studies

Apra Harbor, Guam

September 2009

Prepared for:
Department of the Navy
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EXECUTIVE SUMMARY

The United States Department of Defense (DoD) proposes new construction and improvements to existing waterfront facilities at Apra Harbor, Territory of Guam as follows:

- A new wharf and associated shoreside facilities to support visiting nuclear aircraft carriers (CVN) at one of two alternative locations in Outer Apra Harbor: Polaris Point or the Former Ship Repair facility (Former SRF).
- Improvements to Victor, Uniform, Sierra, Oscar and Papa Wharves and shoreside utilities to support a visiting Marine Corps amphibious task force.
- A new amphibious vehicle laydown (parking) area at Polaris Point.

All of these projects have in-water and near-water construction components with potential adverse impacts to marine ecosystems. This *Habitat Equivalency Analysis (HEA) and Supporting Studies, Apra Harbor, Guam* report is a compilation of technical reports prepared to support the Navy in preparing its *Guam and Commonwealth of Northern Marianas Islands Military Relocation Environmental Impact Statement/Overseas Environmental Impact Statement (November 2009a)* and applications for requisite U.S. Army Corps of Engineers Sections 103/404/10 permits.

On March 31, 2008, U.S. Environemntal Protection Agency and the U.S. Army Corps of Engineers (ACOE) issued revised regulations governing compensatory mitigation for authorized impacts to wetlands, streams, and other waters of the U.S. under Section 404 of the Clean Water Act. Under the new ACOE compensatory mitigation rule, permit applicants are required to mitigate to no net loss of ecological services and function. Habitat Equivalency Analysis (HEA) is a methodology that has been used in a variety of legal and technical contexts to quantify impacts to natural resources and the services/functions they provide, and quantify the amount of restoration/mitigation required to offset documented losses. Coral loss assessment, coral restoration and the parameters used in the HEA are an evolving science. HEA, like any model, relies on user-specified inputs and calculations that simplify complex processes, both of which can introduce uncertainties into model results. However, HEA applications have been published in peer-reviewed technical literature, courts have upheld the use of HEA in litigation, and HEA often underlies settlements reached on cases involving the impacts to and restoration/mitigation of natural resource services and functions. The United States Fish & Wildlife Service (USFWS) and other agencies commonly use HEA to establish the appropriate scale of compensatory restoration in the context of damage assessments conducted under the 1990 Oil Pollution Act (OPA) and the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA), and have endorsed the use of HEA in other Navy dredging projects in Apra Harbor.

Agency interaction included establishment of a HEA/CVN Administrative Working Group that met regularly to discuss the CVN project description, available data, data gaps, and parameters and assumptions for planned studies and modeling. The USFWS hosted a HEA Workshop that informed attendees of the limitations and capabilities of HEA and provided a forum for a discussion of potential mitigation projects that would restore ecological function lost due to dredging in Outer Apra Harbor.

Following a review of compensatory mitigation proposals, two types are being retained for further consideration: artificial reefs and watershed management projects. Guam agencies provided a list of watershed improvement project types and delineated specific watersheds along the southwest coast of Guam.

Key findings of the technical reports are as follows:

<u>Biology:</u>

Inner Apra Harbor Projects

- Coral growth in Inner Apra Harbor was reported on the manmade vertical structures and not on the harbor floor. It is anticipated that the coral loss from these wharf structures during structural repairs would recolonize. The impacts to coral communities would be short-term and localized.

There would be no significant impact and no compensatory mitigation is proposed. A HEA was not warranted for Inner Apra Harbor projects.

- The proposed dredge area fronting Sierra Wharf is characterized by fine-grained mud that comprises the floor of the harbor basin. Organisms that inhabit these habitats are either infaunal, residing within the mud column, or epifaunal, residing on the sediment surface, and the potential additional deposition of sediment associated with dredging would not represent a change in habitat integrity. Any impact to infaunal or epifaunal organisms would be short-term and localized. No significant impact to infaunal or epifaunal organisms was identified and no compensatory mitigation is proposed.

Outer Apra Harbor – CVN Project

- The coral assessment assumed a dredge depth of 60 ft (18 m), which is an overestimate compared to the actual dredge depth of -51.5 ft (-15.7 m), including overdredge. Total area of coral coverage of all classes is for both alternatives is about 71 acres (289,100 m^2) This includes coral cover within the direct impact area of dredging activity and a 656 ft (200-m) buffer delineated as the indirect impact area located around the direct impact area. About 25% and 24% of the area to be dredged contains some level of coral coverage for the Polaris Point and Former SRF alternatives, respectively. Significant adverse impacts to coral communities are anticipated.

- Most of the coral that would be dredged is not pristine and consists of "regrowth" on the bared reef surfaces that were dredged approximately 60 years ago during the creation of Inner Apra Harbor.

- Potential indirect impacts would be minor, based on the modeling results in Section F and the scientific literature on coral sediment tolerance. Indirect impacts are defined as the area where sediment deposition may exceed a rate of 5 milligrams (mg)/square centimeter (cm^2)/day, which is equivalent to deposition of greater than or equal to 0.008 inches (0.2 mm thickness) or 1,000 mg/cm^2 for the 8 to 12 months of dredging. None of the projected contours of sediment deposition extend to the large patch reefs with high coral coverage that are located beyond and adjacent to the project area (i.e., Big Blue Reef, Jade Shoals and Western Shoals). It is unlikely that the project would result in a significant overall decrease of reproductive potential (i.e., coral spawning) of the Apra Harbor community. The area of potential effects comprises a relatively small fraction of the total reef area of Apra Harbor, composed in large part of soft sediment that is not a suitable substratum for coral planular settlement. The duration of increased sediment at a particular location is expected to be short, and plumes restricted in size, so that potential impacts to reproductive cycles would not prolonged. In addition, to date the coral community in the potentially affected area has not been documented to be comprised of unique species that could be lost from the Apra Harbor system. As the project area was dredged in 1946, the existing community is the time-integrated response to the previous impact. Hence, the existing coral community structure provides an estimate of expected pattern of response to the proposed actions.
- Impacts to fish populations, infaunal or epifaunal organisms and water quality would be short-term and localized. A Biological Assessment is being prepared to further describe these impacts. No significant impacts on these resources were identified and no compensatory mitigation is proposed.

Current measurement and numerical modeling of indirect impacts to coral:

- Currents are predominantly wind-driven, and occur as a two-layer system. The surface layer flows in the direction of the wind, and the deeper layer flows in the opposite direction. During typical trade wind conditions, surface flow is to the west out of the harbor, while deeper flow is directed to the east, into the harbor. The exception to this is the entrance channel to the inner harbor, where currents may reverse with the tides. Local bathymetric features and pronounced reef shoals also control local current directions.

- Currents in the project vicinity are normally weak.

- Tidal effects are small in the harbor basins, but are important in the entrance channel to the Inner Apra Harbor, where currents may reverse with the tides.

- A three-dimensional circulation and transport model of the project area was developed using the Environmental Fluid Dynamics Code. The model reproduced both the general circulation patterns indicated by the current meter data, as well as typical current velocities measured in the bottom and surface layers in the project vicinity.

- Fifteen model cases for sediment deposition were completed that bracketed a range of wind forcing conditions, dredging duration, production rates, locations, and suspended sediment release. Dredging was simulated as a 24-hour continuous operation resulting in dredging of 1,800 cubic yards (cy) (1,376 cubic meters [m^3]) per day, and a 10-hour operation resulting in 1,000 cy (760 m^3) in a day. Wind forcing included typical trade winds, strong trade winds, south winds and calm conditions. Use of a silt curtain is included in the models with an efficacy based on the total suspended solids data collected during the recent Alpha /Bravo Wharves Improvement project in the vicinity of the CVN project.

- Sediment deposition resulting from the dredging would be confined largely to the immediate vicinity of the dredge site. Review of the scientific literature to identify deleterious sedimentation rates on corals revealed that there was no specific threshold level of sedimentation that resulted in coral mortality. The literature review (described in Section D) did reveal, however, that negative effects of sediment loading to reef corals were dependent on both the duration and the rate of sediment deposition. Threshold rates cited in the literature range from 5 mg/cm^2 per day to 100 mg/cm^2 per day. Analysis of possible total sediment accumulation during the project indicated that accumulations of greater than 1,000 mg/cm^2, or ¼ inch (6 mm), were confined to within 75 ft (23 m) of the dredge limits at Polaris Point, and to within 39 ft (12 m) of the dredge limits in the rest of the project area. The modeling indicated that sedimentation exceeding 40 mg/cm^2 or 0.008 inch (0.2mm) extended an average distance of 144 ft (44 m) from the dredging.

- The thickness of sediment to be dredged is only 1.6 to 3.3 ft (0.5 to 1 m) throughout most of the project area. The exception is at the proposed Polaris Point wharf area where the embankment is to be dredged. Greater than 13.1 ft (4 m) of material is to be removed in most of this area. Throughout the rest of the site, dredging would move rapidly from site to site: a 75.5 ft by 75.5 ft (23m by 23 m) grid area would require only a half of a day to dredge. This means that exposure to sediment plumes and significant sedimentation (greater than 40 mg/cm^2 (0.008 inch [0.2mm]) per day) would be limited to only one or two days. The exception to this is in the area of the Polaris Point and Former SRF coastline that would be dredged to a specified slope to support the wharf structure, where sediment thicknesses of 13 ft (4 m) or greater are to be dredged.

- Analysis of possible total sediment accumulation during the project indicated that accumulations of greater than 1,000 mg/cm^2, or ¼ inch (6 mm), were confined to within 75 ft (23 m) of the dredge limits at Polaris Point, and to within 39 ft (12 m) of the dredge limits in the rest of the project area. The modeling indicated that sedimentation exceeding 40 mg/cm^2 or 0.008 inch (0.2 mm) extended an average distance of 144 ft (44 m) from the dredging.

- Surface total suspended solids (TSS) plumes exceeding background levels of 3 mg/L are generally predicted to occur only at the dredge site. Plumes near the bottom would be more extensive because most of the suspended sediment is released into the bottom layer, and it also receives all of the TSS contained by the silt curtain. Plume concentrations exceeding the background levels of 3 mg/L typically would extend 262.5 to 394 ft (80 to 120 m) from the dredge site. The plumes would dissipate rapidly following completion of the dredging.

- Worst-case conditions were simulated by increasing the sediment release rate from 1% to 2%, and decreasing silt curtain effectiveness by a factor of four. This approximates the highest 10% TSS measurements recorded outside the silt curtain during dredging for a recent Alpha-Bravo Wharves' improvement project. During these conditions, maximum sediment deposition at the dredge site would be 2,690 mg/cm^2, or 0.6 inches (16 mm), and deposition greater than 40 mg/cm^2, or 2 mm, would occur to a distance of 262.5 ft (80 m) from the dredge site. Surface and bottom TSS concentrations exceeding typical background levels of 3 mg/L would extend 262.5 ft to 328 ft (80 m to 100 m) from the dredge site, respectively.
- Analysis of grab samples collected within the turning basin area indicated that approximately 90% of the surficial sediments were very fine sand sized or coarser, and had a median grain size of approximately 0.1 mm (very fine to fine sand). Sediment cores from the same area classified the material as well-sort sand consisting of 73% sand and gravel and 17% silt (Weston Solutions, 2006). This data suggests that most of the material on the seafloor in the turning basin area that may be impacted by the use of tugboats assisting the aircraft carrier is sand-sized or greater, thereby minimizing the extent and duration of possible plumes that may result from vessel operations. The operational impacts would be short-term, localized and infrequent.

<u>HEA:</u>

- The loss was calculated based on a coral habitat index, which was generated by merging Quickbird multispectral imagery, field survey habitat data (Dollar and Hochberg 2009), and reef rugosity derived from bathymetric data (airborne Lidar and boat hydrographic surveys, obtained from Sea Engineering). Ten categories of coral habitat index ranges were defined that represent the live coral coverage, three dimensional surface area, and rugosity. The total area (three dimensional view) of habitat with some coral coverage is approximately 32.7 acres (132,238 m^2) for the Polaris Point alternative, and approximately 31.7 acres (128,520 m^2) for the Former SRF alternative.
- Polaris Point is expected to result in a loss of approximately 1,048 discounted service acre-years (DSAYs) of coral habitat (across all coral habitat categories), approximately 996 DSAYs due to direct impacts and 52 DSAYs due to indirect impacts. The Former SRF Alternative is expected to result in a loss of approximately 1,023 DSAYs (969 DSAYs due to direct impacts) and 54 DSAYs due to indirect impacts.
- The HEA used artificial reefs as a restoration project. Results indicate that a total of approximately 123 acres (497,765 m^2) of artificial reef are required to compensate for coral reef habitat impacts due to the CVN Polaris Point Alternative. Approximately 121 acres (489,672 m^2) of artificial reef would be required for mitigation of impacts due to the Former SRF Alternative.

Appendix E – Section A: Introduction

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Habitat Equivalency Analysis & Supporting Studies: Section A

Introduction

September 2009

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LIST OF ACRONYMS AND ABBREVIATIONS

$\geq$	greater than or equal to
ACOE	U.S. Army Corps of Engineers
CLTC	Chamorro Land Trust Commission
cm	centimeter(s)
CNMI	Commonwealth of Northern Marianas Islands
CVN	nuclear aircraft carriers
CTD	conductivity temperature and depth meter
cy	cubic yard
DLNR	State of Hawaii Department of Land and Natural Resources
DoD	Department of Defense
EFDC	Environmental Fluid Dynamics Code
EIS/OEIS	Environmental Impact Statement/Overseas Environmental Impact Statement
GOVGUAM	Government of Guam
HEA	Habitat Equivalency Analysis
HHF	Helber Hastert & Fee, Inc.
m^2	square meter(s)
mg/cm^2	milligram(s) per square centimeter
$mg/cm^2/day$	milligram(s) per square centimeter per day
mg/L	milligram(s) per liter
MLLW	Mean Lower Low Water
mm	millimeter
NPS	National Park Service
NEPA	National Environmental Policy Act
NOAA	National Oceanic and Atmospheric Administration
PAG	Port Authority of Guam
pH	potential of hydrogen
SRF	Ship Repair Facility
TEC	TEC Inc.
TSS	Total Suspended Solids
U.S.	United States
USFWS	U.S. Fish and Wildlife Service

The Habitat Equivalency Analysis (HEA) and Supporting Studies report is presented in six sections, with Section A being the Introduction. Subsequent sections are technical reports that could stand alone but are combined under one cover because they are inter-related and were concurrently prepared. The reports are as follows:

- *Section B*: Assessment of the Affected Marine Environment, Outer and Inner Harbor, Guam.
- *Section C:* Marine Ecosystem Impact Analysis CVN Project Outer Apra Harbor, Guam.
- *Section D:* Reconnaissance Surveys of the Marine Environment, Eastern Outer Apra Harbor, Guam, Baseline Assessment of Marine Water Chemistry.
- *Section E:* Current Measurement and Numerical Model Study for CVN.
- *Section F:* Habitat Equivalency Analysis (HEA), Mitigation of Coral Habitat Losses.

1.0 DOCUMENT PURPOSE

The United States Department of Defense (DoD) proposes new construction and improvements to existing waterfront facilities at Apra Harbor, Territory of Guam as follows:

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The project locations are shown on Figure 1. All of these projects have in-water and near-water construction components with potential adverse impacts to marine ecosystems. This *Habitat Equivalency Analysis and Supporting Studies, Apra Harbor, Guam* report is a compilation of five technical reports prepared to support the Navy in preparing its *Guam and Commonwealth of Northern Marianas Islands (CNMI) Military Relocation Environmental Impact Statement/Overseas Environmental Impact Statement (EIS/OEIS)* (NAVFAC Pacific 2009a) and requisite U.S. Army Corps of Engineers (ACOE) Section 103/404/10 permit applications.

The technical reports were prepared to describe baseline environmental conditions, potential direct and indirect adverse impacts due to dredging, and compensatory mitigation analyses. The indirect impact analysis was based on computer modeling that addressed a range of dredging scenarios.

An important component in the development of these technical reports was the interaction of the authors and Navy personnel with federal and Guam agencies, through the establishment of working groups that met regularly between March and December 2008.

Section A, Introduction, describes the proposed projects, the agency interaction, and summarizes the findings of the technical reports.

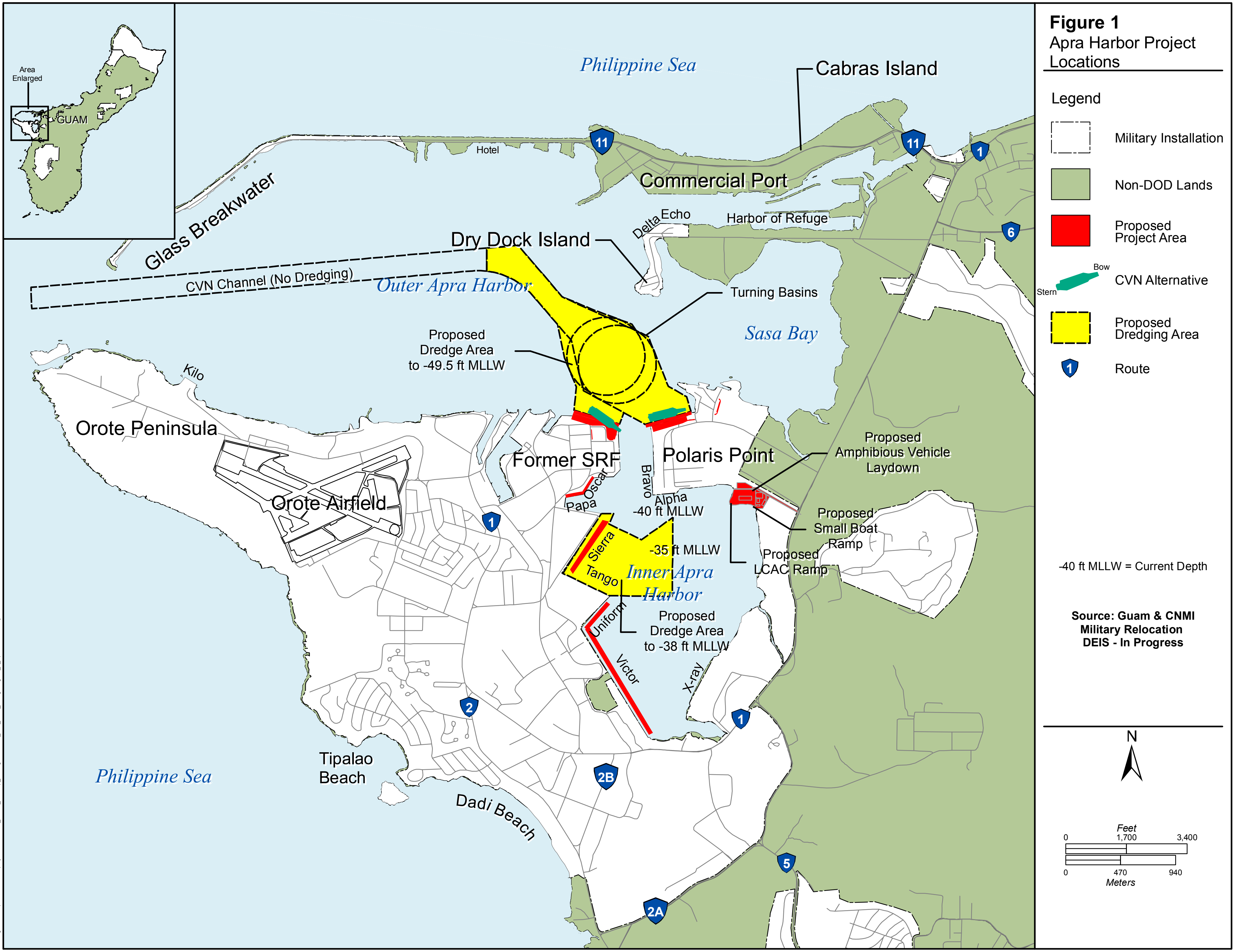

Figure 1
Apra Harbor Project Locations

2.0 PROPOSED PROJECTS

The *Guam and CNMI Military Relocation Draft EIS/OEIS* (NAVFAC Pacific 2009a) provides the individual project alternatives analysis, detailed project descriptions and descriptions of potential environmental impacts. This section provides a brief summary of project descriptions as described in the EIS/OEIS.

2.1 NEW CVN WHARF (OUTER HARBOR)

2.1.1 CVN-capable Berthing Study

An engineering feasibility study (estimated at 30% design), entitled the *CVN-capable Berthing Study*, was prepared for the proposed CVN wharf at either Polaris Point or the Former SRF (TEC 2008a). The study looked at various alignments of the navigation channel, turning basin and the wharf. It included engineering evaluations of utility infrastructure and shoreside operational areas. Dredge volumes were calculated and wharf design were recommended.

Subsequent to the release of the study, one option of three proposed for Polaris Point was selected. In addition, the dredge volumes were refined and turning basin alignments for both alternatives were altered to reduce potential impact on nearby coral shoals. The realignment also made the two proposed turning basin alternatives more similar in footprint. The technical reports presented herein are based on these modifications developed subsequent to the release of the feasibility study. Most of the feasibility study findings are still valid including: navigation channel, structural and infrastructure analyses.

2.1.2 Project Description

The Navy proposes to construct a wharf and supporting infrastructure in Outer Apra Harbor to berth a visiting CVN. The number of port calls and durations would increase to from approximately 16 days per year to 63 days per year. The proposed increase in frequency and duration cannot be accommodated at Kilo Wharf, which is the current location for berthing a visiting CVN. A new wharf is proposed at either Polaris Point or the Former SRF (Figure 1). The alternatives are both at the entrance to the Inner Apra Harbor Channel.

The proposed CVN operations, infrastructure, and the navigation channel through Outer Apra Harbor would be the same for both alternatives. The navigational approach through the Outer Apra Harbor Channel toward Inner Apra Harbor would generally follow the existing approach but would be widened from 200 ft (61 meter [m]) to 600 feet (ft) (183 m). There is a sharp southward bend in the existing channel between Jade and Western Shoals. There are slight differences between the alternatives in the alignment of the turning basins. The project areas between the turning basin boundary and the wharf differ.

The navigational depth requirement for a CVN is -49.5 ft (-15.1 m) Mean Lower Low Water (MLLW). This water depth between the Outer Apra Harbor Channel entrance and the sharp southward bend toward Inner Apra Harbor (Figure 2) ranges between -65 and -170 ft (-20 and -52 m) MLLW. Between the sharp bend and the proposed wharf locations, the depths range from approximately -43 to -130 ft (-13 to -40 m) and dredging would be required in some areas. In those areas being dredged, an additional 2 ft (0.6 m) allowance for overdredge would result in a total dredging depth of -51.5 ft (-15.7 m). The total dredge volume anticipated for the Polaris Point and Former SRF alternatives is estimated at 608,000 cubic yards (cy) (465 cubic meters [m^3] and 479,000 cy [366 m^3]), respectively, including the overdredge.

Historically, mechanical dredging has been used in Apra Harbor and would be described in the Army Corps of Engineers (ACOE) Section 103/404/10 permit application. The ACOE permit application process would also address the impacts of the dredging, dredge material management (Section 404(b) of the Clean Water Act) and construction of structures, e.g. pilings, piers, wharves, etc, (Section 10 of the Rivers and Harbors Act) in waters within federal jurisdiction. The dredged material management options would be beneficial reuse, ocean disposal and upland placement in a dewatering site. The ocean disposal site for Guam is in the process of being designated by the U.S. Environmental Protection Agency and would be available in time for the CVN wharf construction.

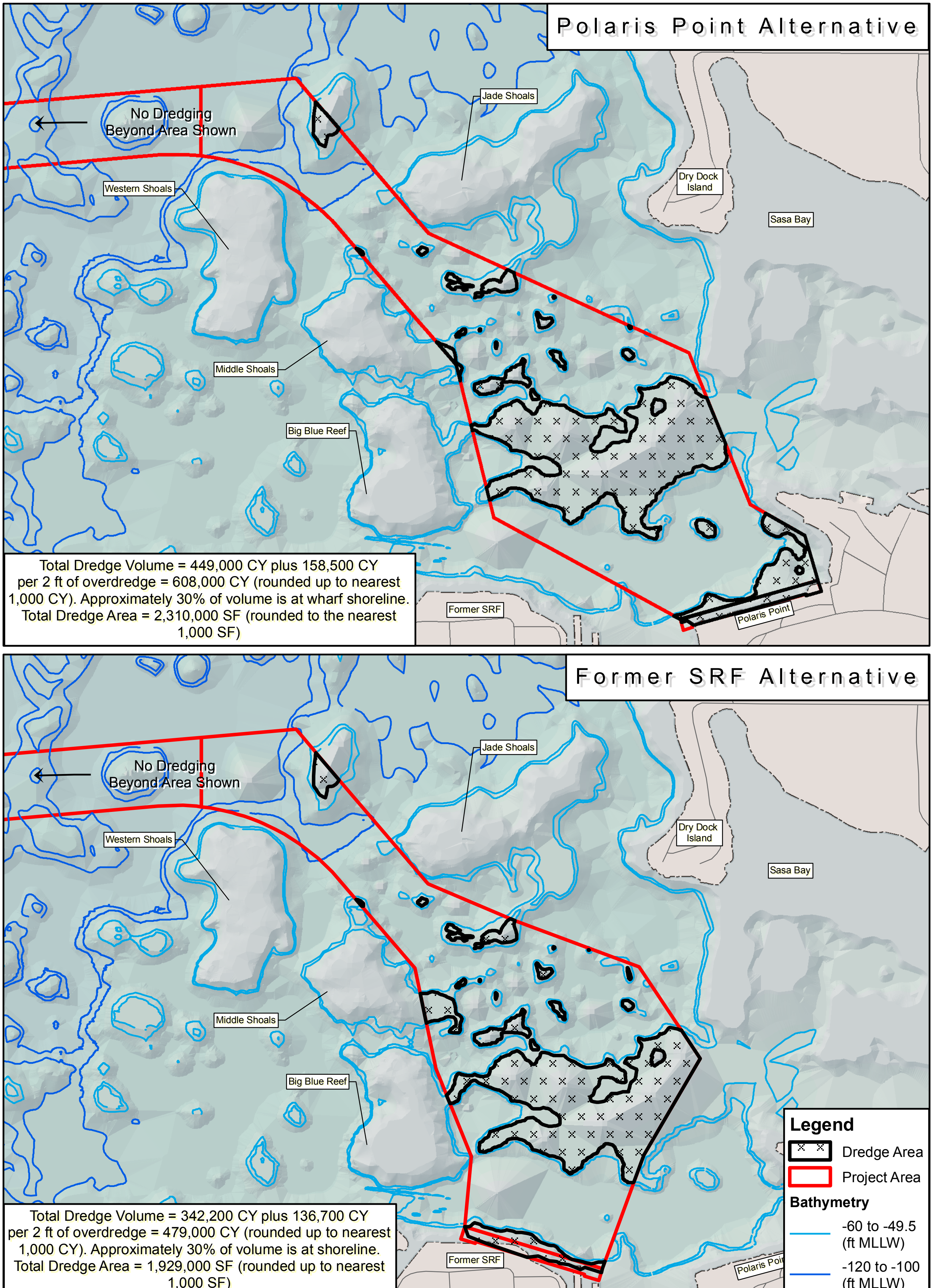

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Figure 2
CVN Alternatives
DRAFT - FOR OFFICIAL USE ONLY
Source: Guam & CNMI Military Relocation DEIS - In Progress

Feet 0 625 1,250
0 170 340 Meters

N

2.2 Inner Harbor Projects

The locations of the Inner Apra Harbor projects are shown on Figure 1. Table 1 summarizes the proposed improvements at each wharf. Structural improvements at existing wharves are proposed at Victor, Uniform, Sierra, Oscar and Papa Wharves. The wharf improvements are likely to remove any coral on the vertical manmade wharf structures. Dredging from -35 ft (-10.7 m) MLLW to - 38 ft (-11.6 m) MLLW is proposed in front of Sierra Wharf. Proposed new facilities include an amphibious vessel laydown area with two concrete boat ramps located east of Alpha Wharf. The ramp facilities would require minor fill to meet the design slope and are similar in construction to small boat ramps observed at marinas for recreational use.

Table 1: CVN Improvements

Location	*Improvements Proposed*

Victor/Uniform Wharves	• No dredging
	• Victor/Uniform- repair concrete wharf deck surface, and replace mooring hardware, fender
	• Strengthen/reconstruct Uniform to meet seismic and typhoon design standards:
	  o Replace sheetpile bulkhead wharf structure to match Victor
	  o Repair voids in soil beneath wharf
	  o Upgrade/install shoreside infrastructure at Victor and Uniform

Sierra Wharf (Tango Wharf structural improvements may be required to meet new dredge depth at Sierra Wharf)	• Dredge from -35 (-10.7 m) to -38 ft (-11.6m) MLLW, approximately 283,170 cy (216 m^3) of dredged material • Wharf strengthening to meet new depth, and seismic and typhoon criteria: repair sheetpile, and tiebacks, and cathodic protection • New concrete deck • Utility/infrastructure improvements
Oscar/Papa Wharves	• No dredging • Minor repair of the concrete bulkhead, no demolition or replacement of support structure • New fender system and mooring hardware
Amphibious Vehicle Laydown Area-Polaris Point	• New construction of two concrete ramps from the Harbor onto paved area for parking amphibious vehicles • Minor cut and fill

2.3 Setting

Apra Harbor is located on the southwestern coast of Guam (Figure 1, inset). The Harbor is divided into Outer Apra Harbor and Inner Apra Harbor; Inner Apra Harbor is located south of Outer Apra Harbor (Figure 1). All ship traffic to and from the Harbor uses the single entrance channel located at the western end of Outer Apra Harbor. Access to Inner Apra Harbor is through a single channel from Outer Apra Harbor. Apra Harbor is the only deep draft harbor on Guam and Outer Apra Harbor is shared by DoD, commercial, and recreational watercraft that range from canoes to CVNs. Access to Inner Apra Harbor is subject to Navy Port Operations approval and is limited to military use, including ships from allied nations.

The Navy owns and manages all of Apra Harbor submerged lands except for a portion fronting Port Authority of Guam (PAG) facilities in the northeast corner of Outer Apra Harbor. The Navy property includes Orote Peninsula, Inner Apra Harbor, Dry Dock Island, and Glass Breakwater (Figure 1). The Navy leases the Former SRF area to the Guam Economic Development and Commerce Authority who subleases it to Guam Shipyard.

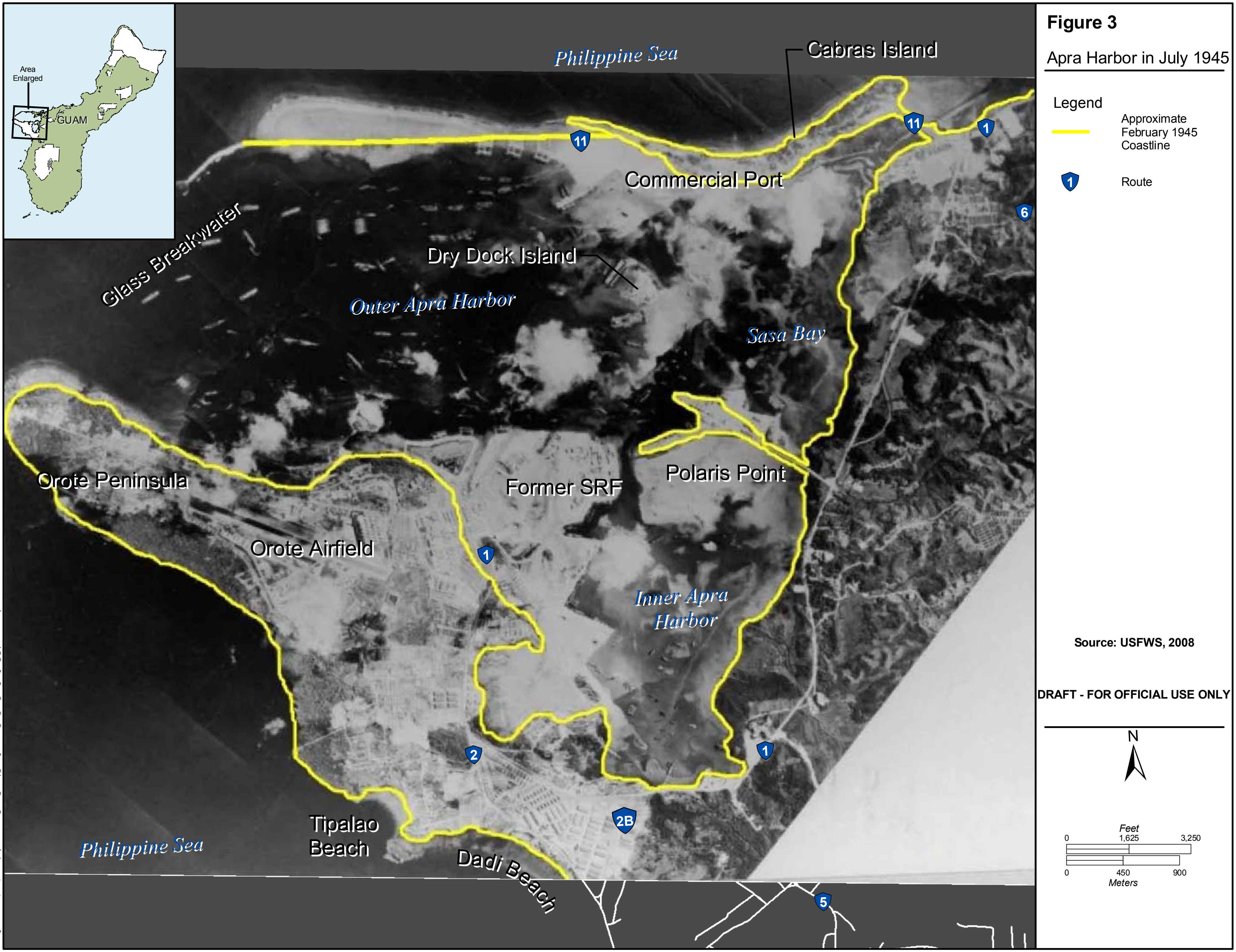
For public health, security and anti-terrorism force protection reasons, the Navy imposes restrictions on non-DoD operations and establishes standoff distances from Navy facilities and ships.

The proposed projects are located in Inner Apra Harbor and areas north of the Inner Apra Harbor entrance channel. The Navy submarine facilities are located at Polaris Point Alpha and Bravo Wharves. X-Ray Wharf is the Supply Wharf and is located in the southeast corner of Inner Apra Harbor. Most of the Inner Apra Harbor wharves are located along the western side. The Guam Shipyard lease area includes Lima, Michael, Oscar and Papa Wharves. Lima Wharf is opposite Polaris Point at the entrance channel.

Outer Apra Harbor Navy assets include Kilo Wharf (the ammunition wharf near the entrance channel), and Echo/Delta Wharves (the fueling wharves at Dry Dock Island). In addition to transiting ship traffic, Outer Apra Harbor is used for military training and recreational activities (e.g., Atlantis Submarine, SCUBA diving, sailing, jetskiing, canoe paddling).

In 1945, the Inner Apra Harbor wharves, the ship repair facility, Polaris Point, and Glass Breakwater were constructed of fill material (Figure 3). The construction depth of the southern portion of Inner Apra Harbor fronting the new wharves was -32 ft (-9.7 m) MLLW and depth in the northern portion was -35 ft (-10.7 m) MLLW. Maintenance dredging occurred in 1978 and 2003 (TEC Inc. 2008b). In 2007, the construction depth of the Inner Apra Harbor Channel and an area south of the Inner Apra Harbor Channel was dredged to -40 ft (-12 m) MLLW to accommodate a new class of submarine, which is about 560 ft (171 m) in length and 42 ft (10 m) wide, at Bravo Wharf on the eastern side of the Inner Apra Harbor Channel.

The original construction depth for the navigation channel north of the Inner Apra Harbor Channel has been estimated between -40 (-12 m) and -50 ft (-15m) MLLW based on coral surveys (Sections B and C). No maintenance dredging has been reported for the area. The navigation channel aligned east-west in Outer Apra Harbor is deep and no construction dredging has occurred (or is proposed). Kilo Wharf, the Navy's ammunition wharf was constructed in 1989 in Outer Apra Harbor near the entrance channel with a construction depth of -45 ft (-13.7 m) MLLW. The wharf was extended and the construction depth changed to -47 ft (-14.3m) MLLW in 2008-2009 (HHF 2007).



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3.0 AGENCY INTERACTION

3.1 EIS/OEIS PARTNERING MEETINGS

To support the Guam and CNMI Military Relocation project, the Navy held a number of regulatory agency briefings between June and August 2007 with federal and local agencies and other stakeholders, collectively referred to as partners. In February 2008, the Navy initiated a partnering strategy to continue the integration among military and government agencies throughout the EIS/OEIS process. There are approximately 260 contacts provided on the agency distribution list.

The February 2008 partnering meeting also established specific working groups for individual resource areas or topics of interest. Due to the size and varied interests of the participants, the following working groups were established to focus on more specific issues: natural resources, cultural resources, compliance, and NEPA. The interactions included formal meetings, informal meetings, and conference calls. The interaction with agencies would continue through the Final EIS/OEIS development.

3.2 HEA/CVN ADMINISTRATIVE WORKING GROUP

The HEA/CVN Administrative Working Group was established as a subset of the natural resources working group. The methodology and focus of this working group was a bi-weekly forum to discuss both the potential impacts related to CVN berthing alternatives and possible compensatory mitigation solutions. The Administrative Working Group meetings were suspended during the preparation and agency review of this report, and Draft EIS/OEIS preparation. Participating agencies include:

- U.S. Fish and Wildlife Service (USFWS)
- National Oceanic and Atmospheric Administration (NOAA)
- U.S. Environmental Protection Agency (Honolulu)
- ACOE – Guam office
- Guam Environmental Protection Agency
- Guam Department of Agriculture
- Guam Bureau of Statistics and Plans
- Guam Division of Aquatic and Wildlife Resources

Joint Guam Program Office representatives and various departments of the Navy, including Commander, Pacific Fleet are also on the distribution list.

In addition to the HEA/CVN Administrative Working Group meetings, USFWS initiated biweekly HEA/CVN Technical Working Group meetings to focus on the survey methodology and logistics for proposed Outer Apra Harbor marine surveys. The Navy conducted field surveys in 2009 to augment the existing data provided in the January HEA and Supporting Studies. The report is "*Assessment of the Benthic Community Structure in the Vicinity of the Proposed Turning Basin and Berthing Area for Carrier Vessel Nuclear (CVN) Apra Harbor, Guam*"(NAVFAC Pacific 2009b), and supercedes the previous coral assessment reviewed by resource agencies in the Early Review Draft EIS/OEIS. This document, a USFWS survey, and a fish survey report are provided in the draft EIS/OEIS appendices (Volume 9)

3.2.1 Meeting Documentation

The meeting records for the HEA/CVN Administrative Working Group through December 2, 2008 are included as the Appendix A to this Section A Introduction. The meetings were both in–person and via the telephone. Most meetings generated action items for participants and an action item list was maintained.

The most recent action item list is dated December 3, 2008 and is included in Appendix B In addition to the working groups discussed above, a two-day HEA workshop (November 5-6, 2008) was hosted by USFWS. Due to scheduling conflicts, GovGuam agencies were unable to attend. The meetings were a valuable forum for exchanging information, learning about limitations and capabilities of HEA, discussing potential mitigation approaches, obtaining input on the assumptions to be used in the technical reports, and discussing preliminary findings and assumptions for subsequent work.

A partnering website was maintained and the CVN/HEA Administrative Working Group materials were stored there. The meeting records, meeting presentations, action item list, and key references and documents are available on the website. The access information is as follows:

Web address: https://extranet.tecinc.com/militaryrelocationeis/references.aspx

Client Username: militaryrelocationeis

Password: partner#2

A list of literature potentially relevant to Apra Harbor was developed and the December 9, 2008 version from USFWS is included as Appendix C. Some of the documents were determined to be irrelevant because of geography or age, as indicated in the list.

3.2.2 HEA/CVN Working Group Challenges

The HEA/CVN Administrative Working Group meetings have been valuable for sharing information and identifying data gaps. Agencies provided input on parameters and assumptions to be used in the HEA and sediment modeling. Consensus was not achieved on every issue.

The key challenge to successful agency interaction has been the Guam and CNMI Military Relocation EIS/OEIS schedule that is dictated by international agreements between the U.S. and the Government of Japan. The EIS/OEIS includes three components: 1) relocation of Marine Corps forces from Okinawa to Guam; 2) construction of a new CVN Wharf at Apra Harbor; and 3) development of Army Missile Defense Facilities on Guam. The proposed Inner Apra Harbor waterfront improvements are related to the Marine Corps. The Marine Corps component is the primary driver of the schedule because the relocation is to occur by 2014, per international agreements. To meet the schedule, a Record of Decision on the EIS is required in 2010.

The CVN project has its own schedule urgency in addition to those described for the Marine Corps relocation. To support the 2006 Quadrennial Defense Review (QDR) and the Navy Fleet Response Plan objectives (detailed in the EIS/OEIS), the Navy plans to station six operationally available and sustainable aircraft carriers in the Pacific Fleet area of responsibility, with the majority deployed in the 7th Fleet area of responsibility that encompasses the western Pacific and Indian Oceans.

The number of Apra Harbor CVN port days would increase and the anticipated increases cannot be accommodated at Kilo Wharf, which is the current CVN transient berth. The purpose of the proposed action is to provide adequate ship berthing and support facilities to allow for extended CVN visits in Guam without disrupting munitions operations at Kilo Wharf or other port operations at Naval Base Guam. The proposed action is needed to replace Kilo Wharf as the transient CVN wharf and is a high priority project for the DoD.

3.3 Compensatory Mitigation

Compensatory mitigation is defined as the restoration, establishment, enhancement, and/or preservation of aquatic resources to offset unavoidable impacts to waters of the United States. After all efforts to minimize and avoid the impacts of the CVN project, there remain unavoidable adverse impacts associated with dredging coral reef ecosystems in Outer Apra Harbor. The compensatory mitigation is subject to approval by ACOE, under the Clean Water Act, through the Section 103/404/10 permit requirements. This section summarizes key milestones in the discussion of compensatory mitigation to date.

3.3.1 In-Lieu Fee and Mitigation Banking Programs

Within the HEA Administrative Working Group, DoD, and the Military Civilian Task Force on Guam there is support for the use of In-Lieu fee or mitigation banking programs to manage, implement and monitor the success of natural resource compensatory mitigation projects on Guam. These programs are not established on Guam and would have to be developed in a timely manner to the satisfaction of the ACOE.

Under mitigation banks, units of restored, created, enhanced, or preserved resources are expressed as "credits" which may subsequently be withdrawn to offset "debits" incurred at a project development site. Ideally, mitigation banks are constructed and functioning in advance of development impacts, and are seen as a way of reducing uncertainty in the CWA Section 404 permit program by having established compensatory mitigation credit available to an applicant.

In-Lieu Fee mitigation occurs in circumstances where a permittee provides funds to an In-Lieu Fee sponsor instead of either completing project-specific mitigation or purchasing credits from an approved mitigation bank. The program sponsor periodically funds a consolidated mitigation project from the proceeds of the accumulated In-Lieu Fees. A memorandum of understanding would be executed among DoD, regulators and stakeholders that establishes an In-Lieu Fee Mitigation Sponsor (typically a non-government organization and a Review Team to determine how the bank would work).

The In-Lieu Fee amount is based upon the compensation costs that would be necessary to restore, enhance, create or preserve coral ecosystems or other habitats with similar functions or values to the one affected. The fee is banked in an investment account until a project is approved for implementation. The In-Lieu Fee mitigation bank would be managed by the In-Lieu Fee Mitigation Sponsor (Sponsor) that uses the accumulated funds to implement projects that restore, enhance, or preserve ecosystems with similar functions and values that are located within the same biophysical region as the permitted disturbance. Key stakeholders, including regulatory agencies, DoD and the Sponsor, form an advisory committee that determines the projects that would be implemented. The Sponsor is responsible for implementing the project according to an approved work plan.

Regardless of whether the Navy implements the project directly or provides funds to an In-Lieu Fee or Mitigation Bank program, all mitigation projects require a mitigation plan approved by ACOE that would include the following components:

- Objective(s) of the compensatory mitigation project
- Site protection instrument to be used
- Baseline information (impact and compensation site)
- Mitigation work plan
- Maintenance plan
- Ecological performance standards
- Monitoring requirements
- Financial assurances
- Site selection information
- Number of credits (fee) to be provided
- Long-term management plan
- Adaptive management plan

3.3.2 Agency Preliminary Mitigation Cost Estimates

PowerPoint presentations (not included in this report) on preliminary Navy findings (i.e., biological surveys, coral mapping, current models) were presented at the March 25, 2008 Administrative Working Group meeting and partners were asked to provide a rough order mitigation cost estimate that the Navy could use in their budget for the CVN project. The response, forwarded by USFWS, was an estimated $102.5 Million for the Polaris Point Alternative. The basis of the cost estimate was the Kilo Wharf Extension project. The estimated cost per acre of direct coral damage was $1.74 Million per acre. This emailed response is included in Appendix C. The response acknowledged that this value represented the worst-case scenario. Additional survey information and information on project description would allow for a more refined estimate. Subsequent to the original estimate, 1) the Commander, U.S. Pacific Fleet representatives answered questions on the project description and alternatives that were considered and dismissed (the alternatives analysis is described in the Guam and CNMI Military Relocation EIS/OEIS), 2) the project description was refined, and 3) USFWS representatives were able conduct a brief SCUBA survey in the CVN project areas using their own resources. The result was a reduction in the partner mitigation cost estimate to approximately $50 Million (See November 5-6 meeting record).

3.3.3 Proposed Compensatory Mitigation Projects

The compensatory mitigation projects are being discussed and options are presented in the Draft EIS/OEIS. Discussions of specific restoration projects among DoD and other agencies did not begin in earnest until the HEA workshop on November 5-6, 2008. Guidelines for project acceptability were:

- Project would replace the loss functions and services of coral reef ecosystems.
- Scientific data are available that the project would, in fact, have the desired result of in-kind replacement. In other words, there must be confidence in the success of the project.
- The ratio of restoration to loss is quantifiable.
- The project is legal.
- The project is feasible.
- Project may enhance but not replace activities that are already occurring or be used to achieve ongoing mandated responsibility.

All proposals discussed would benefit the environment but some were dismissed outright for not meeting Clean Water Act requirements for compensatory mitigation including the guidelines above. The dismissed ideas and the primary reason for dismissal are listed below:

- Marine protected areas: increase enforcement protection of existing areas. Dismissed because transferring DoD funds to other federal agencies or local agencies to support policing action is not legal and enforcement is a pre-existing mandated responsibility.
- Purchase new land for new preserve or to prevent future development that could degrade water quality. Dismissed because it is not feasible in a reasonable time-frame and it would be difficult to demonstrate that coral restoration would be the result.
- Management plans for submerged lands and lands, DoD property or island wide. Dismissed because compensatory mitigation cannot be used to achieve other mandated responsibility as in the case of DoD Lands. Plans do not restore ecological function, therefore are not considered suitable mitigation.
- Aquaculture to increase biomass. Dismissed because it would not replace or restore coral function.
- Research projects to better understand the watershed influences on coral community structure. Compensatory mitigation regulation excludes research because it would not restore ecological function.

There are two compensatory mitigation project proposals that are being retained for further consideration: artificial reefs and watershed management projects.

Artificial reefs would be installed within Outer Apra Harbor in the same watershed as the proposed dredging project. A Navy study prepared during preparation of the Kilo Wharf Extension EIS, identified potential artificial reef locations within Outer Apra Harbor and there would likely be sufficient area available to meet the compensatory mitigation requirements. Further site selection and assessment is required.

Watershed improvement is a collective term to describe a myriad of projects that would remove or diminish anthropogenic stresses on receiving bays that would improve water quality and ultimately result in recolonization or improved growth of existing coral in those bays. At the November 25, 2008 HEA/CVN Administrative Working Group Meeting, Guam agencies provided a watershed management proposal for the watersheds along the southwest coast of Guam for further discussion. The project types were general and site-specific details including location or magnitude of project were not available:

- reforestation/aforestation
- enhancement of riparian areas
- stream bank stabilization
- storm water management
- upgrade wastewater management systems
- purchase private lands for conservation

The Guam Bureau of Statistics and Plans provided Figures 4, 5, 6, and 7, which are included in this report without modification, except for the addition of a location map. Figure 4 delineates the watershed areas included in the mitigation proposal and identified National Park Service (NPS), Chamorro Land Trust Commission (CLTC), and Government of Guam (GOVGUAM) lands. Figure 5 shows the GOVGUAM parcel ownership. Figure 6 shows the riparian areas and Figure 7 shows the badlands and savanna cover for GOVGUAM, CLTC and NPS parcels only.

Guam Coastal Management Program, Bureau of Statistics and Plans drafted a Guam Compensatory Mitigation Plan (March 2009) that addresses terrestrial and aquatic mitigation. Appendix B of the Plan lists candidate terrestrial and aquatic projects, but does not provide project specific detail to be included here. One project that would likely be tied to coral community compensatory mitigation, besides the watershed management projects, is coral transplantation. The HEA presented as Section F includes budget for coral transplantation.

The *Guam and CNMI Military Relocation Draft EIS/OEIS* (NAVFAC Pacific 2009a) outlines the current approach, which is subject to negotiation.

3.3.4 Relative Merits of Artificial Reefs and Watershed Management Projects

As of this publication, the debate on artificial reefs versus watershed management projects as compensatory mitigation continues. A summary of supporting points of view and counterpoints for the two types of compensatory mitigation are presented in Table 2. This is not intended to be a legal brief or literature review supporting all points of view, but an attempt to provide a balanced summary of recurring themes and opinions to assist the reader to better understand the key points of discussion that will continue through the Army Corps of Engineers permit process. Blanks in the table do not necessarily mean that there are no responses or counterpoints. Watershed projects have not been dismissed from consideration.

Table 2: Watershed Management Projects as Compensatory Mitigation

Watershed Projects	
Pros	***Counterpoints/Cons***
1. Restoration of an area where corals previously thrived is likely to be more successful than creating new reefs where corals never existed.	1. Qualitative assessment. Adding suitable substratum in new area may result in better habitat, particularly if the new habitat is sheltered from destructive storm waves.
2. Water quality improvements have been demonstrated to result in coral reef recovery (e.g. Kaneohe Bay after removal of wastewater discharge, also PagoPago Harbor,	2. The relocation of wastewater discharge points originating from point source discharge (domestic waste in Kaneohe and industrial tuna factory waste in Pago Pago) to deeper water was demonstrated in the literature to result in coral recovery. Point sources in the watershed identified for mitigation projects appear to be limited to Umatac-Merizo Sewage treatment plant. In addition, both of these examples cited are in enclosed embayments. There is no guarantee that there will be a positive response in waters off the southwest coast of Guam that are open coastline.
3. Wide support among Guam agencies and federal resource agencies.	3. Watershed management could improve water quality of receiving waters. No one has provided peer-reviewed scientific literature to demonstrate to the permitting agency (ACOE) that a specific project or group of watershed projects would result in a quantifiable amount of water quality improvement that would in turn result in a quantifiable amount of coral function restoration. The proponents of watershed projects have not assisted the Navy in making the case to the ACOE that there is a predictive scalable relationship between a specific watershed project (s) and replacement of coral function. There is no published defensible mitigation ratio that credibly estimates: a. the volume of sediment reduction expected to be achieved per acre (or other spatial unit) of an aforestation/sediment management project, b. the corresponding unit of improvement in water clarity and/or sedimentation in receiving harbors (especially if project participation is limited to portions of a watershed), and c. area of coral regrowth achieved. It is not consistent with compensatory mitigation rules to propose experimental studies/research to determine the ratios of restoration project scale required to replace loss resources for variety of watershed projects.
4. The watershed approach threatens no further harm to reefs and has inherent ecological and social value both on land and in the ocean.	4. Qualitative assessment, but not disputed.
5. The ACOE approved aforestation as compensatory mitigation in the Kilo Wharf Extension Project	5. a. Statisticians and determined that the statistical methods used to establish inputs to the HEA were statistically flawed. The HEA outputs are flawed due to the flawed inputs. b. Comprehensive watershed assessment was not

Watershed Projects	
Pros	***Counterpoints/Cons***
	completed until after the Cetti watershed was selected and there is still very little known about the stressors affecting coral communities in Cetti Bay. c. The Forest Service has suggested that the project would not necessarily significantly reduce the sediment delivered to Cetti Bay unless other actions like culvert redesign and other restoration projects are implemented outside the project area. d. The decline of coral in Cetti Bay has been attributed to extreme sediment loading to the Bay resulting from a project to reconstruct Route 2A. The project was completed almost 20 years ago and for the most part the annual sediment delivery has returned to pre- construction levels, with no apparent improvement in the coral community. There are likely to be other factors such as fresh water delivery form impervious road surfaces. e. Reliance on non-Navy agencies for implementation in accordance with the Cooperative Agreement and the ACOE permit has not been successful. The benefits of having GOVGUAM as sole-source contractor have not been realized. f. The ratios applied in the agency Kilo Wharf Extension HEA for aforestation were based on "personal communication" not peer reviewed literature, or actual data.
7.	7. The proposed projects are in a different watersheds, as well as completely different types of habitat than the area of coral loss. The Compensatory Mitigation for Losses of Aquatic Resources; Final Rule states that when compensating for impacts to marine resources, the location of the compensatory mitigation site should be chosen to replace lost functions and services within the same marine ecological system.
8.	8. Implementing a mitigation project on non-DoD land/submerged land is problematic because the land purchase would require congressional approval and conservation easements would not be legally binding in perpetuity.
9.	9. Watershed project does not represent "in-kind" replacement of lost coral function. A project may directly improve water quality at some level and a secondary impact may be coral recovery/productivity.
10.	10. No evidence that that watershed improvement projects would replace functions and services of similar type and quality as the Apra Harbor coral.
11.	11. Water quality may not be the only factor in the loss of coral in at the mitigation sites proposed,

Watershed Projects	
Pros	***Counterpoints/Cons***
	particularly as they are located on open coastlines subjected to other severe oceanic/meteorological impacts. There is no guarantee that watershed projects would be sufficient to restore coral. Some coral have a high tolerance for sediment.
12.	12. Difficult to tie success or lack of success of coral restoration to a single watershed project or water quality parameter; particularly with other ongoing environmental stresses. Mitigation plan requires ecological performance standards.
13.	13. The lack of scalable restoration information as described under Item 3. hinders the ability to conduct a HEA analysis. HEA is the method preferred by some agencies for assessing loss and replacement.
14.	14. The potential watershed restoration areas are on essentially open coastlines (as opposed to sheltered areas like most of Apra Harbor). As a result, they are subjected to the destructive force of typhoon generated waves, as well as fresh water discharge, that are completely natural phenomena that affect reef structure throughout the Island. For instance, the changes to reef structure in Hawaii from Hurricanes Iwa and Iniki were more influential than anthropogenic stresses. This is a problem when trying to separate natural disturbances on the reefs from anthropogenic, and hence cannot come up with ratios of mitigation/improvement. This also influences measurement of successful outcomes. If the coral does not return, the water quality may be improved but the mitigation fails.

Table 3: Artificial Reefs as Compensatory Mitigation

Artificial Reefs	
Pros	***Counterpoints/Cons***
1. In-kind replacement of coral function. There is scientific literature to support the hypothesis that artificial reefs can be as productive as natural reefs over time. Corals grow on artificial materials in Apra Harbor.	1. a. Artificial Reefs are not a replacement of coral function, but a fish aggregating device (FAD) that would not increase productivity. b. Artificial reefs in Apra Harbor have not been successful.
2. In-place (Apra Harbor) replacement of coral function is preferred. There is sufficient contiguous area based on preliminary siting studies. The Compensatory Mitigation for Losses of Aquatic Resources; Final Rule states that when compensating for impacts to marine resources, the location of the compensatory mitigation site should be chosen to replace lost functions and services within the same marine ecological system.	2. "In –place" is not a requirement.
3. ACOE has recently approved artificial reefs as compensatory mitigation for coral loss in Hawaii, same district (referred to as Haseko mitigation).	3. The Haseko mitigation is not applicable. For more details on this memorandum of agreement see Section 3.4.1.
4. a. The artificial reef structures provide the basis for restoration of functioning coral reef ecosystem. Structure is the precursor to function. Ecological function is difficult for anyone to assess and quantify. Ecological functions change over time. b. Providing fish habitat is one of the most obvious ecological function of natural reefs. An artificial reef that attracts fish would meet that function. If the structure does serve initially as a FAD it does not diminish the function of the coral reef ecosystem. The increased area for foraging in a place where fishing is restricted would be a functional benefit to the larger Apra Harbor ecosystem. If the fish are attracted to the artificial reef, the implication is that existing natural reefs are at or near carrying capacity. There are reports of fishing pressure in Apra Harbor and diminished fish populations, which suggest the reefs are not at carrying capacity.	4. a. Artificial reefs do not replace function they only provide structure and serve as a FAD. b. The FAD would simply attract fish from other suitable habitat and be an easier target for fishing at the artificial reef site, which is already suffering from fishing pressure.
5. There is scientific data from artificial reef installation projects in Hawaii and other tropical areas that provide a basis for quantifying the ratio of reef structure restoration to loss of coral function.	5. There is scientific literature that artificial reefs are not successful in providing new production.
6. Success/lack of success is directly measurable overtime. Avoids the need to assess primary (water quality improvements) and secondary (coral) as with watershed projects.	6.
7. Project would be in Navy submerged lands where access (including fishing) can be controlled.	7.
8. Appropriate artificial reef siting is critical to its success. A Navy study prepared during preparation of the Kilo Wharf Extension EIS, identified suitable artificial reef locations within Outer Apra Harbor. Additional siting studies to identify the most suitable site may be required.	8. There are illegal artificial reefs in Apra Harbor that are not successful.

Artificial Reefs	
Pros	***Counterpoints/Cons***
9. There is sufficient scientific literature on the scaling of restoration projects to be used as inputs to the HEA.	9.
10. Artificial reef placement is practicable and has been done.	10.
11. The Navy agreed to a trial watershed restoration project as mitigation for the Kilo Wharf Extension project. A comparable artificial reef project seems reasonable since the scientific community cannot agree on what mitigation actions have the potential to restore ecological function.	11.

Figure 4: Boundary of Guam Agency Proposed CVN Mitigation Area

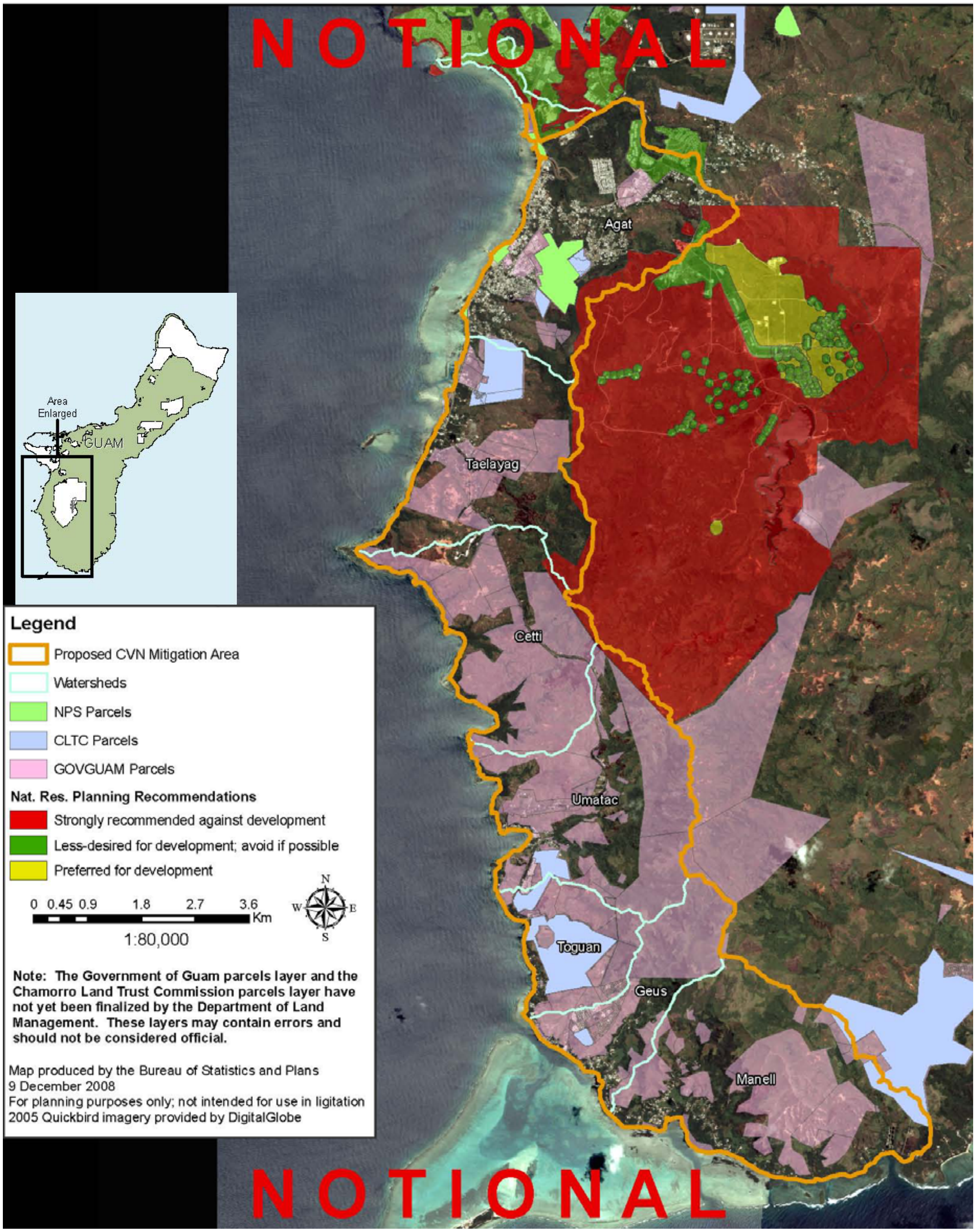


Figure 5: Mitigation Area: GOVGUAM Parcel Ownership

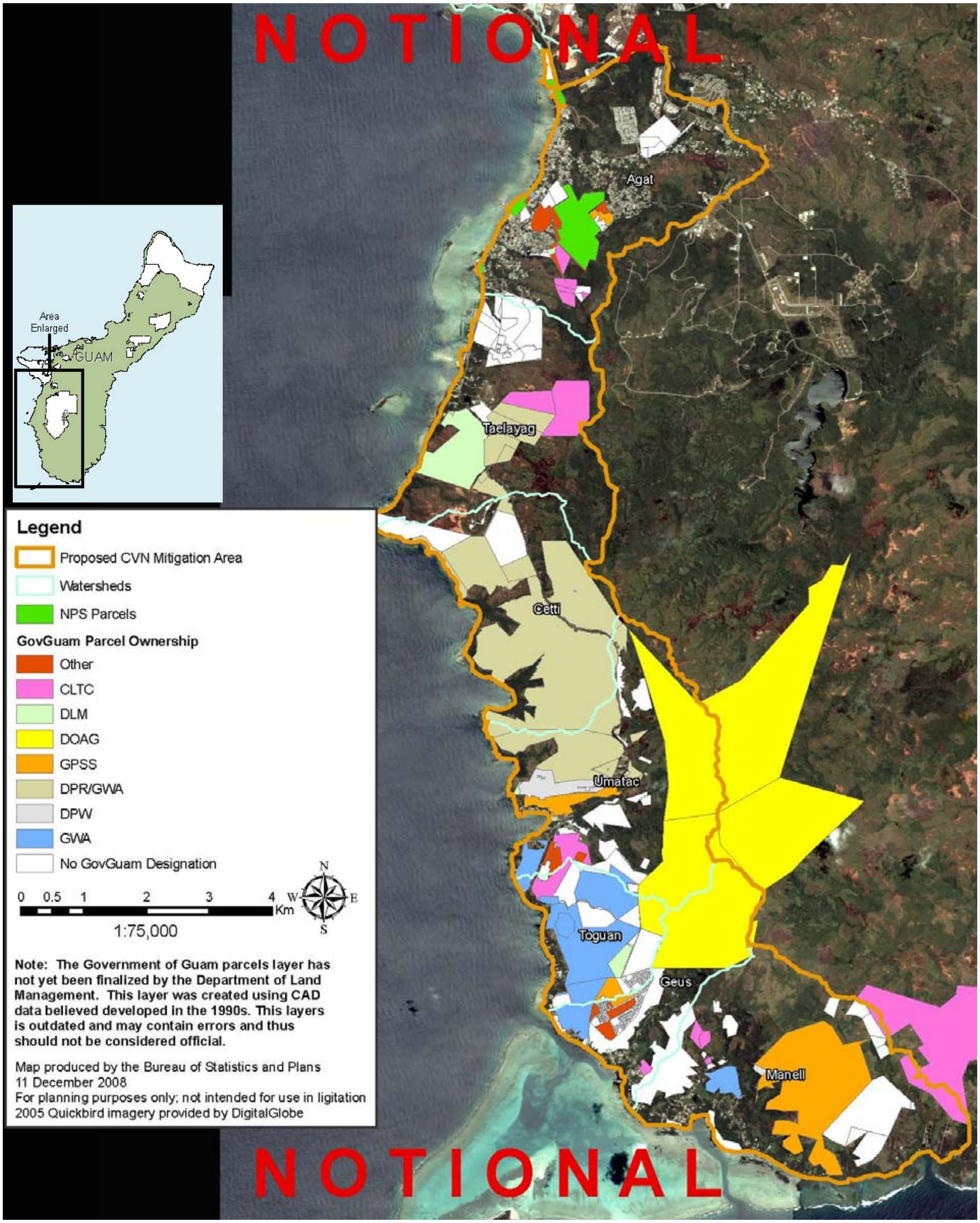


Figure 6: Mitigation Area: Riparian Buffers for Streams

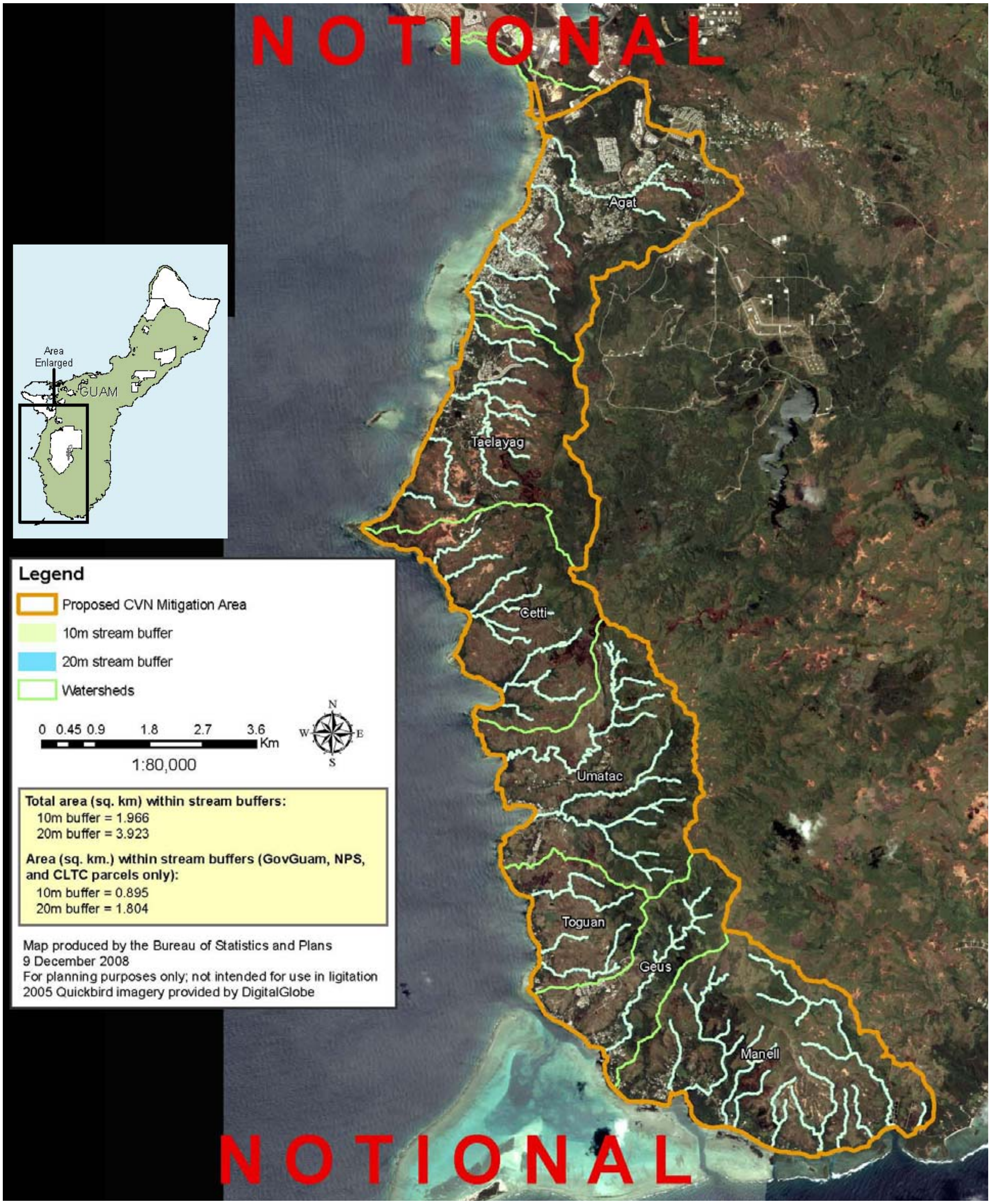
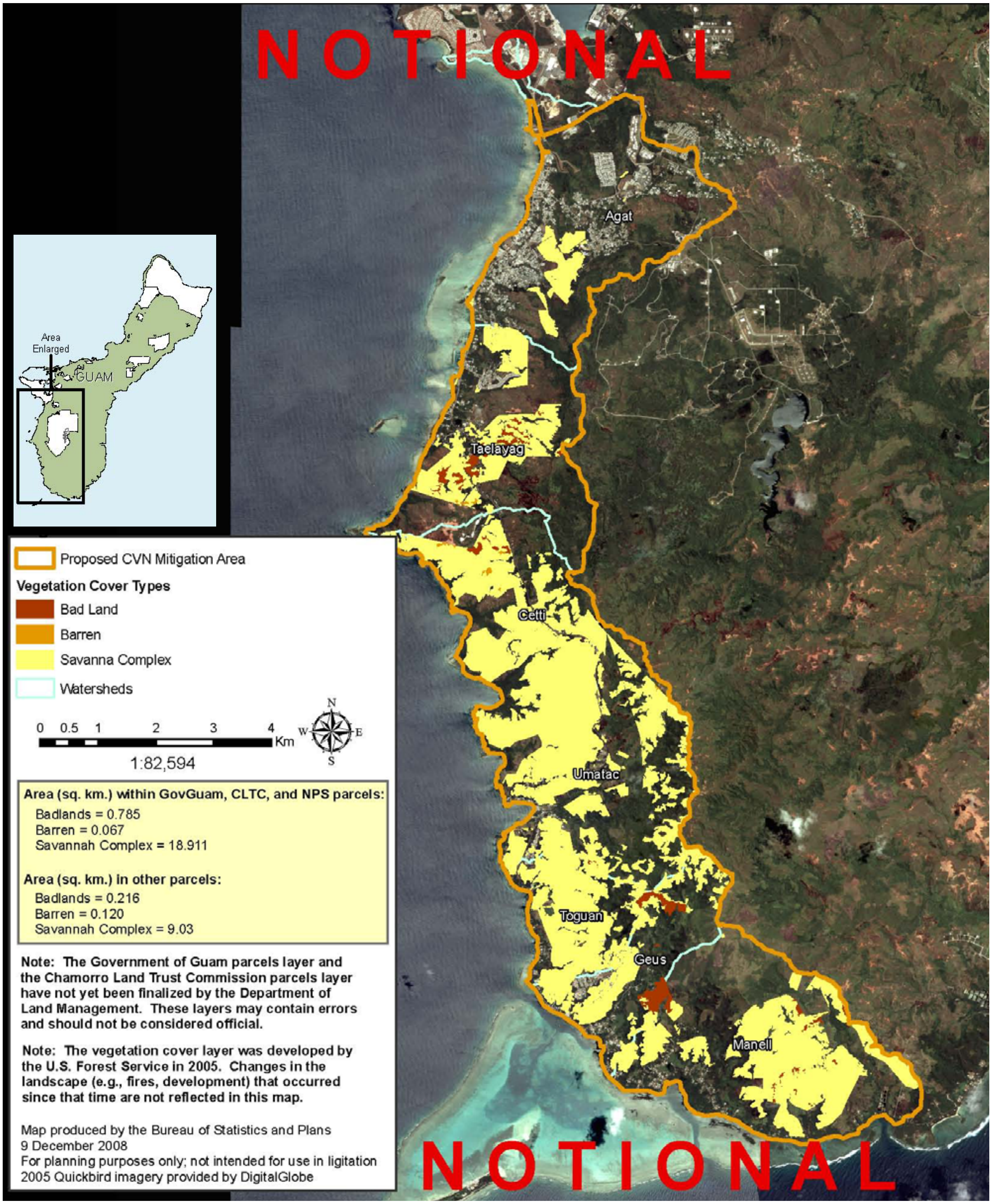


Figure 7: Mitigation Area: Vegetation Types



3.4 REPORT REVIEW AND REVISIONS

The HEA/CVN Administrative Working Group was provided an opportunity to review and comment on the *Draft Habitat Equivalency Analysis and Supporting Studies, Apra Harbor, Guam* document in 2008. The comments received and Navy responses are included in Appendix D. A January version of the *HEA and Supporting Studies Report* was prepared. It was included as an Appendix to the early review draft of *Guam and Commonwealth of Northern Marianas Islands Military Relocation Environmental Impact Statement/Overseas Environmental Impact Statement (EIS/OEIS)* that was distributed to cooperating agencies, in advance of release of the public Draft EIS/OEIS. Unfortunately, the agency review was concurrent with the incorporation of new data and revised HEA model into this August version of the *HEA and Supporting Studies* report, which is included the public Draft EIS/OEIS as Volume 9. The comments received in August 2008 from agencies were similar to those provided in November 2008, because the new field data had not been incorporated.

The most recent public Draft EIS/OEIS (NAVFAC Pacific 2009a) and this September *HEA and Supporting Studies* report address the agency concern regarding the use of percent coral as the only metric in the HEA model for assessing ecosystem function. Consideration of rugosity has been added. Additional field survey data was collected and incorporated to address agency concern that there was insufficient data. The field survey methodologies were peer reviewed to eliminate the concern regarding methodology.

There remain unresolved issues regarding the use of artificial reefs as compensatory mitigation or as means to develop a budget for compensatory mitigation.

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4.0 TECHNICAL REPORTS AND CONCLUSIONS

All of the technical reports are included in their entirety in the Sections B through F following the Introduction (Section A). Each Section has its own list of references, tables, figures and appendices. Important methodologies, assumptions and other details are contained in these sections and the following is a brief summary of the scope and key findings of each report:

SECTION B RECONNAISSANCE SURVEYS OF THE MARINE ENVIRONMENT, EASTERN OUTER APRA HARBOR, GUAM, BASELINE ASSESSMENT OF MARINE WATER CHEMISTRY, BY MARINE RESEARCH CONSULTANTS, PRIMARY AUTHOR: STEPHEN DOLLAR

A baseline set of water samples in the vicinity of eastern Outer Apra Harbor, Guam were collected in November 2007 and January 2008. Thirty stations were established in a grid within the area containing the proposed turning basin and entrance channel for the proposed CVN berthing. Stations were also established in Inner Apra Harbor. At each station samples were collected at the surface, mid-depth and near the bottom and analyzed for turbidity and Total Suspended Solids (TSS). In addition, during the November samplings, vertical profiles of temperature, salinity, dissolved oxygen, and pH were acquired at each of the thirty stations using a conductivity temperature and depth meter (CTD). This section was not updated in September 2009.The results were as follows:

- Results of analyses of turbidity and TSS reveal overall relatively low values throughout the area. Most values of turbidity were below 1 ntu, and most values of TSS were below 2 mg/l. Measures of turbidity and TSS indicated very little vertical or horizontal stratification within the region of study. Results indicated little effect on turbidity and TSS within the Outer Harbor from either the Inner Harbor or Sasa Bay. Stations that showed anomalously high values in November had low values in January, and vice versa of all water quality constituents within each transect. .

- Vertical profiles of temperature, salinity, dissolved oxygen and pH revealed influences of the Inner Harbor and Sasa Bay. A surface layer of low salinity, low temperature water was present in the Inner Harbor, but rapidly dispersed beyond the Inner Harbor entrance. A similar surface layer of low salinity, but not cooler water was present at the eastern end of the study area, revealing influence of westward flow from Sasa Bay. Overall, the effects from the freshwater sources were minor beyond the sources, and the uniform conditions characterized the study area.

- Overall, water quality in outer Apra Harbor, as characterized by the present baseline study was within the limits of compliance of the Guam Water Quality Standards. Several of the measured constituents exceeded specific criteria limits for marine water designated with the M-2 classification, which includes the area of Outer Apra Harbor in the vicinity of proposed CVN activities. It is likely that water quality will change as a result of changing seasonal conditions, particularly following episodic rainfall and runoff events.

Under section 303(d) of the Clean Water Act (Title 33, Chapter 26, Subchapter) 3) requires States/territories to development of a list of impaired waters. Fish advisories for PCBs were the only impairment listed for Apra Harbor and the priority assignment is low. No potential sources or Total Maximum Daily Load was provided. None of the other types of impairment were identified at Apra Harbor.

SECTION C ASSESSMENT OF THE AFFECTED MARINE ENVIRONMENT, OUTER AND INNER HARBOR, GUAM, BY MARINE RESEARCH CONSULTANTS, PRIMARY AUTHOR: STEPHEN DOLLAR

Relevant studies for the proposed project areas were reviewed and findings summarized. The presentation of findings included data not previously reported and generated specifically for the CVN project.

CVN Project Area

Additional field survey data was collected in Summer of 2009 and Section C was revised in August. A stand alone field study report was prepared, "*Assessment of the Benthic Community Structure in the Vicinity of the Proposed Turning Basin and Berthing Area for Carrier Vessel Nuclear (CVN) Apra Harbor, Guam*"(NAVFAC Pacific 2009b). This report will be included in the Draft EIS (NAVFAC Pacific 2009a), but is not included as an appendix to this HEA report.

Data from 67 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.

Table 4 shows the area coverage of each coral class in both square meters (m^2) and acres. Also shown is the percentage of each class with respect to the total area of coral coverage. Based on a benthic habitat map generated using multispectral properties of available satellite remote sensing imagery, about 25% and 24% of the area to be dredged contains some level of coral coverage for the Polaris Point and Former SRF Alternatives, respectively. The coral assessment was to a water depth of 60 ft (18 m) within the dredge area, which is an overestimate relative to the proposed dredge to -51.5 ft (15.7 m), including overdredge. The profiles of coral abundance are similar for both CVN wharf alternatives (Table 4).

The limit of potential indirect impact was delineated 656 ft (200 m) from the direct impact area perimeter. Indirect impacts would likely be due to the dispersion of suspended solids outside of the dredge area. Coral assessment within the indirect impact was also to the 60-ft (18-m) depth.

In both alternatives, the single highest percentage class is the lowest abundance class (>0 to ≤10% cover) which comprises about 37% of area with coral for the Polaris Point alternative and 36% for the Former SRF alternative. In both alternatives, over half (61-62%) of coral cover is within the less than 30% cover classes. Table 4 shows the area coverage of each coral class in both square meters (m^2) and acres. Also shown is the percentage of each class with respect to the total area of coral coverage.

Table 4: Coral Cover in Six Levels for Direct and Indirect Areas at Former SRF and Polaris Point

Coral Level	*FORMER SRF*					
	Direct		*Indirect*		*Total*	
	m^2	*acres (% coral[1])*	*m^2*	*acres (% coral[1])*	*m^2*	*acres (% coral[1])*
Coral = 0%	**149,841**	**37.03**	**189,026**	**46.71**	**338,867**	**83.74**
0% < coral ≤ 10%	34,445	8.51(36)	53,436	13.20 (28)	87,880	21.72 (31)
10% < coral ≤ 30%	24,123	5.96 (25)	37,204	9.19 (20)	61,327	15.15 (21)
30% < coral ≤ 50%	9,274	2.29 (10)	34,502	8.53 (18)	43,776	10.82 (15)
50% < coral ≤ 70%	18,190	4.49 (19)	44,628	11.03 (23)	62,819	15.52 (22)
70% < coral ≤ 90%	10,051	2.48 (10)	21,266	5.25 (11)	31,317	7.74 (11)
Total with coral	**96,083**	**23.74**	**191,036**	**47.21**	**287,119**	**70.95**
Total dredge area	**245,924**	**60.77**	**380,062**	**93.92**	**625,986**	**154.69**
Percent coral cover:		**39%**		**50%**		**46%**

Coral Level	*POLARIS POINT*					
	Direct		*Indirect*		*Total*	
	m^2	*acres (% coral[1])*	*m^2*	*acres (% coral[1])*	*m^2*	*acres (% coral[1])*
Coral = 0%	**186,065**	**45.98**	**219,997**	**54.36**	**406,063**	**100.34**
0% < coral ≤ 10%	37,411	9.24 (37)	54,541	13.48 (29)	91,953	22.72 (32)
10% < coral ≤ 30%	26,058	6.44 (26)	38,523	9.52 (21)	64,581	15.96 (22)
30% < coral ≤ 50%	9,590	2.37 (9)	32,527	8.04 (17)	42,117	10.41 (15)
50% < coral ≤ 70%	17,960	4.44 (18)	41,898	10.35 (22)	59,858	14.79 (21)
70% < coral ≤ 90%	10,950	2.71 (11)	19,642	4.85 (11)	30,591	7.56 (11)
Total with coral	**101,969**	**25.20**	**187,131**	**46.24**	**289,100**	**71.44**
Total dredge area	**288,034**	**71.18**	**407,128**	**100.6**	**695,163**	**171.78**
Percent coral cover:		**35%**		**46%**		**42%**

[1] *coral percent are rounded to nearest percent; therefore total coral % may not be exactly 100%.*
Source: NAVFAC Pacific 2009b

Coral mean size (maximum measurement parallel to the sea floor) is relatively small (8.6 inches [22 cm]) in the proposed turning basin locations, 8.26 inches (21 cm) for the navigation channel, and 6.3 inches (16 cm) for the Polaris Point area. Anchor damage was reported throughout the proposed project areas especially in the Former SRF area in the vicinity of the dry dock that is moored south of Big Blue Reef.

The navigation channel and proposed 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 named Jade Shoals, Western Shoals, and Big Blue Reef. These reefs are outside of the project area. As observed with the coral in the channel bend, the abundance of coral is less on the edge nearest the existing navigation channel versus the edge furthest from the ship traffic.

Inner Apra Harbor Projects

Impacts to the sessile communities found on the man-made structures within Inner Apra Harbor (i.e. piers, pilings, etc) will be short term and localized and will not be included in the HEA. The communities affected during the repair actions associated with the waterfront improvements are anticipated to recolonize quickly. It is anticipated that the coral lost from these structures during wharf improvements would eventually be replaced by new colonies. No compensatory mitigation is proposed for coral loss in Inner Apra Harbor.

The proposed dredge area fronting Sierra Wharf is characterized by fine-grained mud that is typical of the floor of the Inner Apra Harbor basin. Organisms that inhabit these habitats are either infaunal, residing within the mud, or epifaunal, residing on the sediment surface, and the potential additional deposition of sediment associated with dredging would not represent a change in habitat integrity. Any impact to infaunal or epifaunal organisms would be short-term and localized.

Based on the Inner Apra Harbor data that suggests the impacts to Inner Apra Harbor would be short-term and localized and a HEA was not warranted.

SECTION D MARINE ECOSYSTEM IMPACT ANALYSIS CVN PROJECT OUTER APRA HARBOR, GUAM, BY MARINE RESEARCH CONSULTANTS, PRIMARY AUTHOR: STEPHEN DOLLAR

The impact assessment was limited to the CVN project areas and did not include the Inner Apra Harbor project area. The report was updated in August 2009 to reflect July 2009 field survey data (NAVFAC Pacific 2009b). Table 4 summarizes the coral assessment data within the area of direct dredging impact and the area of indirect impact. The area of coral within the direct impact area would be removed.

The indirect impacts would likely result from dispersion of sediment outside of the direct impact area. Review of the scientific literature to identify deleterious sedimentation rates on corals revealed that there was no specific threshold level of sedimentation that resulted in coral mortality. The literature review (described in Section D) did reveal, however, that negative effects of sediment loading to reef corals were dependent on both the duration and the rate of sediment deposition. As expected, the general trend is that the higher the deposition rate, and the longer the period of deposition, the greater the effect. Threshold rates cited in the literature range from 5 mg/cm^2 per day to 100 mg/cm^2 per day. Analysis of possible total sediment accumulation during the project (Section E) indicated that accumulations of greater than 1,000 mg/cm^2, or ¼ inch (6 mm), were confined to within 75 ft (23 m) of the dredge limits at Polaris Point, and to within 39 ft (12 m) of the dredge limits in the rest of the project area. The modeling indicated that sedimentation exceeding 40 mg/cm^2 or 0.008 inch (0.2 mm) extended an average distance of 144 ft (44 m) from the dredging.

For an assessment of indirect impacts, it is assumed that the area of indirect impacts will encompass an area 656ft (200 m) wide surrounding the direct impact dredge area. The area of coral within the indirect impact area that is shallower than 60 ft (18 m) is assumed to be temporarily lost due to indirect dredging impacts, due to increased sediment in the water column. Compared to the modeled sediment dispersion contours described above and in Section E, the size of this designated indirect area is approximately 16 times larger than the modeled indirect impact. A combination of several factors are considered to suggest that the area of actual indirect effect would be considerably smaller, including:

- inherent physiological tolerance of corals to sediment, which includes the ability to remove sediment from living tissue,
- likely sediment composition that will released during dredging (i.e., sand and limestone silt) has been shown to have low impact to corals,
- short duration (~1 day) of dredging at a particular location 990 ft^2 [92 m^2],
- current velocity sufficient to aid in sediment resuspension and removal, and
- steep reef slopes that promotes removal of sediment rather than accumulation in areas of high coral cover.

It is also unlikely that the project would result in a significant overall decrease of reproductive potential (i.e., coral spawning) of the Apra Harbor community. The area of potential effects comprises a relatively small fraction of the total reef area of Apra Harbor. In addition, it has been documented that the non-living benthic surface in the CVN area is covered in large part, by soft sediment that is not a suitable substratum for coral planular settlement. The duration of increased sediment at a particular location is expected to be short, with plumes restricted in size, so that potential impacts to reproductive cycles will not prolonged. In addition, to date the coral community in the potentially affected area has not been documented to be comprised of unique species that could be lost from the Apra Harbor system. As the project area was dredged in 1946, the existing community is the time-integrated response to a previous action that was substantially greater in magnitude, but similar in an operational sense as the proposed action. Hence, the existing coral community structure provides a good estimate of expected pattern of response and recovery to the proposed actions.

SECTION E CURRENT MEASUREMENT AND NUMERICAL MODEL STUDY FOR CVN BERTHING, BY SEA ENGINEERING INC., PRIMARY AUTHOR: MARC ERICKSEN

A detailed current measurement program and numerical modeling analysis were completed to evaluate possible environmental impacts of dredging for the planned construction of CVN capable berthing in Apra Harbor. This section was not updated in August 2009. Analysis and interpretation of the data revealed that currents and circulation in the project area are characterized by the following features:

1. Currents are predominantly wind-driven, and occur as a two-layer system. The surface layer flows in the direction of the wind, and the deeper layer flows in the opposite direction. During typical trade wind conditions, surface flow is to the west out of the harbor, while deeper flow is directed to the east, into the harbor. The exception to this is the entrance channel to the Inner Apra Harbor, where currents may reverse with the tides. Local bathymetric features and pronounced reef shoals also control local current directions.
2. Currents in the project vicinity are normally weak. During trade wind conditions surface currents were typically 0.1 ft /second (s) to 0.3 ft/s (4 to 8 centimeter / second (cm/s)) while bottom layer currents were typically 0.01 ft/s (2 cm/s) to 0.1 ft/s (4 cm/s).
3. The measured currents at all locations were characterized by complex patterns. There were numerous occurrences of sharp spikes in the current speeds and shifts in current direction.
4. Tidal effects are small in the harbor basins, but are important in the entrance channel to the Inner Apra Harbor, where currents may reverse with the tides.

A three-dimensional circulation and transport model of the project area was developed using the Environmental Fluid Dynamics Code. The model included wind and tide forcing, and fresh water inflow into the inner harbor; the dredge plume was simulated by loading the water column with specified quantities of suspended sediment composed of five different grain sizes. The sediment grain distribution was determined from bottom samples taken in the project area. The model calculated transport, dispersion and deposition of the plume of suspended sediments. The model was verified by comparing results for a simulation of December 15 to 17, 2007 trade wind conditions with the actual instrument measurements. The model reproduced both the general circulation patterns indicated by the current meter data, as well as typical current velocities measured in the bottom and surface layers in the project vicinity.

Fifteen model cases were completed, bracketing a range of wind forcing conditions, dredging duration, production rates and dredge locations, and suspended sediment release. Dredging was simulated as a 24-hour continuous operation resulting in dredging of 1,800 cy (1,376 m^3) per day, and a 10-hour operation resulting in 1,000 cy (760 m^3) in a day. Wind forcing included typical trade winds, strong trade winds, south winds and calm conditions. Silt curtain effectiveness was simulated based on 145 days of TSS measurements inside and outside of the silt curtain deployed for the Alpha-Bravo Wharves dredging project in Inner Apra Harbor. These measurements showed that the silt curtains retained 90% of the material inside of the curtain. Model computed TSS levels compared well with the Alpha-Bravo Wharves project measurements outside the silt curtain. Possible worst case conditions were simulated by approximating the highest 10% TSS levels recorded outside of the silt curtain during the Alpha-Bravo dredging project, during strong trade wind conditions. Model runs were completed for nine different locations throughout the project area. Results of the modeling are summarized below:

- Sediment deposition resulting from the dredging is largely confined to the immediate vicinity of the specific dredge site. Maximum sediment deposition of 1,742 mg/cm^2, or 0.4 inches (10 mm), was calculated assuming 24 hours of dredging at a rate of 1,800 cy/day (1,376 m^3/day) (Model case 6.3). The modeling indicated that sedimentation exceeding 40 mg/cm^2, a cited threshold for coral impacts, extended an average distance of 144 ft (44 m) from the dredging.
- Thickness of substrate to be dredged is only 1.6 to 3.3 ft (0.5 to 1 m) throughout most of the project area. Dredging would therefore pass rapidly from site to site; a 75.5 x 75.5 ft (23 by 23 m) grid area would require only a half day for dredging. This means that exposure to sediment plumes and significant sedimentation (greater than 40 mg/cm^2 per day) would be limited to only one or two days. The exception to this is at the Polaris Point coastline, where sediment thicknesses of 13 ft (4 m) or greater are to be dredged.
- Analysis of possible total sediment accumulation during the project indicates that accumulations of greater than 1,000 mg/cm^2, or 0.2 inches (6 mm), are confined to within 75.5 ft (23 m) of the dredge limits at Polaris Point, and to within 32.8 ft (12 m) of the dredge limits in the rest of the project area.
- Surface TSS plumes exceeding background levels of 0.0004 ounces/gallon (3 mg/L) are generally predicted to occur only directly at the dredge site. Plumes near the bottom are more extensive because most of the suspended sediment is released into the bottom layer, and it also receives all of the TSS contained by the silt curtain. Plume concentrations exceeding the background levels of 0.0004 ounces/gallon (3 mg/L) typically extend 262.5 to 394 ft (80 to 120 m) from the dredge site. The plumes dissipate rapidly following completion of the dredging.
- Worst case conditions were simulated by increasing the sediment release rate from 1% to 2%, and decreasing silt curtain effectiveness by a factor of four. This approximates the highest 10% TSS measurements recorded outside the silt curtain during recent dredging at Alpha-Bravo Wharves. During these conditions, maximum sediment deposition at the dredge site is 2,690 mg/cm^2, or 0.6 inches (16 mm), and deposition greater than 40 mg/cm^2, or 0.008 inch (0.2 mm), occurs to a distance of 262.5 ft (80 m) from the dredge site. Surface and bottom TSS concentrations exceeding typical background levels of 3 mg/L extend 262.5 to 328 ft (80 to 100 m) from the dredge site, respectively.

This numerical analysis was designed to approximate, to the extent practical, the dredging that may occur during the CVN project. The circulation model was verified with actual current data recorded in the project site. The sediment grain size was derived from numerous bottom samples collected in the area. Actual, recorded winds and tides were utilized as model inputs. TSS released into water was verified with measurements from the Alpha-Bravo Wharves dredging project. To bracket the range of possible conditions that may occur during the dredging, model cases were completed varying wind forcing and the dredging site, and approximating a worst case scenario. During the actual dredging operations, however, different wind, current, bottom sediment, dredging and other environmental or operational conditions may occur that are not captured in our modeling analysis. Model results are therefore not exact predictions of what would occur, but rather approximations based on the best available information and methodologies.

Analysis of grab samples collected within the turning basin area indicated that approximately 90% of the surficial sediments were very fine sand sized or coarser, and had a median grain size of approximately 0.1 mm (very fine to fine sand). Sediment cores from the same area classified the material as well-sort sand consisting of 73% sand and gravel and 17% silt (Weston Solutions, 2006). This data suggests that most of the material on the seafloor in the turning basin area that may be impacted by tug-assisted aircraft carrier maneuvering is sand-sized or greater, thereby minimizing the extent and duration of possible plumes that may result from vessel operations. The operational impacts would be short-term, localized and infrequent.

SECTION F HABITAT EQUIVALENCY ANALYSIS (HEA) MITIGATION OF CORAL HABITAT LOSSES, BY INDUSTRIAL ECONOMICS INC. PRIMARY AUTHORS: HEIDI CLARK AND MICHAEL DONLAN

Under the new Army Corps of Engineers compensatory mitigation rule, permit applicants are required to mitigate to no net loss of ecological services and function. Habitat Equivalency Analysis (HEA) is a methodology that has been used in a variety of legal and technical contexts to quantify impacts to natural resources and the services/functions they provide, and quantify the amount of restoration/mitigation required to offset documented losses. Coral loss assessment, coral restoration and the parameters used in the HEA are an evolving science. HEA, like any model, relies on user-specified inputs and calculations that simplify complex processes, both of which can introduce uncertainties into model results. However, HEA applications have been published in peer-reviewed technical literature, courts have upheld the use of HEA in litigation, and HEA often underlies settlements reached on cases involving the impacts to and restoration/mitigation of natural resource services and functions. The United States Fish & Wildlife Service (USFWS) and other agencies commonly use HEA to establish the appropriate scale of compensatory restoration in the context of damage assessments conducted under the 1990 Oil Pollution Act (OPA) and the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA), and have endorsed the use of HEA in other Navy dredging projects in Apra Harbor

The HEA addresses direct and indirect impacts to coral habitat arising from dredging to support CVN berthing and maneuvering in Outer Apra Harbor. The Navy's inputs to the HEA are based on site-specific data and analyses, information from relevant literature, and the professional judgment of technical experts.

No HEA was conducted for the Inner Apra Harbor projects for the following reasons:

- Best available data suggests the coral communities in Apra Harbor are growing on manmade vertical wharf structures. There are no coral reefs in Inner Apra Harbor (Belt Collins 2003).

- The substrate in Inner Apra Harbor is soft sediment and any impact to soft bottom communities would be short-term and localized.

The estimated input values for the variables needed to perform HEA for the CVN project loss calculations, included:

- The acreage of coral habitat expected to be affected by dredging, including direct (dredging) and indirect (dredging-related sedimentation) impacts;
- A combined metric, coral habitat index, that includes live coral coverage, three dimensional surface area and rugosity (a measure of the topographic complexity of the reef surrounding the sample point) to establish 10 categories of complexity in coral habitat. Category 1 represents the least coral cover and least complex structure and Category 10 represents the greatest coral cover and most complexity;
- The expected severity and duration of expected impacts, relative to baseline conditions (i.e., the anticipated future condition of coral habitat in the project area if the CVN project never occurred); and
- The shape of the recovery curve, the period over which losses are calculated, expected project timing and an appropriate discount rate.

This analysis focuses on the coral habitat expected to be either permanently lost due to dredging or temporarily affected by sedimentation. The analysis was and report was revised in August 2009 to reflect the new field survey data and a revised approach.

The Polaris Point Alternative is expected to result in a loss of approximately 1,048 discounted service acre-years (DSAYs) [1] of coral habitat (across all coral habitat categories), approximately 996 DSAYs due to direct impacts and 52 DSAYs due to indirect impacts. The Former SRF Alternative is expected to result in a loss of approximately 1,023 DSAYs (969 DSAYs due to direct impacts) and 54 DSAYs due to indirect impacts.

The HEA used artificial reefs as a restoration project. Results indicate that a total of approximately 123 acres (497,765 m^2) of artificial reef are required to compensate for coral reef habitat impacts due to the CVN Polaris Point Alternative. Approximately 121 acres (489,672 m^2) of artificial reef would be required for mitigation of impacts due to the Former SRF Alternative.

[1] The "acre years" metric commonly used in HEA applications provides a spatial and temporal measure of ecological impact to affected habitat. The inputs and calculations underlying HEA "acre year" estimates are described in more detail in subsequent sections of this document. The use of "100% live coral equivalents" normalizes affected coral habitat acres to account for differences in live coral coverage. This metric is discussed in more detail in Section F.

5.0 REFERENCES

Belt Collins 2003. *Final Environmental Assessment Inner Apra Harbor Maintenance Dredging, Guam.* October 2003.

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NAVFAC Pacific 2009a. *Guam & Commonwealth of Northern Mariana Islands Military Relocation EIS/OEIS. November 2009.*

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APPENDIX A
HEA/CVN Administrative Working Group Meeting Records

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USMC Relocation EIS/OEIS
Conference Call –Partnering Meeting
Apra Harbor Projects
March 25, 2008

Attendees

(See attached)

1) Read –aheads provided March 22, 2008 (TEC FTPsite):

- Ecological Assessment of Stony Corals and Associated Organisms in the Eastern Portions of Apra Harbor, Guam August 2007
- PowerPoint presentation "Proposed Military Buildup Apra Harbor Projects"
- DRAFT CVN-capable Berthing Study January 2008, released March 22, 2008.
- Note: There were some problems with downloading the information from the FTP site and it was cleared before some come access it. No better alternative was proposed for relaying large files.

ACTION: Upload files again to FTP (FAITH March 26) and forward notification to partners (VANESSA) – Completed March 26, 2008.

2)Purpose

- Introduce Apra Harbor projects
- Request coral mitigation cost estimate
- Request point of Contacts to participate in future Coral /EFH working group for Apra Harbor Projects
- Present past and future planned actions for marine survey work to support the Apra Harbor projects. Request comments/ list of information (short of 100% design) that would allow a less than "worse case" scenario assumption for the entire project or parts of the project when assessing impacts.

2) March 25 Meeting Objectives:

- Share project descriptions including dredging of Apra Harbor projects:

DRAFT DELIBERATIVE FOR DISCUSSION ONLY: Not releasable through FOIA

Conference Call *USMC RELOCATION EIS/OEIS*

  - CVN (Summarize CVN-capability Berthing Study)
  - Victor/Uniform
  - Sierra/ Tango
  - Oscar/Papa
  - Amphibious ramp

- **Questions:**

  - Clarification of individual graphics
  - CVN- alternatives. Section 404 1B has higher standard for alternatives analysis than NEPA. What other sites were considered? ACTION: Navy will provide site selection reports (Vanessa).
  - What stormwater systems are proposed for new construction? ACTION: Respond to EPA (Vanessa)
  - Where will dredged material be disposed? Response: either upland or ODMDS. Has dredged material been tested for ODMDS disposal? Some sediment testing has been done and results indicate that at least some of materials would be suitable for ODMDS. There was a PCB plume at Sierra /Tango and Ship repair facilities tend to release contaminants. ACTION: provide EPA sediment testing reports (Vanessa).
  - Are there existing amphibious ramps? No
  - Appreciate being involved early, but couldn't it have been earlier? Why didn't agencies see SOWs before now? There just wasn't enough time for the outside review. A meeting was schedule in December to discuss survey plans but was cancelled because of Kilo Wharf meeting obligations. Navy tries to communicate early but when doing feasibility studies –it is often too early to be asking for agency comments because the project may be infeasible.
  - If SOWs are being modified, EPA would like to review them and provide comment. ACTION: EPA to provide comments on Natural Resources SOW to Vanessa.
  - The CVN report is great information as long as the plans don't change. Agencies need as much "Final" engineering design and construction details as possible to avoid asumming "worst case scenario". Navy is

moving toward design-build, so there will not be a 100% design available for review. Agencies can help by providing a list of what is needed to scale back from a worst-case. ACTION: Agencies will provide a summary of data gaps.

- Can turning basin be in Outer Apra Harbor prior to bend since it is tug assisted the entire way? ACTION: Ask engineers/operators (engineers response forwarded to Vanessa March 26, 2008).
- Coral Mitigation Cost estimate: Kilo wharf may be a good basis but indirect impacts were greater than direct. Agencies understand budget programming requires cost estimates before impact analysis, but the cost estimate may not be sufficient for actual mitigation. Navy will consider estimates but can't guarantee that agency estimates will actually be submitted with the budget request. Agencies suggest an assumption of an indirect: direct impact ratio of 2:1, based on Kilo Wharf. ACTION: Agencies will work together to provide a gross cost estimate by April 9.

- ACTION: Agencies will provide POCs for a Coral /EFH working group by April 9.

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

Resource Agency Response to NAVFAC Information Requests Made at the CVN Briefing Meeting
March 25, 2008

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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

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Presentation:

Inner & Outer Harbor Marine Project Overview/Status

- proposed projects and dredging requirements (*Faith Caplan*)
- basis of water currents modeling (*Faith Caplan for Marc Ericksen*): Comments:
  - *current meters are inaccurate at shallow and deep depths*
  - *was historical data used*
  - *set up meeting to discuss model with Marc Ericksen of Sea Engineering.*
- status of benthic characterization (*Steve Dollar*)
  - *provide videos to USFWS for review*
- introduction of HEA objectives (*Michael Donlan by phone*) Comments:
  - *Data collected should have practical application to HEA. Certain parameters or level of detail are not applicable.*
  - *Discussion of potential mitigation projects does not have to wait for surveys.*
  - *Consensus required on the classifications of coral ecosystems that feed into HEA*
  - *Mitigation Trusts being established*

Discussion: Where do we need to go from here? (*Teresa facilitating*)
Actions were recorded on a note board. The list of NOTE BOARD items is on the following pages.

- Were all alternatives fully explored? M. Molina suggests an alternative at drydock island that would move the western coast of drydock island to the east and include fill. This would provide a wide channel away from coral and create a one way loop for the CVN. This would eliminate the need for a turning basin and dredging. Others suggest that it would likely impact the Sasa Marine Reserve that DOD does not recognize. GOVGUAM would object. M. Molina requested that it be considered.
- There is a lack of sufficient project data in the DOPAA or the March 25 presentation to evaluate impacts to the marine ecosystem, therefore the mitigation cost estimate agencies provided for the1391 estimate were based on a worst case scenario; that is the entire dredge footprint entire areas is covered with 100% coral. General discussion on what is required to back off from a worst case: fixed footprint, survey data, construction details, and operation details. In absence of project data, assumptions can be made and language can be incorporated in the contract documents. A follow on meeting with engineers is proposed to address these questions (June 6, 2008).
- Opportunity to update the 1391 budget. The CVN project is multi-year funded project.

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There is very little time to influence the 2010 budget request. Next year this time would be the opportunity to update the 1391, although this type of change is discouraged. Initial proposal was to conduct a rapid ecological assessment in the summer to provide sufficient data to influence the 2010 1391 budget. This type of data is not sufficient for DEIS impact analysis and on further discussion was abandoned for an additional reason that agencies could not meet the schedule.

- Schedule: Ideally, all data and impact assessment would be completed for DEIS. Impossible. Alternatively, half the survey might be completed in Fall '08 and described in the DEIS. The second portion of the survey would be completed Spring '09 and findings incorporated in the final EIS. The biggest challenge in meeting the schedule is the human resources qualified to conduct the survey. There are 3 staff at USFWS that can do surveys and they tend to lead two multi-agency teams in the field. USFWS is committed to other projects: CNMI (MARINES) and Kwajelein (ARMY) this summer and fall. USFWS will try to pull together teams and get back to the HEA group. Important to remember that the data analysis is also time consuming.
- USFWS will prepare a cost proposal for the work required to assess all Apra Harbor projects.
- Budget issues: funding years, sources, flexibility of use, paperwork and lengthy approval processes. Vanessa will explore options and line up approvals.
- Collaboration:
  - Navy participation on survey teams if possible
  - FDM example of good collaboration: survey together and S. Dollar prepare report. Goal is to move to that level of cooperation
  - Important to have only 1 impact assessment, 1 HEA etc
- Survey methodologies/logistics: Need regular meetings (similar to CNMI meeting) to reach consensus on survey details. The attendance would be those involved in the survey task. These meetings would be in addition to the bi-weekly HEA Working Group meetings. Faith/Dwayne will coordinate. Begin after proposal is received.

ATTACHED
NOTE BOARD
ACTION ITEMS 1-21 ATTACHED
ATTENDANCE- ATTACHED

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Interservice Coordination
- Region/JGPO/CPF overlapping projects *need to be addressed together*
- Polaris Point Magazines – has Sec 7 consultation been initiated?

Engineering/Design Operations
- Lines/chains dragging
- Barge operations
- Drydock
- Alternative locations for wharf

Mitigation/Injury

- Private land may be involved
- GovGuam interactions
- GovGuam involvement
- Mitigation trusts (in lieu of banking)
- Comprehensive list of potential projects
    - Connect to injury
        - Data/field work

⇒ Get started Now…

Project Team Coordination
- HEA team coordination
    - Mitigation assessment
    - Impact assessment
    - Need existing data collection methodologies
    - Collaboration impact assessment (via regular conference calls)
        - Define worst case
        - Define other habitats
        - Define roles/responsibilities

Data Gaps
- HEA inputs – replacing loss, life history
- Impact Assessments
    - Basic dredge area
    - Budget creation for 1391 development
    - Use existing data to refine assumptions

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- Define parameters (USFWS to propose in the workplan)

NOTE BOARD *CONT.*

Refine S. Dollar's study:
- Size structure
- Taxonomy
- Growth forms
- Density
- Areas affected
    - Direct
    - Indirect
        - Bathymetry
        - Currents data
        - Historical data… available?
- Community descriptors
    - Equivalence ratio => trade off values
    - Functional replacement
    - Locations/projects

Schedule
- Budgeting
- Mitigation planning
- Refine S. Dollar's data
- Field work… 3-4 weeks for two teams… 6-8 qualified divers
    - UOG
    - DAWR
    - USN
    - Local
    - FWS
    - NOAA
    - Other
- Meet with engineers to discuss engineering assumptions (June 6, 2008)
- CNMI – June/July survey with report due in August
- Currents/sedimentation meeting with Marc Ericksen
    - June 9th at 1 PM
    - Location: NOAA spaces
- DEIS acknowledges preliminary nature of data
- Determine availability of qualified personnel for dive study (USFWS)
- Can a quick baseline study be performed to be used by Feb 09?
- Ed Lynch needs good HEA estimate by Apr 09 to get updates into second round funding

Feb 08 Prelim Goal – basic data for DEIS ⇒ Feb 09 Field Study ⇒ **DEIS** Apr-May (8-10 weeks) ⇒ **HEA** May/June (2-4 weeks)

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Action Item #	Responsibility	Action
1	TEC-FC	Verify that engineers considered seismic conditions in CVN structural design
2	~~TEC-FC~~ PACFLT	CVN ship movement graphic
3	TEC-FC	Circulate munitions report (when available) to answer the question of whether increased operations are anticipated at Kilo due to Relocation
4	NAVFAC -VP	review LCAC laydown for mangrove impact
5	JGPO-TB	Verify the phasing of the JGPO marine projects to better assess survey schedule impacts
6	Ed Lynch (EL)	detail description of CVN/tug positioning and capabilites for CVN movement backwards anc sideways (agency question need for turning basin)
7	EL	Was dry dock island a CVN alternative? Could it be? (Motivation is to minimize loss of coral)
8	EL	Would off-loading planes reduce draft and decrease amount of dredging required? And is practical?
9	EL	Can mitigation cost estimate be adjusted in the FY 2011 budget?

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10	EL	Notify PACFLT additional funding for NAVFAC PAC may be required
11	CNM-Rick Raines	Check on status of NEPA documentation and Sec 7 consultation for magazines/pads propose Orote
12	CNM-Rick Raines	Check details on "pot of money" available for wharf improvments: what projects are propo: are the projects different from JGPO projects. JGPO master planners should be informed.
13	TEC-S.Dollar	Discuss with Dwayne (USFWS) bets way to share survey videos.
14	USFWS-DM	Prepare proposal and cost estimate to outline actions required to address data gaps for all A Habor projects. Availability of human resources will dictate whther there are 2 field events c (SEE item 14)
15	USFWS-Dwayne Mitton	Determine if there are sufficient human resources to conduct a Fall '08 survey
16	USFWS-DM	Coordinate/manage the biweekly logistics meetings to discuss field work details
17	NAVFAC - VP/JGPO	Explore funding options to identify most expedient and flexible. Get buy-in in advance from approval authorities
18	NAVFAC PAC-VP/FC	Coordinate manage biweekly HEA Working Group Meetings, beginning June 19 1st meeting J 19th @ 1300 incl:Michael Molina, Al Eversen, Mike Donlan, Mark Cruz, Guam EPA-Jesse Cruz Wendy W. (EPA)
19	TEC-FC	Ask Marc E to describe existing data & use in June 9 meeting
20	NAVFACPAC-VP	Confirm availability of Navy Biologist/Diver
21	EL	What is impact of a new wharf at former SRF on the dry dock? ED- believes there is a brief or subject.

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June 6, 2008

Purpose: Discuss engineering components of CVN project as requested by USWFS and NMFS on June 2, 2008

Attendance (attached)

Key Topics of discussion:

1. Data needs to assess impacts:
   - Potential for contaminated soils that require special dredging methods?
   - Dredge footprint
   - Total dredge area
   - Dredge methodology- including anchoring systems, dredge transport destination
   - Structural construction methods- including locations of piles, footings
   - Construction area
   - In water work timeframe: work day (8 hours?), workweek (Mon-Friday?), duration (months –which seasons?)
   - Is the dredge footprint delineated on graphics the actual limit of dredge activities? FS: ordinarily we would assume that there would be activities outside of footprint but in this case the proximity of coral would mean that dredging would have to be limited to within footprint shown. There are methods for dredging teams to carefully monitor their positions.
2. Need to work together to discuss site specific best management practices (BMPs):
   - Vanessa Pepi has a CD of BMPs that she will distribute. (ACTION)
   - Ideally, discussion includes the actual designers or construction contractors. Unlikely to have that input by October survey.

   - Timing of discussion best delayed until after the October survey. The additional information will help in development of BMPs and construction documents.
   - Recognize that contractor must retain flexibility over the bulk of the construction, but there is opportunity to insert language in contract documents.
   - The type of contract is unknown. Design-Build is less flexible than traditional. There is an RFP to initiate contractor support for the project.
   - These details are important to assess impacts and provide opportunity to influence design.
   - There are engineering resources in NAVFAC to meet with agencies and discuss BMPs.
3. Surveys are required:
   - there is little baseline information and historical data has limited value since the marine environment is so variable.
   - DOD pays for USFWS to meet Fish and Wildlife Coordination Act requirements
   - The intent is to document the existing conditions; not try to explain the conditions or assign blame for existing conditions.
   - There are documents on the more large scale status of coral reef conditions but these do not provide site specific data (*Status of Coral Reefs in the World*)
   - Assume only the sharp bend channel and two wharf positions are included in the October survey.
4. Alternative CVN locations:
   - All reasonable alternatives need to be identified and those that do not meet criteria for "reasonableness" are mentioned early in the EIS and dismissed from further evaluation. The analysis and rationale for dismissal must be documented and cited in the EIS.

- The key consideration for any project adverse impact avoidance. Navy has already considered alternative channel options and selected the one with least impact, wharf areas were also modified. Most recently, turning basins were reduced.
- Important to document specific changes to the project made to avoid impact. The recent turning basin minimizations will not be in the CVN feasibility study and need to: 1) be vetted through chain of command and 2) documented in a memo. (ACTION-PACFLT)
- Consider cut/fill at Drydock Island for new wharf to avoid turning basin dredging. The access to wharf would be via one-way loop:
  - The alternative may be "unreasonable" based on security, nuclear response (transport of radioactive material on public roads not allowed), insufficient laydown area, incompatible land uses, land acquisition/political aversion.
  - Economics alone is generally not adequate reason for dismissal, but it's the Navy that decides what costs are reasonable. Need to document the economic criteria. Alternative needs to be screened against test for "reasonableness". If it passes additional engineering studies are required- similar to the CVN feasibility study for SRF and Polaris Point
  - Is cut/fill less environmentally damaging than dredging coral? Depends on the site. The drydock site is man-made and predominately silty-sand; therefore, may be less environmental impact /mitigation
  - PACFLT will do the desktop test for reasonableness in the next few weeks (ACTION)
  - How many other alternatives will agencies propose? Navy does not want to keep chasing these alternatives. MM: In addition to Kilo, Echo/Delta, inner harbor wharves, EPA mentioned Glass Breakwater.

5. CVN maneuvering:

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   - Do you need a turning basin? Yes- it is at the minimum radius (length of ship).
   - Reverse is difficult for CVN operators. There is less control.
   - It does not have instant break systems. Full stop is gradual.
6. Schedule for construction:
   - 2011 begin construction
   - 3 year duration
   - Operational in 2014
7. Drydock and SRF:
   - If drydock cannot operate while CVN in port, then they will be compensated.
   - SRF also concerned about impact of blasting and dust on the CVN flight deck
   - SRF sees CVN as potential for more work
8. In partnering meeting, question asked if the draft could be reduced if the air wing flew off the ship; thereby reduce dredge requirement:
   - It would not impact the draft very much
   - The aircraft are accommodated by AAFB on space available basis.
9. Biweekly Survey/logistics meetings will commence in August

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Attendance Record

Date: June 6, 2008
Location: USFWS-HONOLULU
Subject: Engineering components of CVN

Name	Organization	Email
Francis Suganuma	Commander, US Pacific Fleet	francis.suganuma@navy.mil
Vanessa Pepi	NAVFAC Pacific	vanessa.pepi@navy.mil
Alan Everson	NOAA	alan.everson@noaa.gov
Dwayne Minton	USFWS	Dwayne_Minton@fws.gov
Michael Molina	USFWS	michael_molina@fws.gov
Kevin Foster	USFWS	Kevin_b_foster@fws.gov
Faith Caplan	TEC	fcaplan@tecinc.com

Purpose: Marc Ericksen of Sea Engineering presented the Environmental Fluid Dynamics Code (EFDC) current model for Apra Harbor and discussed next steps for developing scenarios to run to assess indirect impacts of plume transport. The basics of this information were presented June 2, 2008 to the HEA Working Group, but Marc was not present to answer questions.

Attendance (attached)

Key Topics of discussion:

1. Acoustic Doppler Current Profilers (ADCPs):
   - 7 water column ADCP vertical arrays located in Inner & Outer Harbor (See figure 1 location map)
   - Installed 11/01/07 to 1/30/08. Time period selected to potentially capture a change in season, but mostly tradewind conditions were observed. It would have been ideal to capture the non-traditional tradewind period; however, the EFDC model can effectively run these scenarios based on wind roses.
   - This data on currents is used to assess currents and circulation in the harbor, and verify (ground truth) the EFDC model.
   - ADCP measurements are not reliable at water depths within approximately 6% of the surface and 6% of the seafloor. There are other means to capture this data but all have limitations (fixed array at surface subject to vandalism and interference with navigation; drift drogues are labor intensive, and provide data only for the specific measurement period and path). The EFDC model is designed to address the dynamic conditions of shallow and bottom conditions. The ADCP data are used only as validation of EFDC model. The EFDC model correlates well with the rest of the water column data and the assumption is it does equally well at the bottom and top layers. The assumption is valid because the water column layer dynamics are inter-related. Whatever happens at the middle of the water column impacts what happens at the surface and bottom. The closed system of Apra Harbor with one access to open water allows for a greater degree of confidence in the model. EFDC is an EPA supported model that has been extensively tested and calibrated. Model information and a list of model applications and

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   calibrations is provided at the following EPA link: http://www.epa.gov/ATHENS/research/modeling/efdc.html
   - Sea Engineering will review previous data collected in the harbor including 6 days of drogue data from 1992 Sea Engineering study in the inner harbor vicinity.
   - Rain events during ADCP? No known significant events. Sea Engineering is checking data record.
   - Swells observed during ADCP? None observed but doubtful that a swell would have a significant impact on currents. It would be difficult to characterize. It may have impact on resuspension of sediment, but would be limited to shallow areas. The impact of swells would be greatest at the entrance to Outer Apra Harbor. Important to distinguish between current and surge. Surges do not increase the current rate. It is likely surges that have been observed washing over Western shoals. Concensus- it is not necessary to run a swell as a "worst case" in the EFDC.

2. **EFDC:**

The EFDC model is a water modeling system approved by the EPA incorporating fully integrated hydrodynamics. It has been extensively used in simulations of rivers, lakes, reservoirs, estuaries, coastal seas, and wetlands.

EFDC Characteristics:

- EFDC can solve for the circulation and transport of material in a complex environment
- 3-dimensional, which allows for variations in water properties and currents at different depths
- Computes suspended sediment transport and deposition
- Allows for the input of variable suspended sediment loadsize distributions and concentrations

Step 1: Set-up model domain, which is all of Inner and Outer Apra Harbor

- Divide model area or domain into grid cells. Grid dimensions range from 20m in the project vicinity to a maximum of 50m further away from project site. There are approximately 12,000 grid cells.
- Depth is specificied at each grid cell, and 3-dimensional flow patterns are modeling by dividing the water column into 10 layers, each representing 10% of the depth.(10 feet of water would result in 10 layers of 1 foot each, and 100 ft of water would result in 10 ft per layer. This provides more refined data at shallow depths).
- Other water column properties such as salinity are specified at each grid cell and for each layer.
- There is some evidence of fresh water flowing into the harbor but there is no stream flow data.

Step 2: Check how field data correlates with EFDC current model:

- The model is verified by completing a model run for a specified period, and comparing model output with ADCP measurement for the same period.
- The model computed current speeds and general circulation patterns correlated well with the ADCP field data.
- Ideally there would have been field data to validate the model for all seasons. There is high level of confidence that the model can reflect the non-tradewind scenario. The model was tested at Kilo Wharf during non-trade days and there was good correlation. Numerous model applications and calibrations have been conducted in previous studies, and are listed on the EPA website (http://www.epa.gov/ATHENS/research/modeling/efdc.html).

General observations:

- Currents are forced by wind stress and tides
- Two layer circulation system:
  - surface flow is in the direction of the wind
  - deep return flow in the opposite direction
- Currents are weak:

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  - bottom layer current speeds were typically less than 5 cm/s
  - surface currents 5-10 cm/s
- Step 3: Dredge Plume Characterization.

Simulating a plume created during dredging requires estimating the total dredging production rate, the percentage of that material that is released into the water column (release rate), the grain size of the material, how the material is distributed vertically through the water column, and the effect of silt curtains. This is an active area of research for the US Army Corps, and some data is available and has been published, mostly from field studies conducted on the east coast. The recently completed Alpha Bravo dredging project in Apra Harbor has provided more than one year of TSS data and turbidity data inside and outside of the silt curtain and at control stations. Following is a list of key model variables presented, and a range of possible values, to specify for completing a model run:

1. **Wind**
   - Typical trades – Dec. 13-18 actual
   - Moderate/strong trades
   - Calm
   - Weak south winds
2. **Dredge Production Rates**
   - Alpha Bravo dredging rates in Inner Harbor channel area – 500-1000cy/10hrs (Dean Bates, pers comm.)
3. **Dredge Release Rates**
   - Ave clamshell 0.5% (Borrowman, 2008)
   - Calibrate with Alpha Bravo data – 4mg/L outside silt curtain
   - Max in literature 4% (DOER-E12)
4. **Vertical Release Distribution/Silt Curtain Impacts**
   - Silt curtain - monitoring data Alpha/Bravo 90% reduction, all release in bottom 20%
   - No silt curtain - 40% bottom, 30% top, rest in middle (Borrowman, 2008)
5. **Grain Size**
   - Use inner and outer harbor sediment sample data

6. **Dredge Location**
   - 7 outside, 1 inside

7. **Impact threshold**
   - Ambient tss 6mg/l Inner Harbor – Alpha Bravo, 131 days
   - Ambient tss 2.9 mg/L – S. Dollar baseline, 2 days Nov 07, Jan 08
   - Sed deposition 0.2mm (40mg/cm^2/day)

Discussion on Model Parameters listed above. Note: not all parameters generated discussion:

- Vertical distribution:
  - Alpha/ Bravo 145 days of data that show silt curtains retain 90% within curtain using a 30-ft deep curtain. EPA heard (reportedly from a silt curtain manufacturer) tha-t beyond 15 ft the silt curtain is not effective. Will have to reach agreement on level of effectiveness to use in model.
  - There is coral below the depth of the silt curtain.
- Grain Size:
  - What about the terrestrial source of sediments= very fine? This could have a greater impact on coral. Marc: porosity may be the more important factor but is also harder to capture. We can work together to agree on a grain size.
  - Applying the average sediment size to the model may not capture the finer sediments that could have greater impact on coral and travel the furthest. Suggest assuming the fine sizes are predominant.
  - Fines have been observed to clump together due to our in association with bacteria. The sticky clumps tend to settle out and could kill coral. Not sure exactly what the mechanism of action is for the mortality. It appears the influx on fresh water tends to trigger the clumping. Dwayne Mitton has a paper that documents this impact. Model can't address this.
    - What do we know about the impact of freshwater on coral in Guam? There is an ASAN War in the Pacific USGS project that looked at fresh water but not at the flocking phenomenon (Marc Capone = resource manager).
    - GOVGUAM has not put flow meters in tributaries to harbor.

- Impact threshold:
  - 1mg/cm2 daily has been used, but discuss further
  - Cumulative impacts of consecutive days of dredging are not possible model scenarios. Coral may be able to clean themselves after one dredge day but not after multiple days. Need to consider how to capture worst case.
  - Coral Spawn June- August. Corals use various mechanisms to reproduce and reproduction takes place year round. Broad cast spawning of eggs and sperm (one reproductive strategy) is most prominent in the June to August time frame around Guam.
- Discussion on how to model cumulative sedimentation during the project. A possible analysis would be to use model results from representative dredge areas, and multiply this be estimated number of days of dredging in that area. Further refinement could include modeling different wind conditions multiplying these results according the frequency of occurrence of these wind conditions. This would require assumptions on where dredging would be occurring during the different seasons.

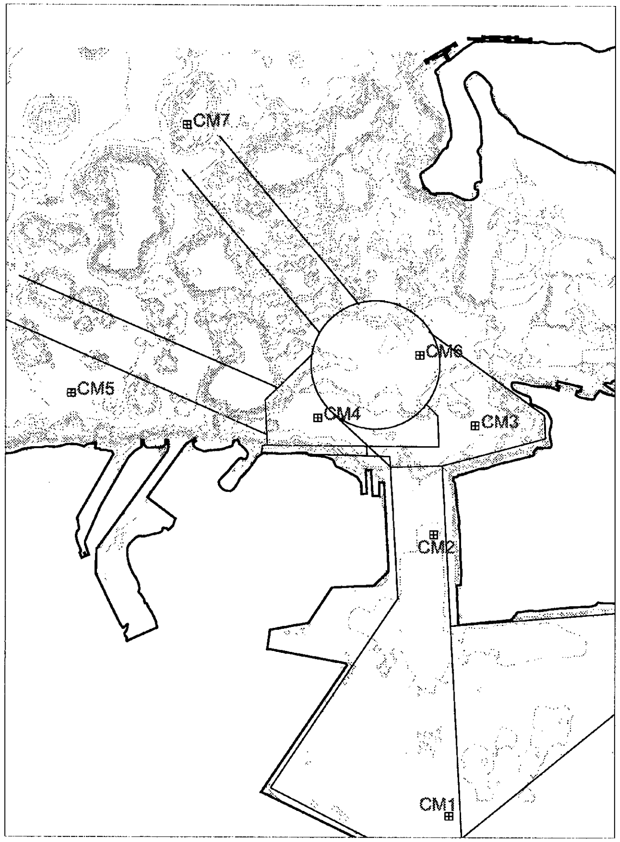
EFDC Limitations:

- It is JUST an analytical tool, but a powerful one. It cannot capture all characteristics of nature. It is the best available technology.
- Does not capture resuspension of sediment. Could increase the dredging to artificially imitate a resuspension due to a wave event.
- Model cannot address the impact of clumping fine sediments and bacteria. There is no way to really generate a worst case scenario to simulate the action.
- Model does not assess cumulative impacts of 145 days of construction.

Action:

- Continue conversation about parameters and model, but will have to wait until Dwayne can attend. No modeling scenarios will be run until agency provides input .

Figure 1 ADCP location map (dredge footprints not current):



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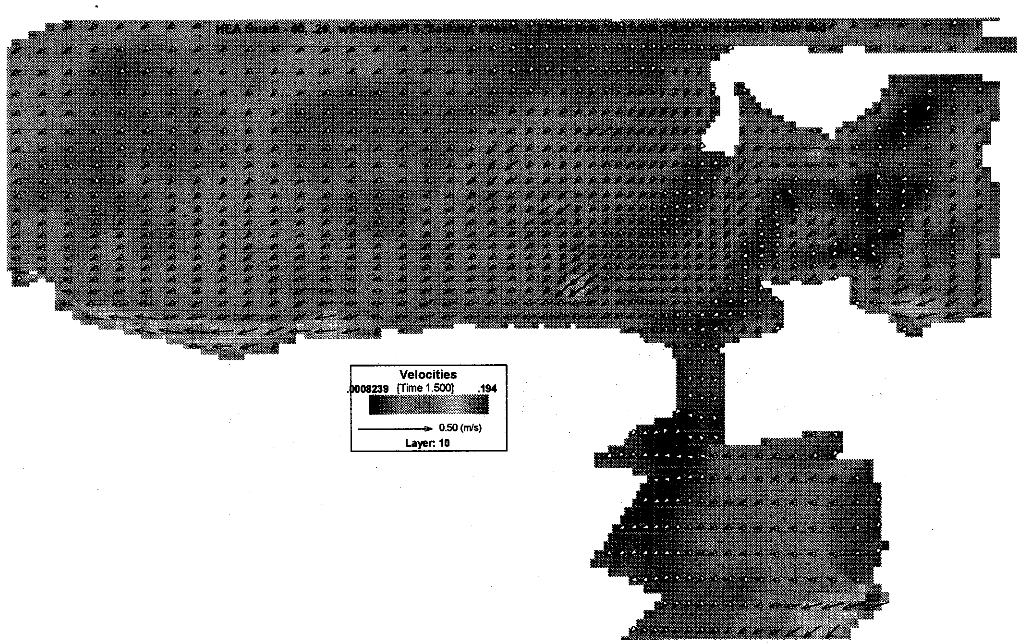
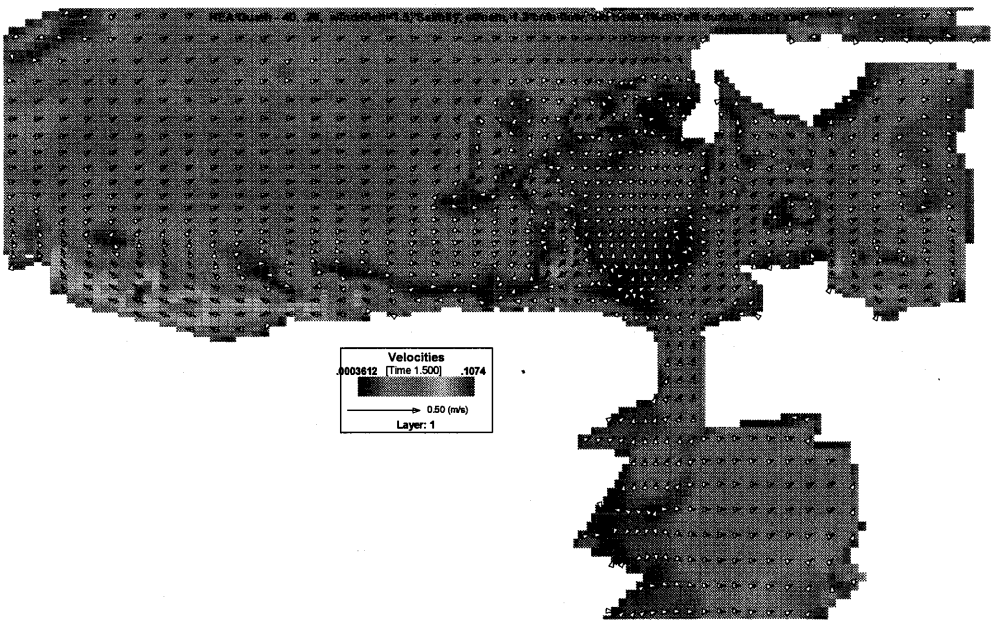


Surface layer velocities, Dec. 16 12pm



Bottom layer velocities, Dec. 16, 12pm

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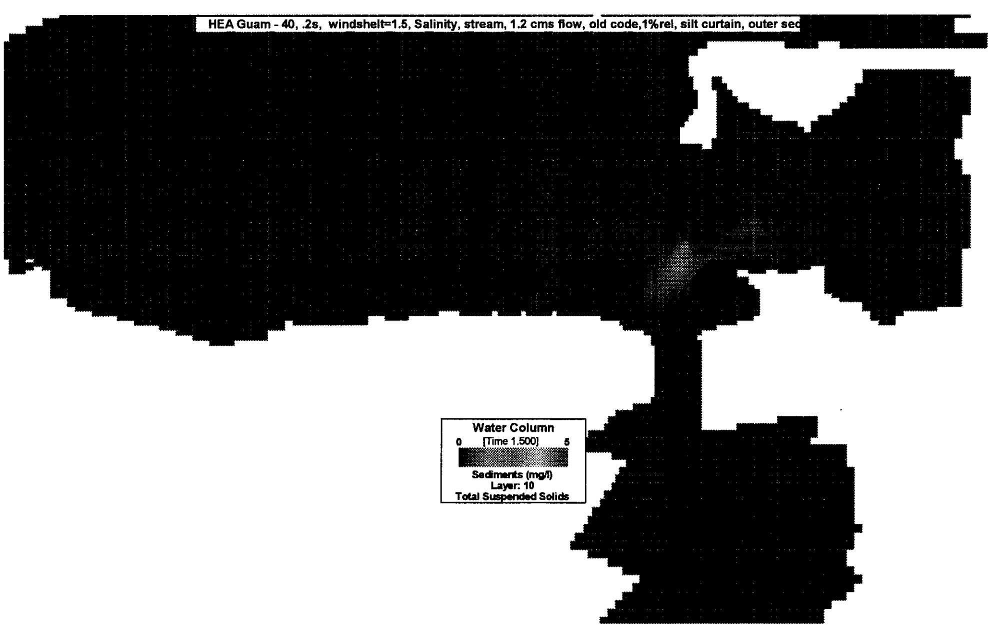
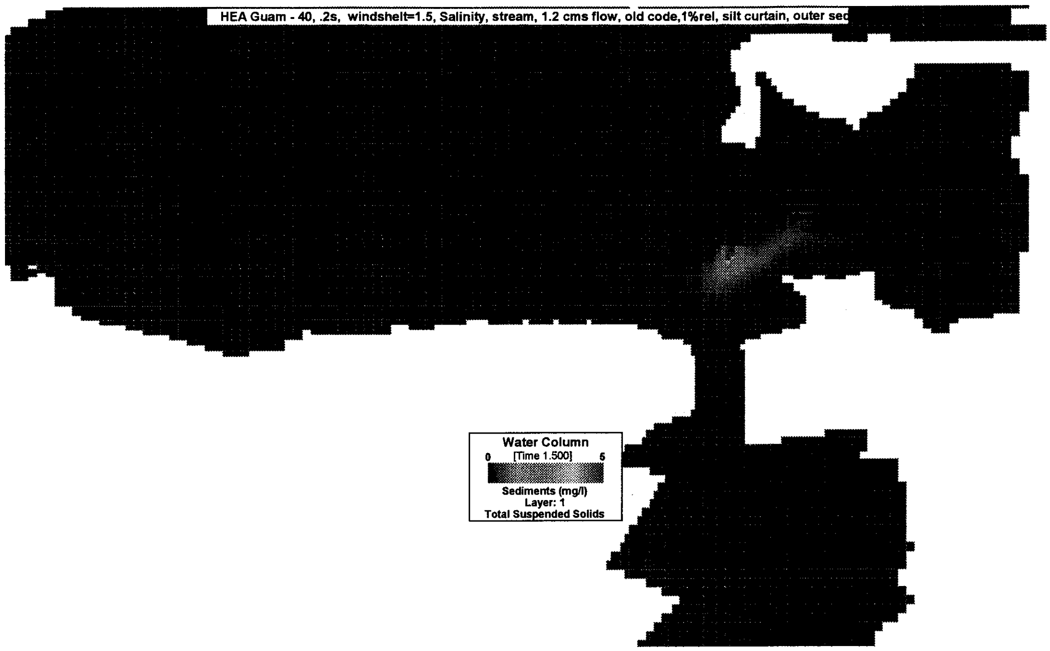


Surface layer TSS plume



Bottom layer TSS plume

HEA WORKING GROUP
MEETING RECORD
June 9, 2008

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

Attendance Record

Date: June 9, 2008
Location: NOAA
Subject: Sea Engineering Currents/Sediment Plume Modeling

Name	Organization	Email
phone ~~Tino Aguon~~		
phone Val Brown	~~SIA~~ NOAA/NMFS	
phone Jay Gutierrez	Guam DAWR	
Alan Everson	NOAA/NMFS	
Steve Smith	NAVY	
Dwayne Minton	FWS	Dwayne_Minton@fws.gov
Faith Caplan	TEC	

CVN/HEA WORKING GROUP –First Biweekly Meeting

MEETING RECORD

June 26, 2008 -Teleconference

Purpose:

1) Establish schedule for teleconferences
2) Review meetings to date on CVN and other JGPO in-water projects

Attendance:

Wendy Wiltse
Jay Gutierrez
Tino Aguon
Mike Molina
Ed Lynch
Frank Dayton
Steve Dollar
Vanessa Pepi
Faith Caplan

Topics of discussion:

1) The next teleconference will be July 10 (Hawaii)/July 11 (Guam) at 1330 (Hawaii)/0930 (Guam). Subsequent meetings will be biweekly. Vanessa will send out invitations with the call-in number prior to each meeting. Those attending acknowledged that attendance will vary, but it is unavoidable with everyone's busy schedules. Navy will look into posting meeting materials (presentations, meeting records etc) to a website.
2) Brief description of 4 meetings held to date on CVN/HEA projects. Meeting records are pending.

March 25, 2008

Objective: 1) present JGPO projects in Apra Harbor with emphasis on CVN wharf and assoc. dredging

2) present what we knew at the time about coral coverage

3) request best guess on coral mitigation cost based on dredged footprint and coral mapping.

4) points of contact for regular follow on meetings (like this phone call)

Agency Response:

Coral mitigation cost of about $430/m2 of coral impact based on Kilo Wharf mitigation, but a worst case scenario was assumed. The entire dredge footprint would be dredged and is

CVN/HEA WORKING GROUP –First Biweekly Meeting
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June 26, 2008 -Teleconference

covered with 100% coral. Total cost was estimated at over $100 M which is about 1/3 of total project cost.

Recommended studies and other information that would help Navy back away from the worst case.

June 2, 2008 Meeting- initiated by JGPO

- Presented the background project info again with updated coral imagery. Discussed the HEA process and inputs needed. Discussed the currents modeling and the parameters needed to assess indirect impacts.
- Brainstorming about what we need to accomplish to meet the EIS deadlines
- Key topics for ongoing discussion:

- need for more engineering and construction information
- mitigation: projects and mitigation trusts
- need for agency/navy coordination on data collection, report writing, & impact assessment for EIS
- data gaps: types of studies and how they would figure into the HEA model
- parameters for HEA model and currents model
- Schedule: USFWS is short on resources to do surveys, but will try for a survey in the Fall to provide some data into the DEIS and part 2 of the survey would be in Spring 2009
    - USFWS will provide proposal that identifies all the survey requirements and will pull together survey teams from multiple agencies
- Action item list is begun

June 6 Meeting:

Francis Suganama of COMPACFLT met with USFWS & NMFS to talk about CVN alternatives, CVN navigation questions (Is turning basin required? Can the CVN reverse into berth?), construction controls that could be built into dredging contract, engineering info that would help move away from worst case scenario for coral mitigation. A new Drydock Island alternative (recommended by Mike Molina) will be assessed by the Navy to see if it meets operational criteria.

CVN/HEA WORKING GROUP –First Biweekly Meeting

MEETING RECORD

June 26, 2008 -Teleconference

June 9 meeting:

Sea Engineering (Marc Ericksen) presented the currents modeling methodology and findings, and answered technical questions on the model and its limitations. The model will be used to assess the potential indirect impact of dredging /sediment plume on coral. The next step is to meet with agencies to discuss the various dredging scenarios that the model will simulate.

Discussion:

EPA asked for more complete alternatives analysis. Revised DOPAA would be the next opportunity. Internal draft for Navy will be August 2008.

Action Items:

1. Navy will look into website posting of relevant materials to avoid use of ftp sites.

CVN/HEA WORKING GROUP

MEETING RECORD

July 24, 2008 -Teleconference

Purpose: Status

Attendance:

Mike Molina
Gerry Davis
Wendy Wiltse
Val Brown
Faith Caplan

Topics of discussion:

1) Vanessa's email request 7/22/08:

"The engineers have a request for you to help them with your requests.

They would like you to draw out exactly what you would like the engineers to look at:

Michael - Please draw out your best concept for the Drydock Island area

Gerry - Please draw out the ship movements you think could happen - the pull-up-and-park scenario. Francis suggested drawing little boats with arrows."

Gerry and Michael have both responded with their drawings. Gerry will resend his.

2) When will be next opportunity to review the DOPAA?
   a. Faith said there would not be another version of the DOPAA released for review because of schedule constraints.
   b. Gerry and others expressed concern that there needs to be another round of DOPAA review before the DEIS: 1) to understand the project better and 2) to make sure major issues were addressed and 3) there are no unresolved issues.
   c. Navy is still working through the 1,000+ comments to determine how to address them. Some comments were contradictory and not all of them will be addressed to every commenter's satisfaction. Teresa Bernhardt sent out a message of the status of responding to comments.

ACTION: Faith will verify whether everyone will: 1) receive their completed comment matrix, 2) receive a summary of everyone's key issues/Navy response, and 3) no formal response – address comments in DEIS.

3) If the revised DOPAA is not available for review, then can the revised alternatives analysis be circulated? It will be inefficient if USFWS submits and executes a proposal

CVN/HEA WORKING GROUP

MEETING RECORD

July 24, 2008 -Teleconference

for field survey in October that does not address all the alternatives. The concern is that the agencies have other commitments and demands on resources. Having to return to the field to address other alternatives is not an efficient use of resources and represents a schedule risk to the Navy. The Dry Dock island alternative may need to be included in survey costs. Michael suggested their proposal could include this extra scope. He will talk to Dwayne.

ACTION: a) Faith will follow-up with COMPAC FLT to try to get the desktop decision on Drydock Island alternative in time for Navy's review of the USFWS proposal.

b) Faith will ask NAVY if the alternatives analysis can be circulated prior to the DEIS.

c) Michael will talk with Dwayne about possibly adding the costs for the Dry Dock island scope of work.

4) The USFWS proposal is drafted and should be finalized next week.
5) Dwayne has initiated the survey logistics meetings to begin next week.
6) Website access seems to be working
7) The next teleconference will be August 7 (Hawaii)/August 8 (Guam) at 1330. Vanessa may not be able to attend.

CVN/HEA WORKING GROUP

MEETING RECORD

August 7, 2008 -Teleconference

Purpose: Status

Attendance:

Dwayne Minton
Wendy Wiltse
Val Brown
JT Hesse
Vanessa Pepi
Faith Caplan

Topics of discussion:

1) USFWS surveys:
    a. First field survey logistics meeting was held in the morning of August 7 and will be held biweekly.
    b. USFWS submitted proposal cost to support CVN construction at Polaris Point. Navy is reviewing it. There is sufficient funding for Phase 1. Navy is reviewing the scope and an interagency services agreement will be drafted.
    c. Proposal does not include Inner Harbor project areas. USFWS may be able to rely on UOG product and conduct limited surveys to supplement UOG work. The USFWS scope of work would be dependent on the UOG work. TEC made the point that the Inner harbor work is still part of the program in the EIS.
2) Status of COMPACFLT action items:
    a. Frances Suganama received the submittals from Gerry Davis and Mike Molina and is forwarding them to technical experts for review and consideration.
    b. JT Hesse will check on status prior to next meeting.
3) When will an alternatives analysis be available for review? This was a question asked at the last meeting that remains on the action item list. TEC responded that there are JGPO meetings being held next week to discuss the comments received and the overall NEPA approach. Hopefully, those meetings will result in a decision regarding the release of a revised alternatives analysis and or response to DOPAA comments.
4) Refine project description for the CVN prior to USFWS surveys. Review BMPS and recent dredge projects for assumptions. New action item.
5) The next teleconference will be August 21 (Hawaii)/August 22 (Guam) at 1330.

CVN/HEA ADMINISTRATIVE WORKING GROUP

MEETING RECORD

August 21, 2008 -Teleconference

Purpose: Status

Attendance:

Dwayne Minton
Mike Molina
Steve Dollar
Wendy Wiltse
Val Brown
Frank Dayton
JT Hesse
Ed Lynch
Mark Ericksen
Robert Wescom
Lisa Fiedler
Mike Donlan
Faith Caplan

Topics of discussion:

1) Action item status:
   - M. Molina suggested dry Dock Island CVN Alternative dismissed due to force protection issues and the sharp turn required for the one way route would not eliminate need for turning basin. Turning basin is at minimum size. M. Molina suggests relocation of turning basin north. Turning basins were specifically oriented to minimize impact to coral but tweaking location is probably possible. **ACTION:** JT HESSE Will ask M. Molina to draw the proposal out so we are sure we understand and Ed Lynch will ask COMPACFLT.
   - Can the CVN use Inner Apra Harbor as a Turning Basin if Polaris Point is alternative? There is an issue with Inner Apra Harbor Berthing because of force protection associated with blocking channel entrance. **ACTION:** Ed Lynch will ask COMPACFLT.
   - The minimum turning radius is approved by COMPACFLT.
   - Clarification of the two CVN-related biweekly meetings: this one and the technical group. This working group should address overall program discussions and the technical group would focus on fieldwork. We should try to keep discussions distinct since there are different audiences.

CVN/HEA ADMINISTRATIVE WORKING GROUP

MEETING RECORD

August 21, 2008 -Teleconference

2) Discuss goal/purpose of the surveys to be conducted in the Fall
   - Funding/ administrative timing may not be complete in time for a Fall survey. September 15th seems to be the go/no go decision date. M. Molina offered support in expediting administrative tasks.
   - The intent of the Fall survey was to: 1) provide minimal affected environment information, primarily through ground truth of S. Dollar's coral imagery, 2) provide agencies enough information to revise their worst case mitigation cost estimate in time for DD1391 submittal. There may be a problem with seasonal degradation of visibility.
   - DD1391 deadline is November, specific date unknown. Unlikely that there is sufficient time to meet the deadline if surveys are in October and impossible if surveys get pushed back to November due to funding issues. There is a mitigation line item of $24 M that may be altered later.
   - Plan B: If Fall survey data is not available, proceed with DEIS preparation based on existing information. Deadline is December to meet internal review deadline. General acknowledgement that this January version (limited release) will be deficient. If 2009 survey is done February there may not be sufficient time for USFWS internal review for inclusion in publically released DEIS in April. HEA requires a month lead time. All data would be incorporated by Final EIS. Maybe survey in January?
   - General concurrence Plan B is not preferred, but the schedule is driving the course of action.
   - Plan B would have Navy proceed with impact assessment/HEA without benefit of USFWS surveys, acknowledging adjustments may be required in the Spring 2009.
   - **ACTION**: JT & USFWS meet August 22, 2008 noon to review proposal.

3) Set up meeting with Sea Engineering and agencies to discuss sediment transport modeling parameters.
   - **ACTION**: D. Minton will coordinate room at USFWS for September 4, 2008 1100 with biweekly meeting to follow at 2:00.
   - **ACTION**: JT Hesse will send out invite

- **ACTION:** Marc Ericksen of Sea Engineering will provide read-aheads to assist those who are participating remotely.

4) Status of agency meetings (Fall) to discuss possible mitigation/restoration projects.
    - The next partnering meeting (date to be finalized) will include a full day break-out session to discuss mitigation and mitigation banking.

5) Set up meeting with Steve Dollar and agencies to review October protocol to ground truth coral imagery
    - **ACTION:** Keep on agenda for the next few meetings

6) Request USFWS identify their HEA expert for planning discussions
    - Bruce Peacock will be assisting USFWS with HEA.
    - Collaborative approach to HEA would have Mike Donlan and Bruce Peacock interact early in the process.
    - Mike Donlan and Bruce Peacock are now both on the Technical Group biweekly meeting distribution list.

7) EIS schedule (to be provided)
    - **ACTION:** F. Caplan to provide

8) The next teleconference will be September 4 (Hawaii)/September 5, 22 (Guam) at **1400** (Hawaii). Note half hour delay.

MEETING 1 (1200 to 1400)

Purpose: Review of Sea Engineering currents model, limitations and parameters

Attendance:

Dwayne Minton
Mike Molina (portion of meeting)
David Burdick (portion of meeting)
Val Brown
JT Hesse
Mark Ericksen
Faith Caplan

Read Aheads: Sea Engineering Powerpoint

Presentation (Marc Ericksen, Sea Engineering):

Discussion Points:

Model Limitations:

- No data for freshwater runoff into the harbor. During rain events, the freshwater has a high sediment load and moves across the surface of the harbor very fast, based on observations of sediment plume. The increased speed could affect dredged plume velocity and distance. During rain events the runoff would have more of an impact than the dredging plume. If data on flow were available it could be input into model. Those present were confident there was no data available for the Apra Harbor watershed, but there is other on-island data. The other data was believed by those present to not be useful. Marc suggests using strong trades as a variable in the model would be comparable to and likely greater impact than fast surface currents from fresh water. Strong trades would represent a worst case.

- ADCPs' accuracy limitations at surface 6% and bottom 6% . There are other means to capture this data but all have limitations (fixed array at surface subject to vandalism and interference with navigation or drift drogues that do not capture surface motion patterns). The EFDC model is designed to address the dynamic conditions of shallow and bottom conditions. The ADCP data are used only as validation of EFDC model. The EFDC model correlates well with the rest of the water column data and the assumption is it does equally well at the bottom and top layers. The assumption is valid because the water column layer dynamics are inter-

CVN/HEA ADMINISTRATIVE WORKING GROUP

MEETING RECORD

September 4, 2008 –Teleconferences (2)

related. Whatever happens at the middle of the water column impacts what happens at the surface and bottom. The closed system of Apra Harbor with one access to open water allows for a greater degree of confidence in the model. It is assumed also that since this an EPA model, they would have validated the accuracy at the top and bottom. Sea Engineering does have 6 days of drogue data from 1992 (surface only) and it correlates with the model (admittedly limited field duration).

- Model does not assess cumulative impacts of consecutive days of construction

Parameters:

- Dredge release rate- clarify that the 4mg/l TSS outside the silt curtain at Alpha/Bravo construction would be used to <u>calibrate</u> the dredge release rate and would not be used to represent release rate inside the silt curtain. Concurrence. Could bracket the dredge release rate based on literature minimum and maximum release rates. Alternatively, could use an average of the worst 10 days of Alpha Bravo TSS data outside the silt curtain for calibration

- Grain size. The .002 grain size corresponds to "silt". Grain size influences settling rate. What about consecutive days of dredging and cumulative sediment load? Cumulative load can be addressed, but is not currently in scope. It may be added in the future.

- Impact thresholds and slough off rates on coral: A broad range of thresholds is reported in the literature (lethal to coral: < 1 mg/cm2 to 100 mg/cm2). Could show contours of 100 mg, 40 mg, 10 mg and 1mg. This is done at the interpretation phase of the modeling.

ACTION: Marc will provide a range of suggested model scenarios for agencies to comment on during next biweekly meeting.

MEETING 2 (1400-1600)

Bi-weekly Meeting

Attendance same as first meeting, with addition of Steve Dollar and Mike Donlan, and departure of Marc Ericksen.

1) Action item administrative status:

- Clarified with Dwayne what turning basin alignment Mike Molina was asking the NAVY to check into. Basically the question is whether the turning basin represents the least damaging to coral. There is deeper water north. **ACTION:** TEC check with engineers.

- Turning basin within Inner Apra Harbor would not eliminate the need to put a turning basin in front of the wharf. The CVN as it exists the narrow channel would have to be rotated at least 45 degrees to berth starboard to. The standards do not allow for creation of partial turning basins.
- JT/USFWS met to discuss Fall surveys. There will be no surveys in October because of administrative funding issues. There could be December surveys followed by Spring surveys. The reason for two survey events is the quantity of field time required and the short amount of time available in the Spring prior to June deadline for input into DEIS. Essentially these surveys represent 2 years of survey work in 6 months.

2) Sea Engineering presentation occurred in the first meeting

3) Two step approach: 1) review, distill existing data, identify data gaps to be addressed in December/Spring surveys 2) HEA. Dwayne suggests a third step is the mitigation discussion, which should be initiated sooner rather than later. Val mentions it is a topic of discussion at the next Military - Civilian task force meeting, occurring next week. **ACTION:** Val will report back on military- civilian task force meeting mitigation discussion. There is an initial list of proposals. **ACTION:** Val will check if the agency mitigation list is releasable and provide to the Navy prior to the next Bi-weekly administrative meeting. Mitigation is also the topic for discussion at the next JGPO partnering meetings. Mitigation banking may change the proposals but consensus among those present was that it is time to initiate discussions. A range of proposals narrowed down to three could be used in the HEA.

CVN/HEA ADMINISTRATIVE WORKING GROUP
MEETING RECORD
September 4, 2008 –Teleconferences (2)

4) **ACTION:** Add mitigation discussion to the next biweekly administration meeting. Goal is to pick the top 3 that can also be readily incorporated into the HEA.

5) **ACTION:** Important that all key stakeholders be represented at the next meeting. JT will ask Lisa Fiedler to mention it at the military civilian task force meeting. JT will also contact agencies directly to encourage participation.

6) September 18 meeting: Discuss HEA. Bruce Peacock and Mike Donlan will present background on HEA. **ACTION:** USFWS authorizes Bruce to work with Mike prior to next meeting.

7) Bibliography of literature was sent to Dwayne to review. **ACTION:** Dwayne will circulate the list for additions.

8) The next teleconference will be September 18 (Hawaii)/September 19 (Guam) at **1330** (Hawaii). This will be a longer meeting.

9) Carry-over items for future agendas:

   - Steve Dollar and USFWS meet to discuss ground-truthing data

AGENDA and MEETING RECORD
HEA/CVN Administrative Working Group

September 23, 2008 - 1230 to 1445 (Hawaii)

Attendees:

Navy:	Charles Sayon, JT Hesse, Stephen Jamison, John Sato
NOAA:	Gerry Davis, Kevin Foster, Steve Kolinski, Valerie Brown (Guam)
USFWS:	Mike Molina (MM), Bruce Peacock
EPA:	Wendy Wiltse
Gov Guam:	Dave Burdick
DAWR:	Jay Gutierrez
USACE:	Frank Dayton
Sea Engineering:	Marc Erickson
Industrial Economics:	Mike Donlan (MD)
NPS:	Heather Best
DAWR:	Jay Gutierrez
TEC:	Karl Bromwell

Agenda:

1) Action item status:
   - Mike Molina inquiry on moving turning basin north to deeper water. Response: engineering feasibility study sited the turning basin to meet operational requirements and minimize impact on coral. Moving the turning basin north would mean longer approach to wharf that would have to be dredged and would not reduce the impact on coral.
2) Dredge scenarios to be run by Sea Engineering: agency concurrence/comments
3) HEA Discussion (Mike Donlan and Bruce Peacock)
4) Mitigation proposals
   - Val Brown: brief the group on Military –Civilian Task Force mitigation discussion
   - Narrow down list to top 3 for DEIS input December 2008
5) CVN EIS Time table
6) Carry-over items to future agendas:
   - Steve Dollar and USFWS discuss ground-truthing of Steve's data

Meeting Record:
@ = action item

1) JT clarified for Mike Molina (MM) the response in action item No. 1 and identified why Dry Dock island doesn't work (i.e. force protection issues and turning radius is too tight on exit from wharf. Mike acknowledged and understood his response.
   - Gerry Davis asked for clarification again on why the entire diameter of the basin is necessary. Why it can the CVN back up more and thus reduce the size of the dredge area, since it appears that tugs will need to back it in for a shorter distance anyway. @ JT explained how it was not operationally doable to back out the vessel, however mentioned he will look into the specifications regarding a longer distance backing with Tugs is not doable.
   - @ Gerry also said it would be helpful if a figure showing movements (i.e. a "vessel tracker") could be available for the CVN route into Wharf. Again, if it's being pushed back a short distance by tugs why not a longer distance?
   - Wendy asked if a list of alternatives could be provided before the Pre-Draft EIS. JT said there would be no release before the PDEIS. MM asked when that would be available, which JT answered "the earliest available would 1.5.09), and however, the PDEIS is prior to a document sent out for public comment.
2) Marc presented model dredge scenarios walking everyone through the process. Attachment provided.
   - @ MM requested a collaboration on suspected variable that would be influencing an increased sediment (i.e. rain, ship movement, silt curtain, etc. were all discussed). The control site should p/u the rain factor associated with increased TSS/TDS. Marc agreed.
   - Marc clarified that tide and waves were not having a great impact on sediment it was mainly wind as the number one key input parameter.
   - @ It was requested that an outer boundary be run (i.e. worst case scenario). Marc said he had three more contract slots open for that and agreed it could be run saving the other two.
   - Wendie asked if new dredging BMP technology could be considered. JT asked if she had any suggestions. She mentioned that in conversation with EPA colleagues the bubble curtain used in support of silt curtains had the potential to decrease silt movement under the silt curtain along the bottom where the coral is. @Wendie will send JT and Frank Dayton references/literature on bubble curtain effectiveness either in use with other BMP technologies or solo.
   - After JT inquired, everyone agreed to move forward with the model Sea Engineer described. Marc agreed to add a worst case scenario (No. 18). All scenarios run will be used for cumulative analysis.
3) Heather Best presented the basic concept of HEA model with Mike Donlan (MD) and Bruce Peacock clarifying process. Attachment provided.
   - Mike Donlan clarified several points of the presentation including: why focusing on coral (although soft bottom habitats will also be dredged), key inputs for quantitative analysis (area impacted, severity, and duration of recovery), etc.

- MM agreed with the coral impacts as focus and that it wasn't necessary to include soft bottom, unconsolidated sediment in the HEA analysis.
- Gerry pointed out and was agreed that there are different ways to address coral habitat (i.e. coral coverage model and/or size matrix model). It was stated that is very important to explain the HEA process in the Draft EIS.
- The Draft HEA, which will be based on the best available information, may I.D. data gaps. It is understood that there is no information on coral size currently. These data gaps could be incorporated into the spring marine survey's for the Final HEA. It is the Navy's understanding that the Resource Agencies were agreement that the HEA and DEIS will move forward with the information that is available at this time. The DEIS HEA will be revised after new data is acquired in the spring surveys.
- MM and Gerry agreed that the HEA process should move forward and all agreed that additional data is needed. Spring data will show this
- JT is worried about timeframe for the spring data to feed into the HEA, however defensible data is the most important factor.
- Gerry noted that certain coral will come back quicker than other species, which is why size relationship to species is important along with live coverage.
- @ JT had three question/comments:
    - Requested that threshold coral recovery rates, based on literature, be shared with the group and discussed before running the HEA model;
    - Need to capture the baseline health of the coral in Apra Harbor study area in the HEA model. The coral is not pristine (i.e. evidence of bleaching and/or disease); how will this input parameter be addressed?; and
    - JT asked to push the HEA conference back to an agreeable timeframe, since there is a date conflict between the HEA conference and the JGPO/Navy Partnering Workshop in Guam. MM said he would like to keep the date. JT mentioned it would be nice to combine the meetings, but didn't offer – bottom line JGPO/Navy Workshop takes precedence.
- It's the Navy's desire to establish a HEA Work Plan and benchmark dates to meet for the completion of the FEIS

4) Val Brown said the last civilian task force mitigation discussion was postponed. She noted that they were looking at the same mitigation identified for Kilo Wharf (watershed).

- @ JT asked if the timeline could be provided for next meeting (October 2nd [3rd for Guam])
- @ Jay Gutierrez said a mitigation plan is being contracted out by DAWR, but most likely the mitigation list developed for Kilo Wharf is Gov Guam's preference for CVN. This list will be provided at the next meeting.

5) @JT requested that if you have any information for the HEA that can be compiled into a Navy Bibliography please forward to Dwayne. The goal is to compile a list to assist the Navy with defining the SOW and data gaps for the spring surveys and to justify the request for funding. It was JT's understanding is that the spring surveys would commence 30-days after distribution of funds. MM agreed that the survey crew would need 30-days to finalized plans (all ready underway) for the effort.

6) Since Steve Dollar and Faith Caplan was not the call to address this carry-over should it be carried over again….MM identified that ground-truthing the data was not doable in the timeframe so it will not be done. It will be looked into in the spring surveys.

Action Items Recap

1. @ JT explained how it was not operationally doable to back out the vessel, however mentioned he will look into the specifications further regarding a longer distance backing with Tugs and why it is not doable. @ Gerry also said it would be helpful if a figure showing movements (i.e. a "vessel tracker") could be available for the CVN route into Wharf. Again, if it's being pushed back a short distance by tugs why not a longer distance
2. @ It was agree to collaborate (Marc and MM) on suspected variables that would be influencing an increased sediment (i.e. rain, ship movement, silt curtain, etc. were all discussed). The control site should p/u the rain factor associated with increased TSS/TDS. @ It was also requested by MM? that an outer boundary be run (i.e. worst case scenario). Marc said he had three more contract slots open for that and agreed it could be run saving the other two.
3. @Wendie will send JT and Frank Dayton references/literature on bubble curtain effectiveness, either as a supporting BMP for silt curtains during dredging operations or as a lone BMP.
4. @ JT had three question/comments:
    - Requested that threshold coral recovery rates, based on literature, be shared with the group and discussed before running the HEA model;
    - Need to capture the baseline health of the coral in Apra Harbor study area in the HEA model. The coral is not pristine (i.e. evidence of bleaching and/or disease); how will this input parameter be addressed?; and
    - JT asked to push the HEA conference back to an agreeable timeframe, since there is a date conflict between the HEA conference and the JGPO/Navy Partnering Workshop in Guam. MM said he would like to keep the date. JT mentioned it would be nice to combine the meetings, but didn't offer – bottom line JGPO/Navy Workshop takes precedence.
5. @ JT asked if the timeline for the mitigation plan could be provided for next meeting (October 2nd [3rd for Guam]) @ Jay Gutierrez said a mitigation plan is being contracted out by DAWR, but most likely the mitigation list developed for Kilo Wharf is Gov Guam's preference for CVN. This list will be provided at the next meeting.

CVN/HEA ADMINISTRATIVE WORKING GROUP

MEETING RECORD

October 16, 2008 1330 (Hawaii) –Teleconference

Purpose: Status

Attendance:

Mike Molina
Chuck Sayon
Frank Dayton
Mike Gawell
Wendy Wiltse
JT Hesse
Faith Caplan

Read Aheads: Wendy Wiltse provided information on Bubble silt curtains

Discussion Points:

1. Action item status:

   - Request for graphic showing CVN navigation into berth for alternatives dismissed:

This was a Gerry Davis request and he is not present, but bottom line is this alternative has been considered and dismissed by COMPACFLT. There won't be any graphics provided for discussion.

   - EPA will provide literature/information on bubble silt curtains

Wendy Wiltse provided the information. Based on information provided, it appears that bubble silt curtains would not be recommended for the CVN dredging projects. Silt curtails do a better job of reducing sediment. Additional information on the subject would be welcome.

   - Resolve HEA workshop schedule conflict with JGPO Partnering meetings

HEA workshop scheduled November 5 & 6 to avoid JGPO Partnering meeting. Unfortunately, there are other conflicts (NERDA workshop) and the Guam agencies are unlikely to be able to attend. Mike Molina described how the HEA Workshop has evolved into a project-specific CVN/HEA workshop to accommodate the JGPO EIS schedule. The workshop was conceived as an educational workshop and would be attended by a broad audience. The shift to project-specific limits the attendance to those who have been involved with the project. This would include Guam people and it is unfortunate that there are schedule conflicts that could not be avoided in the timeframe. There will be meeting minutes taken and distributed. A summary will be presented at the next meeting.

CVN/HEA ADMINISTRATIVE WORKING GROUP

MEETING RECORD

October 16, 2008 1330 (Hawaii) –Teleconference

   - DAWR will provide KILO WHARF mitigation list

Mike Molina sent out a list to those he thought didn't have it.

ACTION: Mike Molina will redistribute to entire HEA working Group.

   - Coral recovery rates to be used in HEA needs further discussion- possibly at HEA workshop

This is an important topic best discussed in the Technical Working Group meetings.

   - Coral health assessment will be incorporated into USFWS SOW for Spring surveys.

Clarification of what this action item is about. Consensus that coral being dredged is not pristine and the Navy would not be expected to compensate for degraded coral as if it were pristine. The Spring surveys would describe coral as it observed, but there would not be a "health assessment" because it would be too time consuming and expensive (MM). But there are ways to describe the health. There are recent studies that may be useful(MM).

2. HEA Workshop
Mentioned above. Attendance about 40 pn. At Fort Shafter. Frank Dayton will attend from Guam.

Discussion of agenda: Very ambitious agenda and some areas may need to be cut back. Do we need to spend time on Pros and Cons of each mitigation project? The important point is to understand how each of the mitigation projects would work into the HEA model. Keep pros and cons discussion brief. The partnering meeting will devote some time to mitigation discussion that will be continued in the HEA Workshop. JT Hesse emphasized need for a mitigation project short list at the end of the workshop. Mike Molina suggests that the potential location of each mitigation is not important at this time. Comments on agenda will be forwarded to Kevin Foster.

In Kilo Wharf project, Navy was not held to a standard of performance for mitigation . There was no guarantee that there would be recovery. JT HESSE request that Mike Molina mention this at the Partnering meeting because he doesn't think everyone is aware that that was the case with Kilo Wharf.

Mike Gawell recommends that Dr. Laurie Ramondo participate in these discussions of mitigation. She has done work on coral transplanting for the Navy. JT Hesse agreed and it may be a good idea to invite her to participate on some of the Technical meeting calls. Mike G. Has talked to her about her findings.

CVN/HEA ADMINISTRATIVE WORKING GROUP

MEETING RECORD

October 16, 2008 1330 (Hawaii) –Teleconference

ACTION: (For everyone, but probably Mike G. is best) ask Dr. Ramondo for data.

ACTION: JT HESSE will submit Navy guest list to Kevin Foster.

3. Spring 2009 USFWS proposal

Navy is working on interagency agreements.

4. Scenarios for sediment modeling (provided with agenda)

No comments.

5. October JGPO Partnering meeting (to include mitigation discussion)
6. Next meeting will be after the HEA workshop on November 13th. Agenda will include HEA workshop summary.

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300 Ala Moana BLVD. 5th Floor
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Attendance:

(Attached to end of Notes)

Read Aheads/Handouts: none

These meeting notes are organized by agenda item (provided at the end of the notes). It is assumed that the reader has the powerpoint presentations and the slide contents are not described, only discussion points.

Day 1: November 5, 2008

1. Interest Identification (interactive):

    - This was not an agenda item.
    - Attendees were asked to write 3 statements of what they hoped to accomplish or learn about in the meeting.
    - Individual statements were posted and grouped by common theme.
    - Groups were ranked by level of interest among all attendees via "dot" voting.
    - Results listed from high to low ranking (list of all points of interest are listed with posters) :
        - Metrics
        - Mitigation
        - Understand HEA
        - Interservice relationships
        - Mitigation Costs
        - CVN-Specific

2. Introduction to HEA [Bruce Peacock (USFWS HEA expert) and Mike Donlan (Navy HEA expert)]. Powerpoint #1 HEA Workshop –provided in separate file.

    Topics:

    - History of HEA
    - Rationale for HEA
    - Advantages of HEA
    - Limitations of HEA

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Comments:

- *Can a volume unit such as cubic meters per year be used instead of a 2-dimensional unit such as square meter per year?* While they have not seen a HEA coral application use a volume-based unit, it is conceptually possible but would require other technical experts to provide those measurements . It might be possible to develop a simplified approach to incorporating volume that segregates coral areas into classes based (at least in part) on volume. Volume units have been used in HEA for other types of habitats (e.g., groundwater).
- *Is the unit of time for restoration based on an assumption and can it be adjusted based on best available information and changing technology?* HEAs can and should incorporate the best information available about the expected future condition of impact and mitigation sites. In some cases relevant site-specific data are available, in other cases assumptions must be made. Any assumptions should be explicitly identified, and the basis for them described. Impacts and mitigation benefits can be evaluated over discrete time periods or in perpetuity. There are examples: a coastal spill that impacts a marsh. How long would the marsh have lasted without the spill? Were there other environmental pressures? This kind of information can be difficult to obtain, but needs to be considered for the time frame addressed by the HEA.
- Catastrophic events can be added to HEA model if inputs are provided to modelers.
- If there is a 75% chance that mitigation would be effective than the area required for restoration would be greater than if the chance that mitigation was successful was 100%. If there are differences of opinion on success, then it is relatively easy to run multiple scenarios in HEA to assess the potential magnitude of benefits. If there is not a big difference, then best to not spend much time working with this particular criteria and move on to the other criteria.
- The HEA appears to be a "black box" or "number cruncher" how can you be sure the end result is not worthless? Hesitate to describe it as garbage in –garbage out but as with any modeling exercise there is an element of truth in the phrase. The onus is on the ecologists to provide the best available information and describe the uncertainty for each input. HEA is actually transparent in how the inputs flow through the process. Through multiple runs one can determine which parameters are most sensitive to change. The HEA does not require all possible information about affected resources but based on ecologists' advice it is important to identify the most important characteristics and use them to inform HEA design and inputs..
- HEA does not provide a dollar value of replacement services, but provides an area required for a particular type of restoration project(s).
- *What if there are no in-kind replacement opportunities?* If there is sufficient information tying the replacement project to restoration of what is lost, then out-

of-kind replacement is not necessary. Typically, one tries try to find mitigation projects providing benefits similar in type to those lost. Out-of-kind replacement can be utilized in a HEA, although often will require development of tradeoff ratios between impacted and restored habitats that complicates the analysis. In addition, valuation approaches (i.e., non-HEA) can be applied to directly estimate lost value due to an impact. However, such studies often are time-consuming and expensive relative to HEA applications.

- *Aforestation was used for Kilo Wharf project and it appeared to be "out of kind" but the purpose was to improve water quality that would in- turn restore coral growth*
- *Definition of services vs. functions?* If there is no human use, then the distinction is not great. In Kilo Wharf project the word service was specifically replaced by function, because it was likely to be more to the layperson than service. *Ecologists often describe structure + function + services. There are distinctions between these terms, which can be addressed later in the meeting. In some cases the distinction may not have a substantive effect on HEA calculations: for example, if you have 19 functions and 19 services and implement in-kind, in-place replacement, then the significance of the distinction may be limited. The loss of habitat is the same for each set of functions. When one moves away from "in-kind" it is that much more difficult to say function is equal to service. Often HEA uses proxies for services in acre-year (or other space-time units) instead of measuring individual services.*
- *Other measurements besides acres of coral cover can be used such as biodiversity and type of coral.*

BREAK

3. Framework of HEA (Bruce & Mike). Powerpoint #2 HEA WORKSHOP
    - "Ecofunction" instead of individual services are used in HEA to avoid double-counting. For example: if one removes X amount of coral and then counts the decline in fish population AND the amount of coral loss you would be double counting the service lost due to the loss of coral. One can account for service loss by looking at producer of services or consumer of services-but not both.
    - *Can HEA determine recovery time for lost service?* Recovery time is an input to HEA calculations, estimated based on the best available information. Assumptions can be made based on surveys of past construction projects to estimate real versus anticipated loss for future projects. This often is a difficult issue, but one that needs to be addressed..
    - *If HEA assumes pristine conditions how can we achieve 100% restoration?* HEA does not assume pristine conditions were lost replaced. The HEA is based on baseline conditions over the period of interest.

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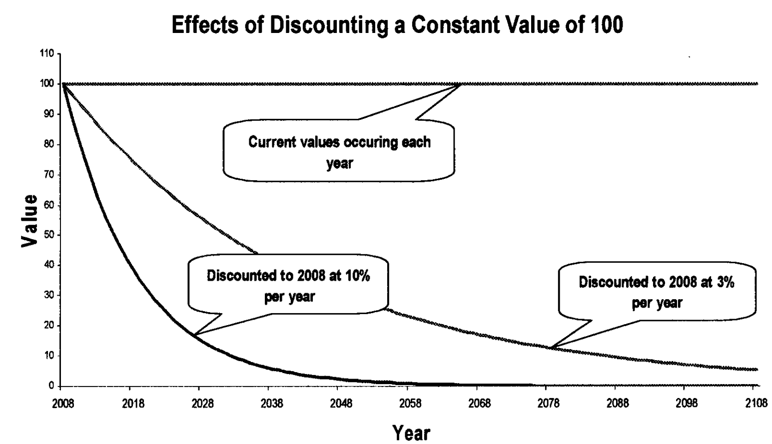

- *How did you determine 3% discount rate was appropriate for Kilo Wharf?* It was not a project-specific decision. There is a body of literature and federal policy (OPA preamble) that use 3%. OM&B has recommended 7% for manufactured capitol and historically 10% was used, but 3% is a better value for coral reefs. This parameter has never been contested in court and should be considered the least of worries when developing inputs for HEA.

