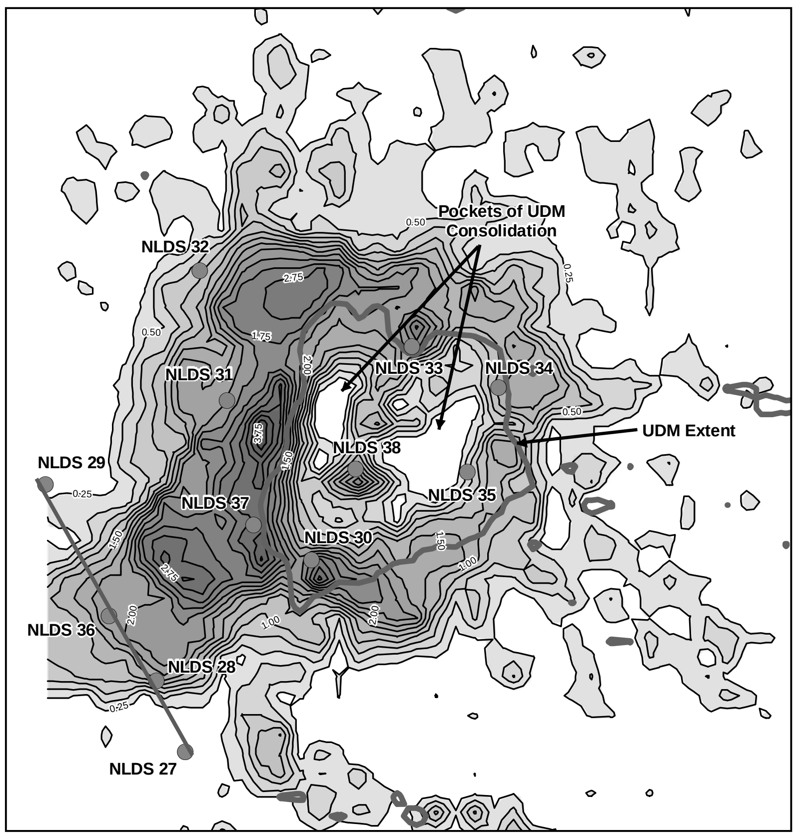
Monitoring Survey at the New London Disposal Site June 2001

Disposal Area Monitoring System DAMOS



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13. ABSTRACT

The New London Disposal Site (NLDS) was monitored in June 2001 as part of the Disposal Area Monitoring System (DAMOS) Program. The survey objectives were to evaluate the physical and chemical composition of the deposited sediment comprising the capped Seawolf Mound and the benthic recolonization status of this mound relative to ambient conditions at the reference areas. Physical and chemical analysis of sediment cores verified the presence of at least 0.5 m of capping dredged material (CDM) over the Seawolf Mound. Additionally, three long cores collected from the inner, middle and outer zones of the Seawolf Mound provided further evidence of the presence of between 1 and 2 m of cap material over most of the disposal mound. There was no evidence of migration or release of contaminants from unacceptably-contaminated dredged material (UDM) layers beneath the cap detected in either the short cores (upper 0.5 m of sediment) or long cores (analyzed to 2 m depth in the sediment). Sediment chemistry results compared to conservative ecological benchmarks indicated negligible potential for adverse effects to benthic infauna that may be in contact with the sediments in the Seawolf Mound, even for the maximum concentrations of contaminants detected in the survey. Overall, the June 2001 coring results indicate that the cap over the Seawolf Mound was a stable, thick layer that continued to effectively isolate the unsuitable sediments from the environment of eastern Long Island Sound.

In support of these findings pertaining to sediment chemistry, Remote Ecological Monitoring of the Seafloor (REMOTS®) sediment-profile imaging and benthic community analysis both indicated the presence of a stable and biologically active benthic community at the time of the June 2001 survey. The benthic recolonization over the surface of the mound was relatively advanced, with abundant evidence of a mature or “equilibrium” community. Surface-dwelling, Stage I polychaetes and tube-dwelling, Stage II amphipods were ubiquitous and abundant. Subsurface-deposit-feeding and carnivorous polychaetes, indicative of Stage III, also were found in relative abundance. Compared to the results of the September 1997 survey conducted 1.5 years following the creation of the capped mound, the benthic community in June 2001 (5 years postcap) was more abundant, had significantly more species present, and had greater diversity and evenness. These results indicate that in the five years since its creation, the Seawolf Mound had become inhabited by an advanced infaunal community comprised of a diverse mix of Stage I, II and III taxa. These results are consistent with expectations based on the standard model of infaunal succession following physical seafloor disturbance in Long Island Sound.

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EXECUTIVE SUMMARY

The New London Disposal Site (NLDS) was monitored by Science Applications International Corporation (SAIC) in June 2001 as part of the Disposal Area Monitoring System (DAMOS) Program. Field operations consisting of sediment coring, sediment-profile imaging, and benthic community sampling were concentrated over the Seawolf disposal mound and three nearby NLDS reference areas. The survey objectives were to evaluate the physical and chemical composition of the deposited sediment comprising the capped Seawolf Mound and the benthic recolonization status of this mound relative to ambient conditions at the reference areas.

Physical and chemical analysis of the June 2001 sediment cores served to verify that the sediment comprising the upper 0.5 m of the Seawolf Mound was capping dredged material (CDM). Seven short cores collected from within the acoustically detectible footprint of the Seawolf Mound verified the presence of at least 0.5 m of CDM. Additionally, three long cores collected from the inner, middle and outer zones of the Seawolf Mound provided further evidence of the presence of between 1 and 2 m of cap material over most of the disposal mound. There was no evidence of migration or release of contaminants from unacceptably-contaminated dredged material (UDM) layers beneath the cap detected in either the short cores (upper 0.5 m of sediment) or long cores (analyzed to 2 m depth in the sediment). Overall, the June 2001 coring results indicate that the cap over the Seawolf Mound was a stable, thick layer that continued to effectively isolate the unsuitable sediments from the environment of eastern Long Island Sound.

Two short cores collected beyond the acoustically detectible footprint of the Seawolf Mound, in areas not included in previous surveys, indicated slightly higher concentrations of some contaminants compared to the remaining Seawolf Mound cores. The concentrations in these samples were less than pre-dredging UDM/CDM concentrations, and may simply reflect variability in the Seawolf CDM. However, based on differences in grain size and chemistry compared to the remainder of the mound, these samples may reflect a non-Seawolf source of dredged material. Possible sources include historic (e.g., pre-Seawolf) dredged material disposal in the region, and dredged material from the Mystic River and Venetian Harbor directed to NDA 95 buoy to the southwest of the Seawolf disposal buoy during the same timeframe as the Seawolf capping activities.

Sediment chemistry results compared to conservative ecological benchmarks indicated negligible potential for adverse effects to benthic infauna that may be in contact with the sediments in the Seawolf Mound, even for the maximum concentrations of contaminants detected in the survey.

In support of these findings pertaining to sediment chemistry, Remote Ecological Monitoring of the Seafloor (REMOTS®) sediment-profile imaging and benthic community analysis both indicated the presence of a stable and biologically active benthic community

at the time of the June 2001 survey. The benthic recolonization over the surface of the mound was relatively advanced, with abundant evidence of a mature or "equilibrium" community. The stations over the disposal mound showed consistent benthic habitat conditions, with median REMOTS® Organism-Sediment Index (OSI) values ranging from moderately disturbed to undisturbed. The overall median OSI of +8.2 (undisturbed benthic habitat quality) reflected moderately-well oxygenated surface sediments (overall RPDof 2.5 cm) and the presence of mainly Stage II and III organisms over the disposal mound. The OSI value for the Seawolf Mound was considerably higher than that observed at the reference areas, where a value of +5.5, attributable to less Stage III activity reflected differences in sediment type.

The sediment-profile images indicated that benthic organisms were abundant over the Seawolf Mound at the time of the June 2001 survey. Dense assemblages of early- to mid-stage colonizers (successional stages I and II) were visible at the sediment surface, and there was ample evidence that larger bodied, deeper dwelling taxa (Stage III) were inhabiting the mound surface in significant numbers. Based on the image interpretation, the community was characterized as representing an advanced, Stage II on III successional status.

Benthic taxonomic data collected at stations across the mound served to verify the sediment-profile image interpretation. Surface-dwelling, Stage I polychaetesand tube-dwelling, Stage II amphipods were ubiquitous and abundant. Subsurface-deposit-feeding and carnivorous polychaetes, indicative of Stage III, also were found in relative abundance. Compared to the results of the September 1997 survey conducted 1.5 years following the creation of the capped mound, the benthic community in June 2001 (five years postcap) was more abundant, had significantly more species present, and had greater diversity and evenness. These results indicate that in the five years since its creation, the Seawolf Mound had become inhabited by an advanced infaunal community comprised of a diverse mix of Stage I, II and III taxa. These results are consistent with expectations based on the standard model of infaunal succession following physical seafloor disturbance in Long Island Sound.

1.0 INTRODUCTION

This report presents the results of a monitoring survey conducted at the Seawolf Mound of the New London Disposal Site (NLDS) in June 2001. The information acquired from this survey was compared to previous surveys of September 1997, July 1998, and August 2000 to evaluate trends in environmental conditions over this capped dredged material mound.

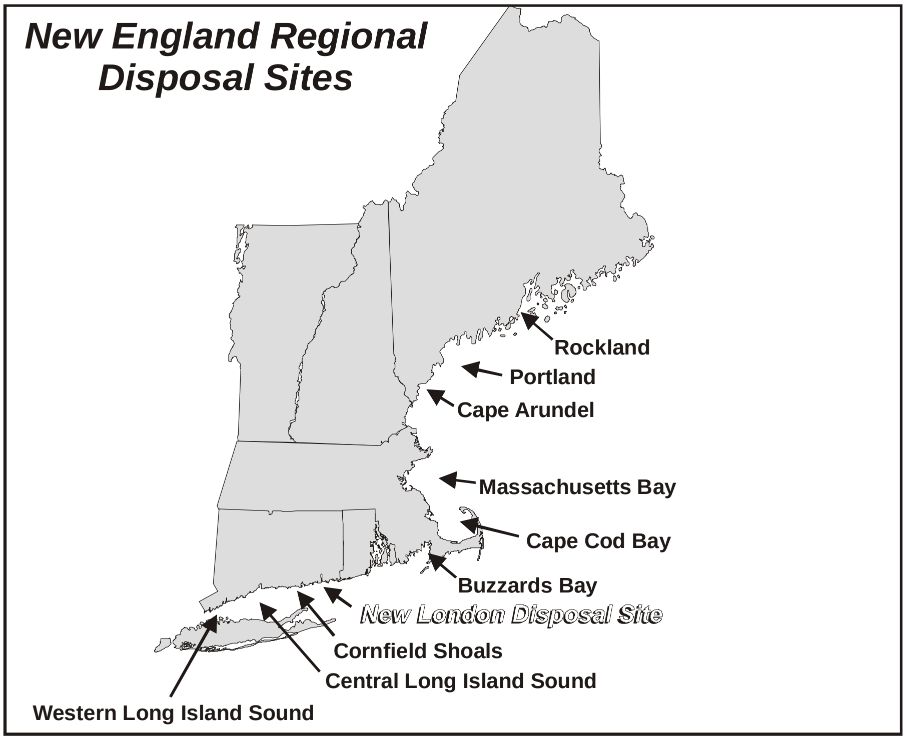
1.1 Background

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

The Thames River, located in southeastern Connecticut, discharges fresh water and sediment from interior New England into eastern Long Island Sound. Military, commercial, and recreational vessels, seeking protection from the open waters of the Atlantic Ocean and Long Island Sound use the mile-wide basin of the lower Thames River and New London Harbor. Maintenance dredging of New London Harbor and adjacent coastal areas is required to ensure navigable waterways and adequate dockage for deep draft vessels. Material generated from dredging operations in the New London region that is classified as suitable for open water disposal is removed by mechanical means, transported by barge, and typically deposited at NLDS in Long Island Sound.

The NLDS is located 5.38 km (3.1 nmi) south of Eastern Point, Groton, Connecticut and is centered at coordinates 41° 16.306´ N, 72° 04.571´ W (NAD 83; Figure 1-2). The disposal site covers a 3.42 km^2 area of seafloor, with water depths that range from 14 m over the NL-RELIC dredged material mound to 24 m at the southern disposal site boundary (Figure 1-3). Currently, this site is utilized for the unconfined disposal of suitable sediments, as well as subaqueous capping of sediments deemed unsuitable for open water disposal.

A



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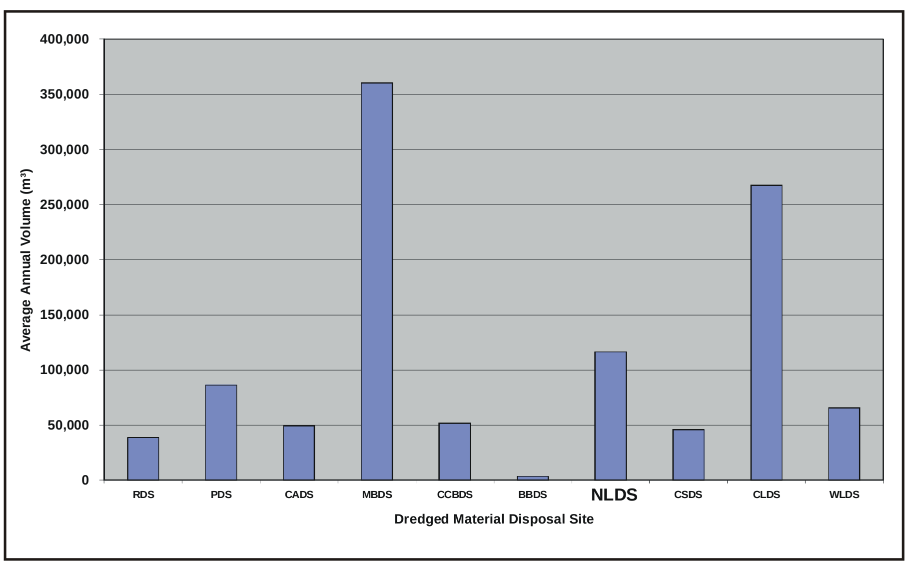


Figure 1-1. Location of the ten dredged material disposal sites along coastal New England (upper panel A) and average annual dredged material disposal volumes at each site for the period 1982 to 2001 (lower panel B)

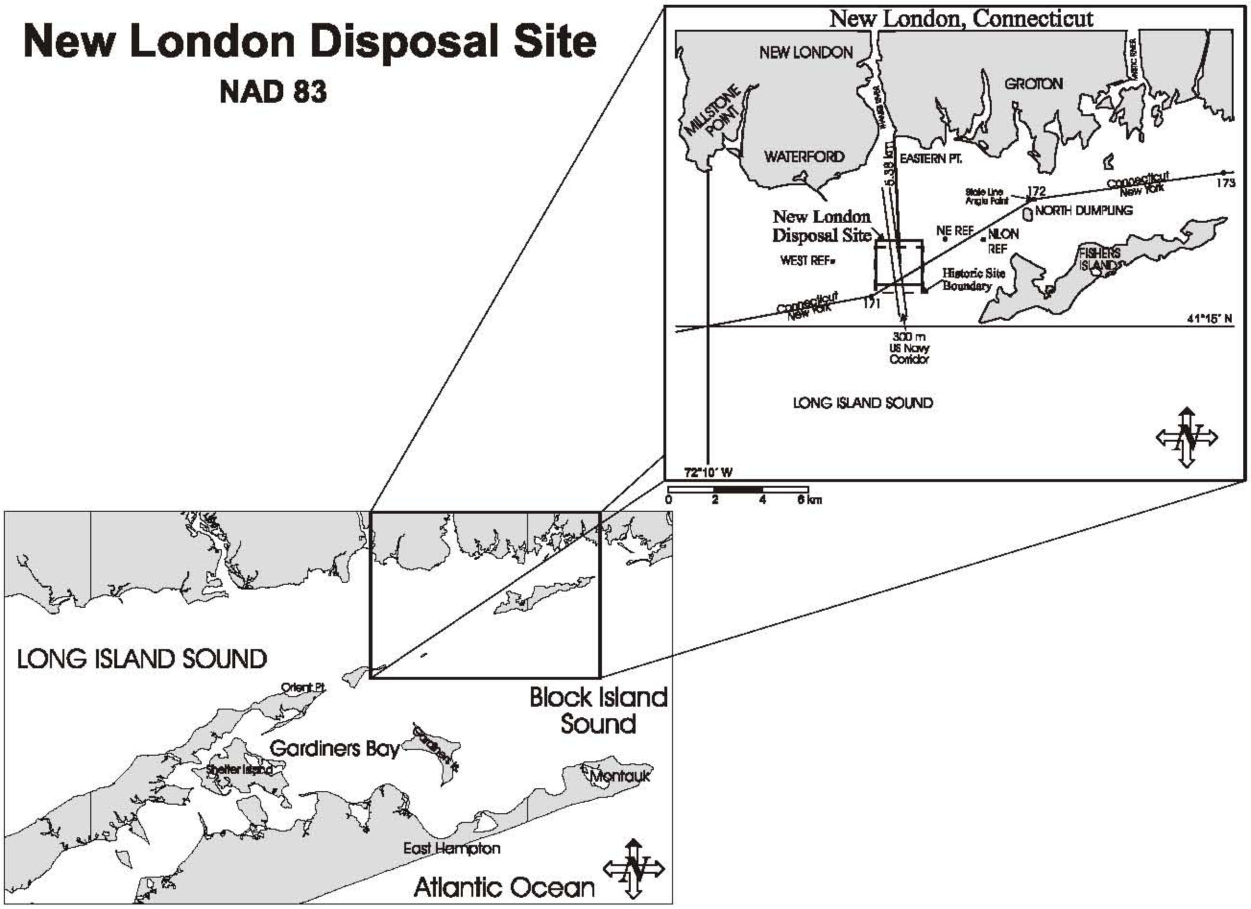


Figure 1-2. Location of the New London Disposal Site in eastern Long Island Sound relative to the surrounding Connecticut and New York coastlines

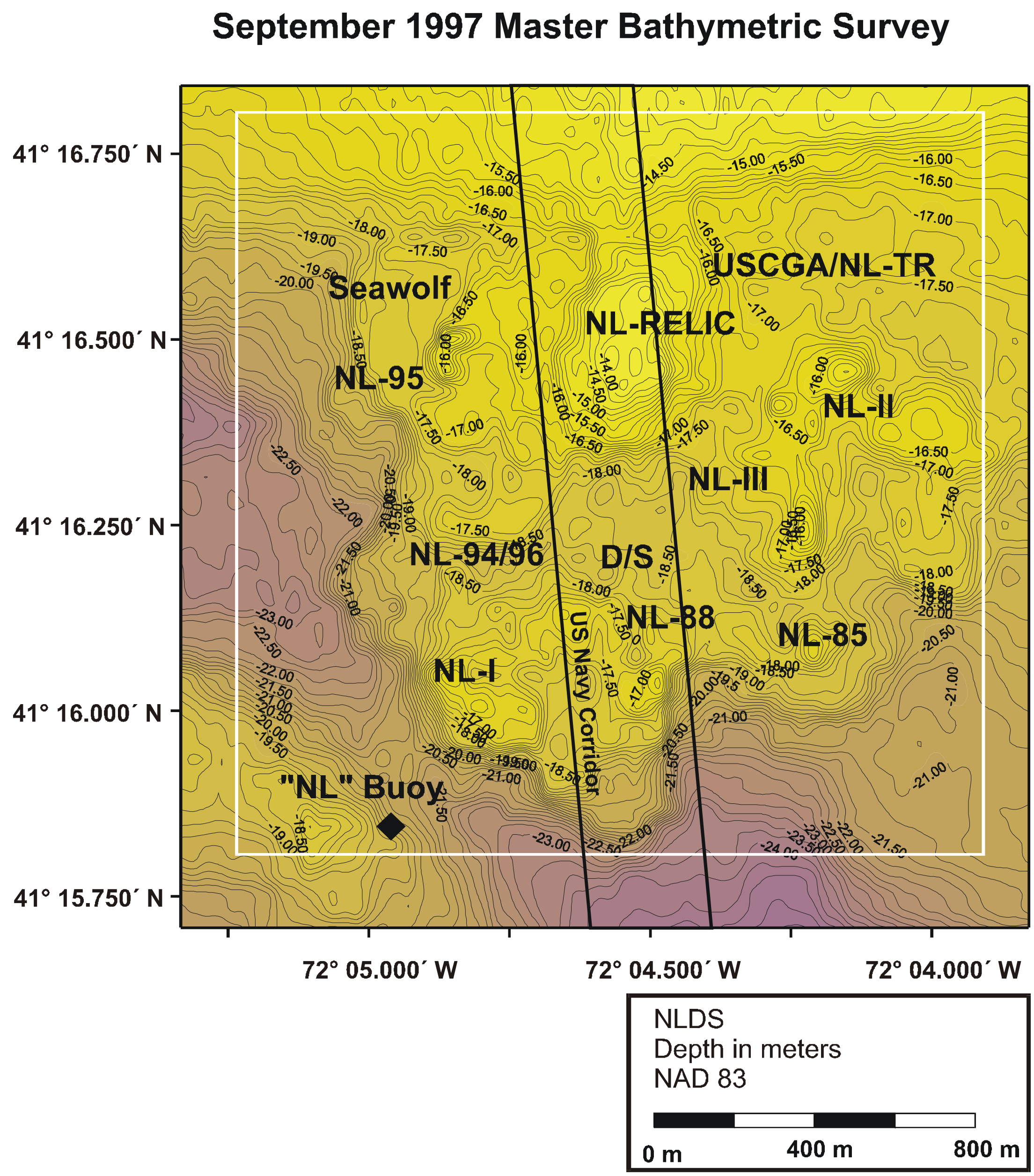


Figure 1-3. Bathymetric chart of the New London Disposal Site displaying the ten discernable mounds on the seafloor relative to the disposal site boundary (white) and 300 m wide U.S. Navy corridor (black). Depth contours are based upon a bathymetric survey conducted by SAIC in September 1997.

Long-term monitoring of the environmental effects of dredged material from specific dredging projects/locations is facilitated by the construction of individual disposal mounds on the seafloor. To reduce the potential effects of bottom currents and storm-generated waves, dredged material mounds at NLDS are developed in a broad, flat manner, maintaining a minimum water depth of 14 meters. This minimum depth also allows for the safe passage of any deep draft vessels transiting through the disposal site (NUSC 1979).

Presently, there are ten discernible mounds (NL-95 is merged with the Seawolf Mound) within the boundaries of the disposal site (Figure 1-3). When necessary, mounds are constructed in phases to allow for capping of material deemed unsuitable for open-water disposal. Capping is a subaqueous containment method that utilizes material determined to be suitable for open-water disposal, or capping dredged material (CDM), to overlay and isolate deposits of unacceptably-contaminated dredged material (UDM) from the surrounding environment (Fredette 1994). The Seawolf Mound, Dow/Stonington (D/S) Mound Complex, and United States Coast Guard Academy (USCGA) Mound are examples of capped mounds at NLDS. These mounds were formed prior to 1997 and have been monitored at regular intervals by the DAMOS Program. The Seawolf Mound is a large capped mound created in the northwestern quadrant of NLDS during the 1995/96 disposal season (Figure 1-3).

1.2 Seawolf Mound

Dredging of the Thames River was deemed necessary when the U.S. Navy decided to homeport the *Seawolf* class submarines in Groton, CT (Maguire Group, Inc. 1995). The Seawolf dredging project and a small-scale Mystic River project resulted in the placement of 306,000 m^3 of UDM at NLDS, which was subsequently covered by 556,000 m^3 of CDM during the 1995/1996 disposal season (SAIC 2001a). An additional 15,500 m^3 of sediments from Venetian Harbor and Mystic River deemed suitable for open-water disposal were placed at the NDA 95 buoy located roughly 250 m to the southwest of the main Seawolf Mound. These smaller projects also contributed to the Seawolf Mound and were documented in the depth difference calculations between sequential bathymetric survey grids. The disposal of maintenance sediment (material dredged within an authorized depth) and new work sediment (material dredged to a newly authorized depth) resulted in a total estimated volume of 877,500 m^3 of sediment (UDM plus CDM) deposited at the Seawolf Mound.

Pre-dredging characterization of the Seawolf Project sediments detected higher levels of polycyclic aromatic hydrocarbons (PAHs) and trace metals (Cu, Cr, and Zn) in a small area adjacent to the proposed submarine berthing areas (Maguire Group, Inc. 1995). These contaminants were found in low (Class I) to moderate (Class II) concentrations

(NERBC 1980) and were attributed to past storage and maintenance of vessels in the area (Maguire Group, Inc. 1995). A fraction of these Seawolf Project sediments with higher contaminant levels were classified as UDM based on biological testing. In addition, a small volume of the Mystic River sediments from Mystic Seaport was also classified as UDM. The placement of the UDM from these projects at NLDS required a comprehensive disposal site monitoring program to ensure adequate coverage of this material with CDM to isolate it from the marine environment.

A series of comprehensive environmental monitoring surveys has been conducted over the Seawolf Mound, both to track the development of this bottom feature, and to assess its long-term fate on the NLDS seafloor. Several bathymetric surveys were sponsored by the U.S. Navy during the 1995–96 disposal season to track post-depositional changes in the mound. Science Applications International Corporation (SAIC) conducted surveys at the Seawolf Mound in 1997 and 1998 through the DAMOS Program, with funding by the U.S. Navy, to meet technical and management objectives of the U.S. Navy five-year monitoring plan (Maguire Group, Inc. 1995). Prior to the June 2001 survey reported here, this mound was last surveyed by DAMOS in August 2000.

1.3 Objectives and Predictions

This survey included the following activities and objectives:

1) a series of sediment cores were collected over the mound to assess the physical and chemical composition of the deposited sediment;
2) sediment grab samples were collected at six stations over the Seawolf Mound for subsequent taxonomic identification and enumeration of benthic infaunal organisms; and
3) a REMOTS® sediment-profile imaging survey was performed to examine benthic recolonization status over the mound in comparison with the benthic taxonomic data.

The June 2001 survey tested the following predictions:

1) geochemical analysis would show the presence of a discrete layer of CDM and an absence of any UDM in the top 0.5 m of the mound, and
2) at five years postdisposal, infaunal succession within the surface sediments of the Seawolf Mound was expected to have resulted in a mature Stage III community, as predicted by the DAMOS tiered monitoring protocol.

To address the first objective, a sediment coring survey was conducted over the Seawolf Mound, and the results compared to those from the 1990, 1992, and 1994 pre-dredge characterization studies, as well as to the 1997 and 1998 postcap coring survey results. To address the second objective, a REMOTS® sediment-profile imaging survey was performed to evaluate the benthic recolonization status and overall benthic habitat quality over the mound relative to nearby reference areas. Benthic community samples also were collected over the mound. The benthic taxonomic results were compared to both the June 2001 REMOTS® results and benthic community results from September 1997 to further evaluate benthic recolonization status.

2.0 METHODS

Field operations involving REMOTS® sediment-profile imaging and sediment grab sampling were performed aboard the M/V *Beavertail* on 21 and 22 June 2001. The sediment coring operations were performed aboard the R/V *CAN-DO* on 27 and 28 June 2001.

2.1 Vessel Positioning

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

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

2.2 Sediment Coring

Sediment cores collected over the Seawolf Mound in the June 2001 survey provided visual cross-sections of the deposited CDM and UDM and samples for determining sediment chemistry profiles to evaluate the integrity of the cap.

2.2.1 Core Collection

A total of 13 vibracores were obtained: 12 over the Seawolf Mound, and 1 collected at the WEST REF reference area (Table 2-1). In accordance with the U.S. Navy monitoring plan, the 12 stations were placed within three separate zones established over the Seawolf Mound; these zones were designed to facilitate spatial comparison of potential contaminants on the horizontal plane, relative to the mound center, or apex. The sampling zones were based on radial distance intervals of 200 m (inner zone = 0–200 m; middle

Table 2-1.
Station Coordinates (NAD 83) and Sampling Plan for Cores Collected over the Seawolf Mound and WEST REF Reference Area, June 2001

Core	Latitude	Longitude	Zone	Type	Length (m)	Sampling Interval(s)
NLDS 27	72° 05.034´ N	41° 16.268´ W	Outer 400-600 m	Short	0.94	0-0.5 m
NLDS 28	72° 05.059´ N	41° 16.317´ W	Outer 400-600 m	Short	1.16	0-0.5 m
NLDS 29	72° 05.161´ N	41° 16.455´ W	Outer 400-600 m	Short	0.82	0-0.5 m
NLDS 30	72° 04.916´ N	41° 16.401´ W	Middle 200-400 m	Short	0.86	0-0.5 m
NLDS 31	72° 04.993´ N	41° 16.512´ W	Middle 200-400 m	Short	1.13	0-0.5 m
NLDS 32	72° 05.017´ N	41° 16.603´ W	Middle 200-400 m	Short	0.95	0-0.5 m
NLDS 33	72° 04.822´ N	41° 16.549´ W	Inner 0-200 m	Short	0.84	0-0.5 m
NLDS 34	72° 04.742´ N	41° 16.519´ W	Inner 0-200 m	Short	1.14	0-0.5 m
NLDS 35	72° 04.771´ N	41° 16.461´ W	Inner 0-200 m	Short	1.22	0-0.5 m
NLDS 36	72° 05.103´ N	41° 16.363´ W	Outer 400-600 m	Long	2.34	0-0.5 m (archived) 0.5-0.75 m 0.75-1.0 m 1.53-1.87 m 1.87-2.40 m (archived)
NLDS 37	72° 04.969´ N	41° 16.425´ W	Middle 200-400 m	Long	2.66	0.04-0.54 m (archived) 0.54-0.79 m 0.79-1.04 m 1.04-2.04 m 2.38-2.70 m (archived)
NLDS 38	72° 04.874´ N	41° 16.464´ W	Inner 0-200 m	Long	2.38	0-0.5 m (archived) 0.5-0.75 m 0.75-1.0 m 1.0-1.99 m 1.99-2.42 m (archived)
NLDS 39	72° 05.970´ N	41° 16.206´ W	WEST REF	Short	0.705	0-0.5 m

zone = 200–400 m; and outer zone = 400–600 m) from the reported position of the U.S. Navy disposal buoy (coordinates 41° 16.506′ N, 72° 04.797′ W; Figure 2-1).

To assess the vertical stratification of the mound, both short and long cores were collected and strategically sampled. Three short cores, at least 0.75 m in length, and one long core, not to exceed 3.0 m, were collected from each of the three designated zones. Short core Stations 33, 34, and 35, and long core Station 38 were located in the inner zone. The middle zone included short core Stations 30, 31, and 32, and long core Station Stations 37. The outer zone contained long core Station 36, and short core Stations 27, 28, and 29. Stations 27 and 29 were located outside the acoustically detectible margins of the Seawolf Mound (Figure 2-1). In addition, one short core was obtained from WEST REF (coordinates 41° 16.206´ W, 72° 05.970´ N) to represent ambient sediment and provide information on background contaminant concentrations. Based upon the convention established as part of the September 1997 and June 1998 surveys, thirteen sampling stations (Stations NLDS 27 through 39) were positioned over the Seawolf Mound and at WEST REF. Stations NLDS 27 through 35 were randomly placed over the Seawolf Mound, while Stations 36, 37, and 38 coincided with 1997/1998 sampling locations. Station NLDS 39 was randomly positioned within a 300 m radius of the WEST REF center coordinate (Figure 2-1).

All cores were obtained with the use of the Ocean Surveys, Incorporated Model 1500 pneumatic vibratory corer attached to a steel barrel with a length of 1.5 or 3 m and an internal diameter of 9.5 cm. A chemically inert, clear Lexane® liner (8.9 cm I.D.) was fitted within the core barrel, with stainless steel core cutter and catcher assemblies secured to the end (Figure 2-2). The pontoon-type coring vessel was positioned directly over each target coring station via a multipoint mooring system. The vibracorer was lowered through the central moon pool of the vessel to the seafloor via a single, steel cable. Air supply and return lines attached to the vibratory head fed air from a deck-mounted compressor to activate the hammer and drive the coring device into the sediments. Exhaust air was then captured and ported to the surface to minimize disturbance of the surface sediments adjacent to the sampling location. Upon attaining an adequate penetration depth, the air supply was cut off. The corer was extracted from the seafloor using a winch and placed on the deck of the research vessel.

Upon retrieval of the coring device, the internal liner containing the sediment sample was removed from the core barrel. The cores were inspected to ensure that there was a sufficient quantity of material for the intended analyses. The core was then closed with a foam plug and plastic core cap to prevent loss of sediment, labeled with a unique identifier, measured, and stored at 4°C with minimal exposure to sunlight. At the

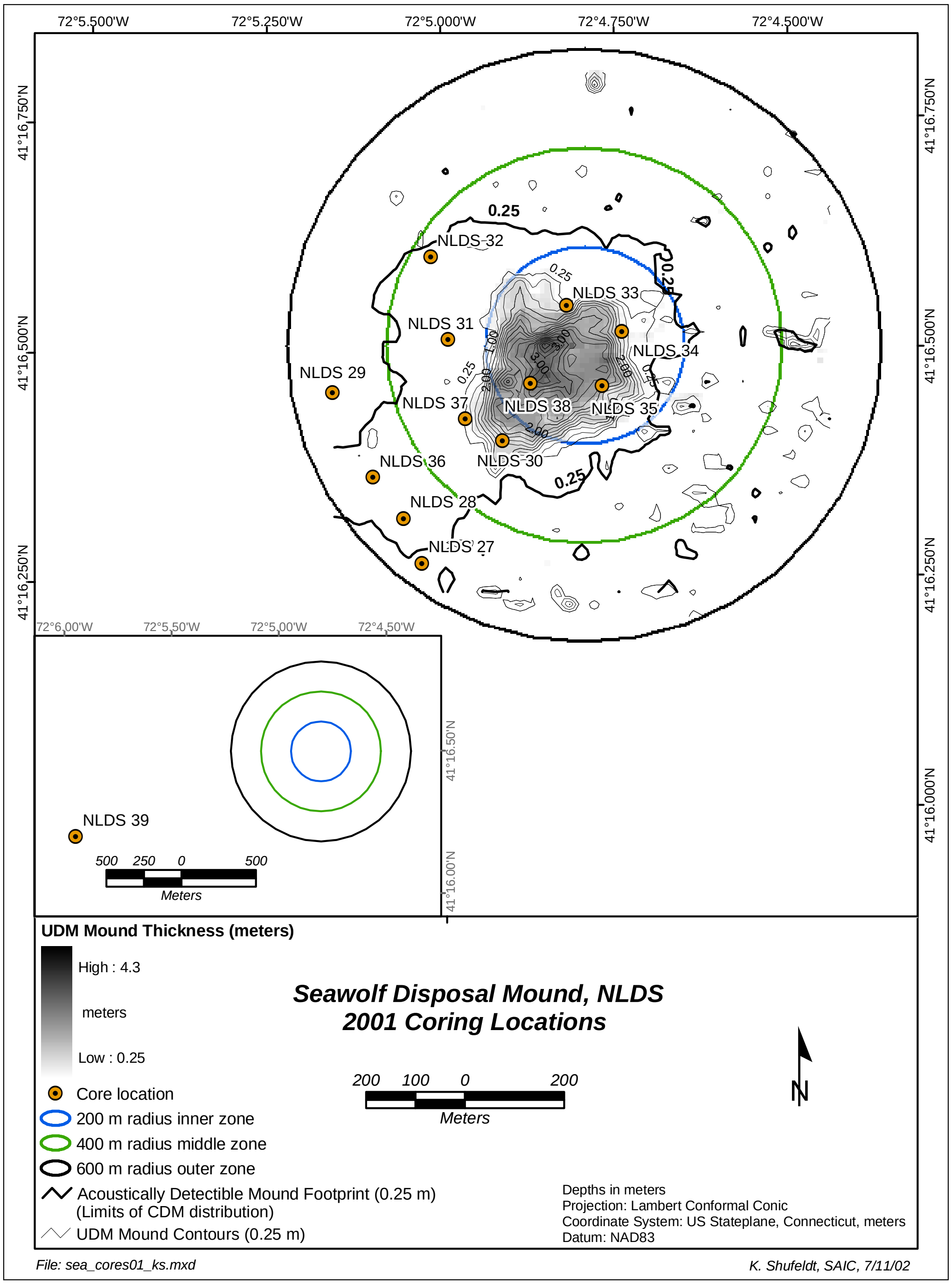


Figure 2-1. Locations of cores collected during the June 2001 monitoring survey over the Seawolf Disposal Mound with respect to radial zones (inner, middle, and outer) and at the West Reference (WEST REF) Area

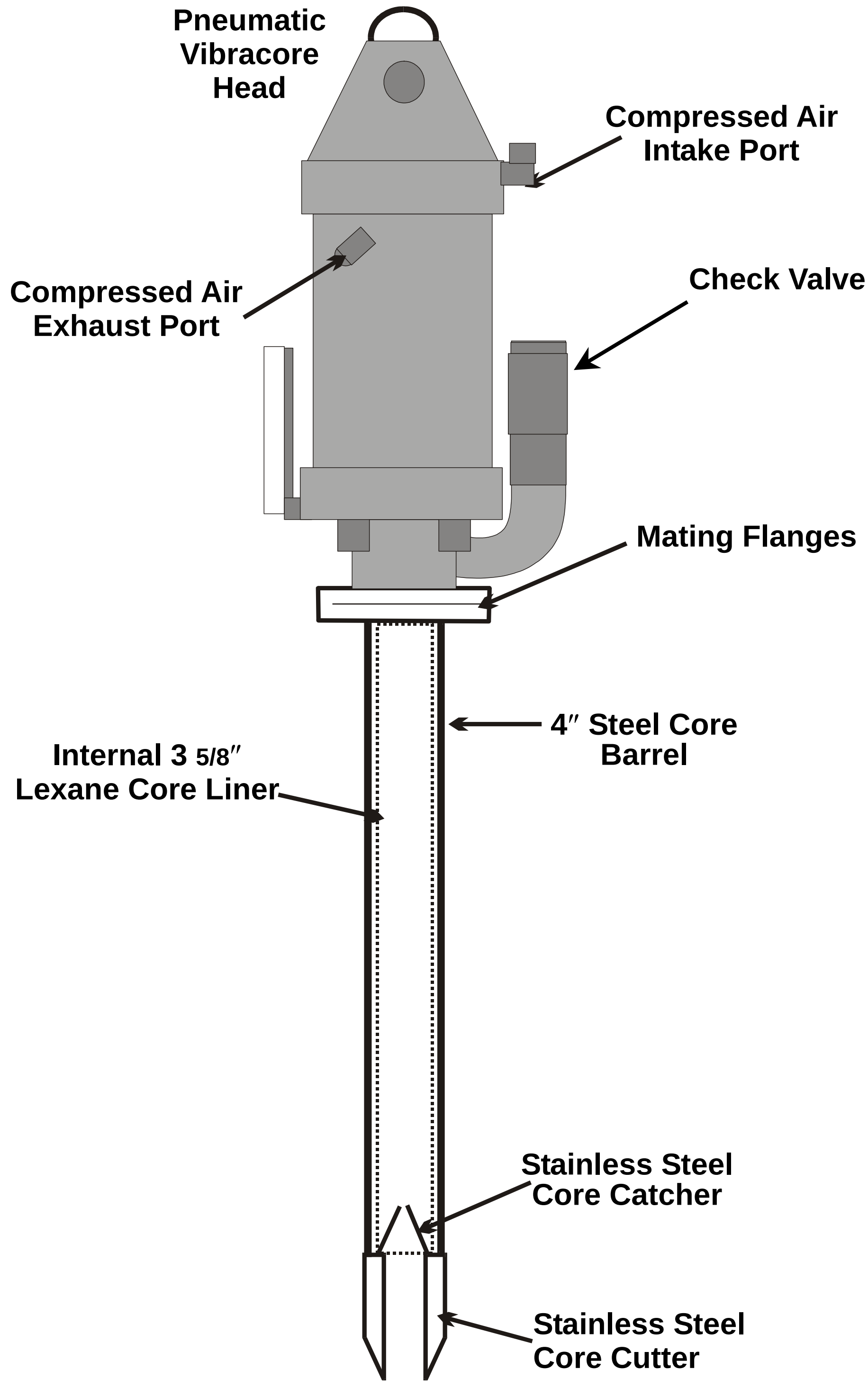


Figure 2-2. Diagram of the vibracore device used for the 2001 coring survey

conclusion of the field operation, all cores were transported to the University of Rhode Island Graduate School of Oceanography (GSO) core storage facility in Narragansett, RI and held at 4°C until analyzed.

