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13. ABSTRACT
The Western Long Island Disposal Site (WLDS) was monitored by Science Applications International Corporation (SAIC) in June 2001 as part of the Disposal Area Monitoring System (DAMOS). The objectives of this survey were to assess the bottom topography and benthic habitat conditions over the area of WLDS that had received dredged material since 1997. Field efforts consisted of precision bathymetry to evaluate changes in bottom topography and a Remote Ecological Monitoring of the Seafloor (REMOTS®) sediment-profile imaging survey to assess benthic conditions and determine the lateral extent of the dredged material on the seafloor. The surveys showed that three distinct mounds (WLIS J, K, and L Mounds) were formed as a result of the disposal operations during the 1997-2001 seasons. The management strategy at WLDS and other DAMOS sites in recent years has involved moving the buoy location at regular intervals to create a ring of dredged material mounds on the seafloor. This creates bowl-like bathymetric features (i.e., an artificial "containment cell") within which large deposits of non-cohesive dredged material could be confined. The creation of WLIS J, K, and L Mounds during the 1997-2001 disposal seasons was intended to fill in the gaps in a previously created ring of mounds to complete a first artificial containment cell at WLDS. The June 2001 bathymetric survey showed that WLIS J Mound was only a subtle deposit and not easily discerned on the seafloor, while WLIS K and WLIS L Mounds were of sufficient height and width to provide containment of a large unconsolidated sediment deposit. Thus, future disposal activity should be directed to the J Mound. A sediment-profile imaging survey grid encompassing the three new mounds indicated a fairly wide distribution of recently deposited sediment on the WLDS seafloor. Dredged material was detected at depths exceeding camera penetration at 24 of the 25 stations occupied. Benthic recolonization over the dredged material deposit was relatively advanced, with evidence of Stage III activity at all stations. Redox Potential Discontinuity (RPD) depths over the newly deposited sediment were shallow to moderate. However, with mean depths per station ranging from 1.1 to 2.8 cm and an overall average value of nearly 1.9 cm, the RPDs were comparable to those documented at the WLDS reference areas. Despite the shallow to moderate RPD depths, median Organism-Sediment Index (OSI) values remained high due to the advanced successional stage status. OSI values ranged from +5 to +9 with an average value of +7.6, comparable to the composite values calculated for the reference areas. The June 2001 field operations also included a REMOTS® survey over two other mounds, WLIS I Mound, which was created five years prior to the survey, and WLIS D Mound, where variable benthic conditions have been observed in the past. These surveys showed that the successional status was also advanced (presence of Stage III organisms) over the WLIS I Mound and that benthic habitat conditions appeared to be stable at WLIS D Mound. In accordance with the DAMOS Tiered Monitoring Protocol, no immediate action is required and only periodic monitoring of WLIS D Mound is recommended during future surveys at WDLS.

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TABLE OF CONTENTS

Page

TABLE OF CONTENTS (continued)

Page

LIST OF TABLES

Page

LIST OF FIGURES

Page

Page

Page

EXECUTIVE SUMMARY

As part of the Disposal Area Monitoring System (DAMOS) Program, Science Applications International Corporation (SAIC) conducted an environmental monitoring survey over the Western Long Island Sound Disposal Site (WLDS) between 23 and 25 June 2001. The objectives of the survey were to assess the bottom topography and benthic habitat conditions over the area of WLDS that had received dredged material since 1997. Field efforts consisted of precision bathymetry to evaluate changes in bottom topography and a Remote Ecological Monitoring of the Seafloor (REMOTS®) sediment-profile imaging survey to assess benthic conditions and determine the lateral extent of the dredged material on the seafloor. The surveys showed that three distinct mounds (WLIS J, K, and L Mounds) were formed as a result of the disposal operations during the 1997–2001 seasons and that benthic recolonization over WLDS was advanced, with evidence of the presence of Stage III biological organisms throughout the survey area.

The management strategy at WLDS and other DAMOS sites in recent years has involved moving the buoy location at regular intervals to create a ring of dredged material mounds on the seafloor. This creates bowl-like bathymetric features (i.e., an artificial "containment cell") within which large deposits of non-cohesive dredged material could be confined. The WLIS C, D, E, F, G and I Mounds were arranged in a ring on the seafloor from disposal activities prior to the 1997 disposal season, and were beginning to form a containment cell. The creation of the WLIS J, K and L Mounds during the 1997–2001 disposal seasons was intended to fill the gaps in that ring of mounds to complete a first artificial containment cell at WLDS. The June 2001 bathymetric survey showed that the WLIS J Mound was only a subtle deposit and not easily discerned on the seafloor. This mound did not display sufficient height or width to be useful as a containment structure. As a result, future disposal activity should be directed to the J Mound to close the first artificial containment cell on the WLDS seafloor. The WLIS K and WLIS L Mounds are of sufficient height and width to provide containment of a large unconsolidated sediment deposit.

A sediment-profile imaging survey grid encompassing the WLIS J, WLIS K, and WLIS L Mounds occupied as part of the 2001 survey effort indicated a fairly wide distribution of recently deposited sediment on the WLDS seafloor. Dredged material was detected at depths exceeding camera penetration at 24 of the 25 stations occupied. Benthic recolonization over the dredged material deposit was relatively advanced, with evidence of Stage III activity present at all stations within the survey grid. Redox Potential Discontinuity (RPD) depths over the newly deposited sediment were considered shallow to moderate. However, with mean depths per station ranging from 1.1 to 2.8 cm and an overall average value of nearly 1.9 cm, the RPDs were comparable to those documented at the WLDS reference areas (average mean RPD depths 1.3, 1.7, and 2.5 cm from reference

areas SW REF, S REF, and SE REF, respectively). Despite the shallow to moderate RPD depths, median Organism-Sediment Index (OSI) values calculated for the recent dredged material deposits remained high due to the advanced successional stage status. OSI values within the 25-station grid ranged from +5 to +9 with an average value of +7.6, comparable to the composite values calculated for the WLDS reference areas.

The June 2001 field operations also included a REMOTS® survey over the WLIS I Mound to assess benthic conditions five years after its formation, as well as a survey at two stations at the WLIS D Mound (Stations D200S and D300S) where variable benthic conditions have been observed in the past. These surveys showed that the successional status was also advanced (presence of Stage III organisms) over the WLIS I Mound and that benthic habitat conditions appeared to be stable at Stations D200S and D300S. In accordance with the DAMOS Tiered Monitoring Protocol, no immediate action is required and only periodic monitoring of these stations is recommended during future surveys at WLDS.

1.0 INTRODUCTION

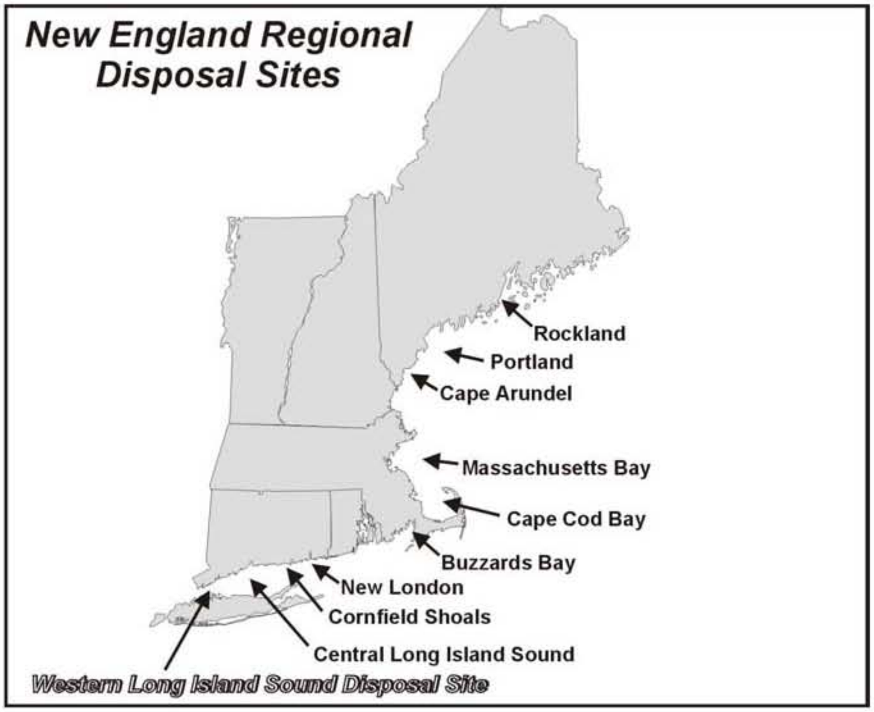
1.1 Background

In 1977, the New England District (NAE) of the U.S. Army Corps of Engineers established the Disposal Area Monitoring System (DAMOS) to monitor the environmental impacts associated with the subaqueous disposal of sediments dredged from harbors, inlets, and bays in the New England region. The DAMOS Program conducts detailed monitoring studies to detect and minimize any physical, chemical, and biological impacts of dredging and dredged material disposal activities. DAMOS monitoring helps to ensure that any effects of sediment deposition on the marine environment are confined to designated seafloor areas and are of limited duration. A flexible, tiered monitoring protocol (Germano et al. 1994) is applied in the long-term management of dredged material disposal at ten open-water sites along the coast of New England (Figure 1-1).

Most of the material generated from dredging projects in the western Long Island Sound region is transported by barge and deposited at the Western Long Island Sound Disposal Site (WLDS). WLDS is located 5.13 km south of Long Neck Point, Noroton, Connecticut between three historic dredged material disposal sites (Stamford, South Norwalk, and Eaton's Neck; Figure 1-2). WLDS was officially opened in 1982 as the single active dredged material disposal site in the western Long Island Sound region (USACE 1982). This 5.29 km^2 site has accepted small to moderate volumes of dredged material originating from Stamford, Norwalk, and other coastal communities of Connecticut and New York (Figure 1-3).

The management strategy at WLDS and other DAMOS sites in recent years has involved moving the buoy location at regular intervals to create a ring of dredged material mounds on the seafloor. This creates bowl-like bathymetric features (i.e., an artificial "containment cell") within which large, non-cohesive dredged material deposits could be confined. Placing non-cohesive material within such an artificial containment cell serves to limit its lateral spread on the seafloor. Although subaqueous capping of unacceptably contaminated dredged material (UDM) has not been employed as a management technique at WLDS, artificial containment cells have proven useful at confining UDM deposits, and facilitate efficient coverage with a layer of capping dredged material (CDM). The success of this management strategy was first demonstrated with the construction of the NHAV 93 Mound at the Central Long Island Sound Disposal Site (CLDS) during the 1993–94 disposal season (Fredette 1994; Morris et al. 1996).

A



B

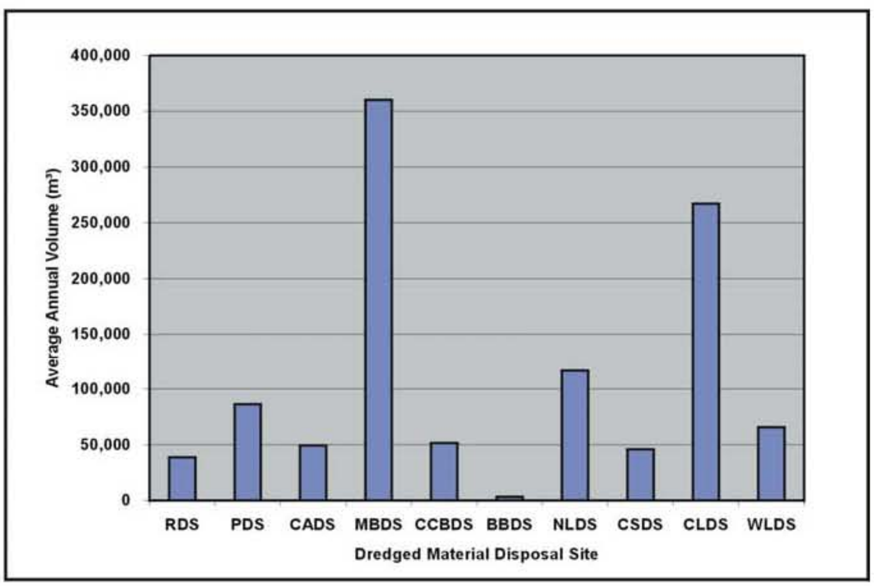


Figure 1-1. Location of disposal sites along coastal New England (A) and average annual dredged material disposal volumes for the ten New England disposal sites based on the period 1982 to 2001 (B)

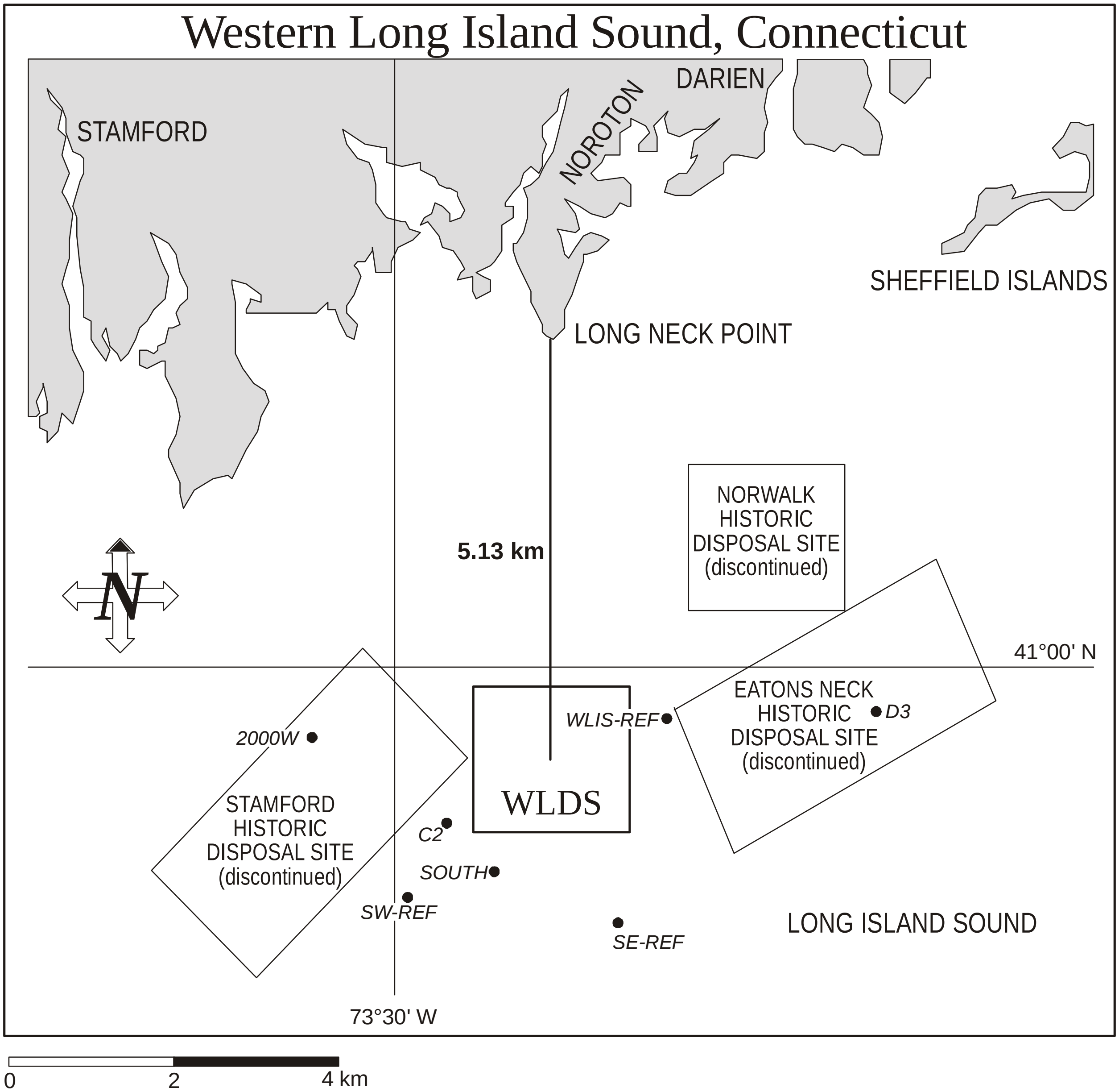


Figure 1-2. Location of the Western Long Island Sound Disposal Site (WLDS) relative to the Connecticut coastline

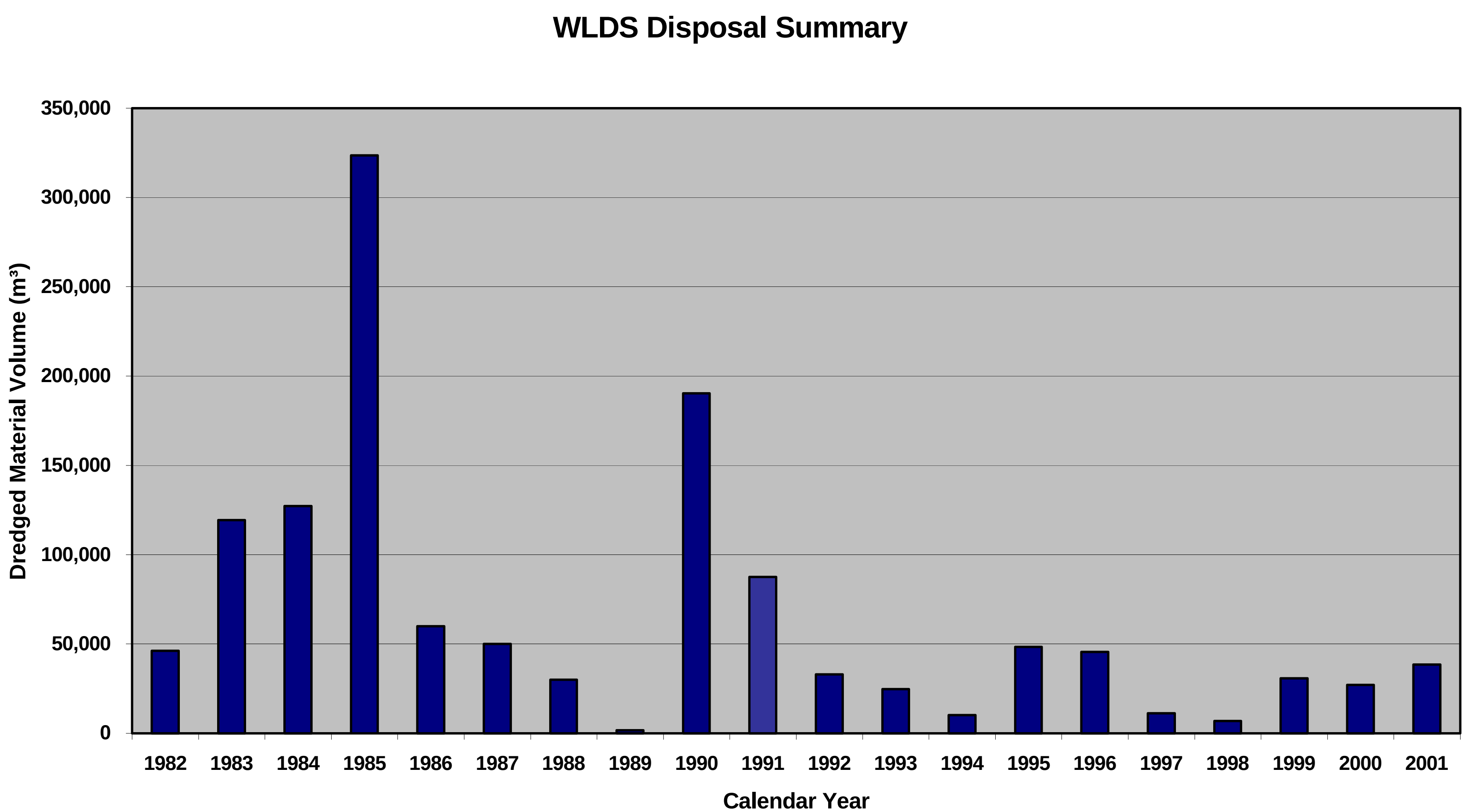


Figure 1-3. Histogram displaying volume of dredged material placed at WLDS during calendar years 1982 to 2001

Bathymetric data were collected over WLDS in July 1996 and September 1997 (Morris 1996; Murray and Saffert 1999). These surveys showed several distinct mounds on the seafloor in the southwest quadrant of WLDS as a result of dredged material disposal at different points (i.e., buoy locations) during annual disposal seasons. The individual mounds within the disposal site correspond to these buoy locations and have been designated with a letter (currently A through J) based on order of development. The letter designation is preceded by the prefix WLIS (Western Long Island Sound) in order to retain the naming convention used in previous DAMOS reports. The disposal buoy locations had been moved strategically over the years, such that the resulting WLIS C, D, E, F, G, and I Mounds were arranged in a ring on the seafloor and beginning to form a containment cell (Figure 1-4).

Since the September 1997 bathymetric survey, a total estimated barge volume of 100,000 m^3 of sediment from numerous small-scale dredging projects has been placed at WLDS during the 97–98, 98–99, 99–00, and 00–01 disposal seasons (Figure 1-3; Appendix A). To continue creating the containment cell in the active southwest quadrant of WLDS, the disposal buoy location has been moved between disposal seasons (Figure 1-4). In September 1997, the WDA 97 buoy was placed at coordinates 40° 59.184´ N, 73° 28.728´ W between the pre-existing WLIS F and H Mounds. Two small dredging projects in the region generated a total volume of 10,700 m^3 during the 1997–98 disposal season. The WDA buoy was re-located to coordinates 40° 59.284´ N, 73° 28.756´ W (WDA 98) between the WLIS H and WLIS E Mounds during the 1998–99 disposal season, marking the disposal point for 33,500 m^3 of dredged material (Figure 1-4). In the fall of 1999, the WDA 99 buoy was deployed at coordinates 40° 59.377´ N, 73° 28.905´ W between the WLIS C and WLIS E Mounds. A reported barge volume of 16,500 m^3 was placed at the WDA 99 buoy during the 1999 and 2000, followed by 39,000 m^3 at this same buoy location (WDA 00) in the 2000–01 disposal season (Figure 1-4). Given the active disposal at WLDS since the September 1997 monitoring survey, one objective of the June 2001 survey was to determine the resulting changes in bottom topography.

The WLIS D Mound is an older dredged material deposit that was developed during the 1989–90 disposal season. This bottom feature is composed of approximately 185,000 m^3 of sediment dredged from multiple small projects in New York and Connecticut (Germano et al. 1993). Between 1990 and 1996, two stations on the southern flank of the disposal mound (D200S and D300S) demonstrated poor benthic habitat conditions, with low reflectance sediments and a patchy Stage I infaunal community. Toxicity testing suggested that high concentrations of organic carbon and resulting high sediment oxygen demand was the basis of the poor habitat conditions detected during the summer surveys (Eller and Williams 1996).

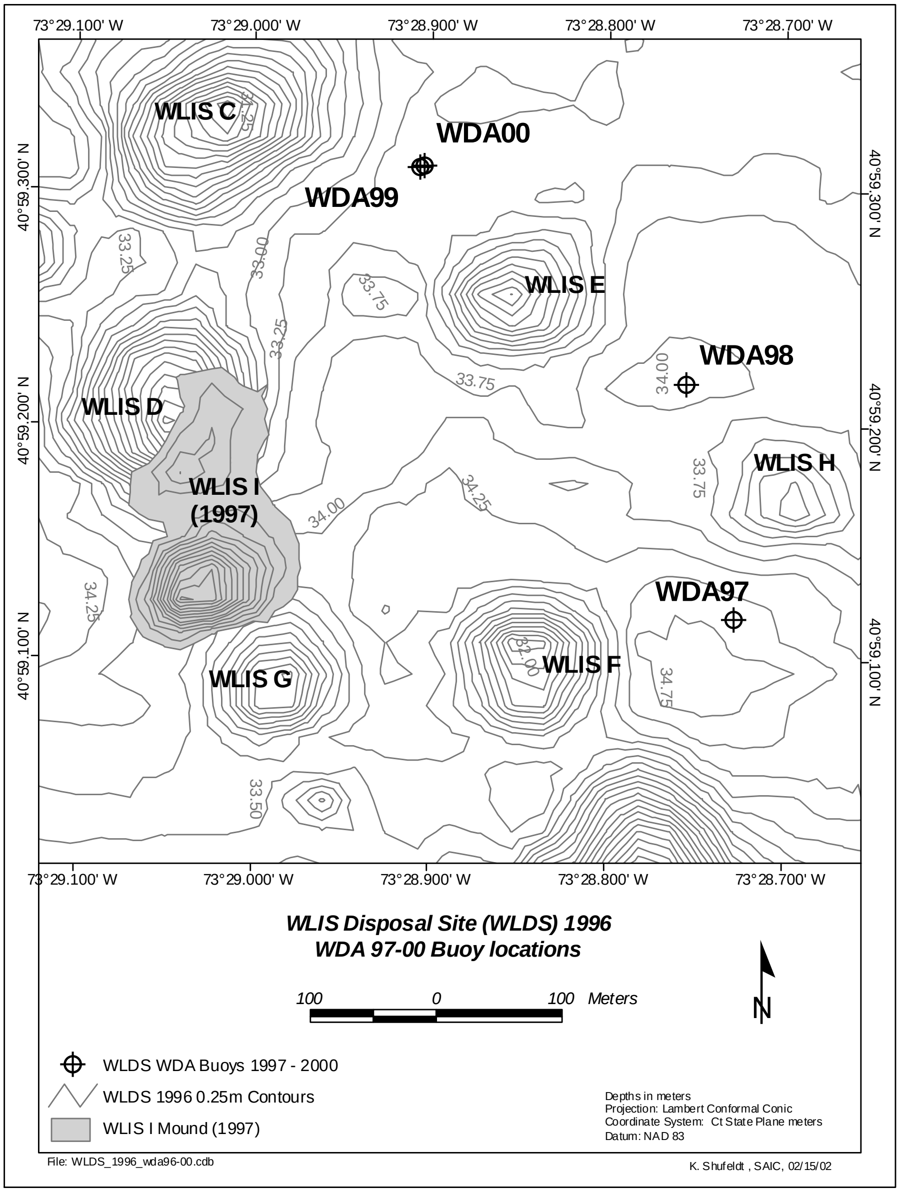


Figure 1-4. Bathymetric chart showing the locations of several disposal mounds in the southwest quadrant of WLDS prior to the June 2001 survey. The chart is based on bathymetric data collected in July 1996, except for the WLIS I Mound formed during the 96–97 disposal season and detected in the September 1997 bathymetric survey. Buoy locations are also shown for the following disposal seasons: 97–98 (WDA 97), 98–99 (WDA 98), 99–00 (WDA 99), and 00–01 (WDA 00).

In September 1996, the WDA 96 buoy was placed at coordinates 40° 59.203´ N, 73° 29.072´ W between the WLIS D and WLIS G Mounds. An estimated 35,000 m^3 of dredged material was placed at this buoy during the 1996–97 disposal season to form the WLIS I Mound (Figure 1-4). It was anticipated that creating a new mound on the southern flank of the WLIS D Mound would provide a new layer of sediment that would serve to isolate the enriched sediment from the marine environment (Murray and Saffert 1999). A second objective of the June 2001 monitoring survey was to verify improvement in benthic habitat conditions over the southern flank of the WLIS D Mound.

During the September 1997 monitoring survey, a potential new reference area (SE REF) was investigated and appeared to be free of any effects from past dredged material placement operations. However, because the western Long Island sound region has been subjected to widespread distribution of dredged material in the past, it was recommended that the proposed SE REF area be examined further before being accepted as a long-term reference area. The additional investigations, conducted during the June 2001 survey, were intended to confirm the absence of any signs of historic dredged material within the SE REF area.

1.2 Objectives and Predictions

In summary, the June 2001 environmental monitoring survey over WLDS included the following activities and objectives:

1) Use precision bathymetric data and Remote Ecological Monitoring of the Seafloor (REMOTS®) sediment-profile imaging to map the distribution of dredged material and determine the changes in bottom topography resulting from dredged material placement operations during the 1997–98, 1998–99, 1999–2000, and 2000–01 disposal seasons.

2) Evaluate benthic recolonization over the area of seafloor affected by the dredged material disposal activity, relative to surrounding reference areas;

3) Assess benthic habitat conditions over the central portion of the WLIS I Mound and historic WLIS D Mound stations; and

4) Examine the bottom topography and benthic habitat conditions of SE REF to further determine its potential for long-term use as a reference area for WLDS.

The field effort tested the following predictions:

1) The past five years of disposal activity at WLDS will result in the formation of three new discrete dredged material mounds (WLIS J, K, and L Mounds). The creation of these mounds will complete the first containment ring within WLDS.

2) Benthic conditions over the area most recently affected by dredged material disposal (WDA survey grid) will show the presence of advanced Stage III organisms. Stage I organisms may be the predominate successional stage at stations located near the WLIS L Mound as some of this material has been in place less than one year.

3) Benthic conditions over the WLIS I Mound will show the presence of Stage III organisms, and the two stations of the WLIS D Mound (Stations D200S and D300S) will show improved benthic conditions over previous surveys.

4) The bathymetric survey over the SE REF reference area will confirm previous side-scan sonar results collected in 1998 that no dredged material exists within the area and that it is therefore suitable for long-term use as a reference area for WLDS.

2.0 METHODS

Field operations involving precision bathymetry and REMOTS® sediment-profile imaging were conducted at WLDS aboard the M/V *Beavertail* from 23 to 25 June 2001. The REMOTS® and single-beam bathymetric survey techniques used during the 2001 survey are standard DAMOS methods and have been well documented in numerous previous reports (Murray and Saffert 1999).

