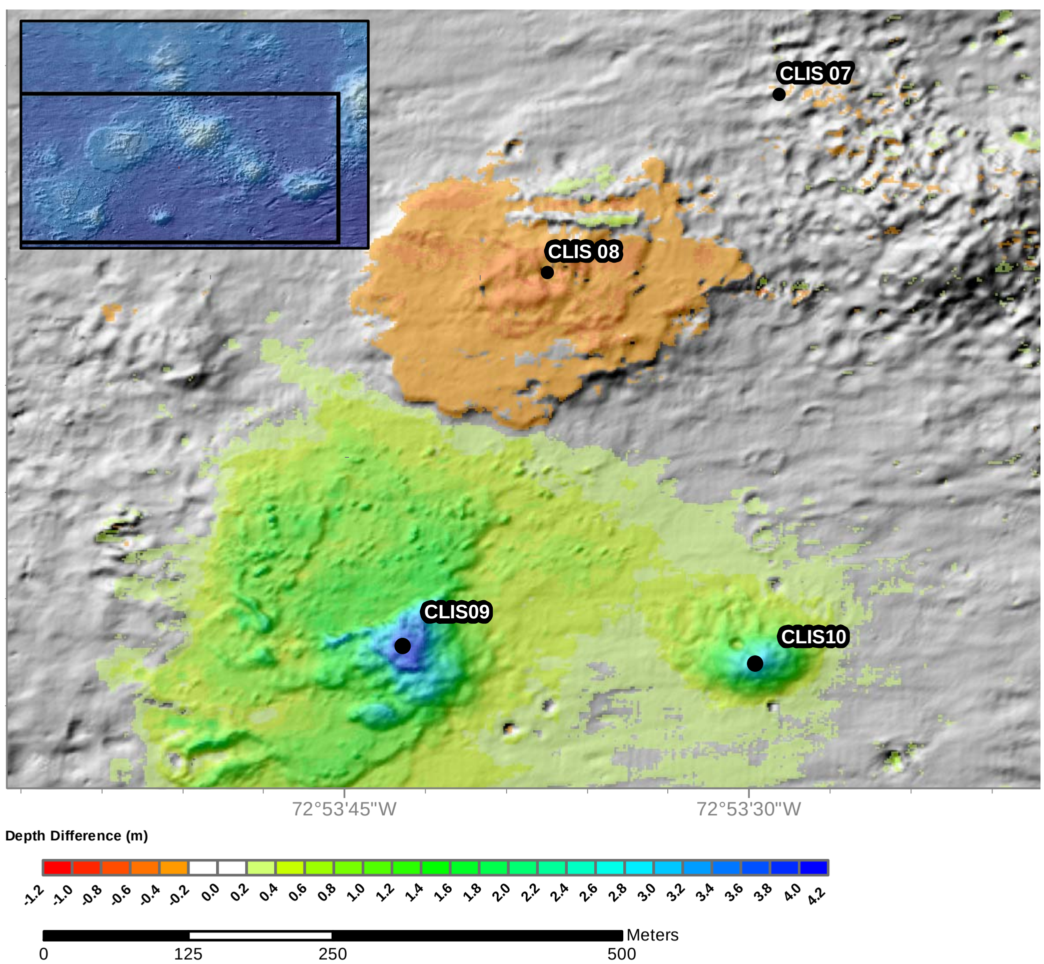
Monitoring Survey at the Central Long Island Sound Disposal Site
September and October 2011

Disposal Area Monitoring System DAMOS

DAMOS
DISPOSAL AREA MONITORING SYSTEM



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AECOM, Germano & Associates, CR Environmental, Inc., CoastalVision

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AECOM
250 Apollo Drive
Chelmsford, MA 01824

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13. ABSTRACT
A monitoring survey was conducted in September and October of 2011 at the Central Long Island Sound Disposal Site (CLDS) as part of the Disposal Area Monitoring System (DAMOS) Program. The 2011 monitoring effort involved a September multibeam bathymetric survey to document changes in seafloor topography and an October sediment-profile imaging (SPI) survey to assess the benthic recolonization status. These surveys were conducted with multiple objectives and covered two separate areas within CLDS: an area in the southwest portion of CLDS, where dredged material disposal activities were concentrated over the period from 2005 to 2011, and an area in the extreme northeast portion of CLDS at a disposal mound created nearly 20 years prior.

The multibeam bathymetric survey revealed that two discrete mounds of dredged material had been created on the seafloor since the previous multibeam bathymetric survey of September 2009. The mounds were labeled by disposal season, as follows: CLIS 09 (2008–09 disposal season) and CLIS 10 (2009–10 disposal season). The size of each mound was generally proportional to the volume of dredged material placed during each season. Depth difference calculations and analysis of side-scan sonar and backscatter results were used to assess the distribution of dredged material and stability of disposal mounds. The new disposal mounds accumulated dredged material and the CLIS 08 mound consolidated. The surfaces of CLIS 08 and NHAV 74 appear to have received fresh dredged material which is apparent in all of the acoustic results. Apart from the presence of the new material, all of the mounds surveyed at CLDS have been stable since 2009.

The 2011 monitoring effort also included a SPI survey to assess the benthic recolonization status of the three mounds created during the 2007–2010 disposal seasons. Two mounds (CLIS 07 and CLIS 09) were characterized by relatively well-developed aRPD depths and an advanced, Stage 3 successional status, comparable to the Stage 3 conditions observed at the three nearby reference areas. In contrast, one mound (CLIS 08) was in an intermediate successional status. Despite the presence of transitional successional stages, the mean aRPD and successional stage values at CLIS 08 were already significantly similar to reference area values.

The 2011 monitoring survey also included multibeam and SPI surveys of the historical Field Verification Program (FVP) mound in the northeastern corner of CLDS. The surface of the FVP mound was stable and had no evidence of sediment transport beyond the several centimeters of fine sand detected in the SPI survey. The SPI results confirmed that the sediments on the surface of the FVP mound were in an advanced stage of benthic succession and significantly similar to reference area conditions. At least one deposit of fresh dredged material appeared to have been placed on the southern margin of the FVP mound since 2005.

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New England District
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696 Virginia Road
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Prepared by:
AECOM, CoastalVision, Germano & Associates, and
CR Environmental, Inc.

Submitted by:
AECOM
250 Apollo Drive
Chelmsford, MA 01824
(978) 905-2100

US Army Corps
of Engineers®
New England District

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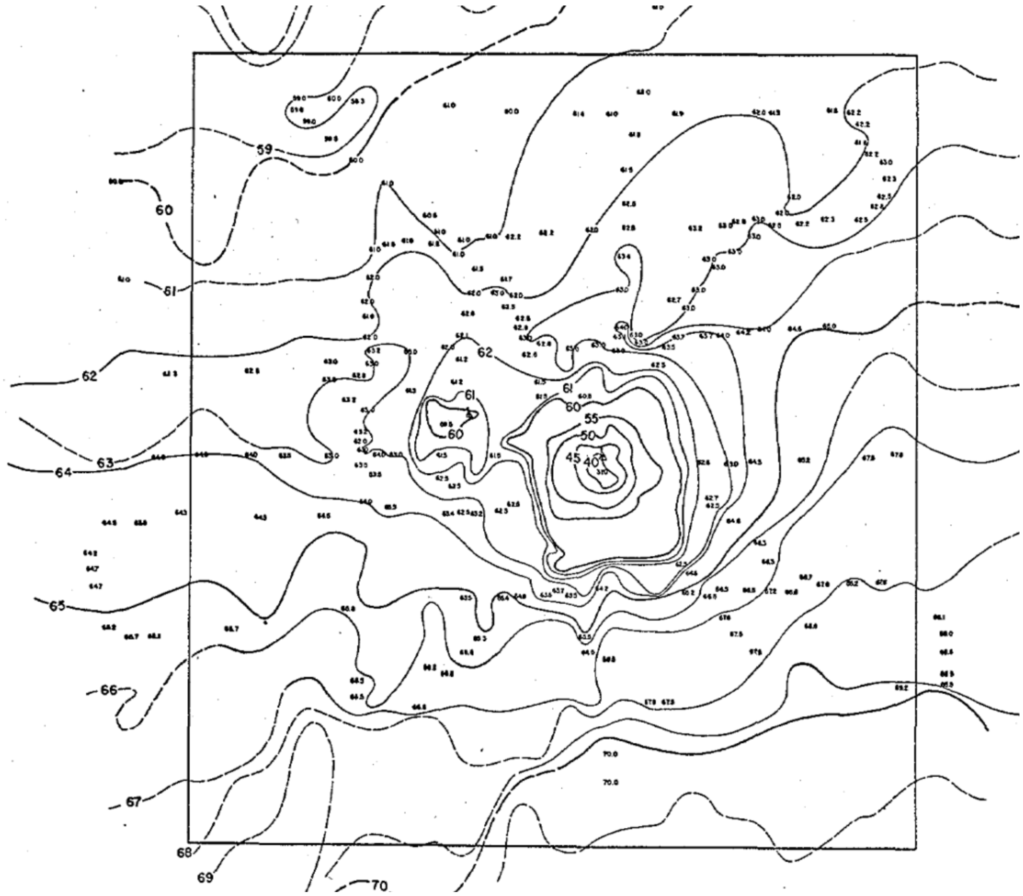

Bathymetric contour map of the first precision navigation point-dumping mound formed at CLDS, March 1974.

From Bokuniewicz et al. 1975 (SR-8).

The dredging and disposal of material from New Haven Harbor in 1973-74 at the old New Haven Disposal Site (now part of CLDS) was the first project in Long Island Sound to be closely monitored with scientific protocols. Many of the methods and findings in this landmark series of studies, conducted by Robert Gordon, Donald Rhoads, Henry Bokuniewicz and Josephine Yingst of the Yale School of Geology and Geophysics, established the approach later adopted by the DAMOS Program. This conical mound is now known as NHAV 74.

Note on units of this report: As a scientific contribution, information and data are presented in the metric system. However, given the prevalence of English units in the dredging industry of the United States, conversions to English units are provided for the general information in Section 1. A table of common conversions can be found in Appendix D.

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EXECUTIVE SUMMARY

A monitoring survey was conducted in September and October of 2011 at the Central Long Island Sound Disposal Site (CLDS) as part of the Disposal Area Monitoring System (DAMOS) Program. The 2011 monitoring effort involved a September multibeam bathymetric survey to document changes in seafloor topography and an October sediment-profile imaging (SPI) survey to assess the benthic recolonization status. These surveys were conducted with multiple objectives and covered two separate areas within CLDS: an area in the southwest portion of CLDS, where dredged material disposal activities were concentrated over the period from 2005 to 2011, and an area in the extreme northeast portion of CLDS at a disposal mound created nearly 20 years prior.

The multibeam bathymetric survey, performed as a standard confirmatory survey as part of the 2011 monitoring at CLDS in the southwestern portion of the site, revealed that two discrete mounds of dredged material had been created on the seafloor since the previous multibeam bathymetric survey of September 2009. The mounds were labeled by disposal season, as follows: CLIS 09 (2008–09 disposal season) and CLIS 10 (2009–10 disposal season). The size of each mound was generally proportional to the volume of dredged material placed during each season. The new mounds (CLIS 09 and CLIS 10) represent additions of dredged material to an existing line of mounds that are coalescing into a berm on the seafloor. The berm represents the wall of a large confined aquatic disposal (CAD) cell intentionally being created in this part of the disposal site, in accordance with DAMOS management objectives.

Depth difference calculations and analysis of side-scan sonar and backscatter results were used to assess the distribution of dredged material and stability of disposal mounds. Unlike the sediment distribution in 2009, the grain size of dredged material placed recently at CLDS appeared relatively uniform. The new disposal mounds accumulated dredged material and the CLIS 08 mound consolidated. The surfaces of CLIS 08 and NHAV 74 appear to have received fresh dredged material which is apparent in all of the acoustic results. Apart from the presence of the new material, all of the mounds surveyed at CLDS have been stable since 2009.

The 2011 monitoring effort also included a SPI survey to assess the benthic recolonization status of the three mounds created during the 2007 through 2010 disposal seasons. Two mounds (CLIS 07 and CLIS 09) were characterized by relatively well-developed aRPD depths and an advanced, Stage 3 successional status, comparable to the Stage 3 conditions observed at the three nearby reference areas.

In contrast, one mound (CLIS 08) was in an intermediate successional status, as evidenced by both high variability among replicate images and the widespread presence of transitional “Stage 1 going to 2” and “Stage 2 going to 3” successional series. As

succession proceeds over time at this mound, it will converge both with reference conditions and with conditions observed at the two other mounds. Despite the presence of transitional successional stages, the mean aRPD and successional stage values at CLIS 08 were already significantly similar to reference area values.

The 2011 monitoring survey also included multibeam and SPI surveys of the historical Field Verification Program (FVP) mound in the northeastern corner of CLDS. The surface of the FVP mound was stable and had no evidence of sediment transport beyond the several centimeters of fine sand detected in the SPI survey. The SPI results confirmed that the sediments on the surface of the FVP mound were in an advanced stage of benthic succession and significantly similar to reference area conditions. At least one deposit of fresh dredged material appeared to have been placed on the southern margin of the FVP mound since 2005.

1.0 INTRODUCTION

A monitoring survey was conducted at the Central Long Island Sound Disposal Site (CLDS) as part of the U.S. Army Corps of Engineers (USACE) New England District (NAE) Disposal Area Monitoring System (DAMOS). DAMOS is a comprehensive monitoring and management program designed and conducted to address environmental concerns associated with use of aquatic disposal sites throughout the New England region. An introduction to the DAMOS Program and CLDS, including a brief description of previous dredged material disposal activities and previous monitoring surveys, is provided below.

1.1 Overview of the DAMOS Program

The DAMOS Program features a tiered management protocol designed to ensure that any potential adverse environmental impacts associated with dredged material disposal are promptly identified and addressed (Germano et al. 1994). For over 35 years, the DAMOS Program has collected and evaluated disposal site data throughout New England. Based on these data, patterns of physical, chemical, and biological responses of seafloor environments to dredged material disposal activity have been documented (Fredette and French 2004).

DAMOS monitoring surveys fall into two general categories: confirmatory studies and focused studies. Confirmatory studies are designed to test hypotheses related to expected physical and ecological response patterns following placement of dredged material on the seafloor at established, active disposal sites. The data collected and evaluated during these studies provide answers to strategic management 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 and contribute to the development of dredged material placement and capping techniques. The 2011 CLDS investigation involved elements of both types of studies - confirmatory monitoring of an area in the south-central portion of CLDS that has actively received dredged material and a focused study of the inactive Field Verification Program (FVP) mound in the northeast corner of the site.

Two primary goals of DAMOS confirmatory monitoring surveys are to document the physical location and stability of dredged material placed into the aquatic environment and to evaluate the biological recovery of the benthic community following placement of the dredged material. Several survey techniques are employed in order to characterize these responses to dredged material placement. Sequential bathymetric measurements are made to characterize the height and spread of discrete dredged material deposits or mounds created at open water sites as well as the accumulation/consolidation of dredged material into confined aquatic disposal (CAD) cells. Sediment-profile imaging (SPI) surveys are performed to provide further physical characterization of the material and to support evaluation of seafloor (benthic) habitat conditions and recovery over time. Each type of data collection activity is conducted periodically at disposal sites, and the conditions found after a defined period of disposal activity are compared with the long-term data set at a specific site to determine the next step in the disposal site management process (Germano et al. 1994). Focused DAMOS monitoring surveys may also feature additional types of data collection activities, such as plan-view underwater camera (PUC) photography, side-scan sonar, towed video, sediment coring, or grab sampling, as deemed appropriate to achieve specific survey objectives.

1.2 Introduction to the Central Long Island Sound Disposal Site

The Central Long Island Sound Disposal Site (CLDS, also historically referred to as CLIS) is located approximately 10.4 km (5.62 nm) south of South End Point, East Haven, Connecticut (Figure 1-1). This general location has been utilized for the disposal of sediments dredged from surrounding harbors for at least 60 years, with well-documented disposal locations since 1973 (ENSR 1998). Starting in 1979, the site has been regularly monitored by the DAMOS Program (ENSR 1998). The U.S. Environmental Protection Agency's (USEPA) most recent designation of the site in 2005 resulted in a slight enlargement of its previous dimensions (USEPA 2004a, 2005). Specifically, the boundary of CLDS was extended northward and eastward to encompass the historical disposal mounds CS-2 and FVP (ENSR 2007). The current boundary of CLDS is a rectangle measuring 4.1 x 2.0 km (total area of 8.2 km2) (2.2 x 1.1 nm [total area of 2.4 nm2]), centered at 41° 08.95' N and 72° 52.95' W (NAD 83) (Figure 1-1).

A comprehensive multibeam bathymetric survey of the entire site conducted in July 2005 showed that the seafloor landscape within the CLDS boundary is characterized by multiple mounds of accumulated dredged material and disposal traces resulting from both historical and more recent placement activities. The seafloor within the boundary of CLDS gently slopes from a depth of 18 m (59 ft) mean lower low water (MLLW) in the northwest to a depth of 22 m (72 ft) (MLLW) in the southeast (Figure 1-2). The placement of dredged material has created localized areas with shallower depths ranging from 14 to 17 m (46 to 56 ft) MLLW.

The early management strategy at CLDS involved the directed placement of small to moderate volumes of sediment to form individual disposal mounds which were spaced relatively far apart within the site boundary (see mounds labeled by name in Figure 1-2). These distinct mounds were then monitored over time to assess stability, thickness of dredged material, and benthic recolonization status relative to previous monitoring results and in comparison to nearby reference areas (Table 1-2).

Since the early 1990s, a modified management strategy has been employed at CLDS, whereby the dredged material is placed in a series of closely spaced or contiguous mounds, with the goal of eventually creating a circular or semicircular berm on the seafloor. The area inside the berm forms a containment cell that could be used for large-scale confined aquatic disposal (CAD) operations. In general, such containment cells would aid in the placement of highly fluid dredged material or material judged to require additional management. Once placed within the confines of the containment cell, the potential for lateral spread of the material is reduced, and it could be covered with additional dredged material as part of long-term management of the site (Fredette 1994). The first containment cell developed at CLDS was used to confine the New Haven 1993 (NHAV 93) mound; a second containment cell was completed in 1999 (Figure 1-4 in Valente et al. 2012). Additional containment cells are currently being developed for future use in the south central portion of the site (Figure 1-2).

Several experimental capping projects were also conducted in the waters of CLDS in the late 1970s and the early 1980s to determine the feasibility and effectiveness of using level-bottom capping to isolate sediment with elevated contaminant or toxicity levels from the marine environment. Seven mounds were formed during this period. Six of the mounds (Norwalk, STNH-N, STNH-S, MQR, CS-1 and CS-2) were capped with coarse- and/or fine-grained material acceptable for unconfined open water placement, the eighth mound, FVP, was left uncapped (Figure 1-2).

The FVP mound was created in the northeast corner of CLDS during the 1982–83 disposal season as part of the joint USEPA/USACE Interagency Field Verification of Testing and Predictive Methodologies for Dredged Material Disposal Alternatives Program, known simply as the Field Verification Program (FVP). The program ran from 1982 to 1988, and its objective was to field-verify existing test methods for predicting the environmental consequences of dredged material disposal under aquatic, wetland, and upland conditions (Peddicord 1988). FVP served as the unconfined open-water placement mound for the program.

The FVP mound was created from the placement of 55,000 m3 (72,000 yd3) of material unsuitable for open water placement dredged from Black Rock Harbor in Bridgeport, CT. The sediment dredged from Black Rock Harbor consisted of black, fine-grained silts and clays with high water content and elevated concentrations of metal and organic contaminants (Scott et al. 1987). Sediment samples collected in Black Rock

Harbor in 1983 showed elevated concentrations of polynuclear aromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs), and several metals including chromium and copper (Myre and Germano 2007). Exposure to the Black Rock Harbor sediments resulted in both chronic and acute effects in several test species, as well as PAH and PCB bioaccumulation (Myre and Germano 2007).

The underlying assumption of the Field Verification Program was that if adverse effects were to be seen from placing sediment with elevated contaminant concentrations on the seafloor, they should occur on this particular mound. A baseline (pre-disposal) survey was conducted in 1982 and additional surveys were conducted as part of the FVP program, with subsequent monitoring conducted under the DAMOS Program, throughout the 1980s and 1990s to evaluate the ecosystem recovery and long-term trends in benthic recolonization on the mound. A series of post-disposal bathymetric surveys showed the formation of a small deposit approximately 200 x 100 m (980 x 330 ft) with a height of 1.8 m (5.9 ft) (Morton et al 1984). The mound has shown a wide range of benthic community responses during monitoring, from an initial classic primary successional recovery (Scott et al. 1987) to episodes of retrograde succession following extreme environmental conditions (i.e. storm events, excessive algal blooms, and hypoxia) experienced in Long Island Sound (Parker and Revelas 1988; Morris 1997). Because the mound was established as an experimental project that verified many of the testing protocols still in use, the continued existence of the uncapped mound and infrequent monitoring has value to the national dredged material management program.

1.3 Previous Surveys at CLDS

As noted above, dredged material placement in the vicinity of CLDS has been regularly monitored since 1979 as part of the DAMOS Program, with monitoring focusing on active disposal mounds or longer term study of sites such as FVP. Recent monitoring of disposal activity in the south-central portion of CLDS was conducted in July 2005 and October 2009 (Valente et al. 2012; ENSR 2007). The historic FVP mound has been surveyed extensively since its creation in 1982 (Table 1-1) and was last surveyed in 2005 (Myre and Germano 2007).

2005 CLDS Baseline Bathymetry

The July 2005 multibeam bathymetric survey was designed to establish a detailed, site-wide, high-resolution baseline bathymetric dataset against which future bathymetric surveys could be compared (ENSR 2007). This high-resolution dataset served to define the location, spatial extent, and long-term stability of mounds and other seafloor feature associated with past disposal activities based on the most recent designation boundaries of the site by USEPA (USEPA 2004a, 2005).

Twenty-seven historic disposal mounds were observed during the 2005 survey (Figure 1-2), the product of over 60 years of dredged material disposal at CLDS. The central and western sections of CLDS were marked with irregular, roughly circular mounds of varying shapes and heights. The eastern section of CLDS, including the area around the FVP mound, consisted of a relatively smooth slope marked by small pits and longitudinal furrows (Figure 3-3 in ENSR 2007). The northwest margin of the disposal site was relatively flat, but marked by numerous circular, ring-shaped deposits ranging in size from 10 to 25 m (ENSR 2007).

2009 CLDS Monitoring Survey

The most recent monitoring effort at CLDS was a standard confirmatory survey including a multibeam bathymetric survey conducted in September 2009 and a SPI survey conducted in October 2009 (Valente et al. 2012). These surveys were conducted over a 1000 x 1500 m (3300 x 4900 ft) rectangular area in the south-central portion of CLDS, based on the disposal of approximately 539,000 m3 (705,000 yd3) of dredged material placed at four different disposal buoy locations between October 2005 and May 2009. The objectives of the 2009 survey were to characterize the seafloor topography and to assess the benthic recolonization status of the area where recent disposal activities occurred.

The disposal activity at CLDS from 2005 to 2009 resulted in the formation of four distinct dredged material mounds (CLIS 05, CLIS 06, CLIS 07, and CLIS 08) (Figure 1-4). The mounds varied widely in terms of their diameter and height, in a manner that was relatively proportional to the estimated volume of material placement during each season. Comparison of the 2009 data with 2005 and 1997 data confirmed that disposal traces (rings, craters, and pits) could be associated with specific disposal conditions (i.e. volume, grain size, or water content of the dredged material), and aided in further describing the area receiving the material. Benthic recolonization was determined to be consistent with expectations related to age of each mound. Average apparent Redox Potential Discontinuity (aRPD) depths were less at the two newer mounds (CLIS 07 and CLIS 08) compared to those at the two older mounds (CLIS 05 and CLIS 06) and at the reference areas. The two older mounds were also characterized by an advanced successional status consisting of deep dwelling Stage 3 organisms. In contrast, the two newer mounds were in an intermediate successional status, characterized by both high variability among replicate images and the widespread presence of transitional stages (Stage 1 to 2 and Stage 2 to 3) (Valente et al. 2012). These results were consistent with successional theory that different stages will appear sequentially over time after a disturbance (Rhoads and Germano 1982, 1986).

Based on the findings of the 2009 CLDS survey, it was recommended that periodic bathymetric and backscatter surveys be conducted to monitor the morphology and stability of historic mounds and the formation of future mounds with the placement of additional dredged material. In addition, it was recommended that benthic recolonization be monitored with SPI to track the expected continued biological recovery at CLIS 07 and CLIS 08 and to monitor biological conditions at future mounds.

FVP Monitoring

The FVP mound was last surveyed in June 2005, when cores were collected for chemical analysis and sediment-profile images were collected to characterize benthic community conditions. Contaminant concentrations in the June 2005 survey were low or below detection limits in reference samples, slightly higher in the FVP mound flank cores, and highest in the central mound cores in samples collected from >10 cm (4 in) below the sediment-water interface. The SPI survey results showed the widespread presence of Stage 3 fauna at the disposal mound, with benthic communities on both the mound apex and flanks functionally equivalent to reference areas. The sediments on the mound apex, however, were characterized by several distinguishing features: 1) persistence of the dredged material optical signature in the subsurface sediments; 2) relatively shallow aRPD depths; and 3) a relative lack of intense, bioturbational reworking of the sediments at depth. Overall, the sediments on the mound apex were found to be not as biogenically mixed as those found in the near-field surrounding flank (Myre and Germano 2007).

Based on the results from the 2005 survey, together with the extensive historical data from this mound, it was concluded that natural recovery of the historical flank sediments of the FVP mound had resulted in little biological and chemical difference relative to reference sediment. Both ambient sedimentation and bioturbation were cited as important processes fostering this recovery. However, observed burrowing into Black Rock Harbor material suggested that bioturbation may serve as a potential conduit for transport of contaminants to the surface, especially in the central mound area. Furthermore, the cumulative record of monitoring at FVP suggested that surface sediments at the center of the mound may have been periodically resuspended, catalyzing occasional retrograde biological succession (Myre and Germano 2007).

Recommendations resulting from the 2005 FVP survey included the collection of high-resolution acoustic imaging data, in combination with point location SPI images, to help elucidate overall topography and near-bottom sediment processes (physical and biological) on and around the FVP mound. Sequential high resolution acoustic surveys were also recommended based on the results of the 2005 baseline bathymetric survey (ENSR 2007) to document any shifts or changes in these bottom features that could potentially affect the disposal area.

1.4 Study Objectives

The 2011 survey of CLDS was designed as both a confirmatory bathymetric and SPI survey over a portion of CLDS actively receiving dredged material and a focused bathymetric and SPI survey over the older FVP mound. The 2011 confirmatory study was focused on the south-central portion of CLDS which has been actively receiving material from navigational and maintenance dredging projects being conducted along the Connecticut shoreline. Since the October 2009 survey, approximately 256,000 m3 (335,000 yd3) of dredged material has been placed at two separate disposal buoy locations within CLDS, continuing the effort to create a large containment cell (Figure 1-3 and Appendix A). Approximately 222,000 m3 (291,000 yd3) of material was placed at the CDA 09 disposal buoy between October 2009 and April 2010. An additional 34,000 m3 (44,000 yd3) of material was placed at the CDA 10 disposal buoy between November 2010 and February 2011. The dredged material primarily originated from the New London Navy Submarine Base during construction of an in-harbor Confined Aquatic Disposal (CAD) cell and was supplemented by other small maintenance and navigation projects along the Connecticut coast (Table 1-2).

Based on the findings of the 2009 CLDS survey, it was recommended that periodic bathymetric and backscatter surveys be conducted to monitor the morphology and stability of historic mounds and the formation of future mounds, and that benthic recolonization should be monitored with SPI at CLIS 07 and CLIS 08 and any future mounds.

Survey components of the confirmatory study were to:

- Conduct a bathymetric survey of the region of CLDS where disposal has taken place since 2009 to document the current topography and

- Conduct a SPI survey to further assess the benthic recolonization status of previously formed CLIS 07 and CLIS 08 mounds, as well as an initial assessment of the more recently formed CLIS 09 mound relative to reference and previous survey results.

Based on the recommendations resulting from the 2005 FVP survey and the 2005 baseline bathymetry survey, the 2011 FVP focused study was designed to further assess the topography and near-bottom sediment processes on and around the historic FVP mound, as well as the continued benthic recovery of the mound, in a continued assessment of the management strategy at the FVP mound.

Survey components of the FVP study were to:

- Conduct a bathymetric survey of the historic FVP mound to document mound topography, including changes in sedimentary furrows and historic craters, and stability relative to previous bathymetric surveys and

- Conduct a SPI survey to assess benthic recolonization status over the central portion of the FVP mound relative to reference areas and previous survey results.

The confirmatory and focused surveys at CLDS were conducted to support the Site Management and Monitoring Plan (USEPA 2004b).

Table 1-1.

DAMOS Monitoring Conducted at FVP Mound

Date	Survey Type	Bathymetry Area (meters) [feet]	No. SPI Stations (by area or mound)	Sediment Analysis	Additional Studies	Reference (DAMOS Contribution #)
1982	FVP Baseline	800x800 [2600x2600]	CLIS: 1 FVP: 51	Grain size	Sediment chemistry	23, 25
1983	FVP Pre-, interim, and post-disposal	800x800 [2600x2600]	FVP: 15	Grain size	Sediment chemistry, Mussel study, diver survey, water column, side-scan	25, 46
1984	FVP post-disposal	800x800 [2600x2600]	CS-1: 11 CS-2: 11 FVP: 92		Sediment chemistry. Side-scan	38, 46
1985	FVP pre- and post-storm monitoring	800x800 [2600x2600]	FVP: 21 CLIS-REF: 12			52
1986	Monitoring	700 x 700 [2300x2300]	FVP: 21 MQR: 17 STNH-N & S: 34 NOR: 17 NHAV74: 17 NHAV83: 17 CS 1 & 2: 17		Sediment chemistry, Benthic biology, Bioaccumulation	63
1987	Monitoring	1200x1200 [3900x3900]	CLIS: 120		CTD, DO, Sediment chemistry	68

Table 1-1 (continued)

Date	Survey Type	Bathymetry Area (meters)	No. SPI Stations	Sediment Analysis	Additional Studies	Reference (DAMOS contribution)
Jun-91	Monitoring	1200x1200 [3900x3900]	CLIS 90: 66 CS-90-1: 13 MQR: 13 NHAV-74: 13 CS-1: 13 FVP: 13 CLIS 88: 13 REF: 39	Grain Size, TOC, Metals, PAHs	CTD, DO, Sediment chemistry	97
Sep-95	Monitoring	NHAV93: 1600 x 1600 [5200x5200] CLIS 94: 1000 x 1000 [3300x3300]	NHAV93: 13 CLIS 94: 13 FVP: 13 REF: 13		Geotechnical coring	118
Sep-99	Monitoring	1000x1000 [3300x3300]	CLIS97/98 & CLIS95/96: 57 NHAV93: 5 FVP: 13 MQR: 13 REF: 13			139
Sep-00	Bathymetric Baseline	2100x4100 [6900x13000]				139
Jun-05	Monitoring		FVP: 20		Sediment cores	175

* Detailed data not available

Table 1-2.

Estimated Volume of Dredged Material Placed at CLDS from October 2009 to February 2011

Location/Permitee	Disposal Dates	Target Buoy Location	Volume (m^3)	Volume (yd^3)
Glen Cove Creek/ Brewer Yacht Yard	10/2009 - 12/2009	CDA 09	19,115	25,001
Housatonic River/ Caswell Cove Marina	10/2009	CDA 09	401	525
Dredging in Stamford Harbor/ Ponus Yacht Club	11/2009 - 11/2009	CDA 09	5,104	6,675
Harbor Woods Condo/ Harbor Woods Condo	11/2009 - 12/2009	CDA 09	2,518	3,293
New London Navy Sub Base	12/2009 - 1/2010	CDA 09	179,399	234,645
Goodsell Point Marina	1/2010 - 1/2010	CDA 09	1,684	2,203
Pine Orchard Maintenance	1/2010 - 2/2010	CDA 09	6,279	8,213
Milford Boat Works	1/2010 - 2/2010	CDA 09	1,993	2,607
Hull Harbor	3/2010 - 4/2010	CDA 09	3,732	4,881
Harbor Point Marina	1/2010	CDA 09	1,940	2,538
Harbor Point Marina	1/2011	CDA 10	390	510
Wright Island Marina, New Rochelle	11/2010 - 12/2010	CDA 10	5,374	7,029
Breakwater Key Marina	10/2010 - 1/2011	CDA 10	9,503	12,429
Guilford Yacht Club	12/2010 - 1/2011	CDA 10	10,276	13,440
Harbor Point Marina	1/2010 - 1/2011	CDA 10	2,331	3,049
Noank Village Boat Club	1/2011 - 1/2011	CDA 10	459	600
Dodson Boat Yard	1/2011 - 2/2011	CDA 10	1,324	1,731
Niantic Dockominium Association	1/2010	CDA 10	1,663	2,175
Stoney Point Association	10/2010 – 11/2010	CDA 10	2,491	3,258
Total			255,976	334,802

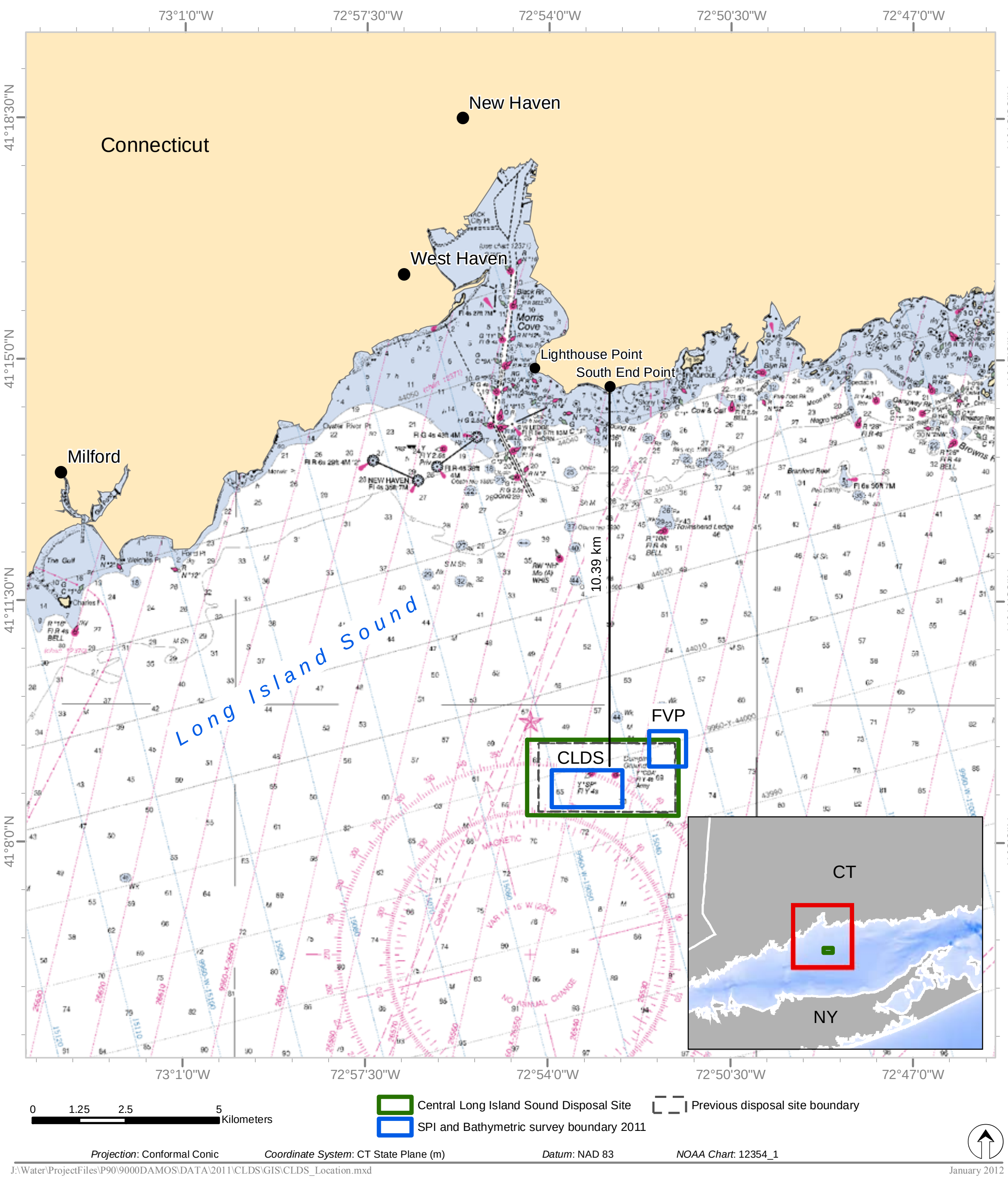


Figure 1-1. Location of Central Long Island Sound Disposal Site

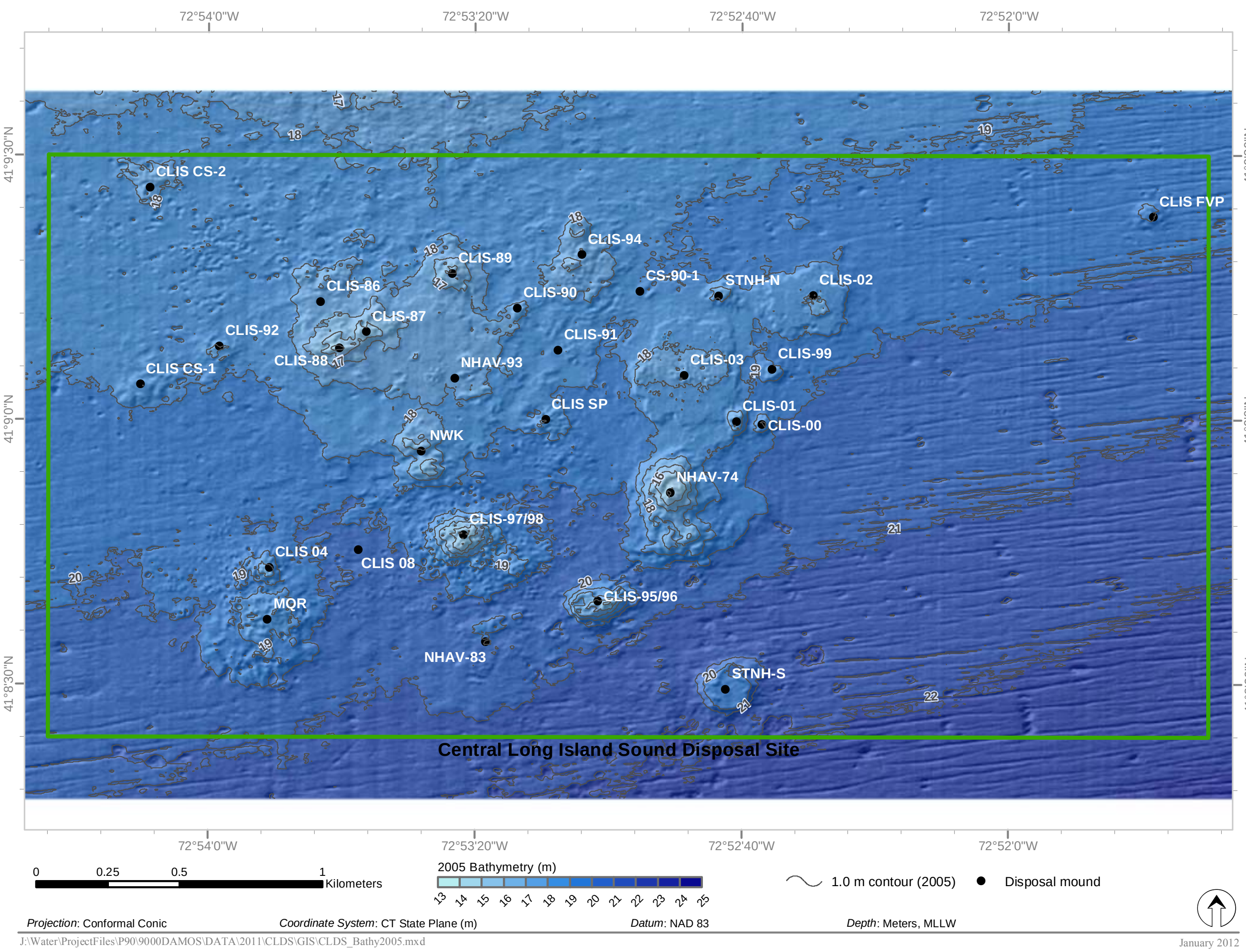


Figure 1-2. Bathymetric data with hillshade relief of the full CLDS from July 2005 survey showing named mound locations

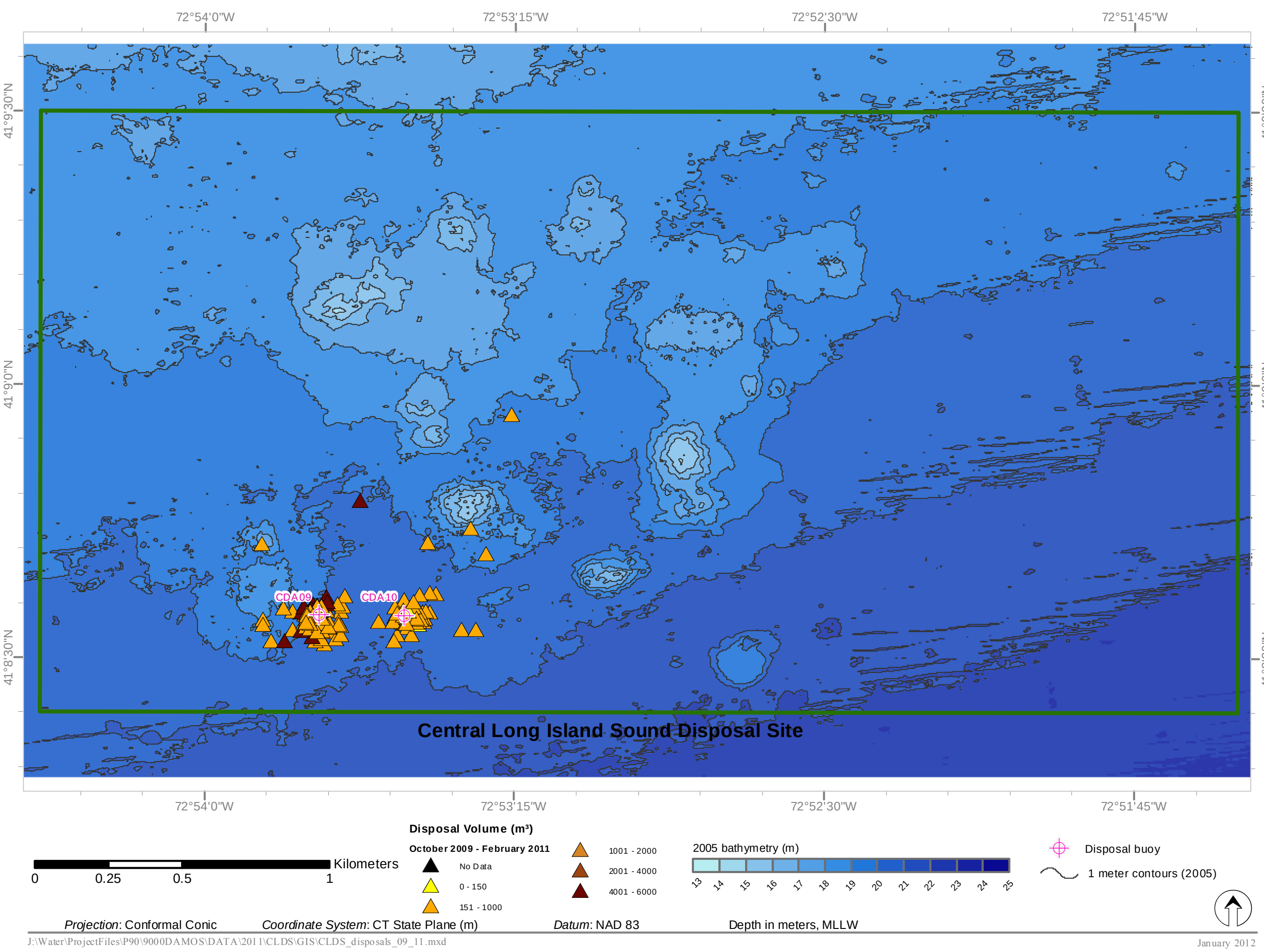


Figure 1-3. Location of disposal buoys and disposals events at CLDS (2009–2011)

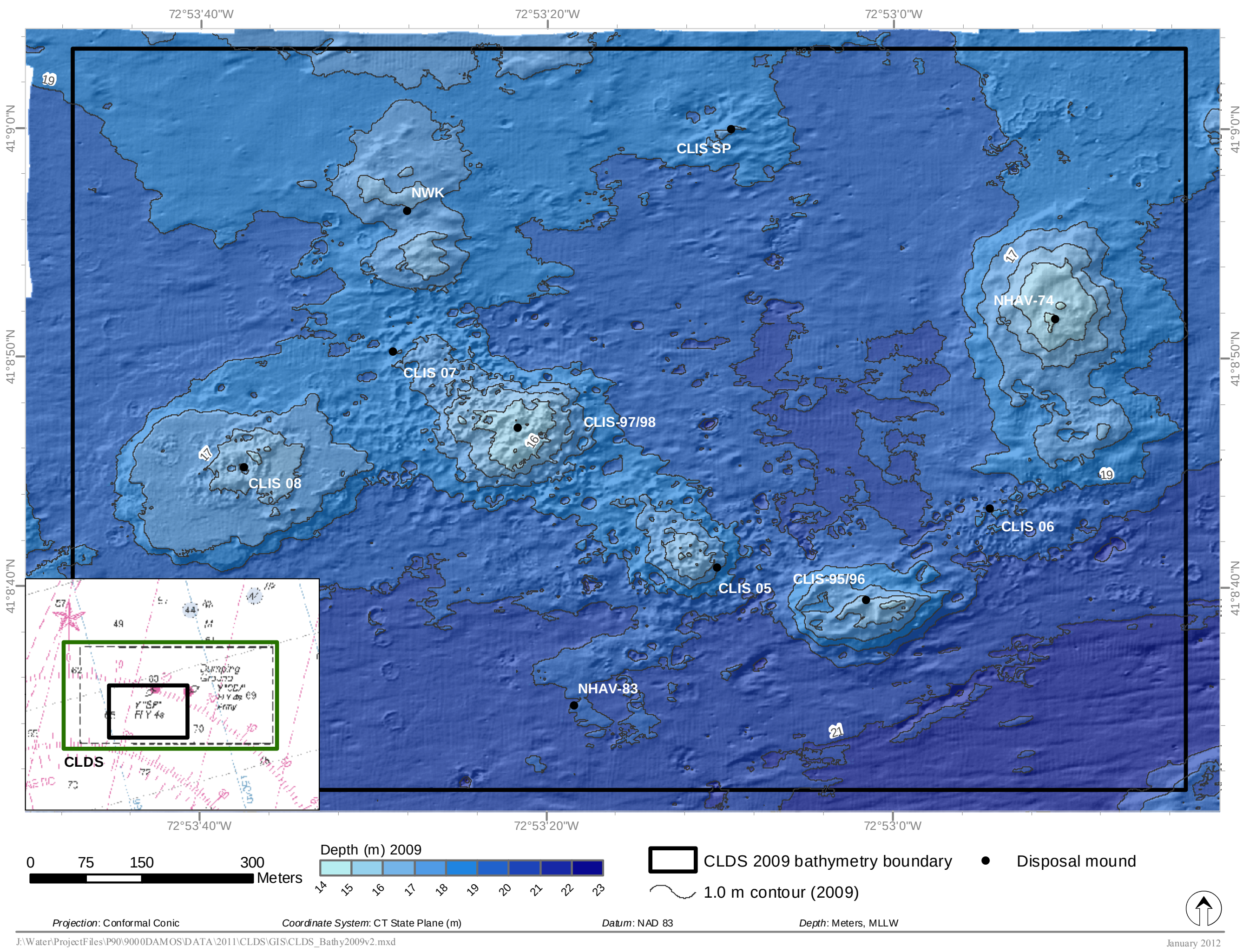


Figure 1-4. Bathymetric data with hillshade relief of CLDS from September 2009 survey of the south central portion of the site

2.0 METHODS

The 2011 surveys conducted at CLDS were performed by AECOM, CR Environmental, Inc., and Germano & Associates. The bathymetric surveys were conducted 26–27 September 2011, and the SPI surveys were conducted 2–3 October 2011. Field activities are summarized in Table 2-1, and an overview of the methods used to collect and analyze the survey data is provided below.

2.1 Navigation and On-Board Data Acquisition

Navigation for the surveys was accomplished using a Trimble AgGPS 132 12-channel Differential Global Positioning System (DGPS) system capable of receiving U.S. Coast Guard (USCG) Beacon corrections as well as OmniStar subscription-based satellite differential corrections. The system is capable of sub-meter horizontal position accuracy. The DGPS system was interfaced to a laptop computer running HYPACK MAX® hydrographic survey software. HYPACK MAX® continually recorded vessel position and DGPS satellite quality and provided a steering display for the vessel captain to accurately maintain the position of the vessel along pre-established survey transects and targets.

Redundant vessel heading measurements were acquired using two compass systems, each capable of providing heading measurements accurate to within 0.05° up to 20 times per second. The primary heading device was a SG Brown Meridian Gyrocompass installed in the forward berth along the vessel's centerline. A dual-antenna Hemisphere VS-100 Crescent Digital compass and DGPS system was installed above the pilot house as a backup for the gyrocompass. Both systems were interfaced to HYPACK® acquisition software.

2.2 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 of dredged material at disposal sites.

2.2.1 Bathymetric Data Collection

The 2011 multibeam bathymetric surveys of designated portions of CLDS and FVP were conducted on 26 September (CLDS) and 27 September (FVP) 2011 aboard the F/V First Light. Data layers generated by the surveys included multibeam bathymetry, sediment acoustic backscatter (beam time-series data), and side-scan sonar data.

The bathymetric survey of the south-central portion of CLDS was conducted over a 1000 x 1900 m area, focusing on recently deposited materials and the surrounding ambient seafloor (Figure 2-1). The CLDS bathymetric survey included a total of 26 survey lines, spaced approximately 40 m apart and oriented in an east-west direction. Four cross-tie lines, spaced 400 m apart, were occupied to assess data quality and the accuracy of tidal corrections (Figure 2-1).

The FVP bathymetric survey was conducted over a 1000 x 950 m portion of the site, centered at the FVP mound (Figure 2-1). The FVP bathymetric survey included a total of 24 survey lines, spaced approximately 40 m apart and oriented in an east-west direction. Three cross-tie lines, spaced 400 m apart, were occupied to assess data quality and the accuracy of tidal corrections (Figure 2-1).

Bathymetric, acoustic backscatter, and side-scan sonar data were collected using a Reson 8101 Multibeam Echo Sounder (MBES). This 240-kHz system forms 101 1.5° beams distributed equiangularly across a 150° swath. The MBES transducer was mounted amidships to the port rail of the survey vessel using a high strength adjustable boom, and the DGPS antenna was attached to the top of the transducer boom. The transducer depth below the water surface (draft) was checked and recorded at the beginning and end of data acquisition.

The MBES topside processor was equipped with components necessary to export depth solutions, backscatter, and side scan sonar signals to the HYPACK MAX® acquisition computer via Ethernet communications. HYPACK MAX® also received and recorded navigation data from the DGPS, motion data from a serially interfaced TSS DMS 3-05 motion reference unit (MRU), and heading data from the Meridian and Hemisphere compass systems. Several patch tests were conducted during the surveys to allow computation of angular offsets between the MBES system components. The system was calibrated for local water mass speed of sound by performing conductivity-temperature-depth (CTD) casts at frequent intervals throughout each survey day with a Seabird SBE-19 Seacat CTD profiler. Additional confirmations of proper calibration, including static draft, were obtained using the "bar check" method, in which a metal plate was lowered beneath the MBES transducer to known depths (e.g., 2.0 and 5.0 m) below the water surface. "Bar-check" calibrations were accurate to within 0.01 m in tests conducted at the beginning and end of each day.

Water depths over the survey area were recorded in meters and referenced to mean lower low water (MLLW) based on water levels recorded at NOAA's New Haven Tide Station #8465705, located approximately 14 km north of the survey areas. A tide gage was also installed at the marina in Branford, CT to serve as a backup to the NOAA data. HYPACK MAX® software was used to manage data acquisition and storage of data from the echosounder and the navigation system. HYPACK MAX® also recorded depth, vessel heave, heading, position, and time along each survey transect line.

2.2.2 Bathymetric Data Processing

MBES bathymetric data were processed using HYSWEEP® software. Data for outer beams greater than 60-degrees offset from nadir (vertical) were excluded from processing to minimize the impact of refraction and vessel motion on data quality. Preliminary steps of data processing included: application of tide corrections; adjustment of beam orientation using the results of patch test calibrations; correction of soundings for minor variations in water column sound velocity; and removal of outlying sounding solutions associated with water column interference (e.g. marine mammals, fish, or suspended debris).

The cleaned and adjusted data were further processed to calculate seafloor elevations based on evaluation of overlapping swath data. Based on the combined estimated average acoustic footprint of the MBES system (~0.4 – 0.8 m diameter), the accuracy of the DGPS (<1.0 m), and anticipate beam steering errors the average sounding solutions present within 2 x 2 m grid cells were accepted as seafloor elevations and exported in delimited ASCII text format for mapping in ArcGIS®10.0 (GIS). The vertical uncertainty of soundings within each of these cells was calculated and exported in ASCII format to aid in statistical assessment of data quality.

Processed bathymetric data were converted to a regularly spaced binary grid representing the seafloor elevation using Golden Software's Surfer V9.0. This grid was used to create bathymetric contours at 20 cm intervals. The grid was also used to create an interactive three-dimensional model of the survey area using IVS3D Fledermaus software.

MBES backscatter data were processed using HYPACK®'s implementation of GeoCoder software developed by NOAA's Center for Coastal and Ocean Mapping Joint

Hydrographic Center (CCOM/JHC). GeoCoder was used to create a mosaic best suited for substratum characterization through the use of innovative beam-angle correction algorithms.

Snippets backscatter data (beam-specific ping time-series records) were extracted from cleaned files and were converted to Generic Sensor Format (GSF) files. Mosaics of beam time-series (BTS) backscatter data were created from GSF data using GeoCoder, and were exported in grey-scale TIF raster format. BTS data were also exported in ASCII format with fields for Easting, Northing, and backscatter (dB). These data were gridded using kriging algorithms and filtered with a mild low-pass Gaussian filter to minimize nadir artifacts. The filtered grids were used to develop maps of backscatter values using 2.0 m (horizontal resolution) node intervals.

The side-scan sonar data were processed using both Chesapeake Technology, Inc. SonarWiz software and HYPACK®'s implementation of GeoCoder software. Individual georeferenced TIF images of each sonar file and georeferenced mosaics with resolutions of 0.1 - 0.2 m/pixel were generated. The mosaic side-scan sonar data were merged with bathymetric data and formatted for 3D display using Fledermaus® software.

2.2.3 Bathymetric Data Analysis

The processed bathymetric grids were converted to rasters, and bathymetric contour lines were generated and displayed using GIS. GIS was also used to calculate depth difference grids between previous surveys and the 2011 bathymetric dataset. The most recent bathymetric survey at CLDS was conducted in 2009, covering the area of recent disposal activity. A baseline bathymetric survey of the entire CLDS, including the FVP mound, was conducted in 2005. The 2009 and 2005 bathymetric survey data were used to generate depth difference grids for the area of recent activity and the FVP mound, respectively. The depth difference grids were calculated by subtracting the 2009 or 2005 survey depth estimates from the 2011 survey depth estimates at each point throughout the grid. The resulting depth differences were contoured and displayed using GIS.

2.3 Sediment-Profile Imaging

Sediment-profile imaging 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. This technique involves deploying an underwater camera system to photograph a cross section of the sediment-water interface. Acquisition of high-resolution sediment-profile images was accomplished using a Nikon D7000 digital single-lens reflex camera with a 16 megapixel image sensor mounted inside an Ocean Imaging Model 3731 pressure housing system. The pressure housing sat atop a wedge-shaped prism with a front faceplate and back mirror. The mirror was mounted at a 45° angle to reflect the profile of the sediment-water interface. As the prism penetrated the seafloor, a trigger activated a time-delay circuit that fired an internal strobe to obtain a cross-sectional image of the upper 15–20 cm of the sediment column (Figure 2-2). The camera remained on the seafloor for approximately 20 seconds to ensure that a successful image had been obtained. Details of the camera settings for each digital image are available in the associated parameters file embedded in each electronic image file. For this survey, the ISO-equivalent was set at 100, shutter speed was 1/160, f8, and storage in compressed raw Nikon Electronic Format (NEF) files (approximately 18 MB each). Electronic files were converted to high-resolution jpeg (8-bit) format files (3264 x 4928 pixels) using Nikon Capture® NX2 software (Version 2.3.1).

Test exposures of the Kodak® Color Separation Guide (Publication No. Q-13) were made on deck at the beginning and end of each survey to verify that all internal electronic systems were working to design specifications and to provide a color standard against which final images could be checked for proper color balance. After deployment of the camera at each station, the frame counter was checked to ensure that the requisite number of replicate images had been obtained. In addition, a prism-penetration depth indicator on the camera frame was checked to verify that the optical prism had actually penetrated the bottom to a sufficient depth. If images were missed or the penetration depth was insufficient, the camera frame stop collars were adjusted and/or weights were added or removed, and additional replicate images were taken. Changes in prism weight amounts, the presence or absence of mud doors (to limit over-penetration in soft sediments), and frame stop collar positions were recorded for each replicate image.

Each image was 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, the field crew kept redundant written sample logs. Images were downloaded periodically to verify successful sample acquisition and/or to assess what type of sediment/depositional layer was present at a particular station. Digital image files were re-named with the appropriate station name immediately after downloading as a further quality assurance step.

2.3.1 SPI Data Collection

The sediment-profile survey at CLDS was initiated 2 October 2011 and completed 3 October 2011 aboard the F/V First Light. An attempt was made to collect plan-view underwater images at CLDS, but highly turbid conditions near the seafloor prevented the acquisition of high resolution images, and thus image collection using the plan-view underwater camera (PUC) was terminated and the camera was removed from the frame. At each station, the vessel was positioned at the target coordinates and the camera was deployed within a defined station tolerance of 10 m. Three replicate SPI were collected at each of the stations.

The 2011 imaging survey design included the collection of SPI at 35 locations within CLDS in the vicinity of recent disposal activity, 15 locations at the historic FVP mound, and 18 locations within three predefined reference areas (Table 2-2, Figures 2-3, through 2-5). The 18 reference stations were distributed among the three reference areas as follows: 6 stations at 4500E REF, 6 stations at CLIS REF, and 6 stations at 2500W REF. Stations were randomly distributed within the preselected areas (Figure 2-3). The 35 stations located within the area of recent disposal at CLDS were distributed as follows: 6 stations at CLIS 07 mound, 14 stations at CLIS 08 mound, and 15 stations at CLIS 09 mound (Figure 2-4). The 15 FVP stations were distributed as follows: 10 stations over the mound center, as defined by the 19.5 m depth contour, based on the 2005 bathymetric dataset, and 5 stations on the flank of the FVP mound (Figure 2-5).

2.3.2 SPI Data Analysis

Computer-aided analysis of the resulting images provided a set of standard measurements that enabled comparison between different locations and different surveys. The DAMOS Program has successfully used this technique for over 30 years to map the distribution of disposed dredged material and to monitor benthic recolonization at disposal sites.

Following completion of data collection, the digital images were analyzed using Adobe Photoshop CS 5 Version 12.1. Images were first adjusted in Adobe Photoshop® to expand the available pixels to their maximum light and dark threshold range. Linear and areal measurements were recorded as number of pixels and converted to scientific units using the Kodak® Color Separation Guide for measurement calibration. Detailed records of all SPI results are included in Appendix C.

Analysis of each SPI 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.

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) measured over the width of sediment-profile images typically ranges from 0 to 4 cm, and may be related to physical structures (e.g., ripples, rip-up structures, mudclasts) 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 (aRPD) Depth–aRPD 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. As the particles are buried or moved down by biological activity, they are exposed to reduced oxygen concentrations in subsurface pore waters and their oxic coating slowly reduces, changing color to dark grey or black. When biological activity is high, the aRPD depth increases; when it is low or absent, the aRPD depth decreases. The aRPD 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 means of replicate values from each station.

2.3.3 Statistical Methods

Statistical analysis was used to aid in the assessment of the benthic recolonization status of the recently formed mounds and the FVP mound relative to reference conditions. The two SPI parameters which are most indicative of recolonization status, and which also lend themselves to quantitative analysis, are the depth of the aRPD (an indirect measure of the degree of biological reworking of surface sediments) and the infaunal successional stage. For the statistical analysis, the mean value for aRPD (based on n=3 replicate images) was utilized, while the maximum value among the three replicates was used as the successional stage rank for each station. The successional stage ranks had possible values between 0 (no fauna present) and 3 (Stage 3); half ranks were also possible for the "in-between" stages (e.g., Stage 1 going to 2 had a value of 1.5).

Traditionally, study objectives have been addressed using point null hypotheses of the form "There is no difference in benthic conditions between the reference area and the disposal mound." An approach using bioequivalence or interval testing is considered to be more informative than the point null hypothesis test of "no difference". In reality, there is always some small difference, and the statistical significance of this difference may or may not be ecologically meaningful. Without an associated power analysis, this type of point null hypothesis testing provides an incomplete picture of the results.

