Monitoring Survey at the
Massachusetts Bay Disposal Site
Fall 2000

Disposal Area Monitoring System DAMOS

D A M O S

DISPOSAL AREA MONITORING SYSTEM

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13. Environmental monitoring of the northeastern quadrant of the Massachusetts Bay Disposal Site (MBDS) was conducted in the Fall of 2000. The purpose of the monitoring was to determine changes in seafloor topography and benthic recolonization since the 1993 baseline survey, using precision bathymetric and Remote Ecological Monitoring of the Seafloor (REMOTS) surveys. Five dredged material mounds (A-E) currently exist within MBDS, formed by the placement of approximately 3.57 million cubic meters of dredged materials over a seven year period. Of this volume, the Boston Harbor Navigation Improvement Project (BHNIP) contributed approximately 2.5 million cubic meters of Boston Blue Clay and glacial till. From January 1994 through 2000 individual disposal mounds were developed in an effort to create a ring of mounds and form an artificial containment cell. Results of the Fall 2000 monitoring effort indicated the formation of four new disposal mounds since September 1993, the largest being MBDS-C (1.38 million cubic meters) which had coalesced with the older MBDS-B mound (850,000 cubic meters) forming the eastern margin of the containment cell. REMOTS sediment profile images collected over the two mounds showed that much of the deposited sediments consisted of Boston Blue Clay, a material which can impede development of stable Stage III populations. As expected, surface sediments of Mounds B and C displayed a benthic community comprised primarily of Stage I polychaetes with some occurrence of Stage III deposit feeders. A higher occurrence of Stage III organisms at the older Mound B was noted. The benthic community status at Mounds B and C appeared to be recovering as anticipated, with Organism Sediment Index (OSI) values ranging from +4.5 to +10, but were lower relative to the surrounding reference areas. It is anticipated recovery at the two mounds will occur over the next few years as Stage III activity becomes more widespread. At reference areas (SE-REF and FG-23), typical background OSI values of ≥+ 6 were noted, which were, however, lower than those encountered in earlier surveys. The lower values were linked to a decline in Stage III organisms, primarily at FG-23, where benthic disturbance relating to lobster fishing activity was noted.

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FALL 2000

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The Massachusetts Bay Disposal Site (MBDS) was monitored by Science Applications International Corporation (SAIC) in the fall of 2000 as part of the Disposal Area Monitoring System (DAMOS). Field operations were concentrated over the active northeastern quadrant of the disposal site and consisted of precision bathymetric and Remote Ecological Monitoring of the Seafloor (REMOTS®) surveys. These surveying techniques were employed to document changes in seafloor topography relative to the 1993 baseline survey, as well as monitor the recolonization of the seafloor subjected to the deposition of large volumes of dredged material.

A total of five discrete dredged material disposal mounds (MBDS-A through MBDS-E) currently exist within the confines of MBDS. These mounds were developed by the placement of approximately 3.57 million cubic meters of sediments removed from the harbors and waterways along the Atlantic Coast of Massachusetts over a seven-year period. By far, the largest single contributor of dredged material was the Boston Harbor Navigation Improvement Project (BHNIP). This infrastructure improvement project yielded approximately 2.5 million cubic meters of Boston Blue Clay and glacial till mechanically dredged from the bottom of Boston Harbor in order to provide the specified control depth, as well as construct large Confined Aquatic Disposal (CAD) cells.

Beginning in January 1994 and continuing through 2000, the DAMOS disposal buoy "MBDA" was strategically placed at several locations surrounding a natural seafloor depression on the MBDS seafloor. Individual disposal mounds of various sizes were developed in close proximity to the MBDA buoy positions in an effort to create a ring of mounds and form an artificial containment cell. Once complete, the artificial containment cell could be used to limit the lateral spread of a future dredged material deposit or be employed as part of a future subaqueous capping project. The success of this mound-complex management strategy was documented during the 1993-94 disposal season at the Central Long Island Sound Disposal Site (CLDS) and has since been adopted at many of the subaqueous dredged material disposal sites in the New England region.

The results of the fall 2000 field effort indicated the formation of four new disposal mounds on the MBDS seafloor since September 1993. The largest disposal mound (MBDS-C) displayed a height of 10 m at the mound apex and a diameter of approximately 750 m along its northwest-southeast axis. Composed of an estimated barge volume of 1.38 million cubic meters of dredged material, the MBDS-C Mound had coalesced with the somewhat older MBDS-B Mound (composed of 850,000 m^3 of sediment) to form a solid beam along the eastern margin of the containment cell.

REMOTS® sediment-profile images were collected over the MBDS-B and MBDS-C Mounds to examine surface sediment composition and evaluate the benthic recolonization status over each disposal mound. The images confirmed the presence of dredged material throughout the survey grid with much of the deposited sediment composed of high-reflectance Boston Blue Clay. Past environmental monitoring surveys at subaqueous dredged material disposal sites have shown that sediments of a glaciomarine origin (i.e., Boston Blue Clay) tend to be very cohesive and devoid of organic matter. Although a firm substrate is ideal for surface dwelling, Stage I benthic infauna and epifauna, this type of material can impede the development of a stable Stage III (burrowing and deposit feeding) population. As a result, dredged material mounds showing a high percentage of glacial clay in the surficial layers often display a slower rate of benthic recolonization relative to typical marine sediment deposits.

In accordance with expectations, the surface sediments of the MBDS-B and MBDS-C Mounds displayed a benthic infaunal community composed primarily of Stage I pioneering polychaetes with some occurrence of Stage III head-down deposit feeders. A spatial trend was noted between the two disposal mounds surveyed as a higher occurrence of Stage III activity was noted at the somewhat older MBDS-B Mound, relative to the stations surrounding the newer MBDS-C Mound. Oftentimes, the depth of bioturbation within the surface sediments was limited to the depth and distribution of clay within the sediment column. Redox Potential Discontinuity (RPD) depths ranging from 1.5 cm to 4.7 cm were detected across the surface of the placed sediments and were often limited by the presence of firm clay, as well.

The benthic community status over the MBDS-B and MBDS-C Mounds appeared to be recovering as anticipated, with Organism Sediment Index (OSI) values ranging from +4.5 to +10, but were lower relative to the surrounding reference areas. The benthic habitat conditions over the two disposal mounds are expected to continue to recover over the next several years, as Stage III activity becomes more widespread and RPD depths deepen as the glacial clay is biologically reworked and additional silts are incorporated through natural deposition.

In general, the benthic environment at the MBDS reference areas continues to display typical background conditions with OSI values ≥+6. However, a comparison of the 2000 sediment-profile photography results with previous data sets show lower OSI values than observed in earlier surveys. The reduced OSI values were linked to a decline in the abundance of Stage III organisms at the SE-REF and FG-23 references areas, relative to historic findings. The low abundance of Stage III organisms was most noticable at reference area FG-23 where some benthic disturbance due to lobster fishing activity was noted.

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 the volumes 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 1-1). These sites are utilized for the cost-effective and environmentally sound disposal of dredged material.

The Massachusetts Bay Disposal Site is one of three regional dredged material disposal sites located off the Massachusetts coast. The MBDS boundary is configured as a circle, centered at 42° 24.106´ N, 70° 34.969´ W (NAD 83), and covers a 10.75 km^2 (3.14 nmi^2) area of seafloor in Massachusetts Bay. It is located approximately 22.2 km (12 nmi) southeast of Gales Point, Manchester, Massachusetts (Figure 1-2). Sediments deposited at MBDS have originated from dredging projects in Boston, Gloucester, and Salem Harbors, as well as various small ports and coastal communities. MBDS was officially designated as an ocean dredged material disposal site by the U.S. Environmental Protection Agency (EPA) in 1993 (EPA 1992; DeAngelo and Murray 1997). Over the past seven years, a total reported barge volume of nearly 3.57 million cubic meters of dredged material was deposited at multiple DAMOS disposal buoy positions (Table 1-1; Appendix A).

In 1992 and 1993, the Third Harbor Tunnel Project was a major contributor of dredged material to the disposal site. Large volumes of Boston Blue Clay, glacial till, and rock removed as part of the project were transported to MBDS for disposal. The blasted rock (approximately 257,000 m^3) was used to construct an artificial reef northeast of the disposal site, while the clay was placed at a DAMOS disposal buoy to form the first dredged material disposal mound (MBDS-A) at the reconfigured MBDS (Figure 1-3). During the mid-1990's (September 1993 through December 1996), small to moderate volumes of dredged material were deposited at the site, with an average annual disposal volume of 59,200 m^3. Infrastructure improvements in the Boston area beginning in 1997 resulted in a dramatic increase in the volume of material transported to and placed at MBDS. A total 3.25 million cubic meters of sediment was deposited at the site over a three-year period (1997 through September 2000), prompting the frequent movement of the DAMOS disposal buoys over MBDS and the development of multiple discrete disposal mounds (Figure 1-4; Table 1-1). The majority of this material consisted of Boston Blue Clay produced by dredging operations in support of the Boston Harbor Navigation Improvement Project (BHNIP).

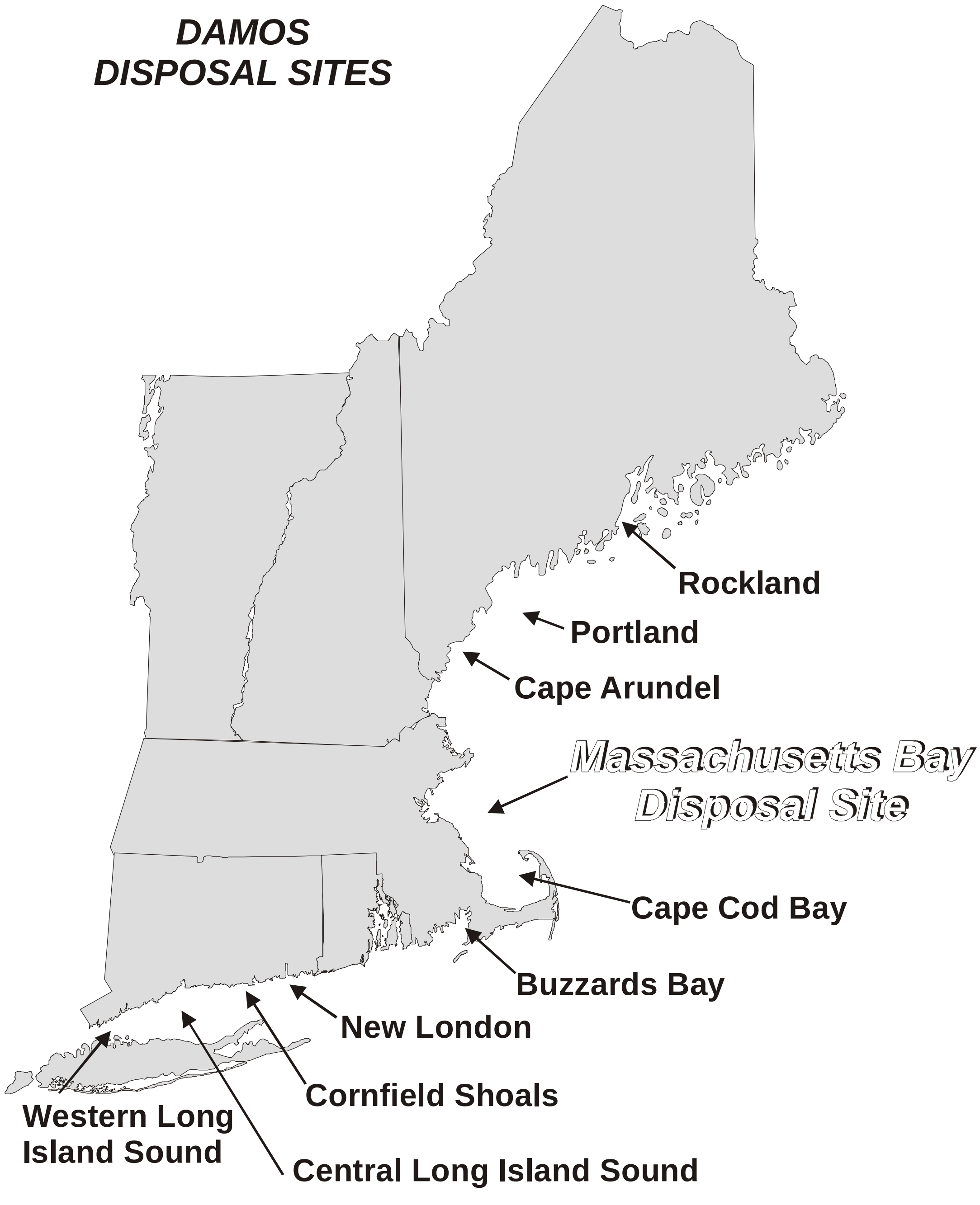


Figure 1-1. Location of the ten regional disposal sites along the coast of New England regularly monitored by the DAMOS Program

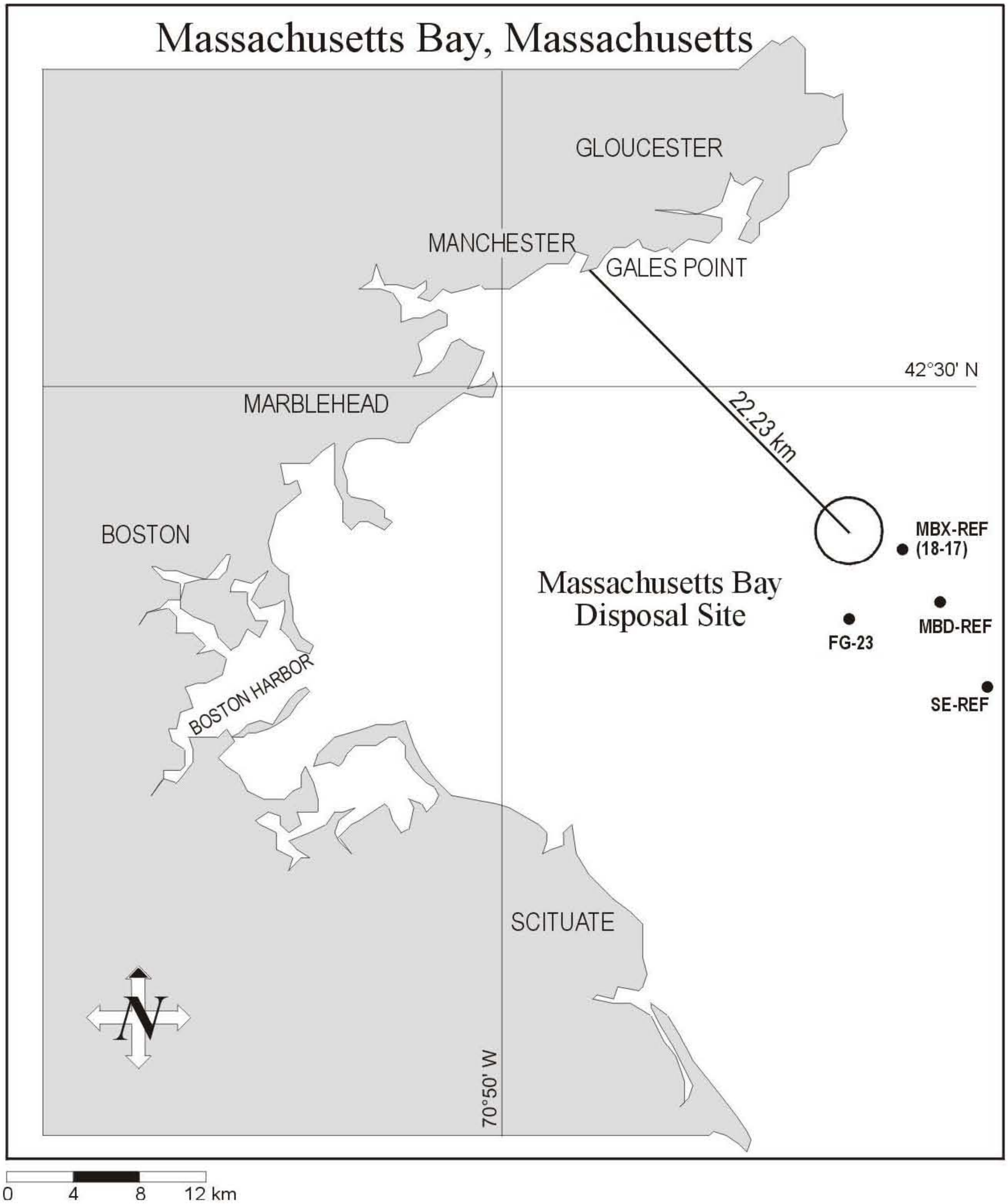


Figure 1-2. Location of the Massachusetts Bay Disposal Site and Reference Areas, relative to the Massachusetts shoreline

Table 1-1

Summary of Dredged Material Disposal at MBDS
1993 through 2000

Massachusetts Bay Disposal Site Disposal Summary			
Disposal Mound	**Buoy Name**	**Reported Barge Volume**	**Dates**
MBDS A	MBDA 93A	26,800 m³	1/7/1993 - 4/4/1993
	Rock Site	256,900 m³ **	
	MBDA 93B	138,300 m³	4/5/1993 - 1/31/1994
	MBDA 94A	23,400 m³	2/1/1994 - 12/15/1994
	Total	**188,500 m³**	
MBDS B	MBDA 94B	38,600 m³	12/16/1994 - 10/24/1995
	MBDA 95	91,800 m³	10/25/1995 - 2/27/1997
	MBDA 97A	143,300 m³	2/28/1997 - 10/7/1997
	MBDA 97B	90,200 m³	10/8/1997 - 2/9/1998
	MBDA 98A	485,500 m³	2/10/1998 - 11/12/1998
	Total	**849,400 m³**	
MBDS C	MBDA 98B	718,800 m³	11/13/1998 - 3/25/1999
	MBDA 99A	659,200 m³	3/26/1999 - 8/2/1999
	Total	**1,378,000 m³**	
MBDS D	MBDA 99B	386,000 m³	8/3/1999 - 10/21/1999
MBDS E	MBDA 99C	152,200 m³	10/22/1999 - 11/28/1999
	MBDA 99D	601,100 m³	11/29/1999 - 6/7/2000
	Total	**753,300 m³**	
MBDS F	MBDA 00A	14,000 m³	6/8/2000 - 9/1/2000
Disposal Site Totals		**3,569,200 m³**	1/1993 - 9/2000
1997-2000 Total Volume		3,250,300 m³	

** not included in totals

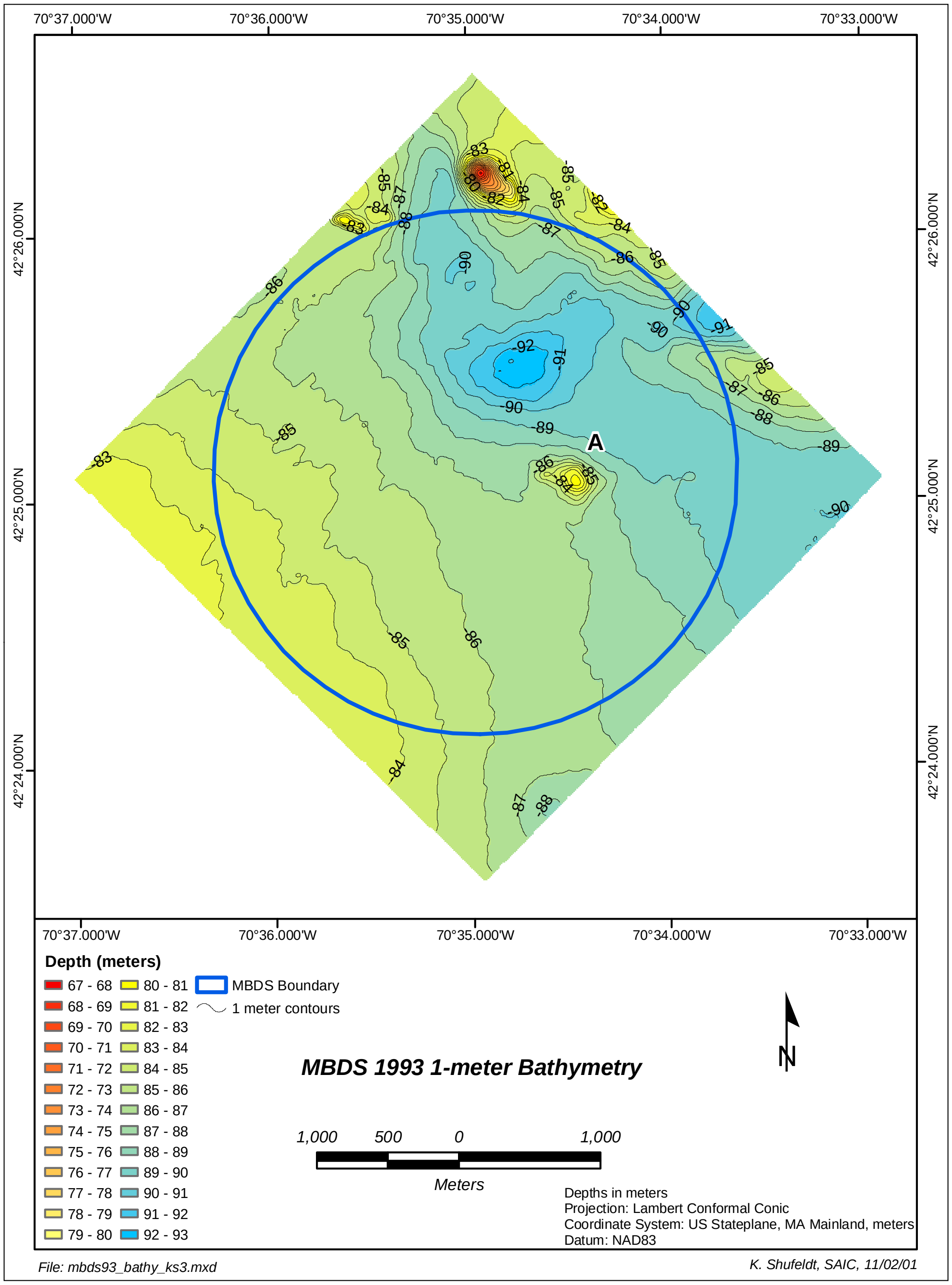


Figure 1-3. Bathymetric contour chart (1.0 m contour interval) of the September 1993 survey area showing one disposal mound (A Mound) within the confines of Massachusetts Bay Disposal Site

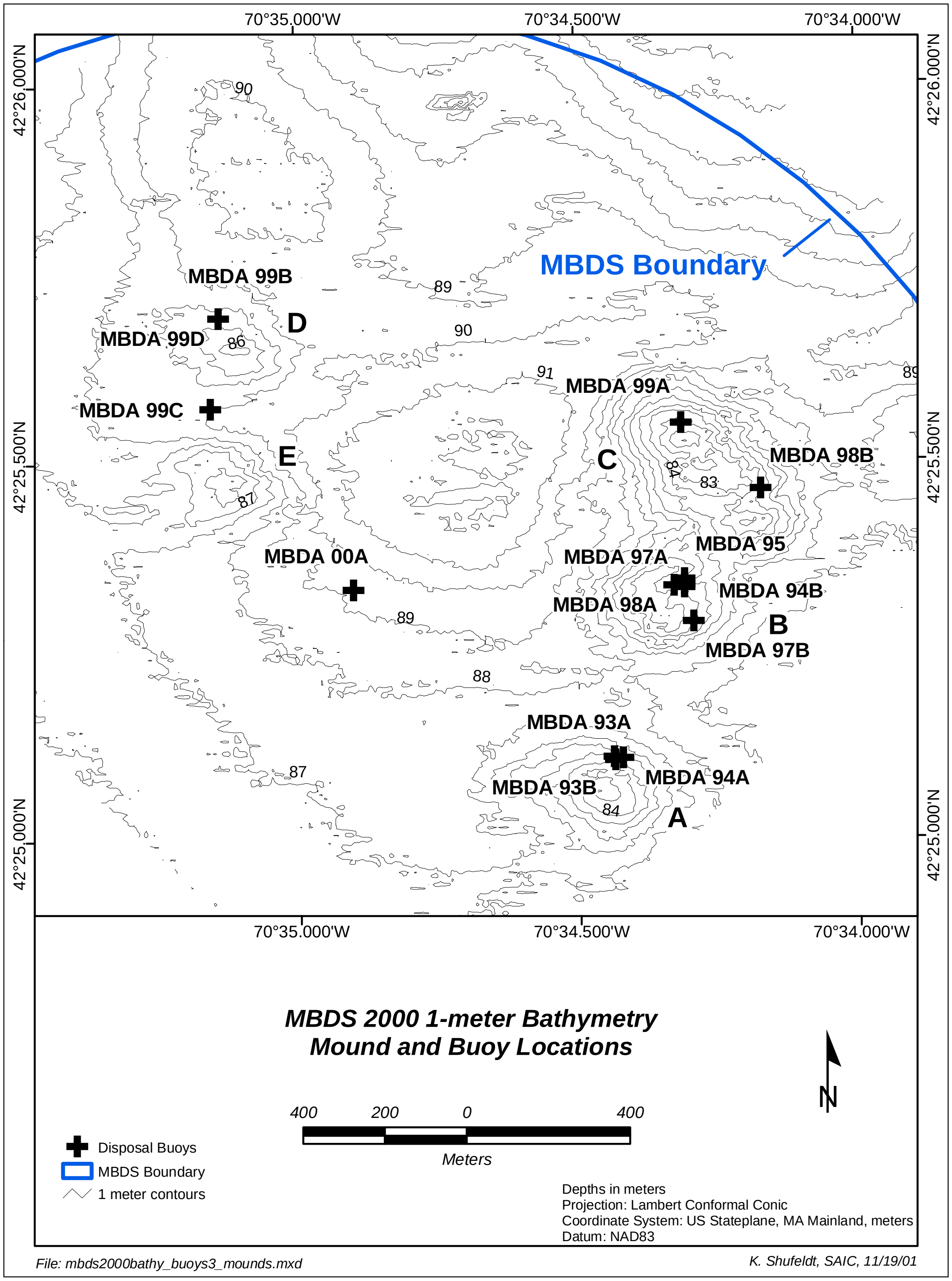


Figure 1-4. DAMOS disposal buoy positions between 1993 and 2000 and resulting disposal mounds formed on the MBDS seafloor, (1.0 m contour interval)

Since disposal operations began in the reconfigured MBDS, the placement of dredged material has been tightly controlled in an effort to develop a ring of disposal mounds on the seafloor (Figure 1-4). Based on the management strategy implemented at the Central Long Island Sound Disposal Site, this network of mounds will eventually form a large artificial containment cell on the seafloor (Morris et al. 1996). The artificial containment cell is to be constructed in a manner that would take advantage of a sizable, natural seafloor depression in the northeastern quadrant of MBDS. Once complete, the containment cell will be capable of accepting a large volume of dredged material, while minimizing the lateral spread of the deposit and reducing the formation of a mound apron. This management technique has been proven to facilitate efficient subaqueous capping operations by concentrating the initial sediment deposit that requires capping. The net result is a reduced need for cap material, while still effectively isolating the entire contaminated sediment deposit from the marine environment.

