MONITORING SURVEY AT THE PORTLAND DISPOSAL SITE SUMMER 2000

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EXECUTIVE SUMMARY

The Portland Disposal Site (PDS) was monitored by Science Applications International Corporation (SAIC) in the summer of 2000 as part of the Disposal Area Monitoring System (DAMOS). Field operations were concentrated around the PDA 98 disposal buoy location and consisted of precision multibeam bathymetric and Remote Ecological Monitoring of the Seafloor (REMOTS®) surveys. These surveying techniques were employed to monitor the development and the benthic recolonization of the dredged material deposit around the PDA 98 buoy.

In November 1998, the DAMOS disposal buoy “PDA 98” was deployed at 43° 34.147´ N, 70° 02.209´ W (NAD83) within a natural containment basin on the PDS seafloor. During the 1998/99 dredging season an estimated barge volume of 471,400 m^3 of sediment was sequentially dredged from the federal channel and various marine terminals in Portland Harbor and placed within PDS. An additional 18,300 m^3 of Portland Harbor dredged material was deposited within PDS during the 1999/00 dredging season. Though most of the material was placed at the PDA 98 buoy, some material was also deposited around the U.S. Coast Guard “DG” buoy, located approximately 650 m northeast of the PDA 98 buoy. Over the two year period, approximately 315,600 m^3 of material was deposited around the PDA 98 buoy and 174,100 m^3 of material was deposited around the DG buoy.

The results of the summer 2000 field effort indicated the formation of two detectable sediment deposits on the PDS seafloor. The deposit in the vicinity of the PDA 98 buoy displayed a maximum height of 2 m and a diameter of 600 m along the northwest-southeast axis of the bottom feature. The second sediment deposit was an accumulation of dredged material placed at the DG buoy, with a height approaching 2 m and a width of approximately 270 m. The reported placement positions obtained from disposal barge logs indicated the majority of the DG deposit was composed of sediments removed from the outer reaches of the federal channel in Portland Harbor, as well as sediment deposited in winter 2000 emanating from two small maintenance projects.

The multibeam depth difference results indicated that most of the dredged material placed near the PDA 98 and DG buoys accumulated in the deeper areas among the bedrock outcrops. Sediment-profile photographs collected in the vicinity of the PDA 98 buoy generally confirmed the findings of the bathymetry, showing the presence of dredged material at 27 of the 28 sediment profile stations, including most of the stations on or around the bedrock outcrops. The surface of the dredged material deposit appeared well oxygenated, with Redox Potential Discontinuity (RPD) depths ranging from 1.4 cm to 6 cm. Furthermore, the REMOTS® photographs confirmed the presence of a well-developed Stage I benthic infaunal population with progression to Stage III at greater than 50% of the stations established around the PDA 98 buoy location.

The benthic community over the dredged material deposit around the PDA 98 buoy appeared to be recovering as anticipated, with Organism-Sediment Index (OSI) values ranging from +3 to +11, but, as expected, was slightly lower relative to the surrounding reference areas. The continued recovery of the seafloor around the PDA 98 buoy is anticipated over the next several years, as Stage III activity becomes more widespread and RPD depths deepen due to increased bioturbation and oxidation of organic matter contained within the deposited sediments.

1.0 INTRODUCTION

1.1 Background

The New England District (NAE) of the U.S. Army Corps of Engineers regulates all coastal dredging operations from Eastport, Maine to Byram, Connecticut. In 1977, the Disposal Area Monitoring System (DAMOS) was developed in response to the recognized need for the managed disposal of sediments dredged from the ports and harbors of the northeastern United States. The DAMOS Program currently oversees the use of ten closely monitored open water disposal sites along coastal New England (Figure 1-1A). These sites are utilized for the cost-effective and environmentally sound disposal of dredged material.

The Portland Disposal Site (PDS) is one of three regional dredged material placement sites located in the waters of Maine. The PDS covers a 3.42 km^2 (1 nmi^2) area of seafloor, centered at latitude 43° 34.105′ N and longitude 70° 01.969′ W (NAD83). It is located approximately 13.2 km (7.1 nmi) east of Dyer Point, Cape Elizabeth, Maine (Figure 1-2). Sediments deposited at PDS have originated from dredging projects in Portland Harbor, Fore River, and many of the smaller rivers and harbors within the Casco Bay region. The seafloor topography at PDS is rough and irregular, including many bedrock outcrops that offer multiple natural containment basins that help to minimize the lateral spread of dredged material following its placement on the bottom. In recent years, there has been significant DAMOS monitoring activity at this site as part of a comprehensive subaqueous capping feasibility study.

This dredged material disposal site typically receives an average annual volume of 99,000 m^3 of dredged material deposited at the U.S. Coast Guard, Class-A; Special Purposes buoy (DG), located in the northern region of the site (Figure 1-1B; Morris 1996). The sediment disposed in close proximity to the DG buoy coalesces into a single large sediment deposit, composed of multiple layers of sediment originating from many different projects. However, dredged material emanating from exceptionally large projects often requires long-term monitoring, and is usually directed to other locations within the disposal site. Such locations are often marked with a secondary buoy to guide the disposal barges to the proper position. As project material is released from the barges at the buoy location, a discrete dredged material deposit, or mound, develops on the seafloor. The practice of creating discrete mounds within the boundaries of PDS facilitates long-term monitoring of material from specific dredging projects.

The various bedrock ridges surrounding the depositional areas provide a measure of protection from wave energy and thus act to contain the deposited dredged material. The steep sides of the depressions or hollows disrupt the near bottom orbital currents of passing storm waves, diminishing the potential for sediment resuspension of a dredged material

A

B

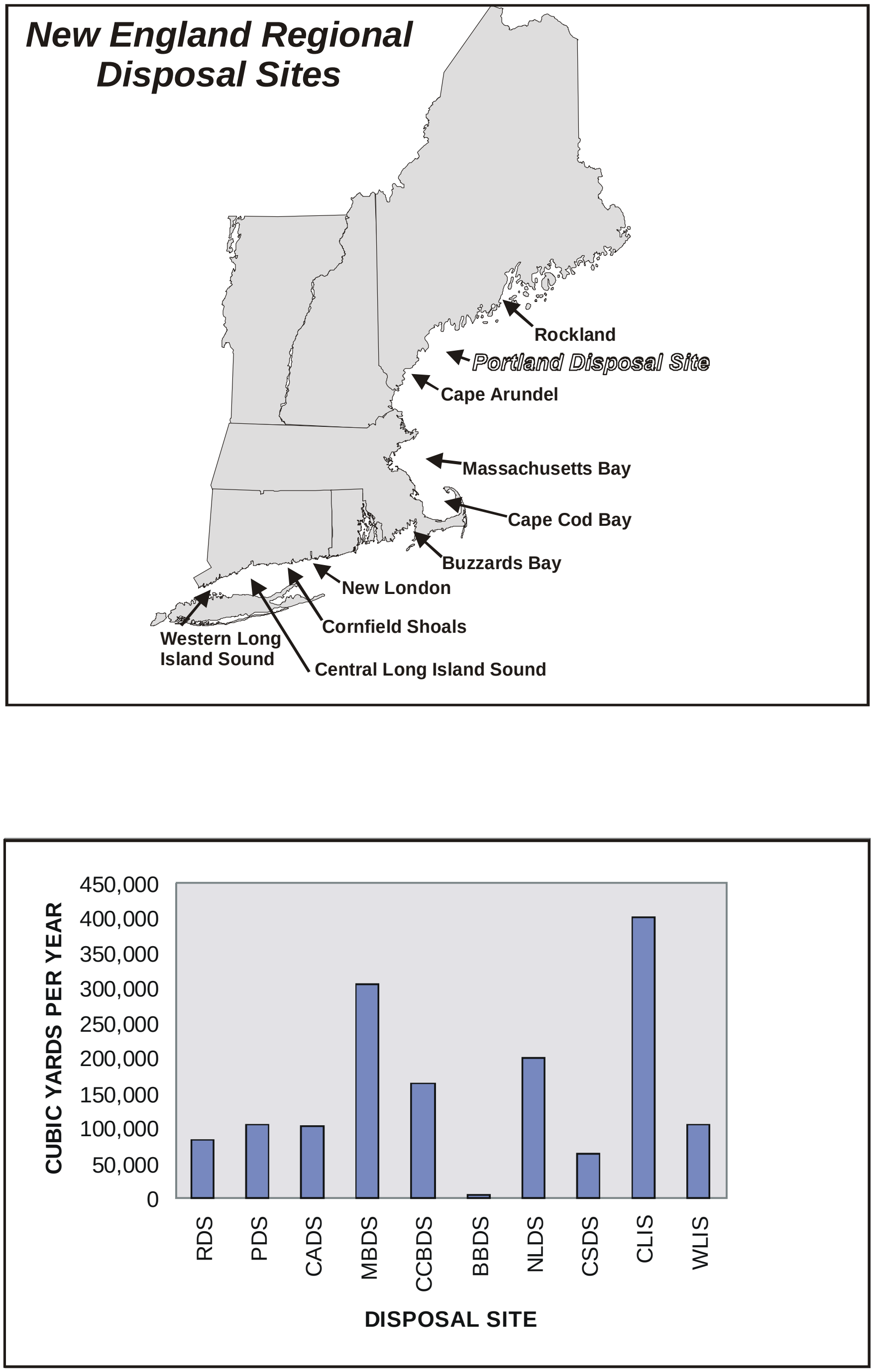


Figure 1-1. Location of dredged material disposal sites along coastal New England (A) and average annual dredged material disposal volumes for the 10 New England disposal sites from 1982 to 1996 (B)

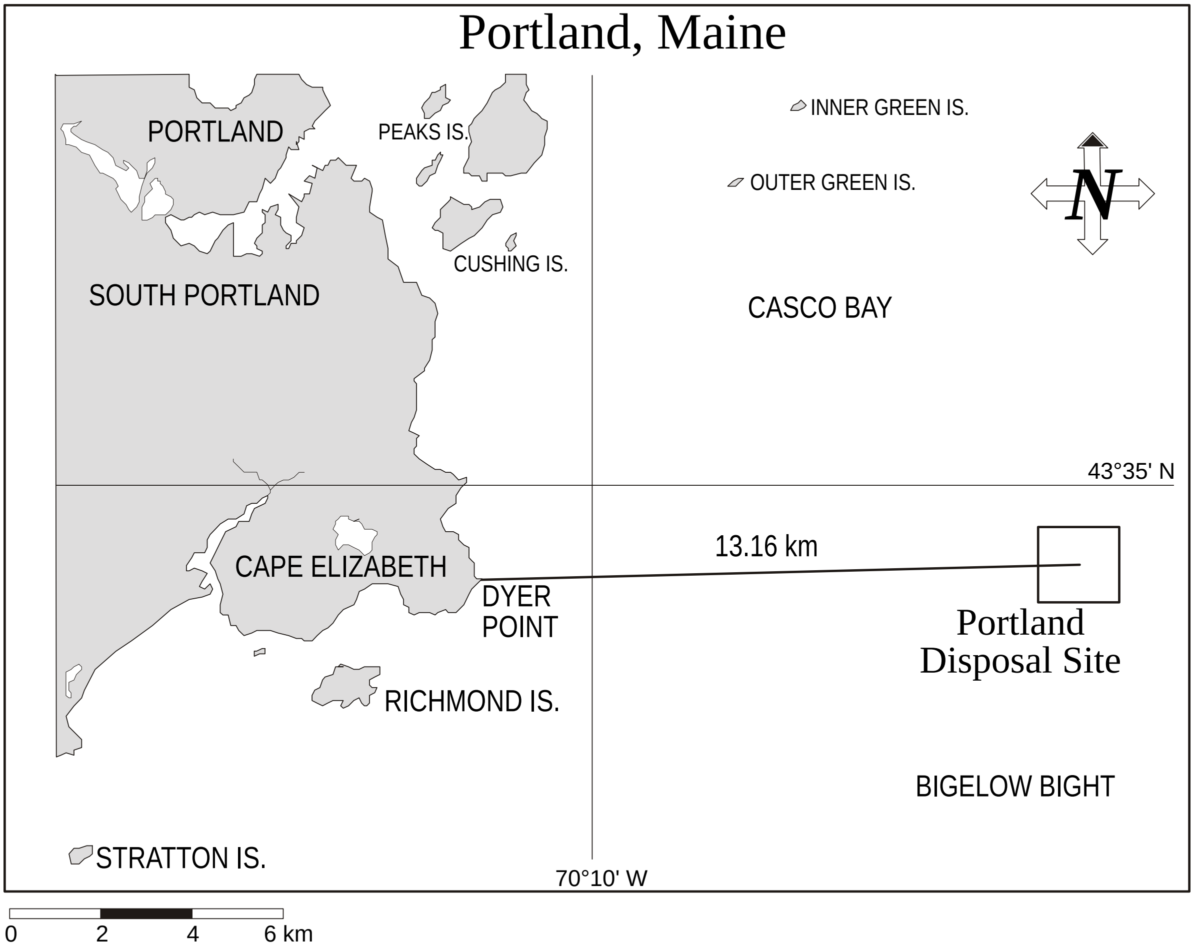


Figure 1-2. Location of the Portland Disposal Site relative to Cape Elizabeth and Casco Bay

deposit. In addition, the rock walls of the natural seafloor features prevent the lateral spread of non-cohesive sediment on the seafloor during the placement process.

1.2 Dredging and Monitoring Activity

Under a previous DAMOS effort, SAIC conducted monitoring operations in September 1998 that included an initial baseline multibeam bathymetric survey of the entire PDS area. In November 1998, the DAMOS disposal buoy "PDA 98" was deployed at 43° 34.147´ N, 70° 02.209´ W (NAD83) within a natural containment basin on the PDS seafloor (Figure 1-3). During the 1998/99 dredging season an estimated barge volume of 471,400 m^3 of sediment was sequentially dredged from the federal channel and various marine terminals in Portland Harbor and placed within PDS. An additional 18,300 m^3 of Portland Harbor dredged material was deposited within PDS during the 1999/00 dredging season (Appendix A). Though a majority of this material was placed at the PDA 98 buoy, a significant amount of material was also deposited around the U.S. Coast Guard "DG" buoy, located approximately 650 m northeast of the PDA 98 buoy. Over the two year period, approximately 315,600 m^3 of material was deposited around the PDA 98 buoy and 174,100 m^3 of material was deposited around the DG buoy.

Dredging of the Portland Harbor began in mid-November 1998, which was divided into several phases, as shown in the timeline of disposal and monitoring activities (Figure 1-4). Although all sediments to be removed from the federal channel had been classified as suitable for unconfined open-water disposal, it was recommended that the interior portions of Portland Harbor's Fore River (consisting of silts and clay) be disposed first and eventually covered by the coarser grained sediments present near the harbor entrance. The first phase of dredging resulted in the removal of an estimated barge volume of 291,500 m^3 of dredged material from the inner Fore River area between 17 November and 16 December 1998. The material was transported to the PDS in 6,000 yd^3 split-hull disposal barges and deposited at the PDA 98 buoy (Figure 1-4). The DAMOS disposal logs showing the volumes of sediment associated with specific dredging projects are presented in Appendix A.

The second phase of the project (mid-December 1998 through early March 1999) consisted of smaller dredging operations removing sediment from individual berthing areas and marinas within Portland Harbor. This material was loaded into smaller, pocket-type disposal barges (500 to 1,200 yd^3) and deposited at the PDA 98 buoy. These smaller dredging projects (Dimillo's Marina, Mobil Oil, and Southport Marine) contributed an additional 5,700 m^3 of dredged material to the PDS (Figure 1-4; Appendix A).

The third and final phase of the 1998/99 project focused on the outer harbor area and occurred through the spring of 1999. An estimated barge volume of 155,800 m^3 was removed from the federal channel, transported to the PDS in 4,000 yd^3 split-hull barges, and deposited at the DG buoy. An additional 18,500 m^3 of material produced by dredging

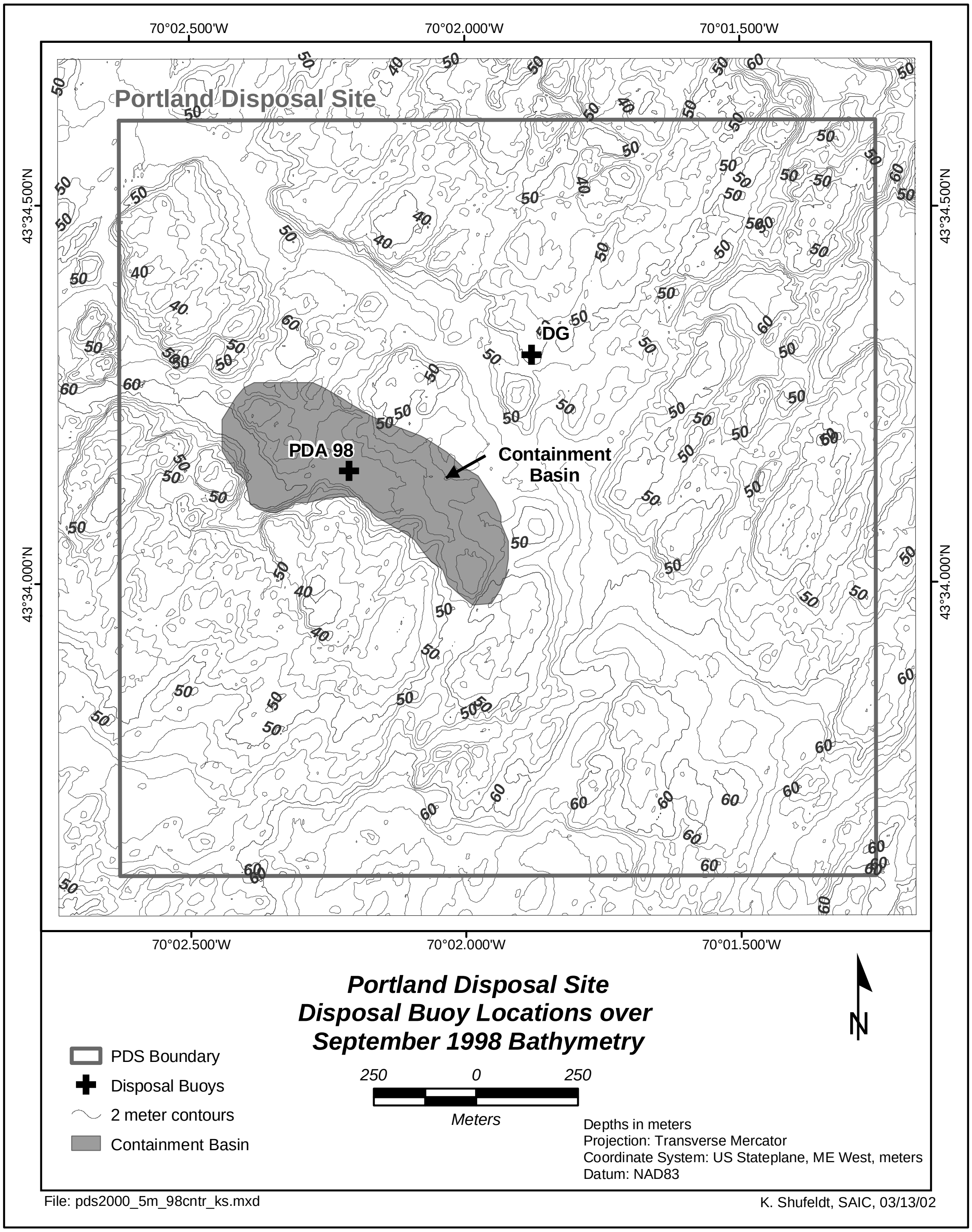


Figure 1-3. Location of the PDA 98 disposal buoy and containment basin relative to the DG buoy and disposal site boundary over September 1998 bathymetry

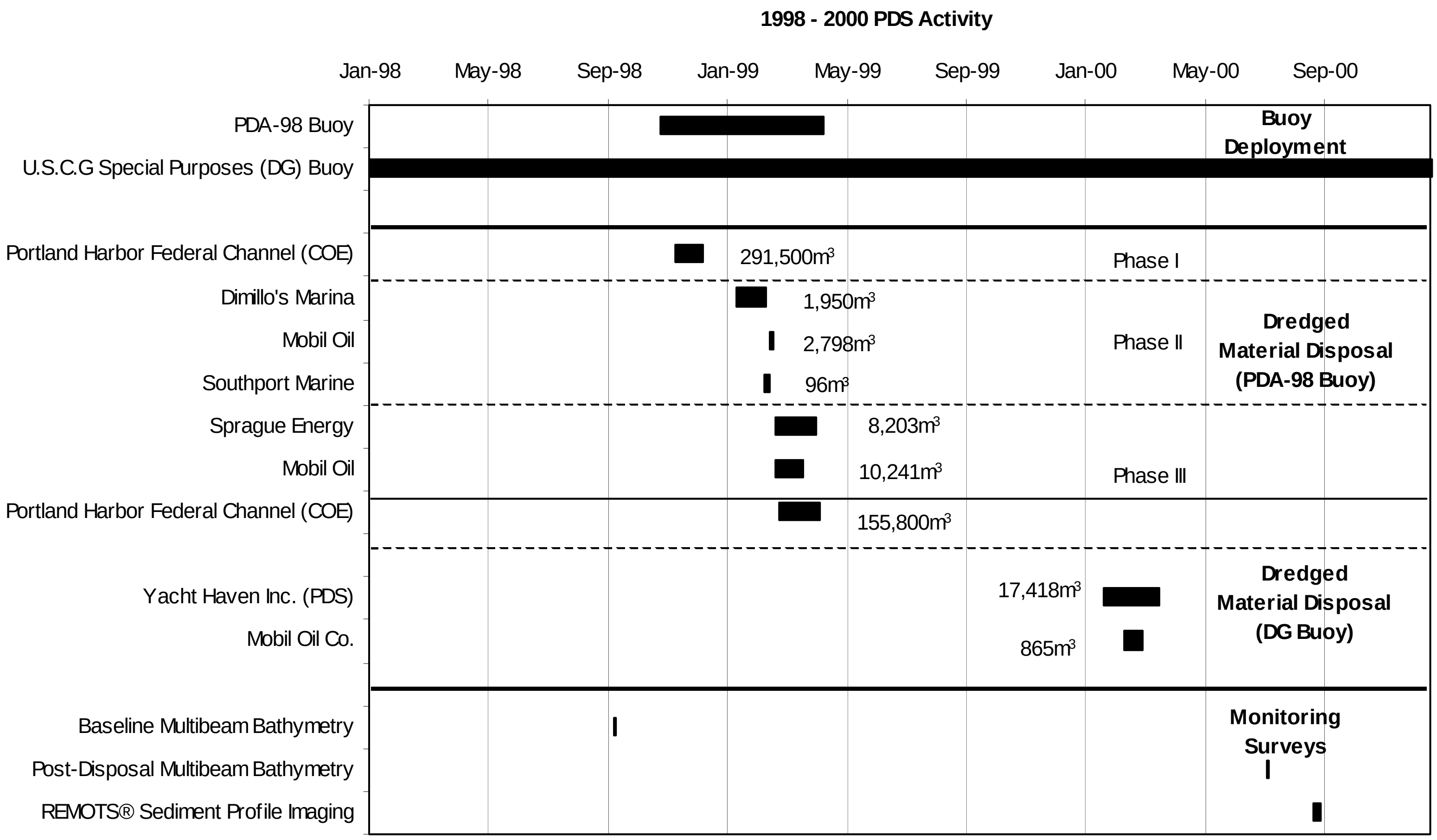


Figure 1-4. Timeline of dredging activity within Portland Harbor and monitoring activities performed at the Portland Disposal Site from September 1998 through September 2000. Dotted lines separate phases of the dredging project, while the solid lines separate buoys and monitoring activities.

projects at the Sprague Energy and Mobil Oil docking facilities was deposited at the PDA 98 buoy during this third phase (Appendix A), using a 1,500 yd^3 pocket-type disposal barge.

During the 1999-2000 dredging season, an additional 18,300 m^3 of material dredged from the Yacht Haven, Inc and Mobil Oil Co. facilities was deposited within the PDS in the vicinity of the DG buoy (Figure 1-4).

In July 2000, SAIC conducted a precision multibeam bathymetric survey over a 4.41 km^2 area at the Portland Disposal Site (PDS) in an effort to document changes in bottom topography resulting from dredged material deposition relative to the September 1998 master survey. In addition, a sediment-profile imaging survey was conducted over the recently formed PDA 98 Mound and portions of the deposit around the DG buoy in September 2000 to verify stability of the sediment deposit and evaluate benthic recolonization. The bathymetric survey was performed on 29 July 2000. Sediment-profile photography operations were conducted in mid-September 2000 as part of a second summer field initiative.

1.3 Objectives and Predictions

The objectives of the summer 2000 field operations consisting of multibeam bathymetric surveying and REMOTS® sediment-profile imaging were:

1. to document changes in seafloor topography around the PDA 98 and DG buoys through depth difference comparisons with the September 1998 baseline multibeam survey; and
2. to evaluate the benthic recolonization status within the surface sediments around the PDA 98 buoy and portions of the deposit around the DG buoy relative to existing conditions at three surrounding reference areas.

The summer 2000 field effort tested the following predictions:

1. that the dredged material placed around the PDA 98 buoy during the 1998/99 disposal season will result in a detectable seafloor deposit existing primarily within a natural containment feature on the PDS seafloor; and

2. that the recently placed dredged material around the PDA 98 buoy will be supporting a well-developed Stage I population with progression into Stage II or Stage III communities, as predicted by the DAMOS tiered monitoring protocols.

2.0 METHODS

Multibeam bathymetry and sediment-profile photography survey operations were performed over the Portland Disposal Site during the summer of 2000. In order to maximize the efficiency of the survey operations, the field activity was divided into two separate efforts. The bathymetric survey was conducted on 29 July 2000 aboard the R/V *Ocean Explorer*, while the sediment-profile photography fieldwork was performed aboard the M/V *Beavertail* from 21 to 22 September 2000.

2.1 Multibeam Data Collection and Processing

2.1.1 Survey Area

The September 2000 multibeam survey was performed over a 2100 × 2100 m area centered at 43° 34.125´ N, 70° 01.958´ W (NAD83) to document any changes in seafloor topography relative to the September 1998 survey (Figure 2-1). In order to maximize the swath coverage of the seafloor, the survey consisted of a square-shaped area with 34 primary lines spaced at 70 m intervals and oriented along an azimuth of 81° (True). Due to their orientation, line lengths ranged from 2,100 to 250 meters. Three cross lines were run perpendicular to the main survey lines (along an azimuth of 172°), with distances ranging from 845 to 2,124 m. In addition, 31 short, fill-lines were occupied over the PDS survey area to fill data gaps or areas of insufficient coverage.

2.1.2 Survey Vessel Positioning

The R/V *Ocean Explorer* was used as the survey platform for multibeam bathymetry survey operations conducted at PDS. This specialized survey vessel is specifically designed and outfitted for high-speed (approximately 11 knots) swath bathymetry data collection (Figure 2-2). The main cabin of the vessel serves as the data collection and first-order-processing center. Upon completion of the survey, all data were delivered to the Data Processing Center for post-processing. Table 2-1 provides a list of characteristics for the R/V *Ocean Explorer*. Precision navigation, helmsman display, and data integration from the multitude of sensors aboard the survey vessel were accomplished with the use of SAIC's Integrated Survey System 2000 (ISS2000). Real-time navigation, data time tagging, and data logging were controlled by the ISS2000 in a Windows NT 4.0 environment.

Table 2-1.

