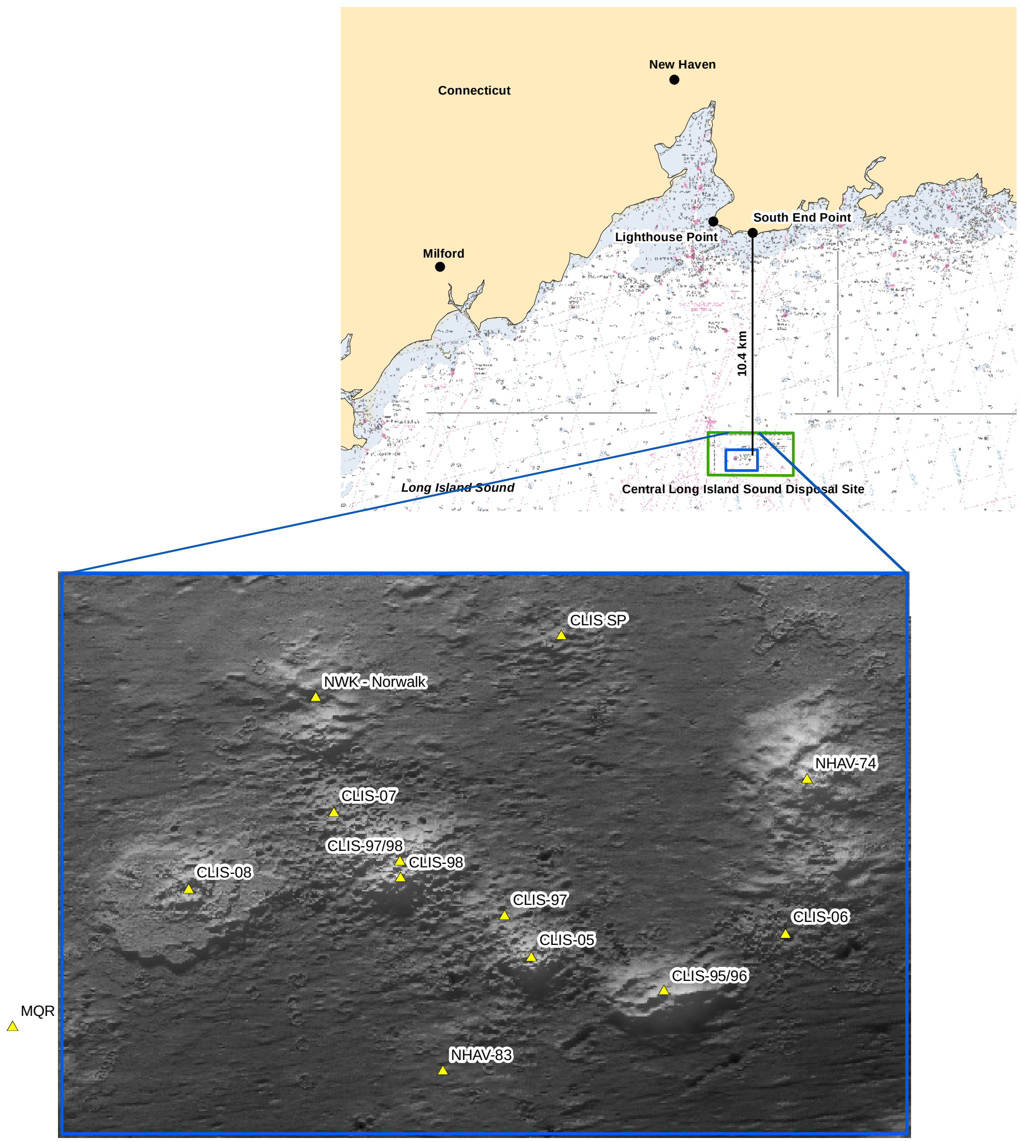
Monitoring Survey at the Central Long Island Sound Disposal Site
October 2009

Disposal Area Monitoring System DAMOS



2009 Bathymetric Survey Area

D A M O S
DISPOSAL AREA MONITORING SYSTEM

Contribution 184
February 2012

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13. ABSTRACT

A monitoring survey was conducted in 2009 at the Central Long Island Sound Disposal Site (CLDS) as part of the Disposal Area Monitoring System (DAMOS) Program. The 2009 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 of several newly created dredged material deposits. These surveys were conducted over a rectangular area in the southwest portion of CLDS, where dredged material disposal activities were concentrated over the period 2005 to 2009.

The 2009 multibeam bathymetric survey revealed that four discrete mounds of dredged material had been created on the seafloor since the previous multibeam bathymetric survey of July 2005. The mounds were labeled by disposal season, as follows: CLIS 05 (2005–06 disposal season), CLIS 06 (2006–07 disposal season), CLIS 07 (2007–08 disposal season), and CLIS 08 (2008–09 disposal season). The size of each mound was generally proportional to the volume of dredged material placed during each season. Comparison of the 2009 data with 2005 and 1997 mapping data confirmed that disposal traces (rings, craters, and pits) can be associated with specific disposal conditions (e.g., volume, grain size, or water content; and whether the area receiving the material is ambient or mound).

Three of the new mounds (CLIS 05, CLIS 06, and CLIS 07) represent additions of dredged material to an existing, crescent-shaped line of mounds that are coalescing into a berm on the seafloor. The berm represents the southern 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. The other mound (CLIS 08) was located outside and to the west of the existing crescent-shaped berm, but this mound also is being used to create a different, newer berm in the southern part of the disposal site.

The SPI survey found that the benthic recolonization status of the each of the four mounds was directly related to its age. The two older mounds (CLIS 05 and CLIS 06), which have had the longest time to recolonize, were characterized by relatively well-developed apparent Redox Potential Discontinuity (aRPD) depths and an advanced, Stage 3 successional status. Benthic conditions over these two mounds were considered comparable to those at the three nearby CLDS reference areas.

The two newer mounds (CLIS 07 and CLIS 08) were found to be 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. As succession proceeds over time at these two newer mounds, it is hypothesized that they will converge both with reference conditions and with conditions observed at the two older mounds.

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TABLE OF CONTENTS

Page

LIST OF TABLES

Page

LIST OF FIGURES

Page

Page

Page

Page

EXECUTIVE SUMMARY

A monitoring survey was conducted in 2009 at the Central Long Island Sound Disposal Site (CLDS) as part of the Disposal Area Monitoring System (DAMOS) Program. The 2009 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 of several newly created dredged material deposits. These surveys were conducted over a rectangular area in the southwest portion of CLDS, where dredged material disposal activities were concentrated over the period 2005 to 2009.

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1.0 INTRODUCTION

A monitoring survey was conducted at the Central Long Island Sound Disposal Site (CLDS) in September and October 2009 as part of the U.S. Army Corps of Engineers (USACE) New England District (NAE) Disposal Area Monitoring System (DAMOS) Program. DAMOS is a comprehensive monitoring and management program designed and conducted to address environmental concerns surrounding the placement of dredged material at aquatic disposal sites throughout the New England region. An introduction to the DAMOS Program and CLDS, including brief descriptions of previous dredged material disposal and site monitoring activities, 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 activities are promptly identified and addressed (Germano et al. 1994). For over 30 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 are designed to test hypotheses related to expected physical and ecological response patterns following placement of dredged material on the seafloor at established disposal sites. The resulting information is used to guide the management of disposal activities at each site.

Two primary goals of DAMOS monitoring surveys are to document the physical location of dredged material placed on the seafloor and to evaluate the environmental impact of placement of the dredged material. Sequential bathymetric measurements are used extensively in the DAMOS Program to characterize the height and spread of discrete dredged material deposits or mounds created at disposal sites. In addition, sediment-profile imaging (SPI) surveys are performed routinely to evaluate the environmental impact of dredged material placement and monitor changes in seafloor (benthic) habitat conditions over time. Following completion of the periodic monitoring activities at each disposal site, the collected data are evaluated to determine the next step in the disposal site management process. The conditions found after a defined period of disposal activity are compared with the long-term data set at a specific site (Germano et al. 1994). Additional types of data collection activities conducted under DAMOS utilize side-scan sonar, plan-view underwater camera (PUC) images, sediment coring, and 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, historically referred to as CLIS) is located approximately 10.4 km 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). Since 1979, the site has been regularly monitored by the DAMOS Program (ENSR 1998). The U.S. Environmental Protection Agency's (USEPA) recent designation of the site resulted in a slight enlargement of its previous dimensions (USEPA 2004). Specifically, the boundary of CLDS was moved slightly northward and eastward to encompass the historical disposal mounds named CS-2 and FVP (ENSR 2007). The current boundary of CLDS is a rectangle measuring 4.1 by 2.0 km (total area of 8.2 km^2); the center of the rectangle has coordinates 41° 08.95' N and 72° 52.95' W (NAD 83) (Figure 1-1).

The long history and the extensive DAMOS monitoring that has occurred at CLDS since 1979 provide a detailed record of disposal events and results that are unique for aquatic disposal of dredged material (ENSR 2007). 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 (Figure 1-2).

The seafloor within the boundary of CLDS gently slopes from a depth of 18 m mean lower low water (MLLW) in the northwest to a depth of 22 m (MLLW) in the southeast (Figure 1-3). The placement of dredged material has created localized areas with shallower depths ranging from 15 to 17 m (MLLW).

Prior to 1984, the management strategy at CLDS involved the controlled 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.

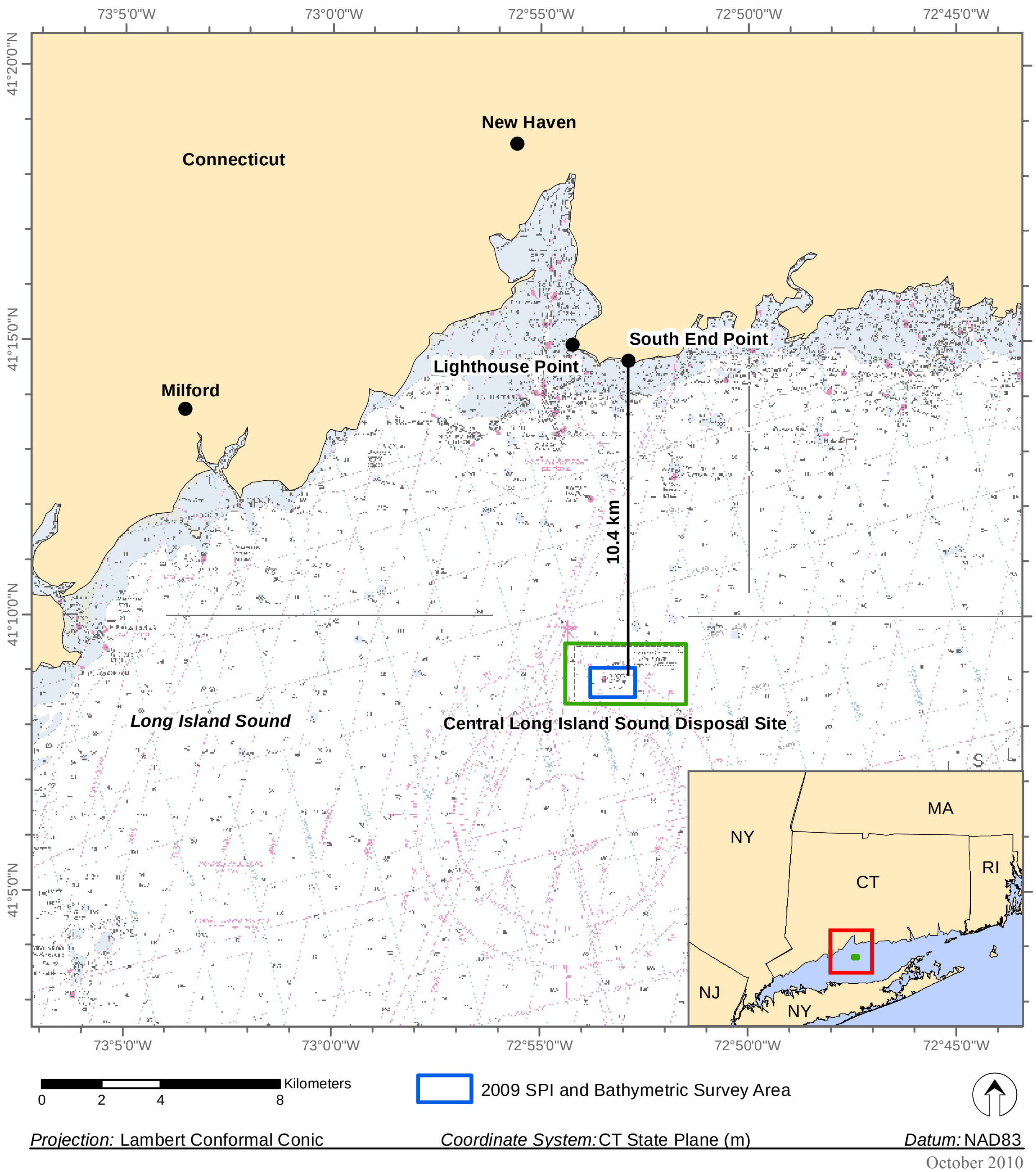


Figure 1-1. Location of the Central Long Island Sound Disposal Site (CLDS)

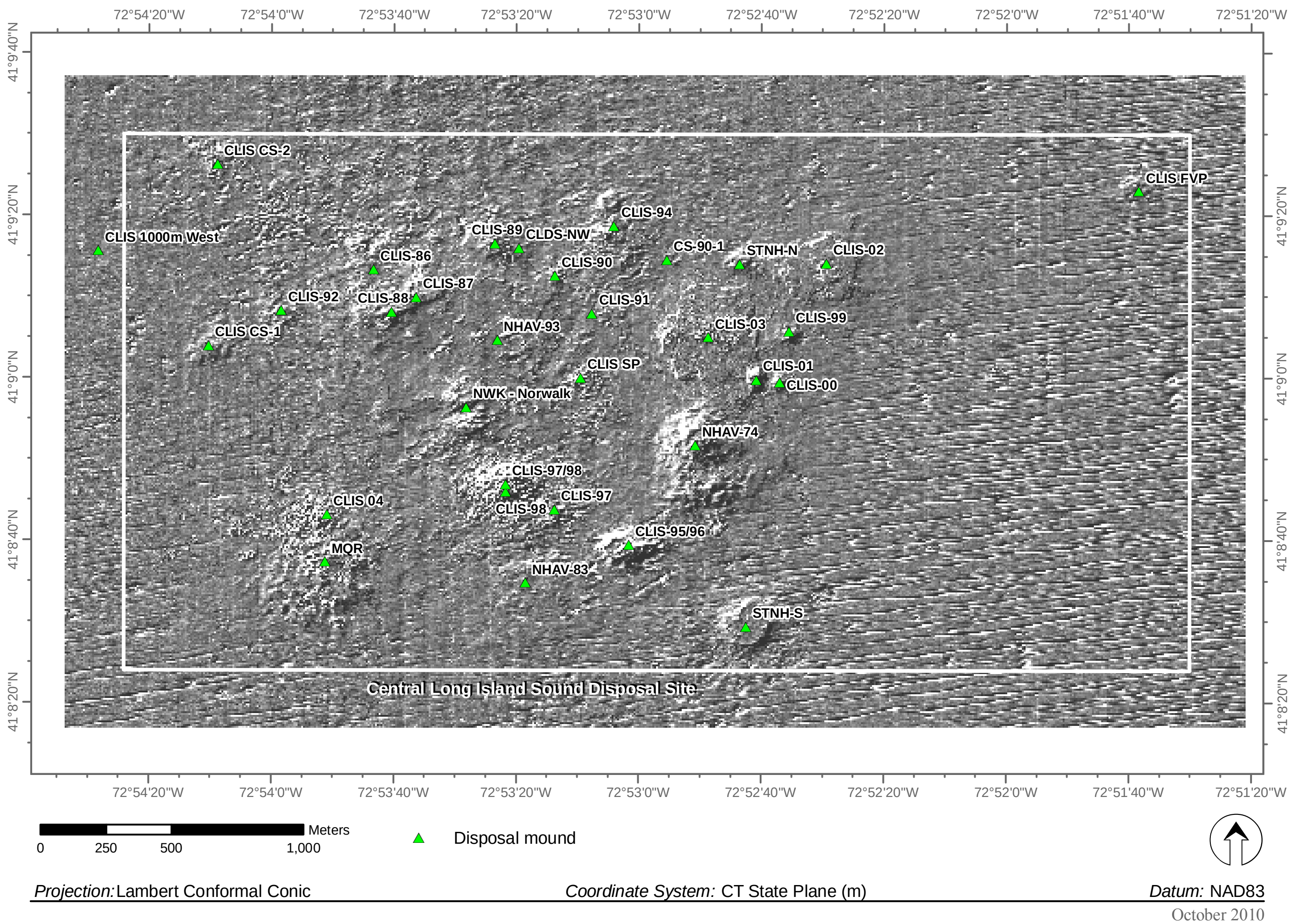


Figure 1-2. Multibeam bathymetric data collected at CLDS in July 2005. The hillshading serves to highlight topographic features, with individual disposal mounds identified by project or year of disposal activity.

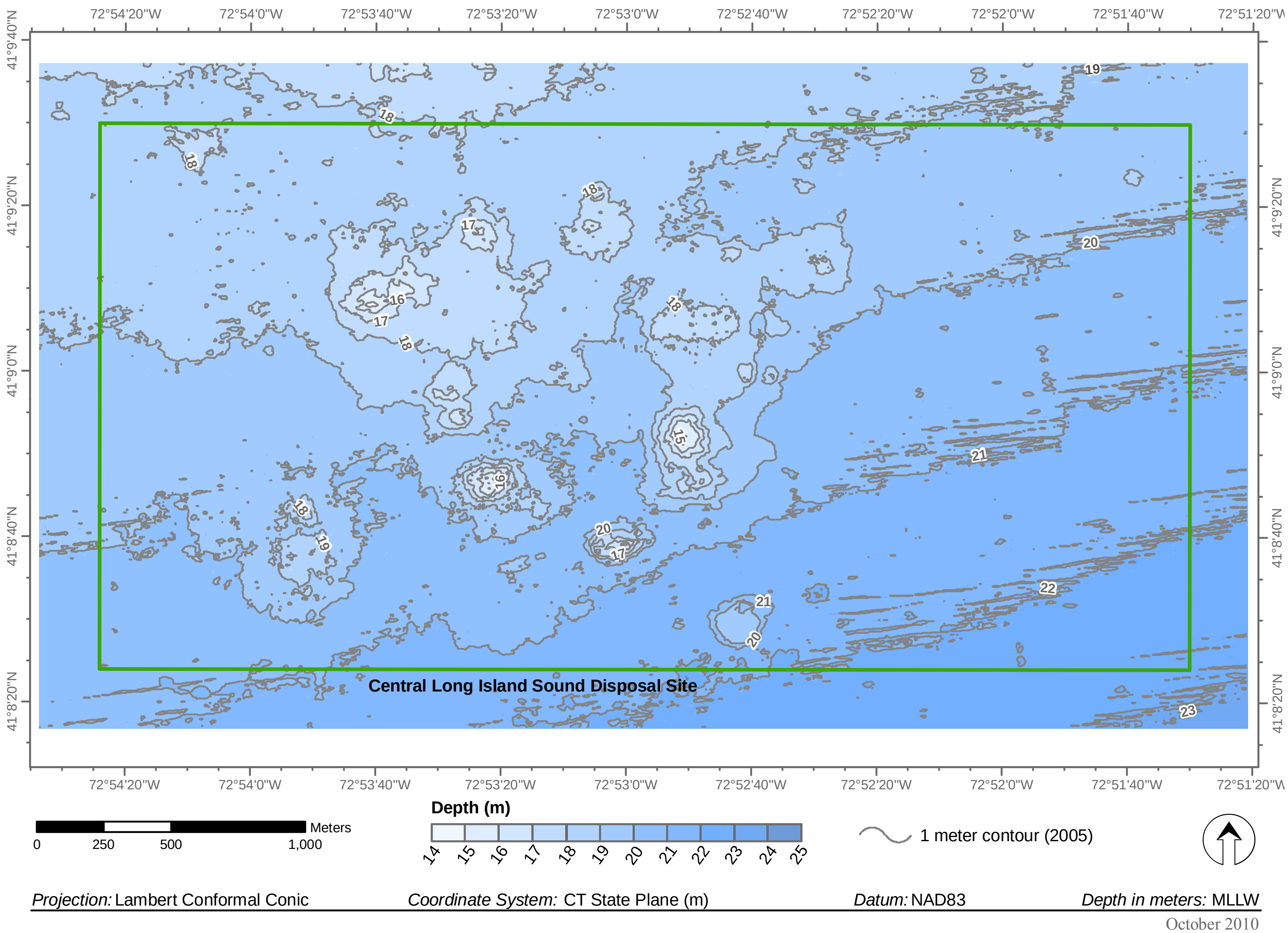


Figure 1-3. Bathymetric map of CLDS from multibeam data collected in 2005 (from ENSR 2007)

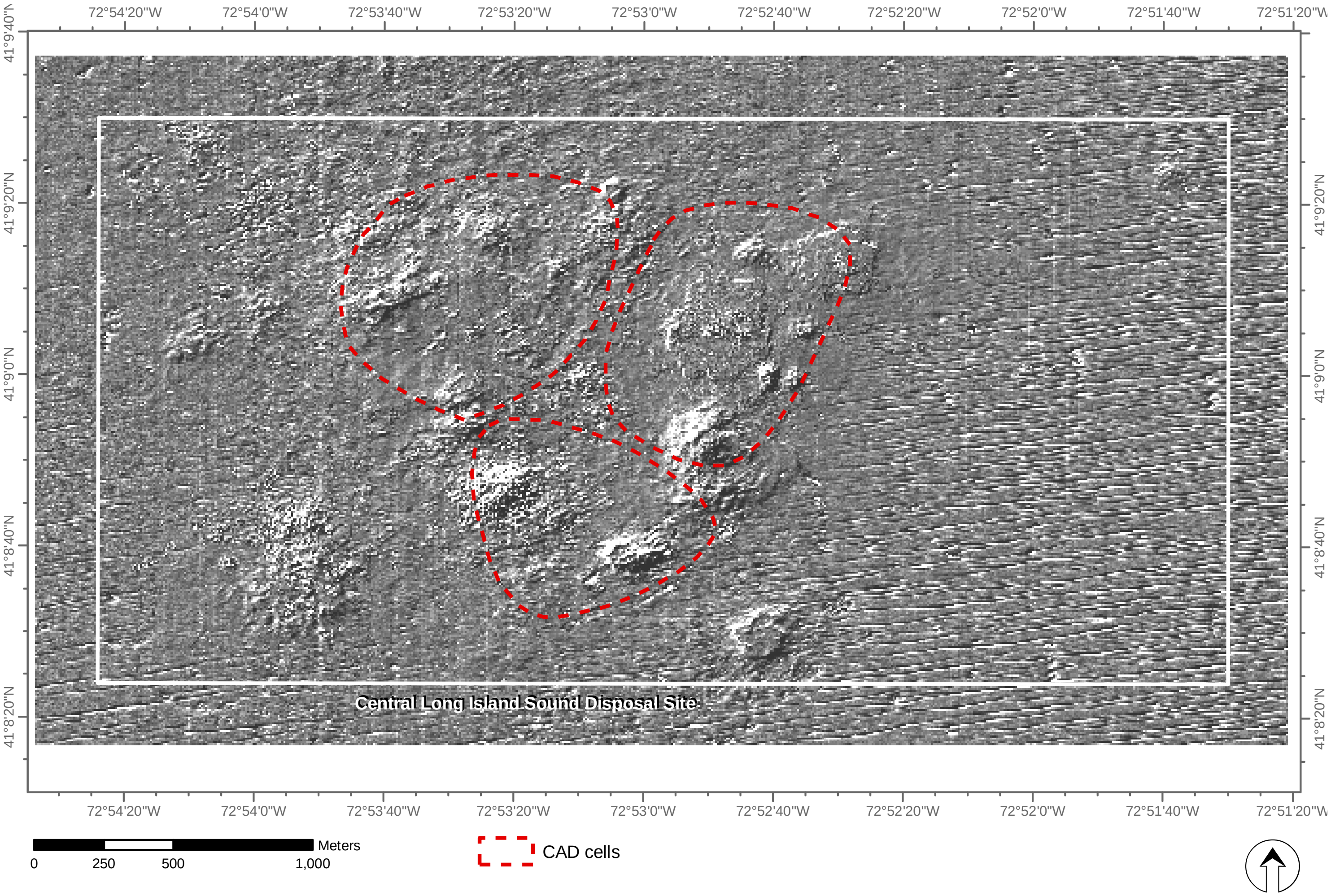
Since the early 1990s, a modified management strategy has been employed at CLDS, whereby the dredged material is placed in a series of closely spaced or contiguous mounds, with the goal of eventually creating a circular or semicircular berm on the seafloor. The space inside the circular berm represents a containment cell to be potentially used for large-scale confined aquatic disposal (CAD) operations. In general, such containment cells aid in limiting the lateral spread on the seafloor of dredged material classified as unsuitable for unconfined open water disposal ("unsuitable dredged material" or "UDM"). Once placed within the confines of the containment cell, the UDM can then be capped with a final overlying layer of suitable material (Fredette 1994).