- *A. Can the replacement area be non-contiguous?* For example, the area required is 14 acres can you create replacement in multiple sites? HEA does not inherently account for synergy of contiguous replacement area, but it could be addressed if the ecologist could provide information that demonstrates the multiple sites result in different losses/gains when compared to losses/gains at a single contiguous location. Bruce & Mike are not aware of any cases where this has been done but it is conceptually possible. B. *If using "in-kind" replacement, then isn't it on both sides of the equation and drop out of calculation?* Yes although it is hard to generalize - one should look at site-specific data and calculations . C. One could look at discontiguous replacement but it can be difficult to get that kind of data. For example, 100 acres contiguous = x loss of function versus 10 parcels of 10 acres results in y loss of function.

- The schedule is very tight and the December HEA will be based on best available information.
- *Why not base HEA on ecosystem structure instead of ecosystem function?* While possible, one could have similar structure in two places but different levels of function and service, for a variety of reasons.. Habitat functions often can be useful as proxies for services, but HEA design will depend on the availability of information and other site-specific considerations.

4. Proposal to skip HEA inputs and cover them later, but decision made to go through slides quickly instead. Powerpoint #3 HEA WORKSHOP.
    - HEA is needed for each type of habitat. Example: acre/year of seagrass is not equal to acre/year of coral. Two restoration projects are required to address both losses.
    - Coral habitat provides food and refuge to fish but it is difficult to quantify therefore one would often use other measures as a proxy (e.g., acres of coral or number of fish).
    - *A. Wouldn't ecosystem approach be easier than individual habitats?* The mitigation should provide services similar to those lost. Typically, this goal can best be met by focusing on impacts to and restoration of habitats within an ecosystem (e.g., marsh, subtidal, intertidal, oyster reef, coral reef, mangroves, etc.) However, in some cases it may be appropriate to measure impacts and benefits on a broader ecosystem basis (e.g., stream habitat, wrapping in riparian, nearby upland, wetted stream areas, etc.) . A key consideration is whether mitigation, expressed in the same units, is expected to provide an appropriate type and level of replacement service. B. *Doesn't this support the idea that acre/year is not a satisfactory assessment of loss of function*? No. It all comes back to the practicality/feasibility of proposed mitigation projects, and the similarity of mitigation benefits to those lost. Ideally, you would replace/restore in-place, in-kind immediately. But often there are delays in being able to restore the site and additional mitigation projects are required for the loss of function in the interim. To the extent out-of-kind mitigation projects are implemented, the evaluation of comparability between acre-years of impact and mitigation will be more complex.

Lunch Break

5. CVN-Specific Information (JT Hesse) Powerpoint #4 HEA WORKSHOP
    - Brief description of CVN project:
        - dredge footprint and S. Dollar coral map shown.
        - *What will be the delay period before actual construction?* Don't know depends on whether project will be design-build or design-bid-build.

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- *Duration of construction?* Unknown at this time. There are only so many dredgers in the world. John Sato spoke to one who would prefer to operate 24 hours as cost savings measure.
- *Which dredging method? They may have different impacts on MMP species?* Don't know. Worst case would have to be considered. S.Dollar: dredge impacts on coral are similar r

ACTION: Meeting with engineers to discuss construction assumptions for EIS (avoid, minimize impacts)

- DEIS will be based on Steve Dollar coral surveys and agency Spring surveys will be included in the Final EIS.
- Issues and Challenges:
    - In-lieu fee program. Agencies and Navy are in favor of in-lieu fee program, but timing could be a stumbling block if in lieu is not established in time. Attendees were confident it could work for this project once the fee was established.

a. Schedule:
    1. ISA for '09 Spring field work by November 15
    2. TEC will incorporate survey results in the Final EIS
    3. ROD 2010

b. *Why are Inner Apra Harbor Projects and coral impacts not being addressed with CVN project?* Navy policy is to not mitigate for coral growth on man-made structures- such as vertical sheetpile. General consensus, based on survey data, is the Inner Apra Harbor seafloor does not contain coral resources and invertebrates would recover quickly.

6. Preliminary HEA: Available Data for Injury Quantification (Mike Donlan) Powerpoint #5 EA Workshop
    - Based on existing information
    - Coral Impact will be key direct impact parameter
    - Hard substrate communities only
    - Navy will not mitigate for soft-bottom habitats, but data could be used in affected environment section of EIS. "hard bottom" is essentially coral skeletons and would include sponges, but only coral will be included in December HEA.
    - *Has baseline temporal variability been considered? One survey in spring will not address this.* We don't live in an ideal world and we will cope with best available data. REDIRECT conversation back to December HEA.
    - Channel was dredged in 1946 during creation of Polaris Point. There is no known "construction dredge depth".
    - *If coral is not 100 years old, why use 100 years for period of analysis?* The age of the coral does not define the period of analysis. The period of analysis should be determined based on expected baseline conditions, and the expected duration of project impacts and mitigation project benefits,
    -

ACTION: When would planned maintenance dredging occur for the CVN dredge area? (Navy- Sato?)

- We don't know what the rate of regrowth of coral would be
- *Western and Jade Shoals may be impacted by this dredging, but not in 1946 dredging.* For the most part Western and Jade shoals will not be directly impacted, but there is a small area in the channel.
- *Does global warming figure into the HEA?* It could if estimates are available of the impact of global warming on the area in the baseline scenario (i.e., without the CVN project).

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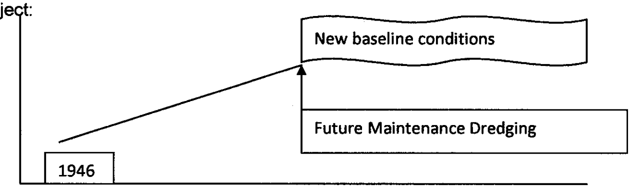
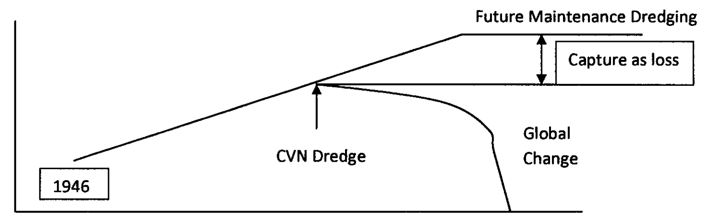
Without project:



With Project:



- Global change hard to characterize. If ignored = worst case (i.e., impact-maximizing) scenario. Restoration projects in same area may increase collective resiliency.
- Mitigation analysis should address global warming if impact analysis does . It may shift where or how project is constructed.
- *Does Navy have a Global Warming planning policy for a set planning period?* Neither USFWS nor Navy has such a plan, but at the regional level the Navy is looking at which mission critical facilities would be impacted. Global change is being added into INRMPs but there is no guidance on how.

BREAK:

Continuation of Powerpoint #5

- *Which areas within S. Dollar's coral mapping are actually going to be affected by dredging? Information is available, but graphic is not compiled yet.*

ACTION: Overlay dredge areas and bathymetry on coral mapping and determine what % of additional area around pinnacles would be collateral damage (Consultants).

- *Should we look at individual coral coverage classes and aggregate later or take average of all classes?*
- *A. How does coral removed at top of steep slope or pinnacle impact the coral on the slope? Pieces could roll down slope damaging coral on the way. B. Would this be indirect or direct impact?* Distinction not important for HEA calculations. C. We would need data of damage to use it in HEA unless we add a % affected assumption in these steep areas. Even if assume all area below is damaged, it would not be appreciable (SD). But assuming 100% damage would be overkill (MM). Kilo Wharf Reef Slope Dredge Buffer, Lost Functions time path was 100% in 2008 and 0% in 2018(RW). Broken coral may increase asexual reproduction and increase recovery, which could be on the mitigation side of the equation.
- *May need to address sedimentation within project area. This is what Marc Ericksen is addressing in his models.* Let's make assumption that all coral within area is *porities rus* and resilient to turbidity. But if we want to be conservative why pick most resilient? Because that is the predominant type of coral observed to date. There will be Spring surveys that may report other types of coral. Marc's assessment of cumulative is limited to where the sediment initially hits ground and does not address sediment moving
- *Do larger colonies necessarily represent greater "ecological value"? This is generally the view that Kolinski takes (BP).* What does ecological value mean (SJ)? Probably refers to reproductive health (MM). This would be too difficult to define (SD) and may be too far in the minutia. Let's live with the data we have (MM). The reason Bruce Peacock is asking is: if classes of cover are important then they should be kept as separate classes for HEA and generate separate projects. If there is little difference among classes, then gross area of coral coverage is all that is important (BP).
    - CONCLUSION: collapse all classes into one class for HEA

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- NEPA document to clarify that more results will be incorporated into FEIS and described process.

ACTION: In DEIS-describe future data that will be available for the FEIS (TEC/NAVY)

- *Can direct impact be combined with indirect impact? (MM)* Prefer to keep separate for now (JT). Smaller colonies do worse in sediment loading. Grain grain size and morphology appears to be important in literature (DM).
- Assume all the same size coral (BP).
- *Format: Will future HEA process beyond December HEA be described in HEA report or EIS?* HEA will be stand alone document based on best available information. EIS will reference the December HEA and introduce future work and data gaps.
- *Is there a way to translate the Spring data into useful HEA inputs to produce acre-years?* Yes- with qualification- and it may be best to see what the data is before trying to anticipate use. This will be addressed –in part- in the sampling plan that is pending.
- *Can we discuss BMPs tomorrow?* This is part of impact minimization that occurs prior to HEA inputs.

DAY 2: November 6, 2008

1. Spring Survey Data Collection (Dwayne Minton) Powerpoint # 6 HEA Workshop
    i. Data Hierarchy: Survey data is larger dataset with EIS data and HEA data being smaller subsets of the same data. Some of the data set will be in the EFH and it may be more qualitative (JT).
    ii. Review Spring Metrics Table (embedded).

Table 1. Variable/metrics selected for data retrieval/collection as part of the marine resource surveys of Apra Harbor to support the CVN Project. Variables/metrics are presented in no particular order.

Variable	Metric	Justification	Necessary For: Ch.3	Ch.4	HEA
Algae Abundance by species (or lowest possible taxonomic level)	Percent of bottom covered	Algae are the primary space competitors with reef building corals and are capable of establishing dominance over corals following a disturbance (e.g. reef phase-shifts). Data will provide qualitative (species list) and quantitative (abundance) data on algal species. This data provide a valuable measure of baseline conditions from which to measure project-impact and scale compensatory mitigation.	X	X	X[1]
Coral colony abundance: density of colonies by species (or lowest possible taxonomic level) and morphological form	# of colonies/m^2	Data will provide qualitative (species list) and quantitative (abundance) data on the primary reef building organisms. This group forms the foundation of the coral reef ecosystem and is general considered the primary group with which to examine during HEA.	X	X	X
Coral colony size	Length of longest axis in centimeters	Colony size is used to assess the size structure of the coral community. This data provides information on coral recruitment and a correlative measure of functional attributes (e.g., topographic complexity, reproductive potential, etc.). Needed to assess the recovery potential of an area. Abundance, form and size are basic parameters for determining equivalency between compensatory mitigation and impact site loss.		X	X
Coral Fragments	To be determined	Data provide insight into recovery dynamics.		X	X[1]
Partial coral colony mortality	% mortality on colonies with complete fission	These data provide a measure of baseline conditions from which to measure project-impact and provides guidance when scaling compensatory mitigation.	X	X	X[1]
Occurrence of gross growth anomalies and/or anomalous patterns of tissue loss by species (or lowest possible taxonomic level)	% of colonies showing the described condition[2]	These data provide a measure of baseline conditions from which to measure project-impact and provide guidance when scaling compensatory mitigation.	X	X	X[1]

[1] Provides supporting information, but may not be a direct entry into the HEA.
[2] Photographs of affected colonies will be sent to a coral disease expert for identification and data be presented by the identified name. In Guam, occurrence is typically low at the gross examination level.

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Variable	Metric	Justification	Necessary For: Ch.3	Ch.4	HEA
Mobile macro-invertebrate density by species (or lowest possible taxonomic level)	# of individuals/m^2	Data will provide qualitative (species list) and quantitative (abundance) data on species that play important functional roles on the reef (e.g., herbivory) and in some cases have cultural significance.	X	X	X[1]
Sessile Macro-invertebrate (especially sponges) abundance by species (or lowest possible taxonomic level)	Percent of bottom covered or other relevant measure (e.g., for sponges)	In Apra Harbor, sessile macro-invertebrates may also be significant competitors with coral for space on the bottom. Data will provide qualitative (species list) and quantitative (abundance) data and can be used to establish baseline conditions from which to measure project-impact and scale compensatory mitigation.	X	X	X[1]
Fish abundance and diversity by species (or lowest possible taxonomic level)	# of individuals/m^2 or # of individuals/minute	Data will provide qualitative (species list) and quantitative (abundance) data on the primary vertebrate organisms on the coral reef. Many of these species play important functional roles on the reef (e.g., herbivory) and have cultural significance. Fish abundance is necessary to computing fish biomass, which is the most appropriate quantitative measure of fishery stocks.	X	X	X[1]
Individual fish size	Length in centimeters	Fish length is necessary to compute fish biomass, which is the most appropriate measure of fishery stocks.		X	X[1]
Occurrence of protected species (e.g. sea turtles)	Presence-absence/site	Unless abundant and/or presence is predictable, data is collected incidentally.	X	X	
Rugosity	Rugosity index	Rugosity is a measure of 3-dimensional structure which "ignores" the underlying biological component (e.g. coral, algae, etc.) of the structure. These data provide a valuable measure of baseline conditions from which to measure project-impact. This data could provide direct guidance or input when scaling compensatory mitigation.		X	X[1]

[1] Provides supporting information, but may not be a direct entry into the HEA.

i. Comfortable that this data will be sufficient but if there any fatal flaws then identify them during presentation. Changing SOW would be problematic.

ii. Definitions: variable = is measurable and metric = unit of measure. The biometric definition describes an established dose-response relationship and differs from the statistical definition (SJ). It is the statistical definition that is being applied (DM).

iii. *# colonies per m^2 may be the only metric applicable to HEA (SD).* Based on *discussions today other metrics could fit into HEA (DM). Counting colonies is not enough (SD).* USFWS will be looking at colony size (DM). *It is difficult to distinguish among colonies when they are interconnected- 10 or 10,000 colonies (SD).* Concur -it is difficult but there are experts (Kolinski and CNMI scientists) participating on survey who can make the distinction (DM). *Would 2 different scientists make the same observation –if not, the data is questionable. Statistics crumbles if scientists don't agree (RW)?Workshop on coral reefs last year concluded it was very difficult for certain species like Porities rus, so the type of coral is important in method effectiveness (RB).*

iv. *There is some disagreement on the time it takes to make these assessments and there is some question of the validity of the data (JT).* This goes back to sample design and the goal is to sample across area of greatest diversity. In recent CNMI survey a team could survey 3-6 sites per day. If there is little to observe –of course -the time at the site could be 5 minutes. Difficult to do more surveys per day due to scuba safety requirements.

v. *Will survey capture vertical growth?* Yes, but uncertain how it will be used. *Would vertical growth have higher density?* Not necessarily. 3D spatial analysis is not part of SOW. If pinnacle is in transect, then survey would not count entire wall.

vi. NMFS coral experts not present so let's move away from details and let Dwayne proceed.

vii. *Do you plan to look for inverts at night when they are is most likely to be observed (FD)?* Not part of sampling plan, but could fit in an evening

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survey at 1 or 2 sites surveyed during the day. *Was night survey done for Kilo Wharf?* Don't know.

viii. Fish abundance and fish size collectively reflect biomass and is the preferred method for assessing fish populations @ the lowest taxonomic level. This data could be used in EIS, HEA and EFH.

ix. Continue through rest of metrics with no comment. Historical aerial photographs of Apra Harbor from 1945-46.

2. HEA Inputs for CVN (Bruce Peacock and Mike Donlan). Powerpoint # 7 HEA Workshop

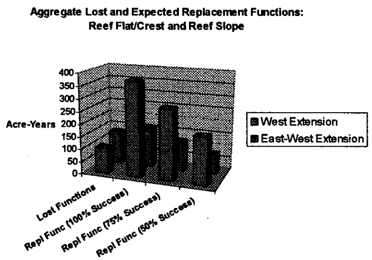
   i. Described Kilo Experience:

      i. similar to December HEA: not enough time or data

      ii. two classes: reef flat crest and reef slope

      iii. two impacts: direct & indirect

      iv. Project: sediment removal @ Cetti Bay. Usually, would try to find a site that with sufficient area (determined by HEA) to offset loss. But in this case only 1 site identified with a fixed size.



v. *What is function on this graph*? Proxy of area of habitat in acre-years, basically an aerial measure of reef flat. *Was class or colony size used?* Explained through following discussion:

- X acres of reef flat crest plus
- Y acres of reef slope

Not broken out by % cover.

How many years would habitat be harmed?

- Indirect loss: 20% for a few years
- Direct loss:100%

x+x+x+x coral cover + y+y+y+y coral cover=total area of coral cover.

Verify same area of restoration available at Cetti Bay. Based on assessment of live plus dead coral coverage. Assumption was dead coral would recover if water quality improved.

vi. *The statistics was flawed with a sample size of 2 at replacement site.* Concur.

vii. *Back to graph: why are red and blue bars for replacement different for the two alternatives if the replacement project is the same for both?* The difference is based on ratios not absolute values. The two alternatives had different footprints and substantial difference in loss.

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viii. *A. If the data is so poor maybe HEA was not the most appropriate method. It appears to be force fit into a specific project instead of determination of size and then finding a project (EL).* There was sufficient data to run the HEA. Could have looked at multiple projects but only one was available (BP). B. *What if there were two bays and two different sampling sizes, would you default to lesser data?* The discussion of high level of comfort versus low level of comfort in the data is based on a meeting of experts and application of common sense. There are multiple factors to consider, including but not limited to the reliability of extrapolations made from available data. HEA is a tool (MD). Data uncertainties can and should be evaluated.

ix. *HGM may be more appropriate than HEA (JS).* HEA can use HGM inputs but HGM has the same challenge as all other methods in dealing with dissimilar habitats (MD). Also HGM does not address timing differences between impact occurrence and mitigation implementation.

x. *(Back to bar graph)How do you calculate success?* You don't. Recognize the uncertainty in mitigation and place reasonable assumptions on the plan. 100% is easy. Lower success is captured in the 50% success. Other success rates could be modeled (BP).

xi. *Was there discounting over time (DH)?* Yes- included as one of the parameters that feed into the HEA.

xii. Conclusion: HEA is an expedited means of assessing what it would take to replace the value loss to the public due to unavoidable impacts. Cheaper than complex economic studies.

xiii. There were disadvantages in the Kilo Project but in the end it served to provide decision makers a distinction between alternatives.

xiv. Discussion of how Spring data will be used in HEA. Conclusion that it is best to see what the data reveals and reconvene to discuss the practical approach. The data often reveals the way to proceed (MD).

xv. CVN: should we aggregate classes of % cover or retain through HEA. Can re-aggregate after if a weighting factor is used.

3. Army Corps Rules (George Young). Powerpoint # 8 HEA Workshop.

- *Is the 5-year of mitigation project monitoring fixed?* No- could be more if mitigation takes longer to achieve. The 5 years is largely based on wetland experience.
- *Is there a good example for a prospectus for establishing in lieu program?* No- most of the history is on the mainland and was for establishment of wetland mitigation banks. Mitigation banking requirements are more stringent. *Is there an Army Corps region that is the best source of information?* Southern California.
- *Do projects have t be within the same watershed as the loss?* The idea is to provide benefit to the hydrological landscape that experienced the loss. So –if you can't replace loss onsite, then what is next best opportunity? Watershed definition is not always straight forward especially in pacific islands.
- *How does replacement of aquatic function fit into the watershed?* The provider must demonstrate how -for each specific project.
- *The insurance limit maximum ($200,000 per account) may be less than the deposit in the mitigation fund. Are multiple accounts required?* No- the insurance is not as critical as the placement in an FDIC institution.
- *Is there a percentage included for overhead?* Prefer not to use a fixed percentage. The goal is to get as much of the money into the project as possible. The prospectus needs to describe the management structure including roles of individuals.
- *Where does interest on the account go?* Back to project –not to sponsor.
- *Is it possible for DoD to attend Army Corps Workshops on the new rules?* Shouldn't be an issue.
- *Who has expressed interest in being a sponsor?* On the mainland there have been a large number of applicants for mitigation banks. The interest in in-lieu fees is far less. Micronesian Conservation trust is interested, but the amount of paperwork is frightening. The mainland has more history and experience.
- Is it possible for all interested parties (DoD, ACOE, NOAA etc) to meet prior to permit submittal to discuss the mitigation projects openly. Yes- successful mitigation is the desirable outcome. This type of cooperation is a natural evolution from the existing permit process. But ACOE must maintain objectivity

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and not favor one party or sponsor over another. *Can Frank Dayton participate more freely than George Young in discussions?* Expect all reps to be involved in projects in their region while maintaining objectivity.

- Is it possible to use mitigation funds for reefs at large and not just coral, for example upgrading the sewage treatment plant. There is no stator restriction except that fees are not to be used for education.
- FYI the Navy has been able to construct projects off base through the Sykes Act. DoD training ranges have potential to use all the mitigation bank funds.
- *Would ACOE prefer a project with assured outcome over one that is more experimental but with great potential?* Depends. The framework of the proposal would provide rationale and justification.
- *Is there a penalty for failed mitigation?* No because funds are not provided upfront for that potential. The Sponsor not the project proponent would assume responsibility. Once the project is accepted by the sponsor DOD is no longer responsible.

LUNCH

Mitigation Discussion:

- Everyone is on-board with in-lieu or mitigation banking, but there are no projects yet.
- JT proposes using artificial reefs as a "proxy" to arrive at a dollar amount that could be applied to projects that have not been identified. Artificial reefs represent the costlier mitigation so this approach would represent the worst case. Apples to apples comparison.
    - George Young said the mitigation must be directed at a specific project (BP).
    - This approach could be used for the DEIS (EL)?
    - Only if DEIS was clear that this was not the last word on the subject and is clear on future data (MM). There is value in running HEA on all projects (MM). In DEIS list short-list of projects – pending more data.

    ACTION: Follow-on meeting to discuss mitigation

    - SOW for agency surveys does not include potential mitigation sites (JT)
    - Recognize lack of time and that sites can't be surveyed (MM).
    - Artificial reef may not be an apples to apples comparison. They may serve only as fish attracting devices for mobile species. (DM)
    - The Navy prepared a paper on artificial reefs that compares the various types and discusses the FAD issue.

  ACTION: JT will provide artificial reef paper to USFWS.

  - Is there a connection between the coral reef and the project? What data are available to quantify that link? This is a key focus of evaluating potential projects from a HEA perspective (MD). Also need to take into account stakeholder preferences.
  - *For WWTP upgrades, isn't this an easy engineering solution? How large must the facility be?* No -2 engineers will develop project at 2 different sizes. Upgrading WWTP serves to improve water quality and the assumption is- it would result in reef health. There is also the aesthetic value (SD). Guam is extending the outfalls into deeper water (RW). There is evidence that secondary sewage is more harmful than primary (SJ).

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- FYI: cost effective proposal is preferred in the regulation.
- If not artificial reef than what? Artificial reef is the easiest to use, from the perspective that such reefs directly provide habitat designed to be similar to that lost (MD).
- Legal question: if DEIS describes one mitigation project is there a legal issue if it changes later (EL)? In Kilo- did not describe aforestation in EIS. There is no correlation that aforestation improves water quality (RW). There is a recent article that may provide link between coral reef and sedimentation based on a Molokai location (MM). But historically, the use of Hawaii data for Guam projects has been frowned upon (JT).

ACTION: USFWS will provide Molokai article tying reforestation to reef improvement

- Best to live the range of mitigation projects open for DEIS (MM). By FEIS must have mitigation plans but details are not required (JN). Would prefer to have permits ready for submittal on the day the ROD is signed (RW). Best to have all the data at the same time for efficiency sake (JS). Navy policy is to not sign ROD until permit application is in hand (JS).
- Back to mitigation: Simpler to use artificial reefs, but need the right ratio for replacement. (RB)
- Key problems for reefs: overfishing and land-based pollution
- Fund enforcement of no fishing in marine protected areas. Disadvantages: 1) legality of transferring DoD funds to other federal agencies or local agencies to support policing action 2) is this really helping agencies to meet existing mission? If so- it is not really an improvement or change, even if the mission is underfunded. 3) fishermen are not in favor of marine reserves so may not be a great place to invest. But the Guam Natural resource report did recommend federal support for management. 4) A project is more suitable than providing money. 5) Difficult to find connection between enforcement and coral reef health 6) would another agency really want the burden of using the finds for enforcement?
- Create or expand preserves. Issues: land acquisition is risky, time consuming and expensive. Must demonstrate the purchase and protection from future development does improve water quality. DoD is able to contribute to a land trust. Landowners may be only interested until a higher and best use comes along.

- Management plans for: submerged lands, non-DoD lands or DoD lands or Guam – wide. Plans are not acceptable mitigation. If DoD lands, INRMP is already supposed to be managing those resources.
- GOVGUAM is still looking at mitigation projects – so our list is not complete. In the room the long list is complete. Which of these is scalable and useable by December?
- Marine aquarium for gene banking? Hard to tie to loss.
- Aquaculture/mariculture to replace fish biomass, but would it replace ecological function? Would have to quantify impacts of overfishing. Reefs in Guam are generally in bad shape. It could be a piece of the puzzle. Increasing the number of herbivores would decrease the algae growth on reefs. There is an old facility that is run-down.

Long list of projects:

i. WWTP upgrades

ii. Aforestation

iii. Seagrass mangrove improvements

iv. Stormwater pollution prevention

v. Natural erosion control

vi. Expand existing preserves

vii. Marine protected areas: increase enforcement protection of existing

viii. Purchase new land for new preserve or to prevent future development that could degrade water quality.

ix. Management plans: submerged lands or DoD lands or island wide

x. Aquaculture to increase biomass

xi. Marine aquarium- gene banking

- Three groups of projects:

i. Water Quality Improvement projects

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ii. Building reefs

iii. Mariculture

- If there is no scalable mitigation, is HEA the right tool? Still need to develop projects whatever method is used. What is driving the bus on HEA? Navy has to show replacement and does not have to use HEA to satisfy ACOE regulation. BUT ACOE consults with other agencies that like HEA as a tool. HGM was considered by USFWS but it is difficult to apply to coral. So there is no use in continuing to debate HEA or no HEA. HEA it is.
- Back to JT suggestion of artificial reefs as worst case to get a cost. May- in fact- not be worst case. Need to consider loss of habitat at artificial reef placement site and impact to MMP species.
- Acknowledgement that agency estimate of $100 million would now be closer to $50 million based on new information since Spring '08.
- Shortlist of projects:

i. Artificial reef is one method to estimate mitigation costs.

ii. A second method is to use Cetti bay as "proxy" for aforestation-based water quality improvement projects. Assume Cetti bay restoration is off the table as a Kilo Wharf project. Are there other Bays around Guam that could be = to a Cetti Bay scenario? Don't need to actually measure dead coral just use Cetti Bay assumptions.

- No concurrence on how to proceed is possible without review by NMFS coral staff.
- Final Proposal for December:

i. Mike Donlan run artificial reef HEA

ii. Bruce Peacock look into feasibility of Cetti Bay model for HEA (?)

iii. **Concurrent** consultation with other agencies that were not in attendance. If they disagree they should provide reasons why not and a better solution.

ACTION: Meet with agencies not in attendance to discuss conclusions

- What type of reef design? Suggestions welcome – will review the Navy paper on artificial reefs

- Where will artificial reef be located? Not site specific.
- Dec 4 last opportunity for input from anyone.
- Dec 11 report due.
- Use existing HEA Administrative working group as forum for further discussion.

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Sign up Nov 4 + Nov 5
HEA Workshop

Nov 4+5	Name	Org.	Email
✓	Kevin Foster	FWS	kevin_b_foster@fws.gov
✓	Steve Helfert	DoD Liaison/USFWS	steve_helfert@fws.gov
✓	Bruce Peacock	NPS	bruce_peacock@nps.gov
✓	Faith Caplan	TEC	frcaplan@tecinc.com
✓	Don Hubner	NOAA/PRD	Donald.Hubner@noaa.gov
✓	Duayne Minton	FWS	Duayne_Minton@fws.gov
✓	Steve Doller	MRC	sdoller@mrc-hawaii.com
	Teresa Bernhard	JGPO	teresa.bernhard@navy.mil
✓	Frank Dayton	Army CoE	francis.m.dayton@usace.army.mil
	Cindy Barger	Army COE	cindy.s.barger@usace.army.mil
✓	Mike Donlan	IEc (Navy contractor)	mcd@indecon.com
	Stephen Jameson	NAVY	Stephen.Jameson@navy.mil
✓	JT Hesse	NAVFAC PAC	jeffrey.hesse@navy.mil
✓	Julia Novotny	NAVFAC HQ	julia.novotny@navy.mil
·	Ed Lynch	COMPACFIT	edward.j.lynch.ctr@navy.mil
✓	Robert Wescom	NAVFAC MARIANAS	robert.wescom@navfac.navy.mil
✓	John Sato	NAVFAC PAC	john.sato@navy.mil
✓	Michael Molina	USFWS - PACIFIC IS.	michael_molina@fws.gov
	Joe Hautzenroder	NAVFAC HQ	joseph.hautzenroder@navy.mil
✓	Rusty Brainard	NOAA/PIFSC/CRED	Rusty.Brainard@noaa.gov
✓	Kevin Nishimura	USACE	kevin.h.nishimura@usace.army.mil
✓ (only)	George Young	CoE	george.p.young@usace.army.mil

Habitat Equivalency Analysis (HEA) Planning Meeting

November 5, 6, 2008

Final Agenda

Wednesday, November 5

8:00-8:30 Introductions and purpose of HEA workshop **[Kevin/Bruce/Mike split]**
- -Goal: Introduce HEA methodology
- -Goal: Reach consensus on CVN-specific HEA issues, within allotted time
- -Next steps and deadlines to be identified at end of second day

8:30-9:45 Introduction to HEA **[Bruce lead, Mike add in]**
9:45-10:00 Break
10:00-11:00 Framework of HEA **[Bruce lead, Mike add in]**
11:00-12:00 HEA Inputs **[Bruce lead, Mike add in]**
12:00-1:00 Working Lunch
12:30-2:00 CVN HEA Introduction **[JT lead, Mike provide more detail on HEA aspects, Bruce add in]**
- -Brief Project Description
- -Dual EIS Needs: Impact Assessment and Mitigation
- -Project Timeline/Key Dates
- -Preliminary HEA (for December Draft EIS)
- -Brief Description of Planned Field Work
- -Post-Field Work HEA (by end of June, for Final EIS)
- -Expected HEA Issues/Challenges

2:00-2:15 Break
2:15-4:00 Preliminary HEA: Available Data and Potential Approaches for Injury Quantification **[Mike lead, Bruce add in]**
- -Dredge Footprint
- -Maps of Live Coral Coverage
- -Dredging Sediment Plume Modeling
- -Relevant Literature
- -Other?
- -Discussion toward consensus decision on approach

Thursday, November 6

8:00-8:45 Data to be Collected through Early 2009 Field Work **[Dwayne lead]**
8:45-10:30 Post-Field Work HEA: Potential Injury Quantification Approaches **[Bruce lead, Mike add in]**
- -Discussion toward consensus decision

10:30-10:45 Break

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10:45-12:00 Permit Requirements/Overview of the **Compensatory Mitigation for Losses of Aquatic Resources; Final Rule** and Considerations for Mitigation and Role of Mitigation Banking / In-Lieu-Fee Arrangements **[George Young, ACOE]**
12:00-1:00 Working Lunch
12:30-2:45 Potential Mitigation Priorities, Data Needs, Quantification Approaches **[Bruce/Mike introduce, generally we expect this session to be more of a discussion – few if any slides required]**
- -Discussion toward consensus decision
- -Upland Reforestation/Sediment Management Projects
- -Artificial Reef Structure Projects
- -Use Restrictions/Marine Protection Areas
- -Water quality improvement
  - -Cesspool elimination / septic conversion
  - -New WWTP(s)
  - -Storm-water runoff

2:45-3:00 Break
3:00-3:15 Impact monitoring and mitigation performance standards **[Bruce lead, Mike add in]**
3:15-4:00 Next Steps **[Bruce/Mike/Kevin split]**
- - CVN HEA Working Group
- -Tasks
- -Deadlines
- -Process

CVN/HEA ADMINISTRATIVE WORKING GROUP

MEETING RECORD

November 25, 2008 1330 (Hawaii) –Teleconference

Purpose: Mitigation /Restoration Projects

Attendance:

Gerry Davis
Tino Aguon
Michael Molina
Dwayne Minton
Wendy Wiltse
Bruce Peacock
Robert Wescom
Steve Dollar
JT Hesse
Faith Caplan

Read Aheads: None

Discussion Points:

1. Restoration project (s) proposed by agencies meeting in Guam Nov 25, 2008 (Guam), presented by Tino: Offsite holistic watershed management to improve water quality of Agat Bay and other nearby bays, through one or more of the following individual projects:
    - Reforestation/aforestation
    - Enhancement of riparian areas
    - Streambank stabilization
    - Stormwater management
    - Upgrade wastewater management systems
    - Purchase private lands for conservation
2. Discussion on Proposal:
    - *Is there survey data on the coral reefs in the Bays?* Yes- there are reports that tie sedimentation to the coral reefs. Bob Richmond of UOG was involved.
    - *This would not be in-kind mitigation and is problematic in the HEA.* It would be handled in the HEA as the Cetti Bay model for Kilo Wharf. It can be considered "apples -to- apples" restoration because the coral

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mitigation and recovery can be tied to coral impacts. There are limitations in data, but there always limitations in data.

- *How many of the projects listed would be required?* This would be a question for ecologists to answer.
- *Is there coral diameter data available for CVN sites?* Not for this HEA, but Spring survey will provide.
- *If we were to run a HEA for this new proposal based on best available information in December '08 would the Cetti Bay data be used?* Yes
- *The statistics used for the Cetti Bay model is not valid based on sample size and overlapping sampling area.* But is based on best available data at the time.
- In summary, we are still proposing two HEA models based on proxies for restoration: artificial reef and Cetti Bay.
- There will be new data in the Spring that would be used instead of data collected for Kilo Wharf.
- *Size frequency times number of colonies is essentially the same as coral cover.* For Kilo - averaged total diameter of coral (not cover) and calculated for 2 different habitat types. *Basically, average total diameter is a proxy for coral cover, regardless of type of coral.*
- Concur that there is a lack of data for the December HEA.
- *How do we use the specific projects proposed in the HEA?* It would take another planning group to decide which of these projects would be implemented.
- Recovery rates for Cetti Bay were set at10 years

3. Funding for Bruce Peacock to conduct Cetti Bay Proxy for Dec 2008 HEA.
    - HEA workshop concluded with proposal for 2 HEAs being run (Dec 2008) with 2 restoration project proxies: artificial reef and Cetti Bay. Mike Donlan was to do the artificial reef model and Bruce Peacock would do the Cetti Bay model. Bruce adds: They planned to work together on loss side of the equation and produce one report.
    - JT and Dwayne Minton discussed funding for Bruce in the weeks following the workshop. Navy attempted to secure funding (ISA or subcontract to TEC) in a timely manner for Bruce's effort, but could not secure funding in time. Dwayne Minton was aware of the funding issue through communications with JT.

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- Mike Molina is unaware that funding had failed and assumed that the Navy would find the funds if not prior to the work, then later.
- JT stated he cannot authorize work and commit Navy funding unless he has those funds at his disposal. Bruce should not be investing any time on this project because he will not be compensated by the Navy to participate in the Dec 2008 HEA. There was not enough time to request funds to meet HEA December schedule.
- When funding options failed, Mike Donlan was asked if he could run both proxies. (This additional work does not represent additional funds for IEC. but a revision to Mike Donlan's existing Scope of Work.)
- Mike Molina questions if the Navy did all that was possible to identify funds.
- Separate discussion on subject of funding may be required.

4. Other mitigation projects were proposed but this one was the one that was recommended for consideration for the CVN project.
5. Gerry Davis would like to have a discussion on the artificial reef proxy. There are things that could be improved over the Kilo Wharf HEA model. This can be discussed offline with JT or at next meeting.
6. Next meeting scheduled for December 2, 2008 1330 (Hawaii).

CVN/HEA ADMINISTRATIVE WORKING GROUP

MEETING RECORD

December 2, 2008 1330 (Hawaii) –Teleconference

Purpose: HEA proxy

Attendance:

Gerry Davis
Tino Aguon
Michael Molina
Dwayne Minton
Jesse Cruz
Mike Gawel
David Burdick
Wendy Wiltse
Bruce Peacock
Frank Dayton
Chuck Sayon
Robert Wescom
Steve Dollar
Michael Donlan
JT Hesse
Faith Caplan

Read Aheads: None specific to meeting, but USFWS provided a critique of artificial reefs

Discussion Points:

1. Until recently, there has not been much feedback from agencies on mitigation project proposals.
2. Navy decision is to use the artificial reef project only as a proxy for the Dec '08 HEA. The Navy believes the scientific data on artificial reefs is more legally defensible. JT & Gerry D. discussed the shortcomings of artificial reefs earlier today.
    1. Gerry: Artificial reefs may be good or bad depending on individual opinion. Most of the research papers are on the use of artificial reefs to improve fisheries not provide for lost ecological value. There are many variables to be considered as inputs to the HEA.
    2. JT: Acknowledge receipt of Mike Molina's critique of artificial reefs provided in email today. Navy welcomes additional critique of artificial reefs as proxy. The discussion will continue and changes will be made after the Spring surveys and will influence the Final EIS.

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3. *Is the only proxy artificial reef?* Yes.
4. JT explains concept of using a proxy: the idea is to assess the impact side of the equation and quantify replacement with artificial reef. The result is no net ecological loss of the resource. Percent coral cover weighted by ranges of coral cover category to obtain total coral cover. Then a ratio of artificial reef replacement to area lost is applied. For Hypothetical Example: if a project impact was 10 acres (weighted to 100% coral cover) and a 5:1 ratio is assumed, it would equal 5 acres replacement (artificial reef) per 1 acre of coral loss. The total dollar figure for the artificial reef proxy would include the physical artificial reef structure, labor to implement in location x, long term monitoring. The total cost would be available for *in lieu* fee. The Navy is not planning to build artificial reefs. Just using them as proxy to obtain mitigation costs.
5. *Is the purpose to approximate cost of mitigation?* Approximate cost of using artificial reef as mitigation.
6. *Does it preclude agency mitigation projects?* No- projects like Tino mentioned in the last meeting could be funded (pending legal review).
7. *This one proxy approach is not consistent with HEA workshop. USFWS has repeatedly stated it would like to have the Cetti Bay HEA in EIS.* True -things have changed as we discussed at the last meeting. We could not provide funding for Bruce Peacock. Proposed that M. Donlan do both proxies, but there are Navy concerns regarding validity of Cetti Bay proxy. Navy chose to eliminate the Cetti Bay proxy HEA.
8. *Mike M. We talk a lot about agency coordination and cooperation, but this is not cooperation.*
9. *No one from Guam participated in HEA Workshop.* USFWS was hosting the meeting and set the date (which was difficult). Wish all could have attended. The Navy attempted to get the conversations on mitigation started months ago. It wasn't until the HEA workshop that USFWS mitigation ideas were discussed. We were hoping to avoid this rush at the last minute and it has been very frustrating for the Navy.
10. *Mike M. All have found project frustrating so let's not go down that road. Bruce P is almost done with his HEA and it could be included in the DEIS.* Navy decision is to go with artificial reef HEA only.
11. *When describing ratios to be used earlier, where did that 5:1 ratio come from?* It was just a fictional example. The actual ratio has not been determined but will be documented in the report.

12. *Whatever project is selected it must show how project will replace loss (Frank D).* Concur and Navy (HQ and legal counsel) would like to talk with ACOE(including legal counsel) to determine if mitigation proposals are legal for federal agency to implement. Frank D: *Good idea.*
13. JT: *For example: Improving wastewater treatment facilities (discussed with Gerry D already today) is a potential project implemented with money identified in artificial reef proxy. Don't know if there are legal issues. No documentation of recovery rates through wastewater treatment plant upgrades.* Gerry D: It is also complicated because of the poor cost to benefit ratio.
14. *USFWS and NOAA can expect formal letter describing the way forward.* Will that letter be before or after ACOE/Navy meeting? *After.*
15. There is value to having allocated money to USFWS to conduct surveys in Spring. This is not the end of discussion.
16. Could Navy/TEC get a map of watershed areas that Tino described for restoration projects at the last meeting? We need to describe the projects in the EIS.

ACTION: *Tino will provide graphic with assistance from Bureau of Statistics and Plans (David Burdick) and* Bureau of Land Management *(BLM).*

17. Frank D. *Isn't that watershed area private land?* Need to check with Chamorro Land Trust and Bureau of Land Management.
18. *Robert W. was just at the BLM office looking for other information and learned that BLM maps have not been updated since 1967.* There are large parcels that are probably subdivided. Zoning probably has not changed. Most of the land area is in Southwest park.
19. *Gerry D.:How will HEA deal with no-site for artificial reef?* There is direct loss of habitat and temporal loss. *Also there is loss at the artificial reef site. If it is placed on soft bottom, then must address that impact.* JT: we are assuming hard bottom substrate mitigation. Navy has not mitigated for soft bottom habitat in the past. *Water movement and chemical changes are also important.* JT: There are no answers to these questions yet (but will be captured in EIS).
20. *What is status of Bruce Peacock's request for information to complete the Cetti Bay HEA?* Navy has not sent specific items to Bruce because there was no funding for Bruce P. to proceed, but can forward information as it becomes available. The project area and coral drawings were delivered to USFWS today. JT will drop off more GIS data this week. Marc Ericksen has completed some models this week but the graphics are not ready for distribution and more model runs are expected over the next few weeks. There is no intent to withhold information, and in this case Navy did not think Bruce P. would be using information provided.

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MEETING RECORD

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3. Army Corps and Navy will discuss meeting schedule.
4. Tentative next meeting Dec16 1330-1530 (Hawaii). May have results from Army Corps / Navy meeting to present.

APPENDIX B
Action Item List
(December 3, 2008)

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HEA Working Group Action Items – Updated December 3, 2008

Item #	Added	Responsibility	Action	Due Date	Interim Status/Findings
1	2-Jun	TEC-FC	Verify that engineers considered seismic conditions in CVN structural design	6-Jun-08	Per CVN-capable berthing study, seismicity was a key fsctor in recommending steel pile structture
2	2-Jun	PACFLT	CVN ship movement graphic	6-Jun-08	a. Per conversation with TEC engineers, this question should be answered by site-specific tug operators & CVN pilots b. Ask FLT to provide
3	2-Jun	TEC-FC	Circulate munitions report (when available) to answer the question of whether increased operations are anticipated at Kilo due to Relocation		report pending completion
4	2-Jun	NAVFAC -VP	review LCAC laydown for mangrove impact	10-Aug-08	reviewed numerous sources including aerial photos and no mangroves/wetlands are in the vicinity of the LCAC laydown area.
5	2-Jun	JGPO-TB	Verify the phasing of the JGPO marine projects to better assess survey schedule impacts	10-Aug	the Inner Apra harbor porjects and the CVN wharf project are being programmed for funding in 2010-2011
6	2-Jun	Frances Suganuma (PACFLT)	detail description of CVN/tug positioning and capabilites for CVN movement backwards and sideways (agency question need for turning basin)	done	6/6 mtg: Frances Suganuma PACFLT: CVN has limited reverse capability. Short distances are OK in reverse but navigational control reduced. CVN requires a turning basin in front of the wharves to avoid reverse. The minimum radius of the basin is the length of a CVN.
7	2-Jun		Was dry dock island a CVN alternative? Could it be? (Motivation is to minimize loss of coral)	done	6/6 mtg: Frances Suganuma PACFLT: No- drydock island was not considered. A desktop study will be done to see if it meets minimum criteria. Desk top study eliminated the proposed Dry Dock Island alterantive. Key reasons force protection (proximity to commercial port), difficulty in providing full shore services, would not eliminate need for turning basin because the angle of the turn is too sharp.
8	2-Jun	EL	Would off-loading planes reduce draft and decrease amount of dredging required? And is this practical?	6/6/2008 meeting	Per Frances Suganuma PACFLT: a. the draft would not be appreciably reduced if planes flew off b. there are minimum design specifications that must be met for operational safety c. There is no room for planes at AAFB
9	2-Jun	EL	Can mitigation cost estimate be adjusted in the FY 2011 budget?	6/6/2008 meeting	
10	2-Jun	EL	Notify PACFLT additional funding for NAVFAC PAC may be required	done	
11	2-Jun	CNM-Rick Raines	Check on status of NEPA documentation and Sec 7 consultation for magazines/pads proposed on Orote		
12	2-Jun	CNM-Rick Raines	Check details on "pot of money" available for wharf improvements: what projects are proposed, are the projects different from JGPO projects. JGPO master planners should be informed.		

HEA Working Group Action Items – Updated December 3, 2008

Item #	Added	Responsibility	Action	Due Date	Interim Status/Findings
13	2-Jun	TEC-S.Dollar	Discuss with Dwayne (USFWS) best way to share survey videos.	done	August 2008 S Dollar and Dwayne are coordinating delivery
14	2-Jun	USFWS-DM	Prepare proposal and cost estimate to outline actions required to address data gaps for all Apra Habor projects. Availability of human resources will dictate whther there are 2 field events or 1 (SEE item 14)	done	Proposal submitted, pending Navy action
15	2-Jun	USFWS-Dwayne Mitton	Determine if there are sufficient human resources to conduct a Fall '08 survey		hopeful….
16	2-Jun	USFWS-DM	Coordinate/manage the biweekly logistics meetings to discuss field work details	August 2008 intiated	Dwayne sentout email of interest/invitation (6/10/08)
17	2-Jun	NAVFAC -VP/JGPO	Explore funding options to identify most expedient and flexible. Get buy-in in advance from approval authorities	done	
18	2-Jun	NAVFAC PAC-VP/FC	Coordinate manage biweekly HEA Working Group Meetings, beginning June 19 1st meeting June 19th @ 1300 incl:Michael Molina, Al Eversen, Mike Donlan, Mark Cruz, Guam EPA-Jesse Cruz, Wendy W. (EPA)	done	meetings are ongoing
19	2-Jun	TEC-FC	Ask Marc E to describe existing data & use in June 9 meeting	9-Jun-08	Meeting held with NMFS, EPA, Guam EPA, USFWS
20	2-Jun	NAVFACPAC-VP	Confirm availability of Navy Biologist/Diver	done	
21	2-Jun	EL	What is impact of a new wharf at former SRF on the dry dock? ED-believes there is a brief on the subject.	6-Jun-08	per Frances Suganuma PACFLT: a. the drydock would not be used if CVN at wharf. There is a safety concern about dust on the flight deck b. SRF will be compensated for standing by c. SRF would cooperate to encourage future business relationahip with Navy, d. the CVN may result in increased work for SRF
22	6-Jun	VP	CD of BMPs distribute to USFWS, NOAA, TEC, PACFLT	done	
23	6-Jun	Frances Suganuma(PACFLT)	Vett reduced dredged footprint with 7th Fleet and document avoidance of coral impact for admin record	Per COMPACFLT reduced radius (minimum) is operationally OK	F. Suganama forward it for review
24	9-Jun	TEC/USFWS	Schedule a follow-up meeting to the currents modelling meeting (item 19) to discuss parameters. August may be the earliest opportunity given Dwayne Mitton schedule.	4-Sep-08	
25	20-Jun	TEC	website of meeting records etc	done	website established and working group provided access details
26	24-Jul	Mike Molina	sketch dry dock island alernative	done	Submitted to Frances Suganama at COMPACFLT for review. To be used in completion of another Action Item.
27	24-Jul	Gerry Davis	sketch approach to Polaris Point	done	submitted to Frances Suganama at COMPACFLT for review
28	24-Jul	TEC/NAVFACPAC	Ask if alternatives analysis could be submitted prior to DEIS?	no time	submitted request to EV/JGPO

HEA Working Group Action Items – Updated December 3, 2008

Item #	Added	Responsibility	Action	Due Date	Interim Status/Findings
29	24-Jul	TEC/NAVFACPAC	Ask what the format will be for DOPAA comments?		submitted request to EV/JGPO. Incoproating changes and comments into DEIS. Organization radically changed.
30	7-Aug	TEC/NAVFACPAC	Develop more detailed CVN construction description	done	in progress. Will be provided in DEIS.
31	21-Aug	PACFLT (ED)	Ask about moving turning basin inside Inner Apra harbor	done	Partial turning basin still required to manuever CVN into place. Navy does not have partial turning basin requirements/specifications. Turning basins are for contingencies not perfect conditions.
32	21-Aug	PACFLT (ED)	Ask about shifting turning basin north	done	Would not eliminate need to remove coral and the turning basin was specifically moved south away from Jade shoals.
33	21-Aug	TEC (Faith)	DEIS project schedule	done-emailed	
34	21-Aug	USFWS/JT	August 22 meeting to discuss USFWS proposal	done	
35	21-Aug	Minton/JT	Coordinate meeting Sept 4, 2008 to discuss SEI modelling	done	
36	21-Aug	TEC/JT	Provide minutes of Sept 4 meeting to all (Lisa Fiedler request)	posted to web	
37	21-Aug	group	schedule meeting to discuss groundtruthing with S. Dollar		Keep on agenda, but will not be possible until Spring survey.
38	21-Aug	SEI	Marc Ericksen (SEI) to provide scenarios for sediment model	done	meeting held to discuss distribute at October 16, 2008 meeting
39	4-Sep	TEC/JT	add mitigation discussion to agenda	done	Sept 23 meeting discussed and will carry forward as needed
40	4-Sep	USFWS	USFWS authorize Bruce Peacock and Mike Donlan to discuss a presentation at biweekly meeting	done	HEA presentation at Sept 23 meeting
41	4-Sep	JT	bibliography of literature sent to USFWS for review and additions	done	no agency commitment to provide an updated list
42	23-Sep	TEC	request for graphic showing navigation into wharf at alternatives dismissed	done	may be in DEIS, but bottom line is CPF dimissed the alternative.
43	23-Sep	EPA/Wiltse	EPA will provide information on "bubble" silt curtain for consideration as BMP. Frank Dayton (ACOE) also requested information.	done	does not appear to be relevant to CVN project
44	23-Sep	USFWS	Navy request that USFWS-sponsored HEA conference be schedule to not conflict with Partnering meetings	done	Meeting will be held Nov 5 & 6
45	23-Sep	DAWR	DAWR will provide KILO Wharf mitigation list since DAWR mitigation plan is not available yet.	done	Mike Molina will distribute to everyone.
46	23-Sep	USFWS	coral recovery rates to be used in HEA need to be discussed further based on literature.	done	at HEA workshop
47	23-Sep	USFWS/NAVY	coral health assessment need to be addressed in Spring Survey. Coral is not likely pristine.	done	address in SOW for Sring surveys to the extent practical. Concurrence that coral not pristine.
48	16-Oct	DAWR/ALL	talk to Dr. Ramondo (sp.?) about coral transplants in Apra Harbor		
49	4,5 Nov	TEC/NAVY	Meeting with engineers to develop construction assumptions /conditions for EIS (avoid/minimize impacts)	ongoing	
50	4,5 Nov	Navy	When would planned maintenance dredging occur for the CVN dredge area?	done	Asked the question, but no one could guess

HEA Working Group Action Items – Updated December 3, 2008

Item #	Added	Responsibility	Action	Due Date	Interim Status/Findings
51	4,5 Nov	Navy Consultants	Overlay dredge areas and bathymetry on coral mapping and determine what % of additional area around pinnacles would be collateral damage	done	
52	4,5 Nov	Navy/TEC	In DEIS, describe future data that will be available for Final EIS	done	
53	4,5 Nov	Navy	Provide Navy paper on artificial reefs.	done	
54	4,5 Nov	USFWS	Provide Molokai article tying reforestation to reef improvement		not available yet.
55	2-Dec	GUAM Agencies	Tino will provide graphic with assistance from Bureau of Statistics and Plans (David Burdick) and Bureau of Land Management (BLM).	done	
56	2-Dec	Navy	Information requested by Bruce Peacock: project area, coral cover, aforestation cost, sediment models		All but sediment models provided by 12/3. Navy will release sediment model runs when all are completed.

APPENDIX C
Reference List

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CVN/HEA Working Group Reference List (*in progress*) Updated 12/9/08

Original list was prepared by the Navy. The following is USFWS assessment of what resources are relevant and which need to be reviewed for relevance.

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These documents have been excluded from further considerable for one or more of the follow reasons:

1. Document is too old. I have somewhat arbitrarily selected 10 years as the cut off. In the last ten years, significant changes and events would have made information collected prior to that no longer reflective of the current situation in Apra Harbor. I acknowledge that even this date may be too far back considering the recent typhoon years.
2. Work was not conducted in the immediate vicinity of the CVN project area. I have chosen to exclude Kilo Wharf information because it is far enough away that the biological survey work would not applicable to the VN project area. However, I seem to recall the Kilo project having some Navy surveys that extended east along the coast; these may be applicable. If this is true, please let me know and I will obtain the documents for review.
3. Document may contain information for the site and be current enough, but is not directly relevant to conducting the survey work (e.g., dredge material management plans, upland work). That does not mean these documents may not be important later. If this happens, the documents will be obtained at that time.

If you aware that one or more of these documents does indeed contain information directly relevant to the CVN project area, please notify me immediately so I can obtain it for consideration.

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APPENDIX D

HEA/CVN Administrative Working Group Comments on Draft

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#	SECTION	Page or Fig/Tbl #	Line #	Command or Org.	Commenter (last name)	Comment	TEC Response	Done
1	A 3.3.3	11	17	Bureau of Statistics and Plans (BSP)	Burdick	As acknowledged by the Navy in this document, our agency, as well as other local and federal, resource agencies, do not currently support the use of artificial reefs as compensatory mitigation. We disagree with the Navy's position that artificial reef structures would replace the loss of coral reef ecosystems, and we contest the assertion that relevant scientific data are available to support the idea that artificial reefs would be appropriate for in-kind replacement in Apra Harbor. And without relevant, high quality, peer-reviewed scientific data, it is not reasonable to quantify the ratio of restoration to loss for Apra Harbor (as opposed to Oahu). Given our positions above, we then must conclude that such a project would not be legal and not feasible. Also, while on-site mitigation is preferred under the Army Corps compensatory mitigation rule, it does not preclude off-site mitigation in instances where on-site mitigation may be more beneficial for a watershed. We believe it is reasonable to assume that the direct, cumulative, and secondary anthropogenic impacts to coral reef ecosystems in Apra Harbor will only increase in the future, and that the viability and perpetuity of mitigation activities within the harbor are in question.	1) Navy acknowledges the difference of opinion on artificial reefs in the scientific community. 2) Agencies have not provided relevant, high quality, peer-reviewed scientific data, to quantify the ratio of restoration to loss for Apra Harbor for the myriad of watershed management projects proposed. It is not consistent with compensatory mitigation rules to propose experimental studies /research on dose-response for various watershed projects. 3) artificial reef project would be legal and there is precedent for the type of mitigation and approval by Army Corps in the same area of responsibility (Honolulu). 4) Disagree with assumption that future projects would impact the effectiveness of coral reef systems in Outer Harbor. Navy would be required to mitigate for that impact. Therefore the argument of future development in Apra harbor is irrelevant. The artificial reefs would be sited in an area suitable for reefs in Outer Apra Harbor. The EIS will address reasonably foreseeable impacts of future projects in the cumulative impact section, but will only address specific projects that have been identified. No change to text.	
2	A 3.3.4	12	23-25	BSP	Burdick	See comment above	See response above	
3	A 3.3.4	12	35	BSP	Burdick	I believe "bays" was intended here instead of "harbors"	Concur. Change will be made.	Done
4	A 3.3.4	12				We understand the Navy's concern regarding the viability of watershed restoration as a viable mitigation option, but an examination of available cadastral data indicate that the Government of Guam actually owns a large amount of often contiguous parcels in this area. This is evident in Section A, Figures 4 and 5.	Revise Bullet as follows: • land ownership issues, given the Navy's understanding that 1) property within the proposed watersheds is owned by multiple entities, with GOVGUAM owning the majority (Figure 4), 2) the acquisition of lands, including GOVGUAM land (from willing sellers) would require Congressional approval, and 3) conservation easements made with landowners would not be legally binding in perpetuity.	Done
5	A 3.3.4	13	8	BSP	Burdick	While in-place mitigation may be preferred, it is not the only option under the Army Corps compensatory mitigation rule, and, in fact, the rule "acknowledges that there are circumstances where off-site or out-of-kind compensatory mitigation may be more beneficial for a watershed." We believe that the current circumstances call for off-site mitigation.	Actual mitigation has not been determined. Conversations on the subject will continue through the DEIS process and Section 404/10 permit application process. Navy acknowledges that off-site mitigation is an option under the CWA. No edit to text.	
6	A 4.0	19	21	BSP	Burdick	The use of coral size here is clearly important for describing the reef community, illustrating that the reef community in question was primarily composed of small colonies (and was thus likely relatively "young"). Using this type of information in a HEA is important, as recovery times for a coral community comprised of young corals would be significantly less than one currently dominated by large, older colonies. This type of data should be collected during the upcoming resource agency impact assessment of the CVN dredging area whenever possible. We acknowledge the difficulty in distinguishing between adjacent colonies of certain species, but insist that in the majority of instances (including when encountering *Porites rus* colonies), colony boundaries can be identified with additional effort. For more problematic species, such as *Pavona cactus*, *Porites cylindrica*, and *Acropora muricata* , it may be necessary to utilize different metrics. In these cases, the thickets could be treated as a single colony, and the thicket dimensions could be measured, along with percent cover (which can be derived from digital photos), and a description of the morphology.	Agreed.HEA was based on best available information at the time of preparation. Field surveys in Spring 2009 will include assessment of coral size. It has been discussed and agreed that terminology to describe non-discrete colony growth forms will be established. No change to text.	
7	A 4.0	20	27	BSP	Burdick	It is difficult to understand how there will be *no* sub-lethal effects to the coral community as a result of the dredging activity. Even if the corals occurring in the vicinity of the dredging appear to be relatively sediment-tolerant, it is evident by the results of models reported in this document that it is anticipated that at least the corals close to the dredging activity will temporarily experience elevated sedimentation rates. It requires energy to remove the sediment, through the production of mucus or ciliary action, and thus it is reasonable to assume that the expenditure of energy required to remove this sediment (which would not have occurred but for the dredging activity), would then not be available for gamete production, growth, defense, etc. The sub-lethal effects may be minimal, but saying that there will be no impacts is likely inaccurate.	The term "no sub-lethal" is changed to "sub-lethal effects are likely to be minimal." While it is true that sedimentation does require energy expenditure, the duration of expected sub-lethal effects is likely to be so short that the period of stress is not significant to the overall functionality of the colonies under stress. It is also possible that ongoing activities, such as ship movements and natural resuspension and transport of sediment has pre-adapted the communities within the dredge areas to the short-term effects of dredging.	Done
8	A 4.0	20	28	BSP	Burdick	Based on the rationale provided above, it is difficult to understand how the project would not result in at least some impact on reproductive potential of the Apra Harbor coral community as a whole. Even setting aside sub-lethal effects, corals will be directly removed during dredging, and thus they will not be contributing gametes to the Apra Harbor population. And while the coral species occurring in the project area are not likely unique to Apra Harbor (setting aside the potential for unique or rare species that may occur at greater depths, and that may be impacted by indirect effects of the dredging), there could potentially be unique genotypes - perhaps more sediment-tolerant genotypes - that may be impacted by the project. Again, it is one thing to say that the impact will be minimal or insignificant (neither of which are certain), and another to imply that there wouldn't be *any* decrease in reproductive potential. Also, it is not clear what the relationship is between the 60+ year age of the coral community and the expectation that no decrease in reproductive potential for the Apra Harbor coral community will result.	see comment above. Also, as mentioned elsewhere in these comments, substrate availability is likely the limiting factor to coral cover in Apra Harbor, and not reproductive capability. If this is the case, and there is a short-term effect on reproductive potential, the results are not likely to effect the overall community structure of Apra Harbor. No change to text proposed.	

#	SECTION	Page or Fig/Tbl #	Line #	Command or Org.	Commenter (last name)	Comment	TEC Response	Done
9	A 4.0	23	19-28	BSP	Burdick	The use of artificial reefs as a proxy for calculating the cost of mitigation needed to offset estimated losses does not seem appropriate. As has already been repeatedly expressed, we do not support the use of artificial reef structures as compensation, as we do not believe there is sufficient evidence to suggest that artificial reefs will adequately replace lost ecosystem function in Apra Harbor. Using artificial reefs to determine the scale and cost of compensatory mitigation does not provide any indication of the scale or cost required by another method, such as watershed restoration. The ratio of replaced to lost ecosystem function would be different, and thus the scale and cost would be different. The cost estimate for an artificial reef mitigation approach should not at all be considered appropriate for transference to a different mitigation approach (e.g., through an in lieu fee system), as a different approach may require a greater or lesser cost to achieve the appropriate level of ecosystem function replacement.	HEA was based on best available information at the time of preparation. There is more information on the implementation of artificial reefs projects than watershed projects that improve water quality. If data tying specific types and scale of watershed projects to a predictable rate of coral restoration were available then it could have been used in the HEA. Even if the rate of coral restoration per type of watershed were identified, specific project locations were not provided. No text edits.	
10	B 1.2.0	1	9	BSP	Burdick	Should the dates be "November 5, 2007" and "January 28, 2008"?	Concur. Text edited.	Done
11	B 1.2.0	1	9	BSP	Burdick	Are two sampling days enough to adequately describe water quality conditions in Apra Harbor?	Based on best available data. More dates, particularly during different weather and sea conditions, as well as during ship movement operations would have been desirable. No edits to text.	
12	C 2.1.2	4	26	BSP	Burdick	Should the dates be "November 3-4, 2007"?	Dates changed.	Done
13	C 2.1.3.2	6	34	BSP	Burdick	It is unclear how the benthic cover of the deeper reef structures (especially those towards the center of the turning basin) was determined using supervised classification, as the spectral signature of these areas would be obscured by relatively high turbidity levels. From looking at the image in Section C, Figure 2, much of the deeper reef area in the turning basin project area is not visible.	All reef at depths of dredging plus 2 ft over dredge (51.5 ft) were visible. No change to text.	
14	C 2.1.3.3	9	25	BSP	Burdick	Was an accuracy assessment conducted? If so, the results of such an assessment do not appear to be included in this report. Usually an accuracy assessment is conducted following the completion of image classification, or accuracy assessment points are collected during the ground truthing surveys. Regardless of when the data are collected, an accuracy assessment should involve collecting benthic cover data in-situ (or through the remote method described in the report) at randomly generated coordinates throughout the study site. If such an accuracy assessment was not conducted, this should be clearly stated in the report, and any claim of accuracy must be avoided. Considering that this data is a key component of the HEA, it would be surprising if an accuracy assessment was not conducted.	An accuracy assessment has been added assessing the accuracy of the classifier. In this case, the classifier is a computer-based, mathematical algorithm that has been trained with quantitative sea-truth 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. To directly assess the accuracy of the map product, it will be necessary to acquire further sea-truth data, which is one of the objectives of future studies.	Done
15	D 3.2	7	13	BSP	Burdick	This assertion is not supported by quantitative data. It is important to understand current recruitment rates in the project area before making such a statement, and the data presented in this report do not provide any indication that this data exists. Unfortunately, coral recruitment data collected by the UOG Marine Lab and the National Park Service at several locations along the western coast of Guam suggest that recruitment rates have declined by 1-2 orders of magnitude in the last few decades. This decline could have been a result of degradation of source reefs and/or pre- and post-settlement mortality, probably associated with poor water quality and substrate condition. As a result, we are concerned that the rates of coral recruitment that have allowed the recovery of coral communities in areas dredged in the past may not be observed on the reefs of today. More information about coral recruitment and other coral demographic information should become available upon completion of the resource agency impact assessment.	Agree that this site specific data is unavailable. To the extent practical, this information will be provided by Spring 2009 surveys. Coral colony parameters will be collected.	
16	D 3.3.1	10	37	BSP	Burdick	As Dr. Dollar stated earlier, the corals at the entrance to Inner Apra Harbor may be pre-adapted, or pre-conditioned, to high sediment conditions. It is not appropriate to assume that corals occurring in the turning basin area - an area that reportedly experiences lower sedimentation rates than the entrance to Inner Apra Harbor - will not be impacted by conditions considered "normal" for the Inner Apra Harbor (but are not likely "normal" for the turning basin area).	Disagree with comment. The same coral species in close proximity to each other are very likely to have the same physiological characteristics with respect to sediment tolerance. In addition, as stated above, it is likely that the corals in the dredge area are subjected to intermittent episodes of high sediment, which have not proven to be lethal. No text edits.	

#	SECTION	Page or Fig/Tbl #	Line #	Command or Org.	Commenter (last name)	Comment	TEC Response	Done
17	D 3.3.2.1	17	1-10	BSP	Burdick	It appears that Dr. Dollar believes that dredging activity will benefit coral reef ecosystems in the project area. This assertion is rife with problems, but I think it will suffice to say that this sentiment is not shared among the majority of the coral reef research community.	Word-checking the entire document reveals that the work "benefit" is never used. The intent of the lines referenced was to present what is in the literature and not make a value judgment. It is documented in in the scientific literature that fragmentation caused by natural destructive events, can result in aspects of increased reef development. For instance, in the Caribbean, which experiences an average of 4.5 hurricanes and 3.4 tropical storms each year (Glynn et al. 1965), the net effect of storm breakage and transport of live coral fragments may be to maintain Caribbean reefs in the highest range of calcification and to redistribute corals so that continued growth is not limited by crowding or proximity to sea level (Highsmith et al. 1980). In addition, as noted in Hawaii, downslope movement of coral fragments broken by storm action appears to widen the narrow slope area thereby increasing suitable substratum for settlement and growth (Dollar and Tribble 1993). Massive coral destruction from storm waves in French Polynesia with downward movement of broken colonies may be an important agent in the formation of detrital cones surrounding atolls (Harmelin-Vivien and Laboute 1986). Such evidence of movement of coral fragment from catastrophic storms may be as important to reef construction as coral growth on a geologic time scale (Dollar and Tribble 1993). Discussing these documented phenomena as possibilities that may occur during the dredging along slope edges in Apra Harbor is in no way adding any value judgments as "benefits." This and additonal literature review are provided in text.	Done
18	D 4.0	18	13-14	BSP	Burdick	see comment above	See corresponding response	
19	D 4.0	18	26-27	BSP	Burdick	see comment on line 7	See corresponding response	
20	D 4.0	18	28-31	BSP	Burdick	see comment on line 8	See corresponding response	
21	F 1.0	1	25-26	BSP	Burdick	see comment on line 9	See corresponding response	
22	F 4.0	5	11-13	BSP	Burdick	We feel strongly that coral percent cover does not adequately capture the functional attributes of the coral community, and thus would not adequately characterize the expected ecosystem function losses associated with the planned dredge and fill activities. The replacement of resource function is required under the Army Corps of Engineers Compensatory Mitigation Rule in order to ensure compliance with the Clean Water Act, and thus an adequate assessment of expected ecosystem function loss is essential.	HEA was based on best available information at the time. The ACOE has approved the use of artificial reefs for mitigation purposes, and the use of percent live coral as a means for estimating mitigation requirements (e.g., HASEKO). Other aspects of coral community structure will be evaluated during planned Spring 2009 surveys. Further discussion is required to determine the applicability of that data to the HEA model. No edits to text.	
23	F 4.0	5	11-13	BSP	Burdick	We also advise against the use of percent coral cover alone as a metric by which compensatory mitigation is scaled using a Habitat Equivalency Analysis (HEA). Percent coral cover does not capture the difference in services provided by different species, colony sizes, and morphologies, and thus does not provide an appropriate quantification of the functional losses for which compensatory mitigation will be scaled. Coral colony density and size class information, on the other hand, can be used to estimate different functional values for different colony sizes, morphologies, and species and are important for estimating the recovery time for each size class of each coral species. For example, the recovery period for a coral reef area dominated by a few, large Porites rus colonies would be considerably (perhaps an order of magnitude) greater than the recovery period required for a dense community of small P. rus colonies. Percent living coral cover for these two coral reef areas, however, could be nearly identical.	Coral colony density, size class information, and other types of data identified in the comment were not available for the project area at the time for report preparation. Spring 2009 survey data will provide requested data. No edits to text.	
24	F 4.5	11	14-15	BSP	Burdick	On what basis is a short recovery time expected? Just because coral growth occurred after dredging decades ago doesn't mean it will occur at the same rate now. The functional form of the recovery trajectory should have a major impact on HEA calculations, and the arbitrary use of a linear recovery curve is completely inappropriate. A more representative recovery curve can be estimated using coral demographic data, which is suggested as a crucial component of the resource agency impact assessment. The recovery period can be substantially different across coral communities, depending on species composition, rates of recruitment, the age of the corals at the time of impact, and other factors. As mentioned above, the recovery period for a coral reef area dominated by a few, large *Porites rus* colonies would be considerably (perhaps an order of magnitude) greater than the recovery period required for a dense community of small *P. rus* colonies.	The 1-2 year recovery time is based on the Brown et al (1990) cited on page 11, line 8. The HEA Model was adjusted to a 5 year recovery time for coral habitat affected by indirect (sediment related impacts). The difference is less than 1%. It applies to sedimentation impacts only, and reflects recovery from what available data and analysis indicates is expected to be a low level of impact. Coral demographic data cited in the comment are not available for the project area. The functional form of recovery has only a minor impact on HEA calculations when recovery occurs rapidly. As noted in the comment, community structure data collected during the planned Spring 2009 surveys will provide some data to evaluate recovery. No edits to text.	
25	F 6.0	14	2-4	BSP	Burdick	see comment on line 9	See relevant response	
26	F 6.0	14	16-17	BSP	Burdick	From our limited knowledge of the Hawai'i artificial reef project referenced here (we are currently reviewing the FEIS, which we found online), it does not appear appropriate to compare that situation to the situation in Apra Harbor.	The CVN project and the HASEKO project both involved mitigation for dredging-related impacts to coral habitat. Same agency reviewed and approved the mitigation. Navy anticipates similar consideration for a project in Guam. No text edits.	
27	F 6.0	15	4-5	BSP	Burdick	It is not clear if an in-lieu fee program will be established in time. Also, see comment on line 9	Concur. Revise sentence to say "an in-lieu fee mitigation bank if it is established in time. "	Done

#	SECTION	Page or Fig/Tbl #	Line #	Command or Org.	Commenter (last name)	Comment	TEC Response	Done
29	F 7.2	16	16-	BSP	Burdick	There are numerous reasons why artificial reef structures are not expected to adequately replace the ecosystem services lost as a result of the CVN project, and, at best, the level of uncertainty of their success is too large to risk failure, especially considering the vast size of the project and the expected scale of compensatory mitigation. Even aside from concerns about the level of coral recruitment to artificial reef structures in Apra Harbor (as mentioned above), there remains serious concerns regarding the appropriateness of creating habitat in what is clearly not a habit-limited ecosystem. Several researchers suggest that placing artificial reef structures near natural reefs would likely act as fish aggregating devices, rather than a means to increase production - especially in heavily fished areas such as Apra Harbor. I have covered this topic in more detail in my comments on the Kilo Wharf FEIS, so I will not go into it here. I urge you to review those comments for a better understanding of our position on this issue. Please don't hesitate to contact me if you would like me to send you the comments.	The comments on the Kilo Wharf project were reviewed and the Navy's response has not changed in the interim. This is a subject that will continue to be discussed through the DEIS and the ACOE Section 404/10 permit application process. There is less certainty of success with watershed improvement projects. Agencies have not provided relevant, high quality, peer-reviewed scientific data, to quantify the ratio of restoration to loss for Apra Harbor for the myriad of watershed management projects proposed. It is not consistent with compensatory mitigation rules to propose experimental studies /research on dose-response for various watershed projects. How many watershed projects of what type and at what scale would it take to restore the loss coral reef function in a specified bay? What is the rate of restoration? Coral habitat will be unavoidably adversely impacted by the project and compensatory mitigation is required. Artificial reefs are believed to provide in-kind, i.e., a resource of a similar structural and functional type to the impacted resource. The Compensatory Mitigation for Losses of Aquatic Resources; Final Rule states that when compensating for impacts to marine resources, the location of the compensatory mitigation site should be chosen to replace lost functions and services within the same marine ecological system. Information in the scientific literature demonstrates that artificial reefs can provide functions and services comparable to natural reefs. Corals grow on artificial materials in Apra Harbor (Smith, 2007). The ACOE has recently approved artificial reefs as mitigation in Hawaii for dredging of coral habitat. The structures provide the basis for restoration of functioning coral reef ecosystem. If the structure does serve as a FAD it does not diminish the function of the coral reef ecosystem. If a wetland is created to replace lost wetland, the attraction of birds from other wetlands areas to the new wetland is not an considered an adverse impact on the wetland function. The structure is provided. The attraction of fish to a new coral reef structure does not diminish the value of a new coral reef ecosystem function.	A
30	F 7.3	17	6	BSP	Burdick	see comment on line 24	See relevant response	
31	F 7.3	17	17-20	BSP	Burdick	On the contrary, there is little coral growth on artificial structures in Apra Harbor - even on wrecks many decades old. Artificial reef structures (known as "reef balls") that have been illegally placed at several locations in the harbor do not appear to exhibit much coral recruitment over the last several (at least 4-5) years. In addition, the corals species observed on these structures are not typical of those impacted by the CVN project.	The Navy requests the Resource Agencies identify any data it is aware of concerning artificial reef placement in Apra Harbor. The lack of success of the illegal artificial reefs could be a function of inadequate analysis of suitable placement sites. In the case of wrecks, it could be a the chemical composition of substrate, e.g., anti-fouling paint that inhibits coral growth. Previous Navy studies have identified viable locations for artificial reefs in Apra Harbor, and the proposed mitigation budget includes funding for additional	
34	General HEA			EPA		EPA does not support the approach of using a "proxy" to describe mitigation for the very significant impacts (>58 acres) to marine ecosystems, and especially to the >40 acre impacts to coral reefs. The ACOE-EPA Mitigation Rule (40 CFR Part 332: Compensatory mitigation for losses of aquatic resources) describes very specific requirements for compensatory mitigation and the DEIS should present mitigation that complies with the rule. The DA permit requires "appropriate and practicable compensatory mitigation", and the DEIS should describe such mitigation in a conceptual if not detailed presentation.	The total project area is 58 acres. There are large areas of soft sediment that would be subject to short-term construction-phase impacts with no anticipated long -term impact. The use of a proxy was determined at the HEA workshop in November 2008 to be the best option based on available information. The Navy's choice of artificial reefs as a proxy was based on a number of factors outlined in the report. Artificial reefs have been approved by Army Corps as compensatory mitigation recently in Hawaii. With appropriate siting and substrate artificial reefs would be appropriate and practicable in Guam and would meet the requirements for restoration of functions and services. No change to text.	
35	General HEA			EPA		Compensatory mitigation must be designed to replace "permitted loses of aquatic resource functions and services" (40 CFR 332.3(d)). Calculating the cost of a proxy mitigation plan may be helpful to Navy, but does not adequately address the need to assess and replace lost functions and services for the DA permit.	Navy acknowledges the EPA opinion on artificial reefs. It is not an opinion shared by all in the scientific community. Artificial reefs have been used as compensatory mitigation recently in Hawaii and other places worldwide. With appropriate siting they would be appropriate in Guam and would meet the requirements for restoration of functions and services in a way that is more demonstrable than watershed improvement projects . No change to text.	
36	General HEA			EPA		EPA supports using the best available scientific methods for assessing the impacts to aquatic resources. We hope that all parties can eventually agree on a functional assessment method that directly measures the functions and services of coral reefs, as some regions have done for wetlands. However, in the absence of a functional assessment method for Pacific corals, we agree with FWS, NMFS, and numerous experts that measurements of individual colony size is essential if we are to use coral reef physical structure as a surrogate for functions and services. We refer you to the EPA Stony coral Rapid Bioassessment Protocol (EPA/600/R-06/167, July 2007) for the colony-dependent assessment method developed and recommended by EPA. This method directly addresses coral reef functions and services. We strongly support including assessment information based on colony-size in the DEIS and will require this for the DA 404 permit and mitigation plan.	The reviewer is misinterpreting the methods of the EPA Stony Coral RBP. While Chapter 2 of this document describes the array of "Coral Reef Attributes and Services," the three measurements recommended in the RBP are 1) coral identification; 2) size, and 3)proportion of live tissue (p. vii). None of these measures "directly address coral reef functions and services" but rather provide the data to develop a set of indicators. In fact on page 12, it is stated that "The Stony Coral RBP provides indicators of coral condition only..." Hence, as with the EPA protocol, all attributes of coral community structure that will be evaluated and deemed as a proxy for coral community function. No change to text.	

#	SECTION	Page or Fig/Tbl #	Line #	Command or Org.	Commenter (last name)	Comment	TEC Response	Done
37	General HEA			EPA		The artificial reef HEA fails to consider the uncertainty of mitigation success as required by the mitigation rule (40CFR 332.3(f)). The analysis as presented underestimates the amount of required mitigation because it fails to account for uncertainty related to rate and extent of recovery, physical stability of the structures, increased fishing, fouling of structures by invasive etc.	There is lack of alternative data to be used that meets the mitigation rule. Non concur with the statement that the analysis is an underestimate. All mitigation proposals have a level of uncertainty, artificial reefs have the least based on available information. The Navy analysis explicitly considers several sources of uncertainty in its calculations. See Section F 10. No change to text.	
38	C			EPA		not reviewed	No response necessary	
39	D			EPA		not reviewed in detail	No response necessary	
40	E			EPA		not reviewed	No response necessary	
41	A	8	20	EPA		for USEPA, delete "Guam offices".	Deleted as suggested.	Done
42	A	11	11	EPA		"replace lost functions and services of coral reef ecosystems"	Edited as suggested.	Done
43	A	12	all	EPA		The DEIS should contain a balanced description of a "viable/practicable" mitigation project, or present a balanced summary of a range of alternative mitigation projects. The tone of the discussion on this page is unbalanced and biased toward artificial reefs. Both the watershed and artificial reef proposals have pros and cons and these should be presented in a balanced way and neutral tone. Unfortunately neither approach is ideal. Again, EPA objects to the proxy approach, but would like to see a balanced discussion of the practicality, pros and cons of artificial reefs if this remains in the DEIS as an option. EPA supports the watershed approach because (1) restoration of an area where corals previously thrived is likely to be more successful than creating new reefs where corals never existed, (2) water quality improvements have been demonstrated to result in coral reef recovery (e.g. Kaneohe Bay after removal of wastewater discharge, also Pagopago Harbor, (3) this approach has wide support among Guam agencies and federal resource agencies, (4) the watershed approach threatens no further harm to reefs and has inherent ecological and social value both on land and in the ocean. Please add these points to the discussion of the watershed approach.	Concur that neither artificial reefs or watershed projects are ideal. Text is modified to present the merits of watershed projects.	Done
44	A	4, -7		EPA		These aerial images do not correspond with the watershed restoration area proposed by Gov. Guam, as EPA understands it. We believe the area proposed is limited to Sella, Cetti, and Fouha watersheds, which are largely uninhabited and where gov Guam is a major landholder. Also, please check whether the upper watershed boundaries are accurate on these figures.	These figures were provided by Bureau of Statistics and Plans in conjunction with proponents of the mitigation plan. The authors of the HEA Report made no substantive edits to the graphics, except to add a location map inset. No edits made to report.	
45	A	20,22	16,11	EPA		Note inconsistency in sediment thresholds for coral impacts	Noted. No edits to text.	
46	B	17	9	EPA		"anomalous outliers" does not appear to be an appropriate description for the samples that exceed M-2 WQS. On what basis are they anomalous? Exceedences are likely to be common in the industrialized harbor and during the winter season and should be considered in the water quality characterization, unless there is reason to suspect the QA or lab analyses were 'anomalous".	There is no reason to suspect lab QA as all samples were run at the same time. In this study, as in all other locations with multiple factors that can influence water quality, "outliers" are not unexpected. As stated in the report..."These results suggest that while TSS and turbidity within the sampling area are generally relatively low, there can be localized and temporary increases." With respect to turbidity, the highest value measured was 1.7 ntu, and is the only sample that could have exceeded Guam Water Quality Standard. No edit to text.	
47	B	Table 1		EPA		In the DEIS, highlight values that exceed water quality standards. Also describe whether or not this area is on Guam's 303(d) list of impaired waters and for what parameters.	The report is edited to highlight the water quality values and add information on 303d impaired waters. Text added and exceedances are highlighted.	Done
48	D	7	10-12	EPA		This statement about sediment tolerance for *P.rus* lacks a citation. The evidence presented, conflicts with the water quality data and statements in Section B about generally good water quality and low turbidity in Apra Harbor. If section B is correct, the *P.rus* . do not experience high suspended solids.	P.rus occurs in the mouth of Inner Apra Harbor, where turbidity has been documented to be higher than in the Outer Harbor. No edits to text.	
49	D	7-9	all	EPA		The discussion of sedimentation impacts to corals is inconsistent within the document sections. Section B states that water quality is good and that any water quality standards exceedences are "anomalous". Yet there is extensive discussion here about corals in Apra Harbor being acclimated to high turbidity/TSS. Also the discussion of sediment impacts to corals is incomplete and does not include some important recent publications such as the review paper by Fabricius (2005), and Weber, Lott, and Fabricius (2006), also the work of Bernardo Vargas-Angel on sublethal effects of sedimentation on corals.	Discussion in section B documents measurements made on two days, and notes that conditions would likely be different under different environmental conditions. Observations and photo-documentation of corals in the mouth of Inner Apra Harbor clearly indicate corals in this area are routinely subjected to high sedimentation/turbidity. The paper by Fabricius addresses terrigenous sediment impact, which is not applicable in this case. Review of the Weber et al paper supports the premise of minimal indirect impacts for the CVN project as they found that there was no measurable photosynthetic stress to test corals after >2 days of exposure to fine and medium grain marine sands, and pure aragonite silt from ground-up coral. These authors concluded that there is a fundamentally different effect to corals exposed to sedimentation by sandy nutrient-poor sediments, such as storm resuspended marine carbonate sediments predominantly found in offshore environments, compared to sedimentation of silt-sized sediments rich in organic matter and nutrients that predominantly occur in nearshore environments. Sections rewritten.	Done

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50	F	1	2	EPA		Clarify in the DEIS project purpose what is meant by "general purpose wharf" as opposed to a narrow purpose of CVN berth. What other uses will occur at the new CVN wharf?	Port Operations has the discretion to dock any vessel at the wharf, typical of other wharves at Apra Harbor. The DEIS contains more operational information than the HEA report. Removed general purpose to avoid confusion.	Done
51	F	1	29-30	EPA		Note that the acreage of direct impacts to aquatic resources exceeds the acres of proposed mitigation for each alternative presented here. This is a direct mitigation ratio, based on area, of less than 1:1. EPA can not accept a permit with such a low mitigation ratio for coral reef resources. The mitigation rule (40 CFR 332.3(f)(1)) requires a minimum one-to-one acreage compensation ratio for difficult to replace resources such as coral reefs. For several reasons sited in this section of the rule, a mitigation ratio greater than 1:1 is required for coral reefs.	The estimated total acreage of "direct" impact is 38.97 acres for the preferred project alternative (Section F, Table 2). The estimated acreage of artificial reef required is 43.47 acres, which exceeds 38.97 acres, therefore resulting in a mitigation ratio greater than one. No change to text.	
52	F	3	Sec.3	EPA		The discussion of coral reef valuation is not directly relevant for Clean Water Act 404 compensatory mitigation. The mitigation rule requires mitigation sufficient to replace lost aquatic resource functions (40 CFR 332.3(f) and does not place any cost or valuation limits on mitigation.	The Navy believes valuation information provides useful context for mitigation decision-making. No change to text.	
53	F	5	30	EPA		"100% live coral equivalent" is an inappropriate measure of impacts for scaling mitigation. Mitigation is required for the full area of impact to aquatic resources including areas with coral cover, and all other aquatic resources. This 100% concept is not ecologically based and does not relate to ecosystem functions. The Mitigation rule requires replacement of lost functions meaning "the physical chemical and biological processes that occur in ecosystems" (40 CFR 322.2 Definitions). Do not carry this analysis based on 100% live coral equivalent into the DEIS or permit application.	The ACOE has approved the use of artificial reefs for mitigation purposes and the use of percent live coral as a means for estimating mitigation requirements (e.g., HASEKO). That mitigation determination utilized "100% coral equivalence" calculations. This type of approach accounts for the fact that some impacted acres have very little live coral, while other areas have a large amount of live coral. Ignoring that distinction would be inappropriate. No change to text.	
54	F	6	2-3	EPA		The aquatic environment that is likely to be subject to indirect impacts from sedimentation should be directly assessed. The DOA permit will require pre-and post construction surveys with sufficient detail to determine the actual extent of sediment impacts.	Hydrographic surveys to verify dredge depths (pre-and post-construction) are typical of Navy dredge project. Additional surveys maybe required under the Army Corps permit. No change to text.	
55	F	6		EPA		The DEIS should estimate the extent of indirect sediment-related impacts from both the Polaris Point and SRF alternatives, based on habitat assessment data, not estimations. The SRF alternative appears to be the least environmentally damaging practicable alternative (LEDPA under CWA 404(b)(1) Guidelines) yet one of the reasons for preferring Polaris Point is that the SRF is closer to Big Blue Reef and more likely to impact corals in this high value area. Data must be provided as to the sedimentation impacts from both alternatives to support the analysis of the LEDPA.	Section E provides detailed modeling of sediment contours applying worst case scenarios. Detailed data on the specific habitat components of each alternative will be collected during spring surveys, after which this comment will be addressed. The DEIS will discuss the LEPDA considerations for both alternatives. The HEA does include indirect impact analysis. No change to text.	
56	F	10	23	EPA		How does the statement about mean coral size relate to the ongoing disagreement among experts on the feasibility of identifying individual colonies, especially for *Porites rus* ? Is *P.rus* covered by this statement on colony size?	USFWS personnel indicate that distinguishing individual colonies of P. rus. is not a problem. No change to text.	
57	F	10	29-31	EPA		This statement about routine high levels of total suspended solids is not supported by the water quality data presented by Dollar. Either this statement is incorrect, or the water quality assessment is not adequate. Since water quality is so important to the analysis of indirect impacts, EPA recommends a more comprehensive assessment of TSS in the harbor to understand the distribution of turbidity in space and time.	The water quality survey presetned in other sections was done on two days only and the results represent the conditions of those two days in terms of standard measures of water quality. The statement about routine high turbidity was made by a different individuals during a different time frame, based on qualitative assessment from underwater observations. There are no current plans for additional water chemistry analyses during the Spring surveys. No change to text.	
58	F	14	T.3	EPA		The recovery period of 2 years from sedimentation impacts is unrealistically low. It does not account for the time for coral recruitment and growth to replace corals (ave size >8 in.) that are killed by sedimentation.	The 1-2 year recovery time is based on the Brown et al (1990) cited on page 11, line 8. Increasing the recovery time to 5 years would have no impact on the HEA, assuming no other variables change. It applies to sedimentation impacts only, and reflects recovery from what available data and analysis indicates is expected to be a low level of impact. Coral demographic data cited in the comment are not available for the project area. The functional form of recovery has only a minor impact on HEA calculations when recovery occurs rapidly. As noted in the comment, community structure data collected during the planned Spring 2009 surveys will provide some data to evaluate recovery. No edits to text.	
59	F	14		EPA		See comment #10 regarding the need for a balanced presentation of viable mitigation alternatives and correct this page accordingly.	see response #10	
60	F	15	4-5	EPA		See comment #19 and address here. Note also that a formal mitigation plan based on a specific project is required for the DA permit (40CFR 332.3(k) (ii)). This document implies that Navy can pay a mitigation fee to an approved in-lieu fee program without identifying all of the components of the mitigation plan before the DA permit is issued; this may not be accurate.	See response to Comment 19. The Navy continues to discuss with ACOE the appropriate means to satisfy the compensatory mitigation rule. Conversations will include the application requirements if a in-lieu fee mitigation banking system is in place versus applicant directed mitigation. Sentence is modified.	Done
61	F	15	23-24, 37	EPA		It is unrealistic to assume that a reef that has developed over 60 years post-dredging can be replaced to 10% of service levels within a year following deployment of artificial reef structures, or be comparable to baseline within 10 years.	The data and analysis underlying Navy HEA assumptions are described in Section F.	

#	SECTION	Page or Fig/Tbl #	Line #	Command or Org.	Commenter (last name)	Comment	TEC Response	Done
62	F	199	Sec.9.0	EPA		See comment #19. This approach of estimating mitigation fee based on cost of a proxy that inappropriately underestimates required mitigation is unacceptable.	There is no evidence provided by the commenter to support that the assertion that a proxy underestimates the required mitigation. No change to document.	
63	A2.3	p. 5	21-22		Kolinski	Is ownership of submerged lands in Apra Harbor a contested/contestable issue? The statement of Navy ownership appears not to reflect such. Is stated management fully compliant with SIKES Act requirements? Clarification on these issues may be necessary.	Navy submerged lands boundaries were established by Congress in the 1970s under the Submerged Lands Act and since then only a few areas have been deeded back to other federal agencies (NPS, USFWS NWR) and the Government of Guam (Guam Commercial Port, part of Sasa Bay). No text edits.	
64	A3.2.2	p. 9	21-27		Kolinski	The wording and apparent intent should be considered for editing. Political commitments are, of necessity, almost always negotiable; it is unclear why such a statement would be made in a draft HEA document. The apparent intent seems to suggest that political commitment takes precedent over appropriate implementation of U.S. law.	Revise statement removing political and replace with reference to "international agreements", which do have a level of inflexibility. The international agreements were made between U.S. Government and Government of Japan. "Appropriate implementation of U.S. Law" will meet the schedule dictated in the agreements.	Done
64	A3.3	p. 9	42-43		Kolinski	Statement on unavoidable adverse impacts appears to be inappropriately limited to dredging "corals" as opposed to coral reef systems. Suggest broadening to encompass "non-coral" resources and services.	Edits made as suggested	Done
66	A3.3.1	p. 10	11		Kolinski	The word "otherwise" is problematic and should be removed as it, and the following sentence, suggest the actual mitigation need not be defined prior to issuance of a permit. Compensatory mitigation is not about costs, but rather replacement of lost ecological functions and services. Absent knowing the particulars of the specific mitigation planned, appropriate determination of the NEPA alternatives (including no action) can not reasonably occur and thus would violate the tenets of NEPA.	Otherwise is deleted. Costs are important for Navy programming and are not intended to be a substitute for replacement of lost ecological functions. NEPA alternatives analysis is presented in the DEIS/OEIS for action alternatives. Alternatives analysis on mitigaiton projects is not required. However, supplemental NEPA documentation may be required on specific mitigation projects.	Done
67	A3.3.1	p. 10			Kolinski	The actual mitigation needs to be defined prior to issuance of a permit. Compensatory mitigation is not about costs, but rather replacement of lost ecological functions and services. Absent knowing the particulars of the actual mitigation planned, appropriate determination of the NEPA alternatives (including no action) can not reasonably occur and thus would violate the tenets of NEPA. To be of use, in lieu fee programs built around specific projects need to already be established or determined (with specifics on timing, implementation, potential crediting, costs and uncertainty) prior to NEPA document review.	Concur that mitigation proposal needs to be reviewed by ACOE during Section 404/10 permit process. Costs are important for Navy programming and are not intended to be a substitute for replacement of lost ecological functions. Additional NEPA documentation will likely be required to address the mitigation proposals in support of the Army Corps 10/404 permits. The NEPA DEIS of Spring 2009 will present a range of mitigation alternatives that would apply to both CVN wharf alternatives. The specific compensatory mitigation project is not relevant to the assessment of the potential significant impacts of dredging under the project alternatives. The 2010 FEIS for the project may be completed prior to the establishment of an in-lieu fee program. Supplemental NEPA documentation will be prepared as necessary. No change to text.	
68	A3.3.2	p. 10-11	35-2		Kolinski	The context of the cost estimates referred to is unclear. What mitigation alternatives were considered that led to the estimates provided?	The basis of the agency cost estimate was the Kilo Wharf Extension project mitigation. A sentence is added to the section to include the basis for the estimate: $1.74 Million/acre of direct coral damage. The estimate was not based on a specific mitigation. No basis for the cost estimate reduction was specified. No edit to text.	
69	A3.3.2	p. 11	4-6		Kolinski	The language here suggests that the data used in the Draft EIS/OEIS will be largely and knowingly incomplete specifically as a result of scheduling, which suggests an additional comment period (i.e. Draft EIS/OEIS) will be necessary to allow for adequate public input in accordance with NEPA.	Best available information will be used to describe unavoidable significant adverse impacts in the DEIS. The information will be sufficient for the alternatives analysis and no additional public comment period will be required. Supplemental NEPA may be required for mitigation proposals. No change to text.	
70	A3.3.3	p. 11	8		Kolinski	Language should be changed from "coral" to coral reef as actions will need to mitigate losses to all coral reef community components impacted, which would encompass much more than just corals. The word mitigation might be used instead of restoration, particularly since the proposed artificial reef project is not restoration.	Edited bullet to say "…replace the lost functions and services of coral reef ecosystems" as suggested by other reviewers.	Done
71	A3.3.3	p. 11	17-25		Kolinski	Actually, artificial reefs would fail to adequately compensate for impacts to the coral reef community for a vast number of reasons. While some may have written literature in support of artificial reef benefits, there is just as much, if not more, published regarding concerns. Artificial reefs primarily are used as a tool for aggregating fish populations for fishing. They might provide limited compensation specific to attempting to mitigate direct economic or recreational fishing loss, however such would expand ecological impacts to the fish populations which would need to be compensated (i.e., compensatory mitigation would be needed for impacts associated with artificial reefs as a compensatory mitigation project). To suggest such as coral reef function and service replacement is analogous to cutting down a forest and replacing it with wire frame structures. The birds may aggregate and perch, and if lucky some lichen and moss may even colonize the structures. Hunters may find it easier to see and shoot their bird prey. However, the functional equivalent of the forest would be far from achieved.	Concur that the scientific literature is split over the value of artificial reefs as compensatory mitigation. Army Corps of Engineers has recently approved the use of artificial reefs as mitigation for coral ecosystem loss in Hawaii. The same consideration is appropriate for a project in Guam. If a wetland is created to replace lost wetland, the attraction of birds from other wetlands areas to the new wetland is not an considered an adverse impact on the wetland function. The structure is provided as compensatory mitigation not the function. The attraction of fish to a new coral reef structure does not diminish the value of a new coral reef ecosystem structure. Proximity of the artificial reef to the munitions wharf would limit the amount of overfishing at the artificial reef. If the structure does serve as a FAD it does not diminish the function of the coral reef ecosystem. As an analogy, if a wetland structure (soils, moisture, vegetation) is created to replace lost wetland, the attraction of birds from other wetlands areas to the new wetland is not an considered an adverse impact on the wetland function. The structure is provided. The attraction of fish to a new coral reef structure does not diminish the value of a new coral reef ecosystem function. No change to text.	

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72	A3.3.3	p. 11	24-25		Kolinski	It is unclear what ongoing discussion the applicant is referring to. The artificial reef proposals put forward thus far have been adamantly rejected by the collection of resource agencies legally responsible for NEPA project reviews due to their inability to compensate loss to natural systems. Consideration should be given to the possibility that continued pursuit of such a controversial mitigation project may be prohibiting cost efficient tax dollar attention towards development of projects that appropriately meet the ecological related mandates and carry less legal liability.	Concur that the scientific literature is split over the value of artificial reefs as compensatory mitigation. Concur agencies are provided opportunity to review the EIS; however they are not legally responsible for deciding compensatory mitigation. The DEIS will present a range of alternatives. Army Corps of Engineers has recently approved the use of artificial reefs as compensatory mitigation for coral ecosystem loss in Hawaii. The same consideration is appropriate for a project in Guam. Agencies have not provided relevant, high quality, peer-reviewed scientific data, to quantify the ratio of restoration to loss for Apra Harbor for the myriad of watershed management projects proposed. It is not consistent with compensatory mitigation rules to propose experimental studies /research on dose-response for various watershed projects. No change to text.	
73	A3.3.3	p. 11-12	26-20		Kolinski	Many of the screening items and justifications discussed lack appropriate description and suggest a very limited review/consideration process. Two items that should be recognized and/or discussed: (1) compensatory mitigation may be used to enhance, but can not replace activities already occurring, nor be used to achieve other mandated responsibilities of the applicant (such as Navy management plan development and implementation); (2) The suggestion (line 36) that only coral needs to be replaced lacks justification when an entire reef system is proposed to be impacted. This is a serious error that should be fully and adequately addressed prior to NEPA review.	The dismissed list of projects is adequately addressed because they each had a fatal flaw including the ones the commenter lists. No further analysis of these projects is required. 1) added text provided after (1) and refer to it as appropriate in the bullets following. 2) added "coral community structure". It is not practical to assess and compensate for each function within an ecosystem under any compensatory mitigation project. The structures provide the basis for restoration of functioning coral reef ecosystem. If the structure does serve as a FAD it does not diminish the function of the coral reef ecosystem. If a wetland is created to replace lost wetland, the attraction of birds from other wetlands areas to the new wetland is not an considered an adverse impact on the wetland function. The structure is provided. The attraction of fish to a new coral reef structure does not diminish the value of a new coral reef ecosystem function.	Done
74	A3.3.4	p. 12-13			Kolinski	See above comments regarding the inappropriateness of artificial reefs as compensatory mitigation for impacts to natural coral reef systems. The applicant should also read and refer to 33 CFR Parts 325 and 332/40 CFR Part 230 for appropriate Army Corp/EPA guidelines regarding compensatory mitigation. A number of rather large items that are of particular concern in this section include, but are not limited to: (1) the suggestion that anyone other than the applicant (i.e. resource agencies) bears the responsibility and liability for compensatory mitigation (lines 11-14); (2) focus on an proxy for determining a cost that could be applied to an undetermined mitigation project, and; (3) the suggestion of that the mitigation be "in place" within Apra Harbor. The guidelines are fairly clear and so will not be reiterated here.	The Navy continues to seek USACE engagement regarding the appropriate means to satisfy the compensatory mitigation rule. The proposed proxy approach is meant as a potential option, until an USACE ruling can be made on the legality of this option. No text edits.	
75	A4.0	p 19	5-7		Kolinski	Attached section B is related to water chemistry. Section C is listed as assessment of the affected marine environment.	Concur. Sections reordered.	
76	C1.0	p1	24-30		Kolinski	The lack of final construction designs and methodologies is problematic in terms of adequately characterizing impacts and determining appropriate compensatory mitigation.	Final designs will not be available until contract awarded. Worst case assumptions have been made where engineering information is not available. There is sufficient design information to approximate impacts based on best available information. Additional information will be obtained in the Spring 2009 surveys. No change to text.	
77		p2	9-13		Kolinski	The information provided is incomplete and does not provide the necessary input for determining mitigation actions (see 2.1 lines 12-13 and comments below).	The DEIS provides more information. Until there is a final design, it is appropriate to make assumptions that are "worst case". No change to text.	
78	C2.1.3.1	p6	30-32		Kolinski	A small caveat that might be considered is that a portion of the dredged coral material remained allowing for individual ages exceeding 62 years, as is suggested in Section C p. 23.	Concur. Report edited.	Done
79	C2.1.3.2	p6	17-19		Kolinski	If such is the case, such information may be valuable to modeling operational impacts resulting from expanded traffic/use of a widened area, which need be considered in assessing impacts and determination of adequate compensatory mitigation associated with the project.	Comment noted. Operational impacts in the wider channel would be limited to the CVN use, which is estimated at three times per year. Other ship traffic to/from Inner Apra Harbor would not require the CVN turning basin and would follow the centerline of the navigation channel as the most direct route through the harbor. The CVN operational impacts would be infrequent, short-term and localized. The other ship traffic impact would be comparable to existing traffic. All ships are asisted by tugs. There is the potential for non-CVN ships to berth at the CVN wharf at Port Ops discretion. These ships would use the CVN turning basin but the ship length and portion of turning basin used is smaller; only two tugs woudl be required; and the impacts to corlal in the vicinity would be short-term and localized. Text added to Section D.	Done

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80	C2.1.3.3	p9	25		Kolinski	There is no clarification on how accuracy was determined in support of the statement. The methods do not describe any data used to validate the extrapolations made. Even with validation, these spectral approaches are extremely limited in accurately discerning communities across extrapolated areas.	An accuracy assessment has been added (see response to comment 14). Additional ground truthing and field validation will be possible with data collected in Spring 2009 surveys.	
81	C2.1.3.3	p9-10	28-1		Kolinski	The information provided may be useful to establishing an appropriate in-water sampling design for collecting necessary information for consideration in the NEPA process, but alone has little value in determining potential mitigation for impacts to the area. Page 4 lines 12-13 summarizes the extent of use of the information, "... the methods and results are meant to provide a broad scale product that provides a preliminary overview of the area of concern". The approach is specifically limited to a very preliminary focus and inexact approach to ascertaining coral cover over very large areas and does little to describe or reflect coral functionality or that of the coral reef system proposed to be impacted.	Best available data was used in the report. Spring 2009 surveys will provide additional data. No change to text.	
82	C2.2.1	p 10	20-25		Kolinski	There appears to be unclarified issues regarding whether the government owned data collected during this study are available and or interpretable (Navy 12/22/08 & 12/23/08 emails). The validity of the 2006 and 2007 assessments may be questioned given the apparent absence of supporting data. This is a potential liability that will be highlighted in official review.	The report is based on best available information. Steve Smith provided the information available form his survey. Spring 2009 surveys will provide additional data. No text edits.	
83	C4.0	p 25	19-23		Kolinski	It should be noted that the judgment on ecological value is subjective and is based on qualitative and gross quantitative observations (many for which supporting data appear to be unavailable) that mainly focus on conglomerate coral cover estimates. Solid quantitative estimates of the various coral reef community components, particularly demographic and size parameters, are needed for adequate decision making regarding proposed alternatives (including no action) and for a justifiable and quantifiable approach to achieving mitigation equivalent to offsetting unavoidable loss.	Comment noted. Spring 2009 survey will provide additional data, including coral metrics to augment best available data and aid final impact analysis. No text edits.	
84	A4.0	p 19	21-24		Kolinski	The presentation of mean size data without measures of variation or density estimates is troublesome. Section C suggests such calculations were never made, and that data used to generate means apparently is "unavailable", which is also problematic for use in NEPA.	NEPA requires use of best available data. Additional data will be collected in Spring 2009 for inclusion in the FEIS. No changes to text.	
85			27		Kolinski	Two factors lead to the question of whether Jade, Western Shoals and Big Blue are actually outside the project area: (1) the project specifics remain partially undefined, and; (2) there is no indication that operational impacts to adjacent areas are being considered, while reporting (Section C, p. 6, lines 17-19) suggests operational impacts will likely occur.	The project limit is established and shown on report figures. Operational impacts in the wider channel would be limited to the CVN use, which is estimated at three times per year. The operational impacts would be infrequent, short-term and localized and would not require mitigation. Other ship traffic would not require a turning basin and would continue to use the narrower channel as the most direct route through the harbor. Add text "Analysis of grab samples collected within the turning basin area indicated that approximately 90% of the surficial sediments were very fine sand sized or coarser, and had a median grain size of approximately 0.1 mm (very fine to fine sand). Sediment cores from the same area classified the material as well-sort sand consisting of 73% sand and gravel and 17% silt (Weston Solutions, 2006). This data suggests that most of the material on the seafloor in the turning basin area that may be impacted by vessel maneuvering is sand sized or greater, thereby minimizing the extent and duration of possible plumes that may result from vessel operations. The operational impacts would be short-term localized and infrequent.	
86			31-34		Kolinski	Does the statement provided about not entering into mitigation discussions with regulatory agencies for coral [and apparently other community] loss in Inner Apra Harbor suggest the Navy has determined the loss of community components and associated functions, while clearly designated to be removed, and requiring a recovery period approaching 60 years, will not be mitigated? Clarification should be provided along with appropriate justifications backed by law. The stated determination appears to create a potential liability which will be highlighted in official review.	Impacts to the sessile communities found on the man-made structures within Inner Apra Harbor (i.e. piers, pilings, etc) will be short term and localized and will not be included in the HEA. The communities effected during the repair actions associated with the waterfront improvements are anticipated to recolonize quickly.	Done
87			44-46		Kolinski	The applicant is legally responsible for adequately characterizing and compensating loss throughout their project area. The stated determination appears to create a potential liability which will be highlighted in official review.	The sentence is misleading and was edited to clarify. Impacts to Inner Apra Harbor are described in Sections C&D. Impacts to the sessile communities found on the man-made structures within Inner Apra Harbor (i.e. piers, pilings, etc) will be short term and localized and will not be included in the HEA. The communities effected during the repair actions associated with the waterfront improvements are anticipated to recolonize quickly.	Done

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88	D2.0	p 2-3	5-26		Kolinski	What is provided here is limited and preliminary, doesn't address the functional aspects of the communities at risk, and appears only to consider corals (using a grossly derived coverage estimate that does not reflect population and morphological characteristics and associated functions). This is problematic in limiting public ability to adequately discern between proposed impact alternatives and appears unsuitable for realistically determining adequate compensatory mitigation. Other comments listed above apply.	Spring 2009 survey will provide additional data. No change to text.	
89	D3.0	p. 6	8-10		Kolinski	The apparent attempt to arbitrary redefine "coral reef ecosystems" within the report as only those areas with greater than 10% coral bottom cover is inappropriate and inconsistent with the portion of EO 13089 referenced. Impacts to all habitat types, including coral reef ecosystem areas supporting less than 10% coral cover, need be considered for impact and alternative analysis as well as compensatory mitigation. Two items that should be highlighted for public consideration here in evaluating the applicability of this impact analysis include comments related to D2.0 p. 2-3 lines 5-26 above about the very preliminary and gross nature of the data upon which the analysis is based and the use of an arbitrarily, unsupported definition as factors limiting any overall relevance of the analysis.	The HEA was based on >0% coral cover. The text in this section of Section D was wrong and is corrected.	Done
90			12-18		Kolinski	Impacts associated with increased military operations within the dredged and surrounding areas need to also be considered for both the alternatives analysis and mitigation modeling.	The DEIS addresses operational impacts. An increase in frequency and duration of CVN visits is proposed. While Navy traffic could increase at any time no- specific mission increases are proposed. The operational impacts of the CVN would be infrequent, short-term and localized. Other ship traffic would follow the centerline of the navigation channel and would not require a turning basin; therefore no indirect impacts to adjacent coral reefs are anticipated. Text on operational impacts is added.	Done
91	D3.2		13-16		Kolinski	The statements are not well supported within the document based on the very limited data and modeling available.	The statements are valid based on best available data. More data will be available from the Spring 2009 surveys. No edit to text.	
92	D3.3.1	p. 7	42-43		Kolinski	Sediment in many of the areas personally examined appeared to be a mix of terriginous and coral reef derived material. The suggestion that all sediments to be influenced by dredging activities are reef derived needs to be substantiated. In addition, the enormity of fine silts within the project area is problematic given the differential impact they tend to have, particularly in somewhat eutrophic areas, to corals.	The area of dredging cannot be considered "eutrophic" in any sense of the word. Results of sediment core analysis reported by Weston Solutions indicated that "sediments in Outer Apra Harbor (within the dredge footpring) and the entrance to the Inner Harbor were coarser-grained, comprised predominantly of a gravelly sand. Hence, terrigenous muds were not a major component of the sediment in the dredge area. Fine silts and sand composed of calcium carbonate have been shown to produce no negative to photosynthetic activity of one species of coral after more than two days of exposure (Weber et al. 2006). While nutrient-rich silts did produce measurable photosynthetic stress after the same exposure, it is not expected that terrigenous sediment retained within the reef framework or in the sediment surface that would be released as a result of dredging would be organic-rich. Evaluation of composition of interstitial reefal material that would be released during dredging, as well as exposed sediment should be a component of future surveys. Report text is edited.	Done
93	D3.3.2.1 - 3.3.2	p. 13-15			Kolinski	Unfortunately, the less than two weeks provided will not allow for review of the referred Section E current measurement and numerical model study. Official review will occur when the Draft EIS is submitted. However, there appears to be a realistic opportunity the applicants should take advantage of to test the validity of their modeling. Similar current modeling and projections of TSS, etc were utilized for projecting impacts at Kilo wharf, which is presently under construction. Any existing water quality samples associated with the dredging should be quickly analyzed and used to determine the actual validity of such modeling. In addition, inadequate timing does not allow for a adequate review of information and calculations provided on sediment impacts to corals. Future review will require investigation of the references presented as well as more recent information than that referred to in the text in relation to the conclusions presented.	Sea Engineering is currently conducting dredge plume modeling at Kilo Wharf. The monitoring has the following components: 1) Deployment of 2 in-situ recording Acoustic Doppler current profilers (ADCPs) and 2 Wetlabs turbidity sensors located to the east and west of the dredging site. These instruments are serviced and the data is downloaded every 3 months. 2) Plume surveys using a boat-mounted ADCP, CTD-turbidity casts and water sampling, conducted for 2 days every 3 months. The in-situ sensors were installed on October 1, 2008. The first plume survey was conducted on January 12-14, 2009. Data is presently being processed. No change to text.	

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94	D3.3.2.1	p. 17	8-9		Kolinski	The suggestion that the project may result in a long-term net increase in coral cover as a result of fragment deposition and growth on undredged slopes appears very unlikely and is not very well supported by the literature cited (BTW, need to include the Highsmith et al. citation in the reference section). First, it should be noted that the literature sited refer to natural repetitive processes that differ quite a bit from the proposed dredge activities. Second, the Section D authors refers to work he himself did which states the following related to storms at his study site: "Living coral was reduced from 46 % to 10 % of bottom cover, with greatest damage in the zones with highest cover. Twelve years later (1992), living coral cover increased to 15 % of total bottom cover. Lack of significant correlation between increase of coral cover and initial cover indicated that recovery was from larval settlement, rather than regeneration of viable fragments"; "In 1992 and 1993 no evidence of CaCO3 accretion was observed on the reef bench. Rubble fragments created by storm stress were deposited on the reef slope with little subsequent lithification." (Dollar and Tribble 1993). Another cited reference, Harmelin-Vivien and Laboute (1986), refer to extensive death and destruction of and caused by coral fragments. Additional studies (Knowlton et al. 1981) report evidence of serious delayed fragment mortality. A more relevant focus should be on secondary impacts associated with movement of the debris through existing communities, as is indicated by literature cited including Dollar and Tribble (1993), Highsmith et al. (1980) and Harmelin-Vivien and Laboute (1986; "...colonies broken on upper slope areas rolled down the slope, proceeding to break other colonies and creating a chain reaction resulting in massive coral destruction"). Given all the dredge projects that have historically occurred in Apra Harbor, are there any data or sites that suggest net increases in coral community composition have or continue to result from dredge activities? Existing evidence, general impressions and reference to available literature from other areas seem to suggest an overwhelming temporal net loss to coral community composition, and expanded loss due to movement of debris, in association with dredging in Apra Harbor. The cumulative loss throughout Apra Harbor associated with dredging seems readily apparent.	This comment is invalid in its entirety. First, there is no reason to expect that coral breakage and transport from catastrophic storm waves qualitatively different than breakage and transport from a dredge bucket. Inspection of the damaged reefs at the mouth of Inner Apra Harbor following initial dredging revealed damage similar to that observed following severe storm impacts in Hawaii. In addition, the effects of storm breakage and transport are well documented in the scientific literature, and have been regarded as one means of redistributing and increasing reef growth on geologic time scales. Because the nature of the CVN dredging will be limited to a depth that is shallower than the much of the surrounding harbor floor, there is no reason to eliminate the possibility that corals broken from the reef tops could not be transported down slope, reorient and continue to grow. Regarding the quote from Dollar and Tribble 1993, the reviewer is remiss in not considering reported results in their entirety. The quoted sentences refer to impacts from a completely catastrophic storm event which nearly eliminated all living corals from the entire reef. This situation is not analogous to the CVN dredging where direct destruction of coral habitat below the dredge limit will not occur. In the preceding paragraphs to those quoted, it is stated that "...Storm waves up to 4 m in height caused fragmentation and transport of parts of the fragile Porites compress framework downslope. Most of the coral fragments were alive a month after the storm, with apparently healthy living tissue covering the skeletons. The peak in living cover shifted 7 m further offshore and 5-10 m deeper, resulting in expansion of the range of Porites compressa." Hence, there is no reason to eliminate fragmentation and relocation as a possible phenomenon that could occur as a result of dredging.	
95	D3.3.2.2		12		Kolinski	Typo - turtles and fish are not macroinvertebrates.	Text edited.	Done
96			16-17		Kolinski	Clarification is needed on what, "… does not contain an abundance of algal species that represent a major food source for turtles" means and what quantitative information exists to support the statement.	Sentence deleted.	Done
97			12-39		Kolinski	No mention is made of potential impacts to non-coral invertebrates. This should be addressed.	Additional data will be collected in Spring 2009.	
98			29-30		Kolinski	The mention of a "depauperate" fish community brings to question: (1) if and how fish presence/absence, numbers and sizes were actually assessed; (2) whether any existing estimates are biased due to overt fish response to diver presence in the water; (3) "depauperate" relative to what; and, (4) how answers to the above relate to comparing alternatives and determining appropriate compensatory mitigation for loss.	Additional data will be collected in Spring 2009. Deleted sentence using depauparate.	Done
99			33-39		Kolinski	Has adequate testing occurred for contaminants in the area to be dredged? Relevant results should be provided.	No installation restoration sites have been identified at the site. Preliminary sediment testing at the alternative wharf sites was conducted.Additional sediment testing will be conducted to support the ACOE Section 404/10 permit application and results would direct the dredged material disposal options. The DEIS presents the preliminary findings. No change to HEA report.	
100	D4.0	p. 18	8-13		Kolinski	The suggestion of rapid recovery is not supported by even a simple examination of numerous dredge areas throughout Apra Harbor.	The existing coral growth within the CVN dredge area is all recovery from previous dredging. No change to text.	
101			13-14		Kolinski	See comment to D3.3.2.1 above.	See relevant response.	
102			26-27		Kolinski	The statement that "no sub-lethal effects to the coral community are anticipated" will require adequate justification which does not appear to be presented.	change "no" to "minimal". See comments above substantiating projected minimal impacts. Sentence removed.	Done
103			28-31		Kolinski	There is some issue with the statement as it is one of scale. Relevance needs to be highlighted from the regulatory perspective (i.e. what is the requirement under law).	Qualifying statements were made based on best available information. No text edits	
104	A Sect C	p. 20	1-33		Kolinski	See above comments.	See response above	
105	A Sect D	p. 20-21	34-7		Kolinski	The water chemistry attachment is actually labeled Section B. See comments below.	Edited order of discussion to be consistent with report sections	
106	B2.0	p. 1	9		Kolinski	Section 1.0 lines 1-2 state the intent of the study is to create a preliminary baseline data set that depicts water quality in the eastern area of Outer Apra Harbor. Line 9 indicates sampling was limited to 2 days, one in November and one in January. The sampling effort was, unfortunately, extremely limited and does not characterize water quality during either wet or dry seasons (lack of temporal replication and seasonal timing), nor does it appear to address conditions associated with military/other activities (passing ships, subs, surface exercises, etc; see Section C 2.1.3.1 lines 16-19, 2.1.3.2 lines 17-19). In general, extreme caution should be applied to any interpretation associated with this limited sampling.	Based on best available data. Concur that data is limited. No edits to text.	

#	SECTION	Page or Fig/Tbl #	Line #	Command or Org.	Commenter (last name)	Comment	TEC Response	Done
107	B3.0	p. 3	17-25		Kolinski	Do the CTD cast data represent Nov 5 or Jan 28 sampling? It is not made clear in the report.	Added text. CTD casts were made in November 2007.	Done
108	B4.0	p. 17			Kolinski	See B2.0 comments above.	Refer to relevant response	
109	A Section E	p. 21-22			Kolinski	Unfortunately, the less than two weeks provided will not allow for review of the Section E current measurement and numerical model study. Official review will occur when the Draft EIS is submitted. However, there appears to be an realistic opportunity the applicants should take advantage of to test the validity of their modeling. Similar current modeling and projections of TSS, etc were utilized for projecting impacts at Kilo wharf, which is presently under construction. Any existing water quality samples associated with the dredging should be quickly analyzed and used to determine the actual validity of such modeling. Of particular concern with CVN is the level of fines that will be suspended by the project. Adequate review of the sediment literature was not possible given the limited time period allowed; however, there are references which focus on sediment composition that show fines forming "marine snow" conglomerates to be very deleterious to corals. Suggested thresholds will need to be reviewed relevant to sediment composition for commenting in the Draft EIS.	Sea Engineering is currently conducting dredge plume modeling at Kilo Wharf. The monitoring has the following components: 1) Deployment of 2 in-situ recording Acoustic Doppler Current Profilers (ADCPs) and 2 Wetlabs turbidity sensors located to the east and west of the dredging site. These instruments are serviced and the data is downloaded every 3 months. 2) Plume surveys using a boat-mounted ADCP, CTD-turbidity casts and water sampling, conducted for 2 days every 3 months. The in-situ sensors were installed on October 1, 2008. The first plume survey was conducted on January 12-14, 2009. Data is presently being processed. No text edits.	
110	F				Kolinski	The reference to "collaboration" with the resource agencies has unfortunately become a misleading statement that should be removed or more fully clarified. The applicant appears to have followed their own road in the process, despite the liability and delay that is likely to result. Similar to the International Coral Reef Initiative, we see the use of artificial reefs as compensatory mitigation to be fraught with problems and shortcomings, and have recommended mitigation alternatives that focus on removal of source impacts to allow natural recovery of degraded systems to occur. This was officially noted in a multi-agency letter to Mr. Bice, Executive Director, JGPO, of the Navy (Dec. 18). In addition, NOAA has in no way supported or collaborated in the development of a "proxy" project, as it is inconsistent with Army Corps of Engineers guidelines on compensatory mitigation.	"collaboratively" is removed. Navy continues to actively engage the agencies in conversations on the subject.	Done
111	F3.0	p. 3-4			Kolinski	The economic valuation perspective is misplaced given the actual mitigation guidance and requirements. The focus of mitigation needs to be centered around functional replacement. A dollar amount does little to do that. A role for economic valuation comes into play when a project has anticipated/demonstrated effects on public income, subsistence, recreation or the like. To mitigate these forms of loss to humans, dollar determinations might be made for ascertaining appropriate avenues for compensating levels of loss.	See response to comment 52 (EPA)	
112	F4.0	p. 5			Kolinski	There are a number of issues with regards to the inputs, which unfortunately affect the relevance of any outcomes in this process. See comments above related to Section C for reference to many of the issues/questions presented. No clarity is given as to why large areas of habitat (i.e., soft bottom, < 1 % live coral cover) are not considered for compensatory mitigation. Unfortunately, coral cover does not at all address variation in functions associated with corals of difference sizes and morphologies, nor does it necessarily characterize or capture projected loss to other coral reef community components. Other parameters should be explored in ensuring appropriate offset of whole community loss. The types of data previously and consistently recommended for collection and modeling are not at all difficult or overly expensive to collect. The absence of relevant data for modeling appears to be the result of an inability (dive regulations) and/or reluctance to collect it.	Infaunal impacts would be short-term and localized as mentioned in the report. No mitigation is required. No change to text. More data will be collected in Spring 2009.	
113	F4.1	p. 5	30-34		Kolinski	There appears to be no ecologically justifiable basis for consolidation of coral reef habitat into "100 % coral equivalent" acres. The method suggests that anything other than live coral has absolutely no functional value that will be mitigated, and that coral cover is not being used as an index that encompasses reef functionality. This process seriously errors at the start in meeting needed equivalency and regulatory requirements.	The ACOE has approved the use of artificial reefs for mitigation purposes and the use of percent live coral as a means for estimating mitigation requirements (e.g., HASEKO). The HASEKO mitigation determination utilized "100% coral equivalence" calculations. This approach makes use of available data and accounts for the fact that some impacted acres have very little live coral, while other areas have a large amount of live coral. Ignoring that distinction would be inappropriate. No change to text.	
114		p. 6	4-7		Kolinski	The assumption of equal coverage appears difficult to justify given many slope habitats fall within this category. Data needs to be collected from areas proposed to be exposed to indirect project related impacts for appropriate modeling. In addition, consideration need be given to operational impacts, as recommended in above comments.	Spring 2009 surveys will include collection of relevant data.No change to text.	
115	F4.4	p. 11	8-11		Kolinski	The applicability of the recovery period is suspect, but will have to be further investigated in review of the Draft EIS.	Comment noted. No change to text	
116	F6.0	p. 14-15			Kolinski	There is no empirical information provided to support the contention that artificial reefs can " ...relatively rapidly provide replacement functions and services of similar type and quality" to those proposed to be impacted. The burden of proof, which resides with the applicant, will need to be met. The NOAA Fisheries position on the use of artificial reefs for compensatory mitigation and/or proxy determination for an alternative compensatory mitigation was made clear in official letter to Mr. Bice (see comments above). Recommend exploration of alternative mitigation projects in order to satisfy regulatory requirements.	The ACOE has approved the use of artificial reefs for mitigation purposes and the use of percent live coral as a means for estimating mitigation requirements (e.g., HASEKO). Percent live coral is not the only metric that will be used to assess impacts to coral. More data will be collected in the Spring 2009 surveys. Mr Bice response to letter is pending. No change to text.	

#	SECTION	Page or Fig/Tbl #	Line #	Command or Org.	Commenter (last name)	Comment	TEC Response	Done
117	F7.1	p. 16			Kolinski	Reference to the HASEKO, Inc. project needs to be updated in consideration of the following: (1) the original compensatory mitigation was determined prior to the issuance new compensatory guidelines for mitigation, and; (2) the project was recently amended in recognition that "In the years since these conditions were established, the scientific understanding of artificial reefs has moved forward significantly, and most scientists currently believe that an artificial reef with a surface area of approximately 1.1 acres would not be sufficient to create useful coral-reef habitat. Rather, a structure of aggregate seafloor structures with a total surface area of this size would function primarily as a fish aggregation device. As such, it would tend to concentrate fish near the structures without providing productive habitat for community growth." HASEKO, Inc. has thus agreed to create a reef 100 acres in size as compensatory mitigation (DLNR 2008). Given applicant acceptance of the HASEKO, Inc. project for determining an adequate ratio, the updated value would equate to a minimum of 100 to 1 artificial reef habitat to natural reef (not 2.5 to 1 as used in the Navy HEA). Simple application of the new ratio to the required artificial reef acreage suggest artificial reef on the order of 1738.8 acres is necessary for offset with the Polaris Point alternative and 1445.8 acres for the Former SRF alternative (gross calculations). Ratio increase to construction/acquisition, deployment, maintenance/repair, coral transplantation and contingency costs suggest either alternative would total well over US$100 million (note, these calculations were very quickly developed, so modeling with the agreed upon ratio needs to occur to fine tune the projected amounts). It is important to note the Navy appears to be on record as having been aware of and allowing the changed dimensions of the HASEKO, Inc. artificial reef to occur.	Based on conversations with parties associated with the compensatory mitigation, the mitigation cost is not related to the increased reef size. The amendment to the mitigation was not based scaling, but was arbitrary. The HEA report uses the reference to Haseko primarily to demonstrate that ACOE approved and artificial reef project for compensatory mitigation. No change to text.	
118	F7.2	p. 16-17			Kolinski	Serious reservations exist regarding the estimated service level gains and timing used within the model. However, further comments will need to be focused on the Draft EIS document due to an inadequacy of available time to review cited and other relevant references. There are numerous artificial structures in Apra Harbor which may provide a better estimate on the type and level of recovery that might occur and the potential for achieving 100 % coral cover (haven't seen an artificial structure within the harbor come even close to such).	No information has been provided by the resource agencies regarding the location of these "illegal" artificial reefs. Siting is critical to the success of the reefs and poor success of illegal artificial reefs is not necessarily a measure of success of appropriately sited reefs.	
119	F10.0	p 23	20-22		Kolinski	Recommend similar modeling occur using the ratio derived from the updated HASEKO amendment.	Based on conversations with parties associated with the compensatory mitigation, the mitigation cost is not related to the increased reef size. The amendment to the mitigation was not based scaling, but was arbitrary. The HEA report uses the reference to Haseko primarily to demonstrate that ACOE approved and artificial reef project for compensatory mitigation. No change to text.	
120	A Sect F	p. 23			Kolinski	See comments related to F.	See response to comments Section F	
121							No response necessary	
122	Note:				Kolinski	Appendix A (HEA/CVN Administrative Working Group Meeting Records) not reviewed due to inadequate time for review provided.	No response necessary	
123						These informal staff-level comments on the "HEA and Supporting Documentation" are provided for your consideration.	No response necessary	
124	Document			USFWS		A NEPA document should be an unbiased assessment of two or more project alternatives to weigh their relative impacts to the environment (natural and human) so that the least damaging course of action can be selected. We are concerned that the document "Habitat Equivalency Analysis and Supporting Studies" does not perform an unbiased analysis of the various mitigation alternatives. First, the document fails to include a full analysis of any alternative other than artificial reefs. A water quality improvement alternative is discussed but dismissed. If not dismissed from consideration as stated on in Sec. A pg. 12 line 17, then we recommend that an as full-as-possible, unbiased analysis be conducted.	The Spring 2009 NEPA document will describe the proposed action alternatives and a range of mitigation alternatives. An impact analysis of proposed action alternatives is required in the DEIS. An impact analysis of mitigation proposals is not required in the DEIS. The selected mitigation project may require supplemental NEPA documentation. No text edits.	
125	Document			USFWS		Throughout the document, subtle, yet systematic, baises toward the "preferred" alternative are apparent. This promotes an adversarial tone to a document that should be unbiased and fact-based. It should noted that Navy requested Resource Agency involvement and we entered into the cooperative process with the goal of helping Navy obtain a document that is technically sound, meets the needs and timeline of the Department of Defense, and complies with relevant environmental law. It is our hope that the tone of this document was inadvertent and will receive significant revision prior to insertion on the Draft EIS. Specific comments, and recommendations are made below that address overarching concern.	Statements of preferences are legitimate and not intended to be adversarial. The preferences are substantiated. No change to text.	
126	Document			USFWS		We realize this document is intended to cover primarily the impact assessment and HEA. This comment is intedended to be a general comment to assist with the development of completed document. The project has the potential to introduce terrestrial non-native invasive species through multiple pathways including, but not limited to, construction equipment, delivery services, foot traffic, vehicles, and other sources that provide conditions for terrestrial non-native invasive species associated with harborage and sanitation. Hazard Analysis and Critical Control Point (HACCP) planning is a pathway risk assessment tool that meets the spirit and intent of Executive Order 13112. The US Fish and Wildlife Service developed a 5-Step HACCP (http://www.haccp-nrm.org/). HACCP uses a transparent decision making process that includes conceptual risk assessment and management. HACCP incorporates monitoring and evaluation of corrective actions. The 5-Step HACCP Planning has recently been accepted as an international standard (ASTM E2590 - 08) for reducing or eliminating the spread of unwanted species during specific processes or practices or in materials or products. We recommend that HACCP plans should be implemented immediately, and implementation should continue until a more rigorous quantitative risk assessment/ management process can be implemented. We recommend that the final impact assessment include an analysis of the potential impact of importing terrestrial non-native species.	The Navy performs ballast water exchange prior to entering Apra Harbor, as they do prior to entering all ports of call. Terrestrial based biosecurity concerns are not addressed in this section of the EIS. A biosecurity plan is being developed for the entire program and the status will be provided in the DEIS. No changes to text.	

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127	Document			USFWS		We realize this document is intended to cover primarily the impact assessment and HEA. This comment is intedended to be a general comment to assist with the development of completed document. Harbor-side support facilities are mentioned as part of the project, but no detailed information is provided. Explicit protocols are needed to mitigate increases in terrestrial non-native species effect. An example would be development and implementation of Integrated Pest Management program around facilities and vessels. We recommend in the DEIS that harbor side facilities, and appropriate plans and operational measures (including biosecurity measures to reduce cargo inspections) to address invasive species concerns be included.	A biosecuirity plan is being developed for the entire project. No text edits.	
128	Document			USFWS		Surveys reported three fish species that were not previously reported and it was speculated that these fish could be related to bilge water discharge. The species names and how invasiveness was determined is not described. If bilge water is a pathway for introduction, then explicit protocols are needed to mitigate this effect. We recommend the project include the development, implementation, monitoring, and enforcement of BMPs for bilge and ballast water operations.	See response to Comment 126.	
129	ES	General		USFWS		Not reviewed	no response necessary	
130	Section A	Figure 2		USFWS		The total acreage of the proposed dredge area would be helpful on this figure. We recommend including total dredge areas for both the Polaris Point and SRF alternatives.	Volume is shown. Area will be added.	
131	Section A	5	6-10	USFWS		The installation of the concrete ramps will result in loss of aquatic habitat. While these losses may be small and may contain habitat considered poor or "undesirable," mitigation for their loss is still required under the Clean Water Act and the Army Corps of Engineer guidelines on compensatory mitigation. We recommend that all habitat that will be unavoidably impacted be accounted for through compensatory mitigation.	HEA is used to assess impacts to coral. Impacts to the area at the ramps is anticipated to be permanent, but impacts are not significant and no compensatory mitigation is proposed. No text edits.	Done
132	Section A	8	14-17	USFWS		The document states that the HEA/CVN Administrative Working Group was has met and continues to meet bi-weekly. According to our records, the last meeting of this working group was on Dec 2, 2008. The working group has not met in over 8 weeks. The USFWS supports the continued operation of this group and their effort to foster better communication and coordination on this project. We recommend: 1) the working group resume bi-weekly meetings, and 2) if meetings are not intended to bi-weekly that the actual schedule be accurately provided in the document.	The meetings were suspended during preparation and review of the HEA. Near-term meetings will focus on the Spring Survey design. Text modified	Done
133	Section A	8	33-34	USFWS		The meeting notes for the Adminsitrative working group are provided in Appendix A, but the meeting records for the Technical Working are provided. These meetings notes are in the possession of the Navy and we recommend that they be included in the Appendix for full disclosure and public review.	Notes from technical meetings have no bearing on the HEA analysis. The intent of the meetings was to discuss Spring Survey methodology. No technical meeting notes were added.	
134	Section A	11	1-6	USFWS		The document concludes that mitigation costs will decline following completion of spring resource surveys. While this is a potential outcome of that project, it is not the only possible outcome. It is presumptive to assume the mitigation cost will decline following additional data collection in an area that has been poorly surveyed to date. We recommend that the word "reductions" (line 3) be replaced with "refinement."	Concur. Deleted sentence.	Done
135	Section A	11	17-25	USFWS		The document accurately states that "Agencies expresed their concern that artificial reefs do not provide a means to define and ensure replacement of lost ecological function." These concerns were submitted to Navy in the form of a document titled "Comments on the "Artificial Reef Feasibility Study" (U.S. Department of the Navy 2007) and the Use of Artificial Reefs for Compensatory Mitigation" (see attached). We recommend that this document be provided as part of Appendix A because its development was a direct result of the HEA workshop in November 2008 and it concisely lays out agency concerns associated with this proposed mitigation project.	The Navy provided the report as a reference in the HEA workshop. The agency response indicated a misunderstanding of the intent of the report. The letter will not be included in the Appendix.	
136	Section A	12	6	USFWS		Extensive scientific data exists demonstrating that water quality has direct impacts on the survival and persistence of coral reefs. Numerous scientific studies exist that show improvement in water quality will promote coral regrowth. To describe this ecological reality as "Based on common sense" is misleading and appears to shed doubt on the scientific basis for the relationship between coral health and water quality. We recommend that this state be modified to reflect the extensive body of scientific literature that conclusively support the importance of water quality to coral reef health and the regrowth of corals that is concommitant with water quality improvements.	The section was rewritten to provide pros and cons of both mitigation proposals.	Done
137	Section A			USFWS		The division of this document into preferred and "Resource Agency" promotes an adversarial tone to the document which we believe is not constructive. We recommend removing such designations where they exist throughout the document and that an unbaised analysis be conducted of all of the altenatives included.	We chose to characterize the different points of view which appear to align along Navy/non-Navy agency lines. It is not meant to be adversarial, but to tell a story. Sections rewritten.	Done
138	Section A	12	11-16	USFWS		The statements included in the lessons learned do not appear to be lessons learned but a list of challenges that were associated with the Kilo Wharf mitigation project. We acknowledge that similar challenges will also be associated with any other water quality improvement projects. While listing these challenges is appropriate, we question why similar challenges have not been listed for the artificial reef mitigation project, including the lack of sufficient and contiguous space identified in which to install the require artificial reef, the potential to harm local fishery stocks, etc. Additionally, the final sentence of this paragraph also applies to all mitigation projects. We recommend that this section be reworded to present an unbaised assessment of this proposed mitigation project.	Section was rewritten.	Done

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139	Section A	13	9	USFWS		The wording in this section implies that USFWS supports the inclusion of artificial reefs as a mitigation "proxy." The USFWS, via a multi-agency letter to the Mr. Bike of the Navy dated Dec. 18 has stated it does not agree with the "proxy" approach taken in this document and believes it does not conform with the Army Corps of Engineer guidelines for mitigation and the Clean Water Act. If Navy wishes to "accommodate Resource Agency project preferences" we suggest it include within the HEA analysis a water quality improvement analysis. We recommend that the wording of this paragraph be changed to make clear we don't explicitly or implicitly support the "proxy" mitigation method that Navy has included in this document.	Changed wording to remove agency preference: "The Navy used artificial reefs project as a "proxy" to determine the level of funding to be set aside for mitigation purposes............and provides the flexibility to implement one or more non-artificial reef projects. "	Done
140	Section A	20	15-20	USFWS		Time was not available to review and comment on the sediment-current modeling study. This review will occur as part of the agency document or public DEIS review.	No response necessary	
141	Section A	20	21-24	USFWS		We support the Navy's desire to produce a scientifically rigorous mitigation proposal. Through our cooperative process with Navy, we have often discussed relationships between sediment impacts and coral health The USFWS has acknowledged information such as dose-response curves do not currently exist, but we believe sufficient and broad range evidence supports the existence of adverse sediment-coral impacts and support taking a precautionary approach. The document here cites coral tolerance to sediment as a justification of small indirect affects but has supplied no supporting scientific literature or a dose-response function. We request that appropriate studies be referenced to support this statement. Even without a dose-response faction, USFWS acknowledges that the adult corals in this area appear to be sediment tolerant, as shown by their existence in the ambient conditions. However, without supporting information as to how much of an increase in sediment loading these species can withstand, we believe the precautionary principle must be enacted and assume that some impact will occur to these species as a result of elevated sediment loads. We recommend that Navy consider the entire predicted area as impacted and remove this line discussion.	HEA was used specifically to avoid precautionary approach, which is perceived as ambiguous. Also see response to Comment 136.	
142	Section A	20	20-27	USFWS		The documents determines that "no sub-lethal affects to the coral community are anticipated" but no scientifically-based information is provided. This project will result in additional sediment and other sediment-associated stresses to corals within the vicinity of this project. Increased mucus production is often considered a sign of stress and studies have shown that increased mucus production can be energetically draining (see Reign and Branch 1995, Edmunds and Davies 1989). Energy lost to increased mucus production is not available for other biological processes. In short, sub lethal effects are expected, but may not be significant relative to the entirety of Apra Harbor. We recommend that the state of "no sub-lethal affects" be changed to acknowledge the occurrence of sub-lethal effects as a result of this project.	"no anticipated impacts" will be changed to "minimal anticipated impacts" While it has been documented that sublethal impacts may occur in corals in the form of transfer of energy from growth to other physiological processes, the duration of antedated sediment impact (1-2 days according to SEI) is not likely sufficient to affect the energetics of coral function to a measurable long-term extent.	Done
143	Section A	22	8-12	USFWS		Time was not available to review and comment on the sediment-current modeling study. This review will occur as part of the agency document or public DEIS review.	No response necessary	
144	Section A	23	23-24	USFWS		No data has been presented to support the determination that impacts to soft sediments would be short-term and localized. We recommend that data be provided to support this statement.	No data on soft sediment communities will be collected. See response to comment 145.	
145	Section A	23	23-24	USFWS		Soft bottom communities are not exempt from the compensatory mitigation regulations and Navy is still required to equitably compensate for any unavoidable impacts to these habitats. We recommend Navy include all submerged aquatic resources in its analysis.	The Navy will not be considering mitigation to impacts to soft bottom infaunal communities because those impacts will be short term and localized. No text edits.	
146	Appen. A					Not reviewed	No response necessary	
147	Section B					Not reviewed	No response necessary	
148	Section C					Not reviewed except section 2.1.2	No response necessary	
149	Section C	2-3		USFWS		One significant potential problem with remote sensing maps is that they often contain a high degree error (<50 accuracy in some cases). As part of any standard method, an accuracy assessment should be conducted to determine the amount error in the maps. No method describing an accuracy assessment (condusion matrrices, etc.) has been provided and no discussion of map accuracy appears to be included in the report. We recommend that an accurracy assessment is conducted for the maps and discussed.	Accuracy assessment has been included. In addition, it is recognized that because of logistic restrictions, the methods used to collect groundtruth data were not optimum. It is anticipated that during future surveys, groundtruth data will be upgraded substantially resulting in a more accurate product. At this time a full accuracy assessment will be conducted.	Done
150	Section D	General		USFWS		This impact assessment appears primarily intended to assess potential dredge/construction impacts on the marine environment, with a primary focus on corals. An impact assessment for the entire project, including shoreline-based facilities and operations, has not been provided and will need to included in the DEIS. We expect that this broader impact assessment will include discussions on impacts associated with invasive species (including both marine and terrestrial), facility construction, and the operational impacts associated with the increased amount of time carriers will spend in Guam. We also recommend that the DEIS include discussions and analysis of cargo quarantine and the measures taken to insure that off-island construction materials and equipment (if needed) do not act as vectors for the spread of invasive species into or out of Guam.	See response to comment 126. DEIS will address biosecurity.	

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151	Section D	General		USFWS		The impact assessment primarily focuses on corals, which, with exception of a brief discussion of non-coral species, excludes all other species and reef functions from the analysis of potential impacts. The cursory examination of other species and habitats lacks sufficient specificity to the site-associated resources, and the general nature of the discussion does allow for an accurate determination of no impact. For example, many of the common reef fish with the dredge site area display high site-fidelity, and while capable of moving, will be displaced by the loss of their habitat and will be required to emigrate to other reef areas. No discussion of the potential affects of fish emigration has been provided. We recommend that the impact assessment cover the range of affected species and habitats with sufficient detail to support the decision making process.	No existing data on baseline conditions for fish emigration. No surveys to address this are planned. It is important to remember that most of the coral in the project area will remain. The areas less than 49.5 ft are being removed and is most cases that that averages a foot or coral removed. No change to text.	
152	Section D	General		USFWS		The impact assessment does not appear to based on current scientific understanding of ecological impacts of sediment on corals and coral reef ecosystems. A review of the literature cited notes only three scientific publications about the effects of sediment on corals and coral reefs communities that are less than 15 years old and several of the most commonly cited scientific studies are not included or do not appear to have been reviewed in their entirety (i.e., cited as an [abstract]). While older literature is relevant to many of the topics discussed, failure to address the range of current ecological opinion is troubling, especially when the only three "more-current" articles that are cited from the vast body of literature display what appears to a minority view or a situation that may be an exception to conventional understanding. We recommend that a more comprehensive review of the available literature be conducted and incorporated into this document.	This is incorrect. Table 2 lists 13 references on sediment effects to corals with publication dates up to 2001. In addition, as noted above a most recent publication (Weber et al. 2006) indicates that impacts from sediment will be minimal owing to the likely composition of the dredge-generated sediment. No text edits.	
153	Section D	6	3-10	USFWS		It is unclear why an arbitrary definition of 10% coral cover is provided to define what constitutes a coral reef. No legal or biological basis for this value is provided, and is inconsistent with Executive Order 13089 and the section on special aquatic sites in the CWA which states: "Coral reefs consist of the skeletal deposit, usually of calcareous or silicaceous materials, produced by the vital activities of anthozoan polyps or other invertebrate organisms present in growing portions of the reef" and makes no requirement of 10% live coral. We recommend that this be arbitrary designation be removed from the document.	See response to comment 89. HEA did include >0 to 10% coral cover but was erroneously described in the text. Text edited .	Done
154	Section D	6	16-18	USFWS		In this section, and elsewhere through out the document, we recommend that discussion of impacts should be made in reference to the coral reef ecosystem or community unless it is specifically intended to only apply to corals or othe specific species. The impact assessment should analyzed potential impacts to the entire marine ecosystem and not just corals.	Change made to "coral reef community" throughout report.	Done
155	Section D	7	6-12	USFWS		The discussion of the sediment tolerance of Porites rus lacks supporting data. While we agree with Navy's assessment of the sediment tolerance of P. rus within the harbor, we also commend the Navy's desire to produce a document that has the highest level of scientific support and credibility. Navy technical experts, through the CVN Technical Working Group, are on record as raising concerns that sediment related impact must be assessed using dose-response functions. The USFWS notes that these functions do not exist for corals in Apra Harbor, but believes that sufficient scientific information is available to assess sediment impacts by using a precautionary approach and the available range of scientific and observational information. We recommend that Navy either provide the appropriate dose-response functions to support this state or clarify its position on the use of dose-response functions.	Time and resources do not allow for specific dose-response experiments for *Porites rus* or any other coral in the dredge area. Empirical data of observations in Apra Harbor and scientific literature on both sediment tolerance and impact to coral, provides the basis for estimating impacts in the project area. Additonal literature review added.	Done
156	Section D	7	13-16	USFWS		No data has been provided to to support the statement that "suspended sediment are unlikely to have significant adverse impacts on the reproductive potential of the coral community in the vicinity of the CVN project." A vast number of scientific studies have demonstrated that sediment loads stress coral colonies. Mucus production, which is the primary mechanism to remove sediment loads, is energetically expensive to produce (Reigl and Branch 1995) and can more than double when under sediment stress (See Brown and Bythel 2005 for a review). While detailed energy budgets are not available, it is not inappropriate to assume that excess energy spent in mucus production would reduce energy available for reproduction. We recommend that supporting data for this statement be provided.	See response to comment 155 on duration of sediment stress. Text edits made to report.	
157	Section D	7	13-16	USFWS		No data has been provided to support the statement that "elevated sediment loads in the water column do not prevent larval settle and growth in this area." The adverse effects of sediment on coral larvae and recruits is well documented in Guam and elsewhere for both suspended sediments and sediment that has settled on the bottom. It is unclear, why the distinction between water column and benthic sediment has been made; current patterns in the area are low and Navy's modeling assessed sediment settled on the bottom. Regardless, coral larvae and recruits have been shown through both field and laboratory studies to be more susceptible to sediment impacts than adults of the same species (numerous scientific studies). No data is provided to demostrate that corals are or have successfully recruited to the project area. With the lack of site-specific data and support scientific data, this statement should be removed from the report and a precautionary approach should be adopted. The better alternative, however, the one we recommend is to collect the site-specific data to demostrate successful coral recruitment to the area.	Data is observational and photo-documented from adjacent area at mouth of Inner Harbor. Also, site-specific data on recruitment in the area prior to dredging will not likely provide any information of the effects from dredging. Data collection during the dredging operation (as recommended) cannot be part of an EIS prepared prior to dredging. No text edits.	

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158	Section D	Sec. 3.3.1		USFWS		This section appears to lack sufficient review of current scientific literature. With the exception of single article, Te (2001), no reference more current than 1990 is cited in the text (this does not include survey work completed by Smith or Marine Research Consultants for the CVN project). This comment should not be taken to imply that older references are invalid, but extensive scientific work on this topic has been conducted in the last 17 years and should be taken into consideration. We recommend that this section be revised to reflect the most current scientific understanding of these issues.	There are more recent literature reports. Report text is amended.	Done
159	Section D	7	38-43	USFWS		This discussion seems to imply that literature that examines terrestrial sediment effects on coral is inappropriate for consideration in this impact assessment. We disagree because: 1) sediments on Guam reef have been shown through several studies to comprise a very large proportion of terrigenously derived material and absent site-specific information to demostrate otherwise, there is no reason to believe that sediments present in the project area are different, and 2) Many of the principle impacts associated with sediments are related to physical (e.g., size, quantity, etc.) and not compositional (e.g, geochemical structure) characteristics. This does not discount differences between carbonate and non-carbonate sediment, such as that pointed out by by the document with reference to light extinction coefficients, and we recommend that studies using terrestrial sediments be used in this analysis, but caveated as appropriate.	Analysis of grab samples collected within the turning basin are indicated that approximately 90% of surficial sediments were very fine sand sized or coarser, and had a median grain size of approximately 0.1mm (very fine to fine sand). Sediment cores from the same area classified the material as well-sort sand consisting of 73% sand and gravel and 17% silt (Weston Solutions 2006). This data suggests that most of the material on the seafloor of the turning basin area that may be impacted by vessel maneuvering is sand - sized or greater, thereby minimizing the extent and duration of possible plumes that may result from vessel operations. Similar text added.	Done
160	Section D	8	38-43	USFWS		The Brown et al. reference describes results from an intertidal coral reef that is expected to have higher flushing rates than the CVN project area. The ability to flush sediments is key to the survival of corals. Numerous studies demonstrate that healthy coral communities are able to regenerate following sediment effects provided the sediment is removed prior to death or later removed from the substrate to allow for successful natural recruitment. Numerous studies have shown a range of recovery potentials, but all are clear that dredging has adverse impacts. If the Brown et al. reference is intended to establish a recover time or potential, we would recommend that a more suitable (and if possible a more current) study be located that better reflected the conditions within Apra Harbor, where currents and wave action are expected to be low and flushing is expected to be slow.	Deposition rates generated by the SEI model, which takes into account hydrodynamic properties which are linked to flushing rates, are shown to be small and of very short duration. The HEA model was adjusted to a 5 year recovery rate for coral habitat affected by indirect (sediment-related) impacts. This had very little impact (<1%) on discounted service acre-years. Text added.	Done
161	Section D	8	18-31	USFWS		The Navy has accurately pointed out that threshold levels are problematic. No single threshold occurs and the computation of thresholds are usually done for chronic events and may not be appropriate here. More appropriate here may be the sediment load on the coral or the bottom and a coral's ability to remove it prior to suffering mortality. Sedimentation rates greater than 0.1 g/cm2 have been shown to kill exposed coral tissue within a few days (Riegl and Branch 1995) and depending on the sediment grain size, damage can occur even faster (Fabricious and Wolanski 2000). Recruitment can be significantly inhibited by 1 mm sediment films that cover >50% of the settlement surface (Hodgson 1990). This information, along with that in Table 2 seem suggest that rates of 100 mg/cm2 for even short durations could cause adverse impacts to coral reefs. We recommend that the discussion be expanded to include other relevant studies that have attempted to look at sediment thresholds and that additional discussion examining sediment loads, sediment deposition and cover of the bottom, and flushing rates be added.	The citations in this comment do not support the reviewers contention, although this discussion can be added to the document. The Fabricus and Wolanski paper deals specifically with "estuarine muds" which as noted are not what SEI and Weston Solutions have found to be the material that will be dredged. The Riegl and Branch paper describes laboratory experiments in which <u>200</u> mg/cm2 of sediment were exposed to corals. However, corals used in these experiments were kept in filtered seawater for 6 weeks prior to the experiments, and it is assumed that filtered seawater was also used during the experiments. Subsequently, the experimental responses of corals does not take into account the effects of naturally occurring turbidity or sedimentation which may have seriously biased the results. In addition, it is unfortunate that the investigators did not continue the experiments to determine if, or how long it took for the corals to return to normal physiological function following the removal of the short-term sediment stress. As noted above, while the short duration of increased sedimentation at the CVN may result in some translocation of energic resources, if such changes are short in duration and recovery to pre-dredge function is rapid, the overall effect to the reef coral community could be essentially insignificant. In this same vein, another laboratory experiment by the same author (Riegl 1994), tissue necrosis and appeared only after a week of continual sand application to stony corals, and there was no death of entire colonies or partial bleaching over this period. The comment about Hodgson's (1990) findings of reduced settlement in laboratory experiments when sediment films cover substratum, are also not especially applicable in areas where naturally occurring sediment is one of the dominant bottom types, and is likely the limiting factor in coral occurrence. Regarding comments on the selection of 40 mg/cm2/day as a threshold, Randall & Birkeland looked at sediment effects to corals in two bays in Guam (including Fouha Bay-area within watershed improvement project agencies propose) and reported the following: "*If the average suspended sediment load was in the range of 1 to 6 gms dry weight (or 5-32 mg/cm2/day), the we would expect a rich coral community of over 100 species covering over 12% of the solid substrate to develop.* " This is for a continual sedimentation rate, so the 40 mg/cm2/day for the 1-2 day duration of the dredging estimated by SEI should represent a low end of the potential impact rate, based on Randall and Birkeland. The reference is: Randall, R.H, and C. Birkeland. 1978. Guam's Reefs and Beaches. Part II. Sedimentation Studies at Fouha Bay and Ylig Bay. Submitted to; Bureau of Planning. Government of Guam. By University of Guam Marine Laboratory. Technical Report No. 47. Report text was edited.	Done

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162	Section D	15	1-8	USFWS		Time was not available to review and comment on the sediment-current modeling study. This review will occur as part of the agency document or public DEIS review. It is unclear what criteria were used to select 1000 mg/cm2 as a "reasonable threshold of sediment accumulation." We recommend that additional clarification on how this value was selected be provided in the impact assessment.	1,000 mg/cm^2 rate was selected as a conservative number based on the literature. Most of the lab studies in the literature review use rates of 200 mg/cm2 for a short term dose. So 1,000 mg/cm2 spread over the course of a year is low in comparison. As noted in the Randall and Birkeland reference, 5-32 $mg/cm^2/day$ is estimated to be normal exposure for Guam reefs and when multiplied by 365 days equals 1,825 to 11,680 $mg/cm^2/yr$, so the value of 1,000 mg/cm^2 is less than the typical sediment exposure. The choice of 1,000 mg/cm^2 is a conservative estimate. Text added.	Done
163	Section D	15	23-26	USFWS		This discussion of downward migration of sediments off the reef slopes seems to contradict earlier discussion about and photographs that show sediments resting on top of P. rues plates. We recommend that this discrepancy be clarified.	Both phenomena can occur; one is not mutually exclusive of the other. No change in text.	
164	Section D	15	27-29	USFWS		See early comment about sediment intolerance for P. rus. Sec. D, pg 12.	see relevant response	
165	Section D	15	30-44	USFWS		No data or study has been cited to support the statements made in this paragraph, yet the paragraph has been presented as if the statements are scientific fact (e.g. impacts would be…). Without supporting data, we recommend that this wording be changed to reflect the uncertainty of these statements.	The paragraph is about sediment type in the project area. A reference to a sediment characterization report is added to the section as well as other literature review. Text edited.	Done
166	Section D	17	1-10	USFWS		The suggestion that the project may result in a net increase in coral cover as a result of fragment reattachment and growth downslope of dredging activities appears is not supported by the literature cited. First, we do not agree that fragmentation from storms is the same as that by dredging. Dredging will crush all corals, whereas storms tend to dislodge specific size and morphological classes of corals. Second, in direct contrast to how it is cited here, the Dollar and Tribble (1993) reference states the following related to storms at their study site: "Living coral was reduced from 46 % to 10 % of bottom cover, with greatest damage in the zones with highest cover. Twelve years later (1992), living coral cover increased to 15 % of total bottom cover. Lack of significant correlation between increase of coral cover and initial cover indicated that recovery was from larval settlement, rather than regeneration of viable fragments" and goes on to say "In 1992 and 1993 no evidence of CaCO3 accretion was observed on the reef bench. Rubble fragments created by storm stress were deposited on the reef slope with little subsequent lithification." Additionally, Harmelin-Vivien and Laboute (1986) refer to extensive death and destruction of and caused by coral fragments. We recommend these apparent literature discrepancies be clarified.	Dredging will not necessarily crush corals to a greater extent than storms. There are observations of broken, but living coral colonies at the mouth of Inner Apra Harbor. Text is modified.	Done
167	Section D	17	1-10	USFWS		This discussion excludes the relevant topic of secondary impacts associated with movement of the debris through existing downslope coral communities, as is indicated by literature cited including Dollar and Tribble (1993), Highsmith et al. (1980) and Harmelin-Vivien and Laboute (1986) the last of which states that "...colonies broken on upper slope areas rolled down the slope, proceeding to break other colonies and creating a chain reaction resulting in massive coral destruction." We recommend that some discussion of potential damage resulting from fragments tumbling down slope be included.	Text modified.	Done
168	Section D	17	12	USFWS		Fish and turtles have been inadvertently been called macro-invertebrates.	Corrected	Done
169	Section D	17	23-32	USFWS		Smith (2007) did not quantify fish, but instead placed fished in open ended "relative abundance" categories (abundant, common, occasional). It is not possible to convert this into meaningful quantitative numbers and determine that "low total number of fishes" were present at the site. We recommend that Navy present the appropriate data with which to draw this conclusion and if quantative numbers do not exist, to conduct appropriate resource surveys.	HEA was based on best available data. Spring surveys will include fish surveys. No text edits.	
170	Section E					Not reviewed	No response required.	
171	Section F	General		USFWS		The statement "The Navy and the Resource Agencies are working collaboratively to determine the mitigation necessary to compensate for the for expected impacts" is misleading. The USFWS is on record that they do not support artificial reef as appropriate mitigation and via a letter to the Mr. Bice of the Navy dated Dec 18 (co-signed by the US EPA and NOAA), we do not support the approach to use a "proxy" to determine a monetary figure for mitigation. We recommend that the Navy clarify this statement to reflect the current nature of this collaborative relationship.	Remove "collaboratively". Collaborative was not meant to imply consensus. Lack of support for artificial reefs is noted.Mr. Bice's response letter was not available at the time of this report preparation.	Done

HEA Supporting Supporting Studies

Comments on Agency Review Draft dated January 23, 2009

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172	Section F	General		USFWS		The use of a "proxy" project to generate a monetary value for the mitigation analysis is inconsistent with Army Corps of Engineers Guidelines. The new Compensatory Mitigation Rule requires mitigation projects be based on the replacement of lost aquatic resource functions and not on a dollar amount. We recommend that discussion of this project as proxy be removed and it be analyzed based on its own merits. We also recommend that Navy analyze a water quality improvement project, and acknowledge that other suitable projects may exist.	Navy acknowledges the agency opinion on artificial reefs. It is not an opinion shared by all in the scientific community. Artificial reefs have been used as compensatory mitigation recently in Hawaii and with appropriate siting would be appropriate in Guam. The key challenge in using watershed management projects for assessing cost is there there is no relationship established in the scientific literature to scale a specific watershed management project to improved water quality and the magnitude, spatial extent and timing of coral habitat benefits. Water quality is not the only factor that impacts coral. A decrease in fish populations due to overfishing could have an impact on coral that would not be altered by watershed improvement projects. These quantifiable relationships are required for the HEA model. If watershed projects are implemented the artificial reef cost could be used as a budget for the watershed projects, since the budget for watershed projects cannot be estimated for lack of science-based inputs to the HEA. Text edits made to this Section to clarify position.	Done
173	Section F	5	19-22	USFWS		It is unclear why areas that will be dredged that contain <1% coral cover are excluded from compensatory mitigation. These areas are important marine habitat that will be adversely impacted. In our opinion, it is inappropriate to exclude these areas from the mitigation analysis. Inclusion of these non-coral areas will require the use of additional biological data to describe the functional role of these areas and their resident community. We recommend that Navy reassess its use of "100% live coral equivalent" and consider data that will be able to appropriately assess the functional capacity of areas that are not dominated by coral. We also recommend that the entire area dredged be included in the impact and HEA analysis.	HEA model did include >0-10% coral cover, but was erroneously described as >1-10%. Report has been modified. O% coral cover is not included in the HEA.	Done
174	Section F	5	30-34	USFWS		No biological or ecological justification is provided for using the artificial "100% live coral equivalent." This term de-values any area with less than 100% coral cover without any relationship to the ecological function those areas play with in a reef. It has no ecological relevance and runs counter intuitive to conventional ecological thought about biodiversity maximums occurring in areas with the highest level of heterogeneity (e.g., the highest coral reef biodiversity would be expected in areas of <100% coral cover). We recommend that this approach to HEA be re-assessed and an approach with greater biological relevance be adopted.	The ACOE has approved the use of artificial reefs for mitigation purposes and the use of percent live coral as a means for estimating mitigation requirements (e.g., HASEKO). The HASEKO mitigation determination utilized "100% coral equivalence" calculations. This approach makes use of available data and accounts for the fact that some impacted acres have very little live coral, while other areas have a large amount of live coral. Ignoring that distinction would be inappropriate. No change in text.	
175	Section F	5	11-13	USFWS		It is unclear how the percent cover of live coral describes the ecological function of a coral reef. Direct coral reef functions are problematic to describe because the methods, time, and resources are often not present to adequately sample the wide range of functions and services provided by a coral reef. A large body of scientific literature has correlated the ecological function of corals with their three-dimensional relief and size. Percent cover of live live coral alone fails to distinguish between coral morphology and size and leads to inappropriate conclusion of equitability. For example, reefs with several larger branching corals provide different functions to a coral reef than reefs comprised of many small encrusting corals. Analysis based on percent cover of live coral alone may erroneously conclude these reefs are equitable. We recommend that data that better relate to the function provided by corals on the reef be used in the impact assessment and HEA. We have recommended in the past the use of colony size and morphology, but acknowledge that other data may be appropriate.	Coral colony size, morphology and other types of data identified in the comment are not available for the project area. As noted above, the ACOE has approved the use of artificial reefs for mitigation purposes and the use of percent live coral as a means for estimating mitigation requirements. Spring surveys will include additional coral parameters. No text change.	
176	Section F	5	35-39	USFWS		The sediment thresholds provided in the HEA document are sufficient to cause complete coral mortality unless they are flushed from the coral prior to smothering. No reference has been provided for the 1 gm/cm2 threshold. It is not clear how this total load relates to commonly cited thresholds in the literature. Ultimately, total load is important, and we commend the inclusion of the total load in the analysis, but are concerned that the potential impacts of this load have not be sufficiently considered. Coral reefs have the ability ot recover from acute sediment stress provided the sediment are removed prior to smothering. No discussion of sediment flushing rates has been provided and it is unclear how long 6-10mm sediment layers will sit on the reef. These levels will have adverse impacts to corals, potentially smothering adults and may significantly impair successful coral recruitment to the area. We recommend that further supporting data be provided for the stated thresholds.	Without field studies to measure currents and removal rates, exact determination of "flushing" cannot be determined. No site- specific data is available or will be collected. SEI reports that sedimentation at any one location will be on the order of 1-2 days, and the threshold limit of 40 mg/cm2 is equivalent to 0.2 mm, and not 6-10 mm. The 6-10 mm deposition is extrapolated over the entire course of the dredging project. No change to text.	
177	Section F	5	1-7	USFWS		The HEA assumed that areas of indirect impact will have the same levels of coral cover as the direct impacted area. No data for the indirect impact areas have been provided, but Navy biologist have noted, and we have agreed, that sloping areas tend to have higher coral abundance than the adjacent flat area to be dredged. The assumption in the HEA is therefore invalid. We recommend that data be collected to estimate the functional contribution of this area and that it be used in the HEA.	We agree that Spring 2009 will provide estimates of coral community structure on the areas that will be affected by indirect impacts. Note, however, that none of the proposed studies will be direct measures of "functional" aspects of the reef communities. No text edits.	
178	Section F	11	8-11	USFWS		Recovery time for areas of indirect impact are estimated at 1-2 years. The reference cited (Brown et. al 1990) studied dredging impacts on intertidal coral reefs in Thailand. This reference does not quantify sediment loads on the reef or level of sediment flushing. It would be expected that intertidal reefs would experience higher flushing rates than the deep, low current-low wave action reefs in the proposed project area. Therefore the data presented in this paper may not be relevant without additional supporting information. Sediments loads in the quantity described (6-10 mm) could result in rapid coral mortality, as demonstrated by several scientific studies. This would impact be exacerbated by low flushing rates. Additionally, this recovery does not take into account replacement of corals with similar ones that would not provide similar ecological function. Recover could be estimated using the colony size and known growth rates, as has been done elsewhere in the HEA, but we recommend using the the largest colony to estimate maximum length of time to recover. We recommend that supporting information on flushing rates or information on growth rates be provided to support the 1-2 recovery year estate.	Hopefully, in-situ data from the effects of dredging at Kilo Wharf can address these issues. However, it is also noted several times in the DEIS that coral communities of similar species composition at the mouth of Inner Apra Harbor have sustained growth under chronic, or continuous high in sedimentation rates. As there has been no discussion of "replacement of coral with similar ones that would provide similar ecological functions" within the dredge area, this part of the comment cannot be addressed. We agree that colony size data, when made available following Spring 2009 surveys can be utilized in the HEA. However, it is not a valid assumption to assume that the entire community function is a result of the largest colony, anymore than a human community function is based solely on the oldest member. Rather, it is more valid to utilize the mean, or average colony size. No text edits.	

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179	Section F	12	14-15	USFWS		It isa unclear how the artificially derived "100% live coral equivalent" describes the functional contribution of corals to the greater coral reef function. We recommend data that more clearly relate to coral function be used in the HEA. (see previous comments)	As noted previously, coral "function" could not be measured directly by anyone. Rather, the proxy for function will be coral community structure, which will be provided by results of Spring 2009 Surveys. The ACOE has approved the use of artificial reefs for mitigation purposes and the use of percent live coral as a means for estimating mitigation requirements (e.g., HASEKO). The HASEKO mitigation determination utilized "100% coral equivalence" calculations. This approach makes use of available data and accounts for the fact that some impacted acres have very little live coral, while other areas have a	
180	Section F	14	13-14	USFWS		The document states: "Given the characteristics of the specific habitat expected to be affected by the CVN project, it is reasonable to believe that artificial reefs can relatively rapidly provide replacement functions and services of similar type and quality." No empirical support is provided to support this statement and the available scientific literature, including the study of artificial reefs assessment commissed by the Navy (Brock 2005) do not support this assessment. See the attached document "Comments on the "Artificial Reef Feasibility Study" (U.S. Department of the Navy 2007) and the Use of Artificial Reefs for Compensatory Mitigation" for further information. Due to the inability of artificial reefs to replace the suite of ecological functions of a natural coral reef, we recommend that this project be dropped from consideration as appropriate mitigation or that additional mitigation projects that will replace the functions not addressed by artificial reefs be developed and included.	The ACOE has approved the use of artificial reefs for mitigation purposes and the use of percent live coral as a means for estimating mitigation requirements (e.g., HASEKO). The Navy will continue to include artificial reefs as compensatory mitigation option. No change to text.	
181	Section F	14	16-21	USFWS		The documents sites the ACOE permit issued to HASEKO, Inc. as justification that artificial reefs are appropriate for mitigation of coral reef impacts. This permit was issued prior to the the new regulatory guidelines for compensatory mitigation. Additionally, HASEKO agreed to a modification of this permit in 2008 in order to obtain a state permit to proceed. According to the amendment to their conservation use permit, the reason for the modification states: "In the years since these [permit] conditions were established, the scientific understanding of artificial reefs has moved forward significantly, and most scientist currently believe that an artificial reef with a surface area of approximately 1.1. acres would not be sufficient to create useful coral-reef habitat. Rather, a structure or aggregate of seafloor structures with a total surface area of this size would function primarily as a fish aggregation device. As such, it would concentrate fish near the structures without providing productive habitat for community growth." The state of Hawaii continues to support the project, but recognizes that the artificial reef structure is for "fisheries enhancement and recreational use." In light of the revision of the cited ACOE permit conditions and the lack scientific support demonstrating that artificial reefs will replace the ecological functions of a natural coral reef, we recommend that the Navy remove artificial reefs from consideration as compensatory mitigation.	The ACOE has approved the use of artificial reefs for mitigation purposes and the use of percent live coral as a means for estimating mitigation requirements (e.g., HASEKO). The HASEKO mitigation determination utilized "100% coral equivalence" calculations. This approach makes use of available data and accounts for the fact that some impacted acres have very little live coral, while other areas have a large amount of live coral. Ignoring that distinction would be inappropriate. The 100 acres agreed upon was not based on science, but was arbitrary based on what the agencies felt was suitable for that specific project to achieve more than a fish aggregating device. In fact, in the MOA between the COE and Haseko, it is stated that "DLNR/DAR believes that, while creation of he specified area of artificial reef (4% of 28 acres, or about 1.1 acres) is sufficient to offset the impact to coral reef caused by the marina entrance channel, it would be undesirable if the area were to be provided as a stand-alone entity. For this reason, the Parties agree that it would not be possible to obtain the requisite permits for such an artificial reef." The situation was unique because there were so few corals in the vicinity, that the mitigation ratio resulted in a very small restoration area, although the DLNR agreed that this area was actually sufficient mitigation. Had the Haseko channel area been populated with higher levels of coral cover, and the mitigation ratio resulted in a larger restoration area, then it is likely that no change in size would have occurred. The MOA also states that Haseko was not	Section A?
182	Section F	15	1-2	USFWS		The discussion of the economic value of the reef is not relevant within the ACOE guidelines on compensatory mitigation. The guidelines clearly state that lost function must be replaced and provides no monetary limitations or cap. We recommend that discussion of reef valuatation be removed from any impact analysis and HEA.	The Navy believes valuation information provides useful context for mitigation decision-making. No change to text.	
183	Section F	18	1-8	USFWS		Proposed compensatory mitigation projects are required to be feasible. The HEA has identified an area of 43.5 acres of artificial reef needed to compensate for the potential impacts from the preferred Polaris Point Alternative. The Artificial Reef Feasibility Study (Navy 2007) assessed sites around Guam suitability to deploy artificial reefs. This study identified only 20.6 non-contiguous acres as suitable for artificial reef deployment. This acreage is not sufficient to offset either alternative and makes this proposed project unfeasible. We recommend that this artificial reef project be removed from the document and that a project that is feasible be analyzed. Previously we have recommended water quality improvement as a potential feasible mitigation project, but we acknowledge that there may be other viable alternatives.	There are additional areas than the 20.6 ac cited. The cited study did not attempt to identify all locations potentially suitable for artificial reef deployment in Apra Harbor or other locations in Guam. The proposed mitigation budget includes substantial funding to address reef siting issues. Artificial reefs can be deployed at more than one site. The Navy believes that the additional funding, building on previous siting work, will be sufficient to identify appropriate deployment locations. No change to text.	
184	Section F	Table 5		USFWS		A ration of 1.1:1 acres of artificial reef to natural reef has been proposed based on the ACOE permit issued HASEKO, Inc. HASEKO agreed to a modification of this permit in 2008 in order to obtain a state permit to proceed. According to the amendment to their conservation use permit, HASEKO, Inc. agreed to establish "an artificial reef that would be close to 100 acres in size" to offset losses and create a viable artificial reef to meet the stated purpose of fisheries enhancement and recreational use. Concerns were raised that artificial reefs smaller than this "would lead to greater vulnerability of reef fish to over fishing, due to concentration of fish at a site readily accessible to fisherman, with no enhancement of fish reproductive rates or growth." No contiguous area of sufficient size has been identified on Guam that is suitable for deployment of large artificial reefs. Additionally, scientific support for does not exist to demonstrate that artificial reefs replace natural reef function, and the installation of small artificial reefs may result in additional harm to Guam's reef. We recommend that artificial reefs be removed from consideration as a mitigation alternative and that a project that is logistically feasible and may replace lost function be included in the analysis. We have recommended that a water quality improvement project be analyzed as a mitigation option, but we acknowledge that other viable projects may exist.	Navy understanding is that the modification in ratio was arbitrary to move negotiation forward and was not based on science. See response to comment 181. No change to text.	
185	1	ES	ES-1	21-23	Gawel	Note that no representatives of the Government of Guam were able to attend the workshop and participate in discussions and decisions made there.	Amended text as suggested. Important to remember that USFWS set the dates and had trouble accommodating everyone. Attendance by Guam agencies would have been welcome. No change to text.	
186	2	ES	ES-2	4	Gawel	Delete "or all", because the limited survey by Steve Smith (August, 2007, Page 25) indicates that at least some large old coral colonies are present that pre-date the WWII dredging.	Edit text as suggested.	Done

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187	3	A 3.2.1	9	1-5	Gawel	Note that no representatives of the Government of Guam were able to attend the workshop and participate in discussions and decisions made there.	Absence of GOVGUAM representatives was unfortunate. There were scheduling challenges for USFWS to reconcile. Text added.	Done
188	4	A 3.3.4	12	26-30	Gawel	Artificial reefs are not acceptable as suitable mitigation, as discussed in numerous conference calls on the EIS for the CVN berthing.	Agreed. It will be collected during upcoming Agency surveys. It has been discussed and agreed that terminology to describe non-discrete colony growth forms will be established. No text edits.	
189	5	A 4.0	19	10-23	Gawel	Coral coverage data is not enough to evaluate values to be lost. Coral colony size data must also be collected and evaluated, allowing for special accommodations to assess sizes of those colonies with difficult to discern boundaries.	HEA was based on best available information. Spring Surveys will provide additional data. No text edits.	
190	6	A 4.0	23	19-28	Gawel	We question use of artificial reefs as the proxy for mitigation estimates. Different mitigation will be sought and this would convert to different mitigation costs. Different proxy estimates need to be made.	Navy will continue to pursue artificial reefs as a possible compensatory mitigation. All compensatory mitigation proposals are problematic. The arguments against artificial reefs are not compelling enough to eliminate artificial reefs from further consideration in favor of another mitigation proposal approved the used of artificial refs in Hawaii. No change to	
191	7	C 1.0	1	27	Gawel	An assessment should be provided of whether hydraulic dredging would have less of an impact to water quality and the impacted marine environment than mechanical dredging . The least damaging method should be required in the SOW for the contractor.	The methodology will remain flexible until the contract is awarded. There are engineering and operational conditions that would be considered in conjunction with environmental issues. No change to text.	
192	8	C 1.0	1	29-30	Gawel	Beneficial uses for the dredged material on Guam should be proposed, assessed and prioritized. Why is this not currently being done? Ocean disposal must not be used as an easy alternative because the material can be very valuable if used on land.	Beneficial reuse is always the preferred option; however, the Navy has stockpile dried material for which a beneficial reuse has not been identified. The MOA with Port Authority Guam remains valid. PAG has not been ready to accept the material. No change to text.	
193	9	C 1.0	2	4-5	Gawel	Ocean disposal will waste the value to Guam of this material. Beneficial uses for the dredged material on Guam should be proposed, assessed and prioritized. Why is this not currently being done? Ocean disposal must not be used as an easy alternative because the material can be very valuable if used on land.	Beneficial reuse is always the preferred option; however, the Navy has stockpile dried material for which a beneficial reuse has not been identified. The MOA with Port Authority Guam remains valid. No change to text.	
194	10	D 3.3.2.2	17	12	Gawel	Turtles and reef fish are not "macro invertebrates"	Text edited.	Done
195	11	D 3.3.2.2	17	23-32	Gawel	The lack of observations of fish, including top predators, during surveys does not mean they are not in the area at all times. During the prolonged disturbance of the proposed dredging certain migrations or activities of important fish species can be impacted, even though they have not yet been recorded. The proposed dredge site and areas of Sasa Bay adjacent to this site are reputed to support seasonal hammerhead shark birthing. This area also is believed to be the best site to obtain broodstock for a species of rabbitfish that has been cultured experimentally as a promising aquaculture species on Guam with very high market value and was, after being cultured, discovered to be a new undescribed species, now named *Siganus randalli*.	It is difficult to assess impacts based on data that has not been recorded. The HEA and future studies will be based on best available information. Spring Surveys in 2009 will include a fish survey. No change to text.	
196	14	D 3.3.2.2	17	12-39	Gawel	There is no mention of other non-coral organisms besides fish and turtles. Because of Navy ship repair and maintenance done at the proposed dredge site (not that done at former SRF) during and after WWII, isn't it likely that pollutants including anti-fouling materials have been deposited in the sediment to be dredged and will be released during dredging to impact sessile invertebrates and planktonic larvae?	No installation restoration sites have been identified at the site. The dredging area is generally hard substrate and resuspension of sediments anticipated to be minor. Preliminary data soil testing data was conducted and additional data will be collected during ACOE Section 404/10 permit application process to provide guidance on dredged material disposal method. DEIS presents preliminary data. No change to text.	
197	12	D 4	18		Gawel	The uniqueness and special value of the proposed dredging impact site has not been recognized throughout this HEA development process. The turbidity and apparent lower diversity of corals and small numbers of fishes observed are implied to lower the relative value of the area. But deeper waters of Apra Harbor are habitat for species that probably are not found anywhere else in US waters. An example is a species of *Pentapodus* (blue whiptail) undescribed, according to Myers (Micronesian Reef Fishes, 1999). The mangrove stand in Sasa Bay, adjacent to the proposed dredging area, although small by Micronesian Island standards, is probably the largest natural mangrove forest in the Pacific on US soil and serves as a nursery to reef and lagoon species. Its adjacent mudflats likewise appear to be unique in the US. The deep protected lagoonal waters linked to these habitats, that will be impacted by the dredging , resemble sites in which I have found new undescribed species and new distributions of species in Micronesia and Fiji. How can such uniqueness be evaluated and measured for losses?	Commenter is being subjective in his assessment as he states in his last sentence how do you measure uniqueness. Deeper waters in Outer Apra Harbor would not be impacted by dredging. The impacted reefs are not pristine or unique. They have been dredged before. Based on the sediment impact assessment of Section F. No impact to Sasa Bay is anticipated. there would be no direct impact because the projecta rea is located west of Sasa Bay. There would be no indirect impact based on the worst-case sediment modelling provided in Section E. Operational impacts due to tugs ppodocking and undocking the CVN would be less than the worst-case dredging impact (no impact) and would be short-term and infrequent (maybe 5-6 times per year). Other ship traffic would not impact the Sasa Bay area. Text added.	Done
198	13	D 4	18		Gawel	Another possible value not being addressed in the HEA approach is that the corals living in the dredged site are subject to many stresses that may have led to colonies that are naturally stress resistant and may be reserves that can survive when others die from increased stresses in the environment such as related to climate change.	Correct, and this is why these areas are likely to be resistant to indirect impacts. No change to text.	