Survey Vessel Characteristics

Vessel Name	LOA (Ft)	Beam (Ft)	Draft (Ft)	Gross Tonnage	Power (Hp)	Registration Number
R/V *Ocean Explorer*	61’	16’4”	3’3”	56	1100	US905425

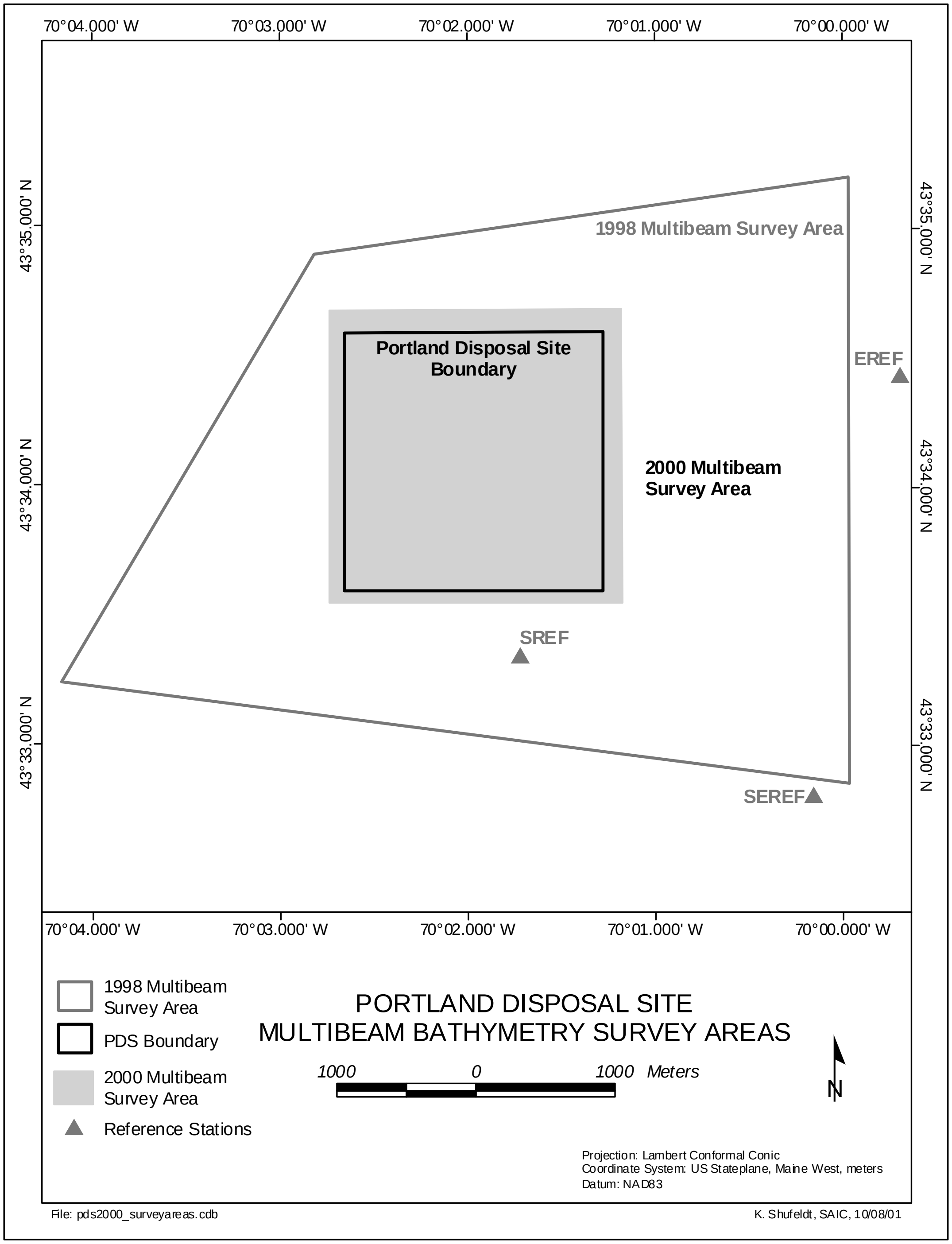


Figure 2-1. Multibeam bathymetric survey area occupied at PDS as part of the July 2000 field operations relative to the September 1998 survey area

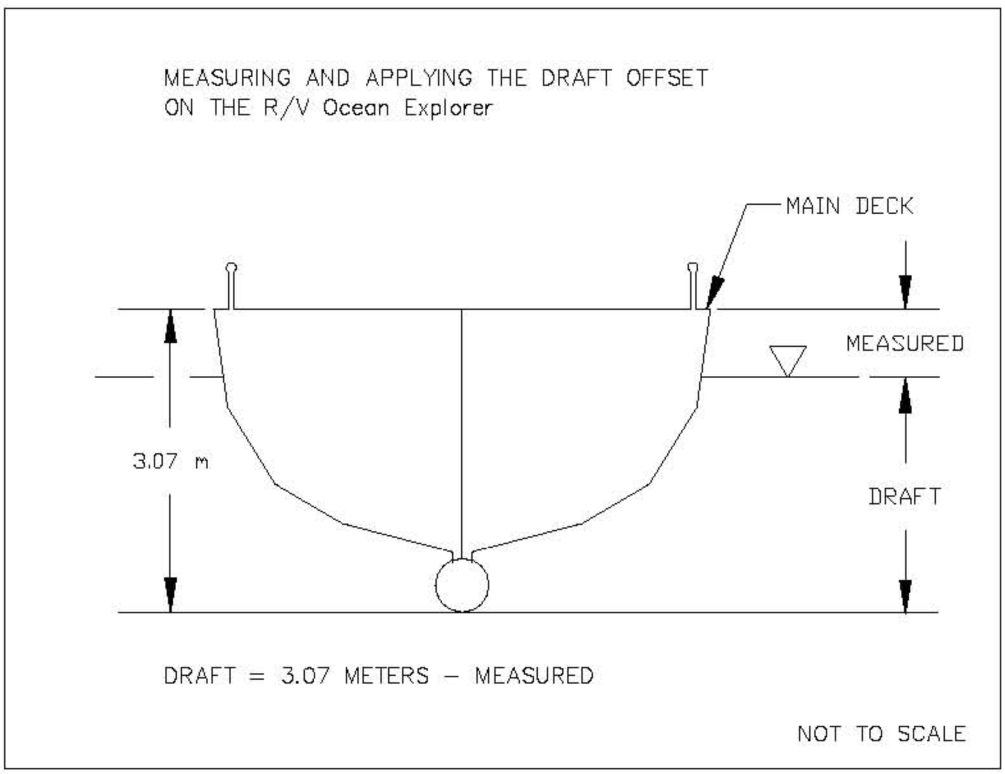


Figure 2-2. R/V Ocean Explorer and draft determination

Positioning information was recorded from multiple independent Global Positioning System (GPS) receiver networks in the North American Datum of 1983 (NAD83). Two, linked GPS receivers embedded within a TSS POS/MV 320, 3-axis Inertial Motion compensation Unit (IMU) were used as the primary source for vessel position and attitude correctors applied to the multibeam data. The POS/MV IMU was interfaced with a Trimble Probeacon Differential Beacon Receiver to improve the positioning data to an accuracy of +/-5 m. Correctors broadcast from the U.S. Coast Guard differential station in Brunswick, ME (316 kHz) were applied to the GPS satellite data. The ISS2000 monitored horizontal dilution of precision (HDOP; quality of the signal); number of satellites, elevation of satellites, and age of correctors to ensure the resulting bathymetric positioning errors did not exceed five meters at the 95% confidence level.

The second GPS system served as a source of position confidence checks and a real-time monitor to verify the navigation information provided by the POS/MV IMU. The secondary system consisted of a Trimble 7400 RSi GPS receiver interfaced with a Leica MX41R Differential Beacon Receiver. Differential correctors broadcast from the U.S. Coast Guard station in Penobscot, ME (290 kHz) were applied to the satellite data. The real-time monitor within ISS2000 raised an alarm when the two DGPS positions differed by more than 10 meters horizontally. All positioning confidence checks were well within the allowable inverse distance of five meters.

2.1.3 Multibeam System Configuration

Because of the swath acoustic coverage provided by multibeam systems, there are several external data sensors that must be incorporated into any multibeam survey. In addition to the position, depth, and water column sound velocity typically required for a single-beam survey, multibeam surveys must also have sensors to accurately measure vessel heading and attitude (i.e., heave, pitch, and roll). On the R/V *Ocean Explorer*, the real-time heading and attitude compensation were accomplished in the multibeam system based on the data output by a POS/MV GPS-aided inertial navigation system. The sensor offsets relative to top centerline of the POS/MV IMU on the R/V *Ocean Explorer* during the PDS survey are shown in Table 2-2.

2.1.3.1 Depth Soundings

A RESON 8101 shallow water, multibeam system was employed for the acquisition of sounding data over the PDS survey area (Table 2-3). The RESON 8101 was mounted on the keel of the survey vessel, and utilizes 101 individual narrow beam (1.5°) transducers capable of yielding a total swath coverage of 150° (75° per side). The actual width of coverage is adjustable through range scale settings with a maximum equivalent to 7.4 times the water depth. The RESON 8101 transducer can transmit up to 12 high frequency (240 kHz) sound pulses, or pings, per second, though that number may be reduced in deeper

Table 2-2.
R/V *Ocean Explorer* Antenna and Transducer Locations Relative to the POS/MV IMU Vessel Reference Point, measurements in meters

Sensor	Offset in ISS2000		POS/MV IMU	
Multibeam RESON 8101 Transducer Hull Mount			X	-1.63
			Y	0.00
			Z	0.70
ODOM Single-beam Transducer	X	-2.04		
	Y	-.018		
	Z	0.80		
Trimble 7400 Antenna	X	-5.70		
	Y	0.00		
	Z	-7.43		
POS/MV GPS Master Antenna			X	-5.70
			Y	-1.00
			Z	-7.44

Table 2-3.
The R/V *Ocean Explorer* System Components

Subsystem	Components
Positioning	TSS-POS/MV Model 320 Position and Orientation System (Dual GPS receivers and IMU)
Vessel Position Quality Monitoring	Trimble 7400 GPS Receiver (Quality Monitoring) Trimble DGPS Beacon Receiver
Integrated Navigation System	SAIC ISS2000
Survey Autopilot	Robertson AP9 Mk II
Multibeam Sonar	RESON 8101 240 kHz Multibeam Depth Sounder
Motion Sensor	TSS-POS/MV Model 320 Position and Orientation System
Data Acquisition and Display	Windows NT Computer running ISS2000 Integrated Survey System Software
Sound Velocity Profiler	Brooke Ocean Technology MVP 30, Moving Vessel Profiler (SVP System)

water where sound travel times are greater. This rapid ping rate provides dense along-track data coverage and allows the survey boat to be operated at higher speeds. During the PDS survey, vessel speed was controlled to yield average along-track coverage of 2.0 pings per square meter of seafloor. Due to the complex bottom topography at PDS, the RESON 8101 horizontal range scale was set for auto tracking to optimize the efficiency of the survey.

Acoustic returns from the seafloor were detected by the transducer array and raw depth values were transmitted to the RESON 6042 topside control unit. The RESON 6042 then applied a series of real-time corrections (i.e., sound velocity, attitude, predicted tides, draft, squat, etc.) to the raw soundings before transmitting them to the ISS2000 for position stamps and data storage. An Odom Echotrac DF 3200 single-beam echosounder was also operated to provide a real-time quality check of the RESON 8101 data.

2.1.3.2 Attitude and Heading Compensation

A single multibeam swath extends a great distance perpendicular to the precise aspect of the transducer at the time of the transmit pulse. As a result, the quality and accuracy of the multibeam data (particularly in the outer beams) is highly dependent upon the precise measurement of the position, motion, and attitude of the survey vessel (e.g., heading, heave, pitch, and roll). Real-time heading and attitude compensation were accomplished in the multibeam system based on the data output by the POS/MV GPS-aided inertial navigation system (Table 2-3). The primary positioning unit (POS/MV IMU) was mounted on the vessel centerline just forward and above the RESON 8101 transducer to minimize positional offsets. The POS/MV heading, heave, pitch, and roll data were transferred to the RESON 6042, which applied corrections to the raw soundings before they were transmitted to the ISS2000 and stored for post processing.

With the vessel underway, the azimuth accuracy of the POS/MV system is +/- 0.05°, one order of magnitude better than the accuracy provided by a gyrocompass. The heave accuracy of the system was 5% of one meter (or 5 cm), and the dynamic accuracy for roll and pitch was ±0.10°. Heading, roll, and pitch biases were determined in a series of patch tests performed in Narragansett Bay during the Sea Acceptance Test. These biases are required to account for any minor misalignment between the mounting of the 8108 transducer and the POS/MV IMU. A complete description of the POS/MV calibration procedure and resulting bias calculations are presented in Appendix B.

2.1.3.3 Sound Velocity

Any acoustic echosounder (single or multibeam) computes a depth by precisely measuring the travel time of a sound pulse that originates from the transducer, reflects off of the seafloor, and returns back to the transducer. The acoustic travel time is multiplied by the speed of sound within the water column, and then divided in half to obtain a depth value. As a result, the accurate determination of the speed of sound within the water column is required for the correct calculation of depth during the survey operation.

Sound velocity in seawater is a function of density, a variable characteristic controlled by water temperature and salinity. A variety of tools exist for the determination of an average water column speed of sound that satisfies the requirements of a single beam system, where the acoustic signal is transmitted straight down through the water column. However, because multibeam systems generate numerous acoustic beams angled-off of the vertical, strong water column density gradients, or pycnoclines, have a greater impact on multibeam data (particularly in the outer beams). When the non-vertical multibeam pings encounter pycnoclines, they tend to be refracted by the change in speed, causing them to strike the seafloor at a different location relative to those traveling through a well-mixed water column. The effects of pycnoclines on multibeam data are corrected in real-time during multibeam surveys by generating refraction models that are based on periodic density profiles for the entire water column.

Portland Disposal Site is located in the mouth of Casco Bay, where the water column generally reflects open ocean conditions and is well–mixed. However, stratification is possible in mid-summer as temperature differences can establish pycnoclines at deeper depths. In addition, the semidiurnal tidal cycle promotes changes in seawater properties within a survey day as less saline and warmer water flows out of Casco Bay into the Gulf of Maine. Density profiles were obtained at approximately two-hour intervals during the PDS survey in order to document changing water column characteristics. A Brooke Ocean Technology Ltd., Moving Vessel Profiler-30 (MVP) sound velocity profiling system was used to determine water column speed of sound. After the velocity cast data were examined, it was sent to the RESON 6042 topside control unit. Within the RESON 6042, a beam refraction model was computed from the speed of sound data, and beam angle correctors were applied to the raw multibeam sounding data received from the RESON 8101 transducer.

2.1.3.4 Static Draft of the Survey Vessel

Raw soundings collected by the RESON 8101 multibeam system reference depth values to the transducer mounted on the underside of the survey vessel. In order to adjust the depth values to the water's surface, a draft corrector was applied to the raw soundings in the RESON 6042 topside control unit. The depth of the transducer below the vessel's main deck (3.07 m) was determined from measurements made during a dry dock period in May 2000. This measurement remains constant as both the deck and the keel are fixed structures on the survey vessel. However, daily draft measurements were made between the main deck and the still water level to compensate for changes in vessel draft due to fuel and water loading (Figure 2-2).

At the beginning and end of each survey day, static draft measurements were made on the port and starboard sides of the survey vessel. The height of the vessel's main deck above the still water level was subtracted from 3.07 m to yield actual draft of the transducer array. The draft measured for the PDS 2000 survey was 1.41 m, which in turn was added to the raw soundings.

2.1.3.5 Settlement and Squat

The configuration of the R/V *Ocean Explorer* allows the collection of high-quality swath bathymetry data at speeds approaching 11 knots. The displacement of water by the survey vessel's hull allows the boat to settle into the water slightly. The faster the hull moves through the water, the greater the volume of water displaced, promoting further settlement. In addition, higher speeds and the resulting increased shaft revolutions per minute (RPMs) also cause the bow of the survey vessel to rise higher in the water and the stern to dip further into the water. This apparent change in vessel's vertical position, relative to the water line, is capable of impacting the hydrographic data set unless settlement and squat correctors are applied.

Measurements of settlement and squat for the R/V *Ocean Explorer* were conducted on 13 May 2000, in Narragansett Bay, RI over an area of seafloor 18 meters below the water's surface. As expected, the correction values increase proportionally with the vessel's speed over ground. A complete description of the measurement procedure is presented in Appendix C.

2.1.3.6 Tidal Corrections

Tidal height corrections for the PDS survey were obtained via the National Oceanic and Atmospheric Administration (NOAA). Both predicted and observed tide information were based on the NOAA tide station at Portland Harbor, ME (8418150) corrected to the appropriate local tide zone. The local tide zone correctors applied to the Portland tide data were -6 minutes for time difference and 95% for height.

Predicted tides were applied in the RESON 6042 topside control unit in real-time during the survey operations. Verified, observed tidal data downloaded from the NOAA CO-OPS web page were applied during the post-processing effort. Tide-corrector files for each tide zone were created from actual tide data using the ISS2000 “TID2HMPS” routine. These corrector files were then applied to the multibeam data using the “APPCORS” program within the ISS2000 Survey Analysis software.

2.1.4 Multibeam Data Collection

Multibeam depth data were collected by the RESON 8101/6042 system in the Generic Sensor Format (GSF). The GSF file format allows flags to be set as an indication of the validity of each ping or beam within the bathymetric data. These flags can be set either in real time during acquisition or later during post processing of the data. The GSF combined with history records inserted into the files in real time and during post processing provides complete tracking of all correctors and processing steps that were applied to the data. Thus, the original GSF file is continually updated without creating multiple redundant multibeam files; no data are deleted, they are only flagged and ignored in the final processing routines.

A real-time coverage monitor was used during data collection to ensure adequate coverage of multibeam data that met or exceeded International Hydrographic Organization (IHO) standards. Multibeam backscatter imagery data, similar to side-scan sonar, were collected in eXtended Triton Format (XTF). These data were collected by the RESON 6042 and stored to the hard drive. The imagery data are useful for bottom-type classification and can be merged into a mosaic image of the seafloor using the Triton Elics ISIS processing software.

2.1.5 Multibeam Data Processing

All data processing was conducted using the SAIC ISS2000 system. Initial navigation quality control was done on the vessel shortly after the data were collected. Where time allowed, multibeam data were edited onboard the vessel using the geoswath editor, which provided both plan and profile views of each beam in its true geographic position and depth. At the end of each day, both the raw and processed data were backed up onto 4 mm tape and shipped to the data processing center in Newport, RI.

In the processing center, manual data editing was completed and reviewed by an ACSM-certified Hydrographer. Verified tide data from the Portland, ME (8418150) station were applied to the multibeam data during this phase of the post-processing. The data collected along the three cross lines were compared to soundings obtained from the same locations along the primary survey lines as a quality control tool. Any questionable data were noted and later evaluated by the lead Hydrographer.

Once the data were fully processed and reviewed, the depth data were gridded into 1×1 m, 5×5 m, and 20×20 m cells. Each cell contained a single depth value derived from averaging all of the soundings that fell within that cell. When large differences were detected between soundings within the same cell, the edited multibeam files were re-examined and re-edited as needed. The resulting gridded data sets were used to evaluate coverage and quality, and to facilitate comparison with older single beam bathymetric data sets.

The product of the depth difference comparison was a graphical representation of the apparent changes in seafloor topography over time. However, due to the variety correctors applied to the acoustic bathymetry data (i.e., tidal; sound velocity; attitude and heading; and settlement and squat) comparisons of sequential bathymetric surveys can only reliably detect changes in depth of 25 cm or greater. As a result, the lateral extent of a dredged material disposal mound or sediment deposit is often below the threshold of the bathymetric data products. Other monitoring techniques are often employed to define the thinner margins of the disposal mound (i.e., sediment-profile imaging).

2.2 REMOTS® Sediment-Profile Imaging

2.2.1 Survey Vessel Navigation and Positioning

For the sediment-profile imaging field operations, differentially-corrected Global Positioning System (DGPS) data, in conjunction with Coastal Oceanographic's HYPACK® navigation and survey software, were used to provide real-time navigation of the survey vessel to an accuracy of ±3 m. A Trimble 4000 RSi GPS receiver was used to obtain raw satellite data and provide vessel position information in the horizontal control of North American Datum of 1983 (NAD83). The GPS receiver was interfaced with a Trimble NavBeacon XL differential receiver to improve overall accuracy of the satellite data to the necessary tolerances. The U.S. Coast Guard differential beacon broadcasting from Brunswick, ME (316 kHz) was utilized for real-time satellite corrections due to its geographic position relative to PDS.

The DGPS data were ported to HYPACK® data acquisition software for position logging and helm display. The target stations for REMOTS® sediment-profile imaging were determined before the commencement of survey operations and stored in a project database. Throughout the survey, individual stations were selected and displayed in order to position the survey vessel at the correct geographic location for sampling. The position of each replicate sample was logged with a time stamp in Universal Time Coordinate (UTC) and a text identifier to facilitate Quality Control (QC) and rapid input into a Geographic Information System (GIS) database.

2.2.2 Sediment-Profile Image Acquisition and Analysis

Remote Ecological Monitoring of the Seafloor (REMOTS®) is a benthic sampling technique used to detect and map the distribution of thin (<20 cm) dredged material layers, map benthic disturbance gradients, and monitor the process of benthic recolonization over the disposal mound. This is a reconnaissance survey technique used for rapid collection, interpretation and mapping of data on physical and biological seafloor characteristics. The DAMOS Program has used this technique for routine disposal site monitoring for over 20 years. The REMOTS® hardware consists of a Benthos Model 3731 Sediment-Profile Camera designed to obtain undisturbed, vertical cross-section photographs (*in situ* profiles) of the upper 15 to 20 cm of the seafloor (Figure 2-3). Computer-aided analysis of each REMOTS® image yields a suite of standard measured parameters, including sediment grain size major mode, camera prism penetration depth (an indirect measure of sediment bearing capacity/density), small-scale surface boundary roughness, depth of the apparent redox potential discontinuity (RPD, a measure of sediment aeration), infaunal successional stage, and Organism-Sediment Index (OSI; a summary parameter reflecting overall benthic habitat quality). REMOTS® image acquisition and analysis methods are described fully in Rhoads and Germano (1982; 1986) and in the recent DAMOS Contribution 128 (SAIC 2001) and therefore not repeated herein.

A total of 28 REMOTS® stations were occupied in close proximity to the PDA 98 buoy position to evaluate benthic habitat conditions in the area subjected to recent placement activity (Figure 2-4; Table 2-4). The eight arms of the star-shaped station grid were oriented to allow the collection of photographs in likely areas of dredged material accumulation. Stations along the east and northeast arms of this grid pattern extended into areas that were also influenced by dredged material placed around the DG buoy. Three replicate photographs were obtained at each of the PDA 98 stations. Three replicates were also collected at each of 13 stations distributed among three reference areas surrounding PDS (EAST REF, SE REF, and SOUTH REF) to provide a comparison between conditions on the PDA 98 Mound versus those on the ambient seafloor (Figure 2-1). Five stations were randomly distributed around the center of SOUTH REF (43° 33.351´ N, 70° 01.722´ W), while four stations were randomly distributed around the centers of both EAST REF (43° 34.434´ N, 69° 59.701´ W) and SE REF (43° 32.807´ N, 70° 00.162´ W; Table 2-4).

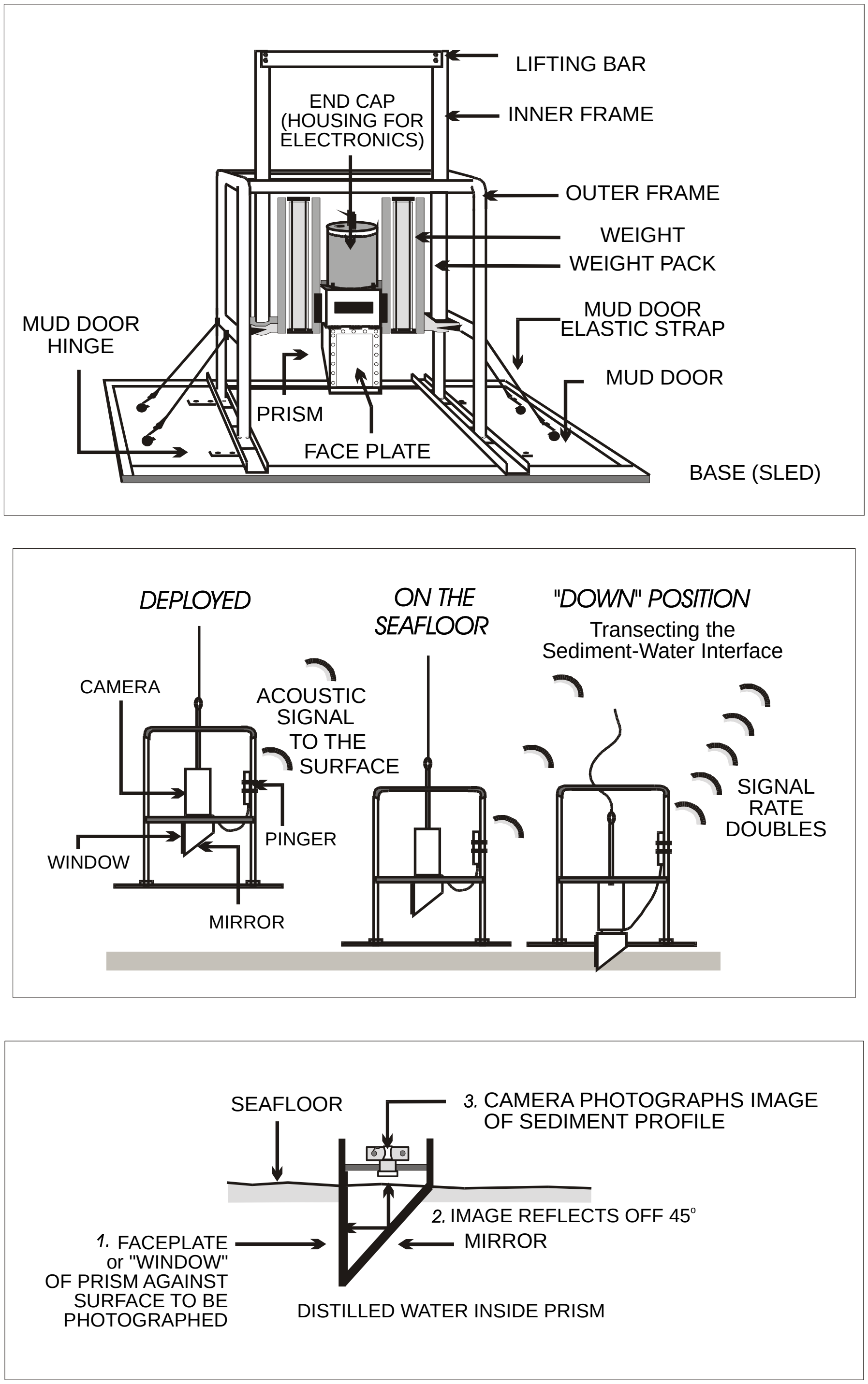


Figure 2-3. Schematic Drawing of the Benthos, Inc. Model 3731 REMOTS® sediment-profile camera and sequence of operation on deployment

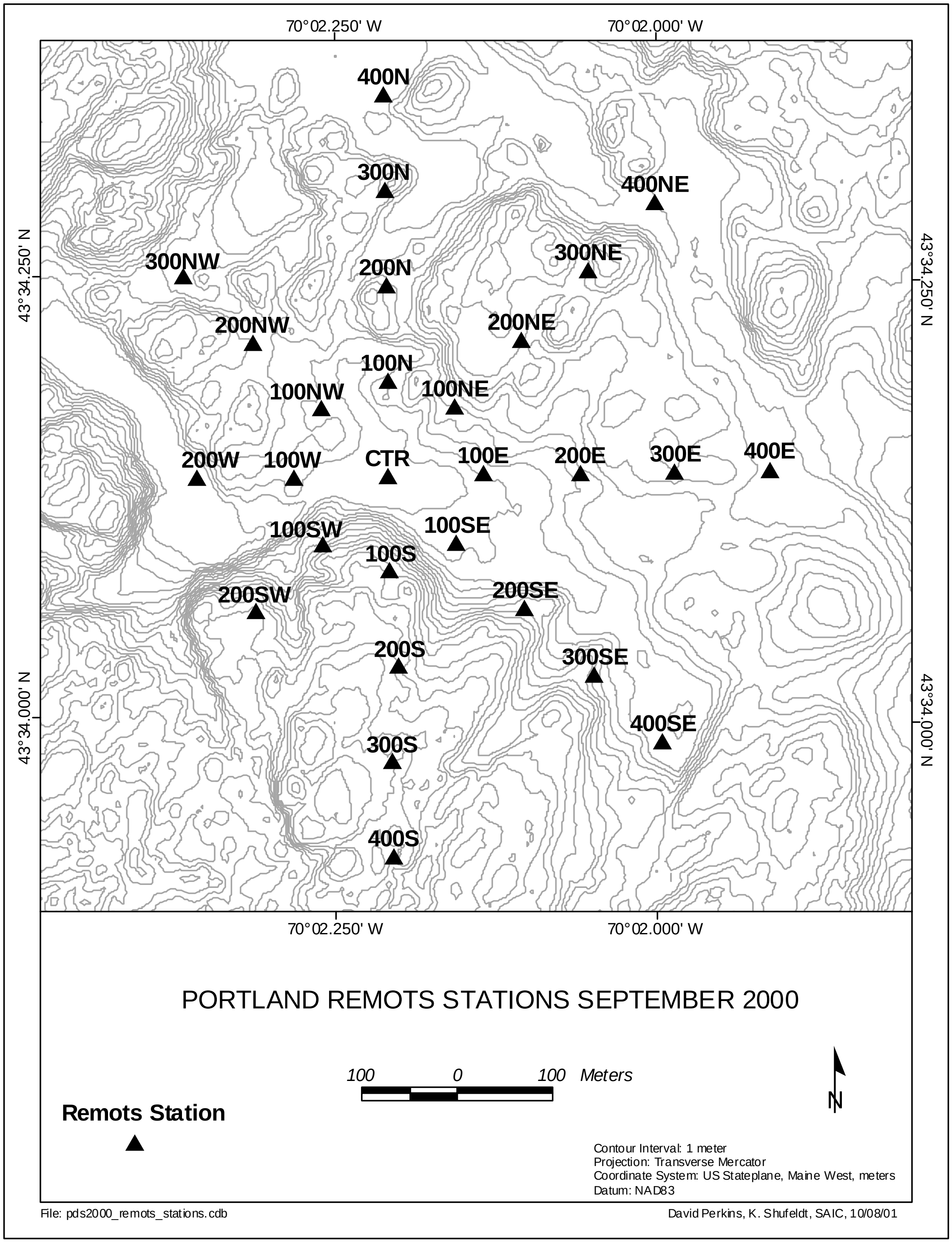


Figure 2-4. REMOTS® Station locations established over the Portland Disposal Site relative to general seafloor topography (1 m contour interval)

Table 2-4.
September 2000 REMOTS® Sediment-Profile Imaging Station Locations (NAD83)

Area	Station	Latitude	Longitude
	CTR	43° 34.147´ N	70° 02.210´ W
	100N	43° 34.201´ N	70° 02.210´ W
	200N	43° 34.255´ N	70° 02.211´ W
	300N	43° 34.309´ N	70° 02.212´ W
	400N	43° 34.363´ N	70° 02.213´ W
	100NE	43° 34.186´ N	70° 02.157´ W
	200NE	43° 34.224´ N	70° 02.105´ W
	300NE	43° 34.263´ N	70° 02.053´ W
	400NE	43° 34.302´ N	70° 02.001´ W
	100E	43° 34.148´ N	70° 02.135´ W
PDS 98	200E	43° 34.148´ N	70° 02.060´ W
CENTER:	300E	43° 34.149´ N	70° 01.986´ W
43° 34.147´ N	400E	43° 34.150´ N	70° 01.912´ W
70° 02.210´ W	100SE	43° 34.109´ N	70° 02.156´ W
NAD 83	200SE	43° 34.072´ N	70° 02.103´ W
	300SE	43° 34.034´ N	70° 02.049´ W
	400SE	43° 33.996´ N	70° 01.996´ W
	100S	43° 34.093´ N	70° 02.208´ W
	200S	43° 34.039´ N	70° 02.201´ W
	300S	43° 33.985´ N	70° 02.206´ W
	400S	43° 33.931´ N	70° 02.205´ W
	200SW	43° 34.070´ N	70° 02.313´ W
	100SW	43° 34.108´ N	70° 02.261´ W
	200W	43° 34.146´ N	70° 02.358´ W
	100W	43° 34.146´ N	70° 02.283´ W
	300NW	43° 34.260´ N	70° 02.369´ W
	200NW	43° 34.222´ N	70° 02.315´ W
	100NW	43° 34.185´ N	70° 02.262´ W
Reference Areas			
EAST REF	EREF 1	43° 34.422´ N	69° 59.838´ W
CENTER:	EREF 2	43° 34.381´ N	69° 59.631´ W
43° 34.434´ N	EREF 3	43° 34.427´ N	69° 59.709´ W
69° 59.701´ W	EREF 4	43° 34.575´ N	69° 59.660´ W
SOUTH REF	SREF 1	43° 33.349´ N	70° 01.644´ W
CENTER:	SREF 2	43° 33.353´ N	70° 01.734´ W
43° 33.351´ N	SREF 3	43° 33.276´ N	70° 01.594´ W
70° 01.722´ W	SREF 4	43° 33.305´ N	70° 01.744´ W
	SREF 5	43° 33.442´ N	70° 01.716´ W
SE REF	SEREF 1	43° 32.784´ N	70° 00.203´ W
CENTER:	SEREF 2	43° 32.851´ N	70° 00.099´ W
43° 32.807´ N	SEREF 3	43° 32.672´ N	70° 00.182´ W
70° 00.162´ W	SEREF 4	43° 32.814´ N	70° 00.164´ W

3.0 RESULTS

3.1 Multibeam Bathymetry

In November 1998, the PDA 98 buoy was deployed over a moderate-sized, natural containment cell to mark the disposal location for the major 1998/99 Portland Harbor dredging project. During the 1998/99 dredging season, 471,400 m^3 of sediment was dredged from Portland Harbor and deposited at PDS. An additional 18,300 m^3 was deposited at PDS during the subsequent 1999/00 dredging season. Over that two year period, approximately 315,600 m^3 of material was deposited around the PDA 98 buoy, and 174,100 m^3 of material was deposited near the DG buoy. The post-disposal multibeam survey was conducted in July 2000 to examine the changes in seafloor topography related to the placement of dredged material at PDS during that two-year period.