2.1 Navigation

Differentially-corrected Global Positioning System (DGPS) data in conjunction with Coastal Oceanographic's HYPACK® navigation and survey software were used to provide real-time navigation of the survey vessel to an accuracy of ±3 m. A DSMPro GPS receiver was used to obtain raw satellite data and provide vessel position information in the horizontal control of North American Datum of 1983 (NAD 83). The GPS receiver was integrated with a differential beacon receiver to improve overall accuracy of the satellite data to the necessary tolerances. The U.S. Coast Guard differential beacon broadcasting from Moriches, New York (293 kHz) was utilized for real-time satellite corrections due to its geographic position relative to WLDS.

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

2.2 Bathymetric Data Acquisition and Analysis

2.2.1 Bathymetric Data Acquisition

To fulfill the objectives of the 2001 WLDS monitoring survey, two separate bathymetric survey areas were defined. The primary survey was used to examine the active southwest quadrant of WLDS and the secondary survey was conducted to examine the SE-REF reference area. A 1000 × 1000 m bathymetric survey centered at the WDA 98 buoy location (coordinates 40° 59.284´ N, 73° 28.756´ W; NAD 83) was completed on 25 June 2001 (Figure 2-1). This survey, which encompassed the areas of all of the recent dredged material placement activity, consisted of 41 lanes oriented in an east/west direction and spaced at 25 m intervals, as well as three cross-check survey lines oriented in a north-south direction. In addition, a 650 × 500 m bathymetric survey centered over the SE REF reference area (coordinates 40° 58.307´ N, 73° 27.696´ W; NAD 83) was also completed on 25 June 2001 (Figure 2-1). This survey, which encompassed the full extent of the SE REF, consisted of 11 lanes oriented in an east/west direction and spaced at 50 m intervals, as well as three cross-check survey lines oriented in a north-south direction.

During the bathymetric survey, the HYPACK® system was interfaced with an Odom Hydrotrac® survey echosounder, as well as the Trimble DGPS receiver. The Hydrotrac® uses a narrow-beam (3°), 208-kHz transducer to make discrete depth measurements and produce a continuous analog record of the seafloor. The Hydrotrac® transmits 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 could be 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 values, sound velocity and draft corrections were applied, and the soundings 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. 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 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.

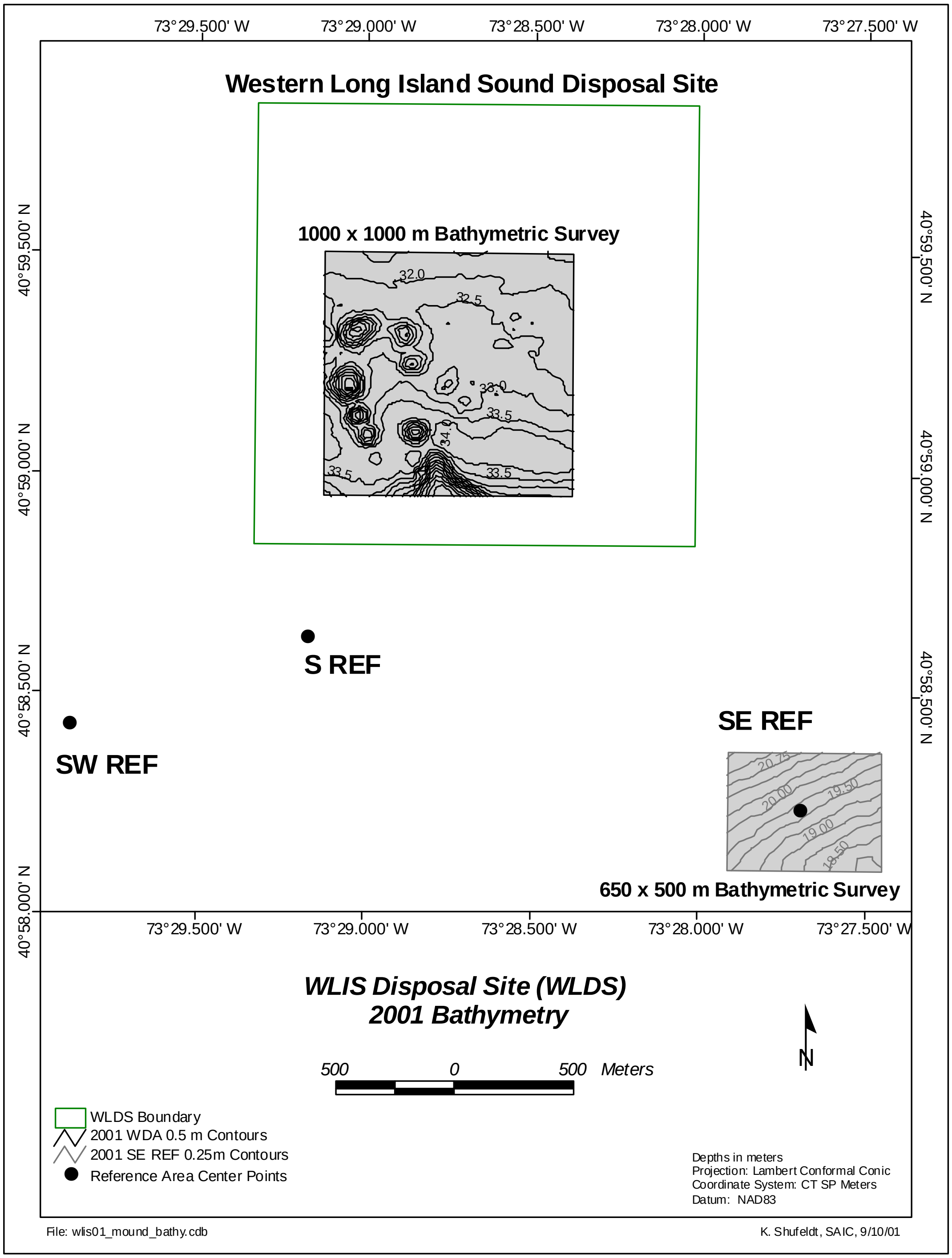


Figure 2-1. The 1.0 km² and 0.25 km² bathymetric survey areas established over WLDS and SE REF, relative to the disposal site boundary and remaining reference areas

Observed tide data were obtained through NOAA's National Water Level Observation Network. The NOAA six-minute tide data were downloaded in the MLLW datum and corrected for tidal offsets. Science Applications International Corporation (SAIC) used the water level data available from the operating NOAA tide station in Bridgeport, Connecticut and applied the published time and height corrections for Greens Ledge, Sheffield Island, Connecticut.

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. After the full data set was verified, it was processed through the HYPACK® Mapper routine to systematically reduce its size. Because of the rapid rate at which a survey echosounder can generate data (approximately ten depths per second), the along-track data density for a single-beam survey tends to be very high (multiple soundings per meter). In most cases, these data sets contain many redundant data points that can be eliminated without any effect on overall data quality. The Mapper routine examines the data along each survey line and then extracts only the representative soundings based on a user-specified distance interval and selection criteria. The output from the Mapper routine is a merged ASCII-xyz (position and corrected depth) file that may contain anywhere from 2–10% of the original data set. These greatly reduced, but still representative, data sets are far more efficient to use in the subsequent modeling and analysis routines. For the June 2001 WLDS survey, the data were mapped at intervals of 5 and 10 m for later analysis.

2.2.3 Bathymetric Data Analysis

The primary intent of the bathymetric data analysis was to evaluate the seafloor surface to identify any unique features and to account for any observed differences with prior surveys. Because single-beam bathymetric survey data typically cover only a small percentage of the total seafloor area (approximately 5%), these analysis tools rely on a large degree of interpolation between the discrete survey data points to generate a three-dimensional seafloor surface model. This interpolation usually works well in flat or gently-sloping areas, but in steep and irregular areas the interpolation of the surface can be very dependent upon the orientation of the survey lines and the density of the data around the area. The bathymetric survey data were gridded through the ArcGis® ArcInfo software module to generate a depth model for the entire survey area, using a grid cell size of 25 × 25 m.

2.3 REMOTS® Sediment-Profile Imaging

REMOTS® sediment-profile imaging is a benthic sampling technique used to detect and map the distribution of thin (<20 cm) dredged material layers, delineate benthic disturbance gradients, and monitor the process of benthic recolonization following physical seafloor disturbance. 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).

Organism-Sediment Index (OSI) values may range from –10 (sediment without visible macrofaunal life in combination with low apparent dissolved oxygen levels and/or presence of methane gas) 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. Because the OSI is calculated using apparent RPD depths and successional stages, indeterminate apparent RPD depths and/or successional stages lead to indeterminate OSI values. REMOTS® image acquisition and analysis methods are described fully in Rhoads and Germano (1982; 1986) and in previous DAMOS reports (e.g., DAMOS Contribution No. 128, SAIC 2001).

The June 2001 REMOTS® survey at WLDS was used to characterize sediment composition, benthic recolonization status, and general habitat conditions. A 25-station rectangular survey grid (WDA survey grid), centered at coordinates 40° 59.284´ N, 73° 28.756´ W, was established over the active area of dredged material disposal (Table 2-1; Figures 2-3 and 2-4). In addition, a grid of 5 stations, consistent with the September 1997 and March 1998 REMOTS® surveys, was re-occupied over the WLIS I Mound to evaluate the continued long-term benthic recovery over this older dredged material deposit. The grid was centered at coordinates 40° 59.209´ N, 73° 29.406´ W, and extended 50 m

Table 2-1.

Coordinates of REMOTS® Stations Sampled over WLDS in June 2001

Area	Station	Latitude (NAD 83)	Longitude (NAD 83)
WDA 98 Grid 40° 59.284′ N 73° 28.756′ W	A1	40° 59.444′ N	73° 28.972′ W
	A2	40° 59.363′ N	73° 28.970′ W
	A3	40° 59.282′ N	73° 28.970′ W
	A4	40° 59.201′ N	73° 28.969′ W
	A5	40° 59.120′ N	73° 28.968′ W
	B1	40° 59.445′ N	73° 28.865′ W
	B2	40° 59.364′ N	73° 28.864′ W
	B3	40° 59.283′ N	73° 28.863′ W
	B4	40° 59.202′ N	73° 28.862′ W
	B5	40° 59.121′ N	73° 28.861′ W
	C1	40° 59.446′ N	73° 28.758′ W
	C2	40° 59.365′ N	73° 28.757′ W
	C3	40° 59.284′ N	73° 28.756′ W
	C4	40° 59.203′ N	73° 28.755′ W
	C5	40° 59.122′ N	73° 28.754′ W
	D1	40° 59.447′ N	73° 28.651′ W
	D2	40° 59.366′ N	73° 28.650′ W
	D3	40° 59.285′ N	73° 28.649′ W
	D4	40° 59.203′ N	73° 28.648′ W
	D5	40° 59.122′ N	73° 28.647′ W
	E1	40° 59.447′ N	73° 28.544′ W
	E2	40° 59.366′ N	73° 28.543′ W
	E3	40° 59.285′ N	73° 28.542′ W
	E4	40° 59.204′ N	73° 28.541′ W
	E5	40° 59.123′ N	73° 28.540′ W
WLIS D Mound	D200S	40° 59.152′ N	73° 29.069′ W
	D300S	40° 59.098′ N	73° 29.069′ W
WLIS I Mound 40° 59.209′ N 73° 29.046′ W	CTR	40° 59.209′ N	73° 29.046′ W
	50N	40° 59.236′ N	73° 29.046′ W
	50S	40° 59.182′ N	73° 29.046′ W
	50E	40° 59.209′ N	73° 29.010′ W
	50W	40° 59.209′ N	73° 29.082′ W

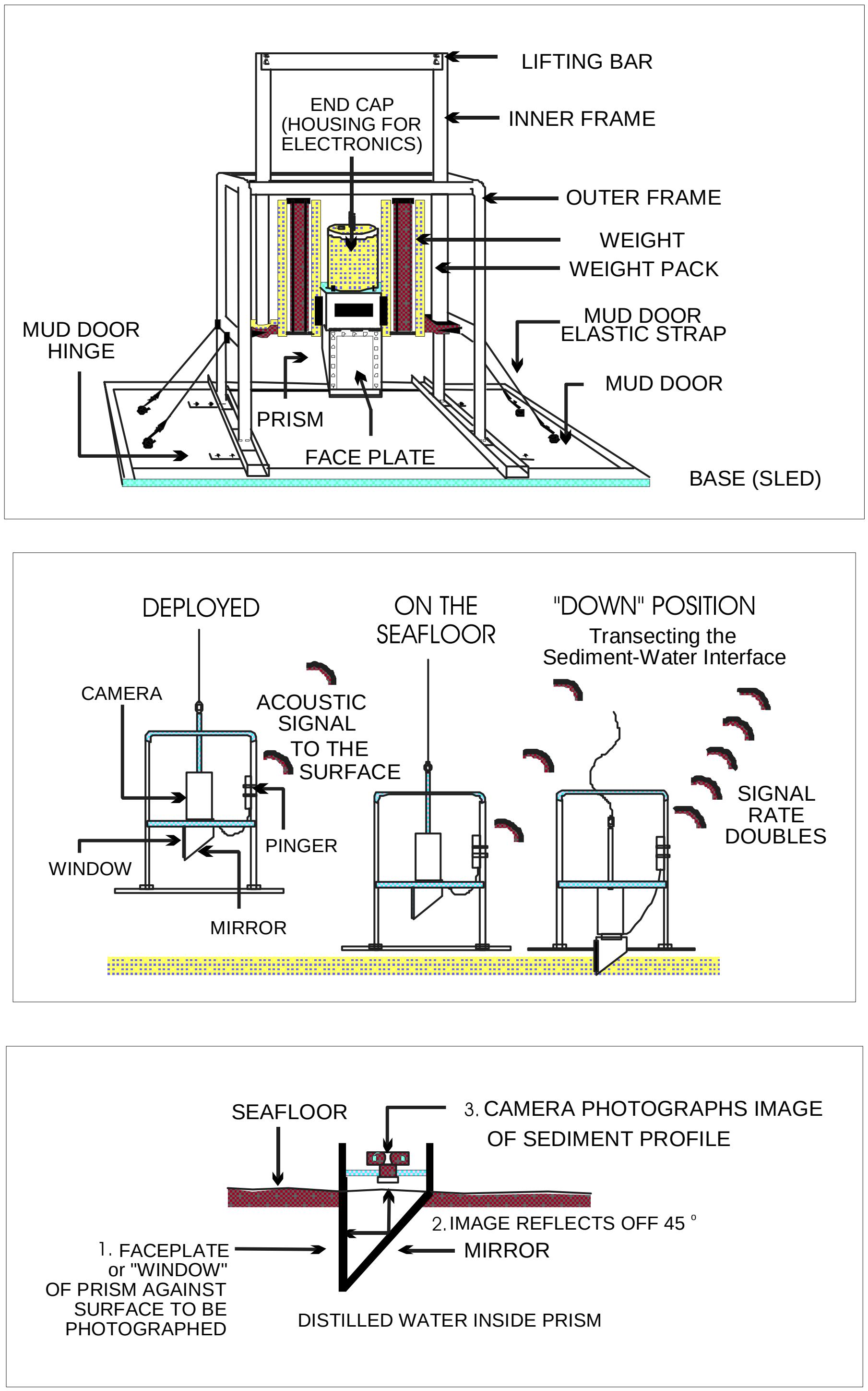


Figure 2-2. Schematic diagram of the Benthos, Inc. Model 3731 REMOTS® sediment-profile camera and sequence of operation on deployment

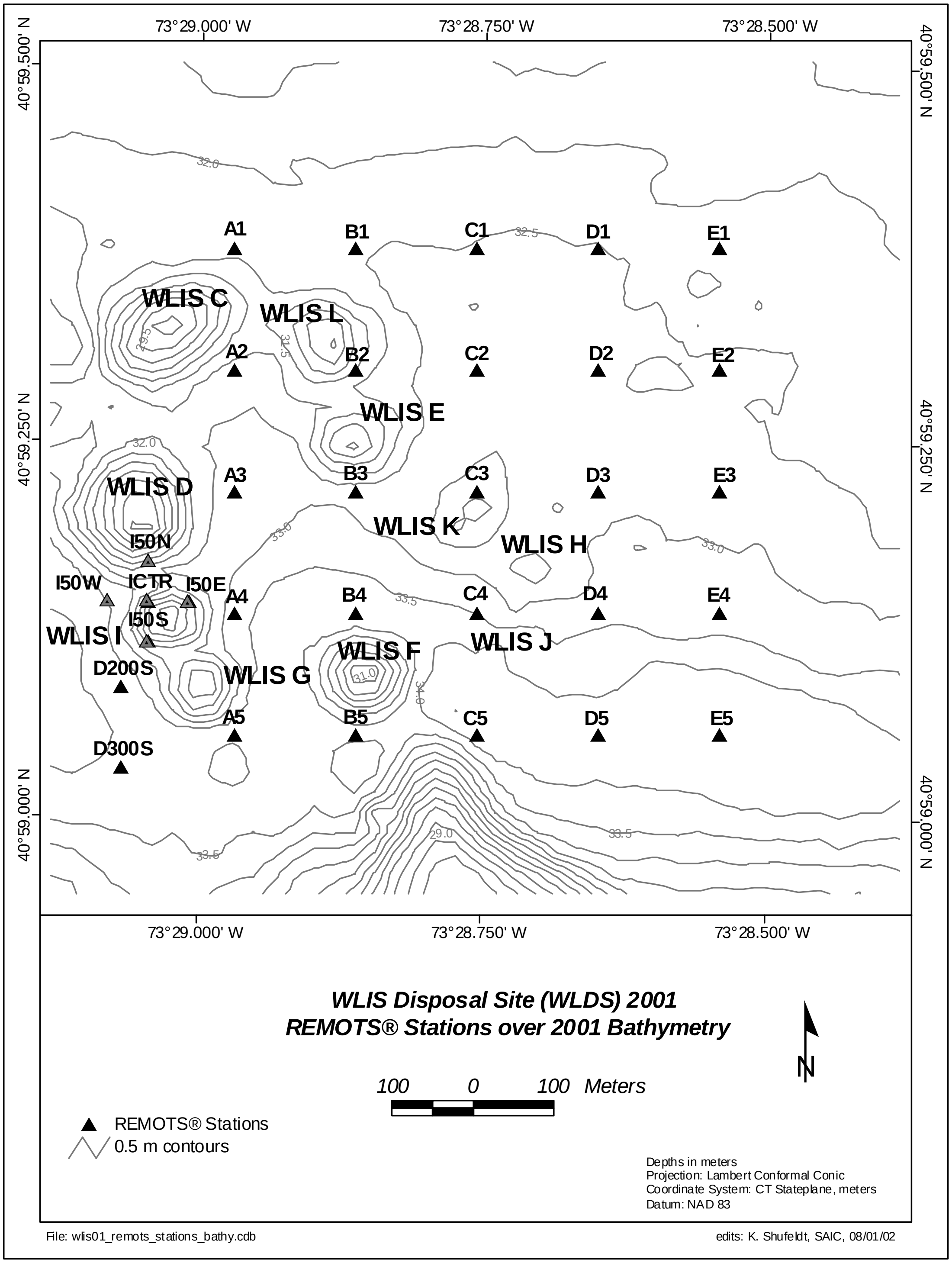


Figure 2-3. June 2001 WLDS REMOTS® stations over the WLIS D and I Mounds and the active disposal area (WDA survey grid), relative to 2001 bathymetry

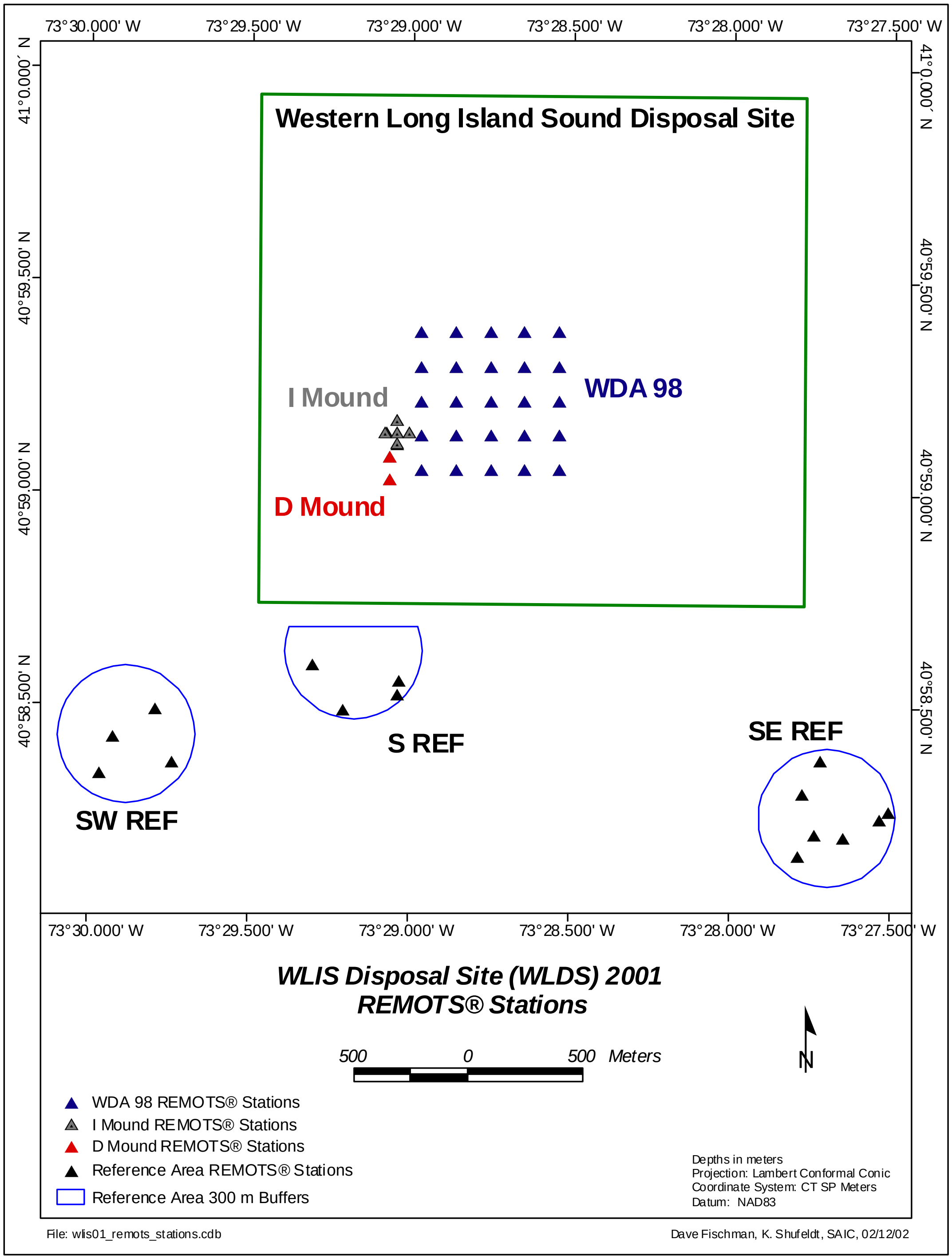


Figure 2-4. June 2001 REMOTS® stations at WLDS and reference areas

to the north, south, east, and west (Table 2-1; Figures 2-3 and 2-4). Two stations (Stations D200S and D300S) originally established over the WLIS D Mound in July 1990 were also re-occupied to verify improvement in benthic habitat quality (Table 2-1; Figures 2-3 and 2-4). At least three replicate REMOTS® images were collected at each station for analysis and comparison with previous data sets.

Data from three reference areas (SE REF, SW REF, and S REF) were used for comparison of ambient western Long Island Sound sediments relative to the dredged material deposited at WLDS through disposal operations (Table 2-2; Figure 2-4). A random sampling scheme was used to select stations within a 300 m radius of the center of each reference area. Seven stations were established over SE REF (coordinates 40°58.307´ N, 73°27.696´ W), while SW REF (coordinates 40°58.403´ N, 73°30.046´ W) and S REF (coordinates 40°58.733´ N, 73°29.171´ W) were each sampled at four randomly selected stations (Table 2-2; Figure 2-4). Three replicate REMOTS® images were obtained at each reference area station.

Table 2-2.

Coordinates of REMOTS® Stations Sampled over the WLDS Reference Areas in June 2001

Area	Station	Latitude	Longitude
SE REF 40° 58.307´ N 73° 27.696´ W	SE REF1	40° 58.440´ N	73° 27.719´ W
	SE REF2	40° 58.361´ N	73° 27.776´ W
	SE REF3	40° 58.319´ N	73° 27.506´ W
	SE REF4	40° 58.260´ N	73° 27.649´ W
	SE REF5	40° 58.214´ N	73° 27.790´ W
	SE REF6	40° 58.266´ N	73° 27.737´ W
	SE REF7	40° 58.302´ N	73° 27.535´ W
S REF 40° 58.733´ N 73° 29.171´ W	SREF1	40° 58.661´ N	73° 29.306´ W
	SREF2	40° 58.553´ N	73° 29.210´ W
	SREF3	40° 58.589´ N	73° 29.039´ W
	SREF4	40° 58.623´ N	73° 29.034´ W
SW REF 40° 58.403´ N 73° 30.046´ W	SW REF1	40° 58.400´ N	73° 29.968´ W
	SW REF2	40° 58.428´ N	73° 29.742´ W
	SW REF3	40° 58.554´ N	73° 29.795´ W
	SW REF4	40° 58.489´ N	73° 29.928´ W

3.0 RESULTS

3.1 Bathymetry

3.1.1 WLDS Survey

Water depths for the 2001 single-beam survey ranged from a minimum of 27.2 m over the natural ridge that lies along the southern edge of the survey area to a maximum of 34.8 m in the natural depression that lies just to the north of the ridge (Figure 3-1). Cross-check comparisons between overlapping bathymetric data points showed strong agreement, with mean differences very close to zero. The subsequent data models created from the gridded survey data clearly showed the recent WLIS J, K, and L Mounds (formed since September 1997) and the older WLIS C, D, E, F, G, H, and I Mounds on the WLDS seafloor (formed prior to 1997; Figures 3-1 and 3-2). Together these ten mounds form the boundary of the first containment cell on the WLDS seafloor. In addition to the labeled disposal mounds, the 2001 bathymetry also depicts the strong vertical profile of the natural ridge.

To further identify the changes in seafloor topography over the past five years, a depth difference comparison was made between the June 2001 and July 1996 bathymetric surveys. The July 1996 bathymetric data (Figure 3-3) were used for this comparison rather than the more recent September 1997 data, due to the more extensive seafloor coverage. To facilitate this comparison, a 950 $\times$ 550 m analysis area was selected around the recent disposal mounds (Figures 3-1, 3-3, and 3-4). The depth differencing confirmed that deposition of material over the past four years resulted in the formation of three new bottom features (WLIS J, K, and L Mounds) on the WLDS seafloor (Figure 3-5). The WLIS I Mound developed as part of the 1996–97 disposal season is also apparent in the depth difference plot due to the use of the July 1996 bathymetry data as the basis for the comparison (Figure 3-5). No dredged material has been directed to the WLIS I Mound for the past five years.

The WLIS J mound resulted from the placement of a total estimated barge volume of 10,700 m^3 of dredged material at the WDA 97 buoy during the 1997–98 disposal season. The mound is a subtle deposit formed within the east-west trending trough that runs through WLDS (Figures 3-2 and 3-5). This mound displayed a height of 0.5 m and a width of approximately 130 m, with morphology roughly conforming to the shape of the trough in the vicinity of the WDA 97 buoy (Figure 3-5).