2.2.2 Core Processing

The Seawolf Mound cores were split, visually described, photographed, and prepared for geochemical and grain size sampling at the GSO Rock and Core Laboratory. Generally, the 0–0.5 m sections of the short cores were used to verify the presence of the capping layer within each zone. The long cores were sampled at consistent vertical intervals to examine the depth of the capping layer and potential differences in chemical contaminant concentrations with depth.

The sampling plan used for analyzing the June 2001 cores was developed in 1997, based on the U.S. Navy monitoring objectives for the Seawolf Mound (Table 2-1; Maguire Group, Inc. 1995). The top 0.5 m of sediment from each of the short cores was mixed (composited) in a stainless-steel bowl, sub-sampled, and placed in a series of pre-cleaned glass jars. The composited samples from each short core were analyzed for sediment grain size, total organic carbon (TOC), polycyclic aromatic hydrocarbons (PAHs), and a suite of trace metals including arsenic (As), cadmium (Cd), chromium (Cr), mercury (Hg), lead (Pb), copper (Cu), nickel (Ni), and zinc (Zn).

The three long cores (Stations 36, 37, and 38) were divided into five sampling intervals (Table 2-1). Each interval was composited in the same manner as the short core samples and labeled accordingly. Three samples collected from each long core, representing the middle intervals, were analyzed for PAHs, zinc (Zn), TOC, and grain size, while the uppermost and lowermost intervals were archived (Table 2-1). Of all the trace metals, zinc was the only inorganic contaminant measured in the material extracted from the long cores collected in 2001, as well as 1997 and 1998. Zinc was used as an indicator of the cap and non-cap sediments because of the strong contrast in concentrations between these two sediment sources. Elevated levels of zinc are common within the sediments surrounding marine terminals and usually associated with electrolysis protection of steel-hulled vessels during long-term mooring.

2.2.3 Laboratory Analysis Methods

The Woods Hole Group Environmental Laboratories (WHG), in Raynham, MA analyzed the core chemistry samples, while the samples collected for grain size and moisture content were analyzed by GeoTesting Express, Incorporated in Boxborough, MA. Analytical methods are summarized in Table 2-2 and described in detail below.

Table 2-2.
Methods for Physical and Chemical Analyses of 2001 Seawolf Core Sub-samples

Core Subsample	Analysis	Method	Instrumentation
All samples	Grain Size	ASTM D422	Sieve/Hydrometer
All samples	Water Content	ASTM D2216	
		SW-846 Method* (USEPA 1997)	
All samples	Total Organic Carbon	9060	
All samples	PAHs	3550A/8270	GC/MS
Short core samples	Trace Metals		
	Arsenic	3051/6020	ICP-MS
	Cadmium	3051/6020	ICP-MS
	Chromium	3051/6020	ICP-MS
	Copper	3051/6020	ICP-MS
	Lead	3051/6020	ICP-MS
	Mercury	NA/7471	CVAA
	Nickel	3051/6020	ICP-MS
All samples	Zinc	3051/6020	ICP-MS

* First value refers to extraction/digestion method, second value refers to analysis method.
PAHs = Polycyclic aromatic hydrocarbons
NA = Not Applicable
GC/MS = Gas Chromatograph/Mass Spectrometer
ICP-MS = Inductively Coupled Plasma Mass Spectrometry
CVAA = Cold Vapor Atomic Absorption

2.2.3.1 Polycyclic Aromatic Hydrocarbons (PAHs)

Sediment Extraction

According to the WHG Standard Operation Procedure, the sediment samples were spiked with surrogate compounds, and extracted by pressurized fluid extraction (Dionex Accelerated Solvent Extractor Model 200) using a methylene chloride acetone solvent solution.

Sediment Analysis

The samples were concentrated and then analyzed using a modified version of EPA SW-846 Method 8270 (USEPA 1997). Analysis of PAHs by Gas Chromatography/Mass Spectrometry with Selected Ion Monitoring (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 was based on a multi-level initial calibration.

2.2.3.2 Trace Metals

Sediment Digestion

Sediments require acid digestion for extraction and detection of trace metals. The WHG utilized EPA SW-846 Method 3051 (USEPA 1997), which provides a rapid multi-element acid leach of sediments. A representative sample of up to 0.5 g was placed in a fluorocarbon microwave vessel with 10 ml of concentrated nitric acid. The vessel was capped and heated in the laboratory microwave for 10 minutes. The acid digests the sample at high temperatures. After cooling, the vessel contents were filtered, centrifuged, or allowed to settle and then diluted to volume and analyzed.

Sediment Analysis

To determine concentrations of As, Cd, Cr, Pb, Cu, Ni, and Zn, the samples were analyzed using EPA SW-846 Method 6020 (USEPA 1997), involving inductively coupled plasma mass spectrometry (ICP-MS). EPA SW-846 Method 7471 (USEPA 1997) was used to detect Hg levels using cold vapor atomic absorption (CVAA). The Hg was reduced to the elemental state and aerated from solution in a closed system. The mercury vapor passed through a cell positioned in the light path of an atomic absorption spectrometer. Absorbance (peak height) was measured as a function of mercury concentration.

2.2.3.3 Sediment Grain Size, Total Organic Carbon, and Moisture Content

Grain Size

Grain size analysis was conducted by GeoTesting Express, 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 (particle size diameters) of greater than 0.0625 mm (<4 phi; sand and gravel), and less than or equal to 0.0625 mm (>4 phi; silt and clay). The wet sieve and dry sieve fractions less than 0.0625 mm (silt and clay) were combined for each sample. The silt and clay fraction was then subdivided using a hydrometer technique, which is based upon differential settling rates of particles. The data on grain size were converted from their respective units (phi or mm) to units of gravel and sand, silt, and clay. For the purpose of this study the following grain size distinction is utilized: gravel (>2.0 mm), coarse sand (0.5 –2.0 mm), medium sand (0.25–0.50 mm), fine sand (0.125–0.25 mm), very fine sand (0.0625–0.125 mm), silt (0.0039–0.0625 mm) and clay (<0.0039 mm).

Total Organic Carbon

TOC analyses were performed using EPA SW-846 Method 9060 (USEPA 1997). In this method, the organic carbon in a sample is converted to carbon dioxide (CO_2) by wet chemical oxidation. The CO_2 formed is then measured directly by an infrared detector. The amount of CO_2 in a sample is directly proportional to the concentration of carbonaceous material in the sample. Results in this report are expressed on a dry weight basis.

Water Content

Water content was determined using ASTM Method D2216. This method defines water content as the ratio of the mass of water contained in the pore spaces of soil or rock material to the solid mass of particles in that material, and expresses it as a percent.

2.3 REMOTS® Sediment-Profile Imaging

Remote Ecological Monitoring of the Seafloor (REMOTS®) sediment-profile imaging is a benthic sampling technique used to detect and map the distribution of thin (<20 cm) dredged material layers, delineate benthic disturbance gradients, and monitor the process of benthic recolonization following the physical seafloor disturbances associated with dredged material disposal. This is a reconnaissance survey technique used for rapid collection, interpretation and mapping of data on physical and biological seafloor characteristics. The DAMOS Program has used this technique for routine disposal site monitoring for over 20 years.

The REMOTS® hardware consists of a Benthos Model 3731 sediment-profile camera designed to obtain undisturbed, vertical cross-section photographs (in situ profiles) of the upper 15 to 20 cm of the seafloor (Figure 2-3). Computer-aided analysis of each REMOTS® image yields a suite of standard measured parameters, including sediment grain size major mode, camera prism penetration depth (an indirect measure of sediment bearing capacity/density), small-scale surface boundary roughness, depth of the apparent redox potential discontinuity (RPD, a measure of sediment aeration), infaunal successional stage, and Organism-Sediment Index (a summary parameter reflecting overall benthic habitat quality).

Organism Sediment Index (OSI) values may range from −10 (azoic with low sediment dissolved oxygen and/or presence of methane gas in the sediment) to +11 (healthy, aerobic environment with deep RPD depths and advanced successional stages). The OSI values are calculated using values assigned for the apparent RPD depth, successional status, and indicators of methane or low oxygen. Because the OSI is calculated using apparent RPD depths and successional stages, indeterminate apparent RPD depths and/or successional stages lead to indeterminate OSI values. REMOTS® image acquisition and analysis methods are described fully in Rhoads and Germano (1982; 1986) and in the recent DAMOS Contribution No. 128 (SAIC 2001b) and therefore not repeated here.

Following completion of capping operations at the Seawolf Mound in 1996, REMOTS® sediment-profile imaging surveys were conducted in September 1997, July 1998, and August 2000 to assess physical and biological characteristics over the surface of this dredged material deposit. These surveys entailed sampling at 29 stations over the Seawolf Mound, as well as at 13 stations located in three nearby reference areas. The September 1997 survey also involved collecting sediment grab samples at six of the REMOTS® stations over the Seawolf Mound (Stations CTR, 75E, 150N, 150W, 300SE, and 300WSW) to assess the composition of the benthic community that was recolonizing

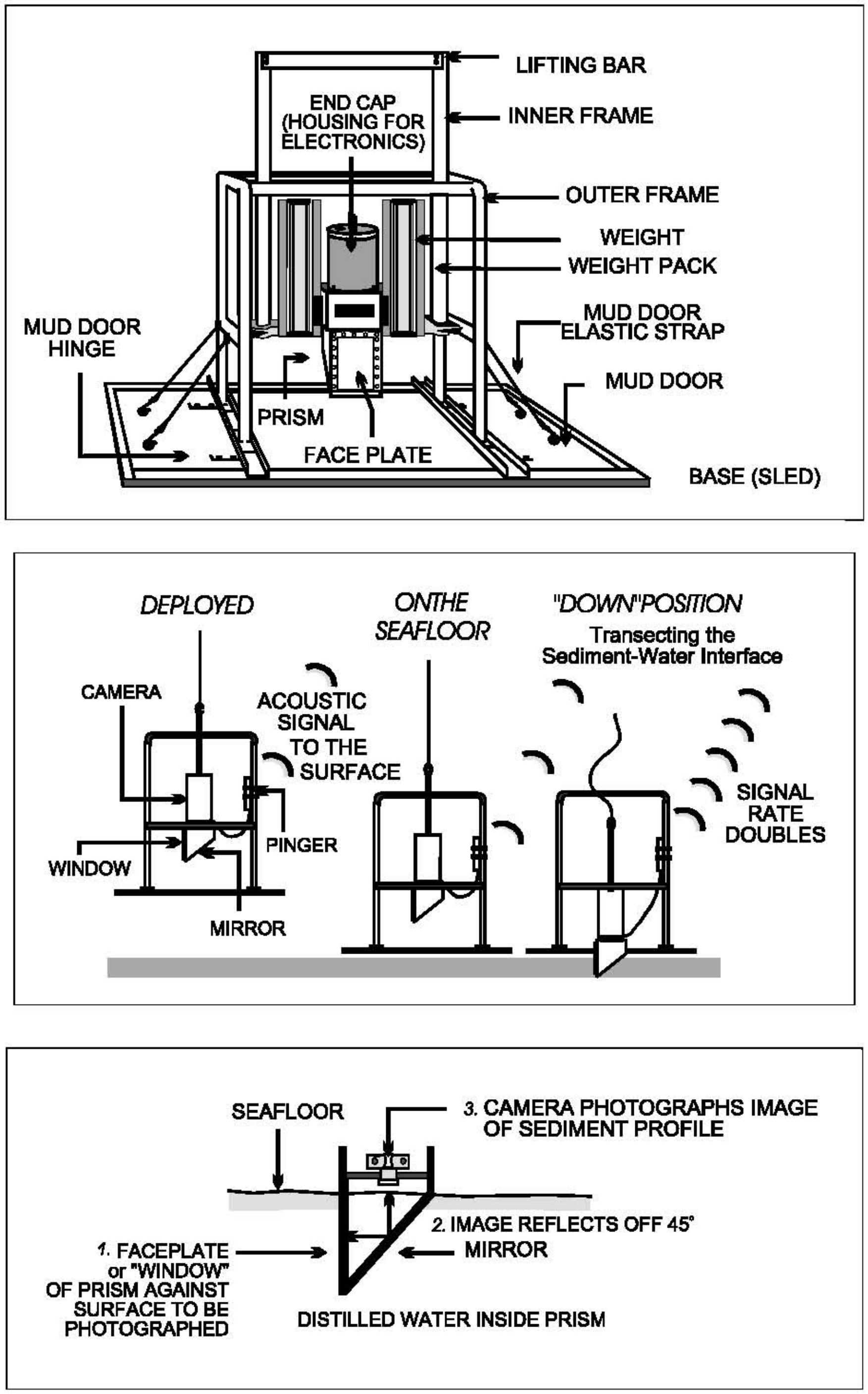


Figure 2-3. Schematic diagram of Benthos, Inc. Model 3731 REMOTS® sediment-profile camera and sequence of operation on deployment

the mound surface. In the June 2001 survey, these six stations were re-occupied to obtain both REMOTS® sediment-profile images and sediment grab samples for benthic community assessment (Table 2-3; Figure 2-4). Three replicate sediment-profile images and a single benthic grab sample were collected at each station.

In the June 2001 survey, sediment-profile images also were collected at three nearby reference areas (NLON REF, NE REF and WEST REF), to allow a comparison of conditions over the Seawolf Mound to those on the ambient seafloor of eastern Long Island Sound (Table 2-3; Figure 2-5). A random sampling scheme was used to select stations within a 300 m radius of the center of each reference area. A total of 13 stations were distributed among the three reference areas: five stations were established over NLON REF (center coordinates 41° 16.666´ N, 72° 01.971´ W), while WEST REF (center coordinates 41° 16.206´ N, 72° 05.971´ W) and NE REF (center coordinates 41° 16.686´ N, 72° 03.371´ W) were each sampled at four randomly selected stations (Table 2-3; Figure 2-5). Three replicate images were obtained at each of the 13 reference area stations.

2.4 Benthic Community Sampling

2.4.1 Sediment Grab Sampling

A 0.04 m^2 Young-modified van Veen grab sampler was used to obtain a single sediment grab sample at each of the six stations over the Seawolf Disposal Mound (Table 2-3; Figure 2-4). The sediment samples were then washed into a bucket and sieved through a 0.5 mm screen. All material remaining on the screen (biota, shell, wood fragments, etc.) was transferred to individual one-liter plastic containers and fixed with a 10% buffered formalin/seawater solution. The samples were left undisturbed for 48 hours, then re-sieved with fresh water and transferred to a Rose Bengal stained, 70% methanol solution for long-term preservation. The samples were delivered to Normandeau Associates, Inc. (NAI) of Bedford, NH for species identification and enumeration.

2.4.2 Laboratory Analysis

The samples received by NAI were inventoried against the Chain-of-Custody form. Each sample was washed through a 0.5 mm mesh screen and elutriated to separate heavy and light fractions of the sample for more efficient sorting. To facilitate sorting, samples that had heterogeneously sized residue and/or organisms were washed through a series of graduated sieves, with the finest sieve being 0.5 mm mesh.

Sorting of the entire sample was conducted using a dissecting microscope. Organisms removed from each sample were placed in vials and labeled by major taxonomic

Table 2-3.
REMOTS® Station Locations over the Seawolf Mound and Reference Areas, June 2001

Area	Station	Latitude (NAD 83)	Longitude (NAD 83)
Seawolf Mound 41° 16.456´ N 72° 04.863´ W	CTR	41° 16.456´ N	72° 04.863´ W
	75E	41° 16.456´ N	72° 04.809´ W
	150N	41° 16.537´ N	72° 04.863´ W
	150W	41° 16.456´ N	72° 04.970´ W
	300SE	41° 16.342´ N	72° 04.711´ W
	300WSW	41° 16.375´ N	72° 05.049´ W
NLON-REF 41° 16.666´ N 72° 01.971´ W	1	41° 16.567´ N	72° 02.047´ W
	2	41° 16.574´ N	72° 01.918´ W
	3	41° 16.655´ N	72° 01.858´ W
	4	41° 16.717´ N	72° 01.976´ W
	5	41° 16.636´ N	72° 02.049´ W
NE-REF 41° 16.686´ N 72° 03.371´ W	1	41° 16.811´ N	72° 03.371´ W
	2	41° 16.691´ N	72° 03.437´ W
	3	41° 16.604´ N	72° 03.329´ W
	4	41° 16.662´ N	72° 03.231´ W
WEST REF 41° 16.206´ N 72° 05.971´ W	1	41° 16.207´ N	72° 05.890´ W
	2	41° 16.126´ N	72° 05.990´ W
	3	41° 16.175´ N	72° 06.101´ W
	4	41° 16.263´ N	72° 05.977´ W

*A single benthic grab sample was also obtained at each of the six REMOTS® stations over the Seawolf Mound.

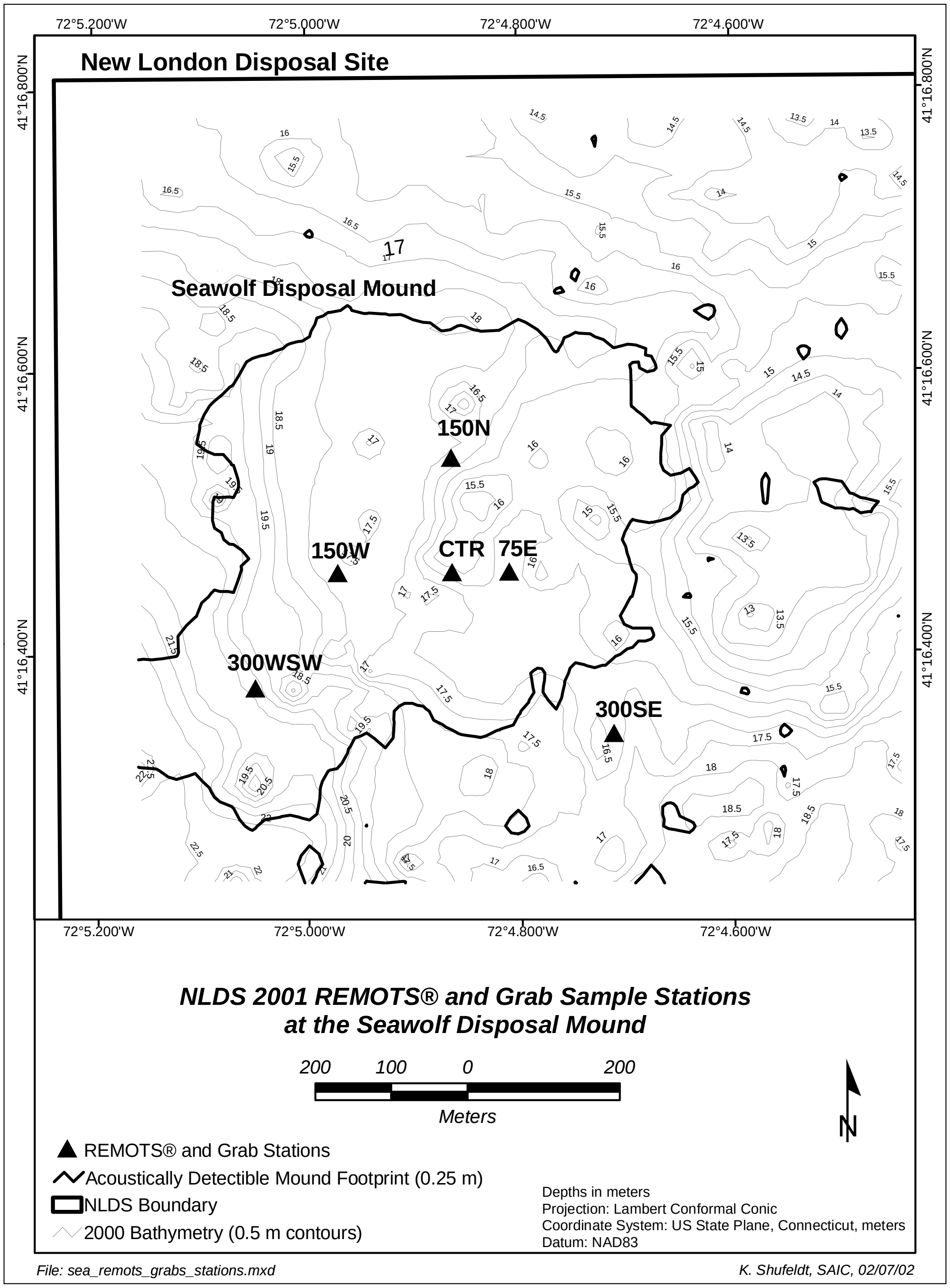


Figure 2-4. June 2001 REMOTS® and benthic grab stations at the Seawolf Disposal Mound relative to the acoustically detectable mound footprint and August 2000 bathymetry

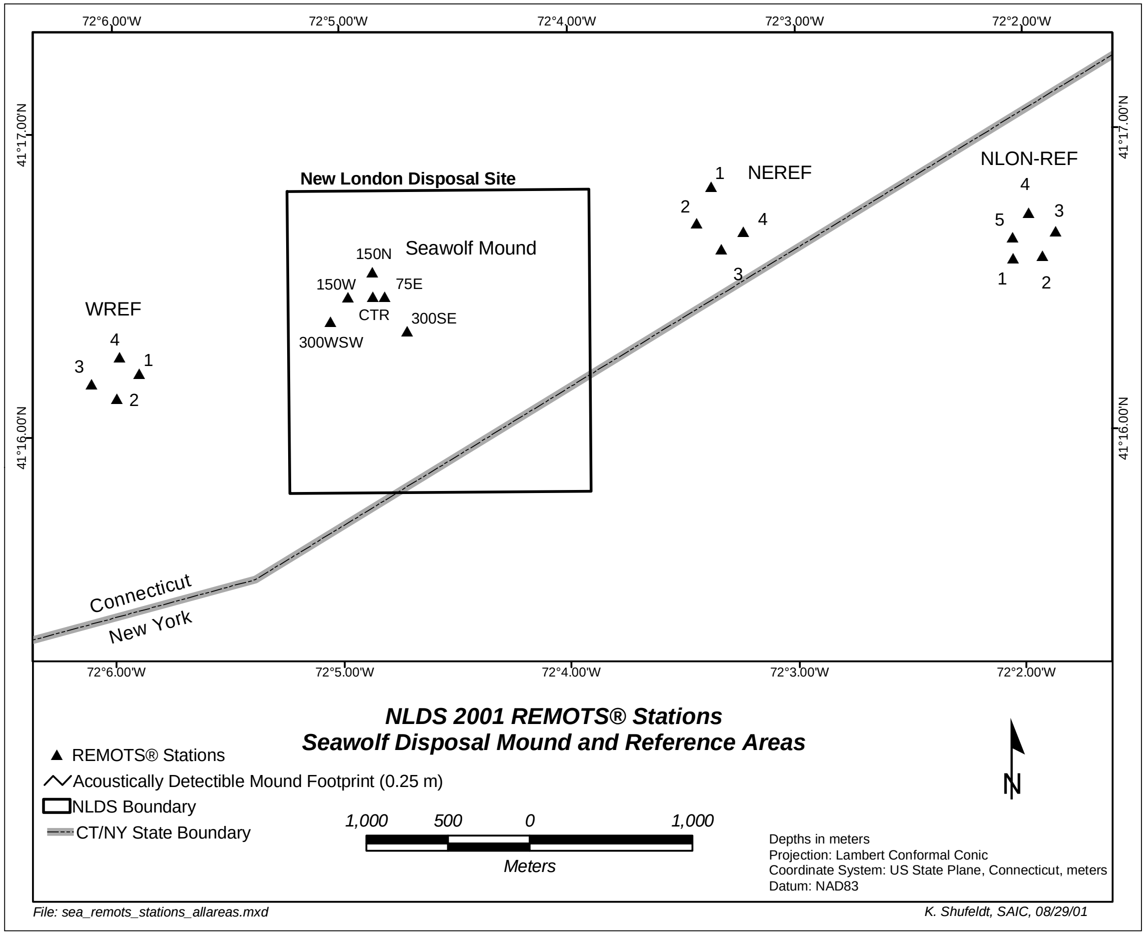


Figure 2-5. June 2001 REMOTS® Stations at the Seawolf Disposal Mound and Reference areas relative to the NLDS boundary and the Connecticut/New York state line

group. Each vial included an internal label with sample identification information. Information pertinent to further processing, as well as processors' initials, was recorded in a log book. Organisms were identified to lowest practical taxon, usually genus or species.

Total faunal abundance and number of species were calculated for each station. In some cases, damaged or small individuals could not be identified to species. These incompletely identified taxa were excluded from species richness when related individuals were present that could be identified more precisely.

2.4.3 Quality Control

Quality control assessment of sorting and identification entailed the reprocessing of 10% of each technician's samples, with a target of at least 95% of the organisms being removed or identified correctly. Quality control of a sorter or taxonomist was performed on a batch sample basis of 10 samples. Results of the Quality Control Program were as follows: one sample (75E) was selected from the batch of six samples for QC. A total of 1509 organisms were sorted and 0 were found during re-sorting, reflecting a 100% initial sorting efficiency. Re-identification of the Phylum *Arthropoda* reflected 98.7% accuracy, of *Mollusca* (100%), *Hydrozoa/Bryozoa* (100%), *Polychaeta* (99%), *Nemertea* (100%), and *Echinodermata* (100%). Sorting and identification tasks met the quality control criteria for the project. Results of all QC checks were recorded on Quality Control Record Sheets and stored with the project file.

2.4.4 Benthic Community Data Analysis

Standard univariate statistics were used to summarize both the September 1997 and June 2001 benthic data, including total and average abundance, total and average number of taxa, and the percentage breakdown of abundance by species. Margelef's species richness (d), Shannon-Weiner diversity (H'), and Pielou's evenness (J') index values were calculated using the PRIMER ecological statistics software package (Clarke and Warwick 1994).

The univariate statistics each provide a measure of only a single community attribute (e.g., species richness, diversity, evenness). In contrast, multivariate statistical techniques involve looking at the benthic community structure as a whole when trying to discern spatial patterns or when comparing among different samples (Clarke 1999). The term "benthic community structure" refers to the concept of looking simultaneously at both species composition and relative abundance to assess the degree of similarity among different stations/samples. For example, two stations having exactly the same species present in exactly the same numbers have identical benthic community structure, while stations having few species in common or the same species in widely different numbers have dissimilar community structure.

Two independent but complimentary multivariate techniques within the PRIMER package were used to evaluate among-station patterns in benthic community structure: hierarchical clustering and non-metric multidimensional scaling (MDS). Both techniques were employed because each provides a valuable and recommended “cross-check” on the other (Clarke and Warwick 1994). These nonparametric methods have the advantage of helping to avoid many of the pitfalls traditionally associated with the use of standard parametric statistical techniques in ecological studies (Germano 1999).

Prior to performing the clustering, the abundance values were square-root transformed, and a matrix was then constructed consisting of Bray-Curtis similarity index values (Bray and Curtis 1957) calculated between each possible pair of stations (i.e., pairwise comparisons). Hierarchical agglomerative clustering with group-average linking was then performed on this similarity matrix (Clarke 1993), and the results displayed by means of a tree diagram or dendrogram showing the Bray-Curtis similarity level at which two samples or groups are considered to have fused.

MDS provides an ordination, or "map," of the stations such that distances between stations on the map reflect corresponding similarities or dissimilarities in community structure. Stations that fall in close proximity to one another on an MDS plot have similar community structure, while those that are farther apart have few taxa in common or the same taxa at different levels of abundance. Like the cluster analysis, non-metric MDS ordination (Kruskal and Wish 1978) was performed on the matrix of Bray-Curtis similarity index values derived from the square root transformed abundance data (Clarke and Green 1988; Clarke 1993).

The ANOSIM (Analysis of Similarities) randomization test within the PRIMER software package was used to test for statistical differences in benthic community structure between the September 1997 and June 2001 samples at the Seawolf Mound. The ANOSIM procedure is analogous to standard parametric analysis of variance (ANOVA) but is based on a nonparametric permutation procedure applied to the Bray-Curtis similarity matrix underlying the ordination of samples (see Clarke and Green 1988; Clarke 1993). The calculated “R statistic” in the ANOSIM test indicates the magnitude of the difference between any two station groups: $R > 0.75$ indicates strong separation (i.e., a large difference in community structure), $0.75 > R > 0.25$ indicates varying degrees of overlap, and $R < 0.25$ indicates little separation between groups. Following the ANOSIM test, the program SIMPER in the PRIMER package was used to identify the species that were the key contributors to the significant difference in benthic community structure.

3.0 RESULTS

3.1 Sediment Coring

As previously indicated (Table 2-1), a total of 12 cores (nine short cores and three long cores) were collected from three zones established over the Seawolf Disposal Mound (NLDS 27-38), and one core (NLDS 39) was collected at WEST REF. The nine short cores ranged in length from 0.82 to 1.16 m (Table 2-1). Similar to previous monitoring efforts in 1997 and 1998, the short cores were distributed over the surface of the inner, middle, and outer zones of the Seawolf Mound to characterize the CDM with regard to contaminant concentration. The physical and geochemical measurements from the June 2001 short cores were evaluated in comparison to the June 2001 reference area data (WEST REF). The three long cores ranged in penetration depth from 2.34 to 2.66 m (Table 2-1). These cores were obtained from the same stations occupied during both the 1997 and 1998 monitoring efforts (inner, middle and outer zones) to identify and examine any changes or trends in the mound. An annotated composite image with a physical description, sub-sampling scheme, and representation of lithology is provided for each core collected as part of the 2001 field effort (Appendix A).

3.1.1 Short Cores

3.1.1.1 Visual Descriptions

The top interval of sediment within the short cores was primarily composed of dark greenish-gray, moist, soft to firm, silty clay, indicative of Thames River CDM. These cores generally exhibited coarsening downward sequences, with layers of silty sand and shell hash detected at depth (Appendix A). Cores 27 and 29, located in the southwestern portion of the outer zone and outside the acoustically detectible margins of the Seawolf Mound, showed dark greenish-gray, silty sand and silty clay with some shell hash in the surface interval. This material was likely representative of historic dredged material pre-dating the Seawolf project sediments disposed at NLDS during the 1995-96 disposal season. Core 30, located in the middle zone, showed the coarsest sediment sequences with a primary lithology of dark grayish-brown to yellow-brown, moist, hard sand and gravel in the upper intervals, before changing color to greenish-gray and becoming finer down core (Appendix A).

Core 39 was the only core collected at WEST REF. This core penetrated 0.7 m into dark greenish-gray, moist, soft to firm, silty, fine sand (Appendix A). Between 0.57 m and 0.66 m, a horizon of clayey silt mixed with fine sand and shell hash was detected.

3.1.1.2 Physical Parameters

Grain Size

Short cores collected during the 2001 survey consisted of mostly fine-grained sediments, containing an overall average of 71.3% silt and clay (Table 3-1). Six of the nine short cores collected at the disposal area were dominated by fine-grained sediment (89-96% fines) within the upper 0.5 m (Figure 3-1; Table 3-1). Predominantly coarse-grained sediments were collected from the surface intervals of one Seawolf Mound station (Core 30 in the middle zone, 34% fines and 66% sand and gravel) and Cores 27 and 29 located beyond the acoustically detectible footprint of the mound in the outer zone (Figure 3-1). Cores 27 and 29 had 28% and 23% fines, respectively, which is comparable to the grain size measured in the ambient sediments sampled in Core 39 from WEST REF, 27% fines and 73% sand and gravel in the upper 50 cm (Table 3-1).

Moisture Content

As expected, moisture content was higher in sediment samples composed primarily of fine-grained material and lower in the cores displaying coarser-grained material (Table 3-1). The fine-grained cores from the disposal area had moisture contents ranging from 47-51%. In contrast, the predominantly coarse-grained cores, including Cores 27, 29, and 30, and the reference area Core 39, had moisture contents on the order of 24-26%. These values clearly reflect differences in grain size, with greater moisture content consistently associated with fine-grained sediments.

Total Organic Carbon

Total organic carbon (TOC) concentrations ranged from 0.92% to 3.6% in the short cores from the disposal area, with an overall average of 2.5% (Table 3-1). As with moisture content, TOC concentrations were reflective of grain size, with higher concentrations corresponding to cores with a prevalence of fine-grained sediment (2.7–3.6%) and lower concentrations corresponding to coarser sediments (0.9–1.7%). The TOC measured at WEST REF (Core 39) was similarly low, 0.7%, consistent with the high sand content and lower percentage of fines.