The 2100 $\times$ 2100 m multibeam bathymetry survey of July 2000 provided resolution that met or exceeded the 1998 master survey and was a useful tool in depth difference comparisons. Similar to the 1998 multibeam bathymetry, the 2000 multibeam data highlighted numerous steep, bedrock ridges and a northwest-southeast trending trough within this complex topographic area (Figures 3-1 and 3-2). A minimum depth of 37 m was detected at the apex of a fairly pronounced bedrock outcrop located approximately 125 m south of the northern disposal site boundary. A maximum depth of 73 m was detected outside the confines of PDS, in a natural basin along the southern margin of the survey area (Figures 3-1 and 3-2). Because it covered a much larger overall survey area, the 1998 baseline multibeam survey indicated a deeper maximum depth (102.5 m) and a shallower minimum depth (28.5 m) than the 2000 survey. When the review of the 1998 survey data was limited to the same area covered by the 2000 survey (primarily within the boundaries of PDS), the minimum and maximum depths agreed well.

In an effort to develop discrete and stable sediment mounds, dredged material disposal operations at PDS have targeted the deeper, depositional areas of the seafloor that are sheltered from major hydrodynamic forces by the surrounding bedrock outcrops. The northwest-southeast trending trough that runs through the center of the disposal site has received the bulk of material that has been deposited since 1979 (Figure 3-1). Two gently sloping bathymetric features corresponding to the current and historic positions of the DG buoy are easily identified within the trough and represent accumulations of dredged material (Figure 3-2). These dredged material disposal mounds have more gradual side slopes compared to the steep profiles of many of the surrounding bedrock areas.

Utilizing the full resolution of the multibeam system, the July 2000 bathymetric data were processed into grid cells of 1 m^2 to generate seafloor models comparable to those created from the 1998 master bathymetric survey data. Depth difference comparisons

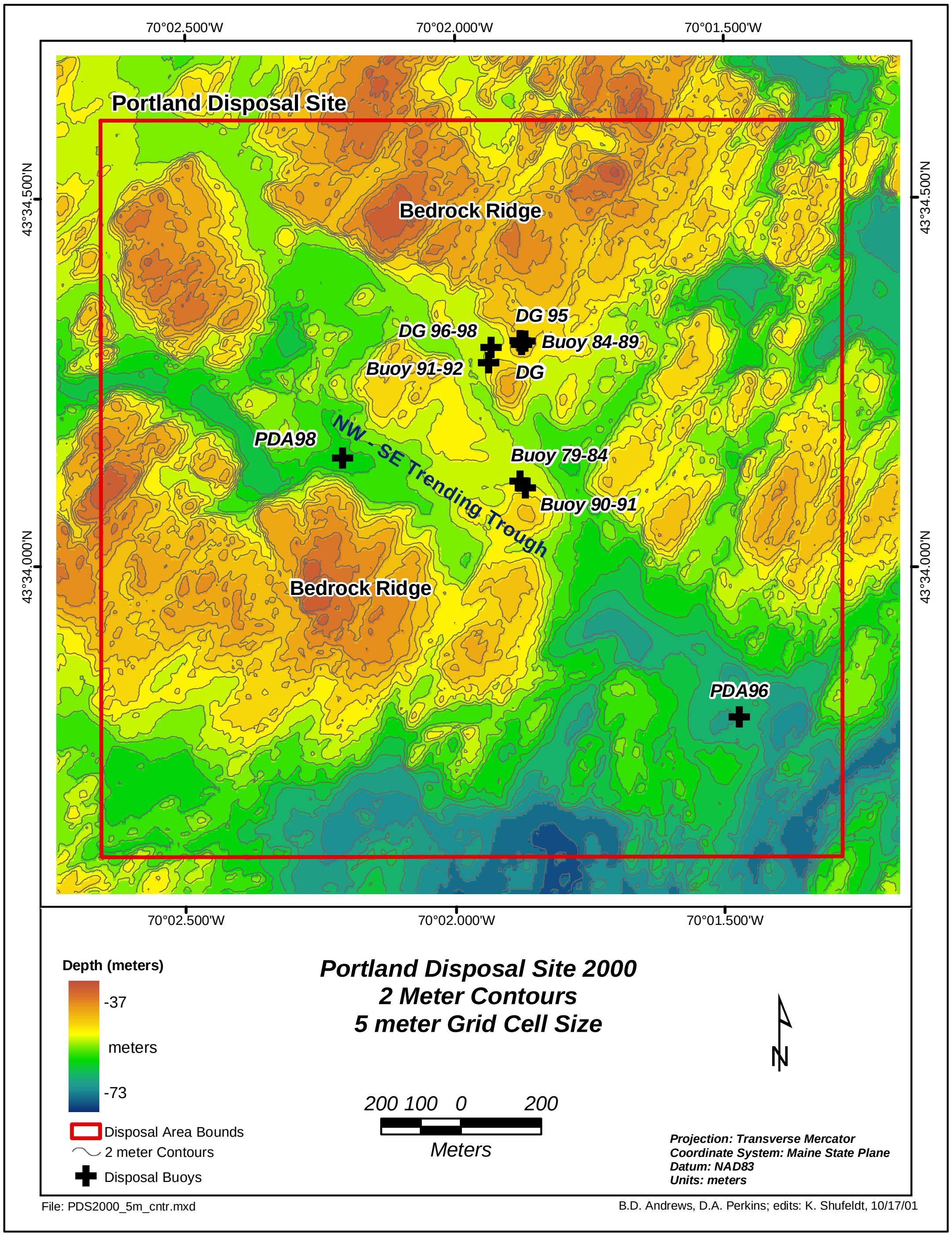


Figure 3-1. Color-filled bathymetric contour map of the 2000 multibeam survey performed over the Portland Disposal Site (2 m contour interval) indicating positions of past disposal buoys and major bottom features

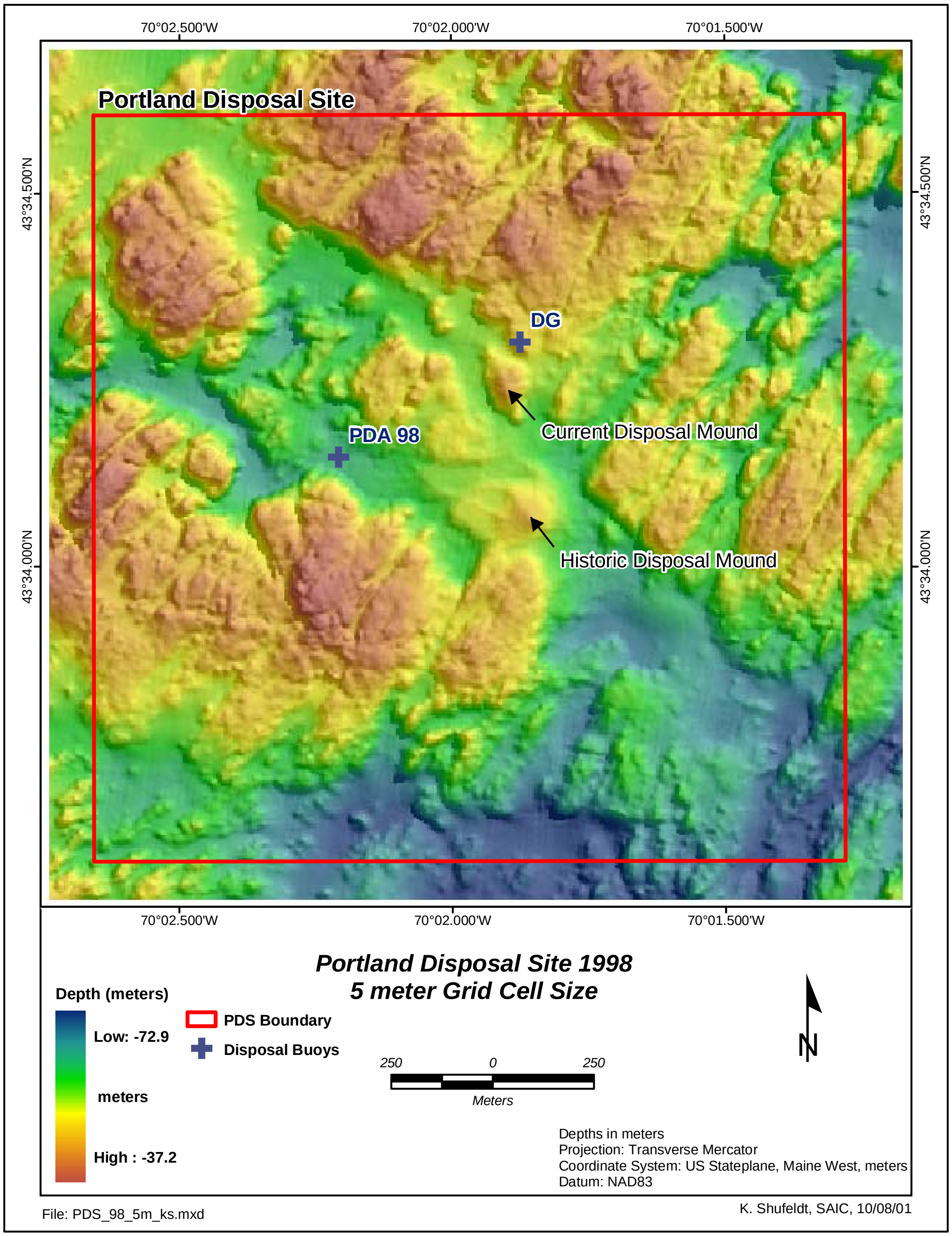


Figure 3-2. Hill-shaded bathymetry of the 2000 multibeam survey completed over the Portland Disposal Site indicating recent disposal buoy locations and seafloor dredged material deposits

between the 1998 and 2000 survey models indicated the apparent accumulation of new material within the natural basin features in close proximity to the PDA 98 and DG buoy positions (Figure 3-3). The consistently positive depth difference values in these areas, as well as the placement locations reported in disposal logs suggest the apparent change in water depth within these basins is the product of dredged material deposition. As a result, it is assumed that the apparent changes in seafloor topography in close proximity to the PDA 98 and DG buoys represents the accumulation of Portland Harbor sediment. Closer examination of the area subjected to dredged material disposal activity indicates the thickness of recently placed sediment ranged from 0.25 m to approximately 2 m, with the majority of the sediment contained within the natural seafloor basin features (Figure 3-4). The acoustically detectable dredged material deposit around the PDA 98 buoy was approximately 650 × 200 m, while the sediment deposit around the DG buoy was approximately 250 × 100 m. Both of these dredged material deposits were oriented along the same northwest/southeast alignment as the main trough feature in this area, but on opposite sides of a substantial bedrock outcrop.

Additional dredged material deposits were also apparent in several of the smaller, nearby basin or trough features adjacent to the PDA 98 and DG mounds (Figure 3-4). Although the depth difference plot displays multiple independent deposits, the spatial distribution of dredged material suggests an apron of sediment less than the 0.25 m threshold of the depth difference comparisons likely connects these thicker accumulations. Furthermore, a significant percentage of the apron material located outside the natural basins has likely accumulated within crevices in the surrounding bedrock outcrops. As the unconsolidated sediment filled the voids in the bedrock that were smaller than the resolution of the swath bathymetric grid cells, the material contained within those voids remains undetectable to acoustic measurement and the depth differencing techniques employed.

In addition to the positive depth differences associated with dredged material deposition, the depth difference comparisons between the 1998 and 2000 multibeam surveys also displayed a significant number of survey artifacts (Figure 3-3). These artifacts were false indications of a change in water depth between the September 1998 and July 2000 surveys. These artifacts were primarily the result of slight differences in the final depth values assigned to each grid cell for each survey, attributed to minor differences in techniques employed during data acquisition (e.g., survey boat configuration and survey line orientation) or correction factors applied to the depth data and/or navigation information. Most of artifact-induced difference areas were very small-scale features comprised of both positive and negative values (not shown) and aligned along a steep gradient associated with irregular areas of the seafloor (e.g., deep crevices within the bedrock, margins of containment basins, etc). These small errors were magnified to

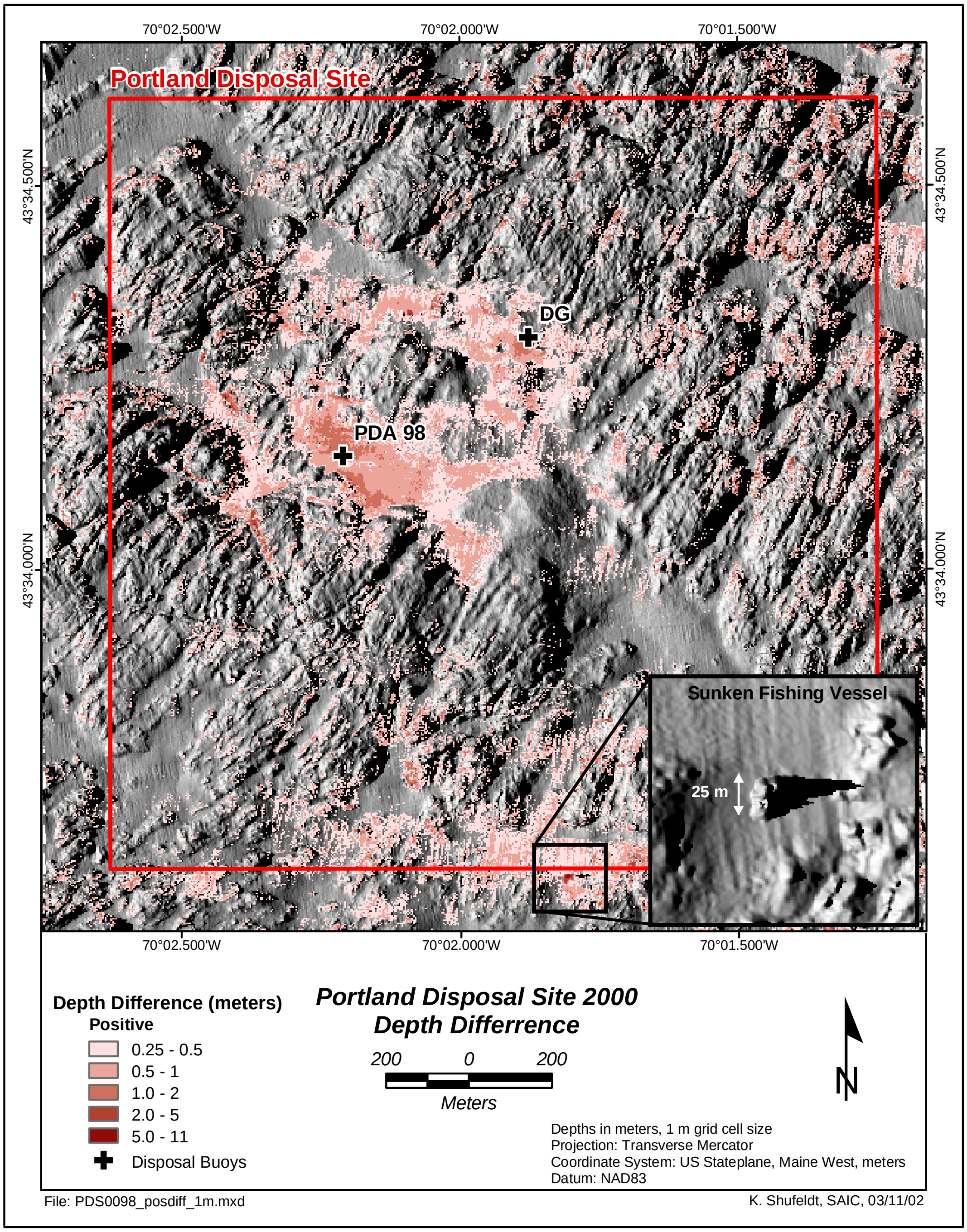


Figure 3-3. Depth difference results between the 1998 and 2000 multibeam surveys draped over hill-shaded bathymetry showing apparent accumulation of dredged material in close proximity to the PDA 98 and DG disposal buoy locations

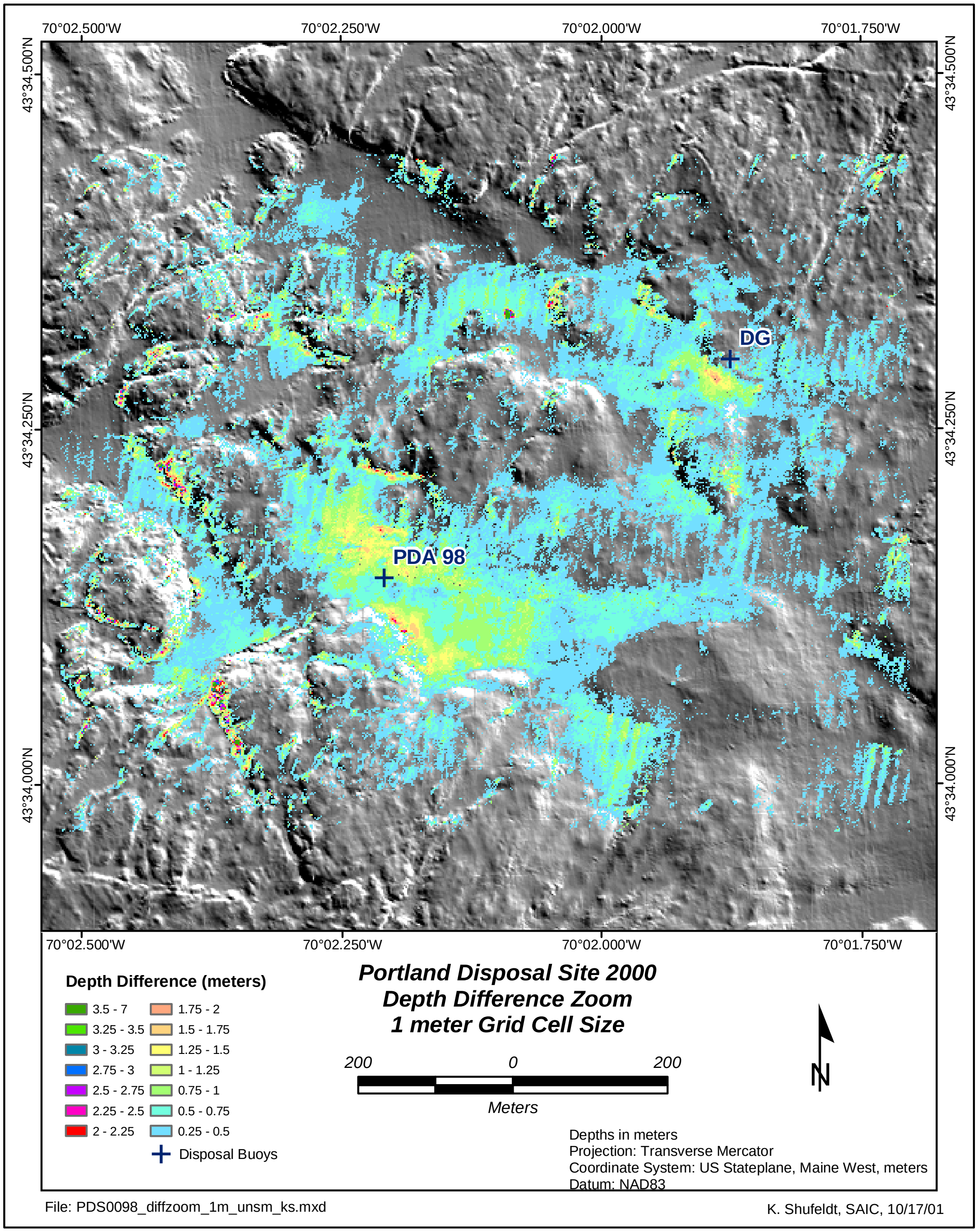


Figure 3-4. Zoomed-in perspective of the depth difference results between the 1998 and 2000 multibeam surveys focusing on the areas of apparent accumulation in close proximity to the PDA 98 and DG disposal buoy locations

0.25 to 0.5 m over areas of high seafloor relief and generally corresponded to areas of complex topography. For the purposes of evaluating the impacts associated with the dredged material deposition, these artifact-induced difference areas were discounted, and the emphasis was placed on identifying and examining those areas in the vicinity of the disposal buoys where large-scale and consistent depth differences were noted (Figure 3-4).

The area of apparent of accumulation (0.25 to 0.5 m) along the southern boundary of the disposal site was also considered survey artifact due to the complex seafloor topography and the lack of any reported dredged material disposal in that area of PDS (Figure 3-3). However, an isolated 9 m depth difference was detected within a small basin feature 30 m outside the PDS boundary (Figure 3-3). Further investigation indicated that this small feature corresponds to the reported position of a 120-foot fishing vessel scuttled over PDS sometime after the 1998 multibeam survey. The swath bathymetry and depth differencing routines were capable of detecting this relatively small object on the PDS seafloor, as well as the potential movement of soft sediment resulting from the impact of the vessel on the bottom.

3.2 REMOTS® Sediment-Profile Imaging

The REMOTS® survey over the PDA 98 Mound was conducted to document benthic recolonization, map the distribution of thin layers of dredged material, and assess the overall impact of dredged material deposition. A complete set of REMOTS® image analysis results for both the PDA 98 Mound and reference area stations is provided in Appendix D; these results are summarized in Tables 3-1 and 3-2.

3.2.1 Dredged Material Distribution and Physical Sediment Characteristics

Dredged material was evident at 27 of the 28 REMOTS® stations occupied over the PDA 98 Mound (Table 3-1 and Figure 3-5). At all 27 stations, the thickness of the dredged material layer extended from the sediment surface to below the REMOTS® camera penetration depth (indicated with a "greater than" sign in Table 3-1 and Figure 3-5). The dredged material observed in the surface and near surface layers of the disposal site was composed mainly of fine-grained, cohesive silt-clay, with an apparent minor fraction of sand (Figure 3-6). Apparent ambient sediment was observed in one of three replicate images at Station 200SW and in the single replicate obtained at Station 400S (Table 3-1). All replicate images displayed a major modal grain size of >4 phi (Table 3-1). Similarly, the sediments at the reference areas were characterized as predominately silt and clay (i.e., grain size major mode of >4; Table 3-2). Dredged material was not evident in any of the replicate images obtained at the reference area stations.

Table 3-1.
Summary of REMOTS® Results for Stations at the PDA 98 Mound

Station	Camera Penetration Mean (cm)	Dredged Material Thickness Mean (cm)	Number of Reps w/ Dredged Material	RPD Mean (cm)	Successional Stages Present	Highest Stage Present	Grain Size Major Mode (phi)	Methane Present	OSI Mean	OSI Median	Boundary Roughness Mean (cm)
100E	10.11	>10.11	3	1.42	I,III	ST_I_ON_III	>4	NO	4.67	4	2.33
100N	11.08	>11.08	3	2.76	I,III	ST_I_ON_III	>4	NO	6.33	6	1.17
100NE	10.54	>10.54	3	1.70	I	ST_I	>4	NO	4	4	1.18
100NW	15.57	>15.57	3	2.49	I,III	ST_I_ON_III	>4	NO	7.67	8	2.16
100S	13.43	>13.43	3	1.82	I,III	ST_I_ON_III	>4	NO	5.33	5	1.34
100SE	17.99	>17.99	3	2.91	I,III	ST_I_ON_III	>4	NO	6	4	2.14
100SW	11.89	>11.89	3	1.65	I,III	ST_I_ON_III	>4	NO	5	3	2.66
100W	13.58	>13.58	2	1.92	I	ST_I	>4	NO	4.50	4.5	1.13
200E	19.24	>19.24	3	1.52	I,III	ST_I_ON_III	>4	NO	5	5	1.30
200N	13.22	>13.22	3	2.37	I	ST_I	>4	NO	5	5	2.12
200NE	14.74	>14.74	3	2.01	I,III	ST_I_ON_III	>4	NO	7	8	1.87
200NW	12.28	>12.28	3	1.80	I,III	ST_I_ON_III	>4	NO	6.67	8	2.06
200S	9.59	>9.59	3	1.74	I,III	ST_I_ON_III	>4	NO	5	5	1.25
200SE	15.98	>15.98	3	2.72	I	ST_I	>4	NO	5.33	5	3.61
200SW	16.61	>11.35	2	2.91	I	ST_I	>4	NO	5.33	5	1.30
200W	20.08	>20.08	3	5.22	I,III	ST_I_ON_III	>4	NO	8.33	7	1.45
300E	9.59	>9.59	3	2.11	I,III	ST_I_ON_III	>4	NO	7	7	2.12
300N	16.61	>16.61	3	3.01	I,III	ST_I_ON_III	>4	NO	6.67	7	2.00
300NE	11.76	>11.76	3	1.77	I	ST_I	>4	NO	4	4	5.99
300NW	21.00	>21.00	3	INDET	INDET	INDET	>4	NO	INDET	INDET	INDET
300S	11.31	>11.31	3	1.37	I	ST_I	>4	NO	3.33	3	1.54
300SE	15.96	>15.96	3	2.52	I	ST_I	>4	NO	5	5	2.51
400E	15.90	>15.90	3	2.25	I,III	ST_I_ON_III	>4	NO	5.67	5	2.20
400N	14.41	>14.41	3	3.14	I,III	ST_I_ON_III	>4	NO	8.33	11	2.11
400NE	15.93	>15.93	3	2.87	I	ST_I	>4	NO	5.33	5	1.01
400S	1.54	0	0	INDET	INDET	INDET	>4	NO	INDET	INDET	1.85
400SE	20.47	>20.47	3	5.96	I,III	ST_I_ON_III	>4	NO	8.33	7	0.90
CTR	10.22	>10.22	3	2.52	I	ST_I	>4	NO	5	5	2.94
AVG	13.95	>13.71	3	2.48					5.76	5.6	2.01
MAX	21.00	>21.00	3	5.96					8.33	11	5.99
MIN	1.54	0	0	1.37					3.33	3	0.90

Table 3-2.
Summary of REMOTS® Results for the Stations Occupied over the PDS Reference Areas

Station	Camera Penetration Mean (cm)	RPD Mean (cm)	Successional Stages Present	Highest Stage Present	Grain Size Major Mode (phi)	Methane Present	OSI Mean	OSI Median	Boundary Roughness Mean (cm)
EAST									
EREF1	10.98	2.21	I,III	ST_I_ON_III	>4	NO	5.67	6	1.74
EREF2	11.37	2.98	I,III	ST_I_ON_III	>4	NO	7.50	7.5	3.04
EREF3	12.99	2.85	I	ST_I	>4	NO	5	5	3.56
EREF4	3.60	3.43	I	ST_I	>4	NO	6	6	1.51
SOUTHEAST									
SEREF1	10.38	2.51	I,III	ST_I_ON_III	>4	NO	6.33	6	1.82
SEREF2	10.92	4.19	I	ST_I	>4	NO	6.50	6.5	2.19
SEREF3	17.95	5.02	I,III	ST_I_ON_III	>4	NO	10	10	2.11
SEREF4	14.87	2.99	I,III	ST_I_ON_III	>4	NO	9.67	10	1.76
SOUTH									
SREF2	7.61	2.61	I	ST_I	>4	NO	5	5	1.16
SREF3	0.06	INDET	INDET	INDET	>4	NO	INDET	INDET	0
SREF4	1.44	INDET	I	ST_I	>4	NO	INDET	INDET	2.03
SREF5	10.17	3.10	I	ST_I	>4	NO	5.5	5.5	1.31
AVG	9.36	3.19					6.73	6.75	1.85
MAX	17.95	5.02					10	10	3.56
MIN	0.06	2.21					5	5	0

The seafloor topography within the confines of the PDS and surrounding areas is characterized as rough and irregular, with areas of soft sediment accumulation in the basins among bedrock outcrops. Hard bottom at Station 400S prevented sufficient camera penetration, precluding measurement of several key REMOTS® parameters (e.g., RPD, successional status, OSI, and boundary roughness). Patches of extremely soft sediment caused the sediment-profile camera to over-penetrate at other stations, obscuring the sediment-water interface and likewise precluding analysis of the above-mentioned parameters. Mean camera penetration depths for the disposal site stations ranged from a relatively high value of 21.0 cm at Station 300NW to an extremely low value of 1.5 cm at Station 400S (overall average of 13.95 cm; Table 3-1). Mean camera penetration measurements ranged from 18.0 cm at Station SEREF 3 to a low penetration value of 0.1 cm at Station SREF 3, reflecting the rocky, irregular topography (overall average of 9.4 cm; Table 3-2). The very shallow penetration values were noted at several of the reference area stations due to hard bottom (rocky conditions), with no data acquired at Station SREF 1 after multiple sampling attempts.