In this application of bioequivalence (interval) testing, the null hypothesis presumes the difference is great, i.e., an inequivalence hypothesis (e.g., McBride 1999). This is recognized as a 'proof of safety' approach because rejection of the inequivalence null hypothesis requires sufficient proof that the difference is actually small. The null and alternative hypotheses to be tested were:

H_0: $d \leq -\delta$ or $d \geq \delta$ (presumes the difference is great)

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

where d is the difference between the reference site and disposal mound means.

If the null hypothesis is rejected, then we conclude 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. Based on historical DAMOS data, δ values of 1 for aRPD and 0.5 for successional stage rank (on the 0–3 scale) have been established.

The test of the interval hypothesis can be broken down into two one-sided tests (TOST) (McBride 1999 after Schuirmann 1987) which are based on the normal distribution, or, more typically, on Student's t-distribution when sample sizes are small and variances must be estimated from the data. The statistics used to test the interval hypotheses shown here are based on such statistical foundations as the Central Limit Theorem (CLT) and basic statistical properties of random variables. A simplification of the CLT says that the mean of any random variable is normally distributed. Linear combinations of normal random variables are also normal, so a linear function of means is also normally distributed. When a linear function of means is divided by its standard error the ratio follows a t-distribution with degrees of freedom associated with the variance estimate. Hence, the t-distribution can be used to construct a confidence interval around any linear function of means.

In the sampling design utilized in the 2011 SPI survey at CLDS, there were seven distinct areas (three reference areas, three recent disposal mounds and FVP mound), and the difference equations of interest are the linear contrasts of each mound mean minus the average of the three reference means, or

$$[(\text{Mean}_{\text{CLIS REF}} + \text{Mean}_{\text{4500E REF}} + \text{Mean}_{\text{2500W REF}}) - (\text{Mean}_{\text{Mound}})]$$

where $\text{Mean}_{\text{Mound}}$ was the mean for one of the disposal mounds (CLIS 07, CLIS 08, or CLIS 09).

The three reference areas collectively represented ambient conditions, but if there were mean differences among these three areas then pooling them into a single reference group will increase the variance beyond true background variability. The effect of keeping the three reference areas separate had little effect on the grand reference mean (when n is equal among these areas), but it maintained the variance as a true background variance for each individual population with a constant mean.

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

$$[(\text{Mean}_{\text{CLIS REF}} + \text{Mean}_{\text{4500E REF}} + \text{Mean}_{\text{2500W REF}}) - (\text{Mean}_{\text{Mound}})] \qquad \text{[Eq.1]}$$

and the standard error of each difference equation was calculated assuming that the variance of a sum is the sum of the variances for independent variables, or:

$$SE(\hat{d}) = \sqrt{\sum_j \left(S_j^2 c_j^2 / n_j\right)} \qquad \text{[Eq.2]}$$

where:

cj = coefficients for the j means in the difference equation, $\hat{d}$ [Eq. 1] (i.e., for equation 1 shown above, the coefficients were 1/3 for each of the 3 reference areas, and -1 for the disposal mound).

S_j^2 = variance for the jth area. If equal variances are assumed, a single pooled residual variance estimate can be substituted for each group, equal to the mean square error from an ANOVA based on all seven groups.

nj = number of replicate observations for the j[th] area.

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 was to reject H_0 if:

$$D_L = \hat{d} - t_{\alpha,\upsilon} se(\hat{d}) > -\delta \quad \text{and} \quad D_U = \hat{d} + t_{\alpha,\upsilon} se(\hat{d}) < \delta \qquad \text{[Eq. 3]}$$

where:

$\hat{d}$ = observed difference in means between the Reference and Mound

$t_{\alpha,\upsilon}$ = upper 100th 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 residual variance estimate was used, it was the residual degrees of freedom from an ANOVA on all groups (total number of stations 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).

Validity of the normality and equal variance assumptions were tested using Shapiro-Wilk's test for normality on the area residuals ($\alpha = 0.05$) and Levene's test for equality of variances among the seven areas ($\alpha = 0.05$). If normality was not rejected but equality of variances was, then the variance for the difference equation was based on separate variances for each group. If systematic deviations from normality were identified, then a non-parametric bootstrapped interval was used.

Table 2-1.

Summary of Field Activities at CLDS

Survey Type	Date	Summary
Bathymetry	26 Sept 2011 (CLDS)	Area: 1900 x 1000 m
		Lines: 30
		Spacing: 40 m
	27 Sept 2011 (FVP)	Area: 1000 x 1000 m
		Lines: 27
		Spacing: 40 m
Sediment-Profile Imaging	2-3 Oct 2011	Total Stations: 68
		CLDS: 35
		CLIS 07: 6
		CLIS 08: 14
		CLIS 09: 15
		FVP: 15
		Reference Site: 18
		4500E: 6
		CLIS REF: 6
		2500W: 6

Table 2-2.

CLDS and Reference Area Target SPI Locations

Station	Latitude (N)	Longitude (W)	Station	Latitude (N)	Longitude (W)
		Disposal Site			
CLIS 08			CLIS 09		
CLDS 1	41° 08.728'	-72° 53.605'	CLDS 21	41° 08.615'	-72° 53.700'
CLDS 2	41° 08.788'	-72° 53.619'	CLDS 22	41° 08.527'	-72° 53.687'
CLDS 3	41° 08.752'	-72° 53.634'	CLDS 23	41° 08.613'	-72° 53.714'
CLDS 4	41° 08.758'	-72° 53.590'	CLDS 24	41° 08.599'	-72° 53.686'
CLDS 5	41° 08.690'	-72° 53.616'	CLDS 25	41° 08.561'	-72° 53.711'
CLDS 6	41° 08.766'	-72° 53.641'	CLDS 26	41° 08.526'	-72° 53.761'
CLDS 7	41° 08.781'	-72° 53.574'	CLDS 27	41° 08.514'	-72° 53.704'
CLDS 8	41° 08.777'	-72° 53.608'	CLDS 28	41° 08.589'	-72° 53.782'
CLDS 9	41° 08.731'	-72° 53.681'	CLDS 29	41° 08.567'	-72° 53.665'
CLDS 10	41° 08.723'	-72° 53.667'	CLDS 30	41° 08.607'	-72° 53.740'
CLDS 11	41° 08.703'	-72° 53.652'	CLDS 31	41° 08.570'	-72° 53.726'
CLDS 12	41° 08.749'	-72° 53.659'	CLDS 32	41° 08.577'	-72° 53.767'
CLDS 13	41° 08.703'	-72° 53.603'	CLDS 33	41° 08.597'	-72° 53.773'
CLDS 14	41° 08.747'	-72° 53.671'	CLDS 34	41° 08.529'	-72° 53.735'
			CLDS 35	41° 08.617'	-72° 53.731'
CLIS 07			FVP		
CLDS 15	41° 08.876'	-72° 53.474'	FVP 1	41° 09.402'	-72° 51.680'
CLDS 16	41° 08.814'	-72° 53.460'	FVP 2	41° 09.409'	-72° 51.634'
CLDS 17	41° 08.874'	-72° 53.443'	FVP 3	41° 09.371'	-72° 51.671'
CLDS 18	41° 08.857'	-72° 53.447'	FVP 4	41° 09.383'	-72° 51.664'
CLDS 19	41° 08.838'	-72° 53.453'	FVP 5	41° 09.380'	-72° 51.675'
CLDS 20	41° 08.856'	-72° 53.466'	FVP 6	41° 09.393'	-72° 51.685'
			FVP 7	41° 09.400'	-72° 51.617'
			FVP 8	41° 09.381'	-72° 51.634'
			FVP 9	41° 09.373'	-72° 51.684'
			FVP 10	41° 09.397'	-72° 51.666'
			FVP 11	41° 09.387'	-72° 51.734'
			FVP 12	41° 09.370'	-72° 51.790'
			FVP 13	41° 09.346'	-72° 51.612'
			FVP 14	41° 09.442'	-72° 51.694'
			FVP 15	41° 09.401'	-72° 51.585'

Table 2-2. (continued)

CLDS and Reference Area Target SPI Locations

Station	Latitude (N)	Longitude (W)
Reference Areas		
2500W 1	41° 09.335'	-72° 55.629'
2500W 2	41° 09.320'	-72° 55.523'
2500W 3	41° 09.194'	-72° 55.448'
2500W 4	41° 09.394'	-72° 55.650'
2500W 5	41° 09.406'	-72° 55.457'
2500W 6	41° 09.266'	-72° 55.451'
4500E 1	41° 09.224'	-72° 50.640'
4500E 2	41° 09.318'	-72° 50.361'
4500E 3	41° 09.204'	-72° 50.586'
4500E 4	41° 09.409'	-72° 50.617'
4500E 5	41° 09.138'	-72° 50.604'
4500E 6	41° 09.220'	-72° 50.527'
REF 1	41° 08.012'	-72° 49.955'
REF 2	41° 08.014'	-72° 50.187'
REF 3	41° 07.995'	-72° 50.028'
REF 4	41° 08.078'	-72° 49.975'
REF 5	41° 07.979'	-72° 49.961'
REF 6	41° 08.150'	-72° 50.189'

Notes: Coordinate system NAD83

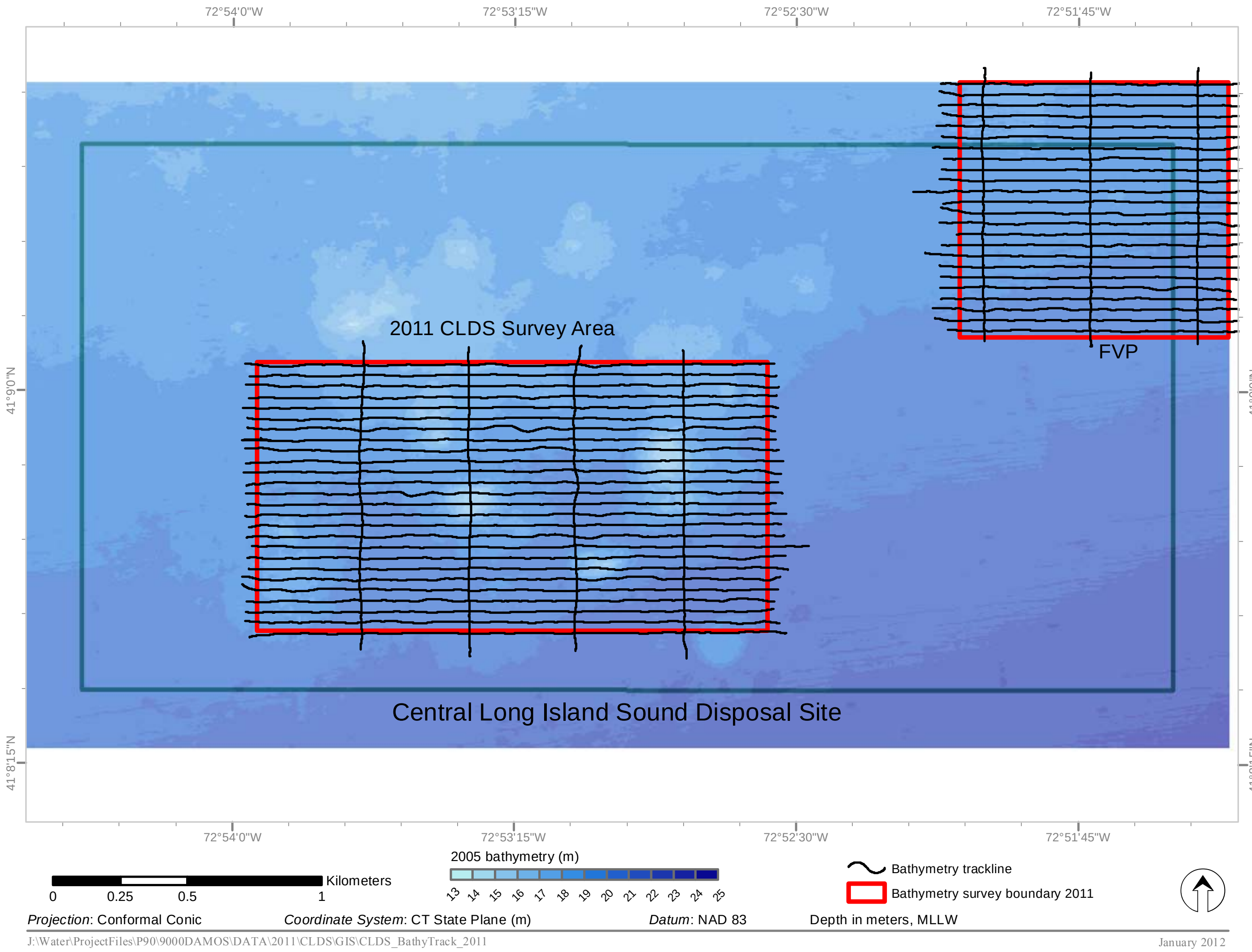


Figure 2-1. CLDS bathymetric survey boundary and tracklines

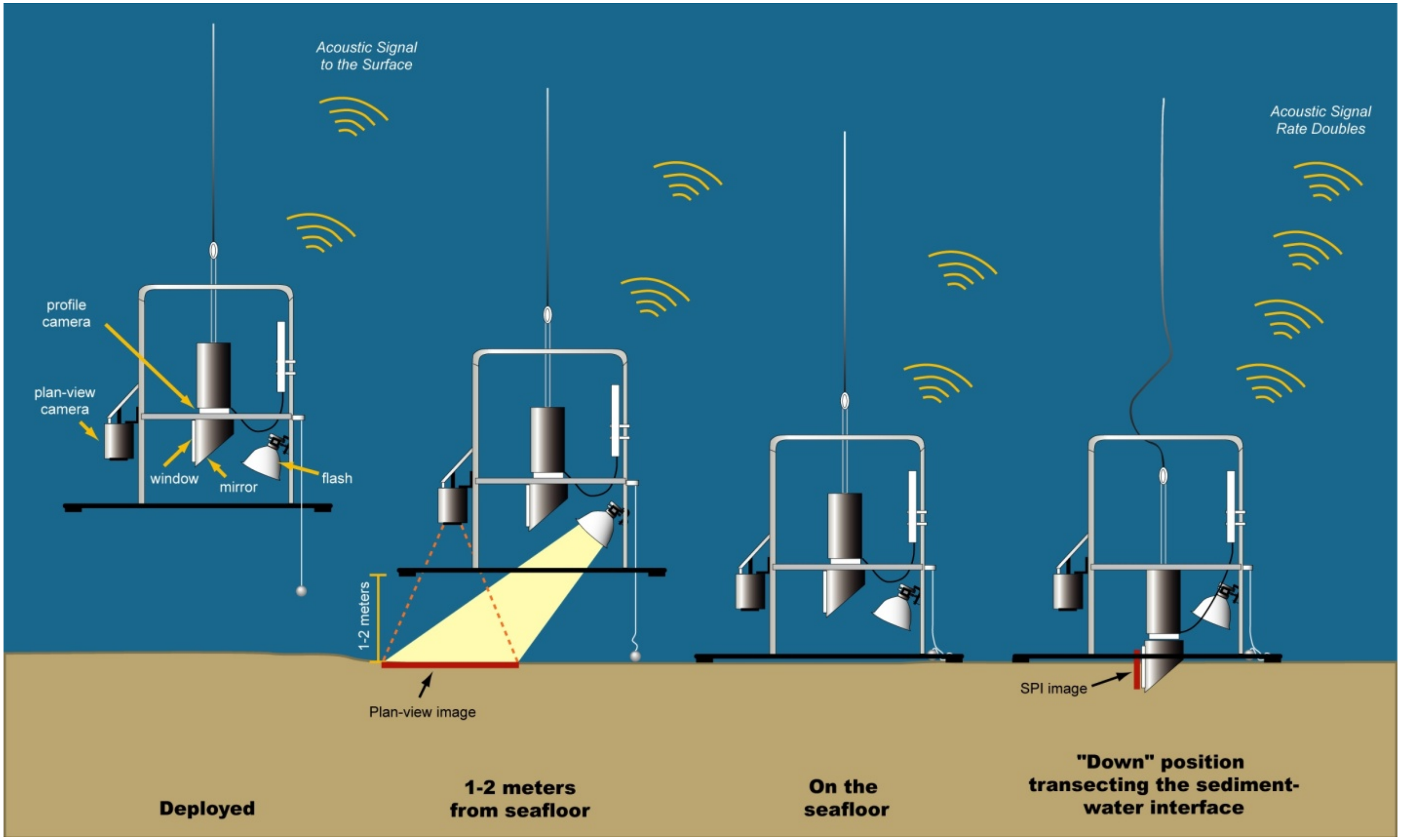


Figure 2-2. Schematic diagram of the SPI camera deployment

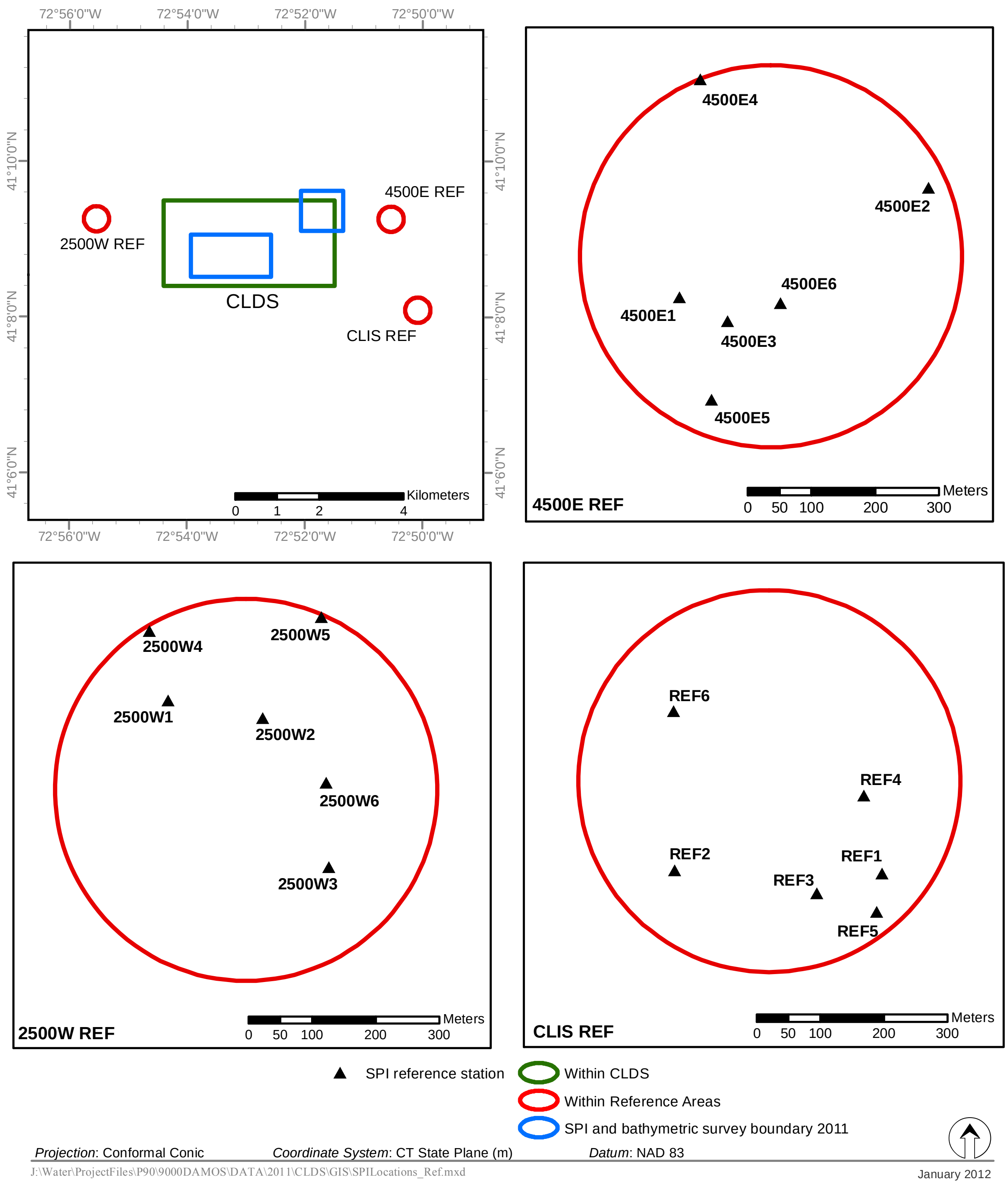


Figure 2-3. Location of 2011 SPI stations at each of three reference areas

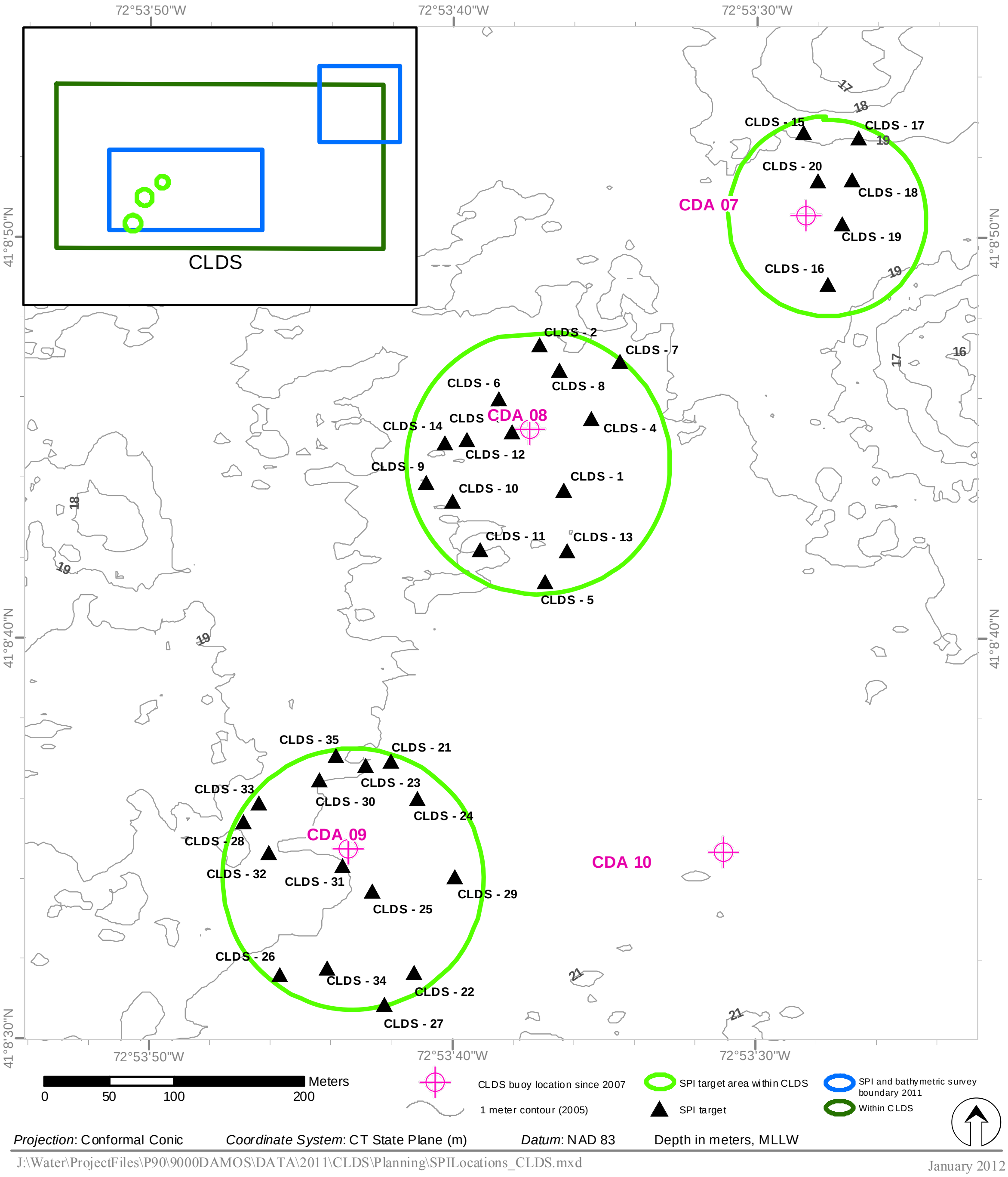


Figure 2-4. 2011 SPI stations located within areas of CLDS that experienced recent disposal activity

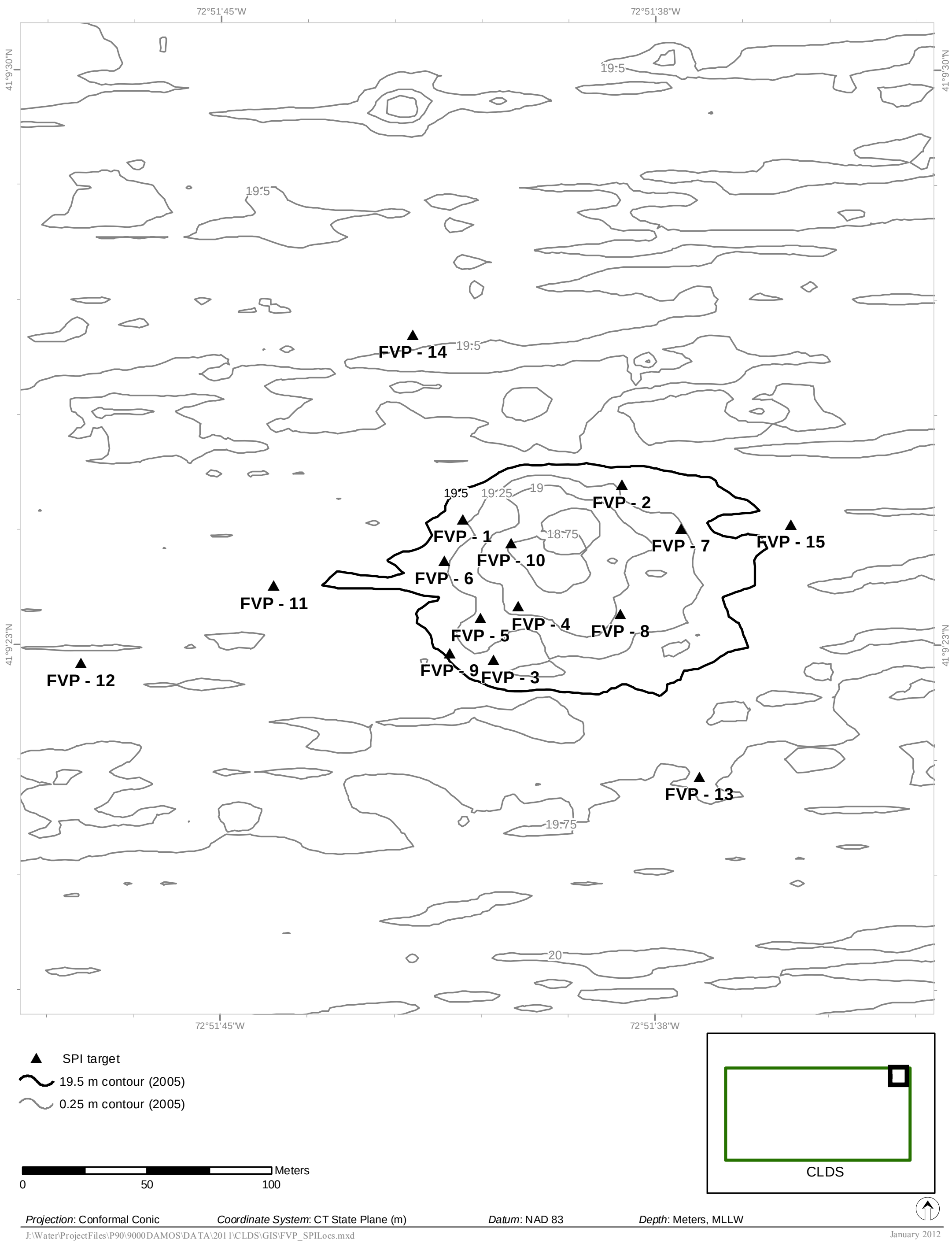


Figure 2-5. 2011 SPI stations located over FVP mound in the northeast corner of CLDS

3.0 RESULTS

Bathymetric surveys were conducted over the area of recent disposal activity on 26 September 2011 and over the historic FVP mound on 27 September 2011. SPI images were collected at three CLDS disposal mounds (CLIS 07, CLIS 08, and CLIS 09) on 1 October 2011 and at the FVP mound and three reference areas on 2 October 2011. Data from these investigations are presented below and in the subsequent tables and figures.

3.1 Bathymetry

3.1.1 Bathymetric Data Quality

Bathymetric data quality for nadir (vertical) beams were assessed by statistical comparison of co-located soundings collected on perpendicular tracklines. Using computation methods specified by the USACE (EM 1110-2-1003), the 95^{th}% Confidence Interval (C.I.) was calculated as 0.13 m for nadir soundings. In order to assess data quality across the MBES swath, within cell (2 m x 2 m) depth variations were mapped and statistically evaluated. The average error within bathymetric grid cells was 0.077 m (0.176 m at the 95^{th}% C.I.).

USACE Guidance for Hydrographic Surveying (EM 1110-2-1003) provides performance standards for data acquired in depths up to 80 feet (24.4 meters) as 0.61 m at the 95^{th}% C.I. for the range of depths at CLDS. The majority of the 2011 CLDS and FVP survey data conform to this performance standard. Non-compliant outliers were confined to the slopes of seabed features where the sounding range within 2.0 m cells was constrained by topography rather than accuracy.

3.1.2 CLDS Mounds

<u>Bathymetry</u>

The natural seafloor of the 2011 CLDS survey area sloped gradually from 14.5 m (MLLW) in the northwest to 22 m (MLLW) in the southeast (Figure 3-1). Several active and historic disposal mounds, along with distinct bottom features, were apparent within the survey area.

The 2011 bathymetric survey extent was coincident with the 2009 survey area to allow for direct comparison of topographic changes between survey years. Disposal activity in the period between the surveys was concentrated at the CDA09 and CDA10 buoy locations (Table 1-2 and Figure 1-3). The placement of approximately 222,000 m3 of material at the CDA09 buoy during the 2009–2010 disposal season resulted in the formation of a distinct mound, CLIS 09, located approximately 350 m south of the CLIS 08 mound. The CLIS 09 mound had a slightly irregular footprint, approximately 100 m in diameter and with a maximum height of 4.0 m above the surrounding bottom (Figure 3-1).

Approximately 34,000 m3 of material had been placed at the CDA10 buoy location prior to the 2011 survey (disposal was occurring at the time of the survey reported here), resulting in the formation of a new mound (CLIS 10) located 300 m east of the CLIS 09 mound. The CLIS 10 mound was roughly circular in shape with a diameter of 80 m and a height of 3.0 m above the surrounding seafloor (Figure 3-1).

A depth comparison between the 2011 and the 2009 bathymetric datasets confirmed the formation of the two new mounds (CLIS 09 and CLIS 10) in the southwestern portion of the survey area (Figure 3-2). A wide distribution of newly placed material was apparent in the depth difference model with 0.2–0.5 m of newly accumulated material stretching over 200 m from the apex of CLIS 09 and over 100 m from the apex of CLIS 10. Accumulation of material was evident beyond the southern extent of the survey area and up to the edge of the CLIS 08 mound to the north (Figure 3-2).

A large area of consolidation, centered around the CLIS 08 mound, was also evident in the depth difference analysis (Figure 3-2). Consolidation of 0.2–0.5 m spanned 200 m in a north-south direction and 300 m in an east-west direction from the center of the CLIS mound, while small pockets of greater consolidation (0.5–0.6 m) were identified at the mound apex. This consolidation pattern was noticeably interrupted along the northern edge of the mound formation by two distinct ridges of apparent sediment accumulation. Both ridges were oriented in an east-west direction and were approximately 100 m long and 10–20 m wide. The ridges were separated by a 10 m wide trough which experienced similar consolidation as the rest of the CLIS 08 mound. This latter feature is described in more detail in the discussion in Section 4.

The NHAV-74 mound continued to be the most prominent feature in this portion of CLDS with a diameter over 300 m and a height of 5 m above the seafloor (Figure 3-1). Despite the absence of recorded disposal activity in the vicinity of NHAV-74 since the creation of the adjacent CLIS 06 mound in the 2006–2007 disposal season (Figure 1-3, Valente et al. 2012, ENSR 2007) a portion of the NHAV-74 mound experienced an area of measureable bathymetric change between 2009 and 2011 (Figure 3-2). The bathymetric change was limited to an area on the southern edge of the main mound formation, in a saddle that separated the main mound from a smaller peak. This roughly circular area was 90–100 m across with a maximum length of 117 m and 8,900 m^2 area. The area consisted of two lobes of apparent sediment accumulation (0.6–1.3 m thick) separated by a 15 m wide east-west oriented v-shaped trough that experienced up to 1.2 m of sediment loss or compaction over the same time period. The volume of sediment loss or compaction in the trough was approximately 400 m^3 and the volume of sediment accumulation within the lobes was approximately 3,900 m^3.

In addition to these more prominent features several relatively low-magnitude negative depth differences (approximately 0.2 m) were identified on isolated portions of the slopes of many of the historic mounds in the survey area. Because the majority of these isolated differences occurred on slopes, these differences may be associated with acoustic discrepancies (e.g., beam width, frequency) between the multibeam systems deployed in 2009 and 2011.

Backscatter and Side-Scan Sonar

Quantitative backscatter, in the form of snippets data, and side-scan sonar images were simultaneously recorded by the MBES system deployed for the bathymetric data collection. Backscatter intensity collected in this manner represents a measure of surficial sediment texture and bottom roughness and is processed to remove slope. Generally, high backscatter intensity is associated with rock or coarse-grained sediment, and low backscatter intensity characterizes finer grained sediments (de Moustier 1986). Side-scan sonar also provides an image of seafloor texture and bottom features, but the intensity of response is influenced by slope (higher slope facing the instrument has higher return). Since the side-scan data was not processed to account for slope it could be processed to a higher resolution than corresponding bathymetric or backscatter data. The higher resolution is possible because the side-scan data are sampled across the entire swath at fixed short intervals. The resolution of side scan data is not constrained by beam - footprint size, as is the case with backscatter or bathymetric data. Instead, resolution is constrained by the width of the 1.5-degree transmit beam and the sampling rate of the system (1 sample / ~3 cm across track) and the acoustic frequency (240 kHz).

Modeled backscatter intensity at CLDS suggested an ambient seafloor backscatter signal of approximately -38 dB (Figure 3-3). Portions of the survey area which consisted of dredged material, based on sonar imagery and relief models, produced higher backscatter signals between -36 dB and -24 dB (Figure 3-3). The recently disposed material at the CLIS 09 and CLIS 10 mounds, along with the most prominent historical mounds (NHAV-74, CLIS 95/96, and CLIS 97/98), produced backscatter signals at the higher end of this range (-26 to -24 dB). The disposed material at the CLIS 08 mound had backscatter signals similar to ambient with the exception of the area at the northern margin of the mound that overlaps with the two ridges noted above (compare Figures 3-2 and 3-3). This area had backscatter signals between -36 and -28 dB.

A side-scan sonar mosaic of the survey area allowed for interpretation of surficial features of the site. This mosaic highlighted clusters of individual disposal events at both recent and historic disposal mounds (Figure 3-4). Several narrow linear features were also evident in the mosaic that were less evident in the snippets backscatter layer, with one prominent arc spanning approximately 1.5 km across the site (Figure 3-4).

3.1.3 FVP Mound

Bathymetry

The FVP mound was apparent in the 2011 bathymetric survey as a slight rise of 0.5 m above the surrounding seafloor to a depth of 19 m MLLW (Figure 3-5). FVP has an overall diameter of approximately 100 m with a small area at the mound apex that is 1.0 m above the ambient seafloor. Longitudinal sedimentary furrows were prevalent in the area around the FVP mound as linear depressions 0.1–0.4 m deep and 5 m across. These features extended across the majority of the survey area in an east-west direction but appeared to be absent, or buried, on the mound surface itself.

The FVP mound had a pockmarked surface with eight to nine shallow depressions consistent with disposal impact craters that were observed on the surface of the mound in 2005 (ENSR 2007). Two additional depressions with raised edges were observed in the 2011 survey that were not apparent in 2005 (Figure 3-5).

Depth difference analysis between the 2011 data and the most recent survey of FVP in 2005 revealed only one measureable change in topography over the mound: an isolated circular area of sediment accumulation (approximately 0.75 m) along the southern edge of the mound flank coincident with the new depressions (Figure 3-6). Four additional isolated areas of sediment accumulation were observed away from the mound. Two of these areas were coincident with circular disposal impact features not observed in 2005, and two were coincident with existing depressions (Figure 3-6).

Backscatter and Side-Scan Sonar

Backscatter intensity at the FVP mound was similar to the CLIS mounds with dredged material signals ranging from -36 to -31 dB and lower signals from the ambient seafloor (Figure 3-7). Variation in the backscatter intensity of the ambient seafloor in the FVP survey extent is likely associated with historic disposal activity in the area. The side-scan sonar mosaic of the FVP survey area accentuated the persistence of disposal impact craters on the surface of the mound almost 30 years after completion of disposal activity, but the most prominent were the paired overlapping rings on the southern edge of the mound coincident with the area of accumulation noted above (Figure 3-8).

3.2 Sediment-Profile Imaging

Detailed image analysis results are provided in Appendix C. The following sections summarize the results for the reference areas and for each of the disposal mounds. Statistical comparisons between the reference areas and disposal mound SPI results for 2011 are presented in Section 3.3.

3.2.1 Reference Areas

Physical Sediment Characteristics

All three of the reference areas were characterized by relatively soft mud (i.e., silt/clay) having a grain size major mode of >4 phi (Table 3-1; Figures 3-9 and 3-10). There was no evidence of dredged material at any of the stations sampled in the reference areas, and no evidence of low dissolved oxygen or sedimentary methane.

Mean replicate camera prism penetration values among the reference area stations ranged from 16.2 to 20.1 cm (Table 3-1). Such high penetration values are typical of the soft, biologically reworked silt/clays that characterize the reference areas. Mean penetration values at several of the 2500W REF stations were higher than those at the other two reference areas (Table 3-1), indicating the presence of particularly soft (i.e., low relative bearing strength) sediments at this location. This reference area is located in shallower depths than the other reference areas (Table 3-1). Means of replicate small-scale boundary roughness ranged from 0.4 to 1.3 cm at the reference stations (Table 3-1); all of this roughness was due to the presence of small-scale biogenic features at the sediment surface (e.g., small pits, mounds, and burrow openings) resulting from surface and subsurface feeding and foraging activities of benthic organisms (Figure 3-11).

Biological Conditions

The means of replicate aRPD depths among the reference area stations ranged from 2.2 to 3.7 cm (Table 3-1, Figure 3-12). There were no consistent patterns of aRPD depth between the reference areas; each area had at least one station mean below 3 cm and the majority above (Figure 3-12). Overall, the aRPD depths at all three of the reference areas were relatively deep and consistent with values measured in past surveys. The 2011 images did show evidence of the surface phytodetrital layer of tan or rust-colored sediment that was observed in the previous CLDS SPI surveys of September 2003 (ENSR 2004) and June 2004 (ENSR 2005; Figure 3-10) but was not observed in October 2009 (Valente et al. 2012).

All of the replicate images from the reference areas showed evidence of Stage 3 taxa (Table 3-1, Figure 3-13). Evidence for the presence of Stage 3 fauna included large-bodied infauna, large subsurface burrows, and/or feeding voids (Figure 3-14). Small tubes constructed by opportunistic Stage 1 taxa were also visible at the sediment surface in at least one of the replicates at five of the reference area stations, resulting in a Stage 1 on 3 successional designation (Table 3-1, Figure 3-14). The mean number of subsurface feeding voids at the reference area stations ranged from 0 to 3, with an overall average of 1 void per image per station (Table 3-1). Despite no evidence of low oxygen conditions or subsurface methane, most of the reference area stations had some evidence of Beggiatoa colonies (Table 3-1).

3.2.2 CLDS Mounds

Physical Sediment Characteristics

At the CLIS 07 and CLIS 08 mounds, the sediment was fine-grained dredged material, consisting of silt/clay with a grain size major mode of >4 phi (Table 3-2; Figures 3-15 and 3-16). A number of stations at the northern margin of the CLIS 08 mound (2, 7, and 8) had light-colored clayey silt distinct from the other stations at the mound (Figure 3-16). At the CLIS 09 mound, most of the dredged material also consisted of silt/clay, but very fine sand (major mode of 4 to 3 phi) occurred as a distinct sand-over-mud stratigraphy at stations 21, 23, 24, 25, 26, and 29 (Table 3-2; Figures 3-

15 and 3-16). These stations were grouped around the northern and eastern margins of the mound (Figure 3-15). Many of the stations at CLIS 09 had a distinct layering with very fine brown or gray sand on the surface, followed by alternating layers of gray, light brown and rust colored silt-clay (Figure 3-17). A group of stations on the west side of the mound (28, 30, 33, 34, 35) had light brown or gray clayey silt layers of varying thickness (Figure 3-17). In many cases, the very fine sand layer also had wood fibers well mixed into the sediment fabric (Figure 3-17). The fine-grained dredged material observed at the majority of stations was reduced, and there was evidence of subsurface methane in four of the stations (Table 3-2).

The means of replicate camera prism penetration depth varied slightly across the disposal site stations, ranging from 12.1 to 18.7 cm (Table 3-2). The stations located over the CLIS 07 mound tended to have consistently deep (>18 cm) penetration depths, reflecting the uniform presence of fine-grained dredged material (Figure 3-18). Over the CLIS 08 and CLIS 09 mounds, the dredged material was more variable in composition, with some stations with more sand and shells present and others with clay. The slightly firmer texture of these stations was reflected in the lower prism penetration values (generally ranging from 12 to 17 cm) observed at the CLIS 08 and CLIS 09 mound stations (Table 3-2; Figure 3-18).

The means of replicate small-scale boundary roughness ranged from 0.5 to 1.4 cm, with an overall site mean of 0.8 cm (Table 3-2). The origin of this small-scale topography was dominated by biological processes among the station replicates (Table 3-2). Physical roughness elements were caused by the presence of clay clumps at some of the stations with fine-grained dredged material, while biological roughness elements were due to features such as feeding pits, burrow openings, and fecal mounds.

Biological Conditions

The mean aRPD values at the stations within CLDS ranged from 1.0 to 3.7 cm, with an overall site average of 2.0 cm (Table 3-2, Figure 3-19). Mean aRPD values varied across the site without a particular pattern, but they were generally lower than reference area values (Figure 3-19).

At the CLIS 07 and CLIS 09 mounds, all of the replicate images except one showed evidence of Stage 3 infauna (Table 3-2, Figure 3-20). Evidence of Stage 3 organisms typically consisted of subsurface feeding voids, burrows, and large polychaete worms (Figure 3-21). Small tubes constructed by opportunistic Stage 1 organisms often were visible at the sediment surface along with the Stage 3 voids and burrows at depth, resulting in Stage 1 on 3 successional designations (Figure 3-22).

At the CLIS 08 mound, evidence of Stage 3 taxa was more sporadic, and there was greater variability among the replicate images compared to the CLIS 07 and CLIS 09 mounds (Table 3-3, Figure 3-20). Benthic succession at this mound appeared to be in an intermediate stage, with many of the replicate images showing evidence of a transition from Stage 1 to 2 or Stage 2 to 3 (Figure 3-23). The mean number of subsurface feeding voids at all mound stations ranged from 0 to 3, with an overall average of 1 void per image per station (Table 3-2).

Many of the replicates at the CLIS 07 and CLIS 08 mounds had trace evidence of incipient Beggiatoa colonies (Table 3-2; Figures 3-22, 3-24). One of the replicates at the CLIS 09 mound (28 A) also had evidence of Beggiatoa colonies (Table 3-2).

3.2.3 FVP Mound

Physical Sediment Characteristics

At the FVP mound, the sediment was fine-grained dredged material, consisting of silt/clay with a grain size major mode of >4 phi (Table 3-2; Figure 3-25). In general, stations from the mound had layers of reduced high organic-content silt-clay beneath the reworked surface layer (Figure 3-26) while the stations off the mound had evidence of dredged material but far less organic content (Figure 3-27). Some replicates on the crest of the FVP mound (3A, 4C, 10C) had very fine sand (4 to 3 phi) or coarse sand (0 phi) as a distinct sand-over-mud stratigraphy (Appendix C; Figure 3-26). Four stations (3, 4, 5, and 9) had replicates with clayey silt that contained distinctive colored fibers that may be wood or plant material (Figure 3-26). One replicate on the flank of the mound (15A) also had sand-over-mud stratigraphy with unusual characteristics: the coarser layer on the surface was reduced but deposited on a well-bioturbated horizon with a discontinuous patchy layer of reworked silt-clay and several large feeding voids (Figure 3-27). This station was located within a sedimentary furrow, but the other replicates from this station did not have the anomalous coarse reduced layer on the surface.

Three stations on the crest of the mound had means of replicate camera prism penetration depths of less than 15 cm (3, 4, and 10, Figure 3-28). These same stations had some fine sand over consolidated clayey silt (Figure 3-26). All other stations on or off the mound had mean penetration depths greater than 16 cm (Table 3-2).

The means of replicate small-scale boundary roughness ranged from 0.2 to 2.2 cm, with an overall site mean of 1.0 cm (Table 3-2). The origin of this small-scale topography was dominated by biological processes among the station replicates (Table 3-2). Physical roughness elements were caused by the presence of clay clumps from camera artifacts at three replicates, while biological roughness elements were due to features such as feeding pits, burrow openings, and fecal mounds (Appendix C).

Biological Conditions

The means of the replicate aRPD values at FVP ranged from 2.0 to 3.7 cm, with an overall site average of 2.9 cm (Table 3-2, Figure 3-29). Means of replicate aRPD values formed two groups, those less than 3 cm were clustered on the top of the mound and at two mound margin stations (11 and 15). The FVP aRPD values were generally very similar to reference area values (compare Tables 3-1 and 3-2).

At the FVP mound, all of the replicate images except one showed evidence of Stage 3 infauna being present (Table 3-2, Figure 3-30). Evidence of Stage 3 organisms typically consisted of subsurface feeding voids, burrows, and large polychaete worms while Stage 2 was evident in active burrowing within the aRPD (Figures 3-31 and 3-32). Small tubes constructed by opportunistic Stage 1 organisms were visible in a few replicates at the sediment surface along with the Stage 3 voids and burrows at depth, resulting in Stage 1 on 3 successional designations (Figure 3-33).

Most of the replicates at the FVP mound had trace evidence of incipient Beggiatoa colonies (Table 3-2; Figure 3-34). One replicate had methane bubbles at depth (Figure 3-35). The mean number of subsurface feeding voids at all FVP stations ranged from 0 to 2, with an overall average of 1 void per image per station (Table 3-2).

3.3 Statistical Comparisons of Mound and Reference Stations

A statistical comparison of mean aRPD and successional stage rank values by sampling location was conducted and is summarized below (Table 3-3 and Figure 3-36).

Mean aRPD Variable

The mean aRPD data from all seven groups (3 reference areas and 4 individual mounds) were combined to assess normality and estimate pooled variance. Results for the normality test indicated that the area residuals (i.e., each observation minus the area mean) were significantly different from normal (Shapiro-Wilk's test p-value = 0.03). Group standard deviations ranged from 0.3 to 0.8 with the smallest standard deviations occurring at the reference stations and FVP mound (Table 3-3). Due to failure of the normality test, bootstrap-t confidence intervals were used to determine results of the inequivalence test (Table 3-4).

When the confidence region for the difference between mean of reference areas and mound is fully contained within the interval [-1, +1], it can be concluded that the two means are significantly equivalent. The CLIS 07, CLIS 08, and CLIS 09 mounds all had significantly lower aRPD values than reference areas with differences in means ranging from 0.9 to 1.3 cm. The FVP mound was significantly equivalent to reference areas with a difference in means of approximately 0.25 cm (Figure 3-36).

Successional Stage Rank Variable

All but the CLIS 08 disposal mound consistently indicated successional stages at Stage 3 or equivalent. The successional stage rank for all reference areas was 3; the mean for each disposal area was also 3 with the exception of CLIS 08 which had a mean rank of 2.75. With identical means and zero variance, no statistics were needed for comparisons between reference areas and the FVP, CLIS 07, and CLIS 09 mounds in order to conclude statistical equivalence.

The rank variables are highly skewed (Figure 3-36), and so a bootstrap-t approach was used for comparisons between reference areas and the CLIS 08 mound (Table 3-5). On average the CLIS 08 mound mean was less than the reference areas by 0.25 rank (the difference between 3-retrograde and 3). The confidence region for the difference between reference areas and the CLIS 08 mound was fully contained within [-0.5, +0.5], so it can be concluded that they are statistically similar ($\hat{d}$ = 0.05). The FVP, CLIS 07, and CLIS 09 mounds were identical to reference areas, with no statistics needed.

Table 3-1.

Summary SPI Results (station means) at the CLDS Reference Areas

Area	Station	Depth (m)	Grain Size Major Mode (phi)	Mean Prism Penetration Depth (cm)	Mean Boundary Roughness (cm)	Dominant Type of Boundary Roughness	Mean aRPD Depth (cm)	Mean # of Subsurface Feeding Voids	Methane Present?	Beggiatoa Observed	Successional Stages Present		
CLIS REF	REF1	25	>4	16.6	0.5	Biological	3.1	0	No	Trace	2 on 3	2 on 3	2 on 3
	REF2	24.7	>4	17.5	0.7	Biological	3.7	3	No	Trace	2 on 3	2 on 3	2 on 3
	REF3	25	>4	17.3	0.7	Biological	3.2	0	No	Trace	2 on 3	2 on 3	2 on 3
	REF4	24.7	>4	17.8	1	Biological	3.3	2	No	Trace	2 on 3	2 on 3	3
	REF5	25	>4	16.6	0.6	Biological	2.9	1	No	Trace	2 on 3	2 on 3	2 on 3
	REF6	24.1	>4	17.5	1.3	Biological	3.7	1	No	Trace	1 on 3	2 on 3	2 on 3
2500W REF	2500W1	17.7	>4	20.1	0.9	Biological	3.2	2	No	Trace	2 on 3	2 on 3	2 on 3
	2500W2	17.7	>4	20	0.7	Biological	3.4	2	No	Trace	2 on 3	2 on 3	2 on 3
	2500W3	18	>4	19.5	0.6	Biological	3.4	2	No	No	2 on 3	2 on 3	2 on 3
	2500W4	17.7	>4	20.1	1.2	Biological	2.8	1	No	No	2 on 3	1 on 3	2 on 3
	2500W5	18	>4	19.9	0.7	Biological	2.6	1	No	Trace	2 on 3	2 on 3	2 on 3
	2500W6	18	>4	19.6	0.7	Biological	3.2	1	No	No	1 on 3	2 on 3	2 on 3
4500E REF	4500E1	20.1	>4	18.3	0.8	Biological	3.3	2	No	Trace	2 on 3	3	1 on 3
	4500E2	20.1	>4	16.2	0.4	Biological	3.4	2	No	No	2 on 3	2 on 3	3
	4500E3	20.4	>4	18.6	0.8	Biological	3.5	0	No	Trace	2 on 3	2 on 3	2 on 3
	4500E4	19.5	>4	16.9	0.6	Biological	2.2	2	No	Trace	1 on 3	2 on 3	1 on 3
	4500E5	20.4	>4	17.3	0.4	Biological	2.9	2	No	Trace	2 on 3	1 on 3	1 on 3
	4500E6	20.4	>4	17.9	0.9	Biological	3.1	1	No	Trace	2 on 3	2 on 3	2 on 3
	Maximum	25		20.1	1.3		3.7	3					
	Minimum	17.7		16.2	0.4		2.2	0					
	Mean	20.9		18.2	0.7		3.2	1					

Table 3-2.

Summary SPI Results (station means) at Disposal Mounds CLIS 07, CLIS 08, CLIS 09, and FVP within CLDS

Mound	Station	Depth (m)	Grain Size Major Mode (phi)	Mean Prism Penetration Depth (cm)	Mean Boundary Roughness (cm)	Dominant Type of Boundary Roughness	Mean aRPD Depth (cm)	Mean # of Subsurface Feeding Voids	Methane Present?	Beggiatoa Observed	Successional Stages Present		
CLIS 07	CLDS15	19.2	>4	18.4	0.6	Biological	2	2	No	Trace	1 on 3	1 on 3	1 on 3
	CLDS16	18	>4	18.7	0.6	Biological	3.7	1	No	Trace	1 on 3	1 on 3	1 on 3
	CLDS17	19.5	>4	18.4	0.6	Biological	1.7	1	No	Trace	2 -> 3	1 on 3	1 on 3
	CLDS18	19.2	>4	18.2	0.6	Biological	1.9	1	No	No	1 on 3	1 on 3	1 on 3
	CLDS19	18.3	>4	18.5	1	Biological	1.7	0	No	Trace	1 on 3	1 on 3	2 -> 3
	CLDS20	19.8	>4	18.2	0.5	Biological	2.5	0.7	No	Trace	1 on 3	1 on 3	1 on 3
CLIS 07	Maximum	19.8		18.7	0.6		3.7	2					
	Minimum	18		18.2	0.5		1.7	0					
	Mean	19		18.4	0.6		2.2	1					

Table 3-2 (continued)

Mound	Station	Depth (m)	Grain Size Major Mode (phi)	Mean Prism Penetration Depth (cm)	Mean Boundary Roughness (cm)	Dominant Type of Boundary Roughness	Mean aRPD Depth (cm)	Mean # of Subsurface Feeding Voids	Methane Present?	Beggiatoa Observed	Successional Stages Present		
CLIS 08	CLDS01	16.8	>4	16.3	0.6	Biological	1	0	No	No	2	1 -> 2	1 -> 2
	CLDS02	17.4	>4	14.3	0.8	Biological	1.4	1	No	No	2 -> 3	2 on 3	2 on 3
	CLDS03	16.5	>4	14.9	1	Biological	1.3	0	No	Trace	2	1 -> 2	1 -> 2
	CLDS04	16.8	>4	14.9	0.5	Biological	1.5	0	No	Trace	2 -> 3	2	1
	CLDS05	18.9	>4	17.1	0.6	Biological	3	0	No	No	2 -> 3	1 -> 2	1 -> 2
	CLDS06	16.8	>4	15.7	0.6	Biological	1.9	2	No	Trace	1 on 3	2 on 3	1 on 3
	CLDS07	17.7	>4	13.4	1.3	Biological	3.4	1	No	No	1 on 3	2 on 3	2 on 3
	CLDS08	16.8	>4	12.5	1.3	Biological	1.8	3	No	No	1 on 3	2 on 3	1 on 3
	CLDS09	17.7	>4	17.9	0.6	Biological	1.6	2	No	No	1	2 -> 3	2 on 3
	CLDS10	17.7	>4	16.3	0.5	Biological	1.5	1	No	Trace	2 on 3	2 on 3	2 on 3
	CLDS11	18	>4	16.2	0.6	Biological	2.1	1	No	Trace	1 on 3	1	1 on 3
	CLDS12	17.1	>4	17.7	0.5	Biological	1.5	0	Yes	Trace	1 on 3	2	2
	CLDS13	18.6	>4	17	0.5	Biological	2.5	1	No	Trace	1 -> 2	1 -> 2	1 on 3
	CLDS14	17.4	>4	17	1.2	Biological	1.1	0	Yes	Trace	2	1 -> 2	2 -> 3
CLIS 08	Maximum	18.9		17.9	1.3		3.4	3					
	Minimum	16.5		12.5	0.5		1	0					
	Mean	17.4		15.8	0.7		1.8	1					

Table 3-2 (continued)

Mound	Station	Depth (m)	Grain Size Major Mode (phi)	Mean Prism Penetration Depth (cm)	Mean Boundary Roughness (cm)	Dominant Type of Boundary Roughness	Mean aRPD Depth (cm)	Mean # of Subsurface Feeding Voids	Methane Present?	Beggiatoa Observed	Successional Stages Present		
CLIS 09	CLDS21	19.5	4-3/>4	12.1	0.9	Physical	1.5	0	No	No	1 on 3	2 on 3	1 on 3
	CLDS22	21.6	>4	16.4	0.6	Biological	1.8	1	No	No	1 on 3	1 on 3	1 on 3
	CLDS23	19.8	4-3/>4	13.1	0.8	Biological	2.6	0	No	No	1 on 3	1 on 3	1 on 3
	CLDS24	20.1	4-3/>4	14.2	0.8	Biological	3.1	0	No	No	2 -> 3	3	3
	CLDS25	18.3	4-3/>4	16.5	0.7	Biological	1.6	1	Yes	No	1 on 3	1 on 3	1 on 3
	CLDS26	20.4	4-3/>4	13.8	1.1	Biological	2.4	0	No	No	1 on 3	1 on 3	1 on 3
	CLDS27	21.6	>4	15.9	0.6	Biological	2.1	2	No	No	2 on 3	2 on 3	2 on 3
	CLDS28	19.5	>4	14.6	1.1	Biological	2.7	0	Yes	Trace	1 on 3	3	2 on 3
	CLDS29	21	4-3/>4	16.1	1.1	Biological	2	2	No	No	1 on 3	1 on 3	1 on 3
	CLDS30	19.8	>4	13.6	0.7	Biological	1.7	0	No	No	1 on 3	2 -> 3	1 on 3
	CLDS31	16.2	>4	18.5	0.7	Biological	3	0	No	No	1 on 3	Ind	1 on 3
	CLDS32	19.5	>4	17.3	0.9	Biological	3.3	1	No	No	1 on 3	1 on 3	1 on 3
	CLDS33	19.5	>4	14	1.4	Physical	1.5	1	No	No	2 on 3	2 on 3	2 on 3
	CLDS34	20.7	>4	13.3	1.4	Biological	1.5	1	No	No	1 on 3	3	1 on 3
	CLDS35	19.8	>4	15.5	0.7	Physical	1.6	1	No	No	1 on 3	1 on 3	1 on 3
CLIS 09	Maximum	21.6		18.5	1.4		3.3	2					
	Minimum	16.2		12.1	0.6		1.5	0					
	Mean	19.8		15	0.9		2.2	1					
All CLIS Mounds	Maximum	21.6		18.7	1.4		3.7	3					
	Minimum	16.2		12.1	0.5		1	0					
	Mean	18.7		16	0.8		2.1	1					

Table 3-2 (continued)

Mound	Station	Depth (m)	Grain Size Major Mode (phi)	Mean Prism Penetration Depth (cm)	Mean Boundary Roughness (cm)	Dominant Type of Boundary Roughness	Mean aRPD Depth (cm)	Mean # of Subsurface Feeding Voids	Methane Present?	Beggiatoa Observed	Successional Stages Present		
FVP	FVP01	19.2	>4	16.6	0.4	Biological	3	2	No	Trace	1 on 3	1 on 3	1 on 3
	FVP02	19.2	>4	17.8	1.4	Biological	3.1	1	No	No	1 on 3	1 on 3	1 on 3
	FVP03	18.9	>4	14.2	1.7	Biological	2.7	2	No	No	3	1 on 3	3
	FVP04	18.9	>4	14.7	0.9	Biological	2.7	1	No	Trace	1 on 3	1 on 3	1 on 3
	FVP05	18.9	>4	16	1.4	Biological	2.9	1	Yes	Trace	2 on 3	2 on 3	2 on 3
	FVP06	18.9	>4	16.2	0.7	Biological	3.7	1	No	Trace	2	2 on 3	2 on 3
	FVP07	19.2	>4	16.4	0.2	Biological	3.7	1	No	Trace	2 on 3	2 on 3	2 on 3
	FVP08	19.2	>4	16.5	0.5	Biological	3.1	2	No	No	2 on 3	2 on 3	2 on 3
	FVP09	18.9	>4	16	0.6	Biological	2.8	0	No	Trace	2 on 3	2 -> 3	2 on 3
	FVP10	18.6	>4	13.8	1.3	Biological	2	1	No	Trace	2 on 3	2 on 3	1 on 3
	FVP11	19.2	>4	18.3	2.2	Physical	2.1	2	No	No	2 on 3	3	2 on 3
	FVP12	18.9	>4	16.9	0.5	Biological	3.3	2	No	Trace	2 on 3	2 on 3	2 on 3
	FVP13	19.8	>4	17.4	0.7	Biological	3.2	0	No	Trace	2 on 3	2 on 3	1 on 3
	FVP14	18.6	>4	17.4	0.7	Biological	3	1	No	Trace	1 on 3	2 on 3	2 on 3
	FVP15	19.8	>4	19.1	1	Biological	2.3	2	No	No	1 on 3	2 on 3	2 on 3
FVP	Maximum	19.8		19.1	2.2		3.7	2					
	Minimum	18.6		13.8	0.2		2	0					
	Mean	19.1		16.5	1		2.9	1					

Table 3-3.

Summary of Station Means by Sampling Location

Site	N	Mean RPD (cm)		Successional Stage Rank		Number of Feeding Voids	
		Mean	Standard Deviation	Mean	Standard Deviation	Mean	Standard Deviation
Reference Areas							
CLIS REF	6	3.3	0.3	3	0	1.2	1.2
4500E REF	6	3.1	0.5	3	0	1.5	0.8
2500W REF	6	3.1	0.3	3	0	1.5	0.5
Mean		3.2		3		1.4	
Disposal Mounds							
2007	6	2.3	0.8	3	0	1.0	0.6
2008	14	1.8	0.7	2.8	0.4	0.9	0.9
2009	15	2.2	0.6	3	0	0.7	0.7
FVP	15	2.9	0.5	3	0	1.3	0.9
Mean		2.3		2.9		0.9	

Table 3-4.

