FINAL REPORT

PILOT PROJECT SURVEY RESULTS FOR THE NEARSHORE BENEFICIAL USE OF DREDGED MATERIAL AT THE SOUTH JETTY OF THE MOUTH OF THE COLUMBIA RIVER (MCR)

Prepared for:

Lower Columbia Solutions Group
506 SW Mill Street, Suite 720
Portland, OR 97201

and

U.S. Army Corps of Engineers, Portland District
333 S.W. First Avenue
Portland, Oregon 97204

Prepared by:

Science Applications International Corporation
18912 North Creek Parkway, Suite 101
Bothell, Washington 98011

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1.0 Introduction

This report presents the monitoring results of a pilot study designed to examine the placement of dredged material in the near shore environment along the Oregon Coast. The pilot study consisted of placing dredged materials from the Mouth of the Columbia River (MCR) navigational channel as a beneficial use at a near shore location. The pilot study was sponsored by the Lower Columbia Solutions Group (LCSG), convened by the governors from the states of Oregon and Washington, which consists of stakeholders interested in and affected by dredged disposal activities in the Lower Columbia River. Stakeholders include commercial crabbers, fishing interests, environmental groups, development interests, the Port of Astoria, and local, state, and federal government agencies including the U.S. Army Corps of Engineers (USACE). The funding for the project was provided by eleven different stakeholders involved in the collaborative effort. The USACE, Portland District provided the dredge Essayons, personnel, and financial support to conduct the pilot project. The Port of Astoria served as the project permittee and contractual agent (in conjunction with the USACE Portland District) for conducting the monitoring of the study area.

1.1 Project Background

The pilot study was designed to evaluate the feasibility of the enhanced disposal of dredged material in a near shore area. This test of the enhanced dumping method was intended to measure per-run ocean-bottom accumulations to verify projected results and help determine the viability of this method. Dredged material from the annual maintenance dredging of the MCR navigational channel was used for the study. The near shore placement area, located to the south of the MCR South Jetty, was selected as a site for the beneficial use of dredged material. Presently, dredged material from MCR maintenance dredging is disposed of at three permitted Ocean Disposal Sites (ODS), including the Shallow Water Site (an expansion of the former disposal Site E), the North Jetty Site, and the Deep Water Site located approximately 6 miles off shore located near the North Jetty of the MCR. Current stakeholder concerns with the existing disposal sites include the limited annual capacity of the SWS and North Jetty Sites, and the removal of material from the littoral zone when disposed at the DWS (Figure 1).

The objective of the pilot study was to evaluate the feasibility of the site-specific beneficial use of the MCR dredged material in the near shore environment. The beneficial uses include:

- Accretion of material in the littoral zone to prevent further erosion to the foundation of the MCR South Jetty. The addition of material to the substrate will help maintain and protect the structural integrity of the jetty by reducing wave energy on the jetty.
- Replenish littoral sands in a previously identified erosive area. Net erosion in the near shore area has resulted in physical changes to the seafloor including exposed ancient laminate clay/mud substrates and increased bottom slope.
- Increase supply of sand substrate for benthic infauna and epibenthic infauna habitat in the near shore area.

1.2 Pilot Study Design

Dredge Essayons

The pilot study design involved the placement of approximately 30,000 cubic yards of dredged material at a new disposal location to the south of the MCR South Jetty. A total of six hopper dredge loads were supplied by the USACE dredge Essayons, placed along six disposal lanes of approximately 6,000 feet long by 500 feet wide. Water depths in the pilot study placement area ranged between –40 to –60 ft mean lower low water (MLLW). The study area is considered a high-energy site, subject to strong currents, tidal influence, and wave action. Material from the hopper dredge was released from approximately 20 to 30 feet below the ocean surface, reducing the potential for lumping and re-suspension of sediments. Material disposed along each transect was initially estimated to spread up to 500 feet in width. Therefore, buffer areas of an additional 500 feet were incorporated between each placement lane to prevent encroachment of material from adjacent lanes.

The source material used for this pilot project was dredged from Quadrant 4, located between River Mile 1.0 and 2.0 the MCR navigational channel, as part of the routine annual maintenance dredging. The dredged material has been evaluated and determined suitable for ocean disposal following the protocols of the Dredged Material Evaluation Framework-Lower Columbia River Management Area (USACE 1998). The navigational channel material was most recently characterized as clean sand to support the maintenance dredging of the authorized federal navigation project and the designation of new ODS off the MCR (USACE 2000). The source area material and native material were expected to have similar physical characteristics.

An ocean research permit was issued on September 13, 2005, by the U.S. Environmental Protection Agency (EPA) to the Port of Astoria, pursuant to Section 102 of the Marine Protection, Research, and Sanctuaries Act (MPRSA or Ocean Dumping Act). The permit allowed the use of enhanced disposal methodology to determine if thin-layer (2”-4” deep) disposal in the nearshore zone was feasible. The permit was issued based on the determination that enhanced disposal methodology has the potential to minimize temporal loss of benthic habitat and minimize impacts to economically important species (i.e. Dungeness crab). In addition, the EPA concluded in their Biological Assessment and Essential Fish Habitat Assessment, that the research project would ‘not likely adversely affect’ listed species under the Endangered Species Act (ESA) and would have negligent to minimal impact to managed species under the Magnuson-Stevens Act (MSA). The National Marine Fisheries Service and U.S. Fish and Wildlife Service concurred with EPA’s Findings (USEPA 2005).

The placement of dredged material at the study site and concurrent monitoring efforts were conducted over a two-day period, September 14th and 15th, 2005, immediately following the issuance of the research permit. Section 2.0 describes the monitoring design and data collection methods that were conducted. The results of the dredged material disposal and monitoring results are provided in Section 3.0.

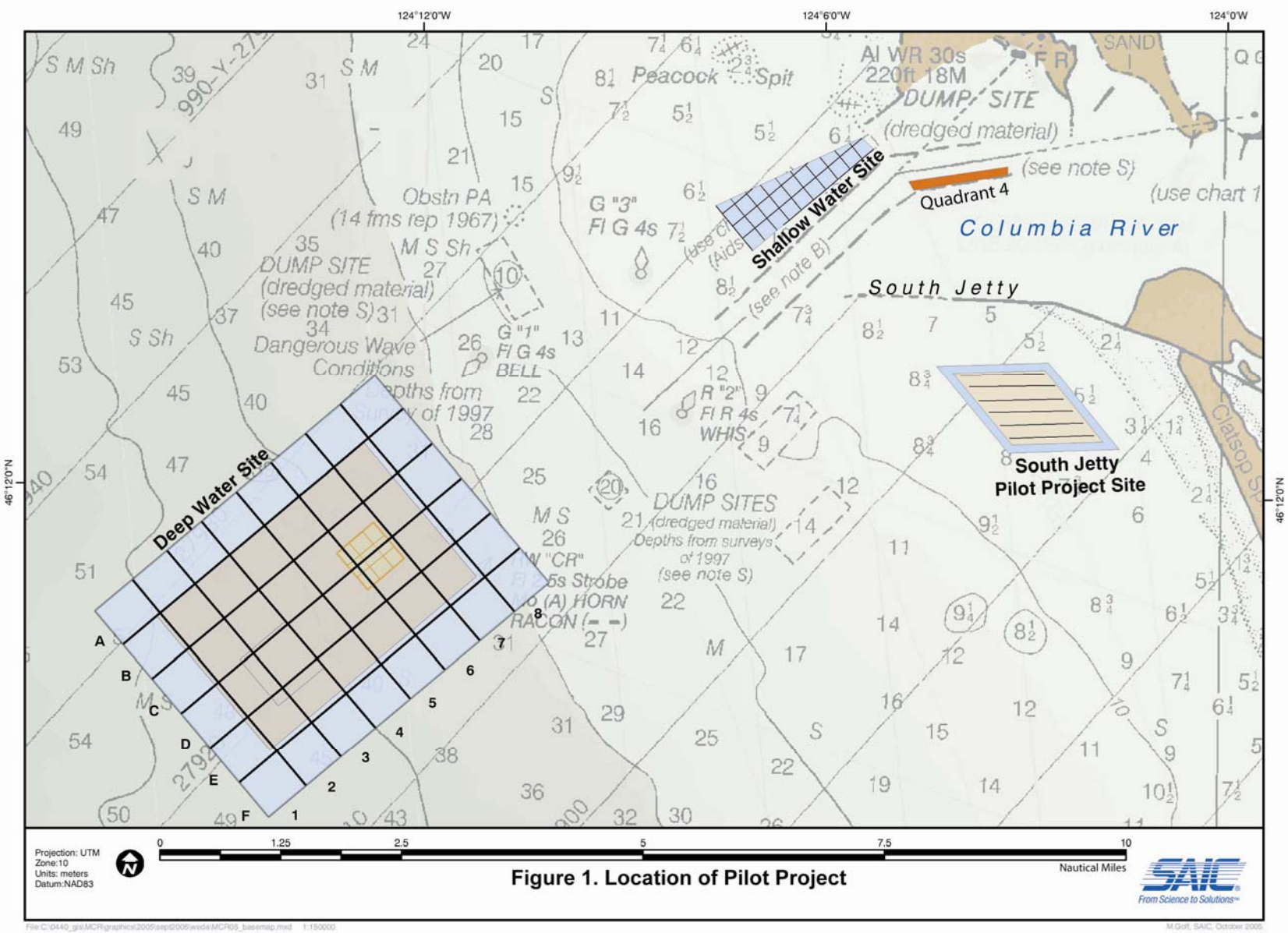

Figure 1. Location of Pilot Project

2.0 Monitoring Study Design and Data Collection Methods

This section provides an overview of the types of data collected for this study and a description of the methods utilized to meet the study objectives. Data collection efforts included sediment profile imaging photography (SPI), sediment grain size distribution, and a multi-beam side-scan sonar survey. The SPI survey and sediment sampling were conducted by Science Applications International Corporation (SAIC). The bathymetric survey was conducted independently by Global Remote Sensing (GRS; Seattle, WA), a subcontractor to Parametrix (Bellevue, WA) under contract with the USACE, Portland District.

2.1 Data Types

The data types collected for this study included still photographs of the sediment-water interface (i.e. sediment profile images) and surface sediment grab samples for analysis of grain size distribution. SPI is a remote photographic method that allows for the visualization of the sediment-water interface and provides a rapid determination of sediment grain size, anaerobic zones, and general biological characteristics. SPI can be deployed at a high sampling density, allowing a more targeted sampling of benthic infauna and conventional parameters. The grain size distribution samples allow for 'ground-truthing' the sediment type seen within the images.

2.1.1 SPI Survey

The SPI survey was conducted using a specially designed, high resolution underwater camera that collects a vertical image of the upper 15-20 cm of the sediment-water interface. A digital-camera equipped Benthos 3731 sediment profile imaging system (Benthos, Inc. North Falmouth, MA) was used to survey the benthic habitat conditions of the study area (Figure 2). The sediment-profile camera consists of a wedge-shaped prism with a Plexiglas face plate and a back mirror mounted at a 45° angle. Light was provided by an internal strobe. The mirror reflects the image of the profile of the sediment-water interface to a digital camera that is mounted horizontally on top of the prism.

Sediment Profile Imaging Camera

The camera prism is mounted on an assembly that can be moved up and down within a stainless steel frame by allowing tension or slack on the winch wire. As the camera is lowered, tension on the winch wire keeps the prism in the up position. Once the camera frame touches the bottom, slack on the winch wire allows the prism to vertically intersect the seafloor. The rate of fall of the prism (6 cm/second) is controlled by an adjustable passive hydraulic piston, which minimizes the disturbance of the sediment-water interface. A trigger is tripped on impact with the bottom, activating a 10 second time-delay on the shutter release; this gives the prism a chance to obtain maximum penetration before a photograph is taken. When the camera is raised from the bottom, a wiper blade automatically cleans off any sediment adhering to the prism faceplate and the strobes are recharged. The camera can then be lowered to collect another replicate image. Due

to the predominately sandy conditions at the site, two weight racks, each capable of holding 125 lb. of lead (in 25 lb. increments), were loaded to maximize penetration.

The SPI survey consisted of collecting a total of 149 digital images from the study area (Figure 2). The total images collected included:

- 12 pre-disposal sampling locations (3 reps each)
- 24 post-disposal sampling locations (3 reps each)
- 41 disposal lane transect sampling locations (1 rep each)

The pre-disposal images were collected at two locations along the length of each disposal lane to characterize the native material at the study area prior to the placement of any dredged material. The post-disposal images were collected at four locations per disposal lane, immediately following the placement of the dredged material, with the one exception of Lane Four, which was sampled the morning after the dredged material was placed. The transect sampling locations were collected on an opportunistic basis as time was available. The purpose of the transect locations were to examine a cross-section of the dredged material placement.

A formal analysis of the SPI survey results was conducted to assess the condition of the benthic habitat and determine the physical characteristics of the surface sediment. A single replicate image was selected for analysis from each location (i.e., 12 pre-disposal, 24 post-disposal, and 41 transect images). Parameters assessed from the images include:

- Grain size mode and range
- Prism penetration depth
- Surface boundary roughness
- Benthic habitat classification
- Infaunal successional stage

Analysis of the SPI images was conducted using the REMOTS (Remote Ecological Monitoring Of The Seafloor) system. REMOTS is a formal and standardized technique for SPI image acquisition, image analysis, and interpretation developed by SAIC scientists (Rhoads and Germano, 1982 and 1986; SAIC, 1986a). Physical and biological parameters were measured directly from the SPI digital images using a computer image analysis system. The image analysis system can discriminate up to 256 different tonal scales, so subtle features can be accurately digitized and measured.

The image analysis software allows the measurement and storage of data from up to 21 different variables for each image. All data were edited and verified by a senior-level scientist before final data synthesis, statistical analyses, and interpretation. The specific REMOTS parameters for this survey included: sediment grain size (major mode and range), optical prism penetration depth, dredged material thickness, surface boundary roughness, benthic habitat, and infaunal successional stage.

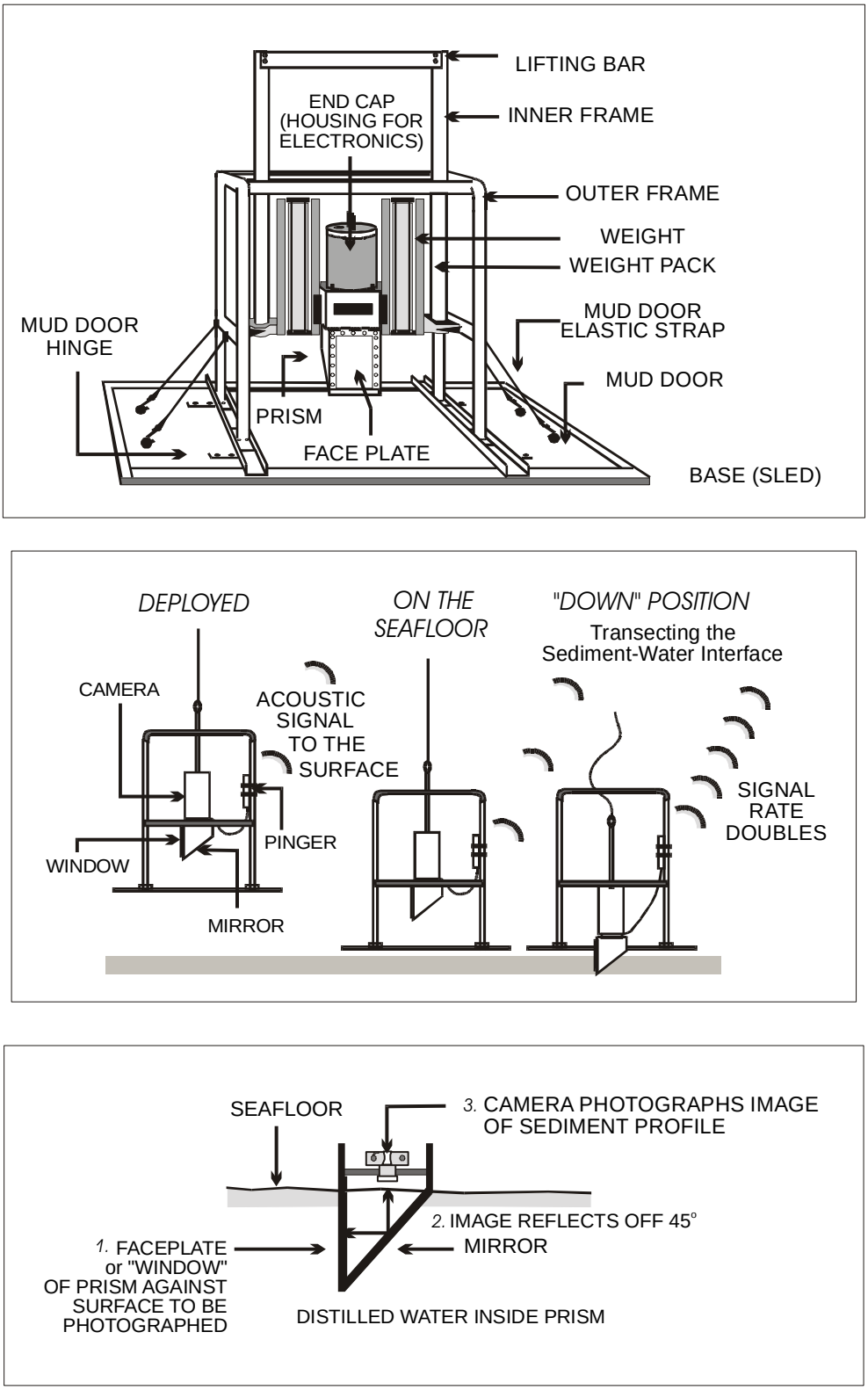

Figure 2. Sediment Profile Imaging Camera

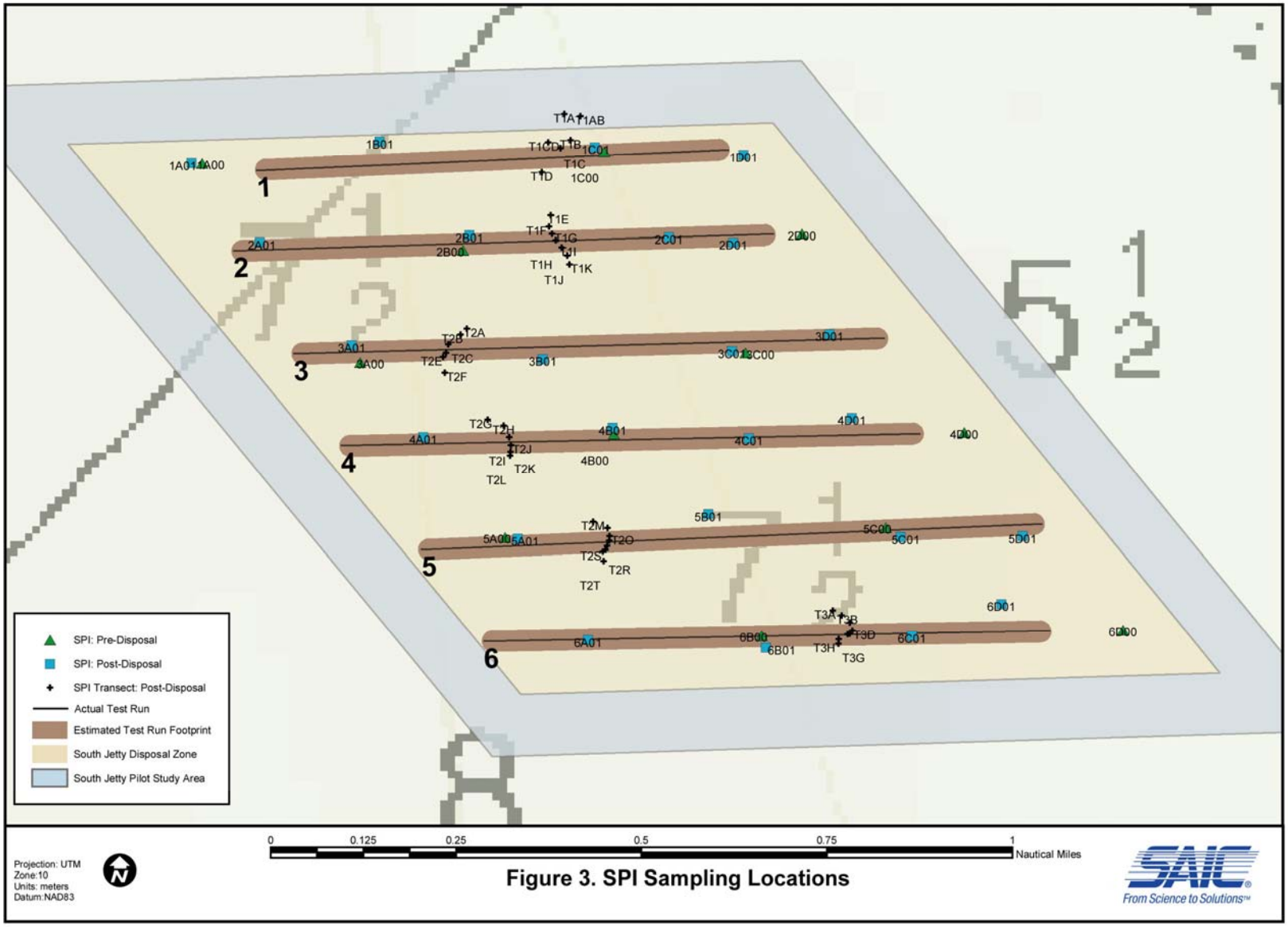

Figure 3. SPI Sampling Locations

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M.Goff, SAIC, October 2005

2.1.1.1 Sediment Grain Size

The sediment grain size major mode and range, in phi (Φ) units, were visually determined from the SPI images by overlaying a grain-size comparator at the same scale. This comparator was prepared by photographing a series of Udden-Wentworth size classes (equal to or less than coarse silt up to granule and larger sizes) through the SPI optical system. Seven grain-size classes are on this comparator: ≥ 4 Φ (silt/clay), 4 to 3 Φ (very fine sand), 3 to 2 Φ (fine sand), 2 to 1 Φ (medium sand), 1 to 0 Φ (coarse sand), 0 to -1 Φ (very coarse sand), and < -1 Φ (gravels). The lower limit of optical resolution is about 62 μm, allowing recognition of grain sizes equal to or greater than coarse silt. The accuracy of this method has been documented by comparing SPI estimates with grain-size statistics determined from laboratory sieve analyses (SAIC, 1986b).

2.1.1.2 Prism Penetration Depth

The prism penetration depth is determined by measuring both the largest and smallest linear distance between the sediment-water interface and the bottom of the image. Observations regarding the nature and condition of the sediment-water interface are also recorded. Comparative penetration depths from stations of similar grain-size give an indication of relative water content and shear strength of the sediment.

2.1.1.3 Surface Boundary Roughness

Surface boundary roughness was determined by measuring the vertical distance (parallel to the image border) between the highest and lowest points of the sediment-water interface. In addition, the origin (physical or biogenic) of this small-scale topographic relief is sometimes evident and can be recorded. In sandy sediments, boundary roughness can be a measure of ripple height. Depending on the type of disposed dredged material, there is the potential to introduce high surface relief on an otherwise “smooth” bottom. Other surface features are noted where evident, including shell fragments/lag deposits, mud-clay clasts, and wood debris.

2.1.1.4 Benthic Habitat Classification

Based on extensive past sediment-profile imaging surveys (Diaz 1995; SAIC 1997a and b), five basic benthic habitat types have been identified: AM = *Ampelisca* mat, SH = shell bed, SA = hard sand bottom, HR = hard rock/gravel bottom and UN = unconsolidated soft bottom. Several sub-habitat types exist within these major categories. During image analysis, each sediment profile images is assigned one of the habitat categories listed in Table 1.

Table 1. Benthic Habitat Categories Assigned to REMOTS Sediment-Profile Images

Habitat AM: *Ampelisca* Mat Uniformly fine-grained (i.e., silty) sediments having well-formed amphipod (*Ampelisca* spp.) tube mats at the sediment-water interface. Other species of benthic infauna may also create mats similar to those of *Ampelisca*.
Habitat SH: Shell Bed A layer of dead shells and shell fragments at the sediment surface overlying sediment ranging from hard sand to silts. Epifauna (e.g., bryozoans, tube-building polychaetes) commonly found attached to or living among the shells. Two distinct shell bed habitats: SH.SI: Shell Bed over silty sediment - shell layer overlying sediments ranging from fine sands to silts to silt-clay. SH.SA: Shell Bed over sandy sediment - shell layer overlying sediments ranging from fine to coarse sand.
Habitat SA: Hard Sand Bottom Homogeneous hard sandy sediments do not appear to be bioturbated, bed forms common, successional stage mostly indeterminate because of low prism penetration. SA.F: Fine sand - uniform very fine sand (4 to 3 Φ) or fine sand sediments (3 to 2 Φ). SA.M: Medium sand - uniform medium sand sediments (grain size: 2 to 1 Φ). SA.G: Medium sand with gravel – predominately medium to coarse sand with a minor gravel fraction.
Habitat HR: Hard Rock/Gravel Bottom Hard bottom consisting of pebbles, cobbles and/or boulders, resulting in no or minimal penetration of the REMOTS camera prism. Some images showed pebbles overlying silty-sediments. The hard rock surfaces typically were covered with epifauna (e.g., bryozoans, sponges, tunicates).
Habitat UN: Unconsolidated Soft Bottom Fine-grained sediments ranging from very fine sand to silt-clay, with a complete range of successional stages (I, II and III). Biogenic features may be common (e.g., amphipod and polychaete tubes at the sediment surface, small surface pits and mounds, large borrow openings, and feeding voids at depth). Several sub-categories: UN.SS: Fine Sand/Silty - very fine sand mixed with silt (grain size range from 4 to 2 Φ), with little or no shell hash. UN.SI: Silty - homogeneous soft silty sediments (grain size range from >4 to 3 Φ), with little or no shell hash. Generally deep prism penetration. UN.SF: Very Soft Mud - very soft muddy sediments (>4 Φ) of high apparent water content and deep prism penetration.

2.1.1.5 Infaunal Successional Stage

The mapping of infaunal successional stages from SPI images is based on the theory that organism-sediment interactions follow a predictable sequence after a major seafloor perturbation. This theory states that primary succession results in "the predictable appearance of macrobenthic invertebrates belonging to specific functional types following a benthic disturbance and these invertebrates interact with sediments in specific ways. Moreover, functional types are the biological units of interest and by definition do not demand a sequential appearance of particular invertebrate species or genera" (Rhoads and Boyer 1982).

Benthic disturbance can result from natural processes, such as seafloor erosion, changes in seafloor chemistry, and predator foraging, as well as from human activities like dredged material disposal, bottom trawling, pollution from industrial discharge, and excessive organic loading. Evaluation of successional stages involves deducing dynamics from structure, a technique pioneered by R. G. Johnson (1972) for marine soft-bottom habitats. The application of this approach to benthic monitoring requires *in situ* measurements of salient structural features of organism-sediment relationships as imaged through REMOTS technology.

Infaunal succession following a major seafloor disturbance initially involves pioneering populations (Primary or Stage I succession) of very small organisms that live at or near the sediment/water interface (Pearson and Rosenberg 1978; Rhoads and Germano 1986). In the absence of further disturbance, infaunal deposit feeders eventually replace these early

successional assemblages. The start of this "infaunalization" process is designated as Stage II. Large, deep-burrowing infauna (Stage III taxa) represents a high order successional stage typically found in areas of low disturbance.

Pioneering assemblages (Stage I assemblages) usually consist of dense aggregations of near-surface living, tube-dwelling polychaetes (Figure 3); alternately, opportunistic bivalves may colonize in dense aggregations after a disturbance (Rhoads and Germano 1982, Santos and Simon 1980a). These functional types are usually associated with a shallow redox boundary; bioturbation depths are shallow, particularly in the earliest stages of colonization (Figure 3).

Many deep-burrowing infauna feed at depth in a head-down orientation. This localized feeding activity results in distinctive excavations called feeding voids. Diagnostic features of these feeding structures include a generally semicircular shape with a flat bottom and arched roof, and a distinct granulometric change in the sediment particles overlying the floor of the structure. The relatively coarse-grained material represents particles rejected by head-down deposit-feeders, as this deep-dwelling infauna preferentially ingest the finer sediment particles. Other subsurface structures, including burrows or methane bubbles, do not exhibit these characteristics. The bioturbation activities of these deposit-feeders are responsible for aerating the sediment and causing the redox horizon to be located several centimeters below the sediment-water interface. The presence of feeding voids indicates the presence of Stage III organisms.

In sandy, dynamic environments such as those found at the MCR, the climax communities may consist primarily of surface dwellers (e.g., *Amphiodia*) that reside in the upper cm of the sediment surface and have few, if any, naturally burrowing community members. These type communities are classified as Stage I communities by REMOTS analysis, reflective of an area influenced by physical factors (e.g., higher energy) and the presence of a sandy substrate. This contrasts to a higher order successional stage that would typically be assigned a climax community (as described above) in a depositional environment dominated by a silt/clay substrate.