The first containment cell developed at CLDS was used to confine the New Haven 1993 (NHAV 93) Mound, and a second containment cell was completed in 1999. Additional containment cells are currently being developed for future use (Figure 1-4).

1.3 Recent Monitoring Activity

Two DAMOS monitoring surveys at CLDS were conducted in June 2004 and July 2005 (ENSR 2005, 2007). As indicated above, 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 clarify the location, spatial extent, and long-term stability of mounds and other seafloor features associated with past disposal activities (Figure 1-2).

The DAMOS monitoring survey conducted in June 2004 involved a single-beam bathymetric survey over the CDA 03 buoy location just northeast of the center of CLDS, where approximately 426,000 m^3 of dredged material was placed between September 2003 and May 2004. This bathymetric survey showed that a new mound, CLIS 03, was created at the location of the CDA 03 buoy, approximately 300 m west of the existing CLIS 99 mound (Figure 1-2). The June 2004 survey also involved the collection of sediment-profile images both at CLDS reference areas and at stations within CLDS that had not been subject to recent disposal activity. The objective of this SPI survey was to assess whether a phytodetrital layer that was observed at the site in September 2003 had persisted or reoccurred in 2004. The diffuse, rust-colored surface layer of phytoplankton detritus that was again observed in the 2004 images was deemed to be the result of a normal condition, most likely resulting from natural settlement of recent phytoplankton blooms as opposed to a long-term continuation of the original 2003 phytodetrital layer (ENSR 2005).



Projection: Lambert Conformal Conic *Coordinate System:* CT State Plane (m) *Datum:* NAD83

October 2010

Figure 1-4. Approximate boundaries of confined aquatic disposal (CAD) cell areas at CLDS (from ENSR 2007)

1.4 Recent Disposal Activity

Between the SPI/bathymetric survey of June 2004 and the multibeam bathymetric survey of July 2005, approximately 78,500 m^3 of dredged material was placed at CLDS. This material formed the mound labeled CLIS 04, located in the southwest quadrant of CLDS just to the north of the historical MQR mound (Figure 1-2).

The most recent monitoring effort involved a multibeam bathymetric survey conducted in September 2009 and a SPI survey conducted in October 2009; these surveys were conducted over a 1000 x 1500 m rectangular area in the southwest portion of CLDS (Figure 1-5). Between October 2005 and May 2009, approximately 539,000 m^3 of dredged material was placed within this broad area. The dredged material was placed at four different disposal buoy locations, as part of the continuing effort to create one or more CAD cells within CLDS. The locations of the disposal buoy and the individual disposal events in each of the four disposal seasons between October 2005 and May 2009 are shown in Figure 1-6; the volume of material associated with each disposal event is depicted in Figure 1-7. Table 1-1 provides a summary of disposal activities by season.

1.5 2009 Survey Objectives

Numerous disposal events have occurred at CLDS within a well-defined area since the July 2005 bathymetric survey; the 2009 survey was designed to address the following two objectives:

1) Characterize the seafloor topography of the area where the recent disposal activities occurred by completing a high-resolution bathymetric survey, and

2) Using SPI, assess the benthic recolonization status (community recovery of the bottom-dwelling organisms) within the surface sediments where the recent disposal activities occurred.

Table 1-1.

Estimated Volume of Dredged Material (in m^3) Placed at CLDS
from October 2005 to May 2009

Project Name	2005 Season (October 05–May 06)	2006 Season (October 06–June 07)	2007 Season (October 07–May 08)	2008 Season (October 08–May 09)
Basin & Yacht Club		2,007		
Bermuda Lagoon	688			
Branford River				16,439
Clinton Harbor Marina				2,332
Connecticut River				1,032
Greenwich Harbor				22,544
Housatonic River		3,861		7,570
Marina basin		4,588		
Menunketesuck & Patchogue rivers	5,505	4,129	11,737	
Milford Harbor		12,444		
Milton Harbor				20,491
New Haven Harbor	18,274			23,982
Norwalk Harbor	111,637			217,670
Norwest Harbor		5,199		
Patchogue River			4,129	
Post Road Yacht Yard				4,358
Saugatuck River		17,280	2,600	306
Terminal				1,854
Wescott Cove				6,040
West Cove				61
West River		9,229	325	
Wilson Cove		918		
TOTAL	**136,104**	**59,654**	**18,790**	**324,680**

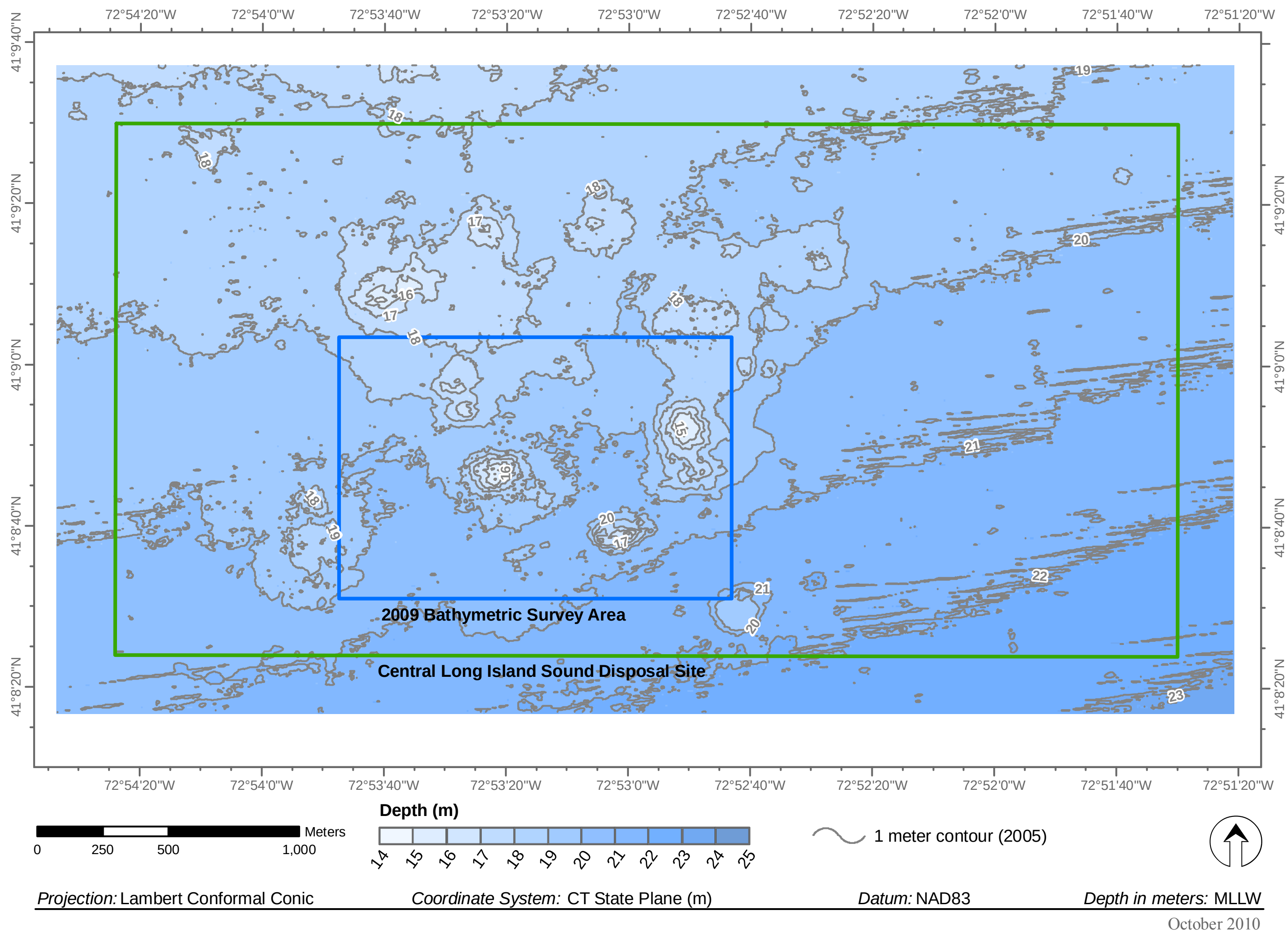


Figure 1-5. Map of CLDS showing the rectangular subarea within which bathymetric and SPI data were collected in September and October 2009.

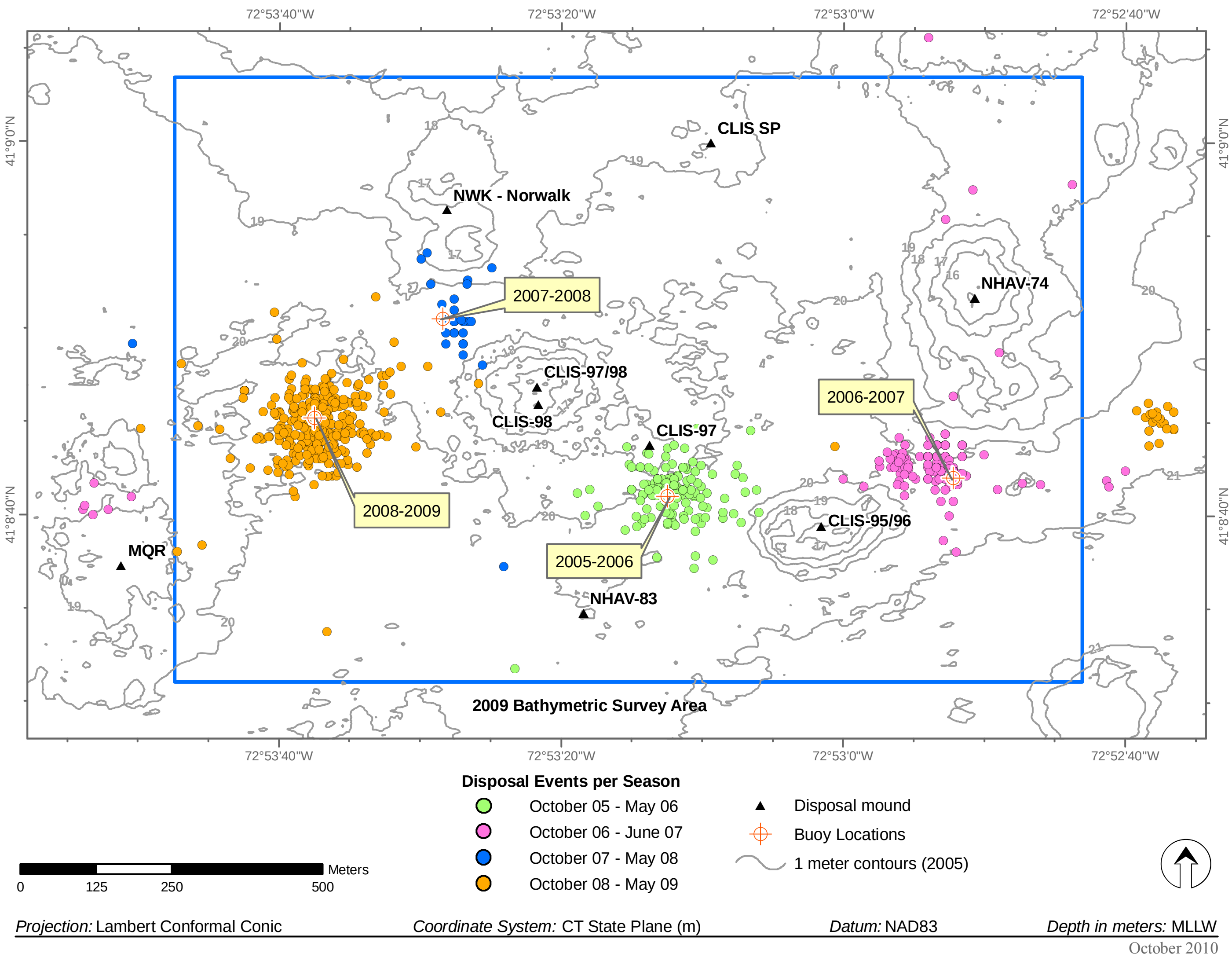


Figure 1-6. Locations of disposal buoys and disposal events at CLDS over the period July 2005 to October 2009

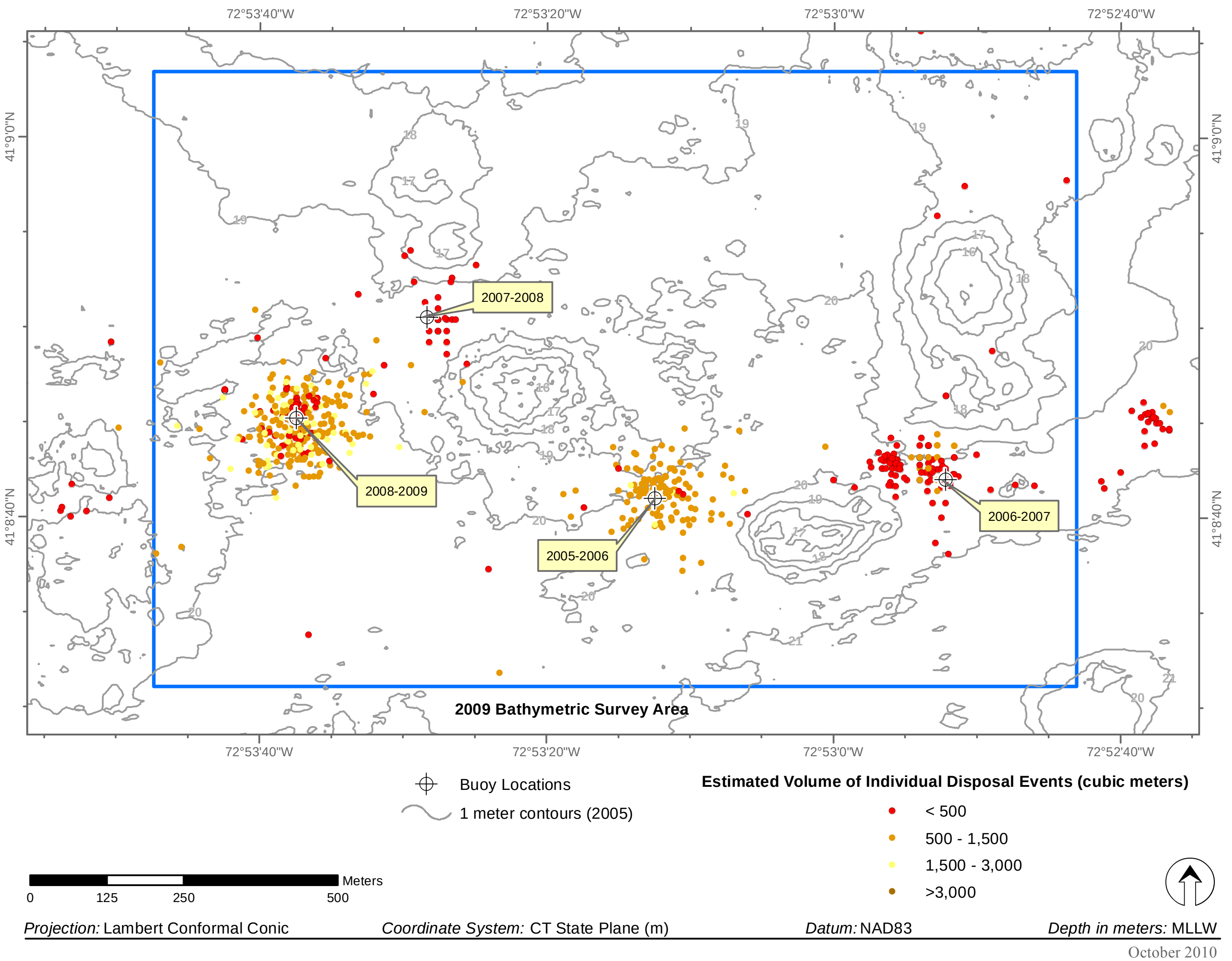


Figure 1-7. Volume of disposal events at CLDS over the period July 2005 to October 2009

2.0 METHODS

2.1 Bathymetric Survey

The bathymetric survey of CLDS was conducted on 21 September 2009 using the 31-ft R/V *Orion*, a survey vessel configured for nearshore multibeam surveys and owned by Substructure, Inc., New Hampshire. The United States Coast Guard (USGC) station in New Haven Harbor, New Haven, Connecticut, was used as the base of operations. The bathymetric survey encompassed a 1000 x 1500 m rectangular area located in the southwestern portion of the disposal site, where recent disposal activities had been concentrated (Figures 1-5 and 1-6). Data were collected along survey lanes spaced 40 m apart with three additional north–south "cross-tie" lines surveyed to assess data quality (Figure 2-1). Precision navigation was provided using real-time kinematic (RTK) differential global positioning system (DGPS). A RTK base station was established at the New Haven Airport, allowing the vessel's navigation system to obtain centimeter-level positional data for most of the survey. The sections that follow provide detailed descriptions of the methods employed for bathymetric survey planning, navigation, data acquisition, and data processing.

2.1.1 Survey Planning

To determine the position of the 1000 x 1500 m survey area, DAMOSVision hydrographers coordinated with NAE scientists and obtained a GIS-formatted digital file with approximate barge disposal coordinates for disposal events between July 2005 and June 2009. These coordinates were imported to ArcView® GIS software, and a proposed survey area encompassing the majority of reported barge disposal coordinates and nearby geologic features of interest was developed and approved by NAE (Figure 1-5). A series of survey lines spaced 40 m apart were designed for the survey area using the navigation software package HYPACK®.

2.1.2 Navigation

A GPS receiver calculates geographic position by monitoring signals from a network of U.S. government satellites. Positions calculated by a stand-alone GPS receiver are generally accurate to within 5 to 10 m due to atmospheric-related interference that degrades the accuracy of the received satellite signals. The USCG maintains a series of GPS base stations around the country that broadcast real-time GPS corrections via an Ultra-High Frequency (UHF) radio network to help improve overall GPS positional accuracy. By applying these standard USCG broadcast GPS corrections, it is possible to achieve submeter horizontal accuracies through what is commonly

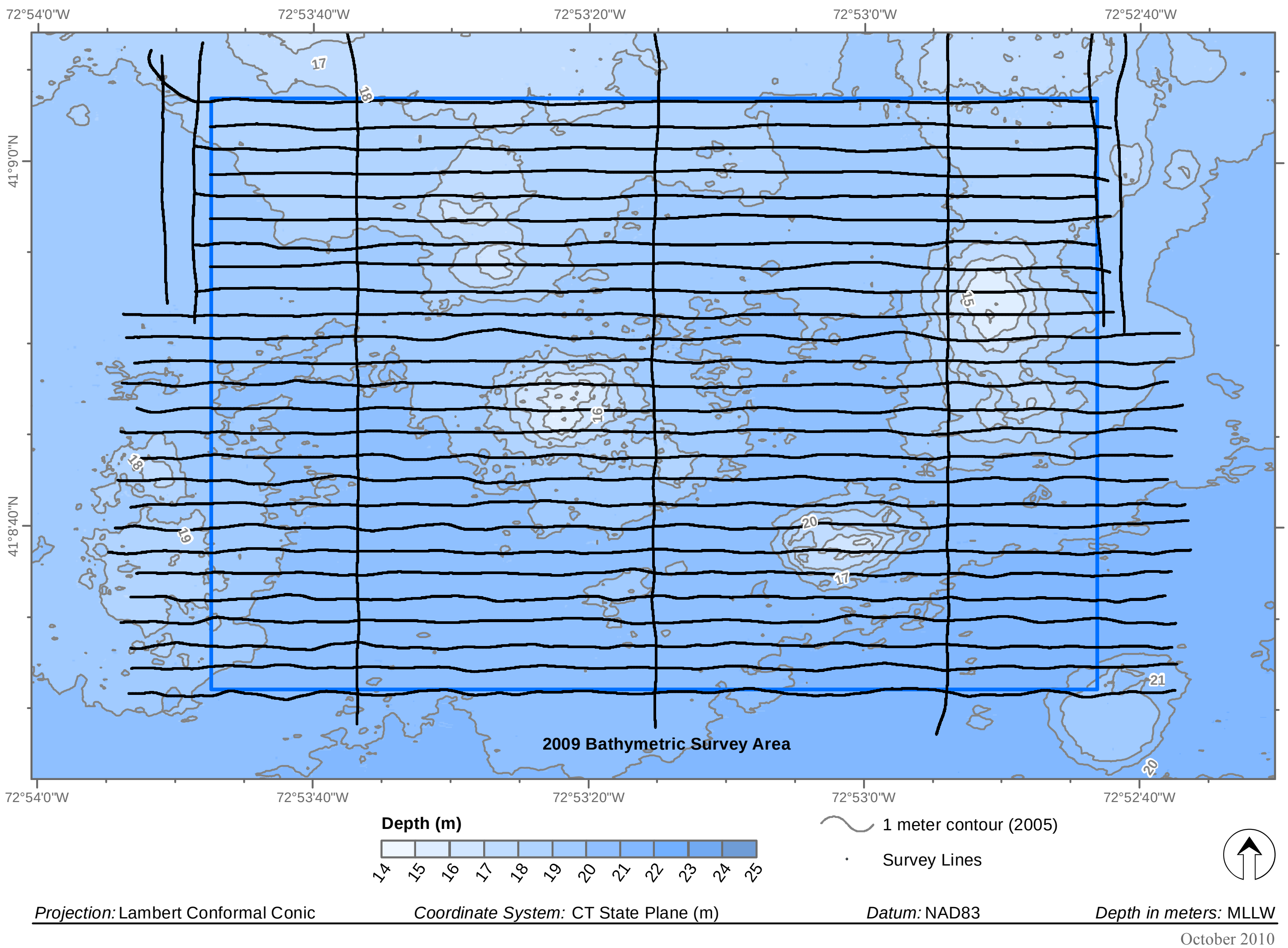


Figure 2-1. Bathymetric survey lanes

referred to as differential GPS (DGPS). With the use of dual-frequency GPS receivers that are capable of much finer resolution and interpretation of the raw satellite signals, it is possible to obtain even greater horizontal and vertical accuracies. A commonly used technique referred to as real-time kinematic (RTK) DGPS entails the establishment of a dual-frequency GPS receiver over a known survey control point that computes and broadcasts high-accuracy GPS corrections via radio or cell modem within a local survey region. If the "rover" dual-frequency GPS unit is able to reliably receive the broadcast RTK corrections and also able to track the same satellites as the base station, then it is possible to achieve both horizontal and vertical accuracies at the centimeter level.

Prior to the start of the multibeam survey operations, Substructure recovered a National Geodetic Survey (NGS) high-order control point (NGS Designation: HVN F) at the nearby New Haven Airport. A Trimble R7 dual-frequency global positioning system (GPS) receiver connected to a Raven AirLink cellular phone modem was set up over this NGS survey mark and used to transmit RTK DGPS correctors to the Applanix Position and Orientation System Marine Vessel (POS MV 320) on R/V *Orion* via another Raven AirLink cellular modem. The R7 GPS was configured as a RTK base station based on the survey mark's published WGS84 geographic position and orthometric height relative to NAVD88 (plus the height of the GPS antenna above the survey monument).

Based on the RTK DGPS correctors received from the base station, the POS MV operated in the Fixed RTK mode throughout most of the survey operations, with position and elevation error estimates that were consistently at the centimeter level. There were occasional, short duration periods when the POS MV operated in the Float RTK mode, due primarily to short interruptions in reception of the DGPS correctors. In these instances, the positional error estimates generally remained low (below 10 cm), though the elevation error estimates during these periods sometimes approached 0.5 m.

In addition to the POS MV RTK DGPS position solution that was the primary survey navigation source, R/V *Orion* also operated a Trimble AG 132 DGPS receiver that used standard USCG NMEA broadcast differential correctors to develop an accurate navigation solution. During survey operations, vessel-positioning confidence checks were performed continually within a real-time monitoring window that displayed the primary positioning data from the POS MV relative to the position data from the independent Trimble AG 132 receiver. With the antenna offsets applied, the differences between the position solutions for these two systems were consistently less than 1 m throughout the survey.

