Monitoring Cruises at the Western Long Island Sound Disposal Site September 1997 and March 1998

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13. ABSTRACT

A monitoring survey was conducted at the Western Long Island Sound Disposal Site (WLIS) from 16 to 18 September 1997 and from 5 to 6 March 1998 aboard the M/V *Beavertail* as part of the Disposal Area Monitoring System (DAMOS) Program. Field efforts in September focused on the active southwestern quadrant of WLIS and consisted of precision bathymetry and Remote Ecological Monitoring of the Seafloor (REMOTS®) to monitor the development, stability, and benthic conditions of the disposal mounds. The September 1997 survey documented changes in bottom topography at the disposal area relative to July 1996. Approximately 35,000 m^3 of dredged material was disposed on the WLIS seafloor during the 1996-1997 disposal season to form the I mound. Using REMOTS® sediment-profile photography, we evaluated the benthic recolonization status and sediment conditions of the new I mound and the 1996 H mound, relative to reference areas, SOUTH and SW-REF.

Additional field work was conducted from 5 to 6 March 1998 to investigate potential sites for a new reference area and compare seasonal effects on benthic conditions in REMOTS® photographs. At the present time, only two reference areas near WLIS have been accepted to represent ambient conditions for the region. The DAMOS protocol requires that three reference areas be used both for comparing the conditions between ambient environments and dredged material disposal mounds, and for evaluation of dredged sediments for disposal permits at WLIS.

Depth difference calculations and mapping of bathymetric data depicted the I mound below the buoy location, 40°59.203´ N, 73°29.072´ W (NAD 27), between the D and G mounds. The mound was 3.7 m high with a diameter of about 150 m. REMOTS® sediment-profile photography indicated benthic recolonization of Stage I organisms in September and more advanced Stage III indicators in March. The redox potential discontinuity (RPD) depths, which indicate depth of sediment oxidation, also increased from September to March.

The H mound was developed in the spring of 1996, when the WDA buoy, deployed at 40°59.228' N, 73°28.732' W, received approximately 15,300 m^3 of sand, silt, and clay. The deposition of this material formed a 1.5 m high mound, approximately 230 m in width. REMOTS® photography detected a solid Stage I pioneering polychaete community with increased evidence of Stage III activity in September relative to the July 1996 survey. RPD depths were shallower in September than July, but did increase again in March. The number of advanced successional status indicators in the photographs increased in the March surveys.

The widespread presence of historic dredged material in the region surrounding WLIS has complicated our ongoing search for a suitable third reference area for this disposal site. Sediments from shipping port along the Connecticut and New York coasts have been dredged and disposed in Long Island Sound since the late 1800s, long before a developed management plan was in operation. In 1954, eight disposal sites were in existence for the western Long Island Sound region. WLIS is located between three of these historic sites which received large volumes of dredged materials until the 1980s. Using side-scan sonar survey real-time data as a guide, we identified a new potential reference area (SE-REF) for WLIS (40°59.203´ N, 73°29.072´ W). Further investigation showed that SE-REF met many of the specified requirements for selection of a reference area. While we recommend SE-REF as a third reference area, we recognize that survey data could not conclusively rule out the presence of historic dredged material. Future monitoring surveys should continue to investigate and confirm the absence of historic dredged material at SE-REF.

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EXECUTIVE SUMMARY

Science Applications International Corporation (SAIC) conducted a monitoring survey at the Western Long Island Sound Disposal Site (WLIS) from 16 to 18 September 1997 and from 5 to 6 March 1998 aboard the M/V *Beavertail* as part of the Disposal Area Monitoring System (DAMOS) Program. Field efforts in September focused on the active southwestern quadrant of WLIS and consisted of precision bathymetry and Remote Ecological Monitoring of the Seafloor (REMOTS®) to monitor the development, stability, and benthic conditions of the disposal mounds. The September 1997 survey documented changes in bottom topography at the disposal area relative to July 1996. Approximately 35,000 m^3 of dredged material was disposed on the WLIS seafloor during the 1996-1997 disposal season to form the I mound. Using REMOTS® sediment-profile photography, we evaluated the benthic recolonization status and sediment conditions of the new I mound and the 1996 H mound, relative to reference areas, SOUTH and SW-REF.

Additional field work was conducted from 5 to 6 March 1998 to investigate potential sites for a new reference area and compare seasonal effects on benthic conditions in REMOTS® photographs. At the present time, only two reference areas near WLIS have been accepted to represent ambient conditions for the region. The DAMOS protocol requires that three reference areas be used both for comparing the conditions between ambient environments and dredged material disposal mounds, and for evaluation of dredged sediments for disposal permits at WLIS. For the first time in DAMOS's history, a high-resolution side-scan sonar survey was used as a guide to locate and investigate a potential reference area. The survey, conducted to the southeast of WLIS, proved valuable in defining a large area that was relatively clear of historic dredged material deposits, which are widespread in the regions surrounding WLIS. A 300 m radius region was identified and referred to as SE-REF. To complete the March surveys, we revisited the REMOTS® stations over the WLIS H and I disposal mounds.

Buoys have been deployed to control disposal operations within the boundaries of WLIS since its initiation as a regional dredged material disposal site in 1982 (WLIS III). Since receiving the first volumes of sediment dredged from coastal Connecticut and New York in 1982, WLIS has been monitored on a semi-annual basis for the U.S. Army Corps of Engineers, New England District (NEA). Currently, a total of nine discrete disposal mounds exist on the WLIS seafloor within an east-west trending seafloor depression that extends through the center of the disposal site. The latest monitoring activity was concentrated over the most recent dredged material deposits, the WLIS H and WLIS I mounds, as well as the reference areas.

Depth difference calculations and mapping of bathymetric data depicted the I mound below the buoy location, 40°59.203´ N, 73°29.072´ W (NAD 27), between the D and G mounds. The mound was 3.7 m high with a diameter of about 150 m. REMOTS® sediment-profile photography indicated benthic recolonization of Stage I organisms in

September and more advanced Stage III indicators in March. The redox potential discontinuity (RPD) depths, which indicate depth of sediment oxidation, also increased from September to March.

The H mound was developed in the spring of 1996, when the WDA buoy, deployed at 40°59.228' N, 73°28.732' W, received approximately 15,300 m^3 of sand, silt, and clay dredged from harbors and creeks along the Connecticut coast and the north shore of Long Island, New York. The deposition of this material formed a 1.5 m high mound, approximately 230 m in width. REMOTS® photography detected a solid Stage I pioneering polychaete community with increased evidence of Stage III activity in September relative to the July 1996 survey. RPD depths were shallower in September than July, but did increase again in March. The number of advanced successional status indicators in the photographs increased in the March surveys.

The widespread presence of historic dredged material in the region surrounding WLIS has complicated our ongoing search for a suitable third reference area for this disposal site. Sediments from shipping ports along the Connecticut and New York coasts have been dredged and disposed in Long Island Sound since the late 1800s, long before a developed management plan was in operation. In 1954, eight disposal sites were in existence for the western Long Island Sound region. WLIS is located between three of these historic sites which received large volumes of dredged materials until the 1980s. Using side-scan sonar survey real-time data as a guide, we identified a new potential reference area (SE-REF) for WLIS (40°59.203´ N, 73°29.072´ W). Further investigation showed that SE-REF met many of the specified requirements for selection of a reference area. While we recommend SE-REF as a third reference area, we recognize that survey data could not conclusively rule out the presence of historic dredged material. Future monitoring surveys should continue to investigate and confirm the absence of historic dredged material at SE-REF.

1.0 INTRODUCTION

The Western Long Island Sound Disposal Site (WLIS) is about 2.7 nmi north of Lloyd Point, New York, and 2.5 nmi south of Long Neck Point, Connecticut, located along the east-to-west axial depression that extends through Long Island Sound (Figure 1-1). Three historic disposal grounds, Stamford, South Norwalk, and Eaton's Neck, surround the active site. To regulate and carefully manage disposal operations in western Long Island Sound, the New England District of the U.S. Army Corps of Engineers (NAE) chose WLIS as the western Sound's only active site in 1982, under the auspices of the Disposal Area Monitoring System (DAMOS) Program (USACE 1982). The established 5.29 km^2 disposal site has accepted small to moderate volumes of dredged material originating from Stamford, Norwalk, and other coastal communities of Connecticut and New York.

The long-term management strategy for disposal of dredged material at WLIS is to form potential containment basins for future use as confined aquatic disposal cells. Some sediments from industrialized harbors have elevated contaminant levels that are best isolated from the marine environment. The containment basins are designed to minimize the lateral spread of fine-grained dredged material during and after disposal and to maximize the overall capacities for containing polluted dredged sediments. Due to the success of capping and containing large volumes of dredged material (over one million cubic meters) at the Central Long Island Sound Disposal Site, potential containment basins continue to be developed at other DAMOS disposal sites in preparation for managing contaminated sediments in the future (Morris et al. 1996). At WLIS, the disposal mounds have been placed in rings to build containment berms in relation to the naturally steep upward slope of the seafloor to the south of the disposal site.

WLIS is set in a fine-grained depositional environment, characterized by relatively weak tidal currents (Knebel et al. 1998). Because many tributaries flow into western Long Island Sound, fine-grained particles are continually added to the estuarine waters and gradually settle out onto the seafloor. To determine the impact of disposed dredged material at the site, reference areas near WLIS are monitored to examine the ambient sediments and monitor benthic conditions for comparison. Before the DAMOS Program was established, disposal operations were not subject to a developed management plan, resulting in an extensive distribution of historic dredged material throughout western Long Island Sound. Since 1991, historic dredged material has been detected at several former WLIS reference areas that therefore were discontinued (3000E, EAST, WLIS-REF, 2000S, and 2000W; Eller and Williams 1996, Charles and Tufts 1996, Morris 1998; Figure 1-2).

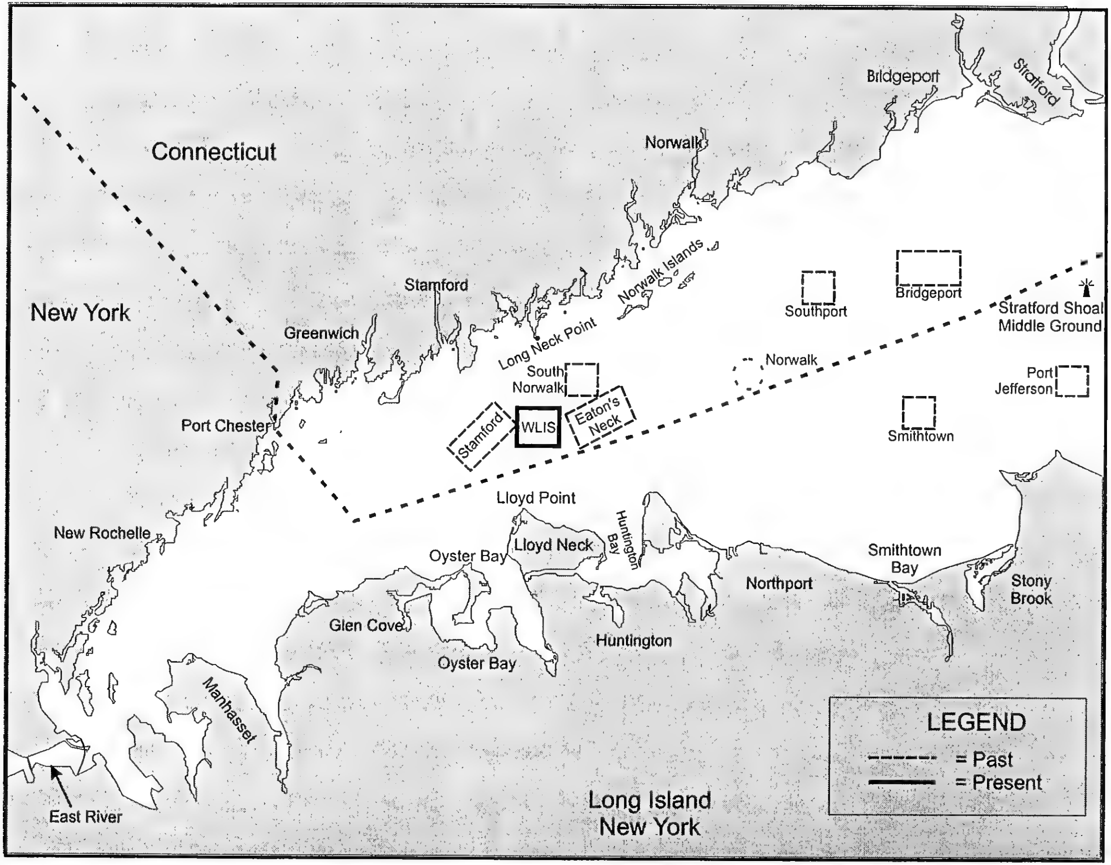


Figure 1-1. Locations of past and present disposal sites within the western Long Island Sound region

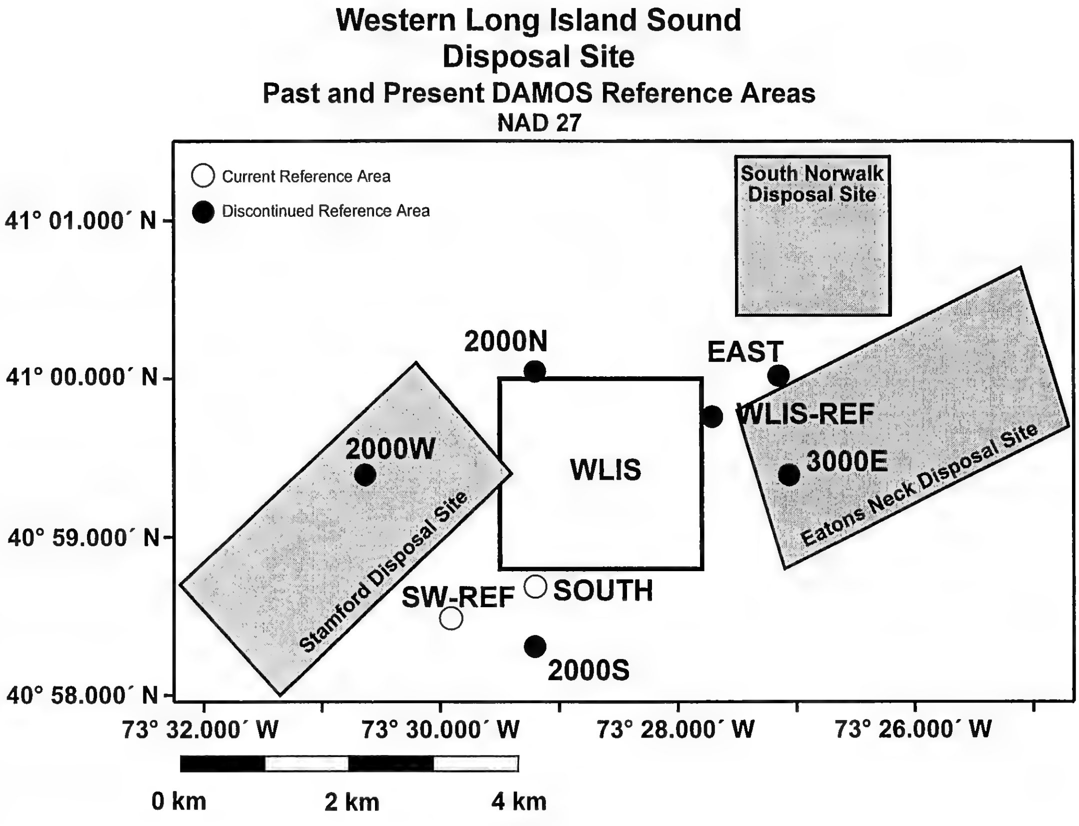


Figure 1-2. Location of current and discontinued WLIS reference areas relative to WLIS and discontinued historic disposal site boundaries

The first objective of the September 1997 survey was to document and delineate the changes in bottom topography of the disposal area relative to July 1996. To continue the development of a containment berm, dredged material was disposed between the existing D and G mounds, forming the I disposal mound. In addition, the I mound was placed so as to cover an isolated area exhibiting apparent low oxygenated conditions and poor recolonization in two of three replicates at one station south of the D mound and east of the G mound during the 1996 REMOTS® survey (Morris 1998). The buoy marking the I mound location was positioned at 40°59.203´ N, 73°29.072´ W and received approximately 35,000 m^3 of new sediment during the 1996-97 disposal season.

The second objective of the monitoring survey was to assess the benthic recolonization status of both the new I mound and the 1996 H mound, relative to two reference areas, SOUTH and SW-REF, surrounding WLIS. This was accomplished through two successive REMOTS® sediment profile surveys. The first was a comprehensive REMOTS® survey conducted in September 1997 over the H and I mounds. In March 1998, five stations near the center of the each mound were profiled and photographed with the REMOTS® camera to assess the health of the benthic community and to compare the results with previous surveys. Both sets of survey data were evaluated on predictions based on previous experience with dredged material monitoring and protocols outlined in the DAMOS Tiered Monitoring Plan (Germano, Rhoads, and Lunz 1994). For the September survey, we predicted that the benthic recolonization at the I mound would be in the early stages of recovery due to recent disposal, with a Stage I assemblage predominant on the mound surface. Evidence of advanced Stage III activity should be apparent only in the surficial sediment layers of the WLIS H mound. Amphipods, Stage II organisms, are not typically found in the western Long Island Sound region probably due to the fine grain size of the sediment and depth of the disposal site (>25 m). With the change in seasonal conditions between the September and March surveys, we expected to see greater RPDs depths and reduced biological activity in early March.

The H mound was formed during the 1995-96 disposal season at 40°59.228' N, 73°28.732' W, to the east of the E and F mounds. Based on recorded barge volumes, a total of 15,300 m^3 of dredged material from Connecticut and New York waterways was disposed at the site, forming a 1.5 m high disposal mound, approximately 230 m in diameter. The 1996 REMOTS® sediment-profile photography survey detected a solid Stage I pioneering polychaete community with some evidence of Stage III activity, as well as deep RPD depths over the majority of the H mound.

The benthic conditions of disposal mounds are compared to reference areas. Three reference areas typically are monitored at each DAMOS disposal site. However, only two reference areas, SOUTH and SW-REF, are currently used at WLIS because historic dredged material has been detected at previously utilized areas. Therefore, the third objective of the September survey was to identify a new potential reference area near WLIS. Selection of the reference area is based on water depth, proximity to the disposal site, grain size, and sediment chemistry (EPA, USACE 1991). Because previous investigations of regions surrounding WLIS have provided clear evidence of historic dredged material, potential reference areas within close proximity to WLIS are limited. To locate an area free of historic dredged material mounds, we utilized a high-resolution side-scan sonar survey that provided real-time data. We were not able to complete the survey in September because excessive lobster gear in the region interfered with the equipment and potentially could have damaged the survey instrument. The side-scan survey was postponed to late winter/early spring, when fishing gear was expected to be less intense in the area.

Although lobster pots and trawl lines continued to pose obstacles in March, the side-scan sonar survey was conducted near the disposal site. The survey was planned to be conducted over a 2000 x 4000 m area east-southeast of the WLIS disposal site. The presence of abundant lobster gear and dredged material on the seafloor prompted on-site revisions to the survey plans.

A potential reference area, SE-REF, was identified at 40°58.301´N, 73°27.722´W (NAD 27) and was recommended for further analysis as a reference area. We conducted a REMOTS® sediment-profile photography survey and collected ten grab samples from SE-REF, within a 300 m radius of the central reference point. The sediment-profile photographs showed ambient sediments with a thin oxidized layer over dark, sulfidic mud composed primarily of silts. No anomalous chemical values were detected in geochemical analyses of the grab samples. The survey data in this report suggested that SE-REF is a strong candidate for the third reference area at WLIS required by DAMOS protocols.

2.0 METHODS

2.1 Time Line

The time line of 1996/1997 disposal activities and 1997/1998 monitoring surveys at WLIS is displayed on Figure 2-1. The reference area investigation was delayed in September because abundant lobster gear in the area obstructed survey lanes and posed a hazard to survey instruments. The investigation was completed in March 1998. The 1996/1997 disposal activities resulted in the formation of the I mound (Figure 2-2). The 1997/1998 disposal activities formed the J mound which will be discussed in the next WLIS report. Figure 2-3 shows the time line for the 1995/1996 disposal season that created the H mound.

2.2 Survey Area

In order to fulfill the objectives of the 1997 WLIS monitoring survey, SAIC conducted a comprehensive field effort consisting of precision bathymetry and REMOTS® sediment-profile photography surveys. The bathymetric survey at WLIS was performed over an 800 x 800 m area centered at the 1996 disposal buoy position, 40°59.203' N, 73°29.072' W (Figure 2-4). The survey covered a total of 25 survey lanes, oriented east/west, with 25-m lane spacing. By comparing current results with those of previous surveys, the size and shape of the new mound was quantified and graphically represented.

2.3 Navigation

Bathymetric data were collected with SAIC's Integrated Navigation and Data Acquisition System (INDAS) to insure accurate comparisons with prior datasets. The system utilizes a Hewett-Packard 9920® series computer to provide real-time navigation and collect position, depth, and time data for later analysis. The Del Norte Trisponder® System provided positioning data to an accuracy of ±3 m in the horizontal control of North American Datum of 1927 (NAD 27) by referencing to shore stations established along the Connecticut coast at the known benchmarks of Norwalk Harbor Power Plant (41°04.248' N, 73°24.501' W) and Greenwich Point (41°00.580' N, 73°34.193' W). A detailed description of the navigation system and its operation can be found in SAIC Report No. 290 (Murray and Selvitelli 1996). Bathymetric surveys at WLIS currently are conducted using NAD27 and the Del Norte navigation system for comparability with previous datasets and master grid. Before a transition can be made to the more recent North Atlantic Datum of 1983 (NAD83) using differential Global Position System (DGPS), a new master grid of the disposal site must be generated with this advanced technology.

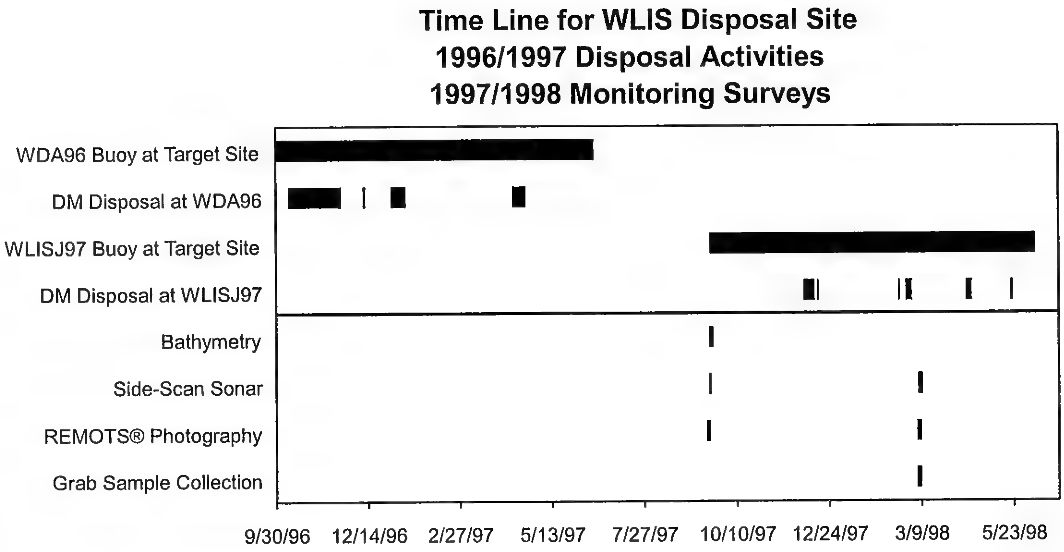


Figure 2-1. Time line for WLIS disposal activities (1996–1997 and 1997–1998) and monitoring surveys, 16–18 September 1997 and 5–6 March 1998

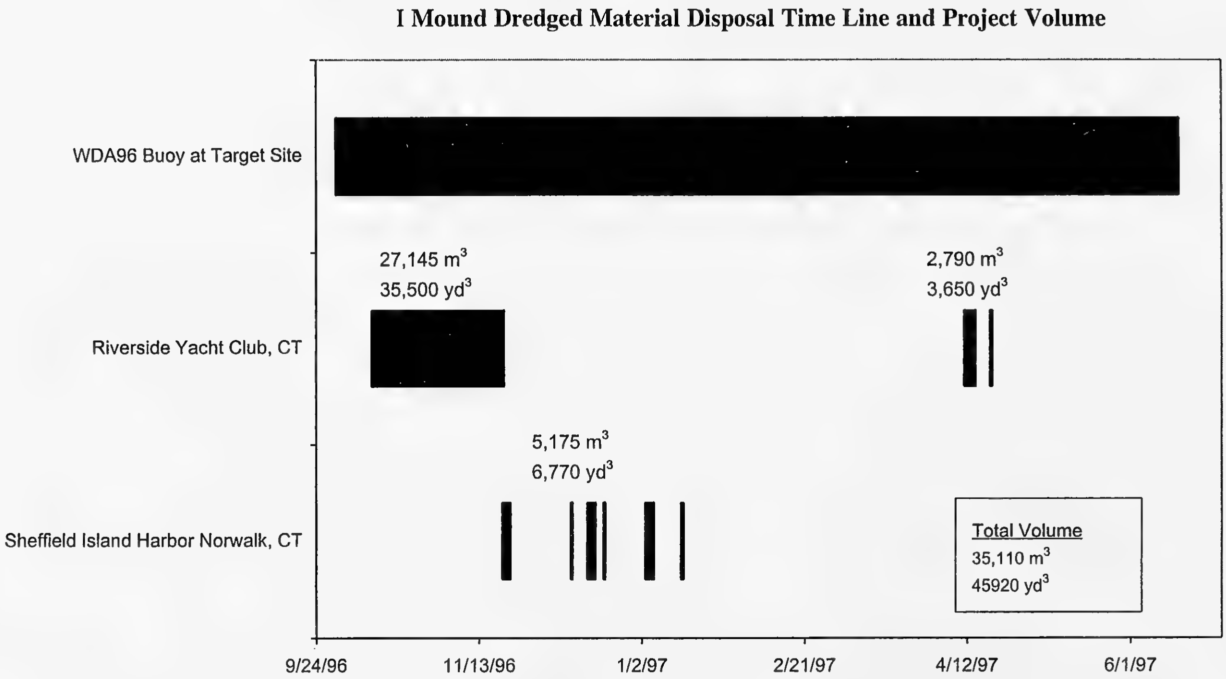


Figure 2-2. Time line for WLIS disposal activities (1996–1997) resulting in the I dredged material mound

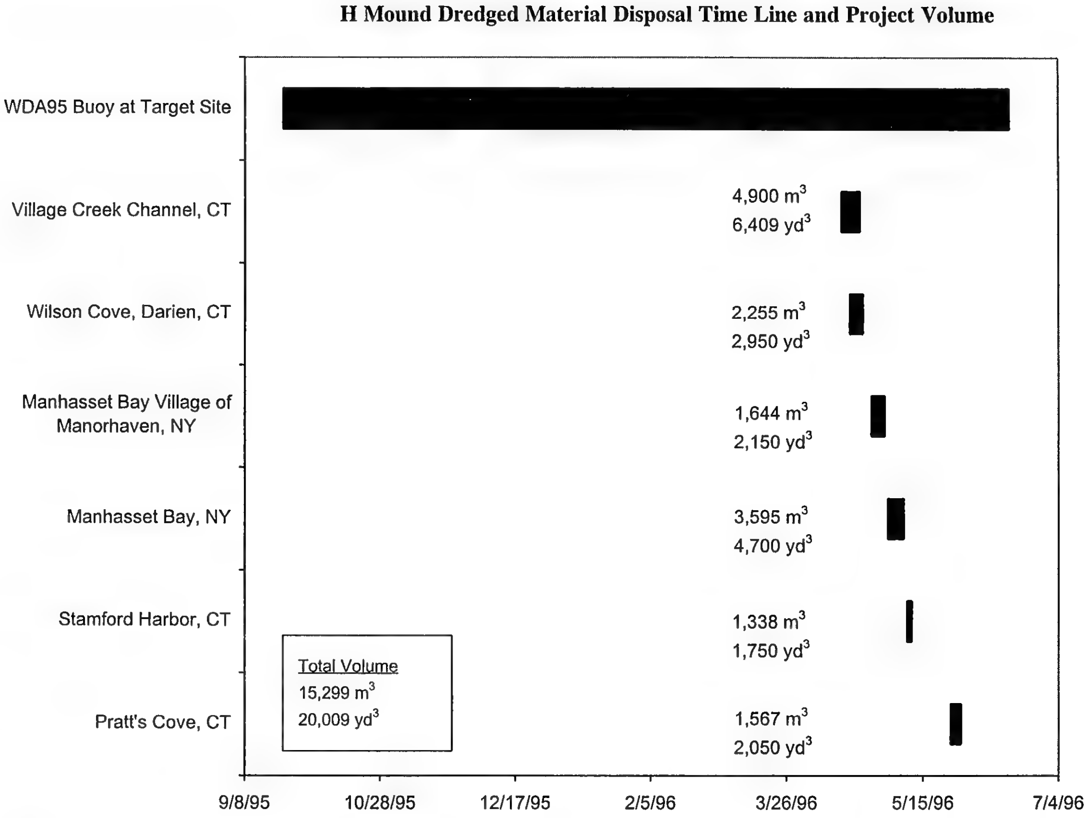
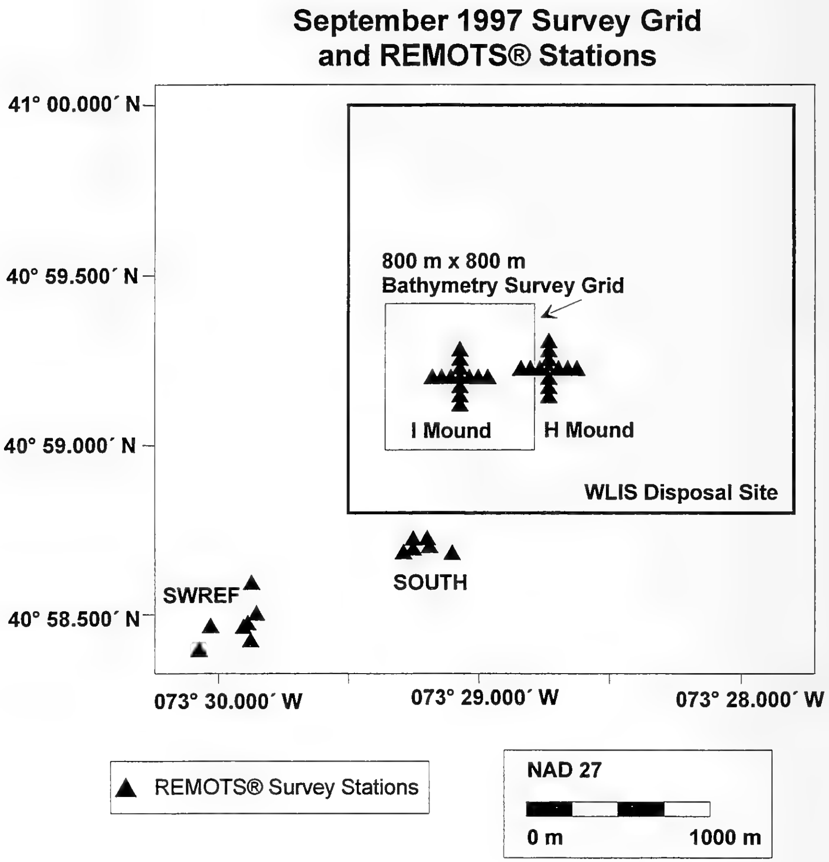


Figure 2-3. Time line for WLIS disposal activities (1995–1996) resulting in the H dredged material mound



September 1997 Survey Grid and REMOTS® Stations

Figure 2-4. Chart of the September 1997 bathymetric survey area and REMOTS® stations relative to the WLIS boundaries

Then future bathymetric surveys may be conducted in NAD83 using DGPS and will be depth differenced to the master grid.

For efficient survey operations at WLIS, SAIC used DGPS data in conjunction with SAIC's Portable Integrated Navigation and Survey System (PINSS) to position the survey vessel over the July 1996 REMOTS® camera stations. A Magnavox 4200D GPS receiver and a Magnavox MX50R differential beacon receiver provided DGPS positioning data to PINSS in the horizontal control of North American Datum of 1983 (NAD 83) to an accuracy of ±5 m. The Coast Guard differential beacon broadcasting from Sandy Hook, New Jersey (286 kHz) was selected for satellite corrections due to its close proximity to WLIS.

The target REMOTS® station locations were calculated in NAD 27, then converted to NAD 83 for real-time navigation using the U.S. Army Topographic Engineering Center's CORPSCON version 3.01. The actual positions of the REMOTS® replicate photographs were recorded in NAD 83 and then converted to NAD 27 with CORPSCON for compatibility with bathymetric data for reporting purposes. All REMOTS® data in the DAMOS Database are stored in the native NAD 83 datum.