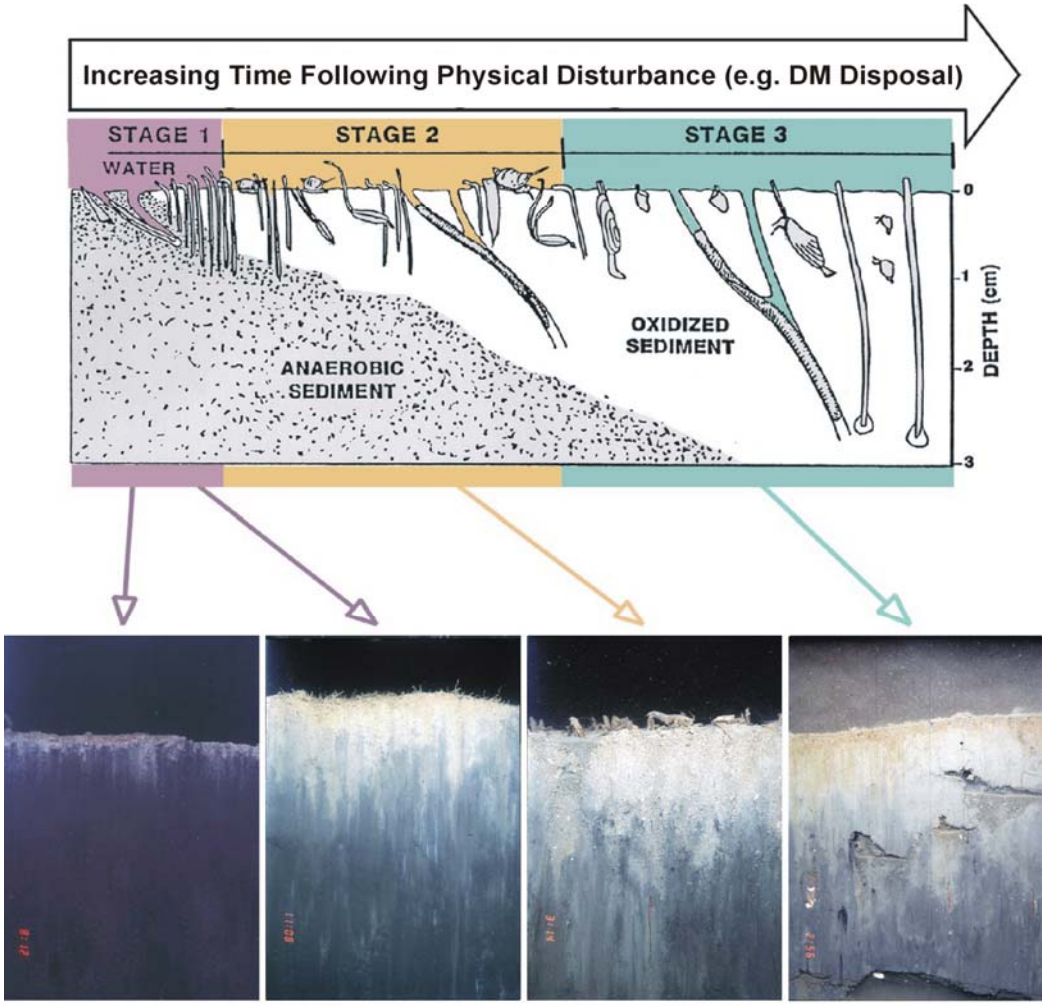

Figure 4. Successional Assemblages and Relationship to SPI Imagery

The drawing at the top illustrates the development of infaunal successional stages over time following a physical disturbance or with distance from an organic loading source (from Rhoads and Germano 1986). The REMOTS images below the drawing provide examples of the different successional stages.

Image A: Image A shows highly reduced sediment with a very shallow redox layer (contrast between light colored surface sediments and dark underlying sediments) and little evidence of infauna.

Image B: Numerous small polychaete tubes are visible at the sediment surface in image B (Stage I), and the redox depth is deeper than in image A.

Image C: A mixture of polychaete and amphipod tubes occurs at the sediment surface in image C (Stage II).

Image D: Image D shows numerous burrow openings and feeding pockets (voids) at depth within the sediment; these are evidence of deposit-feeding, Stage III infauna. Note the RPD is relatively deep in this image, as bioturbation by the Stage III organisms has resulted in increased sediment aeration and causing the redox horizon to be located several centimeters below the sediment-water interface.

2.1.2 Grain Size Analysis

Grain size distributions were characterized by the percent fractions of gravel, sand, silt, and clay comprising the substrate material. Surface sediment (0 to 10 cm) sampling was conducted at 10 locations following the placement of dredged material and completion of the SPI survey (Figure 5). The samples were collected at six locations (one per disposal lane) where dredged material was placed and four locations outside of the disposal lanes where native material was present. A 0.1 m^2 modified Young's van Veen grab sampler was used to collect the surface sediment for grain size distribution analysis. Acceptable grab samples were determined by meeting the following criteria (PSEP 1986):

- Sampler is not overfilled,
- Overlying water is present,
- No leakage of water during recovery,
- Sediment surface is relatively flat with no evidence of disturbance or winnowing, and
- A minimum penetration depth of 10 cm.

Once a sample was accepted, a description of the collected material was then recorded in logbooks including such information as color, texture, odor, presence of biological structures or any other notable observations.

The sediment from each grab was processed in the field. After characterizing the sediment as described above, the sub-samples were collected from the grab and homogenized. An aliquot of the homogenate was then placed in a pre-cleaned glass sample container and kept cool at approximately 4°C during transport and storage. Sample descriptions were recorded and chain-of-custody procedures were used to document the number and location of the grab samples collected. The sediment samples were stored and shipped for analysis to AMTEST Laboratories of Redmond, WA, a Washington State certified analytical laboratory. The analytical method used for determination of grain size distribution was ASTM D-422.

2.1.3 Bathymetric Survey

A multibeam bathymetric survey was conducted by GRS immediately following the placement of dredged material for the pilot study. Backscatter information derived from the multibeam survey was used for further classification of the seafloor at the disposal site. A detailed description of the multibeam investigation methodology is provided in Appendix C.

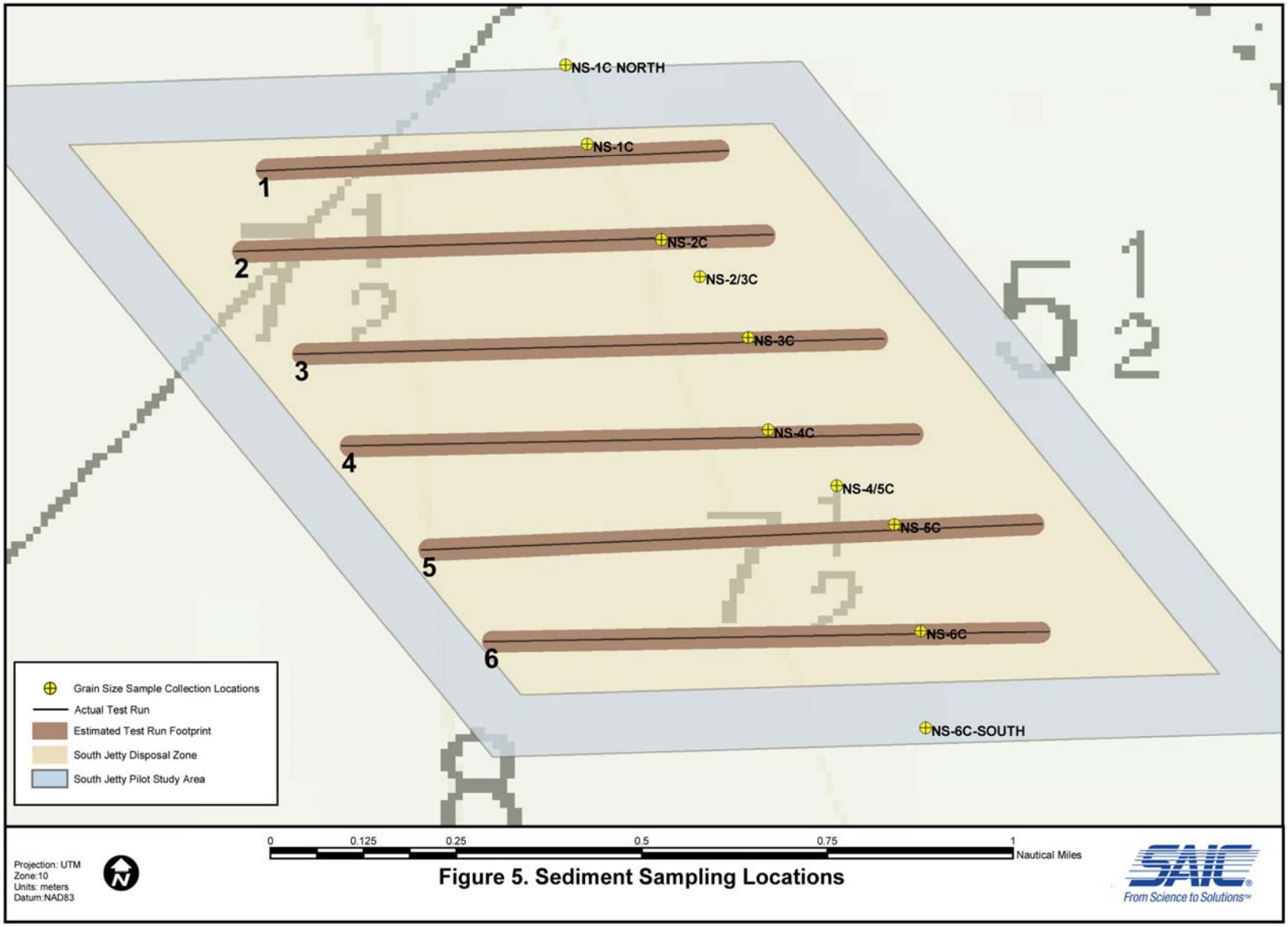

Figure 5. Sediment Sampling Locations

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M.Goff, SAIC, October 2005

2.2 Sampling Platform

Sampling Vessel F/V Iron Lady

The F/V Iron Lady, an 81-ft commercial bottom trawler stationed in Warrenton, Oregon, was used for the SPI and sediment sampling activities. This vessel was outfitted to accommodate both commercial otter trawl demersal fish trawling, as well as scientific and engineering consulting services off the coasts of Washington and Oregon. The F/V Iron Lady is owned by Ms. Trisha Bisby, and registered in South Bend, WA. The vessel is operated by Captain Kevin Dunn, a skipper with more than 20 years of experience in Oregon and Washington coastal waters, including the Columbia River Bar and environs. The vessel is equipped with winches, davits, and an A-frame to accommodate the various sampling instruments. The back deck provided extensive open area to accommodate the sampling gear and operations conducted for this investigation.

2.3 Station Positioning

Prior to field operations, Coastal Oceanographic's HYPACK® Max was used to establish the planned survey lines and stations that were occupied in the survey. Navigation and positioning was accomplished using a differential global positioning system (DGPS) integrated with a computerized navigation system. The use of U.S. Coast Guard differential corrections and a Trimble DSM212L DGPS receiver provided positional accuracy of ± 3 meters. Vessel coordinates were updated every two seconds and transmitted directly to the onboard system. The HYPACK® Max survey and data acquisition software provided real-time data display and a plan-view chart display to aid the helmsman, as well as logged the vessel position and associated data. All station coordinates were reported in latitude and longitude using decimal minutes, accurate to 1/1000 of a minute.

3.0 Results

This section provides a summary of the results of the dredged material placement, SPI image analysis, and grain size distribution analysis. The information for the dredge material placement was provided by the Dredge Essayons via the USACE Portland District. The SPI images that were analyzed are presented in Appendix A. The coordinates for the SPI and sediment sampling locations are provided in Appendix B. A copy of the Parametrix bathymetric report is provided in Appendix C.

3.1 Dredged Material Placement

The placement of dredged material at the near shore site was conducted over a two day period (September 14th and 15th, 2005). The Essayons was commanded by Chief Mate Jeffrey S. McDonald during the pilot study. The weather and sea conditions were favorable during the study with light winds, temperatures between 55° and 60° F, with overcast skies and light drizzle on the 14th, and sunshine on the 15th. Wave conditions consisted of a modest swell between 2 to 3 feet with a long period. The tidal currents were moderated by a relatively small tidal exchange of -1 to +7.5 feet MLLW between lower low and higher high tides.

Data recorded during the disposal runs are presented in the Figures 6 through 11, which graphically displays the displacement and speed profiles of the dredge Essayons during each placement. Table 2 summarizes details of the enhanced disposal effort. The Essayons offloaded material in single continuous run along each disposal lane. The dredge displacement profiles show relatively constant disposal of material over the length of each run. Each disposal run took 8 to 10 minutes, with a ship speed ranging from 2 to 7.5 knots during the placement activities. The dredge turn-around-time was approximately 2.5 to 3.0 hours between dredging at Quadrant 4 in the navigational channel to disposal at the nearshore site. The length of each disposal ranged from 1183 to 1554.8 meter. The volume of dredged material per disposal run ranged from 5520 to 5810 cubic yards.

The average thickness of dredged material could be estimated using the dredged material volumes, the apparent footprint of dredged material using the recorded disposal lane lengths and average width of 180 feet. The estimate of average dredge material deposition ranged from 2.03 to 2.69 inches thick was based on volumetric calculations. The USACE, Portland District estimate a maximum simulated bottom accumulation of 4.8 inches using the MDFATE model of dredged material distribution at the South Jetty (Moritz 2005). The USACE model simulated ocean conditions during the pilot study using field data measured in September 2003 that matched the 2005 tide and wave conditions. These data were used for FATE model simulation of dredged material deposition on the seabed at the South Jetty Site. The parameters utilized in the model simulation included: wave height and direction, depth averaged current direction and velocity, and observed tides. Graphics depicting the model parameters and model simulation results are presented in Appendix D. These estimates are consistent with the goals of the enhanced disposal target depths of 2 to 4 inches identified in the research permit (USEPA 2005).