Table 3-1.
Results of Physical Analysis of Samples Collected from the Seawolf Mound Cores, June 2001

Core/Zone	Composite Sample #	Depth (m)	Radius (m)	Core Type	TOC (%)	Solids (%)	Moisture Content (%)	Gravel/ Sand (%)	Fines (%)
Inner zone, core top									
NLDS 33	33	0-0.50	0-200	Short	3.10	50.2	49.8	4	96
NLDS 34	34	0-0.50	0-200	Short	3.10	52.6	47.4	10	90
NLDS 35	35	0-0.50	0-200	Short	2.80	53.3	46.7	11	89
Average					**3.00**	**52.1**	**47.9**	**8.3**	**91.7**
Middle zone, core top									
**NLDS 30	30	0-0.50	200-400	Short	1.70	74.4	25.6	66	34
NLDS 31	31	0-0.50	200-400	Short	2.70	48.9	51.1	5	95
NLDS 32	32	0-0.50	200-400	Short	3.20	50.3	49.7	9	91
Average					**2.53**	**57.9**	**42.1**	**26.7**	**73.3**
Outer zone, core top									
**NLDS 27	27	0-0.50	400-600	Short	1.10	76.0	24.0	72	28
NLDS 28	28	0-0.50	400-600	Short	3.60	49.3	50.7	4	96
**NLDS 29	29	0-0.50	400-600	Short	0.92	75.4	24.6	77	23
Average					**1.87**	**66.9**	**33.1**	**51.0**	**49.0**
All zones, short cores									
Average					**2.47**	**58.9**	**41.1**	**28.7**	**61.8**
All zones, long cores									
NLDS 38	38-2	0.50-0.75	0-200	Long	3.20	46.9	53.1	4	96
NLDS 38	38-3	0.75-1.00	0-200	Long	3.30	48.7	51.3	5	95
NLDS 38	38-4	1.00-1.99	0-200	Long	3.60	50.3	49.7	12	88
NLDS 37	37-2	0.54-0.79	200-400	Long	2.90	52.4	47.6	8	92
NLDS 37	37-3	0.79-1.04	200-400	Long	2.70	52.3	47.7	10	90
NLDS 37	37-4	1.04-2.04	200-400	Long	3.00	53.9	46.1	11	89
NLDS 36	36-2	0.50-0.75	400-600	Long	3.30	51.9	48.1	9	91
NLDS 36	36-3	0.75-1.00	400-600	Long	3.30	51.8	48.2	3	97
NLDS 36	36-4	1.53-1.87	400-600	Long	1.20	77.1	22.9	72	28
Average					**2.94**	**53.9**	**46.1**	**14.9**	**85.1**
All Data Summary									
Average					**2.71**	**56.4**	**43.6**	**21.8**	**78.2**
Std. Dev.					**0.86**	**10.8**	**10.8**	**27.7**	**27.7**
Maximum					**3.60**	**77.1**	**53.1**	**77**	**97**
Minimum					**0.92**	**46.9**	**22.9**	**3**	**23**
1997 Data Summary Mean					**2.13**	**48.5**	**51.5**	**19**	**81**
1998 Data Summary Mean					**2.89**	**51.0**	**49.0**	**13**	**87**
References									
NLDS 39	39	0-0.50	WEST REF	Short	**0.72**	**76.0**	**24.0**	**73**	**27**
Pre-dredge CDM average (1990 only)								**57.5**	**42.5**
Pre-dredge UDM average (1990 only)								**52.7**	**47.3**

**** indicates coarse-grained cores**

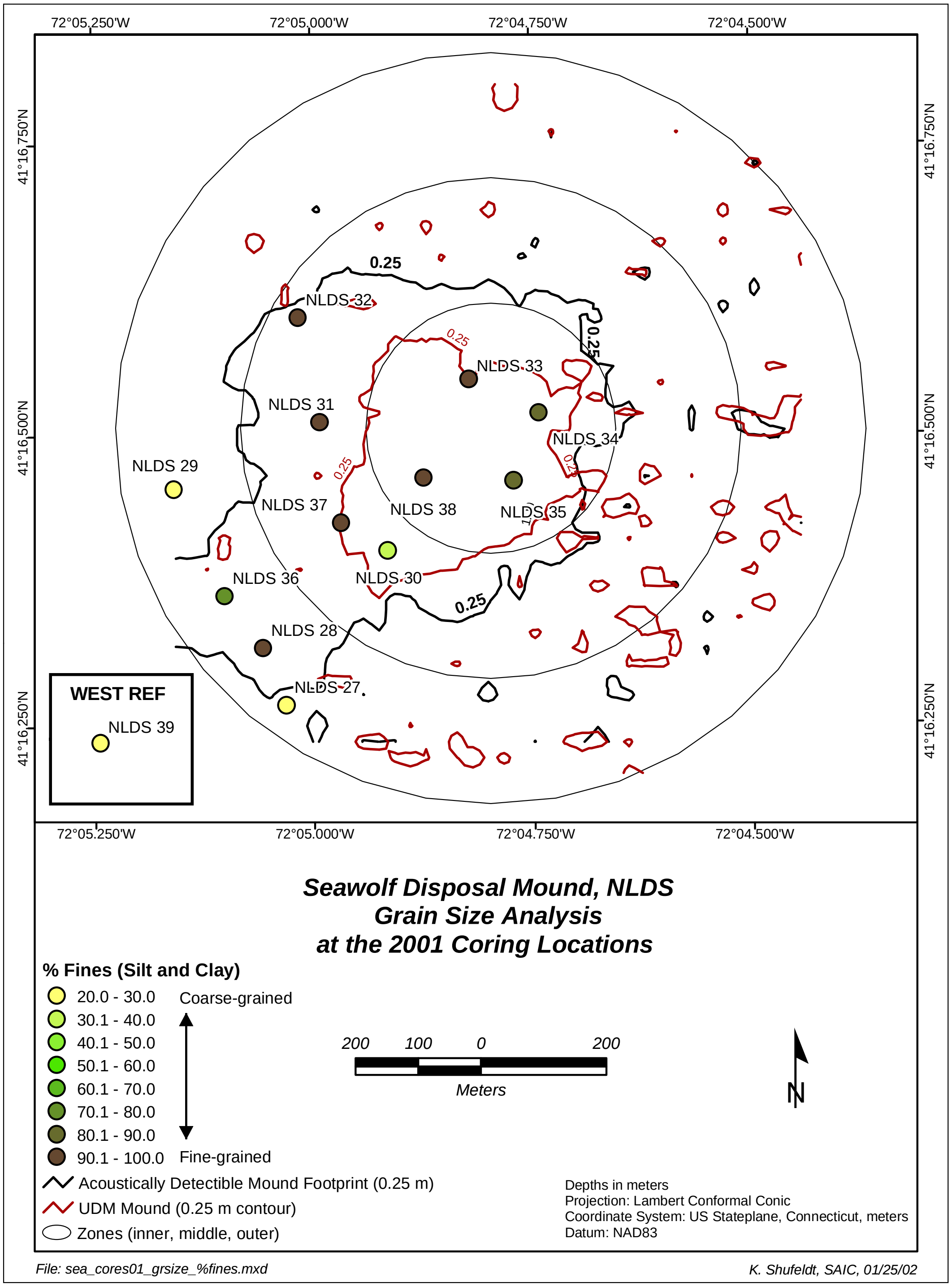


Figure 3-1. Map showing the percentage of the fine-grained sediment fraction (silt and clay) in the 2001 cores collected over the Seawolf Mound and at WEST REF

3.1.1.3 Sediment Chemistry

Trace Metals (Short Cores)

Trace metal concentrations (As, Cd, Cr, Cu, Pb, Hg, Ni, and Zn) were analyzed from the composited sediments obtained from the surface (0 – 0.5 m) interval of the short cores. Results indicated very low concentrations for most samples, with relatively narrow ranges of concentrations among all cores (Table 3-2). The groupings of results according to the inner, middle, and outer zones yielded variable concentrations within each zone, with slightly higher average concentrations in the inner zone primarily attributable to Core 33.

Zinc was used as an indicator for UDM sediment because it was detected at higher concentrations in some of the Seawolf material based on pre-dredging sediment testing results (SAIC 2001a). Overall, Zn concentrations for the 2001 survey short cores exhibited generally low concentrations, with two slightly higher concentrations, including the maximum concentrations detected in Core 33 (160 mg/kg, within the 0.25 UDM contour) and Core 27 (100 mg/kg, beyond the acoustically detectible footprint of the mound). Concentrations for the remaining cores ranged from 25 to 72 mg/kg.

Copper (Cu) and Cr concentrations were also of interest given that they were included in the list of analytes, in addition to Zn and PAHs, for which portions of the Seawolf dredged material were determined to be unsuitable for unconfined, open water disposal (SAIC 2001a). For the 2001 cores, concentrations were low, with Cr concentrations ranging from 14 to 48 mg/kg (average: 31.3 mg/kg), and Cu concentrations ranging from 9.2 to 40 mg/kg (average: 20.2 mg/kg).

Cores 29 and 30, with coarser sediments (23 and 34% fines, respectively), displayed the lowest trace metal concentrations from the disposal area short cores (Table 3-2). Core 27, though comprised of comparable grain size (28% fines), had slightly higher concentrations of some metals including Cd, Cu, and particularly, Pb and Zn (approximately two to three times the concentrations in Cores 29 and 30).

Results indicated that trace metal concentrations generally corresponded to grain size in the short cores, with higher concentrations associated with finer-grained sediments. The data were therefore normalized to grain size (Table 3-3). Trace metal concentrations can be normalized to various geochemical factors to obtain additional information regarding distinctions in metal concentrations among samples. Sediment chemistry can be normalized to certain metals with consistent regional background concentrations (e.g., aluminum and iron), or to grain size or total organic content (TOC). Normalization based

Table 3-2.

Trace Metal Concentrations in Samples Collected from the Seawolf Mound Cores, June 2001

Core/Zone	Composite Sample #	Depth (m)	Radius (m)	Grain Size (% fines)	Core Type	As mg/kg dry	Cd mg/kg dry	Cr mg/kg dry	Cu mg/kg dry	Pb mg/kg dry	Hg mg/kg dry	Ni mg/kg dry	Zn mg/kg dry
Short Cores													
NLDS 33	33	0-0.50	0-200	96	Short	10	0.35	48.0	40.0	34.0	0.12	24.0	160
NLDS 28	28	0-0.50	400-600	96	Short	8.5	0.28	38.0	26.0	22.0	0.074	22.0	71.0
NLDS 31	31	0-0.50	200-400	95	Short	9.5	0.14	36.0	14.0	10.0	<0.020	22.0	58.0
NLDS 32	32	0-0.50	200-400	91	Short	8.9	0.27	39.0	23.0	20.0	0.085	22.0	69.0
NLDS 34	34	0-0.50	0-200	90	Short	9.0	0.21	38.0	20.0	18.0	0.066	22.0	64.0
NLDS 35	35	0-0.50	0-200	89	Short	8.8	0.22	37.0	24.0	20.0	0.091	23.0	72.0
**NLDS 30	30	0-0.50	200-400	34	Short	3.6	0.065	14.0	9.2	7.0	0.029	8.4	25.0
**NLDS 27	27	0-0.50	400-600	28	Short	3.6	0.12	17.0	16.0	30.0	<0.013	9.4	100
**NLDS 29	29	0-0.50	400-600	23	Short	3.6	0.087	15.0	10.0	13.0	0.039	8.5	35.0
Average for all short cores						**7.3**	**0.19**	**31.3**	**20.2**	**19.3**	**0.07**	**17.9**	**72.7**
StDev						**2.8**	**0.10**	**12.5**	**9.5**	**8.8**	**0.03**	**6.9**	**39.3**
Average of fine-grained Cores						**9.1**	**0.25**	**39.3**	**24.5**	**20.7**	**0.09**	**22.5**	**82.3**
*****Average of coarse-grained Cores***						**3.6**	**0.09**	**15.3**	**11.7**	**16.7**	**0.03**	**8.8**	**53.3**
Reference Area Short Core													
NLDS 39	39	0-0.50	WESTREF	27	Short	**3.5**	**0.073**	**12.0**	**7.6**	**8.5**	**0.025**	**8.1**	**28.0**
Long Cores													
NLDS 38	38-2	0.50-0.75	0-200	96	Long								90.0
NLDS 38	38-3	0.75-1.00	0-200	95	Long								54.0
NLDS 38	38-4	1.00-1.99	0-200	88	Long								64.0
Average													**69.3**
NLDS 37	37-2	0.54-0.79	200-400	92	Long								62.0
NLDS 37	37-3	0.79-1.04	200-400	90	Long								71.0
NLDS 37	37-4	1.04-2.04	200-400	89	Long								76.0
Average													**69.7**
NLDS 36	36-2	0.50-0.75	400-600	91	Long								73.0
NLDS 36	36-3	0.75-1.00	400-600	97	Long								77.0
**NLDS 36	36-4	1.53-1.87	400-600	28	Long								34.0
Average													**61.3**
Average for all long cores						**3.6**	**0.091**	**15.3**	**11.7**	**16.7**	**0.034**	**8.8**	**53.3**
All Data Summary													
Average						**7.3**	**0.19**	**31.3**	**20.2**	**19.3**	**0.07**	**17.9**	**72.7**
Std. Dev.						**2.8**	**0.10**	**12.5**	**9.5**	**8.8**	**0.03**	**6.9**	**39.3**
Minimum						**3.6**	**0.07**	**14.0**	**9.2**	**7.0**	**0.03**	**8.4**	**25.0**
Maximum						**10.0**	**0.35**	**48.0**	**40.0**	**34.0**	**0.12**	**24.0**	**160.0**
Ecological Benchmarks[a]													
Threshold Effects Level (TEL)[1]						**7.24**	**0.676**	**52.3**	**18.7**	**30.2**	**0.13**	**15.9**	**124**
Effects Range-Low (ERL)[2]						**8.2**	**1.2**	**81**	**34**	**46.7**	**0.15**	**20.9**	**150**
Effects Range-Median (ERM)[2]						**70**	**9.6**	**370**	**270**	**218**	**0.71**	**51.6**	**410**
Probable Effects Level (PEL)[1]						**41.6**	**4.21**	**160.4**	**108.2**	**112.2**	**0.70**	**42.8**	**271**
Prior Surveys/Test Results													
1997 Data Summary Mean						**7.5**	**0.32**	**38.9**	**28.5**	**25**	**0.12**	**22.3**	**95.3**
1998 Data Summary Mean						**7.2**	**0.17**	**36.2**	**28.4**	**29**	**0.070**	**25.7**	**85.7**
Pre-dredge UDM Average (1992)						**13**	**2.9**	**108**	**139**	**126**	**0.40**	**64.6**	**235**
Pre-dredge UDM Average (1990, 1994))						**7.8**	**1.2**	**39.8**	**32.2**	**44**	**0.20**	**17.2**	**79.4**
Pre-dredge CDM Average (1990, 1994)						**6.3**	**0.70**	**38.9**	**21.6**	**27**	**0.090**	**17.8**	**68.2**

Note: for data below detection, one half of the reported detection limit was used for statistical calculations

a - Ecological benchmarks highlhighted in gray are those for which the maximum detected concentration from the cores exceeds the benchmark.

1 - Mac Donald, 1994

2 - Long et al., 1995

** indicates coarse-grained cores

Table 3-3.

Trace Metal Concentrations Normalized to the Fine-Grained Fraction in Samples Collected from the Seawolf Cores, June 2001

Core/Zone	Composite Sample #	Depth (m)	Radius (m)	Core Type	As mg/kg dry	Cd mg/kg dry	Cr mg/kg dry	Cu mg/kg dry	Pb mg/kg dry	Hg mg/kg dry	Ni mg/kg dry	Zn mg/kg dry
Short Cores												
NLDS 33	33	0-0.50	0-200	Short	10.4	0.36	50.0	41.7	35.4	0.12	25.0	167
NLDS 28	28	0-0.50	400-600	Short	8.85	0.29	39.6	27.1	22.9	0.077	22.9	74.0
NLDS 31	31	0-0.50	200-400	Short	10.0	0.15	37.9	14.7	10.5	<0.021	23.2	61.1
NLDS 32	32	0-0.50	200-400	Short	9.78	0.30	42.9	25.3	22.0	0.093	24.2	75.8
NLDS 34	34	0-0.50	0-200	Short	10.0	0.23	42.2	22.2	20.0	0.066	24.4	71.1
NLDS 35	35	0-0.50	0-200	Short	9.89	0.25	41.6	27.0	22.5	0.091	25.8	80.9
**NLDS 30	30	0-0.50	200-400	Short	10.6	0.19	41.2	27.1	20.6	0.085	24.7	73.5
**NLDS 27	27	0-0.50	400-600	Short	12.9	0.43	60.7	57.1	107	<0.046	33.6	357
**NLDS 29	29	0-0.50	400-600	Short	15.7	0.38	65.2	43.5	56.5	0.17	37.0	152
Average for all short cores					**10.9**	**0.3**	**46.8**	**31.7**	**35.3**	**0.1**	**26.8**	**123.6**
StDev					**2.1**	**0.1**	**9.8**	**13.1**	**29.9**	**0.0**	**5.0**	**95.5**
Average of fine-grained Cores					**9.8**	**0.3**	**42.4**	**26.3**	**22.2**	**0.1**	**24.3**	**88.3**
*****Average of coarse-grained Cores***					**13.0**	**0.3**	**55.7**	**42.6**	**61.4**	**0.1**	**31.7**	**194.3**
Reference Area Core												
NLDS 39	39	0-0.50	WEST REF	Short	13.0	0.27	44.4	28.1	31.5	0.093	30.0	104
Long Cores												
NLDS 38	38-2	0.50-0.75	0-200	Long								93.8
NLDS 38	38-3	0.75-1.00	0-200	Long								56.8
NLDS 38	38-4	1.00-1.99	0-200	Long								72.7
Average												**74.4**
NLDS 37	37-2	0.54-0.79	200-400	Long								67.4
NLDS 37	37-3	0.79-1.04	200-400	Long								78.9
NLDS 37	37-4	1.04-2.04	200-400	Long								85.4
Average												**77.2**
NLDS 36	36-2	0.50-0.75	400-600	Long								80.2
NLDS 36	36-3	0.75-1.00	400-600	Long								79.4
**NLDS 36	36-4	1.53-1.87	400-600	Long								121
Average												**93.7**
Average for all long cores												**81.8**
All Data Summary												
Average					**10.9**	**0.29**	**46.8**	**31.7**	**35.3**	**0.10**	**26.8**	**102.7**
Std. Dev.					**2.1**	**0.09**	**9.8**	**13.1**	**29.9**	**0.03**	**5.0**	**70.1**
Minimum					**8.9**	**0.15**	**37.9**	**14.7**	**10.5**	**0.07**	**22.9**	**56.8**
Maximum					**15.7**	**0.43**	**65.2**	**57.1**	**107.1**	**0.17**	**37.0**	**357.1**
Prior Surveys/Test Results												
1997 Data Summary Mean					**N/A**	**N/A**	**51.7**	**37.9**	**32.2**	**0.16**	**29.5**	**120**
1998 Data Summary Mean					**8.19**	**0.21**	**41.8**	**32.9**	**33.9**	**0.17**	**29.5**	**106**
Pre-dredge UDM Average (1990 only)					**18.4**	**2.8**	**93.6**	**75.8**	**102.6**	**0.47**	**40.5**	**187**
Pre-dredge CDM Average (1990 only)					**13.3**	**1.5**	**82.2**	**45.7**	**56.0**	**0.19**	**37.6**	**144**

Note: for data below detection, one half of the reported detection limit was used for statistical calculations
Values normalized by the fine (silt & clay) fraction
N/A Normalized concentration not available for this analyte in 1997
** indicates coarse-grained cores

on grain size or TOC (e.g., dividing the concentration by grain size or TOC), accounts for the fact that metals and organic compounds are more likely to be associated with the fine-grained size fraction (clay particles and organic matter). Metal concentrations from the 2001 cores were normalized using grain size (Table 3-3). For the most part, results were comparable to the non-normalized data with some narrowing of the differences in concentrations among the fine-grained samples. The normalized data provided additional information regarding more anomalous cores.

Core 30, the middle zone core of the Seawolf Mound that had a substantial layer of coarse sand and gravel in the upper 0.29 m of the core, exhibited lower concentrations for all metals than the other cores from the disposal mound (Table 3-2). However, normalization yielded concentrations directly comparable to the concentrations in the finer-grained cores on the mound (Table 3-3), which suggests that the material had origins comparable to the other cores from the disposal mound.

The slightly higher concentrations of most metals (Cd, Cr, Cu, Pb, Hg, Zn) in Core 33 compared to the other Seawolf Mound cores persisted in the normalized data. Another interesting finding in the normalized data was that short Cores 27 and 29, collected beyond the acoustically detectible footprint of the Seawolf Mound, displayed higher metal concentrations in the normalized data set. Contrary to results for Core 30 (the coarse-grained core for which normalized concentrations appeared much more similar to the fine-grained cores from the disposal mound), the normalized data from Cores 27 and 29 yielded greater concentrations for all metals than the fine-grained cores from the disposal mound (Table 3-3). Although raw metal concentrations detected in Cores 27 and 29 were all lower than the concentrations detected in the fine-grained cores from the disposal mound, the normalized concentrations were all greater than the maximum concentrations from the disposal mound for each metal. The most substantial differences occurred for Pb (107 mg/kg in Core 27 and 56.5 mg/kg in Core 29, compared to the maximum concentration of 35.4 mg/kg from the fine-grained cores). The normalized Zn concentration in Core 27 (357 mg/kg), exceeded the maximum concentration from the fine-grained cores over the disposal mound (167 mg/kg from Core 33), but Core 29 had a slightly lower concentration (152 mg/kg).

Results for Core 27 reported by the analytical laboratory initially included a Pb concentration of 510 mg/kg for the surface interval. Because this value was extraordinarily high relative to the Pb concentrations for the nearby sediments (Cores 28, 29, and 30) the sample was re-analyzed, and the new concentration was detected as 30 mg/kg. The new concentration was considered to be more representative of sediment samples typically found at the Seawolf Mound. While both concentrations of lead in Core 27 were considered valid with respect to lab analysis and quality control, the second reported value was used in statistical analyses and graphics presented herein. The initial result (510 mg/kg) was attributed to sample heterogeneity, specifically, there may have been small, solid pieces of lead (e.g., gunshot, paint flakes, or other such material) removed from the Thames River and deposited with sediment at the Seawolf Mound, which were incorporated into the Core 27 material subjected to testing.

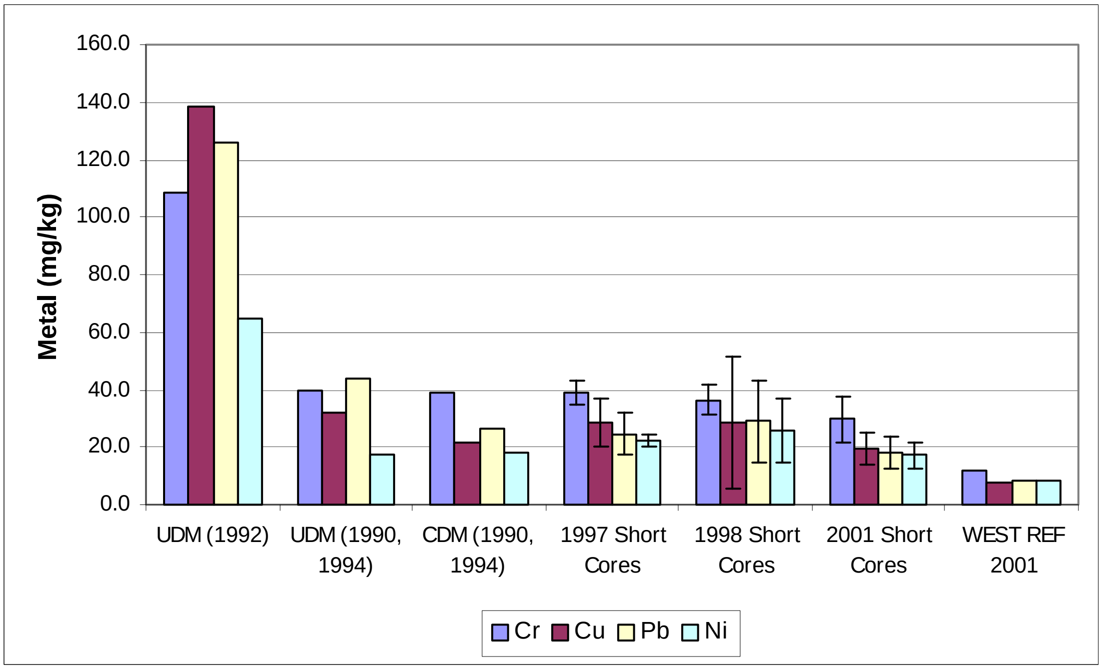
Comparison to Reference

Metal concentrations for the reference area, Core 39, yielded low concentrations of all metals in the upper 0.5 m of sediment. The average metal concentrations computed for all nine cores from the disposal area ranged from 2 to 2.6 times the concentrations detected at the reference area (Table 3-2 and Figure 3-2). However, when normalized to grain size, disposal area concentrations were very similar, and in some cases (e.g., As, Hg, Zn) less than the reference area concentrations (ranging from 0.8 to 1.1 times the reference area concentrations; (Table 3-3 and Figure 3-3). This suggests that differences in metal concentrations between the upper 0.5 m of sediments in the Seawolf Mound and the reference area can be attributed to differences in grain size, and that the fine-grained material sampled in the Seawolf Mound cores did not contain substantially higher concentrations of trace metals.

Comparison to Previous Disposal Mound Surveys

Trace metal concentrations in the short cores were compared to the results from previous disposal mound surveys in 1997 and 1998, as well as to the pre-dredging sediment testing results as described in earlier survey reports (SAIC 2001a). Metal concentrations, including non-normalized and normalized concentrations, from the 2001 short and long cores were compared to the 1997 and 1998 core results (Tables 3-2 and 3-3). Average metal concentrations from the 2001 disposal area short cores were very similar to the average concentrations from the 1997-1998 surveys (Table 3-2), with the average As and Cd concentrations falling within the range of averages from 1997 and 1998, and slightly lower averages calculated for the 2001 data set for the remaining metals (Cr, Cu, Pb, Hg, Ni, and Zn).

Recalculating the 2001 short core averages with Cores 27 and 29 excluded (lower concentrations detected in coarser sediments collected in areas not sampled in 1997-1998) did not appreciably change the 2001 averages, and therefore comparisons to the previous data sets. Similarly, comparisons using normalized metal concentrations did not appreciably alter the comparisons (Table 3-3).



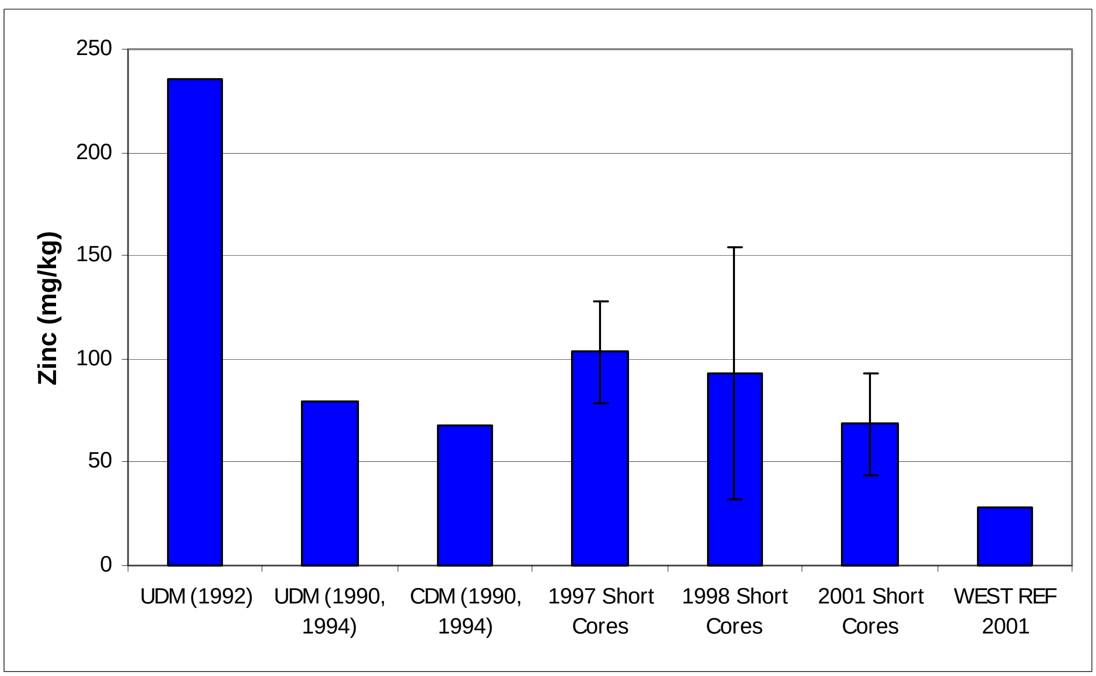
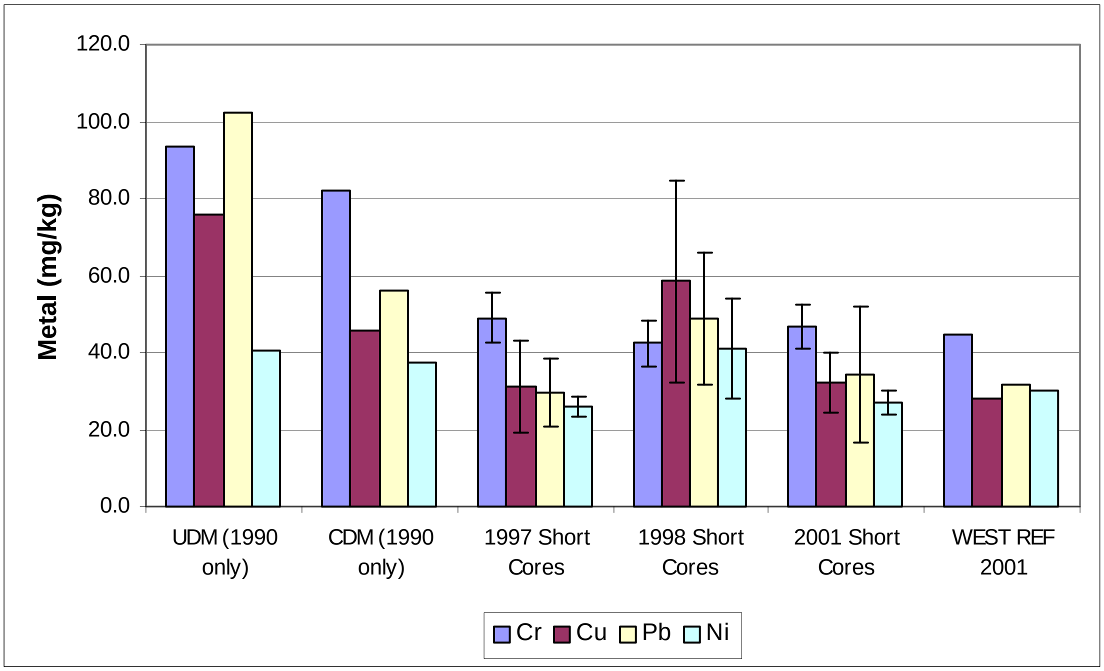


Figure 3-2. Trace metal concentrations in sediment from the Seawolf Mound designated dredging areas (classified as UDM or CDM), the Seawolf Mound 1997, 1998, and 2001 cores, and the WEST REF reference area (2001). Error bars represent 95% confidence intervals.



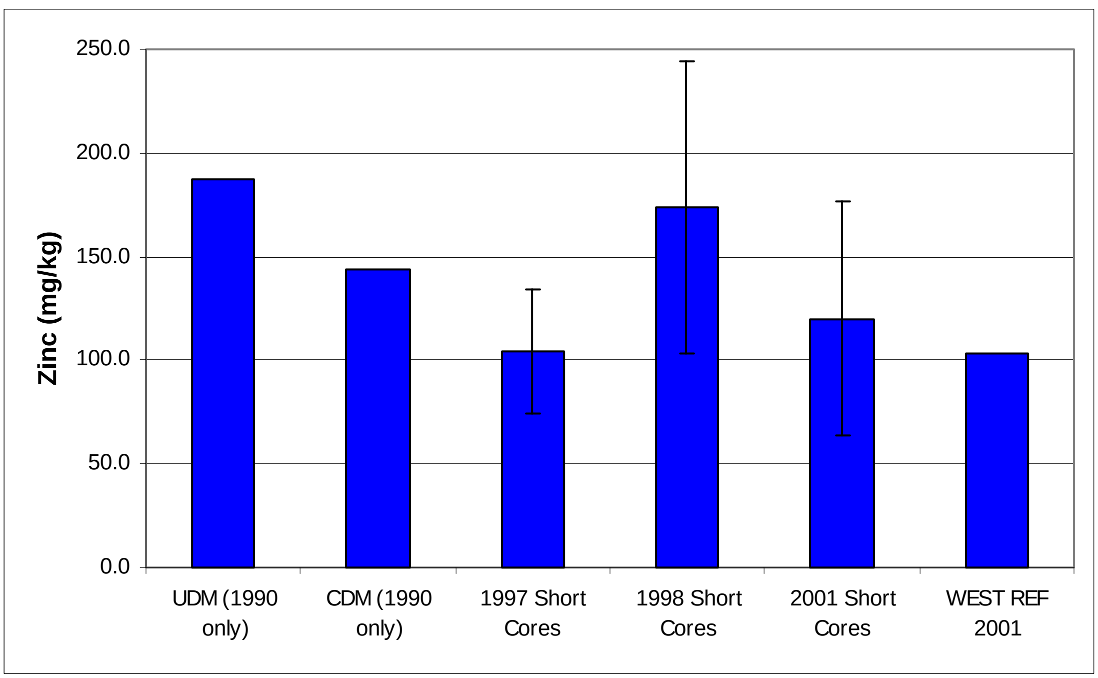


Figure 3-3. Normalized trace metal concentrations in sediment from the Seawolf Mound designated dredging areas (classified as UDM or CDM), the Seawolf Mound 1997, 1998, and 2001 cores, and the WEST REF reference area (2001). Error bars represent 95% confidence intervals.

As indicated above, Core 33 had slightly higher concentrations of most metals when compared to the other short cores in the 2001 survey, most notably Hg (0.12 mg/kg) and Zn (160 mg/kg). The range of Hg concentrations for all short cores from the 1997 survey was 0.04 to 0.28 mg/kg, and in the 1998 survey was non-detect to 0.21 mg/kg. The range of Zn concentrations for all short cores from the 1997 survey was 70.7 to 215 mg/kg, and in the 1998 survey was 40 to 340 mg/kg (40 to 95 mg/kg, with the higher concentrations of 340 mg/kg detected in one core from the outer zone). Comparisons among the other metals indicated similar results, with the 2001 data set indicating a range of concentrations that fell within, or close to the range of concentrations from the earlier surveys (SAIC 2001a). Additionally, in 1997, Core 12A "located 90 m from the location of Core 33" also had relatively higher trace metal concentrations in the surface sediments (SAIC 2001a). Therefore, the results from the 2001 survey reflect variability typical of that previously observed among different samples from the disposal area.

Comparison to Pre-Dredging Sediment Testing Results

Metal concentrations were also compared to pre-dredging sediment test results, which consist of fairly variable results obtained from two different data sets, 1992, and 1990-1994 combined data for UDM and CDM (Table 3-2 and Figure 3-2, Maguire Group, Inc. 1995). The 1992 UDM characterized the most contaminated portions of the material to be dredged (i.e., the upper meter of sediment to be dredged), and had substantially higher concentrations of Cr, Cu, Pb and Zn, and to a lesser extent, Ni (SAIC 2001a). The averages for the 1990 and 1994 results were more reflective of average concentrations throughout the entire depth of sediments proposed to be dredged, which yielded average concentrations that were not markedly different between material classified as UDM and CDM in those surveys (e.g., Cr, Cu, Ni, Zn; Figure 3-2). The similarities in chemical concentrations render that dataset less useful in trying to interpret whether disposal mound samples include UDM or CDM. However, there is still value in comparing Seawolf Mound sediment chemistry results to those concentrations, as substantially higher concentrations could indicate problems with the integrity of the cap material (e.g., physical mixing or some other source of higher contaminant concentrations).

The substantially higher concentrations of some contaminants in the 1992 material are more indicative of the material for which isolation from the marine environment via capping was targeted. Therefore, the 1992 data also provide useful comparisons for disposal mound samples, providing an indication of the likely, highest chemical concentrations that could potentially be present in the Seawolf Mound UDM. In summary, comparisons of the disposal mound results to both data sets (1992 and 1990-1994) provide useful information for purposes of investigating the integrity of the cap material.

Metal concentrations detected over the Seawolf Mound from 1997, 1998, and 2001 surveys exhibited several distinctions from the 1990 and 1994 UDM and CDM. For example, the average Pb concentration in the 2001 short cores was less than half the 1990-1994 UDM concentration, and the Hg concentration was substantially less (Table 3-2). Additionally, the 2001 short core averages were less than the 1990-1994 CDM concentrations for all metals except As and Zn. Arsenic (As) concentrations ranged from 3.6 to 10 mg/kg; six cores from all zones (inner, middle, and outer) had slightly higher As concentrations with respect to the pre-dredging CDM concentration (6.3 mg/kg) and the pre-dredging 1990-1994 UDM concentration (7.8 mg/kg). However, all 2001 As concentrations were below the highest, pre-dredging UDM concentrations reported in the 1992 data set (13 mg/kg).

Zinc concentrations for most of the cores (25 to 72 mg/kg) were comparable to the pre-dredging CDM concentration of 68.2 mg/kg. The 2001 Zn concentrations from Core 27 and Core 33 (100 and 160 mg/kg respectively) were greater than the pre-dredging CDM concentration (68.2 mg/kg) and the pre-dredging 1990/1994 UDM concentrations (79.4 mg/kg), but were substantially lower than the highest, pre-dredging UDM concentrations reported in 1992 (235 mg/kg). Core 33 was collected from the inner zone of the mound, consisted of 96% fines, and displayed higher concentrations of other metals as discussed above (Cr, Cu, and Ni; Table 3-1). These concentrations were greater than the pre-dredge CDM concentrations and slightly greater than the 1990/1994 UDM concentrations, but still substantially below the 1992 UDM averages (Table 3-2).