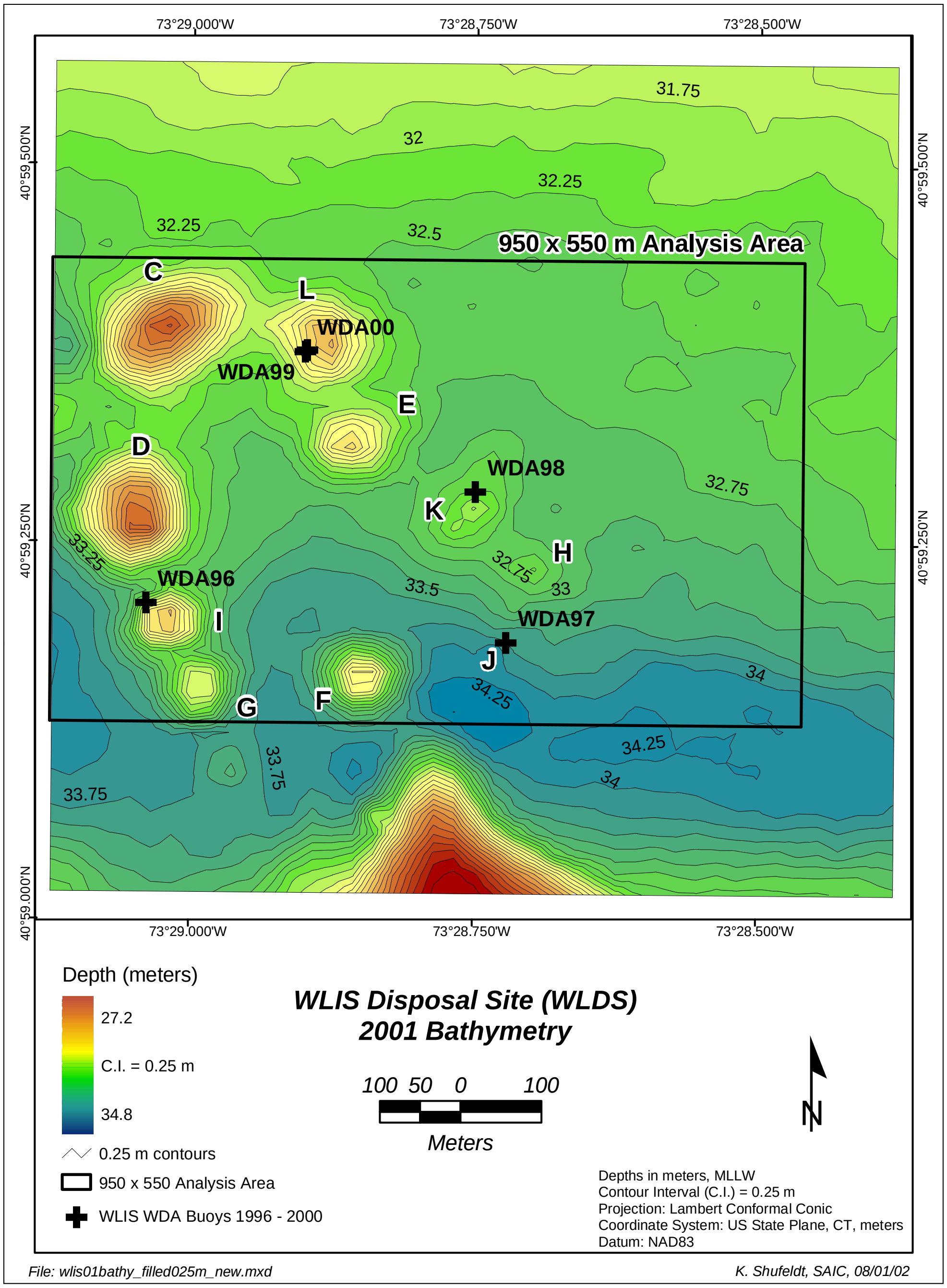


Figure 3-1. Bathymetric chart of the June 2001 1000 × 1000 m survey area within WLDS with the plotted positions of the WDA 96 through WDA 2000 disposal buoys, 0.25 m contour interval. A more detailed view is provided in Figure 3-2.

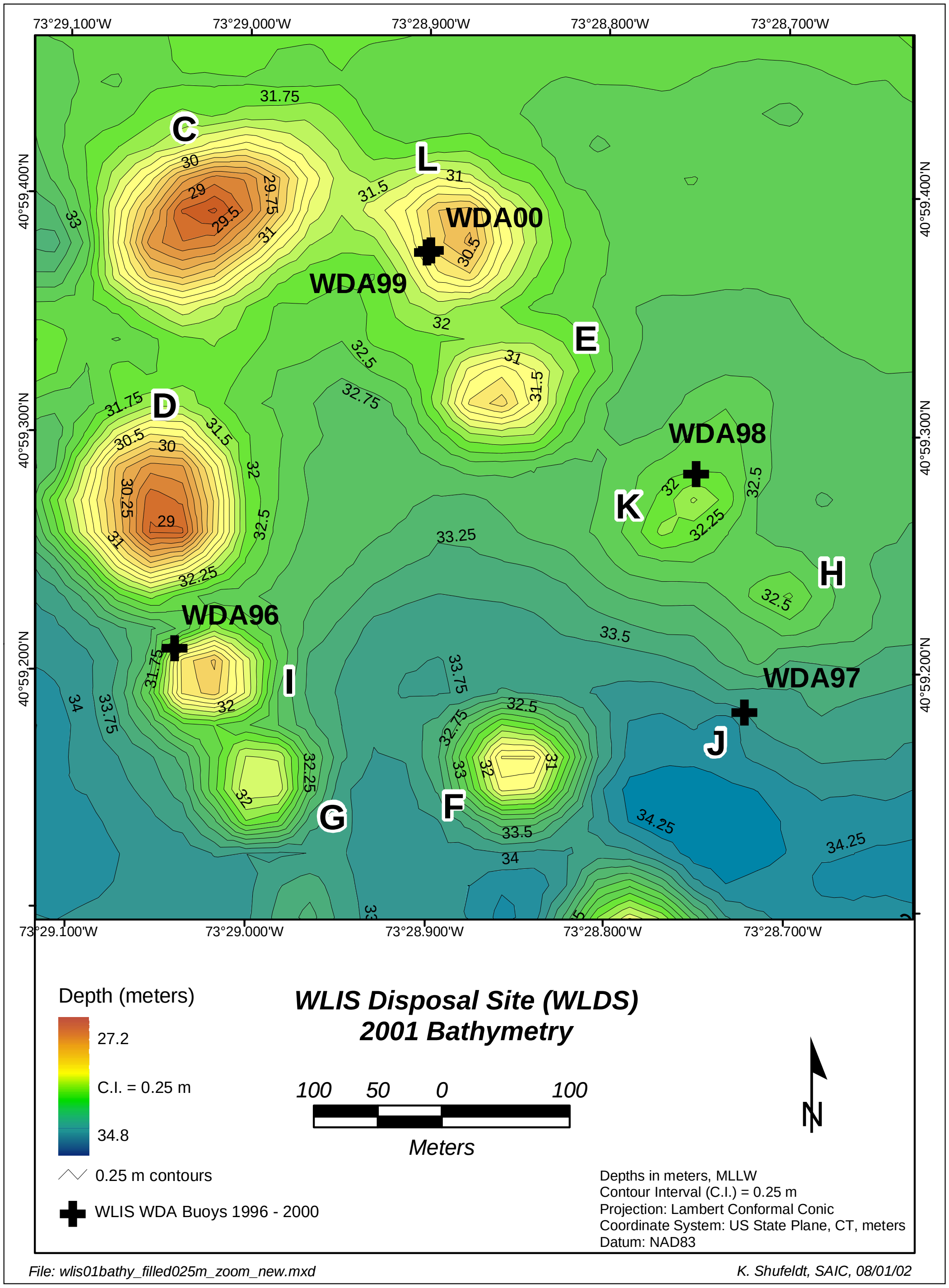


Figure 3-2. Detailed view of the June 2001 bathymetric survey over the active disposal area of WLDS, 0.25 m contour interval

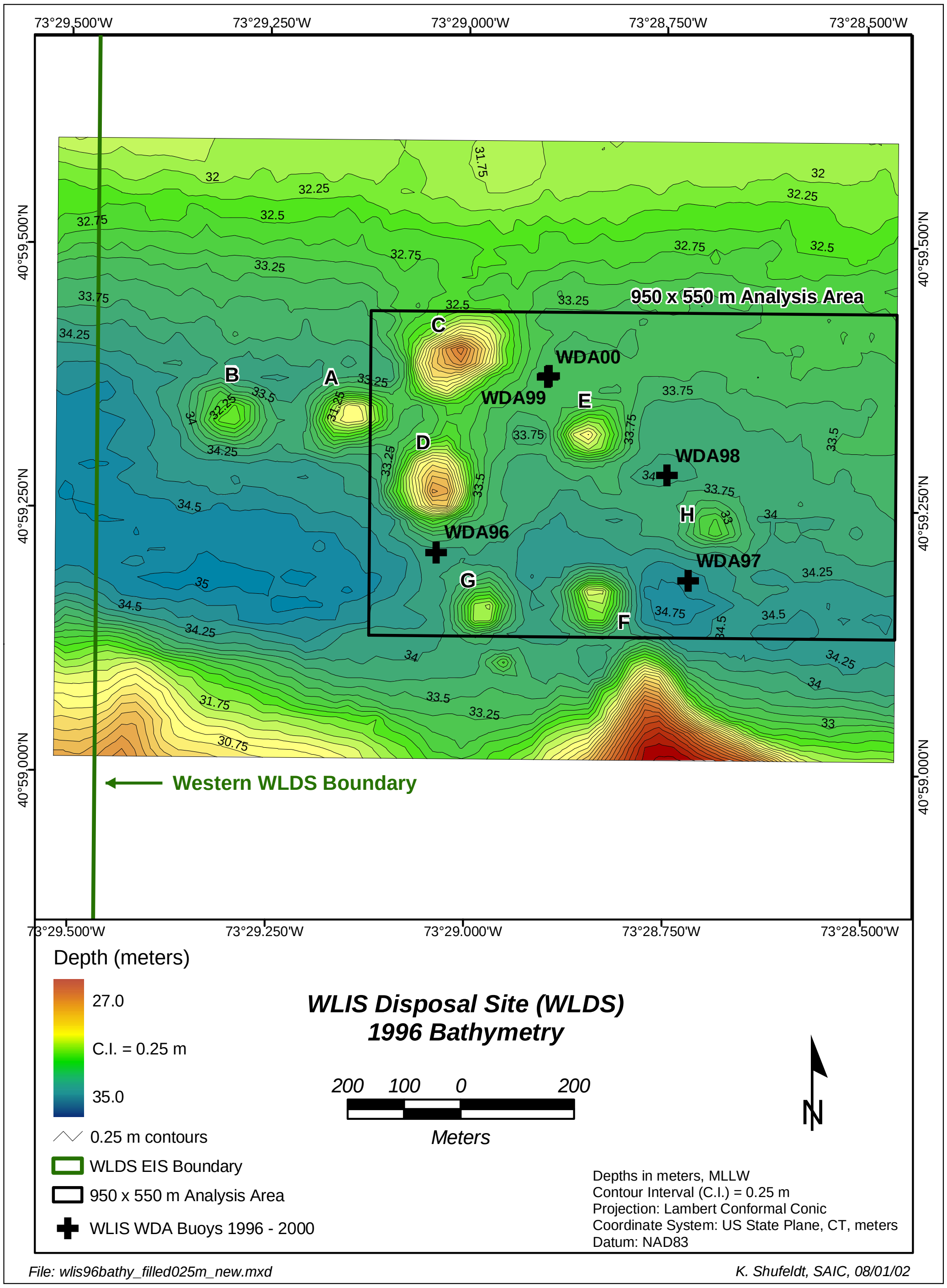


Figure 3-3. Bathymetric chart of the July 1996 1400 × 1000 m survey area over the WLDS, 0.25 m contour interval

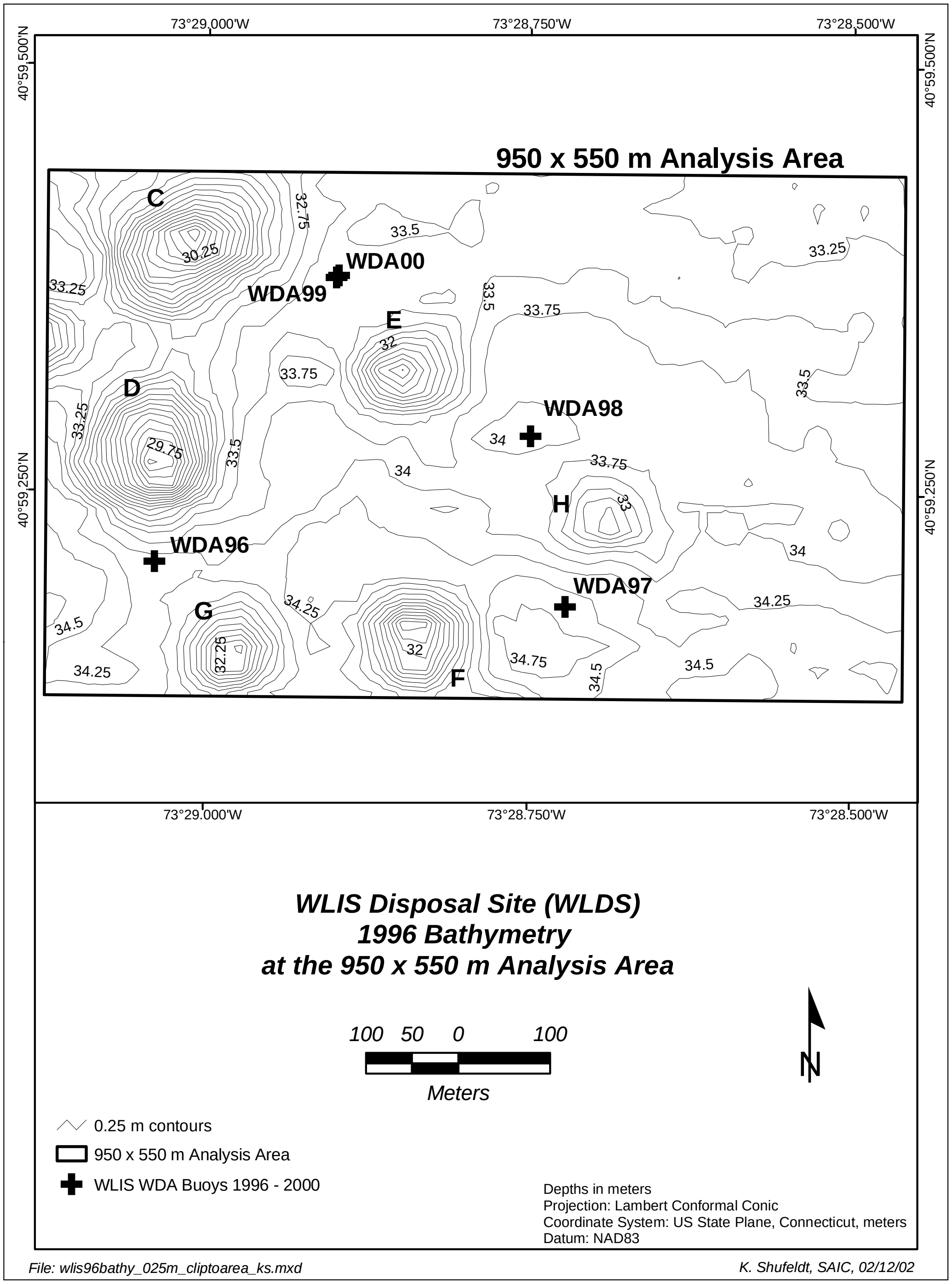


Figure 3-4. Bathymetric chart of the 950 × 550 m analysis area established for the July 1996 survey, 0.25 m contour interval

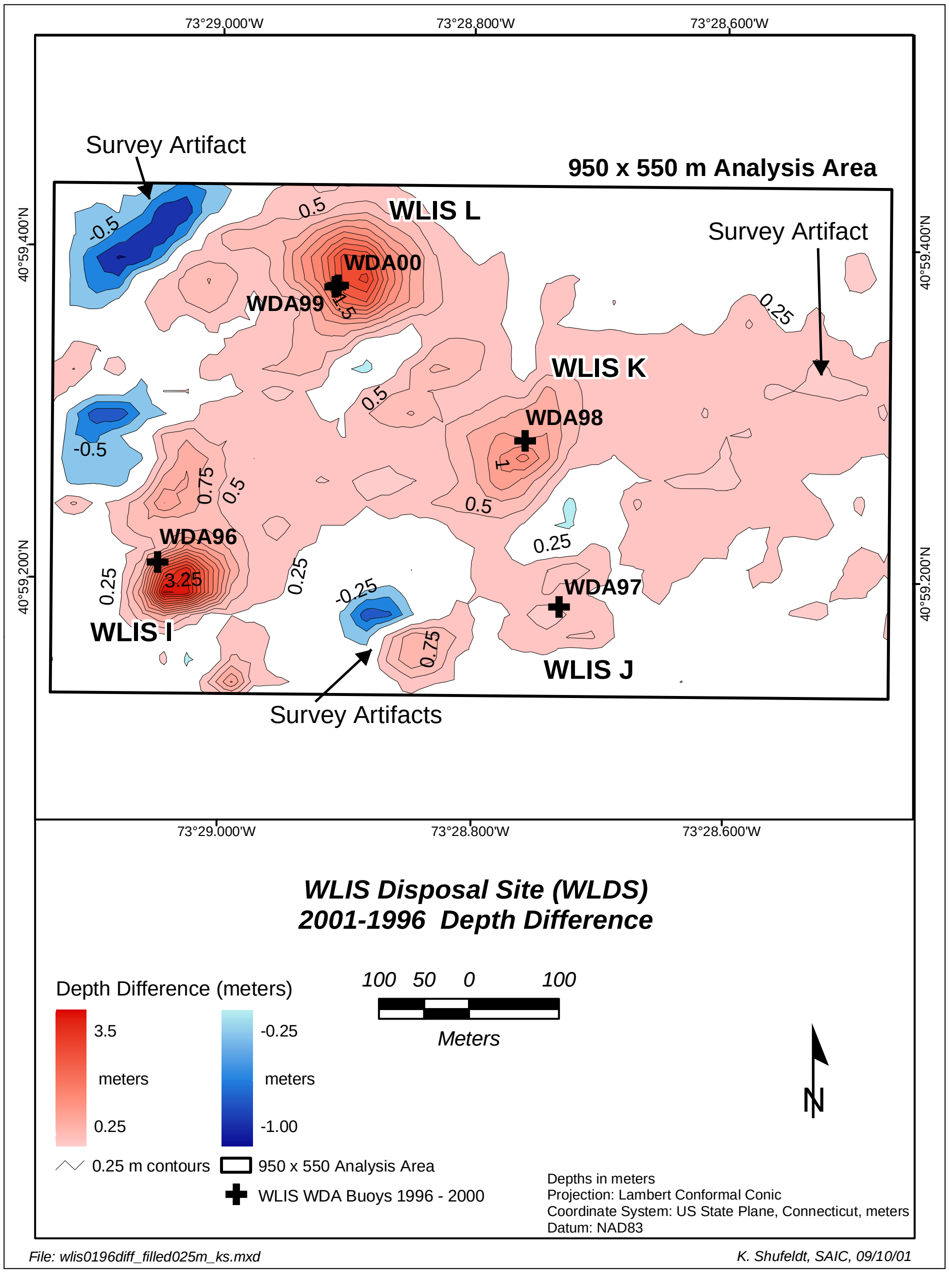


Figure 3-5. Depth difference comparison of the June 2001 bathymetric data versus the July 1996 bathymetric data within the 950 × 550 m analysis area showing total apparent dredged material accumulation (red) and consolidation (blue) within the active area of dredged material disposal, 0.25 m contour interval. The buoy locations (WDA 96 through WDA 00) are also shown.

Compared to the WLIS J Mound, the WLIS K Mound is a larger bottom feature formed by the placement of 33,500 m^3 of sediment at the WDA 98 buoy position (Figures 3-2 and 3-5). The depth difference calculation showed WLIS K as a 1.25 m high disposal mound with a relatively wide dredged material apron 0.25 m thick (Figure 3-5). The apparent accumulations of 0.5 m sediment to the east of the WLIS K Mound are considered to be a survey artifact associated with minor differences between the 1996 and 2001 surveys. This determination is based on the apparent depth (0.5 m) and the distance from the buoy location (150 to 300 m to the east).

The WLIS L Mound is the largest of the disposal mounds created at WLDS between the July 1996 and June 2001 surveys. This bottom feature displayed a height of 2.75 m and a diameter of approximately 325 m (Figures 3-2 and 3-5). A fairly wide dredged material apron was also identified at the base of WLIS L, as well as a survey artifact showing apparent consolidation on the flank of the neighboring WLIS C Mound. The placement of nearly 46,000 m^3 of dredged material at this location over the course of two disposal seasons (1999–2000 and 2000–01) resulted in a bottom feature of sufficient height and width to close the northern portion of the first containment cell on the WLDS seafloor.

3.1.2 SE REF Survey

The 500 × 500 m bathymetric survey over the SE REF reference area found no evidence of large-scale features that might indicate past dredged material placement activity (Figure 3-6). A minimum depth of 18 m was detected in the southeast corner of the survey area, gently sloping to a maximum depth of 21 m in the northwest corner.

3.2 REMOTS® Sediment-Profile Imaging

3.2.1 WDA Survey Grid

REMOTS® results from the WDA survey grid were used to delineate the distribution of dredged material on the seafloor and to evaluate the status of the benthic community. A complete set of REMOTS® image analysis results is provided in Appendix B. Table 3-1 presents a summary of results for the data collected over the WDA 98 survey grid.

3.2.1.1 Dredged Material Distribution and Physical Sediment Characteristics

The REMOTS® images from the WDA 98 survey grid showed that sediments over the active disposal area within WLDS were predominantly silt-clay, with a grain size major

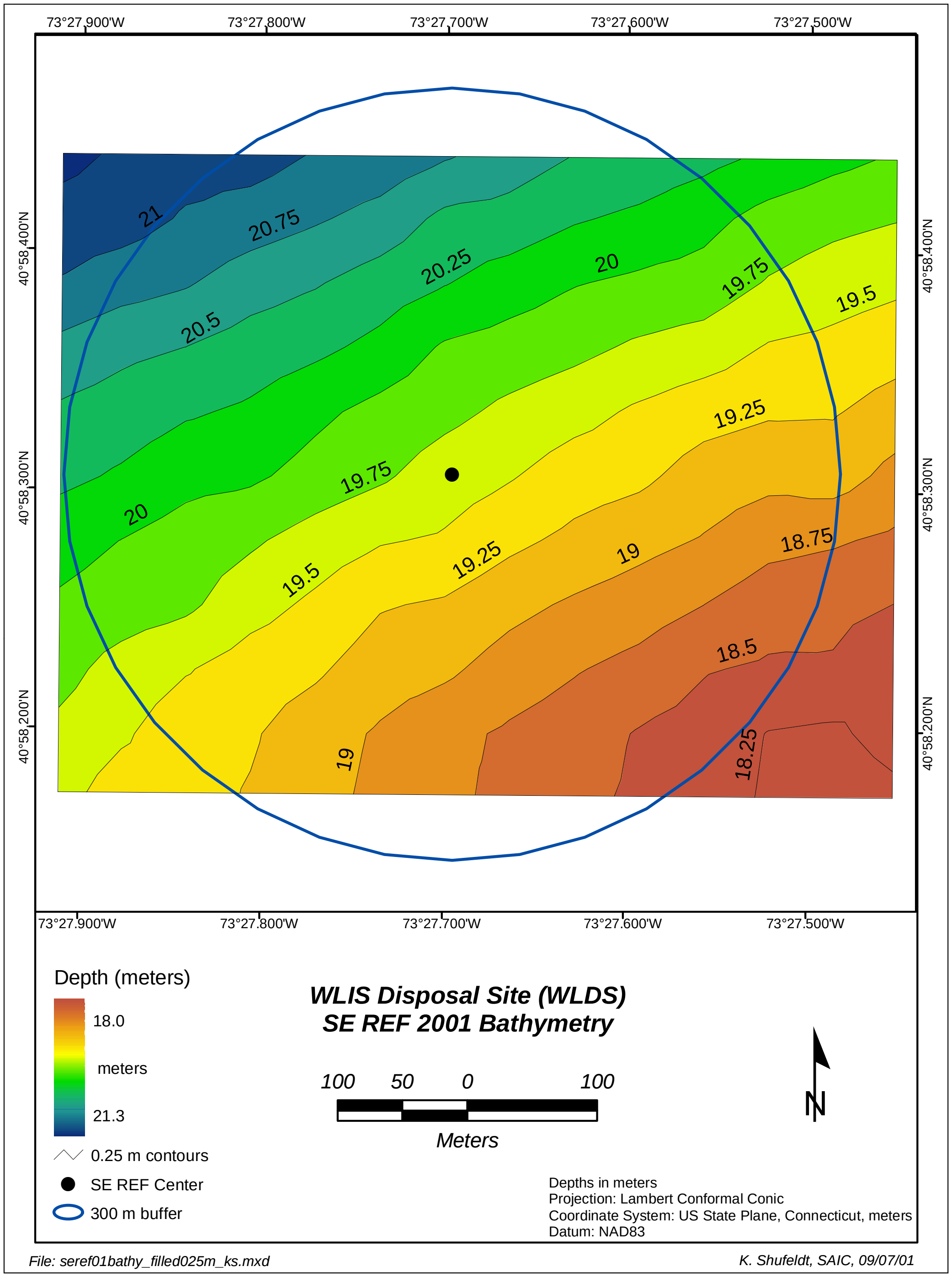


Figure 3-6. Bathymetric chart of the June 2001 650 × 500 m survey area over SE REF relative to the central point and the 300 m sampling radius, 0.25 m contour interval

Table 3-1.

REMOTS® Sediment-Profile Imaging Results Summary for the WDA 98 Survey Grid, June 2001

Station	Camera Penetration Mean (cm)	Dredged Material Thickness Mean (cm)*	Number of Reps w/ Dredged Material	RPD Mean (cm)	Successional Stages Present	Highest Stage Present	Grain Size Major Mode (phi)	Methane Present	OSI Mean	OSI Median	Boundary Roughness Mean (cm)
A1	14.45	>14.45	3	1.66	I,III	ST_I_ON_III	>4	NO	6.33	8	1.13
A2	15.76	>15.76	3	1.87	I,III	ST_III	>4	NO	8.00	8	0.66
A3	16.65	>16.65	3	1.74	I,III	ST_I_ON_III	>4	NO	6.33	8	0.75
A4	14.88	>14.88	3	1.87	I,III	ST_I_ON_III	>4	NO	8.00	8	1.01
A5	14.09	>14.09	3	1.78	I,III	ST_III	>4	NO	8.00	8	1.18
B1	15.30	>15.30	3	2.78	I,III	ST_III	>4	NO	9.33	9	0.76
B2	16.39	>16.39	3	1.85	I,III	ST_III	>4	NO	5.67	8	0.45
B3	14.15	>14.15	3	1.71	I,III	ST_I_ON_III	>4	NO	6.33	7	1.15
B4	13.74	>13.74	3	1.48	I,II,III	ST_II_ON_III	>4	NO	7.33	7	0.33
B5	10.89	>10.89	2	1.82	I,III	ST_III	>4	NO	8.00	8	1.27
C1	17.01	0.0	0	2.02	I,III	ST_I_ON_III	>4	NO	8.33	8	1.39
C2	16.31	>16.31	3	1.88	I,III	ST_I_ON_III	>4	NO	8.00	8	0.49
C3	11.78	>11.78	3	1.94	I,III	ST_I_ON_III	>4	NO	6.67	7	2.39
C4	11.73	>11.73	3	2.25	I,II,III	ST_I_ON_III	>4	NO	6.33	5	1.04
C5	13.43	>13.43	3	1.97	II,III	ST_I_ON_III	>4	NO	7.33	8	0.87
D1	18.86	>18.86	3	1.74	I,III	ST_III	>4	NO	8.00	8	0.80
D2	17.79	>17.79	3	1.53	I,III	ST_I_ON_III	>4	NO	6.33	7	0.85
D3	18.72	>18.72	3	1.63	I,III	ST_I_ON_III	>4	NO	7.33	8	0.64
D4	17.00	>17.00	3	1.12	I,II,III	ST_II_ON_III	>4	NO	5.67	6	1.42
D5	11.24	>11.24	3	1.88	I,II,III	ST_I_ON_III	>4	NO	7.00	8	0.88
E1	15.81	>15.81	3	2.65	I,III	ST_III	>4	NO	9.33	9	0.87
E2	15.65	>15.65	3	1.53	I,III	ST_I_ON_III	>4	NO	6.33	8	1.66
E3	15.61	>15.61	3	2.08	I,II,III	ST_I_ON_III	>4	NO	6.33	6	2.18
E4	17.10	>17.10	3	1.65	I,III	ST_I_ON_III	>4	NO	7.67	8	1.45
E5	16.40	>16.40	3	2.00	I,III	ST_I_ON_III	>4	NO	7.00	7	0.95
AVG	15.23	>14.43	2.84	1.86					7.24	7.60	1.06
MAX	18.86	>18.9	3	2.78					9.33	9.00	2.39
MIN	10.89	0	0	1.12					5.67	5.00	0.33

* Values are means for n=3 replicate images at each station. If dredged material exceeded the prism penetration depth in at least two replicates, then the mean value shown is a minimum estimate of dredged material layer thickness (indicated by the > sign).

mode of >4 phi (Table 3-1). All of the sediment observed in the REMOTS® images was considered to be dredged material, with the exception of Station C1, where ambient sediment was identified. Where detected, the dredged material layer thickness generally extended from the sediment surface to below the imaging depth of the REMOTS® camera prism at each station (Table 3-1; Figures 3-7 and 3-8).

Replicate-averaged camera penetration depths ranged from 10.9 cm at Station B5 to 18.9 cm at Station D1, with an average value of 15.2 cm for the entire survey area (Table 3-1). This is relatively deep penetration, reflecting the soft, fine-grained nature of the dredged material. Replicate-averaged boundary roughness values for the REMOTS® stations within the WDA grid ranged from 0.3 cm at Station B4 to 2.4 cm at Station C3, with an overall average of 1.1 cm, indicating only a minor amount of small-scale surface relief (Table 3-1). Surface roughness at the WDA grid stations was attributed to physical seafloor disturbance associated with dredged material placement. Oxidized mud clasts were common at the sediment-water interface, providing further evidence of past physical disturbance.

3.2.1.2 Biological Conditions and Benthic Recolonization

The apparent redox potential discontinuity (RPD) measured in each REMOTS® image provides an indication of the depth of oxygen penetration into the sediment. The replicate-averaged apparent RPD depths over the WDA grid ranged from 1.1 to 2.8 cm, with an overall average of nearly 1.9 cm (Table 3-1; Figures 3-8 and 3-9). This average value was only slightly lower than the composite RPD value of 2.0 cm for the WLDS reference areas. These results suggest that the deposited sediments in the area around the WLIS J, WLIS K, and WLIS L Mounds were moderately well-aerated, and the depth of oxidation was consistent with that observed on the ambient seafloor at the reference areas.