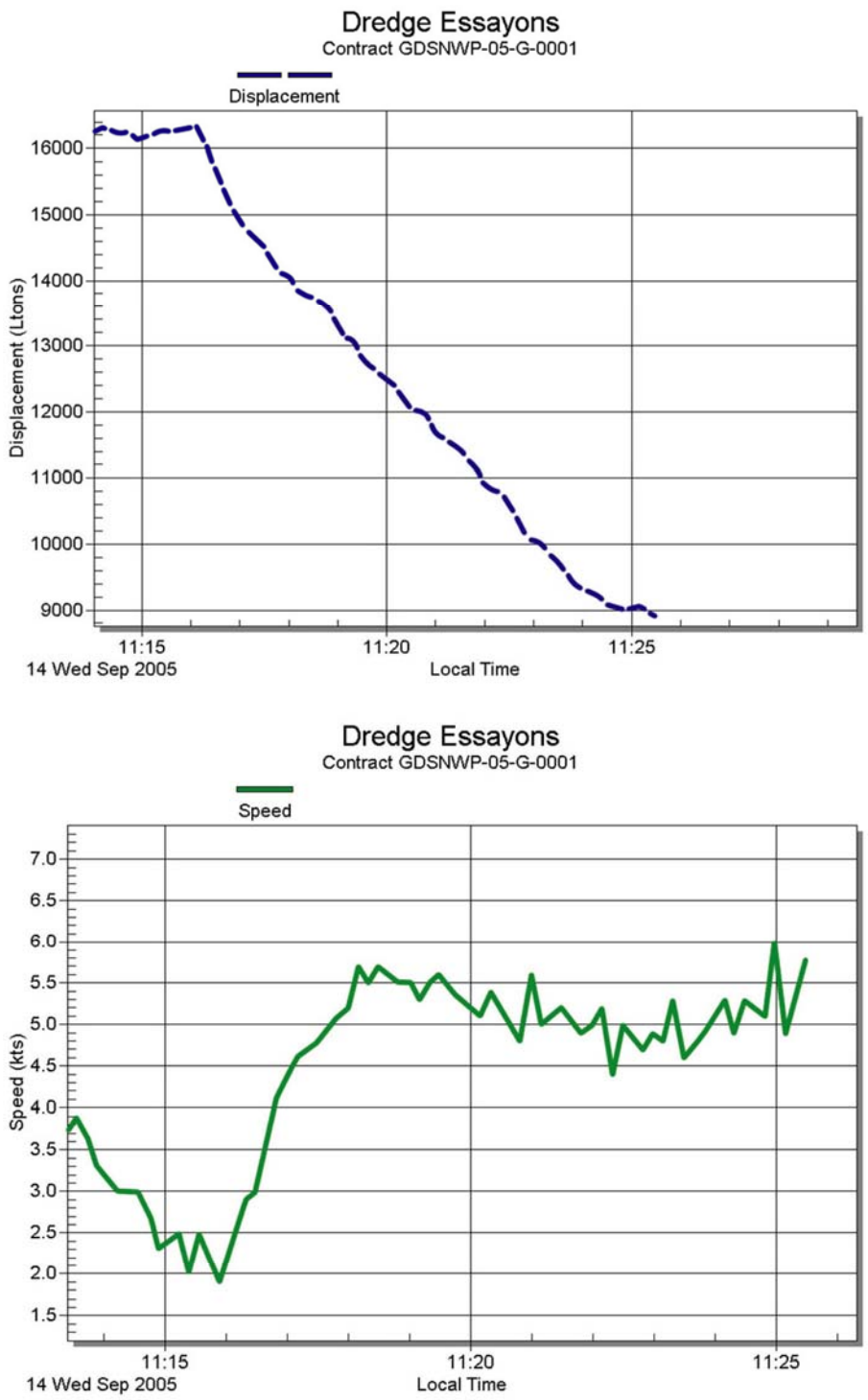

Figure 6. Dredge Displacement and Disposal Speed: Lane 1

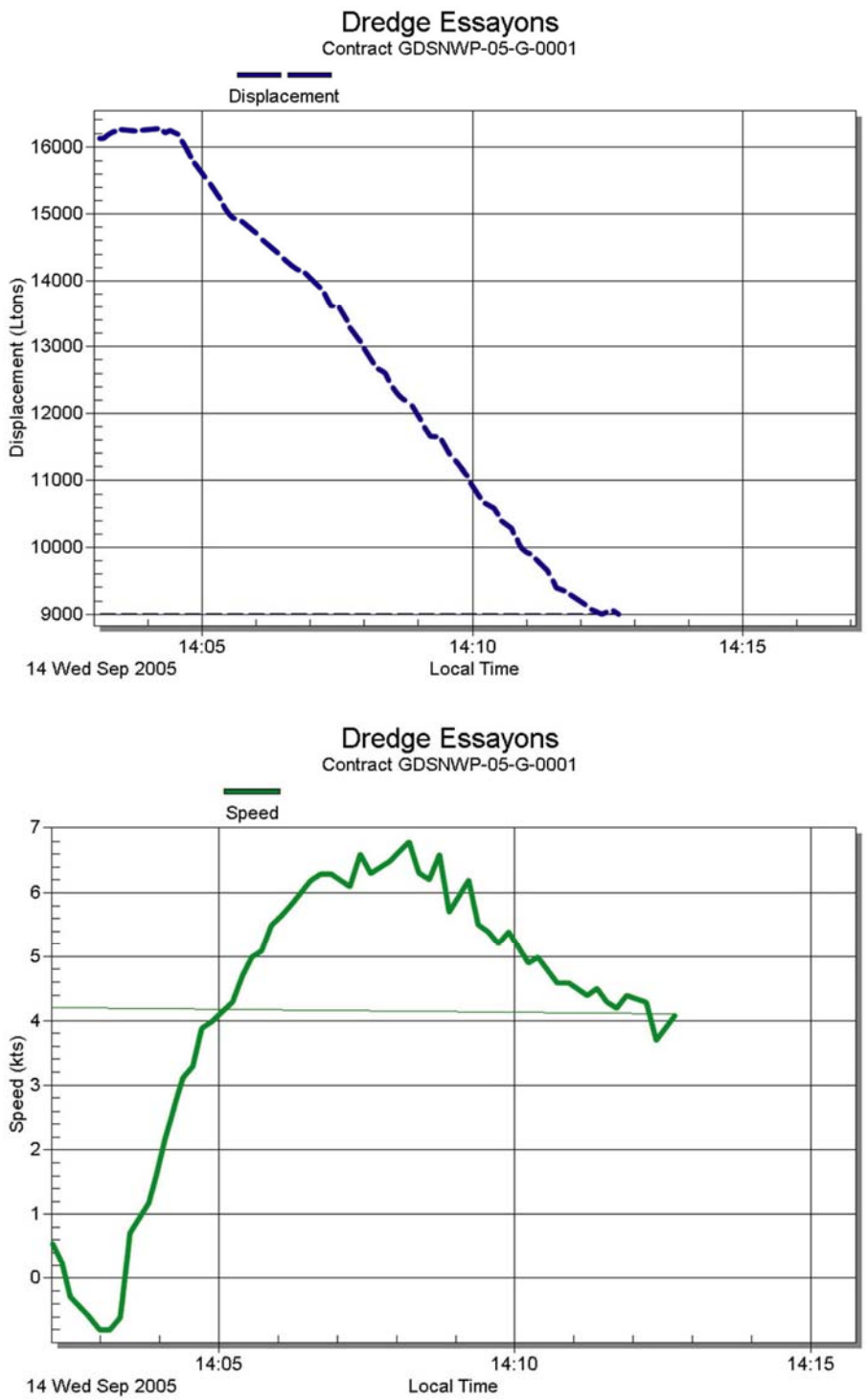

Figure 7. Dredge Displacement and Disposal Speed: Lane 2

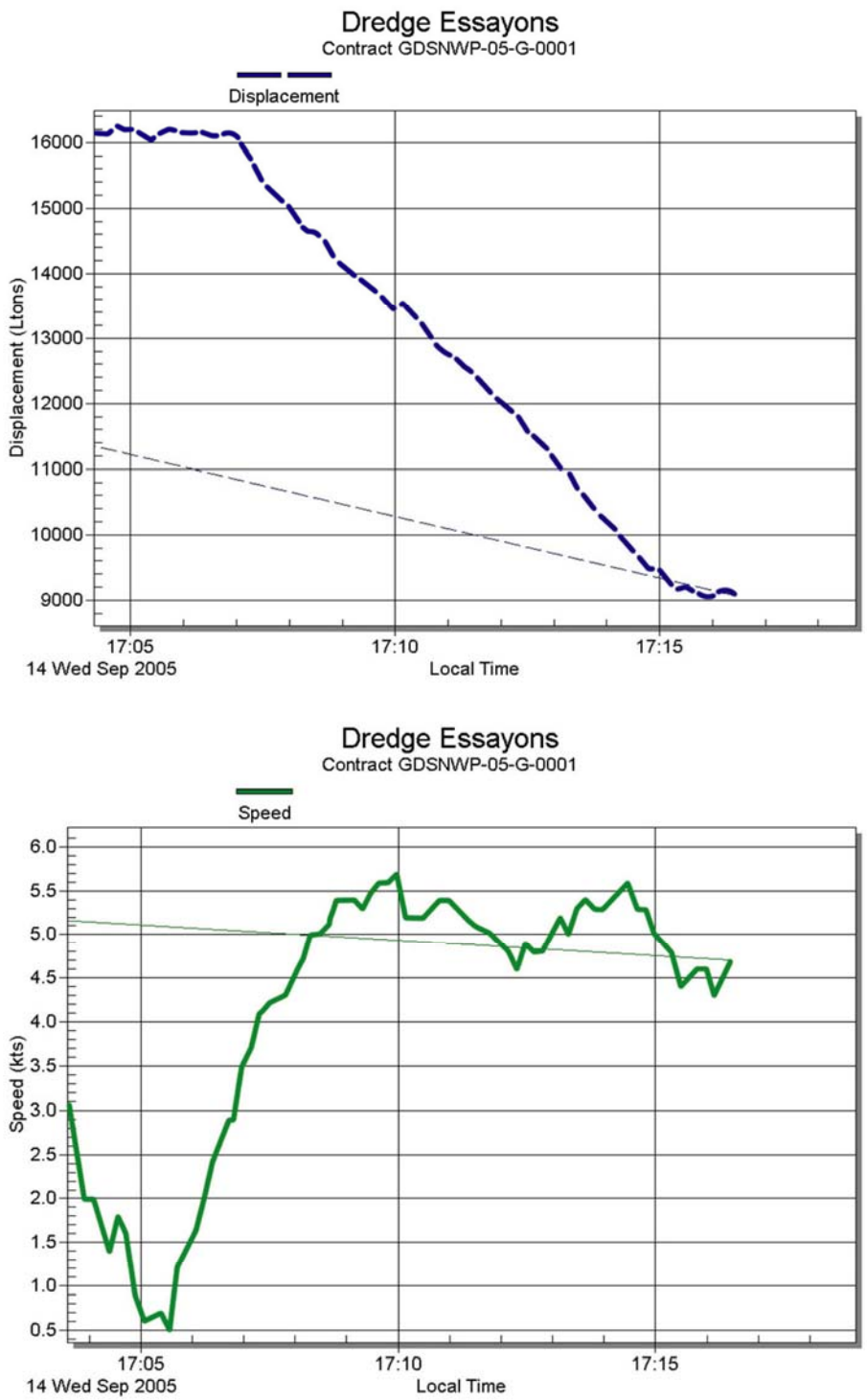

Figure 8. Dredge Displacement and Disposal Speed: Lane 3

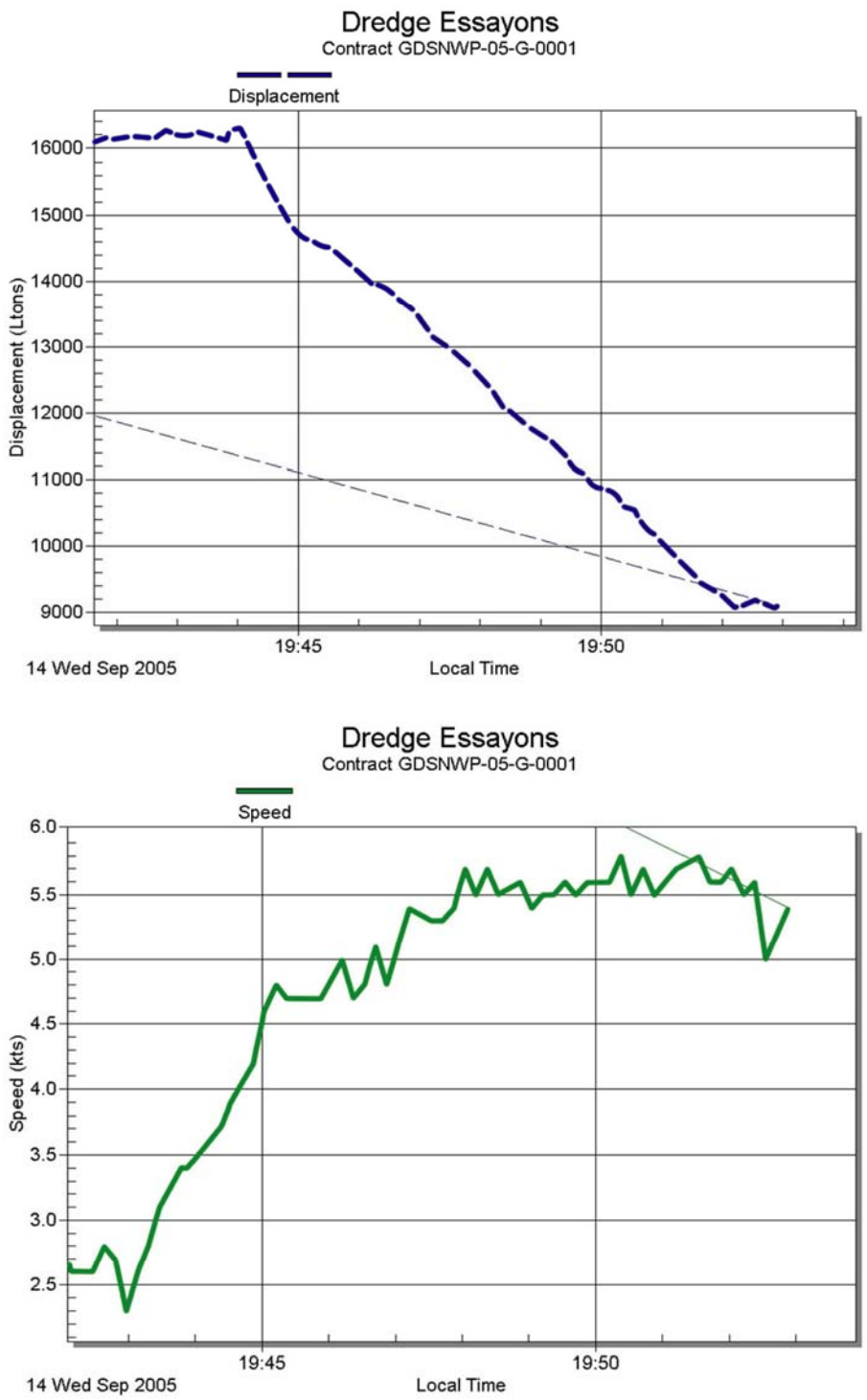

Figure 9. Dredge Displacement and Disposal Speed: Lane 4

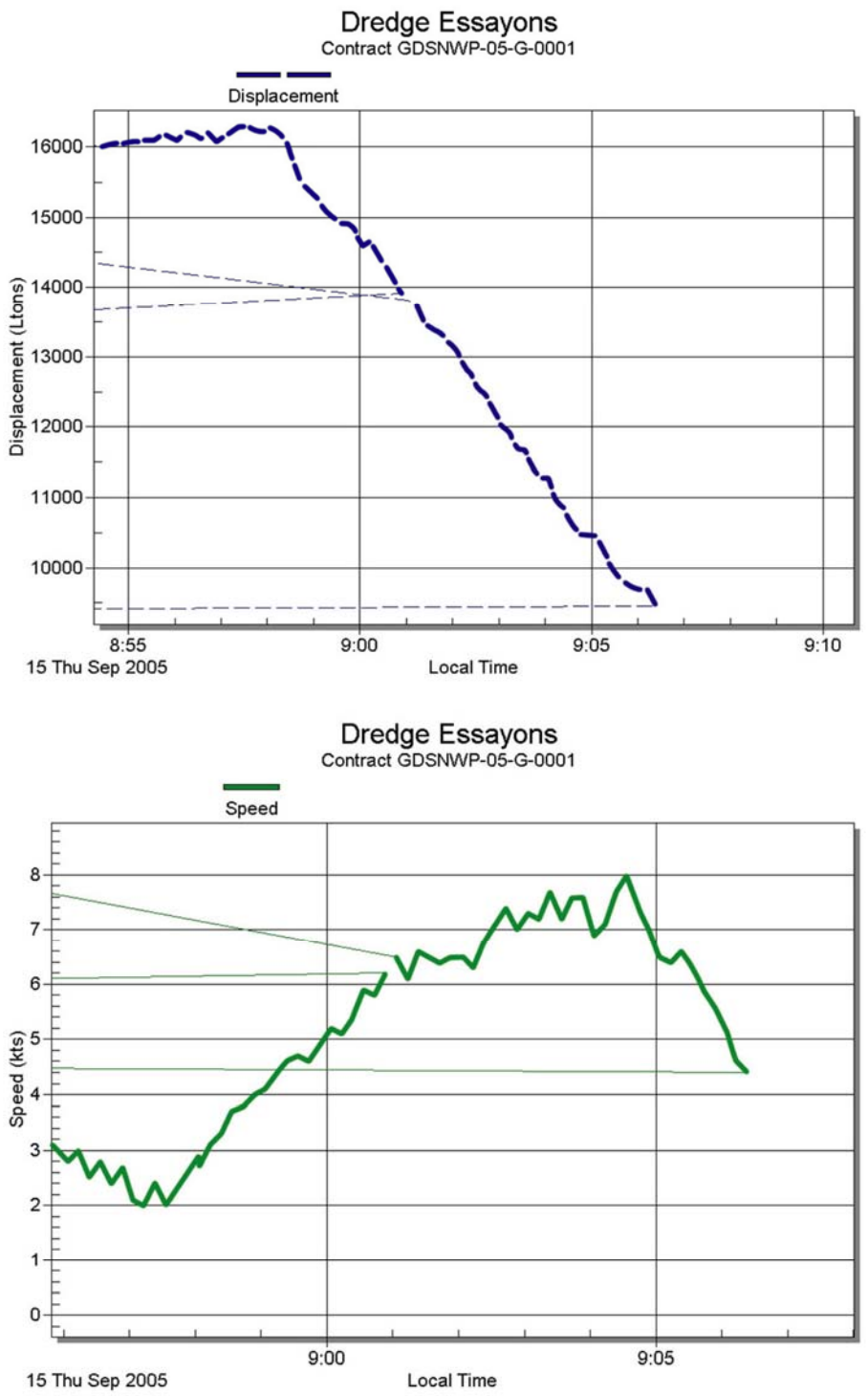

Figure 10. Dredge Displacement and Disposal Speed: Lane 5

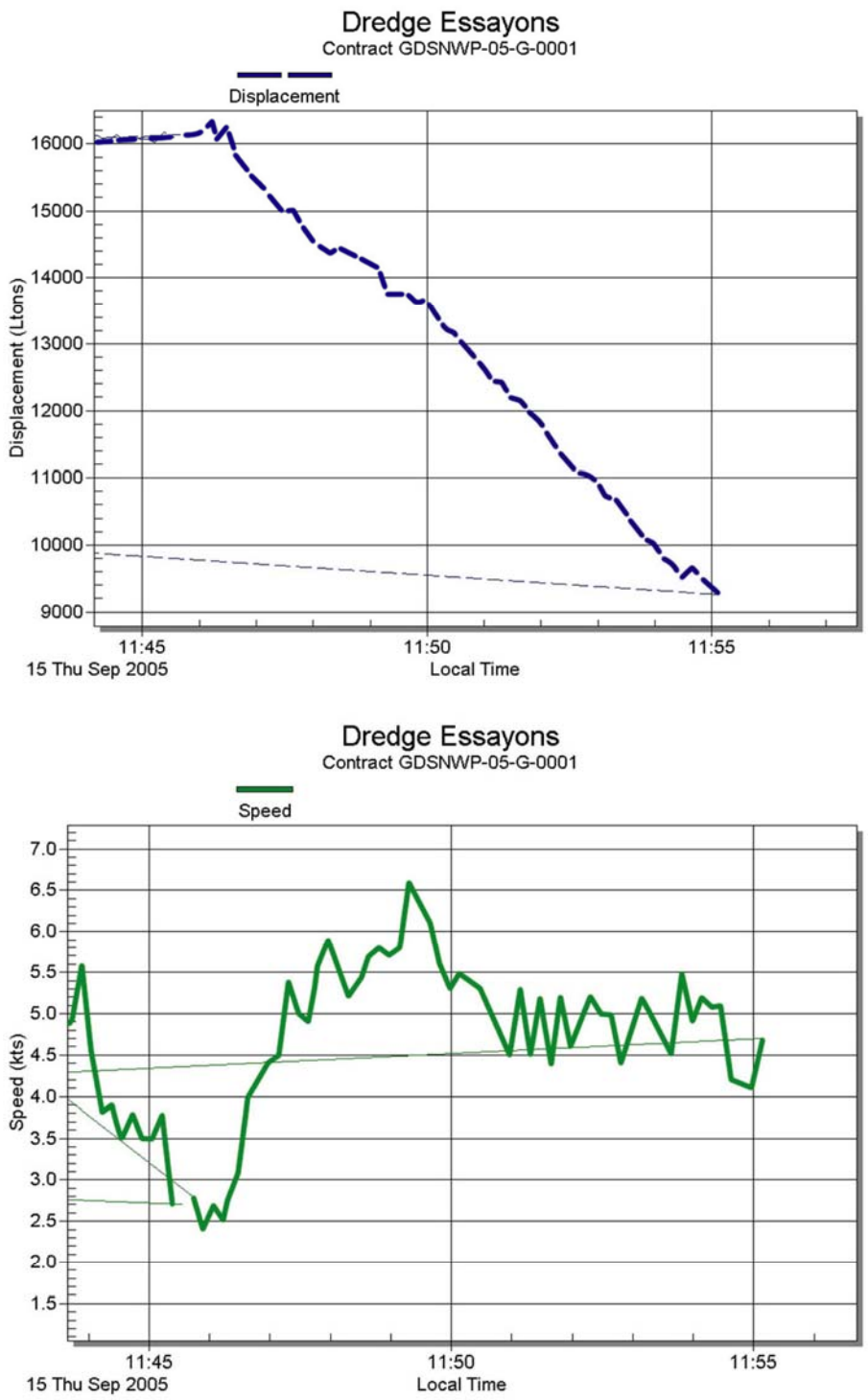

Figure 11. Dredge Displacement and Disposal Speed: Lane 6

Table 2. Dredged Material Placement for Pilot Study

Placement Run	Date	Start Time	End Time	Disposal Duration (min)	Average Dredge Speed (ft/sec)	Distance (feet)	Volume (yds3)	Estimated Average Depth (inches)
1	9/14/05	11:16	11:25	9	9.0	3881	5807	2.69
2	9/14/05	14:04	14:12	8	9.2	4433	5687	2.30
3	9/14/05	17:06	17:16	10	8.1	4849	5520	2.04
4	9/14/05	19:43	19:52	9	8.8	4753	5660	2.14
5	9/15/05	8:58	9:06	8	10.6	5101	5770	2.03
6	9/15/05	11:46	11:55	9	8.3	4648	5810	2.24

3.2 SPI Survey Results

A total of 77 out of 149 images collected were analyzed to represent the pre- and post- disposal conditions at the near shore study area. One representative image from each pre- and post-disposal station located along the disposal lanes, and each transect replicate was analyzed using the REMOTS system to determine several physical and biological parameters and identify the presence of dredged material. A summary of the SPI parameters that were evaluated for this investigation, including grain size major mode, camera penetration, dredged material thickness, boundary roughness, benthic habitat type, and the highest benthic infaunal stage present are summarized in Tables 3, 4, and 5.

It should be noted that some of the post-disposal sampling locations were located outside the footprint of the dredged material placement. Every attempt was made to locate these stations along the center of the actual disposal track of the dredge Essayons. However, positioning information regarding the stop and start locations of the dredge Essayons in Lane 1 were not available at the time the images were collected. In addition, field conditions such as tidal currents and surface wind can affect boat positioning during SPI camera deployment and limit the ability to keep the sampling vessel in the same position for the collection of three consecutive replicates. Finally, while in the field, it was assumed that dredge material may create a depositional footprint up to 500 feet wide. This assumption was corrected to an average footprint width of 180 feet based on evaluation of the bathymetric survey (Moritz 2005). Therefore, during the evaluation of the image collection locations and visual assessments, 6 of the 24 post-disposal images were determined to be located outside the dredged material footprint. The intent of the transect stations was to collect images along a cross-section of the dredged material footprint for each disposal lane. Based on the evaluation of the transect image locations and visual assessments, it was determined that 17 of the 41 images were outside the dredged material footprint.

3.2.1 Grain Size Major Mode

The grain size distribution in SPI images as determined by REMOTS analysis was reported as the major mode in Φ size. The Φ size range for sediments is from –1 Φ (gravel), -1 to 4 Φ (sand), 4 to 8 Φ (silt), to greater than 8 Φ (clay). The pre-disposal survey indicated a grain size distribution that consisted predominately of medium-fine sand (3 to 2 Φ, 92%; 2 to 1 Φ 8%), n = 12). For locations identified within the dredged material footprint during the post-disposal survey, the major mode grain size was primarily coarse medium sand (2 to 1 Φ, 83%; 3 to 2 Φ 17%, n = 18). The six images collected during the post-disposal survey, but determined to be outside the dredged material footprint were split between coarse-medium and medium-fine sand (2 to 1 Φ, 50%; 3 to 2 Φ 50%, n = 6). For the transect survey coarse medium sand was found at all locations within the dredged material footprint (2 to 1 Φ, 100%, n = 24), and a combination of coarse-medium and medium-fine sand was found outside the footprint (2 to 1 Φ, 71%; 3 to 2 Φ29%, n = 17). Based on these findings, the dredged material was consistently coarse medium grained sand and native material was medium-fine grained sand.

Table 3. Summary of SPI Results for Pre-Disposal Survey

Station	Replicate Analyzed[1]	Grain Size Major Mode (Φ)	Prism Penetration Mean (cm)	Dredged Material Thickness Mean (cm)[2]	Boundary Roughness Mean	Benthic Habitat	Highest Stage Present[3]
1A00	2	2 to 1	1.86	NA	0.91	SA.M	ST I
1C00	3	3 to 2	1.67	NA	0.45	SA.F	ST I
2B00	2	3 to 2	5.05	NA	0.97	SA.F	ST I
2D00	1	3 to 2	6.79	NA	1.18	SA.F	ST I
3A00	1	3 to 2	3.83	NA	3.4	SA.F	ST I
3C00	1	3 to 2	5.74	NA	0.76	SA.F	INDET
4B00	1	3 to 2	2.66	NA	2.66	SA.F	INDET
4D00	1	3 to 2	4	NA	0.4	SA.F	INDET
5A00	1	3 to 2	5.99	NA	3.77	SA.F	INDET
5C00	2	3 to 2	5.27	NA	1.14	SA.F	INDET
6B00	2	3 to 2	4.32	NA	0.71	SA.F	INDET
6D00	1	3 to 2	4.53	NA	0.62	SA.F	INDET
Min	**-**	**3 to 2**	**1.67**	**-**	**0.40**	**-**	**-**
Max	**-**	**2 to 1**	**6.79**	**-**	**3.77**	**-**	**-**
Mean	**-**	**-**	**4.31**	**-**	**1.41**	**-**	**-**

Notes:

1: Three replicate images were collected at each sampling location, one replicate per location was selected for image analysis.

2: NA indicates that the substrate does not contain dredged material; thickness estimates are based on camera penetration depth because distinct dredged material layers overlying native material were not discernable.

3: INDET indicates the successional stage was indeterminate.

Table 4. Summary of SPI Results for Post-Disposal Survey

Station	Replicate Analyzed[1]	Grain Size Major Mode (Φ)	Prism Penetration Mean (cm)	Dredged Material Thickness Mean (cm)[2]	Boundary Roughness Mean	Benthic Habitat	Highest Stage Present[3]
1A01	1	2 to 1	3.81	NA	1.2	SA.M	ST I on III
1B01	3	2 to 1	2.22	NA	1.4	SA.M	INDET
1C01	2	2 to 1	4.47	4.47	1.31	SA.M	INDET
1DO1	3	3 to 2	3.86	NA	1.55	SA.F	INDET
2A01	2	2 to 1	4.9	4.9	0.92	SA.M	INDET
2B01	3	2 to 1	4.38	4.38	1.12	SA.M	INDET
2C01	2	2 to 1	4.14	4.14	1.07	SA.M	INDET
2D01	2	2 to 1	3.43	3.43	1.08	SA.M	INDET
3A01	2	2 to 1	4.83	4.83	1.16	SA.M	INDET
3B01	1	2 to 1	4.72	4.72	0.52	SA.M	INDET
3C01	1	2 to 1	5.32	5.32	0.75	SA.M	INDET
3D01	2	3 to 2	4.1	4.1	1.49	SA.F	INDET
4A01	3	2 to 1	4.71	4.71	2.02	SA.M	INDET
4B01	1	3 to 2	3.84	3.84	1.69	SA.F	INDET
4C01	2	2 to 1	5.31	5.31	3.69	SA.M	INDET
4DO1	1	2 to 1	5.06	5.06	0.76	SA.M	INDET
5A01	4	2 to 1	4.45	4.45	0.55	SA.M	INDET
5B01	2	2 to 1	3.24	3.24	1.68	SA.M	INDET
5C01	3	3 to 2	5.23	5.23	1.76	SA.F	INDET
5D01	1	3 to 2	4.67	NA	2.13	SA.F	INDET
6A01	1	2 to 1	5.25	5.25	1.14	SA.M	INDET
6B01	2	2 to 1	6.53	NA	0.91	SA.M	INDET
6C01	1	2 to 1	5.06	5.06	0.66	SA.M	INDET
6D01	3	3 to 2 phi	3.7	NA	1.9	SA.F	ST I
Min	**-**	**3 to 2**	**2.22**	**3.24**	**0.52**	**-**	**-**
Max	**-**	**2 to 1**	**6.53**	**5.32**	**3.69**	**-**	**-**
Mean	**-**	**-**	**4.47**	**4.58**	**1.35**	**-**	**-**

Notes:

1: Three replicate images were collected at each sampling location, one replicate per location was selected for image analysis.

2: NA indicates that the substrate does not contain dredged material; thickness estimates are based on camera penetration depth because distinct dredged material layers overlying native material were not discernable.

3: INDET indicates the successional stage was indeterminate.

Table 5. Summary of SPI Results for Disposal Lane Transect Survey

Station	Replicate Analyzed[1]	Disposal Run	Grain Size Major Mode (Φ)	Prism Penetration Mean (cm)	Dredged Material Thickness Mean (cm)[2]	Boundary Roughness Mean	Benthic Habitat	Highest Stage Present[3]
T1	A	1	3 to 2	3.44	NA	2.09	SA.F	ST I
T1	AB	1	2 to 1	2.8	NA	1.47	SA.M	INDET
T1	B	1	2 to 1	3.56	3.56	1.8	SA.M	INDET
T1	C	1	2 to 1	2.74	2.74	0.84	SA.M	INDET
T1	CD	1	2 to 1	2.98	2.98	1.82	SA.M	INDET
T1	D	1	2 to 1	5.23	5.23	1.01	SA.M	INDET
T1	E	2	2 to 1	1	NA	1.99	SA.M	INDET
T1	F	2	2 to 1	3.05	NA	1.3	SA.M	INDET
T1	G	2	2 to 1	4.03	4.03	1.19	SA.M	INDET
T1	H	2	2 to 1	3.98	3.98	0.78	SA.M	INDET
T1	I	2	2 to 1	4.06	4.06	0.62	SA.M	INDET
T1	J	2	2 to 1	3.46	3.46	1.15	SA.M	INDET
T1	K	2	2 to 1	3.95	NA	2.71	SA.M	INDET
T2	A	3	3 to 2	2.61	NA	1.80	SA.F	INDET
T2	B	3	2 to 1	5.94	5.94	0.35	SA.M	INDET
T2	C	3	2 to 1	3.38	3.38	1.09	SA.M	INDET
T2	D	3	2 to 1	4.82	4.82	0.95	SA.M	INDET
T2	E	3	2 to 1	5.78	5.78	2.40	SA.M	INDET
T2	F	3	2 to 1	5.74	NA	1.41	SA.M	INDET
T2	G	4	2 to 1	4.36	NA	1.41	SA.M	INDET
T2	H	4	2 to 1	5.01	5.01	2.33	SA.M	INDET
T2	I	4	2 to 1	4.25	4.25	1.76	SA.M	INDET
T2	J	4	3 to 2	3.76	NA	2.35	SA.F	ST I
T2	K	4	2 to 1	4.24	4.24	3.37	SA.M	INDET
T2	L	4	2 to 1	5.12	NA	2.64	SA.M	INDET
T2	M	5	2 to 1	6.45	NA	1.14	SA.M	INDET
T2	N	5	2 to 1	4.57	4.57	0.92	SA.M	INDET
T2	O	5	2 to 1	4.61	NA	1.28	SA.M	INDET
T2	P	5	2 to 1	5.22	5.22	2.18	SA.M	INDET
T2	Q	5	2 to 1	1.89	1.89	2.58	SA.M	INDET
T2	R	5	2 to 1	4.69	4.69	0.57	SA.M	INDET
T2	S	5	2 to 1	5.86	NA	1.11	SA.M	INDET
T2	T	5	2 to 1	5.39	NA	0.90	SA.M	INDET
T3	A	6	3 to 2	3.87	NA	1.38	SA.F	INDET
T3	B	6	3 to 2	3.49	NA	2.14	SA.F	INDET
T3	C	6	2 to 1	4.24	NA	1.47	SA.M	INDET

Station	Replicate Analyzed[1]	Disposal Run	Grain Size Major Mode (Φ)	Prism Penetration Mean (cm)	Dredged Material Thickness Mean (cm)[2]	Boundary Roughness Mean	Benthic Habitat	Highest Stage Present[3]
T3	D	6	2 to 1	5.57	5.57	1.93	SA.M	INDET
T3	E	6	2 to 1	2.48	2.48	1.08	SA.M	INDET
T3	F	6	2 to 1	3.68	3.68	1.52	SA.M	INDET
T3	G	6	2 to 1	4.47	4.47	1.49	SA.M	INDET
T3	H	6	2 to 1	4.46	4.46	2.18	SA.M	INDET
Min	**-**	**-**	**3 to 2**	**1.00**	**1.98**	**0.35**	**-**	**-**
Max	**-**	**-**	**2 to 1**	**6.45**	**5.94**	**3.37**	**-**	**-**
Mean	**-**	**-**	**-**	**4.17**	**4.37**	**1.56**	**-**	**-**

Notes:

1: One replicate image was collected at each sampling location and used for image analysis.

2: NA indicates that the substrate does not contain dredged material; thickness estimates are based on camera penetration depth because distinct dredged material layers overlying native material were not discernable.

3: INDET indicates the successional stage was indeterminate.

3.2.2 Prism Penetration Depth

The SPI prism penetration depths were similar for the entire survey ranging from 1.00 to 6.79 cm, with a mean penetration depths of 4.31 cm for the pre-disposal locations, 4.47 cm for the post-disposal locations, and 4.17 cm for the transect locations. Similarly, the mean penetration depth for native material was 4.17 cm (n = 35) compared to 4.35 cm (n = 42) of penetration in locations with dredged material. In general, the relatively shallow prism penetrations were due to the similar sandy substrate of both the native and dredged materials. Since the camera weight was constant throughout each survey, the penetration depths indicate that the consolidation of the sediments in the dredged material footprint is similar to the native substrate.

3.2.3 Dredged Material Thickness

Dredged material thickness was assessed in the 42 images located within the depositional footprint following disposal (Tables 4 & 5). Due to the visual similarities (i.e., color and particle size) and comparable consolidation of the dredged material relative to the native substrate it was not possible to discern a boundary between them. As discussed in Section 3.2.2, the mean prism penetration within the dredged material footprint was 4.35 cm or 1.71 inches, which is less than the average estimated depth (5.16 to 6.83 cm; or 2.03 to 2.69 inches) of dredged material based on volume placed in each disposal lane (Table 2). Therefore, the dredged material thickness could not be determined from the SPI images, and was recorded as equivalent to the prism penetration depth for images showing dredged material.

3.2.4 Mean Small-Scale Boundary Roughness

Small-scale boundary roughness features at the sediment surface are the result of depositional, erosional, and biogenic processes. Scouring of surface sediments by waves and currents, slope failure, or turbidite formation can also create physically induced boundary roughness. For the nearshore SPI survey, the source of boundary roughness was determined to be mainly due to physical processes. Biogenic activity that contributes to boundary roughness includes the formation of fecal mounds, burrow excavation mounds, megafaunal foraging, or feeding pits which were largely absent in the sandy substrate of the nearshore area. The boundary roughness for the native material (n = 35) ranged from 0.40 to 3.77 cm (mean = 1.57 cm), and ranged from 1.00 to 6.79 cm (mean = 1.48 cm) for the areas of dredged material deposition (n = 42). These results indicate that the placement of dredged material in the nearshore did not modify the small-scale substrate topography by introducing an increased surface relief on the existing sandy bottom.

3.2.5 Benthic Habitat Type

The benthic habitat consisted of hard sand bottom and two sub-types were identified in the images collected during the survey: 1) hard sand bottom: fine sand (SA.F) and 2) hard sand bottom: medium sand (SA.M). The native benthic habitat type (n = 35) consisted of both habitat type (SA.F: 52%; SA.M: 49%), whereas the dredged material habitat (n= 42) shifted towards the coarser grained substrate (SA.M: 90%; SA.F: 10%). The slight differences in habitat type are directly correlated to the marginal change in grain size major mode. Homogenous hard sandy

bottoms like the nearshore area are typically not bioturbated and are dominated by physical processes.

3.2.6 Infaunal Successional Stage

The infaunal successional stages observed in the images (n = 77) were Stage I (9%) and one instance of Stage I on III (1%), but for most images the infaunal successional stage was indeterminate (90%). The reasons for the indeterminate qualification are due in part to the native sandy substrate located at the site and the recent placement of dredged material. However, these data also indicate that the nearshore site does not have an established, complex infaunal community. Rather, the sandy substrate and high energy system result in a continuous Stage I community, with a sediment-water interface composed of small, colonizing benthic organisms. The Stage I on III successional stage indicates that the infaunal community has been physically disturbed and is in the process of re-colonization. The overall benthic habitat type is not modified because of similarities between the native sediment and dredged material.

3.3 Grain Size Results

A total of 10 surface sediment samples (0-10 cm) were collected and submitted for grain size distribution analysis. A total of six samples (1C, 2C, 3C, 4C, 5C, and 6C), one from each disposal lane was collected to characterize the dredged material placed at the nearshore study area. Four of the sediment sampling locations (1CN, 2/3C, 4/5C, and 6CS) were collected outside the dredged material footprint. Field observations were relatively consistent between the two substrate types, tan/gray, fine/medium to medium coarse sand, with benthic and epibenthic organisms (amphipods, polychaetes, sand dollars, and hermit crabs) were observed in both native and dredged material samples. A summary of field observations are presented in Table 6.

The quantitative results of the grain size distribution analysis (Table 7 and Figure 12) exemplify the similarities between the native substrate and the dredged material. The mean grain size distribution for the native substrate consisted of 99.3% sand, while the dredged material was 99.47%. The subtle difference between the two sample types was the distribution within the sand fraction. The native material had a slightly higher content of fine sand fraction (50.9%) relative to a medium sand fraction (43.9%). The dredged material was slightly coarser in content between the fine sand fraction (38.4%) and medium sand fraction (55.63%).

The most likely reason for the differences in distribution is the source of the dredged material. Since the dredged material was collected from the MCR navigational channel, the strong river currents combined with an ebb tide create a high energy environment that affects the relative sediment deposition and transport.

Table 6. Grain Size Descriptions

Sediment Sampling Station	Native or Dredged Material	Field Description/Observations
1CN	Native	Tan/gray fine/medium sand, scattered tubes on surface, amphipods and sand dollar observed in sample.
1C	Dredged Material	Medium sand, trace of wood debris, hermit crab on surface, traces of shell pieces, sand dollar, amphipods, and polychaetes observed in sample.
2C	Dredged Material	Homogenous, medium/fine sand, tubes below surface (buried?), scattered woody debris and shell pieces on surface.
2/3C	Native	Tan/gray fine/medium sand, scattered tubes & trace of fine shell debris on surface.
3C	Dredged Material	Tan/gray medium sand, no visible benthic/epibenthic organisms, trace of shell debris.
4C	Dredged Material	Tan/gray coarse/medium sand, traces of shell debris, small sand dollar (1/2 inch), a few tubes.
4/5C	Native	Fine/medium sand, gastropod & hermit crab, black fine-grained material present on surface.
5C	Dredged Material	Relatively homogenous, medium coarse sand, no odor, small tubes and a trace of small scattered shell pieces on surface.
6C	Dredged Material	Homogenous, gray medium coarse sand.
6CS	Native	Fine/medium sand, olive gray w/ some dark patches, small tubes on surface, organic (i.e. fresh fish) odor.

Table 7. Grain Size Distribution (% retention)

Station	Gravel			Sand					Silt				Clay		
				very coarse	coarse	medium	fine	very fine							
phi size (Φ):	< -2	-2	-1	0	+1	+2	+3	+4	+5	+6	+7	+8	+9	+10	> +10
mm:	4.75	4	2	1	0.5	0.25	0.125	0.063	0.032	0.016	0.008	0.004	0.002	0.001	<0.001
1CN	< 0.1	0.10	0.30	0.10	1.3	42.1	53.0	2.90	0.30	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1
1C	< 0.1	< 0.1	< 0.1	0.30	1.00	57.6	38.4	2.80	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1
2C	< 0.1	< 0.1	0.10	0.30	1.90	56.8	38.8	1.90	0.30	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1
2/3C	< 0.1	< 0.1	< 0.1	0.30	0.40	42.9	52.2	4.10	0.30	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1
3C	< 0.1	< 0.1	0.30	0.40	1.20	49.0	44.1	5.00	0.10	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1
4C	< 0.1	< 0.1	< 0.1	0.10	4.60	73.7	19.8	1.30	0.50	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1
4/5C	< 0.1	0.30	0.10	0.50	0.60	52.0	41.7	3.70	0.40	< 0.1	0.40	0.20	< 0.1	< 0.1	< 0.1
5C	< 0.1	< 0.1	0.10	0.40	0.50	44.3	47.1	6.80	< 0.1	< 0.1	0.40	0.20	< 0.1	< 0.1	< 0.1
6C	< 0.1	< 0.1	0.40	0.10	0.90	52.4	42.0	3.30	0.30	< 0.1	0.60	< 0.1	< 0.1	< 0.1	< 0.1
6CS	< 0.1	< 0.1	< 0.1	0.10	0.80	38.8	56.7	2.90	0.60	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1

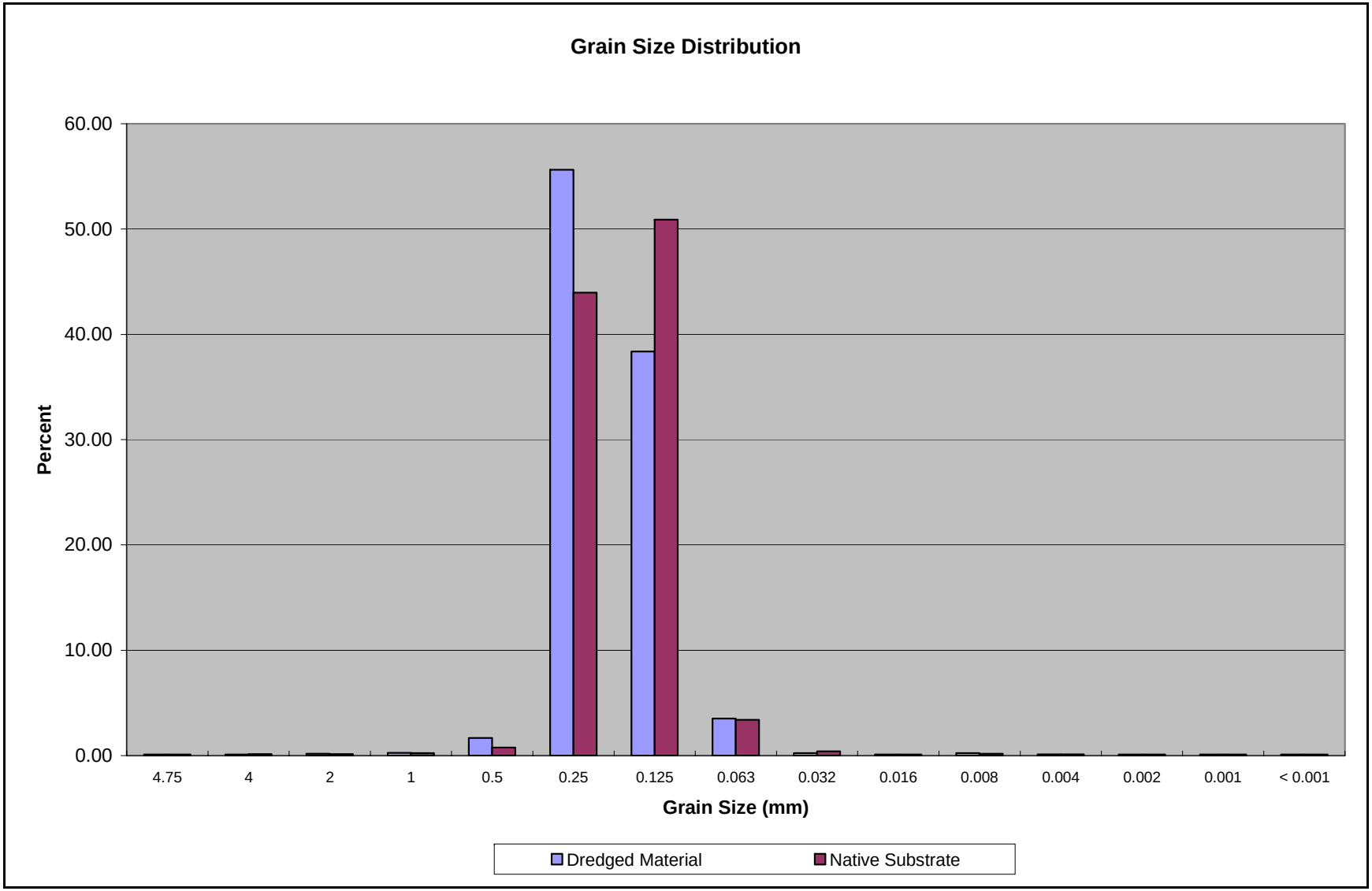

Figure 12. Grain Size Distribution

3.4 Bathymetric Survey

The bathymetric survey of the pilot study site was conducted over three days covering an area of 4.7 km^2 in water depths ranging from 30 to 60 feet deep. Based on the backscatter imagery, the general overview of geomorphic conditions following the placement of dredged material at the site concluded that topography was very flat. The six East-West disposal lanes are visible in the image, but there was no measurable bathymetric relief (Appendix C, Figure: *Area 2D MBES Backscatter Imagery*).

4.0 Discussion

The various data types collected to monitor the enhanced placement of dredged material at the nearshore site were consistent in their findings. The native substrate and the dredged material placed at the nearshore site are very similar in visual and physical characteristics. Subtle differences in the grain size distribution, with the dredge material consisting of slightly more medium grained sand, were evident in the SPI images, grain size analysis, and backscatter imagery. However, these differences in grain size were too subtle to result in notable changes in the seafloor topography or benthic habitat within the nearshore site following the placement of dredged material.

Figures 13 through 16 provide a set of examples that demonstrate seafloor conditions at Stations 2B and 5A, respectively, both before and after the placement of dredged material. These two sets of images reflect both the similarities and contrasts between the native substrate and dredged material. In the pre-disposal images both locations demonstrate a relatively heterogeneous mix of fine-grained sand, with streaks of darker colored particles throughout the sediment horizon. The post-disposal images demonstrate the presence of a more homogenous substrate consisting primarily of medium grained sand. Both pre- and post-disposal substrates demonstrate a similar sediment type (consolidated sand), benthic habitat type, and indeterminate benthic stage, which is typical for higher energy sandy substrates.