For the remaining metals, comparisons of the 2001 short core averages and the 1990-1994 UDM and CDM did not indicate substantial differences (Table 3-2; Figure 3-2). The non-normalized metal concentrations did exhibit substantial differences from the 1992 UDM results for most metals (Figure 3-2). Further comparisons were made between the disposal mound samples and the pre-dredging sediment chemistry using normalized concentrations (Table 3-3). The average, normalized concentrations for all metals from the disposal mound surveys (1997, 1998, and 2001) were less than the average 1990-1994 UDM and CDM concentrations (Figure 3-3).

Despite slightly higher normalized concentrations from the coarse-grained cores (Cores 27 and 29), compared to the remainder of the cores collected from the disposal mound, the concentrations of most metals in Cores 27 and 29 were less than, or comparable to, the concentrations in the 1990-1994 UDM and CDM. The only exception was the maximum, normalized Zn concentration (357 mg/kg) in Core 27, which was substantially greater than the average, normalized UDM (187 mg/kg) and CDM

(144 mg/kg) concentrations (Table 3-3). The non-normalized Zn concentration for Core 27 (100 mg/kg) was still substantially less than the 1992 UDM concentration (235 mg/kg).

PAHs (Short Cores)

A total of 18 individual polycyclic aromatic hydrocarbons (PAHs) were measured in each composite sediment sample obtained from the short cores (Table 3-4). PAH concentrations were generally very low in all the short cores, consisting primarily of non-detects or low concentrations of detected PAH compounds. Acenaphthene and dibenzofuran were reported as below the detection limit ("U") in all short core sediment samples analyzed (Table 3-4), and Core 31 had non-detects for all PAH compounds analyzed. Values below the method detection limit were included in the table at one-half the detection limit to assist in estimating total PAH content.

The sum of low molecular weight (LMW) PAHs ranged from 73 to 206 μg/kg, and the sum of high molecular weight (HMW) PAHs ranged from 154 to 1188 μg/kg (Table 3-4). Total PAHs ranged from 252 μg/kg to 1347 μg/kg. In contrast to the metals results, the PAH concentrations did not display any evidence of trends based on grain size, nor any trends based on location within the disposal area. Among the fairly ubiquitous non-detects and low concentrations, Cores 28 and 29 displayed somewhat higher concentrations of the HMW PAHs, with total concentrations (1188 and 918 μg/kg, respectively) on the order of two to eight times the total concentrations in the remaining cores (154 to 587 μg/kg). In contrast, Core 27, also collected from the outer zone, displayed a HMW PAH concentration (549 μg/kg) that fell within the range of concentrations for the other cores collected in the disposal area. With the exception of somewhat higher HMW PAHs in Cores 28 and 29 from the outer zone, the results do not indicate other apparent trends in PAHs based on location within the disposal area.

PAH concentrations from the reference area, Core 39, also consisted of non-detects or detections at very low concentrations for PAHs (Table 3-4). Using one half the detection limit for non-detects yielded very low PAH concentrations, including a sum of LMW PAHs of 46 μg/kg, sum of HMW PAHs of 111 μg/kg, and total PAHs estimated at 158 μg/kg. Disposal area concentrations were generally slightly higher in comparison to Core 39 (e.g., two to four times higher for LMW PAHs, and 1.5 to ten times higher for HMW PAHs).

Comparison to earlier surveys conducted in 1997 and 1998 indicated a similar range of total PAH concentrations for the 1997 and 1998 surveys, with the exception of the higher total PAH concentrations attributed to the HMW PAHs in Cores 28 and 29 (outer zone) from the 2001 survey (Table 3-5). The total LMW PAHs from the 2001 survey short cores (73 to 206 μg/kg) was greater than the concentrations from the 1997 survey

Table 3-4.
PAH Concentrations in Samples Collected from the Seawolf Mound Short Cores, June 2001

Radial Zone:	Outer zone (400-600 m)							Middle zone (200-400 m)							Inner zone (0-200 m)											WEST REF		TEL[1]	ERL[2]	PEL[3]	ERM[4]
NLDS Core Name:	**27**		**28**		**29**		**Avg**	**30**		**31**		**32**		**Avg**	**33**		**34**		**35**		**Avg**	**Avg**	**Std Dev**	**Max**	**Min**	**39**					
PAH Compound																															
Low Molecular Weight																															
Naphthalene	29		19		18		22.0	9.2	U	14	U	21		10.9	23		9.7	U	15		14.3	15.7	8.6	29	4.6	6.5	U	34.57	160	390.64	2100
2-Methylnaphthalene	12		14	U	10		9.7	9.2	U	14	U	14	U	6.2	14	U	9.7	U	13	U	6.1	7.3	2.3	12	4.6	6.5	U	20.21	70	201.28	670
Acenaphthylene	10		15		12		12.3	9.2	U	14	U	14	U	6.2	14	U	9.7	U	13	U	6.1	8.2	3.5	15	4.6	6.5	U	5.87	44	127.87	640
Acenaphthene	6.8	U	14	U	6.9	U	4.6	9.2	U	14	U	14	U	6.2	14	U	9.7	U	13	U	6.1	5.6	1.6	7	3.4	6.5	U	6.71	16	88.9	500
Fluorene	6.8	U	14	U	11		7.1	9.2	U	14	U	14	U	6.2	14	U	9.7	U	13	U	6.1	6.5	2.2	11	3.4	6.5	U	21.17	19	144.35	540
Phenanthrene	43		55		110		69.3	18		14	U	45		23.3	45		21		29		31.7	41.4	30.0	110	7	7.4		86.68	240	543.53	1500
Anthracene	16		28		38		27.3	9.2	U	14	U	14		8.5	18		20		13	U	14.8	16.9	10.9	38	4.6	6.5	U	46.85	85.3	245	1100
Sum of LMW PAHs	**124**		**159**		**206**		**163**	**73**		**98**		**136**		**102**	**142**		**90**		**109**		**114**	**126.2**	**37**	**206**	**73**	**46**		222.06	634.3	1741.6	7050
High Molecular Weight																															
Fluoranthene	78		180		190		149.3	31		14	U	75		37.7	93		43		53		63.0	83.3	63.3	190	7	15		112.82	600	1493.5	5100
Pyrene	96		200		160		152.0	48		14		100		54.0	130		49		74		84.3	96.8	58.9	200	14	18		152.66	665	1397.6	2600
Benz[a]anthracene	54		160		100		104.7	23		14	U	38		22.7	61		22		34		39.0	55.4	47.7	160	7	9.3		74.83	261	692.53	1600
Chrysene	57		160		91		102.7	23		14	U	46		25.3	57		28		35		40.0	56.0	45.9	160	7	9.7		107.77	384	845.98	2800
Benzo[b]fluoranthene	62		130		90		94.0	30		14	U	48		28.3	67		26		35		42.7	55.0	37.5	130	7	14		NR	NR	NR	NR
Benzo[k]fluoranthene	39		85		63		62.3	16		14	U	28		17.0	36		14		20		23.3	34.2	25.4	85	7	7.1		NR	NR	NR	NR
Benzo[a]pyrene	62		120		96		92.7	28		14	U	40		25.0	57		22		32		37.0	51.6	36.6	120	7	11		88.81	430	736.22	1600
Indeno[1,2,3-cd]pyrene	44		65		58		55.7	18		14	U	25		16.7	31		12		18		20.3	30.9	20.5	65	7	7.6		NR	NR	NR	NR
Dibenz[a,h]anthracene	11		19		14		14.7	9.2	U	14	U	14	U	6.2	14	U	9.7	U	13	U	6.1	9.0	4.8	19	4.6	6.5	U	6.22	63.4	134.61	260
Benzo[g,h,i]perylene	39		55		49		47.7	16		14	U	22		15.0	27		10		15		17.3	26.7	17.3	55	7	6.6		NR	NR	NR	NR
Dibenzofuran	6.8		14		6.9		5.8	9.2	U	14	U	14	U	6.2	14	U	9.7	U	13	U	6.1	6.0	1.4	7	3.4	6.5	U	NR	NR	NR	NR
Sum of HMW PAHs	**549**		**1188**		**918**		**885**	**251**		**154**		**450**		**285**	**587**		**245**		**342**		**391**	**521**	**341**	**1188**	**154**	**111**		--	--	--	--
Total PAHs	**672**		**1347**		**1124**		**1048**	**325**		**252**		**586**		**388**	**729**		**335**		**451**		**505**	**647**	**375**	**1347**	**252**	**158**		--	--	--	--
1997 Summary Mean, Total PAHs							**381**							**203**							**445**	**323**									
1998 Summary Mean, Total PAHs							**292**							**558**							**312**	**387**									

Units are µg/kg dry weight.

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

NR=Not Reported (not readily available in original Maguire Group, 1995 report)

[1]Threshold Effects Level (TEL), MacDonald, 1994

[2] Effects Range - Low (ERL), Long et al, 1995

[3]Probable Effects Level (PEL), MacDonald, 1994

[4] Effects Range - Median (ERM), Long et al, 1995

Table 3-5.

Comparison of PAH Concentrations in Samples Collected from the Seawolf Mound Short Cores in June 2001 to Previous Survey Results

Radial Zone:	Outer zone (400-600 m)						Middle zone (200-400 m)						Inner zone (0-200 m)						WEST-REF			TEL[1]	ERL[2]	PEL[3]	ERM[4]
Year of Coring Survey:	2001 Sediment Cores			2001	1997	1998	2001 Sediment Cores			2001	1997	1998	2001 Sediment Cores			2001	1997	1998	2001	1997	1998				
NLDS Core Name :	27	28	29	Avg	Avg	Avg	30	31	32	Avg	Avg	Avg	33	34	35	Avg	Avg	Avg	39	13	26				
PAH Compound																									
Low Molecular Weight																									
Naphthalene	29	19	18	22.0	3.25	7.3	9.2 U	14 U	21	10.9	4.75	15.0	23	9.7 U	15	14.3	5.3	10.7	6.5 U	4 J	8	34.57	160	390.6	2100
2-Methylnaphthalene	12	14 U	10	9.7	4.0	5.3	9.2 U	14 U	14 U	6.2	4.0	8.7	14 U	9.7 U	13 U	6.1	4.0	5.2	6.5 U	5 U	4 J	20.21	70	201.3	670
Acenaphthylene	10	15	12	12.3	6.5	12.7	9.2 U	14 U	14 U	6.2	5.0	20.7	14 U	9.7 U	13 U	6.1	8.0	14.0	6.5 U	3 J	13	5.87	44	127.9	640
Acenaphthene	6.8 U	14 U	6.9 U	4.6	4.0	5.2	9.2 U	14 U	14 U	6.2	4.0	4.7	14 U	9.7 U	13 U	6.1	4.0	5.5	6.5 U	5 U	4 J	6.71	16	88.9	500
Fluorene	6.8 U	14 U	11	7.1	4.0	5.2	9.2 U	14 U	14 U	6.2	4.0	5.0	14 U	9.7 U	13 U	6.1	4.0	5.3	6.5 U	5 U	4 J	21.17	19	144.4	540
Phenanthrene	43	55	110	69.3	24.0	20.3	18	14 U	45	23.3	11.25	36.0	45	21	29	31.7	27.7	18.7	7.4	9	38	86.68	240	543.5	1500
Anthracene	16	28	38	27.3	9.5	11.7	9.2 U	14 U	14 U	8.5	5.5	21.7	18	20	13 U	14.8	10.0	12.3	6.5 U	4 J	14	46.85	85.3	245	1100
Sum of LMW PAHs	**124**	**159**	**206**	**163**	**55**	**68**	**73**	**98**	**136**	**102**	**39**	**112**	**142**	**90**	**109**	**114**	**63**	**72**	**46**	**35**	**85**	222.1	634.3	1742	7050
High Molecular Weight																									
Fluoranthene	78	180	190	149.3	59.5	32.3	31	14 U	75	37.7	29.75	64.7	93	43	53	63.0	66.7	35.3	15	21	65	112.8	600	1494	5100
Pyrene	96	200	160	152.0	65.0	43.7	48	14 U	100	54.0	32.25	105.0	130	49	74	84.3	78.0	55.3	18	25	88	152.7	665	1398	2600
Benz[a]anthracene	54	160	100	104.7	32.0	21.3	23	14 U	38	22.7	15.25	42.3	61	22	34	39.0	39.3	24.0	9.3	14	32	74.83	261	692.5	1600
Chrysene	57	160	91	102.7	31.5	25.3	23	14 U	46	25.3	14.0	52.0	57	28	35	40.0	34.0	27.3	9.7	12	41	107.8	384	846	2800
Benzo[b]fluoranthene	62	130	90	94.0	29.5	17.7	30	14 U	48	28.3	16.0	34.3	67	26	35	42.7	40.7	17.3	14	14	34	NR	NR	NR	NR
Benzo[k]fluoranthene	39	85	63	62.3	22.5	19.0	16	14 U	28	17.0	10.5	36.3	36	14	20	23.3	22.7	19.3	7.1	8	29	NR	NR	NR	NR
Benzo[a]pyrene	62	120	96	92.7	33.0	24.3	28	14 U	40	25.0	16.25	46.3	57	22	32	37.0	39.3	24.7	11	14	37	88.81	430	736.2	1600
Indeno[1,2,3-cd]pyrene	44	65	58	55.7	3.5	15.0	18	14 U	25	16.7	4.0	28.7	31	12	18	20.3	5.0	14.7	7.6	5 U	25	NR	NR	NR	NR
Dibenz[a,h]anthracene	11	19	14	14.7	21.5	5.2	9.2 U	14 U	14 U	6.2	11.25	5.7	14 U	9.7 U	13 U	6.1	25.7	5.2	6.5 U	9	4 J	6.22	63.4	134.6	260
Benzo[g,h,i]perylene	39	55	49	47.7	21.5	17.3	16	14 U	22	15.0	11.5	32.3	27	10	15	17.3	26.7	17.0	6.6	9	27	NR	NR	NR	NR
Dibenzofuran	6.8 U	14 U	6.9 U	5.8	4.0	--	9.2 U	14 U	14 U	6.2	4.0	--	14 U	9.7 U	13 U	6.1	4.0	--	6.5 U	5 U	--	NR	NR	NR	NR
Sum of HMW PAHs	**549**	**1188**	**918**	**885**	**324**	**221**	**251**	**154**	**450**	**285**	**165**	**448**	**587**	**245**	**342**	**391**	**382**	**240**	**111**	**131**	**382**	**--**	**--**	**--**	**--**
Total PAHs	**672**	**1347**	**1124**	**1048**	**379**	**289**	**325**	**252**	**586**	**388**	**203**	**559**	**729**	**335**	**451**	**505**	**445**	**312**	**158**	**166**	**467**	**--**	**--**	**--**	**--**

Units are µg/kg dry weight.

U = Below detection limit (detection limit dependent upon sample volume); one half of the reported detection limit was used for statistical calculations.

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

NR=Not Reported (not readily available in original Maguire Group, 1995 report)

[1]Threshold Effects Level (TEL), MacDonald, 1994

[2] Effects Range - Low (ERL), Long et al, 1995

[3]Probable Effects Level (PEL), MacDonald, 1994

[4] Effects Range - Median (ERM), Long et al, 1995

(primarily non-detects, with a range from 29 to 85 μg/kg) and the 1998 survey results (35 to 127 μg/kg). However, eliminating the outer zone results from the 2001 data set yielded a more comparable range to the earlier survey results (73 to 142 μg/kg). The sum of HMW PAHs from the 2001 survey short cores (154 to 1188 μg/kg) was also greater than the 1997 (78 to 648 μg/kg) and 1998 (65 to 519 μg/kg) results. Again, eliminating the outer zone cores that are likely influenced by non-Seawolf project sediments, the PAH concentrations in the 2001 data set yielded a range more comparable to the prior surveys (154 to 587 μg/kg).

Evaluation of individual PAH compounds indicated somewhat greater variability in the 2001 results but no evidence of statistically significant differences in the 2001 data with respect to earlier surveys (Figure 3-4). Comparisons of individual PAH compounds to the pre-dredging sediment testing results available for 1990-1994 UDM and CDM indicated no substantive difference in concentrations for most compounds (Figure 3-4).

3.1.2 Long Cores

3.1.2.1 Visual Descriptions

Long Core 36 was collected from the outer zone (400–600 m) and in an area located beyond the 0.25 m contour for Seawolf UDM and within the 0.25 m contour for CDM (Figure 2-1). Core 36 was 2.34 m in length and was marked by coarsening downward sequences ranging from silty clay near the top to clayey silt and clayey sand near the bottom of the core (Appendix A). The upper, fine-grained sequences were similar to those in short Core 28 collected nearby, with approximately 1.50 m of the upper core interval composed of greenish-gray to greenish-black moist, soft to firm, silty clay. Below 1.50 m, there was a gradual coarsening of the sediment to clayey silt and then to clayey sand with sparse gravel, before fining again to clayey silt.

Long Core 37 was collected from the middle zone (200–400 m) and within the 0.25 m UDM contour (Figure 2-1). Core 37 had a total length of 2.66 m, with the surface of the core primarily composed of dark greenish-gray, moist, soft to firm, clay and silty clay (Appendix A). An organic odor was noted throughout the top 2.34 m of the core, while coarser sediment (silt, fine sand with shell hash) emitting a petroleum odor was detected in the bottom 0.32 m of the core. The visual description for the surface interval of Core 37 (at least the upper 0.5 m) was comparable to short cores collected from stations in close proximity (Cores 31 and 32).

Core 38 was collected in the inner zone (0–200 m), well within the UDM footprint (Figure 2-1). Its total length was 2.38 m, and there was an organic odor throughout the core. Dark, greenish-gray to greenish-black, moist, soft to firm, silty clay dominated the

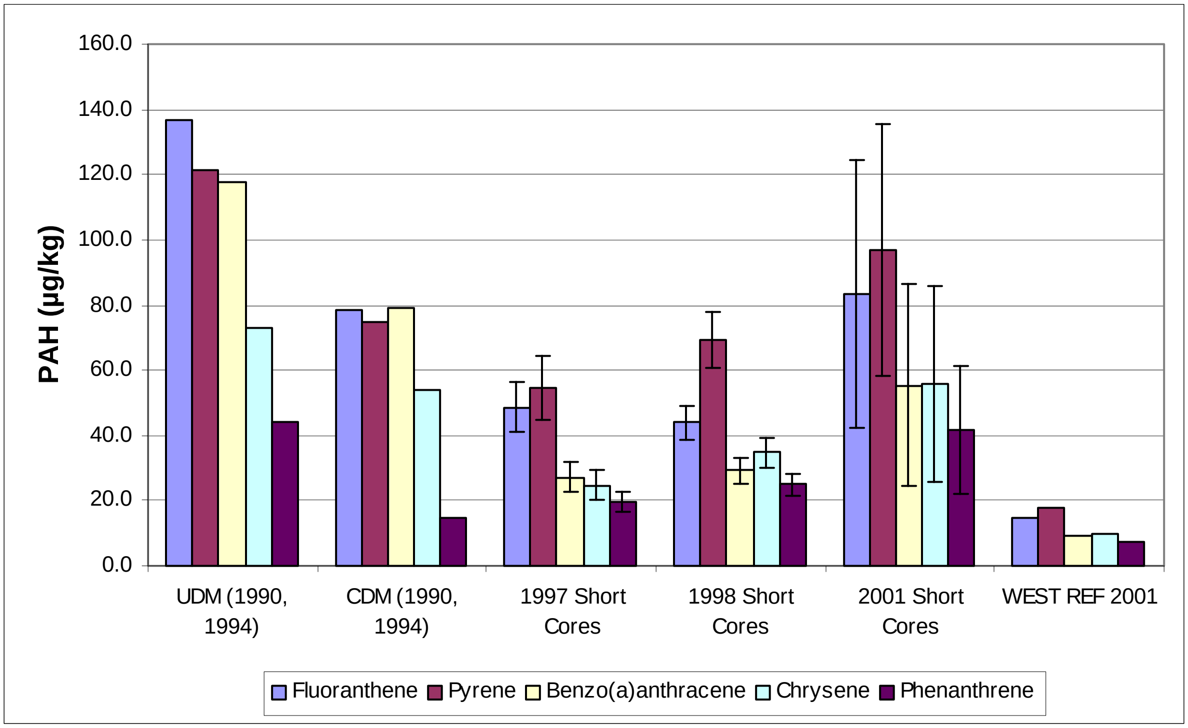


Figure 3-4. Summary of PAH concentrations (µg/kg) for pre-dredged (1990/1994) data and 1997, 1998, and 2001 short cores at the NLDS Seawolf Mound. Error bars represent 95% confidence intervals.

top 1.95 m of the core, with some bands of greenish-black silty clay near the bottom of the interval (Appendix A). The color and lithology of the sediment in the top interval was similar to the CDM detected in the nearby inner zone short Cores 33, 34, and 35. Horizons of sand with a petroleum odor were identified in the deeper intervals, with greenish-black, moist, soft to firm, silty, coarse sand identified as the dominant lithology for the bottom 0.46 m of Core 38.

3.1.2.2 Physical Parameters

Grain Size

Fine-grained sediments (91–96% fines) were detected in the majority of the samples collected from the long cores below the 0.5 m penetration depth (Table 3-1). The predominance of fine-grained sediments persisted with depth in the long cores, with the exception of substantially coarser sediment (28% fines) encountered in the lowest sampling interval (1.5–1.9 m) in Core 36 from the outer zone (Table 3-1).

Moisture Content

Moisture content was determined for three horizons within each long core collected as part of the June 2001 survey, with results directly correlated to grain size and consistent with the results from the short cores. Fine-grained intervals of the long cores (88–96% fines) had moisture contents ranging from 46 to 53% (Table 3-1). The only coarse material, detected at depth in Core 36, had a moisture content of 22.9% (Table 3-1).

Total Organic Carbon

Total organic carbon (TOC) concentrations calculated for the long cores ranged from 1.2% to 3.6% (Table 3-1). Similar to the moisture content results, total organic carbon concentrations were in excess of 2.7% for all long core samples with the exception of the bottom interval of Core 36. The greater sand/gravel content within the 1.5 to 1.9 m horizon of Core 36 was the basis for the relatively low organic carbon content (1.2%).

3.1.2.3 Sediment Chemistry

Trace Metals (Long Cores)

Zinc (Zn) was the only trace metal evaluated in the long core material, as it provided a strong indicator for Seawolf UDM. Zinc concentrations were analyzed for core intervals between 0.5–2 m depth in each core (Table 3-2). Concentrations for all three cores were generally low, ranging from 34 to 90 mg/kg, and fell within the range of Zn concentrations detected in the surface sediments in the short cores (25 to 160 mg/kg). The lowest Zn concentration in the long cores was detected in the coarse sediment in the lowest depth interval (1.5–1.9 m) from Core 36 in the outer zone. Given the coarse nature of the sediment in that sampling interval, when normalized to grain size, the concentration (121 mg/kg) exceeded the other normalized Zn concentrations from the long cores (57 to 94 mg/kg) but fell within the range of normalized Zn concentrations from the short cores.

The highest Zn concentration in the long core samples (90 mg/kg) was detected in the 0.5–0.75 m depth interval from Core 38 (inner zone) and as stated above, was lower than the maximum concentration in the short cores, 160 mg/kg. Given that all but the lower depth interval of Core 36 had very similar grain size, normalization did not provide any additional insights for Zn concentrations in the long cores.

Zinc concentrations in the 2001 long cores were slightly lower (overall average of 66.8 mg/kg, Table 3-2; average of 70.8 mg/kg with anomalously low concentration from the coarse-grained, lower depth interval of Core 36 eliminated) than the Zn concentrations in 1997 long cores (overall average of 96.5 mg/kg, SAIC 2001a), but more comparable to the 1998 long cores (overall average of 78 mg/kg, SAIC 2001a). Additionally, Zn concentrations from the 2001 long cores did not indicate any apparent trend related to sampling zone (e.g., outer, middle, inner zone over the disposal area), or sediment depth (e.g., no evidence of a change in Zn concentration with depth in the long cores, and no evidence of a change with respect to the 0–0.5 m depth interval sampled in the short cores).

PAHs (Long Cores)

Similar to the short cores over the Seawolf Mound, PAH concentrations were generally very low in most of the long cores, consisting of numerous non-detects or low concentrations of detected PAH compounds (Table 3-6). The sum of low molecular weight (LMW) PAHs ranged from 76 to 463 μg/kg, which was comparable to the range of concentrations from the short cores (73 to 206 μg/kg). The sum of high molecular weight (HMW) PAHs ranged from 196 to 1184 μg/kg, which was also comparable to the range of concentrations from the short cores (154 to 1188 μg/kg). Total PAHs ranged from 272 to 1413 μg/kg, comparable to the short core total PAHs (252 to 1347 μg/kg).

The highest concentrations of PAHs occurred in the outer zone, Core 36. PAH concentrations from various depth intervals in long Cores 37 and 38 were consistent and did not show any trends of increasing or decreasing PAH concentrations with depth in the

Table 3-6.
PAH Concentrations in Samples Collected from the Seawolf Mound Long Cores, June 2001

Radial Zone:	Outer zone (400-600 m)							Middle zone (200-400 m)							Inner zone (0-200 m)																
NLDS Core Name:	**36-2**		**36-3**		**36-4**		**Avg**	**37-2**		**37-3**		**37-4**		**Avg**	**38-2**		**38-3**		**38-4**		**38-4B**		**Avg**	**Avg**	**Std dev**	**Max**	**Min**	**TEL[1]**	**ERL[2]**	**PEL[3]**	**ERM[4]**
Depth in core (m):	0.5-0.75		0.75-1.00		1.53-1.87			0.54-0.79		0.79-1.04		1.04-2.04			0.5-0.75		0.75-1.00		1.00-1.99		1.00-1.99										
PAH Compound																															
Low Molecular Weight																															
Naphthalene	50		19		23		30.7	20		15		12		15.7	14	U	13	U	13	U	10	U	6.3	16.4	13.4	50	5	34.57	160	390.64	2100
2-Methylnaphthalene	56		9.6	U	11		23.9	13	U	9.4	U	9.2	U	5.3	14	U	13	U	13	U	10	U	6.3	11.7	15.7	56	4.6	20.21	70	201.28	670
Acenaphthylene	9.6	U	9.6	U	21		10.2	13	U	9.4	U	9.2	U	5.3	14	U	13	U	13	U	10	U	6.3	7.1	5.0	21	4.6	5.87	44	127.87	640
Acenaphthene	9.6	U	9.6	U	9.5		6.4	13	U	9.4	U	9.2	U	5.3	14	U	13	U	13	U	10	U	6.3	6.0	1.5	9.5	4.6	6.71	16	88.9	500
Fluorene	54		9.6	U	14		24.3	13	U	9.4	U	9.2	U	5.3	14	U	13	U	13	U	10	U	6.3	11.4	15.2	54	4.6	21.17	19	144.35	540
Phenanthrene	260		38		110		136.0	23		21		21		21.7	33		18		27		16		23.5	56.7	76.6	260	16	86.68	240	543.53	1500
Anthracene	24		14		40		26.0	13	U	9.4	U	9.2	U	5.3	19		13	U	13	U	10	U	9.3	13.1	11.6	40	4.6	46.85	85.3	245	1100
Sum of LMW PAHs	**463**		**109**		**229**		**267**	**108**		**83**		**79**		**90**	**122**		**96**		**105**		**76**		**100**	**147.0**	**119**	**463**	**76**	222.06	634.3	1741.57	7050
High Molecular Weight																															
Fluoranthene	120		89		220		143.0	41		38		49		42.7	51		40		65		36		48.0	74.9	57.6	220	36	112.82	600	1493.54	5100
Pyrene	160		120		270		183.3	57		54		50		53.7	60		41		63		38		50.5	91.3	73.7	270	38	152.66	665	1397.6	2600
Benz[a]anthracene	71		43		130		81.3	22		17		20		19.7	30		22		29		15		24.0	39.9	35.7	130	15	74.83	261	692.53	1600
Chrysene	120		38		110		89.3	25		19		22		22.0	26		21		31		21		24.8	43.3	38.3	120	19	107.77	384	845.98	2800
Benzo[b]fluoranthene	70		40		100		70.0	28		20		23		23.7	23		22		35		20		25.0	38.1	26.5	100	20	NR	NR	NR	NR
Benzo[k]fluoranthene	33		27		77		45.7	16		11		12		13.0	14	U	13	U	20		10		10.9	22.0	21.2	77	6.5	NR	NR	NR	NR
Benzo[a]pyrene	52		39		120		70.3	24		17		19		20.0	24		20		30		16		22.5	36.1	31.5	120	16	88.81	430	736.22	1600
Indeno[1,2,3-cd]pyrene	35		25		71		43.7	13	U	9.4	U	9.9		7.0	14	U	13	U	17		10	U	8.9	18.8	20.9	71	4.7	NR	NR	NR	NR
Dibenz[a,h]anthracene	19		9.6	U	16		13.3	13	U	9.4	U	9.2	U	5.3	14	U	13	U	13	U	10	U	6.3	8.1	5.1	19	4.6	6.22	63.4	134.61	260
Benzo[g,h,i]perylene	39		24		63		42.0	13	U	9.4	U	9.2	U	5.3	14	U	13	U	14		10	U	8.1	17.4	19.5	63	4.6	NR	NR	NR	NR
Dibenzofuran	9.9		9.6	U	7.2		7.3	13	U	9.4	U	9.2	U	5.3	14	U	13	U	13	U	10	U	6.3	6.3	1.6	9.9	4.6	NR	NR	NR	NR
Sum of HMW PAHs	**729**		**464**		**1184**		**792**	**265**		**214**		**233**		**237**	**284**		**231**		**330**		**196**		**260**	**412.9**	**315**	**1184**	**196**	--	--	--	--
Total PAHs	**1192**		**574**		**1413**		**1059**	**373**		**297**		**312**		**327**	**406**		**327**		**435**		**272**		**360**	**560.0**	**404**	**1413**	**272**	--	--	--	--

Units are µg/kg dry weight.

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

NR=Not Reported (not readily available in original Maguire Group, 1995 report)

[1]Threshold Effects Level (TEL), MacDonald, 1994

[2] Effects Range - Low (ERL), Long et al, 1995

[3]Probable Effects Level (PEL), MacDonald, 1994

[4] Effects Range - Median (ERM), Long et al, 1995

sediment (Figure 3-5). In Core 36, the LMW PAHs had slightly higher concentrations than the other long cores in the 0.5–0.75 m layer in Core 36, though still at relatively low concentrations, and HMW PAHs had higher concentrations in the lowest core layer, 1.5–1.9 m (Table 3-6). Core 36 PAH concentrations exceeded the pre-dredging sediment test results for some compounds at various depths in the core, but did not exhibit a trend of increasing or decreasing concentration with depth in the sediment (Figure 3-5).

Both the short and long cores yielded the highest PAH concentrations in the outer zone (short Cores 28 and 29, and long Core 36). No spatial trends in PAH concentration were evident between Cores 37 and 38 (middle and inner zones respectively), or with depth in the sediment in any of the long cores, including Core 36 (Figure 3-5). Additionally, the long core PAH concentrations from each depth interval were comparable to the range of values detected in the short cores, providing no evidence of any trends in PAH concentration with depth between the surface interval (the upper 0.5 m of sediment analyzed in the short cores) and the deeper intervals analyzed in the long cores.

3.2 REMOTS® Sediment-Profile Imaging

3.2.1 Seawolf Mound

Sediment-profile images were collected at each of the six Seawolf Mound stations (CTR, 75E, 150N, 150W, 300SE, 300WSW) occupied as part of the June 2001 survey. The results of this reconnaissance sampling technique were primarily used as a basis of comparison to the data obtained through sediment grab sampling and full benthic community analysis (results presented in Section 3.3 below). In addition, the REMOTS® results for the mound were compared to ambient sediment data obtained at the three reference areas surrounding NLDS. The complete set of June 2001 REMOTS® image analysis results for the disposal mound and reference area stations is provided in Appendix B; these results are summarized in Tables 3-7 and 3-8.

3.2.1.1 Physical Sediment Characteristics

As anticipated, dredged material was evident in the REMOTS® images at all of the Seawolf Mound stations occupied. The thickness of historic dredged material exceeded the penetration depth of the REMOTS® camera at all stations (i.e., dredged material greater than penetration; Figure 3-6). Similar to previous surveys, the dredged material comprising the surface sediments within the Seawolf Mound was fine grained, composed mainly of silt and clay (>4 phi), while the reference areas were characterized by surface sediments that were predominantly very fine sand (4 to 3 phi) or fine sand (3 to 2 phi; Tables 3-7 and 3-8). Although the grain size was primarily sandy silt and clay at the

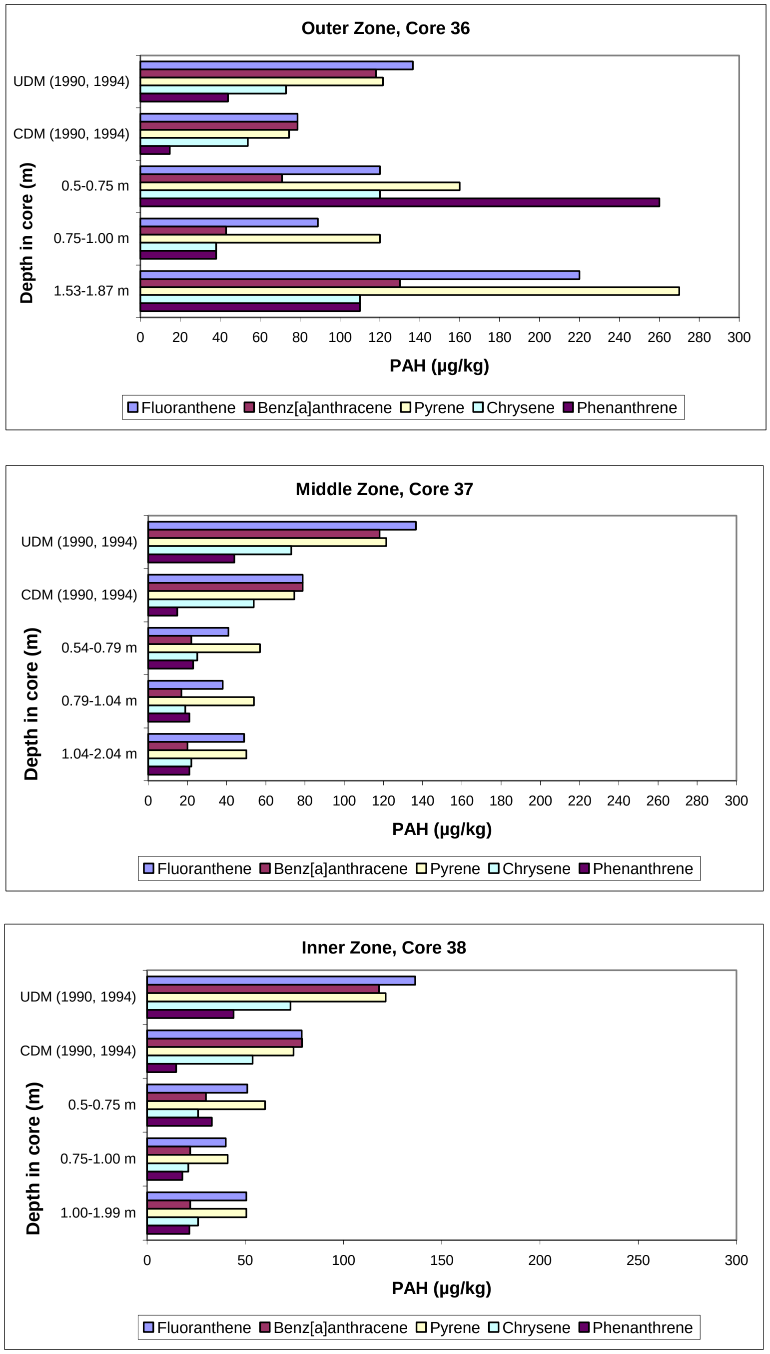


Figure 3-5. Summary of PAH concentrations (μg/kg) for pre-dredged (1990/1994) data and 2001 long cores in each zone (inner, middle, outer) at the NLDS Seawolf Mound

Table 3-7.

REMOTS® Sediment-Profile Imaging Results Summary for the Seawolf Mound, June 2001

Station	Camera Penetration Mean (cm)	Dredged Material Thickness Mean (cm)	Number of Replicate Images w/ Dredged Material	RPD Mean (cm)	Successional Stages Present	Highest Stage Present	Grain Size Major Mode (phi)	Methane Present	OSI Mean	OSI Median	Boundary Roughness Mean (cm)
300WSW	15.34	>15.34	3	3.39	I,II,III	ST_II_ON_III	>4	NO	8.67	9	0.95
300SE	9.41	>9.41	3	2.83	I,III	ST_I_ON_III	4 to 3	NO	8.00	9	1.17
75E	14.37	>14.37	3	2.26	I,II,III	ST_II_ON_III	>4	NO	7.33	9	1.00
CTR	11.86	>11.86	3	1.65	I,II,III	ST_II_ON_III	>4	NO	6.00	6	0.82
150W	12.81	>12.81	3	2.69	I,II,III	ST_I_ON_III	>4	NO	7.67	8	1.83
150N	14.00	>14.00	3	2.03	I,II,III	ST_II_ON_III	>4	NO	7.00	8	1.44
AVG	12.97	>12.97	3	2.47			>4		7.44	8.17	1.20
MAX	15.34	>15.34	3	3.39			4 to 3		8.67	9	1.83
MIN	9.41	>9.41	3	1.65			>4		6.00	6	0.82

Table 3-8.