The overall average boundary roughness value for the PDA 98 stations was 2.0 cm, suggesting a moderate amount of small-scale surface relief. Replicate-averaged boundary values ranged from 6.0 cm at Station 300NE to 0.9 cm at Station 400SE (Table 3-1). There was no obvious spatial pattern to the boundary roughness values. The surface roughness was attributed to physical disturbance at the stations within the disposal site, likely related to the presence of cohesive clay clasts or cohesive dredged material at the sediment-water interface from previous disposal operations (Figures 3-6 and 3-7A). Both oxidized and reduced mud clasts, indicative of recent physical disturbance, were detected in 23 of the 28 stations (e.g., Figure 3-6).

The overall average for the reference area boundary roughness values was 1.9 cm (Table 3-2), which was similar to the average boundary roughness value observed at the disposal site. The surface roughness at the reference areas was attributed to mounds of cohesive mud or mud clasts present at the sediment surface, possibly due to extensive burrowing or bioturbation activity by larger-bodied benthic organisms such as shrimps or lobsters (Figure 3-7B). Furthermore, small rocks and shells were detected at the sediment-water interface in numerous replicate images at the reference areas.

3.2.2 Biological Conditions and Benthic Recolonization

Three parameters were used to assess the benthic recolonization status and overall health of the benthic environment within the disposal site, relative to the three PDS reference areas. The apparent Redox Potential Discontinuity (RPD) depth, infaunal successional status, and the Organism-Sediment Index (OSI) were mapped on station location plots to outline the biological conditions at each station over the PDS 98 Mound (Figures 3-8 and 3-9).

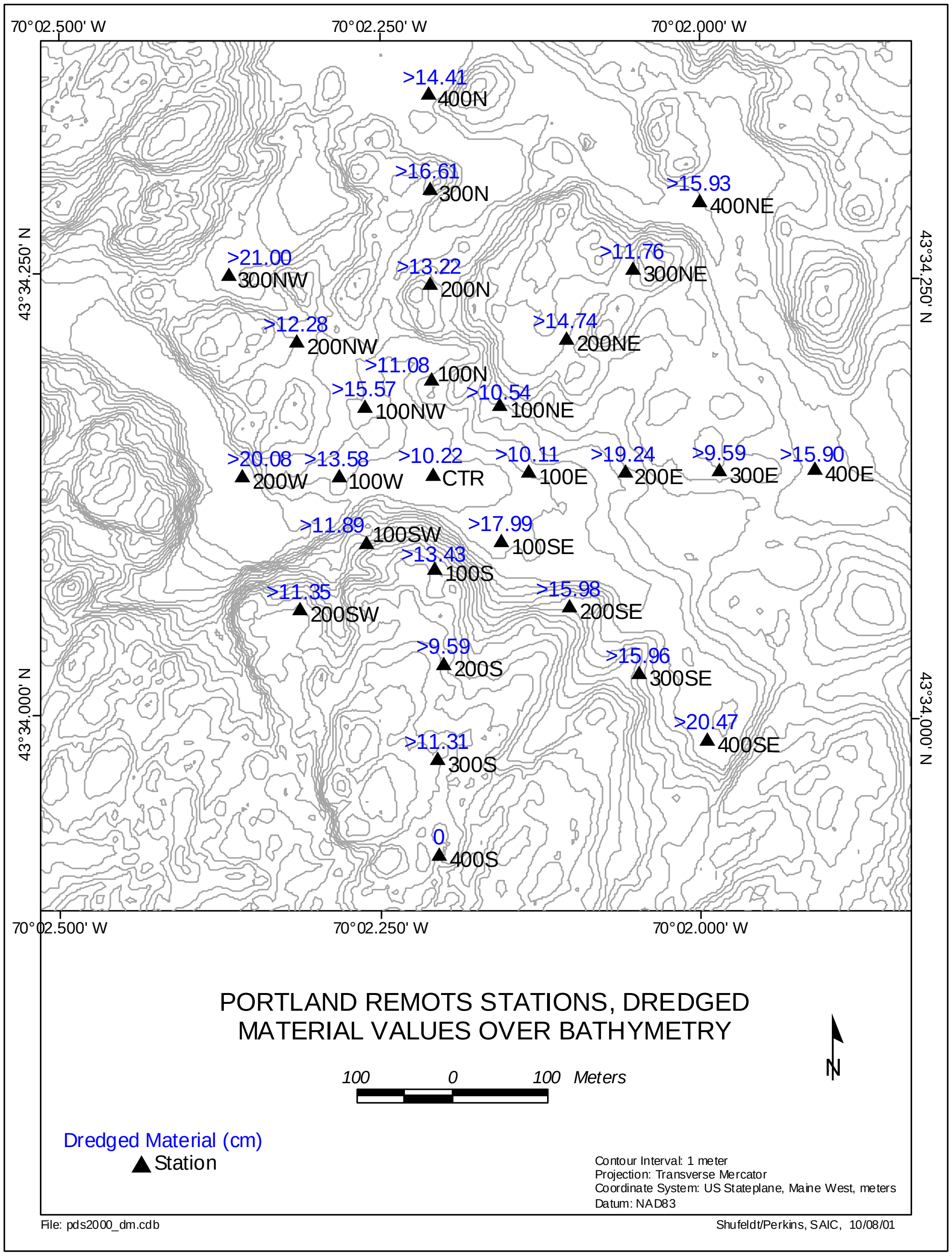


Figure 3-5. Map showing the average penetration of the camera (in centimeters) into the dredged material layer observed in replicate sediment-profile images at each station. A "greater than" sign indicates that the dredged material layer extended below the imaging depth of the sediment-profile camera.

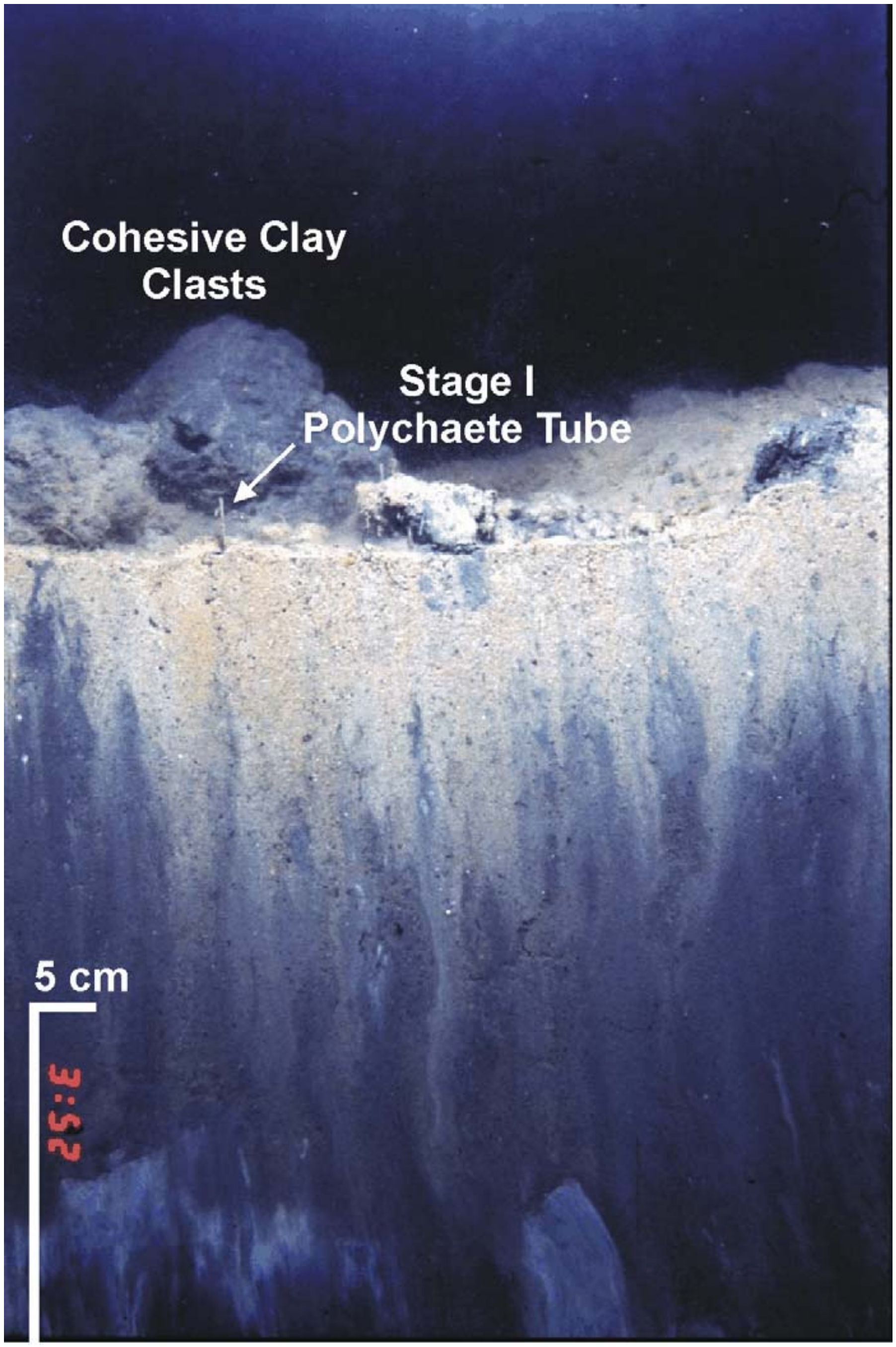
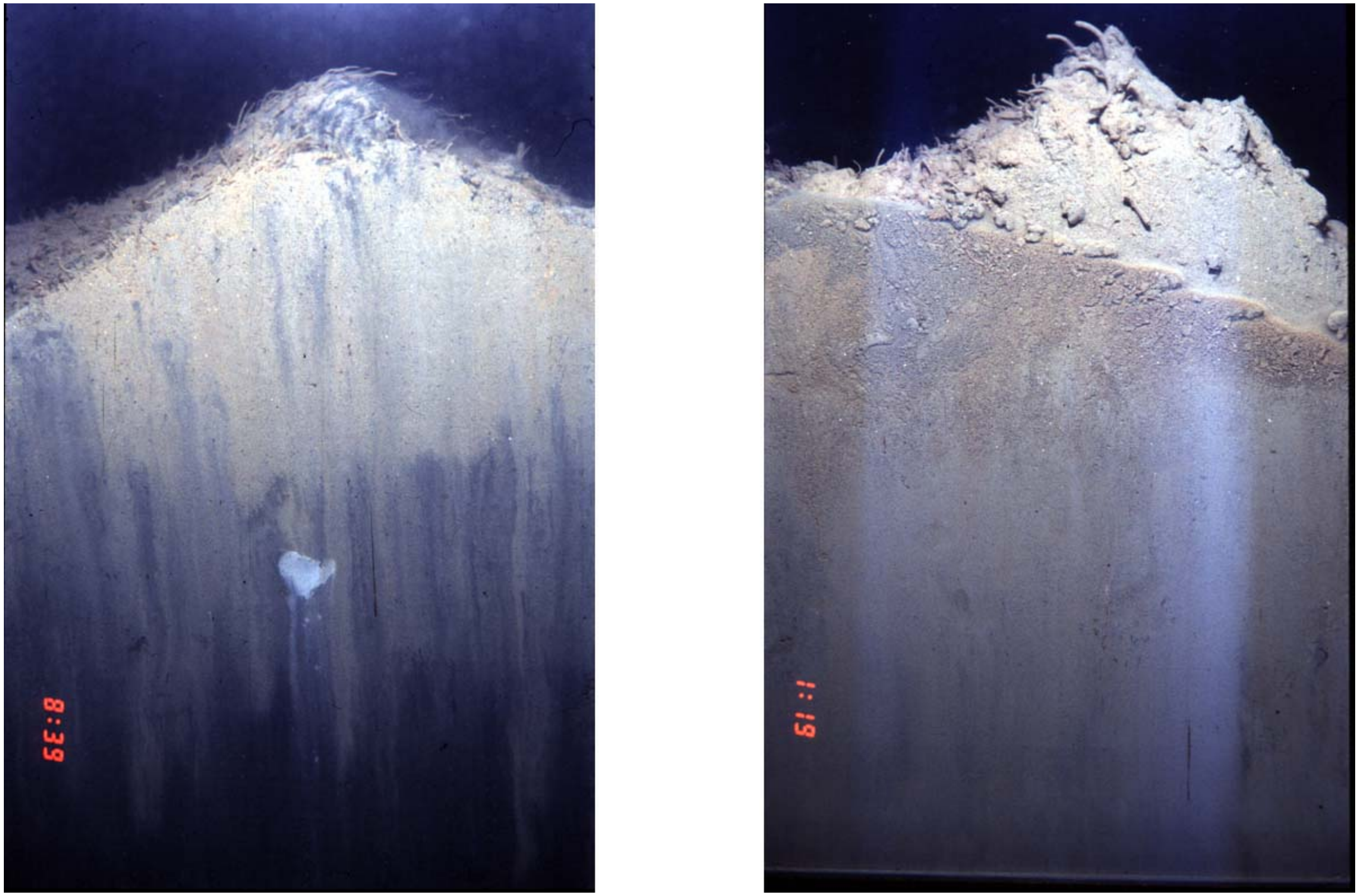


Figure 3-6. REMOTS® image from Station 400E showing predominantly fine-grained dredged material mixed with a small amount of sand extending from the sediment surface to below the imaging depth of the sediment-profile camera. Several large, cohesive clay clasts and a number of small, Stage I polychaete tubes were visible at the sediment surface.



A **B**

Figure 3-7. REMOTS® images from Station 300SE within the PDS (A) and reference area Station SE-REF 2 (B) showing irregular topography (high boundary roughness) attributed to the presence of cohesive mud at the sediment surface. Numerous small polychaete tubes (Stage I) were visible at the sediment surface in both images.

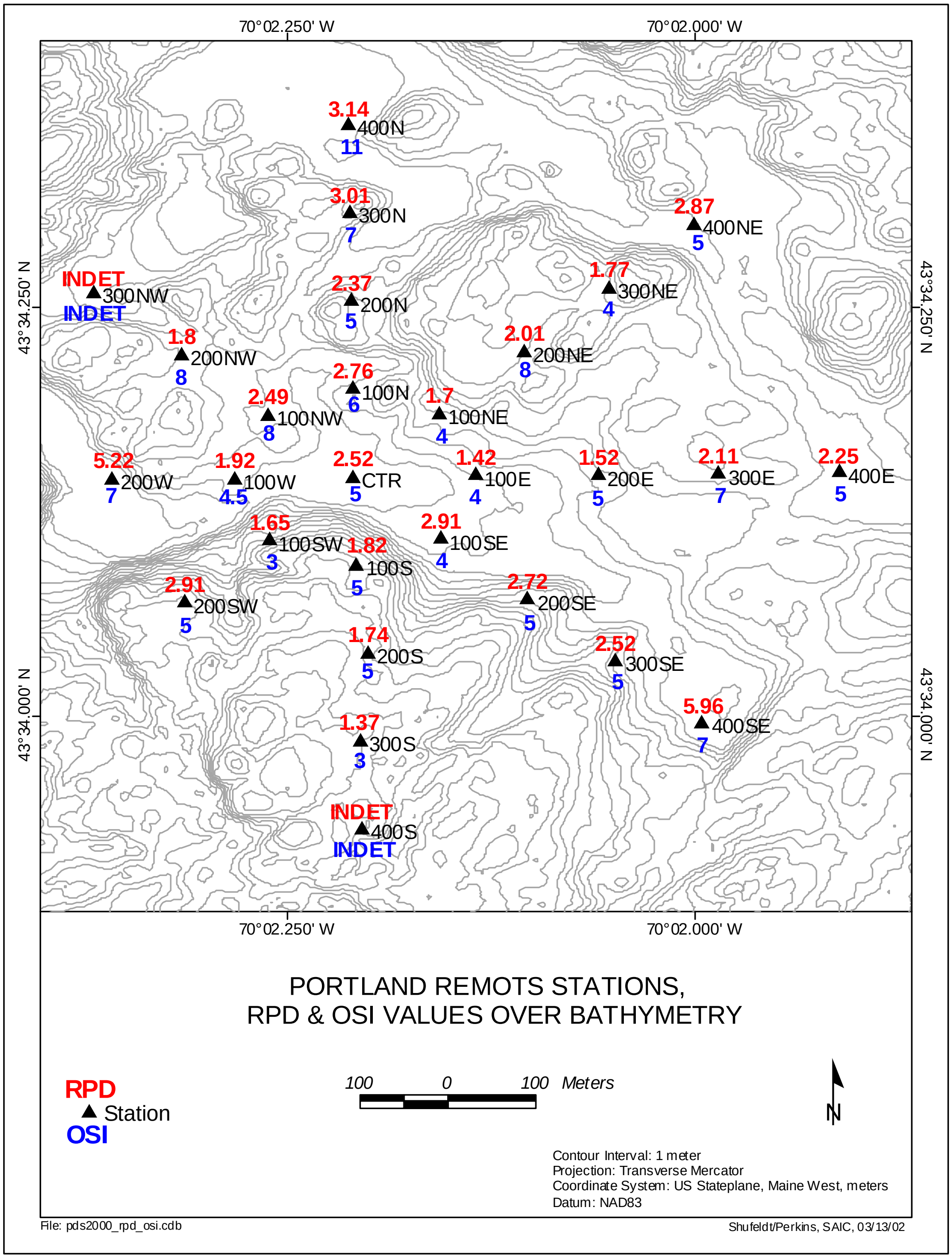


Figure 3-8. Map displaying replicate-averaged RPD and OSI values for each station occupied at the Portland Disposal Site

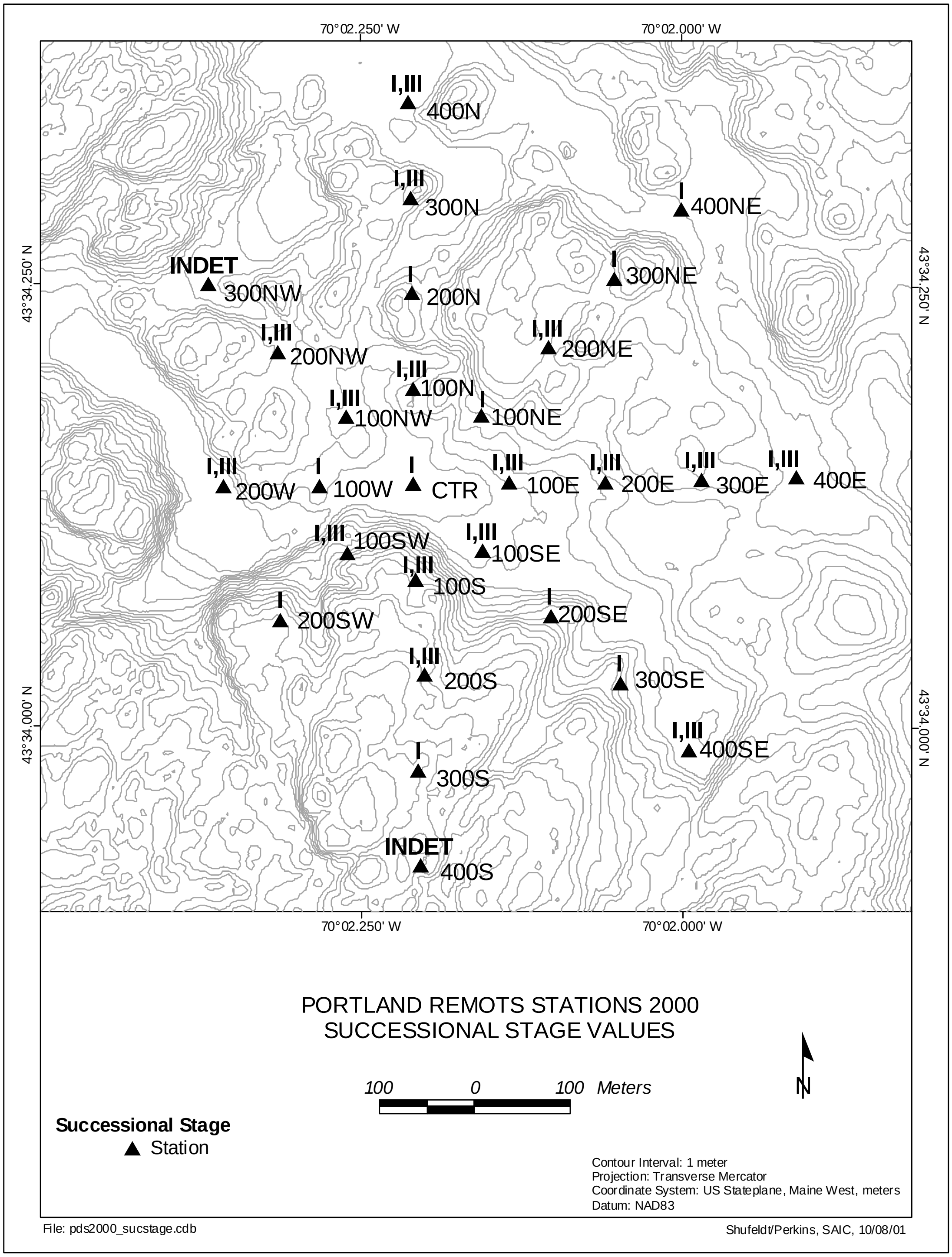


Figure 3-9. Map showing infaunal successional stages present at each station occupied over the Portland Disposal Site

The redox potential discontinuity (RPD) is measured on each image to determine the apparent depth of oxygen penetration into the surface sediment. The replicate-averaged apparent RPD measurements for the disposal site stations ranged from 1.4 cm at Station 300S to 6.0 cm at Station 400SE (Figure 3-8; Table 3-1). The overall RPD average of 2.5 cm suggests the presence of moderately to well-oxygenated surface sediments over the disposal mound. None of the stations occupied within the disposal site showed any evidence of low dissolved oxygen conditions, visible redox rebounds, or traces of methane.

The overall average RPD value for the reference area stations (3.19 cm) was higher than that observed at the disposal site stations (Table 3-2). Replicate-averaged RPD values ranged from 2.2 cm at Station EREF 1 to 5.0 cm at Station SEREF 3, with the deepest apparent RPD measurements observed at the SEREF reference area stations (Table 3-2). There was no evidence of low dissolved oxygen conditions, methane, or visible redox rebounds observed in any of the sediment-profile images from the reference areas.

The successional stage recolonization status over the recent dredged material deposits included predominantly Stage I pioneering polychaetes and Stage III head-down, deposit-feeding infauna (Table 3-1; Figure 3-9). Stage I together with Stage III individuals were noted in 16 of the 28 PDA 98 stations, while 10 stations exhibited only Stage I taxa. Stage I organisms included small, surface dwelling polychaetes, whose tubes were clearly visible at the sediment surface (e.g., Figures 3-6 and 3-7A). When present, Stage III activity was marked by active feeding voids and/or large burrows in the subsurface sediments at the disposal site stations, and was consistently accompanied by Stage I pioneering individuals at the sediment-water interface (Figure 3-10). The combination of both Stage I and Stage III at all the stations within the disposal site suggests that the benthic recolonization status of this area has proceeded as anticipated within a recent dredged material deposit.

The successional status at the reference area stations was comparable to the disposal site stations, with primarily Stage I and Stage III activity (Table 3-2). Dense polychaete tubes were observed at the sediment-water interface in the majority of the station replicates (e.g., Figure 3-7B). In addition, active feeding voids characteristic of deposit-feeding Stage III taxa were detected in 5 of the 13 reference stations. Evidence of Stage III activity was not observed in any of the replicate images at the SREF reference stations, but this result may simply reflect spatial patchiness in the distribution of these larger-bodied organisms and the relatively limited number of images (6) for which the successional stage could be determined. An additional 12 replicate images were attempted at this reference area, but the successional stage could not be determined in these due to either low penetration of the camera or poor image quality.

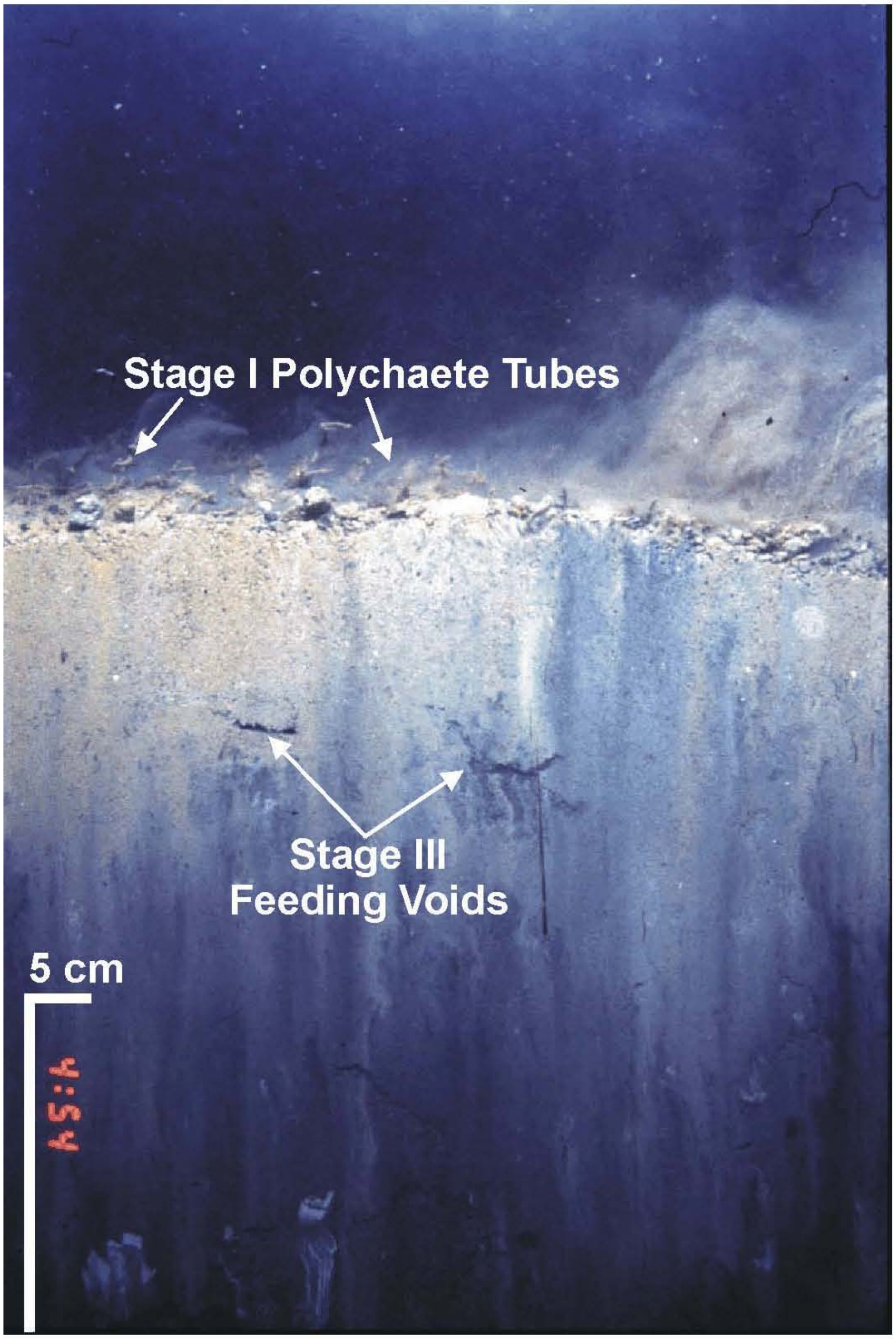


Figure 3-10. REMOTS® image of Station 100SW displaying characteristic Stage I on III activity in the dredged material deposit. Numerous small polychaete tubes were visible at the sediment surface, while two Stage III feeding voids occurred at depth.