Redox rebound intervals, areas showing evidence of intermittent or seasonal oxidation below the oxidized surface layer, were observed in one replicate image from each of three stations (Stations A4, C2, and E3) within the WDA grid. None of the replicate images obtained within the WDA survey grid displayed any evidence of low apparent sediment dissolved oxygen conditions or methane gas production within the sediment.

The successional stage status within the survey area was advanced, with at least one replicate image showing evidence of Stage III activity at all stations (Table 3-1; Figure 3-10). Often Stage I pioneering polychaetes or Stage II (mid-stage colonizers) were detected at the sediment-water interface over Stage III deposit-feeders at depth (Stage I on III; Figure 3-8). Due to the advanced successional stage, median OSI values for the WDA stations

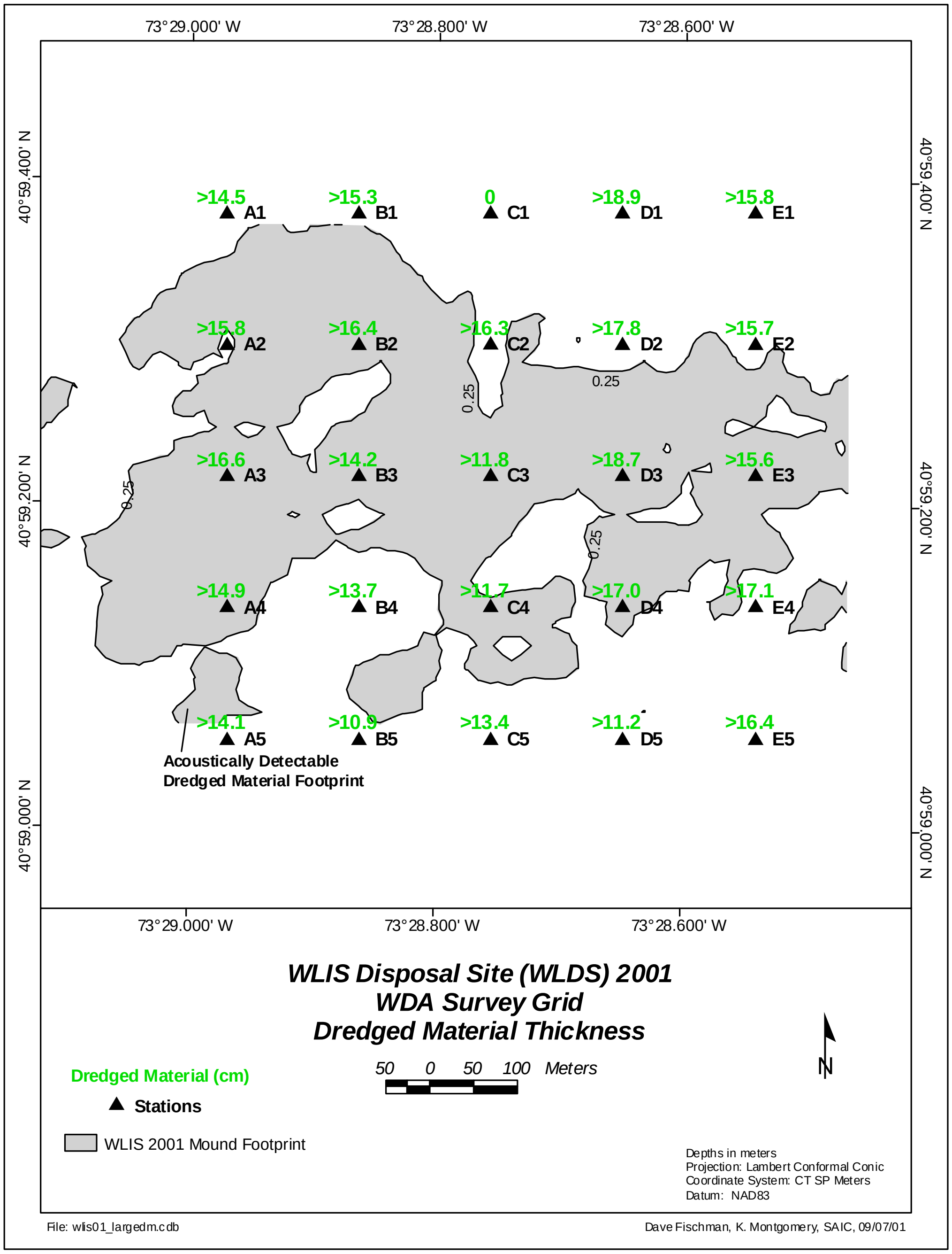


Figure 3-7. Map showing the average measured thickness (in cm) of the dredged material layer at each REMOTS® station over the WDA 98 survey grid relative to the acoustically detectable dredged material footprint (gray). A greater than sign indicates that the dredged material thickness was greater than the camera prism penetration.

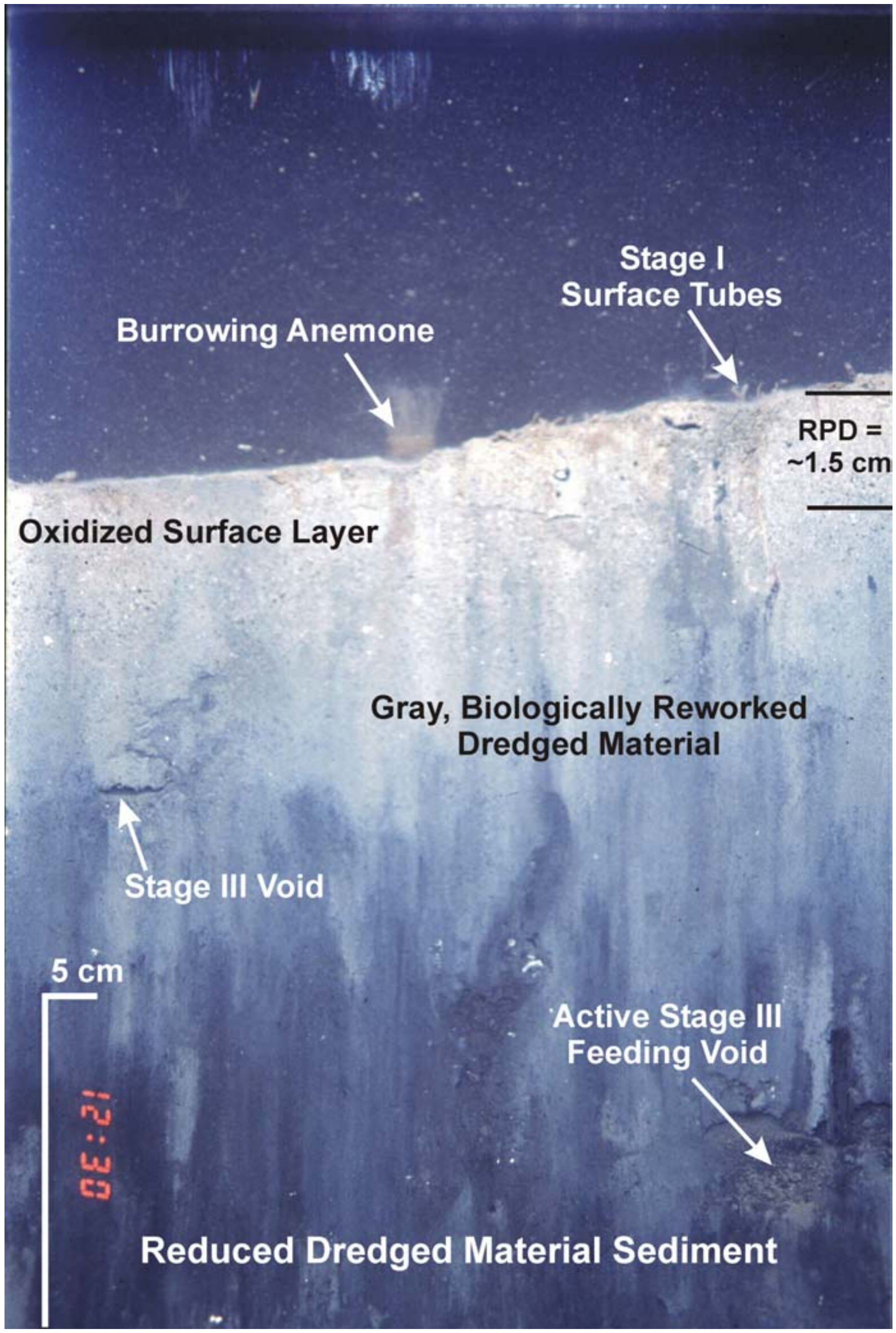


Figure 3-8. REMOTS® image obtained from Station A4 over the active area of dredged material disposal (WDA 98 survey grid) showing fine-grained dredged material extending from the sediment surface to below the imaging depth. The image also shows Stage I pioneering polychaetes at the sediment-water interface and evidence of Stage III activity at depth (Stage I on III).

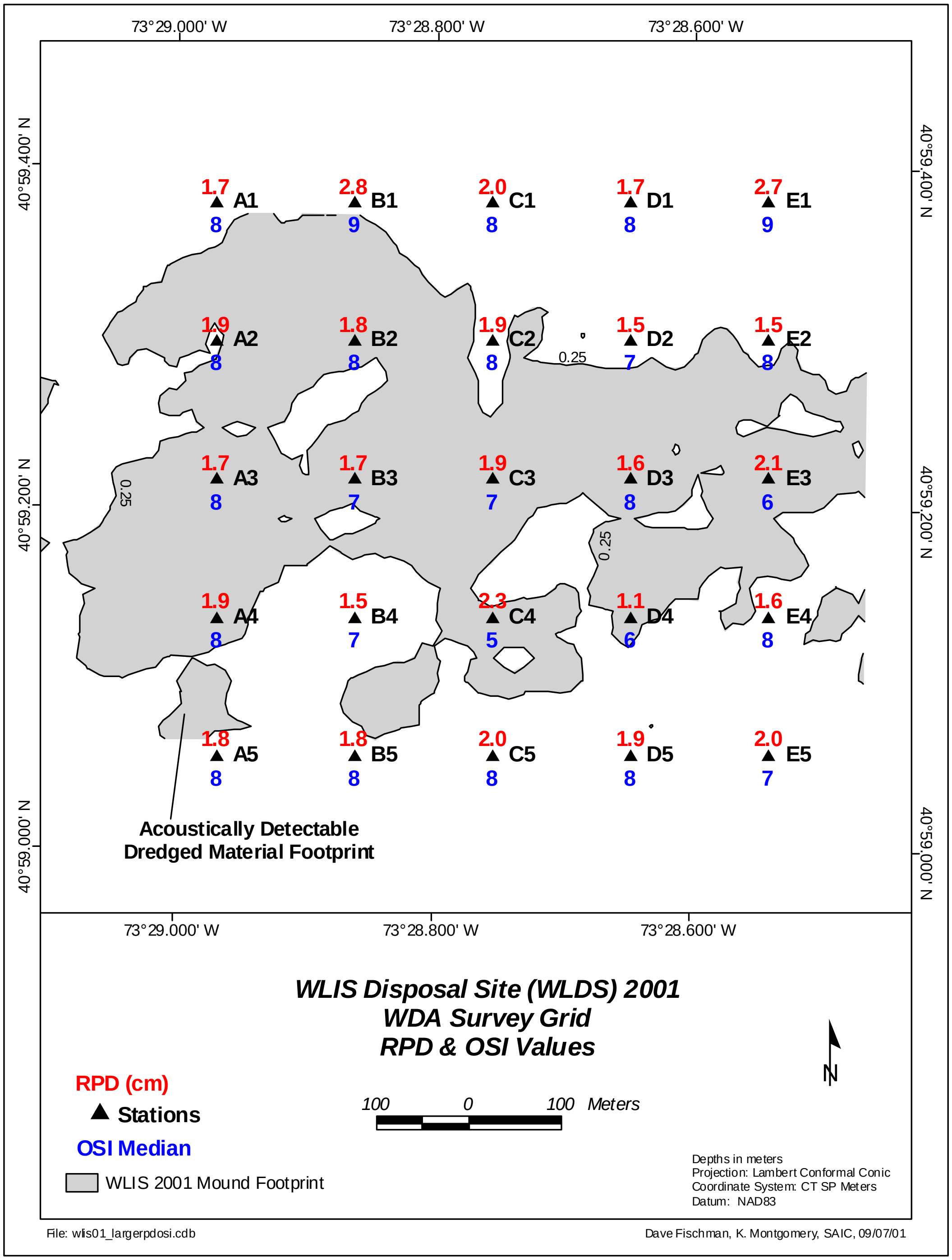


Figure 3-9. Map of replicate averaged RPD depths (red; in cm) and median OSI values (blue) detected within the WDA 98 grid relative to the acoustically detectable dredged material footprint (gray)

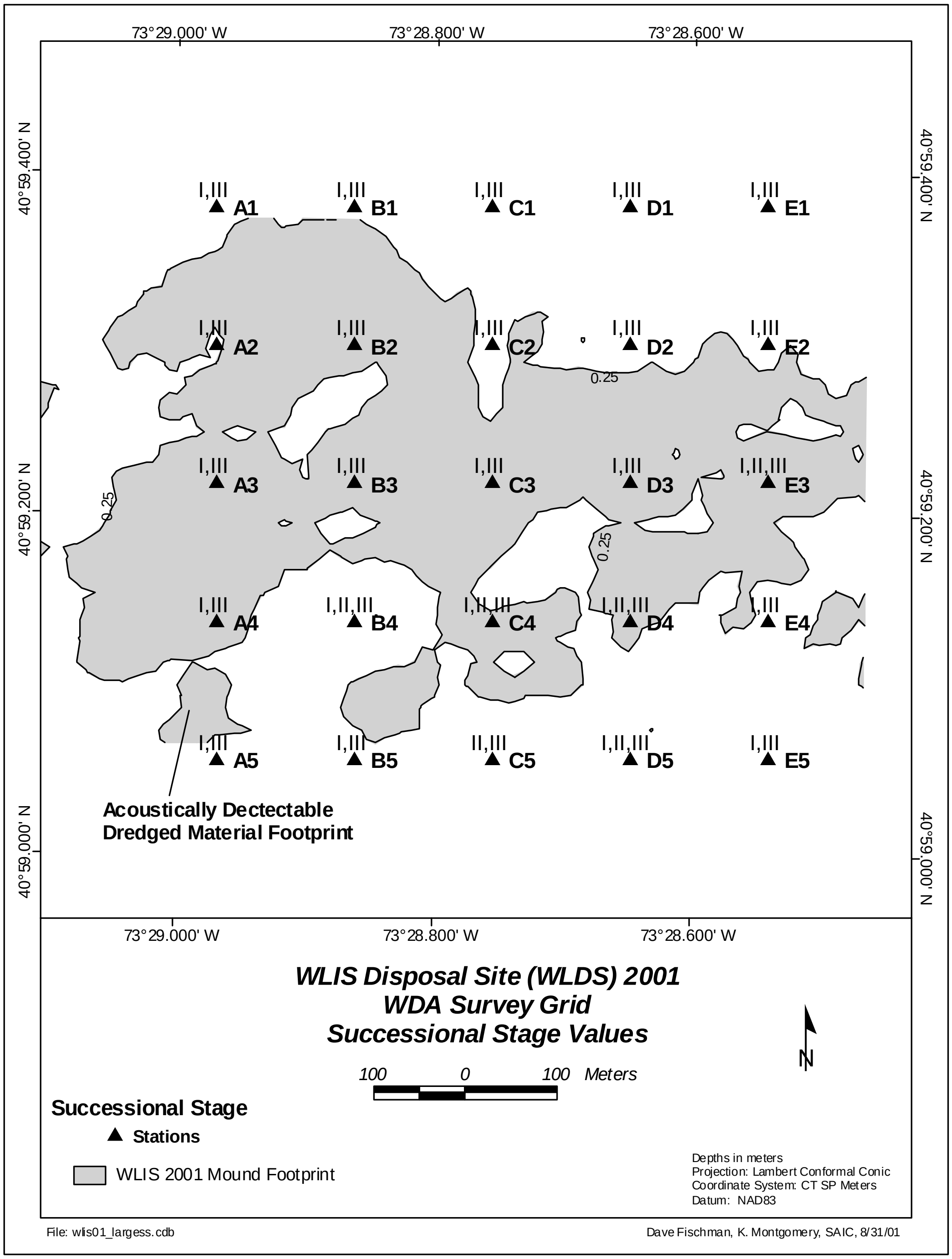


Figure 3-10. Map of successional stage status for the REMOTS® stations established within the WDA 98 survey grid relative to the acoustically detectable dredged material footprint (gray)

ranged from +5 at Station C4 to +9 at Stations B1 and E1, with an overall average of +7.6 (Table 3-1; Figure 3-9). This average is comparable to the composite OSI value calculated for the reference areas (+8), and is indicative of undisturbed or non-degraded benthic habitat quality.

3.2.2 WLIS I and WLIS D Mounds

The primary purpose of the 2001 monitoring survey over the WLIS I Mound and at D Mound Stations D200S and D300S was to assess the benthic habitat conditions over this area, five years after the creation of the WLIS I Mound on the southern flank of the WLIS D Mound. A complete set of REMOTS® image analysis results is provided in Appendix B. Table 3-2 presents a summary of results for the data collected over the WLIS I and WLIS D Mounds.

3.2.2.1 Dredged Material Distribution and Physical Sediment Characteristics

The grain size major mode for all of the stations over the WLIS I and WLIS D Mounds was >4 phi (silt-clay; Table 3-2). The surface sediments were characterized as gray and fine-grained, with signs of biological reworking, over low-reflectance sediment at depth. These results are similar to the sediment grain size of two of the reference areas (SE REF and S REF). The SW REF reference area had a grain size major mode of 4 to 3 phi (very fine sand). No indications of surface coarsening or lag deposits were evident over either of the mounds, indicating that they had not been subjected to erosion or winnowing.

All of the images over the WLIS I and WLIS D Mounds exhibited historic dredged material that exceeded the camera penetration depth. Replicate-averaged camera penetration values ranged from 9.6 cm at Station CTR to 13.3 cm at Station D200S (Table 3-2; Figure 3-11). The mean boundary roughness values ranged from 0.4 to 2.4 cm, with an overall average of 1.1 cm. These values are similar to the values at the three reference areas. Surface roughness was generally attributed to small-scale physical disturbance at the sediment-water interface.

3.2.2.2 Biological Conditions and Benthic Recolonization

The replicate-averaged RPD depths over the WLIS I and WLIS D Mound stations ranged from 0.8 cm at Station CTR to 2.0 cm at Station 50N (Table 3-2; Figure 3-12). The overall average RPD of 1.4 cm was shallower than the composite value for the WLDS reference areas of 2.0 cm, although it was comparable to the average values for two of the

Table 3-2.

REMOTS® Sediment-Profile Imaging Results Summary for the WLIS I and WLIS D Mounds, June 2001

Station	Camera Penetration Mean (cm)	Dredged Material Thickness Mean (cm)*	Number of Reps w/ Dredged Material	RPD Mean (cm)	Successional Stages Present	Highest Stage Present	Grain Size Major Mode (phi)	Methane Present	OSI Mean	OSI Median	Boundary Roughness Mean (cm)
CTR	9.63	>9.63	3	0.81	I,III	ST_I_ON_III	>4	NO	5.00	6	0.87
50N	9.70	>9.70	3	2.00	I,III	ST_III	>4	NO	6.67	8	0.42
50S	10.87	>10.87	3	1.50	I,III	ST_I_ON_III	>4	NO	7.67	8	2.37
50E	10.89	>10.89	3	1.18	I,III	ST_I_ON_III	>4	NO	5.67	6	1.05
50W	12.50	>12.50	3	1.21	I,III	ST_III	>4	NO	7.00	7	0.74
D200S	13.27	>13.27	3	1.89	I,III	ST_I_ON_III	>4	NO	6.67	8	0.50
D300S	13.05	>13.05	3	1.31	I,III	ST_I_ON_III	>4	NO	7.33	8	1.38
AVG	11.41	>11.41	3.00	1.41					6.57	8.00	1.05
MAX	13.27	>13.27	3.00	2.00					7.67	8.00	2.37
MIN	9.63	>9.63	3.00	0.81					5.00	6.00	0.42

* Values are means for n=3 replicate images at each station. If dredged material exceeded the prism penetration depth in at least two replicates, then the mean value shown is a minimum estimate of dredged material layer thickness (indicated by the > sign).

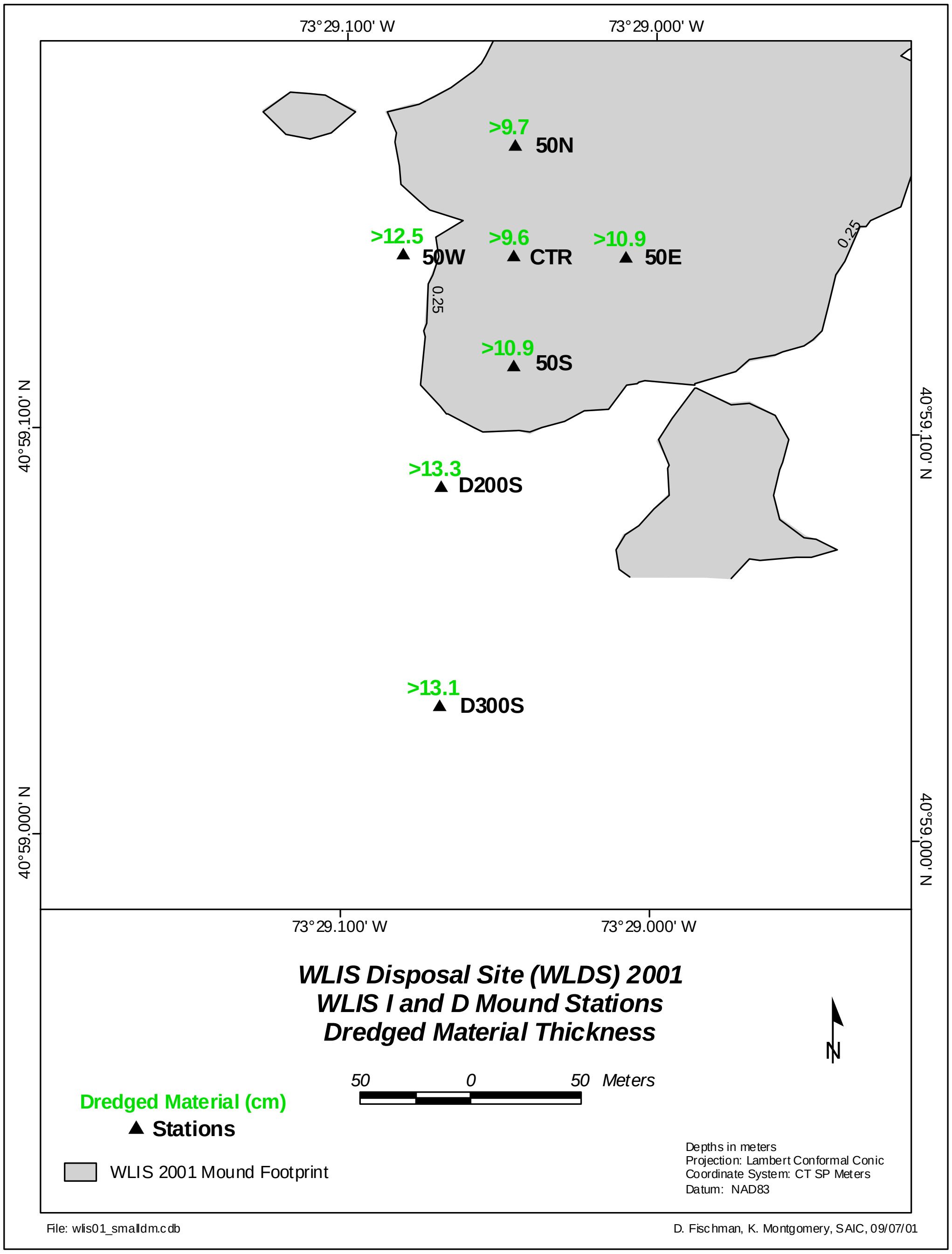


Figure 3-11. Map of replicate averaged dredged material thickness (in cm) over WLIS I and D Mounds relative to the acoustically detectable dredged material footprint (gray). A greater than sign indicates that the dredged material thickness was greater than the camera prism penetration.

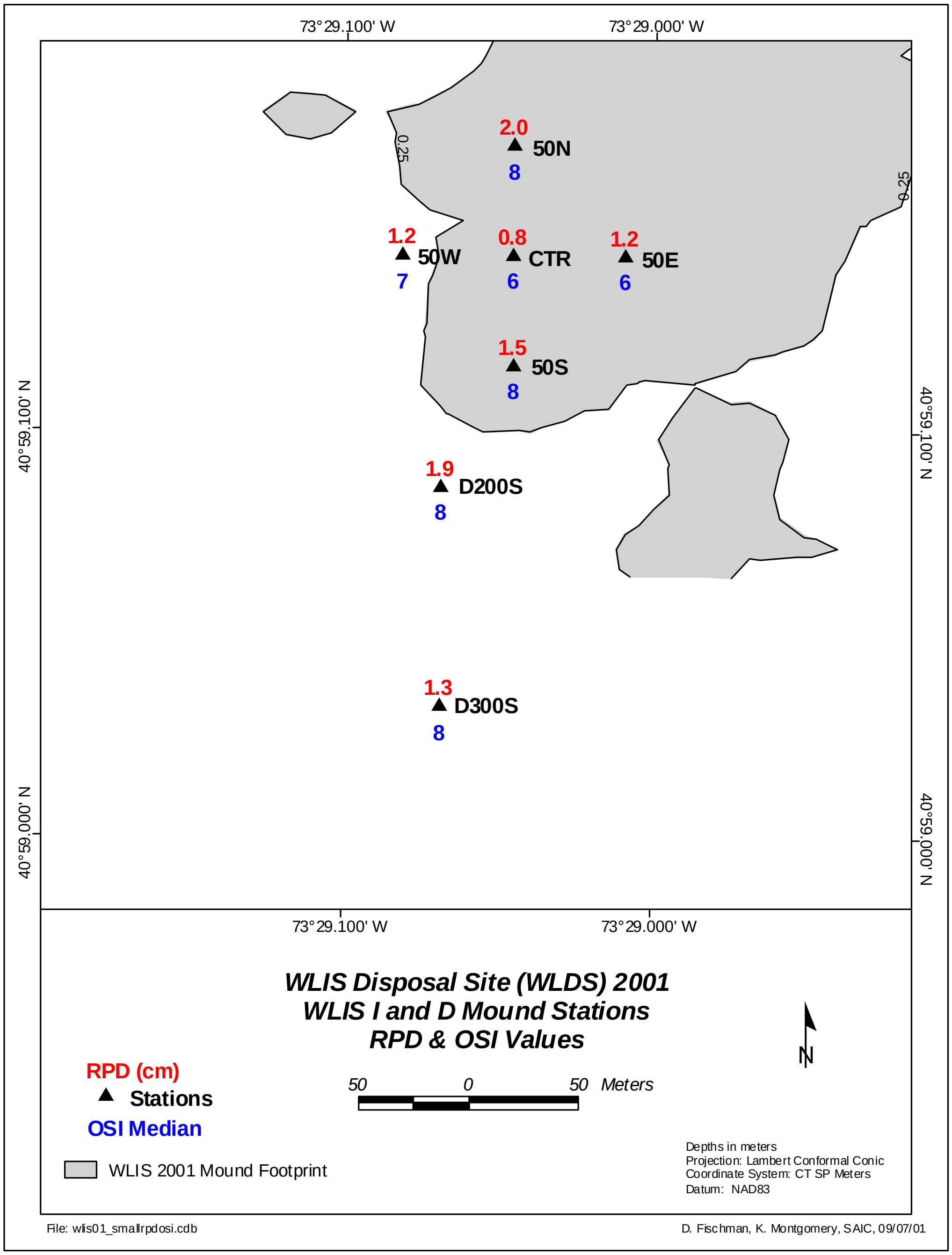


Figure 3-12. Map of replicate averaged RPD depths (red; in cm) and median OSI values (blue) detected over the WLIS I Mound and at WLIS D Mound Stations D200S and D300S relative to the acoustically detectable dredged material footprint (gray)

three reference areas, S REF and SW REF (1.7 cm and 1.3 cm respectively; Section 3.2.3). A redox rebound interval was detected approximately 7 cm below the sediment–water interface in one replicate image obtained from WLIS I Mound Station 50W, suggesting a recent change in dissolved oxygen concentrations. However, no indications of low sediment dissolved oxygen or methane gas production were apparent in any of the replicate images obtained in June 2001.

Evidence of Stage III activity was detected at all stations within the survey grid, with at least one replicate image showing an advanced successional stage present (Table 3-2; Figure 3-13). Three of the five stations over WLIS I and both of the stations over the WLIS D Mound were classified as Stage I over Stage III, where the more established benthic community existed under a dense aggregation of surface-dwelling, opportunistic taxa that actively recolonize surface sediments following a benthic disturbance (Figures 3-14 and 3-15). Despite the relatively shallow RPD depths, the median OSI values over the mound suggested the presence of undisturbed or non-degraded benthic habitat conditions. Primarily due to the presence of an advanced successional stage, median OSI values over the WLIS I and WLIS D Mounds ranged from +6 to +11 (Table 3-2; Figure 3-12). These results are similar to the results found at the three reference areas occupied during this survey. S REF and SW REF reference areas had median OSI values of +8 and +7, respectively (Section 3.2.3). The SE REF reference area had a median OSI value of +8. Overall, the June 2001 REMOTS® analysis indicates that Station D200S had improving benthic conditions and Station D300S had remained stable relative to the previous (March 1998) REMOTS® survey.