2.1.3 Data Acquisition

The primary survey hardware components for the multibeam operations were a hull-mounted Reson 8125 multibeam echosounder and the POS MV system. The POS MV system contains an Inertial Motion Unit (IMU), which is a small black box mounted above the transducer that accurately and rapidly measures vessel motion (heave, pitch, and roll). The POS MV also consists of two dual-frequency GPS receivers (and separate antennas) that are used for the computation of heading, position, and elevation. The IMU and the GPS data are all blended together inside the system. Periodic speed-of-sound profiles were obtained with an Odom Digibar speed-of-sound profiler, and continuous near-surface speed-of-sound values were obtained from a Seabird SBE 37SI CTD sensor mounted near the multibeam sonar array. HYPACK®/HYSWEEP® was the primary software package used to control the data acquisition for the multibeam survey operations. In addition, hardware-specific software tools (e.g., POSView) were run for each of the primary sensors to provide real-time interfacing and monitoring of data quality. The following sections provide an overview of some of the important elements addressed during data acquisition.

2.1.4 Vessel and Sensor Offsets

For multibeam survey operations, the proper measurement and application of offsets between the primary survey sensors is critical for data accuracy. On R/V *Orion*, the horizontal and vertical offsets between the locations of the various sensors (e.g., POS MV Inertial Motion Unit (IMU), 8125 transducer, etc.) have been measured on multiple occasions. The POS MV IMU is mounted directly above the 8125 multibeam array within the sonar plug, and the physical offsets between these two critical sensors have been precisely measured in an engineering laboratory. The offsets for other important sensors (e.g., POS MV GPS antennas, secondary DGPS antenna, etc.) have been measured and confirmed using accurate land survey techniques. In addition, the minor roll, pitch, and heading offsets between the POS MV and the 8125 multibeam array have been consistently measured during numerous patch tests conducted on R/V *Orion* for this identical sensor configuration. For the multibeam survey, all of the measured physical and patch test offsets were entered into the HYSWEEP® survey configuration file and recorded during data acquisition.

2.1.5 Speed of Sound

An Odom Digibar speed-of-sound profiler was used to acquire periodic speed-of-sound profiles during the survey operations. During this survey period, the water column was well mixed and there was little change in the recorded speed-of-sound values throughout any of the profiles. In addition, a Seabird SBE 37SI CTD sensor was mounted near the head of the 8125 multibeam array and provided continuous near-surface speed-of-sound values during all periods of multibeam data acquisition. Confidence checks of the speed-of-sound profiles were conducted by comparing the near-surface speed-of-sound results from the two independent sensors. During the multibeam operations, the speed-of-sound profiles were entered directly into HYPACK® just after they were collected and applied during data acquisition. In addition, the speed-of-sound values from the near-surface CTD sensor were also recorded within the multibeam data files.

2.1.6 Water Levels

During the survey, water levels were monitored within HYPACK® based on the POS MV vertical measurements that were computed from the RTK DGPS base station correctors. The published elevation for the survey control point was relative to the NAVD88 vertical datum, so water level elevations on the survey boat determined within HYPACK® were also relative to this datum. Because of the greater uncertainty in the DGPS elevations during the Float RTK periods, the DGPS vertical reference data were only updated in HYPACK® when the POS MV was operating in the Fixed RTK mode. During the short-term Float RTK periods, the last Fixed RTK reference elevation was used in HYPACK® until the system returned to the Fixed RTK mode.

In addition to the POS MV vertical measurements, water levels during this survey could also be evaluated based on observed MLLW tidal heights recorded at the National Oceanographic and Atmospheric Administration (NOAA) primary tide station operating in New Haven Harbor. Observed tidal data from this station has been used to reduce previous surveys at CLDS to the desired MLLW datum. During postprocessing in HYPACK®, final water level adjustments were made to the sounding data based on either the recorded POS MV vertical data or the observed tides from the New Haven tide station.

To adjust the final soundings to MLLW based on the POS MV data, the recorded vertical height data needed to be adjusted based on the computed offsets between MLLW and NAVD88. A comparison between the averaged and offset RTK vertical data on R/V *Orion* and the preliminary MLLW tides at New Haven Harbor showed strong agreement.

2.1.7 Multibeam Data Acquisition

The real-time multibeam acquisition system used for these surveys included the following primary components:

- Windows XP workstation running HYPACK®/HYSWEEP® for survey planning, data acquisition and integration, survey control, and real-time quality control;
- Reson 8125 multibeam transducer and Reson 81P sonar processor; and
- Applanix POS MV 320 Position and Orientation System with a Raven AirLink for receiving RTK DGPS correctors.

A confidence check of the multibeam echosounder was made using a leadline comparison at the start of the survey day. Multibeam bathymetric data were acquired over the required CLDS survey area by running a series of east–west main scheme survey lines that were spaced at 40-m intervals, as well as three north–south cross-check survey lines.

The user-selectable range scale on the Reson 8125 was adjusted appropriately depending upon the water depth. Real-time multibeam waterfall displays and coverage maps were monitored throughout data acquisition to assess data quality and overall coverage.

During the survey operations, the Reson 8125 was also configured to acquire and output the full suite of available backscatter intensity data (backscatter amplitudes and snippets). The backscatter amplitude and snippet data were recorded within HYPACK® HSX format files. In addition, a variety of raw POS MV data were also recorded through the POSView Ethernet logging option during all survey operations. The raw POS MV data were needed so that the delayed or true heave could be calculated and applied to the multibeam data during postprocessing.

2.1.8 Data Processing

Bathymetric data were processed using HYPACK®/HYSWEEP® software. Processing components included the following:

- Adjustment of data for tide fluctuations,
- Correction of ray bending associated with refraction in the water column,
- Removal of spurious points associated with water-column interference or system errors,
- Development of a grid surface representing depth solutions, and
- Statistical estimation of sounding solution uncertainty.

Tidal adjustments were accomplished using the six-minute MLLW data series acquired at NOAA's New Haven Tide Station (#8465705). The data from this tide station has also been used to adjust previous multibeam survey data sets. This consistency in the data processing approach was judged to have reduced uncertainty when conducting comparisons with previously acquired data.

Correction of sounding depth and position (range and azimuth) associated with refraction due to water-column stratification was conducted using a series of four sound-velocity profiles acquired by the survey team. The water column appeared well mixed during the survey, and data artifacts associated with refraction were relatively fine scale.

Data were filtered to accept only beams falling within the innermost 40 m or within an angular limit of 60 degrees. Spurious sounding solutions were flagged or rejected based on the careful examination of data on a sweep-specific basis. Many of these rejected water-column "soundings" may be associated with biogeochemical phenomenon of potential interest (e.g., sediment degassing).

The 455-kHz Reson 8125 MBES system has a published nadir beam width of 0.5 degrees across track and 1.0 degree along track. Assuming a maximum range of 40 m per channel, the maximum diameter of the beam footprint has been calculated as approximately 0.4 x 0.7 m. Data were reduced to a cell (grid) size of 1.0 x 1.0 m, acknowledging the system's fine-range resolution while accommodating beam position uncertainty. This data reduction was accomplished using HYPACK®'s implementation of CUBE (Combined Uncertainty and Bathymetry Estimator), developed by scientists at the University of New Hampshire/NOAA Center for Coastal and Ocean Mapping (UNH/NOAA CCOM). CUBE statistically analyzes sounding distributions to develop a bathymetric surface which minimizes depth solution uncertainties. CUBE was also used to develop a surface which graphically and mathematically represented the uncertainty of the bathymetric surface.

The average range of cleaned and processed sounding solutions in each 1-m^2 cell was 0.09 m (SD = 0.05 m). Using CUBE, a mean uncertainty per 1-m^2 cell of 0.064 m (SD = 0.036 m) was calculated. It is noteworthy that the most stringent International Hydrographic Organization (IHO) standard for this project depth (Special Order 1A) would call for a 95th percentile confidence interval (95% CI) of 0.27 m (standard deviation of 0.14 m based on two-tailed *t*-distribution).

Reduced data were exported in ASCII text format with fields for Easting, Northing, and MLLW elevation (meters). All data were projected to the Connecticut State Plane, NAD83 (metric). A variety of data visualizations were generated using a combination of IVS3D Fledermaus® (V.7), ESRI ArcMap® (V.9.3), and Golden Software Surfer® (V. 9.7). Visualizations and data products included:

- ASCII databases of all processed soundings including MLLW depths and elevations,
- Contours of seabed elevation (10-cm, 20-cm, and 1.0-m intervals) in DXF format suitable for plotting using GIS and CAD software,
- Georeferenced spectrum-shaded TIF representations of 20-cm elevation contours,
- 3-dimensional surface maps of the seabed created using 2x vertical exaggeration and artificial illumination to highlight fine-scale features not visible on contour layers (delivered in grid and TIF formats), and
- A relief map of the survey area created using 5x vertical exaggeration, delivered in georeferenced TIF format.

2.1.9 Comparison with 2005 Bathymetric Data

Multibeam bathymetric data collected at the survey area in 2005 were provided in ASCII format with a 2-m^2 sounding density. Grids of this data were redundantly constructed using both the Fledermaus® and Surfer® software packages. The 2009 and 2005 data surfaces were compared and the resulting elevation differences were converted to grid format. Visualizations of seabed elevation differences similar to those described for bathymetric data were generated and included contours (10-cm interval) as well as surface and relief layers.

2.1.10 Backscatter Data Processing

Backscatter data, which can provide an estimation of surficial sediment texture based on sediment surface roughness, were extracted from cleaned files and converted to Generic Sensor Format (GSF). Mosaics of beam-angle and beam time-series (BTS) backscatter data were created using HYPACK®'s implementation of GeoCoder software developed by scientists at UNH/NOAA CCOM. A mosaic of unfiltered BTS data was developed and exported in grey-scale TIF format. BTS data were also exported in ASCII format with fields for Easting, Northing, and backscatter (dB). A Gaussian filter was applied to backscatter data to minimize nadir artifacts, and the filtered data were used to develop a grid of backscatter values using a 5-m node interval. The grid was delivered in ESRI FLT raster format to facilitate comparison with other data layers.

2.2 Sediment-Profile Imaging (SPI) Survey

Sediment-profile imaging (SPI) is a monitoring technique used to provide data on the physical characteristics of the seafloor as well as the status of the benthic biological community. The technique involves deploying an underwater camera system to photograph a cross section of the sediment-water interface. In the 2009 survey at CLDS, high-resolution sediment-profile images were acquired using a Nikon® D200 digital single-lens reflex camera mounted inside an Ocean Imaging® Model 3731 pressure housing system. The pressure housing sat atop a wedge-shaped prism with a front faceplate and a 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).

Test exposures of the Kodak® Color Separation Guide (Publication No. Q-13) were made on deck at the beginning and end of the 2009 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 replicates 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, 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 renamed with the appropriate station name immediately after downloading as a further quality assurance step.

Computer-aided analysis of the resulting images provided a set of standard measurements to allow comparisons between different locations and different surveys. The DAMOS Program has successfully used this technique for over 20 years to map the distribution of disposed dredged material and to monitor benthic recolonization at disposal sites. For a detailed discussion of SPI methodology, see ENSR (2004).

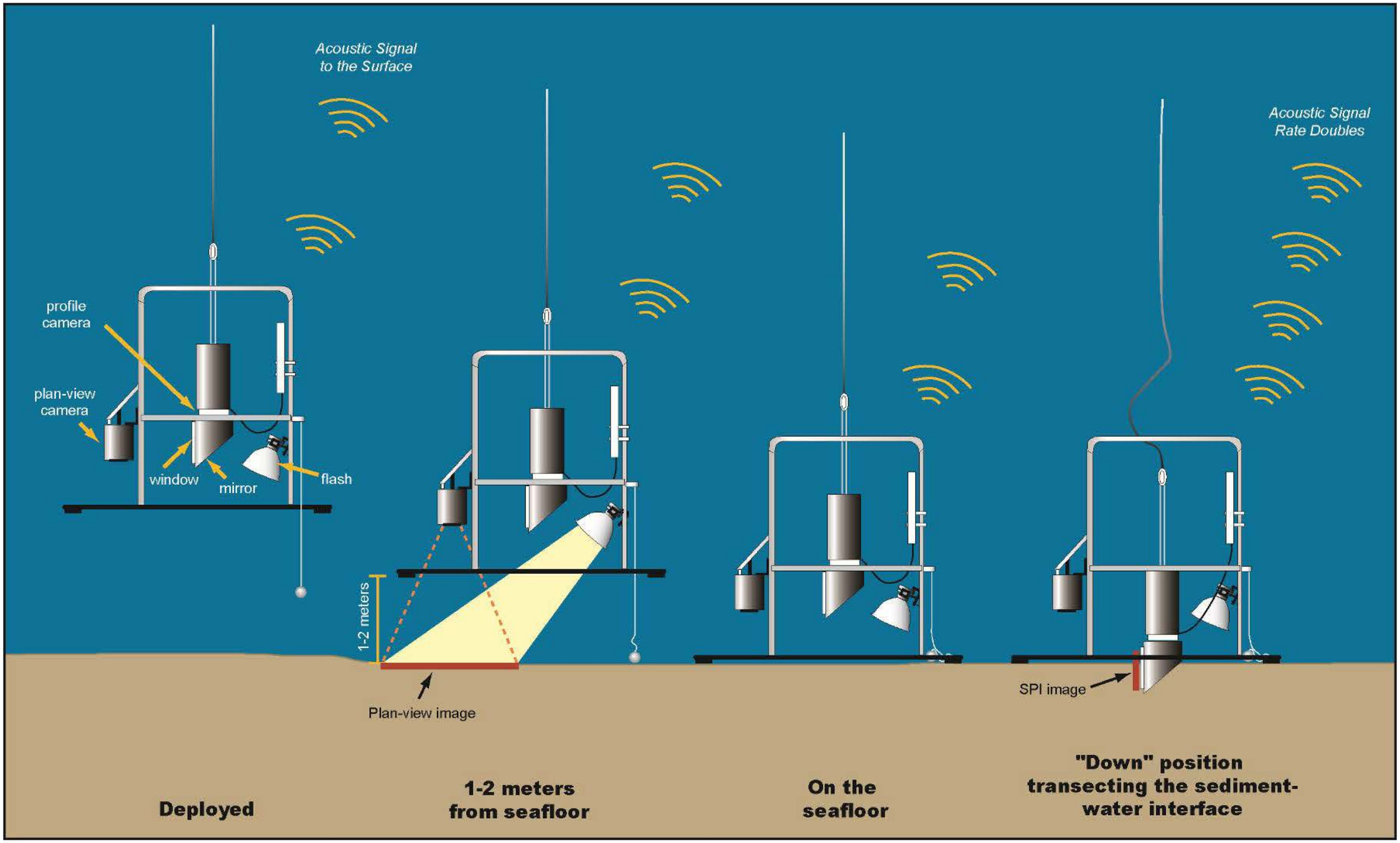


Figure 2-2. Schematic diagram of the SPI camera deployment

2.2.1 Survey Planning and Implementation

The 2009 SPI sampling stations within CLDS were chosen to coincide with the four areas where dredged material disposal activities were concentrated over the period October 2005 to May 2009. The disposal event data were imported to ArcView® GIS software, and four proposed sampling areas consisting of 100-m-radius circles, encompassing the majority of reported barge disposal coordinates, were developed and approved by NAE (Figure 2-3). A total of 40 SPI stations were allocated among the four circles based on relative disposal volume (Figure 2-4). The stations were distributed as follows: 14 stations over the 2008 area, 6 stations over the 2007 area, 9 stations over the 2006 area, and 11 stations over the 2005 area (Figure 2-4). Stations were distributed randomly within each sampling circle. The coordinates of both the disposal site and reference area stations are provided in Table 2-1.

Three previously established CLDS reference areas (upper left panel in Figure 2-5), located west of the disposal site (2500W REF), east of the disposal site (4500E REF), and southeast of the disposal site (CLIS REF), were also sampled to provide a basis of comparison between CLDS sediment conditions and the ambient sediment conditions in Central Long Island Sound. For the 2009 survey, SPI stations were located randomly within a 300-m diameter of the central point of each of the three reference areas. Five stations were allocated to each of the 4500E REF and CLIS REF areas, and 8 stations were allocated to the 2500W REF area, for a total of 18 reference area stations (Table 2-1, Figure 2-5).

Using the 42-ft M/V Shanna Rose as the sampling platform, the SPI survey at CLDS was conducted as planned on 1–2 October 2009. Sediment-profile images were obtained successfully at all 58 of the target stations (40 stations within CLDS and 18 in the three reference areas). With the exception of Station 2 in the 4500E REF reference area, where two replicates were collected, three replicate images were collected at each station for characterization of benthic habitat conditions and infaunal successional status. The replicates were obtained by dropping the camera onto the seafloor three times in rapid succession at each station while the sampling vessel maintained its position within a 10-m radius of the target station coordinates.

2.2.2 SPI Image Analysis

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

Table 2-1.

CLDS Sediment-Profile Image (SPI) Station Target Locations

Station	Latitude (N)	Longitude (W)	Station	Latitude (N)	Longitude (W)
CLDS Locations			CLDS Locations		
1	41° 08.785'	72° 53.652'	31	41° 08.708'	72° 53.258'
2	41° 08.773'	72° 53.674'	32	41° 08.708'	72° 53.216'
3	41° 08.773'	72° 53.653'	33	41° 08.697'	72° 53.236'
4	41° 08.773'	72° 53.610'	34	41° 08.696'	72° 53.194'
5	41° 08.773'	72° 53.567'	35	41° 08.696'	72° 53.174'
6	41° 08.750'	72° 53.674'	36	41° 08.684'	72° 53.260'
7	41° 08.750'	72° 53.566'	37	41° 08.684'	72° 53.152'
8	41° 08.738'	72° 53.652'	38	41° 08.672'	72° 53.216'
9	41° 08.726'	72° 53.630'	39	41° 08.672'	72° 53.173'
10	41° 08.726'	72° 53.587'	40	41° 08.661'	72° 53.237'
11	41° 08.726'	72° 53.567'			
12	41° 08.713'	72° 53.652'	Reference:		
13	41° 08.702'	72° 53.610'	2500W Ref 1	41° 09.252'	72° 55.604'
14	41° 08.702'	72° 53.588'	2500W Ref 2	41° 09.252'	72° 55.513'
15	41° 08.862'	72° 53.486'	2500W Ref 3	41° 09.268'	72° 55.562'
16	41° 08.862'	72° 53.444'	2500W Ref 4	41° 09.221'	72° 55.552'
17	41° 08.850'	72° 53.486'	2500W Ref 5	41° 09.292'	72° 55.566'
18	41° 08.839'	72° 53.443'	2500W Ref 6	41° 09.252'	72° 55.582'
19	41° 08.827'	72° 53.485'	2500W Ref 7	41° 09.291'	72° 55.554'
20	41° 08.815'	72° 53.443'	2500W Ref 8	41° 09.220'	72° 55.540'
21	41° 08.737'	72° 52.931'	4500E Ref 1	41° 09.249'	72° 50.588'
22	41° 08.737'	72° 52.867'	4500E Ref 2	41° 09.253'	72° 50.516'
23	41° 08.726'	72° 52.909'	4500E Ref 3	41° 09.287'	72° 50.571'
24	41° 08.726'	72° 52.845'	4500E Ref 4	41° 09.258'	72° 50.540'
25	41° 08.715'	72° 52.931'	4500E Ref 5	41° 09.209'	72° 50.539'
26	41° 08.702'	72° 52.910'	CLIS REF 1	41° 08.085'	72° 50.112'
27	41° 08.702'	72° 52.867'	CLIS REF 2	41° 08.116'	72° 50.113'
28	41° 08.691'	72° 52.909'	CLIS REF 3	41° 08.130'	72° 50.061'
29	41° 08.690'	72° 52.888'	CLIS REF 4	41° 08.074'	72° 50.027'
30	41° 08.720'	72° 53.195'	CLIS REF 5	41° 08.054'	72° 50.105'

Notes: Coordinate system NAD83

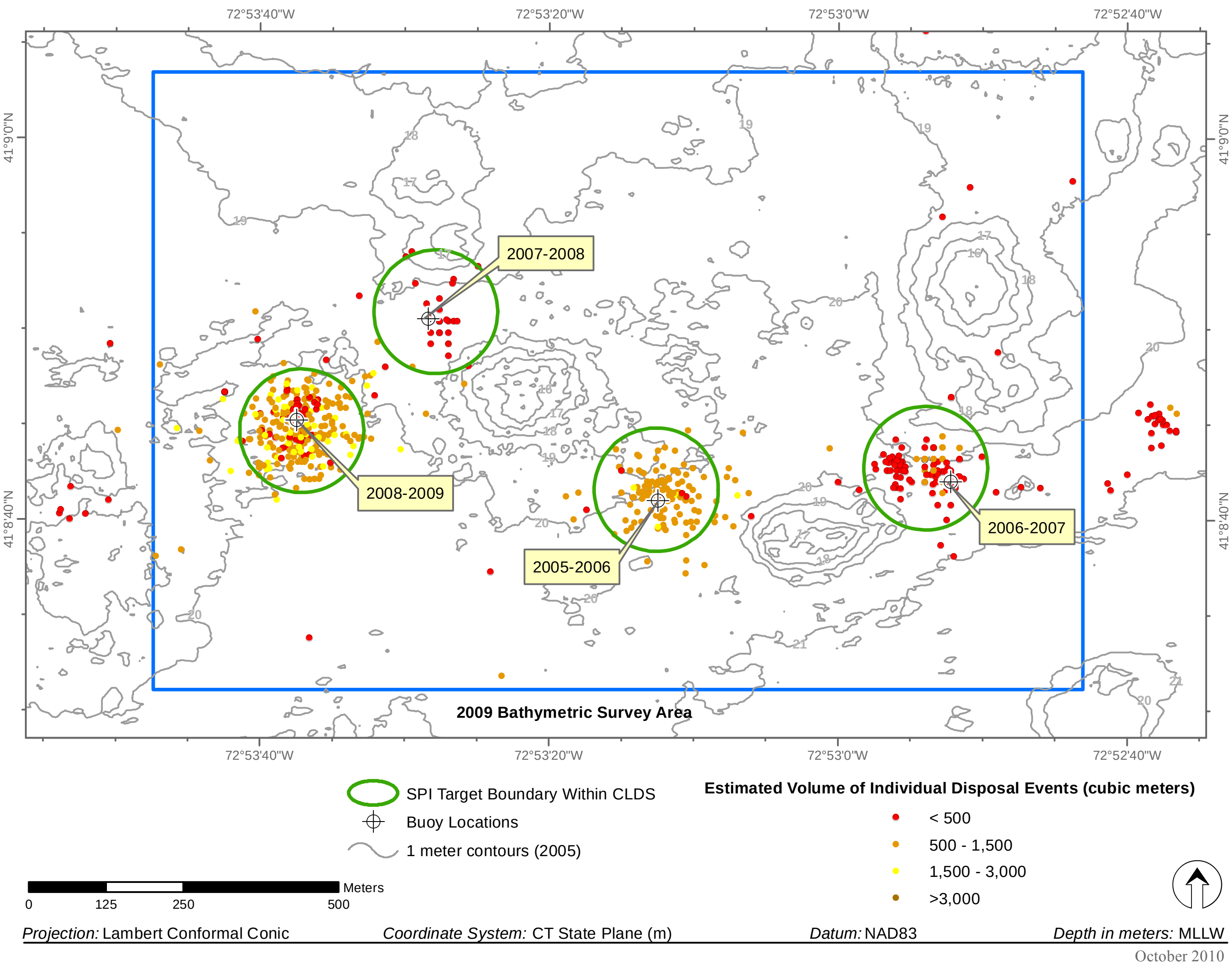


Figure 2-3. SPI stations selected within areas (green circles) that had experienced concentrated disposal activity from 2005 to 2009