Organism-Sediment Index (OSI) values may range from –10 (azoic with low sediment dissolved oxygen and/or presence of methane gas) to +11 (healthy, aerobic environment with deep RPD depths and high Stage III activity). Replicate-averaged median OSI values for the disposal site stations ranged from +3 at Stations 100SW and 300S to +11 at Station 400N, with an overall site average of +5.6 (Figure 3-8; Table 3-1). One of the replicate images from Station 100SE provides an example of an OSI value of +11, with an advanced Stage I on III successional status and a relatively deep RPD of 6.2 cm (Figure 3-11).

The range of OSI values within the disposal site indicated variable benthic habitat recolonization status, ranging from moderately colonized (+3) to highly colonized (+11). The low values calculated at various disposal site stations reflect relatively shallow RPD depths and lack of Stage III infauna. Stations 400SE and 200W both displayed deep RPD depths in all three replicates. However, only one replicate at each station indicated Stage III activity and therefore the overall OSI median values were lower. Station 300S indicated the lowest OSI (+3), as reflected in a shallow mean RPD depth of 1.4 cm and the absence of Stage III individuals in any replicate image (Table 3-1). OSI values for two stations (300NW and 400S) were considered indeterminate due to over- or under-penetration of the camera prism, preventing measurement of several key parameters.

The overall median OSI average value of +6.8 at the reference area stations was slightly higher than that observed at the disposal site stations (Table 3-2). Deeper mean RPD depths coupled with Stage III activity served to elevate the median OSI values to a range of +5 to +10 (Table 3-2). Reference area SE REF exhibited a more highly developed benthic environment than the other two reference stations with deeper RPD depths, Stage III activity, and consequent moderate to high median OSI values for all stations.

Overall, the OSI values at the reference stations reflected well-colonized or undisturbed conditions on the ambient seafloor surrounding PDS. The OSI values at the PDA 98 stations were slightly lower, reflecting the recent disturbance related to the placement of dredged material in preceding months. The September 2000 REMOTS® results indicated that surface sediments in the vicinity of the PDA 98 buoy had been extensively recolonized by a diverse benthic community consisting of both surface-dwelling and deeper-dwelling infauna. This community appeared to be comparable to that observed on the ambient seafloor. Slightly shallower RPD depths at the disposal mound stations probably reflect a higher inventory of organic matter associated with the dredged material and/or the less developed colonization status. It is expected that the RPD depths will gradually deepen over time as the organic matter is consumed and the dredged material continues to experience extensive bioturbation by the recolonizing benthic organisms.

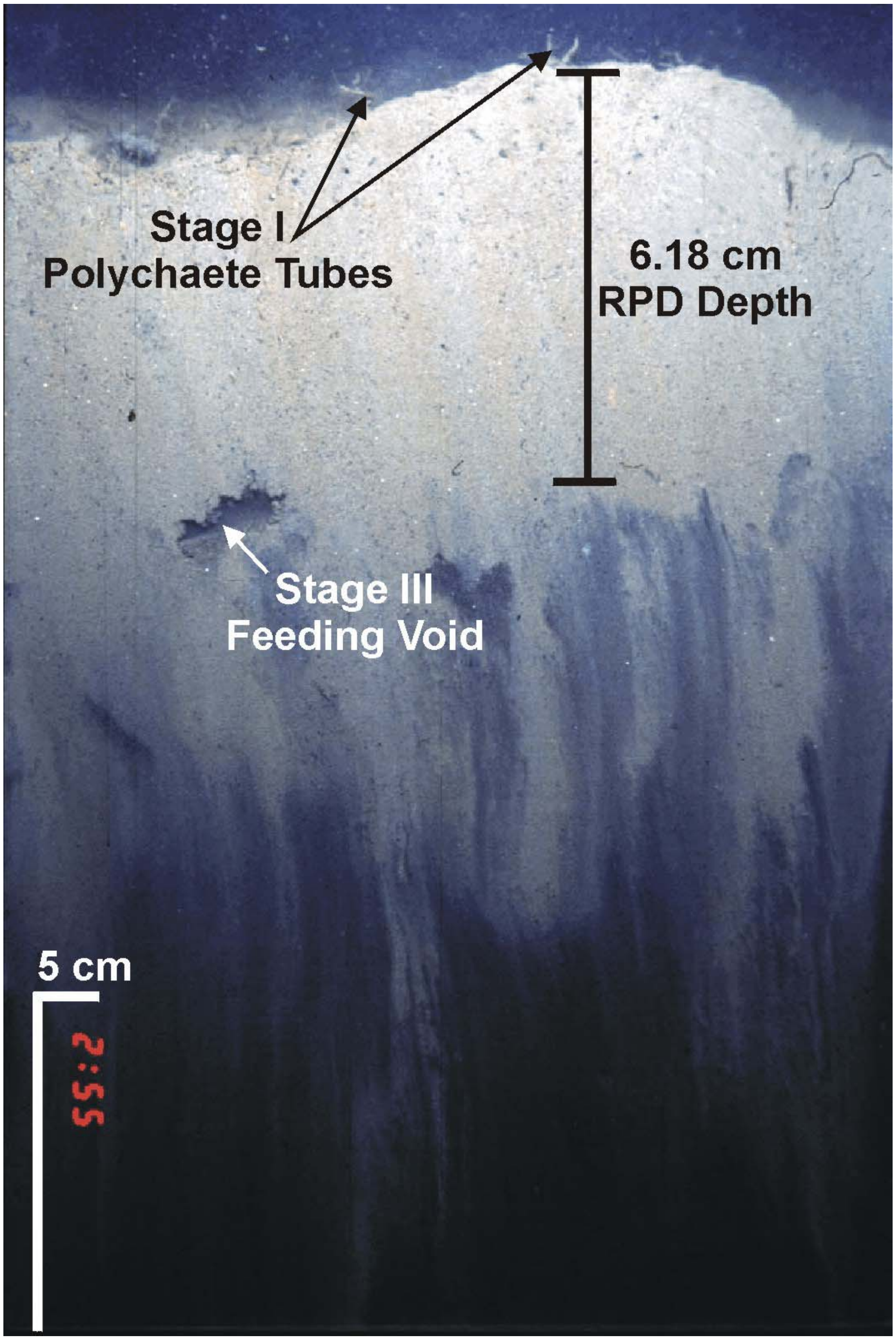


Figure 3-11. REMOTS® image from Station 100SE (replicate A) depicting features of a well-developed benthic infaunal population and deep RPD (6.18 cm) within the PDA 98 dredged material deposit. Stage I polychaetes tubes occurred at the sediment surface, and a Stage III feeding void was visible at depth. This image had an OSI value of +11 (highest possible benthic habitat quality).

4.0 DISCUSSION

4.1 Dredged Material Distribution

The Summer 2000 survey over PDS provided an opportunity to examine an area of the PDS seafloor subjected to a relatively large volume of dredged material deposition. The survey activity over the PDS was fairly unique relative to previous data collection efforts under DAMOS, as a traditional monitoring tool (REMOTS®) was utilized in conjunction with a new technology (multibeam bathymetry) to evaluate the distribution of deposited dredged material. Over the two year period between the two multibeam surveys, approximately 315,600 m^3 of material was deposited around the PDA 98 buoy, and 174,100 m^3 of material was deposited near the DG buoy.

As discussed in Section 3.1, the multibeam depth difference results indicated that most of the dredged material placed near the PDA 98 and DG buoys accumulated in the deeper areas among the bedrock outcrops, with very little apparent accumulation on top of any of the exposed bedrock surfaces. Based on the depth difference results, the morphology of the sediment deposits around both the PDA 98 and the DG buoys tended to follow the confines of the local bathymetry, with most sediment accumulating within the northwest/
southeast trending trough and the deeper areas adjacent to this trough. Around the PDA 98 buoy, it appeared that the steep bedrock outcrop that runs along the southwest side of this deeper trough had a major impact on the deposition patterns in this area. Any material associated with disposal events to the north of this wall was likely contained within the main trough by this feature. The absence of such outcrops to the east and southeast allowed a relatively thick apron of material to form around the central deposit, contributing to the overall size of the PDA 98 deposit.

Based on the disposal logs, there were numerous disposal events up to 200 m south of the PDA 98 buoy, over the top of the prominent bedrock area (Figure 4-1). These events made up a large portion of Phase I disposal during the 1998-99 dredging project, which used large scows (6,000 yd^3 capacity) to deposit 291,500 m^3 of material around the PDA 98 buoy. Though it appeared that a significant volume of the Phase I material was deposited over this bedrock feature, the apparent accumulation of material was below the 0.25 m depth difference threshold for bathymetry (Figure 4-1). Much of the unconsolidated sediment that normally would accumulate as a thick disposal mound apron has likely settled into the numerous crevices and fractures within the bedrock outcrop. As a result, this process of in-filling voids within the exposed bedrock has obscured a significant volume of material from acoustic measurement, rendering a percentage of the total sediment volume undetectable to standard depth differencing techniques.

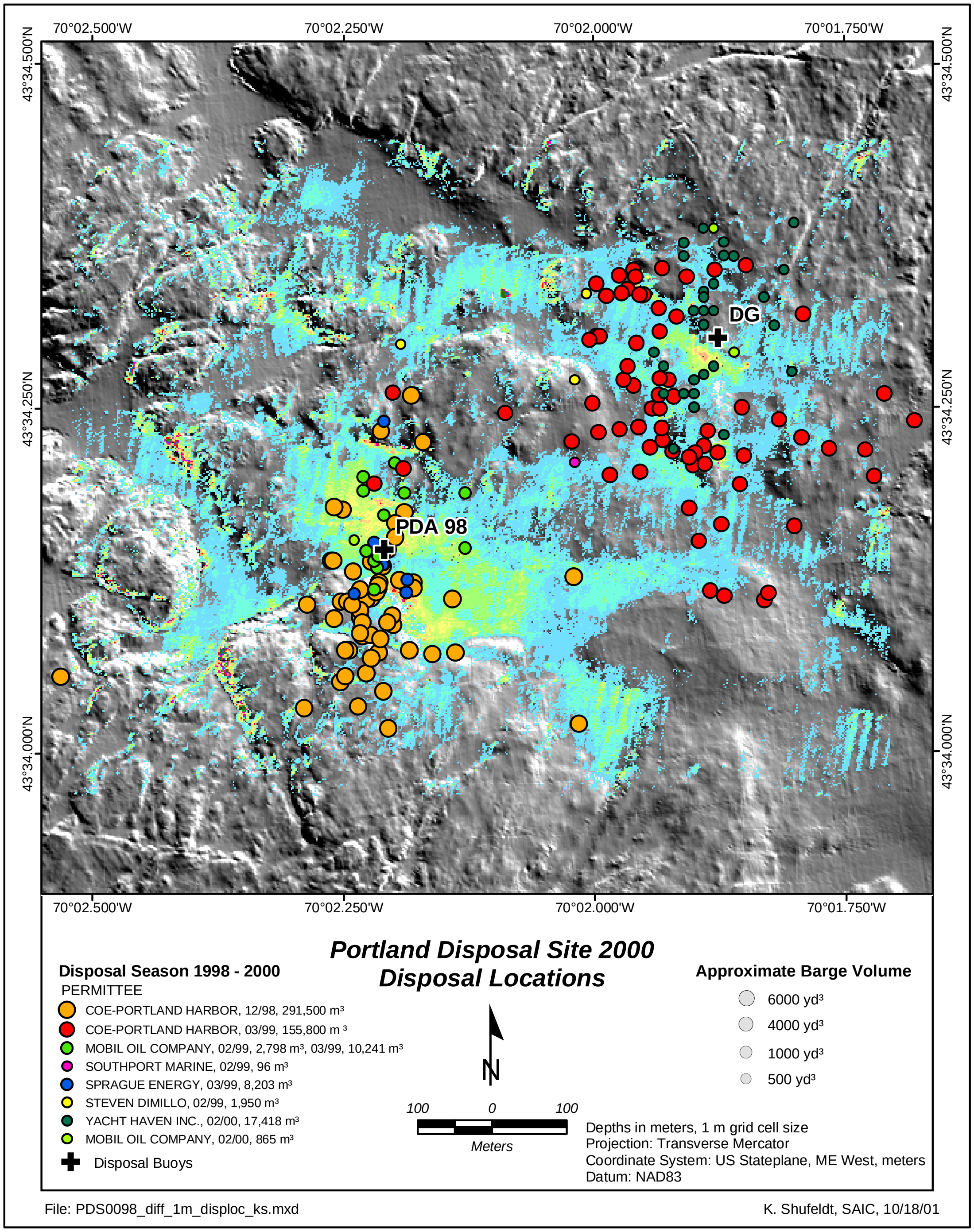


Figure 4-1. Multibeam depth difference results along with plot of barge disposal locations over the Portland Disposal Site between November 1998 and April 2000 as documented by DAMOS disposal logs

Sediment-profile imaging data confirms the presence of a thin layer of dredged material over the surface of this bedrock outcrop south of the PDA 98 buoy, as well as the area surrounding the disposal point. Soft sediment was detected at 27 of the 28 stations occupied as part of the September 2000 survey, as an apron of soft sediment extended 300 m south of the PDA 98 buoy (Figure 4-2). Furthermore, the REMOTS® dredged material extents were based on the sampling grid, and it was likely that the dredged material limits extended beyond the northern, eastern, and western arms of the sampling grid.

4.2 Biological Conditions and Benthic Recolonization

Understanding organism-sediment relationships is essential for documenting long-term change in benthic community structure. The information gained from monitoring the benthic community at dredged material disposal sites with respect to recognizing organism-sediment interactions and patterns of benthic community development is essential to evaluating benthic habitat recovery. Noticeable trends in rate of benthic community recovery can ultimately affect management decisions. Gaining insight into how organism-sediment interactions govern ecological recovery after disturbances can enable environmental managers to develop meaningful evaluations and dredged material management strategies. Oftentimes, monitoring efforts concentrate over recently formed dredged material disposal mounds on the seafloor. The DAMOS tiered monitoring protocol is the basis for this approach, calling for prompt detection and assessment of any adverse impacts on the benthic habitat based upon pre-determined management criteria (Germano et al. 1994). Depending on the situation, the lack of a satisfactory benthic community recovery over a given time frame would initiate one or more management actions, which could include additional monitoring, comprehensive testing, or remediation.

However, the results of comprehensive REMOTS® surveys at many of the regional dredged material disposal sites indicate newly deposited sediments frequently support higher population densities relative to nearby ambient sediments. The dredged material deposits are beneficial to foraging benthic invertebrates by providing a concentrated food source within a competition free space, relative to ambient material (Germano et al. 1994). As a result, dredged material placement mounds often recover at a rate that meets or exceeds expectations by displaying advanced and stable benthic infaunal populations within six months to one year of placement. Once a mound displays this stability, the area of seafloor is examined periodically to be certain no degradation of conditions occurs over the long-term.

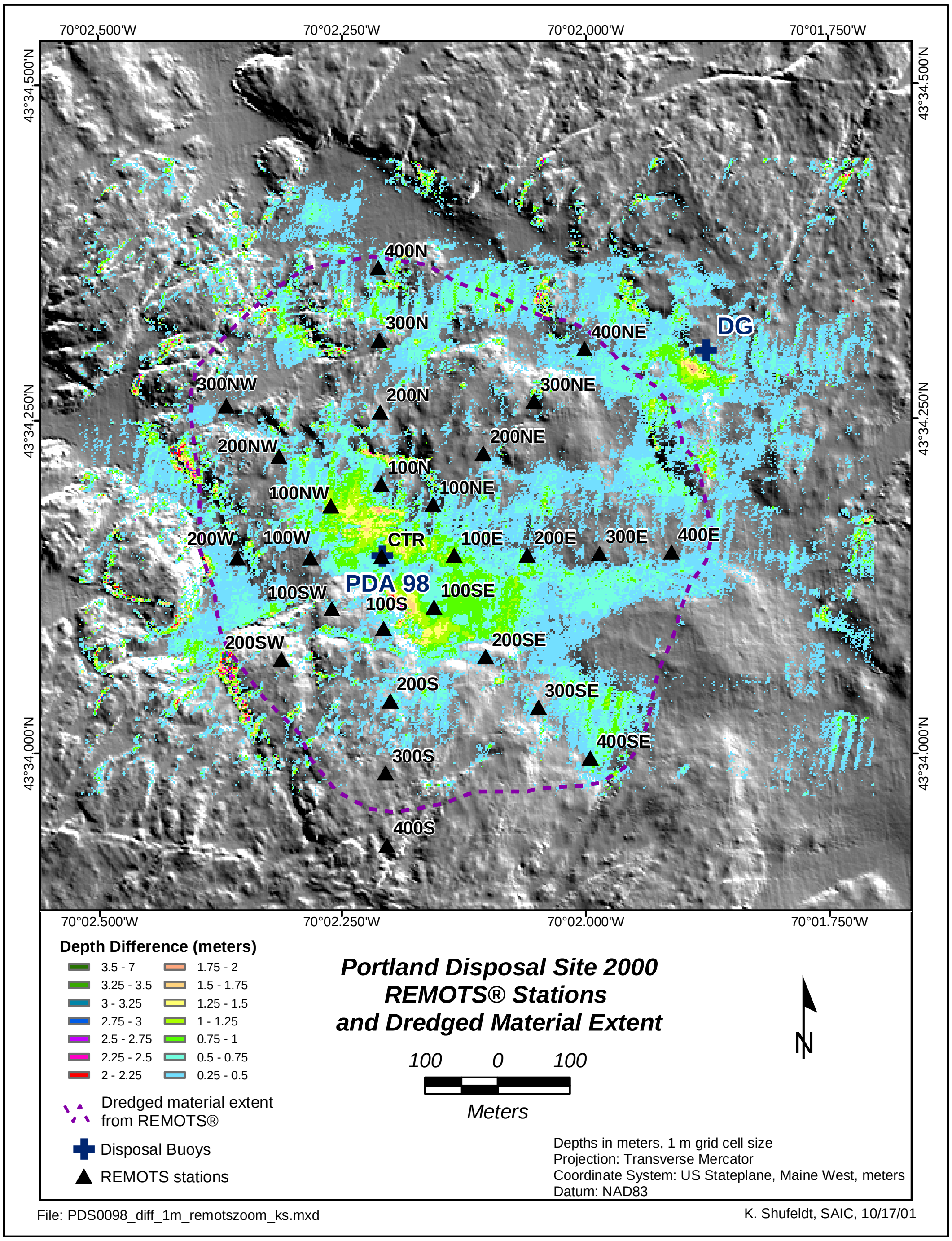


Figure 4-2. Distribution of dredged material in the vicinity of the PDA 98 and DG buoy positions as detected by multibeam depth difference calculations and REMOTS® sediment-profile imaging

The benthic infauna interact with the sediment in specific ways. These organism-sediment relationships that are associated with benthic disturbances, such as seafloor erosion and dredged material deposition, have predictable features that follow specific successional sequences. After disturbance, the infaunal community follows a progressive development from opportunistic low-order successional stages to equilibrium high-order seres (Rhoads and Germano 1986).

Functional groups of benthic organisms identified in REMOTS® images are useful as indicators for determining successional status and benthic recolonization. Immediately following a benthic disturbance, Stage I taxa populate the sediment surface. This successional stage is dominated by small tubiculous polychaetes exploiting resources at the sediment surface. Before an equilibrium system is established within the benthic environment, a transitional stage, Stage II, is often observed. This successional stage may involve the appearance of tubicolous amphipods and bivalves feeding at, or near, the sediment-water interface. As the effects of benthic disturbance subside, Stage III deeply burrowing tube-dwelling infauna ("head-down feeders") dominate the subsurface sediments (Rhoads and Germano 1986).

The September 2000 field operations over the PDA 98 mound represented the first environmental monitoring activity following the formation of this large sediment deposit. The majority of the PDA 98 Mound had been undisturbed on the PDS seafloor for a period of 18 months prior to the September 2000 monitoring event. However, the small volume of dredged material placed at the DG buoy in the winter of 2000 may have impacted the stations established on the northeast periphery of the survey grid somewhat. It was expected, based on the recolonization paradigm, that sufficient time had elapsed for initial stages of benthic recolonization to transpire resulting in the development of a stable Stage I community across the entire disposal mound with the presence of a significant number of Stage II and/or Stage III successional seres.

The September 2000 REMOTS® results indicate that surface sediments comprising the PDA 98 Mound had been recolonized by a benthic community consisting of both surface-dwelling and deeper-dwelling infauna. As anticipated, Stage I individuals were detected at all stations during the September 2000 survey. In addition, evidence of Stage III activity was detected at 15 of the 28 stations occupied over the PDA 98 Mound, and it is notable that two of the stations having Stage I only were located in the area of more recent disposal near the DG Buoy. When present, the Stage III individuals living at depth were accompanied by Stage I organisms at the sediment-water interface. The stations composing the eastern arm of the survey grid displayed consistent results, with a Stage I over Stage III successional stage status. However, the remainder of the survey grid displayed some spatial patchiness with Stage III organisms often present at one station surrounded by or adjacent to stations with only Stage I taxa. The presence of a solid Stage I community at all the stations with some advancement into a Stage III assemblage at greater than 50% of the PDA 98 stations occupied suggests benthic recolonization had proceeded as anticipated over this disposal mound.

Bioturbation within the surficial sediment layers and resulting RPD depths are related to both seasonal changes and the feeding activity of various successional stage assemblages. In general, the thickness of the apparent RPD correlates well with the depth of infaunal bioturbation and is useful in reconnaissance mapping of physical and biological disturbance gradients on the seafloor (Rhoads and Germano 1986). Low RPD values are generally associated with Stage I opportunistic tubicolous organisms, as they have minimal bioturbating effects on sediment (Probert 1984). The thickness of the RPD zone is much thinner when benthic communities are dominated by Stage I individuals because the tubiculous polychaetes feed on resources located at, or near the sediment surface, therefore bioturbation is limited to the top few centimeters of sediment.

In the absence of further disturbance, it is expected that existing low order seres (Stage I) will be displaced by Stage III equilibrium taxa (infaunal deposit feeders) and thus promote the development of deeper bioturbation zones within the sediment. The larger organisms tend to burrow deeper in the sediment column and their foraging activity introduces oxygen-rich bottom waters into the underlying sediment layers. As a result, the Stage III successional stage is normally associated with a deep layer of high-reflectance sediment composing the RPD.

The depth of sediment oxidation is also a useful indicator for assessing the health of a given seafloor environment. Although the RPD values were generally shallower in comparison to the PDS reference areas, the data obtained from the PDA 98 Mound was within expectations for a 6-18 month old sediment deposit. With an average RPD depth of 2.48 cm for the entire dredged sediment mound complex, the level of oxidation within the surface sediments appeared consistent with normal patterns of recovery.

Dredged material deposited at open water disposal sites usually contains elevated levels of organic material relative to the surrounding ambient sediments. The organics serve as a food source for benthic infauna, but are also subject to microbial and chemical oxidation. The biological and chemical (aerobic) consumption of organics increases the total sediment oxygen demand (SOD) within the dredged material. As oxygenated water is introduced into the surface sediment layers through bioturbation activity, the majority of the molecular oxygen is consumed by the benthos as part of respiration and by the chemical oxidation processes. Therefore, there is less oxygen available within the deposited sediments, which is reflected in a relatively shallow RPD.

Ambient sediments on the continental shelf are usually not subject to excess organic loading, and they typically have a lower inventory of organic matter and lower SOD. Therefore, the resident benthic infauna must increase the amount of bioturbation and process more sediment to obtain sufficient amounts of organic material. The increased foraging activity and low SOD promotes the development of a deep RPD within the surface sediments that is typically detected in REMOTS® photographs. However, competition for the limited amount of food may constrain population densities in ambient sediments, relative to dredged material deposits.

The multi-parameter OSI calculation provides a measure of overall benthic habitat quality. In general, the stations occupied over the PDA 98 mound showed variability, with OSI values ranging from moderate (+3) to high (+11). There were no strong spatial patterns to the distribution of median OSI values over the disposal mound, as nine of the 26 stations yielding data (35%) displayed OSI values ≥+6, indicating the presence of a relatively undisturbed benthic environment. In addition, ten of the PDA 98 REMOTS® stations (38%) showed median OSI values of +5, which is comparable to the data obtained from the reference areas. The OSI values that were calculated for the remaining stations (27%) fell below +5, indicating less benthic recovery over portions of the disposal mound, as expected. The low OSI values calculated at the seven of the 26 stations yielding data reflect relatively shallow RPD depths (<2 cm), and lack of apparent Stage III activity. These observed conditions are likely attributed to simple spatial variability in the distribution of Stage III organisms over the recent dredged material deposit.

Overall, the OSI values calculated for the PDA 98 Mound were, as expected, somewhat lower than those observed at the reference area stations (median OSI +6.75 reference area versus +5.6 disposal site). Although still recovering from the seafloor disturbance, the benthic community appeared to be comparable to the ambient seafloor. There were no significant trends observed at either the PDA 98 Mound or the PDS reference areas that would suggest that a change in management strategy is required. Further monitoring over PDA 98 would be beneficial to confirm continued recovery of the disposal mound. It is expected that the RPD depths will gradually deepen over time as the organic matter is consumed by a growing population of Stage III organisms colonizing the dredged material.

4.3 PDS Reference Areas

Reference areas are occupied as part of each benthic community assessment survey performed over a disposal mound to provide insight into the conditions within ambient sediments surrounding the site. This information serves as a baseline to which disposal mound data are compared in part to prevent the impacts associated with regional conditions or large-scale disturbance from affecting interpretation of the disposal mound data. The designated reference areas around PDS (EREF, SEREF, and SREF) have remained constant and are useful for documenting and monitoring benthic conditions in the Casco Bay and Bigelow Bight region. The reference areas have been periodically monitored over the past 11 years and continue to show a favorable benthic environment with mean OSI values ≥+6, indicating a healthy benthic environment. No evidence of widespread disturbance associated with naturally occurring events (i.e., storm waves or bottom currents) or anthropogenic activity (i.e., fishing or dredged material deposition) was identified.

Although there was not an abundance of REMOTS® data available from the 1989 and 1992 surveys at the PDS reference areas because of rocky bottom conditions, it appeared that ecological trends exist both spatially and temporally. The most significant difference observed in the REMOTS® results between the past surveys and the summer 2000 survey was a slight decline in benthic habitat conditions as defined by OSI (Table 4-1). With an overall average OSI of +6.7 during the September 2000 survey, it appears the lower occurrence of Stage III organisms in the replicate images relative to previous years may be the basis for the decline.

The 1989 and 1992 monitoring surveys at PDS indicated comparable mean RPD depths to the 2000 survey (3.2 cm) at the reference areas with measurements of 3.6 cm and 3.0 cm respectively (Table 4-1; Appendix E). In 1989 and 1992, Stage III taxa dominated the sediment within all three reference areas (SAIC 1990, Wiley 1996). These high-order seres together with moderately deep RPD depths resulted in correspondingly high mean OSI values of +9.8 and +8.4 for the 1989 and 1992 surveys, respectively. Based on the lack of dramatic change in RPD depth values over the course of several years, a reasonable assumption can be made that bioturbation rates and associated organism-sediment relationships have been fully established and remained fairly constant in the relatively undisturbed ambient benthic environment. As a result, the differences detected between surveys could be based on the frequency at which Stage III activity was detected by the random sampling pattern over the fairly hard substrate at two of the three reference areas. The trends observed in the comparisons between the 1989, 1992, and 2000 surveys may represent a skewing in the data sets rather than any significant change in the benthic conditions at the reference areas.

The 2000 survey showed a considerable decline in Stage III activity, especially at the stations occupied in SREF. The seafloor within SREF is particularly rocky, with difficulties in data collection well documented in both the 1992 and 2000 surveys. Conditions observed at SREF in 1992 and 2000 could be the product of a thin layer of soft sediment overlying bedrock, as indicated by the reduced camera penetration at these stations (Table 4-1). The scarcity of Stage III infauna in rocky substrates is expected

Table 4-1.

Summary of REMOTS® Results for the Stations Occupied over the PDS Reference Areas 1989 through 2000.