3.2.3 Reference Areas

Data from the three reference areas were used for comparison of ambient western Long Island Sound sediments relative to the dredged material that had been deposited at WLDS through disposal operations. A complete set of REMOTS® image analysis results is provided in Appendix B. Table 3-3 presents a summary of results for the data collected over the WLDS reference areas.

3.2.3.1 Physical Sediment Characteristics

Surface sediments at the SE REF and S REF reference areas were similar in texture to those identified at WLDS, composed of silt and clay, with a grain size major mode of >4 phi (Table 3-3). An oxidized surface layer of silt was identified over a gray, biologically reworked layer of reduced sediment (Figure 3-16). Similar to the disposal site stations, a layer of low-reflectance, reduced sediment was visible at depth in all of the

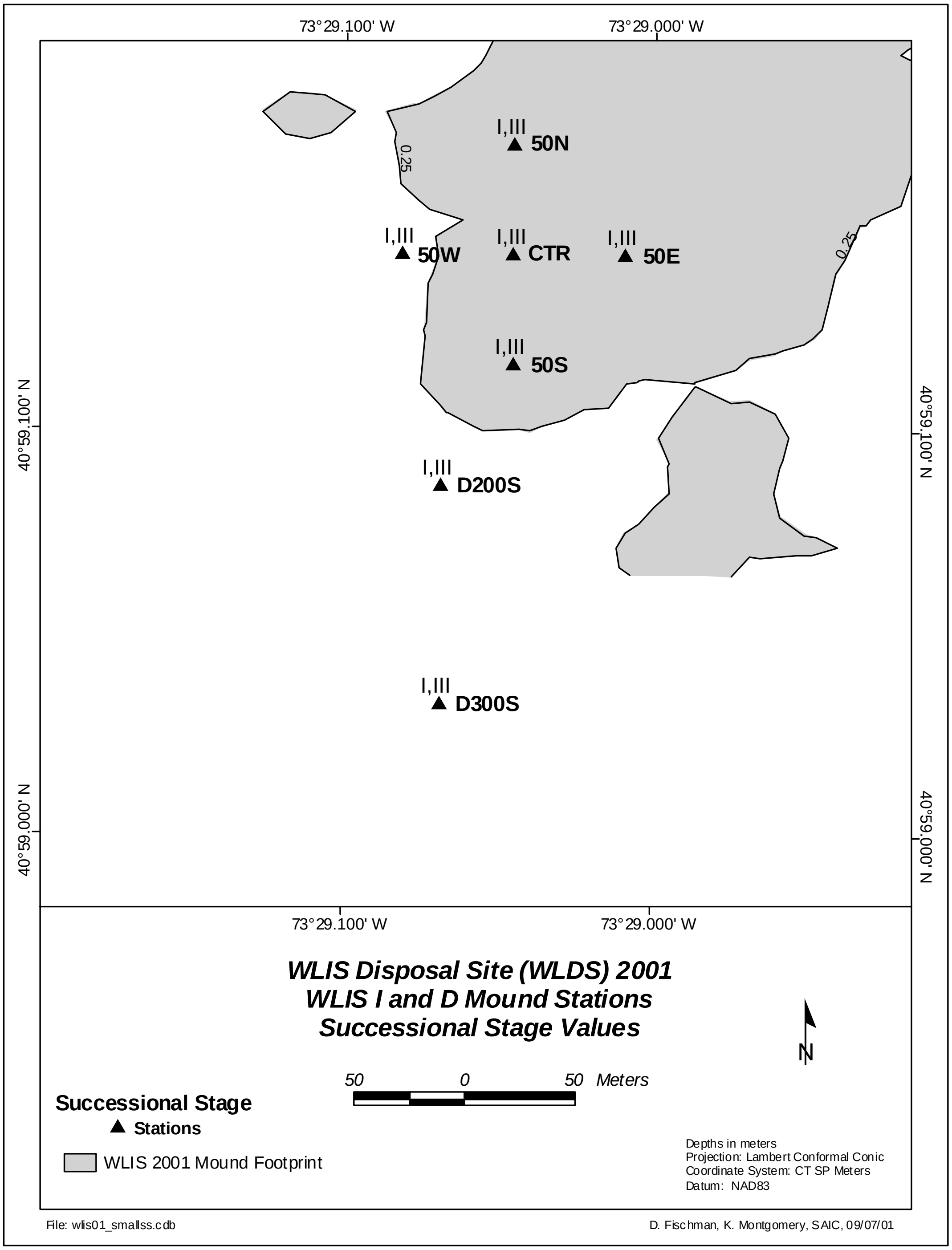


Figure 3-13. Map of successional stage status for the REMOTS® stations established over the WLIS I Mound and Stations D200S and D300S relative to the acoustically detectable dredged material footprint (gray)

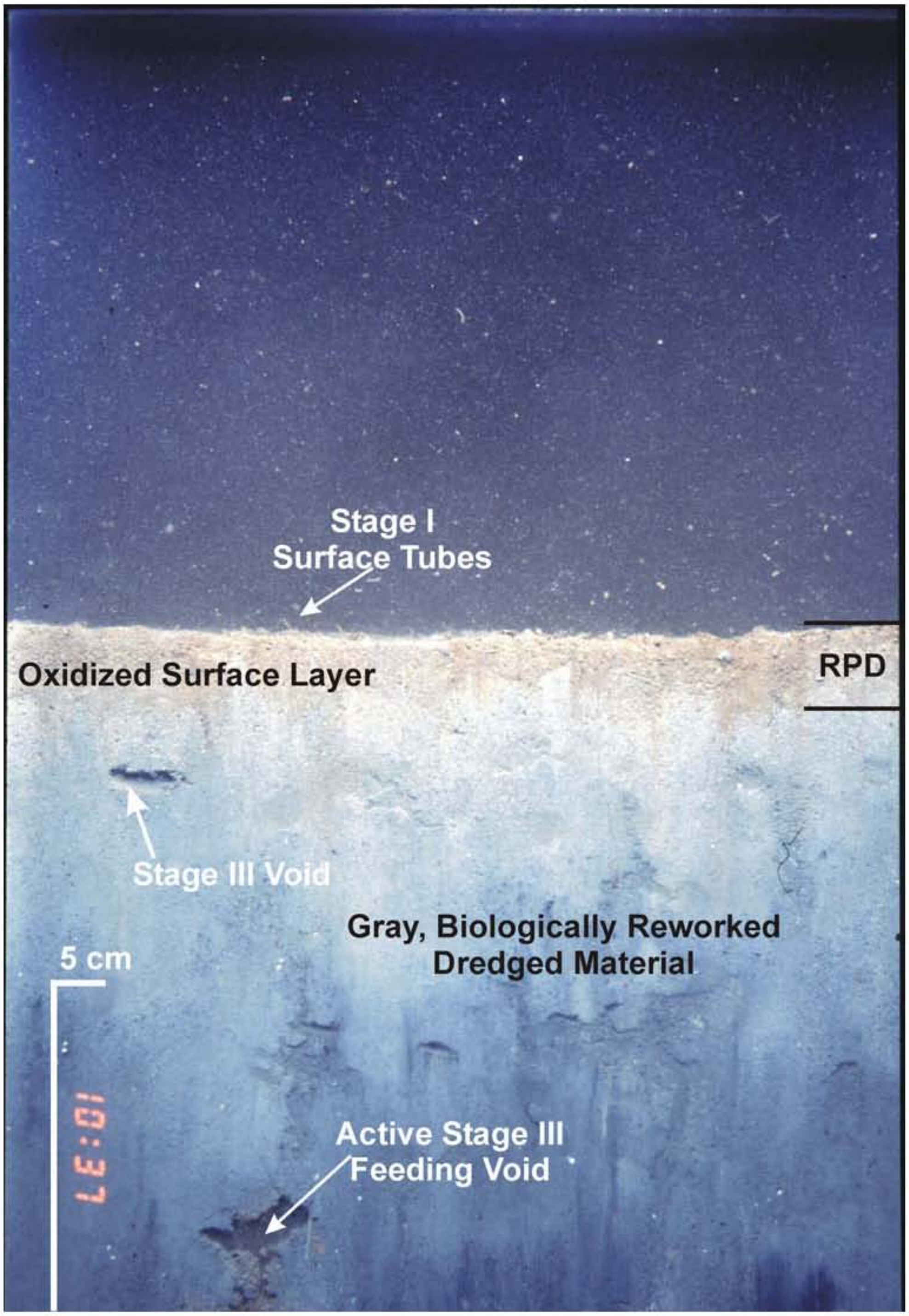


Figure 3-14. REMOTS® image collected from Station CTR over the WLIS I Mound displaying Stage I tube dwellers at the surface with Stage III activity at depth and a shallow to moderate RPD

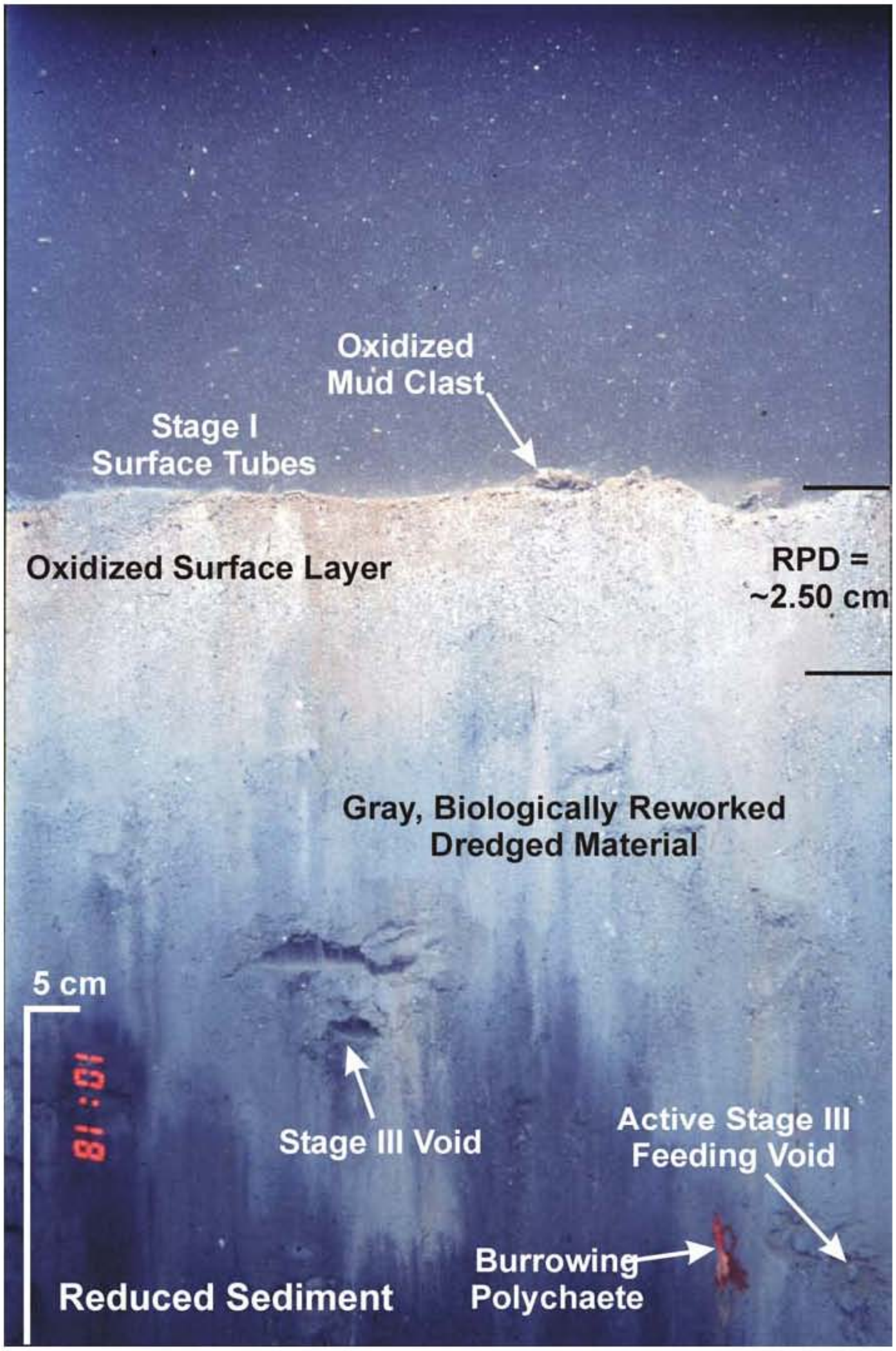


Figure 3-15. REMOTS® image collected from Station D200S showing a relatively deep RPD, Stage I organisms at the surface, and an abundance of Stage III activity at depth to yield an OSI value of +9 for this replicate

Table 3-3.

REMOTS® Sediment-Profile Imaging Results Summary from the WLDS Reference Areas, June 2001

Station	Camera Penetration Mean (cm)	Dredged Material Thickness Mean (cm)*	Number of Reps w/ Dredged Material	RPD Mean (cm)	Successional Stages Present	Highest Stage Present	Grain Size Major Mode (phi)	Methane Present	OSI Mean	OSI Median	Boundary Roughness Mean (cm)
SE REF1	13.58	0	0	2.10	I,III	ST_I_ON_III	>4	NO	7.00	8	0.81
SE REF2	16.52	0	0	2.27	I,III	ST_I_ON_III	>4	NO	8.33	8	0.86
SE REF3	17.77	0	0	2.44	I,III	ST_III	>4	NO	7.67	9	1.17
SE REF4	15.06	0	0	2.77	I,III	ST_I_ON_III	>4	NO	9.00	9	0.48
SE REF5	13.39	0	0	3.42	I,III	ST_I_ON_III	>4	NO	10.33	11	0.59
SE REF6	14.11	0	0	2.28	I,III	ST_I_ON_III	>4	NO	7.33	8	0.63
SE REF7	15.28	0	0	2.08	I,III	ST_I_ON_III	>4	NO	8.00	7	1.96
SREF1	12.75	0	0	1.35	I,III	ST_I_ON_III	>4	NO	6.00	7	1.16
SREF2	14.28	0	0	1.55	I,III	ST_I_ON_III	>4	NO	7.67	8	1.41
SREF3	8.61	0	0	1.90	I,III	ST_III	>4	NO	6.67	8	1.09
SREF4	12.71	0	0	1.88	I,III	ST_I_ON_III	>4	NO	7.67	8	2.26
SW REF1	7.76	0	0	0.81	I,III	ST_I_ON_III	4 to 3	NO	6.33	6	2.41
SW REF2	10.93	0	0	1.13	I,III	ST_I_ON_III	4 to 3	NO	5.67	7	0.60
SW REF3	10.86	0	0	1.14	I,III	ST_I_ON_III	4 to 3	NO	6.00	7	0.52
SW REF4	11.35	0	0	2.11	I,III	ST_I_ON_III	4 to 3	NO	7.00	9	1.16
AVG	13.00	0.00	0.00	1.95					7.38	8.00	1.14
MAX	17.77	0.00	0.00	3.42					10.33	11.00	2.41
MIN	7.76	0.00	0.00	0.81					5.67	6.00	0.48

* Values are means for n=3 replicate images at each station. If dredged material exceeded the prism penetration depth in at least two replicates, then the mean value shown is a minimum estimate of dredged material layer thickness (indicated by the > sign).

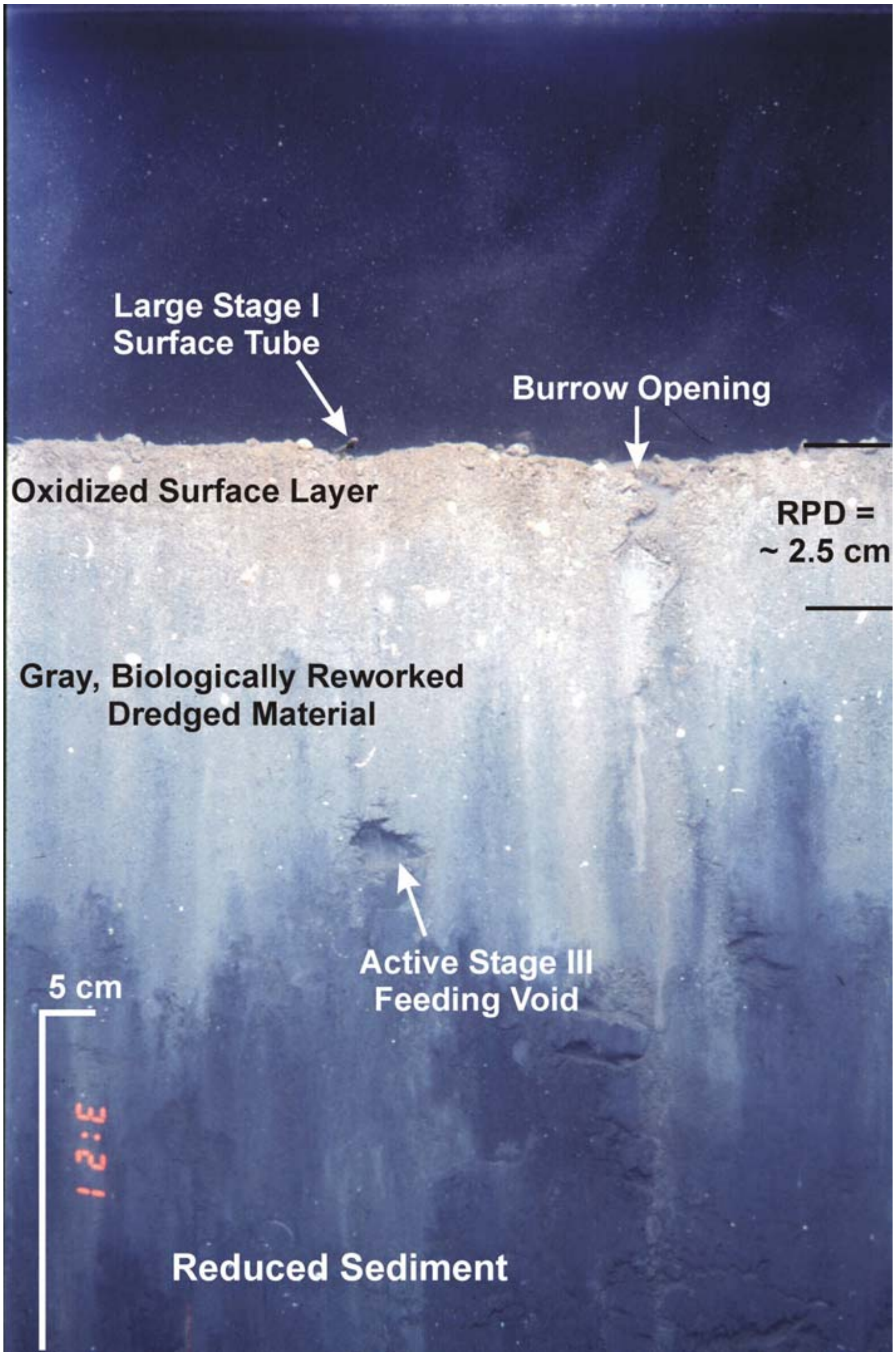


Figure 3-16. REMOTS® image collected from Station SE REF 6 displaying benthic conditions similar to those detected at WLDS, including a moderate to well-developed RPD depth of 2.5 cm, Stage III activity, and reduced sediments at depth

replicate images obtained from SE REF and S REF, indicating high organic loading within the region. The images collected over SW REF displayed a higher fraction of fine sand in the surficial sediment layers, and were classified with a major modal grain size of 4 to 3 phi (very fine sand; Figure 3-17). No indications of dredged material or non-ambient sediments were detected in any of the reference area REMOTS® images.

Replicate-averaged camera penetration depths over the reference areas ranged from 7.8 cm to 17.8 cm, with an overall average of 13 cm. Mean boundary roughness values displayed a wide range as well, with a minimum value of 0.5 cm at Station SE REF 4 and a maximum value of 2.4 cm at SW REF 1 (Table 3-3). An average boundary roughness value of 1.1 cm calculated across all three reference areas indicates only minimal small-scale surface relief.

3.2.3.2 Biological Conditions

The mean apparent RPD depths at the reference areas also showed significant variability, ranging from 0.8 cm at Station SW REF 1 to 3.4 cm at Station SE REF 5. Although the overall average reference area RPD depth of 1.9 cm indicates moderately aerated sediments, SE REF had a deeper average RPD depth (2.5 cm) relative to S REF (1.7 cm) and SW REF (1.3 cm).

The average RPD depth of 2.5 cm at the SE REF reference area indicates relatively deep oxygen penetration into the surface sediments. The shallower apparent RPD depths found at the S REF and SW REF reference areas may indicate higher levels of organic loading at these locations. No indications of a redox rebound interval, low sediment dissolved oxygen conditions, or methane gas production were detected in any of the replicate images from the reference areas.

Stage I on III was the predominant successional stage throughout the three reference areas, indicating that the ambient sediments were supporting a mature and well-established benthic infaunal community at the time of the June 2001 survey (Table 3-3; Figures 3-16 and 3-17). Due to the advanced successional stage, the median OSI values calculated for the reference area stations ranged from +6 at Station SW REF 1 to +11 at SE REF 5, with an overall average of +8, indicating non-degraded or undisturbed benthic habitat conditions (Table 3-3).

Figure 3-17. REMOTS® image collected from Station SW REF 4 displaying a fine sand and silt surficial sediment layer with decreasing sand content at depth

4.0 DISCUSSION

The June 2001 survey represents the first monitoring effort conducted at WLDS since the monitoring surveys conducted in September 1997 and March 1998. The primary focus of the survey was to delineate the dredged material distribution and benthic recolonization status. In addition, follow-on monitoring was performed over the WLIS I Mound and two stations over the WLIS D Mound (Stations D200S and D300S) to examine long-term benthic habitat recovery, in accordance with the DAMOS Tiered Monitoring Protocol. The June 2001 field operations also included a bathymetric survey over the SE REF reference area to confirm the results of the side-scan sonar survey that was conducted in 1998 (Murray and Saffert 1999).

The following discussion addresses each of the four primary survey objectives and evaluates the results in the broader context of the long-term DAMOS management plan for WLDS.

4.1 Dredged Material Distribution

One of the primary objectives of the June 2001 survey was to map the distribution of recently deposited dredged material using bathymetric data and REMOTS® sediment-profile imaging. The results from these two surveys indicated that three new disposal mounds (WLIS J, WLIS K, and WLIS L) had been formed by the placement of approximately 100,000 m^3 of dredged material over the past four years (1997–2001). Depth difference comparisons with the 1996 bathymetric survey data showed the new sediment mounds as discrete bottom features connected by a ridge of material 0.25 m thick, formed by overlapping mound aprons.

Based on the success of the management strategy first demonstrated at CLDS, disposal activity at WLDS over the past several years has been tightly controlled to construct rings of disposal mounds on the seafloor (Morris 1998). Upon completion, these rings of mounds will provide large bowl-like "cells" for lateral containment of dredged material and maximize the available capacity within the 5.29 km^2 area of the disposal site. The construction of the WLIS J, WLIS K, and WLIS L mounds during the 1997–2001 disposal seasons was based upon the recommendations of the July 1996 monitoring survey; the construction of these mounds was predicted to provide the berms necessary to complete the first containment ring at WLDS (Morris 1998). However, it should be noted that the disposal and confinement of UDM within the containment cell has not yet been authorized at WLDS.

The 2001 monitoring results indicate that the WLIS K and WLIS L Mounds were of sufficient height and width to serve effectively as "walls" for the containment cell (Figure 4-1). However, the results also indicate that the WLIS J Mound was only a subtle deposit, not easily distinguishable on the seafloor and therefore not of sufficient height and width to adequately complete the containment ring (Figure 4-1). Future disposal activities should be re-directed to the WLIS J Mound to construct a mound of sufficient height to complete the first containment ring at WLDS.

An estimate of the volume of dredged material that this containment cell would hold was calculated by identifying the "shallow" and "deep" points of the current ring walls and multiplying the difference between the two heights by the surface area of the "ring" connecting the apex of the ten mounds (WLIS C, D, E, F, G, H, I, J, K, and L Mounds; Figure 4-1). Assuming a minimum difference in berm height of approximately 1 m, it is estimated that the completed cell would hold approximately 150,000 m^3 of dredged material when completed (Figure 4-1). If the cell were filled to a maximum height of approximately 3.5 m (an approximate average of the ten mound heights), it is estimated that the cell would hold approximately 525,000 m^3 of dredged material. Filling the cell to this height could result in dredged material breaching the containment berm at points less than 3.5 m in height. In the future, the lower points on the berm may need to be increased to maximize the containment capacity of the cell.

As part of the larger containment ring construction strategy for WLDS, the 1997/1998 survey report recommended additional disposal buoy placement locations to begin construction of a second containment ring within the site (Murray and Saffert 1999). These proposed locations lie to the west of the current containment ring and upon completion of the WLIS J Mound, future dredged material placement should be directed to these locations.

The WDA 98 REMOTS® survey grid represents a new sampling pattern that encompassed a wide-ranging area around the most recently created disposal mounds. With the exception of Station C1, dredged material was detected at all of the stations comprising this survey grid. This result indicates that the WLIS J, WLIS K, and WLIS L mounds were flanked by dredged material aprons generally greater than 11.7 cm in thickness that extended primarily to the northeast of the current containment ring. The stations occupied near the older dredged material mounds (WLIS C, D, E, F, G, H, and I Mounds) showed similar dredged material aprons and dredged material thicknesses.

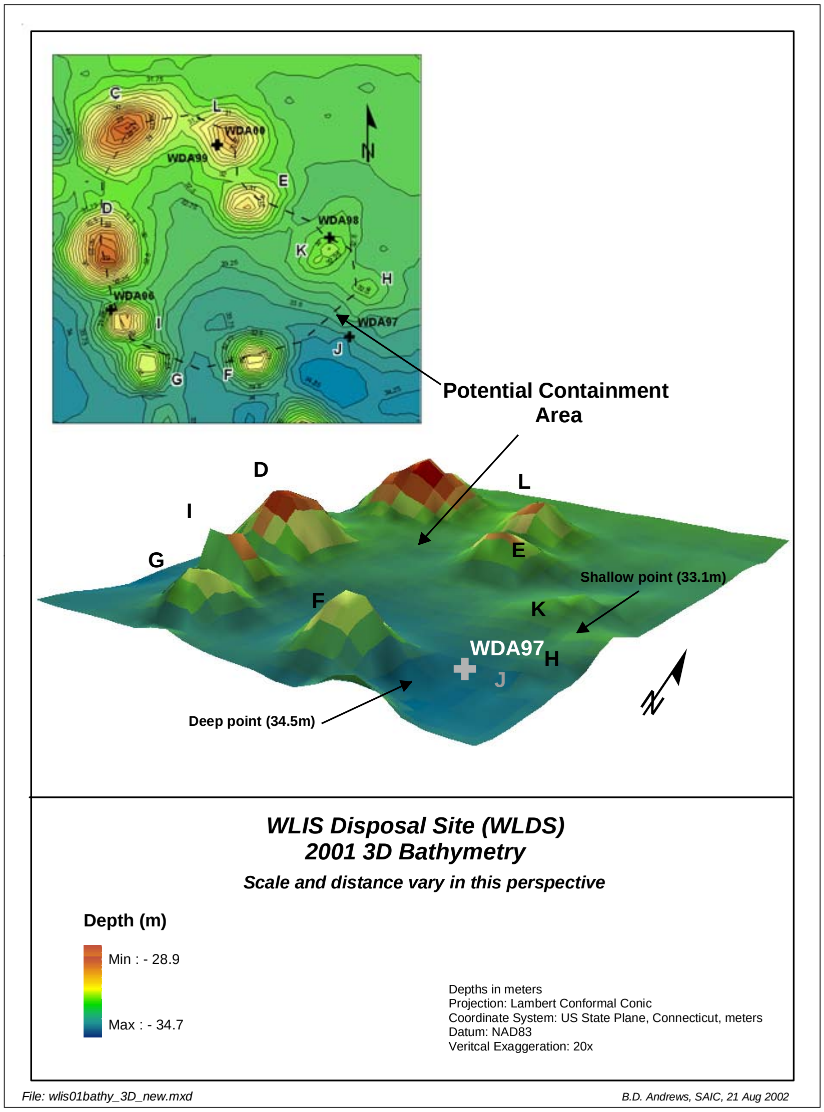


Figure 4-1. Two and three-dimensional view of the first potential containment cell at WLDS based on the June 2001 bathymetric survey. The two-dimensional figure (upper left corner) provides a view of the surface area of the ring when drawn through the apex of the current WLIS Mounds. The three-dimensional view, which has a vertical exaggeration of 20X, provides a visual of the current morphology of the containment ring including the identification of the "low" and "deep" points that were used to calculate the holding capacity of the cell. Based on these two variables it is estimated that the cell could hold between 150,000 and 525,000 cubic meters of dredged material.

4.2 Benthic Recolonization

A second objective of the June 2001 survey was to evaluate benthic recolonization over the area most recently affected by dredged material disposal activities. Overall, the benthic conditions throughout WLDS were relatively advanced at the time of the survey in June 2001, as evidenced by the presence of Stage III organisms in at least one replicate image from each station and relatively high median OSI values (generally greater than +8.0). These results were similar to the results from the three reference area stations.