Summary Statistics and Results of Inequivalence Hypothesis Testing for aRPD Values

Difference Equation	Observed Difference ($\hat{d}$)	SE ($\hat{d}$)	df for SE ($\hat{d}$)	95% Confidence Bounds (lower–upper)	Results
$Mean_{REF}$ – $Mean_{2007}$	0.91	0.33	20	0.5–2.2	d
$Mean_{REF}$ – $Mean_{2008}$	1.3	0.20	28	1.0–1.8	d
$Mean_{REF}$ – $Mean_{2009}$	1.0	0.18	29	0.7–1.3	d
$Mean_{REF}$ – $Mean_{FVP}$	0.25	0.15	29	-0.01–0.5	s

d = Fail to reject the inequivalence hypothesis: the two group means are significantly different
s = Reject the inequivalence hypothesis: the two group means are significantly similar

Difference Equation represents difference between pooled aRPD values for reference areas and individual disposal mounds

Table 3-5.

Summary Statistics and Results of Inequivalence Hypothesis Testing for Successional Stage Values

Difference Equation	Observed Difference ($\hat{d}$)	SE ($\hat{d}$)	df for SE ($\hat{d}$)	95% Confidence Bounds (lower–upper)	Results
$Mean_{REF} - Mean_{2007}$	0.00	0.00	n/a	0.00–0.00	s
$Mean_{REF} - Mean_{2008}$	0.25	0.10	28	-0.13–0.48	s
$Mean_{REF} - Mean_{2009}$	0.00	0.00	n/a	0.00–0.00	s
$Mean_{REF} - Mean_{FVP}$	0.00	0.00	n/a	0.00–0.00	s

d = Fail to reject the inequivalence hypothesis: the two group means are significantly different
s = Reject the inequivalence hypothesis: the two group means are significantly similar

Difference Equation represents difference between pooled Succesional Stage values for reference areas and individual disposal mounds

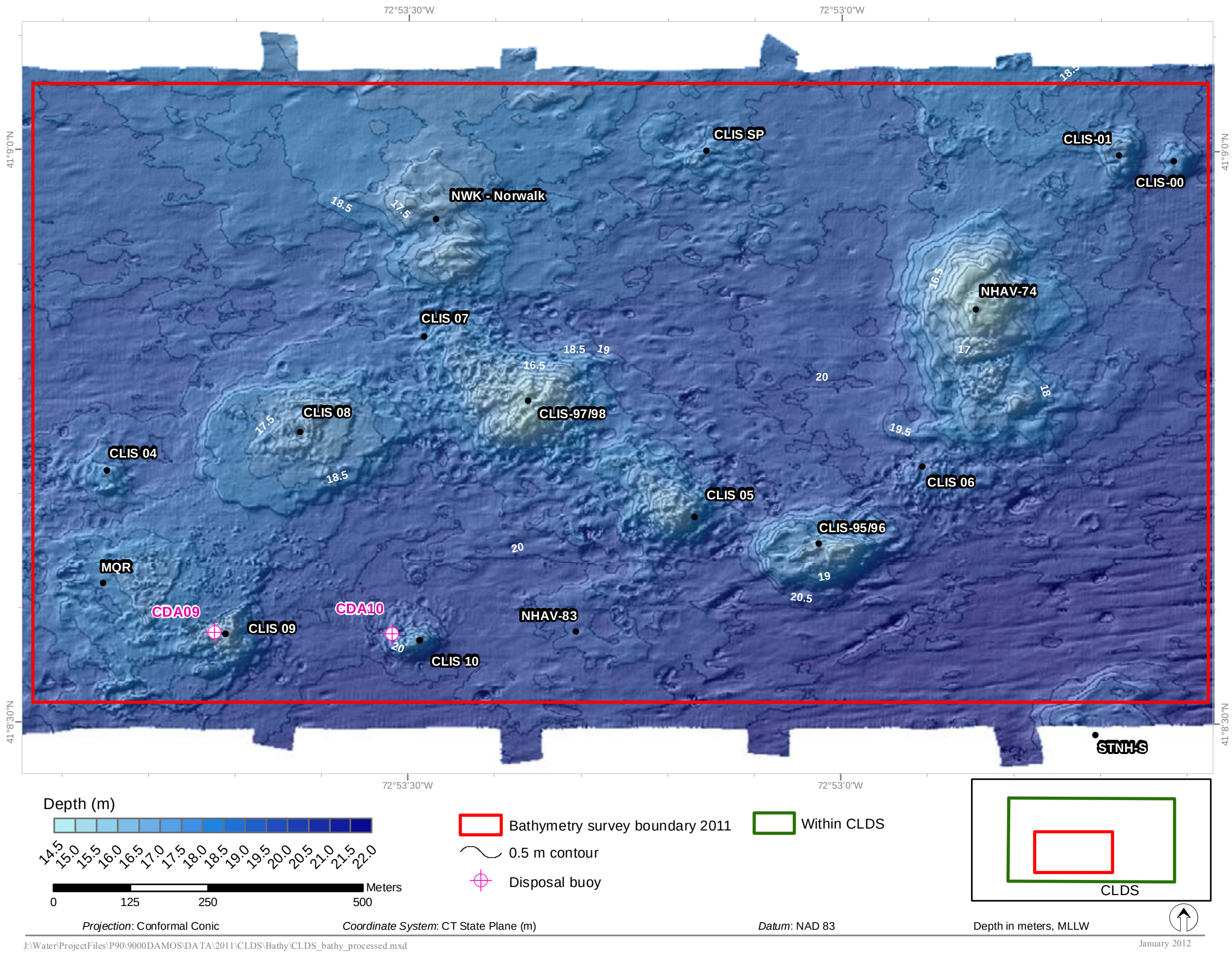


Figure 3-1. Bathymetry of CLDS, September 2011

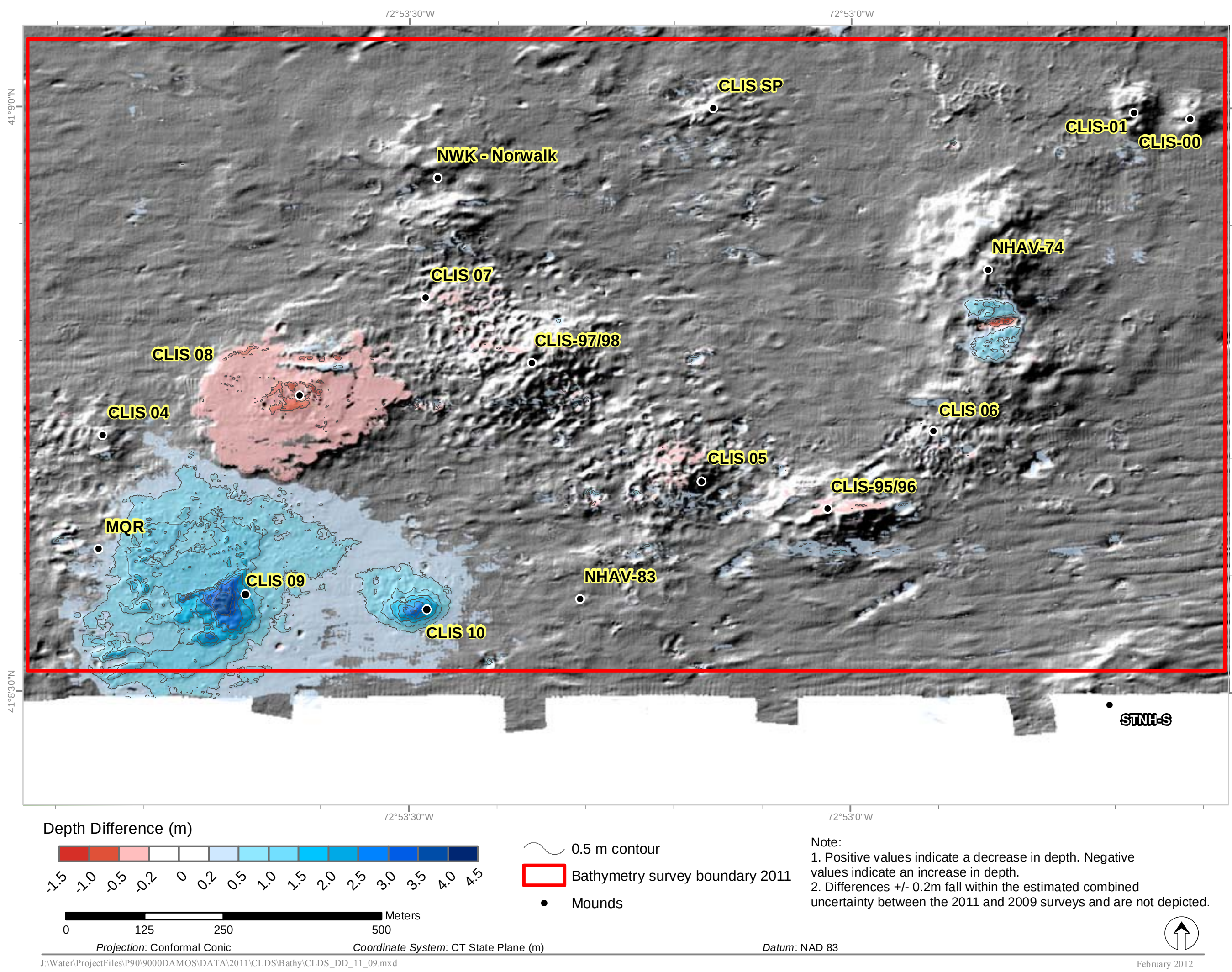


Figure 3-2. Depth difference contour map of south-central portion of CLDS, 2011–2009 (0.5 m contour interval)

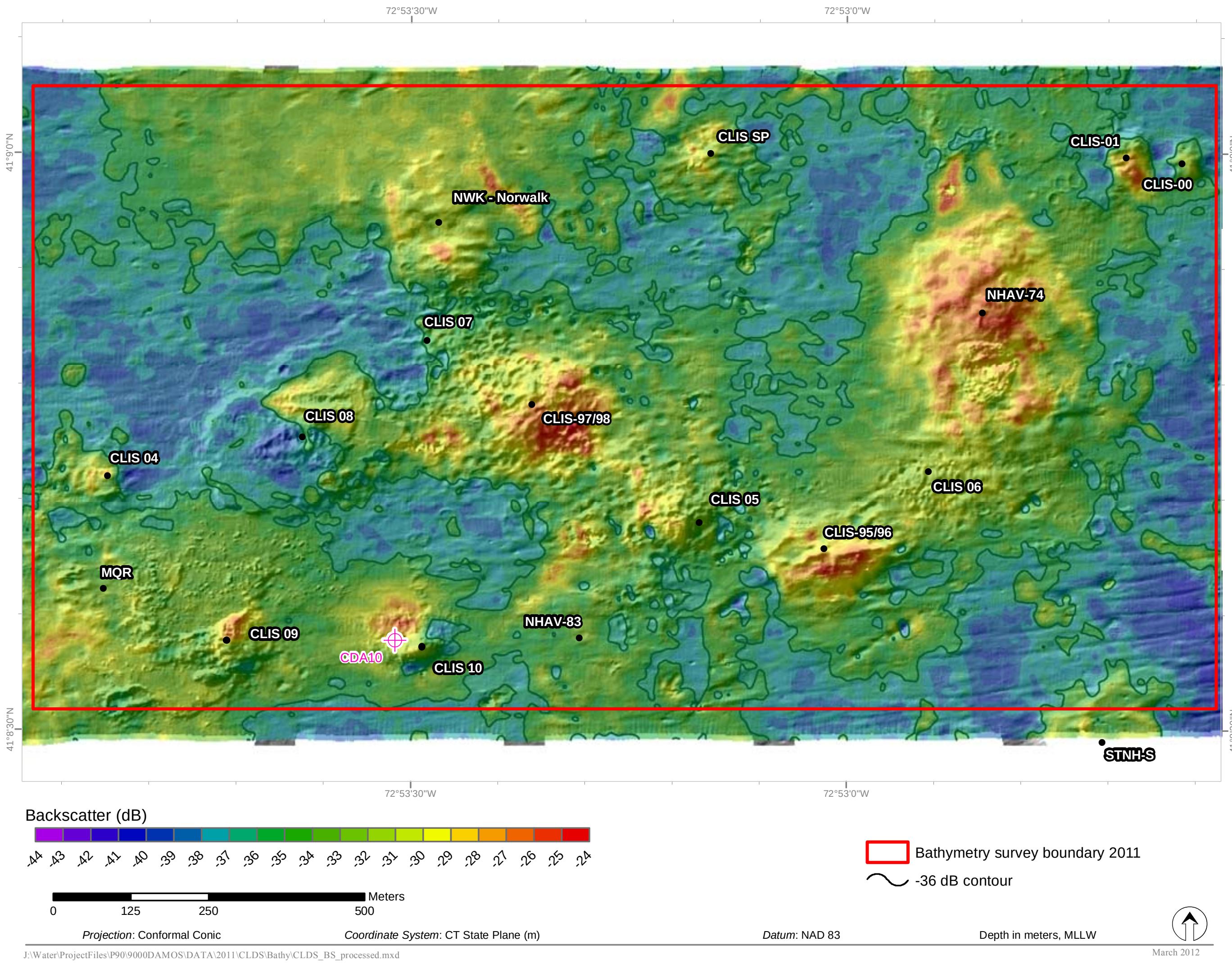


Figure 3-3. Backscatter intensity (dB) at CLDS, September 2011

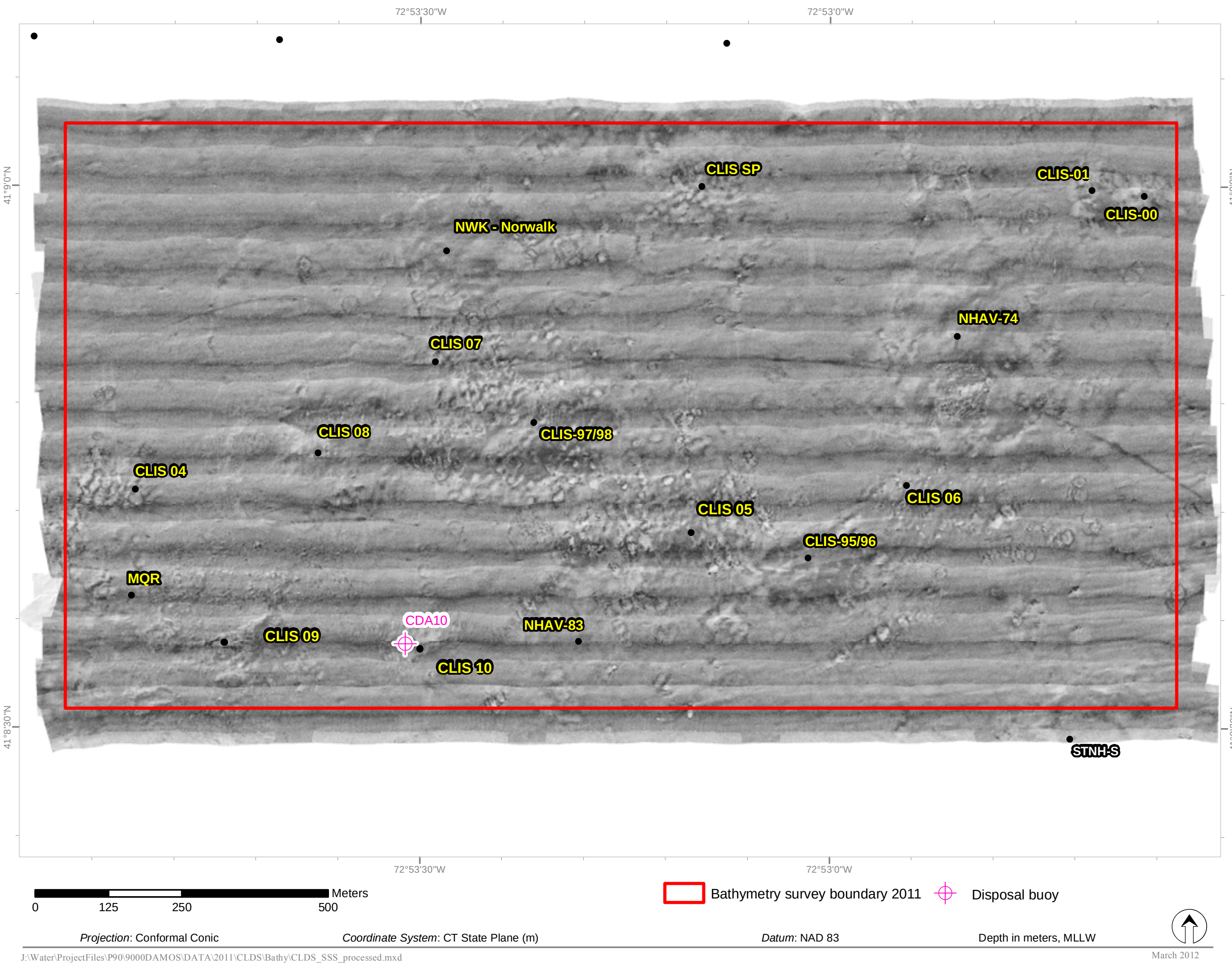


Figure 3-4. Side-scan sonar mosaic of the CLDS survey area, 2011

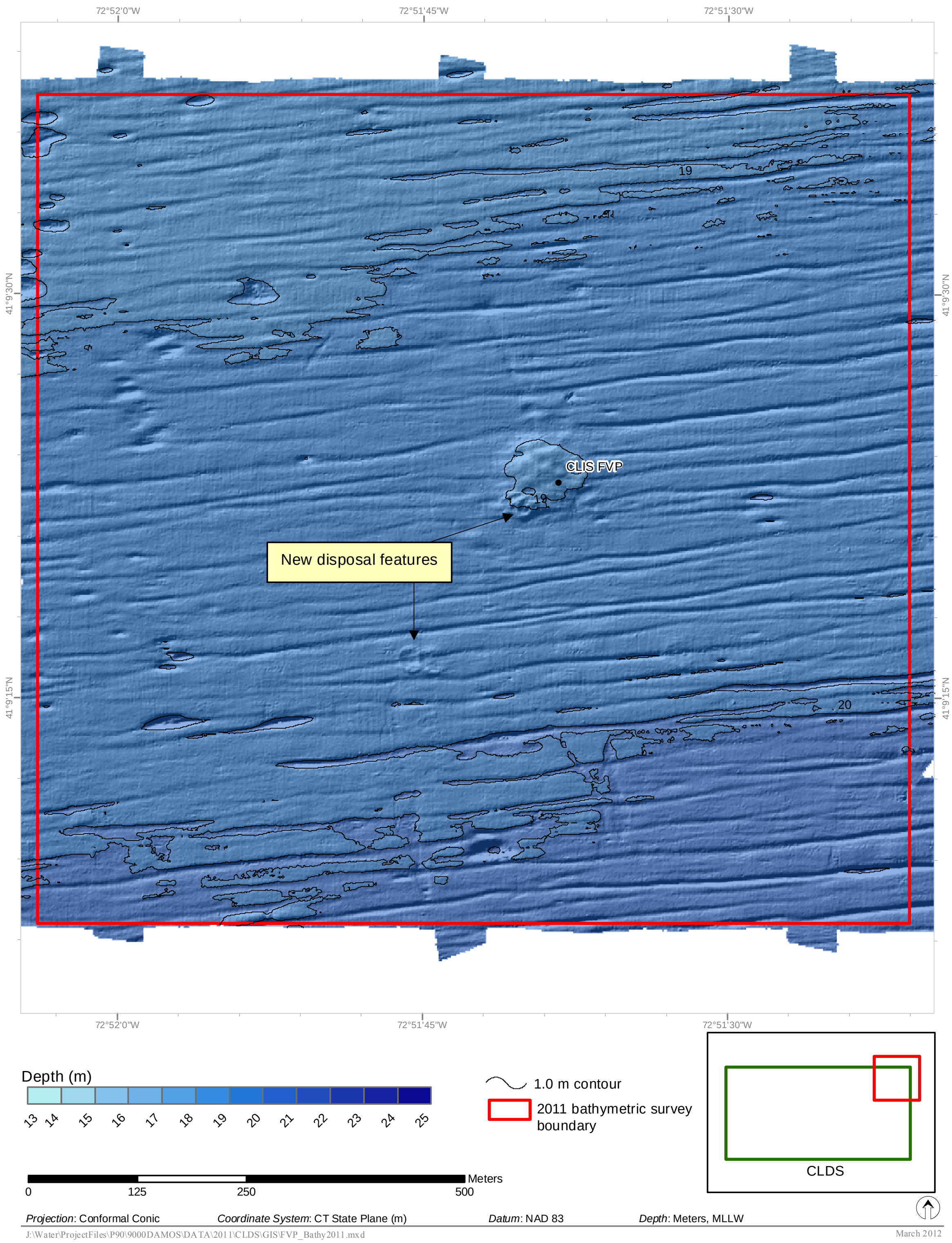


Figure 3-5. Bathymetry of the FVP mound, 2011

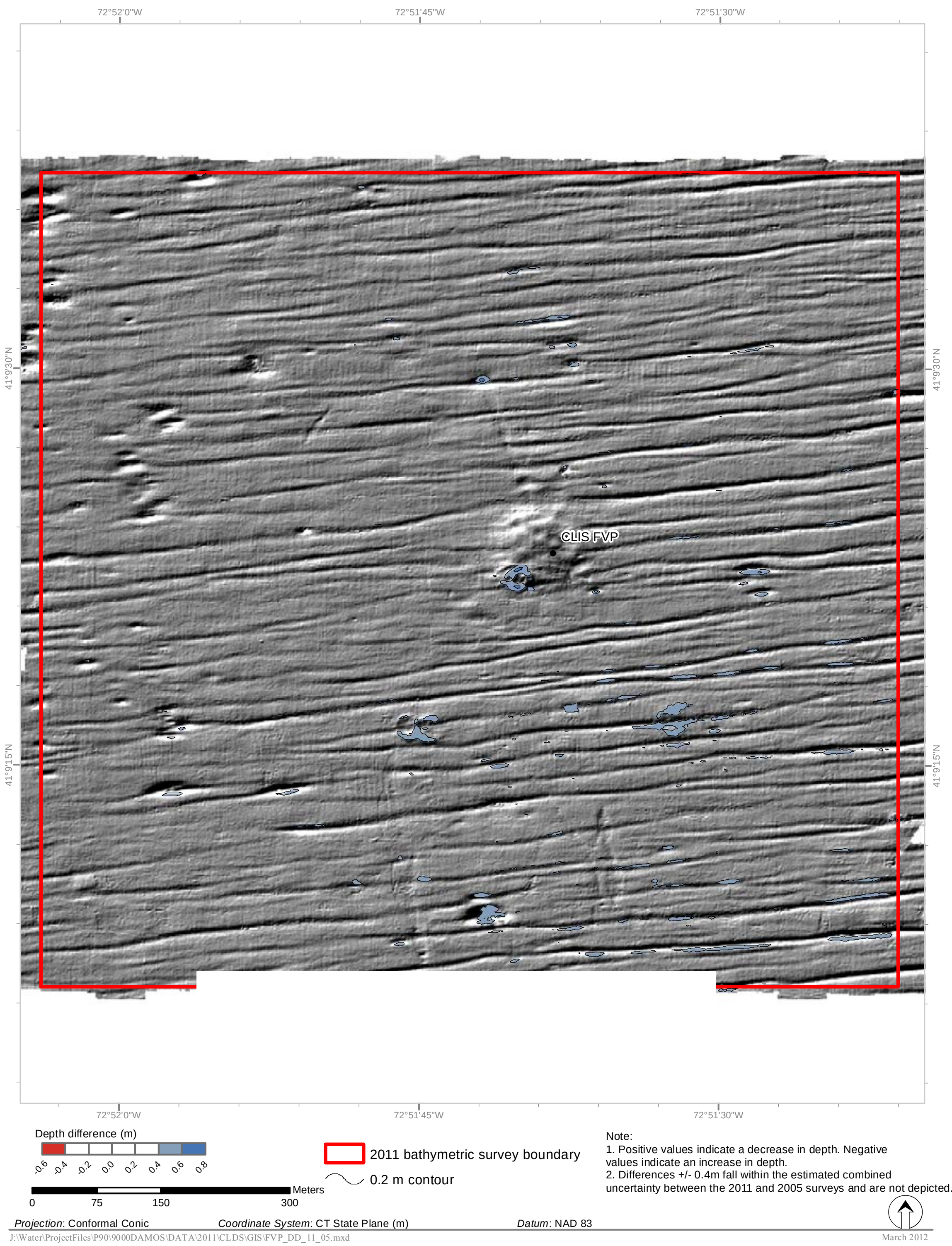


Figure 3-6. Depth difference contour map of FVP mound, 2005–2011 (0.2 m contour interval)

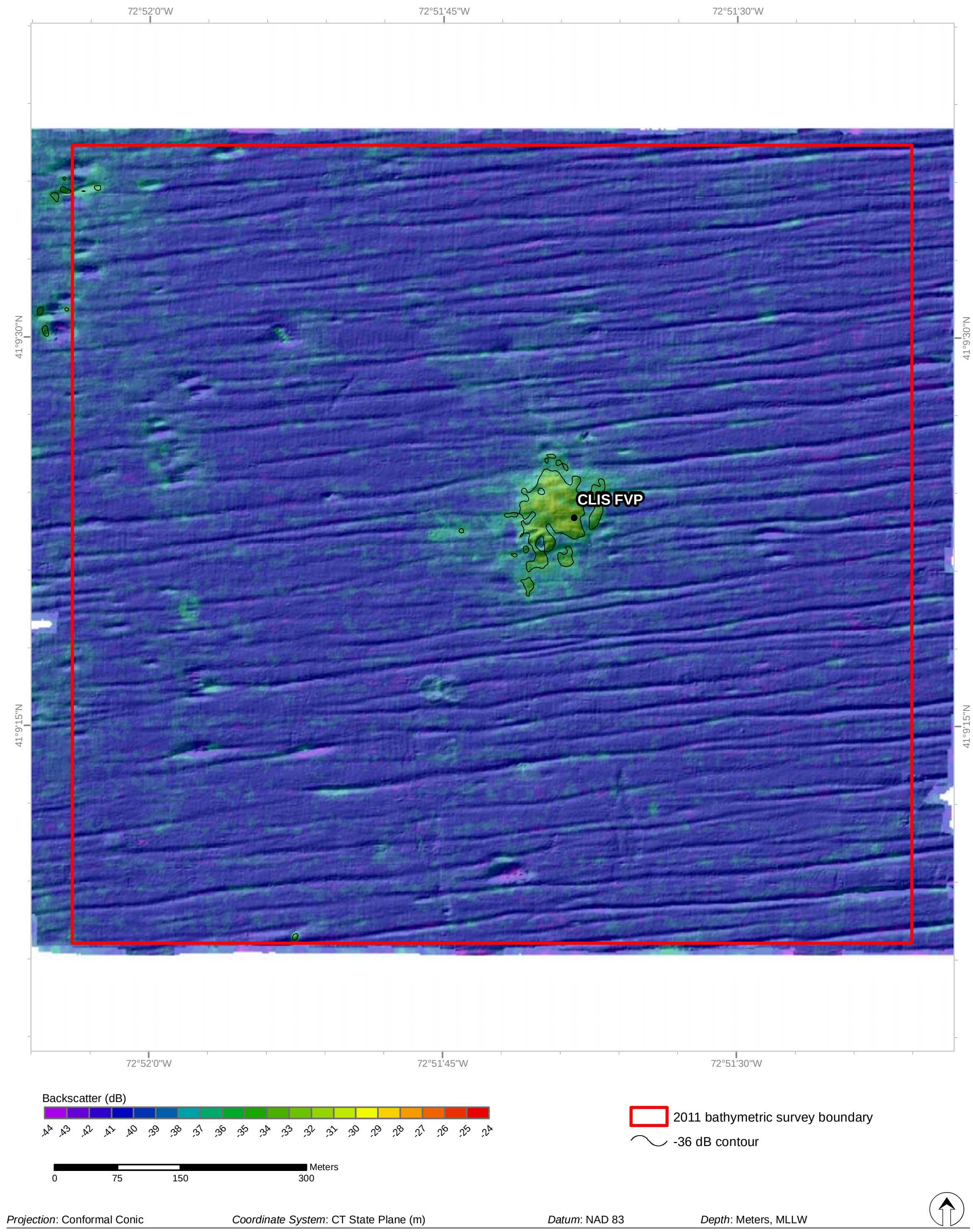


Figure 3-7. Backscatter intensity (dB) of the FVP mound, 2011

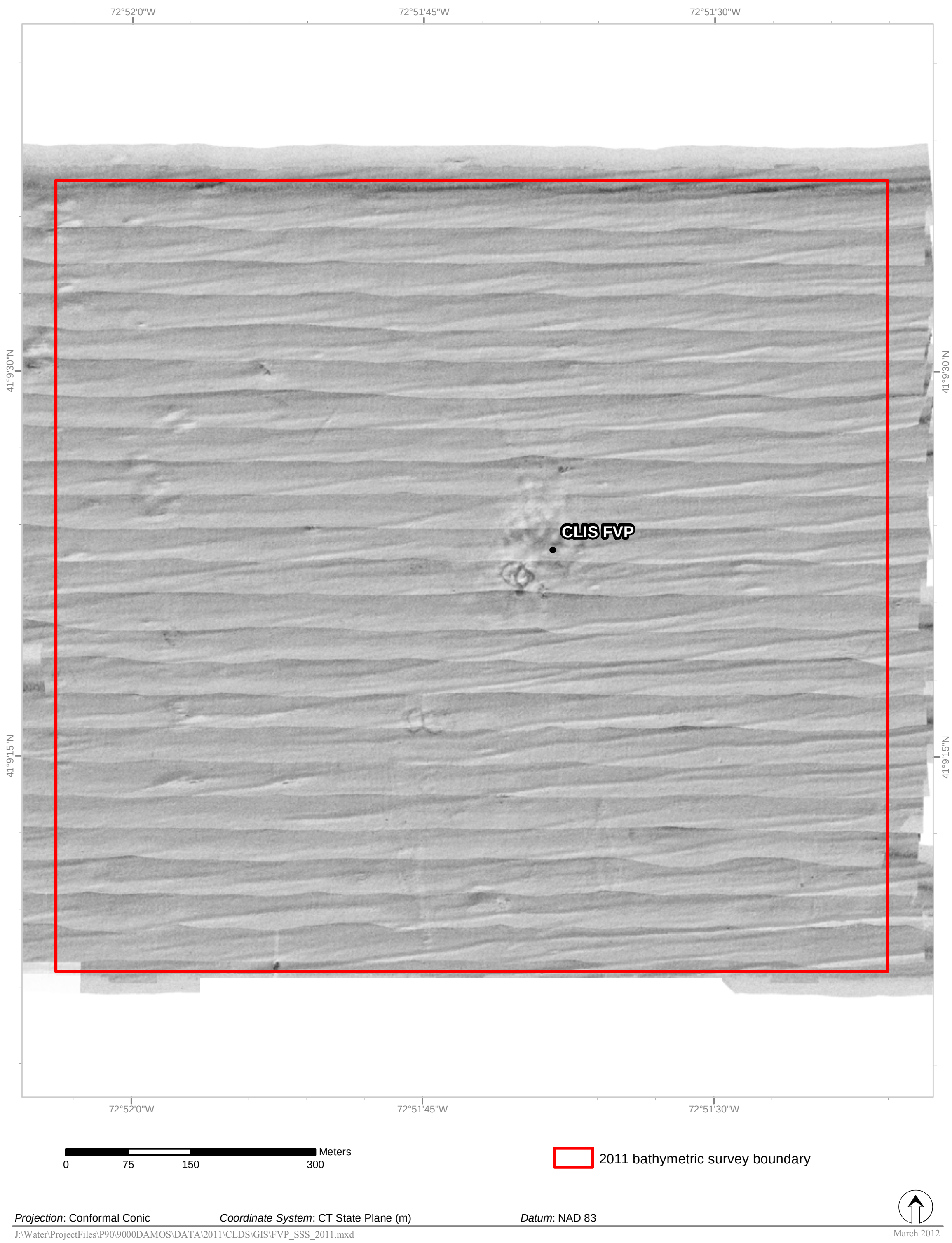


Figure 3-8. Side-scan sonar mosaic of the FVP mound, 2011

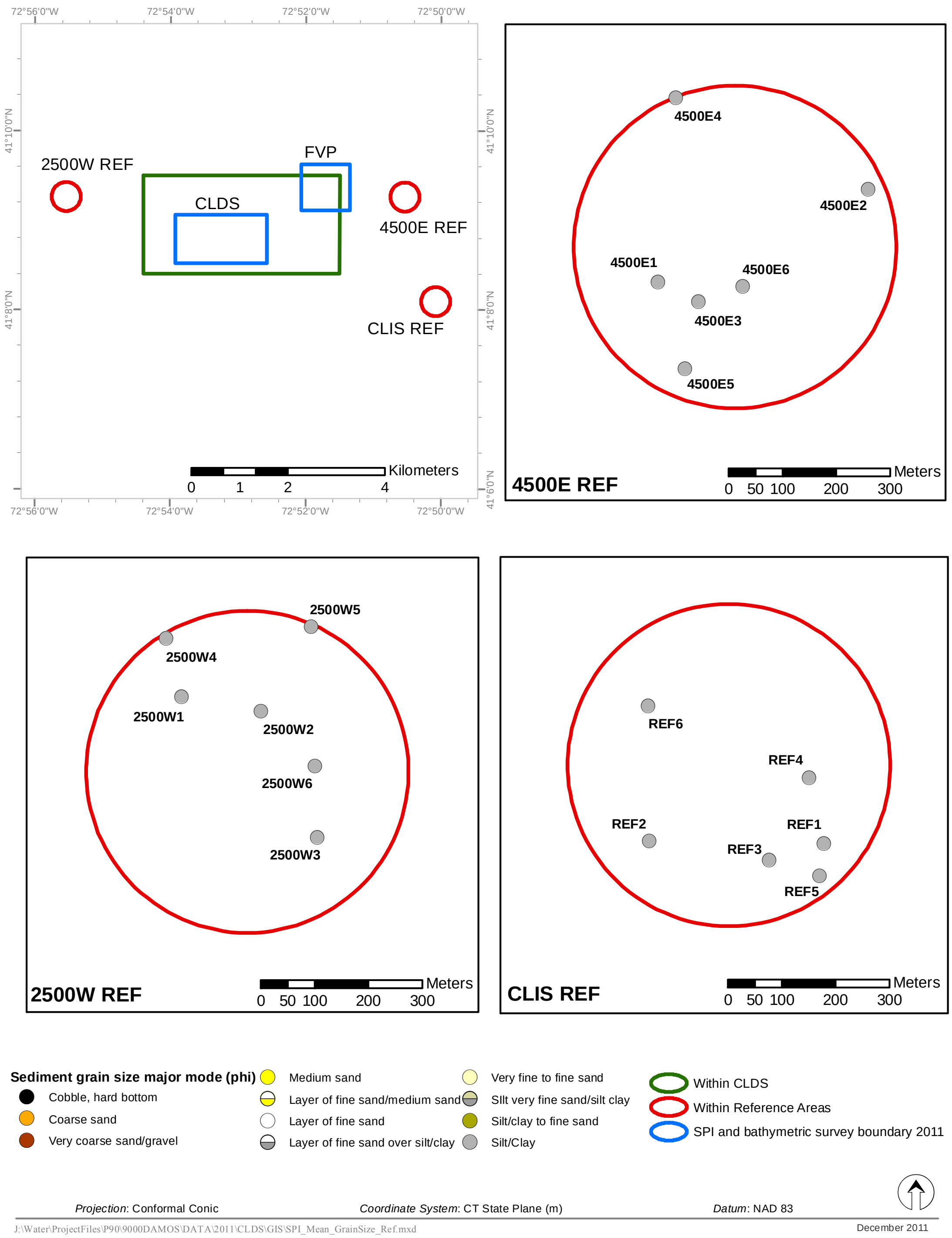


Figure 3-9. Grain size major mode (in phi units) at the reference area SPI stations

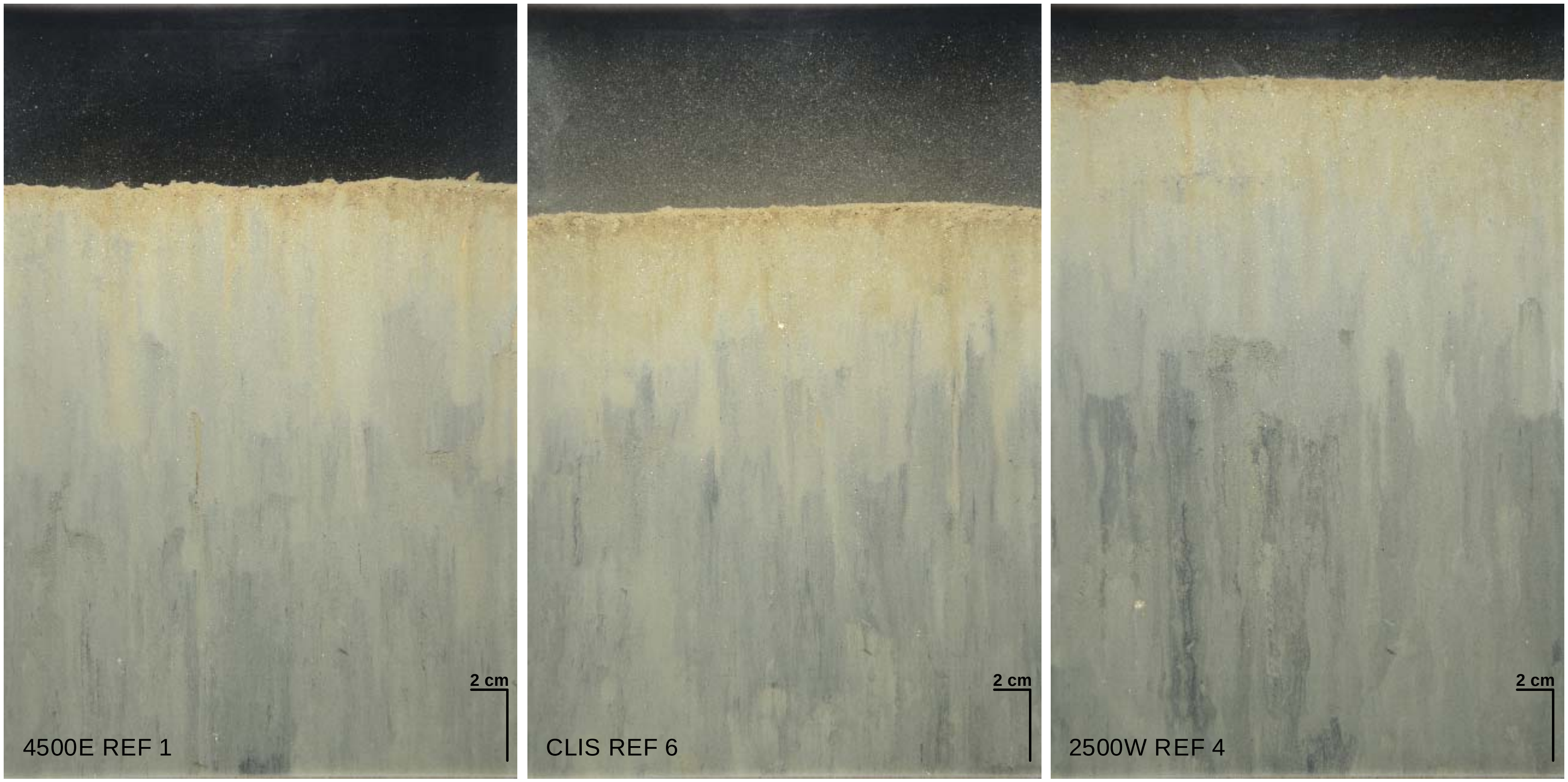


Figure 3-10. Representative profile images illustrating the soft, homogenous mud that characterized each of the three reference areas.

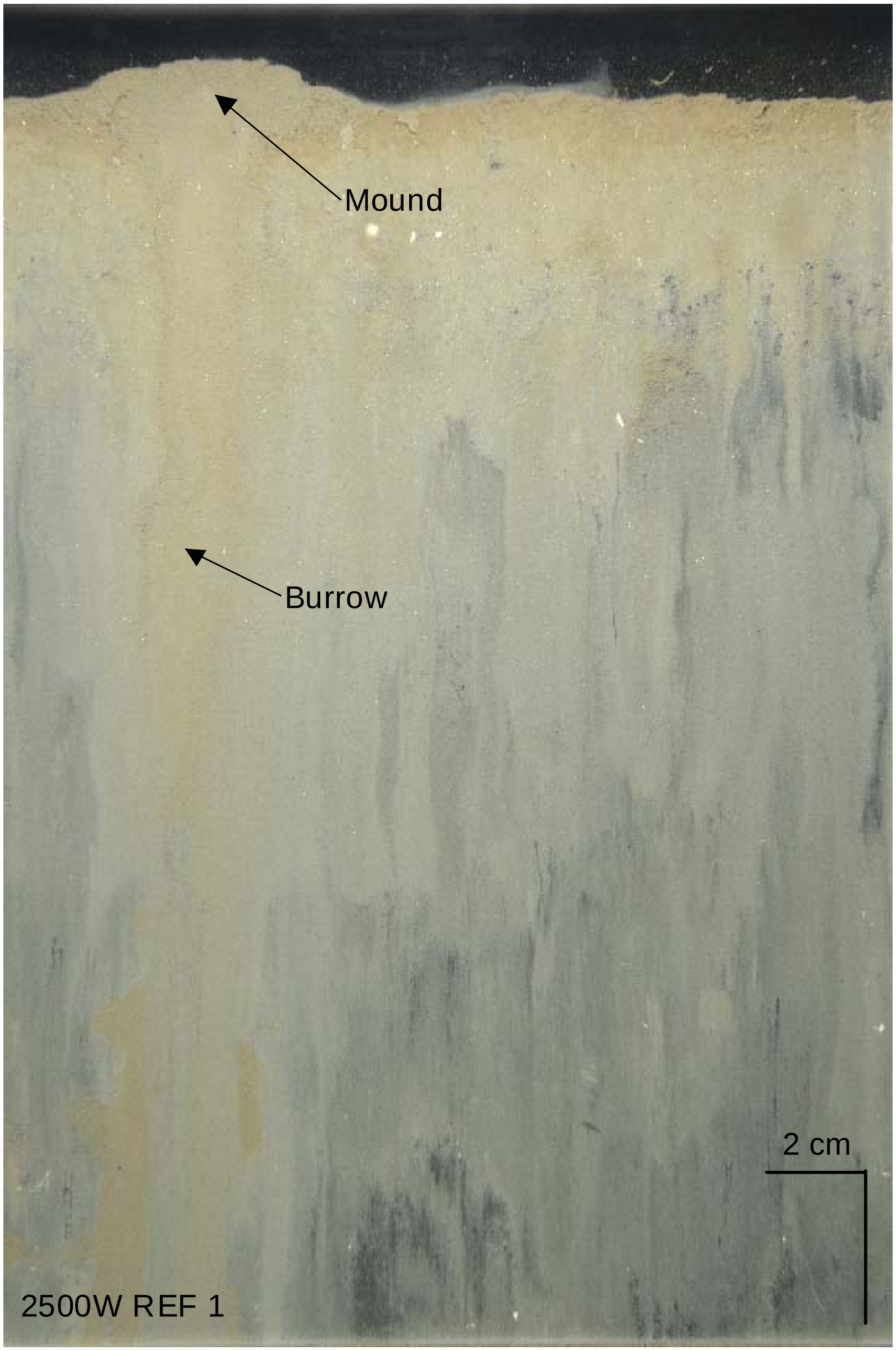


Figure 3-11. Profile image from 2500W REF station 1 showing a large subsurface burrow that culminates in a small mound at the sediment-water interface. This is an example of biological surface roughness.

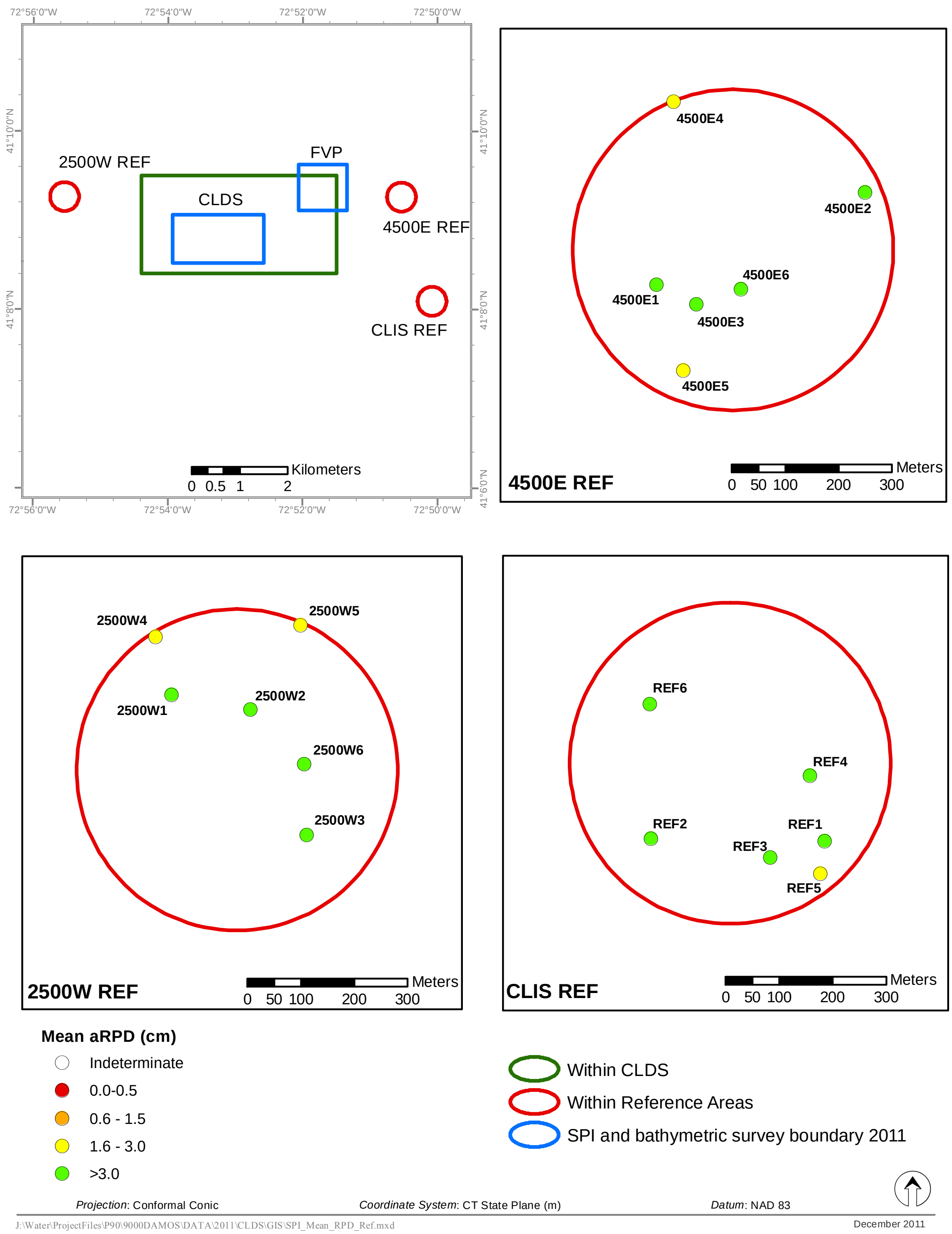


Figure 3-12. aRPD at the reference area SPI stations

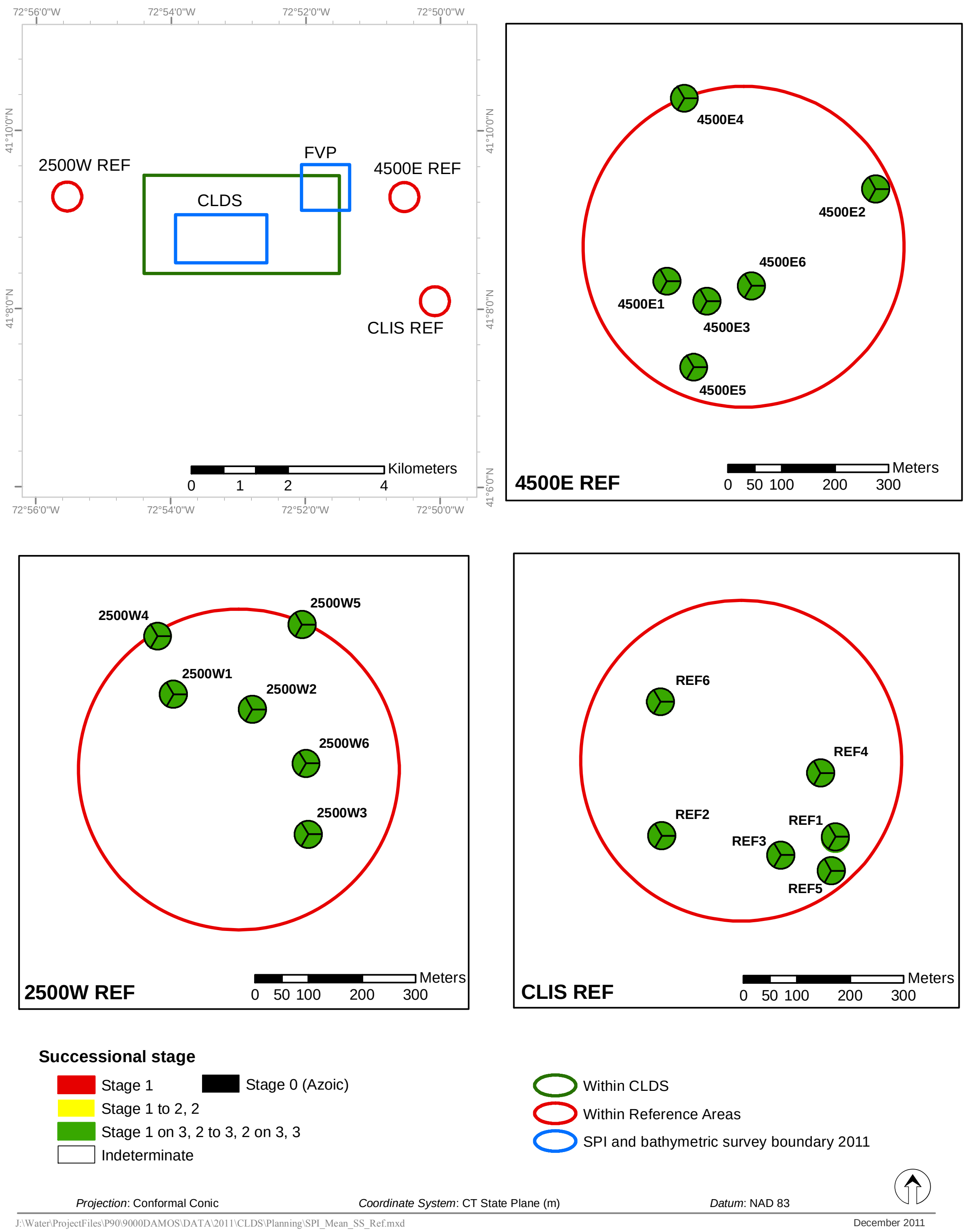


Figure 3-13. Successional Stage at the reference area SPI stations

Figure 3-14. Representative profile images from the reference areas showing evidence of Stage 3 infauna in the form of a large worm (left image), a prominent vertical burrow (center image), and multiple subsurface feeding voids (left and right image). Small tubes on surface indicate presence of Stage 1 infauna on Stage 3 (right image).

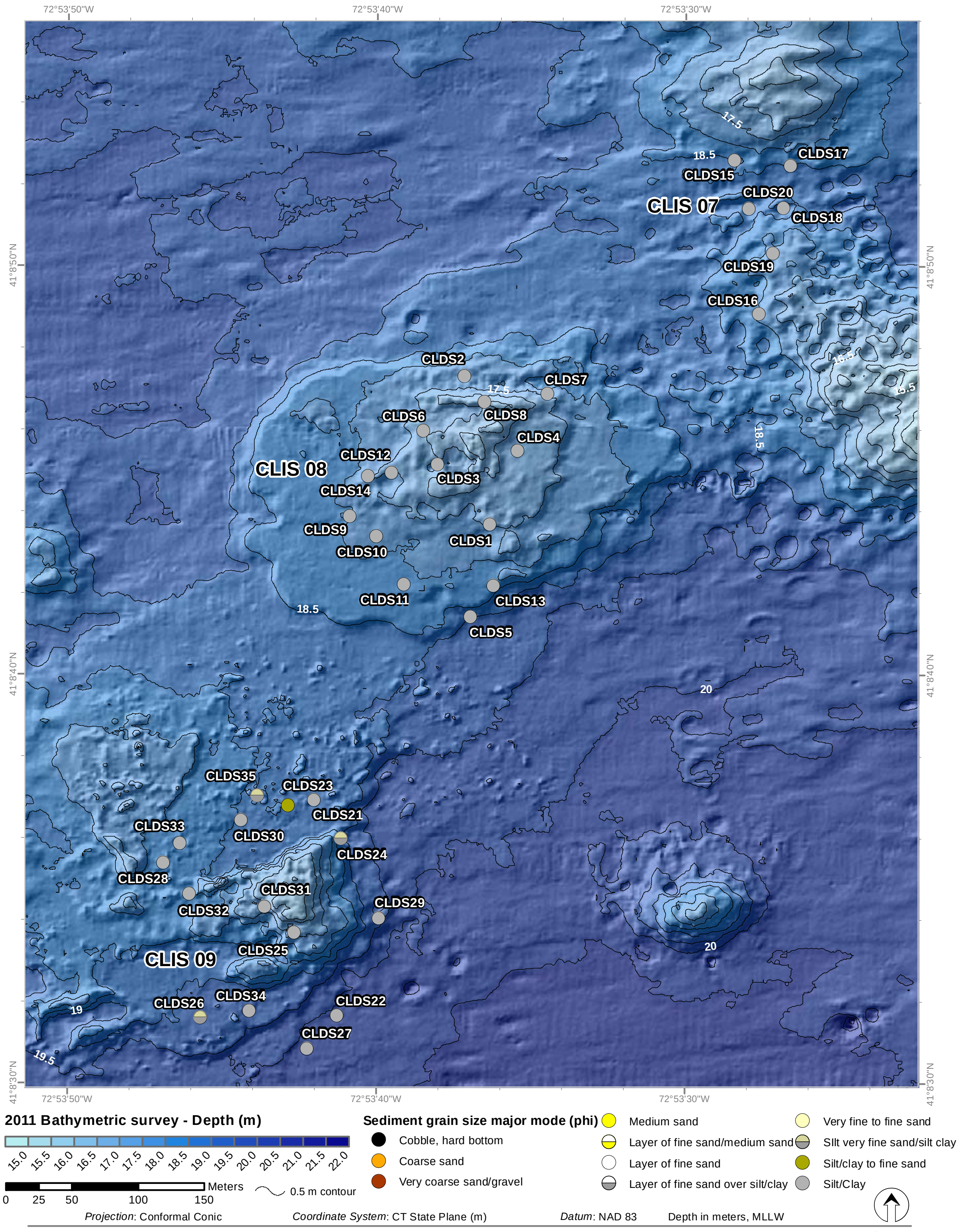


Figure 3-15. Grain size major mode at CLDS

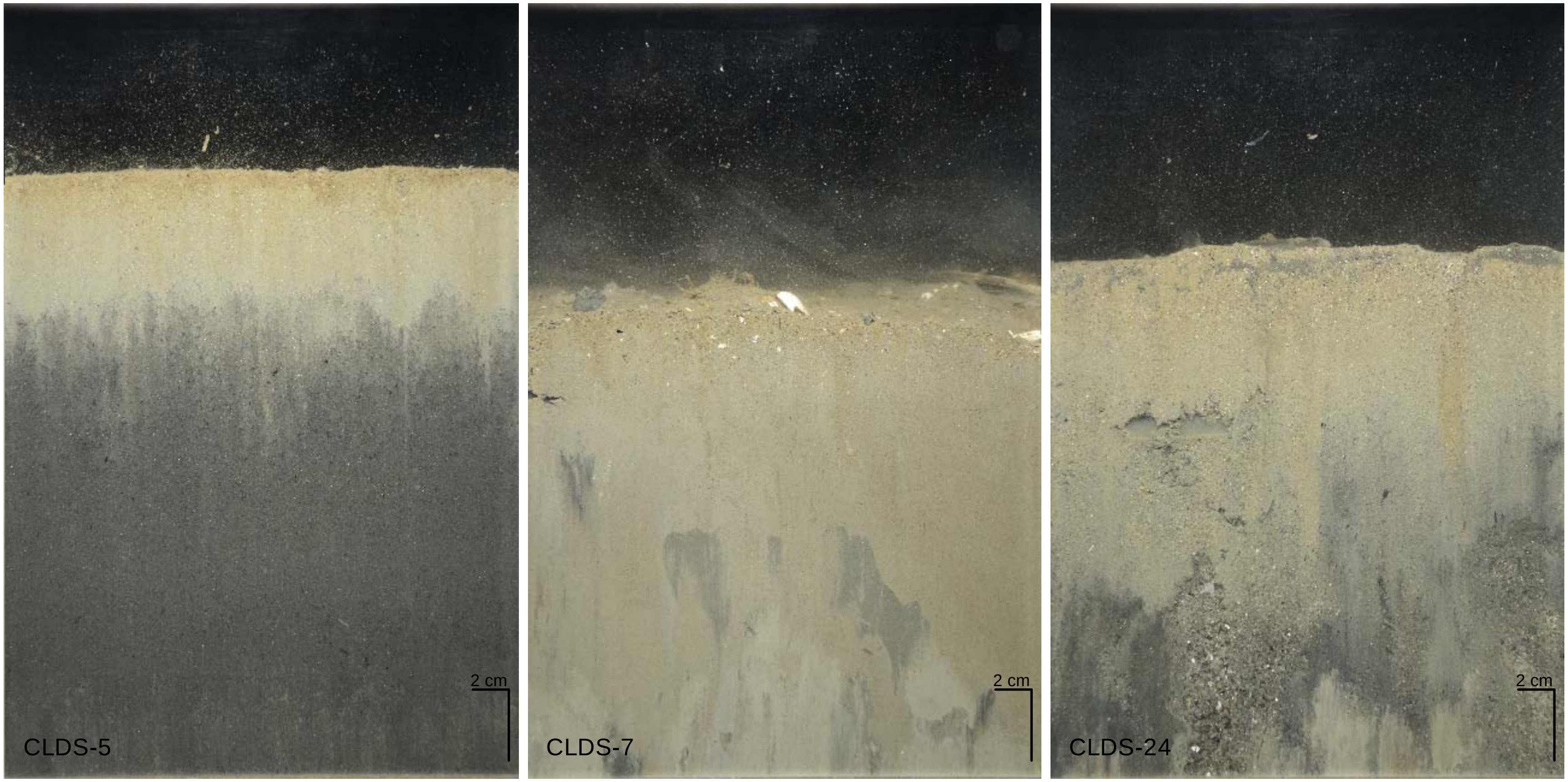


Figure 3-16. Representative profile images from the dredged material placement mounds showing silt-clay deposits at mound CLIS 08 (left image), clay deposits at northern margin of mound CLIS 08 (middle image), and very fine sand layer over silt-clay mixed with coarse sand and silt at mound CLIS 09 (right image).

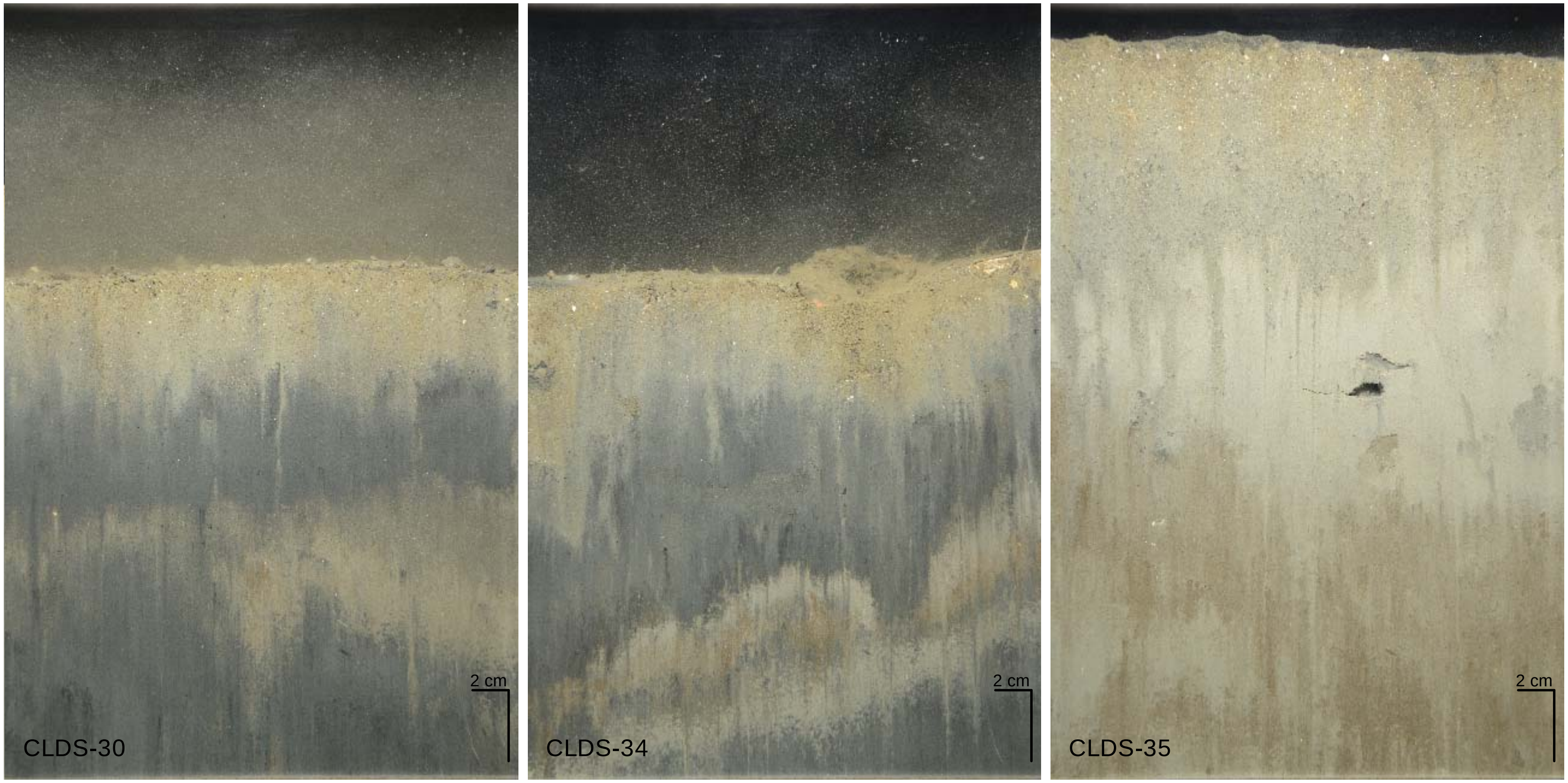


Figure 3-17. Representative profile images from the dredged material placement mound CLIS 09 showing multiple depositional horizons (left and middle image) and very fine sand layer with wood fibers over light colored clayey silt (right image).