Reference Area	Camera Penetration Mean (cm)	RPD Mean (cm)	Successional Stages Present	Highest Stage Present	Grain Size Major Mode (phi)	Methane Present	OSI Mean	OSI Median	Boundary Roughness Mean (cm)
EAST REF AVG									
1989	5.96	3.79	I,III	ST_I_ON_III	>4	NO	10.5	10.5	1.10
1992	7.22	2.59	I,III	ST_III	>4	NO	8.7	8.7	1.41
2000	9.73	2.87	I,III	ST_I_ON_III	>4	NO	6.04	6.12	2.46
SOUTH REF AVG									
1989	5.37	2.83	I,III	ST_I_ON_III	>4	NO	9.2	9.2	1.0
1992	8.22	1.81	I,III	ST_I_ON_III	>4	NO	6.2	6.2	1.01
2000	4.82	2.86	I	ST_I	>4	NO	5.25	5.25	1.13
SOUTHEAST REF AVG									
1989	11.28	3.81	I,III	ST_III	>4	NO	9.6	9.6	0.89
1992	14.11	3.75	I,III	ST_III	>4	NO	9.8	9.8	0.99
2000	13.53	3.68	I,III	ST_I_ON_III	>4	NO	8.1	8.1	1.97
1989									
AVG	8.5	3.6	I,III	ST_I_ON_III		NO	9.8	9.8	0.97
MAX	15.82	5.77		ST_III	4 TO 3		11	11	2.66
MIN	2.55	2.1		ST_I	>4		6	6	0
1992									
AVG	10.97	2.96	I,III	ST_I_ON_III	>4	NO	8.4	8.4	1.08
MAX	18.79	5.53		ST_III	3 TO 4		11	11	2.09
MIN	2.56	1.38		ST_I	>4		3	3	0.44
2000									
AVG	9.36	3.19	I,III	ST_I	>4	NO	6.7	6.8	1.85
MAX	17.95	5.02		ST_I_ON_III	>4		10	10	3.56
MIN	0.06	2.21		ST_I	>4		5	5	0

because of the limitations on burrowing capabilities and organic content of the ambient sediments. The rocky bottom serves as a barrier, limiting the lateral and downward movement of adult Stage III individuals. In general, the presence of Stage I taxa and the relative lack of Stage III activity detected at SREF during the 2000 and 1992 surveys (1989 survey lacked sufficient data needed for comparisons) may reflect a less favorable benthic environment for indicator species at SREF, relative to the other reference areas.

Over the years (from 1989 to 2000), reference area SEREF has continued to indicate a more well-developed benthic infauna compared to surrounding reference areas, having deeper RPD depths, dominance of Stage III taxa and subsequent greater OSI values (+6.3 to +10). The seafloor conditions at SEREF are significantly different in comparison to SREF, with a thick ambient sediment column and reduced presence of rocky substrate (Figure 4-3). The abundance of soft sediment at SEREF is ideal for the development and maintenance of a stable benthic infaunal community. EREF appears to display characteristics of both SEREF and SREF, with areas of hard substrate present at the sediment-water interface, but also offering large pockets of soft sediment within the 300 m sampling radius. The average OSI values for the three surveys performed at EREF over the past 11 years reflect this finding, with average OSI values ranging from +6.1 to +10.5.

It is anticipated that the rocky substrate encountered during the September 2000 survey and previous field data collection efforts will likely continue to pose complications with respect to camera penetration and analysis of key ecological parameters, particularly at SREF. During future survey efforts over the PDS reference areas, it may be advisable to establish target stations over known areas of soft sediment accumulation based on previous REMOTS® data rather than randomly select stations within the 300 m sampling radius. By revisiting a set of constant, pre-determined stations as part of subsequent survey efforts, development of skewed data sets can be prevented and stronger comparisons can be made with historic data.

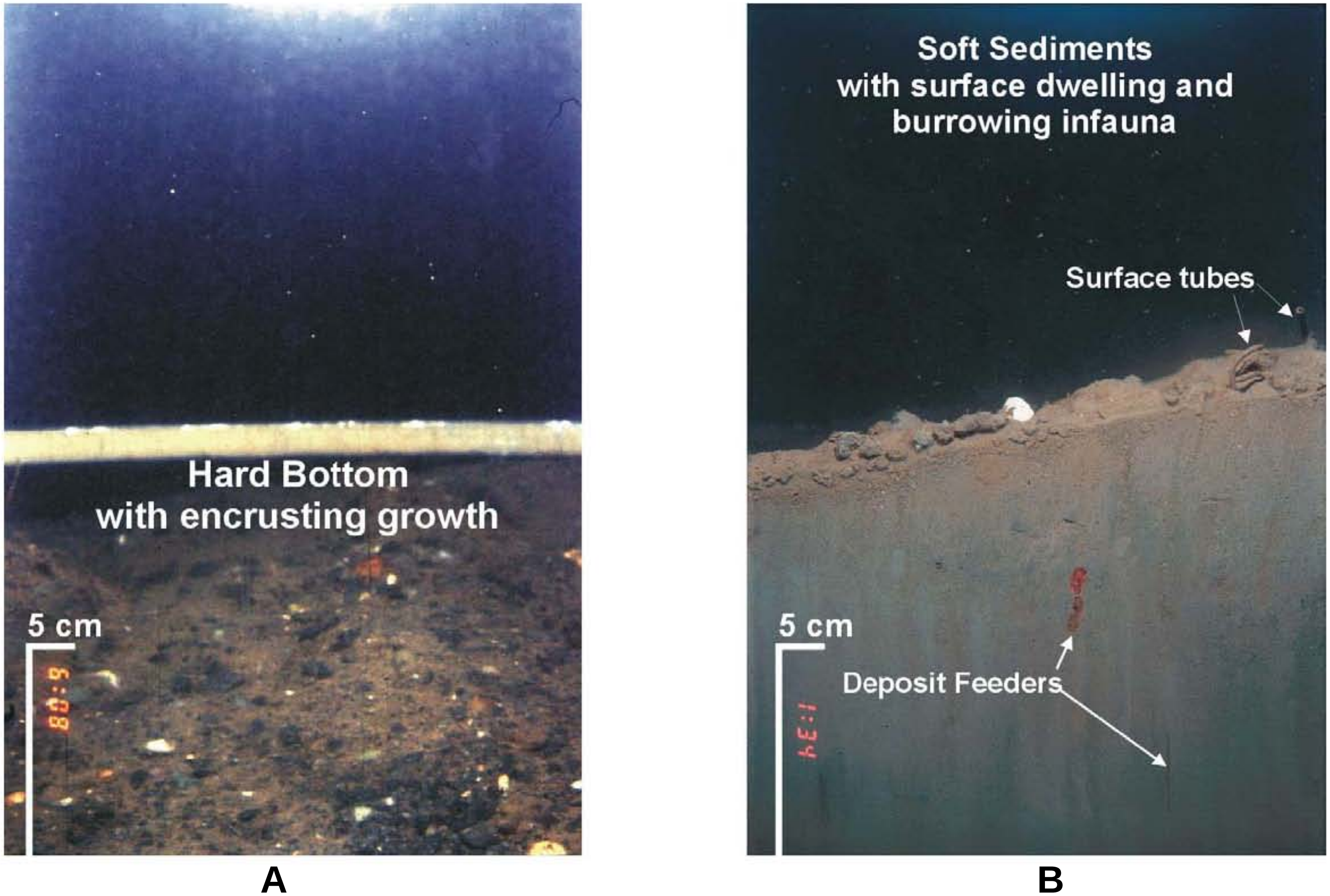


Figure 4-3. REMOTS® images collected from SREF (A) and SEREF (B) showing the differences in composition of the seafloor causing differences in benthic community structure and stability over time

numerous crevices and fractures within the bedrock outcrop, leaving a percentage of the total sediment volume undetectable by bathymetry.

- Overall, the benthic habitat around the PDA 98 deposit appeared to be recovering as anticipated, with OSI values ranging from +3 to +11. At 18 months post disposal, the sediment deposit was supporting an abundant Stage I population, with advancement into Stage III at nearly 60% of the stations yielding data. Benthic community conditions at the PDA 98 Mound (as reflected in OSI values) was slightly lower but comparable to that at the surrounding reference areas.

- Benthic recolonization at the PDA 98 Mound is expected to continue to recover over the next several years, as the Stage III activity becomes more widespread and RPD depths deepen due to increased bioturbation and oxidation of organic material contained within the deposited sediments.

- Comparisons of sediment-profile camera data acquired from the PDS reference areas show an apparent trend of declining OSI values over the course of 11 years (1989 to 2000), particularly at SREF and EREF. However, this trend is likely the product of skewed datasets collected over areas with an abundance of hard seafloor that limits camera penetration. A modification in the method used to establish sampling stations over these reference areas may provide better characterization of the ambient soft-bottom benthic community.

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Appendix A
1998-2000 Disposal Logs

Appendix A1, Disposal Logs

1998 **PDS**

Project: PORTLAND HARBOR MAINE

Permit 1998C0018 **Permittee** COE-PORTLAND HARBOR

Buoy	Departur	Disposal	Return	Latitude	Longitud	Buoy's		Volume
PDA98	11/17/1998	11/17/1998	11/17/1998	43.5687	-70.03645	100'	SW	6133
PDA98	11/17/1998	11/17/1998	11/17/1998	43.570983	-70.036366	100'	W	6000
PDA98	11/18/1998	11/18/1998	11/18/1998	43.569116	-70.03675	100'	E	6000
PDA98	11/18/1998	11/18/1998	11/18/1998	43.5696	-70.0375	100'	E	6000
PDA98	11/19/1998	11/19/1998	11/19/1998	43.570416	-70.036166	65'	W	5600
PDA98	11/19/1998	11/19/1998	11/19/1998	43.568283	-70.03765	100'	W	6500
PDA98	11/19/1998	11/19/1998	11/19/1998	43.568533	-70.037033	80'	W	6000
PDA98	11/19/1998	11/19/1998	11/19/1998	43.568066	-70.037183	100'	E	6000
PDA98	11/20/1998	11/20/1998	11/20/1998	43.568716	-70.036333	100'	W	6500
PDA98	11/20/1998	11/20/1998	11/20/1998	43.567583	-70.0422	50'	W	6000
PDA98	11/21/1998	11/21/1998	11/21/1998	43.58125	-70.036866	75'	W	5800
PDA98	11/21/1998	11/21/1998	11/21/1998	43.569566	-70.036483	60'	E	6000
PDA98	11/22/1998	11/22/1998	11/22/1998	43.567516	-70.03755	80'	E	5800
PDA98	11/22/1998	11/22/1998	11/22/1998	43.569433	-70.036633	40'	E	6100
PDA98	11/22/1998	11/22/1998	11/22/1998	43.57055	-70.036866	60'	W	5800
PDA98	11/23/1998	11/23/1998	11/23/1998	43.581266	-70.03685	85'	W	5600
PDA98	11/23/1998	11/23/1998	11/23/1998	43.56885	-70.037333	85'	W	6100
PDA98	11/25/1998	11/25/1998	11/25/1998	43.5679	-70.0374	90'	W	6000
PDA98	11/25/1998	11/25/1998	11/25/1998	43.568516	-70.037116	90'	W	5600
PDA98	11/25/1998	11/25/1998	11/25/1998	43.56875	-70.036566	90'	W	6000
PDA98	11/26/1998	11/26/1998	11/26/1998	43.568983	-70.0377	100'	W	5900
PDA98	11/27/1998	11/27/1998	11/27/1998	43.568983	-70.037666	90'	W	6100
PDA98	11/28/1998	11/28/1998	11/28/1998	43.56695	-70.03675	90'	W	6100
PDA98	11/28/1998	11/28/1998	11/28/1998	43.568483	-70.037533	50'	W	6000
PDA98	11/29/1998	11/29/1998	11/29/1998	43.568383	-70.037216	60'	W	6000
PDA98	11/29/1998	11/29/1998	11/29/1998	43.5683	-70.037216	60'	W	6200
PDA98	11/30/1998	11/30/1998	11/30/1998	43.568083	-70.03705	60'	W	6100
PDA98	11/30/1998	11/30/1998	11/30/1998	43.568383	-70.037216	70'	W	6500
DG	12/2/1998	12/2/1998	12/2/1998	43.567866	-70.035633	100'	W	6000
PDA98	12/2/1998	12/2/1998	12/2/1998	43.568916	-70.036833	50'	W	6300
DG	12/3/1998	12/3/1998	12/3/1998	43.568516	-70.035683	100'	W	6000
PDA98	12/3/1998	12/3/1998	12/3/1998	43.568233	-70.037183	90'	W	6000
PDA98	12/3/1998	12/3/1998		43.569116	-70.036916			6000
PDA98	12/4/1998	12/4/1998	12/4/1998	43.567616	-70.037116	80'	W	6000
PDA98	12/4/1998	12/4/1998	12/4/1998	43.5679	-70.037466	80'	W	6000
PDA98	12/5/1998	12/5/1998	12/5/1998	43.56785	-70.036016	80'	W	6000
PDA98	12/5/1998	12/5/1998	12/6/1998	43.568483	-70.037433	70'	W	6000
PDA98	12/6/1998	12/6/1998	12/6/1998	43.568966	-70.037033	80'	W	6000
PDA98	12/6/1998	12/6/1998	12/6/1998	43.56865	-70.036333	60'	W	6000
PDA98	12/6/1998	12/6/1998	12/6/1998	43.569066	-70.03685	60'	W	6000
PDA98	12/7/1998	12/7/1998	12/7/1998	43.56845	-70.0381	60'	W	5500
PDA98	12/7/1998	12/7/1998	12/7/1998	43.569266	-70.036633	50'	W	5500

Project: PORTLAND HARBOR MAINE
Permit 1998C0018 **Permittee** COE-PORTLAND HARBOR

Buoy	Departur	Disposal	Return	Latitude	Longitud	Buoy's		Volume
DG	12/7/1998	12/7/1998	12/7/1998	43.567	-70.033583	80'	W	6000
PDA98	12/8/1998	12/8/1998	12/8/1998	43.5682	-70.036666	100'	W	6000
PDA98	12/8/1998	12/8/1998	12/8/1998	43.5679	-70.0364	90'	W	5500
PDA98	12/8/1998	12/8/1998	12/8/1998	43.567866	-70.036916	100'	W	5500
PDA98	12/9/1998	12/9/1998	12/9/1998	43.568316	-70.036683	75'	W	5800
DG	12/9/1998	12/9/1998	12/9/1998	43.568783	-70.033666	100'	W	5800
PDA98	12/9/1998	12/9/1998	12/10/1998	43.5672	-70.03815	60'	W	5500
PDA98	12/10/1998	12/10/1998	12/10/1998	43.5678	-70.037033	100'	W	5900
PDA98	12/10/1998	12/10/1998	12/10/1998	43.568233	-70.036766	100'	W	6250
PDA98	12/11/1998	12/11/1998	12/11/1998	43.568033	-70.036883	80'	W	5800
PDA98	12/11/1998	12/11/1998	12/11/1998	43.56845	-70.03735	80'	W	6300
PDA98	12/12/1998	12/12/1998	12/12/1998	43.56865	-70.036916	80'	W	6000
PDA98	12/12/1998	12/12/1998	12/12/1998	43.567216	-70.03725	100'	W	6200
PDA98	12/13/1998	12/13/1998	12/13/1998	43.568716	-70.0369	100'	W	5500
PDA98	12/13/1998	12/13/1998	12/13/1998	43.568666	-70.036916	40'	W	6100
PDA98	12/14/1998	12/14/1998	12/14/1998	43.5686	-70.03695	60'	W	5600
PDA98	12/14/1998	12/14/1998	12/14/1998	43.569633	-70.03765	80'	W	6100
PDA98	12/15/1998	12/15/1998	12/15/1998	43.568683	-70.036916	80'	W	6000
PDA98	12/15/1998	12/15/1998	12/15/1998	43.5674	-70.036833	100'	W	6100
PDA98	12/15/1998	12/15/1998	12/15/1998	43.567583	-70.037466	100'	W	5800
PDA98	12/16/1998	12/16/1998	12/16/1998	43.5681	-70.037216	100'	W	6200
PDA98	12/16/1998	12/16/1998	12/16/1998	43.568633	-70.037216	80'	W	5600

Project Total Volume: 291,529 CM 381,283 CY
Report Total Volume: 291,529 CM 381,283 CY

Appendix A2, Disposal Logs

1999 **PDS**

Project: LONG WHARF, FORE RIVER
Permit 199402879 **Permittee** SOUTHPORT MARINE

Buoy	Departur	Disposal	Return	Latitude	Longitud	Buoy's	Volume
DG	2/19/1999	2/19/1999	2/19/1999	43.570166	-70.03365	60' W	125
				Project Total Volume:		**96 CM**	**125 CY**

Project: LONG WHARF, FORE RIVER
Permit 199702334 **Permittee** STEVEN DIMILLO

Buoy	Departur	Disposal	Return	Latitude	Longitud	Buoy's	Volume
PDA98	1/20/1999	1/20/1999	1/20/1999	43.569116	-70.036816	60' W	725
DG	1/25/1999	1/25/1999	1/25/1999	43.572216	-70.03345	60' E	700
PDA98	2/2/1999	2/2/1999	2/2/1999	43.5716	-70.036533	60' W	750
DG	2/19/1999	2/19/1999	2/19/1999	43.571166	-70.03365	60' W	375
				Project Total Volume:		**1,950 CM**	**2,550 CY**

Project: FORE RIVER
Permit 199800133 **Permittee** SPRAGUE ENERGY

Buoy	Departur	Disposal	Return	Latitude	Longitud	Buoy's	Volume
PDA98	3/2/1999	3/2/1999	3/2/1999	43.568983	-70.036983	75' N	1100
PDA98	3/3/1999	3/3/1999	3/3/1999	43.5692	-70.036983	100' W	1305
PDA98	3/5/1999	3/5/1999	3/5/1999	43.568933	-70.036816	50' NE	1566
PDA98	3/12/1999	3/12/1999	3/12/1999	43.568933	-70.036833	100' E	1355
PDA98	3/17/1999	3/17/1999	3/17/1999	43.570666	-70.036816	100' SE	1355
PDA98	3/19/1999	3/19/1999	3/19/1999	43.5686	-70.03645	100' S	1316
PDA98	3/20/1999	3/20/1999	3/20/1999	43.56875	-70.036433	10' N	1166
PDA98	4/13/1999	4/13/1999	4/13/1999	43.568583	-70.037316	100' SW	1566
				Project Total Volume:		**8,203 CM**	**10,729 CY**

Project: FORE RIVER
Permit 199803142 **Permittee** MOBIL OIL COMPANY

Buoy	Departur	Disposal	Return	Latitude	Longitud	Buoy's	Volume
PDA98	2/24/1999	2/24/1999	2/24/1999	43.5689	-70.036933	100' S	1305
PDA98	2/24/1999	2/24/1999	2/25/1999	43.570166	-70.036633	50' N	1050
PDA98	2/27/1999	2/27/1999	2/27/1999	43.5689	-70.036933	100' S	1305
PDA98	3/2/1999	3/2/1999	3/2/1999	43.568983	-70.036983	75' N	500
PDA98	3/8/1999	3/8/1999	3/8/1999	43.569833	-70.037166	50' SE	1504
PDA98	3/9/1999	3/9/1999	3/9/1999	43.57	-70.037166	50' S	1566
PDA98	3/10/1999	3/10/1999	3/10/1999	43.5691	-70.037116	50' W	1566
DG	3/14/1999	3/14/1999	3/14/1999	43.569133	-70.035466	100' E	1566
DG	3/17/1999	3/17/1999	3/17/1999	43.5698	-70.035466	50' E	1516
PDA98	3/24/1999	3/24/1999	3/24/1999	43.569533	-70.036816	50' W	1266
PDA98	3/24/1999	3/24/1999	3/24/1999	43.5698	-70.036483	50' N	1366
PDA98	3/25/1999	3/25/1999	3/25/1999	43.568633	-70.036983	75' SW	1500
PDA98	3/31/1999	3/31/1999	3/31/1999	43.569033	-70.036916	100' SW	1044
				Project Total Volume:		**13,039 CM**	**17,054 CY**

Project: PORTLAND HARBOR MAINE
Permit 1998C0018 **Permittee** COE-PORTLAND HARBOR

Buoy	Departur	Disposal	Return	Latitude	Longitud	Buoy's		Volume
DG	3/6/1999	3/6/1999	3/6/1999	43.570533	-70.03325	60'	W	3200
PDA98	3/6/1999	3/7/1999	3/7/1999	43.5701	-70.0365	80'	E	3600
DG	3/8/1999	3/8/1999	3/8/1999	43.570333	-70.029416	100'	W	2800
DG	3/9/1999	3/9/1999	3/9/1999	43.568483	-70.024316	100'	E	2500
DG	3/9/1999	3/9/1999	3/10/1999	43.5685	-70.0305	80'	E	1622
DG	3/10/1999	3/10/1999	3/10/1999	43.570666	-70.028	70	SE	3050
DG	3/10/1999	3/10/1999	3/10/1999	43.57055	-70.031433	80'	E	1200
DG	3/10/1999	3/10/1999	3/10/1999	43.570816	-70.032366	80'	E	1933
DG	3/10/1999	3/10/1999	3/11/1999	43.570466	-70.029883	100'	SE	3050
DG	3/11/1999	3/11/1999	3/11/1999	43.570366	-70.0315	80'	SE	2900
DG	3/11/1999	3/11/1999	3/11/1999	43.5694	-70.03	90'	W	2360
DG	3/12/1999	3/12/1999	3/12/1999	43.57005	-70.032566	40'	SE	2720
DG	3/12/1999	3/12/1999	3/12/1999	43.570316	-70.028816	90'	E	2600
DG	3/12/1999	3/12/1999	3/13/1999	43.570833	-70.030866	50'	E	3000
DG	3/13/1999	3/13/1999	3/13/1999	43.571	-70.0285	75'	S	2300
DG	3/13/1999	3/13/1999	3/13/1999	43.568583	-70.030433	100'	SE	2700
DG	3/13/1999	3/13/1999	3/13/1999	43.572266	-70.026266	75'	E	2250
DG	3/13/1999	3/13/1999	3/13/1999	43.570283	-70.031266	90'	SE	2894
DG	3/14/1999	3/14/1999	3/14/1999	43.570133	-70.031683	80'	S	2570
DG	3/14/1999	3/14/1999	3/14/1999	43.568616	-70.0314	100'	SE	2300
DG	3/14/1999	3/14/1999	3/14/1999	43.572433	-70.0329	80'	SW	2650
DG	3/14/1999	3/14/1999	3/15/1999	43.570566	-70.0329	80'	SE	2720
DG	3/14/1999	3/15/1999	3/15/1999	43.570683	-70.03025	70'	SE	2300
DG	3/15/1999	3/15/1999	3/15/1999	43.571466	-70.01975	90'	W	2450
DG	3/15/1999	3/15/1999	3/15/1999	43.569416	-70.031216	100'	SE	2900
DG	3/17/1999	3/17/1999	3/17/1999	43.57025	-70.030833	100'	S	2670
DG	3/17/1999	3/17/1999	3/17/1999	43.571166	-70.032083	50'	E	3400
DG	3/18/1999	3/18/1999	3/18/1999	43.571183	-70.032233	100'	SE	3300
DG	3/18/1999	3/18/1999	3/18/1999	43.570816	-70.032233	60'	S	2300
DG	3/18/1999	3/18/1999	3/18/1999	43.56855	-70.031166	75'	SE	3300
DG	3/19/1999	3/19/1999	3/19/1999	43.569616	-70.03175	100'	S	3000
DG	3/19/1999	3/19/1999	3/19/1999	43.57	-70.028666	25'	E	2360
DG	3/19/1999	3/19/1999	3/20/1999	43.5702	-70.024916	75'	SE	3300
DG	3/19/1999	3/20/1999	3/20/1999	43.5711	-70.032666	70'	SE	2400
DG	3/20/1999	3/20/1999	3/20/1999	43.57035	-70.0324	60'	SE	2360
DG	3/20/1999	3/20/1999	3/20/1999	43.571966	-70.02985	80'	NE	3200
DG	3/20/1999	3/20/1999	3/20/1999	43.57015	-70.031483	100'	S	2360
PDA98	3/21/1999	3/21/1999	3/21/1999	43.571016	-70.036666	50'	SE	3200
DG	3/21/1999	3/21/1999	3/21/1999	43.5706	-70.032583	90'	S	2730
DG	3/21/1999	3/21/1999	3/21/1999	43.571516	-70.0177	50'	SW	3200
DG	3/22/1999	3/23/1999	3/23/1999	43.571933	-70.03195	50'	NE	2730
PDA98	3/24/1999	3/24/1999	3/24/1999	43.569916	-70.036983	75'	NW	2600
PDA98	3/24/1999	3/24/1999	3/24/1999	43.564016	-70.131066			2000
DG	3/25/1999	3/25/1999	3/25/1999	43.570766	-70.0348	100'	SE	3000
DG	3/25/1999	3/25/1999	3/25/1999	43.570433	-70.032183	100'	SE	2800

Project: PORTLAND HARBOR MAINE

Permit 1998C0018 **Permittee** COE-PORTLAND HARBOR

Buoy	Departur	Disposal	Return	Latitude	Longitud	Buoy's		Volume
DG	3/26/1999	3/26/1999	3/26/1999	43.571166	-70.032833	70'	SE	2800
DG	3/26/1999	3/26/1999	3/26/1999	43.572416	-70.031783	80'	NNE	3300
DG	3/27/1999	3/27/1999	3/27/1999	43.57255	-70.0308	80'	NE	3200
DG	3/27/1999	3/27/1999	3/28/1999	43.572183	-70.033116	80'	N	2800
DG	3/28/1999	3/28/1999	3/28/1999	43.570283	-70.03165	90'	E	3800
DG	3/28/1999	3/28/1999	3/28/1999	43.572333	-70.033283	85'	NW	3500
DG	3/29/1999	3/29/1999	3/29/1999	43.570583	-70.0322	100'	SW	2670
DG	3/29/1999	3/29/1999	3/30/1999	43.5722	-70.0325	75'	N	3800
DG	3/30/1999	3/30/1999	3/30/1999	43.5699	-70.0309	90'	SSE	2720
DG	3/30/1999	3/30/1999	3/30/1999	43.569216	-70.031583	50'	E	2800
DG	3/31/1999	3/31/1999	3/31/1999	43.5717	-70.033283	50'	S	2720
DG	3/31/1999	3/31/1999	3/31/1999	43.57175	-70.032233	25'	SE	3000
DG	3/31/1999	3/31/1999	3/31/1999	43.571616	-70.032616	40'	NW	2250
DG	3/31/1999	3/31/1999	4/1/1999	43.5717	-70.033233	50'	S	3000
DG	4/1/1999	4/1/1999	4/1/1999	43.5725	-70.031316	100'	N	2250
DG	4/1/1999	4/1/1999	4/1/1999	43.5703	-70.032016	80'	S	2500
DG	4/1/1999	4/1/1999	4/1/1999	43.572266	-70.032766	80'	SE	2250
DG	4/1/1999	4/1/1999	4/1/1999	43.570883	-70.03335	80'	SSW	2500
DG	4/2/1999	4/2/1999	4/2/1999	43.5722	-70.032566	80'	N	2400
DG	4/2/1999	4/2/1999	4/2/1999	43.5725	-70.032666	100'	NE	2600
DG	4/2/1999	4/2/1999	4/3/1999	43.57165	-70.0334	40'	S	2632
DG	4/3/1999	4/3/1999	4/3/1999	43.572216	-70.032866	50'	SW	2600
DG	4/3/1999	4/3/1999	4/3/1999	43.572416	-70.032633	50'	NW	1800
DG	4/4/1999	4/4/1999	4/4/1999	43.571333	-70.032766	40'	NE	2250
DG	4/4/1999	4/4/1999	4/4/1999	43.570966	-70.032	80'	E	2500
DG	4/4/1999	4/5/1999	4/5/1999	43.572516	-70.032183	100'	NE	2500
DG	4/5/1999	4/5/1999	4/5/1999	43.570416	-70.0337	100'	S	2250
DG	4/5/1999	4/5/1999	4/5/1999	43.570233	-70.03175	100'	SE	2800
DG	4/6/1999	4/6/1999	4/6/1999	43.570983	-70.03225	50'	SE	2350
DG	4/6/1999	4/6/1999	4/6/1999	43.572033	-70.03225	60'	N	1800
DG	4/7/1999	4/7/1999	4/7/1999	43.570016	-70.033066	80'	SW	2700
				Project Total Volume:		**155,842**	**CM**	**203,821 CY**
				Report Total Volume:		**179,130**	**CM**	**234,279 CY**

Appendix A3, Disposal Logs

2000 **PDS**

Project: Casco Bay - Portland, ME

Permit 198902221 **Permittee** YACHT HAVEN INC.