The RPD depth measured in each REMOTS® image provides an indication of the degree of oxygen penetration into the surface sediments (Section 3.0). A well-developed RPD depth (defined as greater than 3 cm) generally indicates good or healthy sediment aeration as a result of active bioturbation by benthic organisms. In general, the stations occupied during the June 2001 survey had RPD depths between 1 and 3 cm; indicative of moderately well-aerated sediments. With the exception of the stations located in the SE REF reference area, the majority of the stations had RPD depths of less than 2 cm, which can be considered slightly shallow for typical marine sediments. These shallower RPD depths are commonly observed in REMOTS® images obtained in western Long Island Sound and have been attributed to seasonal hypoxic conditions (low dissolved oxygen concentrations in the water column) within the region coupled with a persistently high level of labile organic material within the surface sediments (Murray and Saffert 1999, Morris 1996).

Hypoxia and its associated complications with benthic processes in western Long Island Sound have been documented by DAMOS monitoring efforts since 1985 (SAIC 1987, Morris 1998). Typically, the western half of Long Island Sound begins to become hypoxic in July, reaches its most severe levels during mid to late August, and begins to dissipate in September (CTDEP 2000). Although a number of environmental factors can contribute to hypoxic conditions, two of the main factors affecting WLDS include excessive nutrient loading and the stratification of the overlying water column that prevents the mixing of oxygen-rich surface waters with bottom waters (CTDEP 2000). This stratification and subsequent lack of oxygen replenishment or “turnover” can be especially problematic in areas of deeper water; WLDS is located within the deeper part of Long Island Sound (Figure 4-2) and is therefore more prone to the affects of water stratification and lower dissolved oxygen concentrations. This lack of oxygen, coupled with a high existing sediment organic carbon concentration, can result in shallower RPD depths, as bioturbation of surface sediments by benthic organisms slows in response to the lack of available oxygen.

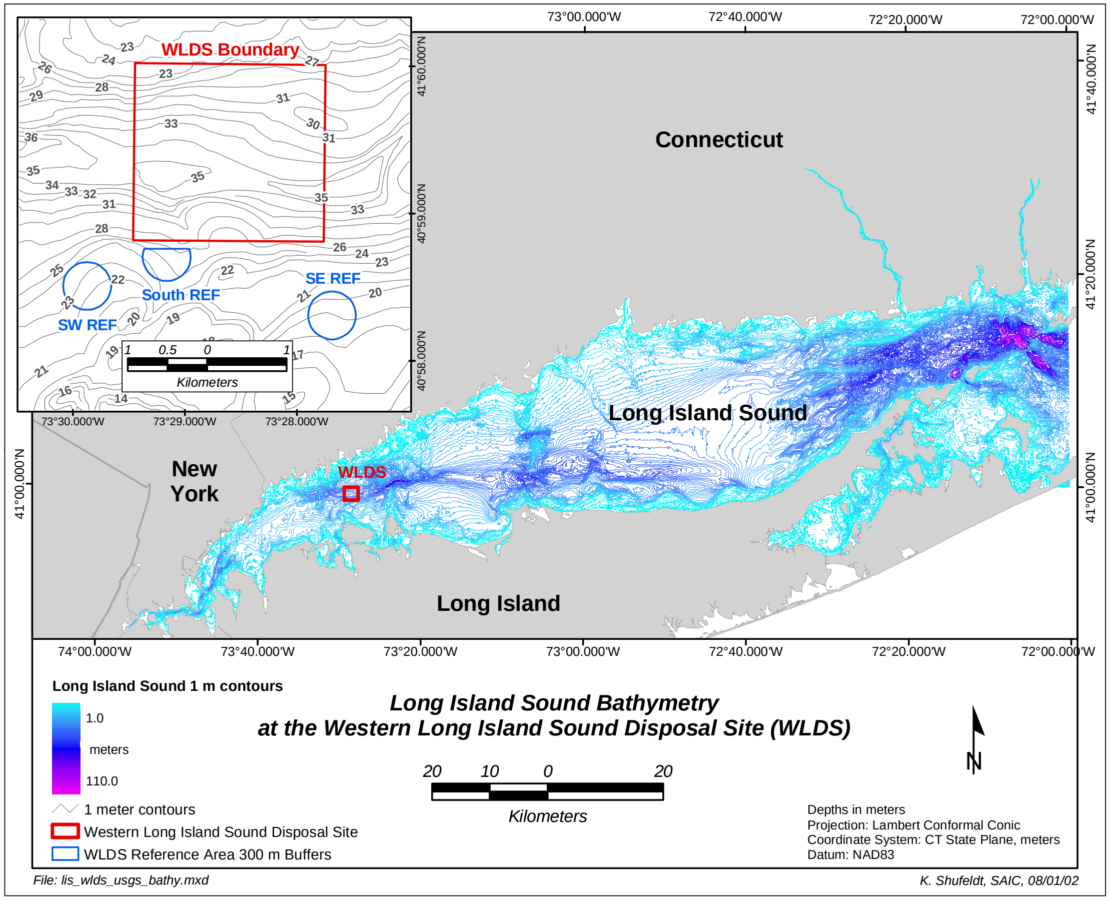


Figure 4-2. Bathymetry of Long Island Sound showing the differences in depth at WLDS and the S REF and SW REF reference areas in comparison to the SE REF reference area. Bathymetric data compiled and published by the U.S. Geological Survey, Woods Hole, MA (Poppe and Polloni 1998).

The Long Island Sound Study (LISS), a U.S. Environmental Protection Agency (EPA) monitoring program, officially recognizes the onset of hypoxia at a dissolved oxygen concentration of 3.0 $mg \cdot l^{-1}$. However, the appearance of hypoxic conditions in the bottom waters and surficial sediment layers has been documented with dissolved oxygen concentrations as high as 5.0 $mg \cdot l^{-1}$ (LISS 1990). Oxygen concentrations of $\geq$5.0 $mg \cdot l^{-1}$ are thought to be protective of most Long Island Sound marine life (LISS 1990).

To track the effect of seasonal hypoxia events on survey results, the near-bottom dissolved oxygen data set for two LISS water quality monitoring stations located near WLDS (LISS Stations C2 and D3; Figure 1-2) was obtained from the Connecticut Department of Environmental Protection (CTDEP), Bureau of Water Management (Figure 4-3). These data support the cyclic nature of hypoxic conditions over time within WLDS; showing water column dissolved oxygen concentrations are highest during the winter months, become hypoxic during late summer (i.e., mid to late August) and then begin to increase again in fall. It is hypothesized that a similar annual trend is seen in the apparent RPD, with shallower RPD depths observed during mid to late summer when bottom waters in western Long Island Sound become hypoxic.

Historical data from four previous WLDS REMOTS® surveys and the most current June 2001 data were compared to the dissolved oxygen data to identify whether or not a temporal trend in annual RPD depths due to fluctuations in dissolved oxygen concentrations and successional stage composition is apparent at WLDS (Figure 4-4; Table 4-1). With the exception of the June 2001 survey data, this comparison generally supports the theory that the RPD depths within WLDS are shallower during the summer months, when hypoxic conditions are most extreme, and deeper during the fall and winter, when dissolved oxygen concentrations are higher. Correlations between dissolved oxygen concentrations and presence of Stage III organisms were less apparent.

Overall mean RPD depths show a general trend of being shallower following prolonged periods of lower dissolved oxygen (Table 4-1). The August 1993 and September 1997 surveys had relatively shallow mean RPD values (1.2 and 1.7 cm, respectively) following extended periods of dissolved oxygen concentrations less than 5 $mg \cdot l^{-1}$ and the July 1996 and March 1998 surveys conducted before the seasonal decline in dissolved oxygen concentrations yielded deeper mean RPD depths (2.4 cm and 2.7 cm, respectively). However, the June 2001 survey results complicate the correlation, with a mean RPD value of 1.7 cm despite favorable dissolved oxygen conditions prior to the survey. The June 2001 survey was conducted in the early summer, following a steady decline in dissolved oxygen but with concentrations still above 6 $mg \cdot l^{-1}$, which would be deemed favorable conditions. These results suggest that the dissolved oxygen

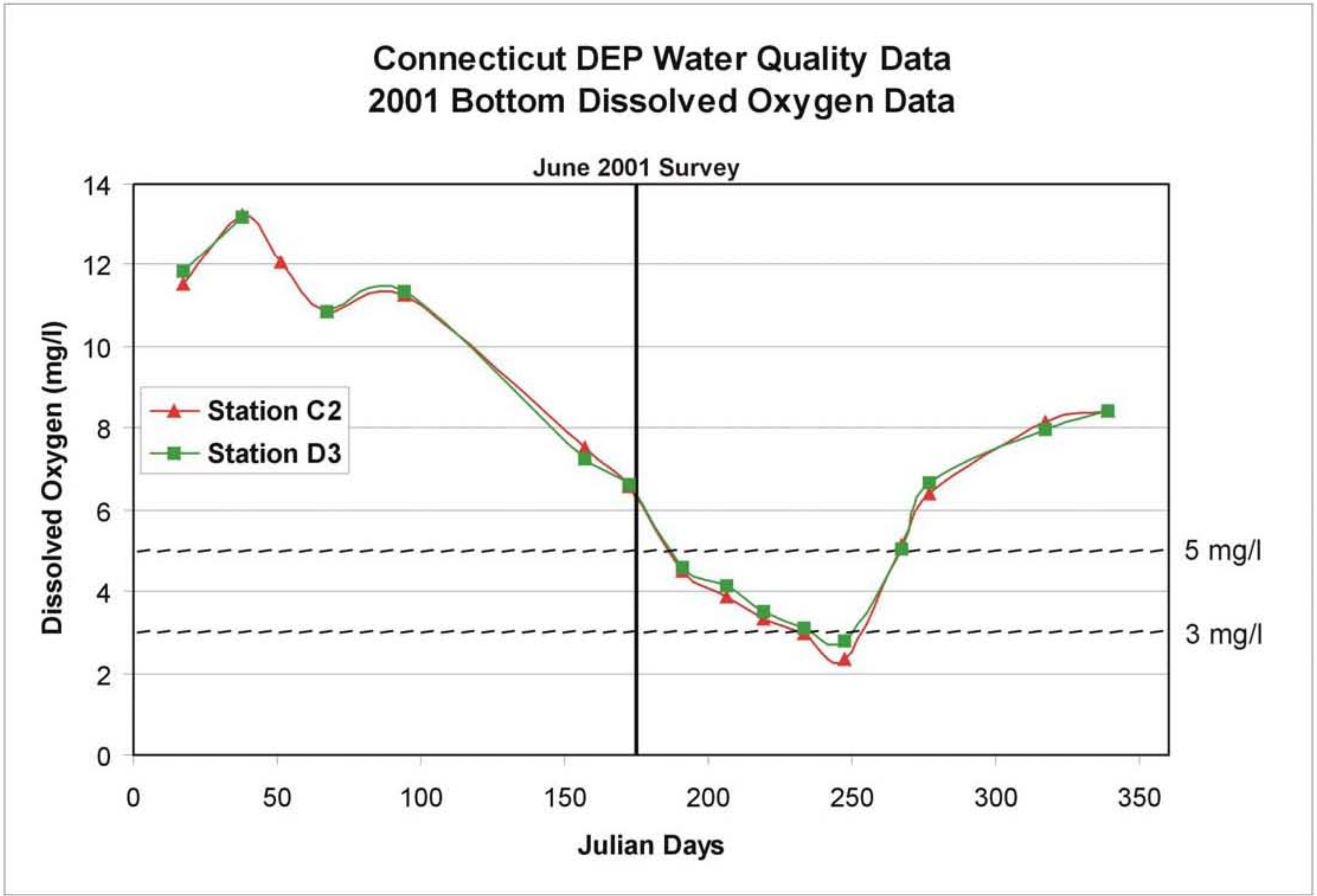


Figure 4-3. Dissolved oxygen concentrations in 2001 at two Connecticut DEP water quality monitoring stations (C2 and D3) located near WLDS

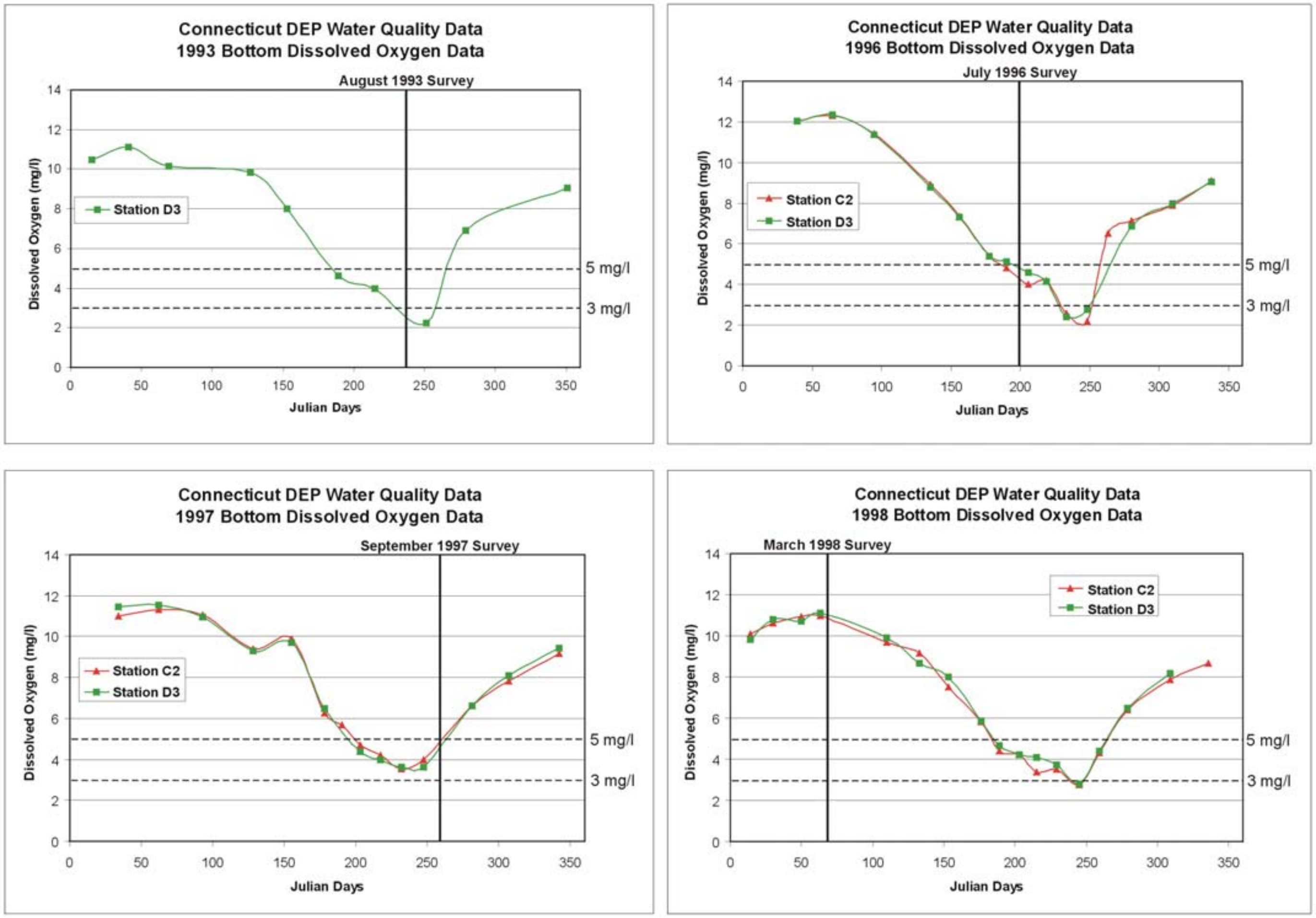


Figure 4-4. Dissolved oxygen concentrations at the Connecticut DEP water quality monitoring stations (C2 and D3) located near WLDS relative to the timing of the 1993, 1996, 1997, and 1998 environmental monitoring surveys

Table 4-1.

Temporal Comparison of RPD Depths and Successional Stages at WLDS

Survey	Survey Area	Mean RPD Depth (cm)	RPD Range (cm)	DO Concentration ($mg \cdot l^{-1}$)	Number and Percentage of Replicate Images w/ Stage III Organisms Present	Duration of Dissolved Oxygen Concentrations $\leq 5 mg \cdot l^{-1}$ prior to survey (from Figure 4-4)	Duration of Dissolved Oxygen Concentrations $\leq 3 mg \cdot l^{-1}$ prior to survey (from Figure 4-4)
August 1993	WLIS A Mound	1.20	----	**~ 2.5**	3/3 (100%)	**52**	**7**
	WLIS D Mound	1.24	0.2-2.2		6/9 (67%)		
	Reference Areas	1.13	0.62-3.0		13/15 (87%)		
	Total	**1.19**	**0.20-3.0**		**22/27 (81%)**		
July 1996	WLIS G Mound	2.42	1.33-3.59	**~ 4.5**	11/39 (28%)	**8**	**N/A**
	WLIS F Mound	N/A	2.15-3.59		N/A		
	WLIS H Mound	2.46	0.39-4.88		7/37 (19%)		
	WLIS D Mound	2.24	1.77-2.74		3/6 (50%)		
	Reference Areas	2.54	0.92-3.89		11/34 (32%)		
	Total	**2.42**	**0.39-4.88**		**32/116 (28%)**		
September 1997	WLIS I Mound	2.02	1.1-4.06	**~ 4.5**	12/31 (39%)	**67**	**N/A**
	WLIS H Mound	1.46	0.71-2.51		15/35 (43%)		
	Reference Areas	1.72	0.85-2.14		18/33 (55%)		
	Total	**1.73**	**0.71-4.06**		**45/99 (45%)**		
March 1998	WLIS I Mound	2.68	1.74-3.46	**~ 11.0**	4/10 (40%)	**N/A**	**N/A**
	WLIS H Mound	2.28	1.69-2.86		10/13 (77%)		
	Reference Areas	3.04	1.8-4.3		49/54 (91%)		
	Total	**2.67**	**1.69-4.30**		**63/77 (82%)**		
June 2001	WDA Survey Grid	1.86	1.12-2.78	**~ 6.5**	64/74 (86%)	**N/A**	**N/A**
	WLIS I Mound	1.34	0.81-2.00		12/15 (80%)		
	WLIS D Mound	1.60	1.31-1.89		4/6 (67%)		
	Reference Areas	1.95	0.81-3.42		36/45 (80%)		
	Total	**1.69**	**0.81-3.42**		**116/140 (83%)**		

concentrations in the overlying water column at WLDS are not the only factor that affects the surface sediment RPD depth. A high level of organic material in the sediments (which is persistent throughout the year) is also an important factor for temporal variability in RPD depths. A comparison of the range of RPD depths for each individual survey date indicates that there can be considerable spatial variability in RPD depths (Table 4-1) that likely reflect localized changes in organic content and circulation patterns.

Effects of seasonal hypoxia on the benthic community are less evident in these comparisons. It is theorized that a significant decrease in dissolved oxygen concentrations within the bottom waters would tend to elevate environmental stress within the benthos. As a result, a corresponding decrease in sediment dissolved oxygen concentrations could result in a decrease in the abundance of deep-dwelling deposit feeders (i.e., Stage III organisms). Based on an evaluation of the data (Table 4-1), there are no readily apparent correlations between evidence of Stage III activity and RPD depths or duration of low dissolved oxygen concentration conditions prior to the survey date. However, other environmental factors (i.e., age of the sediment deposit and sediment oxygen demand) may have influenced these comparisons. For example, the two surveys that were conducted following prolonged periods of low dissolved oxygen concentrations—August 1993 and September 1997—had variable results regarding the prevalence of Stage III organisms, with advanced benthic communities detected at 81% of the stations sampled in 1993 and only 45% of the stations occupied in 1997. The August 1993 survey indicated that a stable and advanced successional stage was present at the majority of stations sampled (81%) despite a significant hypoxia event at the time of the survey, with bottom water dissolved oxygen concentrations below 5 $mg \cdot l^{-1}$ for a period of 52 days prior to the survey effort, and lower than 3 $mg \cdot l^{-1}$one week before the sediment-profile imaging survey was completed.

The lowest prevalence of Stage III organisms for the data set, 28%, occurred in the July 1996 survey following a relatively short duration of eight days with oxygen concentrations below 5 $mg \cdot l^{-1}$. The annual record for CTDEP Stations C2 and D3 shows a gradual decrease in dissolved oxygen concentrations as bottom waters became warmer and the water column began to stratify prior to the survey effort. Bottom water dissolved oxygen concentrations fell below 5 $mg \cdot l^{-1}$ only eight days before the July 1996 survey effort (Figure 4-4). As a result, the low percentage of Stage III organisms observed over the disposal mounds and reference areas must be attributed to environmental factors other than bottom water hypoxia since dissolved oxygen concentrations were still relatively high (4.5 $mg \cdot l^{-1}$) and a mean RPD depth of approximately 2.4 cm was calculated for the areas of seafloor surveyed.

The March 1998 survey, conducted when bottom water temperatures were cold (4° C) and dissolved oxygen concentrations were at their peak (11 $mg \cdot l^{-1}$) indicated Stage III organisms were in relative abundance in the region as feeding voids and burrows were detected in 82% of the images obtained. The June 2001 survey results displayed similar findings, with evidence of Stage III activity detected in 83% of the replicate images, despite somewhat lower dissolved oxygen concentrations (6.5 $mg \cdot l^{-1}$). However, based on the lack of a clear correlation from the earlier surveys, drawing conclusions from these two later surveys would be misleading. In its entirety, the dataset compiled for WLDS suggests that Stage III organisms are active within the benthos regardless of the timing of survey operations. Although relative abundance of deposit feeders has demonstrated some variability over time, a direct correlation between Stage III activity and fluctuations in dissolved oxygen concentrations alone was not apparent.

4.3 Monitoring of the WLIS I and D Mounds

Another objective of the June 2001 survey was to assess the benthic habitat conditions over the central portion of the WLIS I Mound and at two stations located on the apron of the WLIS D Mound (Stations D200S and D300S).

The WLIS I Mound was formed during the 1996–97 disposal season, and benthic conditions were last surveyed in September 1997 and March 1998 (Murray and Saffert 1999). The results of the June 2001 survey were similar to the biological conditions observed in 1997 and 1998 (Table 4-2). During all three surveys, evidence of Stage III organisms was generally present in at least one replicate image at each station, indicating that the dredged material was being recolonized as expected. The RPD depths observed during the 2001 survey were slightly shallower than those observed in 1997 and 1998. Overall, the OSI values from the 2001 survey were indicative of undisturbed or non-degraded benthic habitat quality and were similar to the OSI values reported in 1997 and 1998, indicating negligible temporal changes of benthic conditions for the WLIS I Mound over time.

The WLIS D Mound was created during the 1989–90 disposal season. Since the first biological monitoring survey conducted in 1990, Stations D200S and D300S have shown signs of degraded benthic habitat conditions due primarily to an elevated concentration of labile organic matter in the surface sediments (SAIC 1990). Since 1990, six biological monitoring surveys have been conducted at these stations to monitor temporal conditions (Table 4-3). The 2001 survey indicated that benthic conditions (based on the OSI) had improved at Station D200S, and that undisturbed or non-degraded conditions existed at D300S, similar to what was observed in 1996, and comparable to the

Table 4-2.

Summary of Benthic Habitat Conditions over the WLIS I Mound, 1997–2001

Station	Highest Successional Stage Present			Average RPD Depth (cm)			Median OSI		
	September 1997	March 1998	June 2001	September 1997	March 1998	June 2001	September 1997	March 1998	June 2001
CTR	INDET	Stage I on III	Stage I on III	1.66	3.11	0.81	N/A	7.5	6
50N	Stage I on III	INDET	Stage III	1.33	N/A	2.00	5	N/A	8
50S	Stage III	Stage I on III	Stage I on III	1.65	3.46	1.50	5.5	10	8
50E	Stage III	Stage III	Stage I on III	3.06	1.74	1.18	10	8	6
50W	Stage I on III	Stage III	Stage III	3.85	2.40	1.21	7	5	7

INDET = indeterminate
N/A = not available

Table 4-3.

Summary of Benthic Habitat Conditions at WLIS D Mound Stations D200S and D300S, 1990–2001

Year	Highest Successional Stage Present D200S	Average RPD Depth (cm) D200S	Median OSI D200S	Highest Successional Stage Present D300S	Average RPD Depth (cm) D300S	Median OSI D300S
1990	Stage III	2	7	Stage III	5.3	10
1991	Stage III	2	8	Stage I	1.2	3
1992	Stage III	2.2	6	Stage I	1.5	3
1993	Stage III	0.2	6	INDET	1.7	INDET
1996	Stage III	1.8	-1	Stage III	2.7	8
2001	Stage III	1.9	8	Stage III	1.3	8

reference areas surveyed in 2001. These results are attributed to the stations having received a layer of sediments having less labile organic matter during the creation of the neighboring WLIS I Mound in 1996–97 (Murray and Saffert 1999). These sediments apparently have provided better benthic habitat conditions and have promoted the successful recolonization at this station. The June 2001 survey represents the first monitoring survey at Stations D200S and D300S since the creation of the WLIS I Mound. In accordance with the Tiered Monitoring Protocol, only periodic monitoring of these stations is needed in the future to verify that the improved benthic habitat conditions remains consistent.

4.4 SE REF Reference Area

The final objective of the June 2001 survey was to examine the bottom topography at SE REF to evaluate its suitability for long-term use as a DAMOS reference area for WLDS. In 1998, a side-scan sonar survey was conducted over the potential SE REF reference area to characterize the seafloor sediments and to detect any potential historical dredged material deposits (Murray and Saffert 1999). During the June 2001 survey a bathymetric survey was conducted over the same area to confirm that there were no apparent dredged material deposits within the SE REF reference area. The survey showed no distinct features or bottom topography indicative of past dredged material disposal at SE REF. The June 2001 REMOTS® survey confirmed an absence of recent or historic dredged material at SE REF. Therefore, it is recommended that the SE REF reference area be used for future WLDS field monitoring surveys.

The June 2001 sediment-profile imaging survey also detected deeper RPD depths at the SE REF reference area relative to those observed at S REF and SW REF. These deeper RPDs may have been due to a lower concentration of organic material within the sediments, as SE REF is located in an area of shallower water (approximately 18 to 20 m) compared to the WLDS (approximately 27 to 35 m) and the other two reference areas (22 to 23 m at SW REF, and 25 m at S REF; Figure 4-2). Because it is shallower than nearby areas, SE REF may be less prone to long-term deposition of organic detritus that would then accumulate as organic matter in the sediment. As mentioned previously, high levels of labile organic matter in sediments have negative effects on the available oxygen that is needed for physical and biological processes, both of which affect the development and depth of the RPD. Relatively less of this organic material at SE REF may result in higher levels of available oxygen that subsequently result in deeper RPD depths. Based on this fact, environmental monitoring surveys at WLDS should continue to include the use of multiple reference areas in close proximity of the disposal site to be sure that the full range of ambient conditions is documented and unbiased comparisons are made between the WLDS disposal mounds and ambient sediments within the region.

5.0 CONCLUSIONS AND RECOMMENDATIONS

5.1 Formation of the WLIS J, K and L Mounds

- A total of three new disposal mounds (WLIS J, WLIS K, and WLIS L) were formed on the WLDS seafloor by the placement of approximately 100,000 m^3 of dredged material over the four-year period September 1997 to May 2001.

- The WLIS J Mound is a subtle deposit formed at the WDA 97 buoy position. This bottom feature was not easily distinguished in the June 2001 bathymetric survey due to the small volume of sediment (10,700 m^3) disposed, as well as the seafloor topography surrounding the mound. The mound did not display sufficient height or width to be useful as a containment structure. Future disposal activity should be directed to the WDA 97 buoy position to close the first artificial containment cell on the WLDS seafloor.

- Contrary to WLIS J, the WLIS K and WLIS L Mounds are of sufficient height and width to provide containment for a large unconsolidated sediment deposit. Building upon the pre-existing WLIS H mound to the southeast, the WLIS K Mound closes the eastern side of the ring of disposal mounds. The WLIS L Mound, developed between WLIS C and WLIS E, will likely prevent the lateral spread of a sediment deposit to the northeast.

5.2 Benthic Habitat Conditions

- Despite moderately shallow RPD depths (<2 cm), the June 2001 REMOTS® survey showed non-degraded benthic habitat conditions (OSI values $\geq +6$) over the active area of disposal at WLDS and at the reference areas.

- The successional status over the WLIS I Mound was advanced (presence of Stage III organisms), indicating continued benthic recovery of this five-year-old sediment deposit. The average OSI value for this mound was +6.4, with all stations displaying median OSI values $\geq +6$.

- Benthic habitat conditions were found to be stable at Stations D200S and D300S on the southern flank of Mound D. Despite shallow RPD depths, median OSI values of +8 were calculated for both stations. This represents an improvement in conditions at D200S and no change at D300S, relative to the July 1996 survey. Overall habitat conditions were comparable to the reference areas. Evidence of advanced Stage III conditions was also seen in the majority of the replicate images acquired at these stations. In accordance with the DAMOS Tiered Monitoring Protocol, no immediate action is required. Routine periodic monitoring of these stations is recommended during future surveys at WLDS.

- Benthic habitat conditions at SE REF were comparable to that at S REF and SW REF. A consistently deeper RPD depth at the seven stations occupied over SE REF resulted in slightly higher OSI values, and suggests this area may be subject to less organic loading in comparison to the other surveyed areas of western Long Island Sound.

5.3 SE REF Reference Area Bathymetry

- The results of the bathymetric survey conducted over the SE REF reference area showed no topographical surface relief or bottom topography indicative of past dredged material disposal. SE REF is considered suitable for use as a WLDS reference area in all future survey operations.