#	SECTION	Page or Fig/Tbl #	Line #	Command or Org.	Commenter (last name)	Comment	TEC Response	Done
199	15	F 6.0	13-15		Gawel	Artificial reefs are not acceptable as suitable mitigation, as discussed in numerous conference calls on the EIS for the CVN berthing.	The ACOE has approved the use of artificial reefs for mitigation purposes and the use of percent live coral as a means for estimating mitigation requirements (e.g., HASEKO). The HASEKO mitigation determination utilized "100% coral equivalence" calculations. This approach makes use of available data and accounts for the fact that some impacted acres have very little live coral, while other areas have a large amount of live coral. Ignoring that distinction would be inappropriate. No change to text.	
200	16	F 11.0	24	1-9	Gawel	Again, artificial reefs are not acceptable as suitable mitigation, as discussed in numerous conference calls on the EIS for the CVN berthing.	The ACOE has approved the use of artificial reefs for mitigation purposes and the use of percent live coral as a means for estimating mitigation requirements (e.g., HASEKO). The HASEKO mitigation determination utilized "100% coral equivalence" calculations. This approach makes use of available data and accounts for the fact that some impacted acres have very little live coral, while other areas have a large amount of live coral. Ignoring that distinction would be inappropriate. No change to text.	

Appendix E – Section B: Reconnaissance Surveys of the Marine Environment, Eastern Outer Apra Harbor, Guam, Baseline Assessment of Marine Water Chemistry, By Marine Research Consultants, Primary Author: Stephen Dollar

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Habitat Equivalency Analysis & Supporting Studies: Section B

Reconnaissance Surveys of the Marine Environment, Eastern Outer Apra Harbor, Guam

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Baseline Assessment of Marine Water Chemistry

September 2009

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LIST OF ACRONYMS AND ABBREVIATIONS

~	approximately
°C	degrees Celsius
0/00	parts per 100
CTD	conductivity, temperature, depth
CVN	Nuclear Aircraft Carriers
EPA	Environmental Protection Agency
ft	feet
GPS	Global Positioning System
GWQS	Guam Water Quality Standards
m	meter(s)
mg/L	milligrams per liter
ntu	nephelometric turbidity units
PCBs	Polychlorinated biphenyls
pH	potential of hydrogen
TSS	total suspended solids

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1.0 INTRODUCTION AND PURPOSE

The intent of the study is to create a preliminary baseline data set that depicts water quality in the eastern area of Outer Apra Harbor, primarily in the vicinity of the navigation route and proposed turning basin necessary to accommodate Nuclear Aircraft Carriers (CVN) berthing at a new wharf in Outer Apra Harbor. The purpose of the baseline is to establish a set of conditions that will enable evaluation of changes that might result from dredging, construction and operational procedures in the turning basin, channel and berthing areas.

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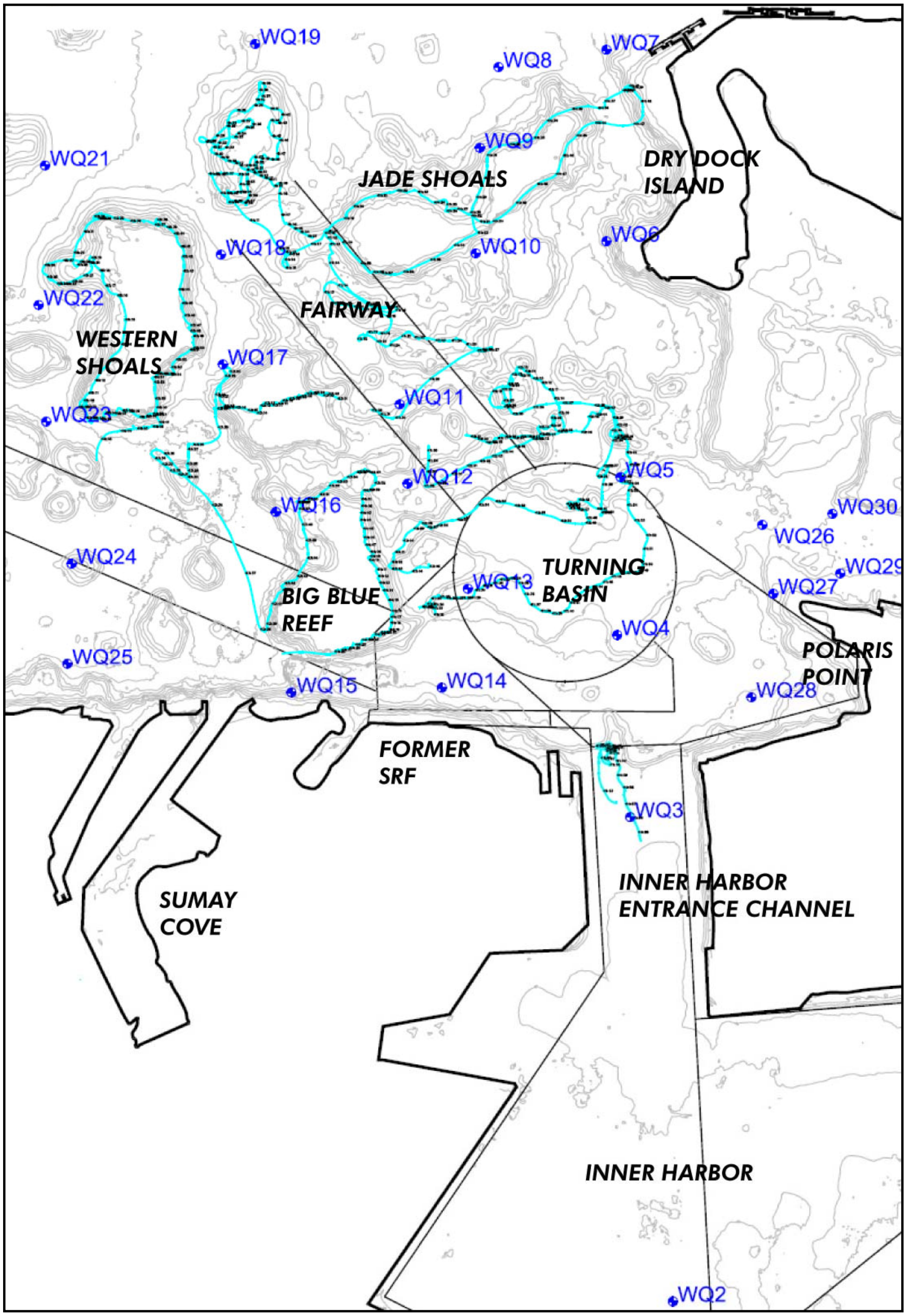
2.0 ANALYTICAL METHODS

All fieldwork was conducted on November 5, 2007 and January 28, 2008 with sampling personnel working from a 22 feet (ft) (6.7 meters [m]) boat. Water quality was evaluated at 30 stations spaced in a grid extending from inside the Inner Harbor entrance channel to the south, Polaris Point to the east, Delta Wharf on Dry Dock Island to the north, and the western edge of Western Shoals to the west (Figure 1).

At each station water samples were collected within the upper 0.5 ft (0.15 m) of the water column, at mid-depth, and 3ft (0.9 m) from the bottom using a 0.5 gallon (1.8-liter), Niskin-type oceanographic sampling bottle. These bottles were lowered to the desired sampling depths with spring-loaded endcaps cocked in an open position ensuring complete flow-through of water. At the desired depth, a messenger released from the surface triggers closure of the endcaps. Following collection, subsamples were placed in 0.06 ounce (500 milliliter) triple-rinsed polypropylene bottles and placed on ice. In addition, at each station, a continuous vertical profile of salinity, temperature, dissolved oxygen and pH was acquired. Latitude and longitude of each sampling station were acquired with a GPS with a reported accuracy of 2.1 to 4 ft (7 to 13 m). Water quality parameters evaluated included: turbidity and total suspended solids (TSS). Turbidity was measured on a Hach Model 2100 turbidity meter, and is reported in nephelometric turbidity units (ntu, level of detection 0.01 ntu). TSS was measured gravimetrically on dried filtrate using a Cahn electrobalance. Vertical profiles of salinity, dissolved oxygen and temperature were acquired on November 5, 2007 using an RBR CTD Model XR-620 calibrated to factory specifications.

Figure 1: Water Quality Station Locations



NOTE: Drawing of eastern Outer Apra Harbor and Inner Harbor showing locations of 29 water quality sampling stations (WQ2-WQ30). Station WQ1 is located in lower portion of Inner Apra Harbor below the boundary of the figure. Also shown are tracks of video transects for ground-truthing remote sensing habitat maps (light blue line). Each ground-truth data point on track is shown as numbered mark.

3.0 RESULTS

Table 1 shows results of measurements of turbidity and TSS at the 30 stations in eastern Apra Harbor in November 2007 and January 2008. No distinct patterns are evident in the data during either survey with respect to either depth or location within the Harbor. Such a result indicates that at the time of these two samplings there was not a large effect to turbidity and suspended solids in the Outer Apra Harbor from water exiting either the Inner Apra Harbor or Sasa Bay. During the November sampling, all values of turbidity were below 1 ntu, including stations located within the Inner Apra Harbor. TSS was above 2 mg/L in 25 of the 90 measurements, and above 20 mg/L at a single sampling site (Station 15-S). Samples from the surface and bottom at Station 15, located between the entrance to Sumay Cove and the floating Dry Dock, were the highest in the data set. In January 2008, three measurements of turbidity exceeded 1 ntu (max of 1.7 ntu at Station 8S). Twenty-six measurements of TSS exceeded 2 mg/L, and three measurements exceeded 20 mg/L, with the highest values at Station 17, located off the eastern edge of Western Shoals (Figure 1). During the January sampling, TSS at Station 15 was among the lowest values, while in November TSS at Station 17 was similarly low. These results suggest that while TSS and turbidity within the sampling area are generally relatively low, there can be localized and temporary increases.

Table 2 shows values of salinity, temperature, dissolved oxygen and pH acquired on November 5, 2007 during 30 conductivity, temperature, and depth (CTD) casts at each station shown in Figure 1. Figures 2 through 5 show plots of these data at stations located along a south to north transect beginning in the center of the Inner Apra Harbor and extending northward through the Inner Apra Harbor entrance channel, turning basin and fairway channel (Stations 3, 4, 13, 12, 11, 18, 21, 30). Examination of profiles of salinity on this transect indicate there is a well-defined layer of low salinity water in the Inner Apra Harbor that diminishes just outside the entrance channel (Figure 2). Throughout the remainder of the transect, the pattern of salinity is essentially constant at all stations with gradually increasing salinity in the upper 33 ft (10 m) of the water column. Below this depth, salinity is constant at all stations at a value of approximately 34‰.

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Table 1. Summary of TSS and Turbididty

Total suspended solids and turbidity measured at the surface (S), mid-water column (M), and bottom (B) of thirty stations in eastern Apra Harbor in November 2007 and January 2008. For station locations.

BOLD =Exceeds Guam Water Quality Standards

November 5, 2008

Station	Depth	TSS (mg/L)	TURBIDITY (ntu)
1	S	3.600	0.720
1	M	4.800	0.250
1	B	0.800	0.430
2	S	3.200	0.350
2	M	1.600	0.350
2	B	1.200	0.200
3	S	0.800	0.360
3	M	2.400	0.180
3	B	2.000	0.380
4	S	0.400	0.130
4	M	6.800	0.350
4	B	0.400	0.210
5	S	0.400	0.380
5	M	0.800	0.190
5	B	0.800	0.350
6	S	6.000	0.220
6	M	4.000	0.350
6	B	1.600	0.120
7	S	1.200	0.330
7	M	0.800	0.290
7	B	0.800	0.340
8	S	1.600	0.140
8	M	4.000	0.310
8	B	1.600	0.170
9	S	1.600	0.340
9	M	2.400	0.130
9	B	0.400	0.310
10	S	0.400	0.150
10	M	0.400	0.330
10	B	0.800	0.170
11	S	0.400	0.290
11	M	0.400	0.140
11	B	0.800	0.290
12	S	0.800	0.120
12	M	1.600	0.300
12	B	4.400	0.230
13	S	2.800	0.360
13	M	3.600	0.210
13	B	1.200	0.330
14	S	1.200	0.140
14	M	0.400	0.290
14	B	0.800	0.120
15	S	**29.600**	0.340
15	M	9.200	0.290
15	B	12.000	0.300
16	S	6.000	0.120
16	M	5.600	0.280
16	B	4.000	0.180

January 2008

Station	Depth	TSS (mg/L)	TURBIDITY (ntu)
1	S	3.600	**1.170**
1	M	2.400	0.580
1	B	2.800	0.780
2	S	1.600	0.570
2	M	2.000	0.370
2	B	3.600	0.520
3	S	1.600	0.310
3	M	0.800	0.420
3	B	3.200	0.300
4	S	1.200	0.470
4	M	1.600	0.350
4	B	1.200	0.390
5	S	0.800	0.460
5	M	1.600	0.330
5	B	1.600	0.250
6	S	1.600	0.390
6	M	2.000	0.300
6	B	1.600	0.560
7	S	1.200	0.340
7	M	2.000	0.320
7	B	2.000	0.260
8	S	0.400	**1.710**
8	M	0.800	0.310
8	B	1.200	0.330
9	S	0.800	0.310
9	M	1.200	0.390
9	B	2.000	0.220
10	S	2.400	0.330
10	M	2.000	0.400
10	B	1.200	0.360
11	S	0.400	0.410
11	M	2.400	0.220
11	B	1.200	0.540
12	S	0.800	0.380
12	M	1.600	0.580
12	B	0.400	0.370
13	S	**25.200**	0.550
13	M	0.800	**1.140**
13	B	0.800	0.240
14	S	1.600	0.290
14	M	2.000	0.270
14	B	0.800	0.460
15	S	0.400	0.260
15	M	0.800	0.350
15	B	1.600	0.230
16	S	4.000	0.530
16	M	5.200	0.380
16	B	5.600	0.480

Table 1. Summary of TSS and Turbididty

Total suspended solids and turbidity measured at the surface (S), mid-water column (M), and bottom (B) of thirty stations in eastern Apra Harbor in November 2007 and January 2008. For station locations.

BOLD =Exceeds Guam Water Quality Standards

November 5, 2008

Station	Depth	TSS (mg/L)	TURBIDITY (ntu)
17	S	0.800	0.310
17	M	0.800	0.100
17	B	2.000	0.600
18	S	10.400	0.150
18	M	10.000	0.320
18	B	4.800	0.110
19	S	0.400	0.330
19	M	1.200	0.130
19	B	2.000	0.400
20	S	0.800	0.130
20	M	0.400	0.300
20	B	0.400	0.170
21	S	0.400	0.380
21	M	1.200	0.140
21	B	0.400	0.350
22	S	0.400	0.150
22	M	0.400	0.320
22	B	2.400	0.170
23	S	1.200	0.310
23	M	0.400	0.130
23	B	1.600	0.310
24	S	1.600	0.300
24	M	1.600	0.130
24	B	0.400	0.330
25	S	2.000	0.170
25	M	2.000	0.310
25	B	0.800	0.140
26	S	4.000	0.290
26	M	1.600	0.130
26	B	2.800	0.310
27	S	1.600	0.130
27	M	0.800	0.280
27	B	0.800	0.130
28	S	1.600	0.140
28	M	0.400	0.290
28	B	0.800	0.310
29	S	1.200	0.370
29	M	1.600	0.220
29	B	2.800	0.350
30	S	0.800	0.200
30	M	1.200	0.500
30	B	1.600	0.880

January 2008

Station	Depth	TSS (mg/L)	TURBIDITY (ntu)
17	S	**39.600**	0.380
17	M	**41.600**	0.340
17	B	2.400	0.330
18	S	0.800	0.270
18	M	1.200	0.500
18	B	2.400	0.360
19	S	2.400	0.270
19	M	0.800	0.230
19	B	2.000	0.440
20	S	0.800	0.470
20	M	5.200	0.220
20	B	2.800	0.560
21	S	11.600	0.830
21	M	2.000	0.340
21	B	1.600	0.260
22	S	2.000	0.530
22	M	14.800	0.360
22	B	0.800	0.410
23	S	2.000	0.350
23	M	1.600	0.270
23	B	0.800	0.420
24	S	0.400	0.500
24	M	3.200	0.340
24	B	2.000	0.350
25	S	7.200	0.370
25	M	2.000	0.360
25	B	16.800	0.250
26	S	1.600	0.460
26	M	1.200	0.480
26	B	1.200	0.280
27	S	1.200	0.480
27	M	4.000	0.340
27	B	0.400	0.260
28	S	0.400	0.550
28	M	2.000	0.580
28	B	0.800	0.460
29	S	1.200	0.350
29	M	0.400	0.270
29	B	0.400	0.430
30	S	5.200	0.280
30	M	3.600	0.340
30	B	0.400	0.640

Table 2.CTD Data

CTD data from casts in eastern Apra Harbor collected on November 5, 2007.

Station .	Depth (m)	Temp (deg C)	pH	Salinity (‰)	dissol O_2 (% sat)	dO2 mg/l
1	0.053	29.734	8.180	33.159	99.813	6.299
	0.163	29.742	8.184	33.144	99.639	6.288
	0.262	29.743	8.184	33.202	99.289	6.263
	0.366	29.750	8.176	33.199	99.150	6.254
	0.518	29.742	8.172	33.187	98.925	6.241
	0.608	29.743	8.169	33.213	98.726	6.228
	0.731	29.750	8.169	33.223	98.495	6.212
	0.930	29.754	8.176	33.324	98.201	6.190
	1.162	29.823	8.169	33.488	98.065	6.169
	1.337	29.838	8.166	33.571	97.840	6.150
	1.522	29.842	8.162	33.593	97.580	6.133
	1.651	29.839	8.160	33.583	97.515	6.129
	1.954	29.844	8.158	33.605	97.339	6.117
	2.242	29.854	8.156	33.609	97.203	6.107
	2.389	29.857	8.127	33.622	97.317	6.114
	2.472	29.858	8.154	33.651	97.743	6.139
	2.750	29.931	8.158	33.655	97.382	6.110
	3.153	29.950	8.158	33.750	96.825	6.070
	3.371	29.975	8.161	33.801	96.413	6.040
	3.505	30.013	8.170	33.803	96.071	6.014
	3.669	30.014	8.171	33.866	95.588	5.982
	3.794	30.064	8.164	33.896	96.512	6.034
	3.940	30.095	8.165	33.911	95.240	5.951
	4.004	30.097	8.172	33.907	96.395	6.023
	4.434	30.087	8.167	33.983	94.869	5.926
	4.772	30.121	8.169	33.920	94.669	5.913
	5.119	30.010	8.180	33.991	94.733	5.925
	5.498	29.999	8.175	33.982	94.840	5.933
	5.901	29.973	8.171	33.980	94.274	5.900
	6.155	29.964	8.168	33.984	93.853	5.874
	6.551	29.962	8.167	33.985	93.685	5.864
	6.719	29.964	8.168	33.974	93.143	5.830
	7.135	29.937	8.173	33.973	92.946	5.820
	7.468	29.911	8.156	33.976	93.007	5.827
	7.828	29.905	8.172	33.983	92.568	5.799
	8.253	29.904	8.181	33.982	92.488	5.795
	8.697	29.904	8.178	33.984	92.611	5.802
	9.012	29.903	8.187	33.984	92.832	5.816
	9.290	29.904	8.192	33.981	92.805	5.814
	9.639	29.897	8.186	33.987	92.794	5.814
	9.979	29.896	8.192	33.988	92.815	5.816
	10.298	29.901	8.187	33.987	92.680	5.807
	10.580	29.900	8.188	33.986	92.147	5.773
	10.768	29.903	8.186	33.430	91.936	5.778
2	0.091	29.593	8.106	33.077	99.179	6.276
	0.200	29.626	8.095	33.148	99.000	6.259
	0.317	29.633	8.091	33.126	98.805	6.246
	0.463	29.634	8.088	33.201	98.533	6.227
	0.570	29.649	8.085	33.296	98.356	6.211
	0.816	29.750	8.082	33.507	98.239	6.186
	1.031	29.781	8.088	33.500	98.171	6.179
	1.342	29.787	8.082	33.549	97.995	6.166
	1.853	29.813	8.085	33.643	97.837	6.150
	1.971	29.877	8.078	33.641	97.802	6.142
	2.337	29.905	8.073	33.711	97.688	6.129
	2.927	29.969	8.076	33.801	97.563	6.112
	3.280	30.030	8.049	33.792	97.517	6.104
	3.581	30.079	8.059	33.893	97.039	6.066
	4.182	30.134	8.027	33.914	96.648	6.035
	4.459	30.148	8.036	33.965	96.005	5.992
	5.098	30.202	8.041	33.950	96.230	6.001
	5.713	30.131	8.049	33.957	96.128	6.002
	6.510	30.089	8.056	33.964	95.908	5.992
	7.262	30.020	8.056	33.967	95.666	5.983
	8.090	30.007	8.053	33.964	101.290	6.336
	8.872	29.982	8.062	33.967	98.391	6.157
	9.409	29.932	8.068	33.964	97.309	6.094
	9.748	29.903	8.068	33.975	94.944	5.949
	9.914	29.891	8.070	33.964	94.532	5.924
	10.252	29.853	8.078	33.978	94.204	5.907
	10.356	29.844	8.082	33.985	93.874	5.887
	10.604	29.844	8.079	33.990	93.464	5.861
	10.977	29.844	8.079	33.989	93.192	5.844
	11.459	29.847	8.086	33.992	92.912	5.826
	11.582	29.847	8.088	33.954	92.702	5.814
3	0.127	29.880	8.088	33.591	98.165	6.166
	0.232	29.884	8.092	33.640	97.978	6.152
4	0.137	29.847	8.058	33.777	98.878	6.207
	0.231	29.844	8.071	33.784	98.725	6.198
	0.438	29.841	8.084	33.806	98.442	6.180
	0.643	29.833	8.089	33.828	98.148	6.161
	0.984	29.833	8.085	33.848	97.892	6.145
	1.296	29.831	8.088	33.853	97.729	6.134
	1.516	29.837	8.081	33.851	97.667	6.130
	1.895	29.825	8.078	33.855	97.669	6.131
	2.286	29.819	8.078	33.860	97.419	6.116
	2.672	29.807	8.077	33.867	97.354	6.113
	3.009	29.798	8.085	33.878	97.121	6.099
	3.347	29.789	8.087	33.880	97.061	6.096
	3.566	29.789	8.090	33.885	96.376	6.052
	3.816	29.790	8.082	33.878	95.849	6.020
	4.351	29.783	8.080	33.882	95.722	6.012
	4.556	29.764	8.046	33.898	96.246	6.046
	4.793	29.770	8.060	33.895	95.583	6.004
	5.065	29.771	8.074	33.893	95.286	5.985
	5.542	29.772	8.073	33.901	95.135	5.976
	5.799	29.776	8.081	33.902	94.874	5.959
	5.826	29.780	8.046	33.907	94.914	5.961
	6.034	29.780	8.061	33.916	94.580	5.939
	6.413	29.784	8.064	33.907	94.467	5.932
	6.821	29.784	8.066	33.909	94.375	5.926
	7.212	29.786	8.075	33.915	94.346	5.924
	7.552	29.785	8.074	33.917	94.316	5.922
	7.938	29.788	8.082	33.923	94.206	5.915
	8.317	29.788	8.078	33.925	94.603	5.940
	8.962	29.789	8.082	33.927	94.173	5.913
	9.583	29.787	8.076	33.933	94.188	5.914
	10.015	29.789	8.074	33.966	94.060	5.904
	10.518	29.801	8.073	33.973	94.247	5.915
	11.216	29.805	8.075	33.981	94.140	5.907
	11.935	29.802	8.072	33.982	94.920	5.957
	12.551	29.807	8.080	33.989	94.245	5.914
	13.176	29.818	8.076	33.990	94.232	5.912
	13.741	29.821	8.073	33.994	94.298	5.915
	14.112	29.823	8.080	33.981	94.197	5.909
	14.212	29.830	8.078	32.243	94.046	5.956
5	0.093	29.926	8.098	33.746	98.437	6.173
	0.209	29.929	8.091	33.741	98.377	6.169
	0.386	29.934	8.085	33.740	98.127	6.153
	0.548	29.936	8.092	33.745	97.967	6.143
	0.772	29.934	8.085	33.748	97.849	6.135
	0.997	29.931	8.053	33.726	97.741	6.130
	1.218	29.840	8.067	33.706	97.459	6.121
	1.409	29.806	8.071	33.769	97.070	6.098
	1.704	29.837	8.074	33.636	96.977	6.094
	2.010	29.702	8.074	33.695	96.685	6.087
	2.161	29.699	8.073	33.637	96.332	6.067
	2.482	29.642	8.074	33.672	95.876	6.042
	2.624	29.634	8.077	33.705	95.349	6.009
	2.820	29.647	8.076	33.705	94.741	5.969
	2.986	29.650	8.077	33.724	94.071	5.926
	3.281	29.682	8.078	33.882	93.654	5.892
	3.520	29.823	8.094	33.829	93.243	5.854
	3.816	29.847	8.096	33.897	93.674	5.877
	3.980	29.868	8.092	33.938	93.646	5.872
	4.182	29.886	8.097	33.929	93.866	5.884
	4.393	29.885	8.091	33.938	94.037	5.895
	4.694	29.884	8.097	33.940	94.331	5.913
	4.993	29.879	8.103	33.941	94.254	5.909
	5.264	29.870	8.106	33.953	94.302	5.912
	5.568	29.866	8.104	33.957	95.668	5.998
	5.671	29.865	8.096	33.959	94.776	5.942
	5.911	29.866	8.100	33.958	94.647	5.934
	6.101	29.860	8.096	33.957	94.719	5.939
	6.287	29.845	8.092	33.964	94.703	5.939
	6.486	29.840	8.099	33.974	94.639	5.936
	6.674	29.842	8.100	33.978	94.591	5.932
	6.844	29.848	8.094	33.983	94.610	5.933
	7.018	29.849	8.092	33.985	94.560	5.929
	7.101	29.850	8.091	33.983	94.647	5.935
	7.361	29.828	8.087	33.987	94.579	5.933
	7.697	29.823	8.089	33.986	94.636	5.937
	8.141	29.817	8.086	33.986	94.564	5.933
	8.486	29.816	8.093	33.990	94.545	5.931
6	0.171	29.752	8.109	33.664	97.861	6.157
	0.229	29.749	8.104	33.669	97.453	6.131
	0.449	29.755	8.108	33.668	96.875	6.094
	0.608	29.752	8.101	33.675	96.417	6.066
	0.773	29.754	8.100	33.671	96.179	6.051
	0.883	29.747	8.106	33.674	95.937	6.036
	1.139	29.743	8.116	33.688	95.685	6.020
	1.460	29.743	8.112	33.682	95.644	6.018
	1.588	29.739	8.118	33.687	95.814	6.029
	2.121	29.735	8.122	33.681	95.923	6.036
	2.218	29.720	8.118	33.695	95.957	6.039
	2.478	29.723	8.114	33.725	95.951	6.037
	2.837	29.750	8.111	33.724	95.900	6.032
	3.378	29.751	8.115	33.705	95.793	6.025
	3.977	29.733	8.100	33.733	95.715	6.021
	4.380	29.883	8.116	33.839	95.569	5.994
	4.656	29.910	8.120	33.919	95.838	6.006
	5.253	29.870	8.140	33.913	94.502	5.926
	5.760	29.844	8.135	33.929	94.148	5.906
	6.074	29.833	8.131	33.937	94.733	5.943
	6.228	29.833	8.134	33.939	94.713	5.942
	6.252	29.835	8.138	33.937	94.832	5.949
	6.619	29.835	8.129	33.933	94.790	5.947
	7.122	29.803	8.130	33.953	94.906	5.957
	7.494	29.794	8.136	33.960	94.867	5.955
	7.554	29.793	8.139	33.964	94.578	5.937
	8.015	29.793	8.105	33.966	94.840	5.953
	8.373	29.792	8.125	33.972	94.679	5.943
	8.839	29.792	8.123	33.977	94.750	5.947
	9.155	29.802	8.122	33.983	94.814	5.950
	9.595	29.809	8.126	33.982	94.788	5.948
	9.845	29.810	8.127	33.988	94.874	5.953
	10.068	29.804	8.127	33.984	94.543	5.933
	10.193	29.824	8.120	33.994	94.476	5.926
	10.659	29.827	8.122	34.003	94.324	5.916
	11.202	29.828	8.122	34.002	96.847	6.074
	11.627	29.827	8.114	33.999	94.673	5.938
	12.064	29.834	8.116	34.018	94.124	5.902
	12.493	29.846	8.112	34.014	93.984	5.893
	12.682	29.844	8.110	34.016	93.754	5.878
	12.825	29.846	8.117	34.012	93.634	5.871
	12.999	29.845	8.119	34.019	93.363	5.854
	13.199	29.842	8.119	34.014	93.098	5.837
	13.402	29.841	8.121	34.016	92.937	5.827
	13.549	29.843	8.121	34.015	93.783	5.880
	13.671	29.843	8.114	34.020	94.325	5.914
	13.888	29.843	8.109	34.023	92.534	5.802
	14.442	29.823	8.117	34.033	92.268	5.787
	14.495	29.821	8.119	34.025	92.063	5.774
	14.901	29.817	8.114	34.021	92.025	5.772
	15.282	29.807	8.122	34.025	91.849	5.762
	15.505	29.806	8.126	34.025	91.870	5.763
	15.764	29.805	8.120	34.031	91.836	5.761
	16.207	29.806	8.117	34.034	91.980	5.770
	16.624	29.805	8.110	34.039	91.986	5.770
	16.979	29.803	8.111	34.052	91.961	5.769
	17.462	29.807	8.108	34.052	91.703	5.752
	17.856	29.803	8.107	34.058	91.438	5.736
	18.377	29.804	8.113	34.060	91.262	5.724
	18.835	29.810	8.114	34.062	90.933	5.703
	19.019	29.803	8.118	34.064	90.601	5.683
	19.502	29.801	8.120	34.069	90.293	5.664
	19.745	29.803	8.112	34.067	90.098	5.651
	20.262	29.803	8.116	34.064	90.008	5.646
	20.856	29.795	8.115	34.073	89.940	5.642
	20.887	29.795	8.106	34.071	89.918	5.641
	20.938	29.794	8.104	34.073	89.767	5.631
	21.027	29.796	8.104	34.066	89.694	5.627
	21.429	29.795	8.100	34.073	89.652	5.624
	21.527	29.796	8.100	34.071	89.577	5.619
	21.866	29.799	8.103	34.078	89.401	5.608
	22.250	29.800	8.088	34.093	89.301	5.601
	22.530	29.806	8.080	34.097	89.016	5.582
	22.949	29.807	8.088	34.100	88.752	5.565
	23.473	29.806	8.085	34.109	88.147	5.527
	23.658	29.807	8.078	34.100	87.572	5.491
7	0.031	30.030	8.043	33.783	99.103	6.203
8	0.065	30.180	8.158	33.815	103.386	6.455
	0.199	30.197	8.158	33.813	102.742	6.413
	0.540	30.136	8.156	33.815	101.715	6.355
	0.914	30.036	8.159	33.779	100.744	6.306
	1.156	30.029	8.153	33.777	100.374	6.283
	1.289	30.088	8.154	33.772	100.338	6.275
	1.643	30.091	8.155	33.803	100.464	6.282
	2.104	29.950	8.154	33.748	100.662	6.310
	2.428	29.900	8.155	33.762	100.744	6.320
	2.719	29.914	8.163	33.774	100.935	6.330
	2.937	29.921	8.162	33.780	101.236	6.348
	3.447	29.918	8.162	33.818	101.679	6.375
	3.888	29.951	8.163	33.865	101.751	6.374
	4.313	29.926	8.175	33.886	101.968	6.390
	4.637	29.915	8.172	33.898	101.766	6.378
	5.114	29.898	8.149	33.904	102.176	6.405
	5.507	29.867	8.166	33.914	101.693	6.377
	5.872	29.852	8.179	33.922	101.501	6.367
	5.969	29.849	8.185	33.923	101.379	6.359
	6.145	29.842	8.182	33.927	100.837	6.326
	6.190	29.843	8.184	33.926	100.412	6.299
	6.276	29.837	8.189	33.927	100.019	6.275
	6.286	29.835	8.191	33.928	99.705	6.255
	6.218	29.836	8.185	33.926	99.405	6.237
	6.252	29.841	8.184	33.922	99.193	6.223
	6.258	29.841	8.181	33.926	98.837	6.200
	6.411	29.835	8.180	33.929	98.402	6.174
	6.591	29.832	8.179	33.929	98.128	6.157
	6.760	29.827	8.188	33.926	97.763	6.134
	7.053	29.824	8.185	33.932	97.375	6.110
	7.390	29.814	8.184	33.933	97.098	6.094
	7.557	29.814	8.183	33.932	96.879	6.080
	7.835	29.812	8.181	33.936	96.708	6.069
	8.186	29.808	8.180	33.935	96.943	6.084
	8.424	29.805	8.180	33.940	97.772	6.137
	8.661	29.796	8.187	33.948	97.054	6.092
	8.957	29.792	8.183	33.956	96.793	6.076
	9.114	29.792	8.189	33.954	96.538	6.060
	9.349	29.791	8.184	33.954	96.618	6.065
	9.528	29.790	8.181	33.954	96.447	6.054
	9.775	29.790	8.189	33.954	96.375	6.050
	9.974	29.791	8.185	33.959	96.367	6.049
	10.234	29.796	8.181	33.962	96.184	6.037
	10.477	29.796	8.181	33.960	96.165	6.036
	10.805	29.797	8.186	33.965	96.073	6.030
	11.090	29.803	8.182	33.968	96.018	6.026
	11.418	29.813	8.178	33.973	95.998	6.023
	11.724	29.801	8.176	33.968	95.866	6.016
	12.071	29.786	8.177	33.969	95.781	6.013
	12.387	29.784	8.179	33.971	95.615	6.002
	12.636	29.784	8.186	33.975	95.582	6.000
	12.930	29.784	8.191	33.973	95.532	5.997
	13.277	29.784	8.192	33.979	95.566	5.999
	13.464	29.785	8.186	33.979	95.563	5.999
	13.738	29.785	8.192	33.979	95.566	5.999
	14.084	29.785	8.188	33.985	95.646	6.004
	14.417	29.795	8.184	33.998	95.662	6.003
	14.715	29.798	8.186	33.999	95.645	6.002
	15.117	29.786	8.182	34.004	95.615	6.001
	15.406	29.787	8.186	34.005	95.636	6.002
	15.743	29.785	8.181	34.004	95.575	5.999
	16.058	29.778	8.178	34.006	95.503	5.995
	16.434	29.770	8.177	34.008	95.360	5.986
	16.675	29.768	8.178	34.012	95.216	5.977
	17.016	29.765	8.178	34.015	95.054	5.967
	17.312	29.760	8.184	34.021	94.996	5.964
	17.684	29.754	8.179	34.024	94.878	5.957
	18.052	29.754	8.184	34.027	94.750	5.949
	18.423	29.754	8.179	34.027	94.740	5.948
	18.740	29.755	8.178	34.031	94.681	5.944
	19.119	29.757	8.177	34.028	94.627	5.941
	19.431	29.757	8.182	34.031	94.592	5.939
	19.773	29.756	8.186	34.030	94.393	5.926
	20.146	29.752	8.182	34.032	94.356	5.924
	20.550	29.751	8.181	34.034	94.358	5.924
	20.953	29.745	8.182	34.033	94.279	5.920
	21.397	29.744	8.179	34.030	94.164	5.913

Table 2.CTD Data

CTD data from casts in eastern Apra Harbor collected on November 5, 2007.

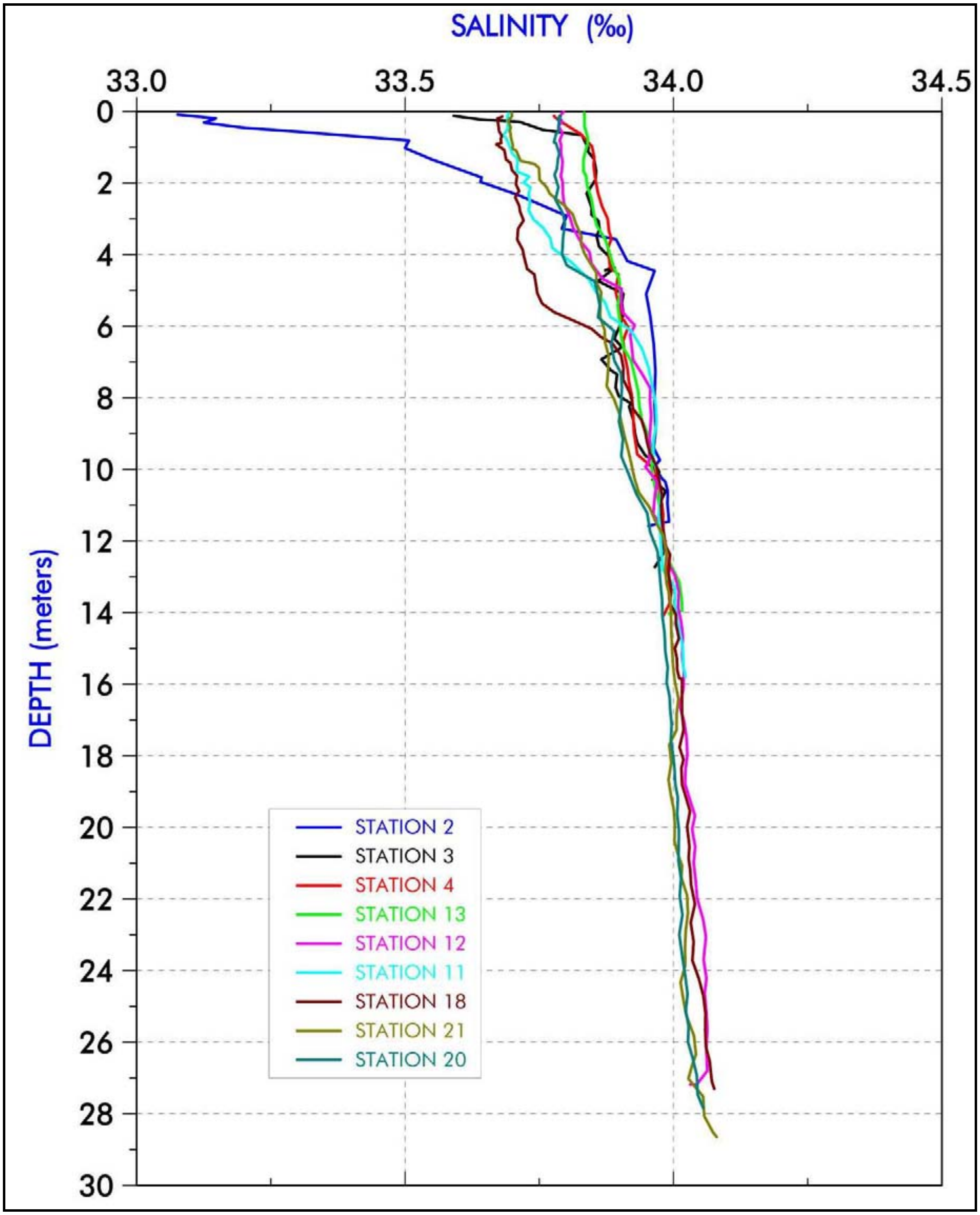
Station .	Depth (m)	Temp (deg C)	pH	Salinity (‰)	dissol O_2 (% sat)	dO2 mg/l
	0.296	29.894	8.087	33.713	97.762	6.135
	0.520	29.920	8.084	33.756	97.537	6.117
	0.669	29.919	8.085	33.830	97.163	6.091
	0.853	29.937	8.083	33.835	97.045	6.082
	1.029	29.896	8.055	33.842	97.691	6.126
	1.120	29.896	8.067	33.840	96.631	6.060
	1.340	29.897	8.078	33.852	96.439	6.047
	1.674	29.901	8.078	33.856	96.388	6.043
	1.909	29.907	8.078	33.855	96.181	6.030
	2.298	29.906	8.086	33.839	96.066	6.023
	2.702	29.872	8.089	33.848	95.951	6.019
	2.888	29.861	8.093	33.848	95.740	6.007
	3.062	29.851	8.094	33.861	95.399	5.986
	3.303	29.852	8.095	33.862	95.017	5.962
	3.485	29.854	8.095	33.857	94.614	5.937
	3.787	29.852	8.093	33.862	94.418	5.924
	4.047	29.860	8.085	33.879	94.581	5.933
	4.355	29.877	8.089	33.887	94.611	5.933
	4.450	29.896	8.082	33.873	94.610	5.932
	4.379	29.891	8.077	33.891	94.448	5.921
	4.744	29.891	8.074	33.860	94.280	5.912
	5.103	29.869	8.081	33.907	94.215	5.908
	5.358	29.920	8.074	33.904	94.178	5.901
	5.676	29.926	8.079	33.907	94.126	5.897
	5.982	29.932	8.082	33.901	94.048	5.892
	6.352	29.918	8.078	33.890	96.386	6.040
	6.589	29.908	8.076	33.904	94.284	5.909
	6.935	29.881	8.082	33.866	94.155	5.905
	7.241	29.849	8.087	33.884	93.903	5.891
	7.350	29.843	8.081	33.895	93.752	5.882
	7.707	29.836	8.078	33.893	94.090	5.904
	7.954	29.823	8.087	33.898	93.755	5.884
	8.153	29.794	8.084	33.920	93.726	5.884
	8.261	29.794	8.082	33.918	93.794	5.889
	8.627	29.790	8.090	33.926	93.750	5.886
	9.030	29.788	8.094	33.929	93.698	5.883
	9.273	29.788	8.096	33.934	93.798	5.889
	9.619	29.794	8.089	33.948	93.908	5.895
	9.736	29.795	8.081	33.962	93.888	5.893
	10.073	29.824	8.079	33.974	93.772	5.883
	10.289	29.828	8.077	33.961	93.866	5.889
	10.610	29.830	8.085	33.985	93.676	5.876
	10.855	29.842	8.079	33.978	93.746	5.879
	11.283	29.841	8.079	33.981	93.223	5.846
	11.619	29.839	8.086	33.977	93.130	5.841
	11.983	29.829	8.092	33.978	92.957	5.831
	12.374	29.827	8.090	33.981	93.363	5.857
	12.735	29.827	8.097	33.965	92.801	5.822

Station .	Depth (m)	Temp (deg C)	pH	Salinity (‰)	dissol O_2 (% sat)	dO2 mg/l
	8.708	29.818	8.099	33.992	94.402	5.922
	8.802	29.816	8.092	33.989	94.597	5.935
	9.000	29.816	8.089	33.987	94.376	5.921
	9.282	29.816	8.098	33.987	94.244	5.913
	9.527	29.815	8.101	33.992	94.264	5.914
	9.701	29.815	8.096	33.990	94.057	5.901
	10.045	29.815	8.063	33.991	94.167	5.908
	10.287	29.815	8.085	33.990	94.051	5.901
	10.598	29.817	8.093	33.995	93.900	5.891
	10.875	29.816	8.092	33.993	93.875	5.889
	11.229	29.816	8.089	33.994	93.792	5.884
	11.766	29.818	8.096	33.996	93.862	5.888
	12.079	29.820	8.094	33.997	93.779	5.883
	12.469	29.821	8.090	34.003	93.805	5.884
	12.957	29.826	8.088	34.014	93.914	5.890
	13.203	29.831	8.093	34.020	93.787	5.881
	13.554	29.834	8.082	34.025	93.648	5.872
	13.674	29.834	8.090	34.024	93.370	5.855
	13.908	29.834	8.093	34.021	92.878	5.824
	14.036	29.829	8.086	34.022	92.496	5.801
	14.268	29.825	8.094	34.023	92.105	5.776
	14.572	29.816	8.099	34.020	91.708	5.752
	14.972	29.816	8.099	34.031	91.495	5.739
	15.044	29.817	8.090	34.029	91.415	5.734
	15.221	29.819	8.087	34.035	91.257	5.724
	15.360	29.818	8.085	34.036	91.081	5.712
	15.460	29.817	8.080	34.038	90.771	5.693
	15.482	29.817	8.080	34.034	90.521	5.678
	15.583	29.816	8.079	34.036	90.219	5.659
	15.585	29.815	8.080	34.038	89.918	5.640
	15.715	29.816	8.081	34.040	89.636	5.622
	15.883	29.815	8.082	34.036	89.472	5.612
	16.113	29.814	8.084	34.037	89.199	5.595
	16.444	29.813	8.091	34.038	89.103	5.589
	16.678	29.813	8.084	34.043	89.124	5.590
	16.898	29.815	8.082	34.050	89.150	5.591
	17.220	29.817	8.078	34.053	89.198	5.594
	17.556	29.819	8.077	34.055	89.275	5.599
	18.024	29.818	8.079	34.061	88.927	5.577
	18.440	29.819	8.085	34.061	88.923	5.576
	18.761	29.820	8.078	34.067	88.807	5.569
	19.088	29.819	8.084	34.066	88.778	5.567
	19.502	29.819	8.086	34.072	88.953	5.578
	19.912	29.818	8.085	34.072	88.411	5.544
	20.255	29.819	8.078	34.073	88.188	5.530
	20.636	29.820	8.075	34.077	88.051	5.521
	20.933	29.820	8.071	34.077	87.822	5.507
	21.116	29.821	8.068	34.076	87.517	5.488
	21.313	29.821	8.073	34.075	87.231	5.470
	21.560	29.821	8.042	34.086	86.963	5.452
	21.819	29.821	8.061	34.087	86.657	5.433
	22.101	29.820	8.060	34.090	86.326	5.412
	22.521	29.821	8.055	34.095	86.217	5.405
	22.871	29.821	8.059	34.098	85.804	5.379
	23.236	29.820	8.052	34.063	85.379	5.354
	23.244	29.820	8.049	34.049	84.797	5.318

Station .	Depth (m)	Temp (deg C)	pH	Salinity (‰)	dissol O_2 (% sat)	dO2 mg/l
	0.074	30.007	8.033	33.772	98.440	6.164
	0.287	30.008	8.032	33.779	97.825	6.126
	0.559	29.941	8.034	33.793	96.594	6.054
	0.747	29.947	8.047	33.788	95.705	5.998
	1.052	29.933	8.052	33.807	95.216	5.968
	1.263	29.934	8.048	33.809	95.252	5.971
	1.613	29.940	8.058	33.795	95.613	5.993
	1.923	29.923	8.044	33.810	96.055	6.022
	2.262	29.921	8.059	33.832	96.262	6.034
	2.562	29.922	8.056	33.831	96.624	6.057
	2.914	29.916	8.069	33.839	96.628	6.057
	3.116	29.910	8.062	33.841	96.688	6.062
	3.244	29.898	8.068	33.849	96.975	6.081
	3.468	29.885	8.074	33.858	97.486	6.114
	3.744	29.884	8.077	33.864	96.785	6.070
	4.040	29.870	8.076	33.879	96.635	6.061
	4.461	29.857	8.076	33.903	96.489	6.052
	4.911	29.855	8.077	33.917	96.406	6.047
	5.287	29.850	8.077	33.911	96.440	6.050
	5.716	29.844	8.085	33.917	96.542	6.056
	5.899	29.844	8.057	33.918	96.693	6.066
	6.567	29.829	8.072	33.924	96.296	6.042
	7.359	29.828	8.083	33.926	96.020	6.025
	7.887	29.821	8.088	33.931	95.200	5.974
	8.130	29.809	8.091	33.941	96.364	6.048
	8.591	29.805	8.087	33.940	96.142	6.034
	9.033	29.804	8.087	33.942	96.314	6.045
	9.355	29.803	8.085	33.943	96.001	6.026
	9.839	29.799	8.087	33.947	95.865	6.017
	10.381	29.792	8.088	33.951	95.762	6.011
	10.742	29.793	8.094	33.955	95.687	6.007
	11.276	29.801	8.097	33.971	95.755	6.009
	11.545	29.803	8.098	33.983	95.979	6.023
	11.889	29.797	8.098	33.982	95.751	6.009
	11.955	29.796	8.067	33.989	95.729	6.008
	12.272	29.795	8.087	34.002	95.441	5.989
	12.704	29.789	8.091	34.009	95.327	5.982
	13.099	29.788	8.088	34.010	95.132	5.970
	13.316	29.787	8.092	34.014	94.902	5.956
	13.556	29.787	8.099	34.013	94.493	5.930
	13.887	29.787	8.094	34.018	94.279	5.917
	14.163	29.787	8.090	34.016	94.216	5.913
	14.429	29.789	8.089	34.020	93.940	5.895
	14.832	29.791	8.088	34.016	93.721	5.881
	15.014	29.791	8.091	34.015	93.616	5.875
	15.384	29.792	8.099	34.016	93.502	5.867
	15.734	29.792	8.096	34.023	93.390	5.860
	16.073	29.793	8.096	34.027	93.235	5.850
	16.354	29.792	8.066	34.026	93.295	5.854
	16.540	29.792	8.084	34.027	92.966	5.833
	17.096	29.790	8.090	34.030	92.755	5.820
	17.167	29.790	8.102	34.028	92.562	5.808
	17.543	29.790	8.097	34.034	92.407	5.798
	18.083	29.791	8.096	34.032	92.361	5.795
	18.463	29.790	8.094	34.036	92.279	5.790
	18.666	29.790	8.096	34.039	92.231	5.787
	19.096	29.788	8.070	34.047	91.998	5.772
	19.657	29.785	8.083	34.050	91.739	5.756
	19.868	29.783	8.089	34.051	91.592	5.747
	20.295	29.782	8.097	34.054	91.393	5.735
	20.610	29.782	8.093	34.054	91.211	5.723
	21.165	29.782	8.093	34.050	91.030	5.712
	21.495	29.780	8.092	34.053	90.861	5.702
	21.921	29.779	8.087	34.056	90.795	5.697
	22.411	29.778	8.086	34.061	90.532	5.681
	22.811	29.777	8.084	34.056	90.389	5.672
	23.133	29.778	8.085	34.058	90.050	5.651
	23.526	29.782	8.076	34.034	89.857	5.639
	23.725	29.782	8.077	34.069	89.677	5.627
	24.064	29.783	8.076	34.069	89.226	5.598
	24.672	29.783	8.077	34.072	88.782	5.570
	24.838	29.782	8.075	34.071	88.394	5.546
	25.367	29.782	8.080	34.075	88.073	5.526
	25.751	29.786	8.082	34.083	87.811	5.509

Station .	Depth (m)	Temp (deg C)	pH	Salinity (‰)	dissol O_2 (% sat)	dO2 mg/l
	21.873	29.737	8.179	34.036	94.245	5.919
	22.220	29.732	8.186	34.035	94.282	5.921
	22.264	29.733	8.183	34.033	94.390	5.928
	22.586	29.733	8.181	34.034	94.469	5.933
	23.022	29.733	8.181	34.033	94.462	5.933
	23.463	29.733	8.186	34.032	94.479	5.934
	23.926	29.751	8.176	34.046	94.546	5.936
	24.248	29.754	8.181	34.048	94.641	5.941
	24.662	29.759	8.172	34.057	94.623	5.939
	24.870	29.767	8.178	34.063	94.369	5.923
	25.297	29.773	8.174	34.062	94.122	5.907
	25.594	29.778	8.175	34.063	93.751	5.883
9	0.066	29.790	8.110	33.692	104.033	6.540
.	0.181	29.798	8.103	33.688	102.573	6.448
	0.385	29.793	8.100	33.689	101.444	6.377
	0.598	29.789	8.097	33.689	100.453	6.315
	0.867	29.780	8.103	33.695	99.748	6.272
	1.098	29.787	8.099	33.690	99.473	6.254
	1.322	29.771	8.106	33.678	99.135	6.235
	1.601	29.757	8.104	33.705	98.933	6.222
	1.795	29.761	8.103	33.699	98.684	6.206
	2.036	29.740	8.110	33.699	98.551	6.200
	2.147	29.735	8.110	33.699	98.170	6.177
	2.409	29.738	8.108	33.684	97.915	6.161
	2.612	29.712	8.111	33.696	97.483	6.136
	2.905	29.706	8.107	33.726	97.089	6.111
	3.069	29.710	8.106	33.725	96.589	6.079
	3.428	29.756	8.124	33.746	95.901	6.030
	3.740	29.788	8.132	33.837	95.297	5.986
	4.026	29.855	8.150	33.910	95.100	5.965
	4.267	29.875	8.158	33.894	95.253	5.973
	4.700	29.850	8.156	33.907	95.608	5.998
	4.941	29.844	8.153	33.909	96.102	6.029
	5.530	29.837	8.151	33.920	96.697	6.067
	5.705	29.837	8.150	33.917	97.258	6.102
	6.144	29.832	8.149	33.921	97.683	6.129
	6.544	29.829	8.149	33.917	98.052	6.153
	6.850	29.827	8.149	33.921	98.130	6.158
	7.237	29.824	8.157	33.921	97.933	6.146
	7.747	29.824	8.152	33.922	97.963	6.147
	8.098	29.816	8.144	33.937	97.740	6.134
	8.571	29.814	8.135	33.950	97.738	6.133
	9.091	29.813	8.139	33.966	97.358	6.109
	9.647	29.806	8.143	33.970	96.492	6.055
	10.025	29.800	8.147	33.974	95.235	5.977
	10.527	29.798	8.149	33.978	93.986	5.898
	10.882	29.799	8.149	33.975	93.772	5.885
	11.238	29.798	8.148	33.977	93.951	5.896
	11.640	29.795	8.158	33.978	93.492	5.868
	12.119	29.788	8.162	33.974	93.397	5.863
	12.587	29.784	8.164	33.980	93.332	5.859
	12.917	29.788	8.169	33.982	93.515	5.870
	13.256	29.791	8.162	33.988	93.710	5.881
	13.677	29.794	8.161	33.990	93.928	5.895
	14.053	29.793	8.167	33.992	94.093	5.905
	14.412	29.787	8.158	34.000	94.135	5.908
	14.701	29.776	8.158	34.003	94.189	5.912
	15.093	29.770	8.164	33.996	94.046	5.904
	15.581	29.755	8.169	34.001	93.928	5.898
	16.067	29.749	8.169	34.006	93.974	5.901
	16.627	29.746	8.174	34.008	94.163	5.913
	17.149	29.750	8.170	34.008	94.402	5.928
	17.729	29.747	8.168	34.010	94.517	5.936
	18.212	29.748	8.163	34.016	94.684	5.946
	18.650	29.749	8.171	34.016	94.755	5.950
	19.106	29.749	8.171	34.020	94.777	5.951
	19.522	29.749	8.175	34.021	95.188	5.977
	19.903	29.748	8.174	34.028	94.836	5.955
	20.486	29.749	8.165	34.032	94.467	5.931
	21.159	29.749	8.161	34.048	94.161	5.912
	21.788	29.758	8.155	34.047	93.916	5.896
	22.386	29.752	8.162	34.048	93.884	5.894
	22.591	29.757	8.158	34.045	93.408	5.864

Figure 2: Apra Harbor South-North Salinity



Plots of vertical profiles of temperature on the south to north transect show a similar pattern in that the profile from Stations 2 and 3 show a tongue of warm subsurface water at a depth of 16.4 ft (5 m) in the Inner Apra Harbor that quickly diminishes outside the entrance channel (Figure 3). With the exception of Station 20, located farthest from the Inner Apra Harbor, which displays a distinct surface layer of warmer water to a depth of 4 m, the remaining profiles indicate nearly uniform temperature (approximately 29.8°C) from the surface to the bottom. The mid-water tongue within the Inner Apra Harbor is also evident in the profiles of dissolved oxygen, which is evident as a spike of elevated oxygen at a depth of 26.2 ft (8 m) (Figure 4). At all other stations, dissolved oxygen decreases gradually from the surface to the bottom from values of oversaturation (approximately 108% saturation) to values of 95-98% saturation near the bottom. It is also apparent that there is a trend in the oxygen saturation data, with lowest values within the Inner Apra Harbor, and gradually increasing values with distance away from the Inner Apra Harbor (northward).

Figure 3: Apra Harbor South-North Temperature

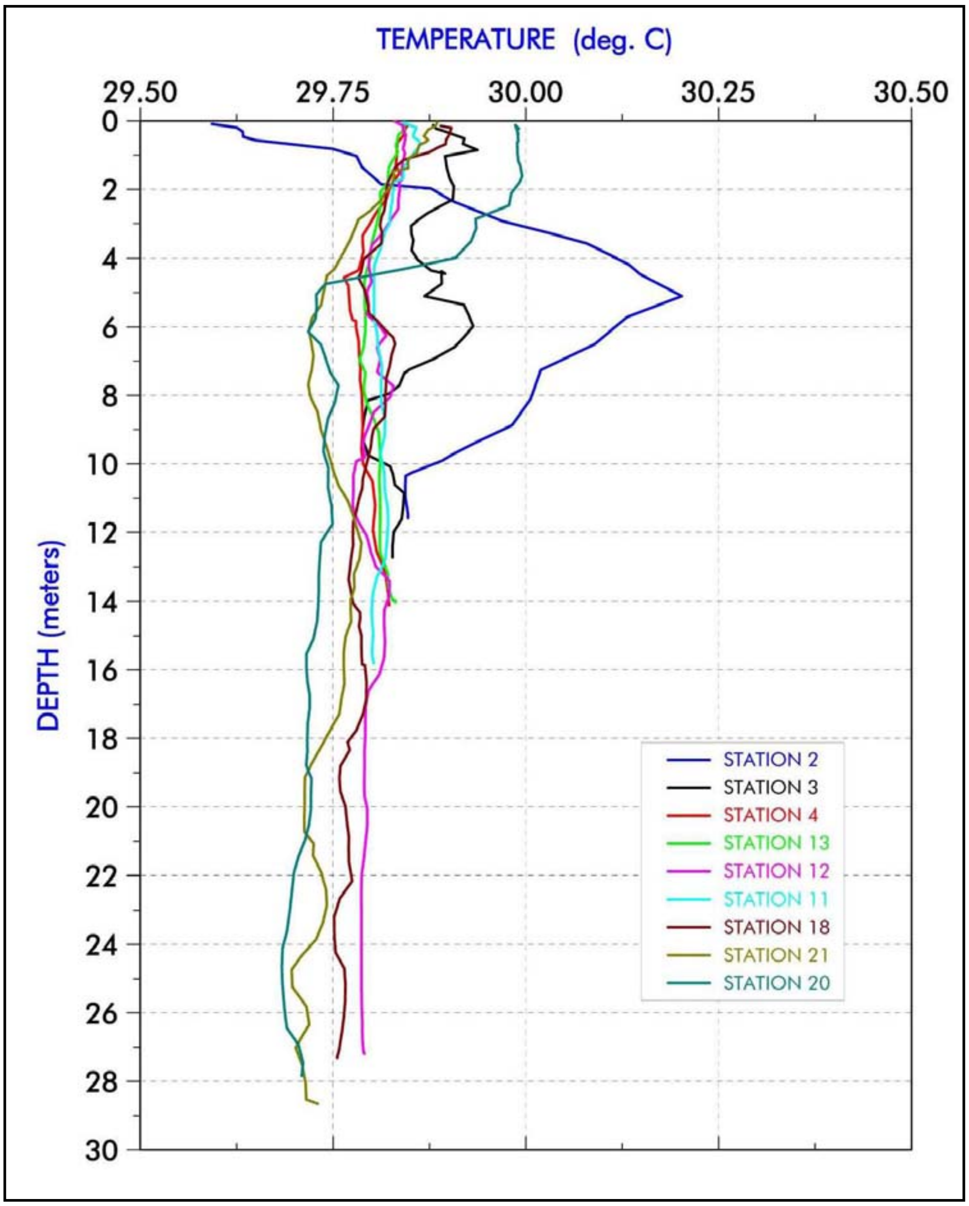
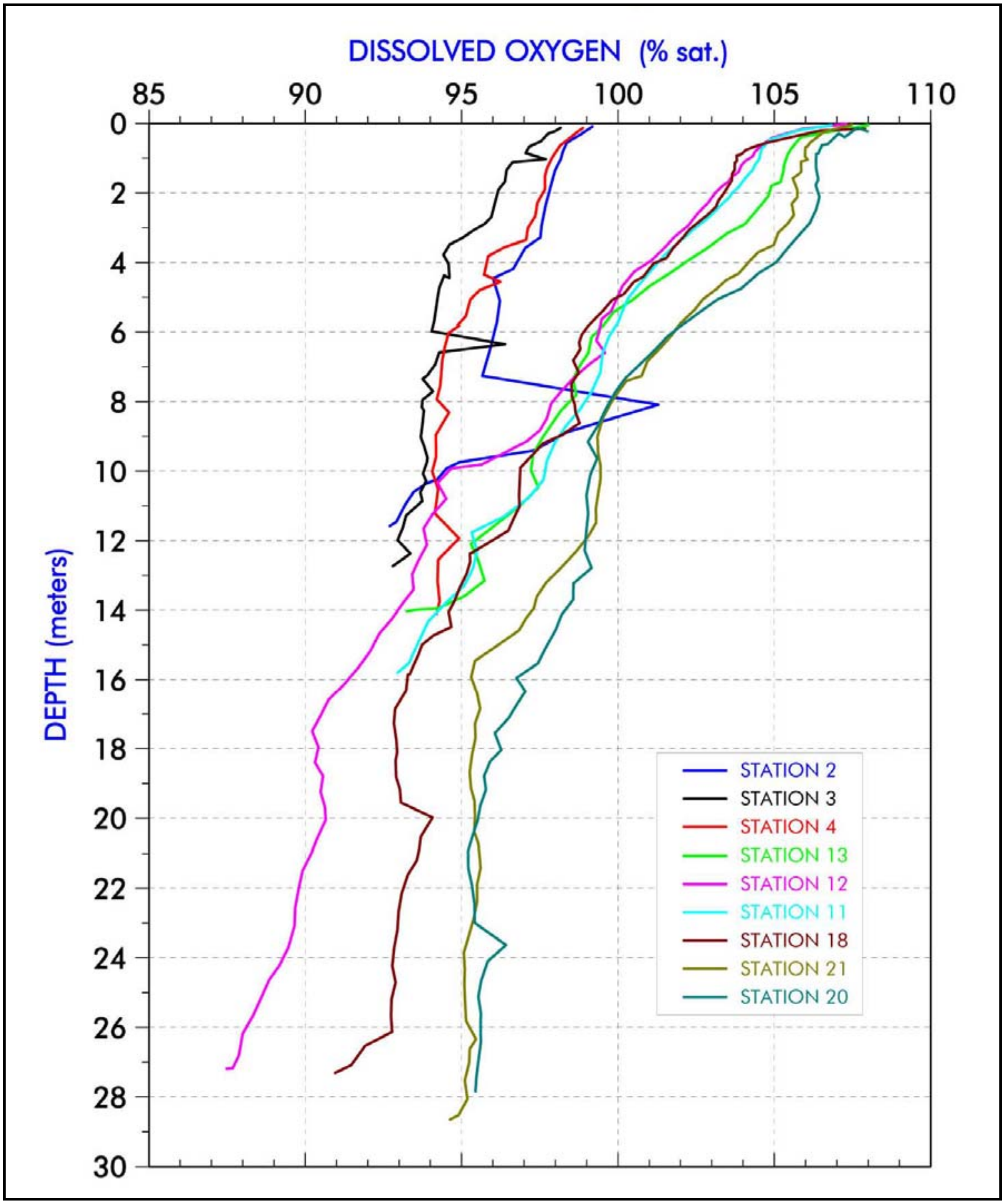
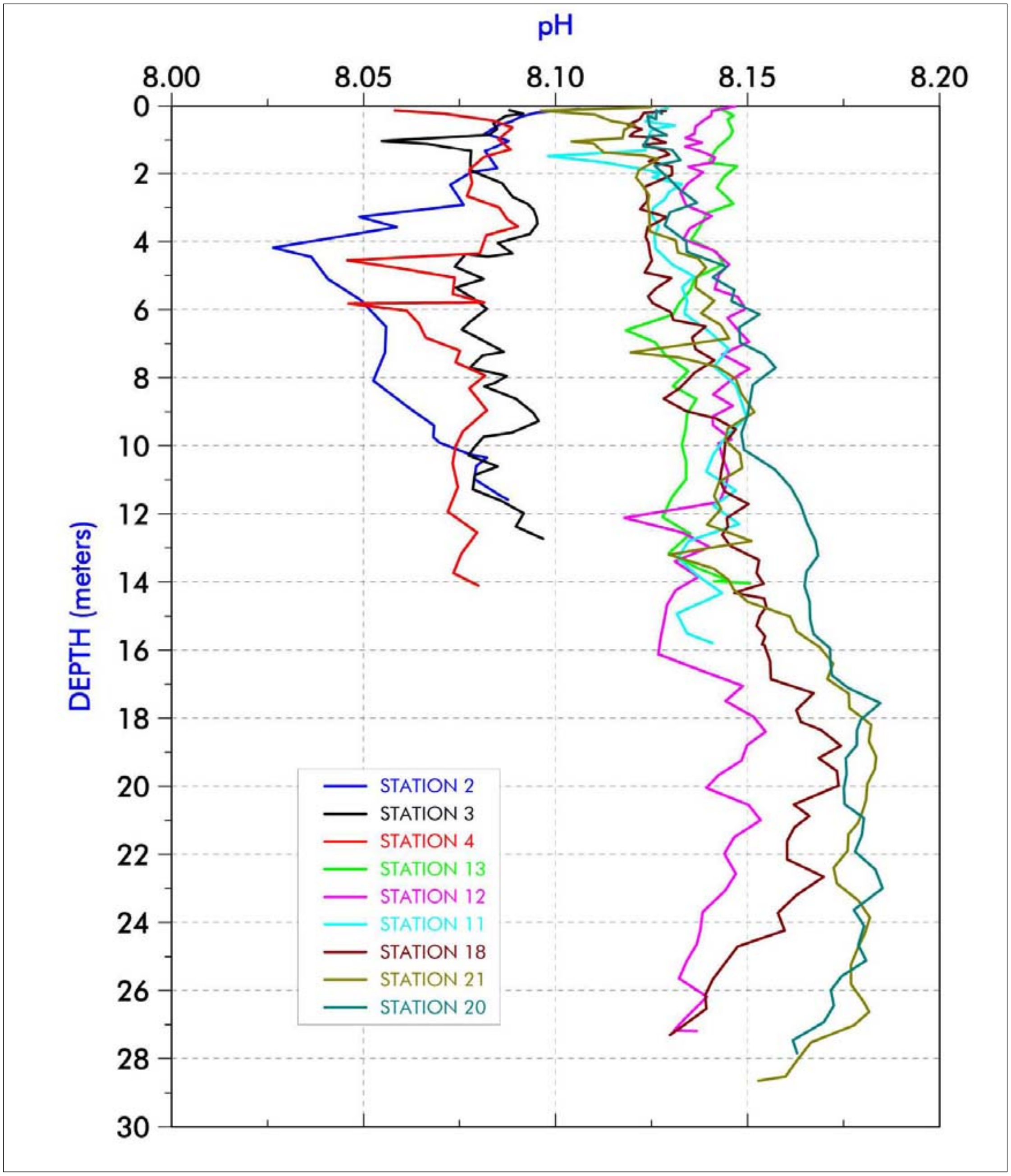


Figure 4: Apra Harbor South-North Dissolved Oxygen



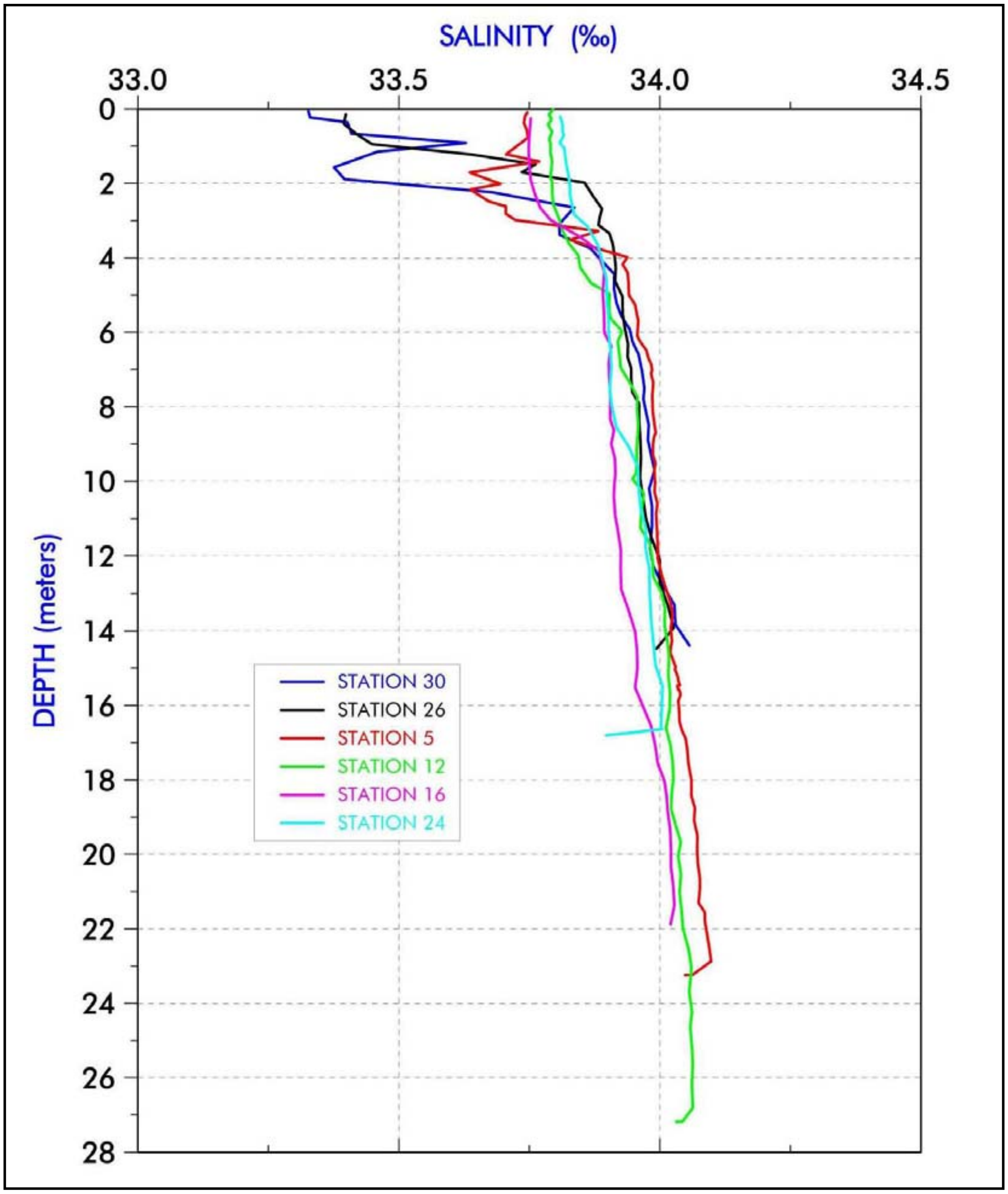
This trend is also distinctly apparent in the profiles of pH for the south to north transect. pH at the Inner Apra Harbor stations (Stations 2 and 3) as well as Station 4 located just north of the Inner Apra Harbor entrance display distinctly lower pH values (8.05-8.10) than the profiles from the Outer Apra Harbor stations (8.15-8.18). Within the Outer Apra Harbor stations, there is also a trend of slightly increasing pH with distance northward (Figure 5).

Figure 5: Apra Harbor South-North pH



Figures 6-9 show another transect of CTD profiles extending from the easternmost area of study north of Polaris Point in a westward direction through the turning basin, and continuing west of Western Shoals. Profiles of salinity display a distinct surface layer in the upper 6.6 ft (2 m) of the water column of reduced salinity at Stations 30 and 26 (Figure 6). There is also a uniform progressive increase in surface salinity with distance westward. The surface layer and progressive increase in salinity indicates westward flow of freshwater from Sasa Bay into the main basin of Apra Harbor. Below a depth of 6.6 (2m), salinity is constant at all stations at a value of approximately 34‰.

Figure 6: Apra Harbor East-West Salinity



Profiles of temperature of the east to west transect indicate a subsurface tongue of cooler water at the easternmost stations, particularly at Station 5 (Figure 7). This feature in not apparent in the south to north transect, which showed the opposite trend of a subsurface layer of warmer water within the Inner Apra Harbor. Beyond Station 5, temperature is nearly uniform from the surface to the bottom at all stations. The tongue of cooler water is also reflected in a layer of lower oxygen at the same depth at Station 5 (Figure 8). All other stations display gradually decreasing levels of oxygen saturation from the surface to the bottom. pH is also lowest throughout the water column at Station 5 (Figure 9), although there is no clear gradient of pH along the rest of the east to west transect.

Figure 7: Apra Harbor East-West Temperature

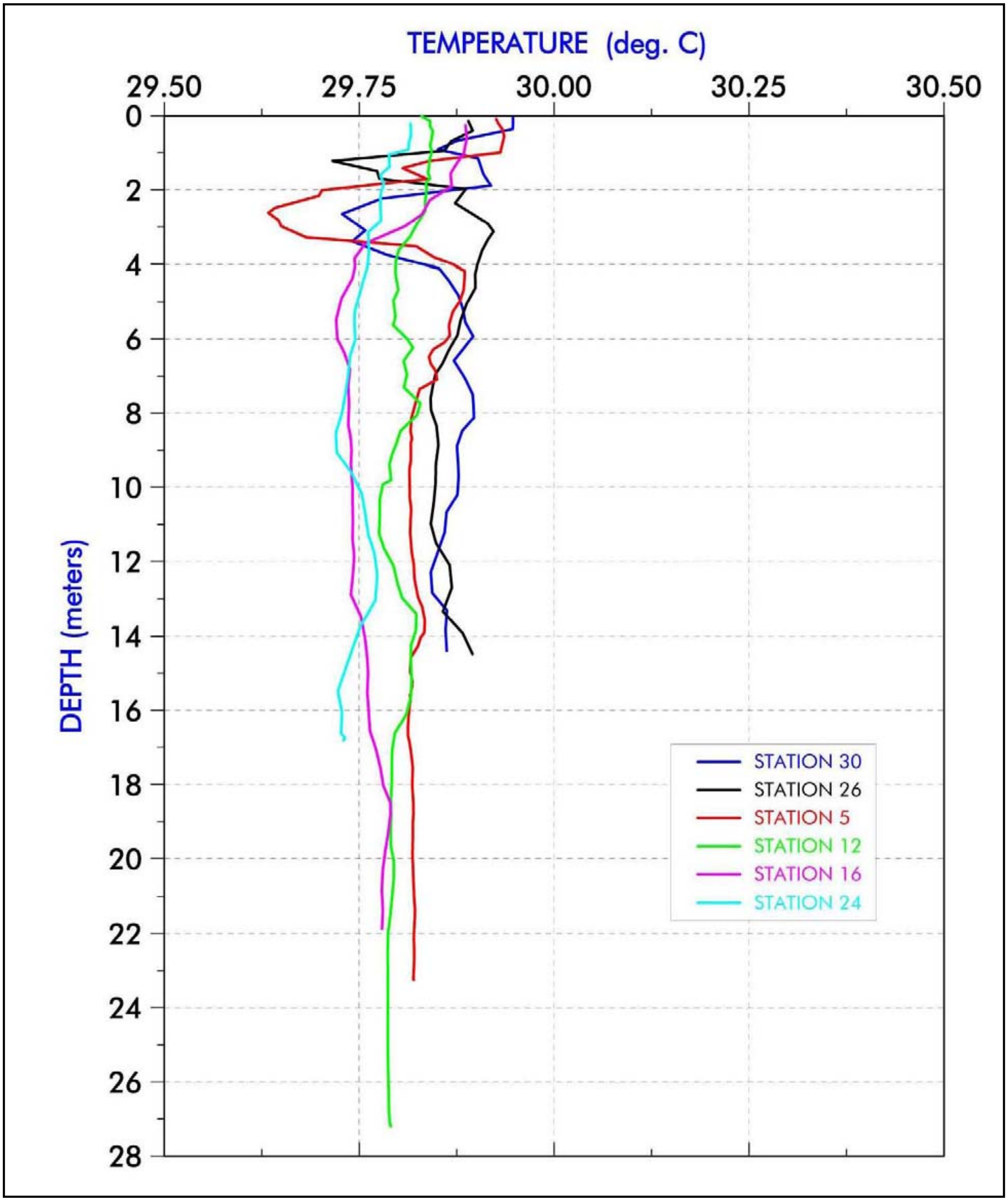


Figure 8: Apra Harbor East-West Dissolved Oxygen

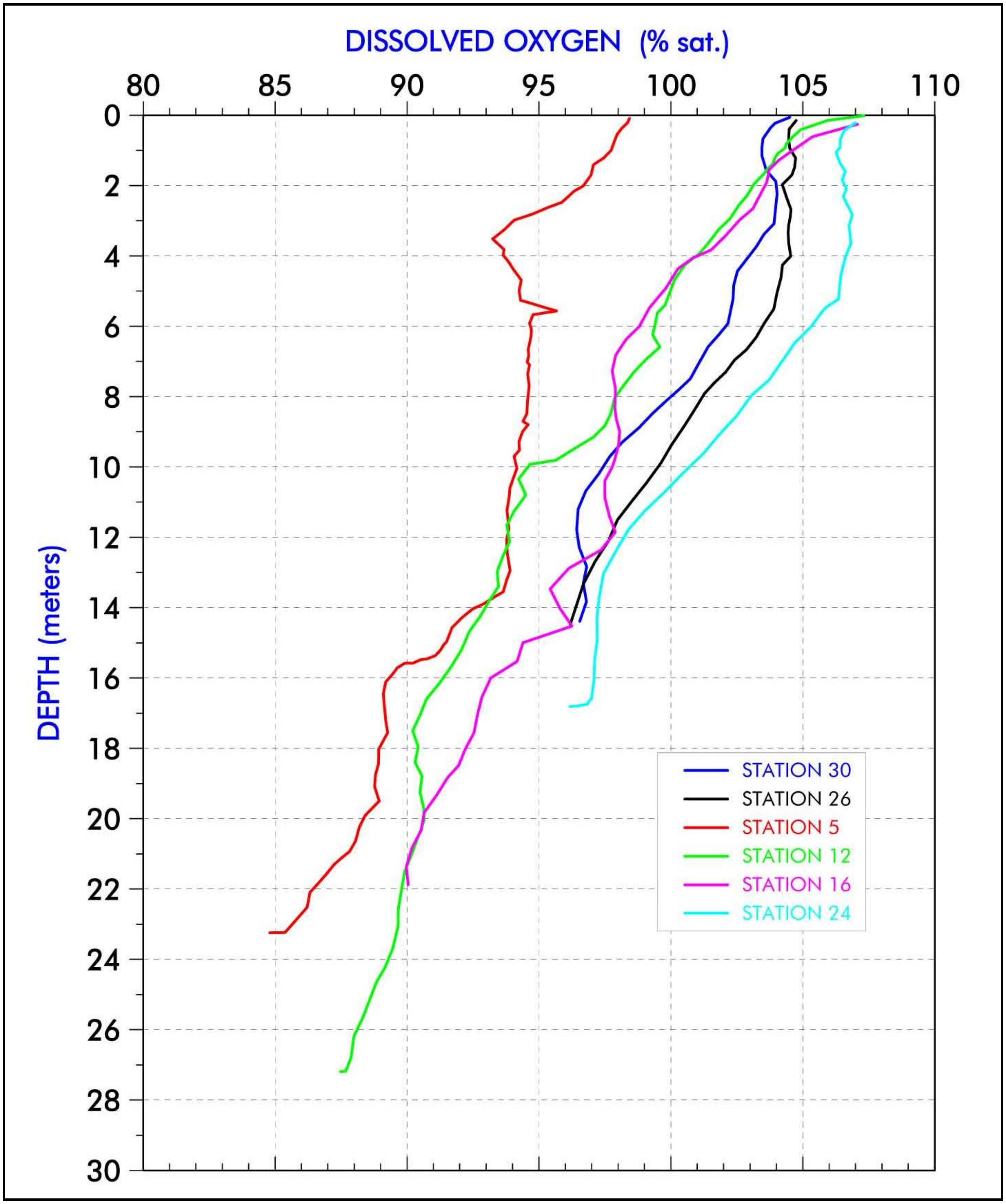
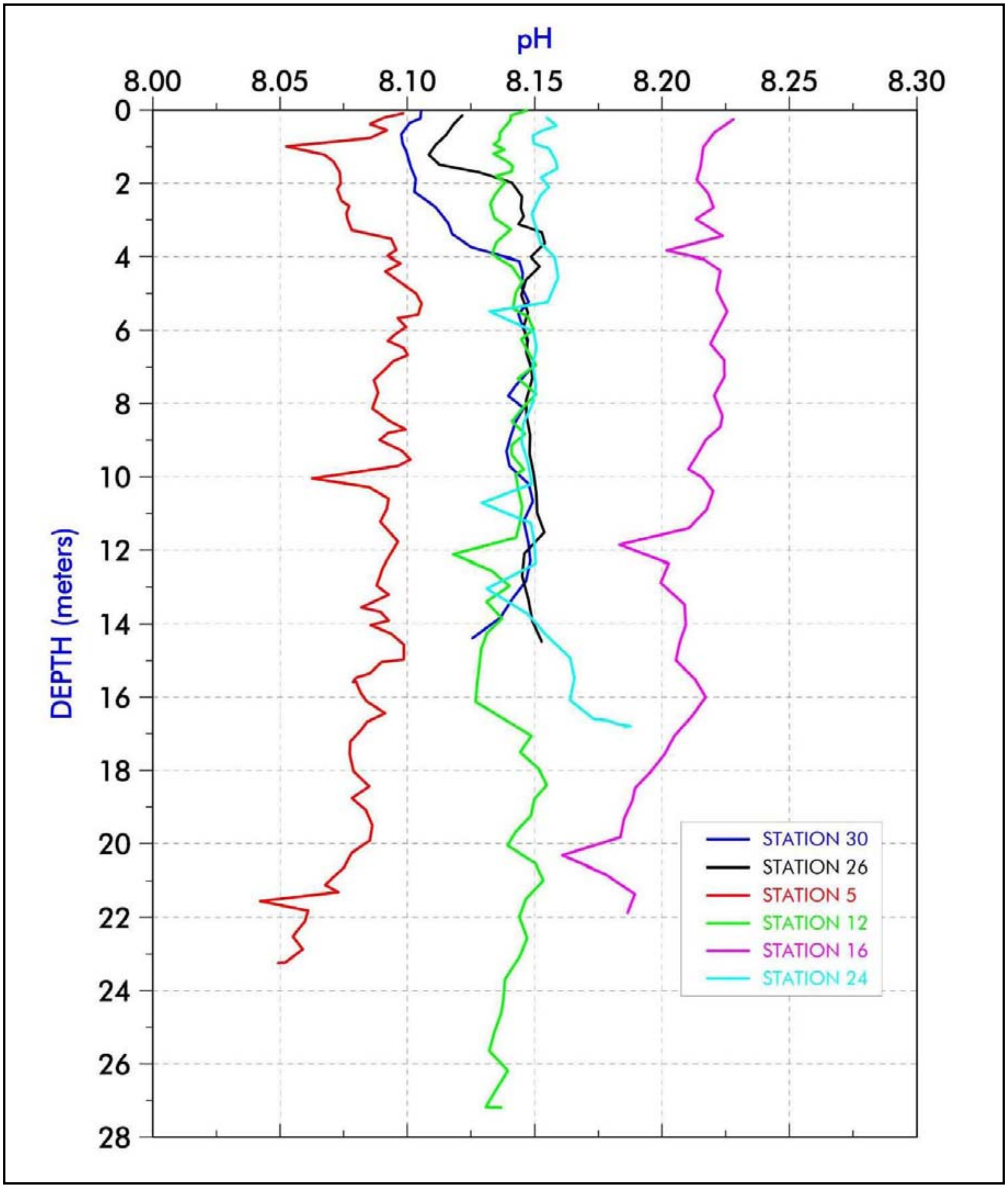


Figure 9: Apra Harbor East-West pH



4.0 COMPLIANCE WITH WATER QUALITY STANDARDS

4.1 Guam Water Quality Standards

The Guam Water Quality Standards (GWQS) (Guam EPA 2001) categorize Apra Harbor as Marine waters, which include estuarine waters, lagoons and bays (§5012 B.). Marine waters are further divided into three sub-categories: M-1 Excellent, M-2 Good, and M-3 Fair. All of Inner and Outer Apra Harbor is designated as M-2, with the exception of a small area near the commercial zone which is designated M-3. Thus, comparison of the results of the present survey with the limits specified for M-2 marine waters provides an indication of the compliance of waters in the vicinity of the proposed CVN site with Guam Water Quality Standards.

The numerical criteria for turbidity for M-2 waters is 1.0 ntu (§5013 C.7) over natural conditions, except when due to natural conditions. Inspection of Table 1 shows a range of turbidity of 0.10 – 0.88 ntu for the November sampling and 0.22 - 1.71 ntu for the January sampling. Hence, all measurements of turbidity in November, and all but three of the samples in January from the Outer Harbor were below the 1 ntu, and hence must be below the GWQS limit. The mean of all measures of turbidity in the Outer Harbor (with the three measures over 1 ntu omitted) is 0.32 ntu. Therefore, three measurement (1.71 ntu) from Station 1S, 8S, 13M have the possibility of exceeded GWQS.

Numerical criteria for TSS for M-2 waters (§5013 C.6) state that concentrations of suspended matter at any point shall not be increased more than 10% from ambient at any time, and the total concentration should not exceed 20 mg/L, except when due to natural conditions. The range of values of TSS in November was 0.4 – 29.6 mg/L, and 0.4 - 41.6 in January (Table 1). Thus, in November a single measurement of TSS exceeded the M-2 standard (Station 15S), while in January three samples were greater than 20 mg/L (Stations13S, 17S, and 17M).

While numerical criteria are not specified, the GWQS also provide ranges of acceptability for several other constituents. For all marine waters, pH shall remain in the range of 6.5-8.5 (§5013 C.2); dissolved oxygen shall not be decreased below 75% saturation (§5013 C.4); salinity shall not change by more than 10% ambient conditions (§5013 C.5); and temperature shall not change by more than 1°C from ambient conditions (§5013 C.9). None of the measures of these constituents from the data set exceed these conditions.

Based on these comparisons of the results of the present survey with GWQS, it can be concluded that on the days of sampling, concentrations of water chemistry constituents in Outer Apra Harbor were within compliance limits with the exception of several samples.

4.2 Impaired Waters

Under section 303(d) of the Clean Water Act (Title 33, Chapter 26, Subchapter 3) states, territories, and authorized tribes are required to develop lists of impaired waters. These are waters that are too polluted or otherwise degraded to meet the water quality standards set by states, territories, or authorized tribes. The law requires that these jurisdictions establish priority rankings for waters on the lists and develop TMDLs for these waters. A Total Maximum Daily Load, or TMDL, is a calculation of the maximum amount of a pollutant that a waterbody can receive and still safely meet water quality standards.

The most recent report for Guam is dated 2006 and is available online [http://iaspub.epa.gov/tmdl_waters10/enviro.control?p_list_id=GU-6&p_cycle=2006]. Fish advisories for Polychlorinated biphenyls (PCBs) were the only impairment listed for Apra Harbor and the priority assignment is low. No potential sources or TMDL was provided. The other potential impairment types listed that did not include Apra Harbor are pathogens, nutrients, organic enrichment/oxygen depletion, turbidity, pesticides, other causes, dioxins, metals (other than mercury), and toxic organics.

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5.0 SUMMARY

- A baseline set of water samples in the vicinity of eastern Outer Apra Harbor, Guam were collected in November 2007 and January 2008. Thirty stations were established in a grid within the area containing the proposed turning basin and entrance channel for the proposed CVN berthing. Stations were also established in Inner Apra Harbor. At each station samples were collected at the surface, mid-depth and near the bottom and analyzed for turbidity and TSS. In addition, during the November samplings, vertical profiles of temperature, salinity, dissolved oxygen, and pH were acquired at each of the thirty stations using a CTD.

- Results of analyses of turbidity and TSS reveal overall relatively low values throughout the area. Most values of turbidity were below 1 ntu, and most values of TSS were below 2 mg/l. Measures of turbidity and TSS indicated very little vertical or horizontal stratification within the region of study. Results indicated little effect on turbidity and TSS within the Outer Harbor from either the Inner Harbor or Sasa Bay. Stations that showed anomalously high values in November had low values in January, and vice versa of all water quality constituents within each transect. .

- Vertical profiles of temperature, salinity, dissolved oxygen and pH revealed influences of the Inner Harbor and Sasa Bay. A surface layer of low salinity, low temperature water was present in the Inner Harbor, but rapidly dispersed beyond the Inner Harbor entrance. A similar surface layer of low salinity, but not cooler water was present at the eastern end of the study area, revealing influence of westward flow from Sasa Bay. Overall, the effects from the freshwater sources were minor beyond the sources, and the uniform conditions characterized the study area.

- Overall, water quality in outer Apra Harbor, as characterized by the present baseline study was within the limits of compliance of the Guam Water Quality Standards. Several of the measured constituents exceeded specific criteria limits for marine water designated with the M-2 classification, which includes the area of Outer Apra Harbor in the vicinity of proposed CVN activities. It is likely that water quality will change as a result of changing seasonal conditions, particularly following episodic rainfall and runoff events.

- There was a fish advisory issued for PCBs in Apra Harbor.

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6.0 REFERENCES CITED

Guam Environmental Protection Agency. 2001. Guam Water Quality Standards. Harmon Plaza Complex Unit D-107. 130 Rojas St. Harmon, Guam 96911.

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Appendix E – Section C: Assessment of the Affected Marine Environment, Outer and Inner Harbor, Guam, By Marine Research Consultants, Primary Author: Stephen Dollar

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Habitat Equivalency Analysis & Supporting Studies: Section C

Assessment of the Affected Marine Environment

Outer and Inner Apra Harbor, Guam

September 2009

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LIST OF ACRONYMS AND ABBREVIATIONS

>	greater than
≤	less than or equal to
%	percent
CNMI	Commonwealth of the Northern Mariana Islands
CPCe	Coral Point Count with Excel Extensions
CVN	Carrier Vessels Nuclear
CSG	Carrier Strike Group
cy	cubic yards
EFH	Essential Fish Habitat
ENVI	Environment for Visualizing Images, Research Systems, Inc.
ft	feet
HAPC	Habitat Areas of Particular Concern
m	meters
m^2	square meters
m^3	meters cubed
MEF	Marine Expeditionary Force
MLLW	Mean Lower Low Water
MRC	Marine Research Consultants
Navy	Department of Navy
REA	Rapid Ecological Assessment
SCUBA	Self Containing Underwater Breathing Apparatus
SRF	Former Ship Repair Facility
TSS	total suspended solids
UOG	University of Guam
U.S.	United States

1.0 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). In addition, the Marine Corps relocation to Guam would increase the number of port days amphibious task forces would be in Apra Harbor. Waterfront improvements in Inner Apra Harbor are proposed to support the increased presence. The biological affected environments for the proposed actions are described herein based on existing data and field surveys.

The *Guam and CNMI Military Relocation Draft Environmental Impact Statement* (Navy 2009) presents the most current project description. The following are brief project descriptions:

CVN Project

The CVN project has 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 alternatives are both at 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 would require widening to 600 ft. The navigational depth requirement for a CVN is -49.5 ft (-15 m) 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 is required between the bend and the alternative wharf sites. A turning basin requiring additional dredging is required 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) MLLW 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 would likely be 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.

Inner Apra Harbor Improvements

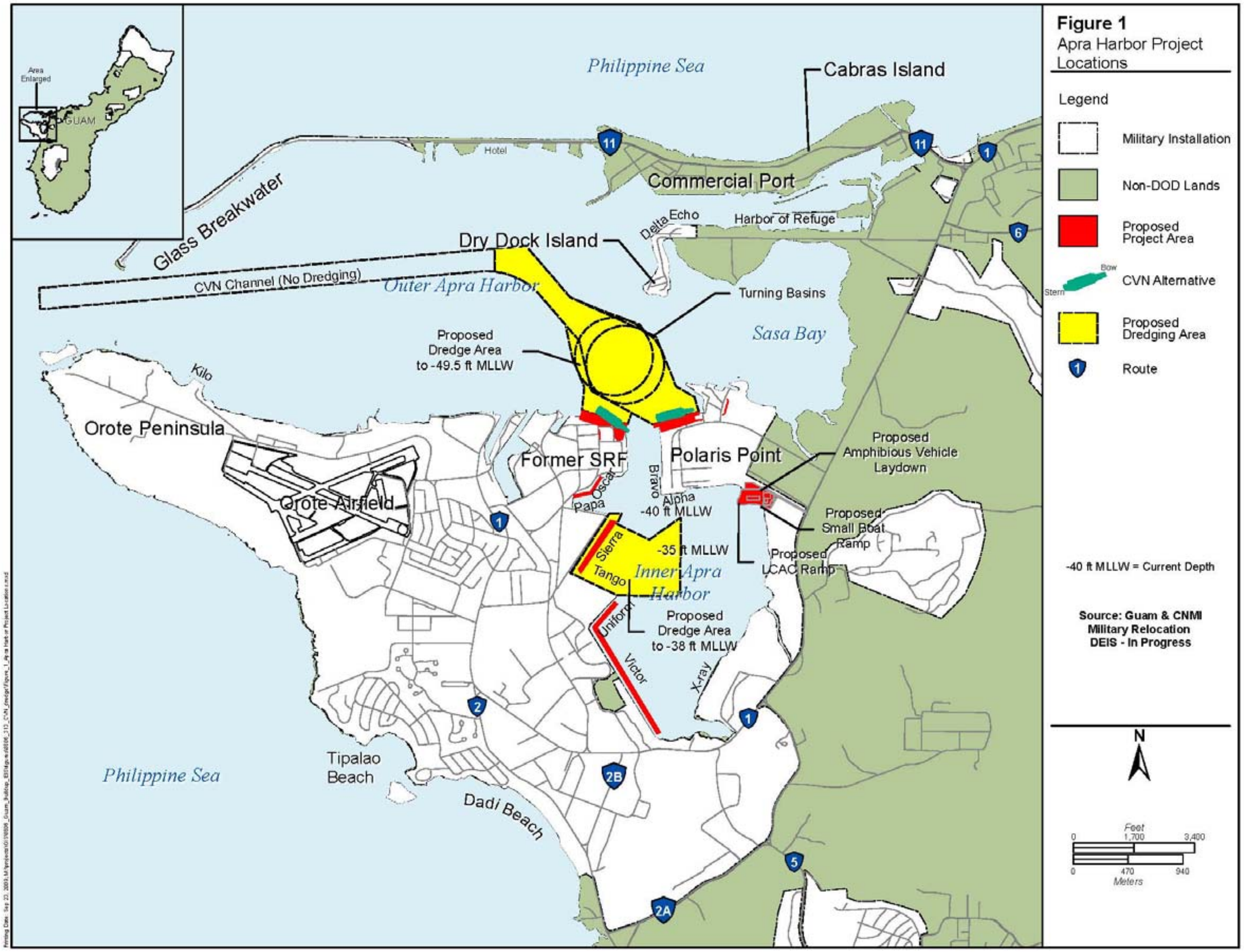
Figure 1 shows the Inner Apra Harbor improvements (Figure 1) locations of wharves and new construction. Victor, Uniform, Sierra, Oscar and Papa Wharves all require some level of structural repair and utility upgrades. Dredging from -35 ft (-10.7 m) to -38 ft (-11.5 m) MLLW is required for Sierra Wharf. New construction is proposed to support an amphibious vehicle parking area with two ramps into the water east of Bravo Wharf. A third ramp is being considered in the long-term master plan at the southernmost coast of Inner Apra Harbor.

Uniform Wharf has sustained the most earthquake damage of the Inner Apra Harbor Wharves and requires structural improvements. New sheet-pile would be installed in front of the existing sheet pile bulkhead and the voids would be filled with aggregate and cement. The concrete wharf deck would be resurfaced. Structural repairs at the other wharves are repairs of sprawling and cracked concrete surfaces.

Dredging is proposed only at Sierra Wharf. The entire Inner Apra Harbor underwent maintenance dredging within the past 5 years and construction dredging to -45 ft (-13.7 m) was completed in 2008 as part of Alpha/Bravo Wharf Improvements.

Implementation of an entrance channel, turning basin for the CVN, as well as the modifications to Sierra Wharf will require dredging of submerged lands in Outer and Inner Apra Harbor, respectively. In order to evaluate the impacts that these dredging activities will have on existing marine resources, this document will present a compilation of existing data sources that describe the affected areas. The combined information will represent the most complete assemblage of information presently available to specifically address the affected areas. Information generated from these sources will also provide necessary input into determining mitigation actions.

Figure 1: Apra Harbor Project Locations



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2.0 CVN ENVIRONMENTS - OUTER APRA HARBOR

2.1 ASSESSMENT OF BENTHIC COMMUNITY STRUCTURE IN THE VICINITY OF THE PROPOSED TURNING BASIN AND BERTHING AREA

2.1.1 Objectives

A key component of evaluating environmental impacts and subsequent mitigation is gaining an insight into the overall habitat composition of the affected area. To address this objective, a plan of study was developed by S.J. Dollar (University of Hawaii) and E.J. Hochberg (Nova Southeastern University) to conduct a field assessment to characterize the CVN impact area. Key elements of the study included benthic transect surveys throughout the areas defined as Direct (dredge footprint) and Indirect (potentially affected by dredge-induced sedimentation). In addition, benthic habitat maps were generated using commercially available remote sensing data calibrated with transect data, and a coral stress index was tested based on chlorophyll content of corals. The entire document, *Assessment of Benthic Community Structure in the Vicinity of the Proposed Turning Basin and Berthing Area for Carrier Vessels Nuclear (CVN), Apra Harbor, Guam* (Dollar and Hochberg 2009), is included in the *Guam and CNMI Military Relocation Draft Environmental Impact Statement*, Volume 9, Appendix J. Presented below is a summary of the report, including several summary tables and figures.

It is important to note that an initial field survey was conducted in November 2008 to develop a preliminary remote sensing map of benthic habitat structure. Owing to Navy restrictions, field data collection was restricted to the use of remote video recording. The results of the initial survey have been superseded by the *Assessment of Benthic Community Structure in the Vicinity of the Proposed Turning Basin and Berthing Area for Carrier Vessels Nuclear (CVN), Apra Harbor, Guam.* (Dollar and Hochberg 2009), and are not included in this document.

2.1.2 Summary (Dollar and Hochberg 2009)

One component of the *Guam and Commonwealth of Northern Marianas Islands Military Relocation Environmental Impact Statement/Overseas Environmental Impact Statement* is 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 (inclusive of 2 ft (0.6 m) overdredge). 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.

Methods were selected to maximize data collection with the shortest duration of fieldwork possible. Benthic community composition was evaluated using a photo-quadrant belt transect method (each belt transect encompassed 108 ft^2 (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 seven 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 from 86 sites in the field to spectral signatures of remote sensing imagery was used to create a map of coral cover over the entire survey area (Figure 2). The resultant analysis produced maps showing six classifications of coral cover:

Class 1: 0% coral

Class 2: > 0% - ≤ 10%

Class 3: >10% - ≤ 30%

Class 4: >30% - ≤ 50%

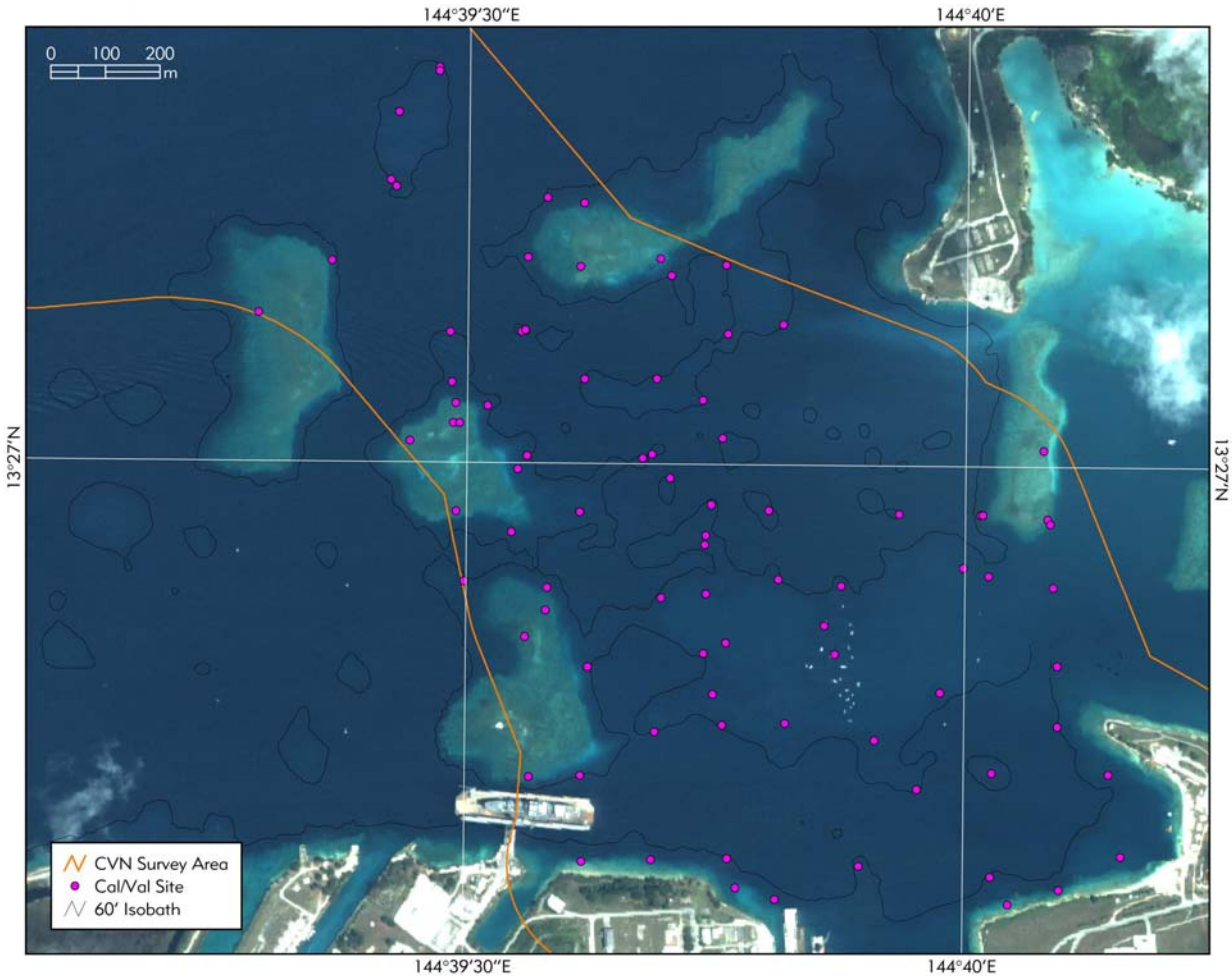
Class 5: >50% - ≤ 70%

Class 6: >70% - ≤ 90%

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).

Figure 2: Aerial Photograph of Eastern Outer Apra Harbor Showing Ground-Truth Data Points Used to Develop Classification Scheme for Coral Habitat Map



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.

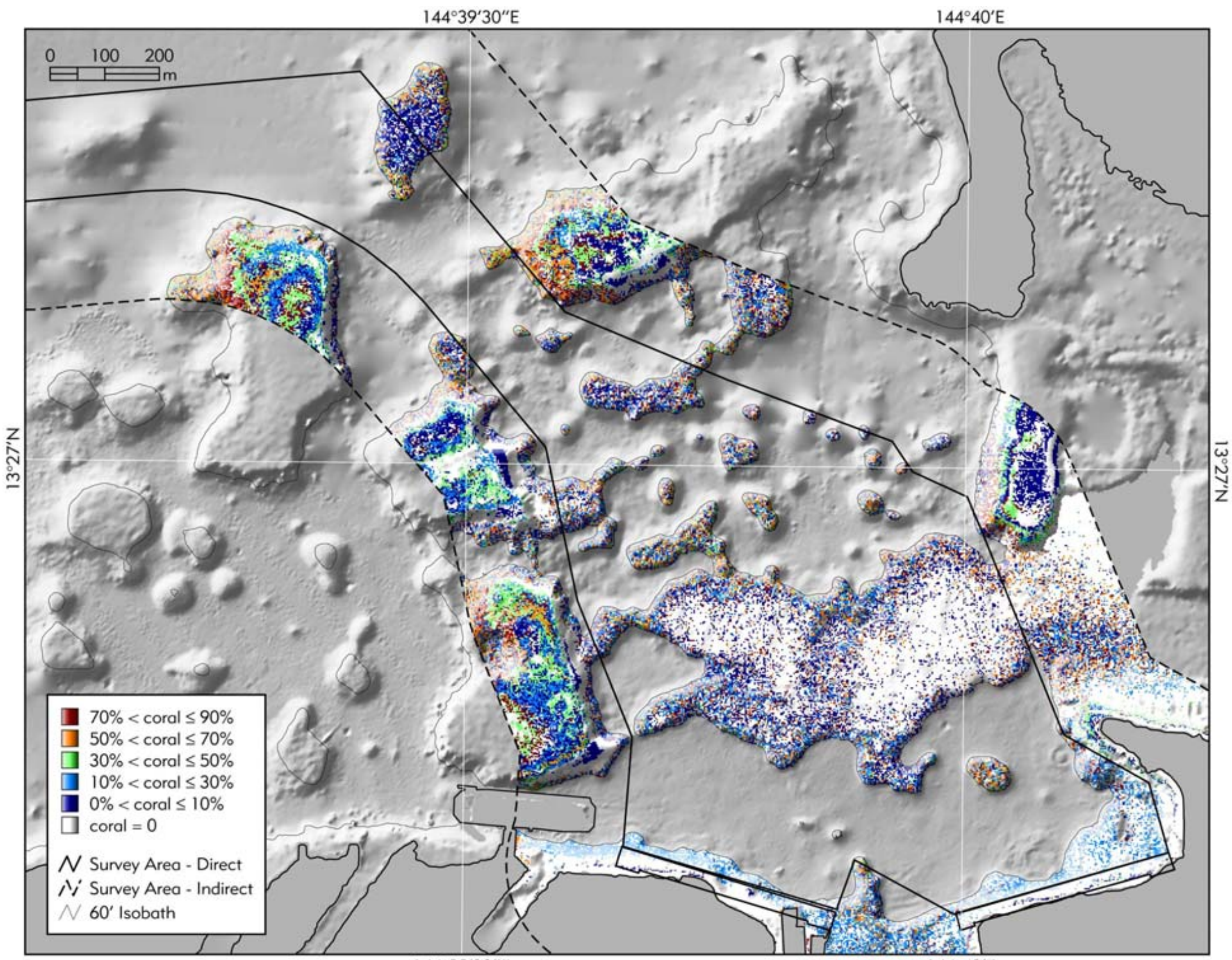
2.1.3 Results

2.1.3.1 Reef Zones - Physical Structure

The structural zonation pattern of the nearshore marine environment off the eastern shoreline in the vicinity of the CVN channel and turning basin is composed primarily of three major biotopes. These three areas are 1) large flat-topped 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 3). These reefs all consist of relatively flat, shallow upper surfaces that are covered primarily with muddy sand and rubble. 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 greatly reduced 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 northwest of Western Shoals and Big Blue Reef, do 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.

Figure 3: Coral Abundance Map of Combined Polaris Point and Former SRF Alternatives



The area demarcated as the project area and turning basin presently does not contain any of the shallow shoal patch reefs (Figures 2 and 3). 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 southern 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.

2.1.3.2 Coral Abundance Map

Figure 4 shows the benthic habitat maps produced by the supervised classification scheme described above for the combined Polaris Point and Former SRF alternatives. Spectral resolution of the image allowed for distinction of six bottom classifications according to coral cover as described above. Table 1 shows the area coverage of each coral class in both square meters (m^2) and acres. Percent of coral in each class is also presented. To overestimate the amount of coral affected, the coral assessment was to a depth of -60 ft (18 m) versus the actual dredge depth of -51.5 ft (15.7 m).

Table 1: Coral Cover in Six Levels for Direct and Indirect Strata at Former SRF and Polaris Point, CVN Alternatives, Apra Harbor Guam

Coral Level	*FORMER SRF*					
	Direct		*Indirect*		*Total*	
	m^2	*acres (% coral[1])*	*m^2*	*acres (% coral[1])*	*m^2*	*acres (% coral[1])*
Coral = 0%	**149,841**	**37.03**	**189,026**	**46.71**	**338,867**	**83.74**
0% < coral ≤ 10%	34,445	8.51(36)	53,436	13.20 (28)	87,880	21.72 (31)
10% < coral ≤ 30%	24,123	5.96 (25)	37,204	9.19 (20)	61,327	15.15 (21)
30% < coral ≤ 50%	9,274	2.29 (10)	34,502	8.53 (18)	43,776	10.82 (15)
50% < coral ≤ 70%	18,190	4.49 (19)	44,628	11.03 (23)	62,819	15.52 (22)
70% < coral ≤ 90%	10,051	2.48 (10)	21,266	5.25 (11)	31,317	7.74 (11)
Total with coral	**96,083**	**23.74**	**191,036**	**47.21**	**287,119**	**70.95**
Total dredge area	**245,924**	**60.77**	**380,062**	**93.92**	**625,986**	**154.69**
Percent coral cover:		**39%**		**50%**		**46%**

Coral Level	*POLARIS POINT*					
	Direct		*Indirect*		*Total*	
	m^2	*acres (% coral[1])*	*m^2*	*acres (% coral[1])*	*m^2*	*acres (% coral[1])*
Coral = 0%	**186,065**	**45.98**	**219,997**	**54.36**	**406,063**	**100.34**
0% < coral ≤ 10%	37,411	9.24 (37)	54,541	13.48 (29)	91,953	22.72 (32)
10% < coral ≤ 30%	26,058	6.44 (26)	38,523	9.52 (21)	64,581	15.96 (22)
30% < coral ≤ 50%	9,590	2.37 (9)	32,527	8.04 (17)	42,117	10.41 (15)
50% < coral ≤ 70%	17,960	4.44 (18)	41,898	10.35 (22)	59,858	14.79 (21)
70% < coral ≤ 90%	10,950	2.71 (11)	19,642	4.85 (11)	30,591	7.56 (11)
Total with coral	**101,969**	**25.20**	**187,131**	**46.24**	**289,100**	**71.44**
Total dredge area	**288,034**	**71.18**	**407,128**	**100.6**	**695,163**	**171.78**
Percent coral cover:		**35%**		**46%**		**42%**

[1] coral percent are rounded to nearest percent; therefore total coral % may not be exactly 100%.
Source: Derived from Classified Habitat Map Using Quickbird Satellite Imagery.

Examination of the coral map and coverage table reveals several important points. Total area of the region to be dredged (direct impact) is approximately 61 acres (245,924 m^2) and 71 acres (288,034 m^2) for Polaris Point and Former SRF alternatives, respectively. Total area of coral coverage of all classes is about 25 acres (101,969 m^2) for the Polaris Point alternative and 24 acres (96,083 m^2) for the former SRF alternative. Hence, about 35% and 39% of the area to be dredged presently contains some level of coral coverage for the Polaris Point and Former SRF alternatives, respectively.

It is also evident that the area within the project boundaries, as well as within the dredge area boundaries does not contain any of the continuous areas of very high cover (>70% coral) that is the dominant cover category on the western margins of the four large shoal reefs bordering the project area. While the mapping results indicate that about 11% of coral for both alternatives is in the highest cover class (>70%), such areas are not concentrated in any particular biotope or region, but are spread across the dredge zones in relatively low densities, mainly at the edges of the dredge perimeters.

In both alternatives, the single highest percentage class is the lowest abundance class (>0 to ≤10% cover) which comprises about 37% of area with coral for the Polaris Point alternative and 36% for the Former SRF alternative. In both alternatives, over half (61- 63%) of coral cover is within the less than 30% cover classes.

The indirect area is an area around the dredge area and was set at a distance of 656 ft (200) m from the dredge area perimeter. The indirect area is an area that may potentially be affected by the dredging impacts in the dredge (direct) area. The potential impacts would be related to dispersion of suspended solids outside of the dredge area. The indirect area is larger than the direct and the coral cover was about 46 acres and 47 acres for Polaris Point and Former SRF, respectively.

2.1.3.3 Accuracy Assessment

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 the 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).

Table 2 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 2). Hence, the map can provide a very accurate assessment of coral containing areas. Possible factors contributing to error were potential geo-referencing 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.

Table 2: Accuracy Assessment (Producer Accuracy) for Satellite-Derived Habitat Map of CVN Area

LEVEL		***0%***	***>0 ≤10%***	***>10% ≤30%***	***>30% ≤50%***	***>50% ≤70%***	***>70% ≤90%***
Predicted Class	0%	90.8	30.8	29.5	10.7	7.9	26.9
	>0%, ≤10%	4.8	46.7	26.0	8.7	6.3	6.5
	>10%, ≤30%	2.3	12.3	34.1	14.6	7.9	20.4
	>30%, ≤50%	0.5	0.4	2.9	40.8	8.4	0
	>50%, ≤70%	0.6	9.4	6.9	24.3	66.8	10.8
	>70%, ≤90%	0.9	0.4	0.6	1.0	2.6	35.5

Note: Values are classification rates (%).
Diagonal values represent correct classifications; off diagonal vales are misclassifications.

To evaluate map accuracy observations in a given class are assigned to each of the possible predicted classes (Table 2). 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 3). 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 3) 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%."

Table 3: Accuracy Assessment (User Accuracy) for Satellite-Derived Habitat Map of CVN Area

LEVEL		***0%***	***>0%, ≤10%***	***>10%, ≤30%***	***>30%, ≤50%***	***>50%, ≤70%***	***>70%, ≤90%***
Predicted Class	0%	89.0	5.0	3.0	0.6	0.9	1.5
	>0%, ≤10%	28.5	45.9	16.0	3.2	4.3	2.1
	>10%, ≤30%	21.5	18.8	32.6	8.3	8.3	10.5
	>30%, ≤50%	11.1	1.4	6.9	58.3	22.2	0
	>50%, ≤70%	4.8	12.4	5.7	11.9	60.5	4.8
	>70%, ≤90%	26.8	1.8	1.8	1.8	8.9	58.9

Note: Values are classification rates (%).
Diagonal values represent correct classifications; off diagonal vales are misclassifications.

The *user* rates allow for correction of area estimates. Using the same example as above, if the map predicts 1,076 (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 3.

Examination of Tables 2 and 3 indicate that accuracy is highest at the end-classes, and decreases toward the "middle" classes of coral cover. Hence, it can be interpreted that with the present level of data, the map provides a good representation of coral vs. non-coral cover, while determination of distinct classes of cover are not as accurate.

2.1.2.4 Summary

A benthic habitat map (limited to six classes of coral cover) of the eastern end of Outer Apra Harbor was produced in 2009 utilizing the multispectral properties of available satellite remote sensing imagery. Calibration-validation data to support the classification scheme were collected using field data in the form of photographic quadrat transects. The map provides an accurate large-scale classification of overall coral coverage within, and adjacent to, the projected dredge area to create an entrance channel and turning basin for aircraft carriers that will berth at either of two alternative sites near the entrance to Inner Apra Harbor. The extent and density of coral cover, is delineated to a degree that can be of value for potential mitigation of reef area altered by the aircraft carrier project.

2.2 ECOLOGICAL ASSESSMENT OF STONY CORALS AND ASSOCIATED ORGANISMS IN THE EASTERN PORTIONS OF APRA HARBOR, GUAM

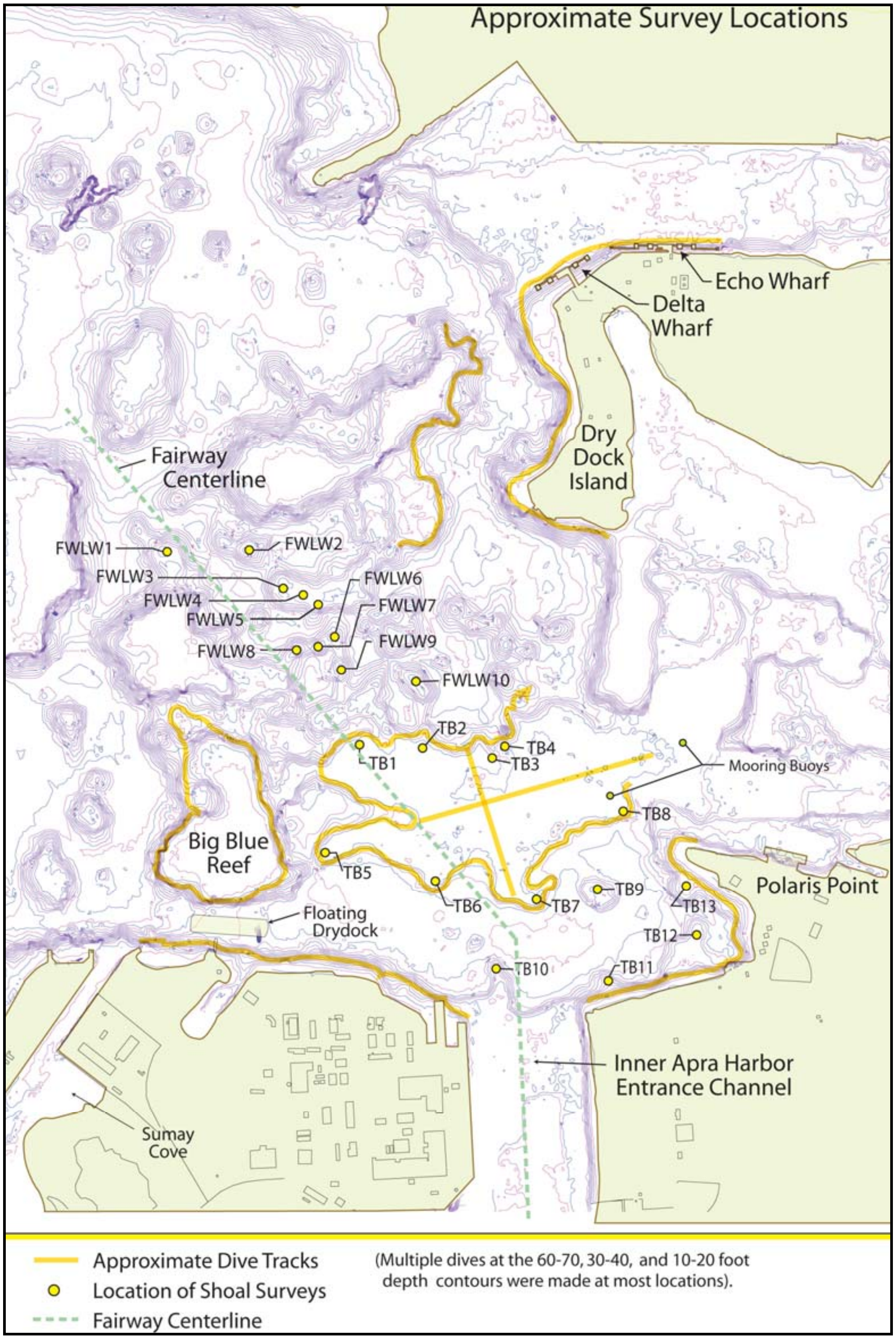
2.2.1 Objectives and Methods

In 2006 and 2007, Stephen H. Smith, Marine Ecologist, Naval Facilities Engineering Service Center, prepared a report dated August 2007 describing the marine environmental resources of the area within, and adjacent to the proposed dredging for the CVN project. The primary objective of the survey was to quantitatively assess the distribution and abundance of Scleractinian (stony) corals within seven selected portions of Apra Harbor. These seven areas were:

1. Mouth of Sumay Cove to Mouth of Inner Apra Harbor;
2. The Southeast component of the Western Shoals complex;
3. Polaris Point and Polaris Bay;
4. CVN turning basin between Inner Apra Harbor entrance, east side of Big Blue reef, and south of Dry Dock Island;
5. Fairway (navigation channel) shoals (Jade and Western);
6. Dry Dock Island; and
7. Delta/Echo Wharves on Dry Dock Island.

Figure 4 shows the locations of dive survey sites at these seven areas. Data collection included determination of presence of coral taxa, frequency of occurrence on transects (utilizing point-quarter methods), relative densities, size distribution, percentage of sea floor coverage, and condition. Qualitative and semi-quantitative data were also gathered on selected species of macroalgae and macrobenthic invertebrates, fin fish, and both threatened and endangered sea turtles. Consideration was also given to Essential Fish Habitat (EFH) and potential Habitat Areas of Particular Concern (HAPC). The scope of the project did not include compilation of an exhaustive species list of all organisms within the study areas. Surveys were accomplished during 152 person dives with the assistance of Naval Base Guam Dive Locker personnel. Also shown is the outline of the project area for the Polaris Point alternative for CVN berthing. Areas shallower than 51.5 ft (15.7 m) are outlined to define regions where dredging would be required.

Figure 4: Dive Tracks and Surveys (Smith 2007)



2.2.2 Results

Overall results indicated that corals and/or coral reefs were present in all locations investigated. Coral development varied dramatically between sites and at different depths, with some locations supporting well developed complex coral reefs and other areas supporting only small patch reefs or sparsely scattered corals.

Seventeen coral families were observed throughout the survey, with only one site (Big Blue Reef east) containing all families. At all other survey sites, the number of families ranged from 5 to 13. Point-Quarter transect data revealed that of the 1,908 quarters surveyed, 69% contained coral, with 49% of all corals measured consisting of the single species *Porites rus*.

Excluding the Sumay Cove to Inner Apra Harbor area where coral cover was less than 0.25% of bottom cover, percentage bottom cover with coral ranged from approximately 2% (Big Blue East) to 100% (Big Blue West). Coral cover at stations within the dredge footprint (turning basin, fairway (navigation channel), and Polaris Point) had coral cover ranging from about 7% to 21%. Total coral cover at Big Blue East sites adjacent to the dredge area was similar to cover within the dredge area (2-18%), while cover on the sides of Big Blue Reef opposite to the dredge area (Big Blue West) was substantially higher (70-100%). On the Big Blue West transects, coral cover was dominated by *Porites rus*, while on the fairway (navigation channel), turning basin, Polaris Point and Big Blue east transects, species distribution was more equitably distributed between *Porites rus* and a variety of other species of *Porites*.

Coral mean size (maximum measurement parallel to the sea floor) is relatively low (8.6 inches (in) [22 cm]) for turning basin sample locations, fairway (navigation channel) Shoals (Jade and Western) (8.3 in [21 cm]), and Polaris Point (6.3 in [16 cm]). (Note it is not apparent in the Smith report where all quantitative survey sites were located, nor how multiple transects at a site were combined to derive overall coral cover shown in histograms. In addition, no error bars are shown in histograms to depict variability within a site).

Qualitative observations of coral condition revealed no areas of extensive bleaching, or disease. Some colonies with hemispherical growth forms (e.g., *Porites lobata*) at survey sites within the dredge footprint (Polaris Point, navigation channel (fairway), and turning basin) were observed to be secreting copious amounts of mucus. As these areas are within the active ship transit lanes, the mucous secretion may be a sediment rejection response to increased sediment resuspension from ship activities.

With respect to existing anthropogenic impacts to reef structure, Smith reports some evidence of apparent anchor and/or anchor chain damage at all sites. Movement of mooring chains on the southern side of the floating dry dock have produced a significant rubble field, although mooring chains on the northern (outer) side of the floating dry dock do not appear to have caused similar damage.

Rigorous population estimates of fin fishes were not included in the scope of this project, although qualitative abundance levels of fish families was estimated. At the survey sites within the dredge footprint (turning basin, fairway (navigation channel), Polaris Point) total number of fish families ranged from 19 to 24. In comparison, the number of fish families at Big Blue West and Dry Dock Island was 41, and 33, respectively. At all locations, the number of fish sightings dropped dramatically when the substratum changed from live coral and rubble to sand.

The endangered hawksbill turtle (*Eretmochelys imbricata*) and the threatened green sea turtle (*Chelonia mydas*) are commonly observed within Apra Harbor. During survey dives for this project, no hawksbill turtles were observed. Nine green sea turtles were observed, five of which were on Big Blue reef. All turtles sighted were between 15 to 23 in (40-60 cm) in length, with no visible fibropapilloma tumors or other signs of injury. Although algal surveys were not conducted, the author suggests that preferred algal forage species were most abundant on Big Blue reef and the fairway (navigation channel), where most turtle sightings occurred.

Neither of the two fish species listed as Species of Concern that occur on Guam (*Cheilinus undulates* and *Bolbometopon muricatum*) were sighted during the survey.

Noteworthy points of discussion in the Smith report are that when reef survey zones were "ranked" according to a variety of variables that include coral cover, diversity, rugosity, coral “health”, and size-frequency distribution, the areas within the dredge footprint (turning basin, navigation channel (fairway) shoals and Polaris Point) ranked lowest on the scale, and were ranked consistently lower than the sites that are outside the footprint. The highest ranking was given to the Big Blue Reef West, likely owing to protection from exposure to water quality factors associated with Inner Apra Harbor and ship-induced effects.

The second highest ranking was granted to the reefs off Dry Dock Island. Smith makes the point that both Polaris Point and Dry Dock Island were artificially created during and shortly after WWII. While the two areas were created at essentially the same time, the coral communities are substantially different, suggesting different ranges of environmental stressors that affect coral community development at the two areas. One potential difference in environmental stressors is the higher range of turbidity and suspended sediment originating from Inner Apra Harbor and ship activities in the vicinity of Polaris Point relative to Dry Dock Island.

Smith states that most fishes found at study sites, even those not normally fished, were of small to medium size, regardless of taxa. Targeted invertebrates such as octopus, lobster and crab, were rarely seen during these surveys, and those that were observed were regarded as "small" in size. Smith's observations support the conclusions of Porter et al. (2005) that overfishing is a significant problem on Guam, and that fin fish and harvested invertebrate stocks are biologically depressed.

HAPC designation is based upon four independent criteria, any one of which may be used to justify designation. These four criteria are: 1) if the ecological function provided by the habitat is "significant"; 2) of the habitat is sensitive to human-induced environmental degradation; 3) if development activities are, or will be stressing the habitat type, and 4) if the habitat is rare.

According to Smith, the Polaris Point area, turning basin, Big Blue Reef east, fairway shoals (Jade and Western) and Delta/Echo Wharves do not meet any of these criteria for HAPC. However, the ecological function of Big Blue Reef west is important and sensitive to human induced environmental degradation, thereby meeting two of the four criteria for HAPC designation.

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3.0 INNER APRA HARBOR

3.1 UOG MARINE BIOLOGICAL SURVEY-INNER APRA HARBOR

3.1.1 Objectives and Methods

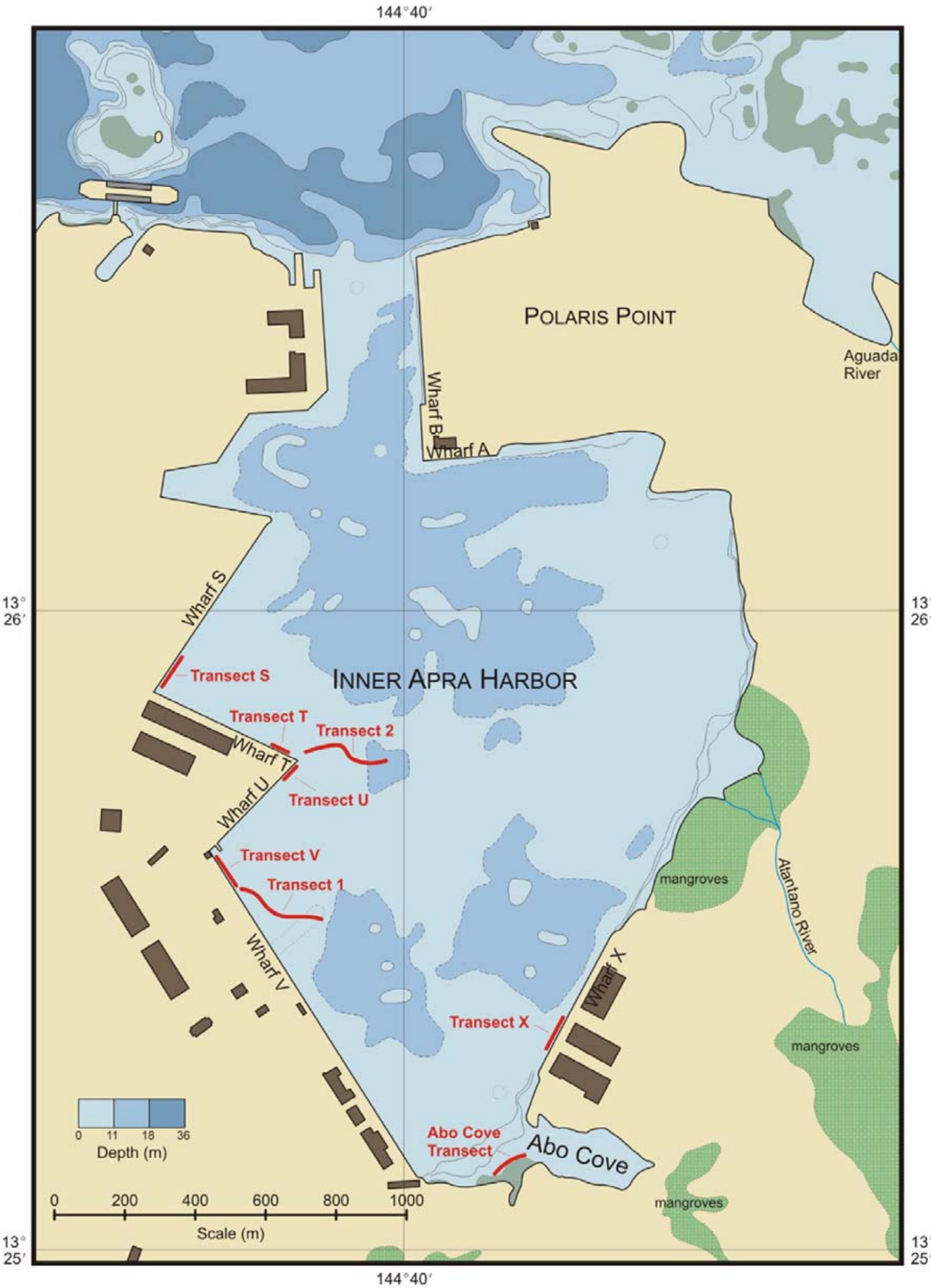
As part of the military build-up on Guam, renovations of existing waterfront facilities and construction of new facilities will be required within Inner Apra Harbor. To identify marine resources that might be affected by the relocation activities, the University of Guam (UOG) Marine Laboratory was contracted to carry out a survey of the marine communities in the southwestern half of Apra Harbor. Specific objectives of the survey included quantification of corals, macroinvertebrates and fish, and evaluation of parameters defining EFH and HAPC.

To date, field surveys for the project are complete, and a draft review report has been submitted. The discussion of the UOG work is taken from the draft report. Methods utilized included Manta tow surveys to assess the overall ecological setting of the region of study. Based on Manta tow observations, three specific areas were selected for quantitative surveys. These included Abo Cove, which was the only area where benthic surveys were conducted on horizontal reef surfaces, and Wharves S, T, U, V and X[1] where surveys of the vertical wharf structures were conducted (Figure 5). Coral community structure was estimated from transects using the Point-Quarter method, while macroinvertebrates and fish were enumerated by divers swimming over defined corridors bounding transect lines.

Also shown in Figure 5 is the outline of the project area for the Former SRF alternative for CVN berthing. Areas shallower than 51.5 ft (15.7 m) are also oulined to define regions where dredging will be required. Note: Coral cover within the dredge area is shown. Other coral within the project area is not shown.

[1] Refers to wharves Sierra (S), Tango (T), Uniform (U), and X-Ray (X).

Figure 5: UOG Transects



3.1.2 Results

In total, 70 benthic taxa were observed in the study, which the authors deemed low compared to benthic surveys in other parts of Apra Harbor. Benthic assemblages on the wharves were substantially different than in Abo Cove, attributed primarily to lower deposition of sediment on the vertical wharves compared to the horizontal substratum in Abo. Sponges contributed most of the biotic diversity to the Wharf faces.

The floor of Inner Apra Harbor consists almost entirely of fine-grained sediments (mud) which is unsuitable for coral settlement. Although corals were absent from the sediment surface, small colonies were observed on metal debris and old pilings elevated above the Harbor floor. No corals were observed on debris at a distance of more than 66 ft (20 m) from the Wharves. Hence, virtually all of the corals encountered at the Wharf sites occurred on vertical surfaces. An estimated total of 28 species of corals and related organisms (non-scleractinian anthozoans) were recorded on surveys. Species richness was highest at X-Ray Wharf (8 species), while a minimum of four species occurred at Abo Cove, Tango, Uniform and Victor Wharves. *Porites lutea* and *Pocillopora damicornis* were the most common species, occurring on 5 of the 6 transects. Species of *Porites* dominated coral coverage, accounting for 83% of total coral cover.

Density 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 predominating. Of the bivalves, two species of oyster (*Malleus decurtatus* and *Spondylus spp*.) and one clam (*Chama spp*.) were abundant. The greatest total density of macroinvertebrates was observed at Victor Wharf (143 individuals/10 m^2), while the lowest density was at Abo Cove (4.4 individuals/10 m^2). As with corals, the only macroinvertebrates observed on Apra Harbor floor were associated with the hard surfaces of debris, no macroinvertebrates were observed on the sediment surface.

Sixty-two species of fish were observed on transects within the Inner Apra Harbor, indicating an impoverished fish fauna. While most of the fish fauna are representative species from protected, turbid lagoons and bays, three species appeared to be new records or invasive to Guam and the Mariana Islands. It is speculated that these new species have not been noted previously in the turbid Inner Apra Harbor.

Overall, wharves provided considerable habitat for a diverse array of fishes compared to the reef at Abo Cove or the Harbor floor offshore of the wharves. Most species of fish were associated with one or more microhabitats provided by wharves which included coral, debris, shells, and soft corals that were attached to the wharves, as well as the structural components of the wharves (pilings, fenders, pipes, cables, etc.). No specific recommendations regarding EFH or HAPC were included in the report.

3.2 INNER APRA HARBOR MAINTENANCE DREDGING: RAPID ECOLOGICAL MARINE ASSESSMENT

3.2.1 Objectives and Methods

In April 2002, Marine Research Consultants was contracted to carry out a baseline survey to characterize physical conditions and biotic composition of the marine environment in Inner Apra Harbor in order to evaluate the potential for impacts from proposed maintenance dredging, as well as disposal of dredged material on land. Maintenance dredging is necessary to return the Harbor depth to a level that allows safe passage and docking of Naval vessels.

An overriding factor when considering effects of the proposed maintenance dredging was that the affected areas have been heavily affected by human activity with essentially no undisturbed natural habitat remaining in the study area. Docking ships results in substantial resuspension of sediment generated by ships transiting from the Outer to Inner Harbors, and the propeller wash of tugboats used to move ships on or off the wharves. Such resuspension is a good proxy of the activities that may accompany the maintenance dredging.

Field surveys employed a method referred to in the scientific literature as a Rapid Ecological Assessment (REA). This method consists of swimming through the entire area of concern, noting major components of physical structure of the habitat, as well as major biotic components. The REA method allows for comparative evaluations between areas, and is very efficient with respect to habitat characterization and time spent in the field.

3.2.2 Results

Results of the REA showed that the water column throughout most of Inner Apra Harbor is a distinct two-layer system, with a relatively clear upper layer (upper 15 to 20 ft [4.5 to 6 m]) and a very turbid lower layer where visibility is essentially zero near the sediment-water interface. The turbid lower layer is a result of resuspension, accompanied by very low settling rates, of fine-grained mud that comprises the floor of the Harbor basin. The stratified water column is reflected in a distinct vertical zonation of biotic composition along much of the sheet piling that comprises the wharves. The lone exception to the pattern of stratification occurred in the entrance channel leading into Inner Apra Harbor where there was no turbid bottom layer, and bottom composition consisted of sand and rubble rather than mud. Dives conducted in Apra Harbor in 1992 by the same authors revealed the same two-layer system. Hence, it appears this is the permanent state of the water column and is not a temporary phenomenon created by ship activity, or transient weather patterns.

Bottom composition throughout the basin of Inner Apra Harbor consists primarily of a gelatinous, fine-grained mud that is easily resuspended into the water column with the slightest movement. In some areas adjacent to the wharves, there is a narrow zone of hard bottom that is generally covered with coarse sand and rubble. This narrow rubble zone generally slopes sharply to the mud basin within several yards of the wharves. While observation of the mud surface was limited owing to very poor visibility, evidence of biotic habitation included numerous holes caused by burrowing infaunal organisms.

The major exception to the pattern described above for the Harbor floor occurs at Inner Apra Harbor channel entrance between Bravo Wharf to the east and Lima Wharf to the west. The area where the sheet piling of the wharf intersects the channel floor consists of a steep slope covered with limestone rubble fragments. At the terminus of the rubble slope the channel floor consists of areas of rock interspersed with fine sand.

A conspicuous difference between this area and the rest of Inner Apra Harbor is the relative clarity of the water column. The typical two-layer water column, which occurs throughout the rest of the Inner Harbor, is not present in the outer channel. While turbidity in the entrance channel is high relative to other areas of Outer Apra Harbor, the water column is clear compared to the rest of the Inner Harbor. In response to the relatively low turbidity of the water column and the hard substratum, the channel floor near the entrance to the Inner Harbor is colonized by a variety of branching, plating, and lobate reef building corals. These corals were growing on the limestone floor of the channel, although much of the solid substratum was covered with a lay of fine-grained sediment. Many of these corals showed some evidence of sediment damage to parts of the colonies.

Assemblages of living coral rapidly decrease in the entrance channel moving in a southerly direction until the bottom consists primarily of sand and barren rock at the approximate midpoint of Bravo Wharf (Wharf B in Figure 5). Substantial debris has accumulated on the bottom in this area, including old tires, concrete pipes, metal frames, and a variety of cables and chains. Biotic composition of the area is restricted to occasional small corals that are largely covered with a layer of sediment.

The two largest areas within the Inner Apra Harbor dredge area with water depths less than 35ft (10.67 m) occurred in the angled "corners" formed by Wharves Oscar, Papa, Quebec and Romeo as well as Sierra and Tango (Figure 6). Wharf Uniform also forms a corner with Wharf Victor, in which docking facilities for small work boats is located. The physical and biotic composition along all of these wharves was similar. The sheet piling along these wharves was relatively barren except for some encrusting sponges and occasional small colonies of the coral *Pocillopora damicornis*. Most of these colonies contained necrotic tissue and were coated with a layer of sediment. Coral and sponges occurred predominantly on the shallower upper half of the pilings, while the lower halves were devoid of macrobiota. Several colonies of *Pocillopora damicornis* were observed on the Harbor floor, apparently as a result of physical breakage from the sheet piling.

Adjacent to the sheet piling, bottom composition consisted of rubble comprised of coral and shell fragments, and sandy mud. The most conspicuous characteristic of the area was the massive accumulation of debris on the Harbor floor adjacent to the Wharves. Debris consisted of pipes, old bumpers and pilings, cables, ropes, bottles, cans, tires, concrete and wood chunks, and even china cups and plates. The densest accumulation of debris was in the corner of Sierra and Tango wharves where the Harbor floor was virtually covered with dumped materials. There was essentially no biotic colonization of the debris field. One curious observation was of a white, flaky material that had aggregated on some of the protruding portions of the pilings. This material did not appear to be of biotic origin, and was easily resuspended in the water column with slight agitation of the surrounding water.

Biotic stratification of the pilings on Victor and X-Ray Wharves corresponded strongly to the stratification of the water column, with essentially very little or no colonization of the wharves within the deeper turbid layer. Such a paucity of colonizing organisms in the lower zone is not surprising owing to the extreme permanent sediment load of the water column.

Biotic composition of the upper pilings, however, was surprisingly different. A relatively large percentage of the pilings were colonized by apparently reef corals in good condition. The great majority of these corals consisted of three species: large heads of the delicately branched *Pocillopora damicornis,* plating and columnar *Porites rus,* and encrusting layers of *Porites lutea.*

Distribution of coral cover varied somewhat between the two Wharves. On X-Ray Wharf, coral cover was similar throughout the length of the wharf, and was comprised of all three species mentioned above in roughly equal distribution. Coral cover averaged about 50-70 percent of wharf surface area in the shallow upper zone. On Victor Wharf, there was a clearly defined horizontal gradient of coral cover. At the northernmost end of the wharf (near the junction with Uniform) coral cover was very low, comprised only of small colonies of *Pocillopora damicornis*. The Harbor floor in this area is composed of a sand/rubble bottom that is littered with abundant junk consisting of tires, cables, pilings, chains, and assorted metal. Within approximately 150 ft (46 m) of the junction, coral cover began increasing with all three species present. At the approximate midpoint of Victor wharf to the southern end, coral cover changed almost solely *to Porites lutea*, which covered nearly the entire submerged upper section of the sheet piles with a thick (3-6 inch [8-15 cm]) veneer. Evenly spaced along the wharf in this area were regular cuts approximately 2 ft (0.6 m) square that removed all coral and exposed the metal of the wharf. These cuts were man-made as they were regularly spaced at the same depth. They also were very recent as the cut edges of the coral colonies were still white and not covered with algal films. Typically algal films or mats cover newly exposed surfaces within several days.

Most of the corals growing on X-Ray and Victor Wharves appear in good condition and thriving with little physical breakage or apparent smothering from sediment. As described above, off Tango and Sierra wharves, scattered heads of *Pocillopora damicornis* colonies were broken from the sheet piling and lying on the sand/rubble bottom. In contrast, off Victor and X-Ray Wharves, there was far more abundant coral colonizing the sheet piling, but none were observed broken and lying on the Harbor floor. Contrary to other areas of the Inner Harbor, where fish were rare, there were numerous small reef fish (particularly of the genera Chromis and Dascyllus) within the interstitial spaces created by the coral colonies.

3.3 MARINE RESOURCE ASSESSMENT IN THE ENTRANCE CHANNEL OF INNER APRA HARBOR

3.3.2 Objectives and Methods

In 2005, Marine Research Consultants (MRC) was contracted to perform an assessment of the marine environment in the area of the entrance channel between Inner and Outer Apra Harbor as part of the planning documentation for Improvements at Alpha and Bravo Wharves (Military Construction Project P-431). Specific concerns regarded dredging of the entrance channel to accommodate the approach and turning basis for a new class of vessel to be berthed at Bravo Wharf.

In 2002, dense stands of growing reef coral were noted in the center of the entrance channel (Marine Research Consultants 2002, Smith 2004). As a result of these observations, it was deemed necessary to conduct a detailed investigation of the entrance channel and surrounding area to quantify the extent of coral cover, as well as develop a detailed description of the coral community structure. The initial period of fieldwork was conducted in August 2004 following initiation, but prior to completion of maintenance dredging of Inner Apra Harbor entrance channel (maintenance dredging provided for a channel depth of -35 ft (-10.7 m) below MLLW). Subsequently, maintenance dredging of the entrance channel was completed in December 2004. In order to determine the condition of the coral community following completion of maintenance dredging, a second field survey was conducted in December 2004. The 2005 report presented the results of the both increments of fieldwork.

The primary method of assessment was creation of a benthic habitat map using a supervised classification of coral abundance based on sea-truthing a georeferenced Quickbird multispectral+panchromatic satellite image of Apra Harbor. Using sea-truth data, the Quickbird image was processed using ENVI software to highlight submerged features, which revealed areas of different bottom composition, including areas of varying degrees of coral cover.

3.3.3 Results

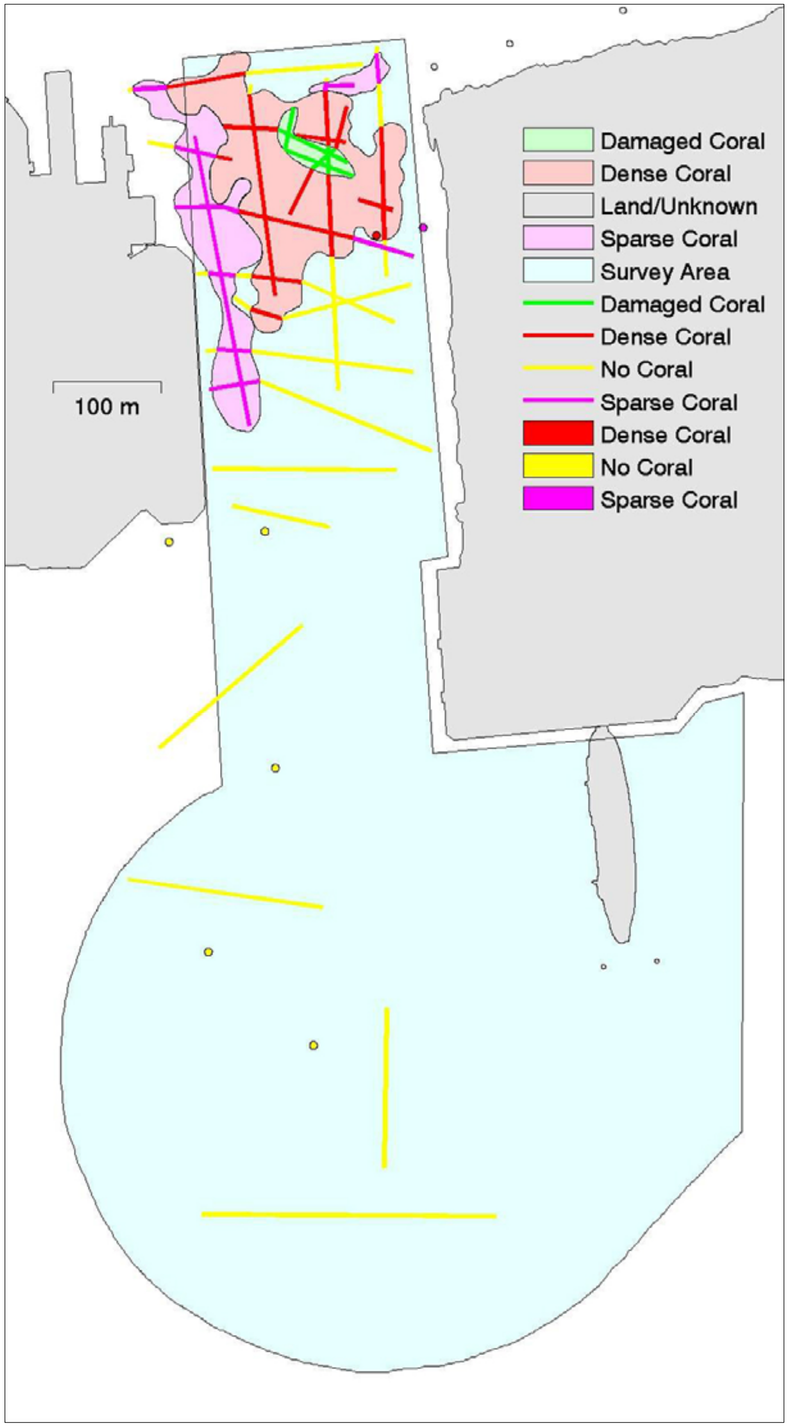
From the outer boundary of the entrance channel (and the northern boundary of the Alpha –Bravo Wharf dredging area) to approximately two thirds of the length of the entrance channel, bottom composition was markedly different than the rest of the inner harbor. Bottom structure in this area consists of a fossil carbonate reef platform that was not completely covered by the deep layer of fine sediment that covers the rest of the Inner Harbor.

Well-developed communities of stony reef-building corals were identified on the carbonate platform within the entrance channel. Coral communities were grouped into two abundance classes—sparse coral with approximate bottom cover less than 25%, and dense coral with bottom cover greater than 25% (Figure 7). The area of dense coral cover extended from the mouth of the entrance channel approximately 656 ft (200 m) south to the approximate center of the channel. An area of sparse coral extended approximately 1,150 ft (350 m) along the western side of the channel adjacent to Lima Wharf (Figure 7).Along the eastern side of the entrance channel, there was no corresponding region of sparse coral, although occasional scattered corals were observed on the bed of sediment lining the Harbor floor. A small area of sediment-covered boulders at the southeastern corner of the entrance channel near the intersection of Alpha and Bravo Wharves was also classified as sparse coral (Figure 7). In addition, the entire sheet piling of Bravo Wharf was covered with a flat encrustation of living corals.

Remote sensing using satellite imagery allowed mapping and quantification of the area coverage of the coral communities. Integrating the mapped area of coral cover revealed a total area of 3.319 acres (13,431 m^2) of sparse coral and 6.832 acres (27,648 m^2) of dense coral, for a total area of approximately 10.151 acres (41,080 m^2) of coral cover in the entrance channel.

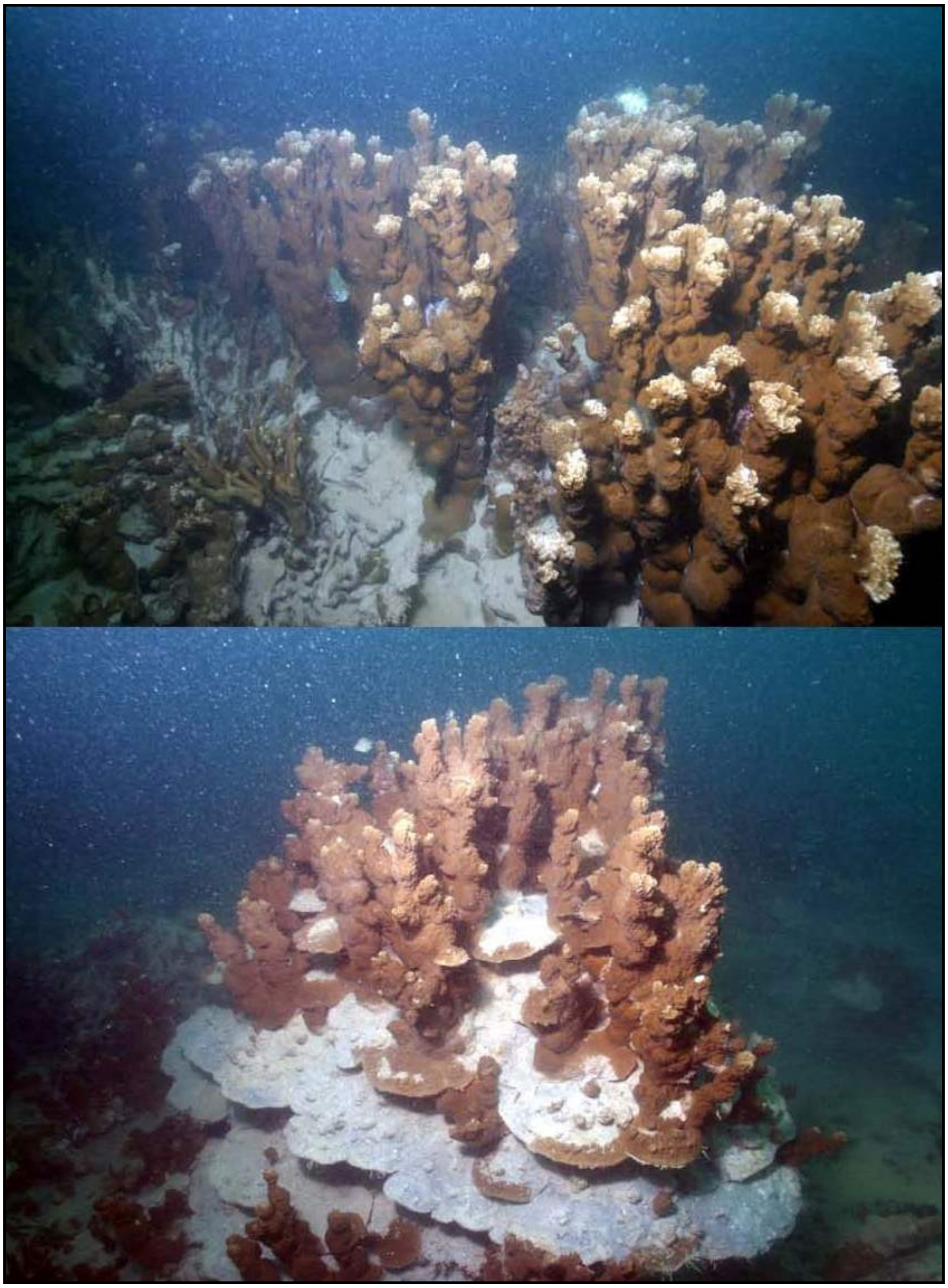
The coral community in the entrance channel to Inner Apra Harbor is comprised of four major species. The most abundant species was *Porites (Synaraea) rus*. This coral species is ubiquitous throughout Apra Harbor, and occurs in a variety of growth forms, particularly overlapping plates and columnular spires. *Porites rus* occurred in the regions of sparse coral as isolated colonies. In the regions of dense coral, *Porites rus* formed massive interconnected structures with both plating, and columnar growth forms (Figures 7 and 8). The abundance of *Porites rus* in the entrance channel indicates that this species is particularly well adapted to thrive in areas of low light and continuous suspended sediment deposition compared to conditions in the Outer Harbor (as these conditions were observed during all episodes of field work). As can be seen in Figures 8 and 9, many of the colonies observed in the entrance channel had layers of silt deposited on the upper surfaces.

Figure 6: Inner Apra Harbor Entrance Channel Transects and Coral Coverage



Note: Figure shows survey area (light blue); underwater transects (straight lines), and bottom composition (see legend). Red indicates zone of "dense" coral cover (>25% of bottom cover); purple indicates "sparse" coral cover (<25% bottom cover); yellow indicates no coral cover; green indicates zone of extensive physical damage to coral community and channel floor.

Figure 7: Photographs of *Porites rus* in the Entrance Channel of Inner Apra Harbor

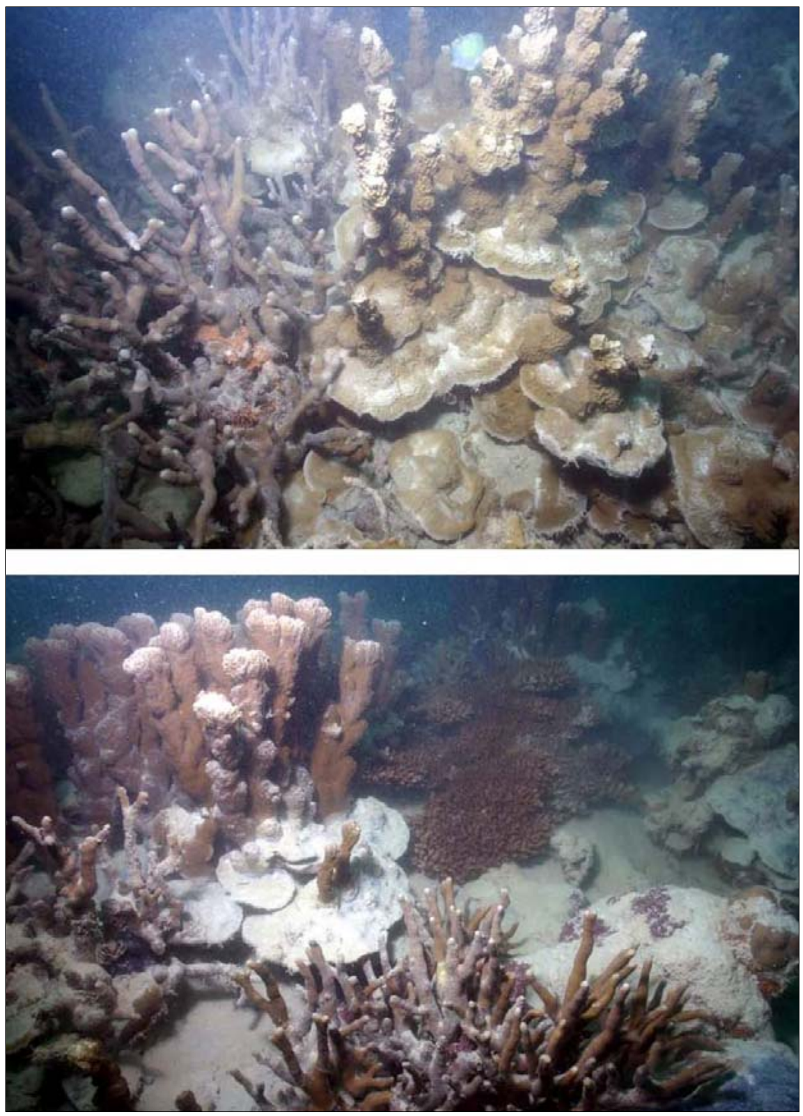


Note: *Porites rus* is the overall most abundant coral found in the entrance channel. Note areas of sediment accumulation on flat plating portions of the colonies. Fine-grained white sediment that comprises the harbor floor is easily resuspended by water motion and settles on coral colonies (Source: MRC 2005).

The other dominant coral in the entrance channel was the branching species *Porites (Porites) cylindrica*. This species occurs as mats of interconnected branches that extend uninterrupted for up to several square meters in some areas of the entrance channel floor (Figure 6). Third in abundance is the finely branched coral *Pocillopora damicornis,* which forms low tabulate colonies plates near the sediment surface (Figure 8).

The staghorn coral *Acorpora* sp. (tentatively identified as *Acorpora. virgata*) was also observed in the entrance channel. While not as abundant as either species of *Porites*, numerous colonies of *Acropora* spp. occurred primarily in the map region identified as sparse coral along the western side of the entrance channel adjacent to Lima Wharf. While there were relatively few species observed within the entrance channel, the species that did occur formed a relatively evenly distributed community, often coexisting in close proximity to each other (Figure 8).

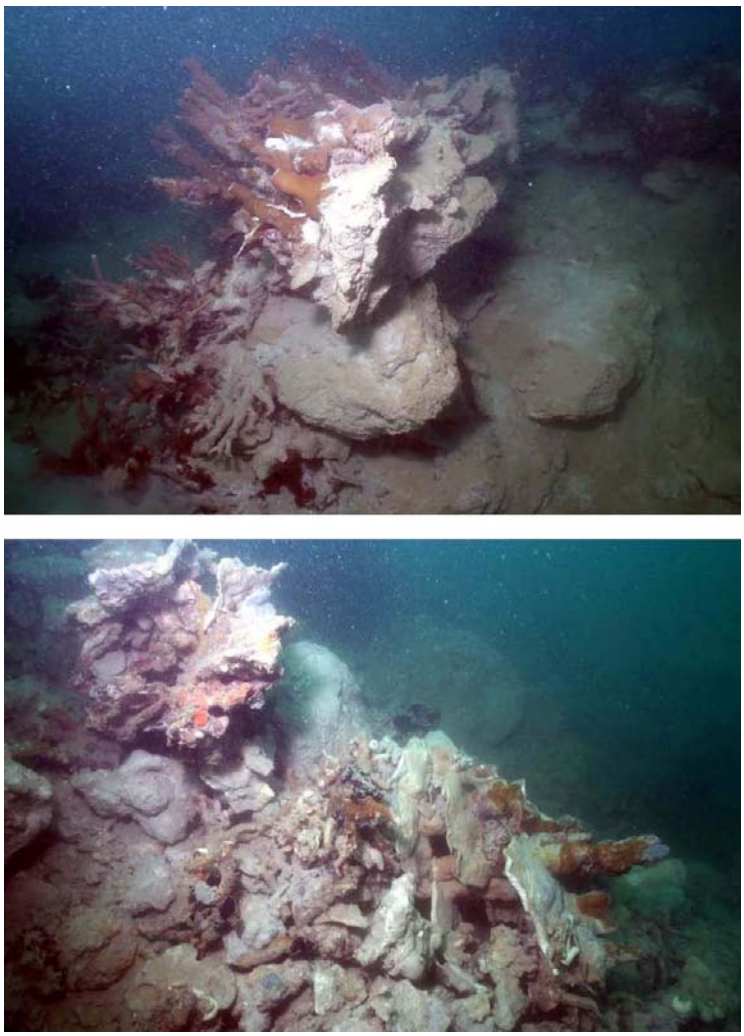
Figure 8: Two Underwater Views of Characteristic Regions of "Dense Coral Cover" in Inner Apra Harbor Entrance Channel



The three dominant coral species that occur throughout the entrance channel (*Porites rus, Porites cylindrica* and *Pocillopora damicornis*) are shown growing in close proximity to each other (Source: MRC 2005).

An important observation within the area of dense coral was the occurrence of a clearly defined area of physical damage to the reef. The impact is likely a result of recent maintenance dredging, and is depicted on Figure 3 as "dredge" area. Physical impact included breakage and overturning of large sections of dense coral (Figure 8). In several areas, vertical cuts extended approximately 3.2 ft (1 m) into the reef limestone platform (Figure 9). While much of the coral in this region was broken from the reef, many of the colonies retained living portions of tissue that will likely continue to grow if left in the current state, and if water velocity is not sufficient to cause movement of the dislodged colonies. Hence, while the area is now structurally different than surrounding unimpacted areas, there is still an abundance of living coral.

Figure 9: Damage to Coral Community in Entrance Channel to Inner Apra Harbor



A nearly vertical cut through the reef is visible in lower photograph (Figure 9). Note that while broken and overturned, much of the living tissue on the colony of *Porites rus* in the upper photo remains alive (Source: MRC 2005).

Integrating the area of each class of coral cover resulted in about 3.39 acres (13,700 m²) of sparse coral and 3.72 acres (15,000 m²) of dense coral (excluding the dredged area) for a total area of approximately 7.11 acres (28,700 m²) of undisturbed coral cover within the entrance channel. During the August 2004 survey the area of dredged coral encompassed approximately 0.37 acres (1,500 m²), and was entirely within the area of dense coral. During the December 2004 survey, the area of dredged coral comprised about 1.58 acres (6,400 m^2). Hence, there was an increase in the area of dredged coral of about 1.21acres (4,900 m^2) between the two surveys.

The only other common invertebrates noted during the course of the survey were a variety of sponges growing between the branches of coral colonies. Motile macroinvetebrats were essentially absent. Observed fish communities were limited to several species of Pomacentrids (damselfish) and Chaetodonts (butterflyfish).

The occurrence of the coral community in the entrance channel was considered somewhat surprising based on the typical physical conditions that prevail in this area. Corals are generally considered to be highly susceptible to damage from sedimentation and usually occur in marine habitats with relatively low turbidity, low sediment deposition, and high incident light levels. The habitat in the entrance channel to Inner Apra Harbor does not exhibit any of these conditions. Rather, physical conditions in the entrance channel are characterized by consistently high turbidity and low light relative to most oceanic settings where corals proliferate (including Outer Apra Harbor). High turbidity appears to be at least in part a result of constant resuspension of the fine grained sediments each time a ship traverses the channel. While physical conditions are undoubtedly harsh in terms of "normal" coral habitats, they are obviously within the physiological tolerance limits of the several species that make up the reef community in the entrance channel to Inner Apra Harbor.

It is important to note that the surveys described above found corals only in the northernmost region of the entrance channel and not of the floor of either the southern portion of Inner Apra Harbor entrance channel or main basin of the Inner Apra Haarbor. Extensive coral cover, however, was documented on the sheet piling within Inner Apra Harbor (Marine Research Consultants 2002). These results suggest that the limiting factor to coral growth in Inner Apra Harbor is a combination of occurrence of hard substratum, and shallow enough depth to avoid the very turbid bottom layer. Both the sheet piling and the limestone platform in the entrance channel provided suitable surfaces for coral settlement and growth. The soft sediment of the Harbor floor, however, did not provide a suitable surface, and remains barren of coral cover.

Inner Apra Harbor channel was constructed following WWII, and was last dredged in 1978. If previous dredging did not affect coral community structure, the maximum age of the observed coral assemblages would be approximately 60 years. If the 1978 dredging created a newly scoured substratum, the minimum age of the observed coral community is approximately 28 years. Such a range of time (approximately 28-60 yrs) is about the same as has been calculated for growth of various climax coral communities in Hawaii (Grigg and Maragos 1974, Dollar 1982). It is likely that if the observed coral colonies in the entrance channel are completely removed by future dredging, regeneration of new communities would reach the present level of succession with 30-60 years.

P-431 dredging,, there was no reason to believe that over the long term (i.e., decades) the area would be recolonized by the same species, in similar community assemblages, as occur at present. The dominant species of corals that occur in the entrance channel are found in abundance throughout Outer Apra Harbor, and the most abundant even line the sheet-piling of Inner Apra Harbor. As a result, the corals were not considered a rare or unique resource.

The investigation of coral communities in the entrance channel of Inner Apra Harbor provided a unique opportunity to add to the understanding of the physical conditions that define the limits of toleration of coral communities with little or no apparent negative effect. Such an understanding should prove valuable for future decisions regarding the most effective and efficient mitigation measures to balance the preservation of coral reef resources with necessary maintenance work in the marine environment.

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4.0 SUMMARY

The purpose of this document is to compile pertinent existing information and data relevant to two proposed actions: 1) creating an environment capable of safe entrance, turning and berthing capabilities for Aircraft Carriers in the eastern portion of Outer Apra Harbor, and 2) improving waterfront facilities along the western side and southern end of Inner Apra Harbor to support Marine Corps training operations.

With respect to CVN requirements, dredging would be required in the turning basin and the channel that leads to the turning basin from Outer Apra Harbor. All available data indicates that most of the affected marine environments in these areas have experienced extensive dredging associated with the creation of Inner Apra Harbor and entrance channel in approximately 1946. Hence, much of the coral community structure within the proposed CVN dredge area can be considered to be no older than approximately 60 years. A large percentage of the dredge area is a large contiguous area that may have previously been a shallow patch reef (similar to surrounding reefs) that was dredged to a depth of approximately 50 ft (15.2 m) in 1946 to allow direct access to the Inner Apra Harbor. With the exception of areas adjacent to the shoreline where the CVN Berths would be placed, the remainder of the dredge area consists of relatively small pinnacles and patch reefs north of the main dredge area. Several large patch reefs with nearly total coral coverage on the western slopes, and high ecological functional value border the proposed CVN dredge area.

Dive surveys indicate that overall coral community composition within the dredge area are of marginal to modest ecological value, based upon the eight criteria (i.e., percentage of sea floor covered by coral, reef complexity and rugosity, species diversity, coral condition, size frequency distribution of coral colonies, diversity and abundance of sessile macro-benthos other than corals (e.g., sponges), diversity and abundance of mobile macro-invertebrates, and the diversity and abundance of fin fishes).

Although multiple coral taxa were observed at sampling locations within the project area, *Porites rus*, *Porites cylindrica* and *Porites lutea* comprised the large majority of coral at all sites within the dredge footprint. Some corals in the project area appear to show signs of stress. Hemispherical species, such as *Porites lutea* were observed to have copious secretions of mucous. It has been shown that corals increase mucus secretion to remove fine particles when turbidity levels are high. These areas are routinely subject to high levels of total suspended solids (TSS); therefore, this response to turbidity is not surprising, but may indicate these corals are stressed.

Results of surveys in Inner Apra Harbor have shown an area of considerable coral coverage within the northern portion of the entrance channel. Subsequent to the survey portions of this area were dredged. South of the entrance channel, within the main basin of the Inner Apra Harbor, corals were predominantly observed only on vertical surfaces of wharves and sheet piles, and metal debris on the Harbor floor. No coral was observed growing on the rubble and sand surfaces of the floor of the Inner Harbor.