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

Station	Camera Penetration Mean (cm)	RPD Mean (cm)	Successional Stages Present	Highest Stage Present	Grain Size Major Mode (phi)	Methane Present	OSI Mean	OSI Median	Boundary Roughness Mean (cm)
NLON REF1	9.52	2.05	I,II,III	ST_II_ON_III	>4	NO	7.00	8	0.96
NLON REF2	8.44	1.64	I	ST_I	>4	NO	3.67	4	0.72
NLON REF3	9.22	2.62	I,III	ST_I_ON_III	4 to 3	NO	7.00	7	0.54
NLON REF4	4.39	2.61	I	ST_I	4 to 3	NO	5.00	5	0.67
NLON REF5	5.85	1.89	I,III	ST_I_ON_III	4 to 3	NO	5.00	4	0.91
NEREF1	11.33	1.59	I,III	ST_I_ON_III	>4	NO	5.50	5.5	1.18
NEREF2	8.54	1.99	I,II,III	ST_I_ON_III	4 to 3	NO	5.50	5.5	0.73
NEREF3	9.55	2.05	I,II,III	ST_II_ON_III	4 to 3	NO	6.33	6	1.04
NEREF4	8.82	1.77	II,III	ST_II_ON_III	4 to 3	NO	7.00	7	1.23
WREF1	8.09	1.00	I,II	ST_I_TO_II	3 to 2	NO	3.33	3	0.93
WREF2	5.96	2.69	I	ST_I	3 to 2	NO	5.00	5	0.63
WREF3	7.20	1.81	I	ST_I	3 to 2	NO	4.00	4	0.45
WREF4	8.27	2.22	I,II,III	ST_II_ON_III	4 to 3	NO	6.33	7	0.88
AVG	7.93	2.02			4 to 3		5.45	5.46	0.84
MAX	11.33	2.69			3 to 2		7.00	7	1.23
MIN	4.39	1.00			>4		3.33	3	0.45

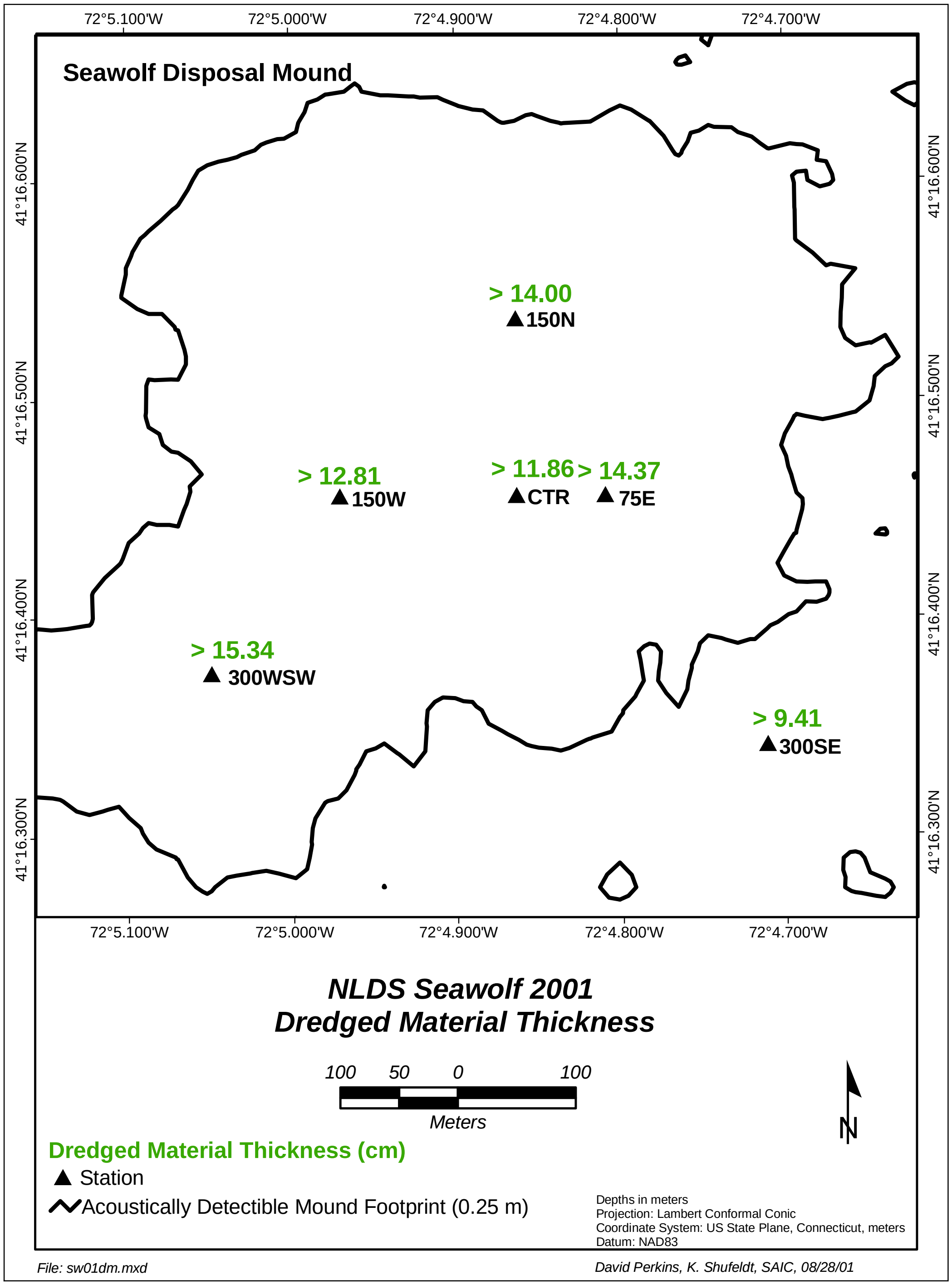


Figure 3-6. Map of dredged material thickness at the Seawolf Mound REMOTS® stations, June 2001

Seawolf Mound, a number of pebbles, rocks, and large shell fragments were noted in all replicate images collected from Station 300SE (Figure 3-7).

The penetration depth of the sediment-profile camera serves as a relative measure of sediment density or compaction. Mean camera penetration measurements for the Seawolf Mound stations varied from 9.4 cm at Station 300SE, where rocks and shells were present, to 15.3 cm at Station 300WSW (average 13.0 cm; Table 3-7). Replicate-averaged boundary roughness values for the REMOTS® stations over the Seawolf Mound ranged from 0.8 cm at Station CTR to 1.8 cm at Station 150W, indicating only minor small-scale surface relief (average of 1.2 cm; Table 3-7). There was no obvious spatial pattern to the boundary roughness values across the surveyed area. In general, boundary roughness values at the reference areas were lower than those at the Seawolf Mound and were mainly attributed to physical effects (Table 3-8). Surface roughness at stations over the Seawolf Mound was attributed to biogenic activity in 10 of the 18 replicate images (55%), while the surface roughness of the remaining replicates was attributed to physical effects. The biogenic surface roughness at the disposal site stations was due principally to the presence of either inhabited or decaying amphipod tubes (*Ampelisca*), burrow openings, polychaete tubes, and hydroids at the sediment-water interface (Figure 3-8). In addition, organic detritus generally was observed at the sediment-water interface. Mud clasts, an indicator of physical disturbance, were detected in only two replicate images.

3.2.1.2 Biological Conditions and Benthic Recolonization

Three parameters were used to assess the benthic recolonization status of the disposal site relative to the reference areas: apparent Redox Potential Discontinuity (RPD) depth, Organism-Sediment Index (OSI), and infaunal successional status. These three parameters were mapped on station location plots to outline the biological conditions at each station at both the Seawolf Mound and the reference areas (Figures 3-9 and 3-10).

The redox potential discontinuity (RPD) measured in each image provides an estimate of the apparent depth of oxygen penetration into the surface sediment. The replicate-averaged apparent RPD measurements for the Seawolf Mound were moderately deep, ranging from 1.7 cm at Station CTR to 3.4 cm at Station 300WSW (Table 3-7; Figure 3-9). The overall average RPD value of 2.5 cm is indicative of relatively well-aerated surface sediments. Lower RPD values were observed at the reference areas (overall average 2.0 cm) and were attributed to considerable amounts of reduced sediment and decaying amphipod tube mats. Replicate image A of Station 300WSW provided an example of a fairly deep RPD of 4.3 cm, with a brown sandy silt over sandy gray clay (Figure 3-8). None of the replicate images obtained within the Seawolf Mound showed

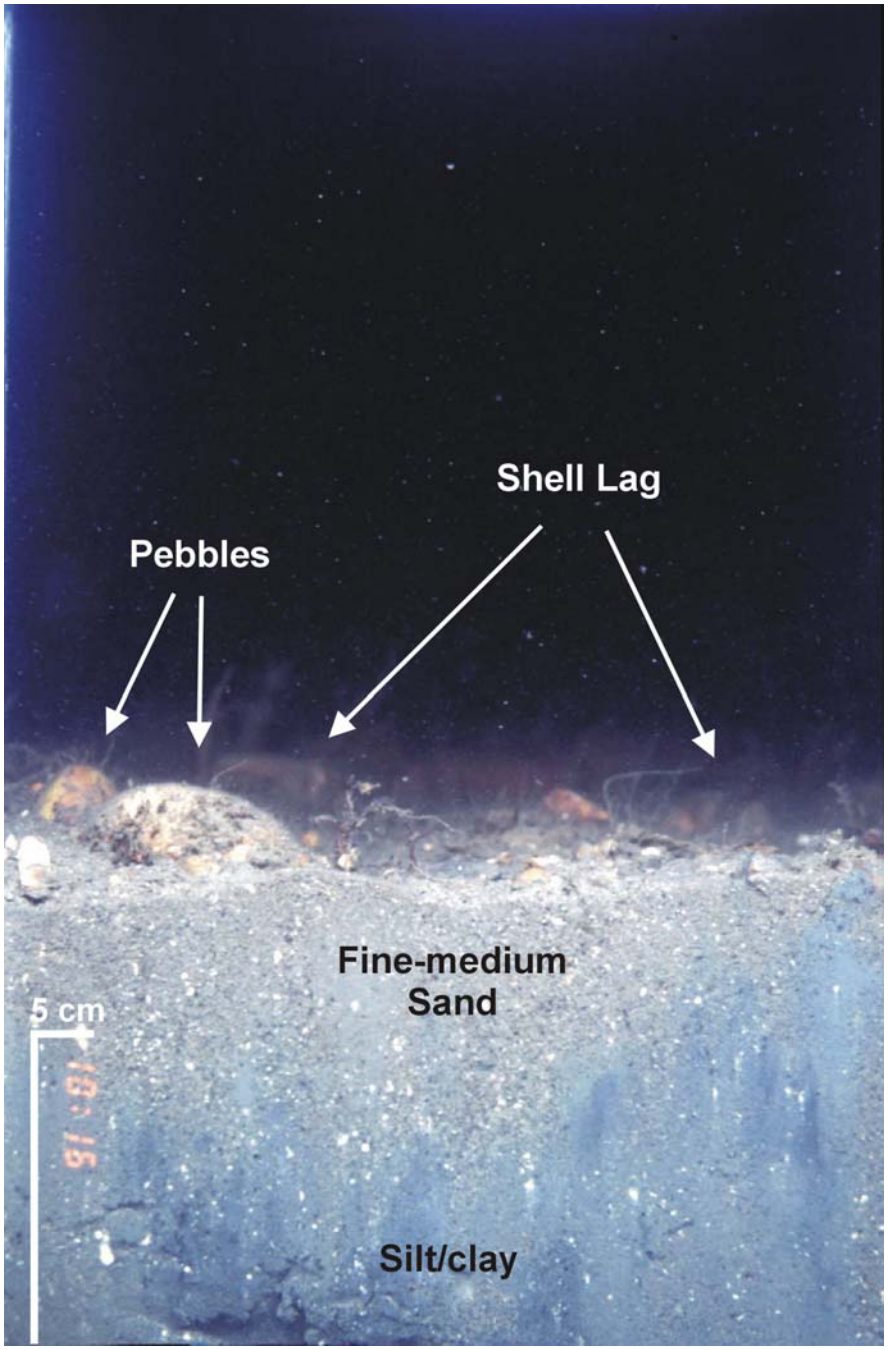


Figure 3-7. REMOTS® image obtained from Station 300SE over the Seawolf disposal mound showing sand, pebbles, and shell at the sediment-water interface resulting from either winnowing or CDM deposition at the nearby Dow/Stonington Mound

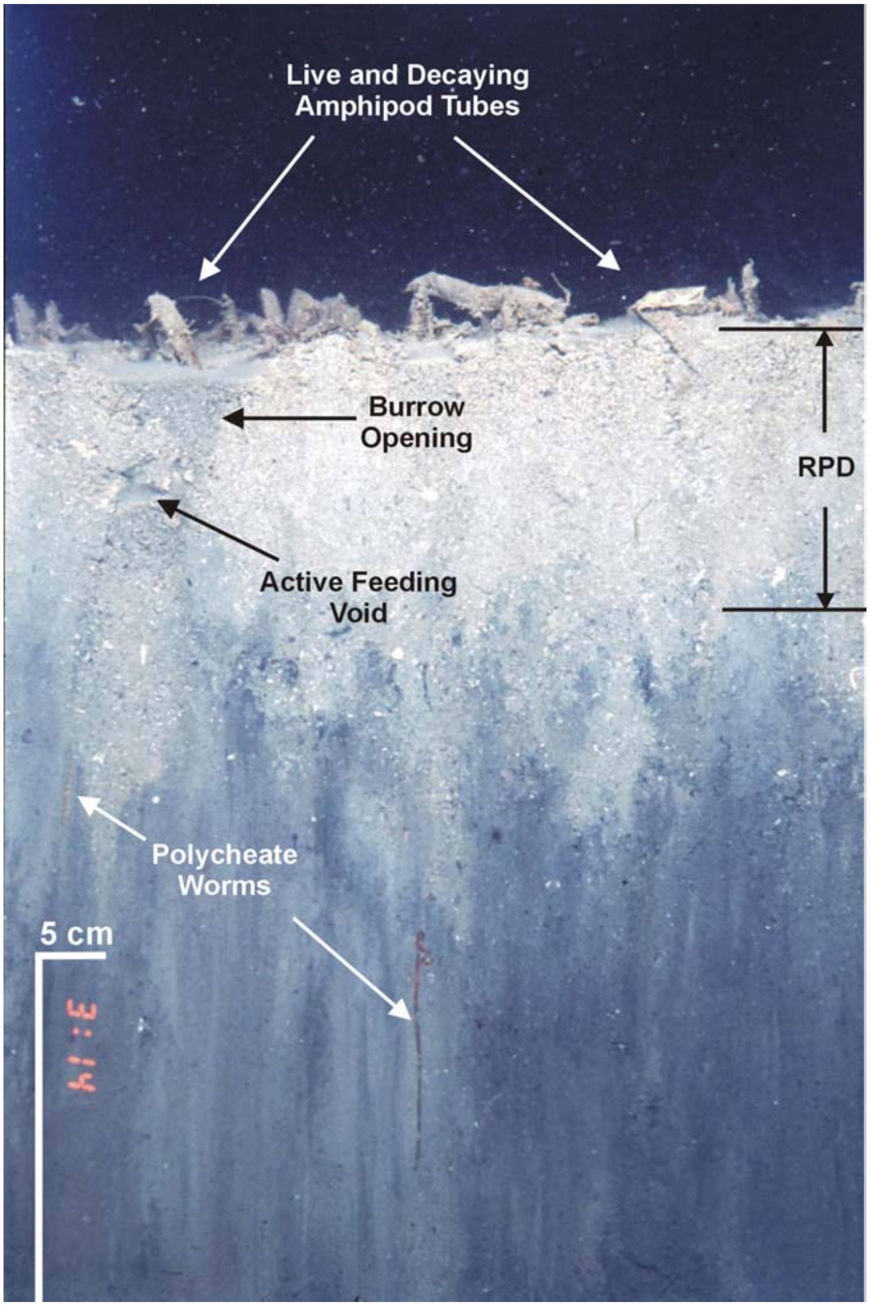


Figure 3-8. REMOTS® image from Station 300WSW over the Seawolf Mound illustrating biologically active sediment with a well-developed RPD (4.3 cm) and an OSI of +11. Polychaete worms and feeding voids are visible within the dredged material. Biogenic surface roughness is attributed to inhabited and decaying amphipod tubes and a burrow opening at the sediment-water interface.

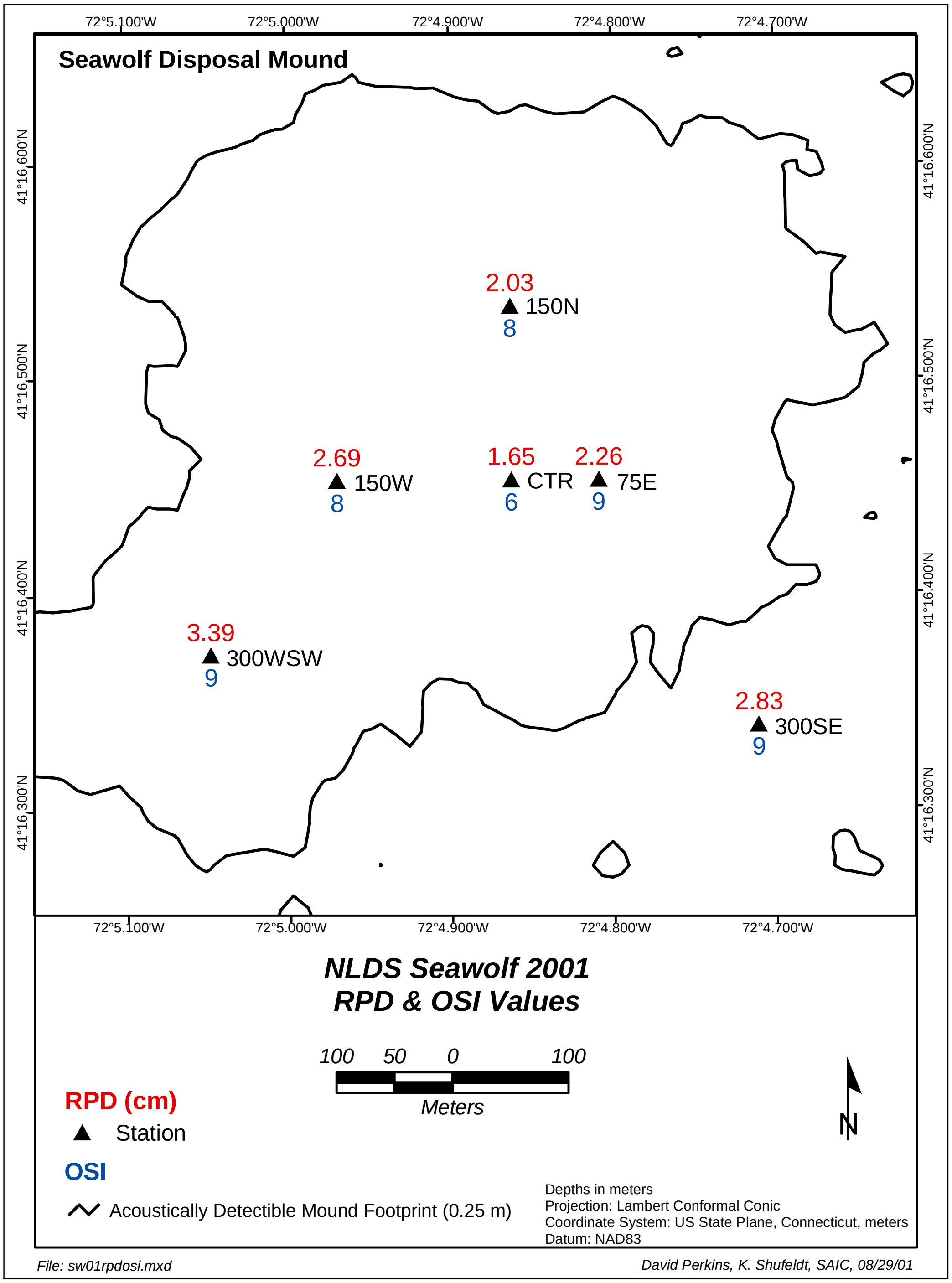


Figure 3-9. Map of mean RPD depths (red) over median OSI values (blue) at the Seawolf Mound REMOTS® stations, June 2001

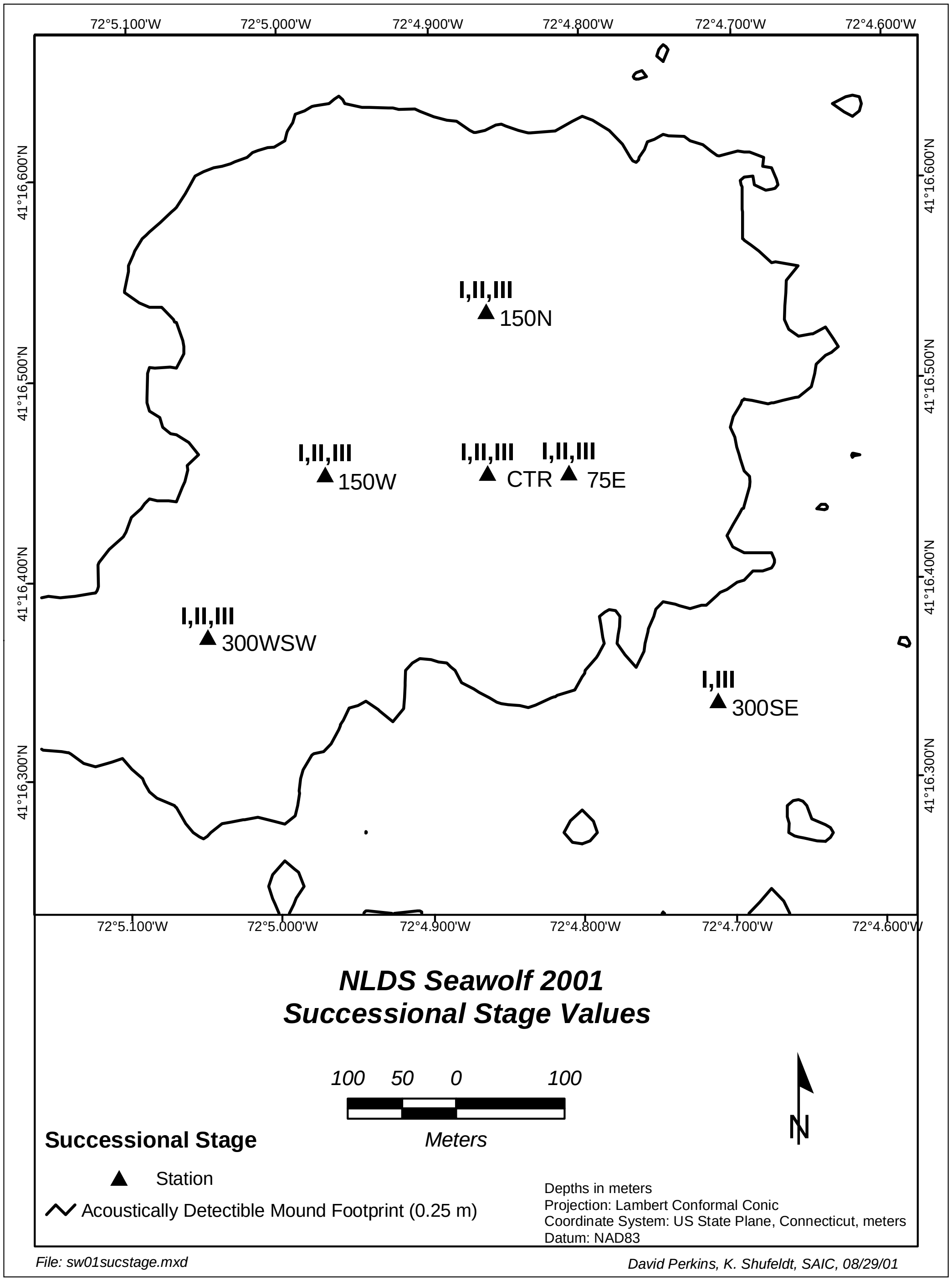


Figure 3-10. Map of infaunal successional stage assemblages present at the Seawolf Mound REMOTS® stations, June 2001

any evidence of apparent low dissolved oxygen conditions, visible redox rebounds, or methane gas entrained within the sediment.

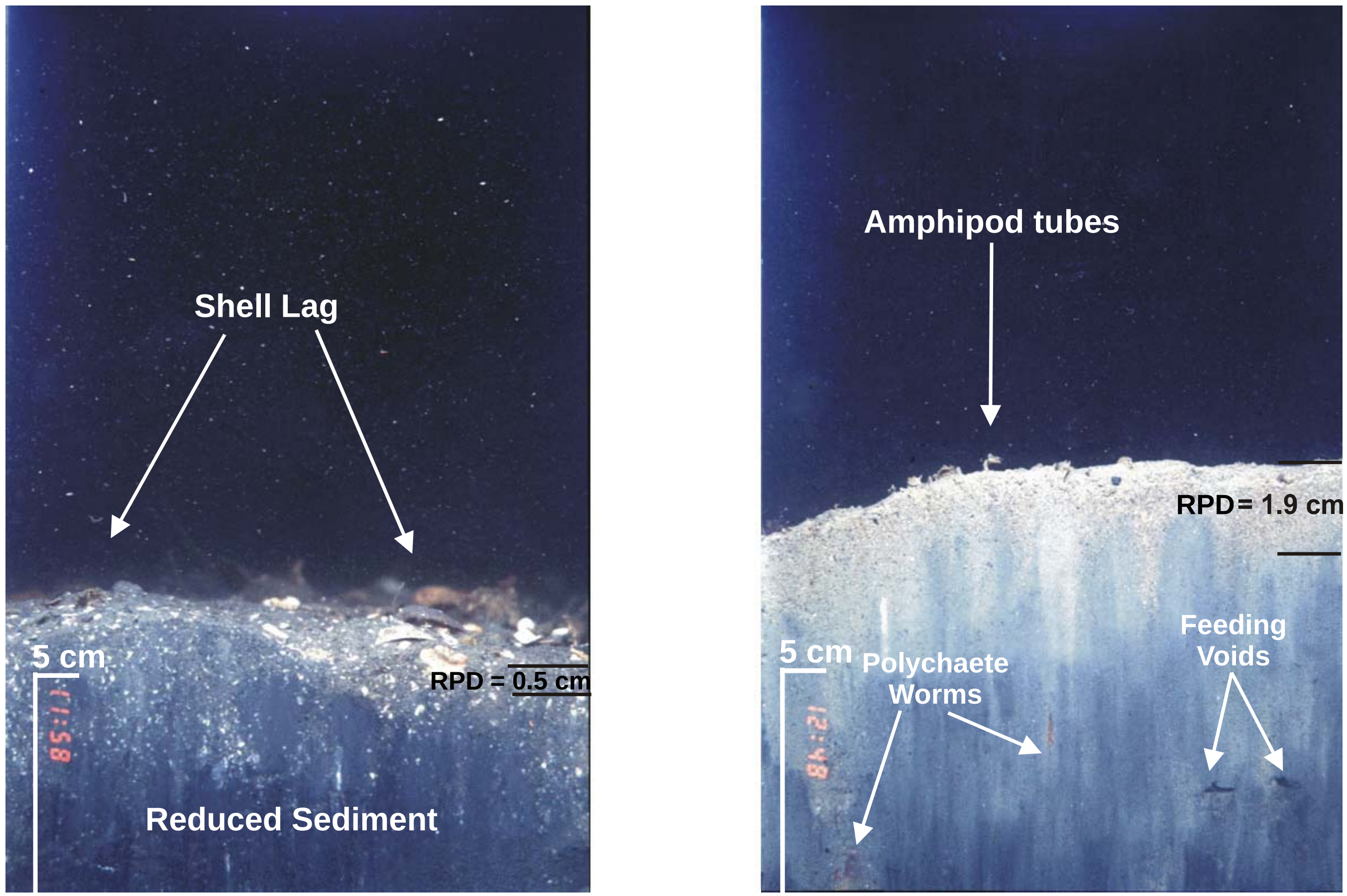
No dredged material has reportedly been deposited on the Seawolf Mound since the 1995/96 disposal season. As anticipated with the significant amount of time lapsing between disposal activity and the June 2001 monitoring event, the successional stage over the Seawolf Mound was relatively advanced. A mixture of tubiculous Stage I polychaetes and Stage II amphipods was observed at the sediment surface together with Stage III feeding voids at depth, resulting in the majority of images being assigned a Stage I on III or Stage II on III designation (Table 3-7; Figure 3-10). The reference areas also exhibited an advanced successional stage, with Stages II and/or III present at 9 of the 13 stations (Table 3-8). Tube-dwelling amphipods (*Ampelisca* sp.), typical of Stage II organisms, were observed at five of the six stations over the Seawolf Mound. Evidence of Stage III activity included active feeding voids produced by head-down, deposit-feeding infauna, as well as burrowing polychaetes visible at depth (Figure 3-8). Overall, the presence of a diverse mixture of Stages I, II, and III at stations over the Seawolf Mound indicated advanced benthic recolonization status.

Replicate-averaged median OSI values for the Seawolf disposal mound stations ranged from +6 at Station CTR to +9 at Stations 300WSW, 300SE, and 75E (overall average of +8.2; Figure 3-9; Table 3-7). This range of values reflects the advanced benthic recolonization status existing over the majority of the Seawolf Mound at the time of the survey. The overall average median OSI value for the Seawolf Mound was substantially higher than the overall value calculated for the reference area stations (+8.2 Seawolf Mound vs. +5.5 Reference Areas).

3.2.2 NLDS Reference Areas

3.2.2.1 Physical Sediment Characteristics

A layer of brown sand over gray and black silty clay was observed at most reference area stations. Dredged material was not detected in any of the analyzed images. The major modal grain size was 4 to 3 (very fine sand) for the majority of the stations, with a grain size of 3 to 2 phi (fine sand) observed at Stations WREF1, WREF2, and WREF3. Considerable amounts of shell fragments (lag) and large shells were observed in the sediment at a majority of the reference area station replicates, particularly at WEST REF. In addition, reduced sediment was observed at depth in many replicate images at all three reference areas, in particular WEST REF stations (Figure 3-11A).



A **B**

Figure 3-11. REMOTS® images from WREF1 (A) and NLON REF1 (B) displaying variability in benthic habitat conditions among the NLDS reference area stations

Reference area mean camera penetration values were relatively low, with the shallowest penetration (4.4 cm) at Station NLON REF4 where large shells were present and the deepest penetration (11.3 cm) at Station NE REF1 (Table 3-8). This is moderately low penetration compared to that of the disposal site stations, attributed to considerable amounts of shell hash and shell beds in the sandy sediments at the reference areas. Replicate-averaged boundary roughness values for all three reference areas were lower than those of the disposal site stations, ranging from 0.5 cm at Station WREF3 to 1.2 cm at Station NE REF4, (average of 0.8 cm; Table 3-8).

3.2.2.2 Biological Conditions

The apparent mean RPD values for the reference areas were slightly lower than the disposal site stations, ranging from a relatively shallow depth of 1.0 cm at Station WREF1 to 2.7 cm at Station WREF2 (overall average of 2 cm; Table 3-8). Replicate images at Station WREF1 exhibited significantly lower RPD depths with reduced sediment at depth. The REMOTS® image of Station WREF1 Replicate C shows poorly aerated surface sediments and a resulting shallow RPD depth of 0.5 cm (Figure 3-11A). Various replicate images from some stations had an RPD that was unmeasurable due to disturbed surfaces, or irregular topography. No indicators for low dissolved oxygen conditions, methane, or visible redox rebounds were present at the reference areas.

Similar to the disposal site stations, a combination of successional stages was observed at the reference areas, with surface-dwelling Stage I polychaetes, Stage II amphipods, and Stage III head-down deposit feeding invertebrate communities present. However, compared to the disposal mound, the reference areas displayed a higher frequency of Stage I taxa and lower frequency of Stage III. Stage II and III individuals were absent from two stations at both the NLON REF and WEST REF reference areas. NE REF appeared to be supporting the most abundant Stage III population.

The median OSI values calculated for the reference areas ranged from +3 at Station WREF1 to +8 at Station NLON REF1, with an overall average of +5.5, but were generally lower than the reported OSI values for the Seawolf Mound stations (Table 3-8). Shallower mean RPD depths coupled with a higher occurrence of only Stage I activity at the NLDS reference areas served to diminish the median OSI values, indicating moderately disturbed benthic habitat quality (OSI values of +3 to +6). The highest median OSI value of +8 was calculated at Station NLON REF1 where in two replicates, Stage III organisms and relatively deep RPD depths were observed (Figure 3-11B).

3.3 Benthic Community Sampling

The sediment grab samples, as they were received following field washing, contained a small percentage of fine shell hash and sediments along with varying amounts of soft detritus material. Evidence of soft tubes of the amphipod *Ampelisca* sp. was noted. Representatives of the phyla *Cnidaria*, *Nemertea*, *Nematoda*, *Annelida*, *Mollusca, Arthropoda*, and *Bryozoa* were present at all stations, with *Entoprocta* and *Hemichordata* being present at only one station, *Porifera* at two stations and *Echinodermata* at four out of the six stations. None of the stations had representatives from all eleven phyla.

Species richness across the six stations totaled 143 discrete taxa. Of the discrete taxa found, 58 were annelids, 31 were arthropods and 25 were molluscs. Colonial cnidarians contributed 11 taxa, bryozoans contributed eight species, and nemerteans were represented by five species. Other phyla, including *Porifera, Nematoda, Entoprocta, Echinodermata*, and *Hemichordata*, were either represented by one species or were not further identified. Station 300SE had the greatest taxa richness with 85 taxa (Figure 3-12). Station 75E was next with 73 taxa, 150W and 150N both had 68 taxa, 300WSW had 60 taxa, and CTR had the lowest taxa richness of 51 (Table 3-9).

Averaging over all stations, mean abundance (numbers/0.04 m^2) was highest for the bivalve *Mytilidae* (558; Table 3-9). Next most abundant was the amphipod *Ampelisca vadorum* (104.7). Ranking third through tenth were the polychaetes *Tharyx acutus*/Cirratulidae (73.1), *Ampharete finmarchia* (56.8), *Monticellinia baptisteae* (36.2), the bivalve *Nucula annulata* (32.0), the polychaetes *Prionospio steenstrupi* (26.3), *Harmothoe extenuata/Polynoidae* (19.6), *Exogone dispar* (14.5), and *Nephtys incisa*/Nephytidae (13.5). Polychaete identifications to the family level, as noted in the above couplets, were combined with specific genus or species identifications because most individuals identified to the family level were too damaged to identify further, but were likely members of the dominant species.