6.0 REFERENCES

CTDEP. 2000. Long Island Sound Ambient Water Quality Monitoring Program: Summer Hypoxia Monitoring Survey 1991–1998 Data Review. Prepared by Connecticut Department of Environmental Protection, Bureau of Water Management, Hartford, CT, 46 pp.

Eller, F. C.; Williams, R. W. 1996. Monitoring cruise at the Western Long Island Sound Disposal Site, July 1992. DAMOS Contribution No. 102 (SAIC Report No. C108). U.S. Army Corps of Engineers, New England Division, Waltham, MA.

Fredette, T. J. 1994. Disposal site capping management: New Haven Harbor. Reprinted from Dredging '94, Proceedings of the Second International Conference, November 13–16, 1994. U.S. Army Corps of Engineers, New England Division, Waltham, MA.

Germano, J. D.; Parker, J.; Williams, R. W. 1993. Monitoring cruise at the Western Long Island Sound Disposal Site, July 1990. DAMOS Contribution No. 85 (SAIC Report No. SAIC-90/7598&C92). U.S. Army Corps of Engineers, New England Division, Waltham, MA.

Germano, J. D.; Rhoads, D. C.; Lunz, J. D. 1994. An integrated, tiered approach to monitoring and management of dredged material disposal sites in the New England region. DAMOS Contribution No. 87 (SAIC Report No. SAIC-90/7575&234). U.S. Army Corps of Engineers, New England Division, Waltham, MA.

Morris, J. T.; Charles, J.; Inglin, D. C. 1996. Monitoring surveys of the New Haven capping project, 1993–1994. DAMOS Contribution No. 111 (SAIC Report No. 319). U.S. Army Corps of Engineers, New England Division, Waltham, MA.

Morris, J. 1998. Monitoring Cruise at the Western Long Island Sound Disposal Site, July 1996. SAIC Report No. 383. Final report submitted to New England District, U.S. Army Corps of Engineers, Waltham, MA.

Murray, P. M.; Saffert, H.L. 1999. Monitoring cruises at the Western Long Island Sound Disposal Site, September 1997 and March 1998. DAMOS Contribution No. 125. U.S. Army Corps of Engineers, New England District, Concord, MA.

Poppe, L.J.; Polloni, C. 1998. Long Island Sound Environmental Studies, Open-File Report 98–502. U.S. Geological Survey, Coastal and Marine Geology Program, Woods Hole Field Station, Woods Hole, MA.

Rhoads, D. C.; Germano, J. D. 1982. Characterization of organism-sediment relation 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 benthic community structure: A new protocol. Hydrobiologia 142:291–308.

SAIC. 1987. Monitoring surveys at the Western Long Island Sound Disposal Site, August and October 1985. DAMOS Contribution No. 55 (SAIC Report No. SAIC-86/7510&C56). US Army Corps of Engineers, New England Division, Waltham, MA.

SAIC. 2001. Monitoring at the New London Disposal Site, 1992–1998, Volume I. DAMOS Contribution No. 128 (SAIC Report No. 515). U.S. Army Corps of Engineers, New England District, Concord, MA.

USACE. 1982. Final environmental impact statement (FEIS) for the designation of a disposal site for dredged material in Western Long Island Sound: WLIS III. 1982. U.S. Army Corps of Engineers, New England Division.

Appendix A

Appendix B

Appendix B1
WDA 98 Survey Grid REMOTS Sediment-Profile Photography Data from the June 2001 Survey

Station	Replicate	Date	Time	Grain Size			Camera Penetration (cm)				Surface Roughness	Apparent RPD Thickness (cm)				Successional Stage	Low DO	OSI	Mud Clasts		Dredged Material Thickness (cm)			Redox Rebound Thickness (cm)			Methane				Comments
				Min	Max	Maj Mode	Min	Max	Range	Mean		Area	Min	Max	Mean				Count	Diameter	Min	Max	Mean	Min	Max	Mean	Diameter	Min	Max	Mean	
A1	A	6/24/2001	14:31	>4	3	>4	15.44	15.72	0.28	15.58	PHYSICAL	23.964	0.28	3.28	1.97	ST_I_ON_III	NO	8	0	0	0	0	0	0	0	0	0	0	0	0	DM>P, BRN SILT/GRY&BLK M, RELIC RPD, SM TUBES, BURROWS-OPENINGS, VOIDS, WORM@Z
A1	B	6/24/2001	14:32	>4	3	>4	12.56	14.45	1.89	13.5	PHYSICAL	6.377	0.06	2.83	1.05	ST_I	NO	3	1	0.23	0	0	0	0	0	0	0	0	0	0	DM>P, BRN SILT/GRY&BLK M, PATCHY RPD, TUBES, REDOX REB OR RELIC RPD?, OX CLST
A1	C	6/24/2001	14:33	>4	3	>4	13.67	14.89	1.22	14.28	PHYSICAL	28.588	1.11	2.78	1.96	ST_I_ON_III	NO	8	0	0	0	0	0	0	0	0	0	0	0	0	DM>P, BRN SILT/GRY&BLK M, TUBES, WIPER CLST, VOIDS,RELIC RPD,BURROW-OPENING,WORMPHYSICAL
A2	A	6/24/2001	13:56	>4	2	>4	15.67	16.28	0.61	15.97	PHYSICAL	25.914	0.61	3.11	1.91	ST_I_ON_III	NO	8	0	0	0	0	0	0	0	0	0	0	0	0	DM>P, BRN SANDY SILT/GREY & BLK MUD, RELIC RPD, TUBES, VOIDS
A2	B	6/24/2001	13:57	>4	2	>4	14.33	15.28	0.94	14.81	PHYSICAL	10.456	0.17	3.67	1.57	ST_I_ON_III	NO	8	5	0.48	0	0	0	0	0	0	0	0	0	0	DM>P, BRN SANDY/GRY&BLK M, TUBES, VOID, OX&RED CLSTS, RELIC RPD, RED SED
A2	C	6/24/2001	13:58	>4	3	>4	16.28	16.72	0.44	16.5	PHYSICAL	28.415	1.28	3.06	2.12	ST_III	NO	8	0	0	0	0	0	0	0	0	0	0	0	0	DM>P, BRN SILT/GREY & BLK M, RELIC RPD, VOIDS, WORM @Z, RED SED
A3	A	6/24/2001	12:55	>4	3	>4	15.88	17.18	1.3	16.53	PHYSICAL	21.842	0.56	2.77	2.01	ST_I_ON_III	NO	8	4	0.22	0	0	0	0	0	0	0	0	0	0	DM>P, BRN SILT/BLK M, TUBES, VOIDS, OX&RED CLASTS, MUD CLUMPS, REDOX REBOUND?
A3	B	6/24/2001	12:56	>4	3	>4	18.42	18.98	0.56	18.7	PHYSICAL	5.185	0.28	1.24	1	ST_I	NO	3	0	0	0	0	0	0	0	0	0	0	0	0	DM>P, BRN SILT/GREY & BLK MUD, PATCHY RPD, WIPER SMEARS
A3	C	6/24/2001	12:56	>4	3	>4	14.52	14.92	0.4	14.72	PHYSICAL	24.436	1.36	2.99	2.22	ST_I_ON_III	NO	8	8	0.53	0	0	0	0	0	0	0	0	0	0	DM>P, BRN SILT/GRY&BLK M, TUBES, VOIDS, OX&RED CLSTS,WIPER CLST, WORM@Z,RED SED
A4	A	6/24/2001	12:29	>4	3	>4	15.37	16.16	0.79	15.76	PHYSICAL	25.987	0.73	3.11	1.99	ST_I_ON_III	NO	8	20	0.35	0	0	0	12.94	15.93	14.44	0	0	0	0	DM>P, BRN SILT/GRY&BLK M, TUBES,VOIDS, OX&RED CLSTS,WORMS,SULFIDIC M,RELIC RPD?
A4	B	6/24/2001	12:30	>4	3	>4	13.39	15.08	1.69	14.24	BIOGENIC	17.491	0.34	2.09	1.51	ST_I_ON_III	NO	8	0	0	0	0	0	0	0	0	0	0	0	0	DM>P, BRN SILT/GRY&BLK M, ANENOME?, TUBES, VOIDS, BURROWING WORM-OPENING,RED SEDBIOGENIC
A4	C	6/24/2001	12:31	>4	3	>4	14.35	14.92	0.56	14.63	PHYSICAL	8.528	0.11	2.71	1.63	ST_I_ON_III	NO	8	8	0.13	0	0	0	0	0	0	0	0	0	0	DM>P, BRN SILT/GRY&BLK M, TUBES, VOIDS, BURROW, OX&RED CLSTS, WIPER CLSTS,SHELLSPHYSICAL
A5	A	6/24/2001	11:20	>4	2	>4	14.7	15.58	0.88	15.14	PHYSICAL	35.114	0.88	4.03	2.71	ST_I_ON_III	NO	9	4	0.3	0	0	0	0	0	0	0	0	0	0	DM>P, BRN SILT/GRY&BLK M, OX CLSTS, WORMS@Z, REDUCED SED@Z
A5	B	6/24/2001	11:21	>4	2	>4	14.09	14.59	0.5	14.34	PHYSICAL	16.364	0.33	2.43	1.11	ST_I_ON_III	NO	7	5	0.13	0	0	0	0	0	0	0	0	0	0	DM>P, BRN SILT/GRY&BLK M, OX CLSTS, VOIDS, SM TUBES, BURROW?
A5	C	6/24/2001	11:21	>4	2	>4	11.71	13.87	2.15	12.79	PHYSICAL	18.551	0.06	3.26	1.52	ST_III	NO	8	5	0.26	0	0	0	0	0	0	0	0	0	0	DM>P, BRN SILT/GRY&BLK M, VOIDS, TUBES?, IRREG TOPO, RED SED @Z
B1	A	6/24/2001	14:37	>4	3	>4	15.72	16.17	0.44	15.94	PHYSICAL	34.145	0.28	3.83	2.79	ST_I_ON_III	NO	9	3	0.3	0	0	0	0	0	0	0	0	0	0	DM>P, BRN SILT/GRY&BLK M, TUBES, VOIDS, RED CLSTS, RELIC RPD, GASTROPOD?
B1	C	6/24/2001	14:40	>4	3	>4	15.83	16.72	0.89	16.28	BIOGENIC	51.226	1.78	6.28	3.82	ST_I_ON_III	NO	11	5	0.18	0	0	0	0	0	0	0	0	0	0	DM>P, BRN SILT/GRY M, TUBES, VOID, BURROW-OPENING, GASTROPOD@SURF,OX&RED CLSTS
B1	E	6/25/2001	15:14	>4	3	>4	13.22	14.17	0.94	13.69	BIOGENIC	22.211	0.11	2.72	1.74	ST_III	NO	8	0	0	0	0	0	0	0	0	0	0	0	0	DM>P,BRN/GRY M,VOIDS, WIPER CLSTS,ANENOME @SURF &BURROWING @Z-N.VECTENSIS,WORMS
B2	A	6/24/2001	13:50	>4	2	>4	16.38	17.06	0.68	16.72	PHYSICAL	17.494	0.06	2.32	1.43	ST_III	NO	5	0	0	0	0	0	0	0	0	11.311	15.76	15.76	15.76	DM>P, BRN SANDY/BLK SULFIDIC M, GASTROPOD, VOIDS, SM METHANE BUBBLE, SHELL BITS
B2	B	6/24/2001	13:50	>4	2	>4	16.27	16.5	0.23	16.38	PHYSICAL	9.052	0.06	3.73	2.22	ST_III	NO	8	4	0.44	0	0	0	0	0	0	0	0	0	0	DM>P, BRN SANDY/GRY&BLK M, VOID, WORMS @Z, OX&RED CLASTS, WIPER CLAST,SULFIDIC MPHYSICAL
B2	C	6/24/2001	13:51	>4	2	>4	15.83	16.28	0.44	16.06	PHYSICAL	17.625	0.11	3.39	1.89	ST_III	NO	8	9	0.39	0	0	0	0	0	0	0	0	0	0	DM>P, BRN SANDY SILT/BLK SULFIDIC M, VOIDS, OX&RED CLSTS,SHELL BITS
B3	A	6/24/2001	13:01	>4	3	>4	15.25	16.44	1.19	15.85	PHYSICAL	38.795	2.09	3.16	2.62	ST_I_ON_III	NO	9	0	0	0	0	0	0	0	0	0	0	0	0	DM>P, BRN SILT/GRY&BLK M, DENSE TUBES, VOIDS, MULINIA?, SHELL BITS, RED SED
B3	B	6/24/2001	13:02	>4	3	>4	13.05	13.9	0.85	13.47	PHYSICAL	19.041	0.62	2.09	1.29	ST_I	NO	3	0	0	0	0	0	0	0	0	0	0	0	0	DM>P, BRN SILT/GREY & BLK MUD, TUBES, WIPER CLAST, RED SED
B3	C	6/24/2001	13:03	>4	3	>4	12.43	13.84	1.41	13.14	BIOGENIC	9.664	0.17	1.98	1.22	ST_I_ON_III	NO	7	5	0.18	0	0	0	0	0	0	0	0	0	0	DM>P, BRN SILT/GRY&BLK M, SM TUBES, BIVALVE,VOIDS,BURROW-OPENING,RED SED,OX CLSTBIOGENIC
B4	A	6/24/2001	12:23	>4	2	>4	15.87	16.26	0.39	16.06	PHYSICAL	19.822	0.11	2.96	2.04	ST_II_ON_III	NO	8	9	0.66	0	0	0	0	0	0	0	0	0	0	DM>P, BRN SILT/GRY&BLK M, VOIDS, MULINIA, TUBE, OX&RED CLSTS, SULFIDIC M, SHELL
B4	B	6/24/2001	12:24	>4	2	>4	14.02	14.13	0.11	14.08	PHYSICAL	8.342	0.28	2.18	1.39	ST_I_ON_III	NO	7	0	0.31	0	0	0	0	0	0	0	0	0	0	DM>P, BRN SILT/GRY & BLK M, TUBES, VOIDS, OX CLASTS, SULFIDIC MUD
B4	C	6/24/2001	12:24	>4	3	>4	10.84	11.34	0.5	11.09	PHYSICAL	13.642	0.22	2.12	1.01	ST_I_ON_III	NO	7	0	0	0	0	0	0	0	0	0	0	0	0	DM>P, BRN SILT/GRY&BLK M, TUBES, VOIDS, SHELL BITS, SULFIDIC MUD
B5	A	6/24/2001	11:27	>4	2	>4	7.18	8.84	1.66	8.01	PHYSICAL	21.349	0.11	3.15	1.97	ST_III	NO	8	0	0	0	0	0	0	0	0	0	0	0	0	DM>P,BRN SILT/SULF BLK M,VOIDS,LG BURROW, SHELLS,WORM, IRREG TOPO,RED SED@SURF
B5	B	6/24/2001	11:28	>4	2	>4	13.32	14.2	0.88	13.76	PHYSICAL	10.463	0.11	2.43	1.67	ST_I_ON_III	NO	8	3	0.22	0	0	0	0	0	0	0	0	0	0	DM>P, BRN SILT/GRY&BLK M, TUBES, VOIDS,RED CLSTS, WORMS@Z, BURROW, WIP CLST
C1	A	6/24/2001	14:44	>4	3	>4	16.67	18.33	1.67	17.5	BIOGENIC	30.322	0.83	3.17	2.12	ST_II_ON_III	NO	8	7	0.31	0	0	0	0	0	0	0	0	0	0	DM>P, SANDY M>P, TUBES, VOIDS, MULINIA, BURROW-OPENING, SHELL BITS, OX&RED CLSTSBIOGENIC
C1	C	6/24/2001	14:46	>4	3	>4	18	18.83	0.83	18.42	BIOGENIC	30.341	1.83	2.89	2.37	ST_I_ON_III	NO	9	8	0.43	0	0	0	0	0	0	0	0	0	0	DM?, SANDY M>P, TUBES, VOID?, LG BURROW-OPENING, OX & RED CLASTS
C1	F	6/25/2001	15:07	>4	3	>4	14.28	15.94	1.67	15.11	PHYSICAL	22.789	0.44	2.17	1.57	ST_I_ON_III	NO	8	4	0.31	0	0	0	0	0	0	0	0	0	0	DM?, BRN SILT/GRY M, TUBES, VOIDS, OX&RED CLSTS, WORM @Z, BURROW OPENING?
C2	A	6/24/2001	13:43	>4	3	>4	17.4	17.68	0.28	17.54	PHYSICAL	25.548	0.51	4.24	2.24	ST_I_ON_III	NO	8	0	0	0	0	0	0	0	0	0	0	0	0	DM>P, BRN SILT/GRY&BLK M, SM TUBES, VOIDS, REDOX REB OR RELIC RPD?, WORM @Z
C2	B	6/24/2001	13:44	>4	3	>4	16.55	17.12	0.56	16.84	PHYSICAL	8.723	0.23	1.81	0.91	ST_I_ON_III	NO	7	1	0.4	0	0	0	7.18	12.94	10.06	0	0	0	0	DM>P, BRN SILT/GRY&BLK M, TUBES, VOIDS, OX CLSTS, WIPER CLSTS, BURROW, RED SED
C2	D	6/25/2001	14:56	>4	2	>4	14.24	14.86	0.62	14.55	PHYSICAL	32.996	1.69	2.99	2.25	ST_I_ON_III	NO	8	0	0	0	0	0	0	0	0	0	0	0	0	DM>P, BRN SILT/GREY & BLK MUD, SM TUBES, VOIDS, LG MUD CLUMPS, RELIC RPD
C3	A	6/24/2001	13:07	>4	3	>4	4.75	10.9	6.16	7.82	PHYSICAL	34.228	1.3	3.73	2.83	ST_I	NO	5	20	0.4	0	0	0	0	0	0	0	0	0	0	DM>P, BRN SILT/GRY&BLK M, SLOPING TOPO, TUBES, OX&RED CLSTS, SHELL, WORMS @Z
C3	B	6/24/2001	13:08	>4	3	>4	14.24	14.46	0.23	14.35	PHYSICAL	15.398	0.56	2.09	1.55	ST_I_ON_III	NO	8	10	0.34	0	0	0	0	0	0	0	0	0	0	DM>P, BRN SILT/GREY & BLK M, TUBES, VOIDS, OX&RED CLASTS, RED SED
C3	C	6/24/2001	13:09	>4	3	>4	12.77	13.56	0.79	13.16	PHYSICAL	21.157	0.73	2.09	1.44	ST_I_ON_III	NO	7	8	0.68	0	0	0	0	0	0	0	0	0	0	DM>P, BRN SILT/GRY M, TUBE, VOID, WORM@Z, LG 0X&RED CLSTS, IRON OXIDE @Z
C4	D	6/25/2001	14:42	>4	3	>4	6.76	7.82	1.06	7.29	BIOGENIC	20.657	0.5	4.02	3.03	ST_I_ON_III	NO	10	0	0	0	0	0	0	0	0	0	0	0	0	DM>P, BRN SILT/BLK M, TUBES,VOIDS, BURROWS-OPENINGS,LG MUD CLUMPS,WORM@Z,RED SEDBIOGENIC
C4	E	6/25/2001	14:42	>4	3	>4	15.42	16.31	0.89	15.87	PHYSICAL	17.164	0.22	2.85	1.86	ST_I	NO	4	12	0.22	0	0	0	0	0	0	0	0	0	0	DM>P, BRN SILT/GREY&BLK MUD, TUBES, SM VOID?, OX & RED CLASTS
C4	F	6/25/2001	14:43	>4	3	>4	11.45	12.63	1.17	12.04	PHYSICAL	27.342	0.95	2.79	1.87	ST_I_ON_III	NO	8	0	0	0	0	0	0	0	0	0	0	0	0	DM>P, BRN SILT/GREY MUD, TUBES, SM VOID, SHELL FRAGS
C5	A	6/24/2001	11:35	>4	2	>4	15.47	16.19	0.72	15.83	PHYSICAL	22.339	0.55	3	2.4	ST_I_ON_III	NO	9	8	0.22	0	0	0	0	0	0	0	0	0	0	DM>P, BRN SILT/GRY&BLK M, TUBES, VOIDS, RED SED @Z
C5	B	6/24/2001	11:36	>4	2	>4	14.36	15.3	0.94	14.83	PHYSICAL	7.486	0.06	4.42	1.69	ST_I_ON_III	NO	8	12	0.22	0	0	0	0	0	0	0	0	0	0	DM>P,BRN SILT/GRY&BLK M, VOIDS,MULINIA?, OX&RED&WIP CLSTS,PATCHY RPD,RED SED@Z
C5	C	6/24/2001	11:37	>4	2	>4	9.16	10.11	0.95	9.64	PHYSICAL	20.878	0.06	4.19	1.82	ST_I_TO_II	NO	5	4	0.26	0	0	0	0	0	0	0	0	0	0	DM>P, BRN SILT/GRY&BLK M, MULINIA, SM TUBES, OX&RED CLSTS, WORM @Z, RED SED
D1	A	6/24/2001	14:50	>4	3	>4	18.44	19.83	1.39	19.14	BIOGENIC	33.555	1.28	3.44	2.36	ST_III	NO	9	5	0.21	0	0	0	0	0	0	0	0	0	0	DM?, BRN SILT/GRY M, VOIDS, ANENOME-TENTACLES @SURF, OX CLSTS, ORG @Z?
D1	B	6/24/2001	14:51	>4	3	>4	18.11	18.5	0.39	18.31	PHYSICAL	15.772	0.44	2.89	1.31	ST_III	NO	7	0	0	0	0	0	0	0	0	0	0	0	0	DM>P, BRN SILT/GRY&BLK M, VOID?, WIPER CLASTS, RED SED, PATCHY RPD, WORM @Z?
D1	C	6/24/2001	14:52	>4	3	>4	18.83	19.44	0.61	19.14	PHYSICAL	10.839	0.78	1.83	1.54	ST_I_ON_III	NO	8	1	0.44	0	0	0	0	0	0	0	0	0	0	DM>P, BRN SILT/GRY&BLK M, TUBES, VOID, BURROW, RED CLAST, REDUCED SED
D2	A	6/24/2001	13:37	>4	3	>4	14.29	15.37	1.07	14.83	PHYSICAL	22.464	0.68	2.77	1.75	ST_I_ON_III	NO	8	6	0.49	0	0	0	0	0	0	0	0	0	0	DM>P, BRN SILT/GRY&BLK M, SM TUBES, VOIDS, OX CLSTS, SULFIDIC M
D2	B	6/24/2001	13:38	>4	3	>4	18.93	19.55	0.62	19.24	PHYSICAL	17.977	0.17	2.09	1.25	ST_I	NO	3	2	0.53	0	0	0	0	0	0	0	0	0	0	DM>P, BRN SILT/GREY & BLK MUD, TUBES, OX&RED CLASTS, WORMS @Z
D2	C	6/24/2001	13:38	>4	3	>4	18.87	19.72	0.85	19.29	PHYSICAL	15.657	0.34	2.37	1.09	ST_I_ON_III	NO	7	6	0.4	0	0	0	0	0	0	0	0	0	0	DM>P, BRN SILT/GRY&BLK M, TUBES, LG VOID, SM VOIDS, OX CLSTS, RED SED, WORMS@Z
D3	A	6/24/2001	13:14	>4	3	>4	19.1	19.72	0.62	19.41	BIOGENIC	20.914	0.56	2.32	1.55	ST_I_ON_III	NO	8	0	0	0	0	0	0	0	0	0	0	0	0	DM>P, BRN SILT/GREY & BLK M, DENSE TUBES, VOIDS, MULINIA?
D3	B	6/24/2001	13:14	>4	3	>4	19.49	19.83	0.34	19.66	PHYSICAL	14.183	0.68	2.26	1.6	ST_I_ON_III	NO	8	15	0.37	0	0	0	0	0	0	0	0	0	0	DM>P, BRN SILT/GRY&BLK M, TUBES, VOIDS, OX&RED CLSTS, WIPER CLST, BURROW
D3	C	6/24/2001	13:15	>4	3	>4	16.61	17.57	0.96	17.09	PHYSICAL	5.627	0.06	1.07	0.55	ST_II_ON_III	NO	6	2	0.18	0	0	0	0	0	0	0	0	0	0	DM>P, BRN SILT/GRY&BLK M, TUBES, MULINIA,VOIDS, OX&RED&WIP CLSTS,M CLUMP,SM RPD
D4	A	6/24/2001	12:07	>4	3	>4	13.69	14.47	0.78	14.08	PHYSICAL	13.953	0.67	2.57	1.64	ST_III	NO	8	15	1.05	0	0	0	0	0	0	0	0	0	0	DM>P, BRN SILT/GRY&BLK M, VOIDS, OX & RED CLASTS, LG MUD CLUMPS, REDOX REB?
D4	B	6/24/2001	12:08	>4	3	>4	18.21	20.28	2.07	19.25	PHYSICAL	6.636	0.11	0.89	0.55	ST_I_ON_III	NO	6	0	0	0	0	0	0	0	0	0	0	0	0	DM>P, BRN SILT/GRY&BLK M, LOW DO?, SHALLOW RPD, VOIDS, SM TUBES, SULFIDIC MUD
D4	C	6/24/2001	12:09	>4	3	>4	16.98	18.38	1.4	17.68	PHYSICAL	16.49	0.11	2.35	1.16	ST_II_ON_III	NO	7	8	0.31	0	0	0	0	0	0	0	0	0	0	DM>P, BRN SILT/GRY&BLK M, TUBES, MULINIA, VOIDS, OX&RED CLSTS, RED SED
D5	B	6/24/2001	11:43	>4	2	>4	10	11.34	1.34	10.67	PHYSICAL	18.092	0.28	2.01	1.24	ST_I_TO_II	NO	4	5	0.36	0	0	0	0	0	0	0	0	0	0	DM>P, BRN SILT/GRT&BLK M, TUBES, OX&RED CLSTS, REDOX REB?, PATCHY RPD
D5	F	6/25/2001	14:32	>4	3	>4	14.47	15.31	0.84	14.89	BIOGENIC	35.657	1.4	3.07	2.48	ST_I_ON_III	NO	9	0	0	0	0	0	0	0	0	0	0	0	0	DM>P, BRN SILT/GRY M, DENSE TUBES, VOIDS, SHELL?, IRREG TOPO
D5	G	6/25/2001	14:33	>4	3	>4	7.93	8.38	0.45	8.16	BIOGENIC	15.177	0.11	3.91	1.93	ST_I_ON_III	NO	8	0	0	0	0	0	0	0	0	0	0	0	0	DM>P, BRN SILT/GRY M, DENSE TUBES, VOIDS, BURROW-OPENING, RED SED @SURF
E1	A	6/24/2001	14:56	>4	3	>4	13.5	14.56	1.06	14.03	PHYSICAL	55.161	3.11	4.39	3.84	ST_I_ON_III	NO	11	0	0	0	0	0	0	0	0	0	0	0	0	AMBIENT, SANDY M>P, TUBES, VOIDS, BURROW-OPENING
E1	B	6/24/2001	14:56	>4	2	>4	13.78	14.28	0.5	14.03	PHYSICAL	32.638	1.11	3.5	2.26	ST_I	NO	5	7	0.22	0	0	0	0	0	0	0	0	0	0	DM>P, BRN SILT/GRY M,TUBES, OX&RED&WIPER CLSTS, LG WORM@Z, VERT BURROW,SM VOID?
E1	C	6/24/2001	14:57	>4	3	>4	18.83	19.89	1.06	19.36	PHYSICAL	26.681	1.39	2.22	1.86	ST_III	NO	8	3	0.3	0	0	0	0	0	0	0	0	0	0	DM>P, BRN SILT/LT GRY&BLK M, VOIDS, FILLED VERTICAL BURROW-OPENING, OX CLSTS
E2	A	6/24/2001	13:28	>4	3	>4	12.66	15.65	2.99	14.15	BIOGENIC	23.771	0.17	2.66	1.64	ST_I_ON_III	NO	8	0	0	0	0	0	0	0	0	0	0	0	0	DM>P, BRN SILT/GRY&BLK M, TUBES, BURROWS/OPENING, VOIDS, SHELL FRAGS, WORMS @Z
E2	B	6/24/2001	13:29	>4	3	>4	19.21	19.66	0.45	19.44	PHYSICAL	19.774	0.9	1.98	1.32	ST_III	NO	7	12	0.23	0	0	0	0	0	0	0	0	0	0	DM>P, BRN SILT/GREY & BLK MUD, SM VOIDS, OX&RED CLASTS, REDOX REB?
E2	C	6/24/2001	13:29	>4	3	>4	12.6	14.12	1.53	13.36	PHYSICAL	23.576	0.73	2.37	1.62	ST_I_ON_III	NO	8	20	0.35	0	0	0	0	0	0	0	0	0	0	DM>P, BRN SILT/GREY M, TUBES, VOIDS, OX&RED CLASTS, WORMS @Z
E3	C	6/24/2001	13:21	>4	3	>4	11.02	15.59	4.58	13.31	PHYSICAL	15.267	0.23	4.07	2.31	ST_I_ON_III	NO	9	7	0.13	0	0	0	0	0	0	0	0	0	0	DM>P, BRN SILT/GRY&BLK M, SLOPING TOPO, TUBES, VOID?, OX&RED CLSTS, RED SED
E3	D	6/25/2001	14:49	>4	3	>4	15.2	16.61	1.41	15.9	PHYSICAL	24.735	0.06	4.86	2.11	ST_I_ON_III	NO	8	0	0	0	0	0	6.61	11.98	9.29	0	0	0	0	DM>P, BRN SILT/GRY&BLK M, TUBES, VOIDS, SHELL FRAGS, RELIC RPD?
E3	F	6/25/2001	14:50	>4	3	>4	17.34	17.91	0.56	17.63	PHYSICAL	26.664	1.24	2.71	1.83	ST_I_ON_III	NO	8	3	0.35	0	0	0	0	0	0	0	0	0	0	DM>P, BRN SILT/ GRY&BLK M, TUBES, VOID, OX CLSTS, MUD CLUMPS-FARFIELD, BURROW
E4	A	6/24/2001	12:00	>4	3	>4	15.59	17.37	1.79	16.48	PHYSICAL	25.881	0.06	2.96	2	ST_I_ON_III	NO	8	6	0.28	0	0	0	0	0	0	0	0	0	0	DM>P, BRN SILT/GRY&BLK M, LG VOIDS, TUBE, OX&RED CLSTS, BURROWS-OPENING
E4	B	6/24/2001	12:01	>4	3	>4	16.98	18.83	1.84	17.91	PHYSICAL	20.41	0.11	3.13	1.56	ST_I_ON_III	NO	8	7	0.34	0	0	0	0	0	0	0	0	0	0	DM>P,BRN SILT/GRY&BLK M, TUBES, VOIDS, OX&RED CLASTS,SHELLS, METHANE?,SULFIDIC MPHYSICAL
E4	C	6/24/2001	12:02	>4	3	>4	16.54	17.26	0.73	16.9	PHYSICAL	16.365	0.39	2.12	1.39	ST_I_ON_III	NO	7	0	0	0	0	0	0	0	0	0	0	0	0	DM>P, BRN SILT/GRY&BLK M, TUBES, SM VOID?, BURROW-OPENING, WIPER CLAST
E5	B	6/24/2001	11:50	>4	2	>4	12.91	14.58	1.68	13.74	PHYSICAL	12.531	0.5	2.12	1.42	ST_I_ON_III	NO	7	0	0	0	0	0	0	0	0	0	0	0	0	DM>P, BRN SILT/GRY&BLK M, SM TUBES, VOIDS, VERT BURROW-OPENING, BLK SULFIDIC MUDPHYSICAL
E5	C	6/24/2001	11:51	>4	3	>4	17.65	18.27	0.61	17.96	PHYSICAL	12.851	0.22	1.45	1.05	ST_I_ON_III	NO	7	15	0.22	0	0	0	0	0	0	0	0	0	0	DM>P, BRN SILT/BLK&GRY M, TUBES, VOIDS, V.RED SED,LG BURROWING WORM,OX&RED CLSTSPHYSICAL
E5	D	6/24/2001	11:54	>4	3	>4	17.26	17.82	0.56	17.54	BIOGENIC	37.87	1.62	3.46	2.65	ST_I	NO	5	10	0.22	0	0	0	0	0	0	0	0	0	0	DM>P, BRN SILT/GRY&BLK M, DENSE TUBES, SHELLS, OX CLASTS