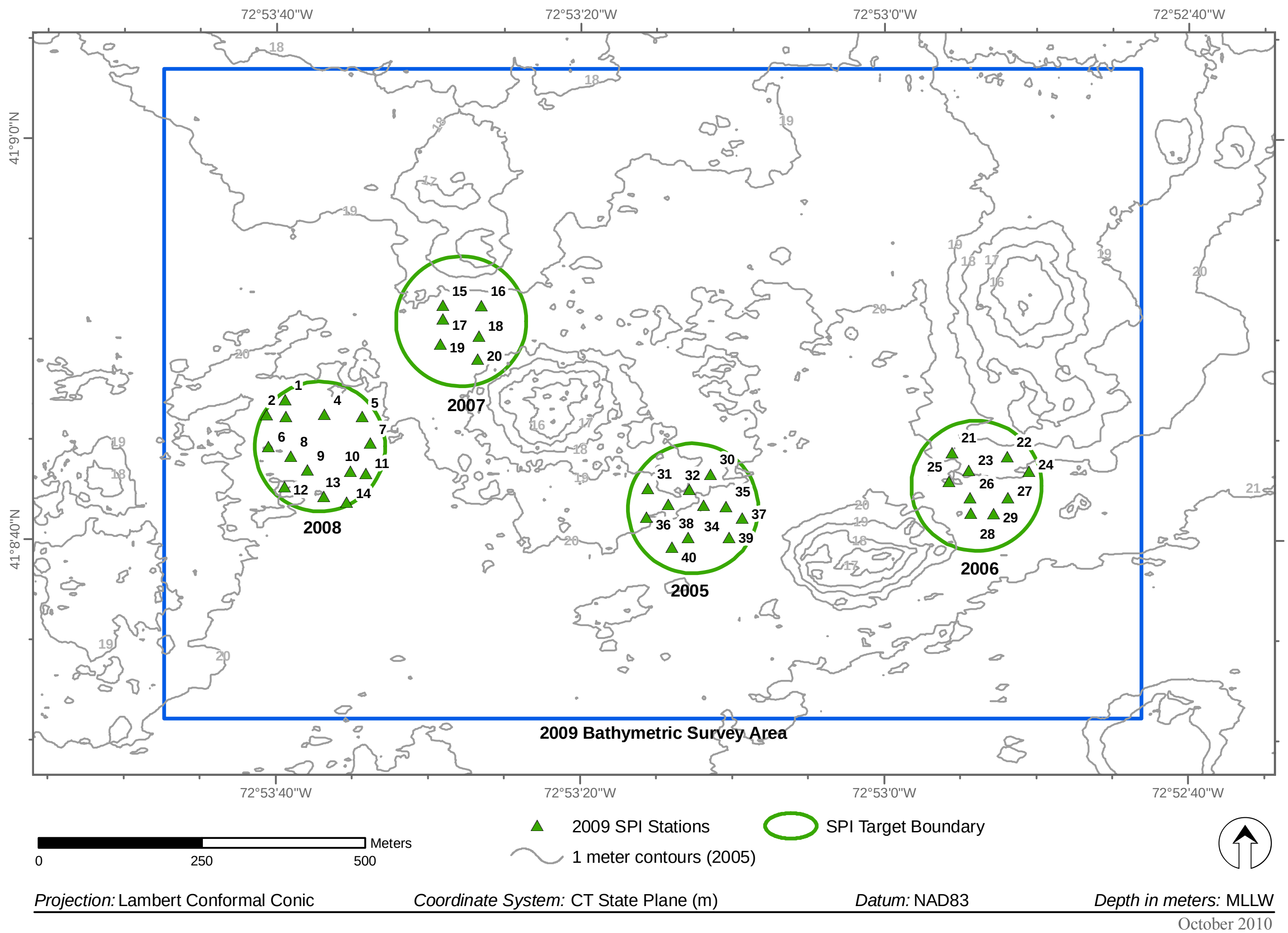


Figure 2-4. 2009 SPI sampling stations, located within areas that had experienced concentrated disposal activity from 2005 to 2009

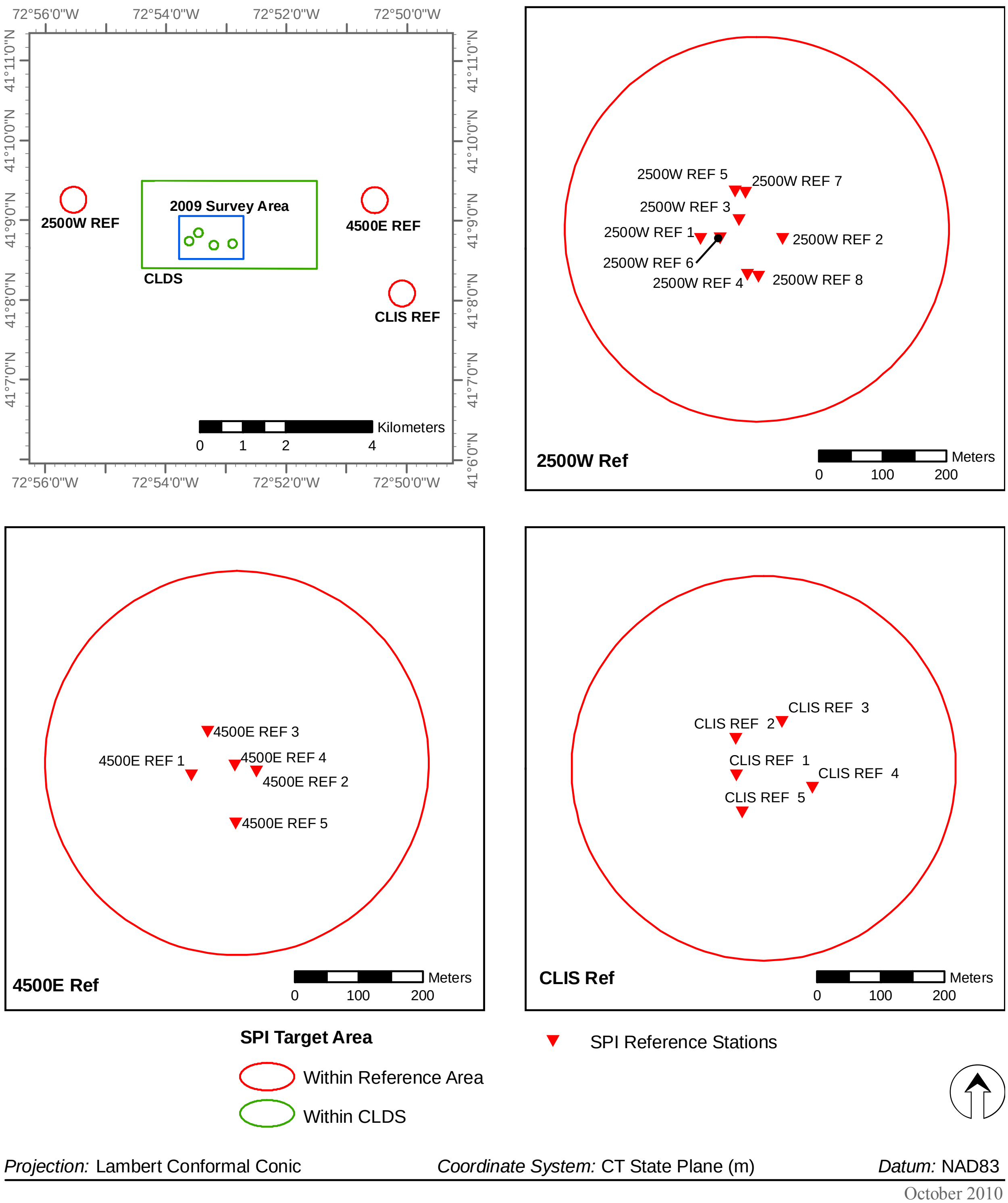


Figure 2-5. Location of 2009 SPI stations at each of the three reference areas

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. A table showing conversions among different grain-size scales is provided in Appendix A. The thickness of any dredged material layers observed in each image was also measured.

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

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, mud clasts) or biogenic features (e.g., burrow openings, fecal mounds, foraging depressions). Biogenic roughness typically changes seasonally and is related to the interaction of bottom turbulence and bioturbation.

Apparent Redox Potential Discontinuity (aRPD) Depth. The RPD is defined as the boundary or horizon that separates the positive electrochemical potential (Eh) region of the sediment column from the underlying negative Eh region. Accurately measuring the location of the Eh = 0 boundary requires the use of microelectrodes. In SPI, the RPD depth is informed by assessing color and reflectance boundaries within the sediment column and is therefore described as the “apparent” RPD (aRPD).

The aRPD provides a measure of the integrated 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 moved downwards by biological activity or buried, they are exposed to reduced oxygen concentrations in subsurface pore waters and their oxic coating slowly reduces, changing color to dark grey or black. When biological activity is high, the aRPD depth increases; when it is low or absent, the aRPD depth decreases.

Infaunal Successional Stage. Infaunal successional stage is a measure of the biological community inhabiting the seafloor. 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). A successional stage was assigned to each image based on the types of biological features that were present (e.g., worm tubes, subsurface burrows, and feeding voids).

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

2.2.3 Statistical Analysis of SPI Data

The objective of the SPI surveys at CLDS was to assess the benthic recolonization status of the mounds relative to reference conditions. Traditionally, this objective has been addressed using point null hypotheses of the form "there is no difference in benthic conditions between the reference areas and the disposal mound(s)." More recently, an approach using bioequivalence or interval testing has been considered to be more informative than the point null hypothesis test of "no difference." 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 the results of this type of point null hypothesis provide an incomplete picture of the results.

In this application of bioequivalence (interval) testing the null hypothesis is chosen as one that 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 this inequivalence null hypothesis requires sufficient proof that the difference is actually small. The null and alternative hypotheses to be tested are

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

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

where d is the difference between a reference area mean and a site mean. If the null hypothesis is rejected, then it can be concluded that the two means are equivalent to one another within $\pm\delta$ units. The size of δ should be determined from historical data and/or best professional judgment to identify a maximum difference that is within background variability or noise and is therefore not ecologically meaningful. Previously established δ values of 1 for aRPD, and 0.5 for successional stage rank on the 0–3 scale were used.

The test of this 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 on Student's *t*-distribution when sample sizes are small and variances must be estimated from the data, as is normally the case. 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 this sampling design, there are actually seven distinct areas, three of which are categorized as reference locations, and the difference equations of interest are average of the three reference means minus the linear contrasts of each mound mean, or

$$[\tfrac{1}{3}(\text{Mean}_{\text{CLIS REF}} + \text{Mean}_{\text{4500E REF}} + \text{Mean}_{\text{2500W REF}}) - (\text{Mean}_{\text{MOUND}})]$$

where $\text{Mean}_{\text{MOUND}}$ is the mean for one of the disposal mounds (CLIS 05, CLIS 06, CLIS 07, or CLIS 08).

The three reference areas collectively represent ambient conditions, but if there are 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 has little effect on the grand reference mean (when n is approximately equal among these areas), but it will maintain 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 is:

$$\tfrac{1}{3}(\text{Mean}_{\text{CLIS REF}} + \text{Mean}_{\text{4500E REF}} + \text{Mean}_{\text{2500W REF}}) - (\text{Mean}_{\text{MOUND}}) \qquad \text{[Eq.1]}$$

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

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

where:

c_j = coefficients for the j means in the difference equation, $\hat{d}$ [Eq. 1] (i.e., for equation 1 shown above, the coefficients are 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 can be 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 7 groups.

n_j = number of replicate observations for the *j*th area (from 5 to 14).

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

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

where:

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

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

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

υ = degrees of freedom for the standard error. If a pooled residual variance estimate is used, it is the residual degrees of freedom from an ANOVA on all groups (total number of samples minus the number of groups); if separate variance estimates are used, degrees of freedom are calculated based on the Brown and Forsythe estimation (Zar 1996, p. 189).

Validity of the normality and equal variance assumptions was 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 the data were transformed to approximate normality, if possible. In comparing the successional stage ranks, which are inherently nonnormal, a nonparametric bootstrapped interval was used, following the bootstrap procedure described in Appendix B.

3.0 RESULTS

3.1 Bathymetric Survey

The disposal activity at CLDS from 2005 to 2009 was concentrated in four areas, resulting in distinct dredged material deposits that are labeled as the CLIS 05 (2005–06 disposal season), CLIS 06 (2006–07 disposal season), CLIS 07 (2007–08 disposal season), and CLIS 08 mounds (2008–09 disposal season) in Figure 3-1. The bathymetric depth difference map serves to more clearly differentiate these four new mounds from the surrounding, existing topography (Figures 3-2 and 3-3). The mounds varied widely in terms of their height and diameter, in a manner that was somewhat proportional to the estimated volume of material disposed during each season (Table 3-1; Figures 3-2 and 3-3). The CLIS 08 mound was by far the largest of the four and corresponded to an estimated barge volume of 324,680 m^3 of dredged material placed during the 2008–09 disposal season. Although the CLIS 07 mound resulted from disposal of a relatively low volume of material (18,790 m^3), it exhibited a greater height and spread than the CLIS 06 mound, which resulted from placement of more than three times as much dredged material (59,654 m^3; Table 3-1).

The CLIS 05 mound (corresponding to the 2005–2006 disposal season) was created roughly midway between the existing CLIS 97/98 and CLIS 95/96 mounds (Figure 3-4). This mound was roughly circular, with a maximum height of about 4.5 m and an irregular diameter of 194–289 m. The CLIS 06 mound was more irregularly shaped, with a maximum height of 1.0 m and a diameter varying between about 103 and 191 m; this mound was formed between the existing NHAV-74 and CLIS 95/96 mounds (Figure 3-4). The CLIS 07 mound was found to have a maximum height of 2.5 m and a diameter between 176 and 178 m; it was created between the existing NWK (Norwalk) and CLIS 97/98 mounds (Figure 3-4). The CLIS 08 mound, with a diameter between 385 and 464 m and a maximum height of 4.5 m, was clearly the largest of the four. This mound was created roughly midway between the existing CLIS 97/98 and MQR mounds. (Note: the MQR mound is located to the west of the 2008 mound, and is not depicted in Figure 3-4 because it is just outside the boundary of the 2009 bathymetric survey.) The intent of placing the CLIS 08 mound midway between the existing CLIS 97/98 and MQR mounds was to begin creating another berm and potentially another CAD area in the southern portion of CLDS.

Table 3-1.

Summary of Mound Size in Relation to Volume Disposed

Disposal Season	Mound Name	Estimated Volume of Material Disposed (m^3)	Maximum Mound Height (m)	Approximate Mound Footprint in East–West Direction (m)	Approximate Mound Footprint in North–South Direction (m)
October 2005 to May 2006	CLIS 05	136,104	4.5	289	194
October 2006 to June 2007	CLIS 06	59,654	1.0	191	103
October 2007 to May 2008	CLIS 07	18,790	2.5	176	178
October 2008 to May 2009	CLIS 08	324,680	4.5	464	385

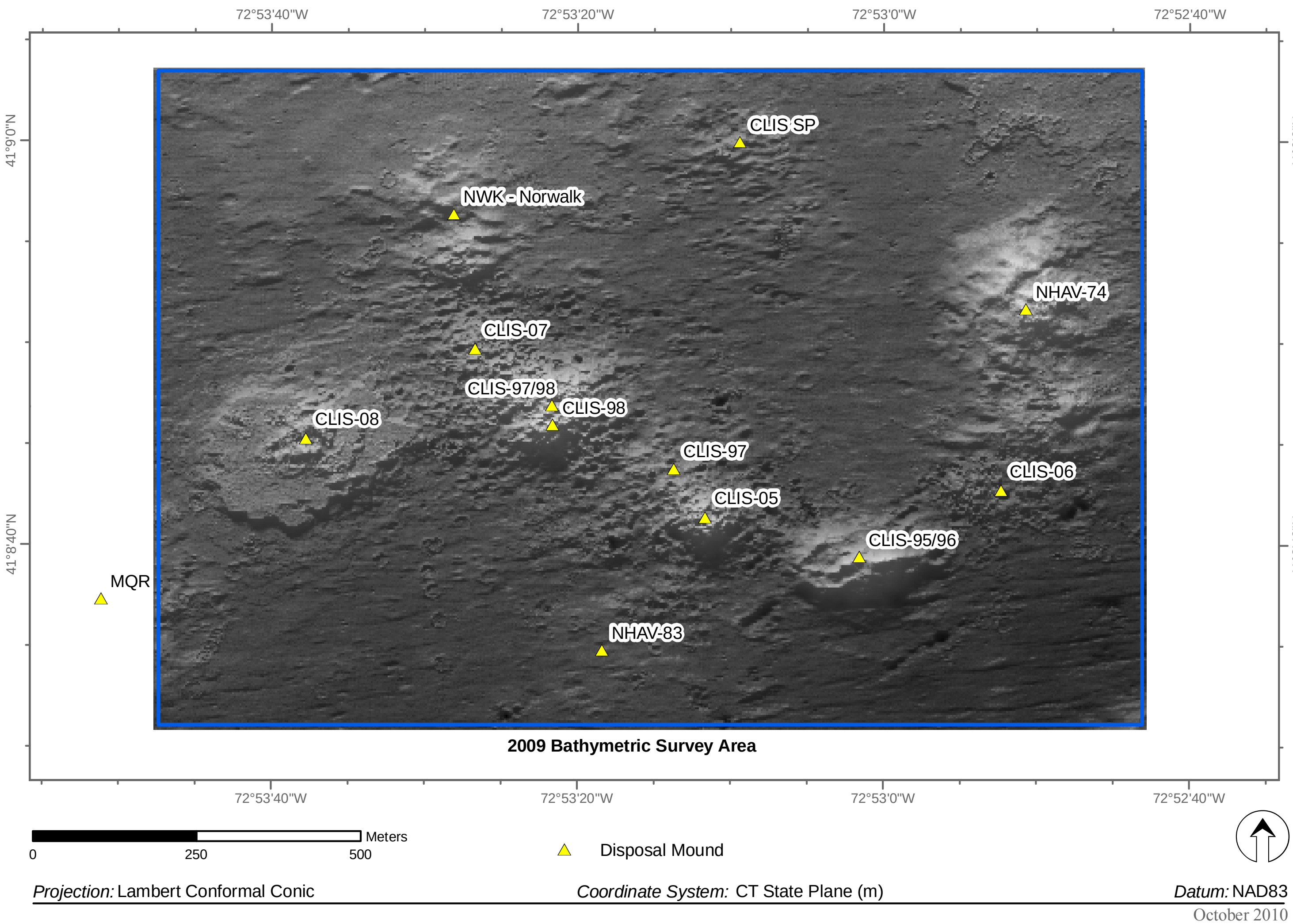


Figure 3-1. Multibeam bathymetric data collected at CLDS in September 2009. The hillshading highlights topographic features, with individual disposal mounds identified by project or year of disposal activity.

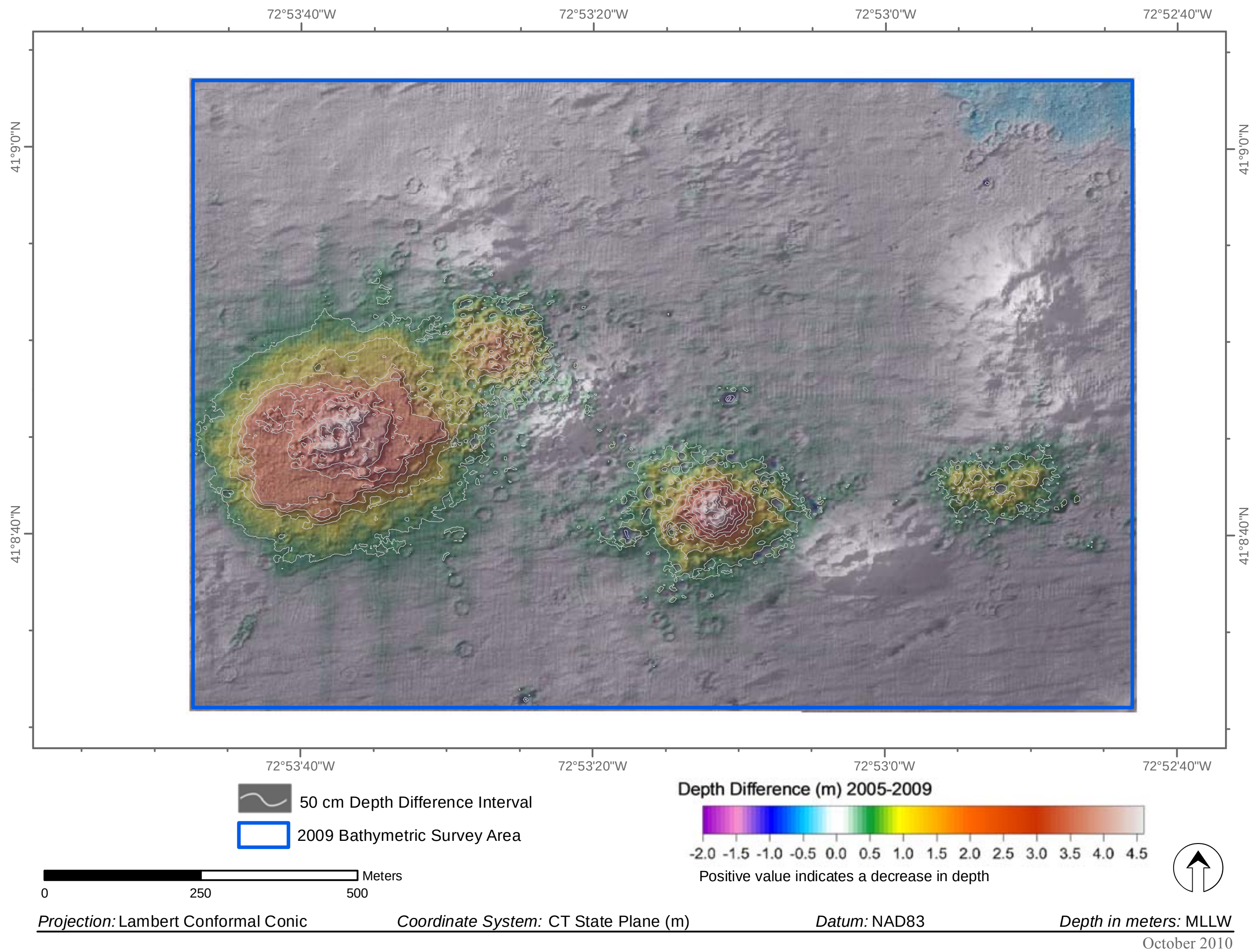


Figure 3-2. Changes in depth (depth difference) that occurred between the 2005 and 2009 multibeam bathymetric surveys