2.4 Bathymetric Data Collection and Processing

An ODOM DF3200 Echotrac® Survey Fathometer with a narrow beam, 208 kHz transducer measured individual depths to a resolution of 3.0 cm (0.1 ft) as described in the DAMOS Navigation and Bathymetry Standard Operating Procedures (Murray and Selvitelli 1996). Depth values transmitted to INDAS were adjusted for transducer depth. The acoustic returns of the Fathometer can reliably detect changes in depth of 20 cm or greater due to the accumulation of errors introduced by the positioning system, changes in sound velocity through the water column, the slope of the bottom, vertical motion of the survey vessel, and tidal corrections.

Observed tidal data were obtained through the National Oceanographic and Atmospheric Administration (NOAA), Ocean and Lake Levels Division's (OLLD) National Water Level Observation Network (NOAA 1997, 1998). This network is composed of 181 water level stations that are located throughout the Great Lakes and coastal regions of the United States. These stations are equipped with the Next Generation Water Level Measurement System tide gauges and satellite transmitters that have collected and transmitted tide data to the central NOAA facility every six minutes since 1 January 1994.

Observed tidal data are available 1 to 6 hours from the time of collection in a station datum or referenced to Mean Lower Low Water (MLLW) and based on Coordinated

Universal Time (UTC). For the 1996 WLIS survey, data from NOAA tide station 8467150 in Bridgeport Harbor, Bridgeport, CT was used for tidal calculations. The NOAA 6-minute tide data were downloaded in the MLLW datum, corrected to local time, and tidal differences based on Greens Ledge, Sheffield Island, Connecticut, were applied.

In order to make valid comparisons between present and past bathymetric surveys of the area, the July 1992 and June 1990 bathymetry models were recorrected to observed MLLW. The OLLD database also provides historic NOAA observed tidal data (31 December 1993 and earlier) as hourly water heights. Through interpolation, a smooth tidal curve was developed to allow for accurate tidal corrections of historic bathymetric data sets.

A Seabird Instruments, Inc. SEACAT SBE 19-01 Conductivity, Temperature, and Depth (CTD) probe was used to obtain sound velocity measurements at the start, midpoint, and end of each survey day. The data collected by the CTD probe were bin-averaged to 1 meter depth intervals to account for the pycnocline (a rapid change in density that creates distinct layers within the water column). A mean sound velocity was then calculated using the bin-averaged values.

The bathymetric data were analyzed using SAIC's Hydrographic Data Analysis System (HDAS), version 1.03. Raw bathymetric data were imported into HDAS, corrected for sound velocity, and standardized to Mean Lower Low Water using the NOAA observed tides. The bathymetric data were then used to construct depth models of the surveyed area. A detailed discussion of the bathymetric analysis technique is provided in the DAMOS Navigation and Bathymetry Standard Operating Procedures (Murray and Selvitelli 1996).

2.5 REMOTS® Sediment-Profile Photography

REMOTS® photography was used to detect the distribution of dredged material layers, map benthic disturbance gradients, and monitor the benthic infaunal recolonization and successional status of the H mound and the I mound, as well as the WLIS reference areas. Cross-sectional photographs of the top 20 cm of sediment were taken for analysis and intercomparison with the ambient sediments of the adjacent WLIS reference areas (SOUTH and SW-REF). The Rhoads and Germano (1982, 1986) protocol for REMOTS® analysis was followed for measurements and interpretation.

Three replicate photographs were taken at 13 stations over the WLIS H and WLIS I mounds (Figure 2-4, Appendix A Table 1). The REMOTS® sampling grids formed a cross-shaped pattern with three stations along each of four arms and one station in the center. The REMOTS® survey over the H mound grid, centered at 40°59.228' N, 73°28.732' W (NAD 27), was sampled every 50 m in accordance with the 1996 survey. The I mound was centered at 40°59.203' N, 73°29.072' W (NAD 27), with station spacing at 50 m. In March 1998, the central five stations were reoccupied for comparison with the September results. In addition, a 25-station radial grid, with three replicate photographs at each station, was conducted over the new reference area, SE-REF, identified in the side-scan sonar survey (Figure 2-5, Appendix A Table 2).

Data from the existing reference areas SOUTH and SW-REF were used for comparison of ambient western Long Island Sound sediments relative to the sediments deposited at WLIS through disposal operations. Reference area SOUTH (40°58.688' N, 73°29.201' W) was sampled at six randomly selected stations and SW-REF (40°58.688' N, 73°29.909' W) was sampled at seven stations.

2.6 Side-Scan Sonar

In an effort to locate potential reference areas to replace 2000W REF, a side-scan sonar survey was attempted over a 2000 x 4000 m area to the east-southeast of WLIS (in September 1997). However, clusters of lobster fishing gear located within the region impeded progress of the survey. As a result, the side-scan sonar survey operations were postponed until late November and then until March.

In March, the planned side-scan sonar survey over a 2000 x 4000 m area east-southeast of the WLIS disposal site was revised due to the presence of abundant lobster gear and dredged material identified on the seafloor. The orientation of the initial survey area was altered to a 1500 x 4000 m area oriented east-west with the northwest corner of the survey located within WLIS (Figure 2-5). A second smaller survey was designed to examine an area south of Eaton's Neck and west of a rocky reef in an area where lobster gear was minimal. This smaller survey consisted of 10 survey lanes measuring 1000 m in length and spaced 100 m apart. Side-scan images of the seafloor within the small 1000 x 1000 m survey identified areas with no apparent dredged material. However, these areas were in relatively shallow water, less than 18 m, that may not be representative of the ecological conditions at WLIS which has depths varying between 30–35 meters. Side-scan operations were continued in the modified 1500 x 4000 m survey area in water depths greater than 18 meters. A potential reference area, SE-REF, was identified at 40°58.301´N, 73°27.722´W, NAD 27, with a mean water depth of 19.5 m.

Side-scan sonar data were collected with an EdgeTech DF1000 towfish. Acoustic signals at a frequency of 100 kHz were emitted from two transducers mounted in the DF1000

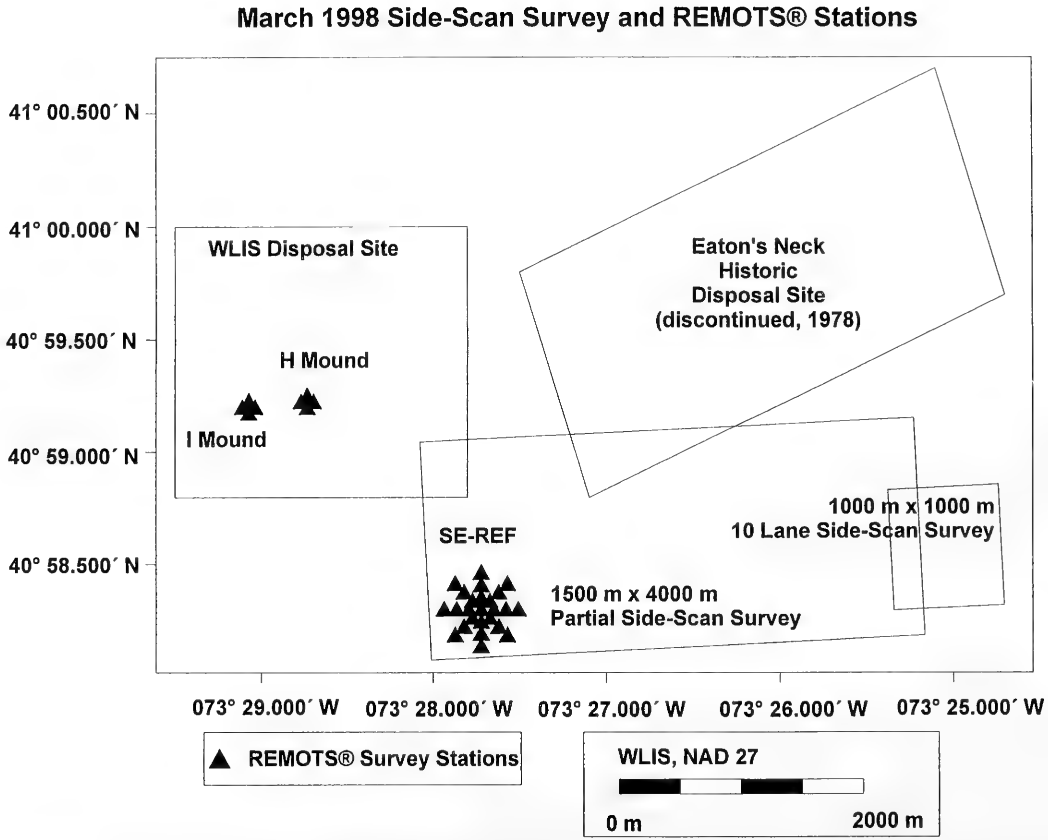


Figure 2-5. Chart of the March 1998 side-scan sonar survey area and REMOTS® stations relative to the WLIS boundaries

dual-frequency (100 kHz and 500 kHz) towfish. The acoustic returns were relayed to an EdgeTech 380 data recorder and 260 thermal printer to produce images of the bottom features. The side-scan sonar survey lanes were spaced at 100 m intervals for 150 percent bottom coverage. Bathymetric readings also were collected during the side-scan sonar survey. Navigation data were obtained in NAD83 using DGPS. Similar to REMOTS® data, the positions were converted to NAD27 for reporting purposes.

2.7 Sediment Grab Sampling

A series of ten sediment grab samples were collected from the identified potential reference area, SE-REF. Prior to the collection of each sample, the grab sampler, sub cores, bowl, and utensils were washed thoroughly with alconox and seawater, and then rinsed with acetone. A 0.1 m^2 Young-modified Van Veen grab sampling device was deployed at random locations within a 300 meter radius of the center. The grab samples were brought on deck and described. Two titanium cores were used to extract four subsamples of the grab sample, which were then homogenized in a stainless-steel bowl. Next, the sediments were placed into labeled, 8 oz and 4 oz pre-cleaned containers from the laboratory. The 8 oz containers were designated to be used for geochemistry analyses, and the 4 oz were to be used for grain size analysis. The containers were sealed with electric tape and placed in a cooler with ice for storage and transport to the lab.

2.8 Laboratory Analyses and Quality Assurance/Quality Control Results

This section describes the methods used for physical and chemical sample preparation, extraction, and analyses of the grab samples. Samples were analyzed for all chemical parameters by the Woods Hole Group Environmental Laboratories (WHG), Raynham, MA. The methods used for analysis of each type of analyte are listed in Table 2-1 and are described in detail in Test Methods for Evaluating Solid Waste EPA SW-846 (EPA 1997). Grain size was analyzed using American Society for Testing and Materials (ASTM) Method D422-63 by Normandeau Associates, Bedford, NH.

2.8.1 Sediment Grain Size and Total Organic Carbon

Grain size analyses were conducted using American Society for Testing and Materials (ASTM) Method D422-63. A sieve analysis was performed in which the sample was separated into size fractions of greater than 62.5 mm (<4 phi; sand and gravel), and less than or equal to 62.5 mm (>4 phi; silt and clay). The gravel and sand fraction was subdivided further by mechanically dry sieving it through a graded series of screens. The wet sieve and dry sieve fractions less than 62.5 mm (silt and clay) were combined for each sample. The silt and clay fraction was then subdivided using a pipet technique based upon

Table 2-1.

Methods of Physical and Chemical Analyses for WLIS Samples

WLIS Samples	Analysis	Method	Instrumentation
All samples	Grain Size	ASTM D422	Sieve/Hydrometer
		SW-846 Method (USEPA 1997)	
All samples	Total Organic Carbon	9060	
All samples	PAHs	8270	GC/MS-SIM
All samples	Trace Metals:		
	Aluminum	6010	ICAP-AES
	Arsenic	7060	GFAA
	Cadmium	7131	GFAA
	Chromium	6010	ICAP-AES
	Copper	6010	ICAP-AES
	Lead	6010	ICAP-AES
	Mercury	7471	CVAA
	Nickel	6010	ICAP-AES
	Zinc	6010	ICAP-AES
All samples	Pesticides/PCBs	8080A	GC-ECD

PAHs = Polynuclear Aromatic Hydrocarbons
GC/MS-SIM = Gas Chromatograph/Mass Spectrometer-Selected Ion Monitoring
GC-ECD = Gas Chromatograph-Electron Capture Device
ICAP-AES = Inductively Coupled Argon Plasma - Atomic Emission Spectrometry
GFAA = Graphite Furnace Atomic Absorption
CVAA = Cold Vapor Atomic Absorption
PCBs = Polychlorinated Biphenyls

differential settling rates of particles. Data on grain size were converted from units of phi (Wentworth 1922) to units of gravel, sand, silt, and clay.

Total organic carbon (TOC) analyses were performed using EPA SW-846 Method 9060 (EPA 1997) by the WHG laboratory. Dried sediment aliquots were pulverized and homogenized prior to analysis. For each day of analysis, two reference samples were analyzed as laboratory control samples (LCS) prior to and after the WLIS samples. In general, organic carbon is measured using a carbonaceous analyzer which converts the organic carbon in a sample to carbon dioxide (CO_2) by either catalytic combustion or wet chemical oxidation. The CO_2 formed is then either measured directly by an infrared detector or converted to methane (CH_4) and measured by a flame ionization detector. The amount of CO_2 or CH_4 in a sample is directly proportional to the concentration of carbonaceous material in the sample. Results expressed in this report are on a dry weight basis.

2.8.2 Polynuclear Aromatic Hydrocarbons (PAHs)

The laboratory extracted ten samples by EPA SW-846 Method 3550A (EPA 1997). Prior to extraction, the samples were spiked with surrogate compounds, and extracted sequentially using methylene chloride: acetone and then methylene chloride. Separate aliquots were weighed, dried in an oven, then reweighed for calculation of the moisture content. The extracted samples were concentrated, treated with activated copper to reduce/remove elemental sulfur, spiked with internal standards, and then analyzed using a modified version of EPA SW-846 Method 8270 (EPA 1997). Method 8270-PAH-SIM (Revision 0; GC/MS-SIM) is a WHG standard operating procedure and a more rigorous method than the standard method 8270. The sample extract containing the semi-volatile compounds was injected into a gas chromatograph (GC) with a narrow-bore fused-silica capillary column. The temperature-programmed GC column separated the analytes, which were detected with a mass spectrometer with selected ion monitoring. In this method of analysis, qualitative identifications are confirmed by analyzing standards under the same conditions used for samples and comparing mass spectra and GC retention times. The mass spectra of the target analytes were compared with the electron-impact spectra of authentic standards for identification. Quantification is based on a multi-level initial calibration. Samples were reported on a dry weight basis in units of μg/kg and were not adjusted for surrogate recovery. Surrogate recovery analyses provide information on a laboratory's detection accuracy on a sample by sample basis. Because the recovery percentages were acceptable, the data were not biased. Therefore, adjustment for surrogate recoveries was not necessary.

2.8.3 Pesticides and Polychlorinated Biphenyls (PCBs)

The WLIS samples were analyzed for organochlorine pesticides and PCB aroclors using a modified version of SW-846 Method 8080A (Gas Chromatography and Electron Capture Detection [GC-ECD] 8080A, Rev. 2, Woods Hole Group). Prior to extraction, the samples were spiked with surrogate compounds, and extracted by sonication using methylene chloride: acetone. The extracted samples were concentrated, exchanged into hexane, and treated with activated copper to reduce/remove elemental sulfur. For these sediments, no additional cleanup was deemed necessary. Extracts were analyzed for target pesticides and PCBs by GC-ECD. Qualitative identifications are confirmed by analyzing standards. PCB Aroclor standards (Aroclors 1016, 1221, 1232, 1242, 1248, 1254, 1260) and toxaphene were analyzed. Samples were reported on a dry weight basis in units of μg/kg and were not adjusted for surrogate recovery.

2.8.4 Metals

The WHG laboratory digested 10 samples for metals analysis by EPA SW-846 Method 3051 (EPA 1997), which provides a rapid multi-element acid leach of sediments. A representative sample of approximately 1 to 2 g wet weight of sediment was digested in a microwave using concentrated nitric acid. Digestates were analyzed by instrumental techniques appropriate for meeting reporting limit requirements. The samples were analyzed using inductively coupled argon plasma-atomic emission spectroscopy (ICAP-AES), using EPA SW-846 Method 6010 (EPA 1997), for aluminum (Al), chromium (Cr), lead (Pb), copper (Cu), nickel (Ni), and zinc (Zn). Arsenic (As; Method 7060) and Cadmium (Cd; Method 7131) were analyzed by graphite furnace atomic absorption spectroscopy (GFAA). Mercury was analyzed by cold vapor atomic absorption spectroscopy (CVAA), Method 7471 (EPA 1997). Results were reported on a dry weight basis in units of mg/kg.

2.8.5 Quality Assurance/Quality Control

Data quality was assessed in relation to specified criteria for precision, accuracy, representativeness, comparability, and completeness (PARCC). Analytical precision was expressed as the percentage of the difference between results of replicate samples (Relative Percent Difference [RPD]). Analytical accuracy of the laboratory was evaluated quantitatively as the percent recovery of a spiked standard compound or surrogate compound added at a known concentration to the sample before the analysis. When spiked duplicates were run, the results were expressed as an RPD to evaluate precision of the analysis of the spiked compounds. By inference, the precision of analysis of other related compounds should be similar. Laboratory accuracy also was evaluated qualitatively by evaluating the laboratory QC information on sample holding times, method blank results, recovery of internal standards, and laboratory quality control samples. The following section defines the various QA/QC requirements and summarizes the data quality objectives for this project.

2.8.5.1 Sample Tracking and Holding Times

SAIC Standard Operating Procedures for sample tracking and custody were followed. All sediment containers and bags were stored at 0-4° C prior to analysis. Chain-of-custody records were maintained for all samples. One container was received with a crack on the bottom of the jar; this sample was selectively sampled only for grain size from the top of the container. All other samples were logged as received in good condition.

The recommended maximum holding times between sampling and extraction are listed for the following: PAH, pesticide and PCB samples, 14 days; metals, 6 months; and mercury (Hg), 28 days. PAH samples must be analyzed within 40 days of extraction (EPA 1997). All holding times for chemical analyses were met. The sediment samples were collected on March 6, 1998. The samples were stored under refrigeration until they could be delivered to the laboratory on March 9, 1998. PAH samples were extracted on March 11, 1998, and analyzed March 21, 1998, meeting the required holding times. Pesticide and PCB extraction/analysis was conducted on most samples on March 19 and 27, 1998, respectively, meeting holding times. Trace metal samples, including Hg, were digested on March 12, 1998, and analyzed from March 13 to 17.

2.8.5.2 Method Blanks

Method blanks are laboratory QC samples that are processed with the samples but contain only reagents. Method blanks test for contamination that the laboratory may have contributed during sample preparation. No target compounds or metals were measured in any of the method blanks.

2.8.5.3 Assessment of Analytical Accuracy

Analytical accuracy is determined by the percent recovery of a known concentration of a compound that is spiked to the environmental sample before analysis. The closer the numerical value of the measurement approaches the actual concentration of the compound, the more accurate the measurement. The percent recovery values are calculated using the following equation:

$$\frac{A_r - A_o}{A_c} \times 100$$

where:
A_r = Total compound concentration detected in the spiked sample
A_o = Concentration of the compound detected in the unspiked sample
A_f = Concentration of the spike added to the sample

Matrix spike samples (MS) and matrix spike duplicates (MSD) are prepared by dividing a sample into multiple aliquots and spiking an aliquot with a known concentration of analyte and finally proceeding with the analysis as though the spike were a sample. Supporting accuracy data were provided by samples spiked with surrogate compounds, as well as spiked blanks and laboratory control samples. Surrogate spikes are analyzed as a check on the laboratory's ability to extract known concentrations of compounds not normally found in the sample, but having similar characteristics. Surrogate compounds, which are the only means of checking method performance on a sample by sample basis, were conducted on all PAH, pesticide, and PCB analyses.

PAH Accuracy. Sample GR-1 was selected for MS/MSD analysis. For the matrix spike analyses, 12 of 16 compounds resulted in percent recovery values that were significantly below the QC limits (<35% recovery). The matrix spike duplicates also were significantly below the QC limits with 10 of the 16 compounds at or below the 10% recovery. The laboratory provided a quality control review and suggested that the low recoveries may be a function of low spike concentrations relative to the existing sediment concentration of the single sample selected for matrix spike analyses. The high variability of moisture content in marine sediments may also affect the results where the same moisture content is applied to replicates which may differ. Despite the low recoveries in the MS/MSD analysis for sample GR-1, the accuracy of the PAH data was considered acceptable because of the additional quality control results. All of the surrogate spike recoveries, which were tested for each sample, were within acceptable limits. Recoveries for PAHs were between 42–128%, with more limited ranges for each surrogate tested. Surrogate recovery percentages indicate the ability of the laboratory to detect a known concentration of compounds that behave similar to those tested in a sample. All spiked targets of the spiked blank met the acceptance criteria with percent recoveries ranging from 63 to 98%. Finally, an instrument reference material (NIST IRM 1491), using an independent-source standard, was tested and all targets also met the acceptance criteria.

Pesticides/PCB Accuracy. Sample GR-9 was selected for MS/MSD analysis. Aldrin, gamma-BHC, heptachlor, dieldrin, and 4,4'-DDT were spiked as representative pesticides. All MS/MSD sample recoveries resulted in acceptable accuracy. Pesticide/PCB samples were spiked with two surrogate compounds, tetrachloro-m-xylene (TMX) and decachlorobiphenyl (DCB). Recovery of DCB was acceptable for all samples, and TMX acceptable in all but one sample (26% recovery; acceptance limits are 30-150%). In addition, two spiked laboratory control samples were within acceptance limits, indicating overall acceptable accuracy for pesticide and PCB data. The WHG laboratory investigated the continuing calibration verification (CCV) samples for negative bias because of the lack of any measured pesticide or PCB data in the WLIS reference samples. CCV exceedences were not considered to have biased the data, so pesticide/PCB results were reported with no qualification.

Metals Accuracy. Sample GR-1 was selected for MS/MSD analysis. The MS/MSD recoveries were considered acceptable for all metals in both the MS and MSD samples except aluminum (Al). Low recoveries of spiked Al were due to the low spiked concentration relative to the natural concentration (19000 mg/kg sample concentration,

~1000 mg/kg spike). All metal recoveries were within acceptable limits for the laboratory control sample, indicating acceptable accuracy for the metals data.

TOC Accuracy. Sample GR-1 was selected for MS/MSD analysis. Recoveries of TOC in both the MS and MSD samples, as well as eight analyses of the standard reference material, indicated acceptable accuracy of the TOC data.

2.8.5.4 Assessment of Analytical Precision

Analytical precision is expressed as the relative percent difference (RPD) between two results. Precision for this dataset was calculated from the RPD between the MS and MSD recovery values. The closer the numerical values of the measurements are to each other, the lower the RPD. Low RPD values indicate a high degree of analytical precision. The relative percent difference (RPD) between two sample results was calculated using the following equation:

$$\mathrm{RPD} = \frac{\mathrm{Samp\,Res} - \mathrm{Dup\,Res}}{(\mathrm{Samp\,Res} + \mathrm{Dup\,Res}/2)} \times 100$$

Sample GR-1 was selected for MS/MSD analyses, except for pesticides/PCBs (GR-9). Precision limits for the RPD of the MS/MSD samples was 35% for PAHs. Of 16 PAH compounds analyzed, 2 were outside of the 35% limit (phenanthrene and benzo(a)anthracene). Overall, the PAH data were considered to be acceptably precise. All pesticide compound MS/MSD recoveries were within 20%, indicating acceptable precision of pesticide data. Pesticide and PCB (all below detection for WLIS samples) detection limits were reported on a sample-specific basis based on the on-column reporting limit, with a PCB on-column calibration standard of 100 ng/ml; these data provide supporting information for the precision of the reporting limit.

All RPDs for MS/MSD metals samples were <10% (most <5%) indicating good precision, except for Al. As stated above, the low relative concentrations of the Al spikes make the MS/MSD recovery data not acceptable for assessment of precision. The RPD between actual sample results of Al was within 10%, indicating acceptable precision of Al analyses. Finally, the RPD results of TOC recoveries in the MS/MSD samples were 2.8% for one day of analysis, and 38.3% for the second. Precision of duplicate TOC analysis for the sample GR-1 was within 10%. Cumulatively, the RPD data indicate an acceptable level of precision for TOC.

3.0 RESULTS

To monitor changes in the topography and benthic conditions at WLIS, we surveyed the southwest quadrant of the disposal site (Figure 2-4) where all disposal activity has occurred since 1982 (Section 3.1). The WLIS disposal mounds have been strategically placed to form potential containment cells. The REMOTS® surveys were focused over the recently deposited I mound (Section 3.2), the 1995-1996 H mound (Section 3.3), and the reference areas South and SW-REF (Section 3.4). In addition to the development of containment basins, the I mound was placed between the D and G mounds to cover an area exhibiting low dissolved oxygen conditions and poor recolonization in the 1996 REMOTS® monitoring survey (Morris 1998).

For the new reference area investigation, using a high-resolution side-scan sonar survey, we located a region identified as SE-REF that appeared to be free of historic dredged material deposits. We also conducted a REMOTS® photography survey to characterize the ambient material and confirm that no dredged material was in the 300-m radius of the center of the reference area (Section 3.5). The ambient sediments had a high sulfide content and were in many cases darker than typical reference areas. However, determination of the contaminant levels in sediment grab samples revealed moderate to low pollution levels similar to ambient sediment conditions of western Long Island Sound.

3.1 WLIS Disposal Site Bathymetry

The September 1997 800 x 800 m bathymetric survey at WLIS detected eight dredged material disposal mounds on the WLIS seafloor (Figure 3-1). The I mound is a result of the most recent deposition. There are a total of nine mounds in the southwest quadrant, including the 1995-1996 H mound which is located to the east of the survey area. Depths in the survey area ranged from 27 m to 35 m. The minimum depth occurred over the southern edge of the survey area, which continues to shoal towards the south to form the terminal moraine of Long Island. This natural containment wall, created by glacial deposition, combined with the strategic placement of the dredged material mounds has resulted in the formation of several basin areas that may serve as potential containment cells for dredged material in the future.

3.2 WLIS I Mound

To continue the development of the dredged material containment berm and basins, material was disposed between the existing D and G mounds. The buoy was positioned at 40° 59.203´ N, 73° 29.072´ W, where approximately 35,000 m^3 of new dredged sediments over the disposal season were placed, forming the I disposal mound.

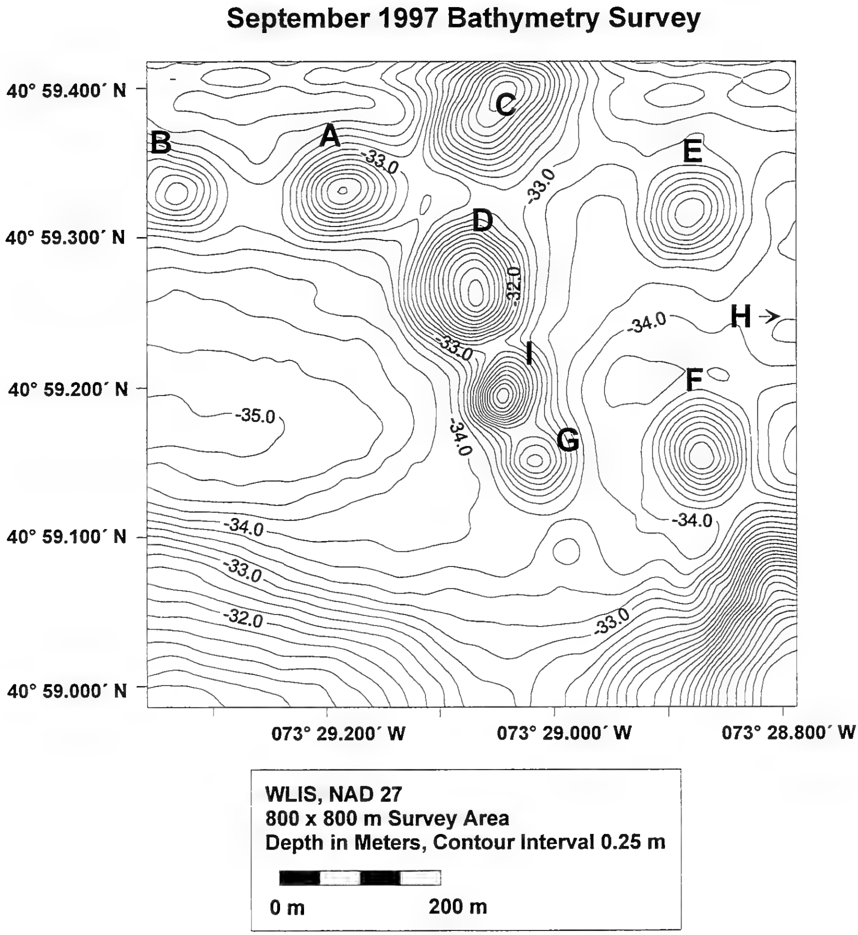


Figure 3-1. Bathymetric chart of the September 1997 800 x 800 m survey area

3.2.1 Bathymetry

We compared the September 1997 bathymetric survey results with the July 1996 survey and calculated the depth difference (Figure 3-2). The bathymetric chart shows the development of the I mound just southeast of the buoy location. The mound reached a maximum height of 3.73 m above the 1996 baseline chart, with an approximate width of 150 m. The 0.25-m apron covers the northwestern portion of the G mound. Previous REMOTS® surveys had indicated poor environmental conditions, characterized by slow recolonization rates and decreased RPD depths due to the oxidation of high labile organic concentrations, in an isolated region south of the D mound and west of the G mound. Although the mound was not placed directly over this area, apron mound material potentially has covered some of the problem region area at 1996 REMOTS® station D200S.

3.2.2 REMOTS® Sediment-Profile Photography

REMOTS® sediment-profile photography was used to document benthic recolonization as well as delineate the placement and any environmental impacts of the recently disposed dredged material. The September 1997 survey occupied a 13-station cross grid with stations located 50 m apart over the I mound (Figure 2-2). The March 1998 survey sampled a 5-station grid, including the center and four 50-m stations for comparison. Complete REMOTS® results for the new disposal mound are available in Appendices B and C.

3.2.2.1 Sediment Grain Size and Stratigraphy

In September 1997, we detected dredged material at all I mound stations and in most replicates. Replicates at 150E indicated a thin layer of dredged material, 6 cm to 7 cm, over ambient sediments. Dredged material thickness was greater than penetration at most of the stations. The average mean camera penetration was 13.40 cm, which was greater than measured at the reference areas (Section 3.4).

A thin layer of brown, oxidized silt over black sulfidic mud characterized the sediment in the photographs. The lighter surface layer indicated the depth of RDP and oxygenation. Redox rebounds, which are stratigraphic differences in color or shade below the surface layer on the sediment-profile image, were evident at Stations 100S, 100W, and 150E, all of which were outside of the 0.25 m depth mound apron identified in the bathymetric survey. The presence of a redox rebound interval in a new sediment deposit suggests a gradual decline in pore water oxygen content, which could be attributable to a decrease in regional bottom water dissolved oxygen concentrations. Redox rebounds tend to be driven by seasonal effects. For the central five stations only, redox rebounds increased

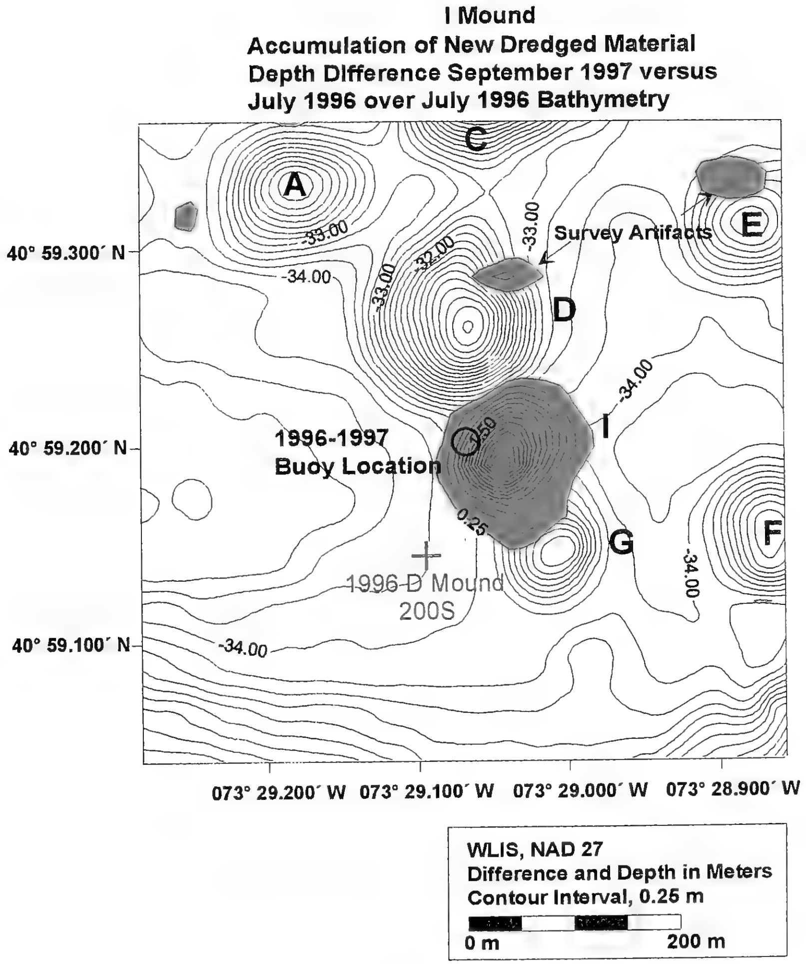


Figure 3-2. Depth difference plot of the I mound, from July 1996 to September 1997 bathymetric surveys over the southwestern quadrant of WLIS

from zero replicates in September to one in March. In some replicates, the distinctions among redox rebounds, multiple dredged material layers, and relict RPDs indicating dredged material over ambient sediments were not clear. These distinctions are discussed further in Section 4.1.3.