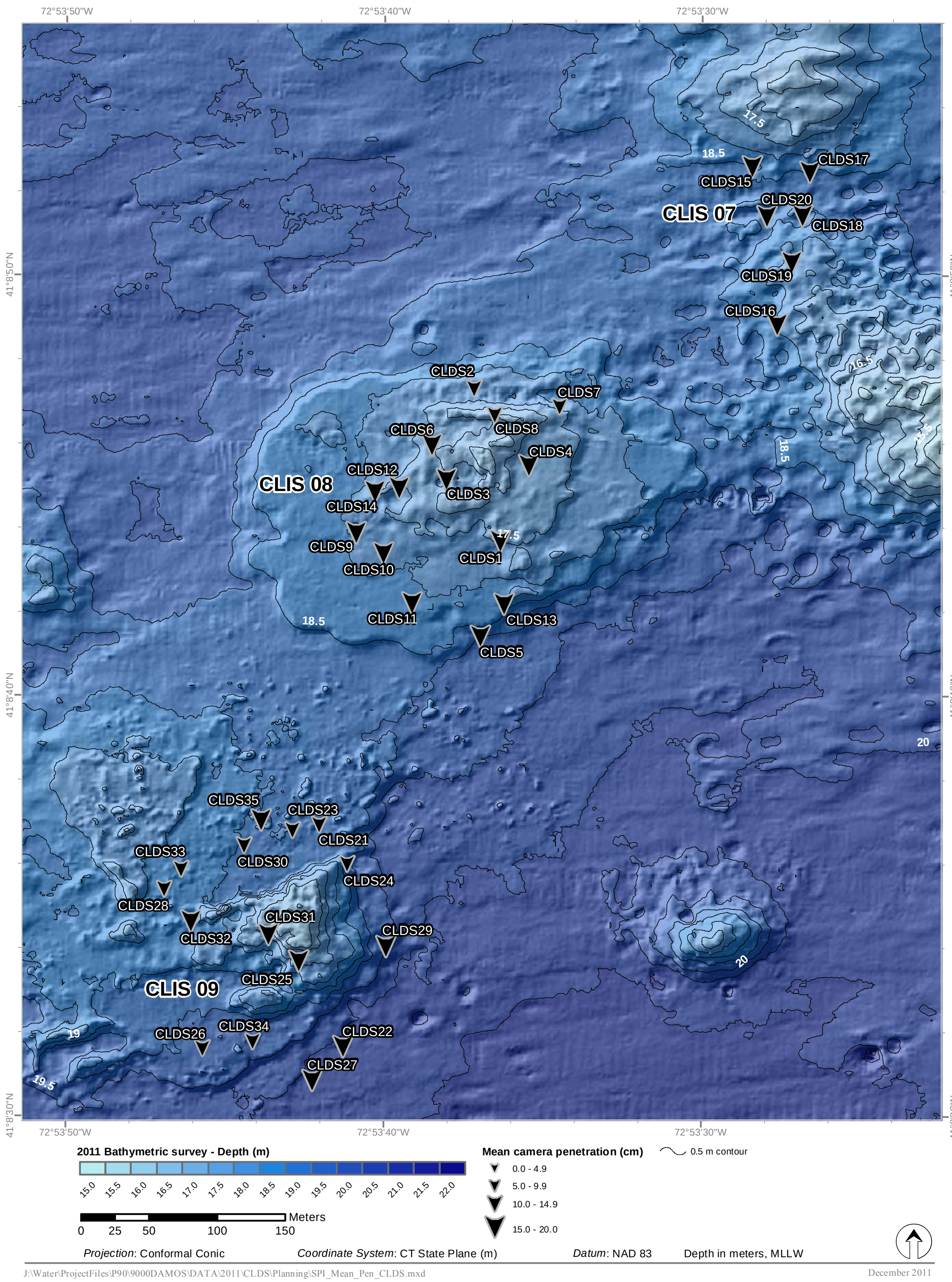


Figure 3-18. Mean camera penetration at CLDS

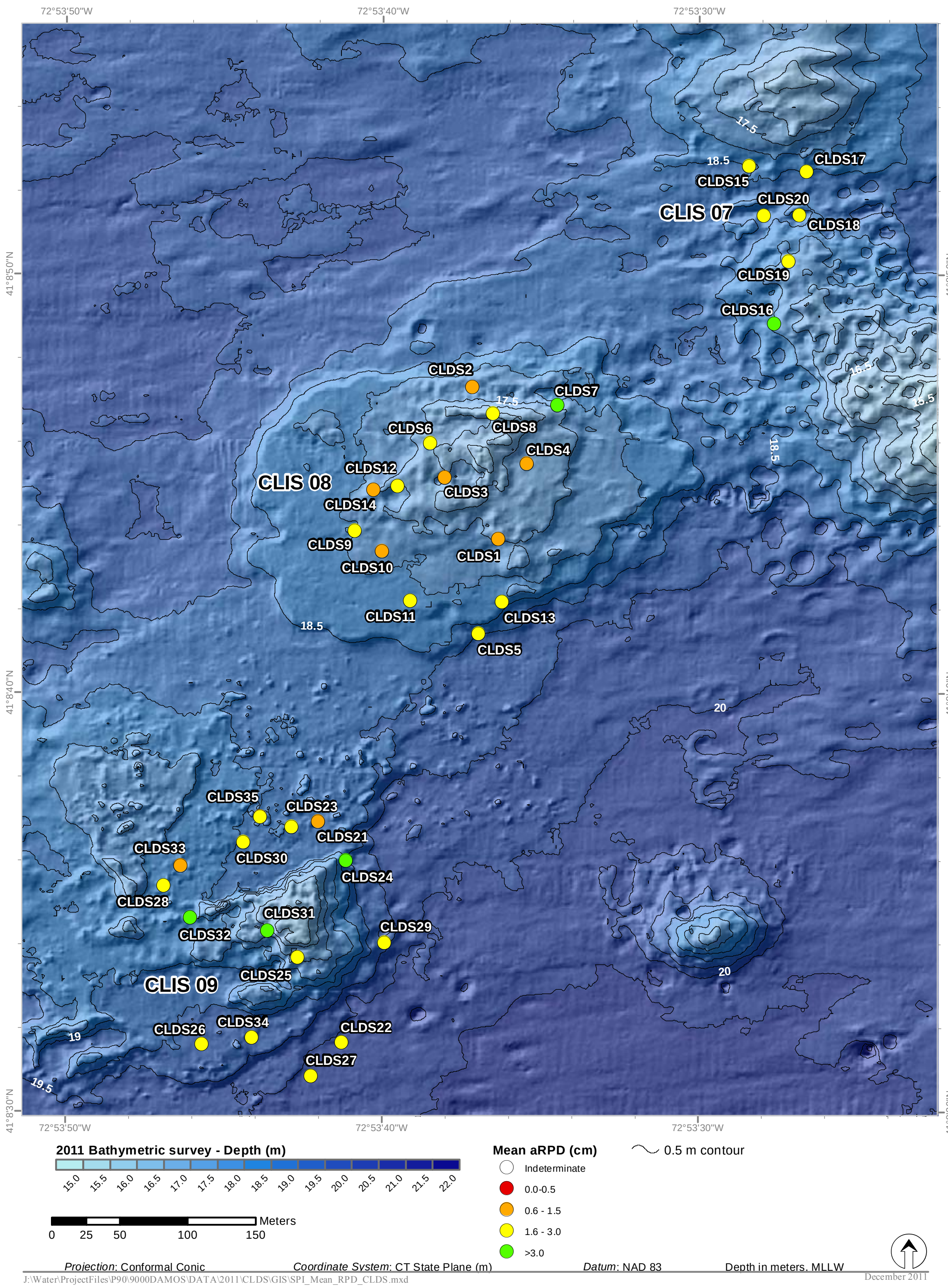


Figure 3-19. Mean aRPD at CLDS

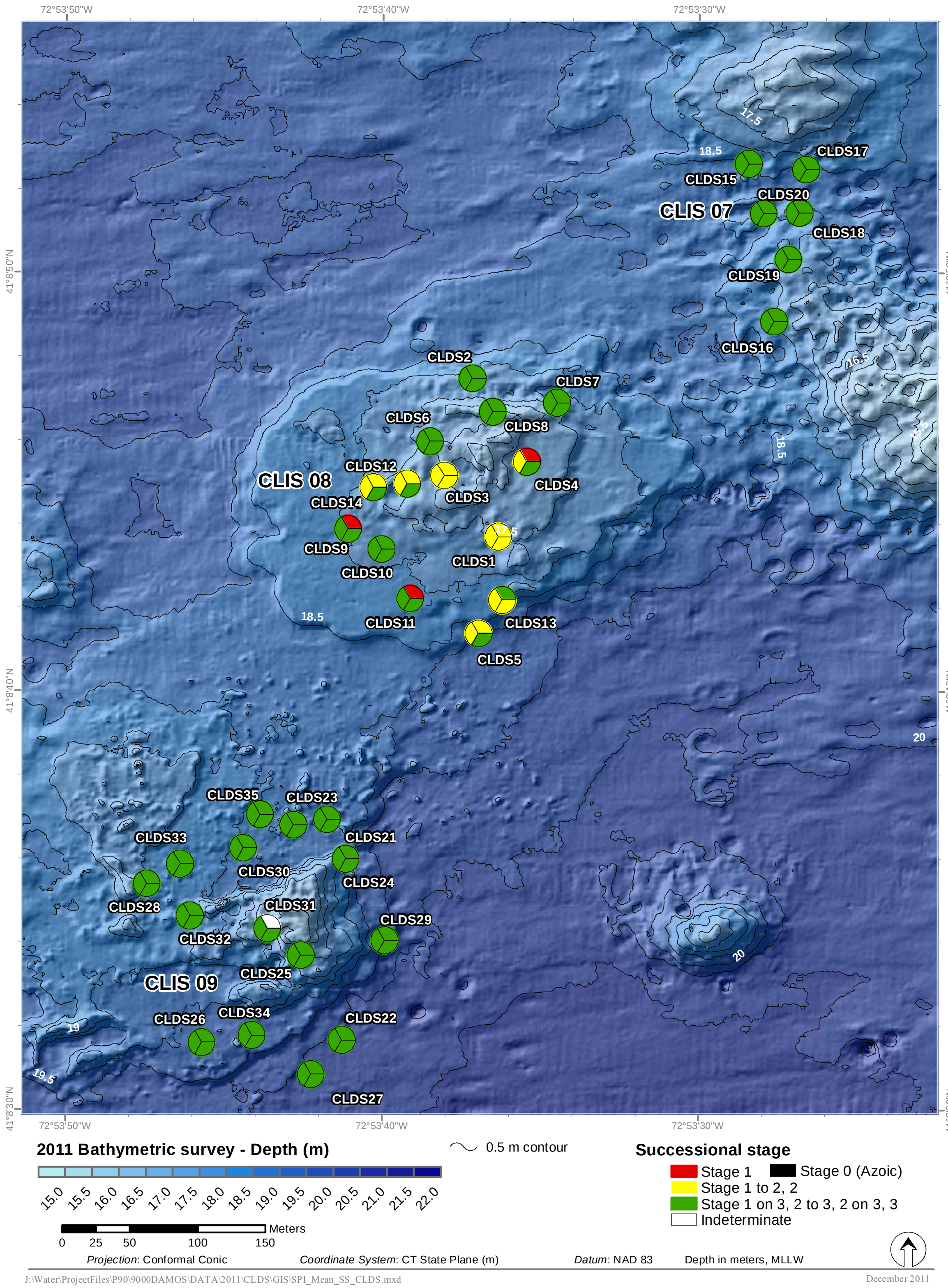


Figure 3-20. Successional Stage at CLDS

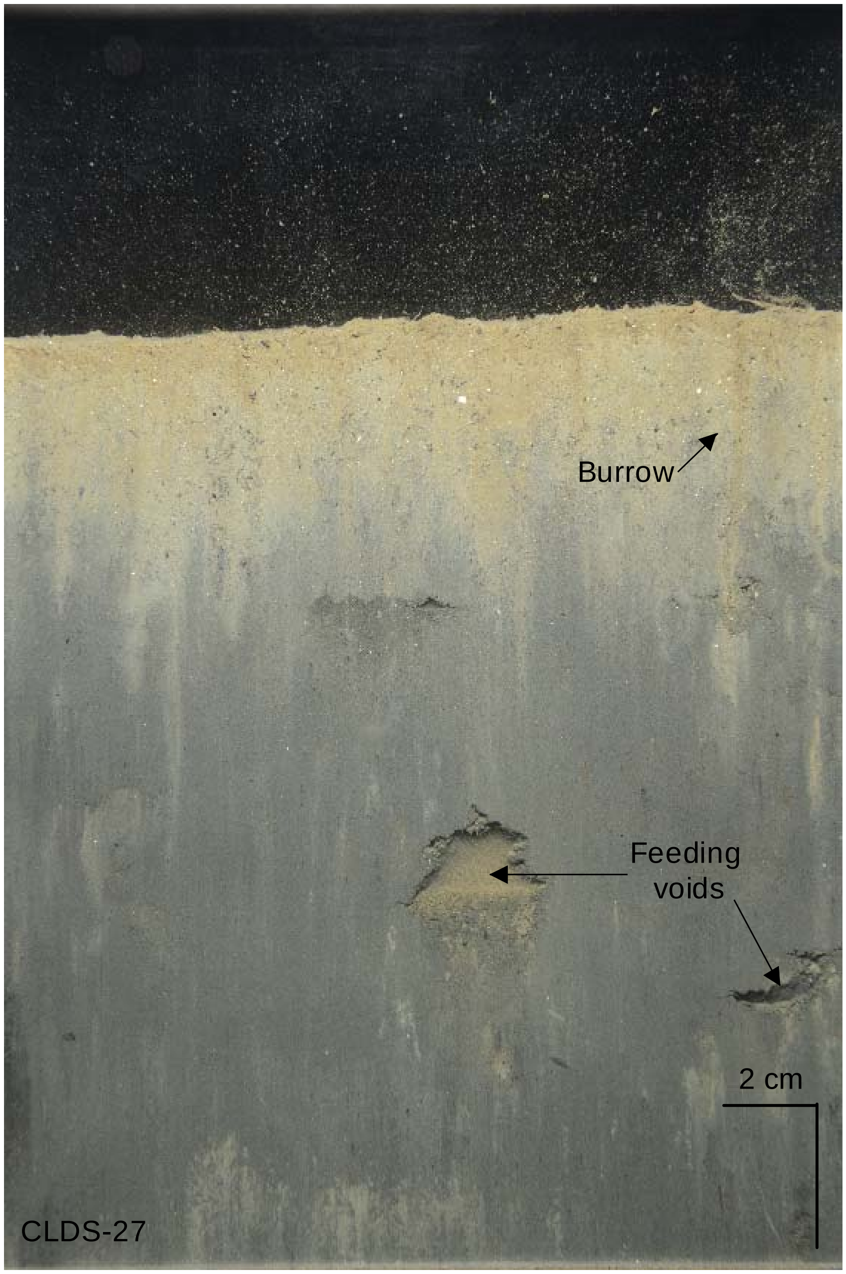


Figure 3-21. Pofile image from CLIS 09 Station 27 A showing a large vertical burrow, feeding voids and traces of burrowing throughout the aRPD (Stage 2) that resulted in a Stage 2 on 3 successional designation.

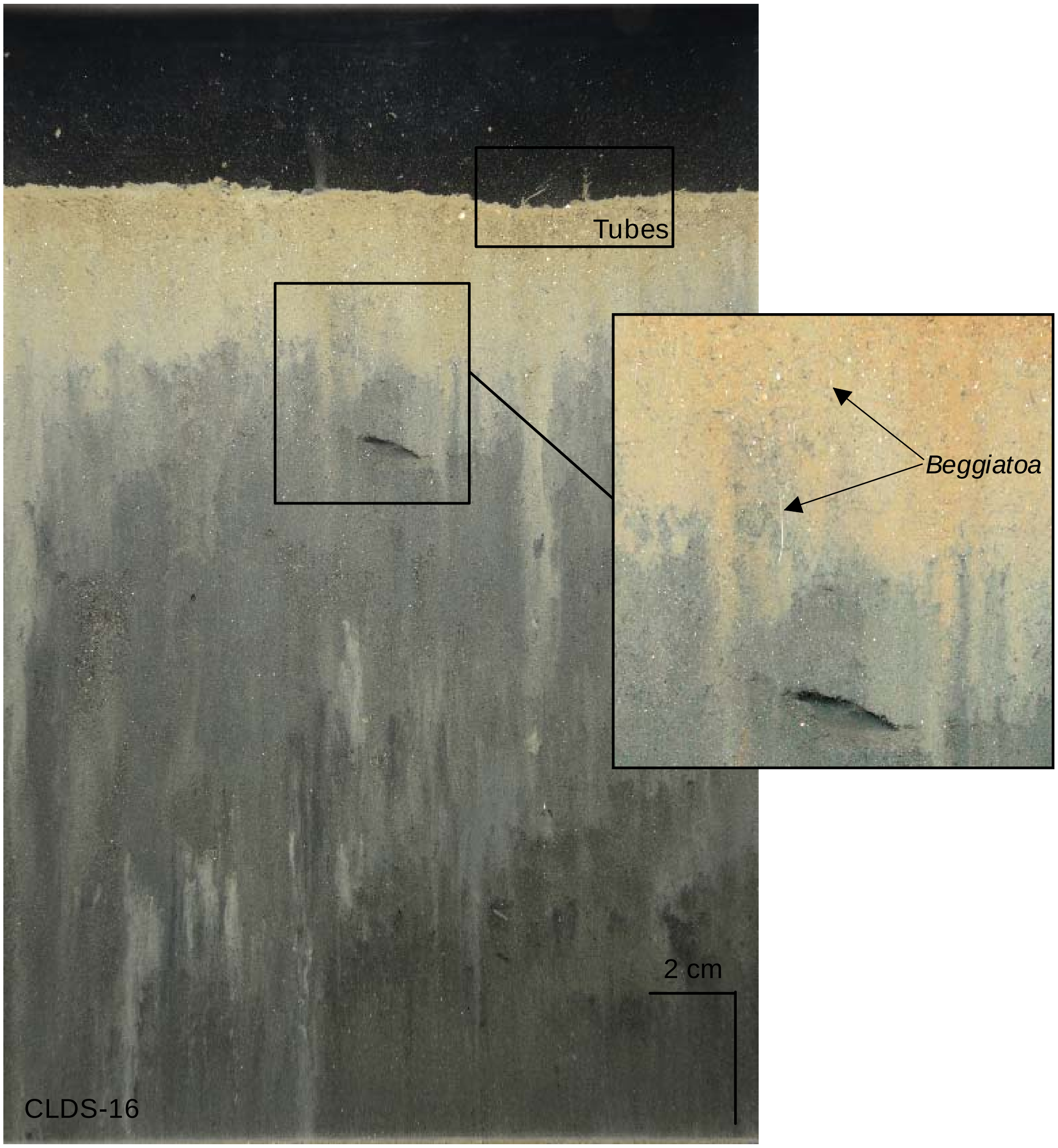


Figure 3-22. Profile image CLIS 07 Station 16A showing feeding voids and a dense assemblage of opportunistic worm tubes at the sediment surface (Stage 1) that resulted in a Stage 1 on 3 successional designation. Inset shows white threads of incipient *Beggiatoa* colonies.

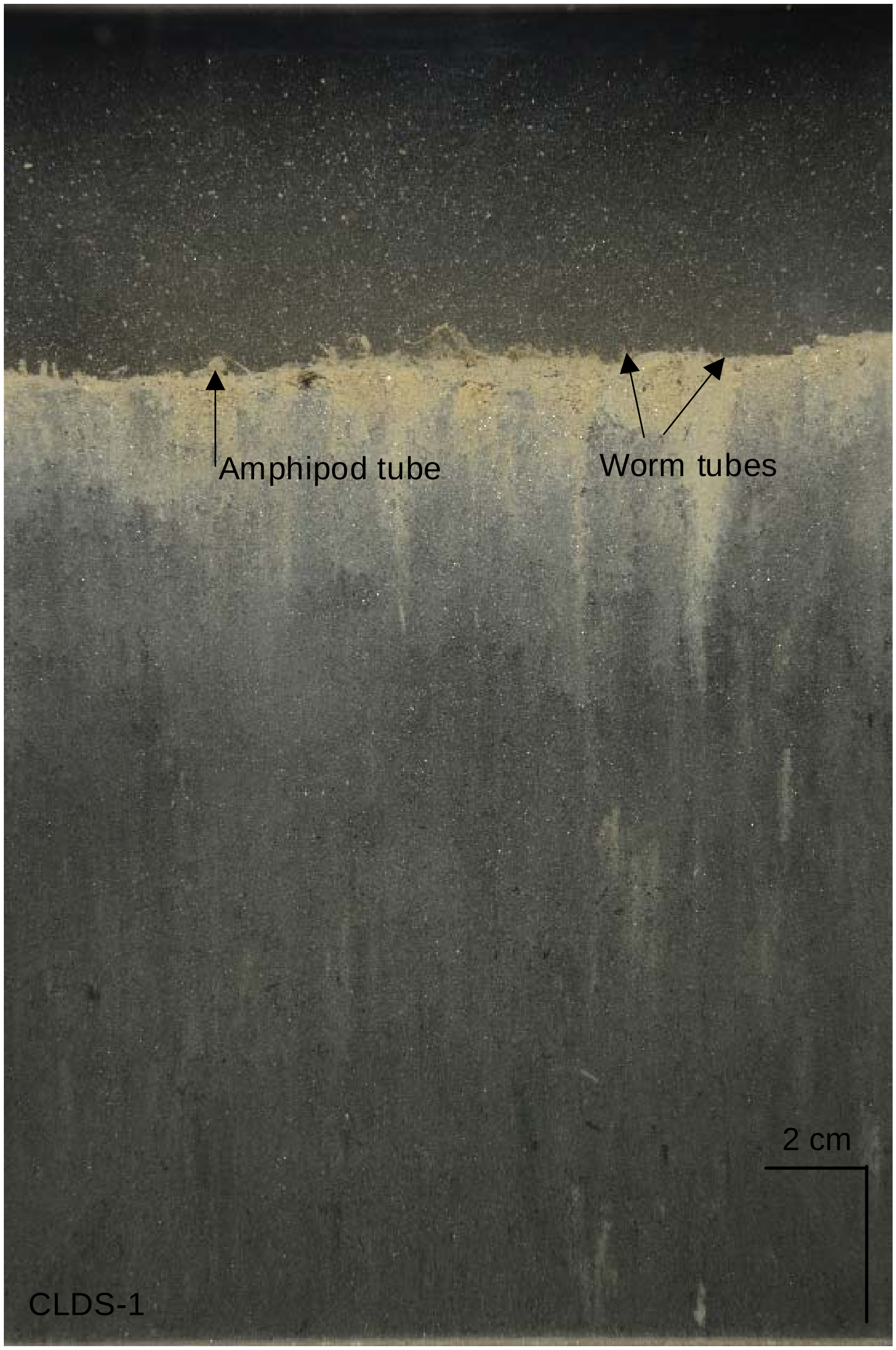


Figure 3-23. Profile image CLIS 08 Station 1B showing the absence of feeding voids, a dense assemblage of opportunistic worm tubes at the sediment surface (Stage 1), and amphipod tubes (Stage 2) that resulted in a Stage 1 on 2 successional designation.

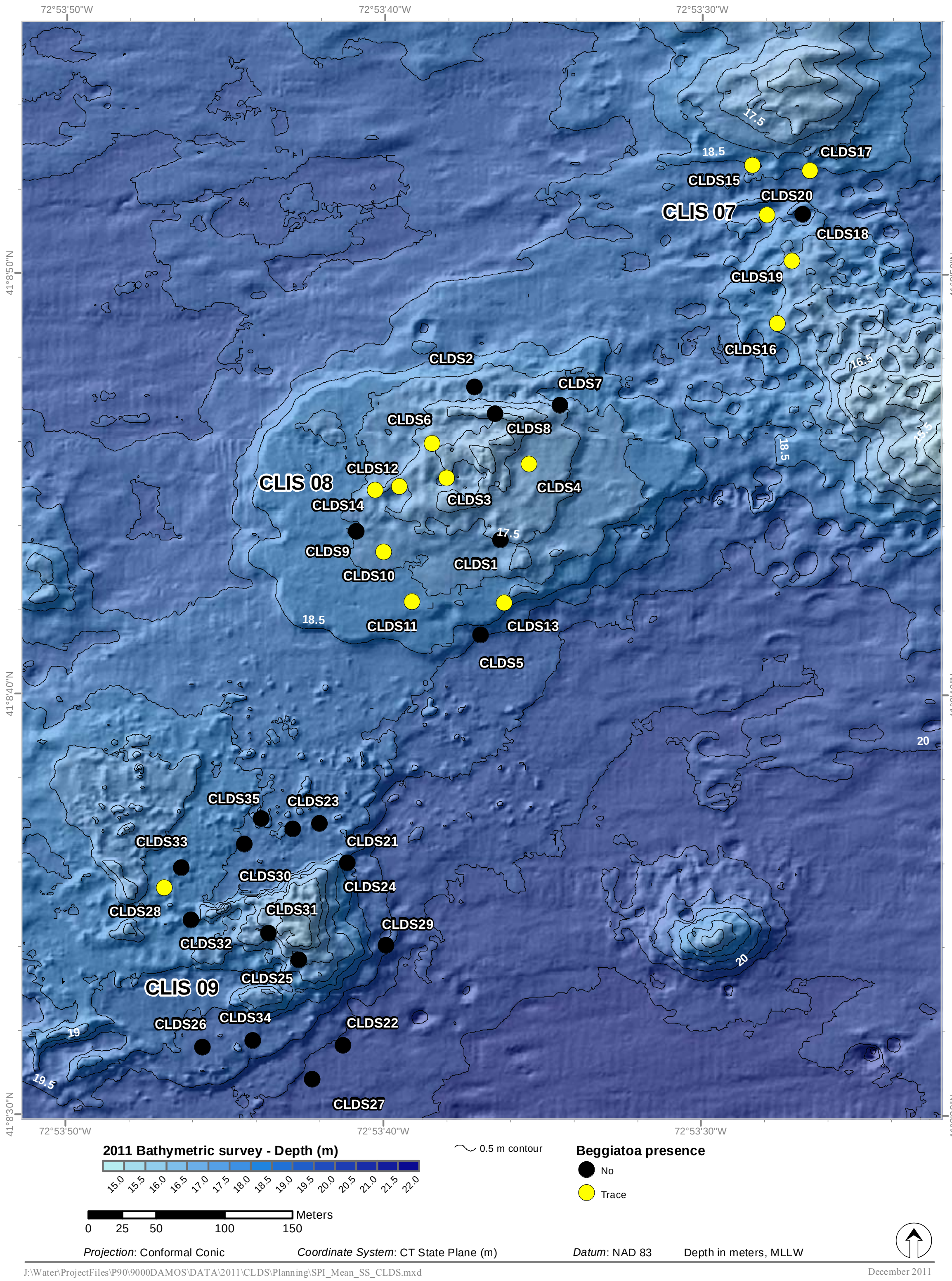


Figure 3-24. Beggiatoa presence at CLDS

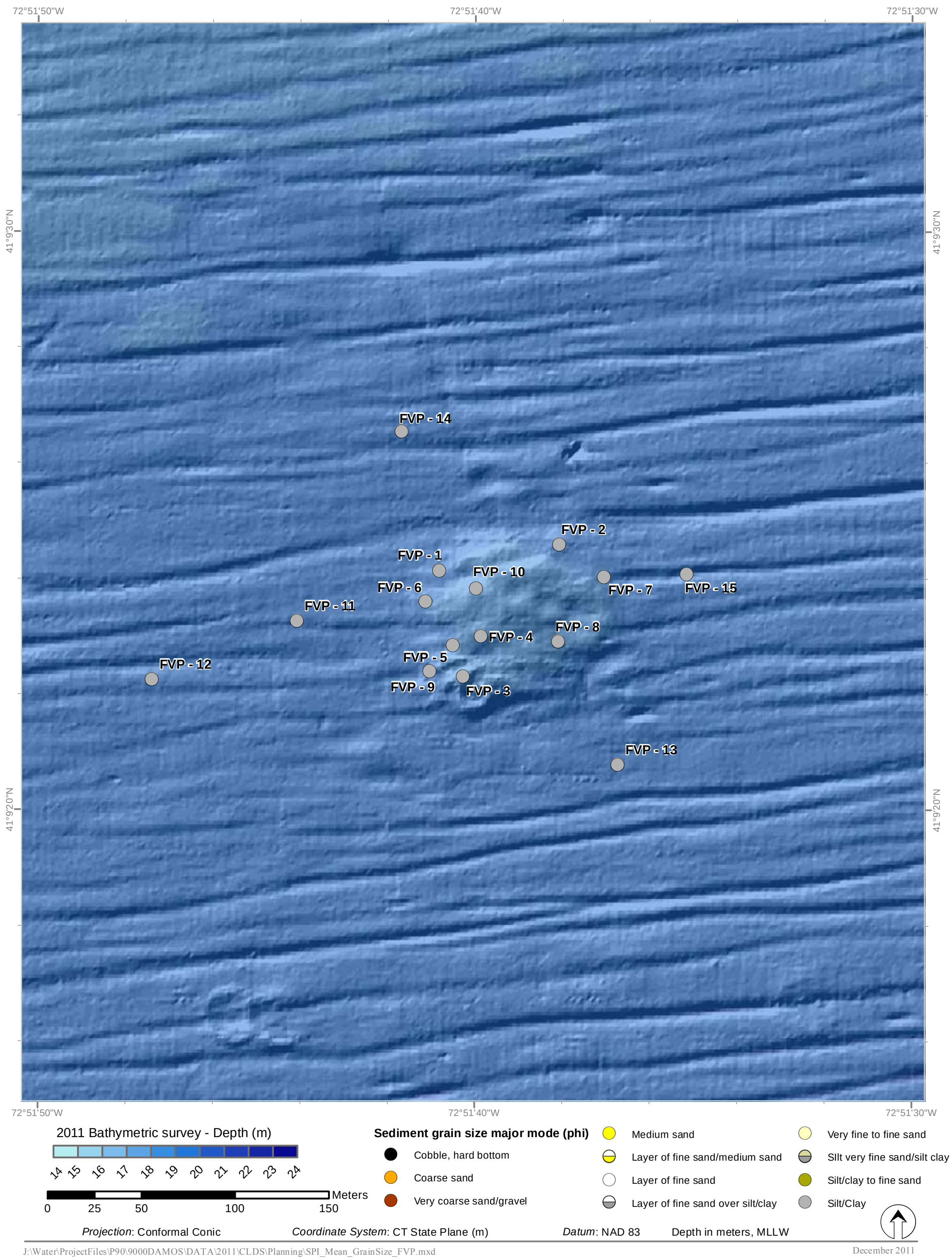


Figure 3-25. Grain size major mode at FVP

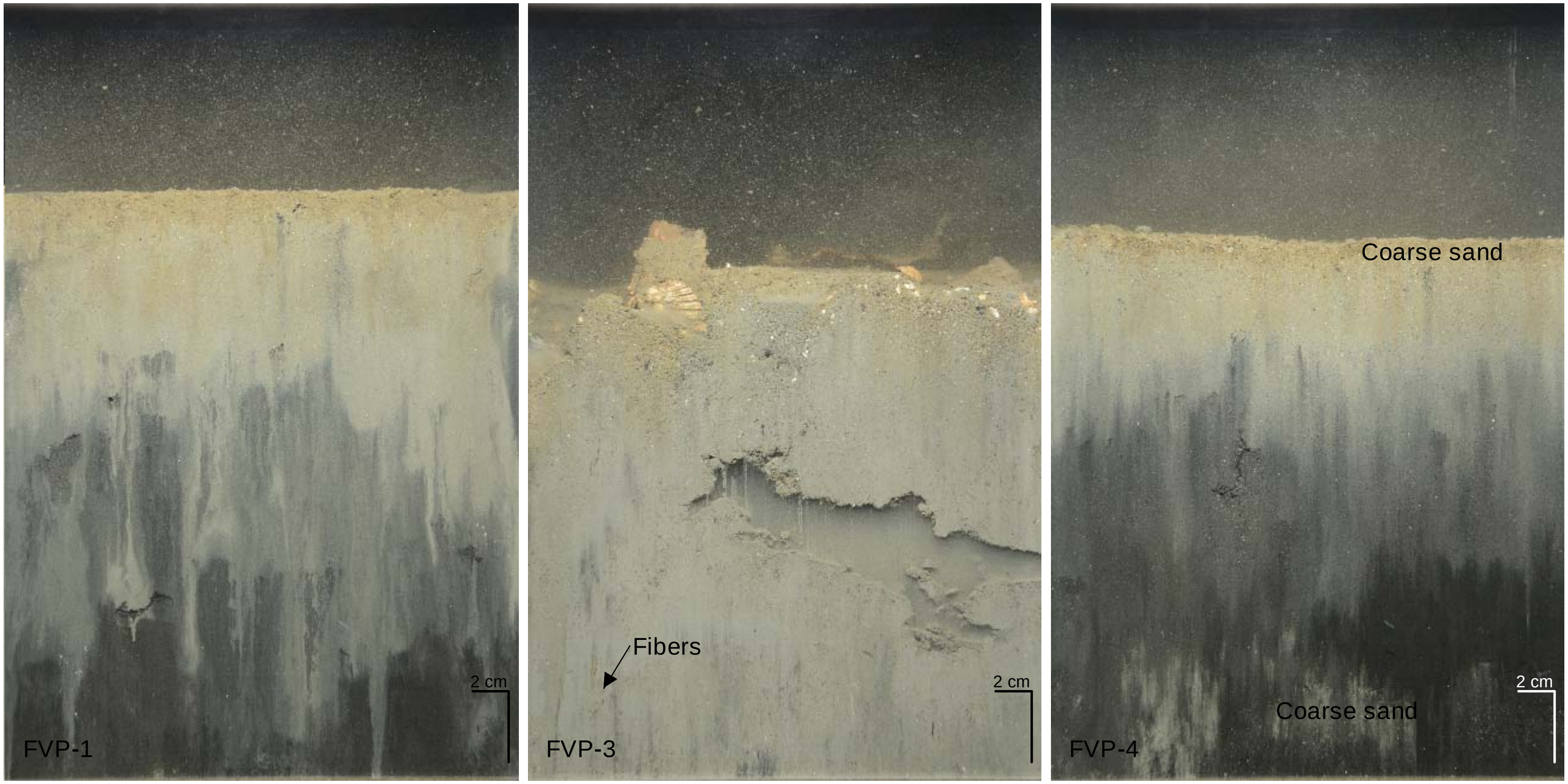


Figure 3-26. Representative profile images from the dredged material placement mound FVP showing very fine sandy silt-clay with high organic content (left image), a fine sand layer over light colored clayey silt with colored fibers (middle image), and multiple depositional horizons of very fine sandy silt-clay with layers of coarse sand at the surface and bottom (right image).

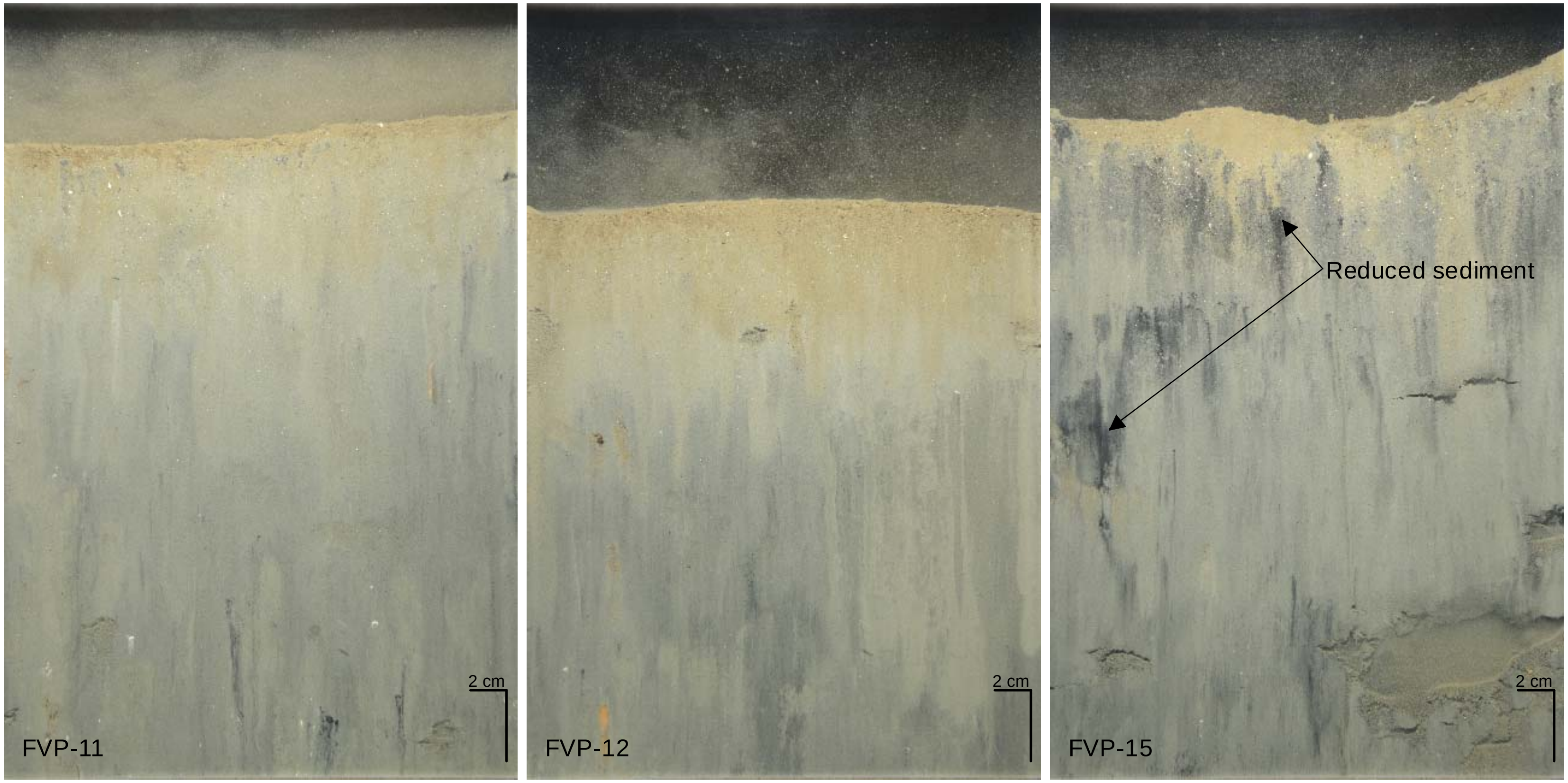


Figure 3-27. Representative profile images from the margin of the dredged material placement mound FVP showing very fine sandy silt-clay with low organic content (left and middle images); an anomalous image from the margin within a sedimentary furrow with a layer of coarser reduced sediment over light colored very fine sandy silt-clay (right image).

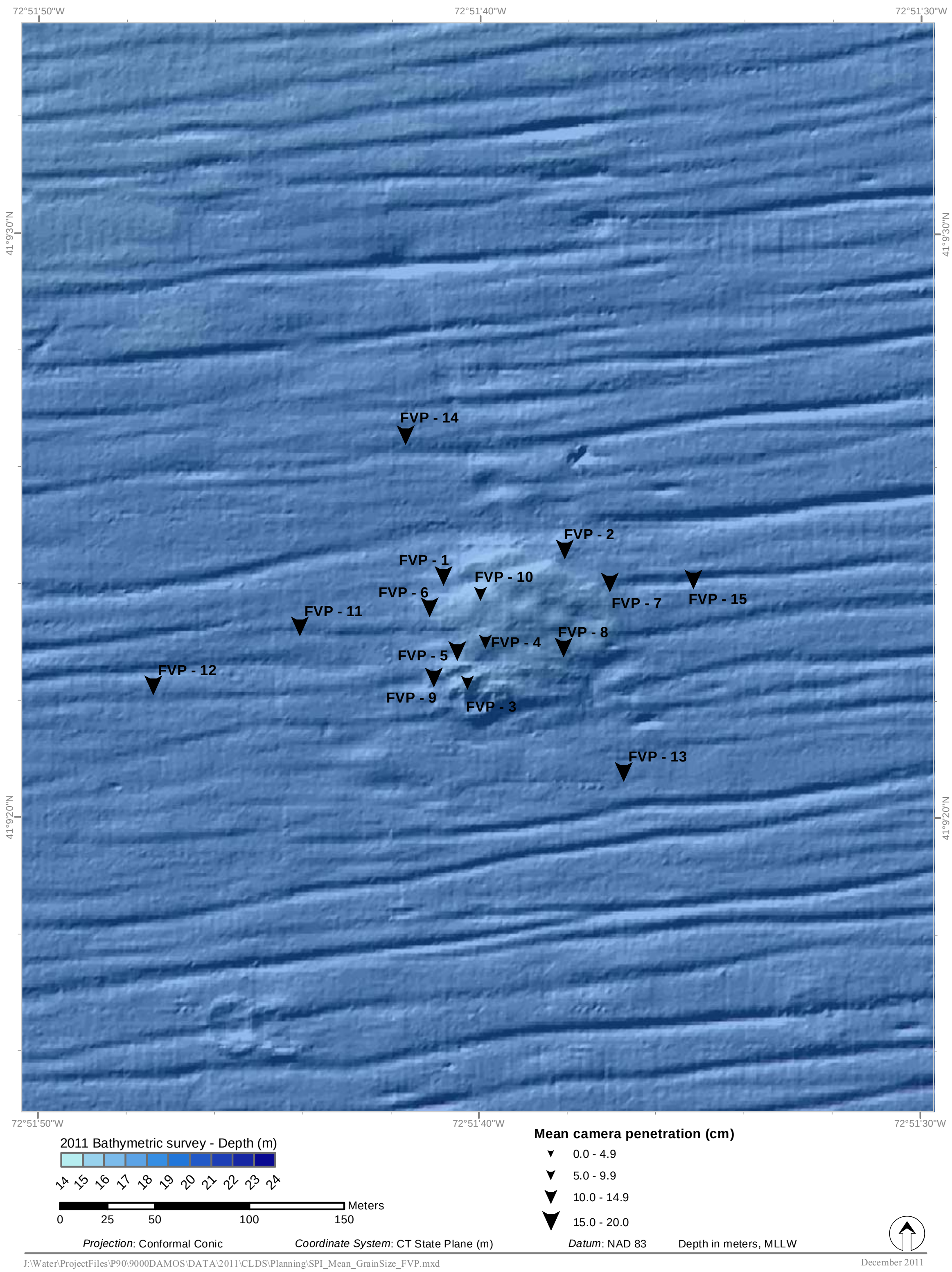


Figure 3-28. Mean penetration at FVP

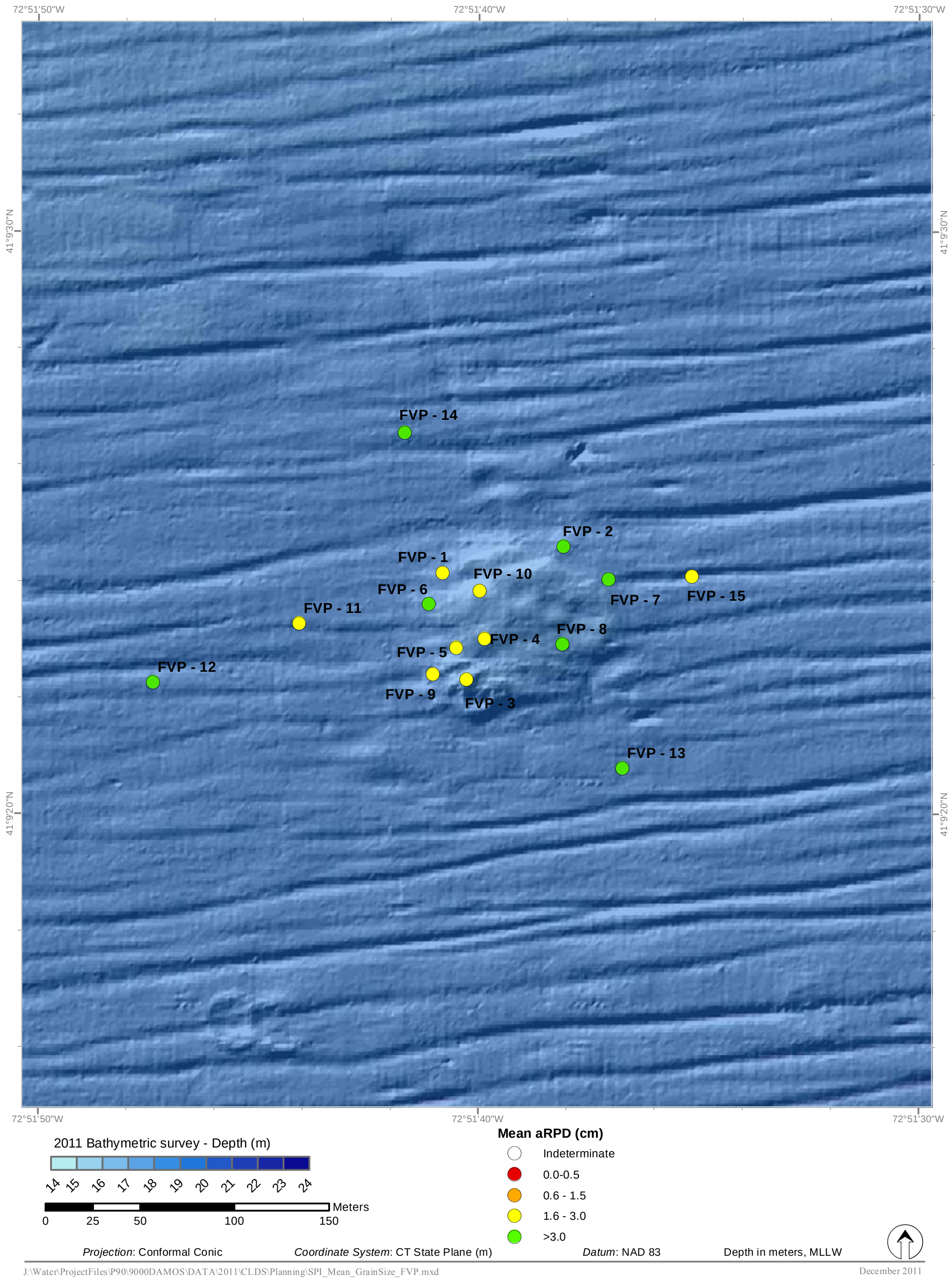


Figure 3-29. Mean aRPD at FVP

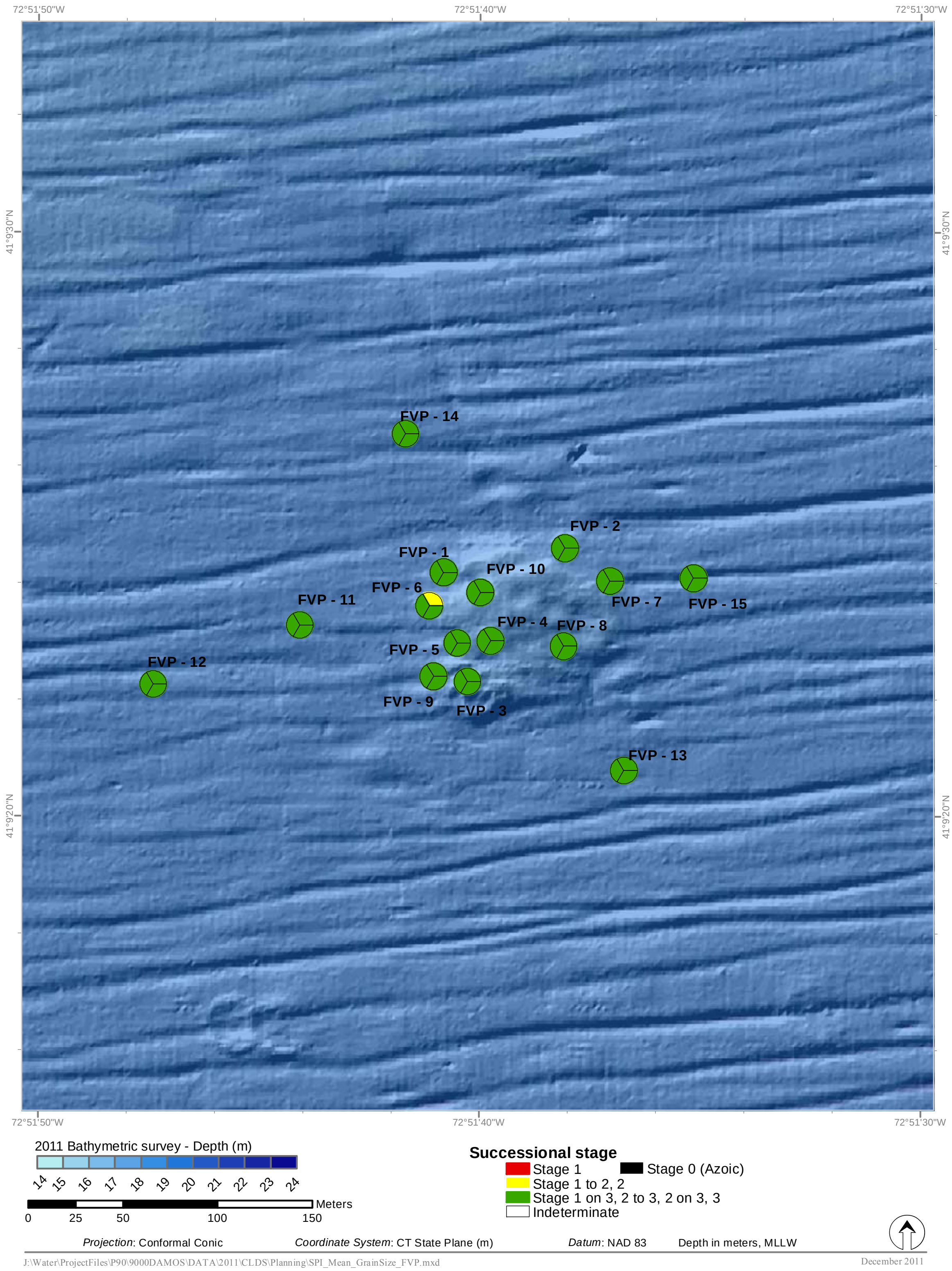


Figure 3-30. Successional Stage at FVP

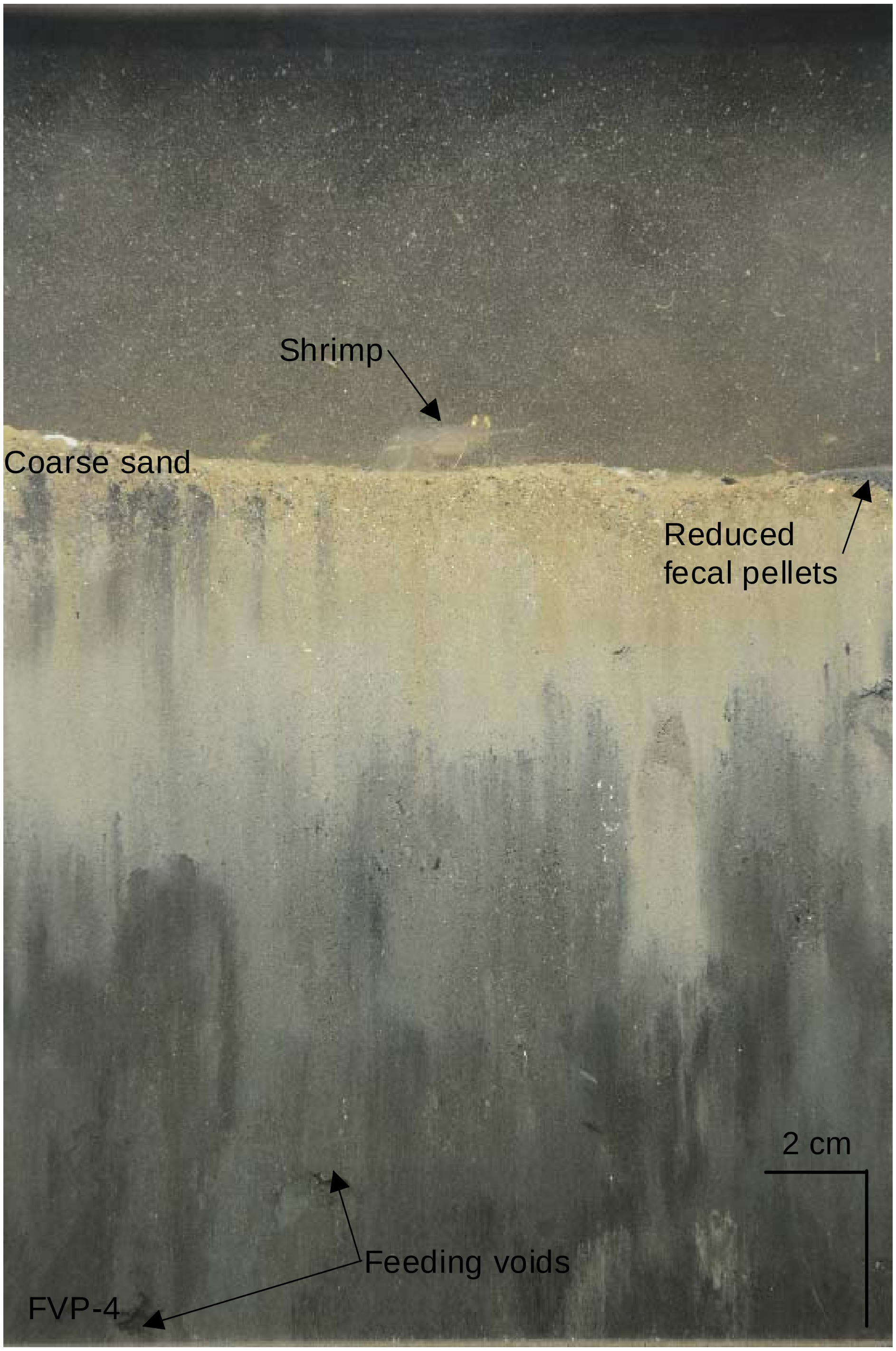


Figure 3-31. Profile image FVP Station 4B showing traces of burrowing throughout the aRPD (Stage 2) and feeding voids, that resulted in a Stage 2 on 3 successional designation. The aRPD at this replicate was 1.9 cm. Shrimp, coarse sand (some reduced), and reduced fecal pellets on surface.

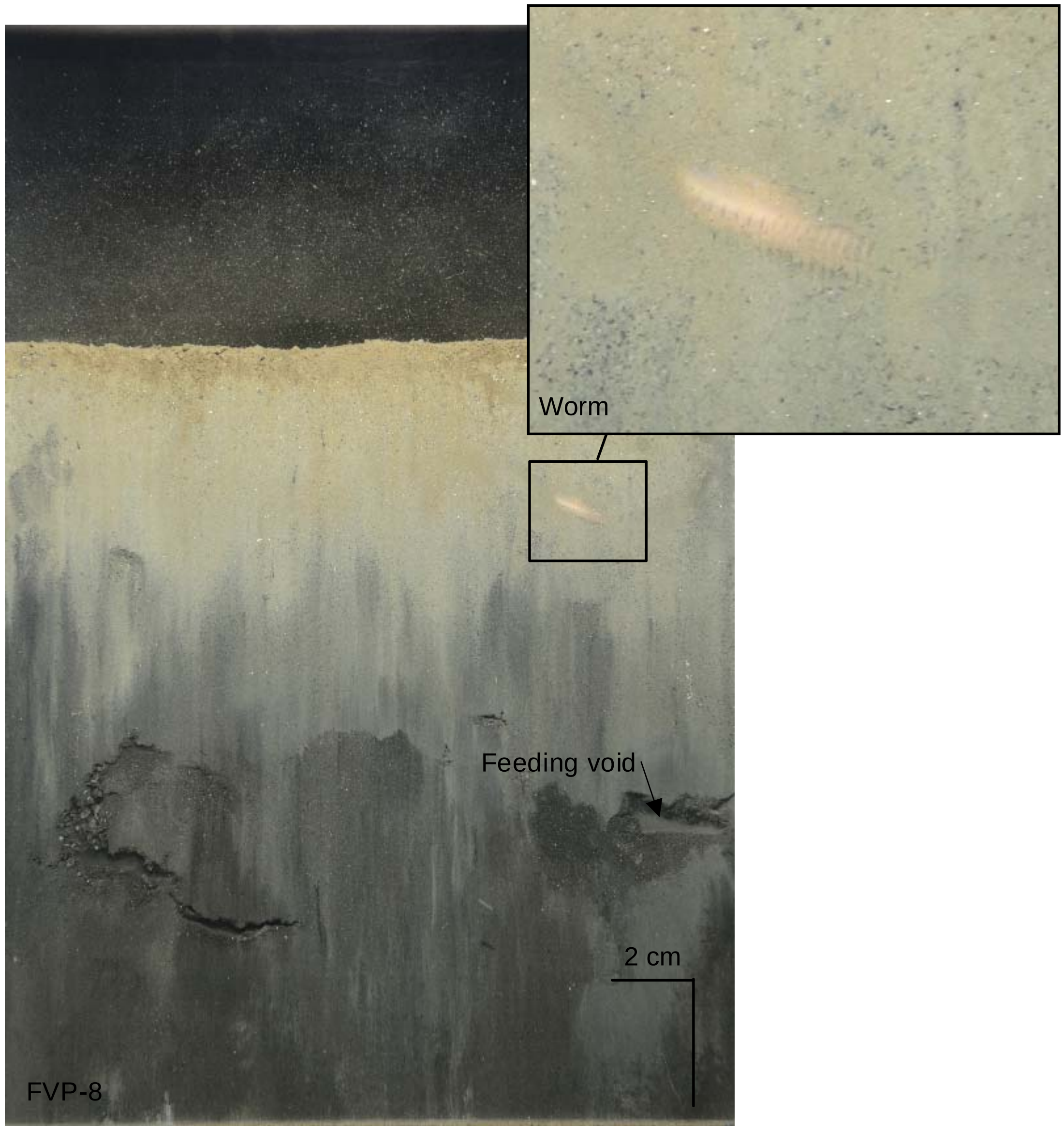


Figure 3-32. Profile image FVP Station 8C showing burrowing within the aRPD (Stage 2) and feeding voids that resulted in a Stage 2 on 3 successional designation. Inset shows a large polychaete worm.

Figure 3-33. Profile image FVP Station 1C showing feeding voids and an assemblage of opportunistic worm tubes at the sediment surface (Stage 1) that resulted in a Stage 1 on 3 successional designation. Inset shows white threads of incipient *Beggiatoa* colonies and Stage 1 worm tubes.