The depositional depth of the dredged material footprint was estimated to average from 2.03 to 2.69 inches based on the volume of material placed at each disposal lane. This depositional estimate is within the targeted depth identified in the permit letter. The visual and physical similarities of the dredged material and native substrate, in conjunction with the prism penetration depth, inhibited the identification of an interface between the deposition and original surface in the SPI images. The bathymetric survey was unable to discern any measurable bathymetric relief following placement, which would indicate that significant mounding of dredged material did not occur. The slightly coarser-grained sand provided the only identifiable physical attribute in each of the data types collected to indicate the presence of dredged material.

The physical characteristics of the native substrate and dredged material are similar enough, as demonstrated in the SPI images, that changes to the seafloor that would adversely affect the benthic habitat are not anticipated. The dredged material provides the same habitat-type for benthic organisms that existed prior to disposal. The native substrate benthic community stage was identified as either indeterminate or as Stage 1 for all the pre-disposal images. This is typical for a sandy substrate in a high energy environment. The benthic community is in a

continual state of flux as a pioneering community due to changes from natural physical processes. The dredged material does not alter the topographic relief in a manner that would affect physical processes along the seafloor, and should be readily adapted to and utilized by the pioneering benthic community that is predominate at the site.

Based on the data collected for the pilot study, enhanced disposal in a nearshore environment appears to be a feasible alternative for the beneficial use of dredged materials from the MCR navigational channel. Further investigations would be warranted to determine the extent of desired benefits from placing the additional material in the littoral zone.

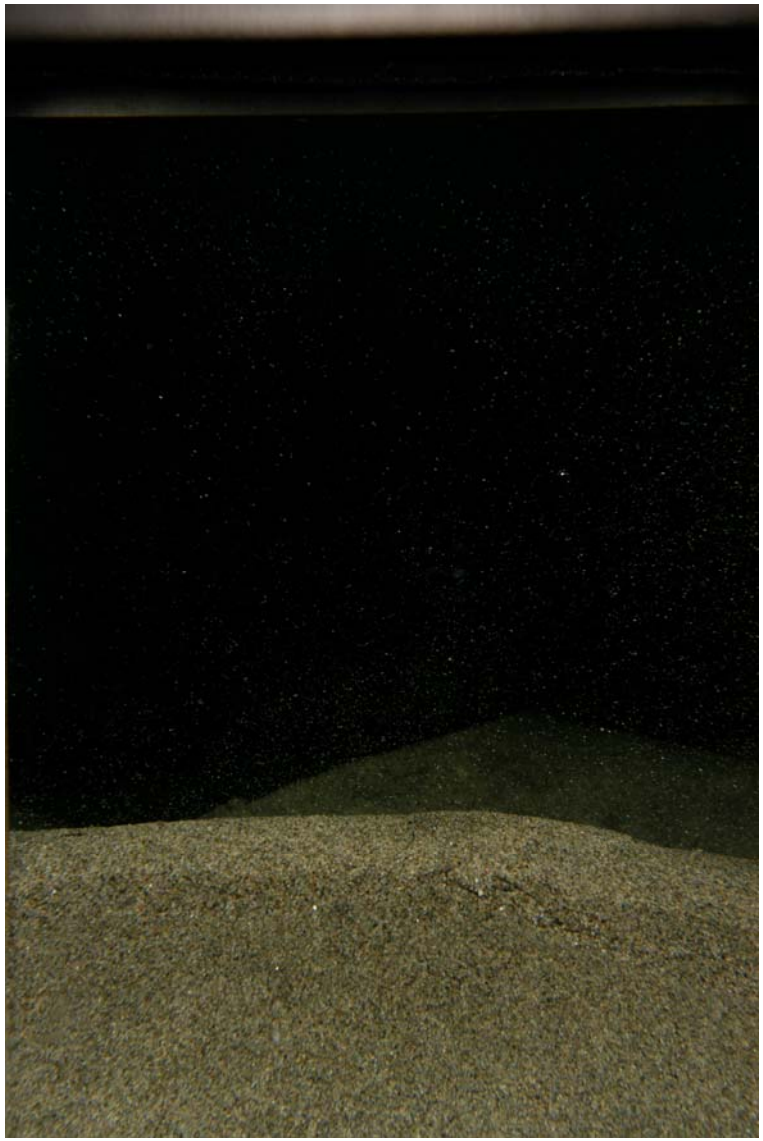

Figure 13. Station 2B Pre-Disposal

Figure 14. Station 2B Post-Disposal

Figure 15. Station 5A Pre-Disposal

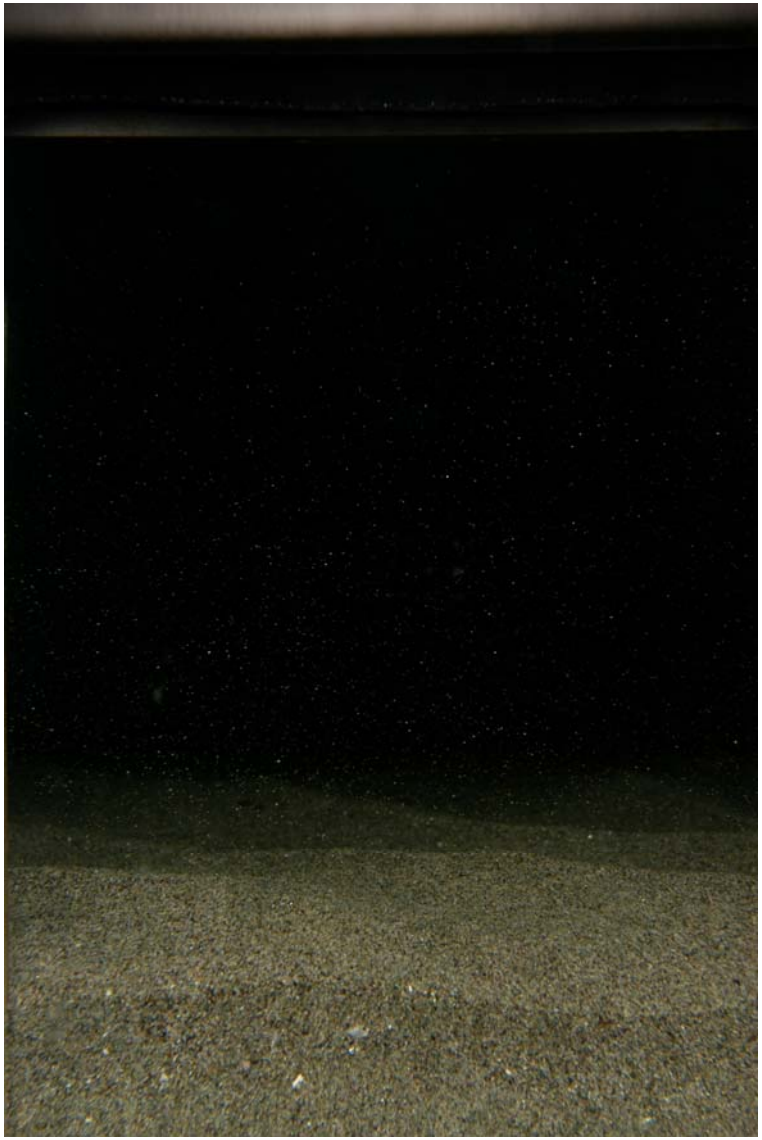

Figure 16. Station 5A Post-Disposal

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Appendix A

SPI Images

Pre-Disposal Survey

Station: 1A00 Replicate: 2

Station: 1C00 Replicate: 3

Pre-Disposal Survey

Station: 2B00 Replicate: 2

Station: 2D00 Replicate: 1

Pre-Disposal Survey

Station: 3A00 Replicate: 1

Station: 3C00 Replicate: 1

Pre-Disposal Survey

Station: 4B00 Replicate: 1

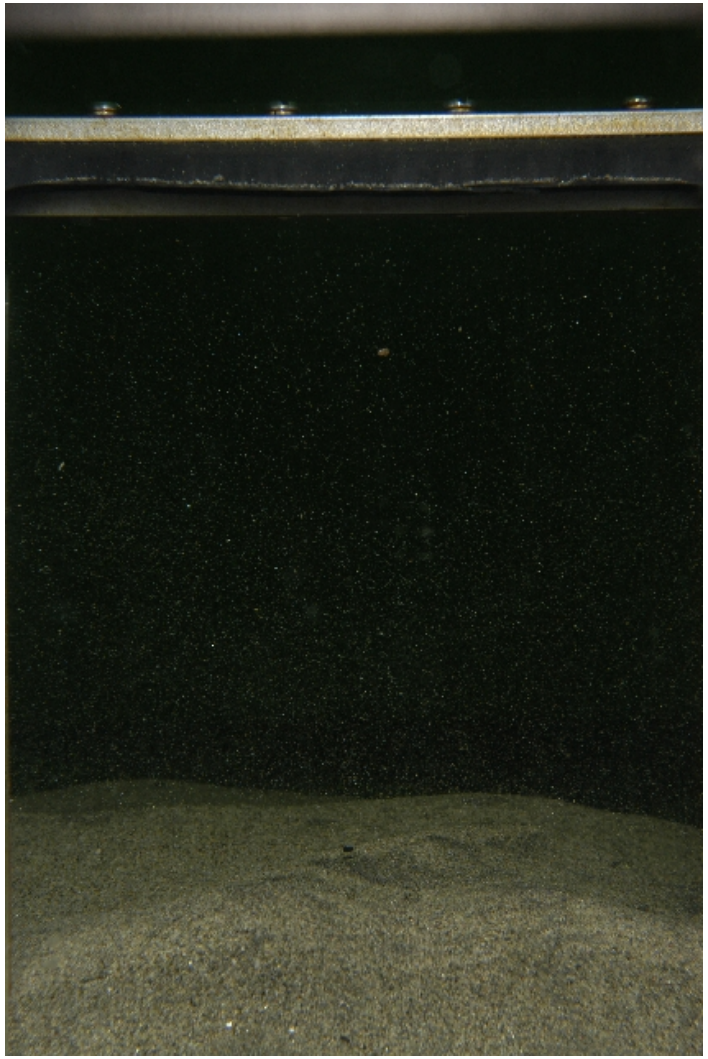
Station: 4D00 Replicate: 1

Pre-Disposal Survey

Station: 5A00 Replicate: 1

Station: 5C00 Replicate: 2

Pre-Disposal Survey



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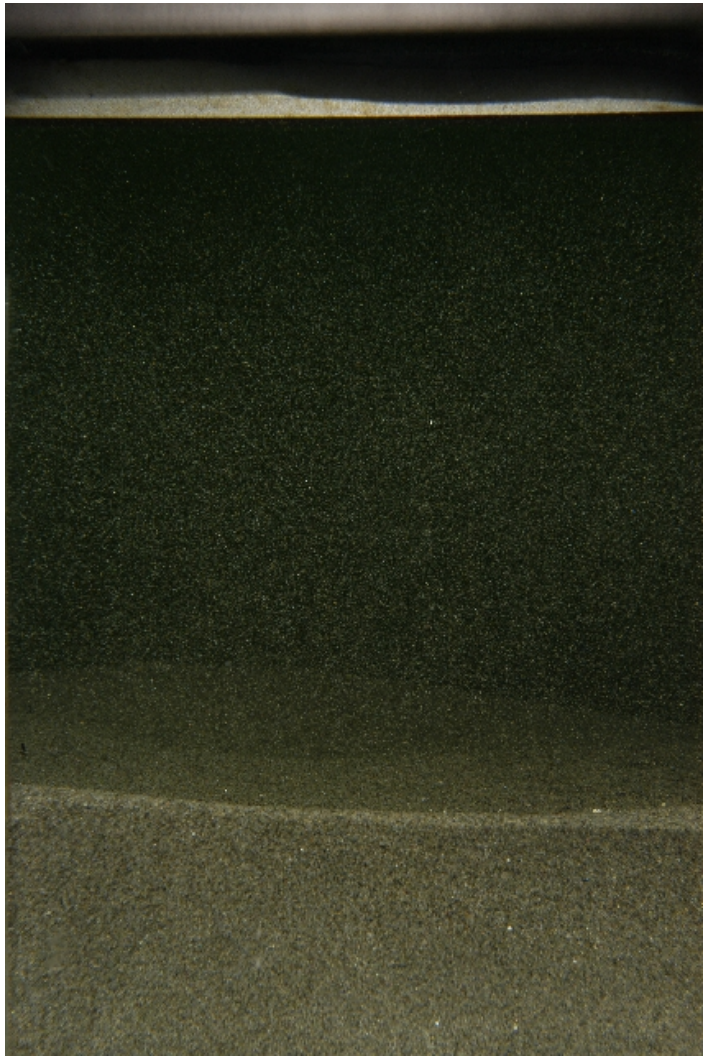


Station: 6D00 Replicate: 1

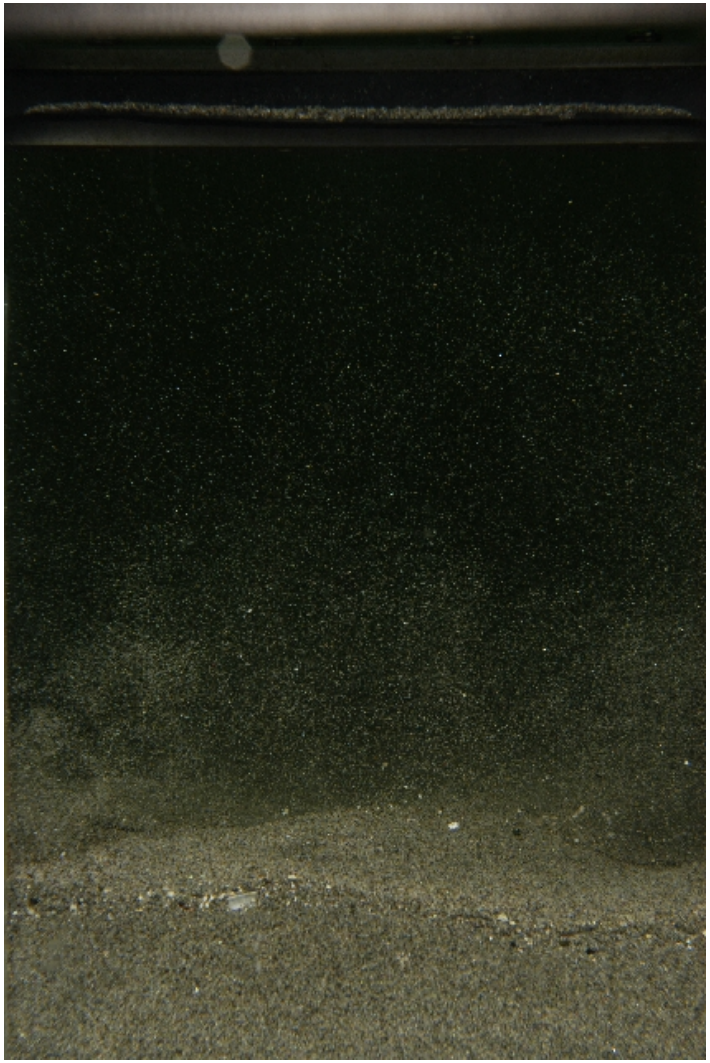
Post-Disposal Survey

Station: 1A01 Replicate: 1

Station: 1B01 Replicate: 3

Post-Disposal Survey

Station: 1C01 Replicate: 2



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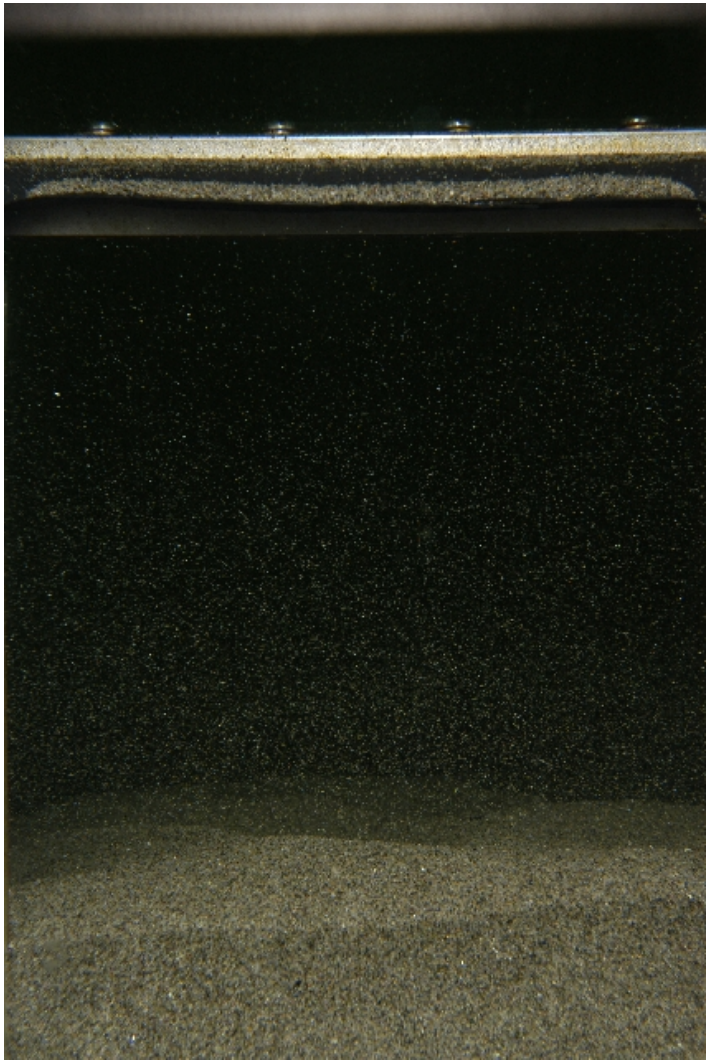
Post-Disposal Survey

Station: 2A01 Replicate: 2

Station: 2B01 Replicate: 3

Post-Disposal Survey

Station: 2C01 Replicate: 2



Station: 2D01 Replicate: 2

Post-Disposal Survey

Station: 3A01 Replicate: 2

Station: 3B01 Replicate: 1

Post-Disposal Survey

Station: 3C01 Replicate: 1

Station: 3D01 Replicate: 2

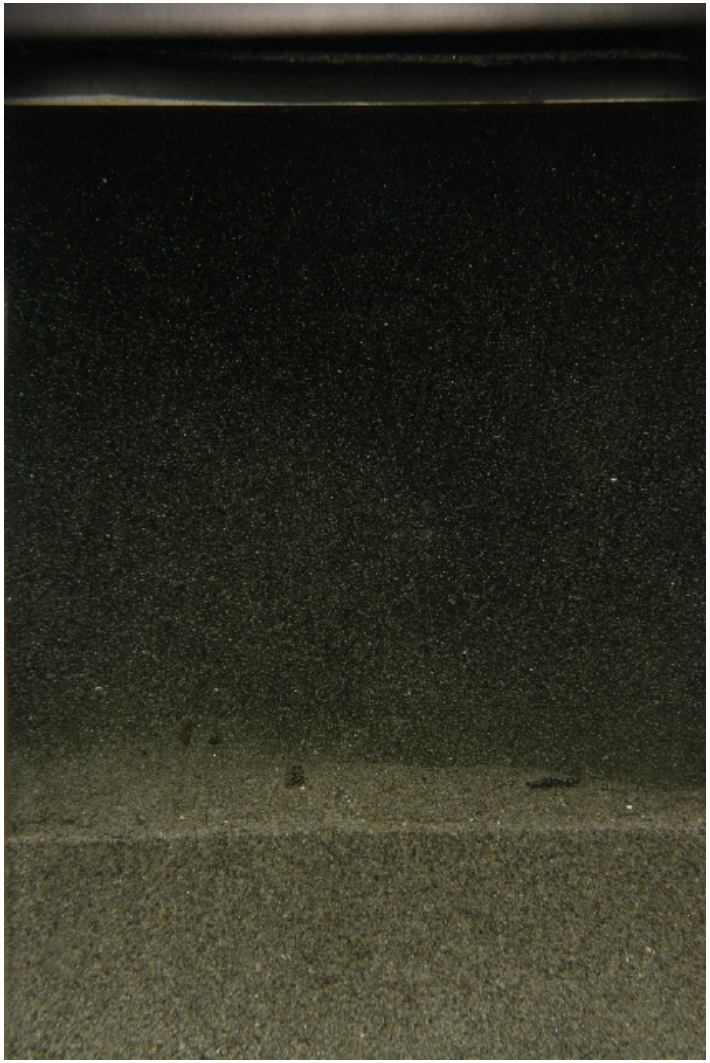
Post-Disposal Survey

Station: 4A01 Replicate: 3

Station: 4B01 Replicate: 1

Post-Disposal Survey

Station: 4C01 Replicate: 2



Station: 4D01 Replicate: 1

Post-Disposal Survey

Station: 5A01 Replicate: 4

Station: 5B01 Replicate: 2

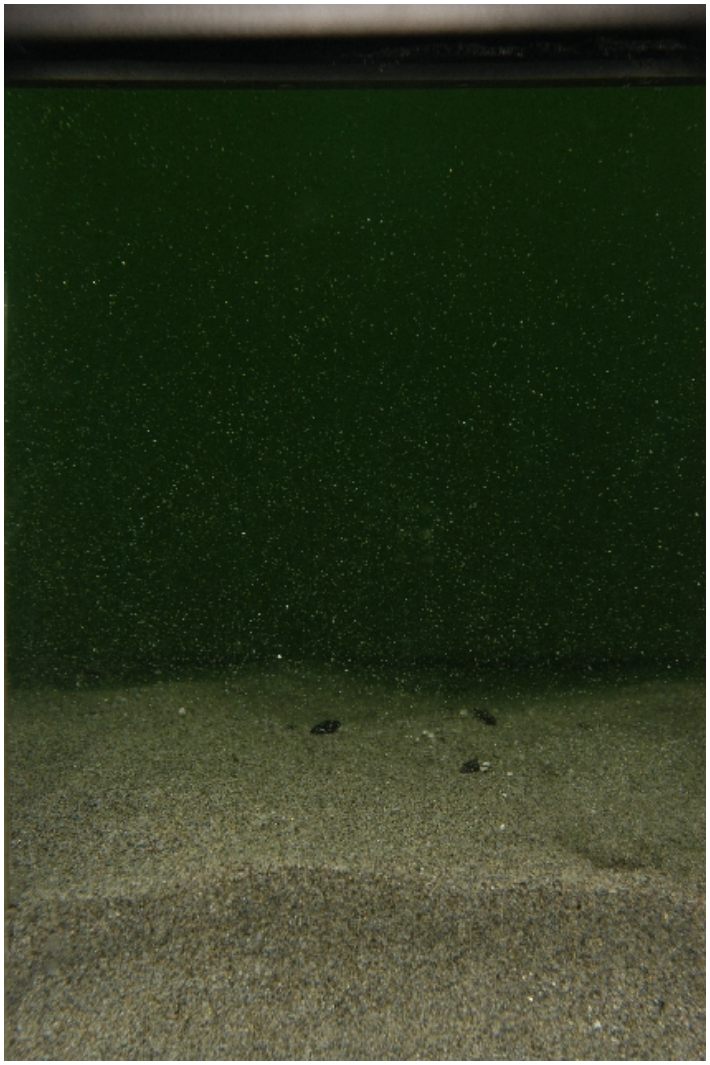
Post-Disposal Survey

Station: 5C01 Replicate: 3

Station: 5D01 Replicate: 1

Post-Disposal Survey

Station: 6A01 Replicate: 1



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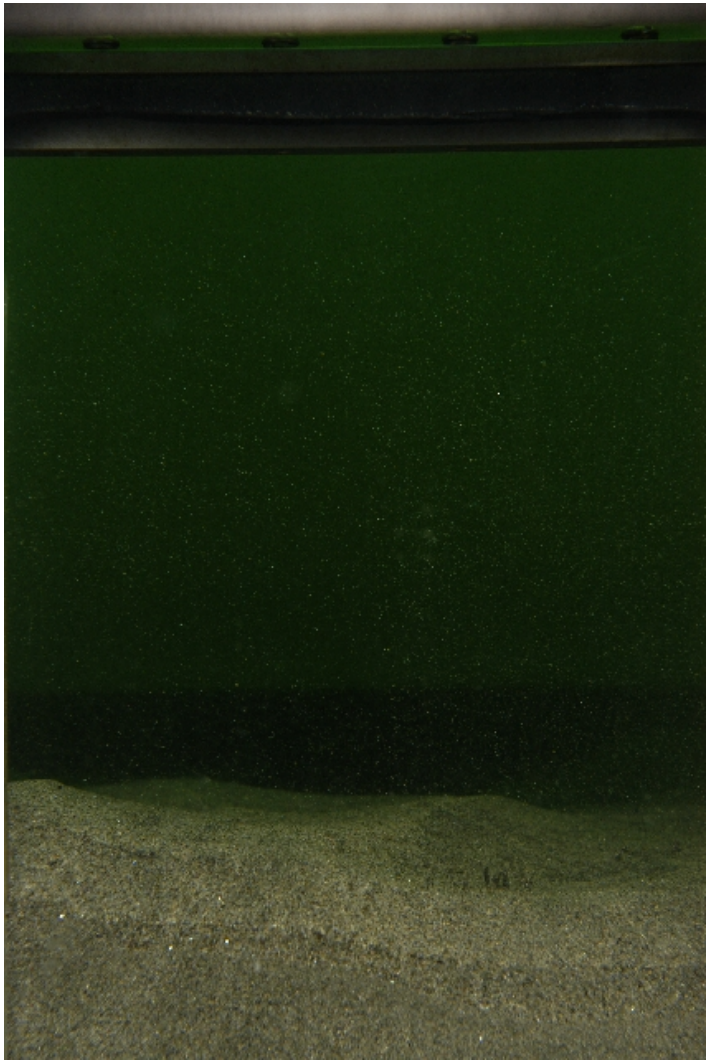
Post-Disposal Survey

Station: 6C01 Replicate: 1



Station: 6D01 Replicate: 3

Disposal Lane Transects Survey

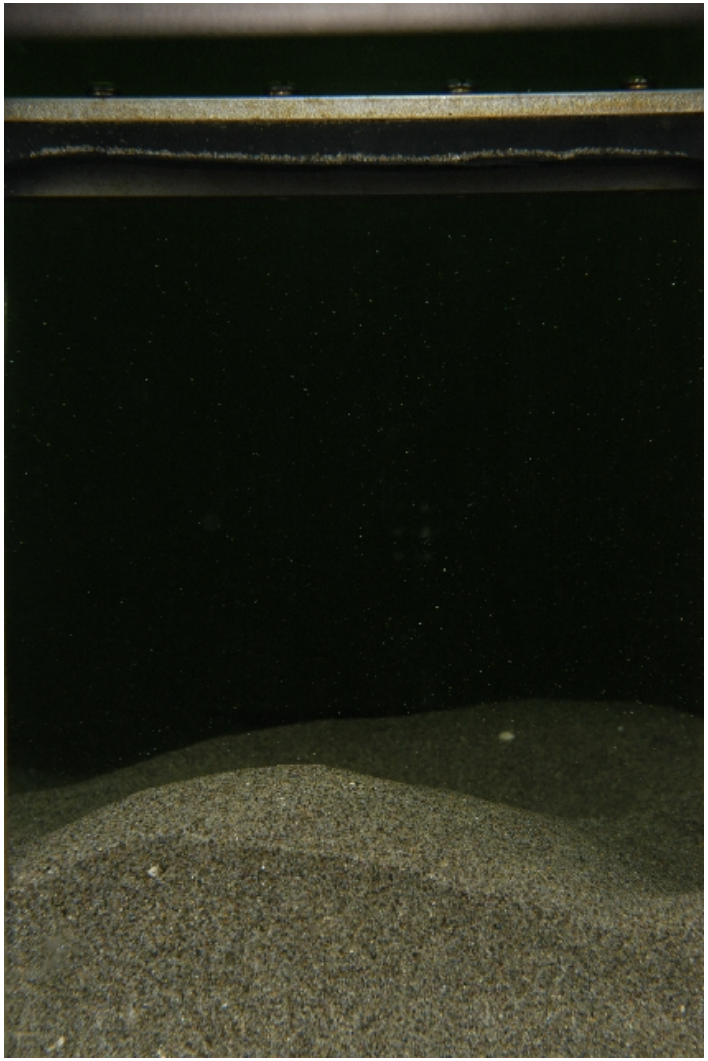
Station: T1 Replicate: A

Station: T1 Replicate: AB

Station: T1 Replicate: B

Station: T1 Replicate: C

Disposal Lane Transects Survey



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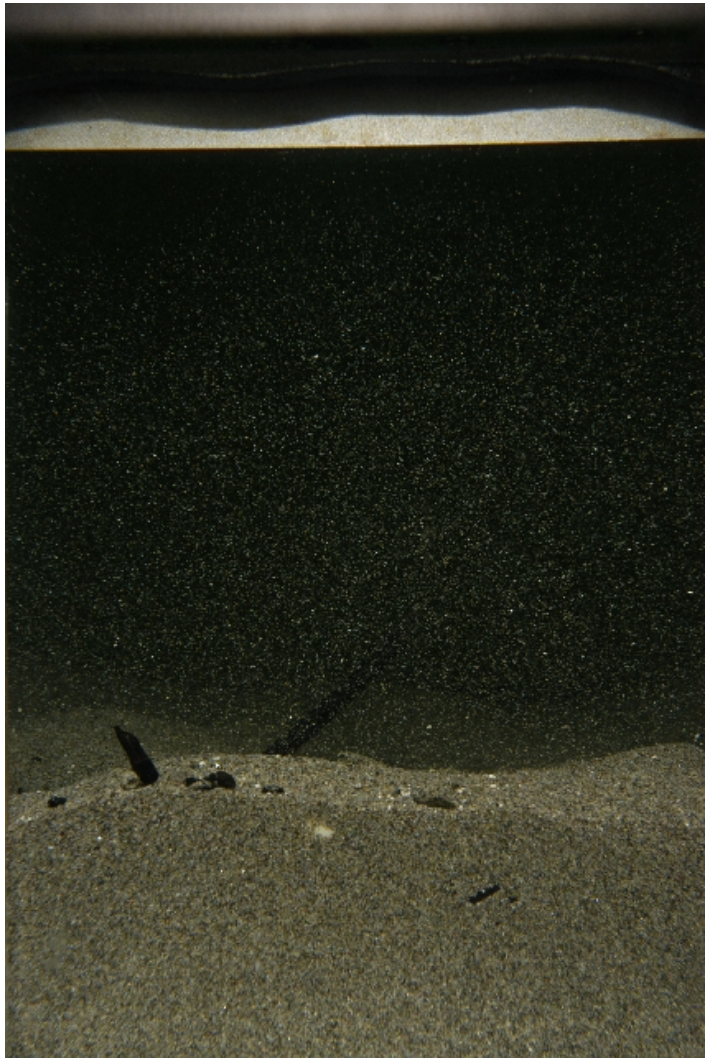

