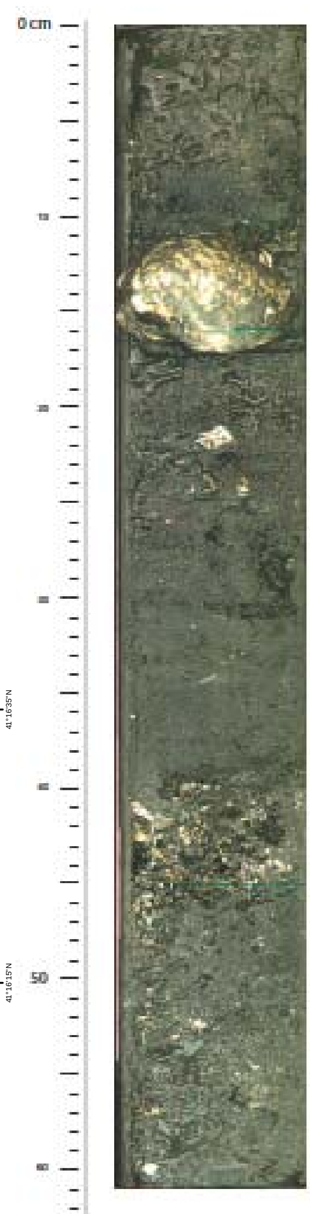
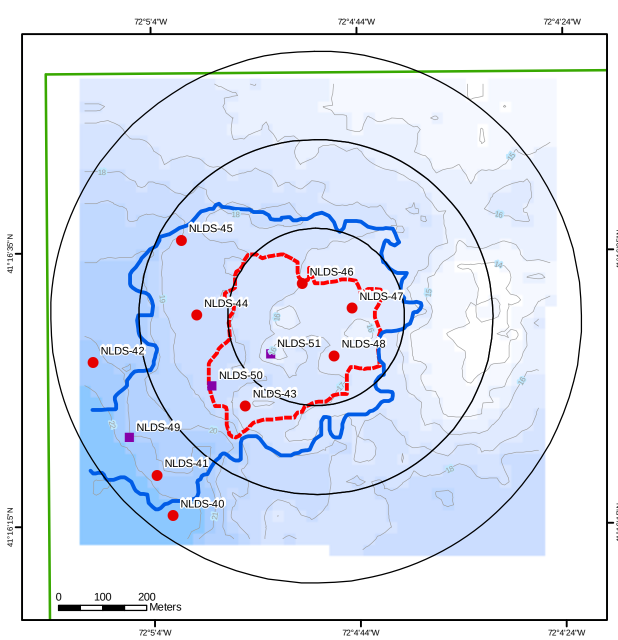
Monitoring Survey at the Seawolf Disposal Mound
June/July 2006

Disposal Area Monitoring System DAMOS



DAMOS
DISPOSAL AREA MONITORING SYSTEM



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13. ABSTRACT

A monitoring survey was conducted at the Seawolf Disposal Mound in the summer of 2006 to fulfill the Year 10 requirement of the monitoring plan, prepared as part of the permit issued for dredging operations at the Groton Submarine Base and in the Thames River channel in Connecticut on behalf of the U.S. Navy. The Seawolf Mound is a capped disposal mound at the New London Disposal Site (NLDS) in Long Island Sound formed in 1995-1996 by the initial placement of over 300,000 m^3 of dredged sediment contaminated with metals and PAHs, followed by the placement of over 550,000 m^3 of dredged capping sediment suitable for unconfined open water disposal.

The Year 10 survey included multi-beam bathymetry, sediment-profile imaging, benthic biological sampling, and sediment coring. The objectives of the surveys were to: 1) document the continued recovery of the surface sediments over the Seawolf Mound by assessing benthic conditions and infaunal successional status in comparison to the conditions detected at three DAMOS reference areas surrounding NLDS, 2) assess the integrity of the cap material by analyzing short and long cores for a suite of physical and chemical parameters, and 3) assess the long term stability of the Seawolf Mound by evaluating changes in bathymetry.

The results of the 2006 Seawolf Mound survey confirmed the biological recovery and stability identified during previous surveys. The multi-beam bathymetry identified no significant changes in the footprint of the mound on the bottom or its depth below the sea surface from the previous survey in 2003. The physical and chemical profiles in the sediment cores collected over the mound indicated a consistent cap sequestering the underlying contaminated horizons, as well as underlying ambient sediments and relic dredged material. The mature benthic community identified on the Seawolf Mound in 2006 showed a complete recovery since initial mound formation, supporting a community with high densities of Stage III fauna no different than that found at the NLDS reference areas.

Collectively, the different monitoring elements of the 2006 survey revealed a fully recovered benthic system that did not appear to be subjected to physical disturbance indicative of large scale sediment movement or chemical disturbance detrimental to the benthic ecosystem. A review of the full series of monitoring events since formation of the Seawolf Mound indicates that the top few centimeters of sediment is apparently subject to periods of transport and deposition within Long Island Sound, however, these transport and deposition processes appear to only affect the uppermost sediment layer, given the long-term stability of the Seawolf Mound, even following the passage of a significant coastal storm in 2002.

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EXECUTIVE SUMMARY

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The results of the 2006 Seawolf mound survey confirmed the biological recovery and stability identified during previous surveys. The multi-beam bathymetry identified no significant changes in the footprint of the mound on the bottom or its depth below the sea surface from the previous survey in 2003. The physical and chemical profiles in the sediment cores collected over the mound indicated a consistent cap sequestering the underlying contaminated horizons, as well as underlying ambient sediments and relic dredged material. The mature benthic community identified on the Seawolf mound in 2006 showed a complete recovery since initial mound formation, supporting a community with high densities of Stage 3 fauna no different than that found at the NLDS reference areas. The less frequent observation of mussels in the 2006 sediment profile imaging was attributed to the random placement of the SPI camera or a reflection of the natural progression of the community.

Collectively, the different monitoring elements of the 2006 survey revealed a fully recovered benthic system that did not appear to be subjected to physical disturbance indicative of large scale sediment movement or chemical disturbance detrimental to the benthic ecosystem. A review of the full series of monitoring events since formation of the Seawolf mound indicates that the top few centimeters of sediment is apparently subject to periods of transport and deposition within Long Island Sound, resulting in varying amount of shell lag and extent of armoring. However, these transport and deposition processes appear to only affect the uppermost sediment layer, given the long-term stability of the Seawolf mound, even following the passage of a significant coastal storm in 2002.

The objectives of the Year 10 monitoring program were fully met. However, given the long-term interest in capping as a management tool for contaminated sediment and the opportunity to build on this long term dataset, performance of periodic multi-beam bathymetric surveying is proposed. Also, repeating portions of the 2006 coring effort during a future survey is recommended to better understand the PAH concentrations observed in the 2006 survey and the potential effect of different analyses and preparation methods between the 2006 and earlier 1998-2001 surveys.

1.0 INTRODUCTION

The New London Disposal Site (NLDS) is an active open-water dredged material disposal site located 5.4 km (3.1 nmi) south of Eastern Point, Groton, Connecticut (Figure 1-1). Disposal in the vicinity of New London has taken place since 1955 (SAIC 2001a) with the formation of multiple disposal mounds on the seafloor. The U.S. Navy initiated a comprehensive study of the New London Disposal Site in 1973 (SAIC 2001a), but the New England District of the U.S. Army Corps of Engineers took over monitoring responsibility of this site with the inception of its Disposal Area Monitoring System (DAMOS) Program in 1977 along with the monitoring of three other active disposal sites in Long Island Sound (Fredette et al. 1993).

The Seawolf mound at NLDS was formed in 1995/1996 from material dredged from Groton, Connecticut on behalf of the Navy as part of homeport development for the Seawolf class of submarines. This mound has been a focus of multiple DAMOS monitoring surveys since that time. An introduction to the DAMOS Program and background on the Seawolf mound, including a brief description of previous dredged material disposal activities at NLDS and previous monitoring surveys, is provided below.

1.1 Overview of the DAMOS Program

DAMOS is a comprehensive monitoring and management program designed and conducted to ensure environmental protection at open-water disposal sites throughout the New England region. For over 30 years the DAMOS Program has collected and evaluated disposal site data throughout New England. Patterns of physical, chemical, and biological responses of seafloor environments to dredged material disposal activity have been documented based on these data (Fredette and French 2004).

DAMOS monitoring surveys are designed to test hypotheses related to expected physical and ecological response patterns following placement of dredged material on the seafloor at established disposal sites. The data collected and evaluated during DAMOS monitoring surveys provide answers to strategic questions in determining the next step in the disposal site environmental management process. Focused studies are periodically undertaken within the DAMOS Program to evaluate inactive/historic disposal sites. Although monitoring of the Seawolf mound was initiated by the U.S. Navy, the DAMOS Program is responsible for the overall management of disposal at NLDS.

1.2 Introduction to the Seawolf Disposal Mound and NLDS Management

The Seawolf disposal mound is a historic, capped disposal mound located in the northwest quadrant of NLDS (Figure 1-1). The Seawolf mound was developed from

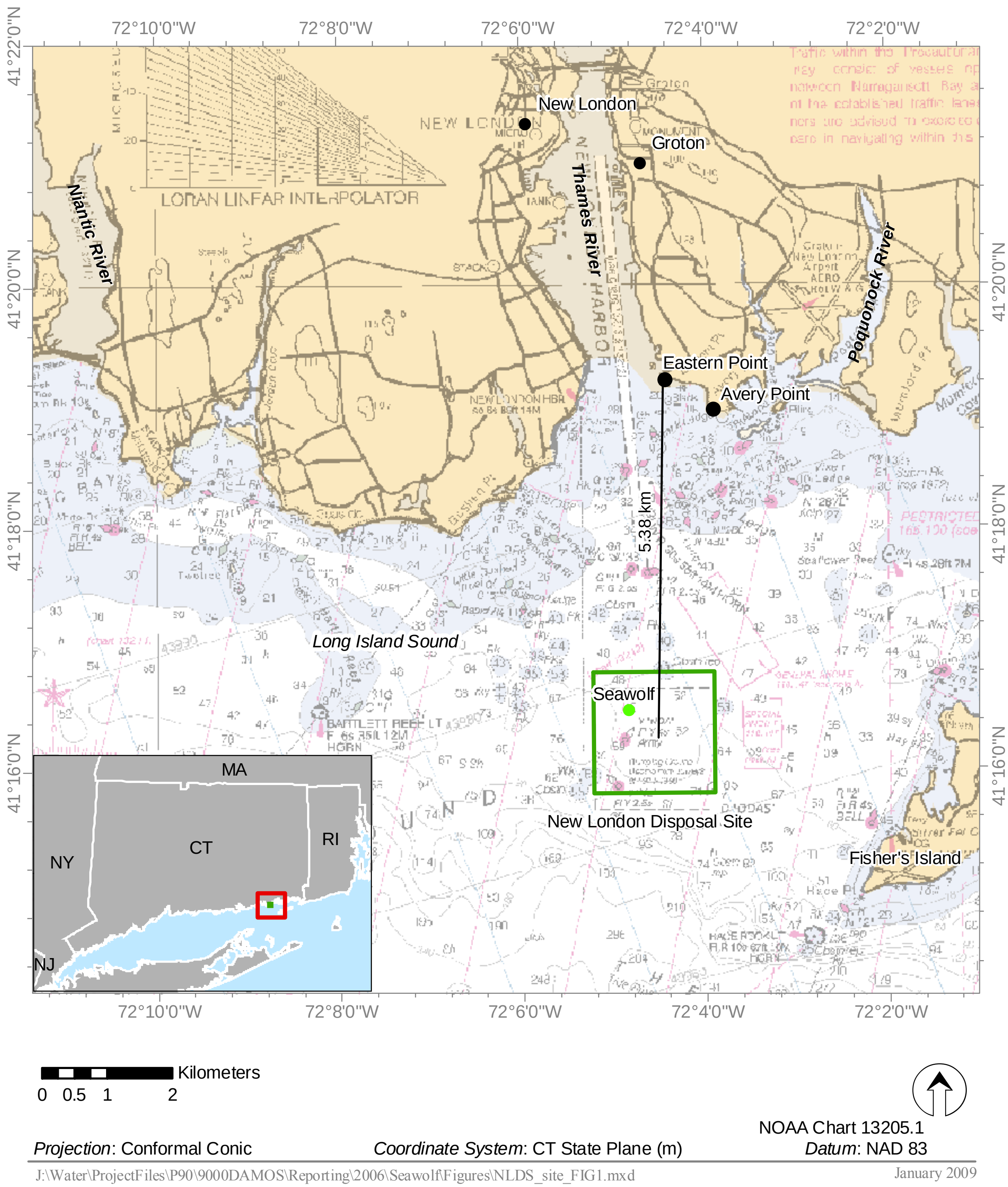


Figure 1-1. Location of the Seawolf mound within the New London Disposal Site, Long Island Sound

material generated by dredging operations at the Groton Submarine Base and in the Thames River channel on behalf of the U.S. Navy during the 1995/96 disposal season. The dredging operations were conducted to accommodate the *Seawolf* class submarines in Groton, Connecticut; this project, along with a small-scale Mystic River dredging project, resulted in the placement at NLDS of 306,000 m^3 of material assessed unsuitable for unconfined open water disposal (termed unacceptable dredged material or UDM). In the same disposal season, this UDM was covered by 556,000 m^3 of coarser grained material dredged from the Thames River channel determined to be suitable for unconfined open-water disposal (termed capping dredged material or CDM). An additional 15,500 m^3 of sediments from Venetian Harbor and Mystic River were also placed in the same region of NLDS during placement of UDM and CDM in 1995/1996, resulting in a total estimated volume of 877,500 m^3 of sediment deposited at the Seawolf mound (SAIC 2001a). This type of capping is a dredged material disposal management strategy that has been used successfully in New England over the past 30 years.

In recent years, management objectives have sought to minimize the lateral spread of dredged material upon disposal at NLDS by taking advantage of the topography of the site and filling in depressions between historic disposal mounds. This approach has the advantage of maximizing the site capacity while minimizing the amount of CDM required to completely cover and contain a UDM deposit (Carey 1998). Additionally, targeted disposal operations have developed broad, flat mounds at NLDS in order to maintain a minimum water depth of 14 m to allow for safe passage of deeper draft vessels and reduce the effects of bottom currents and storm-generated waves on sediments (NUSC 1979).

1.3 Previous Monitoring of Seawolf Disposal Mound

The pre-dredging characterization of the *Seawolf* submarine base project sediments was based on adverse biological testing results likely caused by elevated levels of polycyclic aromatic hydrocarbons (PAHs) and trace metals (copper, chromium, and zinc), thus classifying the sediment as UDM. The disposal of these contaminated sediments required a comprehensive disposal site monitoring program to ensure adequate placement of CDM to isolate the UDM from the environment. The monitoring program included baseline surveys, pre-capping and post-capping surveys to ensure proper placement of UDM and adequate coverage with CDM, and subsequent monitoring surveys to document benthic recovery and potential physical changes over time.

Several types of surveys have been conducted at the Seawolf mound to meet the monitoring requirements specified in the original dredging permit for the project. Periodic surveys were required to document the stability and integrity of the Seawolf mound (Table 1-1). Bathymetric surveys were conducted prior to and during the mound formation as well as at several post-disposal intervals to document changes in bottom topography due to dredged material disposal and longer term consolidation. Sediment-profile imaging was used to assess the benthic recolonization status and to observe any indications of sediment erosion of the

Seawolf mound relative to three reference areas surrounding NLDS. Sediment grab samples were collected to examine the benthic infaunal species diversity and relative abundance over the surface of the Seawolf mound, and sediment cores were collected over the mound to assess the physical and chemical composition of the deposited sediments and to determine the thickness of the CDM layer.

The most recent monitoring conducted at the Seawolf mound prior to 2006 was a post-storm survey designed to investigate any large-scale changes in seafloor topography at the site and to identify potential surface disturbance caused by storm-generated waves (SAIC 2003). Bathymetric surveys were conducted in October 2002 and February 2003 after the passage of an intense coastal storm in the eastern Long Island Sound region to assess the stability of the capped mound and to determine the potential for widespread erosion due to wave-induced sediment transport. Findings indicated no appreciable changes in large-scale mound morphology following the storm event. The results of the sediment-profile imaging and side-scan sonar surveys did not show any evidence of recent disturbance or erosion, and results were consistent with the previous surveys showing a steady recovery of the benthic community to more advanced successional stages. As with the previous two surveys (August 2000 and June 2001), the October 2002 sediment-profile imaging results indicated increasingly more mature, equilibrium (Stage 3) organisms compared to the nearby reference areas.

1.4 Survey Objectives

The 2006 survey at the Seawolf mound was conducted to fulfill the Year 10 requirement of the monitoring plan, prepared as part of the permit issued for the dredging and disposal operations at the Groton Submarine Base and in the Thames River channel on behalf of the U.S. Navy. The Year 10 survey included sediment-profile imaging, bathymetry, sediment grab sampling, and sediment coring. Specifically, the objectives of the surveys were to:

1) Document the continued recovery of the surface sediments over the Seawolf mound by assessing benthic conditions and infaunal successional status in comparison to the conditions detected at three DAMOS reference areas surrounding NLDS,

2) Assess the integrity of the cap material by analyzing short and long cores for a suite of physical and chemical properties, and

3) Evaluate the long term stability of the Seawolf mound by assessing changes in bathymetry in comparison to previous surveys.

Table 1-1.

Overview of Previous Monitoring Surveys at Seawolf Mound since 1997

Date	Purpose of Survey	Bathymetry Area (m x m)	No. SPI Stations	No. Sediment Cores	No. Benthic Grabs	Other Studies	Reference
October 1995	Baseline	1000 x 1000					SAIC 2001a
December 1995	Pre-cap	1000 x 1000					SAIC 2001a
February 1996	Post-cap	1000 x 1000					SAIC 2001a
September 1997	1.5 yr post-cap monitoring	1000 x 1000	Site: 29 Ref: 13	Site: 12 Ref: 1	Site: 6		SAIC 2001a
July 1998	2.5 yr post-cap monitoring	1000 x 1000	Site: 29 Ref: 13	Site: 12 Ref: 1			SAIC 2001a
August 2000	Periodic monitoring	1000 x 1000	Site: 29 Ref: 13				SAIC 2001b
June 2001	5 yr post-cap monitoring		Site: 29 Ref: 13	Site: 12 Ref: 1	Site: 6		SAIC 2004
October 2002	Post-storm monitoring	1000 x 1000	Site: 29 Ref: 13			Side-scan	SAIC 2003
February 2003	Post-storm monitoring	1000 x 1000					SAIC 2003

2.0 METHODS

A team of investigators from AECOM (formerly ENSR), CR Environmental, Ocean Surveys Inc. (OSI), CoastalVision, and Germano & Associates conducted the June/July 2006 surveys at the Seawolf mound. The sediment-profile imaging and benthic grab survey was conducted 13-14 June 2006 aboard the F/V *Shanna Rose*. The sediment coring survey was conducted 17-18 July 2006 aboard the R/V *Candu*, and the bathymetry survey was conducted 19-20 July 2006 aboard the R/V *Able II*. The cores were sub-sampled and analyzed for physical characteristics by the Marine Geomechanics Lab at the University of Rhode Island (URI). Additional chemical analysis of the cores was performed by Alpha Woods Hole Environmental Laboratories.

Field activities are summarized in Table 2-1, and an overview of the methods used to collect, process, and analyze the survey data is provided below. The details of the approach and methods used to collect the data are presented in the project Sampling and Analysis Plan/Quality Assurance Project Plan (QAPP, Appendix A).

2.1 Bathymetry

Bathymetric surveys provide measurements of water depth that, when processed, can be used to map the seafloor topography. The processed data can also be compared with previous surveys to track changes in the size and location of seafloor features. This technique is the primary tool in the DAMOS Program for mapping the distribution and assessing the stability of dredged material at disposal sites.

2.1.1 Bathymetric Data Collection

The 2006 multi-beam bathymetric survey of the Seawolf mound covered a 1000 x 1000 m area (Figure 2-1) in the northwest quadrant of NLDS. The bathymetric survey was conducted 19-20 July 2006 aboard the R/V *Able II*. A total of 37 survey lines, each approximately 25 m apart and oriented in an east-west direction, were occupied as part of the survey (Figure 2-1). Additional tie-lines were occupied perpendicular to the main survey lines to assess data quality.

The bathymetric data were collected using a Reson 8125 Ultra High Resolution Echo Sounder outfitted with a 0.5°, 455-kHz transducer. A motion sensor was combined with the GPS to provide accurate heading and measurement of heave, pitch, and roll. The system was calibrated for local water mass speed of sound by performing conductivity-temperature-density (CTD) casts at frequent intervals throughout the day with a Seabird SBE-19 Seacat CTD profiler.

Water depths over the survey area were recorded in meters and referenced to mean lower low water (MLLW) based on the NOAA tide station located in New London,

Table 2-1.

Seawolf Field Activities Summary, June/July 2006

Survey Type	Date	Summary
Sediment-Profile Imaging	13 June 2006	Stations: 26 Site: 13 Reference: 13
Benthic Biology Grabs	14 June 2006	Stations: 9 Site: 6 Reference: 3
Sediment Coring	17 – 18 July 2006	Stations: 13 Site: 12 Short: 9 Long: 3 Reference: 1 (short)
Multi-Beam Bathymetry	19 - 20 July 2006	Area: 1000 x 1000 m Lines: 37 Spacing: ~25 m

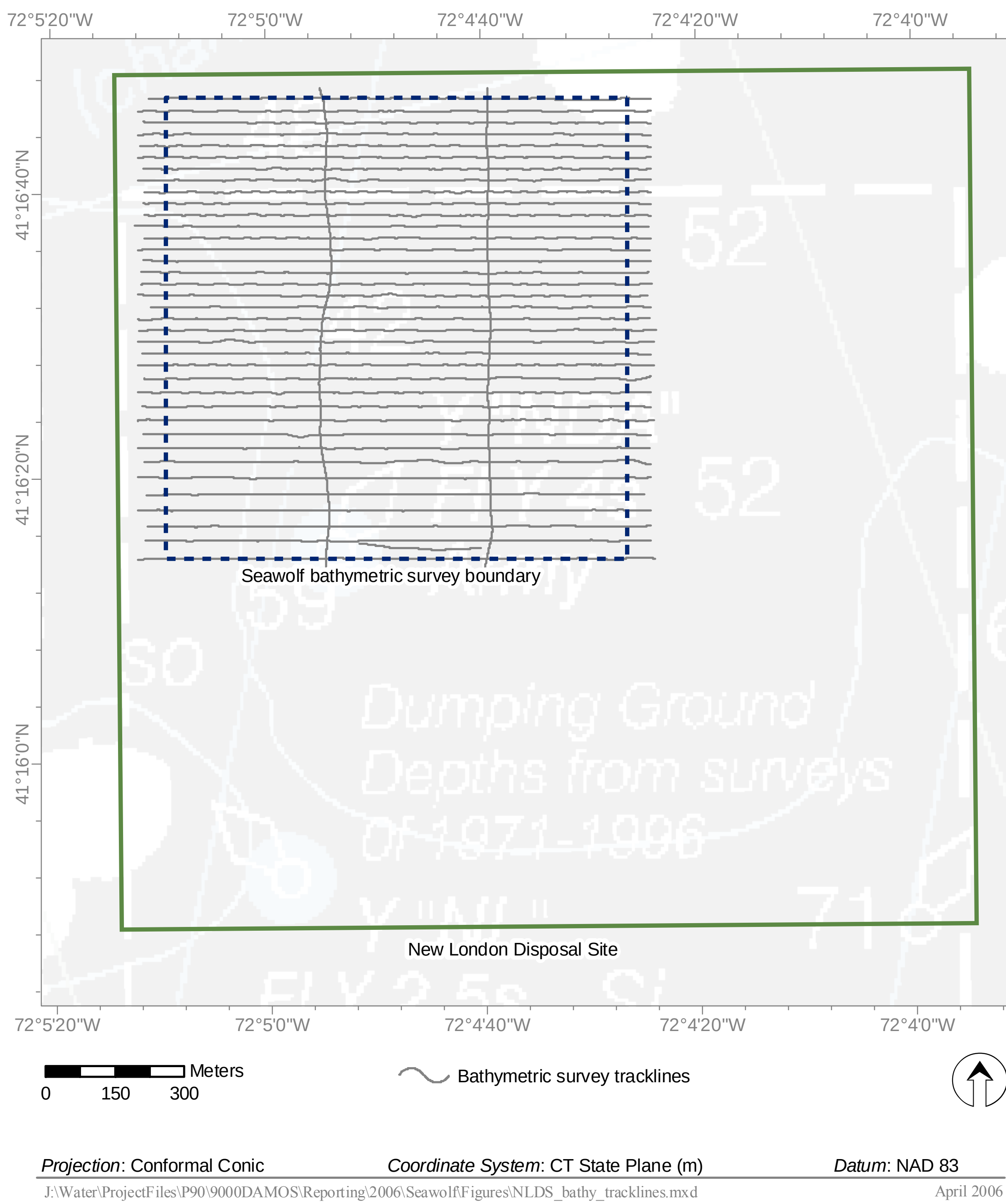


Figure 2-1. Bathymetry survey boundary and tracklines at Seawolf mound, July 2006

Connecticut. The HYPACK® software program managed data acquisition and storage of data from the echosounder and the navigation system. HYPACK® also recorded depth, vessel heave, heading, position, and time along each survey transect line.

2.1.2 Bathymetric Data Processing

The bathymetric data were processed using the HYPACK® software program and included corrections for tidal conditions, local speed of sound, and spurious data points. Tidal correction consisted of transforming the raw measurements of depth below the transducer to seafloor elevation measurements relative to MLLW using the locally collected tidal elevation data. Heave data supplied by the motion sensor was incorporated into the raw data to minimize the effects of vessel motion. The bathymetric data were also reviewed for spurious data points (clearly unrealistic measurements resulting from signal interference), and these points were removed. The final dataset was averaged into 0.5-m square bins. All soundings located within a given bin were averaged, and the average value was assigned to the coordinates at the center of the bin.

2.1.3 Bathymetric Data Analysis

Bathymetric data were analyzed to document changes in seafloor topography in comparison with previous surveys. The corrected bathymetric data were processed for display using a combination of the contouring and surface plotting software program Surfer® 8.0 and the GIS-based software package ArcView® 9.1. Using Surfer®, the processed bathymetry data were converted into grids. Once gridded, bathymetric contour lines were generated and displayed using ArcView®.

Surfer® was also used to generate a depth-difference grid based on prior bathymetry data collected in February 2003. The depth difference grid was calculated by subtracting the July 2006 interpolated depth estimates from the prior depth estimates at each point throughout the grid. The resulting depth differences were contoured and displayed using ArcView®.

2.2 Sediment-Profile Imaging

Sediment-profile imaging (SPI) is a monitoring technique used to provide data on the physical characteristics of the seafloor as well as the status of the benthic biological community. The technique involves deploying an underwater camera system that photographs a cross section of the sediment-water interface. Acquisition of high-resolution SPI images is accomplished using a Nikon® D100 digital single-lens reflex camera mounted inside an Ocean Imaging Systems Model 3731 pressure housing system. Computer-aided analysis of the resulting images provides a set of standard measurements that can be compared between different locations and different surveys. The DAMOS Program has successfully used this technique for over 20 years to map the distribution of disposed dredged material and to monitor benthic recolonization at disposal sites. For a detailed discussion of SPI methodology, see ENSR (2004).

2.2.1 SPI Data Collection

The field team collected SPI images on 13 June 2006 at 13 stations on the Seawolf mound and at 13 reference stations distributed among three previously established reference areas (Table 2-2, Figure 2-2). Six of the stations on the mound (CTR, 75E, 150N, 150W, 300WSW, and 300SE) are locations that were sampled during previous monitoring surveys, and an additional seven stations (SW-01 – SW-07) were randomly located on the mound in order to provide sufficient data to compare mound conditions with those found at the reference areas.

As part of the 2006 survey, three reference areas were surveyed: west of the disposal site (WREF), northeast of the disposal site (NEREF), and east-northeast of the disposal site (NLONREF) to provide a basis of comparison between sediment conditions on the Seawolf mound and the ambient sediment conditions in Long Island Sound. Five reference stations were selected randomly within a 300-m radius of the center the WREF area, and four stations were randomly selected within both the NEREF and NLONREF areas (Table 2-2, Figure 2-2).

At each station, the vessel was positioned at the target coordinates, and the camera frame was deployed within a defined station tolerance of 10 m. At least three replicate SPI images were collected at each of the 26 stations.

Positional data, comprised of horizontal positioning (x- and y-dimensional data) and time (t-dimensional data), were collected using a Trimble® AG-132 Differential Global Position System (DGPS) unit. This system received and processed satellite and land-based beacon data and provided real-time vessel position, typically to sub-meter accuracy. HYPACK® hydrographic survey software, developed by HYPACK, Inc. (formerly Coastal Oceanographics, Inc.), was used to acquire, integrate, and store all positional data from the DGPS as well as bathymetry and station data.

2.2.2 SPI Analysis

Computer-aided analysis of each image was performed to provide measurement of the following standard set of parameters:

- *Sediment Type* - The sediment grain size major mode and range were estimated visually from the images using a grain-size comparator at a similar scale. Results were reported using the phi scale. Conversion to other grain size scales is provided in Appendix B. The presence and thickness of disposed dredged material were also assessed by inspection of the images.

Table 2-2.

Seawolf SPI and Benthic Biology Target Sampling Locations, June 2006

Station	Latitude (N)	Longitude (W)
Seawolf Site		
SW-01	41° 16.397'	72° 04.850'
SW-02	41° 16.433'	72° 04.884'
SW-03	41° 16.449'	72° 04.931'
SW-04	41° 16.402'	72° 04.917'
SW-05	41° 16.506'	72° 04.822'
SW-06	41° 16.471'	72° 04.945'
SW-07	41° 16.462'	72° 04.772'
CTR*	41° 16.456'	72° 04.863'
150N*	41° 16.537'	72° 04.863'
75E*	41° 16.456'	72° 04.810'
300SE*	41° 16.341'	72° 04.711'
300WSW*	41° 16.375'	72° 05.049'
150W*	41° 16.456'	72° 04.970'
Reference Area		
NLONREF-01	41° 16.730'	72° 01.797'
NLONREF-02	41° 16.688'	72° 01.793'
NLONREF-03*	41° 16.678'	72° 02.075'
NLONREF-04	41° 16.606'	72° 02.047'
NEREF-01	41° 16.784'	72° 03.476'
NEREF-02*	41° 16.737'	72° 03.284'
NEREF-03	41° 16.651'	72° 03.286'
NEREF-04	41° 16.811'	72° 03.367'
WREF-01	41° 16.130'	72° 06.063'
WREF-02	41° 16.289'	72° 06.118'
WREF-03	41° 16.267'	72° 06.057'
WREF-04	41° 16.140'	72° 05.890'
WREF-05*	41° 16.164'	72° 05.996'

Datum: NAD 83
*Benthic biology station

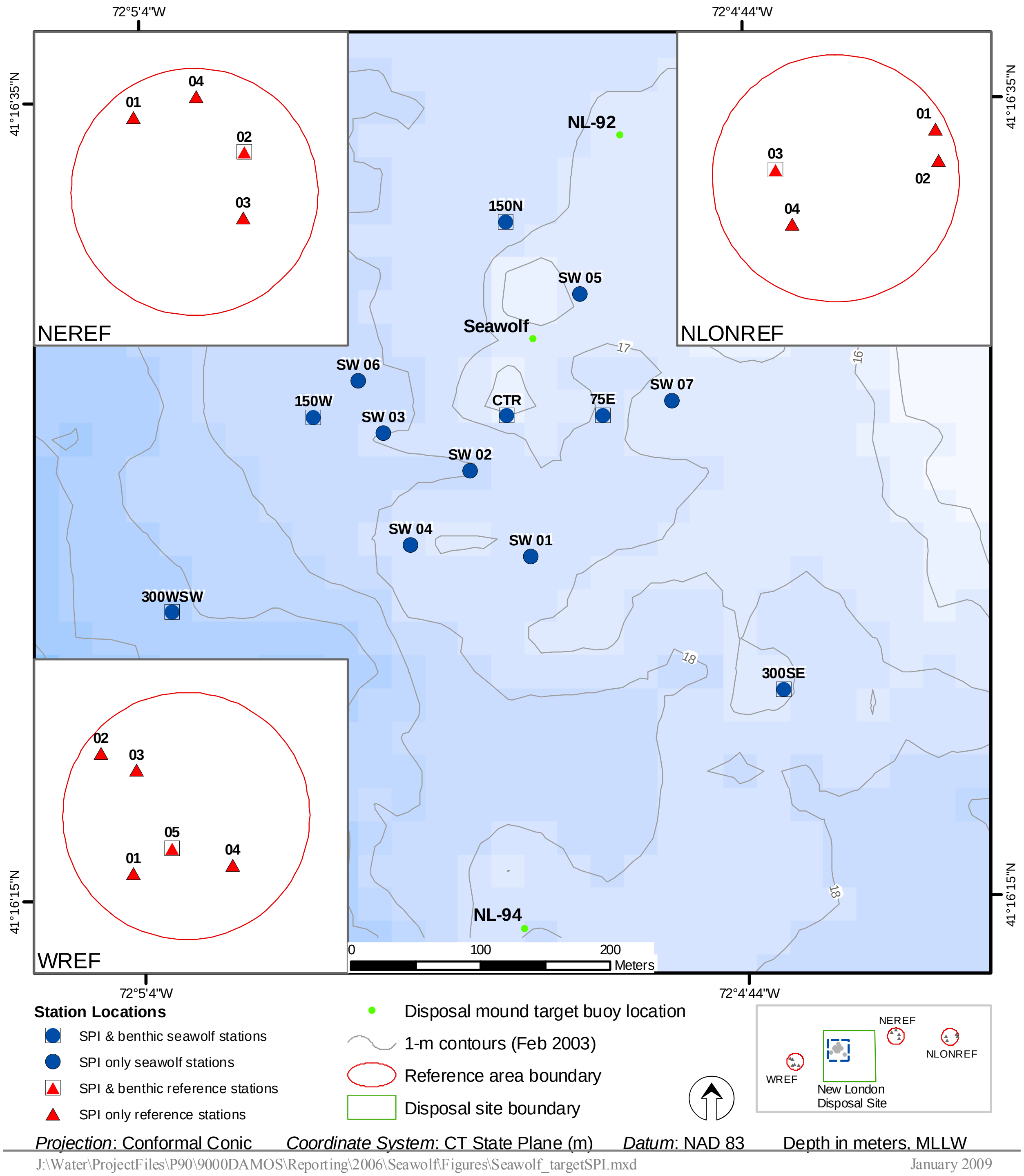


Figure 2-2. SPI and benthic biology stations at the Seawolf mound and three reference areas, June 2006

- *Penetration Depth* - The depth to which the camera penetrated into the seafloor was measured to provide an indication of the sediment density or bearing capacity. The penetration depth can range from a minimum of 0 cm (i.e., no penetration on hard substrates) to a maximum of 20 cm (full penetration on very soft substrates).

- *Surface Boundary Roughness* - Surface boundary roughness is a measure of the vertical relief of features at the sediment-water interface in the sediment-profile image. Surface boundary roughness was determined by measuring the vertical distance between the highest and lowest points of the sediment-water interface. The surface boundary roughness (sediment surface relief) may be related to physical structures (e.g., ripples, rip-up structures, mud clasts) or biogenic features (e.g., burrow openings, fecal mounds, foraging depressions). Biogenic roughness typically changes seasonally and is related to the interaction of bottom turbulence and bioturbational activities.

- *Apparent Redox Potential Discontinuity (RPD) Depth* - RPD provides a measure of the integrated time history of the balance between near surface oxygen conditions and biological reworking of sediments. Sediment particles exposed to oxygenated waters oxidize and lighten in color to brown or light gray. As the particles are moved downwards by biological activity or buried, they are exposed to reduced oxygen concentrations in subsurface pore waters and their oxic coating slowly reduces, changing color to dark gray or black. When biological activity is high, the RPD depth increases; when it is low or absent, the RPD depth decreases. The RPD depth was measured by assessing color and reflectance boundaries within the images.

- *Infaunal Successional Stage* - Infaunal successional stage is a measure of the biological community inhabiting the seafloor. Current theory holds that organism-sediment interactions in fine-grained sediments follow a predictable sequence of development after a major disturbance (such as dredged material disposal), and this sequence has been divided subjectively into three stages (Rhoads and Germano 1982, 1986). Successional stage was assigned by assessing which types of species or organism-related activities were apparent in the images.

Additional components of the SPI analysis included calculation of means and ranges for the parameters listed above and mapping of individual values.

2.2.3 SPI Statistical Analysis

The objective of the SPI survey on the Seawolf mound was to assess the benthic recolonization status of the mound relative to reference conditions. Statistical analysis of the 2006 Seawolf SPI data included bioequivalence tests (or interval tests) to compare biological conditions at the Seawolf mound with those at the reference stations.

The bioequivalence test was used to evaluate the inequivalence hypothesis, in which the true difference between means is postulated to lie beyond a prescribed interval. This approach provides a framework for demonstrating proof of safety, which is particularly appropriate for the evaluation of disposal mounds relative to nearby reference areas for the DAMOS Program. The null hypothesis was chosen as one that presumes the difference between parameter values measured within a disposal site relative to reference areas is great, i.e., an inequivalence hypothesis (e.g., McBride 1999). This is recognized as a 'proof of safety' approach because rejection of this inequivalence null hypothesis requires sufficient proof that the difference is actually small. The null and alternative hypotheses to be tested were:

$$H_0\text{:}\ \ d \le -\delta \ \text{ or } \ d \ge \delta \ \text{(presumes the difference is great)}$$

$$H_A\text{:}\ \ -\delta < d < \delta \ \ \text{(requires proof that the difference is small)}$$

Where:

d = the actual difference between reference mean and site mean for a particular parameter.

δ = the maximum difference expected for that parameter considering background information.

If the null hypothesis is rejected, then it can be concluded that the two means are equivalent to one another within $\pm\delta$ units. The size of δ should be determined from historical data and/or best professional judgment to identify a maximum difference that is within background variability/noise and is therefore not ecologically meaningful. The two key SPI parameters most affected by animal-sediment interactions during the recovery process are RPD and successional stage. Because successional stage is a categorical classification, the successional stage rank was used as a surrogate for this parameter. To determine the expected difference (δ) between an undisturbed seafloor (i.e., reference area) and a recently-disturbed disposal site (i.e., disposal mound) for RPD and successional stage rank, both the mean and range of values in historical DAMOS SPI monitoring data from Long Island Sound were considered (ENSR 2004, 2005). Based on these historical data, it was determined that realistic δ for RPD and successional stage rank values would be 1 for both RPD and SS rank. These difference values were based on the typical spread of RPD and successional stage rank values observed at the reference areas and were representative of a background range.

The test of this interval hypothesis was broken down into two one-sided tests (TOST) (McBride 1999 after Schuirmann 1987) which are based on Student's *t*-distribution. The statistics used to test the interval hypotheses shown here were based on the Central Limit Theorem (CLT) such that the mean of any random variable is normally distributed, and linear combinations of normal random variables are also normal. Hence, a linear function of means is also normally distributed. As a result, the t-distribution can be used to construct a confidence interval around any linear function of means.

In this sampling design, there are actually four distinct areas, three of which are categorized as reference locations, so the difference equation of interest is defined as the average of the 3 reference means minus the mound mean, or

$$[(\text{Mean}_{\text{NEREF}} + \text{Mean}_{\text{NLONREF}} + \text{Mean}_{\text{WREF}})/3 - \text{Mean}_{\text{Mound}}]$$

The three reference areas collectively represent ambient conditions, and if appropriate, were pooled into a single reference group. However, if there are mean differences among these three areas, then pooling them into a single reference group would increase the variance beyond true background variability. Differences among the three reference areas were evaluated prior to comparison with the mound data to determine if pooling the reference areas was appropriate.

The difference equation, $\hat{d}$, for the comparison of interest is:

$$\tfrac{1}{3}\,(\text{Mean}_{\text{NEREF}} + \text{Mean}_{\text{NLONREF}} + \text{Mean}_{\text{WREF}}) - \text{Mean}_{\text{Mound}} \quad \textit{\textbf{or}}$$
$$\text{Mean}_{\text{Pooled Refs}} - \text{Mean}_{\text{Mound}}$$

The standard error of each difference was calculated from the fact that the variance of a sum is the sum of the variances for independent variables, or:

$$SE\,(\hat{d}) = \sqrt{\sum_j \left(S_j^2 c_j^2 / n_j\right)}$$

Where:

c_j = coefficients for the j means in the difference equation, $\hat{d}$ (i.e., for the difference equations shown above, the coefficients are 1/3, 1/3, 1/3, and –1 for areas NEREF, NLONREF, WREF, and the Seawolf mound, respectively; or they would be 1, -1 for reference and mound, respectively, if the three reference areas can be pooled).

S_j^2 = variance for the j th area. If equal variances were assumed, a single pooled variance estimate was substituted for each group, equal to the mean square error from an ANOVA.

n_j = number of replicates for the j^{th} area (4, 4, 5, 13 for areas NEREF, NLONREF, WREF, and mound, respectively, or 13 for both location if reference areas are pooled.

The inequivalence null hypothesis was rejected (and equivalence was concluded) if the confidence interval on the difference of means, $\hat{d}$, was fully contained within the interval [–δ , +δ]. Thus the decision rule is to reject H_0 if:

$$D_L = \hat{d} - t_{\alpha,\upsilon} se(\hat{d}) > -\delta \quad \text{and} \quad D_U = \hat{d} + t_{\alpha,\upsilon} se(\hat{d}) < \delta$$

Where:

$\hat{d}$ = observed difference in means between the reference and mound

$t_{\alpha,\upsilon}$ = upper 100α percentile of a Student's t-distribution with υ degrees of freedom

$se(\hat{d})$ = standard error of the difference.

υ = degrees of freedom for the standard error.

If a pooled variance estimate was used, the degrees of freedom was equal to the sum of the sample sizes for all groups included in the $\hat{d}$ minus the number of groups; if separate variance estimates were used, degrees of freedom were calculated based on the Brown and Forsythe estimation (Zar 1996).

Equality of the reference areas were graphically evaluated using boxplots and summary statistics. Validity of the normality and equal variance assumptions were tested using Shapiro-Wilk's test for normality on the area residuals (α=0.05) and Levene's test for equality of variances among the four areas (α =0.05). If normality was not rejected but equality of variances was rejected, then the variance for the difference equation was based on separate variances for each group. If systematic deviations from normality were identified, then the data were transformed to approximate normality, if possible. Otherwise, a non-parametric bootstrapped interval was used.

2.3 Benthic Biology

Sediment grab samples were collected for benthic community analysis and for characterization of two sedimentary parameters, total organic carbon (TOC) and grain size. A 0.04-m² Ted Young-modified Van Veen grab was used to collect two replicate grab samples at each station. The approach and methods used to collect and analyze the benthic grabs are detailed in Appendix C.

2.3.1 Benthic Biology Data Collection

Benthic biology grabs were collected at six stations located across the Seawolf mound and three stations located within the three reference areas on 14 June 2006. The six stations located across the Seawolf mound coincided with SPI stations and were previously sampled during other monitoring surveys of the Seawolf mound. The three reference stations were randomly selected from the 15 SPI reference stations (Figure 2-2, Table 2-2). Two replicate grabs were collected at each station: one grab was processed for infaunal community analysis, and the other grab was collected for TOC and grain size analyses.

At each station, the vessel was positioned at the target coordinates, and the grab was deployed within a defined station tolerance of 10 m. The samples were checked for penetration depth (10 cm was the maximum and 7 cm was the minimum acceptable penetration depth), depth of the apparent redox potential discontinuity (RPD) layer, sediment color and texture, odor, and observed biota. Grain size and TOC samples were collected from one of the two replicate grabs using a 2.5 cm diameter tube. An aliquot of sediment was placed into a 125-ml clear glass jar for TOC analysis. Grain size samples were placed into a 115 ml (4 oz) plastic bag. The TOC and grain size samples were stored on ice and shipped overnight to the appropriate laboratories: Alpha Woods Hole Environmental Laboratories for TOC and URI for grain size.

The sediment from the second grab was washed into a clean 2.5 gallon plastic bucket and sieved through a 0.5 mm mesh screen. The material retained on the sieve was then placed in an appropriate sample container (1 gallon, 1 liter, or 1 pint) and preserved with 10% formalin. After 48 hours, but within the holding time of 10 days, benthic samples were transferred out of the formalin, rinsed on a 0.5 mm sieve with freshwater and preserved in an 80% ethanol solution. To facilitate the sorting process, all samples were stained in a solution of Rose Bengal.

2.3.2 Benthic Biology Grab Processing

Benthic infaunal samples were sorted using a dissecting microscope to major taxonomic categories, such as polychaetes, arthropods, mollusks, and echinoderms. Following sorting, all specimens were enumerated and identified to the lowest possible taxonomic category (usually species).

The raw data were carefully inspected, and a final dataset was produced for analysis. The final dataset excluded infaunal taxa such as juveniles and indeterminate specimens that could not be identified to the species level, as well as epifauna, shell-borers, and parasites. However, indeterminate benthic infaunal specimens were included in calculations of total density.

2.3.3 Infaunal Community Analysis

The PRIMER statistical package was used to calculate several diversity indices, including Shannon's diversity index (H′), Pielou’s evenness value (J′), and Fisher’s alpha (Clarke and Gorley 2001). Shannon’s index (H′) is based on information theory and is one of the most widely used diversity indices. Shannon’s index assumes that individuals are randomly sampled from an infinitely large population and that all species are present in the sample (Pielou 1975, Magurran 1988). Pielou’s evenness index (J′) expresses H' relative to the maximum value that H' can obtain when all of the species in the sample are perfectly even. Fisher's alpha model of species abundance (Fisher et al. 1943) has also been widely used and is considered one of the best indices for discriminating among subtly different sites (Taylor 1978). Fisher’s alpha is a measure of diversity that is independent of sample size.

2.4 Coring

The July 2006 coring at the Seawolf mound and the subsequent physical characterization and chemical analyses were performed by AECOM (formerly ENSR), OSI, CoastalVision, and a team of laboratories. Cores were collected using vibracoring equipment and were subsequently split, imaged, and sub-sampled at the Marine Geomechanics Lab at URI. Analyses included TOC, PAHs, and metals performed by Alpha Woods Hole Environmental Laboratories and grain size performed by URI. The approach and methods used to collect and analyze the cores are detailed in a project Sampling and Analysis Plan/Quality Assurance Project Plan (QAPP, Appendix A).

2.4.1 Core Collection

Vibracore samples were collected at 12 stations located on the Seawolf mound and at one station located in the reference area, WREF. The samples were distributed among three zones at various distances from the central position of the mound (inner zone [0 to 200 m radius], middle zone [200 to 400 m radius], and outer zone [400 to 600 m radius]) (Table 2-3, Figure 2-3). Four core samples were collected from each zone, one long core approximately 3 m in length and three short cores each 50 cm (0.5 m) in length. The long cores were located in the vicinity of similar cores collected during previous surveys conducted in 1997, 1998, and 2001 and were designed to allow sufficient penetration to reach underlying ambient or “native” material. The short core samples, located within each zone, were intended to provide a representative sampling of overlying cap material. One additional short core was collected at the WREF area.

Table 2-3.