Total abundance among the six stations was highest at 75E (1509), followed by 300SE (1434), 150N (1072), 150W (962), CTR (944) and 300WSW (841; Table 3-9). The ten most abundant species at each station are listed in Table 3-10. The bivalve, *Mytilidae*, was the most abundant species at all six stations and represented over 25% of the abundance at each station: CTR (77.12%), 75E (57.79%), 150N (47.95%), 150W (25.78%), 300SE (48.95%) and 300SWS (33.77%). Because of the dominance of the gregarious settler *Mytilidae*, total abundance excluding this taxa is also shown on Table 3-9. With the exception of Station CTR, mytilid abundance accounted for most of the difference in abundance among stations. *Ampelisca vadorum* was one of the top two dominant species and *Ampharete finmarchica* and *Tharyx acutus*/Cirratilidae were two of

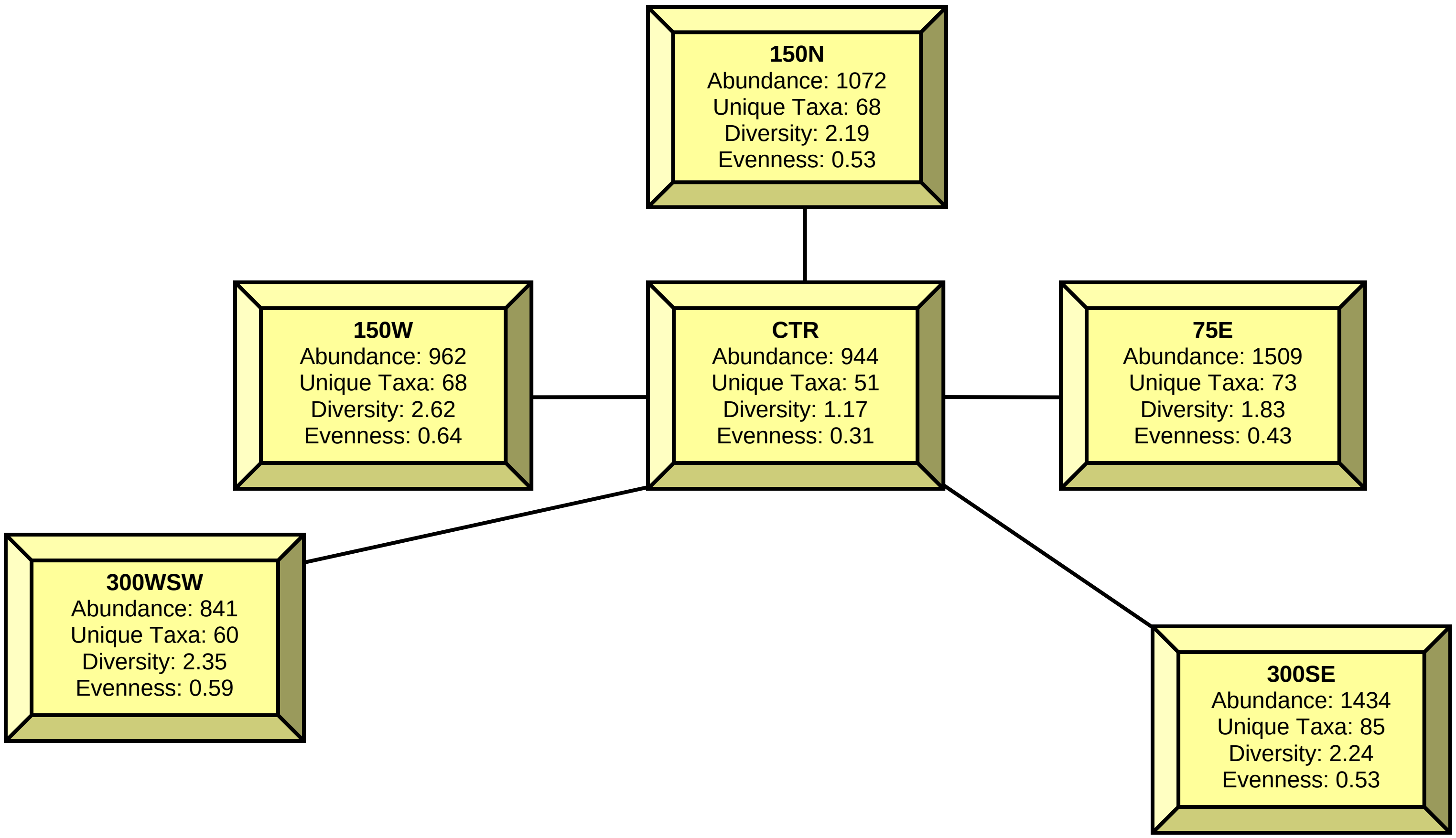


Figure 3-12. Benthic community indices at stations in the New London Disposal Site, Seawolf Mound, June 2001

Table 3-9.
Number of Organisms per 0.04 m² Modified Van Veen Grab, by Station, and Retained on a 0.5 mm Mesh Sieve, New London Disposal Site, 2001

Taxon		Station						95% Confidence Limits		
		Center	75E	150N	150W	300SE	300WSW	Mean	Lower	Upper
Porifera										
	Prosuberites epiphytum					P	P			
Cnidaria										
Anthomedusae										
	Tubularia sp.	P								
	Eudendrium sp.	P				P	P			
Leptomedusae										
	Campanularidae	P	P	P	P	P	P			
	Obelia geniculata		P							
	Obelia sp.	P								
	Clytia sp.		P	P		P	P			
	Calycella syringa	P	P		P	P	P			
	Opercularella pumila			P		P				
	Sertularia tenera	P		P	P	P				
	Sertularia plumulifera					P				
	Halecium sp.	P	P	P	P	P	P			
Anthozoa										
	Anthozoa						1	0.2	-0.3	0.6
Nemertea										
	Nemertea			1				0.2	-0.3	0.6
	Carinomella lactea	1		1		4		1.0	-0.6	2.6
	Micrura sp.	1		1	1			0.5	-0.1	1.1
	Amphiporus cruentatus	1	1				1	0.5	-0.1	1.1
	Amphiporus bioculatus	1	1	5			1	1.3	-0.6	3.3
	Tetrastemma sp.		1					0.2	-0.3	0.6
Nematoda										
	Nematoda	4	20	11	20	16	4	12.5	4.8	20.2
Annelida										
Polychaeta										
	Polynoidae	3	16	2		19	22	10.3	0.1	20.5
	Harmothoe extenuata	1	17	16	16	4	2	9.3	1.2	17.5
	Pholoe minuta		2	1	2	2		1.2	0.1	2.2
	Sthenelais boa		1			1		0.3	-0.2	0.9
	Phyllodoce maculata					3	5	1.3	-0.9	3.6
	Phyllodoce arenae			2	2			0.7	-0.4	1.8
	Phyllodoce sp.	1		1				0.3	-0.2	0.9
	Eumida sanguinea		1					0.2	-0.3	0.6
	Sigambra tentaculata				1			0.2	-0.3	0.6
	Autolytus sp.		2			4		1.0	-0.8	2.8
	Typosyllis alternata		1		2	1		0.7	-0.2	1.5
	Exogone dispar		21	25	27	14		14.5	1.8	27.2
	Exogone hebes				2	3		0.8	-0.6	2.2

Table 3-9. (Continued)

Taxon	Station						95% Confidence Limits		
	Center	75E	150N	150W	300SE	300WSW	Mean	Lower	Upper
Exogone sp.		1					0.2	-0.3	0.6
Sphaerosyllis longicauda			1			1	0.3	-0.2	0.9
Brania clavata		1					0.2	-0.3	0.6
Proceraea cornuta		3		2	2	1	1.3	0.1	2.6
Nereis grayi			1				0.2	-0.3	0.6
Nephtyidae	6	10	13	14	4	15	10.3	5.6	15.1
Nephtys incisa	4	6	4	2		3	3.2	1	5.3
Aglaophamus circinata					2		0.3	-0.5	1.2
Glycera sp.			2	1	1		0.7	-0.2	1.5
Lumbrineridae		1			2		0.5	-0.4	1.4
Ninoe nigripes		12	2	9	3	7	5.5	0.7	10.3
Scoletoma impatiens			1				0.2	-0.3	0.6
Scoletoma hebes					2		0.3	-0.5	1.2
Scoletoma sp.						1	0.2	-0.3	0.6
Protodorvillea gaspeensis			1				0.2	-0.3	0.6
Orbiniidae			2		1		0.5	-0.4	1.4
Leitoscoloplos sp.				1			0.2	-0.3	0.6
Aricidea (acmira)		2	4	8	53	3	11.7	-9.8	33.1
Cirrophorus furcatus		1	2	4	2	1	1.7	0.2	3.1
Levinsenia gracilis		1	1	1			0.5	-0.1	1.1
Spionidae					1		0.2	-0.3	0.6
Prionospio steenstrupi	32	12	23	30	44	17	26.3	14.3	38.4
Spio filicornis				2	1	1	0.7	-0.2	1.5
Spiophanes bombyx					3		0.5	-0.8	1.8
Dipolydora caulleryi	5	2	5	3	51	1	11.2	-9.4	31.7
Dipolydora socialis	28	4	1	4	13		8.3	-2.9	19.5
Spiochaetopterus costarum		1	1		2		0.7	-0.2	1.5
Cirratulidae	3	14	26	56	55	19	28.8	5.8	51.9
Tharyx acutus	17	5	39	134	46	25	44.3	-4.3	93
Monticellina baptisteae	1	14	37	48	110	7	36.2	-6.3	78.6
Cossura sp.				1			0.2	-0.3	0.6
Pherusa affinis		2	1		1	2	1.0	0.1	1.9
Scalibregma inflatum	0	8	8	26	20	1	10.5	-0.4	21.4
Ammotrypane aulogaster				4	1	1	1.0	-0.6	2.6
Mediomastus ambiseta		1	1	6	3	1	2.0	-0.3	4.3
Maldanidae	1	3	1	3	3	2	2.2	1.1	3.2
Asychis elongata		1					0.2	-0.3	0.6
Euclymene collaris		1	4	2	3		1.7	0	3.4
Ampharete finmarchica	19	89	103	31	29	70	56.8	19.8	93.8

Table 3-9. (Continued)

Taxon		Station						95% Confidence Limits		
		Center	75E	150N	150W	300SE	300WSW	Mean	Lower	Upper
	Asabellides oculata	1	2	11	2	1	4	3.5	-0.5	7.5
	Terebellidae					1		0.2	-0.3	0.6
	Pista palmata					2		0.3	-0.5	1.2
	Polycirrus eximius		1		6	1		1.3	-1.1	3.8
	Polycirrus sp.		3	3	2	5		2.2	0.1	4.2
	Terebellides stroemi		3		8			1.8	-1.6	5.2
	Sabellidae		1		2			0.5	-0.4	1.4
	Potamilla reniformis			1	1	1	1	0.7	0.1	1.2
Archiannelid										
	Archiannelida			1		1		0.3	-0.2	0.9
Oligochaeta										
	Oligochaeta		3	1	4	32	1	6.8	-6.2	19.9
Mollusca										
Gastropoda										
	Crepidula plana			1				0.2	-0.3	0.6
	Mitrella lunata	2	21	4	3	3	25	9.7	-1.3	20.6
	Anachis lafresnayi			1	1	2	1	0.8	0	1.6
	Ilyanassa trivittata	1					1	0.3	-0.2	0.9
	Turbonilla interrupta				1			0.2	-0.3	0.6
	Fargoa gibbosa	1						0.2	-0.3	0.6
Nudibranchia										
	Nudibranchia	1						0.2	-0.3	0.6
Bivalvia										
	Nucula annulata	18	69	27	21	9	48	32.0	8.6	55.4
	Anadara transversa					1	1	0.3	-0.2	0.9
	Mytilidae	728	872	514	248	702	284	558.0	292	824
	Musculus niger		1	3				0.7	-0.6	1.9
	Placopecten magellanicus		1		1			0.3	-0.2	0.9
	Anomia simplex					1		0.2	-0.3	0.6
	Anomia squamula	1						0.2	-0.3	0.6
	Cyclocardia borealis		3	2		2		1.2	-0.2	2.6
	Astarte castanea		3	2		4	1	1.7	0	3.4
	Crassinella lunulata			1				0.2	-0.3	0.6
	Cerastoderma pinnulatum	11	5	3	3	13	4	6.5	1.9	11.1
	Mulinia lateralis	1					2	0.5	-0.4	1.4
	Ensis directus					1		0.2	-0.3	0.6
	Tellina agilis		1					0.2	-0.3	0.6
	Pitar morrhuana			1	1			0.3	-0.2	0.9
	Hiatella sp.	2	2	2		3		1.5	0.2	2.8
	Pandora glacialis		1		1			0.3	-0.2	0.9
	Lyonsia hyalina		1					0.2	-0.3	0.6
Arthropoda										
Ostracoda										

Table 3-9. (Continued)

Taxon	Station							95% Confidence Limits	
	Center	75E	150N	150W	300SE	300WSW	Mean	Lower	Upper
Ostracoda	1	4			3	3	1.8	0	3.6
Copepoda									
Harpacticoida				1			0.2	-0.3	0.6
Alteutha depressa	1						0.2	-0.3	0.6
Malacostraca									
Ampelisca abdita	3	1		1		8	2.2	-1	5.4
Ampelisca vadorum	18	168	94	152	30	166	104.7	33.2	176.2
Ampelisca agassizi		2					0.3	-0.5	1.2
Lembos websteri	1		1	2	2		1.0	0.1	1.9
Leptocheirus pinguis	2	3	4	3	2	13	4.5	0.1	8.9
Cerapus tubularis	1				1		0.3	-0.2	0.9
Corophium bonelli	2	13	4	1	11	3	5.7	0.4	11
Erichthonius rubricornis	1		2			2	0.8	-0.2	1.9
Unciola irrorata	6	7	7	4	3	8	5.8	3.8	7.9
Unciola serrata		1		1			0.3	-0.2	0.9
Photis dentata	2	15	9	13	1	12	8.7	2.5	14.8
Ischyrocerus commensalis			1		2		1.4	-0.4	0.5
Jassa marmorata			1				0.2	-0.3	0.6
Phoxocephalus holbolli	2	4		1	12	1	3.3	-1.3	8
Stenopleustes gracilis		2		1	6	9	3.0	-0.9	6.9
Dyopedos monacanthus	1		4	2	3		1.7	0	3.4
Parametopella cypris	3	1				2	1.0	-0.3	2.3
Metopa sp.		3	1		5	2	1.8	-0.2	3.9
Aeginina longicornis	2	4	2	2	3	6	7.7	-3.9	19.3
Luconacia incerta		4					0.7	-1	2.4
Decapoda									
Hippolyte sp.	1						0.2	-0.3	0.6
Crangon septemspinosa					1	1	0.3	-0.2	0.9
Callianassa atlantica					1		0.2	-0.3	0.6
Pagurus annulipes	1	1				2	0.7	-0.2	1.5
Cancer irroratus				1			0.2	-0.3	0.6
Xanthidae		1	5	2	1	4	2.2	0.1	4.2
Panopeus sp.						3	0.5	-0.8	1.8
Pinnixa sayana		2	7	4	4	8	4.2	1	7.3
Bryozoa									
Bryozoa				P					
Alcyonidium polyoum					P				
Bowerbankia gracilis					P				
Electra monostachys			P		P				
Callopora aurita	P			P	P	P			
Bugula turrita				P					
Bicellariella ciliata					P				
Hippoporina verrilli	P				P				

Table 3-9. (Continued)

Taxon	Center	75E	150N	150W	300SE	300WSW	Mean	Lower	Upper
	Station							95% Confidence Limits	
Hippoporina porosa		P	P	P	P	P			
Entoprocta									
Pedicellinida									
Barentsia major						P			
Echinodermata									
Ophiuroidea		1	2	1	1		0.8	0	1.6
Hemichordata									
Enteropneusta									
Saccoglossus kowalewskii					1		0.2	-0.3	0.6
Totals	**944**	**1509**	**1072**	**962**	**1434**	**841**			
Total Excluding Mytilidae	**216**	**637**	**558**	**714**	**732**	**557**			
Total Unique Taxa	**51**	**73**	**68**	**68**	**85**	**60**			

the top three dominant species at four out of the six stations (Table 3-10). The polychaete *Prionospio steenstrupi* and the bivalve *Nucula annulata* were among the dominants at five out of six stations, including Station CTR (Table 3-10).

The majority of the polychaetes at all stations were early- to mid-stage colonizers (i.e., Stage I or II), as indicated by the relatively high numbers of surface deposit feeding species. With the exception of Station CTR, the stations had varying numbers of other feeding groups, particularly subsurface deposit feeders (i.e., Stage III), such as the *Maldanidae, Scalibregmidae, Paraonidae*, and *Lumbrineridae*. Active carnivores, such as *Glyceridae, Syllidae*, *Nephtyidae*, and *Polynoidae,* were also more abundant away from Station CTR. The tube-dwelling amphipod *Ampelisca* is considered to be a mid-successional stage species (i.e., Stage II) and, although present at the CTR station, its abundance was higher at most other stations. Station CTR was dominated almost exclusively by Stage I and II taxa (*Prionospio steenstrupi, Tharyx acutus, Dipolydora socialis, Ampelisca vadorum, Nucula annulata*), with relatively few Stage III organisms.

Diversities (H´) ranged from a low of 1.17 at the Station CTR (evenness 0.31) to a high of 2.62 at Station 150W (evenness 0.64; Figure 3-12). Stations CTR and 75E were similar because of the high abundance of *Mytilidae*. In contrast, the relatively low abundance of *Mytilidae* at Stations 150W and 300WSW contributed to higher diversity and evenness values.

Species composition of the benthic assemblage was compared among the June 2001 stations through hierarchical clustering based on the calculated Bray-Curtis similarity index between each possible pair of stations (Figure 3-13). The Bray-Curtis similarity value linking all six stations was 53%, with 150N and 150W being the most similar stations at 70% Bray-Curtis similarity. The center of the disposal mound was the least similar to the other stations (Figure 3-13), as would be expected from the lower number of unique taxa (51 compared to 60–85 at the other stations) and lower abundance excluding *Mytilidae* (216 compared to 557–732 at the other stations). The characteristic shape of the cluster, however, indicated that species composition (particularly the dominant taxa) was generally similar at all the stations. As indicated in Table 3-10, from five to seven of the dominants at the CTR station were also among the top ten dominants at each of the other stations. Chaining, or addition of stations to the cluster without the formation of distinct groups, was likely related to the large number of taxa that occurred as single individuals, because species with low abundances are weighted disproportionately by numerical classification.

Table 3-10.
Top 10 Dominant Taxa for Each Grab Station (includes non-unique taxa)

TAXON	Mean Count	Percent of Total
Station CTR (944 Total)		
Mytilidae	728	77.12%
Prionospio steenstrupi	32	3.39%
Dipolydora socialis	28	2.97%
Tharyx acutus/Cirratulidae	20	2.12%
Ampharete finmarchica	19	2.01%
Ampelisca vadorum	18	1.91%
Nucula annulata	18	1.91%
Cerastoderma pinnulatum	11	1.17%
Nephtys incisa/Nephtyidae	10	1.06%
Unciola irrorata	6	0.64%
Station 75E (1509 Total)		
Mytilidae	872	57.79%
Ampelisca vadorum	168	11.13%
Ampharete finmarchica	89	5.90%
Nucula annulata	69	4.57%
Harmothoe extenuata/Polynoidae	31	2.19%
Mitrella lunata	21	1.39%
Exogone dispar	21	1.39%
Nematoda	20	1.33%
Tharyx acutus/Cirratulidae	19	1.26%
Nephtys incisa/Nephtyidae	16	1.06%
Station 150N (1072 Total)		
Mytilidae	514	47.95%
Ampharete finmarchica	103	9.61%
Ampelisca vadorum	94	8.77%
Tharyx acutus/Cirratulidae	65	6.07%
Monticellina baptisteae	37	3.45%
Nucula annulata	27	2.52%
Exogone dispar	25	2.33%
Prionospio steenstrupi	23	2.15%
Harmothoe extenuata/Polynoidae	18	1.68%
Nephtys incisa/Nephyidae	17	1.58%

Table 3-10. (Continued)

TAXON	Mean Count	Percent of Total
Station 150W (962 Total)		
Mytilidae	248	25.78%
Tharyx acutus/Cirratulidae	190	19.75%
Ampelisca vadorum	152	15.80%
Monticellina baptisteae	48	4.99%
Ampharete finmarchica	31	3.22%
Prionospio steenstrupi	30	3.12%
Exogone dispar	27	2.81%
Scalibregma inflatum	26	2.70%
Nucula annulata	21	2.18%
Nematoda	20	2.08%
Station 300SE (1434 Total)		
Mytilidae	702	48.95%
Monticellina baptisteae	110	7.67%
Tharyx acutus/Cirratulidae	101	7.05%
Aricidea (acmira) catherinae	53	3.70%
Dipolydora caulleryi	51	3.56%
Prionospio steenstrupi	44	3.07%
Oligochaeta	32	2.23%
Ampelisca vadorum	30	2.09%
Aeginina longicornis	30	2.09%
Ampharete finmarchica	29	2.02%
Station 300WSW (841 Total)		
Mytilidae	284	33.77%
Ampelisca vadorum	166	19.74%
Ampharete finmarchica	70	8.32%
Nucula annulata	48	5.71%
*Tharyx acutus/*Cirratulidae	44	5.23%
Mitrella lunata	25	2.97%
*Harmothoe extenuata/*Polynoidae	24	2.86%
Nephtys incisa/Nephtyidae	18	2.14%
Prionospio steenstrupi	17	2.02%
Leptocheirus pinguis	13	1.55%

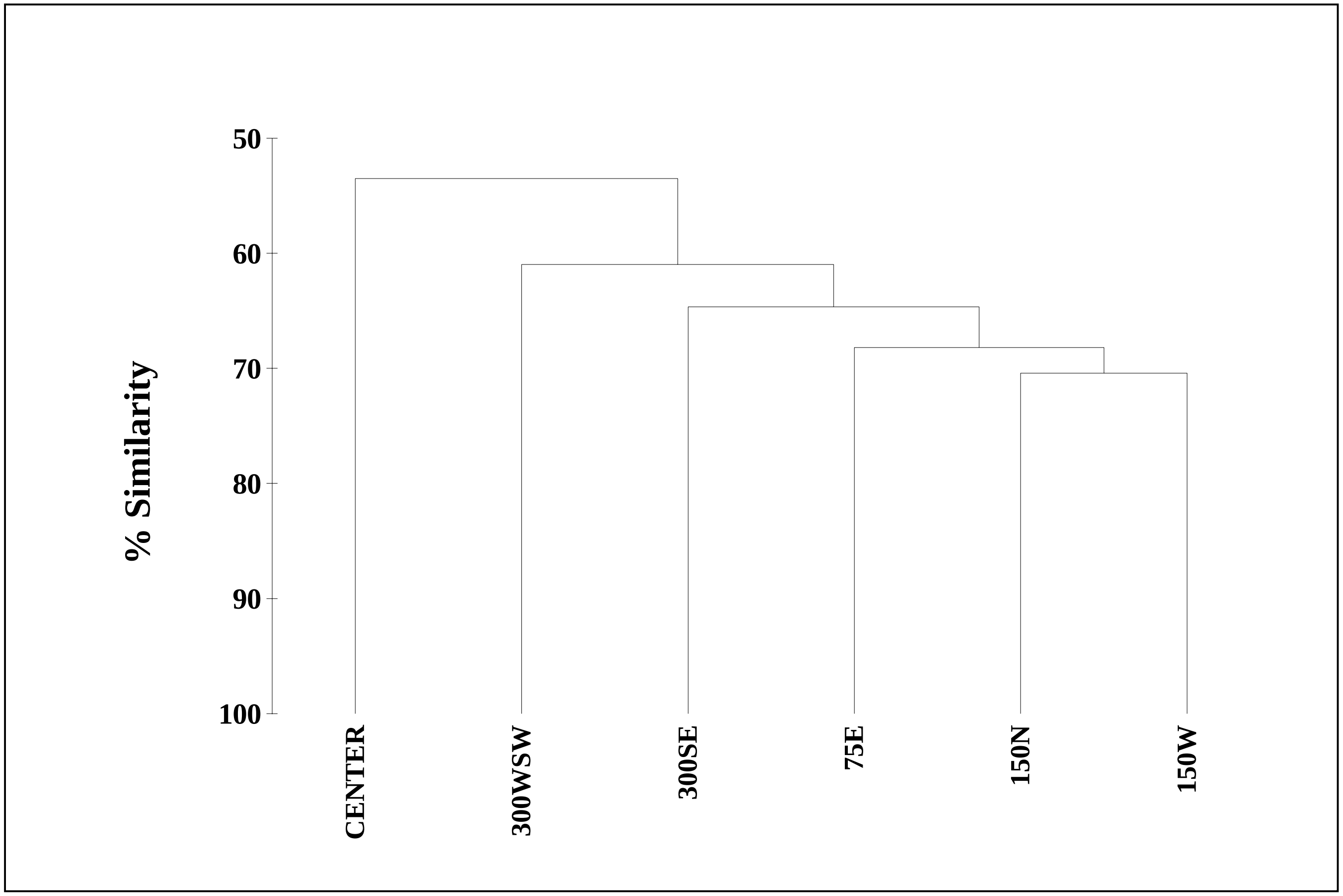


Figure 3-13. Bray-Curtis numerical classification of benthic communities at stations in the New London Disposal Site, Seawolf Mound, June 2001

These results suggested that the benthic community at the CTR station had similarities to the surrounding stations, including many species in common, the dominance by one taxon, and the predominance of early to mid-successional stage species. However, the benthic assemblages in the surrounding stations appeared to reflect a somewhat more advanced recolonization status than at the center. Indications of this were somewhat higher diversity (more taxa, relatively less contribution by one taxon) and the presence of subsurface deposit feeders (mid to late successional stage colonizers).

4.0 DISCUSSION

4.1 Sediment Coring

The objective of the June 2001 coring survey was to assess the physical and chemical composition of surface and subsurface sediments comprising the Seawolf Disposal Mound to determine if a discrete layer of CDM, with a minimum thickness of 0.5 m and with no UDM present, persisted over the Seawolf Mound. Analyses conducted for this assessment included visual core descriptions and geotechnical analyses of core subsamples. As presented in Section 3 above, grain size and stratigraphy in the cores suggested the persistance of at least 0.5 m of cap material at the 2001 coring locations. Additionally, sediment chemistry analyses indicated relatively low levels of trace metals and PAHs in most samples, with comparable results at different locations across the disposal mound, and no evidence of trends in sediment concentrations with depth.

Grain size results for Core 30, located in the southwest region of the mound, displayed anomalous results compared to the other short cores on the disposal mound (see Figure 3-1). Core 30 exhibited a coarse surface layer of 0.29 m of sand and gravel over finer-grained substrate. The normalized metal concentrations were comparable to the fine-grained CDM sampled in the upper 50 cm of the remaining short cores on the disposal mound, suggesting that the underlying material in Core 30 consisted of Seawolf CDM.

While previous surveys have documented spatial variability and occurrence of coarse material over the Seawolf Mound, the thickness of the coarse layer in Core 30 suggested a source other than surface armoring or transport of material from the adjacent seafloor (SAIC 2001a, 2001c). Possible sources include the Venetian Harbor and Mystic River material deposited at the NDA 95 buoy during/after Seawolf CDM disposal (SAIC 2001a), and supplemental cap material directed to the Dow/Stonington (D/S) mound to the southeast in May 2000 (SAIC 2001c). The material bears similarity to the D/S supplemental cap material detected as part of previous monitoring surveys and may have originated from those capping activities (SAIC 2001c).

Cores 27 and 29 were collected beyond the acoustically detectible footprint of the Seawolf CDM, and had substantially coarser grain size than most of the Seawolf Mound short cores (i.e., comparable to the reference area grain size). Normalized metals concentrations, however, displayed somewhat higher concentrations of most metals, particularly lead, in Cores 27 and 29 in comparison to the disposal mound and reference area cores. Based on grain size and chemistry, these cores may have sampled material distinct from the ambient sediments and Seawolf CDM.

Visual observations, grain size, and comparison to the anticipated CDM thickness based on previous depth-difference comparisons (Figure 4-1) support the conclusion that a surface CDM layer of at least 0.5 m thickness persists in the areas sampled on the Seawolf Mound. Chemical analyses provided additional evidence indicating the lack of physical mixing with the underlying UDM, and lack of migration of contaminants into the CDM layer, further confirming the effectiveness of the cap; these results are discussed in more detail below.

Based on the configuration of the disposal mound (see Figure 4-1), short Cores 30, 33, 34, and 35, and long Cores 37 and 38, were located in areas that should consist of UDM buried beneath a substantial layer of CDM. Short Cores 28, 31, and 32, and long Core 36, were located in areas that should consist of pre-Seawolf sediment buried beneath a minimum of 0.5 m of CDM. Short Cores 27 and 29 were located in areas that should consist of pre-Seawolf sediment with only minimal, if any, deposition of Seawolf CDM. However, these groupings do not correspond directly with the previous designations of inner, middle and outer sampling zones.

Additionally, stations in the southwestern region of the disposal mound (e.g., Cores 27, 28, 29 and 36) could potentially have been affected by the disposal of the 15,500 m^3 of sediments from Venetian Harbor and Mystic River that were deposited at the NDA 95 buoy within a similar timeframe as the Seawolf capping disposal. These deposits would have been accounted for in the post-capping bathymetric survey, and would therefore have been included in estimates of Seawolf CDM thickness (e.g., Figure 4-1). However, sediment chemistry for this material would not necessarily be correlated with the Seawolf dredged material and the Seawolf CDM material identified in remaining cores located throughout the Seawolf Mound.

4.1.1 Sediment Composition and Mound Stratigraphy

The bathymetric depth difference comparisons between the 1995 pre-cap and post-cap surveys (1996, 1997, and 1998) indicated that CDM disposal over the mound had resulted in a stable cap layer of at least 0.5 m. Based on the depth-difference comparisons, most of the interior portions of the mound had a cap thickness greater than 1 m, in some areas greater than 3 m isolating the UDM material below (Figure 4-1, SAIC 2001a). The bathymetrically-estimated cap thickness at the 2001 core locations ranged from approximately 0.75–1.0 m (Core 32) to 3.0 m (Core 37), with the exception of Cores 27 and 29 located outside the 0.25 m CDM contour (Figure 4-1). Consolidation of the underlying UDM interfered with the ability to obtain a definitive cap thickness using depth differencing from those surveys in the central portions of the mound (e.g., locations for Cores 33, 34, 35, and 38, Figure 4-1). However, previous coring surveys in 1997 and

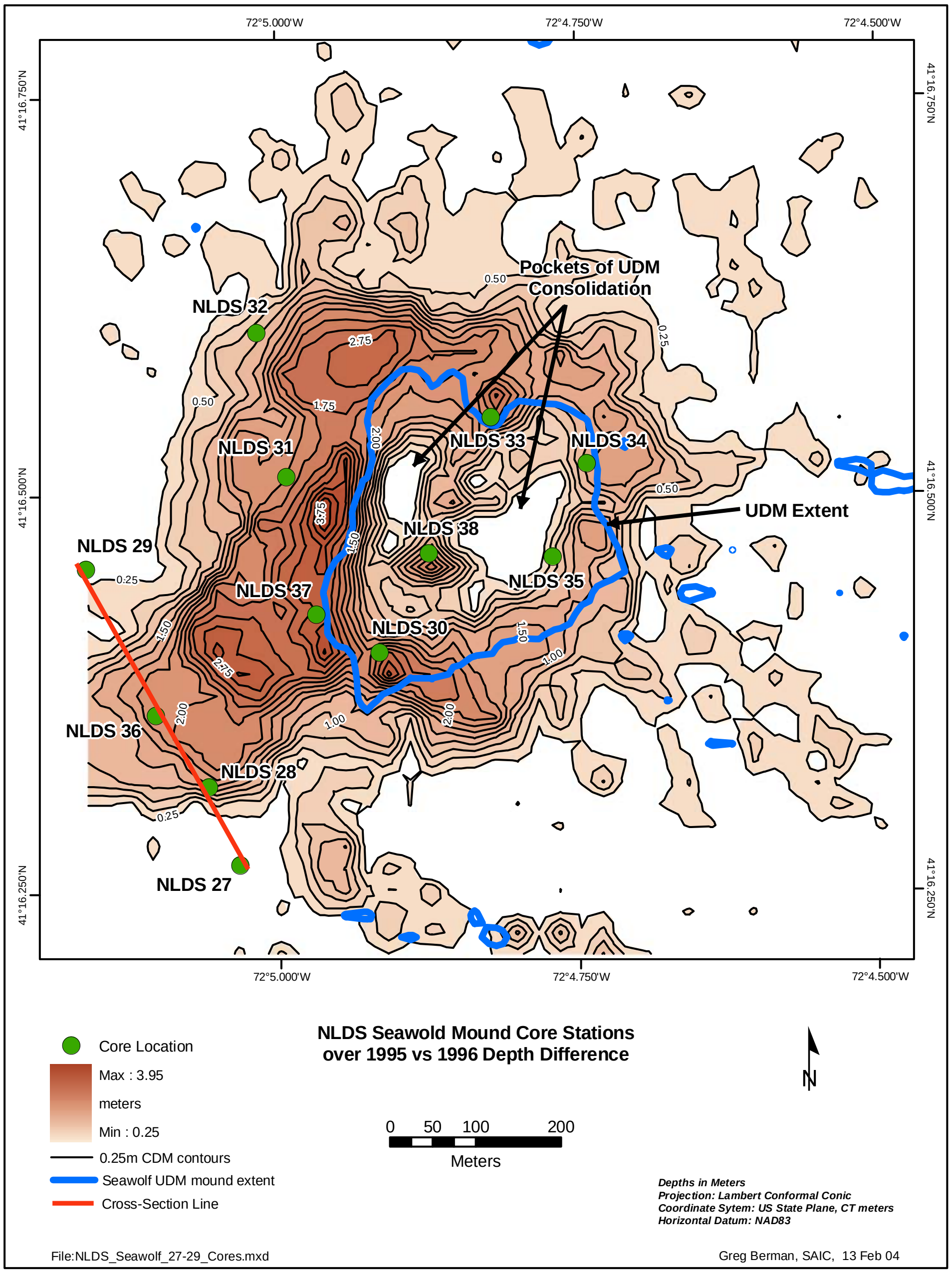


Figure 4-1. Graphic displaying the location of the sediment cores collected over the Seawolf Mound in July 2001, relative to CDM thickness and UDM deposit margins (dark blue line) as detected by sequential bathymetric surveys performed during the 1995-96 disposal season. The red line in the southwest corner represents a bathymetric cross-section within the outer zone (coring) of the Seawolf Mound (See Figure 4-2).

1998 included long cores collected in close proximity to the long core locations in the 2001 investigation.

Long cores collected in 1997 and 1998 (SAIC 2001a) confirmed the presence of at least 1 to 2 m of CDM in the vicinity of the long core locations for the 2001 survey. Specifically, long Core 36 corresponded to the approximate location of Core 4 from the 1997 survey and Core 17 from the 1998 survey, for which no UDM was detected for depths of 1.6 and 1.7 m in the sediment, respectively. Long Core 37 corresponded to the approximate location of Core 6 from the 1997 survey and Core 19 from the 1998 survey, for which no UDM was detected for depths up to 2 m in the sediment. Finally, long Core 38 corresponded to the approximate location of Core 10 from 1997 and Core 23 from 1998, which indicated presence of UDM at depths of 1.8 m and 1.1 m in the sediment (presence of black, oily, sandy material at these depths in Cores 10 and 23, respectively). Based on this information, long Cores 37 and 38 would be expected to penetrate CDM on the order of 1 to 2 m thick underlain by Seawolf UDM. Core 36 would be expected to penetrate CDM on the order of 1 to 2 m thick, underlain by ambient sediments.

It was anticipated that at a minimum, the upper 0.5 m of sediment sampled in the 2001 cores would be comprised of CDM (without any UDM detected), and in the long cores the CDM layer would actually be much thicker than 0.5 m. Short core findings in the 2001 survey supported that conclusion, with the surface interval (0–0.5 m) within the six fine-grained short cores from the disposal mound (Cores 28, 31, 32, 33, 34, and 35) exhibiting sediments that were indicative of CDM from the Thames River dredging project (see Figure 3-1; SAIC 2001a). Additionally, short Core 30 (coarser-grained core collected within the disposal mound) exhibited CDM material at depth, below the coarse surface layer presumably attributable to non-Seawolf disposal activities. Based on both the visual appearance of the sediment in the cores and the location of these cores over the known mound footprint, these results confirm that a layer of CDM measuring at least 0.5 m thick was present over the Seawolf Mound at the time of the August 2001 survey.

Consistent with the 1997 and 1998 surveys, long Cores 37 and 38 from the 2001 survey showed visual evidence of UDM material at depth in the cores. The lower sediment intervals of Core 38 were described as coarse sand and sandy, silty clay, while the bottom 0.3 m (i.e., 1.7–1.9 m depth below mound surface) consisted of coarse sand with a petroleum odor. In Core 37, the bottom 0.3 m of sediment also contained fine sand with a petroleum odor, corresponding to 1.7–2 m depth below the mound surface. These layers were interpreted to be Seawolf UDM and are consistent with the 1997 and 1998 survey results in terms of visual observations of the material and depth of occurrence in cores obtained from the same general locations on the mound. Samples from the bottom sediment layers of Cores 37 and 38 were archived, so no geotechnical or geochemical measurements were taken.

Long Core 36 was located in the outer zone, beyond the 0.25 UDM depth contour but within the 0.25 CDM depth contour (Figure 4-2). Bathymetric depth difference results (1995–96) indicated that 1.75 m of CDM had accumulated at the location of Core 36 (Figure 4-1; SAIC 2001a). Therefore, Core 36 was of sufficient length (2.34 m) to have penetrated through the CDM layer and into the underlying sediment horizon. Grain size results indicated that the upper 1.50 m was composed mostly of silty clay that had been identified as CDM in other cores over the mound (Figure 4-3). At a depth of 1.53 m, the sediment coarsened to sandy silt with gravel and shell hash, with the stratum between 1.53–1.87 m penetration containing only 28% fines (see Table 3-1). The grain size results from this horizon were similar to those from the surface interval of Cores 27 and 29, as well as Core 39 from WEST REF, suggesting the presence of ambient sediments. However, sediment chemistry from these cores indicated higher concentrations of environmental contaminants in Cores 27 and 29 compared to the reference area sediments, as well as the Zn concentration at depth in long Core 36. These findings suggest that these sediments had originated from a non-Seawolf dredged material deposit placed in the northwestern quadrant of NLDS prior to the 1995-96 disposal season. The material in these cores was described as greenish-gray to dark greenish-gray fine sand, as indicated by the visual descriptions and grain size results from Cores 27, 29, and 36. Although this material was coarse-grained like Seawolf UDM, it lacked the distinctive petroleum odor and dark color of the UDM sediment. Possible sources of these sediments are discussed in more detail below with respect to sediment chemistry results.