Physical REMOTS® parameters indicated the surface and near-surface layers of the mound were mainly composed of silt and clay with the major modal grain size consistently reported at >4 phi. Mean camera penetration over the I mound showed no distinct pattern, with the shallowest penetration (7.28 cm) at CTR and the deepest penetration (15.89 cm) at 150N. Replicate-averaged surface roughness values for the REMOTS® camera stations over the I mound ranged generally from 0.52 to 3.16 cm. Although some replicates were indeterminate, surface roughness was attributed primarily to physical effects, with some replicates indeterminate or indicating biogenic activity.

During the March 1998 survey, we detected dredged material at all five central stations over the I mound. The replicates of the 5-station grid were characterized again by a thin layer of oxidized, brown silt over black mud. Although the grain size was primarily silt and clay, some rocks, sand, and large shell fragments were visible at Station 50N. In September, the grain size varied from medium sand to clay. In March, the average penetration depth at 50N (1.90 cm) was significantly less than the depth of 12.7 cm observed in September. The difference in grain size may have affected the penetration depths at 50N. The CTR station had a comparable mean penetration depth of 6.52 cm in March relative to 7.28 cm in September. In contrast, the mean penetration depths increased by about 3 cm for 50E, 50W, and 50S from September to March. The penetration depth indicates the relative sediment water content at sites with similar grain size because the camera acts as a static-load penetrometer (Revelas et al. 1987). In March, surface roughness was attributed to physical effects for CTR, 50N, and 50E, and was indeterminate at 50S and 50W.

3.2.2.2 Benthic Community Assessment

Using three parameters, we determined the benthic recolonization rate and overall health of the project mounds relative to the WLIS reference areas. We examined the infaunal successional status, the apparent Redox Potential Discontinuity (RPD) depth, and the Organism-Sediment Index (OSI). The RPD and OSI values were mapped over the target locations to show the distribution of biological conditions. The Rhoads and Germano (1982, 1986) protocol for REMOTS® analysis was followed for measurements and interpretation. In some replicates, wiper smears obstructed successional stage identification and RPD measurements in both September and March surveys.

The successional status was primarily characterized by Stage I pioneering assemblages of polychaetes in September as predicted by DAMOS protocol. Several replicates indicated the presence of a higher successional status containing Stage III taxa or feeding voids due to the deposit feeder's biological activity (Figure 3-3). The average mean RPD for the I mound was moderate to shallow with a depth of 1.93 cm, varying from 0.92 cm to 6.81 cm. The overall median OSI value was 4 (Figure 3-4, Table 3-1). The central 5-station grid stations, resurveyed in March, had an average RPD of 2.25 cm and OSI of 7 in September.

The successional status in March indicated a slightly greater presence of Stage III organisms (Figure 3-3). The RPD depths were significantly deeper than observed in September with an overall average depth of 2.56 cm (Figure 3-5); however, wiper smears obstructed measurements in a number of replicates. In March, the 5-station grid OSI value of 8 was slightly higher than in September and may be attributed to seasonal effects on sediment oxygen contents and the progression in the successional status (Figure 3-5). No low dissolved oxygen conditions were observed in the replicates from either the September or March survey.

3.3 WLIS H Mound

During the 1995-1996 disposal season, 15,300 m^3 of sand, silt, and clay dredged from the Connecticut and New York waterways were disposed at WLIS and formed the H mound. About two-thirds of the material, 10,060 m^3 barge volume, was dredged from Connecticut's Wlison Cove, Norwalk and Stamford Harbors, and Pratt's Cove. The remaining material, 5,240 m^3 barge volume, derived from New York's Manhasset Bay along the north shore of Long Island. REMOTS® data from the 1996 monitoring survey indicated healthy condition relative to reference values, with a moderate-to-deep RPD and evenly distributed benthic recolonization (Morris 1998). We revisited WLIS H in accordance with DAMOS monitoring protocols to observe the benthic conditions and examine evidence for the predicted advanced successional status that occurs with a healthy benthic recovery over the long-term.

3.3.1 Bathymetry

The September 1997 bathymetric survey area did not extend over the H mound. The 1996 bathymetric survey chart of this smaller area was used as a basemap for the REMOTS® data, showing a sediment mound with a minimum depth of 32.5 m (MLLW) over the apex of the H mound (Figure 3-6).

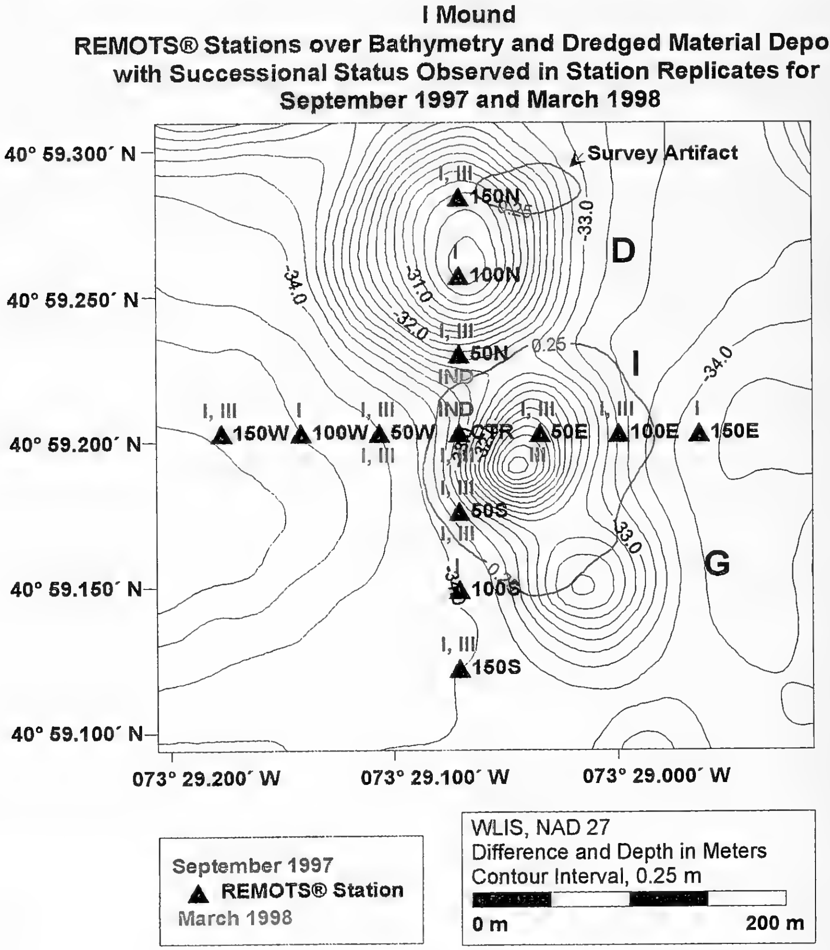


Figure 3-3. Distribution of successional stage assemblages over the I mound, overlaid on September 1997 bathymetry and detectable mound margin

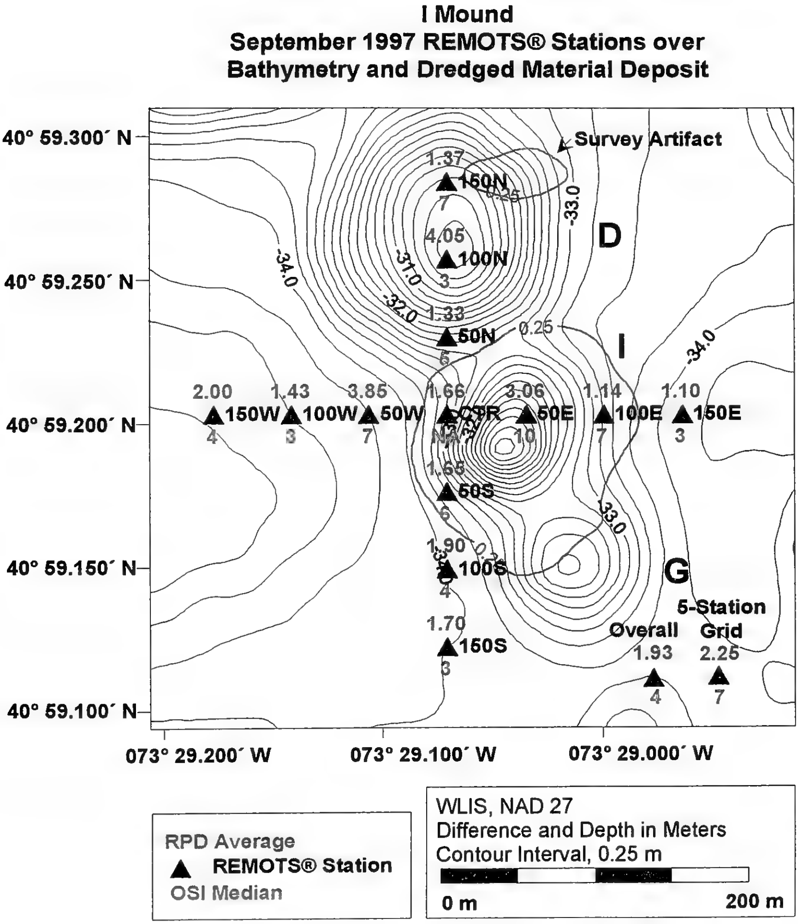

I Mound
September 1997 REMOTS® Stations over
Bathymetry and Dredged Material Deposit

Figure 3-4. Distribution of redox potential discontinuity (RPD) depths and Organism-Sediment Index (OSI) values for September 1997 REMOTS® stations overlaid on bathymetry and detectable mound margin

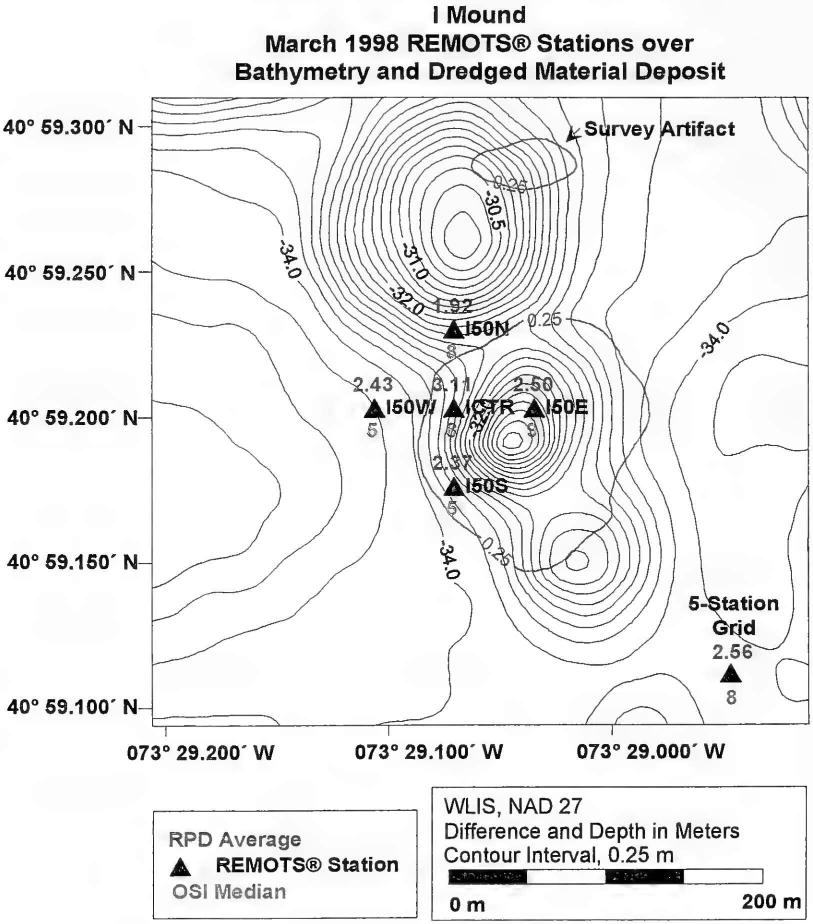


Figure 3-5. Distribution of RPD depths and OSI values for March 1998 REMOTS® stations overlaid on bathymetry and detectable mound margin

Table 3-1

Summary of REMOTS® Results at I Mound Stations in September 1997 and March 1998

I MOUND Summary Table September 1997

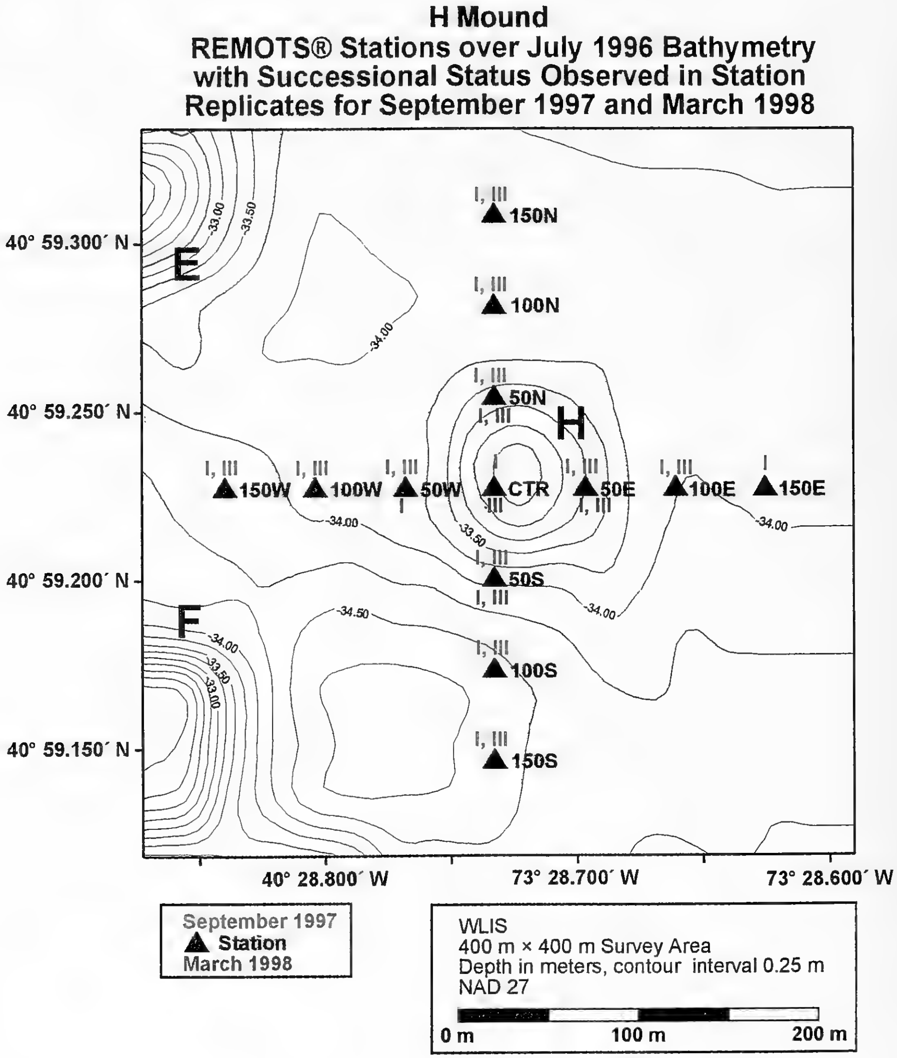
Station	RPD Mean (cm)	Median OSI	Mean Camera Penetration (cm)	Mean Boundary Roughness (cm)
ICTR	1.66	NA	7.28	0.96
I50N	1.33	5.00	12.67	0.67
I50E	3.06	10.00	15.19	1.69
I50S	1.65	5.50	10.18	1.45
I50W	3.85	7.00	12.14	0.52
I100N	4.06	3.00	13.57	1.93
I100E	1.14	7.00	15.74	0.63
I100S	1.90	4.00	12.55	0.96
I100W	1.43	3.00	13.58	0.76
I150N	1.37	7.00	15.89	0.49
I150E	1.10	3.00	15.54	0.41
I150S	1.70	3.00	15.60	0.74
I150W	2.00	4.00	14.31	3.16

I MOUND Summary Table March 1998

Station	RPD Mean (cm)	Median OSI	Mean Camera Penetration (cm)	Mean Boundary Roughness (cm)
ICTR	3.11	7.50	6.52	2.02
I50N	1.92	8.00	1.90	1.29
I50E	2.51	9.00	16.35	0.63
I50S	2.37	5.00	13.07	0.87
I50W	2.43	5.00	14.71	0.78

WLIS Reference Areas September 1997

SOUTH Avg.	1.97	7	9.42	1.09
SOUTH Range	1.04-2.14	3.0-9.0	6.55-11.29	0.89-1.67
SW-REF Avg.	1.47	7	6.24	1.00
SW-REF Range	0.85-1.94	3.0-8.0	4.54-7.78	0.67-1.92



H Mound
REMOTS® Stations over July 1996 Bathymetry with Successional Status Observed in Station Replicates for September 1997 and March 1998

Figure 3-6. Distribution of successional stage assemblages over the H mound overlaid on July 1996 bathymetry

3.3.2 REMOTS® Sediment-Profile Photography

REMOTS® sediment-profile photography was used to document benthic recolonization as well as track the thin layers of dredged material and assess the overall impact of deposition over the surface of the WLIS H mound. The September 1997 survey reoccupied the 13-station 1996 grid. The March 1998 survey sampled a 5-station grid, the center, and 50-m stations for comparison.

3.3.2.1 Sediment Grain Size and Stratigraphy

During the September 1997 survey, we detected and measured dredged material at every station over the H mound. Dredged material thickness over the H mound was greater than penetration at every station except one replicate at 150W, which had a 12-cm thickness over ambient material (Appendix B). With few exceptions, dredged material exceeded the camera penetration depth. Redox rebound intervals, areas showing evidence of intermittent or seasonal oxidation below the currently oxidized surface layer, were noted at many stations over the H mound. Redox rebound is discussed further in Section 4.1.3. The number of redox rebounds decreased from ten replicates in September to seven in March out of a total of 15 replicates at the 5-grid stations. The depth of the redox rebound also decreased 4.24 cm to 2.43 cm (or 6.36 cm to 5.21 cm, excluding stations without rebounds).

Physical REMOTS® parameters indicated the surface and near surface layers of the mound were mainly composed of silt and clay with the major modal grain size consistently reported at >4 phi. Mean camera penetration over the H mound showed no distinct pattern, with the shallowest penetration (10.94 cm) at 50E and the deepest penetration (18.14 cm) at 150W and an overall average of 15.06 cm. The range of camera penetration depths were comparable to 1996 results (12.98–18.57 cm). Replicate-averaged surface roughness values for the REMOTS® camera stations over the H mound ranged from 0.38 cm at 150N to 4.38 cm at 100W. Again, the 1997 results were similar to those observed in 1996, which ranged from 0.64 cm to 3.24 cm at 100S. Although some replicates were indeterminate, surface roughness was attributed both to biogenic activity and, to a lesser extent, physical effects.

We compared the physical REMOTS® parameters of March 1998 to the September survey results. The grain size was predominantly silt and clay (>4 phi). The mean camera penetration depth was an average of 1.40 cm less than the September survey results for the five stations. The mean boundary roughness values covering only the 5-station grid were more consistent in March, ranging between 0.73 and 0.85 cm. Many of the replicates had indeterminate surface roughness values, with five attributed to physical effects and two to biogenic activity.

3.3.2.2 Benthic Community Assessment

Although the majority of replicates had a Stage I successional status in September 1997, there was an increase in the presence of Stage III indicators, both deposit feeders and feeding voids, since the July 1996 survey (Figure 3-6). The mean RPD depths, however, were shallower than observed in previous surveys, with an overall average of 1.44 cm (Figure 3-7) compared to 2.46 cm from July 1996. The Organism-Sediment Index, which is a combination of the previous factors, was close to the 1996 survey results with an overall median of 4. Two replicates with OSIs of 7 at 50W, which had a zero OSI value in 1996 due to low DO, did show improved benthic conditions (Figure 3-7; Table 3-2). No low DO conditions were evident in either September or March surveys.

In March 1998, the benthic conditions at the 5-station grid had improved significantly since September 1997. Evidence of Stage III organisms was found in 10 of the 15 replicates. Stage I organisms were less abundant at both the H and I mounds in March. Stage I organisms, which are polymorphic filter feeders that can easily adapt and recolonize new resources, tend to die back during winter and then increase again in May. The overall mean RPD in March was 2.3 cm (Figure 3-8). The OSI values ranged from 4 to 11 with an overall median of 8 (Figure 3-8; Table 3-2).

3.4 WLIS Reference Areas

As part of the DAMOS tiered monitoring protocols, we collected reference area data in September 1997 to provide a baseline to compare results from the dredged material mounds. A total of thirteen stations were occupied over two reference areas (SOUTH and SW-REF). Complete REMOTS® results for the WLIS reference areas are available in Appendix B. In March, we investigated SE-REF but did not revisit South and SW-REF due to time constraints.

3.4.1 Sediment Grain Size and Stratigraphy

Ambient sediments, characterized by brown silt or very fine sand over mud, were identified in almost all of the replicates. SOUTH Station 1 appeared to contain dredged material, and SW-REF Station 9 was indeterminate. The major mode of grain size was >4 phi for majority replicates, with 3 to 4 phi for 15 replicates. The mean camera penetration at the reference areas, 9.42 cm for SOUTH and 6.24 cm for SW-REF, was

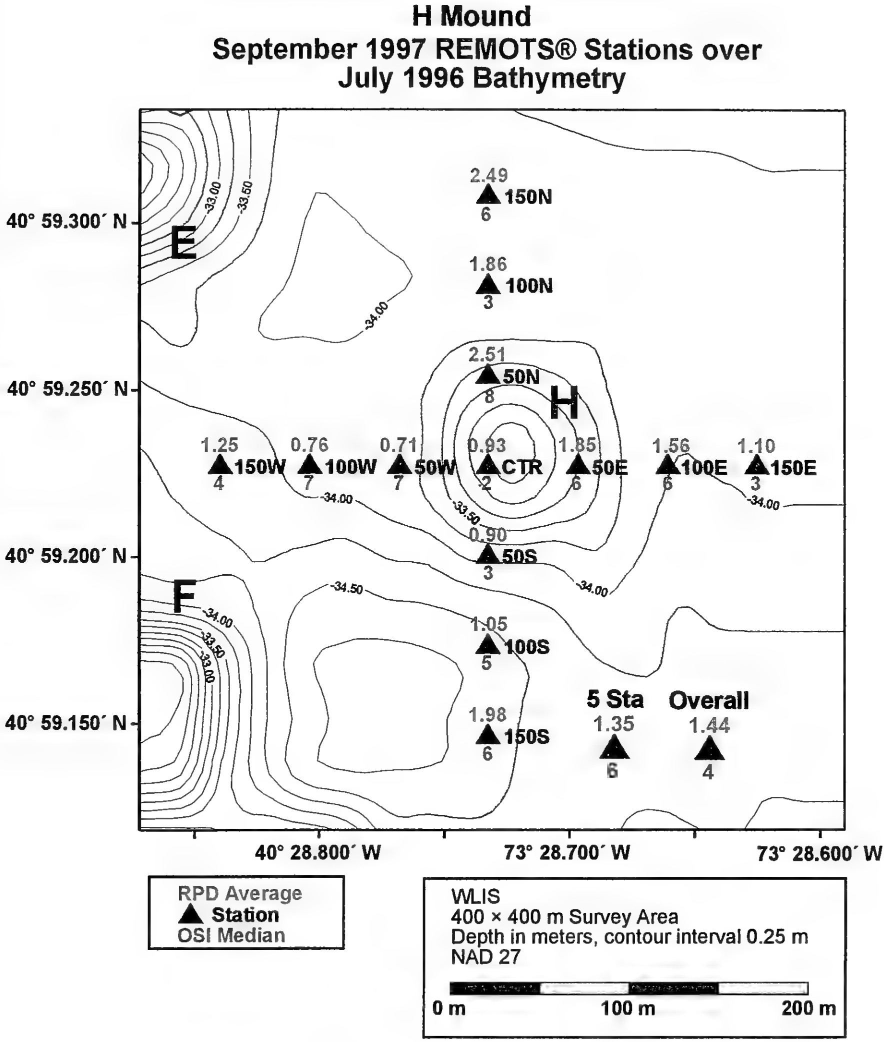


Figure 3-7. Distribution of Redox Potential Discontinuity (RPD) depths and Organism-Sediment Index (OSI) values for September 1997 REMOTS® stations overlaid on July 1996 bathymetry of the H mound

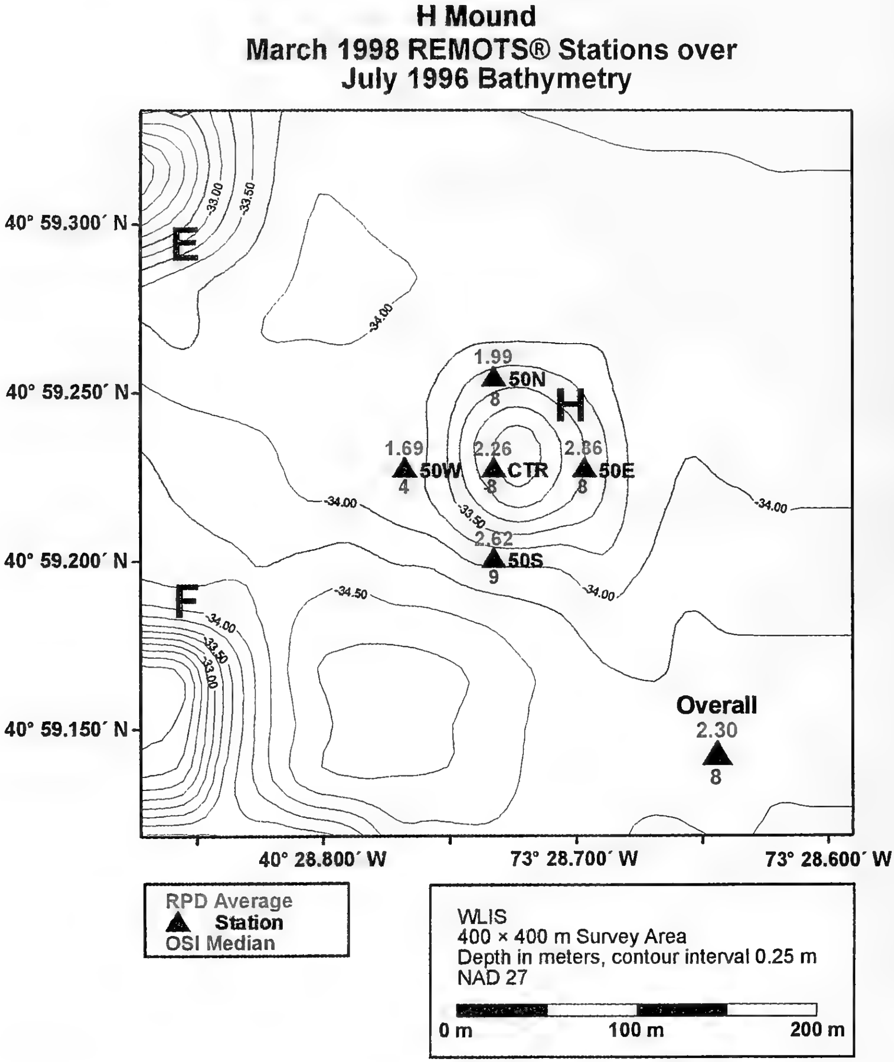


Figure 3-8. Average Redox Potential Discontinuity (RPD) depth (cm) and median OSI values for March 1998 REMOTS® stations overlaid on July 1996 bathymetry

Table 3-2

Summary of REMOTS® Results at H Mound Stations in September 1997 and March 1998

H MOUND Summary Table September 1997

REMOTS Station	RPD Mean (cm)	Median OSI	Mean Camera Penetration (cm)	Mean Boundary Roughness (cm)
HCTR	0.93	2.00	16.55	0.52
H50N	2.51	8.00	17.22	0.66
H50E	1.85	6.00	10.94	2.84
H50S	0.90	3.00	17.89	0.45
H50W	0.71	7.00	14.36	3.78
H100N	1.86	3.00	14.74	0.67
H100E	1.56	6.00	13.23	1.86
H100S	1.05	5.00	13.29	1.13
H100W	0.76	7.00	13.10	4.38
H150N	2.49	6.00	13.66	0.38
H150E	1.10	3.00	16.15	0.93
H150S	1.98	6.00	16.55	0.60
H150W	1.25	4.00	18.14	0.57

H MOUND Summary Table March 1998

REMOTS Station	RPD Mean (cm)	Median OSI	Mean Camera Penetration (cm)	Mean Boundary Roughness (cm)
HCTR	2.26	7.50	12.85	0.73
H50N	1.99	8.00	12.73	0.77
H50E	2.86	8.00	16.06	0.73
H50S	2.62	9.00	12.86	0.75
H50W	1.69	4.00	15.46	0.85

WLIS Reference Areas September 1997

SOUTH Avg.	1.97	7	9.42	1.09
SOUTH Range	1.04-2.14	3.0-9.0	6.55-11.29	0.89-1.67
SW-REF Avg.	1.47	7	6.24	1.00
SW-REF Rang	0.85-1.94	3.0-8.0	4.54-7.78	0.67-1.92

shallower than measured at the I and H mounds (Table 3-3). Boundary roughness was attributed primarily to physical effects.

3.4.2 Benthic Community Assessment

Successional stages were split between Stage I and III organisms. The RPD depths ranged from 0.8 cm to 6.33 cm. The overall median OSI value was 7 for both areas. For SOUTH, the median OSI values ranged from 3 to 9, and for SW-REF, 3 to 8 (Table 3-3). The low OSI values at some stations may have been due to low dissolved oxygen conditions in September (Section 4.1.2).

3.5 New Reference Area Investigation

Previous monitoring surveys have detected historic dredged material at several previous and proposed reference areas surrounding WLIS (EAST, WLIS-REF, 2000S, and 3000E) which were then discontinued. The most recent 1996 REMOTS® survey detected dark, reduced sediments and methane gas bubbles in three replicates from 2000W reference area indicating the presence of weathered dredged material (Morris 1998). This finding was not surprising considering that the reference area was located within the Stamford Historic Disposal Site. To replace 2000W, we conducted a series of surveys to locate an area with a 300 m radius clear of historic dredged material.

3.5.1 Side-Scan Sonar

For the first time, a side-scan sonar survey was used to locate and investigate a potential reference area. The survey in September, however, was limited to a small area by the many lobster pots dispersed throughout the area that obstructed survey operations. We postponed the reference area investigation to the winter, when lobster gear would be less intense in the region.

Although some lobster gear continued to pose hazards in March, the side-scan sonar survey was still conducted near WLIS. The initial side-scan sonar survey was designed over a 2000 x 4000 m area east-southeast of WLIS to locate a region representative of natural ambient conditions. The presence of abundant lobster gear and dredged material on the seafloor prompted on-site revisions.

The orientation of the initial 2000 x 4000 m survey area was altered to due east-west with the northwest corner of the survey located within WLIS and was reduced in size to 1500 x 4000 m (Figure 2-3). A second smaller survey was designed to examine an area north of Eaton's Neck and west of a rocky reef in an area where lobster gear was minimal.

Table 3-3

Summary of REMOTS® Results at SOUTH and SW-REF Reference Area Stations in September 1997

WLIS Reference Areas Summary Table September 1997

Station	RPD Mean (cm)	Median OSI	Mean Camera Penetration (cm)	Mean Boundary Roughness (cm)
SOUTH				
RefS1	2.14	9	11.11	1.67
RefS2	2.06	9	10.43	1.00
RefS3	1.93	5	6.55	0.89
RefS4	1.04	3	9.13	0.79
RefS5	3.00	7	11.29	1.25
RefS6	1.63	6	8.01	0.95
SW-REF				
RfSW7	1.94	8	7.78	0.77
RfSW8	0.85	3	6.60	0.67
RfSW9	1.29	5	5.34	1.92
RfSW10	1.75	7	7.08	0.59
RfSW11	1.75	6	4.54	1.36
RfSW12	1.22	7	6.90	0.82
RfSW13	1.50	7	5.46	0.89
WLIS Reference Areas September 1997				
SOUTH Avg.	1.97	7	9.42	1.09
SOUTH Range	1.04-2.14	3.0-9.0	6.55-11.29	0.89-1.67
SW-REF Avg.	1.47	7	6.24	1.00
SW-REF Range	0.85-1.94	3.0-8.0	4.54-7.78	0.67-1.92

This smaller survey consisted of 10 survey lanes measuring 1000 m in length and spaced 100 m apart. Side-scan images of the seafloor within the small 1000 x 1000 m survey identified areas with no apparent dredged material. However, these areas were in relatively shallow water (< 18 m) which may not be representative of the ecological conditions at WLIS. Side-scan operations were continued in the 1500 x 4000 m survey area in water depths greater than 18 m. Although detection of dredged material was common at depths below 18 m, a potential reference area was identified at 40°58.301´N, 73°27.722´W (NAD 27), with a mean water depth of 19.5 m (Figure 2-5). The center of the new reference area was designated as SE-REF CTR.