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Appendix E – Section D: Maine Ecosystem Impact Analysis CVN Project Outer Apra Harbor, Guam, By Marine Research Consultants, Primary Author: Stephen Dollar

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Habitat Equivalency Analysis & Supporting Studies: Section D

CVN Marine Ecosystem Impact Analysis

Outer Apra Harbor, Guam

September 2009

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LIST OF ACRONYMS AND ABBREVIATIONS

>	greater than
≥	greater than or equal to
≤	less than or equal to
%	percent
COMNAVREG MARIANAS	Commander Navy Region Marianas
CPCe	Coral Point Count with Excel Extensions
CVN	carrier nuclear vessel
cy	cubic yards
EO	Executive Order
EFDC	Environmental Fluid Dynamics Code
ESH	Essential Fish Habitat
ft	feet
ft^2	square feet
HAPC	Habitat Area of Particular Concern
HEA	Habitat Equivalency Analysis
m	meter(s)
m^2	square meters
m^3	cubic meters
$mg/cm^2/day$	milligrams per square centimeter per day
MLLW	mean lower low water
NFESC	Naval Facilities Engineering Service Center
NOAA	National Oceanic and Atmospheric Administration
SEI	Sea Engineering Inc.
SRF	Ship Repair Facility
TSS	total suspended solids

1.0 PROJECT OVERVIEW

The United States Department of the Navy (Navy) proposes to construct a new wharf in Outer Apra Harbor for use by visiting nuclear aircraft carriers (CVN). Two project alternatives ("Polaris Point" and "Former SRF") are proposed and are described in detail in Volume 4 of the *Guam and CNMI Military Relocation Draft Environmental Impact Statement/Overseas Environmental Impact Statement* (Navy 2009).

Both alternatives would require dredging of portions of the existing reef substratum that are presently shallower than a depth of -49.5 feet (ft) (15 meters [m]) mean lower low water (MLLW). While the exact dredging methods have not been determined, the action would require large excavating equipment (e.g., crane and clamshell) with high breaking strength. While Best Management Practices, such as the use of silt containment devices would be employed during the dredging operations, particulate material would be created by the breaking up of the reef surface, the resuspension of particulate material contained within the fossil reef framework, and leakage of sediment slurry out of the clamshell during transfer to scows for transport. This report describes the potential impact of dredging on the ecosystem, with emphasis on effects to reef coral communities as a metric to reflect ecosystem condition.

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2.0 BACKGROUND DATA

Several documents prepared as part of the EIS for the CVN project have been utilized as background data for the present impact analysis. A brief summary of the pertinent information presented in these reports follows:

2.1 ECOLOGICAL ASSESSMENT OF STONY CORALS AND ASSOCIATED ORGANISMS IN THE EASTERN PORTIONS OF APRA HARBOR, GUAM. AUGUST 2007.

In 2006 and 2007, Stephen H. Smith, Marine Ecologist, Naval Facilities Engineering Service Center (NFESC), prepared a report describing the marine environmental resources of the area within and adjacent to the proposed dredging for the CVN project. The primary objective of the survey was to quantitatively assess the distribution and abundance of Scleractinian (stony) corals with seven selected portions of Apra Harbor that included the fairway channel[1], turning basin and the two alternative CVN wharf locations. Overall results indicated that corals and/or coral reefs were present in all locations investigated. Coral development varied dramatically between sites and at different depths, with some locations supporting well developed complex coral reefs and other areas supporting only small patch reefs or sparsely scattered corals. Coral cover at stations within the dredge footprint (turning basin, fairway [i.e., navigation channel], and Polaris Point wharf area) had coral cover ranging from about 7% to 21%.

Adjacent to the project area and west is Big Blue Reef and coral coverage differs between the east and west sides of the reef. Total coral cover at Big Blue Reef East sites, closest to the proposed dredge area was similar to cover within the dredge area (2 to18%), while cover on the sides of Big Blue Reef West was substantially higher (70-100%). On the Big Blue West transects, coral cover was dominated by *Porites rus*, on the fairway, turning basin, Polaris Point wharf area and Big Blue East transects, species distribution was more equitably distributed between *Porites rus* and a variety of other species of *Porites*. Qualitative observations of coral "condition" revealed no areas of extensive bleaching, or disease. Some colonies with hemispherical growth forms (e.g., *Porites lobata*) at survey sites within the dredge footprint (Polaris Point, fairway (i.e., navigation channel), and turning basin) were observed to be secreting copious amounts of mucus. As these areas are within the active ship transit lanes, the mucous secretion may be a sediment rejection response to increased sediment re-suspension from ship activities.

2.2 ASSESSMENT OF BENTHIC COMMUNITY STRUCTURE IN THE VICINITY OF THE PROPOSED TURNING BASIN AND BERTHING AREA FOR CVN (INCLUDED IN VOLUME 9, APPENDIX J OF THE GUAM AND CNMI MILITARY RELOCATION DRAFT ENVIRONMENTAL IMPACT STATEMENT/OVERSEAS ENVIRONMENTAL IMPACT STATEMENT) . AUGUST 2009.

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. A major objective of the survey 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.

Methods were selected to capture the identified data parameters in the most efficient means possible. Benthic community composition was evaluated using a photo-quadrat belt transect method (each belt transect encompassed 10.7 square feet (ft^2) [10 square meters (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

[1] The Fairway Channel or Fairway refers to that portion of the navigation channel that the CVN would travel between Jade and Western Shoals the sharp bend southward toward Inner Apra Harbor and the northern edge of the turning basin.

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 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). The structural zonation pattern of the nearshore marine environment off the eastern shoreline in the vicinity of the CVN channel and turning basin was composed primarily of three major biotopes: large intact patch reefs, dredged patch reefs and pinnacles, and soft sediment harbor floor. The channel and turning basins were bordered by several large "patch reefs" that consist of shallow, flat-topped, steep-sided features. The largest three of these reefs are named Jade and Western Shoals, and Big Blue Reef. These reefs all consisted of relatively flat, shallow upper surfaces that were covered primarily with sand and rubble. 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 to18.3 m), where the slopes intersect the channel floor.

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.

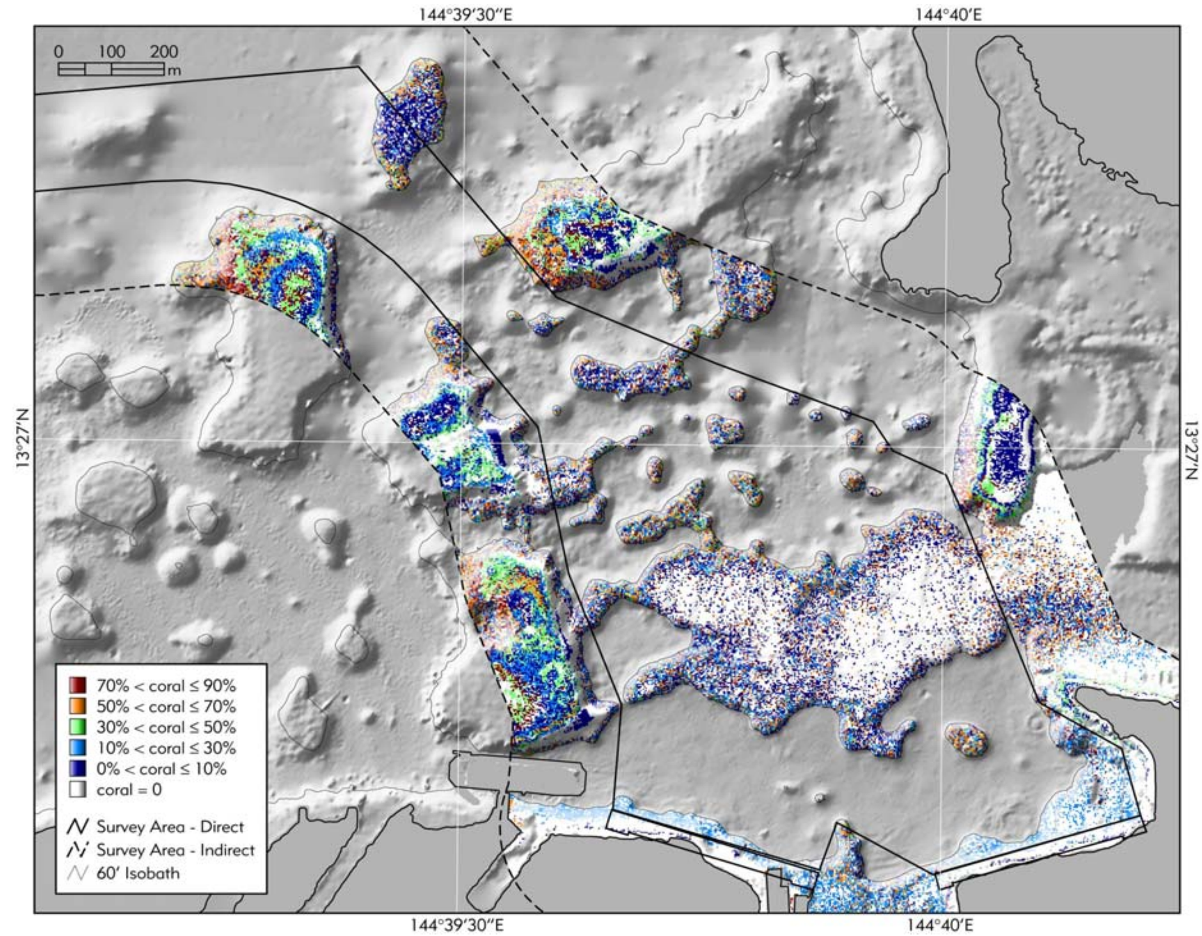
Application of calibration-validation data collected in the field to spectral signatures of remote sensing imagery was used to create a map of coral cover over the entire survey area. For the Former SRF alternative, coral of all classes covered approximately 41% of the bottom within the dredge footprint compared to 43% 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.

The area demarcated as the CVN channel and turning basin did not contain any of the shallow shoal patch reefs. This area was dredged in 1946 to allow safe access to the newly completed Inner Apra Harbor (R. Wescom, COMNAVREG MARIANAS, personal communication). As a result, the shallowest depth within the channel and turning basin was on the order of -40 ft (-12 m) MLLW. It is likely that the large flat area in the southern end of the turning basin was another shoal area similar to the surrounding reefs prior to the 1946 dredging. Dredging likely removed the reef above the 40 foot depth contour, 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 steeply to the channel floor. This suggests that much of the coral within the depth zone to be dredged for the CVN project (< -51.5 ft [-15.6 m] MLLW) is regrowth following the 1946 dredging. The result is a community with a maximum age of 62 years. In addition to the large previously dredged patch reef, there are numerous smaller pinnacles within the dredge footprint, all of which contain some live coral cover.

Figure 1 illustrates the benthic habitat maps produced by a classification scheme using satellite imagery and in-situ calibration/validation sea-truthing for the combined Polaris Point and Former SRF alternatives. Spectral resolution of the image allowed for the distinction of six levels of classification according to coral cover. In Table 1, levels of coral cover are shown for both the Direct Impact Areas (defined as the dredge footprint) and the Indirect Impact areas (defined as about 656 ft [200 m] wide bordering the Direct Impact area that could potentially be impacted by dredge-induced sedimentation).

Figure 1: Coral Abundance Map of Eastern Outer Apra Harbor



Note: Combined project areas for the Polaris Point and Former SRF Alternatives for CVN berthing are shown. Direct Impact area (dredge footprint) is shown by solid black line. Boundary of Indirect Impact area, defined as region 656 ft (200 m) from the Direct Impact boundary, is shown as dashed black line. Coral abundance at depths of 60 ft (18 m) or shallower are shown, while coral deeper than 60 ft (18m) within the project area are not shown.

Table 1: Coral Coverage by Abundance Class Within Direct (Dredge Footprint) and Indirect Impact Areas of CVN Project Site

Coral Level	*FORMER SRF*					
	Direct		*Indirect*		*Total*	
	m^2	*acres (% coral[1])*	*m^2*	*acres (% coral[1])*	*m^2*	*acres (% coral[1])*
Coral = 0%	**149,841**	**37.03**	**189,026**	**46.71**	**338,867**	**83.74**
0% < coral ≤ 10%	34,445	8.51(36)	53,436	13.20 (28)	87,880	21.72 (31)
10% < coral ≤ 30%	24,123	5.96 (25)	37,204	9.19 (20)	61,327	15.15 (21)
30% < coral ≤ 50%	9,274	2.29 (10)	34,502	8.53 (18)	43,776	10.82 (15)
50% < coral ≤ 70%	18,190	4.49 (19)	44,628	11.03 (23)	62,819	15.52 (22)
70% < coral ≤ 90%	10,051	2.48 (10)	21,266	5.25 (11)	31,317	7.74 (11)
Total with coral	**96,083**	**23.74**	**191,036**	**47.21**	**287,119**	**70.95**
Total dredge area	**245,924**	**60.77**	**380,062**	**93.92**	**625,986**	**154.69**
Percent coral cover:		**39%**		**50%**		**46%**

Coral Level	*POLARIS POINT*					
	Direct		*Indirect*		*Total*	
	m^2	*acres (% coral[1])*	*m^2*	*acres (% coral[1])*	*m^2*	*acres (% coral[1])*
Coral = 0%	**186,065**	**45.98**	**219,997**	**54.36**	**406,063**	**100.34**
0% < coral ≤ 10%	37,411	9.24 (37)	54,541	13.48 (29)	91,953	22.72 (32)
10% < coral ≤ 30%	26,058	6.44 (26)	38,523	9.52 (21)	64,581	15.96 (22)
30% < coral ≤ 50%	9,590	2.37 (9)	32,527	8.04 (17)	42,117	10.41 (15)
50% < coral ≤ 70%	17,960	4.44 (18)	41,898	10.35 (22)	59,858	14.79 (21)
70% < coral ≤ 90%	10,950	2.71 (11)	19,642	4.85 (11)	30,591	7.56 (11)
Total with coral	**101,969**	**25.20**	**187,131**	**46.24**	**289,100**	**71.44**
Total dredge area	**288,034**	**71.18**	**407,128**	**100.6**	**695,163**	**171.78**
Percent coral cover:		**35%**		**46%**		**42%**

[1] coral percent are rounded to nearest percent; therefore total coral % may not be exactly 100%.
Source: Derived from Classified Habitat Map Using Quickbird Satellite Imagery.

3.0 IMPACT ANALYSIS

3.1 HABITATS OF CONCERN

The CVN project area consists of several major habitat types, including patch reefs, dredged patch reef flats, and unconsolidated sediment (e.g., sand, mud, rubble). While all habitats are important to consider, “coral reef ecosystems” are perhaps the most important habitats to consider by virtue of Executive Order (EO) 13089 (1998). The EO mandates preservation and protection of U.S. “*coral reef ecosystems”, which are defined as “… those species, habitats and other natural resources associated with coral reefs in all maritime areas and zones subject to the jurisdiction and control of the United States*.” For the purpose of this report, coral reef ecosystems are considered as the zones where living corals constitute greater than 0% bottom cover.

3.2 DIRECT EFFECTS

The proposed actions for the CVN project would result in two types of effects to the coral reef communities. The first type of effect is termed “direct,” which is defined as actual removal of the reef surface during the dredging process. Hence, the area of potential “direct” impact includes the bathymetric footprint of the dredge area (depth limit of -49.5 ft [15 m]), as well as 2 ft (0.6m) of "overdredge" for a total depth of -51.5 ft (15.7 m). As an overestimate of direct impact, the impact analysis assumes a direct impact depth of -60 ft (18m), which predictably results in a larger area of affected habitat.

The Polaris Point Alternative would require a dredge volume of approximately 608,000 cubic yards (cy) (464,849 cubic meters [m^3]) of reef material. Coral of all cover classes as determined by remote sensing mapping covers a surface area of approximately 25 acres (101,969 m^2) of this area (Table 1), while the Former SRF alternative would require an estimated dredge volume of 479,000 cy, with coral covering an area of about 24 acres (96,083 m^2). However, the total area to be dredged is larger for Polaris Point alternative and Former SRF has the highest percentage of coral loss for direct impacts. About 35% and 39% of the area to be dredged (coral assessment assumes 60 ft (18 m) depth) contains some level of coral coverage for the Polaris Point and Former SRF alternatives, respectively (Table 1).

When areas to be dredged (direct effect), are classified by coral abundance class, the lowest percentage of coral cover area to be dredged falls into two classes for both alternatives, 30%-50% and 70%-90%. These two classes combined comprise about 20% of areas with any coral cover for both the Polaris Point and Former SRF alternatives. The highest percentage of coral cover area to be dredged for both alternatives is characterized by the lowest coral cover level (> 0 to ≤ 10%) that accounted for an estimated 36% of the area where corals occurred. About 62% of the areas containing coral to be dredged under both alternatives had less than 30% coral coverage (Table 1).

In addition to dredging, structural impacts to benthic habitats may occur from construction activities related to securing the dredge barge and supporting vessels. Anchors chains and mooring cables would not be placed on or over reef areas that support high percentages of coral cover, such as reef slopes with greater than 70%-90% coral cover. The following practices were conditions of, or were included in the mitigation plan for a recent dredging permit in Outer Apra Harbor (Army Corps of Engineers 2008) and would minimize construction impacts on coral for the CVN project if included in the permit:

1. No in-water blasting.
2. Concrete caissons would be constructed off-site and floated into position.
3. Anchors, anchor chains, wire rope and associated anchor rigging would be restricted to designated areas in sandy harbor bottom or areas of dredging impact area.

4. Operate and anchor all construction associated equipment to avoid contacting coral reef resources during construction activities or extreme weather conditions.
5. Dredging filling of tidal waters would not occur during hard coral spawning periods, usually around the full moons of June, July and August. Contact University of Guam for confirmation of dates.
6. Use silt curtains to enclose areas of in-water work. If a plume is observed over sensitive coral, construction would stop and corrective measures taken.

3.3 POTENTIAL INDIRECT IMPACTS

3.3.1 Background Information of Indirect Impacts to Corals from Sediment

Dredging of reef material within the CVN project area will result in elevated suspended sediment in the water column as a result of both leakage of excavated material from the dredge bucket, and release of fine-grained calcium carbonate mud (micrite) from the interstitial reef framework. While sediment retention devices (i.e., silt curtains) will be deployed to minimize dispersal of this material, it is anticipated that some fraction will escape containment with the potential to affect reef communities. In addition, breakage of coral by the dredge which is not subsequently removed from the seafloor can also result in consequences to the reef habitats that are bordering the dredge sites. For the purposes of this document, these effects are termed “potential indirect impacts.”

On a global scale, the impact of increased sedimentation is one of the most common and serious anthropogenic influences on coral reefs (e.g., Grigg and Dollar 1990). The scientific literature is replete with numerous documented cases of impacts to coral reefs by sedimentation related to the activities of man, as well as laboratory investigations that quantify impacts under controlled conditions. Reviews by Brown and Howard (1985), Grigg and Dollar (1990), Rogers (1990) and Fabricius (2005) provide comprehensive treatment of all aspects of the effects of sedimentation to coral reefs. Impacts associated with sedimentation and sediment burial include reduced photosynthesis and increased respiration (e.g., Riegl and Branch 1995, Philipp and Fabricius 2003, Weber et al., 2006), tissue mortality (e.g., Rogers 1983), reduced growth (e.g., Dodge et al. 1974, Rice and Hunter 1992) and reduced fertilization, larval survivorship, and recruitment (e.g., Gilmour 1999, Babcock and Smith 2000).

While it is clear that increased sedimentation can have a deleterious effect on corals, it is also apparent from the scientific literature that the deleterious effects are not uniform or consistent, with responses depending primarily on a variety of factors including coral growth form and physiological capabilities, duration of exposure, and physiochemical composition of the sediment.

When evaluating the effects of anthropogenically induced sedimentation, it is also important to consider that sediments are resuspended by natural processes in many reef environments, and as a result, most corals are adapted to withstand some level of sediment load. It is well documented since the pioneering work on environmental tolerances of reef corals that some taxa are more resilient to turbidity and sedimentation than others (e.g., Mayer 1918, Yonge 1930, Marshall and Orr 1931, Hubbard and Pocock 1972, Riegl 1995, Wesseling et al. 1999). It has also been shown that corals growing in waters of moderate to extremely high turbidity are not automatically more stressed than their clear-water counterparts (Roy and Smith 1971, Done 1982, Johnson and Risk 1987, Acker and Stern 1990, Riegl 1995, Kleypas 1996, McClanahan and Obura 1997, Woolfe and Larcombe 1998, and Larcombe et al. 2001). Sanders and Baron-Szabo (2005) describe "siltation assemblages" of corals that occur in turbid water and/or muddy reef environments as a result of resilience to sediment through either effective rejection mechanisms or physiological tolerance to intermittent coverage.

Sediment resistance is generally distinguished as occurring by two separate processes: sediment rejection and sediment tolerance, which are reviewed in detail by Sanders and Baron-Szabo (2005). Sediment rejection is the active removal of sediment particles by polyp expansion by water uptake and expulsion ("pumping"), tentacle movement, ciliary action, and mucous secretion. Of note, it has been found that for all corals, it is more difficult to reject sediment from a horizontal surface than from an inclined or vertical surface (e.g., Bak and Elgershiuzen 1976), and on flat surfaces sediment may be pushed to "dump areas" on the corallum (Reigl 1995). Experiments (Anthony 1999) and field measurements (Anthony 2000) indicate that corals from turbid water reefs have a background rate of sediment rejection two to four times higher than their conspecifics in clear-water reefs (Anthony and Fabricius 2000). For sediment clearance, the growth form of a coral is crucial, with branched and erect-foliaceous forms by far the most effective in clearance of sediment of silt to coarse sands (Hubbard and Pocock 1972, Stafford-Smith 1993).

Sediment tolerance, or the ability of a coral to withstand a coating of sediment, differs markedly, ranging from death to localized necrosis to survival without any signs of damage or stress (Hodgson 1990, Wesseling, et al. 1999). Hodgson (1990) reported that for some massive corals, tissue necrosis remained confined to flat and concave surfaces veneered by sediment, whereas unveneered short columns and convex knobs on the same colonies remained in good condition. The acroporid *Montipora* is quite sediment tolerant, and may be veneered for weeks without signs of permanent physiological damage (Hodgson 1990). Similarly, *Porites* is highly tolerant of being sediment-veneered, and can recover even after complete burial for up to three days (Stafford-Smith 1993, Wesseling, et al. 1999). Sofonia and Anthony (2008) found that the coral *Turbinaria mesenterina* on nearshore reefs in the central Great Barrier Reef lagoon was tolerant to sediment loads an order of magnitude higher than most severe sediment conditions *in situ*. The likely mechanisms for such high tolerance were that corals were able to clear themselves rapidly, and that the sediment provides a particulate food source.

It has also been suggested that small colonies may be more resistant to prolonged sedimentation than large colonies owing to higher efficiency in terms of energy expenditure in sediment-rejection behavior (Dodge and Vaisnys 1977). With respect to impacts of sediment stress as a function of frequency, Connell's (1997) pioneering long-term studies of coral reef response to both acute and chronic disturbances have shown that reef systems are more vulnerable to chronic disturbance than to acute, infrequent episodes of stress. Hence, recovery from acute episodes of elevated sedimentation may take place, while the same or even lower levels of sediment stress on a continual basis would result in more extensive, or even permanent detrimental change. Sanders and Baron-Szabo (2005) also report that pulses of a few hours to a few days of rapid sediment fallout exert less of a lasting influence than frequent or chronic sedimentation at lower rates.

While it is generally believed that corals can only survive in waters with low turbidity and suspended particulate loads, it has been documented that apparently flourishing coral communities are found in naturally turbid conditions, although these communities are generally very different than those found in clearer water. For example, a turbid lagoon at Fanning Island (Central Pacific) had an abundance of primarily branching colonies, although the coral community was less diverse than in the clear lagoon with mostly massive and encrusting corals (Roy and Smith 1971, Maragos 1974). Roy and Smith (1971) conclude that while there was a decrease in abundance of coral knolls from the clear to the turbid water (less than 2 m visibility), both areas had lush reef development. In a study of the distribution of coral communities located near two rivers in Guam, Randall and Birkeland (1978) concluded that observed decreases in natural sedimentation rates along a gradient from the river mouths to the open sea explained the increase in number of coral species, from less than 10 in the area exposed to high sedimentation to over 100 in the areas farthest from riverine influence. The authors predicted that sedimentation rates ranging from 162 to 216 mg cm^{-1} d^{-1} will be associated with less than 10 species, while rates of 5 to 32 mg cm^{-1} d^{-1} (open ocean) will be correlated with over 100 species (data converted from original).

Similarly, Bak and Meesters (2000) found coral reefs in the marginal, high turbidity, high sedimentation environment of the Bay of Bantan, NW Java, Indonesia. While high turbidity and sedimentation prevented light penetration, the reefs were characterized by high cover of living coral, and community composition indicated that species capable of tolerating such marginal conditions were common owing to acclimatization.

As summarized in Rogers (1990), the response to coral communities from dredging and other activities which increase sediments in the water can range from only localized or negligible effects on corals to long-term changes. Rogers (1990) makes the point that dredging often affects not only the portion of the reef which is actually removed or smothered but also downstream areas where currents carry increased concentrations of fine suspended particles. Case histories at Johnston Atoll (Brock et al. 1977), Brewers Bay Virgin Islands (Grigg, et al. 1972) report continual resuspension and transport of dredged materials that caused reef degradation years after the dredging ceased.

However impacts are not always severe and long-lasting. The dumping of 2,200 tons of kaolin clay cargo from a freighter grounded on a reef at French Frigate Shoals in the Northwest Hawaiian Islands created large plumes of the suspended clay but had no apparent adverse effects beyond a radius of about 50 m from the grounding site (Dollar and Grigg 1981). Based on a brief qualitative survey, Sheppard (1980) suggested that dredging and blasting in Diego Garcia Lagoon (Indian Ocean) had resulted in variable and low coral cover but no reduction in coral diversity. Construction of Honokohau Harbor on the Island of Hawaii by dredging actually resulted in an overall increase in coral cover because of colonization of newly created harbor surfaces (USACOE 1983). In 1979, work began to extend the runway of the airport at St. Thomas (U.S. Virgin Islands) 726 m into water 27 m deep. Monitoring over a period of 31 months of fish populations, seagrass beds and coral reefs in the vicinity revealed no significant deterioration attributable to the plume from the dredge and fill operation (Rogers 1982).

Although the effects of anthropogenic sedimentation on reef corals have been widely discussed and reviewed in the scientific literature, there are relatively few studies that specifically address the effects of dredging on reef corals at sites where the community has been monitored before, during and after the event. Marzlalek (1981) surveyed reef areas before and after a large-scale dredging project off of Florida, where dredging took place for three months every year for five years. He reported no mass mortality of hard corals after short-term exposure to sediments (a few days), although several colonies showed partial mortality and excessive mucus secretion after prolonged exposure to suspended sediment. Marsalek (1981) suggested that prolonged turbidity was more detrimental than short-term accumulation of sediments. Reduction in other growth parameters, such as calcification, has been ascribed to dredging activities in studies by Bak (1978) and Dodge and Brass (1984), but these studies provided no information on the status of the coral community either before or after the dredging activity so that community effects could not be compared with those at the colony level. Brown et al. (1990) had the opportunity to utilize long-term ecological monitoring to conduct before, during and after studies of the effects of a 9-month dredging of a deep channel to adjacent reef flats at Phuket, Thailand. Reef corals, primarily massive heads of *Porites lutea*, showed as much as 30% reduction in living cover one year after the start of dredging, with a significant decline in diversity. However, after the termination of dredging, the reef recovered rapidly with coral cover values and diversity indices restored to former levels within approximately 22 months after dredging began. No significant changes in linear growth rate, calcification or skeletal density were measured in corals subjected to the increased sediment loads. The authors speculate that the rapid recovery was a result of regeneration of living tissue over formerly dead surfaces of colonies that suffered only partial mortality. The lack of change of growth rate, calcification rate and skeletal density was attributed to the short time that corals were subjected to fatally high concentrations of sediments (days to weeks). Changes that may have occurred during this short period may have been insufficient to affect the annual growth rate or calcification.

An important consideration in the evaluation of sediment effects to corals is the duration of the stress. In an experimental design exposing corals to ten different sediment types at environmentally relevant concentrations (33-160 mg cm^{-2}) Weber, et al. (2006) found that highest stress levels (in terms of reduction of photosynthetic yield of the coral *Montipora peltiformis*) occurred from short-term (20-44 hr) exposure to nutrient-rich silts, whereas no effect was measurable after greater than 48 hr exposure to fine and medium sand, and pure aragonite (calcium carbonate) silt. However, all treatments that showed reduction in photosynthetic yield from sediment loading also exhibited immediate reversal of the trend following removal of sediment exposure (although recover was not complete within the 48-hour recovery period after experiments were terminated). These authors conclude that their findings suggest a fundamentally different outcome of corals exposed to sedimentation by sandy nutrient-poor sediments, such as storm resuspended marine carbonate sediments compared to sedimentation of silt-sized sediments rich in organic matter and nutrients. Philipp and Fabricius (2003) also showed that the photosynthetic activity of *M. peltiformis* decreased linearly with both the amount of sediment and the time it remained on the tissues, which indicated that any threshold value for sedimentation tolerance should incorporate both amount and time. *M. peltiformis* was able to recover function to pre-stress levels if the duration of stress was short (< 24 hrs) or if doses were low. Wesseling et al. (1999) evaluated recovery of corals after full burial in field experiments in the NW Philippines where corals were buried for 0, 6, 20 and 68 hours. Species of *Porites* were not affected by 6 hr burial compared to controls, while increasing burial time had increasingly more serious effects in terms of discoloration and bleaching. Following removal of sediment, recovery took place, with time of recovery (2-4 weeks) proportional to time of burial. Colonies of *Acropora*, however, showed much more sensitivity, with all colonies dying after the 20 hr. treatment.

Reigl and Branch (1995) measured the changes in physiological reactions to sediments. Under what was considered the observed sedimentation levels on South African reefs (200 mg cm^{-2}) corals that had had been adapted to laboratory conditions for six weeks prior to the experiments in filtered seawater showed changes in energy balance by forcing respiratory losses up and photosynthetic production down, with elevated mucus secretion. However, these experiments were not conducted with other varying sediment loads, and recovery was not measured following removal of the sediment.

Some corals have adapted to fluctuating levels of sedimentation. Lirman and Manzello (2009) documented the patterns of resistance and resilience of *Siderastrea radians* to sub-optimal salinity and sediment burial in a series of short-term, long-term, acute, chronic, single-stressor, and sequential-stressor experiments. Under conditions of no salinity stress, *S. radians* was very effective at clearing sediments, and >50% of the colonies surfaces were cleared within 1 hour of burial. However, as burial periods increased, and colonies were covered at multiple chronic intervals, sediment burial resulted in extended photosynthetic recovery periods, reduced growth, and mortality.

It is important to note that effects from deposition of terrigenous sediments emanating from runoff can be substantially different than effects from sediments of marine origin. Te (2001) found that terrigenous sediments had greater light extinction capability than carbonate (reef-derived) sediments. As noted above Weber et al. (2006) found distinctly different responses depending on sediment composition, with substantial less effect from marine carbonates compared to organic-rich terrigenous sediments. Fine silts and sand composed of calcium carbonate have been shown to produce no negative effect to photosynthetic activity on one species of coral after more than two days of exposure (Weber et al. 2006).

Results of sediment core analysis reported by Weston Solutions (2006) indicated that sediment in Outer Apra Harbor (within the CVN dredge footprint) and the entrance to the Inner Apra Harbor were coarser-grained, comprised predominantly of gravelly sand. Analysis of twelve sediment samples collected within the CVN dredge footprint revealed that 79-96% of the samples by weight was composed of calcium carbonate, presumably of marine origin (Dollar and Hochberg 2009). Hence, terrigenous (i.e., non-carbonate) muds are not a major component of the sediment in the CVN dredge area.

In addition, the effects to reef corals from increased sedimentation do not appear to result from any specific “threshold” level. Te (2001) states that "numerous forces in nature and the ability of corals to adjust to higher sediment loading levels makes it impossible to definitively state a generalized threshold level for sediment loading in corals." Table 2 is a summary of the existing scientific literature that categorizes the effects to reef corals, corresponding to the rates and exposure periods of sedimentation.

Table 2: Summary of Existing Literature on Effects to Reef Corals

Effect	*Sedimentation Rate*		*Exposure*	*Reference*
	mg/cm² /day	*g/m² /day*	*Days*	
IMPACT LEVEL AND EFFECT	10 - 30	----	----	ISRS, 2004
LETHAL				
Zero growth rate	1.E+06	----	----	Cortes and Risk, 1985
Limit coral cover and diversity (<10 species and 2% coral cover)	160 - 200	----	42	Randall and Birkeland, 1978
Tissue damage and mortality	40	----	7 (aquaria)	Hodgson, 1989
Tissue damage and mortality	20.8	----	120 (field)	Hodgson, 1989
Coral mortality after some continuous exposure	20	200	----	Hodgson, 1997
Low coral cover and diversity	15	----	13	Loya, 1976
Acropora death	burial		20 hr	Wesseling et al. 1999
SUBLETHAL				
Reduced growth rates	20 - 1,000	----	2	Cortes and Risk, 1985
Limit coral cover and diversity (<10 species and 2% coral cover)	160 - 200	----	42	Randall and Birkeland, 1978
Tissue damage	40	----	7	Hodgson, 1989
Tissue damage	20.8	----	120	Hodgson, 1989
Low coral cover and diversity	15	----	13	Loya, 1976
Effected coral growth	<11	----	31	Te, 2001
Coral bleaching	10 and 14	----	30	Nemeth and Nowlis, 2001
Discoloration of tissue and partial bleaching (Porites)	burial		20-68 hr	Wesseling et al. 1999
Photosynthetic response impaired, but recovered	79-234			Philipp and Fabricius 2002
S. radians effective at clearing at low dose with minor effects	burial		2-24 hr	Lirman and Manzallo 2008
Photosynthetic response varied by sediment type	33-160			Weber et al. 2006
Dimininished productivity and decreased respiration	200		20 min	Riegl and Branch 1995
NO EFFECT REPORTED				
Defined as a "low" sediment rate	40 - 70	----	1	Mohar, 1997
No visible damage	40	----	7	Hodgson, 1989
Considered high concentration of resuspended sediments	>30	----	----	Cortes and Risk, 1985
No visible damage	20.8	----	120	Hodgson, 1989
Rich coral communities (>100 species and >12% coral cover)	5-32	----	42	Randall and Birkeland, 1978
Mean sediment rates and suspended sediment concentrations	< 10	----	----	Rogers, 1990
Mean sediment rate, concern with coral growth inhibition	5.1	51.2	30	Solandt et al., (no date)
Mean sediment rate, concern with coral growth inhibition	3.1	31.1	30	Solandt et al., (no date)
Defined as a "low" sediment rate	3	----	13	Loya, 1976
Mean sediment rate, concern with coral growth inhibition	1.1	11.1	30	Solandt et al., (no date)
Mean sediment rate, concern with coral growth inhibition	0.7	6.7	30	Solandt et al., (no date)
Mean sediment rate, concern with coral growth inhibition	0.4	4.4	30	Solandt et al., (no date)
Concern with possible inhibition of larval settlement	0.5 - 325	----	2	Babcock and Davies, 1991
Mean sediment rate	0.3 - 3.73	----	21-28	Houk, 2001
Porites not affected	burial		6 hr	Wesseling et al. 1999

Units

cm² = cubic centimeter
m² = cubic meter
g = gram
mg = milligram

It is readily apparent from Table 2 that the range of effects to corals extends through the entire spectrum of stress. As expected, the general trend is that the higher the deposition rate, and the longer the period of deposition, the greater the effect. However, it is also apparent that this trend is very species specific. For instance, Hodgson (1989) found that under the same rates of sedimentation in both the field and in aquaria, the response varied considerably between species. Of 22 species exposed to a constant sedimentation rate of 40 mg cm^{-2} d^{-1} for seven days in aquaria, six suffered mortality, seven suffered sublethal tissue damage, and nine did not incur visible damage. Of 36 species exposed to a sedimentation rate of 20.8 mg/cm^2/day for 120 days in the field, seven suffered mortality, 12 experienced tissue damage, and 17 were not visibly affected.

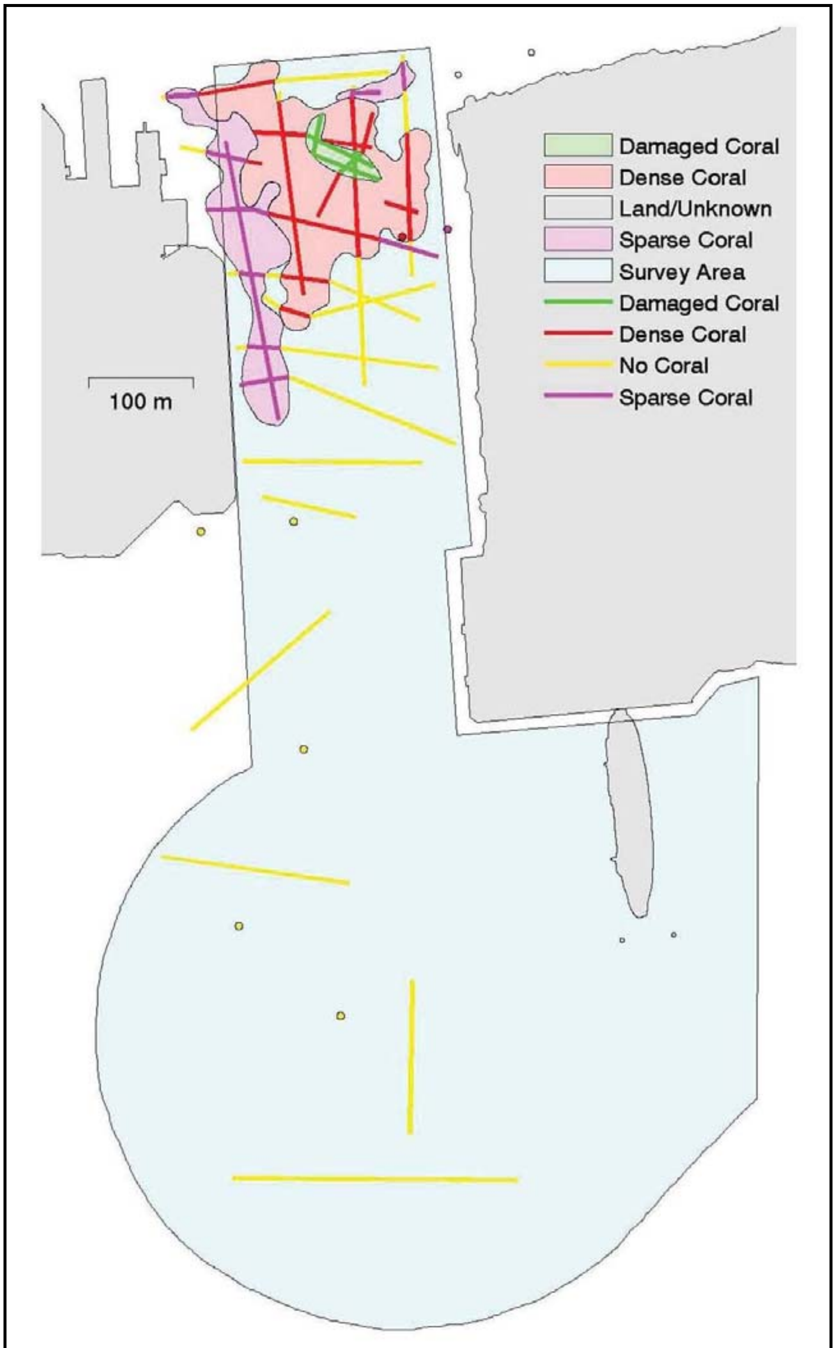
Te (2001) developed a predictive model that tested the hypothesis that the lower the light level, as caused by increased turbidity and sediment loads, the lower the photosynthetic production of corals. His work indicated that while light was the most influential force in coral growth and survival, field experiments in which transplanted corals were subjected to sedimentation rates of <1 mg/cm^2/d to greater than 300 mg/cm^2/d resulted in no mortality and showed no significant effect on growth rates or survivability. Corals used in his study were able to adjust and adapt to even the worst sediment loading levels achieved in the laboratory and the field. No corals subjected to the worst conditions died, and many grew at rates similar to corals growing in areas unaffected by sediment. Rather, strong waves caused by storm events were found to be more detrimental to coral growth and survival in the field than increased sediment loading. In addition, turbidity, as linked to light availability, but not sediment deposition, was found to significantly affect coral growth rates, but not coral survival in both field and laboratory experiments. Te (2001) also found that corals exposed to moderate to high sediment loading, and those growing under shade conditions were able to photo-adapt by increasing light harvesting capacity as evidenced by greater chlorophyll content and increased photosynthetic ability. When re-introduced into conditions with high light intensities, however, corals underwent photo-inhibition that disrupted photosynthetic functions.

The experimental findings by Te (2001) are relevant to reported conditions in the Inner Apra Harbor Channel, adjacent to the CVN dredge area, as well as the CVN dredge area *per se*. Observations in these areas indicates a layer of sediment on virtually all benthic surfaces that are not colonized by living organisms. Marine Research Consultants (2002, 2005) and Smith (2004) have documented well-developed communities of reef corals in the northern portion of the Inner Apra Harbor Channel. Remote sensing using satellite imagery allowed mapping and quantification of the area coverage of the coral communities. Integrating the mapped area of coral cover revealed a total area of 3.32 acres (13,430 square meters [m^2]) of sparse coral and 6.8 acres (27,648 m^2) of dense coral, for a total area of approximately 10.2 acres (41,080 m^2) of coral cover in the entrance channel (Figure 2).

The coral community in the Inner Apra Harbor Channel was comprised of four major species. The most abundant species was *Porites rus.* This coral species is ubiquitous throughout Apra Harbor, and occurs in a variety of growth forms, particularly overlapping plates and columnular spires. *Porites rus* occurred in the regions of sparse coral as isolated colonies. In the regions of dense coral, *Porites rus* formed massive interconnected structures with both plating, and columnar growth forms (Figure 3). The abundance of *Porites rus* in the entrance channel indicates that this species is particularly well adapted to thrive in areas of low light and continuous suspended sediment deposition. As can be seen in Figure 3, many of the colonies observed in the entrance channel had layers of silt deposited on the upper surfaces.

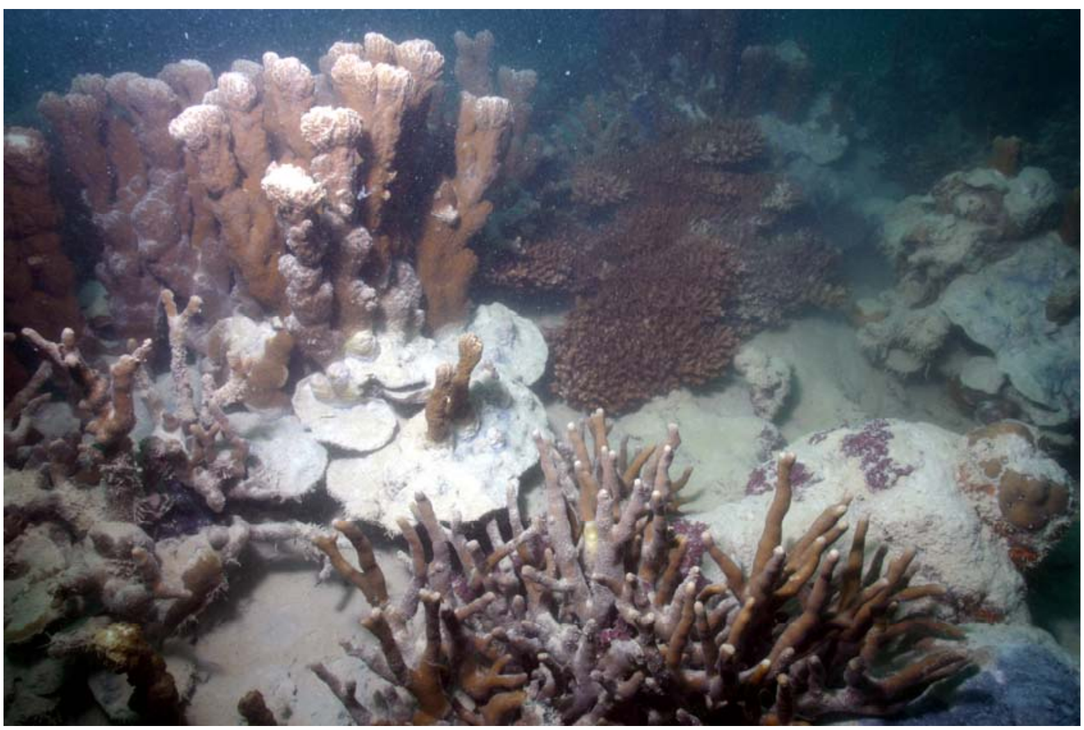
The other dominant coral in the Inner Apra Harbor Channel was the branching species *Porites (Porites) cylindrica.* This species occurs as mats of interconnected branches that extend uninterrupted for several square meters in some areas of the entrance channel floor (Figure 3). Third in abundance is the finely branched coral *Pocillopora damicornis,* which forms low, flat plates near the sediment surface. Similarly, surveys conducted within the CVN dredge area revealed similar coral community structure and physical conditions.

Figure 2: Inner Apra Harbor Entrance Channel Coral Abundance



Note: Map of Apra Harbor Entrance Channel made from GIS layers showing survey area (light blue); underwater transects (straight lines), and bottom composition (see legend). Red indicates zone of “dense” coral cover (>25% of bottom cover); purple indicates “sparse” coral cover (<25% bottom cover); yellow indicates no coral cover; green indicates zone of extensive physical damage to coral community and channel floor. (Source: Marine Research Consultants 2002.)

Figure 3: Two Underwater Views of Characteristic Regions of "Dense Coral Cover" in Inner Apra Harbor



Note: The three dominant coral species that occur throughout the entrance channel (*Porites rus*, *Porites cylindrica* and *Pocillopora damicornis*) are shown growing in close proximity to each other.

Dollar and Hochberg (2009) report that 67 photo-quadrat transects in the CVN survey area showed that coral comprised approximately 22% of benthic cover, while sediment (sand, mud, and rubble) accounted for 35% of bottom cover. On transects with sediment cover greater than approximately 75%, corals were not present. 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. All of these results indicate that sediment cover of the benthic surface is a normal component of the CVN area, and that community structure of the area reflects the interaction between sediment and the adaptive capabilities of component species to exist in a physical regime of high sediment cover. Yap et al. (1998) found that growth and mortality of transplanted nubbins of *Porites rus* and *P. cylindrica* in the northwestern Philippines were not affected at all by rates of sedimentation, indicating that these species are especially pre-adapted for existence in areas of high sedimentation throughout their life histories.

It was also observed during fieldwork that transiting ships into and out of the Inner Apra Harbor created plumes of resuspended sediment that reached the surface directly over the area occupied by dense coral communities. Hence, these communities serve as an example of the expected low level of secondary impact that may occur as a result of the CVN dredging. A major difference, however, is that the effects associated with the ship passage and resuspension will be essentially ongoing and continuous, while the CVN dredging (particularly at any one location) would occur for only a matter of days (SEI 2009, included as Section E of this report). As a result, expected effects from the CVN project would not likely exceed the range of ongoing conditions that occur throughout the Inner Apra Harbor Channel and CVN turning basin.

3.3.2 Results of Indirect Impacts Evaluation

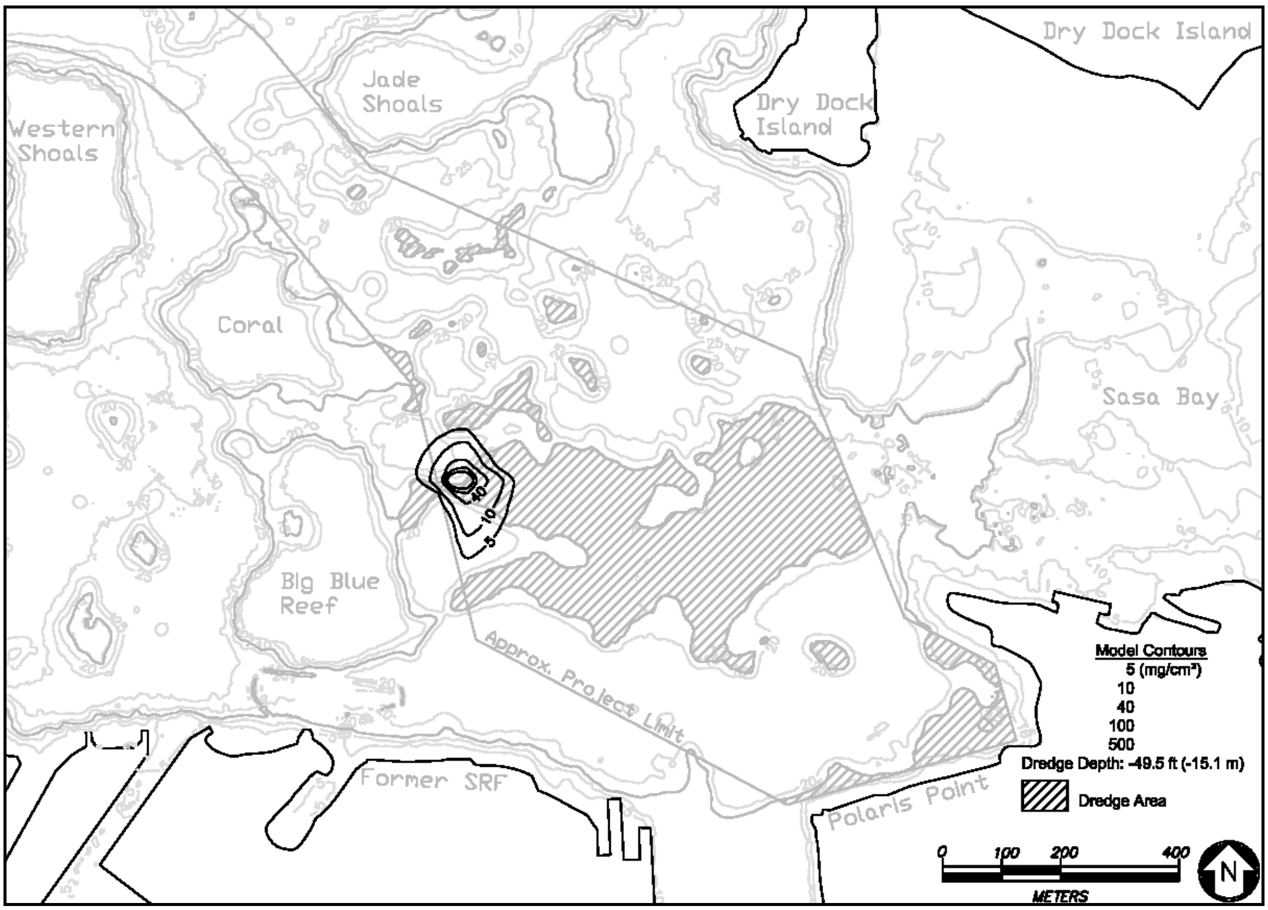
3.3.2.1 Coral Impacts

Plume transport and mixing in coastal waters is a complex process that depends on the characteristics of both the discharge plume and the ambient receiving waters. Plumes would be transported and dispersed by wind and tidally driven currents, and modified by local and regional bathymetric features. Evaluating these processes and possible plume impacts to the environment requires a detailed record of currents in the project site coupled with a numerical modeling analysis. Sea Engineering Inc. (SEI) used field data from seven current meters to calibrate a numerical model applied to the CVN site to evaluate the plume transport and mixing and possible impacts to the environment. The numerical analysis was performed using the EPA-approved Environmental Fluid Dynamics Code (EFDC) model (SEI 2009, included as Section E of the *HEA & Supporting Studies* report). The EFDC model was chosen based on capabilities for 3-dimension computation of suspended sediment transport and deposition, variation in suspended sediment size distributions and concentrations, an input of time-varying flows and concentrations of contaminants of concern. Therefore, adequately characterize the plume for the modeling analysis requires information on the amount of suspended sediment released to the water column, the grain size distribution of the suspended sediment, and the distribution of suspended sediment throughout the water column. Detailed discussion of the criteria for selection of these model inputs is presented in the SEI report.

Plume modeling was conducted by SEI (2009) (Section E of this report) under a variety of wind conditions, suspended sediment generation rates, and sediment release from the surface and bottom of the water column. The modeling results represent dredge plume transport and sedimentation following a single day of dredging at representative sites throughout the project area with duration of dredging varying from 10 hours to 24 hours. These results provide snapshots of the plumes and sedimentary footprints calculated by the model for a particular day of dredging at a particular location. During the actual dredging project, the dredger would be moving continuously, and the dredging would continue for several months. Assuming a daily dredging rate of 1,800 cy (1,376 m^3) per day, based on actual dredging production achieved during the Alpha-Bravo Wharf Improvements dredging project[2], the CVN project would require 8 to 12 months to complete. During this period, accumulations of sediment may occur.

Figure 4 shows one of the 20 modeled plumes (D7) for one scenario that demonstrates the contours of sediment deposition equal to 5, 10, 40, 100, 500 mg/cm^2/day for dredging of 1,800 cy (1,376 m^3) over 24 hr. In this particular model run, located in an area close to Big Blue Reef, it can be seen that virtually all of the plume at deposition rates of 500 and 100 mg cm^{-2} day $^{-1}$ is retained within the dredge footprint. None of the plume envelopes extends past the dredged boundary near Big Blue Reef. Similar scenarios for the remaining model runs indicate little extension of the plumes beyond the project area (see SEI 2009, included as Section E of this report).

Figure 4: Sediment Deposition Contours from Sea Engineering Inc. Model Run 7B (Source: SEI 2009, Section E of this report)



Possible cumulative sedimentation during the project was assessed by extrapolating in time and space the daily results, assuming a 24-hour dredging operation and dredging production of 1,800 cy (1,376 m^3) per day (SEI 2009 model cases 6.1 to 6.7). The steps involved in the analysis included the following:

- Determining the depth of material to be dredged throughout the project area.
- Estimating the rate of movement of the dredging throughout the project area.

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[2] The Alpha and Bravo Wharves improvements project (completed in 2008) involved dredging at the entrance to Inner Apra Harbor in proximity to the proposed CVN wharf structure at Former SRF or Polaris Point.

- Multiplying the daily results from the closest representative area by the appropriate number of days of dredging for that area. This process is repeated throughout the project area; daily results of a representative dredge site are assumed applicable to those grid cells closest to it.
- Summation of the multiplied and extrapolated daily results.

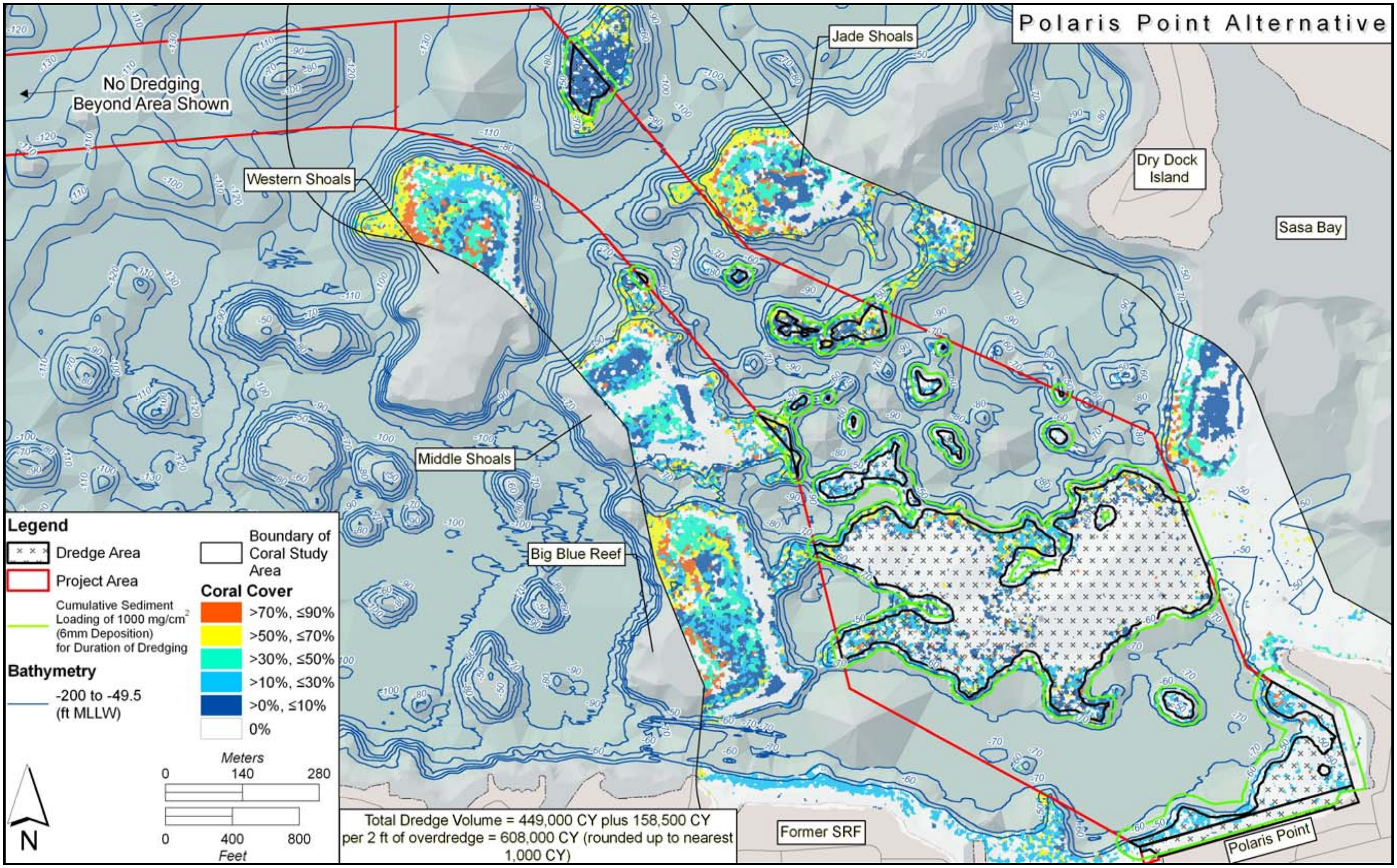
Throughout almost the entire dredge area, only 1.6 to 3.3 ft (0.5 to 1 m) of sediment is to be removed. The exception is at the proposed Polaris Point wharf area where the embankment is to be dredged. Greater than 13.1 ft (4 m) of material is to be removed in most of this area. At a production rate of 1,800 cy (1,376 m^3) per day, dredging operations would proceed through two 75.5 by 75.5 ft (23 by 23 m) grids per day, throughout all of the project area except the Polaris Point wharf area. Such rapid passage of the dredging operation means that prolonged exposure to plumes and significant accumulation of sediment would not occur in most of the project area. In the area adjacent to Polaris Point, it is estimated that 2 to 3 days of dredging would be required for each 75.5 ft by 75.5 ft (23 m by 23 m) grid, compared to a half of a day in the rest of the project area.

Application of these dredging rates per model grid cell, to the daily computed sediment loads provides an estimate of cumulative sedimentation. Sedimentation of 1,000 mg cm^{-2}, or 0.9 inches (6 mm), was selected as a reasonable threshold of sediment accumulation over the duration of the dredging project (8 to12 months). This value was based on results in Randall and Birkeland (1978) who estimated sedimentation rates of 5 to 32 mg/ cm^2/ day for open coastal ocean waters off two bays in Guam (Ylig and Fouha) that supported over 100 coral species. Extrapolating this daily rate to a yearly rate (approximate duration of dredging) equals1,825 -11,680 mg/cm^2/yr. Hence, the value of cumulative sediment of 1,000 mg/ cm^2 is highly conservative as it is only about one-half of the low value of natural oceanic conditions measured in Guam. This thickness corresponds to less than ¼ inch for the duration of dredging, or less than an average of 1 mm accumulation per month. Accumulation of sediment greater than 0.9 inches (6 mm) thick for the duration of dredging occurs only within a distance of 39.4 ft (12 m) from the dredge limit in most of the project area, and within 75.5 ft (23 m) of the dredge limit adjacent to Polaris Point. Figure 5 illustrates the additional area that may be impacted by this accumulated sediment.

While these estimates of potential indirect impacts represent relatively small percentages of the total area of coral reef habitat, they are likely overestimates for several reasons: First, the daily deposition rate of > 0.008 inches (0.2 mm)/day may be within the physiological tolerance limit that corals can effectively remove sediment (e.g., Hubbard and Pocock 1972). Second, sediment can be removed from coral surfaces by physical processes such as wave and current action that occur within the reef habitats. Modeling by SEI (2009, included as Section E of this report) indicates that following the cessation of dredging, TSS in the water column returns to background levels within several hours. With TSS returning to background levels, sediment deposition to the reef surface would also return to background levels within a very short time. Such a scenario could result in regular periods where corals can utilize physiological cleaning mechanism to shed deposited sediment. Third, deposited sediments can be resuspended and removed from the surface of corals by water movement from tidal currents and wave action. Since the duration of dredging at any particular location would be short, moving deposition plumes would not result in substantial sediment accumulation. SEI (2009, included as Section E of this report) reports that currents in the project vicinity are normally weak. During trade wind conditions surface currents were typically 4 to 8 cm/second while bottom layer currents were typically 2 to 4 cm/second. However, Brown (1990) indicates that relatively slow current speeds (<3 cm/second) are often sufficient to remove the small aggregates from the tops and flanks of mound-shaped and branching corals. Hence even the range of typical currents at the bottom layer is likely sufficient to resuspend and remove fine sediment from coral surfaces.

Figure 5: Estimated Limits of Sediment Accumulation Exceeding 0.9 inches (6mm) (1,000 mg/cm²) for the Duration of Dredging (8 to 12 months) Within the CVN Project Site

(Source: SEI 2009, included as Section E in this report)



A fourth factor that would likely result in a reduction in the area that would be affected by sediment deposition is the slope of the reef faces ringing much of the dredged footprint. Most of the dredge area consists of the flattened tops of previously dredged pinnacles and patch reefs. These features generally have steeply sloping margins that extend to the sandy harbor floor. While these reef slopes are among the areas of highest coral cover, indirect impacts from suspended sediment would be mitigated by downgradient flow with little accumulation on the steep reef face. In addition, the predominant coral species that occurs on the reef slopes (*Porites rus*) has been shown to be particularly resistant to sedimentation in the Inner Apra Harbor Channel. The high incidence of presently occurring *P. rus* also indicates that this species is well adapted to the existing conditions in Apra Harbor that will not change substantially as a result of the brief period of dredging. As a result of these factors, the potential impacts from suspended sediment should be short-term and localized.

It is evident in the SEI (2009) modeling results that a large portion of the deposition plume contour occur in habitats other than the coral reef slopes. A large percentage of the sediment plume contour covers the coral platform within the dredge envelope, as well as the areas of the harbor floor that are not covered with coral. These areas without coral are characterized by substantial cover of “unconsolidated sediment” that is primarily sand, mud and rubble. The composition of the sediment in these habitats that will be resuspended during dredging consists primarily of material of marine origin (calcium carbonate).

Hence, while the deposition rate of suspended material may increase temporarily during the period of dredging, it is not likely that this would represent any qualitative change to the sand-covered habitats. Organisms that inhabit these habitats are either infaunal, residing within the sand column, or epifaunal on the surface of the sediment surface, and the potential additional deposition of sediment associated with dredging would not represent a change in habitat integrity. Any impact to infaunal or epifaunal organisms would be short-term and localized. In addition, during periods of substantial water motion (e.g., storm waves), and with ship movements in the channel, sand is episodically resuspended at levels that likely exceed the potential contribution from dredging. As such, these organisms are adapted to high sediment environments, and any impacts would be short-term and localized.

It is also possible that another secondary or indirect effect at the dredge area boundaries is dislodgment of coral colonies by the dredge bucket (that are not collected in the bucket), that subsequently tumble down the sloping sides of the patch reefs and pinnacles. While such tumbling downslope is likely to result in some damage to other corals, and may create more fragments, there is also the possibility that not all fragments will die. In fact, fragmentation as a mode of asexual reproduction in coral has been documented in the scientific literature. As summarized in the review on reproduction by fragmentation in corals, Highsmith (1982) states that fragmentation and subsequent cascading caused primarily by storm wave energy, is "the predominant mode of reproduction in certain corals and an important mode in others.” Highsmith et al. (1980) found that the net effect of frequent storms on Caribbean reefs may be to maintain the reefs in the highest range of reef calcification through high survivorship of coral fragments.

The Highsmith (1980) review also points out that the ecological and geomorphological consequences of fragmentation can be "beneficial" in terms of expanding reef area to sand bottoms that cannot be colonized by larvae, and decreasing reef recovery time from disturbances over strictly sexual reproductive recovery. The Highsmith (1980) review also points out that the ecological and geomorphological consequences of fragmentation can be "beneficial" in terms of expanding reef area to sand bottoms that cannot be colonized by larvae, and decreasing reef recovery time from disturbances over strictly sexual reproductive recovery. As noted above, virtually all of the benthic surfaces within the CVN dredge area that are not covered with living biota are covered with a layer of sand/mud. While dredging activity may result in creation of "new" hard substratum, it is likely that such surfaces would be rapidly covered with a veneer of fine-grained particulate material similar to the existing scenario. Hence, settlement of planulae in this area is likely to be severely restricted.

Downward movement of coral fragments following hurricanes and tropical storms has been well-documented in French Polynesia (Harmelin-Vivien and Laboute 1986) and in Hawaii (Dollar 1982, Dollar and Tribble 1993, and Tsutsui et al. 1987). In addition, as noted in Hawaii, downslope movement of still living coral fragments broken by intermediate intensity storm action appears to widen the narrow reef slope zone area thereby increasing overall coral cover, and adding suitable substratum for planular settlement and growth in areas that were previously sand (Dollar and Tribble 1993). It is also of interest to note that other high intensity storm events of a magnitude that turned virtually all broken fragments into non-living coral rubble did not have the same effect of extending the horizontal margin of the reef (Dollar and Tribble 1993). Hence, there is a clear difference between the effects of intermediate and severe intensity events with respect to fragmentation and associated changes to reef structure.

Massive coral destruction from storm waves in French Polynesia with downward movement of broken colonies may be an important agent in the formation of detrital cones surrounding atolls (Harmelin-Vivien and Laboute 1986). Stimson (1978) has suggested that for branching corals in Hawaii and Enewetak which apparently do not planulate, asexual reproduction by means of colony fragments may be the normal mode of reproduction. In Guam, Birkeland et al. (1979) reported most colonies of staghorn coral (*Acropora aspera*) were derived from fragments, with 79% of colonies living unattached and the remainder, though attached, apparently originating from fragments. Fragmentation, combined with regeneration and fast growth rates, account for dominance of *A. aspera* and *A. acuminata* on inner reef flats in Guam (Randal 1973). On a dredged coral knoll at Diego Garcia Lagoon, Sheppard (1980) found many fragments and detached corals had survived, and subsequent to the dredging many of these living fragments were found to have reattached, contributing significantly to consolidation of the dredge-produced talus. Tudhope and Scoffin (1994) found that most fringing reefs of the southeast coast of Thailand have reef fronts that prograde by splitting, and subsequent regeneration of reef-front massive corals. The large size of the toppled blocks ensures that some of the uppermost polyps are viable above the muddy forereef sediment surface. Lirman (2000) found that the survivorship and propagation of *Acropora palmata* was tied to its capability to recover after fragmentation. Survivorship was not directly related to size of fragments, but by the type of substratum, with the greatest mortality observed on sand. Fragments placed on top of live colonies fused to the underlying tissue and did not experience any loss.

In the Final Environmental Impact Statement for the Kilo Wharf Extension in Apra Harbor, (USFWS 2007) it is stated that with regard to *Porites rus*..."Average fragment numbers exceeded evidence of recent larval recruitment, suggesting a relatively important role of fragmentation in the population dynamics of P. rus in this area." As *P. rus* has been documented as a dominant coral in the CVN dredge area (Smith 2007, Dollar and Hochberg 2009), these multiple reports of fragmentation and transport must be considered as a possible consequence that may occur during the dredging along slope edges in Apra Harbor. It is also important to consider that because of the low wave energy environment at the base of the dredged area, it is not likely that unattached coral fragments would result be moved to the extent of damaging other neighboring corals.

There would be short-term localized and infrequent impacts associated with use of the CVN Wharf at either Polaris Point or Former SRF. Six CVN visits are estimated per year, which would result in 12 tug boat assist events per year. The tug boats would potentially disturb bottom sediments that could potentially resuspend and redeposit on corals in and near the turning basin, including Big Blue Reef. The operational indirect impacts would be far less than those modeled for 10 to 24 hours of dredging (See Section E Figure 6-4C), the deposition contours of which do not extend to Big Blue Reef. The indirect impacts would be minor. The use of the CVN Wharf for other ships would result in less impact than the CVN because only two tugs would be required and while the turning point would remain the center of the turning basin, the ships would be much shorter and the tugs would be further from Big Blue Reef.

Other ship traffic would use the CVN navigation channel that has the same centerline as the current channel but is wider. These other ships would navigate along the centerline and not use the full width of the CVN channel. The indirect impacts to nearby coral would be short-term and comparable to existing ship traffic.

Deposition rates generated by the SEI model, which takes into account hydrodynamic properties linked to flushing rates, are shown to be small and of very short duration. The HEA model (Section F) was adjusted to a 5 year recovery rate for coral habitat affected by indirect (sediment-related) impacts. This had very little impact (<1%) on discounted service acre-years.

3.3.2.2 Impacts to Non-coral Organisms

Perhaps the most conspicuous non-coral macroinvertebrate within the CVN study area is the elephant ear sponge (*Ianthella* spp.), with individuals up to one meter in width commonly occurring in the deeper areas of the harbor floor. Specimens of these sponges were especially common on the southwestern portion of the CVN turning basin. Sponges within the dredge footprint at depths less the dredge limit will be destroyed during the operation. However, many of the sponges observed during the survey of the CVN area contained a visible layer of deposited sediment on the inner surfaces of the bowl-shaped structures (Dollar and Hochberg 2009). As the highest occurrence of these sponges occurred in the area of highest observed sediment deposition, and the organisms do not seem to be negatively affected by sediment deposition in the present scenario, it is likely that the short period of potentially increased sedimentation resulting from the dredging operation will have minimal or non-existent indirect impacts to the populations of *Ianthella* within the Indirect Impact areas.

There is no expectation of adverse impacts to motile macroinvertebrates, turtles or reef fish. Any impacts would be short-term and localized. While green sea turtles (*Chelonia mydas*) occur throughout Apra Harbor, these individuals are highly mobile and can vacate an area during temporarily unfavorable conditions. The reef area in the CVN dredge footprint does not appear to represent a unique or unusual habitat with respect to the entire Apra Harbor reef complex As a result, it is not expected that the proposed construction activity would present any impacts to turtle populations. In addition, following completion of the expansion project, turtles could return to the area with no apparent negative effects. Best management practices to minimize impacts to threatened and endangered species in the area are standard conditions of Army Corps of Engineers dredging permits.

Similarly, it is not expected that the proposed CVN project would result in substantial impacts to reef fish populations. As noted in Smith (2004), NOAA Fisheries and the Western Pacific Regional Fishery Management Council have included all of Apra Harbor within the designated Essential Fish Habitat (ESH) zone for Guam. However, only Jade Shoals in Outer Apra Harbor has been designated as a Habitat Area of Particular Concern (HAPC).

Smith (2007) observed 41 families of reef fish during surveys for the CVN project. He concludes that this relatively low total number of fishes, the small sizes of the individuals and the absence of top level predators (e.g., sharks, jacks, snappers, groupers) indicated a somewhat depauperate fish community. The areas within the dredge footprint are predominantly areas that have been previously dredged during creation of the harbor and turning basin. As a result, most of the Direct Impact area that will be removed consists of relatively flat, previously dredged platforms, with a relatively small component comprised of reef slopes with high levels of topographic complexity. As topographic complexity is a parameter of consideration with respect to fish habitat, the relatively small change in this feature resulting from the dredging activity will have minimal effects to fish. While fish may exit the immediate area adjacent to construction activities, it is not likely that there would be permanent effect to the present populations as a result of the proposed CVN project. Impacts on reef fish populations would likely be short-term and localized.

There is also little or no potential for lasting effects to water quality in the project area. While suspended sediment levels would be elevated during dredging, plume modeling indicates that conditions should return to background levels within hours of the cessation of dredging (SEI 2007). As sediment is presently resuspended during ship operations and by natural processes (e.g., storm waves), it is not anticipated that chemical composition of dredged sediment in the water column would differ from the present situation. Impacts to chemical composition would be short-term and localized. The Army Corps of Engineers permit conditions described for direct impacts would also minimize potential indirect impacts.

4.0 SUMMARY

The removal of coral from within the project footprint would result in unavoidable significant direct impacts requiring compensatory mitigation. However, there are other considerations when assessing the scale of the impacts. The coral community to be dredged cannot be considered "pristine" as t lies within an existing navigation channel and was dredged during the creation of the Inner Apra Harbor in 1946. In addition, not all coral in the project footprint would be removed, as parts of the area are presently deeper than the required dredge depth (-49.5 ft [-15.1 m] MLLW). In most of the areas shallower than -49.5 ft [15.1 m], only about 1 foot [0.3 m] of reef material will be removed to achieve the depth requirement.

After consideration of the factors associated with the CVN project in eastern Outer Apra Harbor, Guam, long-term impacts to coral reef habitats should not represent a major change over the existing condition. As most of the area to be dredged was previously dredged approximately 60 years ago, the present community structure can be considered "regrowth" on the bared reef surface. While the CVN project mitigation models assume 100% loss of this area (Industrial Economics Inc. 2009), within approximately 60 years the second phase of post-dredging regrowth could be comparable to the present conditions. It is also possible that mechanical breakage by the dredge and subsequent cascading of living coral fragments downslope may expand live coral cover to areas previously consisting of unconsolidated sediment.

The region of potential indirect impacts, defined as the area where sediment deposition may exceed a sedimentation rate of 5 mg /cm^2/ day (or deposition of > 0.008 inches (0.2 mm [1]) thickness) or 1,000 mg/ cm^2 for the 8 to 12 months of dredging is similarly small. None of the projected contours of sediment deposition extend to the western sides of large patch reefs characterized by benthic communities with high coral coverage (i.e., Big Blue Reef, and Western Shoals). As documented by Brown at al. (1990) for a deep channel dredging project in Thailand, coral cover on reef flats was reduced from the effects of nearby dredging activity by as much as 30%. Following completion of the project, recovery was rapid (~2 yrs) and complete. While the time scales of recovery would likely differ, it is possible that the response from indirect effects of the CVN dredging will be similar, especially since the coral community consists in large part of a single species (*Porites rus*),which appears to be especially well- adapted to the range of physical conditions that occur in Apra Harbor.

For purposes of HEA modeling, it is assumed that the area of Indirect Impacts will encompass an area 200 m wide bounding the dredge footprint. While such a region represents a conservative estimate; a combination of several factors are considered to suggest that the area of actual indirect effect would be smaller including:

- inherent physiological tolerance of corals to sediment, which includes the ability to remove sediment from living tissue,
- likely sediment composition that will released during dredging (i.e., sand and limestone silt) has been shown to have low impact to corals,
- short duration (~1 day) of dredging at a particular location 990 ft^2 [92 m^2],
- current velocity sufficient to aid in sediment resuspension and removal, and
- steep reef slopes that promotes removal of sediment rather than accumulation in areas of high coral cover.

---

[1] 0.22 mm is comparable to the thickness of a single sheet of aluminum foil(http://en.wikipedia.org/wiki/Aluminum_foil)

It is also unlikely that the project would result in a significant overall decrease of reproductive potential (i.e., coral spawning) of the Apra Harbor community. The area of potential effects comprises a relatively small fraction of the total reef area of Apra Harbor. In addition, it has been documented that the non-living benthic surface in the CVN area is covered in large part, by soft sediment that is not a suitable substratum for coral planular settlement. The duration of increased sediment at a particular location is expected to be short, with plumes restricted in size, so that potential impacts to reproductive cycles will not prolonged. In addition, to date the coral community in the potentially affected area has not been documented to be comprised of unique species that could be lost from the Apra Harbor system. As the project area was dredged in 1946, the existing community is the time-integrated response to a previous action that was substantially greater in magnitude, but similar in an operational sense as the proposed action. Hence, the existing coral community structure provides a good estimate of expected pattern of response and recovery to the proposed actions.

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Appendix E – Section E: Current Measurement and Numerical Model Study for CVN Berthing, By Sea Engineering Inc., Primary Author: Marc Ericksen

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Habitat Equivalency Analysis & Supporting Studies: Section E

Current Measurement and Numerical Model Study for CVN Berthing

Outer Apra Harbor, Guam

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LIST OF ACRONYMS/ABBREVIATIONS

%	percent
ADCP(s)	Acoustic Doppler Current Profiler(s)
COMNAVMAR	Commander, Naval Forces, Marianas
COMNAVREGMARIANAS	Commander, Naval Region, Marianas
cm/s	centimeters per second
cu m	cubic meters
CVN	Carrie Vessel Nuclear
cy	cubic yards
DGPS	Differential Global Positioning System
DOER	Dredging Operations and Environmental Research
EFDC	Environmental Fluid Dynamics Code
EIS	Environmental Impact Statement
EPA	Environmental Protection Agency
ft	feet
ft/hr	feet per hour
ft/s	feet per second
GPS	Global Positioning System
HEA	Habitat Equivalency Assessment
kg	kilogram
kg/s	kilograms per second
KHz	Kilohertz
km	Kilometers
km/h	Kilometers per hour
lb	pounds
m	meter(s)
m/hr	meters per hour
m^3/hr	square meters per hour
mg/cm^2	milligrams per square centimeter
m/s	meters per second
mg/L	milligrams per liter
mi	miles
MLLW	Mean Lower Low Water
mm	Millimeter(s)
mm/s	millimeters per second
mph	miles per hour
NAVFAC Pacific	Naval Facilities Engineering Command, Pacific
ppt	parts per thousand
RDI	RD Instruments, Inc.
SEI	Sea Engineering, Inc.
SI	International Standard (units)
SRF	Ship Repair Facility
U.S.	United States

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1.0 INTRODUCTION

1.1 Overview

The United States (U.S.) Department of Defense proposes1 a new general purpose wharf in Outer Apra Harbor to meet the requirements of a visiting nuclear aircraft carrier (CVN). There are two proposed CVN wharf alternative locations at the entrance to the Inner Apra Harbor channel: Polaris Point and Former Ship Repair Facility (Former SRF). The navigational approach through the Outer Apra Harbor Channel toward Inner Apra Harbor would generally follow the existing approach but would require widening to 600 feet (ft) (183 meters [m]). The navigational depth requirement for a CVN is -49.5 ft (-15 m) Mean Lower Low Water (MLLW). This depth requirement is met between the Outer Apra Harbor Channel entrance and the sharp channel bend toward Inner Apra Harbor. Dredging is required between the channel bend and the alternative wharf sites including a wide area for the proposed CVN turning basin.

The planned activities require preparation of an Environmental Impact Statement (EIS) and Habitat Equivalency Analysis (HEA). In support of the EIS and HEA, Sea Engineering was contracted to conduct a current measurement program in the project area, and a numerical modeling study of sediment plumes resulting from the dredging.

1.2 Construction Alternatives

The *CVN-Capable Berthing Study* by Naval Facilities Engineering Command Pacific (NAVFAC Pacific 2008) presents alternatives for CVN berthing and two are retained in the EIS:

- Alternative 1 – Polaris Point

  This site is located along the northern shore of Polaris Point. The area is also referred to as the Charlie Wharf area, because there reportedly used to be a wharf at the site. The berth is planned along the -50-ft (-15.2 m) depth contour to minimize dredging requirements. There were two dredging options at the eastern end of the proposed wharf. The first requires removal of the protruding point to the north, as shown in Figure 1-2. A second, reduced impact alternative (referred to as Alternative 2A in the CVN), was developed to avoid dredging this point. This alternative is shown in Figure 1-3. It is the reduced impact alternative that is retained in the EIS and is referred to as the Polaris Point Alternative.

- Alternative 2 – Former Ship Repair Facility (Former SRF)

  This site is located along the shoreline of the Former SRF, as shown in Figure 1-1. This is the lowest cost alternative, and requires the least amount of dredging and related coral mitigation costs. This alternative is referred to as the Former SRF Alternative.

The alignment of the alternatives was adjusted subsequent to the *CVN-Capable Berthing Study (2008)* to move the turning basin (and associated dredging) south and away from coral shoals.

1.3 Study Objectives

Sediment loading in the water column due to dredge operations forms a turbid plume that moves with the Apra Harbor currents. Plume transport and mixing in coastal waters is a complex process that depends on the characteristics of both the plume and the ambient receiving waters. The plume will be transported and dispersed due to currents driven by winds and tides, and modified by local and regional bathymetric features. The present study has been conducted to address concerns about possible impacts of sediment contained in dredge plumes. The currents in Apra Harbor are known to be complex. This project has been designed as a long-term (3-month) program to measure the currents in situ during different tide and wind current-forcing regimes a numerical circulation model supplements the measured current data by calculating current flow in the Apra Harbor basin. The measured currents are used to calibrate and verify the numerical model.

[1] Project background provided in *Draft EIS/OEIS for Guam and CNMI Military Relocation* –in progress. Prepared for NAVFAC Pacific. Anticipated DEIS publication in October 2009.

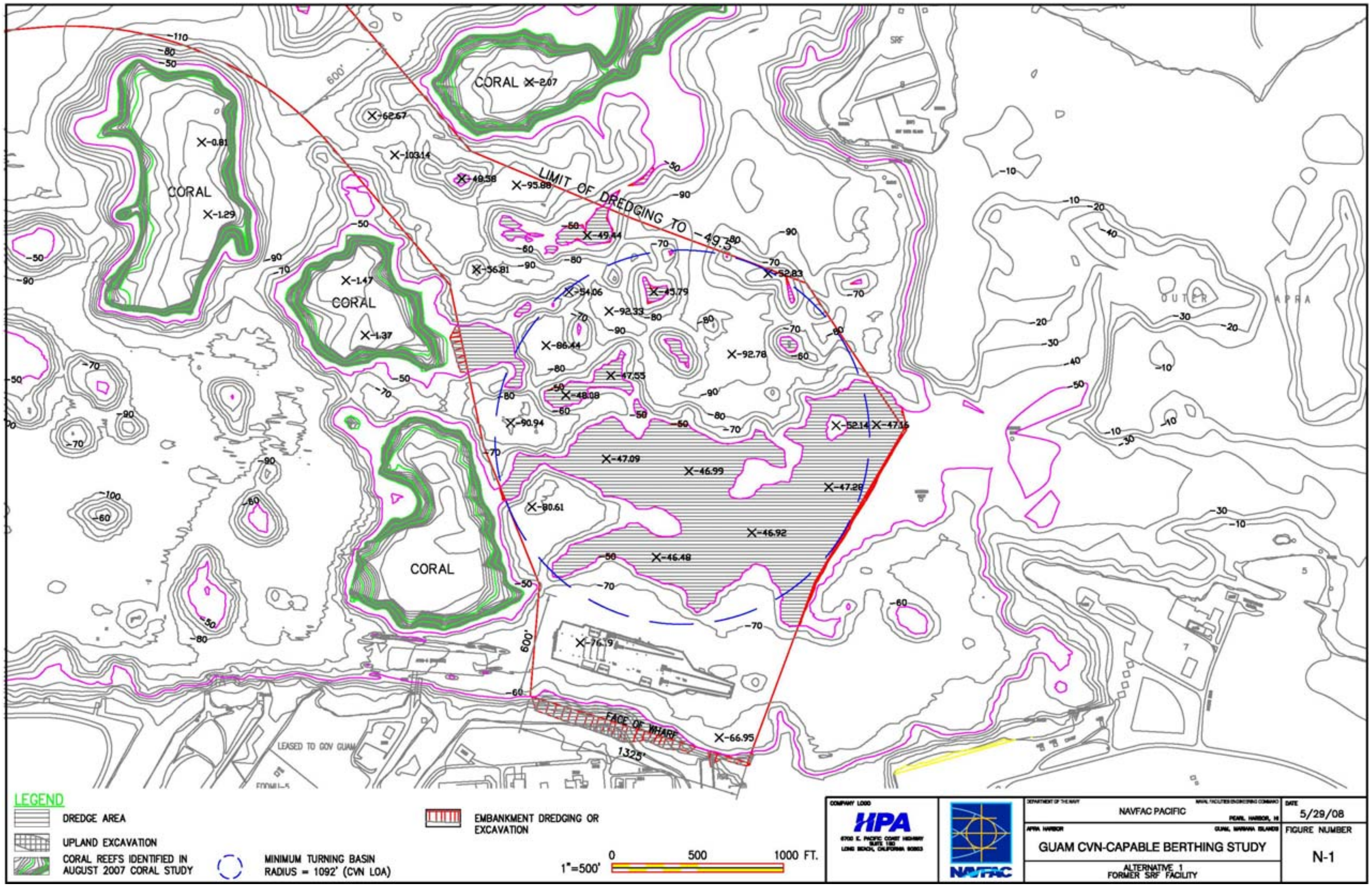


Figure 1-1. CVN Berthing Alternative 1 – Former Ship Repair Facility (SRF) (Source: NAVFAC Pacific 2008)

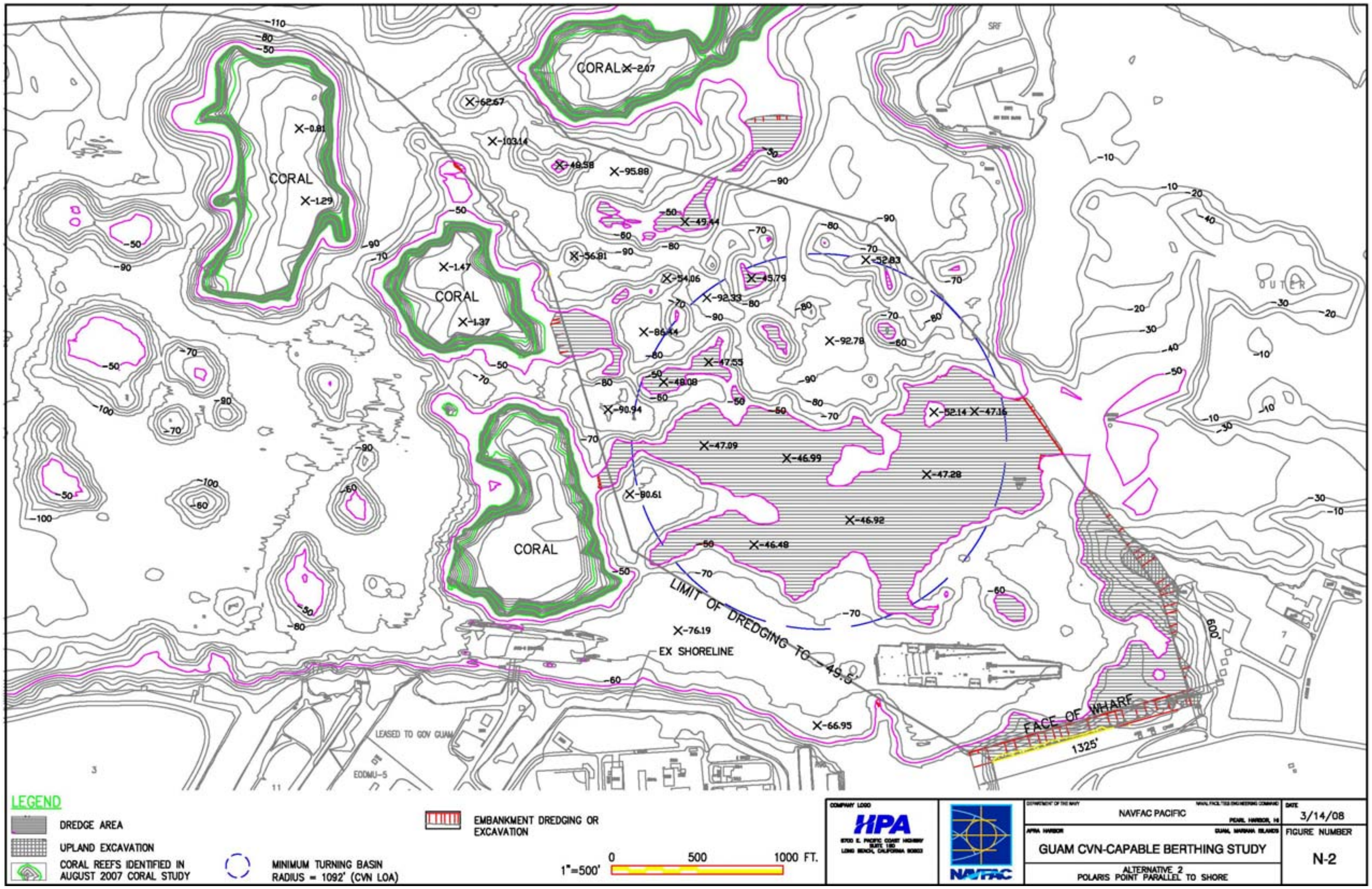


Figure 1-2. CVN Berthing Alternative 2 – Polaris Point Parallel to Shore (Source: NAVFAC Pacific 2008)

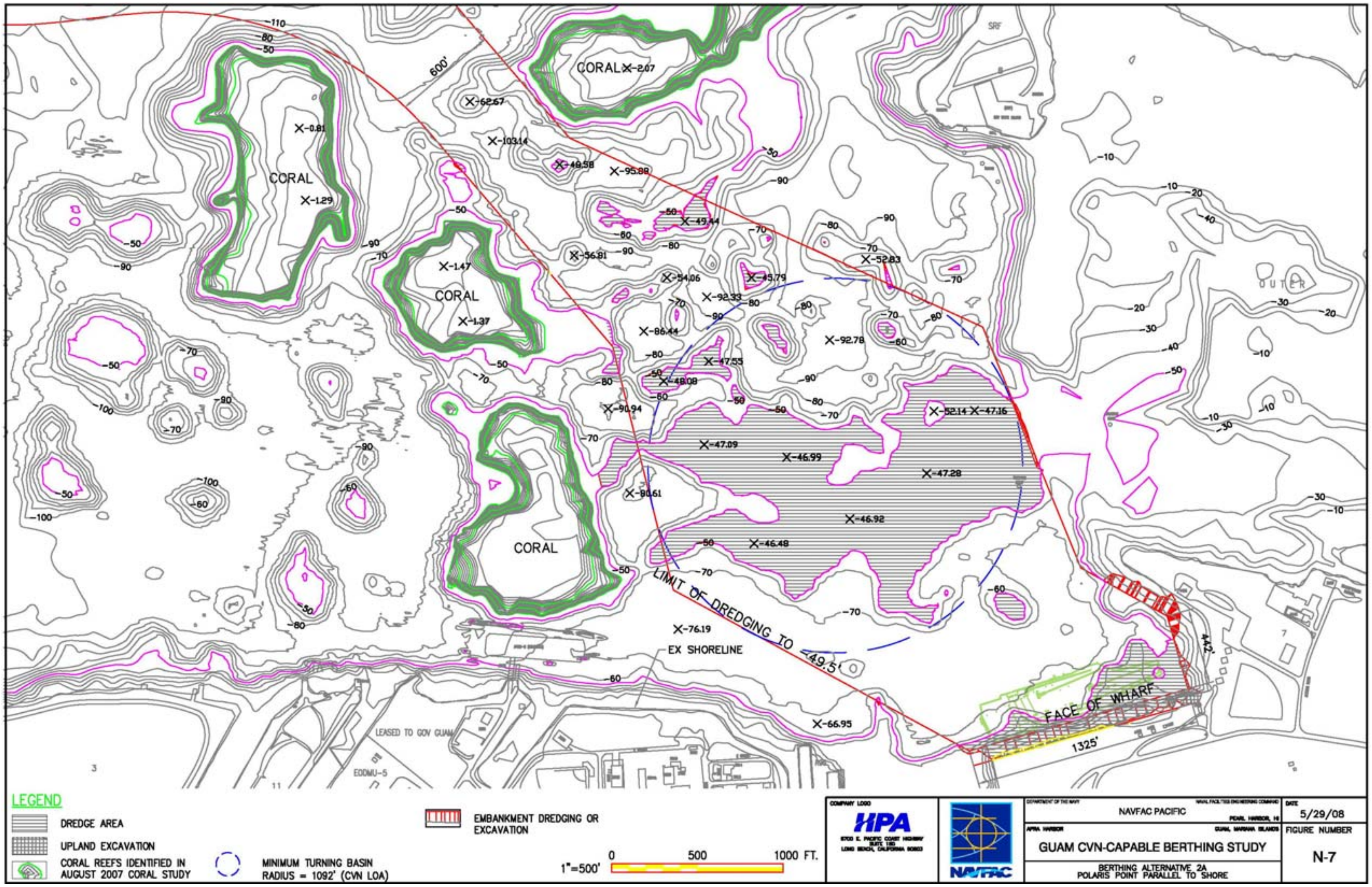


Figure 1-3. CVN Berthing Alternative 2A – Polaris Point Parallel to Shore-Reduced (Source: NAV FAC Pacific 2008)

2.0 OCEANOGRAPHIC CONDITIONS

2.1 Introduction

Guam is the largest and southernmost island in the Marianas Archipelago. It lies about 1,700 miles (2,636 kilometers [km]) south of Japan, 3,500 miles (5,633 km) west of the Hawaiian Islands, and about 1,500 miles (2,414 km) from the Philippines. The geographic location of Guam in the western tropical Pacific Ocean implies generally mild wind and sea conditions most of the time. Like many tropical areas, the weather consists of a dry season and a rainy season. The dry season runs from December to June, and the rainy season runs from July through November. This region is also known to spawn western Pacific tropical storms, typhoons and super-typhoons: some of the strongest storms on Earth. Tropical storm and typhoon occurrences can punctuate the normally mild conditions with periods of extreme weather with intense winds and high waves.

2.2 Climate and Winds

The dominant winds on Guam are the easterly trade winds. There is a distinct seasonality to the wind conditions in Guam. The trades are stronger and steadier in the winter (January to April), while light and variable winds periodically interrupt the trades in the summer typhoon season (July to October). The spring and fall months are transition periods. Figure 2-1 shows wind rose diagrams of data for January and September that show the two distinct wind patterns. The data were collected over the 30-year period from 1961 to 1991 (U.S. Dept. of Agriculture, www.wcc.nrcs.usda.gov/climate/windrose.html). The January data show strongly directional winds from the east-northeast, while the September data show lighter winds from many different directions.

A west wind condition known as a monsoon surge has also been recognized on Guam. During these conditions, tropical low-pressure troughs intensify southeast of the island, and cause periods of westerly winds. They are typically of short duration, and occur with low frequency during the summer months (Guard et al., 1999)

Table 2-1 shows the annual occurrence of winds at the former Agana Naval Air Station, Guam. Winds from east-northeast through southeast occur about 70 % of the time. Wind speeds greater than 25 mph (11 m/s) occur only 0.4 % of the time.

2.3 Geologic Conditions

Orote Point and the surrounding area are composed of re-crystallized coralline limestone known as Mariana Limestone, a dense and highly competent material. The coastal zone in the vicinity of the wharf is composed of fossilized reef platforms and living coral reef systems. The coral flourishes on the steep margins of Apra Harbor, until, at about 100 ft (30 m), the terrain becomes less steep, and marine sediments (fine sand and silt) have accumulated.

Boring logs from previous work indicate that the turning basin and channel dredge areas consist primarily of coarse gravel and sand material. The proposed berthing area adjacent to Polaris Point consists of a combination of silty sediments, and coarse material forming the shoreline. Analysis of grab samples collected within the turning basin area indicated that approximately 90% of the surficial sediments were very fine sand sized or coarser, and had a median grain size of approximately 0.1 mm (very fine to fine sand). Sediment cores from the same area classified the material as well-sort sand consisting of 73% sand and gravel and 17% silt (Weston Solutions, 2006). This data suggests that most of the material on the seafloor in the turning basin area that may be impacted by vessel maneuvering is sand-sized or greater, thereby minimizing the extent and duration of possible plumes that may result from vessel operations. The operational impacts would be short-term, localized and infrequent.

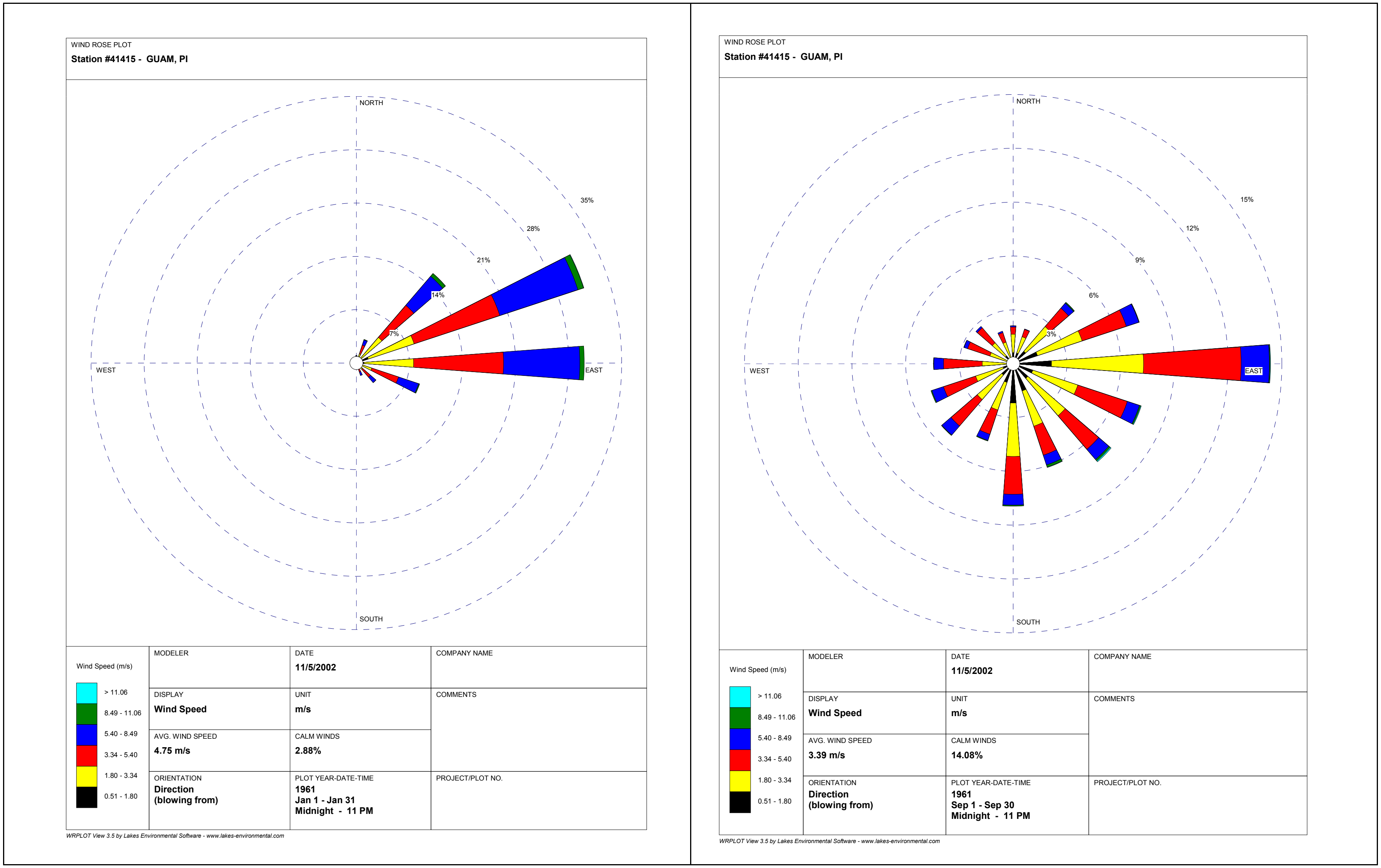


Figure 2-1. January and September Wind Roses Showing Seasonal Strong Trades vs. Variable Conditions (Source: US Dept. of Agriculture, www.wcc.nrcs.usda.gov/climate/windrose.html)

Table 2-1. Annual Percentage Occurrence of Winds on Guam
(Agana Naval Air Station)

Wind Direction	*Wind Speed (knots) (1 knot = 0.5 m/s)*				
	3-7	*8-12*	*13-20*	*21-30*	*Total*
N	0.7	0.3	-	-	1.1
NNE	0.8	0.5	0.1	-	1.5
NE	3.6	2.3	0.6	-	6.5
ENE	7.6	7.1	2.1	-	16.7
E	9.6	12.1	4.5	0.1	26.4
ESE	5.7	9.3	4.2	0.1	19.2
SE	3.2	3.6	1.2	0.1	8.0
SSE	1.4	1.3	0.4	0.1	3.2
S	1.5	0.8	0.2	-	2.6
SSW	0.5	0.3	0.1	-	1.0
SW	0.4	0.2	0.1	-	0.7
WSW	0.2	0.2	-	-	0.4
W	0.3	0.2	0.1	-	0.5
WNW	0.3	0.2	-	-	0.5
NW	0.4	0.2	-	-	0.6
NNW	0.4	0.2	-	-	0.6
CALM					10.5
Total	36.7	38.5	13.8	0.4	100.0
(Source: US Dept. of Agriculture, www.wcc.nrcs.usda.gov/climate/windrose.html)					

2.4 Waves

There are three types of waves that occur in Apra Harbor: 1) Trade wind and other locally generated waves, 2) Ocean swell, and, 3) Waves generated by tropical storms and typhoons.

Trade wind waves. Trade wind waves are locally generated within Apra Harbor. The factors that govern wave generation - wind speed, duration and fetch (the distance over which the wind blows) - are limited for these waves generated within the Harbor. There is a limited fetch distance for waves to be generated due to the location of the project site on the east side of the Harbor and the approach direction of the northeast trade winds. Duration is limited for normal conditions, as the trade winds tend to diminish in intensity during the evening and night. Trade wind speeds in Guam are rarely greater than 20 knots (10.3 m/s), and waves would rarely exceed 2 feet (0.6 m) in height.

Ocean Swell. Ocean swell is generated by storms some distance from the island, in particular mid-latitude winter storms that cross the Pacific Ocean. Ocean swell can also be generated by distant typhoons and tropical storms. The CVN project area is well-protected by Orote Point and the Glass Breakwater, and the Big Blue and Western Reef shoals.

Typhoon Waves. Guam is subject to strong winds associated with tropical storms and typhoons. Due to its proximity to typhoon breeding grounds, the island is threatened year-round with the passage of developing tropical storms and typhoons. Based on information from the US Fleet Weather Central, Guam (now the Joint Typhoon Warning Center), at least 19 typhoons typically occur annually across the western North Pacific and South China Sea.

Several of these storms threaten the Marianas Islands each year. Typhoons generate extreme wave heights, typically greater than 25 ft (7.6 m). The severity of wave impact on Guam is highly dependent on the typhoon intensity, direction of approach, and distance.

An extreme wave height analysis presented in the *CVN Capable Berthing Study* (NAVFAC Pacific 2008) for both ocean swell and locally generated typhoon waves indicates waves heights of 0.9, 4.0 and 7.7 feet (0.3, 1.2 and 2.3 m) at the Polaris Point site, with return periods of 2, 10 and 100 years respectively.

2.5 Currents

Coastal current patterns around Guam are poorly known, except at specific locations where project-related studies have been conducted. The North Equatorial Current, caused by the northeast trade winds, generally sets in a westerly direction near Guam, with speeds of 0.6 to 1.1 knots (0.3 to 0.6 m/s). According to Emery (1962) the North Equatorial Current diverges off Pati Point on the northeast side of the island. The two separate components then flow around the island, converging in the vicinity of Orote Point.

Current studies by Jones and Randall (1971) at the Agana Outfall and Tanguisson Point indicate a reversing current paralleling the shore driven by the semi-diurnal tide and modified by winds, waves, and submarine topography. Little is known of the current structure on the windward, eastern, and southern coasts.

Sea Engineering, Inc. (SEI) conducted current studies at Apra Harbor in 1980 that consisted of drogue studies inside the Harbor and a current meter on Calalan Bank just offshore of the Harbor entrance in 50 ft (15 m) of water depth. The current meter data showed that currents outside the Harbor flowed to the south (SSE through WSW) 75% of the time during ebb tide conditions, and 52% of the time during flood tide conditions. North flowing currents (WNW through NE) occurred 15% of the time during ebb tide conditions, and 33% of the time during flood tide condition. This seems to indicate that the flow off Apra Harbor is predominately to the south, but that flow reversals to the north sometimes occur, and that they are correlated with the tide. Semi-reversing flows like this are indicative of tidal forcing within a regional flow; with the tidal reversing pattern becoming predominant as the background flow weakens. This type of flow pattern also occurs in areas where regional flows converge, as indicated for this location in Emery (1962).

SEI drogue measurements were done over the course of three days in November, 1980, during strong trade wind conditions. Three drogue depths were used: 5 ft (1.5 m), 30 ft (9 m), and 55 ft (16.7 m). It was found that that the surface and mid-depth drogues moved to the west, toward the Harbor entrance, regardless of tide stage, and that the deep drogues moved east, into the Harbor, regardless of tide stage.

Surface currents in the drogue studies ranged from 0.066 to 0.5 feet per second (ft/s) (2 to 16 centimeters/second [cm/s]). Mid-level current speeds were approximately one half of the surface current values. Deep level current speeds were about the same as the mid-level currents, but in a direction approximately opposite, indicating significant shear between the 30- and 55-foot (9- and 16.7-meter) depths.

Guam tides are semi-diurnal with a diurnal inequality. This means that there are two unequal high tides and two unequal low tides each day. The mean tide range is 1.6 ft (0.49 m), with a maximum diurnal range of 2.3 ft (0.17 m). With the relatively small tide range, a resulting small tidal prism inside the Harbor, and the large cross-sectional area of the entrance channel and Outer Apra Harbor, the tidal influence could be expected to be weak. A 1976 study (C.E. Maguire and R.M. Towill, 1976) estimated the maximum tidal current in the entrance channel to be 0.16 ft/s (5 cm/s), with weaker currents in the wider Inner Harbor areas.

SEI (1980) postulated that the currents in the Harbor are primarily wind driven during trade wind conditions. The two layer flow results from the movement of the surface layer out of the Harbor being balanced by an inward moving deeper layer. A detailed current measurement and modeling study conducted by Sea Engineering in 2004 for the Kilo Wharf extension project confirmed the wind-driven two layer flow system. This study found weak currents in the vicinity of Kilo Wharf; surface currents were typically 0.1 to 0.2 ft/s (3 to 6 cm/s) while bottom layer currents were typically less than 0.06 ft/s (2 cm/s). Currents in the entrance channel were stronger, with surface currents averaging 0.3 ft/s (10 cm/s), and bottom layer currents 0.16 to 0.19 ft/s (5 to 6 cm/s).

3.0 FIELDWORK

3.1 ADCP Deployment

3.1.1 Introduction

Seven acoustic doppler current profiler (ADCP) instruments were deployed to measure currents in Apra Harbor for a three-month period between November 1, 2007 and January 30, 2008. Two ADCPs were deployed in the Inner Harbor and the five were deployed in the Outer Apra Harbor within a 1700-meter radius of the Inner Harbor entrance. In addition to ADCP deployment, current measurements were conducted using drogues during the field work. All ADCPs were manufactured by RD Instruments, Inc. (RDI).

3.1.2 Description of Fieldwork

In the Inner Harbor, one ADCP was placed near the southeastern edge of the turning basing (CM1) and one near the entrance of the Harbor (CM2). The first ADCP was planned to be in the turning basin, but due to nearby dredging activities, it was deployed slightly outside the turning basin. In the Outer Apra Harbor, three ADCPs were deployed along the southern shoreline at Charlie Wharf (CM3), SRF Wharf and west side of Sumay Cove entrance (CM5). The remaining two were placed at the eastern edge of the turning basin (CM6) and in the fairway (CM7). The range of water depths at the ADCP stations was 36 feet (11 m) at CM1 to 98 feet (30 m) at CM5. The ADCP instrument locations are shown on Table 3-and Figure 3-1.

Table 3-1. ADCP Station Information

Meter Station	*ADCP ID Number*	*Latitude*	*Longitude*	*Water Depth (m)*
CM1	9049	13°25.823'N	144°40.017E	11.1
CM2	7061	13°26.430'N	144°39.977E	14.1
CM3	2169	13°26.665'N	144°40.065E	22.5
CM4	5941	13°26.678'N	144°39.721E	23.1
CM5	0454	13°26.725'N	144°39.184E	30.1
CM6	7813	13°26.815'N	144°39.942E	14.2
CM7	7856	13°27.306'N	144°39.429E	14.7

3.2 ADCP Retrieval

The ADCP instruments were retrieved on January 30, 2008. All seven ADCP instruments functioned properly during the entire 3-month deployment, with100% data recovery.

Figure 3-1. ADCP Deployment Sites

4.0 FIELD DATA ANALYSIS

4.1 Wind Data

Wind data for the first two-month ADCP deployment period were provided by the staff officer at the U.S. Naval Pacific Meteorological and Oceanography Center West, COMNAVREGMARIANAS. The wind instrument was located on COMNAVMAR at Building 6003, in Apra Harbor. Wind was measured at a standard 32.9 ft (10 m) height and was recorded at a 15-minute interval. For the month of January 2008, wind data was obtained from the Guam Airport.

The time series of wind data at Apra Harbor and Guam Airport are shown as monthly plots in Figure 4-1. Wind roses are shown in Figures 4-2 and 4-3 and the corresponding wind histograms are given in Table 4-1 and Table 4-2, respectively.

The wind data allow categorization of climate regimes for the current meter deployment period. In Guam, November through December is a transitional period between summer, with light and variable winds, and winter, with strong steady trade wind. The wind histograms and wind roses also show that January has stronger and more persistent trade wind than the months of November and December. In January, 2008, 92.5 % of the wind was between the northeast and east directions, with an average speed of 10.9 knots (5.6 m/s). The wind in November and December in the same directional sector occurred 79.1 % of the time with an average speed of 7.8 knots (4.0 m/s).

Current measurements were conducted during the transitional period of November through January in order to capture both light wind and prevailing trade wind conditions. Although the data show predominant trade wind conditions, there were also short periods of light and moderate southerly winds. A strong diurnal periodicity was also noticed in the data, with daily peaks occurring at mid-day throughout the record.

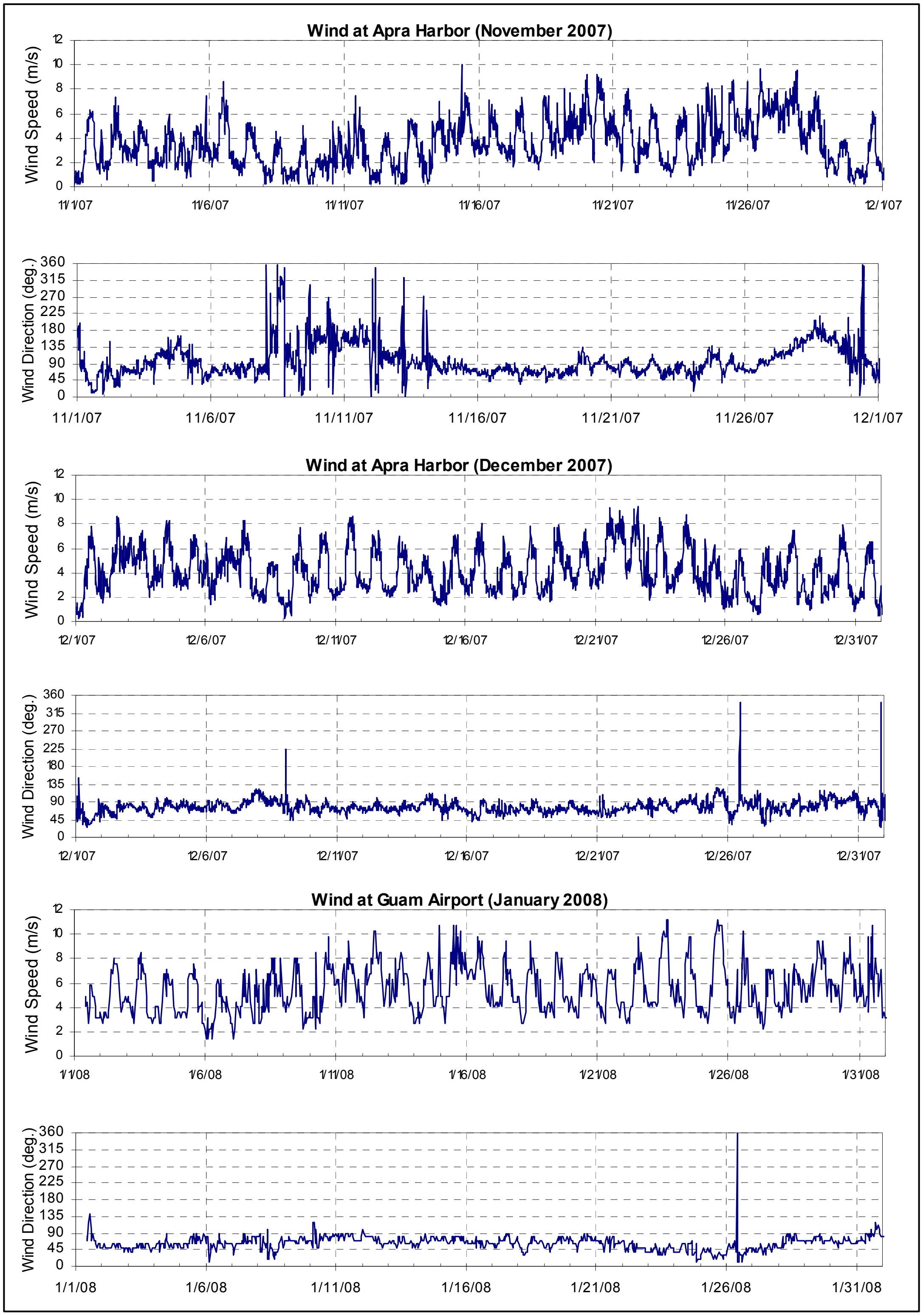


Figure 4-1. Wind for November 2007 to January 2008 at Apra Harbor and Guam Airport

Table 4-1. Wind Histograms for November 2007 and December 2007 at Apra Harbor, Guam

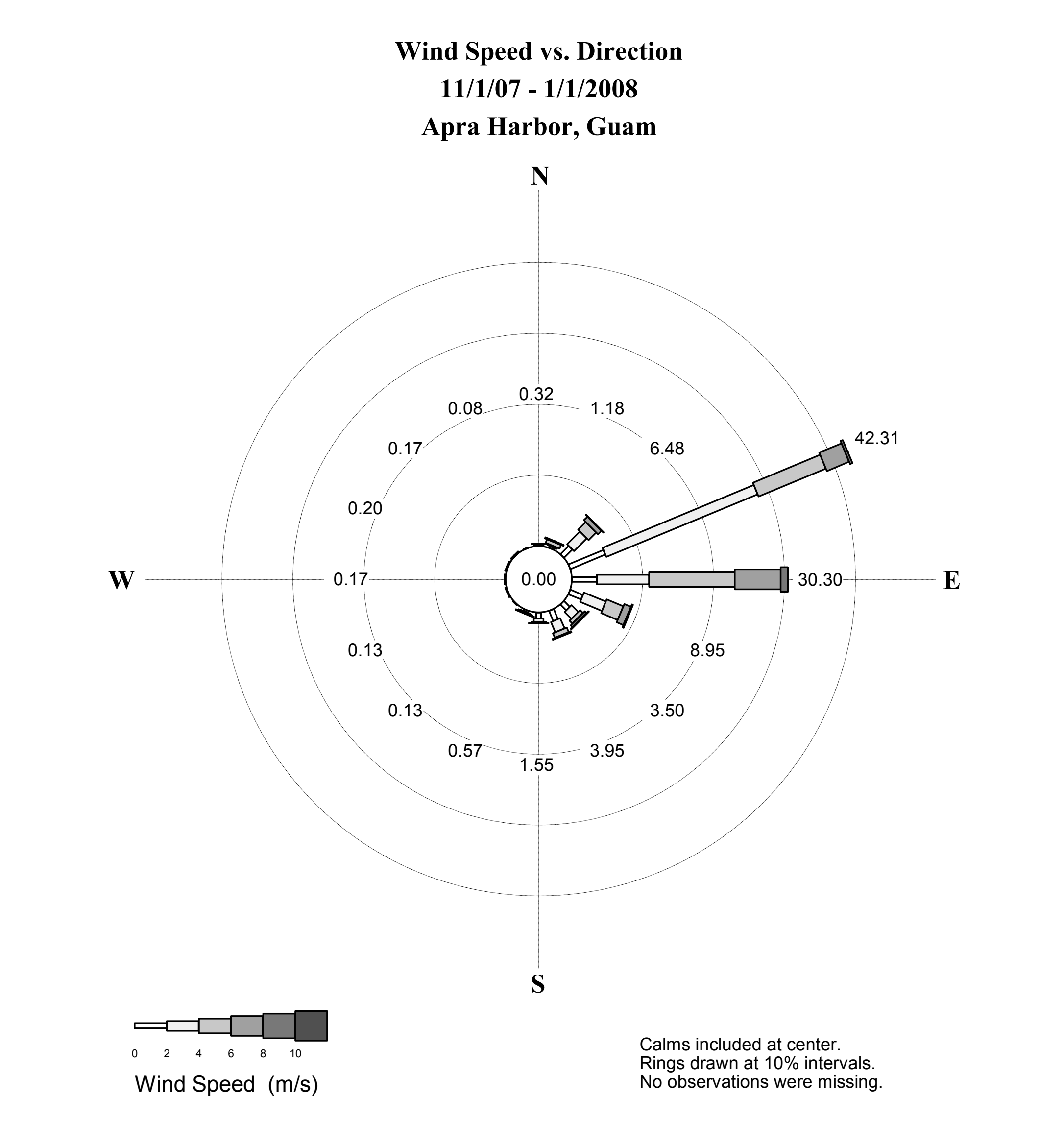
WIND SPEEDS VS. DIRECTIONS
(11/01/07 - 1/1/08)

M/S	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	TOTAL
0-2	.20	.27	1.68	5.33	3.50	1.92	1.16	1.56	.86	.27	.10	.07	.12	.08	.07	.07	17.26
2-4	.08	.20	2.52	23.01	7.30	3.35	1.35	1.55	.44	.08	.02	.07	.05	.12	.10	.00	40.24
4-6	.03	.56	1.53	10.23	12.01	2.54	.54	.69	.17	.10	.02	.00	.00	.00	.00	.02	28.43
6-8	.00	.15	.71	3.40	6.46	.99	.34	.15	.08	.12	.00	.00	.00	.00	.00	.00	12.40
8-10	.00	.00	.03	.34	1.01	.15	.12	.00	.00	.00	.00	.00	.00	.00	.00	.00	1.65
10 <	.00	.00	.00	.00	.02	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.02
INDET																	.00
TOTAL %	.32	1.18	6.48	42.31	30.30	8.95	3.50	3.95	1.55	.57	.13	.13	.17	.20	.17	.08	100.0
AVERAGE	1.7	4.0	3.4	3.6	4.6	3.7	3.2	2.7	2.3	3.3	1.3	1.7	1.5	2.3	2.4	2.0	3.8
MAXIMUM	5.7	7.0	8.1	9.3	10.1	9.2	9.5	7.5	7.8	7.0	4.3	3.8	3.4	3.9	3.6	4.1	10.1
STD DEV	1.7	2.1	1.8	1.6	1.9	1.9	2.1	1.6	1.7	2.4	1.4	1.4	1.3	1.4	1.3	1.2	1.9

Table 4-2. Wind Histogram for January 2008 at Guam Airport

WIND SPEEDS VS. DIRECTIONS
(01/01/08 - 01/31/08)

M/S	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	TOTAL
0-2	.30	.10	.00	.10	.10	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.60
2-4	.40	.70	8.38	6.99	2.59	.00	.10	.00	.00	.00	.00	.00	.00	.00	.00	.00	19.16
4-6	.30	1.40	9.18	18.36	6.29	.60	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	36.13
6-8	.00	1.50	4.19	14.07	10.58	.10	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	30.44
8-10	.00	1.10	1.80	5.99	2.59	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	11.48
10 <	.00	.90	.20	.40	.70	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	2.20
INDET																	.00
TOTAL %	1.00	5.69	23.75	45.91	22.85	.70	.10	.00	.00	.00	.00	.00	.00	.00	.00	.00	100.0
AVERAGE	3.0	6.8	4.9	5.7	6.2	5.2	2.7	.0	.0	.0	.0	.0	.0	.0	.0	.0	5.6
MAXIMUM	5.8	11.2	10.7	10.7	10.7	7.2	2.7	.0	.0	.0	.0	.0	.0	.0	.0	.0	11.2
STD DEV	1.9	2.6	1.9	1.8	1.8	.9	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	2.0



PERCENT OCCURRENCE: Wind Speed (m/s)
LOWER BOUND OF CATEGORY

DIR	0	2	4	6	8	10
N	0.20	0.08	0.03	0.00	0.00	0.00
NNE	0.27	0.20	0.56	0.15	0.00	0.00
NE	1.68	2.52	1.53	0.71	0.03	0.00
ENE	5.33	23.01	10.23	3.40	0.34	0.00
E	3.50	7.30	12.01	6.46	1.01	0.02
ESE	1.92	3.35	2.54	0.99	0.15	0.00
SE	1.16	1.35	0.54	0.34	0.12	0.00
SSE	1.56	1.55	0.69	0.15	0.00	0.00

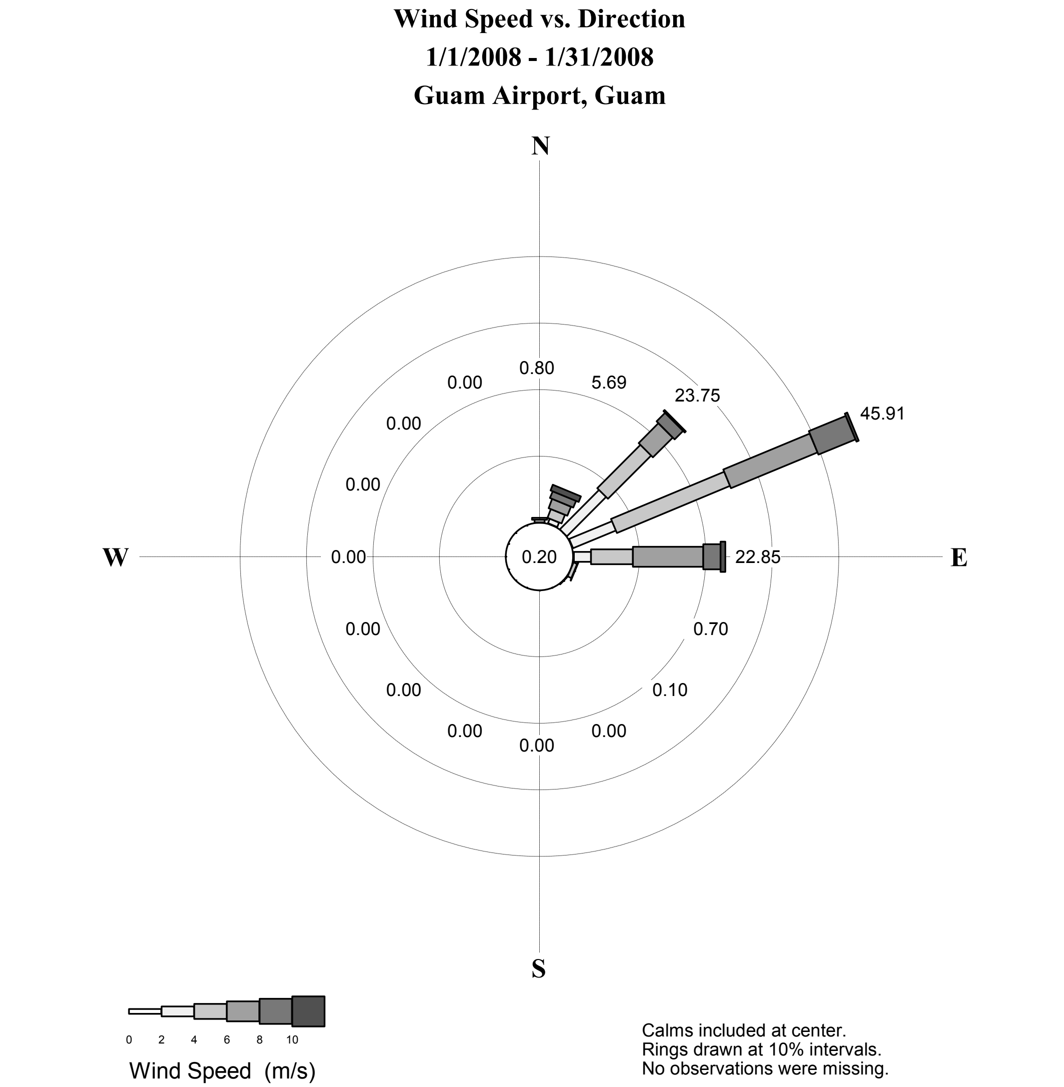
TOTAL OBS = 5944 MISSING OBS = 0

PERCENT OCCURRENCE: Wind Speed (m/s)
LOWER BOUND OF CATEGORY

DIR	0	2	4	6	8	10
S	0.86	0.44	0.17	0.08	0.00	0.00
SSW	0.27	0.08	0.10	0.12	0.00	0.00
SW	0.10	0.02	0.02	0.00	0.00	0.00
WSW	0.07	0.07	0.00	0.00	0.00	0.00
W	0.12	0.05	0.00	0.00	0.00	0.00
WNW	0.08	0.12	0.00	0.00	0.00	0.00
NW	0.07	0.10	0.00	0.00	0.00	0.00
NNW	0.07	0.00	0.02	0.00	0.00	0.00

CALM OBS = 0 PERCENT CALM = 0.00

Figure 4-2. Wind Rose at Apra Harbor During November and December 2007



PERCENT OCCURRENCE: Wind Speed (m/s)
LOWER BOUND OF CATEGORY

DIR	0	2	4	6	8	10
N	0.10	0.40	0.30	0.00	0.00	0.00
NNE	0.10	0.70	1.40	1.50	1.10	0.90
NE	0.00	8.38	9.18	4.19	1.80	0.20
ENE	0.10	6.99	18.36	14.07	5.99	0.40
E	0.10	2.59	6.29	10.58	2.59	0.70
ESE	0.00	0.00	0.60	0.10	0.00	0.00
SE	0.00	0.10	0.00	0.00	0.00	0.00
SSE	0.00	0.00	0.00	0.00	0.00	0.00

TOTAL OBS = 1002 MISSING OBS = 0

PERCENT OCCURRENCE: Wind Speed (m/s)
LOWER BOUND OF CATEGORY

DIR	0	2	4	6	8	10
S	0.00	0.00	0.00	0.00	0.00	0.00
SSW	0.00	0.00	0.00	0.00	0.00	0.00
SW	0.00	0.00	0.00	0.00	0.00	0.00
WSW	0.00	0.00	0.00	0.00	0.00	0.00
W	0.00	0.00	0.00	0.00	0.00	0.00
WNW	0.00	0.00	0.00	0.00	0.00	0.00
NW	0.00	0.00	0.00	0.00	0.00	0.00
NNW	0.00	0.00	0.00	0.00	0.00	0.00

CALM OBS = 2 PERCENT CALM = 0.20

Figure 4-3. Wind Rose at Guam Airport During January 2008

4.2 Current Drogue Measurements

During the course of the current meter deployment and retrievals, current measurements were also collected using window shade drogues. These are made from 6 ft by 8 ft (1.8 m x 2.4 m) plastic tarps suspended at two depths in the water column. The drogues are suspended from a surface buoy to the desired depth, and then tracked using GPS. The drogues move with the water mass at the depth they are located. The drogues are a useful addition to current meter data as they show spatial changes in currents as well as changes in time. Two drogues were deployed, one on the surface at a depth of 3 ft (0.9 m) at the top of the tarp, and one at 20 ft (6.1 m).

Figures 4-4 to 4-7 show the results of 3 days of drogue measurements. During the drogue study wind was mainly easterly with speeds of 8 to 15 knots (4.1 to 7.7 m/s). The highest current speed measured in the Inner Apra Harbor was 0.12 knots (0.61 m/s) with east wind of 8 to 12 knots (4.1 to 6.2 m/s) during a high water slack tide (Figure 4-7). In the Outer Apra Harbor, the fastest drogue current speed was 0.17 knots (0.86 m/s) with east wind of 12 knots (6.2 m/s), also during a high water slack tide (Figure 4-6). A two-layer flow was evident for some deployments. Most data showed that the surface layer moved in westerly directions and the deeper water layer deviated in speed and direction from the surface layer. On one occasion, on November 1, 2007, the surface layer moved easterly and the deeper layer moved southerly in the Inner Apra Harbor during flood tide and northeast wind of 10 knots (5.1 m/s) (Figure 4-4). The surface drogue and the deeper layer drogue in the Outer Apra Harbor on November 2, 2007 moved in nearly opposite directions, the surface layer moving westerly and the deeper layer moving easterly during a flood tide with easterly wind of 11-12 knots (5.7 to 6.2 m/s) (Figure 4-5).

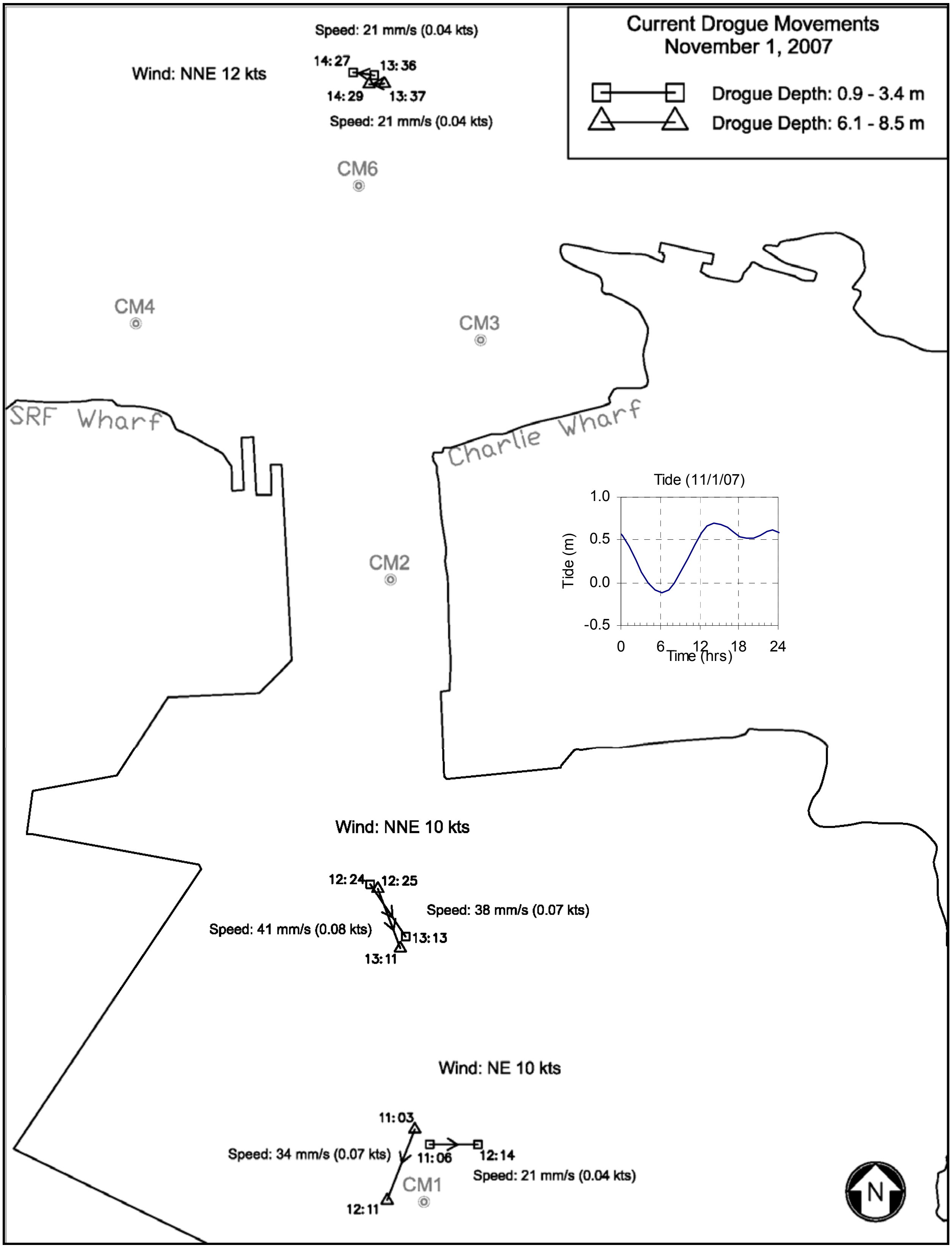


Figure 4-4. Drogue Currents on November 1, 2007

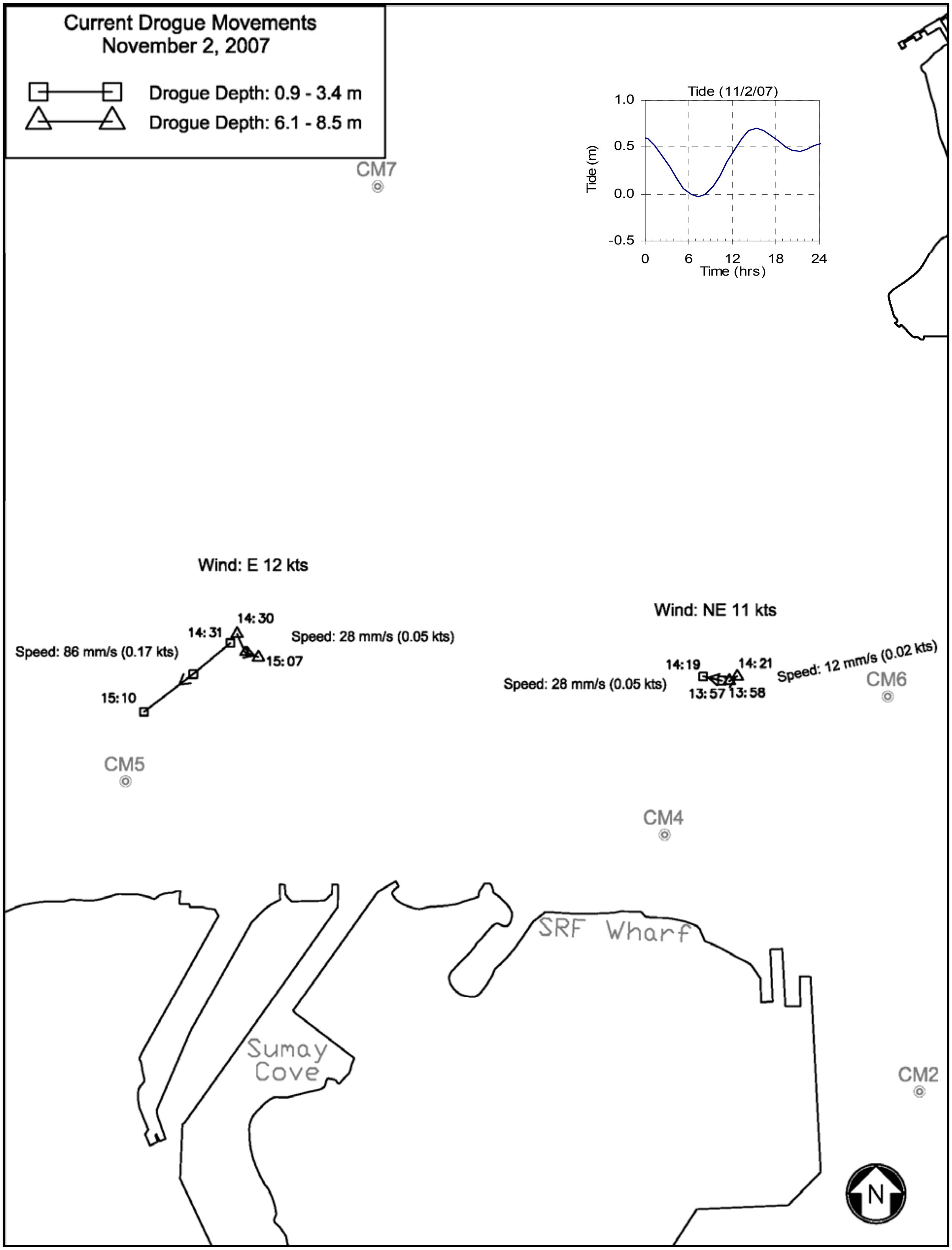


Figure 4-5. Drogue Currents on November 2, 2007

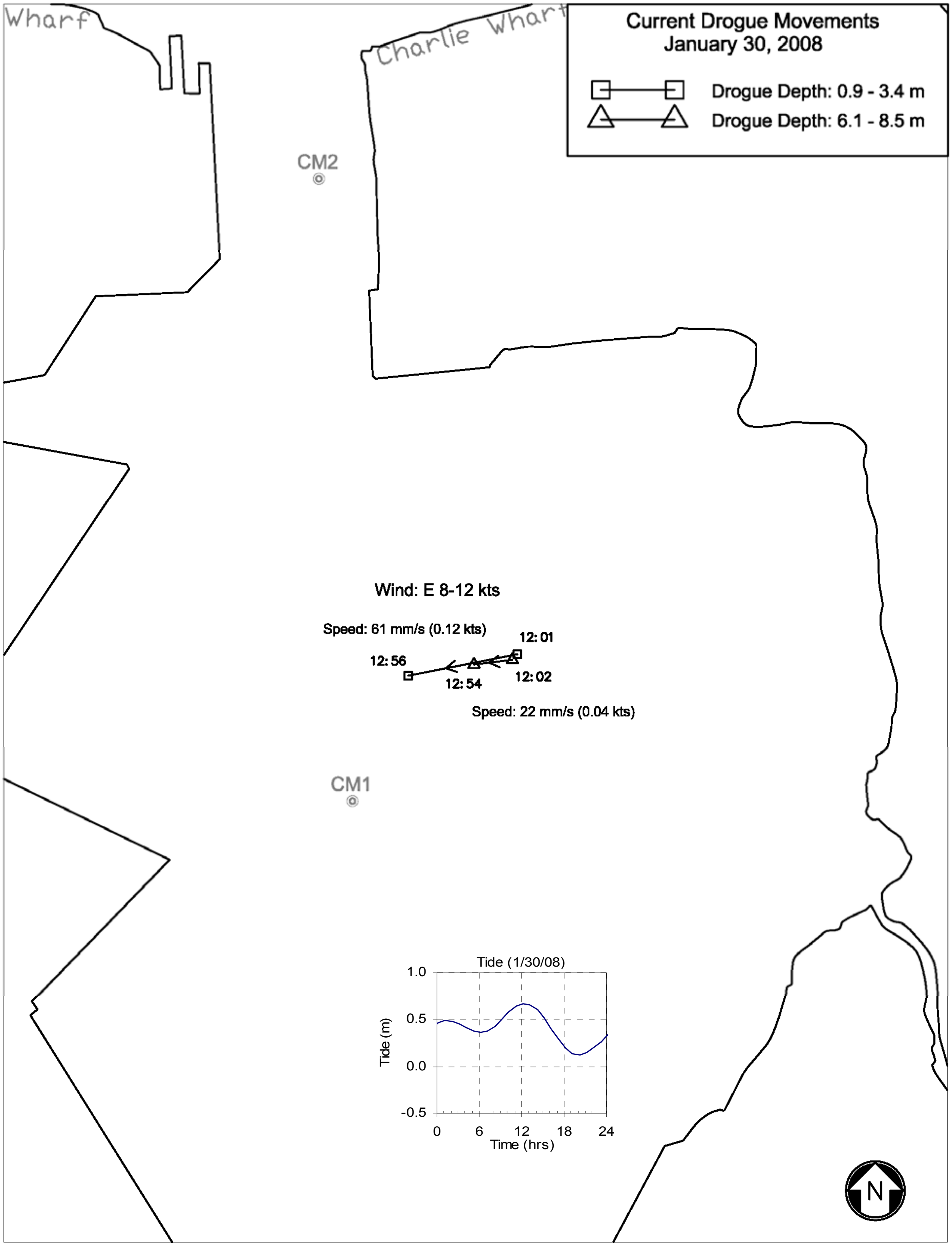


Figure 4-6. Drogue Currents on January 30, 2008 (Case 1)

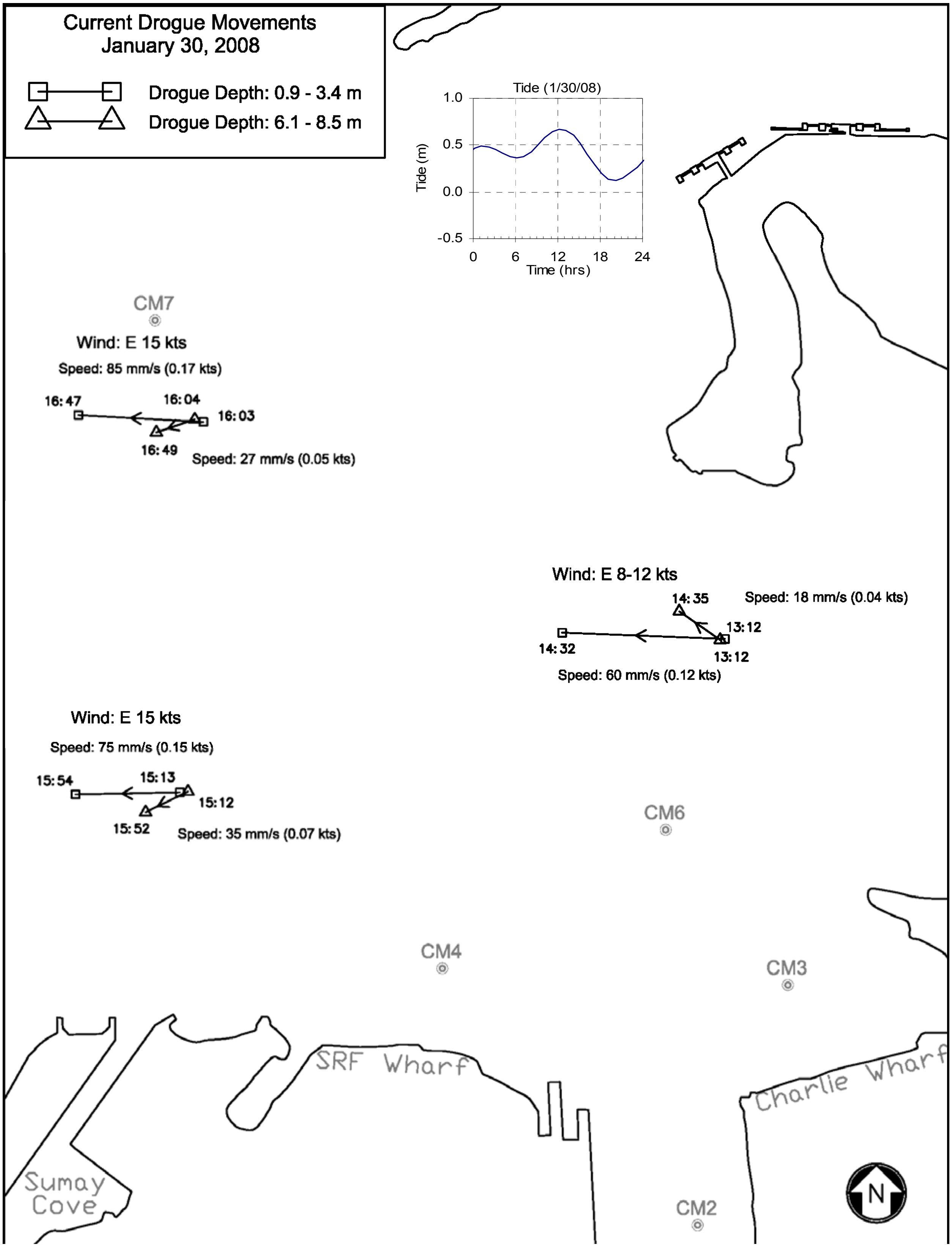


Figure 4-7. Drogue Currents on January 30, 2008 (Case 2)

4.3 ADCP Data

4.3.1 Theory of Operation

ADCPs are sophisticated instruments that use the well-known Doppler Effect to measure water particle movement. The instruments emit acoustic beams that propagate through the water column. Acoustic backscatter from particulates in the water column is shifted to higher frequencies or lower frequencies depending on the relative motion of the particulates to the acoustic beams. By separating the backscatter return by time, different layers of the water column can be measured. In common with all transducer-generated acoustics, the acoustic beams have associated side lobe patterns. At the sea surface, reflections of the side lobes cause noise that can contaminate the data. As a result, the surface layer of six % of the water column plus one bin size is typically not useable data. Also, the acoustic measurement begins at some distance above the instrument. The distance depends on the ADCP frequency and the measurement bin size. Higher frequency instruments can measure closer to the sea surface, and similarly start measurement closer to the instrument.

For this study a variety of instrument frequencies were used: 300, 600, and 1200 kHz. Measurements were conducted using discrete one-meter bin increments. ADCP data collection specifications are listed in Table 4-3.

The ADCPs used in this study were manufactured by RD Instruments (RDI). The instrument results were calculated only in International Standard (SI) units. Instrument collection parameters are listed below.

Instrument Set-Up Specifications

Bin interval: 1 m (3.3 ft)

Sampling Rate:

Ensemble length: 20 minutes

Samples per Ensemble: 50

Sample rate: 24 seconds

Sample description: Data values are the average of 50 samples taken at 24-second intervals over a 20-minute period

Standard deviation of velocity data per ensemble for the setting: 1200 kHz (0.42 cm/s), 600 kHz (0.86 cm/s) and 300 kHz (1.82 cm/s)

4.3.2 ADCP Current Measurements in Apra Harbor

Figure 3-1 in the previous chapter shows the general study area and the seven ADCP deployment locations. The seven ADCP stations are indicated as CM1 through CM7 in the Figure.

CM1 – near southeastern edge of the turning basin in the Inner Apra Harbor

CM2 – near the entrance of the Inner Apra Harbor

CM3 – along Charlie Wharf in the Outer Apra Harbor

CM4 – along SRF Wharf in the Outer Apra Harbor

CM5 - west side of Sumay Cove entrance in the Outer Apra Harbor

CM6 - at the eastern edge of the turning basin in the Outer Apra Harbor

CM7 - in the Fairway in the Outer Harbor

Water depths for the ADCP stations are listed in Table 4-3.

Table 4-3. ADCP Station Information

Meter Station	*ADCP Frequency (kHz)*	*Water Depth (m)*	*Top Bin Depth (m)*	*Number of Bins*
CM1	1200	11.1	1.8	8
CM2	600	14.1	2.3	10
CM3	600	22.5	2.7	18
CM4	600	23.1	2.3	19
CM5	300	30.1	3.2	24
CM6	600	14.2	1.4	11
CM7	600	14.7	1.9	11

4.3.3 ADCP Data (November 1, 2008 to January 30, 2008)

The high resolution of the ADCP data showed the currents in Apra Harbor to be complex. While generally low in average magnitude, currents measured by the instruments are characterized by spikes in both speed and direction.

A 3-day sample of raw ADCP current data from CM6 in the project area during trade wind conditions is presented in Figure 4-8. Individual data points are 20-minute averages. Bin 1 is closest to the meter location at the bottom. Complete data records are presented in Appendix A.

The ADCP data were processed for each 3.3-ft (1-meter) bin. Two data subsets were constructed based upon wind data:

- Two weeks of typical steady trade winds, and
- Moderate southerly winds lasting for nearly two days.

The selected wind conditions are listed in Table 4-4.

Table 4-4. Wind Conditions Selected

Wind Conditions	*Period*		*Average*	
			Speed (m/s)	*Direction (deg)*
Northeast Trade Wind	12/15/07 – 12/28/07	14.0 days	4.1	077
Southerly Wind	11/27/07 – 11/29/07	1.9 days	3.6	158

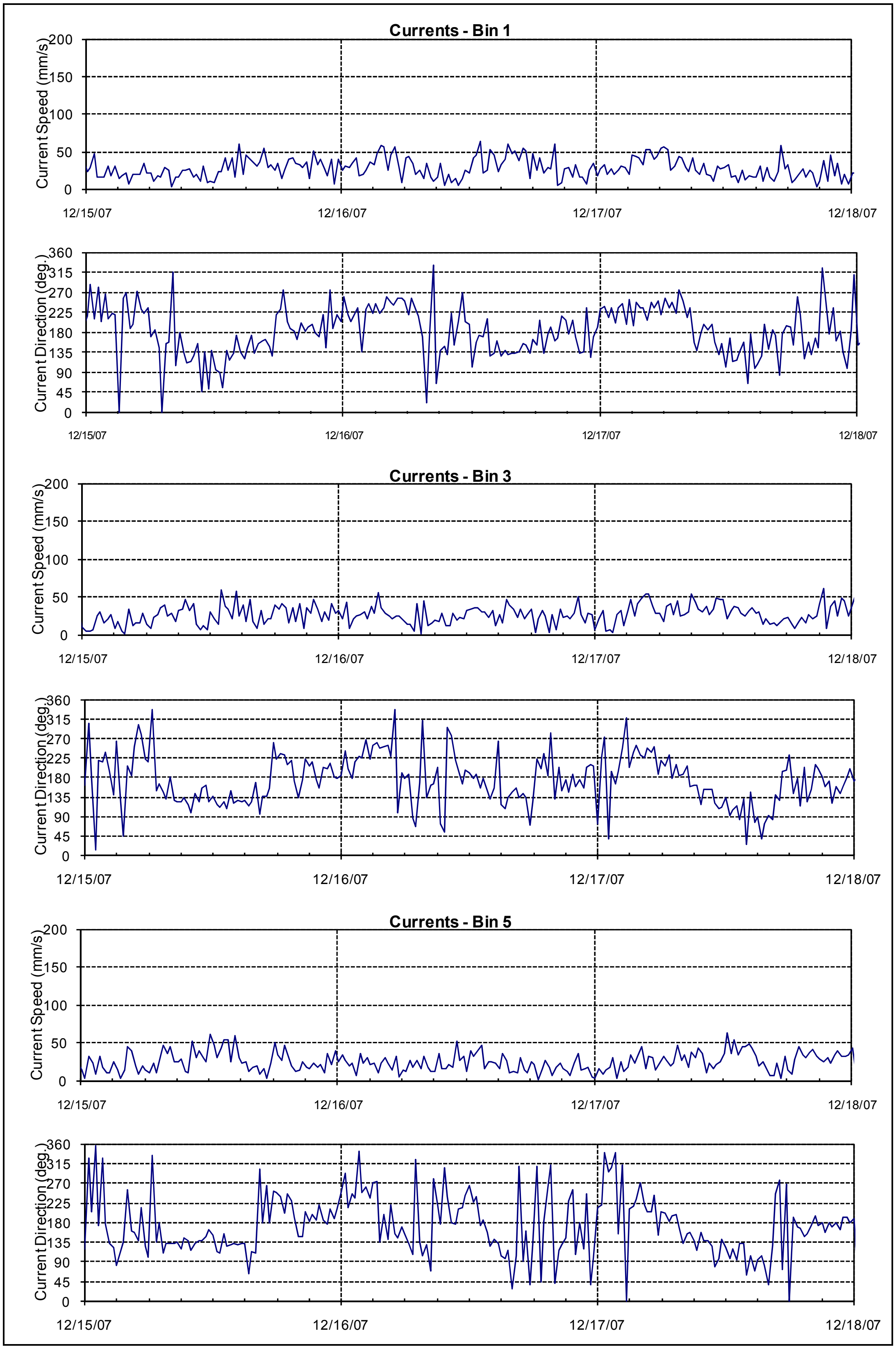


Figure 4-8. ADCP Currents and Water Level at CM6

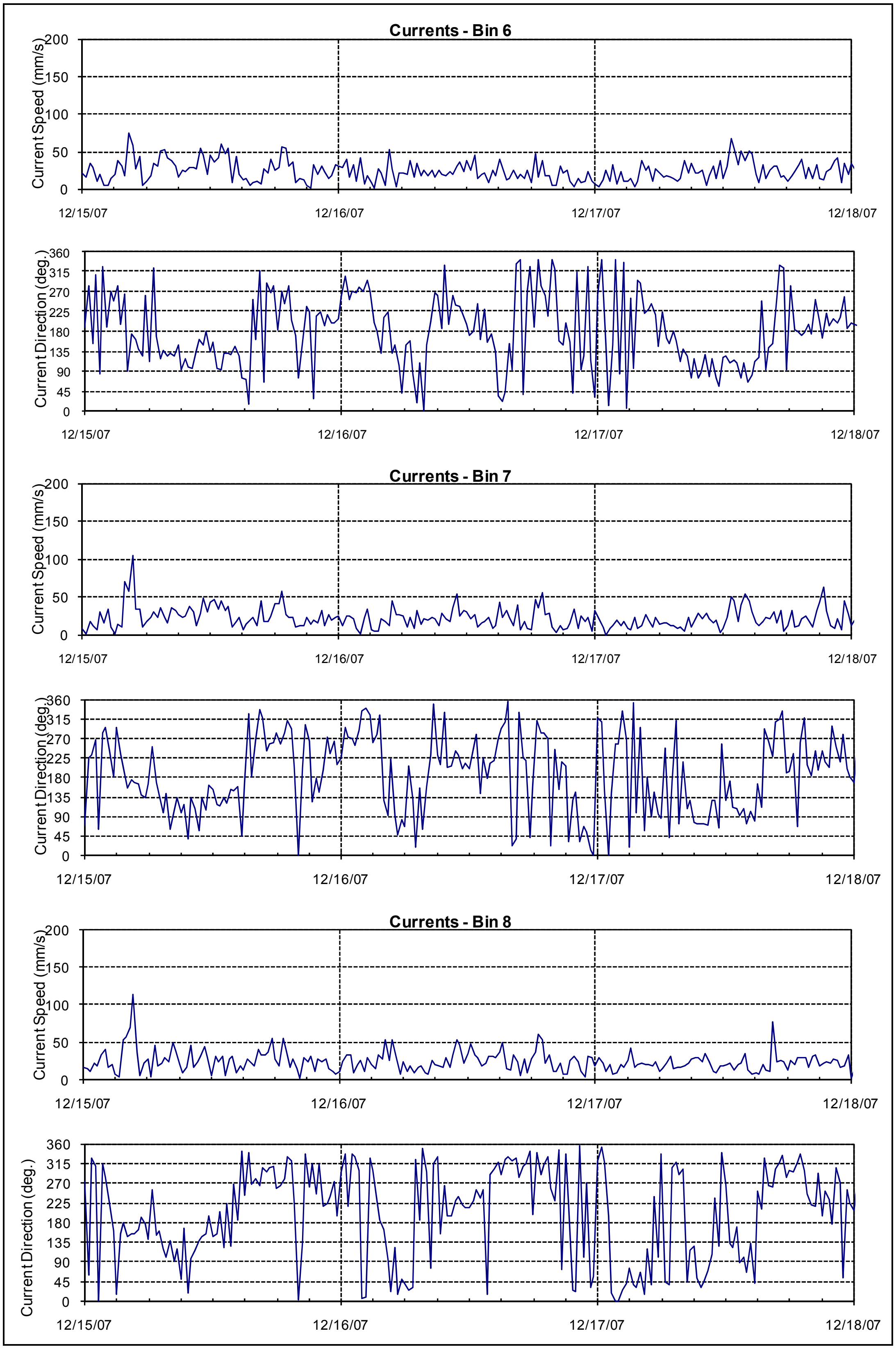


Figure 4-8. Continued

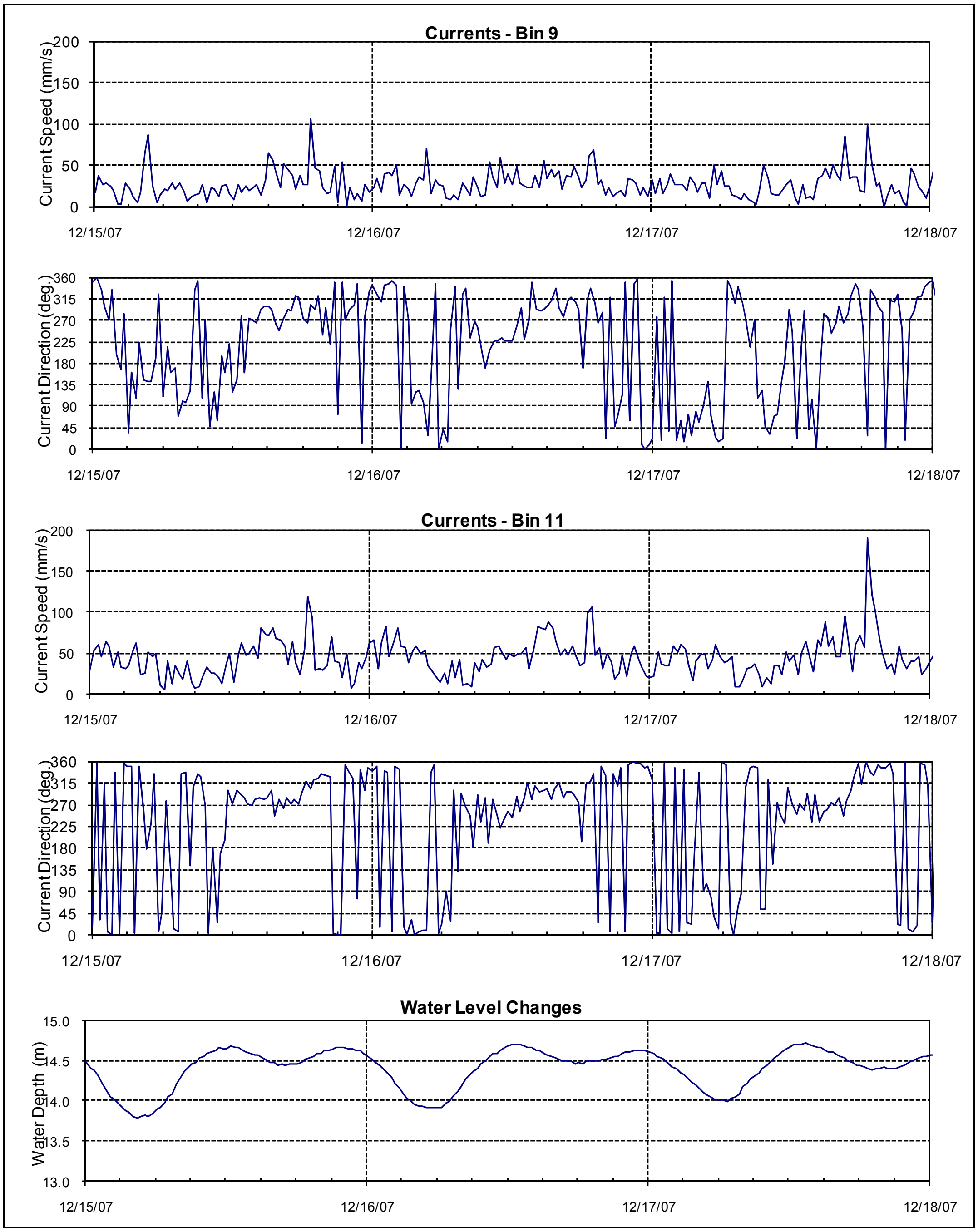


Figure 4-8. Continued

4.3.4 Data Averages

The ADCP data were further processed to reduce data complexity by using time averages of each 3.3ft (1-meter) bin for the two climate subsets defined in Table 4-4, two weeks of typical steady trade winds, and moderate southerly winds for nearly two days. The wind subsets are used to examine wind influence on currents in the study area. Each of the two wind intervals was further separated into two intervals for ebb and flood tide in order to examine the influence of tide on the currents.

The average data values are current vector averages or net currents. These values are the result of the speed and direction averages for each bin over the time period of interest.

Figures 4-9 to 4-15 are net current profiles of all data recorded during the three-month period at each ADCP location. These profiles provide general net current information at ADCP locations for a relatively long period of time. The figures include speed (mm/s), and horizontal direction. A high net current speed suggests dominant current in one direction. A low net current speed suggests low current in one direction or currents in nearly equally distributed opposing directions. The following are brief summaries of the net currents at ADCP locations.

CM1 was located by the southeast limit of the turning basin in the Inner Harbor. The net current had a minimum speed of 4 mm/s at the top layer bin and a maximum speed of 23 mm/s at the bottom layer bin. The current directions gradually changed from north at the top to south-southeast at the bottom.

At CM2, near the entrance of the Inner Harbor, the net current had a minimum speed of 2 mm/s at layer bin 7 and a maximum speed of 48 mm/s at layer bin 3. The net current speeds were nearly similar at the top (37 mm/s) and the bottom (42 mm/s). At this location, the net currents had a clear two layer current profile with a south flow (in to the Harbor) in bin 1 through bin 7 and a north flow (out of the Harbor) near the surface. The flow direction reversed at bins 7 and 8.

At CM3, along Charlie Wharf, flow toward the northeast through south directions (clockwise) was bounded by the shoreline. The net current was relatively small, with the maximum speed of 7 mm/s at the top bin and the minimum speed of 1.5 mm/s at bin 3. At the bottom bin the speed was 4.5 mm/s. The flow directions were between the northeast and east-northeast directions at bins 4 through 18 and approximately southeast at the bottom three bins

At CM4 along SRF Wharf, the net current flow had a noticeable two-layer current structure. The top bin flowed toward the west-northwest, while the rest of the current profile flowed in directions between east and southeast. The maximum speed was 32 mm/s at the bottom bin.

CM5 was located along the southern shoreline in the Outer Harbor, west of the Sumay Cove entrance. The CM5 ADCP site had the deepest water depth of the seven ADCP locations. The maximum net current was 18 mm/s at the top (bin 24), and the minimum speed was 3 mm/s at bin 22. The net current directions near the surface were toward the west. Bins 19 and 20 were transitional layers. At bin 1 through 19, the net current speeds ranged between 9 and 14 mm/s and the directions were between east-northeast and east-southeast. At this site the net current structure was an apparent two-layer flow, with the top 3 bins in one direction (westerly) and the bottom 20 bins in an opposing (easterly) direction.

CM6 was located in the turning basin of the Outer Harbor. The maximum net current speed was 33 mm/s at the top (bin 11. The net current speed at the bottom bin was 15 mm/s. The net current at this site was also a two-layer flow system with a northwest flow near the surface and a southeast flow near the bottom. Bathymetric features likely helped direct flow in a southeast-northeast direction.

At CM7, which was located in the fairway, the maximum net current speed was 39 mm/s at the top (bin 11) and the minimum was 2 mm/s at bin 5. The speed at the bottom bin was 10 mm/s. The net current flow had a noticeable two-layer structure with a transition layer at bin 5. In the upper layer (bins 6 through 11), the net current direction was toward the west-northwest. In the lower layer (bins 1 through 4) the flow direction was to the southeast.

The apparent two-layer flow structures were shown in net currents at five ADCP locations (CM2, CM4, CM5, CM6 and CM7). At CM1 and CM3 the two-layer flow structure was not as apparent as at other ADCP sites.