1.2 Dredged Material Placement at MBDS

Currently, a total of five discrete and distinct dredged material disposal mounds exist on the MBDS seafloor and correspond to the various disposal buoy positions over the past seven years. The MBDS-A Mound is composed of a small volume of dredged material deposited in 1992, as well as an estimated barge volume of 188,500 m^3 of dredged material placed at the 1993 and 1994A positions of the MBDA buoy (Figure 1-4; Table 1-1). From December 1994 to mid-November 1998, a total volume of 849,400 m^3 of sediment dredged from channels and harbors in the region were transported to MBDS and placed on the seafloor, forming the MBDS-B Mound (Table 1-1; Appendix A).

The subsequent disposal mounds (MBDS-C through MBDS-E) were constructed on the MBDS seafloor in a relatively short period of time as the BHNIP contributed large volumes of dredged material from 1998 through 2000. The MBDS-C Mound is the largest of the disposal mounds within the confines of MBDS, composed of nearly 1.38 million cubic meters of dredged material deposited between November 1998 and August 1999 (Table 1-1; Appendix A). The MBDS–D Mound is the smallest disposal mound, composed of approximately 386,000 m^3 of Boston Harbor material placed at the MBDA 99B buoy over a 2.5 month period of time (Figure 1-4; Table 1-1). The MBDS–E Mound represents the last recent sediment deposit constructed within the confines of MBDS as a total estimated barge volume of 753,300 m^3 of dredged material was placed at the MBDA 99C and MBDA 99D buoy positions over the course of 8 months (October 1999 through June 2000). As of 1 September 2000, a sixth disposal mound was being developed on the MBDS seafloor to begin closing an artificial containment cell. At the time of the 2000 environmental monitoring survey, a total volume of 14,000 m^3 from Hingham Bay had been placed at the MBDA 00A buoy to form the first layer of dredged material composing the F Mound (Table 1-1; Appendix A).

1.3 Objectives and Predictions

In the fall of 2000, Science Applications International Corporation (SAIC) conducted a comprehensive monitoring survey at MBDS in support of the DAMOS Program. Data collection efforts were focused in the northeastern portion of the disposal site to document changes in seafloor topography and benthic community recovery following the placement of large volumes of dredged material. Precision bathymetry and sediment-profile photography were utilized to examine the MBDS seafloor in detail and compare the results to previous surveys (1993 and 1994) and the current conditions within the ambient sediments at reference stations outside the disposal site.

The objectives of the 2000 environmental monitoring survey over the Massachusetts Bay Disposal Site were to:

1) document the spatial distribution and morphology of multiple dredged material disposal mounds on the seafloor within the northeastern quadrant of the MBDS; and

2) evaluate the benthic recolonization status over two dredged material disposal mounds developed at MBDS before 1999, relative to the three reference areas surrounding the disposal site.

The fall 2000 field effort tested the following predictions:

- The dredged material deposited at MBDS over the past seven years resulted in the formation of several independent disposal mounds corresponding to the various positions of the MBDA buoy.

- By strategically placing the disposal buoy within the confines of MBDS, placement of dredged material has formed an artificial containment cell on the disposal site seafloor.

- Due to the composition of the deposited sediment, the disposal mounds investigated with sediment-profile photography (MBDS-B and MBDS-C) are expected to be supporting a solid Stage I population with limited progression into Stage II or Stage III communities as predicted by the DAMOS tiered monitoring protocols.

2.0 METHODS

Field operations involving precision bathymetry and sediment-profile photography were conducted at the MBDS aboard the M/V *Beavertail* in fall 2000. The field effort was focused on the northeastern portion of the disposal site to document changes in seafloor topography and benthic community recovery following the deposition of large volumes of dredged material. Although small monitoring efforts were performed over a southern portion of the MBDS as part of the Massachusetts Bay Disposal Site Capping Demonstration Project in 1998 and 1999, the active area of disposal at MBDS was last subjected to environmental monitoring operations in 1994 (SAIC 2001a, Murray 1997).

2.1 Navigation

During the field operations, precise navigation data were provided by a Trimble 4000 RSi Global Positioning System (GPS) receiver interfaced with a Trimble NavBeacon XL differential receiver. Because of its proximity to the survey area, the U.S. Coast Guard differential beacon broadcasting from Portsmouth, NH (288 kHz) was used for generating the real-time differential corrections. During all survey operations, the Trimble DGPS system output real-time navigation data in the horizontal control of North American Datum of 1983 (NAD 83; Latitude and Longitude) at a rate of once per second to an accuracy of ±3 m.

Coastal Oceanographic's HYPACK® survey and data acquisition software was used to provide the real-time interface, display, and logging of the DGPS data. Prior to field operations, HYPACK® was used to define a Universal Transverse Mercator (UTM-Zone 19) grid around the survey area, to establish the planned sediment-profile photography stations and to construct the planned bathymetric survey lines. During the survey operations, the incoming DGPS navigation data were translated into UTM coordinates, time-tagged, and stored within HYPACK®. Depending on the type of field operation being conducted, the real-time navigation information was displayed in a variety of user-defined modes within HYPACK®.

2.2 Bathymetric Data Acquisition and Analysis

2.2.1 Bathymetric Data Acquisition

A 2400 × 2400 m bathymetric survey centered at 42° 25.551´ N, 70° 34.792´ W (NAD 83) was completed over the active area of dredged material placement at MBDS (Figure 2-1). The bathymetric survey consisted of 97 lanes oriented in a northeast/southwest direction, and spaced at 25 m intervals. In addition, survey lines were also run around the perimeter of the survey area to help support the post-processing gridding routines.

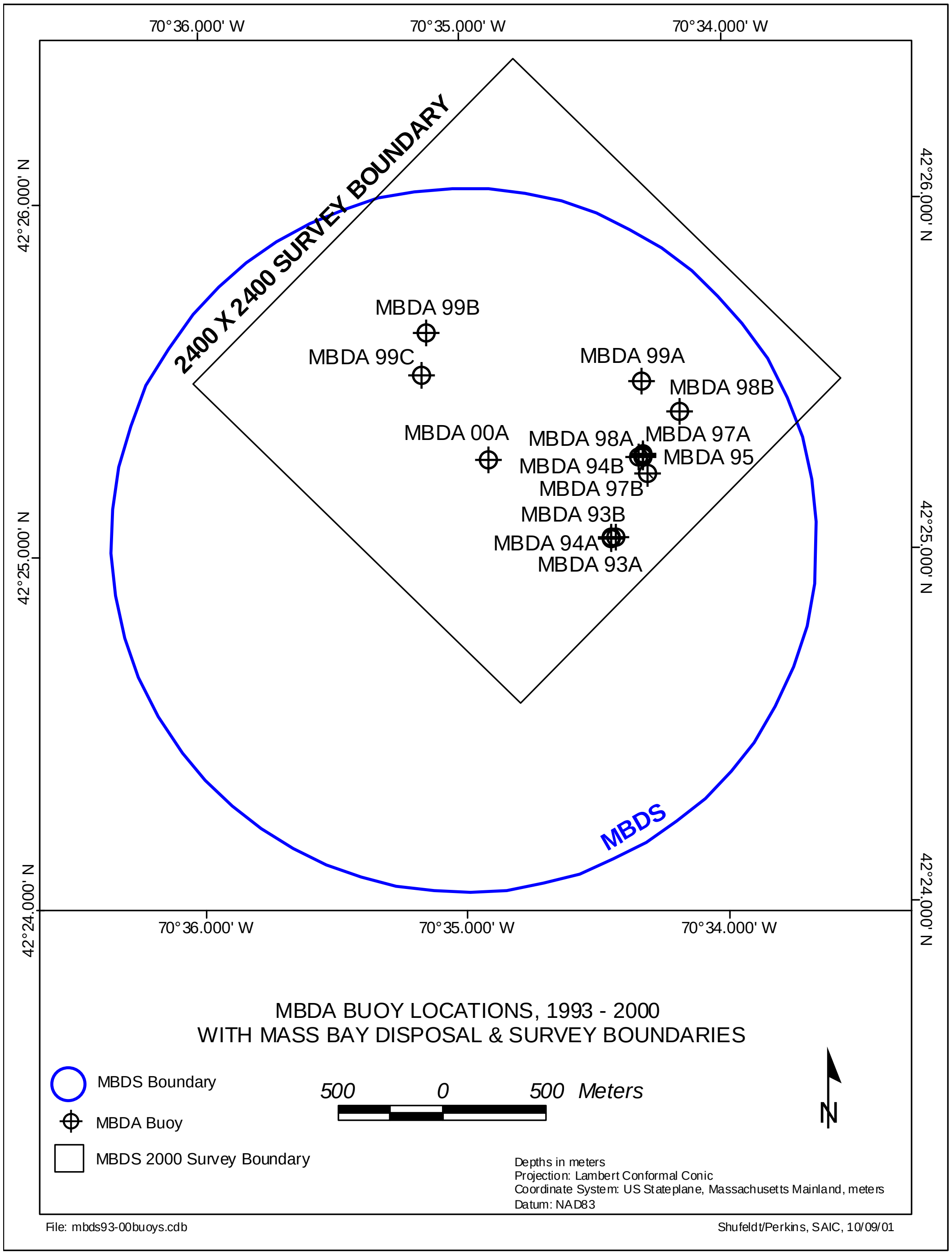


Figure 2-1. 2400 × 2400 m survey area occupied during the September 2000 bathymetric survey and 1993 to 2000 buoy positions relative to current disposal site boundaries

During the bathymetric survey, HYPACK® was interfaced with an Odom Hydrotrac® survey echosounder, as well as the Trimble DGPS. The Hydrotrac® used a narrow-beam (3°), 208-kHz transducer to make discrete depth measurements and produced a continuous analog record of the seafloor. The Hydrotrac® transmitted approximately 10 digital depth values per second (depending on water depth) to the data acquisition system. Within HYPACK®, the time-tagged position and depth data were merged to create continuous depth records along the actual survey track. These records were viewed in near real-time to ensure adequate coverage of the survey area.

2.2.2 Bathymetric Data Processing

The bathymetric data were fully edited and processed using the HYPACK® data processing modules. Raw position and sounding data were edited as necessary to remove or correct questionable data, sound velocity and draft corrections were applied, and the sounding data were reduced to the vertical datum of Mean Lower Low Water (MLLW) using observed tides obtained from the National Oceanic and Atmospheric Administration (NOAA).

During bathymetric survey data acquisition, an assumed and constant water column sound velocity was entered into the Odom echosounder. In order to account for the variable speed of sound through the water column, a Seabird Instruments, Inc. SEACAT SBE 19-01 Conductivity, Temperature, and Depth (CTD) probe was used to obtain sound velocity profiles at the start, midpoint, and end of each field survey day. An average sound velocity was calculated for each day from the water column profile data, and then entered into a HYPACK® sound velocity correction table. Using the assumed sound velocity entered into the echosounder and the computed sound velocity from the CTD casts, HYPACK® then computed and applied the required sound velocity corrections to all of the sounding records.

Observed tide data were obtained through the NOAA National Water Level Observation Network. The NOAA six-minute tide data were downloaded in the MLLW datum and corrected for tidal offsets. SAIC used the water level data available from the operating NOAA tide station in Boston, MA (Station - 8443970) and applied the published time and height corrections based on Gloucester Harbor, MA. After the bathymetric data were fully edited and reduced to MLLW, cross-check comparisons on overlapping data were performed to verify the proper application of the correctors and to evaluate the consistency of the data set.

2.2.3 Bathymetric Data Analysis

The primary intent of the data analysis was to create seafloor surface models from the fully processed bathymetric data, and then to evaluate these models in an attempt to identify any unique features and to account for any observed differences between this survey and the prior 1993 survey. A routine method of accomplishing that goal is to perform depth difference comparisons between similarly gridded data sets from sequential surveys. With this technique, the sorted ASCII-XYZ files were imported into ESRI's ArcView® software, and a grid system was defined over the MBDS survey area. Because the survey track-lines were spaced at 25 m intervals, a cell-size of 12.5 m (along-track) by 25 m (cross-track) was specified to ensure sufficient data coverage to fill each cell. An ArcView® gridding routine was then run to average all of the single-beam data points that fell within each cell and generate a single depth value that was assigned to the center of each cell. The end result of this process was a matrix of depth values that defined a three-dimensional surface model of the survey area. A similar grid-filling process was performed using the 1993 data set. These two grids were then compared (depth differenced) in an attempt to highlight areas of significant change between the two surveys.

2.3 REMOTS® Sediment-Profile Imaging

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 2-2). 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 (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 2001b) and therefore not repeated herein.

A total of 26 REMOTS® sediment-profile photography stations were established over MBDS to evaluate benthic habitat conditions over two dredged material disposal mounds (MBDS-C and MBDS-B). Best effort was made to obtain three replicate images at each station to provide an indication of the consistency of the results. Computed values (e.g., RPD, OSI, etc.) for each of the analyzable replicate images were used to assess the benthic habitat conditions at each station occupied. In order to provide adequate spatial coverage of

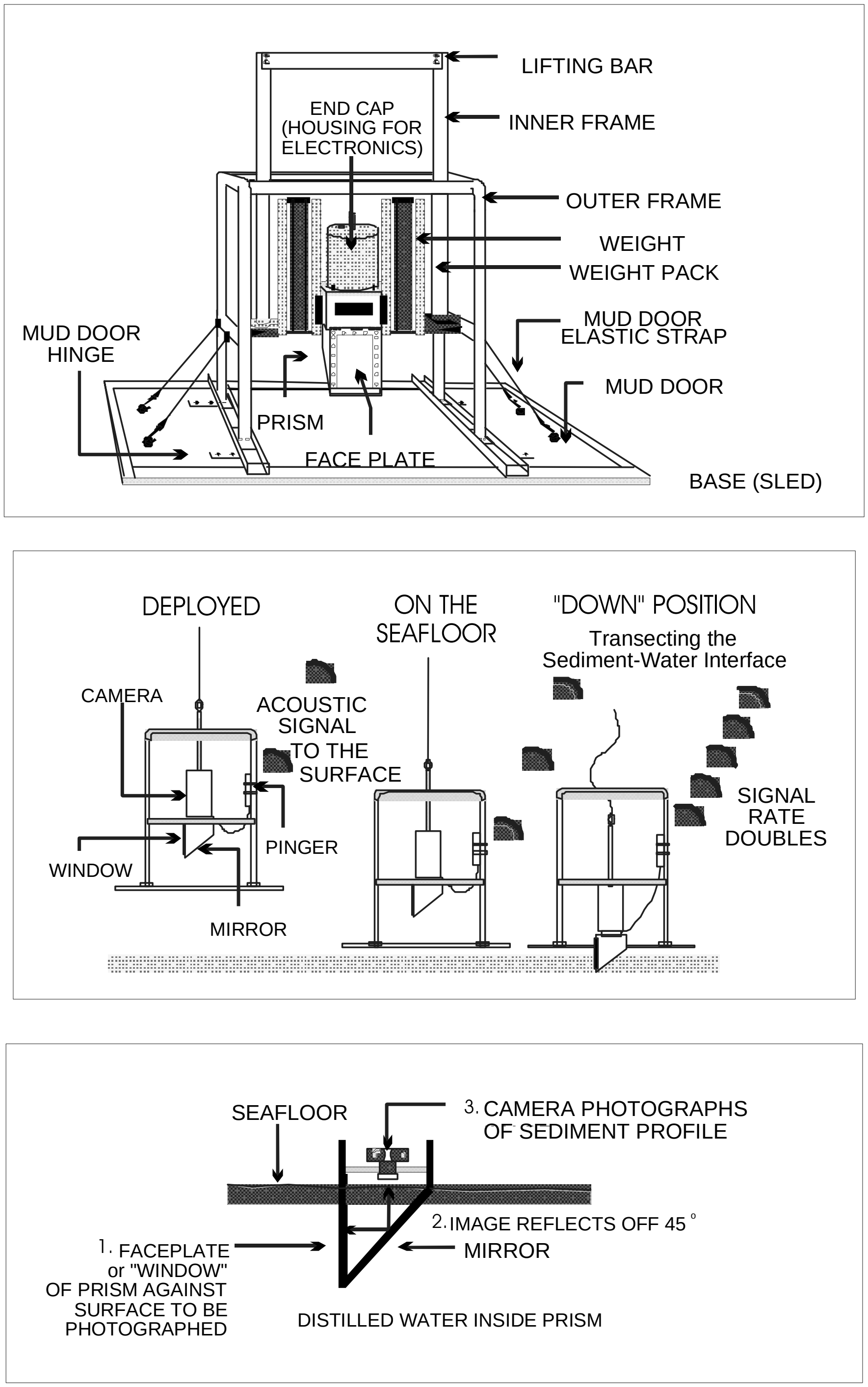


Figure 2-2. Schematic diagram of a Benthos Inc. Model 3731 REMOTS® sediment-profile camera and sequence of operation on deployment

the sediment deposits, two radial sampling grids were merged and modified to minimize station overlap (Figure 2-3). The stations comprising this grid were given the prefix "C" or "B" to indicate their alignment with either the MBDS-C or MBDS-B mounds (Table 2-1).

The MBDS-C grid was centered at 42° 25.461´ N, 70° 34.204´ W (NAD 83) approximately 40 m east-northeast of the MBDA 98-B buoy position (Station C-CTR) and consisted of 14 stations (shown in green and given a "C" prefix in Figure 2-3). The majority of the stations comprising this sampling grid were spaced at 150 m intervals along six radial arms extending 300 m to the north, northeast, east, and northwest. Additional sampling stations were also established 200 m south and west of the center point (Figure 2-3).

The MBDS-B grid was centered at 42° 25.346´ N, 70° 34.359´ W (NAD 83) approximately 40 m west-northwest of the MBDA 98-A buoy position (Station B-CTR) and consisted of 12 stations (shown in red and given an "B" prefix Figure 2-3) spaced at 150 m intervals along four radial arms. The arms of the survey grid extended 300 m to the southeast, southwest, west, and northwest, while the southern arm extended 450 m from the center point.

In addition to the stations established over the disposal mounds, 13 REMOTS® stations were also occupied within several MBDS reference areas located outside the disposal site boundary. Reference data provided insight into the benthic conditions within the ambient sediments and a basis of comparison for the data collected at the disposal site. The survey plan specified sampling of five sediment-profile photography stations at Reference Area FG-23, as well as four stations at SE-REF and four stations at the new MBD-REF. However, it was discovered during the development of this report that an erroneous set of center coordinates within the DAMOS database resulted in sampling of a historic reference area (18-17) rather than the new MBD-REF as originally planned. In 1992, the now historic reference area 18-17 was determined to be no longer representative of ambient conditions (Murray 1994). This reference site was replaced by MBD-REF in 1994 for use in future DAMOS environmental monitoring operations. Originally designated as REF A by the U.S. EPA, MBD-REF is located at 42° 22.706´ N, 70° 30.269´ W (NAD 83) (EPA 1992). Data generated during the field operations pertaining to the erroneous MBD-REF stations have been presented with the prefix MBX-REF.

Due to the sampling of 18-17 (MBX-REF) during the 2000 survey, only the four stations sampled at reference area SE-REF (42° 20.006´ N, 70° 27.969´ W) and five stations occupied at FG-23 (42° 22.706´ N, 70° 34.569´ W) were used in comparison to disposal mound data. However, the four stations sampled at MBX-REF (42° 24.676´ N, 70° 32.769´ W) were useful in re-examining the long-term status of the benthic community within this area of seafloor.

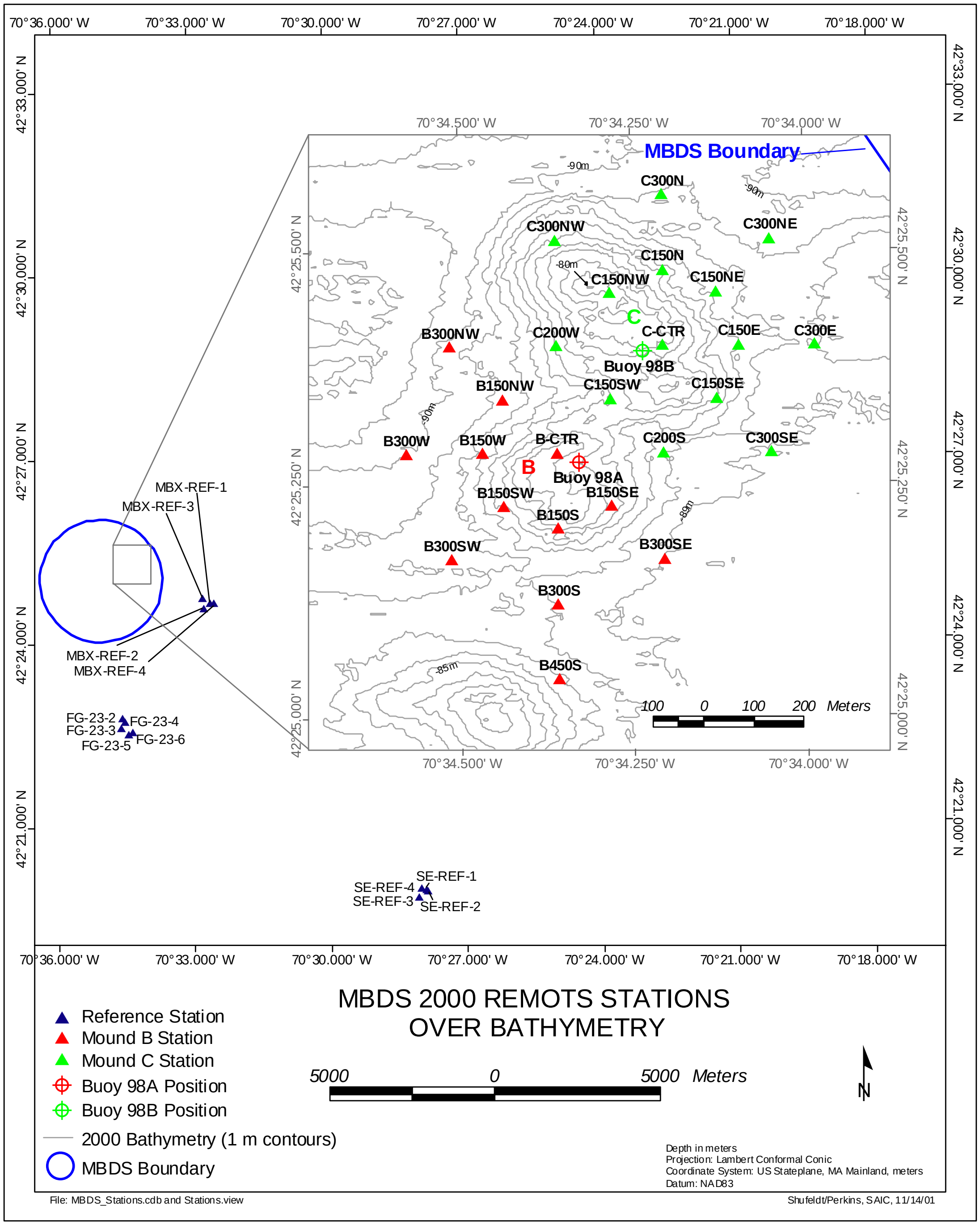


Figure 2-3. Map showing the distribution of MBDS and reference area REMOTS® sediment-profile photography stations. Stations over the MBDS-B (red) and MBDS-C (green) Mounds are shown in detail relative to the MBDS buoy positions and August 2000 bathymetry.