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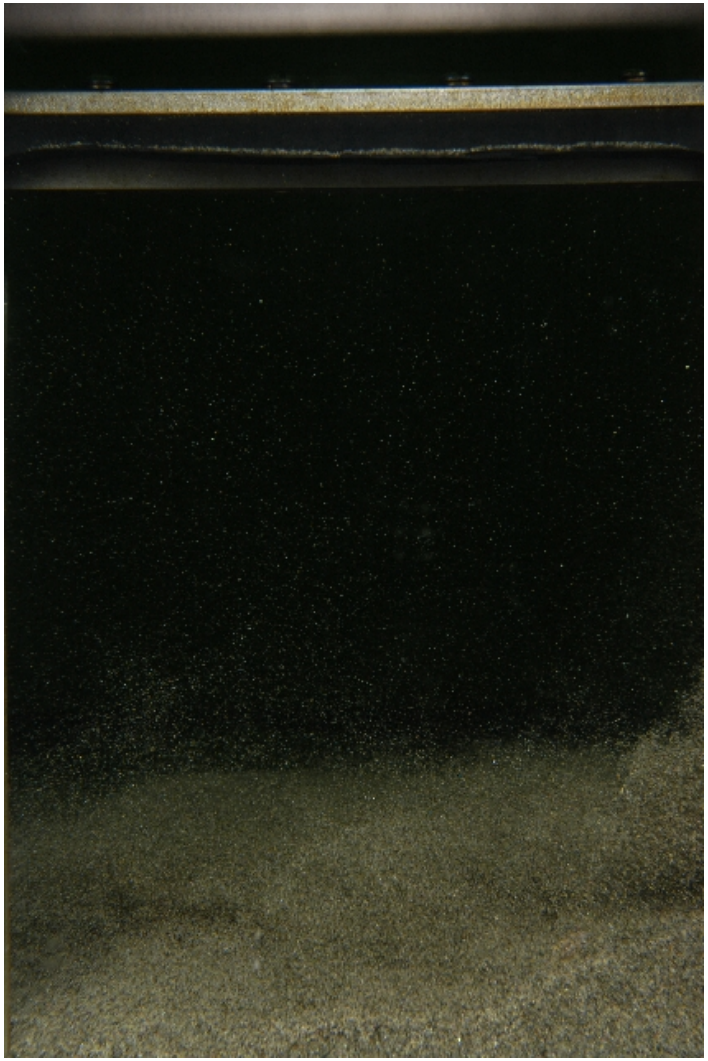

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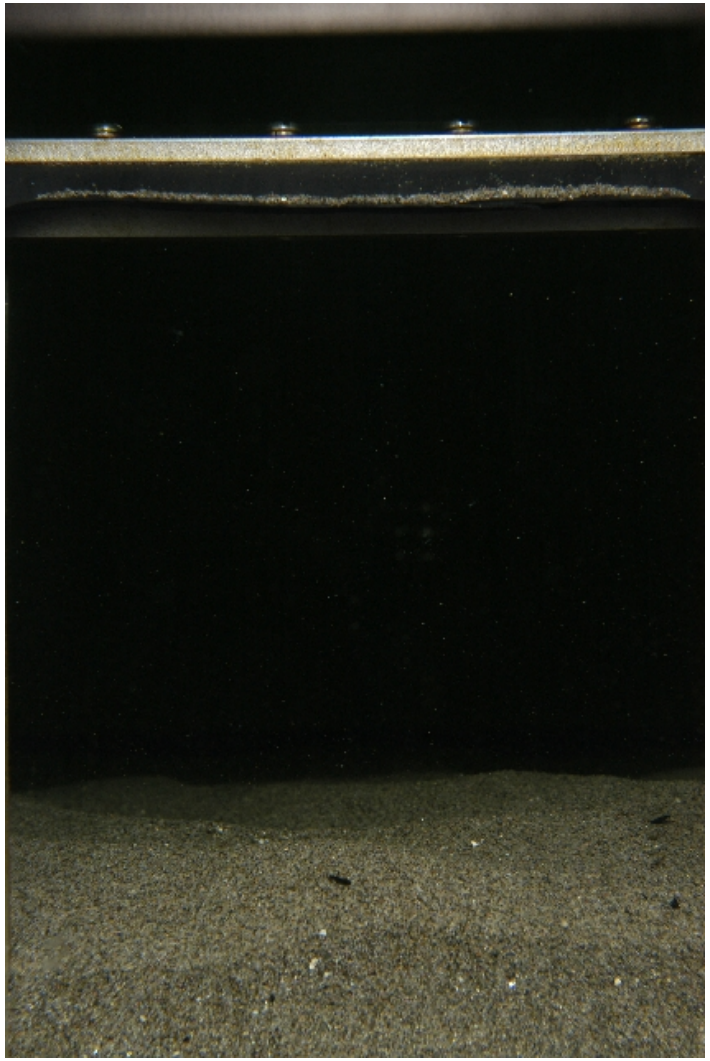
Station: T1 Replicate: F

Station: T1 Replicate: G



Station: T1 Replicate: H

Station: T1 Replicate: I

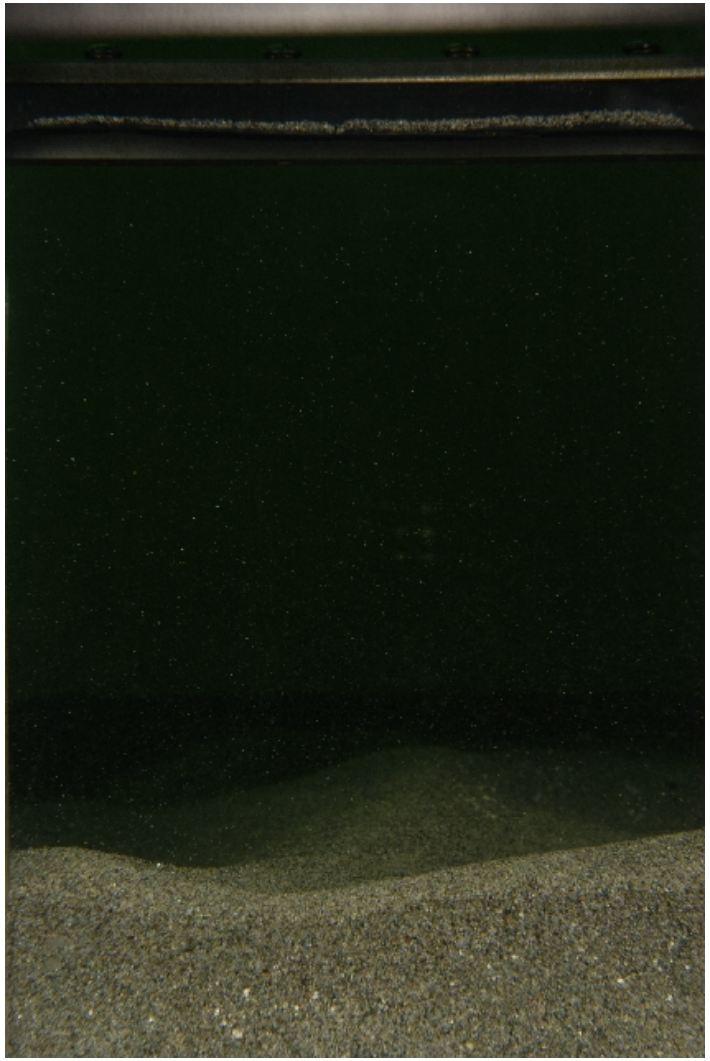
Station: T1 Replicate: J

Disposal Lane Transects Survey

Station: T1 Replicate: K

Station: T2 Replicate: A

Station: T2 Replicate: B



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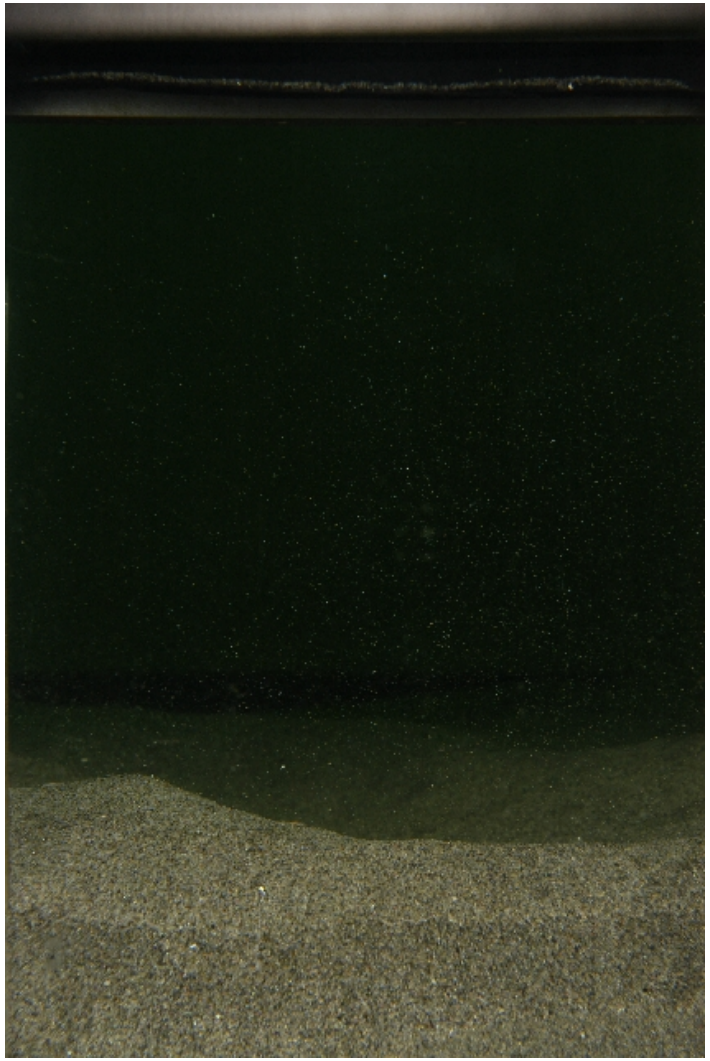

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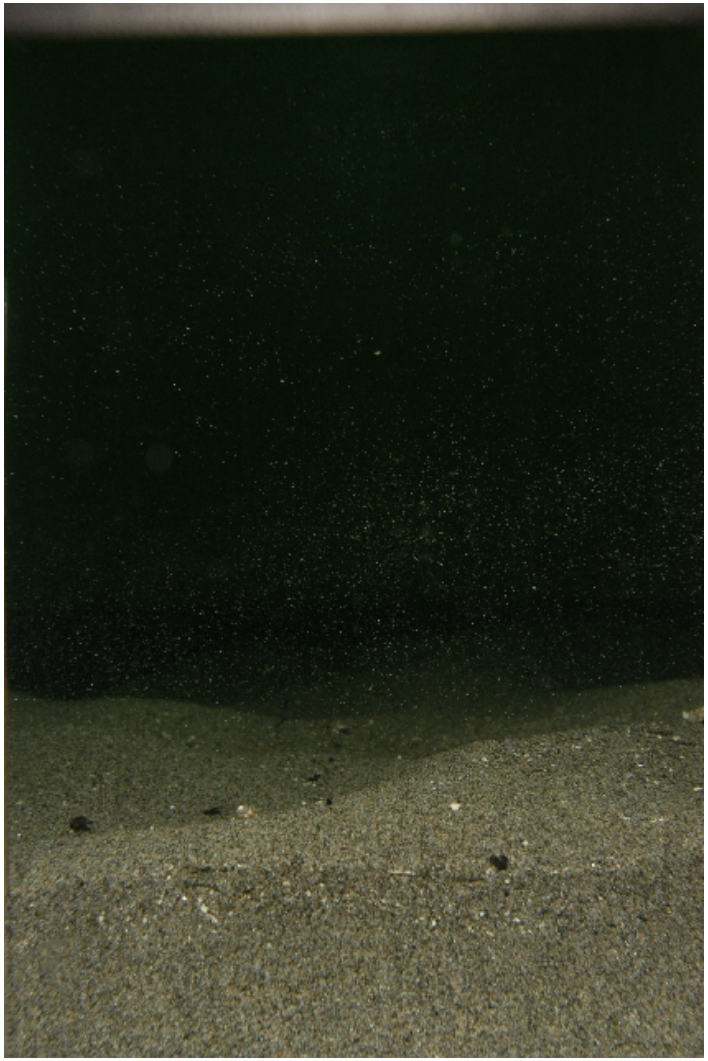

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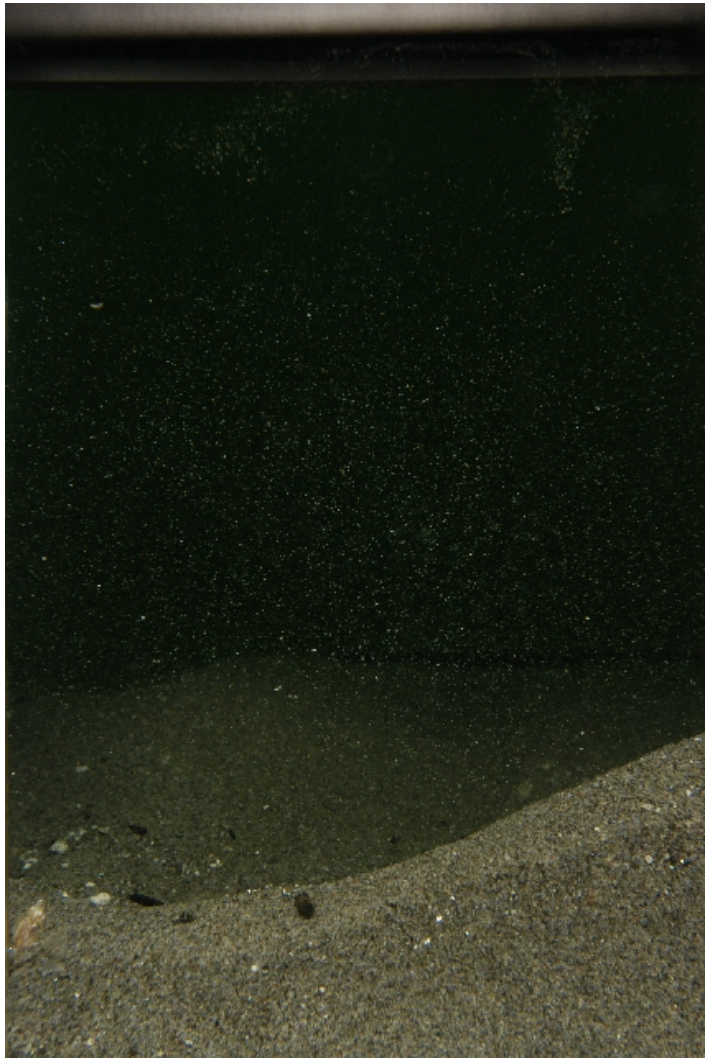
Station: T2 Replicate: I

Station: T2 Replicate: J



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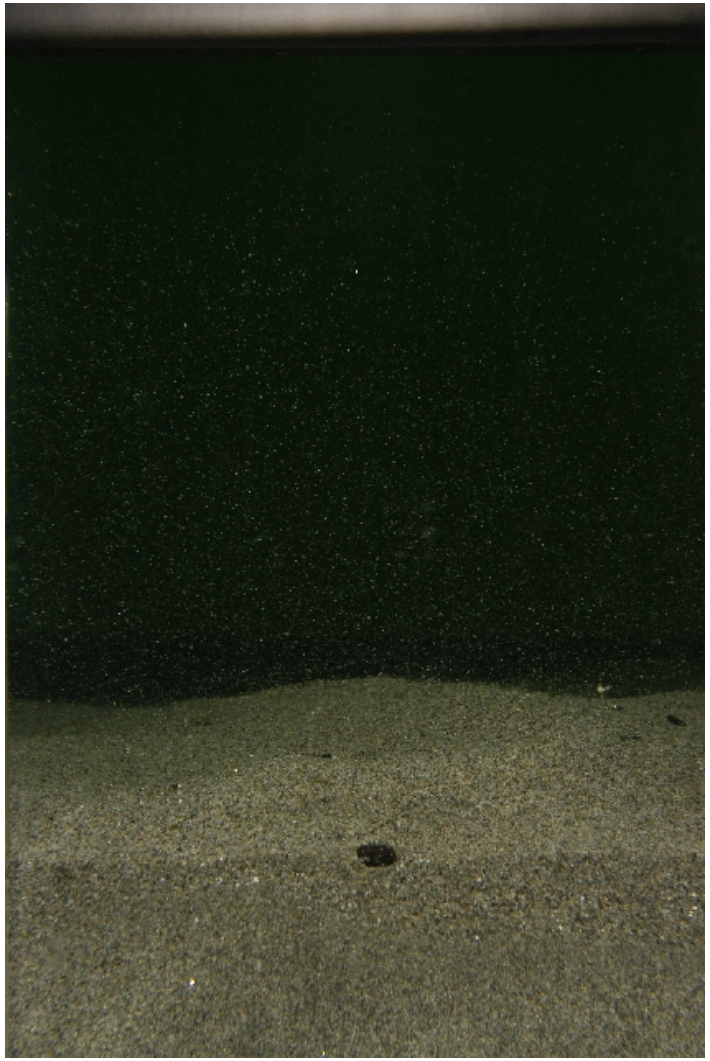

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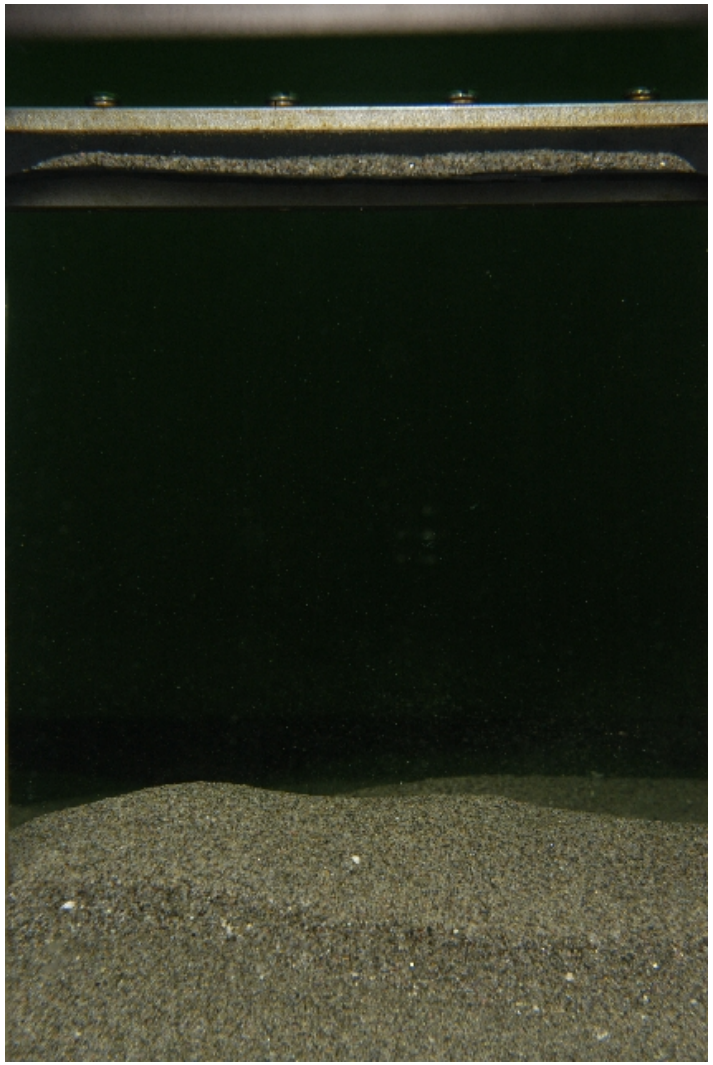

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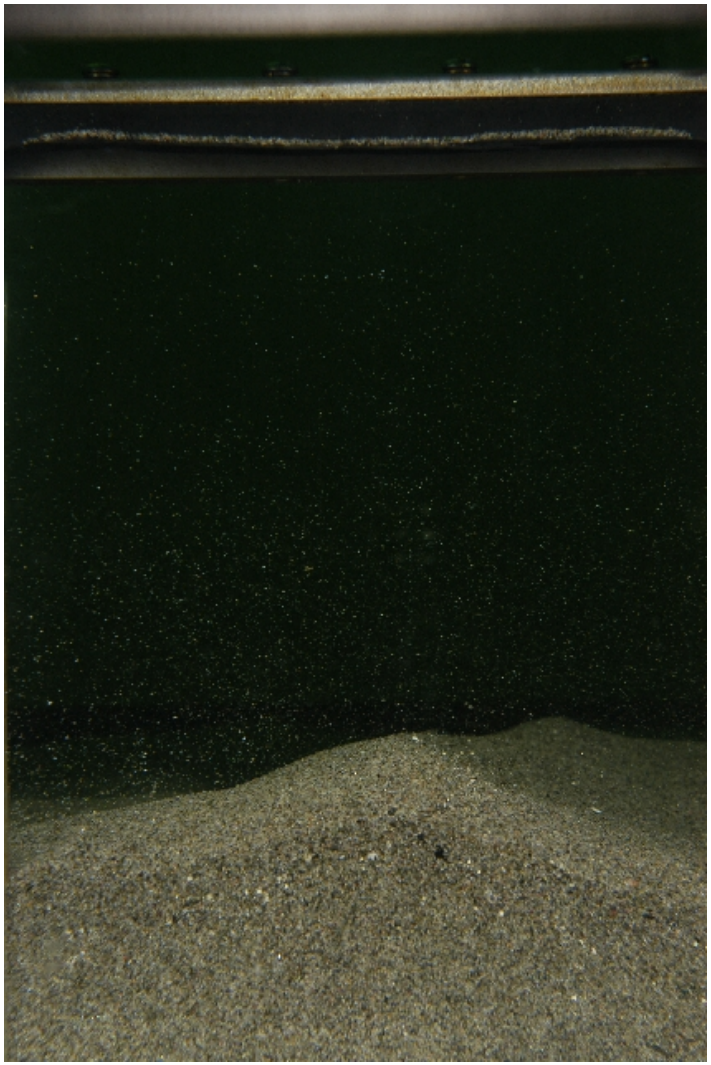

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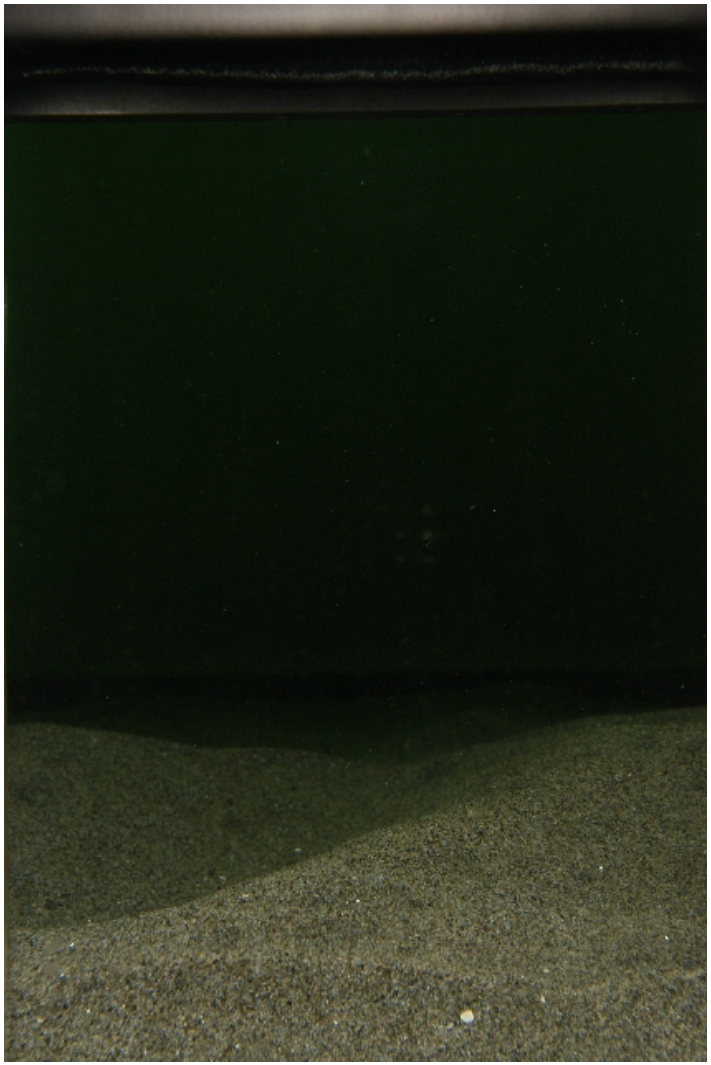
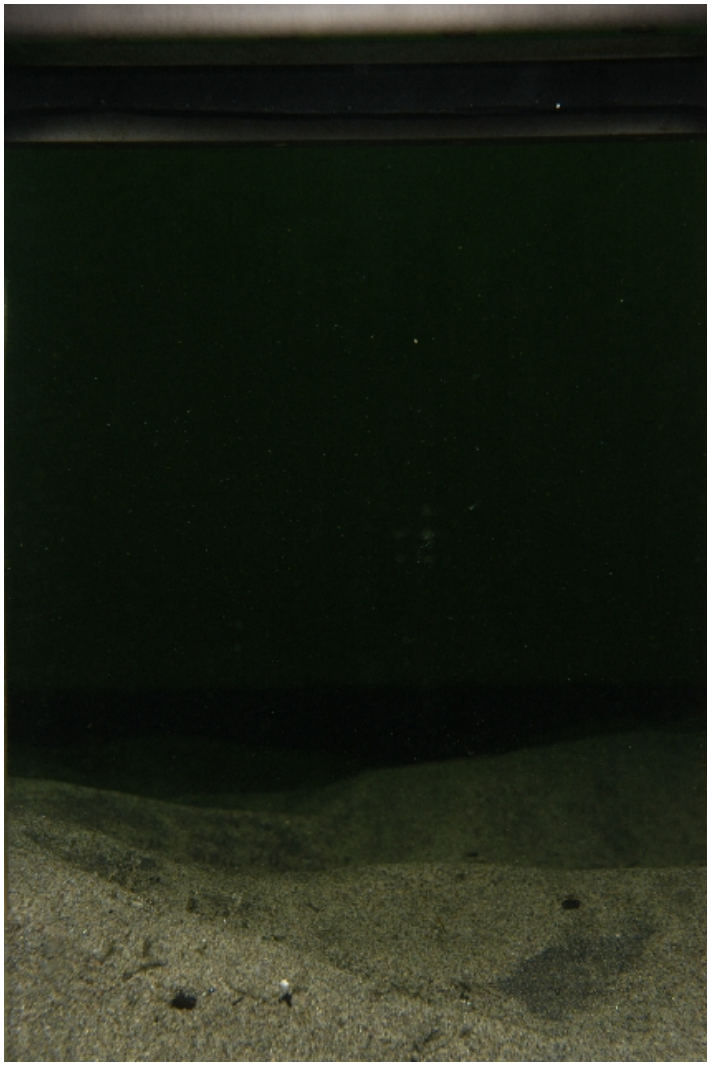
Station: T2 Replicate: R