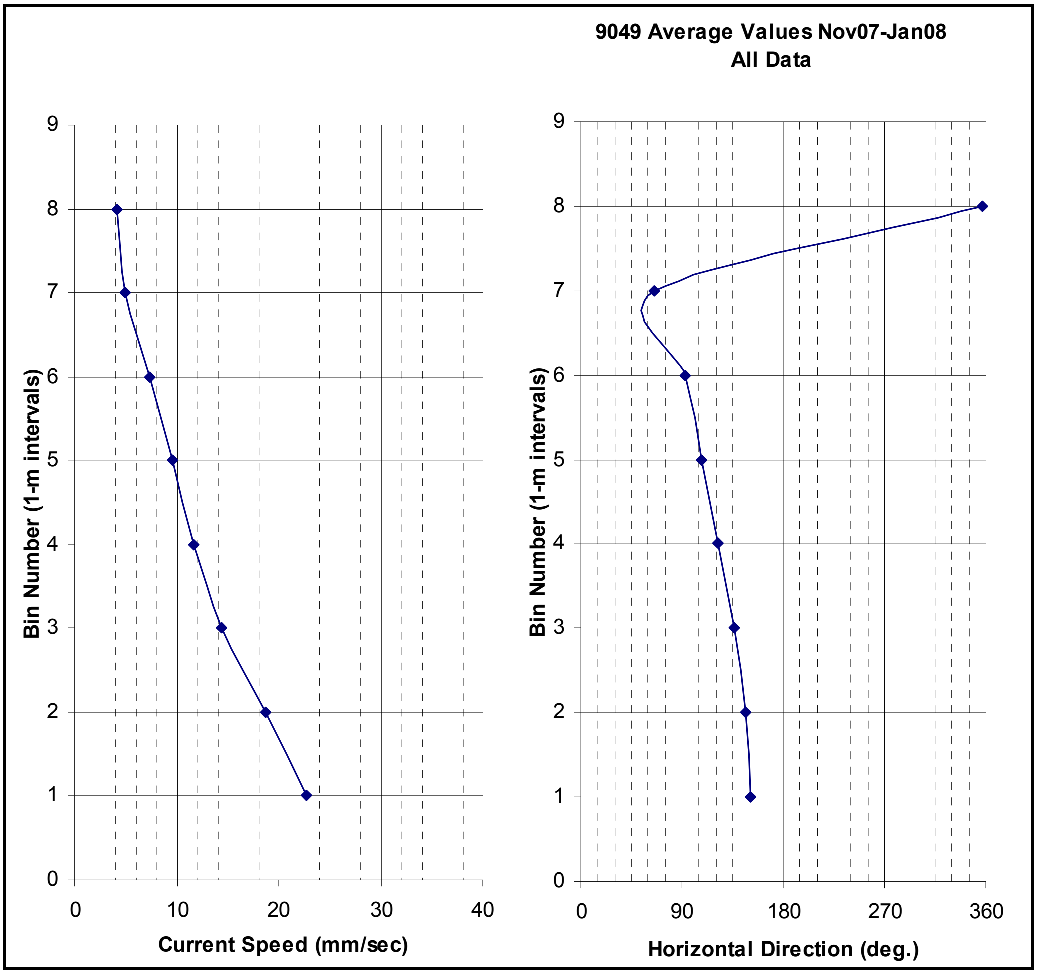


Figure 4-9. Net Current Profiles for All Data at CM1 (11/1/07 – 1/30/08)

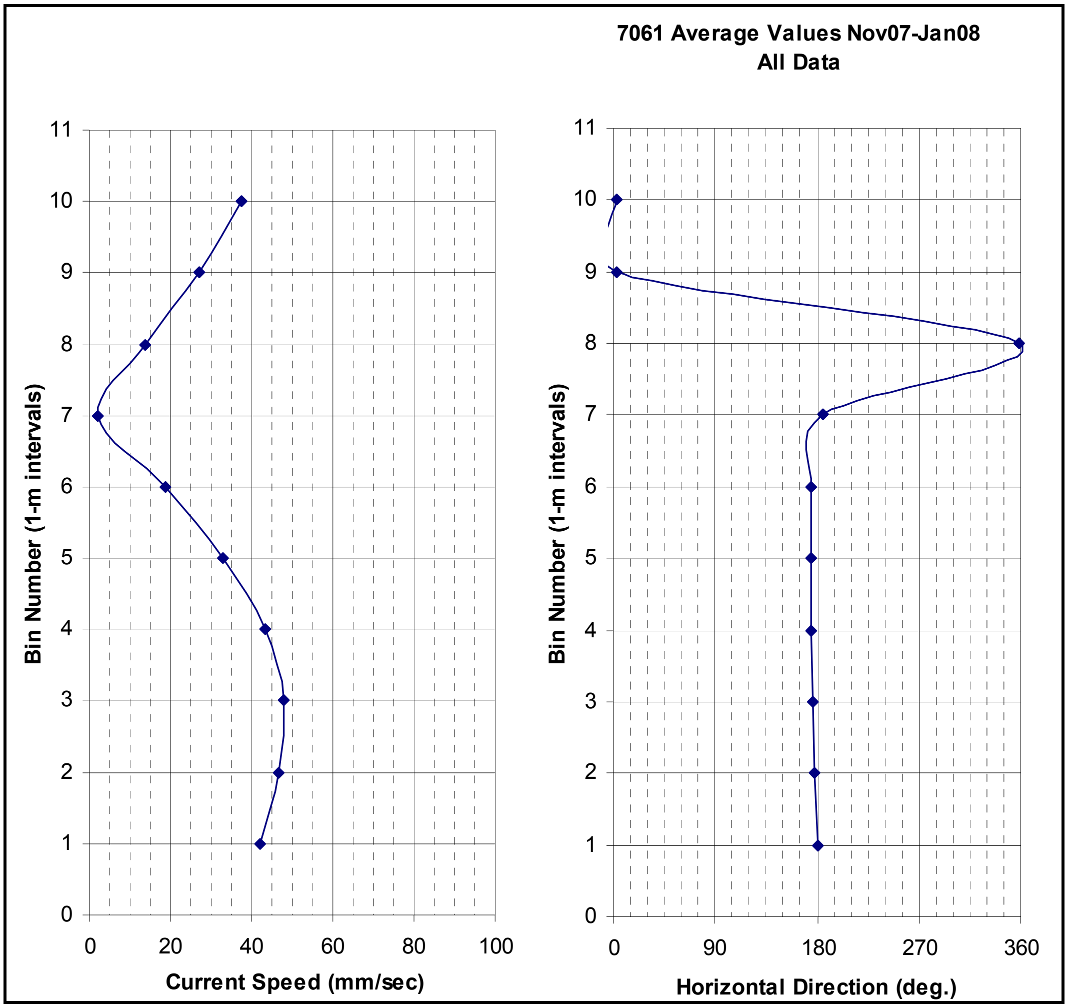


Figure 4-10. Net Current Profiles for All Data at CM2 (11/1/07 – 1/30/08)

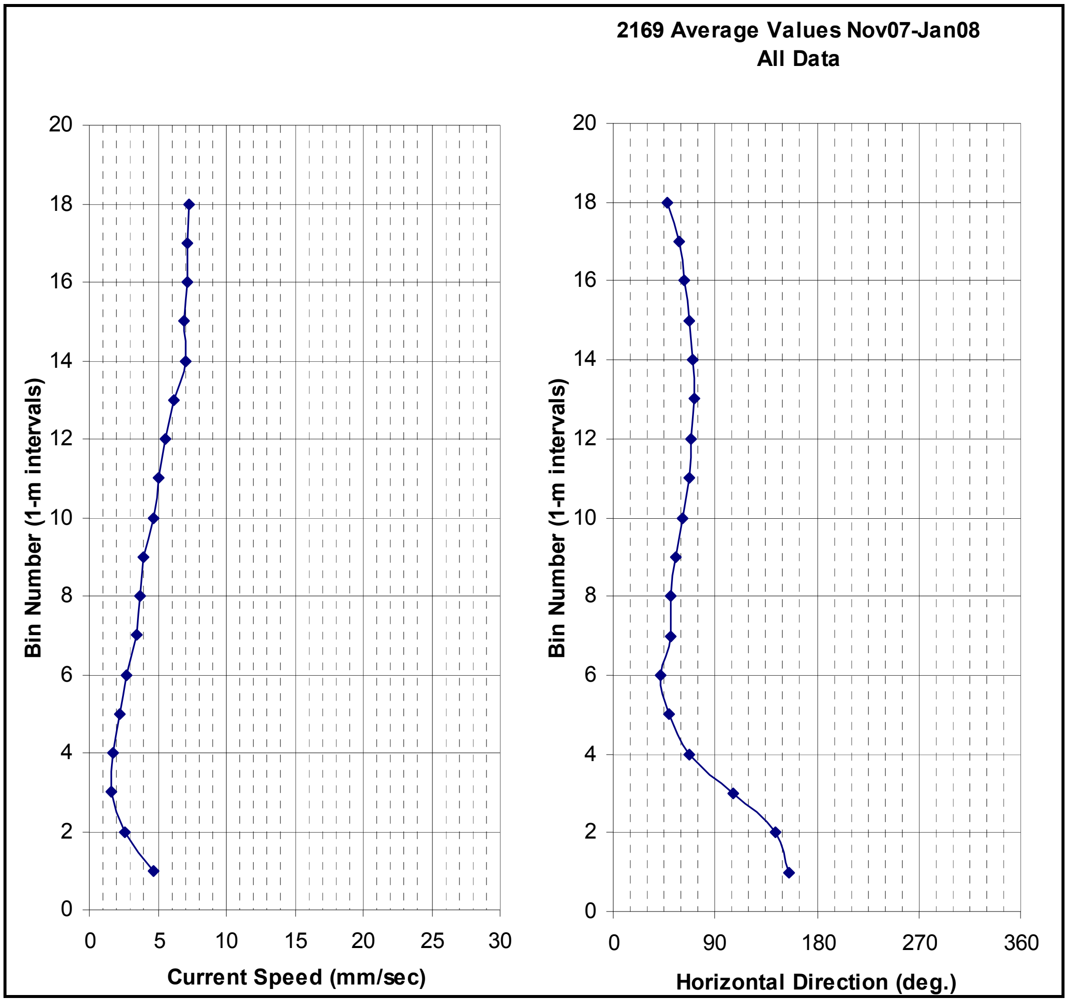


Figure 4-11. Net Current Profiles for All Data at CM3 (11/1/07 – 1/30/08)

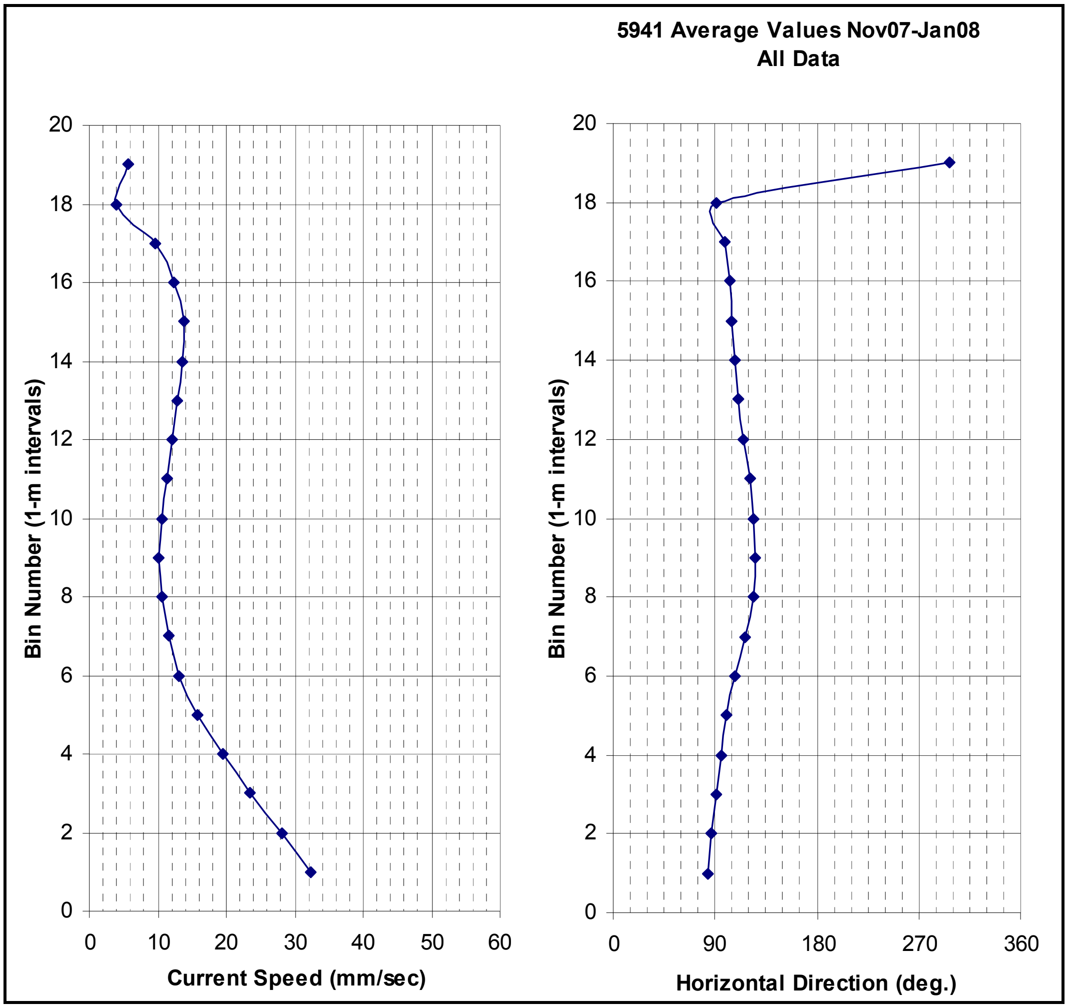


Figure 4-12. Net Current Profiles for All Data at CM4 (11/1/07 – 1/30/08)

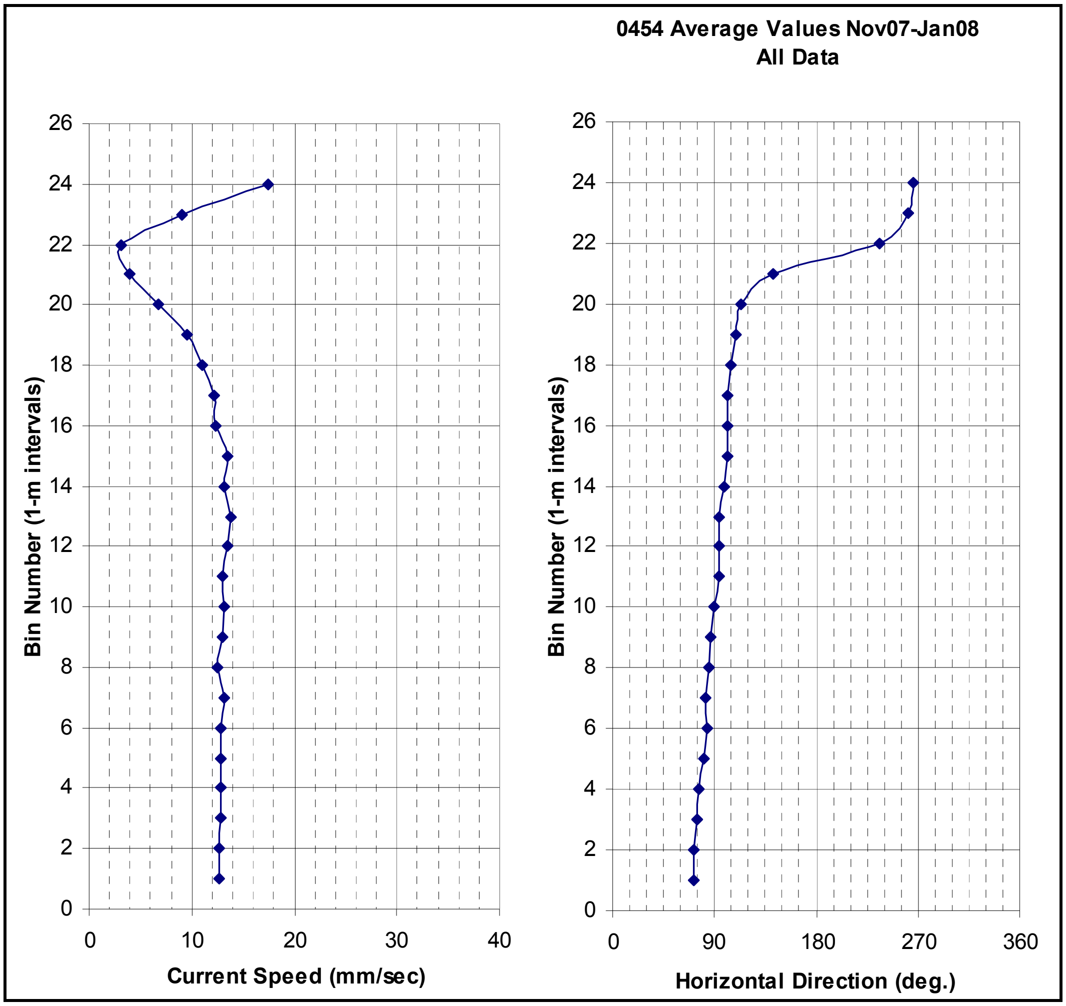


Figure 4-13. Net Current Profiles for All Data at CM5 (11/1/07 – 1/30/08)

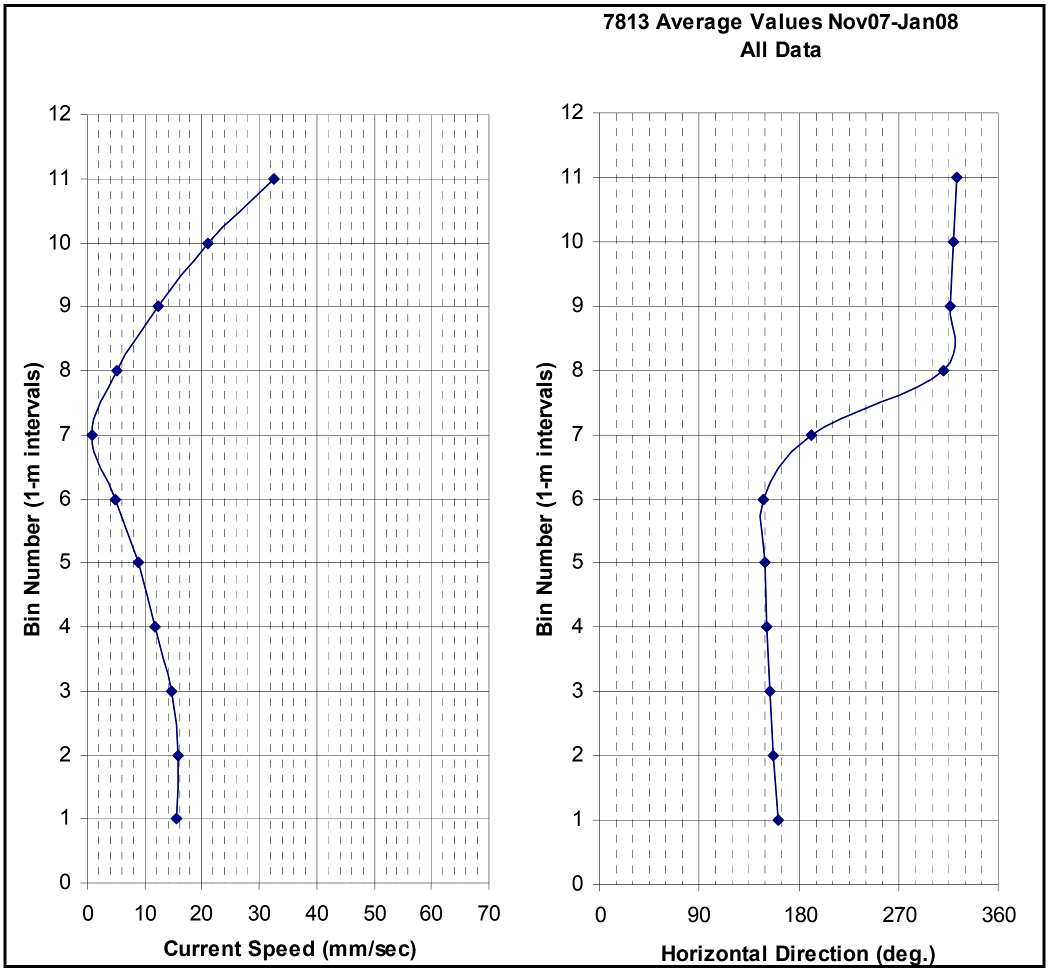


Figure 4-14. Net Current Profiles for All Data at CM6 (11/1/07 – 1/30/08)

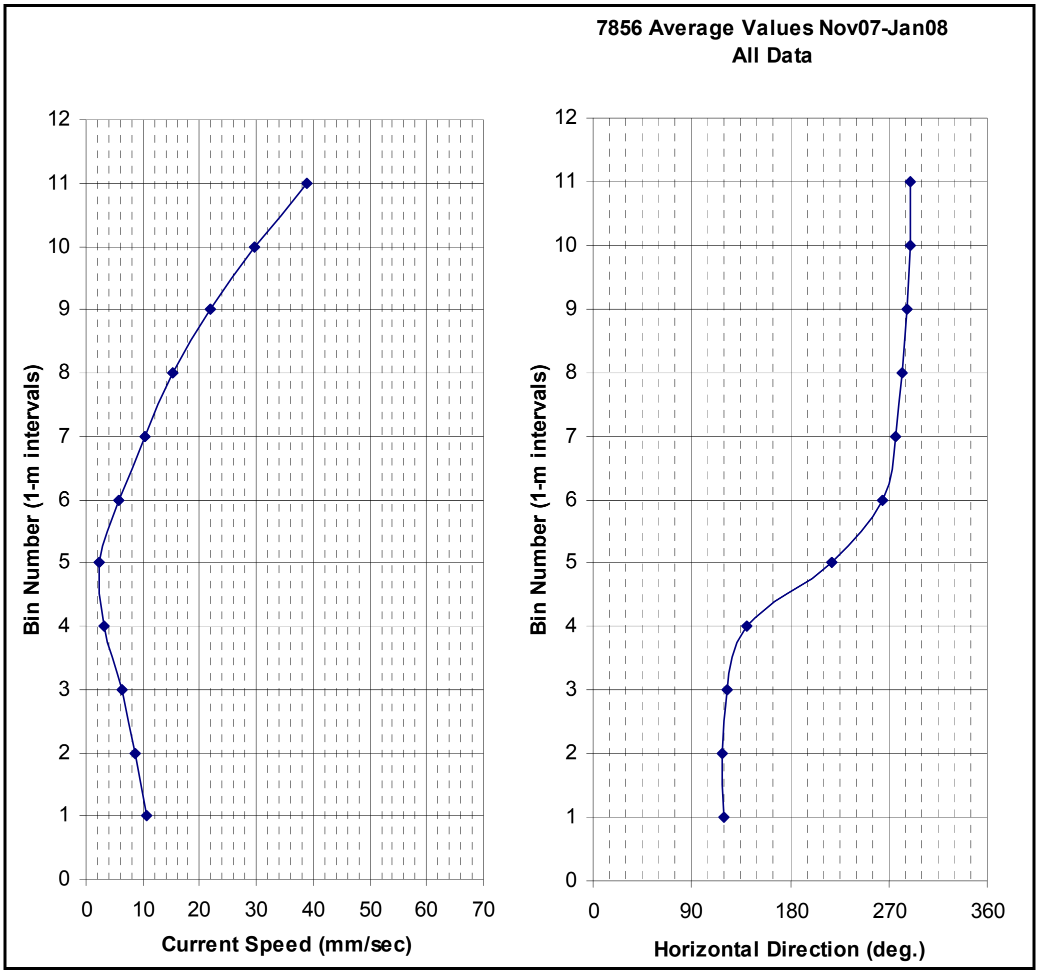


Figure 4-15. Net Current Profiles for All Data at CM7 (11/1/07 – 1/30/08)

4.3.5 Wind Influences on Net Currents

The influence of wind shear stress on current profile characteristics was analyzed by isolating data during two distinct wind events: steady moderate northeast trade winds occurring between 12/15/07 and 12/28/07, and moderate southerly winds that occurred between 11/27/07 and 12/29/07. Figures 4-16 and 4-17 are example profiles from CM1 showing the differences in current flow under the influences of each condition. Figures 4-18 and 4-19 are plan views showing schematic vectors for trade wind and south wind conditions respectively for the top and bottom bins based on the net currents profiles.

In general, the net currents at the top depth layer and the bottom layer on Figures 4-16 and 4-17 flowed in nearly opposite directions. Significant shifts in current direction occurred at CM1, CM3 and CM4 between the trade wind and the southerly wind conditions (Figures 4-18 and 4-19). At CM1 the northwest surface current during the trade winds shifted to the north-northeast during the southerly winds. This surface flow change was caused by the direct wind forcing. These changes are shown in Figure 4-18 and 4-19. At CM3 the northeast surface current during the trade winds turned south-southeast during southerly winds. Conversely, the southeast bottom current during trade winds became an east-northeast current during southerly winds. The net current profiles at CM3 show that the reversals in the current directions between the trade winds and the southerly winds were limited to the currents at the top and bottom bins. At CM4 the westerly surface current during the trade winds changed to the southeast during the southerly winds.

At CM3 and CM4, the top currents moved away from the Inner Harbor entrance during trade winds, but they headed toward the entrance during the southerly winds. The surface current behavior was anomalous at these locations as the wind was generally moving against the current. This may have been due to flow restrictions caused by complex bathymetry and shoreline planform.

The southerly wind effect on the surface layer currents was notably evident at CM1, CM2, CM5 and CM7. However, the southerly wind effects were not as striking as the westerly wind effects shown by Sea Engineering, Inc. (2004). The net current field under the influence of southerly winds did not reverse as was shown for westerly winds, where Harbor inflow was due to surface currents and outflow due to deep currents. This may be due to the short fetch distance for southerly winds in the study area, or due to the short 2-day duration of the wind event. This was likely not enough time to establish a clear flow pattern in Apra Harbor.

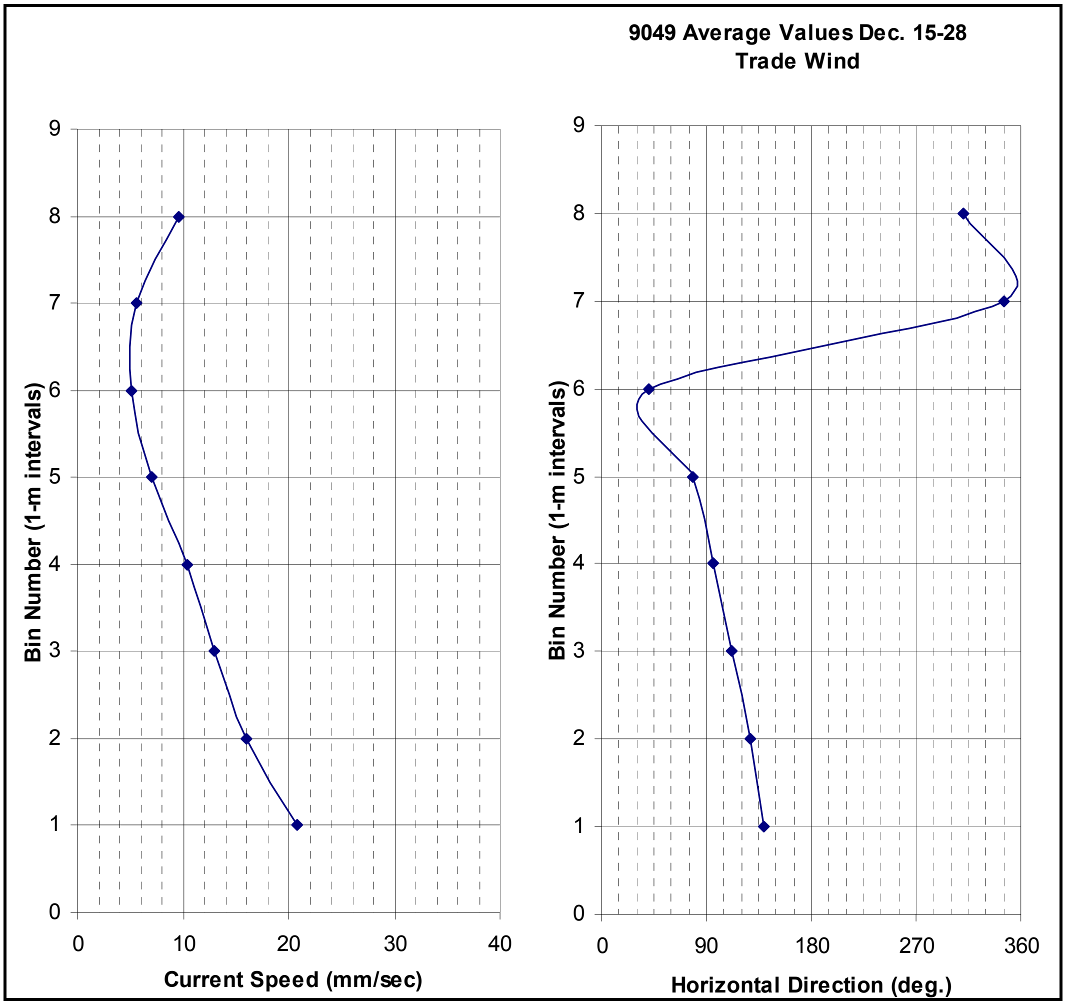


Figure 4-16. Easterly Wind Conditions at CM1 (12/15/07 – 12/28/07)

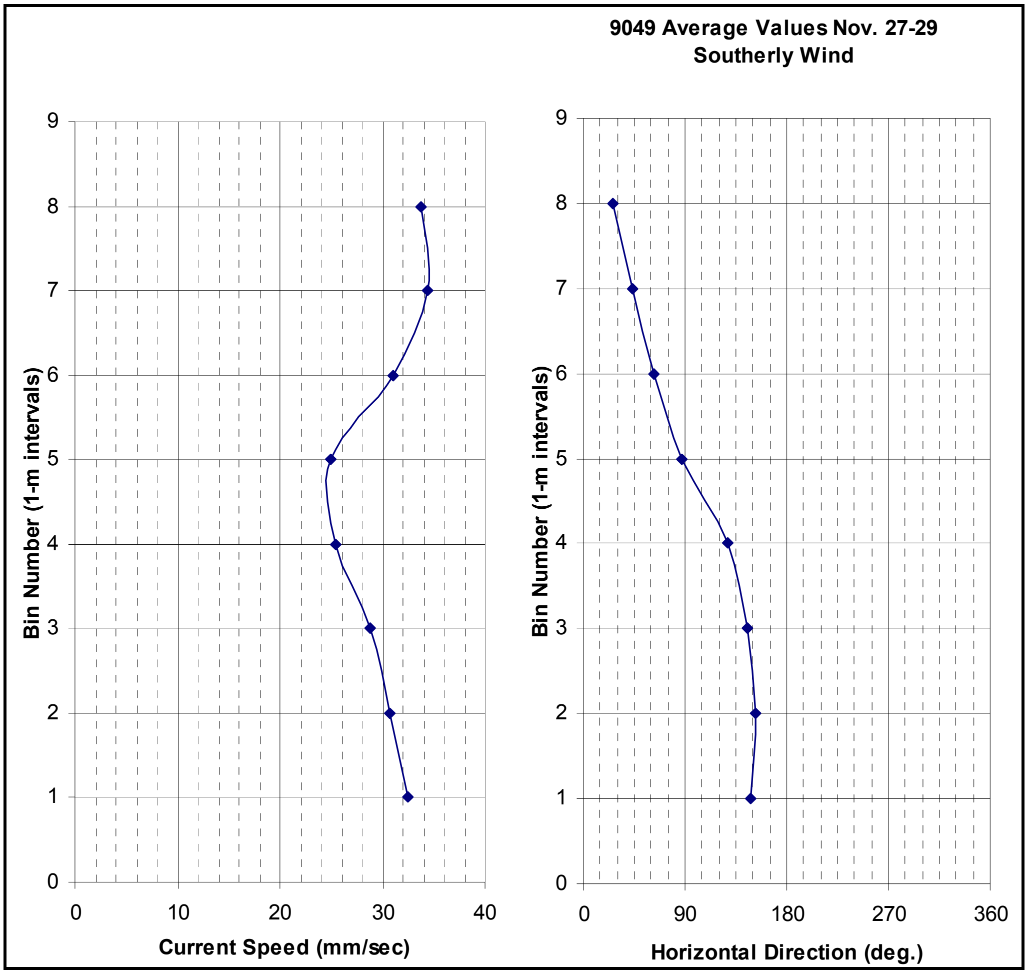


Figure 4-17. Southerly Wind Conditions at CM1 (11/27/07 – 11/29/07)

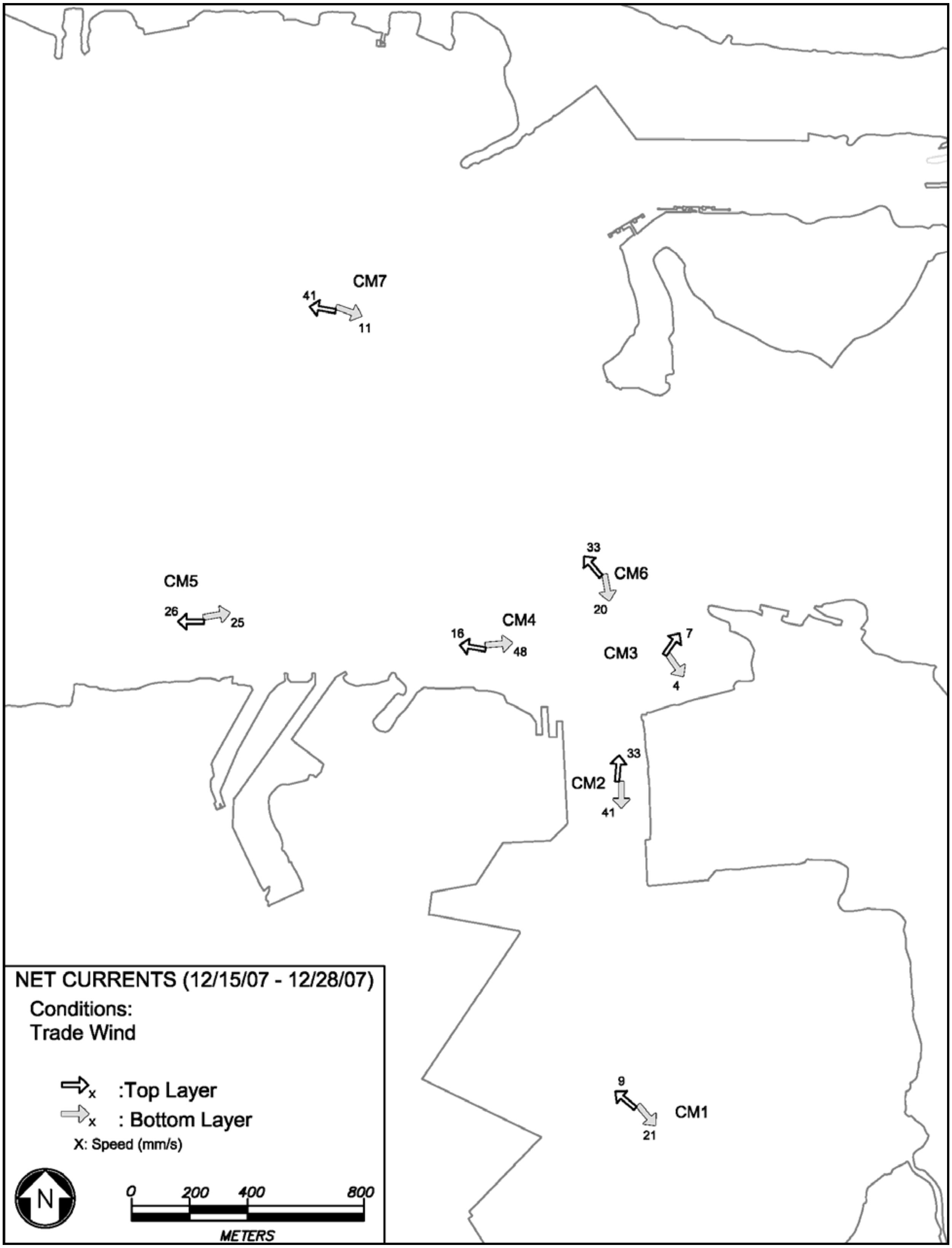


Figure 4-18. ADCP Net Currents During Moderate Trade Winds (12/15/07 – 12/28/07)

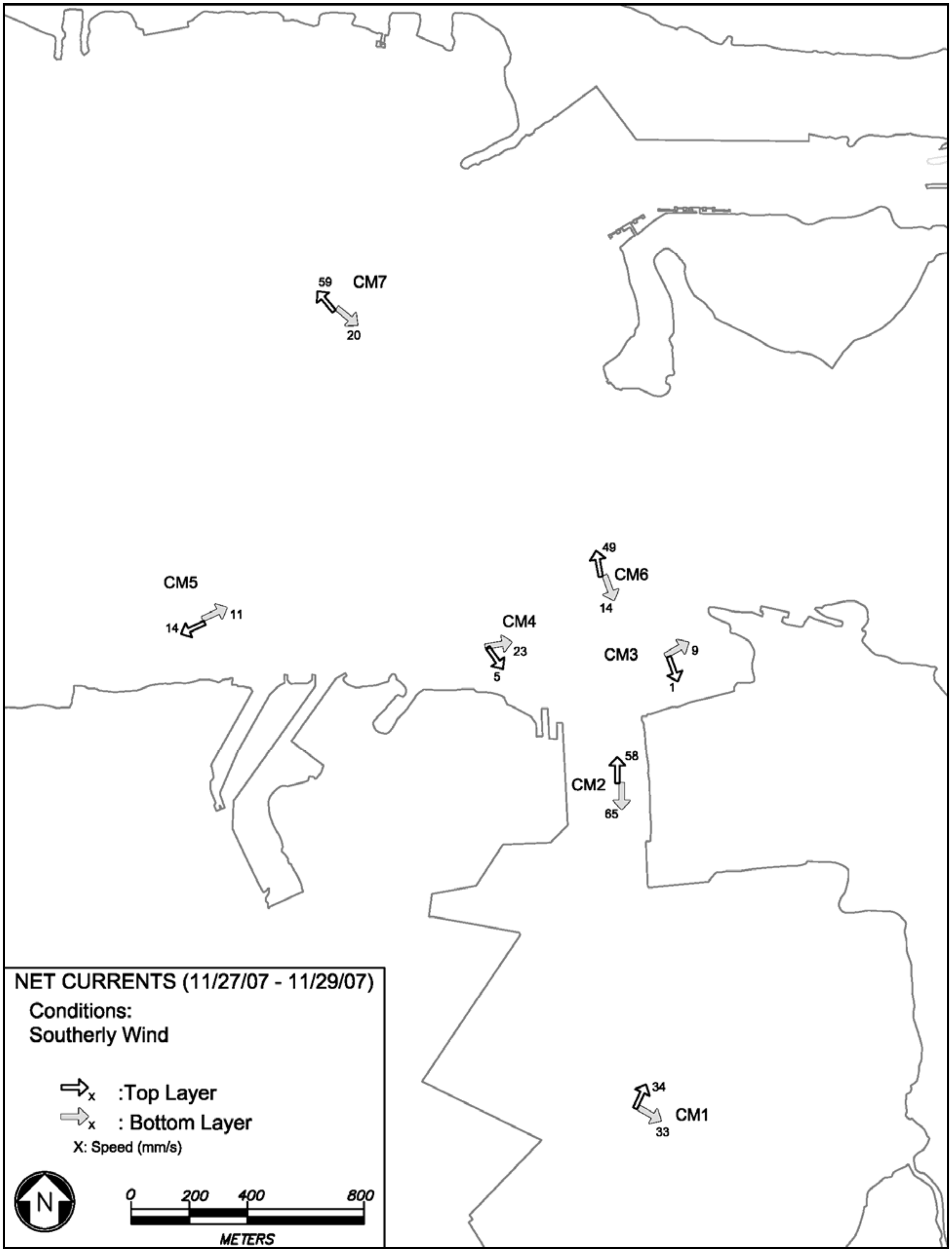


Figure 4-19. ADCP Net Currents During Moderate Southerly Winds (11/27/07 – 11/29/07)

4.3.6 Tidal Influences on Net Currents

Examples of net current profiles for ADCP CM2 during trade winds are given in Figures 4-20 and 4-21. Plan views of net current vectors are presented in Figures 4-22 and 4-25. Net currents at the top and bottom bins are shown on the plan view figures to represent the net currents in the upper layer and in the lower layer.

As pointed out in the previous section, the lower layer is inflow into Apra Harbor and the upper layer is outflow. During the flood tide, more water volume came in through the lower layer and less volume went out in the upper layer. During the ebb tide, the outflow volume increased and the shear zone between the upper layer, lower layer shifted down. The shear zone shift is shown on the net current profiles in Figure 4-20 and 4-21 at CM2. In the figures, the two-layer boundary is between bin 5 and bin 6 during the ebb tide, and it is shifted upward to bin 8 during the flood tide.

The tables and the plan view figures also indicate that the flow speeds in the lower layers generally increased during the flood tides. Similarly, during the ebb tide the flow speeds in the upper layers increased. In Figures 4-22 and 4-23, the flow directions during trade winds did not change significantly between the flood tide and ebb tide at the ADCP locations, except at CM3. This indicates that tidal influence on currents is small in most of the project area. Only the bottom layer direction at CM3 showed a significant shift. The bottom layer shifted from a west-southwest flow during ebb tide shifts to an east-southeast flow during flood tide.

4.4 Field Data Conclusions

The results of this study validate the conclusions made in the previous report by Sea Engineering, Inc. (2004):

- Currents in the project vicinity were typically weak. During trade wind conditions surface currents were typically 4 to 8 cm/s while bottom layer currents were typically 2 to 4 cm/s.
- Currents were primarily forced by wind stress. Net surface flow was in the direction of the wind.
- Net current flow occurred primarily as a two-layer system. Surface flow out of the Harbor was balanced by a deep return flow. Local bathymetric features influenced local current directions.
- Tidal forcing was not a major contributor to the currents, and acted primarily by increasing the flow thickness in the ebb or flood direction. In the channel to the Inner Harbor, tides influenced currents, and may have caused current reversals.

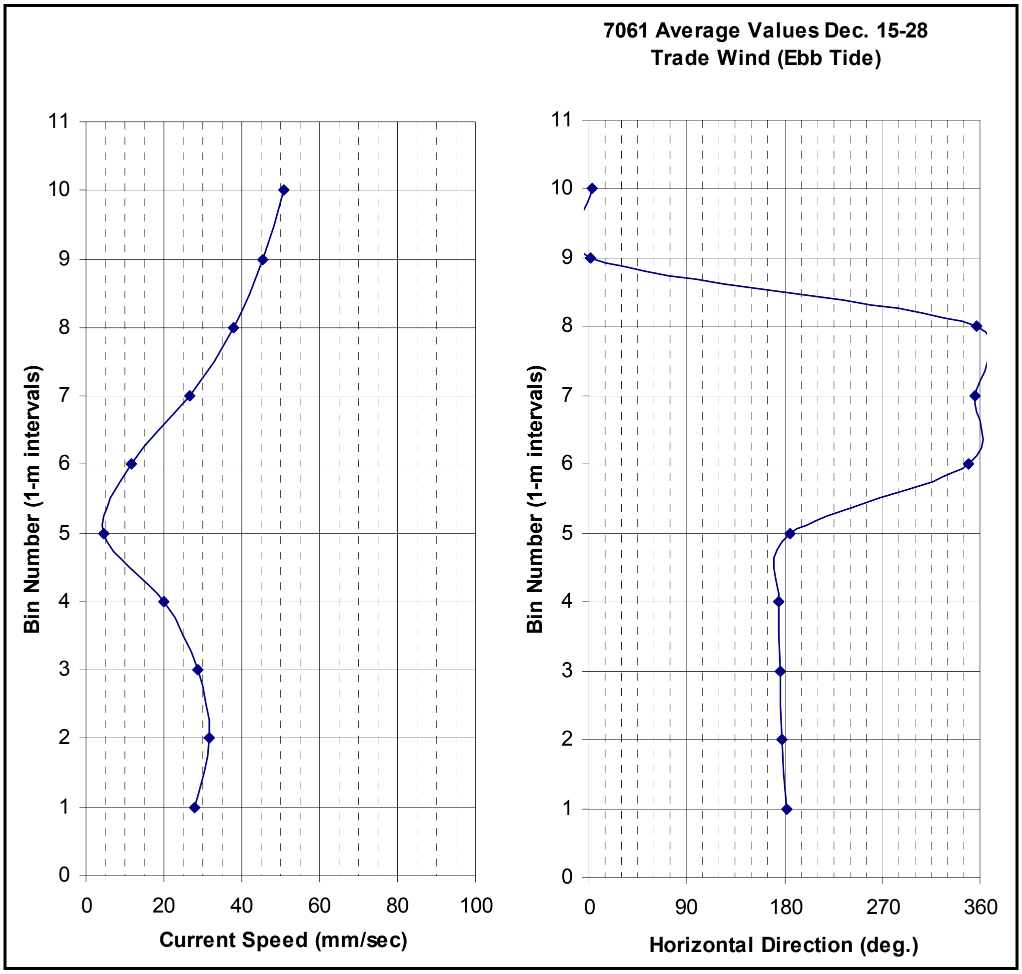


Figure 4-20. Ebb-Tidal Net Current Profiles During Trade Winds at CM2 (12/15/07 – 12/28/07)

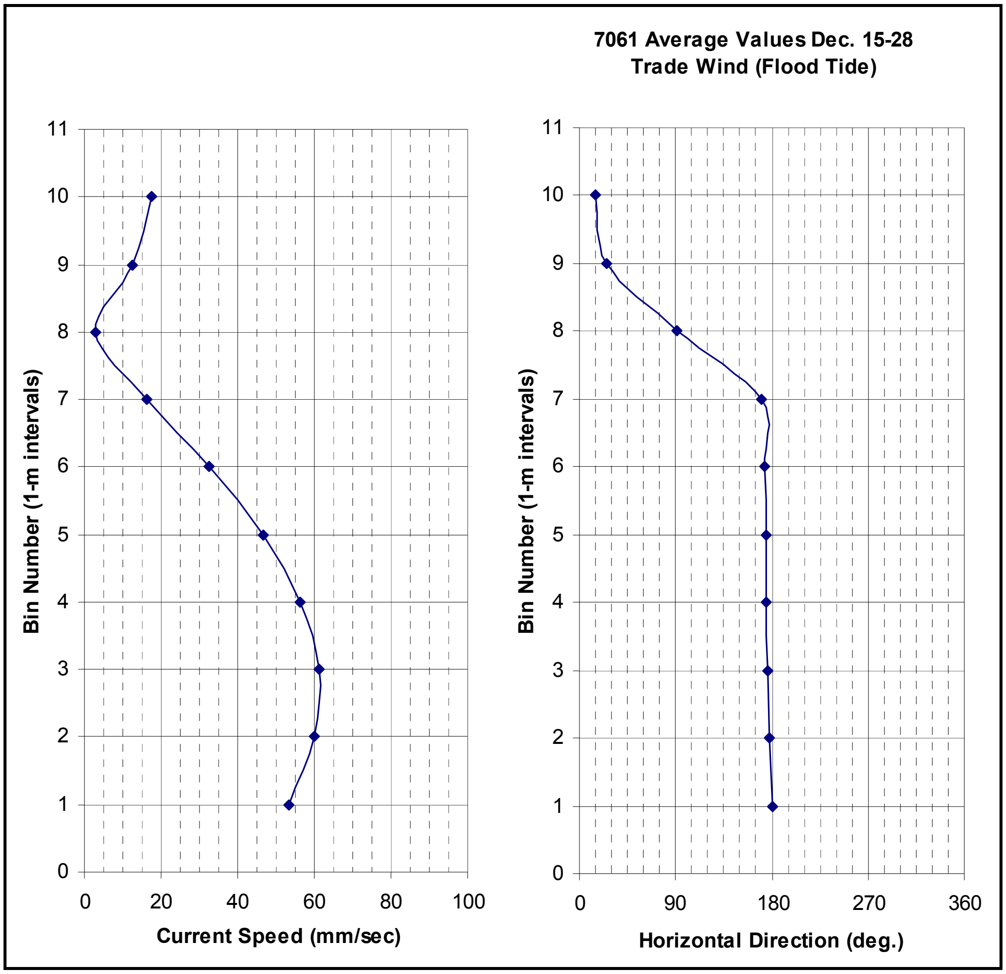


Figure 4-21. Flood-Tidal Net Current Profiles During Trade Winds at CM2 (12/15/07 – 12/28/07)

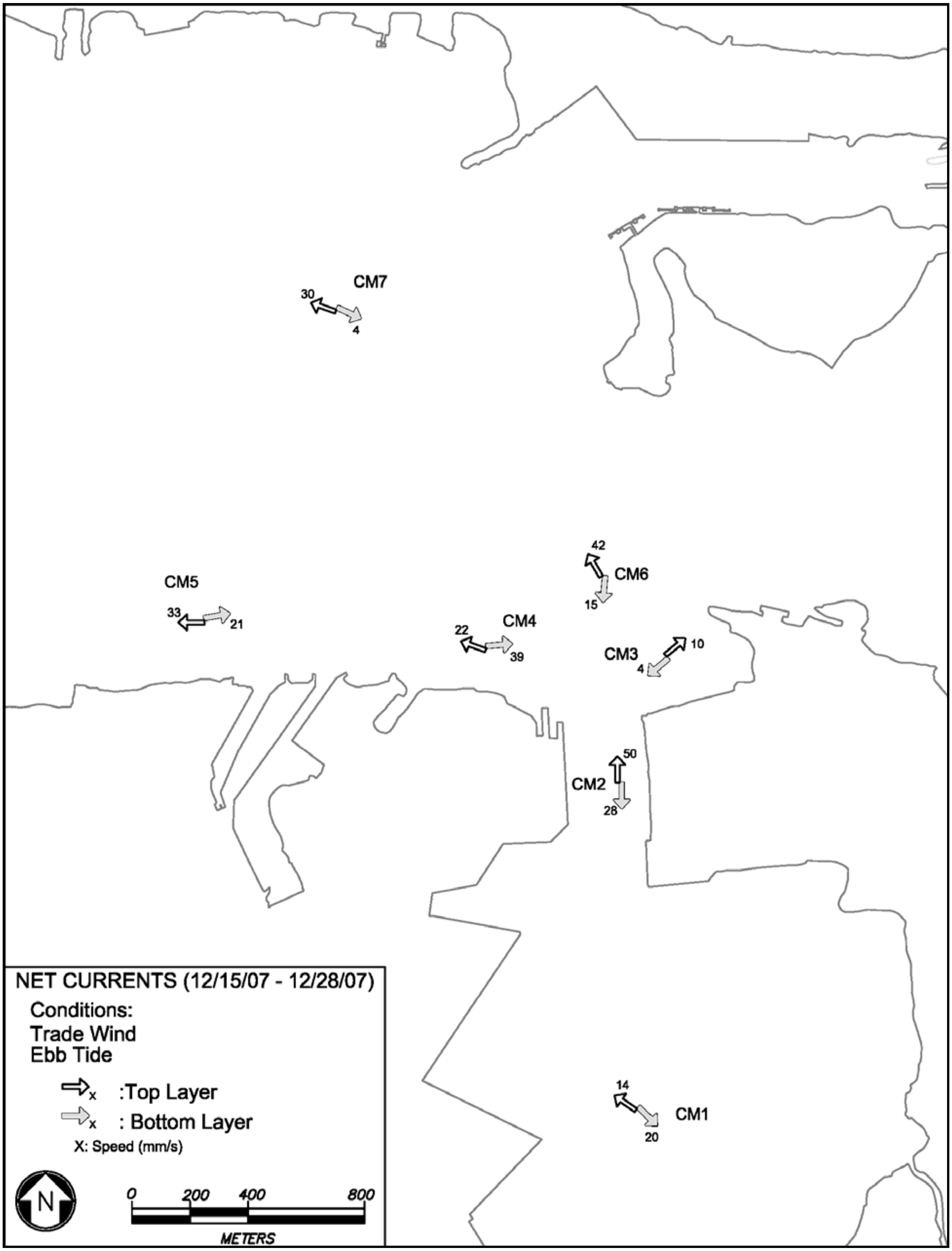


Figure 4-22. ADCP Ebb-Tide Net Currents During Moderate Trade Winds (12/15/07 – 12/28/07)

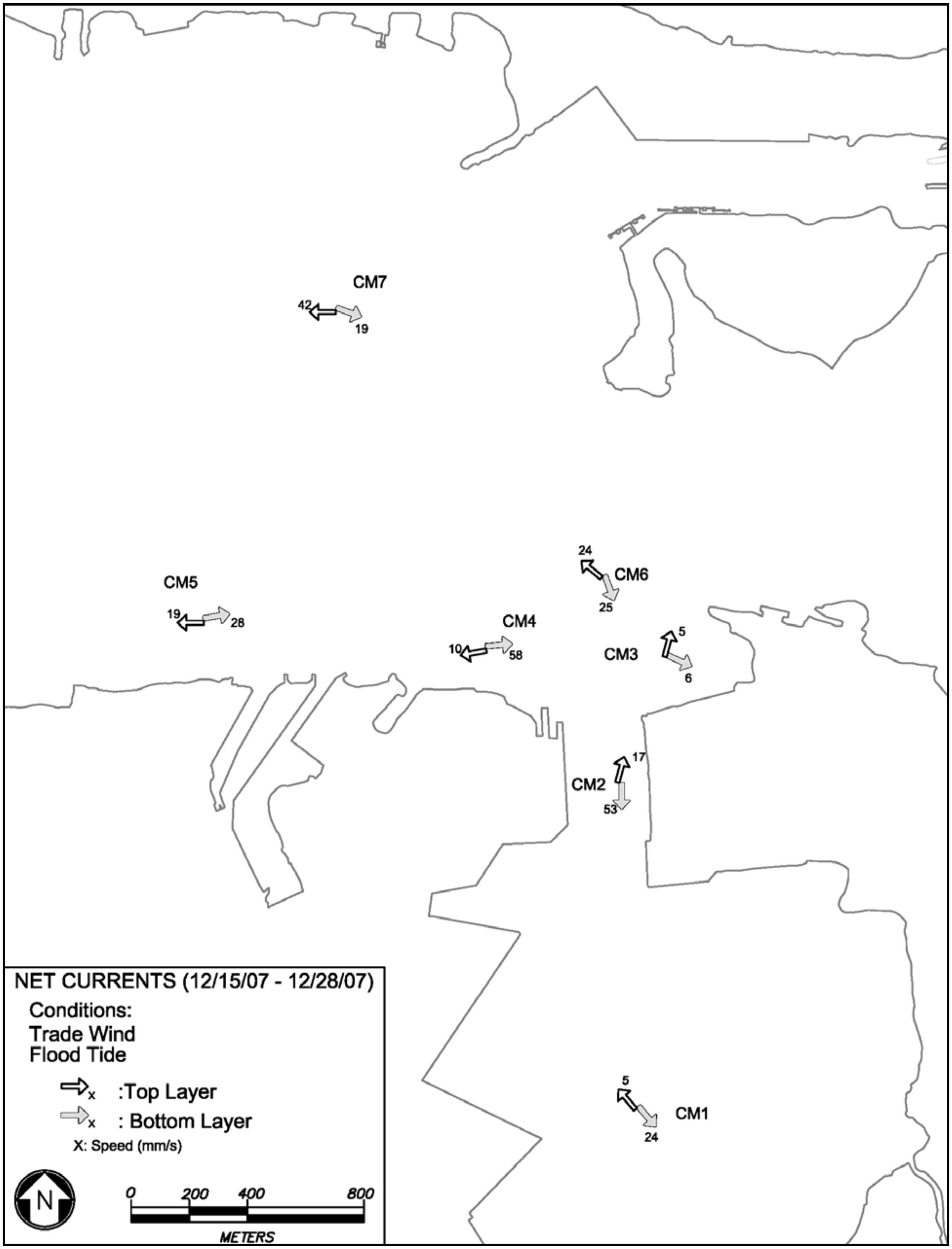


Figure 4-23. ADCP Flood-Tide Net Currents During Trade Winds (12/15/07 – 12/28/07)

5.0 NUMERICAL MODEL

5.1 Description

The dredging for construction of a new wharf, channel and turning basin for CVN berthing in Apra Harbor would result in the formation and transport of a turbid suspended sediment plume in the Harbor. Plume transport and mixing in coastal waters is a complex process that depends on the characteristics of both the discharge plume and the ambient receiving waters. The plume would be transported and dispersed due to currents driven by winds and tides, and modified by local and regional bathymetric features. Evaluating these processes and possible plume impacts to the environment requires a detailed record of currents in the project site coupled with a numerical modeling analysis. As described in the previous report sections, seven current meters were deployed at the project site to measure currents. This current information was used to calibrate a numerical model applied to the site to evaluate the plume transport and mixing and possible impacts to the environment. This and the following report sections describe the development, application and results of a numerical transport model of the site.

The numerical analysis was performed using the Environmental Fluid Dynamics Code (EFDC) model. The model is an EPA approved, state-of-the-art, three dimensional hydrodynamic model developed at the Virginia Institute of Marine Science by John Hamrick (1996) for the EPA to simulate hydrodynamics and water quality in rivers, lakes, estuaries, and coastal regions. The EPA describes the model as one of the most widely used and technically defensible hydrodynamic models in the world. This model was selected because it has the following capabilities:

- The model is 3-dimensional, which allows for variations in water properties and currents at different depths.
- The model computes suspended sediment transport and deposition.
- The model allows input of variable suspended sediment load size distributions and concentrations.
- The model allows input of time varying flows with time varying concentrations of contaminants.

Suspended sediment impacts were assessed using EFDC by specifying rate of suspended sediment loading into the water column. For a given distribution of sediments, the extent of suspended sediment transport was determined from the currents and circulation computed by the model. Additionally, settling and deposition were calculated. Sediment deposition was evaluated by calculation of the critical shear stress term. Sediments would only deposit onto the bottom when the shear stress exerted by currents on the bottom was less than the critical shear stress for deposition of particular sediment. Sediment resuspension was not included in this analysis. Not including sediment resuspension is a realistic assumption during most dredging conditions and results in a more conservative assessment, because there may be storm events that resuspend and further disperse the sediments.

5.2 Model Domain and Grid

EFDC required input of the regional coastal bathymetry. Model inputs and results were constrained to metric units only. Figure 5-1 shows the bathymetry of Apra Harbor in the vicinity of the project area, derived from airborne lidar, and boat hydrographic surveys. The figure shows that the Harbor basin is typically 131 to 164 ft (40 to 50 m) deep, with many patch reefs rising steeply off the bottom. The bottom slopes steeply from the shoreline to the basin bottom. The project area was bounded to the west by Big Blue and Western Shoals, and to the east by Sasa Bay. Inner Apra Harbor is located to the south. Bathymetry was represented in a numerical model through the creation of a grid, and the specification of depth at each grid point. The model grid dimensions were a tradeoff between desired resolution and computer computation capability. To maximize resolution at the project site and computational efficiency, an expanding grid was used for this analysis. Figure 5-2 shows the EFDC model grid. The grid cell size was 66 ft (20 m) on a side at the project site. The grid dimensions expand by 2% with each cell to a maximum size of 164 ft (50 m). This provided maximum resolution at the project site, and less detail at greater distances from the project site. The grid contained 12,000 active computation cells. Figure 5-3 shows color-coded bathymetry overlain on the model grid.

At the open boundary to Apra Harbor, designated by the "W" in the boundary cells in Figure 5-2, tidal water surface elevations were specified. Vertical variability in the water was modeled by dividing the water column into ten layers, each whose thickness is 10% of the total water depth.

5.3 Model Flow Forcings

As discussed in Section 4, currents and circulation within Apra Harbor are driven by winds and tides, with winds predominating. Currents in the numerical model were therefore also forced by numerically applying tidal and wind boundary conditions. Tides were specified at the open boundary to the model (see Figure 5-2 cells marked with W) as a time-varying rise and fall of water level. Figure 5-4 shows the tidal condition applied to the open boundary, corresponding to tides in Apra Harbor from December 15 to 17, 2007. Figure 5-4 shows that the peak flood tide elevations were 2.8 to 2.9 ft (.85 to .87m) (mean lower low water datum), and the ebb tide levels were 0.2 to 0.7 ft (0.05 to 0.2m).

Wind conditions in Apra Harbor were also discussed in Section 2, and could be characterized as east to northeast trade winds which occur nearly 75% of the time, and variable conditions consisting of calm and infrequently occurring winds from the south and west directions. Winds on the island typically also have a strong diurnal variation, peaking in the early afternoons, and significantly weakening during the night. To best characterize the range of possible impacts from wind-driven flows at the project site, 4 different winds conditions were selected for model forcing:

- Typical, diurnally varying trade winds – As discussed previously, typical tradewind speeds peak at about 14 knots (7m/s) in the early afternoon, and drop to about 4.4 knots (2.2 m/s) during the night. To model plume transport under these conditions, actual wind data recorded in Apra Harbor during typical tradewind conditions from December 15 to 17, 2007 were applied to the model. Figure 5-5 shows the model wind input condition. Winds peak in the early afternoon at 14 to 16 knots (7 to 8 m/s), and diminish to 5 to 7 knots (2.5 to 3.5 m/s) during the night. The wind direction input into the model was defined as the wind stress direction, and referred to the direction to which the wind is blowing, rather than the standard convention of the direction the wind was from. Figure 5-5 shows that the wind stress direction was mostly 230 to 270 degrees, corresponding to winds from the northeast (45 degrees) to east (90 degrees), respectively.
- Strong trade winds – To model plume transport during strong trade wind conditions, the typical, diurnally varying trade wind speeds were increased by 25%. This resulted in peak wind speeds in the early afternoon of 17.5 to 20 knots (8.75 to 10 m/s). Wind speeds greater than 20 knots (10 m/s) occurred less than 0.4 % of the time.
- South wind – Winds from the south-southeast to south-southwest occurred nearly 7% of the time. Winds from the south were typically weak, averaging 7 knots (3.5 m/s).
- Calm winds – Periods with no wind occurred 10.5 % of the time in Guam, constituting the next largest component of winds after easterly trade winds.

The wind numerically drove currents in the model through the application of a quadratic stress formulation that converted the wind speed and direction to a stress on the water surface.

5.4 Dredge Plume Characterization

The nature of the plume at the dredging site was a key input to the numerical model. In the EFDC model, the dredge plume was defined by a concentration of suspended sediment in the water column. EFDC then had the capability to transport, disperse and deposit suspended sediment of specified concentration and grain size according to the current patterns calculated by the hydrodynamic model. To adequately characterize the plume for the modeling analysis therefore required information on:

- the amount of suspended sediment released to the water column,
- the grain size distribution of the suspended sediment, and
- the distribution of suspended sediment throughout the water column.

Defining these parameters was frequently difficult because field data during dredging operations was difficult to obtain, and existing available data was limited and specific to a particular dredge site and method. The U.S. Army Corps of Engineers, in fact, has established the Dredging Operations and Environmental Research (DOER) program and characterizing dredge plumes for input into numerical models is an active area of research. Recent research by Hayes and Wu (2001), Hayes et al. (2007) and the DOER program (2000) describe methods for defining the dredge plume, or the amount of dredge material released into the water column, as a %age of material lost or released from the total dredging production rate. For this analysis, we followed the approach presented in these papers. A detailed discussion of the key input variables and the selected values for the modeling analysis are presented below

1. Dredging Production Rate

   Following the approach of Hayes and Wu (2001), Hayes et al. (2007) and DOER (2000), the amount of suspended sediment released into the water column could be determined as a %age of the total dredging production rate. Two inputs were necessary – the total dredging production rate, and the % loss or release rate. The total dredging production rate depends primarily on the dredging method and the material type. Hydraulic dredging in soft clay/silt material can remove more than 47,000 cubic yards (cy) (36,000 cubic meters (cu m)) of material during a 24-hour period, while clamshell dredging in a hard bottom substrate (such as coral) may achieve production rates of less than 1,308 cy (1,000 cu m) in a 24-hour period. The dredging for the CVN project would occur in a coralline/reef derived substrate, most likely using a barge-mounted clamshell dredge. Clamshell dredging production rates in the literature are available only for soft silt/clay harbor environments and range from 11,770 to 47,086 cy (9,000 to 36,000 cu m) per day (Hayes and Wu, 2000). Clamshell dredging production rates applicable to the CVN project were determined through discussions with Black Construction Corporation, which recently completed dredging in Apra Harbor for the Alpha-Bravo Wharves Improvement project. Black Construction cited routine production rates of 500 to 1000 cubic yard per 10-hour dredging day (50 to 100 cy/hour) within the channel to Inner Apra Harbor. This area consisted of harder coralline material compared to the soft silty material located within the Inner Harbor, and is probably similar to what would be dredged for the CVN project. Healy Tibbitts Builders, a Hawaii construction company with extensive dredging experience, reported that a good production rate for barge-mounted clamshell dredging in a reef environment would be about 80 cy/hour (61 cubic meters per hour [m^3/hr]).

   CVN dredging requirements have not been fully defined. For our model input, therefore, we selected two dredging production scenarios:

   a) Dredging 100 cy/hour (76 m^3/hr) during a 10-hour dredging day, for a total production of 1,000 cy (760 m^3) per day.
   b) Dredging 75 cy/hr (57 m^3/hr) during a 24-hour dredging day, for a total production of 1800 cy (1,376 m^3) per day.

   Dredging of 100 cy/hr (the high end of the range of rates cited by Black Construction) was assumed possible for short dredging days of 10 hours, but less likely for continuous dredging operations required for 24-hour work days. For this type of continuous dredging operation, an average rate of 75cy/hr was used.

2. Amount of Suspended Sediment Released into the Water (TSS Load)

   To determine the amount of material released into the water estimating the % of the dredge material that is lost or released during the clamshell dredge process was required. Release rates measured during five different clamshell dredging operations ranged from 0.16% to 0.88%, with an average of 0.45% (Hayes and Wu, 2001). Hayes et al. (2007) cite a characteristic release rate of 0.5% for open clamshell bucket dredging. We selected 1% as a representative, conservative release rate for use in our modeling analysis. To bracket the range of possible conditions, 2% was selected as a possible worst case release rate. The 2% release rate was used to approximate the highest 10% TSS levels measured during the Alpha-Bravo dredging project. Analysis of the TSS monitoring data from the recent Alpha-Bravo dredging project indicated that the highest 10% of the TSS levels measured outside of the silt curtain were approximately 8 times greater than the typical TSS levels measured during the dredging. To simulate this worst case level of material release, and achieve an 8-fold increase in material released outside the silt curtain, we increased the material release rate from 1% to 2% (see Section 5.4), and decreased the silt curtain effectiveness by a factor of 4. The TSS loading to the water column resulting from these loss rates is presented in Table 5-1.

Table 5-1. TSS Load Rates.

Dredging Rate (volume)	*Dredging Rate (mass)*	*Release Rate*	*TSS Loading Rate*
100 cy/hr	36.4 kg/s	1%	0.364 kg/s
100 cy/hr	36.4 kg/s	2%	0.728 kg/s
75 cy/hr	27.3 kg/s	1%	0.273 kg/s
75 cy/hr	27.3 kg/s	2%	0.546 kg/s

3. TSS Grain Size Distribution – The transport and deposition of the suspended sediment in the dredge plume depends on the current patterns and the grain size distribution of the suspended sediment. Larger grains settle rapidly through the water column and will be deposited close to the dredging, while clay material will remain suspended for long periods of time, and will likely be transported out of the project area. Grab samples collected within the project area were analyzed for grain size. The composite grain size distribution is shown in Figure 5-6. This grain size distribution was used for our modeling analysis and is shown in Table 5-2 below. Five discrete grain sizes were selected to represent the material. The table shows that most of the sediment is sand-sized and greater (greater than 0.074 millimeters) and settle out of suspension relatively rapidly –22.8 m/hr for a grain size of 0.1mm, and 329 m/hr for a grain size of 0.38 mm. Clay and silt portions of the sediment settle out much more slowly – 0.008 m/hr for clay particles of 0.002 mm, and 2.3 m/hr for silt particles of 0.032 mm.

Table 5-2. Suspended Sediment Grain Size Distribution

Grain Size (mm)	*Weight Frequency (%)*	*Fall Velocity*
0.002 clay	15	0.008 m/hr
0.032 silt	15	2.3 m/hr
0.055 silt	15	6.9 m/hr
0.1 very fine sand	15	22.8 m/hr
0.38 medium sand	40	329 m/hr

4. Water Column Distribution of TSS – The amount of material spilled or released from the clamshell bucket into the water will vary with depth in the water. Recent research indicates that typically 40% of the material is released near the bottom, 30% near the surface, and 30% through the rest of the water column (Borrowman, 2008, personal communication).

A silt curtain extending from the water surface to near the seafloor, and encircling the dredging operation, would be required during the dredging. The silt curtain would contain the transport of the released dredge material, forcing it to settle around the ongoing dredging operation. A realistic modeling analysis, therefore, should incorporate the effects of silt curtain utilization. A total of 145 days of TSS and turbidity monitoring inside and outside of the silt curtain was completed during the Alpha-Bravo dredging project. This data indicated that the average TSS levels outside of the silt curtain were 10% of the level inside the silt curtain. This reduction level was applied in the modeling analysis for the 80% of the water column that would be enclosed by a silt curtain. The bottom 20% of the water is assumed to be open, and is assumed to be loaded with all of the remainder of material contained by the silt curtain. The resulting water column distribution of TSS was 3% near the surface, 3% from below the surface to near bottom, and the remaining 94% near the bottom. This is shown in Table 5-3 below. Material released outside the silt curtain in the surface and middle portions of the water column was assumed to be silt and clay size.

Table 5-3. Water Column Distribution of TSS

Water Column	*% Release Without Silt Curtain*	*% Outside Silt Curtain (Alpha-Bravo Monitoring Data)*	*% Release With Silt Curtain (Model Input)*
Surface 20%	30	10%	3
Middle 60%	30	10%	3
Bottom 20%	40	-	94

A worst case scenario was approximated by decreasing the silt curtain effectiveness by a factor of four.

5. Dredge Location – Currents and transport processes are affected by local bathymetric features, and thus would change throughout the project area. Model runs were therefore completed assuming dredging at different locations throughout project area. Figure 5-1 shows nine representative dredging locations selected for model runs.

5.5 Model Verification

The first phase of modeling analyses is verifying that the model is both working correctly and also reasonably simulating the natural processes occurring at the site. As mentioned previously, EFDC has been successfully used previously to simulate circulation and transport in a multitude of environments, including the Chesapeake Bay, the Florida Everglades, the James and York River Estuaries, the Potomac River, San Francisco Bay, and Puget Sound. It has been calibrated and verified with extensive field data sets (Tetra Tech, 2002; www.epa.gov/athens/research/modeling/efdc.html).

To verify that EFDC correctly models existing conditions in the project area, a typical trade wind condition was modeled and compared with the current meter measurements. The period of December 15 to 17 was chosen. As discussed in Section 5.3, winds during this period peaked in the early afternoon at 14 to 16 knots (7 to 8 m/s), and diminished to 5 to 7 knots (2.5 to 3.5 m/s) during the night. The wind direction was from the northeast (45 degrees) to east (90 degrees). Wind speed and direction were recorded every 15 minutes at the Port Operations weather station in Inner Apra Harbor. These data were input into the model to closely simulate the environmental conditions. Figure 5-5 shows the model wind input conditions. The current meter data indicated that the current structure was driven primarily by winds, and that during trade winds, there was a layered flow structure with surface layer flow to the west out of Apra Harbor, and bottom layer flow into the Harbor to the east. Figures 6-1A and 6-1B (in the next section) show that EFDC reproduces this general circulation pattern. The figures show the current patterns in the surface layer (Figure 6-1A) and bottom layer (Figure 6-1B).

Comparison of model results with current meter measurements in the project area are shown in Figure 5-7. The figure presents the comparison of model and measured currents at the three current meter sites within the project area: CM3, CM6, and CM7. At each site, measured and model computed currents were compared for top and bottom water layers. The model reproduced the general current magnitudes and diurnal pattern of peak current speeds during the early afternoon, and weaker currents at night. The current meter data was significantly more spiky than the model results, with more extreme highs and lows and shifts in the current speed. This could be due to spatial and temporal differences in the wind data forcing the model. The wind data used in the model were measured at the weather station in Inner Apra Harbor. The current meter sites may have experienced gusts and variations in winds that were not reflected in the wind data, and therefore, not reproduced in the model. Nevertheless, this verification with the current meter data indicated that the EFDC model reproduced the important transport dynamics occurring at the project site.

Model release of TSS into the water column was verified by comparison with the Alpha-Bravo dredge monitoring data. The 145 days of monitoring data indicated that average TSS levels immediately outside of the silt curtain were 4.5 mg/L, measured at a water depth of 15 ft (4.5m). The average TSS concentration computed by the model, using the dredge parameters specified in Section 5.4 above, was 5 mg/L. Thus, the model was closely reproducing TSS levels actually measured during a dredging project in Apra Harbor. Model results were slightly greater, which would permit a more conservative estimate of possible impacts.

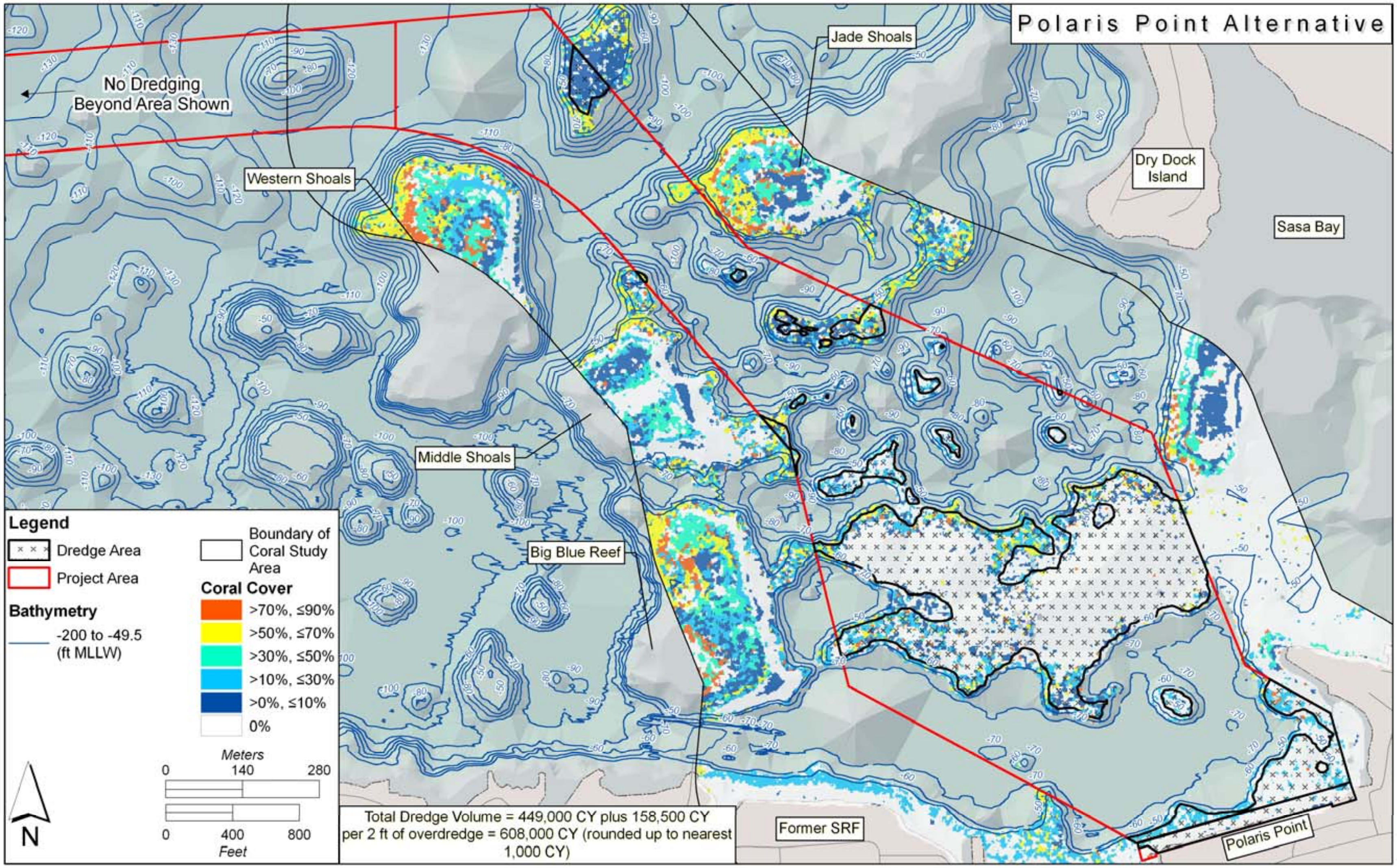


Figure 5-1. Project Site, Area Bathymetry and Model Dredge Locations

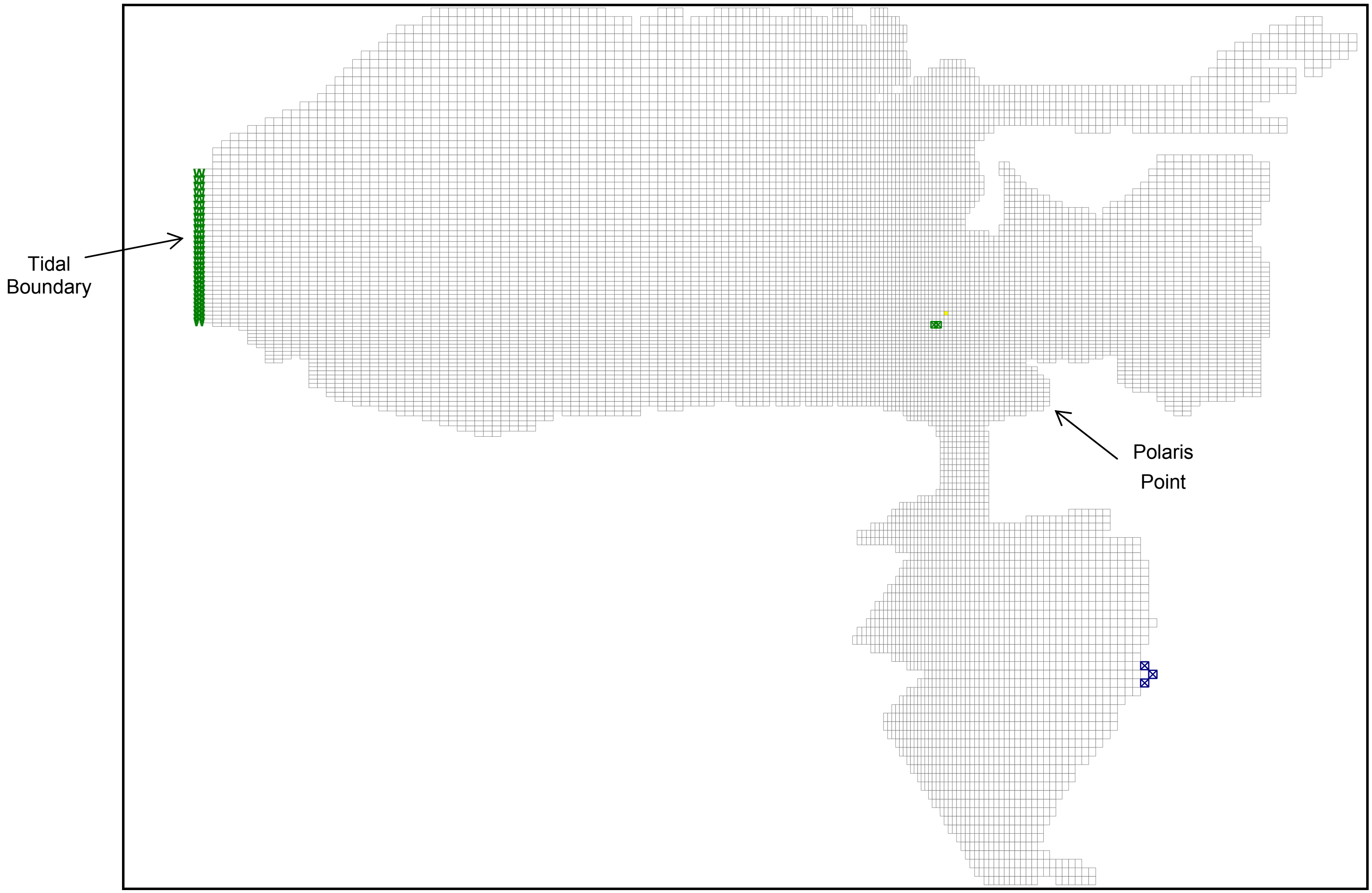


Figure 5-2. Model Grid with 12,000 Cells

The cell size is 20x20 meters offshore of Polaris Point, increasing by 2% each cell to a maximum size of 50 meters. Marked cells indicate boundary inputs.

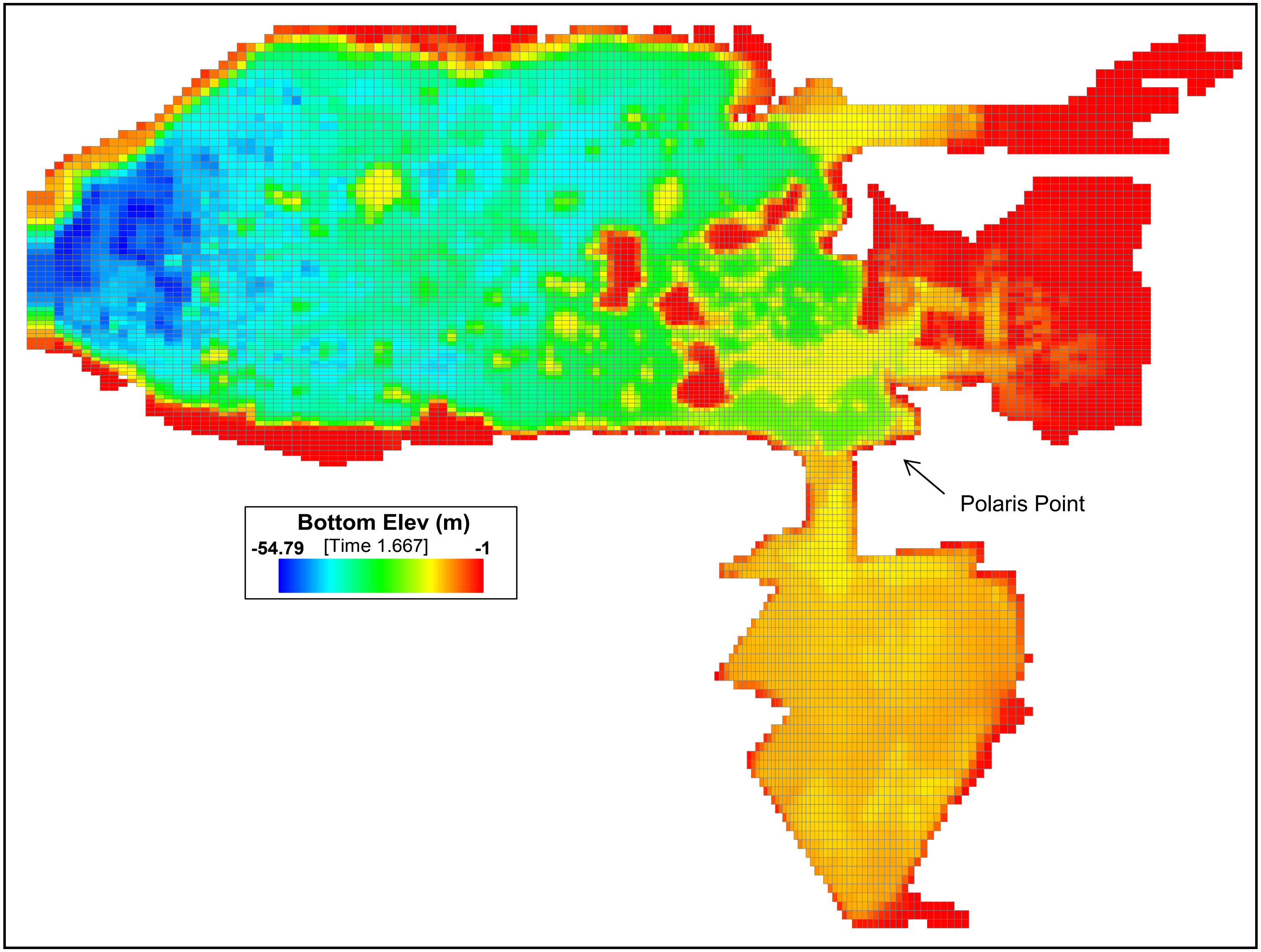


Figure 5-3. Color-Coded Model Bathymetry (in meters) Overlain on the Model Grid

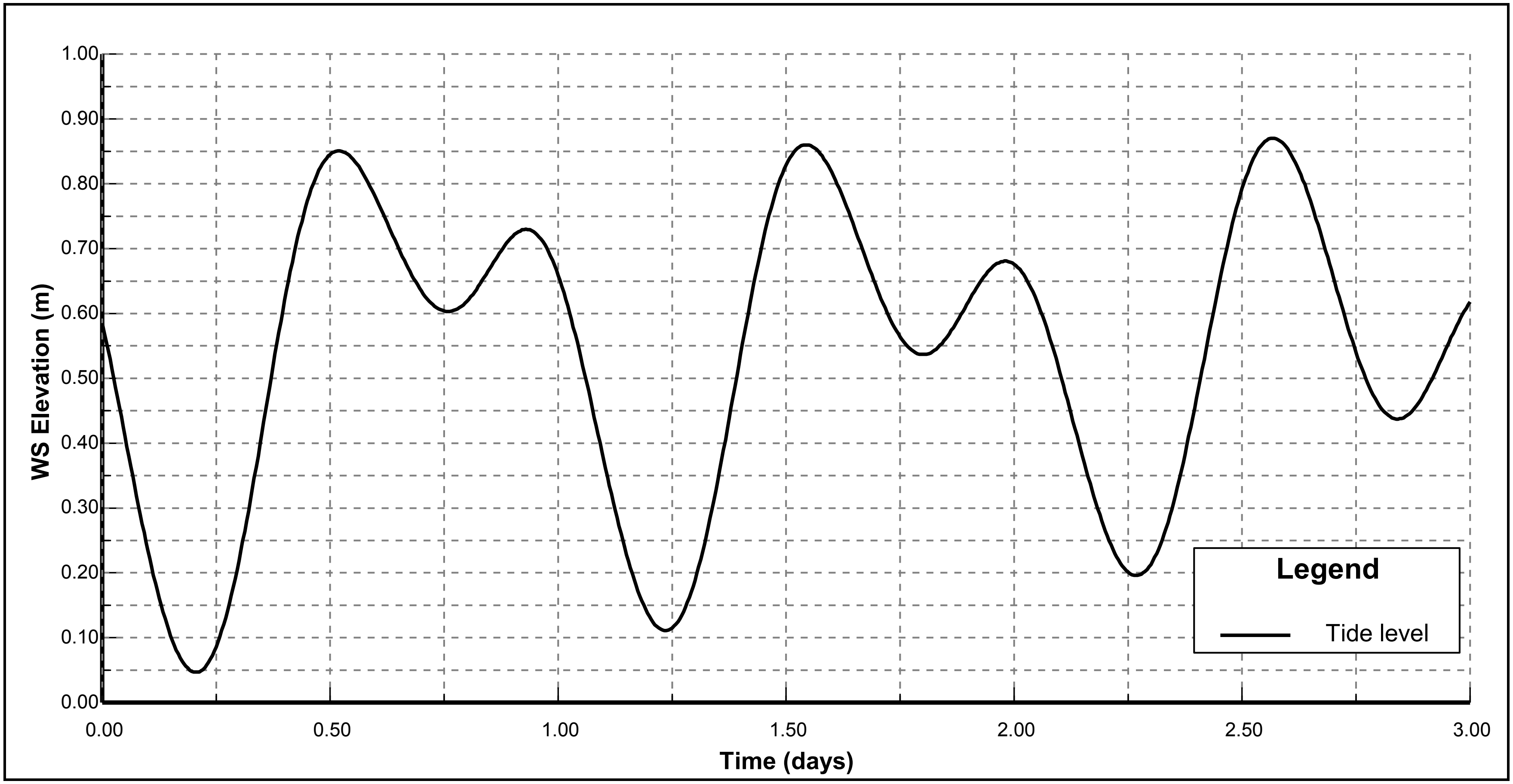


Figure 5-4. December 15 to 17, 2007 Tides Applied at Model Open Boundary

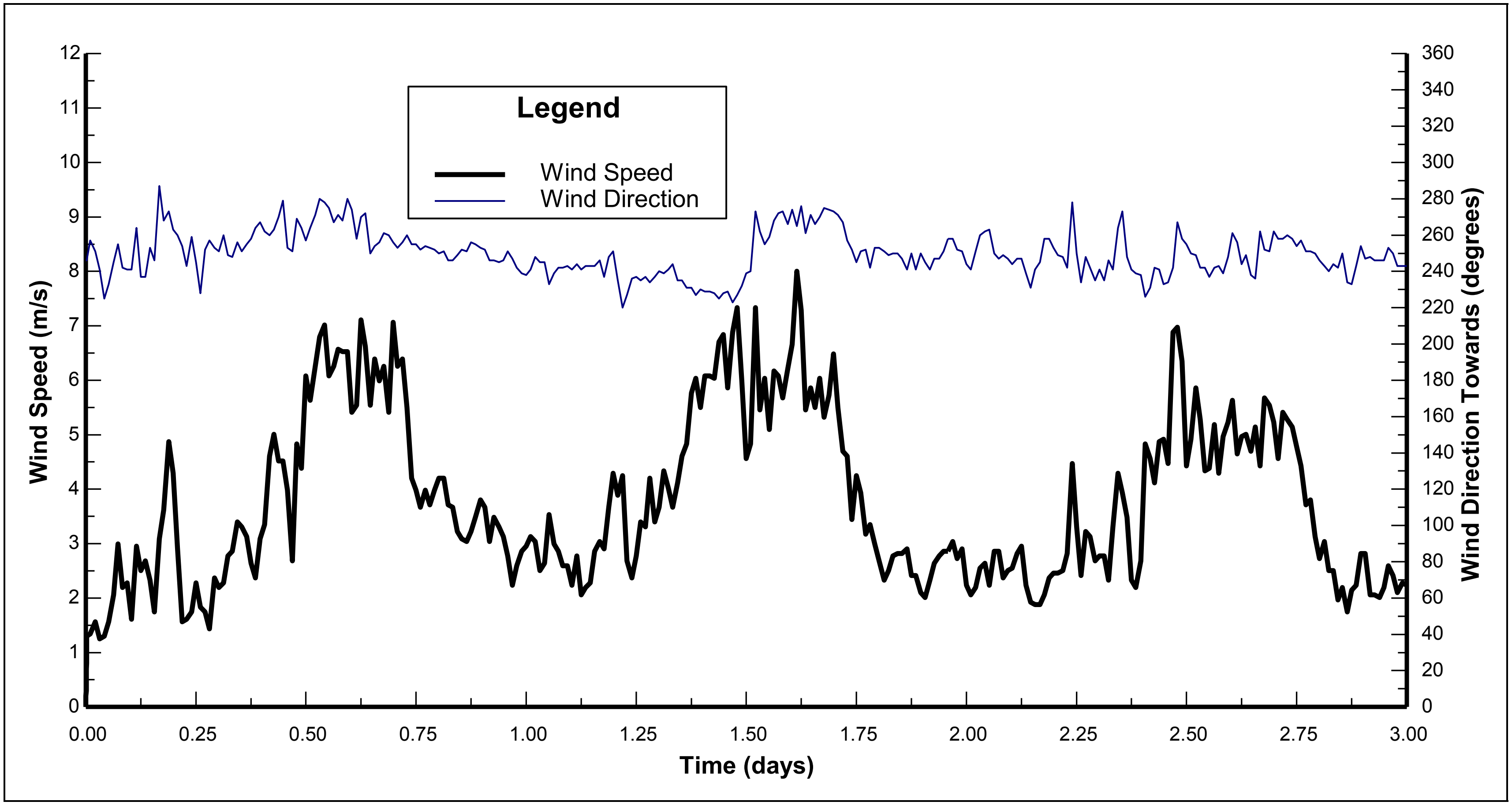


Figure 5-5. December 15 to 17, 2007, Wind Input Conditions

Wind Direction describes the direction that the wind is blowing towards.

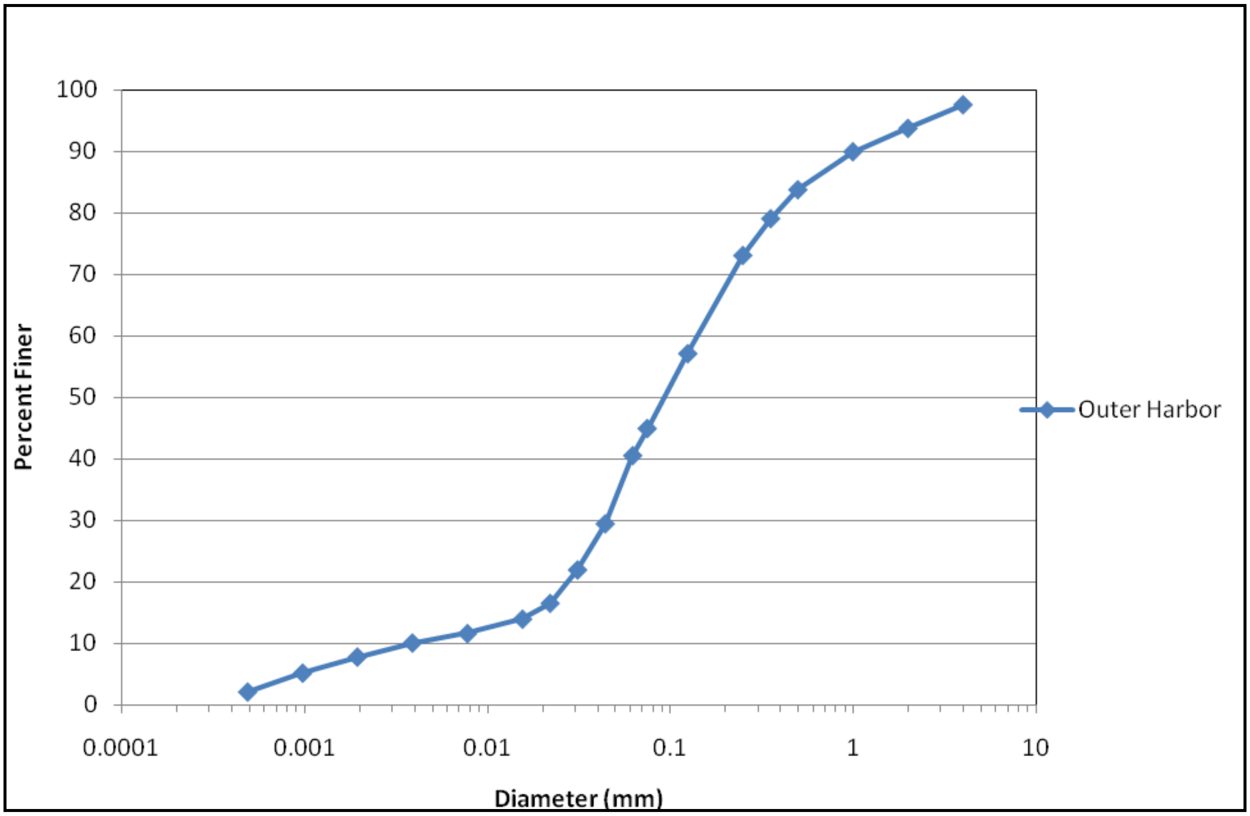


Figure 5-6. Composite Sediment Grain Size Distribution From Grab Samples Collected in CVN Project Area

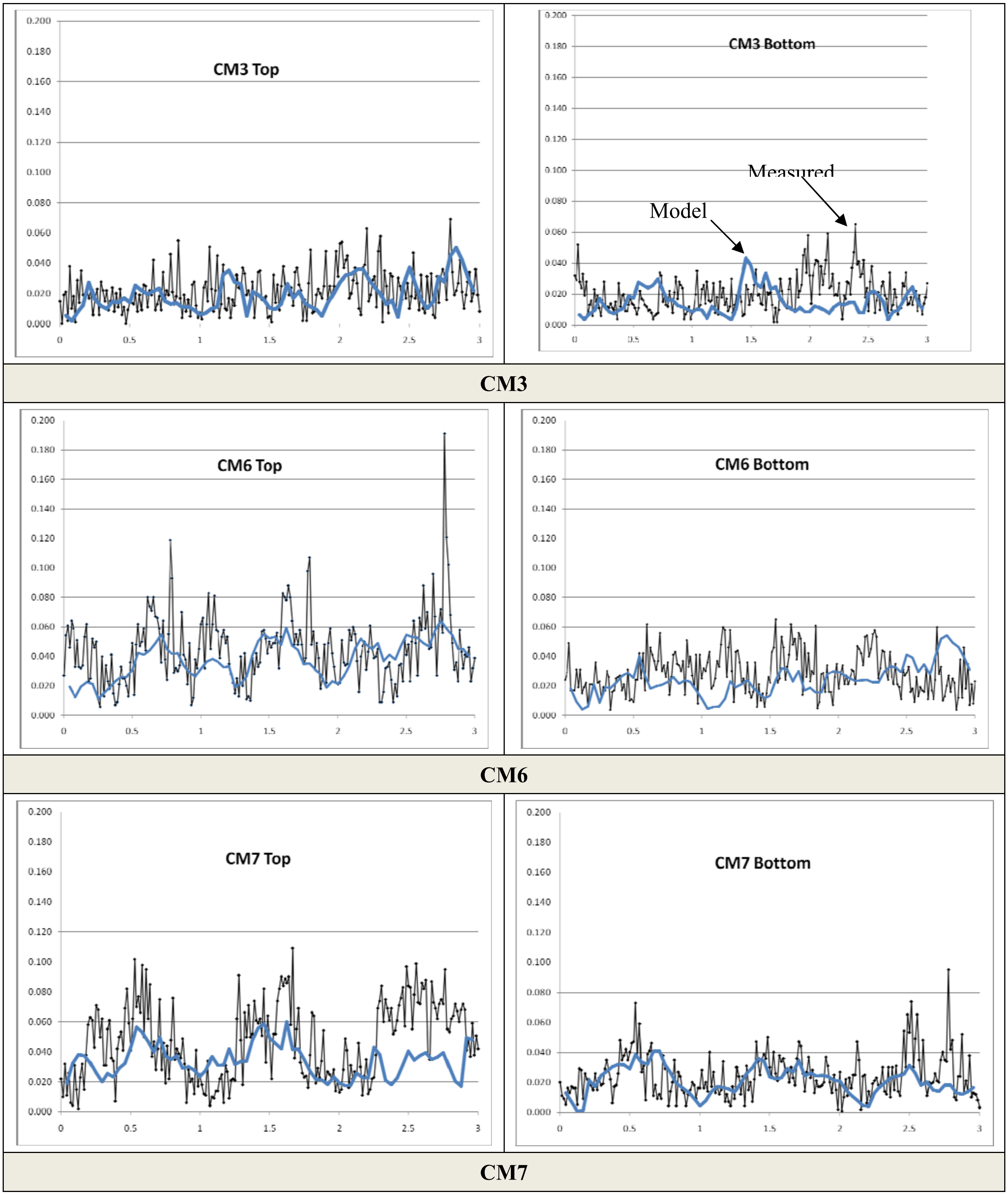


Figure 5-7. Comparison of Model Generated and Measured Current Speeds

Black lines indicate measured data, blue lines are model results.

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6.0 MODEL RESULTS

A series of 20 different model runs were completed using combinations of the input parameters described in Section 5 above. These model runs are listed in Table 6-1, and results are presented below. At every time step for the specified duration of the model run, EFDC calculated currents and water properties at each model grid point. These values could be output at specified times and locations during the model run. Models were run for a time period of 3 days: the first day allowed circulation to become established, dredging was simulated during the second day, and the third day allowed remaining dredging suspended sediment to settle out of the water column. Model output was referenced to decimal days, beginning at 0 and ending at 3 days. Model runs were completed for 24-hour and 10-hour dredging operations.

The model results were presented in several different formats:

1. Velocity Vector Plots – Velocity vector plots of the bottom and surface layers were produced for selected model cases to show the general circulation patterns produced by typical trade winds, moderate trade winds, south winds and calm conditions.
2. TSS Contour Plots – The representative plumes of suspended sediment were displayed in plots showing concentrations of TSS, plotted in mg/L. In the model, the background levels of TSS were assumed to be 0, therefore all TSS values computed by the model derived from the dredging. In the baseline water quality assessment completed for this project, Marine Research Consultants measured near surface, mid-water and near bottom TSS at 30 stations in the project area, on November 5, 2007 and January 28, 2008. The measured TSS values ranged from 0.4 to 29 mg/L, with average of about 3 mg/L. Model results were displayed to a minimum contour interval of 1 mg/L, significantly below typical background levels. In general, these figures showed a snapshot of the plume at its maximum size.
3. Sediment Thickness Contour Plots – EFDC calculated the deposition of sediment as the dredge plume was transported by currents away from the dredge site. Contour plots were prepared for each model case showing the sediment mass and thickness of sediment deposited during the 24-hour dredging operation. The sediment mass was referenced to units of mg/cm^2. Studies on impacts of sedimentation on coral typically reference sedimentation rates in mg/cm^2 per day. This was converted to sediment thickness in millimeters using the estimated wet density of the sediment. Review of the scientific literature to identify deleterious sedimentation rates on corals revealed that there was no specific threshold level of sedimentation that resulted in coral mortality. The literature review did reveal, however, that negative effects of sediment loading to reef corals were dependent on both the duration and the rate of sediment deposition (Marine Research Consultants 2005). Threshold rates cited in the literature range from 5 mg/cm^2 per day to 100 mg/cm^2 per day. The sediment thickness contour plots display contours corresponding to sedimentation of 5, 10, 40, 100 and 500 mg/cm^2.

Table 6-1. Model Cases (Assuming Dredging with Silt Curtains)

Model Case	*Dredge Location*	*Wind*	*Dredging Release*	*Dredge Production*
6.1	D1	Typical Dec. 15-18	Average	1800cy/24hrs
6.2	D3	Typical Dec. 15-18	Average	1800cy/24hrs
6.3	D4	Typical Dec. 15-18	Average	1800cy/24hrs
6.4	D7	Typical Dec. 15-18	Average	1800cy/24hrs
6.5	D8	Typical Dec. 15-18	Average	1800cy/24hrs
6.6	D6	Typical Dec. 15-18	Average	1800cy/24hrs
6.7	D9	Typical Dec. 15-18	Average	1800cy/24hrs
6.8	D1	South	Average	1800cy/24hrs
6.9	D1	Calm		
6.10	D1	Strong trades	Worst 10%	1800cy/24hrs
6.11	D1	Typical Dec. 15-18	Average	1000cy/10hrs
6.12	D2	Typical Dec. 15-18	Average	1000cy/10hrs
6.13	D3	Typical Dec. 15-18	Average	1000cy/10hrs
6.14	D4	Typical Dec. 15-18	Average	1000cy/10hrs
6.15	D5	Typical Dec. 15-18	Average	1000cy/10hrs
6.16	D6	Typical Dec. 15-18	Average	1000cy/10hrs
6.17	D7	Typical Dec. 15-18	Average	1000cy/10hrs
6.18	D8	Typical Dec. 15-18	Average	1000cy/10hrs
6.19	D9	Typical Dec. 15-18	Average	1000cy/10hrs
6.10	D8	Strong trades	Worst 10%	1000cy/24hrs

6.1 December 15 to 18 Winds, 24-hour Dredging at D1

Model case 6.1 was a calculation of the transport of a plume generated by 24 hours of dredging at site D1 during typical trade winds measured December 15 to 18, 2007. The total dredging production for the day was specified to be 1800 cy (1376 m^3), of which 1% is released into the water column. Use of a silt curtain spanning the upper 80% of the water contained 90% of the released material; the bottom 20% of the water column was exposed to the ocean currents, and was loaded with the 40% of material typically released near the bottom, as well as with material contained within the silt curtain.

Figures 6-1A and 6-1B show the general circulation pattern calculated by the model; surface currents generally flowed in the direction of the wind to the west out of Apra Harbor, while bottom currents flow to the east. In the project area, surface current speeds averaged about 4 to 6 cm/s, while bottom layer speeds were 2 to 4 cm/s. In the entrance channel to the inner harbor, currents were stronger, averaging 0.33 ft/s (10 cm/s) to the west in the surface, and 0.20 ft/s (6 cm/s) to the east near the bottom. These results were consistent with the current meter data.

Figures 6-1C and 6-1D show the calculated suspended sediment plume. The plume on the surface was transported downwind in a westerly direction. Peak surface TSS concentrations at the dredge site ranged from 1.7 to 3 mg/L. TSS concentrations exceeding 1 mg/L extend about 820 ft (250 m) to the west. Surface TSS concentrations exceeding typical background levels of 3 mg/L were not predicted by the model. The plume in the bottom layer was much more extensive because most of the suspended sediment was released into the bottom layer of the water column, and it also received all of the TSS contained by the silt curtain. Figure 6-1D shows that the dredging plume primarily was transported towards the south. Peak TSS at the dredge site was calculated to be 50 to 80 mg/L. The size of the plume where TSS concentrations exceeded the background level of 3 mg/L was approximately 328 ft (100 m). Time series plots of TSS showed that the suspended sediment was rapidly dissipated after dredging ceases (see Figures 6.3C and 6.3D).

During the 24 hours of dredging, approximately 51,809 pounds (23,500 kg) of suspended sediment were released into the water column. At the end of the model run of 3 days, approximately 44,092 pounds

(20,000 kg) of sediment (85%) were deposited in the model area, and 7,716 pounds (3,500 kg) remained suspended in the water column. The sedimentary footprint, shown in Figure 6-1E, followed the bottom layer plume. Maximum deposition occurred at the dredging site, where approximately1,399 mg/cm^2, or 1/3 inch (8 mm) of sediment were calculated to be deposited. The primary zone of deposition extended to the south of the dredge site, following the initial transport of the plume. Sediment deposition greater than 40 mg/cm^2, or 0.008 inch (0.2 mm), occurred to a distance of 164 ft (50 m) south of the dredge site.

6.2 December 15 to 18 Winds, 24-hour Dredging at D3

Model case 6.2 was similar to case 6.1 except that dredging was simulated at site D3 on the east edge of the dredge area.

Figures 6-2A and 6-2B show the calculated suspended sediment plume. The plume on the surface was transported downwind in a westerly direction. Peak surface TSS concentrations at the dredge site were approximately 4 mg/L. TSS concentrations exceeding 1 mg/L extended about 328 to 492 ft (100 to 150 m) to the east and west. Surface TSS concentrations exceeding typical background levels of 3 mg/L were predicted only directly at the dredge site. The plume in the bottom layer was much more extensive because most of the suspended sediment was released into the bottom layer of the water column, and it also received all of the TSS contained by the silt curtain. Figure 6-1B shows that the dredging plume primarily was transported towards the east towards Sasa Bay. Peak TSS at the dredge site was calculated to be approximately 30 mg/L. The size of the plume where TSS concentrations exceeded the background level of 3 mg/L was approximately 394 ft (120 m). Time series plots of TSS showed that the suspended sediment was rapidly dissipated after dredging ceases.

The sedimentary footprint resulting from 24 hours of dredging at site D3 is presented in Figure 6-3C. Sedimentation followed the bottom layer plume and extended primarily toward the east. Maximum deposition occurred at the dredging site, where approximately 1,200, or 7 mm of sediment were calculated to be deposited. Sediment deposition greater than 40 mg/cm^2, or 0.008 inch (0.2 mm), occurred to a distance of 164 ft (50 m) east of the dredge site.

6.3 December 15 to 18 Winds, 24-hour Dredging at D4

Model case 6.3 was similar to case 6.1 except that dredging was simulated at site D4, in the dredge area immediately adjacent to Polaris Point.

Figures 6-2A and 6-2B show the calculated suspended sediment plume. The plume on the surface hugged the shoreline, and extended to the east and west. Peak surface TSS concentrations at the dredge site range from 6 to 10 mg/L. TSS concentrations exceeding 1 mg/L extended to the Inner Apra Harbor entrance channel about 820 ft (250 m) to the west. Surface TSS concentrations exceeding typical background levels of 3 mg/L extended about 328 ft (100 m) to the east and west of the dredge site. In the bottom layer, the plume was transported to the east, although lower concentrations also diffused toward the west (Figure 6-3B). Peak bottom layer TSS at the dredge site ranged from 40 to 100 mg/L. Plume concentrations exceed the background level of 3 mg/L extend to the east to the shoreline, a distance of approximately 427 ft (130 m). Figures 6.3C and 6.3D plot the TSS concentration at the dredge site against model time. The Figures show that the suspended sediment was rapidly dissipated after dredging ceases.

The sedimentary footprint resulting from 24 hours of dredging at site D4 is presented in Figure 6-3E. Sedimentation occurred in a diamond shaped footprint, with primary lobes to the east and west. Maximum deposition at the dredging site was 1,742 mg/cm^2, or 10 mm. Sediment deposition greater than 40 mg/cm^2 or 0.008 inch (0.2 mm), occurred to a distance of 148 ft (45 m) east of the dredge site.

6.4 December 15 to 18 Winds, 24-hour Dredging at D7

Model case 6.4 had the same model input parameters as case 6.1, except that dredging was simulated at site D7, along the western boundary of the dredge area, near Big Blue Reef.

Figures 6-4A and 6-4B show the calculated concentrations of suspended sediment in the bottom and surface layers of the water. The plume on the surface was transported downwind to the west. Peak surface TSS concentrations at the dredge site range were approximately 6 mg/L. TSS concentrations exceeding 1 mg/L extended about 7878 ft (240 m) to the west, while concentrations exceeding typical background levels of 3 mg/L extended about 262 ft (80m) to the west (Figure 6-4A). In the bottom layer, the plume was transported primarily to the east and south, although lower concentrations also diffused toward the west (Figure 6-4B). Peak bottom layer TSS at the dredge site ranged from 50 to 60 mg/L. Plume concentrations exceeding the background level of 3 mg/L extended approximately 85 m to the southeast.

The sedimentary footprint resulting from 24 hours of dredging at site D7 is presented in Figure 6-4C. Sedimentation was concentrated primarily in a north-south axis. Maximum deposition at the dredging site was 1364 mg/cm^2, or 1/3 inch (8 mm). Sediment deposition greater than 40 mg/cm^2, or 0.008 inch (0.2 mm) occurred to a distance of 112 ft (34 m) east of the dredge site.

6.5 December 15 to 18 Winds, 24-hour Dredging at D8

Model case 6.5 was similar to cases 6.1 to 6.4, except that dredging was simulated at site D8, along the northern boundary of the main, central dredge area for the project.

Figures 6-5A and 6-5B show the calculated concentrations of suspended sediment in the bottom and surface layers of the water. The plume on the surface was transported downwind to the west-southwest. Peak surface TSS concentrations at the dredge site range were approximately 6 mg/L. TSS concentrations exceeding 1 mg/L extended about 689 ft (210 m) to the west-southwest, while concentrations exceeding typical background levels of 3 mg/L occurred only at the dredge site (Figure 6-4A). In the bottom layer, the plume was transported primarily to the south, with peak bottom layer TSS at the dredge site ranging from 60 to100 mg/L. Plume concentrations exceeding the background level of 3mg/L extended approximately 262 ft (80 m) to the southeast.

Figure 6-4C illustrates the calculated sediment deposition following the 24 hours of dredging at site D8. The sediment was deposited primarily to the south of the dredge site. Maximum deposition of 1,499 mg/cm^2, or 1/3 inch (8 mm) occurred at the dredging site. Sediment deposition greater than 40 mg/cm^2, or 0.008 inch (0.2 mm), extended to a distance of 141 ft (43 m) to the south of the dredge site.

6.6 December 15 to 18 Winds, 24-hour Dredging at D6

Model case 6.6 simulates dredging at site D6, which is located on a small patch reef to the south of Jade Shoals. Other input parameters are the same as case 6.1.

Figures 6-6A and 6-6B show the calculated suspended sediment plume. The plume on the surface was transported downwind to the southwest. Peak surface TSS concentrations at the dredge site were approximately 4.5 mg/L. TSS concentrations exceeding 1 mg/L extended about 328 ft (100 m) to the southwest. Surface TSS concentrations exceeding typical background levels of 3 mg/L were predicted only directly at the dredge site. The plume in the bottom layer was transported primarily to the southeast. Peak TSS at the dredge site was calculated to be up to 110 mg/L. The size of the plume where TSS concentrations exceeded the background level of 3 mg/L was approximately 262 ft (80 m).

Sediment was deposited in a dual lobed pattern extending to the east and south of the dredge site. The sedimentary footprint resulting from 24 hours of dredging at site D6 is presented in Figure 6-6C. Maximum deposition occurred at the dredging site, where approximately 1,050 mg/cm^2, or ¼ inch (6 mm) of sediment were calculated to be deposited. Sediment deposition greater than 40 mg/cm^2, or 0.008 inch (0.2 mm), occurred to a distance of 121 ft (40 m) east and south of the dredge site.

6.7 December 15 to 18 Winds, 24-hour Dredging at D9

Model case 6.7 was similar to case 6.1 except that dredging was simulated at site D9, on a reef shoal at the northwestern limit of the project area.

Figures 6-7A and 6-7B show the calculated suspended sediment plume. The plume on the surface was transported downwind to the southwest. Peak surface TSS concentrations at the dredge site were approximately 4 mg/L. TSS concentrations exceeding 1 mg/L extended about 230 ft (70 m) 0.008 inch to the southwest. Surface TSS concentrations exceeding typical background levels of 3 mg/L are predicted only directly at the dredge site. The plume in the bottom layer was transported primarily to the east and southeast. Peak TSS at the dredge site was calculated to be approximately 20 to 30 mg/L. The size of the plume where TSS concentrations exceed the background level of 3 mg/L was approximately 230 ft (70 m).

Sediment was deposited primarily to the east of the dredge site. The sedimentary footprint resulting from 24 hours of dredging at site D9 is presented in Figure 6-7C. Maximum deposition occurred at the dredging site, where approximately 600 mg/cm^2, or 3.5 mm of sediment were calculated to be deposited. Sediment deposition greater than 40 mg/cm^2, or 0.008 inch (0.2 mm), occurred to a distance of 164 ft (50 m) east of the dredge site.

6.8 South Winds, 24-hour Dredging at D1

Model case 6.8 was a calculation of the transport of a plume generated by 24 hours of dredging at site D1 during typical south winds. Southerly winds occur approximately 7% of the time in Guam, with speeds typically less than 7 knots (3.6 m/s). To evaluate possible plume transport, a model case was completed assuming south winds of 7 knots (3 m/s). The total dredging production for the day was the same as previous model cases, specified to be 1800 cy (1376 m^3), of which 1% is released into the water column. Use of a silt curtain spanning the upper 80% of the water contains 90% of the released material; the bottom 20% of the water column is exposed to the ocean currents, and is loaded with the 40% of material typically released near the bottom, as well as with material contained within the silt curtain.

Figures 6-8A and 6-8B show the general circulation pattern calculated by the model; surface currents generally flowed in the direction of the wind to the north, with typical speeds of 4 to 8 cm/s in the dredge area, and accelerated speeds of up to 14 cm/s in the Inner Apra Harbor entrance channel. Bottom layer currents were predicted to be weak and irregular, with typical speeds of 1 to 3 cm/s.

Figures 6-8C and 6-8D show the calculated suspended sediment plume. The plume on the surface was transported downwind in a northerly direction. However, concentrations were very low because the weak current speeds allowed material to settle through the water column. Peak surface TSS concentrations at the dredge site ranged from 1 to 2 mg/L. Surface TSS concentrations exceeding typical background levels of 3 mg/L were not predicted by the model. The plume in the bottom layer was transported to the southeast, and had TSS concentrations of 60 to 140 mg/L at the dredge site. Peak concentrations were greater than for other model runs because the weak current speeds allowed accumulation of material, and settling from the upper water layers. Figure 6-8D shows that background TSS levels of 3 mg/L are exceeded within 591 ft (180 m) of the dredge site. The suspended sediment was rapidly dissipated after dredging ceases.

The sedimentary footprint calculated by the model during south wind conditions, shown in Figure 6-8E, followed the bottom layer plume, and extended to the southeast. Maximum deposition occurred at the dredging site, where approximately 1515 mg/cm^2, or 9 mm of sediment were calculated to be deposited. Sediment deposition greater than 40 mg/cm^2, or 0.008 inch (0.2 mm), occurred to a distance of 164 ft (50 m) southeast of the dredge site.

6.9 Calm Winds, 24-hour Dredging at D1

Model case 6.9 was a calculation of the transport of a plume generated by 24 hours of dredging at site D1 during periods when there is no wind. After the easterly trade winds, calm conditions are the most commonly occurring wind condition in Guam, occurring approximately 10% of the time. To evaluate possible plume transport, a model case was completed assuming no winds. The total dredging production for the day is the same as previous model cases, specified to be 1800 cy (1376 m^3), of which 1% is released into the water column. Use of a silt curtain spanning the upper 80% of the water contains 90% of the released material; the bottom 20% of the water column is exposed to the ocean currents, and is loaded with the 40% of material typically released near the bottom, as well as with material contained within the silt curtain.

Figures 6-9A and 6-9B show the general circulation pattern calculated by the model; surface currents generally flow out of the Inner Apra Harbor to the north into the Outer Apra Harbor due to fresh water inflow into the Inner Harbor. Surface currents in the Outer Apra Harbor are weak and irregular. Typical surface current speeds are 1 to 5 cm/s. Bottom layer currents are similarly weak and irregular, with typical speeds of 0.5 to 2 cm/s.

Figures 6-9C and 6-9D show the calculated suspended sediment plume. The plume on the surface was transported to the north by currents flowing out of the Inner Apra Harbor. However, concentrations were very low because the weak current speeds allowed material to settle through the water column. Peak surface TSS concentrations at the dredge site ranged from 1 to 2 mg/L. Surface TSS concentrations exceeding typical background levels of 3 mg/L were not predicted by the model. The plume in the bottom layer was transported weakly to the southeast, and had TSS concentrations of 75 to 160 mg/L at the dredge site. Similar to case 6.8, peak concentrations were greater than for other model runs because the weak current speeds allowed accumulation of material, and settling from the upper water layers. Figure 6-9D shows that TSS concentrations exceeding background levels of 3 mg/L extended 250 to the southeast of the dredge site. The suspended sediment was rapidly dissipated after dredging ceased.

The sedimentary footprint calculated by the model during calm wind conditions is shown in Figure 6-9E, and is also oriented to the southeast. Maximum deposition occurred at the dredging site, where approximately 1512 mg/cm^2, or 9 mm of sediment were calculated to be deposited. Sediment deposition greater than 40 mg/cm^2, or 0.008 inch (0.2 mm), occurred to a distance of 164 ft (50 m) southeast of the dredge site.

6.10 Strong Trade Winds, 24-hour Dredging at D1, Highest 10% Release

Model case 6.10 represented a worst case scenario for the release and transport of dredge material at the project site. Analysis of the TSS monitoring data from the recent Alpha-Bravo dredging project indicated that the highest 10% of the TSS levels measured outside of the silt curtain were approximately 8 times greater than the typical TSS levels measured during the dredging. To simulate this worst case level of material release, and achieve an 8-fold increase in material released outside the silt curtain, we increased the material release rate from 1% to 2% (see Section 5.4), and decreased the silt curtain effectiveness by a factor of 4. Worst case transport conditions were simulated by increasing the typical, diurnally varying trade wind speeds by 25%. This resulted in peak wind speeds in the early afternoon of 17.5 to 20 knots (8.75 to 10 m/s). Wind speeds greater than 20 knots (10 m/s) occur less than 0.4 % of the time in Guam.

The total dredging production for the day was the same as previous model cases, specified to be 1800 cy (1376 m^3), however, in this case 2% of the material was released into the water column. Use of a silt curtain spanning the upper 80% of the water contained 60% of the released material; the bottom 20% of the water column was exposed to the ocean currents, and was loaded with the 40% of material typically released near the bottom, as well as with material contained within the silt curtain.

Figures 6-10A and 6-10B show the general circulation pattern calculated by the model; enhanced surface currents generally flow in the direction of the wind to the west out of Apra Harbor, while bottom currents flow to the east. In the project area, surface current speeds averaged about 5 to 10 cm/s, while bottom layer speeds were 2 to 5 cm/s.

Figures 6-10C and 6-10D show the calculated suspended sediment plume. The plume on the surface was transported downwind in a westerly direction. Peak surface TSS concentrations at the dredge site ranged from 10 to 17 mg/L. TSS concentrations exceeding 1 mg/L extend about 1312 ft (400 m) to the west. Surface TSS concentrations exceeding typical background levels of 3 mg/L extended 262ft (80 m) from the dredge site. The plume in the bottom layer was much more extensive because most of the suspended sediment was released into the bottom layer of the water column, and it also received all of the TSS contained by the silt curtain. Figure 6-10D shows that the dredging plume primarily was transported towards the south. Peak TSS at the dredge site was calculated to be 75 to 135 mg/L. The size of the plume where TSS concentrations exceeded the background level of 3 mg/L was approximately 328 ft (100m). Time series plots of TSS show that the suspended sediment was rapidly dissipated after dredging ceases.

During the 24 hours of dredging, approximately 47,000 kg of suspended sediment were released into the water column. At the end of the model run of 3 days, approximately 40,200 kg of sediment (85%) were deposited in the model area, with the rest remaining suspended in the water column. The sedimentary footprint, shown in Figure 6-10E, followed the bottom layer plume. Maximum deposition occurred at the dredging site, where approximately 2690 mg/cm^2, or 16 mm of sediment were calculated to be deposited. The primary zone of deposition extended to the south of the dredge site, following the initial transport of the plume. Sediment deposition greater than 40 mg/cm^2, or 0.008 inch (0.2 mm), occurred to a distance of 262 ft (80 m) south of the dredge site.

6.11 December 15 to 18 Winds, 10-hour Dredging at D1

Model case 6.11 was a calculation of the transport of a plume generated by 10 hours of dredging at site D1 during typical trade winds measured December 15 to 18, 2007. The total dredging production for the day was specified to be 1000 cy (765 m^3), of which 1% is released into the water column. Use of a silt curtain spanning the upper 80% of the water contained 90% of the released material; the bottom 20% of the water column was exposed to the ocean currents, and was loaded with the 40% of material typically released near the bottom, as well as with material contained within the silt curtain.

Figures 6-11A and 6-11B show the calculated concentrations of suspended sediment in the bottom and surface layers of the water. The plume on the surface was transported downwind to the west-southwest. Peak surface TSS concentrations at the dredge site range were approximately 4 mg/L. TSS concentrations exceeding 1 mg/L extended about 1083 ft (330 m) to the west-southwest, while concentrations exceeding typical background levels of 3 mg/L occurred only at the dredge site (Figure 6-4A). In the bottom layer, the plume was transported primarily to the south, with peak bottom layer TSS at the dredge site ranging from 70 to 90 mg/L. Plume concentrations exceeding the background level of 3 mg/L extend approximately 427 ft (130 m) to the southeast.

Figure 6-4C illustrates the calculated sediment deposition following the 10 hours of dredging at site D1. The sedimentary footprint extended primarily to the south of the dredge site, and was smaller than the footprint for case 6.1. This is because dredging for this case occurred only for 10 hours, thereby reducing the daily load of material released into the water. Maximum deposition of 1420 mg/cm^2, or 1/3 inch (8 mm) occurs at the dredging site. Sediment deposition greater than 40 mg/cm^2, or 0.008 inch (0.2 mm), extended only 98 ft (30 m) to the south of the dredge site.

6.12 December 15 to 18 Winds, 10-hour Dredging at D2

Model case 6.12 was similar to case 6.11, except that the dredge site was located at the northeast boundary of the main dredge area, adjacent to the entrance to Sasa Bay.

Figures 6-12A and 6-12B show the calculated concentrations of suspended sediment in the bottom and surface layers of the water. The plume on the surface was transported downwind to the south. Peak surface TSS concentrations at the dredge site range were approximately 4 mg/L. TSS concentrations exceeding 1 mg/L extended about 492 ft (150 m) to the south, while concentrations exceeding typical background levels of 3 mg/L occurred only at the dredge site (Figure 6-12A). In the bottom layer, the plume was transported primarily to the southeast, with peak bottom layer TSS at the dredge site ranging from 30 to 50 mg/L. Plume concentrations exceeding the background level of 3 mg/L extended approximately 525 ft (160 m) to the southeast.

Figure 6-12C illustrates the calculated sediment deposition following the 10 hours of dredging at site D2. The sedimentary footprint extended primarily to the southeast of the dredge site; the 40 mg/cm^2, or 0.008 inch (0.2 mm), contour extended 98 ft (30 m) to the southeast of the dredge site. Maximum deposition of 1040 mg/cm^2, or ¼ inch (6 mm) occurred at the dredging site.

6.13 December 15 to 18 Winds, 10-hour Dredging at D3

Model case 6.13 was similar to case 6.11, except that the dredge site was located at the east boundary of the main dredge area, site D3 adjacent to the entrance to Sasa Bay.

Figures 6-13A and 6-13B show the calculated concentrations of suspended sediment in the bottom and surface layers of the water. The plume on the surface was transported to the east and west. Peak surface TSS concentrations at the dredge site were approximately 6 to 9 mg/L. TSS concentrations exceeding 1 mg/L extended about 492 ft (150 m) from the dredge site, while concentrations exceeding typical background levels of 3 mg/L occurred only within 98 ft (30m) the dredge site (Figure 6-13A). In the bottom layer, the plume was transported primarily to the east into Sasa Bay, with peak bottom layer TSS at the dredge site ranging from 30 to 50 mg/L. Plume concentrations exceeding the background level of 3 mg/L extended approximately 492 ft (150 m) to the east (Figure 6-13B).

Figure 6-13C illustrates that sediment is deposited primarily toward the east of D3. The sedimentary footprint extended primarily to the southeast of the dredge site; the 40 mg/cm^2, or 0.008 inch (0.2 mm), contour extended 131 ft (40 m) to the southeast of the dredge site. Maximum deposition of 1,184 mg/cm^2, or 7 mm occurred at the dredging site. The sedimentary footprint was slightly smaller than that of case 6.2 because the daily dredge production and time were reduced from 1,800 cy (1376 m^3) in 24 hours to 1,000 cy (765 m^3) in 10 hours.

6.14 December 15 to 18 Winds, 10-hour Dredging at D4

Model case 6.14 was similar to case 6.11, except that the dredge site was located at site D4 adjacent to the shoreline at Polaris Point.

Figures 6-14A and 6-14B show the calculated concentrations of suspended sediment in the bottom and surface layers of the water. The surface TSS plume was transported to the west toward the entrance channel to the Inner Apra Harbor. Peak surface TSS concentrations at the dredge site ranged from 5 to 17 mg/L. TSS concentrations exceeding 1 mg/L extended about 820 ft (250 m) from the dredge site, while concentrations exceeding typical background levels of 3 mg/L extended to a distance of 328 ft (100 m) from the dredge site (Figure 6-14A). In the bottom layer, the plume was transported primarily to the east, with peak bottom layer TSS at the dredge site ranging from 50 to 90 mg/L. Plume concentrations exceeding the background level of 3 mg/L extended to the shoreline approximately 328 ft (100 m) to the east (Figure 6-14B). TSS concentrations in the water were elevated at this dredge location relative to other locations because weaker currents and proximity to the shoreline allow the material to build up during dredging.

Figure 6-14C illustrates that the sedimentary footprint was confined to the immediate dredge vicinity. The 40 mg/cm^2, or 0.2 mm, contour extended only 75 ft (23 m) from the dredge location. Maximum deposition of 914 mg/cm^2, or 5 mm occurred at the dredging site.

6.15 December 15 to 18 Winds, 10-hour Dredging at D5

Model case 6.15 presented model results for 10 hours of dredging at site D5, along the southern boundary of the main dredge area, directly outside of the entrance to the Inner Apra Harbor.

The surface TSS plume generated by the dredging was primarily transported downwind to the west. The model predicted maximum TSS concentrations of 3 to 9 mg/L in the surface at the dredge site. TSS concentrations exceeding 1 mg/L extended 656 ft (200 m) from the dredge site, while concentrations exceeding typical background levels of 3 mg/L extended to a distance of 131 ft (40 m) from the dredge site (Figure 6-15A). In the bottom layer, the plume was transported primarily to the east-southeast, with peak bottom layer TSS at the dredge site ranging from 50 to 90 mg/L. Plume concentrations exceeding the background level of 3 mg/L extended approximately 262 ft (80 m) to the east-southeast (Figure 6-15B). TSS concentrations in the water were elevated at this dredge location relative to other locations because weaker currents and proximity to the shoreline allowed the material to build up during dredging.

Sedimentation was also concentrated to the east-southeast of the dredge site. Figure 6-15C illustrates that sediment deposition exceeding 40 mg/cm^2, or 0.2 mm, extended 131 ft (40 m) from the dredge location. Maximum deposition of 1,210 mg/cm^2, or 7 mm occurred at the dredging site.

6.16 December 15 to 18 Winds, 10-hour Dredging at D6

Model case 6.16 presents model results for 10 hours of dredging at site D6, which is located on a small patch reef to the south of Jade Shoals.

Figures 6-16A and 6-16B show the calculated concentrations of suspended sediment in the bottom and surface layers of the water. The plume on the surface was transported downwind to the southwest. Peak surface TSS concentrations at the dredge site range were approximately 5 mg/L. TSS concentrations exceeding 1 mg/L extended about 430 feet (130 m) to the south, while concentrations exceeding typical background levels of 3 mg/L occurred only at the dredge site (Figure 6-16A). In the bottom layer, the plume was transported primarily to the south-southeast, with peak bottom layer TSS at the dredge site ranging from 30 to 50 mg/L. Plume concentrations exceeding the background level of 3 mg/L extended approximately 330 feet (100 m) to the south-southeast.

Figure 6-16C illustrates the calculated sediment deposition following the 10 hours of dredging at site D6. The sedimentary footprint extended primarily to the south and east of the dredge site; the 40 mg/cm^2, or 0.008 inch (0.2 mm), contour extended 115 feet (35 m) to the southeast of the dredge site. Maximum deposition of 1060 mg/cm^2, or 6.2 mm occurred at the dredging site.

6.17 December 15 to 18 Winds, 10-hour Dredging at D7

Model case 6.17 presents model results for 10 hours of dredging at site D7, along the western boundary of the dredge area, near Big Blue Reef.

Figures 6-17A and 6-174B show the calculated concentrations of suspended sediment in the bottom and surface layers of the water. The plume on the surface was transported downwind to the west. Peak surface TSS concentrations at the dredge site range were approximately 12 mg/L. TSS concentrations exceeding 1 mg/L extended about 850 feet (260 m) to the west, while concentrations exceeding typical background levels of 3 mg/L extended about 430 feet (130 m) to the west (Figure 6-17A). In the bottom layer, the plume was transported primarily to the east and south, although lower concentrations also diffused toward the west (Figure 6-17B). Peak bottom layer TSS at the dredge site was 75 mg/L. Plume concentrations exceeding the background level of 3 mg/L extended approximately 360 feet (110 m) to the southeast.

The sedimentary footprint resulting from 10 hours of dredging at site D7 is presented in Figure 6-17C. Sedimentation is concentrated primarily in a north-south axis. Maximum deposition at the dredging site was 1,341 mg/cm^2, or 1/3 inch (8 mm). Sediment deposition greater than 40 mg/cm^2, or 0.008 inch (0.2 mm), occurred to a distance of 108 ft (33 m) east of the dredge site.

6.18 December 15 to 18 Winds, 10-hour Dredging at D8

Model case 6.18 presents model results for 10 hours of dredging at site D8, along the northern boundary of the main, central dredge area for the project.

Figures 6-18A and 6-18B show the calculated concentrations of suspended sediment in the bottom and surface layers of the water. The plume on the surface was transported downwind to the west-southwest. Peak surface TSS concentrations at the dredge site were approximately 8 mg/L. TSS concentrations exceeding 1 mg/L extended about 885 feet (270 m) to the west-southwest, while concentrations exceeding typical background levels of 3 mg/L extended 330 feet (100 m) from the dredge site (Figure 6-18A). In the bottom layer, the plume was transported primarily to the south and southwest, with peak bottom layer TSS at the dredge site ranging from 70 to 100 mg/L. Plume concentrations exceeding the background level of 3 mg/L extended approximately 394 feet (120 m) to the southeast (Figure 6-18B).

Figure 6-18C illustrates the calculated sediment deposition following the 10 hours of dredging at site D8. The sediment was deposited primarily to the south of the dredge site. Maximum deposition of 1,460 mg/cm^2, or 8.5 mm occurred at the dredging site. Sediment deposition greater than 40 mg/cm^2, or 0.008 inch (0.2 mm), extended to a distance of 105 feet (32 m) to the south of the dredge site.

6.19 December 15 to 18 Winds, 10-hour Dredging at D9

Model case 6.19 presents model results for 10 hours of dredging at site D9, on a reef shoal at the northwestern limit of the project area.

Figures 6-19A and 6-19B show the calculated suspended sediment plume. The plume on the surface was transported downwind to the southwest. Peak surface TSS concentrations at the dredge site were approximately 5 mg/L. TSS concentrations exceeding 1 mg/L extended about 328 feet (100 m) to the southwest. Surface TSS concentrations exceeding typical background levels of 3 mg/L were predicted only directly at the dredge site. The plume in the bottom layer was transported primarily to the southeast. Peak TSS at the dredge site was calculated to be approximately 25 to 38 mg/L. The size of the plume where TSS concentrations exceeded the background level of 3 mg/L was approximately 328 feet (100 m).

Sediment was deposited primarily to the east of the dredge site. The sedimentary footprint resulting from 10 hours of dredging at site D9 is presented in Figure 6-19C. Maximum deposition occurs at the dredging site, where approximately 567 mg/cm^2, or 3.3 mm of sediment was calculated to be deposited. Sediment deposition greater than 40 mg/cm^2, or 0.008 inch (0.2 mm), occurred to a distance of 154 feet (47 m) east of the dredge site.

6.20 Strong Trade Winds, 10-hour Dredging at D8, Highest 10% Release

Model case 6.20 represents a worst case scenario for the release and transport of dredge material resulting from 10 hours of dredging at the project site. The model parameters are similar to those for model case 6.10, except that dredging occurred for only 10 hours per day, instead of 24 hours. The model is based on the highest 10% of the TSS levels measured outside of the silt curtain during the Alpha-Bravo dredging project, and thus the material release rate was increased from 1% to 2% (see Section 5.4), and the silt curtain effectiveness was decreased by a factor of 4. Worst case transport conditions were simulated by increasing the typical, diurnally varying trade wind speeds by 25%.

The total dredging production for the day is the same as previous 10-hour model cases, specified to be 1000 cy (765 m^3), however, in this case 2% of the material was released into the water column. Use of a silt curtain spanning the upper 80% of the water contained 60% of the released material; the bottom 20% of the water column was exposed to the ocean currents, and was loaded with the 40% of material typically released near the bottom, as well as with material contained within the silt curtain.

Figures 6-20A and 6-20B show the calculated suspended sediment plume. The plume on the surface was transported downwind in a southwesterly direction. Peak surface TSS concentrations at the dredge site ranged from 15 to 22 mg/L. TSS concentrations exceeding 1 mg/L extend about 1,300 ft (400 m) to the southwest. Surface TSS concentrations exceeding typical background levels of 3 mg/L extended 590 feet (180 m) from the dredge site. Figure 6-20B shows that the dredging plume primarily was transported towards the south and southwest. Peak TSS at the dredge site was calculated to be 70 to 100 mg/L near the bottom. The size of the plume where TSS concentrations exceed the background level of 3 mg/L was approximately 490 feet (150 m).

During the 10 hours of dredging, approximately 27,000 kg of suspended sediment were released into the water column. At the end of the model run of 3 days, approximately 22,300 kg of sediment (83%) were deposited in the model area, with the rest remaining suspended in the water column. The sedimentary footprint, shown in Figure 6-20C, followed the bottom layer plume. Maximum deposition occurred at the dredging site, where approximately 2,690 mg/cm^2, or 15.7 mm of sediment were calculated to be deposited. The primary zone of deposition extended to the south and southwest of the dredge site, and also to the east. Sediment deposition greater than 40 mg/cm^2, or 0.008 inch (0.2 mm), occurred to a distance of 164 feet (50 m) from the dredge site.

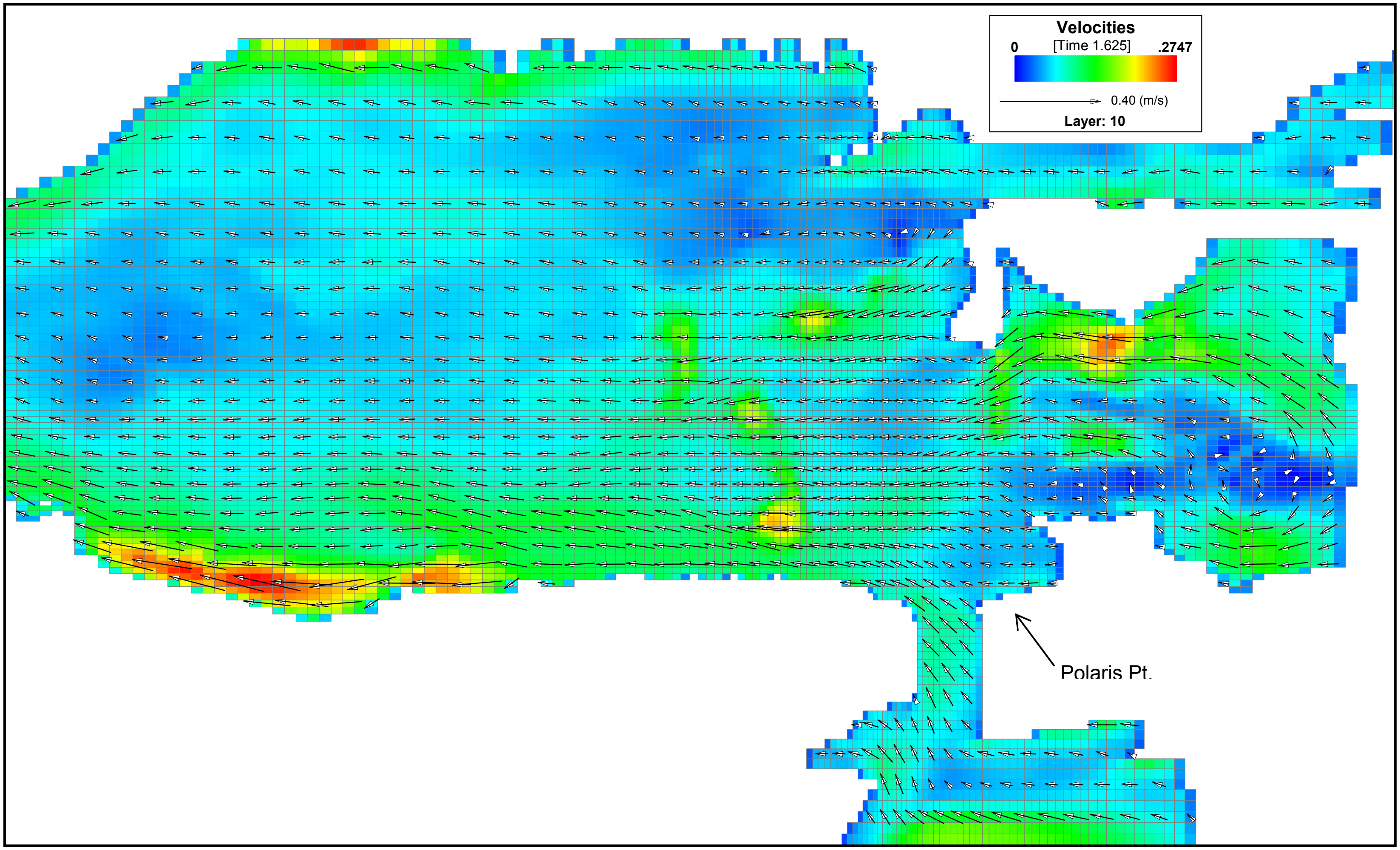

Figure 6-1A. Surface Layer Currents During Typical Trade Winds
(6.1 December 15 to 18 winds, 24-hour dredging at D1)

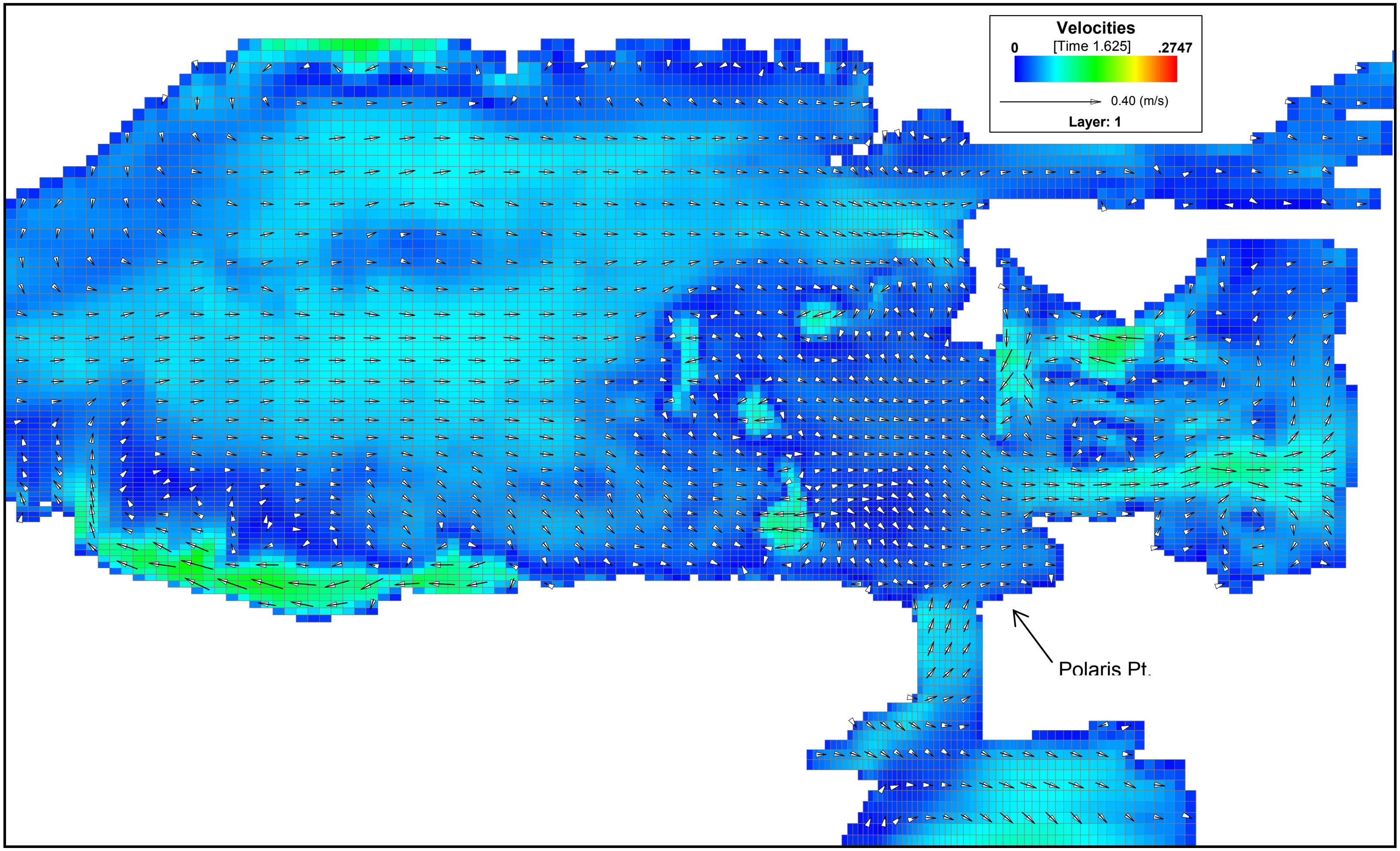

Figure 6-1B. Bottom Layer Currents During Typical Trade Winds
(6.1 December 15 to 18 winds, 24-hour dredging at D1)

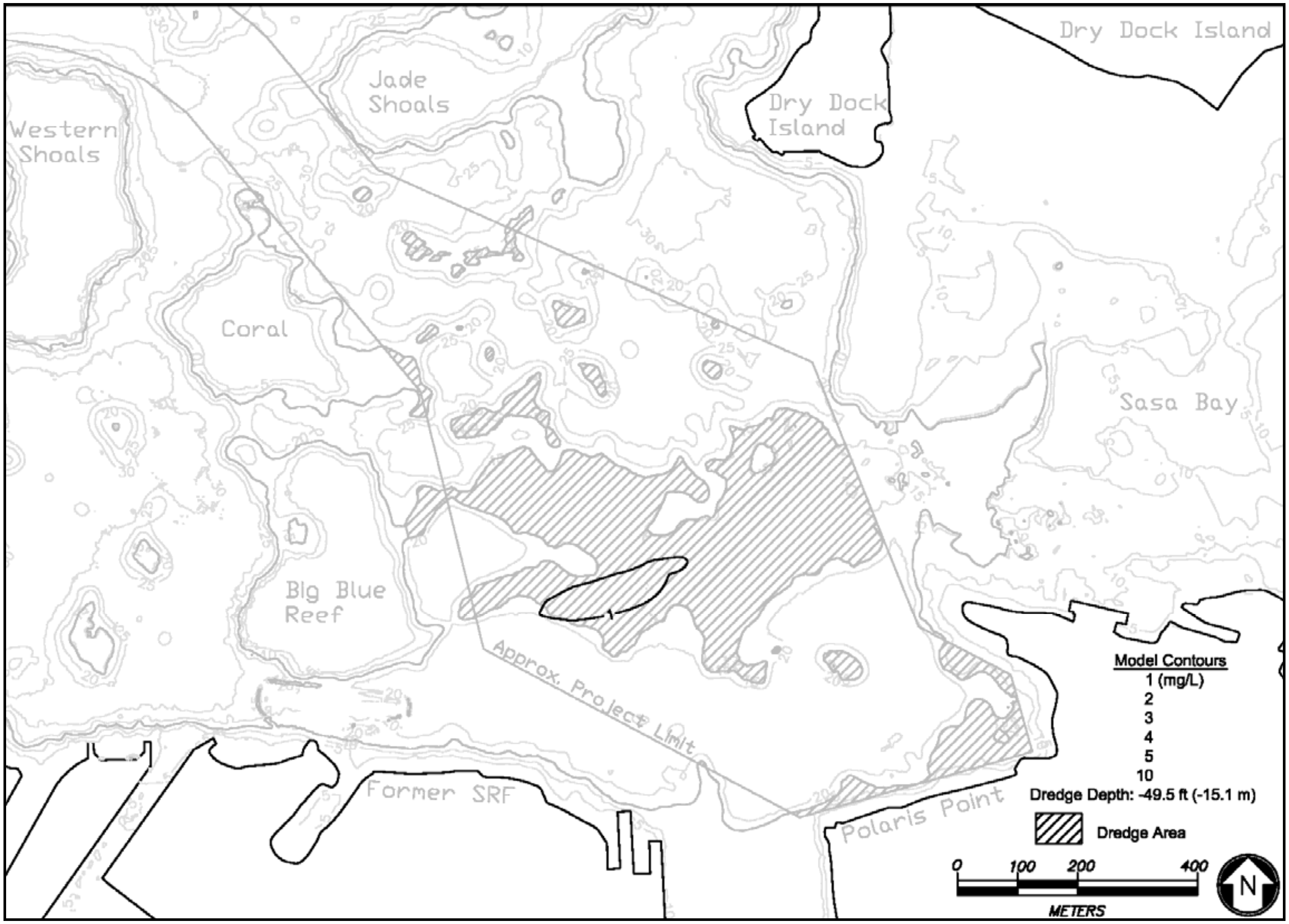

Figure 6-1C. Surface Layer Suspended Sediment Concentration

Contour interval 5mg/L.

(6.1 December 15 to 18 winds, 24-hour dredging at D1)

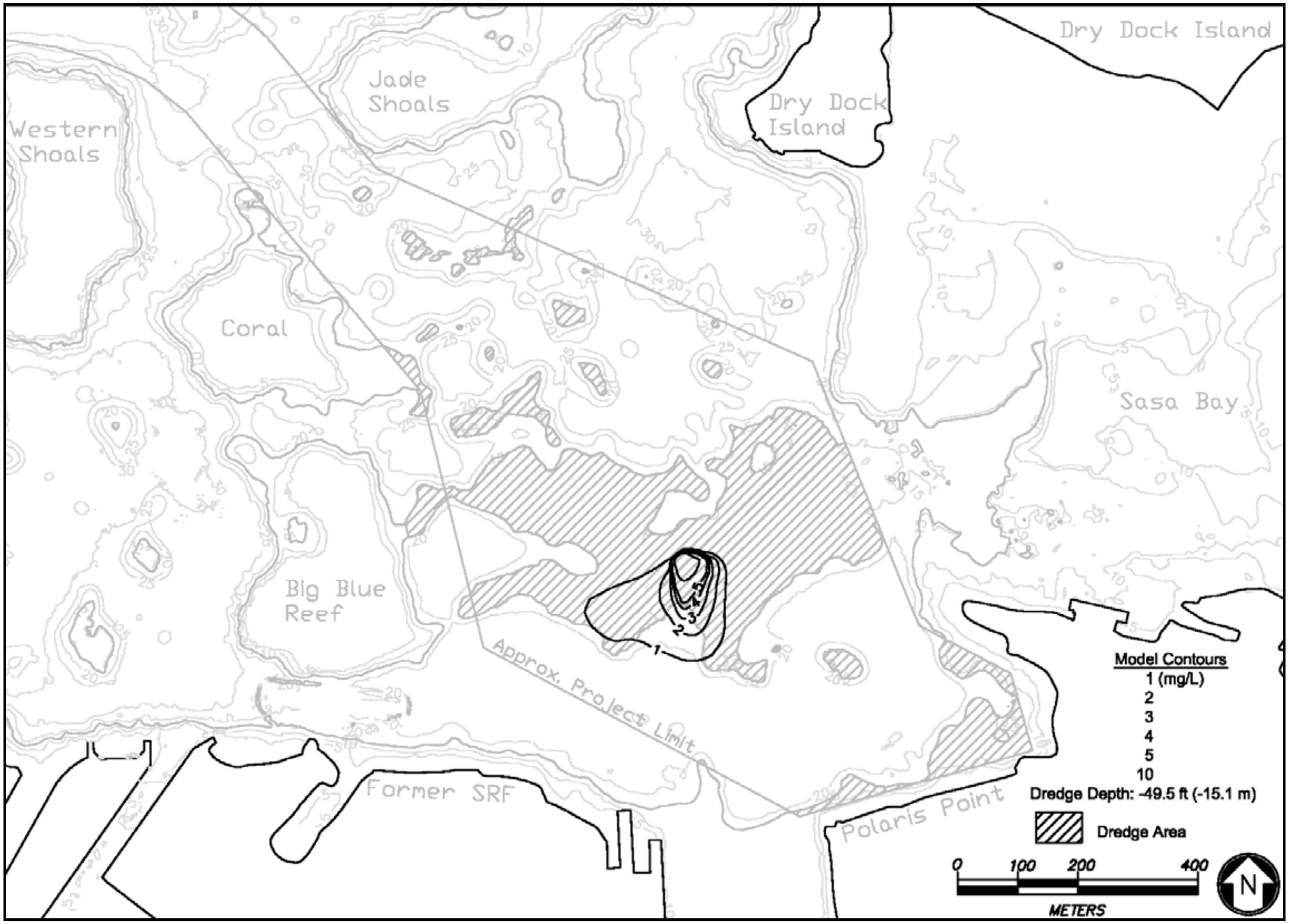

Figure 6-1D. Bottom Layer Suspended Sediment Concentration (6.1 December 15 to 18 winds, 24-hour dredging at D1)

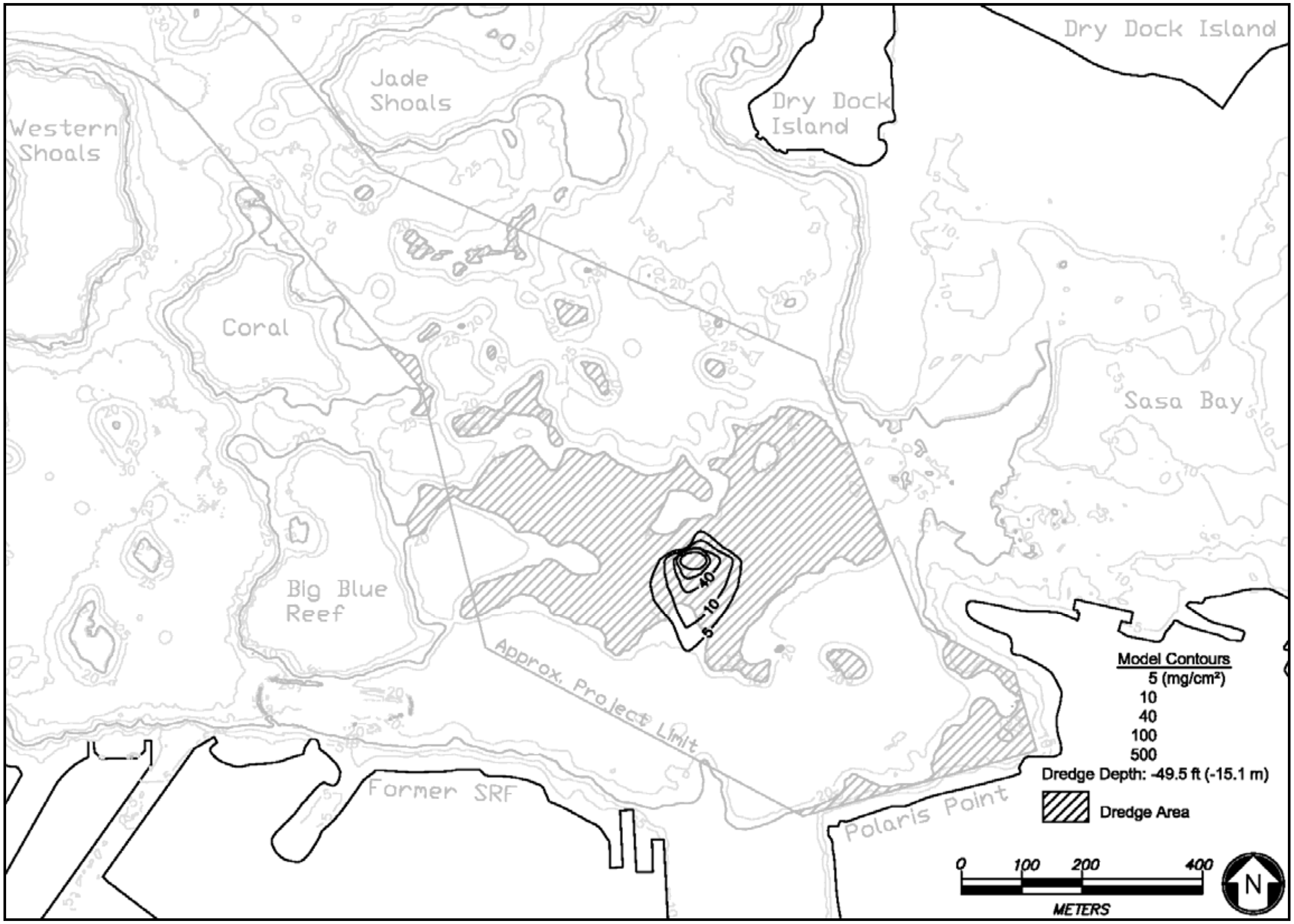

Figure 6-1E. Sediment Deposition

5mg/cm2 =0.03mm; 10mg/cm^2 =.06mm; 40mg/cm^2 =0.2mm; 100mg/cm^2 =0.6mm; 500mg/cm^2 =3mm

(6.1 December 15 to 18 winds, 24-hour dredging at D1)

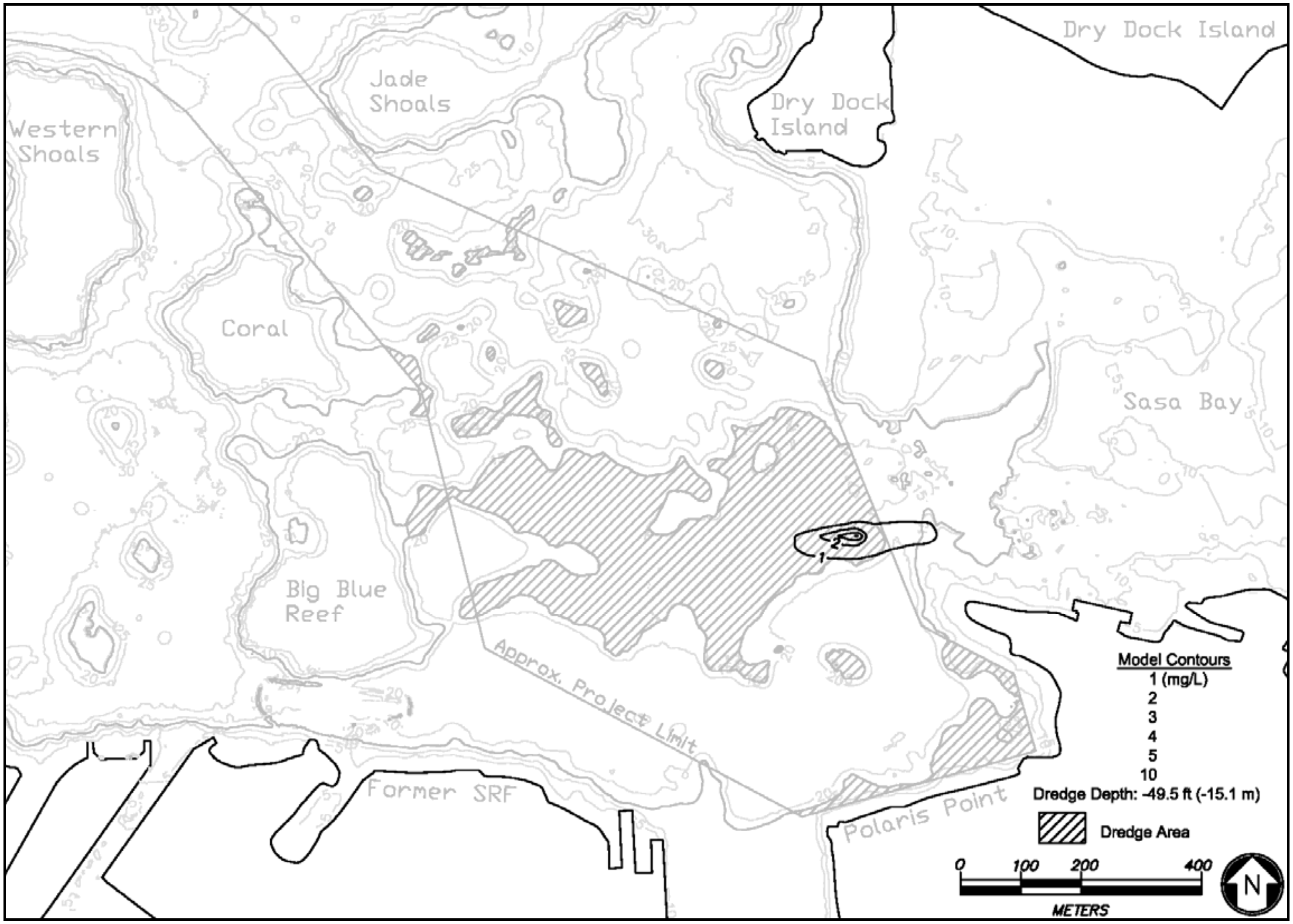

Figure 6-2A. Surface Layer Suspended Sediment Concentration (6.2 December 15 to 18 winds, 24-hour dredging at D3)

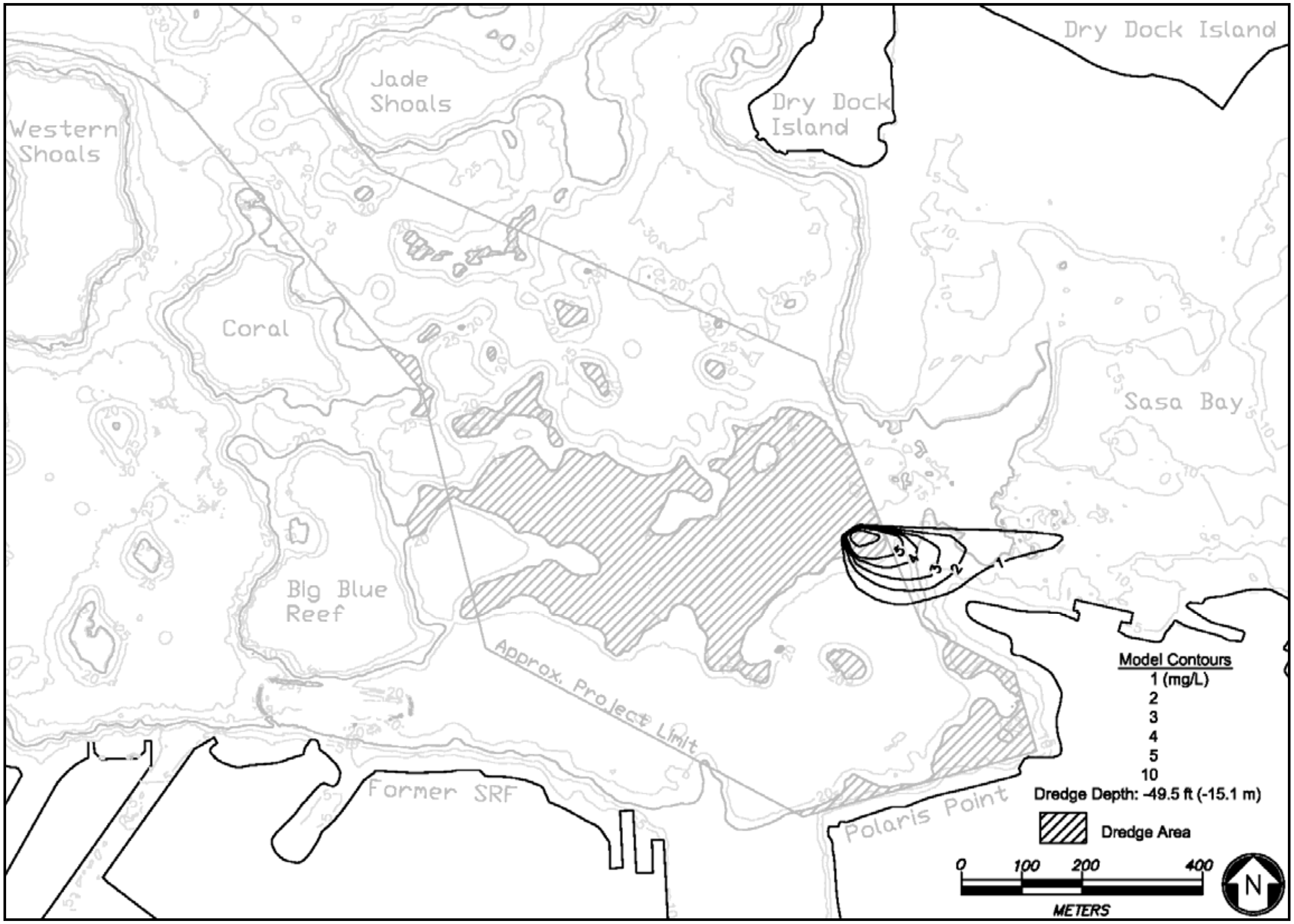

Figure 6-2B. Bottom Layer Suspended Sediment Concentration
(6.2 December 15 to 18 winds, 24-hour dredging at D3)

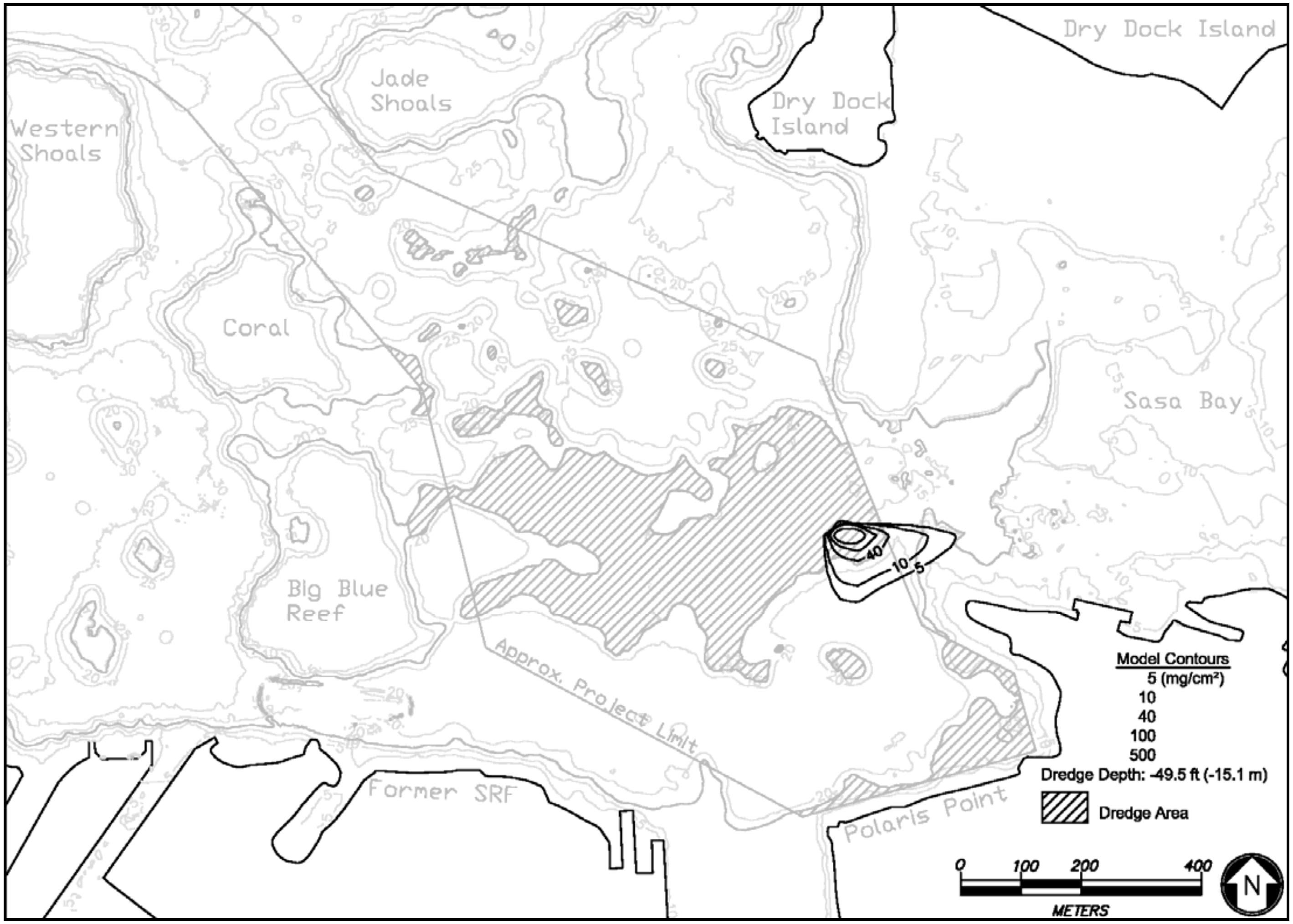

Figure 6-2C. Sediment Deposition

5mg/cm2 =0.03mm; 10mg/cm^2 =0.06mm; 40mg/cm^2 =0.2mm; 100mg/cm^2 =0.6mm; 500mg/cm^2 =3mm

(6.2 December 15 to 18 winds, 24-hour dredging at D3)

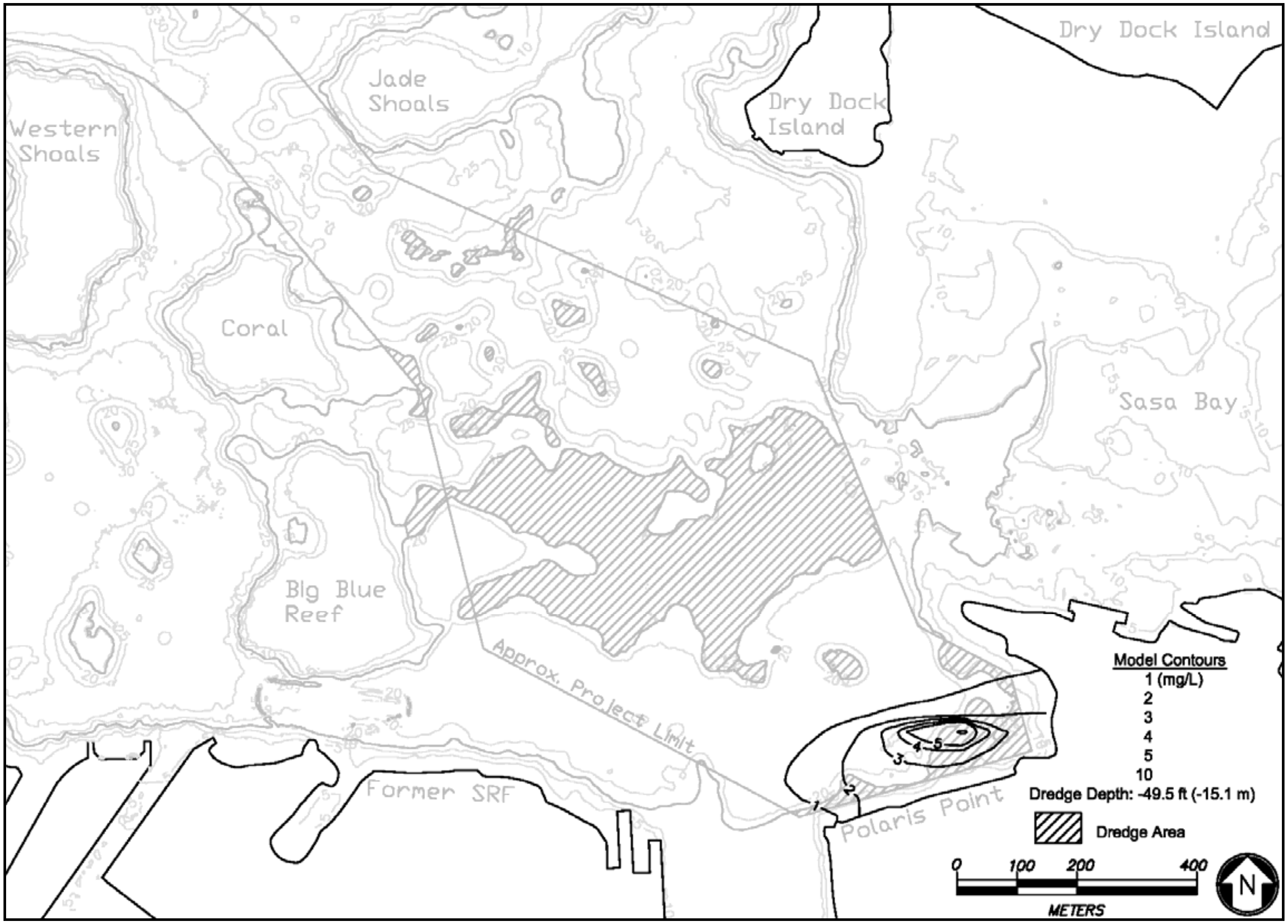

Figure 6-3A. Surface Layer Suspended Sediment Concentration
(6.3 December 15 to 18 winds, 24-hour dredging at D4)

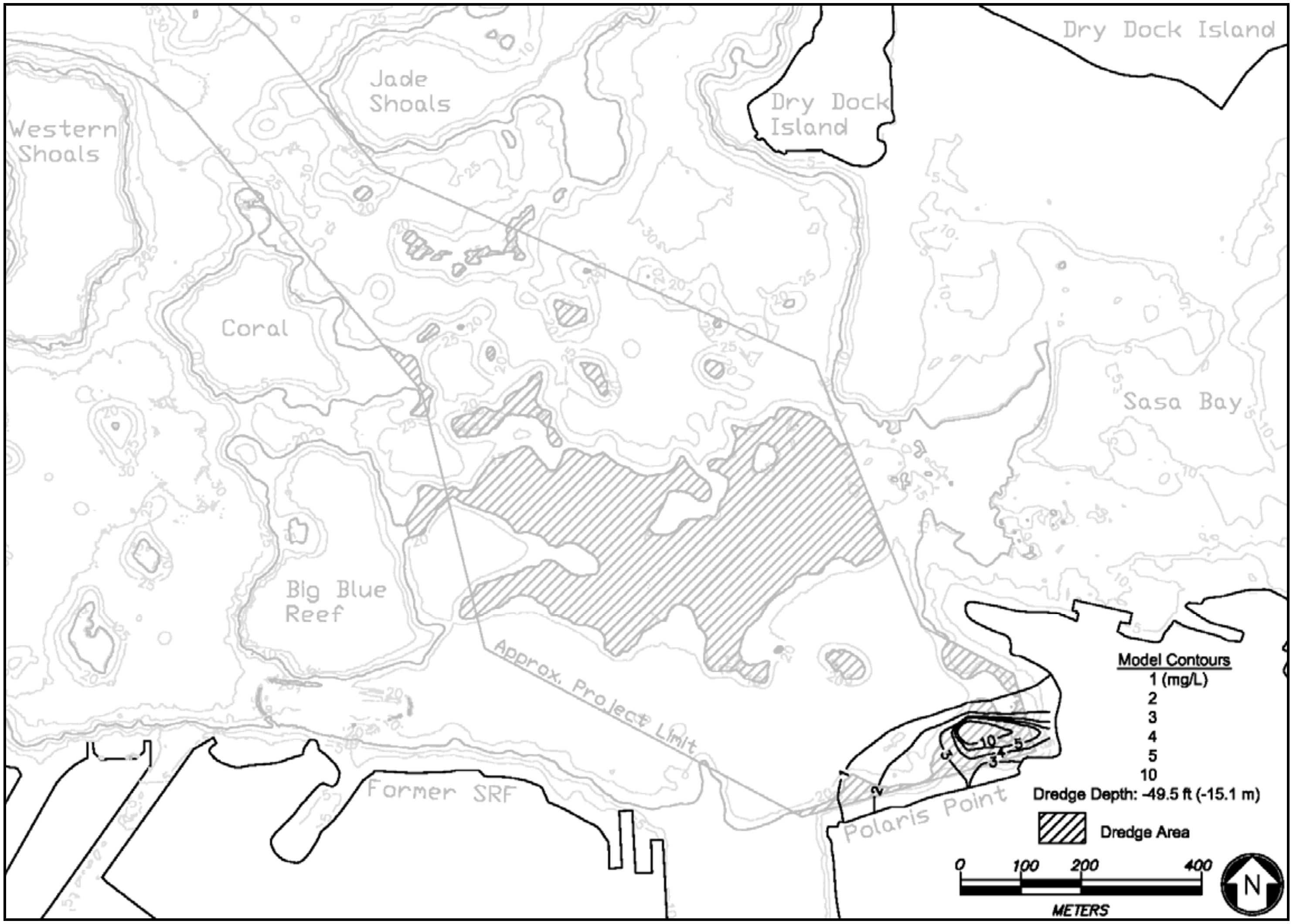

Figure 6-3B. Bottom Layer Suspended Sediment Concentration
(6.3 December 15 to 18 winds, 24-hour dredging at D4)

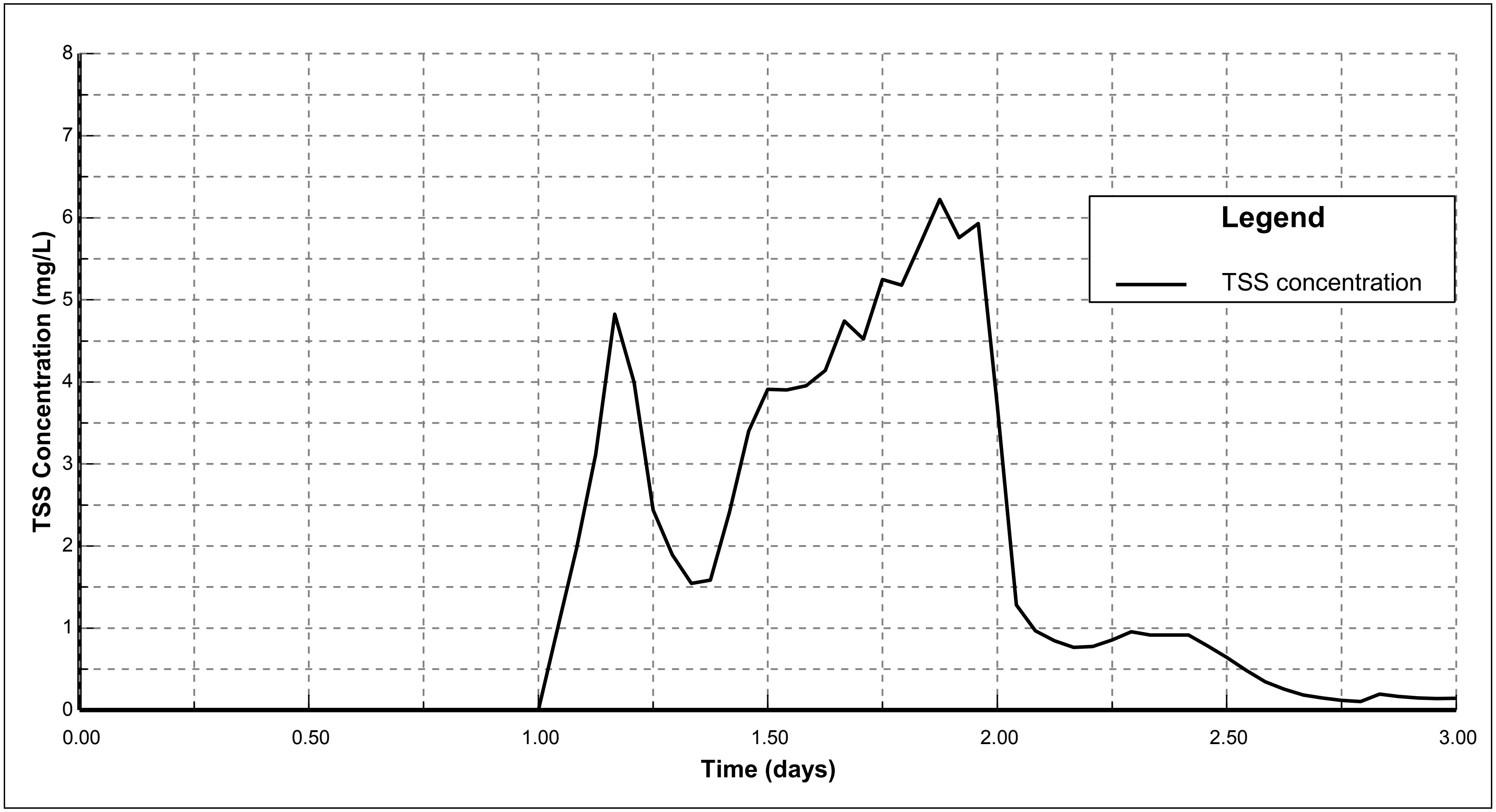

Figure 6-3C. Surface Layer TSS Time Series at the Dredge Site (6.3 December 15 to 18 winds, 24-hour dredging at D4)