Seawolf Sediment Core Target Sampling Locations, July 2006

Station	Latitude (N)	Longitude (W)
Seawolf Site		
NLDS-40	41° 16.268'	72° 05.034'
NLDS-41	41° 16.317'	72° 05.059'
NLDS-42	41° 16.455'	72° 05.161'
NLDS-43	41° 16.401'	72° 04.916'
NLDS-44	41° 16.512'	72° 04.993'
NLDS-45	41° 16.603'	72° 05.017'
NLDS-46	41° 16.549'	72° 04.822'
NLDS-47	41° 16.519'	72° 04.742'
NLDS-48	41° 16.461'	72° 04.771'
NLDS-49	41° 16.363'	72° 05.103'
NLDS-50	41° 16.425'	72° 04.969'
NLDS-51	41° 16.464'	72° 04.874'
Reference Area		
NLDS-52	41° 16.206'	72° 05.97'

Datum: NAD 83

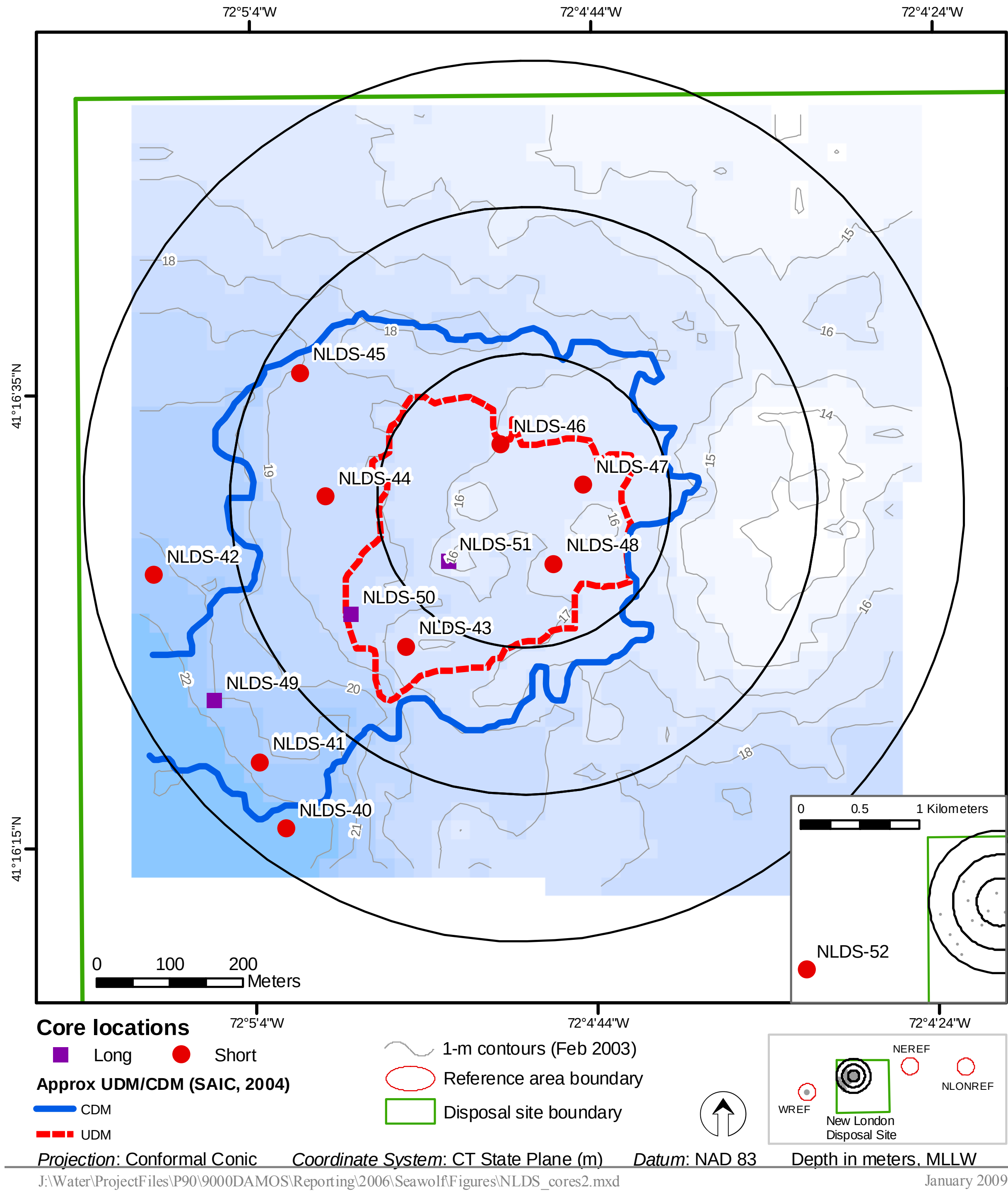


Figure 2-3. Coring locations at Seawolf mound, July 2006

A total of 13 vibracores plus two replicates were collected between 17 and 18 July 2006. Field operations were conducted aboard the 37-foot pontoon coring barge, R/V *Candu,* which was equipped with DGPS, a multipoint anchoring system, and central moon pool for accurate positioning of each core. Vibracoring was performed at the selected stations using a VC 1500 pneumatic coring unit outfitted with a 10-cm (4-inch) steel barrel and stainless steel cutter head (Figure 2-4). The sediment samples were collected in new, clear Lexan liners (8.9 cm (3.5 inch) ID).

For shipboard storage and subsequent transport of the collected cores, water overlying the sediment was removed by cutting the Lexan liner to within 1 cm of the sediment surface. Long core samples were cut into manageable lengths (1 to 2 m) to facilitate insertion into standard coolers for proper storage and preservation on ice. Each core or core section was capped, sealed with tape, labeled, logged, and secured in an upright position. Following completion of the field effort, the cores were transported on ice to the Marine Geomechanics Laboratory URI and stored upright in a walk-in refrigerator.

2.4.2 Core Processing

Processing of the cores was performed at URI. Prior to splitting, any void existing above the sediment-water interface in the upper-most core segment was filled with a high density, low permeability foam material to maintain the as-sampled condition of the core, thus preventing sediment/water migration or the loss of fluidized surficial sediments during the splitting process. In addition, an index tape (labeled along graduated intervals) was affixed to each core tube to maintain the comparable orientation between the two halves of the core subsequent to the split.

Core sections were split length-wise using a device designed to cut the hard plastic liner without disturbing the sediment core. This device cut each core liner axially, using a set of laterally adjustable routers, maneuvered along the length of the core by an electric motor and wire/pulley system. To avoid disturbing the sediments, the depth of cut for the two routers was carefully adjusted to obtain the maximum depth of cut without fully penetrating the core liner. Once the router cut was complete, a straight bladed razor knife was manually used to finish cutting the residual thickness of liner material along the router cut.

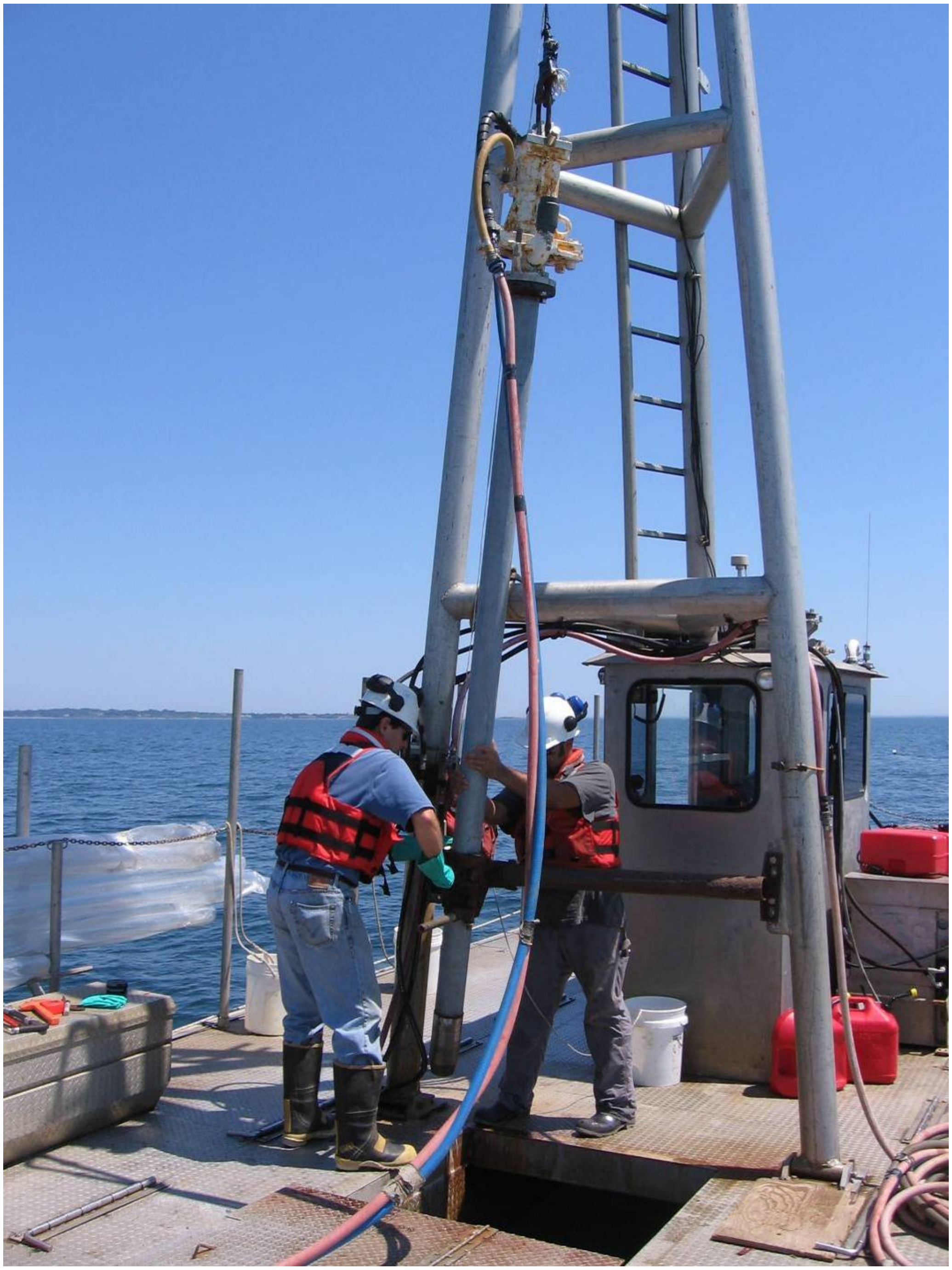


Figure 2-4. Coring operations aboard the R/V *Candu*, July 2006

With the two halves of the liner held together, a titanium wire was drawn through the full length of each sediment sample, thus splitting the sample into two individual halves. One half was immediately wrapped in clear cellophane wrap and transferred to the URI imaging laboratory for high-resolution filming and physical characterization. The remaining half of the core was examined to document surface texture, odor, color, stratigraphic changes, and unique features or anthropogenic materials (e.g., plastic) on log forms (Appendix D). Long core intervals were generally sub-sectioned into the following segments: 0.0 to 0.5 m, 0.5 to 0.75 m, 0.75 to 1.0 m, 1.0 to 2.0 m, and 2.0 to 3.0 m. However, the segment boundaries were adjusted based on visual observations, such that a boundary did not divide visually similar sediments (Appendix D).

Sediment intervals selected for analysis were extracted from the core and transferred to a stainless steel bowl using stainless steel utensils. Sediments were fully homogenized and transferred to the appropriate jars for chemical analysis and grain size determinations. Chemistry samples for TOC, PAHs, and metals were preserved on ice and delivered by courier to Alpha Woods Hole Environmental Laboratories. Sediment samples for grain size were transferred to plastic Zip-lock bags, labeled, and transferred to URI for analysis. Details of sample handling and containerization are provided in the project QAPP (Appendix A).

2.4.3 Mound Sediment Classifications

To evaluate large scale mound characteristics, the predominant layers observed within each core were classified as:

- Surface – Material that has deposited on top of the cap.
- CDM – Coarse grained dredged material that was used to cap the mound.
- UDM – Dredged material unsuitable for unconfined aquatic disposal.
- DM – Dredged material previously disposed at NLDS, beneath the Seawolf mound.
- Native Sediment – Native Long Island Sound sediments in place prior to disposal at NLDS.

Classification into the categories listed above relied primarily on the following characteristics:

- Sediment color and texture,
- Overall appearance (uniform versus disturbed),
- Unusual material contained within the sediment (anthropogenic material), and
- Cross-core marker horizons.

2.4.4 Core Imaging

Core imaging was performed by URI using a GeoTek GeoScan III, digital video camera mounted on a core logger. Prior to imaging, the exposed sediment surface was manually smoothed to minimize changes in focal length. Core images along with complete analysis results are provided in Appendix D.

2.4.5 Core Chemistry

Samples collected from the sediment cores were analyzed for PAHs, TOC, and selected metals (aluminum, arsenic, cadmium, chromium, copper, lead, mercury, nickel, and zinc). Sediments were prepared for PAH analysis according to EPA SW-846 method 3550B and analyzed using method 8270C modified to utilize selected ion mass spectrometer (SIM) mode. TOC measurements were analyzed using the Lloyd Kahn combustion method (USEPA 1988).

Samples collected for metals analysis were prepared according to EPA SW-846 method 3051 and analyzed using method 6020A by inductively coupled plasma-mass spectrometry (ICP-MS). The preparation method (3051) is a rigorous acid digestion method using HNO_3 and HCl. Mercury was also included in the analytical suite of metals and was determined by SW-846 method 7471.

Grain size was determined using a Malvern Mastersizer 2000. Samples were run through a 2 mm screen prior to analysis to ensure that no grains exceeded the limitations of the instrument. The samples were mixed with 15 ml of 4 molar (M) sodium hexametaphosphate and left for a minimum of 48 hours to facilitate dispersion of the grains. Immediately prior to analysis each sample was placed into a hydrosonic bath for 15 minutes to completely separate grains. The Malvern Mastersizer 2000 provided an analysis of grains from 0.02 μm to 2000 μm, the full range of clay, silt, and sand sizes. Each sample was analyzed three times by the Malvern, and the three runs were averaged together to ensure accuracy and precision.

All data were provided by the labs in an electronic format for direct transfer into the project database.

3.0 RESULTS

3.1 Bathymetry

The general bathymetry of the northwest quadrant of NLDS is characterized by depths ranging from 13.5 m over the NL-RELIC mound to 22.5 m in the southwest corner of the survey area (Figure 3-1). The Seawolf mound is located in the center of the survey area in Figure 3-1 as two small apexes with minimum depths of 15.5 to 16 m. Bathymetric features identified in the northwest quadrant of NLDS by the July 2006 survey were similar to those identified during the previous (February 2003) survey (Figure 3-2).

Depth difference comparisons between the July 2006 and February 2003 datasets revealed no significant changes in depth (Figure 3-3). A small decrease in mound height of approximately 0.5 to 1 m was detected over limited portions of the Seawolf mound (Figure 3-3). Other regions of 0.5 to 1 m decreases or increases in height were detected throughout the 2006 bathymetric survey area, although generally no recent reported dredged material disposal activities have occurred in these areas. There was also an apparent 1 to 1.5 m increase in height to the east of the NL-94 mound near the edge of the survey area. It should be noted that the 2006 survey was performed using multi-beam technology while previous surveys were performed using single beam.

An interesting finding of the 2006 Seawolf bathymetry survey was the observation of a large number of targets (40+) protruding off the bottom of the seafloor in the survey area (Figure 3-4). These bathymetric anomalies, which in many cases were mapped on multiple survey lines, had very little width. The tallest mapped target extended upward just over 4 m from the bottom (Table 3-1). The origin of these targets could not be determined, and they were removed from the final processed dataset.

3.2 Sediment-Profile Imaging

The primary objective of the SPI survey was to assess the recolonization status and benthic habitat characteristics of representative areas within the disposal site and at the reference areas. SPI images were collected from a total of 26 stations during the Seawolf survey, 13 stations on the Seawolf mound and 13 stations distributed among three previously established reference areas. At each of theses stations, there are results for three replicate drops of the SPI camera. The three replicate observations were combined to obtain one value per station: the average of replicates was used for the station RPD, and the maximum among replicates was used as the successional stage rank for the station. A summary of SPI results is presented in Table 3-2, and the complete set of SPI results can be found in Appendix B.

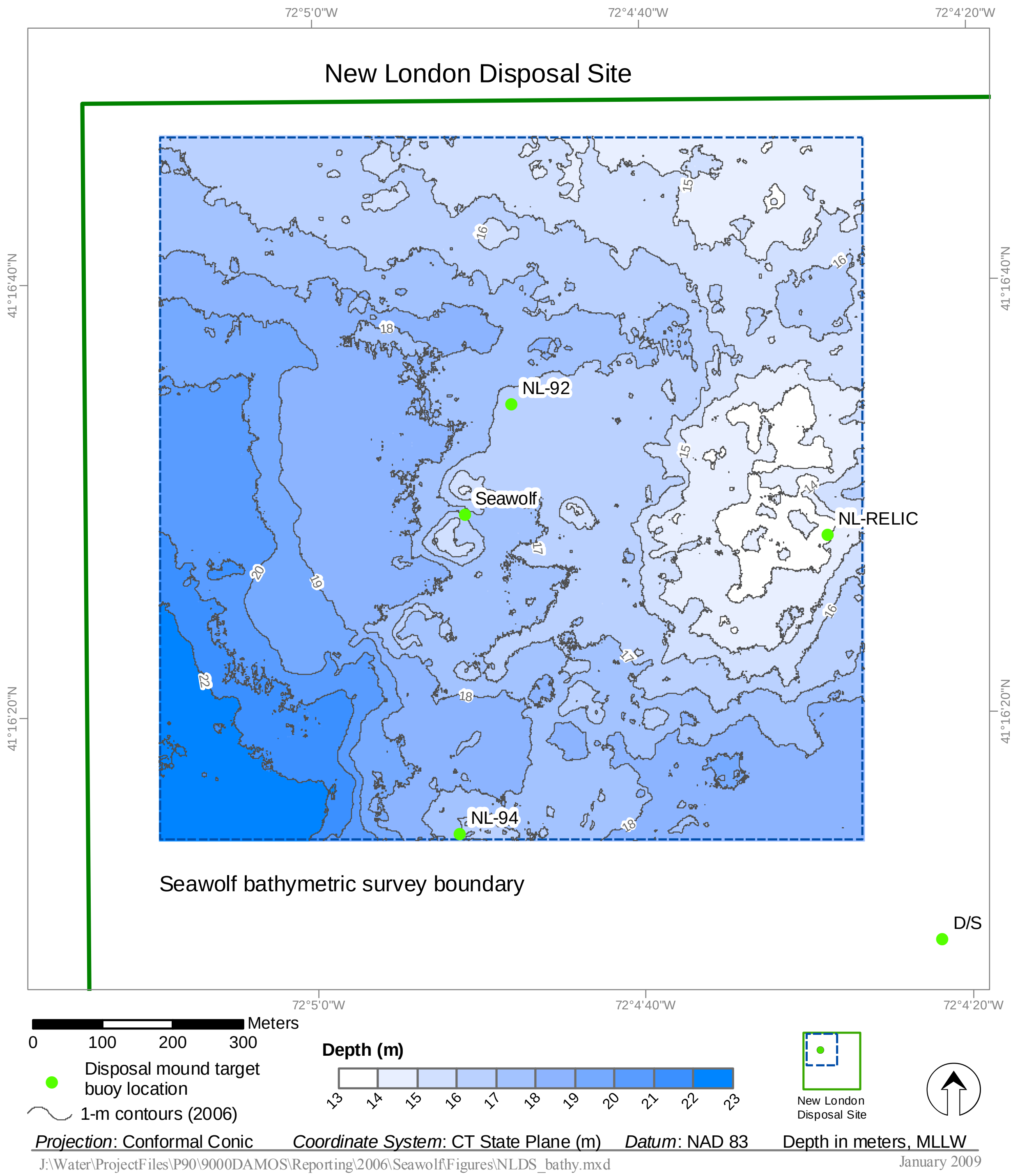


Figure 3-1. Bathymetric contour map of Seawolf survey area, July 2006 (1-m contour interval), with approximate center of disposal mounds noted

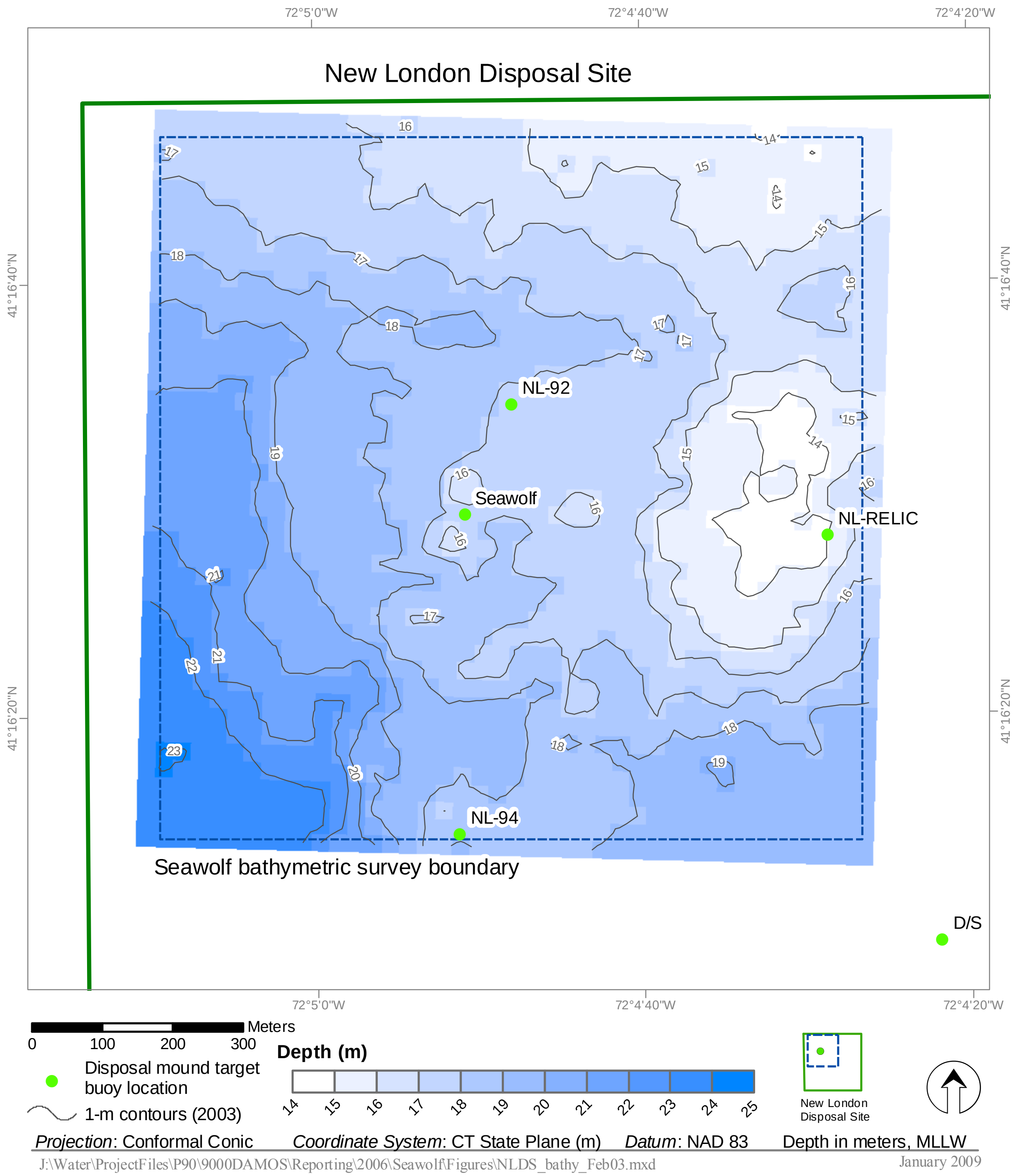


Figure 3-2. Bathymetric contour map of Seawolf survey area, February 2003 (1-m contour interval) with approximate center of disposal mounds noted

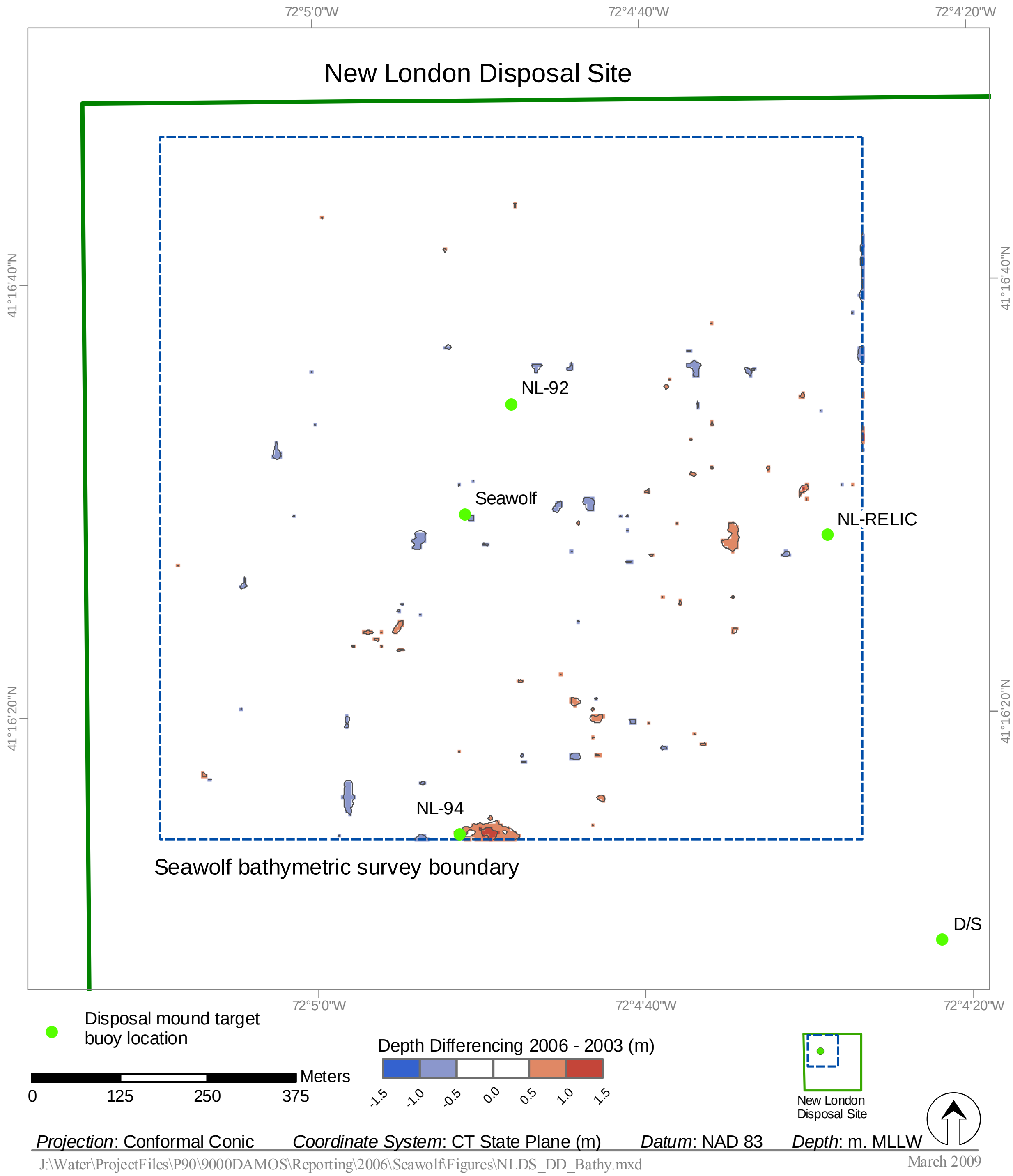


Figure 3-3. Depth difference contour map of Seawolf survey area, February 2003 vs. July 2006 (0.5-m contour interval, 2003 depth minus 2006 depth) with approximate center of disposal mounds noted

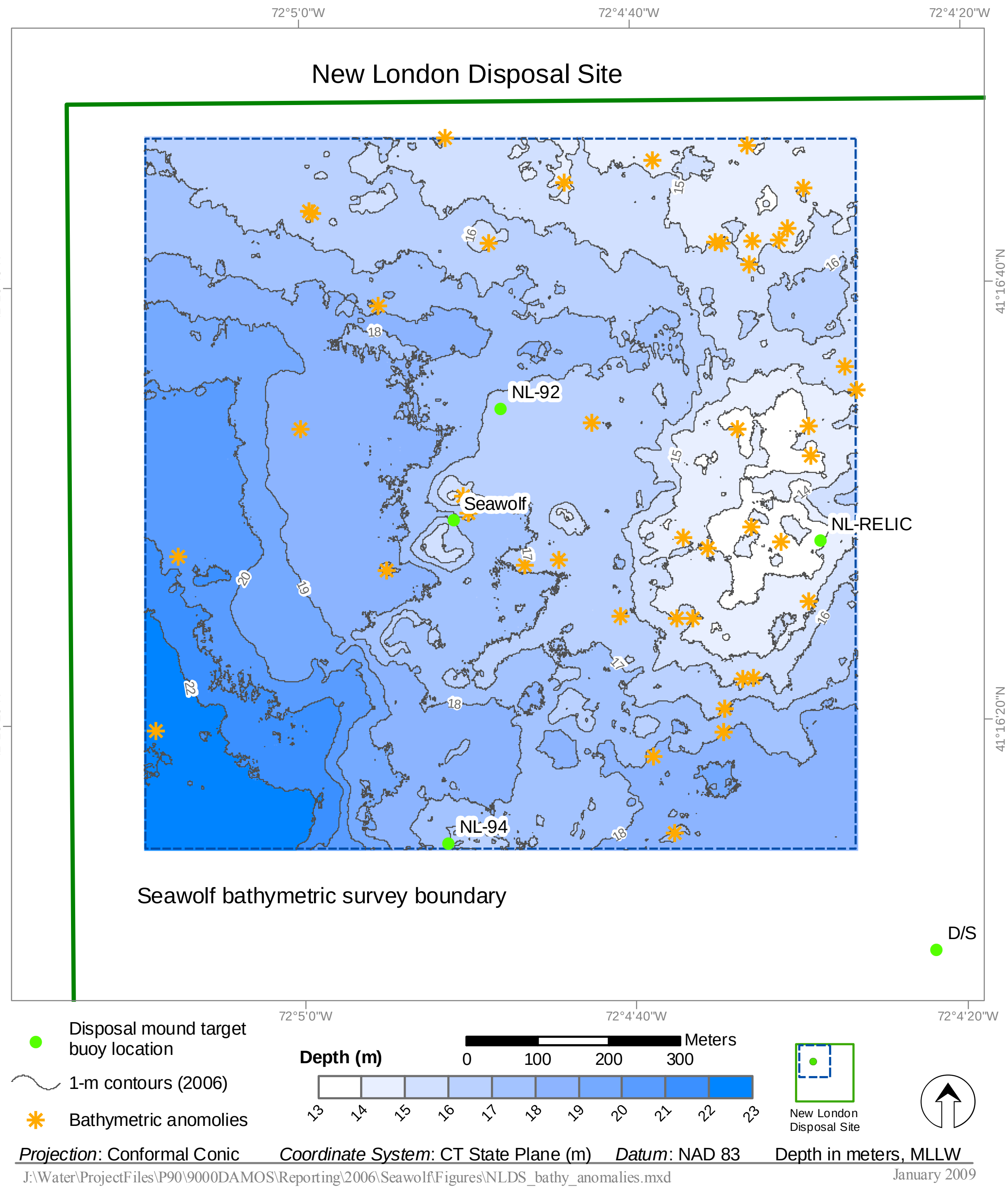


Figure 3-4. Location of bathymetric anomalies observed during 2006 Seawolf bathymetry survey

Table 3-1.

Bathymetric Anomalies, July 2006

Target Name	Latitude (N)	Longitude (W)	Approximate Height (m)	Target Name	Latitude (N)	Longitude (W)	Approximate Height (m)
S1	41° 16.307'	72° 04.648'	1.26	SS1	41° 16.647'	72° 04.347'	1.14
S2	41° 16.329'	72° 05.150'	1.10	SS2	41° 16.779'	72° 04.853'	0.84
S3	41° 16.343'	72° 04.576'	1.18	SS3	41° 16.724'	72° 04.991'	0.63
S4	41° 16.414'	72° 04.680'	2.28	SS4	41° 16.723'	72° 04.987'	0.55
S5	41° 16.454'	72° 04.777'	1.20	SS5	41° 16.651'	72° 04.923'	1.59
S6	41° 16.450'	72° 04.916'	1.93	SS6	41° 16.698'	72° 04.810'	0.49
S7	41° 16.458'	72° 04.742'	2.96	SS7	41° 16.745'	72° 04.733'	0.47
S8	41° 16.493'	72° 04.832'	4.07	SS8	41° 16.760'	72° 04.644'	0.55
S9	41° 16.507'	72° 04.838'	1.13	SS9	41° 16.698'	72° 04.582'	0.40
S10	41° 16.558'	72° 05.001'	2.63	SS10	41° 16.697'	72° 04.575'	0.37
S11	41° 16.555'	72° 04.561'	1.46	SS11	41° 16.772'	72° 04.549'	0.33
S12	41° 16.561'	72° 04.708'	4.06	SS12	41° 16.681'	72° 04.547'	0.33
S13	41° 16.585'	72° 04.440'	3.33	SS13	41° 16.699'	72° 04.544'	0.45
S14	41° 16.264'	72° 05.281'	0.84	SS14	41° 16.699'	72° 04.518'	0.75
S15	41° 16.462'	72° 05.125'	1.00	SS15	41° 16.739'	72° 04.492'	0.44
S16	41° 16.325'	72° 04.577'	0.86	SS16	41° 16.708'	72° 04.509'	0.41
S17	41° 16.248'	72° 04.627'	0.48	SS17	41° 16.603'	72° 04.452'	0.56
S18	41° 16.412'	72° 04.624'	0.74				
S19	41° 16.474'	72° 04.616'	0.72				
S20	41° 16.412'	72° 04.608'	0.50				
S21	41° 16.465'	72° 04.592'	0.76				
S22	41° 16.325'	72° 04.577'	0.89				
S23	41° 16.343'	72° 04.576'	1.16				
S24	41° 16.366'	72° 04.557'	0.42				
S25	41° 16.482'	72° 04.548'	0.68				
S26	41° 16.366'	72° 04.547'	0.63				
S27	41° 16.470'	72° 04.518'	0.59				
S28	41° 16.424'	72° 04.490'	0.48				
S29	41° 16.558'	72° 04.489'	0.59				
S30	41° 16.535'	72° 04.487'	0.54				

Datum: NAD 83

Table 3-2.

Summary of SPI Results for Seawolf Survey, June 2006

Station	Mean Prism Penetration Depth (cm)	Mean RPD Depth (cm)	Mean Boundary Roughness (cm)	Highest Successional Stage Present	Mussels Present?
Reference Areas					
NEREF-01	8.95	2.81	0.90	1 on 3	No
NEREF-02	4.40	2.41	0.64	1 on 3	No
NEREF-03	9.05	2.39	1.01	1 on 3	No
NEREF-04	8.92	2.80	1.13	1 on 3	Yes
NLONREF-01	4.93	2.92	0.86	2-3	No
NLONREF-02	5.90	2.68	0.52	3	No
NLONREF-03	6.53	2.92	1.16	3	No
NLONREF-04	4.21	2.64	1.52	3	No
WREF-01	7.74	3.67	0.95	1 on 3	No
WREF-02	0.00	Indeterminate	0.00	Indeterminate	Yes
WREF-03	8.98	3.09	1.00	1 on 3	No
WREF-04	9.91	3.79	1.57	1 on 3	No
WREF-05	7.82	3.36	0.75	1 on 3	No
Average	6.72	2.96	0.92		
Minimum	0.00	2.39	0.00		
Maximum	9.91	3.79	1.57		
Seawolf Mound					
CTR	7.39	1.19	2.34	1 on 3	No
75E	9.20	1.27	1.21	1 on 3	Yes
150N	10.15	1.20	1.30	1 on 3	No
150W	10.12	1.12	1.47	1 on 3	No
300WSW	10.18	1.66	0.68	1 on 3	No
300SE	5.03	1.71	1.72	3	Yes
SW-01	7.77	1.27	2.23	1 on 3	Yes
SW-02	8.04	1.49	1.68	1 on 3	Yes
SW-03	10.16	1.05	0.71	1 on 3	No
SW-04	5.97	1.84	1.88	1 on 3	Yes
SW-05	9.65	1.41	1.02	1 on 3	No
SW-06	8.65	2.33	3.11	1 on 3	No
SW-07	5.96	1.64	1.36	1 on 3	Yes
Average	8.33	1.47	1.59		
Minimum	5.03	1.05	0.68		
Maximum	10.18	2.33	3.11		

3.2.1 Reference Areas

Physical Sediment Characteristics

Similar to previous surveys at this location, the reference areas were characterized by a surface layer of varying thickness of very fine to fine sand overlying finer sediments (Figure 3-5). The stations at the WREF area had a higher percentage of shell hash and lag deposits in the top layer of sediments than the reference stations in the other two areas, which showed a classic "sand over mud" stratigraphy (Figure 3-6).

Camera prism penetration ranged from 0 to 10 cm over the reference areas (Table 3-2, Figure 3-7); while the stop collar settings were not changed during the survey, a varying number of weights were used in the camera depending on the amount of sand/shell present in the sediment (see Appendix B). The only station where the bottom was sufficiently hard to prevent the camera prism from penetrating at all was at WREF-02 (Figure 3-8); the density of mussel shells at this particular location was sufficient to resist the force of the prism blade on the seafloor. There was no evidence of organic enrichment, low oxygen concentrations in the overlying water, or presence of sub-surface methane gas in any of the images from the reference area stations.

Small-scale boundary roughness values ranged from 0 to 1.6 cm over the reference stations (Table 3-2, Figure 3-9). The small-scale topographic roughness elements at the reference stations were mainly physical in origin (Appendix B), caused by surface ripples or rocks/shells at the sediment surface.

Biological Conditions and Benthic Recolonization

The depth of the apparent RPD ranged from 2.4 to 3.8 cm over the reference areas (Table 3-2, Figure 3-10). All stations at the reference areas (with the exception of the one station in the WREF area where there was no prism penetration) had evidence of Stage 3 fauna (Figure 3-11).

Unlike previous surveys, there were no dense patches of amphipods at the reference areas. While the presence of amphipods was inferred from the presence of their distinctive tubes at many of the stations in all three reference areas, often the tubes were collapsed or reclined on the sediment surface, and, when present, these tubes were at a low density compared with past surveys (Figure 3-12). Mussel distribution was patchy, with the bivalves present at only 2 of the 13 reference stations (Table 3-2).

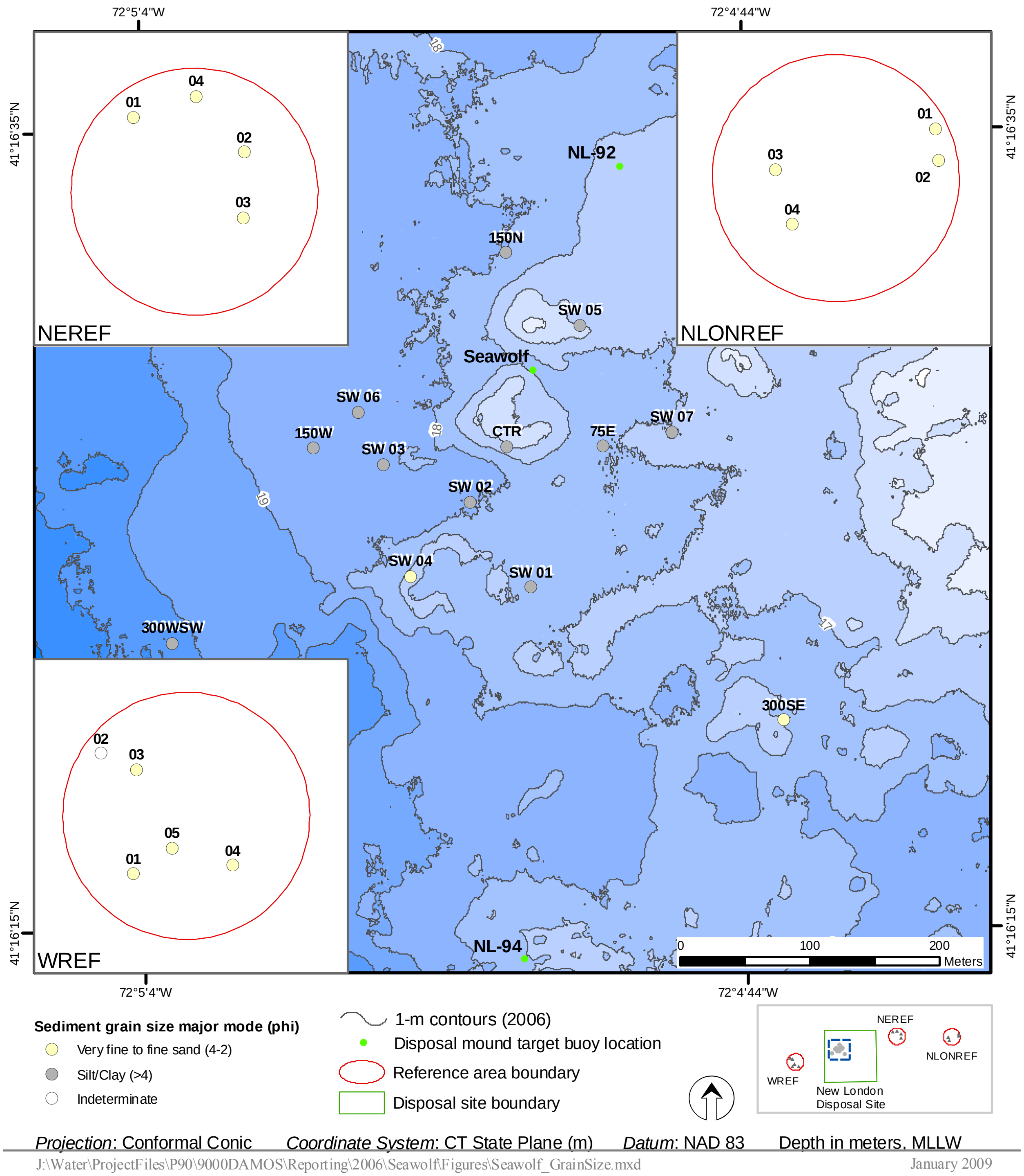


Figure 3-5. Spatial distribution of sediment grain-size major mode (phi) at the Seawolf mound and NLDS reference areas

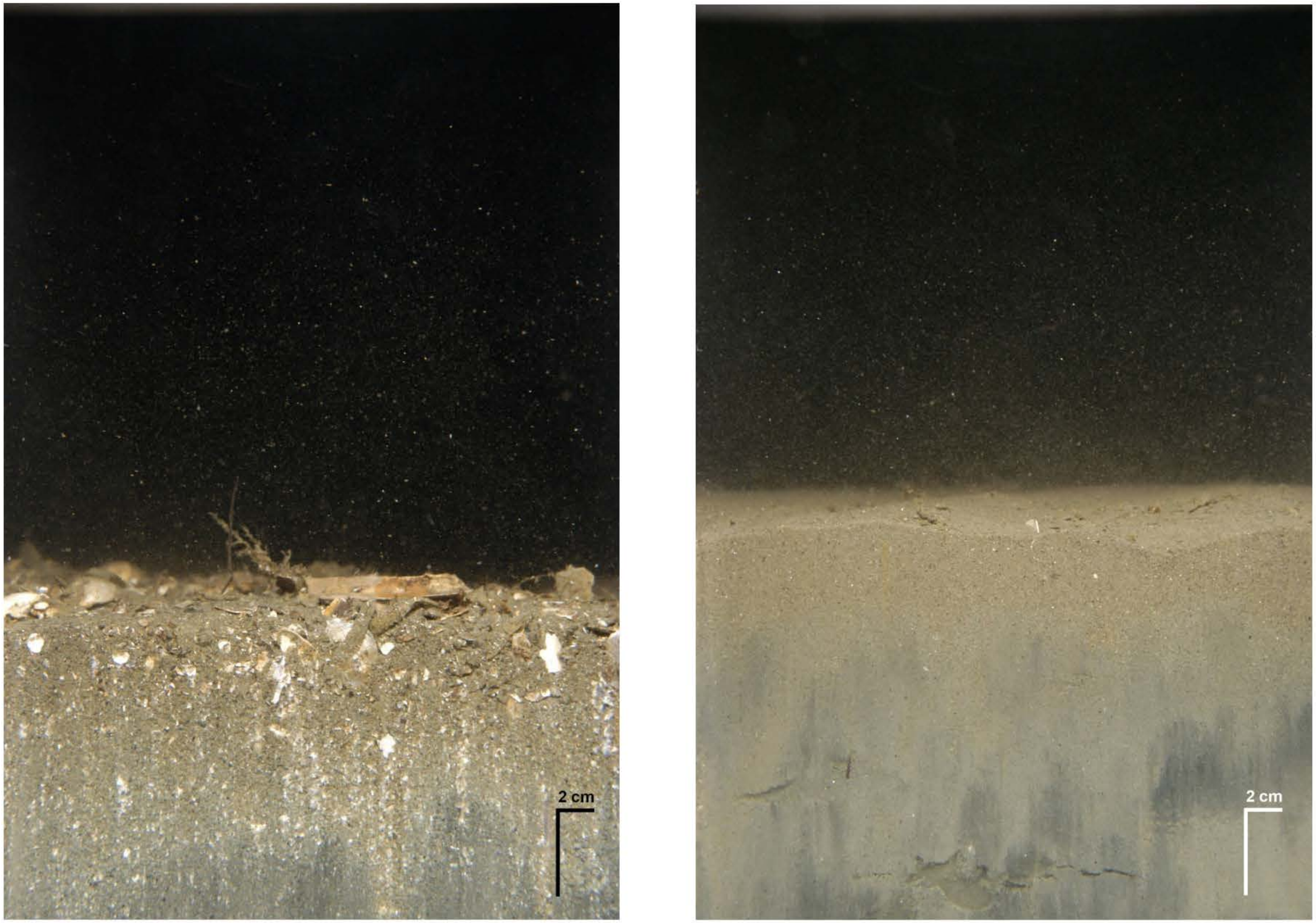


Figure 3-6. The sediments in the WREF area (left) were characterized by a higher percentage of shell fragments in the upper 3-5 cm and shell hash on the sediment surface, whereas the sediments at the other two reference areas had a distinct surface layer of fine or very fine sand over mud (right)

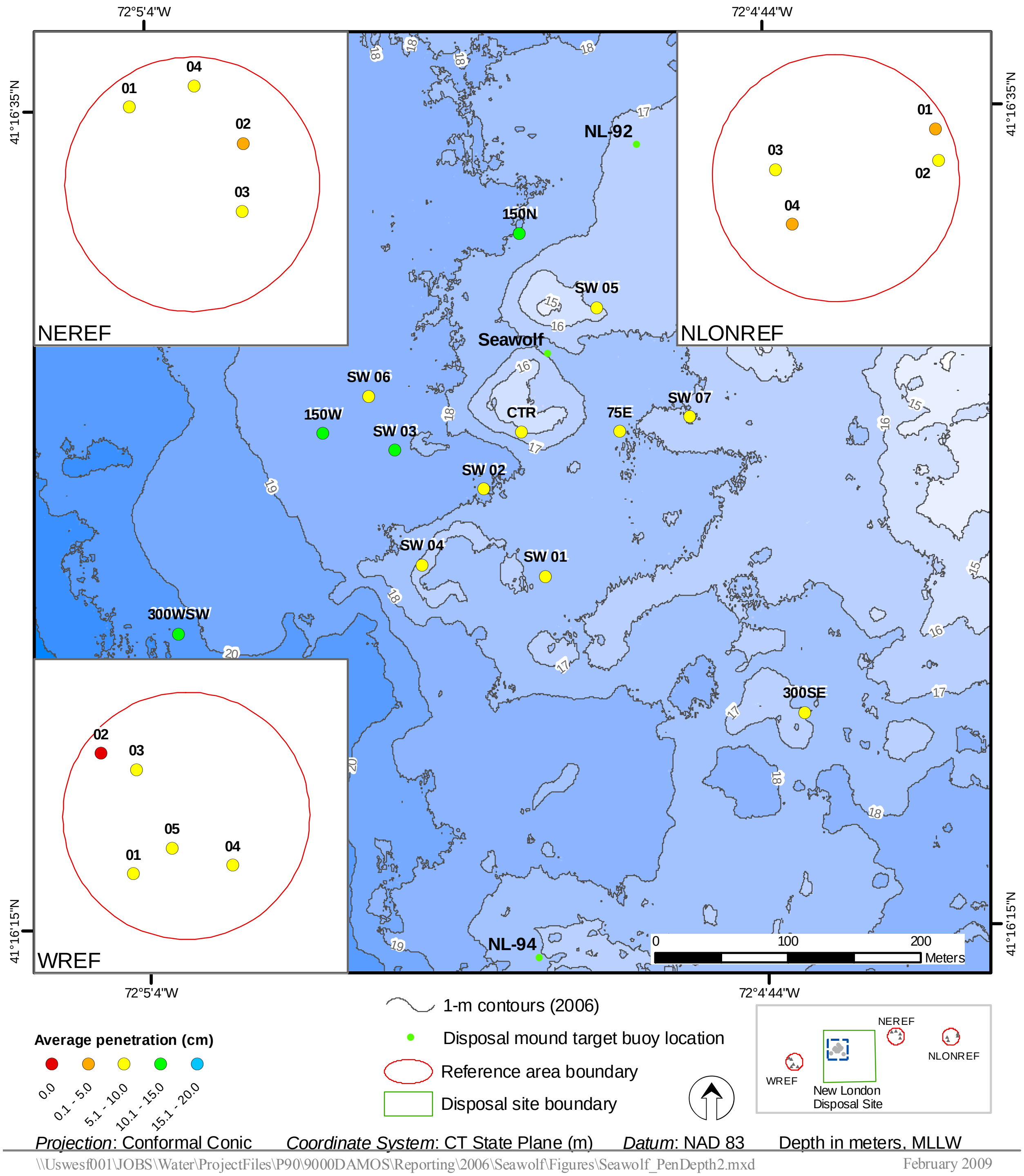


Figure 3-7. Spatial distribution of station-averaged camera prism penetration depth (cm) at the Seawolf mound and NLDS reference areas

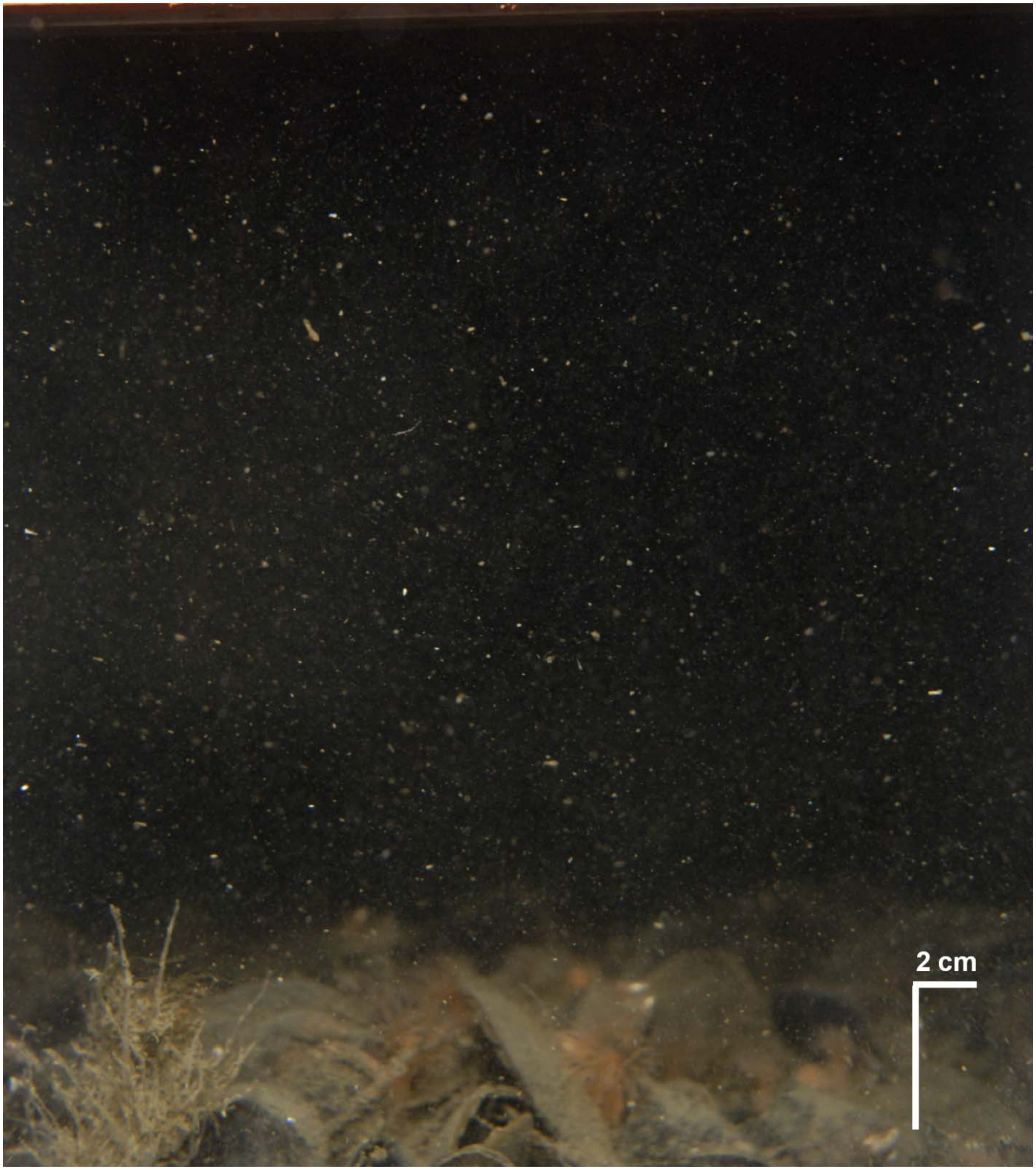


Figure 3-8. The tips of the shells from a dense bed of mussels can be seen in this profile image from Station WREF-02; the mussel bed prevented acquisition of any useable profile camera information at this particular location.