Table 2-1

Massachusetts Bay Disposal Site REMOTS® Sampling Locations

Area	Station	Latitude	Longitude	
		NAD 83		
Disposal Mounds				
MBDS C Mound **42° 25.461´ N** **70° 34.204´ W**	C-CTR	42° 25.461´ N	70° 34.204´ W	
	C150N	42° 25.542´ N	70° 34.204´ W	
	C300N	42° 25.623´ N	70° 34.204´ W	
	C150NE	42° 25.518´ N	70° 34.126´ W	
	C300NE	42° 25.575´ N	70° 34.049´ W	
	C150E	42° 25.461´ N	70° 34.095´ W	
	C300E	42° 25.461´ N	70° 33.985´ W	
	C150SE	42° 25.404´ N	70° 34.127´ W	
	C300SE	42° 25.346´ N	70° 34.049´ W	
	C200S	42° 25.346´ N	70° 34.204´ W	
	C150SW	42° 25.404´ N	70° 34.281´ W	
	C200W	42° 25.461´ N	70° 34.359´ W	
	C150NW	42° 25.518´ N	70° 34.281´ W	
	C300NW	42° 25.575´ N	70° 34.359´ W	
MBDS B Mound **42° 25.346´ N** **70° 34.359´ W**	B-CTR	42° 25.346´ N	70° 34.359´ W	
	B150SE	42° 25.289´ N	70° 34.281´ W	
	B300SE	42° 25.232´ N	70° 34.204´ W	
	B150S	42° 25.265´ N	70° 34.359´ W	
	B300S	42° 25.184´ N	70° 34.359´ W	
	B450S	42° 25.103´ N	70° 34.359´ W	
	B150SW	42° 25.289´ N	70° 34.436´ W	
	B300SW	42° 25.232´ N	70° 34.513´ W	
	B150W	42° 25.346´ N	70° 34.468´ W	
	B300W	42° 25.346´ N	70° 34.577´ W	
	B150NW	42° 25.404´ N	70° 34.436´ W	
	B300NW	42° 25.461´ N	70° 34.513´ W	
Reference Areas				
FG-23 **42° 22.706´ N** **70° 34.569´ W**	FG-23-1	42° 22.578´ N	70° 34.569´ W	*dropped
	FG-23-2	42° 22.846´ N	70° 34.579´ W	
	FG-23-3	42° 22.683´ N	70° 34.587´ W	
	FG-23-4	42° 22.788´ N	70° 34.505´ W	
	FG-23-5	42° 22.581´ N	70° 34.447´ W	
	FG-23-6	42° 22.646´ N	70° 34.345´ W	*added
MBX-REF (18-17) **42° 24.676´ N** **70° 32.769´ W**	MBX-REF-1	42° 24.723´ N	70° 32.613´ W	
	MBX-REF-2	42° 24.643´ N	70° 32.749´ W	
	MBX-REF-3	42° 24.793´ N	70° 32.787´ W	
	MBX-REF-4	42° 24.706´ N	70° 32.536´ W	
SE-REF **42° 20.006´ N** **70° 27.969´ W**	SE-REF-1	42° 20.006´ N	70° 27.911´ W	
	SE-REF-2	42° 19.970´ N	70° 27.884´ W	
	SE-REF-3	42° 19.870´ N	70° 28.074´ W	
	SE-REF-4	42° 20.012´ N	70° 28.037´ W	

3.0 RESULTS

3.1 Bathymetry

Single beam bathymetric soundings were collected at MBDS to define the existing seafloor topography and document changes relative to the September 1993 master survey. The August 2000 survey detected a minimum depth of 67 m over a pronounced glacial feature in the northern corner of the survey area and a maximum depth of 92 m at the base of a natural depression near the center of the survey area (Figure 3-1). In general, the seafloor within this 5.76 km^2 area gradually slopes (0.29° or 0.49% grade) from the margins of the survey towards the center of the survey area.

Five disposal mounds (A-E) surrounding the natural seafloor depression are clearly visible in the contour plot. These bathymetric features are a product of dredged material deposition from 1992 through 2000 and correspond to the reported DAMOS disposal buoy locations for that time period (Figure 3-2). Depth difference calculations based on the September 1993 survey indicate disposal mound peak heights ranging from 3.5 m at the MBDS-D Mound to 9.0 m at the MBDS-C Mound (Figure 3-3). The MBDS-C Mound is the largest of the five mounds, with a diameter of approximately 750 m along the northwest-southeast axis. Disposal records suggest the MBDS-C Mound primarily consists of material removed from Boston Harbor as part of BHNIP. This sediment deposit has coalesced with the MBDS-B Mound, which displays a mound height of approximately 6 m and a width of 500 m. The MBDS-B Mound is composed of nearly 850,000 m^3 of sediment emanating from multiple dredging projects in Massachusetts, including BHNIP and Cohasset Harbor.

The MBDS-D and MBDS-E Mounds are much more subtle deposits, with mound heights of 3.5 and 5 m, respectively (Figure 3-3). These dredged material disposal mounds correspond to the two 1999 positions for the MBDA buoy and are composed of the last of the material excavated as part of BHNIP. In addition, dredging projects at the Pilgrim Electric Nuclear Station and Fort Point Channel contributed a significant volume of material towards the development of these two disposal mounds (Appendix A).

The depth difference calculations also detected approximately 2 m of disposal mound consolidation over the surface of the A Mound. The A Mound was the first sediment deposit formed within the confines of the current MBDS, and has not received any new material since December 1994. Due to the depositional nature of the MBDS seafloor and low bottom current velocities in the region, the apparent reduction in mound height is a product of pore water extrusion over time and does not necessarily indicate movement of material. The areas of apparent accumulation and consolidation in the northern corner of the survey area represent artifacts associated with the high relief of the glacial knoll. Several small-scale survey affects appearing as additional areas of consolidation (0.5 m) were also apparent in

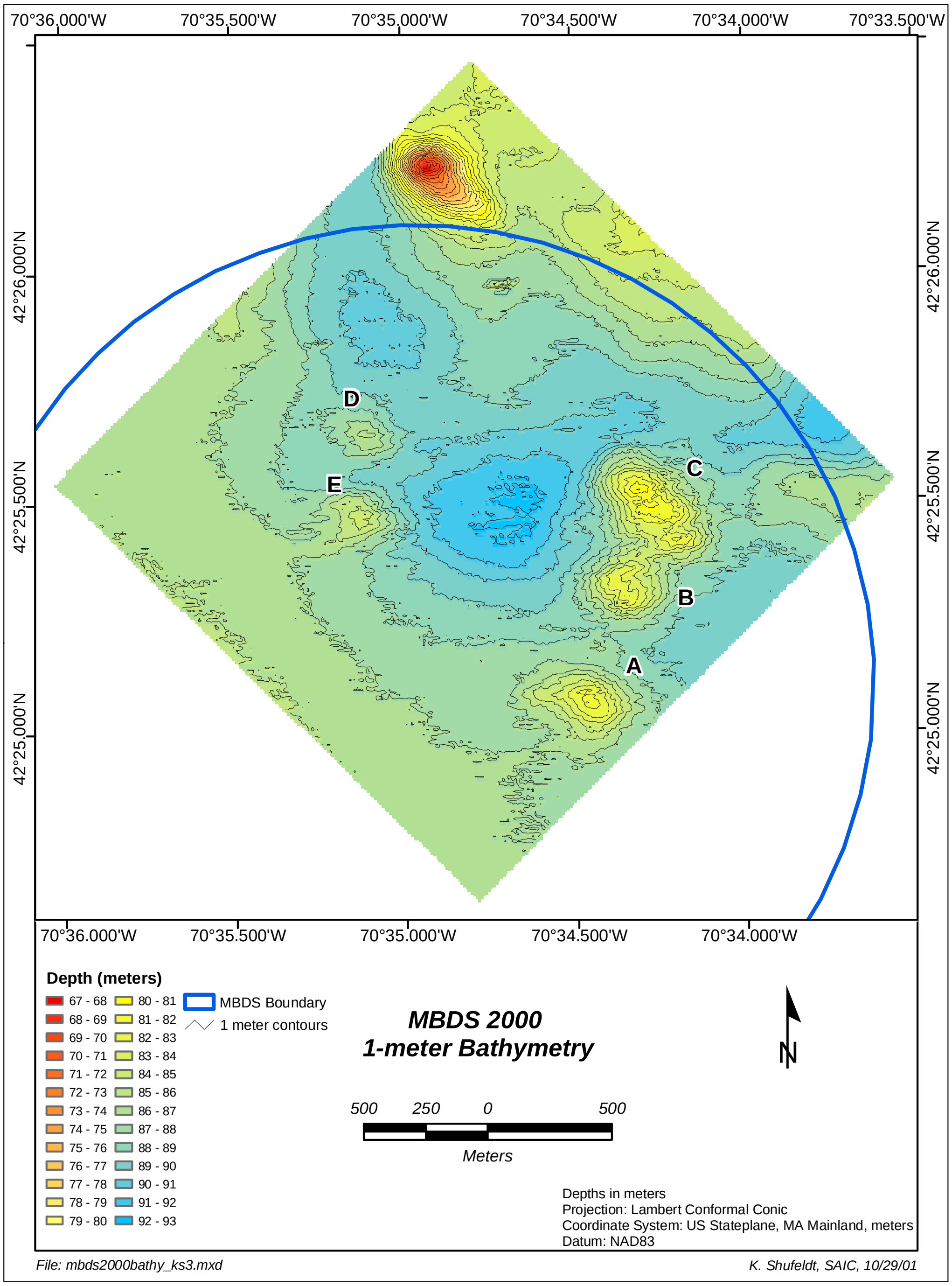


Figure 3-1. Bathymetric contour chart of the 2400 × 2400 m survey area showing five disposal mounds within the confines of Massachusetts Bay Disposal Site, 1.0 m contour interval

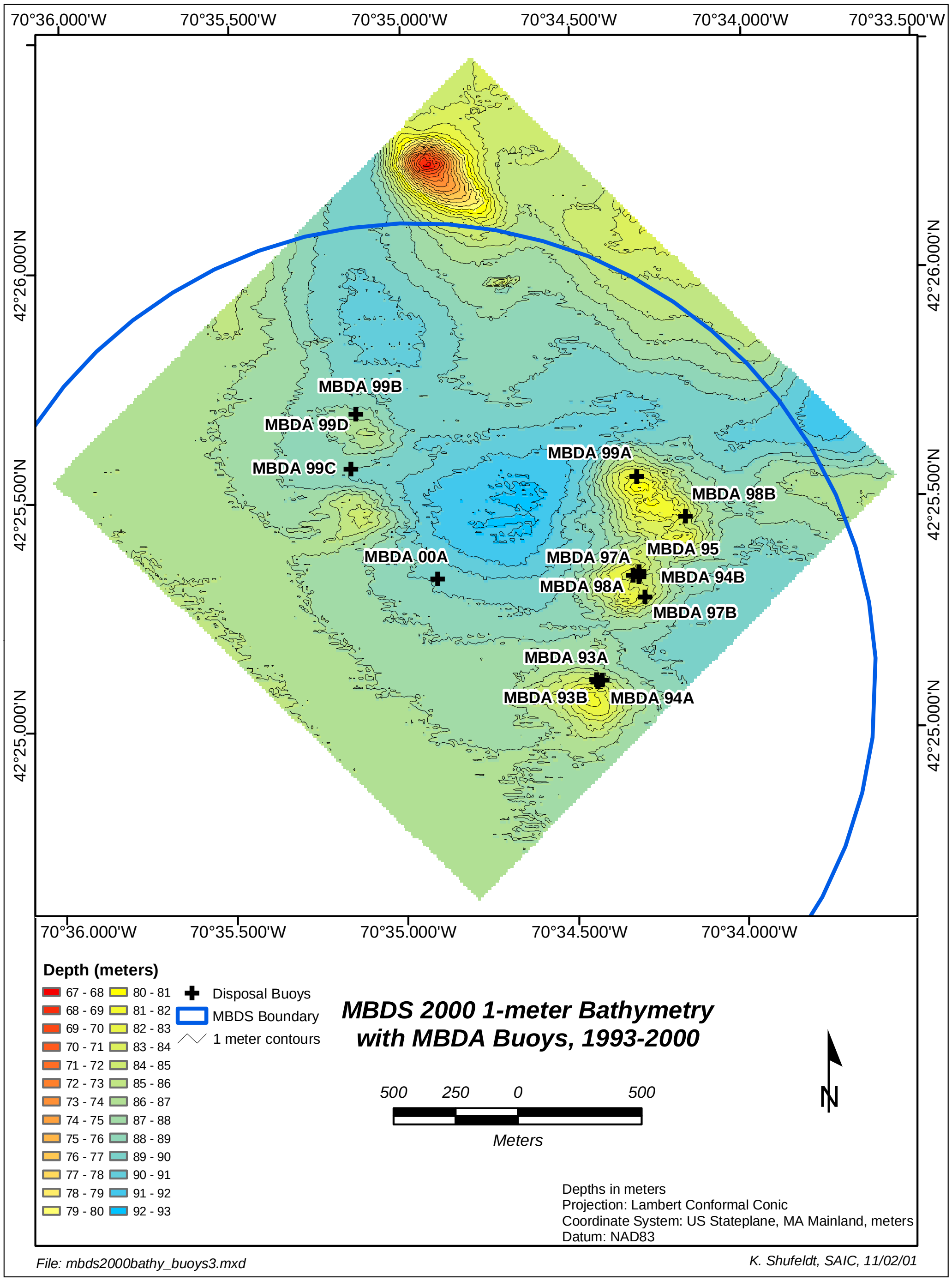


Figure 3-2. Bathymetric contour chart of the 2400 × 2400 m survey area within the Massachusetts Bay Disposal Site, showing disposal buoy positions from 1993 through 2000, relative to detectable bottom features

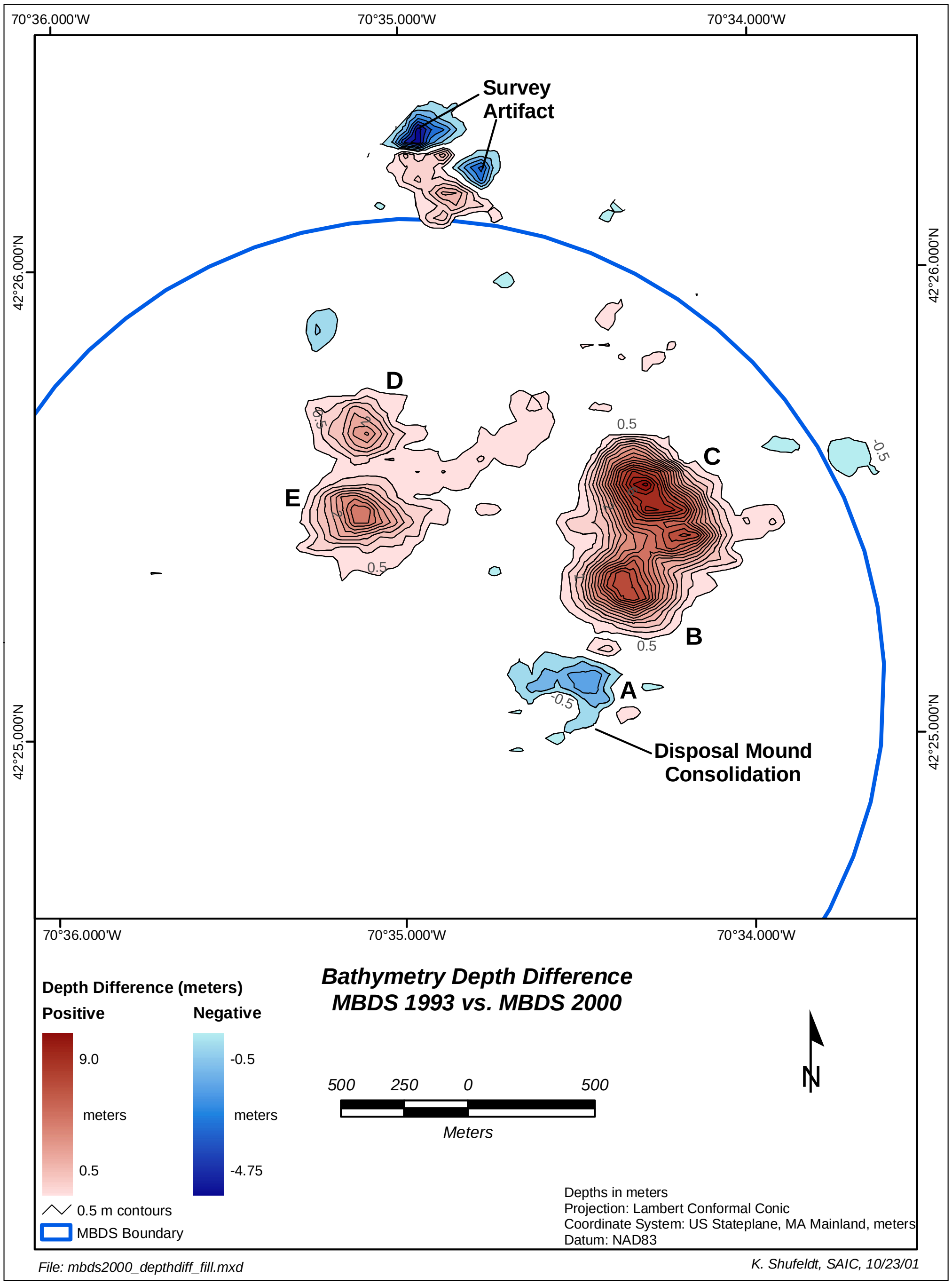


Figure 3-3. Depth difference comparison between the August 2000 and September 1993 bathymetric surveys showing dredged material accumulation (red) over the four most recently created disposal mounds, as well as consolidation (blue) over the MBDS-A Mound constructed in 1992, 0.5 m contour interval.

the depth difference comparisons. These artifacts are attributable to slight differences between the 1993 and 2000 data sets, due to changes in data collection and processing systems.

3.2 REMOTS® Sediment-Profile Imaging

Sediment-profile photography was used to examine sediment composition, benthic recolonization, and infaunal successional status at the MBDS-B and MBDS-C inactive disposal mounds within the boundaries of the MBDS. These results were compared to ambient sediment data obtained from two reference areas surrounding the disposal site (FG-23 and SE-REF). The complete set of REMOTS® image analysis results for the disposal mounds and reference area stations is provided in Appendix B; these results are summarized in Tables 3-1 through 3-3.

3.2.1 MBDS-C Mound

3.2.1.1 Dredged Material Distribution and Physical Sediment Characteristics

Dredged material was evident in the REMOTS® images collected from the stations established over the MBDS-C Mound. The thickness of the dredged material layer exceeded the penetration depth of the REMOTS® camera at all stations (i.e., dredged material greater than penetration). As a result, the dredged material footprint extends beyond the REMOTS® grid established over the MBDS-C Mound and likely overlays the northern flank of the MBDS-B Mound.

Physical REMOTS® parameters indicated the surface and near surface sediment layers at the disposal site were composed mainly of silt and clay. Similar to the reference areas, the major modal grain size observed at all stations was classified as >4 phi, as brown oxidized silt was detected over gray, cohesive clay (Table 3-1). In addition, the fine-grained sediments were often mixed with substantial amounts of very fine sand.

Mean camera penetration depths for most of the MBDS-C stations were relatively high, ranging from 7.5 cm at Station C150SW to 21 cm at Stations C150E, C150SE, C300SE, and C200S (Table 3-1). Due to pockets of soft, unconsolidated sediment at several stations, many replicate images were over-penetrated, obscuring the sediment-water interface and preventing the analysis of RPD, successional status, OSI, and boundary roughness at those stations. Replicate-averaged boundary roughness values over the MBDS-C Mound ranged from 1 cm at Station C300E to 2.8 cm at Station C150SW (1.6 cm average; Table 3-1). In general, boundary roughness values at the disposal site stations were lower than those at the reference areas (2.9 cm average). The surface roughness was classified as physical in the majority of the replicates; however, several replicates exhibited microtopography caused

Table 3-1

REMOTS® Summary Table for the stations over the MBDS-C 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)	OSI Mean	OSI Median	Boundary Roughness Mean (cm)
C-CTR	18.28	>18.28	3	3.84	I	ST_I	>4	6.67	7	1.05
C150N	7.53	>7.53	3	2.38	I	ST_I	>4	5	5	2.50
C300N	19.05	>19.05	3	3.85	I	ST_I	>4	5.5	5.5	1.29
C150NE	17.19	>17.19	3	3.76	I	ST_I	>4	6	6	1.11
C300NE	16.10	>16.10	3	3.56	I	ST_I	>4	6	6	1.20
C150E	21.00	>21.00	3	NA	INDET	INDET	>4	INDET	INDET	INDET
C300E	20.36	>20.36	3	1.54	I,III	ST_I_ON_III	>4	5.5	5.5	1.04
C150SE	21.00	>21.00	3	NA	INDET	INDET	>4	INDET	INDET	INDET
C300SE	21.00	>21.00	3	NA	I	ST_I	>4	INDET	INDET	INDET
C200S	21.00	>21.00	3	NA	I	ST_I	>4	INDET	INDET	INDET
C150SW	7.45	>7.45	3	2.33	I,III	ST_I_ON_III	>4	8.5	8.5	2.78
C200W	16.56	>16.56	3	3.57	I,III	ST_I_ON_III	>4	8	8	1.20
C150NW	14.01	>14.01	3	3.27	I	ST_I	>4	6	7	1.95
AVG	16.96	>16.96	3	3.12				6.35	6.50	1.57
MIN	7.45	7.45	3	1.54				5.00	5.00	1.04
MAX	21.00	>21.00	3	3.85				8.50	8.50	2.78

Table 3-2

REMOTS® Summary Table for the MBDS Reference Areas

Ref Area	Station	Camera Penetration Mean (cm)	RPD Mean (cm)	Successional Stages Present	Highest Stage Present	Grain Size Major Mode (phi)	OSI Mean	OSI Median	Boundary Roughness Mean (cm)
FG-23	2	14.27	4.02	I,II	ST_II	>4	7.33	7	4.57
FG-23	3	10.02	2.91	I,II	ST_I_TO_II	>4	6	6	3.22
FG-23	4	13.36	3.06	I,III	ST_III	>4	6.67	6	1.98
FG-23	5	12.04	2.71	II,III	ST_II_ON_III	>4	8	8	2.84
FG-23	6	16.92	4.29	I	ST_I	>4	6.67	7	1.95
SE-REF	1	12.08	4.17	II,III	ST_II_ON_III	>4	10.33	11	4.07
SE-REF	2	13.05	3.24	II	ST_II	>4	7.67	8	2.79
SE-REF	3	14.63	4.90	I,II,III	ST_III	>4	8.33	7	2.83
SE-REF	4	7.75	2.96	I,II,III	ST_II_ON_III	>4	7	7	1.49
AVG		12.68	3.58				7.56	7.44	2.86
MIN		7.75	2.71				6.00	6.00	1.49
MAX		16.92	4.90				10.33	11.00	4.57

Table 3-3

REMOTS® Summary Table for the stations over the MBDS-B 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)	OSI Mean	OSI Median	Boundary Roughness Mean (cm)
B-CTR	18.74	>18.74	3	2.99	I	ST_I	>4	5	5	0.95
B150SE	11.96	>11.96	3	3.11	I,III	ST_I_ON_III	>4	6.67	7	2.79
B300SE	19.40	>19.40	3	2.29	I	ST_I	>4	4.67	5	0.99
B150S	12.32	>12.32	3	3.26	I,III	ST_I_ON_III	>4	7.33	7	1.74
B300S	18.53	>18.53	3	4.72	I,III	ST_I_ON_III	>4	9.33	10	1.09
B450S	13.64	>13.64	3	3.77	I,III	ST_I_ON_III	>4	7.33	6	1.66
B150SW	13.38	>13.38	3	2.36	I,II,III	ST_I_ON_III	>4	7.33	8	1.36
B300SW	16.14	>16.14	3	1.52	I,III	ST_I_ON_III	>4	7.5	7.5	1.69
B150W	18.92	>18.92	3	2.51	I	ST_I	>4	5	5	1.20
B300W	20.79	>20.79	3	2.41	I	ST_I	>4	4.5	4.5	1.26
B150NW	20.49	>20.49	3	3.18	I,III	ST_I_ON_III	>4	9.5	9.5	1.21
B300NW	16.56	>16.56	3	3.82	I,III	ST_I_ON_III	>4	8.5	8.5	2.72
AVG	16.74	>16.74	3	3.02				6.65	6.73	1.59
MIN	11.96	11.96	3	1.52				4.50	4.5	0.95
MAX	20.79	>21.00	3	4.72				9.50	10	2.79

by biological activity due to the presence of large surface tubes at the sediment-water interface. Sediment surface reworking by organisms was also visible in a number of the replicates. Mud clasts, an indicator of physical activity, were detected in only a few of the stations over the MBDS-C Mound, as well as within multiple replicates collected over the reference areas (Figure 3-4).