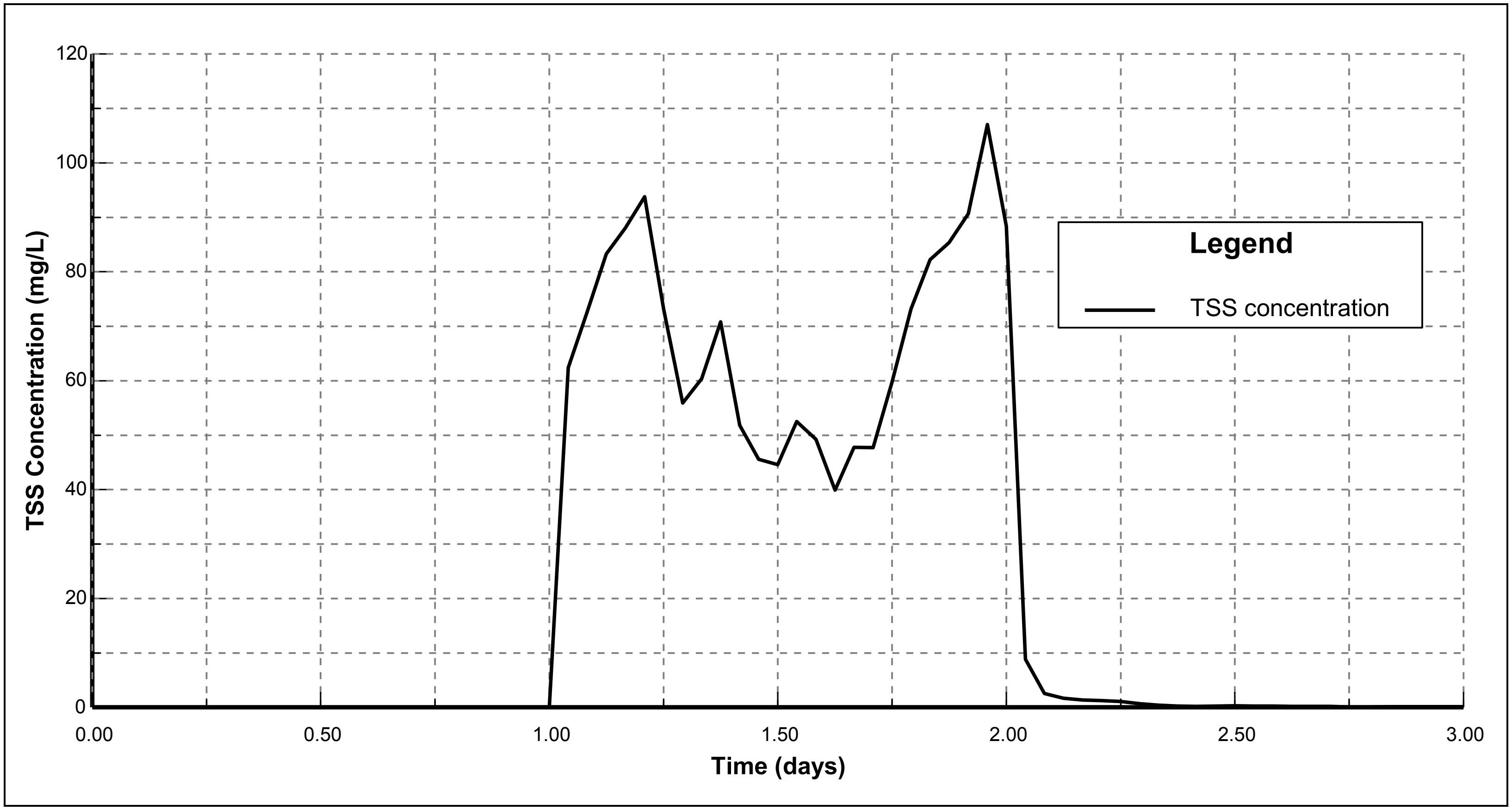

Figure 6-3D. Bottom Layer TSS Time Series at the Dredge Site
(6.3 December 15 to 18 winds, 24-hour dredging at D4)

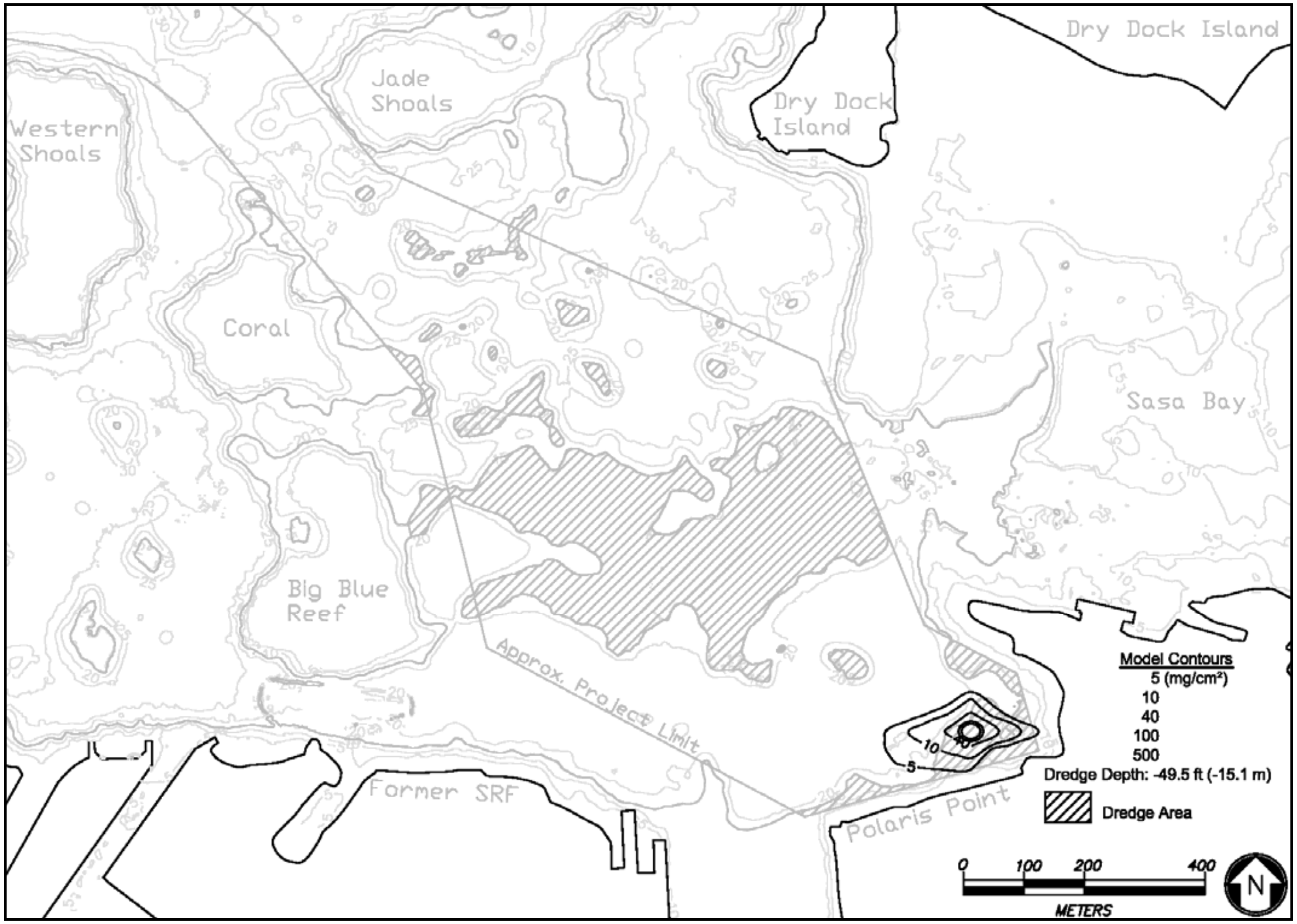

Figure 6-3E. Sediment Deposition

5mg/cm2 =0.03mm; 10mg/cm^2 =0.06mm; 40mg/cm^2 =0.2mm; 100mg/cm^2 =0.6mm; 500mg/cm^2 =3mm

(6.3 December 15 to 18 winds, 24-hour dredging at D4)

(6.4 December 15 to 18 winds, 24-hour dredging at D7)

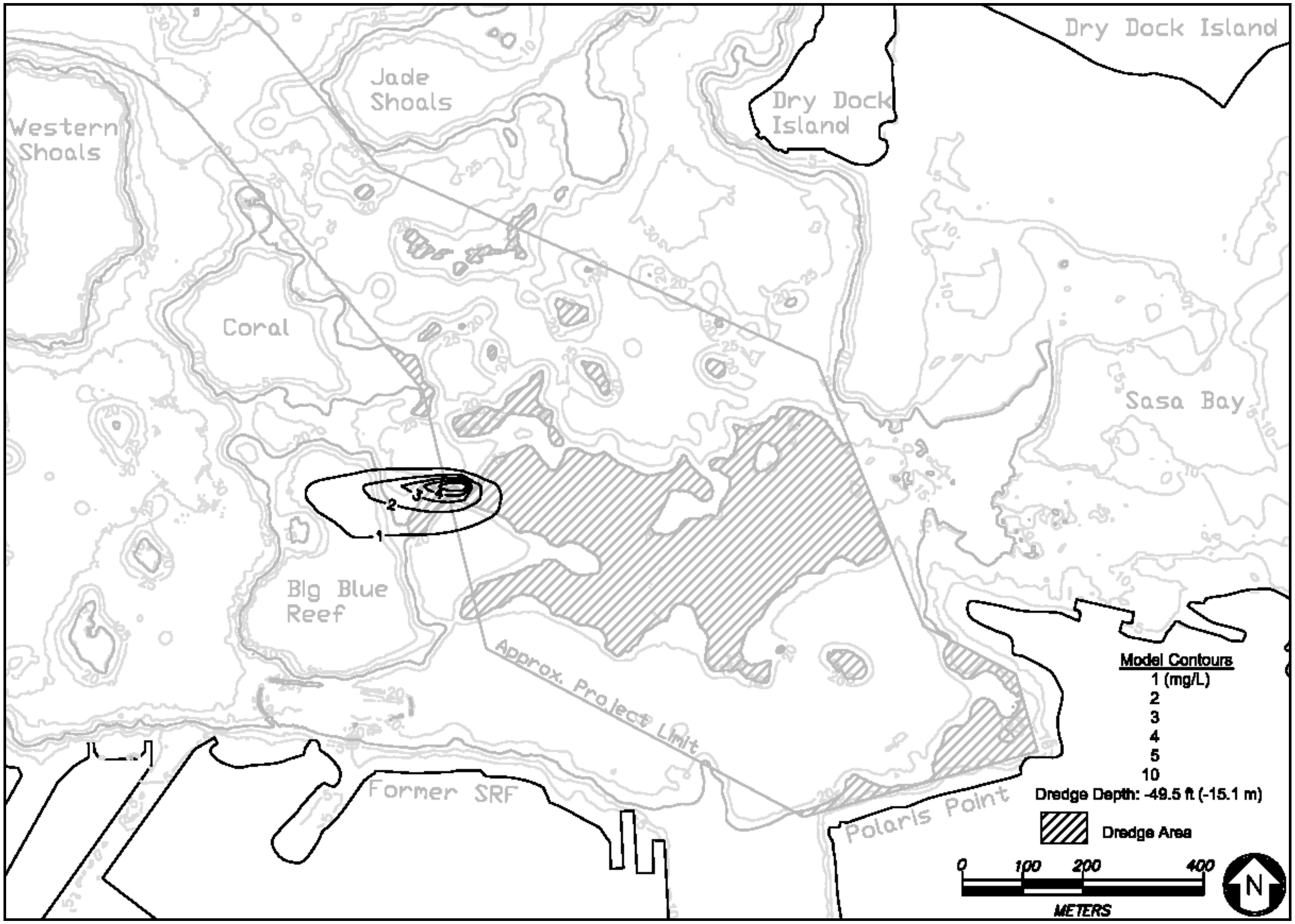

Figure 6-4A. Surface Layer Suspended Sediment Concentration

(6.4 December 15 to 18 winds, 24-hour dredging at D7)

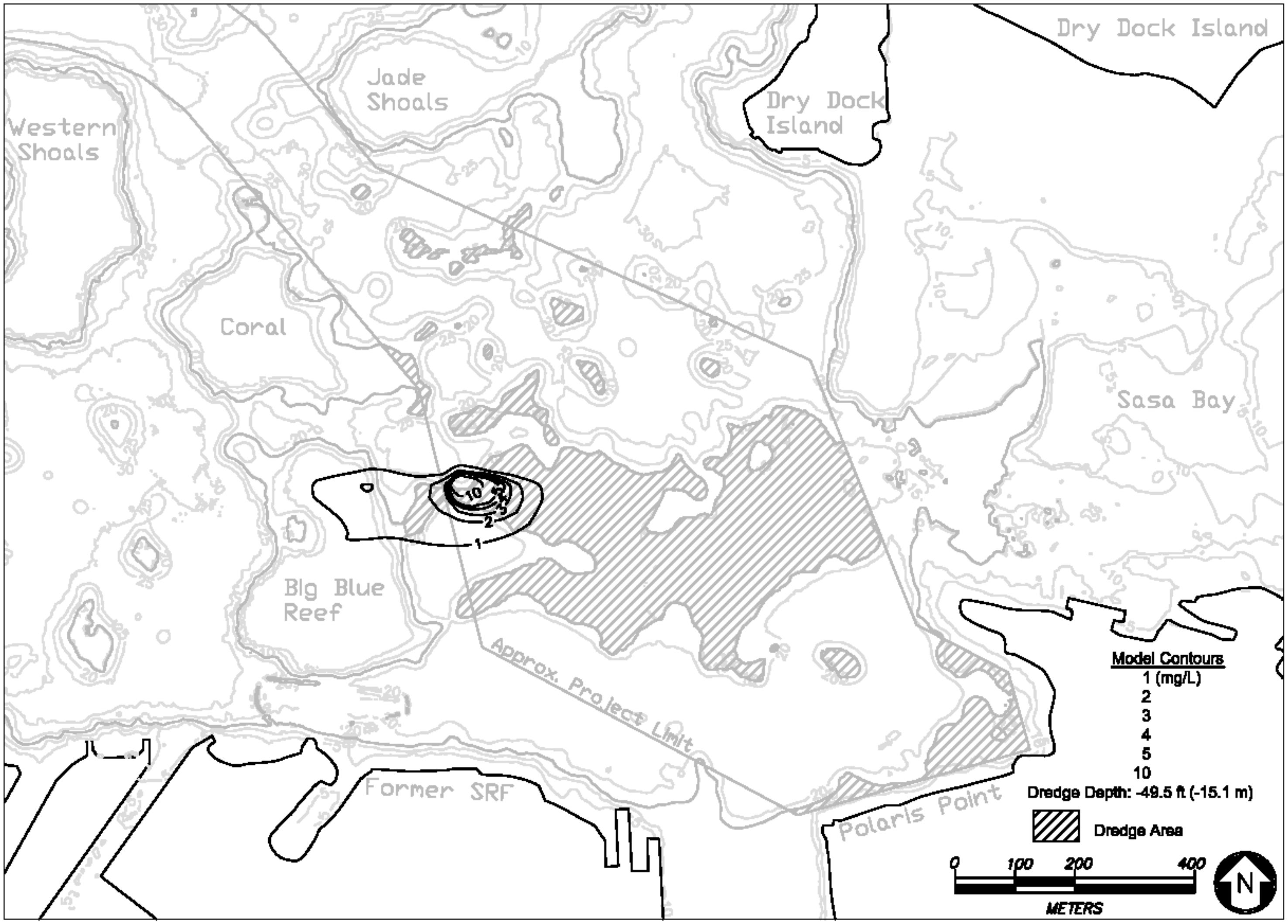

Figure 6-4B. Bottom Layer Suspended Sediment Concentration

(6.4 December 15 to 18 winds, 24-hour dredging at D7)

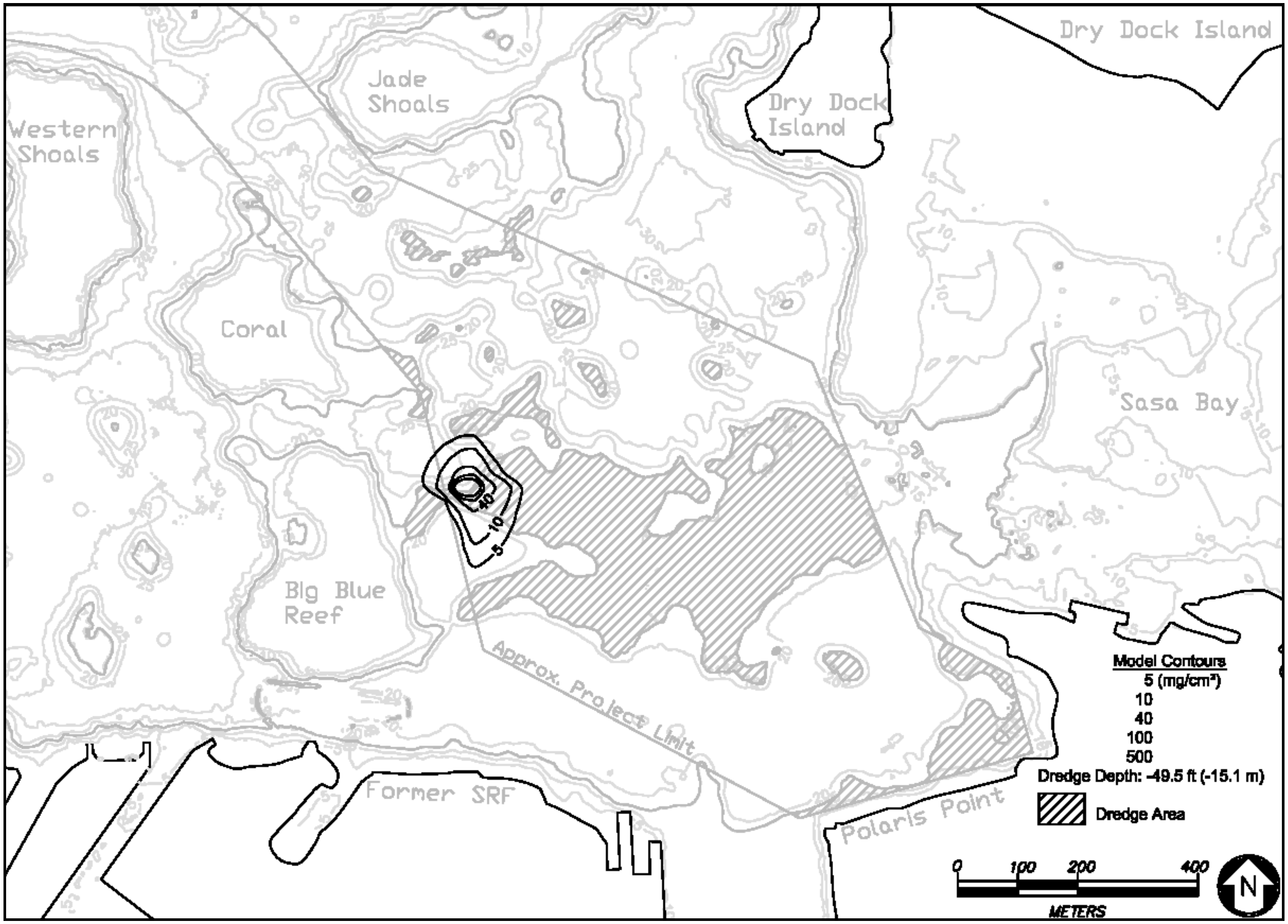

Figure 6-4C. Sediment Deposition

5mg/cm2 =0.03mm; 10mg/cm^2 =.06mm; 40mg/cm^2 =0.2mm; 100mg/cm^2 =0.6mm; 500mg/cm^2 =3mm

(6.4 December 15 to 18 winds, 24-hour dredging at D7)

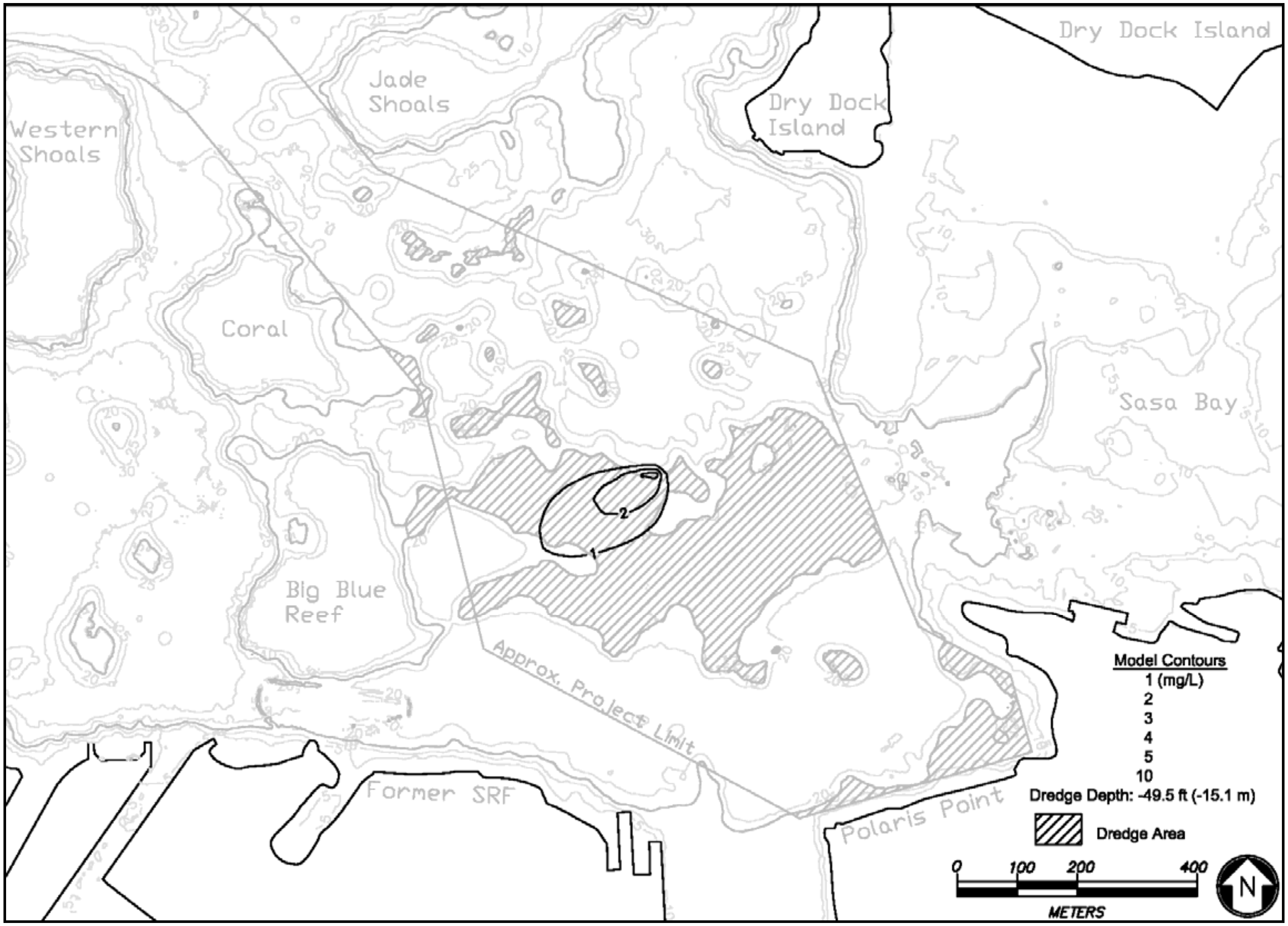

Figure 6-5A. Surface Layer Suspended Sediment Concentration (6.5 December 15 to 18 winds, 24-hour dredging at D8)

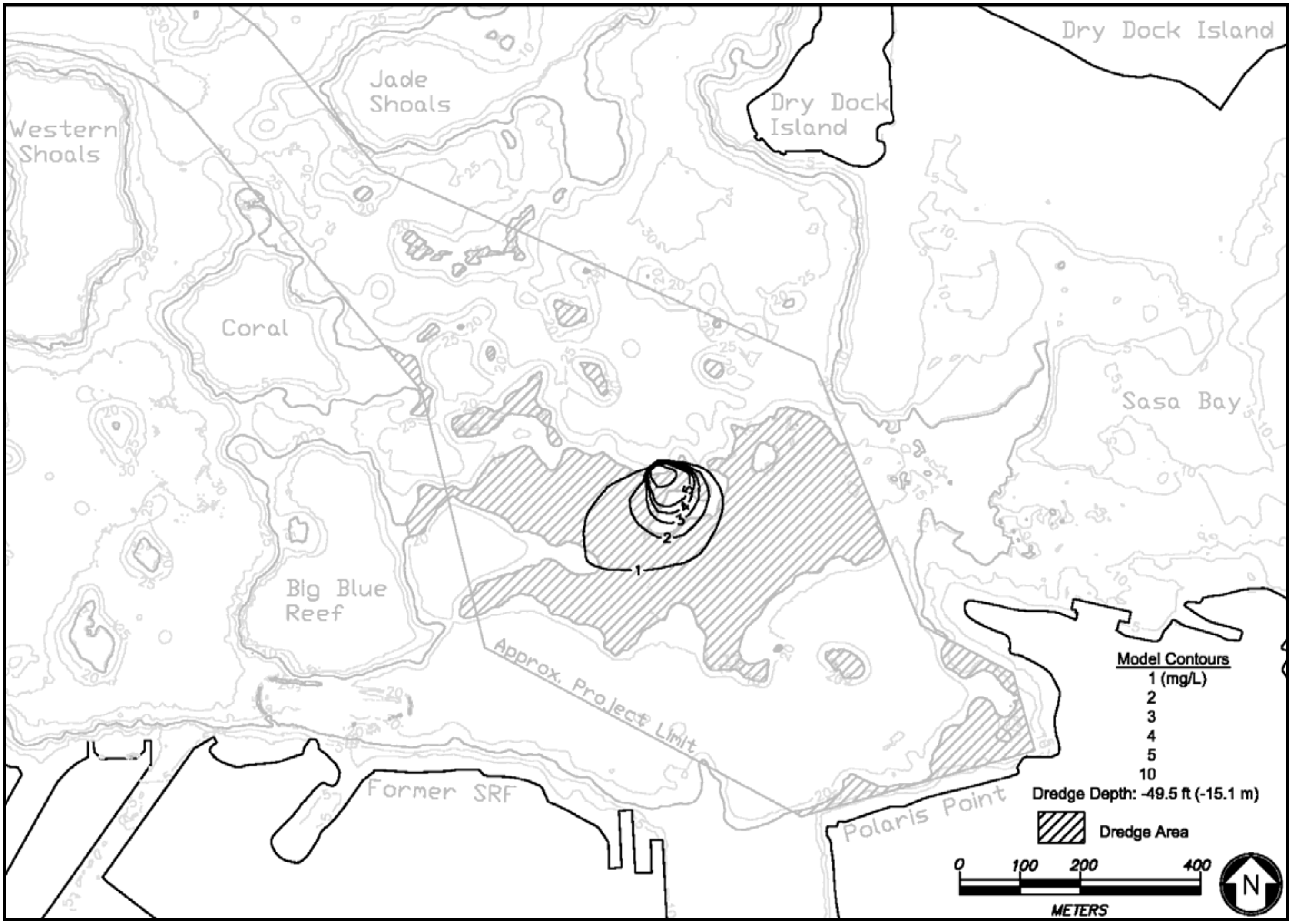

Figure 6-5B. Bottom Layer Suspended Sediment Concentration
(6.5 December 15 to 18 winds, 24-hour dredging at D8)

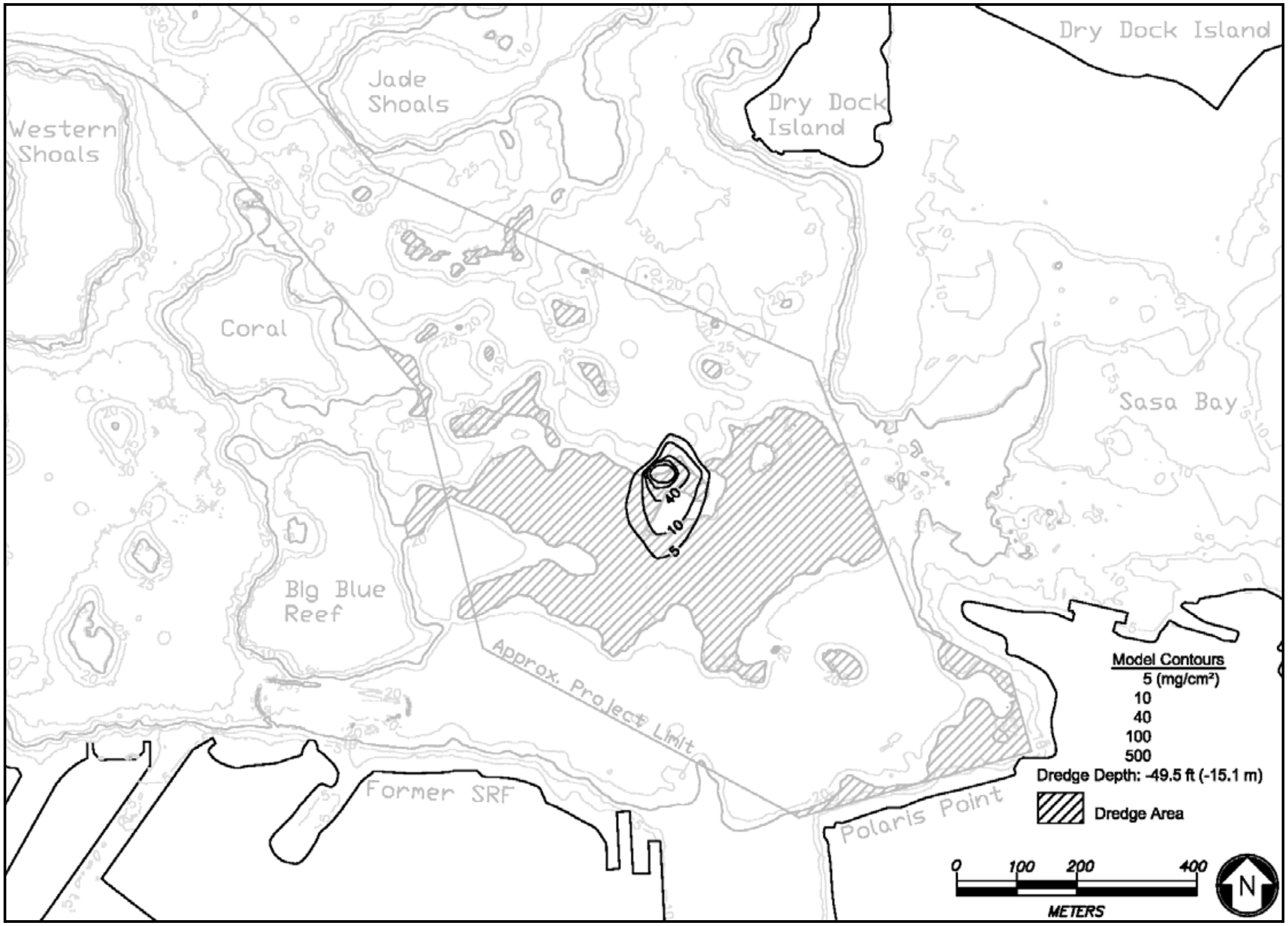

Figure 6-5C. Sediment Deposition

5mg/cm2 =0.03mm; 10mg/cm^2 =0.06mm; 40mg/cm^2 =0.2mm; 100mg/cm^2 =0.6mm; 500mg/cm^2 =3mm

(6.5 December 15 to 18 winds, 24-hour dredging at D8)

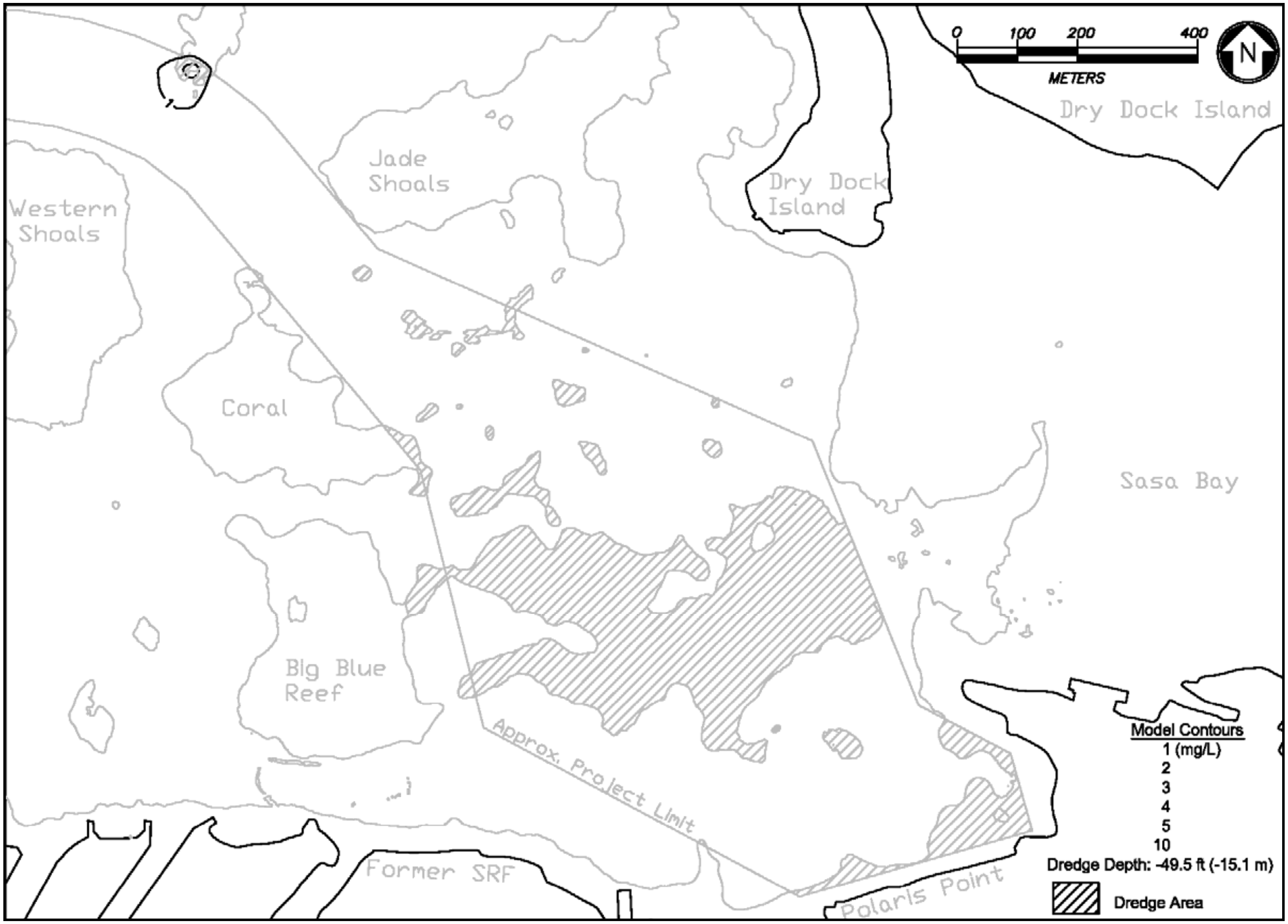

Figure 6-7A. Surface Layer Suspended Sediment Concentration (6.7 December 15 to 18 winds, 24-hour dredging at D9)

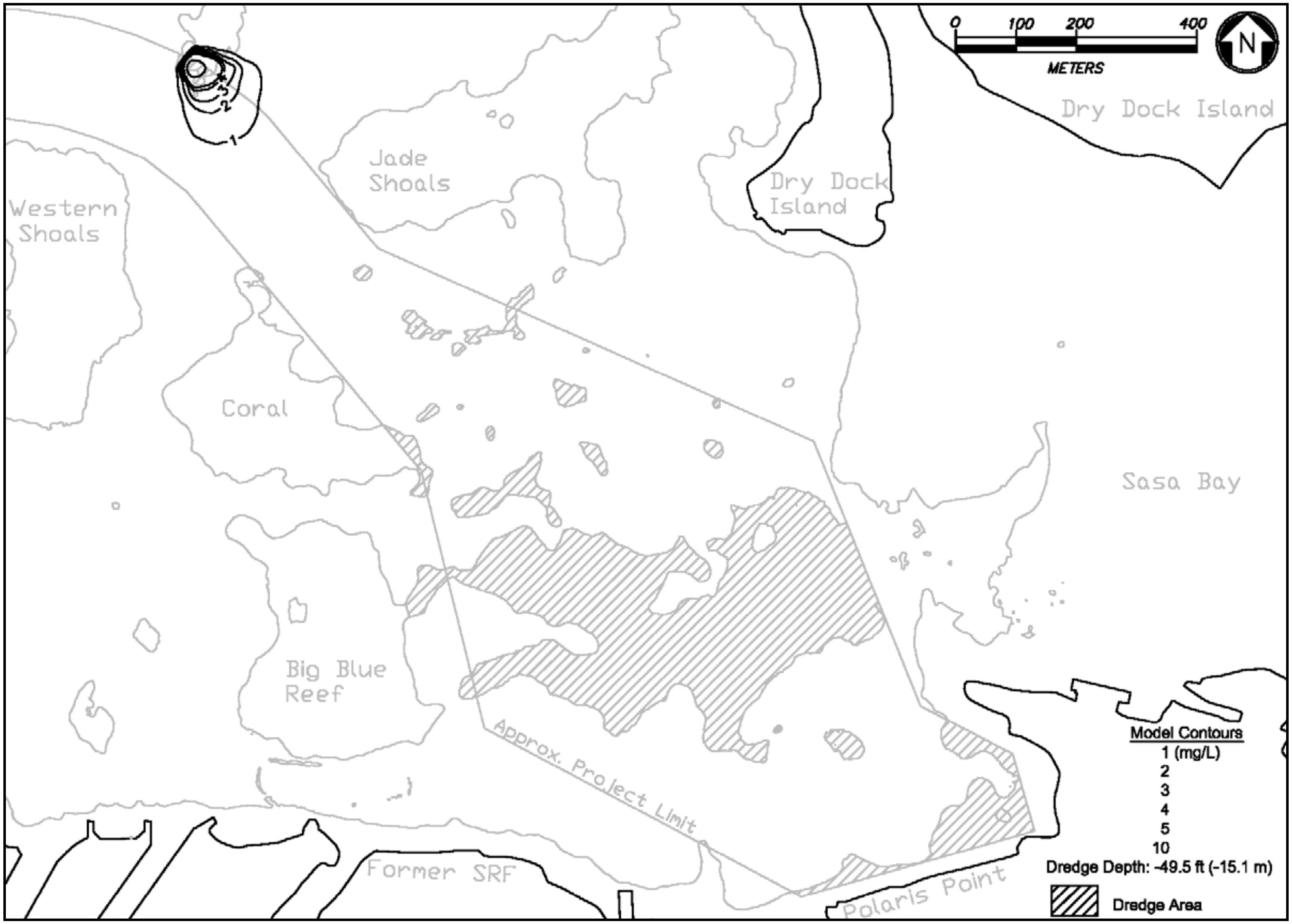

Figure 6-7B. Bottom Layer Suspended Sediment Concentration (6.7 December 15 to 18 winds, 24-hour dredging at D9)

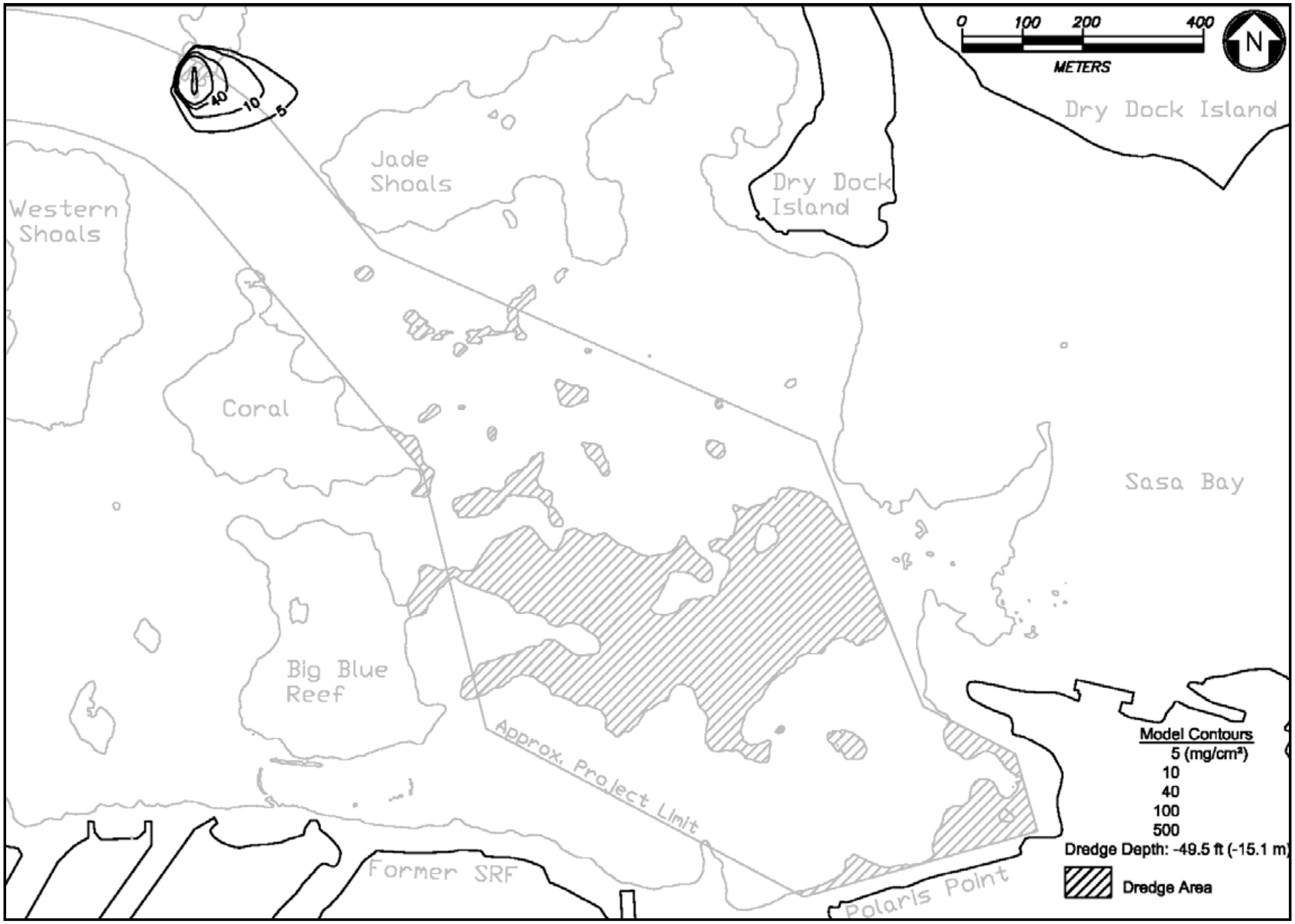

Figure 6-7C. Sediment Deposition

5mg/cm2 =0.03mm; 10mg/cm^2 =0.06mm; 40mg/cm^2 =0.2mm; 100mg/cm^2 =0.6mm; 500mg/cm^2 =3mm

(6.7 December 15 to 18 winds, 24-hour dredging at D9)

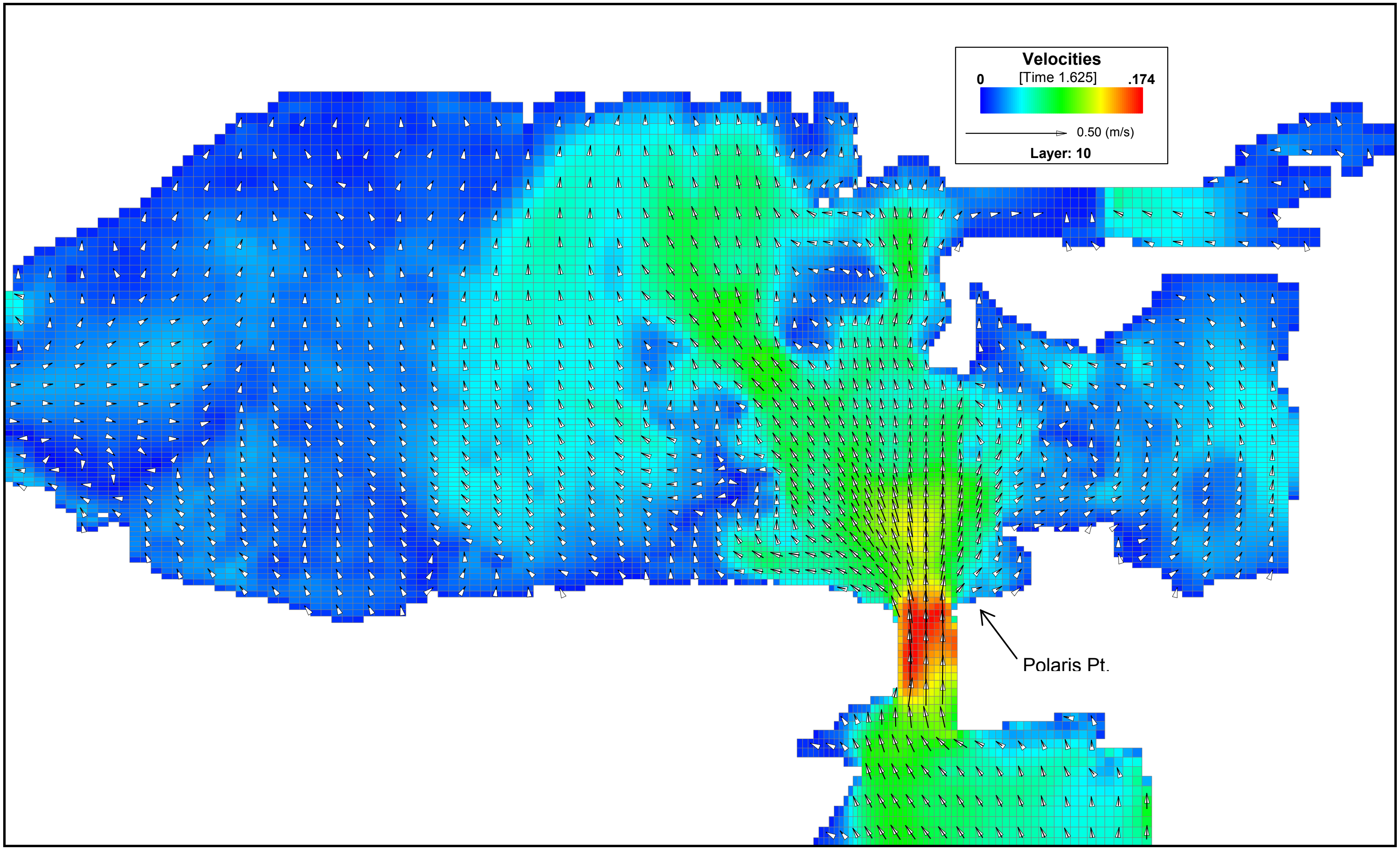

Figure 6-8A. Surface Layer Currents During South Winds
(6.8 South winds, 24-hour dredging at D)

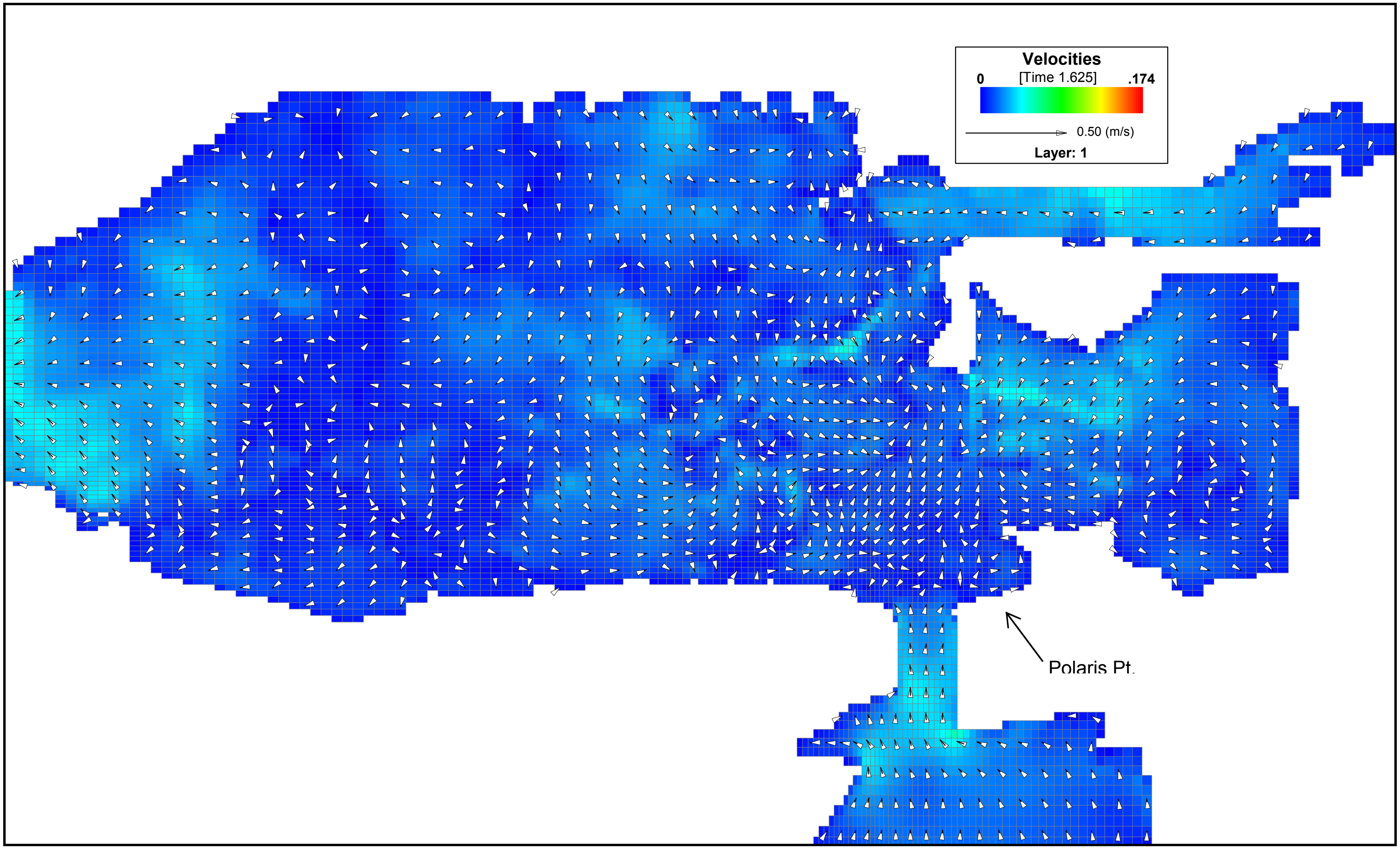

Figure 6-8B. Bottom Layer Currents During South Winds
(6.8 South winds, 24-hour dredging at D)

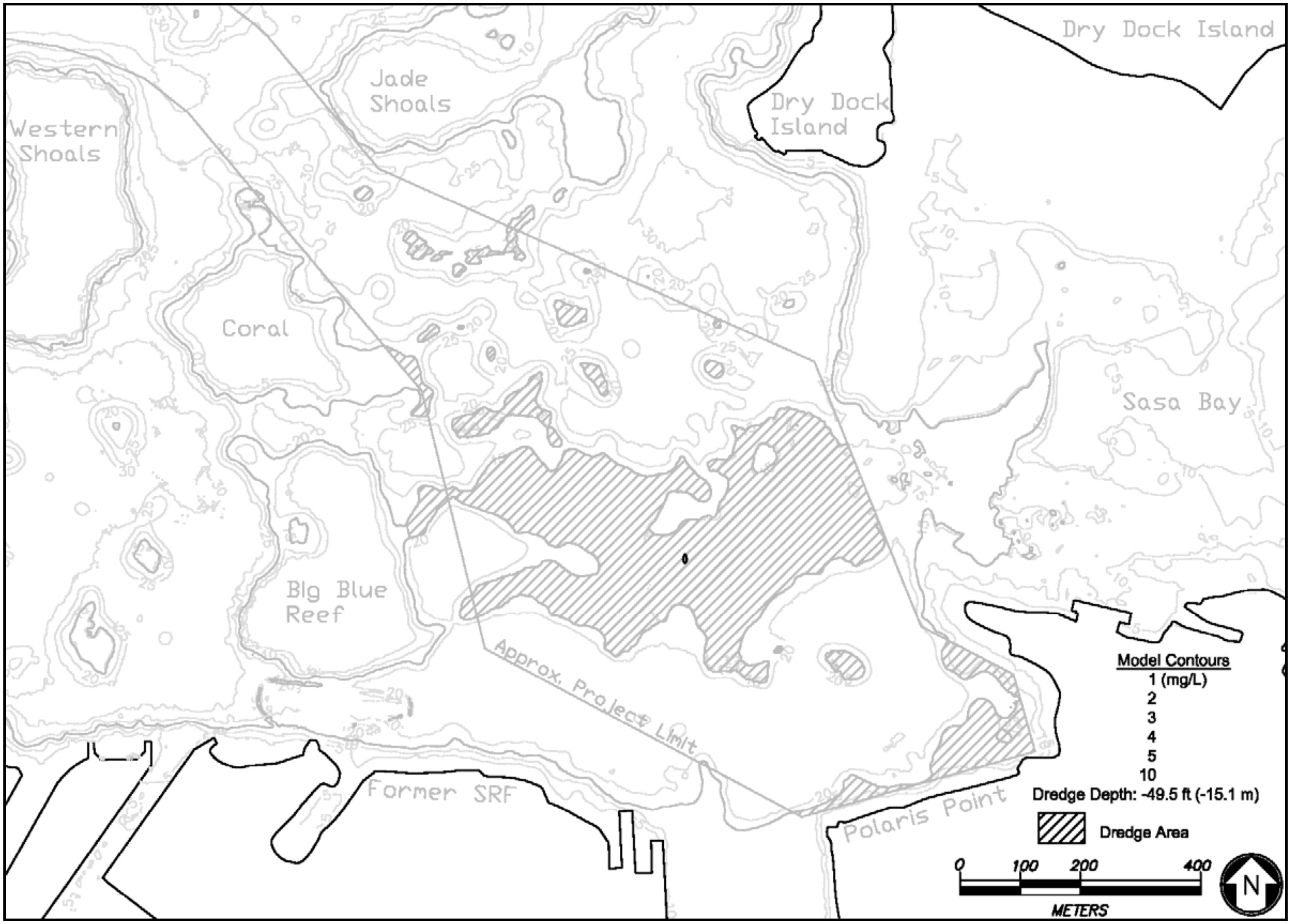

Figure 6-8C. Surface Layer Suspended Sediment Concentration (6.8 South winds, 24-hour dredging at D)

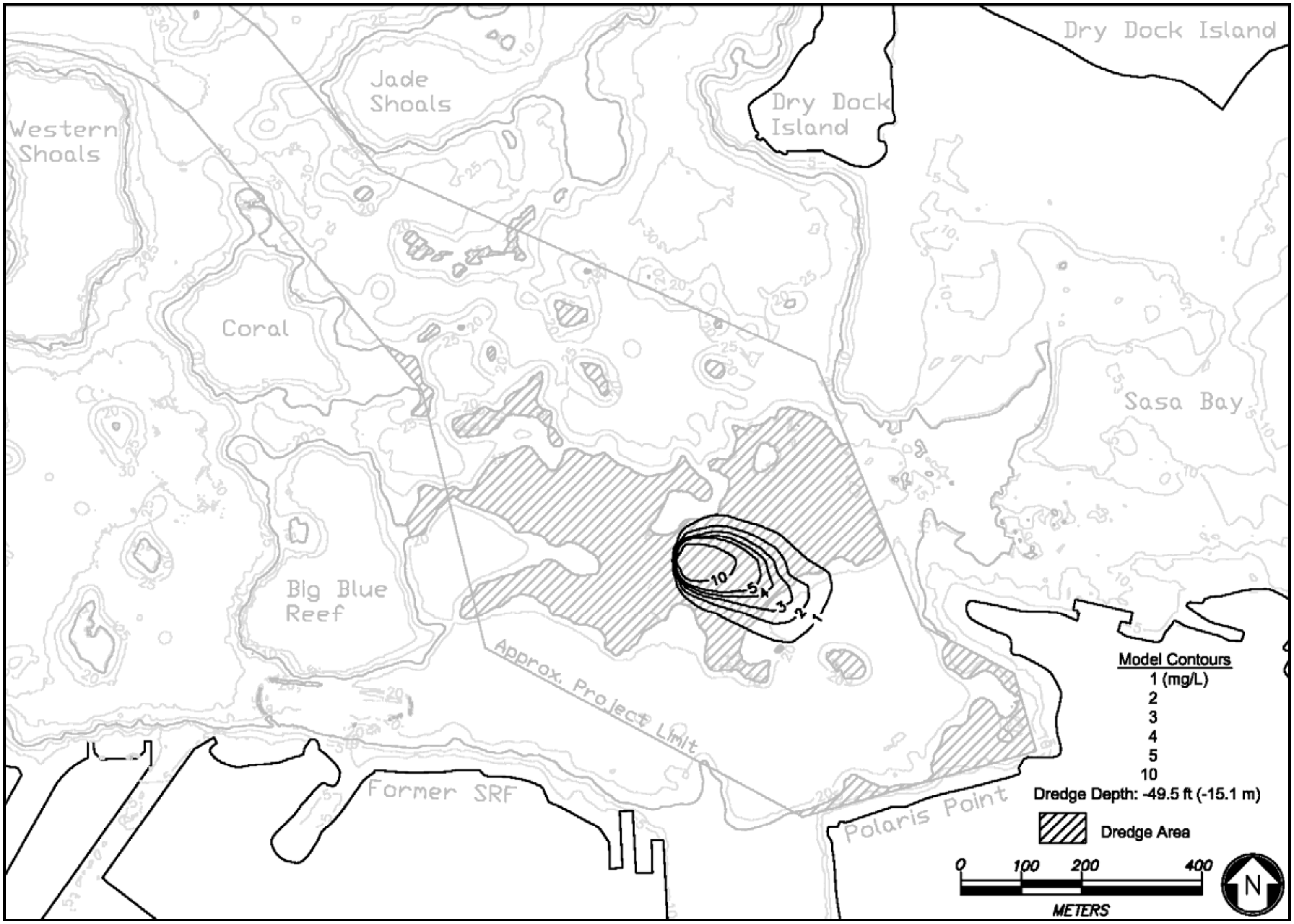

Figure 6-8D. Bottom Layer Suspended Sediment Concentration
(6.8 South winds, 24-hour dredging at D)

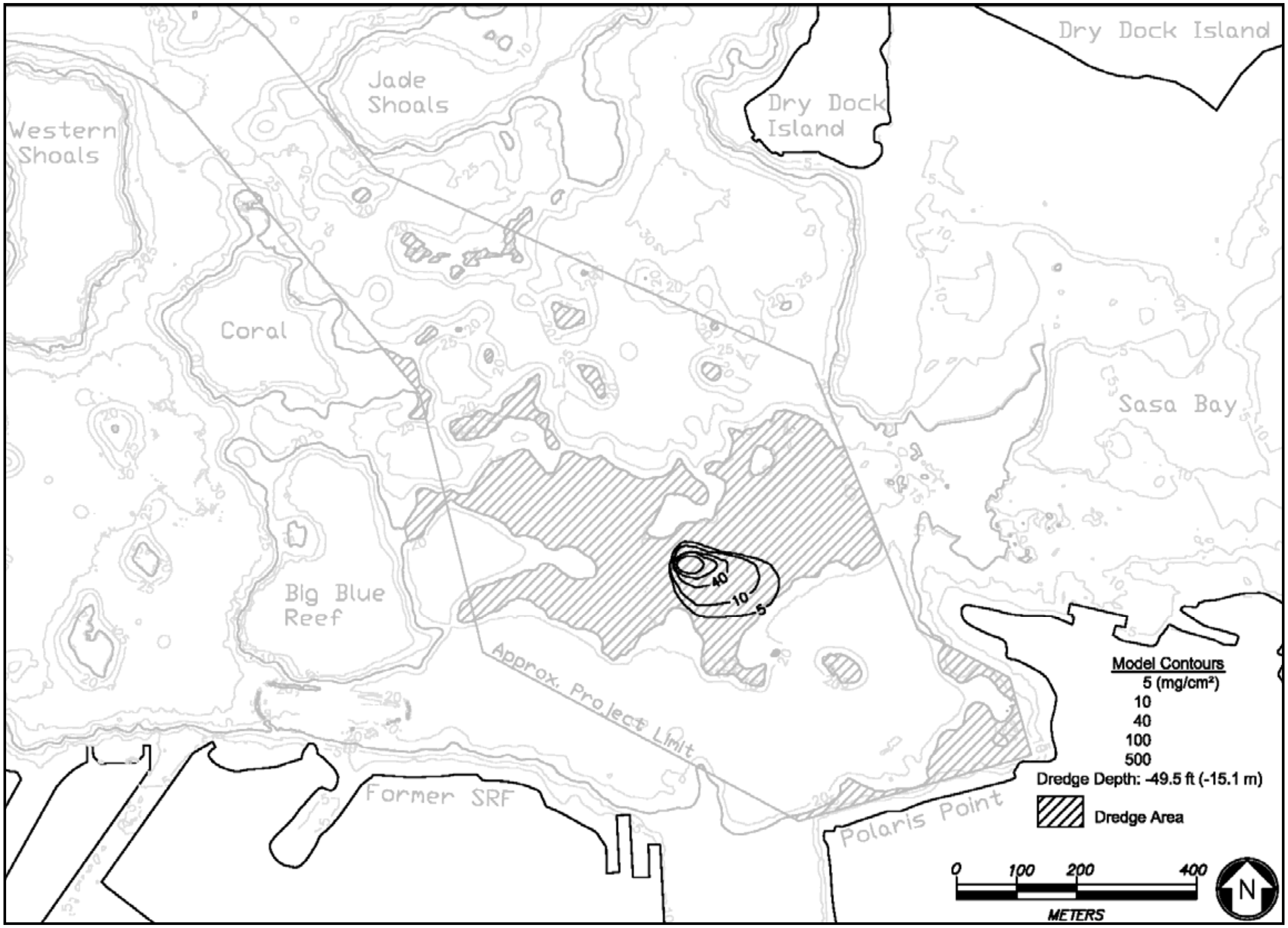

Figure 6-8E. Sediment Deposition

5mg/cm2 =0.03mm; 10mg/cm^2 =0.06mm; 40mg/cm^2 =0.2mm; 100mg/cm^2 =0.6mm; 500mg/cm^2 =3mm

(6.8 South winds, 24-hour dredging at D)

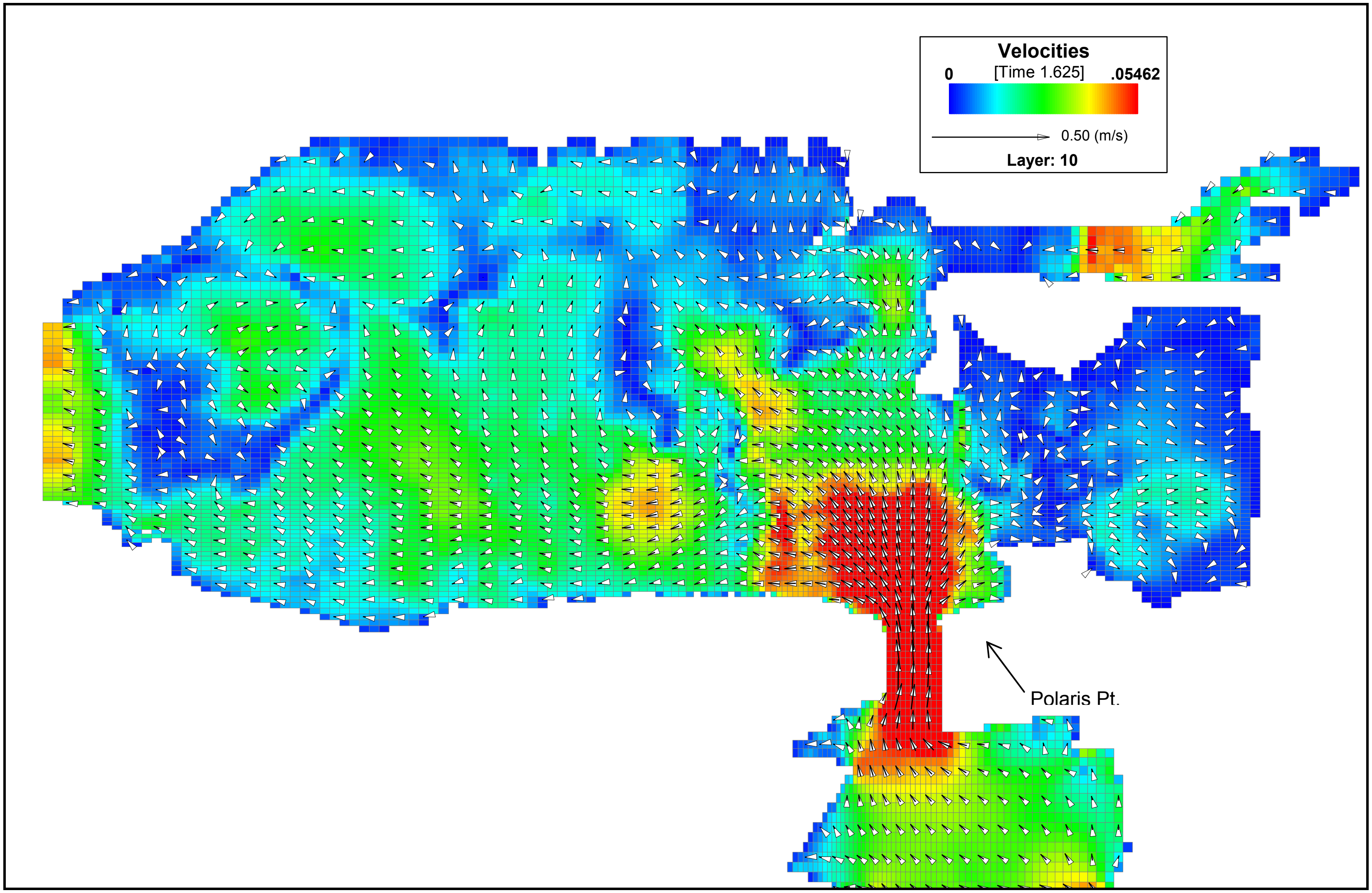

Figure 6-9A. Surface Layer Currents During South Winds

(6.9 Calm winds, 24-hour dredging at D1)

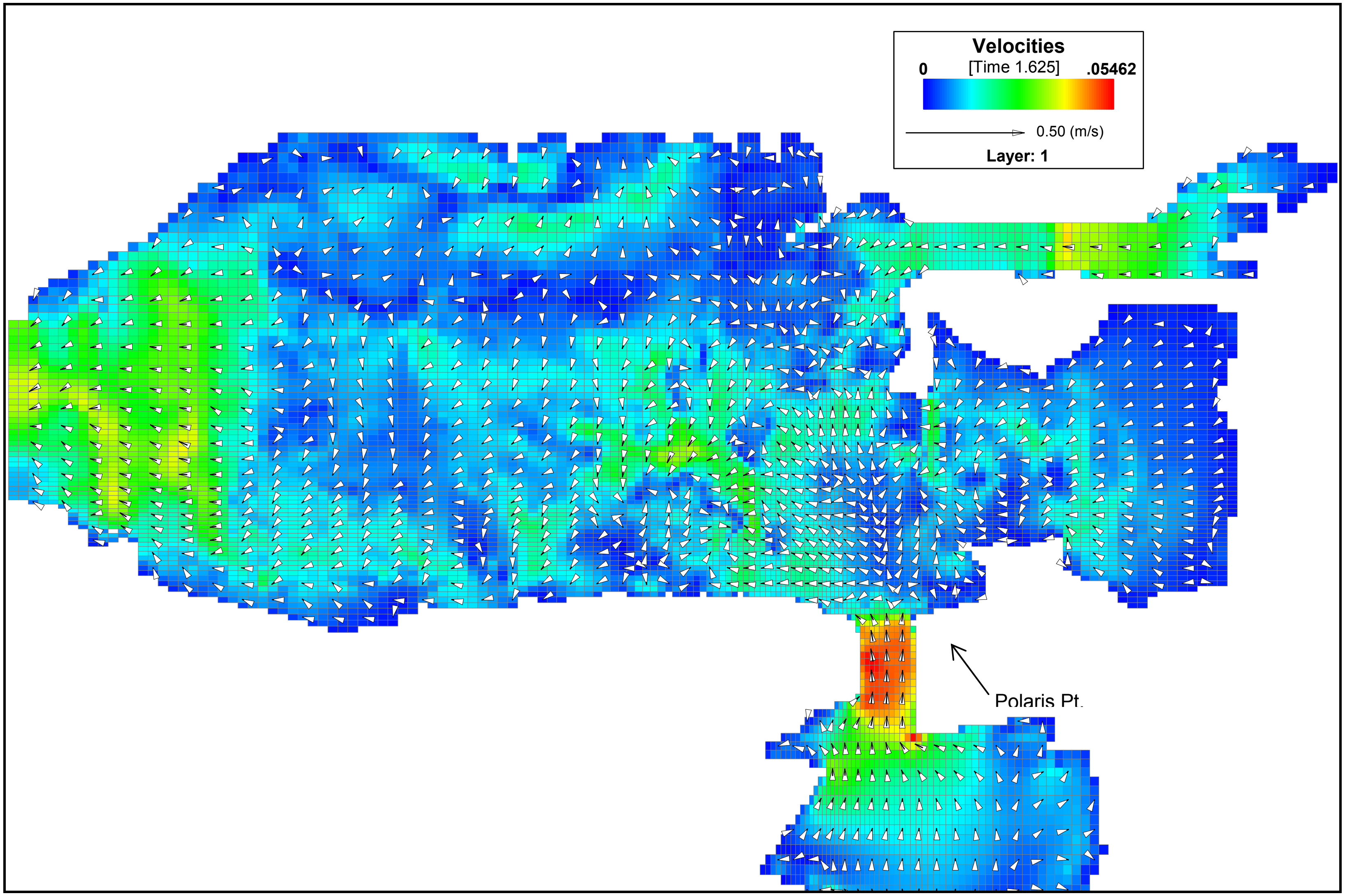

Figure 6-9B. Bottom Layer Currents During South Winds

(6.9 Calm winds, 24-hour dredging at D1)

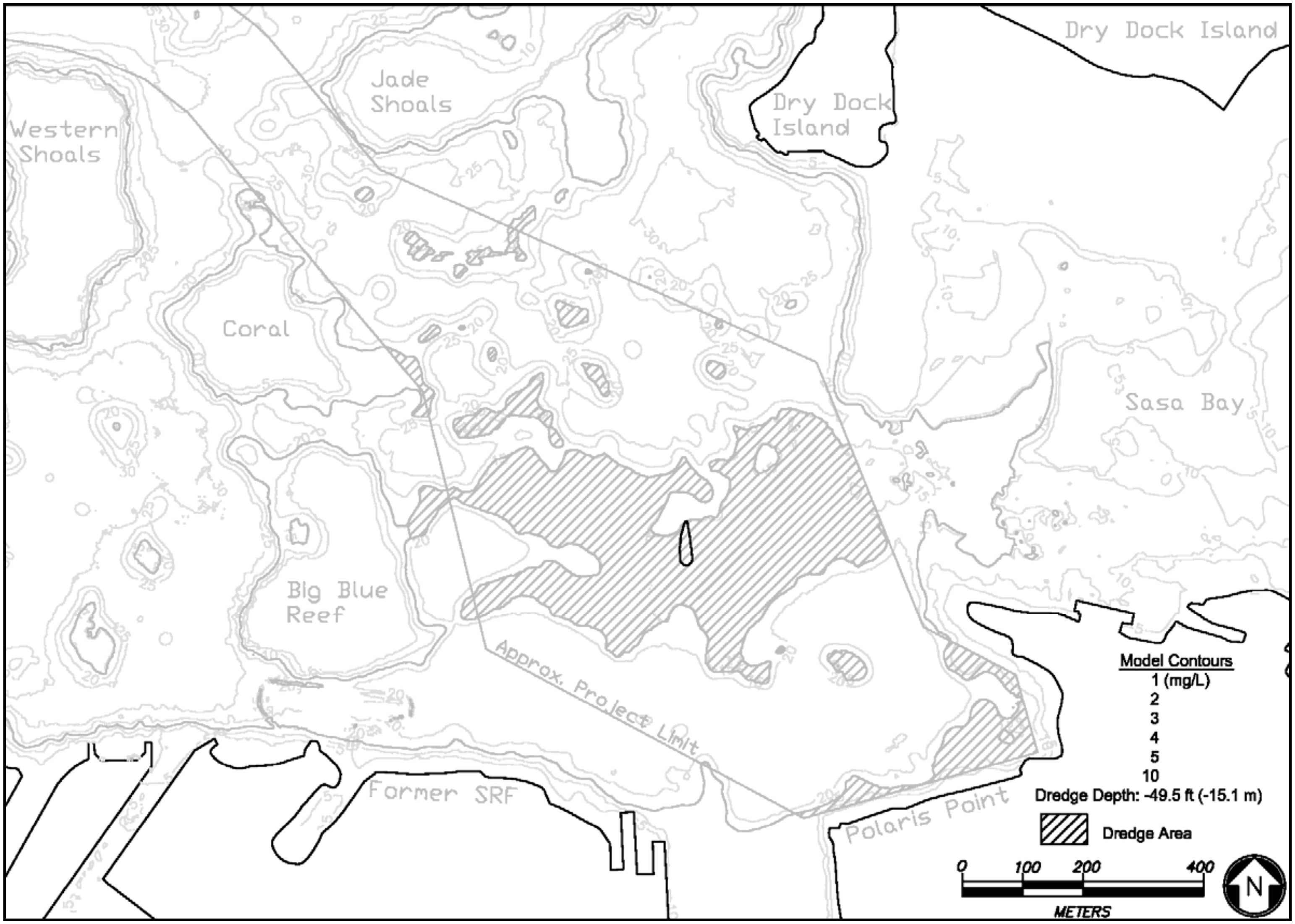

Figure 6-9C. Surface Layer Suspended Sediment Concentration

(6.9 Calm winds, 24-hour dredging at D1)

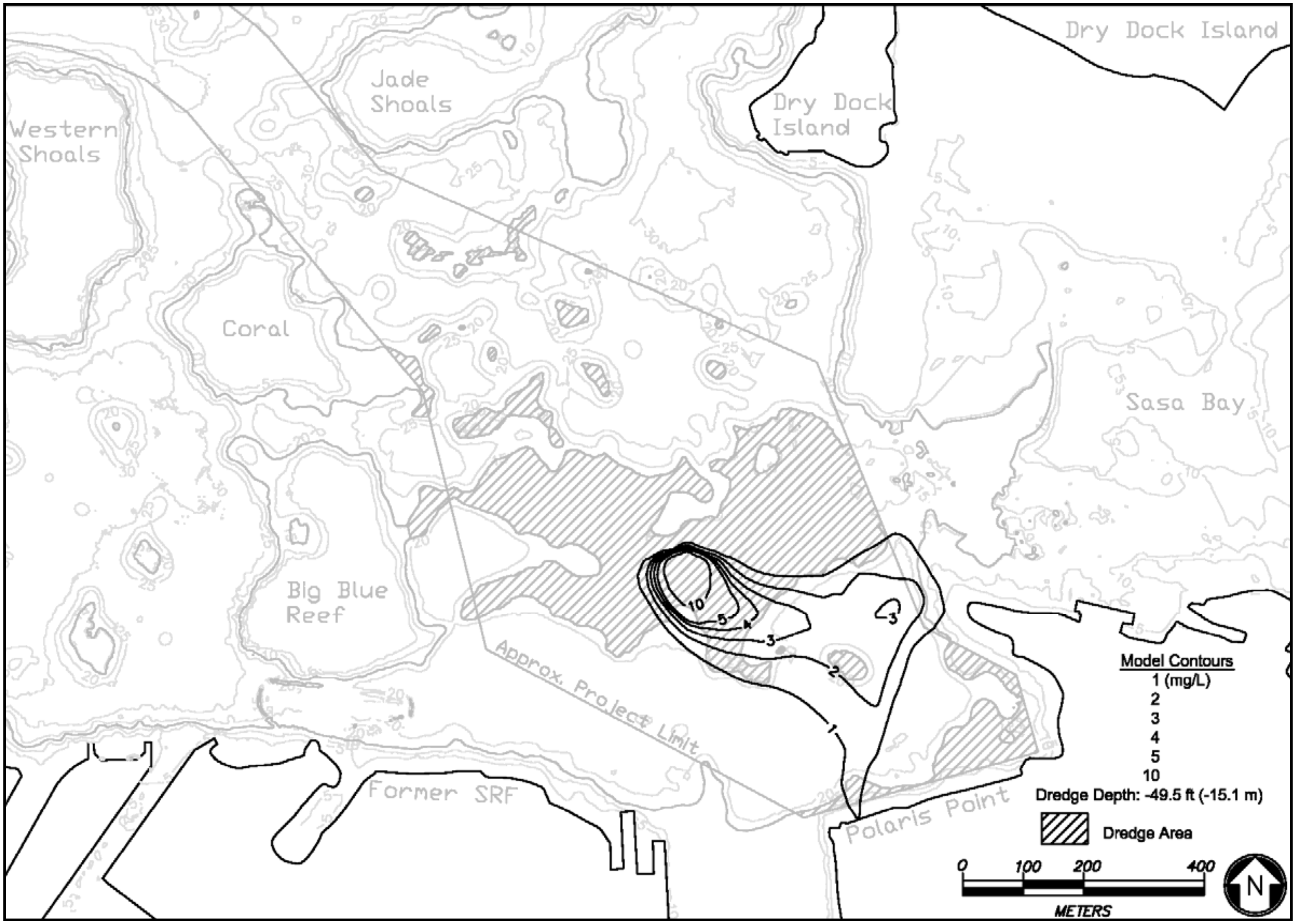

Figure 6-9D. Bottom Layer Suspended Sediment Concentration

(6.9 Calm winds, 24-hour dredging at D1)

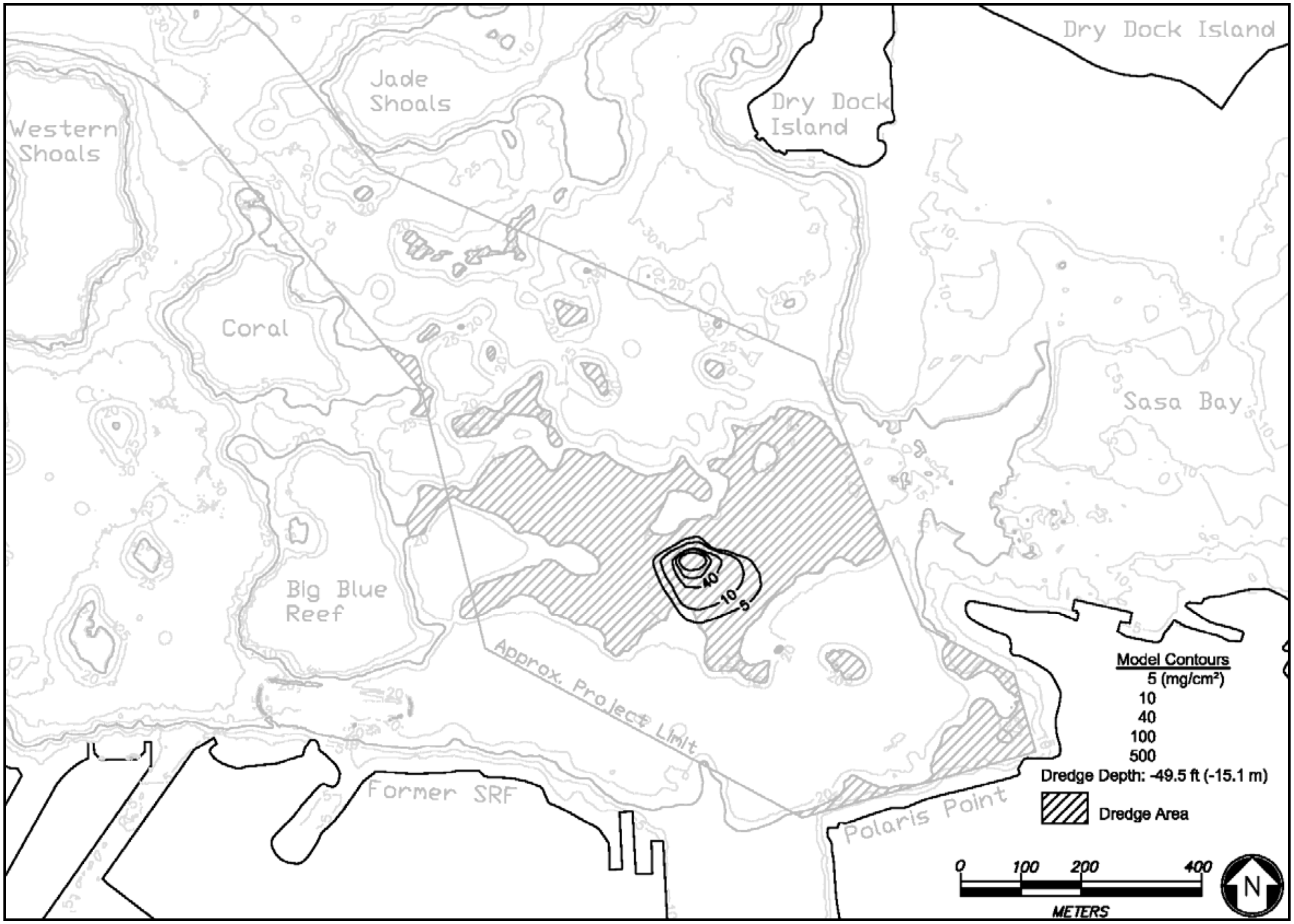

Figure 6-9E. Sediment Deposition

5mg/cm2 =0.03mm; 10mg/cm^2 =.06mm; 40mg/cm^2 =0.2mm; 100mg/cm^2 =0.6mm; 500mg/cm^2 =3mm

(6.9 Calm winds, 24-hour dredging at D1)

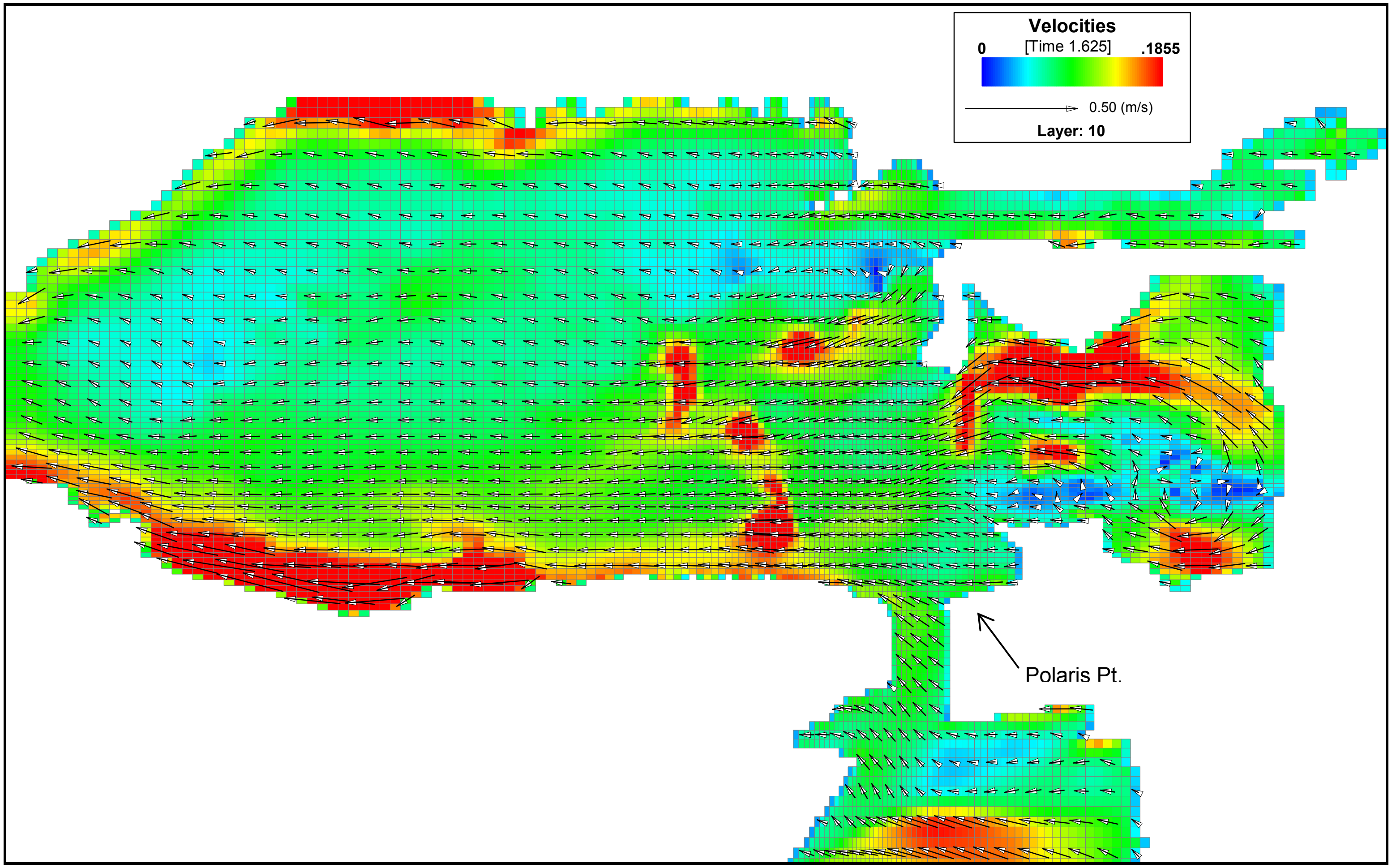

Figure 6-10A. Surface Layer Currents During Strong Trade Winds
(6.10 Strong trade winds, 24-hour dredging at D1, Highest 10% release)

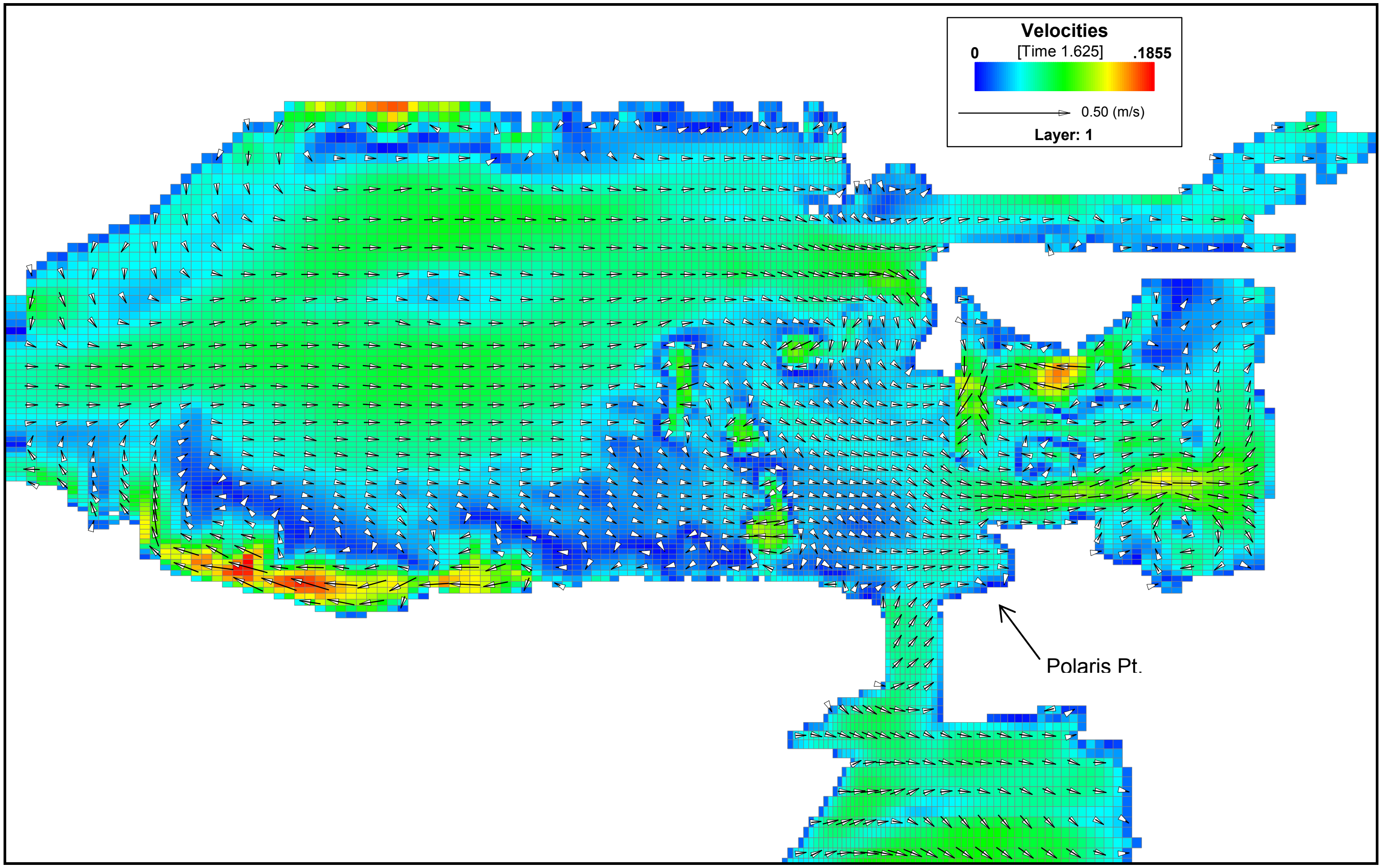

Figure 6-10B. Bottom Layer Currents During Strong Trade Winds

(6.10 Strong trade winds, 24-hour dredging at D1, Highest 10% release)

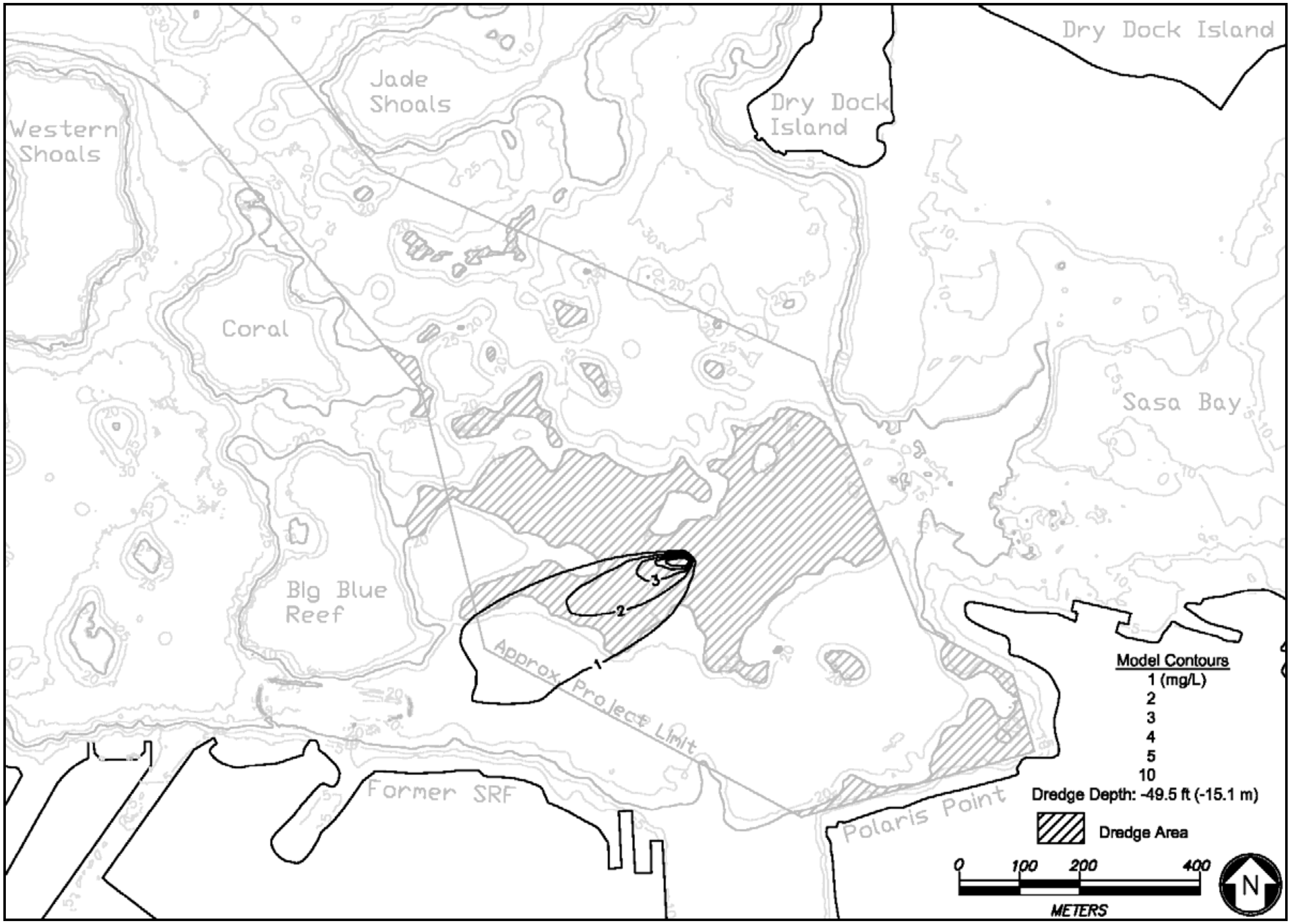

Figure 6-10C. Surface Layer Suspended Sediment Concentration

Figure 6-10D. Bottom Layer Suspended Sediment Concentration

(6.10 Strong trade winds, 24-hour dredging at D1, Highest 10% release)

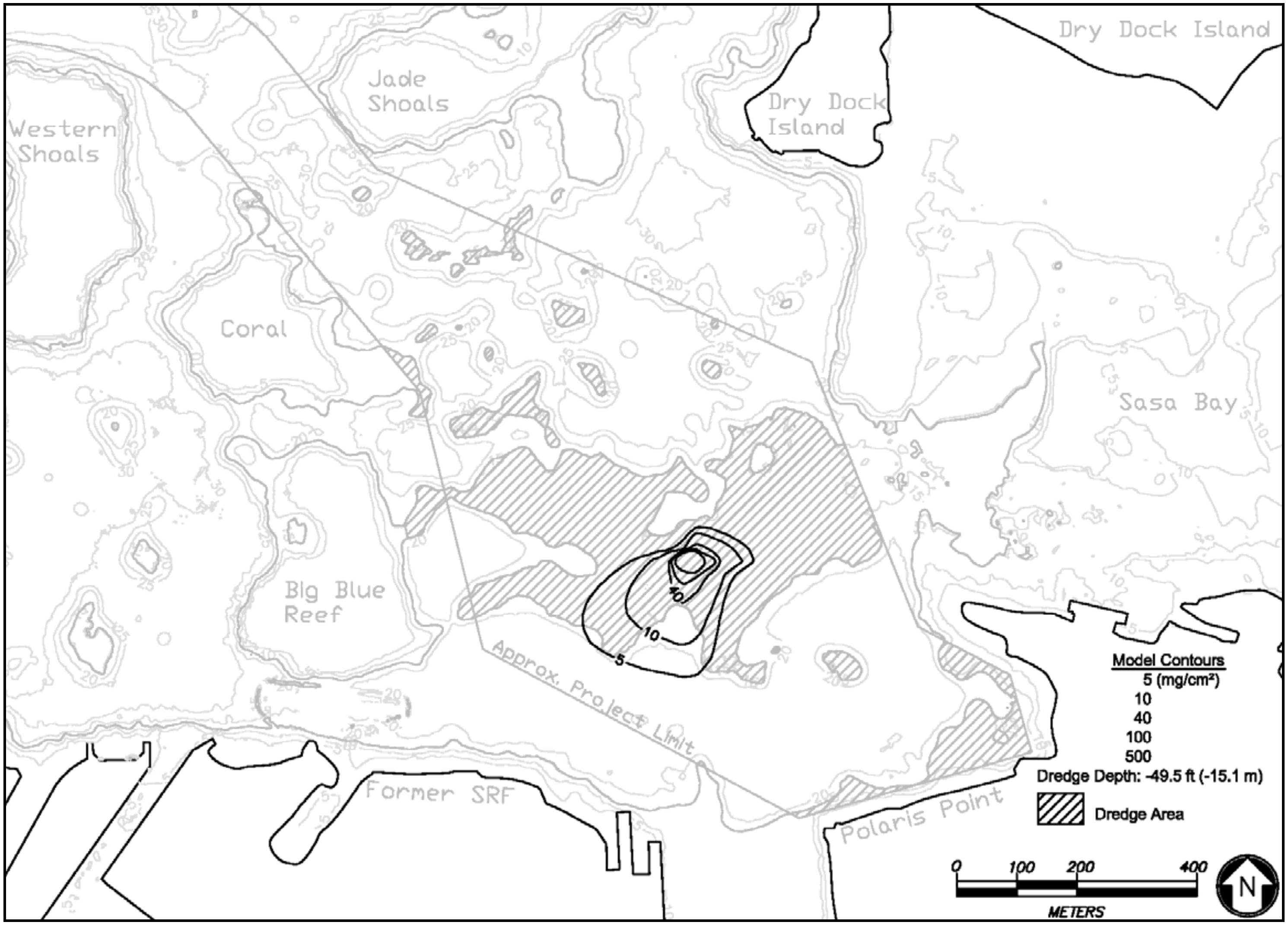

Figure 6-10E. Sediment Deposition

5mg/cm2 =0.03mm; 10mg/cm^2 =0.06mm; 40mg/cm^2 =0.2mm; 100mg/cm^2 =0.6mm; 500mg/cm^2 =3mm

(6.10 Strong trade winds, 24-hour dredging at D1, Highest 10% release)

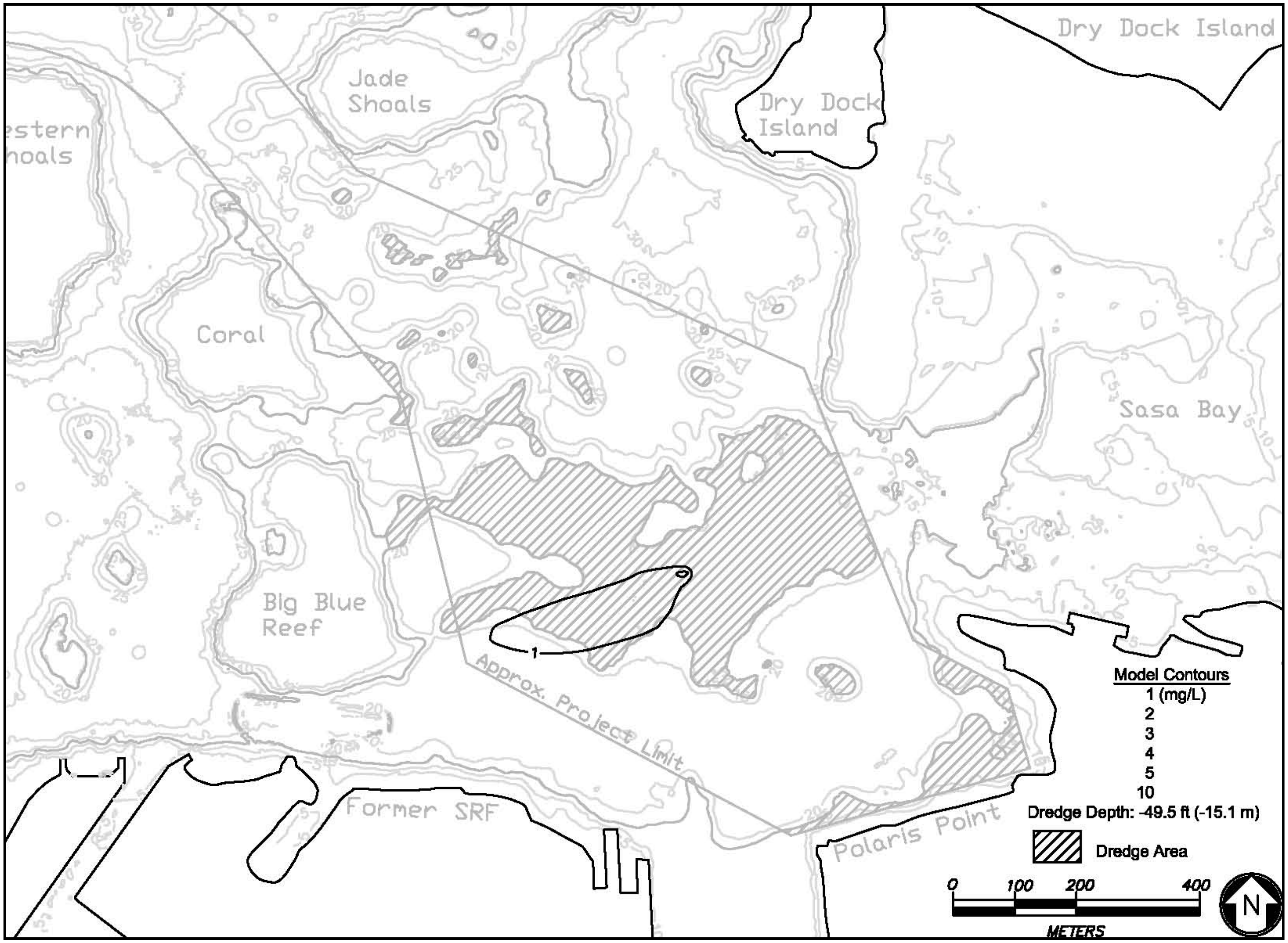

Figure 6-11A. Surface Layer Suspended Sediment Concentration (6.11 December 15 to 18 winds, 10-hour dredging at D1)

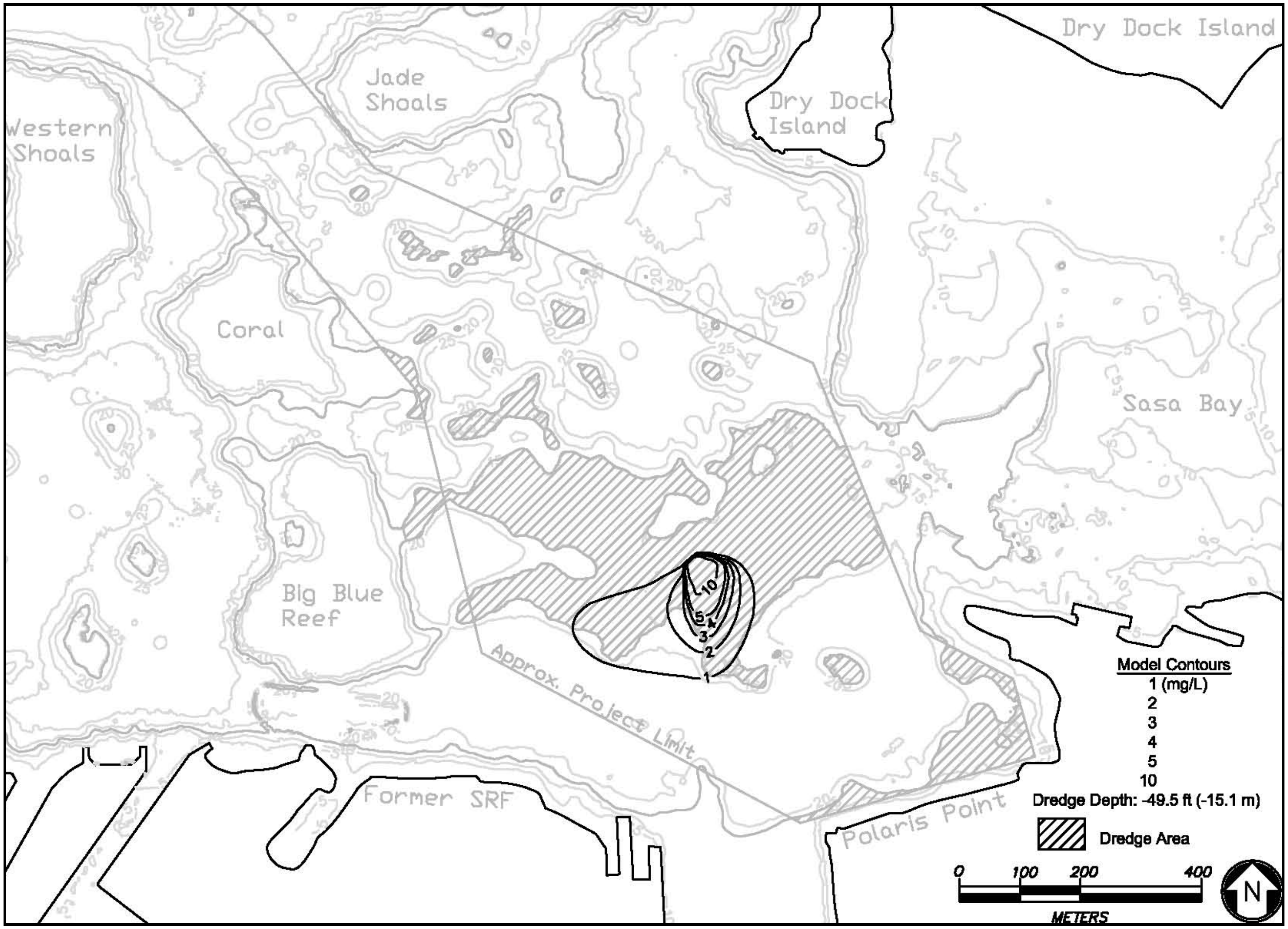

Figure 6-11B. Bottom Layer Suspended Sediment Concentration
(6.11 December 15 to 18 winds, 10-hour dredging at D1)

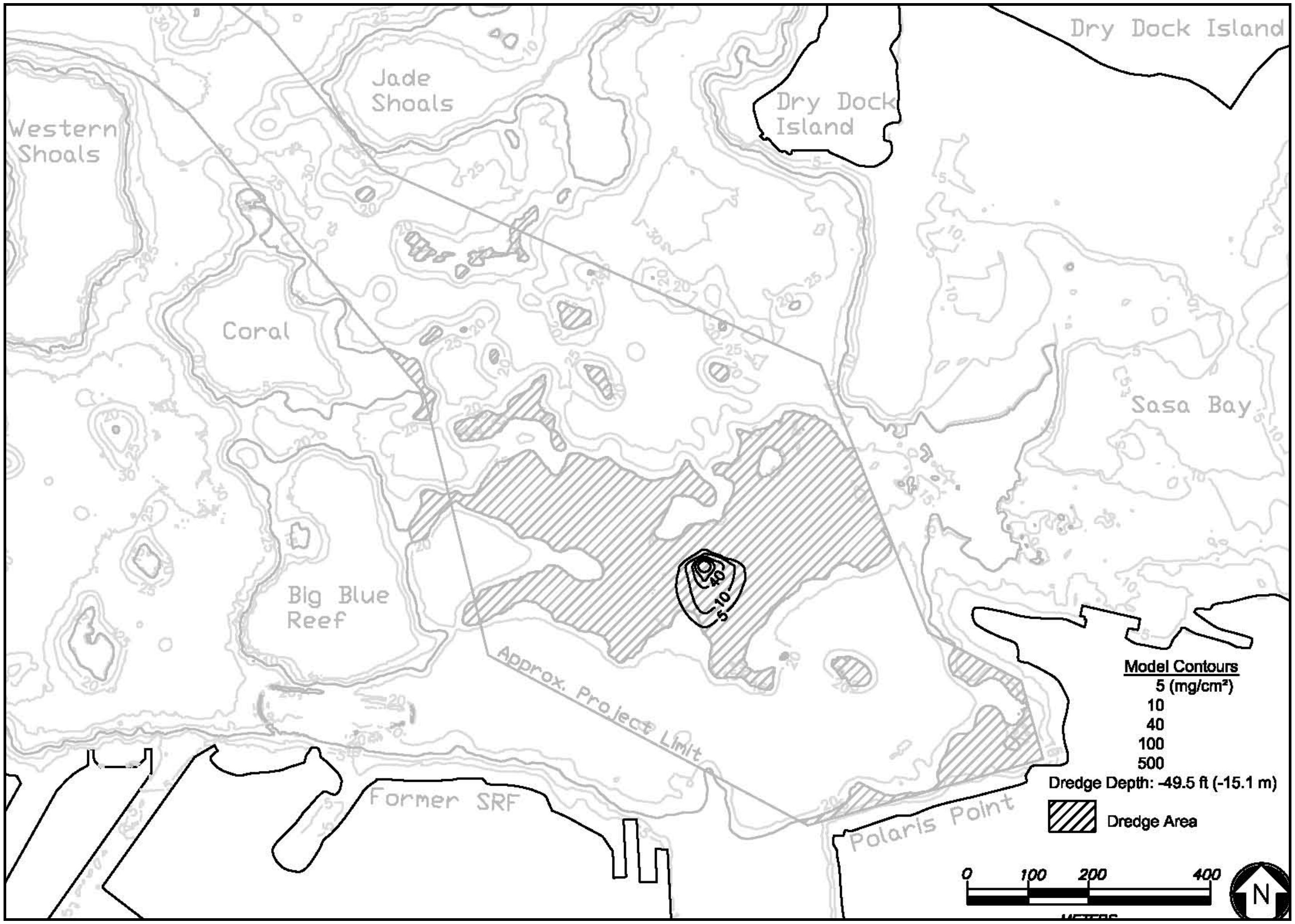

Figure 6-11C. Sediment Deposition

5mg/cm2 =0.03mm; 10mg/cm^2 =0.06mm; 40mg/cm^2 =0.2mm; 100mg/cm^2 =0.6mm; 500mg/cm^2 =3mm

(6.11 December 15 to 18 winds, 10-hour dredging at D1)

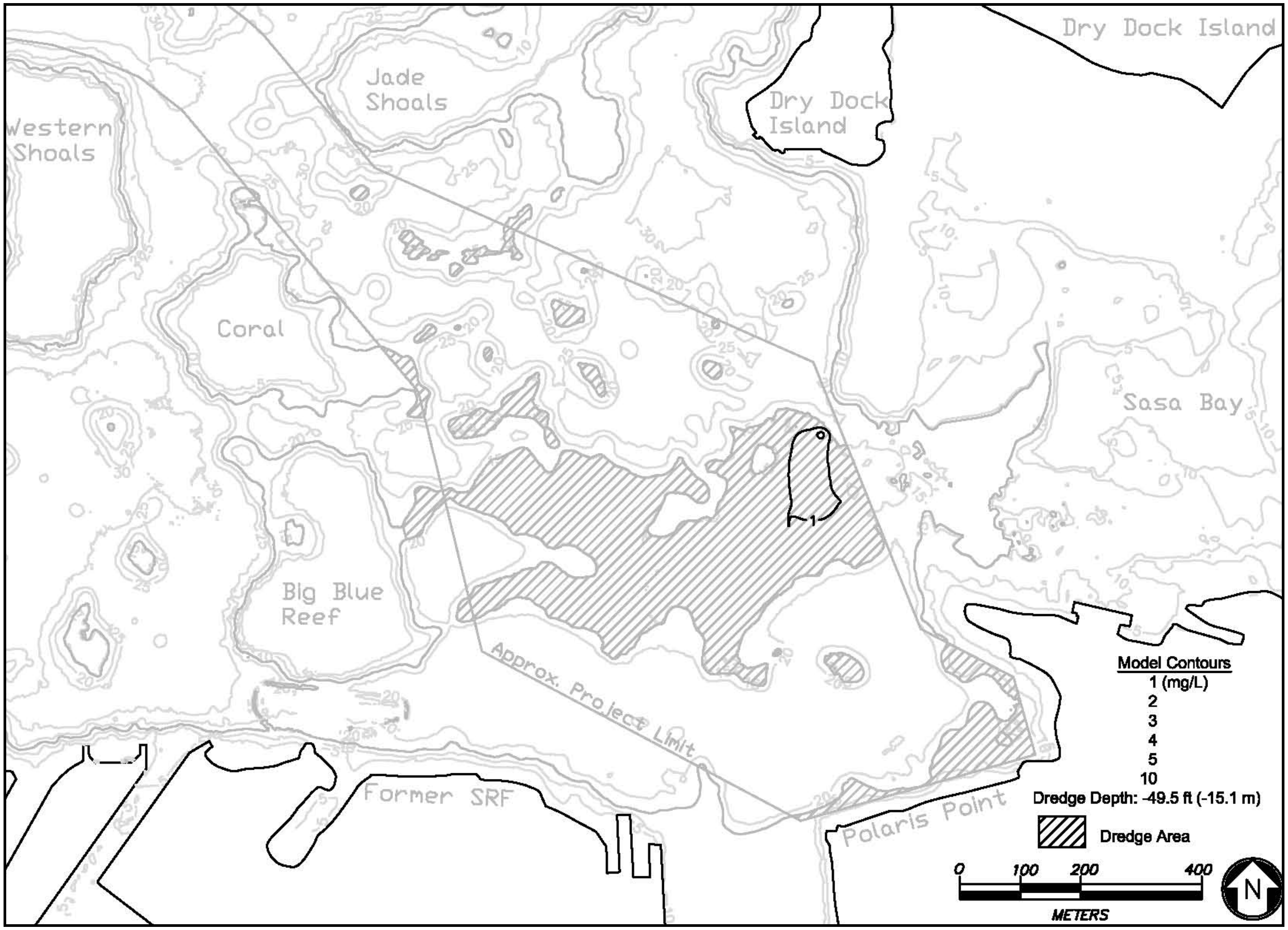

Figure 6-12A. Surface Layer Suspended Sediment Concentration

(6.12 December 15 to 18 winds, 10-hour dredging at D2)

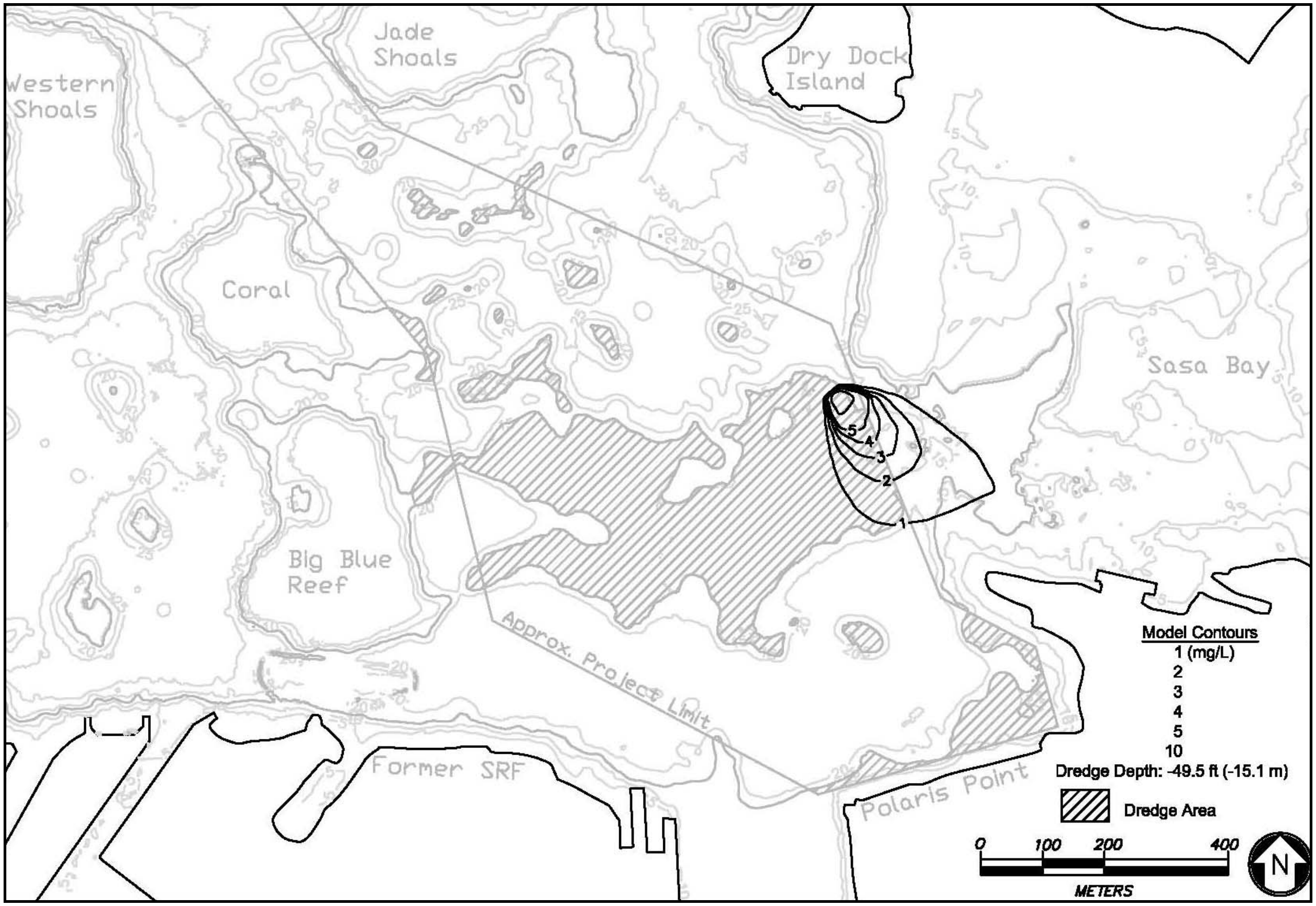

Figure 6-12B. Bottom Layer Suspended Sediment Concentration

(6.12 December 15 to 18 winds, 10-hour dredging at D2)

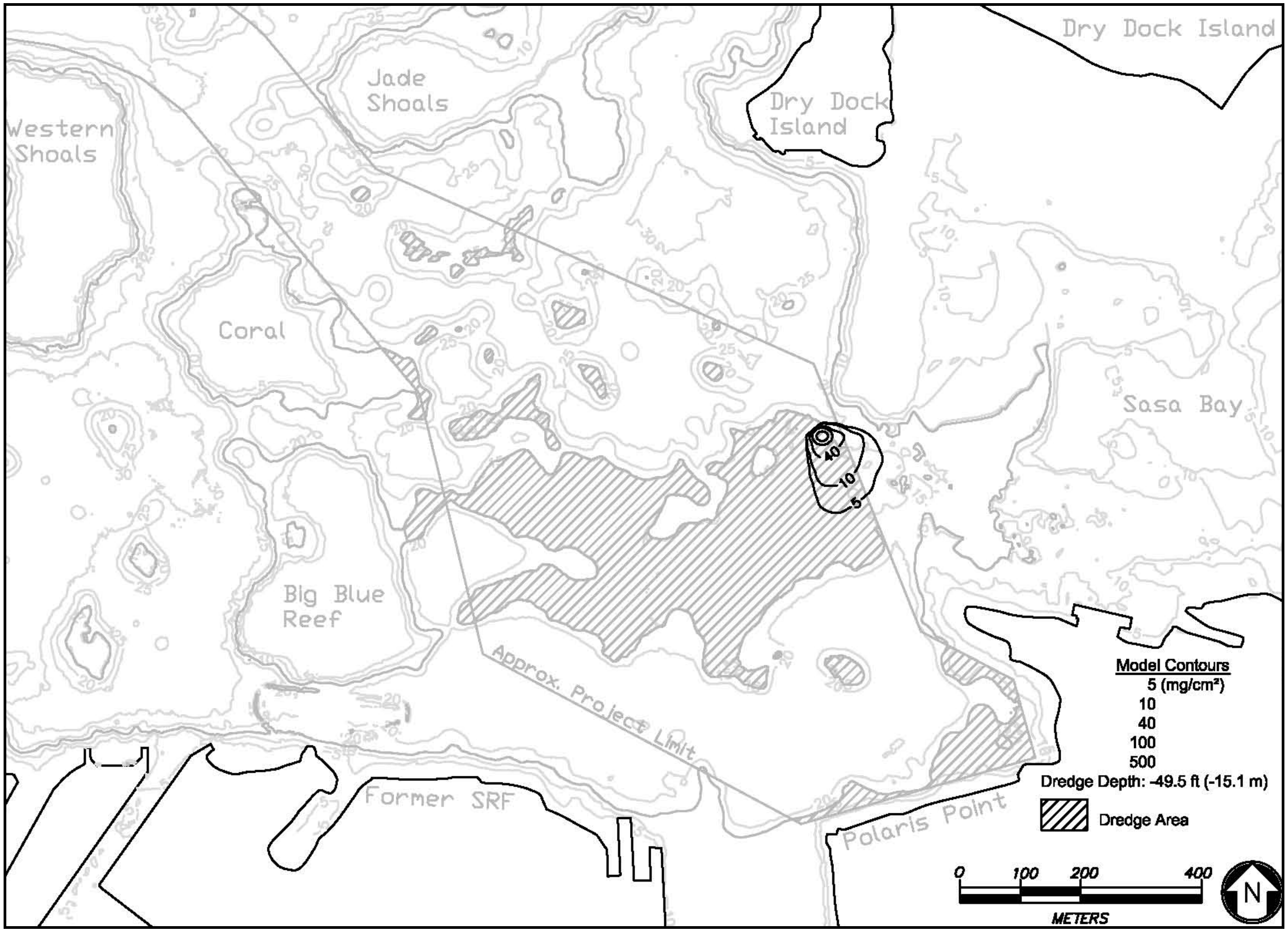

Figure 6-12C. Sediment Deposition

5mg/cm2 =0.03mm; 10mg/cm^2 =0.06mm; 40mg/cm^2 =0.2mm; 100mg/cm^2 =0.6mm; 500mg/cm^2 =3mm

(6.12 December 15 to 18 winds, 10-hour dredging at D2)

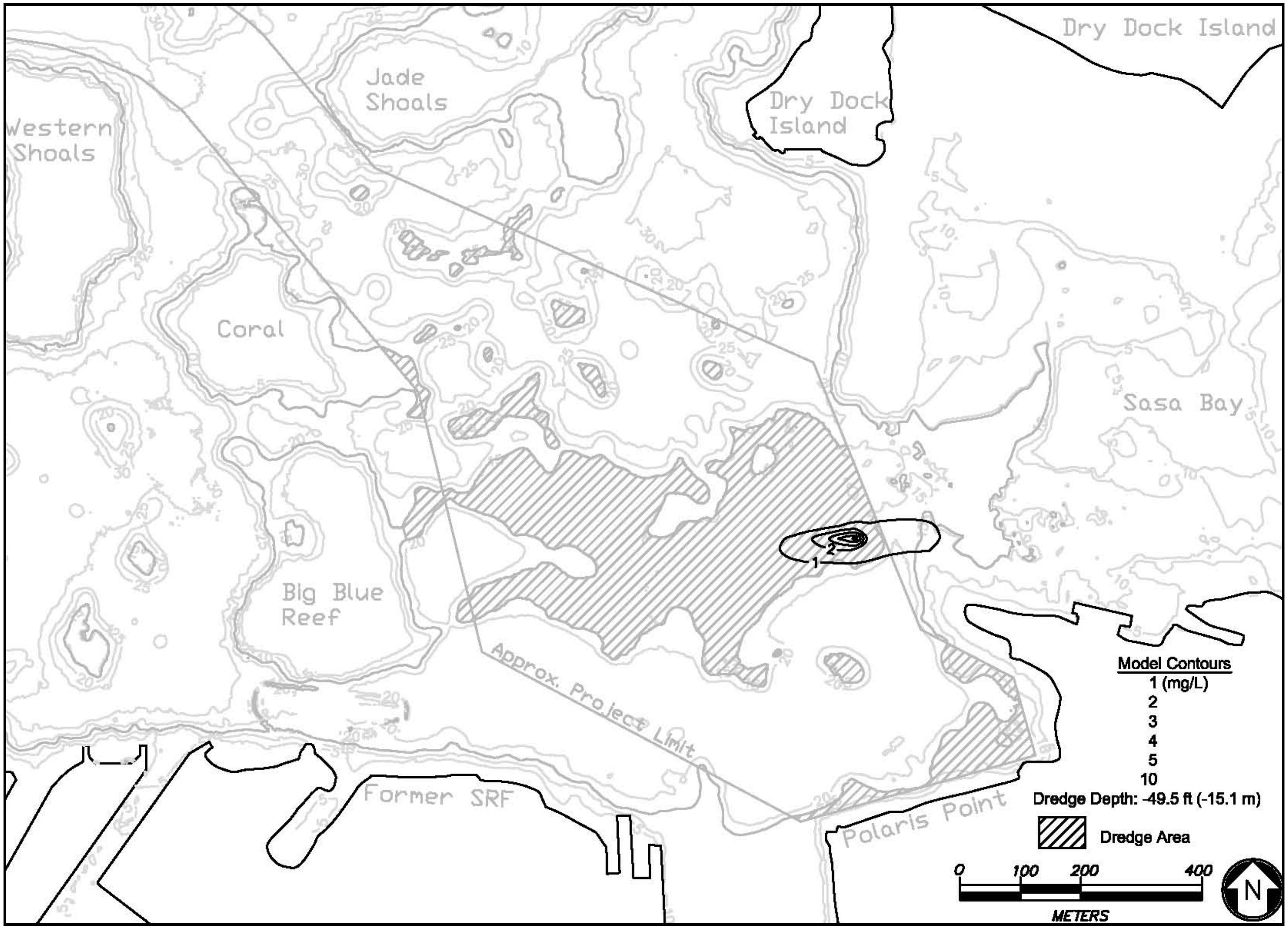

Figure 6-13A. Surface Layer Suspended Sediment Concentration

(6.13 December 15 to 18 winds, 10-hour dredging at D3)

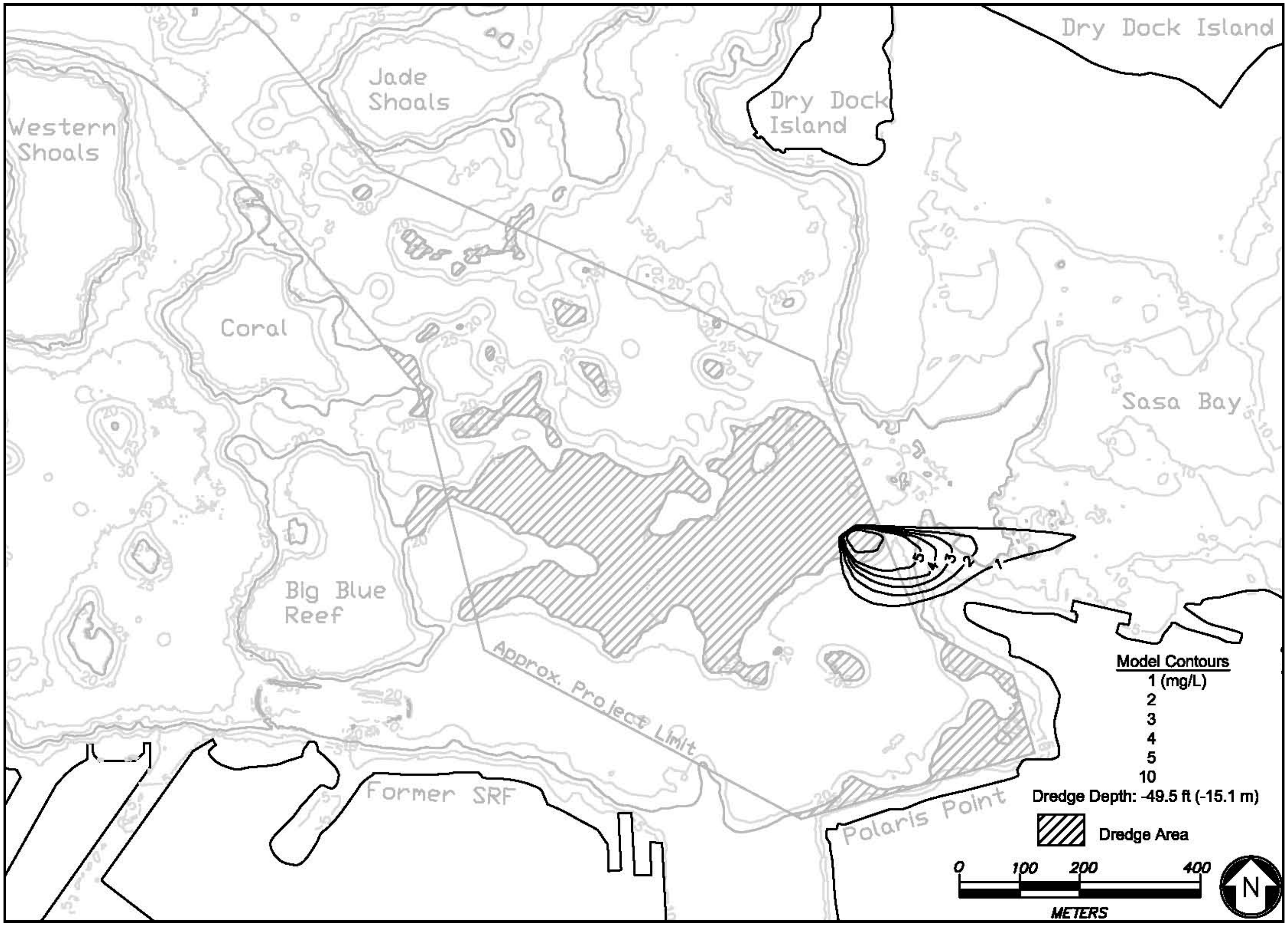

Figure 6-13B. Bottom Layer Suspended Sediment Concentration

(6.13 December 15 to 18 winds, 10-hour dredging at D3)

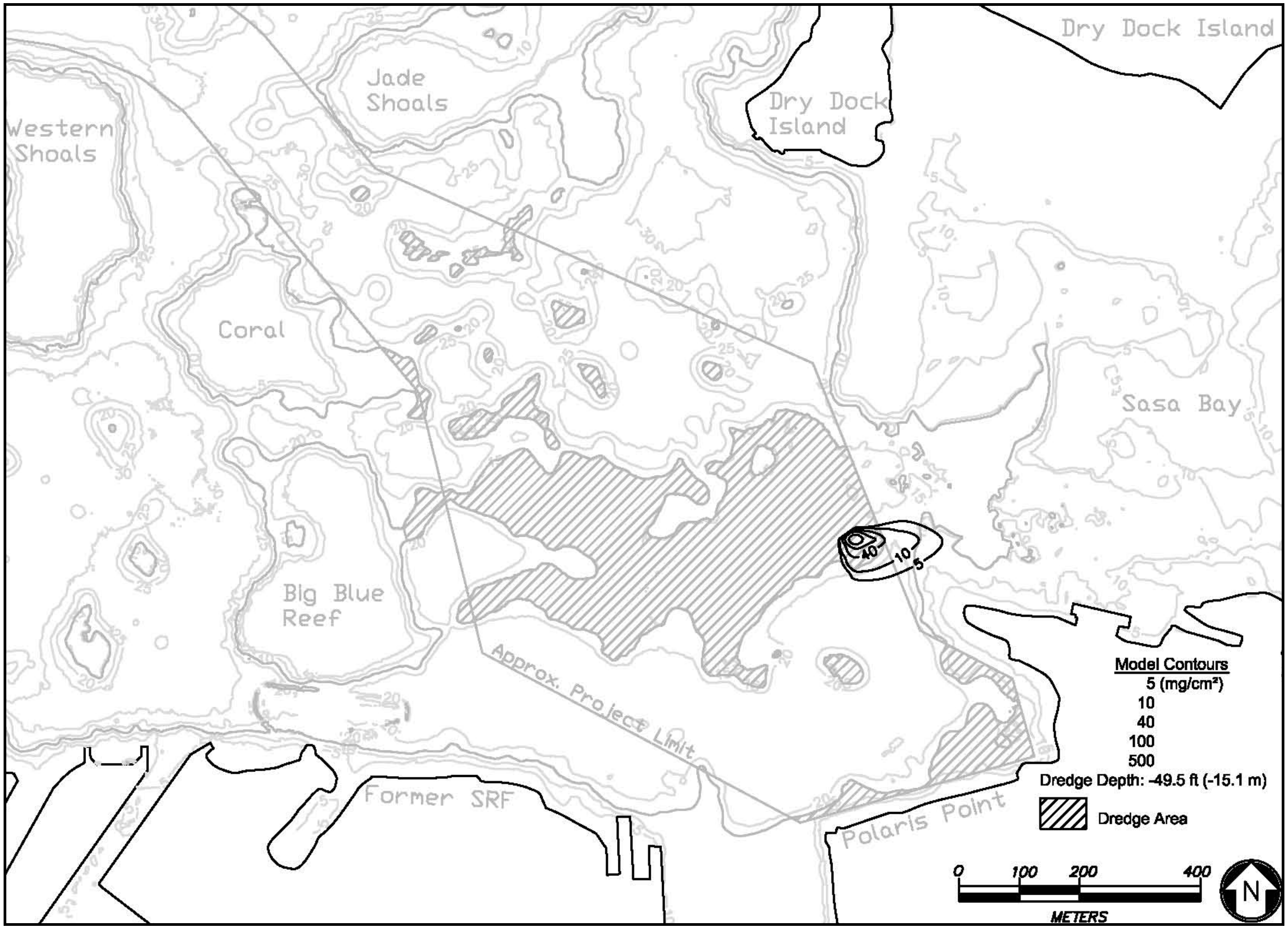

Figure 6-13C. Sediment Deposition

5mg/cm2 =0.03mm; 10mg/cm^2 =0.06mm; 40mg/cm^2 =0.2mm; 100mg/cm^2 =0.6mm; 500mg/cm^2 =3mm

(6.13 December 15 to 18 winds, 10-hour dredging at D3)

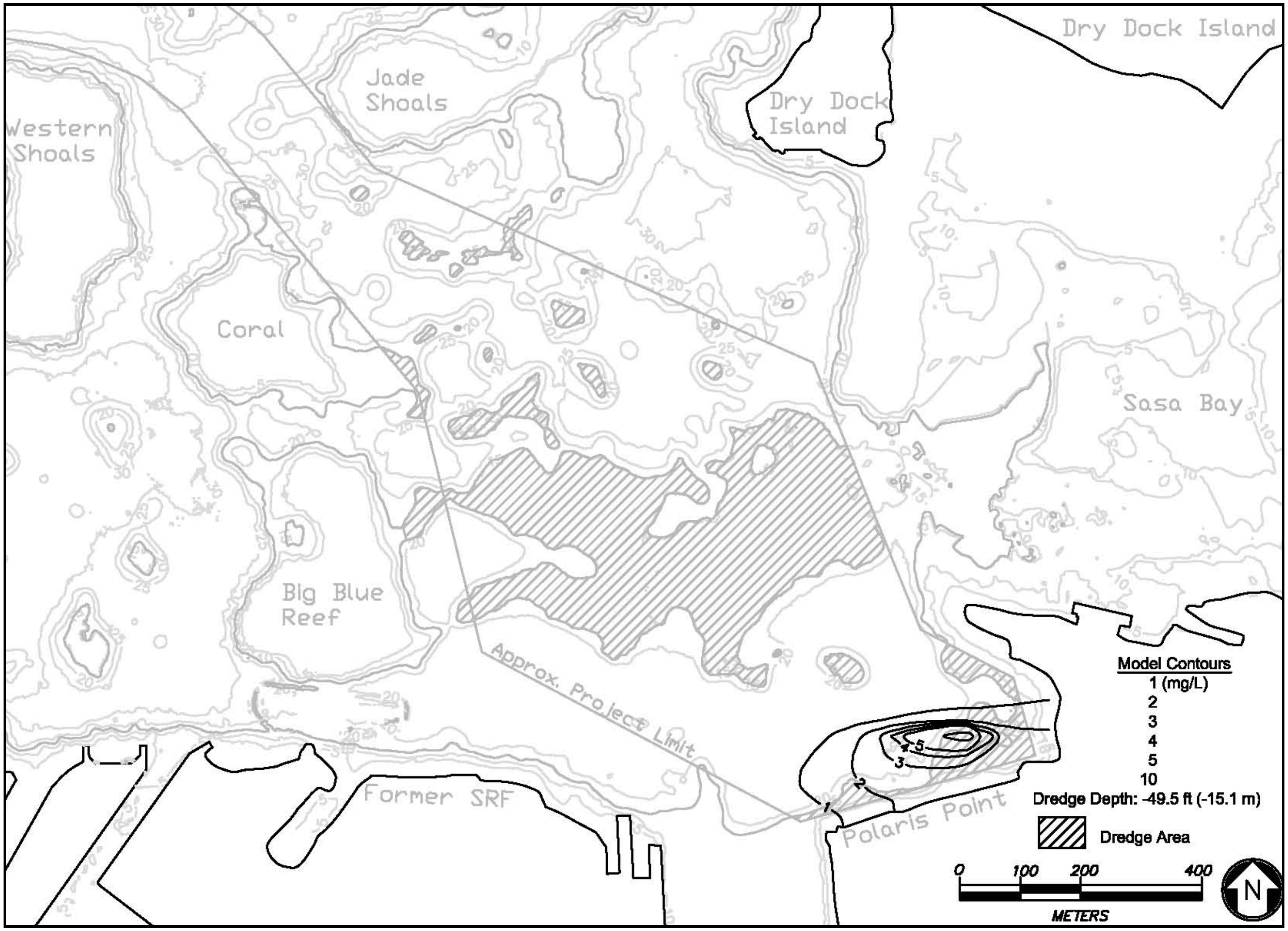

Figure 6-14A. Surface Layer Suspended Sediment Concentration

(6.14 December 15 to 18 winds, 10-hour dredging at D4)

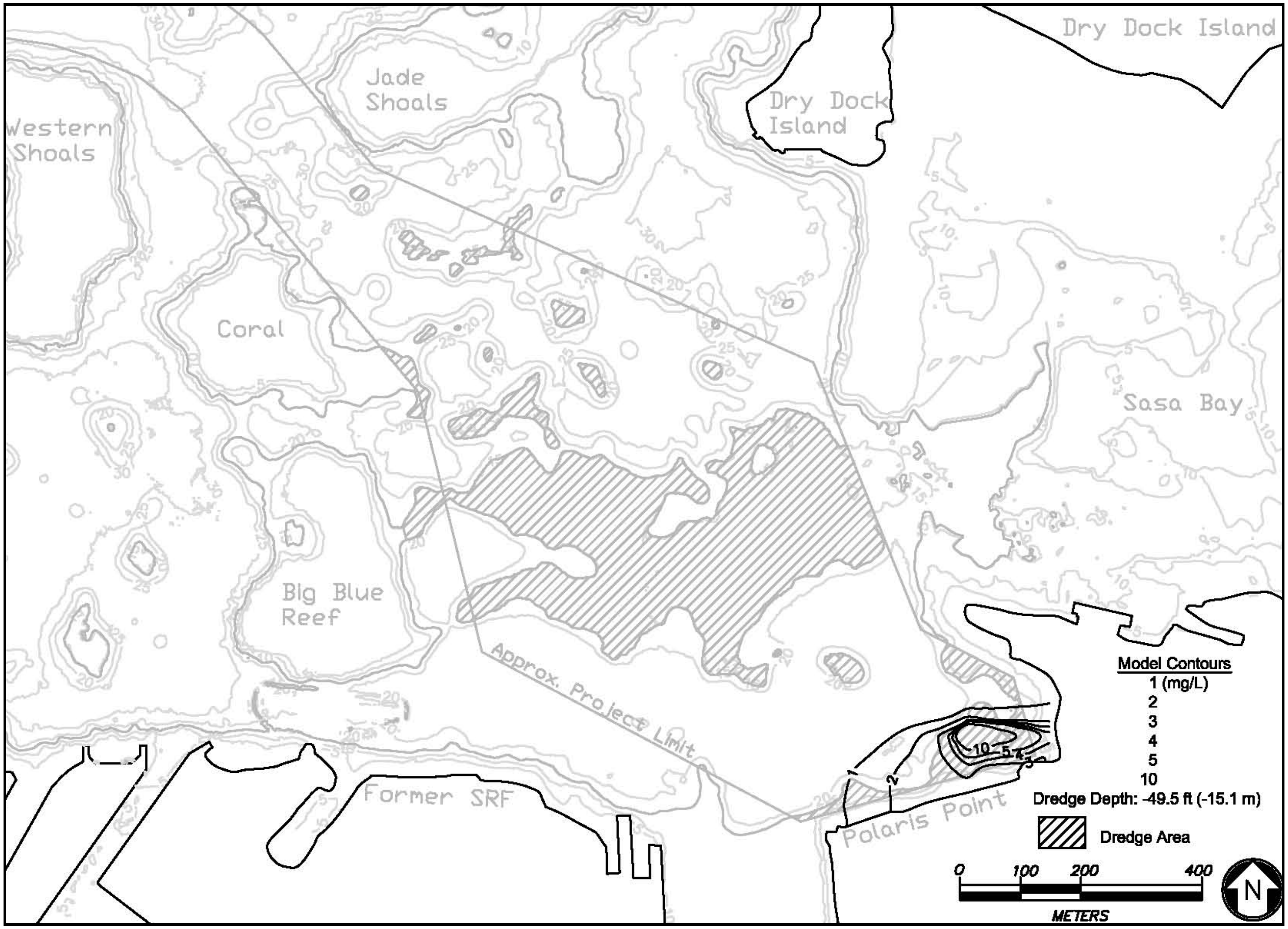

Figure 6-14B. Bottom Layer Suspended Sediment Concentration

(6.14 December 15 to 18 winds, 10-hour dredging at D4)

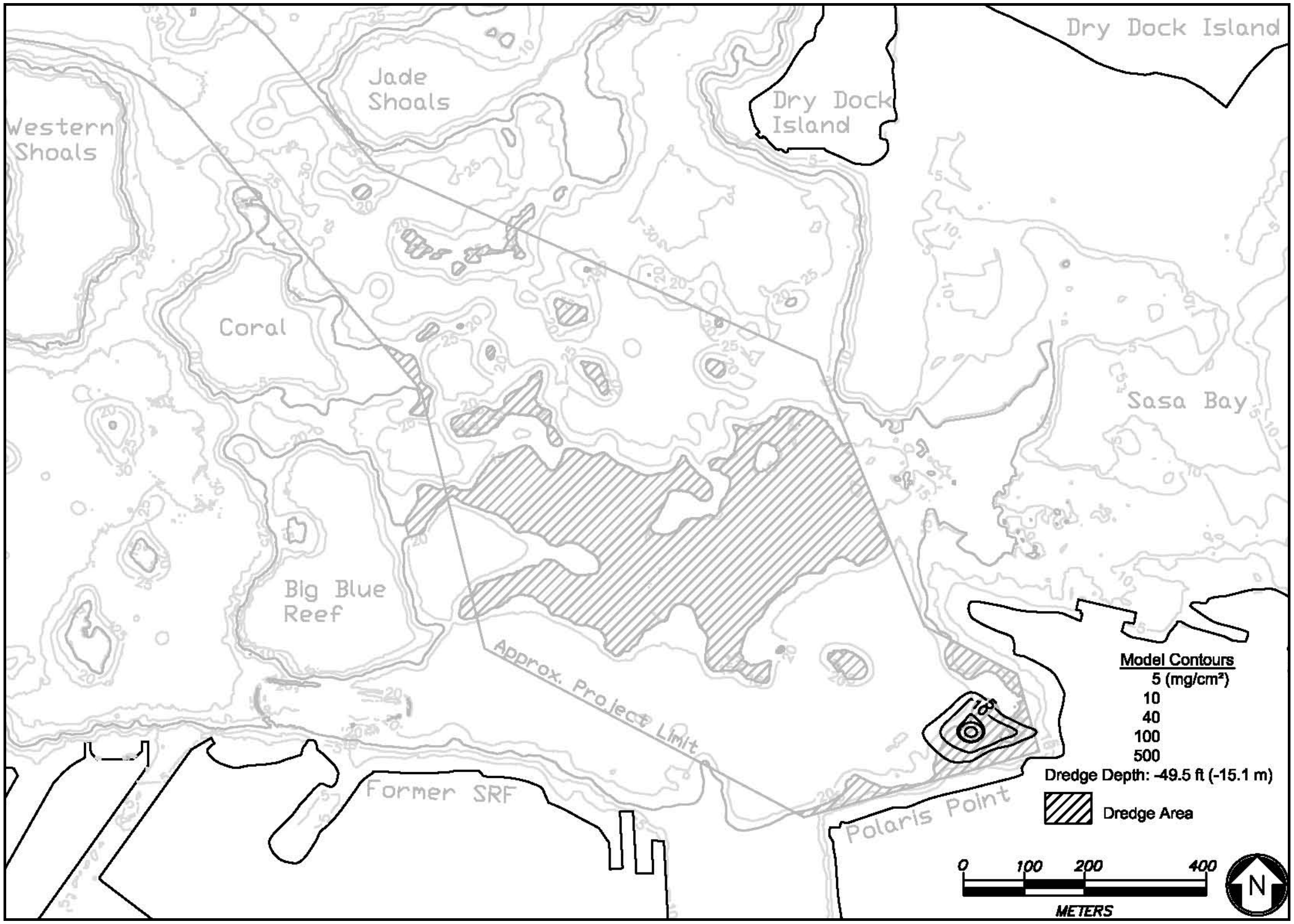

Figure 6-14C. Sediment Deposition

5mg/cm2 =0.03mm; 10mg/cm^2 =0.06mm; 40mg/cm^2 =0.2mm; 100mg/cm^2 =0.6mm; 500mg/cm^2 =3mm

(6.14 December 15 to 18 winds, 10-hour dredging at D4)

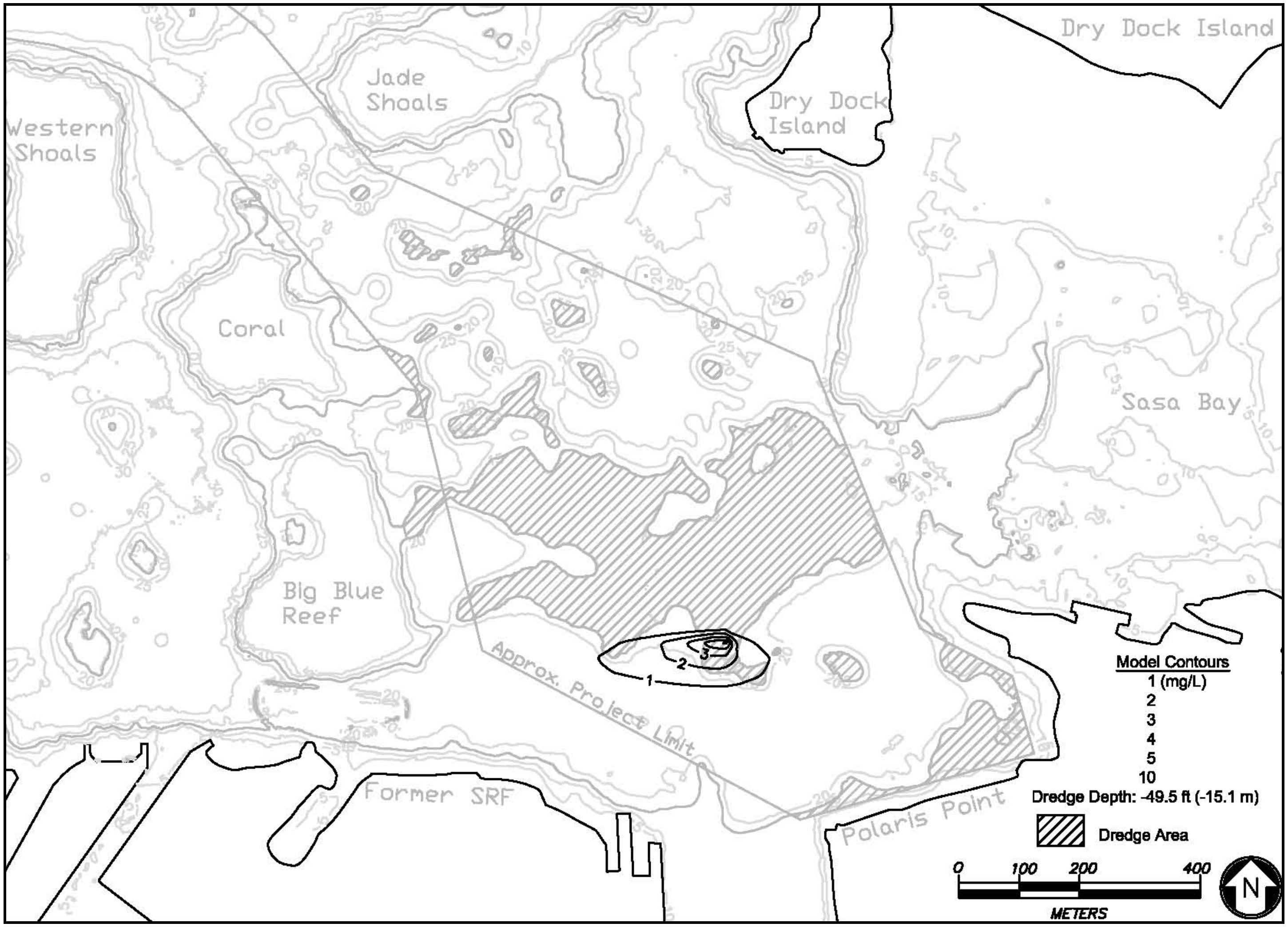

Figure 6-15A. Surface Layer Suspended Sediment Concentration

(6.15 December 15 to 18 winds, 10-hour dredging at D5)

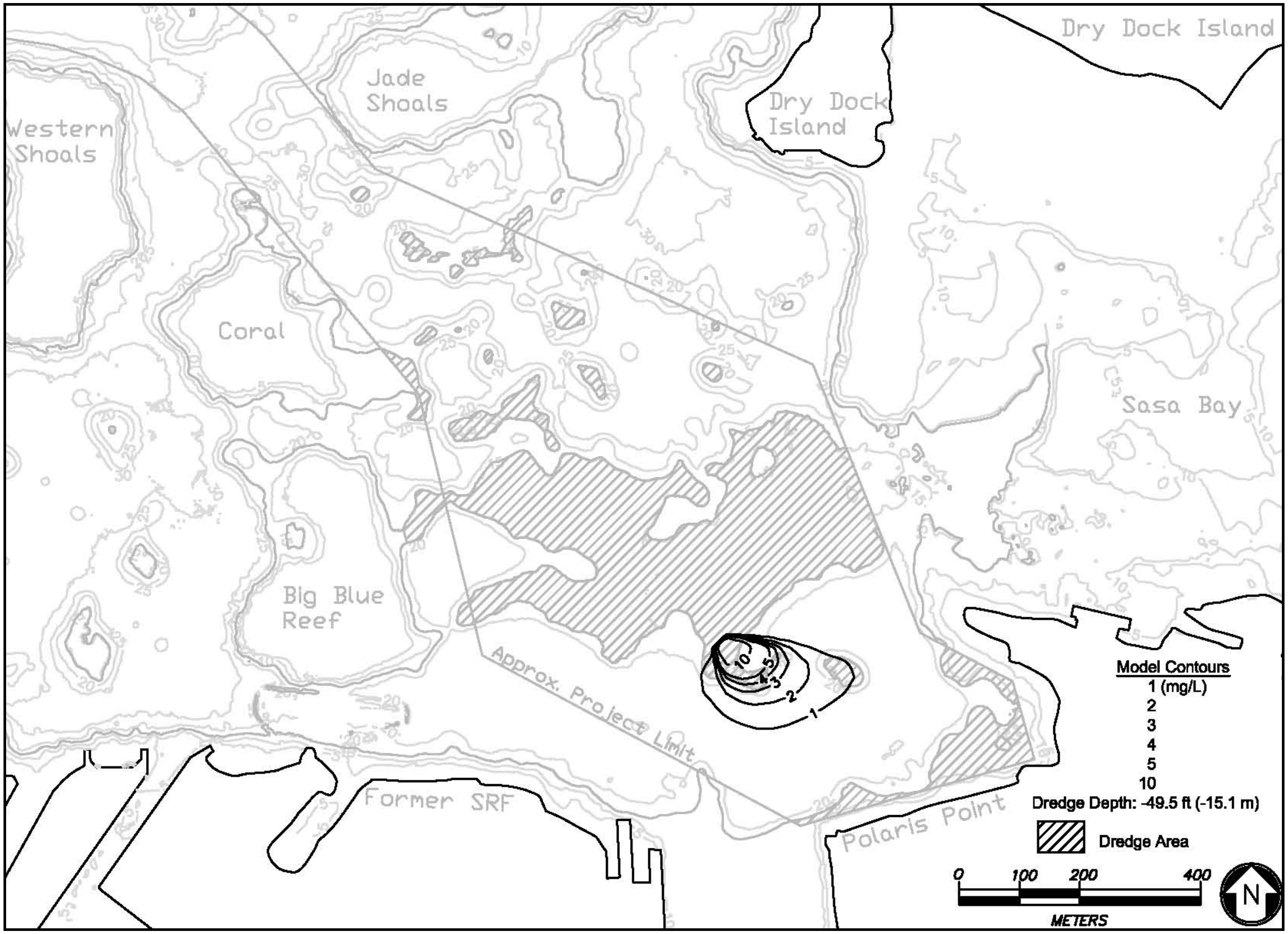

Figure 6-15B. Bottom Layer Suspended Sediment Concentration

(6.15 December 15 to 18 winds, 10-hour dredging at D5)

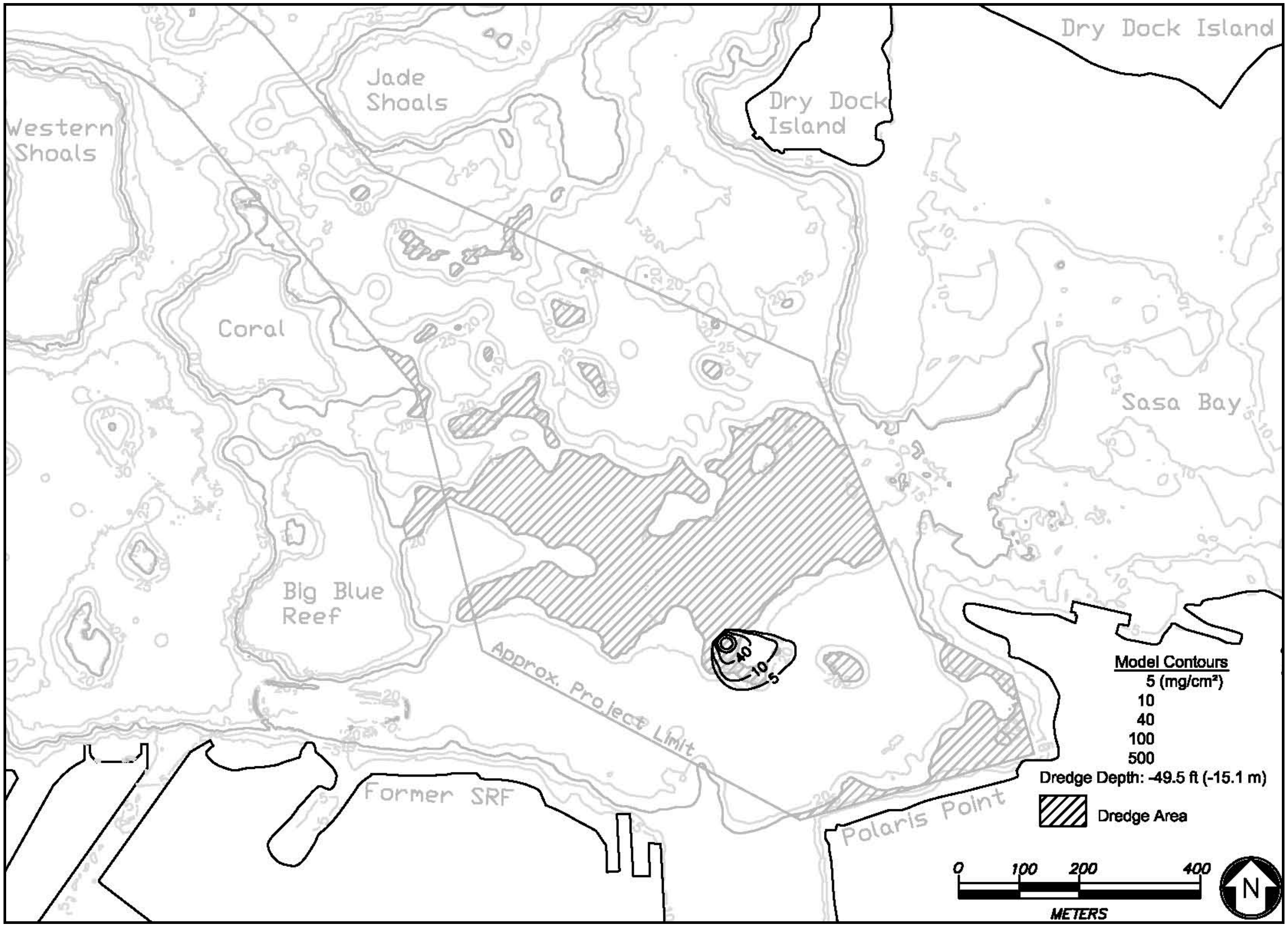

Figure 6-15C. Sediment Deposition

5mg/cm2 =0.03mm; 10mg/cm^2 =0.06mm; 40mg/cm^2 =0.2mm; 100mg/cm^2 =0.6mm; 500mg/cm^2 =3mm

(6.15 December 15 to 18 winds, 10-hour dredging at D5)

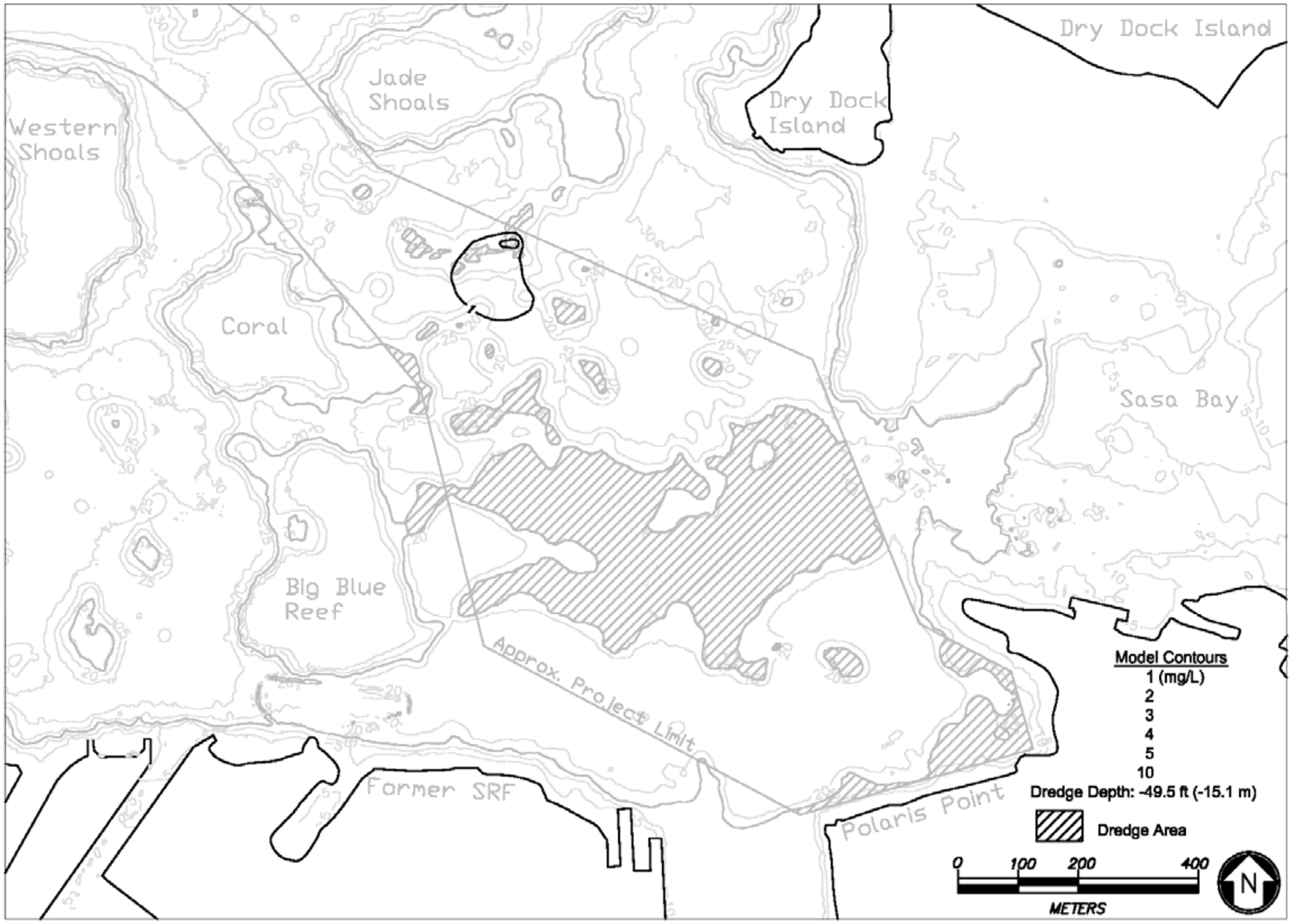

Figure 6-16A. Surface Layer Suspended Sediment Concentration (6.16 December 15 to 18 winds, 10-hour dredging at D6)

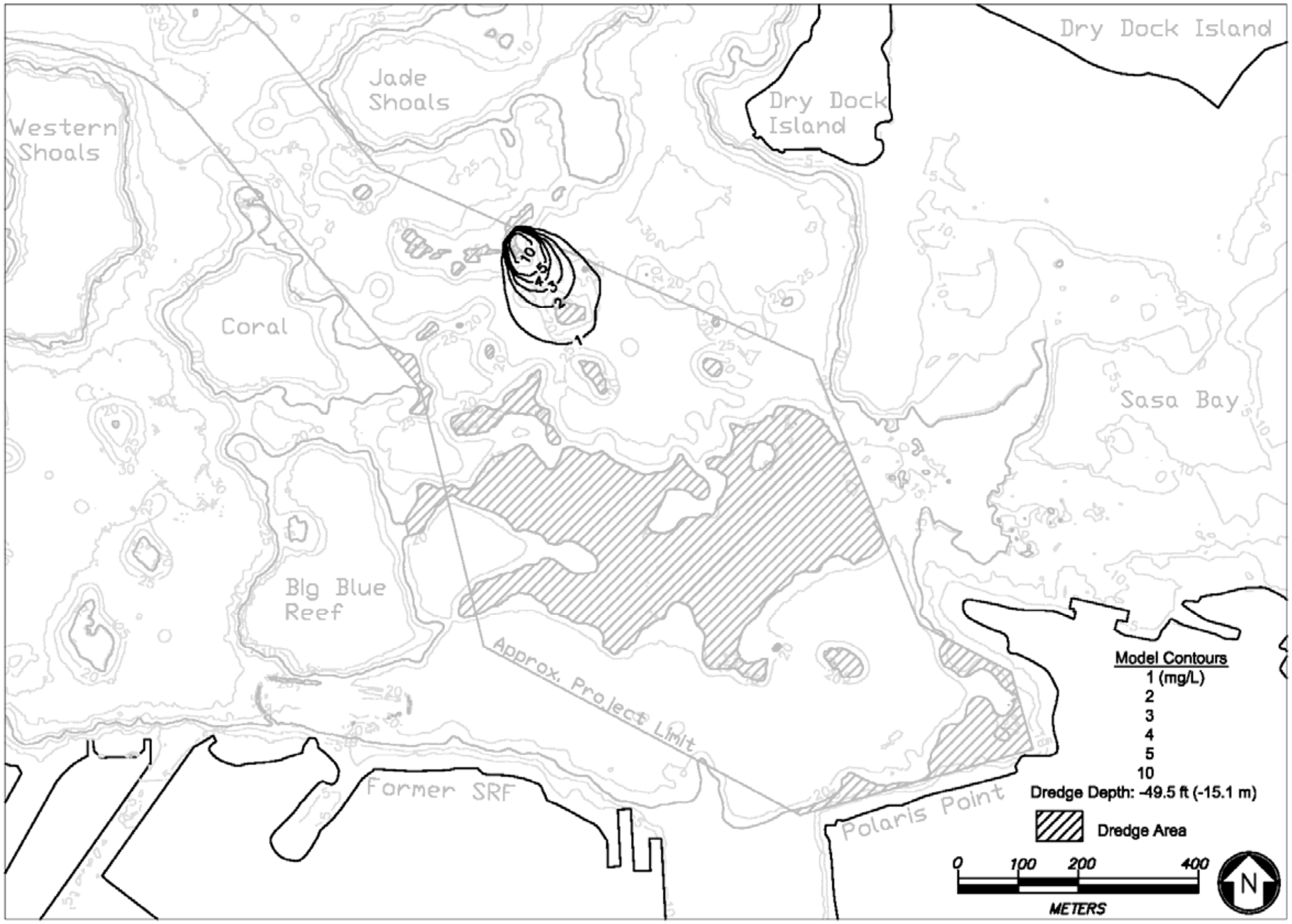

Figure 6-16B. Bottom Layer Suspended Sediment Concentration (6.16 December 15 to 18 winds, 10-hour dredging at D6)

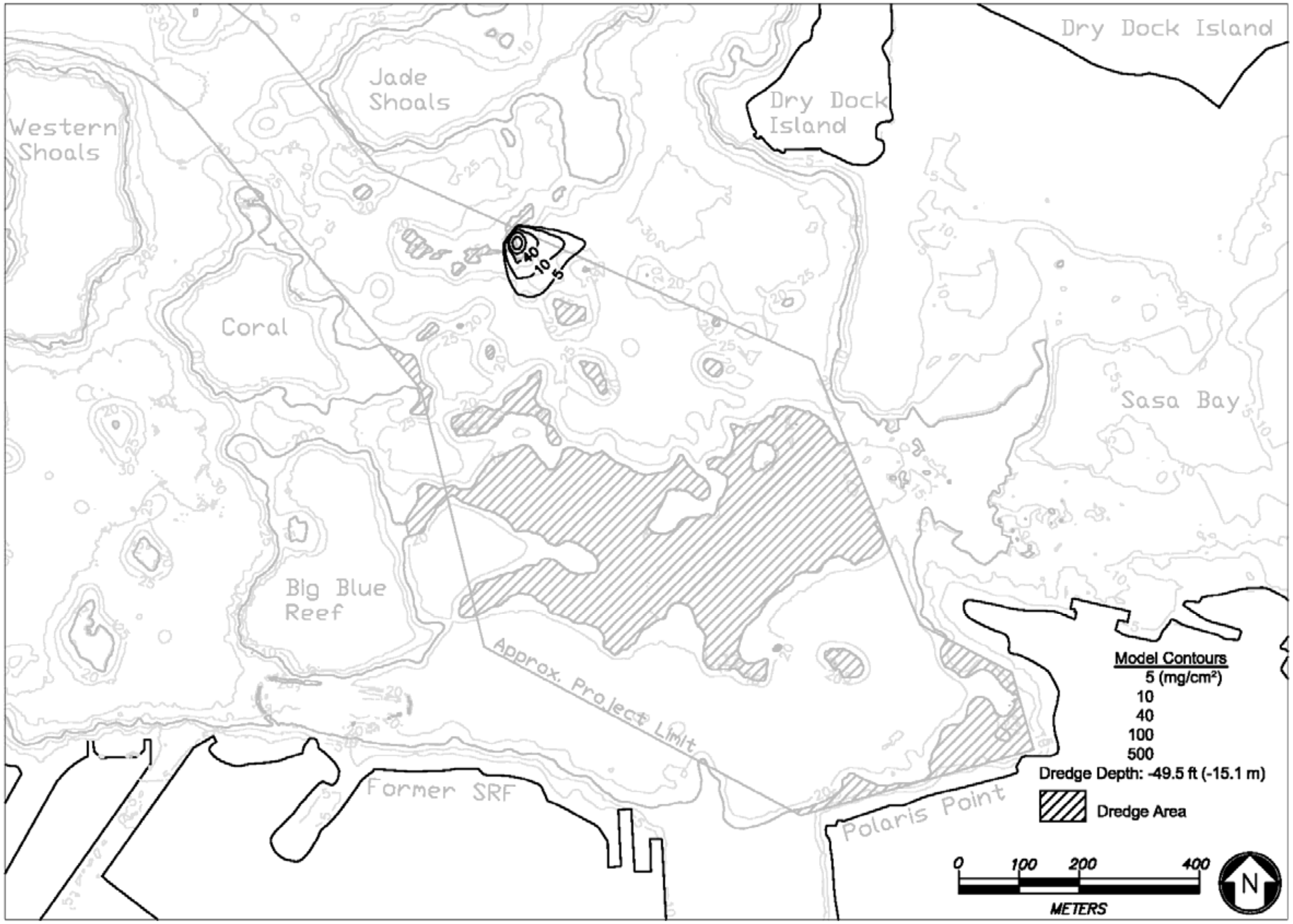

Figure 6-16C. Sediment Deposition

5mg/cm2 =0.03mm; 10mg/cm^2 =0.06mm; 40mg/cm^2 =0.2mm; 100mg/cm^2 =0.6mm; 500mg/cm^2 =3mm

(6.16 December 15 to 18 winds, 10-hour dredging at D6)