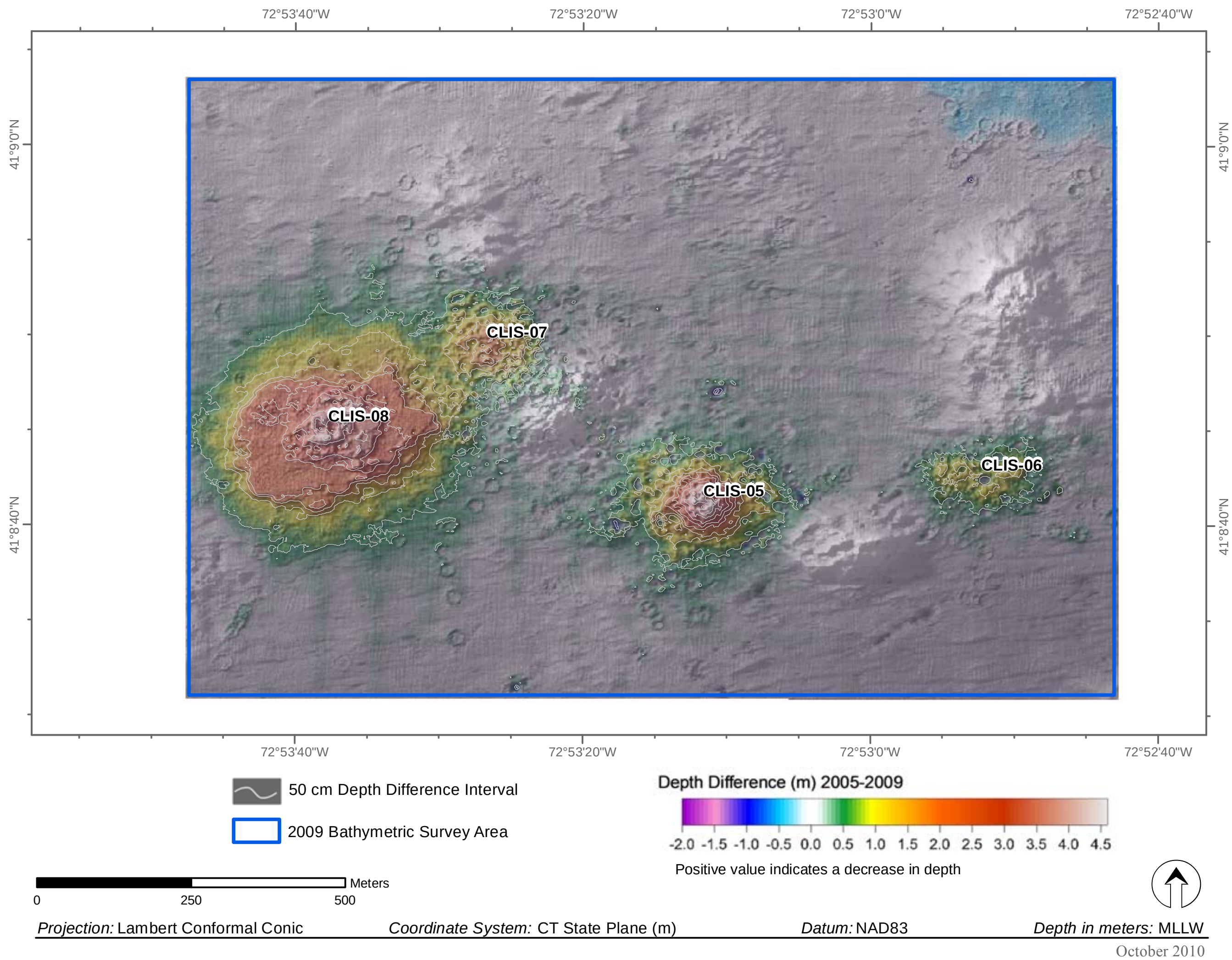
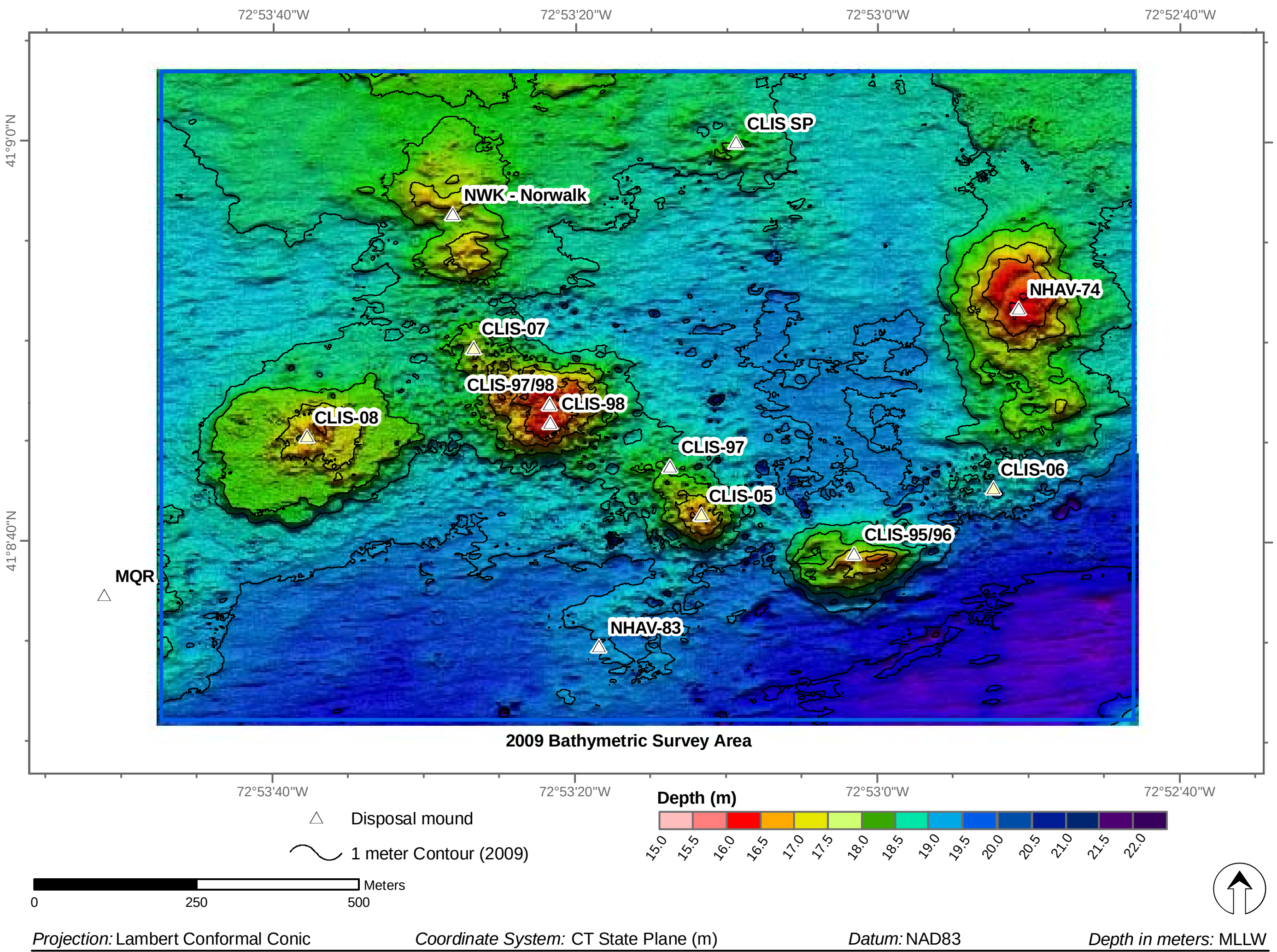


Figure 3-3. Changes in depth (depth difference) that occurred between the 2005 and 2009 multibeam bathymetric surveys. Individual disposal mounds are identified by year of disposal activity.



October 2010

Figure 3-4. Color-coded bathymetry based on the multibeam survey of September 2009. Individual disposal mounds are identified by project or year of disposal activity.

The bathymetry of the survey area in 2009 revealed a relatively flat mound from the 2008–2009 disposal activities and a crescent-shaped array of disposal mounds connecting two large flat mound areas (Figure 3-4). This array consists of the following mounds: NWK, CLIS 07, CLIS 97/98, CLIS 05, CLIS 95/96, CLIS 06, and NHAV-74 (Figure 3-4). The berm formed by the ring of contiguous mounds had a variable height above the surrounding seafloor. Specifically, to the east and west of the CLIS 95/96 mound, the berm was only about 0.5 to 1.0 m higher than ambient seafloor (Figure 3-4). The existing CLIS 97/98, CLIS 95/96, NWK, and NHAV-74 mounds, as well as the new CLIS 05 mound, represented the high points of the berm. At the center of each of these mounds, the berm achieved a height roughly 2 to 3 m above the surrounding seafloor (Figure 3-4).

The CLIS 08 mound, located near the western boundary of the survey area, was another prominent feature of the bathymetric results (Figure 3-4). The CLIS 08 mound was found to be relatively broad and flat, and it was placed between the outside edge of CLIS 07 and MQR. This larger mound thus bridges the gap between CLIS 07 and MQR and could be used to create another CAD area to the west.

Multibeam bathymetry reveals many details of disposal activities previously undetectable with single-beam bathymetry (ENSR 2007). The hillshaded grey scale images provide evidence of individual disposal events (craters, pits, and rings) and the collective result of a disposal season (mounds) (Figure 3-1).

Backscatter intensity was variable across the surveyed area and closely related to locations of past and recent disposal activity (Figures 3-5 and 3-6). Higher backscatter intensity, indicated by the lighter colors (i.e., whites and light greys) in Figure 3-6, indicates areas where the substratum is generally harder or more compact due to the presence of coarser sediments (e.g., sand and gravel) or consolidated finer grained sediments. The darker areas in Figure 3-6 indicate low backscatter intensity associated with softer, fine-grained sediments (e.g., silt/clay). The highest backscatter was observed over the “peaks” or steeper central portions of several of the older disposal mounds, including NHAV-74, CLIS 95/96, CLIS 97/98, and NWK (Figure 3-6). The peak of the CLIS 05 mound also had relatively high backscatter, while the CLIS 06 mound showed high to intermediate backscatter (Figure 3-6). The two newest mounds, CLIS 07 and CLIS 08, were characterized by relatively low backscatter (Figure 3-6).

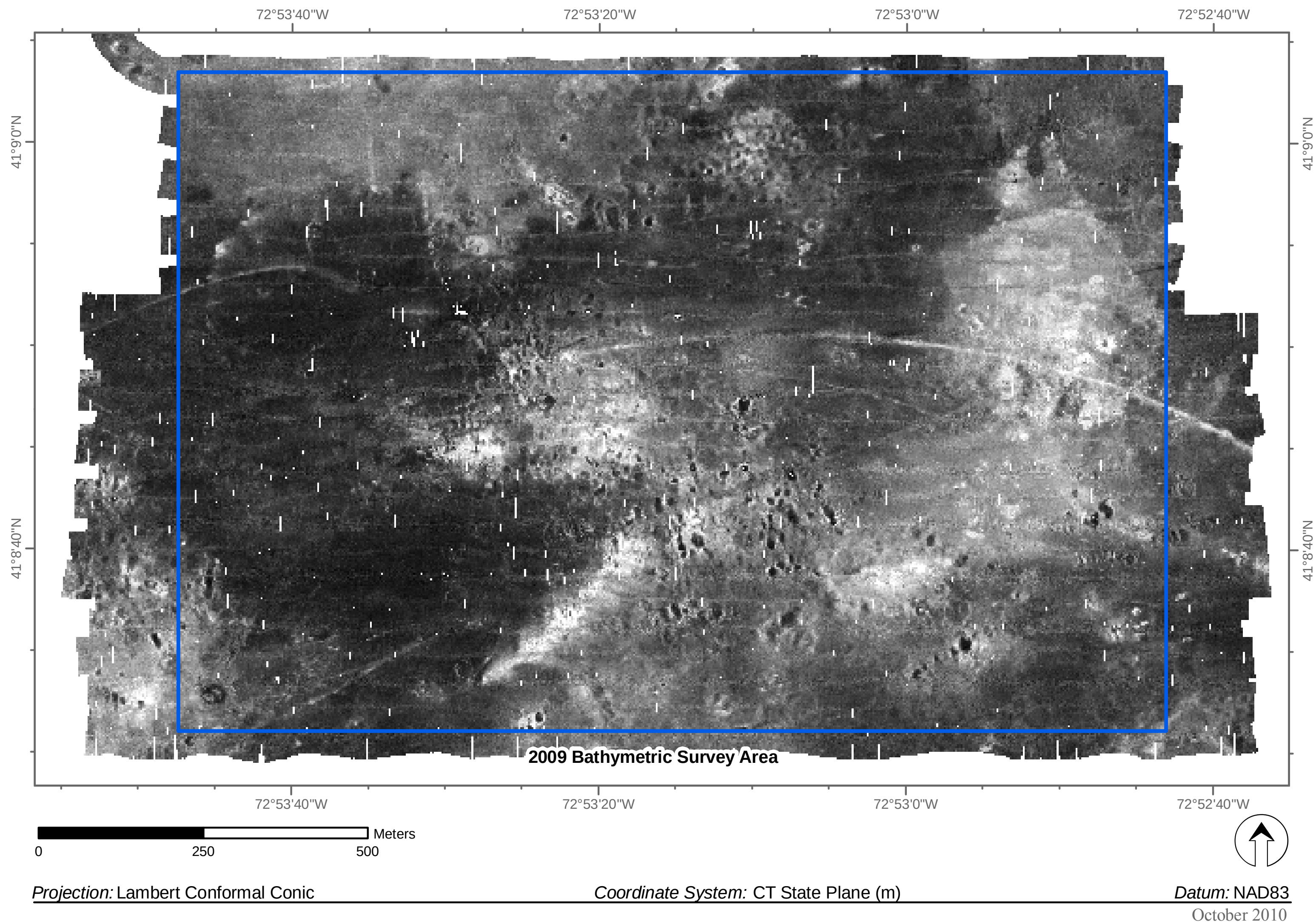


Figure 3-5. Backscatter intensity mosaic collected during the 2009 survey

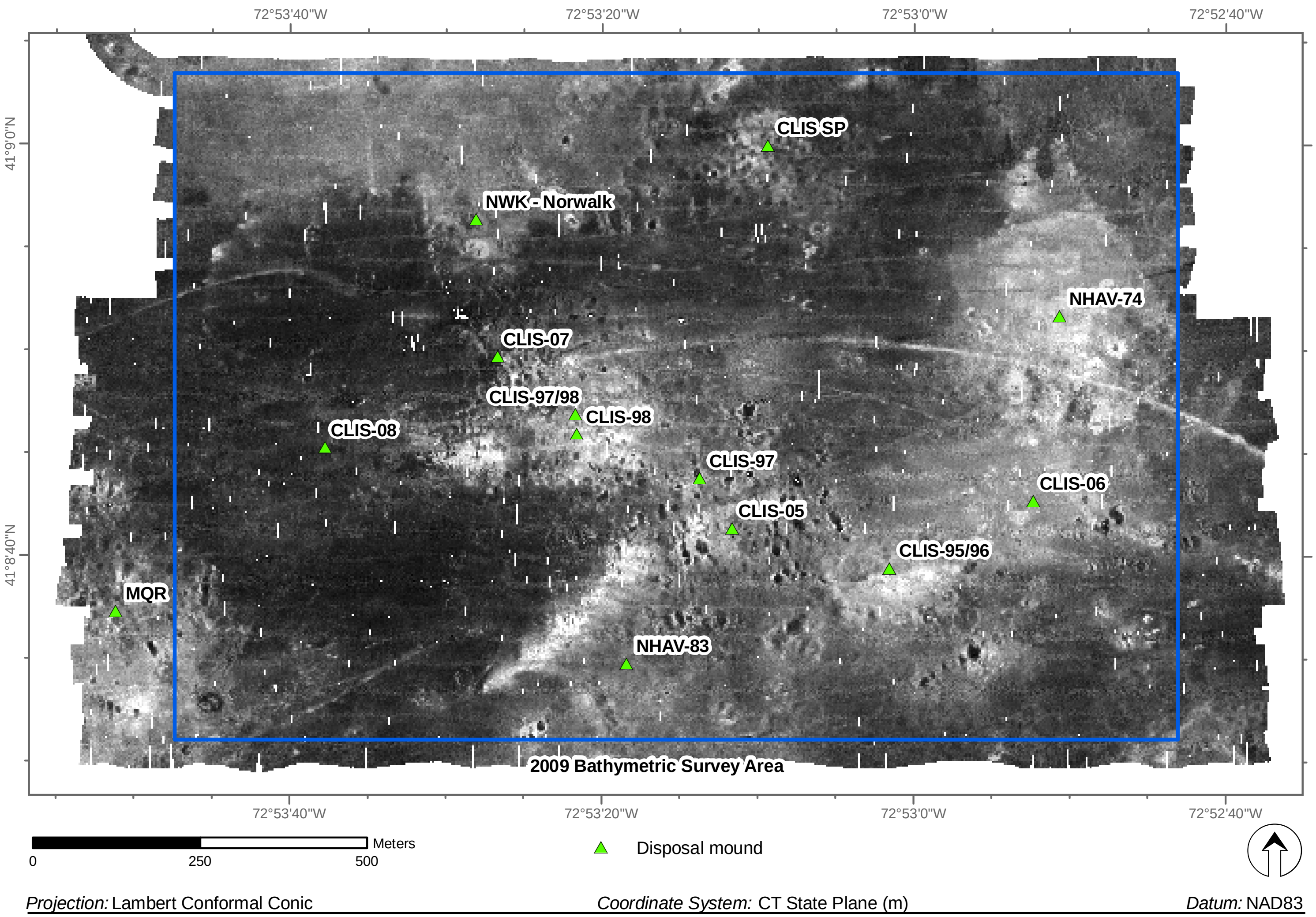


Figure 3-6. Backscatter intensity mosaic collected during the 2009 survey, with individual disposal mounds identified by project or year of disposal activity

3.2 SPI Survey

Detailed image analysis results are provided in Appendix C. The following sections summarize and compare the results for the reference area and disposal site stations.

3.2.1 Reference Area Stations

3.2.1.1 Sediment Physical Characteristics

Similar to past surveys, 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 3-2; Figures 3-7 and 3-8). 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.

Average prism penetration values among the reference area stations ranged from 14.0 to 21.4 cm (Table 3-2). Such high penetration values are typical of the soft, biologically reworked silt/clays that characterize the reference areas. Average penetration values at several of the 2500W REF stations were higher than those at the other two reference areas (Table 3-2), indicating the presence of particularly soft (i.e., low relative bearing strength) sediments at this location. In 9 of the 24 replicate images collected at the 2500W REF stations, the relative softness of the sediment resulted in overpenetration of the profile camera. Station-averaged small-scale boundary roughness ranged from 0.2 to 1.5 cm at the reference stations (Table 3-2); almost 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 the surface and subsurface feeding and foraging activities of benthic organisms (Figure 3-9).

3.2.1.2 Biological Conditions

The average aRPD depths among the reference area stations ranged from 3.4 to 5.8 cm (Table 3-2, Figure 3-10). The highest aRPD values (>4.3 cm) were observed most consistently among the 2500W REF stations, while the other two reference areas had a number of stations where values ranged between 3 and 4 cm (Figure 3-10). Overall, the aRPD depths at all three of the reference areas were relatively deep and consistent with values measured in past surveys. The 2009 images did not show any 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 3-11).

Table 3-2.

Summary of SPI Results for the 2009 CLDS Reference Area Stations

Reference Area	Station	Grain Size Major Mode (phi)	Mean Prism Penetration Depth (cm)	Mean Boundary Roughness (cm)	Mean aRPD Depth (cm)	Mean # of Subsurface Feeding Voids	Successional Stages Present (3 replicates)		
4500E REF	4500E REF 1	>4	17.2	1.5	4.1	3	3	1 on 3	1 on 3
	4500E REF 2	>4	15.7	0.6	4.0	8	1 on 3	1 on 3	1 on 3
	4500E REF 3	>4	17.7	0.5	3.7	5	1 on 3	1 on 3	
	4500E REF 4	>4	14.5	0.7	4.1	7	1 on 3	1 on 3	1 on 3
	4500E REF 5	>4	14.4	0.5	3.5	5	1 on 3	1 on 3	1 on 3
CLIS REF	CLIS REF 1	>4	14.0	0.5	3.5	4	1 on 3	1 on 3	1 on 3
	CLIS REF 2	>4	14.6	0.5	5.3	6	1 on 3	1 on 3	1 on 3
	CLIS REF 3	>4	14.4	0.7	4.5	5	1 on 3	1 on 3	1 on 3
	CLIS REF 4	>4	14.0	0.6	4.3	4	1 on 3	1 on 3	1 on 3
	CLIS REF 5	>4	14.2	0.4	3.4	4	1 on 3	1 on 3	1 on 3
2500W REF	2500W REF 1	>4	20.6	0.7	5.2	2	1 on 3	IND	1 on 3
	2500W REF 2	>4	19.9	1.0	4.3	3	1 on 3	1 on 3	1 on 3
	2500W REF 3	>4	21.4	0.2	5.5	2	1 on 3	IND	1 on 3
	2500W REF 4	>4	21.2	1.5	5.8	2	1 on 3	1 on 3	1 on 3
	2500W REF 5	>4	21.4	0.3	4.6	3	1 on 3	1 on 3	1 on 3
	2500W REF 6	>4	17.4	1.1	4.3	5	1 on 3	1 on 3	1 on 3
	2500W REF 7	>4	17.2	0.5	4.7	3	1 on 3	1 on 3	1 on 3
	2500W REF 8	>4	17.6	0.8	4.7	5	1 on 3	1 on 3	1 on 3

IND=indeterminate

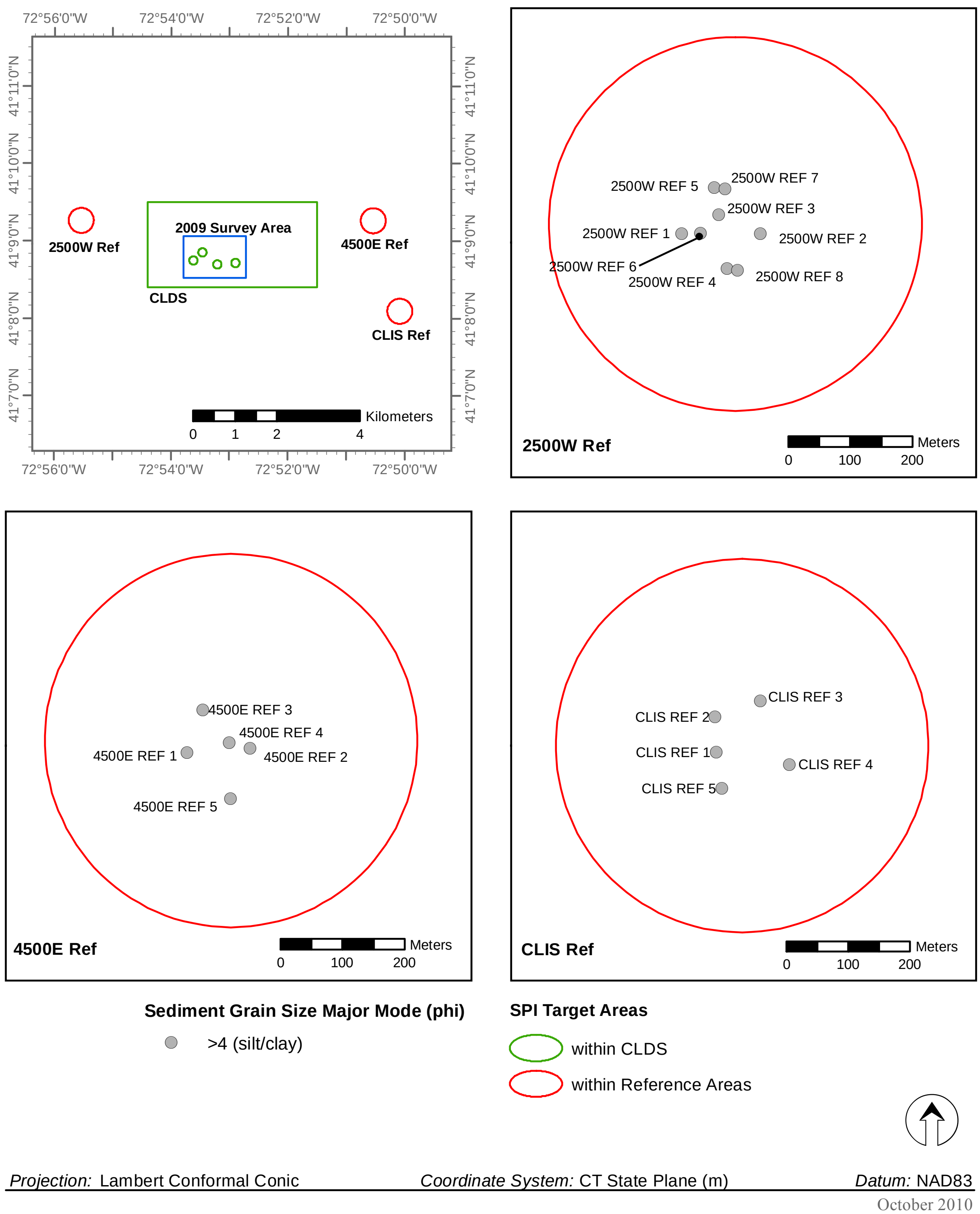
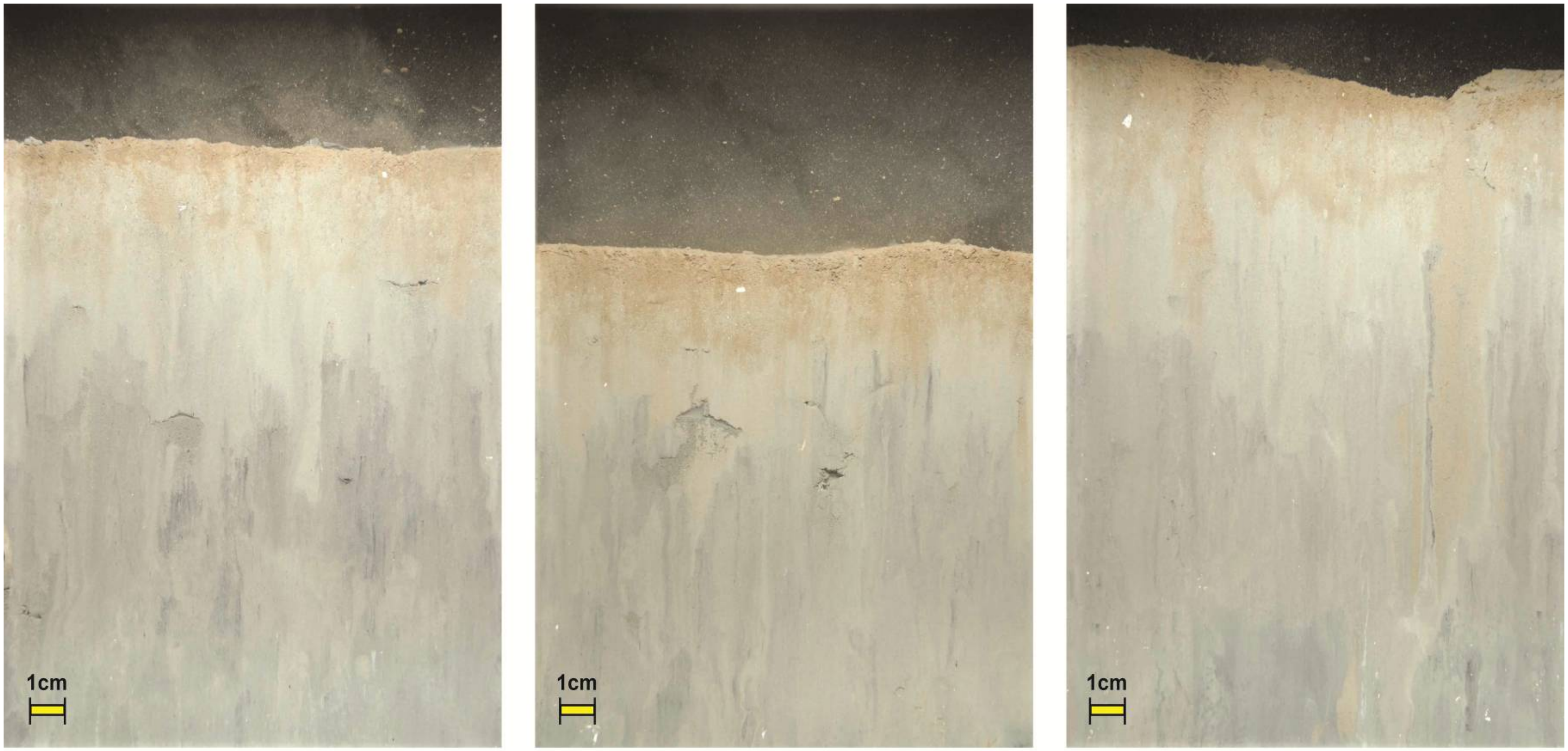