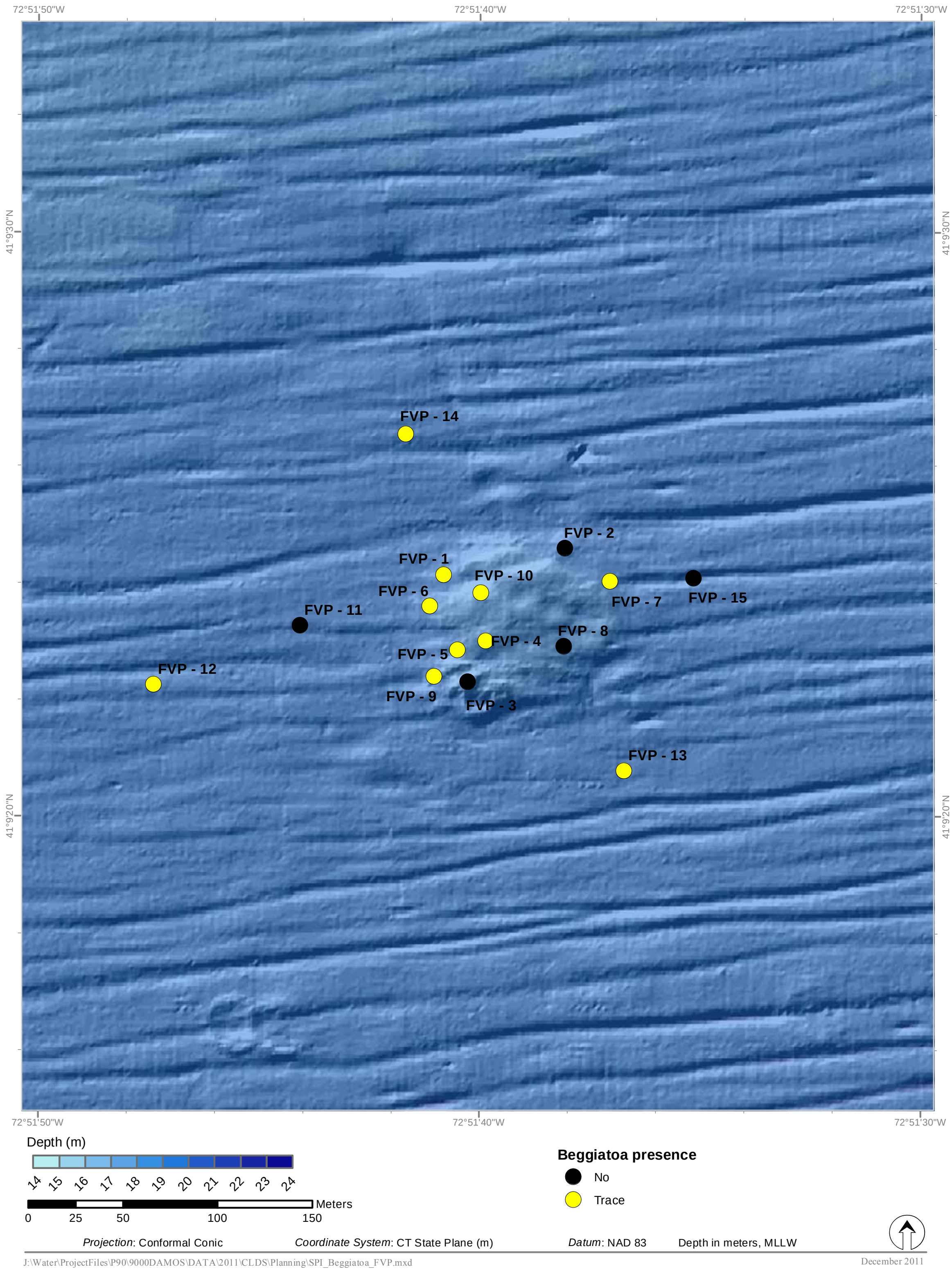


Figure 3-34. *Beggiatoa* presence at FVP

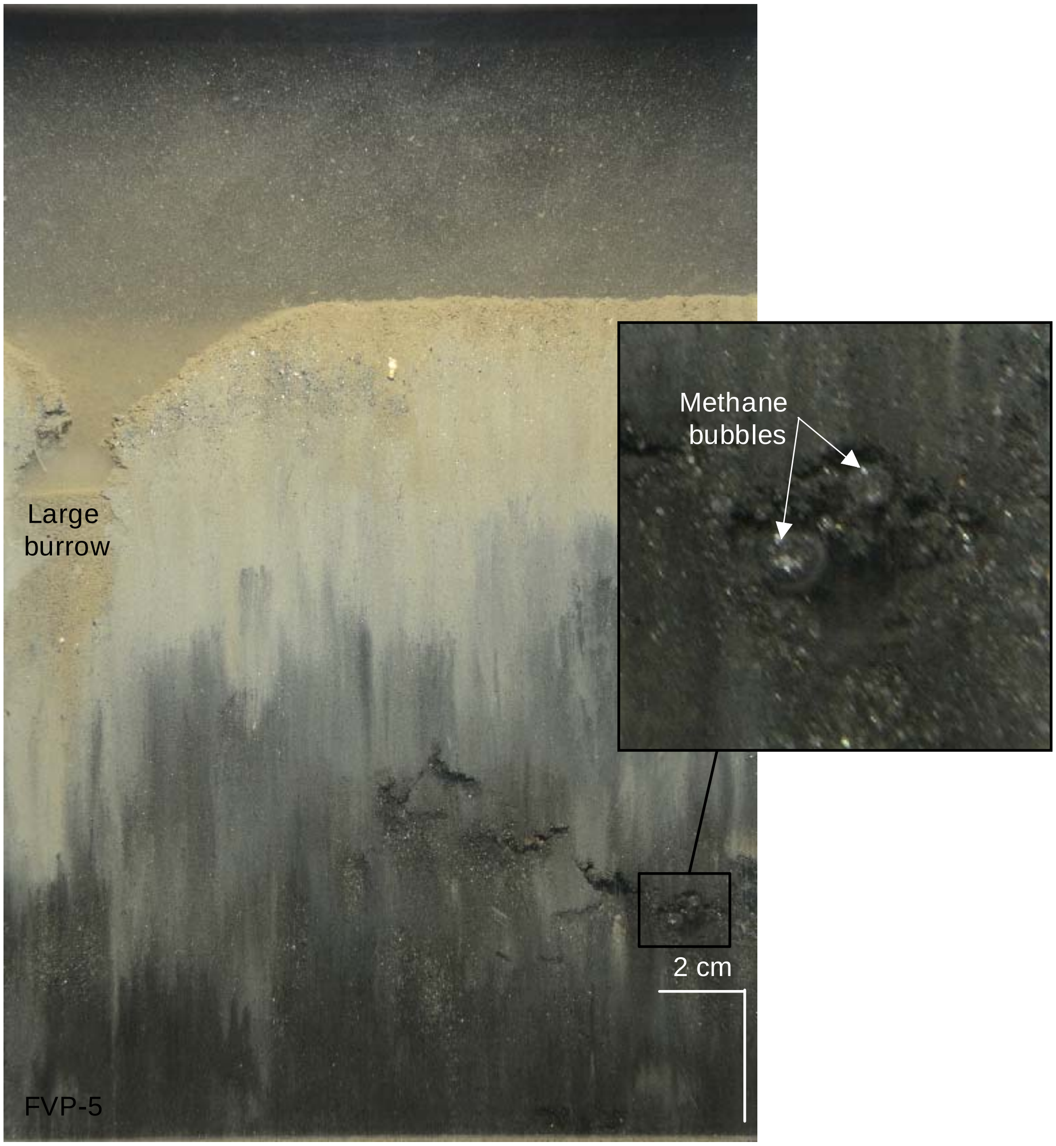
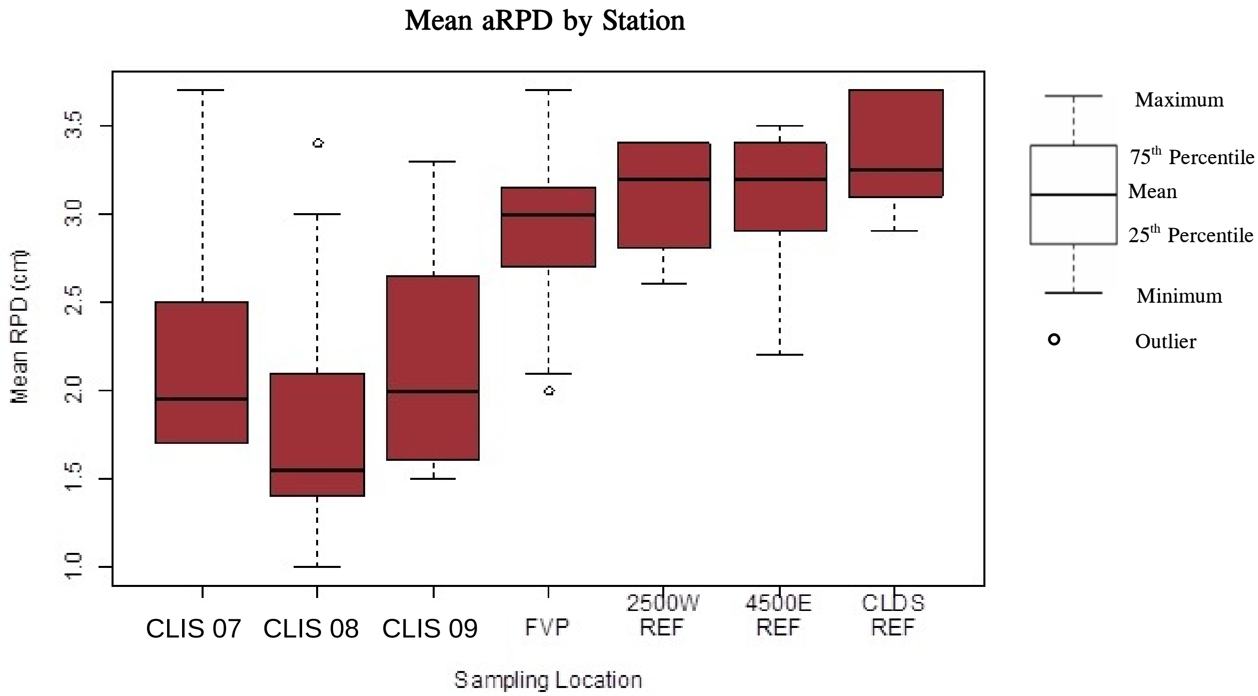


Figure 3-35. Profile image FVP Station 5 showing feeding voids, a large burrow with fecal pellets and burrowing throughout the aRPD that resulted in a Stage 2 on 3 successional designation. Inset shows methane bubbles.



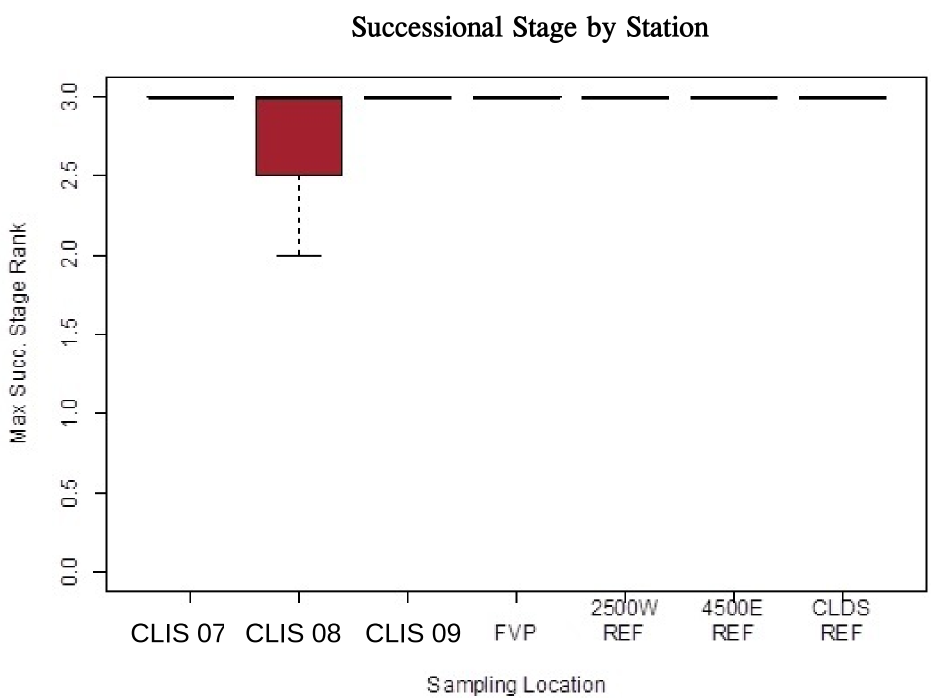


Figure 3-36. Boxplots showing distribution of station mean RPD, and successional stage rank values for 2011 survey.

4.0 DISCUSSION

The 2011 surveys at the Central Long Island Disposal Site (CLDS) had two different objectives. One objective was to conduct confirmatory monitoring of active disposal mounds at the site, and the second objective was to evaluate the historical Field Verification Program (FVP) mound located within CLDS. Preliminary results revealed the need for an additional objective: to assess the condition of older disposal mounds within the survey footprint. For clarity, these objectives are listed below:

1. **Confirmatory survey over active and recently active disposal mounds.** This objective was accomplished by characterizing the seafloor topography, mapping the distribution of newly placed dredged material, and assessing benthic recolonization status within the surface sediments of the area where recent placement activities have occurred.

2. **Assessment of older inactive mounds within the survey area.** This objective was accomplished by characterizing the seafloor topography and relative stability (between surveys) of older inactive mounds within the survey area.

3. **Focused study of the stability of the historical FVP mound.** This objective was accomplished using bathymetric, acoustic, and Sediment Profile Imaging (SPI) survey techniques.

4.1 Confirmatory Survey over Active Portion of CLDS

The active portion of CLDS included the active disposal mounds CLIS 09 and CLIS 10 and the recently active CLIS 07 and CLIS 08 (Figures 1-3 and 3-1). The 2011 survey covered a 0.19 km^2 area in the south central portion of CLDS that contained the majority of the active dredged material placement activities since the last survey (Figures 1-3 and 3-1).

4.1.1 Assessment of Active Mounds: CLIS 09 and CLIS 10

Between October 2009 and February 2011 approximately 256,000 m^3 of dredged material was placed at two separate disposal buoy locations within CLDS. Approximately 222,000 m^3 of material was placed at the CDA 09 disposal buoy between October 2009 and April 2010. An additional 34,000 m^3 of material was placed at the CDA 10 disposal buoy between November 2010 and February 2011. Approximatly 72% of the dredged material placed at CLDS during this period originated from material excavated to form a Confined Aquatic Disposal (CAD) cell at the New London Navy Submarine Base, with the remainder originating from other small maintenance and navigation projects along the Connecticut coast (Table 1-2). The CAD cell material, which largely consisted of consolidated glacial clays excavated below historical deposits, was placed between December 2009 and January 2010. The maintenance material, which consisted of harbor silts and sands was placed before, during, and after the CAD cell material (Table 1-2). As a result, the composition of newly placed material at CLIS 09 and CLIS 10 was expected to be a mixture of consolidated glacial clays and harbor silts and sands.

Physical Condition of Active Mounds

A confirmatory objective of the 2011 survey was to determine the physical location and stability of dredged material in the active portion of CLDS. Dredged material distribution can be assessed with a combination of survey techniques (high resolution bathymetry, acoustic backscatter and side-scan sonar patterns, and SPI results). High resolution bathymetry can detect the overall size and shape of some mounds, particularly when results are compared between sequential surveys in the form of a depth difference map (Figure 4-1). The depth difference between the high resolution surveys of 2011 and 2009 was particularly accurate; these surveys were successful in maintaining a high level of positional accuracy and instrument control.

As expected, a comparison of the difference in depths between the 2009 and 2011 multibeam bathymetric surveys revealed an accumulation of dredged material in the form of two distinct mounds (CLIS 09, CLIS 10) on the seafloor corresponding to placement activity that had occurred since the 2009 survey (Figure 3-2). The overall size of each mound was generally proportional to the volume of dredged material placed during each season (Table 1-2).

The results confirmed that dredged material had accumulated to form an irregular mound at CLIS 09 and a circular mound at CLIS 10. The high accuracy of the sequential multibeam surveys detected a very uniform distribution of a relatively thin layer of dredged material (20–40 cm) over a wide area surrounding CLIS 09 and CLIS 10 (Figure 4-1).

The survey confirmed that the two new mounds were successfully formed to extend an existing partial ring of dredged material mounds that will ultimately form a semi-circular berm (Figure 4-2). As of the 2011 survey, the height of this berm above the surrounding seafloor varied from approximately 0.5 to 5.5 m. The area inside the berm forms a containment cell that can be used for large-scale CAD operations. Containment cells are used for placement of material that requires additional management because of its physical or chemical charateristics. Once placed within the confines of the containment cell, the lateral spread of more fluid dredged material is contained and the material can be capped as needed (Fredette 1994). Completion of the berm will support site management objectives and help to maximize site capacity.

Backscatter and side-scan sonar results can help to reinforce the depth difference model but cannot easily distinguish between recent and older dredged material deposits without a time-series (Figure 4-3). The backscatter patterns over the most recently placed material at CLIS 09 and CLIS 10 had relatively strong returns (compared to ambient) of -29 to -26 dB; similar to those over CLIS 97/98. Stronger backscatter returns could be the result of coarser grain size, increased small-scale surface roughness, or gas bubbles in the sediments (de Moustier 1986). Unlike the sediment distribution in 2009, the grain size of dredged material placed recently at CLDS appeared relatively uniform (Figure 3-15 compared to Figure 4-1 in Valente et al. 2011). One approach to analysis of backscatter that can reveal fresh dredged material is to examine the difference in backscatter between a time-series of successive surveys (Figure 4-4). With closely matched survey instrumentation, the backscatter results can be subtracted to reveal areas with increased backscatter response (rough or coarse surface) from areas with decreased backscatter response (smooth or finer surface). The difference in backscatter returns between 2009 and 2011 revealed that the areas around CLIS 09 and CLIS 10 had patterns of increased backscatter intensity roughly corresponding to the areas of accumulation (compare Figures 4-1 and 4-4). The V-shaped area of increased backscatter intensity over CLIS 08 corresponded to the areas of accumulation discussed below. The broad area of decreased backscatter intensity in the southeast was in an area with no recent dredged material placement. In contrast the area over NHAV-74 that had apparent disturbance did not have a clear signal of increased backscatter intensity.

The side-scan sonar results on their own did not reveal the recent dredged material placement patterns, but could be combined with hillshaded bathymetric results to define surface features (Figure 4-5). The higher resolution of the side-scan data (resolution of 0.1–0.2 m per pixel) allowed for detailed investigation of small-scale features associated with dredged material placement activities. An example of features discernible in side-scan sonar data was the 1.5 km curved linear feature that began in the western margin of the survey and crossed NHAV 74 with an arc to the north before fading to the west near CLIS 08 (Figure 3-4). These curving linear features have been observed in other side-scan sonar results from CLDS and have been interpreted as small amounts of discharge from disposal barges transiting through the site or as fishing trawl scars (ENSR 2007).

Another example of features discernible in side-scan sonar data was a distinct area of small deposits north of CLIS 09 that were not present in the 2009 data and are clearly part of the dredged material placement activities (compare Figures 4-6 and 4-7). The deposits were on average about 5 m in diameter and arranged in linear arrays east to west from 250–350 m long (Figure 4-8). The deposits had a clear signature in the side-scan record but apart from mottling there was no clear relationship between filtered backscatter results and the distribution of these cohesive deposits of silt (Figure 4-9). The deposits were consistent with scattered cohesive clumps of dredged material that likely originated from the dredging of in-harbor CAD cell construction. Their distribution in linear arrays without disposal impact craters most likely resulted from slow release of a loose aggregation of clumps during a moving scow or hopper barge disposal. This placement approach creates a broader distribution of dredged material that does not contribute as much height to mound or berm formation. This placement pattern can be seen in the broad area of 0.5–1.0 m of dredged material accumulation at CLIS 09 (Figures 3-2 and 4-2).

Biological Condition of Active Mounds

Another confirmatory objective of the 2011 survey was to assess the benthic recolonization status of the mound created over the 2009–2010 placement season (CLIS 09). The CLIS 10 mound was not assessed for benthic recolonization because it continued to receive dredged material during the 2011 disposal season. CLIS 09 was characterized by an advanced successional status; all of the replicate images showed abundant evidence that deeper dwelling, Stage 3 organisms were widespread across the surface of the mound (Table 3-2).

Despite the presence of some transitional successional seres, mound-versus-reference statistical comparisons found that group means for apparent Redox Potential Discontinuity (aRPD) and successional status were significantly similar for CLIS 09 and reference values (Tables 3-4 and 3-5). At CLIS 09 the dredged material visible in the surface sediments had a more complex signature than at the other investigated mounds (CLIS 07 and CLIS 08). Many of the profile images showed distinct layering of very fine brown or gray sand over alternating layers of gray, light brown, and rust colored silt-clay (Figure 3-17). The stations with light rust colored silt-clay were located on the margins of the mound near the cohesive blocks described above (Figure 4-9).

In images with fine-grained dredged material that lacked clay, the material was characterized by a dark grey/black appearance at depth and some stations had subsurface methane bubbles (suggesting a high residual inventory of labile organic matter and sulfides). The distinctive layering may reflect mingling of deposits from the Navy Base CAD cells with harbor material.

The aRPD depths were consistently shallower at reference area stations in 2011 than in 2009 (Table 4-1). The depths in 2011 were closer to mean depths from September 1999, June 2001, and September 2003 while the depths in 2009 were similar to June 2004 measurements (SAIC 2002a, ENSR 2004, ENSR 2005). Reference area aRPD depths are interpreted as an indication of ambient conditions within the central Long Island Sound region during the period of monitoring activity; the range observed within the past twelve years is well within expected environmental variation for this region (SAIC 2002b). A clear sign of the progression in successional status at disposal mounds was reflected in the smaller differential between mean reference values and mean disposal mound values for aRPD in 2011 (Table 4-1). This convergence of aRPD values is consistent with the widespread presence of Stage 3 successional stages. Although regional conditions in 2011 appear to have contributed to shallower aRPD depths at reference areas, the disposal mound aRPD depths have increased relative to reference area values. Over time, the Stage 3 organisms inhabiting the surface sediments of these mounds have acted both to consume labile organic matter and to mix oxygenated porewater downward in the sediment column. Both of these processes would serve to increase the depth of the aRPD observed in the profile images despite the depression in aRPD values that appeared to have occurred in the Central Basin of Long Island Sound in 2011.

Summary of Active Mounds

- The CLIS 09 mound had a slightly irregular footprint, approximately 100 m in diameter with a maximum height of 4.0 m above the surrounding bottom.
- The amount of dredged material observed on the seafloor at CLIS 09 was similar to the amount reported to have been placed in this area.
- The CLIS 09 mound had a complex surface texture ranging from clumps of consolidated clay to thin layers of sand, silt and clay.
- Benthic conditions on the CLIS 09 mound had rapidly converged with reference area conditions indicating full recovery from the disturbance of dredged material placement.

- The CLIS 10 mound was roughly circular in shape with a diameter of 80 m and a height of 3.0 m above the surrounding seafloor.
- The amount of dredged material observed on the seafloor at CLIS 10 was similar to the amount reported to have been placed in this area.
- The CLIS 10 mound continued to receive dredged material after this survey, but appeared to have a stable surface texture similar to the surrounding mounds with fresh dredged material.
- The two mounds continued the development of the semi-circular berm in this part of CLDS that can eventually be used to contain a large dredged material placement project.

4.1.2 Assessment of Recently Active Mounds: CLIS 07 and CLIS 08

Two mounds within the survey area received dredged material during the 2007 and 2008 disposal seasons (CLIS 07 and CLIS 08). These mounds were surveyed in 2009 and revisited in the 2011 survey to assess their physical stability and benthic recolonization status (Valente et al. 2012). CLIS 07 received a very small volume of dredged material (18,790 m^3) primarily from the Patchogue River, while CLIS 08 received 324,680 m^3. Norwalk Harbor sediments contributed over 65% of the total volume of sediments deposited at CLIS 08 and much of this volume was silty sand used to cap a number of smaller projects (Mike Ludwig, pers comm. 2012). The CLIS 07 mound was a small mound with noticeable impact craters, while the CLIS 08 mound was a large flat mound with a smaller peaked mound near the center (Valente et al., 2012).

Physical Condition of Recently Active Mounds

The dredged material placed at CLIS 07 appeared unchanged from the survey conducted in 2009; there was no discernible difference in topography (Figure 4-2). The backscatter pattern over this mound was very similar to the patterns seen over other inactive mounds in the area (Figure 4-3). In contrast, the dredged material placed at CLIS 08 in 2008 had an average consolidation of about 0.5 m across the surface of this relatively flat mound by 2011 (Figure 4-2). While consolidation is common with relatively new mounds of this size, the relatively flat profile of the mound and the close vertical control between the 2009 and 2011 surveys resulted in a pattern of consolidation exactly matched to the mound footprint. Most of the SPI stations on CLIS 08 had very fine sandy silt-clay (Appendix B). This material formed the cap of CLIS 08 and was clearly remolded through self-weight consolidation after placement to form the relatively flat mound with a distinct edge. Material placed near the peak of the mound was more cohesive.

A large-scale disturbance feature (50–150 m in extent and 1–2 m in depth) was observed on CLIS 08 (Figure 4-2). The feature was notable for a distinctive V-shaped pattern of backscatter that was coincident with a trough or line of overlapping impact craters about 10 m wide that was not present in 2009 (Figure 4-3). The depth difference was consistent with placement of dredged material after 2008 with a linear depression and flanking lines of accumulation (Figure 4-2). The feature was located on the northern edge of the CLIS 08 mound in an area that received dredged material placement in 2010 (Figure 4-10). The backscatter inside the trough was a lower return than the V-shaped pattern to the west, north, and south. The backscatter pattern was more noticeable than the depth difference pattern (compare Figures 4-2 and 4-3). The difference suggested that the origin or timing of the placement on CLIS 08 affected textural characteristics more than volume. Although this feature was unusual, its linked series of small impact craters was consistent with patterns associated with hopper barge disposal. The textural characteristics of this surface could potentially be indicative of clayey dredged material from the construction of the CAD cells in New London (see Station CLDS 7 in Figure 3-16).

Based on the weight of evidence from bathymetric, acoustic backscatter, and side-scan sonar data, this large-scale disturbance feature appeared likely to have been formed from dredged material placement activities after October 2009. The feature, although it had an unusual signature, did appear to be related to one dredged material placement event and had not disturbed any potentially unsuitable dredged material (UDM) as all material placed at CLIS 08 originated from projects determined to be suitable for open ocean disposal (Valente et al. 2011 and this report). This area of disturbance did not appear to represent any change in condition of the CLIS 08 mound that would warrant further investigation beyond this study.

Biological Condition of Recently Active Mounds

Another confirmatory objective of the 2011 survey was to assess the benthic recolonization status of the two mounds created during the 2008 through 2009 disposal seasons (CLIS 07, 08). In general, both mounds showed substantial progress toward advanced recolonization. CLIS 07 was characterized by an advanced successional status; all of the replicate images showed abundant evidence that deeper dwelling, Stage 3 organisms were widespread across the surface of each mound. In contrast, CLIS 08 with some signs of recent disturbance was in an intermediate successional status, as evidenced by both high variability among replicate images and the widespread presence of transitional "Stage 1 going to 2" and "Stage 2 going to 3" successional seres (Table 3-2).

Despite the presence of transitional successional seres, mound-versus-reference statistical comparisons found that group means for aRPD and successional status were significantly similar for all disposal mounds compared to reference values (Tables 3-4 and 3-5). There was no spatial relationship between the location of transitional successional stages on CLIS 08 and the area of disturbance; all three stations located in the area of disturbance had Stage 3 successional stages in every replicate (Figure 3-20). However, these three stations also had clasts of light-colored clayey silt distinct from other CLIS 08 stations and consistent with fresh or disturbed dredged material similar to that found at CLIS 09 (Figure 4-9). One barge load of dredged material from the New London Navy Base was logged as placed near the location of these three stations in 2010 (Figure 4-10). The timing of the barge load was consistent with construction of the CAD cell in New London that excavated clayey silt.

Most reference area and disposal mound stations had traces of Beggiatoa sp. (Table 3-2 and Figures 3-22 and 3-24), all but one station at CLIS 07 and 8 of 14 at CLIS 08 had traces of Beggiatoa. Beggiatoa is a genus of bacteria in the order Thiotrichales that is associated with high sulfides in sediments; under anaerobic conditions they are able to metabolize and oxidize sulfur compounds (Schmidt et al. 1987). The ability to detect trace or incipient fibers of Beggiatoa in SPI images is a result of the use of a higher resolution imaging sensor in the camera (16 megapixels) in this survey. Previous surveys may have recorded the presence of Beggiatoa traces but were not resolved with the image resolution used (9 megapixels or less). The presence of these traces is an indication of a relatively high sulfide inventory but not anaerobic conditions. Under low oxygen conditions, Beggiatoa colonies will grow and produce dense mats of fibers on the sediment surface. With the ability to detect these incipient colonies, subsequent surveys will begin to provide a pattern of distribution in space and time relative to dredged material placement and reference area conditions.

Summary of Inactive Mounds

- The CLIS 07 mound had the same footprint observed in 2009, approximately 180 m in diameter with a maximum height of 2.5 m above the surrounding bottom.

- The CLIS 07 mound had a distinctive surface texture of disposal impact craters with uniform fine-grained dredged material.
- Benthic conditions on the CLIS 07 mound had converged with reference area conditions indicating full recovery from the disturbance of dredged material placement.
- The large surface area of the CLIS 08 mound had an unusually flat profile with distinct edges with the same footprint observed in 2009.
- The CLIS 08 mound had consolidated 0.2–0.5 m across the surface of the mound which was about 200-300 m in diameter.
- Benthic conditions on the CLIS 08 mound had progressed to an intermediate recolonization status.
- The CLIS 08 mound received what appears to be a single scow load of consolidated clay that created a newly disturbed surface feature.
- Although the new material placed on the mound does not appear to have affected recolonization directly, the mound should continue to be monitored through future confirmatory surveys to follow the progression of recovery.

4.2 Survey Coverage of Older Mounds Surrounding the Active Placement Area

Confirmatory bathymetric surveys typically extend outside of the area of interest in order to provide sufficient undisturbed areas for accurate depth difference calculation. At CLDS this meant that older inactive dredged material disposal mounds were included. The survey area in 2011 included 12 mounds that were not specifically part of the confirmatory survey (Figure 4-1). Of these 12 mounds, a few had minor amounts of apparent consolidation (CLIS 05, CLIS 95/96) but the rest appeared unchanged with the exception of NHAV 74 (Figure 3-2).

4.2.1 Assessment of the NHAV 74 Mound

The NHAV 74 mound had a substantial oval-shaped area on the southern margin of the mound with accumulation and some apparent consolidation (Figure 3-2). This area had no recorded dredged material placement between 2009 and 2011 (Figure 1-3). The area of disturbance over the NHAV 74 mound warranted more careful investigation because the magnitude of depth change might have affected the historical sediments placed at this location.

At the NHAV 74 feature, an analysis of depth change patterns, backscatter results, and side-scan sonar data was conducted. This analysis provided some constraints on the magnitude and nature of the disturbance areas, but did not provide a definitive assessment of the potential consequences of the disturbance. Careful inspection of soundings collected over the NHAV 74 feature suggested optimal performance of the multibeam echo sounder (MBES) and ancillary sensors. The median elevation uncertainty over the feature was only 8 cm at the 95th percentile confidence interval. Uncertainty over the majority of the feature was less than 10 cm, with higher values limited to slopes and areas of high micro-relief. This provided high confidence that the depth difference model represented change with an uncertainty of ±10 cm or less and allowed for calculation of volumes from the change in depth measured across the feature.

The disturbance over the NHAV 74 mound was much more prominent in depth difference analysis than in backscatter results (compare Figure 4-11A and B) and represented a distinct volume change with less textural change than the feature on CLIS 08. The disturbance on NHAV 74 had a shallow trench and large thick deposits of material (displaced or newly deposited). The volume of the trough or trench feature in the center (400 m^3) was an order of magnitude smaller than the volume of material deposited to the north and south (3890 m^3). The lack of correspondence between the volume of the depression and the deposits indicated that some new material had been placed here, not merely displaced. The combination of a small linear depression and large semi-circular areas of accumulation suggest placement of dredged material, perhaps in a sequence from a hopper barge or sequential placement from small scows. While the total volume of deposited material was roughly equivalent to a large scow, there was circumstantial evidence of multiple placement events.

Surface sediments on the southern half of the feature possessed distinctly lower backscatter than the surrounding sediments (Figure 4-11B). Backscatter across most of the southeastern portion of the feature was 1 to 5 dB lower than estimated from normalized 2009 data, while backscatter changes over the northwestern portion of the feature were heterogeneous. Backscatter around an approximately 1–5 m outer boundary zone in the south was lower than surrounding sediments (and consistent with patterns seen in 2009 backscatter). These results of variation in backscatter suggest that the formation of the surface disturbance may have been the result of two or perhaps three dredged material placement events each with different sediment properties.

Side-scan sonar data suggested the presence of at least two faint disposal impact craters (20-25 m in diameter) in the portion of the feature to the south of the central trench (Figure 4-12 A). The side-scan data showed that the surface of the feature was characterized by greater micro-relief than the relatively smooth surrounding seafloor. The individual "clumps" of material could be resolved to a resolution of approximately 50 cm. This texture of individual clumps of dredged material visible inside disposal impact craters was consistent with placement of consolidated clay from CAD cell construction.

The side-scan sonar image of the trough combined with hillshaded bathymetry showed distinct small impact craters (10 m in diameter; Figure 4-12 B inset). The depth difference results also showed craters with a slight trend from southwest to northeast (Figure 4-13 A). These patterns of impact craters were consistent with at least three dredged material placement events from a hopper barge (one inside the trough, perhaps with more consolidated material, and at least one on either side of the trough). There is evidence from other disposal sites that highly consolidated material can produce a depth increase when placed on ambient or unconsolidated dredged material (USACE in press). The trough may represent an initial deposit of dense material which created a line of craters and a depression. Subsequent deposits may have been barge loads of very loose aggregations of smaller clumps of consolidated material that were placed on the layers of ejecta from the initial barge load.

When the backscatter data of the disturbance area was analyzed in the context of the historical deposits of the disposal mound, the disturbance area was visible as an area with rougher texture but lower backscatter return than those of NHAV 74 (Figure 4-13 B). These qualitative analyses were confirmed by rugosity values (a measure of surface roughness derived from bathymetric data) of the disturbance area which were substantially higher than for the surrounding seabed (Figure 4-14). The linear feature observed in the side-scan sonar data was also clearly visible in the backscatter mosaic; it apparently intersected with the new deposit on NHAV 74 (Figure 4-13 B).

Based on the weight of evidence from bathymetric, acoustic backscatter, and side-scan sonar data, this large-scale disturbance feature appears likely to have been formed from dredged material placement activities after October 2009. The feature was most likely the result of placement of dredged material otherwise unaccounted for in disposal logs and its placement could potentially have disturbed historical deposits from the formation of the NHAV 74 mound (Gordon and Pilbeam 1972, Bokuniewicz et al. 1975, 1976, NUSC 1979). The area of increased depth, the ‘trough’, was as much as 1.15 m below the mound surface surveyed in 2009. The trough area and the accumulation areas both had some evidence of circular impact craters (Figures 4-12 A and B). While the trough might represent consolidation from a new series of dredged material placements with some material displaced north and south, it is possible that some of the historical deposits of dredged material placed at NHAV 74 were displaced. The analysis of volumes of disturbed material clearly indicated that new material has been placed both north and south of the trough.

The NHAV 74 mound was one of the first dredged material disposal mounds formed by point-dumping with precision navigation (Bokuniewicz et al. 1975). The project was closely monitored with sequential bathymetric measurements of the mound and turbidity and current meter measurements in the area around the disposal activities (Bokuniewicz et al. 1976). Material forming the NHAV 74 mound included about 1.2 million m^3 of dredged material from the main navigation channel in New Haven Harbor, the United Illuminating Coke Works power station, and several ship berths including New Haven Terminal, Wyatt Oil, and Guilford Harbor (Bokuniewicz et al. 1975). Although biological testing of dredged material was not conducted in 1972, limited chemical analysis of dredged material from the site indicated bulk sediment values for metal and 'oil & grease' several years after disposal were very similar to reference sites and other locations within CLDS (NUSC 1979). The mound itself reached a stable configuration after initial self-weight consolidation and formed the basic template for expectations of the formation and stability of dredged material mounds observed in Long Island Sound since 1978 (Bokuniewicz et al. 1976, NUSC 1978, SAIC 1995). Benthic community analysis and subsequent SPI surveys confirmed that the benthic habitat conditions on the surface of the mound converged with ambient conditions at CLDS within a few years (Gordon et al. 1972, Rhoads and Yingst 1976).

The most likely explanation of the feature identified in the 2011 survey is placement of dredged material away from the target disposal buoy. This can be evaluated with SPI surveys to determine the presence and distribution of relatively fresh dredged material and to assess the condition of the benthic habitat on the disturbed areas. Apart from the area of disturbance that appears to have been created by dredged material placement, the other mounds surveyed at CLDS were stable.

4.2.2 Summary of Older Inactive Mounds

- Of the 12 older inactive mounds in the bathymetry survey area, a few had minor amounts of apparent consolidation (CLIS 05, CLIS 95/96), but the rest appeared unchanged.
- The NHAV 74 capped mound had apparent fresh dredged material placed on the mound creating consolidation, displacement, and accumulation of new material

- The area of disturbance on NHAV 74 should be evaluated with a SPI survey to determine the presence and distribution of the apparent fresh dredged material and to assess the benthic conditions of the disturbed areas.

4.3 Focused Survey of FVP Mound

The historical FVP mound was last surveyed in 2005 (bathymetry, SPI, and coring). Results indicated that the uncapped mound had experienced natural recovery through ambient sedimentation and biological processing of sediments. The physical and biological condition of the mound was stable and healthy, but concerns were raised regarding the potential for near-bottom sediment processes to impede natural recovery through sediment transport. The 2011 survey collected high resolution acoustic data and a focused SPI survey in 2011. A detailed analysis was conducted of the differences in topography and sediment surface textures between 2005 and 2011.

4.3.1 Physical Condition of the FVP Mound

The FVP mound is a deposit of dredged material that was left uncapped as an experiment to evaluate the properties and recovery of contaminated sediment on the seafloor (Myre and Germano 2007). The FVP mound was created from the placement of 55,000 m3 of material classified unsuitable for open water placement that was dredged from Black Rock Harbor in Bridgeport, CT in 1983–84. The cumulative record of monitoring at FVP suggested that surface sediments at the center of the mound may have been periodically resuspended, catalyzing occasional retrograde biological succession (Myre and Germano 2007). A combination of high resolution multibeam bathymetry, snippet backscatter analysis, side-scan sonar imaging, and SPI imaging collected in the 2011 survey was used at FVP to map surface sediment patterns and infer sediment transport conditions as a means of assessing the physical stability of the mound.

The FVP mound was mapped in 2005 with multibeam bathymetry gridded to 2 m and in 2011 with the full suite of acoustic technologies gridded to 2 m for direct comparison. For 3D visualization, bathymetric data was gridded to 1 m (side-scan sonar imagery was mosaicked to 0.1–0.2 m per pixel). Many of the sedimentary features surrounding the mound could be directly compared between the 2005 and 2011 surveys for evidence of any erosion or dynamic change in features (Figure 4-15). The mound surface was examined for evidence of softening or erosion of disposal impact features, and a detailed depth difference analysis was performed. Depth difference calculations between 2005 and 2011 indicated some deposition of sediment in older pits and the formation of new disposal impact craters but remarkably little change in either the FVP mound or the sedimentary furrows (Figure 3-6). The stability of the sedimentary furrows provided strong evidence of the lack of sediment transport over the six years between surveys. In some cases, it was difficult to determine whether differences between survey results (e.g., 2005 and 2011) were due to physical changes in site conditions or differences in measurement tools and methods. An extensive effort was made to examine all acoustic data for consistency and correct for changes in tide conditions to ensure accurate assessment of deposition. A further discussion of survey results to evaluate these areas of deposition is provided below.

Accumulation of sediment on the southern edge of the FVP mound formed an overlapping pair of disposal impact craters that were distinct from the other impact craters on the surface of FVP (Figure 4-15A). The rims of the new craters were raised and had sharp relief; a pattern that is consistent with placement of relatively consolidated dredged material (ENSR 2007). This feature was more clearly discernible in the higher resolution side-scan sonar image than the disposal impact craters from the original formation of the mound in 1983–84 (Figure 4-16 A). The strong, distinct side-scan sonar return contrasted with more muted patterns of impact craters that cover the surface of FVP (Figure 4-17A). The backscatter results were corrected for slope (which can accentuate the side-scan sonar returns) and showed that sediment inside the paired disposal impact craters had a lower return than the sediment on the crater rims and surface of the mound (Figure 4-17B). This pattern of backscatter is consistent with the presence of softer sediment inside the craters. The SPI results from stations 3 and 9 (located on the rims of the craters) had distinct layers of dredged material (light gray clay with reddish fibers in Figure 3-26) similar to those found at CLIS 09 and CLIS 08. Stations 4 and 5, located near the paired craters, had smaller amounts of the fresh dredged material (Appendix C).

The bathymetric data from 2005 contained a minor tidal artifact in the eastern third of the dataset. This represented a consistent depth error of approximately 16 cm. After correction for this artifact, a surface model was constructed based on the elevation difference between the corrected 2005 data and the 2011 data (Figure 4-18). This surface model (a hillshaded surface that represented depth difference) allowed for visualization of smaller differences in seafloor elevation. Elevation differences greater than the calculated confidence interval of 0.2 m were colored and revealed four circular areas of sediment accumulation (Figure 4-18). The circular areas were diagnostic of dredged material deposition and indicated that at least four separate placement activities had occurred in this area since 2009.

Although the area surrounding and over the FVP mound showed little if any signs of active sediment transport (no change in large-scale features, no evidence in SPI images) there was evidence of very minor sediment surface modifications near the mound. In multibeam images collected in 2005, several anomalous features were observed and described (ENSR 2007 and Figure 4-19A). These features were clearly delineated as incised linear marks and small pits, but it was not clear what activity produced them. The marks appeared to be the result of movement of lobster trawl gear on the bottom, but the lobster gear itself was not visible. In 2011, the same marks were visible, but slightly less distinct (Figure 4-19A). It is possible that differences in instrumentation affected the results; the multibeam used in 2005 had a smaller beam angle and higher frequency which would result in detection of smaller features. It is also possible that some combination of bioturbation and sediment resuspension has blurred the marks on the sediment surface. The marks were not visible in backscatter data (Figure 4-19C) and were very faint in the side-scan sonar record from 2011 (Figure 4-19D); the marks were clearly small-scale disturbances of the sediment surface with no change in sediment texture (Figure 4-19). Close examination of the side-scan sonar data revealed that targets consistent with lobster traps were visible in the record and most likely the 'warp' connecting the lobster traps created the marks which are still visible at least six years after they were first recorded (Figure 4-19D inset).

It was clear from these observations that some modification of surface sediment likely occured over the scale of years, but it did not appear to be sufficient to modify the surface of the FVP mound beyond the several centimeters of fine sand detected in the SPI survey (Figures 3-26 and 3-27). It was also not sufficient to remove the marks on the seafloor left by lobster trawls. It was also clear that fresh dredged material had been placed on a portion of the FVP mound, with a distinctive clay signature consistent with construction of in-harbor CAD cells.

4.3.2 Biological Conditions at the FVP Mound

An additional objective of the 2011 survey was to further assess the topography and near-bottom sediment processes on and around the historical FVP mound. There has been some question about whether the surface of the FVP mound still has periods of impaired benthic conditions due to surface disturbance (Myre and Germano 2007). The SPI results, including the benthic habitat conditions, provided insight into the stability of the mound and the near-bottom processes over the mound surface.

Stations on the FVP mound had more high organic-content dredged material beneath a reworked surface layer than stations off the mound, but all stations had aRPD depths and successional stages statistically similar to reference area values (Tables 3-4 and 3-5). There was evidence of small-scale sediment transport over the surface of the mound in the form of fine sand layers (Figure 3-26) but no evidence of larger bedforms such as current or wave ripples. The results of this survey were consistent with the presence of advanced successional benthic conditions over the FVP mound with no evidence of physical disturbance of the mound surface (but see below).

The dominant sedimentary bedforms in the area surrounding the FVP mound were sedimentary furrows (Poppe et al. 2001). These large bedforms are stable features of the seafloor that appear to be generated by mobilization of the seafloor during infrequent storms or extreme tidal events (Poppe et al. 2002). One SPI station (FVP 15) was located in a sedimentary furrow; one replicate from this station exhibited some form of apparent physical disturbance (Figure 3-27). In this one replicate, a thin layer of reduced coarse sediment was deposited on a well-bioturbated horizon; this juxtaposition is consistent with physical disturbance of a buried horizon of reduced sand. It is not consistent with the processes associated with sedimentary furrows (helical transport of surface sediment over long distances and resulting oxidation of the sediment).

Four stations had evidence of fresh dredged material (3, 4, 5, and 9; Appendix C). These stations had distinct layers of clayey dredged material with red plant fibers (Figure 3-6). The stations were located on or near the paired disposal impact craters identified in the acoustic data (Figure 4-17). Each of these stations showed clear signs of recovery, all replicates had evidence of Stage 3 organisms and aRPD values near the mean for FVP (Table 3-2). If the fresh dredged material placement was contemporaneous with the disposal activities associated with other deposits of consolidated clay (e.g., January 2010 placement at CLDS 08), the SPI results would reflect recovery over a 20 month period. The results at FVP stations were consistent with the successional results from those areas affected (CLDS Stations 2, 7, 8; Table 3-2) but had deeper mean aRPD values. The SPI results were consistent with the high resolution acoustic data that detected modification of the surface of the FVP mound from dredged material placement but no mobilization of the sediments on the mound surface or sedimentary furrows immediately adjacent to the mound.

4.3.3 Assessment of the Stability of the FVP Mound

The surface of the FVP mound was stable and had no evidence of sediment transport beyond the several centimeters of fine sand detected in the SPI survey. The SPI results confirmed that the sediments on the surface of the FVP mound were in an advanced stage of benthic succession and significantly similar to reference area conditions. At least one deposit of fresh dredged material had been placed on the southern margin of the FVP mound since 2005.

In 2005 it was concluded that natural recovery of the historical flank sediments of the FVP mound had resulted in little biological and chemical difference relative to reference sediment (Myre and Germano 2007). The presence of Black Rock Harbor material within the uncapped mound, placed there as part of the Field Verification Program, raised the question of whether the mound should remain uncapped with continued monitored natural recovery (MNR) or be capped to augment the natural processes of sedimentation. Since its formation the mound has received an estimated 5-10 cm of new sediment on the surface, and ambient sedimentation has been identified as the primary catalyst of natural recovery (Myre and Germano 2007).

There was some uncertainty about the effect of near-bottom sediment processes on natural recovery on and around the FVP mound (Myre and Germano 2007). The high resolution acoustic imaging results combined with SPI imaging results of FVP succeeded in establishing evidence for the presence of a stable sediment surface that incorporates minor amounts of fine sediment from the water column and minor amounts of fine sand from bedload transport. Based on the results of this study, there is no evidence that near-bottom sediment processes have interfered with MNR within the survey interval from 2005 to 2011.

With resolution of the question of potential delay or disturbance of MNR by sediment transport, the management alternatives of capping the mound or continuing MNR can be more clearly addressed. The decision to cap or not cap the FVP mound should continue to be based on the balance between the risk of leaving the deposit uncapped and the potential for collecting useful information from the unique circumstances of the mound. The environmental risk from the FVP mound is arguably low, considering the small size of the mound, the apparent biological recovery, lack of toxicity of the sediments, and the lack of evidence for interference from sediment transport. The potential for collecting useful information from this unique mound has now increased with the documented presence of fresh dredged material on the surface of FVP. The opportunity to continue to collect useful data should outweigh the limited risks of leaving the mound uncapped.

4.3.4 Summary of the FVP Mound

- The surface of the FVP mound was stable and had no evidence of sediment transport beyond the several centimeters of fine sand detected in the SPI survey.

- Accumulation of sediment on the southern edge of the FVP mound formed an overlapping pair of disposal impact craters that were distinct from the other impact craters on the surface of FVP.

- Acoustic and SPI data results were consistent with placement of one scow load of dredged material on the southern edge of the FVP mound with distinctive clay and wood fiber content.

- The decision to cap or not cap the FVP mound should continue to be based on the balance between the risk of leaving the deposit uncapped and the potential for collecting useful information from the unique circumstances of the mound.

- The environmental risk from the FVP mound is arguably low, considering the small size of the mound, the apparent biological recovery, lack of toxicity of the sediments, and the lack of evidence for interference from sediment transport.

- The potential for collecting useful information from this unique mound has now increased with the documented presence of fresh dredged material on the surface of FVP. The opportunity to continue to collect useful data should outweigh the limited risks of leaving the mound uncapped.

4.4 Tracking Placement of Dredged Material at CLDS

As noted in Section 1.2, management of dredged material disposal at CLDS has involved targeted placement of material at different locations throughout the site in an effort to distribute the material and limit the height of buildup and, in more recent years, to form containment berms on the seafloor. Typically, a target location was marked with a taut-wire buoy and set for one or more disposal seasons until it was determined that a sufficient amount of placement had occurred at that location (based on disposal records and/or bathymetric surveys). As presented in the results and discussion of this report, off-target disposal was identified at several locations (e.g. NHAV-74 and FVP mounds). Occassional, limited, off-target placement is not unexpected given the constraints of weather, mechanical issues, and potential operator error. It is only with the advancement of survey techniques, particularly multibeam bathymetry, that the ability to identify individual placement events has become a standard aspect of site monitoring. Related advancements in position and operations tracking are expected to also help identify and further reduce off-target placement of material. All placement of dredged material at aquatic sites is now required to have automated tracking through the national Corps of Engineers Dredging Quality Management (DQM) Program. Through DQM, disposal scows are outfitted with recording GPS for position, speed, and heading measurements as well as sensors to monitor scow draft and hopper opening. The recorded data (including placement location) are available for review by regulatory staff, typically within 24 hours of each disposal event.

Table 4-1

Comparison of aRPD Values and Succesional Stage from 1999 to 2011

Site	Year	Mean aRPD (cm)	Successional Stage
Reference Areas	1999	3.3	3
Reference Areas	2001	3.1	3
Reference Areas	2003	3.0	3
Reference Areas	2004	4.1	3
Reference Areas	2009	4.4	3
Reference Areas	2011	3.2	3
Disposal Mounds			
CLIS 07	2009	2.7 < Ref	< Ref
	2011	**0.9 <Ref**	**= Ref**
CLIS 08	2009	2.3 < Ref	< Ref
	2011	**1.8 < Ref**	**=Ref**
CLIS 09			
	2011	1.0 < Ref	**= Ref**
Mean		2.3	2.9

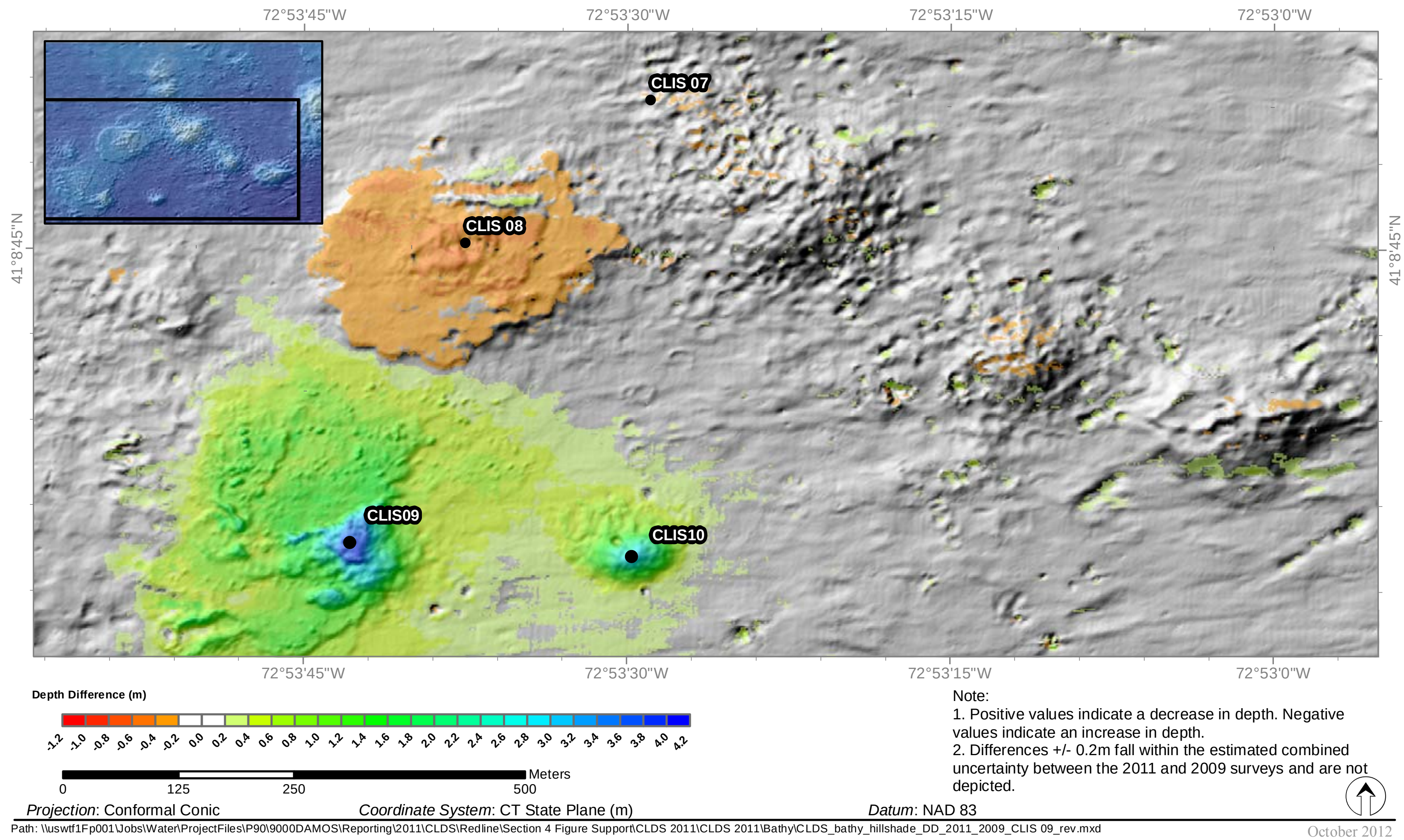


Figure 4-1. Elevation difference interval map of south-central portion of CLDS, 2011–2009.

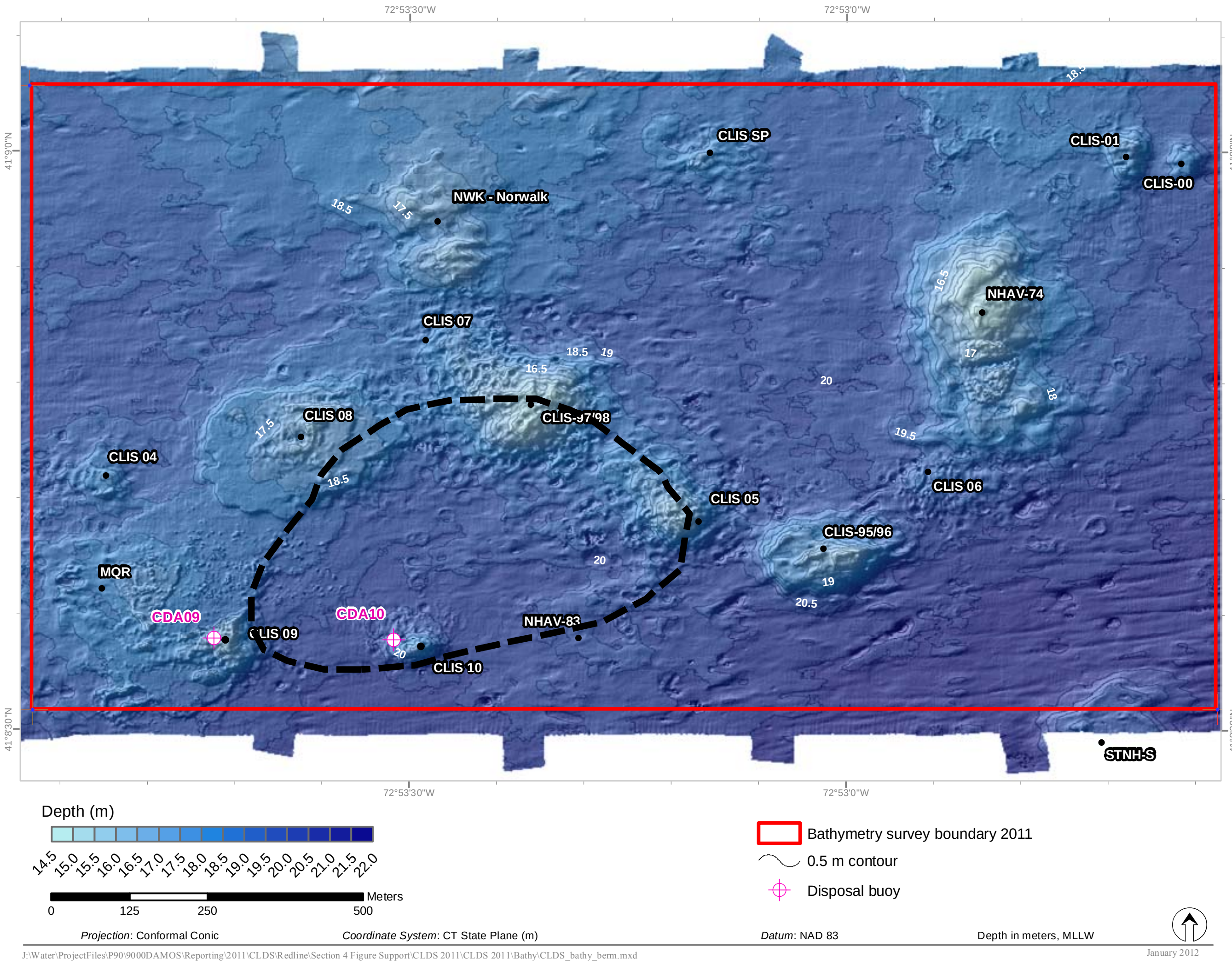


Figure 4-2. Seafloor topography of CLDS in September 2011 with outline of berm of dredged material placed to eventually form a seafloor CAD cell.