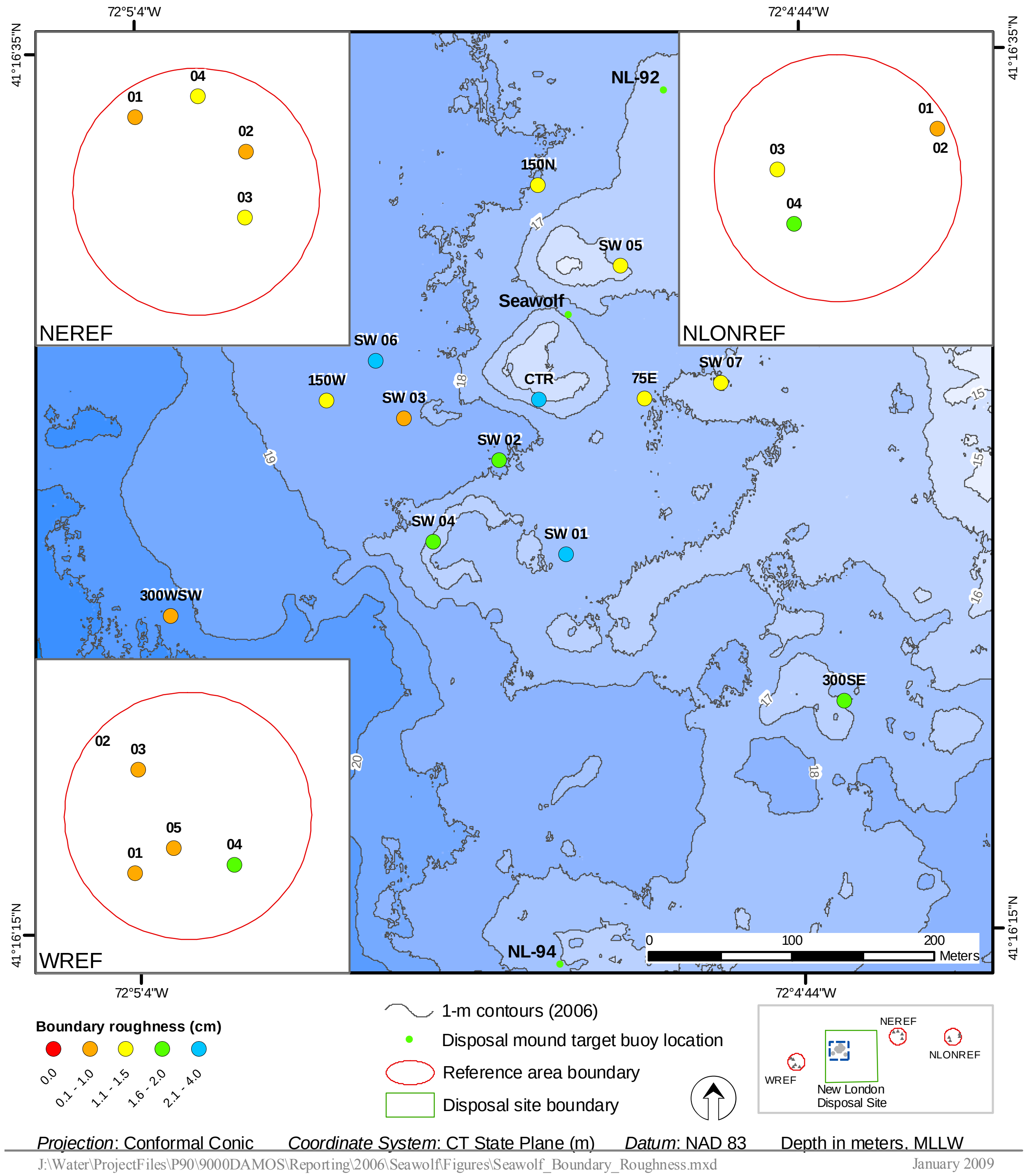


Figure 3-9. Spatial distribution of station-averaged boundary roughness (cm) at the Seawolf mound and NLDS reference areas

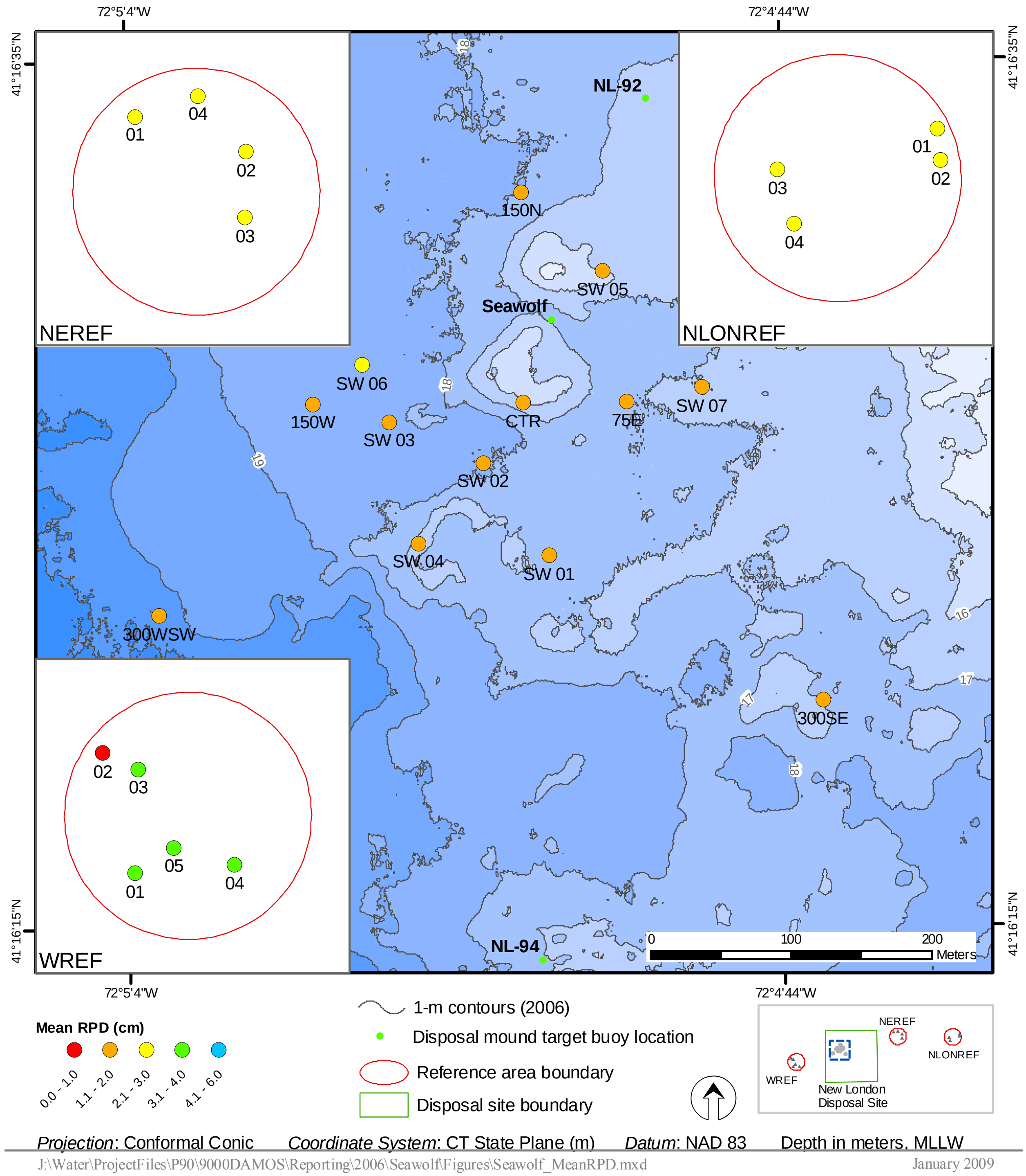


Figure 3-10. Spatial distribution of the station-averaged mean apparent RPD depths (cm) at the Seawolf mound and NLDS reference areas

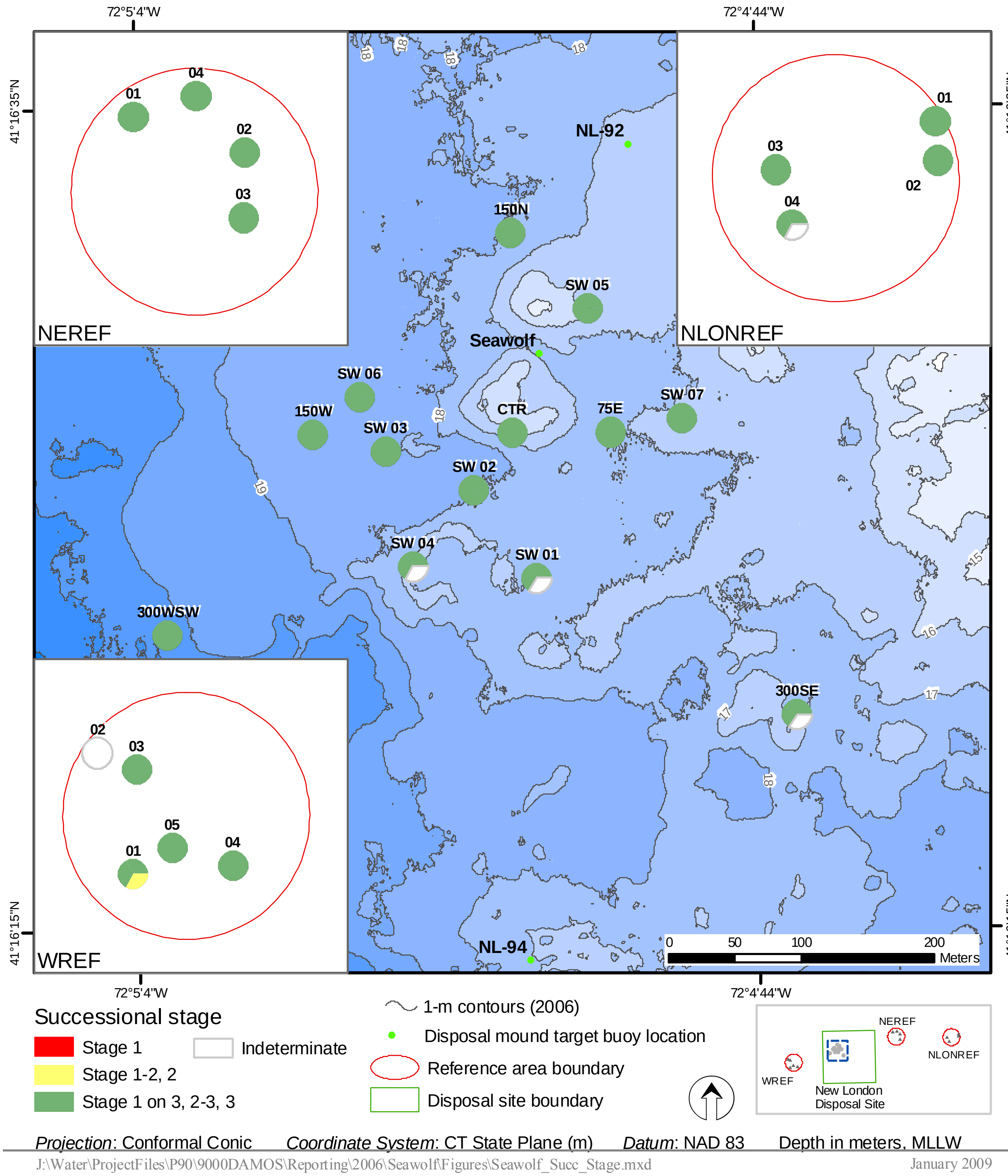


Figure 3-11. Spatial distribution of infaunal successional stages at the Seawolf mound and NLDS reference areas

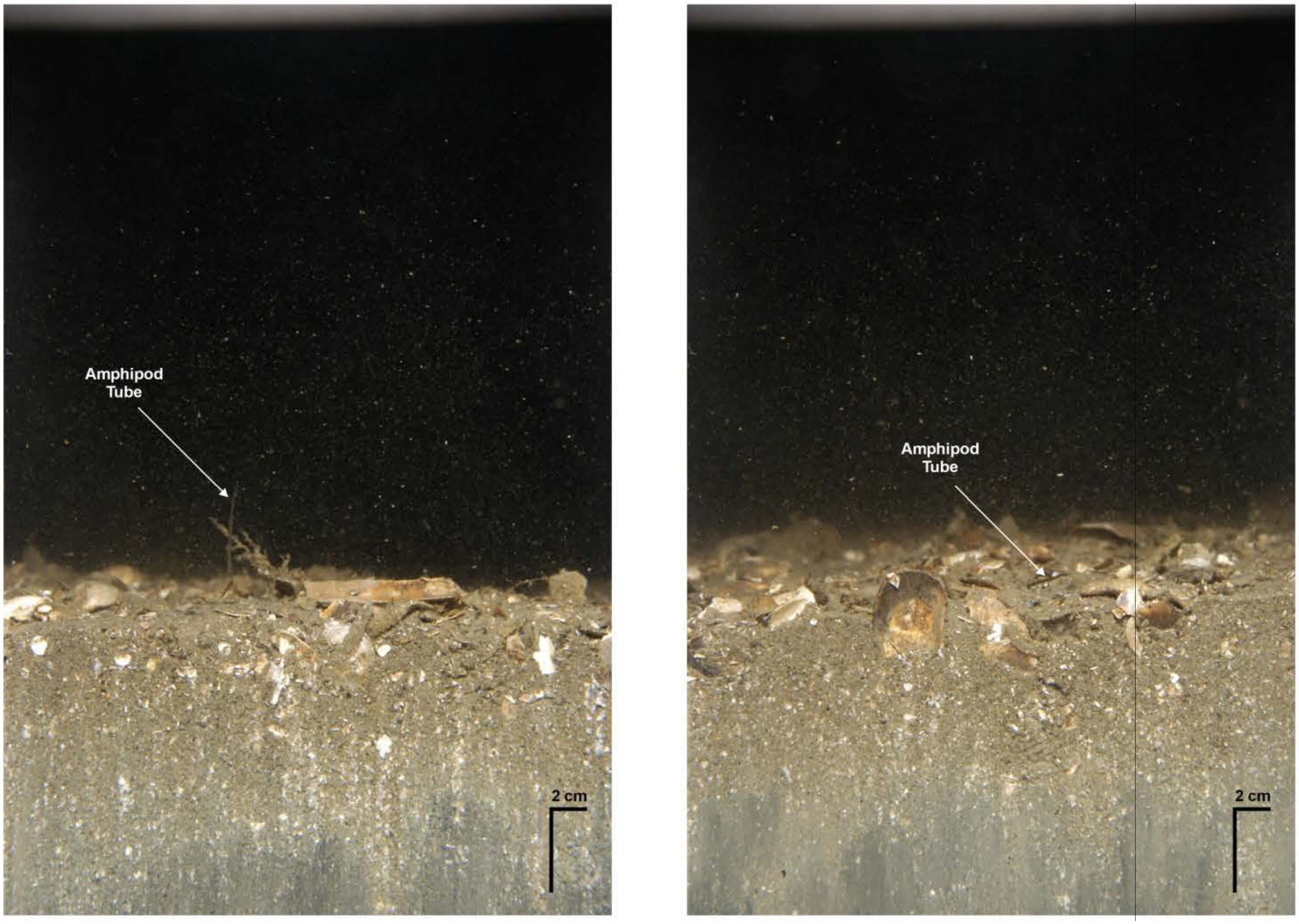


Figure 3-12. These replicate images from Station WREF-01 were the only images where amphipod tubes were found

3.2.2 Seawolf Mound

Physical Sediment Characteristics

Surficial sediments at the Seawolf stations were comprised primarily of silt and clay (Figure 3-5), and one of the most prominent textural features in the profile images was the gray clay (referred to "Gardiners Clay") characteristic of the CDM noted in previous surveys (SAIC 2001a, 2001b; Figure 3-13).

Camera prism penetration ranged from 5 to 10 cm over the Seawolf mound (Table 3-2, Figure 3-7). As reported in past surveys, all 13 of the stations on the Seawolf mound showed evidence of dredged material present in excess of prism penetration depth, and there was no evidence of organic enrichment, low oxygen concentrations in the overlying water, or presence of sub-surface methane gas in any of the images from the mound.

Small-scale boundary roughness values ranged from 0.7 to 3.1 cm, with an overall mound average value of 1.6 cm (Table 3-2, Figure 3-9). The larger boundary roughness values on the disposal mound compared to the reference areas were primarily caused by biogenic activities of the resident infauna (feeding pits, fecal mounds, and burrow openings) (Appendix B).

Biological Conditions and Benthic Recolonization

The depth of the apparent RPD ranged from 1.1 to 2.3 cm over the mound (Table 3-2, Figure 3-10), a distinct departure from the pattern shown in past surveys where the apparent RPD depths over the mound were typically greater than those found at the reference areas. Despite the lower mean apparent RPD values measured in the profile images from the Seawolf mound stations compared to previous surveys, benthic recolonization was at its zenith. All stations on the disposal mound had evidence of Stage 3 fauna (Figure 3-11). Prominent evidence of head-down deposit feeders and burrowing infauna was found at all stations on the disposal mound (Figure 3-14).

Similar to the reference areas, colonies of amphipods were absent from the mound, and mussels displayed a patchy distribution. This was a significant departure from the June 2001 survey, where amphipods were abundant, and mussels were found at every station on the disposal mound. In the 2006 survey, mussels were observed at only 6 of the 13 disposal site stations (Table 3-2, Figure 3-15).

Figure 3-13. The gray clay characteristic of CDM is still evident in the upper portion of the sediment column, as seen in this profile image from Station CTR; however, sufficient time has passed for resident infauna to establish themselves in what was initially a very consolidated, low water-content mud

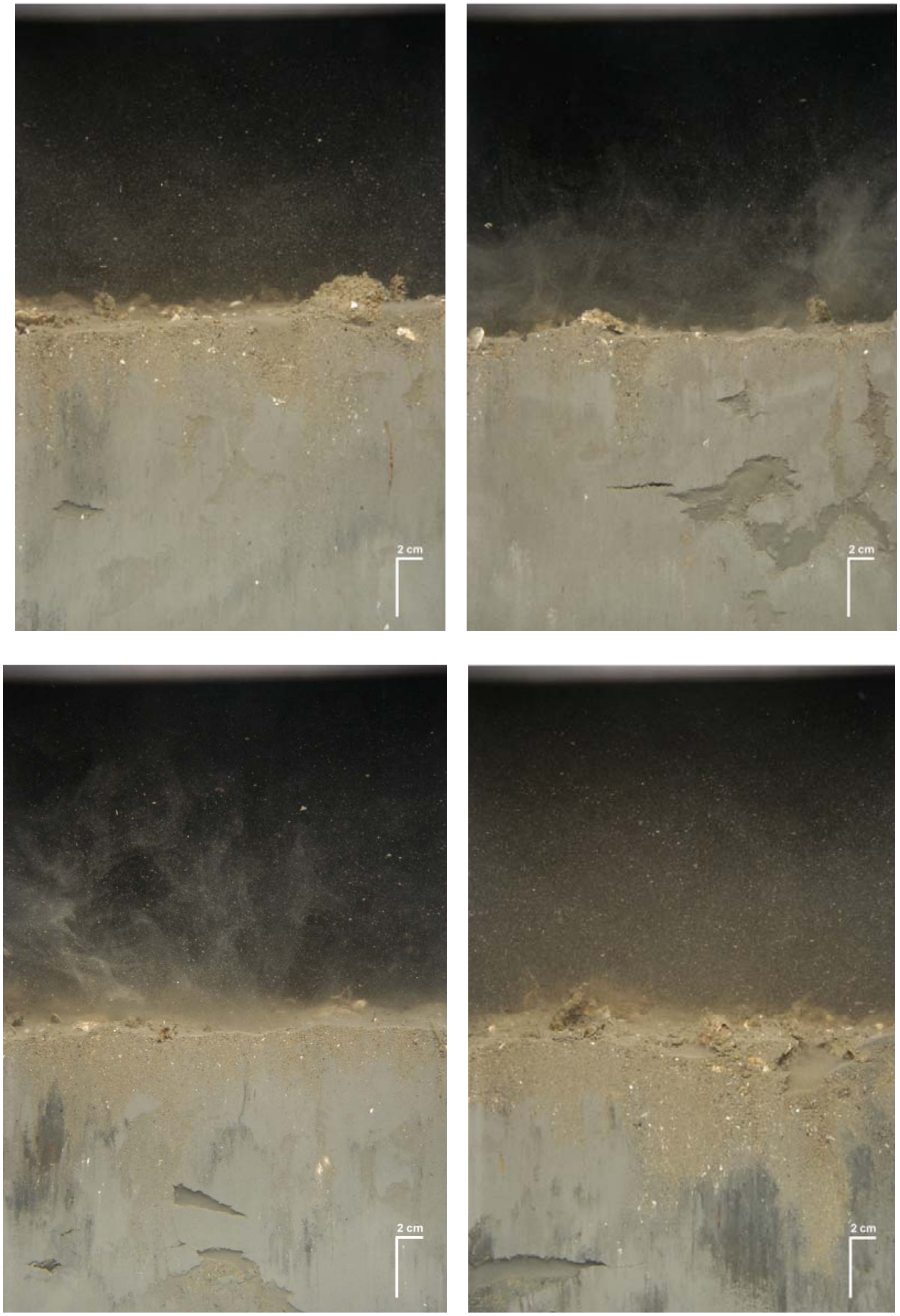


Figure 3-14. Evidence of burrows and feeding voids indicative of Stage 3 fauna was quite prominent in the profile images from the stations sampled on the Seawolf mound

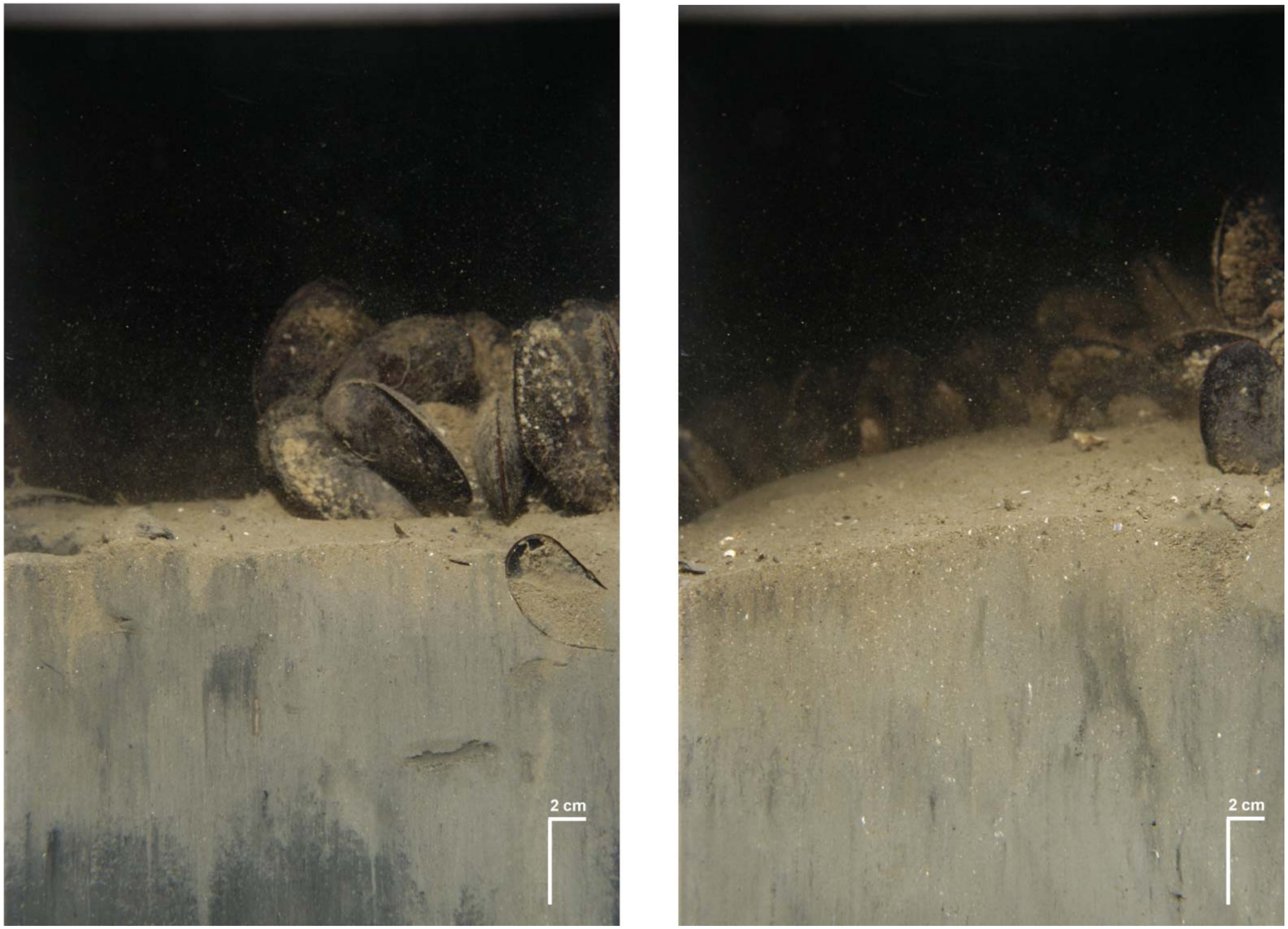


Figure 3-15. These profile images from Station 75E (left) and SW-02 (right) show the patchy nature of the mussel beds on the sediment surface

3.2.3 Statistical Results of SPI Data Analysis

The SPI dataset consisted of 13 stations at the Seawolf mound and 13 stations at the three distinct reference areas (four at NEREF, four at NLONREF, and five at WREF [Figure 2-2]). The three replicate observations from each station were combined to obtain one value per station; the average of replicates was used for the station RPD, and the maximum among replicates was used as the successional stage rank for the station. Successional stage ranks have possible values between 0 (no fauna present) and 3 (Stage 3); half ranks are also possible for the "in-between" stages (e.g., Stage 1-2 has value 1.5). A summary of the mean RPD and successional stage rank values for the stations are shown in Table 3-3 and Figure 3-16.

Mean RPD Variable

The three reference areas showed relatively minor differences in mean RPD values (Table 3-3, Figure 3-5) with WREF having a higher mean than the other two areas. The maximum difference in mean RPD values among reference locations was 0.9 cm (3.5 cm – 2.6 cm), more than twice the standard deviation within reference areas (range of 0.15 to 0.32). Pooling stations across reference areas with different means will increase the estimate of residual variability beyond what is probably the true within-group variance. Consequently, the reference areas were treated separately in the following analysis.

Results of the Shapiro-Wilk's test indicate the RPD area residuals (i.e., each observation minus the area mean) were normal ($p=0.08$). However, the dataset included a single influential (high value) data point, and normality was improved by log-transformation of the data (Shapiro-Wilk's $p=0.51$). For residuals of the log-transformed data, the assumption of equal variances was rejected by Levene's test ($p=0.03$). A separate variance estimate was used to compute the variance for the difference equation (Table 3-4).

The specified δ value of ± 1 was less than both the 95% lower and upper confidence bounds for the observed difference. Therefore, RPD depths at the Seawolf mound were not different from the reference areas within the pre-determined definition of what is "ecologically meaningful" for apparent mean RPD depths.

Successional Stage Rank Variable

All stations had a maximum successional stage rank value of 5 (Stage 3 except for one NLONREF station which had a maximum rank of 4 (Stage 2-3). The observed difference between reference and mound was 0.1 (4.9 – 5.0). Without variation, statistics were not required. The observed difference was within ± 1 unit, thus the successional stage rank values at the Seawolf mound, and reference areas were equivalent within the pre-determined definition of "ecologically meaningful."

Table 3-3.

Summary of Station SPI Parameter Means by Sampling Location

		Mean RPD (cm)		Successional Stage Rank	
Area	**N**	**Mean**	**Standard Deviation**	**Mean**	**Standard Deviation**
Reference Areas					
NEREF	4	2.6	0.23	5	0
NLONREF	4	2.8	0.15	4.8	0.5
WREF	5	3.5	0.32	5	0
Mean:		3.0		4.9	
Seawolf Mound	13	1.5	0.36	5	0

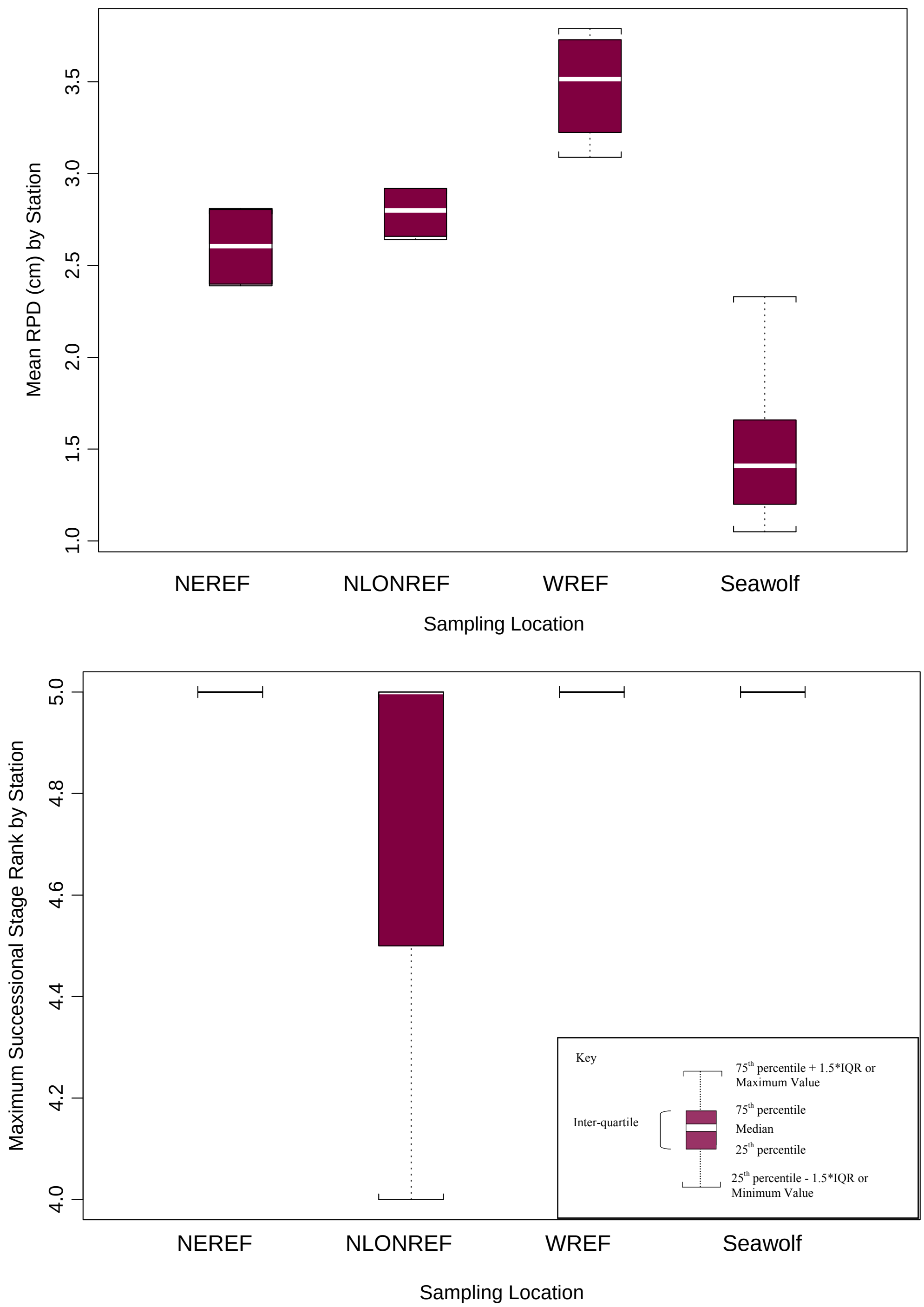


Figure 3-16. Boxplots showing distribution of station mean RPD and successional stage rank values for 2006 Seawolf survey

Table 3-4.

Summary Statistics and Results of Bioequivalence Testing for RPD Values

Difference Equation	**Observed Difference ($\hat{d}$)**	**SE($\hat{d}$)**	**Degrees of Freedom for SE($\hat{d}$)**	**95% Lower Confidence Bound**	**95% Upper Confidence Bound**
Ref – Mound	1.48	0.13	21	1.26	1.70

3.3 Benthic Biology

3.3.1 Reference Areas

Field observations of the individual grab samples collected during the June 2006 benthic survey are provided in Table 3-5. In general, sediments at the three reference stations consisted of silty fine to medium sand, with some shell hash. The sediments were olive/brown over gray in color, had no odor, and had an apparent RPD depth of 2.5 to 4 cm. Animals and tubes were observed in all six grabs and included amphipod and worm tubes, bivalves, snails, and a crab.

For the three reference stations combined, a total of 711 individuals were collected, representing 83 species (Appendix C). The number of species per sample ranged from 38 (Station NEREF-02) to 58 (WREF-03), while the number of individuals ranged from 146 (NEREF-02) to 343 (WREF-05) (Table 3-6). Shannon's H′ ranged from 4.03 at NLONREF-03 to 4.68 at WREF-05. The dominant species was the amphipod *Ampelisca verrilli*, followed by the paranoid polychaete *Aricidea catherinae*, the amphipod *Ampelisca vadorum*, and the polychaetes *Scalibregma inflatum, Monticellina baptisteae*, and *Prionospio steenstrupi*.

3.3.2 Seawolf Mound

Sediments at the six disposal site stations were comprised of sandy silt to medium fine sand with shell hash. These sediments were olive/brown over gray in color, had no odor, and had an apparent RPD depth of 0.8 to 3.0 cm. One quahog was seen on the surface of one of the samples. Aggregations of mussels were present in two samples. An occasional tube was the only other infaunal observation made at the disposal site stations (Table 3-5).

For the six disposal site stations combined, a total of 1310 individuals were collected, representing 86 species (Appendix C). The number of species per sample ranged from 30 (Station 75E) to 48 (Station CTR), while the number of individuals ranged from 141 (Station 75E) to 304 (Station CTR) (Table 3-6). The dominant species was the cirratulid polychaete *Monticellina baptisteae*, followed by the spionid polychaete *Prionospio steenstrupi*, the protobranch bivalve *Nucula annulata*, and the amphipod *Leptocheirus pinguis*. Diversity as measured by Shannon's H′ ranged from 3.92 at Station 300SE to 4.70 at Station 150N. Diversities at the disposal site stations were approximately equivalent to those found at the reference stations (Table 3-6).

Table 3-5.

Field Observations of Benthic Biology Grabs

Station	Sample Type	Sediment Texture	Sediment Color	Sediment Odor	Depth of RPD (cm)	Biology
Reference Areas						
NEREF-02	Bio	Fine silty sand with little shell hash	Olive/brown over gray	No odor	2.5	Tubes; no fauna noted
	Sed	Fine silty sand	Olive/brown over gray	No odor	2.5	Amphipods; a few tubes
NLONREF-03	Bio	Fine sand with shell hash	Olive/brown over gray	No odor	2.8	Bivalves (*Anadara*?); tubes; amphipods
	Sed	Fine sand with shell hash	Olive/brown over gray over black	No odor	2.8	Bivalves; tubes
WREF-05	Bio	Medium sand with silt and shell hash	Olive/brown over gray	No odor	4.0	Crab, snail
	Sed	Medium-fine sand with silt and shell hash	Olive/brown over gray	No odor	3.8	Tube; no fauna noted
Seawolf Mound						
CTR	Bio	Medium-fine sand with silt and clay at depth	Olive/brown over gray	No odor	3.0	No tubes; no fauna noted
	Sed	Medium-fine sand with silt and clay at depth	Olive/brown over gray	No odor	3.0	No tubes; no fauna noted
75E	Bio	Very fine sandy silt with shell hash	Brown/green over gray	No odor	1.6	One tube; no fauna noted
	Sed	Very fine sandy silt with shell hash	Olive/brown over gray	No odor	1.6	A few small tubes; no fauna noted
150N	Bio	Sandy silt over clay with some shell hash	Olive/brown over gray	No odor	3.0	Quahog, tubes
	Sed	Sandy silt over clay with some shell hash	Olive/brown over gray	No odor	2.5	Tubes
150W	Bio	Very fine sandy silt with shell hash	Olive/brown over gray	No odor	2.0	Tubes; no fauna noted
	Sed	Sandy silt with shell hash	Olive/brown over gray	No odor	1.2	No tubes or fauna noted
300SE	Bio	Fine sandy silt	Olive over gray	No odor	1.5	Mussels
	Sed	Silty sand with shell hash	Olive over gray	No odor	2.0	Mussels
300WSW	Bio	Sandy silt with shell hash	Brown green over gray	No odor	1.7	A few tubes; no fauna noted
	Sed	Very fine sandy silt with shell hash	Olive/brown over gray;	No odor	0.8	No tubes; no fauna noted

Table 3-6.

Community Parameters for Benthic Grab Samples

Sample	No. of Species	No. of Individuals per (0.04m²)	H′ (log_2)	J′	Fisher's *alpha*
Reference Areas					
NEREF-02	38	146	4.63	0.88	16.69
NLONREF-03	40	222	4.03	0.76	14.24
WREF-05	58	343	4.68	0.80	20.01
Seawolf Mound					
150N	44	209	4.70	0.86	17.01
150W	44	259	4.42	0.81	15.22
300WSW	32	213	4.09	0.82	10.45
300SE	35	184	3.92	0.76	12.81
75E	30	141	4.01	0.82	11.67
CTR	48	304	4.35	0.78	16.03
NEREF-02	38	146	4.63	0.88	16.69
NLONREF-03	40	222	4.03	0.76	14.24
WREF-05	58	343	4.68	0.80	20.01

3.4 Sediment Coring

Sediment cores were collected over the Seawolf mound from three zones (previously established and relative to the central position of the mound): inner (0 to 200 m), middle (200 to 400 m) and outer (400 to 600 m) (Figure 2-3). Short cores were collected to characterize the physical and chemical attributes of the overlying cap material across the Seawolf mound. A total of 10 short sediment cores (nine locations and one duplicate) were collected over the Seawolf mound with recovered lengths ranging from 61 to 145 cm (Table 3-7). A single short core with a length of 57 cm was collected at WREF. Long cores were collected to detect any patterns in chemical concentrations with depth. A total of four long cores (three locations and one duplicate) were collected in the three zones. Long core lengths ranged from 287 to 300 cm (Table 3-7).

The top 50 cm from each of the short cores was logged and then homogenized to form a single sample per station. The long cores were carefully logged over their full length, and five sample segments were selected from various depth intervals, reflecting the stratigraphy of the core. Pre-selected depths were not consistently analyzed from the long cores to allow investigators the flexibility of capturing unique features/horizons within each core. This segmentation scheme was implemented to avoid sample segments that crossed obvious transitions in sediment properties. These segments from the long cores were homogenized individually to obtain five individual samples per station. From each homogenate, samples for percent TOC, PAHs, metals, and grain size were collected. All short core samples were analyzed, and three of the five samples from each long core were analyzed. The remaining samples were archived.

Lithology (as described by the Marine Geomechanics Lab at URI) and photographs of each core are presented in Appendixes D-1 and D-2, respectively. A vertical scale representing the actual core length in centimeters has been provided for reference and as an index for locating the position of the various segments selected for analysis. Physical (Appendix D-3) and chemical (Appendix D-4) data for each sediment segment selected for analysis are also provided. For any compound undetected in a particular sample, a value of one-half the laboratory detection limit was used for calculation of total PAH.

3.4.1 Short Cores

Visual Description

The short cores from all three zones were composed primarily of stiff, olive clayey silt. Thin dark layers of sandy silt were present in cores in the inner and middle zones. Core NLDS-48, in the inner zone, had a thin layer of black silt and embedded shells at the surface and a pocket of charcoal colored sandy silt in a segment located at a depth of approximately 38 to 45 cm (Appendix D-1). Core NLDS-43, in the middle zone, was coarser on top, with

Table 3-7.

Summary of Core Processing, July 2006

Site	Core	Latitude (N)	Longitude (W)	Type of Core	Recovered Core Length (cm)	No. of Core Sections Submitted for Phys/Chem Analysis	No. of Core Sections Archived
Seawolf Mound							
	NLDS-40	41° 16.268'	72° 05.034'	Short	61	1	0
	NLDS-41	41° 16.317'	72° 05.059'	Short	102	1	0
	NLDS-41-DUP	41° 16.315'	72° 05.058'	Short	107	1	0
	NLDS-42	41° 16.455'	72° 05.162'	Short	142	1	0
	NLDS-43	41° 16.401'	72° 04.916'	Short	145	1	0
	NLDS-44	41° 16.512'	72° 04.993'	Short	132	1	0
	NLDS-45	41° 16.603'	72° 05.016'	Short	122	1	0
	NLDS-46	41° 16.549'	72° 04.822'	Short	60	1	0
	NLDS-47	41° 16.519'	72° 04.742'	Short	61	1	0
	NLDS-48	41° 16.461'	72° 04.771'	Short	132	1	0
	NLDS-49	41° 16.363'	72° 05.103'	Long	292	3	2
	NLDS-50	41° 16.425'	72° 04.970'	Long	287	3	2
	NLDS-51	41° 16.464'	72° 04.874'	Long	290	3	2
	NLDS-51-DUP	41° 16.464'	72° 04.871'	Long	300	3	2
Reference Area							
WREF	NLDS-52	41° 16.206'	72° 05.970'	Short	57	1	0

Datum: NAD 83

the top 15 cm comprised of dark olive medium grained silty sand with a mixture of pebbles and small stones, transitioning to pure clayey silt embedded pockets of dark charcoal colored clayey silt through the remainder of the core. Two of the cores in the outer zone (NLDS-40 and NLDS-42) transitioned to coarser sediments with depth. Whole and/or fragments of clam, mussel, and/or scallop shells were observed in seven of the 10 cores.

At the WREF reference station (NLDS-52), clayey silt was observed at the surface with the quantity of sand increasing with depth through the core. Approximately 35 to 50% shell hash was observed through the full depth of the core (Appendix D-1). This core was much denser than cores from the mound region, with the exception of NLDS-40 and NLDS-42 (located in the outer zone and outside the acoustically detectable footprint of the mound [Figure 2-3]).

Physical Description

Grain Size

The short cores collected in the 2006 survey were primarily dominated by fine-grained sediments (Table 3-8), with an overall average of 69% silt and clay in all of the cores. Two of the short cores in the outer zone (NLDS-40 and NLDS-42, which were located beyond the acoustically detectable footprint of the mound, Figure 2-3) were predominantly sand (87% and 73%, respectively). These cores were similar to the grain size observed in the WREF core (69% sand). The third core in the outer zone (NLDS-41), was located within the CDM region (Figure 2-3), and contained 78% (average of the duplicates) silt and clay.

Total Organic Carbon

TOC averaged 0.9%, and ranged from 0.2% to 1.4% in the 2006 short cores (Table 3-8). The highest values were observed in the cores within the footprint of the mound. The lowest values were observed in cores NLDS-40 and NLDS-42 (0.2% and 0.5%, respectively), which were beyond the acoustically detectable footprint of the mound and which contained coarser-grained sediments. These values were similar to the TOC in the WREF core (0.2%). Overall, TOC observed in the 2006 short cores was lower than the values observed in previous surveys.

Chemistry

The short cores were analyzed for PAHs, eight trace metals (chromium [Cr], copper [Cu], zinc [Zn], arsenic [As], cadmium [Cd], mercury [Hg], lead [Pb], and nickel [Ni]) and aluminum (Al) for reference. The results of the metals analysis of the short cores are summarized in Tables 3-9 and 3-10, PAH results are summarized in Table 3-11, and all results are detailed in Appendix D-4.

Table 3-8.

Grain Size and TOC in Seawolf 2006 Cores

Station	Depth Interval (cm)	Total Sand (%)	Total Silt & Clay (%)	TOC (%)
Short Cores				
Inner Zone				
NLDS-46	0 - 50	15	85	1.37
NLDS-47	0 - 50	12	88	1.13
NLDS-48	0 - 50	16	84	1.10
Average		**14**	**86**	**1.20**
Middle Zone				
NLDS-43	0 - 50	25	75	0.84
NLDS-44	0 - 50	12	88	1.10
NLDS-45	0 - 50	15	85	0.95
Average		**17**	**83**	**0.96**
Outer Zone				
NLDS-40	0 - 50	87	13	0.23
NLDS-41*	0 - 50	22	78	1.18
NLDS-42	0 - 50	73	27	0.49
Average		**61**	**39**	**0.63**
Average, All short cores		**31**	**69**	**0.93**
Long Cores				
Inner Zone				
NLDS-51*	0 – 60	37	63	NA
NLDS-51*	60 – 100	51	49	0.66
NLDS-51*	100 – 125	24	77	0.98
NLDS-51*	125 – 175	23	78	NA
NLDS-51*	200 – 250	21	79	1.55
Middle Zone				
NLDS-50	0 – 50	17	83	NA
NLDS-50	150 – 190	12	88	0.94
NLDS-50	190 – 215	14	86	1.30
NLDS-50	215 – 260	35	65	0.55
NLDS-50	260 – 292	19	81	NA

Table 3-8, (continued).

Grain Size and TOC in Seawolf 2006 Cores

Station	Depth Interval (cm)	Total Sand (%)	Total Silt & Clay (%)	TOC (%)
Outer Zone				
NLDS-49	0 - 50	14	86	NA
NLDS-49	110 – 135	7	93	0.72
NLDS-49	140 – 165	66	34	0.39
NLDS-49	165 – 195	85	15	0.42
NLDS-49	250 – 296	88	12	NA
Average, All long cores		**34**	**66**	**0.83**
All Data Summary				
Average		33	67	0.88
Standard Deviation		27	27	0.37
Maximum		88	93	1.55
Minimum		7	12	0.23
1997 Data Summary Mean		19	81	2.13
1998 Data Summary Mean		13	87	2.89
2001 Data Summary Mean		22	78	2.71
Reference				
NLDS-52 (WREF)	0 - 50	69	31	0.22

* Average of duplicates

Metals

The eight trace metals were detected in all of the short cores at relatively low concentrations (Table 3-9). Concentrations of Cr, Cu, and Zn (previously identified as contaminants of concern in the UDM) along with Ni and Pb are presented graphically in Figure 3-17. The six inner and middle zone cores exhibited similar concentrations for all of the metals. The zone-averaged concentrations of As, Cr, and Ni were higher in the inner and middle zones compared with the outer zone short cores. Two of the outer zone short cores (NLDS-40 and NLDS-42, located off the acoustically detectable footprint of the mound) had lower than average concentrations of all the metals except for Pb and Hg in NLDS-40. Core NLDS-41 (average of the duplicates) had the highest concentrations of all the metals except for As and Hg.

Metals concentrations were typically observed to vary with grain size. To better compare metals concentrations in the short cores, the concentrations were normalized to percent fine-grained sediments (Table 3-10). After normalizing to percent fines, the outer zone short cores (which had a much coarser average grain size) had higher zonal-average concentrations than the inner and middle zones for all of the metals. Highest normalized metals concentrations were observed in outer zone core NLDS-40. Normalized metals concentrations in the inner and middle zones were similar to each other.