The results of the high-resolution side-scan sonar survey over the identified reference area showed an area that appeared relatively free of dredged material (Figure 3-9). Lobster pots and trawl lines marked the seafloor. A dredged material mound was detected to the northwest, outside of the 300-m radius of the reference area center. Some weathered historic dredged material may be present in the southwest section of the new reference area. In the larger 1500 x 4000 m survey area, we did detect dredged material deposits to the north and east of this region outside of SE-REF, which are shown in Figure 3-10 for comparison.

3.5.2 REMOTS® Sediment-Profile Photography

REMOTS® replicates were representative of target locations in the 300 m radius of the potential reference area (Figure 3-11). The figure also shows the 25-station REMOTS® grid relative to ten grab samples taken randomly over SE-REF.

3.5.2.1 Sediment Grain Size and Stratigraphy

Fine-grained silt predominantly characterized the ambient sediments. The photographs showed an oxidized, brown layer with some small shell fragments over black or grey-black mud. Figure 3-12 shows the variation in sample replicates from SE-REF. Replicate 100NW D, with a deep RDP and high OSI value, is representative of many replicates at SE-REF. 100NW D is within the normal grey-scale for REMOTS® replicates, whereas 200SW C contains sediments that are darker in appearance than typical for DAMOS reference areas. Redox rebounds were observed in ten replicates.

The physical REMOTS® parameters were comparable to reference areas SOUTH and SW-REF. The grain size was primarily silt and clay, >4 phi. The mean camera penetration for each station ranged from 7.79 to 15.67 cm, with an overall average of 12.91 cm. In September, penetration depth was shallower at SOUTH and SW-REF, with average mean depths of 9.43 and 6.24 respectively. The mean boundary range averaged 1.52 cm, varying between 0.65 and 4.80 cm. The boundary range was slightly greater

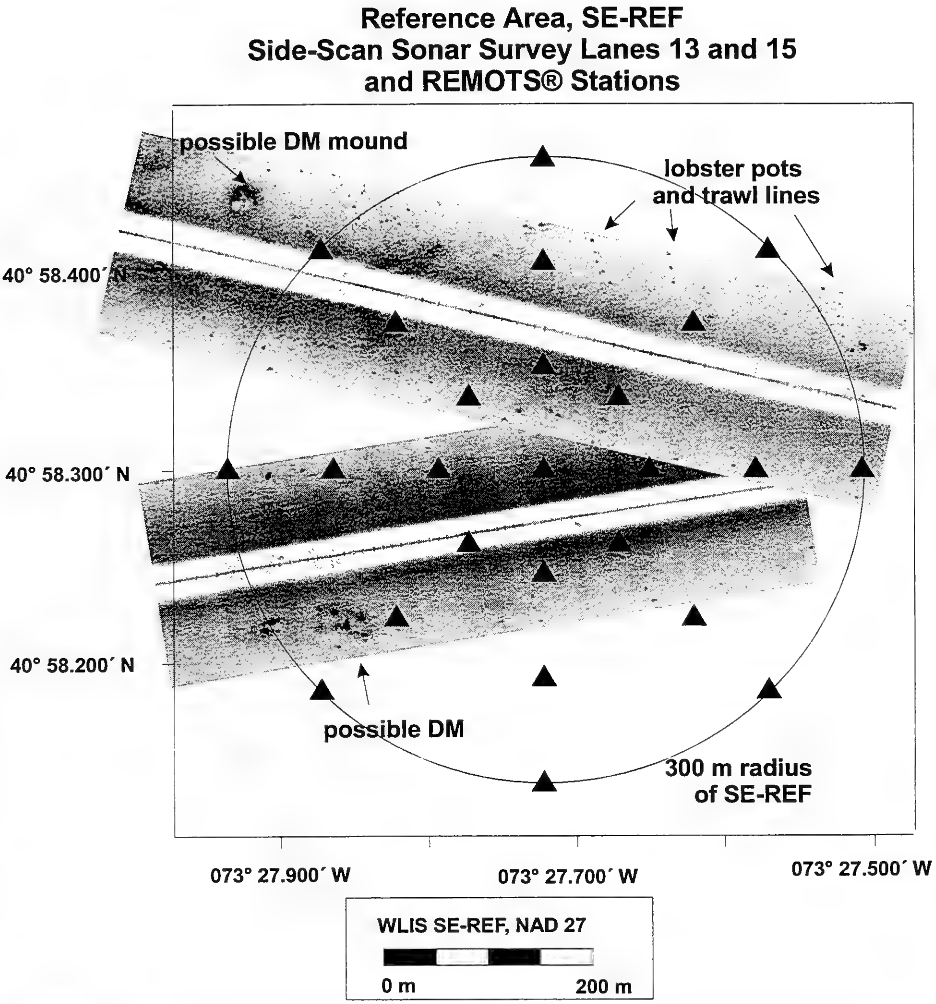


Figure 3-9. Side-scan sonar survey images and REMOTS® stations for the SE-REF reference area investigation. Side-scan images were not mapped according to exact geodetic positions and have been placed as accurately as possible for representation purposes only.

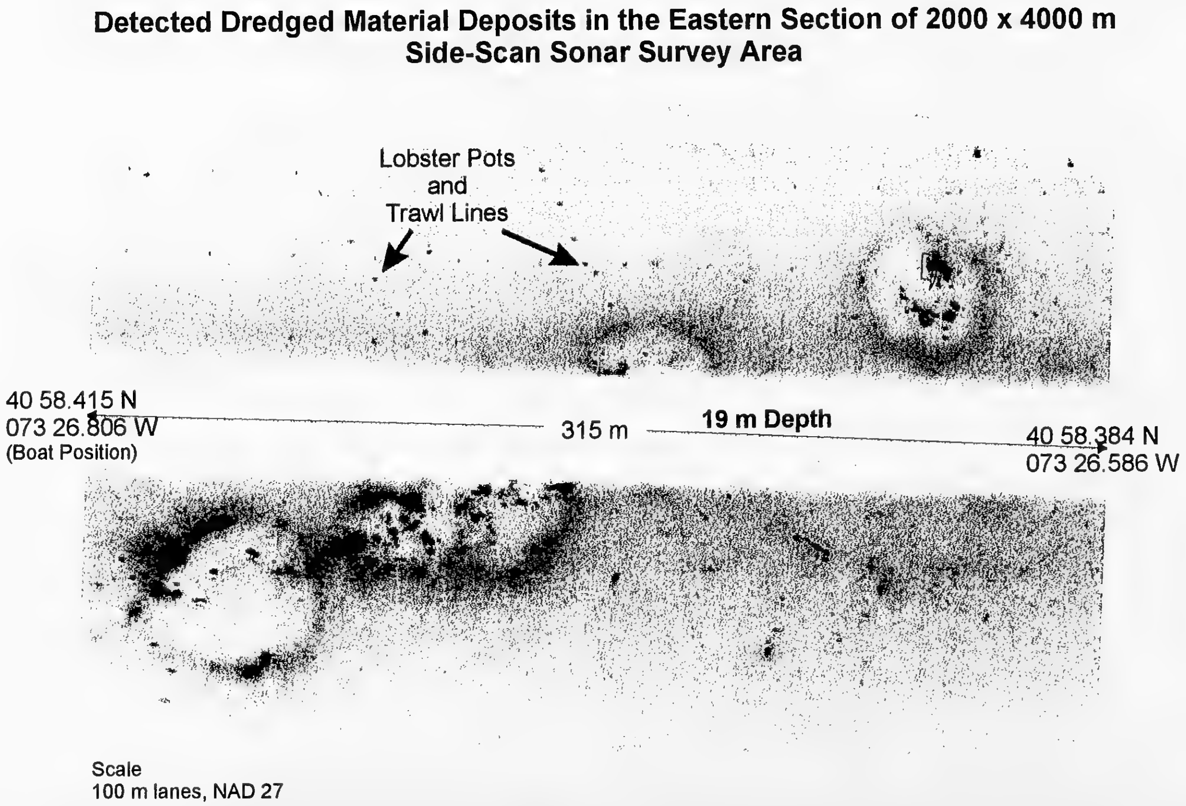


Figure 3-10. Detection of historic dredged material deposits in side-scan lane 13, east of SE-REF in side-scan sonar range

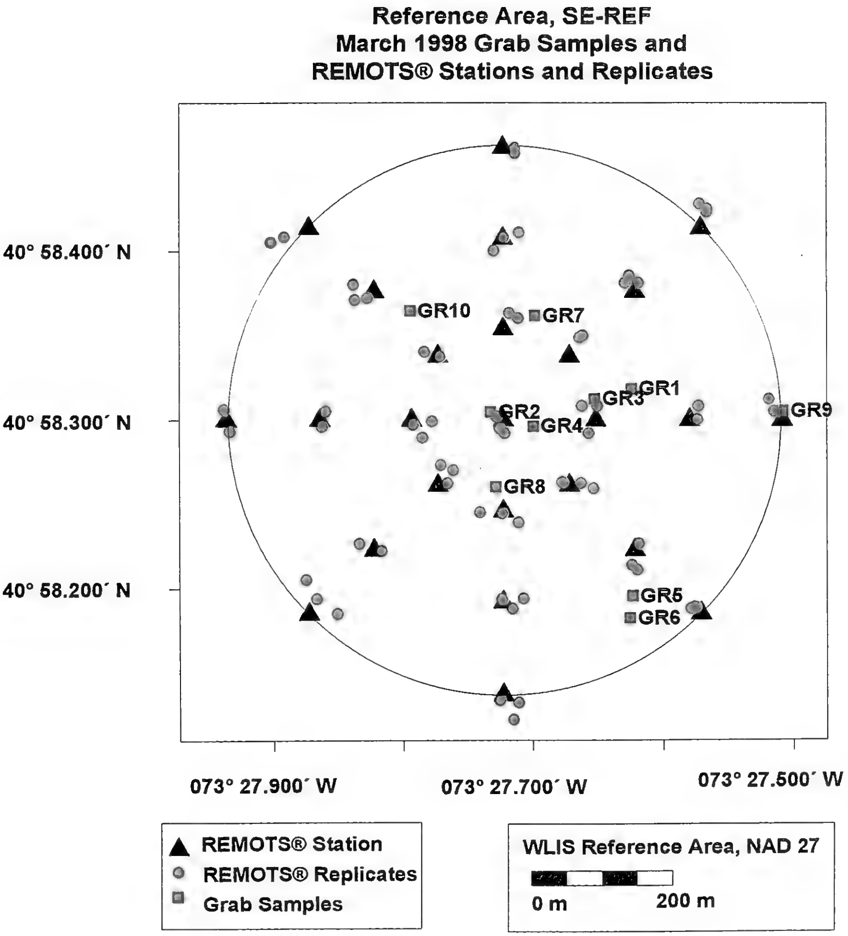


Figure 3-11. REMOTS® replicate locations near target stations and grab sample locations within SE-REF

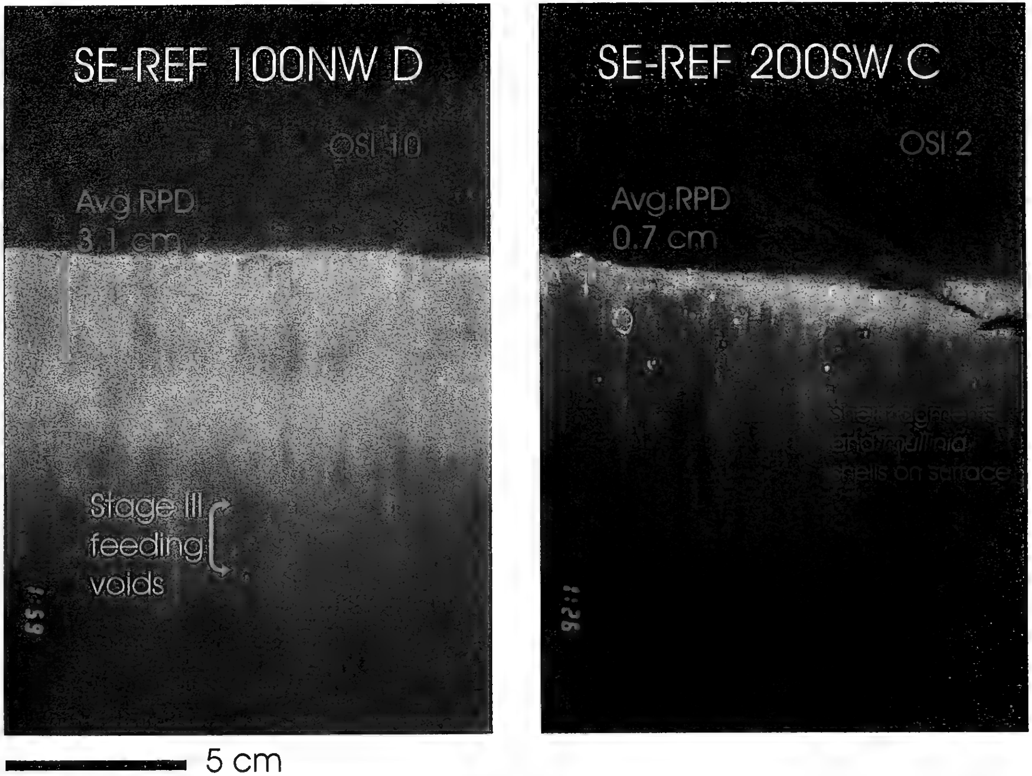


Figure 3-12. Variation between REMOTS® replicates at SE-REF from the March 1998 survey

than seen at the other reference areas in September, which averaged 1.09 cm at SOUTH and 1.00 cm at SW-REF. Physical effects primarily caused surface roughness, although some replicates did indicate biogenic activity or were indeterminate.

3.5.2.2 Benthic Community Assessment

Stage III or Stage I on III indicators characterized most replicates, even though the Stage III feeding voids lacked oxygenated sediment halos (Appendix C). Because the low water temperature in early March reduces the metabolic rate of benthic organisms, the active voids may have been less oxygenated. The lower metabolic rate also decreases the consumption rate of oxygen in the sediments. The lower biological oxygen demand (BOD) results in greater RPD depths. The RPDs at the potential reference area stations were deep, ranging from 1.83 to 4.63 cm and with an average of 3.04 cm. A few replicates (200N C, 300E A, 300SE A, and 200S C) were exceptions with RPDs less than 1 cm. The total OSI values, with a median of 10, were very high for a WLIS reference area (Figure 3-13, Table 3-4). For comparison, in September 1997 the median OSI value of both SOUTH and SW-REF was 7.

3.5.3 Sediment Grab Samples

All sediments collected at random locations in SE-REF with the grab sampler shared similar characteristics with little variation (Figure 3-11). Black, silty clay overlain with a thin (0.2 to 1.0 cm) olive-grey, oxidized layer was observed at each station in the potential reference area. REMOTS® photo 200SW C (Figure 3-12) is representative of the appearance of the grab samples. It is not known how much of the surface, oxidized layer, as visible in 100NW D (Figure 3-12), was resuspended as the sampling device was lowered to the seafloor, immediately prior to sample extraction. The samples were retrieved and brought on deck for description and sub-sampling. The sediments had a fine, pudding-like texture and sulfidic odor. Small shell fragments and *Mulinia* shells covered the surface. A 7-cm polychaete was found in Grab 8, and a worm was observed in Grab 1.

3.5.3.1 Grain Size Results

The ten WLIS reference grab sample grain size data had consistent sand and fine-grained fractions (Table 3-5). Most of the samples had silt (26 to 49%) and fine sand (26 to 41%) as the primary component, with the general classification either a silty fine sand, or sandy silt. One sample (GR-9) was dominated by clay (45%), with nearly equivalent concentrations of silt (26%) and fine sand (28%). Other than GR-9, clay varied from 16 to 28% in the samples. The sand fraction in all of the samples was dominated by fine sand.

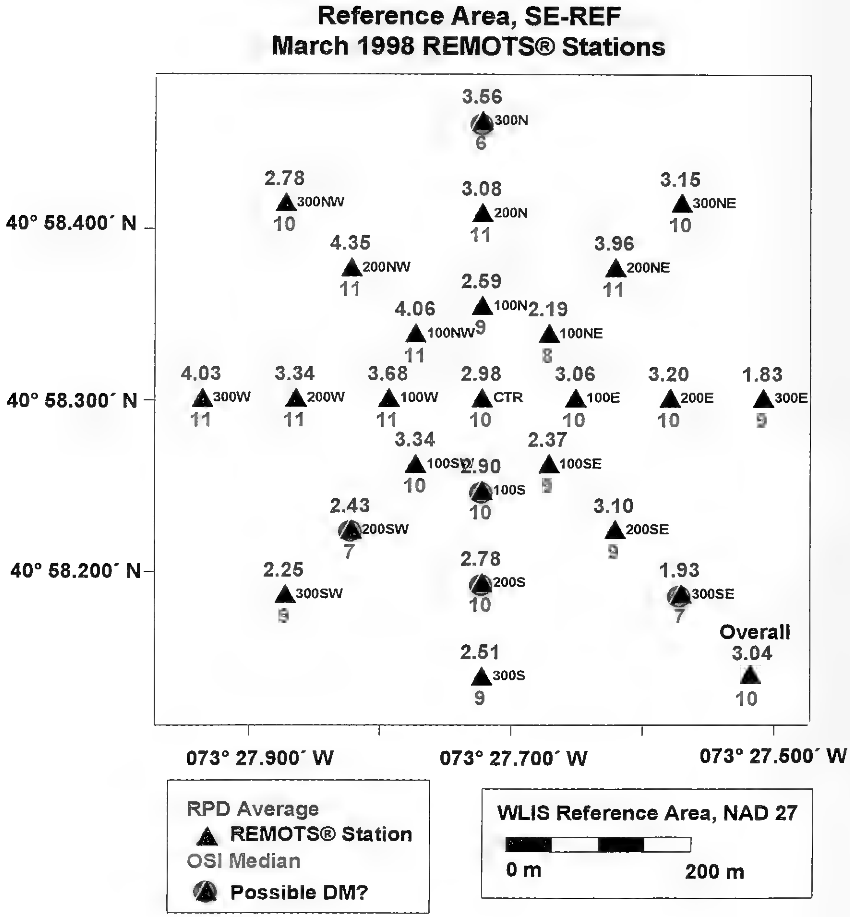


Figure 3-13. Distribution of RPD depths and OSI values for March 1998 REMOTS® stations at SE-REF. Stations that have one or more replicates that may indicate dredged material are circled in green.

Table 3-4

Summary of REMOTS® at SE-REF Reference Area Stations in March 1998

SE-REF March 1998

REMOTS Station	RPD Mean (cm)	Median OSI	Mean Camera Penetration (cm)	Mean Boundary Roughness (cm)
RCTR	2.98	10	14.72	1.40
R100N	2.59	9	13.91	0.65
R200N	3.08	11	11.65	1.83
R300N	3.56	6	7.79	4.01
R100NE	2.19	8	13.18	0.85
R200NE	3.97	11	12.52	0.79
R300NE	3.15	10	11.98	1.01
R100E	3.06	10	15.12	0.56
R200E	3.20	10	12.45	0.90
R300E	1.83	9	9.15	3.05
R100SE	2.37	9	12.80	0.96
R200SE	3.10	9	15.67	0.67
R300SE	1.93	6.5	14.72	4.80
R100S	2.90	10	13.45	0.51
R200S	2.78	10	15.53	1.15
R300S	2.51	9	15.58	0.68
R100SW	3.34	10	13.90	1.63
R200SW	2.43	6.5	10.77	1.90
R300SW	2.25	8.5	15.27	1.51
R100W	3.68	11	14.07	0.87
R200W	3.34	11	7.87	2.21
R300W	4.03	11	14.89	0.49
R100NW	4.06	10.5	9.41	1.89
R200NW	4.35	11	12.16	0.94
R300NW	2.78	10	9.85	3.04
Overall Avg.	3.04	10	12.91	1.52
Range	1.8 - 4.3	6 - 11	7.8 - 15.7	0.65 - 4.80

All samples had >50% fines, with the total fine fraction (silt and clay) ranging from 54 to 71%. There was no particular spatial pattern of grain size in the potential reference area that could be discerned from the grab sample data. The consistency of grain size was best demonstrated by the coefficient of variation (CV) values (variability around the mean) for the major components (>10%). The CVs were all within 20% except for the clay fraction (37%; Table 3-5).

3.5.3.2 Geochemistry Results

Total Organic Carbon (TOC) and Percent Solids. TOC values were very consistent among the WLIS SE-REF samples, ranging from 22,000 to 25,000 mg/kg (2.2 to 2.5%) with a CV of 4.5% (Table 3-6). The data suggest that there were no spatial patterns of organic carbon among the reference station grab samples. Percent solids data were slightly more variable (CV = 5.3%), with values ranging from 35 to 41%.

Polynuclear Aromatic Hydrocarbons (PAHs). The PAH composition of the WLIS SE-REF sediments was relatively consistent in all of the sediment samples, showing low concentrations of both high and low molecular weight PAHs (Table 3-7). In general, the dominant PAHs were pyrogenic (high molecular weight [HMW]), with the highest detected concentrations being fluoranthene, pyrene, and benzo(a)pyrene. The presence of detectable low molecular weight (LMW) PAHs indicated the possible presence of petroleum residues. The greatest variability of individual compounds (CV), ranging from 25 to 71%, occurred in a few samples that had the highest detected values of the compounds (Table 3-7). Stations GR-1, GR-5, GR-9, and GR-10 had the highest PAH concentrations for both HMW and LMW PAHs. Overall, however, the concentrations were lower than the mean reference value calculated from historical WLIS reference station data (Figure 3-14; Murray 1995). Normalizing the data to TOC resulted in a similar pattern between stations. These concentrations were also below the mean values measured in historical sampling. The spatial distribution of these detected PAHs showed no consistent pattern, and no direct relationship to the presence of dredged material as noted in side-scan and REMOTS® data.

Pesticides and Polychlorinated Biphenyls (PCBs). There were no pesticides or PCB arochlors detected at the WLIS SE-REF potential reference area (Table 3-8). Detection limits for pesticides ranged from <10 μg/kg for most compounds to 23-91 μg/kg for methoxychlor and toxaphene. Arochlor detection limits ranged from 46 to 91 μg/kg. The laboratory checked for potential negative bias of the data, and the lack of detected compounds was verified.

Table 3-5.
Grain Size Results for WLIS SE-REF Samples

WLIS Station Name	Gravel (%)	Sand (%)				Silt (%)	Clay (%)	Fine Fraction
		Coarse	Medium	Fine	Total			
GR-1	0.5	0.8	4.5	40	45.3	37.4	16.8	54.2
GR-2	0.2	1.6	2.9	40.5	45	32	22.8	54.8
GR-3	0	0.2	2.5	38.5	41.2	35.7	23.1	58.8
GR-4	0.1	1.4	2.2	38.3	41.9	42.1	15.9	58
GR-5	0.6	0.7	1	26.4	28.1	44.3	27	71.3
GR-6	0.4	1	2.8	37.7	41.5	38.2	19.9	58.1
GR-7	0	1.3	8.4	35.7	45.4	35.1	19.5	54.6
GR-8	0.1	1	1.4	35.4	37.8	34.6	27.5	62.1
GR-9	0	1.1	0.4	28	29.5	25.7	44.8	70.5
GR-10	0.4	2.1	2.9	29.9	34.9	48.9	16.5	65.4
Minimum	0.0	0.2	0.4	26.4	28.1	25.7	15.9	54.2
Maximum	0.6	2.1	8.4	40.5	45.4	48.9	44.8	71.3
Mean	0.2	1.1	2.9	35.0	39.1	37.4	23.4	60.8
Std Dev	0.2	0.5	2.3	5.1	6.4	6.5	8.6	6.4
CV (%) *				14.6	16.3	17.5	36.7	10.5

Coeficient of Variation calculated only for those components >10%.

Table 3-6.
Total Organic Carbon and Percent Solids Results for WLIS SE-REF Samples

WLIS Station Name	Total Organic Carbon (mg/kg)	Solids (%)
GR-1	25000	38.1
GR-2	24000	37.8
GR-3	22000	35.1
GR-4	23000	37.4
GR-5	23000	37.2
GR-6	24000	34.8
GR-7	23000	41.0
GR-8	25000	37.1
GR-9	25000	36.2
GR-10	23000	40.3
Minimum	22000	34.8
Maximum	25000	41.0
Mean	23700	37.5
Std Dev	1059	1.99
CV (%)	4.5	5.3

Table 3-7.

PAH Results for WLIS SE-REF Samples

WLIS Station Name: PAH Compound	GR-1	GR-2	GR-3	GR-4	GR-5	GR-6	GR-7	GR-8	GR-9	GR-10	Min	Max	Mean	Std Dev	CV (%)
Low Molecular Weight															
Naphthalene	32	10	7	21	29	14	24	6	28	37	6	37	21	11	53
2-Methylnaphthalene	23	6 J	11 U	12	21	8 J	14	11 U	18	24	6	24	14	7	54
Acenaphthylene	68	17	6 J	33	51	23	55	11 U	66	66	6	68	39	25	64
Acenaphthene	12	10 U	11 U	5 J	8 J	11 U	6 J	11 U	8 J	12	5	12	7	3	38
Fluorene	13	10	11	5	10	11	6	11	9	11	5	13	10	2	25
Phenanthrene	140	28	16	57	110	55	64	8	95	130	8	140	70	47	67
Anthracene	82	18	9 J	33	60	27	46	11 U	69	76	6	82	43	28	66
Sum of LMW PAHs	370	94	60	166	289	144	215	47	293	356	47	370	203	119	59
High Molecular Weight															
Fluoranthene	430	69	39	150	270	130	160	19	280	270	19	430	182	129	71
Pyrene	350	83	46	170	310	150	210	24	340	340	24	350	202	127	63
Benzo(a)anthracene	170	48	21	93	140	72	150	12	170	170	12	170	105	63	61
Chrysene	190	52	23	100	160	83	150	13	180	180	13	190	113	68	60
Benzo(b)fluoranthene	180	51	19	92	210	86	130	11	150	160	11	210	109	68	63
Benzo(k)fluoranthene	180	41	17	81	98	66	120	10	170	180	10	180	96	65	67
Benzo(a)pyrene	230	62	22	120	190	95	210	15	220	220	15	230	138	86	62
Dibenz[a,h]anthracene	31	9	5	16	28	13	26	11	34	34	5	34	21	11	53
Benzo[g,h,i]perylene	170	40	15	77	140	67	110	8	150	150	8	170	93	60	64
Indeno[1,2,3-cd]pyrene	190	46	16	85	160	75	130	9	170	170	9	190	105	68	64
Dibenzofuran	9	10	11	5	10	11	5	11	7	9	5	11	9	2	27
Sum of HMW PAHs	2130	511	234	989	1716	848	1401	143	1871	1883	143	2130	1173	728	62
Total PAHS	2500	605	294	1155	2005	992	1616	190	2164	2239	190	2500	1376	847	62

Units are ug/kg dry weight.

U = Below detection; one half of the reported detection limit was used for statistical calculations.

J = Estimated value, full reported value was used for statistical calculations.

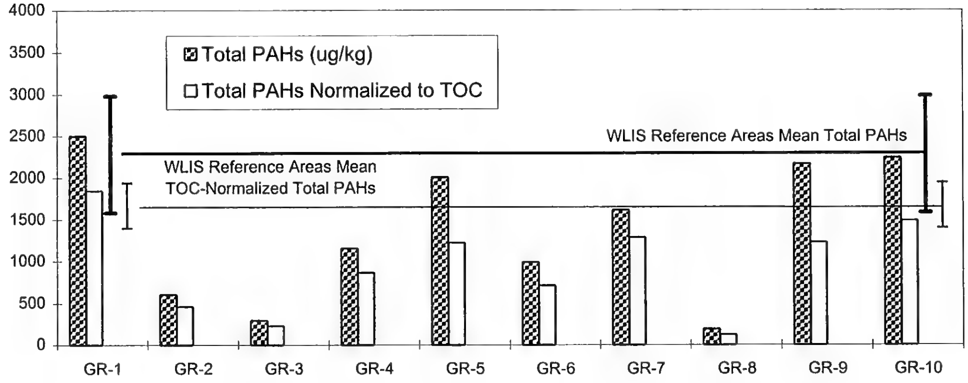


Figure 3-14. Grab sample concentrations of total PAHs and normalized PAHs

Table 3-8.

Pesticide and PCB Results for WLIS SE-REF Samples

WLIS Station Name: Pesticides/PCBs	GR-1	GR-2	GR-3	GR-4	GR-5	GR-6	GR-7	GR-8	GR-9	GR-10
Pesticides										
4,4'-DDD	<5.2	<5.1	<5.5	<5.3	<5.2	<5.5	<4.6	<5.4	<9.1	<4.8
4,4'-DDE	<5.2	<5.1	<5.5	<5.3	<5.2	<5.5	<4.6	<5.4	<9.1	<4.8
4,4'-DDT	<5.2	<5.1	<5.5	<5.3	<5.2	<5.5	<4.6	<5.4	<9.1	<4.8
Aldrin	<2.6	<2.6	<2.8	<2.6	<2.6	<2.8	<2.3	<2.7	<4.6	<2.4
Alpha-BHC	<2.6	<2.6	<2.8	<2.6	<2.6	<2.8	<2.3	<2.7	<4.6	<2.4
Alpha Chlordane	<2.6	<2.6	<2.8	<2.6	<2.6	<2.8	<2.3	<2.7	<4.6	<2.4
Beta-BHC	<2.6	<2.6	<2.8	<2.6	<2.6	<2.8	<2.3	<2.7	<4.6	<2.4
Delta-BHC	<2.6	<2.6	<2.8	<2.6	<2.6	<2.8	<2.3	<2.7	<4.6	<2.4
Dieldrin	<5.2	<5.1	<5.5	<5.3	<5.2	<5.5	<4.6	<5.4	<9.1	<4.8
Endosulfan I	<2.6	<2.6	<2.8	<2.6	<2.6	<2.8	<2.3	<2.7	<4.6	<2.4
Endosulfan II	<5.2	<5.1	<5.5	<5.3	<5.2	<5.5	<4.6	<5.4	<9.1	<4.8
Endosulfan Sulfate	<5.2	<5.1	<5.5	<5.3	<5.2	<5.5	<4.6	<5.4	<9.1	<4.8
Endrin	<5.2	<5.1	<5.5	<5.3	<5.2	<5.5	<4.6	<5.4	<9.1	<4.8
Endrin Aldehyde	<5.2	<5.1	<5.5	<5.3	<5.2	<5.5	<4.6	<5.4	<9.1	<4.8
Endrin Ketone	<5.2	<5.1	<5.5	<5.3	<5.2	<5.5	<4.6	<5.4	<9.1	<4.8
Gamma-BHC	<2.6	<2.6	<2.8	<2.6	<2.6	<2.8	<2.3	<2.7	<4.6	<2.4
Gamma Chlordane	<2.6	<2.6	<2.8	<2.6	<2.6	<2.8	<2.3	<2.7	<4.6	<2.4
Heptachlor	<2.6	<2.6	<2.8	<2.6	<2.6	<2.8	<2.3	<2.7	<4.6	<2.4
Heptachlor Epoxide	<2.6	<2.6	<2.8	<2.6	<2.6	<2.8	<2.3	<2.7	<4.6	<2.4
Methoxychlor	<26	<26	<28	<26	<26	<28	<23	<27	<46	<24
Toxaphene	<52	<51	<55	<53	<52	<55	<46	<54	<91	<48
PCB Aroclors										
Aroclor 1016	<52	<51	<55	<53	<52	<55	<46	<54	<91	<48
Aroclor 1221	<52	<51	<55	<53	<52	<55	<46	<54	<91	<48
Aroclor 1232	<52	<51	<55	<53	<52	<55	<46	<54	<91	<48
Aroclor 1242	<52	<51	<55	<53	<52	<55	<46	<54	<91	<48
Aroclor 1248	<52	<51	<55	<53	<52	<55	<46	<54	<91	<48
Aroclor 1254	<52	<51	<55	<53	<52	<55	<46	<54	<91	<48
Aroclor 1260	<52	<51	<55	<53	<52	<55	<46	<54	<91	<48

Units are ug/kg dry weight.

Metals. Metal concentrations were exceedingly consistent among the ten SE-REF samples, with CV values all <10% except for Cd (15%; Table 3-9). All metals were reported above instrument detection limits in all samples. Station GR-1 had the highest concentrations of Cd, Cr, Cu, Pb, and Zn, but there was no consistent pattern of metal concentrations among any of the other stations.