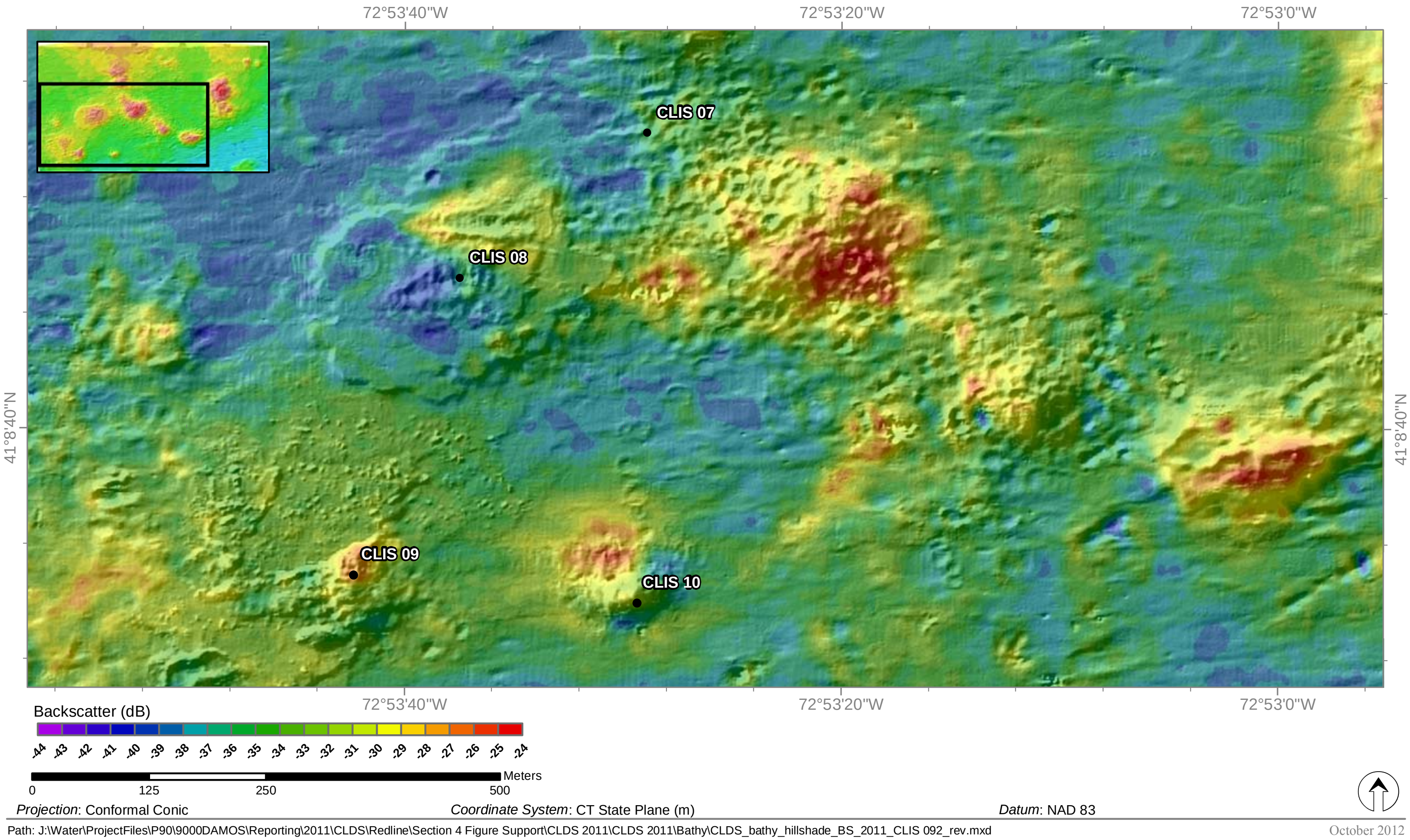


Figure 4-3. Backscatter interval map of south central portion of CLDS, 2011. Backscatter interval 1 dB

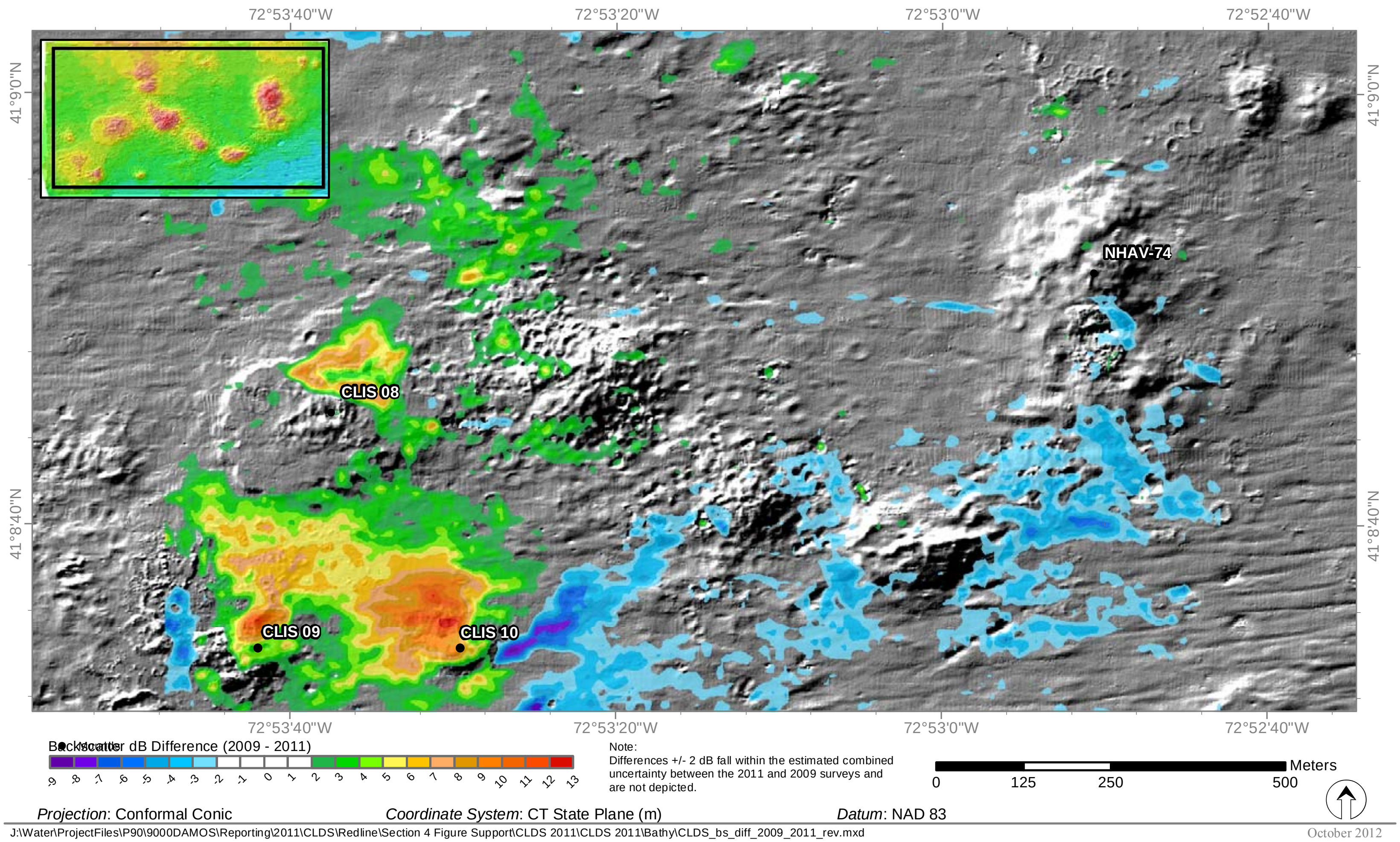


Figure 4-4. Difference in Backscatter results from 2009 to 2011 superimposed on hillshaded bathymetry from 2011.

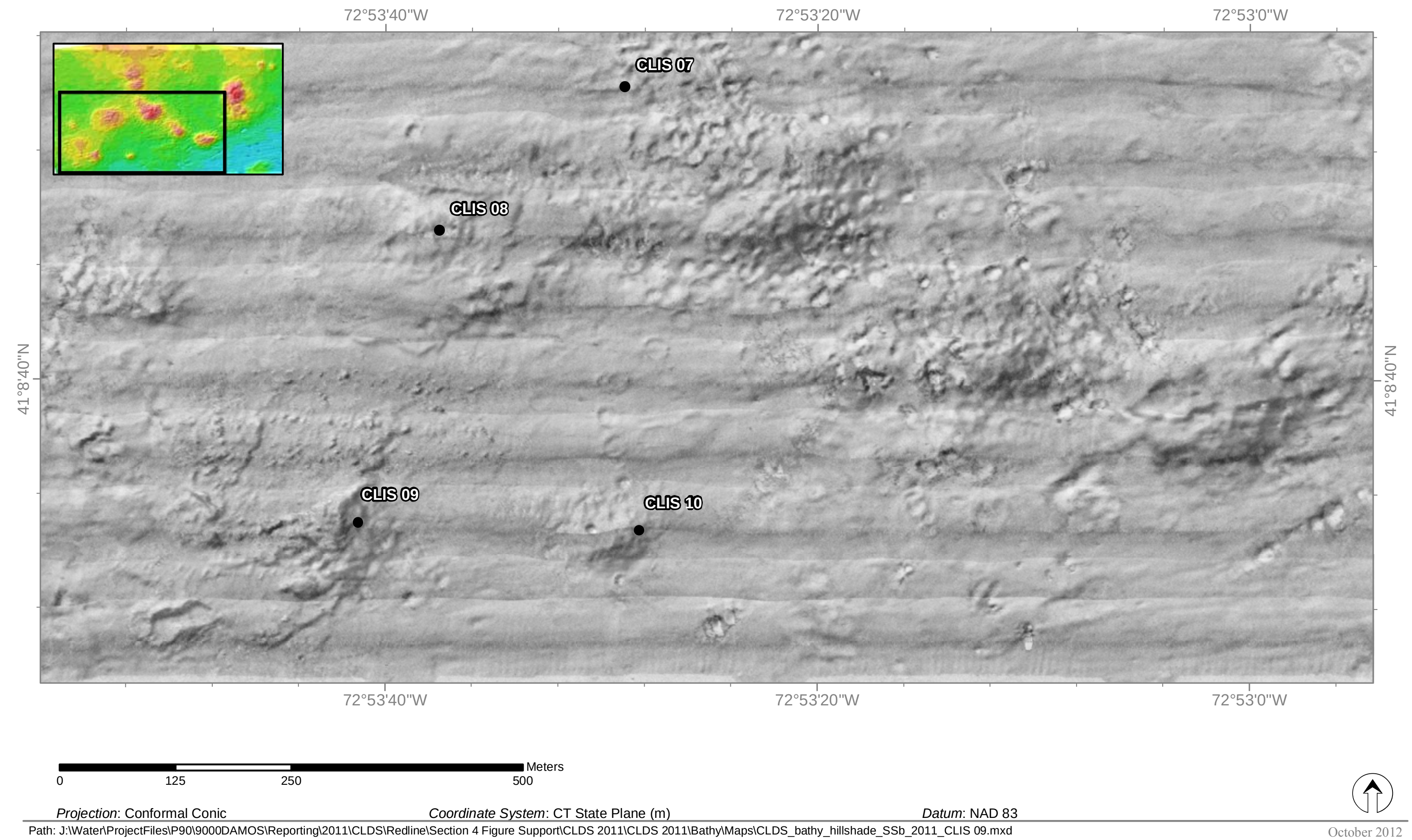


Figure 4-5. Side-scan sonar mosaic of south-central portion of CLDS, 2011. Mosaic is draped over hillshaded bathymetry.

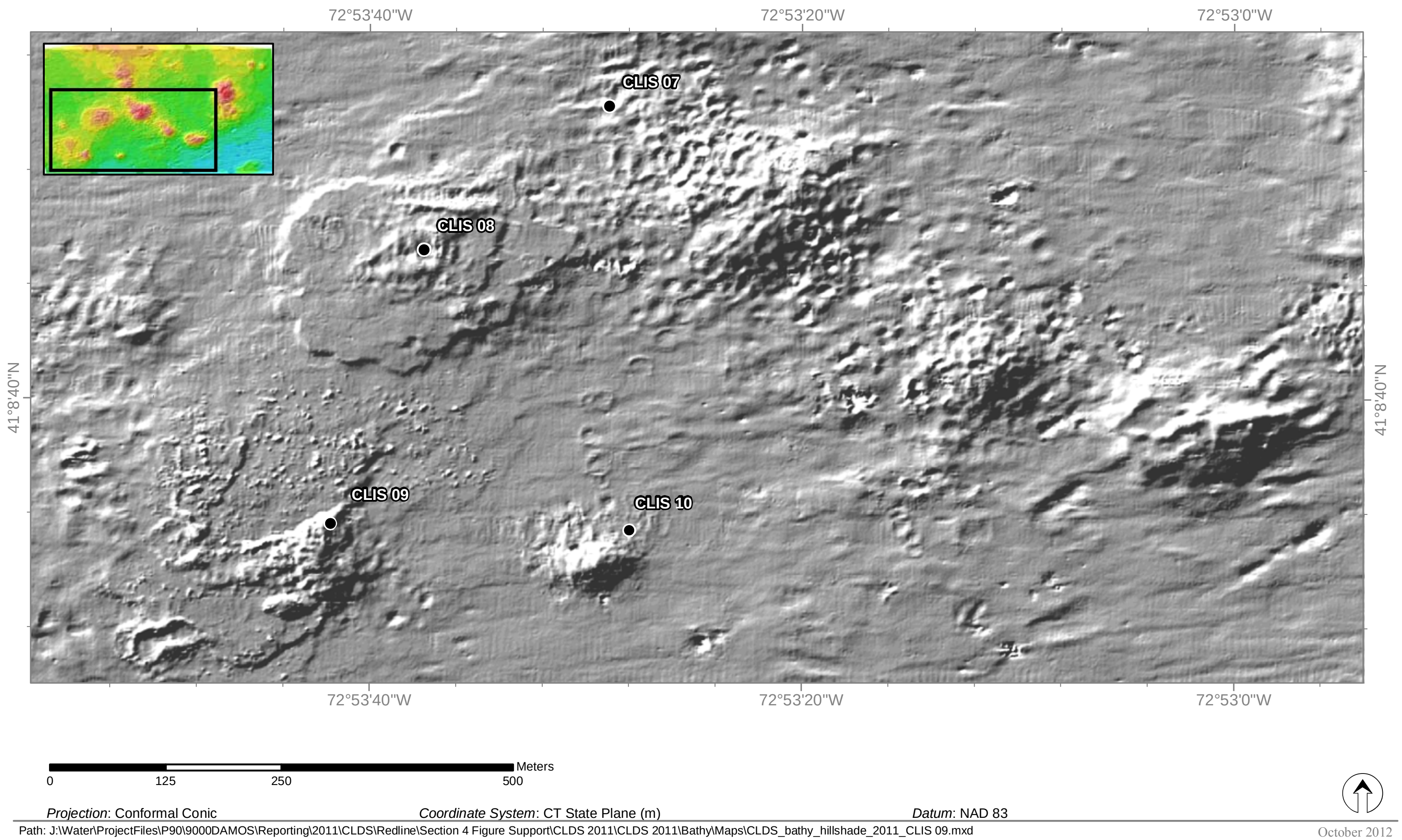


Figure 4-6. Hillshaded bathymetry of south-central portion of CLDS, 2011.

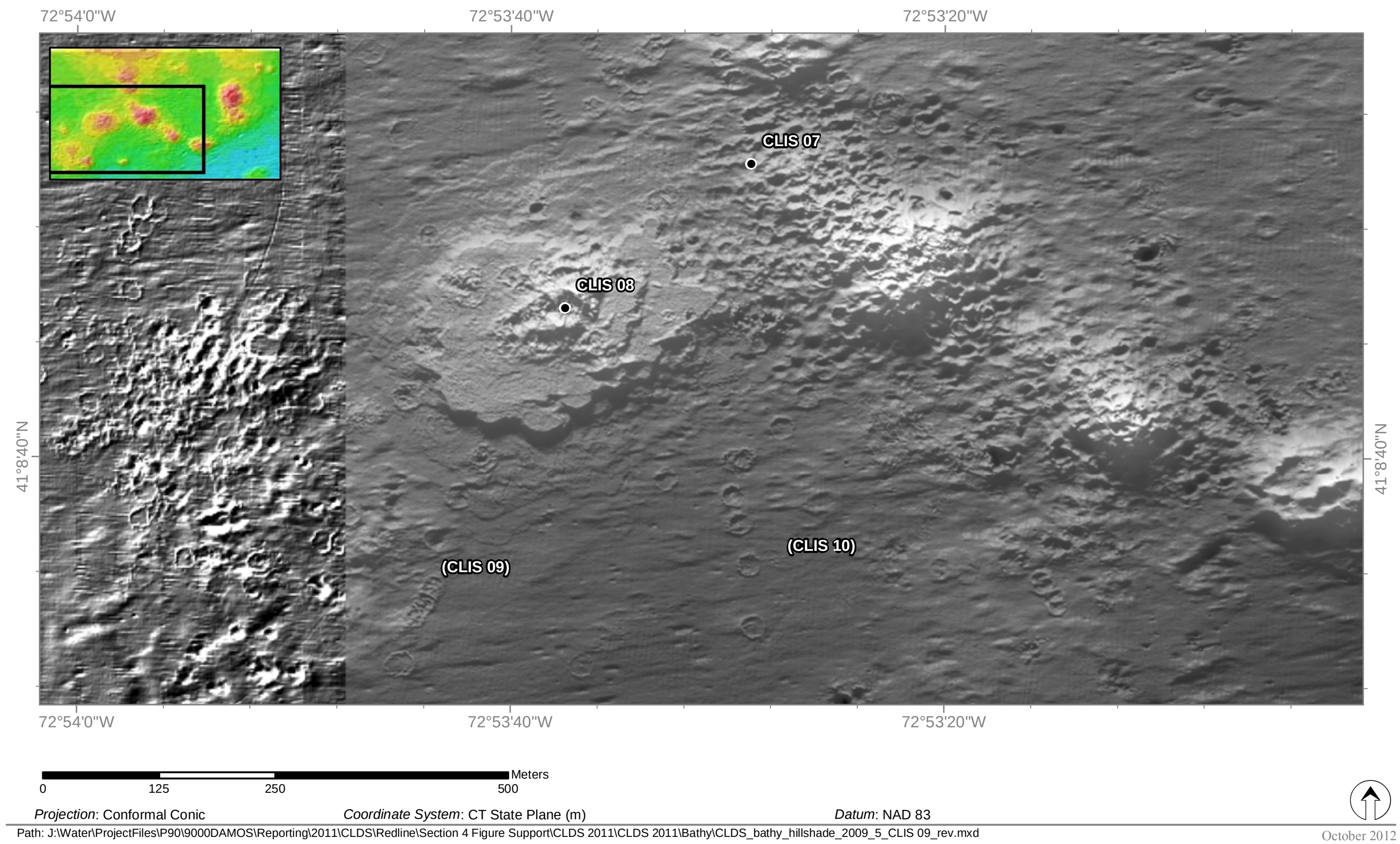


Figure 4-7. Hillshaded bathymetry of south-central portion of CLDS, 2005 (left) and 2009 (right). The location of CLIS 09 and CLIS 10 are based on 2011 bathymetry (Figure 4-5).

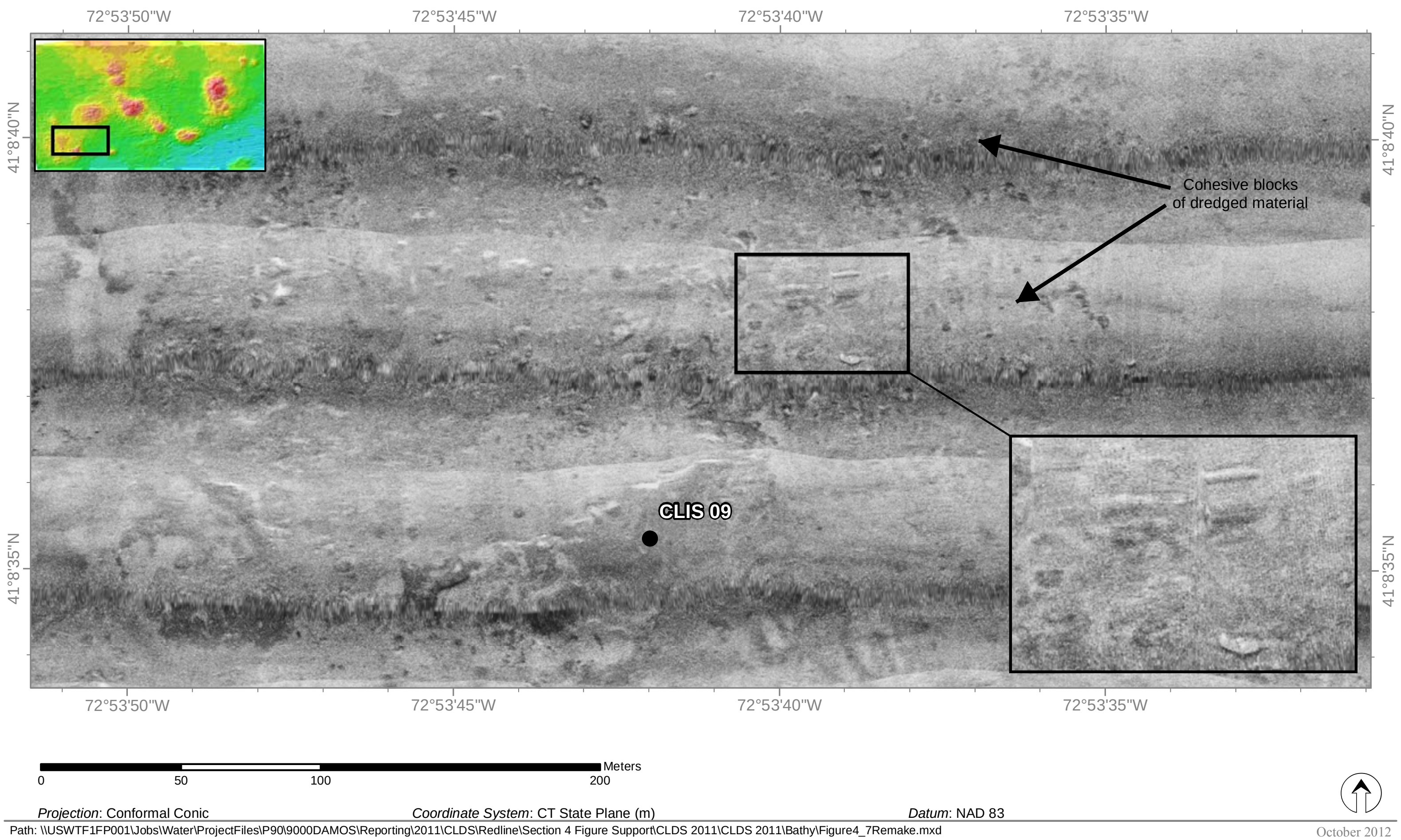


Figure 4-8. Side-scan sonar mosaic of area around CLIS 09. Note linear arrays of cohesive blocks of dredged material. Inset shows angular blocks on right.

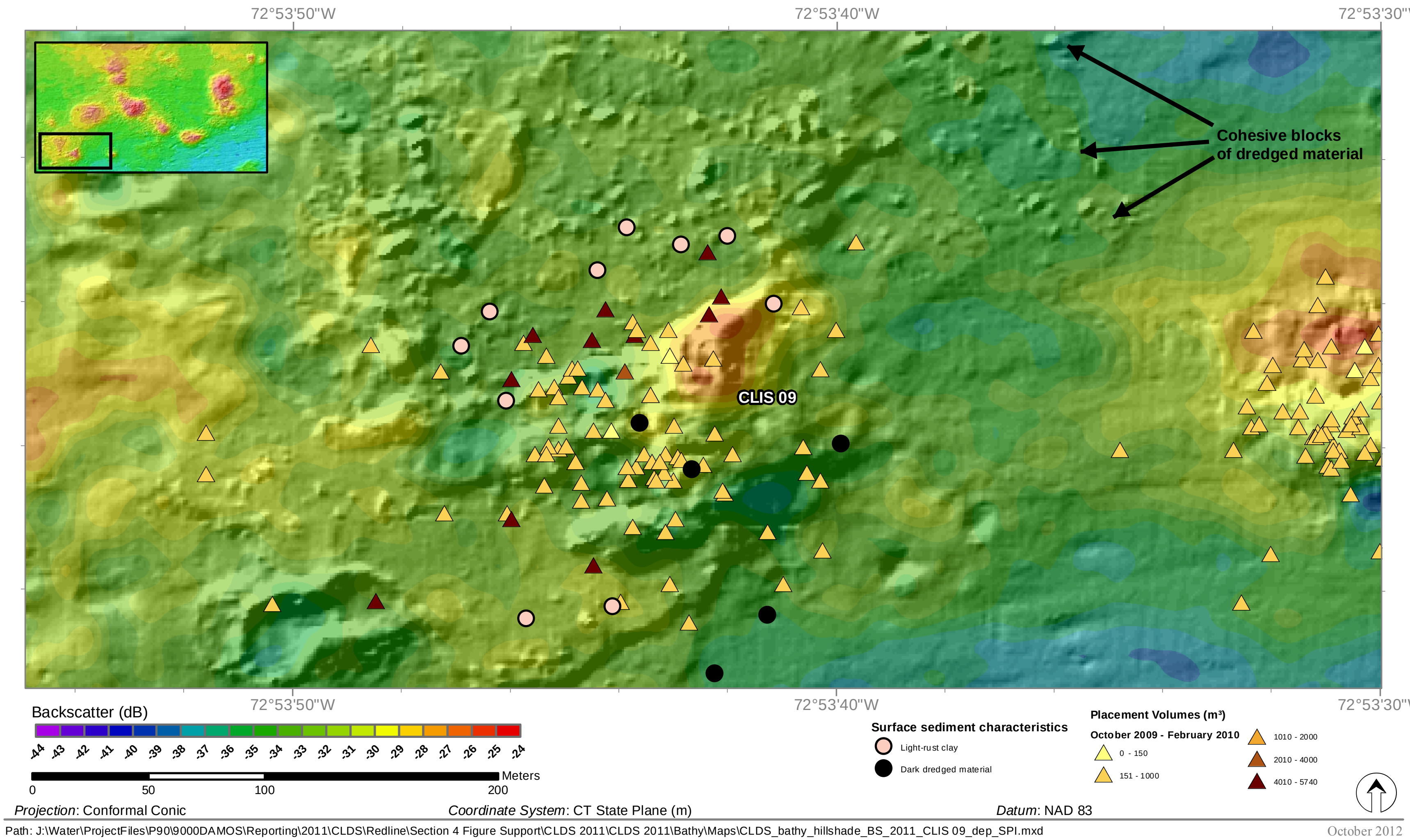


Figure 4-9. Backscatter interval map of area around CLIS 09 with placement events from disposal logsand SPI stations. Backscatter superimposed on hillshaded bathymetry. Note linear arrays of cohesive blocks of dredged material without backscatter signature.

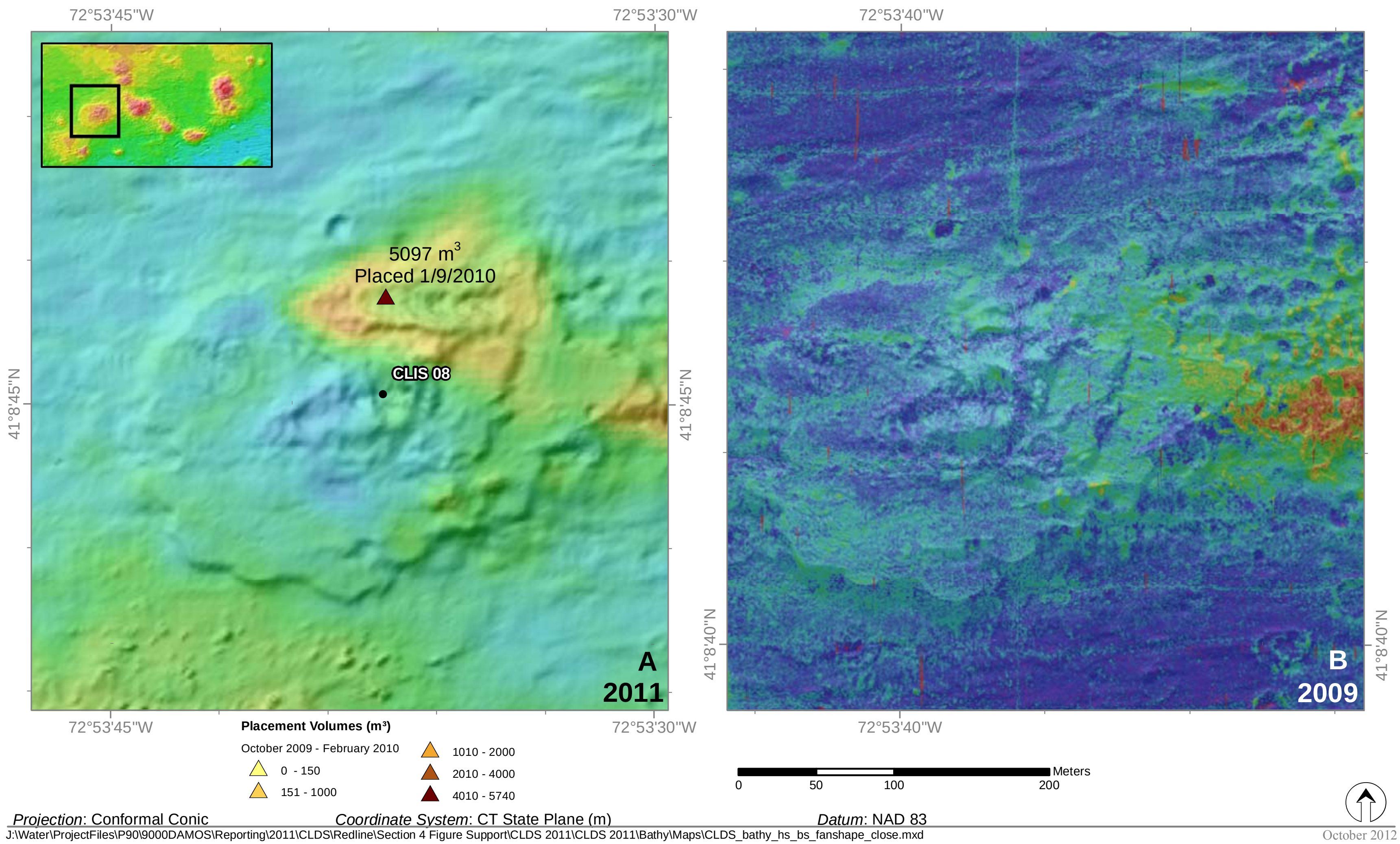


Figure 4-10. Backscatter results of CLIS 08 mound superimposed on hillshaded bathymetry. A. Results from 2011 with location of dredged material placement event from January 2010. B. Results from 2009 prior to placement event

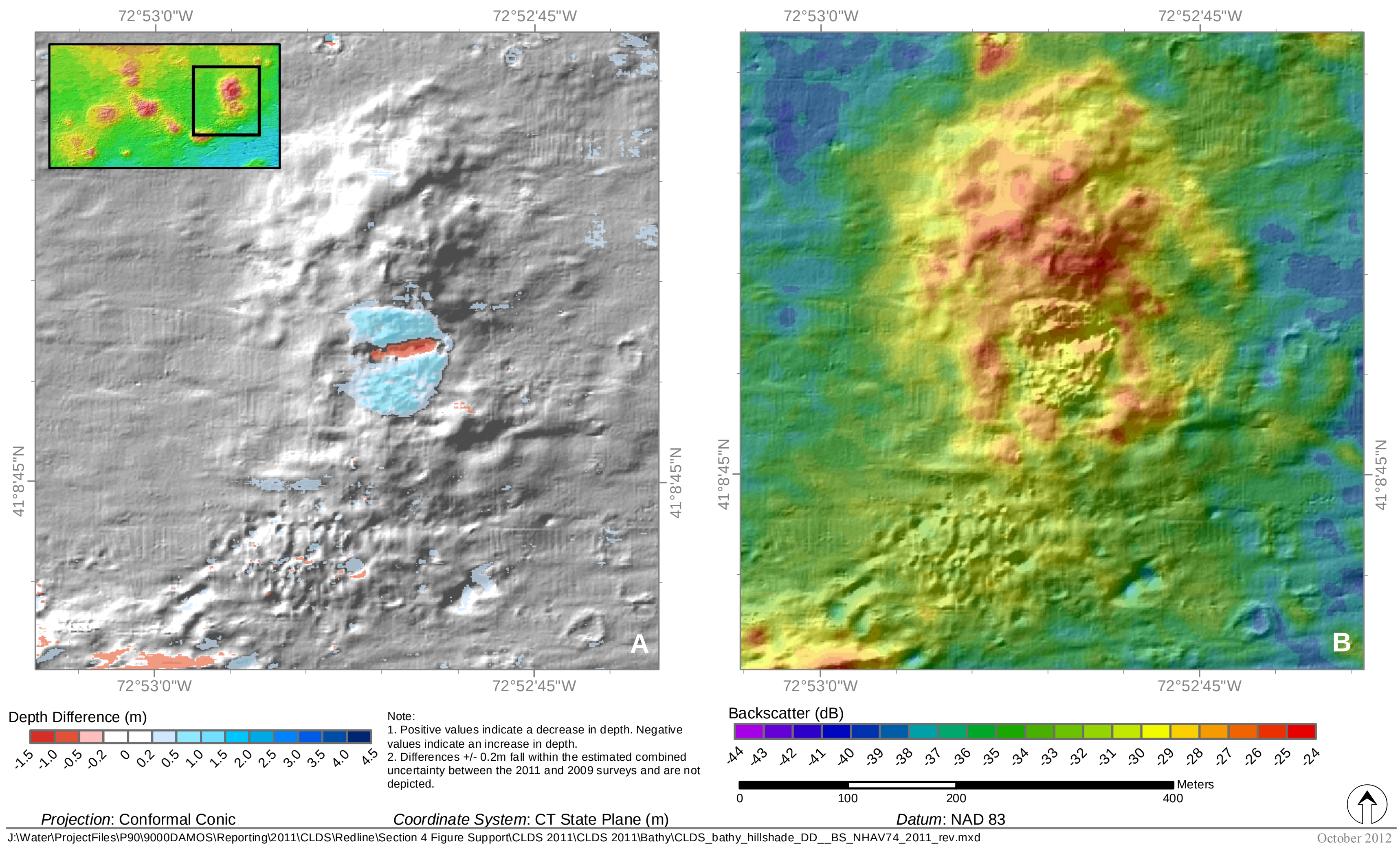


Figure 4-11. A. Elevation difference of NHAV 74 mound from 2009 to 2011. B. Backscatter results from 2011 superimposed on hillshaded bathymetry from 2011.

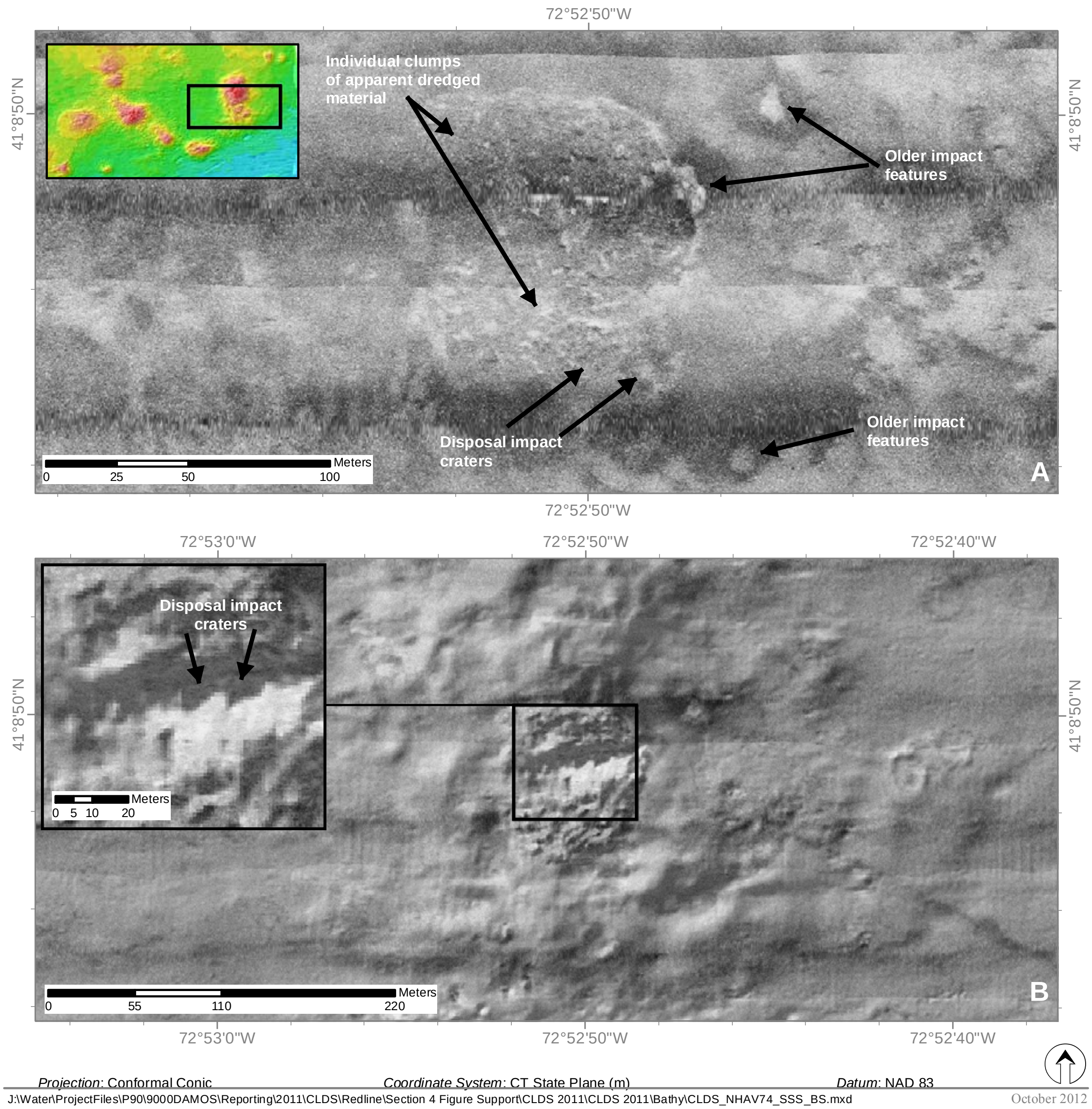


Figure 4-12. Side-scan sonar image from 2011 over NHAV 74. Note circular patterns in rubble area consistent with disposal impact craters and older impact features on flat bottom. Individual clumps of apparent dredged material were measured as small as 50 cm. B. Side-scan sonar image superimposed on hillshaded bathymetry. Inset with small disposal impact craters.

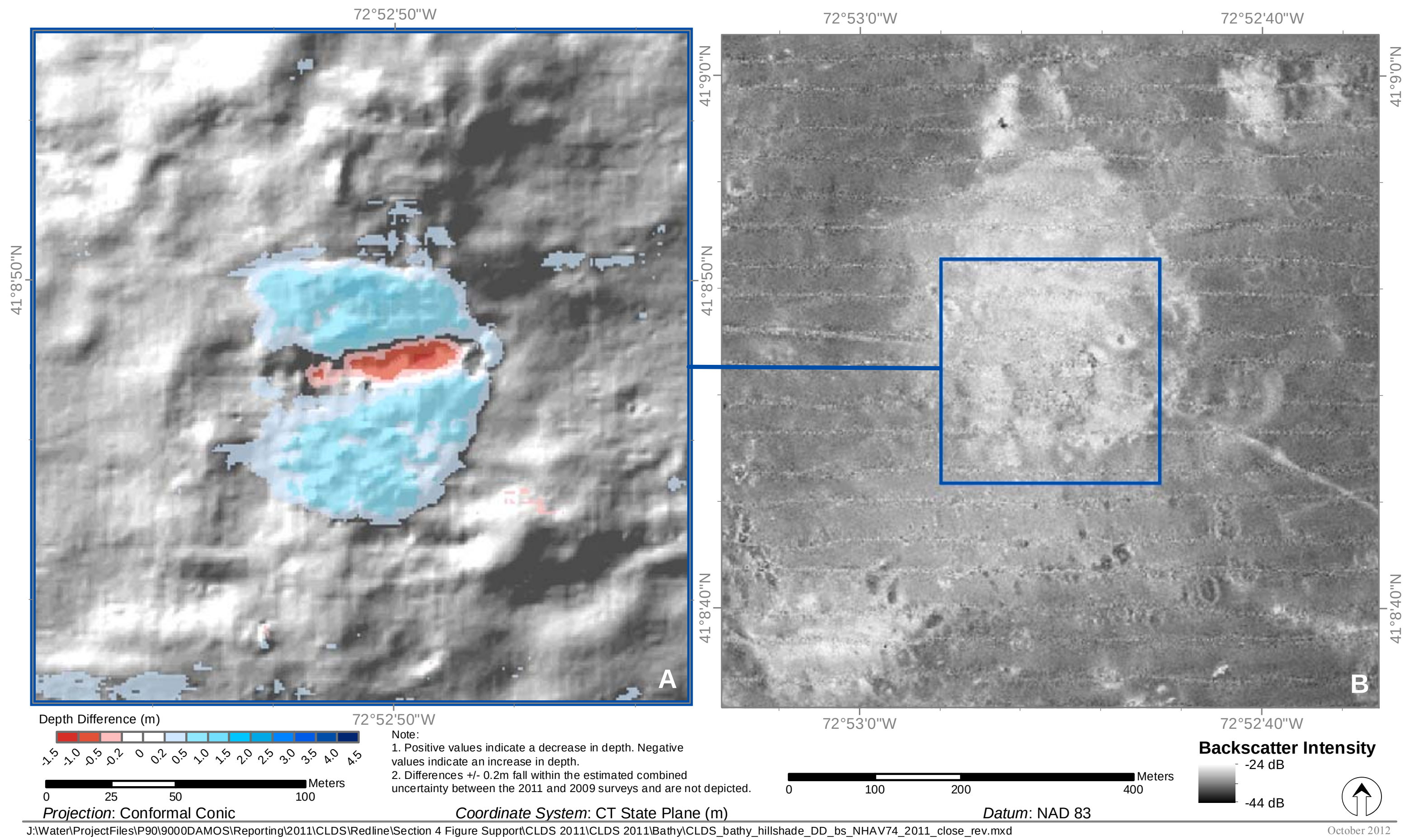


Figure 4-13. A. Depth difference from 2009 to 2011 over disturbance on NHAV 74. Note circular patterns in area with depth increase (red colors) consistent with disposal impact craters. B. Backscatter mosaic from 2011 of NHAV 74. Note broad area of high backscatter (light gray) over NHAV 74 mound with lower backscatter patch of disturbance.

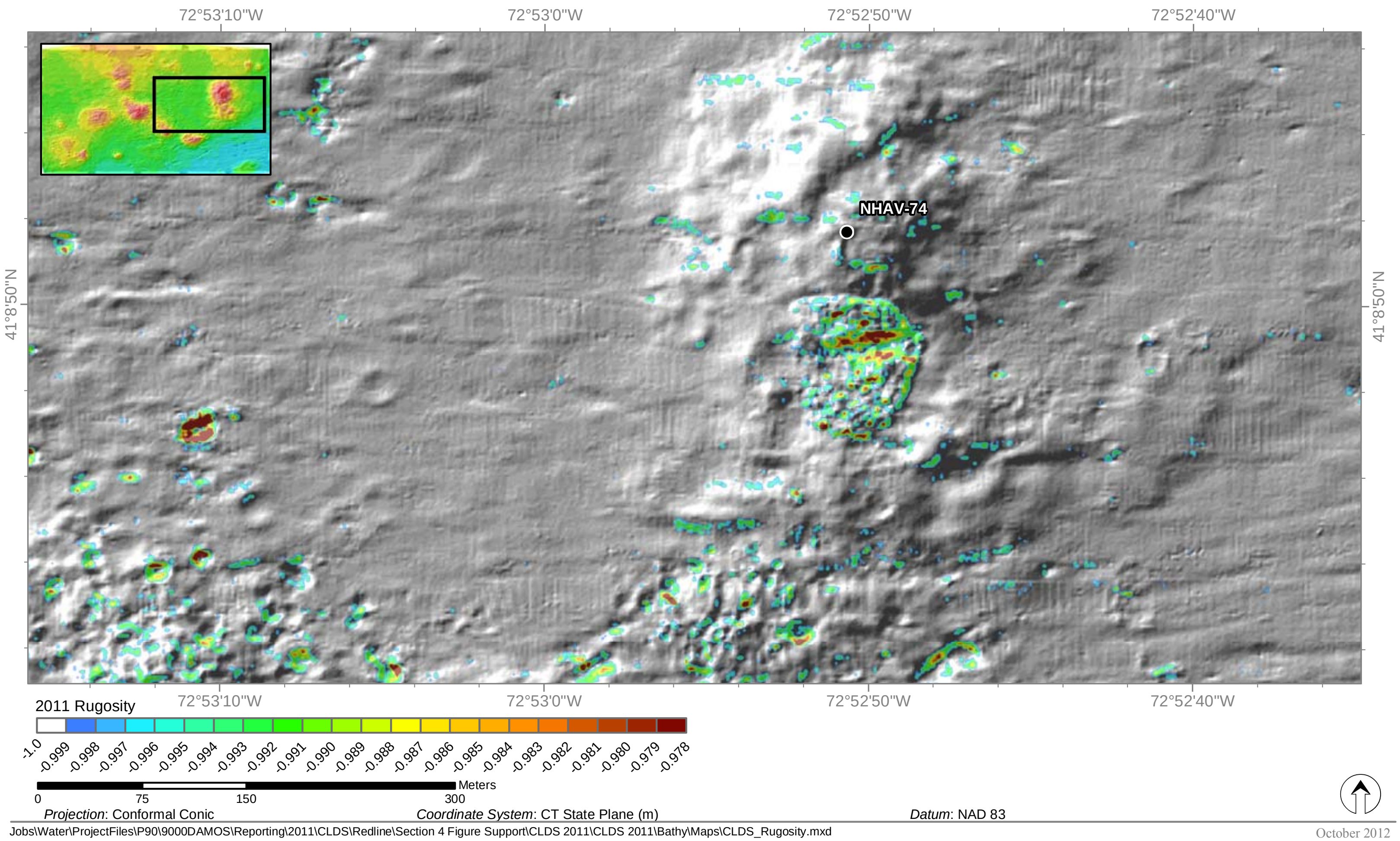


Figure 4-14. Rugosity (a measure of surface roughness) over the NHAV 74 mound highlighting the area of disturbance with a semi-circular pattern on the southern end of the mound.

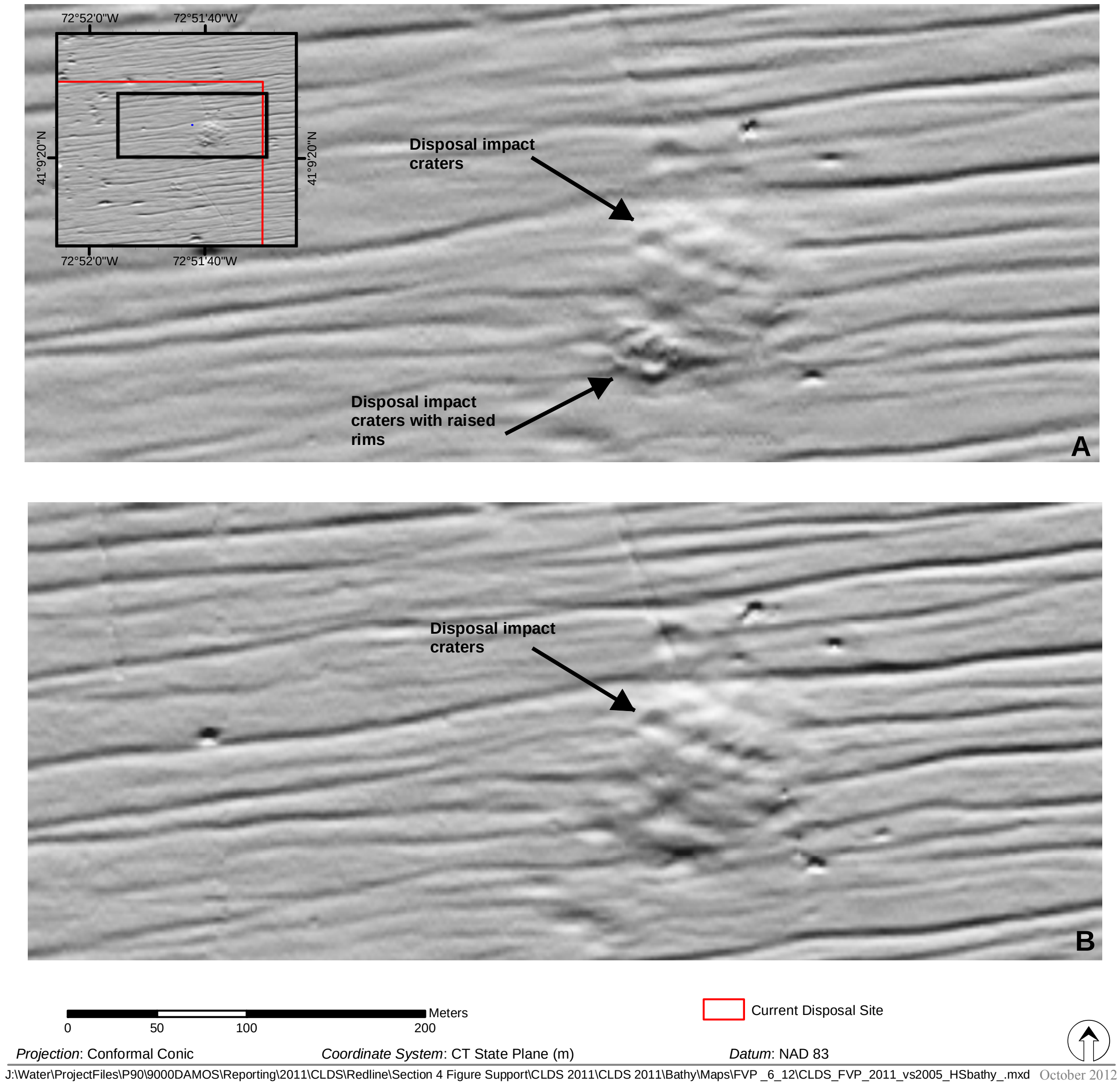


Figure 4-15. A. Hillshaded bathymetry of area around FVP mound. Results from 2011 with 10x vertical exaggeration. Note disposal impact craters. Row of craters in north with no rims. Pair of craters at south of mound with raised rims. B. Results from 2005 with 10x vertical exaggeration. Impact craters do not have raised rims.

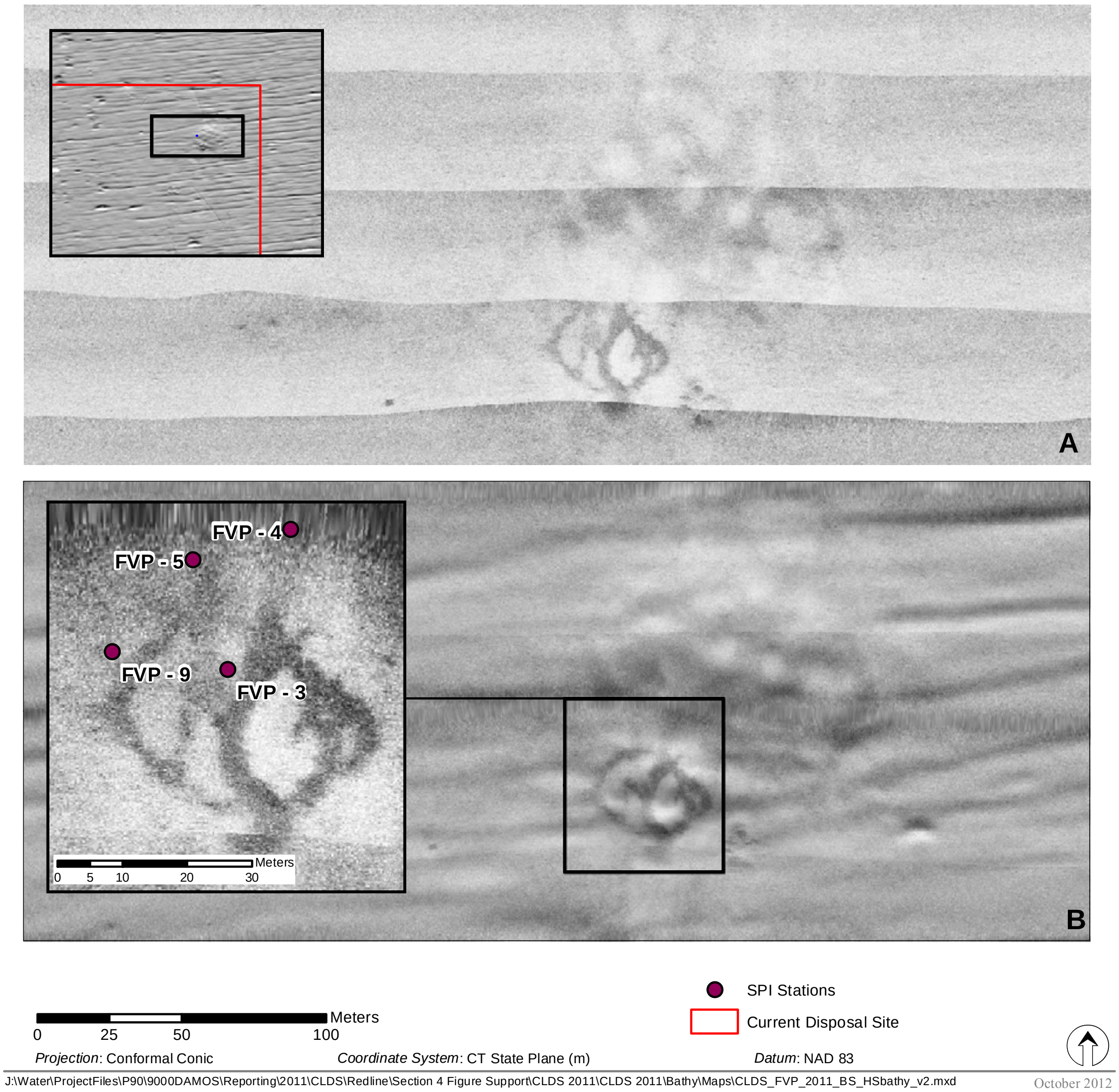


Figure 4-16. A Side-scan sonar mosaic of area around FVP mound. B. Mosaic draped over hillshaded bathymetry. Inset is pair of disposal impact craters at southern edge of FVP mound with location of SPI stations.

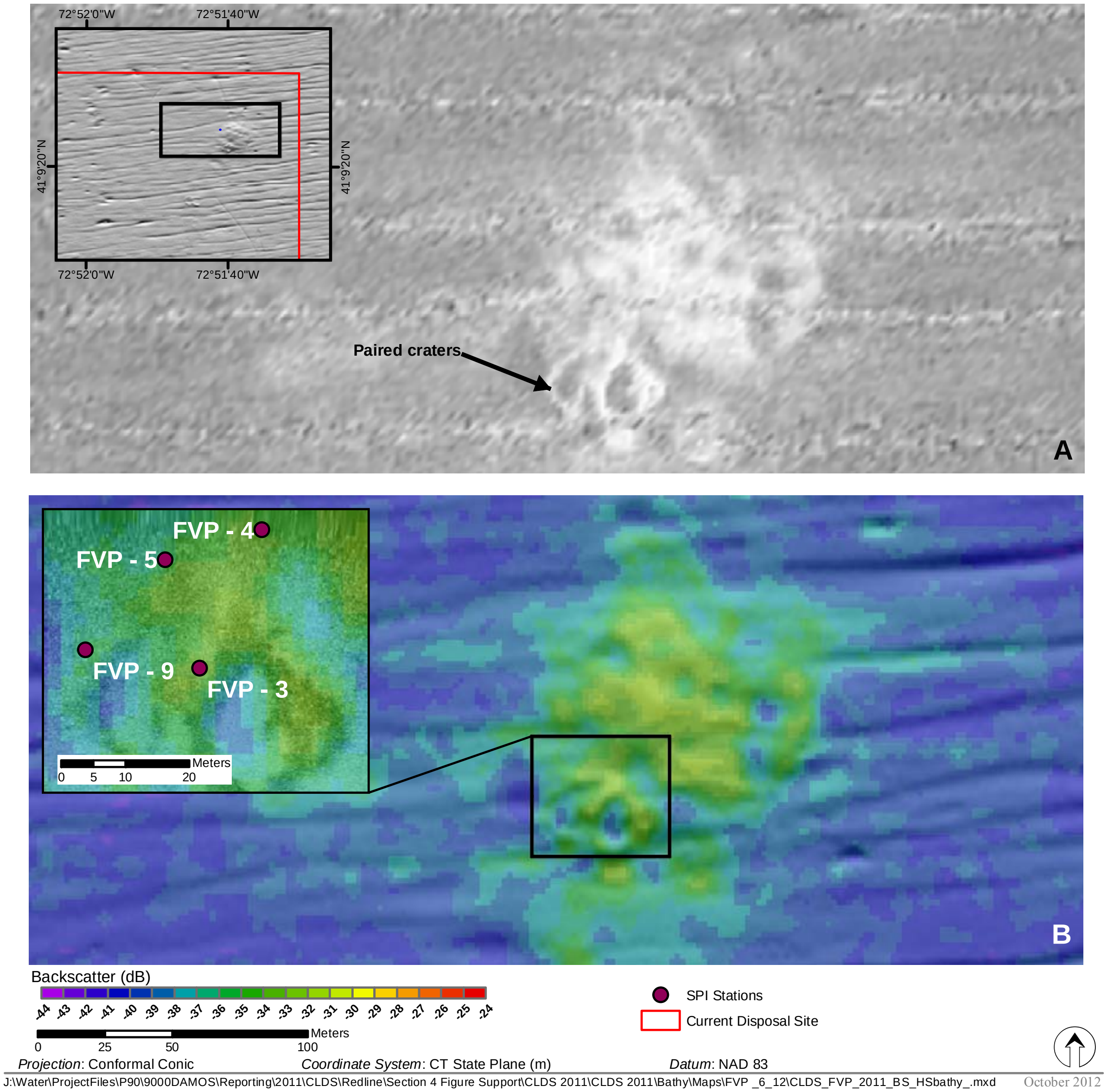


Figure 4-17. A. Backscatter of area around FVP mound. B. Backscatter interval data draped over hillshaded bathymetry. Inset: Backscatter interval data draped over side-scan sonar data with SPI station locations. Backscatter results inside paired craters showed a lower return.

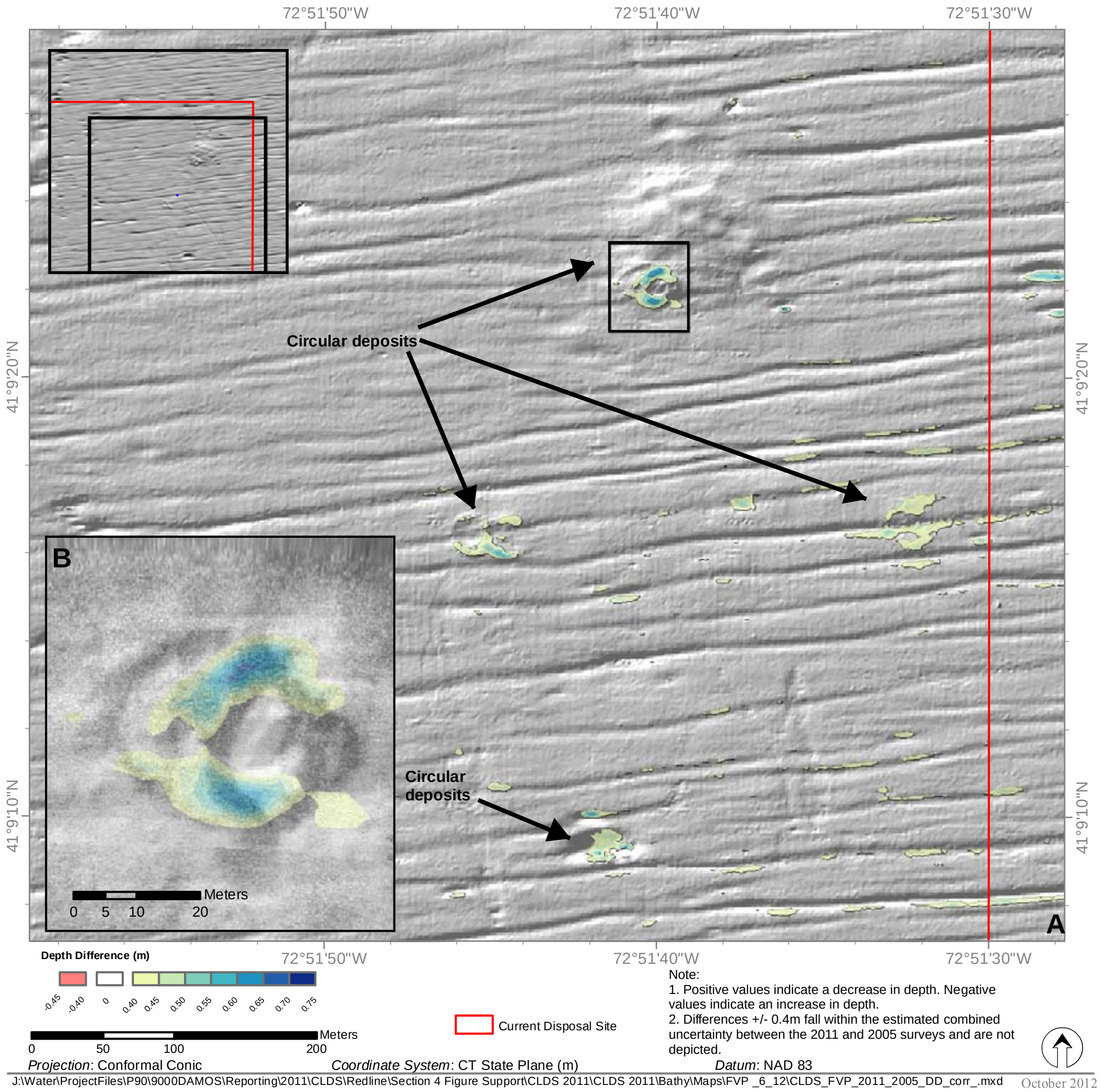


Figure 4-18. A. Surface elevation model of depth difference around FVP mound. Note four areas with circular deposits. B. Inset Side-scan sonar image draped over surface elevation model of craters on FVP.

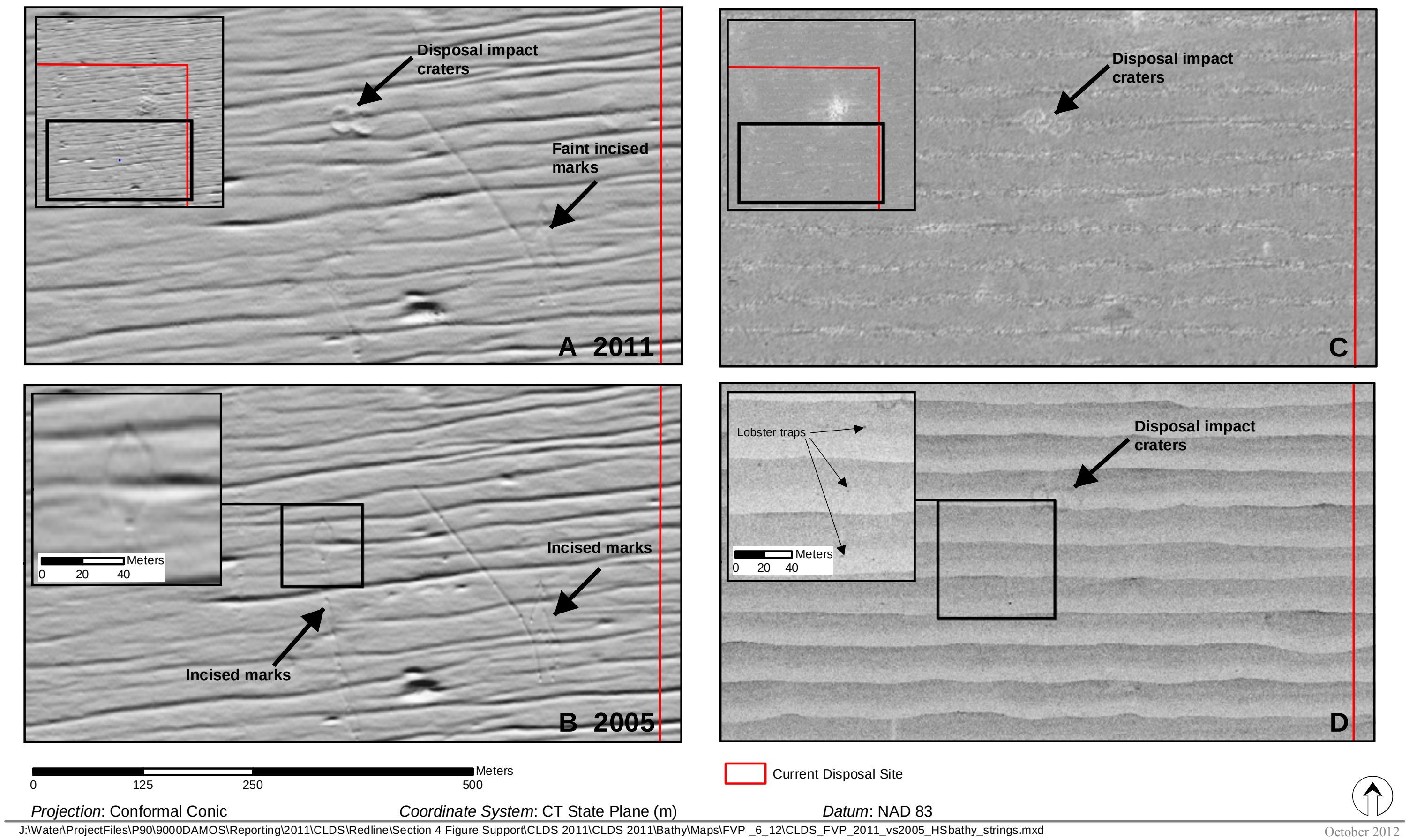


Figure 4-19. Acoustic images of area south of FVP mound. A. 2011 bathymetry with faint incised marks and disposal impact craters. B. 2005 bathymetry with incised marks. Inset with paired marks. C. 2011 backscatter with craters but no marks. D.2011 side-scan sonar with craters, faint marks and lobster traps visble in inset.