The metals concentrations in the short cores were higher than the metals concentrations in the reference area (WREF, Table 3-9, Figure 3-17), with the exception of As in outer zone core NLDS-40 (Table 3-9). When normalized to percent fines, metals concentrations inner and middle zone short cores were similar to reference area concentrations, and concentrations in the outer zone core were higher than the reference area. Normalization of metals concentrations to Al concentration is another method to compare concentrations in sediments of varying grain size. Once normalized to Al, the average metals concentrations in all short cores were similar to the reference area concentrations (Figure 3-18, Table 3-9).

Average short core concentrations of the metals were compared to previous surveys and available pre-dredge UDM and CDM data. A subset of the metals (Cr, Cu, Pb, Ni, Zn) is presented graphically along with the UDM and CDM data in Figure 3-19. CDM and UDM data from 1990 and 1994 represent average concentrations over the dredge depth, while 1992 UDM data represent primarily surficial (upper 0.9 m) dredged sediments, where concentrations were expected to be highest (SAIC 2001a). Metals concentrations in 2006 short cores were similar to previous (1997, 1998, and 2001) average short core metals concentrations, which were all greater than reference area concentrations. Cu and Zn

Table 3-9.

Metals Concentrations in 2006 Seawolf Cores

Station	Depth Interval (cm)	Concentration (mg/kg)								
		As	Cd	Cr	Cu	Pb	Ni	Zn	Hg	Al
Short Cores										
Inner Zone										
NLDS-46	0 - 50	9.6	0.23	40	20	16	24	72	0.037	42000
NLDS-47	0 - 50	9.7	0.22	39	20	15	24	71	0.038	39000
NLDS-48	0 - 50	9.2	0.29	40	34	20	24	79	0.065	39000
Average		**9.5**	**0.25**	**40**	**25**	**17.0**	**24**	**74**	**0.047**	**40000**
Middle Zone										
NLDS-43	0 - 50	7	0.11	26	20	8.8	17	50	0.015	35000
NLDS-44	0 - 50	9.9	0.17	35	17	13	24	71	0.023	41000
NLDS-45	0 - 50	9.8	0.20	36	22	16	24	72	0.029	39000
Average		**8.9**	**0.16**	**32**	**20**	**12.6**	**22**	**64**	**0.022**	**38333**
Outer Zone										
NLDS-40	0 - 50	2.7	0.074	13	9.9	27	8	34	0.047	23000
NLDS-41*	0 - 50	9.2	0.31	42	42	46	39	131	0.058	39500
NLDS-42	0 - 50	3.6	0.09	16	9.7	12	9.3	39	0.030	25000
Average		**5.2**	**0.16**	**24**	**21**	**28**	**19**	**68**	**0.045**	**29167**
Average, short cores		7.9	0.19	32	22	19	22	69	0.04	35833
Maximum, short cores		9.9	0.31	42	42	46	39	131	0.065	42000
Minimum, short cores		2.7	0.07	13	9.7	8.8	8.0	34	0.02	23000
Long Cores										
Inner Zone										
NLDS-51*	0 – 60	NA	NA	NA	NA	NA	NA	NA	NA	NA
NLDS-51*	60 – 100	4.65	0.32	45	68	56	20	240	0.2	34000
NLDS-51*	100 – 125	9.65	0.36	40	168	26	22	91	0.065	37500
NLDS-51*	125 – 175	NA	NA	NA	NA	NA	NA	NA	NA	NA
NLDS-51*	200 – 250	9.95	0.61	56.5	49	38.5	25	113	0.016	42000
Middle Zone										
NLDS-50	0 – 50	NA	NA	NA	NA	NA	NA	NA	NA	NA
NLDS-50	150 – 190	9.4	0.18	40	17	12	24	79	0.024	47000
NLDS-50	190 – 215	10	0.39	46	28	22	26	88	0.058	43000
NLDS-50	215 – 260	7.2	0.39	38	29	27	20	82	0.075	36000
NLDS-50	260 – 292	NA	NA	NA	NA	NA	NA	NA	NA	NA

Table 3-9, (continued).

Metals Concentrations in 2006 Seawolf Cores

Station	Depth Interval (cm)	Concentration (mg/kg)								
		As	Cd	Cr	Cu	Pb	Ni	Zn	Hg	Al
Outer Zone										
NLDS-49	0 – 50	NA	NA	NA	NA	NA	NA	NA	NA	NA
NLDS-49	110 – 135	10	0.13	38	13	8.3	24	65	0.0053	44000
NLDS-49	140 – 165	4.1	0.12	20	14	17	12	52	0.034	30000
NLDS-49	165 – 195	2.7	0.07	9.3	8.9	16	7.1	32	0.03	33000
NLDS-49	250 – 296	NA	NA	NA	NA	NA	NA	NA	NA	NA
Average, long cores		8	0.3	37	44	25	20	94	0.06	
All Data Summary										
Average		7.7	0.2	34	33	22	21	81	0.05	
Standard Deviation		2.8	0.1	13	37	13	8	47	0.04	
Maximum		10.0	0.6	57	168	56	39	240	0.20	
Minimum		2.7	0.1	9	9	8	7	32	0.01	
1997 Data Summary Mean		7.5	0.32	38.9	28.5	25	22.3	95.3	0.12	
1998 Data Summary Mean		7.2	0.17	36.2	28.4	29	25.7	85.7	0.07	
2001 Data Summary Mean		7.3	0.19	31.3	20.2	19.3	17.9	72.7	0.07	
Pre-Dredge UDM Mean (1992)		12.6	2.9	108	139	126	65	235	0.4	
Pre-Dredge UDM Mean (1990, 94)		7.8	1.2	40	32	44	17	79	0.2	
Pre-Dredge CDM Mean (1990, 94)		6.3	0.7	39	22	27	18	68	0.09	
Reference NLDS-52 (WREF)	0 – 50	3.5	0.067	11	6.3	6.9	7.5	28	0.02	13000

* Average of duplicates

Table 3-10.

Metals Concentrations in 2006 Seawolf Cores Normalized to Percent Fines

Station	Depth Interval (cm)	Concentration (mg/kg)							
		As	Cd	Cr	Cu	Pb	Ni	Zn	Hg
Short Cores									
Inner Zone									
NLDS-46	0 – 50	11	0.3	47	24	19	28	85	0.04
NLDS-47	0 – 50	11	0.2	44	23	17	27	80	0.04
NLDS-48	0 – 50	11	0.3	48	40	24	29	94	0.08
Average		**11**	**0.3**	**46**	**29**	**20**	**28**	**86**	**0.05**
Middle Zone									
NLDS-43	0 – 50	9	0.1	35	27	12	23	67	0.02
NLDS-44	0 – 50	11	0.2	40	19	15	27	80	0.03
NLDS-45	0 – 50	12	0.2	42	26	19	28	85	0.03
Average		**11**	**0.2**	**39**	**24**	**15**	**26**	**77**	**0.03**
Outer Zone									
NLDS-40	0 – 50	21	0.6	99	76	206	61	259	0.36
NLDS-41*	0 – 50	12	0.4	53	54	59	50	168	0.07
NLDS-42	0 – 50	14	0.3	60	36	45	35	146	0.11
Average		**15**	**0.4**	**71**	**55**	**103**	**49**	**191**	**0.18**
Average, short cores		12	0.3	52	36	46	34	118	0.09
Maximum, short cores		21	0.6	99	76	206	61	259	0.36
Minimum, short cores		9	0.1	35	19	12	23	67	0.02
Long Cores									
Inner Zone									
NLDS-51*	0 – 60	NA	NA	NA	NA	NA	NA	NA	NA
NLDS-51*	60 – 100	9	0.6	90	138	113	41	487	0.41
NLDS-51*	100 – 125	13	0.5	52	220	33	29	119	0.08
NLDS-51*	125 – 175	NA	NA	NA	NA	NA	NA	NA	NA
NLDS-51*	200 – 250	13	0.8	71	62	48	31	142	0.02
Middle Zone									
NLDS-50	0 – 50	NA	NA	NA	NA	NA	NA	NA	NA
NLDS-50	150 – 190	11	0.2	46	19	14	27	90	0.03
NLDS-50	190 – 215	12	0.5	53	32	26	30	102	0.07
NLDS-50	215 – 260	11	0.6	58	44	41	31	126	0.11
NLDS-50	260 – 292	NA	NA	NA	NA	NA	NA	NA	NA

Table 3-10, (continued).

Metals Concentrations in 2006 Seawolf Cores Normalized to Percent Fines

Station	Depth Interval (cm)	Concentration (mg/kg)							
		As	Cd	Cr	Cu	Pb	Ni	Zn	Hg
Outer Zone									
NLDS-49	0 - 50	NA	NA	NA	NA	NA	NA	NA	NA
NLDS-49	110 – 135	11	0.1	41	14	9	26	70	0.01
NLDS-49	140 – 165	12	0.3	58	41	49	35	151	0.10
NLDS-49	165 – 195	18	0.5	63	60	108	48	215	0.20
NLDS-49	250 – 296	NA	NA	NA	NA	NA	NA	NA	NA
Average, long cores		12	0.5	59	70	49	33	167	0.11
All Data Summary									
Average		12	0.4	56	53	48	34	143	0.10
Standard Deviation		3	0.2	17	51	50	10	100	0.11
Maximum		21	0.8	99	220	206	61	487	0.41
Minimum		9	0.1	35	14	9	23	67	0.01
1997 Data Summary Mean				52	38	32	30	120	0.20
1998 Data Summary Mean				42	33	34	29	106	0.02
2001 Data Summary Mean				47	32	35	27	103	0.01
UDM 1990				84	75	102	37	162	0.35
CDM 1990				59	38	59	31	109	0.08
Reference									
NLDS-52 (WREF)	0 - 50	11	0.2	35	20	22	24	90	0.06

* Average of duplicates

Table 3-11.

Individual PAH Concentrations in Seawolf 2006 Short Cores

Radial Zone:	Outer zone (400-600 m)				Middle zone (200-400 m)				Inner zone (0-200 m)								WREF
Year of Coring Survey:	2006 Sediment Cores			2006	2006 Sediment Cores			2006	2006 Sediment Cores			2006	All Short Cores				2006
NLDS Core Name:	40	41	42	Avg	43	44	45	Avg	46	47	48	Avg	Avg	StDev	Max	Min	52
PAH Compound																	
Low Molecular Weight																	
Naphthalene	18	40	70	43	9	13	23	15	19	16	39	25	27	19	70	9	5.3 U
Acenaphthylene	17	54	230	100	13	16	15	15	28	22	97	49	55	71	230	13	20
Acenaphthene	5.4 U	8	50	21	6.3 U	8.3 U	8 U	8	7.7 U	7.6 U	46	20	13	15	50	5	5.3 U
Fluorene	5.4 U	14	41	20	6.3 U	8.3 U	8 U	8	7.7 U	7.6 U	38	18	12	12	41	5	5.3 U
Phenanthrene	56	95	680	277	20	32	32	28	46	43 J	320	136	147	241	680	20	13
Anthracene	47	46	1000	364	11	15	16	14	29	21	260	103	161	324	1000	11	9
Sum of LMW PAHs	**149**	**257**	**2071**	**826**	**65**	**93**	**102**	**87**	**138**	**118**	**800**	**352**	**421**	**659**	**2071**	**65**	**58**
High Molecular Weight																	
Fluoranthene	260	263	1700	741	56	85	82	74	110	110 J	920	380	398	640	1700	56	31
Pyrene	240	357	1900	832	76	120	120	105	160	160 J	1200	507	481	709	1900	76	39
Benz[a]anthracene	140	135	1200	492	44	43	44	44	94	43 J	500	212	249	459	1200	43	26
Chrysene	120	160	1200	493	52	50	54	52	96	60	520	225	257	457	1200	50	28
Benzo[b]fluoranthene	110	143	580	278	38	49	54	47	93	45	270	136	154	209	580	38	29
Benzo[k]fluoranthene	110	127	780	339	42	44	47	44	84	41	340	155	179	291	780	42	30
Benzo[a]pyrene	140	153	1200	498	57	52	57	55	100	37	490	209	254	455	1200	52	36
Indeno[1,2,3-cd]pyrene	81	89	460	210	29	28	32	30	48	20	200	89	110	169	460	28	23
Dibenz[a,h]anthracene	23	27	140	63	11	10	10	10	16	7.6 U	56	27	33	51	140	10	7
Benzo[g,h,i]perylene	82	99	510	230	36	32	40	36	54	25	240	106	124	187	510	32	26
Sum of HMW PAHs	**1306**	**1553**	**9670**	**4176**	**441**	**513**	**540**	**498**	**855**	**549**	**4736**	**2047**	**2240**	**3096**	**9670**	**441**	**275**
Total PAHs	**1455**	**1810**	**11741**	**5002**	**506**	**605**	**642**	**584**	**992**	**666**	**5536**	**2398**	**2661**	**3752**	**11741**	**506**	**333**
1997 Mean, Total PAHs				**381**				**203**				**445**	**323**				
1998 Mean, Total PAHs				**292**				**558**				**312**	**387**				
2001 Mean, Total PAHs				**1048**				**388**				**505**	**647**				

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.

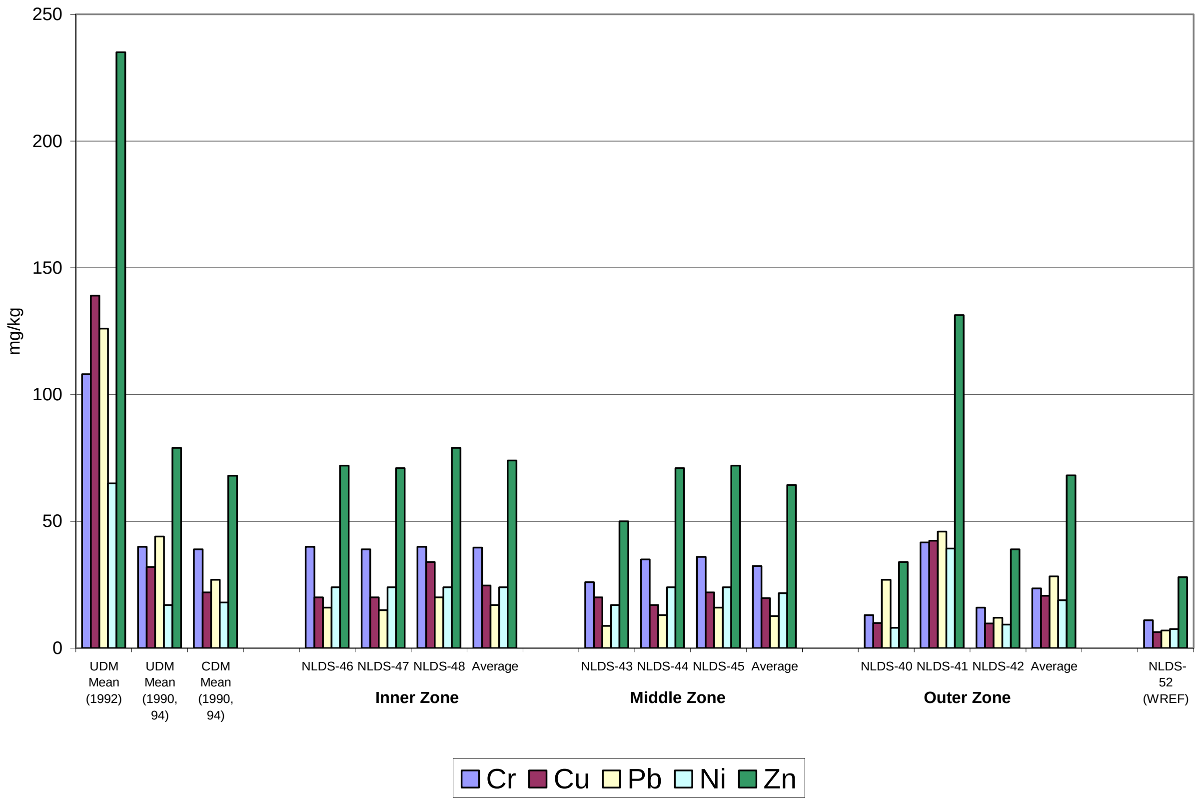


Figure 3-17. Metal concentrations in Seawolf 2006 short cores and pre-dredge surveys

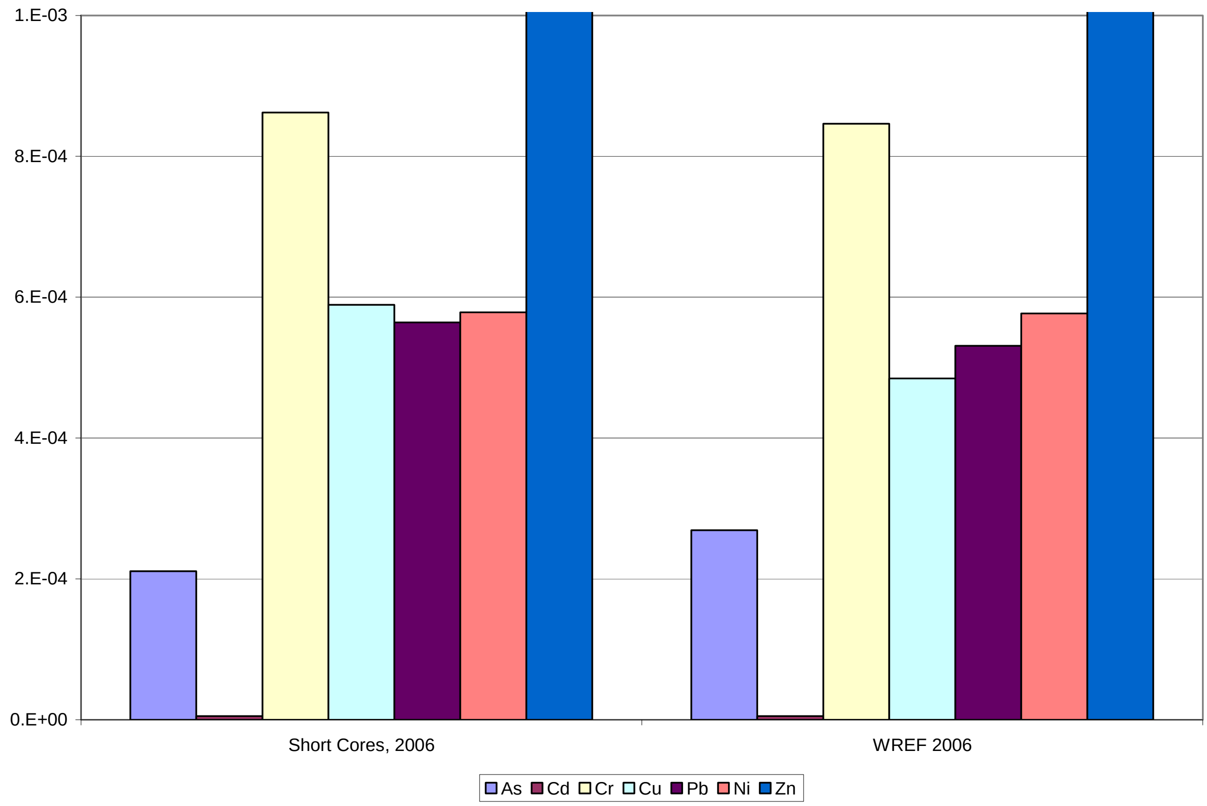
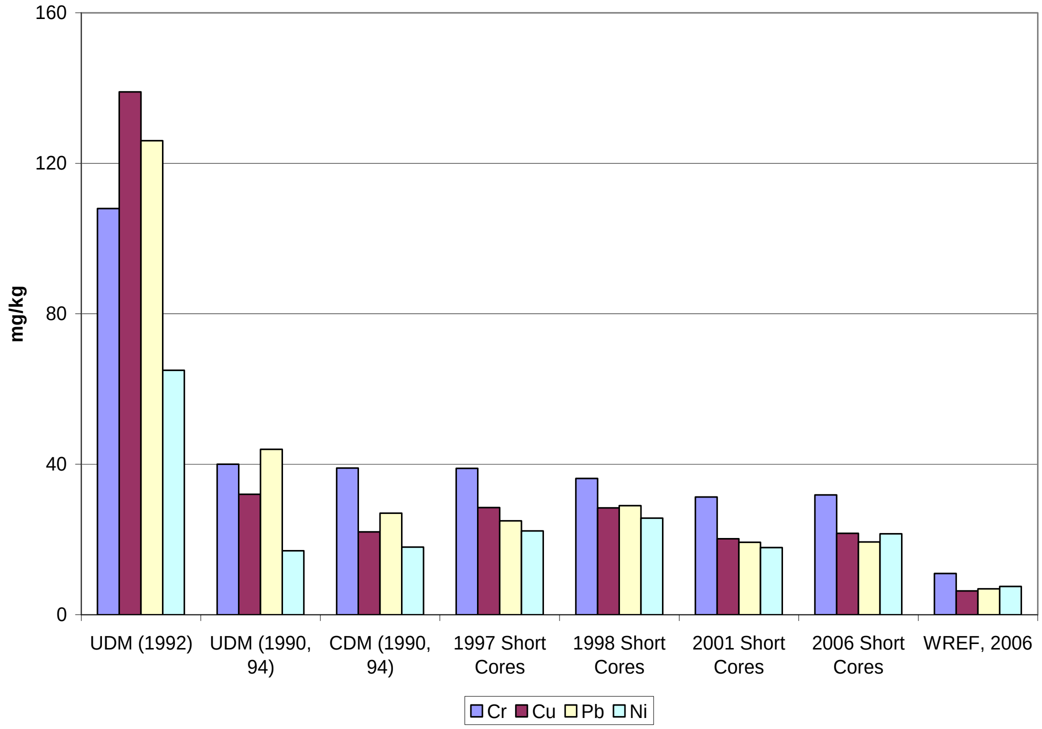


Figure 3-18. Average 2006 Seawolf short cores metal concentrations normalized to aluminum



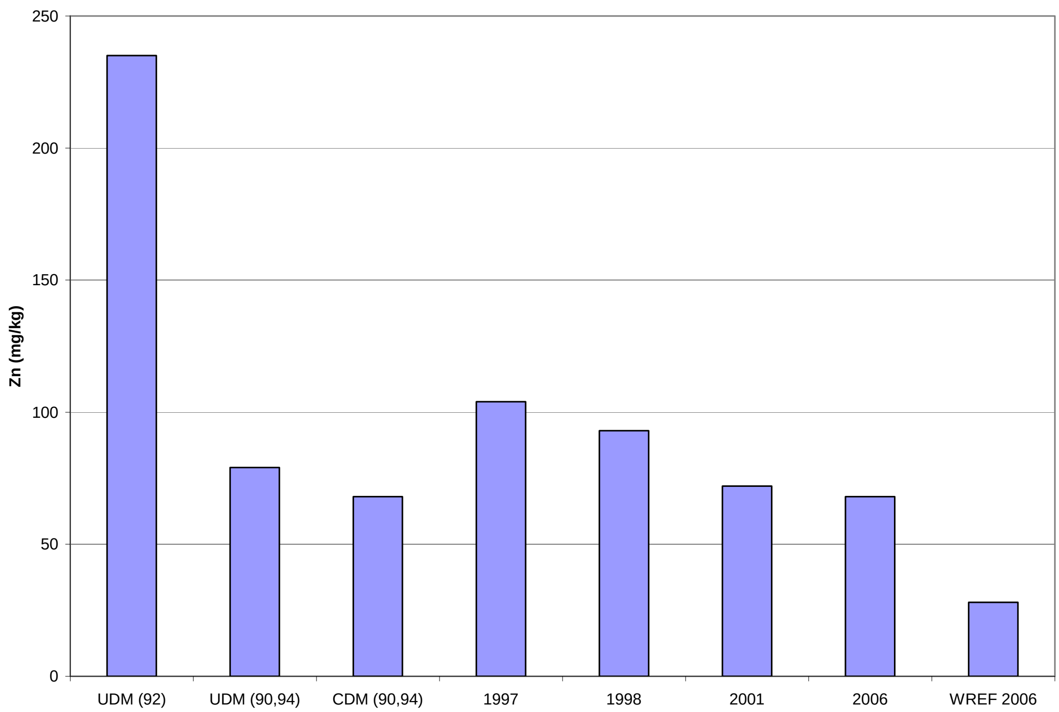


Figure 3-19. Average metals (top) and zinc (bottom) concentrations in Seawolf post-cap short cores and pre-dredge surveys

2006 concentrations fell in between the 1990/94 averages for UDM and CDM, while Pb was slightly lower, and Ni and Cr were slightly higher. All 2006 metals concentrations were significantly lower compared with the most contaminated (1992) UDM. When normalized to percent fines (Figure 3-20), the short core concentrations were generally slightly lower than the 1990 CDM concentrations (the only historical dataset that included grain size data), and higher than the reference area concentrations.

PAHs

Sixteen individual polycyclic aromatic hydrocarbons (PAHs) were analyzed in the short cores (Table 3-11, Figure 3-21). There was a wide range of observed PAHs in the short cores, but overall PAH concentrations in the majority of the short cores were relatively low. Two compounds, acenaphthene and fluorene, were not detected in six of the nine cores. The mean sum of low molecular weight (LMW) PAHs ranged from 65 to 2071 μg/kg, and the mean sum of high molecular weight (HMW) PAHs ranged from 441 to 9670 μg/kg.

In the inner zone, cores NLDS-46 and NLDS-47 had similar LMW PAH concentrations, while HMW PAHs were higher in NLDS-46. Core NLDS-48 had higher concentrations for all PAHs than the other inner zone cores. TOC, grain size, and metals concentrations did not show the wide-ranging variation that was observed in the PAH concentrations in the inner zone cores. The PAH concentrations in the inner cores were generally higher (with the exception of a few compounds in NLDS-47) than the reference area concentrations. The 2006 average total PAH concentration (2398 μg/kg) for the three inner short cores was higher than that observed in the 1997, 1998, and 2001 surveys (312 to 505 μg/kg).

Middle zone short core PAH concentrations were the lowest of the three zones. The LMW PAH average concentration was 87 μg/kg, and the HMW PAH average concentration was 498 μg/kg. Concentrations were slightly elevated compared with reference area concentrations (LMW PAH of 58 μg/kg and HMW PAH of 275 μg/kg). Total middle zone-averaged PAHs in 2006 were similar to previously observed concentrations (203 to 558 μg/kg).

The short cores in the outer zone had the highest PAHs of the three zones in the 2006 survey. Concentrations in cores NLDS-40 and NLDS-41 were similar, but slightly higher in NLDS-41. PAH concentrations in core NLDS-42 were higher for all compounds than any of the other short cores. Both cores NLDS-40 and NLDS-42 were located off of the acoustically detectable footprint of the Seawolf mound, and had much coarser sediments and lower TOC than the other short cores. Outer zone-averaged total PAH concentrations (5002 μg/kg) exceeded the reference area concentrations (333 μg/kg) as well as previously observed outer zone concentrations (381 to 1048 μg/kg).

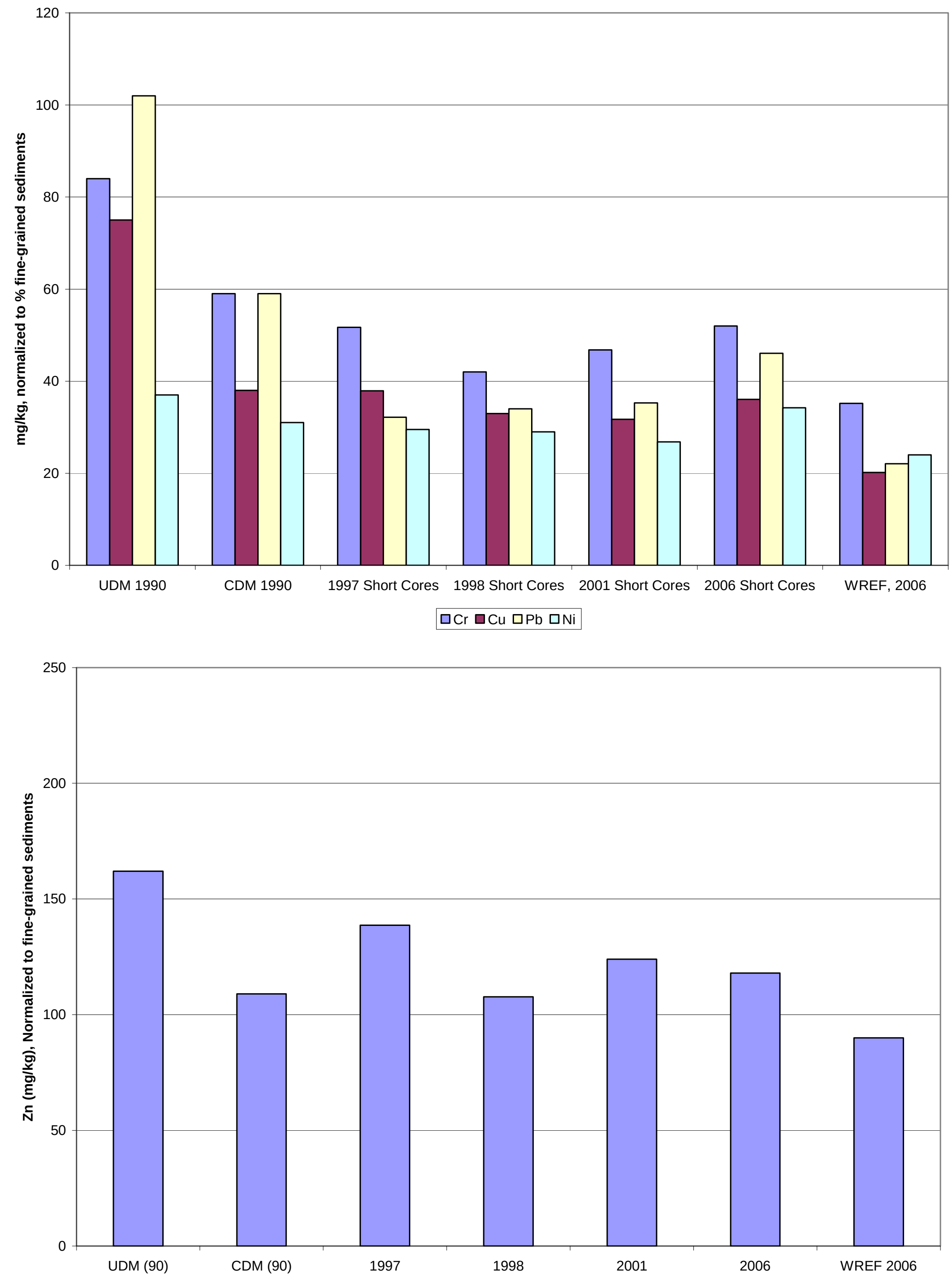


Figure 3-20. Average metals (top) and zinc (bottom) concentrations normalized to percent fines in Seawolf post-cap short cores and pre-dredge surveys

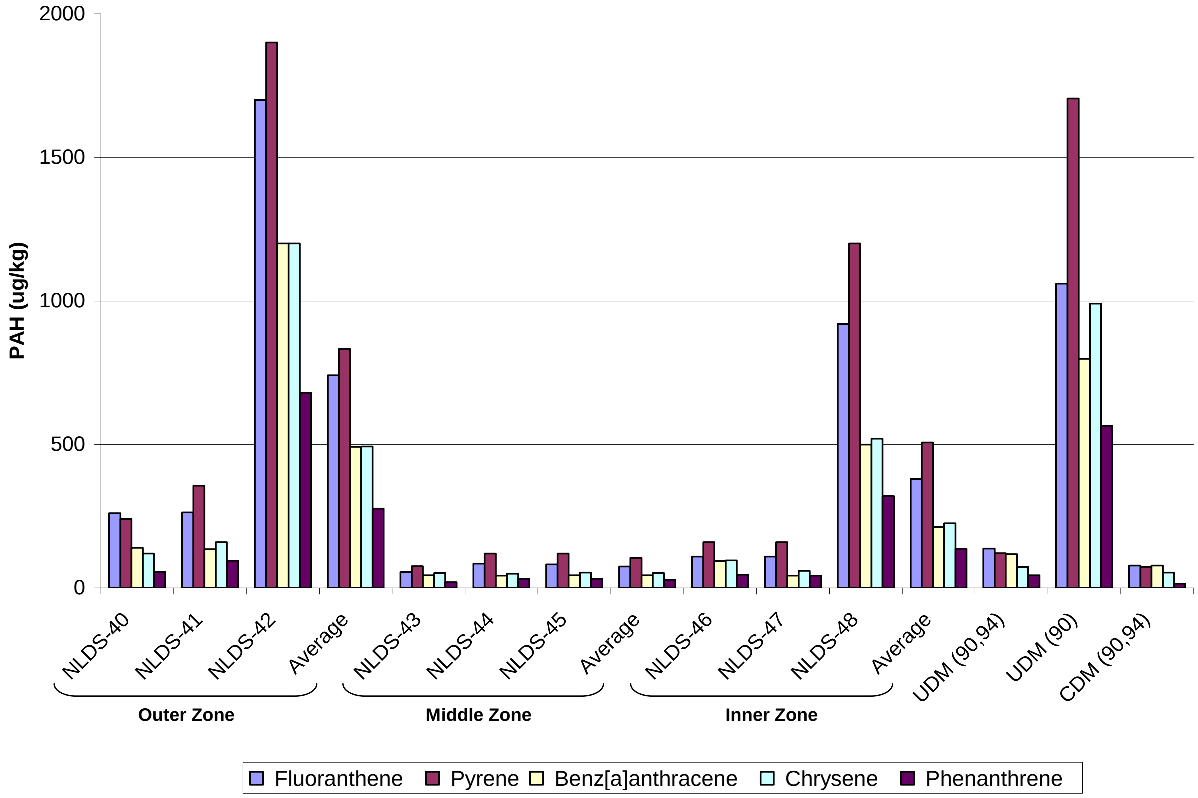


Figure 3-21. Individual PAH concentrations in Seawolf 2006 short cores and pre-dredge surveys

PAH concentrations averaged across cores were higher in 2006 than in previous surveys and higher than the reference area for all compounds (Figure 3-22). The 2006 concentrations were higher than the 1990/1994 CDM and UDM, but lower than the 1992 UDM representative of the surficial material, which had the highest observed UDM concentrations.

3.4.2 Long Cores

Visual Description

Sediments in the long cores were dominated by olive gray clayey silt throughout much of the cores (Appendix D-2). In the inner zone, core NLDS-51 and its duplicate contained a horizon of black silty coarse sand with rocks and pebbles from approximately 60 to 100 cm. Above and below this horizon the cores contained olive gray clayey silt. Both of the duplicate cores had a distinct, although somewhat mixed, interface at 100 cm depth (Appendix D-2). Below the transition, olive clayey silt was observed to the full depth of each core. Sediment samples collected from below the 100 cm interface in these cores all had a distinct odor of petroleum.

In core NLDS-50 (middle zone) the olive sediments began a subtle transition to an olive-brown coloration at a depth of 190 cm, and at 215 cm a color change was observed (Appendix D-2). A minor component of fine sand and shell hash was observed in the clayey silt between depths of 240 to 260 cm. Olive-brown silt was observed in the bottom of this core, below approximately 260 cm. No transition to native materials was observed in the cores in the inner or middle zones.

The upper 140 cm of core NLDS-49 (outer zone) was comprised of olive gray silty clay with a small pocket of black silt and shell fragments located at approximately 75 cm (Appendix D-2). At 140 cm a very sharp interface was observed between olive gray silty clay and black sandy silt. Between 140 cm and another interface at 200 cm, layers of black silt alternated with dark silty coarse sand interspersed with rocks and pebbles. The bottom of the core, below 200 cm, was olive gray, fine-grained sand, characteristic of native sediments in the region.

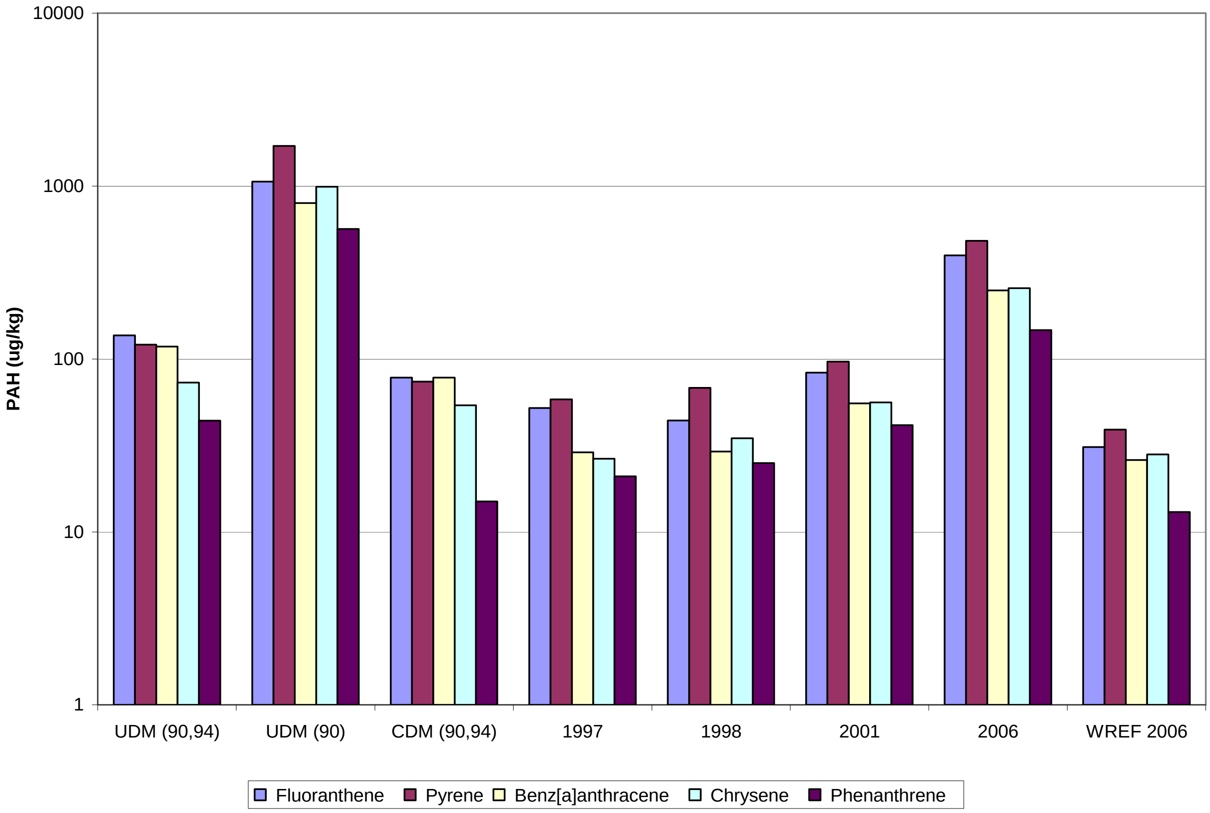


Figure 3-22. Individual PAH concentrations in Seawolf post-cap short cores and pre-dredge surveys

Physical Description

Grain Size

Grain size in the 2006 long cores was generally dominated by silt and clay (Table 3-8). The surface (0-50 cm) segments of the cores ranged from 63% to 86% silt and clay, consistent with the short cores collected within the mound footprint. Cores NLDS-50 and NLDS-51 were consistently fine-grained throughout, with the exception of the 60 to 100 cm segment of inner zone NLDS-51 (49% silt and clay) and the 215-260 cm segment of middle zone NLDS-50 (65% silt and clay). Core NLDS-49 (outer zone) was fine-grained in the upper 135 cm, coarsening with depth to 88% sand in the bottom-most (250 to 296 cm) segment.

Total Organic Carbon

TOC in the long cores averaged 0.8%, and ranged from 0.4% to 1.6% (Table 3-8). As in the short cores, TOC was generally correlated with grain size, but showed no pattern with location on the mound or depth in the core. Also similar to the short cores, TOC in the 2006 long cores was lower overall than previous surveys. The average of all data was 0.83%, compared with overall averages of 2.1% (1997), 2.9% (1998), and 2.7% (2001).

Chemistry

Three segments of each of the long cores were analyzed for eight trace metals and 16 PAHs. The cores were divided into five segments, based on visual observation. The top (~0 to 60 cm) segment and one of the lower segments of each core were not analyzed for metals and PAHs. Analyzed segments were selected to provide representation of sediments that were visually classified as CDM or UDM material.

Metals

Metals concentration in inner zone core NLDS-51 showed no clear depth pattern (Table 3-9, Figure 3-23). One segment (60 to 100 cm) had coarser sediments (49% silt and clay) than the other two segments (77% and 79% silt and clay), but this variation in grain size did not correspond to variations in metals concentrations. The highest concentrations of As, Cd, Cr, and Ni were found at depth (200 to 250 cm), while the highest concentrations of Cu, Pb, Zn, and Hg were observed within the 60 to 125 cm depth intervals. With the exception of Cu and Zn, metals concentrations in the NLDS-51 depth intervals varied over a small range. The highest concentrations of Cr, Cu, Pb, and Zn in the long cores were observed in this core.

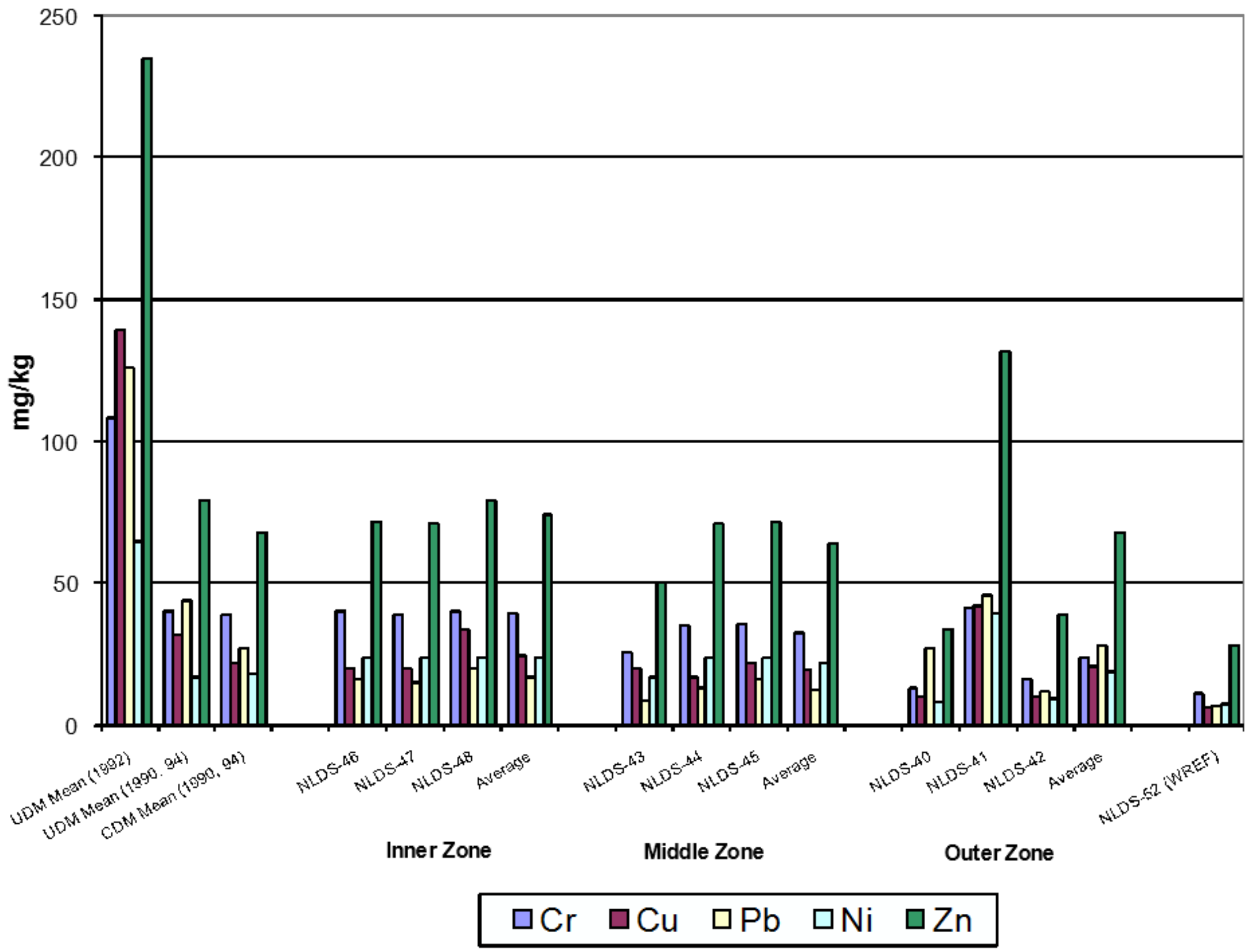


Figure 3-23. Metals concentrations in Seawolf 2006 long core segments and pre-dredge surveys

Metals concentrations in middle zone core NLDS-50 were generally low, with little variation and no pattern with depth (Table 3-9, Figure 3-23). The highest concentrations for all metals were observed in one of the two lower analyzed segments (190 to 215 cm or 215 to 260 cm), both of which were visually classified as UDM.

In outer zone core NLDS-49, observed metals concentrations were lower than those in the other two long cores. The highest concentrations were observed in one of the upper two segments analyzed (110 to 135 cm or 140 to 165 cm), but there was little variation with depth. Metals concentrations in the upper segments of core NLDS-49 were similar to those of NLDS-50; both of these upper layers were visually classified as CDM. With the exception of Cu and Pb, metals concentrations decreased with depth in the core.

In previous Seawolf surveys, only Zn was measured in the long cores. The average 2006 long core Zn concentration (94 mg/kg) is consistent with average Zn concentrations observed in previous surveys (82 mg/kg to 97 mg/kg). In 1998 and 2001, the highest long core Zn concentrations were observed in the inner zone, in the deeper segment (100 to 200 cm) in 1998, and in the upper segment (50-75 cm) in 2001. Normalization to grain size did not change the observed patterns of Zn concentrations (Table 3-10, Figure 3-24).

Metals concentrations in the 2006 long cores were compared to available CDM and UDM data (Table 3-9, Figure 3-23). The middle and outer zone long core metals concentrations were similar to or lower than average CDM and UDM concentrations, and lower than the 1992 UDM concentrations, representative of the surficial sediments with the highest UDM contamination. Metals concentrations in the inner zone core were generally in between the lower 1990/1994 UDM and CDM concentrations, and the higher, surficial 1992 UDM concentrations. Zn in the 60 to 100 cm segment and Cu in the 100 to 125 cm segment were on the order of the highest measured UDM concentrations. Normalization to grain size (Table 3-10, Figure 3-24) did not change the overall patterns observed in the metals concentration; however, there were fewer available normalized CDM and UDM data for comparison.

PAHs

PAH concentrations varied from long core to long core and within cores (Table 3-12). The sum of LMW PAHs ranged from 48 µg/kg to 10,600 µg/kg, and the sum of HMW PAHs ranged from 80 µg/kg to 28,500 µg/kg. Average long core PAH concentrations were higher than average short core PAH concentrations for all compounds.

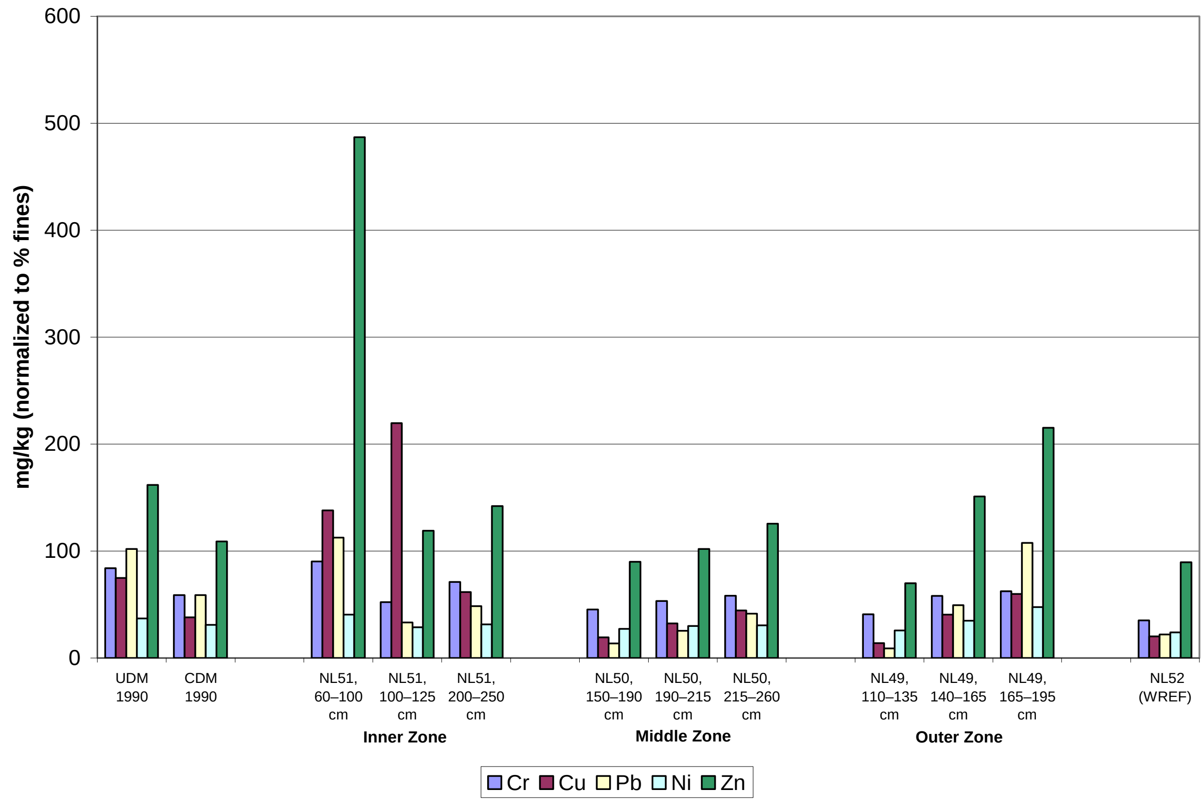


Figure 3-24. Metals concentrations normalized to percent fines in Seawolf 2006 long core segments and pre-dredge surveys

Table 3-12.