Overall, the grain size results and visual observations from the short and long cores in the 2001 survey suggested (1) the persistence of at least 0.5 m of CDM over the Seawolf Mound, (2) cap thickness of 1.7 m at Core 37 and 38 locations, and (3) collection of non-Seawolf-derived dredged sediments in the lower depth interval of long Core 36 and short Cores 27 and 29. Sediment chemistry was used to provide additional supporting evidence for these determinations regarding CDM, UDM, and non-Seawolf sediments as well as to provide evidence that physical mixing or contaminant migration from the UDM layer below had not resulted in increased levels of contaminants in the CDM layer over the mound.

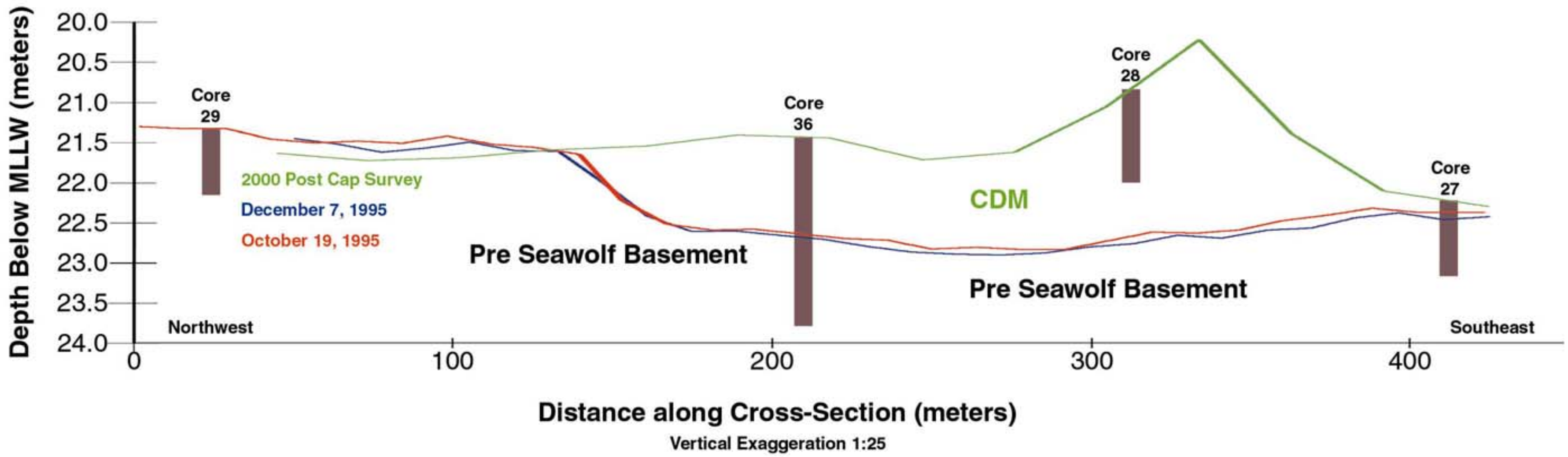


Figure 4-2. Bathymetric cross-section of the Seawolf Mound along a line connecting Cores 29, 36, 28, and 27 collected as part of the July 2001 survey (see Figure 4-1). The red line represents seafloor topography as detected in the October 1995 baseline survey performed by Gahagan and Bryant on behalf of the US Navy. The blue line represents seafloor topography as detected during the December 1995 precap survey to characterize the UDM deposit. The green line represents the seafloor topography and subsequent CDM thickness as detected in August 2000 monitoring survey performed in support of DAMOS.

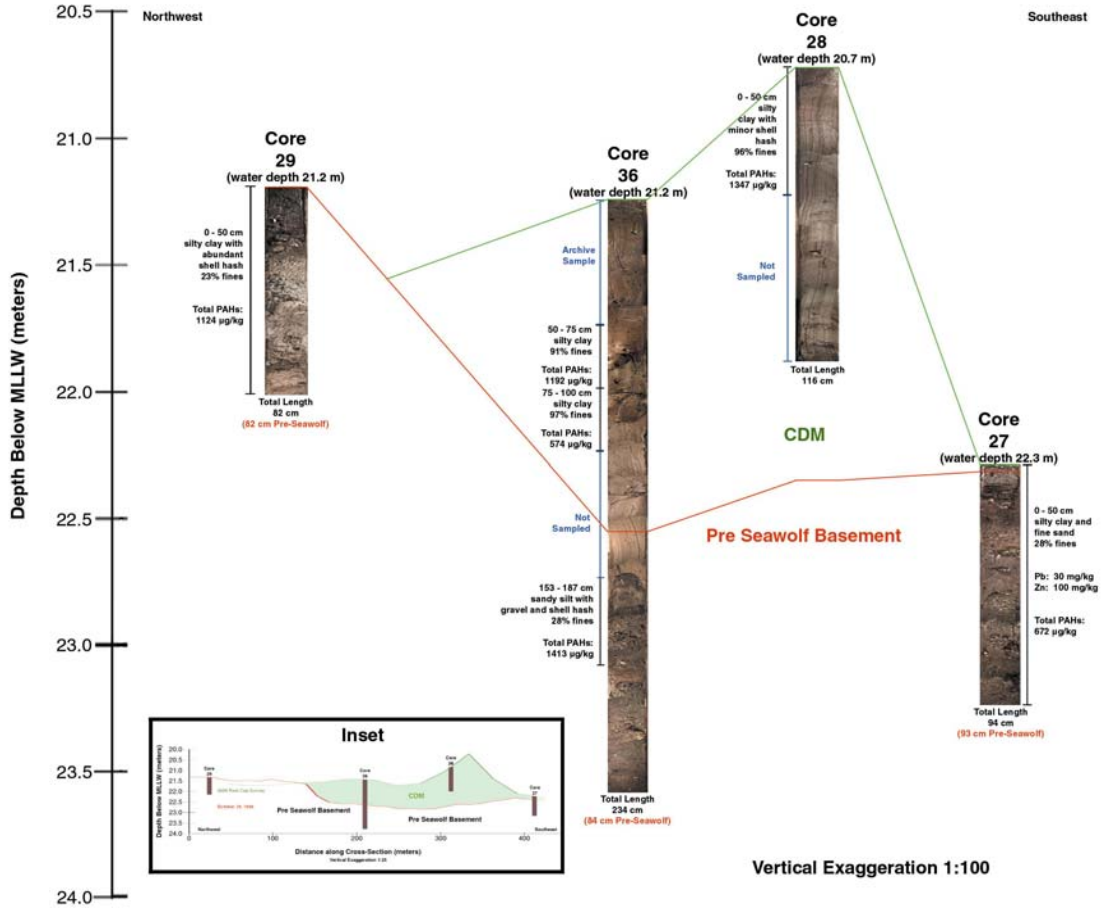


Figure 4-3. Comparative graphic displaying the digital images and detailed descriptions of vibracores collected in July 2001 relative to the interfaces between Seawolf CDM and water, as well as Seawolf CDM and pre-Seawolf basement material

4.1.2 Sediment Chemistry

Metals

Trace metal concentrations (As, Cd, Cr, Cu, Pb, Hg, Ni, and Zn) from the surface (0–0.5 m) interval of the short cores and depth intervals to 2 m in the long cores yielded relatively low concentrations of metals. Grouping results for the inner, middle, and outer zones of the disposal mound yielded variable concentrations within each zone, but considerations of concentrations based on comparable grain size distributions indicated similar concentrations for all cores collected within the acoustically detectible footprint of the mound. Metal concentrations normalized to grain size yielded results directly comparable to the normalized concentrations for the reference area (with disposal mound concentrations ranging from 0.8–1.1 times the reference area values), which consists of coarser grain size than the Seawolf CDM. These results indicated no evidence of higher trace metal concentrations in the CDM layer covering the Seawolf Mound.

Zinc, copper and chromium were contaminants of concern based on the pre-dredging sediment testing results for portions of the Seawolf material (SAIC 2001a). Chromium and Cu concentrations were low in the 2001 survey results, suggesting no contamination from the underlying UDM. Overall, Zn concentrations for the 2001 survey were also low for both short and long core samples. Two higher Zn concentrations occurred in Core 33 (which had higher concentrations of most metals compared to the other fine-grained cores from the disposal mound) and Core 27 (beyond the acoustically detectible footprint of the mound). Long cores were analyzed for Zn at depth in the sediment, and yielded concentrations well within the range of concentrations detected in the short cores. Therefore, the long cores provided no indication of increased Zn concentrations with depth in the sediment.

Core 30 exhibited a coarse surface layer of sand and gravel over a layer of finer-grained material; normalization to grain size for the composite sample suggested that the underlying fine-grained material consisted of Seawolf CDM. The remainder of the fine-grained cores yielded comparable results with relatively narrow ranges of concentrations (Cores 28, 31, 32, 34, and 35).

Core 33 in the inner zone exhibited slightly higher concentrations of most metals compared to the remainder of the disposal mound cores, which persisted in the normalized data. The most dramatic differences were evident for Hg (0.12 mg/kg) and Zn (160 mg/kg). However, concentrations from Core 33 fell within, or very close to, the range of concentrations detected in previous surveys (1997 and 1998), suggesting Core 33 was reflective of the range of variability previously detected across the disposal mound (SAIC 2001a).

Cores 27 and 29 were located in areas beyond the acoustically detectible footprint of the Seawolf Mound, in areas not sampled during the 1997 and 1998 coring surveys. These cores exhibited coarser grain size than the Seawolf CDM and normalized metal concentrations indicated greater concentrations of most metals compared to the disposal mound samples and the reference area, particularly Pb and Zn. However, despite being slightly higher with respect to the other 2001 core results, the normalized metal concentrations in these cores were still comparable to, or less than, the average concentrations reported from the 1990-1994 UDM and CDM sediment testing results (with the exception of the maximum Zn concentration detected in Core 27; see Table 3-3). Therefore, these cores could reflect variability in the Seawolf CDM material, or could include sediments that originated from non-Seawolf related dredged material disposal activities in the area. Possible sources of non-Seawolf dredged material include historic (e.g., pre-Seawolf) disposal activities, and disposal of the Mystic River and Venetian Harbor material at the NDA 95 buoy that occurred within the same timeframe as the Seawolf capping activities.

The 2001 survey results yielded trace metal concentrations directly comparable to, or less than, results from previous surveys in 1997 and 1998, lower than the average pre-dredging UDM and CDM concentrations from 1990 and 1994, and well below the concentrations reported in the 1992 pre-dredging sediment test results, which were indicative of the material to be dredged with the greatest concentrations of contaminants (SAIC 2001a). These comparisons provide evidence for relatively low concentrations of contaminants in the Seawolf cap material. Because it is unlikely that contaminant concentrations would have *decreased* over time in the cap material over the mound, concentrations that are lower than previous disposal mound surveys and pre-dredging sediment characterizations also give an indication of the variability inherent in the sediment chemistry. Based on these results, the metals concentrations detected in the cores from the 2001 survey were not indicative of contamination from the UDM material underlying the Seawolf CDM.

PAHs

PAH concentrations were generally very low in the short and long cores from the 2001 survey, with the exception of somewhat higher PAHs in several outer zone cores. Despite being slightly higher with respect to the very low reference area PAHs, most of the cores in the 2001 survey exhibited very low PAH concentrations, with numerous compounds not detected or detected at low concentrations (see Tables 3-4 and 3-6). Most cores exhibited PAH concentrations comparable to previous surveys (1997 and 1998 surveys) and pre-dredging sediment test results (1990-1994) and did not give any indication of trends based on location across the disposal mound or with depth in the sediment (Table 4-1).

Exceptions were evident in the outer zone, including somewhat higher concentrations of HMW PAHs in short Cores 28 and 29, and higher concentrations at various depths of LMW and HMW PAHs in long Core 36. Core 27, also located in the outer zone and beyond the acoustically detectible footprint of the Seawolf Mound, had PAH concentrations comparable to the remaining Seawolf Mound cores. Individual PAH compounds had relatively low concentrations in Cores 28 and 29, but the sum of HMW PAHs was two to three times the sums calculated for the other short cores. Higher concentrations in Core 29 and at depth in Core 36 could reasonably be attributed to historic (i.e., pre-Seawolf) dredged material disposal activities in the area. However, Core 28 was located well within the CDM layer of the Seawolf Mound and likely consisted entirely of CDM material (Figures 4-1 and 4-2). Metal concentrations in Core 28 were directly comparable to the other fine-grained short cores from the disposal mound (see Table 3-2). Therefore, the greater HMW PAH concentrations in Core 28 may be reflective of variability in the Seawolf CDM material, or may reflect variability introduced by material deposited at the nearby NDA 95 buoy located less than 100 m to the northeast of this station (Mystic River and Venetian Harbor material deposited during the Seawolf capping activities).

The consistently low PAH concentrations detected in the short and long cores from the 2001 survey, lack of spatial trends across the disposal mound, and lack of any evidence for changes in PAH concentration with depth in the sediment, indicate that the sediments in the CDM layer of the Seawolf Mound have not been affected by higher PAHs that may be present in UDM below the cap material.

Given the total thickness of much of the CDM layer over the mound, conclusions regarding the integrity of the CDM layer are most compelling for the lower depth intervals of the long cores. In previous monitoring surveys, it was determined that long cores obtained in the general vicinity of Stations 37 and 38 had penetrated into UDM. That determination was based on visual observations of the material at depth in the cores, presence of an oily sheen and petroleum odor, and a trend of increasing contaminant concentrations, including PAHs, with depth in the cores. Long Cores 37 and 38 from the 2001 survey indicated sediments with a similar appearance in the deepest portion of the cores. They also had a petroleum odor, but did not exhibit a trend of increasing PAH concentration with depth.

Table 4-1.

Comparison of PAH Concentrations in Samples Collected from the Seawolf Mound Long Cores in June 2001 to Previous Survey Results

Radial Zone:	**Outer zone (400-600 m)**								
Depth in core (m):	**0.50-0.75**			**0.75-1.00**			**1.00-2.00**		
Year of Coring Survey:	2001	1997	1998	2001	1997	1998	2001	1997	1998
NLDS Core Name:	36	4	17	36	4	17	36	4	17
Trace Metals									
Zinc (Zn)	73	86	95	77	84	70	34	116	78
PAH Compound									
Low Molecular Weight									
Naphthalene	50	5 J	13	19	7 J	22	23	5 J	32
2-Methylnaphthalene	56	8 U	6 J	9.6 U	7 U	7 J	11	7 U	15
Acenaphthylene	9.6 U	8 U	13	9.6 U	11	19	21	11	46
Acenaphthene	9.6 U	8 U	10 U	9.6 U	7 U	5 J	9.5	7 U	9 J
Fluorene	54	8 U	10 U	9.6 U	7 U	6 J	14	7 U	8 J
Phenanthrene	260	23	35	38	36	33	110	28	58
Anthracene	24	12	16	14	16	26	40	14	43
Sum of LMW PAHs	**463**	**72**	**103**	**109**	**91**	**118**	**229**	**79**	**211**
High Molecular Weight									
Fluoranthene	120	56	56	89	110	56	220	78	120
Pyrene	160	61	85	120	120	86	270	89	180
Benz[a]anthracene	71	38	29	43	71	62	130	44	81
Chrysene	120	45	36	38	58	66	110	44	98
Benzo[b]fluoranthene	70	43	23	40	69	44	100	38	69
Benzo[k]fluoranthene	33	23	28	27	39	40	77	35	66
Benzo[a]pyrene	52	38	32	39	69	51	120	49	98
Indeno[1,2,3-cd]pyrene	35	4 J	22	25	7 J	27	71	4 J	59
Dibenz[a,h]anthracene	19	23	10 U	9.6 U	42	5 J	16	31	12
Benzo[g,h,i]perylene	39	25	25	24	43	29	63	30	66
Dibenzofuran	9.9	8.0	--	9.6 U	7 U	--	7.2	7 U	--
Sum of HMW PAHs	**729**	**364**	**346**	**464**	**635**	**466**	**1184**	**449**	**849**
Total PAHs	**1192**	**672**	**636**	**839**	**1160**	**876**	**2148**	**820**	**1578**

Radial Zone:	**Middle zone (200-400 m)**								
Depth in core (m):	**0.50-0.75**			**0.75-1.00**			**1.00-1.75**		
Year of Coring Survey:	2001	1997	1998	2001	1997	1998	2001	1997	1998
NLDS Core Name:	37	6	19	37	6	19	37	6	19
Trace Metals									
Zinc (Zn)	62	83	65	71	84	73	76	79	62
PAH Compound									
Low Molecular Weight									
Naphthalene	20	10	17	15	10	18	12	11	8 J
2-Methylnaphthalene	13 U	6 J	7 J	9.4 U	6 J	7 J	9.2 U	6 J	10 U
Acenaphthylene	13 U	7 J	26	9.4 U	10	21	9.2 U	9	7 J
Acenaphthene	13 U	7 U	10 U	9.4 U	7 U	5 J	9.2 U	7 U	10 U
Fluorene	13 U	7 U	5 J	9.4 U	7 U	6 J	9.2 U	7 U	10 U
Phenanthrene	23	19	42	21	36	43	21	28	13
Anthracene	13 U	8	33	9.4 U	13	25.0	9.2 U	10	8 J
Sum of LMW PAHs	**108**	**64**	**140**	**83**	**89**	**125**	**79**	**78**	**66**
High Molecular Weight									
Fluoranthene	41	49	100	38	90	74	49	76	25
Pyrene	57	59	160	54	100	120	50	80	38
Benz[a]anthracene	22	31	70	17	48	43	20	39	12
Chrysene	25	25	79	19	39	50	22	34	16
Benzo[b]fluoranthene	28	31	54	20	50	32	23	40	11
Benzo[k]fluoranthene	16	16	53	11	26	39	12	22	12
Benzo[a]pyrene	24	27	73	17	47	47	19	37	14
Indeno[1,2,3-cd]pyrene	13 U	7 U	42	9.4 U	6 J	29	9.9	4 J	10 J
Dibenz[a,h]anthracene	13 U	17	8 J	9.4 U	30	6 J	9.2 U	25	10 U
Benzo[g,h,i]perylene	13 U	18	48	9.4 U	32	33	9.2 U	28	11
Dibenzofuran	13 U	7 U	--	9.4 U	7 U	--	9.2 U	7 U	--
Sum of HMW PAHs	**265**	**287**	**687**	**214**	**475**	**473**	**233**	**392**	**159**
Total PAHs	**373**	**351**	**827**	**297**	**564**	**598**	**312**	**470**	**225**

Radial Zone:	**Inner zone (0-200 m)**									**TEL[1]**	**ERL[2]**	**PEL[3]**	**ERM[4]**
Depth in core (m):	**0.50-0.75**			**0.75-1.00**			**1.00-2.00**						
Year of Coring Survey:	2001	1997	1998	2001	1997	1998	2001	1997	1998				
NLDS Core Name:	38	10	23	38	10	23	38	10	23				
Trace Metals													
Zinc (Zn)	90	76	58	54	78	72	64	71	130	124	150	271	410
PAH Compound													
Low Molecular Weight													
Naphthalene	14 U	7 J	5 J	13 U	8 U	8 J	13 U	5 J	20	34.57	160	390.64	2100
2-Methylnaphthalene	14 U	8 U	10 U	13 U	8 U	10 U	13 U	8 U	9	20.21	70	201.28	670
Acenaphthylene	14 U	6 J	8 J	13 U	8 U	14	13 U	5 J	22	5.87	44	127.87	640
Acenaphthene	14 U	8 U	10 U	13 U	8 U	10 U	13 U	8 U	6 J	6.71	16	88.9	500
Fluorene	14 U	8 U	10 U	13 U	8 U	10 U	13 U	8 U	7 J	21.17	19	144.35	540
Phenanthrene	33	13	12	18	11	26	27	12	56	86.68	240	543.53	1500
Anthracene	19	5 J	8 J	13 U	5 J	16	13 U	4 J	33	46.85	85.3	245	1100
Sum of LMW PAHs	**122**	**55**	**63**	**96**	**56**	**94**	**105**	**50**	**153**	222.06	634	1741.6	7050
High Molecular Weight													
Fluoranthene	51	36	20	40	34	55	65	28	130	112.82	600	1493.5	5100
Pyrene	60	44	31	41	37	94	63	32	180	152.66	665	1397.6	2600
Benz[a]anthracene	30	24	11	22	16	40	29	14	55	74.83	261	692.53	1600
Chrysene	26	20	15	21	16	45	31	14	69	107.77	384	845.98	2800
Benzo[b]fluoranthene	23	24	11	22	15	35	35	17	46	NR	NR	NR	NR
Benzo[k]fluoranthene	14 U	13	11	13 U	8 U	36	20	10	46	NR	NR	NR	NR
Benzo[a]pyrene	24	25	14	20	14	48	30	15	53	88.81	430	736.22	1600
Indeno[1,2,3-cd]pyrene	14 U	8 U	9 J	13 U	8	27	17	8 U	34	NR	NR	NR	NR
Dibenz[a,h]anthracene	14 U	16	10 U	13 U	9	6 J	13 U	12	6 J	6.22	63.4	134.61	260
Benzo[g,h,i]perylene	14 U	16	10 U	13 U	10	33	14	12	37	NR	NR	NR	NR
Dibenzofuran	14 U	8 U	--	13 U	8 U	--	13 U	8 U	--	NR	NR	NR	NR
Sum of HMW PAHs	**284**	**234**	**142**	**231**	**175**	**419**	**330**	**170**	**656**	--	--	--	--
Total PAHs	**406**	**289**	**205**	**327**	**231**	**513**	**435**	**220**	**809**	--	--	--	--

Units for Trace metals are mg/kg; Units for PAH's are µg/kg dry weight.

U = Below detection limit (detection limit dependent upon sample volume); one half of the reported detection limit was used for statistical calculations.

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

NR=Not Reported (not readily available in original Maguire Group, 1995 report)

[1]Threshold Effects Level (TEL), MacDonald, 1994

[2] Effects Range - Low (ERL), Long et al, 1995

[3]Probable Effects Level (PEL), MacDonald, 1994

[4] Effects Range - Median (ERM), Long et al, 1995

Visual observations from the 2001 survey suggest penetration to UDM at depth in these cores (1.7 m below the surface). This material was not analyzed for sediment chemistry; however, the overlying depth intervals in Cores 37 and 38 had relatively low concentrations of trace metals and PAHs, and provided no indication of chemical gradients with depth in the core. This supports the conclusion that the cap material continues to function to isolate higher contaminants in the underlying Seawolf UDM.

Slightly higher HMW PAH concentrations detected in long Core 36 suggested similarities to the surface sediment of Cores 28 and 29 in the outer zone. Unlike the slightly higher metals concentrations detected in the short cores in the outer zone, the higher HMW PAH concentrations were substantially greater than the results from previous surveys in 1997 and 1998, as well as reference area concentrations (Table 4-1). As discussed above regarding the metal concentrations, samples from this region of the disposal mound could include material derived from non-Seawolf related disposal activities, including historic (e.g., pre-Seawolf disposal) activities in the region, and disposal at the nearby NDA 95 buoy that occurred within the same timeframe as the Seawolf Mound capping activities. Conclusive determinations regarding specific sources are difficult, given the occurrences of greater HMW PAH concentrations in Core 28, presumably consisting of Seawolf-disposal period material, and greater concentrations of PAHs and some metals at depth in long Core 36 (presumably pre-Seawolf material beneath the substantial Seawolf deposit in this location of the mound; Figure 4-1). As previously reported, long Core 17A, collected in 1998 at the same location as Core 36, might have been influenced by historic contamination in the existing, pre-Seawolf sediments (SAIC 2001a).

4.1.3 Comparisons to Conservative Ecological Screening Levels

Metals

Several data compilations exist to evaluate the possible toxicological significance of various inorganic and organic chemical contaminants in marine sediments. Through the National Oceanic and Atmospheric Administration (NOAA), Buchman (1999) has compiled a set of Screening Quick Reference Tables (SQuiRTS) that list multiple benchmarks for aquatic and marine sediments, including Threshold Effects Levels (TEL) and Probable Effects Level (PEL) published by MacDonald in 1994, as well as Effects Range-Low (ER-L), and the Effects Range-Median (ER-M) refined by Long et al. in 1995. These ecological benchmarks were used to provide a basis of comparison for the Seawolf sediments, based on non-normalized contaminant concentrations. The TEL values are considered very protective screening criteria since they represent sediment concentrations rarely associated with adverse effects to benthic organisms, while the PEL represents the concentration above which adverse biological effects are frequently expected to occur (MacDonald 1994). Calculated under different methodology, the ER-L and ER-M values represent the lower 10th and 50th percentiles of all concentrations of a particular contaminant observed to cause a biological effect, over a wide range of studies and species (Long and Morgan 1990; Long et al. 1995). These benchmarks, particularly the TELs and ER-Ls, are considered very conservative screening levels for determining the potential for adverse ecological effects from contaminants in sediments.

The average metal concentrations from the nine short cores from the disposal area were below conservative ecological screening levels (ER-Ls provided in Table 3-2). Additionally, for Cr, Pb, Hg, and Zn, the site-wide average concentrations (e.g., average for all nine cores) were lower than the highly conservative TELs. The concentrations from individual cores only exceeded the ER-L concentrations slightly in some cores for As, Cu (Core 33 slightly above ER-L), Ni (six cores at slightly above ER-L), and Zn (Core 33, slightly above ER-L). For the long cores, Zn concentrations were all below the conservative TEL and would be considered low. These results support the conclusions from the analytical results that metals concentrations would be considered low and do not indicate potential for adverse effects to benthic infauna.

PAHs

Comparisons of the maximum PAH concentrations from the short cores to conservative ecological benchmarks for PAHs (for compounds for which benchmarks are available, Table 3-4) indicate concentrations below the highly conservative TELs for most compounds, with only minor exceedances for some compounds (at concentrations well below the conservative ER-L concentrations). This includes those PAH concentrations that were higher with respect to the other samples analyzed, including the HMW PAH compounds in Cores 28 and 29. Similarly, PAH concentrations for the long core samples from the inner and middle zone (Cores 37 and 38) were all below the published TEL concentration. In some cases the detection limits for core sample analysis were greater than the TEL value, but not substantially above that concentration such that the sample results were still indicative of negligible potential for ecological effects (e.g., lower than ER-L concentrations).

The higher PAH concentrations in Core 36 from the outer zone included results that exceeded the TELs and for some compounds and slightly exceeded the ER-Ls. For example, several LMW PAH compounds in the 0.5–0.75 m and the 1.5–1.9 m intervals in Core 36 exceeded the TEL concentration. Fluorene (maximum concentration of 54 μg/kg), exceeded the ER-L concentration of 19 μg/kg, and phenanthrene (260 μg/kg) exceeded the

ER-L concentration of 240 μg/kg. The HMW PAHs from the same depth intervals occasionally exceeded TEL concentrations, however none exceeded ER-Ls.

This suggests that these higher PAH concentrations with respect to the other cores in the survey (e.g., HMW PAHs in short Cores 28 and 29, LMW PAHs in the 0.5–0.75 m depth interval in Core 36, and HMW PAHs in the 0.5–0.75 m and 1.5–1.9 m depth interval in Core 36), would still be considered low PAH concentrations and unlikely to be associated with potential adverse ecological effects. Additionally, exceedances of benchmarks in Core 36, though not appreciable, were detected at depths below 0.5 m which is below the typical depth range of burrowing benthic organisms (i.e., juvenile lobster), further minimizing the potential for adverse ecological effects.

4.2 Benthic Recolonization Status

4.2.1 REMOTS® Sediment-Profile Imaging

Under the DAMOS tiered monitoring protocol (Germano et al. 1994), surveys are conducted at regular intervals to verify that populations of benthic organisms recover (i.e., recolonize) over dredged material disposal mounds in a manner consistent with expectations. Therefore, a primary objective of the June 2001 survey over the Seawolf Mound was to evaluate the benthic recolonization status at five years post-CDM deposition. This objective was addressed through the use of two different, but complimentary, sampling techniques: REMOTS® sediment-profile imaging and benthic grab sampling/taxonomic analysis.

The June 2001 REMOTS® sediment-profile imaging survey re-occupied six stations over the Seawolf Mound that were sampled previously in 1997, 1998, and 2000. The June 2001 survey was conducted as specified in the U.S. Navy five-year monitoring plan. Grab samples for benthic taxonomic analysis also were obtained at the six stations in June 2001; benthic grab samples had been obtained previously at these same six stations in 1997 (1.5 years postcapping).

The REMOTS® images obtained in June 2001 showed that fine-grained dredged material (CDM) continued to be present at all six stations over the Seawolf Mound, in layers that were thicker than the penetration depth of the sediment-profile camera. These results are consistent with those of the three previous REMOTS® surveys conducted over this mound since the completion of capping operations in 1996. Likewise, sediments consisting predominantly of very fine sand (4 to 3 phi) and fine sand (3 to 2 phi) continued to be found at the three NLDS reference areas (e.g., Figure 3-11A).

The June 2001 REMOTS® results indicated that the CDM comprising the surface of the Seawolf Mound had been colonized by a diverse benthic community consisting of both surface-dwelling and deeper-dwelling infauna. This community appeared to be slightly more advanced than that observed on the ambient seafloor at the NLDS reference areas. Specifically, Stage III was found along with both Stage I and/or Stage II taxa in 10 of the 18 (56%) replicate images obtained over the Seawolf Mound in June 2001, compared to only 10 of the 39 (26%) images collected at the reference areas.

The overall median OSI value of +8.2 for the REMOTS® stations over the Seawolf Mound is indicative of undisturbed benthic habitat at the time of the June 2001 survey. This relatively high value reflects both the moderately deep oxygenation of the surface sediments observed over the mound (overall average RPD depth of 2.5 cm) and the presence of mainly Stage II and III organisms.

The OSI value of +8.2 for the Seawolf Mound was higher than at the reference areas, where a value of +5.5 suggested moderately disturbed benthic conditions. The lower OSI values at the reference areas reflected shallower RPD depths and a higher relative frequency of images showing only Stage I organisms (Figure 4-4). Because the NLDS reference areas are predominantly sandy, they are less able to support abundant populations of larger bodied, deposit-feeding, Stage III organisms that preferentially burrow and feed in soft, muddy, organic-rich sediments (Figure 4-4). Therefore, the lower reference area OSI values are more readily attributed to the difference in sediment type compared to the Seawolf Mound than to different degrees of benthic disturbance.

The long-term REMOTS® results over the Seawolf Mound indicate a steady improvement in benthic habitat condition. As expected, RPD depths have generally deepened over the past five years to reflect increased levels of bioturbation by recolonizing infauna and associated consumption of organic matter within the surface sediments (Table 4-2). Likewise, overall average OSI values have increased steadily from +5.1 in 1997 to +8.2 in 2001, reflecting both deeper RPD depths and an increase in the abundance of advanced successional stages (Table 4-2). A series of images from Station 300WSW illustrates the progressive improvement in benthic habitat condition over time (Figure 4-5).

The June 2001 results for the NLDS reference areas indicated a general decline in OSI values compared to previous surveys (Table 4-3). Reference areas NLON REF and NE REF exhibited comparable results to previous years, with OSI values decreasing only slightly, while the decline in average values at WEST REF was more significant (Table 4-3). A dominance of Stage I organisms and shallower RPD depths at all of the reference areas in June 2001 explain the observed trend in OSI values. It is possible that these

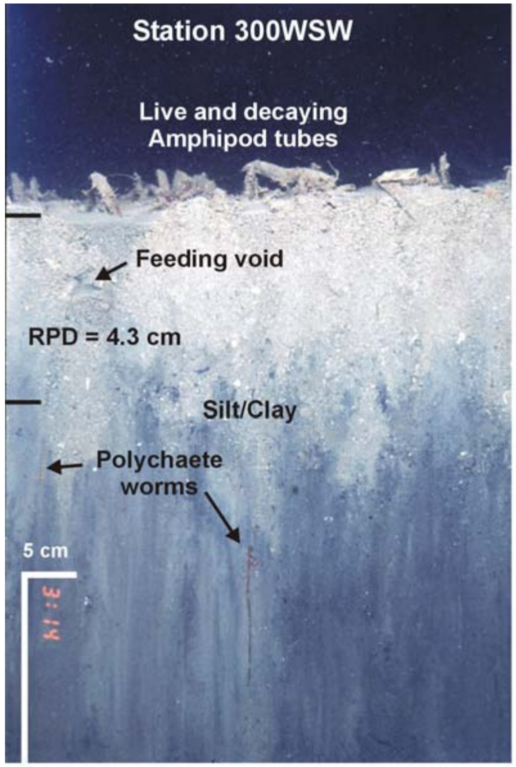
Table 4-2.
Seawolf Disposal Mound REMOTS® Sediment-Profile Imaging Results (Benthic Recolonization) Summary for the 1997, 1998, 2000, and 2001 Surveys

Station		RPD Mean (cm)				Successional Stages Present				Highest Stage Present				OSI Median			
Seawolf	**Area**	1997	1998	2000	**2001**	1997	1998	2000	**2001**	1997	1998	2000	**2001**	1997	1998	2000	**2001**
CTR	Apex	NA	1.24	2.44	**1.65**	INDET	I, II, III	I, II, III	**I,II,III**	INDET	ST_I_ON_III	ST_I_ON_III	**ST_II_ON_III**	NA	6.5	5	**6**
75E	Plateau	0.71	1.63	4.35	**2.26**	I, II, III	II, III	II, III	**I,II,III**	ST_II_TO_III	ST_II_ON_III	ST_II_ON_III	**ST_II_ON_III**	5.5	7.5	9	**9**
150N	Apex	NA	1.76	2.48	**2.03**	II	AZOIC, I	II, III	**I,II,III**	ST_II	ST_I	ST_II_ON_III	**ST_II_ON_III**	NA	4	7	**8**
150W	Plateau	1.59	1.01	3.48	**2.69**	I, II	I, III	I, II, III	**I,II,III**	ST_II	ST_I_ON_III	ST_II_ON_III	**ST_I_ON_III**	4	7	11	**8**
300SE	Apron	1.91	1.99	3.62	**2.83**	II, III	I, II	I, II, III	**I,III**	ST_II_ON_III	ST_II	ST_II_ON_III	**ST_I_ON_III**	8	5	9	**9**
300WSW	Plateau	0.47	2.06	2.02	**3.39**	I, II, III	I, II, III	II, III	**I,II,III**	ST_II_ON_III	ST_II_ON_III	ST_II_ON_III	**ST_II_ON_III**	3	3	6	**9**
AVG		1.17	1.62	3.07	**2.47**									5.13	5.50	7.83	**8.17**
MAX		1.91	2.06	4.35	**3.39**									8.00	7.50	11.00	**9.00**
MIN		0.47	1.01	2.02	**1.65**									3.00	3.00	5.00	**6.00**

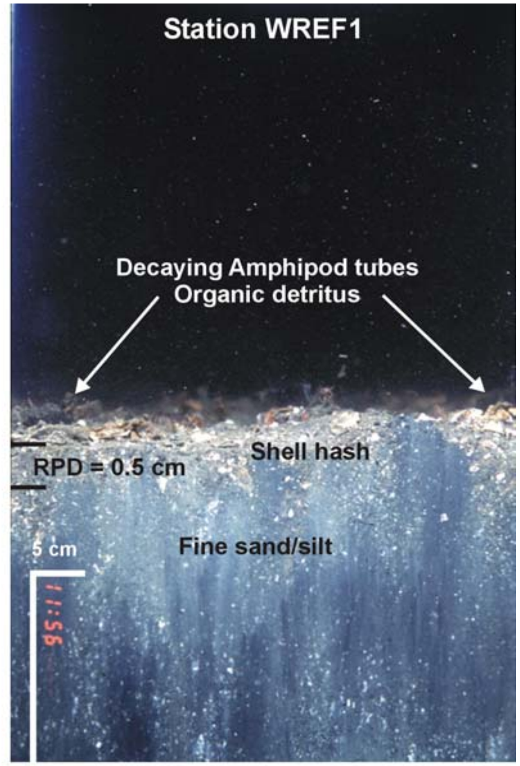
Table 4-3.