Figure 3-7. Grain size major mode (in phi units) at the reference area SPI stations, October 2009



4500E REF Station 3, Replicate D | CLIS REF Station 2, Replicate A | 2500W REF Station 2, Replicate A

Figure 3-8. Representative profile images illustrating the soft, homogenous mud that characterized each of the three reference areas

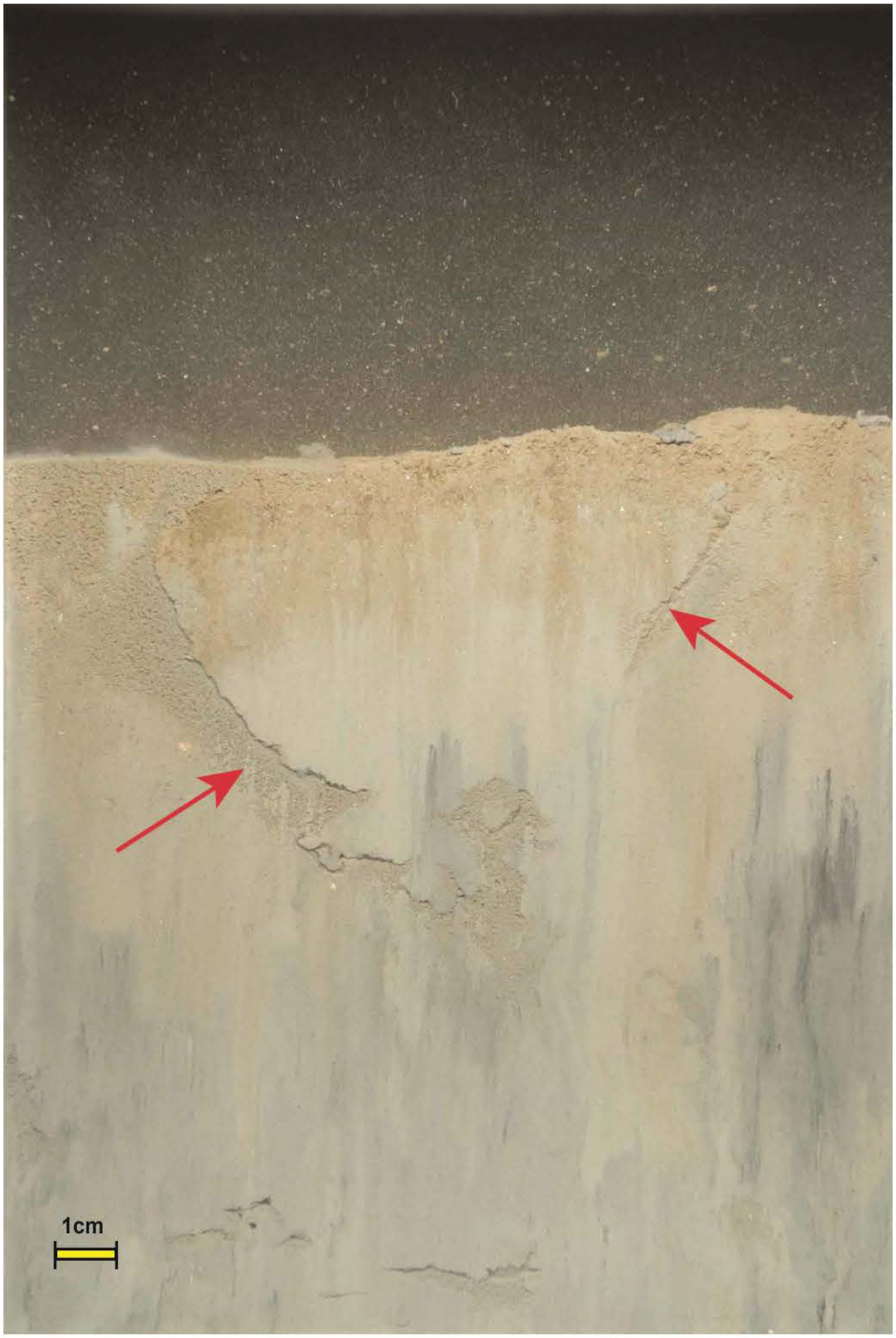


Figure 3-9. Profile image from CLIS REF station 2 showing subsurface burrows (arrows) that culminate in small mounds at the sediment-water interface. This is an example of biogenic surface roughness.

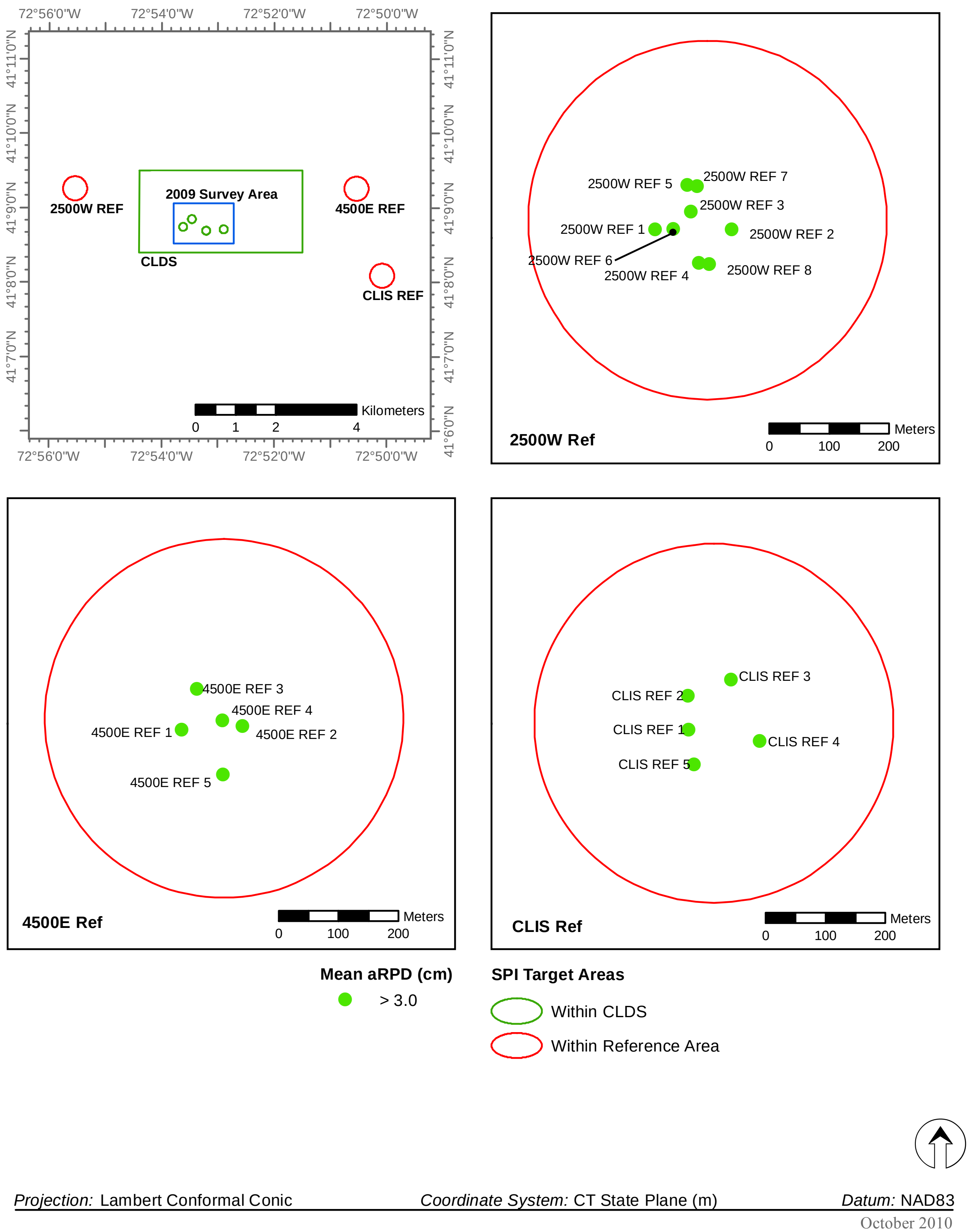


Figure 3-10. Average aRPD depths at the reference area SPI stations, October 2009

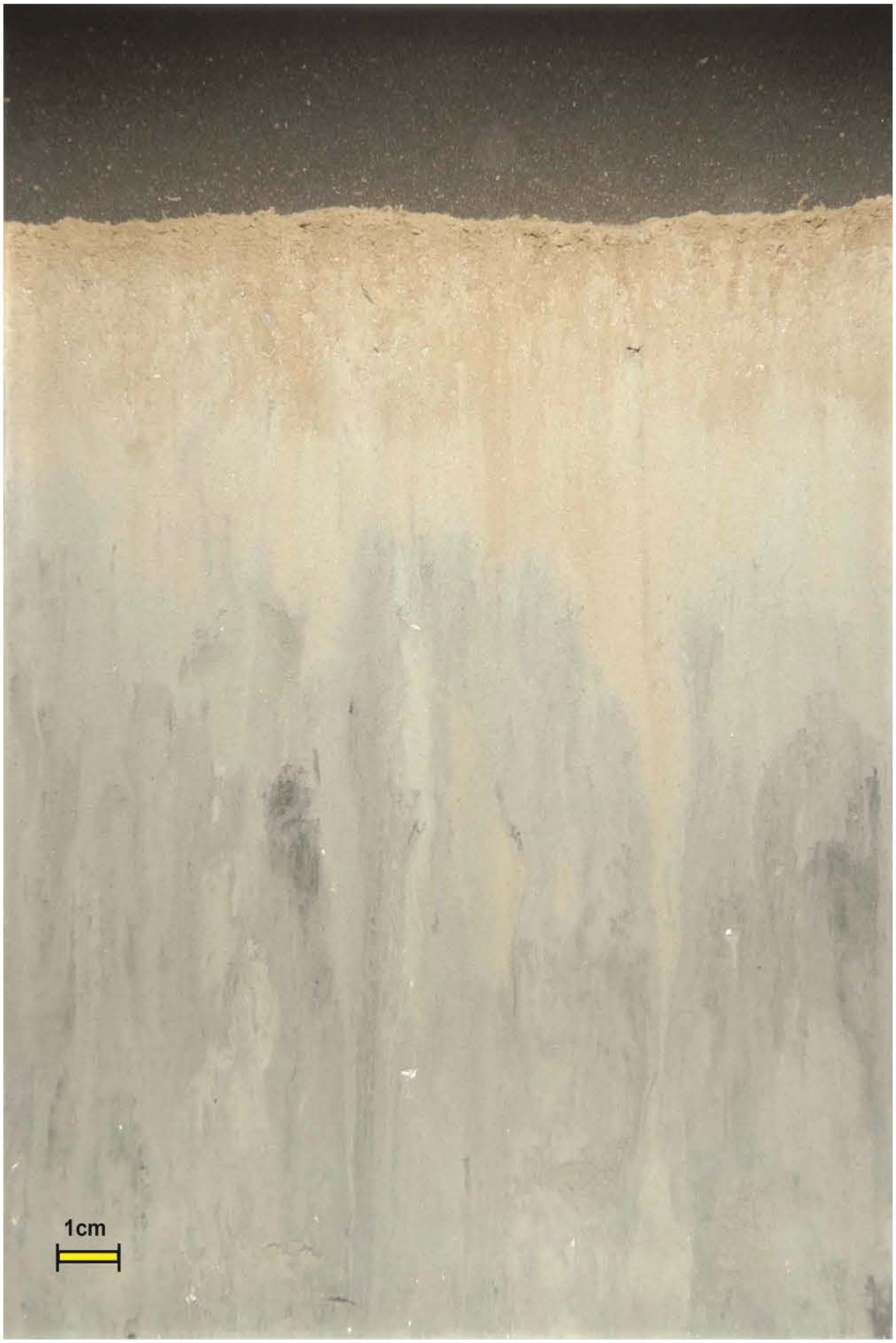


Figure 3-11. Representative profile image from 4500E REF station 4 showing a normal aRPD contrast of light brown oxidized surface sediment overlying darker grey reduced sediment. There was no evidence of a rust-colored phytodetrital layer in any of the images from the 2009 survey.

With the exception of two images from the 2500W REF area where the profile camera overpenetrated, all of the replicate images from the reference areas showed evidence of Stage 3 taxa (Table 3-2, Figure 3-12). Evidence for the presence of Stage 3 fauna included large subsurface burrows, feeding voids, and/or large-bodied infauna (Figure 3-13). Small tubes constructed by opportunistic Stage 1 taxa were also visible at the sediment surface at many of the reference area stations, resulting in a Stage 1 on 3 successional designation (Table 3-2, Figure 3-14). The average number of subsurface feeding voids at the reference area stations ranged from 2 to 8, with an overall average of 4 voids per image per station (Table 3-2).

3.2.2 Disposal Site Stations

3.2.2.1 Sediment Physical Characteristics

Dredged material was observed in the profile images at all 40 disposal site stations (Table 3-3). At all of these stations, the dredged material extended from the sediment surface to below the imaging depth of the profile camera, causing the measured dredged material thickness to be expressed with a "greater than" sign in Table 3-3.

At the CLIS 07 and CLIS 08 mounds, the dredged material was uniformly fine-grained, consisting of silt/clay having a grain size major mode of >4 phi (Table 3-3; Figures 3-15 and 3-16). At the CLIS 05 mound, most of the dredged material also consisted of silt/clay, but fine sand (major mode of 3 to 2 phi) occurred at station 33 and a distinct sand-over-mud stratigraphy was observed at station 36 (Table 3-3; Figures 3-15 and 3-17). At the CLIS 06 mound, the dredged material consisted of very fine (4 to 3 phi) to fine sand (3 to 2 phi) mixed with varying amounts of silt/clay (Table 3-3; Figures 3-15 and 3-18). Although the fine-grained dredged material observed at the majority of stations was reduced (black or dark grey in color below the surface oxidized layer as shown in Figure 3-16), there was no evidence of low dissolved oxygen in the overlying water or subsurface methane generation at any of the locations sampled (Appendix C).

Station-averaged camera prism penetration depth varied across the disposal site stations, ranging from 5.5 to 20.9 cm (Table 3-3). The stations located over the CLIS 07 and CLIS 08 mounds tended to have consistently deep (>15 cm) penetration depths, reflecting the uniform presence of fresh, fine-grained (i.e., muddy) dredged material. Over the CLIS 05 and CLIS 06 mounds, the dredged material had been in place longer and was more variable in composition, with considerably more sand present. The relative firmness of this sand is reflected in the lower prism penetration values (generally ranging from 5 to 15 cm) observed at the CLIS 05 and CLIS 06 mound stations (Table 3-3).

Table 3-3.

Summary of SPI Results for the 2009 CLDS Disposal Site Stations

Mound	Station	Grain Size Major Mode (phi)	Mean Prism Penetration Depth (cm)	Mean Boundary Roughness (cm)	Mean aRPD Depth (cm)	Mean Dredged Material Thickness (cm)	Mean # of Subsurface Feeding Voids	Successional Stages Present (3 replicates)		
CLIS 08	1	>4	19.7	0.8	1.4	>19.7	1	2 going to 3	2 on 3	2 going to 3
	2	>4	17.2	0.7	1.6	>17.2	2	2 going to 3	2 going to 3	1 on 3
	3	>4	18.5	0.6	2.7	>18.5	1	2	IND	1 on 3
	4	>4	16.5	0.7	2.7	>16.5	2	2 going to 3	2	2
	5	>4	14.8	1.1	2.6	>14.8	1	2	1 going to 2	2 going to 3
	6	>4	17.3	1.2	2.8	>17.3	1	2	2 going to 3	2 going to 3
	7	>4	17.8	0.9	1.7	>17.8	0	2	1 on 3	1
	8	>4	18.5	0.7	0.9	>18.5	0	1 going to 2	1	2
	9	>4	17.9	1.3	2.1	>18.0	0	1 going to 2	2	1 going to 2
	10	>4	15.5	0.8	2.2	>15.5	1	1 going to 2	2 going to 3	2 going to 3
	11	>4	17.0	0.5	2.5	>17.0	1	1 on 3	1 going to 2	1 going to 2
	12	>4	15.3	2.1	2.1	>15.3	1	1 going to 2	1 going to 2	1 on 3
	13	>4	17.3	0.7	2.0	>17.3	1	1 going to 2	1 going to 2	2 going to 3
	14	>4	17.0	0.6	1.5	>17.0	0	2 going to 3	1	2 going to 3
CLIS 07	15	>4	17.5	2.7	1.3	>17.5	2	1 going to 2	2 going to 3	1
	16	>4	12.9	1.1	1.3	>12.9	1	1 going to 2	1 going to 2	1 on 3
	17	>4	19.1	0.8	2.1	>19.1	1	1 going to 2	1 going to 2	1 on 3
	18	>4	16.8	0.7	1.5	>16.8	1	1 on 3	2	2
	19	>4	20.9	0.4	2.0	>20.9	0	1 going to 2	1	IND
	20	>4	13.4	0.5	1.7	>13.4	1	1 on 3	1 on 3	1 on 3

IND=Indeterminate

Table 3-3., continued

Summary of SPI Results for the 2009 CLDS Disposal Site Stations

Mound	Station	Grain Size Major Mode (phi)	Mean Prism Penetration Depth (cm)	Mean Boundary Roughness (cm)	Mean aRPD Depth (cm)	Mean Dredged Material Thickness (cm)	Mean # of Subsurface Feeding Voids	Successional Stages Present (3 replicates)		
CLIS 06	21	4 to 3	9.5	1.2	4.0	>9.5	1	3	1 on 3	1 on 3
	22	3 to 2	10.2	1.2	5.4	>10.2	1	1 on 3	1 on 3	1 on 3
	23	3 to 2	6.4	1.1	4.6	>6.4	0	3	3	3
	24	4 to 3	10.6	1.6	4.8	>10.6	5	3	3	1 on 3
	25	3 to 2	6.7	1.1	3.3	>6.7	1	1 on 3	3	3
	26	4 to 3	7.9	1.3	3.2	>7.9	1	1 on 3	3	1 on 3
	27	4 to 3	10.4	1.4	3.3	>10.4	1	3	3	1 on 3
	28	3 to 2	10.6	1.0	3.6	>10.6	3	1 on 3	1 on 3	3
	29	3 to 2	10.7	1.3	3.6	>10.7	2	1 on 3	1 on 3	3
CLIS 05	30	>4	10.8	1.1	2.0	>10.8	4	1 on 3	1 on 3	1 on 3
	31	>4	18.9	0.5	3.5	>18.9	4	1 on 3	1 on 3	1 on 3
	32	>4	11.5	1.3	2.2	>11.5	4	2 on 3	1 on 3	1 on 3
	33	3 to 2	5.5	2.4	3.0	>5.5	6	1 on 3	3	1 on 3
	34	>4	10.8	3.9	1.4	>10.8	2	1 on 3	1 on 3	1 on 3
	35	>4	12.4	0.7	2.6	>12.4	1	2 going to 3	2 going to 3	1 on 3
	36	3 to 2/>4	13.9	0.8	2.7	>13.9	6	1 on 3	1 on 3	1 on 3
	37	>4	14.6	1.9	4.0	>14.6	5	1 on 3	1 on 3	1 on 3
	38	>4	15.8	0.8	4.1	>15.8	4	1 on 3	1 on 3	1 on 3
	39	>4	14.1	1.4	2.2	>14.1	1	2 going to 3	1 on 3	1 on 3
	40	>4	13.3	0.8	3.4	>13.3	5	1 on 3	1 on 3	1 on 3