Individual PAH Concentrations in Seawolf 2006 Long Cores

	Outer Zone NLDS-49				Middle Zone NLDS-50				Inner Zone NLDS-51				All Long Cores			
Depth Interval (cm)	**110-135**	**140-165**	**165-195**	**Avg**	**150-160**	**190-215**	**215-260**	**Avg**	**60-100**	**100-125**	**200-250**	**Avg**	**Avg**	**StDev**	**Max**	**Min**
PAH Compound																
Low Molecular Weight																
Naphthalene	8 U	400	41	150	10	28	57	32	127	26	70	74	85	124	400	8
Acenaphthylene	8 U	1000	73	360	12	47	69	43	63	40	99	67	157	318	1000	8
Acenaphthene	8 U	490	6.9	168	7.6 U	8.9	14	10	49	11	39	33	70	158	490	7
Fluorene	8 U	580	12	200	7.6 U	14	27	16	66	18	50	45	87	186	580	8
Phenanthrene	8 U	5500	120	1876	23	93	160	92	470	96	235	267	745	1788	5500	8
Anthracene	8 U	2600	76	895	14	48	86	49	180	51	124	118	354	844	2600	8
Sum of LMW PAHs	**48**	**10570**	**329**	**3649**	**74**	**239**	**413**	**242**	**954**	**242**	**617**	**604**	**1498**	**3413**	**10570**	**48**
High Molecular Weight																
Fluoranthene	8 U	6500	500	2336	66	300	430	265	1175	325	765	755	1119	2049	6500	8
Pyrene	8 U	6300	760	2356	81	300	640	340	1030	300	740	690	1129	1969	6300	8
Benz[a]anthracene	8 U	3400	330	1246	37	110	230	126	440	119	295	285	552	1077	3400	8
Chrysene	8 U	3200	290	1166	46	140	260	149	470	158.5	335	321	545	1006	3200	8
Benzo[b]fluoranthene	8 U	1600	210	606	34	130	210	125	370	128.5	280	260	330	490	1600	8
Benzo[k]fluoranthene	8 U	1700	220	643	31	120	200	117	305	105	235	215	325	525	1700	8
Benzo[a]pyrene	8 U	2900	330	1079	43	130	210	128	385	122	305	271	493	912	2900	8
Indeno[1,2,3-cd]pyrene	8 U	1200	150	453	23	80	120	74	220	75	180	158	228	371	1200	8
Dibenz[a,h]anthracene	8 U	430	49	162	7.6 U	24	38	23	70	21	55	48	78	134	430	8
Benzo[g,h,i]perylene	8 U	1300	160	489	27	90	140	86	240	81	200	174	250	401	1300	8
Sum of HMW PAHs	**80**	**28530**	**2999**	**10536**	**396**	**1424**	**2478**	**1433**	**4705**	**1435**	**3390**	**3176**	**5048**	**8927**	**28530**	**80**
Total PAHs	**128**	**39100**	**3328**	**14185**	**470**	**1663**	**2891**	**1675**	**5659**	**1677**	**4006**	**3781**	**6547**	**12331**	**39100**	**128**

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.

The highest PAH concentrations for all compounds were observed in outer zone core NLDS-49, in the 140 to 165 cm segment, and were generally one to two orders of magnitude higher than other long core PAH concentrations. This segment, and the segment below it, were classified as relict dredged material, based on visual appearance. In the segment above (110 to 135 cm), which was visually classified as CDM, no PAHs were detected. The PAH concentrations in the bottom segment of core NLDS-49 (165 to 195 cm) were more typical of PAH concentrations observed in the other long cores.

Middle zone core NLDS-50 had the lowest average PAH concentrations among the 2006 long cores. Three compounds, acenaphthene, fluorene, and dibenz[a,h]anthracene, were not detected in the upper segment, which was visually classified as CDM. PAH concentrations for all compounds increased with depth in the core.

All of the PAH compounds were detected in inner zone core NLDS-51. The lowest concentrations were detected in the middle (100 to 125 cm) segment, one of the two lower segments visually classified as UDM. The upper (60 to 100 cm) segment was visually classified as CDM, and had the highest PAH concentrations within the core for most compounds. PAH concentrations in the upper segment were similar to those observed in inner zone short core NLDS-48.

3.4.3 Classification of Mound Sediments

CDM and UDM were visually identified in the inner and middle zone long cores (Appendix D-2). In the four cores (three locations plus one duplicate), 100 to 190 cm of CDM overlaid 100 to 150 cm of UDM, with no native sediments or historical dredged material in the cores. The UDM was generally darker in color than the overlying CDM. The transition between the CDM and UDM was visible in the cores.

A CDM layer 140-cm thick was identified in the outer zone long core, overlaying 60 cm of historic dredged material (Appendix D-2). Ambient sediments were observed beneath the historic material. A sharp interface separated the lighter, fine-grained cap material from the coarse-grained historic dredged material. As previously discussed, this core was located beyond the extent of the acoustically detectable UDM mound.

3.5 Data Quality

Chemical analyses were performed at Alpha Woods Hole Group Laboratory in two batches, also known as Sample Delivery Groups (SDGs). All short cores were analyzed in the first SDG, and all long cores were analyzed in the second. Equipment blank, matrix spike, standard reference material (SRM), and laboratory control sample (LCS) data were used to evaluate chemical data accuracy; matrix spike and matrix spike duplicate samples were used to evaluate precision.

The equipment blank associated with the sample set was largely clean of parameters of interest. None of the PAH compounds were detected, and only a few metals were detected at levels below laboratory reporting limits. Selected metal analytes were measured outside of the target matrix spike data quality thresholds (75 to 125%), but SRM and LCS results were well within accuracy limits. Selected metals exceeded the precision target of 20% (as relative percent difference); all metals were 75% or less relative percent difference.

PAH accuracy measurements were all within laboratory and QAPP defined control limits, although precision measured as relative percent difference between duplicate sample spikes for phenanthrene, fluoranthene, pyrene, and benzo(a)anthracene exceeded the target of 30%; all were 42% relative percent difference or less. This is reasonable agreement for PAH analyses of separate aliquots of sediment from the same jar representing a homogenized single core interval. LCS results were excellent for PAH compounds. The agreement of PAH results between the collocated cores NLDS-41 and NLDS-41-DUP was reasonable for PAH data from separate but collocated core samples with similar lithology. All RPDs were within 50% except for fluoranthene at 64.2%. The agreement of PAH results between the collocated cores NLDS-51 and NLDS-51-DUP is much poorer and corroborated by the lithology differences documented for these samples described in Appendix D-1. RPDs for the 100 to 125 cm segment of the core exceed 100% for all detected PAHs. RPDs for PAH result pairs in the 60 to 100 cm and 200 to 250 cm segments are generally in the 30-100% range. The high RPDs are probably attributable to local heterogeneity in the mound sediments.

4.0 DISCUSSION

A monitoring survey was performed at the Seawolf mound in 2006 to fulfill the 10-year post-cap monitoring requirements as part of the overall comprehensive monitoring plan established as part of the permit issued for the dredging and disposal operations at the Groton Submarine Base and in the Thames River channel on behalf of the U.S. Navy. The 2006 survey included performance of bathymetry, sediment-profile imaging, benthic biological sampling, and coring with the following objectives:

1) Document the continued recovery of the surface sediments over the Seawolf mound by assessing benthic conditions and infaunal successional status in comparison to the conditions detected at three DAMOS reference areas surrounding NLDS,

2) Assess the integrity of the cap material by analyzing short and long cores for a suite of physical and chemical properties, and

3) Evaluate the long term stability of the Seawolf mound by assessing changes in bathymetry in comparison to previous surveys.

4.1 Biological Recovery of Mound Sediments

Although there were some differences between the results from the 2006 survey and those from the previous surveys, the overall data set indicates a complete recovery of the benthic community at the Seawolf mound. Differences noted in 2006 included a lack of ubiquitous populations of *Ampelisca*, limited numbers of *Chaetopterus* tubes projecting above the sediment-water interface, reduced frequency of mussel beds, and a smaller RPD depth relative to the reference areas. However, the 2006 data also revealed relatively high densities of other Stage 3 fauna in all stations sampled on the dredged material mound, indicating that mature successional assemblages now occupy the Seawolf mound. Further, there was no detectable difference in benthic community successional stage on the mound compared to reference areas.

A review of past monitoring results suggests that one of the main impediments to a more rapid establishment of Stage 3 fauna at this particular site was the geotechnical makeup of the Gardiner Clay placed as CDM and seen in most of the surface layers throughout the mound. As dredged and placed, this clay appeared to be stiff and initially fairly resistant to biological reworking; however, over the past 10 years, physical weathering and the population cycle of various invertebrate assemblages that settled on the mound reworked this clay layer to the point where it was fairly riddled with infaunal burrows and feeding voids (e.g., Figure 3-10) and supported a relatively dense population of deposit feeders.

The differences in detected mussel beds between the 2006 survey and previous surveys (reduced frequency in 2006 at both the mound and reference areas) may represent natural variations of epifauna in an open bottom (with limited hard substrate) area such as NLDS or may have been related to the SPI measurement technique. Given the relatively limited window width of the SPI faceplate as compared to the potential patch size of mussel beds, it is possible that mussels were present at more locations than indicated by the SPI results (Table 3-1), but the camera drops weren't close enough to the shell clusters to detect them. If documenting the presence or absence of mussels at the site is an important resource management objective, plan-view photography could be incorporated as part of future monitoring surveys in order to effectively sample a much larger area of bottom.

In summary, in the ten years since disposal activity at the Seawolf mound ceased, the benthic communities on the disposal mound have converged with those on the ambient seafloor, with little difference between mound and reference areas other than bathymetric elevation and sediment texture. Future monitoring is expected to show the same degree of natural variability in benthic community assemblage and patch size as seen on the ambient seafloor (Rhoads and Germano 1982).

4.2 Cap Integrity over the Seawolf Mound

Sediment cores were collected to confirm the presence of a cap layer at the surface and to validate the previously observed stratigraphy in the Seawolf mound, which provides evidence for containment of UDM deposits below capping material. A total of 14 cores were collected over the mound from the three zones previously established relative to the approximate central position of the mound: inner (0 to 200 m), middle (200 to 400 m), and outer (400 to 600 m). Ten "short" cores were collected for evaluation of the upper 50 cm cap horizon of the mound, and four "long" cores approximately 3 m in length were collected to evaluate the transition to the deeper capped UDM sediments. Several of the 2006 cores were targeted at locations cored in previous surveys for comparison (Figure 4-1). In addition, a single short core was collected at the reference area WREF for comparison.

Overall, the physical characteristics of the cored sediment as well as chemical analyses of sediment samples supported previous findings of a consistent layer of CDM over the surface of the Seawolf mound with UDM sequestered beneath the CDM. However, there were several anomalies in the data that warranted further review as discussed below.

Short cores collected during the 2006 survey were comprised mainly of olive colored clayey silt, consistent with previous survey results and with the description of the Thames River CDM deposited as the cap over the Seawolf mound (SAIC 2004). All short cores, with the exception of NLDS-42 and the lower portion of NLDS-40, exhibited this material throughout their entire upper 50 cm. Cores NLDS-40 and NLDS-42 consisted of much coarser material, similar to reference area sediment and were consistent with previous cores

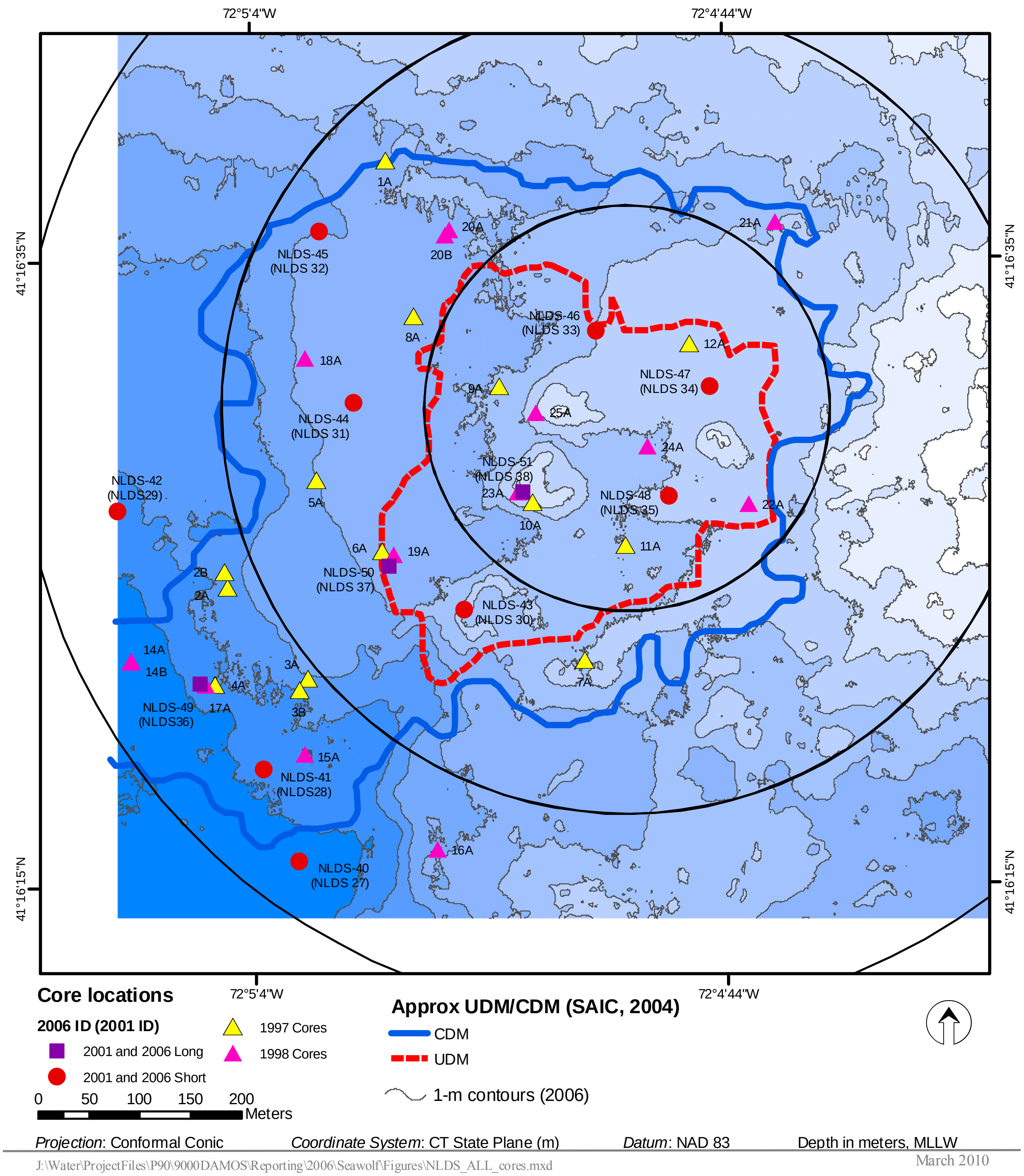


Figure 4-1. Locations of 1997, 1998, 2001, and 2006 Seawolf sediment cores

collected at these locations (NLDS-27 and NLDS-29, Figure 4-2). With their location on the edge of the acoustically detectable footprint of the mound (Figure 4-3) cores NLDS-40 and NLDS-42 were considered representative ambient NLDS sediment rather than part of the Seawolf mound.

Metals concentrations in the 2006 cores were generally consistent with both the pre-mound CDM and UDM data (Maguire Group, Inc. 1995) as well as the post-mound coring and analyses performed in 1997 (SAIC 2001a), 1998 (SAIC 2001b), and 2001 (SAIC 2004). PAH concentrations in the 2006 cores were generally higher than in previous surveys. For the short cores, the average total PAH concentration was driven largely by higher values at two locations, core NLDS-42 in the outer zone and core NLDS-48 in the inner zone. Removal of these two cores from the average reduces the 2006 average total PAH concentration in the short cores by approximately a factor of 3 (to 954 ug/mg), which is still higher than observed in previous surveys but much closer to the 2001 average concentration (Table 3-11). As discussed above, core NLDS-42 was located just outside of the acoustically detectable footprint of the Seawolf mound (Figure 4-3) and had physical characteristics similar to ambient NLDS and reference area sediments (which likely include relic dredged material). Hence, the elevated PAH concentrations at this location are attributed to relic dredged material disposal at the site.

For short core NLDS-48 located in the inner zone of the Seawolf mound, PAH concentrations were higher than the average pre-dredge CDM as well as the 1990/1994 average UDM concentrations and approached the concentration of the 1992 surficial pre-dredge samples of UDM (Figure 3-21). However, on further review of the pre-dredge data, it was determined that the individual sample PAH concentrations from the 1990/1994 pre-dredge CDM samples exhibited significant variation. In particular, one sample noted as “Sample 20 from Dredging Area 4” had elevated PAH concentrations, while the metals concentrations were consistent with the other CDM samples (Table 4-1). These pre-dredge concentrations from CDM Sample 20 were comparable to those of 2006 core NLDS-48 (Table 4-1). Given the observed variability in material classified as CDM, as well as the elevated PAHs in Sample 20 paired with metals concentrations lower than those of UDM material, it is possible that NLDS-48 was located in a pocket of CDM with PAH concentrations higher than the overall average CDM concentrations. The co-location of NLDS-48 with cores from previous surveys without anomalous PAH concentrations indicates that this pocket of elevated PAHs was very localized. This is consistent with previous observations of the preservation of small scale spatial heterogeneity from sediments in the dredge area to the disposal location (Fredette et al., 1992). Small scale heterogeneity was further supported by the variations in some concentrations detected in the duplicate cores collected in 2006 (short core NLDS-41 and long core NLDS-51, Appendix D-3 and D-4).

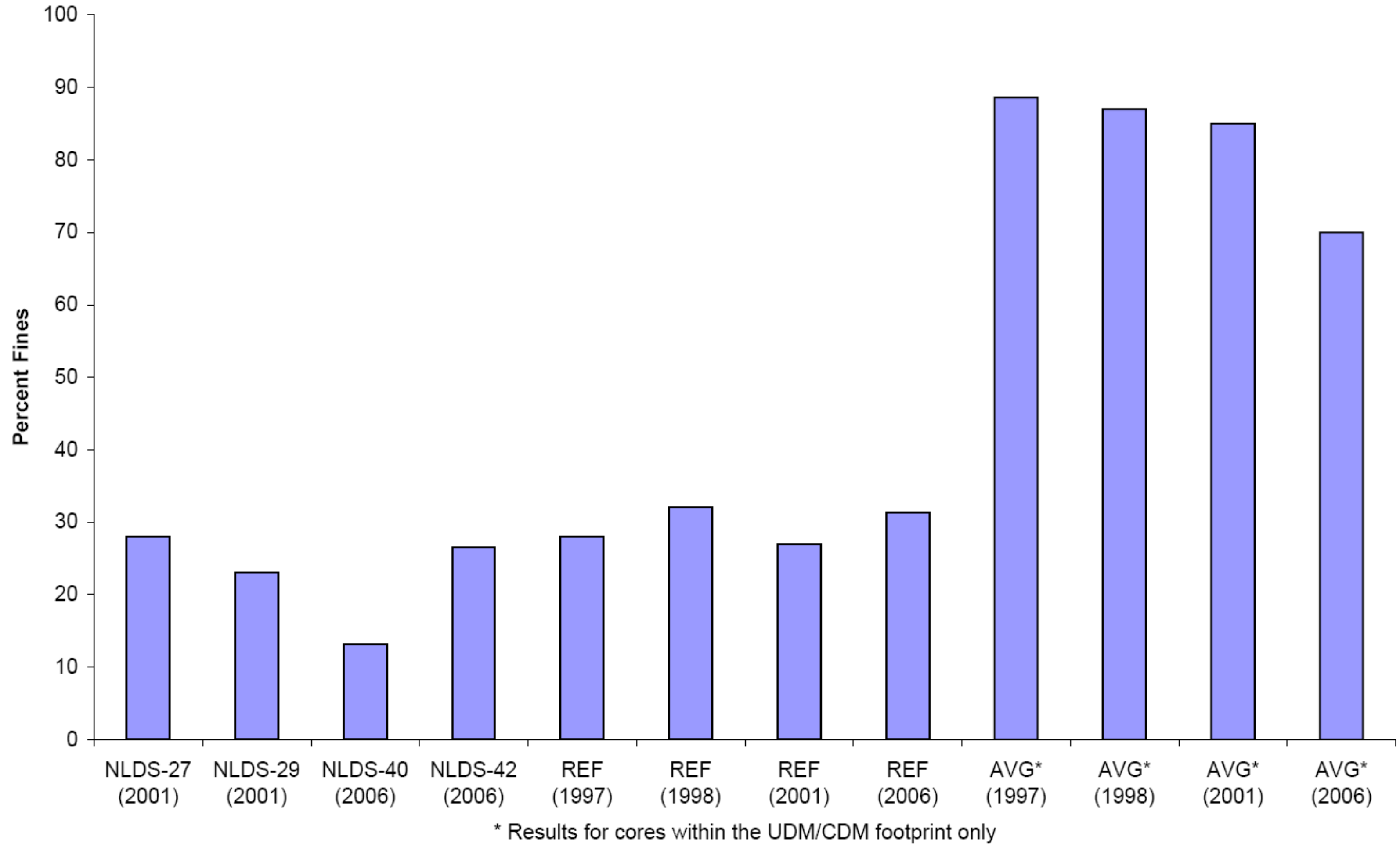


Figure 4-2. Comparison of grain size of cores NLDS-40 and NLDS-42 compared to benchmarks at Seawolf mound

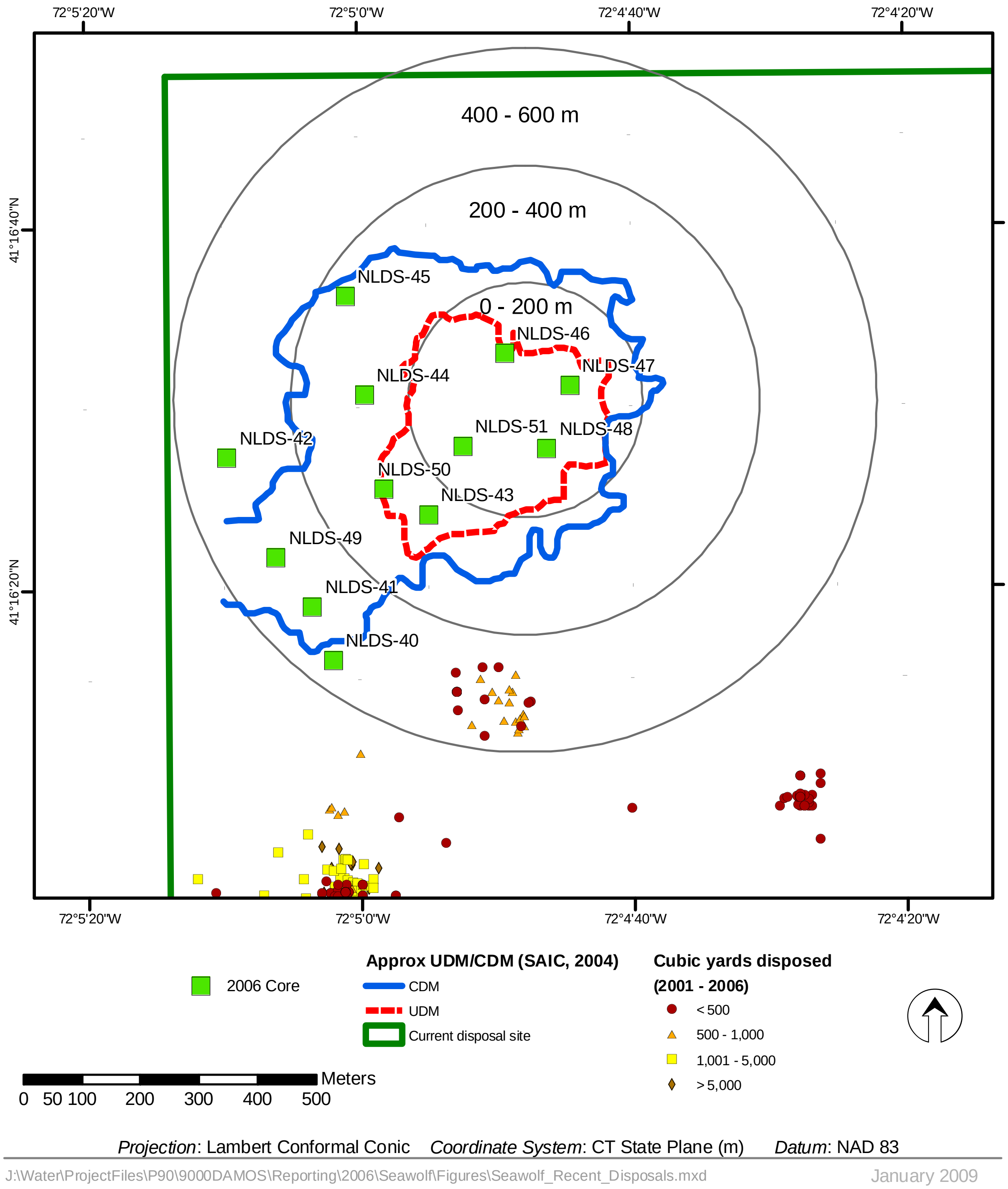


Figure 4-3. Reported 2001-2006 dredged material disposal locations in the vicinity of the Seawolf mound

Table 4-1.

Comparison of NLDS-48 with Pre-dredge CDM Concentrations

	2006 NLDS-48	1990 CDM, Area 4, Sample 20*	1990 CDM Average*	1990, 94 CDM Average*
Metals (mg/kg)				
As	11	5.5	5.9	6.3
Cd	0.3	0.8	1.2	0.7
Cr	48	22	27.8	38.9
Cu	40	10.7	17.9	21.6
Pb	24	20.7	27.7	26.5
Ni	29	13	14.5	17.8
Zn	94	46.3	51.6	68.2
Hg	0.08	0	0	0.09
PAHs (µg/kg)				
Fluoranthene	920	1100	124	79
Benz[a]anthracene	500	649	141	79
Pyrene	1200	1024	114	74
Chrysene	520	567	89	54
Phenanthrene	320	87	16	15

* Maguire Group, Inc. 1995

Beyond the elevated PAH concentrations in cores NLDS-42 and NLDS-48 noted above, PAH concentrations were generally still elevated in the 2006 cores relative to previous data sets (Tables 3-11 and 3-12). One potential explanation for elevated PAH concentrations in 2006 could be different analytical methods used between the different surveys. A review of historical laboratory reports indicated that analytical methods for PAHs were generally consistent for all surveys. There were, however, variations in the preparation techniques and aliquot volumes, and these differences could account for the somewhat higher average PAH concentrations with removal of cores NLDS-42 and NLDS-48 from the data set.

For the deeper segments of the longer cores, the higher concentrations could potentially be attributed to a modified segmentation scheme for the long cores in 2006; sample segments were not assigned based on predetermined intervals along the core length, but were selected based on a detailed visual inspection of the split core that assigned more homogeneous segments. For example, the shallowest segment analyzed from inner zone long core NLDS-50 and its duplicate extended from 60 to 100 cm below the top of the core and was selected because of its dark appearance and distinct break from the overlying material (Appendix D-2). This 60 to 100 cm segment had elevated PAH, with a total concentration of 5.7 mg/kg (Table 3-12) while lower concentrations were reported in the segments beneath it (Appendix D-2). The higher concentration of the 60 to 100 cm segment would not have been identified had it been included in a longer, predetermined core segment.

4.3 Long Term Stability of the Seawolf Mound

The 2006 bathymetry survey was the latest of seven surveys performed over a 10-year period, following cessation of disposal and capping at the Seawolf mound in 1996. Given the bathymetric anomalies that were detected in the 2006 survey (Section 3.1, Figure 3-4) the entire data set was re-evaluated to determine the potential source of the anomalies and to ensure the quality of the 2006 bathymetric data for comparison with previous data sets. The 2006 bathymetric data were analyzed by OSI (AECOM subcontractor for the DAMOS Program who performed the survey), CR Environmental (alternate AECOM subcontractor for bathymetric surveys), and the University of New Hampshire (UNH) Center for Coastal and Ocean Mapping (technical advisor for bathymetry). OSI's review did not identify any problems or sources of concern in the instrument calibration, data collection, recording or processing procedures, and concluded that there was no error in the data collection or reporting. CR Environmental and UNH also analyzed the raw bathymetric dataset. A potential explanation for the anomalies could be gas bubbles interfering with the acoustic signal, but the persistence of the anomalies between separate survey lines and the absence of methane in the SPI images make this explanation unlikely. Fishing gear on the seafloor can also result in anomalous bathymetric data, but the number of anomalies, the consistent height off the bottom, and the lack of any surface floats makes this explanation unlikely as well. Although the source of the bathymetric anomalies was not fully resolved, the extensive independent analysis of the data set confirmed the overall quality of the data.

The entire bathymetric record of seven surveys over 10 years was reviewed to evaluate long term stability of the Seawolf mound. The time series of bathymetric data from these surveys indicated an initial period of consolidation in the year following creation of the mound and cessation of disposal (comparing the 1996 post-cap survey to the 1997 survey, SAIC 2001a). Subsequent surveys in 1998, 2000, 2002, and 2003 confirmed a stable mound that changed little in height or shape over the following seven years (SAIC 2001a, 2001b, 2003, 2004). Significantly, the post-storm surveys performed in 2002 and 2003 following the passage of a large coastal storm showed minimal changes in bathymetry, as evidenced by depth-differencing with the previous, pre-storm survey. Overall, the 2006 bathymetric data continued to demonstrate a stable mound structure both in footprint on the seafloor and height with the twin peaks of the mound remaining distinct and at a depth of just under 16 m (Figure 3-1). A depth difference comparison of the 2006 bathymetry with that of the previous survey in 2003 revealed only small areas of both depth increases and decreases at or near the limit of bathymetric resolution of approximately ±0.5 m (Figure 3-3). These could represent very limited areas of consolidation and/or scour (depth increases) or deposition (depth decrease) over time, or they could represent artifacts of comparison of the more complete coverage of the multi-beam survey in 2006 with the single-beam survey in 2003.

As noted in previous reports, near-bottom currents in eastern Long Island Sound are sufficient to move sediments (SAIC 2001b; Waddell et al., 2001), causing periodic bedload transport of sediments over the NLDS and the adjacent reference areas. This bedload transport could be responsible for periodically altering the observed surface layer of sediments on the Seawolf mound, as evidenced by the noticeable lack of a sandy surface layer on the mound stations found in the 2006 survey; past surveys (SAIC 2001a, 2001b, 2003, 2004) have alternately shown shell lag, armoring, and evidence of winnowing at mound stations that were not present at the mound locations sampled in this survey. However, given the long-term stability of the 10-year bathymetric record, particularly following the storm event in 2002, the bottom currents over the Seawolf mound do not appear to be large enough to cause large scale scour.

5.0 CONCLUSIONS

The 2006 Seawolf survey completes the monitoring requirements of the U.S. Navy Groton Submarine Base dredging permit. The series of monitoring surveys performed approximately 1, 2, 5, and 10 years following Seawolf mound development provide a long-term history of mound conditions. The 2006 Year 10 survey included multi-beam bathymetry, sediment-profile imaging, benthic biological sampling, and sediment coring, performed to track the long-term biological recovery and physical/chemical stability of the mound.

The results of the 2006 Seawolf mound survey confirmed the biological recovery and stability identified during previous surveys. The multi-beam bathymetry identified no significant changes in the footprint of the mound on the bottom or its height above the bottom from the previous survey in 2003. The physical and chemical profiles in the sediment cores collected over the mound indicated a consistent cap sequestering the underlying UDM horizons, as well as underlying ambient sediments and relic dredged material. The variability identified in the cored mound deposits further supported the model of preservation of the sediment heterogeneity during mechanical dredging and barge placement into disposal mounds (Fredette et al. 1992).

The mature benthic community identified on the Seawolf mound in 2006 showed a complete recovery since initial mound formation, supporting a community with high densities of Stage 3 fauna no different than that found at the NLDS reference areas. The less frequent observation of mussels in the 2006 sediment-profile imaging was attributed to the random placement of the SPI camera or a reflection of the natural variations of the epifaunal community in an open bottom area (temporal patterns are consistent with those observed throughout Long Island Sound).

Collectively, the different monitoring elements of the 2006 survey revealed a fully recovered benthic system that does not appear to be subjected to physical disturbance indicative of large scale sediment movement or chemical disturbance detrimental to the benthic ecosystem. A review of the full series of monitoring events since formation of the Seawolf mound indicates that the regional surficial sediment texture is apparently subject to periods of transport and deposition, resulting in varying amounts of shell lag and extent of armoring. However, these transport and deposition processes appear to only affect the uppermost sediment layer, given the long-term stability of the Seawolf mound, even following the passage of a significant coastal storm in 2002 (SAIC 2003).

As the objectives of this study and the 10 year monitoring program were fully met, no specific follow up investigations are required. However, given the long-term interest in capping as a management tool for contaminated sediment and the opportunity to build on this long term dataset, the following recommendations are proposed:

R1) To better understand the PAH concentrations observed in 2006, perform an additional coring survey, collecting sediment cores both on the mound and in ambient sediments, revisiting short core locations. Split samples, sent to different labs and analyzed with both the 2006 and the 1998-2001 preparation methods, would provide insight into the potential effect of different analyses on the resulting concentrations.

R2) For future assessment of the stability of the Seawolf mound, performance of periodic multi-beam bathymetric surveying is proposed as an alternative to coring. Multi-beam surveying offers the advantage of full coverage of the seafloor and the ability to resolve small scale features on the bottom. Using the 2006 multi-beam survey as a baseline, more robust depth difference comparisons can be made with future surveys.

R3) If documenting the presence or absence of mussels at the site is considered an important resource management objective, plan-view photography or video transects could be performed to effectively sample a larger area of the bottom than traditional sediment profile imaging. The plan-view photography/videography could also provide data to understand small scale surficial features and sediment transport.

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APPENDIX A

QUALITY ASSURANCE PROJECT PLAN

QUALITY ASSURANCE PROJECT PLAN

for

Seawolf Disposal Mound Survey

New London Disposal Site

LONG ISLAND SOUND

JUNE 2006

Prepared by:

ENSR

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1.0 Project Description

1.1 Introduction

The Seawolf 2006 Field Survey will be an investigation of a capped dredged material disposal mound located at the New London Disposal Site (NLDS) in Long Island Sound outside New London, Connecticut (Figure 1). The Seawolf disposal mound is a historic, capped disposal mound developed during the 1995/96 disposal season from material generated by dredging operations at the Groton Submarine Base and in the Thames River channel on behalf of the US Navy. This mound was last characterized in February 2003 with a multi-beam bathymetry survey and in June 2001 with the collection of sediment-profile imagery (SPI). The proposed 2006 monitoring will be conducted to satisfy the permit issued for the dredging project and will include precision multi-beam bathymetry, sediment profile imagery, sediment grab sampling for benthic community characterization, and vibracore sampling for the analysis of specific parameters.

This Quality Assurance Project Plan (QAPP) presents the organization, objectives, planned activities, and specific quality assurance/quality control (QA/QC) procedures associated with the sediment evaluation. Specific protocols for sampling and initial handling are described in accordance with Methods for Collection, Storage and Manipulation of Sediments for Chemical and Toxicological Analyses: Technical Manual (EPA, 2001). Protocols for sample storage and analysis are in accordance with the specified EPA methods (EPA, 1996). QA/QC procedures have been structured in accordance with EPA requirements, regulations, guidance, and applicable technical standards.

1.2 Site Name, Location, and Description

The New London Disposal Site (NLDS) is located 5.38 km (3.1 nm) south of Eastern Point, Groton, Connecticut and is centered at 41deg 16.306'N, 72deg 04.571'W (NAD-83). The disposal site covers a 3.42 km2 area of seafloor, with water depths ranging from 14 to 24 meters. Currently, this site is utilized for the unconfined disposal of suitable sediments, as well as sub-aqueous capping of sediments deemed unsuitable for open water disposal.

The Seawolf Mound is a capped dredged material disposal mound developed in the northwestern quadrant of NLDS in 1995-1996 as the product of a large improvement dredging project in the Thames River. The disposal and capping of material generated from improvement dredging associated with home-porting the Seawolf class submarines in Groton, CT. and other smaller maintenance dredging projects, resulted in a total estimated volume of 877,500 m3 of sediment deposited at the Seawolf Mound.

1.3 Objectives

The purpose of this study is to evaluate the long term stability of the Seawolf Mound by examining the thickness of capping material, investigating for any potential migration of underlying unsuitable dredged material from under the cap, and evaluating the assimilation of capping material to the natural background conditions of indigenous sediment. This study will also document the continued recovery of surface sediments at the Seawolf Mound by assessing benthic conditions and infaunal successional status in comparison to the conditions observed by the concomitant sampling of three DAMOS reference areas surrounding NLDS.

1.4 Project Approach

The continued investigative monitoring of the project disposal mound is being conducted to comply with the monitoring plan prepared in accordance with the permit issued for the Seawolf dredging project. Monitoring specified in the plan includes a precision multi-beam bathymetric survey, sediment profile imaging, benthic community grab sampling, and collecting sediment vibracores to be analyzed for selected parameters.

To accomplish the specified objectives of the project, the signature boundaries of the Seawolf disposal mound will be characterized by collecting multi-beam bathymetry data over a 1000 x 1000-meter area of the mound and evaluating depth differences and comparing surface features of the mound with those determined by the previous multi-beam bathymetry survey conducted in 2003.

Further characterization of the integrity of the cap will be determined by the collection and analysis of sediment vibracores at 12 stations on the Seawolf Mound. Sediment vibracores, ranging in length from 50 centimeters to 3 meters will be split lengthwise, visually described/documented, sub-sampled, and analyzed to determine vertical grain size and selected chemical parameters including Total Organic Carbon (TOC), metals, and poly-aromatic hydrocarbons (PAHs) found on the Priority Pollutant List. The physical and chemical data obtained from the core samples at the Seawolf Mound will be compared to those obtained from a designated reference station (WEST-REF) to determine whether unsuitable dredged material has migrated from underneath the capping materials atop the disposal mound. Table 1-1 summarizes the target parameters and corresponding detection limit requirements selected for the Project.

Sediment profile images or a cross-sectional photograph of the top 20 centimeters of sediment, along with sediment sampling for the characterization of benthic community structure will be collected from 13 stations and appropriate reference stations. The results of these two investigations will determine the extent of discernable differences in benthic conditions between the Seawolf Mound and ambient sediments.

The target positions for filed sampling are summarized and depicted in the Field Sampling Plan.

1.5 Schedule of Activities and Deliverables

The project schedule is presented in the following table.

Project Task	Schedule (2006)
Field Program (SPI / benthic grabs)	13/14 June
Field Program (bathymetry)	26 June
Field Program (sediment vibracoring)	11 July
Draft Bathymetry Map	14 July
Core Splitting	17/18 July
Physical Testing Complete	31 July
Chemical Analysis Complete	31 July
Benthic Enumeration Complete	18 August
SPI Images Reviewed	18 August
Data Validation	18 August
Draft Synthesis Report	29 September

2.0 Project Organization and Responsibilities

Under contract to Oak Environmental, ENSR and participating sub-contractors will be performing the field investigation. Sub-contractors include Ocean Surveys Incorporated (OSI) for multi-beam bathymetry and vibracoring support, Germano and Associates for the performance of Sediment Profile Imaging (SPI) and CR Environmental Incorporated which will be providing a survey vessel to assist in the SPI study and benthic community sampling. ENSR will oversee sample analysis, and evaluate/discuss the results in a draft synthesis report. Laboratory services will be provided under subcontract to ENSR.

The various management, QA, field, and laboratory responsibilities of key project personnel are defined below.

2.1 Management Responsibilities

Contract Technical Manager

The Oak Environmental Project Manager is Bruce Newman.

ENSR Project Manager

The ENSR Project Manager, Mr. Steve Wolf, has responsibility for technical, financial, and scheduling matters. Other duties, as necessary, include:

- Assigning duties and orienting project staff to the specific needs and requirements of the project,
- Ensuring that data assessment activities are conducted in accordance with the QAPP,
- Approving project-specific procedures and internally prepared plans, drawings, and reports,
- Serving as the focus for coordinating all field and laboratory task activities, communications, reports, technical reviews and other support functions, and for facilitating sampling activities as needed to achieve the technical requirements of the Project, and for
- Maintaining the Project files.

ENSR Health and Safety Officer

The ENSR Project Health and Safety Officer, Ms. Kathy Harvey will serve as a health and safety advisor to the project including reviewing field sampling plans, recommending appropriate personal protective equipment (PPE) to protect ENSR personnel from any potential hazards, and conducting accident investigations in the unlikely event an injury has occurred during the completion of this Project.

ENSR Task Managers

Each ENSR Task Manager is responsible for overseeing the day-to-day activities associated with his/her task and for communicating progress, challenges, and any potential data quality issues to the ENSR Project

Manger. The Task Managers are also responsible for contributing to the preparation of the Field Summary Report. The Task Managers are as follows:

Field Task Manager – Mr. Don Boyé will be responsible for implementing the field program in accordance with the Field Sampling Plan, QAPP, and Site Safety Health Plan, arranging the required sub-contract services and, managing the overall field budget.

Analytical Task Manager – Mr. Dion Lewis will be responsible for developing the sub-contracts for laboratory services, acting as the liaison between field and laboratory personnel, and for assessing the quality of the analytical data submitted by the laboratories.

Data Manager – Ms. Heather Wayne will be responsible for managing project data information systems including EDD specifications, database oversight, documentation of all database related decisions, and output.

2.2 Quality Assurance Responsibilities

ENSR Project QA Officer

The ENSR Project QA Officer, Ms. Debra McGrath, has overall responsibility for quality assurance oversight. The ENSR Project QA Officer communicates directly to the ENSR Project Manager. Specific responsibilities include:

- Reviewing and approving the SAP/QAPP,
- Reviewing and approving QA procedures, including any modifications to existing approved procedures,
- Ensuring that QA audits of the various phases of the project are conducted as required,
- Providing QA technical assistance to project staff,
- Ensuring that data validation/data assessment is conducted in accordance with the SAP/QAPP, and
- Reporting on the adequacy, status, and effectiveness of the QA program to the ENSR Project Manager.

2.3 Laboratory Responsibilities

The laboratories providing project support to the physical and chemical testing of field samples are listed below.

Organization	Contact	Tasks
Alpha Woods Hole Group 375 Paramount Drive Suite 2 Raynham, MA. 02767-5154	Edie Hutchinson 508-822-9300	Analysis of sediment TOC, metals, and PAH compounds.
GeoPlan Associates 1145 Massachusetts Avenue Boxborough, MA 01719	Peter Rosen (978) 635-0424	Measurement of sediment grain size and moisture content (biology samples).
University Of Rhode Island Geo-Mechanics Lab		Lab support for splitting, photographing, and sub-sectioning sediment core samples (core grainsize).

Laboratory Manager

The Laboratory Manager is ultimately responsible for data produced by their respective laboratory. Specific responsibilities include:

- Implementing and adhering to the laboratory QA manual and all corporate policies and standard procedures within the laboratory,
- Approving the standard operating procedures (SOPs),
- Maintaining adequate staffing to meet the schedule for the delivery of data, and
- Implementing all corrective actions related to internal/external audit findings.

Laboratory QA Coordinator

The Laboratory QA Coordinator reports to the Laboratory Manager. Specific responsibilities include:

- Approving SOPs,
- Assessing and maintaining the laboratory QA manual implementation within the facility operations,
- Recommending resolutions for ongoing or recurrent non-conformances within the laboratory,
- Performing QA assessments, and
- Reviewing and approving corrective action plans for non-conformances, tracking trends of non-conformances to detect systematic problems, and initiating additional corrective actions as needed.

Laboratory Project Manager

The Laboratory Project Manager will serve as the primary point of contact between the laboratory and ENSR. Specific responsibilities of the Laboratory Project Manager include:

- Monitoring project requirements for a specified project,
- Acting as a liaison between ENSR and laboratory staff,
- Reviewing project data packages and electronic data deliverables (EDDs) for completeness and compliance to the agreed upon format for the data package, and
- Monitoring, reviewing, and evaluating the progress and performance of assigned analyses.

2.4 Field Responsibilities

ENSR Field Task Manager

The ENSR Field Task Manager, Mr. Don Boyé, has the overall responsibility for completing all field activities in accordance with the Survey Plan, QAPP, and Health and Safety Plan (HASP) and will facilitate communications between ENSR project management and the field team. Specific responsibilities for the ENSR Field Task Manager will include:

- Planning and coordinating field survey and sampling activities,
- Establishing sub-contracts for support services
- Briefing ENSR and sub-contract personnel on the Project HASP before field operations,
- Briefing ENSR personnel on guidelines for proper recordkeeping and field documentation,
- Mobilizing and demobilizing the field team and subcontractors,
- Assigning specific duties and directing ENSR and sub-contract personnel in the field,
- Resolving logistical challenges which may potentially affect field activities, including equipment malfunctions or availability, personnel conflicts, or safety issues stemming from weather and/or sea conditions, and
- Implementing field QC procedures for the collection of field measurements and records and for ensuring that field samples are properly collected, labeled, preserved, and handled and/or shipped in accordance with accepted chain-of-custody procedures,

ENSR Field Survey Personnel

ENSR field survey personnel report directly to the ENSR Field Task Manager.

The responsibilities of the field team include:

- The collection of data and field samples in accordance with the methods and quality assurance procedures specified in the Field Survey Plan and Project QAPP,
- Ensuring that field instruments are properly operated, calibrated, and maintained, and that adequate documentation is kept for all instruments,
- Collecting the required QC samples and thoroughly documenting QC sample collection,
- Ensuring that field documentation and data are complete and accurate, and

- Communicating any nonconformance or potential data quality issues to the ENSR Field Task Leader.

<u>Sub-contracted Field Support Services</u>

Field support services will be provided by the following organizations:

Organization	Contact	Tasks
Ocean Surveys Inc. 91 Sheffield Street Old Saybrook, CT 06475 (860) 388-4631	George Reynolds	Marine logistical support: Providing a survey vessel, licensed captain, qualified hydrographer and all necessary equipment to perform multi-beam bathymetry survey. Providing a specialty sampling platform, licensed captain, qualified crew, and all necessary equipment and supplies to conduct vibracoring.
CR Environmental Inc. 639 Boxberry Hill Road East Falmouth, MA. 02536 (508) 564-4121	Chip Ryther	Marine logistical support: Providing a survey vessel, and licensed captain to assist in conducting SPI survey and collect benthic community samples.
Germano and Associates 12100 SE 46th Place Bellevue, WA. 98006 (425) 865-0199	Joe Germano	Providing the SPI camera, qualified operators and necessary supplies required conduct SPI survey.

2.5 Training

All personnel performing work on this study will be qualified to perform their assigned tasks. Prior to starting work, the Chief Scientist or Project QA Officer will review specific instructions, covering the following areas:

- Organization and lines of communication and authority,
- Overview of the SAP/QAPP,
- QA/QC requirements,
- Documentation requirements, and
- Health and safety requirements.

All laboratory sample processing and analysis techniques must be performed by fully trained personnel, for whom training certificates are maintained in QA Department files.

3.0 Data Quality Requirements and Assessments

The overall QA objective for this study is to develop and implement procedures for accurate field sampling, laboratory analysis, chain of custody methods, and reporting. Field station positioning must be highly accurate to locate specific sampling sites on the seafloor. Subsequent laboratory analysis must be precise so that measured chemical concentrations are representative of the in-situ conditions in order to accurately evaluate capping efficiency.

Specific procedures for sampling, chain of custody, laboratory instrument calibration, laboratory analysis, reporting of data, internal QC, audits, preventive maintenance of field equipment, and corrective action are described in subsequent QAPP sections.

3.1 Precision

3.1.1 Definition

Precision is a measure of the degree to which two or more measurements agree.

3.1.2 Field Variability

Twelve core samples will be collected from the Seawolf Mound, four cores in each of three designated zones around the center of the mound. The replicate sampling within each individual zone should be sufficient to assess lateral variability around the disposal mound. A low degree of variability is anticipated since previous surveys conducted in 2003 confirmed the integrity of the cap.

3.1.3 Laboratory Precision Objectives

Precision in the laboratory is assessed through the calculation of relative percent difference (RPD) for duplicate samples. The equations to be used for precision can be found in Section 12.1. Precision control limits are provided in Table 8-1. The objective for this project is better than 30% for the chemical constituents that are measured an order of magnitude above the laboratory reporting limit.

3.2 Accuracy

3.2.1 Definition

Accuracy is the degree of agreement between the observed value and an accepted reference or true value.

3.2.2 Field Accuracy Objectives

Sub-meter accurate vessel positioning is a fundamental aspect of field surveying and will be accomplished using a Differential Global Positioning System (DGPS) and confirmed with a real-time display of vessel position on an electronic nautical chart. Accuracy in the field is also assessed through the adherence to all sample handling, preservation, and holding time requirements.

3.2.3 Laboratory Accuracy Objectives

Laboratory accuracy is assessed through the analysis laboratory control samples (LCSs), spiked samples, Standard Reference Materials (SRMs) and surrogate compounds, and the subsequent determination of percent recoveries (%Rs). The equations to be used for accuracy in this project can be found in Section 12.2. Accuracy control limits are listed in Table 8-1.