Station: T2 Replicate: S

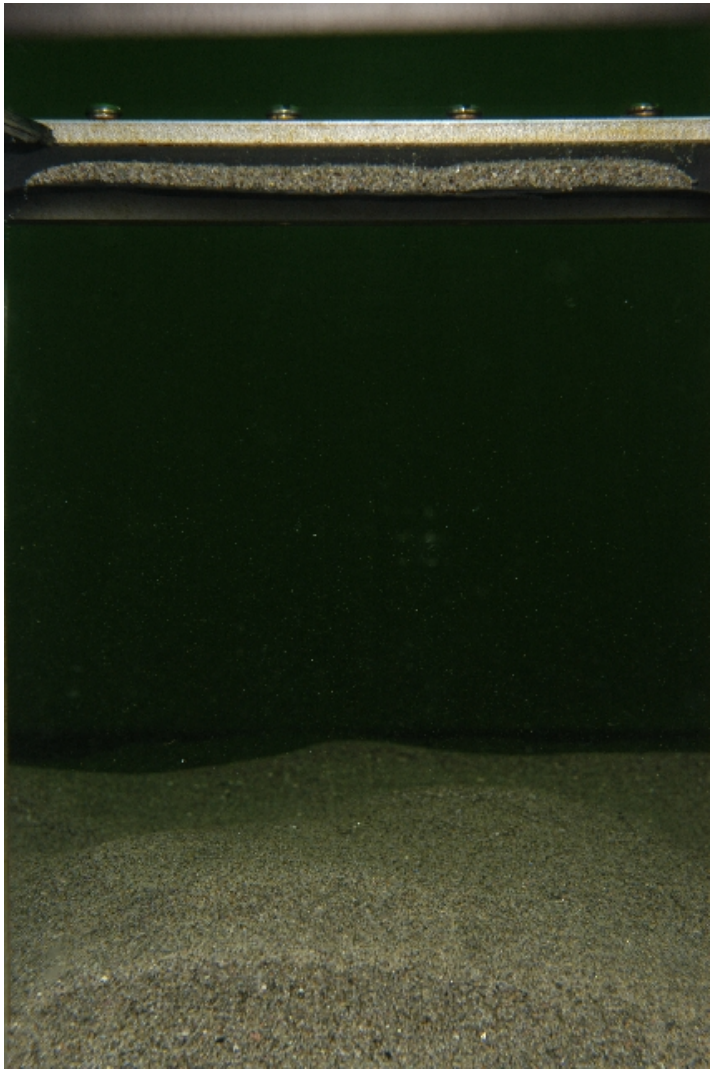
Disposal Lane Transects Survey

Station: T2 Replicate: T



Station: T3 Replicate: A

Station: T3 Replicate: B



Station: T3 Replicate: C

Station: T3 Replicate: D

Station: T3 Replicate: E

Station: T3 Replicate: F

Station: T3 Replicate: G

Station: T3 Replicate: H

Appendix B

SPI and Surface Sediment Sampling Location Coordinates

UTM Zone 10 N - METERS

STATION	X	Y	LAT	LON	TIME	DATE	EVENT	DESCR
1A-00-1	417995.4	5119134.9	46.22085	-124.0633	9:29:38	9/14/2005	PRE	SPI
1A-00-2	418024.2	5119131.1	46.22081	-124.0629	9:30:38	9/14/2005	PRE	SPI
1A-00-3	418035.8	5119132.4	46.22083	-124.0628	9:31:28	9/14/2005	PRE	SPI
1C-00-1	418989.2	5119171.6	46.22129	-124.0504	9:40:15	9/14/2005	PRE	SPI
1C-00-2	419027.3	5119160	46.2212	-124.0499	9:41:21	9/14/2005	PRE	SPI
1C-00-3	419041.5	5119157.1	46.22117	-124.0497	9:42:28	9/14/2005	PRE	SPI
1C-00-4	419051	5119157.3	46.22117	-124.0496	9:43:26	9/14/2005	PRE	SPI
2B-00-1	418688.3	5118909.7	46.2189	-124.0543	9:48:37	9/14/2005	PRE	SPI
2B-00-2	418675.3	5118913	46.21893	-124.0544	9:49:30	9/14/2005	PRE	SPI
2B-00-3	418670.5	5118914.6	46.21894	-124.0545	9:50:26	9/14/2005	PRE	SPI
2D-00-1	419516	5118936.6	46.21924	-124.0435	9:57:57	9/14/2005	PRE	SPI
2D-00-2	419521.3	5118953.8	46.2194	-124.0435	9:58:51	9/14/2005	PRE	SPI
2D-00-3	419523.6	5118964.6	46.2195	-124.0434	9:59:41	9/14/2005	PRE	SPI
3A-00-1	418429.2	5118640.3	46.21645	-124.0576	10:16:21	9/14/2005	PRE	SPI
3A-00-2	418418.2	5118631.4	46.21637	-124.0577	10:17:06	9/14/2005	PRE	SPI
3A-00-3	418414.4	5118635.2	46.2164	-124.0578	10:17:56	9/14/2005	PRE	SPI
3C-00-1	419388.7	5118680.1	46.21692	-124.0451	10:06:30	9/14/2005	PRE	SPI
3C-00-2	419381.3	5118655.7	46.2167	-124.0452	10:07:29	9/14/2005	PRE	SPI
3C-00-3	419379.3	5118649.6	46.21664	-124.0453	10:08:28	9/14/2005	PRE	SPI
4B-00-1	419020.4	5118437.5	46.21469	-124.0499	10:24:42	9/14/2005	PRE	SPI
4B-00-2	419051.5	5118453.3	46.21484	-124.0495	10:25:43	9/14/2005	PRE	SPI
4B-00-3	419065.9	5118460.1	46.2149	-124.0493	10:26:37	9/14/2005	PRE	SPI
4D-00-1	419896.4	5118465.5	46.21505	-124.0385	10:33:02	9/14/2005	PRE	SPI
4D-00-2	419926.8	5118457.7	46.21498	-124.0381	10:34:02	9/14/2005	PRE	SPI
4D-00-3	419942.8	5118454.4	46.21495	-124.0379	10:34:56	9/14/2005	PRE	SPI
5A-00-1	418800.3	5118179.3	46.21234	-124.0527	10:49:39	9/14/2005	PRE	SPI
5A-00-2	418780.6	5118194.5	46.21248	-124.0529	10:50:26	9/14/2005	PRE	SPI
5A-00-3	418776.3	5118203.7	46.21256	-124.053	10:51:20	9/14/2005	PRE	SPI
5C-00-1	419766.6	5118232.2	46.21293	-124.0402	10:40:14	9/14/2005	PRE	SPI
5C-00-2	419731.1	5118219.1	46.21281	-124.0406	10:41:26	9/14/2005	PRE	SPI
5C-00-3	419722.3	5118214.8	46.21277	-124.0407	10:42:21	9/14/2005	PRE	SPI
6B-00-1	419406.9	5117943.6	46.21029	-124.0448	10:57:42	9/14/2005	PRE	SPI
6B-00-2	419421.5	5117948.4	46.21034	-124.0446	10:58:26	9/14/2005	PRE	SPI
6B-00-3	419437.8	5117953.1	46.21038	-124.0444	10:59:17	9/14/2005	PRE	SPI
6D-00-1	420292.4	5117972.6	46.21066	-124.0333	11:05:35	9/14/2005	PRE	SPI
6D-00-2	420323.3	5117962.2	46.21057	-124.0329	11:06:32	9/14/2005	PRE	SPI
6D-00-3	420335.7	5117958.2	46.21054	-124.0328	11:07:25	9/14/2005	PRE	SPI
1A-01-1	418018	5119140	46.22089	-124.063	12:02:25	9/14/2005	POST1	SPI
1A-01-2	417997	5119131.3	46.22081	-124.0633	12:03:20	9/14/2005	POST1	SPI
1A-01-3	417998.6	5119122.8	46.22074	-124.0632	12:04:11	9/14/2005	POST1	SPI
1B-01-1	418479	5119180.4	46.22131	-124.057	11:56:07	9/14/2005	POST1	SPI
1B-01-2	418467.1	5119185.5	46.22136	-124.0572	11:56:51	9/14/2005	POST1	SPI
1B-01-3	418464.8	5119190.6	46.2214	-124.0572	11:57:52	9/14/2005	POST1	SPI
1C-01-1	419024.4	5119170.3	46.22129	-124.05	11:49:42	9/14/2005	POST1	SPI
1C-01-2	419004.6	5119171.4	46.2213	-124.0502	11:50:33	9/14/2005	POST1	SPI
1C-01-3	418999.7	5119173.5	46.22131	-124.0503	11:51:26	9/14/2005	POST1	SPI
1D-01-1	419378.9	5119176.5	46.22139	-124.0454	11:43:55	9/14/2005	POST1	SPI
1D-01-2	419375.3	5119152.3	46.22117	-124.0454	11:44:51	9/14/2005	POST1	SPI
1D-01-3	419378.2	5119145.7	46.22111	-124.0454	11:45:39	9/14/2005	POST1	SPI
2A-01-1	418157.7	5118909.9	46.21884	-124.0611	14:31:18	9/14/2005	POST1	SPI
2A-01-2	418167.3	5118932.9	46.21905	-124.061	14:32:23	9/14/2005	POST1	SPI
2A-01-3	418173.1	5118940.8	46.21912	-124.061	14:33:18	9/14/2005	POST1	SPI
2B-01-1	418676.6	5118924.2	46.21903	-124.0544	14:55:24	9/14/2005	POST1	SPI
2B-01-2	418690.9	5118950.7	46.21927	-124.0542	14:56:23	9/14/2005	POST1	SPI
2B-01-3	418703.6	5118964	46.21939	-124.0541	14:57:21	9/14/2005	POST1	SPI
2C-01-1	419145.1	5118946.7	46.21929	-124.0484	15:01:05	9/14/2005	POST1	SPI
2C-01-2	419189.2	5118945.7	46.21929	-124.0478	15:02:18	9/14/2005	POST1	SPI
2C-01-3	419211.1	5118945	46.21928	-124.0475	15:03:16	9/14/2005	POST1	SPI
2D-01-1	419325	5118935.5	46.21921	-124.046	15:05:25	9/14/2005	POST1	SPI
2D-01-2	419350.7	5118932	46.21918	-124.0457	15:06:19	9/14/2005	POST1	SPI
2D-01-3	419374.2	5118928.3	46.21915	-124.0454	15:07:27	9/14/2005	POST1	SPI
3A-01-1	418419.2	5118664.5	46.21666	-124.0577	17:38:10	9/14/2005	POST1	SPI
3A-01-2	418396.8	5118674.8	46.21675	-124.058	17:39:01	9/14/2005	POST1	SPI
3A-01-3	418388.6	5118682.3	46.21682	-124.0581	17:39:47	9/14/2005	POST1	SPI

UTM Zone 10 N - METERS

STATION	X	Y	LAT	LON	TIME	DATE	EVENT	DESCR
3B-01-1	418892.1	5118654.7	46.21663	-124.0516	17:32:25	9/14/2005	POST1	SPI
3B-01-2	418874.5	5118640	46.2165	-124.0518	17:33:14	9/14/2005	POST1	SPI
3B-01-3	418865.1	5118636.1	46.21646	-124.0519	17:33:56	9/14/2005	POST1	SPI
3C-01-1	419376.3	5118662.8	46.21676	-124.0453	17:25:43	9/14/2005	POST1	SPI
3C-01-2	419346.9	5118659.5	46.21673	-124.0457	17:26:42	9/14/2005	POST1	SPI
3C-01-3	419337.3	5118664.7	46.21678	-124.0458	17:27:32	9/14/2005	POST1	SPI
3D-01-1	419592.1	5118697.6	46.2171	-124.0425	9:22:52	9/15/2005	POST1	SPI
3D-01-2	419590.5	5118702.4	46.21714	-124.0425	9:23:19	9/15/2005	POST1	SPI
3D-01-3	419592.6	5118704.8	46.21717	-124.0425	9:23:34	9/15/2005	POST1	SPI
4A-01-1	418592.3	5118434.9	46.21462	-124.0554	9:46:46	9/15/2005	POST1	SPI
4A-01-2	418576	5118446.4	46.21472	-124.0556	9:47:40	9/15/2005	POST1	SPI
4A-01-3	418570.3	5118449.8	46.21475	-124.0557	9:48:28	9/15/2005	POST1	SPI
4B-01-1	419052.4	5118469.2	46.21498	-124.0495	9:40:25	9/15/2005	POST1	SPI
4B-01-2	419048.7	5118469.3	46.21498	-124.0495	9:41:16	9/15/2005	POST1	SPI
4B-01-3	419048.2	5118468.1	46.21497	-124.0495	9:42:08	9/15/2005	POST1	SPI
4C-01-1	419414.5	5118451.7	46.21487	-124.0448	9:33:12	9/15/2005	POST1	SPI
4C-01-2	419389.3	5118443.6	46.21479	-124.0451	9:34:24	9/15/2005	POST1	SPI
4C-01-3	419388.1	5118443.4	46.21479	-124.0451	9:35:15	9/15/2005	POST1	SPI
4D-01-1	419663	5118496.3	46.2153	-124.0416	9:28:19	9/15/2005	POST1	SPI
4D-01-2	419646.3	5118493.9	46.21528	-124.0418	9:29:16	9/15/2005	POST1	SPI
4D-01-3	419642.4	5118492.4	46.21526	-124.0418	9:30:09	9/15/2005	POST1	SPI
5A-01-1	418765.6	5118168.6	46.21224	-124.0531	9:53:38	9/15/2005	POST1	SPI
5A-01-2	418811.4	5118191.3	46.21245	-124.0525	9:55:25	9/15/2005	POST1	SPI
5A-01-3	418813.3	5118193.4	46.21247	-124.0525	9:56:14	9/15/2005	POST1	SPI
5A-01-4	418817.8	5118195.4	46.21249	-124.0525	9:57:04	9/15/2005	POST1	SPI
5B-01-1	419251.7	5118235	46.2129	-124.0468	10:01:29	9/15/2005	POST1	SPI
5B-01-2	419287.5	5118252.4	46.21306	-124.0464	10:02:31	9/15/2005	POST1	SPI
5B-01-3	419306	5118260.7	46.21314	-124.0462	10:03:23	9/15/2005	POST1	SPI
5C-01-1	419741.4	5118215.6	46.21278	-124.0405	10:07:10	9/15/2005	POST1	SPI
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5C-01-3	419779.6	5118181.4	46.21248	-124.04	10:09:05	9/15/2005	POST1	SPI
5D-01-1	420039.7	5118207.9	46.21275	-124.0366	10:12:36	9/15/2005	POST1	SPI
5D-01-2	420072.7	5118197.5	46.21266	-124.0362	10:13:35	9/15/2005	POST1	SPI
5D-01-3	420085.4	5118193	46.21262	-124.036	10:14:22	9/15/2005	POST1	SPI
6A-01-1	418952.2	5117954	46.21033	-124.0507	12:16:55	9/15/2005	POST1	SPI
6A-01-2	418987	5117937	46.21019	-124.0502	12:18:01	9/15/2005	POST1	SPI
6A-01-3	418998.9	5117930.6	46.21013	-124.0501	12:18:49	9/15/2005	POST1	SPI
6B-01-1	419404.5	5117921.8	46.2101	-124.0448	12:22:51	9/15/2005	POST1	SPI
6B-01-2	419431.4	5117918.3	46.21007	-124.0445	12:23:49	9/15/2005	POST1	SPI
6B-01-3	419447.8	5117918.7	46.21008	-124.0443	12:24:40	9/15/2005	POST1	SPI
6C-01-1	419760	5117943.4	46.21034	-124.0402	12:28:01	9/15/2005	POST1	SPI
6C-01-2	419797	5117947.8	46.21038	-124.0397	12:29:04	9/15/2005	POST1	SPI
6C-01-3	419814	5117954.1	46.21044	-124.0395	12:29:52	9/15/2005	POST1	SPI
6D-01-1	419976.3	5117994.1	46.21082	-124.0374	12:32:11	9/15/2005	POST1	SPI
6D-01-2	420019.6	5118027.4	46.21112	-124.0369	12:33:19	9/15/2005	POST1	SPI
6D-01-3	420033.2	5118043.1	46.21126	-124.0367	12:34:04	9/15/2005	POST1	SPI
6D-01-4	420045.4	5118051.2	46.21134	-124.0365	12:34:44	9/15/2005	POST1	SPI
T1-A	418928.5	5119254	46.22203	-124.0512	15:18:16	9/14/2005	POST1	SPI TRANSECT
T1-AB	418968.7	5119249.3	46.22199	-124.0507	15:42:16	9/14/2005	POST1	SPI TRANSECT
T1-B	418943.8	5119188.5	46.22144	-124.051	15:20:04	9/14/2005	POST1	SPI TRANSECT
T1-C	418918.5	5119169	46.22126	-124.0513	15:21:48	9/14/2005	POST1	SPI TRANSECT
T1-CD	418887.7	5119183.7	46.22139	-124.0517	15:40:08	9/14/2005	POST1	SPI TRANSECT
T1-D	418872.6	5119109.1	46.22072	-124.0519	15:24:17	9/14/2005	POST1	SPI TRANSECT
T1-E	418894.7	5119000.2	46.21974	-124.0516	15:26:48	9/14/2005	POST1	SPI TRANSECT
T1-F	418890.3	5118972	46.21949	-124.0517	15:28:13	9/14/2005	POST1	SPI TRANSECT
T1-G	418897.8	5118954.2	46.21933	-124.0516	15:30:00	9/14/2005	POST1	SPI TRANSECT
T1-H	418907.4	5118937.7	46.21918	-124.0514	15:31:28	9/14/2005	POST1	SPI TRANSECT
T1-I	418922.3	5118920.4	46.21903	-124.0512	15:32:56	9/14/2005	POST1	SPI TRANSECT
T1-J	418935.3	5118900	46.21884	-124.0511	15:34:28	9/14/2005	POST1	SPI TRANSECT
T1-K	418940.5	5118878.2	46.21865	-124.051	15:35:55	9/14/2005	POST1	SPI TRANSECT
T2-A	418685.1	5118715.7	46.21716	-124.0543	10:52:54	9/15/2005	POST1	SPI TRANSECT
T2-B	418669.5	5118701.1	46.21702	-124.0545	10:54:16	9/15/2005	POST1	SPI TRANSECT
T2-C	418638.1	5118677.3	46.21681	-124.0549	10:56:06	9/15/2005	POST1	SPI TRANSECT
T2-D	418633.2	5118655.6	46.21661	-124.0549	10:57:30	9/15/2005	POST1	SPI TRANSECT

UTM Zone 10 N - METERS

STATION	X	Y	LAT	LON	TIME	DATE	EVENT	DESCR
T2-E	418625.4	5118645.5	46.21652	-124.055	10:58:57	9/15/2005	POST1	SPI TRANSECT
T2-F	418629.8	5118605.9	46.21616	-124.055	11:00:32	9/15/2005	POST1	SPI TRANSECT
T2-G	418736.3	5118489.7	46.21513	-124.0536	11:03:18	9/15/2005	POST1	SPI TRANSECT
T2-H	418777.3	5118474.4	46.215	-124.053	11:04:46	9/15/2005	POST1	SPI TRANSECT
T2-I	418790.4	5118446.6	46.21475	-124.0529	11:06:10	9/15/2005	POST1	SPI TRANSECT
T2-J	418795.2	5118426.1	46.21456	-124.0528	11:07:34	9/15/2005	POST1	SPI TRANSECT
T2-K	418794.3	5118409.4	46.21441	-124.0528	11:08:51	9/15/2005	POST1	SPI TRANSECT
T2-L	418793	5118399.6	46.21432	-124.0528	11:10:14	9/15/2005	POST1	SPI TRANSECT
T2-M	419000.4	5118233.6	46.21286	-124.0501	11:14:03	9/15/2005	POST1	SPI TRANSECT
T2-N	419036.3	5118218.1	46.21272	-124.0496	11:15:32	9/15/2005	POST1	SPI TRANSECT
T2-O	419041.7	5118198	46.21254	-124.0496	11:16:59	9/15/2005	POST1	SPI TRANSECT
T2-P	419040.3	5118185.7	46.21243	-124.0496	11:18:22	9/15/2005	POST1	SPI TRANSECT
T2-Q	419035.4	5118173.3	46.21232	-124.0496	11:19:52	9/15/2005	POST1	SPI TRANSECT
T2-R	419030.3	5118163.1	46.21223	-124.0497	11:21:08	9/15/2005	POST1	SPI TRANSECT
T2-S	419024.5	5118158.8	46.21219	-124.0498	11:22:25	9/15/2005	POST1	SPI TRANSECT
T2-T	419026.7	5118135	46.21197	-124.0497	11:23:49	9/15/2005	POST1	SPI TRANSECT
T3-A	419599.2	5118011.6	46.21093	-124.0423	12:41:31	9/15/2005	POST1	SPI TRANSECT
T3-B	419621	5117999.2	46.21082	-124.042	12:43:07	9/15/2005	POST1	SPI TRANSECT
T3-C	419641.7	5117980.4	46.21065	-124.0418	12:44:29	9/15/2005	POST1	SPI TRANSECT
T3-D	419648	5117960.3	46.21047	-124.0417	12:45:48	9/15/2005	POST1	SPI TRANSECT
T3-E	419641.2	5117952.9	46.21041	-124.0418	12:47:12	9/15/2005	POST1	SPI TRANSECT
T3-F	419636.1	5117952.7	46.2104	-124.0418	12:48:26	9/15/2005	POST1	SPI TRANSECT
T3-G	419614.1	5117939.1	46.21028	-124.0421	12:50:01	9/15/2005	POST1	SPI TRANSECT
T3-H	419612.6	5117928.1	46.21018	-124.0421	12:51:17	9/15/2005	POST1	SPI TRANSECT
NS-1C	418985.2	5119180.9	46.22138	-124.0505	14:19:57	9/15/2005	POST1	GRAIN SIZE
NS-1C NORTH	418931.2	5119377.6	46.22314	-124.0512	14:27:06	9/15/2005	POST1	GRAIN SIZE
NS-2/3C	419267.1	5118849.2	46.21843	-124.0468	14:04:45	9/15/2005	POST1	GRAIN SIZE
NS-2C	419170.8	5118941.4	46.21925	-124.048	14:12:06	9/15/2005	POST1	GRAIN SIZE
NS-3C	419387.5	5118694.7	46.21705	-124.0452	13:54:49	9/15/2005	POST1	GRAIN SIZE
NS-4/5C	419608.6	5118324.3	46.21374	-124.0422	13:37:33	9/15/2005	POST1	GRAIN SIZE
NS-4C	419437.4	5118464.8	46.21499	-124.0445	13:47:27	9/15/2005	POST1	GRAIN SIZE
NS-5C	419752.9	5118226.6	46.21288	-124.0404	13:28:01	9/15/2005	POST1	GRAIN SIZE
NS-6C	419818.4	5117961	46.2105	-124.0395	13:07:57	9/15/2005	POST1	GRAIN SIZE
NS-6C-SOUTH	419832	5117719.4	46.20833	-124.0392	13:18:54	9/15/2005	POST1	GRAIN SIZE
START TR1	419339.7	5119164.8	46.22128	-124.0459	15:45:11	9/14/2005	POST1	TEST RUN
START TR2	419451.6	5118953.6	46.21939	-124.0444	14:40:19	9/14/2005	POST1	TEST RUN
START TR3	419728.6	5118692.6	46.21707	-124.0407	17:27:43	9/14/2005	POST1	TEST RUN
START TR4	419817.9	5118455	46.21494	-124.0395	8:44:22	9/15/2005	POST1	TEST RUN
START TR5	420122.6	5118228.7	46.21294	-124.0356	9:43:01	9/15/2005	POST1	TEST RUN
START TR6	420142.4	5117960.3	46.21053	-124.0353	12:05:24	9/15/2005	POST1	TEST RUN
STOP TR1	418157.9	5119112.8	46.22067	-124.0612	15:51:06	9/14/2005	POST1	TEST RUN
STOP TR2	418101	5118912	46.21885	-124.0619	14:47:19	9/14/2005	POST1	TEST RUN
STOP TR3	418251.1	5118653.6	46.21655	-124.0599	17:40:37	9/14/2005	POST1	TEST RUN
STOP TR4	418369.7	5118424.7	46.2145	-124.0583	8:45:32	9/15/2005	POST1	TEST RUN
STOP TR5	418569.2	5118163.9	46.21218	-124.0557	9:44:00	9/15/2005	POST1	TEST RUN
STOP TR6	418725.8	5117934	46.21013	-124.0536	12:06:28	9/15/2005	POST1	TEST RUN

Appendix C

Mouth of the Columbia River Offshore Disposal Site Study Investigations, Provisional Report prepared by Global Remote Sensing, dated December 12, 2005

Mouth of the Columbia River Offshore Disposal Site Study
Multibeam Investigations
VOLUME 1 of 1

Provisional Report

Report No:

Prepared for:

U.S. Army Corps of Engineers
Portland District
333 SW First Ave.
Portland, Oregon 97208-2946

Submitted by:

Global Remote Sensing
3840 West Marginal Way
Seattle, WA 98106

Phone 503-838-1628
Fax 503-838-1629
* * *
12 December 2005

QUALITY ASSURANCE

This report has been prepared by:

R Mcgee
J Brantner
J. Hawkins
Project Managers

J. Brantner
R. McGee
M. Leo
L. Fonseca
Data Processors

J. Brantner
Surveyor

Issue No.	Date	Description	Checked	Approved
0		Preliminary Report		

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Appendices

Appendix A Survey Equipment Specifications
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1. INTRODUCTION

The U.S. Army Corps of Engineers, Portland District is conducting a study to identify bottom characteristics of existing and potential offshore sites and adjacent areas, relating to the disposal of material dredged from the Columbia River mouth (MCR) navigation channel. Multibeam surveys will provide detailed bathymetry of these area. Backscatter information derived from the multibeam survey will be used for bottom classification.

Precision bathymetry was used to obtain complete detailed coverage of the seafloor within the areas of survey as presented in Figure 1-1 and Table 1-1 and outlined in the Statement of Work dated June 13th, 2005 and revised July 27th, 2005, to exclude areas 3B, 3D, and 4A through 4D. The multibeam surveys provide detailed bathymetry of these areas, while the backscatter information derived from the multibeam survey will be used for quantitative bottom classification. Actual survey ranges (line spacing) were based on 125% to 200% coverage's within each of the priority areas. Individual coverage was determined by depth of area, speed, ping rate and line spacings to obtain complete seafloor coverage along with detailed information of the seafloor.

Table 1-1

Area	Descriptor	Distance Offshore	Area km^2	Water Depth ft
1A	DWS	10 to 15	42	180 to 310
1B	SWS	1 to 4	8.1	30 to 80
2A	MCR channel north	0 to 5	7.1	10 to 90
2B	MCR channel offshore	0.5 to 5	4.4	50 to 80
2C	Clatsop Spit	0 to 6	5.2	10 to 70
2D	South Jetty	4 to 5	4.7	30 to 60
2E	MCR channel east	5 to 6	2.7	10 to 130
3A	Offshore SWS	5 to 6	4.4	50 to 70
3C	ODMDS A	0 to 5	12.3	30 to 90

Surveys were conducted 15 August 2005 to 16 September 2005. The multibeam bathymetric surveys were conducted aboard two vessels; the M/V *Oakland Pilot,* a 51' retired pilot vessel from the Harbor of Oakland, CA, with a 16.5' beam, weighing 43 gross tons and drawing just over 6-ft of water and the R/V *Minotaur,* a 29' aluminum vessel with a 8.5' beam, weighing 8 gross tons, with a draft of 2-ft.

1.1 Project Geodesy

Survey was conducted in State Plane, NAD 83, Oregon North. All measurements are in units of Survey Feet. Depths are referenced to MLLW. Following is the geodetic summary of the survey:

Projection: State Plane, NAD 83, Oregon North
Survey Units: US Survey Feet
Vertical Datum: MLLW

2. SCOPE OF WORK

2.1 Offshore Geophysical Surveys

The final scope of work included two elements, namely multibeam bathymetry and MBES backscatter data acquisition/processing within nine designated survey areas as shown by Figure 1-1. The survey would be accomplished by repeated passes over the survey area spaced at intervals determined by the depth. Line spacing was based on 125% to 200% coverage's within the priority areas as a function of water depth. Area information was provided by USACOE.

2.2 Reporting and Charting

Reporting and charting were carried out by Global Remote Sensing (GRS) in their offices in Seattle, WA. This final report includes a description of the methods, surveys, and processing required to deliver a full-coverage description of seabed conditions. Deliverables included with this report are:

- Multibeam bathymetry (see Figure 2-1):
    - Sun-illuminated image of seafloor
    - ASCII XYZ file of gridded elevations
    - Bathymetric contours in agreed intervals
    - Trackline plots
- MBES Backscatter imagery (see Figure 2-2):

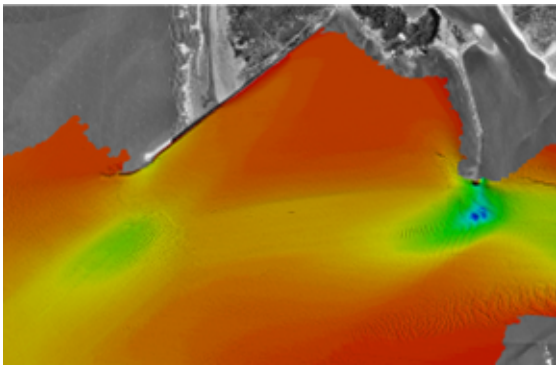


Figure 2-1. Example Sun-illuminated image of Seafloor from MCR survey.

Figure 2-2. Backscatter image of Seafloor.

3. METHODOLOGY

3.1 Offshore Survey Operations

3.1.1 Equipment and Personnel

Surveys were conducted aboard the survey vessels Oakland Pilot and Minotaur. The Oakland Pilot was transited to Astoria from Garibaldi, OR and mobilized out of the Hammond Marina. The R/V Minotaur was transited from Seattle, WA to Astoria and was also mobilized out of the Hammond Marina. The following personnel were involved in carrying out the MCR survey:

Figure 3-1. The Oakland Pilot

Figure 3-2. R/V Minotaur

Jeremiah Brantner	Project Manager and Senior Hydrographer, Global Remote Sensing, LLC
Kevin Tomanka	Hydrographer, Seafloor Systems Inc.
Jed Gray	Hydrographer, Seafloor Systems Inc.
Ryan Poff	Hydrographer, Global Remote Sensing, LLC
Steve Lemke	Hydrographer, Global Remote Sensing, LLC
Jim	Captain, Oakland Pilot
Mark Drage	Captain, R/V Minotaur

Data processing was conducted in the offices of Global Remote Sensing, LLC (GRS).

Jeremiah Brantner	Data Processing Manager, GRS
Kevin Tomanka	MBES Data Processing, SSI
Jed Gray	MBES Data Processing, SSI
Mike Leo	MBES Data Processing, GRS
Richard McGee	Backscatter Processing, GRS
Luciano Fonseca	Backscatter Processing, CCOM UNH
Daryl Pickworth	Charting and Mapping, GRS

3.1.2 Operations Summary and Calibrations

Survey operations consisted of multibeam echosounder (MBES) patch test calibrations, measurement of water column sound velocity distribution, and completion of concurrent multibeam surveys.

Sea conditions during surveys ranged from calm to very rough with the Coast Guard closing the Columbia River Bar on several occasions. Conditions were generally considered sufficient for MBES survey, however conditions were sometimes exceeded in some cases due to restrictions in acquisition timeframe. Actual weather conditions are documented in the daily survey report (Appendix B). All sea trials, calibrations, and surveys were completed by 16 September 2005.

Calibration of the multibeam system involves running a patch test on a newly installed or recently changed sonar mount location or position. The patch test is run to account for roll, pitch, and yaw (degrees) static offsets of the multibeam sensor as well as latency (milliseconds) from the navigation system. Procedures for the acquisition and processing of the patch test data as carried out for MCR can be found in the Caris HIPS & SIPS user's manual[1]. In summary, a series of survey trials were performed over known seafloor configurations run in opposite directions and/or varying survey speeds. Data were then processed to determine actual offsets based on calculated differences in the data sets collected over the same bottom area. The roll test was conducted over fairly flat terrain, running a single survey line in opposite directions. A steeply sloping seafloor was used for the latency, pitch and yaw tests. For pitch, a single line oriented perpendicular to shore was run in opposite directions at normal survey speed. The yaw test required two parallel lines separated by a factor of 1.5 to 2 times the water depth, perpendicular to shore, run in the upslope direction at normal survey speed. The latency test was run over the same area but at different survey speeds. The data were post-processed using Caris HIPS to determine offset values for latency, roll, pitch and yaw. Patch test results are presented in Table 3-1.

Table 3-1. Patch Test Offset Corrections

Oakland Pilot

Patch Test	Offset Correction
Roll (degrees)	2.050
Pitch (degrees)	2.800
Yaw (degrees)	-1.300
Navigation Latency (ms)	700

Minotaur

Patch Test	Offset Correction
Roll (degrees)	0.690
Pitch (degrees)	1.600
Yaw (degrees)	6.000
Navigation Latency (ms)	300

[1] Caris, 2004. Caris HIPS & SIPS User's Guide

3.1.3 DGPS Positioning and Navigation

Oakland Pilot

A CSI Wireless MBX-3 was used to deliver RTCM corrections. Differential positions were obtained by a TSS POS MV attitude and position system, allowing for inertial corrections in the event of a DGPS loss. Position coordinates were transmitted via NMEA0183 GGA strings transmitted across serial communications. All systems received the same GGA string with offset corrections applied independently within each survey system.

Navigation control was accomplished with the Hypack Max hydrographic survey system. Hypack received data from the positioning system, performed the appropriate geodetic transformations, and stored the position information as a backup of navigation data. Primary navigation data was stored directly with the sonar data.