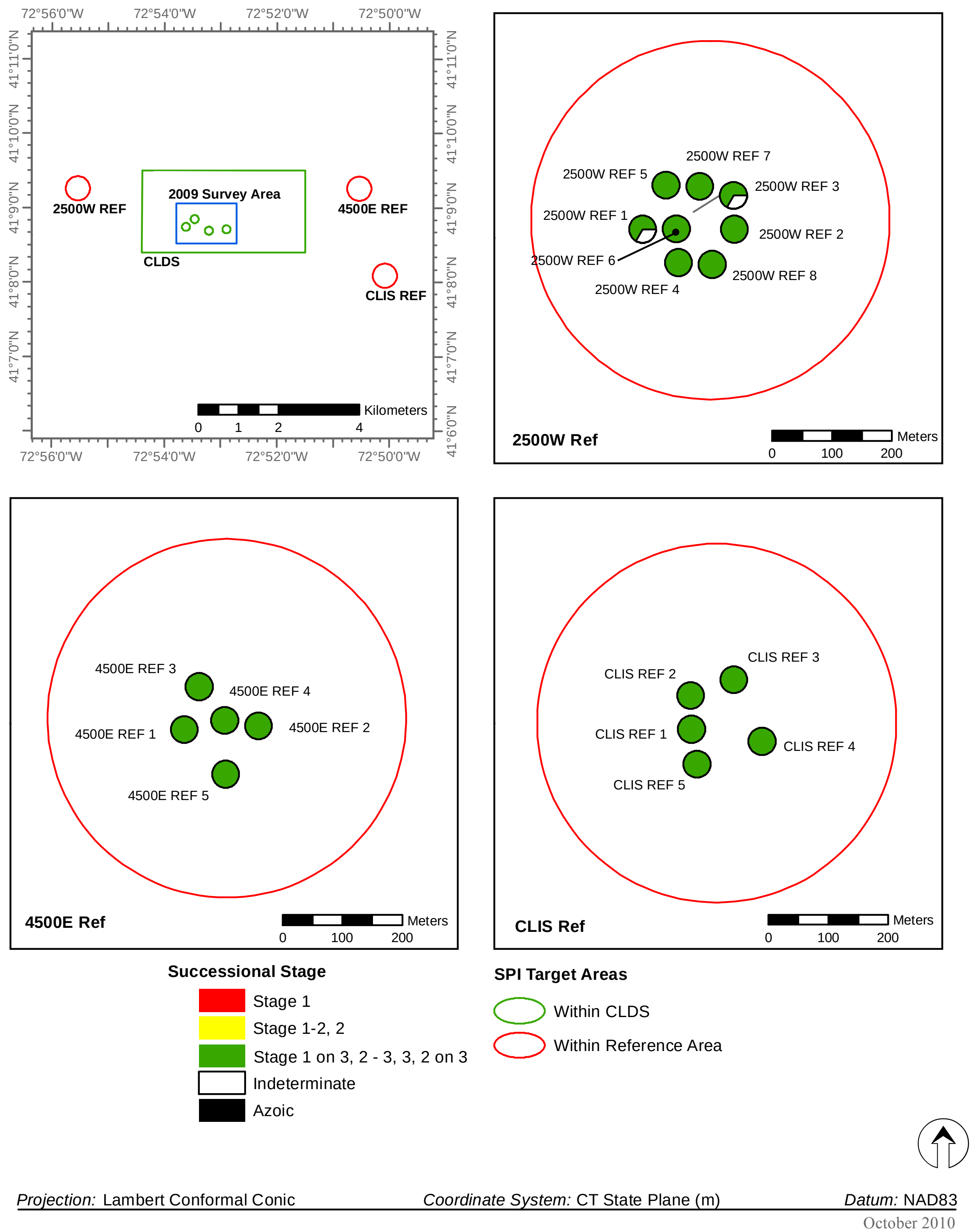
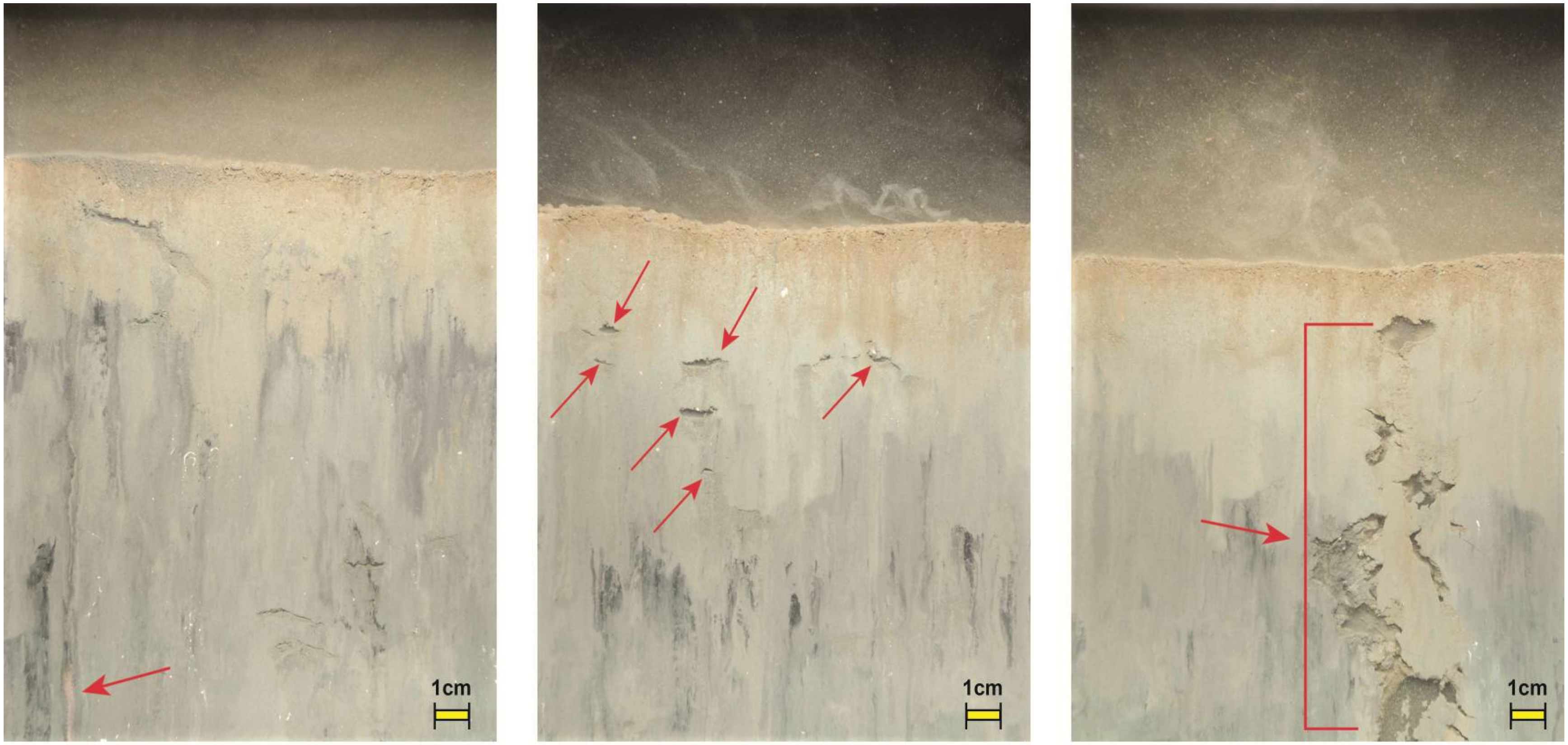


Figure 3-12. Infaunal successional stages at the reference area SPI stations, October 2009



4500E REF Station 5, Replicate A

4500E REF Station 2, Replicate A

CLIS REF Station 4, Replicate D

Figure 3-13. Representative profile images from the reference areas showing evidence of Stage 3 infauna in the form of a large worm (left image), multiple subsurface feeding voids (center image), and a prominent vertical burrow (right image).

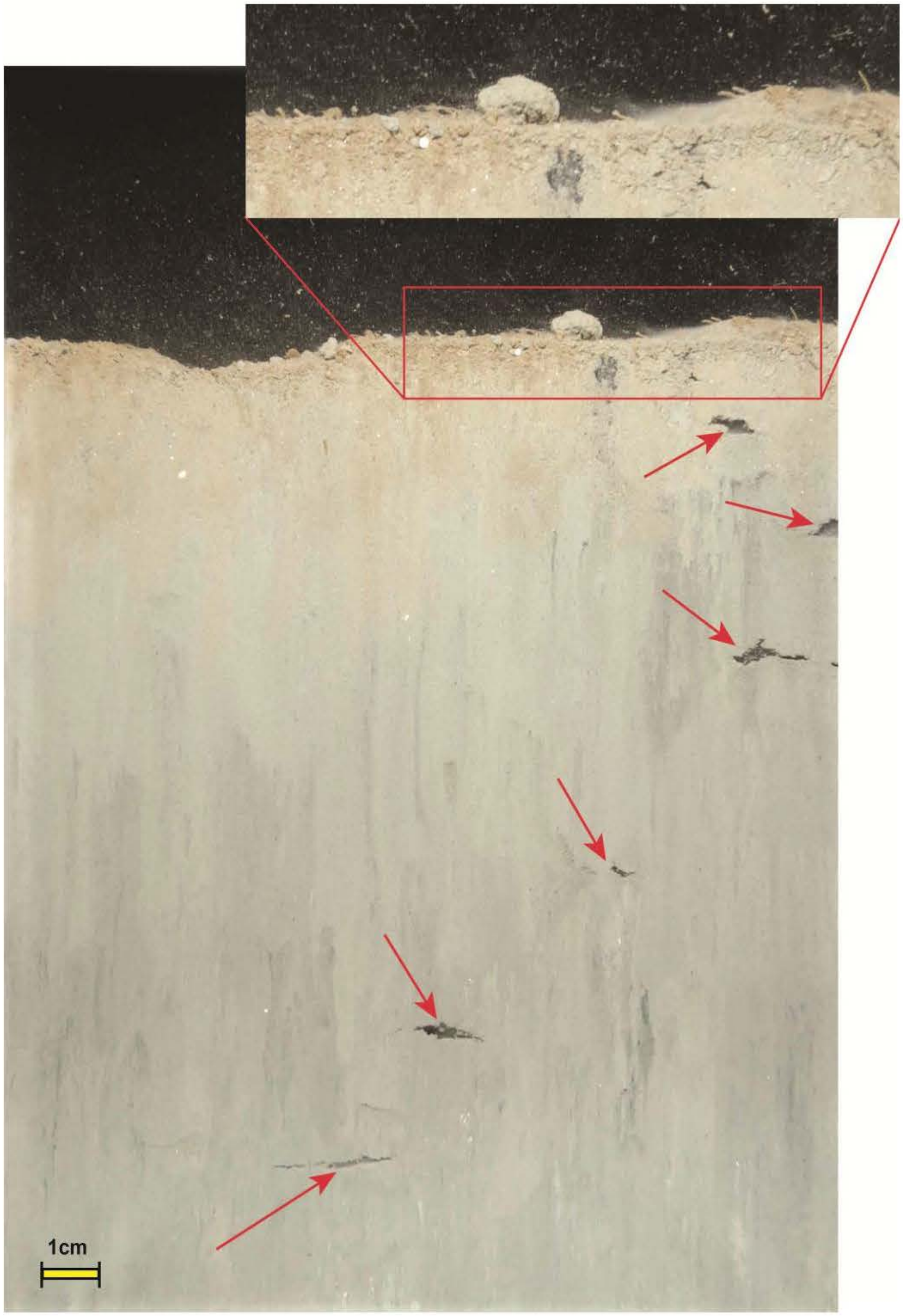


Figure 3-14. Profile image from 2500W REF station 6 providing an example of Stage 1 on 3. Multiple feeding voids occur at depth (arrows), while small Stage 1 worm tubes are visible at the sediment surface (inset).

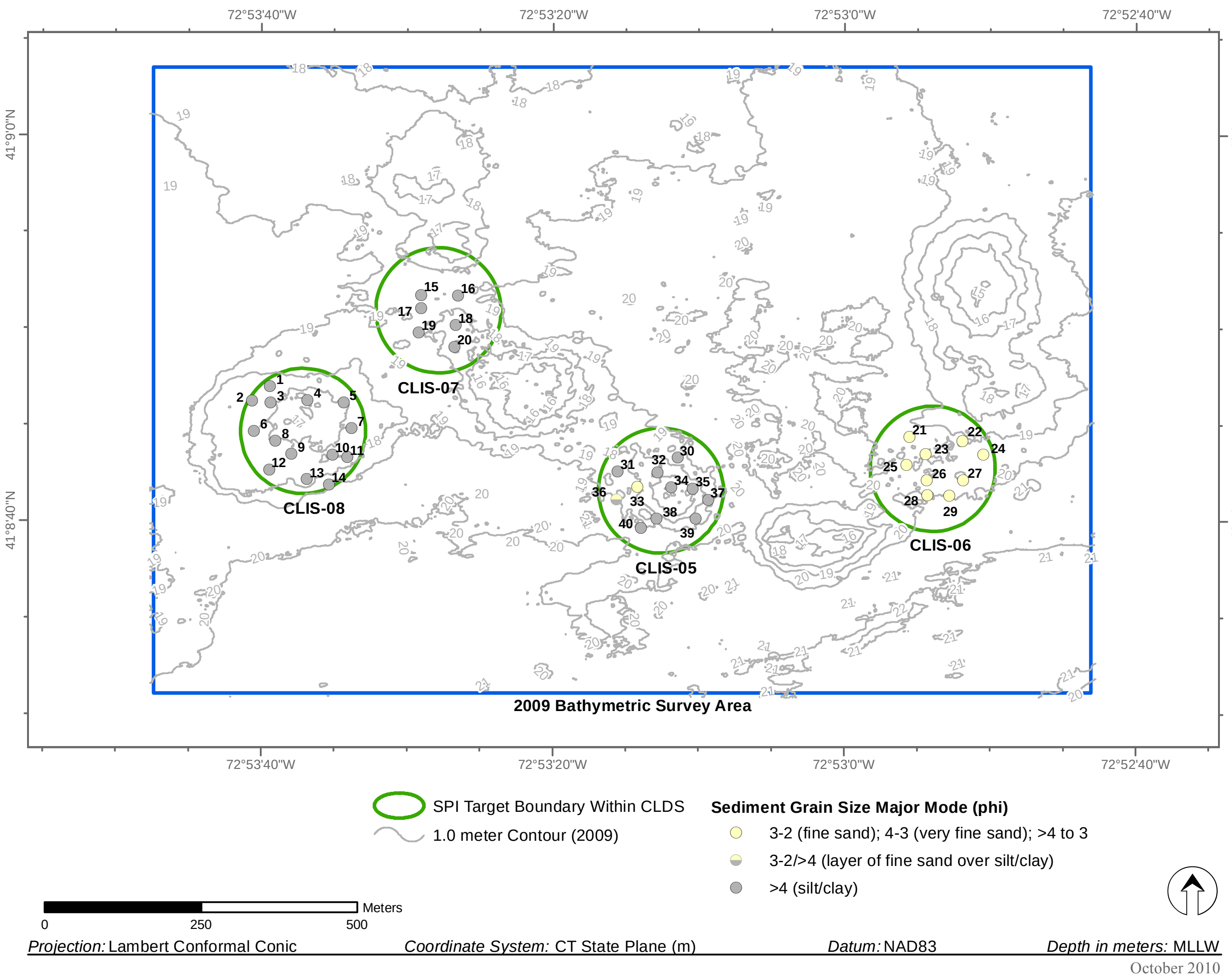
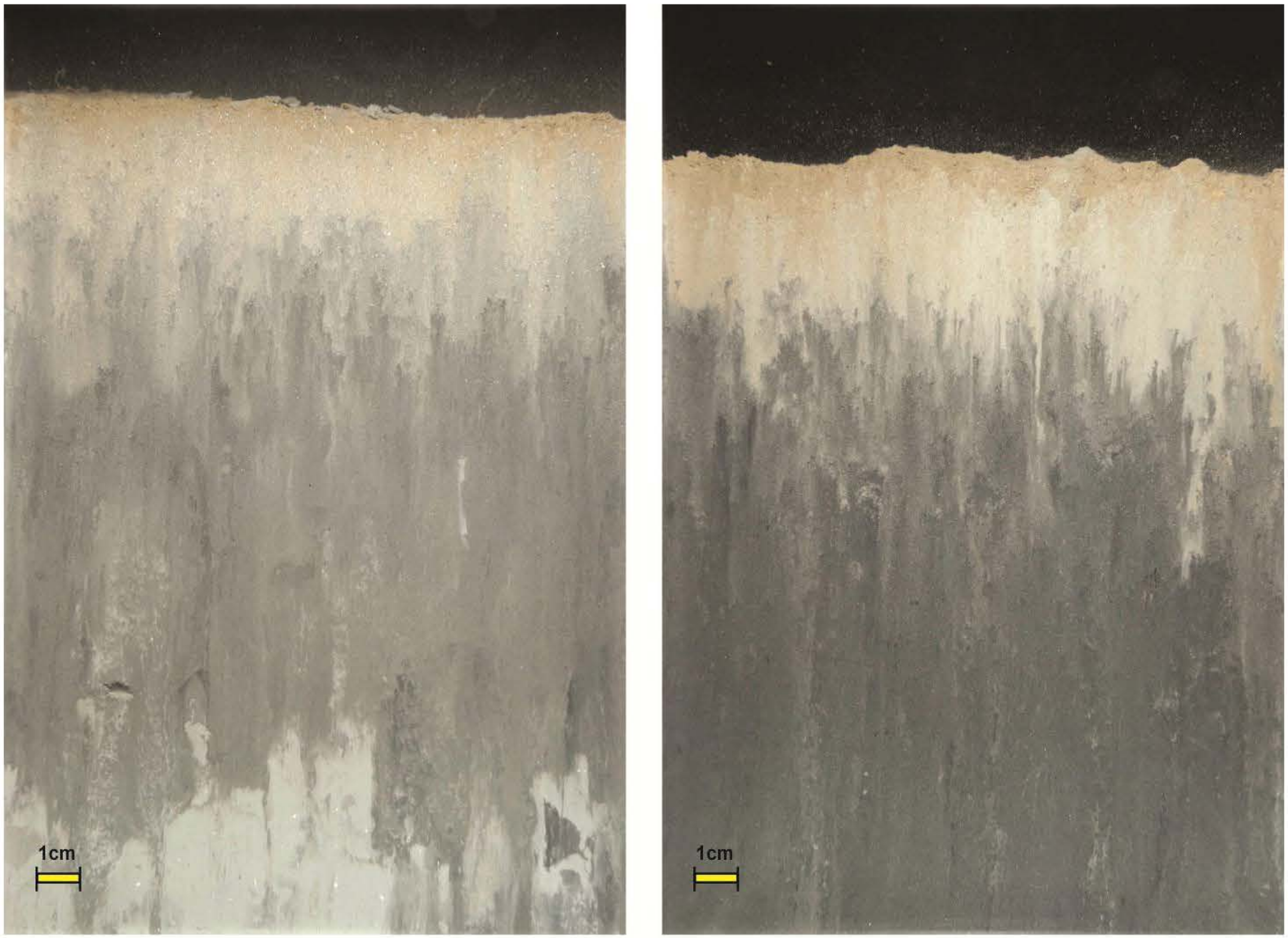


Figure 3-15. Grain size major mode (in phi units) at CLDS stations, October 2009

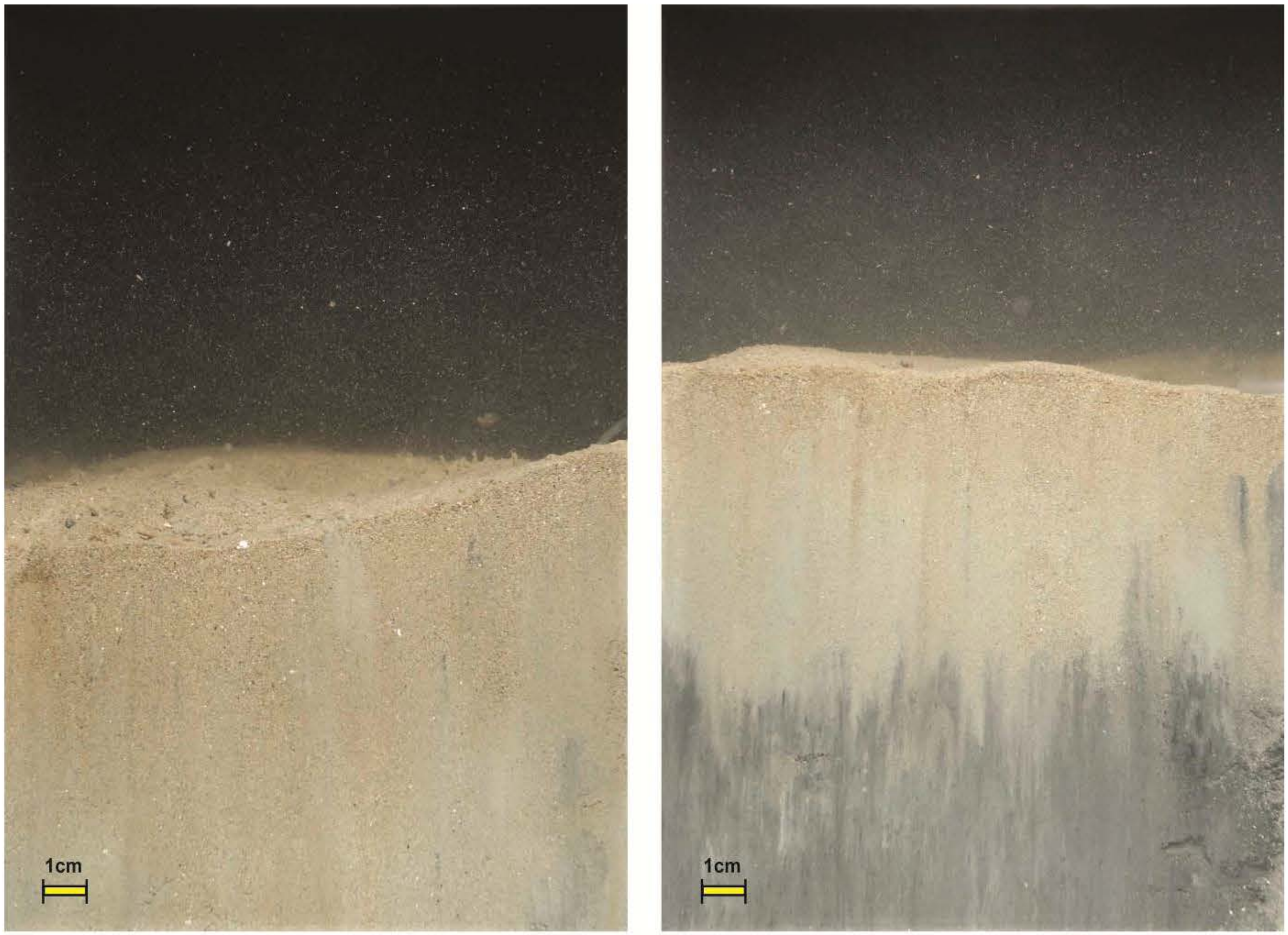


CLDS Station 18, Replicate A

CLDS Station 3, Replicate A

Figure 3-16. Representative profile images showing typical reduced, fine-grained dredged material (grain size major mode of >4 phi) at the 2007 (left image) and 2008 (right image) mounds

Figure 3-17. Profile image showing sand-over-mud stratigraphy at station 36 located on the 2005 mound



CLDS Station 24, Replicate D

CLDS Station 29, Replicate B

Figure 3-18. Profile images from the 2006 mound showing fine sand (left image) and sand-over-mud stratigraphy (right image)

Station-averaged small-scale boundary roughness ranged from 0.4 to 3.9 cm, with an overall site average of 1.1 cm (Table 3-3). The origin of this small-scale topography was split approximately equally between physical and biological processes among the station replicates (Appendix C). 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.

3.2.2.2 Biological Conditions and Benthic Recolonization

The mean aRPD values at the stations within CLDS ranged from 0.9 to 5.4 cm, with an overall site average of 2.6 cm (Table 3-3, Figure 3-19). The highest average aRPD values, ranging from 3.6 to 5.4 cm, were found consistently among the stations at the CLIS 06 mound (Figure 3-19). Four of the stations at the CLIS 05 mound had relatively high values of 3.0 to 4.1 cm, while the other stations at this mound had intermediate values ranging from 1.4 to 2.7 cm (Figure 3-19). At the CLIS 07 and CLIS 08 mounds, average aRPD values fell in the low to intermediate range of 0.9 to 2.8 cm (Table 3-3, Figure 3-19).

At the CLIS 05 and CLIS 06 mounds, all of the replicate images showed evidence of Stage 3 infauna being present (Table 3-3, Figure 3-20). Evidence of Stage 3 organisms typically consisted of subsurface feeding voids and burrows (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 07 and CLIS 08 mounds, evidence of Stage 3 taxa was more sporadic, and there was greater variability among the replicate images compared to the CLIS 05 and CLIS 06 mounds (Table 3-3, Figure 3-20). Benthic succession at these mounds 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).