3.2.1.2 Biological Conditions and Benthic Recolonization

Three parameters were used to assess the benthic recolonization status and overall condition of the disposal site stations relative to the reference areas: the apparent Redox Potential Discontinuity (RPD) depth, Organism-Sediment Index (OSI), and infaunal successional status. These three parameters were mapped on station location plots to outline the biological conditions at each station at MBDS (Figures 3-5 and 3-6).

The RPD depth was measured on each image to estimate the apparent penetration of oxygen into the sediment. The replicate-averaged apparent RPD measurements for the MBDS-C Mound were relatively deep, ranging from 1.5 cm at Station C300E to 3.9 cm at Station C300N (3.1 cm average; Figure 3-5). These values were slightly shallower, but comparable to RPD depths detected at the FG-23 and SE-REF reference areas (3.6 cm average; Tables 3-1 and 3-2). Low dissolved oxygen conditions, visible redox rebounds, or evidence of methane gas entrained within the sediment were not apparent in any of the replicate images collected over the MBDS-C mound.

The successional stage recolonization status at MBDS-C included principally Stage I pioneering polychaetes at the sediment surface with evidence of Stage III taxa (i.e., head-down, deposit-feeding infauna) inhabiting the subsurface sediments at three of the eleven stations yielding data (Table 3-1). Dominated by Stage I individuals, the stations around the MBDS-C Mound were often densely populated by small, opportunistic polychaetes present at the surface of the dredged material (Figures 3-6 and 3-7A). Stage III activity marked by active feeding voids and burrows in the subsurface sediments were noted at stations C300E, C150SW, C200W (Figures 3-6 and 3-7B).

Many of the images collected from the MBDS REMOTS® stations displayed high reflectance, gray clay at depth. This material is very cohesive, which tends to inhibit colonization by burrowing organisms. In addition, this material typically has lower concentrations of the organic material that would normally be exploited as a food source by deposit feeding invertebrates. As a result, bioturbation is expected to be limited to the material near the sediment-water interface (1 to 3 cm) at stations displaying substantial amounts of clay.

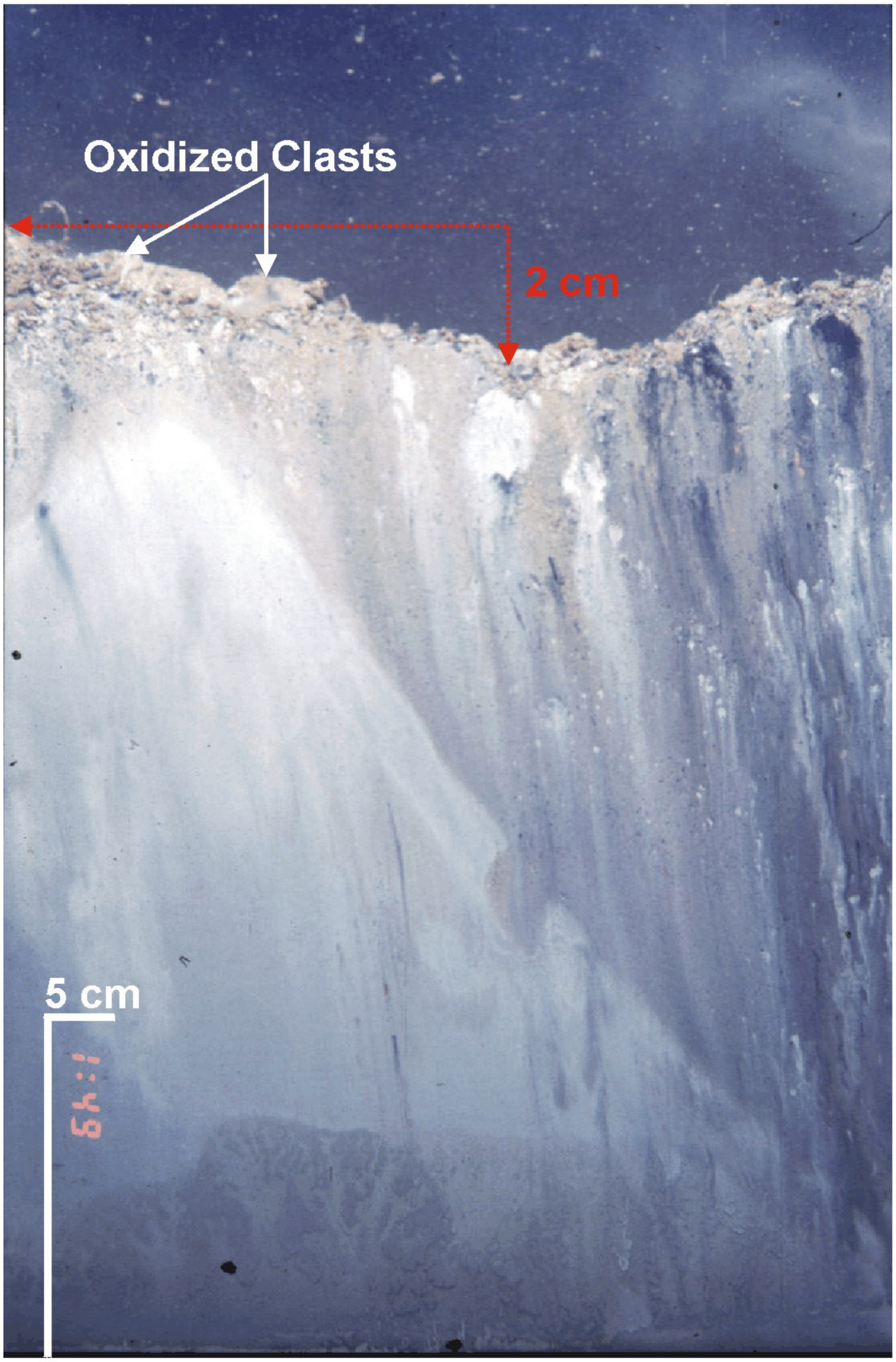


Figure 3-4. REMOTS® image from Station C-CTR displaying high boundary roughness and multiple small, oxidized mud clasts at the surface

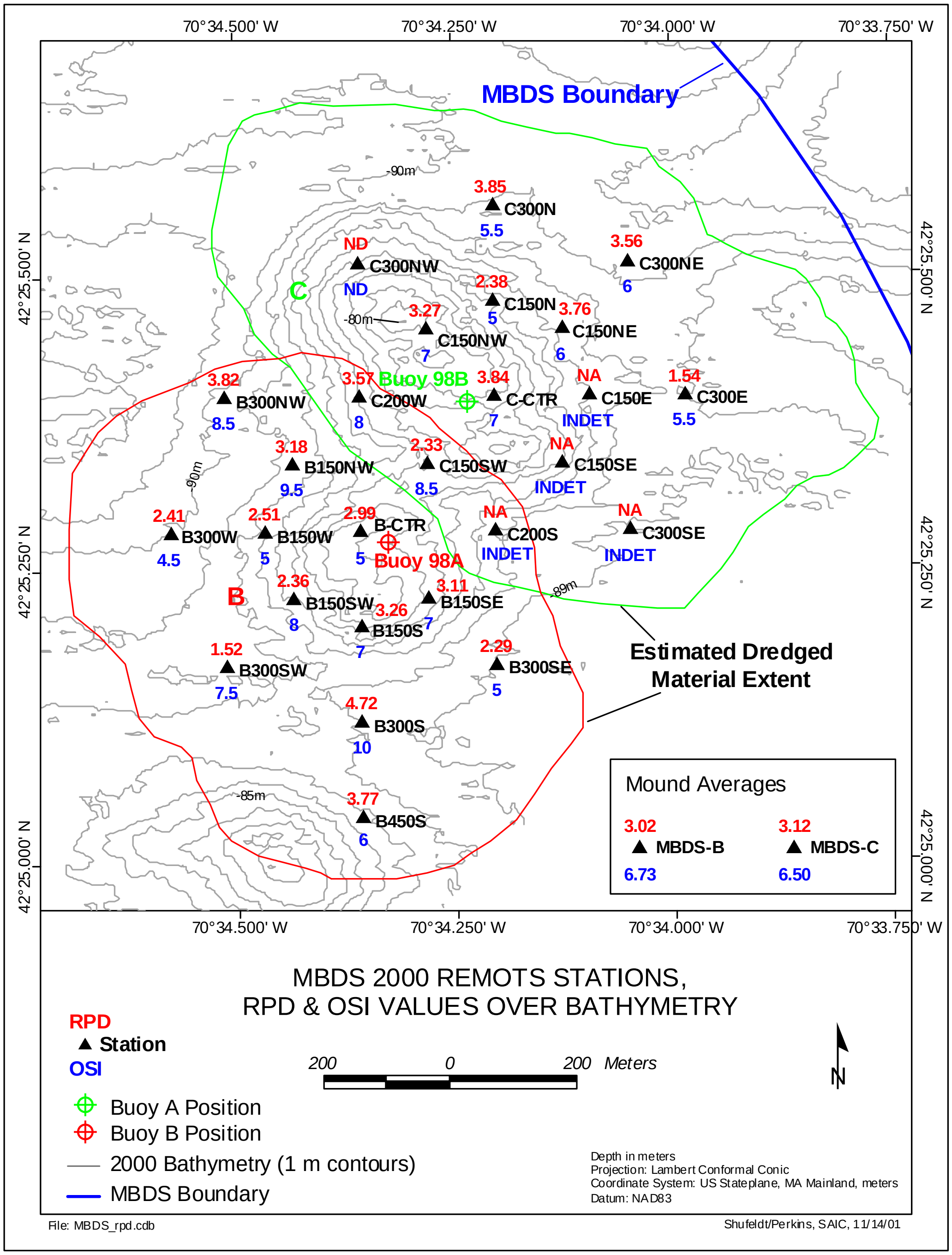


Figure 3-5. Map of replicate-averaged RPD (red) and median OSI (blue) values calculated for the REMOTS® sediment-profile photography stations occupied over the estimated extent of dredged material comprising the MBDS-B (red) and MBDS-C (green) Mounds.

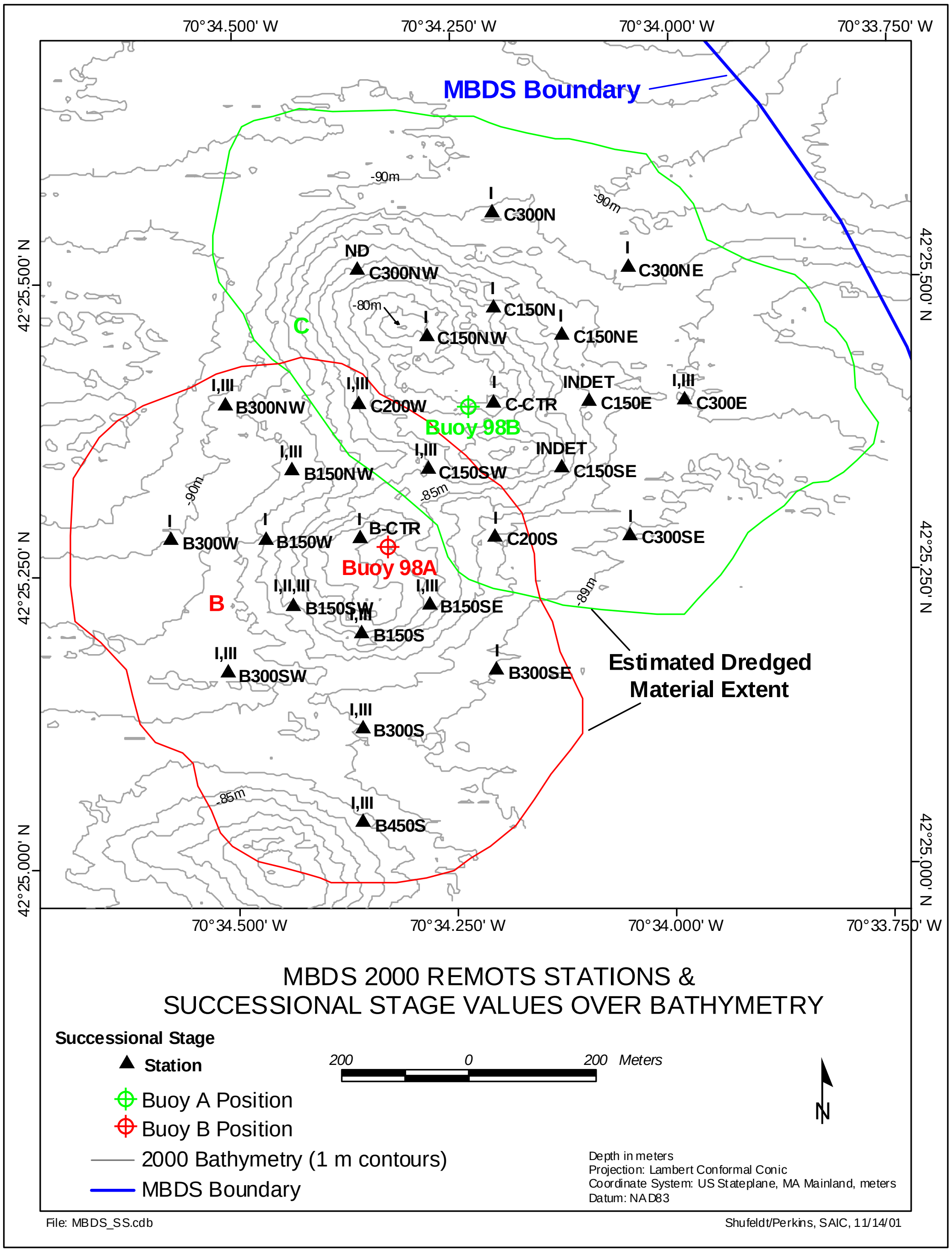
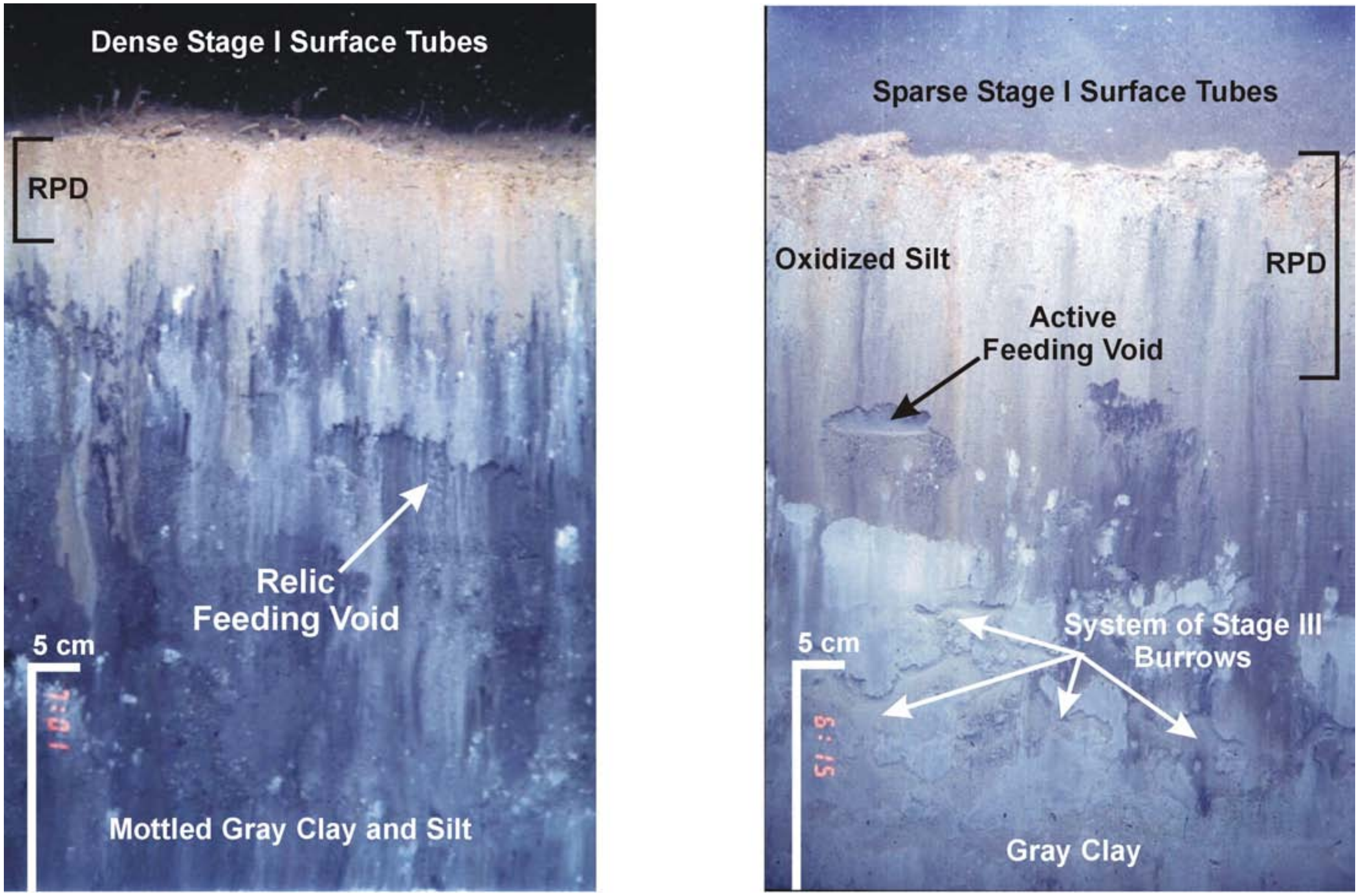


Figure 3-6. Map of the successional stage values for the REMOTS® sediment-profile photography stations occupied over the estimated extent of dredged material comprising the MBDS-B (red) and MBDS-C (green) Mounds.



A **B**

Figure 3-7. Sediment-profile images collected from Station C150NE (**A**) illustrating a stable Stage I population comprised of large, surface tube dwelling polychaetes and Station C200W (**B**) displaying evidence of Stage III activity in the subsurface sediments

Organism-Sediment Index values may range from –10 (azoic with low sediment dissolved oxygen and/or the presence of methane gas in the sediment) to +11 (healthy, aerobic environment with deep RPD depths and advanced successional stages). The OSI values are calculated using values assigned for the apparent RPD depth, successional status, and indicators of methane or low oxygen.

Replicate-averaged median OSI values for the stations over MBDS-C were considered moderate to high for a one-year old dredged material disposal mound, ranging from +5 at Station C150N to +8.5 at Station C150SW (Figure 3-5; Table 3-1). With Stage III activity being relatively scarce, the OSI values calculated for the MBDS-C Mound stations were primarily due to relatively deep RPD depths (3.1 cm). As expected, the disposal site station median OSI values were generally lower than the ambient sediments observed at the reference areas, which had a range of +6 to +11 and an overall average of +7.4 (Table 3-2). However, these conditions are indicative of an area recovering from the benthic disturbance caused by the recent deposition of dredged material

3.2.2 MBDS-B Mound

3.2.2.1 Dredged Material Distribution and Physical Sediment Characteristics

Completed in November 1998, the MBDS-B Mound was formed by the placement of nearly 850,000 m^3 of dredged material over a four-year period. The surface sediment over the MBDS-B Mound is composed of 485,500 m^3 of material dredged from Boston Harbor as part of the initial phases of the BHNIP. The surficial sediment layers of the MBDS-B Mound were quite similar to the material detected over the more recent MBDS-C Mound, as a layer of tan to brown oxidized silt was detected over gray clay, mottled with low reflectance silt and varying amounts of sand. Similar to the MBDS-C Mound, a major modal grain size of >4 phi was observed at all MBDS-B stations (Table 3-3). Dredged material thickness exceeded camera penetration depth in all replicate images. As a result, the dredged material footprint extended beyond the REMOTS® grid established over the MBDS-B Mound and has likely been partially covered by MBDS-C Mound sediments deposited at the MBDS-98B buoy to the northeast (Figure 3-5).

Replicate-averaged camera penetration depths ranged from nearly 12 cm at Station B150SE to 20.8 cm at Station B300W (Table 3-3). Over-penetration of the REMOTS® camera prism was noted in several replicate images collected over the MBDS-B Mound, but was less prevalent relative to MBDS-C, likely due to the age of the disposal mound (two years) and increased consolidation time. Boundary roughness values were quite similar to the MBDS-C Mound, ranging from approximately 1 cm to 2.8 cm (1.6 cm average). Surface roughness was classified as physical in nature at all stations with the exception of B450S, as large tubes at the sediment water interface prompted a biogenic classification (Figure 3-8).

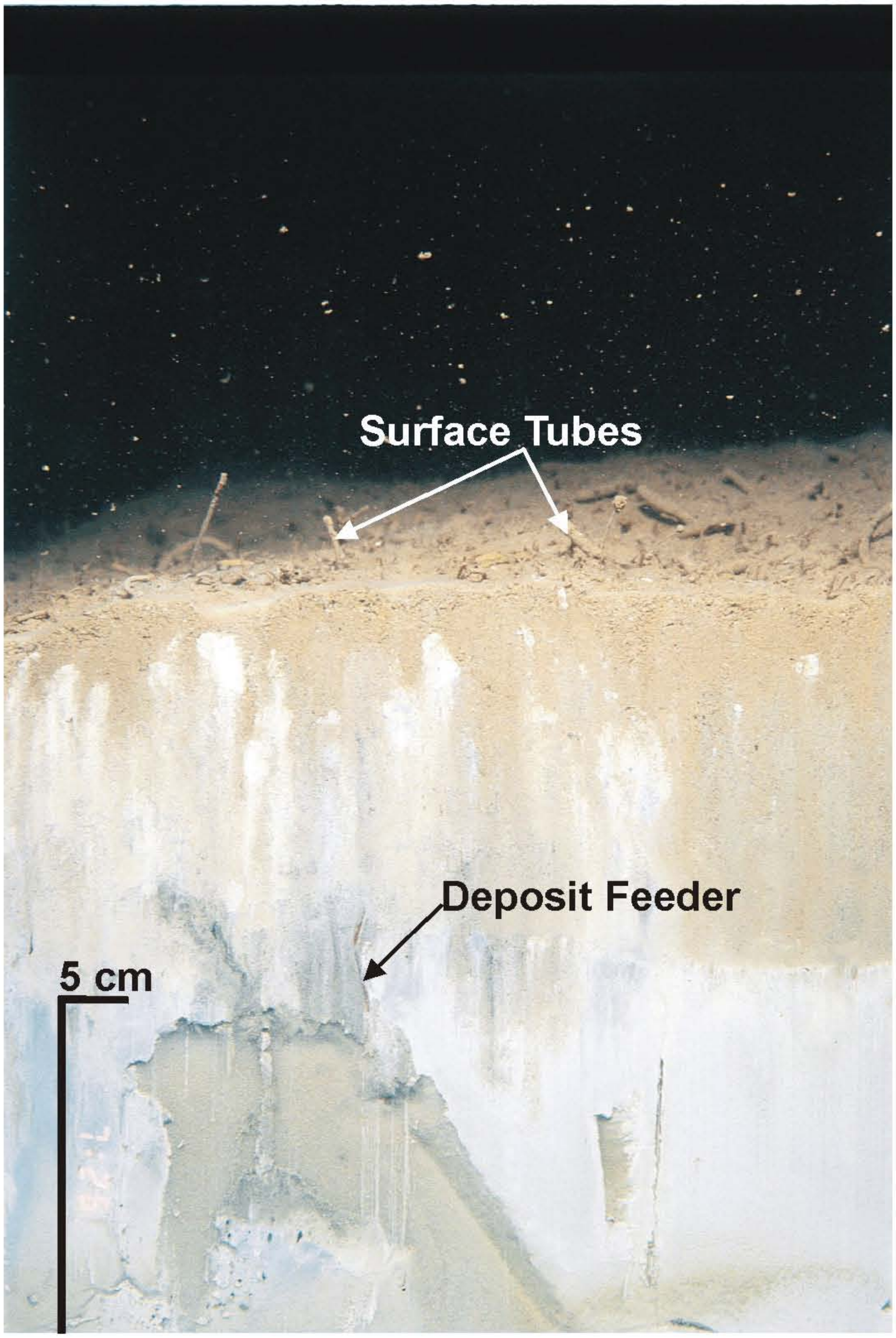


Figure 3-8. REMOTS® image obtained from Station B450S, replicate C showing a biogenic surface roughness due to the presence of large tubes at the sediment water interface. A small deposit feeding polychaete is visible as a red streak at depth within a dark silt deposit surrounded by high reflectance, gray clay.