Buoy	Departur	Disposal	Return	Latitude	Longitud	Buoy's		Volume
DG	2/8/2000	2/8/2000	2/8/2000	43.571266	-70.030033	90'	SW	750
DG	2/10/2000	2/10/2000	2/10/2000	43.571166	-70.031666	80'	W	750
DG	2/11/2000	2/11/2000	2/11/2000	43.572666	-70.031	100'	E	750
DG	2/15/2000	2/15/2000	2/15/2000	43.571	-70.031666	90'	W	750
DG	2/17/2000	2/17/2000	2/17/2000	43.571333	-70.031333	80'	WS	750
DG	2/17/2000	2/17/2000	2/18/2000	43.570833	-70.031666	90'	E	750
DG	2/22/2000	2/22/2000	2/22/2000	43.572	-70.0315	100'	E	630
DG	2/23/2000	2/23/2000	2/23/2000	43.5725	-70.030166	80'	E	750
DG	2/24/2000	2/24/2000	2/24/2000	43.572833	-70.031166	80'	E	750
DG	2/25/2000	2/25/2000	2/25/2000	43.571	-70.031833	90'	E	750
DG	2/28/2000	2/28/2000	2/28/2000	43.572666	-70.031833	100'	E	750
DG	3/1/2000	3/1/2000	3/1/2000	43.573	-70.0315	100'	E	750
DG	3/2/2000	3/2/2000	3/2/2000	43.571	-70.032166	100'	W	750
DG	3/3/2000	3/3/2000	3/3/2000	43.570833	-70.031666	100'	W	750
DG	3/6/2000	3/6/2000	3/6/2000	43.570333	-70.032	100'	W	750
DG	3/8/2000	3/8/2000	3/8/2000	43.571833	-70.0315	100'	W	700
DG	3/8/2000	3/8/2000	3/8/2000	43.572166	-70.0305	100'	E	700
DG	3/9/2000	3/9/2000	3/9/2000	43.571833	-70.0315	90'	E	800
DG	3/13/2000	3/13/2000	3/13/2000	43.571333	-70.032166	90'	W	750
DG	3/16/2000	3/16/2000	3/16/2000	43.57267	-70.03117	80 ft	E	750
DG	3/20/2000	3/20/2000	3/21/2000	43.57123	-70.0315	80 ft	E	750
DG	3/21/2000	3/21/2000	3/21/2000	43.5715	-70.03233	60 ft	E	750
DG	3/22/2000	3/22/2000	3/22/2000	43.57183	-70.03033	60 ft	E	750
DG	3/23/2000	3/23/2000	3/23/2000	43.572	-70.03167	80 ft	E	750
DG	3/24/2000	3/24/2000	3/24/2000	43.572233	-70.0315	80 ft	E	750
DG	3/27/2000	3/27/2000	3/27/2000	43.57233	-70.03133	80 ft	E	750
DG	3/29/2000	3/29/2000	3/29/2000	43.57283	-70.03183	80 ft	E	750
DG	3/30/2000	3/30/2000	3/30/2000	43.5705	-70.03117	100	E	750
DG	3/31/2000	3/31/2000	3/31/2000	43.572	-70.03133	80	E	500
DG	4/5/2000	4/5/2000	4/6/2000	43.57217	-70.0315	80 ft	E	750
DG	4/6/2000	4/6/2000	4/6/2000	43.57307	-70.03	80 ft	E	700
				Project Total Volume:		**17,418**	**CM**	**22,780 CY**

Project: FORE RIVER

Permit 199803142 **Permittee** MOBIL OIL COMPANY

Buoy	Departur	Disposal	Return	Latitude	Longitud	Buoy's		Volume
PDA98	3/1/2000	3/1/2000	3/1/2000	43.569233	-70.037316			379
DG	3/8/2000	3/8/2000	3/8/2000	43.5715	-70.031	50'	S	376
DG	3/19/2000	3/19/2000	3/19/2000	43.573	-70.03133	100	N	376
				Project Total Volume:		**865**	**CM**	**1,131 CY**
				Report Total Volume:		**18,282**	**CM**	**23,911 CY**

Appendix B
Heave, Pitch, Roll Biases

The POS/MV IMU was used for heave, roll, pitch, and heading. The accuracy of the sensor was 5 cm for heave, ± 0.10° dynamic accuracy (± 0.05° static) for roll and pitch. The dynamic heading accuracy of the unit is +/- 0.05°.

Heading, roll, and pitch biases were determined in a series of tests performed in the Narragansett Bay during the Sea Acceptance Test. Prior to conducting any of the tests, an SVP was collected by the MVP-30 and entered into the RESON system. Initially, the roll, pitch, and heading biases were set to 0° in the RESON system.

SAIC used a combination of the geoswath editor and a spreadsheet to compute the roll bias between the POS/MV IMU and the transducer. This technique was developed and used on the Gulf of Mexico project for roll bias determination over flat bottom. Because the bottom is seldom truly flat, the test is accomplished by running the same line in opposite directions over a smooth bottom. An area is selected for the measurements, and an equal number of port and starboard depth pairs is measured from each direction. The apparent port to starboard slope of the bottom is computed for each pair of measurements. Averaging the equal number of slopes from each direction removes the bottom slope and leaves the roll bias. If a roll bias was in the system at the time of the test, it is added algebraically to the apparent slope to compute the values to be averaged. On 11 May 2000 (Julian day 132), three separate determinations of roll bias were made and then averaged for a bias value of 0.18. Roll bias results are shown in Table B2-1.

After the roll bias was calculated and entered into the RESON system, timing latency test and then pitch bias tests were conducted. Timing latency testing was conducted by running the same line in the same direction, at slow speeds then at fast speed, over distinct rocks on the bottom. The geoswath editor was used to measure the positions of the rocks from data taken at the two speeds. Differences in positions of the rocks were less than one meter and were both positive and negative in sign as well as across track. This indicated no timing latency, only the scatter associated with DGPS positioning.

Pitch bias testing was conducted by running the same line as for timing latency, but in the opposite direction at the same speed. Positioning of the rocks was similar to the timing results, indicating no pitch bias. Since there was no discernable timing latency or pitch bias as a result of these tests, a bias of 0.0° was kept in the system for the survey.

Following the roll and pitch bias tests, a heading bias test was conducted by running parallel lines in opposing directions so that the outer beams of adjacent swaths ensonified the same rocks used for timing and pitch. Positioning of the rocks was similar to the results of the timing and pitch tests, indicating no heading bias. Therefore, a heading bias of 0.0° was kept in the system for this survey. Table B2-1 contains the results of the Accuracy test conducted on 13 May 2000 (Julian day 134). Roll, pitch, and heading biases applied in the CLIS survey are shown in Table B2-2.

Table B2-1. Roll Bias Results for R/V Ocean Explorer

	Roll Bias Determination		Julian Day:	132	date:	11 May 2000
	File numbers:	132.d06 & 132.d08				
	from geoswath		from geoswath	apparent	bias already	bias to enter
#	depth port m.	depth stbd m.	swath width m.	slope	in ISS2000	in ISS2000
1	40.33	37.36	105.30	0.81	0.00	0.81
2	40.38	37.45	105.30	0.80	0.00	0.80
3	40.25	37.41	105.30	0.77	0.00	0.77
4	40.16	37.74	105.30	0.66	0.00	0.66
5	40.20	38.11	105.30	0.57	0.00	0.57
6	40.74	38.29	105.30	0.67	0.00	0.67
7	40.34	38.16	105.30	0.59	0.00	0.59
8	40.25	38.09	105.30	0.59	0.00	0.59
9	40.36	37.97	105.30	0.65	0.00	0.65
10	40.36	38.02	105.30	0.64	0.00	0.64
11	39.27	40.20	105.30	-0.25	0.00	-0.25
12	39.36	40.27	105.30	-0.25	0.00	-0.25
13	39.41	40.40	105.30	-0.27	0.00	-0.27
14	39.47	40.81	105.30	-0.36	0.00	-0.36
15	39.34	40.29	105.30	-0.26	0.00	-0.26
16	39.13	40.13	105.30	-0.27	0.00	-0.27
17	38.98	39.86	105.30	-0.24	0.00	-0.24
18	38.84	39.77	105.30	-0.25	0.00	-0.25
19	38.63	39.83	105.30	-0.33	0.00	-0.33
20	38.56	39.77	105.30	-0.33	0.00	-0.33
			mean bias to enter in ISS2000			0.20
			standard deviation first direction			0.09
			standard deviation second direction			0.04

	Roll Bias Determination		Julian Day:	132	date:	11 May 2000
	File numbers:		132.d05 & 132.d10			
	from geoswath		from geoswath	apparent	bias already	bias to enter
#	depth port m.	depth stbd m.	swath width m.	slope	in ISS2000	in ISS2000
1	37.11	37.81	105.30	-0.19	0.00	-0.19
2	37.09	37.88	105.30	-0.21	0.00	-0.21
3	37.20	37.98	105.30	-0.21	0.00	-0.21
4	37.20	38.36	105.30	-0.32	0.00	-0.32
5	37.43	38.65	105.30	-0.33	0.00	-0.33
6	37.84	38.82	105.30	-0.27	0.00	-0.27
7	38.11	38.84	105.30	-0.20	0.00	-0.20
8	38.16	38.91	105.30	-0.20	0.00	-0.20
9	37.11	37.79	105.30	-0.18	0.00	-0.18
10	37.08	37.77	105.30	-0.19	0.00	-0.19
11	39.98	37.59	105.30	0.65	0.00	0.65
12	39.83	37.54	105.30	0.62	0.00	0.62
13	39.75	37.50	105.30	0.61	0.00	0.61
14	39.70	37.52	105.30	0.59	0.00	0.59
15	39.59	37.50	105.30	0.57	0.00	0.57
16	39.54	37.50	105.30	0.55	0.00	0.55
17	39.45	37.41	105.30	0.55	0.00	0.55
18	39.56	37.30	105.30	0.61	0.00	0.61
19	39.27	36.84	105.30	0.66	0.00	0.66
20	39.31	36.75	105.30	0.70	0.00	0.70
			mean bias to enter in ISS2000			0.19
			standard deviation first direction			0.05
			standard deviation second direction			0.05

	Roll Bias Determination		Day:	132	date:	11-May-00
	File numbers:		132.d04 & .d09			
	from geoswath		from geoswath	apparent	bias already	bias to enter
#	depth port m.	depth stbd m.	swath width m.	slope	in ISS2000	in ISS2000
1	37.68	36.04	105.30	0.45	0.00	0.45
2	37.68	36.13	105.30	0.42	0.00	0.42
3	37.70	36.16	105.30	0.42	0.00	0.42
4	37.70	36.18	105.30	0.41	0.00	0.41
5	37.77	36.11	105.30	0.45	0.00	0.45
6	37.75	36.11	105.30	0.45	0.00	0.45
7	37.79	36.13	105.30	0.45	0.00	0.45
8	37.81	36.09	105.30	0.47	0.00	0.47
9	37.84	36.09	105.30	0.48	0.00	0.48
10	37.91	36.11	105.30	0.49	0.00	0.49
11	36.84	37.24	105.30	-0.11	0.00	-0.11
12	36.83	37.29	105.30	-0.13	0.00	-0.13
13	36.88	37.31	105.30	-0.12	0.00	-0.12
14	36.86	37.34	105.30	-0.13	0.00	-0.13
15	36.83	37.31	105.30	-0.13	0.00	-0.13
16	36.86	37.27	105.30	-0.11	0.00	-0.11
17	36.86	37.36	105.30	-0.14	0.00	-0.14
18	36.83	37.43	105.30	-0.16	0.00	-0.16
19	36.84	37.34	105.30	-0.14	0.00	-0.14
20	36.86	37.27	105.30	-0.11	0.00	-0.11
			Mean bias to enter in ISS2000			0.16
			Standard deviation first direction			0.03
			Standard deviation second direction			0.02
Average of three tests			***Mean bias to enter in ISS2000***			***0.18***

Table B2-2. Roll, Pitch, and Heading Bias for the R/V Ocean Explorer

Bias	**Value**
Roll	0.18
Pitch	0.00°
Heading	0.00°

Appendix C
Settlement and Squat Calculations for the R/V Ocean Explorer

Measurements of settlement and squat were conducted near 41° 31’ 56”N, 071° 19’ 30”W on 13 May 2000 (Julian day 134), in 18 meters of water off the end of the Coddington Cove breakwater, Narragansett Bay, RI. The following procedures were used to determine the settlement correctors:

Measurement by Surveyor’s Level and Rod, the preferred method when the attitude sensor (IMU) and the transducer are not co-located.

1. Used a surveyor’s level and a level rod with target, or a stadia board to measure the elevation of a spot above the attitude sensor (IMU) on the survey boat as the boat was operated at different shaft RPMs.
2. Selected a location to set up a surveyor’s level (“level”) overlooking adequate water for the survey vessel to run a survey line at various speeds, including full speed. Established communication between “level” and the boat.
3. Selected the “static” point for initial measurements, which was the point at which the vessel was to hold station.
4. Planned the “settlement and squat” survey line through “static”. The vessel ran this line at various shaft RPM settings to make settlement and squat measurements. The line ran more nearly toward the “level” than across in front of it. This made it more likely that the observer was able to focus on and read, or direct the reading, of the level rod on the boat. For this reason, a breakwater end was chosen.
5. Marked a spot on the vessel above the attitude sensor (IMU) so that the level rod was always held at the same point on the boat.
6. Stopped the vessel at “static” with the starboard side toward “level”.
   A. Held the rod on mark with face toward “level”.
   B. Adjusted the rod target according to signals from “level”.
   C. On signal from “level”, recorded time and rod reading from target.
   D. Repeated the reading at least three times.
   E. The NOAA water level gauge at Newport was used to record water levels.
7. On a signal from the surveyor at “level”, made way on “settlement and squat” survey lines at predetermined shaft RPM.
   A. On survey track, held rod on mark with face toward “level”.
   B. Adjusted rod target according to signals from “level”.
   C. On signal from “level”, recorded time and rod reading from target. Readings were taken as nearly as possible at “static” to reduce errors from level instrument adjustment and earth curvature.
   D. Repeated the reading at least three times.
   E. The NOAA water level gauge at Newport was used to record water levels.
8. Increased speed to the predetermined shaft RPM settings up to and including full speed, and reran “settlement and squat” tests as described in Step 7.
9. Computed the settlement and squat correctors:

A. Computed the water level correctors from the time of the “static” reading to the time of each of the shaft RPM observations. (Water level during shaft RPM pass minus water level “static”).
B. Applied the water level corrector to each of the shaft RPM rod observations.
C. Subtracted the corrected rod reading at each shaft RPM from the rod reading at “static”. These differences are the settlement and squat correctors to be applied when operating at the corresponding shaft RPM.
D. Constructed a lookup table of shaft RPM and settlement and squat correctors so that the computer may interpolate a corrector based upon the shaft RPM entered into the system during the survey.
E. Entered these values in the ISS2000 *.cfg file.

All results are reported in Table C3-1.

Table C3-1. Settlement Results for the R/V/ Ocean Explorer

Engine RPM	**Speed Knots***	**Settlement Meters**
0	0	0.00
600	5	0.01
800	7	0.02
1100	10	0.03
1300	11	0.04
1500	12	0.08
1900	15	0.22

* NOTE: The speed in knots listed in Table C3-1 were not used in the Settlement and Squat Lookup Table, but are given here as approximate average values.

Appendix D
Detailed REMOTS® Sediment-Profile Imaging Results

Appendix D

PDS REMOTS® Sediment-Profile Photography Data from the 2000 Survey

Station	Replicate	Date	Successional Stage	Grain Size (phi) Min	Grain Size (phi) Max	Grain Size (phi) Maj Mode	Mud Clasts Count	Mud Clasts Avg. Diam	Camera Penetration (cm) Min	Camera Penetration (cm) Max	Camera Penetration (cm) Range	Camera Penetration (cm) Mean	Dredged Material Thickness (cm) Min	Dredged Material Thickness (cm) Max	Dredged Material Thickness (cm) Mean	Redox Rebound Thickness Min	Redox Rebound Thickness Max	Redox Rebound Thickness Mean	Apparent RPD Thickness (cm) Min	Apparent RPD Thickness (cm) Max	Apparent RPD Thickness (cm) Mean	Methane Count	Methane Min	Methane Max	Methane Mean	OSI	Surface Roughness	Low DO	Comments
100E	A	9/22/2000	ST_I	3	>4	>4	0	0	7.61	9.89	2.28	8.75	7.61	9.89	>8.75	0	0	0	0.11	2.56	1.66	0	0	0	0	4	PHYSICAL	NO	DM>P; M>P; LG CLAY CLAST; TUBES
100E	B	9/22/2000	ST_I_ON_III	3	>4	>4	3	0.67	5.28	8.56	3.28	6.92	5.28	8.56	>6.92	0	0	0	0.11	1.78	0.73	0	0	0	0	6	PHYSICAL	NO	DM>P; M>P; CLAY CLAST; OX&RED CLASTS; VOID; POSS BURROW OPENING
100E	C	9/22/2000	ST_I	3	>4	>4	2	0.29	13.94	15.39	1.44	14.67	13.94	15.39	>14.67	0	0	0	0.06	3.61	1.87	0	0	0	0	4	PHYSICAL	NO	DM>P; M>P; OX CLASTS; EDGE OF CLAY CLAST; WORM @ Z
100N	A	9/22/2000	ST_I	3	>4	>4	10	0.89	12.67	14.11	1.44	13.39	12.67	14.11	>13.39	0	0	0	0.72	4.5	3.64	0	0	0	0	6	PHYSICAL	NO	DM>P; M>P; CLAY CLAST @ Z; OX CLASTS; TUBES
100N	B	9/22/2000	ST_I_ON_III	3	>4	>4	6	0.22	10.22	10.78	0.56	10.5	10.22	10.78	>10.5	0	0	0	0.32	4.05	1.93	0	0	0	0	8	PHYSICAL	NO	DM>P; M>P; CLAY @ Z; VOID; OX CLASTS
100N	E	9/22/2000	ST_I	3	>4	>4	2	0.38	8.59	10.11	1.52	9.35	8.59	10.11	>9.35	0	0	0	0.54	3.97	2.7	0	0	0	0	5	PHYSICAL	NO	DM>P; M>P; TUBES; WOMRS @ Z
100NE	A	9/22/2000	ST_I	3	>4	>4	0	0	10.73	12.87	2.13	11.8	10.73	12.87	>11.8	0	0	0	0.34	3.99	2.48	0	0	0	0	5	PHYSICAL	NO	DM>P; M>P; TUBES
100NE	B	9/22/2000	ST_I	3	>4	>4	6	0.39	10.11	10.56	0.45	10.34	10.11	10.56	>10.34	0	0	0	0.06	2.87	1.52	0	0	0	0	4	PHYSICAL	NO	DM>P; M>P; SOME CLAY @ Z; OX&RED CLASTS; TUBES
100NE	C	9/22/2000	ST_I	3	>4	>4	0	0	8.99	9.94	0.96	9.47	8.99	9.94	>9.47	0	0	0	0.06	2.58	1.11	0	0	0	0	3	PHYSICAL	NO	DM>P; M>P; BURROW OPENING; DENSE TUBES
100NW	A	9/22/2000	ST_I_ON_III	3	>4	>4	0	0	14.55	17.27	2.73	15.91	14.55	17.27	>15.91	0	0	0	0.32	7.33	3.92	0	0	0	0	11	PHYSICAL	NO	DM>P; M>P; SMALL VOIDS
100NW	B	9/22/2000	ST_I_ON_III	3	>4	>4	0	0	15.08	15.67	0.59	15.37	15.08	15.67	>15.37	0	0	0	0.16	3.21	1.84	0	0	0	0	8	PHYSICAL	NO	DM>P; M>P; VOID; TUBES
100NW	C	9/22/2000	ST_I	3	>4	>4	0	0	13.85	17.01	3.16	15.43	13.85	17.01	>15.43	0	0	0	0.16	2.73	1.7	0	0	0	0	4	PHYSICAL	NO	DM>P; M>P; TUBES; WORMS @ Z
100S	A	9/22/2000	ST_I	3	>4	>4	0	0	12.89	14.28	1.39	13.58	12.89	14.28	>13.58	0	0	0	0.33	3.28	2.11	0	0	0	0	4	PHYSICAL	NO	DM>P; M>P; CLAY CLASTS @ Z; TUBES
100S	B	9/22/2000	ST_I_ON_III	3	>4	>4	6	0.28	10.83	11.44	0.61	11.14	10.83	11.44	>11.14	0	0	0	0.11	2.28	0.99	0	0	0	0	7	PHYSICAL	NO	DM>P; M>P; DENSE TUBES; VOIDS; BURROWS; WORM&CLAY @Z; OX&RED CLASTS
100S	C	9/22/2000	ST_I	3	>4	>4	3	0.34	14.55	16.57	2.02	15.56	14.55	16.57	>15.56	0	0	0	0.06	6.46	2.37	0	0	0	0	5	PHYSICAL	NO	DM>P; M>P; SHELL; WIPR CLSTS/SMR; CLAY@Z; RED CLASTS
100SE	A	9/22/2000	ST_I_ON_III	3	>4	>4	1	0.54	18.45	19.73	1.28	19.09	18.45	19.73	>19.09	0	0	0	3.21	7.74	6.18	0	0	0	0	11	PHYSICAL	NO	DM>P; M>P; VOID; TUBES; RED CLAST
100SE	B	9/22/2000	ST_I	3	>4	>4	8	0.46	16.58	18.56	1.98	17.57	16.58	18.56	>17.57	0	0	0	0.05	2.19	1.02	0	0	0	0	3	PHYSICAL	NO	DM>P; M>P; PPA; OX&RED CLASTS; DENSE;TUBES; CLAY@Z
100SE	C	9/22/2000	ST_I	3	>4	>4	0	0	15.72	18.88	3.16	17.3	15.72	18.88	>17.3	0	0	0	0.16	2.51	1.54	0	0	0	0	4	PHYSICAL	NO	DM>P; MUD W/CLAY>P; DENSE SURFACE TUBES
100SW	A	9/22/2000	ST_I_ON_III	3	>4	>4	6	0.53	11.74	12.58	0.84	12.16	11.74	12.58	>12.16	0	0	0	0.39	3.93	2.72	0	0	0	0	9	PHYSICAL	NO	DM>P; M>P; SOME CLAY @ Z; VOIDS; BURROWS; TUBES; OX&RED CLASTS
100SW	B	9/22/2000	ST_I	3	>4	>4	0	0	8.37	9.55	1.18	8.96	8.37	9.55	>8.96	0	0	0	0.11	1.63	0.89	0	0	0	0	3	PHYSICAL	NO	DM>P; SANDY-CLAYEY M>P; TUBES
100SW	E	9/22/2000	ST_I	3	>4	>4	0	0	11.57	17.53	5.96	14.55	11.57	17.53	>14.55	0	0	0	0.06	2.19	1.35	0	0	0	0	3	PHYSICAL	NO	DM>P; SANDY-CLAYEY M>P; BURROWS
100W	A	9/22/2000	ST_I	3	>4	>4	6	0.61	14.72	16.17	1.44	15.44	14.72	16.17	>15.44	0	0	0	0.06	2.78	1.56	0	0	0	0	4	PHYSICAL	NO	DM>P; M>P; OX&RED CLASTS; TUBES
100W	D	9/22/2000	ST_I	3	>4	>4	12	0.61	11.3	12.12	0.82	11.71	11.3	12.12	>11.71	0	0	0	0.16	3.97	2.27	0	0	0	0	5	PHYSICAL	NO	DM>P; M>P; OX&RED CLASTS; TUBES
200E	A	9/21/2000	ST_I	2	>4	>4	0	0	17.37	18.21	0.84	17.79	17.37	18.21	>17.79	0	0	0	0.5	2.29	1.4	0	0	0	0	3	PHYSICAL	NO	DM>P; SANDY MUD/M/CLAY; CLAY @Z; TUBES
200E	B	9/21/2000	ST_I_ON_III	2	>4	>4	0	0	18.88	20.39	1.51	19.64	18.88	20.39	>19.64	0	0	0	0.06	2.57	0.9	0	0	0	0	7	PHYSICAL	NO	DM>P; SANDY MUD/CLAY; VOID; TUBES; WORM @ Z
200E	C	9/21/2000	ST_I	2	>4	>4	0	0	19.5	21.06	1.56	20.28	19.5	21.06	>20.28	0	0	0	1.32	3.42	2.26	0	0	0	0	5	PHYSICAL	NO	DM>P; SANDY MUD/CLAY; CLAY @ Z
200N	F	9/22/2000	INDET	3	>4	>4	0	0	10.38	11.9	1.52	11.14	10.38	11.9	>11.14	0	0	0	NA	NA	NA	0	0	0	0	99	PHYSICAL	NO	DM>P; M>P; PULL AWAY
200N	G	9/22/2000	ST_I	3	>4	>4	0	0	11.9	14.29	2.39	13.1	11.9	14.29	>13.1	0	0	0	NA	NA	NA	0	0	0	0	99	INDET	NO	DM>P; M>P; FLUID CLAST LAYER; CLAY FLECKS; TUBES
200N	H	9/22/2000	ST_I	3	>4	>4	3	0.28	14.18	16.63	2.45	15.41	14.18	16.63	>15.41	0	0	0	0.21	4.47	2.37	0	0	0	0	5	PHYSICAL	NO	DM>P; M>P; OX CLASTS
200NE	A	9/22/2000	ST_I_ON_III	3	>4	>4	0	0	15.56	16.63	1.07	16.1	15.56	16.63	>16.1	0	0	0	0.16	6.11	2.7	0	0	0	0	9	PHYSICAL	NO	DM>P; M>P; CLAY CLASTS @ Z; VOID; DENSE SURF TUBES
200NE	B	9/22/2000	ST_I_ON_III	3	>4	>4	3	0.62	10.06	12.87	2.81	11.46	10.06	12.87	>11.46	0	0	0	0.06	2.53	1.56	0	0	0	0	8	PHYSICAL	NO	DM>P; SANDY-CLAYEY M>P; VOIDS; OX CLASTS
200NE	D	9/22/2000	ST_I	3	>4	>4	6	0.57	15.79	17.53	1.74	16.66	15.79	17.53	>16.66	0	0	0	0.39	3.76	1.78	0	0	0	0	4	PHYSICAL	NO	DM>P; M>P; OX CLASTS; CLAY @ Z
200NW	C	9/22/2000	ST_I_ON_III	3	>4	>4	0	0	20.21	20.91	0.7	20.56	20.21	20.91	>20.56	0	0	0	0.32	4.32	2.02	0	0	0	0	8	PHYSICAL	NO	DM>P; M>P; VOID; TUBES; WIPER CLASTS/SMEAR
200NW	E	9/22/2000	ST_I_ON_III	3	>4	>4	12	0.53	4.73	7.23	2.5	5.98	4.73	7.23	>5.98	0	0	0	0.05	3.21	1.85	0	0	0	0	8	PHYSICAL	NO	DM>P; M>P; OX&RED CLASTS; VOID; LRG SURF CLAY CLAST
200NW	F	9/22/2000	ST_I	3	>4	>4	0	0	8.8	11.79	2.99	10.3	8.8	11.79	>10.3	0	0	0	0.05	2.5	1.52	0	0	0	0	4	PHYSICAL	NO	DM>P; M>P; FLUID CLAST LAYER; BURROWS; TUBES
200S	B	9/22/2000	ST_I	3	>4	>4	3	0.45	9.1	10.56	1.46	9.83	9.1	10.56	>9.83	0	0	0	0.62	3.99	2.91	0	0	0	0	5	PHYSICAL	NO	DM>P; SANDY/MUDDY CLAY>P; OX-CLAY CLSTS; BURROWS; CLAY FRACTURES
200S	C	9/22/2000	ST_I	3	>4	>4	4	0.22	10.9	11.46	0.56	11.18	10.9	11.46	>11.18	0	0	0	0.22	2.42	1.3	0	0	0	0	3	PHYSICAL	NO	DM>P; MUDDY CLAY>P; OX-CLAY CLSTS; TUBES; CLAY FRACTURES @Z
200S	E	9/22/2000	ST_I_ON_III	3	>4	>4	0	0	6.9	8.64	1.74	7.77	6.9	8.64	>7.77	0	0	0	0.05	2.26	1.02	0	0	0	0	7	PHYSICAL	NO	DM>P; MUDDY CLAY>P; BURROW OPENING; VOID; BURROWS
200SE	A	9/21/2000	ST_I	2	>4	>4	6	0.74	17.77	21.01	3.24	19.39	17.77	21.01	>19.39	0	0	0	0.11	4.3	2.66	0	0	0	0	5	PHYSICAL	NO	DM>P; SANDY MUD/M; VOID; BURROW; OX CLASTS; WORM @Z
200SE	D	9/22/2000	ST_I	2	>4	>4	4	0.52	12.85	16.3	3.45	14.58	12.85	16.3	>14.58	0	0	0	0.1	4.1	2.48	0	0	0	0	5	PHYSICAL	NO	DM>P; M W/CLAY CLASTS>P; OX&RED CLASTS
200SE	H	9/22/2000	ST_I	3	>4	>4	3	0.28	11.9	16.03	4.13	13.97	11.9	16.03	>13.97	0	0	0	0.76	4.73	3.01	0	0	0	0	6	PHYSICAL	NO	DM>P; M>P; OX CLASTS; CLAY CLASTS @ Z; TUBES
200SW	C	9/22/2000	ST_I	3	>4	>4	6	0.45	15	16.57	1.57	15.79	0	0	0	0	0	0	0.62	6.63	4.62	0	0	0	0	7	PHYSICAL	NO	MUD>P; OX CLASTS; TUBES
200SW	F	9/22/2000	ST_I	3	>4	>4	0	0	13.26	14.57	1.3	13.91	13.26	14.57	>13.91	0	0	0	0.27	2.83	1.64	0	0	0	0	4	PHYSICAL	NO	DM>P; M>P; BURROW OPENINGS; TUBES
200SW	G	9/22/2000	ST_I	3	>4	>4	8	0.55	19.62	20.65	1.03	20.14	19.62	20.65	>20.14	0	0	0	0.6	3.86	2.46	0	0	0	0	5	PHYSICAL	NO	DM>P; M>P; OX&RED CLASTS; TUBES; CLAY CLAST
200W	A	9/22/2000	ST_I_ON_III	3	>4	>4	0	0	18.9	20.95	2.05	19.93	18.9	20.95	>19.93	0	0	0	1.53	6.84	4.78	0	0	0	0	11	PHYSICAL	NO	DM>P; M>P; SM VOID; WORMS @ Z
200W	B	9/22/2000	ST_I	3	>4	>4	0	0	19.22	20.56	1.33	19.89	19.22	20.56	>19.89	0	0	0	3.37	7.37	5.93	0	0	0	0	7	PHYSICAL	NO	DM>P; M>P
200W	E	9/22/2000	ST_I	3	>4	>4	0	0	19.95	20.92	0.98	20.43	19.95	20.92	>20.43	0	0	0	2.53	5.95	4.95	0	0	0	0	7	PHYSICAL	NO	DM>P; M>P; TUBES
300E	D	9/21/2000	ST_I	3	>4	>4	0	0	8.32	11.56	3.24	9.94	8.32	11.56	>9.94	0	0	0	1.79	3.58	2.61	0	0	0	0	5	PHYSICAL	NO	DM>P; GREY CLAY
300E	G	9/22/2000	ST_I_ON_III	2	>4	>4	0	0	7.94	9.94	2	8.94	7.94	9.94	>8.94	0	0	0	0.05	4.42	2.46	0	0	0	0	9	PHYSICAL	NO	DM>P; M>P; CLAY @Z; VOIDS; TUBES
300E	I	9/22/2000	ST_I_ON_III	3	>4	>4	1	0.5	9.33	10.44	1.11	9.89	9.33	10.44	>9.89	0	0	0	0.28	2.61	1.26	0	0	0	0	7	PHYSICAL	NO	DM>P; M>P; CLAY CLASTS @ Z; TUBES; VOIDS; CLAY CLAST ON SURF
300N	A	9/21/2000	ST_I	3	>4	>4	0	0	20.5	20.95	0.45	20.73	20.5	20.95	>20.73	0	0	0	1.06	7.54	4.75	0	0	0	0	7	PHYSICAL	NO	DM>P; M>P; TUBES
300N	F	9/22/2000	ST_I	3	>4	>4	8	0.83	11.56	13.56	2	12.56	11.56	13.56	>12.56	0	0	0	0.28	2.78	1.67	0	0	0	0	4	PHYSICAL	NO	DM>P; M>P; OX&RED CLASTS; PPA
300N	I	9/22/2000	ST_I_ON_III	3	>4	>4	8	0.39	14.78	18.31	3.54	16.54	14.78	18.31	>16.54	0	0	0	0.06	4.72	2.62	0	0	0	0	9	PHYSICAL	NO	DM>P; M>P; VOIDS; OX&RED CLASTS
300NE	A	9/22/2000	INDET	3	>4	>4	0	0	5	17	12	11	5	17	>11	0	0	0	NA	NA	NA	0	0	0	0	99	INDET	NO	DM>P; DISTD SURF; FLUID CLAST LAYER; LRG CLAY CLASTS
300NE	C	9/22/2000	ST_I	3	>4	>4	6	0.68	12.58	13.99	1.4	13.29	12.58	13.99	>13.29	0	0	0	0.22	3.2	1.77	0	0	0	0	4	PHYSICAL	NO	DM>P; M>P; PPA; TUBES; OX&RED CLASTS
300NE	E	9/22/2000	ST_I	3	>4	>4	0	0	8.7	13.26	4.56	10.98	8.7	13.26	>10.98	0	0	0	NA	NA	NA	0	0	0	0	99	INDET	NO	DM>P; M>P; FLUID CLAST LAYER; LRG SURF CLAY CLAST
300NW	A	9/22/2000	INDET	2	>4	>4	0	0	21	21	INDET	21	21	21	>21	0	0	0	NA	NA	NA	0	0	0	0	99	INDET	NO	DM>P, OVERPENETRATION, BURROW
300NW	B	9/22/2000	INDET	3	>4	>4	0	0	21	21	INDET	21	21	21	>21	0	0	0	NA	NA	NA	0	0	0	0	99	INDET	NO	DM>P, OVERPENETRATION
300NW	C	9/22/2000	INDET	3	>4	>4	0	0	21	21	INDET	21	21	21	>21	0	0	0	NA	NA	NA	0	0	0	0	99	INDET	NO	DM>P, OVERPENETRATION, VOIDS
300S	A	9/22/2000	ST_I	3	>4	>4	2	0.35	10.28	11.4	1.12	10.84	10.28	11.4	>10.84	0	0	0	0.06	3.03	1.46	0	0	0	0	3	PHYSICAL	NO	DM>P; M>P; SOME CLAY @ Z; TUBES; OX CLASTS
300S	B	9/22/2000	ST_I	3	>4	>4	0	0	8.54	9.78	1.24	9.16	8.54	9.78	>9.16	0	0	0	0.11	1.74	1.02	0	0	0	0	3	PHYSICAL	NO	DM>P; M>P; CLAY @ Z; BURROW; REDUCED SEDIMENT
300S	C	9/22/2000	ST_I	3	>4	>4	4	0.34	12.81	15.06	2.25	13.93	12.81	15.06	>13.93	0	0	0	0.22	3.26	1.62	0	0	0	0	4	PHYSICAL	NO	DM>P; M>P; CLAY @ Z; OX CLASTS
300SE	D	9/22/2000	ST_I	2	>4	>4	7	0.44	17.6	19.3	1.7	18.45	17.6	19.3	>18.45	0	0	0	0.95	4.4	2.72	0	0	0	0	5	PHYSICAL	NO	DM>P; M>P; OX&RED CLASTS; TUBES
300SE	G	9/22/2000	ST_I	3	>4	>4	0	0	13.59	17.45	3.86	15.52	13.59	17.45	>15.52	0	0	0	0.33	4.95	3.13	0	0	0	0	6	PHYSICAL	NO	DM>P; M>P; CLAY CLAST @ Z; DENSE TUBES; IRREG TOPOGRAPHY
300SE	I	9/22/2000	ST_I	3	>4	>4	3	0.38	12.93	14.89	1.96	13.91	12.93	14.89	>13.91	0	0	0	0.05	3.21	1.7	0	0	0	0	4	PHYSICAL	NO	DM>P; M>P; RED CLASTS
400E	D	9/22/2000	ST_I_ON_III	3	>4	>4	2	0.22	17.89	19.11	1.22	18.5	17.89	19.11	>18.5	0	0	0	0.11	3.68	2.53	0	0	0	0	9	PHYSICAL	NO	DM>P; M>P; CLAY CLAST @Z; FLUID IN VOID; TUBES; OX CLASTS
400E	E	9/22/2000	ST_I	3	>4	>4	0	0	14.39	17.44	3.06	15.92	14.39	17.44	>15.92	0	0	0	0.06	4.17	1.44	0	0	0	0	3	PHYSICAL	NO	DM>P; M>P; BURROW OPENING; TUBES; CLAY @ Z; WIPER CLASTS/SMEAR
400E	F	9/22/2000	ST_I	3	>4	>4	5	1.35	12.11	14.44	2.33	13.28	12.11	14.44	>13.28	0	0	0	0.21	4	2.79	0	0	0	0	5	PHYSICAL	NO	DM>P; M>P; OX&RED CLASTS; TUBES; LG CLAY CLASTS @SURF
400N	C	9/22/2000	ST_I_ON_III	3	>4	>4	0	0	18.5	19.5	1	19	18.5	19.5	>19	0	0	0	0.05	5.79	4.17	0	0	0	0	11	PHYSICAL	NO	DM>P; M>P; VOID; TUBES
400N	D	9/22/2000	ST_I_ON_III	3	>4	>4	0	0	10.73	14.61	3.88	12.67	10.73	14.61	>12.67	0	0	0	1.32	5.32	3.97	0	0	0	0	11	PHYSICAL	NO	DM>P; M>P; VOID; TUBES
400N	E	9/22/2000	ST_I	3	>4	>4	2	0.26	10.84	12.3	1.46	11.57	10.84	12.3	>11.57	0	0	0	0.06	2.36	1.29	0	0	0	0	3	PHYSICAL	NO	DM>P; M>P; OX CLASTS; WIPER CLASTS/SMEAR
400NE	A	9/22/2000	ST_I	3	>4	>4	0	0	15.06	15.39	0.34	15.22	15.06	15.39	>15.22	0	0	0	0.63	3.32	2.29	0	0	0	0	5	PHYSICAL	NO	DM>P; M>P; DENSE SURFACE TUBES
400NE	B	9/22/2000	ST_I	3	>4	>4	5	0.26	15.06	15.84	0.79	15.45	15.06	15.84	>15.45	0	0	0	0.42	4.53	3.51	0	0	0	0	6	PHYSICAL	NO	DM>P; M>P; TUBES; OX&RED CLASTS
400NE	C	9/22/2000	ST_I	3	>4	>4	4	0.39	16.18	18.09	1.91	17.13	16.18	18.09	>17.13	0	0	0	0.21	4.16	2.8	0	0	0	0	5	PHYSICAL	NO	DM>P; M>P; OX CLASTS; TUBES
400S	C	9/22/2000	INDET	3	>4	>4	0	0.45	0.62	2.47	1.85	1.54	0	0	0	0	0	0	NA	NA	NA	0	0	0	0	99	PHYSICAL	NO	SANDY M>P; UNDERPEN; OX CLASTS
400SE	H	9/22/2000	ST_I_ON_III	3	>4	>4	0	0	19.83	20.96	1.12	20.39	19.83	20.96	>20.39	0	0	0	4.53	7.21	6.22	0	0	0	0	11	PHYSICAL	NO	DM>P; M>P; VOID; TUBES
400SE	I	9/22/2000	ST_I	3	>4	>4	2	0.4	20.34	20.79	0.45	20.56	20.34	20.79	>20.56	0	0	0	0.32	6.58	4.55	0	0	0	0	7	PHYSICAL	NO	DM>P; M>P; OX&RED CLASTS
400SE	J	9/22/2000	ST_I	3	>4	>4	0	0	19.89	21.01	1.12	20.45	19.89	21.01	>20.45	0	0	0	4.37	8.47	7.12	0	0	0	0	7	PHYSICAL	NO	DM>P; M>P; TUBES
CTR	A	9/22/2000	ST_I	3	>4	>4	0	0	5.4	6.52	1.12	5.96	5.4	6.52	>5.96	0	0	0	0.05	4.79	3.25	0	0	0	0	6	PHYSICAL	NO	DM>P; M>P; DENSE TUBES
CTR	B	9/22/2000	ST_I	3	>4	>4	0	0	16.42	17.91	1.5	17.17	16.42	17.91	>17.17	0	0	0	0.05	5.24	2.33	0	0	0	0	5	PHYSICAL	NO	DM>P; M>P; SURFACE TUBES
CTR	C	9/22/2000	ST_I	3	>4	>4	0	0	4.44	10.64	6.2	7.54	4.44	10.64	>7.54	0	0	0	0.48	4.06	1.99	0	0	0	0	4	PHYSICAL	NO	DM>P; M>P; BURROW OPENING; TUBES