R/V Minotuar

A CSI Wireless DGPS MAX Differential Global Position Ststem (DGPS) was used to collect RTCM corrections, differential GPS positions were obtained using an Octopus F180, allowing for inertial corrections in the event of a DGPS loss. Position coordinates were transmitted via NMEA0183 GGA strings transmitted across serial communications. All systems received the same GGA string with offset corrections applied independently within each survey system.

Navigation control was accomplished with the Hypack Max hydrographic survey system. Hypack received data from the positioning system, performed the appropriate geodetic transformations, and stored the position information as a backup of navigation data. Primary navigation data was stored directly with the sonar data.

3.1.4 Sound Velocity and Tidal Corrections

- 3.1.4.1 Sound Velocity Corrections

Oakland Pilot

A Reson SV15 Sound Velocity profiler was used to collect sound velocities through the full water column depth. A SVP cast was completed at least every two hours in the water zone associated with each survey section. Results of the SVP cast were applied to the MBES data during real time survey acquisition.

R/V Minotaur

A Seabird Model SBE19 CTD profiler was used to collect sound velocities through the full water column depth. A CTD cast was completed at least every two hours in the water zone associated with each survey section. Results of the CTD cast were applied to the MBES data during real time survey acquisition.

- 3.1.4.2 Tide Measurements

Observed tidal measurements were collected at Hammond Marina using the CCALMR/OHSU tide gauge (Figure 3-1). This gauge is located in close proximity to the USACOE gauge, at 46 12.166N 123 57.107W. All tide measurements

were recorded in MSL and converted to MLLW in post processing. See http://www.ccalmr.ogi.edu/CORIE/data/publicarch/methods_meanings_tide.html for formats and quality control procedures. All observed measurements were then adiusted using MCR tidal corrector data to correct for variability in tidal cy Tidal correctors were provided by USACOE and were developed

Figure 3-1, Hammond Marina Tide Station

3.1.5 Bathymetry

The integrated multibeam survey package assembled for this survey included the components shown in Table 3-2.

Table 3-2. Multibeam System Components

Oakland Pilot

Measurement	Model
Multibeam Sonar	Kongsberg-Simrad EM 3002
Attitude (Heave, Pitch, and Roll) and Heading	TSS POS M/V
Positioning	CSI Wireless MBX-3 Differential Receiver / TSS POSM/V
MBES Data Acquisition	Kongsberg Seafloor Information System (SIS)
Navigation	Hypack Max Survey System

Minotaur

Measurement	Model
Multibeam Sonar	Kongsberg-Simrad EM 3002
Attitude (Heave, Pitch, and Roll) and Heading	Octopus F180
Positioning	CSI Wireless Differential GPS / Octopus F180
MBES Data Acquisition	Kongsberg Seafloor Information System (SIS)
Navigation	Hypack Max Survey System

A TSS POSMV 320 position and orientation system, shown in figure 3-2, measured attitude and heading onboard the Oakland Pilot. The POSMV was mounted under one of the ship's galley tables as close to the sonar head as possible, all lever arms were surveyed in and accounted for within the POS M/V. The attitude and heading sensor provides dynamic corrections for vessel motion and actual sonar orientation relative to water level. The attitude sensor provides real-time measurement of heading and transducer heave, pitch, and roll. A detailed system description is provided in Appendix A.

Figure 3-2. Attitude Sensor Installation; Oakland Pilot.

The R/V Minotaur was fitted with an Octopus F180, shown in Figure 3-3, delivering heave, roll, pitch, heading and positioning information in real time, it provides the marine user with highly accurate and reliable motion and position data. The F180 was mounted under a seat in the cabin as close to the transducer as possible, all lever arms were then applied to the F180 which corrected motion output

Figure 3-3, F180

to accommodate the offsets. A detailed system description is provided in Appendix A.

3.1.6 Kongsberg EM 3002

A Kongsberg EM 3002 high-resolution focused multibeam echosounder (Figure 3-4) was utilized to collect the bathymetry on each vessel. The EM 3002 is an advanced multibeam echosounder with extremely high resolution and dynamically focused beams. It is suited for detailed seafloor mapping and inspection with water depths between 0.5 and 150 meters. Due to its electronic pitch compensation system and roll stabilized beams, the system performance is stable even in foul weather conditions. The mounting bracket for the multibeam (see Figure 3-3) was positioned to provide minimal operational offsets of the transducer head relative to vessel attitude. Actual static transducer attitude was determined during calibration of the system. A detailed system description is provided in Appendix A.

3.1.7 System Installation

Figure 3-4 Kongsberg EM 3002 Sonar Head

Oakland Pilot

The multibeam sonar transducer was mounted approximately amidships off the starboard railing. The POSMV antennas were mounted directly above the motion sensor using pre-existing mounting brackets. This configuration was surveyed to precisely position all instrument offsets relative to the motion sensor. For this survey, the motion sensor is the selected reference point.

R/V Minotaur

The multibeam sonar transducer was mounted approximately amidships off the starboard railing. The F180 antennas were mounted directly above the motion sensor using pre-existing mounting brackets. This configuration was surveyed to precisely position all instrument offsets relative to the motion sensor. For this survey, the motion sensor is the selected reference point.

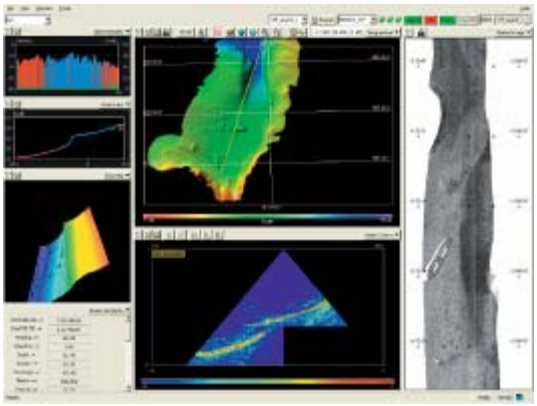


Figure 3-5. Real Time Acquisition Control.

3.1.8 Backscatter Imagery

The Simrad EM multibeam echo sounders all have beam backscattering strengths and optional seabed image reflectivity as part of their data output. These data were acquired for later bottom classification tasks.

3.1.8 Data Acquisition

The Kongsberg Seafloor Information System (SIS) was used to log all data packets during survey (Figure 3-5). SIS is a real time software application designed as the user interface for Kongsberg hydrographic instruments. The main task of SIS is to be a logical and user friendly interface for the surveyor, providing the functionality needed for running a survey efficiently. A detailed system description is provided in Appendix A.

3.2 Data Processing

3.2.1 Bathymetry

Multibeam post-processing was performed using Caris HIPS bathymetric processing system. After completion of patch test calibrations (refer to Section 4.1.2) the data were edited to remove bad or low quality data points. Depths were automatically adjusted within Caris for navigation, attitude, tide, and speed of sound. A mapping grid resolution consistent with the spatial resolution of the survey was then projected onto the survey area. For this survey a 3-meter resolution grid was developed. The final processing step involved geoencoding all corrected data into the survey grid. An output file containing spatial coordinates for all gridded data points (e.g., easting, northing, and depth elevation in MLLW) was created for input into AutoCAD and Terramodel for final chart development and generation of the DTM and contours, respectively. A final contour editing process was conducted to provide contours sufficient for the CADD formats of the engineering drawings.

3.2.2 Backscatter Imagery

Backscatter post-processing was initially performed with Caris SIPS Sidescan Image Processing Software. Navigation data was cleaned to remove any GPS spikes and then the data was combined with adjacent data to create mosaics of each survey area. After completing this process and making comparisons with the bathymetry corresponding areas, questions arose about Caris SIPS ability to handle the data. Several options were explored as alternatives to Caris SIPS, The data was sent to the University of New Hampshire's Center for Coastal and Ocean Mapping (CCOM) for final processing. The following describes the processes performed at CCOM.

During the mosaic preparation, it was necessary to radiometrically correct the backscatter intensities registered by the Simrad system, to geometrically correct and position each acoustic sample in a projection coordinate system and to interpolate properly the intensity values into a final backscatter map. Initially, the original backscatter time series registered in the Simrad image datagrams were corrected for angle varying gains, beam pattern, and filtered for speckle removal. All samples of the time series were preserved during all the operations, ensuring that the full data resolution was used for the final mosaicking. The time series was then slant-range corrected based on beam bathymetry. Subsequently, each backscatter sample of the series was mapped in a Lambert Conformal Conic projected coordinate system (State Plane 83 Oregon North), in accordance to an interpolation scheme that resembles the acquisition geometry. An anti-aliasing algorithm was applied in parallel to the mosaicking procedure. Overlap among parallel lines was resolved by a priority table based on the distance of each sample from the ship track; a blending algorithm was applied to minimize the seams between overlapping lines.

4. SURVEY RESULTS

The survey was broken up into nine separate areas that were each surveyed individually. A summary of the nine survey areas and general descriptions of observed geomorphic conditions are presented in Table 4-1. Bathymetric imagery with contours, backscatter imagery and survey trackline charts are included with this report as 11x17 format (half-size) plots. The original D-Size charts are provided in digital AutoCad format with corresponding .pdf format digital files for client reproduction. A cdrom is included with this report that includes all digital charts.

Table 4-1. Survey Area Summary

Area	Descriptor	Distance Offshore	Area km^2	Water Depth ft
1A	DWS	10 to 15	42	180 to 310
1B	SWS	1 to 4	8.1	30 to 80
2A	MCR channel north	0 to 5	7.1	10 to 90
2B	MCR channel offshore	0.5 to 5	4.4	50 to 80
2C	Clatsop Spit	0 to 6	5.2	10 to 70
2D	South Jetty	4 to 5	4.7	30 to 60
2E	MCR channel east	5 to 6	2.7	10 to 130
3A	Offshore SWS	5 to 6	4.4	50 to 70
3C	ODMDS A	0 to 5	12.3	30 to 90

Area	Overview of Geomorphic Condition
1A	Uniform offshore slope, 2 dump sites visible in backscatter
1B	Flat topography with ship channel in south; large sand wave field dominates area
2A	Flat topography with ship channel in south; sand waves track around north boundary of area
2B	Channel with scour area near end of North Jetty; large sand waves surround scour
2C	Flat topography in south with channel to the north; large sand waves dominate channel edge in northern area
2D	Very flat topography; Backscatter shows 6 E-W disposal tracks, no measurable bathymetric relief
2E	Channel with vertical escarpment to the north; deep scour with large sand waves in SW of area, area has two hard targets mid channel
3A	Flat topography, nondescript area
3C	Scour at end of South Jetty with several hard targets; shoal area west of jetty

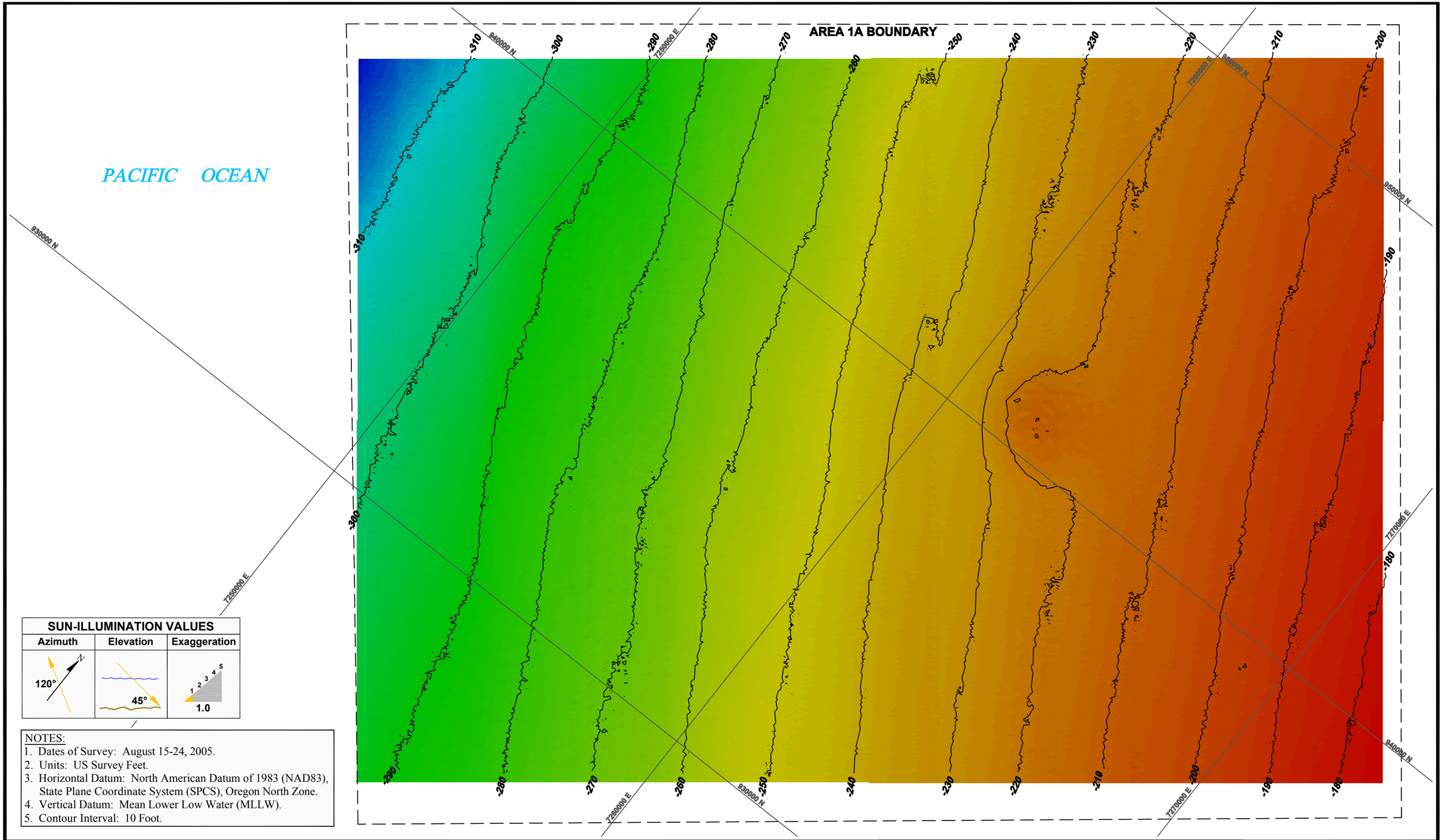
4.1 Lessons Learned

The combination of survey location and project acquisition schedule posed significant challenges for delivery of high quality mapping products. The Columbia River Bar can be a difficult and dangerous environment for seagoing operations, especially surveys. Weather and tides often combine to produce sea states considered hazardous to navigation. Adaptive survey management methods were required to complete as much of the survey scope as possible, with operations changing on a daily basis. Due to funding constraints, it was requested that surveys be performed to the limit possible for acquiring acceptable survey data. In some instances, this may have produced degradation in survey quality. For example, Area 2D suffered due to heavy sea conditions during the three days given to survey the area, requiring some filtering to remove unreal motion artifacts on an otherwise flat seafloor surface. Future surveys of this scope and magnitude in the MCR vicinity should be planned to be carried out earlier in the season, closer

to June/July rather than August/September and should have a large acquisition window to allow surveyors to be more selective with regards to weather standby situations. This would increase survey production during good survey sea states and enhance overall mapping quality.

The largest issue encountered while processing the data sets was spatial variations in tidal correction. It was decided during negotiations to use observed tide measurements rather than Real-time Kinematic (RTK) GPS tides. Tide measurements were collected at Hammond Marina and converted to reflect tidal differences between Hammond Marina and the river mouth. When applied to the data sets obvious tidal busts became visible, usually showing as much as a 1 to 3 foot bust between data collected on different survey days. This process was done several times using different tide stations, in an attempt to resolve this problem. When all attempts failed a tedious day-to-day tidal manipulation was undergone to improve bathymetric imagery. This process while improving image appearance may take away from overall vertical survey accuracy. It is recommended that future surveys utilize the ability to acquire accurate RTK GPS vertical data; effectively eliminating the tidal issues experienced using the recording tide gage at Hammond. An RTK transmitting base station is maintained at MCR by the Portland District and should be used for all future survey work in this area.

To complete the survey within the agreed time frame, the survey was carried out using multiple survey vessels. The data was cleaned and processed in a central field office and aboard ship during survey operations. This process was very successful except for the application of tidal corrections. Verified tide data were not available until the completion of surveys, at which time the tidal issue was discovered. Again, RTK tidal acquisition would have eliminated this issue.



SUN-ILLUMINATION VALUES		
Azimuth	Elevation	Exaggeration
120°	45°	1.0

NOTES:
1. Dates of Survey: August 15-24, 2005.
2. Units: US Survey Feet.
3. Horizontal Datum: North American Datum of 1983 (NAD83), State Plane Coordinate System (SPCS), Oregon North Zone.
4. Vertical Datum: Mean Lower Low Water (MLLW).
5. Contour Interval: 10 Foot.

APPROVED BY:	R. McGee
CHECKED BY:	J. Brantner
DRAWN BY:	D. Pickworth
DATE:	12/12/05
SCALE:	1" = 2000'
FILE NAME:	1A-05_11x17.dwg

GRS global remote sensing

Parametrix
411 108TH AVENUE N.E., SUITE 1800
BELLEVUE, WASHINGTON 98004
T. 425.458.6200 F. 425.458.6363
www.parametrix.com

Mouth of the Columbia River Multibeam Bathymetric Survey
Columbia River, Oregon

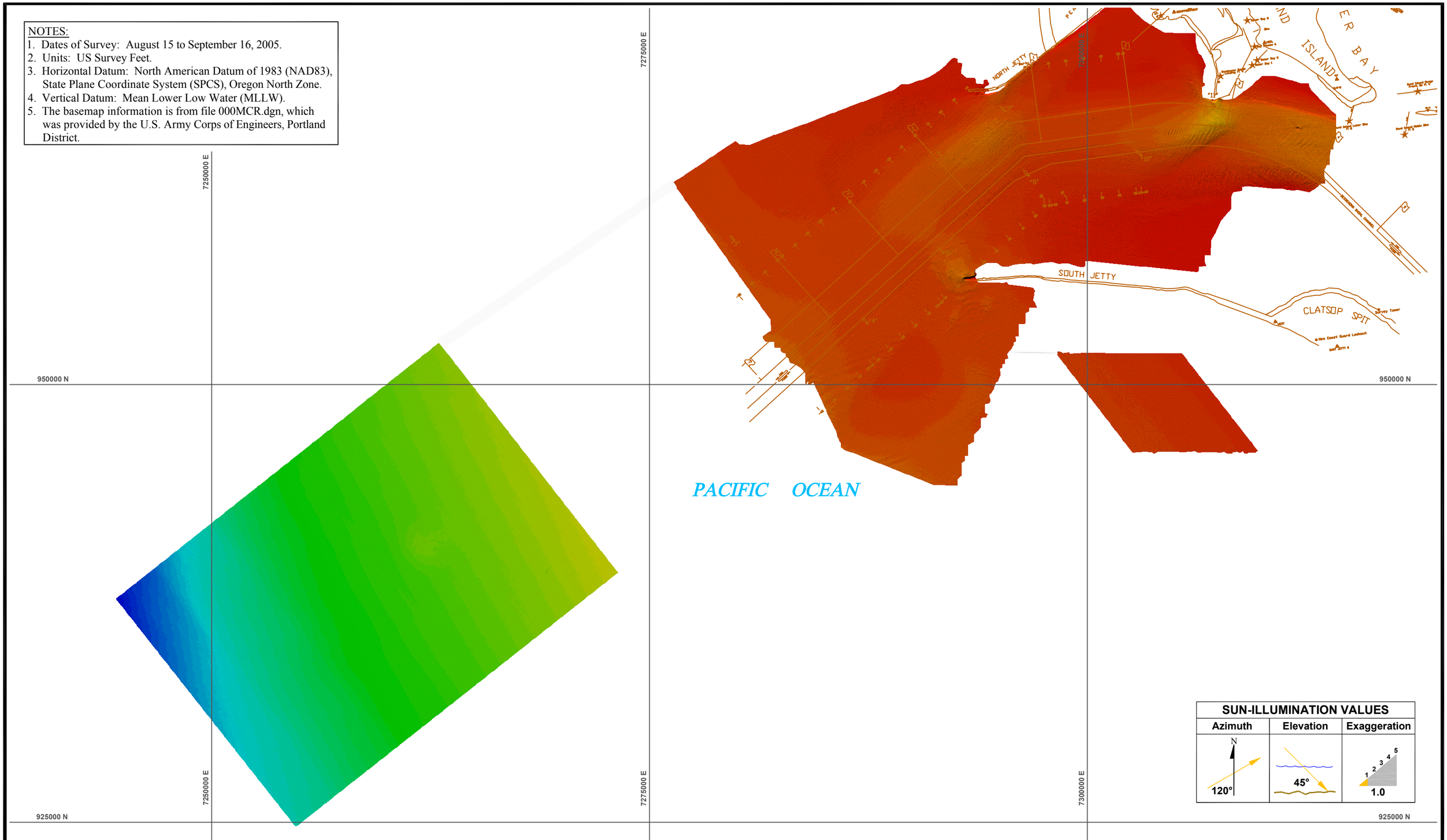
AREA 1A MBES BATHYMETRIC CONTOURS AND SUN-ILLUMINATED IMAGERY

U.S. Army Corps of Engineers

2000 0 2000 4000
SCALE: 1" = 2000'
Units in Feet

SHEET 5A OF 5A

NOTES:
1. Dates of Survey: August 15 to September 16, 2005.
2. Units: US Survey Feet.
3. Horizontal Datum: North American Datum of 1983 (NAD83), State Plane Coordinate System (SPCS), Oregon North Zone.
4. Vertical Datum: Mean Lower Low Water (MLLW).
5. The basemap information is from file 000MCR.dgn, which was provided by the U.S. Army Corps of Engineers, Portland District.



APPROVED BY:	R. McGee
CHECKED BY:	J. Brantner
DRAWN BY:	D. Pickworth
DATE:	12/12/05
SCALE:	1" = 5000'
FILE NAME:	Cov_11x17.dwg

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Mouth of the Columbia River Multibeam Bathymetric Survey
Columbia River, Oregon

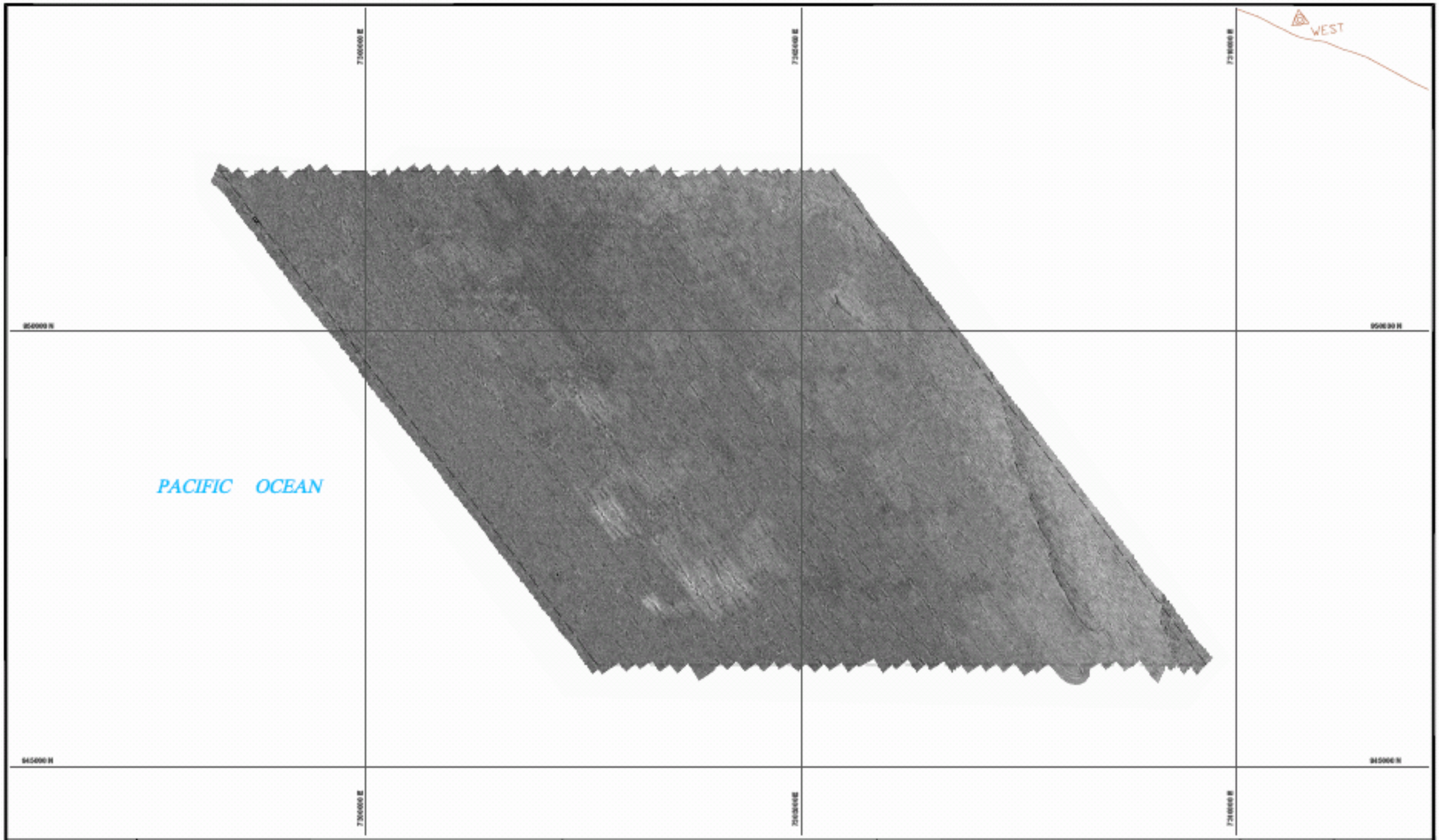
COVERAGE AREA MBES SUN-ILLUMINATED IMAGERY

U.S. Army Corps of Engineers

5000 0 5000 10000
SCALE: 1" = 5000'
Units in Feet

N

SHEET 1B OF 1E



Mouth of the Columbia River Multibeam Bathymetric Survey
Columbia River, Oregon

AREA 2D MBES BACKSCATTER IMAGERY

1000

SCALE: 1" = 1000'
Units in Feet

Appendix D

USACE FATE Model Parameters and Results for Dredged Material Deposition Simulation