3.2.2.2 Biological Conditions and Benthic Recolonization

The surface of the MBDS-B Mound appeared to be well-oxygenated, as moderate to deep RPD depths were noted at the majority of the stations occupied during the fall 2000 survey. Replicate-averaged RPD depths ranged from 1.5 cm at Station B300SW to 4.7 cm at Station B300S, with an overall average of 3 cm for the disposal mound (Figure 3-5; Table 3-3). The RPD depths over the MBDS-B Mound were slightly shallower than, but comparable to, values calculated for the FG-23 and SE-REF reference areas (3.6 cm average; Table 3-2). None of the images acquired over the MBDS-B stations displayed low dissolved oxygen conditions, visible redox rebounds, or evidence of methane gas entrained within the sediment.

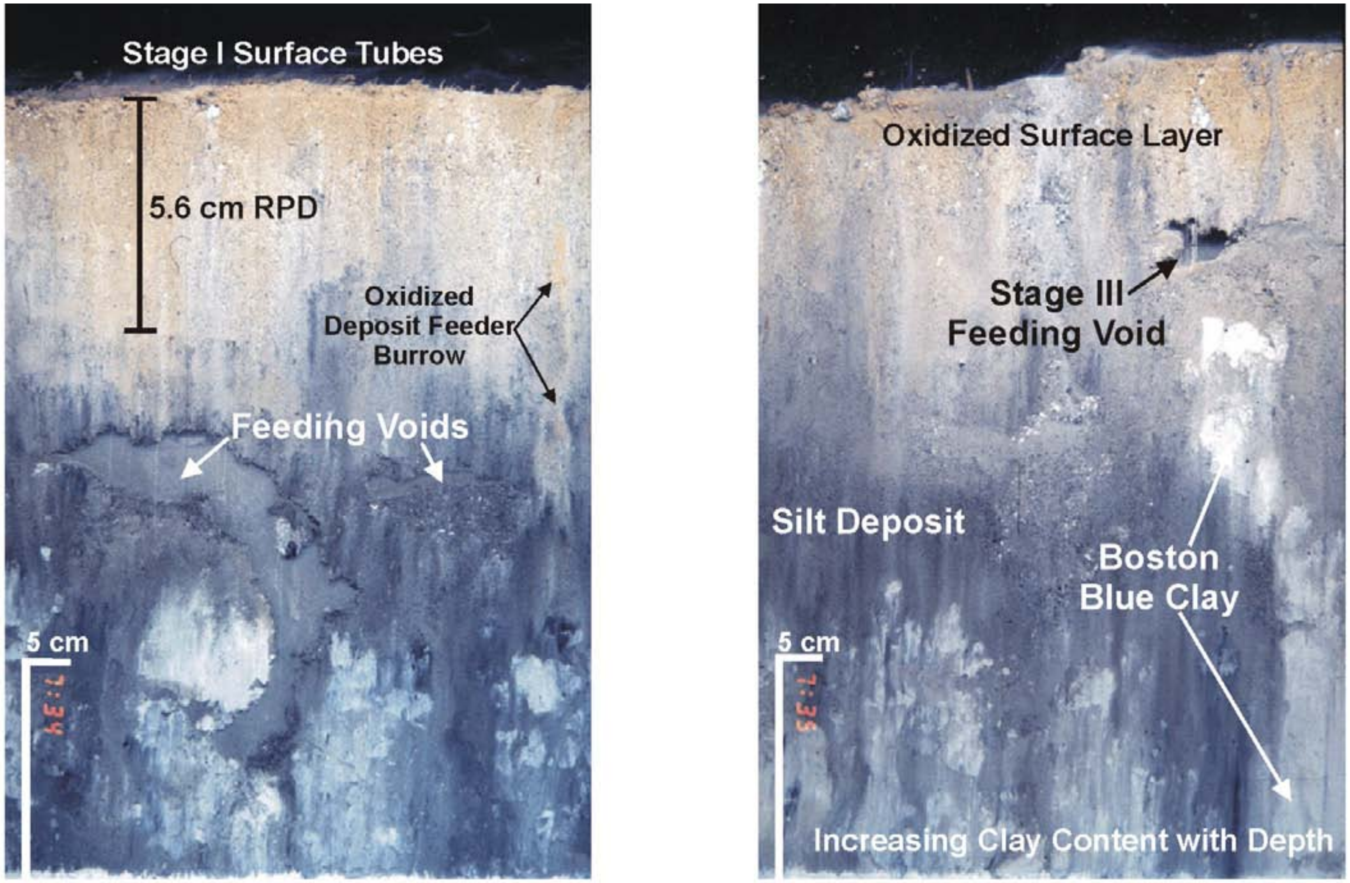
As anticipated, the older MBDS-B Mound appeared to support a more advanced benthic infaunal population in comparison to the MBDS-C Mound. Stage I surface-dwelling polychaetes were noted in all replicate images, and evidence of Stage III activity (subsurface feeding voids and burrows) was detected at eight of the twelve sampling stations over MBDS-B (Figure 3-6; Table 3-3). The development of an advanced benthic infaunal community at the remaining stations (B-CTR, B300SE, B150W, and B300W) may be delayed somewhat by the high percentage of cohesive glacial clay and corresponding lack of organic matter to serve as a food source.

The deep RPD depths and abundance of Stage III activity resulted in the calculation of relatively high OSI values for the surface of the MBDS-B Mound. Overall, the older dredged material deposit showed slightly higher median OSI values relative to MBDS-C, but lower than the composite reference area value of +7.4 (Table 3-2). OSI values over the MBDS-B Mound ranged from +4.5 at Station B300W to +10 at Station B300S, with an overall average of +6.7 (Figure 3-5; Table 3-3). Replicates B and C of Station B300S served as the best examples of the well-developed benthic infaunal population occupying MBDS-B, with the presence of Stage III activity (active feeding voids), deep RPD depths of 5.6 cm and 3.37 cm, and OSI values of +11 and +10, respectively (Figure 3-9).

3.2.3 MBDS Reference Areas

3.2.3.1 Physical Sediment Characteristics

Similar to the findings over the MBDS disposal mounds, fine-grained sediment (silts and clay) characterized the ambient seafloor at the MBDS reference areas. No traces of dredged material or other deposited sediments were evident in any of the analyzed images. Replicate-averaged camera penetration values at sampling stations within FG-23 and SE-REF ranged from 7.8 cm to 20.4 cm (average of 12.7 cm; Table 3-2). Boundary roughness at the reference areas was relatively high, as values ranged from 1.5 cm to 4.57 cm with an



B C

Figure 3-9. Sediment-profile images obtained from Station B300S (replicates B and C) showing deep RPD depths and Stage I over Stage III successional status (surface tubes with active burrows and feeding voids at depth), over a mottled dredged material deposit consisting of dark silt and Boston Blue Clay overall average 2.9 cm (Table 3-2). Small-scale physical disturbance was the primary cause for the surface roughness; however, evidence of active sediment reworking was visible at numerous stations in all the reference areas. The REMOTS® image of Station SE-REF 04C depicts a heavily reworked sediment surface over an active feeding void at depth (Figure 3-10A). In addition, Replicate D of Station FG-23-03 exhibits reworked sediment and rough sediment surface conditions (Figure 3-10B). Some of the fractured and clumping surface sediment may be due to biological reworking, and some may be due to physical disturbance (e.g., fishing activity).

3.2.3.2 Biological Conditions

The replicate-averaged apparent RPD measurements for the two valid MBDS reference areas were relatively deep, ranging from 2.7 to 5.3 cm with a composite value of 3.6 cm (Table 3-2). There were no distinct differences in RPD depth noted between the two reference areas, nor indications of low dissolved oxygen conditions, methane gas, or visible redox rebounds present.

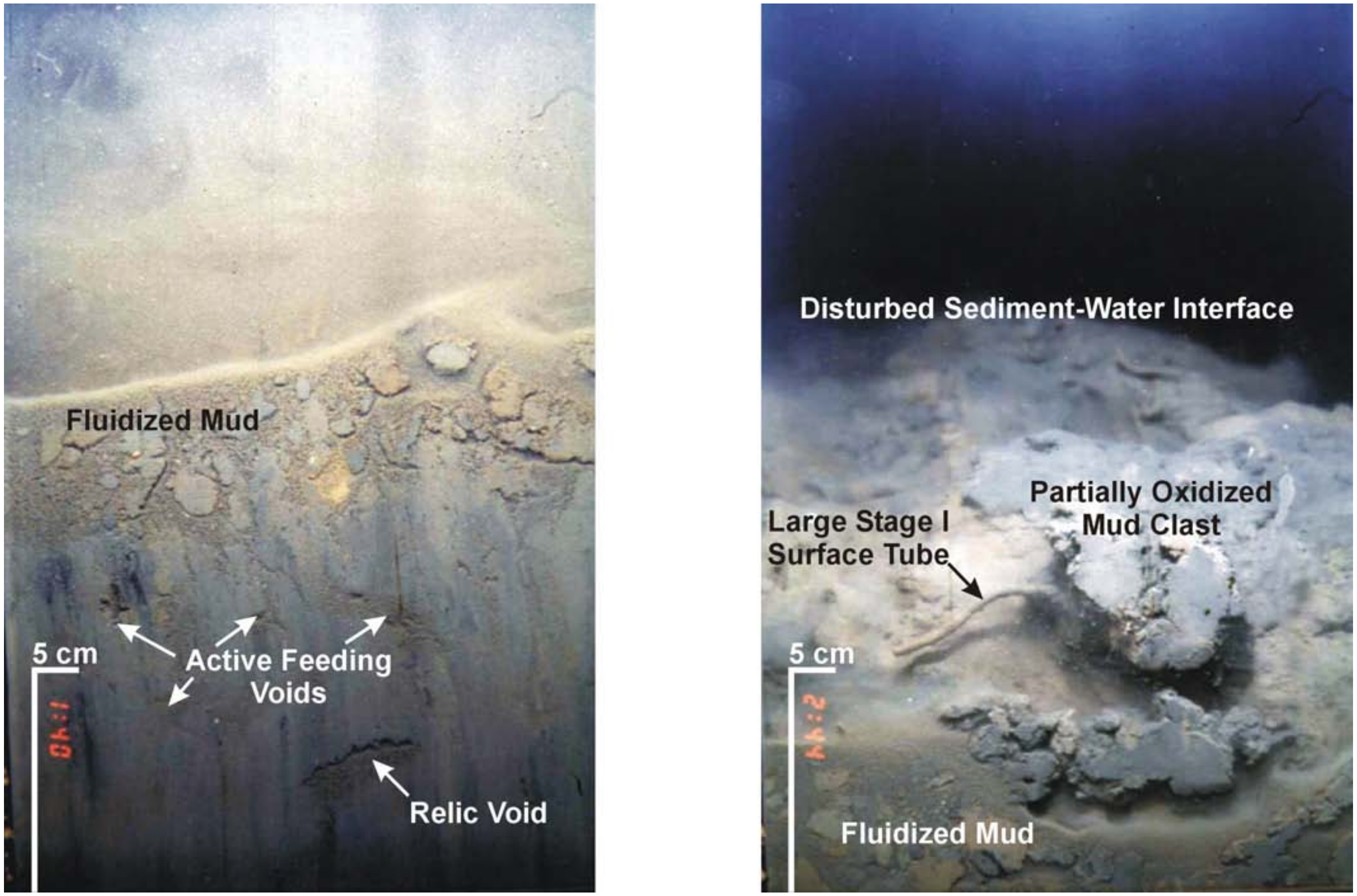
Overall, the reference areas displayed healthy benthic environments capable of supporting a stable infaunal population. A combination of successional stages was observed, with Stage I pioneering polychaetes, Stage II infaunal amphipods, and Stage III head-down deposit feeding invertebrate communities inhabiting the ambient sediments. The majority of Stage I individuals were observed at the FG-23 stations (9 replicates), while Stage II organisms were more prevalent at the SE-REF stations (9 replicates) and evidence of Stage III activity was detected at both reference areas (Table 3-2).

Based on the advanced successional stages and deep RPD depths, OSI values were high for both FG-23 and SE-REF. The median OSI values for the SE-REF stations ranged from +7 to +11, with an average value of +8.3 for this reference area (Table 3-2). The stations at FG-23 displayed slightly lower RPD values along with more Stage I individuals in comparison to SE-REF, and thus yielded lower median OSI values ranging from +6 to +8 (average value of +6.8). The composite OSI value for the reference stations was +7.4, indicative of a healthy benthic environment and slightly higher than the values calculated for the MBDS-B and MBDS-C disposal mounds.

3.2.4 MBX Reference Area

3.2.4.1 Physical Sediment Characteristics

As previously stated in Section 2.3, the data collected from the MBX stations were representative of the historic MBDS reference area 18-17 located approximately 3.5 km west of MBDS. Due to the findings of previous studies performed over 18-17, these data were considered invalid for comparison with the results acquired over the MBDS disposal



A **B**

Figure 3-10. Sediment-profile images obtained from SE REF 04 (**A**) displaying heavy surface reworking with active feeding voids at depth and Station FG-23-03 (**B**) showing recent physical disturbance as indicated by the presence of partially oxidized mud clasts and large worm tubes visible at the sediment-water interface mounds. However, the data set was deemed useful in evaluating benthic habitat conditions at 18-17 since it was last sampled in 1992.

Consistent with the findings within FG-23 and SE-REF, the surficial sediments within MBX (18-17) were composed primarily of fine-grained silts and clay, yielding a major modal grain size of >4 phi. No recent or historic dredged material was apparent in any of the replicate photographs, as brown, oxidized silt was detected over olive gray silty clay (Figure 3-11). Replicate-averaged camera penetration depths were fairly high within the fine-grained sediment, with values ranging between 12 to 20.4 cm and an overall average value of 16.6 cm (Table 3-4). Boundary roughness measurements were found to be small to moderate, ranging from 0.8 to 2 cm, and the origin of the surface roughness was classified as physical in the majority of the replicate images obtained from MBX.

3.2.4.2 Biological Conditions

In general, the RPD depths measured at MBX were quite deep, as replicate-averaged values ranged from 4 cm at Station MBX-REF 02 to nearly 5.3 cm at MBX-REF 04 (average 4.75 cm; Table 3-4 and Figure 3-11). Comparisons to the FG-23 and SE-REF data indicate the depth of oxygenation within the MBX sediments was somewhat deeper than the other reference areas. Low dissolved oxygen conditions, visible redox rebounds, or evidence of methane gas entrained within the sediment were not apparent in any of the replicate images collected.

The benthic infaunal community within the MBX sediments was quite advanced, as Stage II and Stage III organisms were found in relative abundance within the subsurface sediments. Stage I organisms were also detected at the sediment-water interface, but not observed in the dense aggregations detected at FG-23 and within the disposal site. The deep RPD depths coupled with the presence of Stage II and Stage III organisms at MBX-REF served to elevate the median OSI values, which ranged from +7 to +11 (Table 3-4). The overall average for this area of Massachusetts Bay seafloor was +9.5, indicating a healthy, undisturbed benthic environment. In fact, the results calculated for MBX-REF (18-17) indicate benthic habitat conditions exceeded those of both FG-23 and SE-REF.

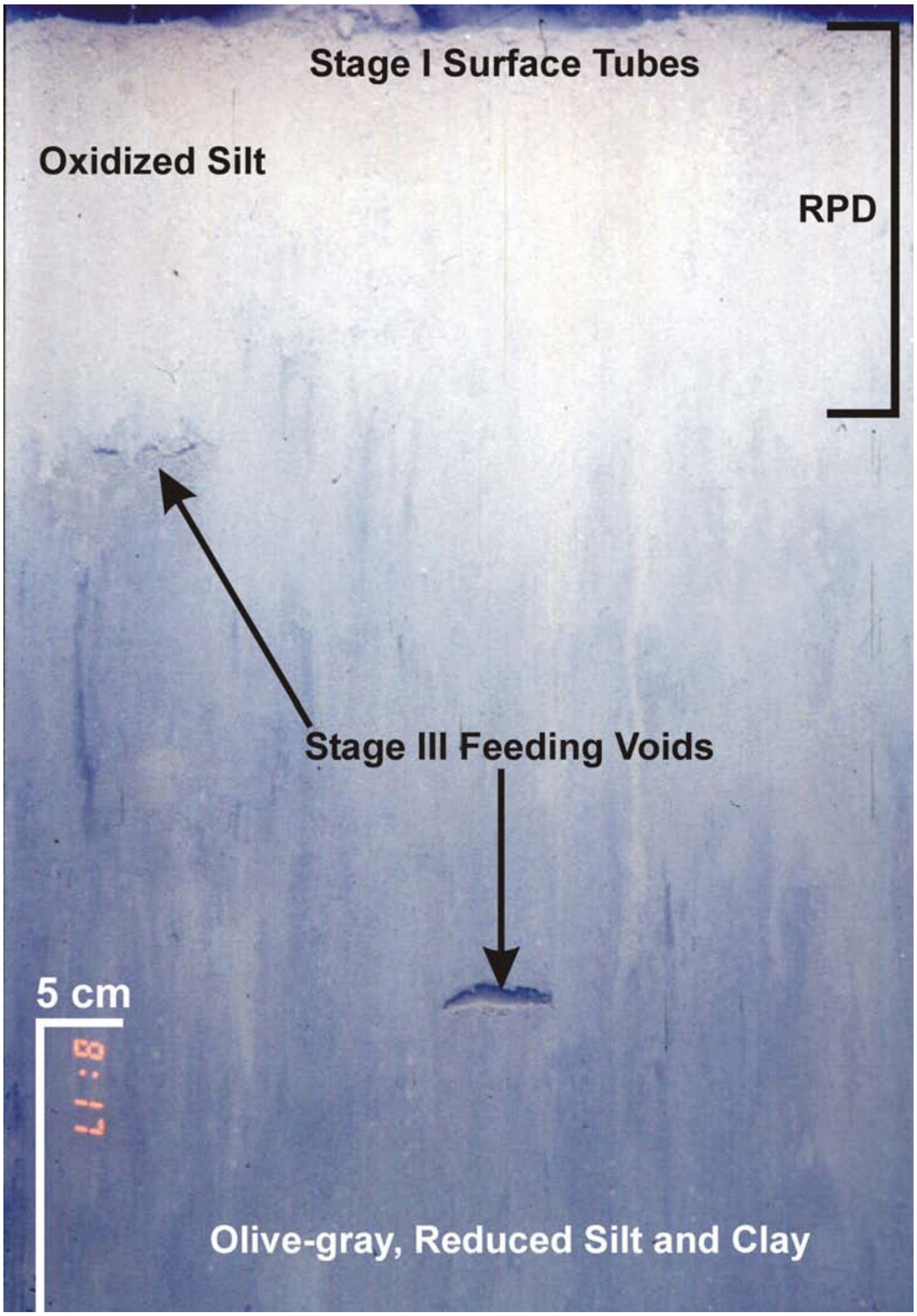


Figure 3-11. Sediment-profile image obtained from Station MBX-REF 04 illustrating the composition of sediment at this historic reference area (18-17), as a tan oxidized surface layer was detected over an olive-gray silty clay. Note the depth of the RPD (5 to 7.5 cm), the presence of Stage I tubes at the sediment water interface, and Stage III feeding voids at depth. The physical and biological conditions displayed in this image equated to an OSI value of +11.

Table 3-4

REMOTS® Summary Table for the MBX (18-17) Reference Area

Ref Area	Station	Camera Penetration Mean (cm)	RPD Mean (cm)	Successional Stages Present	Highest Stage Present	Grain Size Major Mode (phi)	OSI Mean	OSI Median	Boundary Roughness Mean (cm)
MBX-REF	1	19.67	5.13	I,III	ST_I_ON_III	>4	8.33	7	1.39
MBX-REF	2	14.24	4.06	III	ST_III	>4	10	10	2.01
MBX-REF	3	11.99	4.55	I,II,III	ST_II_ON_III	>4	9.33	10	1.26
MBX-REF	4	20.39	5.26	I,III	ST_I_ON_III	>4	11	11	0.82
AVG		16.57	4.75				9.67	9.50	1.37
MIN		11.99	4.06				8.33	7.00	0.82
MAX		20.39	5.26				11.00	11.00	2.01

4.0 DISCUSSION

Boston Blue Clay is a type of glaciomarine sediment deposited approximately 12,000 to 15,000 years ago by melt water expelled from the retreating Laurentide ice sheet; it is similar to other clay formations encountered along coastal New England and Canada (Sugden and John 1990). As the sediment-laden water flowed from the retreating glacier, it became impounded behind large-scale morainal deposits (i.e., Stellwagen Bank and Long Island) forming large freshwater lakes. As the melt water reached the glacial lake, differential settling based on density and particle structure caused the formation of many well-sorted sediment deposits. As would be expected, larger grained material settled close to the source and clay-sized particles were transported furthest from their point origin and eventually deposited in a low-energy environment. The glacial clay formations were composed of many layers of fine, silicate material, which settled out of suspension over time to form thick beds. Due to its origin, glacially derived clay tends to be very cohesive and devoid of organic material.

As the glaciers of the Wisconsin era receded, sea level began to rise and the freshwater glacial lakes became inundated with seawater, changing the sedimentary processes. The resulting marine and estuarine environments were now prone to the deposition of a coarser grained sediment from terrestrial run-off, producing an overburden of sand or organically enriched silt over the clay formation. Maintenance dredging of the channels and anchorage areas within many of the ports of New England requires the removal of this overburden (consisting primarily of silt) through mechanical means. This dredged material is often placed at open water disposal sites and regularly monitored to ensure that benthic recolonization on the sediment deposit follows the criteria set-forth in the DAMOS tiered monitoring protocol (Germano et al. 1994a). However, a need for significantly deeper waterways within these same harbors arises occasionally, prompting improvement dredging which entails excavation of the glacially derived clays and tills to meet the specifications of the new channel design. The BHNIP was one such improvement dredging project, requiring the removal of an estimated barge volume of nearly 2.5 million cubic meters of Boston Blue Clay and glacial till. This material was mechanically dredged from Boston Harbor and transported to MBDS for disposal over the course of 2.5 years. Other infrastructure improvement projects within Boston Harbor (i.e., Third Harbor Tunnel, Conley Terminal, and Fort Point Terminal) also yielded Boston Blue Clay, but in much smaller volumes.

4.1 Distribution of Dredged Material

The 2000 monitoring effort was focused on the active northeastern portion of MBDS to document changes in seafloor topography and benthic community recovery following the deposition of large volumes of dredged material. Depth difference comparisons between the September 1993 and August 2000 bathymetric surveys detected four new disposal mounds on the MBDS seafloor resulting from seven years of dredged material placement. The average diameter of the disposal mounds based on acoustic data was approximately 500 m, with heights above the seafloor ranging from 3.5 m to 10 m. The oldest disposal mound (MBDS-A; developed before the 1993 survey) displayed signs of consolidation, with a 2 m reduction in mound height over the past seven years. The bathymetric data comparisons also indicated that each disposal mound was concentrated near their respective buoy locations. With a height of 10 m at the apex, the MBDS-C Mound displayed a side slope of approximately 1.9° or a 3.3% grade, suggesting the disposal mound will be quite stable. Although the peaks of the other three mounds were not as prominent, each formed a discrete deposit on the seafloor that was similar in shape and appearance to the MBDS-C Mound.