The mean metal values were compared with historical reference values compiled from other WLIS reference areas (Murray 1995). The mean values measured in the SE-REF stations were higher than all mean values reported for the historical data (Table 3-9). Cadmium, Pb, Ni, and Zn were within one standard deviation of the historical mean, while the remaining metals (As, Cr, Cu, and Hg) were all within two standard deviations. The 95% confidence levels for SE-REF stations and the WLIS Reference Area dataset were compared (Figure 3-15). The 95% confidence intervals were determined by multiplying the standard deviation of the SE-REF dataset ($n=10$) by 2.26 and of the WLIS-REF dataset ($n>20$) by 1.96 (Mendenhall 1979). The overlapping intervals for each metal indicates no significant statistical difference between the potential reference area and the compiled reference area dataset.

Metals were also evaluated normalized to the fine-grained fraction (Table 3-10). The normalized metals data were overall more variable than the metals data, with CVs ranging from 5 to 22%. All of the normalized metal mean values were within two standard deviations of the WLIS compiled reference area normalized mean, and the mean values for Cd, Ni, and Zn were within one standard deviation. Metals also were normalized to Al, resulting in similar ranges and CVs as the data normalized to fine grain size.

Table 3-9.

Metals Results for WLIS SE-REF Samples

Parameter: WLIS Station Name	Aluminum	Arsenic	Cadmium	Chromium	Copper	Lead	Mercury	Nickel	Zinc
GR-1	19000	8.8	0.94	69	87	59	0.36	26	180
GR-2	21000	8.6	0.78	61	73	48	0.30	24	160
GR-3	19000	7.4	0.63	62	76	51	0.32	24	160
GR-4	21000	8.2	0.71	64	77	51	0.33	25	170
GR-5	22000	7.6	0.68	67	79	57	0.31	26	170
GR-6	21000	7.5	0.69	68	81	57	0.34	28	180
GR-7	20000	8.6	0.70	64	86	51	0.39	24	160
GR-8	20000	8.9	0.61	60	75	48	0.37	23	160
GR-9	21000	9.1	0.59	62	74	51	0.33	25	160
GR-10	21000	7.8	0.75	62	74	47	0.32	24	160
Minimum	19000	7.4	0.59	60	73	47	0.31	23	160
Maximum	22000	9.1	0.94	69	87	59	0.39	28	180
Mean	20500	8.3	0.71	64	78	52	0.34	25	166
Std Dev	972	0.63	0.107	3.11	5.01	4.22	0.027	1.45	8.43
CV (%)	4.7	7.7	15.1	4.9	6.4	8.1	7.8	5.8	5.1

WLIS Reference Area Values*									
Mean		5.9	0.6	43.4	56.3	41.4	0.199	21.9	141
Std Dev		2.1	0.28	12	17.4	15.6	0.096	7.8	28
Mean + 1 Std Dev		8.0	0.88	55.4	73.7	57	0.295	29.7	169
Mean + 2 Std Dev		10.1	1.16	67.4	91.1	72.6	0.391	37.5	197

Units are mg/kg dry weight, except for total solids (%).

*Murray 1995

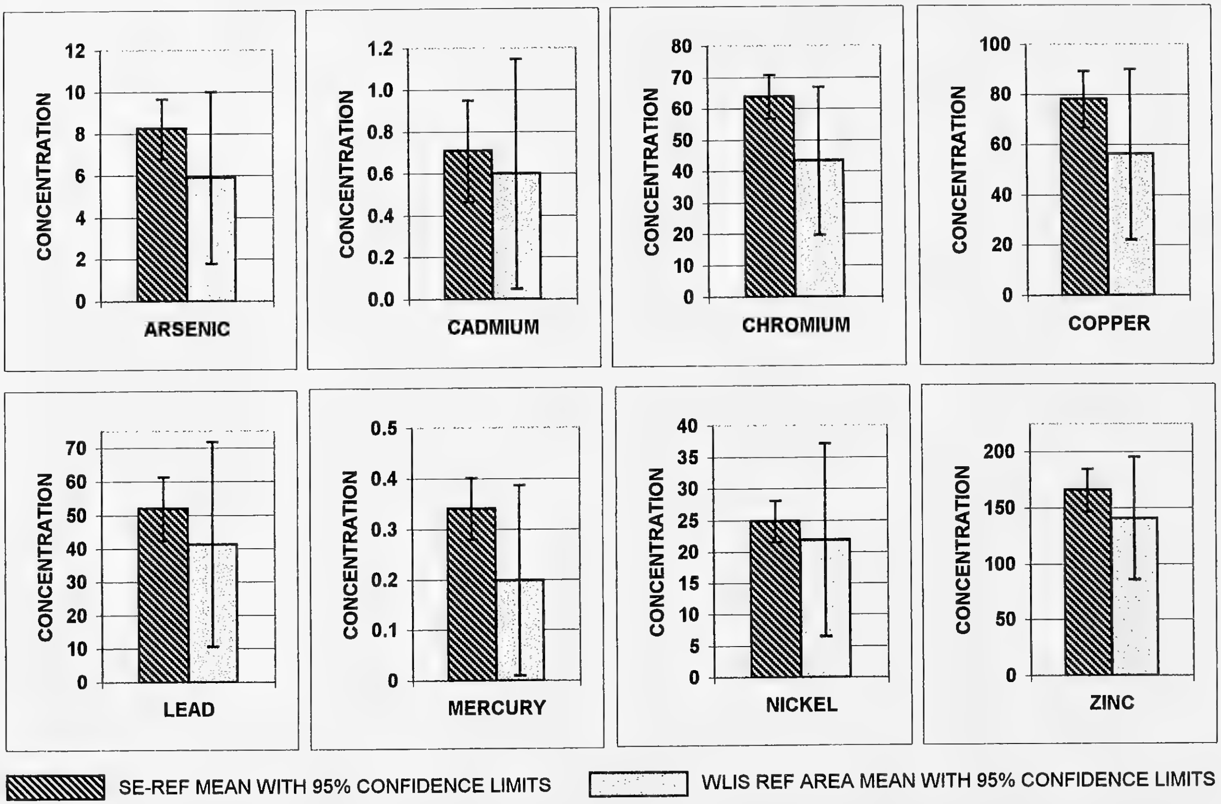


Figure 3-15. SE-REF and WLIS Reference Area (Murray 1995) mean metal concentrations (ppm). Comparison of the 95% confidence levels indicates no significant statistical difference between SE-REF and the WLIS reference area dataset.

Table 3-10
Results of Metals Normalized to Fine Grain Size for WLIS SE-REF Samples

Parameter: WLIS Station Name	Aluminum	Arsenic	Cadmium	Chromium	Copper	Lead	Mercury	Nickel	Zinc
GR-1	19000	0.16	0.017	1.27	1.61	1.09	0.0066	0.48	3.32
GR-2	21000	0.16	0.014	1.11	1.33	0.88	0.0055	0.44	2.92
GR-3	19000	0.13	0.011	1.05	1.29	0.87	0.0054	0.41	2.72
GR-4	21000	0.14	0.012	1.10	1.33	0.88	0.0057	0.43	2.93
GR-5	22000	0.11	0.010	0.94	1.11	0.80	0.0043	0.36	2.38
GR-6	21000	0.13	0.012	1.17	1.39	0.98	0.0059	0.48	3.10
GR-7	20000	0.16	0.013	1.17	1.58	0.93	0.0071	0.44	2.93
GR-8	20000	0.14	0.010	0.97	1.21	0.77	0.0060	0.37	2.58
GR-9	21000	0.13	0.008	0.88	1.05	0.72	0.0047	0.35	2.27
GR-10	21000	0.12	0.011	0.95	1.13	0.72	0.0049	0.37	2.45
Minimum	19000	0.11	0.008	0.88	1.05	0.72	0.0043	0.35	2.27
Maximum	22000	0.16	0.017	1.27	1.61	1.09	0.0071	0.48	3.32
Mean	20500	0.14	0.012	1.06	1.30	0.86	0.0056	0.41	2.76
Std Dev	972	0.02	0.003	0.13	0.19	0.12	0.0009	0.05	0.34
CV (%)	4.7	13.3	21.8	11.9	14.4	13.5	15.3	11.6	12.2

WLIS Reference Area Values*									
Mean		0.10	0.011	0.76	0.98	0.65	0.0034	0.39	2.22
Std Dev		0.02	0.007	0.21	0.26	0.15	0.0014	0.10	0.56
Mean + 1 Std Dev		0.12	0.018	0.97	1.24	0.80	0.0048	0.49	2.78
Mean + 2 Std Dev		0.14	0.025	1.18	1.5	0.95	0.0062	0.59	3.34

*Murray 1995

4.0 DISCUSSION

The first two major objectives of the 1997–98 survey at WLIS were to document the changes in bottom topography of the disposal site relative to July 1996, and assess the benthic recolonization status of the new I mound and the 1996 H mound relative to two reference areas, SOUTH and SW-REF (Section 4.1). The I and H mounds were surveyed in both September 1997 and March 1998 to evaluate the response of the benthic community, and observe changes in seasonal conditions.

The third major objective was to identify a new potential reference area near WLIS to replace 2000W (Section 4.2). The sediments at the new proposed reference area, SE-REF, were characterized through a REMOTS® survey and grab sampling. Although a few images from the side-scan and REMOTS® surveys suggested possible historic dredged material within SE-REF boundaries, the overall side-scan and REMOTS® survey data and geochemical analysis of grab samples indicated ambient sediments with acceptable, low concentrations of contaminants of concern for a reference area.

4.1 Dredged Material Monitoring at Mounds H and I

4.1.1 Development of Contaminant Cells

The I mound was formed during the most recent disposal activities at WLIS, over the disposal location between the D and G mounds. This disposal location was selected to add to a ring of disposal mounds forming a containment berm. These berms can create basins for minimizing the spread of disposed sediments to optimize capping or isolation of dredged sediments and maximizing volume capacity (Figure 4-1).

To continue the formation of containment berms, dredged material may be placed to the south of the G mound (1), between E and H mounds (2), and between C and E mounds (3) in the future. Figure 4-1 shows a three-dimensional view of the mounds and containment basins. A very large basin area could be created with the additional placement of disposal mounds to the west of the survey area at locations 4, 5, and 6. The 1996 survey report also suggests another containment possibility in the depression just east of the F mound. The containment berm would include the natural ridge of the Long Island Sound moraine margin and the H and F mounds plus two disposal mounds between the H mound and the naturally occurring ridge to the south (Morris 1998).

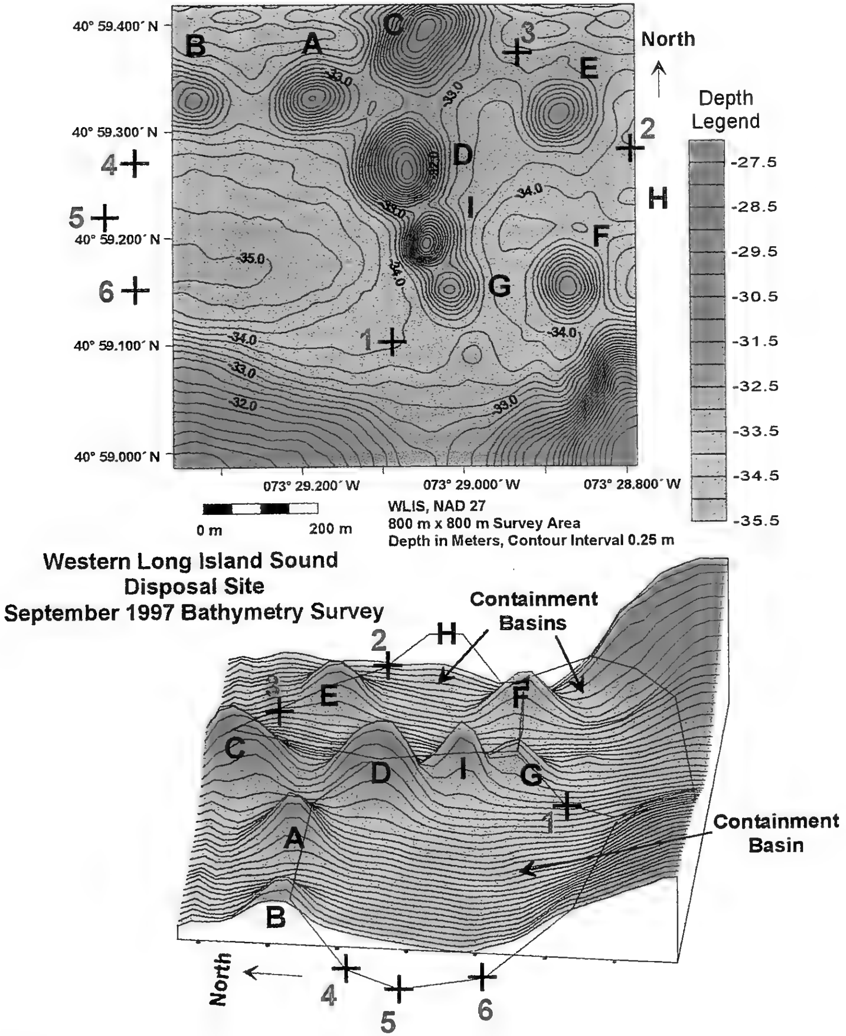


Figure 4-1. Bathymetric chart and three-dimensional view of the 1997 survey area with recommended disposal locations to complete potential containment basins. Note the change in perspective.

Table 4-1.

Navigation Positions of Future Disposal Mounds

Approximate Location		Longitude, NAD 27	Latitude, NAD 27
South of the G mound	1	073° 29.088′ W	40° 59.100′ N
C-E	2	073° 28.794′ W	40° 59.280′ N
E-H	3	073° 28.932′ W	40° 59.376′ N
West of survey area	4	073° 29.406′ W	40° 59.274′ N
	5	073° 29.442′ W	40° 59.220′ N
	6	073° 29.406′ W	40° 59.154′ N

4.1.2 Dissolved Oxygen in Western Long Island Sound

Since 1985, hypoxia (low dissolved oxygen conditions) and its associated complications with benthic recolonization have been documented in DAMOS monitoring reports of WLIS (Morris 1998, SAIC 1987). Because of these complications in the summer, the monitoring survey was scheduled for late-September after the fall turnover of the water column. The western half of the Sound becomes hypoxic in the late summer, with dissolved oxygen falling below 1 mg· l^{-1} and, in specific regions, to 0.0 mg·l^{-1} (CT DEP 1997). Hypoxia is a direct result of eutrophication, the excessive nutrient loading and organic matter enrichment of the estuarine waters of Long Island Sound. The increased input of nitrogen concentrations from terrestrial sources results in artificially abundant phytoplanktonic populations. As the excessive organic matter settles and decomposes on the seafloor, the greatest depletion of oxygen occurs in the bottom waters, which may become anoxic at depth. The problem is exacerbated in the late summer by the stratification of the Sound waters into two separate layers, with a warm layer over cool, denser waters. Because limited mixing occurs, the bottom waters do not become reoxygenated by photosynthesis and wave action which supply oxygen to the surface waters.

The Long Island Sound Study (LISS), a U.S. Environmental Protection Agency (EPA) management program, officially recognizes the onset of hypoxia at DO concentrations below 3.0 mg l^{-1} (LISS 1990, CT DEP 1997). In experimental tests, DO concentrations at 5.0 mg l^{-1} or greater had few adverse effects on marine life (LISS 1990). Concentrations of DO below 5.0 mg l^{-1} have been shown to reduce survival of some planktonic larvae and growth of a variety of organisms, and DO concentrations below 3.0 mg l^{-1} tend to have more severe effects on marine life.

Bottom dissolved oxygen concentrations are measured by the Connecticut Department of Environmental Protection (CTDEP) Bureau of Water Management (Figure 4-2). The data were collected as part of the LISS Summer Hypoxia Monitoring Program and consisted of surface and bottom water DO values for eighteen primary stations throughout 1997 and 1998, and a number of secondary summer/fall stations (July to October). Annual stations C2 and D3 and seasonal monitoring stations 5, 8, and 9 were selected for their proximity to WLIS (Figure 4-2). Both surface and bottom waters were tested at each station. Because the bottom water concentrations were measured approximately 5 meters above the actual substrate, the dissolved oxygen in the water near the sediment surface is most likely lower than the observed values.

In 1997, the dissolved oxygen conditions did not drop as low as reported in previous years during the late summer months. Although the oxygen concentrations decreased sharply from June 4 to June 27, the levels did not fall below 3.6 mg l^{-1} during the summer or fall. However, recovery was slower in September 1997 than in 1996 due to warmer temperatures. During the September survey, the overlying bottom waters at stations 5 and 8 had DO levels of 4.6 mg l^{-1}. The dissolved oxygen increased from 7.8 to 10.8 mg l^{-1} over the winter months and peaked in March at 11.1 mg l^{-1}, during the second survey time (Figure 4-2). Although the overlying bottom waters did not become hypoxic, the water near the sediment interface may have been so in certain regions.

4.1.3 Hypoxia and Seasonal Effects on Benthic Community Parameters

Seasonal changes affect the environmental conditions of the seafloor observed in the REMOTS® surveys. We observed shallower RPD and lower OSI values at SW-REF in September 1997 relative to July 1996, indicating that the reference area was affected by the late summer hypoxia. Although the stations at reference area SOUTH in late September 1997 had OSI values and RPD depths similar to the July 1996 stations, the numbers were comparable to SW-REF (Table 3-3).

Figures 4-3 and 4-4 show replicates from South and SW-REF, respectively, that are representative of the variability among replicates in each area. Two of the eighteen replicates at South did have deeper RPDs than South 2A which contributed to deeper average RPD depth. As the temperature of the air and water decreases in the fall and into the winter, mixing of the stratified layers of the Sound occurs and dissolved oxygen concentrations increase (Figure 4-2). Surveys over the I and H mound indicated greater RPD depths and improved conditions in March relative to September.

Water temperature is directly correlated with the metabolic activity of benthic organisms. Seasonal changes in bottom sediment temperature were recorded at a central

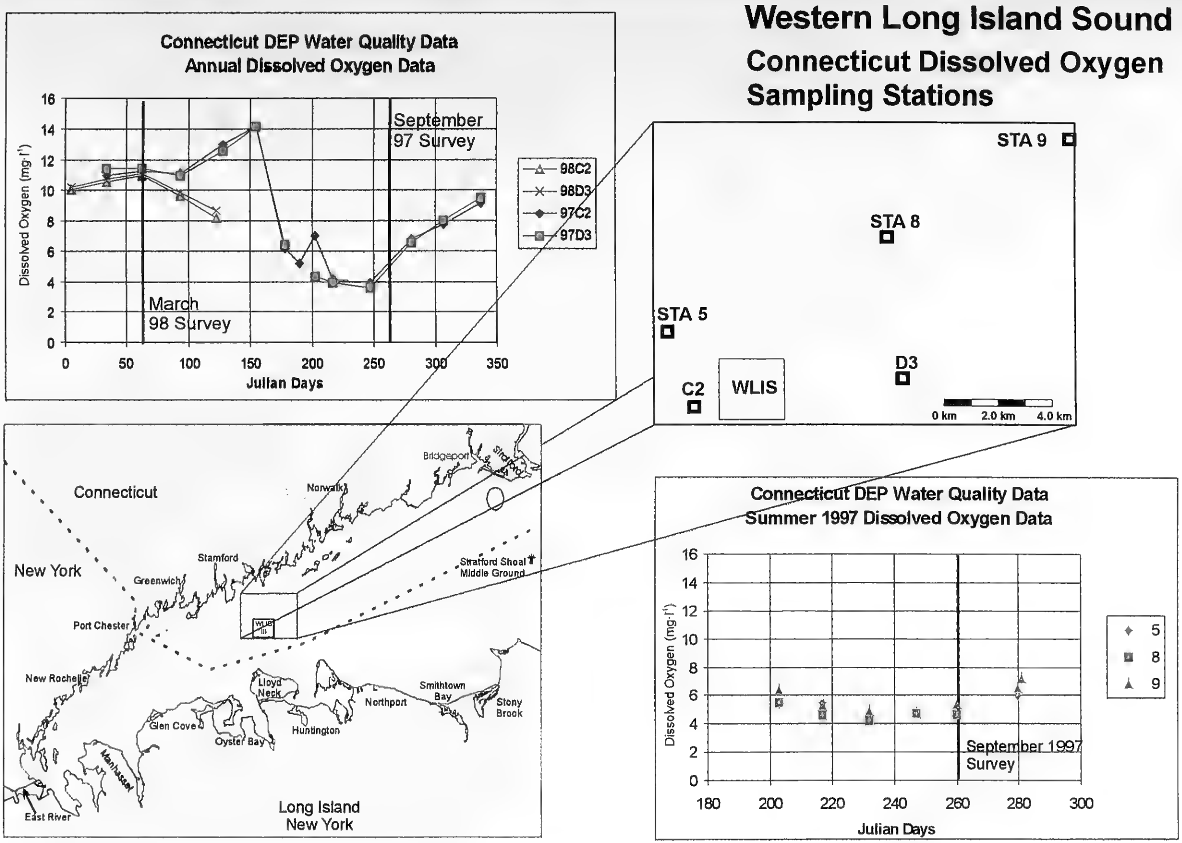


Figure 4-2. Position of the Connecticut Department of Environmental Protection Dissolved Oxygen Sampling Stations and bottom DO trends at annual and seasonal monitoring stations

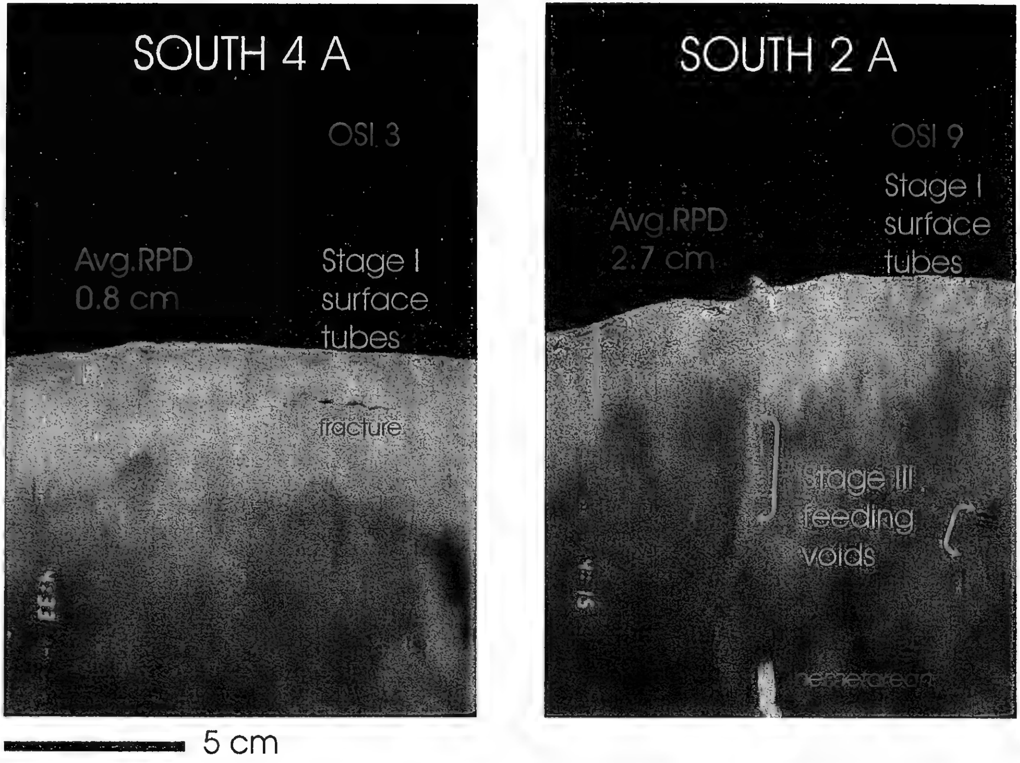


Figure 4-3. REMOTS® replicates from the September 1997 survey at SOUTH showing variability in benthic conditions in the reference area

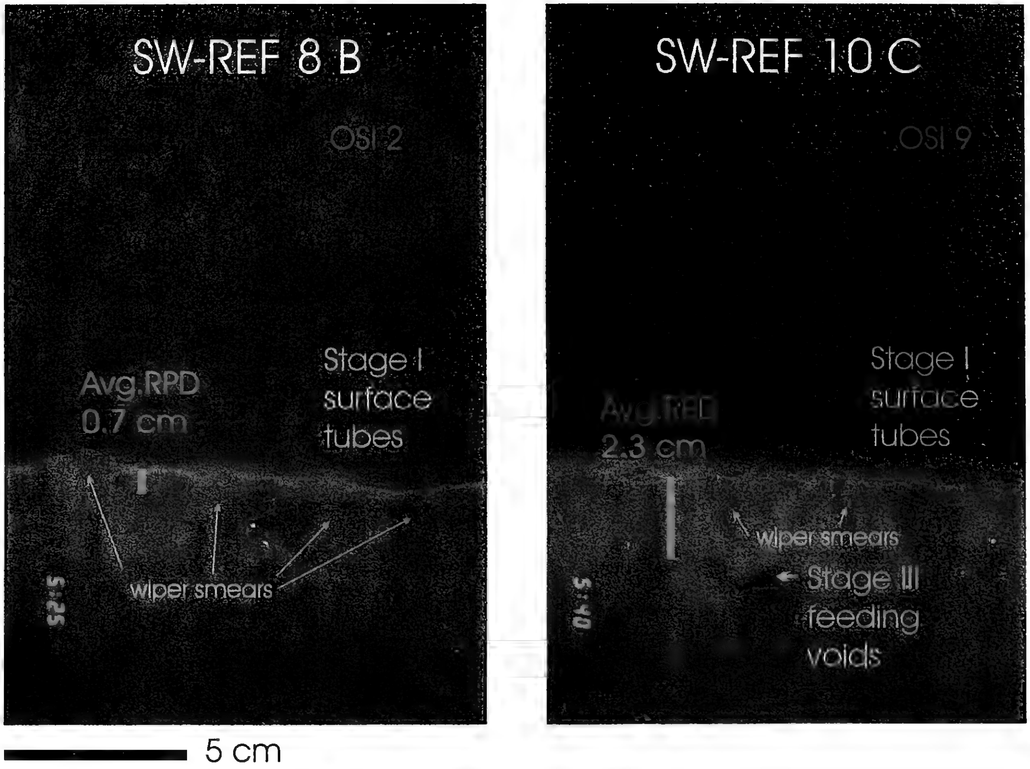


Figure 4-4. REMOTS® replicates from the September 1997 survey at SW-REF showing variability in benthic conditions in the reference area

LIS location from July 1974 to January 1976, with the highest temperatures (about 22° C) in late August and lowest (about 3° C) in March (Rhoads and Boyer 1982). Therefore, metabolic activities, such as bioturbation and decomposition, were expected to be noticeably greater in September than March. Greater bioturbation would suggest greater oxygenation of the sediment and redox layer. However, the decomposition of organic matter, which increases both the chemical and biological oxygen demands, also occurs at a faster rate in warmer waters. The cause and effect relationships of RPDs, metabolic rates, and dissolved oxygen conditions of the waters are complex (Rhoads and Germano 1982). Stage I species, which are known to die off in the cooler waters in the winter and then rapidly reproduce and recolonize in the spring, were less common in March than in September.

Redox rebounds observed at the disposal mounds represent retrograde conditions caused by decreases in pore water irrigation by benthos and/or higher rates of oxygen consumption at depth. The depth of the RPD decreases and rebounds upwards. The rebound tends to be a result of seasonal changes in water temperature, metabolic rates, and chemical reaction rates. For instance, when organic matter settles on the seafloor and begins decomposing, the oxygen demand of the sediments increases, decreasing the RPD. The organic matter attracts pioneering Stage I organisms which are filter feeders that are not effective at exchanging pore water with surface water and are associated with shallow RPD depths (Rhoads and Germano 1982).

Redox rebounds were visible in both September and March at the H mound, and to a lesser extent at the I mound and the potential reference area, SE-REF (Figures 4-5 and 4-6). Replicate H100NA shows the spatial variability of redox rebound. Because redox rebounds were not visible in photographs of ambient sediments from SOUTH or SW-REF in September, the higher organic matter concentration of the dredged sediments most likely has contributed to the redox rebounds at the disposal mounds. In March, decreased metabolic rates primarily account for the redox rebounds at the disposal mounds and at SE-REF

Redox rebounds at times appeared similar to relic RPDs. For a few replicates, the measured redox rebound actually represents the depth of the relic RPD. Both redox rebounds and relic RPDs are characterized by a lighter band of sediment, with a higher reflectance than the surrounding sediments, in the middle or lower section of the image (Rhoads and Germano 1990). A relic RPD as observed in I 150EA (Figure 4-6), occurs when a relatively thin layer of dredged material is placed over the ambient sediments and represents the former ambient RPD. A new RPD will be formed at the sediment surface. The thickness of the recently deposited dredged material can be measured from the surface to the top of the relic RPD. The appearance of layered dredged material also results from multiple barge load disposals during the same season such as detected in H50NA in

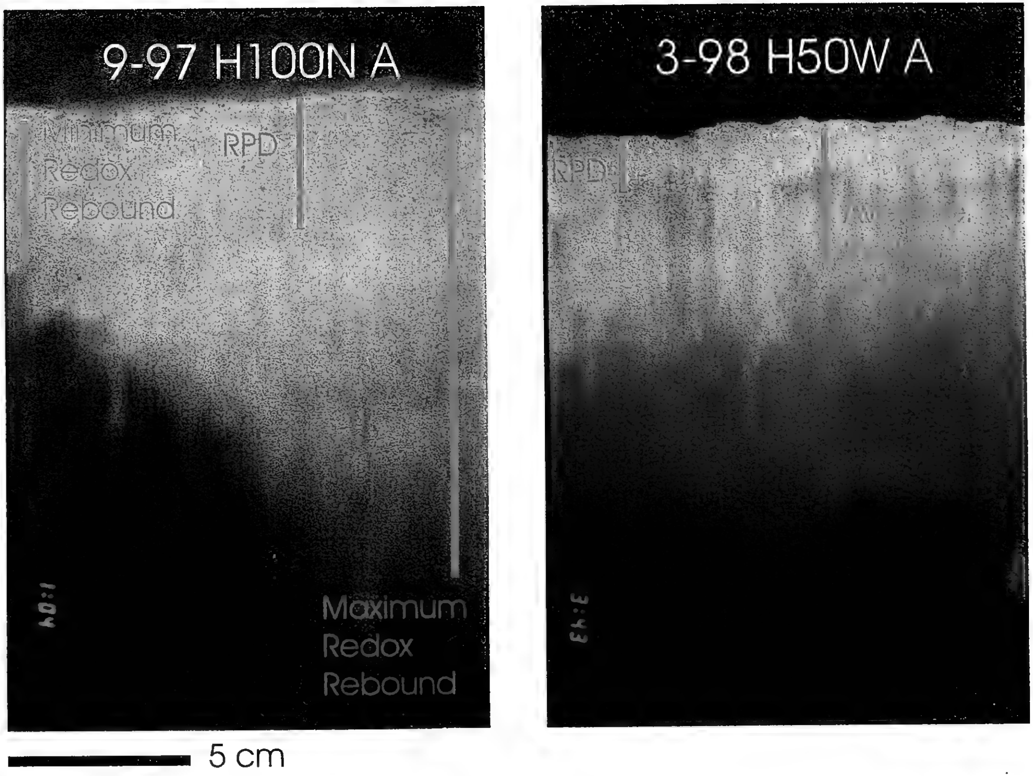


Figure 4-5. REMOTS® replicates over the H mound with redox rebounds. H100NA from September shows a highly variable redox rebound and deep RPD. H50WA shows a shallower RPD and more consistent redox rebound.

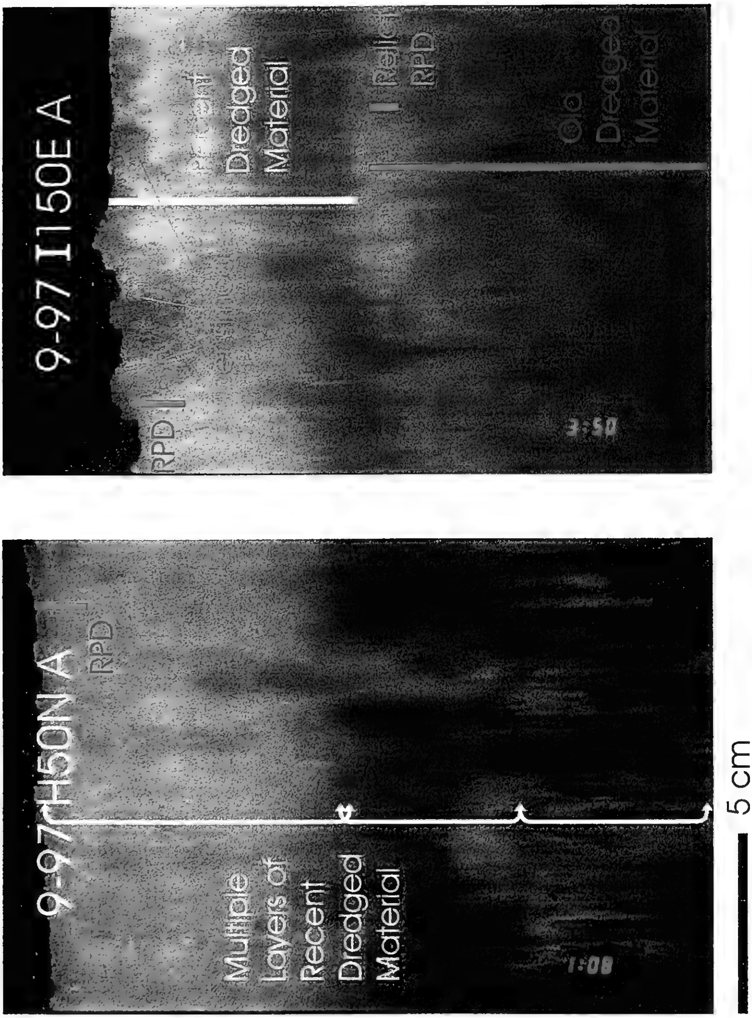


Figure 4-6. REMOTS® replicates H50NA showing multiple layers of recently disposed dredged material in contrast to I150EA showing recently disposed dredged material over old dredged material

September (Figure 4-6). The slides were reanalyzed in some cases to determine whether images indicated redox rebounds, relic RPDs, or dredged material layering due to multiple disposals of barge loads at the buoy location during one disposal season.