3.3 Measures to Ensure the Collection of Representative Field Data

To ensure that the data generated during the project will accurately represent field conditions and the mound/cap characteristics it is imperative that the samples be collected in a manner that properly preserves the in-situ chemical and physical conditions. Furthermore, 12 cores (plus a comparative reference site core) will be collected from the Seawolf Mound to ensure that the final data set adequately represents the condition of the cap.

Careful measurement of the core penetration and recovery will be made to gauge any compression that occurs during the coring process. Once collected, sediments will be stored, handled, and analyzed according to the protocols specified in Field Survey Plan.

3.4 Completeness

3.4.1 Definition

Completeness is a measure of the amount of valid data obtained from a measurement system compared to the expected amount under normal conditions. "Normal conditions" are defined as the conditions expected if the sampling plan was implemented as planned.

3.4.2 Field Completeness Objectives

Field completeness as it relates to this investigation is a measure of the amount of valid samples collected. The field completeness objective is greater than 90 percent. The equation for completeness is presented in Section 12.3 of this FSP/QAPP.

3.4.3 Laboratory Completeness Objectives

Laboratory completeness is a measure of the amount of valid measurements obtained from all valid samples submitted to the laboratory. The equation for completeness is presented in Section 12.3 of this FSP/QAPP. The laboratory completeness objective is greater than 95 percent.

3.5 Comparability

3.5.1 Definition

Comparability expresses the confidence with which one data set can be compared to another.

3.5.2 Measures to Ensure Field Comparability

Comparability is dependent upon the proper design of the sampling program and will be satisfied by ensuring that the FSP/QAPP is followed and that proper sampling techniques are used. Maximum comparability with previous data sets is expected because the same field design has been specified.

3.5.3 Measures to Ensure Laboratory Comparability

Comparability is also dependent on the use of nationally recognized EPA or equivalent analytical methods and the reporting of data in standardized units. Table 1-1 lists the recognized EPA methods that have been specified for this project.

4.0 Field Survey and Sampling Program

The field program details are defined in the project survey plan. A specialized 37-foot coring vessel (R/V Can-do) with 4'x5' moon-pool will be utilized for the coring effort at the Seawolf Mound and a 35-foot survey vessel will be used for the multi-beam survey; these two vessels will be operated by Ocean Surveys Incorporated. SPI images and the collection of sediment grab samples for benthic community characterizations will be completed from the 42-foot survey vessel R/V Shanna Rose equipped with a hydraulic A-frame and winch, operated by CR Environmental. As indicated, accurate vessel positioning is essential for the successful collection of site sediments and field data. Navigational positioning will be accomplished using a Trimble 4000 RS DGPS receiver (or equal) interfaced with HYPACK hydrographic software or the OSI Maretrack Navigation and Data Logging System. Site depth will be monitored using both an echo sounder and a checked with a weighted sounding line. The target coring locations and collection procedures are fully detailed in the survey plan. Laboratory handling details are further defined in the following sections.

4.1 Multi-beam Bathymetry Survey

A multi-beam bathymetry survey shall be conducted in a 1000 x 1000 meter survey area over the Seawolf disposal mound covering the same area previously surveyed in 2001 as shown in Figure 2.

The bathymetric data will be collected by a Reson 8125 Ultra High Resolution Echo Sounder outfitted with a 0.5º 455-kHz transducer (or equal system). The multi-beam sounding system will be equipped with a TSS DMS 2-05i Motion Sensor for measuring heave, pitch, and roll and a TSS Meridian Gyro Compass to provide accurate heading guidance. The data collected will be calibrated for local water speed of sound by performing conductivity-temperature-density (CTD) casts at frequent intervals throughout the day with a Seabird SBE-19 Seacat CTD profiler. The accuracy of the bathymetry data will be determined by a bar check. Water depths at Seawolf will be recorded in meters and referenced to mean lower low water (MLLW) based on local tidal information obtained from the NOAA Tide Station located in New London, Connecticut.

Bathymetric data will be stored electronically in HYPACK, a hydrographic surveying software package that will manage data acquisition and the storage of data from the echosounder, the Trimble DGPS navigation system, and MRU, resulting in a record of depth, position, vessel heave, pitch and roll, vessel heading, and the time along each survey transect line. A redundant back-up of bathymetry data will also be recorded on a high-resolution trace on a thermal printer.

4.1.1 Bathymetric Data Processing

Bathymetric data processing will be accomplished using the HYPACK software program to correct data for local tidal conditions, vessel motion, and local speed of sound. All spurious data points (clearly unrealistic measurements resulting from signal interference) will be removed from the record during data processing. Tidal correction will consist of transforming the raw measurements of depth below the transducer to seafloor elevation measurements relative to MLLW using the locally collected tidal elevation data. Heave data supplied by the vessels motion reference unit (MRU) will be applied to the raw data to minimize the effects of vessel motion during data acquisition. The final data set will be “binned” into 0.5-meter square bins. The average value of all data collected within each bin will be determined and this value will be assigned to the coordinates at the center of the bin for plotting purposes.

4.1.2 Bathymetric Data Analysis

Corrected bathymetric data will be displayed the contouring and surface plotting software program, Surfer® 8.0 and the GIS-based software package ArcView® 9.1. Bathymetry data will be gridded in Surfer® and then contoured and plotted using ArcView®.

Data will be compared to previous to the multi-beam survey conducted in 2003 to evaluate changes in seafloor topography. This will be completed in Surfer® by calculating depth-difference grids based on prior baseline surveys. Three-dimensional hill-shaded renderings of the bathymetric data will also be created using the ArcView® 9.1 3-D Analyst toolbox. The hill-shade grid will enhance the three-dimensional qualities of the multi-beam bathymetric data by simulating a light source with an azimuth of 315 degrees and an altitude of 45 degrees illuminating the seafloor.

4.2 Sub-Sampling Procedures for Core Samples

Sediment cores collected from the stations shown on Figure 3 will be maintained on ice (4oC) from the time of collection until actual processing in the lab at the University of Rhode Island (URI) Geo-Mechanics Lab. Short core samples (50 centimeters in length) will be transported intact from the field to the processing laboratory; long cores (3 meters in length) may be cut into equal halves to facilitate shipping and handling. At the URI lab, core samples will split, photographed, characterized for sediment stratigraphy, and sub-sampled. Cores will be handled in the following manner:

1) A single core will be placed on a covered laboratory bench, accurately measured, and cut in half length-wise using a clean stainless steel shearing device (since Lexan liners are going to be used), exposing the sediment material.

2) The sediment core will then be split into two equal halves down the horizontal centerline of the core. The core will be cut from top to bottom so that the cleanest material is encountered first, followed by the more contaminated material. A stainless steel wire will be used to cut each core in half. New wire will be used for each core.

3) A visual description of the stratigraphy (color, texture, odor, location of visual transitions in sediment properties) will be noted on a log form and then the core shall be photographed.

4) Sediment cores will be sub-sectioned to obtain the appropriate sampling material, defined as follows: For short core samples, the top 50 centimeters will be sub-sectioned in its entirety resulting in the generation of one single composite sample. For long cores, the core will be sub-sectioned into the following segments (measured from the top of core) – 0.0 to 0.5 meters, 0.5 to 0.75 meters, 0.75 to 1.0 meters, 1.0 to 2.0 meters, and 2.0 to 3.0 meters, resulting in the generation of five composite samples. (NOTE: The location of segment boundaries shall be adjusted as needed to account for any visual transitions). Each individual composite segment shall be transferred to a stainless steel container and thoroughly homogenized prior to actually collecting materials in glass sample containers. A newly decontaminated knife shall be used in cutting each segment boundary. A

dedicated stainless steel bowl and set of utensils shall be used in handing sediment materials from each segment.

5) Each discrete sample taken from the prepared homogenate shall be containerized in the appropriate sample container provided by the analytical laboratory (summarized in Table 4-1) for subsequent analysis. All sample containers will be properly labeled with the core ID, the appropriate ID for the segment length, the date and time of collection at the URI lab, and the intended parameter for analysis. (NOTE: The 0.0 to 0.5 meter and 2.0 to 3.0 meter segments from the long cores are to be archived at the analytical laboratory).

6) Samples shall be packed in protective bubble-wrap bags and maintained on ice (4°C) from the time of collection until actual analysis. Samples shall be shipped to the appropriate destination laboratory within 48 hours of collection. Grain size samples must not be frozen, but may be stored either chilled (4°C) or at ambient temperature in airtight containers.

All sample handling tools used during the splitting, segment transferring, segment homogenization, and sample collection will be constructed of stainless steel and will be decontaminated with lab detergent, DIW, and solvents between the processing of each core as described in Section 4.2.2.

4.2.1 Sediment Sample Preservation, Containerization, and Holding Times

Upon completing the processing of core samples, individual sediment samples will be transferred to the appropriate sample jars listed in Table 4-1 for subsequent storage and chemical analysis.

Storage jars will be cleaned by the manufacturer to meet or exceed U.S. EPA specifications. Certificates of analysis are provided with each bottle lot and maintained on file to document conformance to EPA specifications.

4.2.2 Equipment Decontamination – Processing Sediment Cores

All bowls and utensils used in the processing of core samples will be decontaminated using the following procedure:

1) Remove all adhering sediment with lab soap and DIW mixture

2) Rinse with DIW

3) Rinse with DCM

4) Rinse with Acetone

5) Seal the utensils in Al foil unless they are to be reused immediately

4.2.3 Sediment QC Sample Collection

As indicated in the field survey plan, a replicate core will be collected for field QC purposes from a select Seawolf station. For laboratory QC (replicate and spiking exercises), one segment horizon per 20 will be selected. These “QC horizons” must not be collected near cap/mound interfaces to avoid “gradient smearing” in the vicinity of the visual interface.

Field rinseate blanks are considered unnecessary for this program because a new, previously unused core liner will be used at each location.

4.2.4 Sediment Sample Labeling

The Seawolf Mound will have 12 coring locations (NLDS-40 through NLDS-51) plus a reference station WEST-REF. For labeling purposes, the field sample ID will consist of SD06 indicating a sediment sample collected in 2006, followed by the coring location (as listed above), plus any pertinent information regarding any core splitting conducted in the field for the long 3-meter core samples to facilitate shipping ex. SD06-NL51-0 to 1.5 meters and SD06-NL51-1.5 to 3.0 meters for the two halves of the 3 meter core collected from station NLDS-51. The label applied to the field core samples shall also carry the following information: Project-SEAWOLF, date and time of collection, initials of sample collector, and preservation methods.

Further segmentation of the field core, conducted at the University of Rhode Island Geo-Mechanics Lab for purpose of preparing the required sample homogenate, will require the following labeling convention. For the short cores (NLDS-40 through NLDS-48), the segment length will simply be 50 centimeters therefore an example sample ID for station NLDS-40 would be SD06-NL40-50. For the long cores (NLDS-49 through NLDS-51), the proposed segment lengths are 0.0 to 0.5 meters, 0.5 to 0.75 meters, 0.75 to 1.0 meters, 1.0 to 2.0 meters, and 2.0 to 3.0 meters; a sample ID for the top two samples at station NLDS-51 would be SD06-NL51-0.0-0.5, and SD06-NL51-0.5-0.75, respectively. Lab duplicates will have –DUP appended to the end of each respective duplicate sample. The label applied to each of the sample jar used to collect an aliquot of sediment intended for lab analysis shall also carry the following information: Project-SEAWOLF, date and time of collection, initials of sample collector, preservation methods, and the intended analysis (metals, PAH, TOC, grain size, etc.).

4.2.5 Sediment Sample Transfer/Shipments

Sediment samples that are shipped from URI to supporting laboratories for chemical analysis shall be packaged in protective plastic to prevent breakage and preserved on ice; samples intended for grain size analysis shall be shipped without ice. Custody seals are to be applied to shipping coolers and sample receipt forms must be filled out upon receipt at the laboratory.

4.3 SPI Survey

Sediment-profile imaging (SPI) is a monitoring technique used to provide data on the physical characteristics of the seafloor as well as the status of the benthic biological community. The technique involves deploying an underwater camera system that photographs a cross section of the sediment-water interface. Computer-aided analysis of the resulting images provides a set of standard measurements that can be compared between different locations and different surveys. The DAMOS Program has successfully used this technique for over 20 years to map the distribution of disposed dredged material and to monitor benthic recolonization at disposal sites

4.3.1 SPI Data Acquisition

The 2006 SPI survey of the Seawolf Mound includes 13 stations located within the boundaries of the Seawolf site and 13 stations distributed within three reference areas. A cross-sectional image of the top 20 cm (8 inches) of sediment shall be collected at each station.

Seawolf stations are identified as CTR, 75E, 150N, 150W, 300SE, and 300WSW plus 7 additional stations SW01 through SW07 placed randomly around a 150-meter radius of the central point of the Seawolf mound (Figure 4). Three images shall be collected at each of 13 stations (39 images total). The three designated reference areas associated with the New London Disposal Site are identified as NLON-REF, NE-REF, and WEST-REF on Figure 5. Reference area data will provide information on benthic conditions within the ambient sediments and represent a basis for comparison with data collected from the project mound. Reference SPI stations were randomly located within a 300 meter radius of the central location for each reference area as follows: four stations will be occupied at each of two selected reference areas and five stations will be occupied at the third reference area. Three images shall be collected at each of 13 reference stations (39 images total).

At each survey location, the survey vessel will be positioned at the designated target coordinates to within a tolerance of 10 meters. Three replicate sediment-profile images will be collected at each of the 26 stations for characterization of small-scale (i.e. within-station) spatial variability.

Acquisition of high-resolution SPI images will be accomplished by Germano and Associates using an Ocean Imaging Model 3731 pressure housing system with a Nikon D100 digital single-lens reflex camera (or equal). The system is comprised of a camera installed inside a pressure housing mounted atop a wedge-shaped prism with a clear front faceplate and a mirror mounted at a 45° angle to reflect the profile of the sediment-water interface. As the prism penetrates the seafloor, a trigger activated time-delay circuit will fire an internal strobe to obtain a cross-sectional image of the upper 15 to 20 centimeters of the sediment column. Once in position, the camera will remain on the seafloor for approximately 20 seconds to ensure that a successful image had been obtained. After each deployment of the camera, the frame counter will be checked to ensure that the requisite number of replicates was obtained. In addition, the prism penetration depth indicator on the camera frame will be checked to verify that the optical prism has penetrated sufficiently into the bottom.

Two types of adjustments to the SPI system are typically made in the field: (1) Physical adjustments to the frame stop collars and/or adding/subtracting lead weights to the frame to control penetration in harder or softer sediments. If images were missed or the penetration depth was insufficient, the camera frame stop collars will be adjusted and/or the payload weight adjusted accordingly, and additional replicate images collected until a satisfactory image set has been obtained. Changes in prism weight amounts, the presence or absence of mud doors, and frame stop collar positions will be recorded for each replicate image. (2) Electronic software adjustments to the Nikon D100 to control camera settings.

Each image will be assigned a unique time stamp in the digital file attributes by the camera's data logger and cross-checked with the time stamp in the navigational system's computer data file. In addition, redundant hand-written sample log sheets will be maintained by survey personnel. Digital images will be downloaded periodically to verify successful sample acquisition or to assess what type of sediment/depositional layer was present at a particular station. Digital images will be promptly re-named with the appropriate station name immediately upon downloading as a further quality assurance step.

Test exposures of the Kodak® Color Separation Guide (Publication No. Q-13) will be made on deck at the beginning and end of each survey to verify that all internal electronic systems are working to design specifications and to obtain a color standard against which final images can be checked for proper color balance.

4.3.2 SPI Data Analysis

Each SPI image will be subjected to a computer-aided analysis to determine a value for each of the following standard parameters:

- Sediment Type: The sediment grain size (major mode and range) will be estimated visually from the images using a grain-size comparator at a similar scale and results will be reported using the phi scale. The presence and thickness of any apparent disposed dredged material will also be assessed by inspection of the images.
- Penetration Depth: The depth to which the camera penetrated the seafloor will be measured to provide an indication of the sediment density or bearing capacity and will be expressed as a value ranging from a minimum of zero (i.e., no penetration on hard substrates) to a maximum of 20 centimeters (full penetration on very soft substrates).
- Surface Boundary Roughness: Surface boundary roughness, a measure of the vertical relief of features at the sediment-water interface, will be determined for each sediment-profile image. Surface boundary roughness will be determined by measuring the vertical distance between the highest and lowest points of the sediment-water interface. The surface boundary roughness (sediment surface relief) measured over the width of sediment-profile images should reside in the range of 0.02 to 3.8 centimeters, as influenced by physical structures (e.g., ripples, rip-up structures, mud clasts) or biogenic features (e.g., burrow openings, fecal mounds, foraging depressions).
- Apparent Redox Potential Discontinuity (RPD) Depth: RPD provides a measure of the integrated time history of the balance between near surface oxygen conditions and biological reworking of sediments. Sediment particles exposed to oxygenated waters oxidize and lighten in color to brown or light grey. The RPD depth will be measured by assessing color and reflectance boundaries within each image.
- Infaunal Successional Stage: Infaunal successional stage is a measure of the biological community inhabiting the seafloor. Current theory holds that organism-sediment interactions in fine-grained sediments follow a predictable sequence of development after a major disturbance (such as dredged material disposal), and this sequence has been divided subjectively into three stages (Rhoads and Germano 1982, 1986). Successional stage will be determined by assessing species or organism-related activities apparent in each image.
- Organism-Sediment Index (OSI): OSI is a summary parameter incorporating the apparent mean RPD depth, successional stage, and presence of methane or low oxygen and reflects the seafloors' response to natural or anthropogenic disturbance. This parameter will be determined for each image in accordance with accepted characterization methods (Revelas et al. 1987).

4.4 Benthic Community Characterization

One benthic grab sample will be taken at six stations using a stainless-steel $0.04m^2$ Ted-Young grab sampler deployed from a boat using a hydraulic winch and A-frame. The sampler is slowly lowered through the water column so as not to generate a pressure wave ahead of the sampler which would flush organisms away from the underside of sampler prior to impact. A counterweighted latch holds the jaws of the grab sampler in the opened set position during deployment. This configuration is held static until the grab sampler impacts the bottom and lifting cable tension is lost, at which point the latch mechanism drops clear and the sampler is ready to collect a sediment sample. The action of hauling back on the lifting cable mechanically closes the jaws of the sampler thereby capturing a sediment sample within the bucket.

Upon recovery, the grab sampler is placed on a stand, at which point, the inspection panels on top of the grab are opened and the condition of the sample inspected for quality. The criteria for an acceptable benthic sample are outlined in the following section.

4.4.1 Acceptance Criteria for Benthic Samples

The Chief Scientist shall inspect the condition of the grab sampler and sediment contents to determine whether a benthic sample can be accepted. Acceptance criteria include:

- Sediment surface is more or less level and intact over the entire surface area of the grab
- Depth of the sediment retained is approximately 7 cm as measured at the center of the grab
- The grab should be tightly closed; little or no water should be leaking from the sample
- Shell hash or coarse material visible on the surface is acceptable as long as all the criteria stated above have been satisfied.
- Grabs that are only partially filled, or obviously slumped or pitched due to the grab hitting at an angle are not acceptable.
- If the grab is filled to the top, it is considered acceptable unless sediment has a dimpled appearance indicating contact with the underside of the inspection panels or if sediment is lost when the doors are opened; such samples will have penetrated too deep.

The field team will adjust their sampling to account for local sediment conditions including adding or removing weight to control depth of penetration and possibly adding pads (boards) to the underside of the grab frame to prevent over-penetration in very soft sediments. During the course of sampling a station, it may become obvious that the sediment conditions are not suitable for successful grab sampling. The most common situation is the presence of sediments that contain rocks and shell hash. Such sediments prevent the jaws of the grabs from closing and retention of suitable samples. Before abandoning a station, the Chief Scientist shall attempt to reposition the boat to locate more suitable sediments. The minimum criterion for abandoning such a station is five sequential unsuccessful sampling attempts, or a 70% failure rate. The Chief Scientist may elect to attempt further sampling, but will use his/her judgment given the time limitations and priorities of the field program.

4.4.2 Processing Benthic Samples

Prior to processing, the sample will be visually inspected and descriptive information such as surface texture, color, smell, and visible fauna or debris recorded. By visual observation and the use of a small ruler, the depth of the apparent redox RPD potential discontinuity (RPD) layer will be determined and recorded. The sediment depth in the grab will also be measured and recorded as the penetration depth of the grab.

Each biology sample will then be processed as follows.

- The grab will be opened and the contents dumped into a collecting bucket (containing a pore spout) placed under the stand on which the grab rests. Any sediment remaining in the grab will be washed directly into the bucket.
- The bucket will be transferred to a sample-processing table where it will be elutriated. This technique involves washing the sample with filtered seawater until the water flows from the bucket through the pore spout and onto the 0.5-mm mesh sieve. Lightweight particles are carried out of the bucket with the flow of water; silt passes through the sieve while the organisms that are floated onto the sieve are retained. Heavier sediment particles and organisms (i.e., molluscs and starfish) concentrate at the bottom of the bucket. Elutriation continues until the water flowing from the bucket is clear, indicating that all of the fine sediments have been removed.
- The material retained on the sieve is carefully washed through a funnel into a pre labeled sample jar where it will be preserved in 10% buffered (borax) formalin. An extra spoonful of borax will be added to the sample jar prior to use.
- The heavy fraction remaining in the bucket will likewise be transferred to separate labeled jar and similarly preserved. The light and heavy fractions may be combined if appropriate. This technique completely eliminates direct sieving of the animals and minimizes specimen fragmentation.

The Seawolf Mound will have six sediment grab sample locations for benthic community assessment, CTR, 75E, 150N, 150W, 300SE, and 300WSW, plus three designated reference stations. For labeling purposes, the sample ID will consist of SD06 indicating a sediment sample collected in 2006, followed by the sampling location (as listed above), and completed with a suffix of BIO; a biology sample obtained from station CTR would be SD06-CTR-BIO. The label applied to each sample jar shall also carry the following information: Project-SEAWOLF, date and time of collection, initials of sample collector, and preservation methods.

Prior to processing another sample, the sieves will be carefully inspected to ensure that all organisms were removed. All equipment including buckets, sieves, and funnels used in the above process will be thoroughly cleaned prior to processing the next sample in order to preclude cross contamination. Equipment will be rinsed with seawater and will be examined thoroughly to ensure that there are no adhering organisms. Sieves will be cleaned using a pressurized jet of water and scrubbing with a stiff brush.

After 48 hours, but within 2 weeks, the samples will be reopened and the formalin decanted into a storage container. The samples shall be sieved again with seawater and then rinsed with freshwater. This process removes remaining sediment particles and salt from the samples. These samples will then be preserved in 80% ethanol and re-sealed. These samples will then be shipped to the sorting laboratory for further processing. The formalin residue will be stored as hazardous and disposed of in an appropriate manner.

5.0 Sample Custody

Data authenticity depends on strict chain-of-custody, which will be adhered to for this study. Sample custody is addressed in three parts: field sample collection, laboratory analysis, and final evidence files.

A sample or evidence file is considered to be under a person's custody if

- the item is in the actual possession of a person;
- the item is in the view of the person after being in actual possession of the person;
- the item was in the actual physical possession of the person but is locked up to prevent tampering;
- the item is in a designated and identified secure area.

5.1 Field Custody Procedures

Field logbooks will provide the means of recording the chronology of data collecting activities performed during the investigation. As such, entries will be described in as much detail as possible so that a particular situation could be reconstructed without reliance on memory.

- All samples will be identified with sample numbers, sampling locations and date/time of collection. The sample numbering system is presented in Section 4.4.
- Sample labels will be completed for each sample using waterproof ink unless prohibited by weather conditions. For example, a logbook notation would explain that a pencil was used to fill out the sample label because the pen would not function in wet weather.
- Samples will be accompanied by a properly completed chain-of-custody form. The sample numbers and locations will be listed on the chain-of-custody form. When transferring the possession of samples, the individuals relinquishing and receiving will sign, date, and note the time on the record. This record documents the transfer of custody of samples from the sampler to another person, to another laboratory, or to/from a secure storage location.
- All shipments will be accompanied by the chain-of-custody record identifying the contents. The original record will accompany the shipment, and copies will be retained by the sampler and placed in the project files.
- Following the core splitting exercise, samples will be properly packaged for shipment and dispatched to the appropriate laboratory for analysis, with a separate signed custody record enclosed in and secured to the inside top of each sample box or cooler. Shipping containers will be locked and secured with strapping tape and custody seals for shipment to the laboratory. The custody seals will be attached to the front right and back left of the cooler and covered with clear plastic tape after being signed by field personnel. The cooler will be strapped shut with strapping tape in at least two locations.

- If the samples are sent by common carrier, the waybill will be used. Waybills will be retained as part of the permanent documentation. Commercial carriers are not required to sign off on the custody forms since the custody forms will be sealed inside the sample cooler and the custody seals will remain intact.

5.2 Laboratory Custody Procedures

Samples will be received and logged in by a designated sample custodian or his/her designee. Upon sample receipt, the sample custodian will:

- Examine the shipping containers to verify that the custody tape is intact,
- Examine all sample containers for damage,
- Determine if the temperature required for the requested testing program has been maintained during shipment and document the temperature on the chain-of-custody records,
- Compare samples received against those listed on the chain-of-custody,
- Verify that sample holding times have not been exceeded,
- Examine all shipping records for accuracy and completeness,
- Sign and date the chain-of-custody immediately (if shipment is accepted) and attach the waybill,
- Note any problems associated with the coolers and/or samples on the cooler receipt form and notify the Laboratory Project Manager, who will be responsible for contacting the ENSR Chemistry Task Manager,
- Attach laboratory sample container labels with unique laboratory identification and test; and
- Place the samples in the proper laboratory storage.

Following receipt, samples will be logged in according to the following procedure:

- The samples will be entered into the laboratory tracking system. At a minimum, the following information will be entered: project name or identification, unique sample numbers (both client and internal laboratory), type of sample, required tests, date and time of laboratory receipt of samples.
- The Laboratory Project Manager will be notified of sample arrival.
- The completed chain-of-custody, waybills, and any additional documentation will be placed in the final evidence file.

5.3 Project Evidence Files

The final evidence files will be the central repository for all documents that are relevant to sampling and analysis activities as described in this FSP/QAPP Addendum. ENSR is the custodian of the final evidence files and will maintain the contents of the files, including all relevant records, reports, logs, field notebooks, pictures, subcontractor reports, and data reviews in a secured, limited access area.

The final evidence files will include at a minimum:

- Field logbooks,
- Field data and data deliverables,
- Photographs,
- Drawings,
- Field forms,
- Electronically captured data files,
- Laboratory data deliverables,
- Data validation and assessment reports,
- Progress reports, QA reports, interim project reports, etc.; and
- All custody documentation (forms, air bills, etc.).

6.0 Calibration Procedures

This section describes the calibration procedures and frequency at which these procedures will be performed.

6.1 Field Instruments

Field navigation instruments will be checked daily, prior to use. Checking procedures will be consistent with the manufacturer's recommendations. The multi-beam bathymetry system will be calibrated and tested in accordance with the procedures outline in the US Army Corps of Engineers Manual "Engineering and Design – Hydrographic Surveying", document EM 1110-2-1003, dated January 2002. All checking procedures will be documented in the field records. Records will include the checking date/time, name of the person performing the check, and the results.

6.2 Laboratory Instruments

Calibration procedures for laboratory instruments will consist of initial calibrations, initial calibration verifications, and continuing calibration verification. The SOP for each analysis performed in the laboratory describes the calibration procedures, their frequency, acceptance criteria, and the conditions that will require recalibration. This information is summarized in the laboratory QA Manuals included on the CD appended to this QAPP.

The laboratory maintains documentation for each instrument which includes the following information: instrument identification, serial number, date of calibration, analyst, calibration solutions, and the samples associated with these calibrations.

Calibration procedures for laboratory instrumentation will consist of initial calibrations, initial calibration verifications, and continuing calibration verification. Detailed descriptions of the calibration procedures are included in the laboratory SOPs, which describe the calibration, frequency, acceptance criteria, and the conditions that will require recalibration. A summary of this information is provided in Table 6-1.

7.0 Analytical Procedures

7.1 Field Analyses

There are no field chemical analyses associated with the survey.

7.2 Laboratory Analyses

Samples will be analyzed by the laboratories identified in Section 2. The target analytes, project-required detection limits, and analytical methods are listed in Table 1-1. Laboratory specific SOPs are provided in the following table.

Analyte Group	Laboratory SOP No.	Equivalent Method No.
PAHs	O-007, Analysis of Polynuclear Aromatic Hydrocarbons by Gas Chromatography/Mass Spectrometry with Selected Ion Monitoring	SW-846 3550B (EPA, 1986) SW-846 8270c Modified (EPA, 1996)[1]
ICP/AES Metals	*Metals Prep:* MP-001, Acid Digestion of Solid Samples for Metals Analysis MP-003, Microwave Assisted Acid Digestion of Sediments, Soils, Tissues and Waters *Metals:* M-001, Inductively Coupled Plasma-Mass Spectrometry M-006, Mercury Determination in Solids by Cold Vapor Atomic Absorption	SW-846 3051 (EPA, 1986) SW-846 6010B (EPA, 1986)
TOC	W-028, Total Organic Carbon in Soil, Sediment and Water	Lloyd Kahn TOC Method (EPA, 1988)
Grain size	ASTM D422	ASTM D422C-98

[1]EPA Method modified to run in selected ion mass spectrometer mode

8.0 Internal Quality Control Checks

8.1 Field Quality Control

Two additional cores will be collected from the Seawolf mound, one from each of two randomly selected stations, as a field QC measure. Additionally:

- All activities will be performed by appropriately trained personnel,
- Work will be conducted in conformance with project-specific protocols.

8.2 Laboratory Quality Control

The laboratories utilized for this study have existing QC programs which ensure the reliability and validity of the measurements performed. Additionally, the following requirements apply to all laboratory analyses:

- All activities will be performed by appropriately trained personnel,
- Work will be conducted in conformance with project-specific protocols and laboratory SOPs,
- All steps of analysis will be documented as described in Section 9.1.2 and the records retained on file,
- Reviews of records will be conducted by supervisory personnel on a routine basis (at least weekly),
- All data will be reviewed and validated by laboratory personnel prior to its release.

8.2.1 Chemical Analyses

The QC requirements for analytical methodologies include the following:

- Method blanks
- Surrogate Internal Standards (PAHs)
- LCS/LCSDs
- MS/MSDs
- SRMs

The QC checks for each parameter and method (frequencies, control limits, and corrective actions) are detailed in the attached laboratory SOPs and summarized in Table 8-1.

9.0 Data Reduction, Validation, and Reporting

All generated data will be reduced and validated prior to reporting. No data will be disseminated by the laboratory until it has been subjected to the procedures summarized below.

9.1 Data Reduction

9.1.1 Field Data Reduction Procedures

Measurements, station location, and sample collection information will be transcribed directly into the field logbook or onto standardized forms. If errors are made, results will be legibly crossed out, initialed and dated by the person recording the data, and corrected in a space adjacent to the original (erroneous) entry. Field data will be reviewed by the Chief Scientist to ensure that records are complete, accurate, and legible.

9.1.2 Laboratory Data Reduction Procedures

Laboratory data reduction procedures will be performed according to the following protocol. All information related to analysis will be documented in controlled laboratory logbooks, instrument printouts, or other approved forms. All entries that are not generated by an automated data system will be made neatly and legibly in permanent waterproof ink. Information will not be erased or obliterated. Corrections will be made by drawing a single line through the error and entering the correct information adjacent to the cross out. All changes will be initialed, dated, and, if appropriate, accompanied by a brief explanation. Unused pages or portions of pages will be crossed out to prevent future data entry. Laboratory records will be reviewed by the Section Leaders on a regular basis; and by the Laboratory QA Manager periodically, to verify adherence to documentation requirements.

Analytical results for the sediment samples will be reported on a dry weight basis.

Prior to being released as final, laboratory data will proceed through a tiered review process. Data verification starts with the analyst or technician who performs a 100 percent review of the data to ensure the work was done correctly the first time. It is the responsibility of the analyst or technician to ensure that the verification of data in his or her area is complete. The data reduction and initial verification process must ensure that:

- Sample preparation and analysis information is correct and complete,
- Results are correct and complete,
- The appropriate SOPs have been followed and are identified in the project records,
- Proper documentation procedures have been followed,
- All non-conformances have been documented,
- Project-specific requirements have been met,
- The data generated have been reported with the appropriate number of significant figures as defined by the method or otherwise specified by the client.

Following the completion of the initial verification by the analyst or technician, a systematic check of the data will be performed by an experienced peer, Section Leader, or designee. This check will be performed to ensure that initial review has been completed correctly and thoroughly. The second level reviewer will examine the data signed by the analyst or technician. This review will include an evaluation of all items required in the raw data package. Any exceptions noted by the analyst or technician must be reviewed. Included in this review will be an assessment of the acceptability of the data with respect to:

- Adherence of the procedure used to the requested SOP,
- Correct interpretation of data,
- Correctness of numerical input when computer programs are used (checked randomly),
- Correct identification and quantitation of constituents with appropriate qualifiers,
- Numerical correctness of calculations and formulas (checked randomly)
- Acceptability of QC data,
- Documentation that instruments were operating according to method specifications (calibrations, performance checks, etc.),
- Documentation of dilution factors, standard concentrations, etc.,
- Sample holding time assessment.

This review will also serve as verification that the process the analyst or technician has followed is correct in regard to the following:

- The procedure follows the project-required methods and specific instructions,
- Nonconforming events have been addressed by corrective action as defined on a nonconformance memo,
- Valid interpretations have been made during the examination of the data and the review comments of the initial reviewer are correct,
- The package contains all of the necessary documentation for data review and report production and results are reported in a manner consistent with the method used for preparation of data reports.

A third-level review will be performed by the Laboratory Project Manager before results are submitted to the client. This review serves to verify the completeness of the data report and to ensure that project requirements are met for the analyses performed. The items to be reviewed will include:

- Results are present for every sample in the analytical batch, reporting group, or sample delivery group,
- Every parameter or target compound requested is reported with either a value or reporting limit,
- The correct units and correct number of significant figures are utilized,
- All non-conformances, including holding time violations, and data evaluation statements that impact the data quality are accompanied by clearly expressed comments from the laboratory,

- The final report is legible, contains all the supporting documentation required by the project, and is in either the standard format or in the client-required format.

A narrative to accompany the final report will be finalized by the Laboratory Project Manager. This narrative will include relevant comments collected during the earlier reviews.

9.2 Data Validation

ENSR will be responsible for performing an independent review of the analytical data, although formal data validation is beyond the scope of this project. All reported data, however, will provide full backup so that a data validation can be performed at some future date if needed.

9.3 Data Analysis

9.3.1 GIS/Spatial Analysis

Vertical mound/cap stratigraphy will be mapped across each site using graphical methods including specialized software developed for this purpose.

9.3.2 Statistics

ENSR will review the data when available and evaluate the best statistical approach. This may include principal components analysis (PCA) as performed in previous studies to examine vertical gradient inflections.

9.4 Meetings

One review meeting is planned to discuss survey findings before the draft report is prepared. Other meetings may be scheduled as needed.

9.5 Data Reporting

9.5.1 Laboratory Data Reporting

AWHG, GeoPlan, and University of Rhode Island Geo-Mechanics Lab will provide analytical results within 45-days following sample receipt. At a minimum, the data packages from the analytical chemistry laboratories will include the following:

- Case narrative, describing any data quality issues,
- Sample results (dry weight units),
- QC results (blanks, laboratory duplicates, SRMs, etc.),
- Internal standard recoveries (PAHs),
- Percent moisture results,
- Electronic Data Deliverable.

9.5.2 Status Reports

Monthly written status reports will accompany the submittal of invoices outlining the work accomplished for that billing period. A monthly record of related phone conversations and written correspondence will also be provided.

9.5.3 Draft Report

A draft report will be prepared that includes results of the survey. The report will discuss the project background, approach, methods, result presentation, and a discussion.

9.5.4 Final Report

One round of comments will be accepted after 30-day review period, at which time, a final report will be prepared. The final report will be submitted 2 weeks after the receipt of comments.

9.6 Data Management

ENSR will maintain validated laboratory data in an Access database during the course of this study.

10.0 Performance and Systems Audits

Performance and system audits are conducted as needed to verify that sampling and analysis are performed in accordance with the procedures established in the FSP/QAPP.

10.1 System Audits

10.1.1 Field System Audits

A system audit of field activities is not scheduled.

10.1.2 Laboratory System Audits

Laboratory audits are not planned for this project.

10.2 Performance Audits

Performance audits are not applicable to the field portion of this program. Within the laboratory, performance audits involve the preparation and submittal of blind performance evaluation (PE) samples, which are analyzed as part of the laboratory QA program. The analytical laboratories (AWHG) has been approved by the U.S. Corps of Engineers for HTRW project measurements.

11.0 Preventive Maintenance

11.1 Field Equipment

The field equipment for this project includes a vibracore sampler and a 0.04m2 Ted-Young sediment sampler. Field instruments will include a DGPS, Motion Reference Unit (MRU) and a multi-beam transducer. The ENSR Chief Scientist will be responsible for ensuring that all field sampling equipment and are free from obvious defects, damage, and contamination and are properly functioning. At a minimum, this will entail checking the equipment prior to commencing the survey and performing daily operational checks and calibration as described in the manufacturer's instructions. OSI will have the responsibility for ensuring that the bathymetric survey instrumentation is operating correctly and has been properly calibrated prior to the collection of field data.

11.2 Laboratory Equipment

Routine preventative maintenance is conducted by the laboratory to minimize the occurrence of instrument failure and other system malfunctions. Designated laboratory employees will regularly perform routine schedule maintenance and repair of (or coordinate with the vendor for repair of) all instruments. All maintenance that is performed is documented in the laboratory's operating record. All laboratory instruments are maintained in accordance with manufacturer's specifications and laboratory SOPs.

11.3 Inspection/Acceptance Requirements for Supplies and Consumables

For this project, critical supplies will be tracked through ENSR's system in the following manner.

Critical Supplies and Consumables	Inspection Requirements and Acceptance Criteria	Responsible Individual
Sample jars and bottles	Visually inspected upon receipt for cracks, breakage, cleanliness. Must be accompanied by certificate of analysis.	Field Scientist
Field measurement equipment	Functional checks to ensure proper calibration and operating capacity	Field Scientist
Sampling equipment	Visually inspected for obvious defects, damage, and contamination	Field Scientist

Supplies and consumables not meeting acceptance criteria will initiate the appropriate corrective action. Corrective measures may include repair or replacement of measurement equipment, and/or notification of vendor and subsequent replacement of defective or inappropriate materials. All actions will be documented in the project files.

12.0 Data Assessment

The project data will be provided to the data users in a review meeting before preparation of a synthesis report. The (draft) report will include a description of the analytical procedures and additional information useful for interpreting the data. The report will include stratigraphic comparisons across the disposal mound and an assessment of any vertical chemical contaminant migration through the cap.

The data quality indicators (DQI) reviewed during the conduct of these studies includes precision, accuracy, sensitivity, and completeness. Measurement sensitivity (project required detection limits) is defined in Table 1-1 and the fixed laboratories will be required to achieve, or nearly achieve, the minimum levels listed to ensure data usability. Further, Table 8-1 specifies the quality indicator objectives established for the project. The calculations associated with these DQI assessments are detailed below:

12.1 Precision

The RPD between MS/MSD and/or LCS/LCSDs are calculated to compare to precision objectives. The RPD will be calculated according to the following formula.

$$RPD = \frac{(Amount\ in\ Sample\ 1 - Amount\ in\ Sample\ 2)}{0.5\,(Amount\ in\ Sample\ 1 + Amount\ in\ Sample\ 2)}\, x\, 100$$

12.2 Accuracy

Accuracy will be assessed by determining %Rs for surrogate compounds (PAHs), matrix spikes, and SRMs. Percent recovery will be determined according to the following equation:

$$\%R = \frac{Experimental\ Concentration}{Known\ Amount\ Added}\, x\, 100$$

Method blank results will be compared to reporting limit (RL) concentrations to ensure that data are free from contamination.

12.3 Completeness

Completeness is the ratio of the number of valid sample results to the total number of samples analyzed or processed. Following completion of the testing, the percent completeness will be calculated by the following equation:

$$Completeness = \frac{(number\ of\ valid\ measurements)}{(number\ of\ measurements\ planned)}\, x\, 100$$

12.4 Representativeness and Comparability

Representativeness is a measure of how well a sample or set of samples represents the population characteristics. Comparability is a measure of how well measured data compare to historical data or other independent sources. Efforts to ensure representativeness and comparability are discussed Sections 3.3 and 3.5.

13.0 Corrective Action

Corrective action is the process of identifying, recommending, approving, and implementing measures to counter unacceptable procedures or out-of-limit QC performance that can affect data quality. Corrective action can occur during field activities, laboratory analyses, data validation, and data assessment.

13.1 Field Corrective Action

Corrective action in the field may be needed if sampling procedures require modification, etc. due to unexpected conditions. If corrective action is necessary, the ENSR Chief Scientist will first notify the ENSR Project Manager. The ENSR Project Manager, in consultation with the Contract/Technical Manager and the ENSR Project QA Officer, will approve the corrective measure. No staff member will initiate corrective action without prior communication of findings through the proper channels. However, if this communication protocol cannot be completed in a timely fashion, the ENSR Chief Scientist has authorization to approve corrective action and to ensure proper measures are implemented by the field team.

Corrective actions will be implemented and documented in the field record book. Documentation will include:

- A description of the circumstances that initiated the corrective action,
- The action taken in response,
- The final resolution, and
- Any necessary approvals.

13.2 Laboratory Corrective Action

Corrective action in the laboratory may occur prior to, during, and after initial analyses. A number of conditions such as broken sample containers, omissions or discrepancies with chain-of-custody documentation, and potentially high concentration samples may be identified during sample log-in or just prior to analysis. Following consultation with laboratory analysts and Section Leaders, it may be necessary for the Laboratory QA Manager to approve the implementation of corrective action. The laboratory SOPs specify some conditions during or after analysis that may automatically trigger corrective action or optional procedures. These conditions may include sample dilutions, additional sample extract cleanup, automatic re-injection/re-analysis when certain QC criteria are not met, loss of sample through breakage or spillage, etc.

The analyst may identify the need for corrective action. The Section Leader, in consultation with the staff, will approve the required corrective action to be implemented by the laboratory staff. The Laboratory QA Manager will ensure implementation and documentation of the corrective action. If the nonconformance causes project objectives not to be achieved, the ENSR Project Manager will be notified. The ENSR Project Manager will contact all levels of project management for concurrence with the proposed corrective action.

These corrective actions are performed prior to release of the data from the laboratory. The corrective action will be documented in both the laboratory's corrective action files, and the narrative data report sent from the laboratory to the ENSR Project Manager. If the corrective action does not rectify the situation, the laboratory will contact the ENSR Project Manager, who will determine the action to be taken and inform the appropriate personnel.

13.3 Corrective Action During Data Review and Assessment

The need for corrective action may be identified during data review or assessment. Potential types of corrective action may include re-sampling by the field team or re-injection/re-analysis of samples by the laboratory. These actions are dependent upon the ability to mobilize the field team and whether the data to be collected is necessary to meet the required QA objectives. If the ENSR data reviewer or assessor identifies a corrective action situation, the ENSR Project Manager will be responsible for informing the appropriate personnel. All corrective actions of this type will be documented by the ENSR Project Manager.

14.0 Quality Assurance Reports

QA reports will be submitted to the ENSR Project Manager to ensure that any problems identified during the sampling and analysis programs are investigated and the proper corrective measures taken in response. The QA reports will be prepared for any significant QA/QC problems and describe recommended corrective actions and the outcome of those actions.

15.0 References

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USACE, 1997. Chemical Quality Assurance for HTRW Projects. EM 200-1-6. October, 1997.

Table 1-1 Analytical Methods and Project-Required Detection Limits (dry weight units).

Parameter	Method Reference	Method Number	Project Required RL	RL Units
Physical Tests				
Total Solids/Water Content	ASTM	D-2216	1.0	%
Grain Size Analysis Sieve & Hydrometer	ASTM	D-422	1.0	%
Metals				
Copper	SW-846	6020	5	ppm
Arsenic	SW-846	6020	5	ppm
Cadmium	SW-846	6020	0.3	ppm
Chromium	SW-846	6020	5	ppm
Mercury	SW-846	7471A	0.02	ppm
Lead	SW-846	6020	5	ppm
Nickel	SW-846	6020	5	ppm
Zinc	SW-846	6020	5	ppm
Aluminum (Total – HF Digestion)[1]	SW-846	6010B	50	ppm
Conventional Analyses				
TOC	Lloyd Kahn	--	0.1	ppm
PAHs (Priority Pollutant List)				
Acenaphthene	SW-846	8270C-SIM	0.02	ppm
Acenaphthylene	SW-846	8270C-SIM	0.02	ppm
Anthracene	SW-846	8270C-SIM	0.02	ppm
Benzo(a)anthracene	SW-846	8270C-SIM	0.02	ppm
Benzo(a)pyrene	SW-846	8270C-SIM	0.02	ppm
Benzo(b)fluoranthene	SW-846	8270C-SIM	0.02	ppm
Benzo(k)fluoranthene	SW-846	8270C-SIM	0.02	ppm
Benzo(g,h,i)perylene	SW-846	8270C-SIM	0.02	ppm
Chrysene	SW-846	8270C-SIM	0.02	ppm
Dibenz(a,h)anthracene	SW-846	8270C-SIM	0.02	ppm
Fluoranthene	SW-846	8270C-SIM	0.02	ppm
Fluorene	SW-846	8270C-SIM	0.02	ppm
Indeno(1,2,3-cd)pyrene	SW-846	8270C-SIM	0.02	ppm
Naphthalene	SW-846	8270C-SIM	0.02	ppm
Phenanthrene	SW-846	8270C-SIM	0.02	ppm
Pyrene	SW-846	8270C-SIM	0.02	ppm
[1]- Total Aluminum using HF Digestion Method (Method 3052), other metals by 3050B				

Table 4-1 Sample Container, Preservation, and Holding Time Requirements

Sediment Parameters[1]	Sample Volume/Mass	Container Material	Preservation	Storage Condition	Holding Times[2]	Receiving Lab[3]
Grain Size & Moisture Content	500 g	Plastic	Airtight	NA	Undetermined	GEO
Grain Size QC (1 per 20)	*1000 g*	*Plastic*	*Airtight*	*NA*	*Undetermined*	*GEO*
TOC Lloyd Kahn	4-oz/120 g	Glass	Chill or Freeze	-20 °/4±2 °C	14 d	*AWHG*
PAHs, TPH					14 d (solid)/ 40 d (extract)	AWHG
TOC, PAH, TPH QC (1 per 20)	*8-oz/240 g*	*Glass*	*Chill or Freeze*	*-20 °/4±2 °C*	*14 d*	*AWHG*
Metals	2-oz/40 g	Glass	Chill or Freeze	-20 °/4±2 °C	180 d	*AWHG*
Metals QC (1 per 20)	*3-oz/60 g*	*Glass*	*Chill or Freeze*	*-20 °/4±2 °C*	*180 d*	*AWHG*

[1]Shaded QC samples represent quantities required for QC (duplication, spiking) exercises. Amount listed includes the mass needed to make both background and QC measurements.

[2]Allowable holding time is from the time that samples are collected.

[3]GEO: GeoPlan Associates; AWHG: Alpha Woods Hole Group

Table 6-1 Calibration Frequency and Criterion for Laboratory Instrumentation

Instrument and Parameter	Calibration Frequency	Calibration Standards	Acceptance Criteria
GC/MS PAHs	Initial: As needed	Initial: 5 standards 0.2, 0.5, 1.0, 2.0, 3.0 ug/mL	Initial: %RSD <30 for all CCC[1] analytes; Average %RSD <15% for individual target compounds
	Continuing: Every 12-18 h	Continuing: Mid-point standard 1.0 ug/mL	Continuing: %D <20 for all CCC analytes
Combustion Analyzer TOC	Initial: Annually	Initial: 6 standards 0, 400, 2000, 4000, 16000, 24000, ug Carbon	Initial: Correlation Coefficient ≥0.995
	Continuing: Every 12 hours	Continuing: 1 standard within calibration range	Continuing: CCV within 20% of true value.
ICP-AES Metals	Initial: Daily	Initial: Minimum of three standards and calibration blank. ~50, 200, 1000μg/L	Initial: r >0.995
	Continuing: Every 10 samples and at the end of the analytical run	Continuing: Mid-point standard of each metal. ~500 μg/L	Continuing: CCV within 10% of true value.

[1]CCC: Calibration Check Compounds (as defined in SW-846 8270C).

Table 8-1 Internal QC Checks

QC Sample*	Units	Grain Size	TOC	Metals	PAHs	*Corrective Action*
Method Blank	Conc	-	< RL	< RL	< RL	*1*
Surrogate Spikes	% Rec	-	-	-	30-150	*2*
Matrix Duplicate	% RPD	20	20	-	35	*3*
Matrix Spike	% Rec	-	-	75-125	30-150	*4*
MSD	% RPD	-	-	20	50	*5*
LCS	% Rec	-	80-120	80-120	30-150	*6*
SRM	% Rec	-	WIL	WIL	WIL	*7*

Corrective Action Codes:

1 Re-extract and re-analyze samples with concentrations <20x the method blank result and narrate.

2 Re-extract sample or re-analyze sample if within hold time. Discuss with Project Chemist immediately.

3 Flag results, narrate and discuss with Project Chemist.

4. If LCS (and SIS) are within specifications, flag results. If ND results contain high bias, narrate, otherwise re-prepare and re-analyze affected samples.