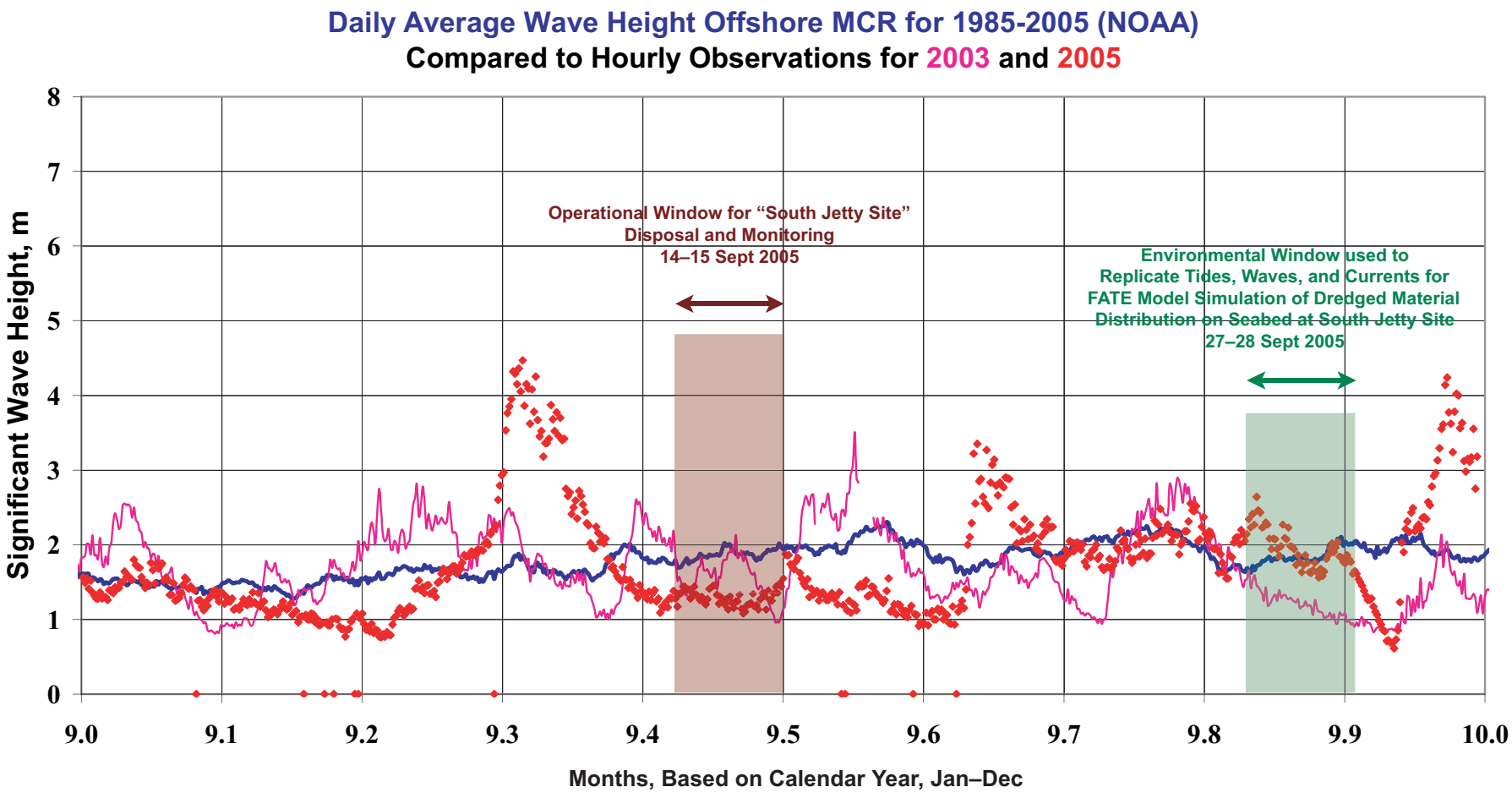


Figure D-1. Daily Average Wave Height Offshore MCR

From Science to Solutions™

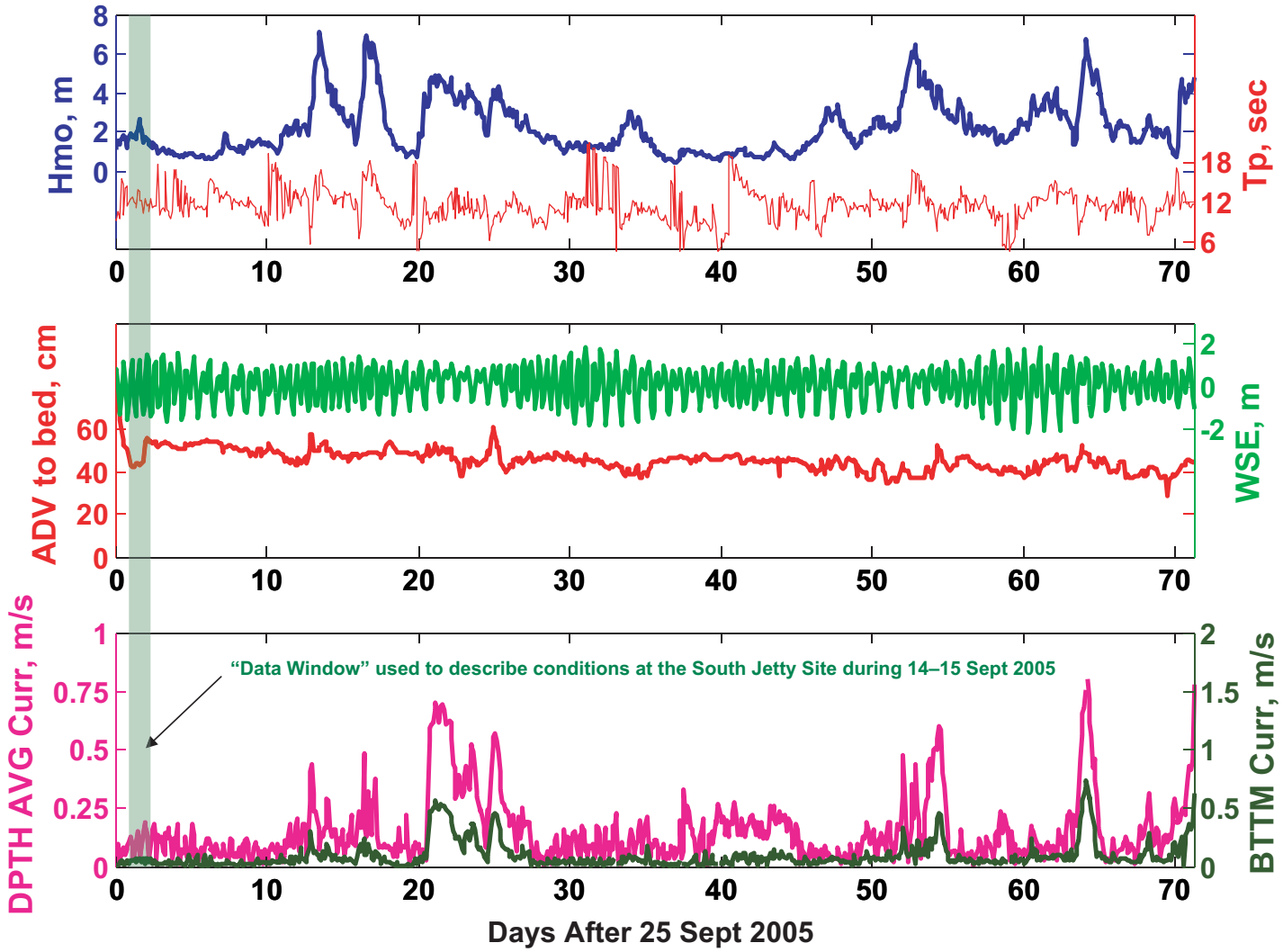


Figure D-2. 2003 Data at South Jetty Site

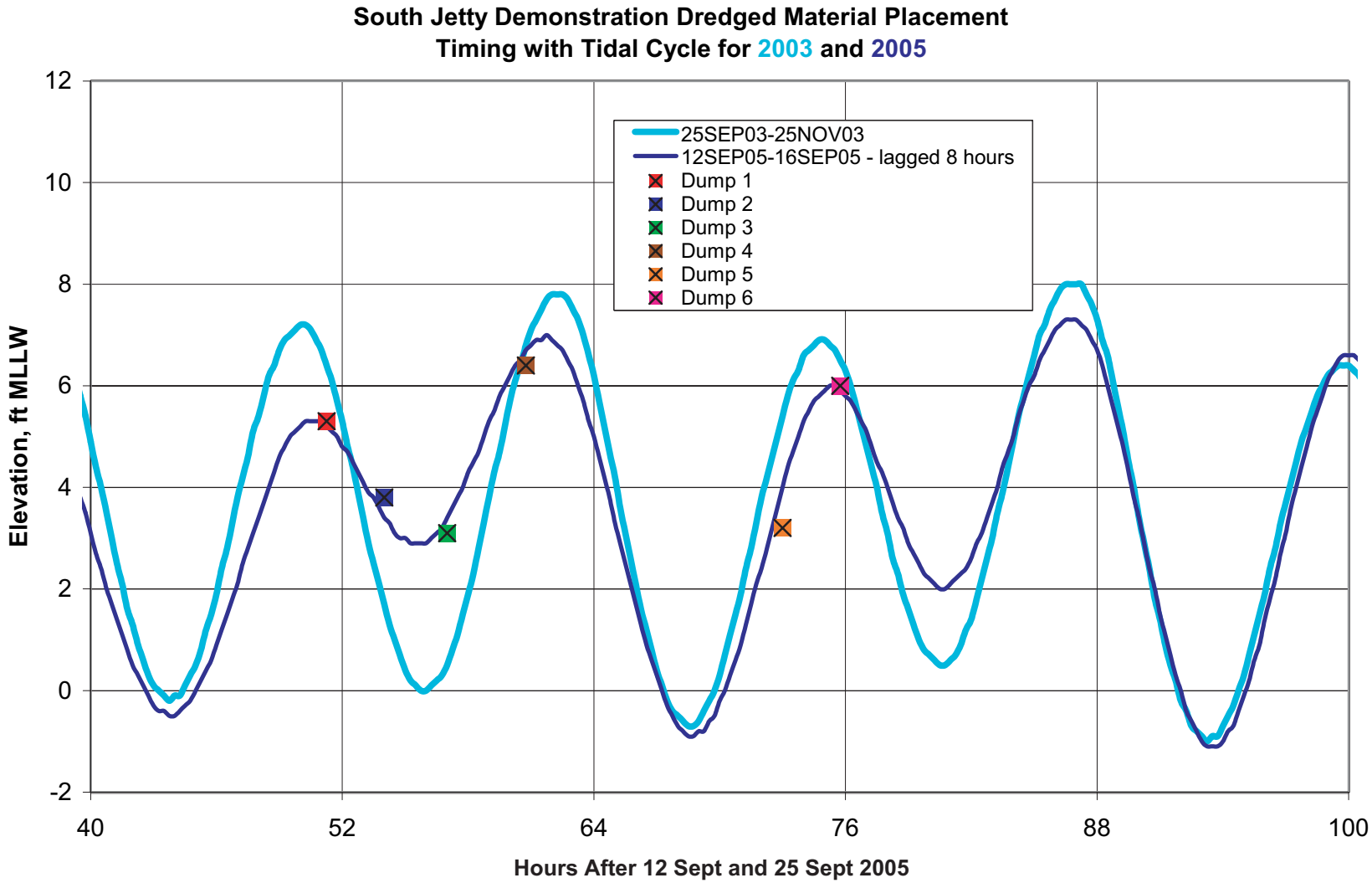
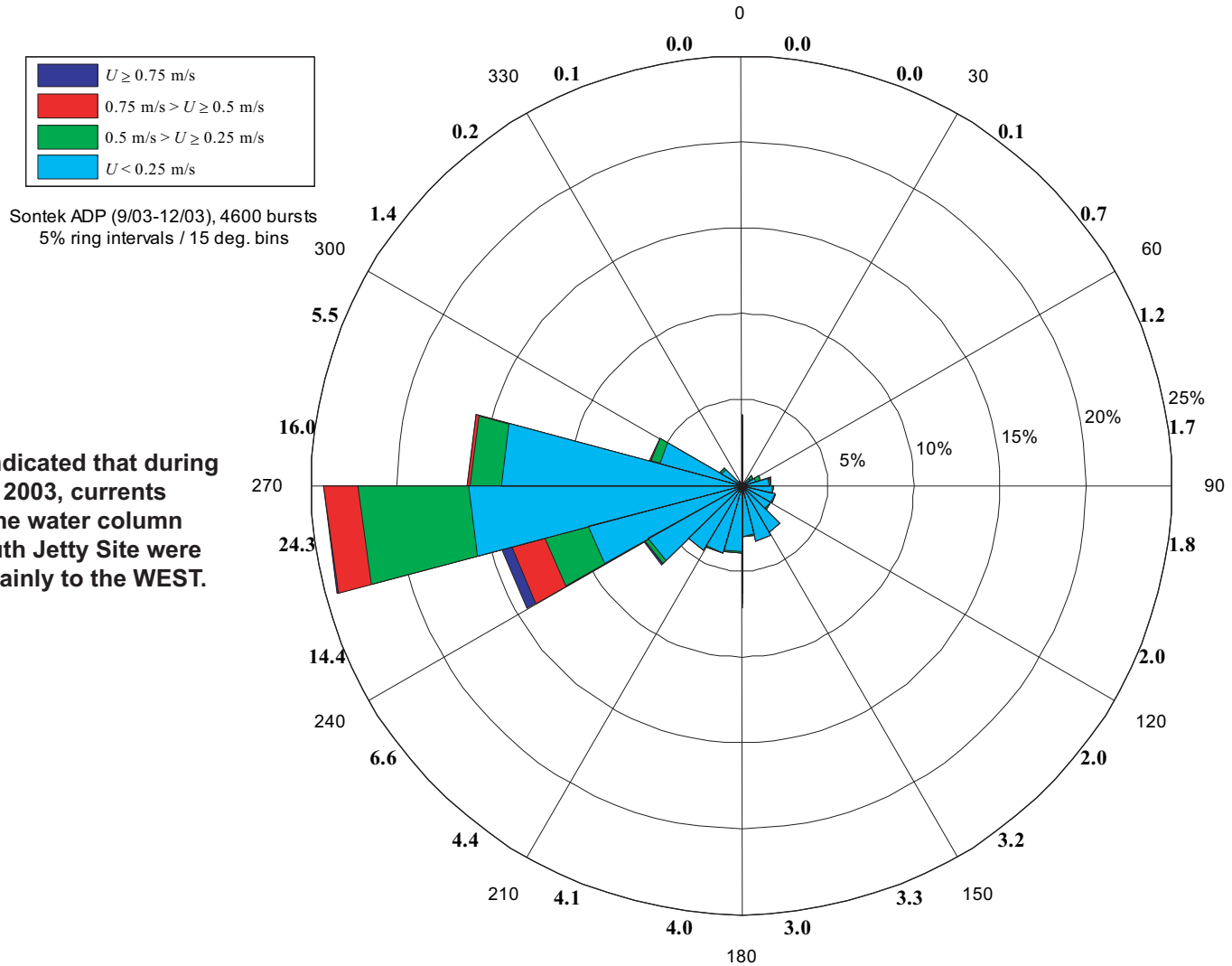


Figure D-3. South Jetty Demonstration Dredged Material Placement Timing with Tidal Cycle for 2003 and 2005

From Science to Solutions™



Results indicated that during Sept–Dec 2003, currents through the water column at the South Jetty Site were flowing mainly to the WEST.

Figure D-4. Depth Averaged Currents (elevation 1.6–14 m above sensor)

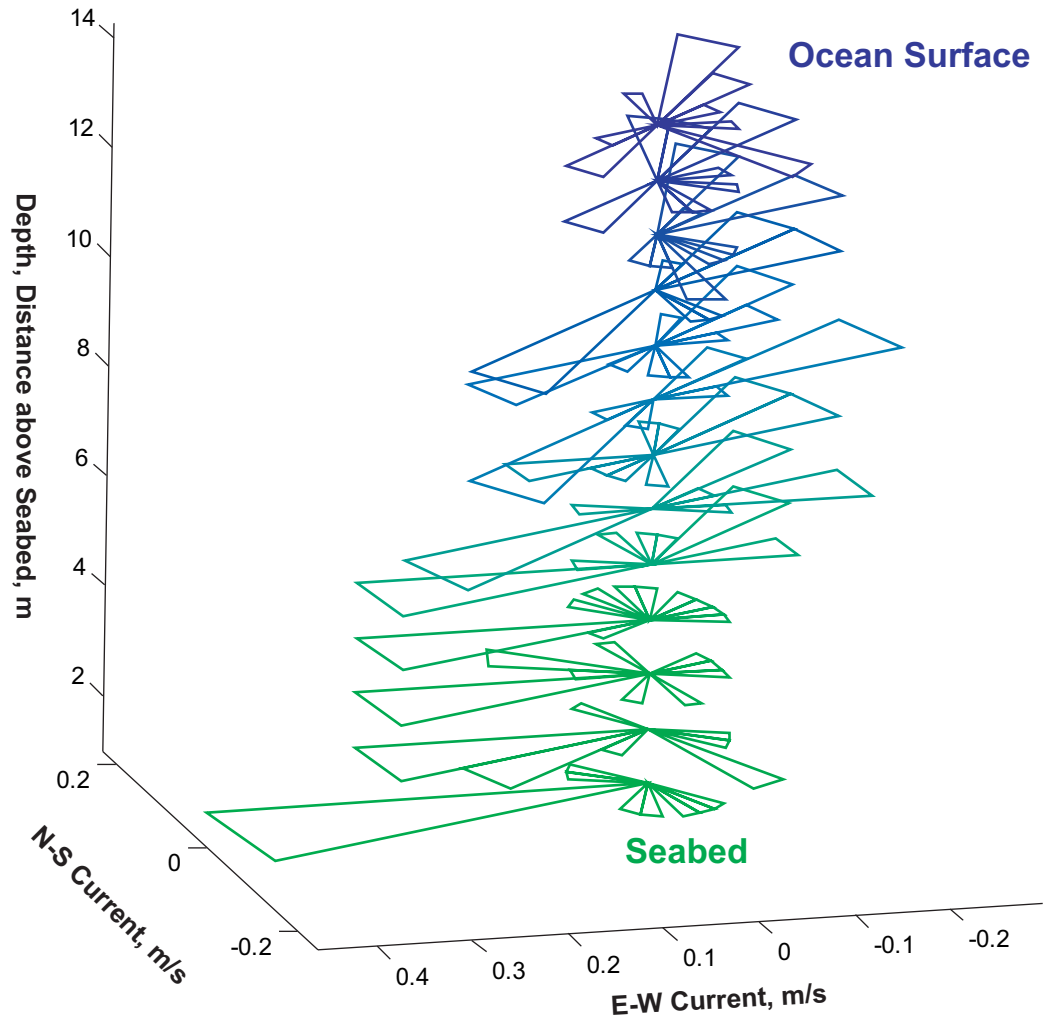


Figure D-5. Distribution of Current through Water Column at South Jetty Site during Sept–Nov 2003

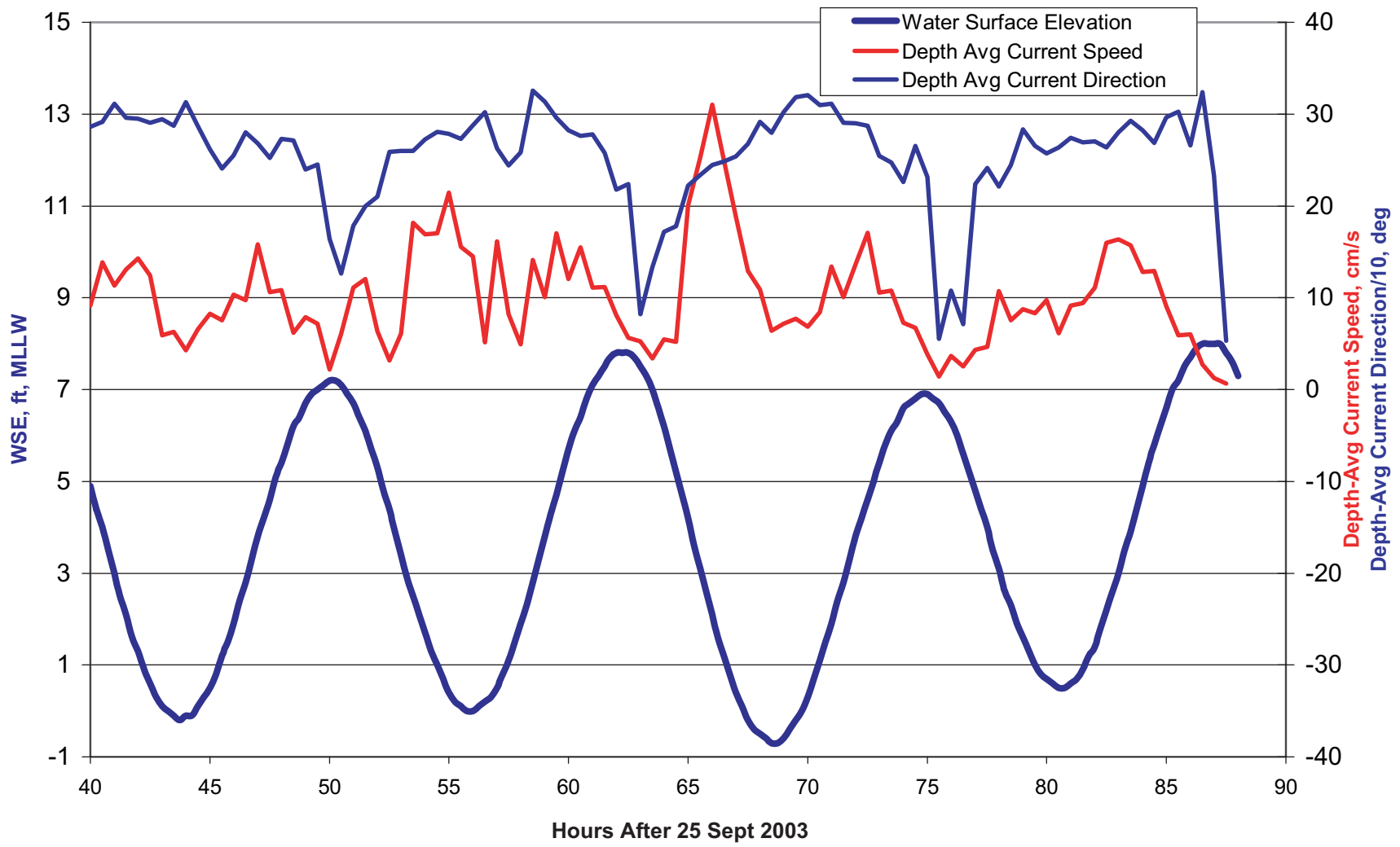


Figure D-6. Observed Tide and Depth Averaged Current at MCR South Jetty Site during 27–28 Sept 2003 (used to simulate 2005 disposal)

From Science to Solutions™

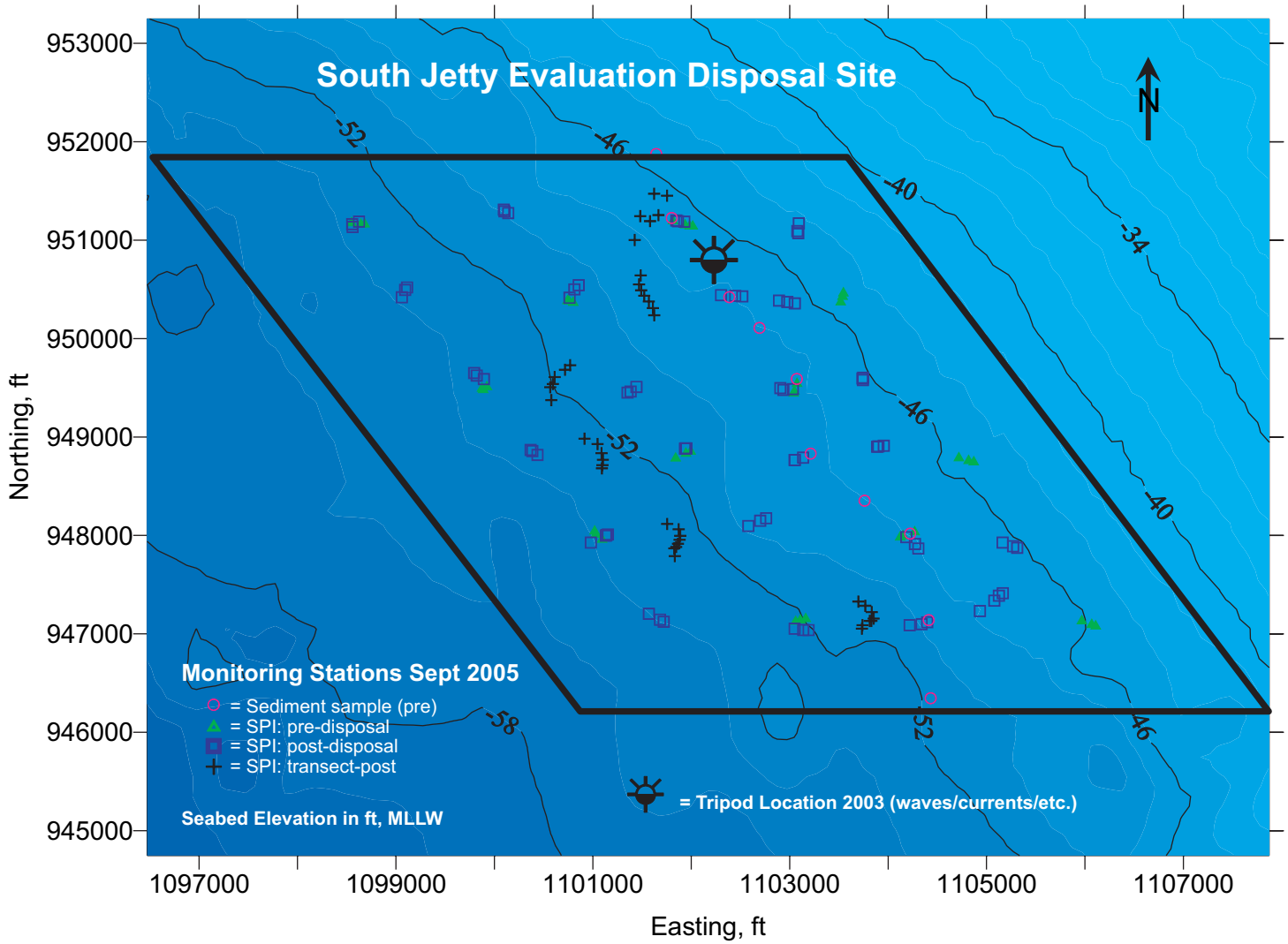


Figure D-7. South Jetty Pilot Study Disposal Site

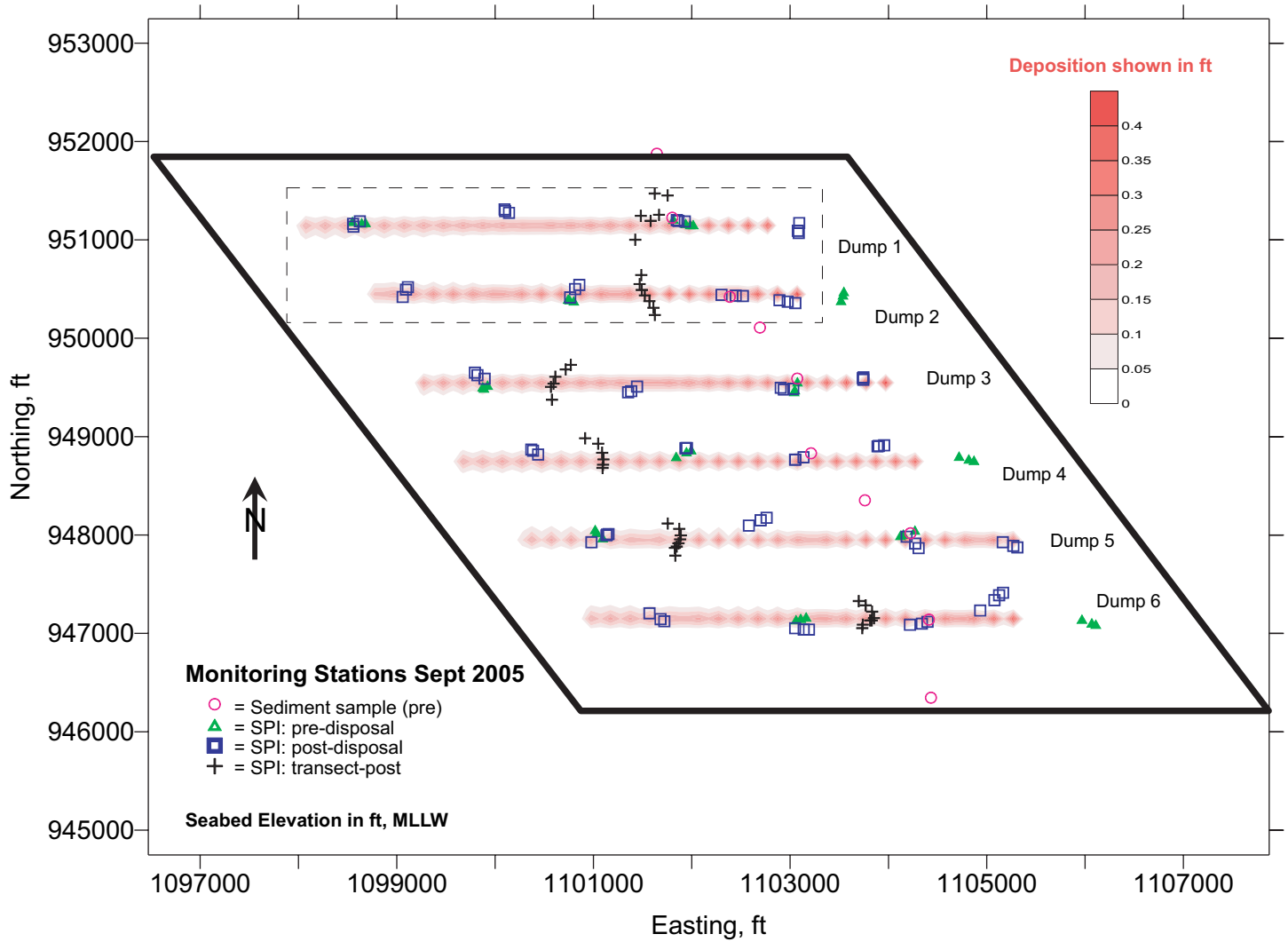
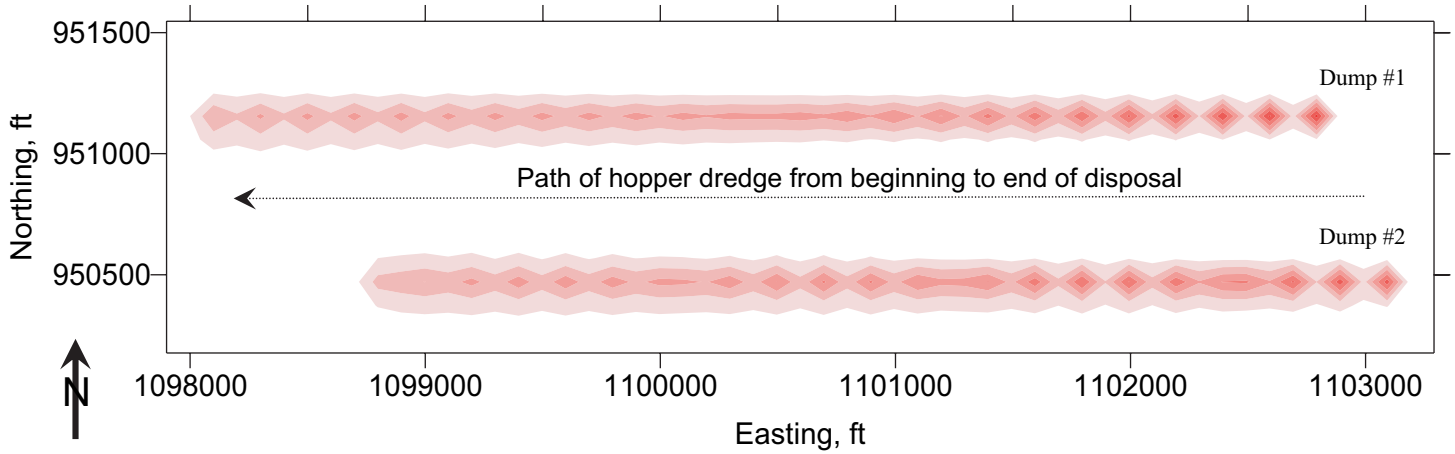
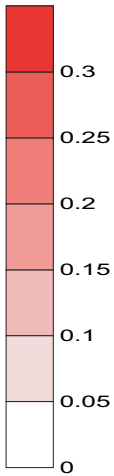


Figure D-8. MDFATE Model Simulation of Dredged Material Distribution on Seabed at South Jetty Site for Six Disposal Events Conducted by Hopper Dredge Essayons during 14–15 Sept 2005



Deposition shown in ft



Dump 1(1256): 5,000 cy placed 14 Sept 2005: 11:16 - 11:25 am, Avg vessel speed = 9.0 ft/sec
tide elevation = 5.3 ft MLLW, depth averaged current = 6 cm/sec at 223 deg

Dump 2(1257): 5,000 cy placed 14 Sept 2005: 14:04 - 14:12 am, Avg vessel speed = 9.2 ft/sec
tide elevation = 3.8 ft MLLW, depth averaged current = 11 cm/sec at 290 deg

Dump 3(1258): 5,000 cy placed 14 Sept 2005: 17:06 - 17:16 am, Avg vessel speed = 8.1 ft/sec
tide elevation = 3.1 ft MLLW, depth averaged current = 7 cm/sec at 226 deg

Dump 4(1259): 5,000 cy placed 14 Sept 2005: 19:43 - 19:52 am, Avg vessel speed = 8.8 ft/sec
tide elevation = 6.4 ft MLLW, depth averaged current = 9 cm/sec at 270 deg

Dump 5(1265): 5,000 cy placed 15 Sept 2005: 8:58 - 9:06 am, Avg vessel speed = 10.6 ft/sec
tide elevation = 3.2 ft MLLW, depth averaged current = 10 cm/sec at 310 deg

Dump 6(1266): 5,000 cy placed 15 Sept 2005: 11:46 - 11:55 am, Avg vessel speed = 8.3 ft/sec
tide elevation = 6.0 ft MLLW, depth averaged current = 7 cm/sec at 70 deg

Figure D-9. MDFATE Model Simulation of Dredged Material Distribution on Seabed at South Jetty Site

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