4.1.4 Summary of Benthic Conditions at H and I Mounds

The H mound has been successfully recolonized supporting a benthic community with an advanced successional status. Formed during the 1995-1996 disposal season, the H mound was observed in the 1996 REMOTS® survey to have a solid Stage I pioneering polychaete community with some evidence of Stage III activity. Stage II activity is not typical in the western Long Island Sound region. In the September 1997 REMOTS® survey, we again observed a predominance of Stage I surface tube dwellers with an increase in the number of replicates with Stage III feeding voids. However, the RPDs were decreased from the July survey. By March 1998, feeding voids were apparent in almost every replicate indicating a healthy Stage III community over the H mound. Deposit feeders are known to survive over the winter months, whereas shallow-living organisms have a higher mortality in the winter months (Rhoads et al. 1977). Although Stage I organisms were present in March, they were less abundant. Layering of dredged material disposed during the 1995-1996 disposal season was apparent in many images. Redox rebounds were less apparent and shallower in March than September. Because metabolic rates are depressed in the colder winter months, the correlated depth of oxidation tends to decrease. However, the RPD depths were greater in March, which indicates that the sediments were affected by hypoxia in September. Decomposition of organic matter is greater in the summer and increases the sediment oxygen demand, whereas oxygen is controlled by physical diffusional processes in the winter.

The I mound, created during the 1996–97 disposal season, also indicated improved conditions from September to March. However, the changes were less dramatic when only the 5-grid stations were compared. RPD depths and OSI values were lower in the outside stations which were notably at greater water depths. The successional status in September was advanced for a recently deposited mound and continued to indicate a healthy recovery in March. Figure 4-7 shows a lobster living at 150W and shrimp at 50S B on the disposal mound.

Although the I mound, the most recent deposit at WLIS, has not been placed directly over an isolated problem area identified in the 1996 report, the apron of the mound likely covers this region. Concern had been expressed over the slow recolonization rates at Station D200S, to the east of the G mound, apparently due to low dissolved oxygen conditions. I mound stations, 50W and 50S, close to D200S, indicated favorable benthic conditions during both September and March surveys.

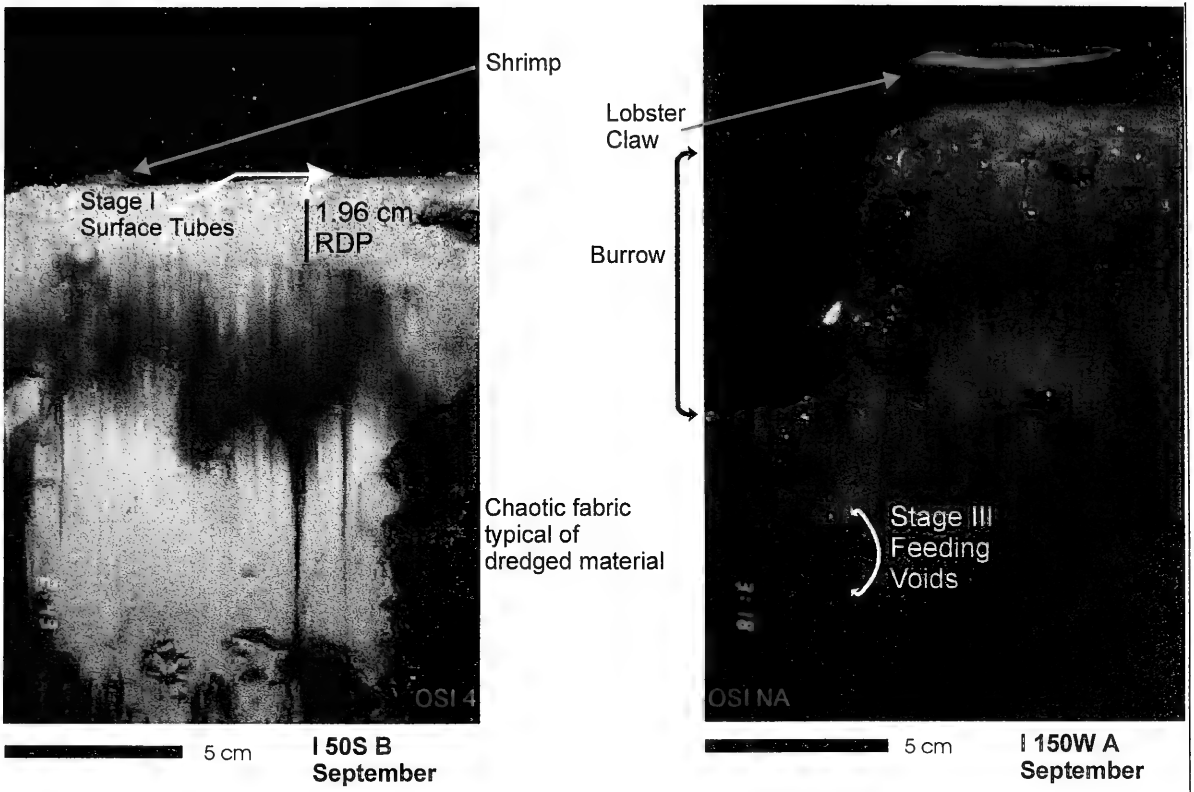


Figure 4-7. September 1997 REMOTS® photographs at the I mound showing healthy benthic conditions for a recently disposed dredged material mound with a shrimp and lobster living on the bottom sediments

4.2 New Reference Area Investigation at SE-REF

Reference areas are necessary for assessing the environmental impacts of dredged material disposal and for classifying the suitability of dredged material for disposal through the permit evaluation process. Selection of a reference area is based on proximity to the disposal site, sediment chemistry, and similar water depths and grain size (EPA and USACE 1991). Reference sediments should be representative of ambient conditions and free of historic dredged material or other unnatural contamination or disturbances (EPA and USACE 1997). Reference areas provide a control region of ambient conditions for comparison with results of sediment-profile photography and geochemistry analyses at the disposal mounds.

Disposal operations before 1977 occurred throughout Long Island Sound both in the historic disposal sites and the surrounding regions. From 1954 to 1972, an estimated total of 22 million cubic yards of dredged material was disposed at eight sites in western Long Island Sound, with sixty percent (13.2 million cubic yards) at Eaton's Neck which is close to WLIS (Fredette et al. 1993). Since 1983, dredged material disposal has been directed to positioned buoys in the southwestern quadrant of WLIS and has been carefully monitored and managed.

During monitoring surveys, the benthic conditions at disposal mounds are compared to observations of ambient sediments at reference areas. Although three reference areas are required according to DAMOS protocol, only two reference areas, SOUTH and SW-REF, currently qualify to represent ambient conditions. 2000W was the latest reference area to be discontinued due to the detection of historic dredged material in many REMOTS® replicates during monitoring surveys (Morris 1998). Low DO conditions and methane bubbles were observed in the area both in 1992 and 1996. Figure 1-2 displays the location of 2000W, which is within the boundaries of the historic Stamford Disposal Site, in addition to five other discontinued reference areas relative to WLIS. All six have been abandoned due to the clear evidence of dredged material. In addition, REMOTS® data collected randomly to the north and east of WLIS indicated that historic dredged material was widespread throughout these regions (Eller and Williams 1996). Therefore, all of the regions surrounding WLIS, except the southeast, have been investigated prior to this report and historic dredged material has been detected in every direction.

To replace 2000W, we investigated the southeast region and identified a potential reference area, SE-REF. We characterized the sediments using multiple survey techniques, including: side-scan sonar, REMOTS® sediment-profile photography, and sediment grab sampling with geochemical and grain size analyses.

The survey data collected over SE-REF indicated fine-grained, ambient sediments that tended to have a high sulfide content. The side-scan images show even, weak to moderate backscatter for the area, similar to USGS side-scan results for the region. The USGS characterized the area as a combination of reworking and sorting and fine-grained sediment deposition environment (Knebel et al. 1998). The sediment grab samples all appeared to be very similar in composition and indicated uniform ambient conditions characteristic of fine-grained sediment deposition environments. Below the thin oxidized surface layer, the sediments were dark and had a sulfidic odor. Overall, the grab samples corresponded to REMOTS® photographs from the area. Grain size analysis showed that silts and clays were predominant in all grab samples similar to observations of grain size in REMOTS® photographs. REMOTS® results indicated deep RPDs, Stage III successional status, and high OSI values such as seen in 100N D (Figure 3-13). However, the sediments tended to be very dark with low reflectance values relative to typical conditions at reference areas such as SOUTH and SW-REF. Although some replicates did show lighter sediments that were less sulfidic, the dark sediments found throughout SE-REF might be characteristic of the western Long Island Sound ambient sediments.

The mean water depth at SE-REF was 19.5 m, which is shallower than the average depth at WLIS. Water depths ranged from 27 m to 35 m in the latest bathymetric survey over the disposal mounds in the southeast quadrant of WLIS. The survey data over the area of SE-REF indicated that the area was free of distinct topographic features or steep slopes, although both are present just south of SE-REF. Although the water depth was shallower at SE-REF relative to WLIS, the relief appeared to be acceptable for a reference area.

Consistent concentrations of the tested metals and organics were measured in the sediment grab samples. No pesticides or PCBs were detected. The PAHs were at or below the mean historic reference area values for WLIS (Figure 3-14). The low but slightly variable PAH levels had a patchy spatial distribution that did not correlate with location. The metals values were higher than the standard reference area data for WLIS, but were within one to two standard deviations of the mean values. Figure 3-15 shows overlapping 95% confidence levels for SE-REF and the WLIS Reference Area datasets and no significant statistical difference. The fine-grained sediments, such as those at SE-REF, have a large surface area that attracts and accumulates trace metals (Horowitz 1985). In addition, the sediments have high reduced iron and sulfide concentrations indicated by the dark appearance of the sediments. Both iron hydroxide and organic matter have large surface areas that easily collect trace metals and are chemically reactive. Because Long Island Sound is surrounded by intensely urbanized areas and has a large drainage basin, contaminants from many point and non-point sources enter the waters of the Sound and settle in the bottom sediments of depositional environments and may be characteristic of the current ambient sediments (Turgeon et al. 1989). No samples had anomalous values typical of dredged material deposits for any of the geochemical analyses.

Although some survey data suggested the possibility of historic dredged material within the 300 m radius of SE-REF, the evidence was rather ambiguous. Some possible weathered dredged material was identified in the southwest section of SE-REF in the side-scan sonograph (Figure 3-9). The mottled relief with no definite shadows typical of rocks or boulders may represent disposed dredged material that has been on the seafloor for a long time. This marked area could also be attributed to remaining glacial debris or exposed bedrock associated with the small knoll feature on the southern flank of the reference area. If this is the case, the presence of the knoll and glacial debris may indicate winnowing in the southwest section.

REMOTS® stations 300N, 300SE, 100S, 200S, and 200SW indicated possible dredged material in a few replicates. Replicate C at 300NW was indeterminate because the surface was disturbed by either a large burrow or camera penetration, or possibly both. Replicate 100S C had a mottled sediment profile which provided the most convincing indication of dredged material for REMOTS® photographs (Figure 4-8). Replicates A and C at 300SE and B at 300N had high boundary roughness values and dark sediments with very shallow RPD depths. Replicate C at 200SW also was very sulfidic and had a thin RPD layer (Figure 3-13). However, as mentioned previously, sulfidic sediments are characteristic of the western Long Island Sound region. The high boundary roughness values are most likely due to recent physical disturbances at the sediment-water interface (i.e., trawling, dragging of lobster gear across the bottom, etc.). Abundant lobster gear in the area was observed in both September and March and is visible in the side-scan survey images at SE-REF. Because fishing practices, such as lobstering, that affect the bottom sediments are intensive at WLIS and the surrounding regions, some unnatural disturbances of the substrate are expected at all reference areas that are within close proximity to WLIS.

In summary, the recent survey data indicated that SE-REF meets sufficient reference area requirements to replace 2000W as the third reference area for WLIS. SE-REF is within 1500 m of the WLIS boundary and appeared to have a moderate topographic relief. The fine-grained sediments, primarily composed of fine sand, silt, and clay, were similar to observations of grain size at WLIS and the previous reference areas. Due to the widespread distribution of dredged material in the region, it is unlikely that a reference area with a complete lack of evidence of dredged material will be found. Although the side-scan and REMOTS® detected possible historic dredged material, the evidence was equivocal. No methane bubbles, such as those seen in many replicates showing sulfidic dredged material at 2000W, were present at SE-REF. All ten grab samples indicated

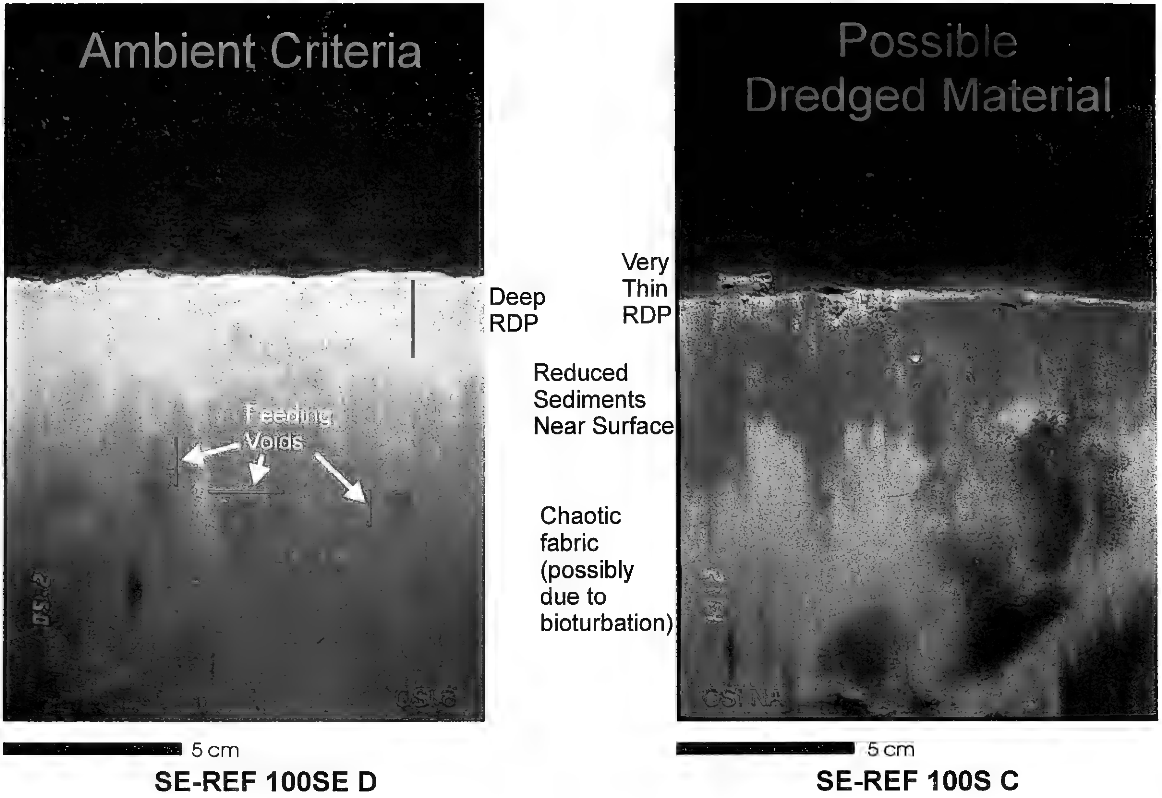


Figure 4-8. REMOTS® replicates from the March 1998 survey showing the criteria for ambient sediments and the detection of possible historic dredged material

ambient sediments. PCBs were absent, and PAHs concentrations were at or below mean reference area values for WLIS.

5.0 CONCLUSIONS AND RECOMMENDATIONS

The 1997 and 1998 monitoring cruises accomplished both the monitoring objectives at the Western Long Island Sound Disposal Site and the new reference area investigation and characterization tasks at SE-REF.

Comparisons with the 1996 report showed that a distinct mound, WLIS I, was developed at the 1996-1997 buoy between the D and the G mounds. The I mound contributed to the development of a containment berm and potential basins for future capping operations of dredged sediments. The small to moderate size of the mound was consistent with the volume reported in disposal barge logs. The apron of the I mound appears to cover the area identified at D200S to the east of G mound that had a negative OSI value in 1996. The benthic community on and surrounding the mound indicated a healthy recovery and rapid recolonization rate. Stage I organisms were predominant in September, although several replicates from both the September and March surveys indicated advanced Stage III deposit feeder activity. The I mound, or alternatively the D and G mounds, should be resurveyed in the next monitoring survey at WLIS to monitor the continued recovery and health of the benthic environment over these disposal mounds.

REMOTS® surveys over the 1995-1996 H mound showed improvements in the benthic conditions. Although the RPD depths in September were slightly depressed due to the seasonal low oxygen conditions, the successional status had advanced since 1996. In March, all replicates indicated feeding voids and, except 50W, a Stage III successional status and deeper mean RPD depth.

Seasonal conditions did affect the benthic conditions observed in the REMOTS® sediment-profile photographs. Although hypoxia was not as severe as in previous years, the low dissolved oxygen conditions in the bottom waters did reduce the RPD depths and OSI values in September at both the disposal mounds and reference areas. Redox rebounds were common at the H mound and present at a few stations at the I mound both in September and March surveys. Despite observations of deep RPD depths in March, redox rebounds were visible at the SE-REF which were not seen at the reference areas in September.

To continue the ongoing development of a containment berm and basins, future disposal mounds may be placed south of G (1), C-E (2), and E-H (3) as well as between H and the natural, steep slope near the southern border of the disposal site. The basins may then be used to optimize capping or isolation of dredged sediments by containing the spread of sediments on the seafloor. A larger basin area could easily be constructed with additional placement of mounds at locations 4, 5, and 6 on Figure 4-1.

The side-scan survey conducted in March 1998 was useful in identifying a new potential reference area near WLIS to replace 2000W and fulfill the DAMOS protocol for three reference areas. The survey data and sediment characterization show that SE-REF meets sufficient reference area requirements, including proximity to WLIS, grain size, and sediment chemistry. No compelling evidence of historic dredged material was found. However, the reference area should be accepted with some caution. Although the benthic conditions and ecology appeared to be very similar to WLIS, the water depth at SE-REF is about 10 m shallower than WLIS. A patchy area detected in the side-scan images in the southwest section of WLIS potentially may be weathered, historic dredged material or glacial debris related to the small knoll feature that is to the south of the reference area. SE-REF and its southern flank should be investigated further with a comprehensive bathymetric survey during the next monitoring survey at WLIS. To insure the absence of dredged material within SE-REF, we also recommend that at least seven stations be occupied in future REMOTS® monitoring surveys at the reference area.

Because historic dredged material has been detected throughout the region surrounding WLIS, selection of potential reference areas is limited. Using a variety of surveying techniques, we have located an area that is relatively free of historic dredged material. The survey data show that SE-REF is a strong candidate for a reference area and is representative of ambient conditions in the region.

6.0 REFERENCES

Charles, J.; Tufts G. J. 1996. Monitoring cruise at the Western Long Island Sound Disposal Site, August 1993. SAIC Report No. 325. Final report submitted to U.S. Army Corps of Engineers, New England Division, Waltham, MA.

Connecticut DEP. 1997. The atmosphere and hypoxia in LIS nitrogen removal program. http://dep.state.ct.us/water/atmoslis.htm and http://dep.state.ct.us/water/water.htm

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.

EPA/USACE 1991. Evaluation of Dredged Material Proposal for Ocean Disposal – Testing Manual. EPA-503/8/91/001, Washington, DC.

EPA 1997. Test Methods for Evaluating Solid Waste. EPASW-846. Laboratory Manual Physical/Chemistry Methods. Office of Solid Waste and Emergency Response, Washington, DC.

Fredette, T. J.; Kullberg, P. G.; Carey, D. A.; Morton, R. W.; Germano, J. D. 1993. Twenty-five years of dredged material disposal site monitoring in Long Island Sound: A long-term perspective. Proceedings of the Long Island Sound Research Conference, New Haven, CT. 23–24 October 1992. 153-161.

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.

Horowitz, A. J. 1985. A primer on trace metal – sediment chemistry. U.S. Geological Survey water supply paper 2277. U.S.G.S. Alexandria, VA.

Knebel, H. J.; Signell, R. P.; Rendigs R. R.; Poppe, L. J.; List, J. H. *In Press*. Seafloor environments in the Long Island Sound estuarine system. Marine Geology.

Long Island Sound Study (LISS). 1990. Status report and interim actions for hypoxia management. U.S. Environmental Protection Agency, Region I, Boston, MA and Region II, New York, NY.

Mendenhall, W. 1979. Introduction to Probability and Statistics, 5th Ed. Duxbury Press, North Scituate, 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. 1995. DAMOS Reference Area Data Analyses. SAIC Report No. 357. Final report submitted to U.S. Army Corps of Engineers, New England Division, Waltham, MA.

Murray, P. M.; Selvitelli, P. 1996. DAMOS navigation and bathymetry standard operating procedures. SAIC Report No. 290. Final report submitted to U.S. Army Corps of Engineers, New England Division, Waltham, MA.

National Oceanographic and Atmospheric Administration (NOAA). 1997, 1998. Oceanographic Products and Services on-line data. http://www.opsd.nos.nooa.gov/opsd.html.

Revelas, E. C.; Germano, J. D.; Rhoads, D. C. 1987. Reconnaissance of Benthic Environments. Coastal Zone '87. WW Div./ASCE, Seattle, WA.

Rhoads, D. C.; Aller, R. C.; Goldhaber, M. B. 1977. The influence of colonizing benthos on physical properties and chemical diagenesis of the estuarine seafloor. In *Ecology of Marine Benthos*, ed. B. C. Coull, pp. 113–38. University of South Carolina Press.

Rhoads, D. C.; Boyer, L. F. 1982. Chapter I. The Effects of Marine Benthos on Physical Properties of Sediments: A Successional Perspective. Animal-Sediment Relations. Planum Publishing Corporation.

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.

Rhoads, D. C.; Germano, J. D. 1990. The use of REMOTS® imaging technology for disposal site selection and monitoring. In "Geotechnical Engineering of Ocean Waste Disposal." (K. Demass; R. Chaney, eds.). ASTM Symp. Vol. 1, January 1989, Orlando, FL, pp. 50–64.

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). U.S. Army Corps of Engineers, New England Division, Waltham, MA.

Turgeon, D. D.; Gottholm B. W.; McMahon K. D.; Robertson A. 1989. National Status and Trends Program for Marine Environmental Quality: Toxic Contaminants in Long Island Sound. Dept. of Commerce, NOAA, Ocean Assessments Division, Rockville, MD.

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.

Wentworth, C. K. 1922. A scale of grade and class terms of clastic sediments. J. Geo. 30:377–390.

APPENDIX A
Navigation Positions for REMOTS® Stations

Table 1. Navigation Positions for WLIS September 1997 REMOTS® Survey

WLIS September 1997 REMOTS Stations NAD 1927				NAD 83	
Area	Station	Latitude	Longitude	Latitude	Longitude
WLIS I MOUND 40° 59.203′ N 073° 29.072′ W (1996-97)	CTR	40° 59.203′ N	073° 29.072′ W	40° 59.209′ N	073° 29.046′ W
	50N	40° 59.230′ N	073° 29.072′ W	40° 59.236′ N	073° 29.046′ W
	100N	40° 59.257′ N	073° 29.072′ W	40° 59.263′ N	073° 29.046′ W
	150N	40° 59.284′ N	073° 29.072′ W	40° 59.290′ N	073° 29.046′ W
	50S	40° 59.176′ N	073° 29.072′ W	40° 59.182′ N	073° 29.046′ W
	100S	40° 59.149′ N	073° 29.072′ W	40° 59.155′ N	073° 29.046′ W
	150S	40° 59.122′ N	073° 29.072′ W	40° 59.128′ N	073° 29.046′ W
	50E	40° 59.203′ N	073° 29.036′ W	40° 59.209′ N	073° 29.010′ W
	100E	40° 59.203′ N	073° 29.001′ W	40° 59.209′ N	073° 28.975′ W
	150E	40° 59.203′ N	073° 28.965′ W	40° 59.209′ N	073° 28.939′ W
	50W	40° 59.203′ N	073° 29.108′ W	40° 59.209′ N	073° 29.082′ W
	100W	40° 59.203′ N	073° 29.143′ W	40° 59.209′ N	073° 29.117′ W
	150W	40° 59.203′ N	073° 29.179′ W	40° 59.209′ N	073° 29.153′ W
WLIS H MOUND 40° 59.228′ N 073° 28.732′ W (1995-96)	CTR	40° 59.228′ N	073° 28.732′ W	40° 59.234′ N	073° 28.706′ W
	50N	40° 59.255′ N	073° 28.732′ W	40° 59.261′ N	073° 28.706′ W
	100N	40° 59.282′ N	073° 28.732′ W	40° 59.288′ N	073° 28.706′ W
	150N	40° 59.309′ N	073° 28.732′ W	40° 59.315′ N	073° 28.706′ W
	50S	40° 59.201′ N	073° 28.732′ W	40° 59.207′ N	073° 28.706′ W
	100S	40° 59.174′ N	073° 28.732′ W	40° 59.180′ N	073° 28.706′ W
	150S	40° 59.147′ N	073° 28.732′ W	40° 59.153′ N	073° 28.706′ W
	50E	40° 59.228′ N	073° 28.696′ W	40° 59.234′ N	073° 28.670′ W
	100E	40° 59.228′ N	073° 28.661′ W	40° 59.234′ N	073° 28.635′ W
	150E	40° 59.228′ N	073° 28.625′ W	40° 59.234′ N	073° 28.599′ W
	50W	40° 59.228′ N	073° 28.768′ W	40° 59.234′ N	073° 28.742′ W
	100W	40° 59.228′ N	073° 28.803′ W	40° 59.234′ N	073° 28.777′ W
	150W	40° 59.228′ N	073° 28.839′ W	40° 59.234′ N	073° 28.813′ W
Reference Areas					
SOUTH 40° 58.688′ N 073° 29.201′ W	RefS1	40° 58.727′ N	073° 29.197′ W	40° 58.733′ N	073° 29.171′ W
	RefS2	40° 58.704′ N	073° 29.190′ W	40° 58.710′ N	073° 29.164′ W
	RefS3	40° 58.684′ N	073° 29.102′ W	40° 58.690′ N	073° 29.076′ W
	RefS4	40° 58.686′ N	073° 29.287′ W	40° 58.692′ N	073° 29.261′ W
	RefS5	40° 58.726′ N	073° 29.251′ W	40° 58.732′ N	073° 29.225′ W
	RefS6	40° 58.696′ N	073° 29.251′ W	40° 58.702′ N	073° 29.136′ W
SWREF 40° 58.487′ N 073° 29.909′ W	RfSW7	40° 58.397′ N	073° 29.072′ W	40° 58.403′ N	073° 30.046′ W
	RfSW8	40° 58.426′ N	073° 29.875′ W	40° 58.432′ N	073° 29.849′ W
	RfSW9	40° 58.476′ N	073° 29.885′ W	40° 58.482′ N	073° 29.859′ W
	RfSW10	40° 58.595′ N	073° 29.871′ W	40° 58.601′ N	073° 29.845′ W
	RfSW11	40° 58.466′ N	073° 29.902′ W	40° 58.472′ N	073° 29.876′ W
	RfSW12	40° 58.468′ N	073° 29.029′ W	40° 58.474′ N	073° 30.003′ W
	RfSW13	40° 58.505′ N	073° 29.853′ W	40° 58.511′ N	073° 29.827′ W

Table 2. Navigation Positions for WLIS March 1998 REMOTS® Survey

WLIS March 1998 REMOTS Stations NAD 1927				NAD 83	
Area	Station	Latitude	Longitude	Latitude	Longitude
WLIS Reference Area Investigation 40° 58.301′ N 073° 27.722′ W	CTR	40° 58.301′ N	073° 27.722′ W	40° 58.307′ N	073° 27.696′ W
	100N	40° 58.355′ N	073° 27.722′ W	40° 58.361′ N	073° 27.696′ W
	200N	40° 58.409′ N	073° 27.722′ W	40° 58.415′ N	073° 27.696′ W
	300N	40° 58.463′ N	073° 27.722′ W	40° 58.469′ N	073° 27.696′ W
	100S	40° 58.247′ N	073° 27.722′ W	40° 58.253′ N	073° 27.696′ W
	200S	40° 58.193′ N	073° 27.722′ W	40° 58.199′ N	073° 27.696′ W
	300S	40° 58.139′ N	073° 27.722′ W	40° 58.145′ N	073° 27.696′ W
	100E	40° 58.301′ N	073° 27.651′ W	40° 58.307′ N	073° 27.625′ W
	200E	40° 58.301′ N	073° 27.580′ W	40° 58.307′ N	073° 27.553′ W
	300E	40° 58.301′ N	073° 27.508′ W	40° 58.307′ N	073° 27.482′ W
	100W	40° 58.301′ N	073° 27.793′ W	40° 58.307′ N	073° 27.767′ W
	200W	40° 58.301′ N	073° 27.865′ W	40° 58.307′ N	073° 27.839′ W
	300W	40° 58.301′ N	073° 27.936′ W	40° 58.307′ N	073° 27.910′ W
	100NE	40° 58.339′ N	073° 27.672′ W	40° 58.345′ N	073° 27.646′ W
	200NE	40° 58.378′ N	073° 27.621′ W	40° 58.383′ N	073° 27.595′ W
	300NE	40° 58.416′ N	073° 27.571′ W	40° 58.422′ N	073° 27.545′ W
	100NW	40° 58.339′ N	073° 27.773′ W	40° 58.345′ N	073° 27.746′ W
	200NW	40° 58.378′ N	073° 27.823′ W	40° 58.383′ N	073° 27.797′ W
	300NW	40° 58.416′ N	073° 27.873′ W	40° 58.422′ N	073° 27.847′ W
	100SE	40° 58.263′ N	073° 27.873′ W	40° 58.269′ N	073° 27.646′ W
	200SE	40° 58.225′ N	073° 27.621′ W	40° 58.231′ N	073° 27.595′ W
	300SE	40° 58.187′ N	073° 27.571′ W	40° 58.192′ N	073° 27.545′ W
	100SW	40° 58.263′ N	073° 27.571′ W	40° 58.269′ N	073° 27.746′ W
	200SW	40° 58.225′ N	073° 27.823′ W	40° 58.231′ N	073° 27.797′ W
	300SW	40° 58.187′ N	073° 27.873′ W	40° 58.192′ N	073° 27.847′ W
WLIS I MOUND 40° 59.203′ N 073° 29.072′ W (1996-97)	CTR	40° 59.203′ N	073° 29.072′ W	40° 59.209′ N	073° 29.046′ W
	50N	40° 59.230′ N	073° 29.072′ W	40° 59.236′ N	073° 29.046′ W
	50S	40° 59.176′ N	073° 29.072′ W	40° 59.182′ N	073° 29.046′ W
	50E	40° 59.203′ N	073° 29.036′ W	40° 59.209′ N	073° 29.010′ W
	50W	40° 59.203′ N	073° 29.108′ W	40° 59.209′ N	073° 29.082′ W
WLIS H MOUND 40° 59.228′ N 073° 28.732′ W (1995-96)	CTR	40° 59.228′ N	073° 28.732′ W	40° 59.234′ N	073° 28.706′ W
	50N	40° 59.255′ N	073° 28.732′ W	40° 59.261′ N	073° 28.706′ W
	50S	40° 59.201′ N	073° 28.732′ W	40° 59.207′ N	073° 28.706′ W
	50E	40° 59.228′ N	073° 28.696′ W	40° 59.234′ N	073° 28.670′ W
	50W	40° 59.228′ N	073° 28.768′ W	40° 59.234′ N	073° 28.742′ W