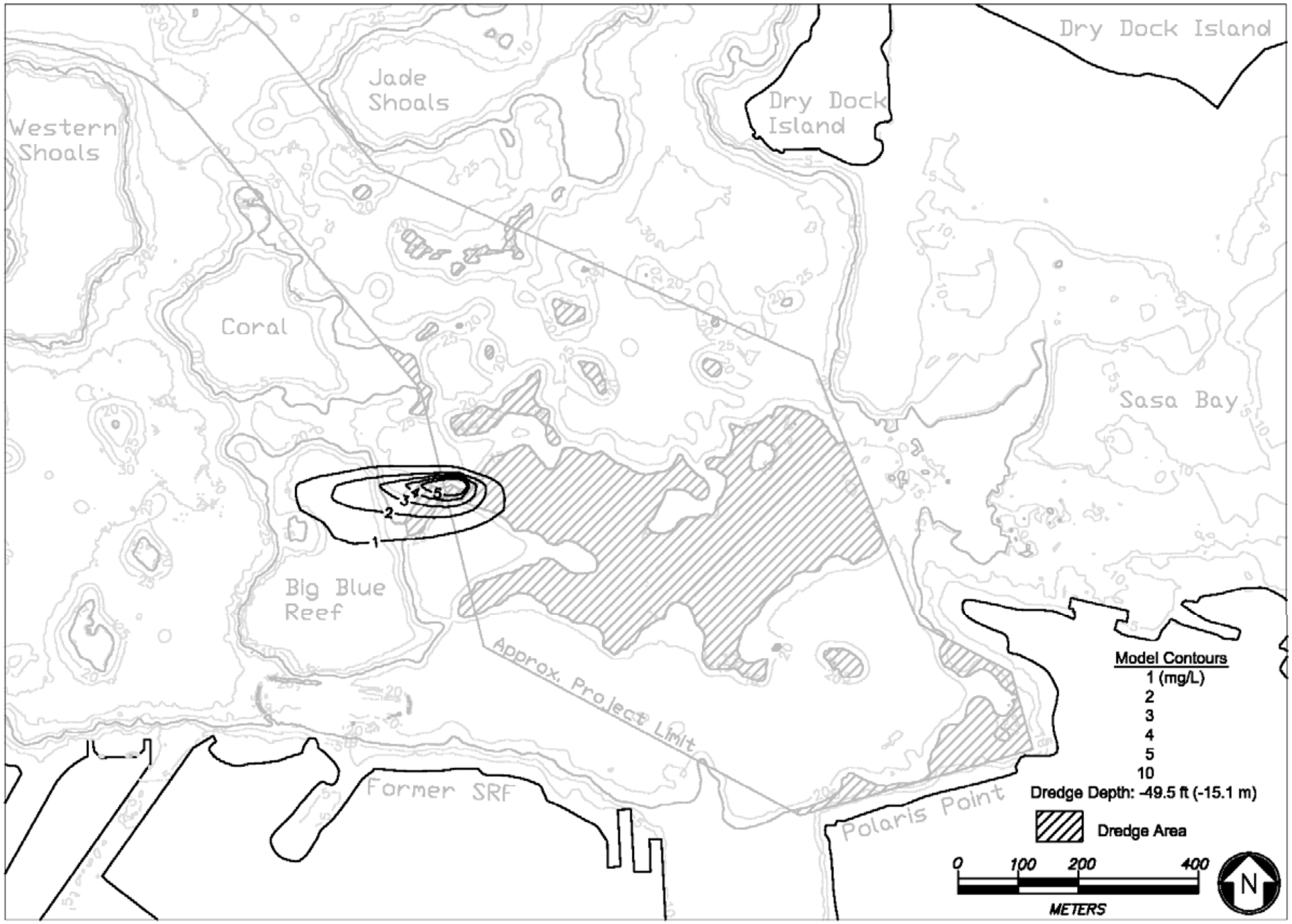

Figure 6-17A. Surface Layer Suspended Sediment Concentration (6.17 December 15 to 18 winds, 10-hour dredging at D7)

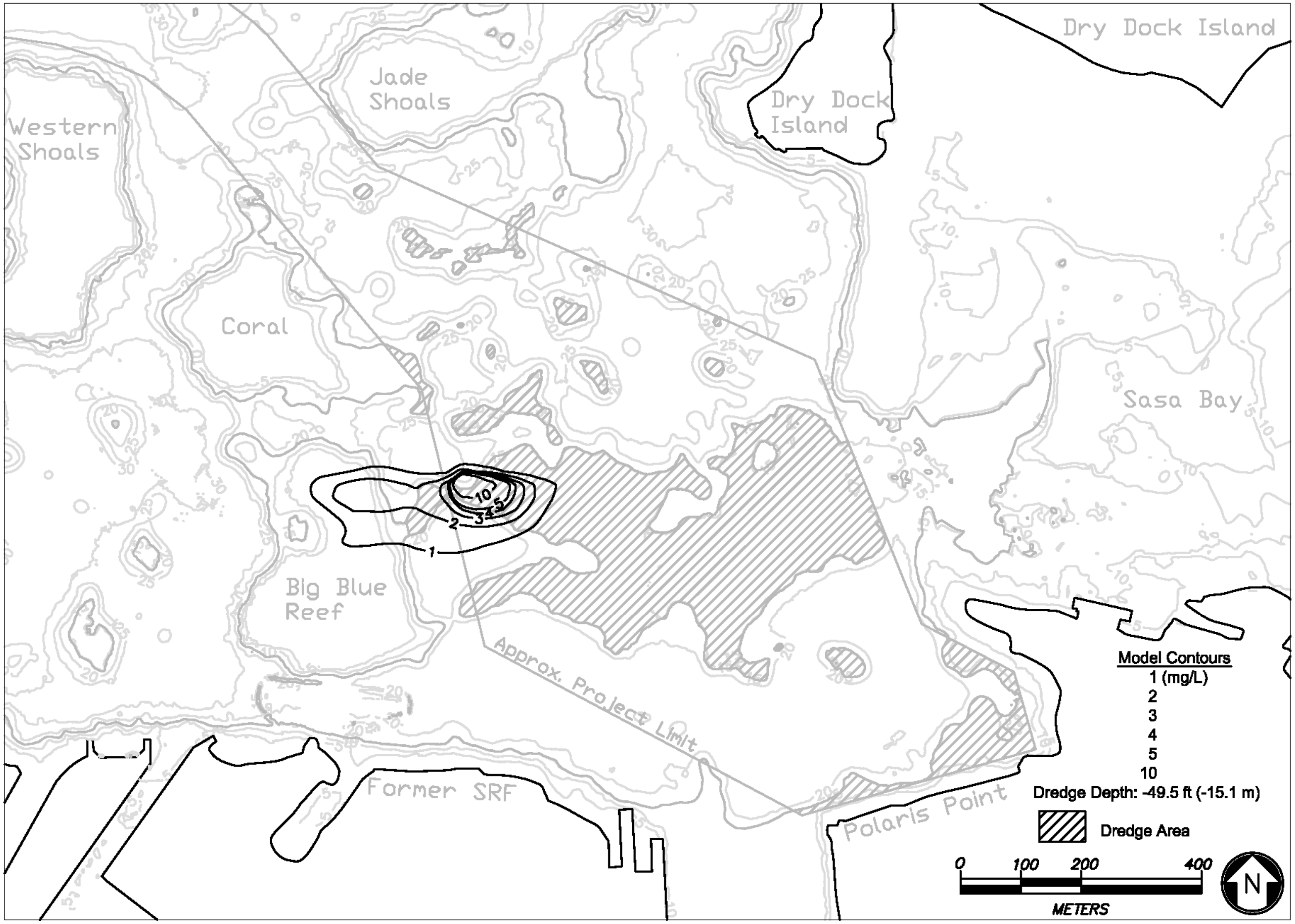

Figure 6-17B. Bottom Layer Suspended Sediment Concentration (6.17 December 15 to 18 winds, 10-hour dredging at D7)

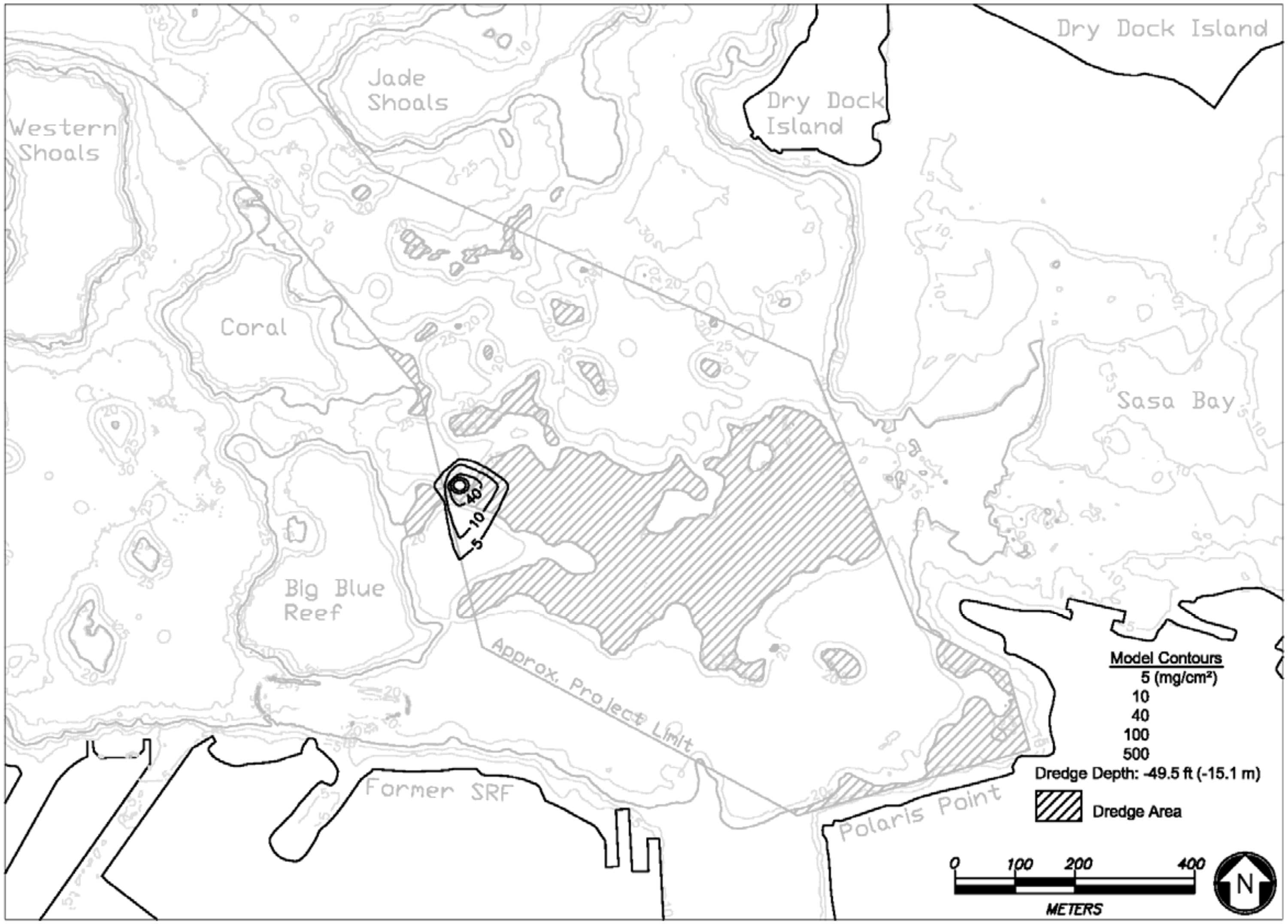

Figure 6-17C. Sediment Deposition

5mg/cm2 =0.03mm; 10mg/cm^2 =0.06mm; 40mg/cm^2 =0.2mm; 100mg/cm^2 =0.6mm; 500mg/cm^2 =3mm

(6.17 December 15 to 18 winds, 10-hour dredging at D7)

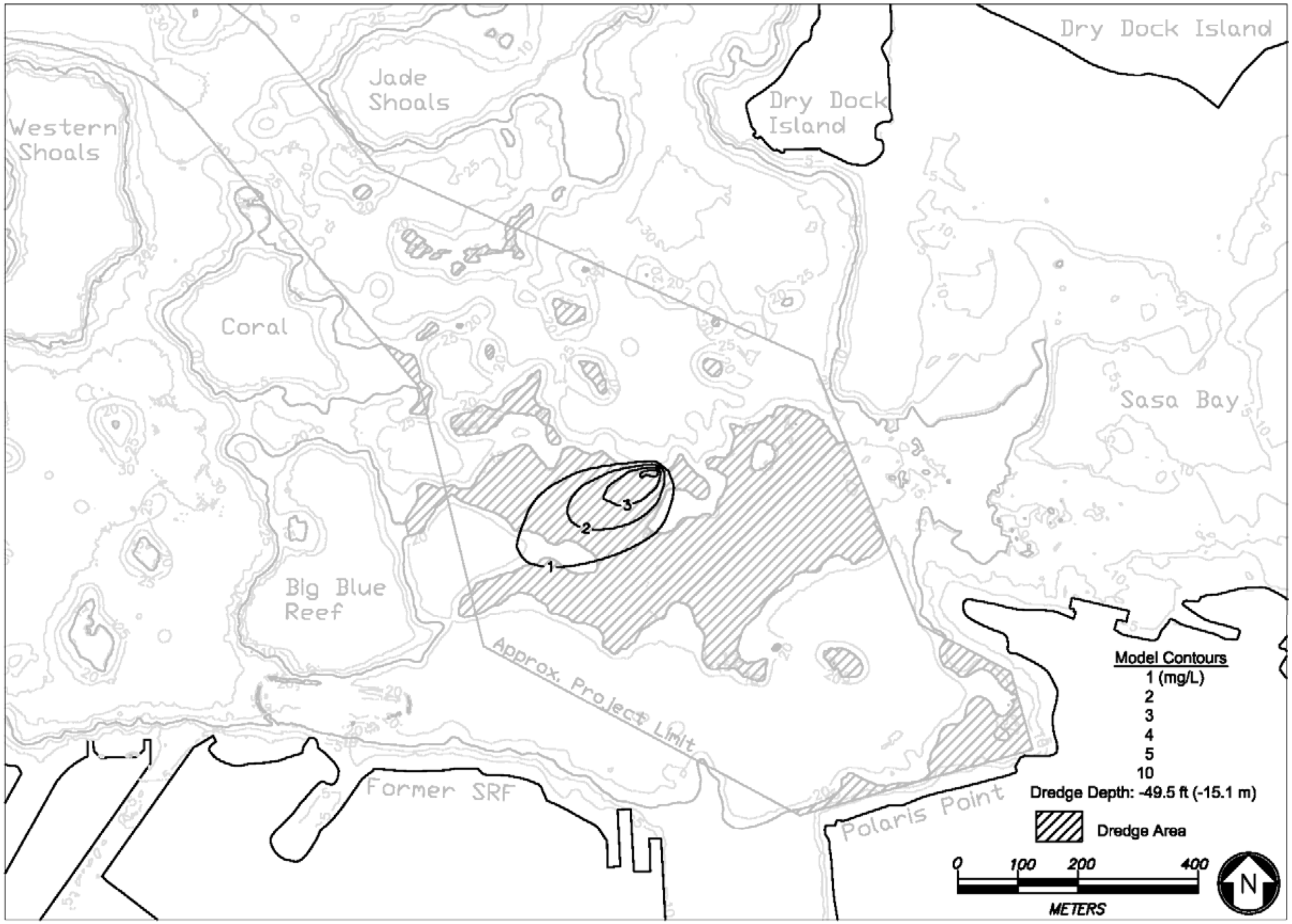

Figure 6-18A. Surface Layer Suspended Sediment Concentration

(6.18 December 15 to 18 winds, 10-hour dredging at D8)

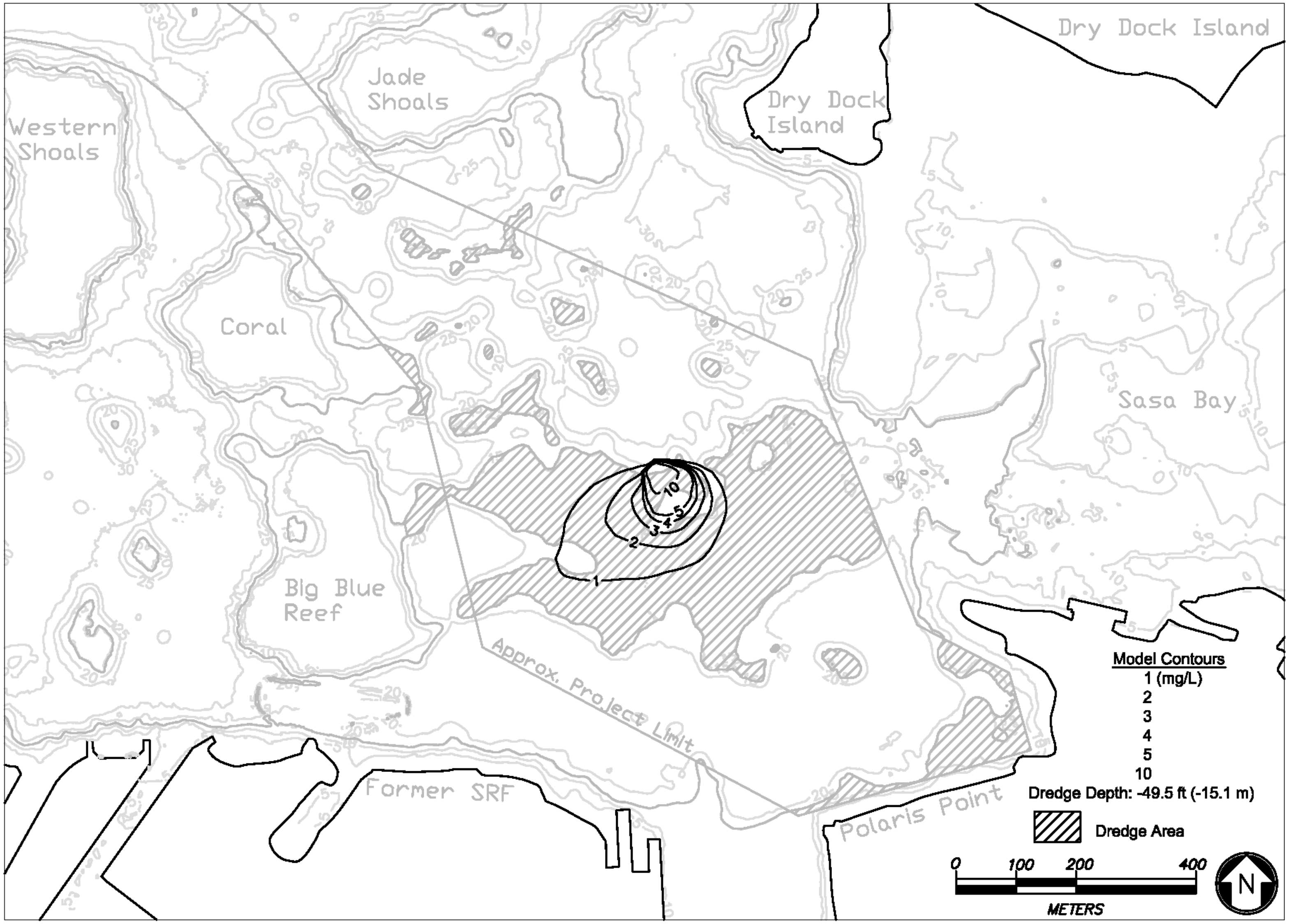

Figure 6-18B. Bottom Layer Suspended Sediment Concentration

(6.18 December 15 to 18 winds, 10-hour dredging at D8)

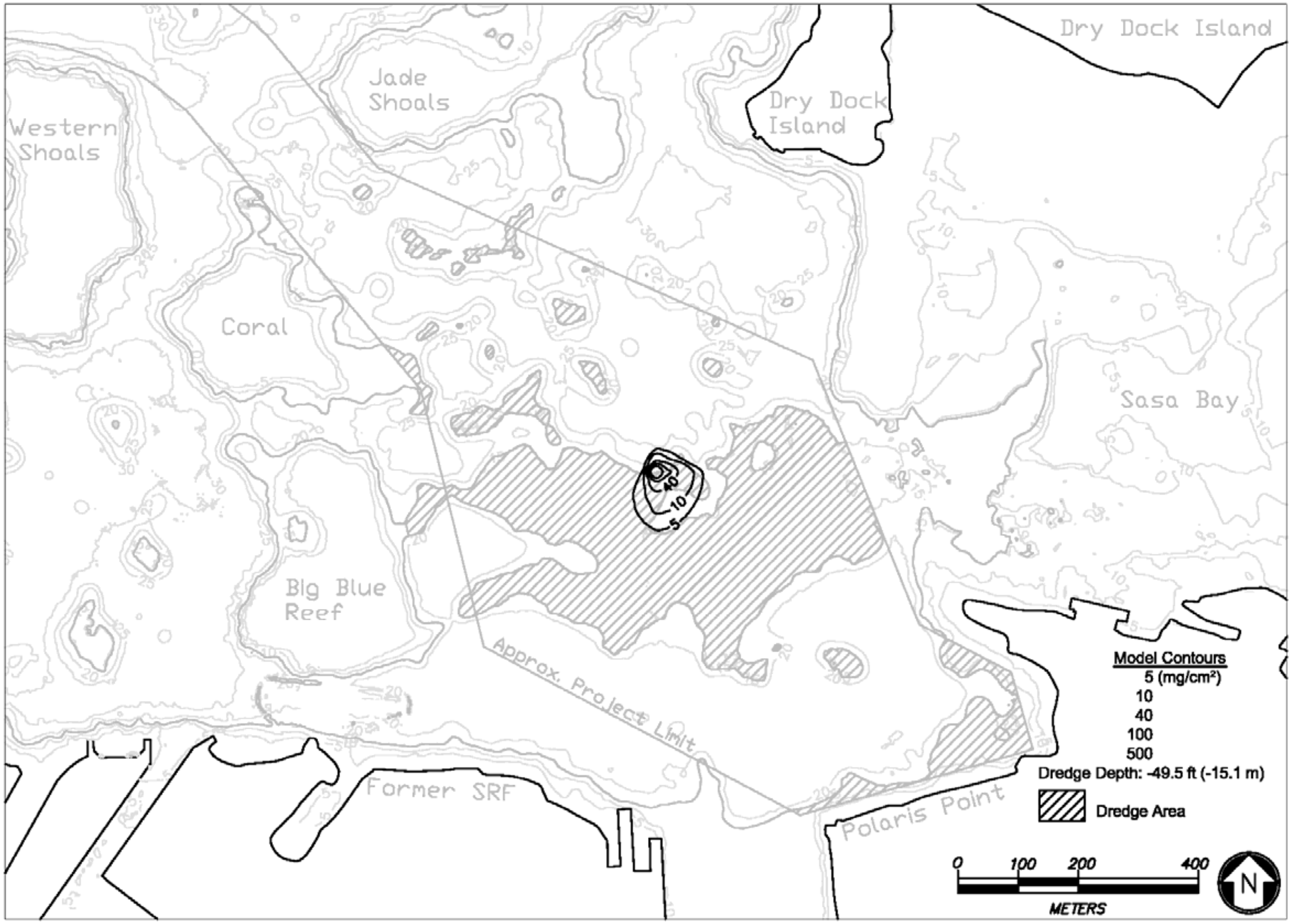

Figure 6-18C. Sediment Deposition

5mg/cm2 =0.03mm; 10mg/cm^2 =0.06mm; 40mg/cm^2 =0.2mm; 100mg/cm^2 =0.6mm; 500mg/cm^2 =3mm

(6.18 December 15 to 18 winds, 10-hour dredging at D8)

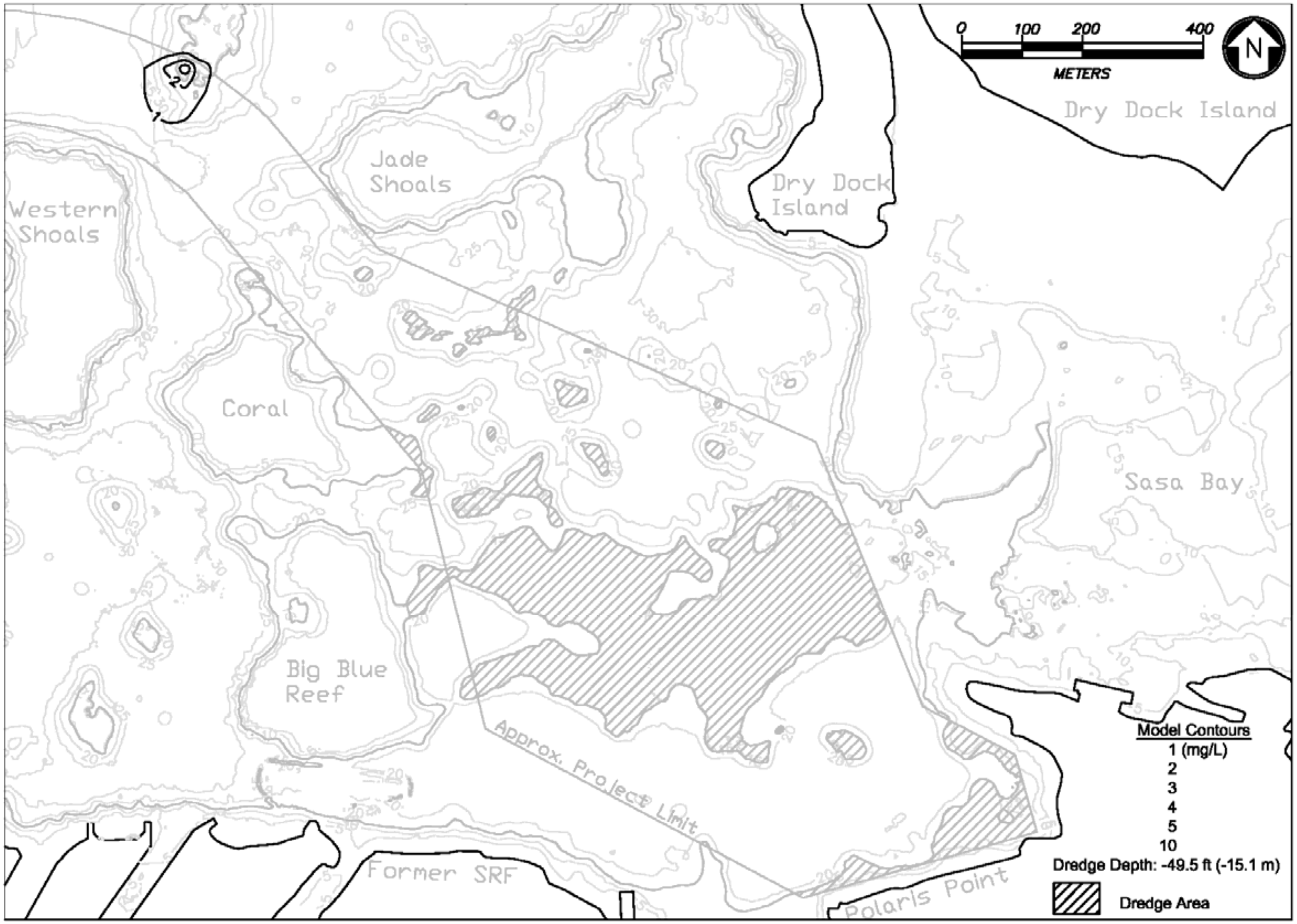

Figure 6-19A. Surface Layer Suspended Sediment Concentration (6.19 December 15 to 18 winds, 10-hour dredging at D9)

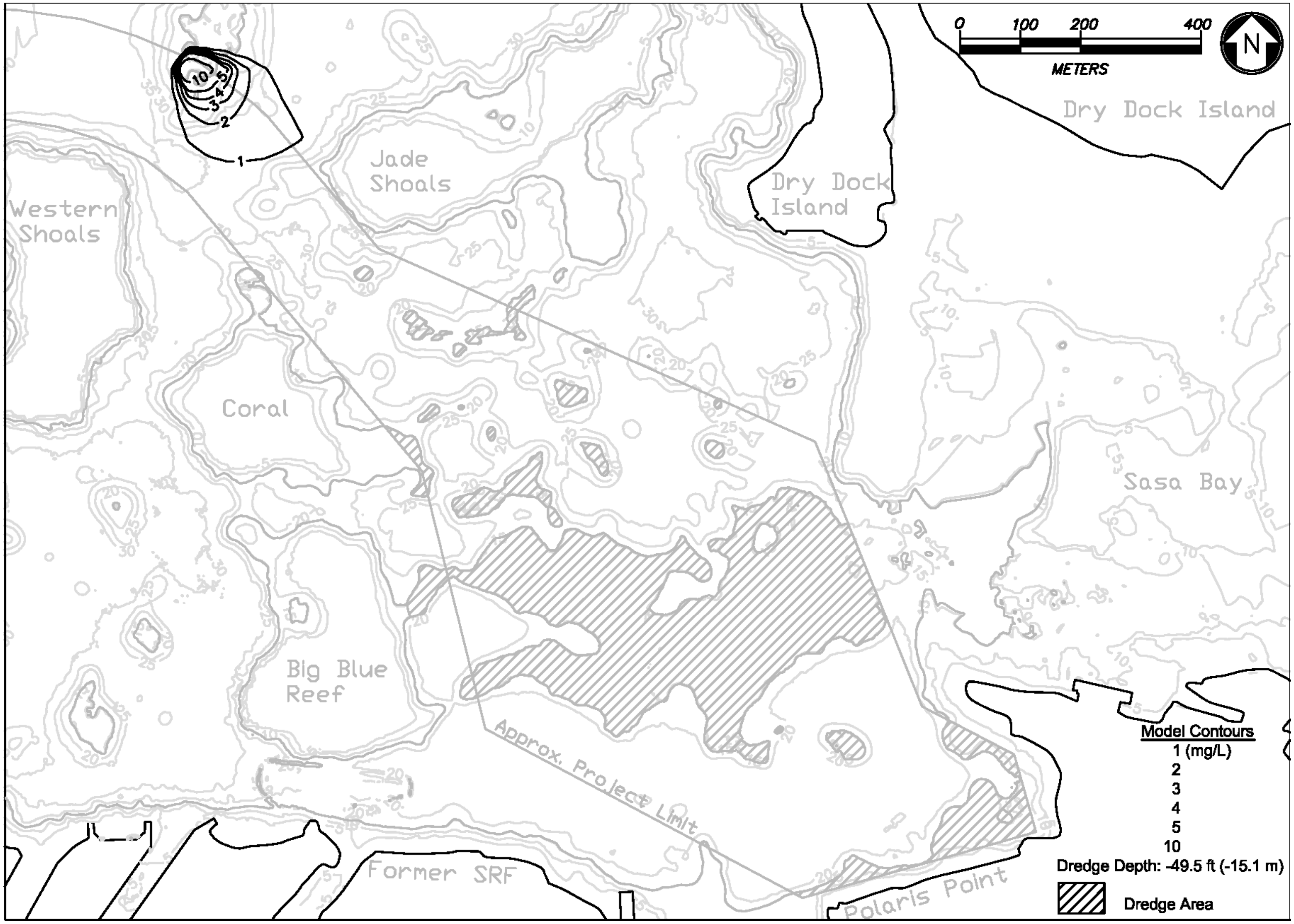

Figure 6-19B. Bottom Layer Suspended Sediment Concentration
(6.19 December 15 to 18 winds, 10-hour dredging at D9)

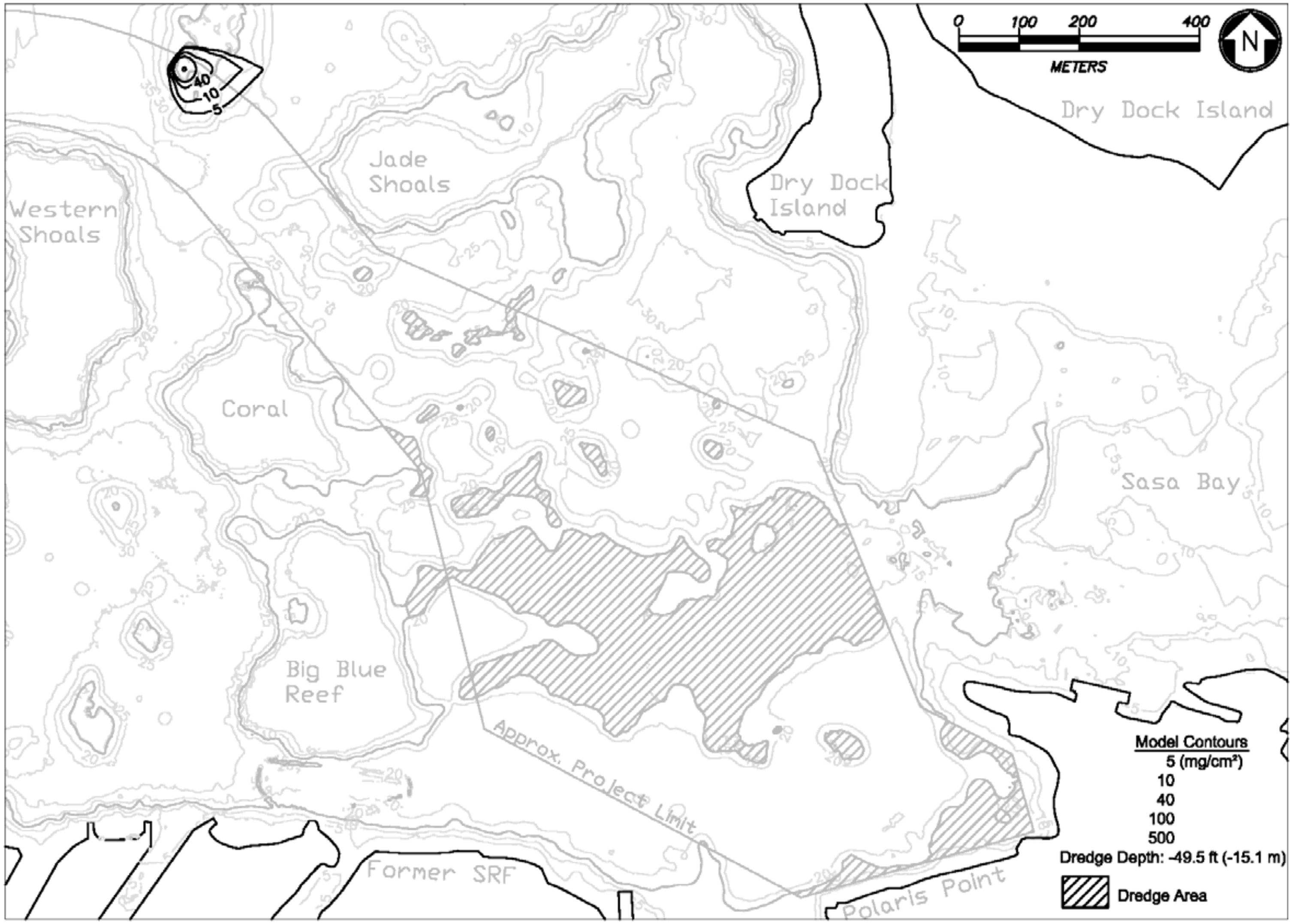

Figure 6-19C. Sediment Deposition

5mg/cm^2 =.03mm; 10mg/cm^2 =.06mm; 40mg/cm^2 =.2mm; 100mg/cm^2 =.6mm; 500mg/cm^2 =3mm

(6.19 December 15 to 18 winds, 10-hour dredging at D9)

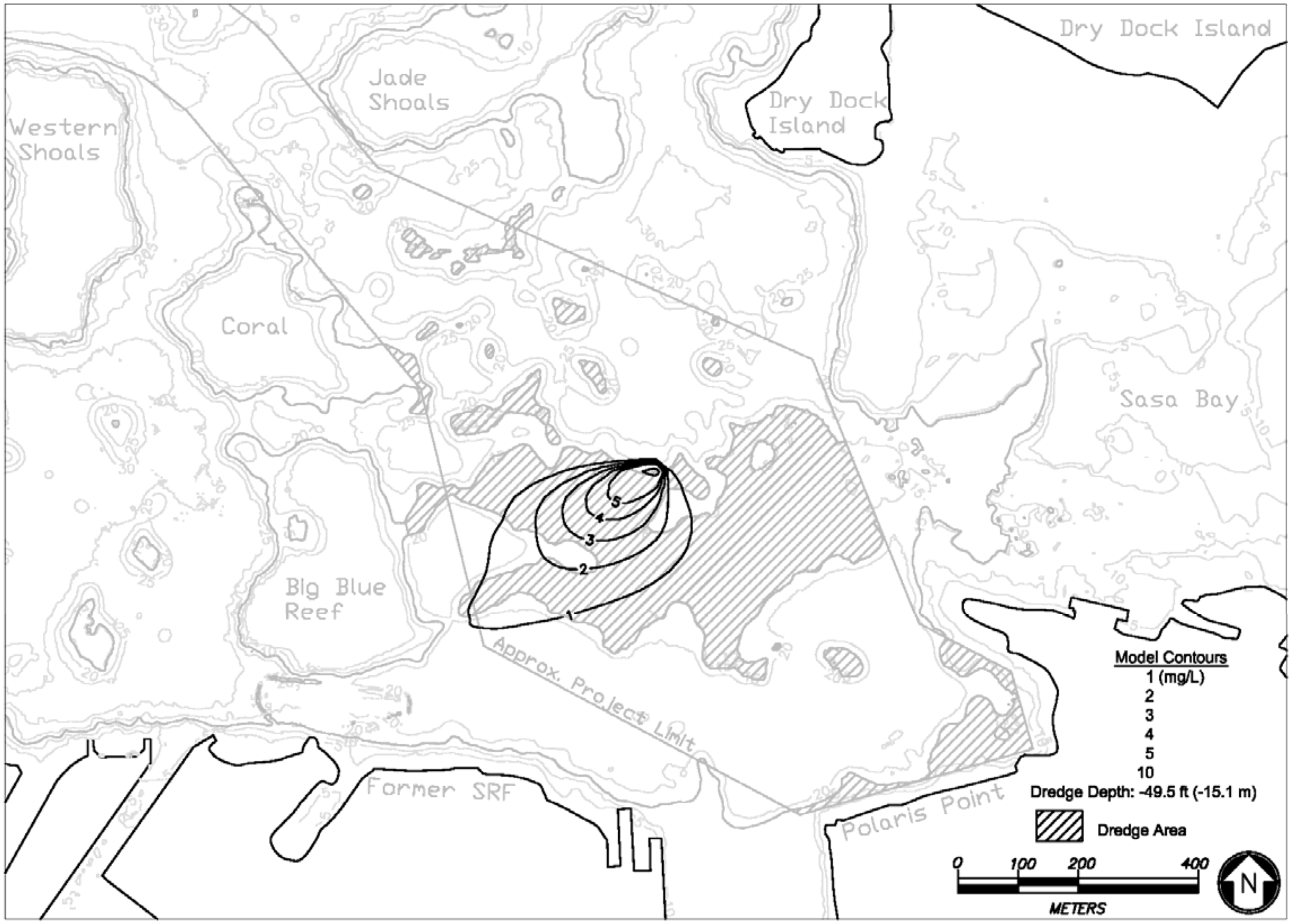

Figure 6-20A. Surface Layer Suspended Sediment Concentration

(6.20 Strong trade winds, 10-hour dredging at D8, Highest 10% release)

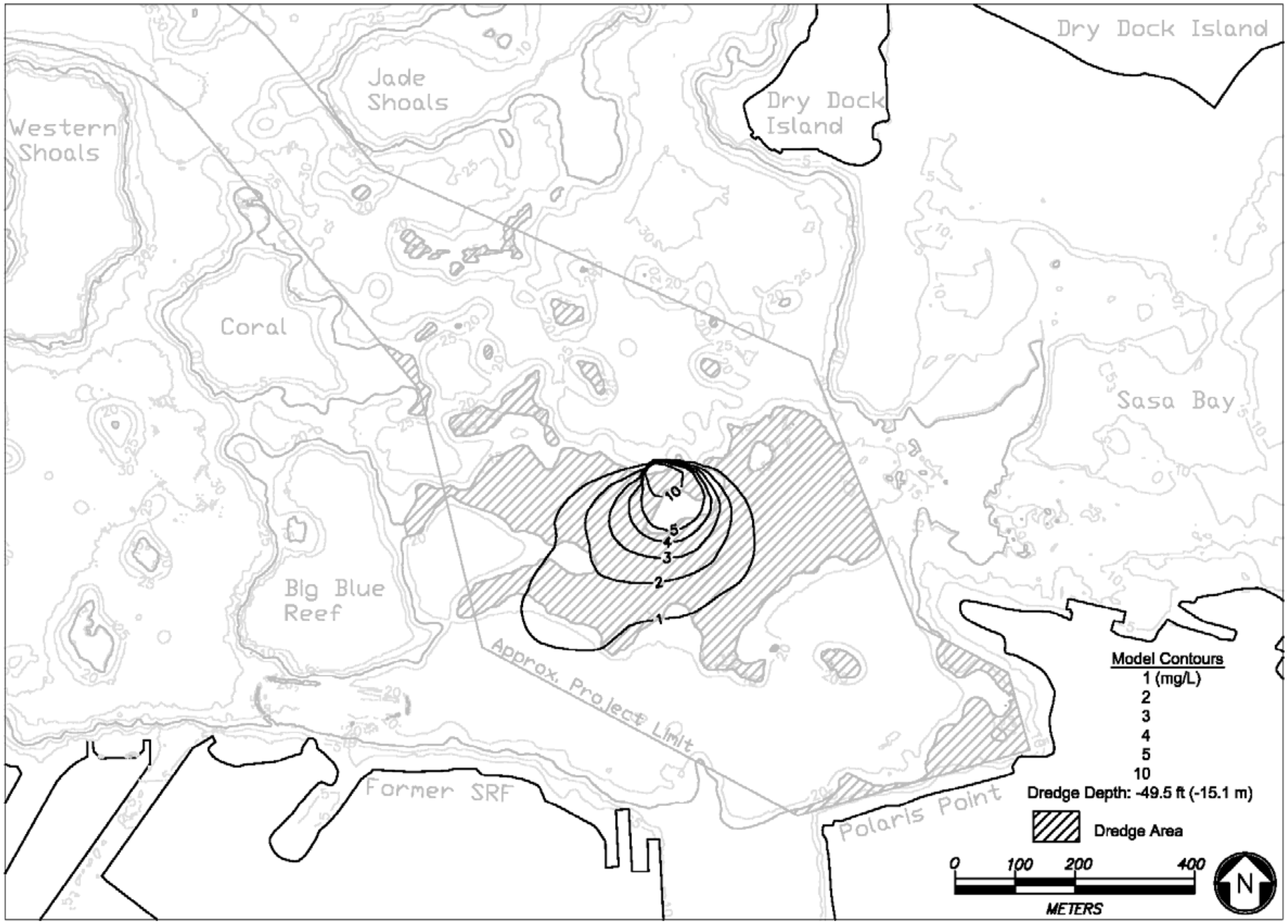

Figure 6-20B. Bottom Layer Suspended Sediment Concentration

(6.20 Strong trade winds, 10-hour dredging at D8, Highest 10% release)

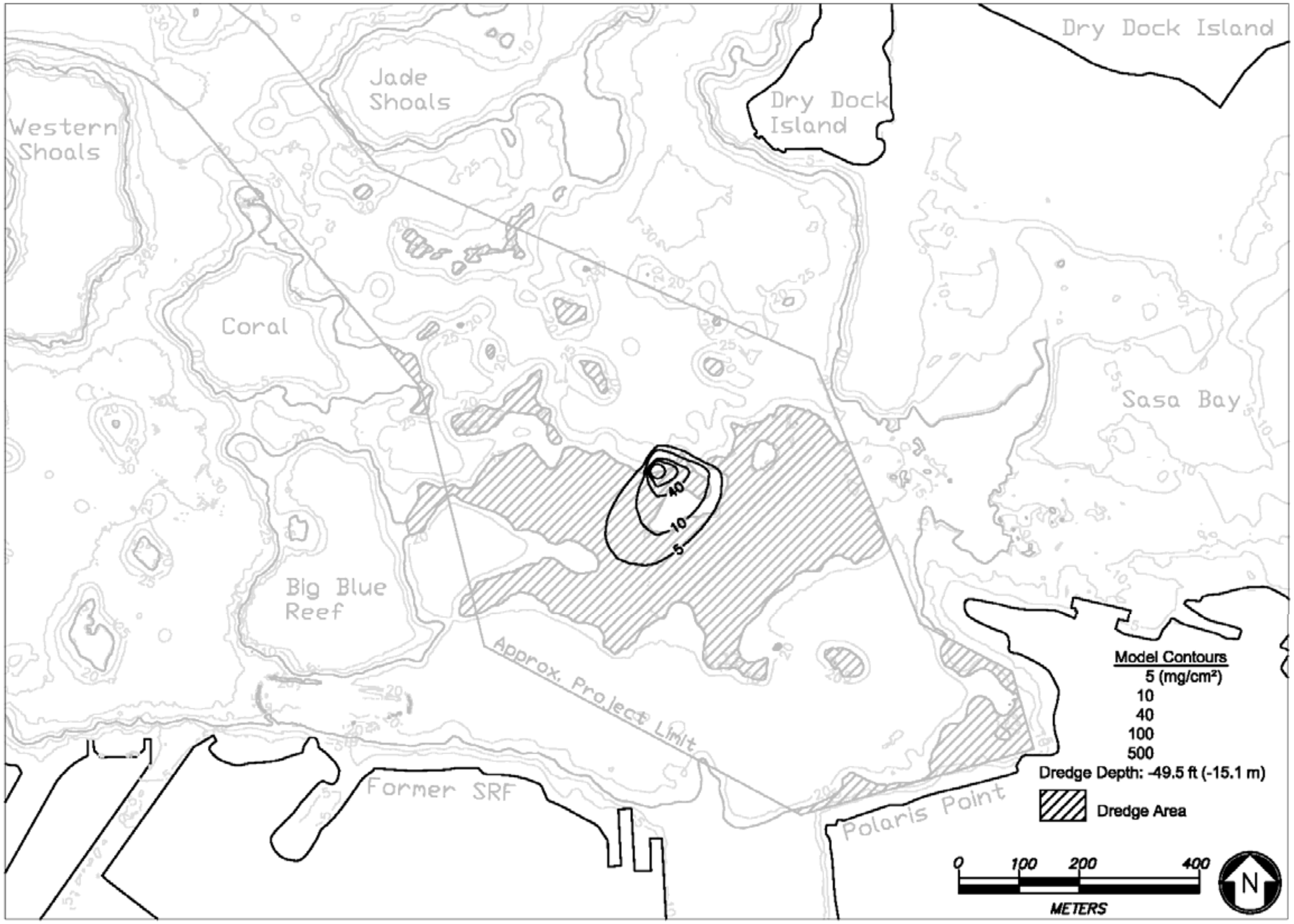

Figure 6-20C. Sediment Deposition

5mg/cm2 =0.03mm; 10mg/cm^2 =0.06mm; 40mg/cm^2 =0.2mm; 100mg/cm^2 =0.6mm; 500mg/cm^2 =3mm

(6.20 Strong trade winds, 10-hour dredging at D8, Highest 10% release)

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7.0 CUMULATIVE ANALYSIS

The modeling results presented in Section 6 above represent dredge plume transport and sedimentation following a single day of dredging at representative sites throughout the project area. The dredging duration is varied from 10 hours to 24 hours. These results provide snapshots of the plumes and sedimentary footprints calculated by the model for a particular day of dredging at a particular location. During the actual dredging project, the dredger would be moving continuously, and the dredging would continue for several months. Assuming a daily dredging rate of 1,800 cy (1,376 m^3) per day, based on actual dredging production achieved during the Alpha-Bravo dredging project, the CVN project would require 8 to 12 months to complete. During this period, accumulations of sediment may occur.

Possible cumulative sedimentation during the project was assessed by extrapolating in time and space the daily results presented in Section 6, assuming a 24-hour dredging operation and dredging production of 1,800 cy (1,376 m^3) per day (Model cases 6.1 to 6.7). The steps involved in the analysis included the following:

- Determining the depth of material to be dredged throughout the project area.
- Estimating the rate of movement of the dredging throughout the project area.
- Multiplying the daily results from the closest representative area by the appropriate number of days of dredging for that area. This process is repeated throughout the project area; daily results of a representative dredge site are assumed applicable to those grid cells closest to it.
- Summation of the multiplied and extrapolated daily results.

Figure 7.1 presents the dredging isopachs (thickness of sediment to be dredged) for the project. The figure shows that throughout almost the entire dredge area, only 1.7 to 3.3 ft (0.5 to 1 m) of sediment would be removed. The exception is adjacent to Polaris Point where the shoreline embankment would be dredged. Greater than 13 ft (4 m) of material are to be removed in most of this area. The overdredge allowance could add up to 2 ft (0.6 m) to the isopachs shown in Figure 7-1.

At a production rate of 1,800 cy (1,376 m3) per day, dredging operations would proceed through two 23x23 meter-sized grids per day, throughout all of the project area except Polaris Point. Such rapid passage of the dredging operation means that prolonged exposure to plumes, and significant accumulation of sediment would not occur in most of the project area.

In the area adjacent to Polaris Point, it is estimated that 2 to 3 days of dredging would be required for each 23x23 meter grid, compared to ½ day in the rest of the project area.

Application of these dredging rates per model grid cell to the daily computed sediment loads (provided by the model runs) provides an estimate of cumulative sedimentation. Sedimentation of 1,000 mg/cm^2, or ¼ inch (6 mm), was selected as a reasonable threshold of sediment accumulation over the duration of the dredging project. Accumulation of sediment greater than ¼ inch (6 mm) thick occurs only within a distance of 39 ft (12 m) from the dredge limit in most of the project area, and within 75.5 ft (23 m) of the dredge limit adjacent to Polaris Point. Figure 7-2 illustrates the additional area that may be impacted by this accumulated sediment.

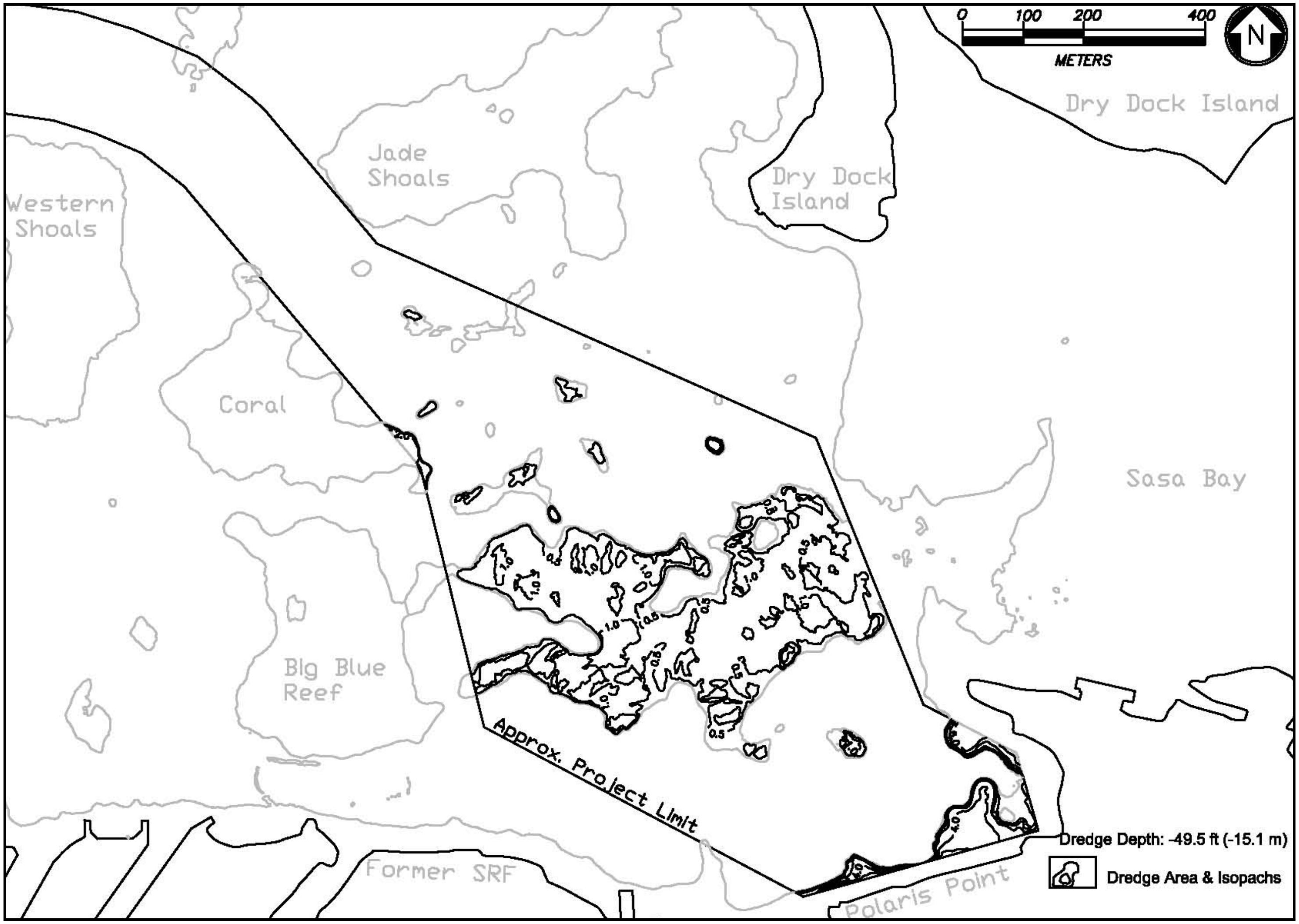

Figure 7-1. Thickness of Sediment to be Dredged, in Meters (not Including Overdredge)

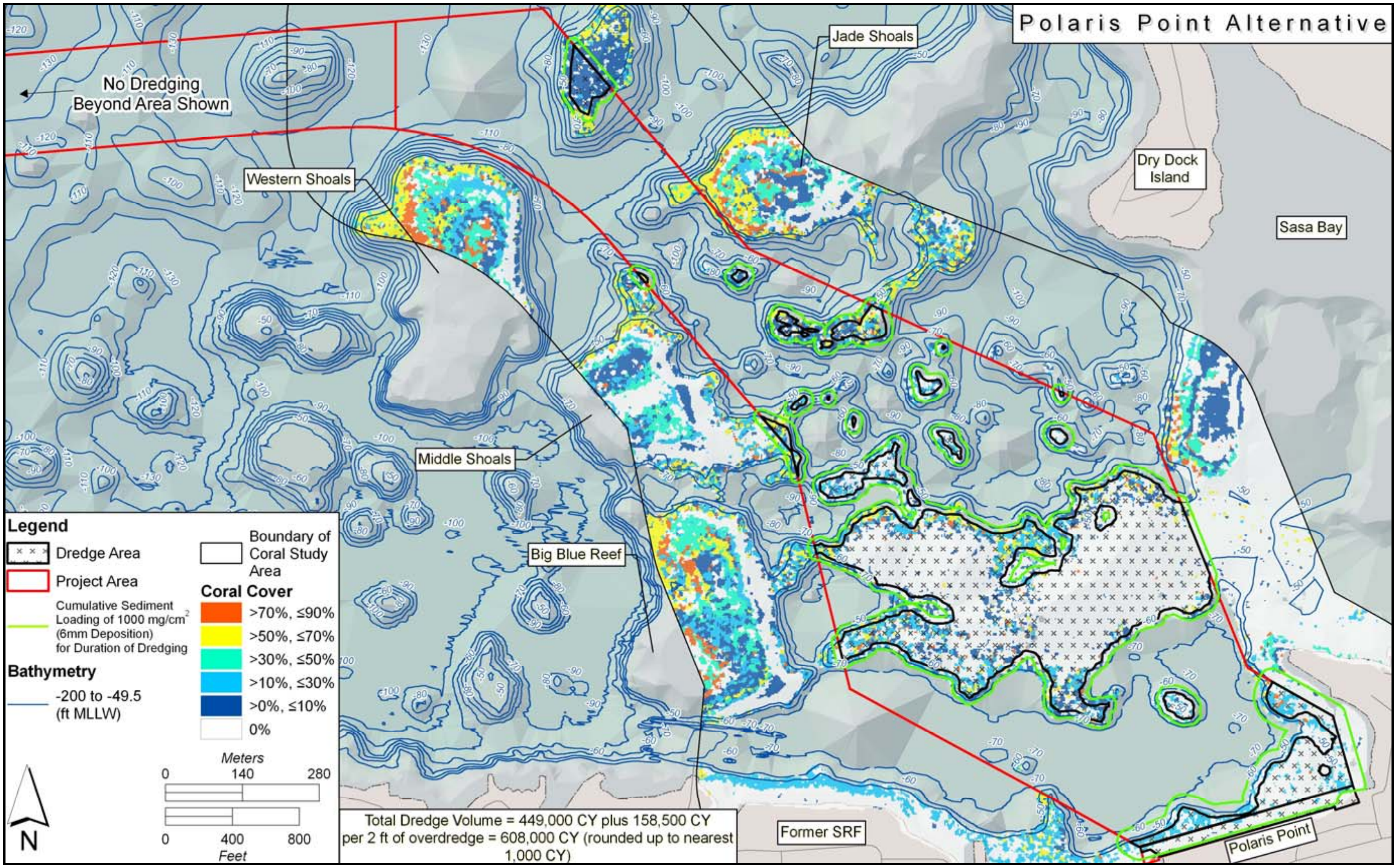

Figure 7-2. Estimated Limits of Sediment Accumulation Exceeding ¼ inch (6 mm) (1,000 mg/cm^2) During the Entire Dredging Duration

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8.0 SUMMARY AND CONCLUSIONS

A detailed current measurement program and numerical modeling analysis were completed to evaluate possible environmental impacts of dredging for the planned construction of CVN capable berthing in Apra Harbor. The current measurement program involved the deployment of 7 ADCPs from November 1, 2007 to January 30, 2008 at different locations in the project vicinity. The instruments achieved full data recovery. Analysis and interpretation of the data revealed that currents and circulation in the project area are characterized by the following features:

- Currents are predominantly wind-driven, and occur as a two-layer system. The surface layer flows in the direction of the wind, and the deeper layer flows in the opposite direction. During typical trade wind conditions, surface flow is to the west out of the Harbor, while deeper flow is directed to the east, into the Harbor. The exception to this is the entrance channel to the Inner Apra Harbor, where currents may reverse with the tides. Local bathymetric features and pronounced reef shoals also control local current directions
- Currents in the project vicinity are normally weak. During trade wind conditions surface currents were typically 4 to 8 cm/s while bottom layer currents were typically 2 to 4 cm/s.
- The measured currents at all instruments were characterized by complex patterns. There were numerous occurrences of sharp spikes in the current speeds and shifts in current direction.
- Tide effects are small in the Harbor basins, but are important in the entrance channel to the Inner Apra Harbor, where currents may reverse with the tides.

A three-dimensional circulation and transport model of the project area was developed using the Environmental Fluid Dynamics Code (EFDC). The model included wind and tide forcing, and fresh water inflow into the Inner Apra Harbor; the dredge plume was simulated by loading the water column with specified quantities of suspended sediment composed of 5 different grain sizes. The sediment grain distribution was determined from bottom samples taken in the project area. The model calculated transport, dispersion and deposition of the plume suspended sediments. The model was verified by comparing results for a simulation of December 15 to 17, 2007 trade wind conditions with the actual instrument measurements. The model reproduced both the general circulation patterns indicated by the current meter data, as well as typical current velocities measured in the bottom and surface layers in the project vicinity.

Twenty model cases have been completed, bracketing a range of wind forcing conditions, dredging duration and production rates, dredge locations and suspended sediment release. Dredging was simulated as a 24-hour continuous operation resulting in dredging of 1,800 cy (1,376 m^3) per day, and a 10-hour operation resulting in 1,000 cy (760 m^3) in a day. Wind forcing included typical trade winds, strong trade winds, south winds and calm conditions. Use of a silt curtain was simulated based on 145 days of TSS measurements inside and outside of the silt curtain deployed for the Alpha-Bravo dredging project in Inner Apra Harbor. These measurements showed that the silt curtains retained 90% of the material inside. Model computed TSS levels compared well with the Alpha-Bravo measurements outside the silt curtain. Possible worst case conditions were simulated by approximating the highest 10% TSS levels recorded outside of the silt curtain during the Alpha-Bravo dredging project, during strong trade wind conditions. Model runs were completed for 9 different locations throughout the project area. Results of the modeling are summarized below:

1. Sediment deposition resulting from the dredging was largely confined to the immediate vicinity of the dredge site. Maximum sediment deposition of 1,742 mg/cm^2, or 0.4 inch (10 mm), was calculated assuming 24 hours of dredging at a rate of 1,800 cy/day (1,376 m^3/day) (Model case 6.3). The modeling indicated that sedimentation exceeding 40 mg/cm^2 or 0.008 inch (0.2mm), a

cited (Section D) threshold for coral impacts, extended an average distance of 144 ft (44 m) from the dredging.

2. Thickness of sediment to be dredged was only 0.5 to 1 m throughout most of the project area. Dredging will therefore pass rapidly from site to site; a 23 x23 m grid area would require only a half of a day to dredge or 990 ft^2 [92 m^2] per day. This means that exposure to sediment plumes and significant sedimentation (greater than 40 mg/cm^2 or 0.008 inch [0.2mm] per day) would be limited to only 1 or 2 days. The exception to this is in the area adjacent to Polaris Point, where sediment thicknesses of 13 ft (4 m) or greater are to be dredged.
3. Analysis of possible total sediment accumulation during the project indicated that accumulations of greater than 1,000 mg/cm^2, or ¼ inch (6 mm), were confined to within 75 ft (23 m) of the dredge limits at Polaris Point, and to within 39 ft (12 m) of the dredge limits in the rest of the project area.
4. Surface TSS plumes exceeding background levels of 3 mg/L were generally predicted to occur only directly at the dredge site. Plumes near the bottom were more extensive because most of the suspended sediment was released into the bottom layer, and it also received all of the TSS contained by the silt curtain. Plume concentrations exceeding the background levels of 3 mg/L typically extended 262 to 394 ft (80 to 120 m) from the dredge site. The plumes dissipated rapidly following completion of the dredging.
5. Worst case conditions were simulated by increasing the sediment release rate from 1% to 2%, and decreasing silt curtain effectiveness by a factor of 4. This approximates the highest 10% TSS measurements recorded outside the silt curtain during dredging at Alpha-Bravo. During these conditions, maximum sediment deposition at the dredge site was 2,690 mg/cm^2, or 16 mm, and deposition greater than 40 mg/cm^2, or 0.008 inch (0.2 mm), occurred to a distance of 262 ft (80 m) from the dredge site. Surface and bottom TSS concentrations exceeding typical background levels of 3 mg/L extend 262 and 328 ft (80 and 100 m) from the dredge site, respectively.
6. This numerical analysis was designed to approximate as closely as possible the dredging that may occur during the CVN project. The circulation model was verified with actual current data recorded in the project site. The sediment grain size was derived from numerous bottom samples collected in the area. Actual, recorded winds and tides were utilized as model inputs. And TSS released into water was verified with measurements from the Alpha-Bravo Wharves dredging project. To bracket the range of possible conditions that may occur during the dredging, model cases were completed varying wind forcing and the dredging site, and approximating a worst case scenario. During the actual dredging operations, however, different wind, current, bottom sediment, dredging and other environmental or operational conditions may occur that are not captured in our modeling analysis. Model results are therefore not exact predictions of what would occur, but rather approximations based on the best available information and methodologies.
7. Analysis of grab samples collected within the turning basin area indicated that approximately 90% of the surficial sediments were very fine sand sized or coarser, and had a median grain size of approximately 0.1 mm (very fine to fine sand). Sediment cores from the same area classified the material as well-sort sand consisting of 73% sand and gravel and 17% silt (Weston Solutions, 2006). This data suggests that most of the material on the seafloor in the turning basin area that may be impacted by vessel maneuvering is sand-sized or greater, thereby minimizing the extent and duration of possible plumes that may result from vessel operations. The operational impacts would be short-term, localized and infrequent.

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APPENDIX A
CURRENT METER DATA

Current Histograms
At CM1
($13^{o}25.823$'N, $144^{o}40.017$'E)

Selected Depth Bin Numbers: 1, 2, 3, 4, 5, 6, 7, 8
Data Period: 11/1/07 – 1/30/08

CURRENT SPEEDS VS. DIRECTIONS
(Water Depth: Bin 1)
(11/1/07 - 1/30/08)

MM/S	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	TOTAL
0-20	.66	.63	.93	1.30	1.56	2.77	2.81	3.37	3.00	2.61	1.84	1.61	1.04	.63	.49	.37	25.61
20-40	.08	.39	.60	1.31	2.18	5.18	8.70	12.61	7.08	4.43	2.84	1.64	.90	.31	.14	.17	48.54
40-60	.02	.02	.20	.37	1.21	2.95	4.54	6.41	3.68	.91	.49	.17	.17	.08	.00	.00	21.21
60-80	.00	.00	.02	.06	.29	1.37	.96	.93	.26	.05	.03	.00	.00	.00	.00	.00	3.97
80-100	.00	.00	.00	.00	.02	.23	.15	.19	.00	.00	.00	.00	.00	.00	.00	.00	.59
100 <	.00	.00	.00	.00	.02	.05	.00	.02	.00	.00	.00	.00	.00	.00	.00	.00	.08
INDET																	.00
TOTAL %	.76	1.04	1.75	3.04	5.27	12.54	17.16	23.51	14.01	8.00	5.21	3.41	2.10	1.02	.63	.54	100.0
AVERAGE	13.0	16.1	21.5	23.2	31.1	35.7	34.2	34.2	30.9	25.6	25.0	21.7	20.9	18.4	15.1	13.7	30.6
MAXIMUM	40.0	42.0	73.0	76.0	107.0	110.0	92.0	111.0	77.0	65.0	69.0	48.0	49.0	56.0	33.0	33.0	111.0
STD DEV	9.0	9.6	14.3	14.5	17.3	19.2	15.3	14.5	13.5	11.5	11.5	10.7	11.5	11.9	8.1	9.3	15.6

CURRENT SPEEDS VS. DIRECTIONS
(Water Depth: Bin 2)
(11/1/07 - 1/30/08)

MM/S	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	TOTAL
0-20	.83	.88	1.41	1.92	2.30	3.37	3.86	4.48	3.60	3.45	2.35	1.59	1.31	1.17	.77	.66	33.96
20-40	.34	.74	1.17	2.09	3.77	4.87	7.08	9.87	7.49	3.97	1.87	1.16	.79	.40	.25	.15	46.01
40-60	.05	.05	.19	.32	1.79	2.73	2.63	3.80	2.35	1.07	.51	.15	.05	.05	.00	.02	15.74
60-80	.00	.00	.00	.08	.23	1.33	.60	.85	.51	.11	.02	.02	.00	.00	.00	.00	3.74
80-100	.00	.00	.02	.00	.05	.17	.08	.17	.03	.00	.00	.00	.00	.00	.00	.00	.51
100 <	.00	.00	.00	.00	.00	.05	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.05
INDET																	.00
TOTAL %	1.22	1.67	2.78	4.40	8.14	12.51	14.24	19.17	13.98	8.59	4.74	2.92	2.15	1.62	1.02	.83	100.0
AVERAGE	15.6	18.2	21.3	23.0	29.4	33.7	30.1	31.0	29.2	24.6	22.1	19.7	18.4	14.5	13.3	13.0	27.6
MAXIMUM	44.0	43.0	86.0	78.0	98.0	107.0	97.0	97.0	83.0	71.0	66.0	65.0	45.0	46.0	29.0	42.0	107.0
STD DEV	9.7	10.6	12.0	12.8	15.4	19.4	15.3	15.7	14.2	12.9	12.5	11.2	10.1	9.9	7.7	8.7	15.7

Histograms: Current Speed vs. Direction in Bin 1 and Bin 2 at CM1

CURRENT SPEEDS VS. DIRECTIONS
(Water Depth: Bin 3)
(11/1/07 - 1/30/08)

MM/S	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	TOTAL
0-20	1.59	2.04	2.32	2.90	3.95	4.11	4.33	4.67	3.32	3.14	2.43	2.26	1.56	1.68	1.13	1.27	42.68
20-40	.59	.88	1.84	2.87	4.25	6.24	5.82	7.17	4.65	3.20	1.54	1.13	.56	.49	.37	.39	41.99
40-60	.05	.05	.45	.63	1.88	2.52	1.44	1.90	1.59	.94	.43	.23	.09	.03	.02	.05	12.30
60-80	.00	.02	.05	.05	.39	.85	.31	.43	.26	.05	.02	.00	.00	.00	.00	.00	2.41
80-100	.00	.00	.00	.02	.03	.09	.06	.22	.11	.00	.00	.00	.00	.00	.00	.00	.53
100 <	.00	.00	.00	.00	.00	.03	.00	.05	.02	.00	.00	.00	.00	.00	.00	.00	.09
INDET																	.00
TOTAL %	2.22	2.98	4.65	6.47	10.51	13.84	11.96	14.43	9.95	7.32	4.42	3.62	2.21	2.21	1.51	1.70	100.0
AVERAGE	15.3	16.4	21.8	23.0	27.4	30.2	26.2	27.6	27.9	23.6	21.4	18.7	16.8	14.5	14.1	14.6	24.8
MAXIMUM	46.0	64.0	61.0	86.0	99.0	109.0	88.0	116.0	118.0	68.0	64.0	58.0	53.0	42.0	41.0	55.0	118.0
STD DEV	9.5	9.8	12.7	12.3	16.0	17.4	14.2	16.0	15.9	13.2	12.2	12.0	10.2	8.8	8.3	9.9	15.1

CURRENT SPEEDS VS. DIRECTIONS
(Water Depth: Bin 4)
(11/1/07 - 1/30/08)

MM/S	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	TOTAL
0-20	1.87	2.75	2.77	4.12	4.40	5.16	4.60	4.33	3.26	3.17	2.22	1.93	1.82	1.68	1.37	1.93	47.40
20-40	.97	1.59	2.15	3.95	5.27	5.36	4.77	5.08	3.69	2.75	1.73	.71	.70	.36	.51	.82	40.41
40-60	.06	.11	.51	.91	1.84	1.70	1.21	1.05	1.00	.42	.46	.15	.08	.03	.03	.03	9.59
60-80	.02	.05	.14	.11	.54	.53	.22	.32	.19	.02	.02	.00	.00	.00	.03	.00	2.16
80-100	.00	.00	.00	.02	.06	.06	.02	.14	.05	.00	.00	.00	.00	.00	.00	.00	.34
100-120	.00	.00	.00	.00	.02	.00	.00	.05	.02	.00	.00	.00	.00	.00	.00	.00	.08
120 <	.00	.00	.00	.00	.00	.00	.00	.02	.00	.00	.00	.00	.00	.00	.00	.00	.02
INDET																	.00
TOTAL %	2.92	4.50	5.56	9.11	12.13	12.81	10.81	10.98	8.20	6.35	4.43	2.80	2.60	2.07	1.95	2.78	100.0
AVERAGE	16.8	18.1	22.3	22.6	27.7	26.3	24.0	25.5	25.1	20.9	21.6	16.6	16.5	13.8	16.7	15.6	23.0
MAXIMUM	60.0	76.0	66.0	91.0	101.0	95.0	88.0	124.0	104.0	60.0	62.0	58.0	59.0	44.0	70.0	57.0	124.0
STD DEV	11.0	11.2	13.1	12.8	16.1	16.0	13.2	16.6	14.8	11.6	12.8	11.3	10.0	8.5	11.0	8.6	14.4

Histograms: Current Speed vs. Direction in Bin 3 and Bin 4 at CM1

CURRENT SPEEDS VS. DIRECTIONS
(Water Depth: Bin 5)
(11/1/07 - 1/30/08)

MM/S	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	TOTAL
0-20	2.46	3.41	3.23	4.65	4.31	4.46	4.23	4.70	3.49	2.90	2.44	2.19	1.79	1.70	1.90	2.70	50.58
20-40	1.58	2.01	2.73	4.56	5.65	4.65	3.71	3.48	2.83	1.98	1.70	1.28	.83	.62	.63	.85	39.09
40-60	.14	.19	.74	1.13	1.87	1.61	.79	.79	.51	.36	.19	.19	.05	.05	.02	.11	8.70
60-80	.05	.06	.09	.08	.39	.22	.19	.25	.05	.02	.00	.02	.00	.00	.03	.02	1.44
80-100	.00	.00	.00	.03	.05	.03	.03	.00	.00	.02	.00	.00	.00	.00	.00	.00	.15
100-120	.00	.00	.00	.02	.02	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.03
120-140	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
140 <	.00	.00	.00	.00	.00	.00	.00	.00	.02	.00	.00	.00	.00	.00	.00	.00	.02
INDET																	.00
TOTAL %	4.22	5.67	6.80	10.46	12.28	10.97	8.94	9.21	6.89	5.27	4.33	3.68	2.67	2.36	2.58	3.68	100.0
AVERAGE	19.1	19.0	23.0	23.5	26.8	25.4	23.2	22.4	21.4	19.9	19.5	18.5	16.2	15.6	15.6	15.7	21.9
MAXIMUM	69.0	72.0	68.0	108.0	116.0	86.0	96.0	78.0	159.0	87.0	57.0	69.0	52.0	44.0	74.0	70.0	159.0
STD DEV	11.2	11.2	13.1	13.5	15.3	14.9	13.8	14.1	13.6	11.7	10.3	11.5	10.3	9.5	10.3	10.9	13.5

CURRENT SPEEDS VS. DIRECTIONS
(Water Depth: Bin 6)
(11/1/07 - 1/30/08)

MM/S	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	TOTAL
0-20	2.64	3.94	3.75	4.90	3.95	4.17	3.21	3.41	2.36	2.66	1.90	2.70	2.09	2.18	2.32	3.34	49.53
20-40	1.70	2.44	2.89	4.20	4.90	4.36	3.15	2.43	1.92	1.85	1.58	1.82	1.58	1.44	1.25	1.47	38.96
40-60	.36	.66	.87	1.28	1.70	1.47	1.02	.60	.20	.23	.43	.29	.11	.15	.09	.14	9.61
60-80	.02	.03	.12	.12	.39	.28	.14	.08	.05	.08	.05	.09	.03	.05	.00	.06	1.58
80-100	.00	.00	.02	.05	.12	.02	.05	.00	.00	.02	.00	.00	.00	.00	.02	.02	.29
100-120	.00	.00	.00	.02	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.02
120-140	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
140 <	.00	.00	.00	.00	.00	.00	.00	.00	.02	.00	.00	.00	.00	.00	.00	.00	.02
INDET																	.00
TOTAL %	4.71	7.08	7.65	10.57	11.06	10.29	7.57	6.52	4.54	4.84	3.95	4.91	3.80	3.82	3.68	5.02	100.0
AVERAGE	20.2	20.8	22.9	23.8	27.7	25.2	24.9	21.5	20.4	20.4	22.5	21.1	18.9	18.6	17.1	17.8	22.4
MAXIMUM	65.0	67.0	80.0	104.0	95.0	92.0	81.0	79.0	159.0	93.0	67.0	74.0	71.0	65.0	85.0	82.0	159.0
STD DEV	12.2	12.3	13.9	14.8	16.3	14.8	14.8	13.0	13.7	12.9	13.0	13.2	10.8	11.5	10.3	11.9	14.0

Histograms: Current Speed vs. Direction in Bin 5 and Bin 6 at CM1

CURRENT SPEEDS VS. DIRECTIONS
(Water Depth: Bin 7)
(11/1/07 - 1/30/08)

MM/S	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	TOTAL
0-20	3.26	4.08	3.58	3.77	3.23	2.94	2.92	2.64	2.05	2.02	1.84	2.33	2.50	2.64	2.89	3.62	46.32
20-40	1.98	3.09	3.38	4.06	3.89	3.12	2.38	1.82	1.39	1.56	1.42	1.82	2.69	2.60	2.07	1.75	39.02
40-60	.54	.76	.83	1.54	1.53	1.19	.65	.57	.34	.32	.53	.76	.77	.36	.32	.34	11.35
60-80	.22	.06	.19	.31	.57	.40	.11	.06	.11	.08	.15	.23	.14	.03	.08	.15	2.89
80-100	.03	.02	.03	.06	.15	.02	.02	.00	.00	.00	.00	.00	.00	.03	.00	.00	.36
100-120	.00	.00	.02	.00	.02	.00	.00	.00	.00	.02	.00	.00	.00	.00	.00	.00	.05
120 <	.00	.00	.00	.00	.00	.00	.00	.00	.00	.02	.00	.00	.00	.00	.00	.00	.02
INDET																	.00
TOTAL %	6.03	8.00	8.03	9.75	9.39	7.66	6.07	5.10	3.89	4.02	3.94	5.14	6.10	5.65	5.36	5.86	100.0
AVERAGE	22.5	21.5	24.3	26.8	29.4	26.5	23.4	21.8	21.5	22.0	24.4	25.4	24.9	21.7	20.9	19.8	24.0
MAXIMUM	89.0	86.0	107.0	97.0	114.0	87.0	84.0	75.0	78.0	129.0	78.0	75.0	78.0	91.0	78.0	77.0	129.0
STD DEV	15.5	13.2	14.7	15.9	18.3	16.3	14.1	13.6	14.1	15.5	16.3	16.3	14.5	13.1	12.4	13.3	15.3

CURRENT SPEEDS VS. DIRECTIONS
(Water Depth: Bin 8)
(11/1/07 - 1/30/08)

MM/S	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	TOTAL
0-20	2.98	3.77	3.26	3.11	3.03	2.39	1.65	1.81	1.99	1.92	1.79	2.07	2.49	2.75	2.67	3.17	40.85
20-40	2.77	3.29	3.57	3.68	3.43	2.52	1.61	1.75	1.59	1.30	1.62	1.99	3.35	3.34	2.60	2.52	40.91
40-60	.77	1.05	1.14	1.30	.99	.70	.53	.23	.22	.40	.56	1.08	1.99	1.65	.60	.39	13.59
60-80	.28	.17	.20	.57	.23	.08	.08	.14	.09	.08	.20	.31	.66	.34	.14	.22	3.78
80-100	.03	.06	.00	.15	.03	.02	.05	.00	.00	.02	.06	.05	.12	.03	.03	.02	.66
100 <	.00	.02	.02	.02	.02	.02	.03	.00	.00	.02	.02	.00	.03	.02	.00	.02	.20
INDET																	.00
TOTAL %	6.83	8.36	8.19	8.82	7.72	5.72	3.94	3.92	3.89	3.72	4.25	5.50	8.65	8.13	6.04	6.32	100.0
AVERAGE	24.9	24.7	25.8	29.4	26.1	23.9	25.4	22.4	21.3	22.8	27.2	29.0	32.7	29.3	23.8	22.1	26.2
MAXIMUM	99.0	100.0	100.0	100.0	100.0	114.0	118.0	76.0	69.0	110.0	105.0	90.0	108.0	107.0	92.0	111.0	118.0
STD DEV	15.7	15.1	14.8	18.6	15.6	14.4	17.7	14.4	13.0	16.1	18.3	17.5	19.1	16.5	14.4	14.9	16.5

Histograms: Current Speed vs. Direction in Bin 7 and Bin 8 at CM1

Current Histograms
At CM2
($13^{o}26.430'N$, $144^{o}39.977'E$)

Selected Depth Bin Numbers: 1, 3, 4, 5, 6, 7, 8, 10
Data Period: 11/2/07 – 1/30/08

CURRENT SPEEDS VS. DIRECTIONS
(Water Depth: Bin 1)
(11/1/07 - 1/30/08)

MM/S	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	TOTAL
0-20	.62	.56	.46	.46	.60	.85	1.07	1.70	2.10	1.67	.97	.83	.70	.54	.46	.57	14.17
20-40	.91	.39	.17	.14	.23	.46	1.67	5.15	9.70	5.73	1.85	.51	.20	.32	.40	.63	28.48
40-60	.37	.09	.03	.02	.02	.06	.48	5.52	14.79	4.94	.36	.05	.03	.02	.06	.25	27.07
60-80	.14	.00	.00	.00	.00	.00	.05	2.75	12.48	2.30	.11	.02	.00	.02	.03	.09	17.99
80-100	.05	.00	.00	.00	.00	.00	.02	1.04	6.52	.94	.02	.00	.02	.00	.00	.05	8.64
100-120	.03	.00	.00	.00	.00	.00	.03	.19	2.35	.19	.02	.02	.00	.00	.00	.02	2.83
120-140	.00	.00	.00	.00	.00	.00	.02	.03	.54	.06	.00	.00	.00	.00	.00	.00	.65
140-160	.00	.00	.00	.00	.00	.00	.00	.00	.14	.00	.00	.00	.02	.00	.00	.00	.15
160-180	.00	.00	.00	.00	.00	.00	.00	.00	.02	.00	.00	.00	.00	.00	.00	.00	.02
180-200	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
200 <	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.02	.00	.02
INDET																	.00
TOTAL %	2.12	1.04	.66	.62	.85	1.38	3.32	16.36	48.64	15.84	3.32	1.42	.96	.90	.97	1.61	100.0
AVERAGE	32.2	21.0	16.7	14.2	15.7	19.3	27.5	45.8	58.4	44.2	27.4	19.9	20.0	18.0	25.2	30.1	47.6
MAXIMUM	101.0	55.0	53.0	45.0	53.0	46.0	128.0	126.0	171.0	133.0	116.0	103.0	155.0	65.0	208.0	111.0	208.0
STD DEV	20.5	12.9	10.7	9.1	10.3	9.6	17.3	21.7	25.2	21.7	15.4	14.2	21.1	10.5	27.4	21.6	26.1

CURRENT SPEEDS VS. DIRECTIONS
(Water Depth: Bin 3)
(11/1/07 - 1/30/08)

MM/S	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	TOTAL
0-20	.65	.49	.57	.46	.49	.71	.90	1.55	1.75	1.42	.96	.83	.54	.39	.57	.54	12.82
20-40	.82	.40	.28	.19	.22	.63	1.55	4.82	7.23	3.66	1.16	.53	.28	.23	.26	.60	22.85
40-60	.46	.22	.02	.03	.00	.02	.51	6.29	12.89	3.24	.20	.08	.03	.02	.12	.14	24.26
60-80	.22	.09	.00	.00	.02	.02	.12	4.71	13.03	1.47	.03	.00	.00	.03	.05	.14	19.92
80-100	.06	.00	.00	.00	.00	.02	.05	2.26	8.79	.53	.02	.00	.00	.00	.00	.05	11.76
100-120	.03	.00	.00	.00	.00	.00	.05	.77	4.81	.11	.02	.00	.02	.00	.02	.03	5.84
120-140	.00	.00	.00	.00	.00	.00	.03	.20	1.84	.03	.00	.00	.00	.00	.00	.00	2.10
140-160	.00	.00	.00	.00	.00	.00	.00	.02	.34	.00	.00	.00	.02	.00	.00	.00	.37
160-180	.00	.00	.00	.00	.00	.00	.00	.00	.06	.00	.00	.00	.00	.00	.00	.00	.06
180-200	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
200 <	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.02	.00	.02
INDET																	.00
TOTAL %	2.24	1.21	.87	.68	.73	1.39	3.20	20.61	50.73	10.46	2.38	1.44	.88	.66	1.04	1.50	100.0
AVERAGE	34.2	27.7	17.9	17.5	17.0	20.9	32.2	53.9	66.8	42.7	25.1	19.1	21.0	20.3	26.5	32.2	54.2
MAXIMUM	105.0	75.0	59.0	44.0	66.0	84.0	139.0	158.0	170.0	128.0	105.0	56.0	145.0	69.0	205.0	114.0	205.0
STD DEV	21.7	19.1	10.4	9.8	11.8	12.1	21.5	25.4	28.3	21.8	14.5	11.4	23.8	14.9	29.6	22.7	30.0

Histograms: Current Speed vs. Direction in Bin 1 and Bin 3 at CM2

CURRENT SPEEDS VS. DIRECTIONS
(Water Depth: Bin 4)
(11/1/07 - 1/30/08)

MM/S	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	TOTAL
0-20	.45	.83	.49	.49	.70	.73	1.24	1.24	1.68	1.28	.94	1.00	.82	.80	.68	.80	14.18
20-40	1.08	.77	.37	.17	.28	.53	1.93	5.76	7.23	3.65	1.44	.65	.28	.36	.68	.90	26.07
40-60	.66	.26	.06	.03	.00	.03	.87	6.61	11.50	2.95	.32	.11	.08	.05	.11	.42	24.06
60-80	.23	.09	.00	.00	.00	.06	.19	4.82	10.74	1.14	.00	.00	.00	.03	.08	.17	17.55
80-100	.15	.00	.00	.00	.00	.03	.09	2.35	7.56	.40	.00	.02	.00	.02	.02	.05	10.68
100-120	.02	.00	.00	.00	.00	.00	.02	1.16	3.49	.15	.02	.00	.00	.00	.02	.00	4.87
120-140	.00	.00	.00	.00	.00	.00	.06	.20	1.64	.03	.00	.00	.00	.00	.00	.00	1.93
140-160	.00	.00	.00	.00	.00	.02	.00	.09	.45	.00	.00	.00	.00	.02	.00	.00	.57
160-180	.00	.00	.00	.00	.00	.00	.00	.00	.08	.00	.00	.00	.00	.00	.00	.00	.08
180-200	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
200 <	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.02	.00	.02
INDET																	.00
TOTAL %	2.60	1.96	.93	.70	.97	1.39	4.39	22.23	44.36	9.61	2.72	1.78	1.17	1.27	1.59	2.33	100.0
AVERAGE	38.1	26.0	20.4	15.9	15.3	24.4	32.4	55.1	65.4	41.7	25.9	19.9	17.2	20.9	27.3	31.0	51.7
MAXIMUM	103.0	76.0	58.0	49.0	34.0	147.0	135.0	156.0	171.0	134.0	100.0	80.0	55.0	143.0	216.0	83.0	216.0
STD DEV	21.4	16.8	12.5	10.6	8.2	21.2	21.0	26.0	29.2	21.8	12.6	11.4	12.0	20.8	25.5	18.8	30.1

CURRENT SPEEDS VS. DIRECTIONS
(Water Depth: Bin 5)
(11/1/07 - 1/30/08)

MM/S	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	TOTAL
0-20	1.16	1.13	.94	.82	.83	1.04	.97	1.76	2.04	1.95	.91	1.04	.97	.85	1.02	1.10	18.53
20-40	1.68	1.17	.54	.53	.53	.96	2.07	6.20	6.33	4.03	1.73	.60	.54	.82	.96	1.47	30.16
40-60	1.21	.39	.09	.14	.06	.19	.91	6.21	10.11	2.87	.45	.03	.05	.05	.32	.96	24.03
60-80	.48	.11	.00	.00	.00	.03	.19	3.96	7.74	1.00	.05	.02	.02	.00	.11	.39	14.08
80-100	.08	.02	.00	.00	.00	.03	.05	1.76	5.84	.26	.00	.02	.00	.02	.02	.19	8.27
100-120	.00	.00	.00	.00	.00	.02	.02	.94	1.95	.08	.02	.00	.00	.00	.02	.02	3.04
120-140	.02	.00	.00	.00	.00	.00	.05	.34	.94	.00	.00	.00	.00	.00	.00	.00	1.34
140-160	.00	.00	.00	.00	.00	.00	.05	.09	.22	.00	.00	.00	.00	.00	.00	.00	.36
160-180	.00	.00	.00	.00	.00	.02	.00	.03	.08	.00	.00	.00	.00	.02	.00	.00	.14
180-200	.00	.00	.00	.00	.00	.00	.00	.00	.05	.00	.00	.00	.00	.00	.00	.00	.05
200-220	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
220 <	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.02	.00	.02
INDET																	.00
TOTAL %	4.62	2.81	1.58	1.48	1.42	2.27	4.30	21.29	35.29	10.20	3.15	1.70	1.58	1.75	2.46	4.11	100.0
AVERAGE	35.1	25.9	19.7	19.9	17.9	24.0	34.4	51.9	61.1	37.5	27.4	19.1	18.2	21.9	28.2	35.5	45.7
MAXIMUM	121.0	86.0	52.0	59.0	59.0	178.0	150.0	169.0	197.0	117.0	112.0	97.0	67.0	162.0	222.0	110.0	222.0
STD DEV	20.0	16.2	10.8	12.8	11.7	21.1	22.3	27.2	28.9	20.0	13.8	13.1	11.9	17.8	23.5	21.6	28.7

Histograms: Current Speed vs. Direction in Bin 4 and Bin 5 at CM2

CURRENT SPEEDS VS. DIRECTIONS
(Water Depth: Bin 6)
(11/1/07 - 1/30/08)

MM/S	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	TOTAL
0-20	1.39	1.58	1.27	1.11	.93	1.50	1.38	2.01	2.02	2.04	1.41	1.47	1.19	1.36	1.05	1.45	23.15
20-40	3.23	1.79	.74	.74	.79	.79	2.07	5.32	6.10	4.11	1.70	.94	.63	1.28	1.55	2.66	34.44
40-60	2.41	1.08	.26	.11	.05	.28	1.00	4.88	7.45	2.24	.31	.11	.11	.14	.59	1.85	22.87
60-80	1.24	.22	.02	.02	.02	.05	.22	2.55	5.53	.68	.09	.09	.00	.05	.09	.74	11.59
80-100	.19	.03	.00	.00	.00	.02	.09	1.48	2.64	.28	.02	.00	.00	.00	.06	.19	4.99
100-120	.03	.00	.00	.00	.00	.00	.05	.51	1.11	.02	.00	.00	.00	.00	.03	.05	1.79
120-140	.02	.00	.00	.00	.00	.00	.03	.23	.48	.00	.00	.00	.00	.00	.02	.00	.77
140-160	.00	.00	.00	.00	.00	.03	.03	.00	.19	.02	.00	.00	.00	.02	.00	.00	.28
160-180	.00	.00	.00	.00	.00	.00	.02	.02	.03	.00	.00	.00	.00	.00	.00	.00	.06
180-200	.00	.00	.00	.00	.00	.00	.00	.00	.03	.00	.00	.00	.00	.00	.00	.00	.03
200-220	.00	.00	.00	.00	.00	.00	.00	.00	.02	.00	.00	.00	.00	.00	.00	.00	.02
220 <	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.02	.00	.02
INDET																	.00
TOTAL %	8.50	4.70	2.29	1.98	1.78	2.66	4.88	17.00	25.60	9.38	3.52	2.61	1.93	2.84	3.40	6.94	100.0
AVERAGE	39.7	30.1	21.1	19.4	19.7	22.6	33.7	47.9	55.2	34.6	24.9	20.8	17.8	22.1	30.9	36.8	39.8
MAXIMUM	131.0	98.0	76.0	69.0	63.0	153.0	172.0	169.0	210.0	158.0	93.0	78.0	49.0	147.0	239.0	115.0	239.0
STD DEV	20.1	17.2	12.7	11.4	11.3	20.2	23.4	26.3	28.5	19.6	13.8	14.3	10.9	15.7	23.4	20.4	26.0

CURRENT SPEEDS VS. DIRECTIONS
(Water Depth: Bin 7)
(11/1/07 - 1/30/08)

MM/S	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	TOTAL
0-20	2.02	1.65	1.65	1.31	1.19	1.55	1.42	1.62	1.14	2.01	1.34	1.44	1.64	1.73	1.58	1.85	25.15
20-40	4.48	2.81	1.58	1.08	.68	.99	1.84	3.77	4.60	3.21	1.70	.90	.82	1.38	2.50	4.53	36.87
40-60	4.05	1.67	.39	.22	.12	.25	.73	3.11	4.50	1.68	.42	.12	.15	.25	1.05	3.46	22.16
60-80	2.94	.51	.06	.03	.02	.05	.12	1.36	2.81	.46	.08	.02	.02	.08	.17	1.21	9.92
80-100	.80	.12	.02	.00	.00	.02	.08	.85	1.24	.14	.02	.00	.03	.02	.02	.39	3.72
100-120	.20	.00	.00	.00	.02	.00	.09	.19	.48	.08	.02	.00	.00	.00	.00	.08	1.14
120-140	.05	.02	.00	.00	.00	.02	.05	.09	.19	.05	.00	.00	.00	.00	.02	.00	.46
140-160	.00	.00	.00	.00	.00	.02	.02	.12	.09	.02	.00	.00	.00	.00	.02	.00	.28
160-180	.02	.00	.00	.00	.00	.02	.00	.03	.12	.00	.00	.00	.00	.00	.00	.00	.19
180-200	.00	.00	.00	.00	.00	.00	.02	.02	.02	.02	.00	.00	.00	.00	.00	.00	.06
200-220	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.02	.00	.02
220-240	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
240-260	.00	.00	.00	.00	.00	.00	.00	.00	.02	.00	.00	.00	.00	.00	.00	.00	.02
260-280	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
280 <	.00	.00	.00	.00	.00	.00	.00	.00	.02	.00	.00	.00	.00	.00	.00	.00	.02
INDET																	.00
TOTAL %	14.56	6.78	3.69	2.64	2.02	2.89	4.36	11.16	15.22	7.66	3.57	2.47	2.66	3.45	5.36	11.51	100.0
AVERAGE	45.1	33.8	23.8	21.1	19.7	23.1	33.1	45.5	52.2	34.0	26.0	19.3	20.0	21.6	30.2	39.0	37.2
MAXIMUM	160.0	121.0	80.0	72.0	104.0	174.0	198.0	182.0	282.0	183.0	118.0	74.0	84.0	86.0	207.0	105.0	282.0
STD DEV	23.2	19.1	13.5	12.2	14.2	22.1	25.8	27.7	30.0	22.5	15.3	10.9	14.1	14.3	19.4	19.7	24.9

Histograms: Current Speed vs. Direction in Bin 6 and Bin 7 at CM2

CURRENT SPEEDS VS. DIRECTIONS
(Water Depth: Bin 8)
(11/1/07 - 1/30/08)

MM/S	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	TOTAL
0-20	2.02	1.65	1.65	1.31	1.19	1.55	1.42	1.62	1.14	2.01	1.34	1.44	1.64	1.73	1.58	1.85	25.15
20-40	4.48	2.81	1.58	1.08	.68	.99	1.84	3.77	4.60	3.21	1.70	.90	.82	1.38	2.50	4.53	36.87
40-60	4.05	1.67	.39	.22	.12	.25	.73	3.11	4.50	1.68	.42	.12	.15	.25	1.05	3.46	22.16
60-80	2.94	.51	.06	.03	.02	.05	.12	1.36	2.81	.46	.08	.02	.02	.08	.17	1.21	9.92
80-100	.80	.12	.02	.00	.00	.02	.08	.85	1.24	.14	.02	.00	.03	.02	.02	.39	3.72
100-120	.20	.00	.00	.00	.02	.00	.09	.19	.48	.08	.02	.00	.00	.00	.00	.08	1.14
120-140	.05	.02	.00	.00	.00	.02	.05	.09	.19	.05	.00	.00	.00	.00	.02	.00	.46
140-160	.00	.00	.00	.00	.00	.02	.02	.12	.09	.02	.00	.00	.00	.00	.02	.00	.28
160-180	.02	.00	.00	.00	.00	.02	.00	.03	.12	.00	.00	.00	.00	.00	.00	.00	.19
180-200	.00	.00	.00	.00	.00	.00	.02	.02	.02	.02	.00	.00	.00	.00	.00	.00	.06
200-220	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.02	.00	.02
220-240	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
240-260	.00	.00	.00	.00	.00	.00	.00	.00	.02	.00	.00	.00	.00	.00	.00	.00	.02
260-280	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
280 <	.00	.00	.00	.00	.00	.00	.00	.00	.02	.00	.00	.00	.00	.00	.00	.00	.02
INDET																	.00
TOTAL %	14.56	6.78	3.69	2.64	2.02	2.89	4.36	11.16	15.22	7.66	3.57	2.47	2.66	3.45	5.36	11.51	100.0
AVERAGE	45.1	33.8	23.8	21.1	19.7	23.1	33.1	45.5	52.2	34.0	26.0	19.3	20.0	21.6	30.2	39.0	37.2
MAXIMUM	160.0	121.0	80.0	72.0	104.0	174.0	198.0	182.0	282.0	183.0	118.0	74.0	84.0	86.0	207.0	105.0	282.0
STD DEV	23.2	19.1	13.5	12.2	14.2	22.1	25.8	27.7	30.0	22.5	15.3	10.9	14.1	14.3	19.4	19.7	24.9

Histograms: Current Speed vs. Direction in Bin 8 at CM2

CURRENT SPEEDS VS. DIRECTIONS
(Water Depth: Bin 10)
(11/1/07 - 1/30/08)

MM/S	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	TOTAL
0-20	1.34	1.11	1.05	.99	.70	.70	.80	.51	.65	.48	.45	.43	.62	.70	.94	1.24	12.70
20-40	5.35	4.77	1.95	1.19	.93	.59	.73	.94	.77	.74	.40	.39	.20	.80	1.31	3.85	24.91
40-60	9.44	5.15	1.21	.26	.15	.22	.45	.66	.74	.15	.08	.05	.12	.11	1.08	4.39	24.26
60-80	8.50	2.95	.25	.05	.06	.06	.23	.32	.31	.09	.02	.02	.00	.03	.36	3.32	16.56
80-100	6.24	1.47	.09	.05	.02	.02	.15	.28	.11	.05	.02	.02	.00	.03	.09	2.30	10.92
100-120	2.75	.39	.03	.00	.00	.00	.11	.29	.20	.00	.00	.00	.00	.02	.09	1.04	4.91
120-140	1.05	.15	.02	.00	.00	.03	.11	.25	.12	.00	.00	.00	.00	.00	.05	.45	2.22
140-160	.45	.06	.02	.00	.00	.02	.05	.12	.11	.02	.00	.00	.00	.00	.00	.39	1.22
160-180	.22	.00	.00	.00	.00	.00	.08	.14	.08	.00	.00	.00	.00	.00	.03	.08	.62
180-200	.22	.02	.00	.00	.00	.06	.02	.15	.06	.00	.00	.00	.00	.00	.02	.05	.59
200-220	.05	.03	.00	.00	.00	.00	.02	.09	.08	.00	.00	.00	.00	.00	.00	.06	.32
220-240	.11	.02	.00	.00	.00	.00	.03	.03	.03	.00	.00	.00	.00	.00	.00	.03	.25
240-260	.03	.00	.00	.00	.00	.00	.02	.02	.08	.00	.00	.00	.00	.00	.00	.00	.14
260-280	.03	.00	.00	.00	.00	.00	.00	.00	.06	.00	.00	.00	.00	.00	.00	.02	.11
280-300	.02	.00	.00	.00	.00	.00	.00	.05	.02	.00	.00	.00	.00	.00	.00	.03	.11
300-320	.02	.00	.00	.00	.00	.00	.00	.03	.00	.00	.00	.00	.00	.00	.00	.00	.05
320-340	.02	.02	.00	.00	.00	.00	.00	.00	.03	.00	.00	.00	.00	.00	.00	.00	.06
340-360	.00	.00	.00	.00	.00	.00	.00	.02	.00	.00	.00	.00	.00	.00	.00	.00	.02
360-380	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
380-400	.00	.00	.00	.00	.00	.00	.00	.00	.02	.00	.00	.00	.00	.00	.00	.00	.02
400 <	.02	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.02
INDET																	.00
TOTAL %	35.83	16.13	4.60	2.53	1.85	1.68	2.78	3.91	3.46	1.53	.96	.90	.94	1.68	3.97	17.23	100.0
AVERAGE	68.3	51.5	34.4	25.5	25.0	34.7	52.5	78.1	74.0	29.7	23.4	22.5	19.4	25.3	40.1	61.9	56.9
MAXIMUM	411.0	332.0	145.0	94.0	82.0	192.0	247.0	358.0	382.0	147.0	89.0	97.0	49.0	103.0	193.0	298.0	411.0
STD DEV	35.3	27.6	20.4	16.3	15.6	38.2	48.7	67.0	73.4	23.1	16.5	16.1	12.8	18.2	28.1	36.3	39.5

Histograms: Current Speed vs. Direction in Bin 10 at CM2

Current Histograms
At CM3
(13°26.665'N, 144°40.065'E)

Selected Depth Bin Numbers: 1, 2, 3, 7, 10, 12, 15, 18
Data Period: 11/2/07 – 1/30/08

CURRENT SPEEDS VS. DIRECTIONS
(Water Depth: Bin 1)
(11/2/07 - 1/30/08)

MM/S	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	TOTAL
0-20	3.01	4.27	3.65	4.01	3.34	3.27	2.95	2.92	3.23	3.29	2.95	3.15	2.76	2.62	2.12	2.79	50.31
20-40	1.64	2.45	3.55	4.43	3.62	2.01	1.18	2.12	3.54	3.84	2.90	2.25	1.79	1.31	1.18	1.33	39.13
40-60	.11	.17	.80	1.01	.48	.11	.08	.42	1.29	1.84	.47	.27	.67	.34	.03	.09	8.19
60-80	.00	.02	.03	.11	.02	.02	.00	.03	.59	.70	.05	.02	.08	.05	.02	.03	1.75
80-100	.00	.00	.00	.00	.00	.00	.00	.02	.25	.12	.00	.00	.00	.00	.00	.00	.39
100-120	.00	.00	.00	.00	.00	.00	.00	.00	.12	.06	.00	.00	.00	.00	.00	.00	.19
120 <	.00	.00	.00	.00	.00	.00	.00	.00	.03	.02	.00	.00	.00	.00	.00	.00	.05
INDET																	.00
TOTAL %	4.76	6.91	8.03	9.56	7.45	5.41	4.21	5.50	9.06	9.87	6.36	5.68	5.30	4.32	3.35	4.24	100.0
AVERAGE	16.6	17.9	22.8	24.0	22.0	18.2	16.5	20.4	30.9	30.8	22.2	19.4	21.8	19.0	17.6	17.2	22.3
MAXIMUM	45.0	61.0	62.0	75.0	67.0	63.0	57.0	85.0	130.0	130.0	68.0	69.0	76.0	75.0	60.0	61.0	130.0
STD DEV	9.4	9.8	11.9	12.8	11.4	9.1	9.2	12.7	22.2	20.0	11.9	11.3	14.4	12.6	9.5	9.8	14.6

CURRENT SPEEDS VS. DIRECTIONS
(Water Depth: Bin 2)
(11/2/07 - 1/30/08)

MM/S	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	TOTAL
0-20	3.40	4.10	3.91	4.33	3.57	3.15	3.27	3.37	3.31	3.41	3.12	3.55	3.06	3.49	2.96	3.38	55.39
20-40	1.42	2.23	3.57	4.05	3.23	1.93	1.39	1.81	2.56	2.85	3.12	2.35	2.18	1.50	1.40	1.34	36.93
40-60	.08	.09	.44	.84	.69	.17	.06	.31	1.17	.86	.36	.41	.44	.31	.06	.16	6.44
60-80	.00	.00	.02	.08	.02	.00	.00	.06	.48	.19	.02	.00	.06	.03	.00	.00	.95
80-100	.00	.00	.00	.00	.00	.00	.00	.00	.16	.08	.00	.00	.00	.00	.00	.00	.23
100 <	.00	.00	.00	.00	.00	.00	.00	.00	.05	.00	.00	.00	.00	.00	.00	.00	.05
INDET																	.00
TOTAL %	4.90	6.42	7.94	9.31	7.50	5.25	4.72	5.55	7.72	7.39	6.61	6.31	5.74	5.33	4.43	4.88	100.0
AVERAGE	16.1	17.6	21.1	22.5	21.6	18.6	16.2	18.5	27.9	24.4	21.3	20.0	20.2	17.7	16.5	16.3	20.3
MAXIMUM	45.0	49.0	60.0	72.0	62.0	46.0	50.0	70.0	110.0	88.0	62.0	53.0	66.0	66.0	47.0	59.0	110.0
STD DEV	8.4	8.8	11.1	12.6	11.9	9.6	8.7	12.5	20.4	16.2	11.3	11.1	12.3	12.0	8.9	9.6	12.8

Histograms: Current Speed vs. Direction in Bin 1 and Bin 2 at CM3

CURRENT SPEEDS VS. DIRECTIONS
(Water Depth: Bin 3)
(11/2/07 - 1/30/08)

MM/S	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	TOTAL
0-20	3.62	4.57	3.63	4.38	4.10	4.07	2.79	3.46	3.15	3.32	2.96	3.80	3.37	3.38	3.02	3.74	57.37
20-40	1.86	2.49	3.49	4.43	3.26	1.86	1.40	1.90	2.10	2.21	2.29	2.42	2.25	1.67	1.56	1.43	36.62
40-60	.06	.16	.33	.64	.37	.20	.05	.36	.92	.78	.31	.44	.47	.22	.12	.06	5.49
60-80	.00	.00	.00	.05	.05	.00	.00	.03	.19	.12	.00	.00	.00	.00	.00	.00	.44
80 <	.00	.00	.00	.02	.00	.00	.00	.00	.03	.02	.02	.00	.00	.00	.00	.00	.08
INDET																	.00
TOTAL %	5.53	7.22	7.45	9.51	7.78	6.13	4.24	5.75	6.39	6.45	5.58	6.66	6.08	5.27	4.71	5.24	100.0
AVERAGE	16.6	17.5	20.5	21.4	20.2	16.9	16.6	19.0	23.9	22.3	20.2	19.5	19.7	17.5	17.6	15.4	19.3
MAXIMUM	46.0	55.0	54.0	80.0	78.0	54.0	47.0	69.0	80.0	92.0	83.0	59.0	56.0	50.0	48.0	51.0	92.0
STD DEV	8.7	9.4	10.2	11.5	11.7	9.8	9.1	11.8	16.0	14.8	11.3	11.3	11.6	10.3	8.9	8.9	11.5

CURRENT SPEEDS VS. DIRECTIONS
(Water Depth: Bin 7)
(11/2/07 - 1/30/08)

MM/S	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	TOTAL
0-20	4.26	5.08	4.66	4.90	4.23	4.08	3.09	3.59	3.02	3.40	3.20	3.70	3.01	3.74	3.13	3.70	60.77
20-40	2.21	2.70	3.59	3.82	3.18	2.17	1.59	1.36	1.61	1.65	1.73	1.65	1.78	1.95	1.90	2.15	35.03
40-60	.25	.23	.36	.70	.51	.36	.12	.08	.12	.08	.17	.23	.20	.12	.11	.17	3.84
60 <	.00	.00	.03	.17	.12	.03	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.36
INDET																	.00
TOTAL %	6.72	8.01	8.64	9.59	8.04	6.64	4.80	5.02	4.76	5.13	5.10	5.58	4.99	5.82	5.14	6.02	100.0
AVERAGE	17.8	17.7	20.1	21.6	20.6	18.6	17.2	15.6	17.0	16.4	17.9	16.9	18.3	17.3	17.9	17.4	18.3
MAXIMUM	55.0	52.0	74.0	75.0	76.0	74.0	47.0	59.0	45.0	54.0	50.0	59.0	55.0	54.0	50.0	51.0	76.0
STD DEV	10.2	9.5	10.5	12.7	12.6	11.3	9.0	9.1	9.2	9.5	9.4	9.9	10.5	9.4	9.3	9.7	10.5

Histograms: Current Speed vs. Direction in Bin 3 and Bin 7 at CM3

CURRENT SPEEDS VS. DIRECTIONS
(Water Depth: Bin 10)
(11/2/07 - 1/30/08)

MM/S	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	TOTAL
0-20	3.57	4.44	4.15	4.66	3.93	4.37	3.32	3.74	3.12	3.16	2.46	2.67	2.81	3.40	3.16	3.45	56.41
20-40	2.49	2.92	3.82	4.54	3.74	2.57	2.17	1.79	1.47	1.61	1.29	1.73	1.86	2.01	1.75	1.95	37.70
40-60	.14	.34	.72	1.04	1.01	.42	.23	.19	.05	.12	.03	.16	.22	.34	.19	.11	5.32
60-80	.02	.02	.08	.22	.12	.02	.00	.00	.02	.00	.00	.02	.03	.02	.00	.00	.55
80 <	.02	.00	.00	.02	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.03
INDET																	.00
TOTAL %	6.24	7.72	8.76	10.48	8.81	7.37	5.72	5.72	4.65	4.90	3.79	4.57	4.91	5.77	5.10	5.50	100.0
AVERAGE	18.0	19.1	21.9	23.7	23.1	18.3	19.0	17.2	16.3	16.9	17.3	19.0	19.5	19.1	18.3	16.8	19.5
MAXIMUM	80.0	61.0	71.0	92.0	77.0	72.0	59.0	50.0	65.0	50.0	46.0	60.0	67.0	67.0	59.0	52.0	92.0
STD DEV	10.7	10.1	12.0	14.1	13.8	10.8	10.0	9.4	9.1	9.0	9.2	10.5	11.7	10.9	10.2	9.4	11.4

CURRENT SPEEDS VS. DIRECTIONS
(Water Depth: Bin 12)
(11/2/07 - 1/30/08)

MM/S	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	TOTAL
0-20	3.37	4.13	3.65	4.30	4.13	4.16	3.35	3.10	2.98	2.74	2.60	2.98	2.56	2.85	2.79	3.77	53.48
20-40	2.46	3.06	3.80	4.94	3.98	3.65	2.56	1.93	1.75	1.67	1.39	1.47	1.31	1.86	1.81	1.95	39.57
40-60	.31	.36	.89	1.04	1.18	.48	.39	.27	.09	.12	.14	.20	.16	.27	.23	.20	6.35
60-80	.05	.00	.08	.19	.08	.03	.03	.00	.02	.00	.00	.00	.02	.03	.02	.02	.55
80-100	.00	.02	.00	.00	.00	.00	.00	.00	.02	.00	.00	.00	.00	.00	.00	.00	.03
100 <	.00	.02	.02	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.03
INDET																	.00
TOTAL %	6.19	7.58	8.43	10.48	9.37	8.33	6.33	5.30	4.85	4.54	4.13	4.65	4.04	5.00	4.85	5.94	100.0
AVERAGE	19.9	20.3	23.2	24.1	23.7	20.8	20.4	19.0	18.2	17.6	17.8	17.4	17.6	19.1	18.8	17.9	20.4
MAXIMUM	69.0	110.0	101.0	70.0	66.0	63.0	68.0	50.0	92.0	57.0	58.0	55.0	60.0	62.0	71.0	71.0	110.0
STD DEV	11.4	11.4	13.0	13.2	13.0	11.4	11.4	10.3	10.5	10.3	9.9	10.7	10.7	11.3	10.9	11.0	11.8

Histograms: Current Speed vs. Direction in Bin 10 and Bin 12 at CM3

CURRENT SPEEDS VS. DIRECTIONS
(Water Depth: Bin 15)
(11/2/07 - 1/30/08)

MM/S	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	TOTAL
0-20	3.65	3.65	3.49	4.13	4.01	3.57	2.85	3.16	2.40	2.29	2.14	2.25	2.20	2.74	2.92	3.07	48.52
20-40	2.78	3.41	4.51	4.91	4.41	3.71	2.78	1.92	1.89	1.25	1.06	1.34	1.37	1.81	1.87	2.26	41.27
40-60	.61	.72	.84	1.17	1.43	.84	.65	.34	.36	.16	.31	.16	.17	.30	.33	.28	8.67
60-80	.02	.16	.17	.20	.11	.12	.08	.11	.08	.03	.03	.02	.02	.02	.05	.02	1.22
80-100	.05	.03	.02	.02	.00	.00	.00	.05	.02	.00	.00	.00	.02	.00	.00	.00	.19
100-120	.00	.00	.08	.00	.00	.00	.02	.00	.02	.00	.00	.00	.00	.00	.00	.00	.11
120-140	.00	.02	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.02
140-160	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
160-180	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
180 <	.00	.02	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.02
INDET																	.00
TOTAL %	7.09	8.00	9.11	10.43	9.96	8.25	6.38	5.58	4.76	3.73	3.54	3.76	3.77	4.86	5.16	5.63	100.0
AVERAGE	21.7	23.7	25.0	24.8	24.7	23.3	23.6	20.6	22.1	19.0	19.0	18.1	19.7	19.8	20.0	19.6	22.3
MAXIMUM	96.0	183.0	116.0	82.0	68.0	72.0	106.0	90.0	101.0	66.0	63.0	66.0	83.0	69.0	75.0	60.0	183.0
STD DEV	13.3	16.5	15.2	13.2	13.3	12.9	13.8	14.7	14.3	11.5	12.4	11.4	11.2	11.6	11.9	10.8	13.6

CURRENT SPEEDS VS. DIRECTIONS
(Water Depth: Bin 18)
(11/2/07 - 1/30/08)

MM/S	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	TOTAL
0-20	3.10	3.60	2.96	3.68	2.99	2.85	2.21	2.06	1.64	1.61	1.62	2.25	2.45	2.63	2.37	3.16	41.19
20-40	3.34	4.19	5.07	5.58	4.32	2.70	1.71	1.61	1.40	1.17	1.34	1.54	2.20	2.76	2.87	2.81	44.61
40-60	.75	.89	1.68	1.65	1.47	.62	.39	.45	.36	.58	.30	.27	.55	.62	.47	.31	11.35
60-80	.06	.14	.28	.34	.19	.05	.06	.11	.14	.16	.08	.02	.06	.05	.02	.06	1.81
80-100	.00	.00	.14	.06	.03	.00	.00	.06	.14	.03	.02	.00	.02	.00	.00	.00	.50
100-120	.00	.08	.06	.05	.02	.00	.00	.02	.02	.00	.00	.00	.00	.00	.00	.00	.23
120-140	.00	.03	.02	.05	.00	.00	.00	.02	.06	.02	.00	.00	.00	.00	.00	.00	.19
140-160	.00	.03	.02	.00	.00	.00	.00	.00	.02	.03	.00	.00	.00	.00	.00	.00	.09
160-180	.00	.00	.02	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.02
180-200	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
200-220	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
220 <	.00	.00	.00	.02	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.02
INDET																	.00
TOTAL %	7.25	8.96	10.24	11.43	9.01	6.22	4.38	4.32	3.77	3.59	3.35	4.07	5.27	6.06	5.72	6.35	100.0
AVERAGE	22.8	25.6	30.2	28.8	27.5	22.9	21.8	24.9	29.2	27.4	22.4	20.1	22.6	23.3	23.3	21.0	25.2
MAXIMUM	67.0	152.0	168.0	233.0	106.0	77.0	69.0	124.0	141.0	146.0	83.0	61.0	81.0	66.0	61.0	67.0	233.0
STD DEV	12.9	18.2	18.7	18.6	15.2	12.6	13.2	18.7	24.3	21.9	13.8	11.7	13.7	12.2	11.4	11.1	16.3

Histograms: Current Speed vs. Direction in Bin 15 and Bin 18 at CM3

Current Histograms
At CM4
($13^{o}26.678$'N, $144^{o}39.721$'E)

Selected Depth Bin Numbers: 1, 3, 8, 13, 15, 17, 18, 19
Data Period: 11/2/07 – 1/30/08

CURRENT SPEEDS VS. DIRECTIONS
(Water Depth: Bin 1)
(11/2/07 - 1/30/08)

MM/S	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	TOTAL
0-20	1.28	1.25	1.57	1.96	2.00	2.49	1.53	1.70	1.11	1.47	1.06	1.14	1.51	1.65	1.06	1.03	23.81
20-40	.53	.83	1.68	4.63	6.83	4.65	2.23	1.26	.55	.51	.61	.90	1.29	1.15	.98	.70	29.35
40-60	.05	.16	1.01	6.80	9.17	3.12	.62	.16	.14	.03	.11	.05	.27	.42	.08	.03	22.20
60-80	.00	.02	.17	5.35	8.81	.84	.14	.00	.02	.02	.00	.00	.08	.11	.00	.00	15.55
80-100	.00	.00	.03	2.60	4.15	.14	.03	.00	.00	.00	.02	.02	.02	.00	.00	.00	7.00
100-120	.00	.00	.00	.78	.95	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	1.73
120-140	.00	.00	.00	.11	.14	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.25
140-160	.00	.00	.00	.02	.06	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.08
160 <	.00	.00	.00	.02	.02	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.03
INDET																	.00
TOTAL %	1.86	2.25	4.48	22.27	32.12	11.24	4.55	3.12	1.81	2.03	1.79	2.11	3.17	3.34	2.12	1.76	100.0
AVERAGE	16.0	20.7	29.0	53.6	55.5	34.2	27.4	19.4	19.0	15.9	19.9	19.7	22.5	23.9	21.3	17.5	41.2
MAXIMUM	46.0	67.0	94.0	163.0	163.0	94.0	92.0	55.0	75.0	70.0	86.0	86.0	87.0	72.0	55.0	43.0	163.0
STD DEV	9.3	12.3	17.0	25.2	24.0	17.8	15.2	10.8	13.0	9.9	12.1	11.8	14.3	15.2	10.6	8.8	25.7

CURRENT SPEEDS VS. DIRECTIONS
(Water Depth: Bin 3)
(11/2/07 - 1/30/08)

MM/S	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	TOTAL
0-20	1.59	1.81	1.95	2.26	2.82	3.21	2.35	1.73	1.50	1.56	1.31	1.59	1.43	1.53	1.23	1.59	29.47
20-40	.51	1.00	2.20	5.96	9.09	6.50	2.85	1.47	1.06	1.04	.83	1.11	1.43	1.39	.83	.59	37.86
40-60	.05	.08	.75	4.99	9.18	4.02	.90	.37	.20	.14	.06	.09	.16	.19	.16	.03	21.38
60-80	.00	.00	.06	2.25	5.10	1.04	.11	.00	.02	.00	.00	.02	.05	.06	.02	.00	8.72
80-100	.00	.00	.02	.53	1.31	.16	.00	.00	.02	.00	.02	.00	.00	.00	.00	.00	2.04
100-120	.00	.00	.00	.06	.37	.02	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.45
120-140	.00	.00	.00	.02	.05	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.06
140 <	.00	.00	.00	.00	.02	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.02
INDET																	.00
TOTAL %	2.15	2.88	4.97	16.06	27.94	14.95	6.22	3.57	2.79	2.74	2.21	2.81	3.07	3.17	2.23	2.21	100.0
AVERAGE	14.9	17.8	25.2	40.8	45.6	34.2	26.3	21.4	20.8	18.6	19.1	18.6	21.1	21.8	19.8	15.0	33.0
MAXIMUM	47.0	50.0	90.0	133.0	148.0	107.0	77.0	56.0	81.0	49.0	86.0	71.0	72.0	78.0	60.0	49.0	148.0
STD DEV	9.5	10.0	14.4	20.4	21.4	17.0	13.6	11.7	12.5	10.0	11.5	11.3	12.5	12.6	11.5	8.7	20.4

Histograms: Current Speed vs. Direction in Bin 1 and Bin 3 at CM4

CURRENT SPEEDS VS. DIRECTIONS
(Water Depth: Bin 8)
(11/2/07 - 1/30/08)

MM/S	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	TOTAL
0-20	1.67	1.87	1.87	2.87	3.34	3.49	3.46	3.68	2.90	2.88	2.74	2.95	2.28	2.21	1.65	1.62	41.49
20-40	.70	1.11	1.47	3.45	5.41	6.27	5.08	4.01	3.71	2.78	2.60	2.26	2.07	1.28	.84	.81	43.85
40-60	.06	.19	.58	1.79	3.10	2.32	1.53	.87	.47	.30	.42	.39	.12	.14	.08	.11	12.47
60-80	.02	.02	.02	.45	.76	.34	.14	.05	.03	.00	.05	.05	.03	.00	.00	.00	1.95
80-100	.00	.00	.03	.09	.05	.02	.00	.00	.00	.03	.00	.00	.00	.00	.00	.00	.22
100 <	.00	.00	.00	.00	.00	.00	.00	.00	.02	.00	.00	.00	.00	.00	.00	.00	.02
INDET																	.00
TOTAL %	2.45	3.18	3.96	8.65	12.66	12.44	10.21	8.61	7.13	5.99	5.82	5.64	4.51	3.63	2.57	2.54	100.0
AVERAGE	16.3	18.8	24.6	29.7	31.6	28.9	26.2	23.1	23.1	21.4	22.6	21.5	20.4	18.1	17.0	17.2	24.7
MAXIMUM	60.0	75.0	91.0	97.0	86.0	84.0	71.0	72.0	102.0	85.0	74.0	66.0	67.0	51.0	56.0	59.0	102.0
STD DEV	11.0	12.0	14.2	17.2	16.4	14.4	12.9	12.2	12.0	11.4	11.9	11.6	10.8	10.3	10.2	10.6	14.1

CURRENT SPEEDS VS. DIRECTIONS
(Water Depth: Bin 13)
(11/2/07 - 1/30/08)

MM/S	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	TOTAL
0-20	1.62	1.68	2.01	2.85	3.15	3.68	3.15	3.29	2.60	2.51	2.09	2.12	1.68	1.76	1.59	1.56	37.36
20-40	1.01	1.73	2.37	3.68	5.96	6.25	4.72	4.48	3.03	2.48	1.62	1.57	1.68	1.39	1.09	.98	44.05
40-60	.17	.22	.64	2.04	3.41	2.21	1.61	1.15	.55	.31	.33	.25	.28	.23	.25	.12	13.78
60-80	.03	.00	.12	.83	1.28	.56	.23	.05	.08	.03	.02	.00	.08	.06	.05	.00	3.41
80-100	.00	.00	.00	.19	.55	.17	.03	.03	.00	.02	.02	.02	.02	.00	.02	.02	1.06
100-120	.00	.00	.00	.08	.17	.03	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.28
120 <	.00	.00	.00	.00	.03	.02	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.05
INDET																	.00
TOTAL %	2.84	3.63	5.15	9.67	14.55	12.93	9.75	9.00	6.25	5.35	4.07	3.96	3.74	3.45	2.99	2.68	100.0
AVERAGE	19.0	21.2	25.3	32.8	36.9	30.0	27.7	25.2	23.4	21.2	21.5	20.4	22.7	21.0	21.0	18.5	27.0
MAXIMUM	65.0	54.0	69.0	109.0	135.0	121.0	90.0	92.0	70.0	90.0	96.0	93.0	98.0	73.0	92.0	84.0	135.0
STD DEV	12.5	10.8	13.6	20.1	21.6	16.9	14.1	13.2	12.4	11.8	12.7	12.4	13.9	13.0	14.2	11.8	16.8

Histograms: Current Speed vs. Direction in Bin 8 and Bin 13 at CM4

CURRENT SPEEDS VS. DIRECTIONS
(Water Depth: Bin 15)
(11/2/07 - 1/30/08)

MM/S	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	TOTAL
0-20	1.56	1.73	2.14	2.60	2.99	3.77	2.76	2.84	2.35	2.26	1.79	1.98	1.76	1.82	1.42	1.68	35.47
20-40	1.00	1.48	2.42	4.35	5.50	5.41	4.46	3.68	2.46	2.09	1.47	1.45	1.68	1.50	1.59	1.31	41.85
40-60	.11	.31	.53	2.17	3.71	2.98	1.84	1.06	.61	.33	.19	.31	.59	.34	.27	.20	15.55
60-80	.06	.03	.05	1.06	2.04	.58	.23	.23	.06	.05	.02	.06	.05	.09	.05	.00	4.66
80-100	.03	.00	.03	.36	.95	.30	.05	.02	.03	.00	.02	.02	.03	.00	.05	.02	1.89
100-120	.00	.00	.00	.09	.17	.12	.03	.00	.00	.00	.00	.00	.00	.00	.03	.00	.45
120 <	.00	.00	.00	.00	.08	.03	.02	.00	.00	.00	.00	.00	.00	.00	.00	.00	.12
INDET																	.00
TOTAL %	2.76	3.56	5.16	10.63	15.45	13.19	9.39	7.83	5.52	4.72	3.48	3.82	4.12	3.76	3.40	3.21	100.0
AVERAGE	20.8	21.2	24.4	35.4	40.8	32.5	29.1	26.2	24.3	21.9	20.5	21.7	24.8	22.4	24.2	19.6	29.0
MAXIMUM	99.0	64.0	86.0	114.0	134.0	129.0	131.0	87.0	88.0	65.0	85.0	85.0	84.0	74.0	117.0	91.0	134.0
STD DEV	15.0	12.7	13.4	21.5	23.9	19.8	16.2	14.2	14.4	12.0	11.3	13.7	14.7	14.3	17.5	11.8	19.0

CURRENT SPEEDS VS. DIRECTIONS
(Water Depth: Bin 17)
(11/2/07 - 1/30/08)

MM/S	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	TOTAL
0-20	2.26	2.46	2.28	2.73	2.87	2.84	2.43	2.64	2.25	2.15	1.87	1.93	2.45	2.00	1.75	1.95	36.85
20-40	1.39	1.67	2.26	3.65	4.93	4.10	3.29	2.88	1.96	1.73	1.42	2.28	2.37	2.46	1.98	1.68	40.06
40-60	.30	.33	.69	2.12	3.38	2.40	1.50	1.06	.42	.27	.39	.47	.87	.95	.59	.20	15.94
60-80	.03	.08	.12	1.12	1.82	.83	.31	.16	.11	.03	.00	.09	.20	.22	.08	.02	5.22
80-100	.00	.00	.03	.20	.67	.11	.11	.05	.02	.00	.00	.05	.05	.05	.02	.03	1.37
100-120	.00	.00	.00	.05	.16	.12	.06	.00	.00	.00	.00	.02	.00	.00	.00	.03	.44
120-140	.00	.00	.00	.00	.03	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.03
140-160	.00	.00	.00	.00	.05	.00	.02	.00	.02	.00	.00	.00	.00	.00	.00	.00	.08
160 <	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.02	.00	.00	.02
INDET																	.00
TOTAL %	3.98	4.54	5.38	9.87	13.91	10.40	7.72	6.78	4.77	4.18	3.68	4.83	5.94	5.69	4.41	3.91	100.0
AVERAGE	20.0	20.4	25.4	34.4	40.2	33.5	30.3	26.6	23.7	21.0	21.8	25.0	26.1	28.1	25.3	22.1	28.9
MAXIMUM	69.0	78.0	86.0	105.0	153.0	114.0	149.0	95.0	148.0	77.0	58.0	100.0	86.0	164.0	81.0	109.0	164.0
STD DEV	12.3	12.8	15.1	20.3	23.8	19.8	19.0	15.5	16.0	11.9	12.2	15.3	16.2	17.7	13.8	14.6	18.8

Histograms: Current Speed vs. Direction in Bin 15 and Bin 17 at CM4

CURRENT SPEEDS VS. DIRECTIONS
(Water Depth: Bin 18)
(11/2/07 - 1/30/08)

MM/S	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	TOTAL
0-20	2.14	2.26	2.20	2.37	2.37	2.25	2.12	1.96	1.65	1.86	2.20	2.26	2.48	2.78	2.20	2.59	35.68
20-40	1.78	2.06	2.29	3.17	4.05	3.43	2.60	2.49	1.72	1.72	2.09	2.54	3.60	4.24	2.76	1.84	42.38
40-60	.33	.27	.58	1.73	2.67	2.04	1.28	.89	.28	.22	.39	.72	1.29	1.56	.86	.44	15.53
60-80	.02	.02	.12	.72	1.17	.62	.36	.25	.08	.03	.03	.14	.44	.42	.22	.02	4.65
80-100	.00	.00	.00	.11	.39	.22	.11	.00	.03	.00	.02	.05	.06	.05	.05	.02	1.09
100-120	.00	.00	.00	.05	.20	.08	.06	.02	.00	.00	.00	.02	.02	.03	.00	.00	.47
120-140	.00	.00	.00	.00	.03	.03	.02	.03	.00	.00	.00	.00	.00	.02	.00	.00	.12
140-160	.00	.00	.00	.00	.00	.02	.00	.02	.00	.00	.00	.00	.00	.00	.00	.00	.03
160-180	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.02	.00	.00	.00	.02
180-200	.00	.00	.00	.00	.00	.00	.02	.00	.00	.00	.00	.00	.00	.00	.00	.00	.02
200 <	.00	.00	.00	.00	.00	.00	.00	.00	.02	.00	.00	.00	.00	.00	.00	.00	.02
INDET																	.00
TOTAL %	4.26	4.60	5.19	8.14	10.88	8.69	6.56	5.66	3.77	3.82	4.72	5.72	7.91	9.09	6.08	4.90	100.0
AVERAGE	21.1	21.1	24.3	32.5	38.3	34.6	31.3	28.3	24.1	21.1	22.4	25.4	29.7	29.3	27.3	21.5	28.6
MAXIMUM	62.0	69.0	66.0	119.0	139.0	144.0	189.0	147.0	211.0	66.0	85.0	111.0	173.0	131.0	98.0	81.0	211.0
STD DEV	12.2	11.7	13.1	19.8	22.8	21.5	21.4	18.6	19.1	11.8	12.4	15.8	18.0	17.6	15.4	12.5	18.6

CURRENT SPEEDS VS. DIRECTIONS
(Water Depth: Bin 19)
(11/2/07 - 1/30/08)

MM/S	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	TOTAL
0-20	2.15	2.29	1.72	1.76	1.75	1.72	1.43	1.40	1.53	1.76	1.61	2.31	2.48	2.95	2.39	2.48	31.72
20-40	2.12	2.00	1.92	2.43	2.45	2.56	2.15	1.70	1.42	1.47	1.82	2.84	4.69	5.21	4.63	3.09	42.49
40-60	.30	.39	.53	1.08	1.75	1.29	1.08	.58	.50	.30	.39	1.47	2.93	3.45	1.76	.97	18.74
60-80	.03	.05	.05	.34	.56	.37	.28	.14	.11	.02	.05	.25	.83	1.33	.50	.06	4.96
80-100	.00	.00	.00	.05	.19	.27	.28	.08	.02	.00	.00	.00	.16	.31	.09	.05	1.48
100-120	.00	.00	.00	.02	.03	.09	.06	.03	.02	.00	.02	.03	.00	.08	.00	.00	.37
120-140	.00	.00	.00	.00	.00	.00	.03	.03	.00	.00	.00	.00	.00	.02	.02	.00	.09
140-160	.00	.00	.00	.00	.00	.00	.02	.00	.00	.00	.00	.00	.02	.00	.00	.00	.03
160-180	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.03	.00	.03
180-200	.00	.00	.00	.00	.00	.00	.02	.02	.02	.00	.00	.00	.00	.00	.00	.00	.05
200-220	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
220-240	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.02	.00	.00	.02
240 <	.00	.00	.00	.00	.00	.00	.00	.00	.02	.00	.00	.00	.00	.00	.00	.00	.02
INDET																	.00
TOTAL %	4.60	4.72	4.21	5.68	6.72	6.30	5.35	3.98	3.62	3.54	3.88	6.89	11.10	13.35	9.42	6.64	100.0
AVERAGE	22.0	22.3	24.6	30.3	35.1	33.8	35.5	28.9	27.4	21.6	23.6	28.7	34.3	36.4	31.7	25.6	30.4
MAXIMUM	63.0	77.0	78.0	102.0	114.0	110.0	196.0	182.0	246.0	67.0	111.0	111.0	143.0	237.0	162.0	99.0	246.0
STD DEV	11.5	12.5	13.6	17.9	20.2	22.1	25.5	23.1	24.7	12.0	13.6	16.4	18.4	21.5	18.2	14.7	19.4

Histograms: Current Speed vs. Direction in Bin 18 and Bin 19 at CM

Current Histograms
At CM5
(13°26.725'N, 144°39.184'E)

Selected Depth Bin Numbers: 1, 5, 10, 13, 15, 18, 21, 24
Data Period: 11/2/07 – 1/30/08

CURRENT SPEEDS VS. DIRECTIONS
(Water Depth: Bin 1)
(11/2/07 - 1/30/08)

MM/S	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	TOTAL
0-20	1.23	1.56	1.37	1.54	1.25	1.14	1.37	1.32	1.03	.93	1.25	.70	1.03	1.12	.93	1.53	19.30
20-40	2.49	2.73	3.40	3.97	4.13	3.44	2.62	2.26	1.65	1.28	1.65	1.90	1.71	1.87	1.81	2.10	39.00
40-60	1.34	1.74	2.88	3.33	3.83	2.38	1.84	1.09	.76	.92	.69	.84	1.06	1.42	1.12	1.21	26.46
60-80	.37	.65	1.21	1.90	1.82	1.28	.55	.48	.26	.31	.23	.33	.50	.53	.47	.31	11.21
80-100	.08	.22	.34	1.07	.70	.31	.08	.06	.03	.03	.05	.08	.11	.08	.06	.06	3.36
100-120	.02	.03	.03	.12	.17	.03	.03	.00	.02	.00	.00	.02	.03	.05	.02	.02	.58
120-140	.00	.00	.02	.02	.02	.02	.00	.00	.00	.00	.02	.00	.00	.00	.00	.00	.08
140 <	.00	.00	.00	.02	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.02
INDET																	.00
TOTAL %	5.53	6.93	9.25	11.98	11.91	8.60	6.48	5.22	3.75	3.47	3.88	3.86	4.44	5.06	4.41	5.23	100.0
AVERAGE	33.6	36.1	40.8	45.5	44.5	41.2	35.8	33.2	31.4	34.3	30.6	35.1	35.8	36.1	35.3	31.7	38.0
MAXIMUM	103.0	107.0	125.0	145.0	123.0	124.0	114.0	88.0	102.0	87.0	133.0	114.0	106.0	110.0	100.0	106.0	145.0
STD DEV	18.1	20.1	20.8	23.4	21.8	20.6	18.4	18.2	17.2	18.1	18.4	19.0	20.3	20.3	19.4	18.2	20.7

CURRENT SPEEDS VS. DIRECTIONS
(Water Depth: Bin 5)
(11/2/07 - 1/30/08)

MM/S	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	TOTAL
0-20	1.50	1.54	1.78	1.18	1.79	1.79	1.45	1.70	1.20	.90	1.00	.89	1.03	1.12	1.18	1.31	21.35
20-40	2.01	2.91	3.60	3.92	4.30	3.91	3.04	2.59	2.01	1.90	1.48	1.68	1.62	1.59	1.87	1.87	40.29
40-60	1.18	1.92	2.37	3.60	3.61	2.85	2.07	1.42	.93	1.01	.62	.70	.95	.89	.72	1.43	26.27
60-80	.36	.72	1.09	1.43	1.76	1.07	.62	.53	.30	.28	.22	.19	.42	.30	.17	.23	9.69
80-100	.03	.06	.36	.50	.53	.31	.06	.09	.05	.02	.03	.02	.03	.03	.03	.06	2.21
100-120	.00	.00	.02	.05	.03	.03	.02	.00	.00	.00	.00	.00	.00	.00	.00	.02	.16
120 <	.00	.00	.00	.02	.00	.02	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.03
INDET																	.00
TOTAL %	5.08	7.15	9.20	10.70	12.02	9.98	7.26	6.32	4.49	4.11	3.35	3.47	4.05	3.92	3.97	4.92	100.0
AVERAGE	31.7	34.9	38.4	42.4	41.3	38.5	35.4	32.7	31.2	33.0	30.2	31.1	33.5	32.3	29.6	32.8	35.9
MAXIMUM	94.0	99.0	112.0	134.0	112.0	120.0	106.0	97.0	90.0	80.0	88.0	90.0	88.0	89.0	86.0	101.0	134.0
STD DEV	18.0	18.1	20.2	20.1	20.6	19.9	17.8	18.2	17.2	16.7	17.0	16.4	17.9	17.7	16.2	17.7	19.1

Histograms: Current Speed vs. Direction in Bin 1 and Bin 5 at CM5

CURRENT SPEEDS VS. DIRECTIONS
(Water Depth: Bin 10)
(11/2/07 - 1/30/08)

MM/S	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	TOTAL
0-20	1.60	1.79	1.48	1.93	1.88	1.90	1.25	1.54	1.43	1.37	.95	1.23	1.11	1.25	1.17	1.06	22.94
20-40	2.13	2.74	3.38	4.39	4.41	3.77	3.44	2.85	1.85	1.90	1.42	1.62	1.43	1.95	1.85	1.82	40.96
40-60	1.12	1.64	2.38	3.61	3.32	3.10	2.52	1.45	1.00	.86	.81	.67	.87	.67	.67	.86	25.54
60-80	.17	.37	.64	1.15	1.88	1.48	.87	.33	.42	.14	.14	.25	.22	.20	.19	.19	8.64
80-100	.03	.06	.12	.42	.39	.30	.12	.12	.02	.02	.00	.00	.02	.02	.02	.02	1.67
100-120	.00	.00	.02	.05	.03	.05	.02	.00	.00	.00	.02	.03	.00	.00	.00	.00	.20
120 <	.00	.00	.00	.00	.03	.02	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.05
INDET																	.00
TOTAL %	5.06	6.60	8.02	11.56	11.95	10.61	8.22	6.29	4.72	4.28	3.33	3.80	3.64	4.08	3.89	3.94	100.0
AVERAGE	29.7	31.7	36.0	39.4	40.9	39.4	37.3	33.1	31.3	29.0	30.8	29.7	31.1	29.5	28.9	30.5	34.8
MAXIMUM	95.0	89.0	107.0	112.0	120.0	121.0	107.0	91.0	85.0	86.0	102.0	114.0	92.0	94.0	82.0	84.0	121.0
STD DEV	16.6	17.1	17.8	19.8	20.7	20.7	18.0	17.2	18.0	15.7	16.4	17.8	17.4	16.3	15.5	15.5	18.7

CURRENT SPEEDS VS. DIRECTIONS
(Water Depth: Bin 13)
(11/2/07 - 1/30/08)

MM/S	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	TOTAL
0-20	1.35	1.37	1.79	2.07	1.71	2.09	1.35	1.59	1.37	1.32	1.28	1.11	.95	1.35	.95	1.23	22.89
20-40	2.15	2.62	3.43	3.89	4.56	4.28	3.21	2.94	2.15	1.82	1.70	1.68	1.48	1.62	1.15	1.76	40.45
40-60	.93	1.50	2.01	3.19	3.96	3.47	2.23	1.67	.97	.75	.89	.86	.78	.69	.62	.70	25.20
60-80	.22	.31	.64	1.56	1.88	1.62	1.03	.42	.11	.20	.25	.39	.20	.31	.08	.19	9.41
80-100	.00	.06	.11	.25	.40	.33	.23	.08	.05	.02	.03	.05	.00	.03	.02	.03	1.68
100-120	.00	.00	.03	.05	.12	.08	.03	.00	.00	.00	.00	.02	.00	.00	.00	.00	.33
120-140	.00	.00	.00	.00	.02	.00	.00	.00	.00	.00	.00	.00	.00	.02	.00	.00	.03
140 <	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.02	.00	.00	.02
INDET																	.00
TOTAL %	4.66	5.86	8.00	11.01	12.66	11.87	8.08	6.70	4.64	4.11	4.14	4.10	3.41	4.03	2.82	3.91	100.0
AVERAGE	29.8	32.7	35.2	39.2	41.9	39.7	39.0	33.0	29.9	28.9	30.8	32.7	31.4	30.8	29.1	29.5	35.3
MAXIMUM	77.0	92.0	109.0	113.0	124.0	119.0	109.0	91.0	88.0	84.0	90.0	119.0	78.0	154.0	90.0	85.0	154.0
STD DEV	15.6	16.7	18.3	20.0	20.8	20.2	19.6	17.1	15.8	16.1	17.2	18.6	15.5	20.7	15.9	16.1	19.1

Histograms: Current Speed vs. Direction in Bin 10 and Bin 13 at CM5

CURRENT SPEEDS VS. DIRECTIONS
(Water Depth: Bin 15)
(11/2/07 - 1/30/08)

MM/S	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	TOTAL
0-20	1.21	1.11	1.35	1.65	1.90	1.74	1.45	1.51	1.42	1.56	1.06	1.25	1.17	1.18	.97	1.23	21.76
20-40	1.71	2.63	2.91	3.60	4.19	3.68	3.57	2.73	2.23	1.76	1.54	1.82	1.54	1.76	1.67	1.76	39.09
40-60	.87	1.29	1.85	3.15	3.88	3.63	2.94	1.76	1.32	.75	.92	.81	.98	1.00	.83	.69	26.66
60-80	.14	.40	.58	1.34	1.76	1.70	1.28	.64	.23	.25	.20	.25	.30	.17	.16	.19	9.58
80-100	.02	.06	.06	.22	.47	.69	.26	.09	.05	.05	.03	.02	.11	.08	.02	.03	2.24
100-120	.00	.02	.05	.03	.06	.14	.14	.00	.03	.00	.02	.03	.02	.02	.02	.00	.56
120-140	.00	.00	.00	.00	.03	.03	.02	.00	.00	.00	.00	.00	.00	.00	.00	.00	.08
140-160	.00	.00	.00	.00	.00	.02	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.02
160-180	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
180-200	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
200 <	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.02	.00	.00	.02
INDET																	.00
TOTAL %	3.96	5.51	6.81	9.98	12.29	11.62	9.66	6.73	5.28	4.36	3.77	4.17	4.11	4.22	3.64	3.89	100.0
AVERAGE	29.0	33.8	35.8	39.4	41.8	43.1	40.4	34.6	32.1	29.3	31.8	30.8	33.1	32.0	31.4	29.6	36.2
MAXIMUM	84.0	106.0	113.0	100.0	133.0	145.0	123.0	99.0	114.0	93.0	100.0	109.0	105.0	211.0	108.0	94.0	211.0
STD DEV	16.0	17.5	18.6	19.4	21.0	22.5	20.8	17.9	17.5	17.5	17.6	18.1	19.5	20.8	16.5	16.7	19.9

CURRENT SPEEDS VS. DIRECTIONS
(Water Depth: Bin 18)
(11/2/07 - 1/30/08)

MM/S	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	TOTAL
0-20	1.15	1.64	1.15	1.40	1.62	1.45	1.67	1.37	1.35	1.28	1.04	.98	1.37	1.34	1.18	1.14	21.13
20-40	1.99	2.52	2.60	3.30	3.69	3.80	2.90	2.83	2.20	1.87	1.95	2.29	1.74	1.88	1.53	1.76	38.86
40-60	.83	1.15	1.54	2.73	3.13	3.05	2.46	1.64	1.31	1.06	1.18	1.42	1.17	.97	.73	.87	25.23
60-80	.20	.33	.65	1.21	1.53	1.85	.89	.51	.34	.20	.39	.45	.55	.40	.20	.16	9.87
80-100	.03	.09	.12	.42	.86	.56	.28	.14	.11	.08	.11	.16	.09	.12	.06	.06	3.30
100-120	.00	.00	.02	.05	.34	.36	.08	.06	.00	.02	.02	.06	.08	.02	.00	.03	1.12
120-140	.00	.00	.02	.05	.08	.05	.05	.00	.00	.00	.00	.00	.05	.00	.00	.00	.28
140-160	.00	.00	.02	.02	.05	.03	.00	.00	.00	.00	.00	.02	.00	.00	.00	.00	.12
160-180	.00	.00	.00	.02	.02	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.03
180-200	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.02	.00	.00	.00	.02
200 <	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.02	.02	.00	.00	.03
INDET																	.00
TOTAL %	4.20	5.73	6.12	9.19	11.31	11.15	8.32	6.56	5.31	4.50	4.69	5.37	5.08	4.75	3.71	4.02	100.0
AVERAGE	30.3	31.3	36.6	41.3	46.1	45.3	39.5	35.2	33.0	31.2	35.0	37.2	37.4	34.0	30.9	31.3	37.7
MAXIMUM	90.0	99.0	156.0	174.0	163.0	146.0	125.0	112.0	89.0	107.0	117.0	152.0	213.0	220.0	95.0	111.0	220.0
STD DEV	16.2	17.7	20.0	23.0	26.6	24.7	21.8	19.2	18.0	17.5	19.9	21.4	26.2	23.3	18.1	18.2	22.4

Histograms: Current Speed vs. Direction in Bin 15 and Bin 18 at CM5

CURRENT SPEEDS VS. DIRECTIONS
(Water Depth: Bin 21)
(11/2/07 - 1/30/08)

MM/S	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	TOTAL
0-20	.92	1.04	1.00	1.45	1.01	1.31	1.26	1.37	1.20	1.62	1.17	1.53	1.28	1.48	1.04	1.09	19.76
20-40	1.73	2.04	2.09	2.24	3.21	2.76	2.60	2.43	2.13	2.38	2.12	2.62	2.38	2.60	2.12	1.45	36.89
40-60	.73	.97	1.53	1.96	2.35	2.24	1.81	1.50	1.23	1.11	1.46	2.21	2.43	1.60	1.37	.72	25.21
60-80	.25	.34	.34	1.00	1.42	1.26	1.00	.50	.31	.44	.64	1.01	1.35	.97	.33	.20	11.35
80-100	.03	.05	.16	.34	.62	.51	.30	.08	.06	.09	.20	.55	.62	.45	.08	.02	4.16
100-120	.02	.00	.03	.30	.39	.19	.08	.00	.02	.03	.05	.16	.19	.05	.02	.00	1.50
120-140	.00	.00	.02	.08	.06	.14	.02	.00	.00	.00	.00	.05	.09	.02	.00	.00	.47
140-160	.00	.00	.00	.08	.09	.05	.02	.00	.00	.00	.00	.00	.02	.00	.02	.00	.26
160-180	.00	.00	.00	.03	.03	.00	.00	.00	.00	.00	.00	.03	.05	.02	.00	.00	.16
180-200	.00	.00	.00	.00	.02	.00	.00	.00	.00	.00	.00	.02	.02	.03	.00	.00	.08
200-220	.00	.00	.00	.00	.03	.00	.00	.00	.00	.00	.00	.00	.02	.00	.00	.00	.05
220-240	.00	.00	.00	.00	.02	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.02
240-260	.00	.00	.00	.00	.02	.02	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.03
260-280	.00	.00	.00	.02	.00	.00	.00	.00	.00	.00	.00	.00	.00	.02	.00	.00	.03
280-300	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.02	.00	.00	.00	.00	.02
300-320	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
320 <	.00	.00	.00	.00	.02	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.02
INDET																	.00
TOTAL %	3.68	4.44	5.15	7.49	9.28	8.47	7.07	5.87	4.95	5.67	5.64	8.18	8.44	7.23	4.97	3.47	100.0
AVERAGE	32.2	32.4	36.3	45.8	50.3	45.9	40.7	34.3	33.1	32.2	37.3	43.4	47.5	41.3	35.1	30.4	40.3
MAXIMUM	110.0	85.0	132.0	264.0	332.0	242.0	146.0	89.0	102.0	104.0	110.0	283.0	209.0	274.0	154.0	93.0	332.0
STD DEV	18.2	17.5	19.1	30.8	34.2	28.3	22.6	18.0	18.1	19.3	20.6	28.4	29.0	27.9	19.2	17.3	25.9

Histograms: Current Speed vs. Direction in Bin 21 at CM5

CURRENT SPEEDS VS. DIRECTIONS
(Water Depth: Bin 24)
(11/2/07 - 1/30/08)

MM/S	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	TOTAL
0-20	.78	.86	.79	.65	.72	.69	.62	.70	1.00	.75	.72	1.12	.93	.98	.97	.97	13.24
20-40	1.35	1.35	1.25	1.43	1.31	1.78	1.46	1.06	1.37	1.68	2.02	2.51	3.16	2.32	2.07	1.71	27.85
40-60	.76	.83	1.11	1.12	1.07	1.29	.90	.86	1.25	1.25	2.04	2.91	3.24	2.45	1.42	1.20	23.69
60-80	.47	.36	.36	.45	.69	.62	.64	.51	.44	.70	1.39	2.73	3.69	2.35	.93	.39	16.71
80-100	.12	.12	.33	.40	.45	.33	.20	.19	.05	.26	.59	1.56	2.74	1.53	.36	.17	9.41
100-120	.03	.05	.19	.26	.25	.09	.12	.14	.06	.11	.26	.78	1.17	.48	.17	.12	4.30
120-140	.03	.02	.09	.12	.26	.20	.02	.03	.05	.06	.06	.26	.45	.28	.08	.06	2.09
140-160	.02	.05	.03	.11	.05	.05	.06	.02	.05	.03	.02	.09	.23	.05	.03	.00	.87
160-180	.03	.00	.03	.17	.08	.02	.02	.02	.02	.02	.00	.06	.11	.03	.02	.00	.61
180-200	.00	.02	.03	.06	.08	.02	.02	.00	.00	.00	.02	.05	.09	.06	.02	.00	.45
200-220	.00	.00	.02	.03	.02	.03	.02	.00	.00	.00	.00	.03	.08	.02	.00	.00	.23
220-240	.00	.00	.02	.05	.03	.00	.00	.00	.00	.00	.00	.02	.06	.00	.00	.00	.17
240-260	.00	.00	.00	.00	.02	.02	.00	.02	.00	.00	.00	.02	.03	.02	.02	.00	.12
260-280	.00	.00	.00	.03	.00	.00	.00	.00	.00	.00	.00	.00	.08	.02	.00	.00	.12
280-300	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
300-320	.00	.00	.00	.03	.02	.00	.00	.00	.00	.00	.00	.02	.03	.02	.00	.00	.11
320-340	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
340-360	.00	.00	.00	.02	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.02
360 <	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.02	.00	.00	.00	.00	.02
INDET																	.00
TOTAL %	3.60	3.64	4.24	4.95	5.03	5.12	4.08	3.54	4.27	4.86	7.12	12.16	16.10	10.59	6.07	4.63	100.0
AVERAGE	40.2	38.9	49.3	63.6	60.6	49.8	46.5	45.7	39.5	45.2	50.1	60.4	67.7	59.3	46.2	39.5	53.8
MAXIMUM	178.0	191.0	220.0	349.0	301.0	252.0	201.0	246.0	176.0	162.0	196.0	371.0	302.0	305.0	252.0	134.0	371.0
STD DEV	27.0	28.1	36.9	55.5	46.3	35.8	31.6	31.0	27.0	27.7	26.9	36.7	40.7	34.9	30.0	24.9	37.0

Histograms: Current Speed vs. Direction in Bin 24 at CM5

Current Histograms
At CM6
($13^o26.815$'N, $144^o39.942$'E)

Selected Depth Bin Numbers: 1, 3, 5, 6, 7, 8, 9, 11
Data Period: 11/2/07 – 1/30/08

CURRENT SPEEDS VS. DIRECTIONS
(Water Depth: Bin 1)
(11/2/07 - 1/30/08)

MM/S	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	TOTAL
0-20	1.06	1.15	1.26	1.81	2.15	3.74	3.65	3.96	3.70	3.57	2.89	2.29	1.64	1.42	.92	1.29	36.51
20-40	.47	.53	.59	1.26	2.26	4.85	7.94	8.91	5.97	4.82	3.17	2.17	1.51	.87	.45	.53	46.30
40-60	.08	.36	.17	.20	.42	1.17	3.67	3.71	1.98	.92	.90	.95	.27	.09	.05	.14	15.08
60-80	.02	.03	.00	.02	.02	.12	.55	.64	.17	.06	.09	.20	.11	.02	.02	.00	2.06
80 <	.00	.00	.00	.00	.00	.00	.05	.00	.00	.00	.00	.00	.00	.00	.00	.00	.05
INDET																	.00
TOTAL %	1.62	2.07	2.03	3.29	4.85	9.89	15.85	17.22	11.82	9.37	7.05	5.61	3.52	2.40	1.43	1.97	100.0
AVERAGE	17.8	22.4	19.5	19.7	22.6	24.8	31.5	30.6	27.3	24.3	24.5	26.4	23.1	19.2	17.8	17.5	26.2
MAXIMUM	72.0	75.0	54.0	70.0	60.0	72.0	87.0	75.0	70.0	63.0	77.0	79.0	70.0	62.0	63.0	51.0	87.0
STD DEV	12.2	15.8	12.0	12.1	11.9	12.7	14.6	14.0	12.5	11.8	13.2	15.9	13.8	11.1	10.5	11.7	13.9

CURRENT SPEEDS VS. DIRECTIONS
(Water Depth: Bin 3)
(11/2/07 - 1/30/08)

MM/S	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	TOTAL
0-20	1.15	1.04	1.40	2.07	2.18	3.28	3.54	3.70	3.70	2.90	2.67	2.12	1.76	1.37	1.14	1.15	35.18
20-40	.55	.73	.95	1.70	3.10	5.86	7.70	7.99	5.51	3.87	3.18	2.76	1.67	1.03	.78	.67	48.05
40-60	.09	.17	.20	.20	.75	2.29	4.07	2.99	1.37	.64	.50	.69	.47	.05	.08	.05	14.61
60-80	.00	.00	.02	.03	.03	.22	.95	.50	.05	.00	.02	.11	.09	.00	.03	.00	2.04
80 <	.00	.02	.00	.00	.00	.02	.05	.02	.00	.00	.00	.00	.02	.00	.00	.00	.11
INDET																	.00
TOTAL %	1.79	1.97	2.57	4.01	6.07	11.67	16.31	15.19	10.62	7.41	6.36	5.68	4.01	2.45	2.03	1.87	100.0
AVERAGE	17.7	20.5	20.3	20.8	24.6	28.6	32.7	30.1	25.5	23.6	22.9	25.2	24.0	18.2	19.9	17.4	26.3
MAXIMUM	51.0	81.0	64.0	61.0	69.0	81.0	86.0	81.0	66.0	59.0	69.0	77.0	91.0	46.0	67.0	47.0	91.0
STD DEV	11.6	13.0	12.1	10.9	12.3	13.8	15.6	14.0	11.9	11.0	11.3	13.7	14.6	11.1	11.9	10.3	13.9

Histograms: Current Speed vs. Direction in Bin 1 and Bin 3 at CM6

CURRENT SPEEDS VS. DIRECTIONS
(Water Depth: Bin 5)
(11/2/07 - 1/30/08)

MM/S	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	TOTAL
0-20	1.75	2.11	1.81	2.14	2.82	3.35	3.06	3.74	3.31	3.48	2.35	2.81	2.06	2.09	1.65	2.21	40.74
20-40	1.17	1.22	1.31	2.00	3.32	5.10	5.90	5.07	3.70	3.37	2.62	2.68	2.37	2.21	1.65	1.43	45.12
40-60	.19	.06	.17	.31	.87	2.40	2.82	1.95	.58	.36	.34	.75	.80	.28	.22	.17	12.27
60-80	.00	.00	.00	.02	.14	.41	.50	.30	.06	.00	.03	.05	.14	.02	.05	.02	1.72
80 <	.00	.00	.00	.00	.03	.02	.09	.00	.02	.00	.00	.00	.00	.00	.00	.00	.16
INDET																	.00
TOTAL %	3.10	3.38	3.29	4.46	7.19	11.28	12.37	11.06	7.66	7.21	5.35	6.29	5.36	4.60	3.57	3.84	100.0
AVERAGE	19.0	18.2	19.8	21.5	25.3	29.4	30.9	27.4	23.0	20.7	22.2	23.2	25.7	22.3	21.5	19.5	24.6
MAXIMUM	49.0	55.0	59.0	64.0	84.0	82.0	93.0	77.0	96.0	55.0	63.0	70.0	76.0	64.0	68.0	69.0	96.0
STD DEV	10.9	9.8	10.9	12.1	14.0	15.3	15.5	14.6	12.5	10.8	11.3	13.0	15.0	11.9	11.9	10.7	13.9

CURRENT SPEEDS VS. DIRECTIONS
(Water Depth: Bin 6)
(11/2/07 - 1/30/08)

MM/S	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	TOTAL
0-20	2.06	2.00	1.97	2.68	2.65	2.93	3.29	3.46	2.81	2.93	2.48	2.93	2.54	2.70	2.71	2.20	42.34
20-40	1.65	1.42	1.76	2.23	3.10	4.41	5.24	3.73	2.85	2.48	2.31	2.73	2.89	2.71	2.84	2.25	44.60
40-60	.20	.19	.36	.27	.95	1.90	2.14	1.14	.62	.22	.31	.70	.78	.67	.51	.48	11.45
60-80	.02	.02	.02	.05	.08	.42	.34	.16	.12	.02	.03	.00	.11	.08	.02	.00	1.47
80 <	.00	.00	.00	.00	.00	.02	.08	.05	.00	.00	.00	.00	.00	.00	.00	.00	.14
INDET																	.00
TOTAL %	3.93	3.62	4.10	5.22	6.78	9.68	11.09	8.53	6.41	5.65	5.13	6.36	6.32	6.16	6.08	4.93	100.0
AVERAGE	20.2	20.3	22.0	21.3	25.2	29.5	29.2	25.1	23.1	20.2	21.3	22.6	25.1	23.0	22.5	21.7	24.1
MAXIMUM	63.0	62.0	66.0	67.0	76.0	82.0	87.0	84.0	76.0	67.0	62.0	59.0	72.0	79.0	60.0	58.0	87.0
STD DEV	11.2	11.6	11.6	11.4	13.4	16.0	15.6	14.4	13.2	10.7	11.4	12.2	13.4	13.2	11.7	12.4	13.6

Histograms: Current Speed vs. Direction in Bin 5 and Bin 6 at CM6

CURRENT SPEEDS VS. DIRECTIONS
(Water Depth: Bin 7)
(11/2/07 - 1/30/08)

MM/S	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	TOTAL
0-20	2.50	2.18	2.04	2.71	2.18	3.03	2.39	2.99	2.40	2.23	2.54	2.90	2.78	3.07	2.98	2.68	41.61
20-40	2.09	2.12	2.15	2.50	2.68	3.71	3.62	3.10	2.09	1.87	2.17	3.01	3.60	3.98	3.12	2.92	44.73
40-60	.45	.37	.28	.45	.62	1.51	1.59	.69	.41	.25	.20	.64	.97	1.01	.95	1.04	11.45
60-80	.02	.02	.05	.06	.12	.25	.47	.16	.08	.08	.03	.14	.17	.12	.16	.08	2.00
80-100	.00	.02	.00	.00	.00	.00	.03	.06	.00	.00	.00	.03	.00	.02	.00	.02	.17
100 <	.00	.00	.00	.00	.00	.00	.02	.02	.00	.00	.00	.00	.00	.00	.02	.00	.05
INDET																	.00
TOTAL %	5.05	4.71	4.52	5.72	5.61	8.50	8.11	7.02	4.98	4.43	4.94	6.72	7.52	8.20	7.22	6.74	100.0
AVERAGE	21.6	22.1	21.8	22.2	24.7	27.2	30.4	24.7	22.4	21.2	20.6	23.6	25.6	25.4	25.1	24.9	24.4
MAXIMUM	63.0	84.0	68.0	71.0	74.0	78.0	107.0	105.0	69.0	72.0	64.0	93.0	77.0	82.0	103.0	88.0	107.0
STD DEV	12.5	12.1	12.1	12.4	13.7	15.3	17.1	15.7	12.7	12.5	11.1	13.8	14.0	14.0	14.7	14.0	14.2

CURRENT SPEEDS VS. DIRECTIONS
(Water Depth: Bin 8)
(11/2/07 - 1/30/08)

MM/S	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	TOTAL
0-20	2.71	2.74	2.60	2.43	2.40	2.43	2.00	2.07	1.87	2.12	1.87	2.67	2.56	2.60	2.82	2.71	38.63
20-40	2.95	2.15	1.92	1.75	2.32	2.53	2.57	2.39	1.67	1.50	1.87	2.68	3.91	5.27	5.02	4.32	44.82
40-60	.92	.47	.28	.44	.64	.84	1.14	.62	.37	.31	.27	.62	1.68	1.67	2.03	1.19	13.49
60-80	.20	.08	.03	.02	.11	.23	.30	.14	.12	.02	.05	.12	.39	.30	.34	.25	2.70
80-100	.00	.00	.00	.00	.00	.03	.05	.05	.00	.00	.00	.03	.03	.02	.05	.05	.30
100 <	.00	.00	.00	.00	.00	.02	.00	.02	.00	.00	.00	.00	.00	.00	.00	.03	.06
INDET																	.00
TOTAL %	6.78	5.44	4.83	4.63	5.47	6.08	6.05	5.29	4.04	3.95	4.05	6.13	8.58	9.86	10.26	8.55	100.0
AVERAGE	25.6	22.6	20.9	21.4	23.6	26.9	28.8	26.0	22.8	20.2	22.3	24.1	29.3	29.0	29.7	27.8	25.9
MAXIMUM	79.0	78.0	64.0	60.0	72.0	103.0	86.0	115.0	71.0	76.0	64.0	91.0	88.0	91.0	81.0	106.0	115.0
STD DEV	14.8	13.1	10.8	12.5	13.7	16.2	17.3	16.7	14.3	12.6	12.3	14.5	15.7	14.3	15.2	15.5	15.0

Histograms: Current Speed vs. Direction in Bin 7 and Bin 8 at CM6

CURRENT SPEEDS VS. DIRECTIONS
(Water Depth: Bin 9)
(11/2/07 - 1/30/08)

MM/S	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	TOTAL
0-20	2.85	2.23	1.87	1.68	1.84	1.65	1.34	1.87	1.19	1.75	1.51	2.32	2.28	2.54	2.76	2.78	32.47
20-40	4.10	2.96	2.09	1.61	1.47	1.93	1.62	1.62	1.19	1.04	1.39	2.40	4.26	5.58	5.88	5.57	44.71
40-60	1.54	.64	.25	.39	.31	.70	.55	.45	.19	.27	.42	.86	2.03	2.95	3.49	2.71	17.75
60-80	.36	.06	.00	.00	.00	.12	.25	.12	.09	.08	.11	.06	.36	.95	.94	.58	4.09
80-100	.12	.00	.02	.00	.00	.02	.05	.09	.00	.00	.02	.00	.02	.11	.22	.11	.76
100-120	.03	.02	.00	.00	.00	.00	.00	.02	.02	.00	.00	.00	.00	.02	.02	.06	.17
120 <	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.02	.00	.03	.05
INDET																	.00
TOTAL %	9.01	5.91	4.23	3.68	3.62	4.43	3.81	4.18	2.67	3.13	3.45	5.65	8.94	12.16	13.30	11.84	100.0
AVERAGE	29.5	25.1	22.3	22.3	21.2	26.5	28.9	25.7	23.8	21.9	25.0	24.6	30.6	34.0	34.6	32.7	28.9
MAXIMUM	119.0	102.0	81.0	59.0	54.0	81.0	95.0	107.0	118.0	78.0	91.0	77.0	85.0	129.0	111.0	137.0	137.0
STD DEV	17.3	13.4	11.4	12.0	12.1	15.4	18.2	18.4	15.8	14.3	15.2	13.7	15.4	17.5	17.5	18.0	16.7

CURRENT SPEEDS VS. DIRECTIONS
(Water Depth: Bin 11)
(11/2/07 - 1/30/08)

MM/S	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	TOTAL
0-20	1.40	1.11	.72	.69	.53	.59	.50	.80	.67	.62	.69	1.08	1.17	1.37	1.23	1.50	14.66
20-40	4.27	2.12	.98	.55	.58	.36	.42	.67	.51	.80	.95	1.81	2.90	4.01	4.68	4.76	30.36
40-60	4.48	1.87	.47	.11	.06	.19	.20	.39	.30	.31	.51	1.17	2.96	5.29	5.63	5.49	29.43
60-80	3.17	.78	.09	.05	.02	.02	.09	.12	.09	.12	.05	.27	1.37	2.84	3.28	3.73	16.08
80-100	1.08	.25	.02	.00	.00	.00	.00	.05	.06	.03	.03	.08	.42	.98	1.08	1.76	5.83
100-120	.70	.02	.00	.00	.00	.02	.02	.00	.08	.02	.00	.00	.16	.34	.33	.70	2.37
120-140	.17	.00	.00	.00	.00	.00	.00	.05	.03	.00	.00	.00	.05	.12	.09	.19	.70
140-160	.02	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.02	.00	.06	.16	.25
160-180	.02	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.03	.06	.11
180-200	.03	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.02	.05	.09
200-220	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.02	.02
220-240	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.06	.06
240 <	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.02	.02	.03
INDET																	.00
TOTAL %	15.33	6.14	2.28	1.39	1.19	1.17	1.23	2.07	1.75	1.90	2.23	4.40	9.05	14.96	16.44	18.48	100.0
AVERAGE	51.5	39.8	29.3	23.3	22.0	24.1	29.1	30.8	35.5	30.6	30.0	33.7	44.6	48.9	50.1	54.5	45.9
MAXIMUM	194.0	103.0	81.0	71.0	62.0	101.0	100.0	137.0	126.0	118.0	97.0	89.0	140.0	136.0	249.0	246.0	249.0
STD DEV	26.8	20.0	15.6	13.8	12.7	17.1	19.0	24.9	27.9	19.8	16.5	17.4	22.7	23.1	24.8	31.0	26.2

Histograms: Current Speed vs. Direction in Bin 9 and Bin 11 at CM6

Current Histograms
At CM7
($13^o27.306'N$, $144^o39.429'E$)

Selected Depth Bin Numbers: 1, 3, 5, 6, 7, 8, 10, 11
Data Period: 11/1/07 – 1/30/08

CURRENT SPEEDS VS. DIRECTIONS
(Water Depth: Bin 1)
(11/1/07 - 1/30/08)

MM/S	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	TOTAL
0-20	1.56	1.96	1.77	2.32	3.18	3.83	3.24	2.39	2.27	2.56	1.93	1.94	1.85	2.08	1.76	1.74	36.39
20-40	1.34	1.28	1.56	2.73	5.31	7.75	5.46	3.10	2.45	1.79	1.54	1.96	2.22	2.15	1.82	1.67	44.14
40-60	.31	.14	.19	.51	2.56	5.03	2.41	.68	.45	.39	.43	.57	.63	.68	.42	.45	15.84
60-80	.02	.06	.00	.03	.82	1.34	.40	.09	.02	.00	.00	.06	.15	.12	.06	.06	3.24
80-100	.00	.00	.00	.02	.08	.15	.05	.00	.03	.00	.00	.02	.02	.02	.00	.00	.37
100 <	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.02	.00	.00	.00	.02
INDET																	.00
TOTAL %	3.23	3.44	3.52	5.60	11.95	18.10	11.56	6.27	5.22	4.74	3.90	4.55	4.89	5.05	4.06	3.92	100.0
AVERAGE	21.3	20.0	20.4	23.0	31.9	34.5	29.7	24.6	22.7	20.1	22.2	23.9	26.1	25.2	23.7	23.5	26.9
MAXIMUM	61.0	75.0	59.0	86.0	95.0	96.0	92.0	71.0	96.0	56.0	59.0	84.0	105.0	95.0	79.0	64.0	105.0
STD DEV	12.9	12.6	10.6	12.4	16.8	16.9	15.0	13.0	12.5	11.5	12.4	14.2	15.7	14.8	13.1	13.8	15.4

CURRENT SPEEDS VS. DIRECTIONS
(Water Depth: Bin 3)
(11/1/07 - 1/30/08)

MM/S	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	TOTAL
0-20	1.73	2.42	2.21	2.67	3.24	3.07	2.50	2.67	2.02	2.05	2.28	2.55	2.25	2.21	1.87	2.45	38.20
20-40	1.64	1.62	1.42	2.86	4.31	5.85	4.34	2.99	2.10	2.25	1.76	2.45	2.86	3.09	2.24	2.04	43.80
40-60	.25	.19	.12	.57	2.36	3.50	1.70	.59	.34	.37	.54	.69	.97	1.02	.76	.32	14.29
60-80	.02	.02	.00	.06	.63	1.31	.32	.05	.03	.06	.02	.12	.23	.23	.09	.03	3.23
80-100	.00	.00	.00	.02	.09	.19	.02	.03	.06	.00	.00	.00	.06	.00	.00	.00	.46
100 <	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.02	.00	.00	.00	.02
INDET																	.00
TOTAL %	3.63	4.24	3.75	6.17	10.63	13.92	8.87	6.33	4.55	4.74	4.60	5.82	6.39	6.54	4.95	4.85	100.0
AVERAGE	21.2	18.9	18.5	22.6	30.9	35.0	29.7	23.9	23.5	22.6	21.9	24.2	27.7	27.0	26.0	21.5	26.4
MAXIMUM	79.0	72.0	50.0	83.0	93.0	95.0	82.0	82.0	85.0	67.0	72.0	72.0	112.0	79.0	66.0	65.0	112.0
STD DEV	12.0	11.1	9.9	12.8	17.4	18.3	15.1	13.1	14.3	12.4	13.4	14.0	16.8	15.2	14.1	12.3	15.6

Histograms: Current Speed vs. Direction in Bin 1 and Bin 3 at CM7

CURRENT SPEEDS VS. DIRECTIONS
(Water Depth: Bin 5)
(11/1/07 - 1/30/08)

MM/S	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	TOTAL
0-20	2.05	1.77	2.04	2.18	2.28	2.33	2.30	2.33	2.15	2.55	1.90	2.50	2.65	2.61	2.10	2.47	36.21
20-40	1.67	1.47	.96	2.21	3.66	4.83	3.23	2.82	2.11	2.35	2.35	3.58	3.41	4.49	3.57	2.45	45.15
40-60	.23	.11	.14	.43	1.51	2.47	1.30	.54	.43	.49	.65	1.14	1.90	2.18	1.13	.68	15.33
60-80	.03	.00	.00	.05	.26	.73	.26	.03	.11	.06	.03	.23	.42	.49	.17	.06	2.93
80-100	.00	.00	.00	.00	.11	.05	.02	.00	.02	.00	.00	.00	.06	.06	.02	.00	.32
100 <	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.06	.00	.00	.06
INDET																	.00
TOTAL %	3.98	3.35	3.13	4.86	7.83	10.40	7.10	5.73	4.82	5.45	4.92	7.45	8.44	9.89	6.98	5.66	100.0
AVERAGE	21.3	19.5	18.0	22.5	29.6	32.8	28.6	23.5	23.9	22.9	24.9	27.2	30.6	31.4	27.4	24.1	26.9
MAXIMUM	75.0	51.0	53.0	62.0	89.0	99.0	82.0	76.0	90.0	75.0	67.0	79.0	94.0	107.0	81.0	68.0	107.0
STD DEV	12.2	10.2	10.4	12.2	16.9	16.6	14.9	12.2	14.1	12.8	12.6	14.4	17.1	17.2	14.0	13.0	15.2

CURRENT SPEEDS VS. DIRECTIONS
(Water Depth: Bin 6)
(11/1/07 - 1/30/08)

MM/S	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	TOTAL
0-20	1.90	1.74	1.47	2.01	1.87	2.52	2.15	2.38	2.08	2.07	2.08	2.90	2.79	2.30	1.94	2.25	34.45
20-40	1.64	1.23	1.40	1.81	2.82	3.52	3.06	2.28	1.76	2.22	2.41	3.94	4.60	4.80	3.77	2.59	43.85
40-60	.35	.15	.19	.37	1.05	1.79	1.25	.90	.49	.62	.90	1.45	2.84	2.92	2.05	.96	18.27
60-80	.02	.00	.00	.03	.14	.56	.14	.05	.05	.03	.08	.23	.68	.52	.32	.19	3.03
80-100	.00	.00	.00	.00	.00	.00	.02	.02	.00	.00	.00	.02	.09	.14	.05	.00	.32
100 <	.00	.00	.00	.00	.02	.00	.00	.00	.00	.00	.00	.00	.03	.03	.00	.00	.08
INDET																	.00
TOTAL %	3.90	3.13	3.06	4.21	5.90	8.38	6.61	5.62	4.38	4.94	5.46	8.54	11.04	10.71	8.13	5.99	100.0
AVERAGE	21.9	19.8	21.2	21.5	27.6	30.6	28.0	24.7	22.9	23.7	25.7	27.6	33.0	33.5	31.4	26.5	27.8
MAXIMUM	77.0	57.0	52.0	66.0	101.0	78.0	86.0	97.0	66.0	66.0	78.0	83.0	116.0	112.0	94.0	73.0	116.0
STD DEV	12.4	10.8	11.2	11.5	14.9	16.9	14.8	13.7	13.9	12.6	14.0	15.0	17.9	17.5	15.5	14.6	15.6

Histograms: Current Speed vs. Direction in Bin 5 and Bin 6 at CM7

CURRENT SPEEDS VS. DIRECTIONS
(Water Depth: Bin 7)
(11/1/07 - 1/30/08)

MM/S	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	TOTAL
0-20	1.87	1.56	1.59	1.62	1.82	2.01	2.10	1.90	2.07	2.28	1.91	2.47	2.38	2.67	1.96	1.74	31.95
20-40	1.81	1.19	1.22	1.44	1.96	2.69	2.48	2.39	1.65	2.22	2.56	3.77	4.66	5.28	4.29	2.78	42.38
40-60	.52	.20	.09	.42	.82	1.00	1.06	.37	.48	.65	1.05	2.28	3.38	3.72	2.47	1.67	20.19
60-80	.08	.02	.00	.03	.14	.20	.15	.14	.08	.05	.22	.34	1.27	.94	.63	.35	4.63
80-100	.00	.00	.00	.00	.02	.00	.02	.03	.00	.00	.00	.05	.37	.20	.06	.05	.79
100 <	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.06	.00	.00	.06
INDET																	.00
TOTAL %	4.28	2.96	2.90	3.50	4.75	5.90	5.82	4.83	4.28	5.20	5.74	8.91	12.05	12.87	9.42	6.59	100.0
AVERAGE	23.6	20.2	19.6	22.8	26.8	27.8	27.5	24.7	23.0	23.6	27.7	31.2	37.3	35.3	33.8	32.0	29.6
MAXIMUM	66.0	64.0	51.0	65.0	82.0	78.0	92.0	87.0	72.0	62.0	77.0	92.0	95.0	112.0	85.0	99.0	112.0
STD DEV	14.2	11.7	9.6	13.4	15.0	15.5	15.4	14.3	13.9	13.6	15.0	16.2	19.2	18.3	16.5	17.0	16.9