5.0 CONCLUSIONS

The multibeam bathymetric survey, performed as a standard confirmatory survey as part of the 2011 monitoring at CLDS, revealed that two discrete mounds of dredged material had been created on the seafloor as a result of disposal activities during the previous two years. The size of each mound was consistent with the volume of dredged material placed in each location.

The new mounds (CLIS 09, CLIS 10) represented additions of dredged material to an existing, crescent-shaped line of mounds that are coalescing into a berm on the seafloor. The area inside the berm will eventually form a containment cell that can be used for large-scale CAD operations. The berm represents the southern wall of a large CAD area being formed in this part of the disposal site. The northern flank of the CLIS 09 mound was relatively flat, and additional material may be required to complete the berm between CLIS 08 and CLIS 09. The CLIS 10 mound has begun to join with the CLIS 09 and NHAV 83 mound. It is recommended that additional disposal activities be directed to fully connect these all four of these mounds in the future (CLIS 08, CLIS 09, CLIS 10, NHAV 83).

Depth difference calculations and analysis of side-scan sonar and backscatter results were used to assess the distribution of dredged material and stability of disposal mounds. Unlike the sediment distribution in 2009, the grain size of dredged material placed recently at CLDS appeared relatively uniform. The new disposal mounds accumulated dredged material and the CLIS 08 mound consolidated. The surface of CLIS 08 appeared to have received fresh dredged material which was apparent in all of the acoustic results.

The 2011 confirmatory monitoring effort also included a SPI survey to assess the benthic recolonization status of the three mounds created during the 2007 through 2010 disposal seasons. Two mounds (CLIS 07 and CLIS 09) were characterized by relatively well-developed aRPD depths and an advanced, Stage 3 successional status, comparable to the Stage 3 conditions observed at the three nearby reference areas.

In contrast, one mound (CLIS 08) was in an intermediate successional status, as evidenced by both high variability among replicate images and the widespread presence of transitional “Stage 1 going to 2” and “Stage 2 going to 3” successional series. As succession proceeds over time at this mound, it will converge both with reference conditions and with conditions observed at the two other mounds. Despite the presence of transitional successional stages, the mean aRPD and successional stage values at CLIS 08 were already significantly similar to reference area values.

The physical condition of older inactive mounds within the survey area was assessed through analysis of acoustic data from 2009 compared to acoustic results from 2011. Of the twelve older inactive mounds in the survey area, a few had minor amounts of consolidation (CLIS 05 and CLIS 95/96) but the rest appeared unchanged. The NHAV 74 capped mound had apparent fresh dredged material placed on the mound creating consolidation, displacement, and accumulation of new material. Apart from the presence of the new material at NHAV 74, all of the older mounds surveyed at CLDS have been stable since 2009.

The 2011 focused study included multibeam and SPI surveys of the historical FVP mound. The surface of the FVP mound was stable and had no evidence of sediment transport beyond the several centimeters of fine sand detected in the SPI survey. The SPI results confirmed that the sediments on the surface of the FVP mound were in an advanced stage of benthic succession and significantly similar to reference area conditions. At least one deposit of fresh dredged material had been placed on the southern margin of the FVP mound since 2005.

The results of both the confirmatory survey and focused study at CLDS demonstrated that dredged material placement can be effectively mapped with high resolution acoustic methods. With careful attention to processing, tidal data, calibration, and operation of multibeam systems, thin layers (<30 cm) of fresh dredged material can be detected and mapped. This approach is enhanced if sequential surveys at a site are well-registered and can be directly compared.

Based on the findings of the 2011 CLDS survey, the following recommendations are proposed:

R1) Periodic bathymetric and backscatter surveys should be conducted (as necessary) to monitor the morphology and stability of historical mounds and the formation of future mounds.

R2) Dredged material placement should be directed to locations, north, south and east of the CLIS 09 mound to complete the CAD area south of the CLIS 98 mound.

R3) Benthic recolonization should be monitored with SPI surveys at CLIS 08, CLIS 09, and any future mounds formed as a result of disposal activity.

R4) The new dredged material deposit at NHAV 74 should be monitored with SPI and high-resolution acoustic surveying (side-scan sonar) to assess the benthic recolonization status and physical condition of the area.

R5) The dredged material deposit at FVP should be monitored with SPI surveys and high-resolution acoustic surveys and compared with benthic recolonization status and physical condition of the uncapped portion of the mound and reference areas.

R6) When feasible, the bathymetric and backscatter results from sequential surveys should be compared to evaluate disposal traces and sediment transport features at CLDS (sedimentary furrows, impact craters, etc.).

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Appendix A

Disposal Barge Logs for CLDS
September 2009 to September 2011

Disposal Barge Logs for
Central Long Island Sound Disposal Site
September 2009 to September 2011

Project Name	Permittee	Permit Number	Disposal Site	Disposal Date	Volume (yd3)	Volume (m3)	Latitude (degrees)	Longitude (degrees)	Distance From Buoy (ft)	Direction From Buoy
GLEN COVE CREEK	BREWER YACHT YARD AT GLEN COVE	NAE20064279	CLDS	10/11/2009	1200	917.52	41.14251667	-72.89613333	75 ft	W
GLEN COVE CREEK	BREWER YACHT YARD AT GLEN COVE	NAE20064279	CLDS	10/14/2009	1200	917.52	41.14245	-72.8948	75 ft	ESE
GLEN COVE CREEK	BREWER YACHT YARD AT GLEN COVE	NAE20064279	CLDS	10/19/2009	1200	917.52	41.14308333	-72.89453333	75 ft	E
GLEN COVE CREEK	BREWER YACHT YARD AT GLEN COVE	NAE20064279	CLDS	10/20/2009	1200	917.52	41.14278333	-72.89461667	40 ft	SE
GLEN COVE CREEK	BREWER YACHT YARD AT GLEN COVE	NAE20064279	CLDS	10/22/2009	1200	917.52	41.14323333	-72.89445	80 ft	E
GLEN COVE CREEK	BREWER YACHT YARD AT GLEN COVE	NAE20064279	CLDS	10/25/2009	1200	917.52	41.14225	-72.89471667	75 ft	SE
GLEN COVE CREEK	BREWER YACHT YARD AT GLEN COVE	NAE20064279	CLDS	10/28/2009	1200	917.52	41.14283333	-72.89506667	90 ft	S
HOUSATONIC RIVER	CASWELL COVE MARINA ASSOC.	NAE2004988	CLDS	10/29/2009	525	401.415	41.14311667	-72.89508333	15	
GLEN COVE CREEK	BREWER YACHT YARD AT GLEN COVE	NAE20064279	CLDS	11/2/2009	1200	917.52	41.1421	-72.8952	100 ft	SSE
GLEN COVE CREEK	BREWER YACHT YARD AT GLEN COVE	NAE20064279	CLDS	11/4/2009	1200	917.52	41.14275	-72.89531667	50 ft	S
DREDGING IN STAMFORD HARBOR	PONUS YACHT CLUB	NAE20043021	CLDS	11/5/2009	750	573.45	41.14305	-72.89581667	120 ft	
GLEN COVE CREEK	BREWER YACHT YARD AT GLEN COVE	NAE20064279	CLDS	11/7/2009	1200	917.52	41.14245	-72.89531667	70 ft	S
DREDGING IN STAMFORD HARBOR	PONUS YACHT CLUB	NAE20043021	CLDS	11/7/2009	750	573.45	41.14318333	-72.89605	150 ft	
DREDGING IN STAMFORD HARBOR	PONUS YACHT CLUB	NAE20043021	CLDS	11/8/2009	750	573.45	41.143	-72.89566667	100 ft	
DREDGING IN STAMFORD HARBOR	PONUS YACHT CLUB	NAE20043021	CLDS	11/9/2009	750	573.45	41.14306667	-72.89646667	200 ft	
GLEN COVE CREEK	BREWER YACHT YARD AT GLEN COVE	NAE20064279	CLDS	11/9/2009	1200	917.52	41.14238333	-72.89451667	90 ft	SE
DREDGING IN STAMFORD HARBOR	PONUS YACHT CLUB	NAE20043021	CLDS	11/10/2009	750	573.45	41.14308333	-72.8958	150 ft	
DREDGING IN STAMFORD HARBOR	PONUS YACHT CLUB	NAE20043021	CLDS	11/11/2009	750	573.45	41.1426	-72.89501667	150 ft	
GLEN COVE CREEK	BREWER YACHT YARD AT GLEN COVE	NAE20064279	CLDS	11/15/2009	1000	764.6	41.14218333	-72.89555	85 ft	SSW
DREDGING IN STAMFORD HARBOR	PONUS YACHT CLUB	NAE20043021	CLDS	11/15/2009	725	554.335	41.14313333	-72.89593333	200 ft	
GLEN COVE CREEK	BREWER YACHT YARD AT GLEN COVE	NAE20064279	CLDS	11/16/2009	1200	917.52	41.14356667	-72.89435	50 ft	NE
DREDGING IN STAMFORD HARBOR	PONUS YACHT CLUB	NAE20043021	CLDS	11/16/2009	700	535.22	41.14251667	-72.89645	100 ft	
GLEN COVE CREEK	BREWER YACHT YARD AT GLEN COVE	NAE20064279	CLDS	11/18/2009	1200	917.52	41.143	-72.89596667	25 ft	NW
DREDGING IN STAMFORD HARBOR	PONUS YACHT CLUB	NAE20043021	CLDS	11/18/2009	750	573.45	41.1425	-72.89526667	200 ft	
GLEN COVE CREEK	BREWER YACHT YARD AT GLEN COVE	NAE20064279	CLDS	11/20/2009	1200	917.52	41.1431	-72.89523333	90 ft	NNE
GLEN COVE CREEK	BREWER YACHT YARD AT GLEN COVE	NAE20064279	CLDS	11/22/2009	1200	917.52	41.14225	-72.8953	85 ft	SE
GLEN COVE CREEK	BREWER YACHT YARD AT GLEN COVE	NAE20064279	CLDS	11/24/2009	1200	917.52	41.14265	-72.89528333	70 ft	SE
HARBOR WOODS CONDO	HARBOR WOODS CONDO	NAE20082387	CLDS	11/25/2009	359	274.4914	41.14298333	-72.8954	25 ft	S
GLEN COVE CREEK	BREWER YACHT YARD AT GLEN COVE	NAE20064279	CLDS	11/30/2009	1200	917.52	41.14275	-72.89498333	90 ft	ESE
HARBOR WOODS CONDO	HARBOR WOODS CONDO	NAE20082387	CLDS	11/30/2009	600	458.76	41.14283333	-72.89766667	20 ft	N
HARBOR WOODS CONDO	HARBOR WOODS CONDO	NAE20082387	CLDS	12/1/2009	650	496.99	41.14316667	-72.89683333	10 ft	N
HARBOR WOODS CONDO	HARBOR WOODS CONDO	NAE20082387	CLDS	12/1/2009	359	274.4914	41.14298333	-72.8954	30 ft	S
HARBOR WOODS CONDO	HARBOR WOODS CONDO	NAE20082387	CLDS	12/1/2009	700	535.22	41.14266667	-72.89766667	30 ft	N
GLEN COVE CREEK	BREWER YACHT YARD AT GLEN COVE	NAE20064279	CLDS	12/2/2009	1200	917.52	41.14318333	-72.8954	50 ft	N

Disposal Barge Logs for
Central Long Island Sound Disposal Site
September 2009 to September 2011

Project Name	Permittee	Permit Number	Disposal Site	Disposal Date	Volume (yd3)	Volume (m3)	Latitude (degrees)	Longitude (degrees)	Distance From Buoy (ft)	Direction From Buoy
HARBOR WOODS CONDO	HARBOR WOODS CONDO	NAE20082387	CLDS	12/4/2009	625	477.875	41.14216667	-72.89733333	20 ft	N
GLEN COVE CREEK	BREWER YACHT YARD AT GLEN COVE	NAE20064279	CLDS	12/4/2009	1200	917.52	41.14331667	-72.89463333	50 ft	ENE
GLEN COVE CREEK	BREWER YACHT YARD AT GLEN COVE	NAE20064279	CLDS	12/7/2009	1200	917.52	41.14265	-72.89453333	75 ft	SE
NEW LONDON NAVY SUB BASE		NAE20081390	CLDS	12/28/2009	3159.413992	2415.687938	41.384988	-72.089645		
NEW LONDON NAVY SUB BASE		NAE20081390	CLDS	12/28/2009	6190.788477	4733.47687	41.385933	-72.089585		
NEW LONDON NAVY SUB BASE		NAE20081390	CLDS	12/29/2009	4601.125926	3518.020883	41.384772	-72.08964		
NEW LONDON NAVY SUB BASE		NAE20081390	CLDS	12/30/2009	5870.827984	4488.835076	41.38554	-72.089597		
NEW LONDON NAVY SUB BASE		NAE20081390	CLDS	1/2/2010	5878.663374	4494.826016	41.14232	-72.895693		
NEW LONDON NAVY SUB BASE		NAE20081390	CLDS	1/4/2010	4644.911934	3551.499665	41.3853	-72.08957		
NEW LONDON NAVY SUB BASE		NAE20081390	CLDS	1/5/2010	7511.097942	5742.985487	41.385325	-72.089885		
NEW LONDON NAVY SUB BASE		NAE20081390	CLDS	1/5/2010	4267.706996	3263.088769	41.385552	-72.089498		
NEW LONDON NAVY SUB BASE		NAE20081390	CLDS	1/5/2010	5230.906996	3999.551489	41.385632	-72.089388		
NEW LONDON NAVY SUB BASE		NAE20081390	CLDS	1/6/2010	5731.081481	4381.984901	41.385422	-72.088962		
NEW LONDON NAVY SUB BASE		NAE20081390	CLDS	1/6/2010	3376.131687	2581.390288	41.384838	-72.089035		
NEW LONDON NAVY SUB BASE		NAE20081390	CLDS	1/6/2010	5978.403292	4571.087157	41.384923	-72.089403		
NEW LONDON NAVY SUB BASE		NAE20081390	CLDS	1/7/2010	5028.016461	3844.421386	41.386032	-72.089172		
NEW LONDON NAVY SUB BASE		NAE20081390	CLDS	1/7/2010	3146.139918	2405.538581	41.384678	-72.089885		
NEW LONDON NAVY SUB BASE		NAE20081390	CLDS	1/7/2010	3531.364609	2700.08138	41.143072	-72.895532		
NEW LONDON NAVY SUB BASE		NAE20081390	CLDS	1/9/2010	6666.350617	5097.091682	41.146458	-72.893728		
NEW LONDON NAVY SUB BASE		NAE20081390	CLDS	1/9/2010	5838.011523	4463.74361	41.143527	-72.895105		
NEW LONDON NAVY SUB BASE		NAE20081390	CLDS	1/10/2010	6550.110288	5008.214326	41.142502	-72.896105		
NEW LONDON NAVY SUB BASE		NAE20081390	CLDS	1/11/2010	5978.403292	4571.087157	41.143287	-72.895097		
NEW LONDON NAVY SUB BASE		NAE20081390	CLDS	1/11/2010	6629.939095	5069.251432	41.143307	-72.895627		
NEW LONDON NAVY SUB BASE		NAE20081390	CLDS	1/12/2010	6013.52428	4597.940664	41.143355	-72.895045		
NEW LONDON NAVY SUB BASE		NAE20081390	CLDS	1/12/2010	6666.350617	5097.091682	41.143038	-72.89611		
NEW LONDON NAVY SUB BASE		NAE20081390	CLDS	1/13/2010	5732.372016	4382.971644	41.14321	-72.89548		
NEW LONDON NAVY SUB BASE		NAE20081390	CLDS	1/14/2010	6629.939095	5069.251432	41.143213	-72.895997		
NEW LONDON NAVY SUB BASE		NAE20081390	CLDS	1/15/2010	6593.527572	5041.411182	41.142175	-72.896802		
NEW LONDON NAVY SUB BASE		NAE20081390	CLDS	1/16/2010	6557.20823	5013.641413	41.14319	-72.895702		
NEW LONDON NAVY SUB BASE		NAE20081390	CLDS	1/17/2010	5225.744856	3995.604517	41.382908	-72.089582		
NEW LONDON NAVY SUB BASE		NAE20081390	CLDS	1/18/2010	6937.08642	5304.096277	41.384108	-72.089672		
NEW LONDON NAVY SUB BASE		NAE20081390	CLDS	1/19/2010	5018.798354	3837.373221	41.383787	-72.089895		
NEW LONDON NAVY SUB BASE		NAE20081390	CLDS	1/19/2010	-2534.979424	-1938.245267	41.3834	-72.089588		
NEW LONDON NAVY SUB BASE		NAE20081390	CLDS	1/19/2010	2123.114403	1623.333273	41.383798	-72.089617		
HARBOR POINT MARINA		NAE20081486	CLDS	1/20/2010	-1264.816461	-967.078666	41.143128	-72.895302		

Project Name	Permittee	Permit Number	Disposal Site	Disposal Date	Volume (yd3)	Volume (m3)	Latitude (degrees)	Longitude (degrees)	Distance From Buoy (ft)	Direction From Buoy
NEW LONDON NAVY SUB BASE		NAE20081390	CLDS	1/20/2010	5916.365432	4523.653009	41.383785	-72.089427		
HARBOR POINT MARINA		NAE20081486	CLDS	1/20/2010	753.4880658	576.1169751	41.143263	-72.895487		
NEW LONDON NAVY SUB BASE		NAE20081390	CLDS	1/21/2010	3946.824691	3017.742159	41.38338	-72.089505		
NEW LONDON NAVY SUB BASE		NAE20081390	CLDS	1/21/2010	6111.420576	4672.792173	41.38322	-72.089473		
NEW LONDON NAVY SUB BASE		NAE20081390	CLDS	1/22/2010	6191.433745	4733.970241	41.383402	-72.089972		
NEW LONDON NAVY SUB BASE		NAE20081390	CLDS	1/22/2010	4625.000823	3536.275629	41.383633	-72.089467		
HARBOR POINT MARINA		NAE20081486	CLDS	1/22/2010	519.9934156	397.5869656	41.143225	-72.895313		
GOODSELL POINT MARINA		NAE200202487	CLDS	1/22/2010	551.7958848	421.9031335	41.142708	-72.895128		
NEW LONDON NAVY SUB BASE		NAE20081390	CLDS	1/23/2010	5695.683951	4354.919949	41.383815	-72.089262		
GOODSELL POINT MARINA		NAE200202487	CLDS	1/23/2010	550.1366255	420.6344639	41.142653	-72.89551		
GOODSELL POINT MARINA		NAE200202487	CLDS	1/23/2010	561.1983539	429.0922614	41.142843	-72.895692		
GOODSELL POINT MARINA		NAE200202487	CLDS	1/24/2010	539.9045267	412.8110012	41.142767	-72.895873		
NEW LONDON NAVY SUB BASE		NAE20081390	CLDS	1/24/2010	5176.796708	3958.178763	41.383642	-72.089495		
NEW LONDON NAVY SUB BASE		NAE20081390	CLDS	1/25/2010	1887.683951	1443.323149	41.383647	-72.089613		
NEW LONDON NAVY SUB BASE		NAE20081390	CLDS	1/27/2010	6181.293827	4726.21726	41.383497	-72.089848		
NEW LONDON NAVY SUB BASE		NAE20081390	CLDS	1/27/2010	4436.859259	3392.42259	41.383053	-72.089472		
PINE ORCHARD MAINTENANCE		NAE20081521	CLDS	1/27/2010	495.38107	378.7683661	41.142583	-72.895617		
NEW LONDON NAVY SUB BASE		NAE20081390	CLDS	1/27/2010	5866.864198	4485.804365	41.383653	-72.08959		
PINE ORCHARD MAINTENANCE		NAE20081521	CLDS	1/28/2010	519.163786	396.9526308	41.142735	-72.895258		
NEW LONDON NAVY SUB BASE		NAE20081390	CLDS	1/28/2010	1890.449383	1445.437598	41.383663	-72.08953		
PINE ORCHARD MAINTENANCE		NAE20081521	CLDS	1/28/2010	596.3193416	455.9457686	41.142703	-72.895468		
NEW LONDON NAVY SUB BASE		NAE20081390	CLDS	1/29/2010	4041.310288	3089.985846	41.383715	-72.089417		
NEW LONDON NAVY SUB BASE		NAE20081390	CLDS	1/29/2010	2219.259259	1696.84563	41.383872	-72.08943		
NEW LONDON NAVY SUB BASE		NAE20081390	CLDS	1/30/2010	4617.626337	3530.637098	41.383187	-72.089628		
MILFORD BOAT WORKS		NAE20082050	CLDS	1/30/2010	278.8477366	213.2069794	41.1436	-72.8953		
MILFORD BOAT WORKS		NAE20082050	CLDS	1/31/2010	266.126749	203.4805123	41.142637	-72.895755		
PINE ORCHARD MAINTENANCE		NAE20081521	CLDS	2/2/2010	488.0987654	373.200316	41.142683	-72.8946		
MILFORD BOAT WORKS		NAE20082050	CLDS	2/2/2010	681.9555556	521.4232178	41.143227	-72.895473		
PINE ORCHARD MAINTENANCE		NAE20081521	CLDS	2/2/2010	564.4246914	431.559119	41.142747	-72.895432		
PINE ORCHARD MAINTENANCE		NAE20081521	CLDS	2/3/2010	531.8847737	406.6790979	41.142628	-72.895943		
PINE ORCHARD MAINTENANCE		NAE20081521	CLDS	2/3/2010	554.1004115	423.6651747	41.142717	-72.895393		
MILFORD BOAT WORKS		NAE20082050	CLDS	2/3/2010	682.508642	521.8461077	41.143005	-72.89575		
PINE ORCHARD MAINTENANCE		NAE20081521	CLDS	2/4/2010	508.8395062	389.0586864	41.142748	-72.89599		
MILFORD BOAT WORKS		NAE20082050	CLDS	2/4/2010	603.7860082	461.6547819	41.143077	-72.895773		
PINE ORCHARD MAINTENANCE		NAE20081521	CLDS	2/5/2010	519.9012346	397.516484	41.142955	-72.89563		

Disposal Barge Logs for
Central Long Island Sound Disposal Site
September 2009 to September 2011

Project Name	Permittee	Permit Number	Disposal Site	Disposal Date	Volume (yd3)	Volume (m3)	Latitude (degrees)	Longitude (degrees)	Distance From Buoy (ft)	Direction From Buoy
MILFORD BOAT WORKS		NAE20082050	CLDS	2/5/2010	93.93251029	71.82079737	41.142843	-72.895603		
PINE ORCHARD MAINTENANCE		NAE20081521	CLDS	2/5/2010	431.7761317	330.1360303	41.142728	-72.895237		
PINE ORCHARD MAINTENANCE		NAE20081521	CLDS	2/9/2010	478.2353909	365.6587799	41.142775	-72.89583		
PINE ORCHARD MAINTENANCE		NAE20081521	CLDS	2/10/2010	599.3613169	458.2716629	41.142782	-72.895922		
PINE ORCHARD MAINTENANCE		NAE20081521	CLDS	2/12/2010	488.0987654	373.200316	41.142658	-72.895378		
PINE ORCHARD MAINTENANCE		NAE20081521	CLDS	2/13/2010	467.81893	357.6943539	41.14286	-72.895867		
PINE ORCHARD MAINTENANCE		NAE20081521	CLDS	2/13/2010	425.7843621	325.5547233	41.143008	-72.895892		
PINE ORCHARD MAINTENANCE		NAE20081521	CLDS	2/16/2010	543.6839506	415.7007486	41.14268	-72.895333		
HULL HARBOR		NAE20044113	CLDS	3/6/2010	469.6625514	359.1039868	41.14257	-72.895745		
HULL HARBOR		NAE20044113	CLDS	3/7/2010	358.4921811	274.1031216	41.142655	-72.895373		
HULL HARBOR		NAE20044113	CLDS	3/9/2010	499.8979424	382.2219667	41.142698	-72.895518		
HULL HARBOR		NAE20044113	CLDS	3/10/2010	501.1884774	383.2087098	41.142722	-72.895352		
HULL HARBOR		NAE20044113	CLDS	3/19/2010	635.5884774	485.9709498	41.142968	-72.895867		
HULL HARBOR		NAE20044113	CLDS	3/20/2010	668.8658436	511.414824	41.14247	-72.895487		
HULL HARBOR		NAE20044113	CLDS	3/21/2010	634.2979424	484.9842067	41.142608	-72.895028		
HULL HARBOR		NAE20044113	CLDS	3/28/2010	362.2716049	276.9928691	41.142858	-72.89528		
HULL HARBOR		NAE20044113	CLDS	3/31/2010	375.4534979	287.0717445	41.142723	-72.895775		
HULL HARBOR		NAE20044113	CLDS	4/2/2010	375.4534979	287.0717445	41.142747	-72.895928		
BREAKWATER KEY MARINA		NAE19991265	CLDS	10/6/2010	293.3201646	224.2725979	41.142815	-72.891467		
BREAKWATER KEY MARINA		NAE19991265	CLDS	10/9/2010	218.2847737	166.9005379	41.142702	-72.891463		
BREAKWATER KEY MARINA		NAE19991265	CLDS	10/9/2010	369.3695473	282.4199559	41.142742	-72.891652		
BREAKWATER KEY MARINA		NAE19991265	CLDS	10/11/2010	297.9292181	227.7966802	41.142922	-72.892077		
BREAKWATER KEY MARINA		NAE19991265	CLDS	10/12/2010	377.5736626	288.6928224	41.142862	-72.892088		
BREAKWATER KEY MARINA		NAE19991265	CLDS	10/13/2010	362.0872428	276.8519058	41.142937	-72.892347		
BREAKWATER KEY MARINA		NAE19991265	CLDS	10/19/2010	355.81893	272.0591539	41.142858	-72.892332		
BREAKWATER KEY MARINA		NAE19991265	CLDS	10/20/2010	385.0403292	294.4018357	41.142887	-72.891553		
BREAKWATER KEY MARINA		NAE19991265	CLDS	10/21/2010	370.3835391	283.195254	41.142873	-72.891777		
BREAKWATER KEY MARINA		NAE19991265	CLDS	11/1/2010	392.4148148	300.0403674	41.142597	-72.891822		
BREAKWATER KEY MARINA		NAE19991265	CLDS	11/3/2010	370.4757202	283.2657356	41.142818	-72.892012		
BREAKWATER KEY MARINA		NAE19991265	CLDS	11/4/2010	326.6897119	249.7869537	41.143328	-72.891987		
BREAKWATER KEY MARINA		NAE19991265	CLDS	11/6/2010	355.81893	272.0591539	41.142853	-72.891843		
BREAKWATER KEY MARINA		NAE19991265	CLDS	11/7/2010	363.1934156	277.6976856	41.143123	-72.892073		
BREAKWATER KEY MARINA		NAE19991265	CLDS	11/12/2010	414.4460905	316.8854808	41.142863	-72.891767		
BREAKWATER KEY MARINA		NAE19991265	CLDS	11/13/2010	370.4757202	283.2657356	41.142792	-72.891908		
BREAKWATER KEY MARINA		NAE19991265	CLDS	11/14/2010	304.2897119	232.6599137	41.142867	-72.892292		

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BREAKWATER KEY MARINA		NAE19991265	CLDS	11/16/2010	385.3168724	294.6132807	41.14284	-72.891988		
BREAKWATER KEY MARINA		NAE19991265	CLDS	11/17/2010	348.5366255	266.4911039	41.142787	-72.891722		
BREAKWATER KEY MARINA		NAE19991265	CLDS	11/20/2010	-326.0444444	-249.2935822	41.143175	-72.891752		
WRIGHT ISLAND MARINA, NEW ROCHELLE		NAN200611	CLDS	11/21/2010	521.744856	398.9261169	41.14275	-72.89205		
BREAKWATER KEY MARINA		NAE19991265	CLDS	11/22/2010	378.126749	289.1157123	41.142878	-72.891933		
BREAKWATER KEY MARINA		NAE19991265	CLDS	11/23/2010	385.0403292	294.4018357	41.142867	-72.891922		
WRIGHT ISLAND MARINA, NEW ROCHELLE		NAN200611	CLDS	11/24/2010	421.2674897	322.1011226	41.14317	-72.89192		
WRIGHT ISLAND MARINA, NEW ROCHELLE		NAN200611	CLDS	11/28/2010	487.6378601	372.8479078	41.14277	-72.89188		
BREAKWATER KEY MARINA		NAE19991265	CLDS	11/28/2010	370.3835391	283.195254	41.142895	-72.891805		
BREAKWATER KEY MARINA		NAE19991265	CLDS	11/29/2010	377.7580247	288.8337857	41.142843	-72.891953		
WRIGHT ISLAND MARINA, NEW ROCHELLE		NAN200611	CLDS	11/30/2010	502.3868313	384.1249712	41.1431	-72.89222		
BREAKWATER KEY MARINA		NAE19991265	CLDS	11/30/2010	363.1934156	277.6976856	41.14293	-72.891768		
WRIGHT ISLAND MARINA, NEW ROCHELLE		NAN200611	CLDS	12/1/2010	582.5843621	445.4440033	41.14363	-72.8907		
BREAKWATER KEY MARINA		NAE19991265	CLDS	12/3/2010	370.4757202	283.2657356	41.143048	-72.891725		
WRIGHT ISLAND MARINA, NEW ROCHELLE		NAN200611	CLDS	12/3/2010	636.9711934	487.0281745	41.14322	-72.89168		
BREAKWATER KEY MARINA		NAE19991265	CLDS	12/4/2010	363.1934156	277.6976856	41.143098	-72.89168		
WRIGHT ISLAND MARINA, NEW ROCHELLE		NAN200611	CLDS	12/4/2010	593.6460905	453.9018008	41.14282	-72.892		
WRIGHT ISLAND MARINA, NEW ROCHELLE		NAN200611	CLDS	12/5/2010	572.4444444	437.6910222	41.14322	-72.89153		
WRIGHT ISLAND MARINA, NEW ROCHELLE		NAN200611	CLDS	12/7/2010	482.1069959	368.6190091	41.14313	-72.89158		
WRIGHT ISLAND MARINA, NEW ROCHELLE		NAN200611	CLDS	12/10/2010	716.2469136	547.6423901	41.14252	-72.88965		
BREAKWATER KEY MARINA		NAE19991265	CLDS	12/10/2010	356.0032922	272.2001172	41.142873	-72.89182		
BREAKWATER KEY MARINA		NAE19991265	CLDS	12/11/2010	296.6386831	226.8099371	41.142923	-72.89217		
WRIGHT ISLAND MARINA, NEW ROCHELLE		NAN200611	CLDS	12/12/2010	522.6666667	399.6309333	41.14238	-72.89167		
WRIGHT ISLAND MARINA, NEW ROCHELLE		NAN200611	CLDS	12/15/2010	607.473251	464.4740477	41.14252	-72.88905		
BREAKWATER KEY MARINA		NAE19991265	CLDS	12/17/2010	348.6288066	266.5615855	41.142835	-72.89197		
BREAKWATER KEY MARINA		NAE19991265	CLDS	12/18/2010	363.3777778	277.8386489	41.142892	-72.891918		
BREAKWATER KEY MARINA		NAE19991265	CLDS	12/19/2010	363.3777778	277.8386489	41.142767	-72.891908		
WRIGHT ISLAND MARINA, NEW ROCHELLE		NAN200611	CLDS	12/20/2010	381.6296296	291.7940148	41.15243	-72.85793		
GUILFORD YACHT CLUB		NAE20071989	CLDS	12/21/2010	238.7489712	182.5474634	41.14365	-72.89095		
GUILFORD YACHT CLUB		NAE20071989	CLDS	12/22/2010	454.4526749	347.4745152	41.14278	-72.89118		
GUILFORD YACHT CLUB		NAE20071989	CLDS	12/23/2010	373.3333333	285.4506667	41.14515	-72.8977		
GUILFORD YACHT CLUB		NAE20071989	CLDS	12/30/2010	417.5802469	319.2818568	41.14563	-72.88928		
BREAKWATER KEY MARINA		NAE19991265	CLDS	12/31/2010	312.1251029	238.6508537	41.14316	-72.892058		
GUILFORD YACHT CLUB		NAE20071989	CLDS	12/31/2010	428.6419753	327.7396543	41.14305	-72.89092		
GUILFORD YACHT CLUB		NAE20071989	CLDS	1/1/2011	484.872428	370.7334584	41.1428	-72.89148		

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GUILFORD YACHT CLUB		NAE20071989	CLDS	1/2/2011	556.7736626	425.7091424	41.14307	-72.8912		
GUILFORD YACHT CLUB		NAE20071989	CLDS	1/2/2011	552.1646091	422.1850601	41.14483	-72.88865		
GUILFORD YACHT CLUB		NAE20071989	CLDS	1/3/2011	579.81893	443.3295539	41.14518	-72.89103		
BREAKWATER KEY MARINA		NAE19991265	CLDS	1/4/2011	370.6600823	283.4066989	41.142962	-72.891672		
GUILFORD YACHT CLUB		NAE20071989	CLDS	1/4/2011	465.5144033	355.9323128	41.14277	-72.893		
GUILFORD YACHT CLUB		NAE20071989	CLDS	1/4/2011	636.9711934	487.0281745	41.14237	-72.89223		
BREAKWATER KEY MARINA		NAE19991265	CLDS	1/5/2011	356.0954733	272.2705988	41.142763	-72.891748		
GUILFORD YACHT CLUB		NAE20071989	CLDS	1/5/2011	512.526749	391.8779523	41.14218	-72.89238		
BREAKWATER KEY MARINA		NAE19991265	CLDS	1/6/2011	348.1679012	266.2091773	41.142712	-72.891938		
GUILFORD YACHT CLUB		NAE20071989	CLDS	1/6/2011	510.6831276	390.4683193	41.14285	-72.89122		
BREAKWATER KEY MARINA		NAE19991265	CLDS	1/7/2011	370.6600823	283.4066989	41.142773	-72.892422		
GUILFORD YACHT CLUB		NAE20071989	CLDS	1/7/2011	459.9835391	351.703414	41.14285	-72.89132		
GUILFORD YACHT CLUB		NAE20071989	CLDS	1/8/2011	470.1234568	359.4563951	41.14298	-72.892		
GUILFORD YACHT CLUB		NAE20071989	CLDS	1/11/2011	364.1152263	278.4025021	41.14288	-72.89113		
GUILFORD YACHT CLUB		NAE20071989	CLDS	1/11/2011	295.9012346	226.246084	41.14295	-72.89135		
GUILFORD YACHT CLUB		NAE20071989	CLDS	1/15/2011	347.5226337	265.7158058	41.1429	-72.89127		
GUILFORD YACHT CLUB		NAE20071989	CLDS	1/16/2011	383.473251	293.2036477	41.1427	-72.89192		
NOANK VILLAGE BOAT CLUB		NAE20082563	CLDS	1/17/2011	274.5152263	209.8943421	41.143595	-72.891345		
GUILFORD YACHT CLUB		NAE20071989	CLDS	1/17/2011	562.3045267	429.9380412	41.1429	-72.89138		
HARBOR POINT MARINA		NAE20081486	CLDS	1/18/2011	326.5053498	249.6459905	41.143437	-72.891945		
GUILFORD YACHT CLUB		NAE20071989	CLDS	1/18/2011	338.3045267	258.6676412	41.14308	-72.8911		
GUILFORD YACHT CLUB		NAE20071989	CLDS	1/19/2011	121.6790123	93.03577284	41.14283	-72.89142		
HARBOR POINT MARINA		NAE20081486	CLDS	1/20/2011	184.1777778	140.8223289	41.142668	-72.891382		
GUILFORD YACHT CLUB		NAE20071989	CLDS	1/20/2011	346.600823	265.0109893	41.14908	-72.88762		
NOANK VILLAGE BOAT CLUB		NAE20082563	CLDS	1/23/2011	325.9522634	249.2231006	41.142795	-72.89156		
GUILFORD YACHT CLUB		NAE20071989	CLDS	1/23/2011	330.0082305	252.324293	41.14278	-72.89137		
GUILFORD YACHT CLUB		NAE20071989	CLDS	1/23/2011	336.4609053	257.2580082	41.14307	-72.89133		
GUILFORD YACHT CLUB		NAE20071989	CLDS	1/25/2011	487.6378601	372.8479078	41.14275	-72.89148		
DODSON BOAT YARD		NAE20062960	CLDS	1/25/2011	311.8485597	238.4394087	41.143235	-72.892323		
GUILFORD YACHT CLUB		NAE20071989	CLDS	1/25/2011	450.7654321	344.6552494	41.14288	-72.89155		
GUILFORD YACHT CLUB		NAE20071989	CLDS	1/26/2011	456.2962963	348.8841481	41.1429	-72.89153		
GUILFORD YACHT CLUB		NAE20071989	CLDS	1/28/2011	460.9053498	352.4082305	41.14283	-72.8913		
DODSON BOAT YARD		NAE20062960	CLDS	1/29/2011	297.0995885	227.1623453	41.143228	-72.891582		
GUILFORD YACHT CLUB		NAE20071989	CLDS	1/30/2011	512.526749	391.8779523	41.14287	-72.89145		
DODSON BOAT YARD		NAE20062960	CLDS	1/30/2011	259.7662551	198.6172787	41.14312	-72.891987		

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GUILFORD YACHT CLUB		NAE20071989	CLDS	1/31/2011	503.308642	384.8297877	41.14273	-72.89187		
DODSON BOAT YARD		NAE20062960	CLDS	2/1/2011	319.0386831	243.9369771	41.143033	-72.892248		
DODSON BOAT YARD		NAE20062960	CLDS	2/7/2011	144.6320988	110.5857027	41.14308	-72.8918		
DODSON BOAT YARD		NAE20062960	CLDS	2/17/2011	398.7753086	304.903601	41.143355	-72.891603		

Appendix B

Grain Size Scale Conversions

APPENDIX B

Grain Size Scale Conversions

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

Appendix C

Sediment-Profile Imaging Results

APPENDIX C
Sediment-Profile Imaging Results
CLDS
September 2011

Station	Replicate	Date	Time	Stop Collar Settings (in.)	# of weights per chassis	Water Depth (ft)	Calibration Constant	Grain Size Major Mode (phi)	Grain Size Maximum (phi)	Grain Size Minimum (phi)	Penetration Area (sq.cm)	Average Penetration (cm)	Minimum Penetration (cm)	Maximum Penetration (cm)	Boundary Roughness (cm)	Boundary Roughness Type	RPD Area (sq.cm)	Mean RPD (cm)	Mud Clast Number	Mud Clast State	Methane	Low DO?	# of Feeding Voids	Void Minimum Depth (cm)	Void Maximum Depth (cm)	Void Average Depth (cm)	Successional Stage	Comments
CLDS - 1	A	10/2/2011	6:18:14	13	1	55	14.571	>4	1	>4	226.1909949	15.52	15.07	15.68	0.61	Biological	21.79	1.50	0	-	none	no	0	-	-		Stage 2	Very fine sandy silt-clay. Debris at SWI. Few amphipod and other tubes at SWI. End of burrow or closed burrow below aRPD to right of center.
CLDS - 1	B	10/2/2011	6:19:03	13	1	55	14.571	>4	1	>4	234.3532619	16.08	15.79	16.57	0.79	Biological	10.23	0.70	0	-	none	no	0	-	-		Stage 1 -> 2	Very fine sandy silt-clay. Debris and some tubes, some amphipod, at surface. aRPD is patchy and somewhat discontinuous.
CLDS - 1	C	10/2/2011	6:19:51	13	1	55	14.571	>4	1	>4	250.3047709	17.18	17.07	17.46	0.39	Biological	13.34	0.92	2	red	none	no	0	-	-		Stage 1 -> 2	Very fine sandy silt-clay. Mud clasts on surface is camera artifact. Many small tubes and few amphipod ones on surface.
CLDS - 2	A	10/2/2011	6:48:07	13	1	57	14.571	>4-3	0	>4	212.6720796	14.60	13.86	14.75	0.89	Biological	17.09	1.17	0	-	none	no	0	-	-		Stage 2 -> 3	Silty very fine sand, grading to somewhat coarser particles at surface. Bit of debris on surfac. Shell on surface. Few amphipod tubes at SWI. Medium burrow connected to surface below shell.
CLDS - 2	C	10/2/2011	6:49:39	13	1	57	14.571	>4	0	>4	219.5770664	15.07	14.68	15.32	0.64	Biological	27.06	1.86	4	red	none	no	1	7.33	8.46	7.90	Stage 2 on 3	Very fine sandy silt-clay. Few amphipod tubes. Mud clasts on surface. Large burrow/pit on right is artifact from shell drag-down by prism. Few shell fragments at surface on large burrow. Oxidized sediment around void.
CLDS - 2	D	10/2/2011	6:50:13	13	1	57	14.571	>4	0	>4	191.0916765	13.11	12.71	13.54	0.82	Biological	18.15	1.25	4	red/oxy	none	no	2	3.82	5.69	4.76	Stage 2 on 3	Very fine sandy silt-clay. Debris, shells, algae bits on surface. Few amphipod tubes at surface. Much of image has oxidized sediment, either from relict aRPD or deeper burrowing.
CLDS - 3	A	10/2/2011	6:58:58	13	1	54	14.571	>4	1	>4	232.5907699	15.96	15.61	16.32	0.71	Biological	35.34	2.43	10+	red	none	no	0	-	-		Stage 2	Very fine sandy silt-clay. Mud clasts across surface (camera artifacts). Few tubes at surface. Few shallow sand-lined burrows.
CLDS - 3	B	10/2/2011	6:59:44	13	1	54	14.571	>4	1	>4	206.60607	14.18	13.86	14.46	0.61	Biological	12.69	0.87	0	-	none	no	0	-	-		Stage 1 -> 2	Very fine sandy silt-clay. Some amphipod tubes at surface. Closed or former burrow at depth. Possible Beggiatoa threads at base of aRPD
CLDS - 3	C	10/2/2011	7:00:29	13	1	54	14.571	>4	1	>4	213.632263	14.66	13.89	15.46	1.57	Biological	9.68	0.66	3	red	none	no	0	-	-		Stage 1 -> 2	Very fine sandy silt-clay. Debris, shell fragments, and mud clasts on surface.
CLDS - 4	A	10/2/2011	7:04:02	13	1	55	14.571	>4	1	>4	222.0223746	15.24	14.96	15.57	0.61	Biological	13.23	0.91	4	red	none	no	0	-	-		Stage 2 -> 3	Very fine sandy silt-clay. Debris, shell fragments, and collapsed tubes on surface. Couple collapsed or old voids at depth on right.
CLDS - 4	B	10/2/2011	7:04:48	13	1	55	14.571	>4	1	>4	211.7317251	14.53	14.39	14.75	0.36	Biological	35.38	2.43	0	-	none	no	0	-	-		Stage 2	Very fine sandy silt-clay. Bivalve shell and fragment at surface. Few tubes and bit of debris on right at surface. Shallow burrowing through aRPD.
CLDS - 4	C	10/2/2011	7:05:36	13	1	55	14.571	>4	1	>4	219.4010962	15.06	14.79	15.46	0.68	Biological	16.20	1.11	10+	red/oxy	none	no	0	-	-		Stage 1	Very fine sandy silt-clay. Debris (some algal) and shell fragments at surface. Few amphipod tubes. Small to medium mud clasts from camera at surface.
CLDS - 5	B	10/2/2011	8:48:57	13.5	1	62	14.571	>4	1	>4	249.5441931	17.13	16.68	17.50	0.82	Biological	40.21	2.76	10+	red	none	no	1	10.91	12.41	11.66	Stage 2 -> 3	Very fine sandy silt-clay. Small to medium mud clasts (camera artifact) on surface.
CLDS - 5	C	10/2/2011	8:49:55	13.5	1	62	14.571	>4	1	>4	248.1839016	17.03	16.61	17.32	0.71	Biological	45.64	3.13	3	red/oxy	none	no	0	-	-		Stage 1 -> 2	Very fine sandy silt-clay. Mud clasts are small, on surface. Few amphipod tubes. Burrowing through aRPD.
CLDS - 5	D	10/2/2011	8:51:04	13.5	1	62	14.571	>4	0	>4	251.2279668	17.24	17.11	17.39	0.29	Biological	43.20	2.96	1	oxy	none	no	0	-	-		Stage 1 -> 2	Very fine sandy silt-clay. Few amphipod tubes. Burrowing through aRPD.
CLDS - 6	A	10/2/2011	7:43:59	13.5	1	55	14.571	>4	1	>4	218.9610113	15.03	14.79	15.29	0.50	Biological	18.39	1.26	5	red/oxy	none	no	2	4.31	5.30	4.81	Stage 1 on 3	Very fine sandy silt-clay. Bits of debris and collapsed tubes at surface.
CLDS - 6	B	10/2/2011	7:44:45	13.5	1	55	14.571	>4	1	>4	239.4745526	16.44	16.32	16.75	0.43	Biological	48.51	3.33	3	red/oxy	none	no	2	3.86	7.79	5.83	Stage 2 on 3	Very fine sandy silt-clay. At least one amphipod tube at surface. End of a polychaete . Voids look connected. Reduced fecal pellets at base of larger void.
CLDS - 6	C	10/2/2011	7:45:29	13.5	1	55	14.571	>4	1	>4	227.6221328	15.62	14.93	15.75	0.82	Biological	14.42	0.99	10+	red/oxy	none	no	1	3.71	6.64	5.18	Stage 1 on 3	Very fine sandy silt-clay. Small and medium mud clasts on surface (camera artifacts). Shallow sand-lined burrows. Void is large.
CLDS - 7	A	10/2/2011	7:14:01	13	1	58	14.571	>4	0	>4	191.3064877	13.13	12.25	13.39	1.14	Biological	81.32	5.58	8	red	none	no	0	-	-		Stage 1 on 3	Very fine sandy silt-clay with coarser particles in upper 2 cm. Bivalve shell fragments at surface. On left edge of image, burrow or void 1.5 cm or so below surface. Appears to be relatively recent DM deposit but highly reworked (burrows throughout, exceptionally deep aRPD extending to depth of image at right edge).
CLDS - 7	B	10/2/2011	7:14:51	13	1	58	14.571	>4	0	>4	194.5931646	13.35	12.64	13.86	1.21	Biological	37.24	2.56	8	red	none	no	1	7.46	8.32	7.89	Stage 2 on 3	Very fine sandy silt-clay with coarser particles in the upper 2-3 cm.. Small mud clasts grouped on left at surface. Sand-lined burrows in upper cm.
CLDS - 7	C	10/2/2011	7:15:40	13	1	58	14.571	>4	0	>4	197.9556302	13.59	12.93	14.39	1.46	Physical	31.31	2.15	10+	red	none	no	1	0.96	2.29	1.63	Stage 2 on 3	Very fine sandy silt-clay. Medium to large mud clasts on surface from camera, chaotic fabric typcial of fairly fresh DM deposit. Shell fragments at surface. Void is shallow, within upper level of aRPD. Bisected clam within base of void.
CLDS - 8	B	10/2/2011	7:09:16	13	1	55	14.571	>4-3	1	>4	181.4892041	12.46	11.00	13.32	2.32	Physical	41.16	2.83	0	-	none	no	2	2.75	8.73	5.74	Stage 1 on 3	Very fine sandy silt-clay with coarser particles in upper 3-5 cm. Bits of debris and shell fragments on surface. Bivalve shell incorporated into sed. Few shallow sand-lined burrows. Fairly fresh DM deposit that has been intensively re-worked at depth by deposit feeders.
CLDS - 8	C	10/2/2011	7:10:04	13	1	55	14.571	>4	0	>4	192.1028974	13.18	12.86	13.57	0.71	Biological	10.25	0.70	0	-	none	no	5	3.04	8.43	5.74	Stage 2 on 3	Very fine sandy silt-clay. Few amphipod tubes in background on surface, few collapsed tubes as well. Shallow sand-lined burrows.
CLDS - 8	D	10/2/2011	7:10:55	13	1	55	14.571	>4	0	>4	174.3485408	11.97	11.54	12.32	0.79	Biological	26.75	1.84	0	-	none	no	2	5.19	6.66	5.93	Stage 1 on 3	Very fine sandy silt-clay. Debris, few bivalve shell fragments, and some tangled debris/tubes on surface. Tubes. Small pit in middle with small bivalve at base of pit. Shallow sand-lined burrows.
CLDS - 9	A	10/2/2011	8:05:23	13.5	1	58	14.571	>4	0	>4	273.6672757	18.78	18.39	19.32	0.93	Biological	17.89	1.23	0	-	none	no	0	-	-		Stage 1	Very fine sandy silt-clay. Debris on surface. Few tubes in the background.
CLDS - 9	C	10/2/2011	8:07:13	13.5	1	58	14.571	>4	1	>4	252.0678209	17.30	17.11	17.57	0.46	Biological	24.19	1.66	0	-	none	no	2	4.16	5.82	4.99	Stage 2 -> 3	Very fine sandy silt-clay. Few tubes, few amphipod tubes. Shallow burrowing. Voids are small.
CLDS - 9	D	10/2/2011	8:08:16	13.5	1	58	14.571	>4	1	>4	256.5805098	17.61	17.43	17.75	0.32	Biological	28.11	1.93	0	-	none	no	3	4.47	12.36	8.42	Stage 2 on 3	Very fine sandy silt-clay. Few small tubes, couple amphipod tubes at SWI. Two large voids somewhat connected.
CLDS - 10	A	10/2/2011	8:14:39	13.5	1	58	14.571	>4	1	>4	234.079123	16.06	15.82	16.54	0.71	Biological	23.21	1.59	0	-	none	no	2	3.84	5.37	4.61	Stage 2 on 3	Very fine sandy silt-clay. Some short thin tubes at SWI. Larger burrow extending down from SWI on right.
CLDS - 10	C	10/2/2011	8:16:22	13.5	1	58	14.571	>4	1	>4	243.0507134	16.68	16.46	16.86	0.39	Biological	30.26	2.08	0	-	none	no	1	4.58	5.61	5.10	Stage 2 on 3	Very fine sandy silt-clay. Couple tubes, at least one collapsed on surface. Burrowing throughout aRPD. Void is at base of aRPD on left.
CLDS - 10	D	10/2/2011	8:17:14	13.5	1	58	14.571	>4	1	>4	234.8422916	16.12	15.86	16.32	0.46	Biological	10.48	0.72	0	-	none	no	0	-	-		Stage 2 on 3	Very fine sandy silt-clay. Few small thin tubes and amphipod tubes at surface. Shallow burrowing. Large polychaete at 5.6 cm against faceplate.
CLDS - 11	A	10/2/2011	8:39:32	13.5	1	59	14.571	>4	1	>4	241.6735224	16.59	16.36	16.89	0.54	Biological	36.06	2.47	0	-	none	no	1	6.18	6.57	6.38	Stage 1 on 3	Very fine sandy silt-clay. Small tubes @ SWI, aRPD is deeper on left. One former/closed void. Shallow burrowing.
CLDS - 11	B	10/2/2011	8:40:31	13.5	1	59	14.571	>4	1	>4	224.6792256	15.42	15.07	15.79	0.71	Biological	26.76	1.84	1	red	none	no	0	-	-		Stage 1	Very fine sandy silt-clay. Small tubes @ WIS with shallow burrowing.
CLDS - 11	C	10/2/2011	8:41:25	13.5	1	59	14.571	>4	1	>4	240.5487281	16.51	16.32	16.75	0.43	Biological	29.12	2.00	2	red	none	no	1	5.90	6.56	6.23	Stage 1 on 3	Very fine sandy silt-clay. Evidence of burrowing in aRPD. Void is just below aRPD.
CLDS - 12	A	10/2/2011	7:51:36	13.5	1	56	14.571	>4	2	>4	237.0016034	16.27	16.04	16.50	0.46	Biological	24.45	1.68	0	-	none	no	1	8.22	12.34	10.28	Stage 1 on 3	Very fine sandy silt-clay. Couple tubes at SWI and in background. Shallow burrowing. Large megafaunal transected burrow on left
CLDS - 12	B	10/2/2011	7:52:33	13.5	1	56	14.571	>4	2	>4	261.2303678	17.93	17.61	18.00	0.39	Biological	26.69	1.83	0	-	none	no	0	-	-		Stage 2	Very fine sandy silt-clay. Some tubes at SWI, couple amphipod tubes. Shallow burrowing.
CLDS - 12	C	10/2/2011	7:53:31	13.5	1	56	14.571	>4	2	>4	273.7711041	18.79	18.43	19.07	0.64	Biological	15.04	1.03	0	-	YES	no	0	-	-		Stage 2	Very fine sandy silt-clay. Debris at surface. Few amphipod tubes at SWI. Methane bubbles at mid depth, streaks of organically enriched subsurface sediment.
CLDS - 13	B	10/2/2011	8:54:40	13.5	1	61	14.571	>4	1	>4	259.3468092	17.80	17.68	17.89	0.21	Biological	44.27	3.04	1	red	none	no	0	-	-		Stage 1 -> 2	Very fine sandy silt-clay. Small mud clasts on surface. Bit of debris at surface. Burrowing through aRPD. Polychaete at 7cm.
CLDS - 13	C	10/2/2011	8:55:44	13.5	1	61	14.571	>4	1	>4	249.4926376	17.12	16.68	17.50	0.82	Biological	34.63	2.38	10+	red/oxy	none	no	0	-	-		Stage 1 -> 2	Very fine sandy silt-clay. Small to large mud clasts (camera artifacts) on surface. Shallow burrowing.
CLDS - 13	D	10/2/2011	8:57:20	13.5	1	61	14.571	>4	1	>4	233.8775445	16.05	15.64	16.25	0.61	Biological	29.91	2.05	3	oxy	none	no	3	4.32	11.04	7.68	Stage 1 on 3	Very fine sandy silt-clay. Bits of debris on surface. Few tubes at SWI. Shallow burrowing.
CLDS - 14	A	10/2/2011	7:57:18	13.5	1	57	14.571	>4	1	>4	225.2633948	15.46	15.43	16.07	0.64	Biological	20.71	1.42	3	red/oxy	none	no	0	-	-		Stage 2	Very fine sandy silt-clay. Debris-covered surface. Shallow burrowing.
CLDS - 14	B	10/2/2011	7:58:12	13.5	1	57	14.571	>4	1	>4	251.5911469	17.27	16.89	17.71	0.82	Biological	14.68	1.01	3	red/oxy	none	no	0	-	-		Stage 1 -> 2	Very fine sandy silt-clay. Small mud clasts on surface. Some tubes at surface.
CLDS - 14	C	10/2/2011	7:59:10	13.5	1	57	14.571	>4	2	>4	267.4042314	18.35	16.96	18.96	2.00	Biological	12.54	0.86	3	red	YES	no	0	-	-		Stage 2 -> 3	Very fine sandy silt-clay. Pit on left. Bits of debris and small mud clasts at surface. At least one amphipod tube at surface, at far left. Methane bubbles at depth.
CLDS - 15	A	10/2/2011	10:36:40	13.5	1	63	14.571	>4	1	>4	248.1236771	17.03	16.82	17.25	0.43	Biological	16.46	1.13	4	red	none	no	0	-	-		Stage 1 on 3	Very fine sandy silt-clay. Small mud clasts and tubes at surface. Burrowing evident at depth (portions of worms against faceplate)
CLDS - 15	C	10/2/2011	10:39:22	13.5	1	63	14.571	>4	1	>4	271.6145625	18.64	18.36	18.96	0.61	Biological	27.78	1.91	0	-	none	no	4	3.75	12.79	8.27	Stage 1 on 3	Very fine sandy silt-clay. Some amphipod tubes at SWI. Multiple depositional horizons evident with voids in each layer.
CLDS - 15	D	10/2/2011	10:40:09	13.5	1	63	14.571	>4	1	>4	286.6228473	19.67	19.21	20.11	0.89	Biological	43.99	3.02	1	red	none	no	1	3.19	3.37	3.28	Stage 1 on 3	Very fine sandy silt-clay. Multiple depositional intervals from sequential DM deposits.
CLDS - 16	A	10/2/2011	9:03:30	13.5	1	59	14.571	>4	1	>4	267.8506935	18.38	18.04	18.55	0.50	Biological	36.72	2.52	1	red	none	no	1	4.76	5.12	4.94	Stage 1 on 3	Very fine sandy silt-clay. Few tubes/debris at surface on right. Evidence of burrowing through aRPD.
CLDS - 16	B	10/2/2011	9:04:25	13.5	1	59	14.571	>4	1	>4	285.6400448	19.60	19.22	20.07	0.85	Biological	66.84	4.59	2	red	none	no	1	10.78	10.96	10.87	Stage 1 on 3	Very fine sandy silt-clay. Few small tubes and couple amphipod tubes at surface, multiple depositional horizons visible.
CLDS - 16	D	10/2/2011	9:06:19	13.5	1	59	14.571	>4	0	>4	264.9564122	18.18	17.96	18.31	0.35	Biological	57.30	3.93	0	-	none	no	0	-	-		Stage 1 on 3	Silt-clay with very fine sand in upper 3-5 cm; evidence of multiple depositional horizons and subsurface burrowing
CLDS - 17	A	10/2/2011	10:44:09	13.5	1	64	14.571	>4	1	>4	285.1010738	19.57	19.40	19.78	0.37	Biological	20.35	1.40	2	oxy	none	no	0	-	-		Stage 2 -> 3	Very fine sandy silt-clay. Multiple depositional intervals from sequential DM deposits, evidence of subsurface burrowing.
CLDS - 17	B	10/2/2011	10:44:58	13.5	1	64	14.571	>4	0	>4	278.3010513	19.10	18.87	19.24	0.37	Biological	28.07	1.93	0	-	none	no	0	-	-		Stage 1 on 3	Very fine sandy silt-clay. Some amphipod tubes at SWI. Multiple depositional horizons evident with evidence of subsurface burrowing at depth.
CLDS - 17	C	10/2/2011	10:46:48	13.5	1	64	14.571	>4	1	>4	241.6563041	16.58	16.08	17.08	0.99	Biological	25.24	1.73	1	red	none	no	2	6.99	9.96	8.48	Stage 1 on 3	Very fine sandy silt-clay. Bit of debris at surface. Few amphipod tubes. Multiple depositional horizons with strata boundaries interrupted by bioturbation.
CLDS - 18	B	10/2/2011	10:52:32	13.5	1	63	14.571	>4	1	>4	289.5959864	19.87	19.59	20.20	0.62	Biological	15.25	1.05	1	red	none	no	1	8.94	9.15	9.05	Stage 1 on 3	Very fine sandy silt-clay. Few amphipod tubes at SWI, multiple depositional horizons, evidence of subsurface burrowing.