5 Investigate, re-analyze or flag results – organics: per CA code #4.

6 If other QC sample results are acceptable, flag results. If ND results contain high bias, narrate, otherwise re-extract, re-analyze, and discuss with Project Chemist.

7 Report, flag results and narrate.

Figure 1 NLDS/Seawolf Location

Figure 2 Multi-Beam Survey Boundaries

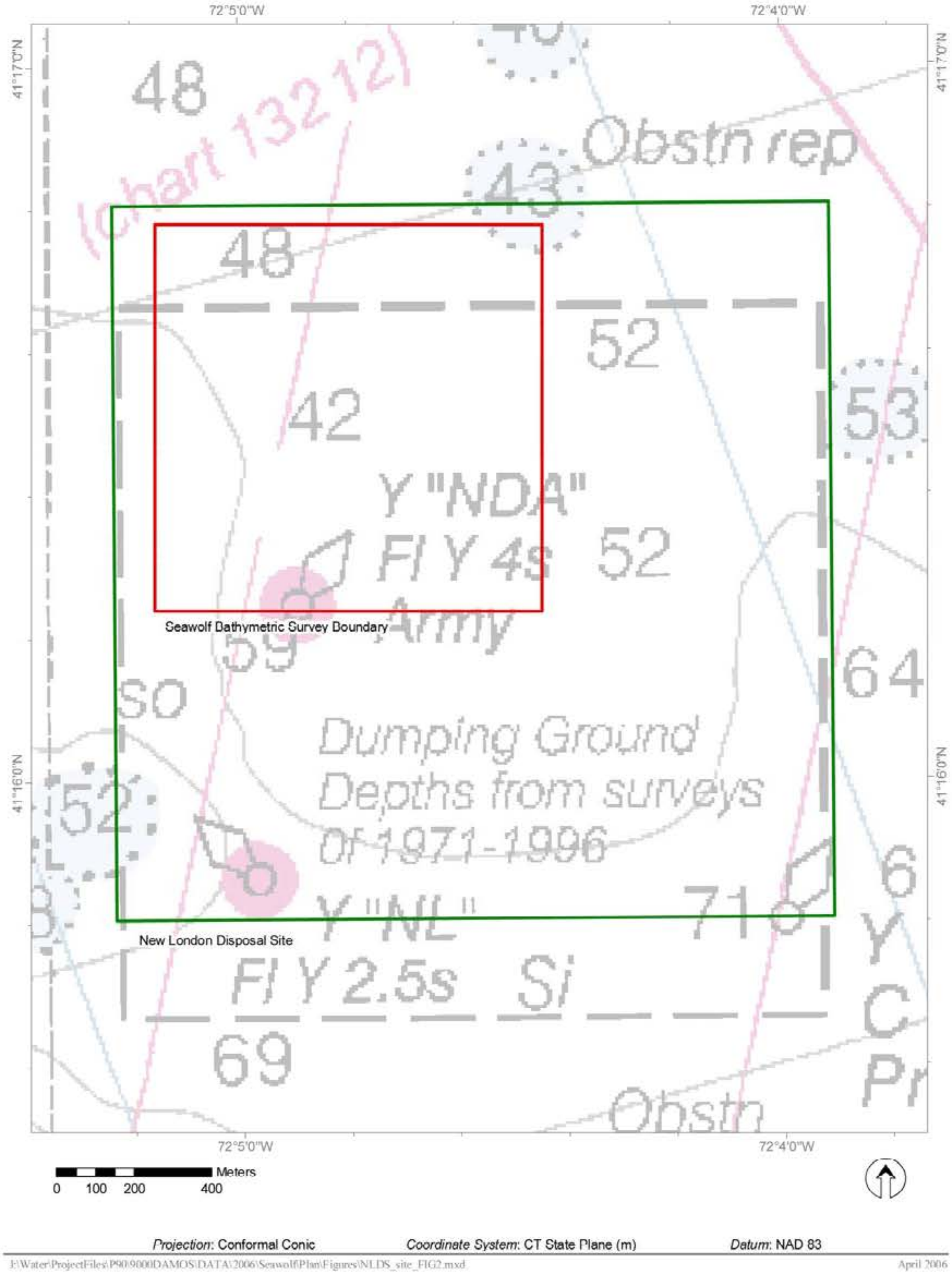


Figure 3 Sediment Coring Locations

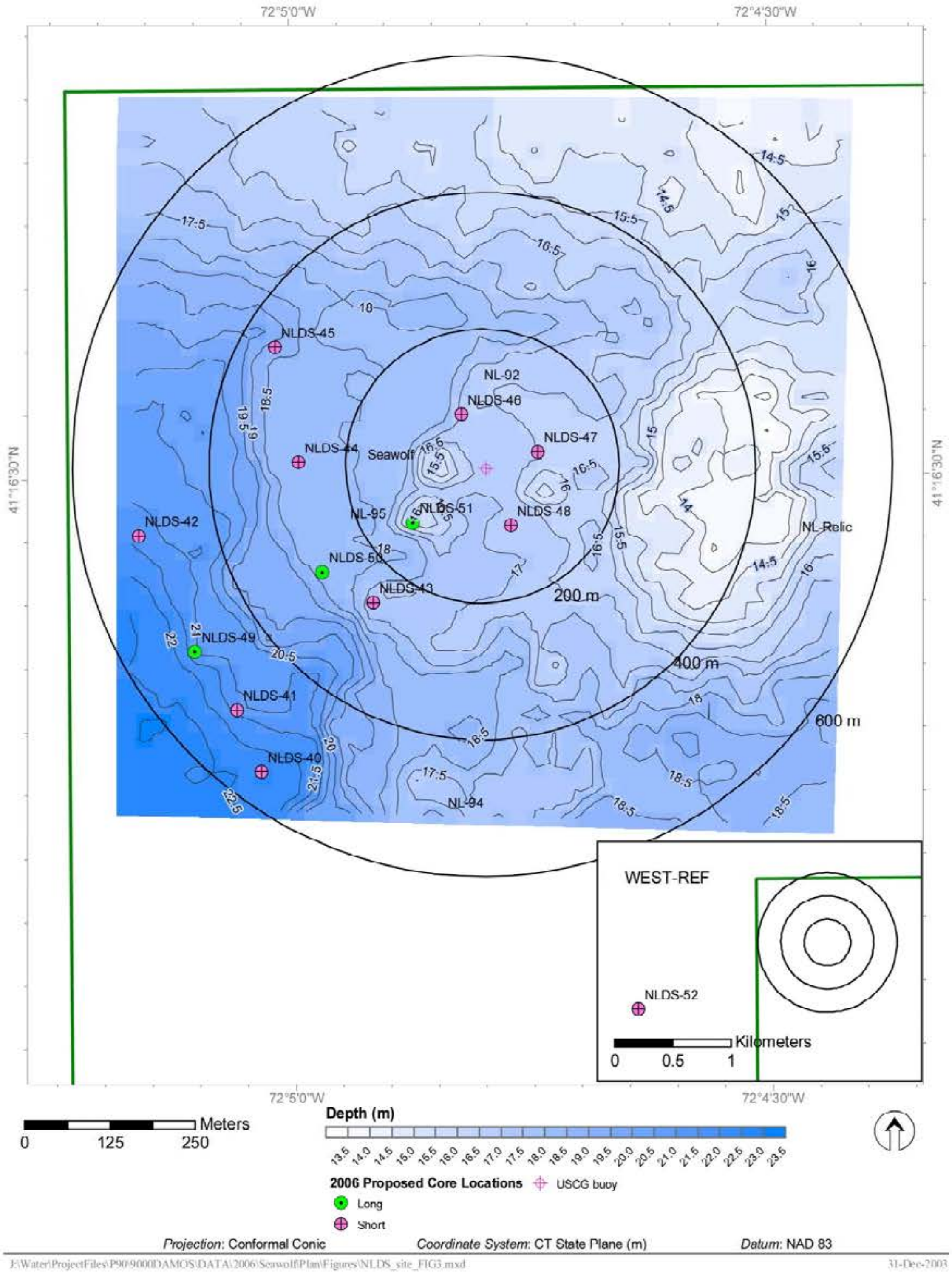


Figure 4 Sediment Profile Imaging Stations – Seawolf

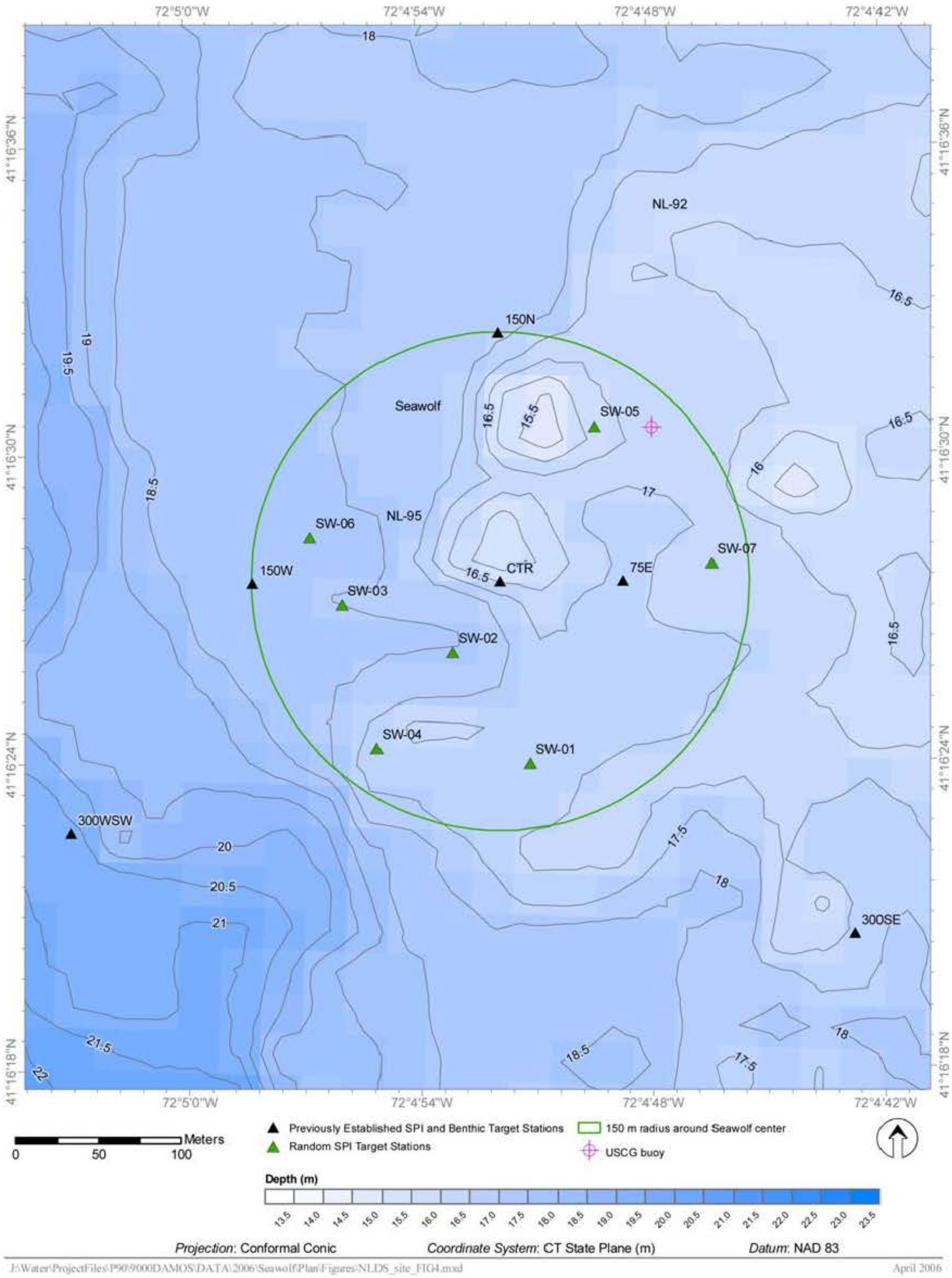


Figure 5 Sediment Profile Imaging Stations – NLDS Reference Stations

APPENDIX B

SEDIMENT-PROFILE IMAGE SURVEY RESULTS

Appendix B-1
Grain Size Scale for Sediments

Phi (Φ) size	Size range (mm)	Size class (Wentworth class)
< -1	> 2	Gravel
0 to –1	1 to 2	Very coarse sand
1 to 0	0.5 to 1	Coarse sand
2 to 1	0.25 to 0.5	Medium sand
3 to 2	0.125 to 0.25	Fine sand
4 to 3	0.0625 to 0.125	Very fine sand
> 4	< 0.0625	Silt/clay

Table B-2
Sediment-Profile Image Results for Reference Areas

STATION	DATE	TIME	Stop Collar Setting (in)	# of Lead Weights per Carriage	Calibration Constant	Grain Size Major Mode (phi)	Grain Size Maximum (phi)	Grain Size Minimum (phi)	Penetration Area (sq.cm)	Penetration Mean (cm)	Penetration Minimum (cm)	Penetration Maximum (cm)	Boundary Roughness (cm)	Boundary Roughness Type	RPD Area (sq.cm)	Mean RPD (cm)	Mud Clast Number	Mud Clast State	-	METHANE	TOTAL DM AREA	TOTAL DM MEAN	TOTAL DM MIN	TOTAL DM MAX	Low DO?	Mussels covering sed. surface?	COMMENT	Feeding Void #	Void Minimum Depth (cm)	Void Maximum Depth (cm)	Void Average Depth (cm)	Successional Stage	OSI
NE Ref 01 A	6/13/2006	9:14:54	13	3	14.46	4-3	2	>4	123.96	8.57	8.21	8.97	0.76	Biological	36.24	2.51	0	-		None	0.00	0	-	-	No	No	Tan to light gray silty very fine sand. Void in lower center. Burrow and mound at upper left. Polychaete above void. RPD physically influenced. Appears siltier at depth. SWI washed. A few sand tubes at SWI.	1	6.71	7.02	6.86	Stage 1 on 3	9
NE Ref 01 B	6/13/2006	9:15:40	13	3	14.46	4-3	2	>4	132.67	9.18	8.74	9.76	1.02	Biological	44.86	3.10	0	-		None	0.00	0	-	-	No	No	Tan to light gray silty very fine sand. RPD physically influenced. Appears siltier at depth. SWI washed. A few sand tubes at SWI. Void at far left and two voids at far right, one lined to SWI with a burrow. Algae in background. Sorting greater in upper 2-3 cm of sed column corresponding to RPD. Patches of oxidized sediment at depth.	3	3.37	5.55	4.46	Stage 1 on 3	10
NE Ref 01 C	6/13/2006	9:16:43	13	3	14.46	4-3	2	>4	131.78	9.11	8.43	9.34	0.91	Physical	40.89	2.83	0	-		None	0.00	0	-	-	No	No	Tan to light gray silty very fine sand. RPD physically influenced. Appears siltier at depth. SWI washed. A few sand tubes at SWI. Bedforms. Voids in upper center, lower center and lower left. Polychaete in left void. Algae in background. Sorting greater in upper 2-3 cm of sed column corresponding to RPD. Patches of oxidized sediment at depth. Three reps very similar.	3	3.37	8.89	6.13	Stage 1 on 3	9
NE Ref 02 A	6/13/2006	8:50:17	13	0	14.46	3-2	1	>4	66.98	4.63	4.41	4.98	0.57	Physical	30.96	2.14	0	-		None	0.00	0	-	-	No	No	Tan to medium gray, firm, slightly silty fine sand. SWI washed. Upper 2-3 cm well-sorted. Several shallow, oxidized burrows and a few tubes at SWI. RPD dominantly physical in nature. Minor shell fragments at SWI. Oxidized burrow in center; penetration insufficient to see subsurface voids similar to NE Ref 01	0	-	-	-	Stage 1 on 3	8
NE Ref 02 B	6/13/2006	8:51:26	13	0	14.46	3-2	1	>4	65.15	4.51	4.10	4.84	0.74	Physical	42.76	2.96	0	-		None	0.00	0	-	-	No	No	Tan to medium gray, firm, slightly silty fine sand. SWI washed. Upper 2-3 cm well-sorted. Several shallow, oxidized burrows and a few tubes at SWI and a very small void in far left. Polychaete in lower left-center. RPD dominantly physical in nature. Similar to A.	1	3.34	3.45	3.40	Stage 1 on 3	9
NE Ref 02 C	6/13/2006	8:52:25	13	0	14.46	3-2	1	>4	58.80	4.07	3.59	4.22	0.62	Physical	30.61	2.12	0	-		None	0.00	0	-	-	No	No	Tan to medium gray, firm, slightly silty fine sand. SWI washed. Upper 2-3 cm well-sorted. Several shallow, oxidized burrows. RPD dominantly physical in nature. Minor shell fragments at SWI. Large burrow in left background. Three reps are very similar.	0	-	-	-	Stage 1 on 3	8
NE Ref 03 A	6/13/2006	9:22:05	13	3	14.46	4-3	2	>4	132.24	9.15	8.54	9.65	1.10	Biological	34.91	2.41	0	-		None	0.00	0	-	-	No	No	Tan to light medium gray very silty, very fine sand. Top 2-3 cm better sorted than underlying material and there is some physical influence on RPD. Oxidized sediment-filled void in lower center and polychaete in lower left. Numerous shallow. Oxidized burrows. SWI washed and a couple of tubes at SWI background.	1	5.86	6.48	6.17	Stage 1 on 3	9
NE Ref 03 B	6/13/2006	9:22:54	13	3	14.46	4-3	2	>4	132.26	9.15	8.74	9.42	0.68	Biological	31.77	2.20	0	-		None	0.00	0	-	-	No	No	Tan to light medium gray very silty, very fine sand. Top 2-3 cm better sorted than underlying material and there is some physical influence on RPD. Voids at far left, bottom left center and upper right. Polychaete at far left. Several oxidized shallow burrows and dense tubes at center SWI background. SWI washed and incipient bedform. Very similar to A.	3	2.24	8.57	5.40	Stage 1 on 3	8
NE Ref 03 C	6/13/2006	9:24:02	13	3	14.46	4-3	2	>4	128.05	8.86	8.21	9.45	1.25	Physical	36.85	2.55	0	-		None	0.00	0	-	-	No	No	Tan to light medium gray very silty, very fine sand. Top 2-3 cm better sorted than underlying material and there is some physical influence on RPD. Void in upper right and polychaetes in upper and lower left. SWI washed and incipient bedform. Three reps are very similar.	1	2.89	3.20	3.04	Stage 1 on 3	9
NE Ref 04 A	6/13/2006	9:08:08	13	3	14.46	4-3	2	>4	142.60	9.86	9.31	10.36	1.05	Physical	33.86	2.34	0	-		None	0.00	0	-	-	No	No	Tan to light medium gray very silty, very fine sand. Top 2-3 cm better sorted than underlying material and there is some physical influence on RPD. Numerous voids at left of frame. Several tubes at SWI. SWI washed . Polychaete at upper right and nice oxidized burrow at mid-left.	4	3.14	9.00	6.07	Stage 1 on 3	9
NE Ref 04 B	6/13/2006	9:09:05	13	3	14.46	4-3	2	>4	119.20	8.24	7.41	9.39	1.98	Physical	44.89	3.10	0	-		None	0.00	0	-	-	No	Yes	Tan to light medium gray very silty, very fine sand. Top 2-3 cm better sorted than underlying material and there is some physical influence on RPD. Void at bottom center and bottom left. Several oxidized burrow traces. SWI washed and some algae at left background along with shell debris. A few tubes at SWI.	2	5.38	7.61	6.50	Stage 1 on 3	10

Table B-2
Sediment-Profile Image Results for Reference Areas

STATION	DATE	TIME	Stop Collar Setting (in)	# of Lead Weights per Carriage	Calibration Constant	Grain Size Major Mode (phi)	Grain Size Maximum (phi)	Grain Size Minimum (phi)	Penetration Area (sq.cm)	Penetration Mean (cm)	Penetration Minimum (cm)	Penetration Maximum (cm)	Boundary Roughness (cm)	Boundary Roughness Type	RPD Area (sq.cm)	Mean RPD (cm)	Mud Clast Number	Mud Clast State	.	METHANE	TOTAL DM AREA	TOTAL DM MEAN	TOTAL DM MIN	TOTAL DM MAX	Low DO?	Mussels covering sed. surface?	COMMENT	Feeding Void #	Void Minimum Depth (cm)	Void Maximum Depth (cm)	Void Average Depth (cm)	Successional Stage	OSI
NE Ref 04 C	6/13/2006	9:10:10	13	3	14.46	4-3	2	>4	124.98	8.64	8.38	8.74	0.37	Physical	42.56	2.94	0	-		None	0.00	0	-	-	No	No	Tan to light medium gray very silty, very fine sand. Top 2-3 cm better sorted than underlying material and there is some physical influence on RPD. Void at bottom right of the sed column. Large polychaete in center. Several deep, oxidized burrow traces. Bedforms. Three reps similar and similar to NE REf 01 and 03	1	7.05	8.29	7.67	Stage 1 on 3	9
NLon Ref 01 A	6/13/2006	9:36:09	13	2	14.46	4-3	2	>4	72.72	5.03	4.78	5.35	0.57	Physical	42.32	2.93	0	-		None	0.00	0	-	-	No	No	Firm, tan to very light gray, well sorted, very fine sand. RPD physically modified. A few shallow, oxidized burrows. SWI washed and small bedform. Dynamic.	0	-	-	-	Stage 2 -> 3	8
NLon Ref 01 B	6/13/2006	9:37:09	13	2	14.46	4-3	2	>4	71.77	4.96	4.24	5.43	1.19	Physical	47.70	3.30	0	-		None	0.00	0	-	-	No	No	Firm, tan to very light gray, well sorted, very fine sand. RPD physically modified. Burrow in upper left and several shallow to moderately deep oxidized burrow traces across width of frame. SWI washed and small bedform. Dynamic. Similar to A.	0	-	-	-	Stage 2 -> 3	9
NLon Ref 01 C	6/13/2006	9:38:11	13	2	14.46	4-3	2	>4	69.25	4.79	4.24	5.06	0.82	Physical	36.48	2.52	0	-		None	0.00	0	-	-	No	No	Firm, tan to very light gray, well sorted, very fine sand. SWI washed and small bedform. A few sand tubes visible in background. Numerous oxidized shallow burrows and organism in upper center. Dynamic. All three reps similar.	0	-	-	-	Stage 2 -> 3	8
NLon Ref 02 A	6/13/2006	9:45:12	13	4	14.46	4-3	2	>4	85.21	5.89	5.77	6.20	0.42	Physical	34.27	2.37	0	-		None	0.00	0	-	-	No	No	Firm, tan to light gray, moderately sorted, slightly silty, very fine sand. Void in upper center and upper left, left one may be pectinarid. SWI washed. Several shallow oxidized burrows extending downward 3-4 cm from SWI. RPD contrast subtle.	2	0.76	1.95	1.36	Stage 3	9
NLon Ref 02 B	6/13/2006	9:46:01	13	4	14.46	4-3	2	>4	96.85	6.70	6.28	6.99	0.71	Biological	40.85	2.82	0	-		None	0.00	0	-	-	No	No	Firm, tan to light gray, moderately sorted, slightly silty, very fine sand. Left side of sed column intensively bioturbated and reduced sediment being brought to SWI. Nice burrow and mound in right center too. A few fecal castings on SWI. SWI washed. Several shallow oxidized burrows extending downward 3-4 cm from SWI. RPD contrast subtle. Nice pic.	3	1.42	5.55	3.48	Stage 3	9
NLon Ref 02 C	6/13/2006	9:46:58	13	4	14.46	4-3	2	>4	74.04	5.12	4.92	5.35	0.42	Physical	41.35	2.86	0	-		None	0.00	0	-	-	No	No	Firm, tan to light gray, moderately sorted, slightly silty, very fine sand. Several shallow oxidized burrows extending downward 3-4 cm from SWI. RPD contrast subtle. Void in center of frame. Tube at left SWI and SWI washed. Three reps are similar.	1	2.60	3.34	2.97	Stage 3	9
NLon Ref 03 A	6/13/2006	9:52:00	13	4	14.46	4-3	2	>4	81.00	5.60	5.06	5.89	0.82	Physical	38.69	2.68	0	-		None	0.00	0	-	-	No	No	Firm, tan to light gray, slightly shelly, slightly silty very fine sand. Several shallow oxidized burrows and distinct burrow at far right. Several tubes at SWI background. SWI washed. Minor shell debris at SWI.	0	-	-	-	Stage 3	9
NLon Ref 03 B	6/13/2006	9:52:49	13	4	14.46	4-3	0	>4	105.73	7.31	6.59	7.78	1.19	Physical	44.49	3.08	0	-		None	0.00	0	-	-	No	No	Firm, tan to light gray, shelly, very silty very fine sand. Numerous shell fragments and shells at SWI, some dragged down. Wood fragment at far right and it is also dragged down. Several oxidized burrow traces in upper sediment column and oxidized path at mid right and lower left. Nice tube at center SWI.	0	-	-	-	Stage 3	10
NLon Ref 03 C	6/13/2006	9:54:31	13	4	14.46	4-3	0	>4	96.33	6.66	6.22	7.70	1.47	Physical	43.35	3.00	0	-		None	0.00	0	-	-	No	No	Firm, tan to light gray, shelly, slightly silty very fine sand. Dragdown of shell at center. A few cobbles in background with epiphytic/epizoan coatings. Pocket of oxidized sediment in far right lower corner. A few fine tubes at SWI and SWI washed.	0	-	-	-	Stage 3	9
NLon Ref 04 A	6/13/2006	9:58:36	13	4	14.46	4-3	2	>4	72.31	5.00	4.13	5.74	1.61	Physical	33.12	2.29	0	-		None	0.00	0	-	-	No	No	Very firm, tan to light gray, well-sorted, slightly silty very fine sand. Bedform. Small void in lower center and tube at SWI background. SWI washed.	1	3.76	4.75	4.26	Stage 3	9
NLon Ref 04 B	6/13/2006	9:59:48	13	4	14.46	4-3	2	>4	49.43	3.42	2.41	3.88	1.47	Physical	40.40	2.79	0	-		None	0.00	0	-	-	No	No	Very firm, tan to light gray, well-sorted, slightly silty very fine sand. Bedform. Proteinaceous tube in right background. Shell/cobble in left background. RPD physically dominated. Similar to A.	0	-	-	-	Ind	Ind
NLon Ref 04 C	6/13/2006	10:00:39	13	4	14.46	4-3	2	>4	60.99	4.22	3.28	4.75	1.47	Physical	40.96	2.83	0	-		None	0.00	0	-	-	No	No	Very firm, tan to light gray, well-sorted, slightly silty very fine sand. Bedform. Tubes in background. RPD physically dominated. Shell at mid depth, evidence of burrows at bottom of image. Three reps are similar.	0	-	-	-	Stage 2 -> 3	8
W Ref 01 A	6/13/2006	10:16:33	13	4	14.46	4-3	1	>4	101.70	7.03	6.76	7.50	0.74	Physical	53.51	3.70	0	-		None	0.00	0	-	-	No	No	Tan to gray, very shelly, silty very fine sand. Abundant shell debris at SWI and collapsed Ampelisca tubes. Polychaete lower right. Several shell types present. Numerous oxidized burrow traces. RPD may be elongated by dragdown.	0	-	-	-	Stage 1 on 3	10

Table B-2
Sediment-Profile Image Results for Reference Areas

STATION	DATE	TIME	Stop Collar Setting (in)	# of Lead Weights per Carriage	Calibration Constant	Grain Size Major Mode (phi)	Grain Size Maximum (phi)	Grain Size Minimum (phi)	Penetration Area (sq.cm)	Penetration Mean (cm)	Penetration Minimum (cm)	Penetration Maximum (cm)	Boundary Roughness (cm)	Boundary Roughness Type	RPD Area (sq.cm)	Mean RPD (cm)	Mud Clast Number	Mud Clast State	-	METHANE	TOTAL DM AREA	TOTAL DM MEAN	TOTAL DM MIN	TOTAL DM MAX	Low DO?	Mussels covering sed. surface?	COMMENT	Feeding Void #	Void Minimum Depth (cm)	Void Maximum Depth (cm)	Void Average Depth (cm)	Successional Stage	OSI
W Ref 01 B	6/13/2006	10:17:32	13	4	14.46	4-3	0	>4	104.94	7.26	6.79	7.70	0.91	Physical	59.38	4.11	0	-		None	0.00	0	-	-	No	No	Tan to gray, very shelly, silty very fine sand. Abundant shell debris at SWI and some Ampelisca tubes. Several shell types present and shell fragment are old.. Numerous oxidized burrow traces. RPD may be elongated by dragdown.	0	-	-	-	Stage 2 -> 3	10
W Ref 01 C	6/13/2006	10:18:20	13	4	14.46	4-3	0	>4	129.17	8.93	8.40	9.62	1.22	Physical	46.36	3.21	0	-		None	0.00	0	-	-	No	No	Tan to gray, very shelly, silty very fine sand. Abundant shell debris at SWI. Several shell types present and shell fragment are old.. Numerous oxidized burrow traces and a few tubes at SWI. Three reps are very similar.	0	-	-	-	Stage 2	8
W Ref 02 A	6/13/2006	10:23:52	13	4	14.46	Ind	Ind	Ind	0.00	0.00	0.00	0.00	0.00	Ind	0.00	0.00	0	-		None	0.00	0	-	-	No	No	No penetration - hard substrate. Epizoan in background.	0	-	-	-	Ind	Ind
W Ref 02 B	6/13/2006	10:25:07	13	4	14.46	Ind	Ind	Ind	0.00	0.00	0.00	0.00	0.00	Ind	0.00	0.00	0	-		None	0.00	0	-	-	No	No	No penetration - hard substrate. Epizoan in background.	0	-	-	-	Ind	Ind
W Ref 02 C	6/13/2006	10:26:09	13	4	14.46	-4 - -5	-5	>4	0.00	0.00	0.00	0.00	0.00	Ind	0.00	0.00	0	-		None	0.00	0	-	-	No	Yes	No penetration - hard substrate. Epizoan in foreground, cobble and old shell.	0	-	-	-	Ind	Ind
W Ref 03 A	6/13/2006	10:30:46	13	4	14.46	4-3	0	>4	131.76	9.11	8.94	9.34	0.40	Biological	38.36	2.65	0	-		None	0.00	0	-	-	No	No	Tan to gray, very shelly, silty very fine sand. Abundant shell fragments throughout sediment column. Several oxidized burrow traces. Small voids at far right and polychaete at lower left.	2	5.12	7.05	6.08	Stage 1 on 3	9
W Ref 03 B	6/13/2006	10:32:04	13	4	14.46	4-3	0	>4	127.12	8.79	8.35	9.45	1.10	Biological	46.43	3.21	0	-		None	0.00	0	-	-	No	No	Tan to gray, very shelly, silty very fine sand. Abundant shell fragments throughout sediment column. Several oxidized burrow traces and large polychaete in center of frame. A few small tubes at SWI. Similar to Rep A.	0	-	-	-	Stage 1 on 3	10
W Ref 03 C	6/13/2006	10:32:55	13	4	14.46	4-3	0	>4	130.69	9.04	8.15	9.65	1.50	Biological	49.24	3.41	0	-		None	0.00	0	-	-	No	No	Tan to gray, very shelly, silty very fine sand. Abundant shell fragments throughout sediment column. Several oxidized burrow traces. Multi chambered void complex at lower right and biogenic depression at SWI above voids. Three reps are morphologically similar.	3	6.45	8.15	7.30	Stage 1 on 3	10
W Ref 04 A	6/13/2006	10:39:28	13	4	14.46	4-3	0	>4	144.22	9.97	9.59	10.41	0.82	Physical	48.44	3.35	0	-		None	0.00	0	-	-	No	No	Tan to gray, extremely shelly, silty very fine sand. Abundant shell fragments throughout sediment column and intact disarticulated shells at SWI.. Several oxidized burrow traces. Two very small voids/feeding pockets at left. Dragdown at right and RPD interpolated across disturbance feature. Several small tubes at SWI.	2	5.94	9.08	7.51	Stage 1 on 3	10
W Ref 04 B	6/13/2006	10:40:22	13	4	14.46	4-3	0	>4	133.13	9.21	8.57	10.04	1.47	Physical	46.72	3.23	0	-		None	0.00	0	-	-	No	No	Tan to gray, extremely shelly, silty very fine sand. Abundant shell fragments throughout sediment column and intact disarticulated shells at SWI.. Several oxidized burrow traces. Two large active voids at lower left and polychaete in upper right. Several sand or protein tubes at SWI and algae at left background. Similar to Rep A.	2	5.35	9.08	7.22	Stage 1 on 3	10
W Ref 04 C	6/13/2006	10:41:19	13	4	14.46	4-3	0	>4	152.70	10.56	9.14	11.54	2.41	Physical	69.20	4.79	0	-		None	0.00	0	-	-	No	No	Tan to gray, extremely shelly, silty very fine sand. Abundant shell fragments throughout sediment column and intact disarticulated shells at SWI.. Several oxidized burrow traces. Flank of large active void at far left. Some dragdown of RPD. A few tubes at SWI and SWI appears washed. Three reps morphologically very similar.	1	4.19	6.51	5.35	Stage 1 on 3	11
W Ref 05 A	6/13/2006	10:44:38	13	4	14.46	4-3	0	>4	110.64	7.65	7.10	7.92	0.82	Physical	42.24	2.92	0	-		None	0.00	0	-	-	No	No	Tan to gray, shelly, silty very fine sand. Abundant shell fragments throughout sediment column. Small void in center. A couple of tubes at SWI background. SWI washed.	1	3.88	4.47	4.17	Stage 1 on 3	9
W Ref 05 B	6/13/2006	10:45:28	13	4	14.46	4-3	0	>4	111.55	7.71	7.30	8.04	0.74	Physical	50.14	3.47	0	-		None	0.00	0	-	-	No	No	Tan to gray, shelly, silty very fine sand. Abundant shell fragments throughout sediment column. Void at bottom center of frame and patch of oxidized sediment above it. Smeared mud tube at upper right. SWI washed. Similar to Rep A.	1	7.16	7.38	7.27	Stage 1 on 3	10
W Ref 05 C	6/13/2006	10:46:23	13	4	14.46	4-3	0	>4	116.91	8.08	7.81	8.49	0.68	Physical	53.57	3.71	0	-		None	0.00	0	-	-	No	No	Tan to gray, extremely shelly, silty very fine sand. Abundant shell fragments throughout sediment column and intact disarticulated shells at SWI.. Several oxidized burrow traces and polychaete in lower center. Three reps very similar but rep C has the most shell fragments.	0	-	-	-	Stage 1 on 3	10

Table B-3
Sediment-Profile Image Results for Seawolf Mound

STATION	DATE	TIME	Stop Collar Setting (in)	# of Lead Weights per Carriage	Calibration Constant	Grain Size Major Mode (phi)	Grain Size Maximum (phi)	Grain Size Minimum (phi)	Penetration Area (sq.cm)	Penetration Mean (cm)	Penetration Minimum (cm)	Penetration Maximum (cm)	Boundary Roughness (cm)	Boundary Roughness Type	RPD Area (sq.cm)	Mean RPD (cm)	Mud Clast Number	Mud Clast State	METHANE	TOTAL DM AREA		TOTAL DM MEAN		TOTAL DM MIN		TOTAL DM MAX	Low DO?	Mussels covering sed. surface?	COMMENT	Feeding Void #	Void Minimum Depth (cm)	Void Maximum Depth (cm)	Void Average Depth (cm)	Successional Stage	OSI
CTR A	6/13/2006	11:23:02	13	1	14.46	>4	-5	>4	113.20	7.83	6.85	8.63	1.78	Physical	23.44	1.62	0	-	None	113.20	>	7.83	>	6.85	>	8.63	No	No	Tan to light buff gray, cohesive, slightly shelly, slightly fine sandy, silt/clay DM>P, Some chaotic fabric. Oxidized voids, burrows and several polychaetes in sediment column. RPD defined largely by change in porosity at SWI. Cobbles at left SWI. Possible incipient lag at SWI.	3	1.22	6.30	3.76	Stage 1 on 3	8
CTR B	6/13/2006	11:24:21	13	1	14.46	>4	-5	>4	83.40	5.77	4.30	6.82	2.52	Biological	14.42	1.00	0	-	None	83.40	>	5.77	>	4.30	>	6.82	No	No	Tan to light buff gray, cohesive, slightly shelly, slightly fine sandy, silt/clay DM>P. Large void in center with biogenic mound above it. Small void in lower left. Cobble/lag st SWI. Similar to rep A.	2	1.21	5.94	3.58	Stage 1 on 3	7
CTR C	6/13/2006	11:25:14	13	1	14.46	>4	-5	>4	124.15	8.59	6.85	9.56	2.72	Biological	13.65	0.94	2	Oxidized	None	124.15	>	8.59	>	6.85	>	9.56	No	No	Tan to light buff gray, cohesive, slightly shelly, slightly fine sandy, silt/clay Large void complex dominated subsurface and biogenic mound above. Thin RPD that is highly influenced by physical processes. Mudclasts at left, and mudclast/cobbles at right background. Three reps are generally similar.	2	1.05	8.97	5.01	Stage 1 on 3	7
75E A	6/13/2006	12:15:20	13	1	14.46	>4	1	>4	131.01	9.06	8.71	9.76	1.05	Biological	9.33	0.65	0	-	None	131.01	>	9.06	>	8.71	>	9.76	No	Yes	Tan to gray, slightly sandy silt/clay. Appears to be a paleo RPD 4 cm down from SWI. Voids in upper left, and far right. Mussel shells at SWI. A few tubes in background. DM>P and DM looks old and reworked. Much clayie than reference.	3	1.56	5.38	3.47	Stage 1 on 3	6
75E B	6/13/2006	12:16:55	13	1	14.46	>4	-5	>4	98.04	6.78	5.94	7.67	1.73	Physical	17.81	1.23	0	-	None	98.04	>	6.78	>	5.94	>	7.67	No	No	Tan to gray, shelly, sandy silt/clay. Possible layering with reduced band below RPD. Shell fragments, cobble at SWI. A few shallow burrows. Not similar to rep A. Burrow at left, pit of fecal pellets to right from head-down deposit feeder.	0	-	-	-	Stage 1 on 3	7
75E C	6/13/2006	12:17:48	13	1	14.46	>4	1	>4	169.89	11.75	11.15	12.00	0.85	Biological	27.87	1.93	0	-	None	169.89	>	11.75	>	11.15	>	12.00	No	Yes	Tan to dark gray, sandy silt/clay. Possible layering with reduced band below RPD and another faint band at depth. Mussel shells at left SW and a few small tubes in background. Void at left with reduced sediment being brought to the SWI. Similar to A. DM>P and DM appears old and reworked.	1	2.66	6.31	4.48	Stage 1 on 3	8
150N A	6/13/2006	12:04:30	13	1	14.46	>4	1	>4	134.60	9.31	8.77	10.16	1.39	Biological	7.20	0.50	0	-	None	134.60	>	9.31	>	8.77	>	10.16	No	No	Tan to light buff gray, fine sandy, silt/clay. DM>P. Layering present with normally graded depositional units. Voids at right. SWI is washed and RPD appears to have been physically removed. Similar substrate to CTR.	3	3.76	6.93	5.35	Stage 1 on 3	6
150N B	6/13/2006	12:05:29	13	1	14.46	>4	1	>4	149.59	10.35	9.54	10.78	1.24	Biological	19.99	1.38	0	-	None	149.59	>	10.35	>	9.54	>	10.78	No	No	Tan to light buff gray, fine sandy, silt/clay. DM>P. Voids at right and oxidized sediment filled voids at left. Several shallow burrow traces. Substrate similar to Rep A but without layering. SWI is washed with shell fragments at SWI and incipient sand lag at SWI.	4	2.02	10.19	6.10	Stage 1 on 3	7
150N C	6/13/2006	12:06:39	13	1	14.46	>4	0	>4	155.95	10.79	10.24	11.52	1.27	Biological	24.70	1.71	0	-	None	155.95	>	10.79	>	10.24	>	11.52	No	No	Tan to light buff gray, fine sandy, silt/clay. DM>P. Faint layering that is being obscured with time. Voids and sediment filled voids/burrows throughout subsurface sediment. Maldanid polychaete at right. SWI is washed with shell and fine sand lag. Three reps are similar.	5	1.64	6.54	4.09	Stage 1 on 3	8
150W A	6/13/2006	11:39:50	13	1	14.46	>4	1	>4	150.59	10.41	10.07	10.95	0.88	Biological	12.26	0.85	0	-	None	150.59	>	10.41	>	10.07	>	10.95	No	No	Tan to light buff gray, fine sandy, silt/clay. DM>P. Faint layering that is being obscured with time along with a few clots of allochthonous clays at depth. Large void complex/gallery at right. SWI is washed with some shell fragments and incipient sand lag. Similar to 150N and CTR.	4	1.61	10.27	5.94	Stage 1 on 3	7
150W B	6/13/2006	11:40:46	13	1	14.46	>4	0	>4	134.63	9.31	7.95	10.58	2.63	Biological	15.30	1.06	0	-	None	134.63	>	9.31	>	7.95	>	10.58	No	No	Tan to light buff gray, fine sandy, silt/clay. DM>P. Large void at far left and small void in upper right. Biogenic depression at left SWI and several tubes and epiphyte/epizoans at SWI. Polychaete lower right-center. SWI washed and some shell lag.	2	0.76	5.35	3.06	Stage 1 on 3	7
150W C	6/13/2006	11:41:47	13	1	14.46	>4	0	>4	153.62	10.62	10.19	11.09	0.91	Biological	21.14	1.46	0	-	None	153.62	>	10.62	>	10.19	>	11.09	No	No	Tan to light buff gray, fine sandy, silt/clay. DM>P. Faint layering that is becoming obscured with time. Large void at left and oxidized sediment filled void at right. Several small polychaetes in upper sediment column. SWI washed and has shell fragment and sand proto-lag. Three reps are similar and substrate similar to 150N and CTR.	3	3.88	8.63	6.25	Stage 1 on 3	7
300 WSW A	6/13/2006	10:57:20	13	1	14.46	>4	0	>4	155.54	10.76	10.38	11.35	0.96	Biological	23.85	1.65	0	-	None	155.54	>	10.76	>	10.38	>	11.35	No	No	Tan to light buff gray, fine sandy, silt/clay. DM>P. Faint layering of darker gray organic silt/clay that is becoming obscured with time. Sediment column riddled with active feeding voids. Several tubes at SWI. SWI sandier than underlying material and appears to be occasionally washed. Some shell fragments at SWI.	5	2.21	10.72	6.47	Stage 1 on 3	8
300 WSW B	6/13/2006	10:58:15	13	1	14.46	>4	1	>4	138.19	9.56	9.22	9.79	0.57	Biological	25.61	1.77	0	-	None	138.19	>	9.56	>	9.22	>	9.79	No	No	Tan to light buff gray, fine sandy, silt/clay. DM>P. Faint layering of darker gray organic silt/clay that is becoming obscured with time. Active feeding voids in lower left center and several oxidized sediment filled pockets/voids throughout sediment column. SWI washed. Patch of organics at left. Similar to Rep A.	3	5.01	9.51	7.26	Stage 1 on 3	8

Table B-3
Sediment-Profile Image Results for Seawolf Mound

STATION	DATE	TIME	Stop Collar Setting (in)	# of Lead Weights per Carriage	Calibration Constant	Grain Size Major Mode (phi)	Grain Size Maximum (phi)	Grain Size Minimum (phi)	Penetration Area (sq.cm)	Penetration Mean (cm)	Penetration Minimum (cm)	Penetration Maximum (cm)	Boundary Roughness (cm)	Boundary Roughness Type	RPD Area (sq.cm)	Mean RPD (cm)	Mud Clast Number	Mud Clast State	METHANE	TOTAL DM AREA		TOTAL DM MEAN		TOTAL DM MIN		TOTAL DM MAX	Low DO?	Mussels covering sed. surface?	COMMENT	Feeding Void #	Void Minimum Depth (cm)	Void Maximum Depth (cm)	Void Average Depth (cm)	Successional Stage	OSI
300 WSW C	6/13/2006	10:59:04	13	1	14.46	>4	1	>4	147.94	10.23	10.07	10.58	0.51	Biological	22.62	1.56	0	-	None	147.94	>	10.23	>	10.07	>	10.58	No	No	Tan to light buff gray, fine sandy, silt/clay. DM>P. Patches of organic sediment that may have once appeared continuous. Active feeding void at left center. SWI washed. A few tubes at SWI. Three reps are generally similar.	2	1.98	7.70	4.84	Stage 1 on 3	8
300 SE A	6/13/2006	12:26:22	13	1	14.46	-4 - -5/3-2	-5	>4	55.36	3.83	2.60	5.01	2.40	Physical	29.03	2.01	0	-	None	Ind		Ind		Ind		Ind	No	No	Tan, shelly cobbles over fine to medium sand. SWI washed and cobbles encrusted with barnacles. Possible old DM but unclear.	0	-	-	-	Ind	Ind
300 SE B	6/13/2006	12:27:59	13	1	14.46	4-3	-3	>4	66.89	4.63	3.79	5.18	1.39	Physical	15.70	1.09	0	-	None	66.89	>	4.63	>	3.79	>	5.18	No	Yes	Tan to medium gray clayey very fine sand. DM>P. Agglomerate of mussel shells at SWI. Several oxidized burrows and proto-voids within the sediment column. A few cobbles at SWI.	0	-	-	-	Stage 3	7
300 SE C	6/13/2006	12:28:55	13	1	14.46	>4	1	>4	96.13	6.65	6.28	7.64	1.36	Physical	29.29	2.03	0	-	None	96.13	>	6.65	>	6.28	>	7.64	No	Yes	Tan to medium gray clayey very fine sand. DM>P. Agglomerate of mussel shells at SWI with intact and disarticulated shells present. Oxidized void at far left. Some dragdown of RPD. Interpreted to be DM.	1	3.08	3.59	3.34	Stage 3	8
SW 01 B	6/13/2006	11:09:18	13	1	14.46	>4	1	>4	133.44	9.23	8.94	10.30	1.36	Biological	24.78	1.71	0	-	None	133.44	>	9.23	>	8.94	>	10.30	No	No	Tan to light buff gray, fine sandy, silt/clay. DM>P. Faint layering of organ silt. Sediment column riddles with active voids and polychaete at lower right. SWI washed and some shell fragments at SWI.	4	3.34	8.04	5.69	Stage 1 on 3	8
SW 01 C	6/13/2006	11:10:11	13	1	14.46	>4	1	>4	67.47	4.67	2.94	6.34	3.39	Physical	24.08	1.67	0	-	None	67.47	>	4.67	>	2.94	>	6.34	No	Yes	Tan to gray silt/clay with covering of mussels at SWI. Mussels appear to be ripped up from somewhere else based on attachment filaments splayed and covering of sediment on some. Dragdown of RPD and stage indeterminate. Different from rep B.	0	-	-	-	Ind	Ind
SW 01 D	6/13/2006	11:11:09	13	1	14.46	>4	1	>4	136.07	9.41	8.57	10.50	1.92	Physical	6.36	0.44	0	-	None	136.07	>	9.41	>	8.57	>	10.50	No	No	Tan to gray, slightly sandy silt/clay with odd texture. DM>P. Faint layering of organic silt. Small active voids and burrows in upper right. Sediment column has been physically denuded of RPD. Disarticulated shells at SWI. Very different from other reps.	3	2.89	4.70	3.79	Stage 3	6
SW 02 A	6/13/2006	11:18:02	13	1	14.46	>4	1	>4	132.03	9.13	8.01	10.07	2.07	Physical	17.49	1.21	0	-	None	132.03	>	9.13	>	8.01	>	10.07	No	Yes	Tan to gray, slightly sandy silt/clay. DM>P. Faint layering of organic silt that is being obscured. Several deep oxidized burrow trace and transected burrow at lower right. SWI has mussels in background and mussels appear in "living" orientation. DM is old and converging with ambient.	0	-	-	-	Stage 3	7
SW 02 B	6/13/2006	11:19:00	13	1	14.46	>4	0	>4	109.63	7.58	7.07	8.01	0.93	Physical	17.21	1.19	0	-	None	109.63	>	7.58	>	7.07	>	8.01	No	No	Tan to gray, slightly sandy silt/clay. DM>P. Void at lower right and small void at left. Several sediment-filled burrow and void traces throughout sediment column. Polychaete in lower right void and two polychaetes in upper left. SWI washed and shell fragments/lag at SWI.	2	5.46	7.70	6.58	Stage 1 on 3	7
SW 02 C	6/13/2006	11:19:56	13	1	14.46	>4	1	>4	107.05	7.40	6.17	8.21	2.04	Physical	29.80	2.06	0	-	None	107.05	>	7.40	>	6.17	>	8.21	No	Yes	Tan to gray, slightly sandy silt/clay. DM>P. Distinct upper layer of gray silt/clay. Mussels at left. SWI is washed and sandier than underlying sediment. Similar to Rep A. Several oxidized burrow traces extending to near the bottom of the frame.	0	-	-	-	Stage 2 -> 3	7
SW 03 A	6/13/2006	11:29:02	13	1	14.46	>4	1	>4	147.68	10.21	9.73	10.44	0.71	Biological	18.82	1.30	0	-	None	147.68	>	10.21	>	9.73	>	10.44	No	No	Tan to light buff gray, fine sandy, silt/clay. DM>P. Faint layering that is becoming obscured. Void at far right and another at far left. Numerous burrow and void traces throughout the sediment column. Polychaetes in upper center. SWI shows signs of being winnowed and washed.	2	6.37	8.69	7.53	Stage 1 on 3	7
SW 03 B	6/13/2006	11:30:02	13	1	14.46	>4	1	>4	144.73	10.01	9.62	10.61	0.99	Biological	13.27	0.92	0	-	None	144.73	>	10.01	>	9.62	>	10.61	No	No	Tan to light buff gray, fine sandy, silt/clay. DM>P. Large void at left and smaller void In upper right. Several void and burrow traces in upper sediment column. Sand and shell fragments at SWI, washed and winnowed Morphologically similar to A.	2	2.21	4.87	3.54	Stage 1 on 3	7
SW 03 C	6/13/2006	11:31:03	13	1	14.46	>4	1	>4	148.49	10.27	10.07	10.50	0.42	Biological	13.26	0.92	0	-	None	148.49	>	10.27	>	10.07	>	10.50	No	No	Tan to light buff gray, fine sandy, silt/clay. DM>P. Vestige of faint layerin Large voids at lower left and active, sediment-filled void and burrow at center-right.. Several void and burrow traces in upper sediment column. Sand and shell fragments at SWI, washed and winnowed. Three reps are very similar.	3	5.06	9.99	7.53	Stage 1 on 3	7
SW 04 A	6/13/2006	11:02:40	13	1	14.46	>4	1	>4	145.73	10.08	9.34	12.34	3.00	Biological	20.62	1.43	0	-	None	145.73	>	10.08	>	9.34	>	12.34	No	Yes	Tan to medium gray, slightly sandy silt/clay. DM>P. Some layering visible Mussels cover SWI. Voids with oxidized sediment in lower left. Some disturbance of RPD from mussel shell dragdown.	2	7.44	9.22	8.33	Stage 1 on 3	7
SW 04 B	6/13/2006	11:03:37	13	1	14.46	3-2	1	>4	36.91	2.55	2.18	2.83	0.65	Physical	36.91	2.55	0	-	None	36.91	>	2.55	>	2.18	>	2.83	No	Yes	Tan, poorly sorted silty fine sand. DM>P. Mussels at SWI. A couple of shallow burrows. Different from rep A.	0	-	-	-	Ind	Ind
SW 04 C	6/13/2006	11:04:21	13	1	14.46	3-2	-2	>4	76.32	5.28	3.68	5.66	1.98	Physical	22.47	1.55	0	-	None	76.32	>	5.28	>	3.68	>	5.66	No	Yes	Tan, poorly sorted silty fine sand. DM>P. Mussels at SWI. A couple of shallow burrows. Different from rep A and similar to B. Some small gravel/cobble at SWI and is a lag deposit.	0	-	-	-	Stage 2 -> 3	7