APPENDIX B
September 1997 REMOTS® Surveys

H MOUND

H MOUND			Successional	Grain Size (phi)			Mud Clasts		Camera Penetration				Dredged Material Thickness			Redox Rebound Thickness			Apparent RPD Thickness					Surface	Additional		Low	
Station	Replicate	Date	Stage	Min	Max	Maj. Mode	Count	Avg Diam	Min	Max	Range	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Methane	OSI	Roughness	Measurements cm		DO	Comments
HCTR	A	9/16/97	INDET	>4	3	>4	1	0.73	19.43	19.95	0.52	19.69	19.40	19.95	19.55	2	5	3.5	0.62	2.49	1.40	0	NA	BIOGENIC	NOADDM	0	NO	dm>pen; chaotic fabric,feeding voids/fractures at depth
HCTR	D	9/18/97	ST_I	>4	3	>4	3	0.67	14.56	15.03	0.47	14.79	14.56	14.87	14.61	3.8	5.7	4.5	0.20	0.80	0.50	0	2	BIOGENIC	NOADDM	0	NO	dm>pen; bk wiper clast;collasped feeding void?
HCTR	E	9/18/97	INDET	>4	4	>4	0	0	14.87	15.44	0.57	15.16	14.82	15.49	15.20	0	0	0	NA	NA	0.90	0	NA	PHYSICAL	NOADDM	0	NO	dm>pen; wiper clast/smears at surf; bk sed with lg patch brown 9-15cm; RPD extrap
H50N	A	9/16/97	ST_I	>4	3	>4	0	0	19.38	20.16	0.78	19.77	19.38	20.10	19.85	6.79	8.81	7.8	1.09	2.59	1.89	0	4	BIOGENIC	NOADDM	0	NO	dm>pen; multiple dm layers
H50N	B	9/16/97	ST_I_ON_III	>4	3	4 to 3	0	0	14.25	14.77	0.52	14.51	14.09	14.77	14.50	8.8	10	9.3	1.35	3.01	2.12	0	8	BIOGENIC	NOADDM	0	NO	dm>pen; wiper clast/smearing; multiple dm layers; feeding void
H50N	C	9/16/97	ST_I_ON_III	>4	3	>4	1	0.83	17.05	17.72	0.67	17.38	16.84	17.82	17.40	10	13	11	1.55	5.08	3.53	0	10	BIOGENIC	NOADDM	0	NO	dm>pen; multiple dm layers,feeding voids
H50E	D	9/18/97	ST_I_ON_III	>4	3	>4	0	0	11.68	13.47	1.79	12.58	11.33	13.52	12.32	0	0	0	1.22	2.76	2.09	0	8	PHYSICAL	NOADDM	0	NO	dm>pen; dm topography
H50E	E	9/18/97	ST_I	>4	3	>4	0	0	15.20	15.82	0.61	15.51	15.20	15.87	15.54	0	0	0	1.30	2.00	1.60	0	4	PHYSICAL	NOADDM	0	NO	dm>pen; wiper clasts & smearing; RPD extrapolated; worm
H50E	F	9/18/97	ST_I	>4	3	>4	0	0	1.68	7.81	6.12	4.74	1.6	7.7	4.5	0	0	0	NA	NA	NA	0	NA	PHYSICAL	NOADDM	0	NO	underpen; dm>pen; thin br sand/bk sed,wiper smear; dm surf topography
H50S	C	9/16/97	ST_III	>4	3	>4	0	0	20.21	20.57	0.36	20.39	20.21	20.67	20.48	0	0	0	0.40	1.00	0.50	0	6	INDET	NOADDM	0	NO	dm>pen; wiper streaks?; feeding voids at depth
H50S	D	9/18/97	ST_I	>4	4	>4	0	0	15.85	16.42	0.57	16.14	15.80	16.42	16.12	6.58	8.5	7.54	0.78	2.02	1.39	0	3	BIOGENIC	NOADDM	0	NO	dm>pen; br silt/bk mud; drag-down; relict void?
H50S	E	9/18/97	ST_I	>4	4	>4	0	0	16.92	17.33	0.41	17.13	16.92	17.28	17.05	NA	NA	7	0.50	1.00	0.80	0	3	INDET	NOADDM	0	NO	dm>pen; wiper clast & smearing; RPD extrapolated
H50W	D	9/18/97	ST_I_ON_III	>4	3	>4	0	0	18.21	18.88	0.66	18.55	18.01	18.88	18.48	NA	NA	3.5	0.26	1.58	0.93	0	7	INDET	NOADDM	0	NO	dm>pen; fine sm surf tubes
H50W	E	9/18/97	ST_I_ON_III	>4	3	>4	0	0	15.26	16.12	0.87	15.69	15.31	16.07	15.67	3	6	5	0.60	1.50	1.00	0	7	PHYSICAL	NOADDM	0	NO	dm>pen; fine sand/mud; wiper clast & smearing; RPD variable/extrapolated
H50W	F	9/18/97	INDET	>4	3	>4	0	0	3.93	13.72	9.80	8.83	3.83	14.18	7.79	0	0	0	NA	NA	0.20	0	NA	PHYSICAL	NOADDM	0	NO	dm>pen; dm topography; bk sed, diffusional RPD
H100N	A	9/16/97	ST_I_ON_III	>4	3	4 to 3	0	0	17.72	18.76	1.04	18.24	17.67	18.45	18.02	5.65	13.01	9.33	3.21	4.72	4.09	0	11	BIOGENIC	NOADDM	0	NO	dm>pen; oxid. feeding voids at depth; variable RPD depth
H100N	D	9/18/97	ST_I	>4	3	>4	0	0	16.06	16.37	0.31	16.22	16.01	16.37	16.15	0	0	0	0.57	2.40	1.00	0	3	BIOGENIC	NOADDM	0	NO	dm>pen; patchy RPD
H100N	E	9/18/97	ST_I	>4	3	>4	0	0	9.44	10.10	0.66	9.77	9.39	10.15	9.84	0	0	0	0.05	1.07	0.50	0	2	INDET	NOADDM	0	NO	dm>pen; thin br sand/ltbkdm/bkdm poss feeding void?,rippled?
H100E	D	9/18/97	ST_I	>4	3	>4	0	0	11.73	12.39	0.66	12.06	11.68	12.39	11.99	0	0	0	0.46	2.23	1.12	0	3	PHYSICAL	NOADDM	0	NO	dm>pen; wiper clast/smear, sm surf tubes; sm topography; relict voids?
H100E	E	9/18/97	ST_I_ON_III	>4	3	>4	0	0	11.52	13.15	1.62	12.34	11.62	13.45	12.24	6.5	9.04	7.77	NA	NA	2.00	0	8	PHYSICAL	NOADDM	0	NO	dm>pen; bk sed w/br layer; dm topography; RPD variable/extrap; shell?on surf,worm
H100E	F	9/18/97	INDET	>4	3	>4	0	0	13.65	16.95	3.30	15.30	13.45	16.85	15.10	0	0	0	NA	NA	NA	0	NA	INDET	NOADDM	0	NO	dm>pen; bk sed; wiper clasts covering surf, worm
H100S	D	9/18/97	ST_I	>4	3	>4	0	0	16.15	16.72	0.57	16.43	16.04	16.72	16.34	4.17	7.45	5.81	0.30	1.50	0.85	0	3	BIOGENIC	NOADDM	0	NO	dm>pen. small surf tubes
H100S	E	9/18/97	ST_III	>4	4	>4	2	1.7[illegible]	11.51	12.19	0.68	11.85	11.41	12.24	11.79	3.49	4.58	4.04	NA	NA	NA	0	NA	INDET	NOADDM	0	NO	dm>pen; bk/gr bands; bk wiper clasts at surf
H100S	F	9/18/97	ST_I_ON_III	>4	3	>4	0	0	10.52	12.66	2.14	11.59	10.57	12.76	11.62	0	0	0	0.10	3.12	1.25	0	7	PHYSICAL	NOADDM	0	NO	dm>pen; poss. feeding voids
H100W	B	9/16/97	ST_III	>4	3	>4	0	0	13.80	19.69	5.89	16.74	13.59	19.64	15.84	0	0	0	NA	NA	1.00	0	NA	PHYSICAL	NOADDM	0	NO	dm>pen; wiper smearing; thin RPD?, feeding voids; sloped surface; RPD extrap
H100W	D	9/18/97	ST_I	>4	3	>4	0	0	7.40	13.59	6.20	10.49	7.50	13.70	11.64	0	0	0	NA	NA	0.20	0	2	PHYSICAL	NOADDM	0	NO	dm>pen; rounded dm clast; bk sed; diffusional RPD
H100W	E	9/18/97	ST_I_ON_III	>4	3	>4	1	0.91	11.56	12.60	1.04	12.08	11.72	12.76	11.91	0	0	0	0.26	3.23	1.07	0	7	INDET	NOADDM	0	NO	dm>pen; bk sed; wiper clasts?; feeding voids?
H150N	A	9/16/97	ST_III	>4	3	>4	0	0	18.24	18.70	0.47	18.47	18.25	18.74	18.40	12.23	14.2	13.21	2.00	3.00	2.50	0	9	BIOGENIC	NOADDM	0	NO	dm>pen, feeding voids at depth; layered DM
H150N	D	9/18/97	ST_I	>4	4	>4	0	0	8.96	9.38	0.41	9.17	8.81	9.38	8.97	0	0	0	2.07	4.30	3.29	0	6	BIOGENIC	NOADDM	0	NO	dm>pen; br silt/bk; wiper streaks?
H150N	E	9/18/97	ST_I	4	4	>4	0	0	13.21	13.47	0.26	13.34	13.16	13.68	13.36	4.56	6.79	5.67	0.67	2.07	1.69	0	4	BIOGENIC	NOADDM	0	NO	dm>pen; br silt/bk; wiper clasts&smearing
H150E	D	9/18/97	ST_I	>4	3	>4	0	0	13.71	14.26	0.56	13.98	13.80	14.20	14.00	0	0	0	NA	NA	1.00	0	3	BIOGENIC	NOADDM	0	NO	dm>pen; wiper clasts/smearing over surf, RPD extrap
H150E	E	9/18/97	ST_I	>4	3	>4	0	0	18.43	19.09	0.66	18.76	18.53	18.93	18.65	0	0	0	NA	NA	1.50	0	3	BIOGENIC	NOADDM	0	NO	dm>pen; wiper clasts/smearing, RPD extrap
H150E	F	9/18/97	ST_I	>4	3	>4	0	0	14.92	16.50	1.57	15.71	14.97	16.90	15.66	0	0	0	NA	NA	0.80	0	3	INDET	NOADDM	0	NO	dm>pen; wiper clasts/smear over surf; gr-bk sed, RPD extrap
H150S	B	9/16/97	ST_I_ON_III	>4	3	4 to 3	0	0	18.21	18.88	0.68	18.55	18.11	18.72	18.38	0	0	0	NA	NA	2.96	0	9	BIOGENIC	NOADDM	0	NO	dm>pen; br/bk sed; wiper artifacts?, RPD extrap,feeding voids at depth
H150S	D	9/16/97	ST_I	>4	3	>4	0	0	15.99	16.35	0.36	16.17	15.94	16.35	16.10	0	0	0	0.31	1.51	0.99	0	3	BIOGENIC	NOADDM	0	NO	dm>pen; sm surf tubes
H150S	E	9/18/97	ST_I	>4	3	>4	0	0	14.53	15.31	0.78	14.92	14.53	15.31	14.88	0	0	0	NA	NA	NA	0	NA	INDET	NOADDM	0	NO	dm>pen,S/M
H150W	A	9/16/97	ST_I	>4	3	>4	0	0	19.01	19.58	0.57	19.30	18.91	19.37	19.00	NA	NA	3	0.20	1.00	0.60	0	2	BIOGENIC	NOADDM	0	NO	dm>pen; bk dm band at depth
H150W	B	9/16/97	ST_I	>4	3	>4	1	0.97	18.37	18.67	0.31	18.52	NA	NA	12.00	0	0	0	1.70	2.60	2.00	0	4	INDET	Relict RPD	12	NO	dm/old dm; bands of br&gr silt; layered dm, relict RPD
H150W	D	9/18/97	ST_I_ON_III	>4	3	>4	0	0	16.20	17.03	0.83	16.61	16.20	16.93	16.64	0	0	0	0.47	2.14	1.16	0	7	PHYSICAL	NOADDM	0	NO	dm>pen; sm. surf tubes,fractures at depth

I MOUND

I MOUND			Successional	Grain Size (phi)			Mud Clasts		Camera Penetration				Dredged Material Thickness			Redox Rebound Thickness			Apparent RPD Thickness					Surface	Additional		Low	
Station	Replicate	Date	Stage	Min	Max	Maj Mode	Count	Avg Diam	Min	Max	Range	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Methane	OSI	Roughness	Measurements cm		DO	Comments
ICTR	B	9/16/97	INDET	>4	3	4 to 3	0	0	1.95	2.97	1.03	2.46	1.38	2.82	2.27	0	0	0	0.20	1.50	1.10	0	NA	PHYSICAL	NOADDM	0	NO	underpen; dm>pen; fine sand, shell hash
ICTR	C	9/16/97	INDET	>4	3	4 to 3	1	1.03	14.46	15.44	0.97	14.95	14.36	14.97	14.66	0	0	0	1.00	3.20	2.00	0	NA	PHYSICAL	NOADDM	0	NO	dm>pen; bk mud clasts; active or relict feeding voids?
ICTR	D	9/18/97	INDET	>4	3	4 to 3	0	0	4.00	4.87	0.87	4.44	3.95	4.87	4.38	0	0	0	1.23	2.56	1.89	0	NA	PHYSICAL	NOADDM	0	NO	shallow pen; dm>pen; hi sand content in surf water
I50N	A	9/16/97	ST_I	>4	2	4 to 3	0	0	16.31	16.97	0.67	16.64	16.30	17.00	16.62	0	0	0	0.20	1.40	1.00	0	3	PHYSICAL	NOADDM	0	NO	dm>pen; S/M/S/M; wiper artifact; sm surf tubes
I50N	B	9/16/97	ST_I_ON_III	>4	2	4 to 3	0	0	14.62	15.38	0.77	15.00	14.67	15.33	15.02	0	0	0	0.30	2.00	1.50	0	7	INDET	NOADDM	0	NO	dm>pen; wiper clast&smearing; sandy; RPD extrap ;relict RPD?,feeding voids
I50N	C	9/16/97	INDET	>4	3	4 to 3	0	0	6.10	6.67	0.56	6.38	6.05	6.62	6.28	0	0	0	NA	NA	NA	0	NA	PHYSICAL	NOADDM	0	NO	dm>pen; RPD extrap
I50E	A	9/16/97	ST_I	>4	3	4 to 3	0	0	15.03	16.60	1.57	15.81	15.08	16.70	15.87	0	0	0	NA	NA	NA	0	NA	PHYSICAL	NOADDM	0	NO	dm>pen; chaotic fabric,shell fragments & surf scour; feeding voids?
I50E	B	9/16/97	ST_III	>4	3	>4	1	0.86	10.61	11.62	1.02	11.12	10.51	11.68	10.92	0	0	0	0.30	7.36	3.06	0	10	PHYSICAL	NOADDM	0	NO	dm>pen; marbled sed; minor wiper smears; feeding voids
I50E	C	9/16/97	ST_I_ON_III	>4	3	4 to 3	0	0	17.41	19.90	2.49	18.65	17.41	19.80	18.57	0	0	0	NA	NA	NA	0	NA	PHYSICAL	NOADDM	0	NO	dm>pen; wiper clast?,chaotic fabric; burrow; feeding voids
I50S	B	9/16/97	ST_I	>4	2	>4	0	0	15.08	15.85	0.77	15.46	15.23	15.85	15.64	0	0	0	0.56	3.95	1.96	0	4	PHYSICAL	NOADDM	0	NO	dm>pen; chaotic fabric; fractures in cohesive clast; shrimp on surf
I50S	C	9/16/97	INDET	>4	3	4 to 3	0	0	4.82	7.49	2.67	6.15	4.21	7.49	6.66	0	0	0	0.67	1.90	1.53	0	NA	PHYSICAL	NOADDM	0	NO	dm>pen,wiper artifact,chaotic fabric; RPD estimated,lg shell; feeding voids?
I50S	D	9/18/97	ST_III	>4	3	>4	0	0	8.46	9.38	0.92	8.92	8.51	9.33	8.91	0	0	0	0.77	2.10	1.46	0	7	PHYSICAL	NOADDM	0	NO	dm>pen, wiper clast&smeaing: chaotic fabric,feeding voids?
I50W	A	9/16/97	ST_I_ON_III	>4	2	4 to 3	0	0	12.03	12.74	0.71	12.39	11.98	12.59	12.12	0	0	0	NA	NA	3.00	0	9	BIOGENIC	NOADDM	0	NO	dm>pen; wiper artifacts/smearing,RPD extrap.; dm layering; sm surf tube
I50W	B	9/16/97	ST_I	>4	2	4 to 3	0	0	13.91	14.62	0.71	14.26	13.76	14.57	14.16	0	0	0	4.37	6.60	5.53	0	7	PHYSICAL	Sand thicknes	7.3	NO	dm>pen; sed fracture along bedding plate
I50W	C	9/16/97	ST_I	>4	2	3 to 2	0	0	9.70	9.85	0.15	9.77	9.59	9.95	9.70	0	0	0	2.28	3.71	3.01	0	6	BIOGENIC	Sand thicknes	5.9	NO	dm>pen; minor wiper artifacts; sm surf tubes
I100N	A	9/16/97	INDET	>4	3	4 to 3	0	0	8.97	12.10	3.13	10.54	8.87	12.05	9.83	0	0	0	5.85	8.97	6.81	0	NA	PHYSICAL	NOADDM	0	NO	dm>pen; fracture/chaotic fabric; wiper clast &smeaing
I100N	B	9/16/97	INDET	>4	3	4 to 3	0	0	14.15	15.23	1.08	14.69	13.18	15.44	14.46	0	0	0	NA	NA	NA	0	NA	BIOGENIC	Relict RPD?	8.5	NO	dm>pen; relict feeding voids and RPD?, wiper smears; shell hash at surf
I100N	C	9/16/97	ST_I	>4	3	>4	0	0	14.69	16.28	1.58	15.48	14.59	16.22	15.44	0	0	0	0.20	2.00	1.30	0	3	INDET	NOADDM	0	NO	dm>pen, wiper artifacts, variable RPD
I100E	A	9/16/97	ST_I_ON_III	>4	3	>4	0	0	17.30	18.01	0.71	17.65	17.24	18.06	17.79	0	0	0	NA	NA	1.00	0	7	PHYSICAL	NOADDM	0	NO	dm>pen,wiper clasts&smearing,relict?feeding voids&chaotic fabric; RPED extrap
I100E	C	9/16/97	ST_I_ON_III	>4	3	4 to 3	0	0	17.70	18.06	0.36	17.88	17.55	18.11	17.74	0	0	0	0.10	4.00	1.50	0	7	PHYSICAL	Relict RPD	11	NO	dm>pen,wiper clast&smearing,RPD extrap,relict RPD?,feeding voids,shell hash
I100E	D	9/18/97	ST_III	>4	3	>4	0	0	11.28	12.09	0.82	11.68	0	0	0	0	0	0	0.46	1.69	0.92	0	7	INDET	NOADDM	0	NO	old dm; feeding voids
I100S	A	9/16/97	ST_I	>4	2	3 to 2	0	0	12.87	13.95	1.08	13.41	12.82	14.00	13.41	6.92	8.46	7.69	0.92	2.72	1.66	0	4	PHYSICAL	Sand thicknes	7.5	NO	dm>pen; wiper smears?; multiple dm layers
I100S	B	9/16/97	ST_I	>4	2	4 to 3	0	0	11.85	12.77	0.92	12.31	11.80	12.82	12.22	10.46	12.56	11.51	0.62	4.10	1.86	0	4	INDET	NOADDM	0	NO	dm>pen; br silt/br sand/bk; multiple dm layering
I100S	C	9/16/97	ST_I	>4	2	4 to 3	0	0	11.49	12.36	0.87	11.92	11.33	12.36	11.88	11.33	12.21	11.77	1.08	2.97	2.19	0	4	INDET	NOADDM	0	NO	dm>pen; S/M/S; muliple dm layering; sm white streaks?; sm surf tubes
I100W	A	9/16/97	ST_I	>4	3	>4	0	0	8.17	8.78	0.61	8.48	8.07	8.63	8.33	2.5	4	3	0.36	1.88	1.06	0	3	INDET	NOADDM	0	NO	dm>pen,wiper smearing; fracture; relict RPD
I100W	B	9/16/97	ST_I	>4	3	4 to 3	0	0	15.28	15.89	0.61	15.58	15.18	15.74	15.44	NA	NA	2.5	0.51	2.34	1.74	0	4	BIOGENIC	NOADDM	0	NO	dm>pen; fracture at contact; chaotic fabric at depth; relict RPD
I100W	C	9/16/97	ST_I	>4	3	4 to 3	0	0	16.14	17.21	1.07	16.68	16.04	17.31	16.36	0	0	0	NA	NA	1.50	0	3	BIOGENIC	Relict RPD	12	NO	dm>pen; wiper artifacts,RPD extrap; sm surf tubes?; relict RPD
I150N	A	9/16/97	ST_I_ON_III	>4	3	>4	0	0	14.97	15.63	0.66	15.30	14.97	15.84	15.35	0	0	0	0.10	1.80	0.95	0	7	PHYSICAL	Sand thicknes	1.7	NO	dm>pen; RPD thin&variable; feeding voids; shell hash on surf
I150N	B	9/16/97	ST_I	>4	3	4 to 3	1	0.56	17.56	18.02	0.46	17.79	17.41	18.07	17.80	0	0	0	0.30	2.00	1.50	0	3	PHYSICAL	NOADDM	0	NO	dm>pen; relic(active?) feeding voids; shell hash; relict RPDs
I150N	C	9/16/97	ST_III	>4	3	4 to 3	0	0	14.42	14.77	0.36	14.59	14.21	14.77	14.46	0	0	0	0.71	2.49	1.65	0	8	PHYSICAL	NOADDM	0	NO	dm>pen; active feeding voids?
I150E	A	9/16/97	ST_I	>4	3	4 to 3	0	0	16.11	16.87	0.76	16.49	6.20	8.00	6.70	NA	NA	6.7	NA	2.50	1.20	0	3	PHYSICAL	NOADDM	0	NO	dm/old dm; wiper clasts&artifacts;RPD extrap;shell hash in sand; relict RPD?
I150E	B	9/16/97	ST_I	>4	3	4 to 3	0	0	14.49	14.95	0.46	14.72	5.00	7.50	5.55	NA	NA	5.5	NA	1.50	1.00	0	3	INDET	NOADDM	0	NO	dm/old dm, wiper clasts &smearing; RPD extrap
I150E	C	9/16/97	ST_I	>4	3	4 to 3	0	0	15.41	15.41	0.00	15.41	6	7.6	6.5	6	7.6	6.5	NA	NA	NA	0	NA	BIOGENIC	NOADDM	0	NO	dm/old dm; wiper clasts &smearing; gr&bk bands; shell hash
I150S	A	9/16/97	ST_I	>4	3	>4	0	0	15.69	16.26	0.56	15.97	15.64	16.21	15.77	0	0	0	0.77	1.79	1.24	0	3	INDET	NOADDM	0	NO	dm>pen; wiper smearing?, relic feeding void and RPD?; multiple dm layers
I150S	[illegible]	9/16/97	INDET	>4	3	4 to 3	0	0	14.36	15.79	1.44	15.08	13.95	15.38	14.56	0	0	0	1.08	3.18	2.15	0	NA	BIOGENIC	NOADDM	0	NO	dm>pen; S/M/S/M; wiper artifact; lg feeding void partially infilled w/ sand?
I150S	C	9/16/97	ST_III	>4	2	4 to 3	0	0	15.64	15.85	0.21	15.74	15.38	15.95	15.63	0	0	0	NA	NA	NA	0	NA	INDET	NOADDM	0	NO	dm>pen; lg wiper artifacts; multiple dm layering; feeding voids; worm
I150W	A	9/16/97	ST_III	>4	3	>4	0	0	8.68	17.26	8.58	12.97	8.68	17.36	14.43	0	0	0	NA	NA	NA	0	NA	BIOGENIC	NOADDM	0	NO	dm>pen; v.thin sand/bk sulfidic sed; sm (relic?) feeding voids; lobster & burrow
I150W	B	9/16/97	ST_I	>4	3	>4	0	0	13.50	13.76	0.25	13.63	13.40	13.81	13.58	0	0	0	0.50	3.00	1.80	0	4	BIOGENIC	NOADDM	0	NO	dm>pen,br/gr/bk mud; wiper artifacts&clasts,RPD extrap; feeding voids
I150W	C	9/16/97	ST_I	>4	3	>4	0	0	15.99	16.65	0.66	16.32	16.09	16.70	16.12	0	0	0	NA	NA	2.20	0	4	BIOGENIC	NOADDM	0	NO	dm>pen; wiper artifacts; RPD extrap; sm surf tubes

REF AREAS

WLIS Ref Areas			Successional	Grain Size (phi)			Mud Clasts		Camera Penetration				Dredged Material Thickness			Redox Rebound Thickness			Apparent RPD Thickness					Surface	Low	
Station	Replicate	Date	Stage	Min	Max	Maj Mode	Count	Avg Diam	Min	Max	Range	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Methane	OSI	Roughness	DO	Comments
RefS1	A	9/16/97	INDET	>4	3	>4	0	0	9.08	11.99	2.91	10.54	9.08	12.04	10.62	0	0	0	0.66	1.94	1.26	0	NA	PHYSICAL	NO	dm or amb?; wiper artifacts&smearing; sloped surf; fractures
RefS1	D	9/16/97	ST_I_ON_III	>4	3	>4	0	0	10.97	12.50	1.53	11.73	0	0	0	0	0	0	0.10	7.40	3.15	0	10	INDET	NO	ambient;br&gr silt; feeding voids; surf tubes
RefS1	E	9/18/97	ST_I_ON_III	>4	3	>4	0	0	10.77	11.33	0.56	11.05	0	0	0	0	0	0	0.50	3.50	2.00	0	8	BIOGENIC	NO	ambient; br/gr silt; feeding voids; worm
RefS2	A	9/16/97	ST_I_ON_III	>4	3	>4	0	0	10.66	12.65	1.99	11.66	0	0	0	0	0	0	1.43	3.62	2.67	0	9	INDET	NO	ambient; nemertean
RefS2	B	9/16/97	ST_I	>4	3	>4	0	0	12.55	13.01	0.46	12.78	0	0	0	0	0	0	NA	NA	1.00	0	3	INDET	NO	ambient; br-gr silt;wiper clast & smearing;RPD extrap
RefS2	D	9/18/97	ST_III	>4	3	>4	0	0	6.58	7.14	0.56	6.86	0	0	0	0	0	0	NA	NA	2.50	0	9	INDET	NO	ambient; br-gr silt,wiper clasts&smearing; RPD extrap
RefS3	C	9/16/97	ST_I	>4	3	4 to 3	0	0	3.08	3.83	0.77	3.44	0	0	0	0	0	0	0.66	3.01	1.48	0	3	PHYSICAL	NO	ambient; shallow pen; minor wiper smear
RefS3	D	9/18/97	ST_I	>4	3	4 to 3	0	0	8.88	9.80	0.92	9.34	0	0	0	0	0	0	1.68	2.60	2.32	0	5	PHYSICAL	NO	ambient; br&gr silt;wiper clast&smearing
RefS3	E	9/18/97	ST_III	>4	[illegible]	>4	0	0	6.38	7.35	0.97	6.86	0	0	0	0	0	0	2.00	2.00	2.00	0	8	BIOGENIC	NO	ambient; wiper clast &smearing; feeding voids (fracture?)
RefS4	A	9/16/97	ST_I	>4	3	4 to 3	0	0	10.05	10.76	0.71	10.40	0	0	0	0	0	0	0.25	1.52	0.80	0	3	PHYSICAL	NO	ambient; br/gr silt; fracture; sm surf tubes
RefS4	B	9/16/97	ST_I	>4	3	>4	0	0	7.37	7.68	0.30	7.53	0	0	0	0	0	0	NA	NA	1.00	0	3	PHYSICAL	NO	ambients; br/gr silt; wiper artifacts; 2 shrimps?; RPD extrap
RefS4	C	9/16/97	ST_I	>4	3	>4	0	0	8.79	10.15	1.36	9.47	0	0	0	0	0	0	0.45	2.98	1.33	0	3	PHYSICAL	NO	ambient; old dm?; br/gr silt; sm surf tubes
RefS5	A	9/16/97	ST_I	>4	3	>4	0	0	13.06	14.23	1.17	13.65	0	0	0	0	0	0	4.18	7.65	6.33	0	7	PHYSICAL	NO	ambient; sm surf tubes
RefS5	C	9/16/97	ST_III	>4	3	>4	0	0	8.84	10.61	1.77	9.72	0	0	0	0	0	0	0.05	2.63	1.27	0	7	PHYSICAL	NO	ambient; old dm?; fractures(feeding voids?); shell lag
RefS5	D	9/18/97	INDET	>4	3	>4	0	0	10.10	10.91	0.81	10.51	0	0	0	0	0	0	0.61	2.53	1.41	0	NA	PHYSICAL	NO	ambient; br/gr silt
RefS6	A	9/16/97	ST_I	>4	3	>4	0	0	3.11	4.90	1.79	4.01	0	0	0	0	0	0	0.51	2.35	1.26	0	3	PHYSICAL	NO	ambient; br/gr silt; shells and surf scour lag; patchy RPD
RefS6	B	9/16/97	ST_I_ON_III	>4	3	>4	0	0	8.21	8.72	0.51	8.47	0	0	0	0	0	0	NA	NA	2.00	0	8	PHYSICAL	NO	ambient; wiper smears; RPD extrap
RefS6	C	9/16/97	ST_I_ON_III	>4	3	>4	0	0	11.28	11.84	0.56	11.56	0	0	0	0	0	0	NA	NA	NA	0	NA	BIOGENIC	NO	ambient; wiper artifacts; sm surf tubes; shrimp?; feeding void?
RfSW7	A	9/16/97	ST_I_ON_III	>4	3	>4	0	0	8.23	8.64	0.40	8.43	0	0	0	0	0	0	0.86	2.83	1.88	0	8	PHYSICAL	NO	ambient; br/gr silt; feeding voids
RfSW7	B	9/16/97	INDET	>4	3	>4	0	0.61	7.27	8.08	0.81	7.68	0	0	0	0	0	0	NA	NA	NA	0	NA	PHYSICAL	NO	ambient; wiper smear?; bioturb & sm feeding void; shell? on surf
RfSW7	C	9/16/97	ST_III	>4	3	>4	0	0	6.67	7.78	1.11	7.22	0	0	0	0	0	0	NA	NA	2.00	0	8	PHYSICAL	NO	ambient; wiper artifacts; RPD extrap
RfSW8	A	9/16/97	ST_I	>4	3	4 to 3	0	0	6.01	6.16	0.15	6.09	0	0	0	0	0	0	NA	NA	1.00	0	3	INDET	NO	ambient; br/gr silt; RPD extrapolated
RfSW8	B	9/16/97	ST_I	>4	3	4 to 3	0	0	6.50	7.36	0.86	6.93	0	0	0	0	0	0	NA	NA	0.71	0	2	PHYSICAL	NO	ambient; wiperclasts&smearing; RPD extrap;shrimp?
RfSW8	C	9/16/97	ST_III	>4	3	>4	0	0	6.26	7.27	1.01	6.77	0	0	0	0	0	0	0.30	1.97	0.84	0	7	PHYSICAL	NO	ambient;br-gr silt; surf disturbed?; shell frag;RDSI; feeding void
RfSW9	A	9/16/97	ST_I	>4	3	4 to 3	0	0	4.09	5.15	1.06	4.62	0	0	0	0	0	0	0.51	2.07	1.10	0	3	BIOGENIC	NO	ambient; br/gr silt;fecal casting in distance; very sm feeding voids?; insect?
RfSW9	B	9/16/97	INDET	>4	3	4 to 3	0	0	0.10	4.49	4.39	2.30	NA	NA	NA	0	0	0	NA	NA	NA	0	NA	INDET	NO	indet; shallow pen; shell-drag down; disturbed
RfSW9	C	9/16/97	ST_I_ON_III	>4	3	>4	0	0	8.94	9.24	0.30	9.09	0	0	0	0	0	0	0.30	2.93	1.48	0	7	INDET	NO	ambient; br/gr silt; shrimp?
RfSW10	B	9/16/97	ST_I_ON_III	>4	3	4 to 3	0	0	6.67	7.12	0.45	6.89	0	0	0	0	0	0	0.61	1.60	1.50	0	7	INDET	NO	ambient; shallow pen; S/M
RfSW10	C	9/16/97	ST_I_ON_III	>4	3	4 to 3	0	0	6.46	7.07	0.61	6.77	0	0	0	0	0	0	1.52	3.74	2.26	0	9	PHYSICAL	NO	ambient; wiper artifacts; feeding void; surf scour
RfSW10	D	9/16/97	ST_I	>4	3	4 to 3	0	0	7.22	7.93	0.71	7.58	0	0	0	0	0	0	NA	NA	1.50	0	3	PHYSICAL	NO	ambient; wiper artifacts; 4 shrimps
RfSW11	A	9/16/97	ST_I	>4	3	4 to 3	0	0	2.48	4.34	1.87	3.41	0	0	0	0	0	0	NA	NA	NA	0	NA	PHYSICAL	NO	ambient; shallow pen; shell frags and surf scour lag; rippled?
RfSW11	B	9/16/97	ST_I	>4	3	4 to 3	0	0	5.91	6.82	0.91	6.36	0	0	0	0	0	0	NA	NA	1.87	0	4	PHYSICAL	NO	ambient;br/gr silt;wiper artifacts;surf scour;RPDextrap
RfSW11	C	9/16/97	ST_I_ON_III	>4	3	4 to 3	0	0	3.18	4.50	1.31	3.84	0	0	0	0	0	0	NA	NA	1.62	0	8	PHYSICAL	NO	ambient;wiper artifacts;br/gr silt;feeding voids;smsurf tubes;RPDextrap
RfSW12	A	9/16/97	ST_III	>4	3	>4	0	0	7.27	8.18	0.91	7.73	0	0	0	0	0	0	0.76	2.42	1.38	0	7	BIOGENIC	NO	ambient; br/gr sed; burrow; feeding void
RfSW12	B	9/16/97	INDET	>4	3	>4	0	0	7.68	8.08	0.40	7.88	0	0	0	0	0	0	NA	NA	1.00	0	NA	PHYSICAL	NO	ambient; br/gr siltwiper artifacts; RPD extrap
RfSW12	C	9/16/97	INDET	>4	3	>4	0	0	4.49	5.66	1.16	5.08	0	0	0	0	0	0	0.45	3.08	1.29	0	NA	PHYSICAL	NO	ambient; br/gr silt; feeding void; sm surf tubes?
RfSW13	A	9/16/97	ST_I_ON_III	>4	3	4 to 3	0	0	4.60	5.25	0.66	4.92	0	0	0	0	0	0	NA	NA	1.50	0	7	PHYSICAL	NO	ambient;br/gr silt;wiper artifacts; sm surf tubes; RPD extrap
RfSW13	B	9/16/97	ST_I_ON_III	>4	2	3 to 2	0	0	4.44	4.90	0.45	4.67	0	0	0	0	0	0	NA	NA	NA	0	NA	INDET	NO	ambient; wiper clasts & smearing; burrow; feeding void & worm?
RfSW13	C	9/16/97	ST_I	>4	3	4 to 3	0	0	6.01	7.58	1.57	6.79	0	0	0	0	0	0	NA	NA	1.50	0	3	PHYSICAL	NO	ambient; br/gr-bk sed;3 shrimp (crangon)