For the past eight years, the management strategy at MBDS was to form an artificial containment cell on the flat seafloor that would eventually provide additional capacity for the placement of dredged sediments. This containment cell would be created by developing a ring of individual disposal mounds around a natural depression on the MBDS seafloor. The coalescing MBDS-B and MBDS-C Mounds form the beginnings of a solid, relatively high (6-10 m) berm along the eastern margin of the containment cell. With continued disposal mound development in the northeast quadrant of the disposal site over the next five to ten years, an artificial containment cell could be completed for use in future subaqueous capping projects or to confine the lateral spread of a non-cohesive sediment deposit (Figure 4-1; Table 4-1).

Table 4-1

Recommended Points for Future Dredged Material Placement

Point	Latitude	Longitude
	NAD 83	
1	42° 25.301´ N	70° 34.727´ W
2	42° 25.851´ N	70° 35.005´ W
3	42° 25.860´ N	70° 34.734´ W
4	42° 25.765´ N	70° 34.402´ W

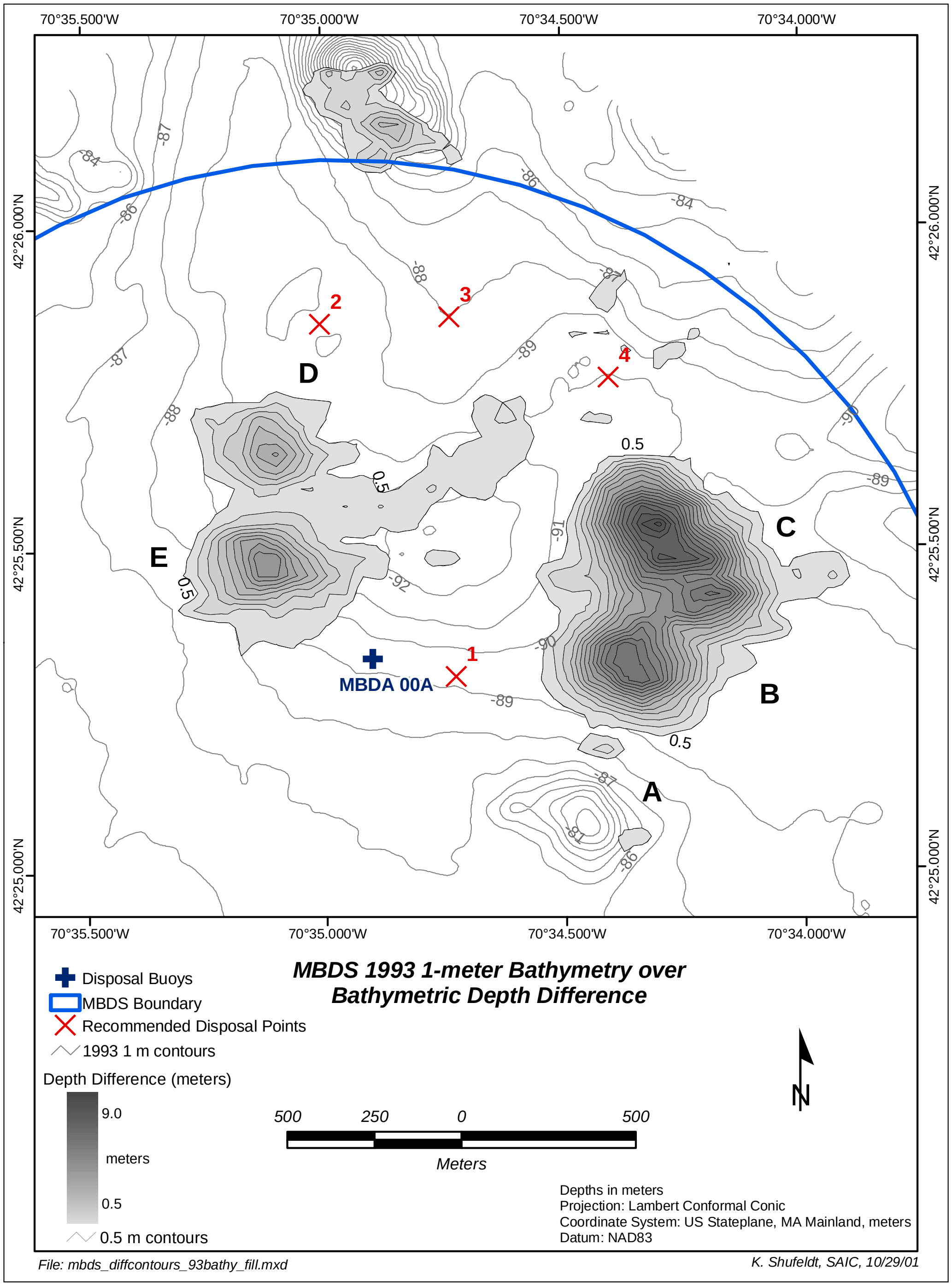


Figure 4-1. Bathymetric plot showing the current configuration of the artifical containment cell at MBDS, as well as the recommended locations for future placement of dredged material

The surface sediment composition of the MBDS-B and MBDS-C Mounds displayed a significant percentage of high reflectance Boston Blue Clay. However, layers of granule, sand, and pockets of silt were detected in multiple replicate photographs confirming the presence of sediment from multiple sources (Figure 4-2; Appendix A). The images collected at the sediment-profile photography stations established around the MBDA 98A and MBDA 98B buoy positions did not extend beyond the area impacted by the placement of dredged material. As a result, the outward extent of the apron for either the MBDS-B or MBDS-C Mounds could not be identified. However, based on the type and volume of sediment disposed, as well as the morphology of the MBDS-B and MBDS-C Mounds, the aprons of dredged material sediment that were too thin to be detected acoustically likely extend 150 to 200 m beyond the 0.25 m base contour of the depth difference plot (Figure 4-3).

4.2 Biological Conditions and Benthic Recolonization

The MBDS-B and MBDS-C Mounds had existed on the MBDS seafloor for a period of at least 13 months prior to the fall 2000 monitoring effort. The 2000 survey over MBDS therefore provided the opportunity to examine an area of seafloor subjected to a large volume of dredged material after sufficient time had elapsed for initial stages of benthic recolonization to occur. Based on the DAMOS tiered monitoring protocol, a one-year old disposal mound is expected to support a stable Stage I community with the presence of a significant number of Stage II and/or Stage III successional seres.

The results of past comprehensive REMOTS® surveys at many of the other New England regional dredged material sites indicate that newly deposited sediments composed primarily of silts frequently supported higher population densities relative to nearby ambient sediments. The dredged material deposits are beneficial to foraging invertebrates by providing a concentrated food source within a competition free space, relative to ambient material (Germano et al. 1994a). As a result, dredged material placement mounds often recover at a rate that meets or exceeds expectations by displaying an advanced and stable benthic infaunal population within six months to one year of placement.

However, previous data have also shown that the cohesive nature of glacially derived clay, as well as the lack of organic material within the deposit, tends to slow the recovery process. Firm glacial deposits that are beneficial for surface tube dwelling, pioneering polychaetes (Stage I) are considered difficult substrata for burrowing infauna (Stage II and Stage III) to establish a niche. In addition, these deposits cannot be exploited as a food source by deposit feeders, thereby limiting the depth of bioturbation. For the 2000 REMOTS® stations displaying considerable amounts of clay, bioturbation was expected to remain at a horizon at or near the sediment-water interface (1 to 3 cm) where brown silt (RPD) was observed over gray clay (Figure 4-4). The limited bioturbation observed among disposal site stations was not necessarily the product of sediment contamination, but rather

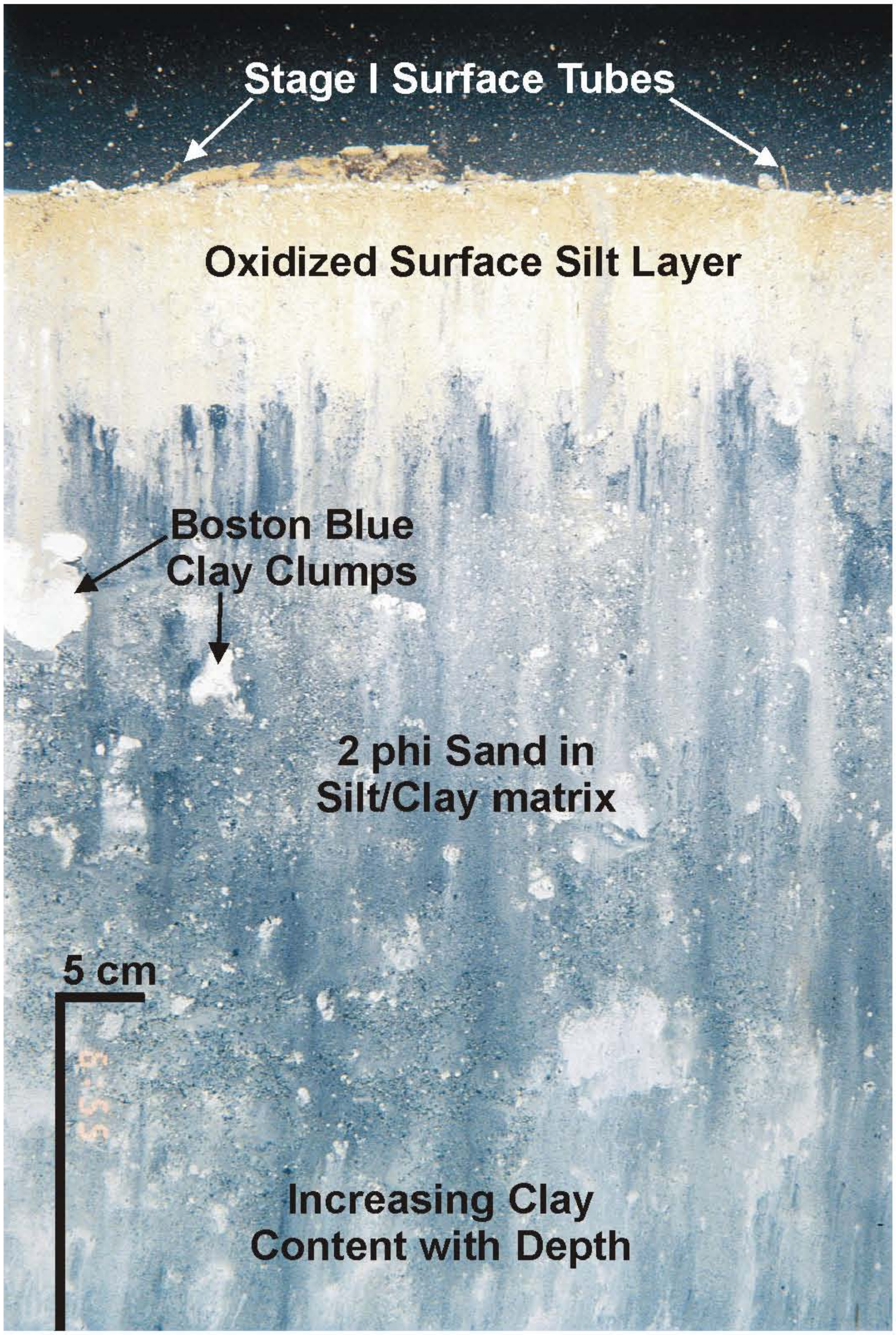


Figure 4-2. Sediment-profile image obtained from Station C-CTR displaying the various classes of sediment (clay, silt, and sand) composing the MBDS-C disposal mound

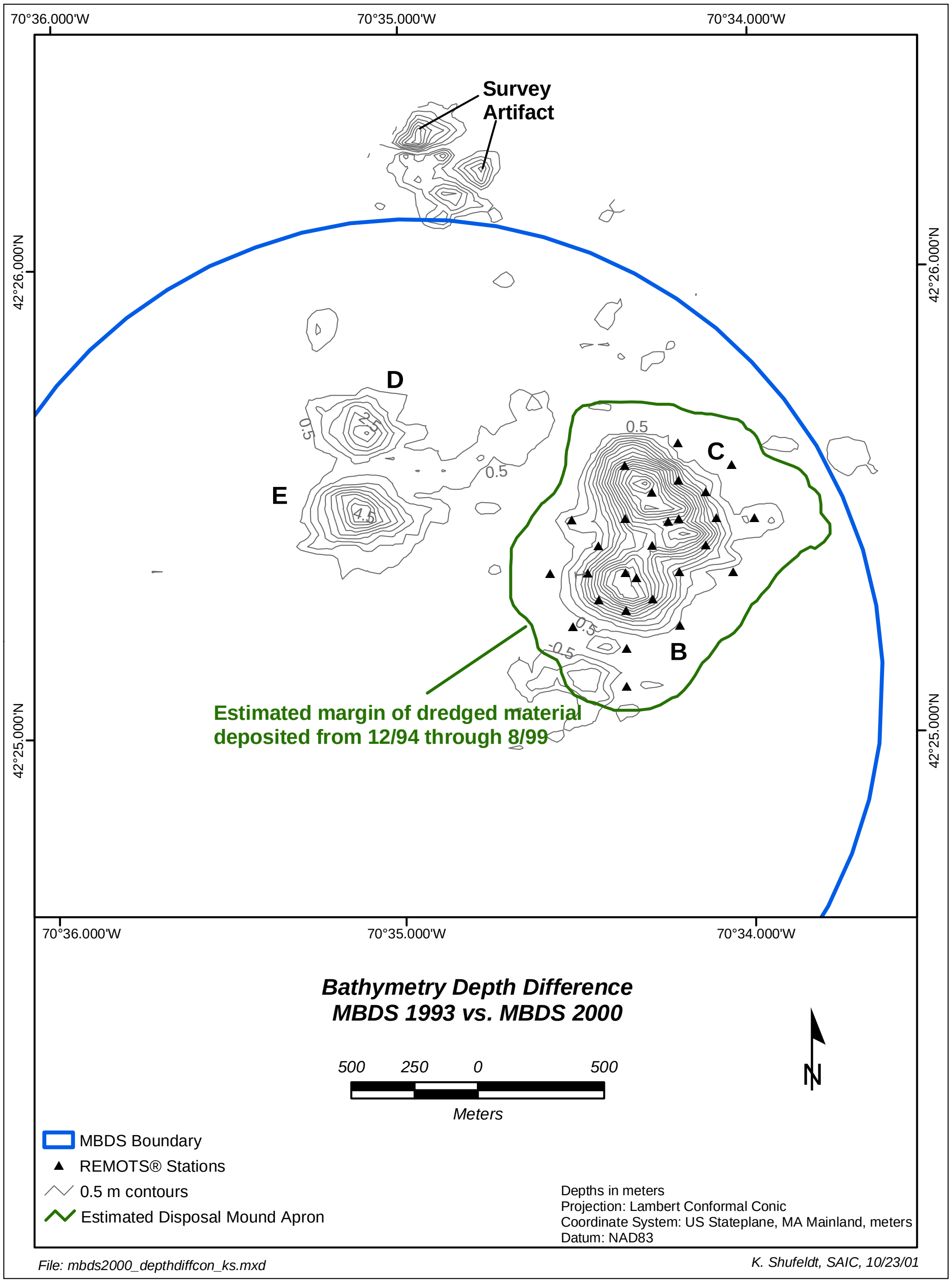


Figure 4-3. Depth difference contour map showing REMOTS® sediment-profile photography stations and the estimated margin of dredged material deposited from December 1994 through August 1999

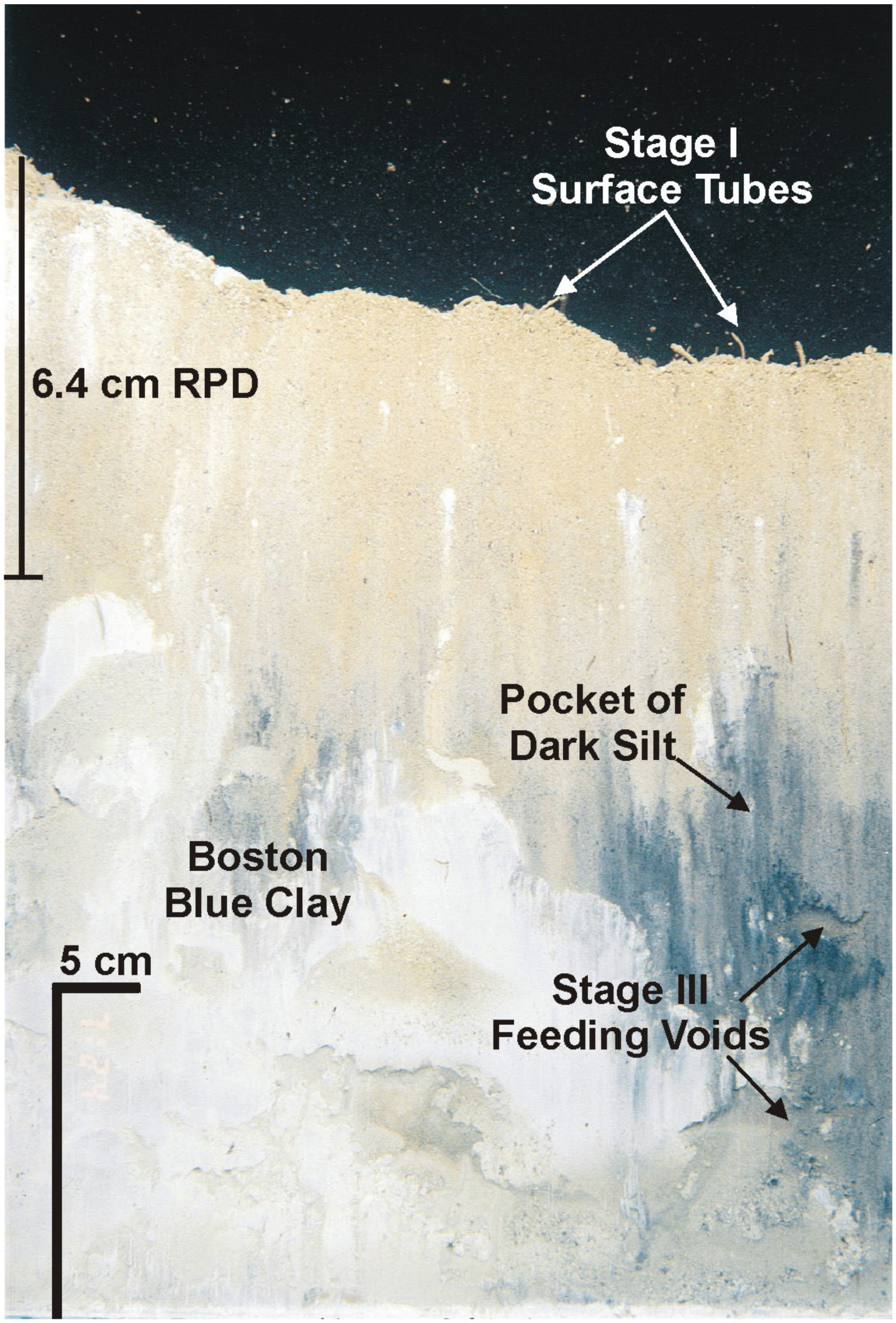


Figure 4-4. Sediment-profile image obtained from Station B450S showing advanced benthic recolonization (Stage I on III) and a deep RPD above a large clump of cohesive Boston Blue Clay

an artifact of the nature of the material itself. Ultimately, the disposal mounds are expected to support an advanced benthic community. However, this will require significantly more time relative to disposal mounds consisting of a high percentage of silt, in order to permit the biological reworking of the sediment to slowly break down the clay deposit.

The Fall 2000 REMOTS® results indicated that the surface sediments comprising the two disposal mounds had been moderately recolonized by an abundant benthic community and were supporting a stable Stage I population. As was observed at MBDS during the 2000 survey and consistent with ecological models, Stage I opportunistic tubicolous organisms (polychaetes) were detected at all stations 13 months after the last disposal event. The end-member stages (Stages I and III) were easily recognized in REMOTS® images by the presence of dense assemblages of near-surface polychaetes (Stage I) or the presence of subsurface feeding voids created by errant polychaetes (Stage III taxa). Stage I polychaetes were present at the sediment surface while Stage III organisms were present at depth in the sediment at 11 of the 24 REMOTS® stations yielding data.

In general, benthic recolonization was proceeding as expected over the surveyed dredged material disposal mounds at MBDS. However, the sediment profile data indicated a difference in the successional stage status of the two disposal mounds surveyed.

A higher occurrence of Stage III activity was noted at the stations over the older MBDS-B Mound relative to the stations surrounding the newer MBDS-C Mound. This suggested that benthic conditions over the surface of the MBDS-B Mound were more conducive for burrowing infauna given the increased time on the seafloor and opportunity for biological reworking of the deposited sediments. In addition, when present at the MBDS-C Mound, Stage III activity was noted at stations located on the periphery of the survey grid in close proximity to MBDS-B. The MBDS-B Mound was completed in November 1998, allowing nearly two years with minimal disturbance for an advanced benthic community to establish itself over the surface of the sediment deposit. It is anticipated that as time progresses, benthic conditions at the stations over the MBDS-C Mound will show improvement and support an advanced benthic infaunal community.

Although Boston Blue Clay deposits may be difficult to burrow through and offer little nourishment for deposit feeding invertebrates processing the material, one benefit to the benthic infauna pertains to low overall sediment-oxygen demand (SOD). Patterns of benthic community recovery documented at other regional dredged material disposal sites suggest that disposal mounds consisting of organically enriched silts tend to be recolonized at a slower rate and subject to higher stress levels due to increased SOD (Morris 1998). Dredged material deposits consisting primarily of glacial clay are not subject to high levels of chemical oxidation of organics in the sediment. As a result, a significant percentage of the molecular oxygen incorporated into the surface sediments will be available to support biological processes, and reflected in the development of deeper RPD depths, relative to silt deposits.

The depth of the apparent oxidation in the sediment column is an important time-integrator of dissolved oxygen conditions within sediment pore waters and is also a useful indicator for assessing the health of a benthic ecosystem. RPD depths for the stations over the disposal mounds indicated that the surface sediments were well-oxygenated and appeared consistent with normal patterns of recovery, with an overall RPD average of 3.1 cm. Although the RPD values were slightly shallower in comparison to the MBDS reference areas (overall RPD average of 3.9 cm), the data obtained from the two disposal mounds within MBDS were well within expectations for a recent sediment deposit. Similar to the successional stage patterns among the two disposal mounds, RPD depths were higher at stations on the MBDS-B Mound where more time has passed for the effects of bioturbation to be observed. Likewise, it is anticipated that bioturbation within the sediment at MBDS-C will increase as time progresses, producing comparable or deeper RPDs relative to MBDS-B and the reference areas.

Better conclusions concerning benthic community condition and productivity were yielded by the multi-parameter REMOTS® Organism-Sediment Index (OSI), constructed to characterize habitat quality of soft-bottom benthic environments. This index has proven to be an excellent parameter for mapping disturbance gradients in an area and documenting ecosystem recovery after disturbance. In general, the disposal site stations showed variable benthic habitat conditions with median OSI values ranging from moderately disturbed (+4.5) to a fully developed (+10). The high OSI values calculated at the stations over the disposal mounds reflected relatively high RPD depths and the presence of Stage I and Stage III infauna. Consistent with the benthic recolonization and RPD findings, the MBDS-B Mound stations showed slightly higher median OSI values relative to the MBDS-C Mound stations (range of +4.5 to +10 and +5 to +8.5, respectively). Two-thirds (14 of the 21 stations yielding data) displayed median OSI values ≥+6, indicating the presence of a well-developed benthic community at disposal mounds. The OSI values that were calculated for the stations falling below +6 (33.3%) indicate a need for continued benthic recovery and additional monitoring during future surveys.

Overall, the OSI values calculated for the disposal mounds were somewhat lower than those observed at the reference area stations (median OSI +8.1 reference area versus +6.7 MBDS), which is common for recently deposited dredged material. Stage III taxa dominated the sediment (69%) within the reference areas during the 2000 survey with occurrences of Stage I and II at most stations as well. Stage II organisms represent the transitional stage and are often accompanied by both Stage I and Stage III taxa. The high-order seres together with moderately deep RPD depths (overall mean RPD of 3.9 cm) resulted in correspondingly higher median OSI values at the reference areas, relative to the disposal mounds.

The OSI values calculated for the reference areas and disposal mound stations ranged from +6 to +11 and +4.5 to +10, respectively. All reference area stations (100%) displayed median OSI values in the upper benthic quality range of ≥+6. Although still recovering from seafloor disturbance at varying time intervals, the benthic community at the disposal mounds appeared to be comparable to the ambient seafloor. No significant trends were observed at either of the two disposal mounds or the reference areas that would suggest that a change in management strategy is required. Future monitoring of the MBDS-C Mound would be useful to confirm the continued recovery of benthic habitat conditions similar to those detected at the MBDS-B Mound.