NLDS Reference Area REMOTS® Sediment-Profile Imaging Results (Benthic Recolonization) Summary for the 1997, 1998, 2000, and 2001 Surveys

Reference Area Station	RPD Mean (cm)				Successional Stages Present				Highest Stage Present				OSI Median			
Survey:	1997	1998	2000	**2001**	1997	1998	2000	**2001**	1997	1998	2000	**2001**	1997	1998	2000	**2001**
NLON REF																
NLON REF1	2.27	3.29	2.48	**2.05**	I,II,III	I,II	I,II	**I,II,III**	ST_I_ON_III	ST_II	ST_II	**ST_II_ON_III**	5	6	5	**8**
NLON REF2	2.55	2.56	1.96	**1.64**	I,II,III	II,III	I,II	**I**	ST_II_ON_III	ST_II_ON_III	ST_II	**ST_I**	9	8	6	**4**
NLON REF3	2.48	2.52	2.8	**2.62**	II,III	I,III	II,III	**I,III**	ST_II_TO_III	ST_I_ON_III	ST_II_ON_III	**ST_I_ON_III**	7.5	5	8	**7**
NLON REF4	1.81	2.5	2.41	**2.61**	I,II,III	I,II	II	**I**	ST_II_ON_III	ST_I_TO_II	ST_II	**ST_I**	5	7	7	**5**
NLON REF5				**1.89**				**I,III**				**ST_I_ON_III**				**4**
SUMMARY	**2.28**	**3.29**	**2.41**	**2.16**									**6.63**	**6.5**	**6.5**	**5.6**
NE REF																
NE REF1	1.92	1.87	1.99	**1.59**	I,II,III	I,II	I,II	**I,III**	ST_II_ON_III	ST_II	ST_I_TO_II	**ST_I_ON_III**	6	5.5	5	**5.5**
NE REF2	2.43	1.85	3.58	**1.99**	II, III	II	I,II	**I,II,III**	ST_II_TO_III	ST_II	ST_I_TO_II	**ST_I_ON_III**	6.5	6	7	**5.5**
NE REF3	2.59	2.01	2.4	**2.05**	I,II	I,II,III	I,III	**I,II,III**	ST_II	ST_I_ON_III	ST_I_ON_III	**ST_II_ON_III**	7	6	9	**6**
NE REF4	2.65	1.55	2.5	**1.77**	I,II	I,II,III	I,II,III	**II,III**	ST_II	ST_II_ON_III	ST_I_ON_III	**ST_II_ON_III**	7	7	6	**7**
NE REF5	2.07	1.71			I,II,III	I,II			ST_II_ON_III	ST_II			8	5		
SUMMARY	**2.33**	**1.8**	**2.62**	**1.85**									**6.9**	**5.9**	**6.75**	**6.0**
WEST REF																
WREF1	2.42	3.68	3.3	**1.0**	I,II	I,II,III	II,III	**I,II**	ST_II	ST_I_ON_III	ST_II_ON_III	**ST_I_TO_II**	6	10	8	**3**
WREF2	3.48	2.9	2.46	**2.69**	II,III	I,II	II	**I**	ST_II_ON_III	ST_I_TO_II	ST_II	**ST_I**	10	7	7	**5**
WREF3	2.10	3.98	3.16	**1.81**	II	NA	II,III	**I**	ST_II	NA	ST_II_ON_III	**ST_I**	6	NA	8	**4**
WREF4	1.75	2.74	2.5	**2.22**	I,II	II	I,II	**I,II,III**	ST_II	ST_II	ST_II	**ST_II_ON_III**	5.5	8	7	**7**
WREF5			3.06				I,II				ST_II				8	
SUMMARY	**2.44**	**3.33**	**2.9**	**1.93**									**6.88**	**8.33**	**7.6**	**4.75**
AVG	2.35	2.55	2.66	**2.02**									6.81	6.64	7.0	**5.46**
MAX	3.48	3.98	3.58	**2.69**									10	10	9	**7**
MIN	1.75	1.55	1.96	**1.00**									5	5	5	**3**



A



B

Figure 4-4. REMOTS® images from Seawolf Mound Station 300WSW (A) and Reference Area Station WREF1 (B) illustrating differences in sediment type and benthic habitat quality. Disposal mound Station 300WSW (A) consists of softer, fine-grained sediment and displays an OSI of +11 due to a well-developed RPD and a feeding void at sediment depth. Station WREF1 (B) is characterized by a sandy substrate and displays a shallow RPD depth and a Stage II successional status. Live and decaying amphipod tubes (*Ampelisca*) are visible at the sediment-water interface in both REMOTS® images.

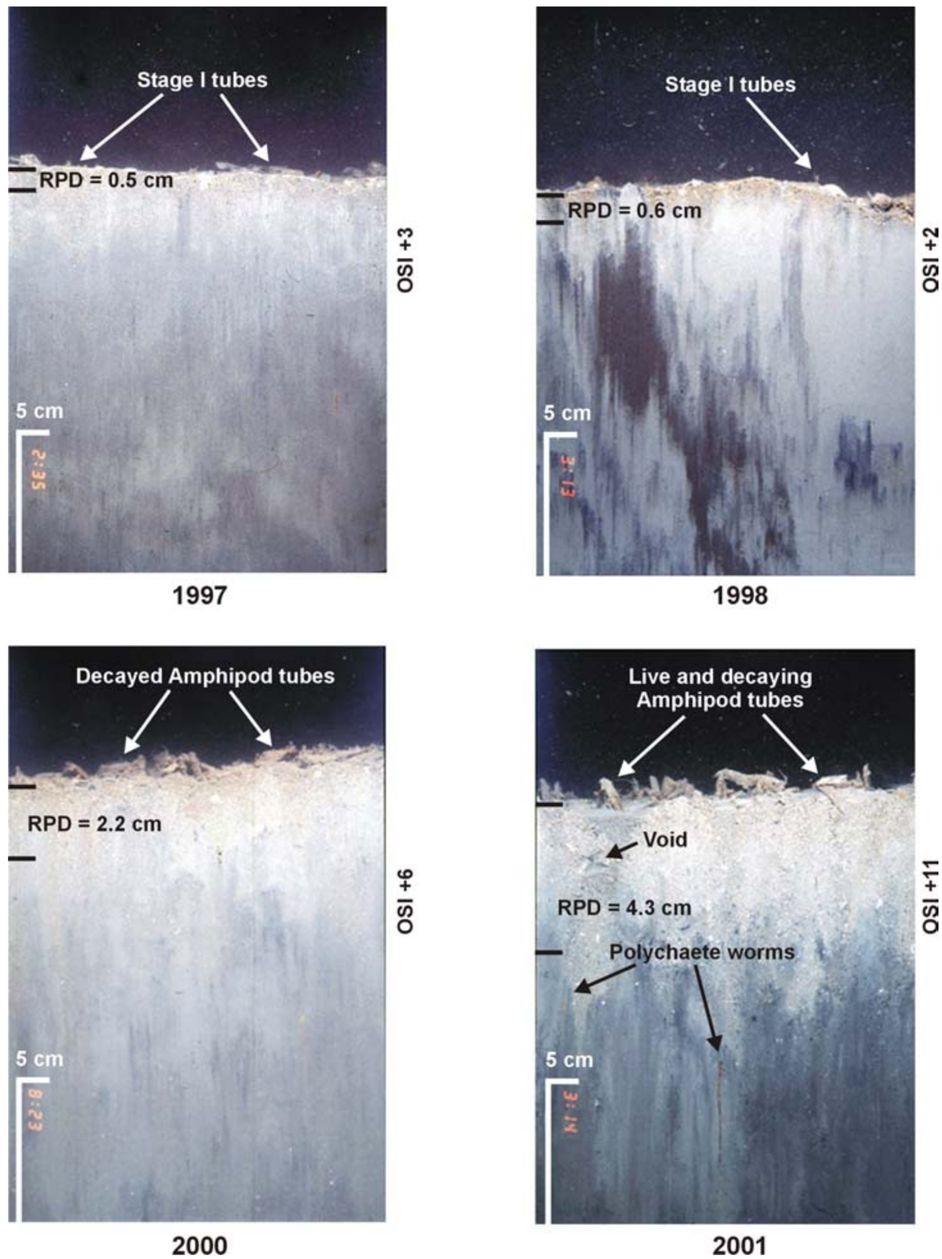


Figure 4-5. A series of REMOTS® images collected from Station 300WSW in the 1997, 1998, 2000, and 2001 surveys illustrating an increase in OSI values and benthic habitat conditions over 4 surveyed years. Apparent RPD depths have deepened over the years from a shallow depth of 0.5 cm in 1997 to a well-developed depth of 4.3 cm in 2001. Advanced successional stages (Stages II and III) marked by amphipod tubes and feeding voids were more prevalent in the 2000 and 2001 surveys.

results simply reflect natural seasonal variations in organic loading and organism abundance at the reference areas, and the results of future routine monitoring surveys are needed to help determine whether there is any real temporal trend emerging in overall benthic habitat quality in the area surrounding NLDS.

Benthic recolonization over the surface of the Seawolf Mound has been an ongoing process since creation of this bottom feature in 1996. The results of REMOTS® surveys conducted in September 1997, July 1998, August 2000, and June 2001 indicate a consistent pattern of increasing "infaunalization" over this mound, with the initial recolonizing community of surface-dwelling opportunists (mainly polychaetes and to some extent amphipods) being gradually supplemented with larger bodied, deeper dwelling taxa (deposit-feeding polychaetes and bivalves). In September 1997, only 4 of the 18 replicate images collected at the six benthic taxonomy stations showed evidence of Stage III taxa, while the other images revealed dominance of Stages I and II. Since the September 1997 survey, the percentage of images showing evidence of Stage III has increased steadily (6 of 18 in July 1998, 9 of 18 in August 2000, and 10 of 18 in June 2001), while Stage I and II taxa have continued to be observed in relative abundance. The steady increase with time in the abundance of Stage III equilibrium taxa is consistent with expectations based on previous investigations in Long Island Sound and elsewhere (McCall 1977; Pearson and Rosenberg 1978), that are the basis of the REMOTS® successional model (Rhoads et al. 1978; Rhoads and Boyer 1982; Rhoads and Germano 1982; 1986).

4.2.2 Benthic Taxonomy

All of the benthic samples collected over the Seawolf Mound in June 2001 had relatively high numbers of juvenile mussels (Family Mytilidae), probably reflecting a seasonal recruitment event. Larger mussels are sometimes observed attached to hard substrate in sediment-profile images collected within and around NLDS, but these epifaunal organisms are not considered typical constituents of benthic infaunal communities. For the present analysis, the Mytilids were considered ephemeral members of the benthic community and therefore not included in calculations of summary statistics.

Excluding the Mytilidae, a relatively small group of species was numerically dominant across the six stations. This group included the amphipod *Ampelisca vadorum* and the polychaetes *Ampharete finmarchica* and *Tharyx acutus*/Cirratulidae, which together accounted for 37% of the total overall abundance. Other numerical dominants across all six stations included the polychaetes *Monticellina baptisteae*, *Prionospio steenstrupi*, *Exogone dispar*, and *Aricidea catherinae*, the bivalve *Nucula annulata*, and Nematodes. Overall, there was a relatively high degree of similarity in species composition among the six stations, particularly in terms of the dominant taxa. This is reflected in the cluster analysis dendrogram, which shows >50% Bray-Curtis similarity among all six stations (Figure 3-13).

Station CTR was the least similar to the other five stations, having both lower total abundance excluding Mytilidae (221 compared to a range of 557 to 732 at the other five stations) and the lowest number of taxa (51 compared to 60–85). Similar results were obtained in the September 1997 survey and attributed to the greater physical disturbance experienced at the mound apex compared to the outlying mound plateau and apron regions, as well as to the presence of a surface layer of gray consolidated glacial clay at this location. The June 2001 REMOTS® sediment-profile images confirmed the continued presence of cohesive gray clay at stations near the mound apex. The lower food value of this clay and its relative resistance to penetration by infaunal organisms remain as plausible explanations for the observed dissimilar benthic community structure at Station CTR.

A comparison of the September 1997 and June 2001 benthic taxonomy data (Table 4-4) supports the conclusion that the Seawolf Mound has experienced steady recolonization by benthic organisms over time. Both the total and average (i.e., per station) numbers of individuals and taxa increased between the two years, with concomitant increases in diversity, evenness and species richness (Table 4-4). Several of the species that were numerically dominant in September 1997 were also among the dominants in June 2001, including the Stage II bivalve *Nucula annulata*, the tube-dwelling Stage II amphipod *Ampelisca vadorum*, and the Stage I polychaetes *Monticellina baptistae*, *Prionospio steenstrupi*, and *Tharyx acutus*. The relative abundance of these dominants differed between the two years, and some of the abundant species in 1997 (notably the Stage I polychaete *Mediomastus ambiseta*) were not among the dominants in 2001 (Table 4-3).

Both cluster analysis (Figure 4-6) and multidimensional scaling (Figure 4-7) provide graphic illustrations of the difference in community structure between the September 1997 and June 2001 surveys. The 1997 and 2001 stations form distinct groups in both representations, with Station CTR being less similar to the other five stations in both years. The ANOSIM test confirmed a statistically significant difference in community structure between 1997 and 2001 ($R = 0.841$), and the 30 species that contributed most strongly to this difference are listed in Table 4-5. This table shows that there were significant changes in the relative abundance of many of the dominant Stage I and II taxa. In addition, increases in both the abundance and diversity of Stage III organisms relative to 1997 were noted in the 2001 data set. Arrows superimposed on the MDS plot show the infaunal successional pattern underlying the 1997–2001 differences in community structure (Figure 4-8). These results suggest a substantial amount of progression has occurred within the benthic community over the four-year recovery period.

Table 4-4.
Comparison of the September 1997 and June 2001 Benthic Taxonomy Data

	1997	**2001**
Number of stations (samples)	6	6
Total number of individuals (all samples combined)	2,533	3,414
Total number of taxa (all samples combined)	100	143
Average no. individuals/station (± 1 s.d.)	422 ± 373	569 ± 188
Average no. of taxa/station (± 1 s.d.)	39 ± 16	67 ± 12
Avg. Shannon-Wiener diversity (H') ± 1 s.d.	2.47 ± 0.4	3.13 ± 0.19
Avg. Pielou's evenness (J') ± 1 s.d.	0.68 ± 0.11	0.73 ± 0.04
Avg. Margelef's species richness (d)	7.08 ± 2.1	11.3 ± 1.52
Ten most-abundant taxa, all samples combined (% of total abundance)	Nucula annulata (20%) Monticellina baptisteae (15%) Mediomastus ambiseta (13%) Prionospio steenstrupi (13%) Ampelisca vadorum (6%) Oligochaeta spp. (4%) Tharyx acutus (4%) Crepidula plana (2%) Anadara transversa (1%) Leptocheirus pinguis (1%)	Ampelisca vadorum (19%) Ampharete finmarchica (10%) Tharyx acutus (8%) Monticellina baptisteae (6%) Nucula annulata (6%) Cirratulidae (5%) Prionospio steenstrupi (5%) Exogone dispar (3%) Nematoda (2%) Aricidea (acmira) catherinae (2%)

Table 4-5.

List of the 30 Taxa Contributing Most Strongly to the Significant Difference in Benthic Community Structure between the September 1997 and June 2001 Surveys

Species/taxa	Successional Classification	Avg. abundance		% contribution to overall dissimilarity
		1997	2001	
Ampelisca vadorum	Stage II amphipod	28	105	4%
Ampharete finmarchica	Stage I polychaete	5	57	3%
Mediomastus ambiseta	Stage I polychaete	56	2	3%
Cirratulidae	Stage I polychaete	0	29	3%
Monticellina baptistae	Stage I polychaete	63	36	3%
Tharyx acutus	Stage I polychaete	16	44	2%
Nucula annulata	Stage II bivalve	88	32	2%
Nematoda	?	0	12	2%
Nephtyidae	Stage III polychaetes	0	10	2%
Prionospio steenstrupi	Stage I polychaete	55	26	2%
Mitrella lunata	? (gastropod)	0	10	2%
Exogone dispar	Stage III polychaete	2	14	2%
Polynoidae	Stage III polychaetes	0	10	2%
Crepidula plana	? (gastropod)	8	<1	2%
Photis dentata	Stage II amphipod	<1	9	2%
Diploydora caulleryi	Stage I polychaete	0	11	2%
Scalibregma inflatum	Stage III polychaete	0	10	2%
Oligochaeta spp.	Stage I opportunists	17	7	1%
Cerastoderma pinnulatum	? bivalve	<1	6	1%
Ampharetidae spp.	Stage I polychaetes	5	0	1%
Aricidea catherinae	Stage III polychaete	2	12	1%
Harmothoe extenuata	Stage III polychaete	1	9	1%
Anadara transversa	? (bivalve)	6	<1	1%
Diploydora socialis	Stage I polychaete	5	8	1%
Aeginina longicornis	Stage II amphipod	0	3	1%
Pinnixa sayana	? (decapod crustacean)	0	4	1%
Unciola irrorata	Stage II amphipod	3	6	1%
Ninoe nigripes	Stage III polychaete	2	5	1%
Asabellides oculata	Stage I polychaete	<1	3	1%
Corophium bonelli	Stage I/II amphipod	<1	6	1%

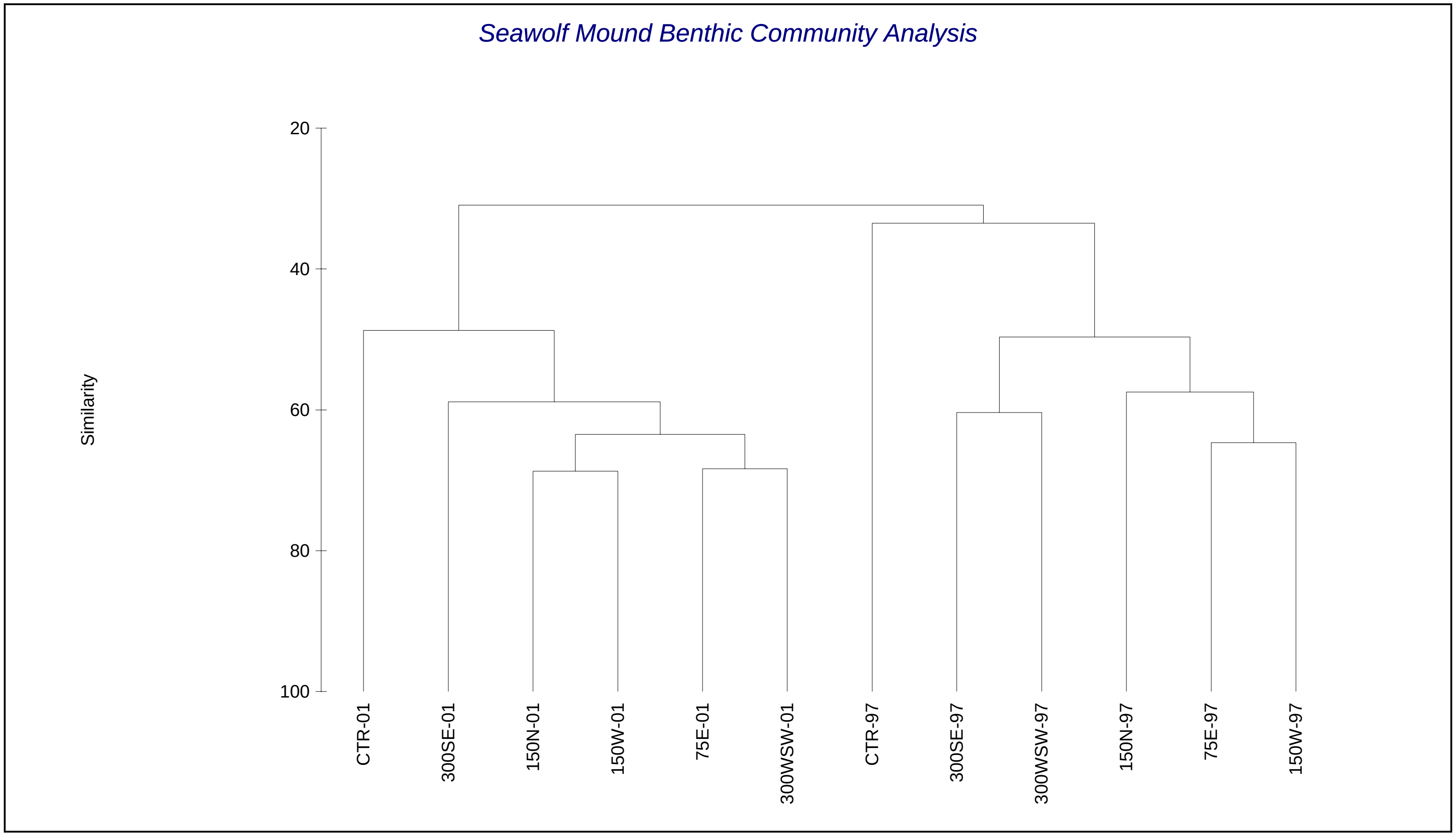


Figure 4-6. Cluster analysis dendrogram displaying the difference in community structure between the September 1997 and June 2001 surveys. The number following the station name indicates the year of sampling (e.g., CTR-01 indicates Station CTR sampled in June 2001).

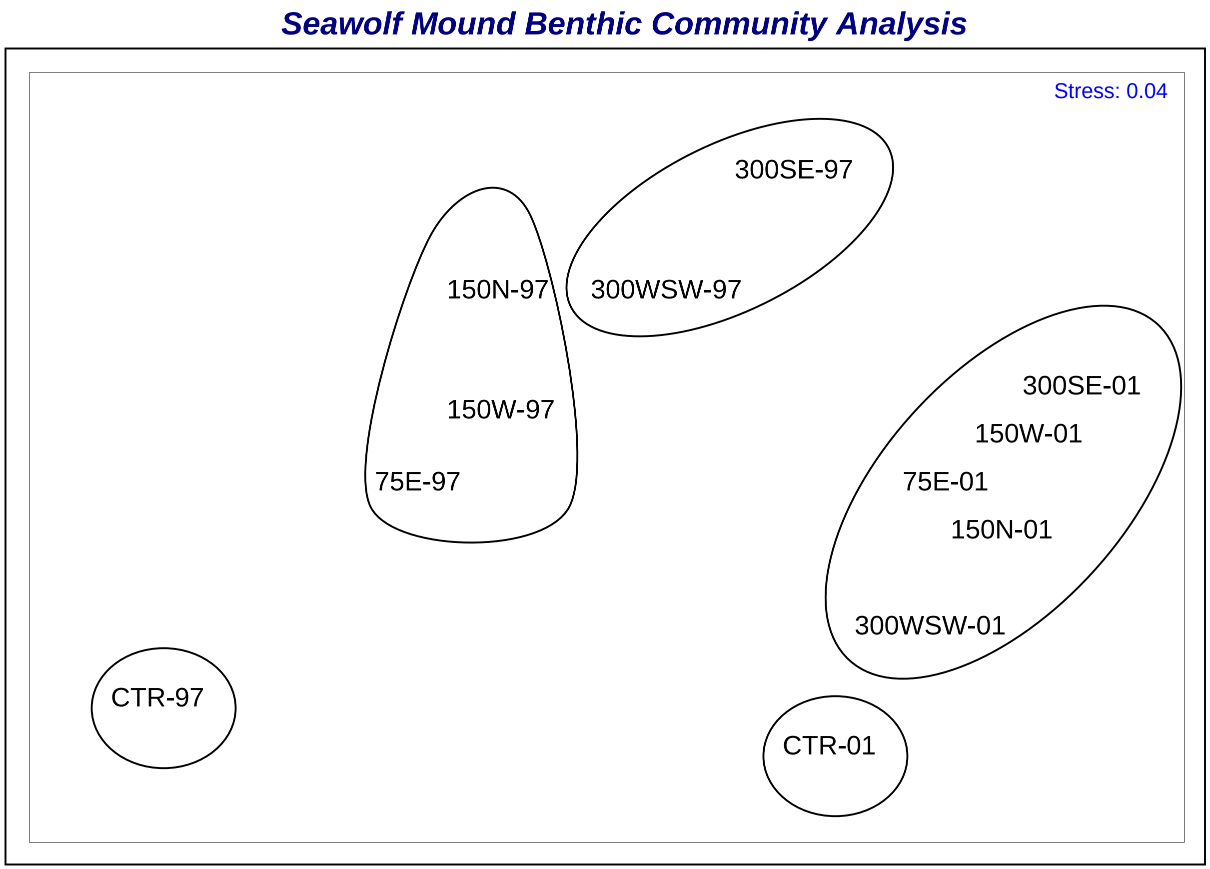


Figure 4-7. Two-dimensional MDS plot displaying the difference in community structure between the September 1997 and June 2001 surveys. The "stress" value in the upper right-hand corner indicates the degree of difficulty in representing the relationships among stations in this two-dimensional view. In general, stress values less than 0.05 indicate good ordering of the stations in two-dimensionals, with little prospect for misleading interpretation.

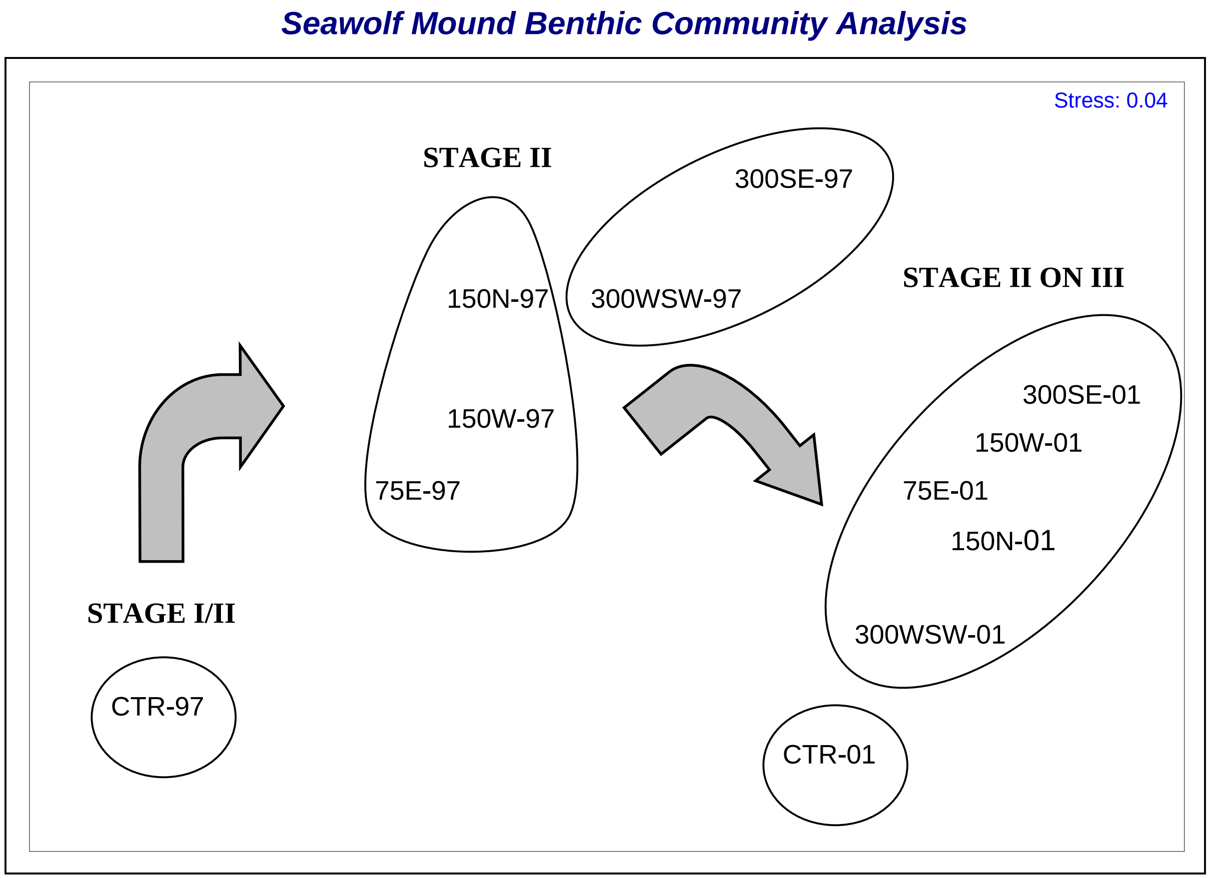


Figure 4-8. Two-dimensional MDS plot showing the infaunal successional pattern underlying the 1997–2001 differences in benthic community structure. The "stress" value in the upper right-hand corner indicates the degree of difficulty in representing the relationships among stations in this two-dimensional view. In general, stress values less than 0.05 indicate good ordering of the stations in two-dimensionals, with little prospect for misleading interpretation.

Comparisons between the average abundance values calculated for 1997 and 2001 surveys presented in Table 4-5 indicate the majority of the Stage I (59%) and Stage II (83%) species inhabiting the surficial sediments of the Seawolf Mound showed an increase in overall abundance. In addition, several of the known opportunistic species (i.e., Oligochetes, *Mediomastus ambiseta, Prionospio steenstrupi*) displayed a noticeable reduction in average number of individuals detected. Such changes are not unexpected, as populations of these surface-dwelling opportunists are known to vary as diversity increases during the progression from early recolonization to full benthic community recovery.

Of greater ecological significance was the increase in the numbers of polychaetes (Stage III) detected within the surficial sediments in comparison to 1997. Representatives of the families Polynoidae and Nephtyidae were absent in 1997, but found in relatively high numbers in 2001. This finding indicates the existence of an ample food source (biomass) to sustain populations of these large-bodied carnivores. Overall, the average abundance values for all Stage III species (deposit-feeding and carnivorous) inhabiting the Seawolf Mound in 1997 (e.g., *Aricidea catherinae*, *Ninoe nigripes*, *Exogone dispar*, *Harmothoe extenuata*) increased in the 2001 data, suggesting the consistent development of an advanced benthic community over the four-year period. These findings are indicative of increased species diversity over the surface of the Seawolf Mound as the benthic community status has progressed from the early stages of recovery in 1997 to that of stability in 2001.

In the MDS plot (Figure 4-7), the 1997 station groupings are looser than in 2001, indicating a higher degree of among-station dissimilarity in species composition and abundance. This is attributed to the stronger gradient in physical disturbance that existed in 1997 (1.5 years postdisposal) moving from the mound apex (Stations CTR and 75E) to the mound plateau (Stations 150N and 150W) and apron regions (Stations 300SE and 300WSW). With the exception of Station CTR, the tighter grouping of the June 2001 stations indicates much greater among-station similarity in community structure. At five years postdisposal, sufficient time had passed following the original disturbance for the benthic community across the mound to converge on a common, advanced successional endpoint. The cohesive clay at Station CTR is a vestige of this disturbance that has continued to impede succession relative to the other stations. As the clay breaks down over time and greater amounts of organic matter become incorporated, recolonization is expected to proceed at this station, albeit more slowly than at other stations.

4.2.3 Evaluation of Benthic Community Status

Both the REMOTS® images and benthic taxonomy results are useful for assessing benthic recolonization status over the Seawolf Mound. The images revealed an abundant and diverse mixture of both surface-dwelling and deeper dwelling organisms. Feeding voids, evidence of the presence of subsurface deposit feeders, were observed in 10 of the 18 (55%) replicate images obtained at the six stations. In all ten of these images, Stage I polychaete tubes and/or Stage II amphipod tubes were also present at the sediment surface, resulting in infaunal successional designations of Stage I on III or Stage II on III. Stage I polychaete tubes, either alone or together with Stage II amphipod tubes, were observed in the remaining eight images, resulting in successional designations of Stage I or Stage I advancing to Stage II.

Overall, the REMOTS® results indicate that benthic recolonization over the surface of the Seawolf Mound was relatively advanced at the time of the June 2001 survey, with abundant evidence of a mature or "equilibrium" community (*sensu* McCall 1977) consisting of head-down, subsurface-deposit-feeding infauna (i.e., Stage III). There also continued to be a Stage I/II community visible at the sediment surface, consisting mainly of abundant, small, tube-dwelling polychaetes and amphipods. It is not uncommon for both opportunistic, Stage I and II surface-dwellers to be observed together with deeper dwelling, Stage III infauna in sediment-profile images, resulting in "Stage I on III" or "Stage II on III" successional designations (Rhoads and Germano 1986). Recently, Zajac (2001) has proposed modifications to the REMOTS® infaunal successional model in which a variety of endpoints (e.g., combinations of Stages I, II and III) are possible in Long Island Sound.

The benthic taxonomy data serve to ground-truth the REMOTS® successional stage designations. Surface-dwelling, Stage I polychaetes (e.g., *Ampharete finmarchica*, *Tharyx acutus*, *Monticellina baptistae*, Cirratulidae, and *Prionospio steenstrupi*) and the tube-dwelling, Stage II amphipod *Ampelisca vadorum* were among the most ubiquitous and abundant organisms collected across the mound (see Table 3-10). The protobranch bivalve *Nucula annulata*, considered a late Stage II/early Stage III species, also was found in relative abundance. Both the Stage I polychaetes and Stage II amphipods were present at high enough densities at each station to be readily visible in the sediment-profile images, resulting in all images being assigned at least a Stage I or II successional designation.

Subsurface-deposit-feeding, Stage III polychaetes, including *Scalibregma inflatum*, the Paraonid *Aricidea (acmira) catherinae*, the Lumbrinerid *Ninoe nigripes* and Family Maldanidae, also were present in relative abundance at all of the stations except CTR (see Table 3-10). Carnivorous polychaetes like *Exogone dispar*, *Harmothoe extenuata*, *Nephtyidae*, and *Glycera* are also indicative of mature, Stage III assemblages and were relatively abundant away from Station CTR. The taxonomy data showing significant numbers of deeper dwelling, deposit-feeding taxa therefore indicates advanced, Stage III recolonization over most of the Seawolf Mound. Given the abundance of surface dwellers along with the subsurface deposit feeders, the benthic assemblage at five of the six stations in June 2001 was best characterized as a well-developed Stage II on III community. At Station CTR, the continued dominance of surface-dwelling opportunists and the relative absence of deeper deposit-feeding and carnivorous polychaetes suggest less advanced recolonization. The community at this station was best characterized as Stage I, with some advancement into Stage II due to the presence of *Ampelisca vadorum* and *Nucula annulata*.

Except for Station CTR, there was good agreement between the sediment-profile imaging results, which indicated the widespread presence of Stages I on III and/or II on III, and the benthic taxonomy data. Two of the REMOTS® images obtained at Station CTR indicated Stage I only or Stage I advancing to Stage II conditions, consistent with the taxonomic results, while the third image indicated the presence of Stage II on III. The evidence of Stage III in only one of the three replicate images may be reflecting the lower abundance of subsurface-deposit-feeding polychaetes at this station. In general, the REMOTS® results suggested a more advanced recolonization status at this station (Stage II on III) than concluded from the taxonomy results (Stage I advancing to II). As discussed above, the cohesive gray clay at this station near the mound apex probably continues to represent a poorer food source and a hindrance to penetration by significant numbers of deeper dwelling, Stage II/III infauna.

5.0 CONCLUSIONS AND RECOMMENDATIONS

- Physical and chemical analyses of vibracores collected in June 2001 served to verify that sediment comprising at least the upper 0.5 m of the Seawolf Mound was capping dredged material (CDM). Specifically, seven short cores collected within the acoustically detectible footprint of the mound confirmed the presence of at least 0.5 m of CDM at various locations, and three long cores confirmed CDM thickness for the inner, middle, and outer zones of the mound on the order of 1 to 2 m thick.

- Results of sediment chemistry analyses for cores from the disposal area were comparable to previous surveys conducted in 1997 and 1998, and comparable to, or less than, the pre-dredging sediment testing results for UDM and CDM. Results indicated lack of physical and chemical contamination of the surface sediments, including relatively thick CDM layers sampled in the long cores.

- Two cores collected beyond the acoustically detected footprint of the mound (Cores 27 and 29), in areas not sampled during the 1997 and 1998 surveys, exhibited somewhat higher concentrations of metals and PAHs when compared to the samples from the disposal mound and reference area. Concentrations were still generally less than the pre-dredging UDM/CDM concentrations. This material likely reflects non-Seawolf related dredged material disposal in the vicinity and may consist of historic (e.g., pre-Seawolf) material and/or material deposited at the NDA 95 buoy near these stations and within the same timeframe as the Seawolf capping activities.

- Sediment chemistry compared to conservative ecological benchmarks indicates negligible potential for adverse effects to benthic infauna that may be in contact with the sediments in the Seawolf Mound, even for the maximum concentrations of environmental contaminants detected in the survey.

- REMOTS® sediment-profile images showed that benthic organisms were abundant over the Seawolf Mound at the time of the June 2001 survey. Dense assemblages of early- to mid-stage colonizers (successional stages I and II) were visible at the sediment surface, and there was ample evidence that larger-bodied, deeper-dwelling taxa (Stage III) were inhabiting the mound surface in significant numbers.

- Based on the REMOTS® image interpretation, the benthic community was characterized as representing an advanced, Stage II on III successional status. The median OSI value of +8.2 for the Seawolf Mound indicated undisturbed benthic habitat condition. This median OSI value for the Seawolf Mound was higher than the median value of +5.5 at the NLDS reference areas. The lower reference area value reflects a difference in sediment type (coarser material) that likely accounted for comparatively less Stage III activity.

- Benthic taxonomic data collected at the Seawolf Mound stations served to verify the REMOTS® image interpretation. The benthic community was found to consist of both surface-dwelling opportunists and subsurface deposit feeders indicative of an advanced successional stage.

- Compared to the results of the September 1997 survey conducted 1.5 years following creation of the capped mound, the benthic community in June 2001 (five years postcap) was more abundant, had significantly more species present, and had greater diversity and evenness. These results showing an advanced benthic recolonization of the Seawolf Mound at five years postcap were consistent with expectations based on the standard model of benthic infaunal succession in Long Island Sound.

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