APPENDIX C
March 1998 REMOTS® Surveys

APPENDIX C
March 1998 REMOTS® Surveys

REF AREAS

New Ref			Successional	Grain Size (phi)			Mud Clasts		Camera Penetration				Dredged Material Thickness			Redox Rebound Thickness			Apparent RPD Thickness					Surface			Low	
Station	Replicate	Date	Stage	Min	Max	Maj Mod	Count	Avg Dia	Min	Max	Range	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Methane	OSI	Roughness			DO	Comments
RCTR	D	3/6/98	ST_III	>4	3	>4	0	0	13.43	13.69	0.25	13.56	0	0	0	0	0	0	2.73	4.34	3.23	0	10	PHYSICAL	NOADDM	0	NO	ambient; br silt/bk sulfidic mud; feeding voids
RCTR	E	3/6/98	ST_I_ON_III	>4	3	>4	0	0	14.39	16.82	2.42	15.61	0	0	0	0	0	0	1.72	3.33	2.42	0	9	PHYSICAL	NOADDM	0	NO	ambient; br silt/bk mud,feeding voids; shell hash
RCTR	F	3/6/98	ST_III	>4	3	>4	0	0	14.24	15.76	1.52	15.00	0	0	0	0	0	0	2.50	7.00	3.29	0	10	PHYSICAL	NOADDM	0	NO	ambient; br silt/bk mud,wiper smears,RPD extrap,active&relict feeding voids
R100N	A	3/5/98	ST_III	>4	3	>4	0	0	13.71	14.33	0.62	14.02	0	0	0	0	0	5.5	2.32	3.35	2.80	0	9	INDET	Redox Reb. 6 cm	6.35	NO	ambient; br silt/bk mud; wiper smears;RPD extrap; active feeding voids?
R100N	B	3/5/98	ST_III	>4	3	>4	0	0	13.45	14.12	0.67	13.79	0	0	0	0	0	6.5	NA	NA	2.37	0	9	PHYSICAL	Est. depth of RPD	2.37	NO	ambient;S/M,lg wiper smear; br silt/gr/bk mud, feeding voids
R200N	C	3/5/98	ST_III	>4	4	>4	0	0	4.17	7.97	3.80	6.07	0	0	0	0	0	0	NA	NA	0.1	0	6	PHYSICAL	est depth of RPD	0.1	NO	ambient;.1cm br silt/bk sulfidic mud,wiper smear over profile;shell frags at surf, feeding voids
R200N	D	3/6/98	ST_I_ON_III	>4	3	>4	0	0	13.40	14.12	0.72	13.76	0	0	0	0	0	0	3.30	5.00	4.27	0	11	INDET	NOADDM	0	NO	ambient; br silt/bk sulfidic mud; sm surf tubes; feeding voids
R200N	E	3/6/98	ST_I_ON_III	>4	3	>4	0	0	14.64	15.62	0.98	15.13	0	0	0	0	0	0	3.66	6.04	4.86	0	11	PHYSICAL	NOADDM	0	NO	ambient; br silt/bk sulfidic mud,wiper c;asts&smears, RPD extrap; feeding voids
R300N	B	3/5/98	INDET	>4	3	>4	0	0	0.31	7.66	7.34	3.98	0	0	0	0	0	0	NA	NA	NA	0	NA	PHYSICAL	NOADDM	0	NO	ambient?; underpen; disturbed surf; 2cm wiper clast over surf,feeding void
R300N	D	3/6/98	ST_I	>4	>4	>4	0	0	11.25	11.93	0.68	11.59	0	0	0	0	0	6	3.23	3.85	3.56	0	6	INDET	NOADDM	0	NO	ambient,br silt/gr/bk mud,wiper smears,fracture near surf,smsurf tubes;active void?
R100NE	A	3/5/98	ST_I_ON_III	>4	3	>4	0	0	12.84	13.97	1.13	13.40	0	0	0	0	0	0	1.60	3.35	2.19	0	8	PHYSICAL	NOADDM	0	NO	ambient; br silt/bk sulfidic mud,active? feeding voids; shell hash
R100NE	B	3/5/98	ST_III	>4	3	>4	3	0.58	12.68	13.25	0.57	12.96	0	0	0	0	0	0	NA	NA	NA	0	NA	INDET	NOADDM	0	NO	ambient?,br silt/bk mud,wipersmears?,active feeding voids; shell hash
R200NE	A	3/5/98	INDET	>4	3	4 to 3	5	0.64	9.59	10.77	1.19	10.18	0	0	0	0	0	0	1.65	6.70	3.81	0	NA	PHYSICAL	NOADDM	0	NO	ambient; br silt/bk sulfidic mud,variable RPD; feeding voids?
R200NE	D	3/6/98	ST_III	>4	3	>4	0	0	14.33	15.15	0.82	14.74	0	0	0	0	0	6	3.35	5.00	4.12	0	11	PHYSICAL	NOADDM	0	NO	ambient; br silt/bk sulfidic mud;minor wiper smears; feeding voids
R200NE	E	3/6/98	INDET	>4	3	>4	0	0	12.47	12.84	0.36	12.65	0	0	0	0	0	0	NA	NA	NA	0	NA	PHYSICAL	NOADDM	0	NO	ambient,br silt/bk mud; severe wiper smearing
R300NE	A	3/5/98	ST_III	>4	3	>4	0	0	12.42	12.84	0.41	12.63	0	0	0	0	0	0	3.25	4.38	3.74	0	10	INDET	NOADDM	0	NO	ambient,br silt/bk mud; wiper smears; feeding voids,
R300NE	B	3/5/98	INDET	>4	3	>4	0	0	10.93	12.11	1.19	11.52	0	0	0	0	0	0	1.75	2.99	2.56	0	NA	PHYSICAL	NOADDM	0	NO	ambient; br silt/bk mud; severe wiper smearing; RPD extrap; feeding voids
R300NE	C	3/5/98	INDET	>4	3	>4	2	1.61	11.08	12.53	1.44	11.80	0	0	0	0	0	0	NA	NA	NA	0	NA	PHYSICAL	NOADDM	0	NO	ambient; br silt/bk mud; wiperclast?&smears; shell hash
R100E	A	3/5/98	ST_III	>4	3	>4	0	0	14.77	14.87	0.10	14.82	0	0	0	0	0	0	2.82	3.95	3.39	0	10	INDET	NOADDM	0	NO	ambient,br silt/bk mud;active? feeding voids; fracture at depth; shell hash
R100E	D	3/6/98	ST_III	>4	3	>4	0	0	16.62	17.38	0.77	17.00	0	0	0	0	0	0	0.87	2.15	1.72	0	8	PHYSICAL	NOADDM	0	NO	ambient,br silt/bk mud,wiper smearing;RPD extrap,relict/inactive voids,feeding voids
R100E	E	3/6/98	ST_I_ON_III	>4	3	>4	0	0	13.13	13.95	0.82	13.54	0	0	0	0	0	0	3.03	4.87	4.07	0	11	PHYSICAL	NOADDM	0	NO	ambient; br silt/bk mud; sm surf tubes; feeding voids; nephtys
R200E	A	3/5/98	ST_I_ON_III	>4	3	>4	0	0	11.28	12.41	1.13	11.85	0	0	0	0	0	0	2.36	4.10	3.28	0	10	PHYSICAL	NOADDM	0	NO	ambient; br silt/bk sulfidic mud; pull-away; sm surftubes; feeding voids
R200E	C	3/5/98	INDET	>4	3	>4	0	0	12.72	13.38	0.67	13.05	0	0	0	4.5	7	5.5	2.67	3.74	3.12	0	NA	PHYSICAL	NOADDM	0	NO	ambient; br silt/gr/bk sulfidic mud; wiper smears; RPD extrap; feeding voids?
R300E	A	3/5/98	INDET	>4	3	>4	0	0	0.31	4.77	4.46	2.54	0	0	0	0	0	0	0.05	1.64	0.93	0	NA	INDET	NOADDM	0	NO	ambient; underpen,br silt/bk sulfidic mud,disturbed surf(lg burrow?)
R300E	D	3/6/98	ST_I_ON_III	>4	3	>4	0	0	13.07	13.91	0.83	13.49	0	0	0	0	0	0	0.76	4.64	2.72	0	9	PHYSICAL	NOADDM	0	NO	ambient; br silt/gr-bk mud; shell hash; variable RPD
R300E	F	3/6/98	ST_III	>4	4	>4	0	0	9.48	13.33	3.85	11.41	0	0	0	0	0	0	NA	NA	NA	0	NA	PHYSICAL	NOADDM	0	NO	ambient; br silt/bk mud,rippled?,feeding void(fracture?),shell hash
R100SE	D	3/6/98	ST_I_ON_III	>4	3	>4	0	0	12.63	13.08	0.45	12.85	0	0	0	0	0	0	0.91	2.88	1.82	0	8	BIOGENIC	NOADDM	0	NO	ambient,br silt/gr-bk mud,feeding voids; shell hash
R100SE	E	3/6/98	ST_III	>4	3	>4	0	0	13.48	13.89	0.40	13.69	0	0	0	5.4	8.5[illegible]	6.99	0.91	3.80	2.50	0	9	BIOGENIC	NOADDM	0	NO	ambient,br silt/gr/bk sulfidic mud,wiper smears;RPD extrap,feeding voids
R100SE	F	3/6/98	ST_I_ON_III	>4	4	>4	0	0	10.86	12.88	2.02	11.87	0	0	0	6	12	8	0.80	4.50	2.80	0	8	PHYSICAL	NOADDM	0	NO	ambient,wipering smears,RPD extrap,br silt/gr mud,feeding voids; shell hash
R200SE	D	3/6/98	ST_I_ON_III	>4	3	>4	0	0	17.47	18.33	0.86	17.90	0	0	0	0	0	0	1.06	3.74	2.36	0	9	BIOGENIC	NOADDM	0	NO	amb; dm at depth?,thin br/bk sulfidic mud,wiper smears?,lg burrow(or dragdown?),shell frag
R200SE	E	3/6/98	ST_III	>4	3	>4	0	0	14.65	15.10	0.45	14.87	0	0	0	0	0	0	2.12	3.64	2.63	0	9	BIOGENIC	NOADDM	0	NO	ambient; br silt/bk mud,wiper smears;active or relict feeding voids?,shell hash;mercenera?
R200SE	F	3/6/98	ST_III	>4	3	>4	0	0	13.89	14.60	0.71	14.24	0	0	0	6.67	7.32	7	3.99	4.70	4.32	0	11	BIOGENIC	NOADDM	0	NO	ambient; wiper smears; RPD extrap; br silt/gr/bk mud,feeding voids
R300SE	A	3/5/98	ST_I	>4	3	>4	0	0	13.03	17.02	3.99	15.03	0	0	0	0	0	0	0.05	2.12	0.81	0	3	PHYSICAL	Lt bk band	8.08	NO	dm?,thin br silt/bk mud,lt/bk bands at depth;shell hash at surf,hi bd roughness
R300SE	B	3/5/98	ST_I_ON_III	>4	3	>4	0	0	18.64	19.09	0.45	18.86	0	0	0	0	0	0	1.46	4.14	3.05	0	10	BIOGENIC	NOADDM	0	NO	ambient; br silt/gr/bk mud; wiper smears; RPD extrap; shell hash
R300SE	C	3/5/98	INDET	>4	4	>4	0	0	5.30	15.25	9.95	10.28	0	0	0	0	0	0	NA	NA	NA	0	NA	INDET	NOADDM	0	NO	dm?; mud clast; wiper smears?; shell fragments
R100S	A	3/6/98	INDET	>4	3	>4	0	0	14.39	14.60	0.20	14.49	0	0	0	0	0	0	1.38	2.98	2.26	0	NA	INDET	NOADDM	0	NO	ambient; br silt/bk mud
R100S	B	3/6/98	ST_III	>4	3	>4	0	0	13.38	14.09	0.71	13.74	0	0	0	0	0	0	NA	NA	3.54	0	10	PHYSICAL	est depth of RPD	3.54	NO	ambient; br silt/gr-bk mud; wiper smears; active? feeding voids
R100S	C	3/6/98	INDET	>4	3	>4	3	1.64	11.82	12.42	0.61	12.12	?	?	?	0	0	0	NA	NA	NA	0	NA	INDET	NOADDM	0	NO	dm?; mottled sed profile?; wiper smear&clast
R200S	A	3/6/98	ST_I_ON_III	>4	3	>4	0	0	15.96	16.41	0.45	16.19	0	0	0	0	0	0	1.97	2.93	2.37	0	9	IOLOGICA	NOADDM	0	NO	ambient; br silt/bk sulfidic mud; wiper smear; feeding voids
R200S	B	3/6/98	INDET	>4	3	>4	0	0	13.64	14.80	1.16	14.22	0	0	0	0	0	0	NA	NA	1.82	0	NA	PHYSICAL	Est. depth of RPD	1.82	NO	ambient?; br silt/gr/bk mud; wiper smears; shell hash
R200S	C	3/6/98	ST_I_ON_III	>4	3	>4	0	0	15.26	17.09	1.84	16.17	0	0	0	0	0	0	3.32	5.66	4.14	0	11	PHYSICAL	NOADDM	0	NO	ambient,br silt/bk mud,wiper smears;RPD extrap,surf tubes,feeding voids;shell hash
R300S	A	3/6/98	ST_I	>4	3	>4	0	0	15.41	15.77	0.36	15.59	0	0	0	0	0	0	1.07	2.55	1.75	0	4	BIOGENIC	NOADDM	0	NO	ambient; brsilt/bk sulfidic mud; surf tubes; minor wiper smears
R300S	B	3/6/98	ST_III	>4	3	>4	0	0	14.54	15.26	0.71	14.90	0	0	0	0	0	0	NA	NA	3.52	0	10	INDET	est. depth of RPD	3.52	NO	ambient; br silt/bk sulfidic mud; wiper smears; feeding voids; shell hash
R300S	C	3/6/98	ST_III	>4	3	>4	0	0	15.77	16.73	0.97	16.25	0	0	0	0	0	0	1.89	2.76	2.26	0	9	INDET	NOADDM	0	NO	ambient; brsilt/bk sulfidic mud; wiper artifacts; RPD extrap; feeding voids
R100SW	A	3/6/98	ST_I_ON_III	>4	3	>4	0	0	15.00	15.35	0.35	15.18	0	0	0	0	0	0	3.74	4.85	4.28	0	11	INDET	NOADDM	0	NO	ambient; br silt/bk mud; dewatering pipe; RPD extrap
R100SW	B	3/6/98	ST_I_ON_III	>4	3	>4	0	0	8.33	12.37	4.04	10.35	0	0	0	0	0	0	NA	NA	3.54	0	10	PHYSICAL	est. depth of RPD	[illegible].54	NO	ambient; br silt/bk sulfidic mud; wiper smears; sloped surf; voids; shell hash
R100SW	C	3/6/98	ST_III	>4	3	>4	0	0	15.91	16.41	0.51	16.16	0	0	0	0	0	0	0.50	4.50	2.20	0	8	INDET	NOADDM	0	NO	ambient,br silt/gr/bk sulfidi sed,wiper smear,RPD extrap,shell hash
R200SW	A	3/6/98	ST_III	>4	3	>4	1	3.08	7.32	9.90	2.58	8.61	0	0	0	0	0	0	3.48	4.90	4.14	0	11	PHYSICAL	NOADDM	0	NO	ambient; br silt/gr mud; wiper smear. rock/clast in distance; surf tubes; voids
R200SW	C	3/6/98	ST_I	>4	3	>4	0	0	12.32	13.54	1.21	12.93	?	?	?	0	0	0	0.30	1.20	0.72	0	2	PHYSICAL	NOADDM	0	NO	dm?, thin br silt/bk sulfidic mud,dk bk band at depth; fracture at surf; voids; shell hash
R300SW	A	3/6/98	ST_I_ON_III	>4	3	>4	0	0	17.68	18.76	1.08	18.22	0	0	0	0	0	0	0.26	2.50	2.00	0	8	PHYSICAL	NOADDM	0	NO	ambient; br silt/bk mud,wiper smear?,RPD extrap;surf tubes; active? feeding voids,shell hash
R300SW	B	3/6/98	ST_III	>4	3	>4	0	0	10.77	13.97	3.20	12.37	0	0	0	0	0	0	NA	NA	NA	0	NA	PHYSICAL	NOADDM	0	NO	ambient; br silt/bk mud; wiper smears;active? feeding voids; worm?,shell fragments
R300SW	C	3/6/98	ST_I_ON_III	>4	3	>4	1	0.[illegible]2	15.10	15.35	0.25	15.23	0	0	0	0	0	4.5	1.57	2.83	2.50	0	9	BIOGENIC	NOADDM	0	NO	ambient; br silt/gr/bkmud; wiper smears,sm surf tubes;active? feeding voids
R100W	A	3/5/98	ST_III	>4	3	>4	0	0	13.85	14.46	0.62	14.15	0	0	0	0	0	0	3.13	4.72	3.94	0	11	INDET	NOADDM	0	NO	ambient; br silt/bk sulfidic mud; feeding voids at depth; shell hash
R100W	D	3/6/98	ST_III	>4	3	4 to 3	4	0.64	15.64	16.56	0.92	16.10	0	0	0	0	0	0	2.56	3.69	3.24	0	10	PHYSICAL	NOADDM	0	NO	ambient,S/M,br silt/bk sulfidic mud,wiper smears&clasts?,feeding voids
R100W	E	3/6/98	ST_III	>4	3	>4	0	0	11.44	12.51	1.08	11.97	0	0	0	5.59	8.97	7.28	3.13	5.13	3.87	0	11	PHYSICAL	NOADDM	0	NO	ambient; br silt/gr/bk sulfidic mud,wiper smears; shell hash
R200W	A	3/5/98	ST_III	>4	3	>4	0	0	13.33	13.85	0.51	13.59	0	0	0	7.44	8.46	7.95	4.15	5.08	4.63	0	11	PHYSICAL	NOADDM	0	NO	ambient, br silt/gr/gr-bkmud; feeding voids
R200W	B	3/5/98	INDET	>4	3	4 to 3	0	0	0.20	4.10	3.90	2.15	0	0	0	0	0	0	NA	NA	2.05	0	NA	PHYSICAL	Est depth of RPD	2.05	NO	ambient; br silt/bk mud?; underpen; shell hash, erosional
R300W	A	3/5/98	ST_I_ON_III	>4	3	>4	0	0	14.36	14.56	0.21	14.46	0	0	0	0	0	0	3.18	4.87	4.03	0	11	BIOGENIC	NOADDM	0	NO	ambient or old dm?; br silt/bk sulfidic mud,wiper smears,sm surf tubes,feeding void,shell hash
R300W	C	3/5/98	ST_III	>4	3	>4	0	0	14.92	15.69	0.77	15.31	0	0	0	0	0	0	3.18	4.87	4.03	0	11	INDET	NOADDM	0	NO	ambient or old dm?; br silt/bk sulfidic mud; wiper clasts&smears; feeding voids
R100NW	A	3/5/98	ST_I_ON_III	>4	4	>4	0	0	3.69	7.17	3.48	5.43	0	0	0	0	0	0	4.00	6.00	5.00	0	11	PHYSICAL	NOADDM	0	NO	ambient; shallow pen,br silt,wiper smears,RPD extrap,feeding voids
R100NW	D	3/6/98	ST_III	>4	3	>4	0	0	13.23	13.54	0.30	13.38	0	0	0	0	0	0	2.47	3.54	3.12	0	10	BIOGENIC	NOADDM	0	NO	ambient; br silt/gr-bk mud, feeding voids
R200NW	A	3/5/98	ST_I	>4	3	>4	0	0	11.57	12.47	0.91	12.02	0	0	0	0	0	0	2.27	4.55	3.33	0	6	BIOGENIC	NOADDM	0	NO	ambient; br silt/gr-bk mud; feeding voids?; shell hash
R200NW	B	3/5/98	ST_I_ON_III	>4	4	>4	0	0	12.17	13.28	1.11	12.73	0	0	0	0	0	0	4.85	6.01	5.48	0	11	BIOGENIC	NOADDM	0	NO	ambient; br silt/gr-bk mud; wiper clast and smearing; smsurf tubes; feeding voids
R200NW	C	3/5/98	ST_I_ON_III	>4	3	4 to 3	0	0	11.31	12.12	0.81	11.72	0	0	0	7.5	9	8	3.43	4.65	4.25	0	11	PHYSICAL	NOADDM	0	NO	ambient; br silt/gr-bk mud; sm surf tubes,feeding voids
R300NW	B	3/5/98	ST_I_ON_III	>4	3	>4	0	0	13.38	13.79	0.41	13.59	0	0	0	0	0	0	1.90	3.33	2.78	0	9	PHYSICAL	NOADDM	0	NO	ambient,br silt/bk mud,wiper clasts&smears,RPD extrap,feeding voids; shell hash
R300NW	C	3/5/98	INDET	>4	4	>4	0	0	0.05	7.59	7.54	3.82	0	0	0	0	0	0	NA	NA	1.64	0	NA	INDET	Est. depth of RPD	1.64	NO	Indeterminant;disturbed;drag-down;sm.area of br silt/bk mud
R300NW	D	3/5/98	ST_I_ON_III	>4	3	>4	0	0	11.54	12.72	1.18	12.13	0	0	0	0	0	0	2.77	4.72	3.91	0	11	BIOGENIC	NOADDM	0	NO	ambient,br silt/bk mud,feeding voids;relict voids at depth,fracture?,sm surf tube?,shell hash

H MOUND

H MOUND			Successional	Grain Size (phi)			Mud Clasts		Camera Penetration				Dredged Material Thickness			Redox Rebound Thickness			Apparent RPD Thickness					Surface	Low	
Station	Replicate	Date	Stage	Min	Max	Maj Mode	Count	Avg Dia	Min	Max	Range	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Methane	OSI	Roughness	DO	Comments
HCTR	A	3/6/98	INDET	>4	2	>4	0	0	11.07	12.04	0.97	11.56	10.97	12.04	11.30	0	0	0	1.53	4.54	3.18	0	NA	INDET	NO	dm>pen; pocket of gr clay; worm; voids?
HCTR	B	3/6/98	ST_III	>4	3	>4	0	0	13.11	13.62	0.51	13.37	13.12	13.60	13.40	5.82	7.19	6.51	1	2.5	2.2	0	8	INDET	NO	dm>pen; wiper smear;RPD extrap;dm layering; worm; voids?
HCTR	C	3/6/98	ST_III	>4	3	>4	0	0	13.27	13.98	0.71	13.62	13.26	14.00	13.60	3.98	5.41	4.69	0.77	1.99	1.41	0	7	PHYSICAL	NO	dm>pen; wiper smears; RPD extrap;dm layering; feeding voids
H50N	A	3/6/98	ST_III	>4	3	>4	0	0	9.54	10.61	1.07	10.08	9.54	10.82	10.00	0	0	0	0.31	1.79	0.9	0	7	PHYSICAL	NO	dm>pen; thin RPD; active feeding void; shell lag at surf
H50N	B	3/6/98	ST_I_ON_III	>4	3	>4	0	0	14.03	14.8	0.77	14.41	14.03	14.80	14.47	0	0	0	2	4	3	0	9	INDET	NO	dm>pen; wiper smears;RPD extrap; active&relic feeding voids?
H50N	C	3/6/98	ST_I_ON_III	>4	3	>4	0	0	13.47	13 93	0.46	13.7	13.42	13 98	13.70	0	0	0	1.22	2 86	2.08	0	8	INDET	NO	dm>pen; wiper smears; feeding voids
H50E	A	3/6/98	ST_I_ON_III	>4	2	>4	0	0	15.31	15.61	0.31	15.46	15.20	15.51	15.33	5.15	5.15	5.15	1.33	2.6	1.84	0	8	BIOLOGICAL	NO	dm?>pen; feeding voids; surf tubes?; rippled surf
H50E	B	3/6/98	ST_I_ON_III	>4	2	>4	0	0	19.34	20.46	1.12	19.9	19.35	20.41	20.01	0	0	0	2.7	5.61	4.6	0	11	INDET	NO	dm>pen; wiper smears; RPD extrap; feeding voids
H50E	C	3/6/98	ST_I	>4	2	>4	1	0.25	12.45	13 21	0.77	12.83	12.50	13 27	12.76	5	6.17	5.59	1.43	3.16	2.14	0	4	BIOLOGICAL	NO	dm>pen; wiper smears; RPD extrap; feeding voids; worm; surf tubes?
H50S	A	3/6/98	ST_III	>4	2	>4	0	0	11.53	12 04	0.51	11.79	11.53	12.14	11.96	0	0	0	2.04	3.27	2.67	0	9	INDET	NO	dm>pen; feeding voids; camera cable
H50S	B	3/6/98	ST_III	>4	2	>4	0	0	13.93	15.26	1.33	14.59	14.03	15.26	14.78	0	0	0	1.22	3.27	2.57	0	9	INDET	NO	dm>pen; wiper clast&smears; RPD extrap; active? feeding voids
H50S	C	3/6/98	ST_III	>4	3	>4	0	0.71	11.99	12.4	0.41	12.19	11.89	12.30	12.12	0	0	0	NA	NA	NA	0	NA	PHYSICAL	NO	dm>pen;wipersmear&clasts?;br silt/gr-bk mud; active feeding void
H50W	A	3/6/98	ST_I	>4	3	>4	0	0	16.84	17.5	0.66	17.17	16.79	17.45	17.05	3.42	4.18	3.8	0.92	2.3	1.56	0	4	PHYSICAL	NO	dm>pen; rippled surf; surf tubes; feeding voids?
H50W	B	3/6/98	INDET	>4	3	>4	0	0	14.13	15.41	1.28	14.77	14.12	15.42	14.71	3.5	6	5	NA	NA	NA	0	NA	PHYSICAL	NO	dm>pen; severe wiper smears; feeding voids?
H50W	C	3/6/98	ST_I	>4	3	>4	0	0	14.13	14.74	0.61	14.44	14.11	14.75	14.48	4.85	6.63	5.74	0.82	2.91	1.82	0	4	INDET	NO	dm>pen; wiper smears&clast; RPD extrap;feeding voids?

I MOUND

I MOUND			Successional	Grain Size (phi)			Mud Clasts		Camera Penetration				Dredged Material Thickness			Redox Rebound Thickness			Apparent RPD Thickness					Surface	Low	
Station	Replic	Date	Stage	Min	Max	Maj. Mode	Count	Avg Diam	Min	Max	Range	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Methane	OSI	Roughness	DO	Comments
ICTR	A	3/6/98	ST_I	>4	3	4 to 3	0	0	5.56	8.16	2.60	6.86	5.61	8.11	6.74	0	0	0	2.04	5.1	3.4	0	6	PHYSICAL	NO	dm>pen; wiper smears; RPD extrap; shell hash; rippled?
ICTR	B	3/6/98	ST_I_ON_II	>4	3	>4	0	0	5.46	6.89	1.43	6.17	5.46	6.79	6.05	0	0	0	2.04	3.47	2.81	0	9	PHYSICAL	NO	dm>pen; wiper smears; RPD extrap; feeding voids; surf tubes?
I50N	A	3/6/98	INDET	>4	<-1	4 to 3	0	0	0.31	1.89	1.58	1.10	0.30	1.91	1.08	0	0	0	NA	NA	NA	0	NA	PHYSICAL	NO	underpen;dm>pen; shells&rock lag on surf; sand; poor sorting
I50N	B	3/6/98	INDET	>4	0	3 to 2	0	0	0.82	1.63	0.81	1.22	0.80	1.65	1.25	0	0	0	NA	NA	NA	0	NA	PHYSICAL	NO	underpen;dm>pen; rocks&shell lag on surf; sand; cohesive surface crust
I50N	C	3/6/98	INDET	>4	2	4 to 3	0	0	2.65	4.13	1.48	3.39	2.81	4.03	3.45	0	0	0	NA	NA	NA	0	NA	PHYSICAL	NO	dm>pen; sand; wiper smears?;surf scour; hydroids; rippled?
I50E	A	3/6/98	ST_III	>4	3	>4	0	0	7.40	8.37	0.97	7.88	7.14	8.11	7.70	0	0	0	1.28	4.13	1.92	0	8	PHYSICAL	NO	dm>pen; br silt/bk mud;wiper smear;RPD extrap;active feeding void?;shell frag
I50E	B	3/6/98	ST_III	>4	3	>4	0	0	10.31	10.77	0.46	10.54	10.36	10.71	10.44	0	0	0	1.02	2.19	1.55	0	8	PHYSICAL	NO	dm>pen; br silt/bk mud; wiper smears;RPD extrap;feeding voids
I50E	C	3/6/98	ST_III	>4	3	4 to 3	0	0	8.27	12.30	4.03	10.28	8.47	12.35	10.60	0	0	0	NA	NA	NA	0	NA	PHYSICAL	NO	dm>pen; br silt w/ bk wiper smears; deep RPD?; feeding voids
I50S	A	3/6/98	ST_I_ON_II	>4	3	>4	0	0	9.59	10.36	0.77	9.97	9.64	10.31	10.05	0	0	0	2.3	5.87	3.46	0	10	INDET	NO	dm>pen; chaotic fabric at depth; feeding voids; hydroids
I50S	B	3/6/98	ST_I	>4	3	4 to 3	0	0	9.69	11.43	1.73	10.56	9.44	11.43	10.74	0	0	0	NA	NA	NA	0	NA	INDET	NO	dm>pen;wiper artifacts;fractured gr clay at depth;feeding voids?; hydroids
I50S	C	3/6/98	INDET	>4	3	>4	0	0	10.92	11.43	0.51	11.17	10.82	11.43	11.08	0	0	0	NA	NA	NA	0	NA	INDET	NO	dm>pen; S/M?; wiper smears; hydroids?; poss. worm
I50W	A	3/6/98	ST_I	>4	3	>4	0	0	8.01	8.62	0.61	8.32	7.91	8.67	8.26	0	0	0	0.92	3.01	2.37	0	5	INDET	NO	dm>pen; br silt/bk mud
I50W	B	3/6/98	ST_I	>4	3	>4	0	0	10.36	10.66	0.31	10.51	10.26	10.66	10.45	4.23	5.56	4.9	1.17	2.7	2.43	0	5	INDET	NO	dm>pen; br S/bk mud;wiper smears; RPD extrap; layered
I50W	C	3/6/98	ST_III	>4	3	>4	0	0	6.58	6.79	0.20	6.68	6.48	6.89	6.63	0	0	0	NA	NA	NA	0	NA	INDET	NO	dm>pen; br silt/bk mud; severe wiper smear; feeding voids