Appendix B2

WLDS I Mound REMOTS Sediment-Profile Photography Data from the June 2001 Survey

Station	Replicate	Date	Time	Grain Size			Camera Penetration (cm)				Surface Roughness	Apparent RPD Thickness (cm)				Successional Stage	Low DO	OSI
				Min	Max	Maj Mode	Min	Max	Range	Mean		Area	Min	Max	Mean			
I50E	A	6/24/2001	10:55	>4	2	>4	11.55	12.54	0.99	12.04	PHYSICAL	8.083	0.17	3.26	1.83	ST_I_ON_III	NO	8
I50E	B	6/24/2001	10:55	>4	3	>4	10	11.22	1.22	10.61	PHYSICAL	15.244	0.11	2	0.7	ST_I_ON_III	NO	6
I50E	C	6/24/2001	10:56	>4	3	>4	9.56	10.5	0.94	10.03	BIOGENIC	10.198	0.06	2	1	ST_I	NO	3
I50N	D	6/25/2001	15:23	>4	2	>4	10	10.44	0.44	10.22	PHYSICAL	37.183	1.55	3.43	2.72	ST_III	NO	9
I50N	E	6/25/2001	15:23	>4	2	>4	9.5	9.89	0.39	9.7	BIOGENIC	12.187	0.55	2.04	1.27	ST_I	NO	3
I50N	F	6/25/2001	15:24	>4	2	>4	8.95	9.39	0.44	9.17	PHYSICAL	38.383	0.88	3	2	ST_I_ON_III	NO	8
I50S	A	6/24/2001	10:24	>4	3	>4	3.9	7.12	3.22	5.51	BIOGENIC	6.484	0.45	1.41	0.96	ST_I_ON_III	NO	7
I50S	B	6/24/2001	10:25	>4	3	>4	15.59	16.21	0.62	15.9	PHYSICAL	10.491	0.23	3.56	1.57	ST_I_ON_III	NO	8
I50S	C	6/24/2001	10:26	>4	3	>4	9.55	12.82	3.28	11.19	BIOGENIC	7.58	0.11	4.29	1.97	ST_I_ON_III	NO	8
I50W	B	6/24/2001	10:32	>4	2	>4	12.09	12.88	0.79	12.49	PHYSICAL	5.543	0.06	1.09	0.5	ST_I_ON_III	NO	6
I50W	C	6/24/2001	10:32	>4	2	>4	12.2	13.39	1.19	12.8	PHYSICAL	6.982	0.2	2.5	1.75	ST_I_ON_III	NO	8
I50W	D	6/24/2001	10:33	>4	2	>4	12.09	12.32	0.23	12.2	PHYSICAL	7.604	0.06	2.66	1.38	ST_III	NO	7
ICTR	A	6/24/2001	10:37	>4	2	>4	10.45	10.62	0.17	10.54	PHYSICAL	15.757	0.06	1.98	1.15	ST_I_ON_III	NO	7
ICTR	B	6/24/2001	10:38	>4	2	>4	8.47	10	1.53	9.24	PHYSICAL	5.025	0.17	1.36	0.54	ST_I	NO	2
ICTR	C	6/24/2001	10:39	>4	2	>4	8.64	9.55	0.9	9.1	PHYSICAL	5.157	0.06	1.19	0.74	ST_I_ON_III	NO	6

Station	Replicate	Date	Time	Mud Clasts		Dredged Material			Redox Rebound			Methane				Comments
				Count	Diameter	Min	Max	Mean	Min	Max	Mean	Dia.	Min	Max	Mean	
I50E	A	6/24/2001	10:55	10	0.35	0	0	0	0	0	0	0	0	0	0	DM>P, BRN SILT/GRY&BLK M, TUBES, VOIDS, OX&RED CLASTS, WORM @Z, RED SED@Z
I50E	B	6/24/2001	10:55	1	0.21	0	0	0	0	0	0	0	0	0	0	DM>P, BRN SILT/GRY&BLK M, TUBES, VOIDS-RED SED, THIN RPD,WIP CLST, BURROW
I50E	C	6/24/2001	10:56	0	0	0	0	0	0	0	0	0	0	0	0	DM>P, BRN SILT/GRY&BLK M, TUBES, WIPER CLSTS, GASTROPOD, BURROW-OPENING
I50N	D	6/25/2001	15:23	11	0.22	0	0	0	0	0	0	0	0	0	0	DM>P, BRN SILT/GRY&BLK M, NUMEROUS VOIDS, OX & RED CLASTS, LG M CLSTS-FARFIED
I50N	E	6/25/2001	15:23	7	0.21	0	0	0	0	0	0	0	0	0	0	DM>P, BRN SILT/GRY M, BURROW-OPENING, RED CLASTS, GASTROPOD
I50N	F	6/25/2001	15:24	0	0	0	0	0	0	0	0	0	0	0	0	DM>P, BRN SILT/GRY M, TUBES, VOIDS, BURROW OPENING
I50S	A	6/24/2001	10:24	10	0.3	0	0	0	0	0	0	0	0	0	0	DM>P, BRN SILT/GRY M, UPEN,TUBES, VOIDS, BURROW/OPENING, IRREG TOPO,OX CLASTS
I50S	B	6/24/2001	10:25	0	0	0	0	0	0	0	0	0	0	0	0	DM>P, BRN SILT/GRY&BLK M, SM TUBES, VOIDS, POSSIBLE MULINIA?
I50S	C	6/24/2001	10:26	0	0	0	0	0	0	0	0	0	0	0	0	DM>P, BRN SILT/GRY&BLK CLAY, VOIDS, VERT BURROW/OPNING,IRREG TOPO, PATCHY RPD
I50W	B	6/24/2001	10:32	3	0.53	0	0	0	5.48	8.14	6.81	0	0	0	0	DM>P, BRN SILT/GRY&BLK M, TUBES, VOIDS, PATCHY & SHALLOW RPD, RED CLSTS
I50W	C	6/24/2001	10:32	9	0.37	0	0	0	0	0	0	0	0	0	0	DM>P, BRN SILT/GRY&BLK M, TUBES, VOID, REDUCED CLASTS
I50W	D	6/24/2001	10:33	0	0	0	0	0	0	0	0	0	0	0	0	DM>P, BRN SILT/GRY&BLK M, VOIDS, BURROWING ANEMONE-FARFIELD?
ICTR	A	6/24/2001	10:37	0	0	0	0	0	0	0	0	0	0	0	0	DM>P, BRN SILT/GRY&BLK M, TUBES, NUMEROUS VOIDS, WORM @Z
ICTR	B	6/24/2001	10:38	0	0	0	0	0	0	0	0	0	0	0	0	DM>P, BRN SILT/GRY&BLK M, THIN&PATCHY RPD, WIPER CLST, TUBES, IRREG TOPO
ICTR	C	6/24/2001	10:39	12	0.29	0	0	0	0	0	0	0	0	0	0	DM>P, BRN SILT/GRY&BLK M, PULL AWAY-RPD?, OX&RED CLASTS, VOID, TUBES

Appendix B3

WLDS D Mound REMOTS Sediment-Profile Photography Data from the June 2001 Survey

Station	Replicate	Date	Time	Grain Size			Camera Penetration (cm)				Surface Roughness	Apparent RPD Thickness (cm)				Successional Stage	Low DO	OSI
				Min	Max	Maj Mode	Min	Max	Range	Mean		Area	Min	Max	Mean			
D200S	A	6/24/2001	10:18	>4	2	>4	12.91	13.52	0.61	13.21	BIOGENIC	12.36	0.06	3.74	2.75	ST_I_ON_III	NO	9
D200S	B	6/24/2001	10:18	>4	2	>4	12.96	13.35	0.39	13.16	PHYSICAL	6.123	0.06	2.18	1.08	ST_I	NO	3
D200S	C	6/24/2001	10:19	>4	3	>4	13.18	13.69	0.5	13.44	PHYSICAL	21.474	0.34	2.96	1.84	ST_I_ON_III	NO	8
D300S	A	6/24/2001	10:11	>4	3	>4	12.18	14.3	2.12	13.24	PHYSICAL	8.077	0.22	2.5	1.79	ST_I_ON_III	NO	8
D300S	B	6/24/2001	10:11	>4	3	>4	11.45	12.74	1.28	12.09	PHYSICAL	7.345	0.06	0.95	0.55	ST_I	NO	6
D300S	C	6/24/2001	10:12	>4	3	>4	13.46	14.19	0.73	13.83	PHYSICAL	13.268	0.39	3.63	1.6	ST_I_ON_III	NO	8

Station	Replicate	Date	Time	Mud Clasts		Dredged Material			Redox Rebound			Methane				Comments
				Count	Diamete	Min	Max	Mean	Min	Max	Mean	Diameter	Min	Max	Mean	
D200S	A	6/24/2001	10:18	0	0	0	0	0	0	0	0	0	0	0	0	OLDER DM>P, BRN SILT/GRY&BLK M, TUBES,VOIDS, WORMS@Z, BURROW OPNING,RED SED@Z
D200S	B	6/24/2001	10:18	6	0.18	0	0	0	0	0	0	0	0	0	0	OLDER DM>P, BRN SILT/GRY&BLK M, TUBES, OX&RED CLSTS,RED SED,THIN& PATCHY RPD
D200S	C	6/24/2001	10:19	0	0	0	0	0	0	0	0	0	0	0	0	OLDER DM>P, BRN SILT/GRY&BLK M, RED SED@Z?, REDOX REB?, TUBES, VOIDS, BURROW
D300S	A	6/24/2001	10:11	6	0.22	0	0	0	4.18	5.88	5.03	0	0	0	0	OLDER DM>P, BRN SILT/BLK SULFIDIC M, TUBES, VOIDS, OX&RED CLSTS, RED SED@Z
D300S	B	6/24/2001	10:11	0	0	0	0	0	0	0	0	0	0	0	0	OLDER DM>P, SANDY/GRY&BLK SULF. M, WIPER CLST,SHALLOW&PATCHY RPD, V.BLK RED SED
D300S	C	6/24/2001	10:12	0	0	0	0	0	0	0	0	0	0	0	0	OLDER DM>P, BRN SILT/GRY&BLK M, TUBES, VOID, WIPER CLST

Appendix B4

WLDS Reference Area REMOTS Sediment-Profile Photography Data from the June 2001 Survey

Station	Replicate	Date	Time	Grain Size			Camera Penetration (cm)				Surface Roughness	Apparent RPD Thickness (cm)				Successional Stage	Low DO	OSI	Mud Clasts		Dredged Material Thickness (cm)			Redox Rebound Thickness (cm)			Methane				Comments
				Min	Max	Maj Mode	Min	Max	Range	Mean		Area	Min	Max	Mean				Count	Diameter	Min	Max	Mean	Min	Max	Mean	Diameter	Min	Max	Mean	
SEREF1	A	6/24/2001	8:32	>4	3	>4	16.63	17.36	0.73	16.99	PHYSICAL	27.882	0.56	3.31	2.44	ST_I	NO	5	5	0.4	0	0	0	0	0	0	0	0	0	0	M>P, BRN/GRY&BLK STREAKY M, TUBES, OX&RED CLASTS, RED SED@Z
SEREF1	D	6/24/2001	15:09	>4	3	>4	12.25	13.2	0.96	12.72	PHYSICAL	27.067	0.39	3.48	2.17	ST_I_ON_III	NO	8	0	0	0	0	0	0	0	0	0	0	0	0	M>P, TUBES, VOIDS, SHELL FRAGS, WORM @Z
SEREF1	E	6/24/2001	15:10	>4	3	>4	10.67	11.4	0.73	11.04	PHYSICAL	25.171	0.73	2.42	1.7	ST_I_ON_III	NO	8	8	0.29	0	0	0	0	0	0	0	0	0	0	M>P, TUBES, VOIDS, FILLED VERT BURROW, OX&RED CLSTS, WIPER CLST,SHELL BITS
SEREF2	B	6/24/2001	8:27	>4	3	>4	17.39	18.22	0.83	17.81	PHYSICAL	31.675	1.5	3	2.19	ST_I_ON_III	NO	8	0	0	0	0	0	0	0	0	0	0	0	0	M>P, TUBES, VOIDS, WORMS @Z, SHELL FRAGS, GASTROPOD
SEREF2	C	6/24/2001	8:28	>4	2	>4	16.89	17.44	0.56	17.17	PHYSICAL	24.596	0.83	5	2.75	ST_I_ON_III	NO	9	8	0.22	0	0	0	0	0	0	0	0	0	0	M>P, TUBES, VOID, BURROW OPENING-OCCUPIED, SHELL FRAGS, RED SED@Z
SEREF2	F	6/24/2001	15:17	>4	3	>4	13.99	15.17	1.18	14.58	PHYSICAL	11.455	0.11	3.31	1.86	ST_I_ON_III	NO	8	4	0.42	0	0	0	0	0	0	0	0	0	0	M>P, TUBES, VOID, BURROW, SHELL FRAGS, OX CLASTS
SEREF3	A	6/24/2001	8:17	>4	3	>4	16.89	18.06	1.17	17.47	PHYSICAL	40.402	0.61	6	3.13	ST_I_ON_III	NO	10	0	0	0	0	0	0	0	0	0	0	0	0	M>P, TUBES, VOIDS, WORMS@Z, SHELL FRAGS, RED CLASTS?
SEREF3	B	6/24/2001	8:18	>4	3	>4	18.78	19.67	0.89	19.22	PHYSICAL	29.012	0.56	5	2.26	ST_III	NO	9	0	0	0	0	0	0	0	0	0	0	0	0	M>P, BRN/GRY & BLK M, VOIDS, SHELL BITS, RED SED@Z
SEREF3	C	6/24/2001	8:19	>4	3	>4	15.89	17.33	1.44	16.61	PHYSICAL	26.623	0.44	2.78	1.94	ST_I	NO	4	12	0.3	0	0	0	0	0	0	0	0	0	0	M>P, TUBES, SHELL BITS, OX&RED CLASTS, DIST SURF,RED SED@Z
SEREF4	A	6/24/2001	8:08	>4	3	>4	19.11	19.44	0.33	19.28	PHYSICAL	31.112	2	5	3.5	ST_I_ON_III	NO	10	0	0	0	0	0	0	0	0	0	0	0	0	M>P, TUBES, VOIDS, SHELL FRAGS, V.BLK RED SED @Z, SHELL @Z
SEREF4	D	6/24/2001	15:26	>4	3	>4	11.83	12.28	0.44	12.06	BIOGENIC	12.005	2.4	5.5	2.78	ST_I_ON_III	NO	9	0	0	0	0	0	0	0	0	0	0	0	0	M>P, VOIDS, TUBES, SHELL FRAGS, WORM@Z,BURROW OPENING/FECAL MOUND,RED SED@Z
SEREF4	E	6/24/2001	15:30	>4	3	>4	13.5	14.17	0.67	13.83	PHYSICAL	20.026	0.67	2.89	2.04	ST_I_ON_III	NO	8	3	0.18	0	0	0	0	0	0	0	0	0	0	M>P, TUBES, VOIDS, SHELL FRAGS, RED SED @Z, OX CLSTS
SEREF5	A	6/24/2001	7:52	>4	3	>4	18.98	19.55	0.56	19.27	PHYSICAL	51.499	1.64	5.48	4	ST_I_ON_III	NO	11	12	0.23	0	0	0	0	0	0	0	0	0	0	M>P, VOIDS, WORMS @Z, SHELL FRAGS, TUBE?, RED SED@DEPTH
SEREF5	D	6/25/2001	15:40	>4	3	>4	11.44	11.89	0.44	11.67	PHYSICAL	49.943	1.28	5.94	3.83	ST_I_ON_III	NO	11	0	0	0	0	0	0	0	0	0	0	0	0	M>P, TUBES, NUMEROUS VOIDS, SHELL FRAGS,BURROW OPENING?, RED SED@Z
SEREF5	F	6/25/2001	15:42	>4	3	>4	8.83	9.61	0.78	9.22	PHYSICAL	15.352	0.06	4.72	2.43	ST_I_ON_III	NO	9	0	0	0	0	0	0	0	0	0	0	0	0	SANDY M>P, VOIDS, TUBES, SHELL FRAGS, REDUCED WIPER CLAST @SURF, GASTROPODS @SURF
SEREF6	D	6/24/2001	15:21	>4	3	>4	13.78	14.17	0.39	13.97	BIOGENIC	29.004	0.67	3.33	3	ST_I_ON_III	NO	9	4	0.35	0	0	0	0	0	0	0	0	0	0	SANDY M>P, MANY VOIDS, TUBES, BURROW OPENING, SHELL FRAGS, WORM@Z,OX CLSTS
SEREF6	E	6/24/2001	15:22	>4	3	>4	12.89	13.56	0.67	13.22	PHYSICAL	10.516	0.17	3.89	2.31	ST_I	NO	5	5	0.43	0	0	0	0	0	0	0	0	0	0	M>P, TUBES, RED CLASTS, SHELL FRAGS
SEREF6	F	6/24/2001	15:23	>4	3	>4	14.72	15.56	0.83	15.14	PHYSICAL	22.299	0.83	2.22	1.54	ST_I_ON_III	NO	8	0	0	0	0	0	0	0	0	0	0	0	0	M>P, TUBES, RED SED@Z, VOID,SHELL FRAGS, BURROW OPENING,LG TUBE
SEREF7	A	6/24/2001	8:13	>4	3	>4	17.61	18.17	0.56	17.89	PHYSICAL	29.725	1.22	5	3.5	ST_I_ON_III	NO	10	0	0	0	0	0	0	0	0	0	0	0	0	M>P, VOIDS, BURROW, TUBES, SHELL FRAGS, RED SED@Z
SEREF7	B	6/24/2001	8:13	>4	3	>4	12.5	17.22	4.72	14.86	PHYSICAL	7.452	0.17	2.22	1.45	ST_I_ON_III	NO	7	0	0	0	0	0	0	0	0	0	0	0	0	M>P, RED SED@Z, PATCHY RPD, TUBES, VOIDS
SEREF7	F	6/24/2001	15:36	>4	3	>4	12.78	13.39	0.61	13.08	PHYSICAL	18.635	0.67	2.61	1.29	ST_I_ON_III	NO	7	10	0.22	0	0	0	0	0	0	0	0	0	0	MUD>P, TUBES, VOIDS, OX&RED CLSTS, SHELL FRAGS,LG OXIDIZED BURROW
SREF1	A	6/24/2001	9:05	>4	2	>4	13.54	15.17	1.63	14.35	PHYSICAL	32.248	1.57	2.7	2.26	ST_I_ON_III	NO	9	0	0	0	0	0	0	0	0	0	0	0	0	SANDY M>P, SM TUBES, VOIDS, BURROW OPENING?
SREF1	B	6/24/2001	9:06	>4	2	>4	8.71	9.89	1.18	9.3	PHYSICAL	11.061	0.06	1	0.5	ST_I	NO	2	0	0	0	0	0	0	0	0	0	0	0	0	SANDY M>P, DENSE SM TUBES, WIPER CLAST, SHALLOW&PATCHY RPD
SREF1	C	6/24/2001	9:07	>4	2	>4	14.27	14.94	0.67	14.61	PHYSICAL	17.003	0.22	2.19	1.3	ST_I_ON_III	NO	7	0	0	0	0	0	0	0	0	0	0	0	0	SANDY M>P, SM TUBES, SM VOID, GASTROPOD @SURF, MUD SNAIL
SREF2	A	6/24/2001	8:59	>4	2	4 to 3	11.8	12.58	0.79	12.19	BIOGENIC	27.043	0.67	3.48	2.1	ST_I_ON_III	NO	8	0	0	0	0	0	0	0	0	0	0	0	0	SANDY M>P, TUBES, VOIDS, BURROWS/OPENING, WORM @Z
SREF2	B	6/24/2001	8:59	>4	2	>4	13.76	15.56	1.8	14.66	PHYSICAL	14.978	0.17	2	1	ST_I	NO	7	0	0	0	0	0	0	0	0	0	0	0	0	SANDY M>P, SM TUBES, SHELL BITS, SM WORMS @Z
SREF2	C	6/24/2001	9:00	>4	2	>4	15.17	16.8	1.63	15.98	PHYSICAL	11.333	0.06	2.47	1.56	ST_I_ON_III	NO	8	0	0	0	0	0	0	0	0	0	0	0	0	SANDY M>P, SM TUBES, VOIDS, WIPER CLAST, RELIC DM?
SREF3	A	6/24/2001	8:46	>4	2	>4	9.33	10.22	0.9	9.78	PHYSICAL	17.783	0.06	2.81	2.01	ST_I_ON_III	NO	8	0	0	0	0	0	0	0	0	0	0	0	0	SANDY M>P, SM TUBES, VOIDS, SHELL @SURF
SREF3	B	6/24/2001	8:46	>4	2	>4	9.38	11.07	1.69	10.22	PHYSICAL	37.328	0.73	5.39	2.92	ST_III	NO	9	3	0.24	0	0	0	0	0	0	0	0	0	0	SANDY M>P, VOID, RED CLASTS, WIPER CLSTS, BURROW OPENING
SREF3	C	6/24/2001	8:47	>4	2	>4	5.51	6.18	0.67	5.84	PHYSICAL	10.332	0.06	1.91	0.78	ST_I	NO	3	3	0.24	0	0	0	0	0	0	0	0	0	0	SANDY M>P, SHALLOW RPD, GASTRPODS @SURF, RED SED
SREF4	A	6/24/2001	8:52	>4	2	>4	9.55	10.22	0.67	9.89	PHYSICAL	19.753	0.22	2.81	1.92	ST_I_ON_III	NO	8	0	0	0	0	0	0	0	0	0	0	0	0	SANDY M>P, VOIDS, TUBES, WORMS @Z, PATCHY RPD
SREF4	B	6/24/2001	8:53	>4	2	>4	12.08	17.36	5.28	14.72	PHYSICAL	8.933	0.5	2.5	1.5	ST_I_ON_III	NO	7	0	0	0	0	0	0	0	0	0	0	0	0	SANDY M>P, SM TUBES, LG VOIDS, WORM @Z, SLOPING & IRREG TOPO, PATCHY RPD
SREF4	C	6/24/2001	8:54	>4	2	>4	13.09	13.93	0.84	13.51	PHYSICAL	20.695	0.06	3.31	2.23	ST_I_ON_III	NO	8	0	0	0	0	0	0	0	0	0	0	0	0	SANDY M>P, TUBES, VOIDS, WORM @Z, BURROW
SWREF1	A	6/24/2001	9:43	>4	2	4 to 3	2.58	4.33	1.74	3.46	PHYSICAL	19.848	0.22	1.91	1.42	ST_I_ON_III	NO	7	0	0	0	0	0	0	0	0	0	0	0	0	SANDY M>P, UNDERPEN, VOIDS, TUBES, LG TUBE, WORM @Z?
SWREF1	B	6/24/2001	9:44	>4	2	4 to 3	7.87	12.7	4.83	10.28	PHYSICAL	16.499	0.1	0.5	0.49	ST_I_ON_III	NO	6	3	0.42	0	0	0	0	0	0	0	0	0	0	FINE SAND,BLK/GRY SULF M, TUBES,V.THIN RPD,VOID,RED&WIP CLSTS,V.RED SED,SLOP TOPO
SWREF1	C	6/24/2001	9:45	>4	2	4 to 3	9.21	9.89	0.67	9.55	PHYSICAL	11.691	0.1	0.8	0.53	ST_I_ON_III	NO	6	0	0	0	0	0	0	0	0	0	0	0	0	SANDY M/GRY&BLK M, VOIDS, TUBES, SHALLOW RPD, V.BLK RED SED-SULFIDIC,WORM@Z
SWREF2	A	6/24/2001	9:37	>4	2	>4	11.18	11.69	0.51	11.43	PHYSICAL	23.658	0.34	3.48	1.91	ST_I_ON_III	NO	8	0	0	0	0	0	0	0	0	0	0	0	0	SANDY M>P, TUBES, VOID, WORM @Z
SWREF2	B	6/24/2001	9:38	>4	2	4 to 3	10.39	10.73	0.34	10.56	PHYSICAL	26.645	0.51	2.4	1.03	ST_I_ON_III	NO	7	0	0	0	0	0	0	0	0	0	0	0	0	SANDY M>P, SM TUBES, VOID, OX CLAST?, REDUCED SED
SWREF2	C	6/24/2001	9:38	>4	2	4 to 3	10.34	11.29	0.96	10.81	PHYSICAL	5.209	0.22	1.63	0.46	ST_I	NO	2	0	0	0	0	0	0	0	0	0	0	0	0	SANDY M>P, TUBES, SHALLOW RPD, WIPER CLAST
SWREF3	A	6/24/2001	9:58	>4	2	4 to 3	11.01	11.29	0.28	11.15	PHYSICAL	20.199	0.39	2.36	1.51	ST_I_ON_III	NO	8	0	0	0	0	0	0	0	0	0	0	0	0	MUDDY SAND>P, SM TUBES, VOIDS, SM WORMS @Z
SWREF3	B	6/24/2001	9:58	>4	2	4 to 3	10.06	10.28	0.22	10.17	PHYSICAL	14.513	0.45	1.52	0.97	ST_I_ON_III	NO	7	0	0	0	0	0	0	0	0	0	0	0	0	MUDDY SAND>P, SHALLOW&PATCHY RPD, VOIDS, WIPER CLASTS, BURROW OPENING?
SWREF3	C	6/24/2001	9:59	>4	2	>4	10.73	11.8	1.07	11.26	PHYSICAL	5.887	0.06	1.85	0.94	ST_I	NO	3	3	0.31	0	0	0	0	0	0	0	0	0	0	SANDY M>P, TUBES, OX &RED CLASTS, WIPER CLAST, SHALLOW&PATCHY RPD
SWREF4	A	6/24/2001	9:51	>4	2	4 to 3	10.51	12.08	1.57	11.29	PHYSICAL	29.494	1.01	3.54	2.42	ST_I_ON_III	NO	9	3	0.22	0	0	0	0	0	0	0	0	0	0	MUDDY SAND>P, NUMEROUS VOIDS, OX CLASTS, SHELL BITS, WORM @Z?
SWREF4	B	6/24/2001	9:52	>4	2	4 to 3	11.29	12.36	1.07	11.83	PHYSICAL	11.51	0.62	2.47	1.4	ST_I	NO	3	0	0	0	0	0	0	0	0	0	0	0	0	MUDDY SAND>P, TUBES,IRREGULAR TOPO, PATCHY RPD
SWREF4	C	6/24/2001	9:52	>4	2	4 to 3	10.51	11.35	0.84	10.93	PHYSICAL	15.151	1.29	5	2.51	ST_I_ON_III	NO	9	5	0.21	0	0	0	0	0	0	0	0	0	0	MUDDY SAND>P, TUBES, VOIDS, RED CLASTS, WIPER CLAST, RED SED@BURROW?

INDEX