CURRENT SPEEDS VS. DIRECTIONS
(Water Depth: Bin 8)
(11/1/07 - 1/30/08)

MM/S	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	TOTAL
0-20	1.44	1.59	1.19	1.44	1.14	1.56	1.25	1.62	1.56	1.65	1.88	1.98	2.44	2.32	1.64	1.99	26.67
20-40	2.27	1.20	.90	1.02	1.44	1.87	2.07	1.87	2.05	2.18	2.53	3.80	5.26	5.09	4.60	3.29	41.43
40-60	.76	.32	.15	.23	.62	.82	.69	.54	.52	.82	1.22	2.44	4.18	4.20	3.47	2.21	23.20
60-80	.17	.00	.06	.02	.08	.17	.12	.05	.09	.06	.28	.77	1.81	1.62	1.20	.76	7.25
80-100	.00	.00	.00	.00	.03	.02	.00	.02	.00	.00	.02	.06	.26	.32	.22	.17	1.11
100-120	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.09	.15	.05	.02	.31
120-140	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.02	.00	.00	.02
140 <	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.02	.00	.00	.02
INDET																	.00
TOTAL %	4.63	3.12	2.30	2.70	3.30	4.43	4.14	4.09	4.23	4.71	5.93	9.04	14.05	13.74	11.17	8.43	100.0
AVERAGE	27.6	21.3	21.9	21.2	28.2	28.3	27.8	25.4	25.2	26.2	29.5	34.0	38.8	39.4	38.4	34.8	32.6
MAXIMUM	69.0	55.0	71.0	71.0	87.0	83.0	73.0	91.0	77.0	78.0	83.0	90.0	111.0	145.0	117.0	107.0	145.0
STD DEV	15.2	12.5	13.5	12.6	16.5	15.6	14.7	13.8	13.5	14.3	15.8	17.5	19.2	20.7	18.6	19.2	18.4

Histograms: Current Speed vs. Direction in Bin 7 and Bin 8 at CM7

CURRENT SPEEDS VS. DIRECTIONS
(Water Depth: Bin 10)
(11/1/07 - 1/30/08)

MM/S	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	TOTAL
0-20	.80	.94	.71	.74	.59	.80	.43	.90	.88	1.17	.90	1.56	1.31	1.70	1.44	1.13	15.99
20-40	1.62	1.06	.65	.51	.45	.73	.74	.77	1.05	1.96	2.04	3.21	5.02	5.37	4.54	3.19	32.91
40-60	1.05	.17	.14	.17	.31	.25	.37	.34	.51	.63	1.42	3.66	4.85	5.09	4.91	3.94	27.80
60-80	.48	.03	.02	.03	.03	.05	.09	.08	.11	.15	.65	2.04	3.35	2.81	2.90	2.28	15.09
80-100	.17	.00	.02	.03	.00	.03	.00	.00	.02	.03	.11	1.10	1.45	1.00	1.30	.86	6.11
100-120	.02	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.15	.43	.19	.35	.35	1.50
120-140	.02	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.02	.11	.05	.17	.12	.48
140 <	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.08	.05	.12
INDET																	.00
TOTAL %	4.15	2.21	1.53	1.48	1.37	1.85	1.64	2.08	2.56	3.95	5.11	11.73	16.51	16.21	15.68	11.93	100.0
AVERAGE	37.9	23.4	21.9	23.2	25.9	25.1	30.8	25.9	29.0	29.3	37.6	47.0	50.2	45.9	50.1	50.0	43.5
MAXIMUM	120.0	69.0	85.0	88.0	76.0	82.0	79.0	76.0	85.0	87.0	93.0	124.0	137.0	132.0	157.0	151.0	157.0
STD DEV	21.6	12.4	14.0	17.8	16.0	17.1	15.5	16.6	16.4	15.7	18.7	23.3	23.8	21.8	25.1	24.8	23.8

CURRENT SPEEDS VS. DIRECTIONS
(Water Depth: Bin 11)
(11/1/07 - 1/30/08)

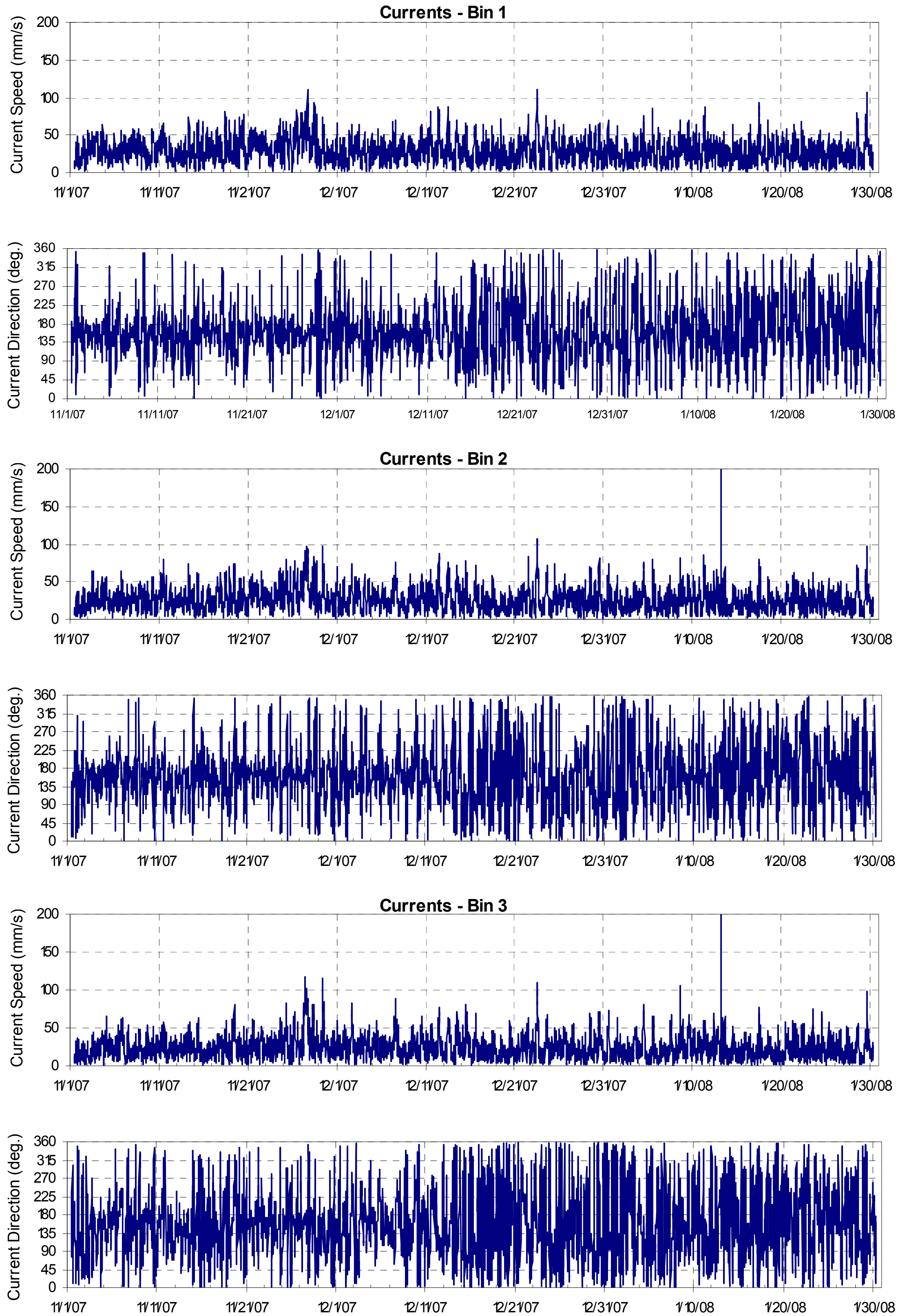
MM/S	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	TOTAL
0-20	.66	.82	.45	.34	.34	.52	.51	.46	.51	.71	.73	1.17	1.10	1.27	1.00	.94	11.53
20-40	1.14	.59	.32	.39	.22	.43	.42	.88	.90	1.27	1.87	2.67	3.47	4.09	3.78	2.59	25.02
40-60	.97	.20	.05	.08	.05	.12	.29	.28	.49	.65	1.54	4.04	5.20	5.02	5.31	3.41	27.70
60-80	.52	.06	.02	.00	.00	.05	.03	.06	.11	.22	.97	3.10	4.28	3.24	3.97	2.82	19.45
80-100	.19	.03	.00	.00	.00	.00	.00	.00	.00	.05	.32	1.91	2.38	1.53	2.30	1.68	10.39
100-120	.03	.00	.02	.00	.00	.00	.00	.00	.00	.00	.09	.60	.88	.59	1.25	.60	4.06
120-140	.00	.00	.00	.00	.00	.00	.00	.00	.02	.00	.02	.20	.15	.06	.40	.25	1.10
140-160	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.02	.05	.02	.28	.19	.54
160-180	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.02	.00	.09	.08	.19
180 <	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.02	.02	.03
INDET																	.00
TOTAL %	3.52	1.70	.85	.80	.60	1.13	1.25	1.68	2.02	2.89	5.54	13.72	17.52	15.80	18.40	12.58	100.0
AVERAGE	40.8	25.2	23.0	22.3	19.4	24.5	28.4	29.1	31.5	32.8	44.7	56.0	57.7	52.0	60.9	58.9	52.2
MAXIMUM	110.0	86.0	104.0	54.0	47.0	73.0	79.0	69.0	120.0	82.0	120.0	141.0	173.0	149.0	187.0	194.0	194.0
STD DEV	22.7	18.0	16.2	12.9	12.2	15.7	16.7	14.5	17.7	18.1	23.2	26.5	25.9	24.4	30.5	30.4	28.1

Histograms: Current Speed vs. Direction in Bin 10 and Bin 11 at CM7

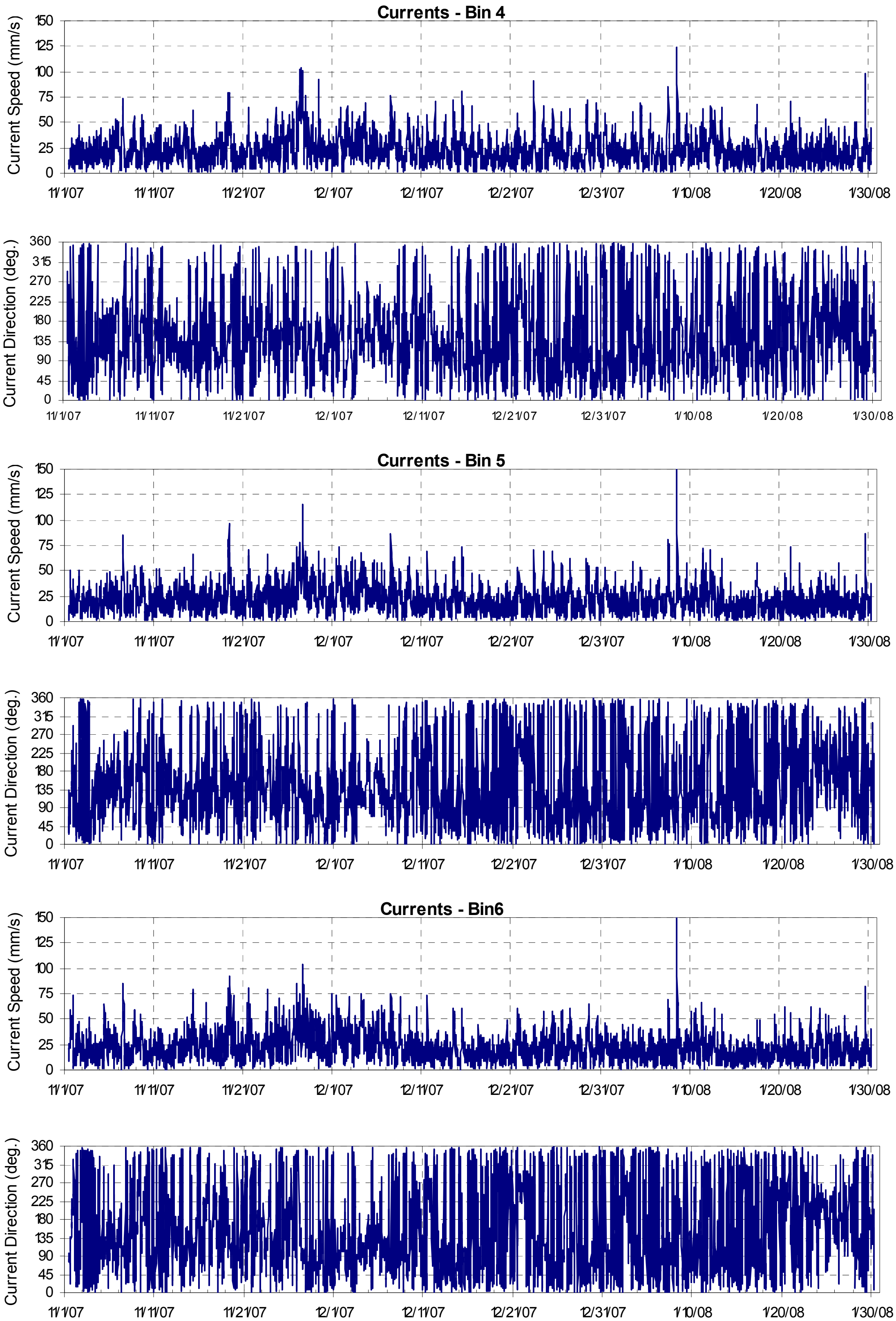
ADCP Current and Water Level Time Series
At CM1
($13^o25.823$'N, $144^o40.017$'E)

Selected Depth Bin Numbers: 1, 2, 3, 4, 5, 6, 7, 8
Data Period: 11/2/07 – 1/30/08

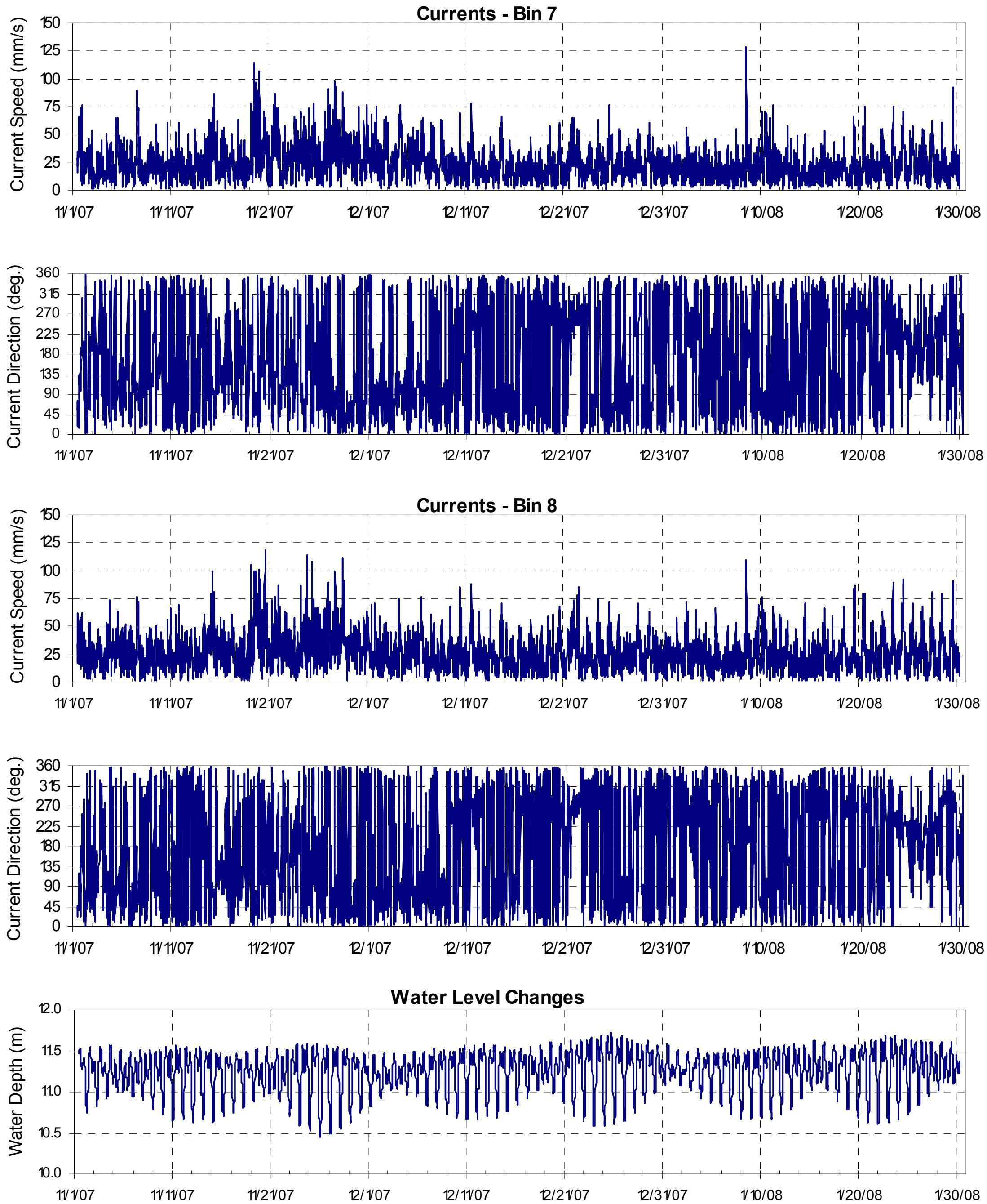
Time series: ADCP current speeds and directions in Bins 1, 2 and 3 at CM1



Time series: ADCP current speeds and directions in Bins 4, 5 and 6 at CM1



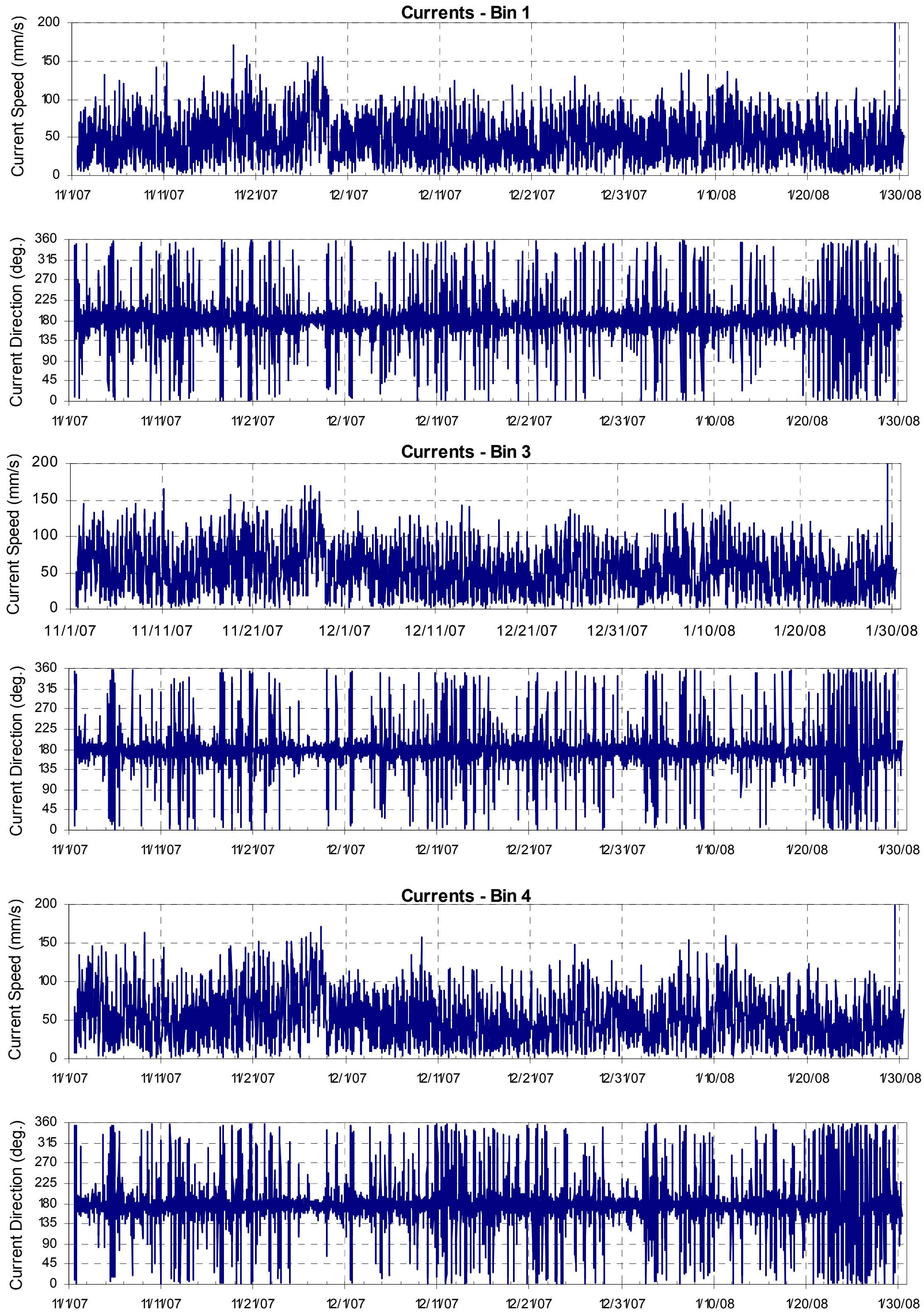
Time series: ADCP current speeds and directions in Bins 7 and 8, and water level changes at CM1



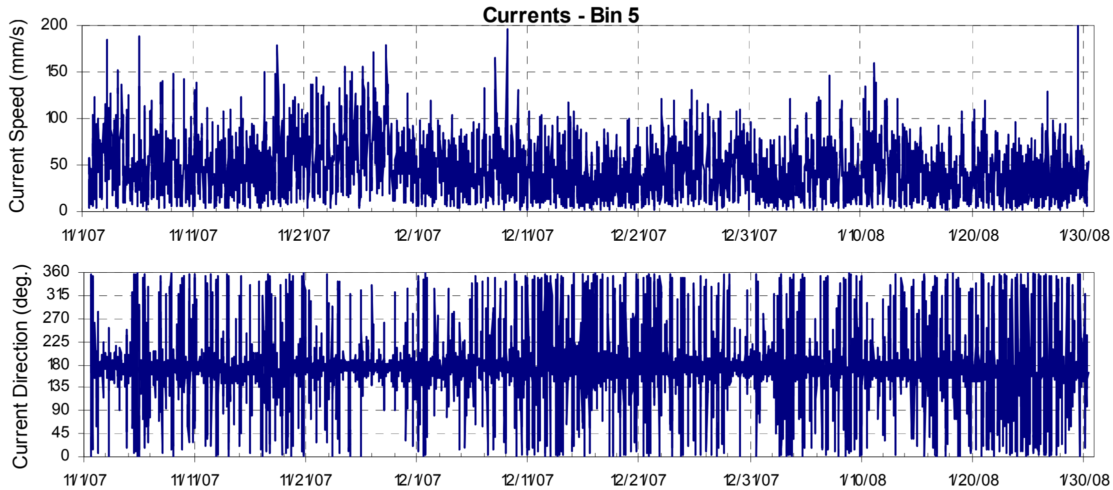
ADCP Current and Water Level Time Series
At CM2
(13°26.430'N, 144°39.977'E)

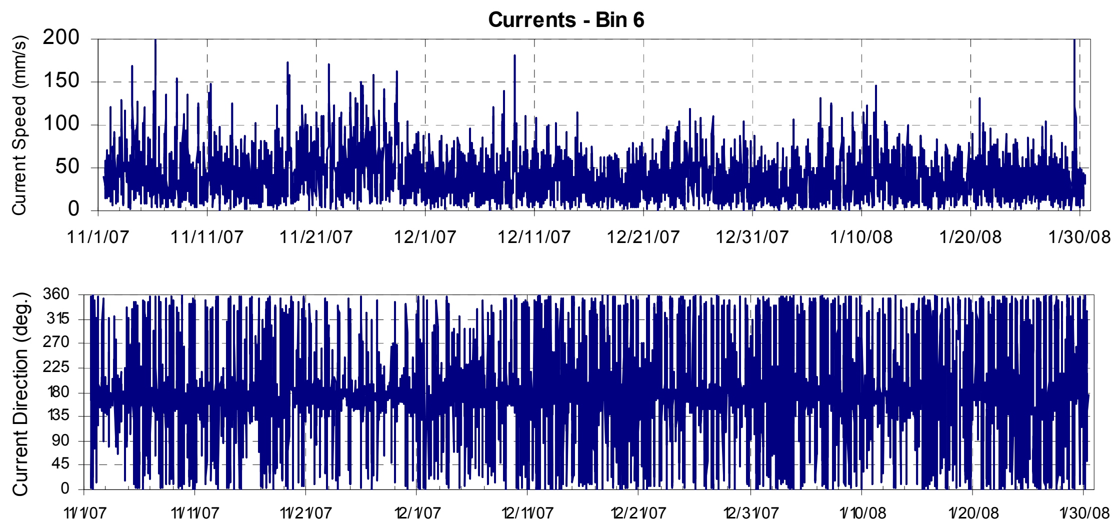
Selected Depth Bin Numbers: 1, 3, 4, 5, 6, 7, 8, 10
Data Period: 11/1/07 – 1/30/08

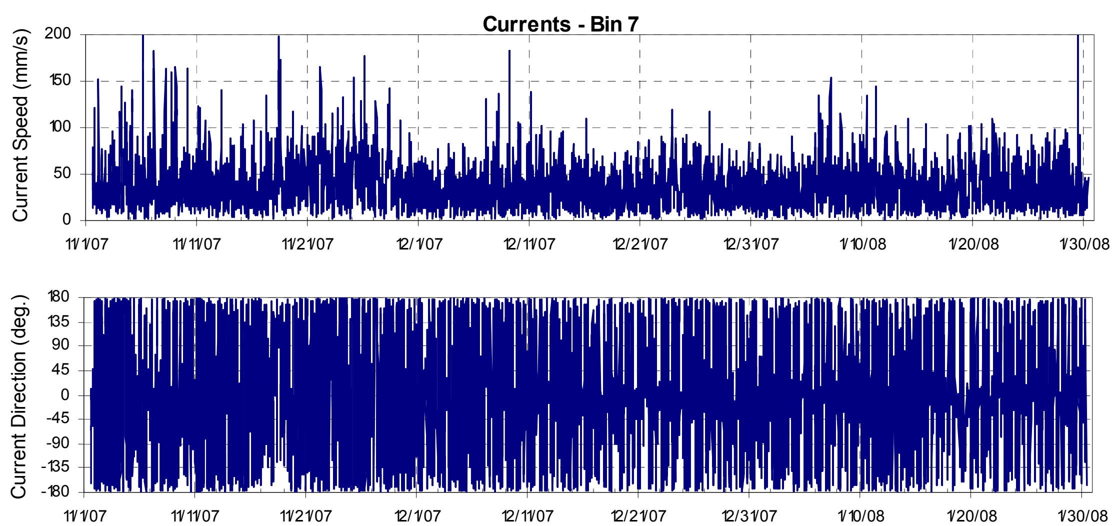
Time series: ADCP current speeds and directions in Bins 1, 3 and 4 at CM2



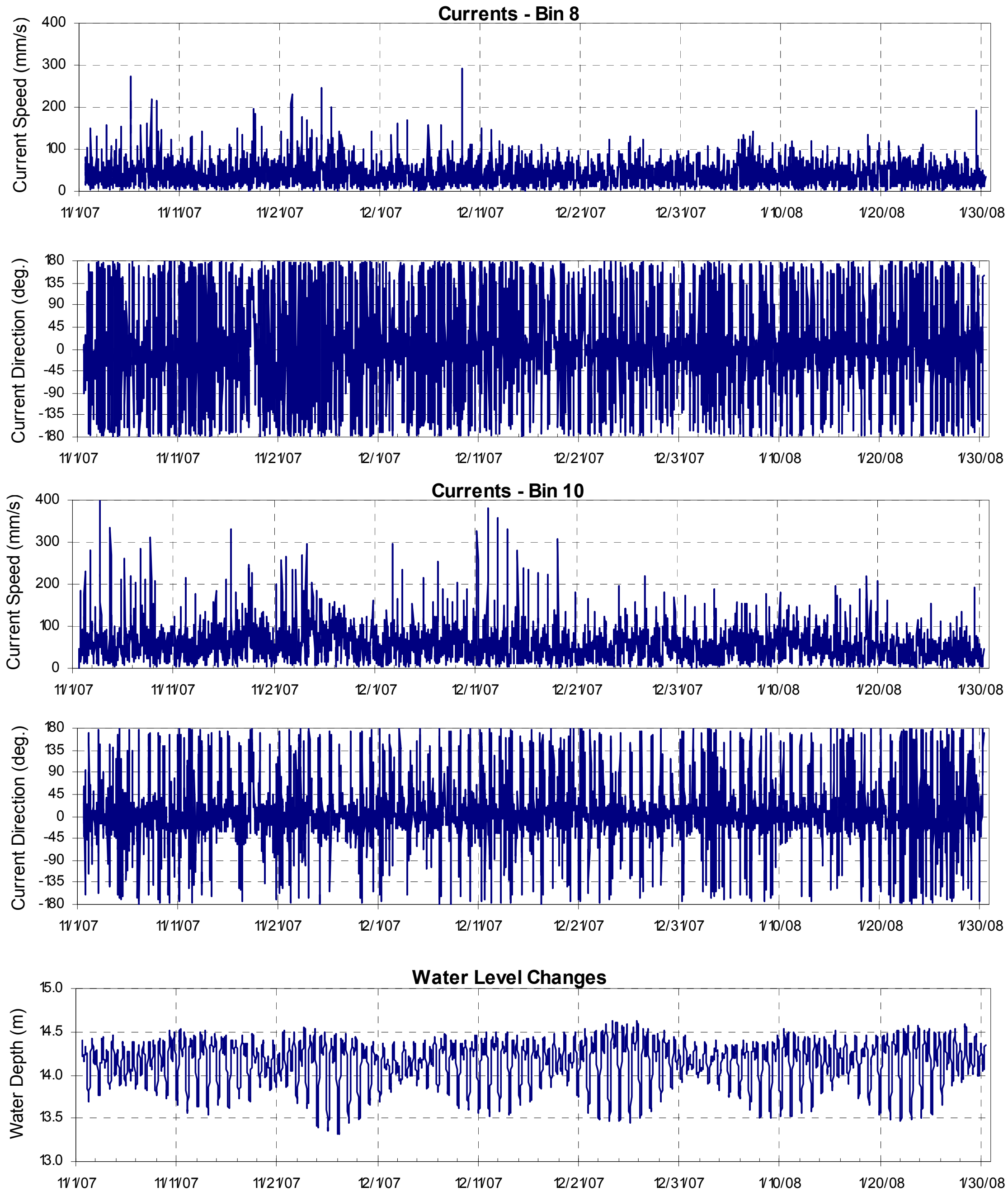
Time series: ADCP current speeds and directions in Bins 5, 6 and 7 at CM2







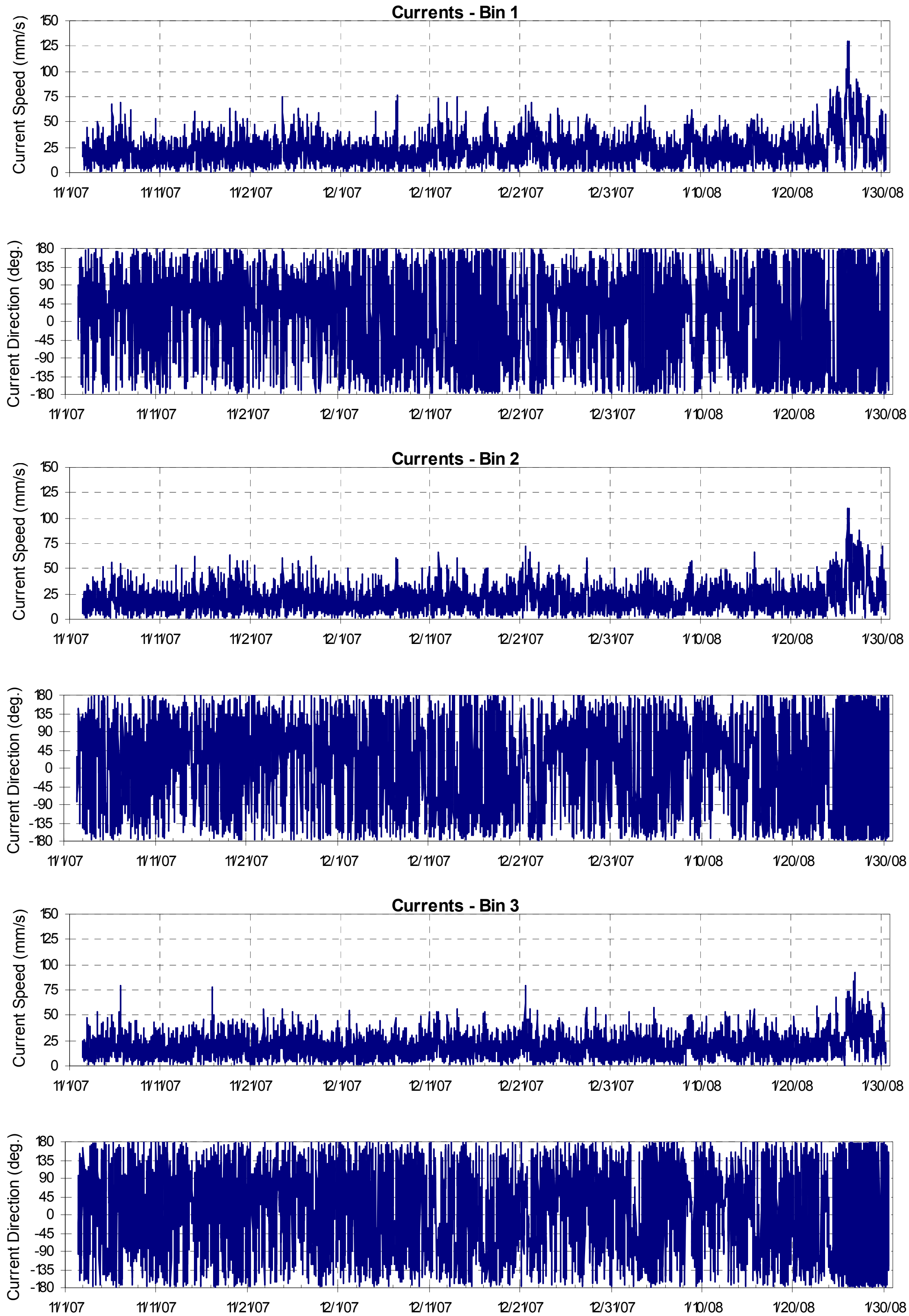
Time series: ADCP current speeds and directions in Bins 8 and 10, and water level changes at CM2



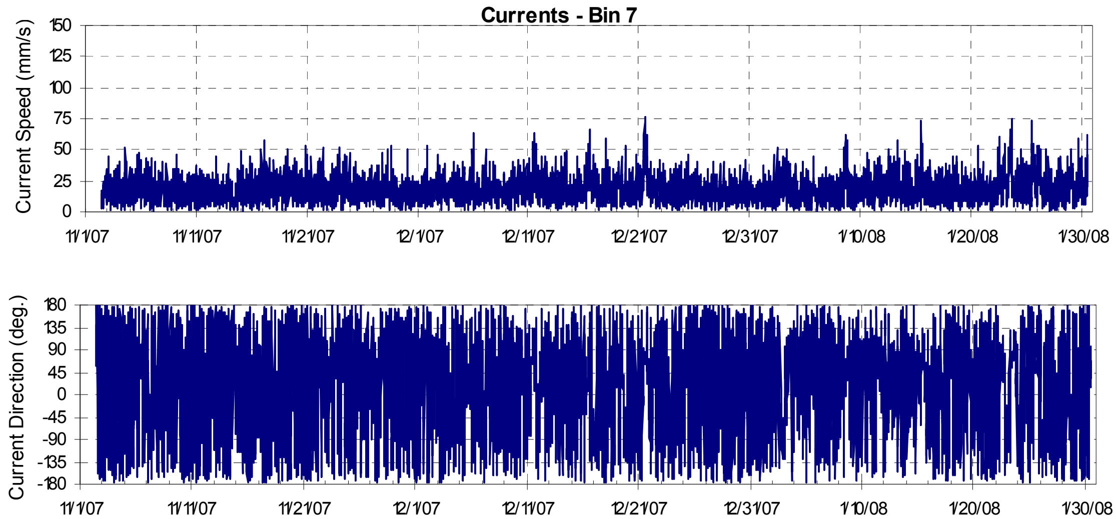
ADCP Current and Water Level Time Series
At CM3
(13°26.665'N, 144°40.065'E)

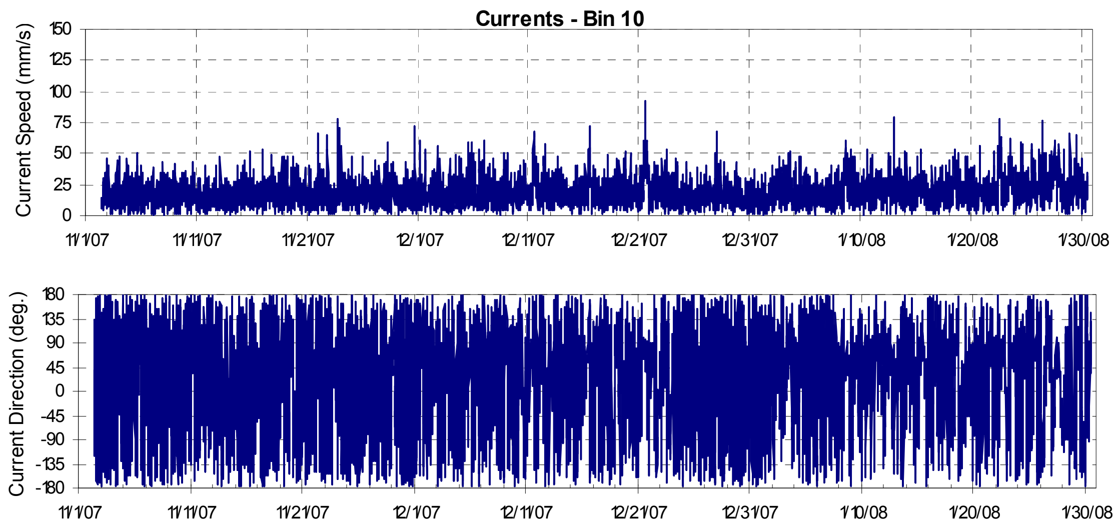
Selected Depth Bin Numbers: 1, 2, 3, 7, 10, 12, 15, 18
Data Period: 11/2/07 – 1/30/08

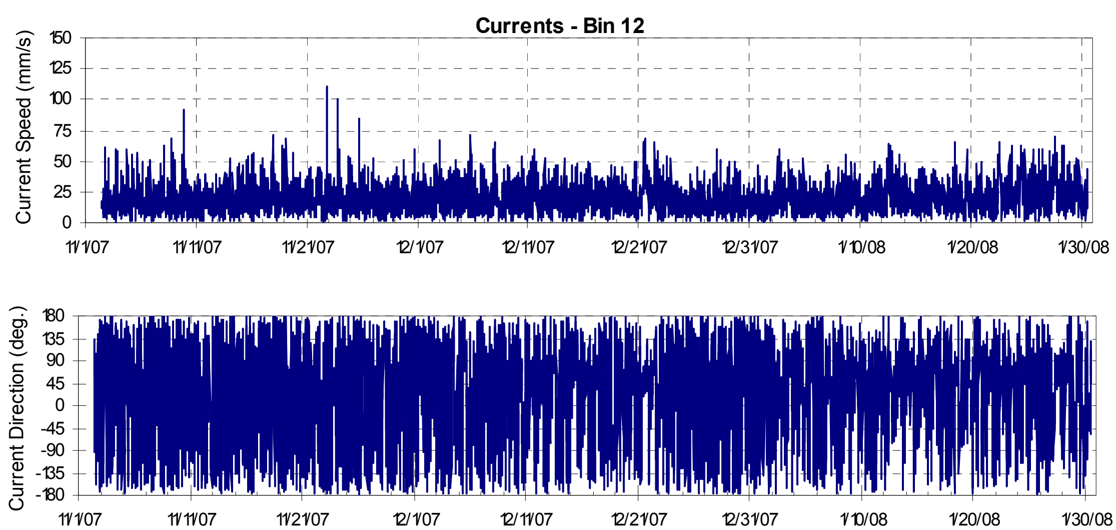
Time series: ADCP current speeds and directions in Bins 1, 2 and 3 at CM3



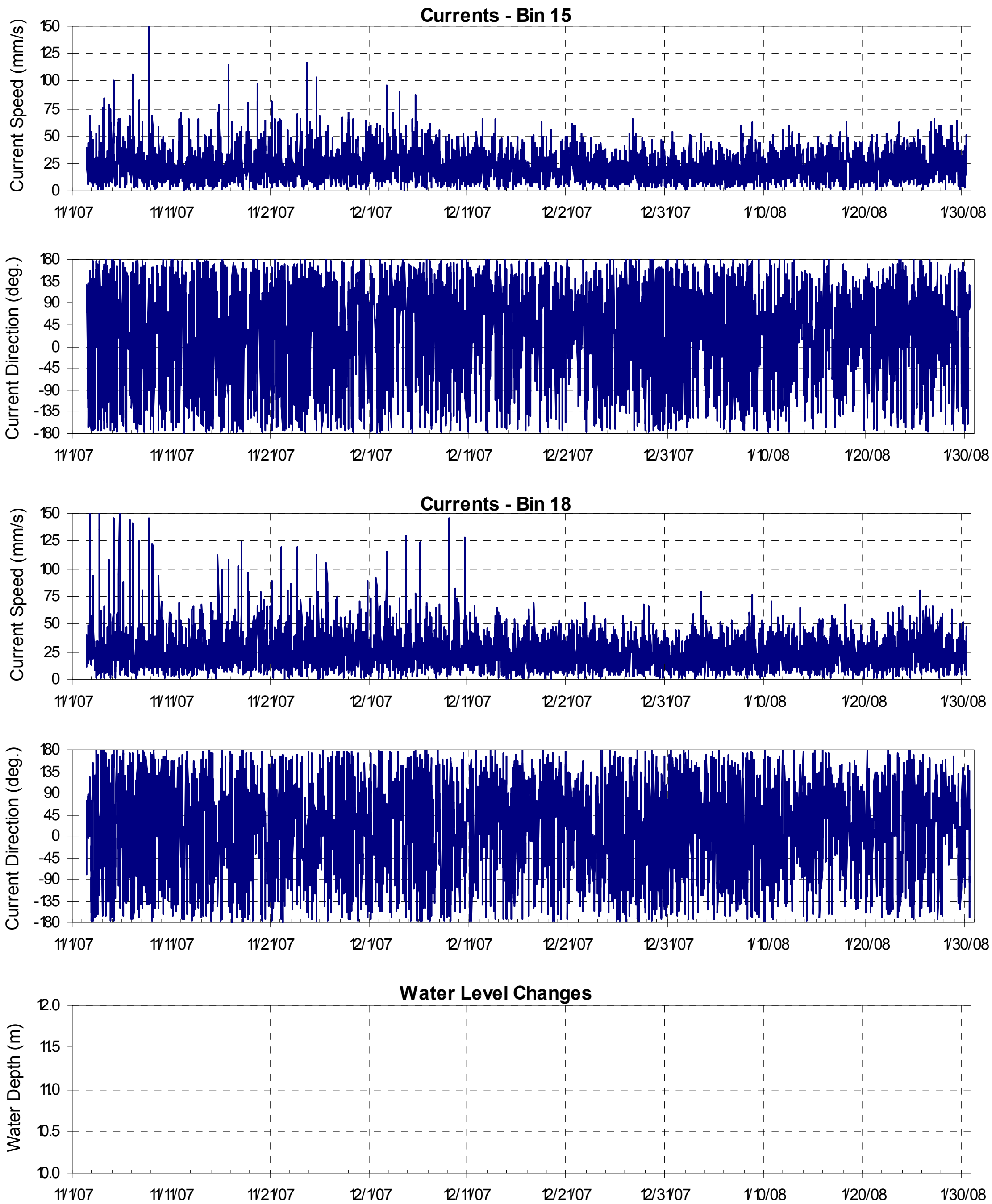
Time series: ADCP current speeds and directions in Bins 7, 10 and 12 at CM3







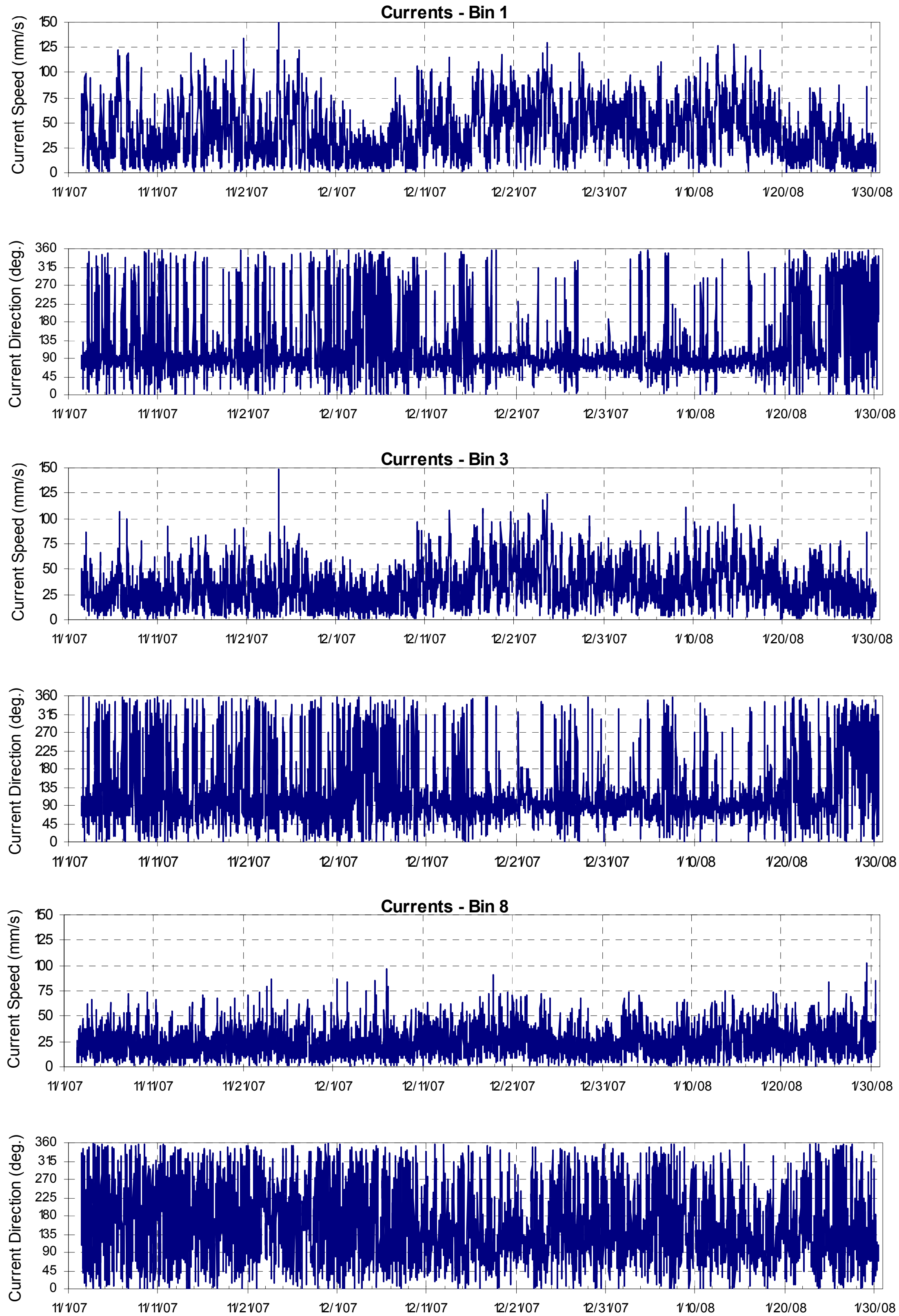
Time series: ADCP current speeds and directions in Bins 15 and 18 at CM3



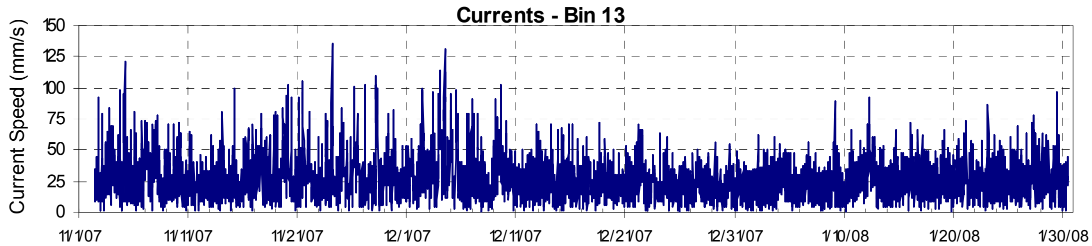
ADCP Current and Water Level Time Series
At CM4
(13°26.678'N, 144°39.721'E)

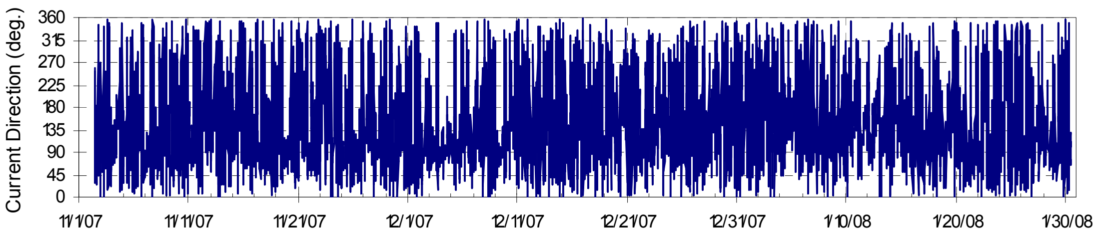
Selected Depth Bin Numbers: 1, 3, 8, 13, 15, 17, 18, 19
Data Period: 11/2/07 – 1/30/08

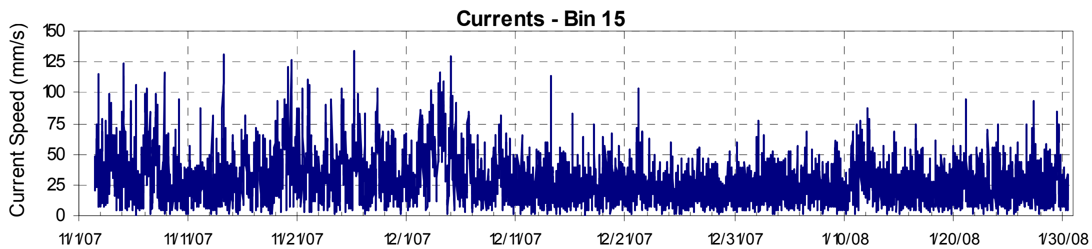
Time series: ADCP current speeds and directions in Bins 1, 3 and 8 at CM4

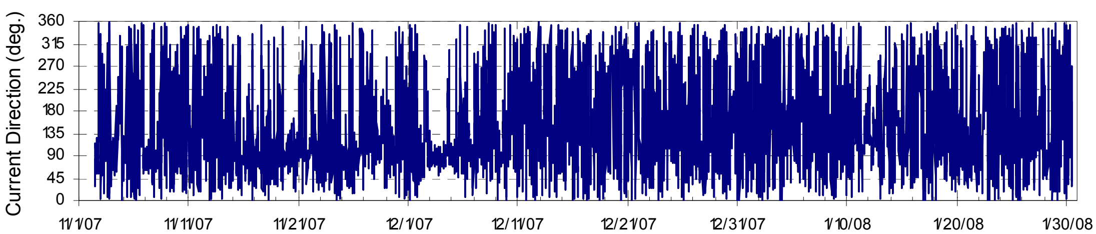


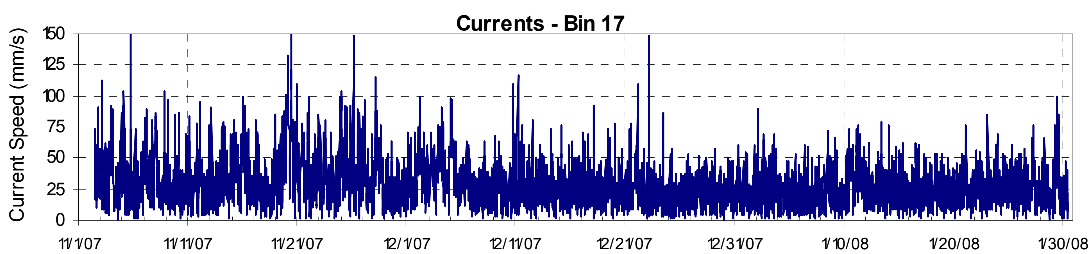
Time series: ADCP current speeds and directions in Bins 13, 15 and 17 at CM4

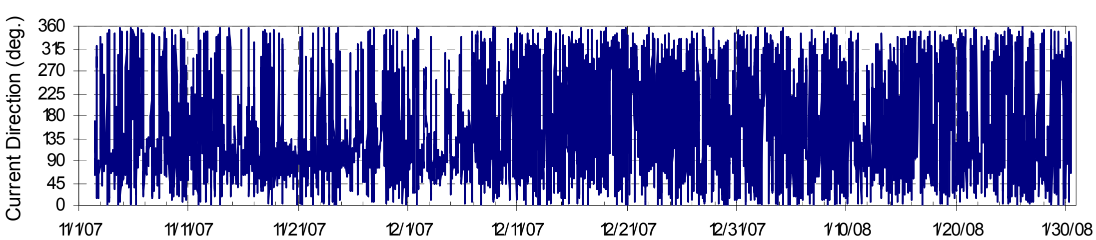




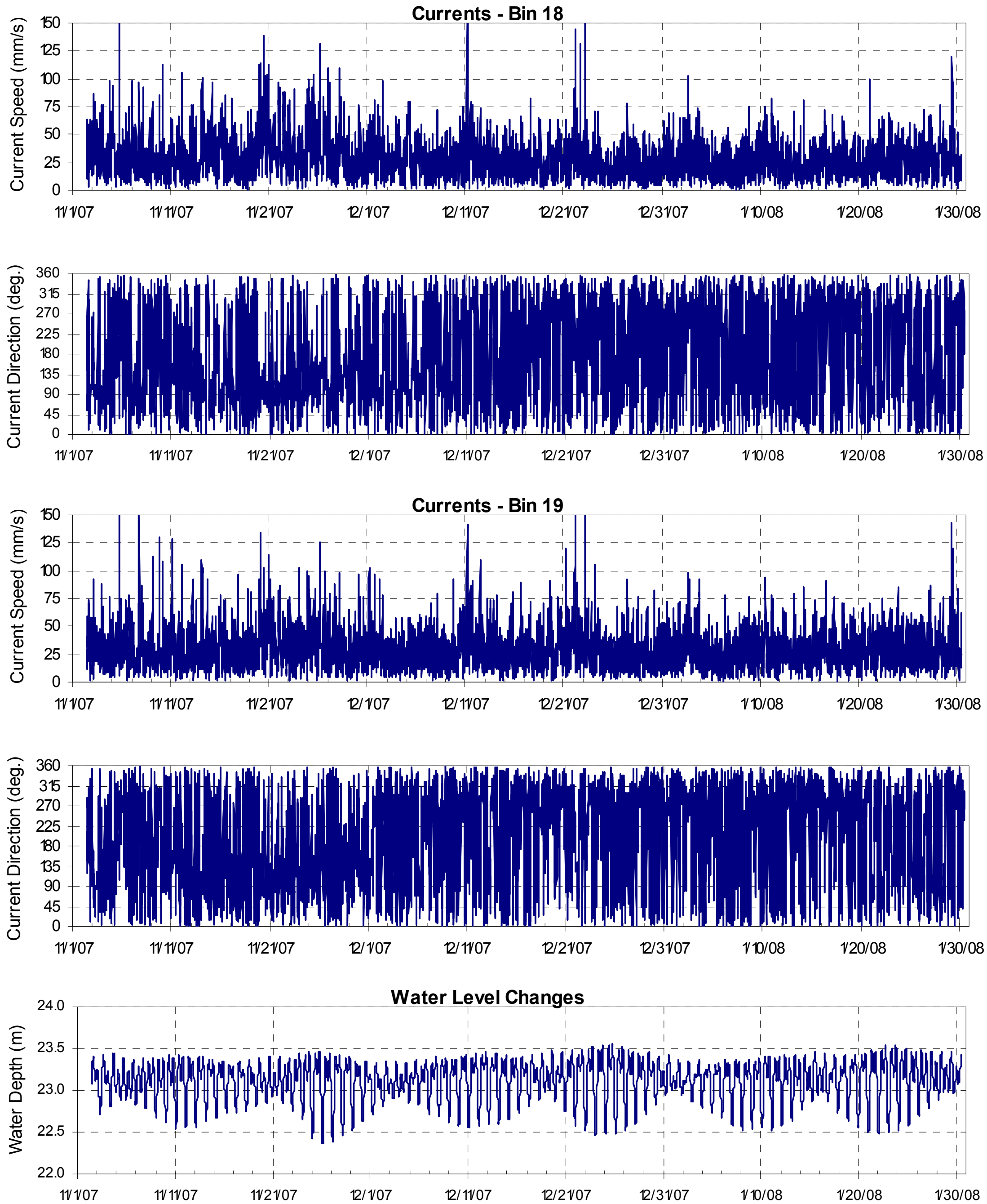








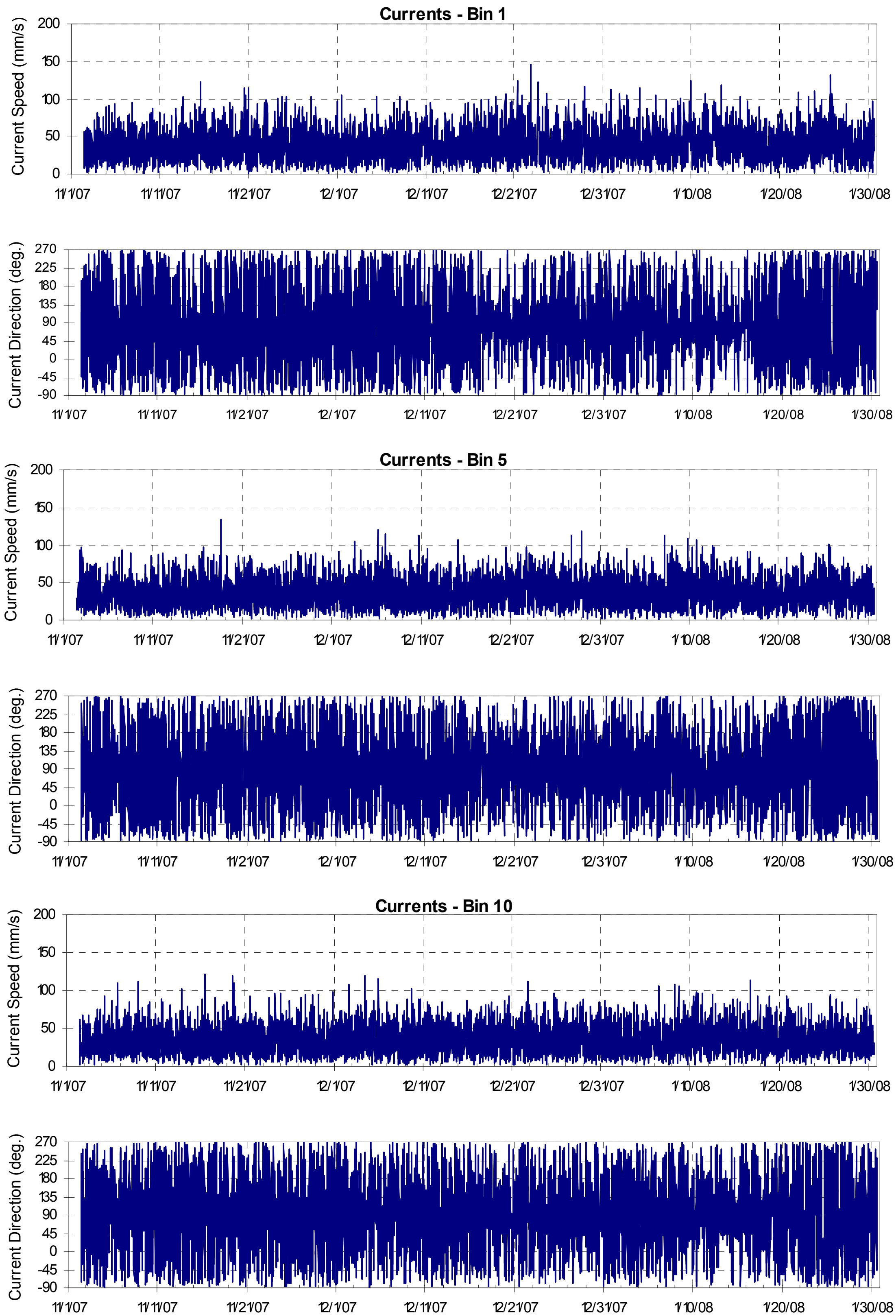
Time series: ADCP current speeds and directions in Bins 18 and 19, and water level changes at CM4



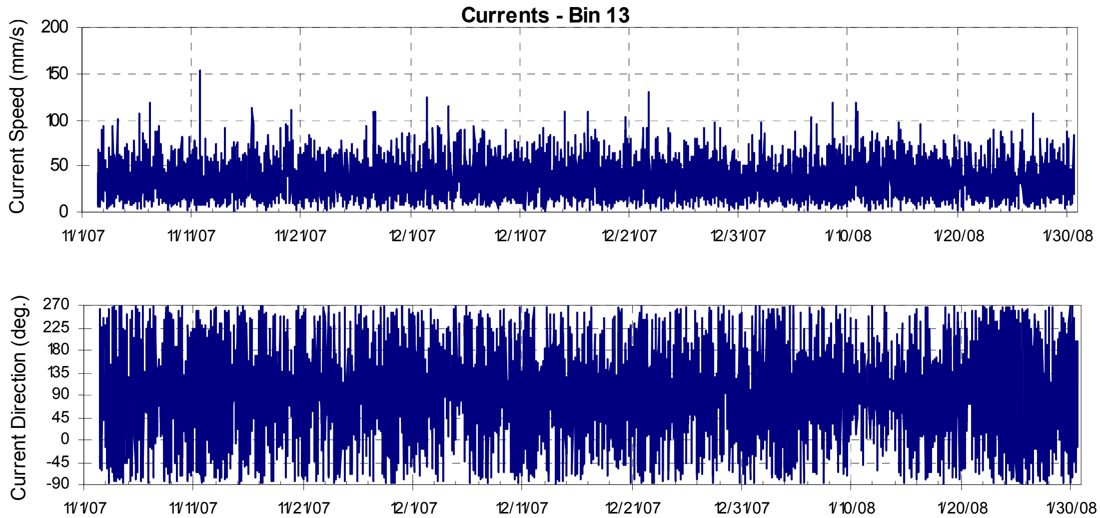
ADCP Current and Water Level Time Series
At CM5
($13^o26.725$'N, $144^o39.184$'E)

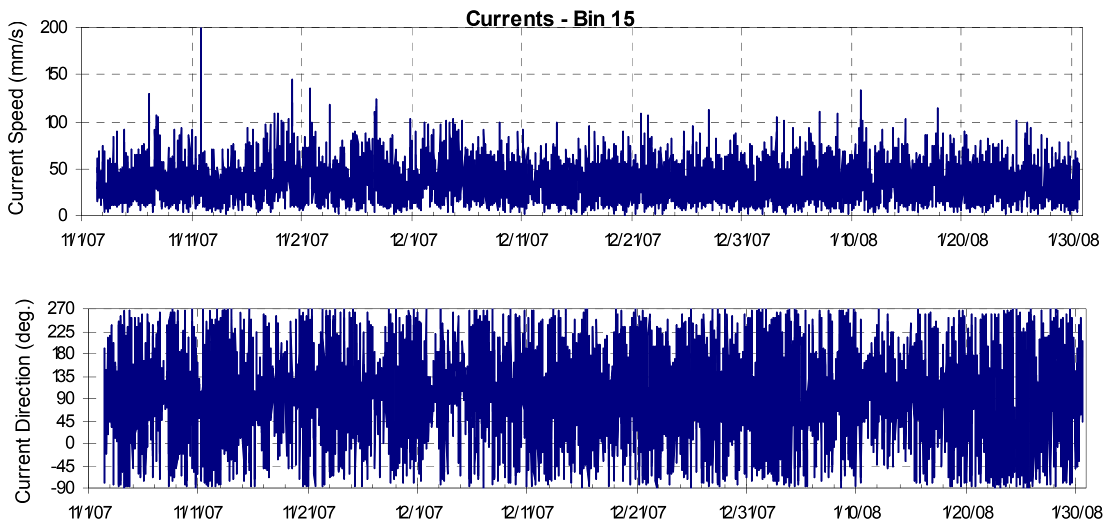
Selected Depth Bin Numbers: 1, 5, 10, 13, 15, 18, 21, 24
Data Period: 11/2/07 – 1/30/08

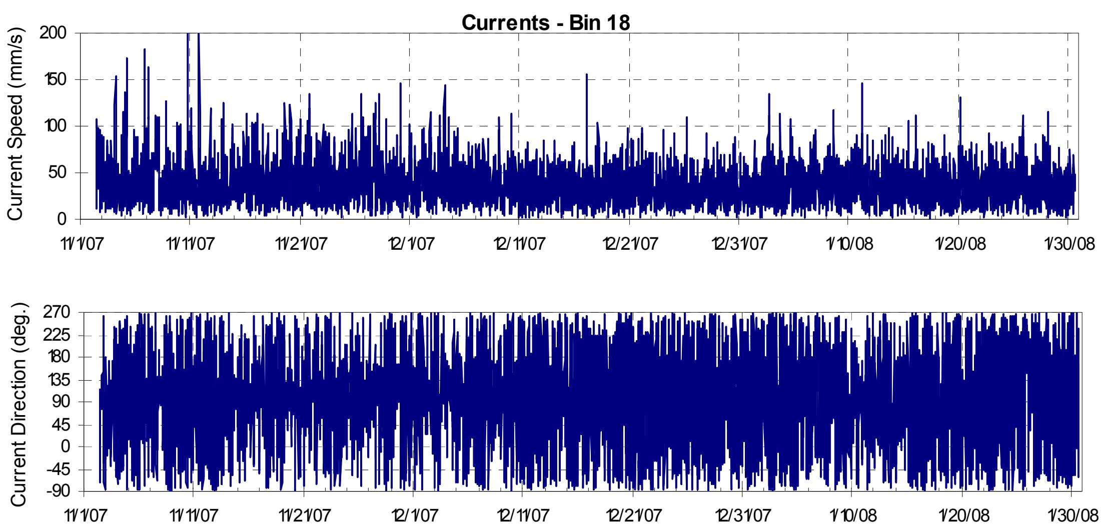
Time series: ADCP current speeds and directions in Bins 1, 5 and 10 at CM5



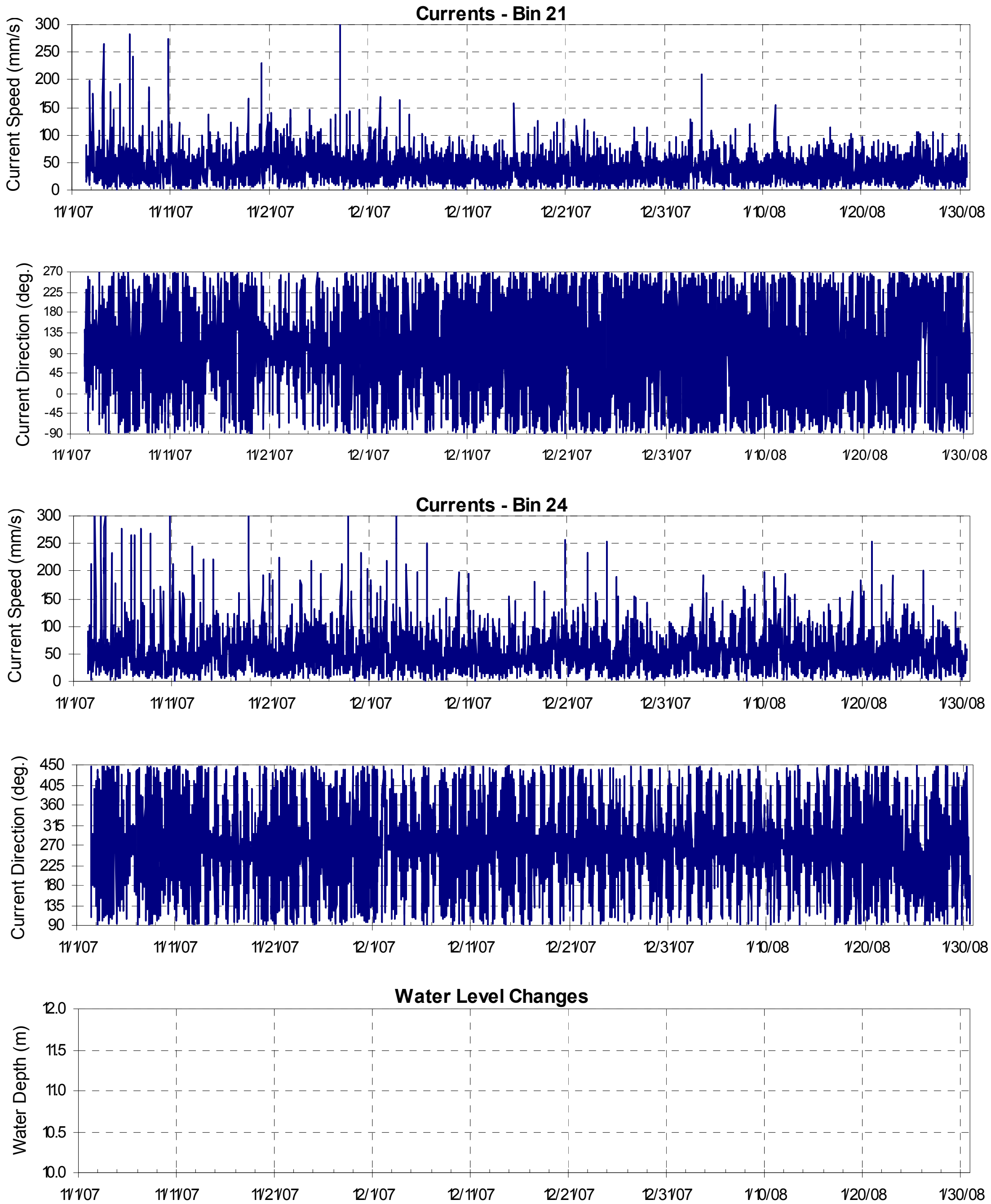
Time series: ADCP current speeds and directions in Bins 13, 15 and 18 at CM5







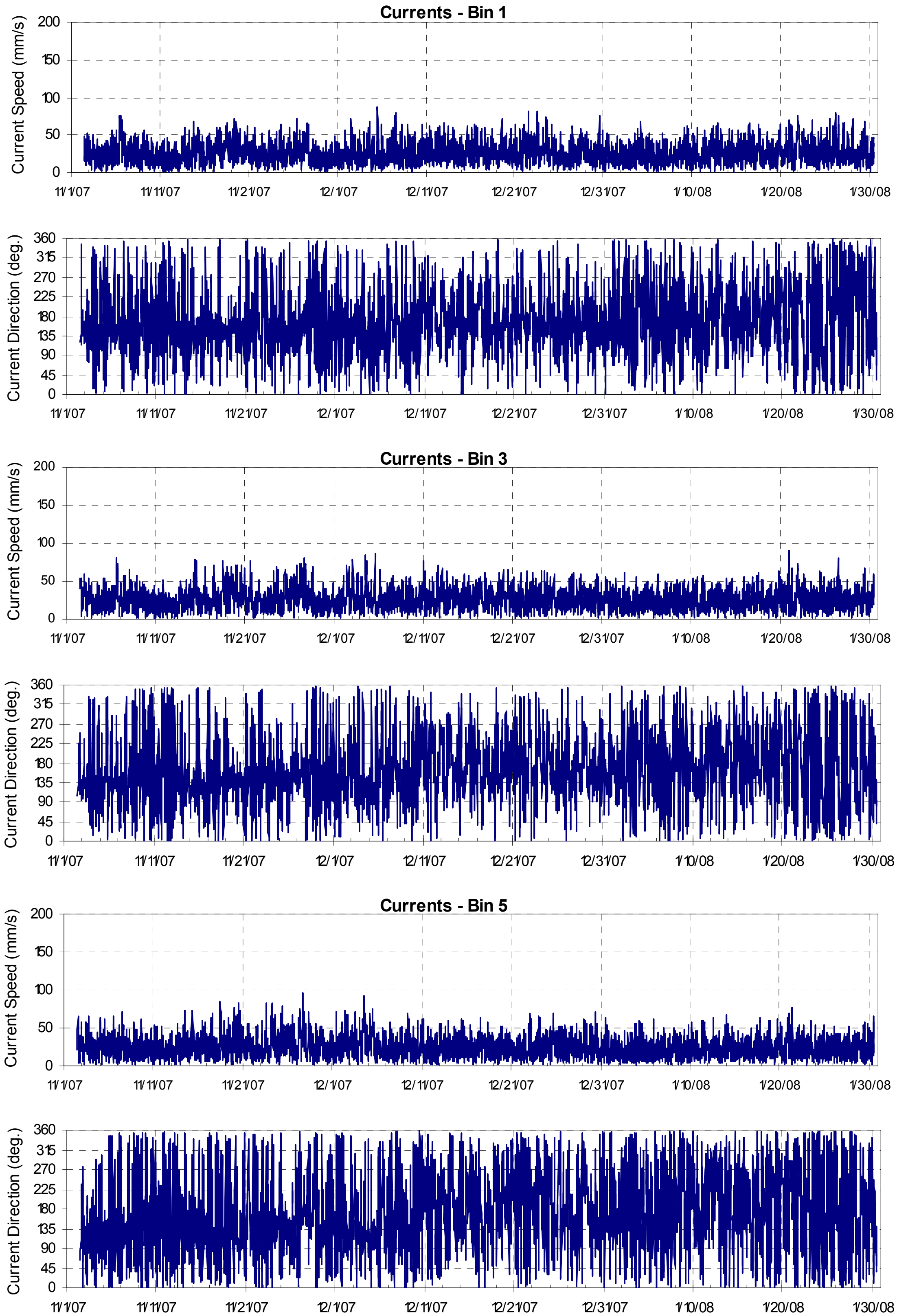
Time series: ADCP current speeds and directions in Bins 21 and 24 at CM5



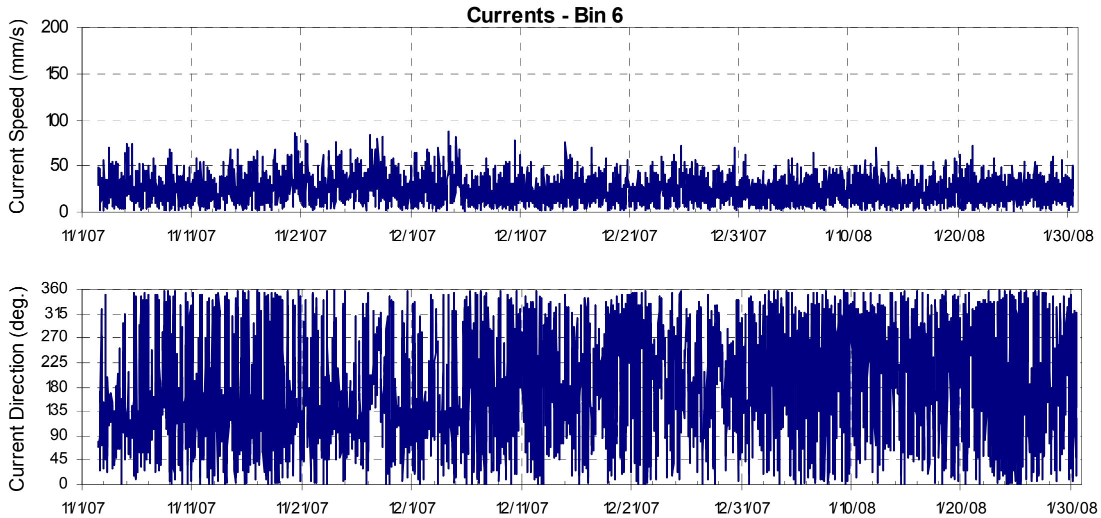
ADCP Current and Water Level Time Series
At CM6
(13°26.815'N, 144°39.942'E)

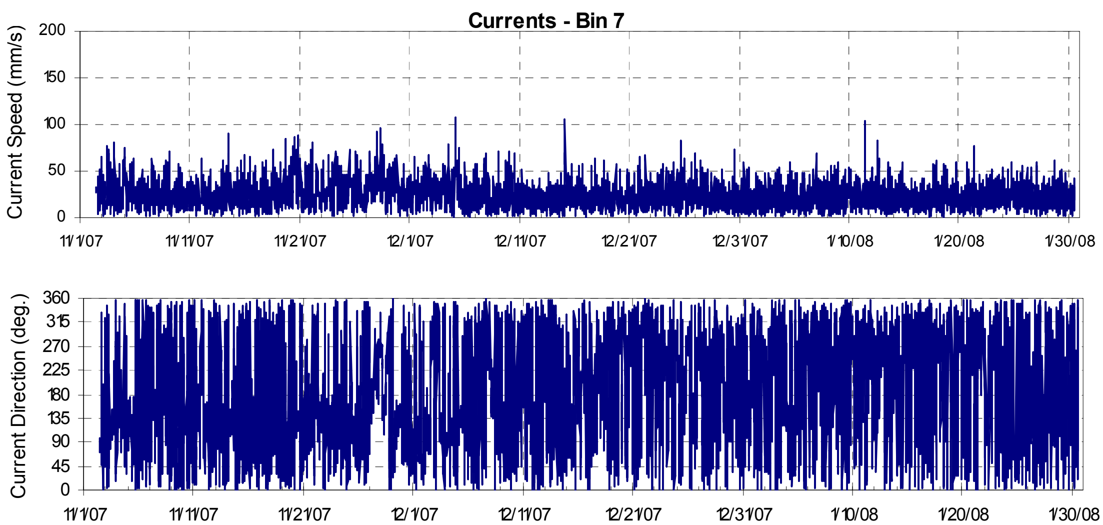
Selected Depth Bin Numbers: 1, 3, 5, 6, 7, 8, 9, 11
Data Period: 11/2/07 – 1/30/08

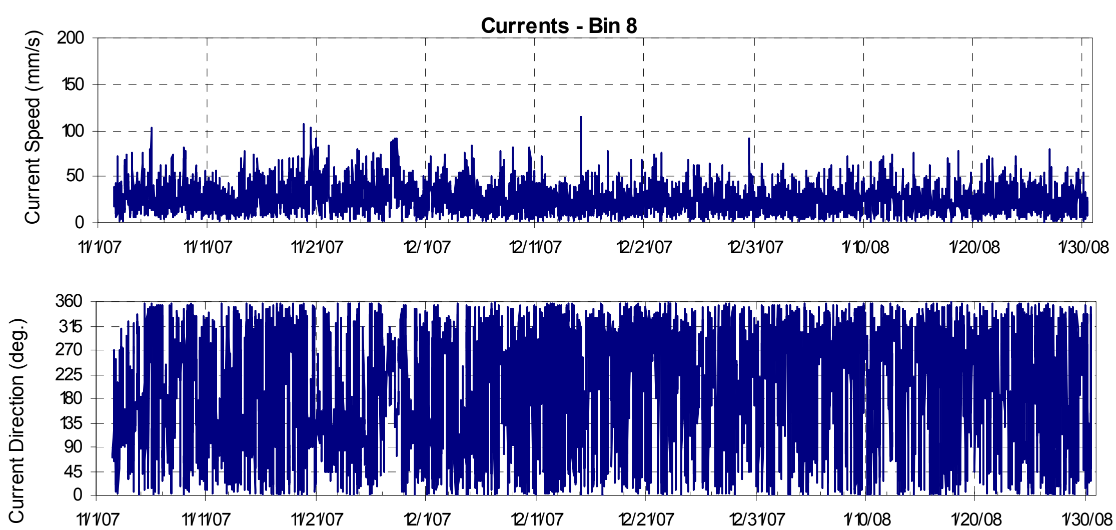
Time series: ADCP current speeds and directions in Bins 1, 3 and 5 at CM6



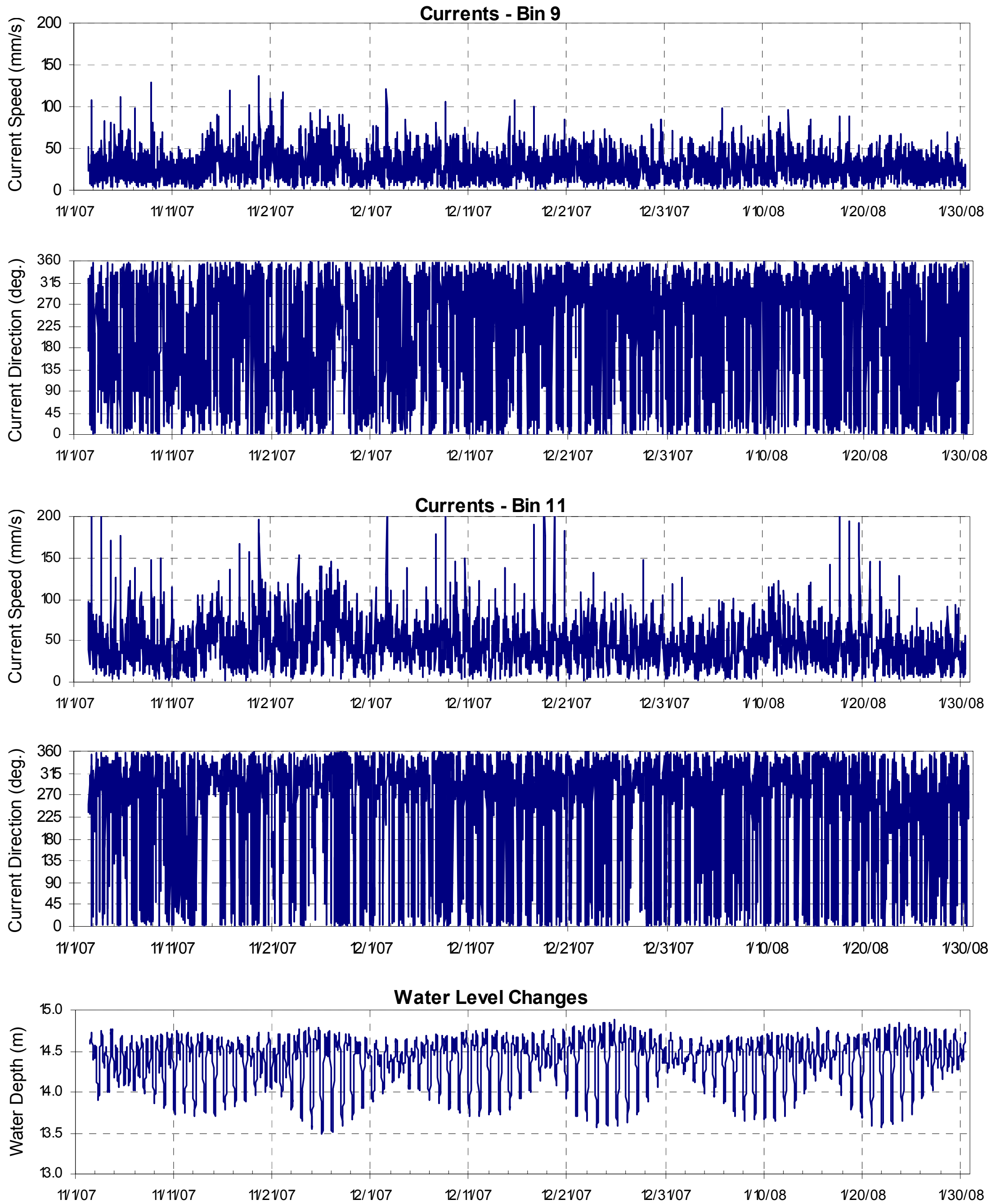
Time series: ADCP current speeds and directions in Bins 6, 7 and 8 at CM6







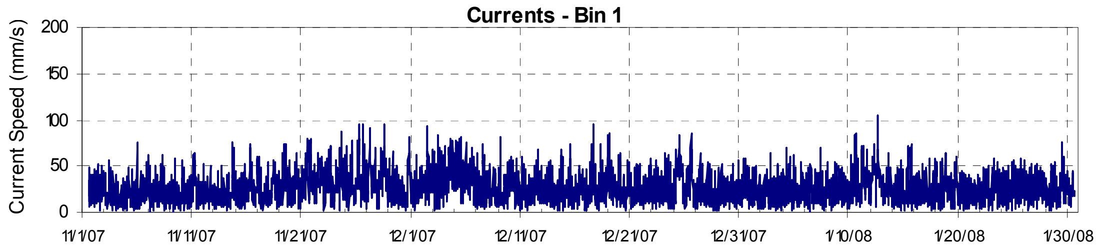
Time series: ADCP current speeds and directions in Bins 9 and 11, and water level changes at CM6

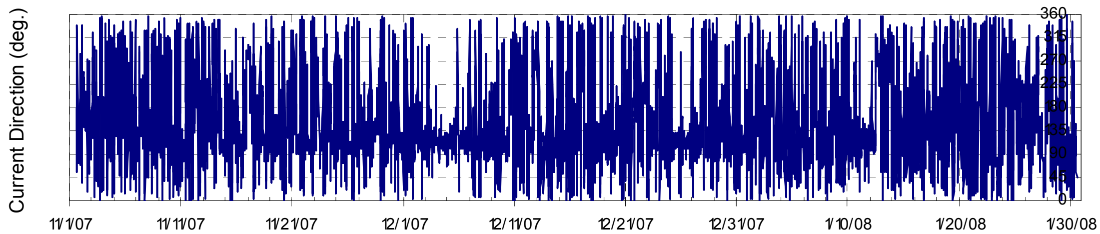


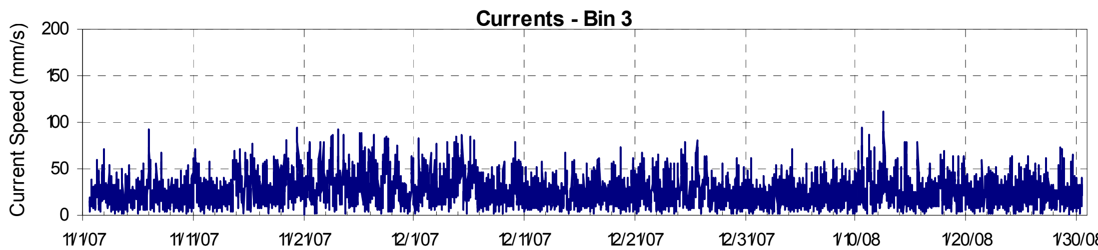
ADCP Current and Water Level Time Series
At CM7
(13°27.306'N, 144°39.429'E)

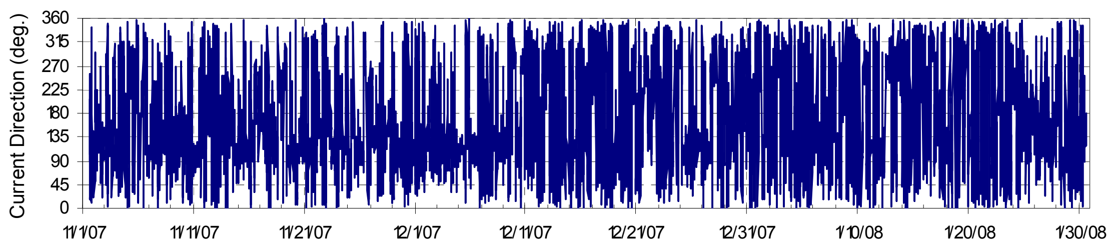
Selected Depth Bin Numbers: 1, 3, 5, 6, 7, 8, 10, 11
Data Period: 11/1/07 – 1/30/08

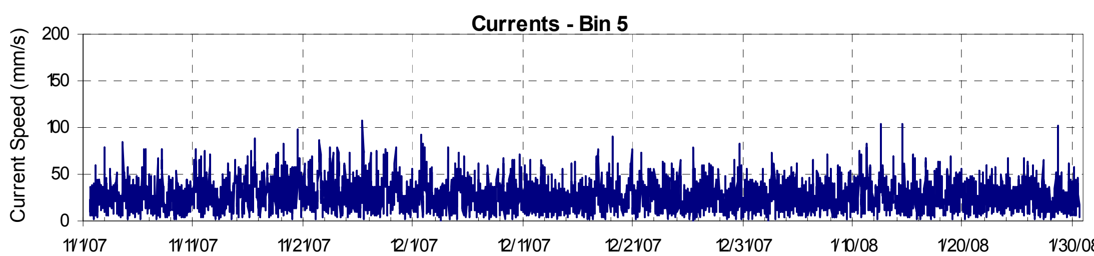
Time series: ADCP current speeds and directions in Bins 1, 3 and 5 at CM7

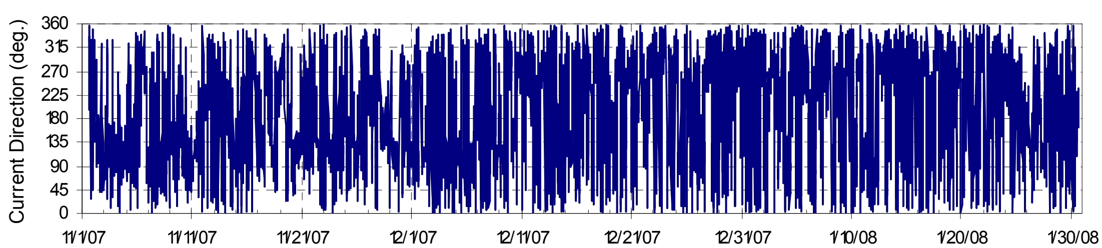




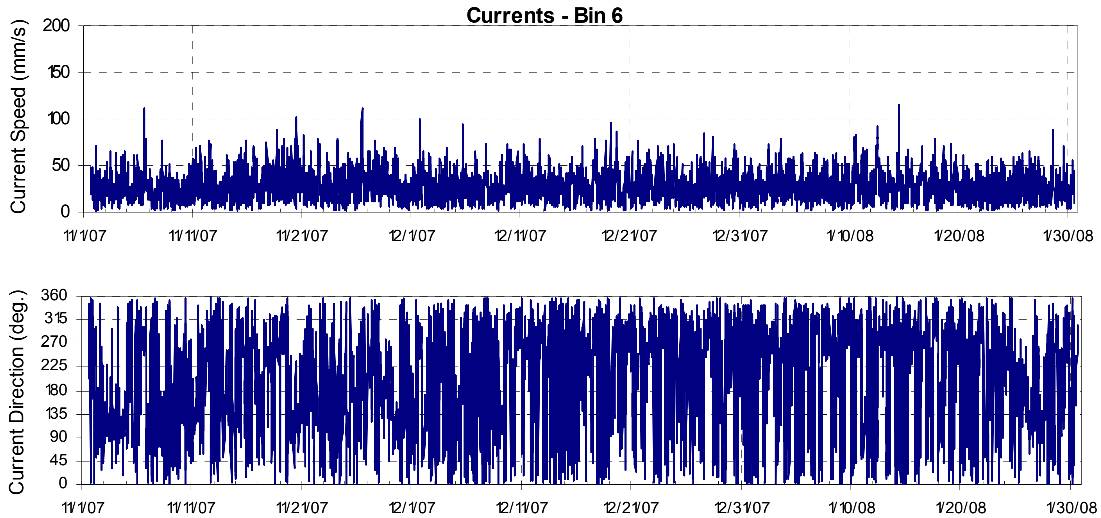


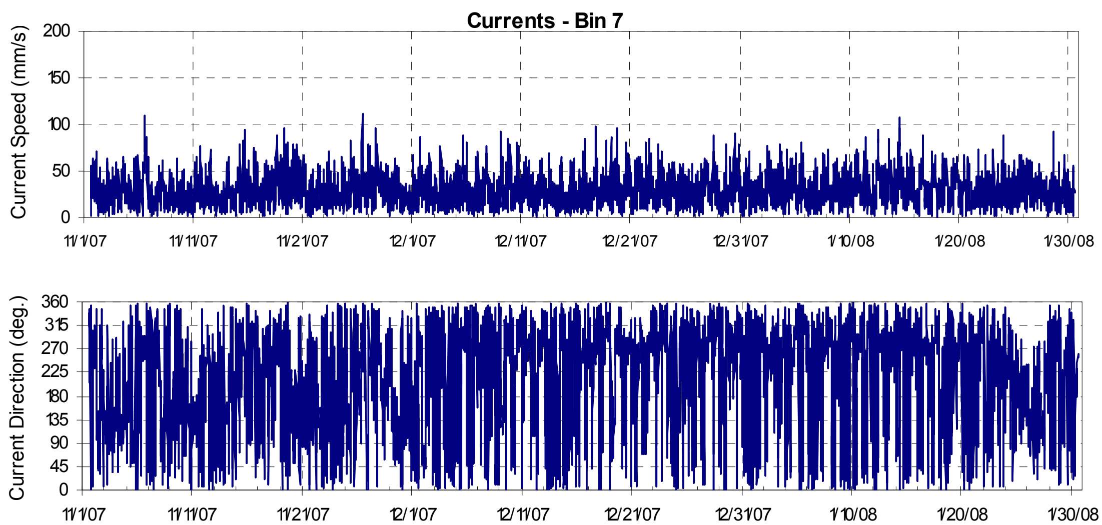


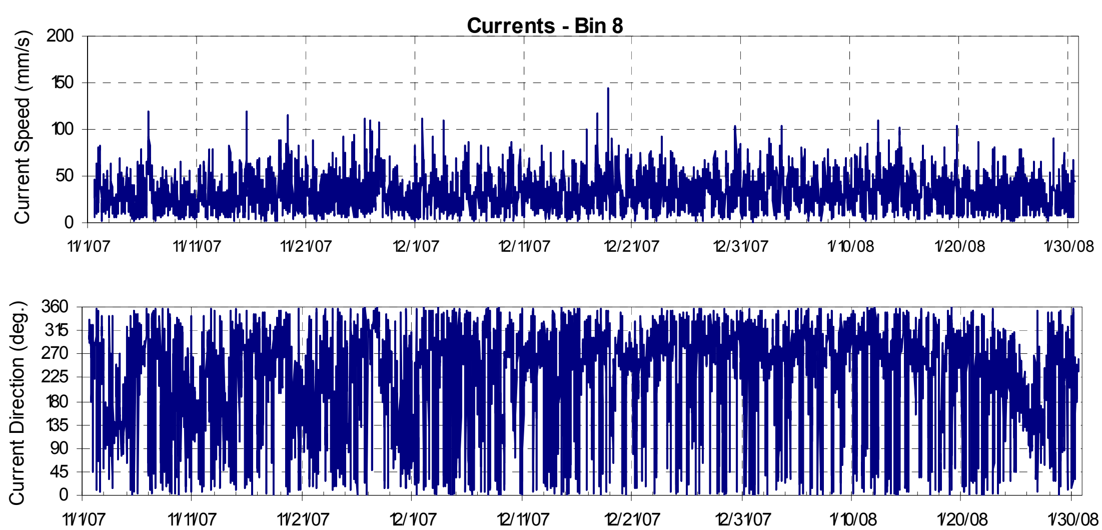




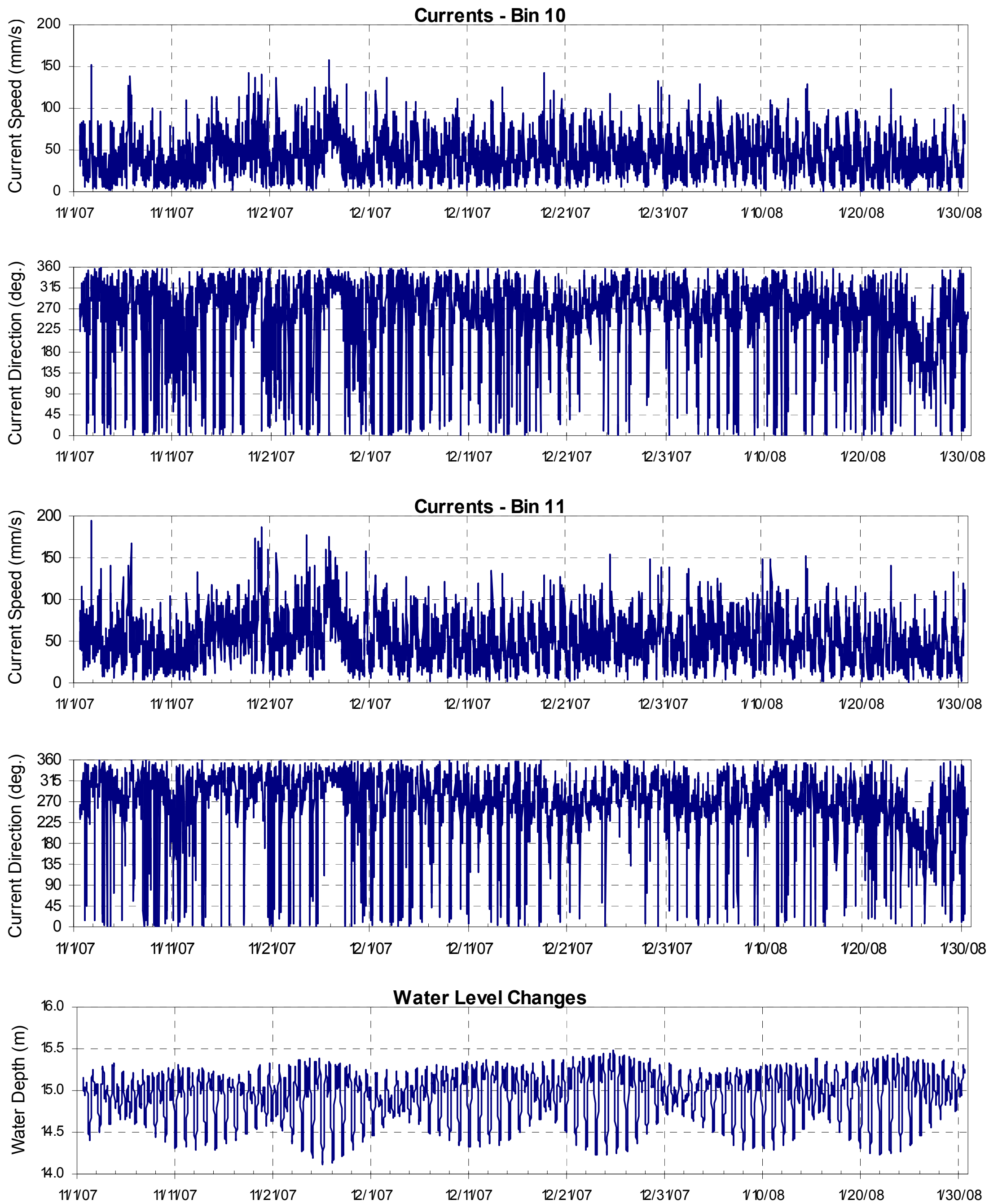
Time series: ADCP current speeds and directions in Bins 6, 7 and 8 at CM7







Time series: ADCP current speeds and directions in Bins 10 and 11, and water level changes at CM7



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Appendix E – Section F: Habitat Equivalency Analysis (HEA) Mitigation of Coral Habitat Losses, By Industrial Economics Inc., Primary Authors: Heidi Clark and Michael Donlan

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Habitat Equivalency Analysis & Supporting Studies: Section F

Habitat Equivalency Analysis
Mitigation of Coral Habitat Losses

Outer Apra Harbor, Guam

September 2009

Prepared for:
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LIST OF ACRONYMS AND ABBREVIATIONS

>	greater than
%	percent
ACOE	Army Corps of Engineers
cm	centimeter(s)
CVN	Carrier Vessel Nuclear
DSAYs	discounted service acre-years
ft	feet
ha	hectare
HDAR	Hawaii Department of Land and Natural Resources, Division of Aquatic Resources
HEA	Habitat Equivalency Analysis
HHF	Helber Hastert & Fee, Planners
in	inches
LIDAR	Light Detection and Ranging
m	meter(s)
m^2	square meter(s)
mg/cm^2	milligram(s) per square centimeter
NOAA	National Oceanic and Atmospheric Administration
PCQ	Point Centered Quarter
SRF	Ship Repair Facility
TSS	total suspended solids

1.0 OVERVIEW

The United States Department of the Navy (Navy) proposes a new wharf in Outer Apra Harbor[1] to meet the requirements of a visiting nuclear aircraft carrier (CVN). There are two proposed CVN wharf alternative locations at the entrance to the Inner Apra Harbor Channel: Polaris Point and Former Ship Repair Facility (Former SRF). The project involves dredging certain areas in Outer Apra Harbor to allow berthing and transit of CVNs. Project alternatives are described in detail in the *Guam and CNMI Military Relocation Draft Environmental Impact Statement/Overseas Environmental Impact Statement (Navy 2009).*

The Navy is working with federal and Guam agencies including: the United States Fish & Wildlife Service, the National Oceanic and Atmospheric Administration Fisheries Service, the U.S. Environmental Protection Agency, the Guam Department of Agriculture, and the Guam Environmental Protection Agency (collectively referred to as the "Resource Agencies") to determine the mitigation necessary to compensate for expected impacts to coral habitat due to project activities.

Under the new Army Corps of Engineers compensatory mitigation rule, permit applicants are required to mitigate to no net loss of ecological services and function. Habitat Equivalency Analysis (HEA) is a methodology that has been used in a variety of legal and technical contexts to quantify impacts to natural resources and the services/functions they provide, and quantify the amount of restoration/mitigation required to offset documented losses. Coral loss assessment, coral restoration and the parameters used in the HEA are an evolving science. HEA, like any model, relies on user-specified inputs and calculations that simplify complex processes, both of which can introduce uncertainties into model results. However, HEA applications have been published in peer-reviewed technical literature, courts have upheld the use of HEA in litigation, and HEA often underlies settlements reached on cases involving the impacts to and restoration/mitigation of natural resource services and functions. The United States Fish & Wildlife Service (USFWS) and other agencies commonly use HEA to establish the appropriate scale of compensatory restoration in the context of damage assessments conducted under the 1990 Oil Pollution Act (OPA) and the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA), and have endorsed the use of HEA in other Navy dredging projects in Apra Harbor.

Compensatory mitigation is being derived through the use of the HEA, a tool used to estimate the type and magnitude of restoration required to offset ecological impacts arising from a specified event. The HEA addresses direct and indirect impacts to coral habitat arising from dredging to support CVN berthing and maneuvering in Outer Apra Harbor. The Navy's inputs to the HEA are based on site-specific data and analyses, information from relevant literature, and the professional judgment of technical experts. With respect to impact quantification, HEA results indicate that approximately 1,048 acre-years (424.1 ha) are anticipated to be lost due to the direct and indirect effects of dredging for the Polaris Point Alternative Approximately, 1,023 acre-years (414.0 ha) would be lost due to dredging for the Former SRF Alternative.

The Navy has identified construction of artificial reefs versus watershed management projects to compensate for lost coral habitat in Outer Apra Harbor for the HEA. Because quantitative estimates of the levels of habitat improvement can be developed for an artificial reef project, the HEA used the provision of artificial reefs as a way to calculate the scope of mitigation needed to offset the estimated losses. Estimates of the marine habitat benefits that artificial reef could provide are based on site-specific data and analyses, information from relevant literature, and the professional judgment of technical experts. Results indicate that a total of approximately 123 acres (49.8 ha) of artificial reef are required to

[1] Project background provided in *Draft EIS/OEIS for Guam and CNMI Military Relocation*. Prepared for NAVFAC Pacific. Anticipated DEIS publication in November 2009.

compensate for coral reef habitat impacts due to the Polaris Point Alternative.2 Approximately 121 acres (49.0 ha) of artificial reef would be required for mitigation of impacts due to the Former SRF Alternative.

[2] Assuming deployment of 300 Z-blocks per acre of subtidal bottom, a common approach utilized by the State of Hawaii's artificial reef program. As site-specific conditions warrant, mitigation needs also could be met using greater Z-block densities on proportionally fewer acres (or vice-versa). Such changes likely would have a negligible effect on mitigation cost estimates presented in this chapter.

2.0 INTRODUCTION

As noted above, the Navy proposes to construct a new wharf at one of two alternative locations in Outer Apra Harbor: Polaris Point or the Former Ship Repair facility (Former SRF). The project is located in Outer Apra Harbor on the western coast of Guam, the southern-most and largest island in the Marianas archipelago in the western Pacific Ocean. HEA calculations were performed for each of the project alternatives. Implementation of either of these Alternatives would involve construction of docking facilities, dredging a turning basin and navigation channel.

The Navy and the Resource Agencies are engaged in discussions on the mitigation necessary to compensate for expected impacts to coral habitat arising from dredging-related activities. Mitigation requirements are being determined through the use of HEA, a technique commonly applied in natural resource damage assessment and similar contexts to estimate the type and magnitude of restoration (or mitigation) required to offset ecological impacts arising from a specified event. In general terms, information required to apply the HEA methodology includes estimates of: 1) the geographic extent, severity, and duration of habitat impacts; 2) the timing, magnitude and duration of mitigation project benefits; and 3) an appropriate discount rate, used to adjust for differences in timing between impacts and restoration benefits. Other factors, including mitigation project costs and likelihood of success, can be incorporated to evaluate cost-effectiveness and/or other project evaluation criteria, as appropriate.

HEA is a methodology that has been used in a variety of legal and technical contexts to quantify impacts to natural resources and the services/functions they provide, and quantify the amount of restoration/mitigation required to offset documented losses. Coral loss assessment, coral restoration and the parameters used in the HEA are an evolving science. HEA, like any model, relies on user-specified inputs and calculations that simplify complex processes, both of which can introduce uncertainties into model results. However, HEA applications have been published in peer-reviewed technical literature, courts have upheld the use of HEA in litigation, and HEA often underlies settlements reached on cases involving the impacts to and restoration/mitigation of natural resource services and functions. The United States Fish & Wildlife Service (USFWS) and other agencies commonly use HEA to establish the appropriate scale of compensatory restoration in the context of damage assessments conducted under the 1990 Oil Pollution Act (OPA) and the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA), and have endorsed the use of HEA in other Navy dredging projects in Apra Harbor.

The purpose of this report is to provide a transparent, objective evaluation of the type and scale of mitigation required to offset estimated coral habitat losses associated with the CVN project. This document summarizes coral habitat HEA inputs and results, describes the mitigation approach employed in this analysis, and provides specific ecological scaling and cost information for the identified mitigation alternative.

Prior to getting into the details of the HEA analysis, however, we provide a brief summary of information from the technical literature concerning the total economic value of Guam coral reefs. In the Navy's view, this information provides important, relevant context for stakeholders involved in mitigation decision-making.

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3.0 CORAL REEF VALUATION

While the HEA methodology provides information about the expected cost of replacing coral reef functions and services lost due to the CVN project, it also is relevant to consider the value of impacted reefs. Conceptually, estimates of lost value can be considered an upper bound for replacement costs. If the value of something lost is $X, it does not make sense to pay more than $X to replace it.

While difficult to develop a comprehensive estimate of the total economic value of complex natural resources such as coral habitat, several dozen coral reef valuation studies have been published in relevant technical literature. To help understand the potential value of Guam reefs expected to be impacted by the CVN project, we conducted a preliminary search and review of this literature. This search identified over 50 potentially relevant articles, which report a wide range of reef values, reflecting variability in geographic location, demographics, the types and quantities of services valued; the quality of reefs studied, the quality of the studies themselves, and other factors. Studies most commonly examined the economic value or contribution of coral reefs in a recreational and commercial context – fewer address the broader range of services provided by coral reefs (e.g., shoreline protection, biodiversity, cultural use, non-use values, etc.). Because many studies focus on a narrow set of reef services, in ecological, economic and/or demographic contexts different from Guam, most of the literature identified is of limited utility in assessing the potential value of coral reefs expected to be impacted by the CVN project.

However, van Beukering et al. (2005) present a Guam-specific study, utilizing multiple methods to estimate the total economic value of Guam's reefs associated with tourism, water-based recreation, fishing, coastal protection, biodiversity and amenity value (with adjustments made in an effort to address double-counting issues). One of the methods employed was an attribute-based choice survey administered through in-person interviews with 400 Guam residents. The results of this study are summarized in Table 1 below (reproduced from page 82 of the report)[3]. The area column indicates the area of reef in Guam associated with each value category.

Table 1. Spatial Variation of Values of Coral Reefs in Guam

Value Category ($2005)	*Area of Coral (square kilometers)*
Range $0 - $1,000,000	37.62
Range $1,000,0000 - $2,000,000	18.51
Range $2,000,0000 - $3,000,000	1.64
Range $3,000,0000 - $4,000,000	11.68
Range $4,000,0000 - $5,000,000	0.37
Range $5,000,0000 - $6,000,000	0.21
Range $6,000,0000 - $7,000,000	0.71
Range $7,000,0000 - $8,000,000	0.01
Range $8,000,0000 - $9,000,000	0.07
Range $9,000,0000 - $10,000,000	0.05
Range $10,000,0000 - $11,000,000	0.72
Total	71.59

These results suggest a weighted average value for Guam's coral reefs of $1.78 million ($2005) per square kilometer per year, which translates to $0.0081 million ($2009) per acre per year (assuming a 3% annual inflation rate and using the conversion of 247.105 acres [99.99 ha] per square kilometer). Based on this estimate, the average value of a permanently lost acre of coral habitat is $0.27 million ($2009), assuming an annual discount rate of 3%.

[3] Values in Exhibit 1 are $2005 per km^2 of reef per year.

Currently available information discussed in subsequent sections of this document indicates that the CVN project (Polaris Point Alternative) will result in the permanent loss of approximately 33 acres (0.13 km^2), which implies a lost value of approximately $8.9 million ($2009).[4] Sedimentation-related impacts, expected by the Navy to affect a substantially smaller amount of acreage and last only a few years, have a negligible effect on the valuation estimate.

Study authors acknowledge uncertainties in their analysis, and suggest a valuation range extending between 34% below and 28% above their "core" estimate. This implies a lost reef value for the CVN project (Polaris Point Alternative) between approximately $5.9 and $11.4 million ($2009).[5]

[4] The Former SRF Alternative is expected to require approximately 32 acres of dredging, which suggests a lost value of roughly $8.7 million.

[5] The corresponding range in lost value for the Former SRF Alternative is $5.7 to $11.1 million.

4.0 HEA IMPACT INPUTS

As a first step in determining appropriate mitigation, HEA impact inputs to estimate potential coral habitat losses due to dredging were developed, based on currently available information. These inputs reflect site-specific data and analyses, information from relevant literature, and the professional judgment of technical experts familiar with the project plans, potentially affected habitats and biota, environmental impact assessment, and the HEA methodology.

The estimated input values for the variables needed to perform HEA loss calculations, included:

- The acreage of coral habitat expected to be affected by dredging, including direct (dredging) and indirect (dredging-related sedimentation) impacts;
- Live coral coverage, three dimensional surface area and rugosity (a measure of the topographic complexity of the reef surrounding the sample point) to characterize differences between coral habitat that will impact the type and level of functions and services provided by them;
- The expected severity and duration of expected impacts, relative to baseline conditions (i.e., the anticipated future condition of coral habitat in the project area if the CVN project never occurred); and
- The shape of the recovery curve, the period over which losses are calculated, expected project timing and an appropriate discount rate.

This analysis focuses on the coral habitat expected to be either permanently lost due to dredging or temporarily affected by sedimentation. Much of the habitat within the dredge footprint is unconsolidated soft sediment with no coral cover (Smith, 2007; Dollar and Hochberg, 2009). Soft bottom habitat is not addressed in this HEA.

4.1 CHOICE OF HEA METRIC

HEA is a methodology that helps stakeholders evaluate whether the natural resource services lost as a result of an injury and those provided by the compensatory restoration are comparable in terms of type, quality and magnitude. HEA requires that practitioners estimate impacts and mitigation using a common metric (or metrics) that reasonably reflects the type, quality and magnitude of ecosystem services provided by the resource in question, recognizing that such services can be difficult to fully identify and/or quantify. While the choice of metric is critical to the HEA process, there may be no single universal metric applicable to all coral reef situations. Viehman et al. (2009) provide a review of coral reef metrics used in HEA applications in terms of robustness, flexibility and predictive value. These authors recognize that while relatively simple metrics that have been historically used, future directions will undoubtedly move toward a more holistic system of metrics that more accurately reflect the complexity of coral reef systems.

Traditionally, a two-dimensional measurement of all living coral tissue in terms of either percent cover or absolute area has been used as a single HEA input metric. The advantage of a coral cover metric is that the service flow is intuitive; the amount of total coral cover injured requires that a similar amount of coral cover is restored. Coral cover has been a common parameter in reef assessments since the initial pioneering studies in the field of coral reef science. As in the present case of the CVN field surveys, measurement of coral cover is straightforward and data is collected relatively easily and rapidly. In addition, with a single coral metric that treats all species equally, no weighing factors are required within the HEA to equate for different levels of service contributions by different species.

On the other hand, a coral cover metric alone does not address variations in ecosystem services provided by different coral species or functional groups, nor whether services scale with size or age. However, such a species-oriented approach that is not based solely on overall coral cover requires knowledge of such species-specific factors as growth rates and variation in ecosystem services as a function of size. It is important to note that rarely have such coral species functions been defined with respect to differentiation by species, growth forms, colony sizes, and within a particular habitat. Thus, both the strength and the weakness of coral cover metrics is the non-inclusion of population or species-specific ecosystem services.

Viehman et al. (2009) also point out that one of the criticisms of two-dimensional metrics such as coral cover or size-frequency distributions is that none adequately capture the factors associated with the complexities associated with the three-dimensionality of reef systems. Services associated with the three-dimensional structure of the reef, and captured within a metric included in the HEA equation, would be a step in the direction of achieving a more encompassing picture of reef function. When coupled with a biological metric (e.g., coral cover) a metric representing the physical complexity of the reef could produce a combined attribute that takes a step toward the "holistic" system of metrics that Viehman et al. (2009) suggest is the direction of future HEA applications.

With the concept of combining biological and three-dimensional structural habitat factors in mind, the Navy team developed a composite metric for use in the CVN HEA. More specifically, a relative "coral habitat index" was developed that described the convolution of coral cover and topographical complexity of the reef. In this case, topographic complexity is defined as rugosity of the reef, and is calculated as the ratio of the slope of the bottom to horizontal distance across the bottom. As both coral cover and rugosity are parameters that are generally accepted by reef science and management communities as important components of reef structure and function, the combined metric should reflect some "value" of a reef. In addition, both of these parameters are available from the remote sensing products developed from satellite imagery and calibration/validation data generated from the CVN field surveys conducted in April-May 2009 (see Dollar and Hochberg 2009). Hence, values of the habitat index are available for each pixel (pixel area of 5.76 m^2) of the entire study area of approximately 700,000 m^2 within Apra Harbor.

The detailed steps in developing the habitat index are presented in Appendix A. In brief, the habitat index is developed as follows. First, the proportional coral cover in each pixel is multiplied by the three-dimensional surface area of that pixel, resulting in a three-dimensional coral area. The resulting value is then multiplied by a two-dimensional rugosity value, convolving coral cover with reef structure. A value of 1 is then added to the result, and the base-10 logarithm is calculated in order to spread out the index more evenly. "Levels" are chosen as 10 equally spaced bins across the range of habitat values, which are then tracked through the HEA as described throughout this chapter.

4.2 HABITAT TYPE AND AFFECTED ACREAGE

Based on pixel counts from the remote sensing map, the total area ("plan" view) with any level of coral coverage is about 24 acres (96, 073 m^2) for the Former SRF alternative and about 25 acres (101,981 m^2) for the Polaris Point alternative. The area calculations assume dredge depth of 60 ft (18 m), which is an overestimate compared to the proposed dredged depth of 51.5 ft (15.7 m), including overdredge.

Data and analysis from Dollar and Hochberg (2009) also allow estimation of the three dimensional area of coral habitat within the dredge footprint. This is accomplished by merging Quickbird multispectral imagery, field survey habitat data (Dollar and Hochberg 2009), and reef rugosity derived from bathymetric data (airborne Lidar and boat hydrographic surveys, obtained from Sea Engineering). Table 2 shows the ten categories of coral habitat that integrate the readily available, study area-wide data on live coral coverage, three dimensional surface area, and rugosity. See Appendix A for a description of the methodology used to develop the coral habitat categories. This combined parameter, "coral habitat index", is presented in a logarithmic scale.

As shown in Table 3, the total area (three dimensional view) of habitat with some coral coverage is approximately 33 acres (132,238 m^2) for the Polaris Point alternative, and approximately 32 acres (128,520 m^2) for the Former SRF alternative. These areas are predictably greater than the two dimensional areas described above. These three dimensional calculations are also based on the overestimated 60-ft (18m) dredge depth.

The acreage of coral habitat subject to "indirect" impacts (i.e., dredging-related sedimentation) was conservatively defined to include coral habitat within 656 ft (200 m) of the outer edge of the dredge area. Plume modeling results (Sea Engineering 2009)[6] suggest that cumulative sediment deposition during CVN project construction totaling at least 1,000 mg/cm^2 (approximately 6 mm based on site-specific sediment characteristics) will only accumulate up to about 39 feet (ft) (12 m) beyond the area subject to direct impacts (see Figure 1).[7] Thus plume modeling suggests that any indirect impacts associated with this level of sediment accumulation 0.23 inches (at least 6 mm) will affect an additional estimated14.5 acres (5.85 ha) coral habitat for both the Polaris Point and Former SRF alternatives. Nevertheless, the Navy conservatively assumes that coral habitat up to 656 yards (200 m) from the dredge footprint will be subject to impacts from sedimentation. Table 2 classifies coral habitat subject to indirect effects using the same categories, methodology and data described above for direct impacts. Category 1 represents the least amount of coral coverage and rugosity, and Category 10 represents the most coral coverage and rugosity.

Table 2. Coral Habitat Index Categories

Coral Habitat Index Category	***Coral Habitat Index Range of Values (log_{10})***
Category 1	0 to ≤ 0.235
Category 2	0.235 to ≤ 0.471
Category 3	0.471 to ≤ 0.706
Category 4	0.706 to ≤ 0.942
Category 5	0.942 to ≤ 1.177
Category 6	1.177 to ≤ 1.413
Category 7	1.413 to ≤ 1.648
Category 8	1.648 to ≤ 1.884
Category 9	1.884 to ≤ 2.119
Category 10	2.119 to ≤ 2.355

[6] See Section E of *Habitat Equivalency Analysis and Supporting Studies.*

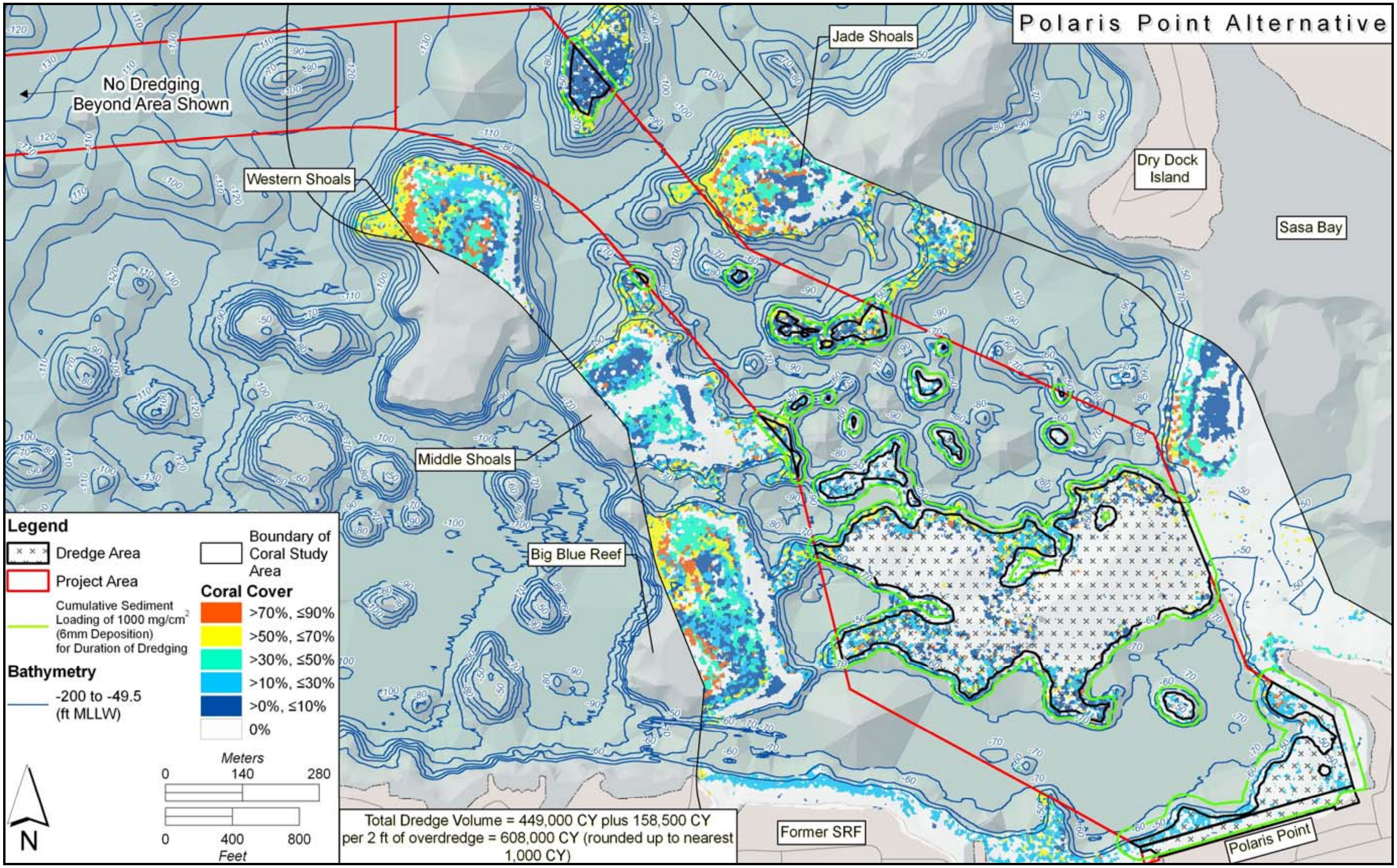
[7] Model results suggest that the maximum sediment accumulation at any location beyond the dredge footprint will be approximately 1 centimeter.

Table 3. Coral Habitat Area (3-dimensional) Subject to Direct and Indirect Impacts

Project Alternative	*Coral Habitat Index Category*	*Direct Impact Area*		*Indirect Impact Area*	
		Area (square meters)	*Area (acres)*	*Area (square meters)*	*Area (acres)*
Polaris Point	Category 1	40,337	9.96	54,712	13.51
	Category 2	32,382	8.00	50,202	12.40
	Category	23,810	5.88	62,345	15.40
	3Category	21,685	5.36	41,354	10.21
	4Category 5	9,454	2.34	27,009	6.67
	Category 6	3,573	0.88	20,260	5.00
	Category 7	951	0.23	12,829	3.17
	Category 8	47	0.01	4,266	1.05
	Category 9	0	0	1,111	0.27
	Category 10	0	0	716	0.18
	Subtotal	132,238	32.7	274,804	67.9
Former SRF	Category 1	38,349	9.47	56,751	14.02
	Category 2	30,882	7.63	50,316	12.43
	Category 3	23,667	5.85	63,885	15.78
	Category 4	22,049	5.45	43,925	10.85
	Category 5	9,298	2.30	28,915	7.14
	Category 6	3,470	0.86	22,489	5.55
	Category 7	780	0.19	14,863	3.67
	Category 8	25	0.01	5,146	1.27
	Category 9	0	0	1,244	0.31
	Category 10	0	0	716	0.18
	Subtotal	128,520	31.7	288,250	71.2

Notes:
Area estimates provided by Dollar and Hochberg (personal communication, 2009), derived from their 2009 spring survey data (Dollar and Hochberg 2009). These area estimates are based on 3-dimensional assessment and differ from the planar (2-dimensional) areas described in the *Assessment of benthic Community structure in the Vicinity of the Proposed Turning Basin and Berthing Area for Carrier Vessel Nuclear (CVN) Apra Harbor (Volume 9 Appendix J of the EIS/OEIS),*

Figure 1. Estimated Limits of Sediment Accumulation Exceeding ¼ inch (6 mm) During the Entire Dredging Duration



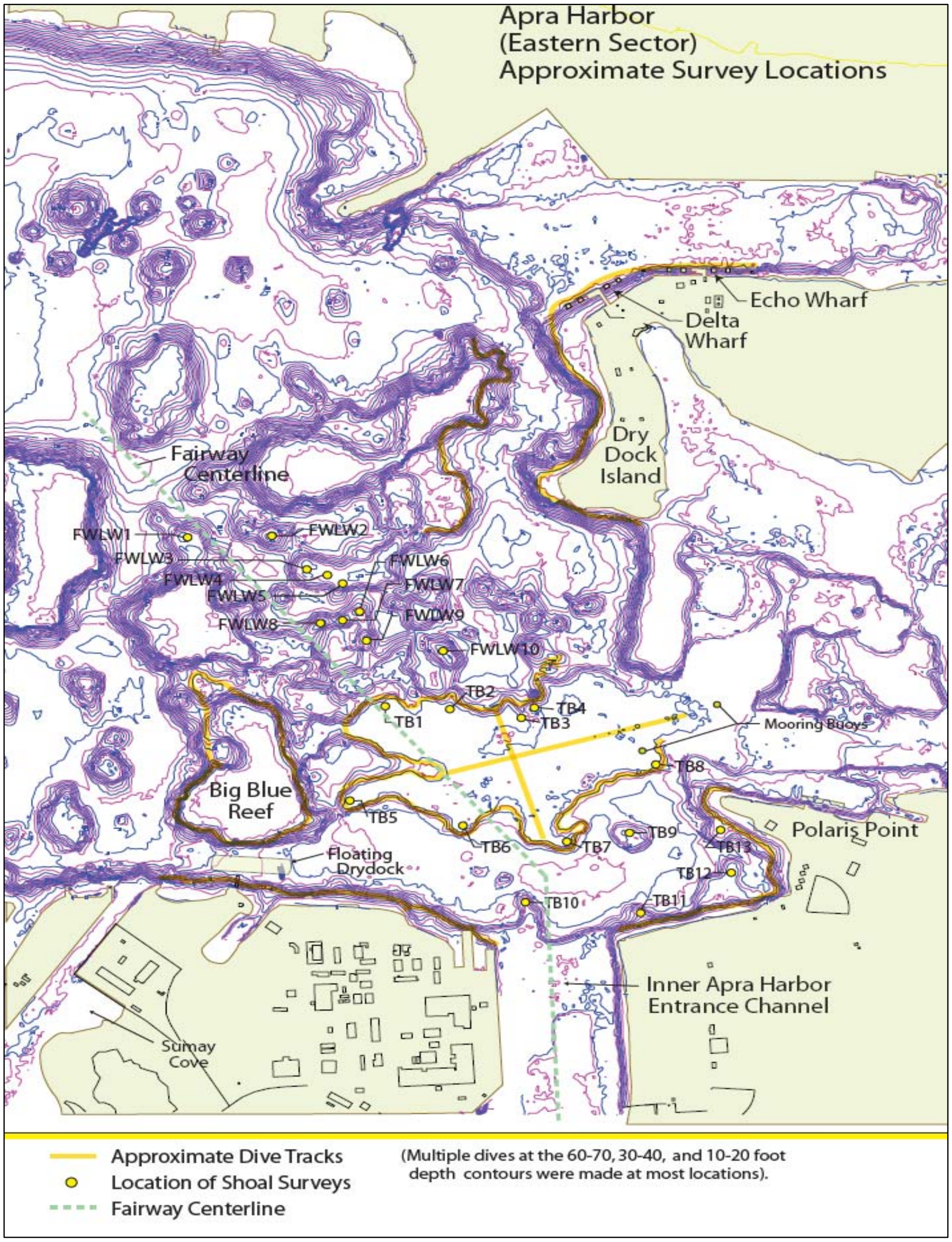
4.3 BASELINE CONDITION OF AFFECTED CORAL HABITAT

HEA calculations require an understanding of the condition of affected resources in the absence of the planned impact. Smith 2007 provides information concerning the condition of coral habitat in the project area. That study provides information obtained from 152 person dives in the eastern portions of Apra Harbor during July 2006 and May 2007. The dives were supported by the Naval Base Guam Dive Locker. Approximate shoal survey locations are shown in Figure 2 (reproduced from Smith 2007).

Some of the shoal sampling locations and dive tracks in Smith 2007 are in portions of eastern Apra Harbor that are not expected to be impacted by the CVN project. Based on descriptions provided in Smith 2007, dive tracks (yellow lines in Figure 2) near Polaris Point, Turning Basin (i.e., near and between sampling locations with the prefix “TB”) and Fairway (sample sites with the prefix “FWLW”) appear to be within areas expected to be impacted by the CVN project. Fairway is a term used to describe the ship navigation channel. All shoal sampling locations also appear to be within the project area. In the opinion of Smith (2007) coral habitat expected to be affected by the CVN project currently is, in general, “of marginal to modest ecological value.” Relevant excerpts and data from Smith (2007) include:

- When reef survey zones are "ranked" by scaling a variety of variables (percentage of sea floor covered by coral, reef complexity and rugosity, species diversity, coral “health", size frequency distribution of coral colonies, diversity and abundance of sessile macro-benthos other than corals (e.g., sponges), diversity and abundance of mobile macro-invertebrates, and the diversity and abundance of fin fishes), the areas within the dredge footprint (Turning Basin, Fairway (i.e. navigation channel) Shoals and Polaris Point) rank lowest on the scale, and are consistently lower ranked than the sites that are outside the footprint. The highest ranking was given to the Big Blue Reef West, likely owing to protection from exposure to water quality factors associated with Inner Apra Harbor and ship-induced effects.
- The coral reefs at in the Fairway [channel between Western and Jade Shoals], and Turning Basin] appear to be of marginal to modest ecological value, based upon the eight criteria [i.e.,].
- The coral reef in the Polaris Point/Bay segment is of marginal quality and showed the greatest signs of stress. This stress appeared to be due in part to high levels of total suspended solids (TSS) coming from Inner Apra Harbor.
- Coral diversity (as measured by relative densities) is low. Although multiple coral taxa were observed at sampling locations within the project area, *Porites rus*, *Porites cylindrica* and Porites spp. comprised a substantial majority of all coral observed.
- Coral mean size (maximum measurement parallel to the sea floor) is relatively low, and some corals in the project area appear to show signs of stress.
- In the Polaris Point/Bay area, a substantial percentage of the coral at all depth contours was growing on metallic and/or concrete debris. It is arguable whether or not the Polaris Point/Bay community should be considered a coral reef. What is clear, however, is that more of the corals within the Polaris Point/Bay segment had copious mucous secretions and more algal overgrowth than at any other location in Apra Harbor evaluated during the current study or other recent Navy studies.

Figure 2. Survey Locations from Smith 2007 (Figure 4 in Smith 2007)



Data and analysis from the spring 2009 survey are provided elsewhere, but summary observations and descriptions of impact area coral habitat in the spring survey report (Dollar and Hochberg 2009) include:

- 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. This area was dredged in 1946 to allow safe access to the newly completed Inner Apra Harbor (R. Wescom, personal communication).

- "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".
- 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. In addition, many colonies growing in areas of abundant sediment had portions of the colonies covered with fine-grained sand or mud.
- 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 [described below]). Of the area in both alternatives that contains any coral, this class comprises about 38% of the total. In both alternatives, over half (~75%) of area with any coral cover is within Classes 2 and 3 (i.e., $0\% < \text{coral} \leq 30\%$).
- 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 7-9% of bottom cover and 20% 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.
- Size-frequency distribution of the longest chord length of the four most abundant corals in the CVN survey area are provided, 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). Dollar and Hochberg state "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 31 inches (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. In all strata, the two size classes with a lower bound of 1.9 inches (5 cm) and an upper bound of 7.9 inches (20 cm) were the most abundant.

4.4 INITIAL SERVICE LOSS

This parameter provides a measure of the severity of the adverse effect by estimating the percentage of ecological services lost at the initiation of dredging activities. For direct impacts, the HEA assumes an initial 100% loss in ecological services (i.e., suffer a complete loss of ecological function). For indirect impacts, affected habitat is expected to experience an initial 25% loss. This estimate is consistent with the expectation that cumulative sedimentation caused by dredging is expected to be low (less than approximately one centimeter in affected areas), and the relatively lower sensitivity of dominant coral in affected area (*Porites rus* and *Porites cylindrica*) to such levels of sedimentation.

4.5 DURATION OF INJURY

Areas directly impacted by dredging are considered permanently injured, and therefore experience a 100% loss in ecological services in perpetuity (i.e., no recovery). Any recovery would be lost during future maintenance dredging.

Indirect impacts are expected to be temporary, and affected areas are expected to recover to baseline condition within five years, which the Navy believes to be a conservative assumption in light of the expected low level of initial impact and relevant literature (e.g., Brown et al.'s (1990) study of dredging impacts on intertidal coral reefs at Ko Phuket, Thailand, which suggests a one to two year recovery period is reasonable for impacts of this type).

4.6 RECOVERY TRAJECTORY

As noted above, areas subject to direct impacts are not expected to recover. For areas subject to indirect effects, linear recovery is utilized for HEA purposes. Given the relatively short recovery time expected for these areas, the functional form of the recovery trajectory has a minimal impact on HEA calculations.

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5.0 HEA IMPACT RESULTS

The information provided above facilitates an estimate of the discounted service acre-years expected to be lost due to CVN dredging-related activities. The "acre-year" metric allows the analysis to consider not only the number of acres lost, but also injury severity and recovery over time. A loss of one acre-year equates to a complete loss of ecological function provided by the identified habitat for one year. Such a loss could be arrived at in numerous ways (e.g., 50% degradation of two acres of habitat for one year, 10% degradation of five acres of habitat for two years, 5% degradation of one acre of habitat for 20 years, etc.).

The simplified examples above do not take into account the effects of discounting, which is applied in the HEA methodology to convert losses occurring in different years into a single, common year. We apply a 3% annual discount rate in our calculations, which is the most common discount rate used in HEA applications and one that research indicates reasonably reflects society's general preference for current use and enjoyment of resources, compared to future resource use and enjoyment (NOAA 1999, Freeman 1993). The sum of these discounted losses across years represents the present value acre-years of ecological services lost.

Tables 4 and 5 summarize the data used in the HEA calculations to estimate CVN-related coral habitat impacts and the resulting loss estimates. As shown in Tables 3 and 4, Polaris Point is expected to result in a loss of approximately 1,048 discounted service acre-years (DSAYs) of coral habitat (across all coral habitat categories), approximately 996 DSAYs due to direct impacts and 52 DSAYs due to indirect impacts. The Former SRF Alternative is expected to result in a loss of approximately 1,023 DSAYs (969 DSAYs due to direct impacts) and 54 DSAYs due to indirect impacts.

Table 4. HEA Loss Calculations for Direct Impacts Arising from the CVN Project

Project Alternative	Habitat Index Category	Year Dredging Occurs	Estimated Post-Dredging Service Level (Initial)	Year Recovery Begins	Length of Recovery Period (years)	Shape of Recovery Curve	Post-Dredging Service Level	End of HEA Analysis Period	Estimated Loss (2009 DSYs)
Direct Impacts									
Polaris Point	Category 1	2012 (a)	0% (b)	None (c)	No Recovery (c)	N/A (c)	0% (c)	Perpetuity (d)	303.93
	Category 2								243.99
	Category 3								179.40
	Category 4								163.39
	Category 5								71.23
	Category 6								26.92
	Category 7								7.17
	Category 8								0.35
	Category 9								0.00
	Category 10								0.00
	Subtotal								996.37
Former SRF	Category 1	2012 (a)	0% (b)	None (c)	No Recovery (c)	N/A (c)	0% (c)	Perpetuity (d)	288.95
	Category 2								232.69
	Category 3								178.32
	Category 4								166.13
	Category 5								70.06
	Category 6								26.15
	Category 7								5.88
	Category 8								0.18
	Category 9								0.00
	Category 10								0.00
	Subtotal								968.36

Notes:
a) Estimated year for dredging implementation.
b) Assumes complete loss of coral habitat services, beginning immediately after dredging.
c) Assumes ongoing maintenance of dredge channel will prevent significant re-establishment of coral in dredged areas.
d) HEA impacts calculated in perpetuity.
Refer to Table 2 for the Coral Habitat Index range per category

Table 5. HEA Loss Calculations for Indirect Impacts Arising from the CVN Project

Project Alternative	Habitat Index Category	Year Dredging Occurs	Estimated Post-dredging Service level (Initial)	Year Recovery Begins	Length of Recovery Period (Years)	Shape of Recovery Curve	Post-Dredging Service Level	Estimated Loss (2009 DSYs)
Indirect Impacts								
Polaris Point	Category 1 Category 2 Category 3 Category 4 Category 5 Category 6 Category 7 Category 8 Category 9 Category 10 Subtotal	2012 (a)	75% (b)	2013 (c)	5 (d)	Linear (e)	100% (f)	10.31 9.46 11.75 7.79 5.09 3.82 2.42 0.80 0.21 0.13 51.79
Former SRF	Category 1 Category 2 Category 3 Category 4 Category 5 Category 6 Category 7 Category 8 Category 9 Category 10 Subtotal	2012 (a)	75% (b)	2013 (c)	5 (d)	Linear (e)	100% (f)	10.70 9.48 12.04 8.28 5.45 4.24 2.80 0.97 0.23 0.13 54.32

Notes:

a) Estimated year for dredging implementation.
b) A modest (25%) initial service level loss is consistent with the expectation that cumulative sedimentation caused by dredging is expected to be low (less than approximately 1 cm), and the expected low sensitivity of dominant coral in affected area (*Porites rus* and *Porites cyindrica*) to such levels of sedimentation.
c) Recovery is assumed to begin the year after the completion of dredging (i.e. 2013).
d) A five-year recovery time is conservative in light of the expected low level of initial impact and relevant literature (e.g., Brown et al's (1990) study of dredging impacts on intertidal coral reefs at Ko Phuket, Thailand, which suggests a one to two year recovery period is reasonable for impacts of this type).
e) For simplicity (and in the absence of field data warranting a different approach), a linear recovery rate is utilized for HEA purposes.
f) Affected coral communities are expected to fully recover ton baseline condition.

Refer to Table 2 for the Coral Habitat Index range per category

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6.0 MITIGATION ALTERNATIVES

To mitigate the predicted impacts to marine habitat in Apra Harbor due to the CVN project, potential projects were proposed that would provide compensatory ecological services similar in type and magnitude to those lost.

One alternative proposed by the Resource Agencies involves watershed management projects to control the flow of sediment into one or more bays in Guam, as is planned for Cetti Bay to mitigate for the losses due to Kilo Wharf extension (under construction). Reduced sediment load is expected to improve water quality, which may allow existing corals to improve and to re-colonize currently degraded areas. The Navy has not incorporated this mitigation approach into its HEA, however, due to an absence of data needed to reliably estimate the scale of project required. Ultimately, one needs to determine the number of acres of reforestation/sediment management needed to generate sufficient improvements in coral habitat to offset expected CVN project impacts. While HEA calculations can be run to estimate required project scale under various hypothetical scenarios, at the current time readily available information is not sufficient to determine which scenario is most likely to reflect reality.

To make that determination, quantitative information linking measureable changes in watershed management to quantified improvements in water quality and coral habitat over time is needed. While that type of information may be obtainable, to the Navy's knowledge such data has not been collected for bays in Guam. Further, the extent to which watershed management approaches would involve private landowners, and the magnitude of likely improvements that could be obtained without private landowner participation (or with their partial participation), adds to the uncertainties associated with this alternative.

The Navy understands that a sediment management project is of high priority to the Resource Agencies. To determine the level of funding to be applied for watershed management (or other project priorities identified by Resource Agencies), the Navy estimates the cost of an appropriately sized artificial reef project. The funding resources identified can then be used, via an in-lieu fee/mitigation bank program if it established in time, to implement mitigation projects like watershed management (or other projects lacking definitive scientific information). The in-lieu fee/mitigation bank program would require a mitigation plan as would a permitee-directed mitigation project.

As discussed in more detail in following sections of this document, well-designed and properly placed artificial reefs can be effective in establishing productive reef habitat for the complete matrix of marine life associated with natural reefs (e.g., macrobenthos, marine invertebrates, fishes, and corals). As described previously in this chapter, the coral reef habitat expected to be impacted by the CVN project appears to be "of marginal to modest ecological value" (Smith 2007, page 28) for reasons unrelated to the CVN project. Given the characteristics of the specific habitat expected to be affected by the CVN project, it is reasonable to believe that artificial reefs can relatively rapidly provide replacement functions and services of similar type and quality.

Creation of an artificial reef was the mitigation approach required to address the loss of coral habitat associated with the Ocean Point Marina project in Hawaii. As stated in a 2004 memorandum of agreement between the project proponent (HASEKO, Inc.) and Hawaii's Department of Land and Natural Resources, Aquatic Resources Division and the U.S. Army Corp of Engineers, Pacific Ocean Division, artificial reef mitigation was required by Special Condition #13 to HASEKO's Department of the Army Permit (PODCO 2117). See HDAR 2007, Appendix B.

The U.S. Army Corp of Engineers has supported artificial reefs as compensatory mitigation for coral habitat loss in other districts. For example, the Jacksonville Florida District issued permit 200202344 (IP-DEB) on February 11, 2003 permitted the creation of nearshore artificial reefs as compensation for losses for the Broward County beach nourishment project.

In addition to being an appropriate mitigation approach that has been applied in similar circumstances in Hawaii, readily available information suggests that an artificial reef project is likely to be an achievable, cost effective action compared to the alternatives noted previously in this section.

As discussed in detail in Section A, Chapter 3.3 and briefly described below, the Navy uses artificial reefs as the mitigation project in the HEA to derive compensatory mitigation costs because 1) artificial reefs are one of the potential mitigation projects and 2) there is a lack of a published defensible scientific literature that estimates:

- the volume of sediment reduction expected to be achieved per acre (or other spatial unit) of an aforestation/sediment management project,
- the corresponding unit of improvement in water clarity and/or sedimentation in receiving harbors (especially if project participation is limited to portions of a watershed), and;
- the area of coral regrowth achieved, and the likely magnitude of growth ,due to improved water clarity and/or reduced sedimentation.

These quantifiable relationships are required for the HEA model. If watershed projects are implemented the artificial reef cost could be used as a budget for the watershed projects, since the budget for watershed projects cannot be estimated for lack of science-based inputs to the HEA.

Although a detailed discussion of mitigation implementation is beyond the scope of this document, an in-lieu fee mitigation bank program potentially could potentially apply those funds to watershed management and/or other projects expected to lead to improvements in coral habitat, thereby providing replacement functions and services similar in type and quality to those lost. In this manner, artificial reef project would be used as a “proxy” to determine a reasonable funding level for mitigation efforts. Inputs used in the artificial reef HEA calculations are identified and discussed below.

7.0 HEA ARTIFICIAL REEF HEA MITIGATION INPUTS

To assist in the evaluation of artificial reef as a mitigation alternative, the HEA inputs were developed to estimate the amount of artificial reef habitat required to offset coral reef habitat losses associated with the CVN project. These inputs are based on site-specific data and analyses, information from relevant literature, and the professional judgment of technical experts.

7.1 REEF DESIGN AND EQUIVALENCE RATIO RELATIVE TO BASELINE REEFS

A typical pattern for Z-block placement utilized by the State of Hawaii deploys up to approximately 300 Z-blocks per acre of subtidal bottom in approximately six "sets" of 50 Z-blocks each, resulting in 15 feet (w) x 15 feet (l) x 12 feet (h) [4.5m (w) x 4.5m (l) x 3.7 m (h)] dimensions for each set (HHF 2007). An alternate deployment proposed for the Kalaeloa artificial reef intended to mitigate impacts to coral reef habitat arising from the Ocean Pointe Marina project (also referred to as Hoakalei Marina) would place 350-400 Z-blocks in a single set with dimensions approximately 100 feet (30.5 m) in diameter and 20 feet (6 m) in height (HDAR 2007).

Applying the algorithm used to assign injuries to Habitat Index Categories, an acre of artificial reef (i.e., 300 Z-blocks deployed in a site-appropriate configuration) would be classified in Category 1. Therefore, the Navy utilizes a 1:1 ratio for artificial reef to injured Category 1 reef. Recognizing the greater coral cover, surface area, and/or rugosity of Category 2 habitat, the Navy assumes a 2:1 artificial reef to injured Category 2 reef, a 3:1 ratio artificial reef to injured Category 3 reef, and so on.

7.2 ESTIMATED SERVICE LEVEL GAINS AND TIMING

Some habitat-related services provided by coral reefs (e.g., ecological services associated with substrate, crevasses, and crenulations that provide shelter for variety of organisms) will be replaced within months of artificial reef deployment, as organisms take advantage of the engineered structure provided by the artificial reef. For example, fish have been observed to make use of artificial reef structures within months of their creation (Brock 2005). Artificial reefs comprised of rock piles in the Komodo National Park in Indonesia quickly developed a biofilm, were colonized by coralline algae and other encrusting organisms, and within the first year had many hard coral recruits 0.8 – 1.6 inches (2-4 cm) in diameter (Fox et al 2005). Consistent with these observations, the Navy estimates artificial reefs will provide 10% of baseline service levels in the year immediately following deployment.

Given the baseline condition of affected coral habitat, it is likely that comparable functions and services can be provided by an artificial reef within a decade, on average. Factoring into this estimate is data from Smith 2007, which suggest a baseline coral habitat condition that can be described as not very diverse, young/early successional, and partially degraded. This is not surprising given that much of the area expected to be impacted by the CVN project was subject to substantial dredging during and immediately following World War II and continues to be subject to a variety of anthropogenic stresses.

Further, relevant technical literature suggests that comparable coral communities can be established relatively quickly. For example, initial monitoring results from Fox, et al. (2005) confirmed substantial coral recruitment and growth within the first few years of artificial reef (rock pile) placement in lower current areas in Indonesia. *Porites spp*, the dominant coral present in affected areas, can grow quickly. For example, growth rates of *Porites rus* observed in the Philippines (0.94 in (2.4 cm) per year (from Custodio and Yap 1997) relative to mean coral sizes in the impact area (6.29 - 8.6 in (16-22 cm) suggest that coral can achieve a size comparable to baseline within 10 years. Lirman, et al. (2003) documented rapid development of coral communities on artificial reefs in the Florida Keys dominated by *Porties astreoides* - species richness and abundance were nearly indistinguishable between the restoration structures and reference habitats after six years. Although not on an artificial reef, Colgan (1987) found that species richness, cover and composition recovered within 12 years after a major predation by starfish in Guam, indicating that coral communities can develop quickly on appropriate structure and substrate in appropriate locations. The Navy mitigation budget also includes substantial funds for coral transplantation from areas within the dredge footprint to or near artificial reef locations to speed colonization.

Given the information described above, the Navy estimates that artificial reefs will replace 85% of natural reef functions and services within 10 years of deployment (on average - some specific areas may recover faster, others more slowly). A maximum of 85% services (relative to services provided by affected coral habitat in its "baseline" condition) is incorporated into Navy HEA calculations, conservatively assuming that artificial reefs (even after accounting for equivalence ratios) will not fully achieve the same level of services provided by affected reef habitat.

For simplicity (and in the absence of field data warranting a different approach), a linear recovery rate is utilized for HEA purposes. This implies an annual service gain of 8.3%, based on a 10 year period post-deployment for artificial reefs to provide comparable replacement functions and services. The Navy estimates that this type of artificial reef will provide ecological benefits for 100 years. This estimate is based on the two-block design described above and inclusion of substantial maintenance and contingency allowances in the project budget.

7.3 ARTIFICIAL REEF SITE SELECTION AND POTENTIAL ADVERSE IMPACTS

Site selection is important, both to ensure that artificial reefs are placed in locations where coral communities will develop as anticipated, and to avoid the potential for inadvertent, adverse impacts to neighboring areas resulting from changes to current patterns, natural sediment deposition and removal processes, and/or other factors. Identification of specific locations for artificial reefs in Apra Harbor or other areas in Guam is outside the scope of this document. Nevertheless, numerous observations of coral growing on artificial surfaces in Guam, technical literature documenting success in the region at establishing coral and associated biotic communities at artificial reefs and initial artificial reef siting work undertaken as part of the Kilo Wharf project support the feasibility of this approach. To ensure proper attention is given to siting issues, the Navy's proposed budget for the CVN artificial reef mitigation project includes substantial funding for planning, data collection and site selection.

Some soft bottom habitat will be lost due to the placement of an artificial reef. That is, the habitat directly underlying the footprint of the reef structure and its corresponding ecological services will be permanently altered. The HEA calculations assume there would be no future use or productivity from the coral habitat that will be dredged. Coral regrowth would presumably be removed during future maintenance dredging events to maintain the required water depth. However, there would likely be coral regrowth that could provide minor functions/services provided by dredged areas, which could offset losses of habitat on which artificial reefs are placed. The artificial reef placement sites are expected to also be areas with limited ecological contributions.

8.0 ARTIFICIAL REEF HEA RESULTS

The information provided in this report was used to develop an estimate of the DSAYs gained per acre of artificial reef, discounted in the same manner as HEA loss calculations. Given a total expected loss of 1,048 DSAYS (Table 5), a total of approximately 123 acres (49.8 ha) of artificial reef is required to compensate for coral habitat impacts expected due to the Polaris Point Alternative (Table 6). Results indicate that each acre of artificial reef will provide approximately 22.1 DSAYs (Table 7). Approximately 121 acres (49.0 ha) of artificial reef are required for mitigation of impacts due to the Former SRF Alternative. These calculations assume the natural reef to artificial reef equivalence ratios identified in Table 6 and "standard" artificial reef deployment of 300 Z-blocks per acre. If desired by stakeholders, more (or fewer) Z-blocks could be deployed over a proportionally smaller (or larger) area to meet site and project needs, with negligible impact on project costs.

Table 6. Summary of Coral Habitat Loss Estimates

Project Alternative	*Direct Loss*		*Indirect Loss*		*Total Loss*	
	Habitat Index Category	*Estimated Loss (DSAYs)*	*Habitat Index Category*	*Estimated Less (DSAYs)*	*Habitat Index Category*	*Estimated Loss (DSAYs)*
Polaris Point	Category 1	303.93	Category 1	10.31	Category 1	314.24
	Category 2	243.99	Category 2	9.46	Category 2	253.45
	Category 3	179.40	Category 3	11.75	Category 3	191.15
	Category 4	163.39	Category 4	7.79	Category 4	171.18
	Category 5	71.23	Category 5	5.09	Category 5	76.32
	Category 6	26.92	Category 6	3.82	Category 6	30.74
	Category 7	7.17	Category 7	2.42	Category 7	9.59
	Category 8	0.35	Category 8	0.80	Category 8	1.16
	Category 9	0.00	Category 9	0.21	Category 9	0.21
	Category 10	0.00	Category 10	0.13	Category 10	0.13
	Subtotal	996.37	Subtotal	51.79	Subtotal	1,048.16
Former SRF	Category 1	288.95	Category 1	10.70	Category 1	299.64
	Category 2	232.69	Category 2	9.48	Category 2	242.17
	Category 3	178.32	Category 3	12.04	Category 3	190.36
	Category 4	166.13	Category 4	8.28	Category 4	174.41
	Category 5	70.06	Category 5	5.45	Category 5	75.51
	Category 6	26.15	Category 6	4.24	Category 6	30.39
	Category 7	5.88	Category 7	2.80	Category 7	8.68
	Category 8	0.18	Category 8	0.97	Category 8	1.15
	Category 9	0.00	Category 9	0.23	Category 9	0.23
	Category 10	0.00	Category 10	0.13	Category 10	0.13
	Subtotal	968.36	Subtotal	54.32	Subtotal	1,022.68

Table 7. Estimate of Artificial Reef Acreage Required to Offset Anticipated Coral Habitat Losses

Project Alternative	Habitat Index Category	Artificial Reef to Natural Coral Habitat Equivalence Ratio	Mitigation requirement Adjusting for Equivalence Rations (DSAYs (a)	Year Mitigation Begins	Estimated Services Level Gain (Initial)	Estimated Services Level Gain (Final)	Years Until Final Service Level Gain Achieved	Shape of Recovery Curve	Length of Benefits Calculation (Years)	Gain per Acre of Artificial Reef (DSAYs)	Estimated Quantity of Artificial Reef Required (Acres) (b)
Polaris Point	Cat 1	1:1	314.24	2012	10%	85%	10	Linear	100	22.14	14.19
	Cat 2	2:1	506.89								22.90
	Cat 3	3:1	573.44								25.90
	Cat 4	4:1	684.73								30.93
	Cat 5	5:1	381.61								17.24
	Cat 6	6:1	184.44								8.33
	Cat 7	7:1	67.10								3.03
	Cat 8	8:1	9.25								0.42
	Cat 9	9:1	1.88								0.09
	Cat 10	10:1	1.35								0.06
	Subtotal		2,724.93								123.08
Former SRF	Cat 1	1:1	299.64	2012	10%	85%	10	Linear	100	22.14	13.53
	Cat 2	2:1	484.34								21.88
	Cat 3	3:1	571.08								25.80
	Cat 4	4:1	697.64								31.51
	Cat 5	5:1	377.54								17.05
	Cat 6	6:1	182.32								8.24
	Cat 7	7:1	60.74								2.74
	Cat 8	8:1	9.24								0.42
	Cat 9	9:1	2.11								0.10
	Cat 10	10:1	1.35								0.06
	Subtotal		2,686.00								121.26

Notes:
(a) Numbers in this column equal the estimated total loss for each category identified in Table 5 multiplied by the appropriate artificial reef to natural coral habitat equivalence ratio.
(b) Artificial reef acreage estimates reflect "standard" deployment of 300 Z-blocks per acre. If desired by stakeholders, more (or fewer) Z-blocks could be deployed over a proportionally smaller (or larger) area to meet site and project needs, with negligible impact on project costs.

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Appendix A

Calculations of Coral "Habitat" Index for HEA Modeling

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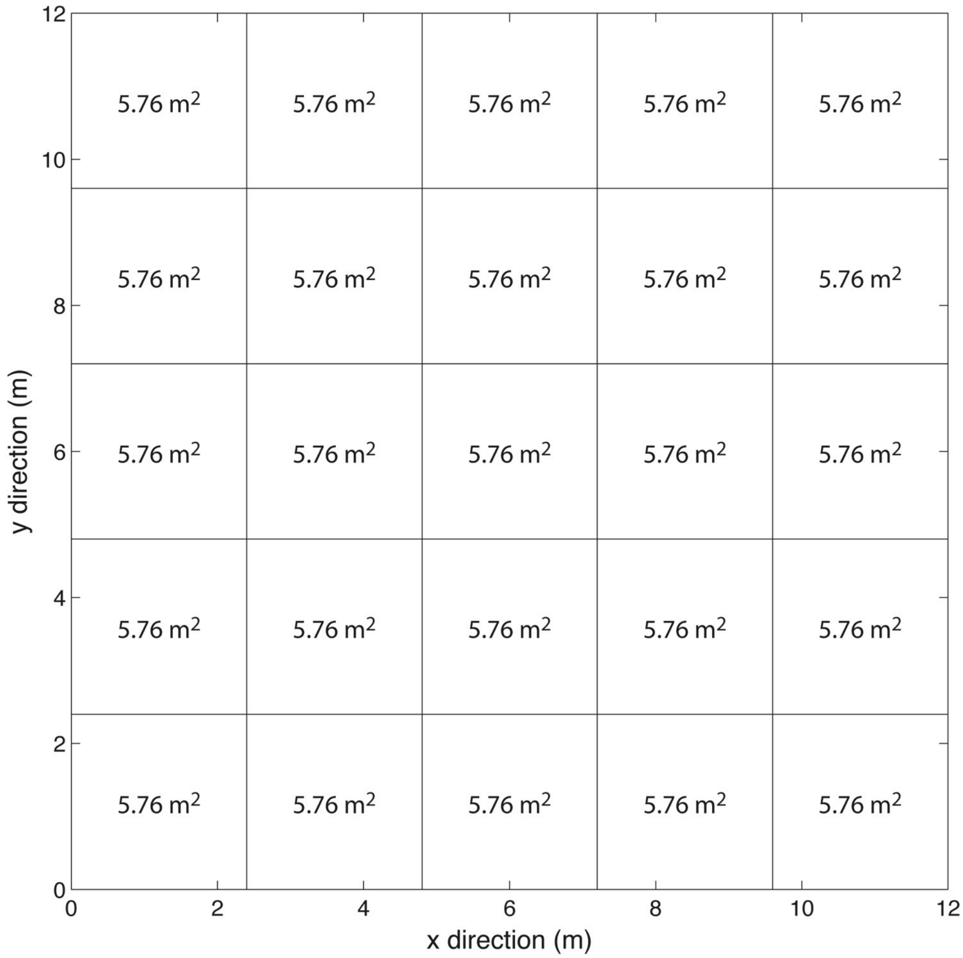
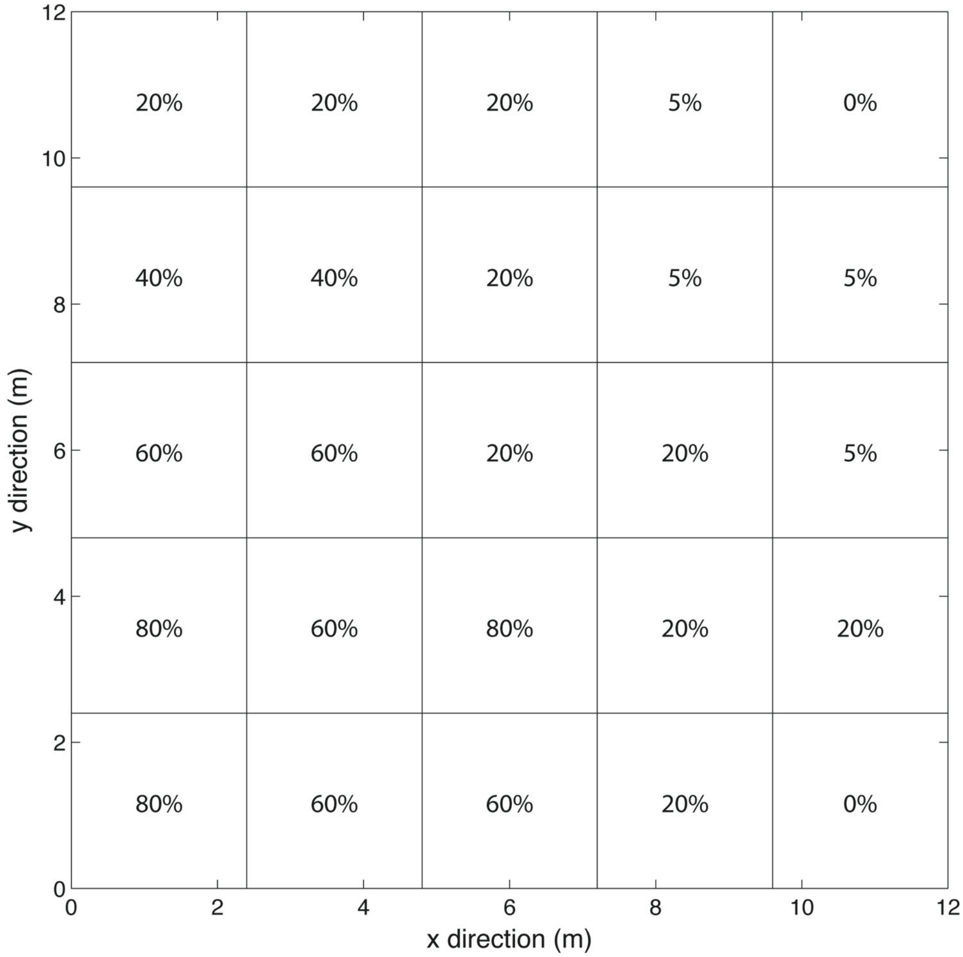
Calculations of Coral "Habitat" Index

The Quickbird image is in plan view. This is how it sees the reef:



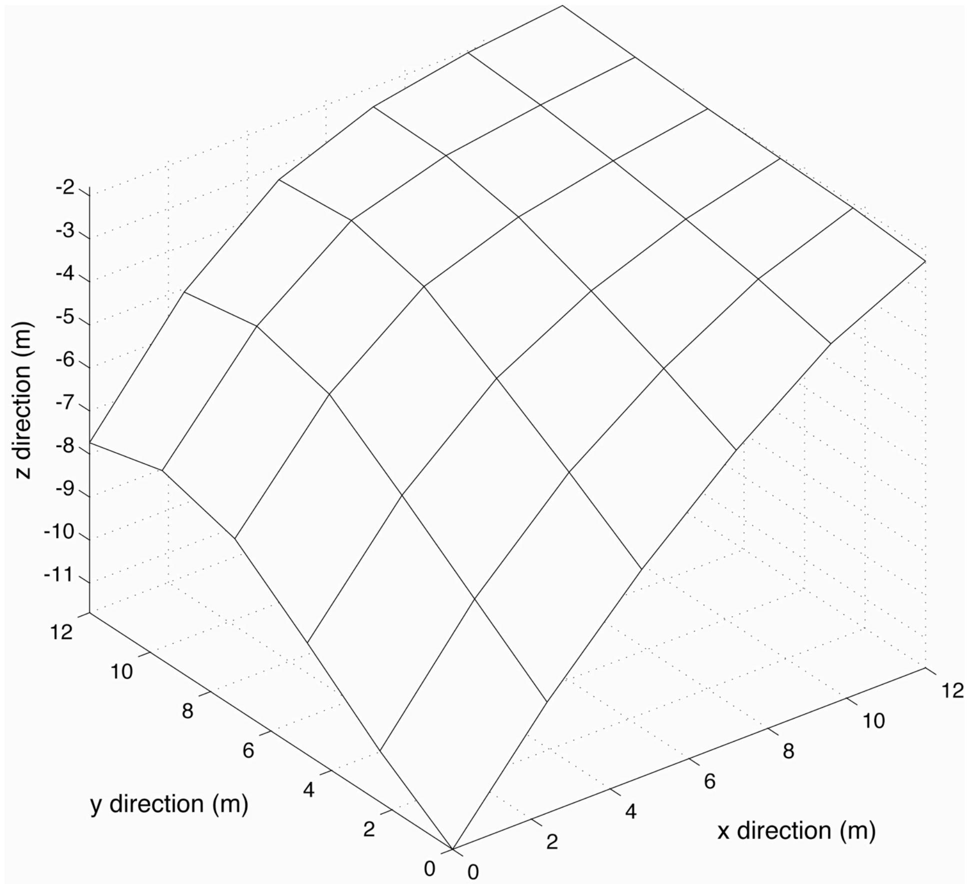
Each pixel is 2.4 m × 2.4 m, or 5.76 m^2. There are 25 pixels in this example, for a total plan-view surface area of 144 m^2.

The image processing and classification use the Quickbird image to identify the percent cover of coral in each pixel. This is the result:



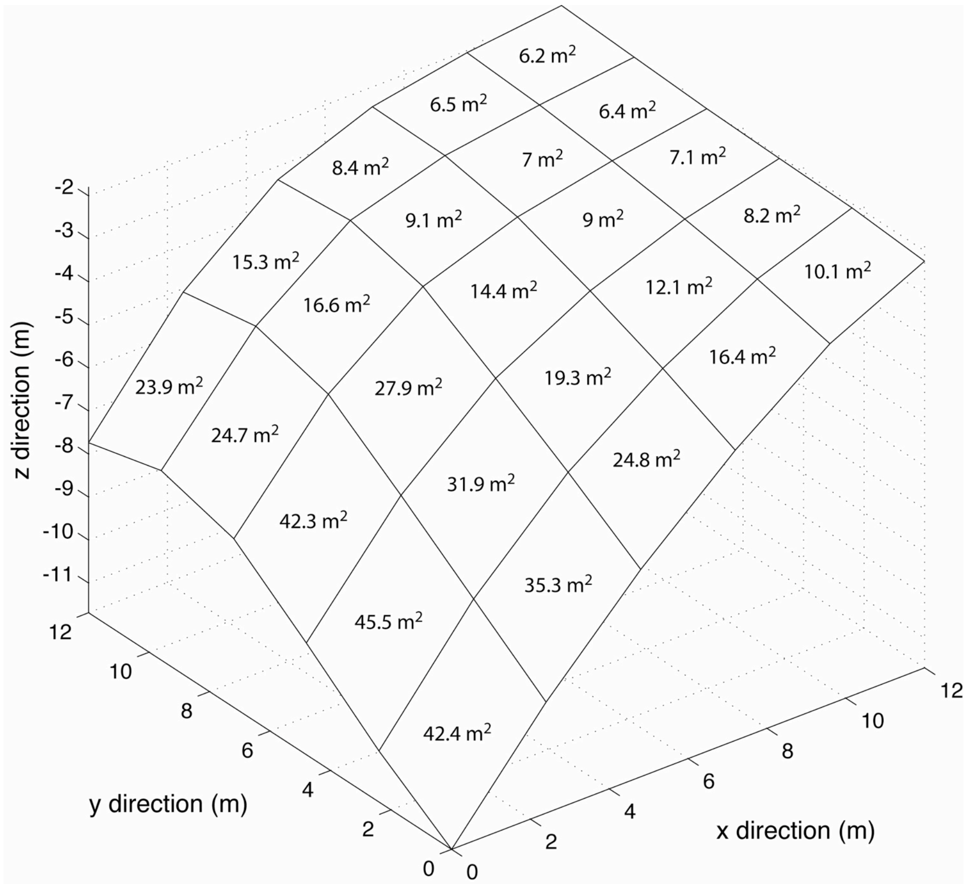
This example contains all the final classes used in the CVN Spring Survey.

The actual reef surface is three-dimensional. Using the available acoustic and lidar soundings, a bathymetric surface was created for the survey area. This is what the surface looks like:



There are still 25 pixels, and the (x,y) coordinates of their corners are still in the same positions. The difference is the addition of the vertical (z) component that describes the vertical offset of each pixel corner. In this example, the depth of the reef ranges from 2 m to nearly 12 m.

By including the z component, it is possible to compute the three-dimensional surface area of each pixel:



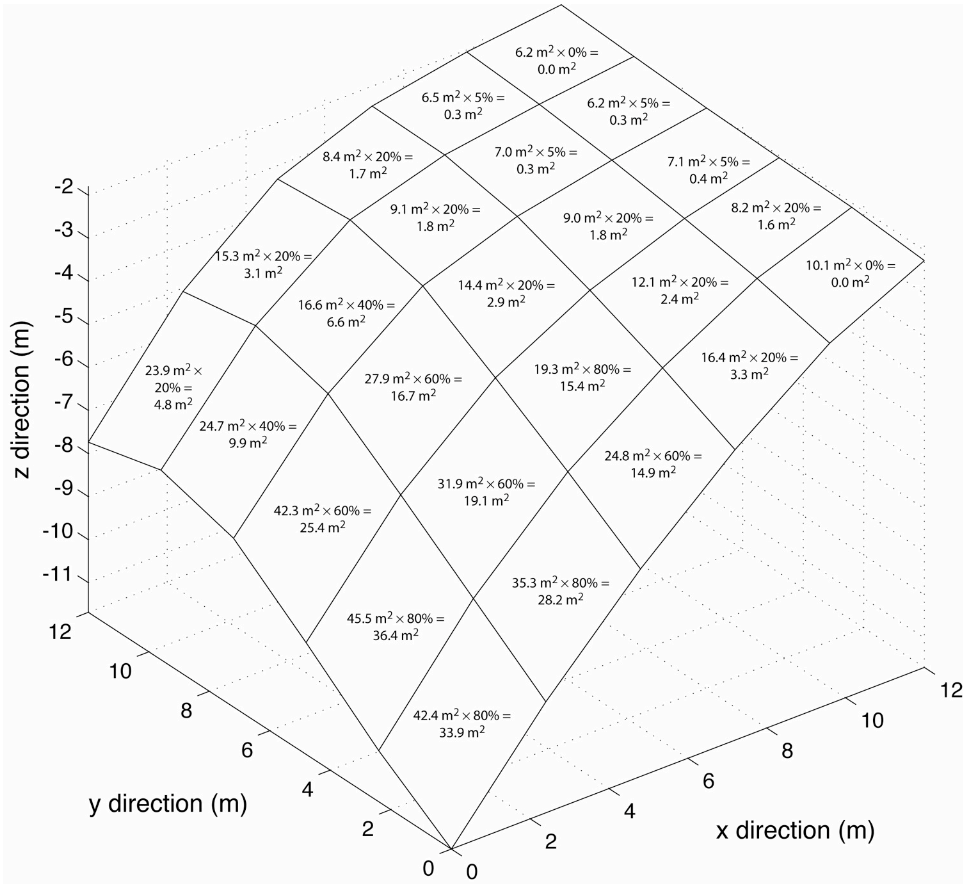
These surface areas are computed using simple geometry. As is obvious, pixels that are close to flat have surface areas near the minimum of 5.76 m^2, while pixels that have steep slopes have much higher three-dimensional surface area. The total surface area in this example is 470.8 m^2.

<u>To calculate rugosity</u>, divide the three-dimensional surface area by the plan-view surface area:

$$470.8 \text{ m}^2 \div 144 \text{ m}^2 = 3.3.$$

This is the rugosity value for the center pixel only (surface area of 14.4 m^2 above). Thus, rugosity describes the topographic complexity of the reef surrounding the pixel of interest. Computing rugosity for other pixels requires moving the 5 × 5 window and recalculating the three-dimensional surface area.

To compute three-dimensional coral area, simply multiply the three-dimensional surface area of each pixel by its percent cover:



These values describe how much coral is in each pixel. To finalize the "habitat" index, multiply the three-dimensional coral area of a pixel by its rugosity value. In this example,

$$2.9\ \text{m}^2 \times 3.3 = 9.57$$

This represents coral surface area convolved with topographic complexity. The distribution of these values is strongly skewed. To reduce the skewness, add one to the value above:

$$9.57 + 1 = 10.57$$

Then take the base-10 logarithm:

$$\log_{10}(10.57) = 1.02$$

This is the "habitat" index value for the center pixel in this example. Note that pixels with 0% coral will have "habitat" index values of 0.

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