4.3 MBDS Reference Areas

As part of each benthic community assessment survey performed over a disposal mound, multiple stations are occupied within designated reference areas for the purposes of documenting and monitoring benthic conditions within ambient sediment. The information gathered from the reference areas serves as a baseline to which on-site disposal mound data are compared to prevent the impacts associated with regional conditions or large-scale disturbance from affecting the interpretation of the disposal mound data. Over the last decade, several reference areas have been employed as part of the environmental monitoring of MBDS. Reference areas FG-23, SE-REF, 18-17, and MBD-REF have been occupied over multiple surveys spanning years 1990 through 2000 (Germano et al. 1994b). The consistency of use of FG-23 and SE-REF has permitted long-term benthic community assessment in the region.

The 2000 survey enabled comparisons to be made between previous surveys (1990, 1992, and 1994) concerning the long-term benthic status at reference areas FG-23 and SE-REF. Remaining consistent with previous surveys, the 2000 REMOTS® data for reference areas FG-23 and SE-REF showed an advanced successional stage assemblage with Stage II and Stage III organisms present at the majority of stations sampled and a range of OSI values from +6 to +11. Overall, the two reference areas have continued to show a favorable benthic environment supporting a well-established benthic community with minimal cyclic benthic disturbance associated with naturally occurring events such as storm waves or bottom currents.

The most significant difference observed in the 2000 REMOTS® data obtained from reference areas FG-23 and SE-REF was a somewhat less frequent occurrence of Stage III organisms and subsequent lower OSI values compared to previous monitoring events. This slight decline in benthic conditions was more noticeable in reference area FG-23, where in 1994 median OSI values ranged from +10.5 to +11 and in 2000 median OSI values ranged from +6 to +8 (Murray 1997). Apart from a slight deviance from previous surveys with respect to median OSI values resulting from fewer Stage III taxa, the benthic community during the 2000 survey at reference areas FG-23 and SE-REF appeared to be abundant and quite active. RPD depths were fairly deep, as the level of oxygenation in the ambient sediment of FG-23 and SE-REF ranged from 2.9 to 4.9 cm.

In general, the reference areas indicate a well-established and diverse benthic environment with moderately deep RPD depths, dominance of an advanced successional stage, and subsequent high OSI values. These results are indicative of a stable, biologically active environment supporting an advanced benthic community. However, benthic habitat conditions at the MBDS reference areas, as represented by OSI values, appear to be slightly lower during the 2000 survey relative to previous surveys. An apparent decline in the abundance of Stage III organisms in the replicate photographs collected at FG-23 is the primary cause for the lower OSI values in 2000. Based on the lack of dramatic change in successional status over the course of several years at reference areas FG-23 and SE-REF, it is believed that organism-sediment relationships continue to be fully established and not subject to any notable disruption to the benthic community. In summary, the reference areas have continued to display sound benthic conditions over the past 11 years and in the absence of major benthic disturbance, should remain a stable and biologically active environment.

In 1992, the now historic reference area 18-17 was determined to be no longer representative of ambient conditions based on its proximity to the disposal site and the results of detailed sediment chemistry analyses. Sediment samples collected in 1989 indicated an elevated level of 4,4´ DDE (1,1-dichloro-2,2-bis (chlorophenyl) ethylene), a derivative of the pesticide DDT, at one station located within the sampling radius of 18-17 (Murray 1994). When normalized to total organic carbon (TOC) content (2.2%), concentrations of DDE were found to be comparable to the values calculated for the NOAA National Status and Trends (NS&T) reference areas located throughout Massachusetts Bay (Murray 1994).

Over the years, reference area 18-17 has sustained a consistently undisturbed benthic environment compared to surrounding reference areas, with deeper RPD depths, dominance of Stage III taxa, and subsequent high OSI values. Survey activity completed over 18-17 in 1990 and 1992 documented the presence of deep RPDs and advanced successional stages. The OSI values calculated for the sampling stations occupied over 18-17 were consistently high, with median values of +11 quite common. However, the differences in chemical composition detected between reference areas 18-17 and FG-23 in 1989 suggested that historic dredged material disposal activity at the former Industrial Waste Site (IWS) or Interim MBDS had impacted conditions at 18-17. As a result, reference area 18-17 was abandoned and MBD-REF was selected as a replacement.

Reference area 18-17 (MBX-REF) was inadvertently sampled during the 2000 survey, but provided an opportunity to re-examine the long-term status of the benthic community within this reference area. In accordance with previous data sets, reference area 18-17 (MBX-REF) appeared to display undisturbed or non-degraded benthic habitat conditions, with deeper RPD depths and an advanced successional stage in comparison to FG-23 and SE-REF. During the 2000 survey, stations within 18-17 (MBX-REF) displayed overall mean RPD depths of 4.8 cm, Stage III taxa present at all stations, and an overall mean

OSI value of +9.7. Reference areas FG-23 and SE-REF showed overall mean RPD depths of 3.4 cm and 3.8 cm, and overall mean OSI values of +6.9 and +8.3, respectively. The findings of the 2000 survey over 18-17 (MBX-REF) suggest the chemical trends detected during the 1989 sediment chemistry evaluation have not resulted in any a long-term impacts on benthic community populations or diversity.

5.0 CONCLUSIONS

- Depth difference comparisons between the September 1993 and August 2000 bathymetric surveys detected four new disposal mounds on the MBDS seafloor, ranging in mound height from 3.5 m to 10.0 m. The oldest disposal mound (MBDS-A Mound; developed before the 1993 survey) displayed signs of consolidation, with a 2 m reduction in mound height over the past seven years.

- The process of strategically placing the DAMOS disposal buoy within the confines of MBDS over the past seven years has facilitated the development of an artificial containment cell on the seafloor. The five disposal mounds developed since 1992 began to form a ring of disposal mounds, which could be utilized to contain a large non-cohesive dredged material deposit or employed as part of a large-scale confined aquatic disposal (CAD) project in the future. The two largest mounds (MBDS-B and MBDS-C), which have coalesced, now form a solid berm along the eastern margin of the cell. Over the next five to ten years, dredged material should be directed to several key locations that will facilitate completion of the first artificial containment cell at MBDS.

- Benthic recolonization is proceeding as expected over the historic dredged material deposits at MBDS. Sediment-profile photography results indicate the older MBDS-B Mound is supporting a stable benthic infaunal population with Stage III activity noted at the majority of stations sampled. Sediment-profile images collected over the more recent, MBDS-C Mound showed Stage I individuals were predominant, but relatively deep RPD depths were the basis for OSI values of +5 and above.

- Benthic habitat conditions at the reference areas (FG-23 and SE REF), as represented by OSI values, appear to be slightly higher in comparison to the MBDS Mound data. A significant percentage of the disposal mounds on the MBDS seafloor are composed of Boston Blue Clay. The cohesive nature of the sediment, as well as the lack of organic material to exploit as a food source, tend to slow the recovery process. However, the dredged material disposal mounds are expected to support a stable benthic community in the future.

- Reference area MBX-REF (18-17), inadvertently sampled as part of the fall 2000 monitoring survey, appeared to display undisturbed benthic habitat conditions, with deeper RPD depths and an advanced successional stage in comparison to FG-23 and SE-REF. This reference site was replaced by MBD-REF in 1994 as sediment chemistry data suggested the area was no longer representative of ambient conditions. The findings of the 2000 survey over MBX-REF (18-17) suggest the chemical trends detected in 1989 have not produced any long-term impacts on benthic community populations or diversity.

6.0 REFERENCES

DeAngelo, E. C.; Murray, P. M. 1997. Baseline Survey of the Reconfigured Massachusetts Bay Disposal Site, 14 September 1993. DAMOS Contribution No. 115. U.S. Army Corps of Engineers, New England Division, Waltham, MA.

EPA. 1992. Designation of an ocean dredged material disposal sit in Massachusetts Bay: Final Environmental Impact Statement, July 1992. U.S. Environmental Protection Agency, Region I, Boston, MA.

Germano, J.D.; Rhoads, D.C.; Lunz, J.D. 1994a. An integrated, tiered approach to monitoring and management of dredged material disposal sites in the New England region. DAMOS Contribution No. 87. U.S. Army Corps of Engineers, New England Division, Waltham, MA.

Germano, J.D.; Parker, J.; Charles, J. 1994b. Monitoring cruise at the Massachusetts Bay Disposal Site, August 1990. DAMOS Contribution No. 92. U.S. Army Corps of Engineers, New England Division, Waltham, MA.

Morris, J.T. 1998. Monitoring cruise at the Central Long Island Sound Disposal Site, July 1996. DAMOS Contribution No. 120. U.S. Army Corps of Engineers, New England District, Concord, MA.

Morris, J.T.; Charles, J.; Inglin D. 1996. Monitoring surveys of the New Haven capping project 1993-1994. DAMOS Contribution No. 111. U.S. Army Corps of Engineers, New England Division, Waltham, MA.

Murray, P.M. 1994. Chemical analysis of sediment sampling at the Massachusetts Bay Disposal Site : 5-7 June 1989. SAIC Report No. C98. Submitted to the U.S. Army Corps of Engineers, New England Division, Waltham, MA.

Murray, P. M. 1997. Monitoring Cruise at the Massachusetts Bay Disposal Site, August 1994. DAMOS Contribution No. 116. U.S. Army Corps of Engineers, New England Division, Waltham, MA.

Rhoads, D. C.; Germano, J. D. 1982. Characterization of organism-sediment relations using sediment-profile imaging: An effective method of Remote Ecological Monitoring of the Seafloor (REMOTS® System). Mar. Ecol. Prog. Ser. 8:115-128.

Rhoads, D. C.; Germano, J. D. 1986. Interpreting long-term changes in community structure: A new protocol. Hydrobiologia 142:291-308.

SAIC. 2001a. Massachusetts Bay Disposal Site Capping Demonstration Project, 1998-2000. SAIC Report No. 551. Draft Report submitted to the US Army Corps of Engineers, New England District, Concord, MA.

SAIC. 2001b. Monitoring at the New London Disposal Site 1992-1998: Volume I. DAMOS Contribution No. 128. U.S. Army Corps of Engineers, New England District, Concord, MA.

Sugden, D.E.; John, B.S. 1976. Glaciers and landscapes, a geomorphological approach. Edward Arnold, Hodder and Stoughton, New York, NY.

APPENDIX A
DAMOS Disposal Summary for MBDS
January 1993 through September 2000

Appendix A, Disposal Logs
1993-2000 Disposal Season at MBDS

Buoy	**MBDA93A**					
Project:	COHASSET HARBOR	**Volume:**	6,098	CM	7,975	CY
Project:	THIRD HARBOR TUNNEL	**Volume:**	20,644	CM	27,000	CY
		Buoy Total Volume:	26,742	CM	34,975	CY
Buoy	**MBDA93B**					
Project:	NEPONSET LANDING	**Volume:**	16,362	CM	21,400	CY
Project:	ESSEX RIVER	**Volume:**	16,827	CM	22,008	CY
Project:	THIRD HARBOR TUNNEL	**Volume:**	90,322	CM	118,130	CY
Project:	PORT NORFOLK	**Volume:**	11,928	CM	15,600	CY
Project:	ESSEX RIVER	**Volume:**	1,224	CM	1,601	CY
Project:	ESSEX RIVER	**Volume:**	1,679	CM	2,196	CY
		Buoy Total Volume:	138,343	CM	180,935	CY
Buoy	**ROCKSIE**					
Project:	THIRD HARBOR TUNNEL	**Volume:**	239,037	CM	312,630	CY
Project:	WEYMOUTH FORE RIVER	**Volume:**	17,815	CM	23,300	CY
		Buoy Total Volume:	256,852	CM	335,930	CY
Buoy	**MBDA94A**					
Project:	DION BASIN, SALEM HARBOR, MA	**Volume:**	6,996	CM	9,150	CY
Project:	SALEM HARBOR HISTORIC SITE	**Volume:**	8,181	CM	10,700	CY
Project:	DANVERS AND BASS RIVERS	**Volume:**	3,938	CM	5,150	CY
Project:	ESSEX RIVER	**Volume:**	1,453	CM	1,900	CY
Project:	PORT NORFOLK	**Volume:**	1,529	CM	2,000	CY
Project:	HODGKINS COVE	**Volume:**	1,300	CM	1,700	CY
		Buoy Total Volume:	23,397	CM	30,600	CY
Buoy	**MBDA94B**					
Project:	SCITUATE HARBOR	**Volume:**	7,990	CM	10,450	CY
Project:	MILL WHARF MARINA	**Volume:**	2,867	CM	3,750	CY
Project:	PISCATAQUA RIVER, PORTSMOUTH, NH	**Volume:**	18,886	CM	24,700	CY
Project:	DANVERS AND BASS RIVERS	**Volume:**	1,835	CM	2,400	CY
Project:	MARINA MAINTENANCE DREDGING	**Volume:**	6,996	CM	9,150	CY
		Buoy Total Volume:	38,574	CM	50,450	CY

Buoy MBDA95

Project:	COHASSET HARBOR	**Volume:**	5,842	CM	7,640	CY
Project:	WEYMOUTH FORE RIVER	**Volume:**	4,244	CM	5,550	CY
Project:	PLYMOUTH HARBOR	**Volume:**	8,908	CM	11,650	CY
Project:	NEPONSET RIVER	**Volume:**	2,263	CM	2,960	CY
Project:	ALLERTON HARBOR AT HULL, MA	**Volume:**	40,279	CM	52,680	CY
Project:	SCITUATE HARBOR	**Volume:**	3,422	CM	4,475	CY
Project:	HINGHAM HARBOR	**Volume:**	26,869	CM	35,141	CY
		Buoy Total Volume:	91,825	CM	120,096	CY

Buoy MBDA97A

Project:	WEYMOUTH FORE RIVER	**Volume:**	3,307	CM	4,325	CY
Project:	INNER CONFLUENCE, BOSTON	**Volume:**	109,032	CM	142,600	CY
Project:	PILGRIM NUCLEAR STATION	**Volume:**	27,105	CM	35,450	CY
Project:	HINGHAM HARBOR	**Volume:**	2,447	CM	3,200	CY
Project:	GULF OIL TERMINAL, CHELSEA RIVER	**Volume:**	1,376	CM	1,800	CY
		Buoy Total Volume:	143,267	CM	187,375	CY

Buoy MBDA97B

Project:	FORT POINT CHANNEL BOSTON, MA	**Volume:**	12,692	CM	16,600	CY
Project:	HINGHAM HARBOR	**Volume:**	74,854	CM	97,900	CY
Project:	WEYMOUTH BACK RIVER	**Volume:**	2,676	CM	3,500	CY
		Buoy Total Volume:	90,223	CM	118,000	CY

Buoy MBDA98A

Project:	FORT POINT CHANNEL BOSTON, MA	**Volume:**	1,223	CM	1,600	CY
Project:	BRIDGWAYE INN MARINA	**Volume:**	4,970	CM	6,500	CY
Project:	HINGHAM HARBOR	**Volume:**	2,753	CM	3,600	CY
Project:	GULF OIL TERMINAL, CHELSEA RIVER	**Volume:**	1,376	CM	1,800	CY
Project:	JUBILEE YACHT CLUB	**Volume:**	994	CM	1,300	CY
Project:	WOLLASTON & SQUANTUM YACHT	**Volume:**	6,499	CM	8,500	CY
Project:	WEYMOUTH BACK RIVER	**Volume:**	8,067	CM	10,550	CY
Project:	BOSTON HARBOR	**Volume:**	426,417	CM	557,700	CY
Project:	COHASSET MAINT DREDGING	**Volume:**	33,184	CM	43,400	CY
		Buoy Total Volume:	485,483	CM	634,950	CY

Buoy	**MBDA98B**					
Project:	FORT POINT CHANNEL BOSTON, MA	**Volume:**	27,717	CM	36,250	CY
Project:	SCITUATE HARBOR	**Volume:**	33,948	CM	44,400	CY
Project:	CHELSEA RIVER	**Volume:**	4,939	CM	6,460	CY
Project:	BAILEYS CREEK	**Volume:**	2,447	CM	3,200	CY
Project:	WOLLASTON & SQUANTUM YACHT	**Volume:**	54,363	CM	71,100	CY
Project:	BOSTON HARBOR	**Volume:**	572,078	CM	748,205	CY
Project:	COHASSET MAINT DREDGING	**Volume:**	23,320	CM	30,500	CY
		Buoy Total Volume:	718,812	CM	940,115	CY
Buoy	**MBDA99A**					
Project:	FORT POINT CHANNEL BOSTON, MA	**Volume:**	79,977	CM	104,600	CY
Project:	BOSTON HARBOR	**Volume:**	579,196	CM	757,515	CY
		Buoy Total Volume:	659,173	CM	862,115	CY
Buoy	**MBDA99B**					
Project:	FORT POINT CHANNEL BOSTON, MA	**Volume:**	55,778	CM	72,950	CY
Project:	BOSTON HARBOR	**Volume:**	330,238	CM	431,910	CY
		Buoy Total Volume:	386,016	CM	504,860	CY
Buoy	**MBDA99C**					
Project:	FORT POINT CHANNEL BOSTON, MA	**Volume:**	26,264	CM	34,350	CY
Project:	PILGRIM NUCLEAR STATION	**Volume:**	24,544	CM	32,100	CY
Project:	BOSTON HARBOR	**Volume:**	75,848	CM	99,200	CY
Project:	WINTHROP HARBOR	**Volume:**	25,499	CM	33,350	CY
		Buoy Total Volume:	152,155	CM	199,000	CY
Buoy	**MBDA99D**					
Project:	FORT POINT CHANNEL BOSTON, MA	**Volume:**	41,977	CM	54,900	CY
Project:	PILGRIM NUCLEAR STATION	**Volume:**	7,837	CM	10,250	CY
Project:	SCITUATE HARBOR	**Volume:**	7,722	CM	10,100	CY
Project:	South River	**Volume:**	11,545	CM	15,100	CY
Project:	BOSTON HARBOR	**Volume:**	475,199	CM	621,500	CY
Project:	COHASSET MAINT DREDGING	**Volume:**	2,447	CM	3,200	CY
Project:	WINTHROP HARBOR	**Volume:**	38,459	CM	50,300	CY
Project:	Hingham Bay	**Volume:**	15,904	CM	20,800	CY
		Buoy Total Volume:	601,090	CM	786,150	CY
Buoy	**MBDA00A**					
Project:	Hingham Bay	**Volume:**	14,030	CM	18,350	CY
		Buoy Total Volume:	14,030	CM	18,350	CY
		Report Total Volume:	3,825,983	CM	5,003,901	CY

APPENDIX B
Detailed REMOTS® Sediment-Profile Photography Results

Appendix B1

REMOTS® Sediment-Profile Imaging Results from the MBDS-C Mound

Station	Replicate	Date	Time	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					
MBDS C Mound																											
C-CTR	A	8/23/2000	18:53	ST_I	2	>4	>4	0	0	19.52	20.21	0.69	19.87	19.52	20.21	>19.87	0	0	0	0.63	3.86	3.07	0	6	PHYSICAL	NO	DM>P; BRN M/GREY CLAY; COHESIVE CLAY @ Z; BURROW @ DEPTH?
C-CTR	C	8/23/2000	18:55	ST_I	2	>4	>4	2	0.53	18.41	18.89	0.48	18.65	18.41	18.89	>18.65	0	0	0	2.65	7.25	4.14	0	7	PHYSICAL	NO	DM>P; BRN M/GREY CLAY; RED&OX CLASTS
C-CTR	E	10/23/2000	13:49	ST_I	3	>4	>4	4	0.32	15.32	17.31	1.99	16.32	15.32	17.31	>16.32	0	0	0	0.75	6.83	4.31	0	7	PHYSICAL	NO	DM>P; BRN M/GRY CLAY; OX&RED CLST; TUBES; WORM @Z
C150N	D	10/23/2000	13:38	INDET	3	>4	>4	0	0	8.03	10.05	2.02	9.04	8.03	10.05	>9.04	0	0	0	NA	NA	NA	0	99	PHYSICAL	NO	DM>P; BRN M/COHES.GREY CLAY; RED SED@SURF; DIST SURF
C150N	E	10/23/2000	13:38	ST_I	2	>4	>4	5	0.38	6.61	11.34	4.73	8.98	6.61	11.34	>8.98	0	0	0	0.11	3.87	2.43	0	5	PHYSICAL	NO	UNDERPEN; DM>P; BRN M/CLAY; OX&RED CLASTS; DIST SURFACE
C150N	F	10/23/2000	13:39	ST_I	2	>4	>4	0	0	4.19	4.95	0.75	4.57	4.19	4.95	>4.57	0	0	0	0.05	3.39	2.32	0	5	PHYSICAL	NO	UPEN; DM>P; BRN M/CLAY; RED SED @SURF; FECAL CASTS @SURF
C150NE	A	8/23/2000	19:00	ST_I	2	>4	>4	0	0	16.24	18.36	2.12	17.3	16.24	18.36	>17.3	0	0	0	1.75	7.2	4.83	0	7	PHYSICAL	NO	DM>P; BRN M/GREY-BLK CLAY?
C150NE	B	8/23/2000	19:01	ST_I	3	>4	>4	0	0	16.83	17.67	0.85	17.25	16.83	17.67	>17.25	0	0	0	0.42	3.86	2.9	0	5	BIOGENIC	NO	DM>P; BRN M/GREY CLAY; DENSE TUBES; COHESIVE CLAY @Z; BURROW?
C150NE	C	8/23/2000	19:02	ST_I	3	>4	>4	0	0	16.83	17.2	0.37	17.01	16.83	17.2	>17.01	0	0	0	1.48	5.08	3.55	0	6	BIOGENIC	NO	DM>P; BRN M/GREY CLAY; DENSE TUBES; COHESIVE CLAY @Z; BURROW?
C150E	A	10/23/2000	19:32	INDET	3	>4	>4	0	0	21	21	INDET	21	21	21	>21	0	0	0	NA	NA	NA	0	99	INDET	NO	OVERPENETRATION; DM>P; MOTTLED SOFT GREY CLAY
C150E	C	10/23/2000	19:34	INDET	2	>4	>4	0	0	21	21	INDET	21	21	21	>21	0	0	0	NA	NA	NA	0	99	INDET	NO	OVERPENETRATION; DM>P; MOTTLED SOFT GREY CLAY
C150E	F	10/24/2000	20:35	INDET	3	>4	>4	0	0	21	21	INDET	21	21	21	>21	0	0	0	NA	NA	NA	0	99	INDET	NO	DM>P; BRN M/GRY-BLK CLAY; OVERPEN; BURROW
C150SE	A	10/23/2000	19:37	INDET	3	>4	>4	0	0	21	21	INDET	21	21	21	>21	0	0	0	NA	NA	NA	0	99	INDET	NO	OVERPENETRATION; DM>P; MOTTLED SOFT GREY CLAY
C150SE	C	10/23/2000	19:39	INDET	2	>4	>4	0	0	21	21	INDET	21	21	21	>21	0	0	0	NA	NA	NA	0	99	INDET	NO	OVERPENETRATION; DM>P; MOTTLED SOFT GREY CLAY
C150SE	D	10/23/2000	19:39	INDET	3	>4	>4	0	0	21	21	INDET	21	21	21	>21	0	0	0	NA	NA	NA	0	99	INDET	NO	OVERPENETRATION; DM>P; MOTTLED SOFT GREY CLAY
C150SW	B	8/23/2000	18:45	ST_I_ON_III	2	>4	>4	0	0	6.3	8.41	2.12	7.35	6.3	8.41	>7.35	0	0	0	0.26	4.44	2.76	0	9	BIOGENIC	NO	DM>P; BRN M/GREY CLAY; VOIDS; DENSE TUBES; COHESIVE CLAY @ Z
C150SW	C	8/23/2000	18:45	ST_I_ON_III	2	>4	>4	0	0	5.82	9.26	3.44	7.54	5.82	9.26	>7.54	0	0	0	0.48	2.75	1.9	0	8	PHYSICAL	NO	DM>P; BRN M/GREY CLAY; RED&OX CLASTS; VOID; COHESIVE CLAY @Z
C150NW	D	10/23/2000	13:42	ST_I	2	>4	>4	5	0.32	13.55	15.81	2.26	14.68	13.55	15.81	>14.68	0	0	0	0.32	6.34	4.04	0	7	PHYSICAL	NO	DM>P; BRN M/COH.CLAY; LG.TUBE; WORM @Z; REWORKED SURFACE
C150NW	F	10/23/2000	13:43	ST_I	2	>4	>4	0	0	13.55	15.27	1.72	14.41	13.55	15.27	>14.41	0	0	0	0.43	6.72	3.92	0	7	PHYSICAL	NO	DM>P; SANDY M/GREY CLAY; TUBES; WORM@Z; DIST SURF
C150NW	G	10/23/2000	13:44	ST_I	2	>4	>4	0	0	11.99	13.87	1.88	12.93	11.99	13.87	>12.93	0	0	0	0.05	3.98	1.85	0	4	PHYSICAL	NO	DM>P; BRN M/GREY-BLK CLAY; STICKS?; DIST SURFACE
C200S	A	10/23/2000	19:57	INDET	3	>4	>4	0	0	21	21	INDET	21	21	21	>21	0	0	0	NA	NA	NA	0	99	INDET	NO	OVERPENETRATION; DM>P; MOTTLED SOFT GREY CLAY
C200S	B	10/23/2000	19:57	INDET	3	>4	>4	0	0	21	21	INDET	21	21	21	>21	0	0	0	NA	NA	NA	0	99	INDET	NO	OVERPENETRATION; DM>P; MOTTLED SOFT GREY CLAY
C200S	D	10/24/2000	19:12	ST_I	3	>4	>4	0	0	21	21	INDET	21	21	21	>21	0	0	0	NA	NA	NA	0	99	INDET	NO	DM>P; BRN M/GRY CLAY; OVERPEN; TUBES; WORMS @Z
C200W	F	10/20/2000	21:39	INDET	-1	-1	<-1	0	0	21	21	INDET	21	21	21	>21	0	0	0	NA	NA	NA	0	99	INDET	NO	UNDERPENETRATION; DM?; ROCK/BIG CLAY CHUNK
C200W	K	10/24/2000	18:15	ST_I	2	>4	>4	0	0	10.11	11.71	1.6	10.91	10.11	11.71	>10.91	0	0	0	1.82	4.92	3.56	0	6	PHYSICAL	NO	DM>P; SANDY M/GREY CLAY; BURROWS?
C200W	L	10/24/2000	18:15	ST_I_ON_III	2	>4	>4	0	0	17.38	18.18	0.8	17.78	17.38	18.18	>17.78	0	0	0	1.93	4.97	3.58	0	10	PHYSICAL	NO	DM>P; BRN M/GREY CLAY; TUBES; LARGE FEEDING VOID
C300N	G	10/23/2000	13:33	INDET	3	>4	>4	0	0	21	21	INDET	21	21	21	>21	0	0	0	NA	NA	NA	0	99	INDET	NO	OVERPENETRATION; DM>P; COHESIVE CLAY
C300N	I	10/24/2000	20:50	ST_I	2	>4	>4	0	0	18.82	20.16	1.34	19.49	18.82	20.16	>19.49	0	0	0	4.01	6.52	5.44	0	7	PHYSICAL	NO	DM>P; SANDY M/BLK CLAY; MULINIA?; COH. CLAY
C300N	J	10/24/2000	20:51	ST_I	2	>4	>4	3	0.21	16.04	17.27	1.23	16.66	16.04	17.27	>16.66	0	0	0	0.16	4.28	2.25	0	4	PHYSICAL	NO	DM>P; BRN M/BLK CLAY; BURROW?; RED CLSTS; WORM@Z
C300NE	C	8/23/2000	19:09	ST_I	2	>4	>4	0	0	7.78	10.16	2.38	8.97	7.78	10.16	>8.97	0	0	0	1.22	5.03	3.38	0	6	PHYSICAL	NO	DM>P; BRN M/BLK M-GREY CLAY; TUBES
C300NE	E	10/23/2000	19:27	INDET	3	>4	>4	0	0	21	21	INDET	21	21	21	>21	0	0	0	NA	NA	NA	0	99	INDET	NO	OVERPENETRATION; DM>P; MOTTLED SOFT GREY CLAY
C300NE	H	10/24/2000	19:31	ST_I	3	>4	>4	4	0.38	17.7	18.93	1.23	18.32	17.7	18.93	>18.32	0	0	0	0.27	6.04	3.73	0	6	PHYSICAL	NO	DM>P; BRN M/GRY CLAY; WORMS@Z; SHELL FRAG?; OX CLST
C300E	A	10/23/2000	19:45	INDET	3	>4	>4	0	0	21	21	INDET	21	21	21	>21	0	0	0	NA	NA	NA	0	99	INDET	NO	OVERPENETRATION; DM>P; MOTTLED SOFT GREY CLAY
C300E	D	10/24/2000	20:41	ST_I_ON_III	3	>4	>4	5	0.4	18.66	20.21	1.55	19.44	18.66	20.21	>19.44	0	0	0	0.6	4.4	2.41	0	9	PHYSICAL	NO	DM>P; BRN M/GRY CLAY; SMALL VOID; TUBES; OX CLASTS
C300E	E	10/24/2000	20:42	ST_I	2	>4	>4	0	0	20.37	20.91	0.53	20.64	20.37	20.91	>20.64	0	0	0	0.27	1.03	0.67	0	2	PHYSICAL	NO	DM>P; BRN M/GRY CLAY; OVERPEN; WORM@Z; SURFACE REWORKING
C300SE	B	10/23/2000	19:52	INDET	3	>4	>4	0	0	21	21	INDET	21	21	21	>21	0	0	0	NA	NA	NA	0	99	INDET	NO	OVERPENETRATION; DM>P; MOTTLED SOFT GREY CLAY
C300SE	C	10/23/2000	19:53	INDET	2	>4	>4	0	0	21	21	INDET	21	21	21	>21	0	0	0	NA	NA	NA	0	99	INDET	NO	OVERPENETRATION; DM>P; MOTTLED SOFT GREY CLAY
C300SE	E	10/24/2000	19:21	ST_I	3	>4	>4	3	0.3	21	21	INDET	21	21	21	>21	0	0	0	NA	NA	NA	0	99	INDET	NO	DM>P; M/BLK CLAY; OVERPEN; SURF REWORKING; OX CLSTS;TUBES