Appendix D

PDS Reference Area REMOTS® Sediment-Profile Photography Data from the 2000 Survey

Station	Replicate	Date	Successional Stage	Grain Size (phi)			Mud Clasts		Camera Penetration (cm)				Dredged Material Thickness (cm)			Redox Rebound Thickness			Apparent RPD Thickness (cm)			Methane				OSI	Surface Roughness	Low DO	Comments
				Min	Max	Maj Mode	Count	Avg. Diam	Min	Max	Range	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Count	Min	Max	Mean				
EREF1	B	9/22/2000	ST_I_ON_III	3	>4	>4	12	0.96	12.51	12.99	0.48	12.75	0	0	0	0	0	0	1.26	2.89	2.04	0	0	0	0	8	PHYSICAL	NO	M>P; TUBES; VOID; OX&RED CLAST MOUND
EREF1	C	9/22/2000	ST_I	3	>4	>4	6	0.4	12.46	15.67	3.21	14.06	0	0	0	0	0	0	0.05	4.49	3.42	0	0	0	0	6	PHYSICAL	NO	M>P; FLUID CLAST LAYER; OX&RED CLASTS; BURROW
EREF1	E	9/22/2000	ST_I	3	>4	>4	3	0.44	5.38	6.9	1.52	6.14	0	0	0	0	0	0	0.11	2.39	1.18	0	0	0	0	3	PHYSICAL	NO	M W/CLAY>P; OX&RED CLASTS; TUBES
EREF2	C	9/22/2000	ST_I	2	>4	>4	1	0.13	9.44	13.97	4.53	11.7	0	0	0	0	0	0	0.61	5.03	3.27	0	0	0	0	6	PHYSICAL	NO	M>P; TUBES; WORMS @ Z; OX CLAST
EREF2	E	9/22/2000	ST_I_ON_III	3	>4	>4	3	0.92	10.27	11.82	1.55	11.04	0	0	0	0	0	0	0.21	3.8	2.69	0	0	0	0	9	PHYSICAL	NO	M>P; TUBES; BURROW OPENING; VOID; OX CLASTS
EREF3	A	9/22/2000	ST_I	3	>4	>4	6	0.39	12.91	15.25	2.35	14.08	0	0	0	0	0	0	0.06	4.58	2.67	0	0	0	0	5	PHYSICAL	NO	SANDY M>P; TUBES; WORMS @ Z; OX&RED CLASTS
EREF3	B	9/22/2000	ST_I	3	>4	>4	2	1.51	11.06	14.8	3.74	12.93	0	0	0	0	0	0	0.06	4.58	2.99	0	0	0	0	5	PHYSICAL	NO	M>P; OX CLASTS; WORM IN BURROW; SURFACE TUBES
EREF3	C	9/22/2000	ST_I	3	>4	>4	0	0	9.66	14.25	4.58	11.96	0	0	0	0	0	0	0.45	4.69	2.88	0	0	0	0	5	PHYSICAL	NO	M>P; BURROW OPENING; WORMS @ Z; TUBES
EREF4	F	9/22/2000	ST_I	3	>4	>4	0	0	2.85	4.36	1.51	3.6	0	0	0	0	0	0	1.73	4.53	3.43	0	0	0	0	6	INDET	NO	AMBIENT MUD>P; RPD>P; FLUID CLAST LAYER
SEREF1	A	9/22/2000	ST_I	3	>4	>4	4	0.37	8.66	11.39	2.73	10.03	0	0	0	0	0	0	0.91	4.81	3.07	0	0	0	0	6	PHYSICAL	NO	M>P; TUBES; PPA; OX CLASTS; WORM @ Z
SEREF1	B	9/22/2000	ST_I	3	>4	>4	15	0.45	9.89	11.98	2.09	10.94	0	0	0	0	0	0	0.7	3.37	2.29	0	0	0	0	5	PHYSICAL	NO	M>P; OX&RED CLASTS; TUBES; SHELL PIECE; WORM @ Z
SEREF1	C	9/22/2000	ST_I_ON_III	3	>4	>4	0	0	9.84	10.48	0.64	10.16	0	0	0	0	0	0	0.05	4.39	2.17	0	0	0	0	8	PHYSICAL	NO	M>P; PPA; TUBE; VOID
SEREF2	A	9/22/2000	ST_I	3	>4	>4	15	0.54	12.57	16.36	3.8	14.47	0	0	0	0	0	0	0.64	7.01	4.72	0	0	0	0	7	PHYSICAL	NO	M>P; TUBES; OX CLASTS; FLUID CLAST LAYER; IRREGULAR MOUND
SEREF2	B	9/22/2000	ST_I	3	>4	>4	0	0	11.87	12.46	0.59	12.17	0	0	0	0	0	0	0.21	4.87	3.66	0	0	0	0	6	PHYSICAL	NO	M>P; PPA; TUBES
SEREF2	C	9/22/2000	ST_I	3	>4	>4	0	0	5.03	7.22	2.19	6.12	0	0	0	0	0	0	NA	NA	NA	0	0	0	0	99	PHYSICAL	NO	M>P; MUD CLAST LAYER; TUBES;
SEREF3	B	9/22/2000	ST_I_ON_III	3	>4	>4	3	0.83	17.97	20.48	2.51	19.22	0	0	0	0	0	0	1.23	8.88	7.27	0	0	0	0	11	PHYSICAL	NO	M>P; OX CLAST; TUBES; SMALL VOIDS
SEREF3	C	9/22/2000	ST_I_ON_III	2	>4	>4	15	0.45	15.83	17.54	1.71	16.68	0	0	0	0	0	0	1.68	3.84	2.77	0	0	0	0	9	PHYSICAL	NO	M>P; OX CLASTS; VOID
SEREF4	A	9/22/2000	ST_I_ON_III	3	>4	>4	6	0.55	14.17	14.81	0.64	14.49	0	0	0	0	0	0	0.42	5.11	3.53	0	0	0	0	10	PHYSICAL	NO	M>P; VOID; TUBES; OX CLASTS
SEREF4	B	9/22/2000	ST_I_ON_III	3	>4	>4	12	0.25	14.28	15.56	1.28	14.92	0	0	0	0	0	0	0.05	3.42	2.26	0	0	0	0	9	PHYSICAL	NO	M>P; OX CLASTS; VOID/BURROW; WORM @ Z
SEREF4	C	9/22/2000	ST_I_ON_III	3	>4	>4	20	0.38	13.53	16.9	3.37	15.21	0	0	0	0	0	0	0.32	6.52	3.19	0	0	0	0	10	PHYSICAL	NO	M>P; VOID; OX CLASTS; TUBES; FLUID CLAST LAYER
SREF2	A	9/22/2000	ST_I	3	>4	>4	8	0.37	6.8	8.03	1.24	7.42	0	0	0	0	0	0	0.39	3.6	2.34	0	0	0	0	5	PHYSICAL	NO	SANDY M>P; TUBES; RED CLASTS
SREF2	B	9/22/2000	ST_I	3	>4	>4	10	0.18	6.8	8.03	1.24	7.42	0	0	0	0	0	0	1.69	4.21	2.92	0	0	0	0	5	PHYSICAL	NO	SANDY M>P; DENSE TUBES; RED CLASTS
SREF2	C	9/22/2000	ST_I	3	>4	>4	8	0.18	7.47	8.48	1.01	7.98	0	0	0	0	0	0	1	3.89	2.58	0	0	0	0	5	PHYSICAL	NO	SANDY M>P; DENSE TUBES; RED CLASTS
SREF3	J	9/22/2000	INDET	-1	>4	>4	0	0	0.06	0.06	0	0.06	0	0	0	0	0	0	NA	NA	NA	0	0	0	0	99	PHYSICAL	NO	HARD BOT; NO PEN; RED CLASTS OR SM ROCKS?; SM ROCKS; SHELLS
SREF4	D	9/22/2000	ST_I	-1	>4	>4	0	0	0.43	2.46	2.03	1.44	0	0	0	0	0	0	NA	NA	NA	0	0	0	0	99	PHYSICAL	NO	M>P; LOW PEN; ROCKS
SREF5	A	9/22/2000	ST_I	3	>4	>4	8	0.45	10.96	12.08	1.12	11.52	0	0	0	0	0	0	0.67	4.38	3.29	0	0	0	0	6	PHYSICAL	NO	M>P; SURFACE TUBES
SREF5	F	9/22/2000	ST_I	3	>4	>4	15	0.81	11.35	13.37	2.02	12.36	0	0	0	0	0	0	1.29	3.65	2.91	0	0	0	0	5	PHYSICAL	NO	M>P; OX CLASTS; TUBES; LG CLAST AT SURFACE ON RT
SREF5	H	9/22/2000	INDET	3	>4	>4	0	0	6.24	7.02	0.79	6.63	0	0	0	0	0	0	NA	NA	NA	0	0	0	0	99	INDET	NO	PPA; FLUID CLAST LAYER

Appendix E
Summary of REMOTS® Results for the PDS Reference Areas
1989 – 2000

Appendix E

REMOTS® Results for the Stations Occupied over the PDS Reference Areas During the 1989 Survey

Reference Area	Camera Penetration Mean (cm)	RPD Mean (cm)	Successional Stages Present	Highest Stage Present	Grain Size Major Mode (phi)	Methane Present	OSI Mean	OSI Median	Boundary Roughness Mean (cm)
EAST REF'89									
CTR	5.83	3.91	I,III	ST_I_ON_III	>4	NO	11	11	2.66
100N	3.43	2.98	I,III	ST_I_ON_III	>4	NO	9	9	0.99
200N	2.55	2.85	I	ST_I	>4	NO	INDET	INDET	1.07
300N	ND	ND	ND	ND	ND	ND	ND	ND	ND
100E	4.38	3.74	I,III	ST_I_ON_III	>4	NO	10	10	0.99
200E	ND	ND	ND	ND	ND	ND	ND	ND	ND
300E	ND	ND	ND	ND	ND	ND	ND	ND	ND
100S	ND	ND	ND	ND	ND	ND	ND	ND	ND
200S	ND	ND	ND	ND	ND	ND	ND	ND	ND
300S	5.48	3.81	I,III	ST_I_ON_III	>4	NO	11	11	1.75
100W	9.4	4.7	I,III	ST_I_ON_III	>4	NO	11	11	0
200W	10.62	4.51	I,III	ST_I_ON_III	>4	NO	11	11	0.23
300W	ND	ND	ND	ND	ND	ND	ND	ND	ND
AVG	5.96	3.79	I,III	ST_I_ON_III	>4	NO	10.5	10.5	1.10
SOUTH REF '89									
CTR	4.19	2.74	I,III	ST_I_ON_III	>4	NO	9	9	0.61
100N	4.76	2.58	I,III	ST_I_ON_III	>4	NO	9	9	0.76
200N	ND	ND	ND	ND	ND	ND	ND	ND	ND
300N	6.17	3.29	I,III	ST_I_ON_III	>4	NO	10	10	0.91
100E	ND	ND	ND	ND	ND	ND	ND	ND	ND
200E	INDET	INDET	INDET	INDET	INDET	INDET	INDET	INDET	INDET
300E	ND	ND	ND	ND	ND	ND	ND	ND	ND
100S	ND	ND	ND	ND	ND	ND	ND	ND	ND
200S	ND	ND	ND	ND	ND	ND	ND	ND	ND
300S	ND	ND	ND	ND	ND	ND	ND	ND	ND
100W	5.26	2.73	I,III	ST_I_ON_III	>4	NO	9	9	1.98
200W	6.47	2.8	I,III	ST_I_ON_III	>4	NO	9	9	0.68
300W	ND	ND	ND	ND	ND	ND	ND	ND	ND
AVG	5.37	2.83	I,III	ST_I_ON_III	>4	NO	9.2	9.2	1.0
SOUTHEAST REF '89									
CTR	11.54	3.52	III	ST_III	>4	NO	10	10	1.9
100N	10.54	4.05	I,III	ST_I_ON_III	>4	NO	11	11	0.61
200N	8.11	3.27	I,III	ST_I_ON_III	>4	NO	10	10	1.45
300N	9.52	4.49	III	ST_III	>4	NO	11	11	1.22
100E	13.31	4.86	I,III	ST_I_ON_III	>4	NO	11	11	0.46
200E	14.08	2.87	I,III	ST_I_ON_III	>4	NO	9	9	0.93
300E	15.82	3.61	III	ST_III	>4	NO	10	10	1.39
100S	11.94	3.6	I,III	ST_I_ON_III	>4	NO	10	10	0.32
200S	15.35	5.77	I,III	ST_I_ON_III	>4	NO	11	11	0.48
300S	ND	ND	ND	ND	ND	ND	ND	ND	ND
100W	8.55	4.02	I	ST_I	>4	NO	7	7	0.7
200W	9.05	3.6	I	ST_I	4 TO 3	NO	6	6	0.48
300W	7.54	2.1	INDET	INDET	4 TO 3	NO	INDET	INDET	0.71
AVG	11.28	3.81	I,III	ST_III	>4	NO	9.6	9.6	0.89

Appendix E

REMOTS® Results for the Stations Occupied over the PDS Reference Areas During the 1992 Survey

Reference Area	Camera Penetration Mean (cm)	RPD Mean (cm)	Successional Stages Present	Highest Stage Present	Grain Size Major Mode (phi)	Methane Present	OSI Mean	OSI Median	Boundary Roughness Mean (cm)
EAST REF '92									
CTR	3.08	3.04	INDET	INDET	3 TO 4	NO	INDET	INDET	2.0
100N	INDET	INDET	INDET	INDET	INDET	INDET	INDET	INDET	INDET
200N	INDET	INDET	INDET	INDET	INDET	INDET	INDET	INDET	INDET
300N	INDET	INDET	INDET	INDET	INDET	INDET	INDET	INDET	INDET
100E	INDET	INDET	III	ST_III	INDET	INDET	INDET	INDET	INDET
200E	INDET	INDET	INDET	INDET	INDET	INDET	INDET	INDET	INDET
300E	3.73	INDET	I,III	ST_I_ON_III	>4	NO	INDET	INDET	2.09
100S	10.6	2.31	I,III	ST_I_ON_III	>4	NO	9	9	0.44
200S	INDET	INDET	INDET	INDET	INDET	INDET	INDET	INDET	INDET
300S	INDET	INDET	INDET	INDET	INDET	INDET	INDET	INDET	INDET
100W	7.4	2.21	I,III	ST_I_ON_III	3 TO 4	NO	8	8	1.42
200W	11.31	2.81	I,III	ST_I_ON_III	>4	NO	9	9	1.02
300W	INDET	INDET	INDET	INDET	INDET	INDET	INDET	INDET	INDET
AVG	7.22	2.59	I,III	ST_III	>4	NO	8.7	8.7	1.41
SOUTH REF '92									
CTR	6.5	2.02	I,III	ST_I_ON_III	>4	NO	8	8	0.83
100N	INDET	INDET	INDET	INDET	INDET	INDET	INDET	INDET	INDET
200N	9.77	1.82	I,III	ST_I_ON_III	3 TO 4	NO	6	6	1.09
300N	17.55	1.85	I,III	ST_I_ON_III	>4	NO	8.5	8.5	1.10
100E	INDET	INDET	INDET	INDET	INDET	INDET	INDET	INDET	INDET
200E	2.56	1.38	I	ST_I	3 TO 4	NO	3	3	1.13
300E	5.93	1.94	I	ST_I	>4	NO	4	4	1.19
100S	INDET	INDET	INDET	INDET	INDET	INDET	INDET	INDET	INDET
200S	INDET	INDET	INDET	INDET	INDET	INDET	INDET	INDET	INDET
300S	2.96	INDET	INDET	INDET	>4	NO	INDET	INDET	0.67
100W	8.2	1.79	I,III	ST_I_ON_III	>4	NO	5.3	5.3	1.15
200W	12.26	1.86	I,III	ST_I_ON_III	3 TO 4	NO	8.5	8.5	0.93
300W	INDET	INDET	INDET	INDET	INDET	INDET	INDET	INDET	INDET
AVG	8.22	1.81	I,III	ST_I_ON_III	>4	NO	6.2	6.2	1.01
SOUTHEAST REF '92									
CTR	17.17	4.79	I,III	ST_III	>4	NO	11	11	0.84
100N	14.99	2.46	I,III	ST_I_ON_III	>4	NO	9	9	0.78
200N	14.78	3.06	I,III	ST_III	>4	NO	10	10	1.17
300N	13.66	3.08	I,III	ST_III	>4	NO	11	11	0.86
100E	18.79	4.91	I,III	ST_III	>4	NO	11	11	1.92
200E	16.91	5.53	I,III	ST_III	>4	NO	9	9	1.41
300E	18.06	5.5	I,III	ST_I_ON_III	>4	NO	11	11	0.95
100S	15.66	2.96	I,III	ST_III	>4	NO	9	9	1.02
200S	12.19	5.45	INDET	INDET	>4	NO	INDET	INDET	0.63
300S	3.21	INDET	INDET	INDET	>4	NO	INDET	INDET	0.58
100W	14.32	2.95	I,III	ST_III	>4	NO	10	10	0.89
200W	12.76	1.75	I,III	ST_I_ON_III	>4	NO	8	8	0.97
300W	10.92	2.51	I,III	ST_III	>4	NO	9	9	0.89
AVG	14.11	3.75	I,III	ST_III	>4	NO	9.8	9.8	0.99

Appendix E

REMOTS® Results for the Stations Occupied over the PDS Reference Areas During the 2000 Survey

Reference Area	Camera Penetration Mean (cm)	RPD Mean (cm)	Successional Stages Present	Highest Stage Present	Grain Size Major Mode (phi)	Methane Present	OSI Mean	OSI Median	Boundary Roughness Mean (cm)
EAST REF '00									
EREF1	10.98	2.21	I,III	ST_I_ON_III	>4	NO	5.67	6	1.74
EREF2	11.37	2.98	I,III	ST_I_ON_III	>4	NO	7.50	7.5	3.04
EREF3	12.99	2.85	I	ST_I	>4	NO	5	5	3.56
EREF4	3.60	3.43	I	ST_I	>4	NO	6	6	1.51
AVG	9.73	2.87	I,III	ST_I_ON_III	>4	NO	6.04	6.12	2.46
SOUTH REF '00									
SREF2	7.61	2.61	I	ST_I	>4	NO	5	5	1.16
SREF3	0.06	INDET	INDET	INDET	>4	NO	INDET	INDET	0
SREF4	1.44	INDET	I	ST_I	>4	NO	INDET	INDET	2.03
SREF5	10.17	3.10	I	ST_I	>4	NO	5.5	5.5	1.31
AVG	4.82	2.86	I	ST_I	>4	NO	5.25	5.25	1.13
SOUTHEAST REF '00									
SEREF1	10.38	2.51	I,III	ST_I_ON_III	>4	NO	6.33	6	1.82
SEREF2	10.92	4.19	I	ST_I	>4	NO	6.50	6.5	2.19
SEREF3	17.95	5.02	I,III	ST_I_ON_III	>4	NO	10	10	2.11
SEREF4	14.87	2.99	I,III	ST_I_ON_III	>4	NO	9.67	10	1.76
AVG	13.53	3.68	I,III	ST_I_ON_III	>4	NO	8.1	8.1	1.97