Note: ind = indeterminate; Mud clast state: o=oxidized, r=reduced, b=both oxidized and reduced

APPENDIX C
Sediment-Profile Imaging Results
CLDS
September 2011

Station	Replicate	Date	Time	Stop Collar Settings (in.)	# of weights per chassis	Water Depth (ft)	Calibration Constant	Grain Size Major Mode (phi)	Grain Size Maximum (phi)	Grain Size Minimum (phi)	Penetration Area (sq.cm)	Average Penetration (cm)	Minimum Penetration (cm)	Maximum Penetration (cm)	Boundary Roughness (cm)	Boundary Roughness Type	RPD Area (sq.cm)	Mean RPD (cm)	Mud Clast Number	Mud Clast State	Methane	Low DO?	# of Feeding Voids	Void Minimum Depth (cm)	Void Maximum Depth (cm)	Void Average Depth (cm)	Successional Stage	Comments
CLDS - 18	C	10/2/2011	10:53:26	13.5	1	63	14.571	>4	1	>4	259.704489	17.82	17.42	18.20	0.78	Biological	43.59	2.99	1	red	none	no	2	5.65	7.84	6.75	Stage 1 on 3	Very fine sandy silt-clay. Tubes on surface. Burrowing throughout aRPD depth.
CLDS - 18	D	10/2/2011	10:54:13	13.5	1	63	14.571	>4	1	>4	244.5709524	16.78	16.54	16.97	0.43	Biological	22.27	1.53	0	-	none	no	1	2.90	3.14	3.02	Stage 1 on 3	Very fine sandy silt-clay. Multiple depositional horizons from past DM disposal evident.
CLDS - 19	A	10/2/2011	9:11:25	13.5	1	60	14.571	>4	1	>4	291.4817173	20.00	19.72	20.26	0.54	Biological	39.24	2.69	0	-	none	no	0	-	-		Stage 1 on 3	Very fine sandy silt-clay. Few tubes at SWI. Polychaete at depth to left of center, multiple depositional horizons evident.
CLDS - 19	B	10/2/2011	9:12:33	13.5	1	60	14.571	>4	1	>4	254.6536461	17.48	16.49	18.07	1.58	Physical	12.97	0.89	4	red/oxy	none	no	0	-	-		Stage 1 on 3	Very fine sandy silt-clay with coarser particles in upper 3-4 cm. Multiple depositional horizons evident along with subsurface burrowing.
CLDS - 19	C	10/2/2011	9:13:29	13.5	1	60	14.571	>4	0	>4	263.3324245	18.07	17.77	18.66	0.88	Biological	23.28	1.60	3	red/oxy	none	no	0	-	-		Stage 2 -> 3	Very fine sandy silt-clay. Few amphipod tubes at SWI. Portion of starfish arm visible against faceplate, multiple depositional horizons from past DM disposal.
CLDS - 20	B	10/2/2011	11:04:09	13.5	1	65	14.571	>4	1	>4	270.7443171	18.58	18.28	18.92	0.64	Biological	28.26	1.94	0	-	none	no	1	5.11	5.37	5.24	Stage 1 on 3	Very fine sandy silt-clay. Few tubes at surface. Shallow burrowing, voids at depth, multiple depositional horizons.
CLDS - 20	C	10/2/2011	11:05:00	13.5	1	65	14.571	>4	1	>4	258.2627092	17.72	17.50	18.04	0.54	Biological	50.53	3.47	0	-	none	no	0	-	-		Stage 1 on 3	Very fine sandy silt-clay. Bits of debris on surface. Few amphipod tubes at SWI. Shallow burrowing, mulitple depositional horizons from past DM disposal.
CLDS - 20	D	10/2/2011	11:05:49	13.5	1	65	14.571	>4	1	>4	266.4886483	18.29	18.23	18.58	0.35	Biological	29.55	2.03	6	red/oxy	none	no	1	13.98	15.82	14.90	Stage 1 on 3	Very fine sandy silt-clay. Small to medium mud clasts on surface (camera artifacts). Evidence of multiple depositional horizons.
CLDS - 21	A	10/2/2011	11:11:42	13.5	1	64	14.571	>4-3	1	>4	172.1845857	11.82	11.40	12.26	0.86	Biological	20.67	1.42	0	-	none	no	0	-	-		Stage 1 on 3	Very fine sandy silt-clay with higher fraction of sand than previous stations. Grayish, sandy sediment at surface from recent disturbance or deposit. Evidence of multiple horizons, buried aRPD and polychaetes at depth against faceplate.
CLDS - 21	C	10/2/2011	11:13:17	13.5	1	64	14.571	>4	1	>4	158.8317559	10.90	10.46	11.70	1.23	Physical	ind	ind	0	-	none	no	0	-	-		Stage 2 on 3	Very fine sandy silt-clay. Orange sediment at depth that appears to have wood fibers, graying, sandy sediment at surface. Few amphipod tubes in background. Bits of debris on surface and incorporated in sediment. Large pit/burrow extending from SWI to near base of image from penetration artifact (most likely a shell from SWI dragged down).
CLDS - 21	D	10/2/2011	11:14:07	13.5	1	64	14.571	>4	0	>4	198.6946453	13.64	13.41	14.02	0.61	Physical	21.78	1.49	2	oxy	none	no	0	-	-		Stage 1 on 3	Very fine sandy silt-clay. Mud clasts on surface. Grayish, sandy sediment at surface from recent deposit or trawling disturbance. Bits of debris at surface and incorporated into sediment. Evidence of subsurface burrowing.
CLDS - 22	A	10/2/2011	12:36:32	13.5	1	71	14.571	>4	1	>4	235.9443274	16.19	15.82	16.59	0.78	Biological	33.35	2.29	3	red/oxy	none	no	0	-	-		Stage 1 on 3	Very fine sandy silt-clay.Few tubes on surface. Voids & subsurface burrowing.
CLDS - 22	B	10/2/2011	12:37:17	13.5	1	71	14.571	>4	0	>4	240.5439851	16.51	16.16	16.78	0.62	Biological	21.20	1.46	0	-	none	no	0	-	-		Stage 1 on 3	Very fine sandy silt-clay with higher fraction of sand in upper 3-4 cm. Yellow polychaetes at 5.8 and 11.2cm. Evidence of former voids and deep burrowing.
CLDS - 22	C	10/2/2011	12:38:07	13.5	1	71	14.571	>4	1	>4	238.3695873	16.36	16.27	16.81	0.54	Biological	22.86	1.57	10+	red/oxy	none	no	2	5.62	15.02	10.32	Stage 1 on 3	Very fine sandy silt-clay. Small mud clasts (camera artifact) across surface. .Evidence of burrowing throughout
CLDS - 23	B	10/2/2011	11:16:07	13.5	1	65	14.571	>4-3	1	>4	1523.779642	10.58	9.98	10.89	0.91	Biological	24.91	1.71	0	-	none	no	0	-	-		Stage 1 on 3	Silty very fine sand with woody fibers, profile very similar to Station 21. Small bivalve in upper 2 cm at center. Evidence of multiple depositional horizons & burrowing at depth.
CLDS - 23	C	10/2/2011	11:16:51	13.5	1	65	14.571	>4-3	1	>4	200.6905419	13.77	13.52	14.24	0.72	Biological	30.33	2.08	2	red/oxy	none	no	1	12.75	13.11	12.93	Stage 1 on 3	Silty very fine sand with bits of debris incorporated in upper sed. Small bivalve ~2cm below SWI at center. Multiple depositional horizons and edge of void in lower right edge.
CLDS - 23	D	10/2/2011	11:17:38	13.5	1	65	14.571	4-3/>4	0	>4	158.8134215	10.90	10.62	11.46	0.83	Biological	58.05	3.98	6	red	none	no	0	-	-		Stage 1 on 3	Very fine sand over silt-lcay with coarser at surface. Small to medium mud clasts (camera artifact) Thin polychaete at 6.3 cm. Bits of debris incorporated in sediment, burrowing at depth.
CLDS - 24	A	10/2/2011	13:07:13	13.5	1	66	14.571	4-3/>4	0	>4	201.4856362	13.83	13.73	13.97	0.24	Biological	36.71	2.52	0	-	none	no	0	-	-		Stage 2 -> 3	Very fine sand over silt-clay. Thin layer of grayish sediment at surface. Some amphipod tubes at SWI. Bivalve <2cm below SWI at center. Some evidence of burrowing- small- in aRPD, coarser sand at depth (multiple depositional events).
CLDS - 24	C	10/2/2011	13:08:44	13.5	1	66	14.571	4-3/>4	0	>4	201.2516736	13.81	13.20	14.56	1.36	Physical	35.13	2.41	0	-	none	no	0	-	-		Stage 3	Very fine sand over silt clay, coarser at surface. Large oyster shell on surface. Bits of grayish sed on surface. Coarser sand horizons at depth, mulitple depositional events.
CLDS - 24	D	10/2/2011	13:09:38	13.5	1	66	14.571	4-3/>4	-1	>4	218.1375385	14.97	14.42	15.23	0.80	Biological	64.17	4.40	0	-	none	no	1	4.68	5.08	4.88	Stage 3	Very fine and fine sand over silt caly with patches of coarser sediment at depth. Void is within aRPD, polychaete visible against faceplate at subsurface right mid-depth.
CLDS - 25	A	10/2/2011	12:54:55	13.5	1	60	14.571	>4	0	>4	265.8771768	18.25	17.83	18.68	0.86	Biological	24.40	1.67	1	red	none	no	1	12.30	12.55	12.43	Stage 1 on 3	Very fine sandy silt-clay with mottled blue clay inclusion. Evidence of subsurface burrowing
CLDS - 25	B	10/2/2011	12:55:46	13.5	1	60	14.571	4-3/>4	1	>4	244.8459482	16.80	16.41	17.16	0.75	Biological	31.95	2.19	6	red/oxy	none	no	1	5.30	6.99	6.15	Stage 1 on 3	Silty very fine sand over silt-clay. Debris, mud clasts, and collapsed tubes on surface. Thin polychaete at center at base on aRPD. Burrowing through aRPD.
CLDS - 25	C	10/2/2011	12:56:35	13.5	1	60	14.571	>4	0	>4	210.2088954	14.43	14.24	14.88	0.64	Biological	15.17	1.04	3	oxy	none	no	1	4.38	4.67	4.53	Stage 1 on 3	Very fine sandy silt-clay with sandy gray sediment recently deposited on surface. Sparse amphipod density, shallow burrowing, multiple depositional horizons.
CLDS - 26	A	10/2/2011	12:17:05	13.5	1	67	14.571	4-3/>4	0	>4	201.0913275	13.80	13.41	14.24	0.83	Biological	40.02	2.75	0	-	none	no	0	8.44	9.91	9.18	Stage 1 on 3	Silty very fine sand over silt clay. Some amphipod tubes in background and at SWI, few collapsed on surface. Shallow burrowing. Mulitple depositional horizons, edge of void at right edge of image.
CLDS - 26	B	10/2/2011	12:17:53	13.5	1	67	14.571	4-3/>4	0	>4	198.7951456	13.64	12.87	14.42	1.55	Biological	37.19	2.55	10+	red/oxy	none	no	0	-	-		Stage 1 on 3	Very fine sandy silt-clay. Small to medium mud clasts at surface. Chaotic fabric typical of DM disposal, evidence of subsurface burrowing throughout.
CLDS - 26	C	10/2/2011	12:18:43	13.5	1	67	14.571	4-3/>4	0	>4	203.7842095	13.99	13.44	14.42	0.99	Biological	29.29	2.01	10+	red/oxy	none	no	0	-	-		Stage 1 on 3	Profile simiar to Station 21, very fine sandy silt-clay. Few amphipod tubes at SWI. Multiple depositional horizons with evidence of subsurface burrowing.
CLDS - 27	A	10/2/2011	12:29:24	13.5	1	71	14.571	>4	1	>4	240.3751494	16.50	16.22	16.89	0.67	Biological	27.76	1.91	0	-	none	no	3	4.98	12.12	8.55	Stage 2 on 3	Very fine sandy silt-clay. Few short amphipod tubes at SWI. Burrowing through aRPD, including one long burrow extending through on right. Polychaete visible near shallowest void ~ 5cm.
CLDS - 27	B	10/2/2011	12:30:14	13.5	1	71	14.571	>4	1	>4	228.1152878	15.66	15.47	16.00	0.54	Biological	37.76	2.59	5	red/oxy	none	no	1	8.55	9.12	8.84	Stage 2 on 3	Very fine sandy silt-clay. Short amphipod tubes on surface. Burrowing through aRPD. Bivalve at ~2cm at center.
CLDS - 27	C	10/2/2011	12:31:11	13.5	1	71	14.571	>4	1	>4	227.0950991	15.59	15.28	15.84	0.56	Biological	27.20	1.87	5	red/oxy	none	no	3	6.05	12.48	9.27	Stage 2 on 3	Very fine sandy silt-clay. Few amphipod tubes at SWI. Subsurface burrowing throughout profile.
CLDS - 28	A	10/2/2011	11:35:10	13.5	1	64	14.571	>4	1	>4	249.9530099	17.15	16.51	17.69	1.18	Biological	46.86	3.22	0	-	none	no	0	-	-		Stage 1 on 3	Very fine sandy silt-clay with traces of wood fibers and incipient Beggiatoa. Multiple depositional horizons and evidence of subsurface burrowing throughout.
CLDS - 28	B	10/2/2011	11:35:53	13.5	1	64	14.571	>4	0	>4	206.8803484	14.20	13.41	15.07	1.66	Biological	55.19	3.79	0	-	Yes	no	1	8.21	9.21	8.71	Stage 3	Very fine sandy silt-clay with traces of wood fiber; classic biogenic mound and associated void at depth. Methane at lower right edge of photo
CLDS - 28	C	10/2/2011	11:36:39	13.5	1	64	14.571	>4	1	>4	179.8273918	12.34	12.29	12.87	0.59	Biological	14.80	1.02	0	-	none	no	0	-	-		Stage 2 on 3	Very fine sandy silt-clay traces of wood fiber in profile and dense bed of amphipod tubes. Evidence of subsurface burrowing.
CLDS - 29	A	10/2/2011	12:48:48	13.5	1	69	14.571	>4	0	>4	243.2795145	16.70	15.74	17.56	1.82	Biological	25.99	1.78	0	-	none	no	1	2.45	2.76	2.61	Stage 1 on 3	Very fine sandy silt-clay with higher fraction of coarser particles in upper 2-4 cm. Few short tubes at SWI. Void is at base of aRPD.
CLDS - 29	B	10/2/2011	12:49:32	13.5	1	69	14.571	>4	0	>4	228.4718716	15.68	15.36	15.87	0.51	Biological	38.12	2.62	0	-	none	no	2	13.71	15.43	14.57	Stage 1 on 3	Very fine sandy silt-clay. Thin layer of grayish sandy sediment at surface, appears to originate as pseudofeces at right. Small gastropod at SWI. Few short amphipod tubes in background.
CLDS - 29	C	10/2/2011	12:50:15	13.5	1	69	14.571	>4	0	>4	231.2953861	15.87	15.31	16.27	0.96	Biological	24.05	1.65	0	-	none	no	4	1.90	6.35	4.13	Stage 1 on 3	Very fine sandy silt-clay with coarser particles in upper 3-5 cm. Some grayish sandy pseudofeces at surface. Few short amphipod at SWI. Evidence of burrowing at base of aRPD, on left.
CLDS - 30	A	10/2/2011	11:46:20	13.5	1	65	14.571	>4	1	>4	184.3194346	12.65	12.37	13.04	0.67	Biological	24.53	1.68	0	-	none	no	0	-	-		Stage 1 on 3	Very fine sandy silt-clay. Multiple depositional horizons. Shallow burrowing. Orangish sed at depth, similar to subsurface sediments from Station 21.
CLDS - 30	B	10/2/2011	11:47:07	13.5	1	65	14.571	4-3/>4	1	>4	209.7873043	14.40	14.05	14.64	0.59	Biological	21.62	1.48	10+	red/oxy	none	no	0	-	-		Stage 2 -> 3	Silty very fine sand over silt-clay. Multiple depositional horizons. Couple of amphipod tubes at SWI.
CLDS - 30	C	10/2/2011	11:47:56	13.5	1	65	14.571	>4	1	>4	198.6232608	13.63	13.17	14.08	0.91	Biological	26.89	1.85	0	-	none	no	0	-	-		Stage 1 on 3	Very fine sandy silt-clay with what appears to be wood fibers mixed in sediment.Polychaete against faceplate at 5.7cm on right.
CLDS - 31	D	10/3/2011	13:01:41	16	3	53	14.571	4-3/>4	0	>4	236.3542802	16.22	15.74	16.70	0.96	Biological	40.35	2.77	0	-	none	no	0	-	-		Stage 1 on 3	Very fine sandy silt-clay. Bits of grayish sed in upper cm. Burrowing in upper cm. On far right, opening to larger burrow at edge.
CLDS - 31	E	10/3/2011	6:01:01	16	3	53	14.571	>4	1	>4	310.80	ind	>21.33	>21.33	Ind	ind	ind	ind	-	-	none	no	1				indeterminate	Very fine sandy silt-clay. Over-penetration. aRPD is present. Void is surrounded by reduced sed & may be relict.
CLDS - 31	G	10/3/2011	6:02:28	16	3	53	14.571	>4	1	>4	303.4558813	20.83	20.61	21.01	0.40	Biological	48.47	3.33	0	-	none	no	0	-	-		Stage 1 on 3	Very fine sandy silt-clay. Some short amphipod tubes at SWI. Shallow sand-lined burrows in upper 2cms. Portion of worm visible against faceplate.
CLDS - 32	B	10/2/2011	12:00:32	13.5	1	64	14.571	>4	1	>4	273.9768079	18.80	17.72	19.27	1.55	Biological	34.01	2.33	6	red/oxy	none	no	0	-	-		Stage 1 on 3	Very fine sandy silt-clay with mulitple depositional horizons and traces of wood fibers in sediment.Evidence of subsurface burrowing throughout profile.
CLDS - 32	C	10/2/2011	12:01:22	13.5	1	64	14.571	>4	1	>4	281.0066877	19.29	18.92	19.59	0.67	Biological	51.36	3.53	0	-	none	no	0	-	-		Stage 1 on 3	Very fine sandy silt-clay with traces of wood/plant fibers throughout sediment \Burrowing through aRPD, evidence of subsurface burrowing.
CLDS - 32	D	10/2/2011	12:02:11	13.5	1	64	14.571	>4	0	>4	201.5492884	13.83	13.62	14.13	0.50	Biological	58.43	4.01	9	red/oxy	none	no	2	7.79	11.42	9.61	Stage 1 on 3	Very fine sandy silt-clay with traces of wood/plant fibers in sediment.Burrowing through aRPD.
CLDS - 33	A	10/2/2011	11:39:23	13.5	1	64	14.571	>4	0	>4	213.4356268	14.65	14.02	15.52	1.50	Physical	16.35	1.12	0	-	none	no	3	3.36	8.36	5.86	Stage 2 on 3	Very fine sandy silt-clay with high percentage of wood/plant fibers throughout. Surface is covered with plant debris- shell fragments. Bed of thicker amphipod tubes interwoven with debris.
CLDS - 33	B	10/2/2011	11:40:13	13.5	1	64	14.571	>4	0	>4	199.2219381	13.67	12.63	14.21	1.58	Biological	15.43	1.06	0	-	none	no	0	-	-		Stage 2 on 3	Very fine sandy silt-clay with wood fibers, amphipod near SWI. Large burrow on right is artifact caused by prism dragging down shell or debris through sediment column.
CLDS - 33	C	10/2/2011	11:40:57	13.5	1	64	14.571	>4	0	>4	200.3766453	13.75	13.41	14.53	1.12	Physical	31.89	2.19	9	red/oxy	none	no	0	-	-		Stage 2 on 3	Very fine sandy silt-clay with wood/plant fibers . Medium mud clasts (camera artifacts) on surface. Few amphipod tubes collapsed on surface and in background. Patches of orangish sed at depth.
CLDS - 34	A	10/2/2011	12:23:08	13.5	1	68	14.571	>4	1	>4	181.6995712	12.47	12.20	12.85	0.64	Physical	20.95	1.44	6	red	none	no	0	-	-		Stage 1 on 3	Very fine sandy silt-clay with multiple depositional horizons. Amphipod just below SWI to left. Shallow sand-lined burrows. Small white bivalve on right. Bits of orangish sed at depth.
CLDS - 34	B	10/2/2011	12:23:51	13.5	1	68	14.571	>4	0	>4	195.0554102	13.39	12.26	14.32	2.06	Biological	24.91	1.71	0	-	none	no	2	3.12	8.30	5.71	Stage 3	Very fine sandy silt-clay. Shell fragments and small debris at surface. Burrow opening filled with reduced pseudofeces.
CLDS - 34	C	10/2/2011	12:24:34	13.5	1	68	14.571	>4	1	>4	205.79581	14.12	13.57	14.99	1.42	Biological	20.23	1.39	0	-	none	no	0	-	-		Stage 1 on 3	Very fine sandy silt-clay with multiple depositional horizons. Amphipod tubes at SWI. Tangle of larger sand tubes on surface and right. Part of burrow or void at left edge. Indication of burrowing below aRPD to left. Bits of orangish sed (wood fibers) at depth.
CLDS - 35	A	10/2/2011	11:53:39	13.5	1	65	14.571	4-3/>4	0	>4	188.7706237	12.96	12.82	13.30	0.48	Physical	22.04	1.51	0	-	none	no	0	-	-		Stage 1 on 3	Very fine sandy silt-clay with grayish sandy sediment between SWI and oxidized sediment; sediment with traces of wood fibers at depth.Evidence of sub-surface burrowing.
CLDS - 35	B	10/2/2011	11:54:25	13.5	1	65	14.571	4-3/>4	0	>4	303.4626172	20.83	20.39	21.28	0.88	Physical	26.14	1.79	1	red	none	no	2	8.59	9.96	9.28	Stage 1 on 3	Silty very fine sand over clay over silt-clay with wood fibers. Bit of gray sandy sediment layer at SWI. Multiple depositional horizons.
CLDS - 35	C	10/2/2011	11:55:11	13.5	1	65	14.571	>4	1	>4	185.865561	12.76	12.42	13.12	0.70	Biological	20.22	1.39	1	red	none	no	0	-	-		Stage 1 on 3	Very fine sandy silt-clay with depositional layer at depth with high wood fiber content (orange sediment). Shallow sand-lined burrows in upper cm. Polychaete at center- J-shaped.

Note: ind = indeterminate; Mud clast state: o=oxidized, r=reduced, b=both oxidized and reduced

Station	Replicate	Date	Time	Stop Collar Settings (in.)	# of weights per chassis	Water Depth (ft)	Calibration Constant	Grain Size Major Mode (phi)	Grain Size Maximum (phi)	Grain Size Minimum (phi)	Penetration Area (sq.cm)	Average Penetration (cm)	Minimum Penetration (cm)	Maximum Penetration (cm)	Boundary Roughness (cm)	Boundary Roughness Type	RPD Area (sq.cm)	Mean RPD (cm)	Mud Clast Number	Mud Clast State	Methane	Low DO?	# of Feeding Voids	Void Minimum Depth (cm)	Void Maximum Depth (cm)	Void Average Depth (cm)	Successional Stage	Comments
FVP - 1	A	10/3/2011	12:39:09	13	1	63	14.571	>4	1	>4	216.8080368	14.88	14.50	15.07	0.56	Biological	41.81	2.87	10+	red/oxy	none	no	3	4.51	9.52	7.02	Stage 1 on 3	Very fine sandy silt-clay. Small mud clasts on surface. Shallow burrowing. Small opening of larger burrows or closed voids in addition to those counted.
FVP - 1	C	10/3/2011	12:40:52	13	1	63	14.571	>4	1	>4	264.5554672	18.16	17.96	18.41	0.46	Biological	47.82	3.28	0	-	none	no	1	3.96	5.13	4.55	Stage 1 on 3	Very fine sandy silt-clay. Few amphipod tubes at SWI. Few white threads, possible Beggiatoa threads. Sand-lined burrows in upper few cms.
FVP - 1	D	10/3/2011	12:41:43	13	1	63	14.571	>4	0	>4	243.337786	16.70	16.59	16.89	0.29	Biological	39.98	2.74	0	-	none	no	2	6.75	11.91	9.33	Stage 1 on 3	Very fine sandy silt-clay. Shallow burrowing and through aRPD, larger one on far right.
FVP - 2	A	10/3/2011	13:31:25	13.5	1	63	14.571	>4	1	>4	273.0988701	18.74	17.85	19.14	1.29	Biological	29.51	2.03	0	-	none	no	0	-	-		Stage 1 on 3	Very fine sandy silt-clay. One amphipod tube at SWI on right. Shallow burrowing. Edge of void network on left edge of image.
FVP - 2	B	10/3/2011	13:32:26	13.5	1	63	14.571	>4	1	>4	257.6180963	17.68	17.58	17.88	0.29	Biological	49.92	3.43	2	red	none	no	1	9.55	9.80	9.68	Stage 1 on 3	Very fine sandy silt-clay. Voids and subsurface burrowing at depth
FVP - 2	C	10/3/2011	13:33:14	13.5	1	63	14.571	>4	1	>4	245.3881875	16.84	14.77	17.53	2.76	Biological	56.85	3.90	5	red/oxy	none	no	1	10.54	16.38	13.46	Stage 1 on 3	Very fine sandy silt-clay. Medium mud clasts on surface (camera artifact). Surface slopes down to right in right 1/3 of image for large biogenic pit with Maldanid tube.
FVP - 3	A	10/3/2011	13:00:33	13	1	62	14.571	4-3/>4	0	>4	197.2435986	13.54	11.46	14.26	2.81	Physical	35.24	2.42	2	red	none	no	1	4.10	9.93	7.02	Stage 3	Silty very fine and fine sand over silt clay. Shells on surface. Scallop shell stuck in sediment at SWI. Bits of debris incorporated in sed in upper cm. Large void, texture of sediment very different from previous two replicates
FVP - 3	B	10/3/2011	13:01:28	13	1	62	14.571	>4	1	>4	235.2767567	16.15	16.00	16.25	0.24	Biological	53.30	3.66	2	red/oxy	none	no	3	10.22	12.26	11.24	Stage 1 on 3	Very fine sandy silt-clay. Evidence of burrowing through aRPD. Depositional horizon with wood fibers in oxidized layer at depth; check disposal log to see if DM dumped in this area, bottom layer has similar sediment texture to CLDS 21.
FVP - 3	D	10/3/2011	13:03:10	13	1	62	14.571	>4	0	>4	188.2478945	12.92	11.99	14.05	2.06	Biological	30.86	2.12	0	-	none	no	1	9.63	12.85	11.24	Stage 3	Very fine sandy silt-clay. Shell fragments and bits of debris at surface. Pit with redcued fecal pellets, extending down through large burrow to large void, burrow continues past void. Edge of possible additional void at left edge of image. Unusual sediment profile for location unless additional material placed for cap.
FVP - 4	A	10/3/2011	12:47:55	13	1	62	14.571	>4	0	>4	206.6454491	14.18	13.60	14.99	1.39	Biological	51.14	3.51	0	-	none	no	0	-	-		Stage 1 on 3	Very fine sandy silt-clay. Few small tubes collapsed at surface. Ttubiculous fauna in background. Polychaete at 6.5cm
FVP - 4	B	10/3/2011	12:48:40	13	1	62	14.571	>4	0	>4	210.2206533	14.43	14.13	15.07	0.94	Biological	28.28	1.94	0	-	none	no	2	11.48	14.39	12.94	Stage 1 on 3	Very fine sandy silt-clay. Shrimp on surface. Gray fecal pellets on surface at right associated with burrow openting.
FVP - 4	C	10/3/2011	12:49:34	13	1	62	14.571	>4	0	>4	224.2392403	15.39	15.15	15.63	0.48	Biological	37.44	2.57	4	red/oxy	none	no	0	-	-		Stage 1 on 3	Very fine sandy silt-clay with coarser particles in upper 2-3 cm and traces of Beggiatoa colonies.Small gastropod in background on left. Few tubes and amphipod tubes collapsed on surface. Evidence of burrowing through aRPD. J-shaped burrow below aRPD at center.
FVP - 5	A	10/3/2011	12:51:54	13	1	62	14.571	>4	1	>4	229.3935329	15.74	13.57	16.33	2.75	Biological	28.44	1.95	0	-	Yes	no	3	8.89	12.50	10.70	Stage 2 on 3	Very fine sandy silt-clay. Pit with fecal pellets on left. Shallow burrowing and near base of aRPD. Methane bubbles at depth on right.
FVP - 5	B	10/3/2011	12:52:45	13	1	62	14.571	>4	1	>4	234.8485492	16.12	15.66	16.51	0.86	Biological	45.62	3.13	1	red	none	no	0	-	-		Stage 2 on 3	Very fine sandy silt-clay. Evidence of burrowing through aRPD. Evidence of subsurface burrowing.
FVP - 5	D	10/3/2011	12:54:18	13	1	62	14.571	>4	1	>4	236.1978999	16.21	15.95	16.54	0.59	Biological	50.85	3.49	0	-	none	no	1	6.16	6.94	6.55	Stage 2 on 3	Very fine sandy silt-clay. Traces of Beggiatoa in surface oxidized layer; amphipod tube in background. Burrowing through aRPD, including closing end of large burrow. Polychaete at 7.65 cm.
FVP - 6	B	10/3/2011	12:34:56	13	1	62	14.571	>4	1	>4	239.2293502	16.42	16.19	16.65	0.46	Biological	55.40	3.80	0	-	none	no	1	14.72	15.68	15.20	Stage 2	Very fine sandy silt-clay. Shell frag (?) ~1cm below SWI. Evidence of burrowing through aRPD; traces of Beggiatoa in surface oxidized layer. Relict void at depth.
FVP - 6	C	10/3/2011	12:35:43	13	1	62	14.571	>4	1	>4	244.6917601	16.79	16.25	17.16	0.91	Biological	53.37	3.66	8	red	none	no	2	10.88	12.87	11.88	Stage 2 on 3	Very fine sandy silt-clay. Traces of Beggiatoa in oxidized layer. Evidence of burrowing through aRPD.
FVP - 6	D	10/3/2011	12:36:47	13	1	62	14.571	>4	1	>4	225.4034336	15.47	15.17	15.98	0.80	Biological	52.40	3.60	0	-	none	no	1	9.47	12.18	10.83	Stage 2 on 3	Very fine sandy silt-clay. Traces of Beggiatoa in oxidized layer. Evidence of burrowing through aRPD.
FVP - 7	A	10/3/2011	13:25:29	13.5	1	63	14.571	>4	1	>4	242.728128	16.66	16.59	16.81	0.21	Biological	60.37	4.14	0	-	none	no	2	2.89	15.55	9.22	Stage 2 on 3	Very fine sandy silt-clay. Traces of Beggiatoa in oxidized layer. Evidence of burrowing through aRPD.
FVP - 7	B	10/3/2011	13:26:26	13.5	1	63	14.571	>4	0	>4	237.171595	16.28	16.11	16.30	0.19	Biological	56.97	3.91	0	-	none	no	0	-	-		Stage 2 on 3	Very fine sandy silt-clay. Few tubes, amphipods at surface. Evidence of burrowing through aRPD.
FVP - 7	C	10/3/2011	13:27:22	13.5	1	63	14.571	>4	0	>4	236.3899127	16.22	16.22	16.43	0.21	Biological	43.80	3.01	7	red/oxy	none	no	0	-	-		Stage 2 on 3	Very fine sandy silt-clay. Traces of Beggiatoa in surface oxidized layer. Evidence of burrowing through aRPD. Polychaete against faceplate at 9 cm.
FVP - 8	A	10/3/2011	13:19:36	13.5	1	63	14.571	>4	1	>4	249.6654391	17.13	16.86	17.66	0.80	Biological	50.33	3.45	0	-	none	no	2	15.58	17.37	16.48	Stage 2 on 3	Very fine sandy silt-clay. Burrowing throughout aRPD and in subsurface sediments.
FVP - 8	B	10/3/2011	13:20:25	13.5	1	63	14.571	>4	0	>4	244.7758591	16.80	16.59	17.02	0.43	Biological	41.70	2.86	7	red/oxy	none	no	1	10.04	15.52	12.78	Stage 2 on 3	Very fine sandy silt-clay. Shallow burrowing in upper cms and throughout subsurface.
FVP - 8	C	10/3/2011	13:21:29	13.5	1	63	14.571	>4	0	>4	227.8002553	15.63	15.47	15.74	0.27	Biological	43.71	3.00	0	-	none	no	3	7.46	11.75	9.61	Stage 2 on 3	Very fine sandy silt-clay. Burrowing throughout aRPD. Nereid against faceplate at base of aRPD.
FVP - 9	A	10/3/2011	12:56:29	13	1	62	14.571	>4	0	>4	231.2713721	15.87	15.66	16.38	0.72	Biological	37.82	2.60	0	-	none	no	0	-	-		Stage 2 on 3	Very fine sandy silt-clay. Few amphipod tubes at SWI. Small polychaete at 5.58cm. Some clay inclusions with evidence of wood fibers at depth, similar to seds at CLDS Station 21; looks like relatively recent material placed at this site.
FVP - 9	B	10/3/2011	12:57:18	13	1	62	14.571	>4	1	>4	237.6391217	16.31	16.16	16.49	0.32	Biological	47.83	3.28	4	red/oxy	none	no	0	-	-		Stage 2 -> 3	Very fine sandy silt-clay. Traces of Beggiatoa in surface oxidized layer. Few tubes, some collapsed, at SWI. Evidence of burrowing through aRPD.
FVP - 9	C	10/3/2011	12:58:05	13	1	62	14.571	>4	1	>4	230.4543562	15.82	15.44	16.27	0.83	Biological	35.15	2.41	0	-	none	no	1	4.42	4.62	4.52	Stage 2 on 3	Very fine sandy silt-clay. Traces of Beggitoa in surface oxidized layer. Evidence of small burrows in upper few cm. Void is small and near base of aRPD. Sediment has clay inclusions with traces of wood fiber, similar to replicate A and CLDS Station 21...recent allocthonous input.
FVP - 10	A	10/3/2011	12:43:27	13	1	61	14.571	>4	0	>4	201.8809414	13.85	13.49	14.61	1.12	Biological	38.14	2.62	3	red/oxy	none	no	2	8.62	13.50	11.06	Stage 2 on 3	Very fine sandy silt-clay with higher fraction of coarser particles in upper 2-3 cm. Evidence of subsurface burrowing.
FVP - 10	B	10/3/2011	12:44:12	13	1	61	14.571	>4	1	>4	217.5167603	14.93	14.66	15.14	0.48	Biological	29.09	2.00	4	red	none	no	0	-	-		Stage 2 on 3	Very fine sandy silt-clay. Traces of Beggiatoa in surface oxidized layer. Gastropod on surface at left. Few small tubes at SWI. Shallow burrowing and evidence of deeper burrowing at base of aRPD.
FVP - 10	C	10/3/2011	12:45:25	13	1	61	14.571	4-3/>4	0	>4	183.689549	12.61	11.13	13.54	2.41	Physical	18.63	1.28	0	-	none	no	0	-	-		Stage 1 on 3	Silty very fine sand over silt clay with some coarser particles in upper 2 cm; dense assemblage of larger polychaete tubes in background
FVP - 11	A	10/3/2011	11:37:57	13	1	63	14.571	>4	1	>4	254.1744213	17.44	16.62	17.88	1.26	Physical	22.93	1.57	0	-	none	no	3	2.95	17.18	10.07	Stage 2 on 3	Very fine sandy silt-clay. Large tube (~4cm long) on surface. Contrast this profile with "typical" FVP sediment cross section, e.g. Station FVP-7; extensive subsurface burrowing.
FVP - 11	B	10/3/2011	11:38:44	13	1	63	14.571	>4	1	>4	278.6486672	19.12	17.50	21.92	4.42	Physical	ind	ind	6	red	none	no	2	1.38	18.11	9.75	Stage 3	Very fine sandy silt-clay. Large mud clasts on surface, disturbed by sampling a previous rep (rep D in same condition, so only 2 good reps for measurement at this station)
FVP - 11	C	10/3/2011	11:39:31	13	1	63	14.571	>4	1	>4	267.1426675	18.33	18.01	18.98	0.96	Biological	39.70	2.72	0	-	none	no	2	1.65	17.64	9.65	Stage 2 on 3	Very fine sandy silt-clay. Shallow burrowing, and through aRPD. One void is small and within aRPD on right. Polychaete at 6.9cm against faceplate.
FVP - 12	A	10/3/2011	11:31:32	13	1	62	14.571	>4	0	>4	236.94108	16.26	15.92	16.43	0.51	Biological	47.28	3.24	0	-	none	no	2	3.62	3.84	3.73	Stage 2 on 3	Very fine sandy silt-clay. Couple collapsed tubes on surface. Evidence of burrowing through and at base of aRPD, trace Beggiatoa in surface oxidized layer. Polychaete against faceplate at base of image. Profile texture similar to previous station (FVP 11) and very different from ones like FVP 7
FVP - 12	B	10/3/2011	11:32:21	13	1	62	14.571	>4	1	>4	249.2559846	17.11	16.83	17.40	0.56	Biological	48.53	3.33	10+	red	none	no	1	8.11	8.30	8.21	Stage 2 on 3	Very fine sandy silt-clay. As in Replicate A, higher albedo for subsurface sediments compared to other FVP stations. Evidence of burrowing throughout profile.
FVP - 12	C	10/3/2011	11:33:08	13	1	62	14.571	>4	1	>4	254.378471	17.46	17.21	17.72	0.51	Biological	49.43	3.39	4	red/oxy	none	no	2	3.99	16.43	10.21	Stage 2 on 3	Very fine sandy silt-clay. As in Replicate A, higher albedo for subsurface sediments compared to other FVP stations. Evidence of burrowing throughout profile.
FVP - 13	A	10/3/2011	13:43:38	13.5	1	65	14.571	>4	1	>4	251.6222755	17.27	17.02	17.99	0.96	Biological	51.99	3.57	0	-	none	no	0	-	-		Stage 2 on 3	Very fine sandy silt-clay. Traces of Beggiatoa in surface oxidized layer. Burrowing through aRPD. Evidence of deeper burrowing at base of aRPD.
FVP - 13	B	10/3/2011	13:44:22	13.5	1	65	14.571	>4	1	>4	263.3253498	18.07	17.93	18.33	0.40	Biological	52.93	3.63	0	-	none	no	0	-	-		Stage 2 on 3	Very fine sandy silt-clay. Evidence of subsurface burrowing throughout depth of profile.
FVP - 13	D	10/3/2011	13:45:59	13.5	1	65	14.571	>4	1	>4	245.76441	16.87	16.42	17.16	0.74	Biological	34.64	2.38	0	-	none	no	1	11.70	13.26	12.48	Stage 1 on 3	Very fine sandy silt-clay. Evidence of subsurface burrowing throughout depth of profile, traces of Beggiatoa in surface oxidized layer.
FVP - 14	A	10/3/2011	11:44:11	13	1	61	14.571	>4	0	>4	270.8206041	18.59	18.31	18.76	0.46	Biological	28.46	1.95	1	red	none	no	0	-	-		Stage 1 on 3	Very fine sandy silt-clay. Small tubes at surface, appears to be recent deposition of thin, silty fine sand reduced layer, ca 2 cm in thickness; evidence of subsurface burrowing.
FVP - 14	B	10/3/2011	11:44:58	13	1	61	14.571	>4	1	>4	244.4607668	16.78	16.54	17.10	0.56	Biological	54.17	3.72	9	red/oxy	none	no	3	9.15	11.75	10.45	Stage 2 on 3	Very fine sandy silt-clay. Small to medium mud clasts on surface (camera artifacts). Evidence of burrowing throughout profile, high albedo subsurface like Station FVP 12; Beggiatoa traces in surface oxidized layer.
FVP - 14	D	10/3/2011	11:46:38	13	1	61	14.571	>4	1	>4	243.7701585	16.73	16.00	17.05	1.04	Biological	48.97	3.36	0	-	none	no	0	-	-		Stage 2 on 3	Very fine sandy silt-clay. At least one amphipod tube at surface. Burrowing throughout profile, traces of Beggiatoa in surface oxidized layer.
FVP - 15	A	10/3/2011	13:37:25	13.5	1	65	14.571	>4	0	>4	278.1972827	19.09	18.49	20.69	2.19	Biological	12.68	0.87	0	-	none	no	4	8.27	18.65	13.46	Stage 1 on 3	Very fine sandy silt-clay with coarser particles in upper 4-6 cm; darker, reduced sediment on surface (recent allochtonous deposit); cross section has fabric of either fairly recent disposal or disturbance by trawling.
FVP - 15	B	10/3/2011	13:38:15	13.5	1	65	14.571	>4	0	>4	286.0401329	19.63	19.32	19.72	0.40	Biological	46.91	3.22	1	red	none	no	1	9.63	10.20	9.92	Stage 2 on 3	Very fine sandy silt-clay. Sediment texture very different from previous replicate, this one looks more like "typical" FVP profile with subsurface burrowing and high albedo sediments throughout.
FVP - 15	C	10/3/2011	13:39:09	13.5	1	65	14.571	>4	1	>4	270.9229179	18.59	18.47	18.84	0.37	Biological	40.84	2.80	3	red/oxy	none	no	1	7.07	8.08	7.58	Stage 2 on 3	Very fine sandy silt-clay. Small mud clasts at surface. Burrowing through aRPD and most of subsurface profile.

Note: ind = indeterminate; Mud clast state: o=oxidized, r=reduced, b=both oxidized and reduced

APPENDIX C
Sediment-Profile Imaging Results
Reference
September 2011

Station	Replicate	Date	Time	Stop Collar Settings (in.)	# of weights per chassis	Water Depth (ft)	Calibration Constant	Grain Size Major Mode (phi)	Grain Size Maximum (phi)	Grain Size Minimum (phi)	Penetration Area (sq.cm)	Average Penetration (cm)	Minimum Penetration (cm)	Maximum Penetration (cm)	Boundary Roughness (cm)	Boundary Roughness Type	RPD Area (sq.cm)	Mean RPD (cm)	Mud Clast Number	Mud Clast State	Methane	Low DO?	# of Feeding Voids	Void Minimum Depth (cm)	Void Maximum Depth (cm)	Void Average Depth (cm)	Successional Stage	Comments
REF1	A	10/3/2011	6:56:51	13	1	82	14.571	>4	1	>4	238.0029994	16.33	16.03	16.73	0.70	Biological	42.47	2.91	0	-	none	no	0	-	-		Stage 2 on 3	Very fine sandy silt-clay. Evidence of subsurface burrowin, sparse trace of Beggiatoa in surface layer.
REF1	B	10/3/2011	6:57:38	13	1	82	14.571	>4	1	>4	245.7321963	16.86	16.65	17.02	0.37	Biological	49.64	3.41	3	red	none	no	1	10.14	13.84	11.99	Stage 2 on 3	Very fine sandy silt-clay. Burrowing, including a large one to right, through aRPD. Void is large.
REF1	D	10/3/2011	6:59:14	13	1	82	14.571	>4	2	>4	241.3987658	16.57	16.33	16.83	0.51	Biological	45.20	3.10	10+	red	none	no	0	-	-		Stage 2 on 3	Very fine sandy silt-clay. Small to medium-large mud clasts at surface (camera artifacts). Burrowing through and below aRPD. Small bits of polychaete visible against faceplate at 10.78 cm, sparse trace of Beggiatoa in surface oxidized layer.
REF2	B	10/3/2011	6:37:27	13	1	81	14.571	>4	2	>4	261.1849105	17.92	17.83	18.20	0.37	Biological	52.97	3.64	0	-	none	no	3	14.75	17.80	16.28	Stage 2 on 3	Very fine sandy silt-clay. Several amphipod tubes SWI. Burrowing through aRPD. Evidence of subsurface burrowing to depth of profile; sparse traces of Beggiatoa in surface layer.
REF2	C	10/3/2011	6:38:20	13	1	81	14.571	>4	2	>4	239.7421549	16.45	16.30	16.75	0.46	Biological	54.71	3.75	2	red	none	no	2	5.59	8.40	7.00	Stage 2 on 3	Very fine sandy silt-clay. Evidence of subsurface burrowing and sparse traces of Beggiatoa in surface layer.
REF2	D	10/3/2011	6:39:09	13	1	81	14.571	>4	2	>4	264.5855994	18.16	17.61	18.82	1.21	Biological	55.31	3.80	10+	red	none	no	3	8.49	17.25	12.87	Stage 2 on 3	Very fine sandy silt-clay. Small to medium mud clasts at surface (camera artifact). Evidence of burrowing throughout profile; sparse traces of Beggiatoa in surface layer.
REF3	A	10/3/2011	6:43:49	13	1	82	14.571	>4	1	>4	233.4310625	16.02	16.97	17.53	0.56	Biological	53.64	3.68	4	red/oxy	none	no	0	-	-		Stage 2 on 3	Very fine sandy silt-clay. Evidence of burrowing throughout profile; sparse traces of Beggiatoa in surface layer.
REF3	B	10/3/2011	6:44:40	13	1	82	14.571	>4	2	>4	271.6575088	18.64	18.20	19.14	0.94	Biological	34.45	2.36	10+	red	none	no	0	-	-		Stage 2 on 3	Very fine sandy silt-clay. Small mud clats at surface (camera artifacts). Large burrow opening on right. Small polychaete near base of aRPD on left; trace Beggiatoa in surface oxidized layer.
REF3	C	10/3/2011	6:45:30	13	1	82	14.571	>4	2	>4	251.627736	17.27	16.97	17.61	0.64	Biological	53.00	3.64	10+	red	none	no	1	15.23	17.37	16.30	Stage 2 on 3	Very fine sandy silt-clay. Tubes and tube fragments lying on surface. Evidence of burrowing through aRPD and to depth of profile.
REF4	A	10/3/2011	7:05:28	13	1	81	14.571	>4	2	>4	249.106938	17.10	16.65	17.56	0.91	Biological	50.83	3.49	0	-	none	no	2	10.79	11.84	11.32	Stage 2 on 3	Very fine sandy silt-clay with coarser particles in upper layer. Evidence of subsurface burrowing throughout profile.
REF4	B	10/3/2011	7:06:14	13	1	81	14.571	>4	1	>4	268.3961214	18.42	18.25	18.55	0.29	Biological	46.06	3.16	0	-	none	no	2	2.01	13.25	7.63	Stage 2 on 3	Very fine sandy silt-clay. Some short tubes at SWI. Burrowing throughout profile; sparse traces of Beggiatoa in surface oxidized layer.
REF4	C	10/3/2011	7:07:01	13	1	81	14.571	>4	2	>4	260.9821363	17.91	17.24	18.92	1.69	Physical	ind	ind	10+	red	none	no	1	3.65	5.51	4.58	Stage 3	Silt. Medium to large mud clasts at surface, profile disturbed by camera; however, extensive burrowing throughout profile, high density of Stage 3 taxa at this location.
REF5	A	10/3/2011	6:50:11	13	1	82	14.571	>4	2	>4	231.3785286	15.88	15.31	16.46	1.15	Biological	43.75	3.00	0	-	none	no	1	6.91	7.66	7.29	Stage 2 on 3	Very fine sandy silt-clay. Area of fecal pellets in 'cone' on left in upper 1.5 cm. Burrowing throughout profile; sparse traces of Beggiatoa present in surface oxidized layer.
REF5	B	10/3/2011	6:50:56	13	1	82	14.571	>4	2	>4	263.8199995	18.11	17.80	17.91	0.11	Biological	33.29	2.28	6	red/oxy	none	no	0	-	-		Stage 2 on 3	Very fine sandy silt-clay. Small mud clasts (camera artifacts) at surface. Burrowing throughout profile, sparse traces of Beggiatoa present in surface oxidized layer.
REF5	D	10/3/2011	6:52:32	13	1	82	14.571	>4	2	>4	230.8514749	15.84	15.66	16.16	0.51	Biological	50.72	3.48	6	red/oxy	none	no	3	6.99	12.53	9.76	Stage 2 on 3	Very fine sandy silt-clay. Small mud clasts (camera artifacts) at surface. Burrowing throughout profile, sparse traces of Beggiatoa present in surface oxidized layer.
REF6	B	10/3/2011	6:29:59	13	1	79	14.571	>4	2	>4	240.6226236	16.51	15.28	17.96	2.68	Physical	48.95	3.36	1	red	none	no	0	-	-		Stage 1 on 3	Very fine sandy silt-clay. Right third of SWI is disturbed from previous replicate image sampling, sparse traces of Beggiatoa present in surface oxidized layer.
REF6	C	10/3/2011	6:30:41	13	1	79	14.571	>4	1	>4	256.7087509	17.62	17.08	18.04	0.96	Biological	58.41	4.01	6	red/oxy	none	no	0	-	-		Stage 2 on 3	Very fine sandy silt-clay. Burrowing throughout profile, sparse traces of Beggiatoa present in surface oxidized layer.
REF6	D	10/3/2011	6:31:25	13	1	79	14.571	>4	2	>4	269.6911265	18.51	18.41	18.71	0.29	Biological	53.25	3.65	0	-	none	no	3	4.47	5.94	5.21	Stage 2 on 3	Very fine sandy silt-clay. Burrowing throughout profile, sparse traces of Beggiatoa present in surface oxidized layer.
2500W1	A	10/3/2011	5:05:17	13.5	1	58	14.571	>4	2	>4	279.856863	19.21	18.76	19.45	0.69	Biological	37.66	2.58	0	-	none	no	2	2.44	13.22	7.83	Stage 2 on 3	Very fine sandy silt-clay. Burrowing throughout profile, sparse traces of Beggiatoa present in surface oxidized layer.
2500W1	B	10/3/2011	5:06:08	13.5	1	58	14.571	>4	2	>4	298.1625463	20.46	20.04	21.09	1.04	Physical	39.18	2.69	1	red	none	no	4	2.19	18.83	10.51	Stage 2 on 3	Very fine sandy silt-clay. Mud clast is longer shaving from wiper blade; evidence of burrowing throughout profile.
2500W1	C	10/3/2011	5:07:00	13.5	1	58	14.571	>4	2	>4	299.8401222	20.58	20.18	21.04	0.86	Biological	62.48	4.29	2	red	none	no	0	-	-		Stage 2 on 3	Very fine sandy silt-clay. Burrowing throughout profile, sparse traces of Beggiatoa present in surface oxidized layer, transected oxidized burrow on left.
2500W2	A	10/3/2011	5:12:24	13.5	1	58	14.571	>4	2	>4	288.2259498	19.78	19.43	20.34	0.91	Physical	48.01	3.29	0	-	none	no	2	11.00	11.55	11.28	Stage 2 on 3	Very fine sandy silt-clay. Burrowing throughout profile, sparse traces of Beggiatoa present in surface oxidized layer.
2500W2	B	10/3/2011	5:13:18	13.5	1	58	14.571	>4	2	>4	278.8556663	19.14	19.00	19.43	0.42	Biological	51.82	3.56	0	-	none	no	2	11.46	17.29	14.38	Stage 2 on 3	Very fine sandy silt-clay. Bivalve at ~1.5cm to right of center. Small tubes lying at SWI on right. Extensive bioturbation throughout profile.
2500W2	C	10/3/2011	5:14:11	13.5	1	58	14.571	>4	2	>4	305.7820957	20.99	20.50	21.36	0.86	Biological	49.02	3.36	7	red/oxy	none	no	1	19.84	20.62	20.23	Stage 2 on 3	Very fine sandy silt-clay. Burrowing evidence throughout profile, large void at base of image.
2500W3	B	10/3/2011	5:41:39	13.5	1	59	14.571	>4	2	>4	279.8171651	19.20	19.00	19.75	0.75	Biological	53.70	3.69	2	red	none	no	2	4.77	16.20	10.49	Stage 2 on 3	Very fine sandy silt-clay. One amphipod tube at SWI. Evidence of burrowing throughout profile.
2500W3	C	10/3/2011	5:42:34	13.5	1	59	14.571	>4	2	>4	285.0436792	19.56	19.35	20.07	0.72	Biological	49.81	3.42	10+	red/oxy	none	no	3	14.13	18.70	16.42	Stage 2 on 3	Very fine sandy silt-clay. Small to medium mud clasts at surface (camera artifacts). Evidence of burrowing throughout profile.
2500W3	D	10/3/2011	5:43:19	13.5	1	59	14.571	>4	2	>4	287.6650373	19.74	19.64	19.94	0.29	Biological	46.96	3.22	2	red	none	no	2	4.05	18.89	11.47	Stage 2 on 3	Very fine sandy silt-clay. Small bivalve burrowing at SWI on left. Evidence of burrowing through aRPD. Burrowing throughout profile.
2500W4	B	10/3/2011	4:58:19	13.5	1	58	14.571	>4	2	>4	286.6942318	19.68	19.11	20.07	0.96	Biological	48.14	3.30	0	-	none	no	0	-	-		Stage 2 on 3	Very fine sandy silt-clay. Burrowing throughout profile, edge of void transected at base of image.
2500W4	C	10/3/2011	4:59:10	13.5	1	58	14.571	>4	1	>4	300.276899	20.61	19.64	21.30	1.66	Physical	36.49	2.50	10+	red/oxy	none	no	2	14.34	18.46	16.40	Stage 1 on 3	Very fine sandy silt-clay. Medium to large mud clasts on surface (camera artifacts). Burrowing throughout profile
2500W4	D	10/3/2011	5:00:01	13.5	1	58	14.571	>4	1	>4	289.8572114	19.89	19.43	20.34	0.91	Biological	35.74	2.45	0	-	none	no	0	-	-		Stage 2 on 3	Very fine sandy silt-clay. Area of reduced pseudofeces at far right of SWI. Evidence of burrowing throughout profile, transected oxidized burrows at depth.
2500W5	A	10/3/2011	4:47:29	13.5	1	59	14.571	>4	2	>4	284.9711787	19.56	19.64	20.34	0.70	Biological	40.23	2.76	0	-	none	no	1	17.31	17.84	17.58	Stage 2 on 3	Very fine sandy silt-clay. Few short tubes, probably amphipod, at SWI. Burrowing throughout profile.
2500W5	B	10/3/2011	4:48:31	13.5	1	59	14.571	>4	1	>4	286.8536812	19.69	19.37	19.99	0.62	Biological	22.00	1.51	1	oxy	none	no	1	17.95	19.35	18.65	Stage 2 on 3	Very fine sandy silt-clay. Few short tubes at SWI. Burrowing throughout profile, large burrow/void transected at lower left corner.
2500W5	C	10/3/2011	4:49:16	13.5	1	59	14.571	>4	1	>4	300.0162319	20.59	20.09	20.98	0.89	Biological	52.28	3.59	2	red/oxy	none	no	2	3.19	15.13	9.16	Stage 2 on 3	Very fine sandy silt-clay. Few short polychaete and amphipod tubes at SWI. Burrowing throughout profile, sparse traces of Beggiatoa in surface oxidized layer.
2500W6	A	10/3/2011	5:21:23	13.5	1	59	14.571	>4	2	>4	280.1505917	19.23	18.90	19.59	0.69	Biological	47.45	3.26	5	red/oxy	none	no	1	7.69	7.82	7.76	Stage 1 on 3	Very fine sandy silt-clay. Very small mud clasts at surface (camera artifact). Few short tubes lying on surface. Burrowing throughout profile.
2500W6	C	10/3/2011	5:23:03	13.5	1	59	14.571	>4	2	>4	288.062156	19.77	19.51	20.23	0.72	Biological	42.35	2.91	1	red	none	no	0	-	-		Stage 2 on 3	Very fine sandy silt-clay. Bed of short amphipod tubes in background. Burrowing throughout profile.
2500W6	D	10/3/2011	5:24:16	13.5	1	59	14.571	>4	2	>4	289.8217583	19.89	19.64	20.34	0.70	Physical	51.63	3.54	3	red	none	no	1	6.61	6.87	6.74	Stage 2 on 3	Very fine sandy silt-clay. Small to medium mud clasts on surface (camera artifacts). Couple tubes laying on surface. Evidence of burrowing throughout profile.
4500E1	B	10/3/2011	10:41:04	13	1	66	14.571	>4	1	>4	255.7667623	17.55	17.16	17.77	0.62	Biological	59.27	4.07	6	red/oxy	none	no	1	3.24	5.11	4.18	Stage 2 on 3	Very fine sandy silt-clay. Evidence of burrowing throughout profile; sparse traces of Beggiatoa in surface oxidized layer.
4500E1	C	10/3/2011	10:41:59	13	1	66	14.571	>4	2	>4	272.7384002	18.72	18.28	18.92	0.64	Physical	49.87	3.42	10+	red/oxy	none	no	1	3.63	4.32	3.98	Stage 3	Very fine sandy silt-clay. Small to large mud clasts (camera artifacts) across SWI. Evidence of subsurface burrowing
4500E1	D	10/3/2011	10:42:49	13	1	66	14.571	>4	2	>4	271.8902956	18.66	18.09	19.11	1.02	Biological	34.43	2.36	6	red/oxy	none	no	3	13.96	18.16	16.06	Stage 1 on 3	Very fine sandy silt-clay. Burrowing throughout profile, sparse traces of Beggiatoa present in surface oxidized layer.
4500E2	A	10/3/2011	11:00:49	13	1	66	14.571	>4	2	>4	239.7642757	16.45	16.25	16.73	0.48	Biological	51.17	3.51	0	-	none	no	2	10.90	16.25	13.58	Stage 2 on 3	Very fine sandy silt-clay. Evidence of burrowing throughout profile.
4500E2	B	10/3/2011	11:01:38	13	1	66	14.571	>4	2	>4	227.4301998	15.61	15.47	15.71	0.24	Biological	48.39	3.32	3	red/oxy	none	no	3	5.66	14.15	9.91	Stage 2 on 3	Very fine sandy silt-clay. Few short tubes visible at and below SWI. Evidence of burrowing throughout profile.
4500E2	C	10/3/2011	11:02:23	13	1	66	14.571	>4	1	>4	240.5095284	16.51	16.25	16.73	0.48	Biological	50.55	3.47	10+	red/oxy	none	no	0	-	-		Stage 3	Very fine sandy silt-clay. Small to medium-large mud clasts at surface (camera artifact). Evidence of deeper burrowing, sparse traces of Beggiatoa in surface oxidized layer.
4500E3	A	10/3/2011	10:47:08	13	1	67	14.571	>4	1	>4	298.618076	20.49	16.83	17.53	0.70	Biological	58.32	4.00	1	oxy	none	no	0	-	-		Stage 2 on 3	Very fine sandy silt-clay. Burrowing throughout profile, sparse traces of Beggiatoa present in surface oxidized layer.
4500E3	B	10/3/2011	10:47:58	13	1	67	14.571	>4	2	>4	263.8561501	18.11	17.50	18.31	0.80	Biological	50.42	3.46	6	red/oxy	none	no	0	-	-		Stage 2 on 3	Very fine sandy silt-clay. Evidence of burrowing throughout profile.
4500E3	D	10/3/2011	10:49:38	13	1	67	14.571	>4	1	>4	249.0070356	17.09	16.75	17.56	0.80	Biological	44.39	3.05	0	-	none	no	0	-	-		Stage 2 on 3	Very fine sandy silt-clay. Evidence of burrowing throughout profile.
4500E4	A	10/3/2011	11:11:26	13	1	64	14.571	>4	1	>4	241.1809055	16.55	16.41	16.70	0.29	Biological	32.78	2.25	3	red	none	no	4	8.78	16.38	12.58	Stage 1 on 3	Very fine sandy silt-clay. Long tube laying on surface. Bioturbation most likely exceeds depth of prism penetration.
4500E4	C	10/3/2011	11:13:13	13	1	64	14.571	>4	2	>4	246.6586007	16.93	16.27	17.08	0.80	Biological	28.30	1.94	6	red/oxy	none	no	1	2.67	3.83	3.25	Stage 2 on 3	Very fine sandy silt-clay. Evidence of burrowing throughout profile.
4500E4	D	10/3/2011	11:14:05	13	1	64	14.571	>4	1	>4	250.0119988	17.16	16.81	17.40	0.59	Biological	36.48	2.50	2	red	none	no	0	-	-		Stage 1 on 3	Very fine sandy silt-clay. Burrowing throughout profile, sparse traces of Beggiatoa present in surface oxidized layer.
4500E5	A	10/3/2011	10:33:39	13	1	67	14.571	>4	2	>4	262.5931105	18.02	17.83	18.17	0.35	Biological	34.95	2.40	6	red	none	no	0	-	-		Stage 2 on 3	Very fine sandy silt-clay. .Areas of reduced, organically enriched sediment below aRPD, sparse traces of Beggiatoa in surface oxidized layer.
4500E5	B	10/3/2011	10:34:19	13	1	67	14.571	>4	2	>4	255.4990405	17.53	17.37	17.77	0.40	Biological	34.82	2.39	3	oxy	none	no	5	5.30	8.36	6.83	Stage 1 on 3	Very fine sandy silt-clay. No organically enriched sediment, stark contrast to previous replicate; evidence of burrowing throughout profile.
4500E5	C	10/3/2011	10:35:08	13	1	67	14.571	>4	1	>4	236.0074814	16.20	16.14	16.59	0.46	Biological	58.00	3.98	5	red	none	no	0	-	-		Stage 1 on 3	Very fine sandy silt-clay. Similar to replicate B, evidence of burrowing throughout profile.
4500E6	A	10/3/2011	10:52:59	13	1	67	14.571	>4	1	>4	249.7517103	17.14	16.86	17.40	0.54	Biological	55.82	3.83	0	-	none	no	0	-	-		Stage 2 on 3	Very fine sandy silt-clay. Burrowing throughout profile, sparse traces of Beggiatoa present in surface oxidized layer.
4500E6	B	10/3/2011	10:53:49	13	1	67	14.571	>4	1	>4	267.0820246	18.33	17.34	19.11	1.77	Biological	33.86	2.32	5	red/oxy	none	no	2	11.11	15.78	13.45	Stage 2 on 3	Very fine sandy silt-clay. Evidence of burrowing throughout profile, bioturbation depth most likely exceeds prism penetration depth.
4500E6	D	10/3/2011	10:53:31	13	1	67	14.571	>4	2	>4	266.1050014	18.26	18.01	18.55	0.54	Biological	43.72	3.00	1	oxy	none	no	2	2.81	17.71	10.26	Stage 2 on 3	Very fine sandy silt-clay. Burrowing throughout profile, sparse traces of Beggiatoa present in surface oxidized layer.

Note: ind = indeterminate; Mud clast state: o=oxidized, r=reduced, b=both oxidized and reduced

Appendix D

Common Unit Conversions

Common Unit Conversions

Metric	English
Area	
1 Square Kilometer (km^2)	247.12 Acres
Length	
1 Kilometer (km)	0.62 Miles (mi)
1 Kilometer (km)	0.54 Nautical Miles (nmi)
1 Meter (m)	3.28 Feet (ft)
1 Centimeter (cm)	0.39 Inches (in)
Volume	
1 Cubic Meter (m^3)	35.31 Cubic Feet (ft^3)
1 Cubic Meter (m^3)	1.31 Cubic Yards (yd^3)