Appendix B2

REMOTS® Sediment-Profile Imaging Results from the MBDS-B Mound

Station	Replicate	Date	Time	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					
MBDS B Mound																											
B-CTR	A	8/23/2000	18:38	ST_I	2	>4	>4	0	0	13.76	14.71	0.95	14.23	13.76	14.71	>14.23	0	0	0	1.32	3.92	2.99	0	5	BIOGENIC	NO	DM>P; BRN M/GREY CLAY; DENSE TUBES; WORM & COHESIVE CLAY @ Z
B-CTR	D	10/23/2000	14:01	INDET	3	>4	>4	0	0	21	21	INDET	21	21	21	>21	0	0	0	NA	NA	NA	0	99	INDET	NO	OVERPENETRATION; DM>P; MOTTLED GREY CLAY
B-CTR	E	10/23/2000	14:01	INDET	3	>4	>4	0	0	21	21	INDET	21	21	21	>21	0	0	0	NA	NA	NA	0	99	INDET	NO	OVERPENETRATION; DM>P; MOTTLED GREY CLAY
B150SE	A	8/23/2000	19:47	ST_I	2	>4	>4	0	0	11.32	16.24	4.92	13.78	11.32	16.24	>13.78	0	0	0	0.11	10.74	4.21	0	7	PHYSICAL	NO	DM>P; BRN M/GREY CLAY; LG COHESIVE CLAY SURF-Z
B150SE	B	8/23/2000	19:48	ST_I_ON_III	2	>4	>4	0	0	7.35	9.37	2.01	8.36	7.35	9.37	>8.36	0	0	0	0.22	3.66	2.17	0	8	PHYSICAL	NO	DM>P; BRN M/GREY CLAY; SM VOIDS; COHESIVE CLAY @ Z
B150SE	C	8/23/2000	19:49	ST_I	2	>4	>4	0	0	13.02	14.44	1.43	13.73	13.02	14.44	>13.73	0	0	0	1.06	4.92	2.94	0	5	PHYSICAL	NO	DM>P; BRN M/GREY CLAY; COHESIVE CLAY @ Z
B150S	A	8/23/2000	19:41	ST_I	2	>4	>4	0	0	12.33	14.02	1.69	13.17	12.33	14.02	>13.17	0	0	0	0.05	6.56	3.06	0	6	PHYSICAL	NO	DM>P; BRN M/GREY CLAY; POSS BURROW OPNG; TUBES; SM VOID ON LEFT?
B150S	B	8/23/2000	19:42	ST_I	2	>4	>4	0	0	16.3	18.73	2.43	17.51	16.3	18.73	>17.51	0	0	0	1.04	6.5	4.32	0	7	PHYSICAL	NO	DM>P; BRN M/GREY CLAY; COHESIVE CLAY @ Z; FRACTURES @ Z
B150S	C	8/23/2000	19:43	ST_I_ON_III	2	>4	>4	0	0	5.71	6.83	1.11	6.27	5.71	6.83	>6.27	0	0	0	0.44	3.88	2.4	0	9	PHYSICAL	NO	DM>P; BRN M; TUBES; BURROW OPNG/VOID
B150SW	A	8/23/2000	18:31	ST_I_ON_III	2	>4	>4	0	0	10.69	12.65	1.96	11.67	10.69	12.65	>11.67	0	0	0	0.05	3.86	2.1	0	8	BIOGENIC	NO	DM>P; BRN M/GREY CLAY; DENSE TUBES; VOIDS; LG/SM COHESIVE CLAY @ Z
B150SW	B	8/23/2000	18:32	ST_I_ON_III	2	>4	>4	0	0	15.77	17.04	1.27	16.4	15.77	17.04	>16.4	0	0	0	0.05	6.51	2.83	0	9	PHYSICAL	NO	DM>P; BRN M/GREY CLAY; SM VOID; SM COHESIVE CLAY CHUNKS @ Z
B150SW	C	8/23/2000	18:33	ST_I_TO_II	2	>4	>4	0	0	11.64	12.49	0.85	12.06	11.64	12.49	>12.06	0	0	0	0.32	4.44	2.14	0	5	BIOGENIC	NO	DM>P;BRN M/BLK-GREY CLAY; POSS. JUV. AMPELISCA?;DENSE TUBES
B150W	D	10/20/2000	21:18	ST_I	2	>4	>4	0	0	14.15	15.36	1.2	14.75	14.15	15.36	>14.75	0	0	0	0.05	5.63	2.51	0	5	INDET	NO	DM>P; BRN M/BLK-GREY CLAY; PPA; DIST SURFACE
B150W	E	10/20/2000	21:19	INDET	3	>4	>4	0	0	21	21	INDET	21	21	21	>21	0	0	0	NA	NA	NA	0	99	INDET	NO	OVERPENETRATION; DM>P
B150W	F	10/20/2000	21:20	INDET	3	>4	>4	0	0	21	21	INDET	21	21	21	>21	0	0	0	NA	NA	NA	0	99	INDET	NO	OVERPENETRATION; DM>P
B150NW	D	10/20/2000	21:22	INDET	3	>4	>4	0	0	21	21	INDET	21	21	21	>21	0	0	0	NA	NA	NA	0	99	INDET	NO	OVERPENETRATION; DM>P; WORMS @Z?
B150NW	H	10/24/2000	19:03	ST_I_ON_III	3	>4	>4	0	0	20.48	20.91	0.43	20.7	20.48	20.91	>20.7	0	0	0	0.32	6.2	3.58	0	10	PHYSICAL	NO	DM>P; BRN M/GRY CLAY; WORMS@Z; BURROWS; DEEP VOID
B150NW	I	10/24/2000	19:04	ST_I_ON_III	3	>4	>4	0	0	18.77	20.75	1.98	19.76	18.77	20.75	>19.76	0	0	0	1.68	3.91	2.78	0	9	PHYSICAL	NO	DM>P; BRN M/GRY CLAY; TUBES; VOID; COH CLAY
B300SE	B	10/23/2000	14:23	ST_I	2	>4	>4	0	0	18.06	18.87	0.81	18.47	18.06	18.87	>18.47	0	0	0	0.16	4.3	1.76	0	4	PHYSICAL	NO	DM>P; BRN M/GRY-BLK CLAY; TUBES; REWORKED SURFACE
B300SE	C	10/23/2000	14:23	ST_I	3	>4	>4	1	0.32	18.98	20.59	1.61	19.78	18.98	20.59	>19.78	0	0	0	0.38	7.15	2.5	0	5	PHYSICAL	NO	DM>P; BRN M/GRY-BLK CLY; TUBES; REDUCED SED @SURF; COH.CLAY
B300SE	D	10/23/2000	14:24	ST_I	3	>4	>4	3	0.32	19.68	20.22	0.54	19.95	19.68	20.22	>19.95	0	0	0	0.65	6.45	2.61	0	5	PHYSICAL	NO	DM>P; BRN M/GRY CLAY; OX CLASTS; TUBES; VERTICAL BURROW?
B300S	A	8/23/2000	19:33	ST_I	3	>4	>4	0	0	17.35	18.57	1.22	17.96	17.35	18.57	>17.96	0	0	0	3.12	6.83	5.32	0	7	PHYSICAL	NO	DM>P; BRN M/GREY CLAY; LG TUBES; COHESIVE CLAY @ Z
B300S	B	8/23/2000	19:34	ST_I_ON_III	2	>4	>4	0	0	18.47	18.84	0.37	18.65	18.47	18.84	>18.65	0	0	0	3.44	7.25	5.58	0	11	PHYSICAL	NO	DM>P; BRN M/GREY CLAY; DENSE TUBES; COH. CLAY @Z; BURROW; VOID
B300S	C	8/23/2000	19:35	ST_I_ON_III	2	>4	>4	5	0.48	18.15	19.84	1.69	18.99	18.15	19.84	>18.99	0	0	0	0.11	6.4	3.27	0	10	PHYSICAL	NO	DM>P; BRN M/GREY CLAY; VOID; OX CLASTS; COHESIVE CLAY @ Z
B300SW	B	8/23/2000	18:20	ST_I_ON_III	3	>4	>4	0	0	12.06	14.02	1.96	13.04	12.06	14.02	>13.04	0	0	0	0.49	3.39	1.88	0	8	PHYSICAL	NO	DM>P; BRN M/GREY CLAY; COHESIVE CLAY CHUNKS @ Z; WORM @ Z; VOIDS
B300SW	C	8/23/2000	18:21	ST_I_ON_III	3	>4	>4	0	0	19.37	20.95	1.59	20.16	19.37	20.95	>20.16	0	0	0	0.11	2.49	1.16	0	7	PHYSICAL	NO	DM>P; BRN M/GREY CLAY; VOID; WORM & COHESIVE CLAY CHUNKS @ Z
B300SW	D	10/23/2000	14:06	INDET	2	>4	>4	0	0	14.46	15.97	1.51	15.22	14.46	15.97	>15.22	0	0	0	NA	NA	NA	0	99	INDET	NO	DM>P; SANDY M/GRY CLAY; CHAOTIC FABRIC
B300W	D	10/20/2000	21:11	ST_I	2	>4	>4	1	0.33	19.73	20.98	1.26	20.36	19.73	20.98	>20.36	0	0	0	2.46	5.3	4.31	0	7	PHYSICAL	NO	DM>P; BRN M/GREY CLAY; WORMS @Z; DIST. SURF
B300W	E	10/20/2000	21:11	INDET	2	>4	>4	1	0.33	21	21	INDET	21	21	21	>21	0	0	0	NA	NA	NA	0	99	INDET	NO	OVERPENETRATION; DM>P; VOID
B300W	F	10/20/2000	21:13	ST_I	3	>4	>4	0	0	21	21	INDET	21	21	21	>21	0	0	0	0.22	0.82	0.51	0	2	PHYSICAL	NO	OVERPENETRATION; DM>P; WORM @SURF; SHALLOW RPD
B300NW	D	10/20/2000	21:30	ST_I_ON_III	2	>4	>4	3	0.33	18.85	20.66	1.8	19.75	18.85	20.66	>19.75	0	0	0	3.55	4.75	4.21	0	11	PHYSICAL	NO	DM>P; BRN SANDY M/GREY CLAY; VOIDS; OX CLASTS; TUBES
B300NW	E	10/20/2000	21:31	INDET	3	>4	>4	0	0	21	21	INDET	21	21	21	>21	0	0	0	NA	NA	NA	0	99	INDET	NO	OVERPENETRATION; DM>P; WORMS @Z
B300NW	H	10/24/2000	18:32	ST_I	2	>4	>4	4	0.27	7.11	10.75	3.64	8.93	7.11	10.75	>8.93	0	0	0	2.62	4.28	3.42	0	6	PHYSICAL	NO	DM>P; BRN M/GREY CLAY; COH.CLAY; DIST SURF
B450S	A	8/23/2000	19:24	ST_I_ON_III	3	>4	>4	0	0	15.29	18.57	3.28	16.93	15.29	18.57	>16.93	0	0	0	2.59	6.4	5.08	0	11	PHYSICAL	NO	DM>P; BRN M/GREY CLAY; VIOD; LG COHESIVE CLAY @ Z
B450S	C	8/23/2000	19:26	ST_I	3	>4	>4	0	0	12.8	13.44	0.63	13.12	12.8	13.44	>13.12	0	0	0	0.16	6.08	3.27	0	6	BIOGENIC	NO	DM>P; BRN M/GREY CLAY; WORMS & COHESIVE CLAY @ Z; DENSE TUBES
B450S	G	10/24/2000	17:54	ST_I	3	>4	>4	0	0	10.32	11.39	1.07	10.86	10.32	11.39	>10.86	0	0	0	1.39	4.33	2.96	0	5	BIOGENIC	NO	DM>P; BRN M/YEL.CLAY; DENSE LG.TUBES; PULL AWAY

Appendix B3

REMOTS® Sediment-Profile Imaging Data from the MBDS Reference Areas

Station	Replicate	Date	Time	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					
FG-23																											
2	D	9/24/2000	15:05	ST_II	3	>4	>4	1	2.16	10.29	17.25	6.96	13.77	0	0	0	0	0	0	1.32	5.64	4.62	0	9	PHYSICAL	NO	M>P; SLOPING SURF; SURFACE REWORKING=INFAUNAL AMPS
2	E	9/24/2000	15:06	ST_I	3	>4	>4	0	0	12.99	15.98	2.99	14.49	0	0	0	0	0	0	2.25	4.07	3.06	0	6	PHYSICAL	NO	M>P; SM SURF TUBE
2	F	9/24/2000	15:07	ST_I	2	>4	>4	8	0.41	12.66	16.42	3.76	14.54	0	0	0	0	0	0	1.97	6.53	4.38	0	7	INDET	NO	; BURROW?; DIST SURFACE; PPA
3	D	9/24/2000	14:44	INDET	3	>4	>4	4	0.82	1.72	3.43	1.72	2.57	0	0	0	0	0	0	NA	NA	NA	0	99	PHYSICAL	NO	M>P; ROUGH SURF; REWORKING OF SED; CLAY CLASTS
3	E	9/24/2000	14:45	ST_I_TO_II	3	>4	>4	4	0.82	13.24	15.98	2.75	14.61	0	0	0	0	0	0	2.06	5.29	4.04	0	8	PHYSICAL	NO	M>P; ROUGH SURF; WORMS?
3	F	9/24/2000	14:45	ST_I	3	>4	>4	4	0.82	10.29	15.49	5.2	12.89	0	0	0	0	0	0	0.38	2.57	1.77	0	4	PHYSICAL	NO	M>P; SLOPING SURF
4	D	9/24/2000	14:59	ST_III	3	>4	>4	4	0.82	8.68	9.75	1.08	9.22	0	0	0	0	0	0	0.93	3.99	2.96	0	9	PHYSICAL	NO	M>P; REWORKING OF SED SURF; FEEDING VOIDS
4	E	9/24/2000	15:00	ST_I	3	>4	>4	4	0.82	15.88	18.28	2.4	17.08	0	0	0	0	0	0	2.84	4.75	3.62	0	6	PHYSICAL	NO	M>P; SURF DIST
4	F	9/24/2000	15:00	ST_I	3	>4	>4	4	0.82	12.55	15	2.45	13.77	0	0	0	0	0	0	0.98	3.87	2.6	0	5	PHYSICAL	NO	M>P; BURROW
5	A	9/24/2000	14:38	ST_II_ON_III	3	>4	>4	4	0.82	8.24	10.2	1.96	9.22	0	0	0	0	0	0	2.45	4.07	3.26	0	10	PHYSICAL	NO	M>P; MUD CLAST; WORM; VOID
5	B	9/24/2000	14:39	ST_II	3	>4	>4	4	0.82	13.04	13.82	0.78	13.43	0	0	0	0	0	0	1.96	3.97	3.3	0	8	BIOGENIC	NO	M>P; LG WORM ON SURF; REWORKING OF SURF SED
5	C	9/24/2000	14:39	ST_II	3	>4	>4	4	0.82	10.59	16.37	5.78	13.48	0	0	0	0	0	0	0.98	3.11	1.57	0	6	PHYSICAL	NO	M>P; WORM
6	D	10/20/2000	20:27	ST_I	3	>4	>4	6	0.32	14.68	15.27	0.59	14.97	0	0	0	0	0	0	2.53	4.84	3.6	0	6	PHYSICAL	NO	M>P; OX CLASTS; WORM @Z; SHELL @Z; DIST SURF
6	E	10/20/2000	20:28	ST_I	2	>4	>4	0	0	15.65	18.76	3.12	17.2	0	0	0	0	0	0	1.08	7.04	4.8	0	7	PHYSICAL	NO	M>P; BURROW?; YELLOW CLAY STREAKS
6	F	10/20/2000	20:28	ST_I	2	>4	>4	5	0.32	17.53	19.68	2.15	18.6	0	0	0	0	0	0	0.05	6.4	4.48	0	7	PHYSICAL	NO	M>P; OX&RED CLASTS; TUBES
SE-REF																											
1	A	9/24/2000	13:44	ST_II_ON_III	3	>4	>4	0	0	8.58	11.72	3.14	10.15	0	0	0	0	0	0	2.6	6.37	4.16	0	11	PHYSICAL	NO	M>P; WORMS; FEEDING VOID
1	B	9/24/2000	13:45	ST_II	3	>4	>4	1	2.32	9.66	14.71	5.05	12.18	0	0	0	0	0	0	0.98	6.17	3.79	0	9	PHYSICAL	NO	M>P; SM SURF TUBE; LG MUD CLAST; SLOPING SURF
1	C	9/24/2000	13:46	ST_II_ON_III	3	>4	>4	1	2.32	11.91	15.93	4.02	13.92	0	0	0	0	0	0	1.86	6.52	4.57	0	11	PHYSICAL	NO	M>P; FEEDING VOID; SURFACE BURROWS=INFAUNAL AMPS
2	A	9/24/2000	13:50	ST_II	3	>4	>4	1	2.32	13.87	16.18	2.3	15.02	0	0	0	0	0	0	3.28	4.22	3.74	0	8	PHYSICAL	NO	M>P; SURFACE REWORKING=INFAUNAL AMPS
2	B	9/24/2000	13:50	ST_II	3	>4	>4	1	2.32	11.72	15.05	3.33	13.38	0	0	0	0	0	0	2.35	6.08	3.99	0	9	PHYSICAL	NO	M>P; POLYCHAETE TUBES; SEDIMENT REWORKING
2	C	9/24/2000	13:51	ST_II	3	>4	>4	1	2.32	9.36	12.11	2.75	10.74	0	0	0	0	0	0	0.22	3.99	1.98	0	6	PHYSICAL	NO	M>P; REWORKING SURF SED=AMPS; WORMS
3	A	9/24/2000	13:57	ST_I	3	>4	>4	1	2.32	11.96	16.62	4.66	14.29	0	0	0	0	0	0	0.05	7.05	4.04	0	7	PHYSICAL	NO	M>P; ROUGH SURF
3	B	9/24/2000	13:57	ST_I_TO_II	3	>4	>4	1	2.32	10.34	12.89	2.55	11.62	0	0	0	0	0	0	1.37	5.05	3.5	0	7	PHYSICAL	NO	M>P; SURF TUBES
3	C	9/24/2000	13:58	ST_III	2	>4	>4	1	2.32	17.35	18.63	1.27	17.99	0	0	0	0	0	0	6.62	7.65	7.15	0	11	INDET	NO	M>P; DIST SURF; REWORKING OF SURF SED; BURROW; VOIDS
4	A	9/24/2000	13:39	ST_I	3	>4	>4	0	0	5.93	6.81	0.88	6.37	0	0	0	0	0	0	1.96	3.82	2.94	0	5	PHYSICAL	NO	M>P; REWORKING OF SURF SED; SM SURF TUBES
4	B	9/24/2000	13:39	ST_II	3	>4	>4	0	0	3.82	5.49	1.67	4.66	0	0	0	0	0	0	NA	NA	NA	0	99	PHYSICAL	NO	M>P; SURF DIST; REWORKING OF SURF SED; PPA
4	C	9/24/2000	13:40	ST_II_ON_III	3	>4	>4	0	0	11.27	13.19	1.91	12.23	0	0	0	0	0	0	0.44	5.46	2.98	0	9	PHYSICAL	NO	M>P; REWORKING OF SURF SED=INFAUNAL AMPS; FEEDING VOID