Table B-3
Sediment-Profile Image Results for Seawolf Mound

STATION	DATE	TIME	Stop Collar Setting (in)	# of Lead Weights per Carriage	Calibration Constant	Grain Size Major Mode (phi)	Grain Size Maximum (phi)	Grain Size Minimum (phi)	Penetration Area (sq.cm)	Penetration Mean (cm)	Penetration Minimum (cm)	Penetration Maximum (cm)	Boundary Roughness (cm)	Boundary Roughness Type	RPD Area (sq.cm)	Mean RPD (cm)	Mud Clast Number	Mud Clast State	METHANE	TOTAL DM AREA	TOTAL DM MEAN		TOTAL DM MIN		TOTAL DM MAX		Low DO?	Mussels covering sed. surface?	COMMENT	Feeding Void #	Void Minimum Depth (cm)	Void Maximum Depth (cm)	Void Average Depth (cm)	Successional Stage	OSI
SW 05 A	6/13/2006	12:09:59	13	1	14.46	>4	0	>4	122.32	8.46	8.01	9.17	1.16	Biological	28.41	1.96	0	-	None	122.32	>	8.46	>	8.01	>	9.17	No	No	Tan to light buff gray, fine sandy, silt/clay. DM>P. Faint layering that is becoming obscured. Void in upper right. Numerous burrow and void traces throughout the sediment column. Shell fragments at sand at SWI. Likely sor washing/winnowing.	1	3.11	3.85	3.48	Stage 3	8
SW 05 B	6/13/2006	12:10:51	13	1	14.46	>4	0	>4	145.12	10.04	9.48	10.38	0.91	Biological	15.73	1.09	0	-	None	145.12	>	10.04	>	9.48	>	10.38	No	No	Tan to light buff gray and medium gray, fine sandy, silt/clay. DM>P. Chaotic fabric. Small void in upper left. Numerous burrow and void traces throughout the sediment column. Shell fragments at sand at SWI, mussels ir left background.. Likely some washing/winnowing.	1	2.74	2.97	2.86	Stage 1 on 3	7
SW 05 C	6/13/2006	12:11:55	13	1	14.46	>4	0	>4	151.04	10.45	10.10	11.09	0.99	Biological	17.03	1.18	0	-	None	151.04	>	10.45	>	10.10	>	11.09	No	No	Tan to gray, slightly sandy silt/clay. DM>P. SWI winnowed with sand and shell fragments at SWI. Voids in upper left, mid-left and lower right. Three reps are similar.	3	1.19	9.71	5.45	Stage 1 on 3	7
SW 06 A	6/13/2006	11:34:21	13	1	14.46	>4	0	>4	132.58	9.17	8.71	9.62	0.91	Biological	38.63	2.67	0	-	None	132.58	>	9.17	>	8.71	>	9.62	No	No	Tan to gray, slightly sandy silt/clay. DM>P. Upper 2-3 distinctly sandier and shellier than underlying sediment. Large void in lower left and several polychaetes is sediment column. Nice fecal string at left SWI. Shell fragments and a few tubes at SWI.	1	7.19	8.69	7.94	Stage 1 on 3	9
SW 06 B	6/13/2006	11:35:26	13	1	14.46	>4	0	>4	144.65	10.00	8.83	11.15	2.32	Biological	34.83	2.41	0	-	None	144.65	>	10.00	>	8.83	>	11.15	No	No	Tan to gray, slightly sandy silt/clay. DM>P. Upper 2-3 distinctly sandier and shellier than underlying sediment. Faint layering. Large void in lower center. Shell fragments and a few tubes at SWI. Similar to Rep A.	1	5.72	8.06	6.89	Stage 1 on 3	9
SW 06 C	6/13/2006	11:36:17	13	1	14.46	>4	0	>4	97.99	6.78	3.99	10.10	6.11	Physical	Ind	1.91	0	-	None	97.99	>	6.78	>	3.99	>	10.10	No	No	Disturbed, but similar to previous two reps in general morphological properties, Tan fleshy bit in mass of shell in background. Void at right. RPD is linear measurements from undisturbed portion of SWI.	1	0.82	7.53	4.17	Stage 3	8
SW 07 A	6/13/2006	12:20:46	13	1	14.46	>4	-3	>4	67.79	4.69	3.85	5.32	1.47	Physical	13.56	0.94	0	-	None	67.79	>	4.69	>	3.85	>	5.32	No	Yes	Tan to light gray, very sandy silts; penetration stopped by shells. Dm>P. Shell and sand at SWI. Firm.	0	-	-	-	Stage 2 -> 3	6
SW 07 B	6/13/2006	12:21:47	13	1	14.46	>4	0	>4	133.70	9.25	8.97	9.73	0.76	Biological	25.95	1.79	0	-	None	133.70	>	9.25	>	8.97	>	9.73	No	No	Tan to light gray, fine sandy silt/clay. DM>P. Void in lower right and far lower left. Upper 2-3 cm is distinctly sandier than underlying sediment. Polychaete at left. SWI washed.	2	5.69	9.42	7.56	Stage 1 on 3	8
SW 07 C	6/13/2006	12:22:36	13	1	14.46	>4	0	>4	56.94	3.94	3.17	5.01	1.84	Physical	31.53	2.18	0	-	None	56.94	>	3.94	>	3.17	>	5.01	No	Yes	Tan to gray, fine sandy silt/clay. DM>P. SWI covered with mussels. This station shows nearly the complete range of DM in each replicate.	0	-	-	-	Stage 1 on 3	8

APPENDIX C

BENTHIC BIOLOGY SURVEY RESULTS

Table C-1
Infaunal species and counts for disposal site stations sampled during the Seawolf survey, June 2006

Taxon	Disposal Site Stations						Total
	150 N	150 W	300 WSW	300SE	75 E	CTR	
Monticellina baptisteae	11	45	12	46	11	14	139
Prionospio steenstrupi	22	27	20	7	30	22	128
Nucula annulata		12	20	3	21	58	114
Leptocheirus pinguis	15	19	47			14	95
Tharyx sp. A	14	22	2	10	3	41	92
Harmothoe extenuata	9	16	2	22	4	13	66
Ampharete finmarchica	18	15	8	1		19	61
Tharyx acutus	3	4		33	14	2	56
Aricidea catherinae	24	5	6	3	3	13	54
Ampelisca vadorum	7	18	18		1	3	47
Monticellina dorsobranchialis	4	9	3	6	6	5	33
Pitar morrhuana	7	9	9		3	5	33
Cerastoderma pinnulatum	8	3	12			8	31
Ninoe nigripes	5	3	9	2	6		25
Scoletoma hebes		2		2	4	14	22
Tharyx sp. B			3			19	22
Levinsenia gracilis	3	3	10	2	1	1	20
Mediomastus ambiseta	2	1	5	3	5	4	20
Nephtys incisa	6	2	3	3	3	3	20
Polycirrus eximius	2		1	5	8	1	17
Euclymene collaris	1	2	1	1	1	7	13
Unciola irrorata	4	2	4		1	1	12
Glycera americana	3		1	2	2	3	11
Ophelina acuminata	3	1	2	1	3	1	11
Monocorophium sextonae	3	5		1		1	10
Scalibregma inflatum	3	3	2	1		1	10
Exogone dispar	5			3			8
Anadara transversa	1		3			3	7
Astarte undata	2	2	2			1	7
Panopeus herbstii	1	2	1	1	1	1	7
Phyllodoce maculata		1		3		3	7
Tellina agilis	1	1	1	3	1		7
Leitoscoloplos acutus	1	2	2		1		6
Axiognathus squamatus				5			5
Lepidonotus squamatus	1	3		1			5
Owenia fusiformis	3	2					5
Phoxocephalus holbolli	1	2		1	1		5
Sigambra tentaculata	1	3			1		5
Erichthonius brasiliensis	3	1					4
Petricola pholadiformis			1			3	4
Capitella capitata complex				3			3
Capitella jonesi				2		1	3
Cirrophorus furcatus		2				1	3
Sthenelais boa				3			3
Autolytus prolifer		1				1	2
Ceriantheopsis americanus		1				1	2

Taxon	Disposal Site Stations						Total
	150 N	150 W	300 WSW	300SE	75 E	CTR	
Eobrolgus spinosus				1		1	2
Ischyrocerus anguipes	2						2
Lucinoma filosa					2		2
Lyonsia hyalina		1	1				2
Onchidoridae sp. 1	1					1	2
Pandora gouldiana	1	1					2
Placopecten magellanicus			1			1	2
Potamilla reniformis						2	2
Sabellaria vulgaris						2	2
Unciola serrata	2						2
Ampelisca abdita						1	1
Anachis lafresnayi				1			1
Arabella iricolor				1			1
Boonea seminuda						1	1
Corophiidae spp. indet.		1					1
Crassicorophium bonelli			1				1
Crassinella lunulata		1					1
Cyclocardia borealis	1						1
Diastylis quadrispinosa					1		1
Diastylis sculpta	1						1
Dipolydora socialis	1						1
Dyopedos monocanthus		1					1
Ensis directus					1		1
Exogone hebes				1			1
Flabelligera sp. 1						1	1
Lyonsia arenosa						1	1
Metopella angusta						1	1
Microdeutopus anomalus						1	1
Micropthalmus sczelkowii					1		1
Odostomia eburnea						1	1
Parametopella cypris						1	1
Pholoe minuta				1			1
Phoronis architecta		1					1
Phyllodoce mucosa		1					1
Pinnixa chaetopterana		1					1
Pinnixa sayana	1						1
Scoletoma fragilis	1						1
Spio filicornis					1		1
Spiochaetopterus costarum						1	1
Spiophanes bombyx	1						1
Grand Total	209	259	213	184	141	304	1310

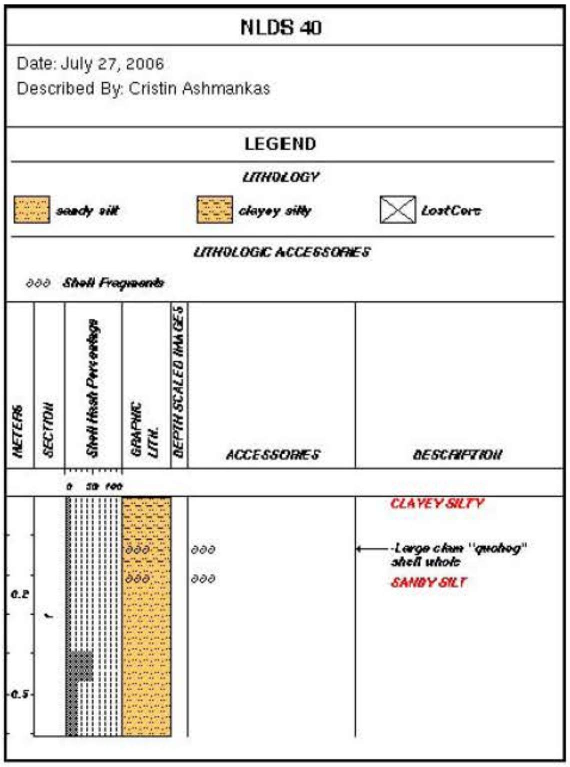
Table C-2
Infaunal species and counts for reference stations sampled during the Seawolf survey, June 2006

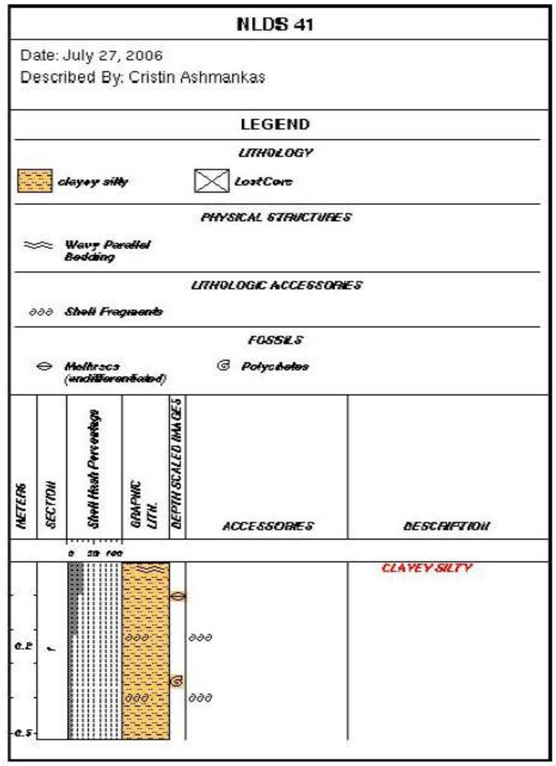
Taxon	Reference Stations			Total
	NE REF 02	NLON REF 03	WEST REF 05	
Ampelisca verrilli	15	74	4	93
Aricidea catherinae		9	55	64
Ampelisca vadorum		8	47	55
Scalibregma inflatum	13	13	26	52
Monticellina baptisteae	6	17	19	42
Prionospio steenstrupi	14	9	19	42
Nephtys incise	7	8	12	27
Spiophanes bombyx	5	6	13	24
Ampharete finmarchica	4	5	14	23
Euclymene collaris		10	12	22
Harmothoe extenuata	3		12	15
Leptocheirus pinguis	2	4	9	15
Ampelisca abdita	13			13
Microdeutopus anomalus		11		11
Cirrophorus furcatus			10	10
Monticellina dorsobranchialis	3	2	5	10
Ninoe nigripes	8	1	1	10
Polycirrus eximius	7		2	9
Spiochaetopterus costarum	5	1	3	9
Unciola irrorata	3	3	3	9
Exogone hebes	1		7	8
Ischyrocerus anguipes	1	2	5	8
Tharyx acutus		5	3	8
Cyclocardia borealis	1		6	7
Tellina agilis	2	3	2	7
Anachis lafresnayi			6	6
Bostrichobranchus pilularis	6			6
Nephtys bucera	4		1	5
Sthenelais boa	3	1	1	5
Monocorophium sextonae		4		4
Owenia fusiformis	1	1	2	4
Pitar morrhuana	3	1		4
Aglaophomus circinata		3		3
Astarte undata	1	1	1	3
Astyris lunata	1	1	1	3
Glycera americana		2	1	3
Parougia caeca			3	3
Turbonilla elegantula	1		2	3
Unciola serrata			3	3
Arabella iricolor		1	1	2
Axiognathus squamatus	1	1		2
Byblis serrata			2	2
Carinomella lactea			2	2
Caulleriella sp. B			2	2
Cerastoderma pinnulatum			2	2
Crassicorophium bonelli			2	2

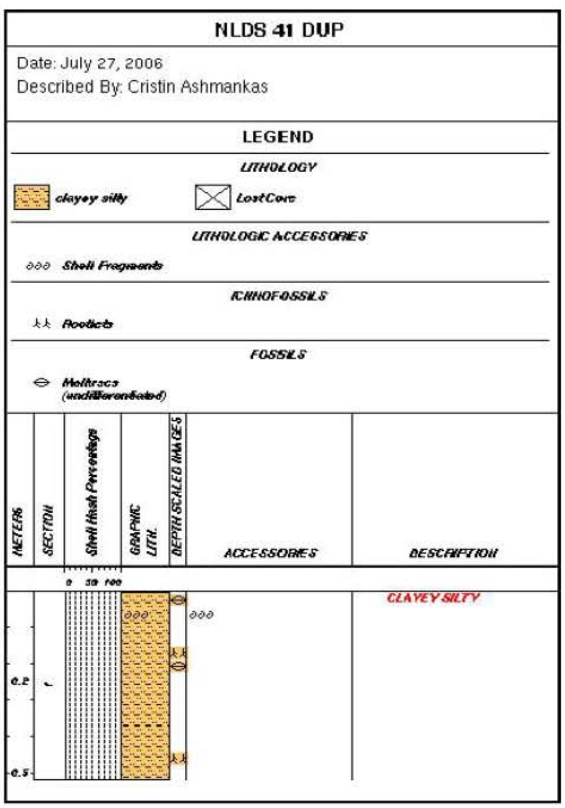
Taxon	Reference Stations			Total
	NE REF 02	NLON REF 03	WEST REF 05	
Ensis directus		2		2
Erichthonius brasiliensis		2		2
Lepidonotus squamatus		2		2
Musculus discors			2	2
Nucula delphinodonta	2			2
Phoronis architecta	1		1	2
Phoxocephalus holbolli			2	2
Phyllodoce arenae			2	2
Phyllodoce maculata		2		2
Phyllodoce mucosa	2			2
Potamilla reniformis		1	1	2
Syllis alternate	1		1	2
Anadara transversa		1		1
Autolytus prolifer			1	1
Cancer irroratus			1	1
Clymenella torquata		1		1
Crassinella lunulata			1	1
Diastylis sculpta	1			1
Dipolydora socialis			1	1
Dyopedos monocanthus	1			1
Fargoa bartschi			1	1
Leitoscoloplos acutus	1			1
Levinsenia gracilis		1		1
Nereis grayi	1			1
Notomastus latericeus			1	1
Nucula annulata			1	1
Ophiura sarsi		1		1
Panopeus herbstii		1		1
Photis pollex	1			1
Placopecten magellanicus			1	1
Polygordius sp. A			1	1
Protodorvillea gaspeensis			1	1
Ptilanthura tenuis			1	1
Sabellaria vulgaris		1		1
Scoletoma fragilis	1			1
Scoletoma hebes			1	1
Syllides benedicti			1	1
Grand Total	146	222	343	711

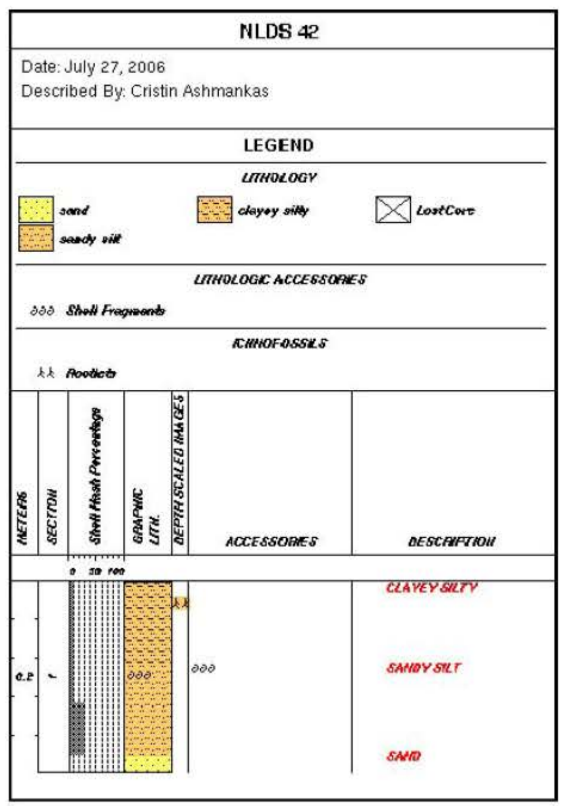
APPENDIX D

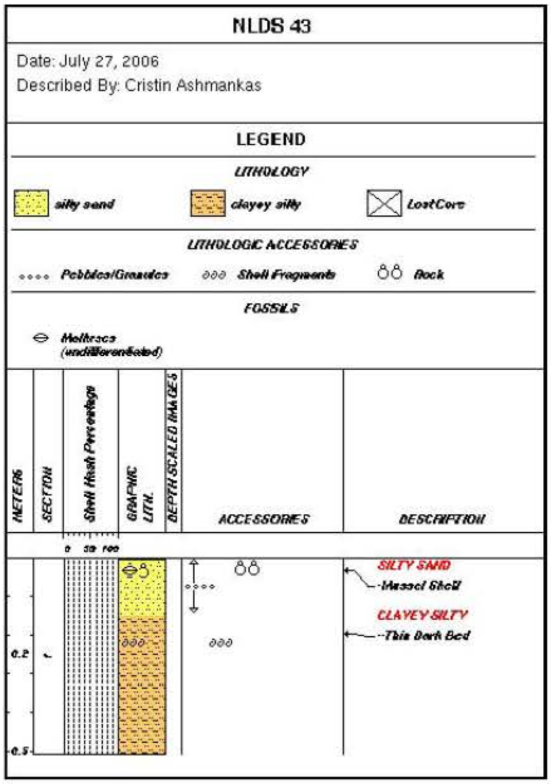
CORING SURVEY RESULTS

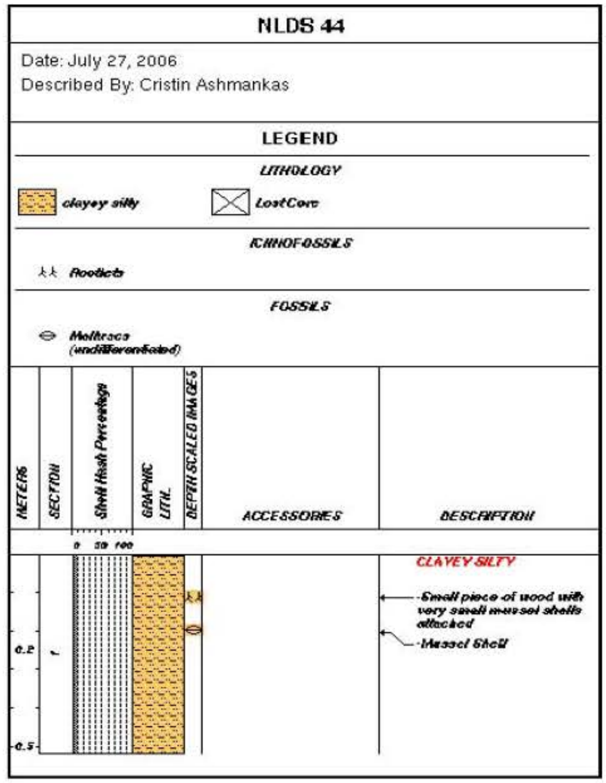

NLDS 40
Date: July 27, 2006
Described By: Cristin Ashmankas
LEGEND
LITHOLOGY
sandy silt
clayey silty
Lost Core
LITHOLOGIC ACCESSORIES
Shell Fragments
METERS
SECTION
Shell Hash Percentage
GRAPHIC LITH.
DEPTH SCALED IMAGES
ACCESSORIES
DESCRIPTION
0 50 100
CLAYEY SILTY
Large clam "quohog" shell whole
SANDY SILT
0.2
0.5

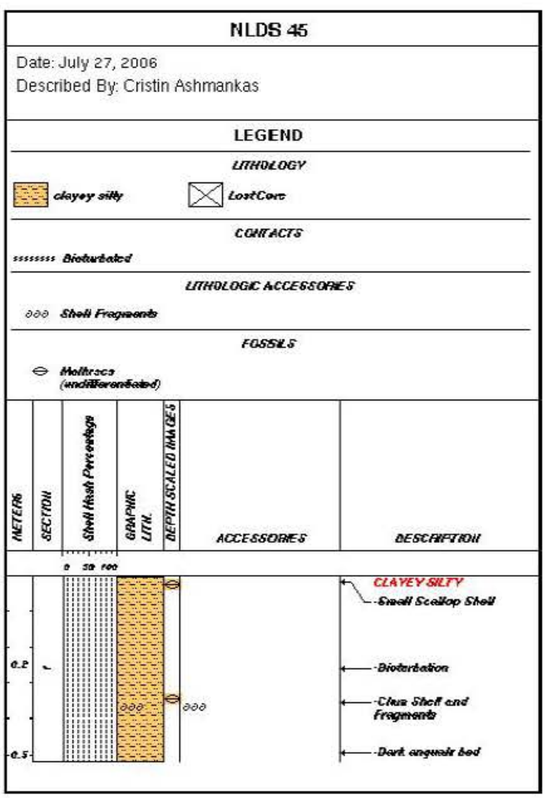

NLDS 41
Date: July 27, 2006
Described By: Cristin Ashmankas
LEGEND
LITHOLOGY
clayey silty
Lost Core
PHYSICAL STRUCTURES
Wavy Parallel Bedding
LITHOLOGIC ACCESSORIES
Shell Fragments
FOSSILS
Mollusca (undifferentiated)
Polychaetes
METERS
SECTION
Shell Hash Percentage
GRAPHIC LITH.
DEPTH SCALED IMAGES
ACCESSORIES
DESCRIPTION
0 50 100
CLAYEY SILTY
0.2
0.5

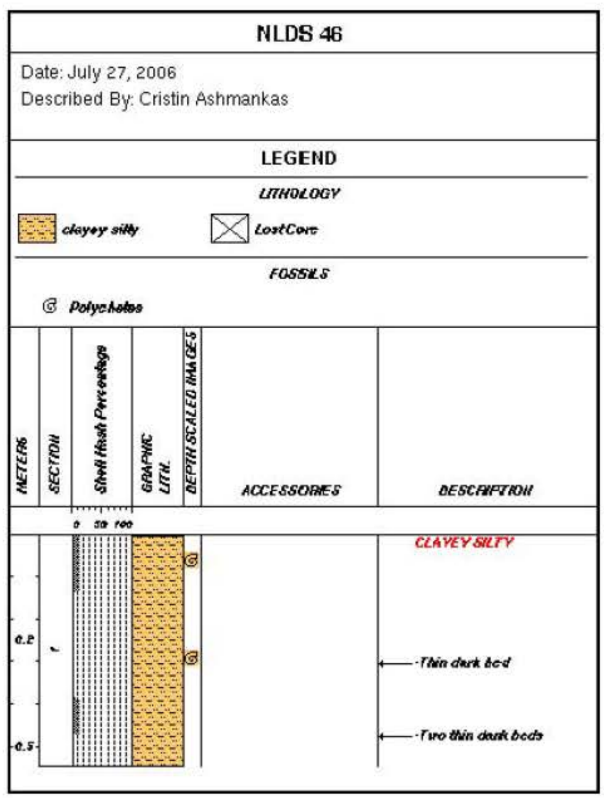

NLDS 41 DUP
Date: July 27, 2006
Described By: Cristin Ashmankas
LEGEND
LITHOLOGY
clayey silty
Lost Core
LITHOLOGIC ACCESSORIES
Shell Fragments
ICHNOFOSSILS
Rootlets
FOSSILS
Mollusca (undifferentiated)
METERS
SECTION
Shell Hash Percentage
GRAPHIC LITH.
DEPTH SCALED IMAGES
ACCESSORIES
DESCRIPTION
0 50 100
CLAYEY SILTY
0.2
0.5

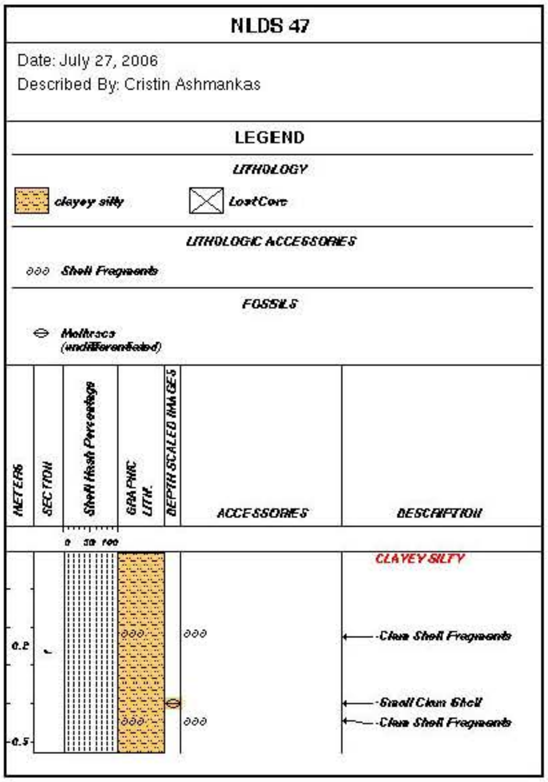

NLDS 42
Date: July 27, 2006
Described By: Cristin Ashmankas
LEGEND
LITHOLOGY
sand
clayey silty
Lost Core
sandy silt
LITHOLOGIC ACCESSORIES
Shell Fragments
ICHNOFOSSILS
Rootlets
METERS
SECTION
Shell Hash Percentage
GRAPHIC LITH.
DEPTH SCALED IMAGES
ACCESSORIES
DESCRIPTION
0 50 100
CLAYEY SILTY
SANDY SILT
SAND
0.2

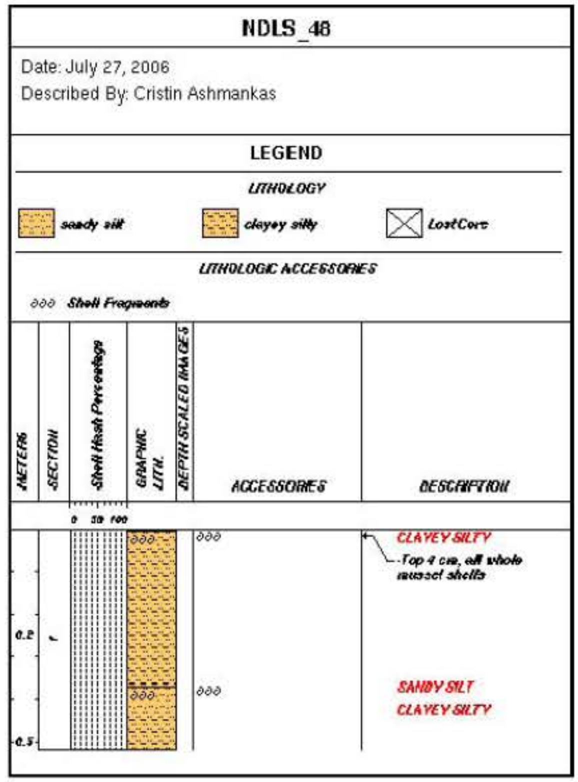

NLDS 43
Date: July 27, 2006
Described By: Cristin Ashmankas
LEGEND
LITHOLOGY
silty sand
clayey silty
LostCore
LITHOLOGIC ACCESSORIES
Pebbles/Granules
Shell Fragments
Rock
FOSSILS
Mollusca (undifferentiated)
METERS
SECTION
Shell Hash Percentage
GRAPHIC LITH.
DEPTH SCALED IMAGES
ACCESSORIES
DESCRIPTION
0 50 100
SILTY SAND
-Mussel Shell
CLAYEY SILTY
-Thin Dark Bed
0.2
0.5

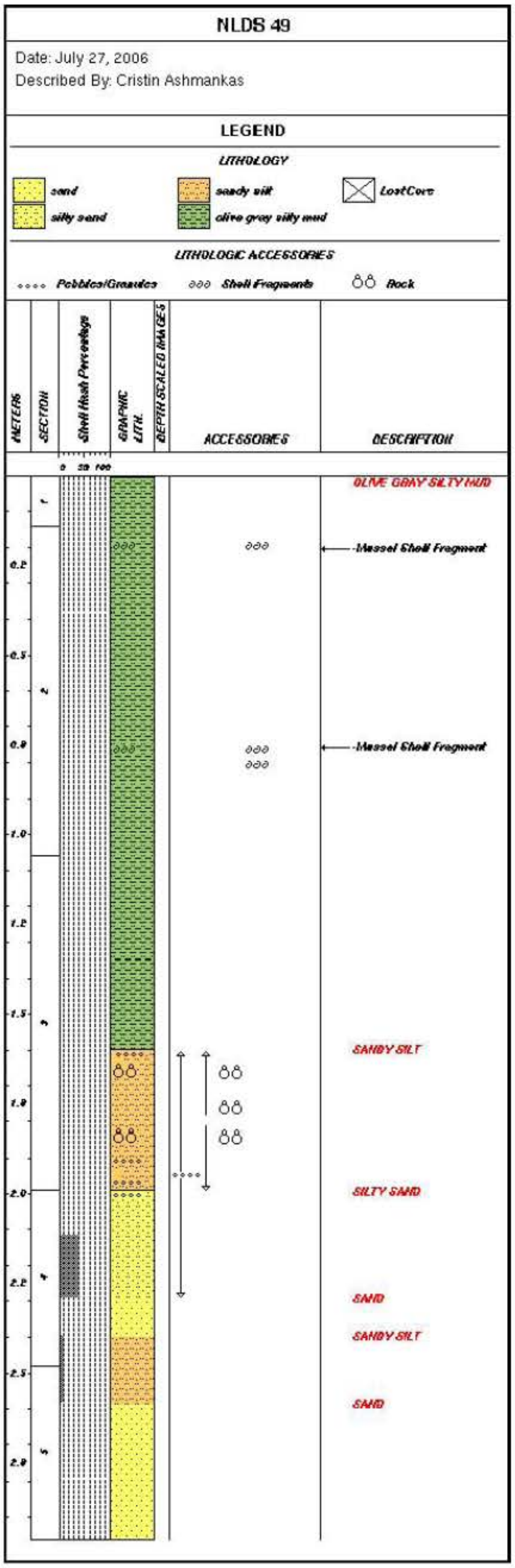

NLDS 44
Date: July 27, 2006
Described By: Cristin Ashmankas
LEGEND
LITHOLOGY
clayey silty
LostCore
ICHNOFOSSILS
Rootlets
FOSSILS
Mollusca (undifferentiated)
METERS
SECTION
Shell Hash Percentage
GRAPHIC LITH.
DEPTH SCALED IMAGES
ACCESSORIES
DESCRIPTION
0 50 100
CLAYEY SILTY
-Small piece of wood with very small mussel shells attached
-Mussel Shell
0.2
0.5

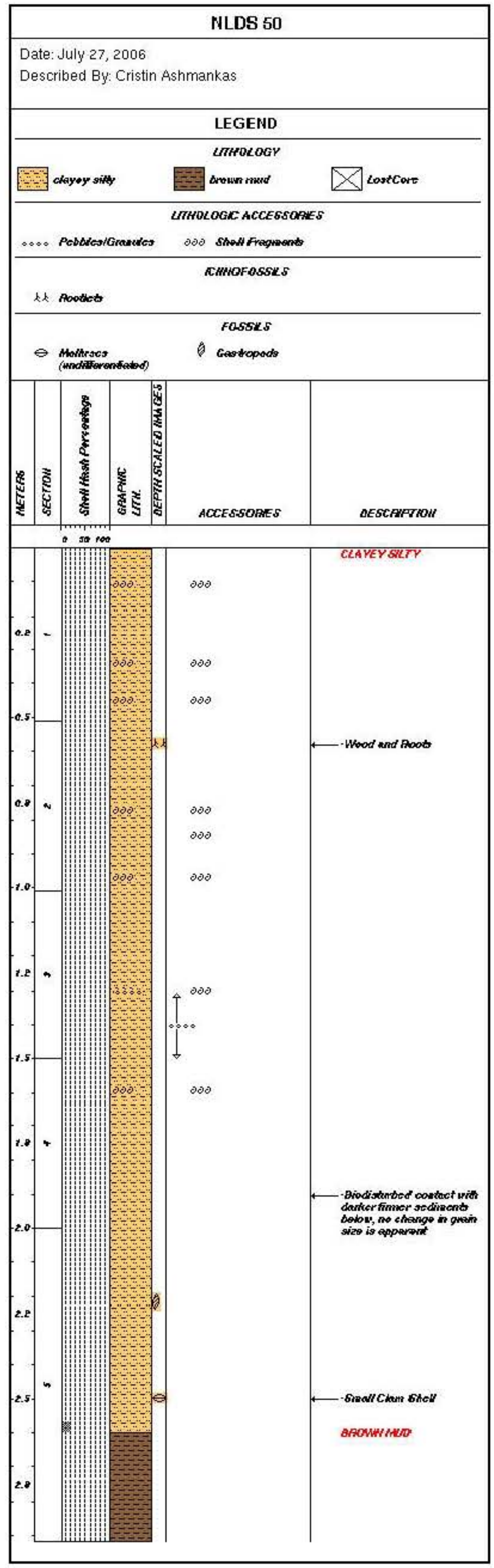

NLDS 45
Date: July 27, 2006
Described By: Cristin Ashmankas
LEGEND
LITHOLOGY
clayey silty
LostCore
CONTACTS
Bioturbated
LITHOLOGIC ACCESSORIES
Shell Fragments
FOSSILS
Mollusca (undifferentiated)
METERS
SECTION
Shell Hash Percentage
GRAPHIC LITH.
DEPTH SCALED IMAGES
ACCESSORIES
DESCRIPTION
0 50 100
CLAYEY SILTY
-Small Scallop Shell
-Bioturbation
-Clam Shell and Fragments
-Dark angular bed
0.2
0.5

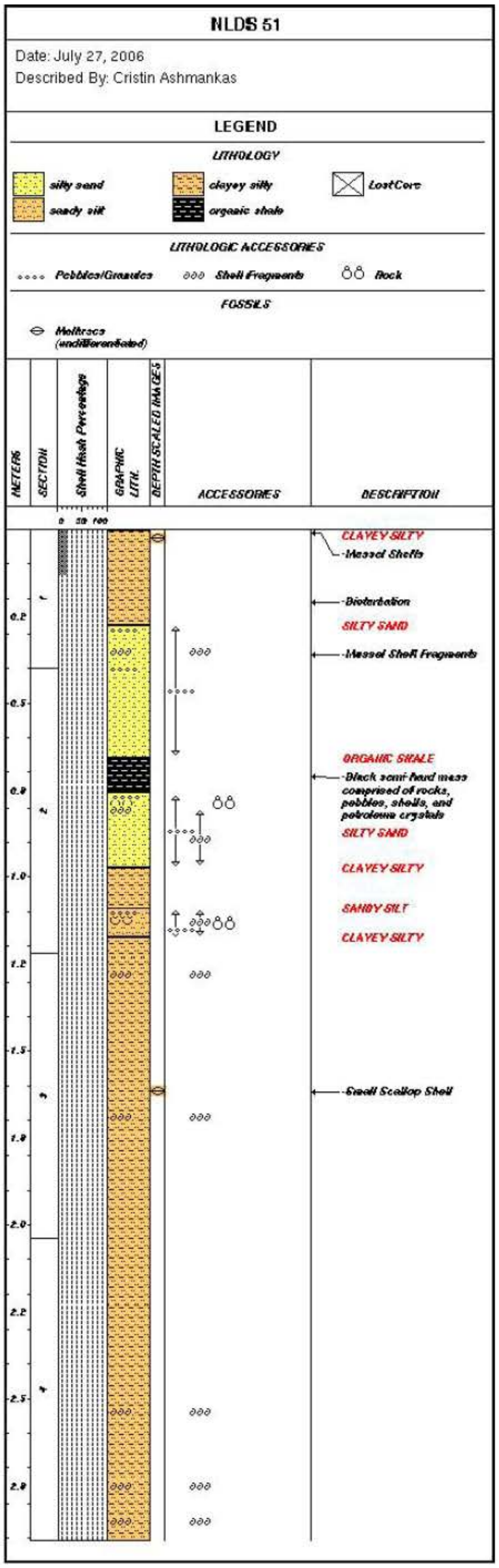

NLDS 46
Date: July 27, 2006
Described By: Cristin Ashmankas
LEGEND
LITHOLOGY
clayey silty
LostCore
FOSSILS
Polychaetes
METERS
SECTION
Shell Hash Percentage
GRAPHIC LITH.
DEPTH SCALED IMAGES
ACCESSORIES
DESCRIPTION
0 50 100
CLAYEY SILTY
-Thin dark bed
-Two thin dark beds
0.2
0.5

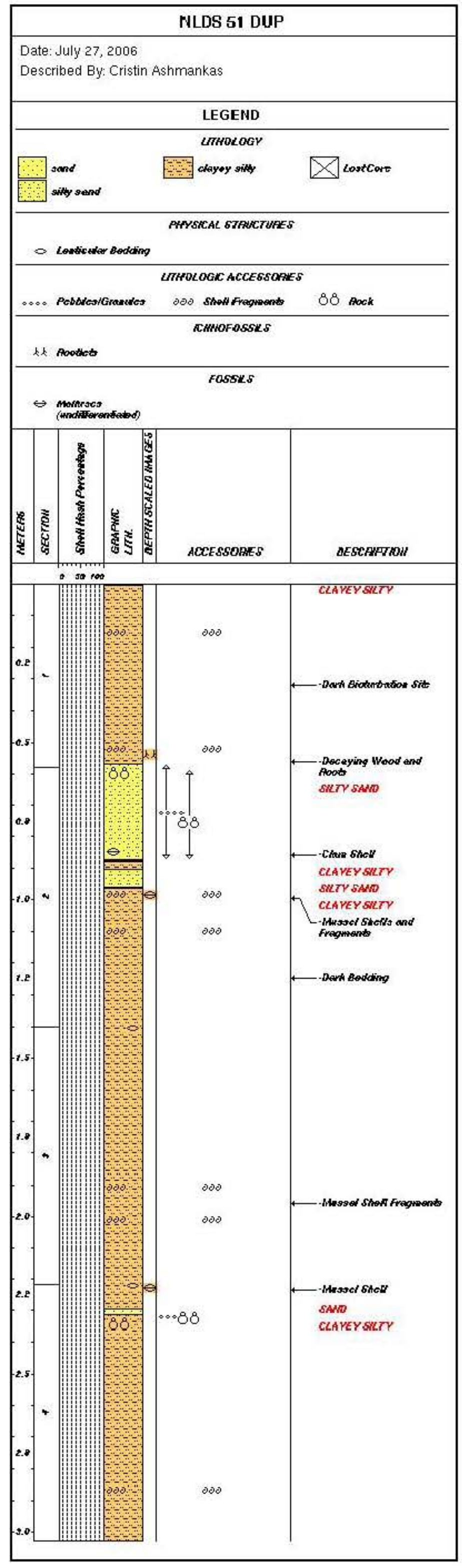

NLDS 47
Date: July 27, 2006
Described By: Cristin Ashmankas
LEGEND
LITHOLOGY
clayey silty
LostCore
LITHOLOGIC ACCESSORIES
Shell Fragments
FOSSILS
Mollusca (undifferentiated)
METERS
SECTION
Shell Hash Percentage
GRAPHIC LITH.
DEPTH SCALED IMAGES
ACCESSORIES
DESCRIPTION
0 50 100
CLAYEY SILTY
0.2
-Clam Shell Fragments
-Small Clam Shell
-Clam Shell Fragments
0.5

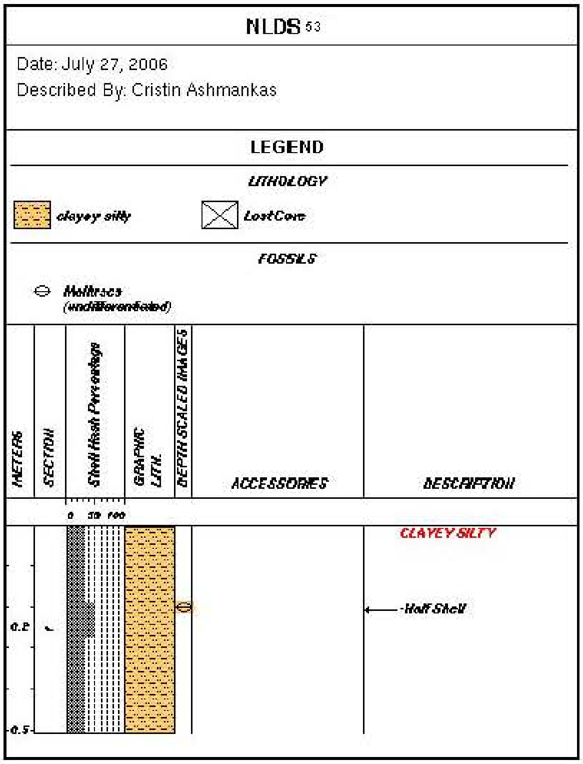

NDLS_48
Date: July 27, 2006
Described By: Cristin Ashmankas
LEGEND
LITHOLOGY
sandy silt
clayey silty
LostCore
LITHOLOGIC ACCESSORIES
Shell Fragments
METERS
SECTION
Shell Hash Percentage
GRAPHIC LITH.
DEPTH SCALED IMAGES
ACCESSORIES
DESCRIPTION
0 50 100
CLAYEY SILTY
-Top 4 cm, all whole mussel shells
0.2
SANDY SILT
CLAYEY SILTY
0.5


NLDS 49
Date: July 27, 2006
Described By: Cristin Ashmankas
LEGEND
LITHOLOGY
sand
silty sand
sandy silt
olive gray silty mud
Lost Core
LITHOLOGIC ACCESSORIES
Pebbles/Granules
Shell Fragments
Rock
METERS
SECTION
Shell Hash Percentage
GRAPHIC LITH.
DEPTH SCALED IMAGES
ACCESSORIES
DESCRIPTION
0 50 100
OLIVE GRAY SILTY MUD
Mussel Shell Fragment
Mussel Shell Fragment
SANDY SILT
SILTY SAND
SAND
SANDY SILT
SAND


NLDS 50
Date: July 27, 2006
Described By: Cristin Ashmankas
LEGEND
LITHOLOGY
clayey silty
brown mud
Lost Core
LITHOLOGIC ACCESSORIES
Pebbles/Granules
Shell Fragments
ICHNOFOSSILS
Rootlets
FOSSILS
Mollusca (undifferentiated)
Gastropods
METERS
SECTION
Shell Hash Percentage
GRAPHIC LITH.
DEPTH SCALED IMAGES
ACCESSORIES
DESCRIPTION
0 50 100
CLAYEY SILTY
Wood and Roots
Biodisturbed contact with darker firmer sediments below, no change in grain size is apparent
Small Clam Shell
BROWN MUD


NLDS 51
Date: July 27, 2006
Described By: Cristin Ashmankas
LEGEND
LITHOLOGY
silty sand
sandy silt
clayey silty
organic shale
LostCore
LITHOLOGIC ACCESSORIES
Pebbles/Granules
Shell Fragments
Rock
FOSSILS
Mollusca (undifferentiated)
METERS
SECTION
Shell Hash Percentage
GRAPHIC LITH.
DEPTH SCALED IMAGES
ACCESSORIES
DESCRIPTION
CLAYEY SILTY
-Mussel Shells
-Bioturbation
SILTY SAND
-Mussel Shell Fragments
ORGANIC SHALE
-Black semi-hard mass comprised of rocks, pebbles, shells, and petroleum crystals
SILTY SAND
CLAYEY SILTY
SANDY SILT
CLAYEY SILTY
-Small Scallop Shell


NLDS 51 DUP
Date: July 27, 2006
Described By: Cristin Ashmankas
LEGEND
LITHOLOGY
sand
silty sand
clayey silty
LostCore
PHYSICAL STRUCTURES
Lenticular Bedding
LITHOLOGIC ACCESSORIES
Pebbles/Granules
Shell Fragments
Rock
ICHNOFOSSILS
Rootlets
FOSSILS
Mollusca (undifferentiated)
METERS
SECTION
Shell Hash Percentage
GRAPHIC LITH.
DEPTH SCALED IMAGES
ACCESSORIES
DESCRIPTION
CLAYEY SILTY
-Dark Bioturbation Silt
-Decaying Wood and Roots
SILTY SAND
-Clam Shell
CLAYEY SILTY
SILTY SAND
CLAYEY SILTY
-Mussel Shells and Fragments
-Dark Bedding
-Mussel Shell Fragments
-Mussel Shell
SAND
CLAYEY SILTY


NLDS 53
Date: July 27, 2006
Described By: Cristin Ashmankas
LEGEND
LITHOLOGY
clayey silty
Lost Core
FOSSILS
Mollusca
(undifferentiated)
METERS
SECTION
Shell Hash Percentage
GRAPHIC LITH.
DEPTH SCALED IMAGES
ACCESSORIES
DESCRIPTION
0 50 100
CLAYEY SILTY
Half Shell
0.2
0.5