3.3 Statistical Comparisons

3.3.1 Mean aRPD Depths

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 indicate that the area residuals (i.e., each observation minus the area mean) were normally distributed (Shapiro-Wilk's test, p-value = 0.7). Group standard

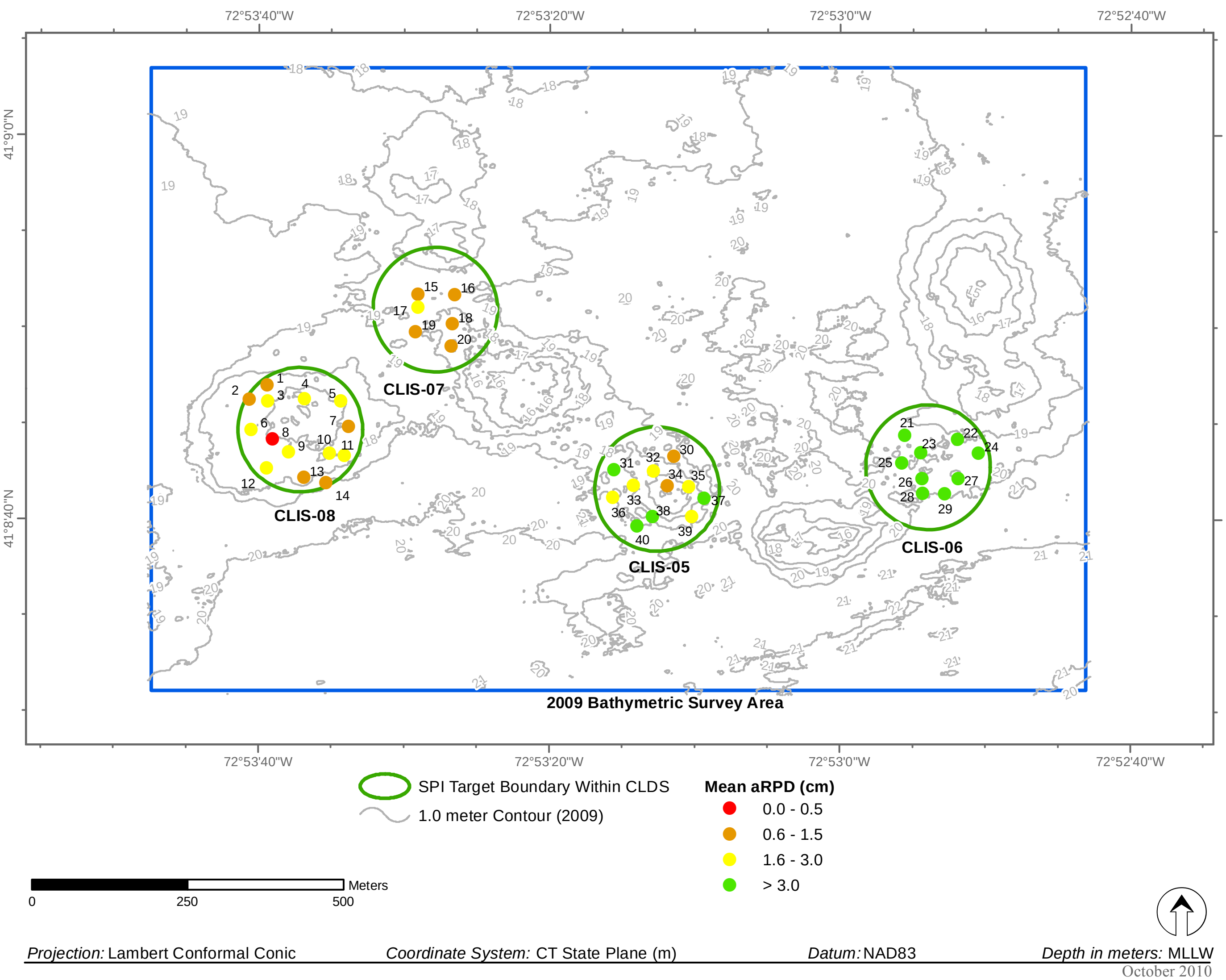


Figure 3-19. Average aRPD depths at the CLDS SPI stations, October 2009

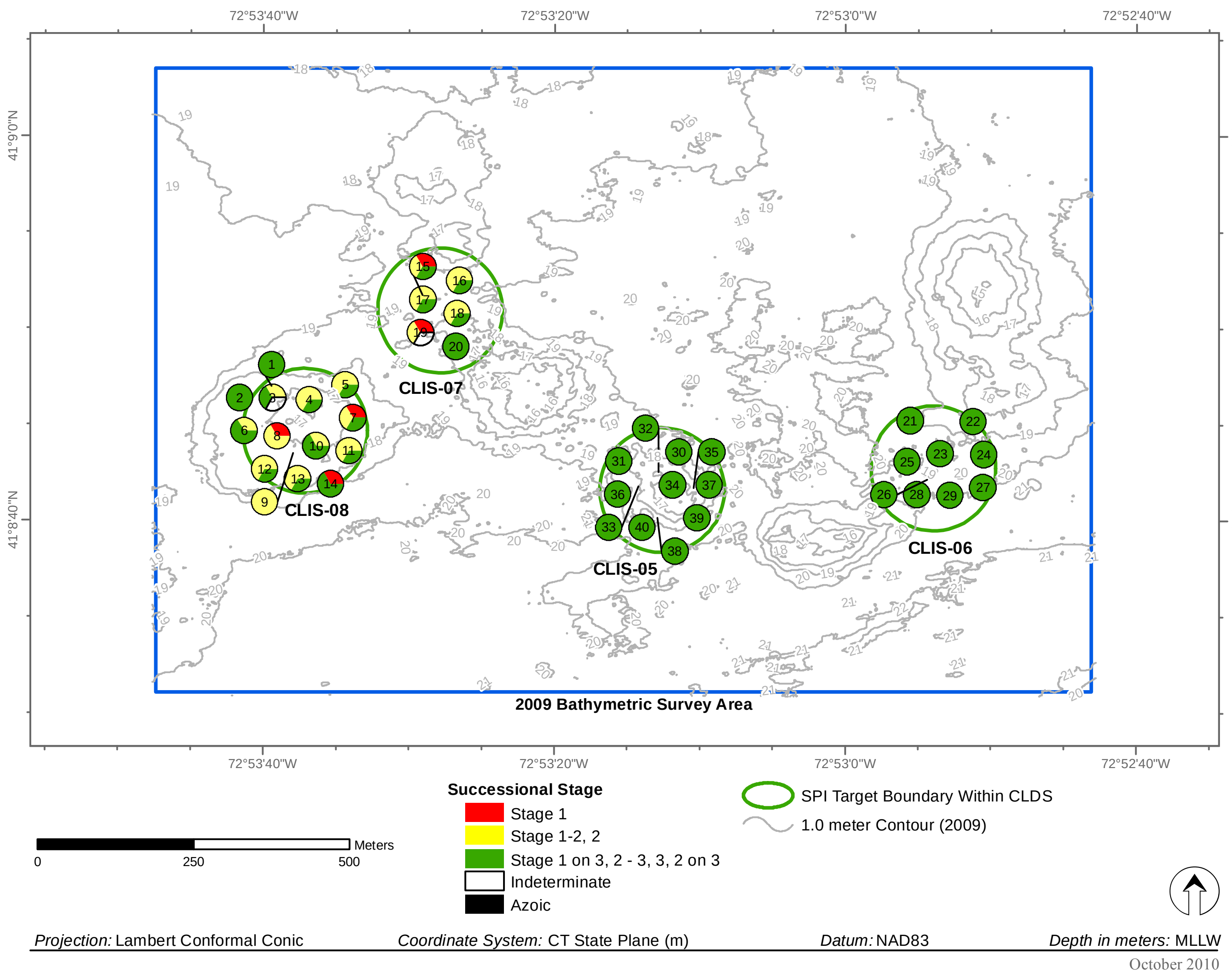


Figure 3-20. Infaunal successional stages at the CLDS SPI stations, October 2009

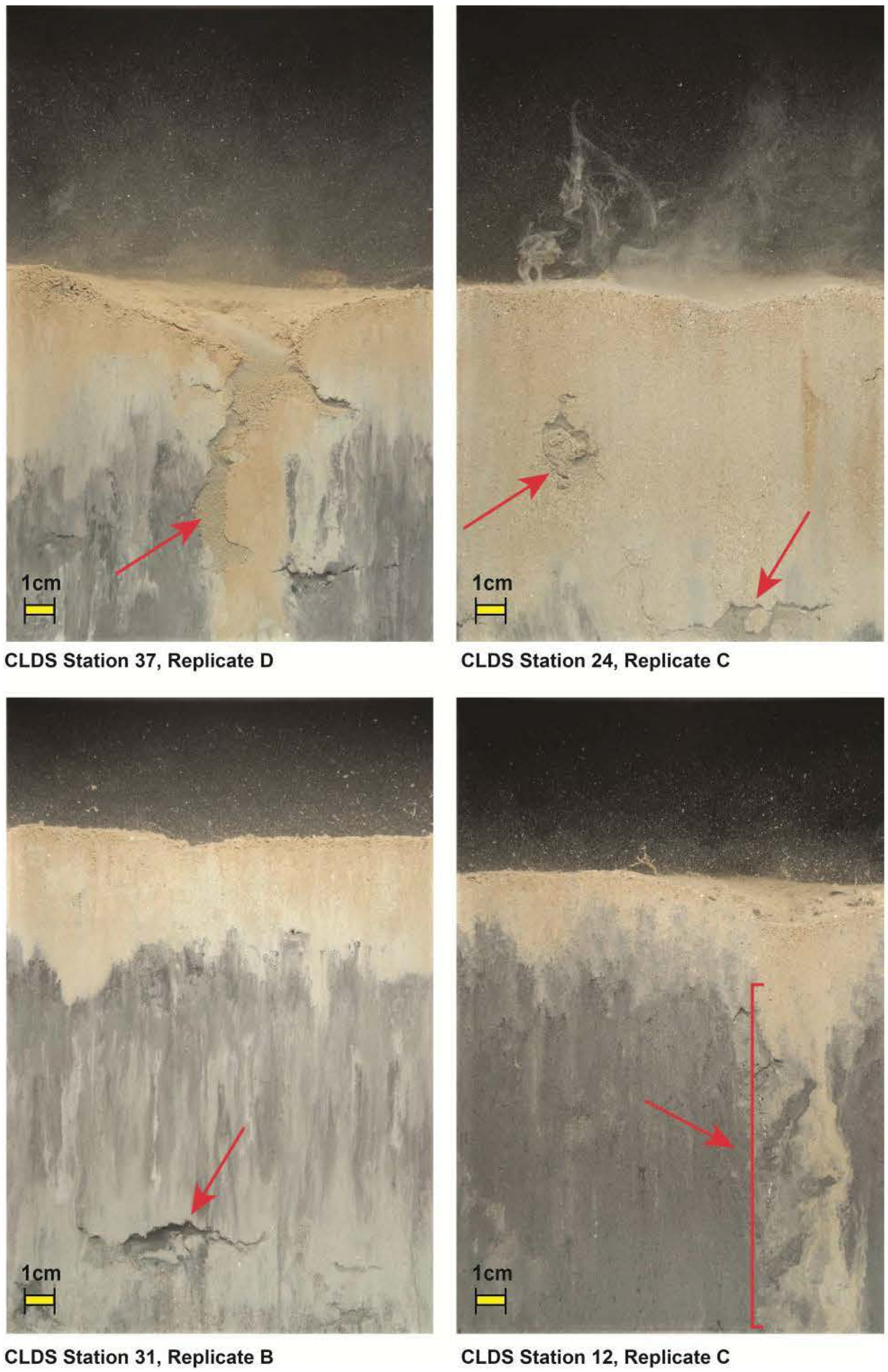


Figure 3-21. Evidence of Stage 3 infauna was observed in profile images at various CLDS stations. Illustrated clockwise from the upper left are a large vertical burrow opening, feeding voids in sandy dredged material, a vertical oxidized burrow, and a large deep feeding void.

Figure 3-22. Profile image showing a large vertical burrow (Stage 3) and a dense assemblage of opportunistic worm tubes at the sediment surface (Stage 1), resulting in a Stage 1 on 3 successional designation.

Figure 3-23. Profile image from station CLDS-09 at the 2008 mound illustrating a transitional successional status from Stage 1 to 2. Small Stage 1 worm tubes are visible at the sediment surface, and numerous small tunnels produced by burrowing Stage 2 meiofauna (e.g., crustaceans and bivalves) occur just below the surface.

deviations ranged from 0.3 to 0.9 with the smallest standard deviations occurring at 4500E REF reference area and the CLIS 07 Mound (Table 3-4). Levene's test for equality of variances was not rejected (p>0.05), so a single pooled variance estimate was used for all groups.

If the confidence region for the difference between the mean for the reference areas and each mound was fully contained within the interval [-1, +1], the two means were considered significantly equivalent. Disposal mounds CLIS 05, CLIS 07, and CLIS 08 all had significantly lower average aRPD values than the reference areas, with differences in means ranging from 1.5 to 2.7 cm (Table 3-4, Figure 3-24). In contrast, the average aRPD value for the CLIS 06 mound was significantly equivalent to reference, with a difference in means of approximately 0.34 cm (Table 3-4, Figure 3-24).

3.3.2 Successional Stage Ranks

Both the CLIS 05 and CLIS 06 mounds consistently had successional stages of Stage 3 or equivalent. Likewise, the successional stage rank for all of the reference areas was 3. With identical means and zero variance, no statistics were needed to conclude statistical equivalence in successional stages between the reference areas and the CLIS 05 and CLIS 06 mounds (Table 3-5, Figure 3-24). In contrast, the CLIS 07 and CLIS 08 mounds had mean successional stage ranks of 2.7 and 2.6, respectively (Table 3-5, Figure 3-24). Because the successional stage rank variables are inherently nonnormal, the bootstrap-*t* approach described in Appendix B was used. The resulting statistical test indicated that the CLIS 07 and CLIS 08 mounds differed significantly from the reference areas in terms of mean successional stage rank (Table 3-5).

Table 3-4.

Summary Statistics and Results of Inequivalence Hypothesis for aRPD Values

Difference Equation	**Observed Difference ($\hat{d}$)**	**SE($\hat{d}$)**	**df for SE($\hat{d}$)**	**95% Lower Confidence Bound**	**95% Upper Confidence Bound**	
$Mean_{REF} - Mean_{CLIS\ 05}$	1.5	0.25	51	1.1	1.9	d
$Mean_{REF} - Mean_{CLIS\ 06}$	0.34	0.27	51	-0.11	0.80	s
$Mean_{REF} - Mean_{CLIS\ 07}$	2.7	0.31	51	2.1	3.2	d
$Mean_{REF} - Mean_{CLIS\ 08}$	2.3	0.24	51	1.9	2.7	d

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.

Table 3-5.

Summary Statistics and Results of Bootstrap-*t* Inequivalence Hypothesis for Successional Stage Rank Values

Difference Equation	Observed Difference ($\hat{d}$)	SE($\hat{d}$)	df for SE($\hat{d}$)	95% Lower Confidence Bound	95% Upper Confidence Bound	
$Mean_{REF} - Mean_{CLIS\ 05}$	0	0	N/A	0	0	s
$Mean_{REF} - Mean_{CLIS\ 06}$	0	0	N/A	0	0	s
$Mean_{REF} - Mean_{CLIS\ 07}$	0.3	0.23	20	-0.35	0.62	d
$Mean_{REF} - Mean_{CLIS\ 08}$	0.4	0.10	28	0.25	0.60	d

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.

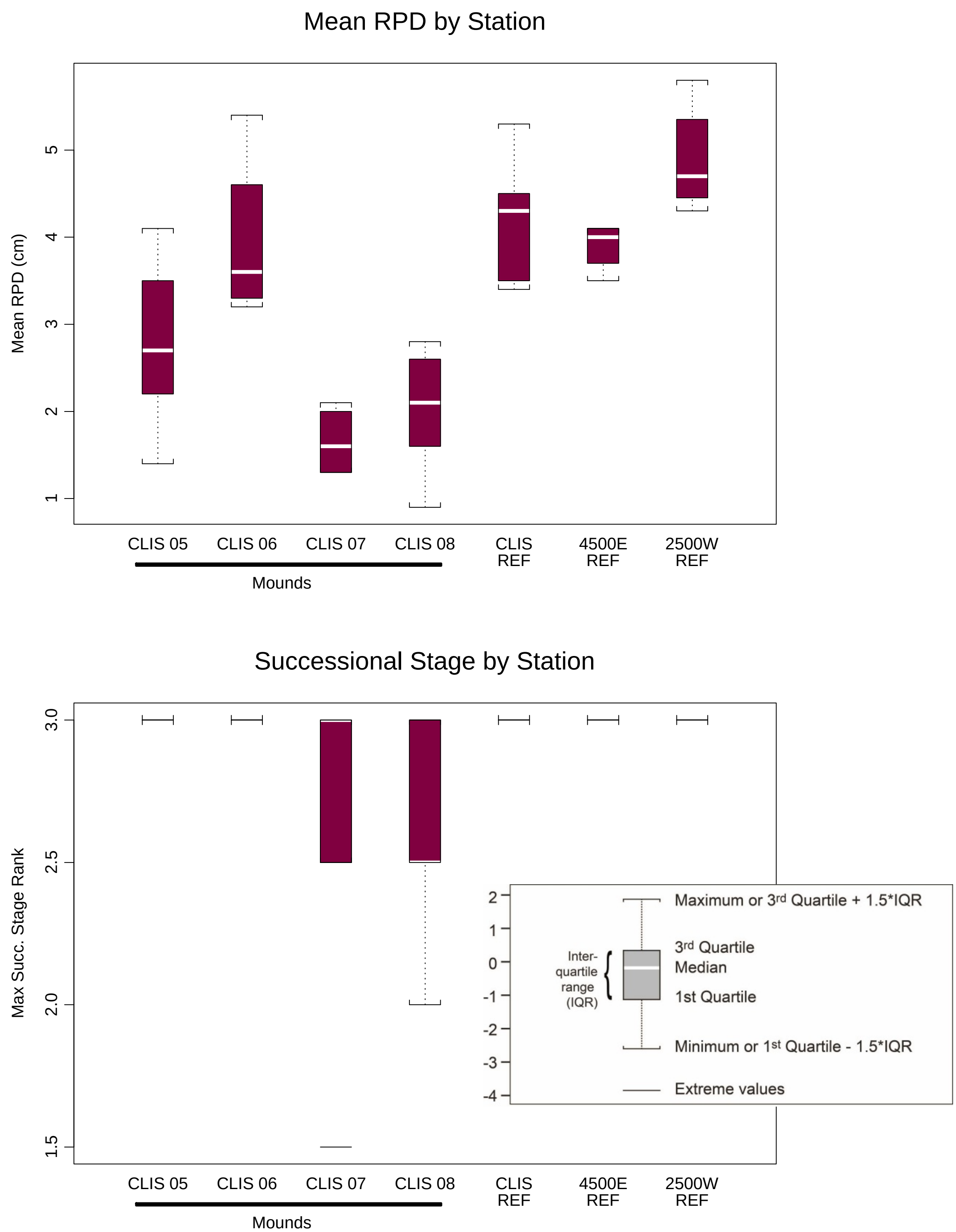


Figure 3-24. Boxplots showing distribution of mean aRPD values and successional stage rank values at CLDS mounds and reference areas for the 2009 SPI survey

4.0 DISCUSSION

The objectives of the 2009 CLDS survey were to characterize the seafloor topography, distribution of dredged material, and to assess the benthic recolonization status within the surface sediments of the area where recent disposal activities have occurred. These disposal activities were concentrated over four different areas corresponding to four consecutive disposal seasons (2005 to 2008). These objectives were accomplished using bathymetric, SPI, and PUC survey techniques.

4.1 Seafloor topography

As expected, the “depth difference” comparison between the 2005 and 2009 multibeam bathymetric surveys revealed that a significant accumulation of dredged material (i.e., a distinct mound) was created on the seafloor in each of the four areas that corresponded to disposal season activity (Figure 3-3).

The overall size of each mound generally was proportional to the volume of dredged material disposed during each season (Table 3-1). Three of the new mounds (CLIS 05, CLIS 06, and CLIS 07) represented additions of dredged material to the existing, crescent-shaped line of mounds that have coalesced into a nearly continuous berm on the seafloor (Figure 3-4). As of the 2009 survey, the height of this berm above the surrounding seafloor was variable, ranging from approximately 0.5 to 3 m. The berm as it currently exists represents the southern “wall” of a fairly large CAD area that has been created in this area of CLDS, consistent with site management objectives. The CLIS 08 mound has begun to form a berm connecting the MQR mound with the CLIS 07, NWK, CLIS 88, CLIS 92, and CS-1 mounds (Figures 1-4 and 3-4).

4.2 Distribution of Dredged Material

Dredged material distribution can be assessed with a combination of survey techniques (high resolution bathymetry, backscatter patterns and SPI results). There was generally good agreement between the SPI grain size results and the map of backscatter intensity (Figure 4-1). Specifically, there was relatively high backscatter in the area of CLIS 06 mound, suggesting a harder or more compact substrate due to the presence of coarser sediments (e.g., sand and gravel). The profile images at this mound confirmed the widespread presence of relatively firm, fine to very fine sand (Figure 3-18). At the CLIS 05 mound, there was intermediate backscatter, and the SPI results indicated that the surface sediments were comprised predominantly of firm silt/clay, as well as some sand (Figure 3-17). The firmer texture of the dredged material over this mound presumably

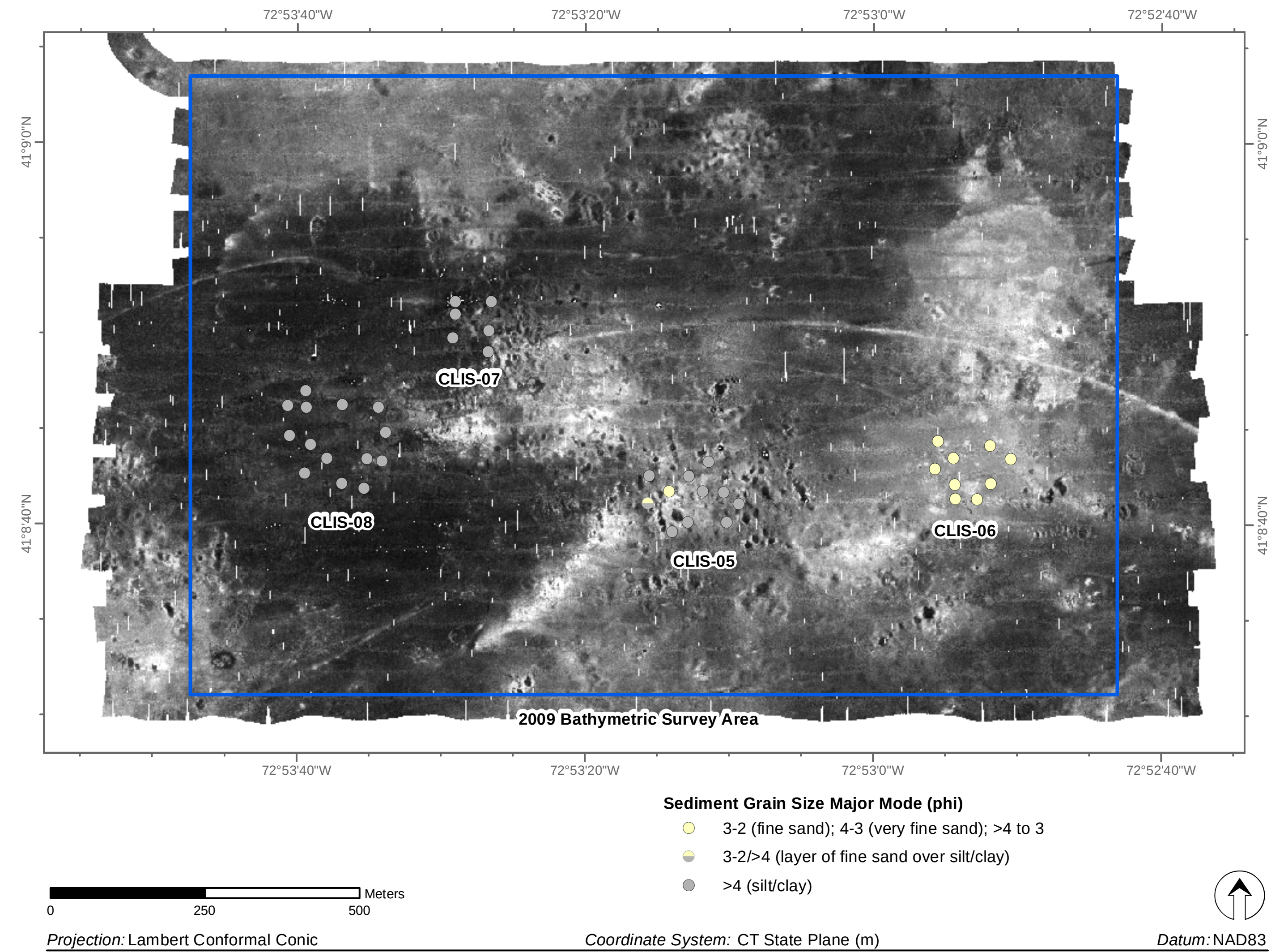


Figure 4-1. Backscatter mosaic at CLDS (2009) with the grain size major mode (phi) from the SPI survey

reflected the greater amount of time that it had to consolidate compared to the other three mounds (Figure 4-2).

In contrast, there was relatively low backscatter associated with the CLIS 07 and CLIS 08 mounds, and the profile images indicated that both mounds were comprised of soft silt/clay of apparent high water content (Figure 3-16). Because the fine-grained dredged material at these two mounds was of more recent origin, it is reasonable to assume that it was still in the process of undergoing dewatering and consolidation at the time of the 2009 survey.

The backscatter results can also be used to track the development and reworking of disposal traces (ENSR 2007). Depending on several factors including water depth, the water content of dredged material, and the grain size of both the dredged material and the surrounding seafloor; the impact of the disposed material on the bottom may form craters of various shapes or ring shapes, or it may result in a relatively smooth bottom . The disposal traces can be seen in the backscatter mosaic (Figure 3-5) as well as in the multibeam data (Figure 3-1). For the four disposal seasons covered by this survey, the four resulting mounds exhibited distinct characteristics in terms of topographic features at the scale of 10–100 m that did not directly correspond with variations in grain size results from the SPI survey (Figures 4-3, 4-4, 4-5, and 4-6). The larger mounds appear to have developed sufficient sediment thickness for the ongoing disposal activities to have deformed the mound surface; the deformation resulted in pits in one instance (CLIS 05, Figure 4-3) and a flat plateau in another instance (CLIS 08, Figure 4-6). The smaller mounds developed more ring structures with fine-grained material (CLIS 07, Figure 4-5) and small pits with sandy material (CLIS 06, Figure 4-4).

Further insight into the patterns of disposal traces can be gained by comparison with backscatter and multibeam results from prior surveys (Figure 4-7). Side-scan sonar results from CLDS published by USGS were collected in June 1997 prior to most of the disposal activity in the survey area (Poppe et al. 2001). These results clearly showed the NHAV-74, CLIS 95/96, MQR and NWK mounds as well as numerous traces of barge disposal (high reflectance patches) associated with some of the mounds (Figure 4-7). Many of the traces were faint but still visible in the 2009 results and some disposal impact craters have been filled or covered with new material (Figure 3-5).

Disposal traces have been observed and catalogued at CLDS with regard to the history of disposal sequences (ENSR 2007). A simple categorization was documented based on the 2005 bathymetry and 1997 backscatter results (ENSR, Table 4-1). Observation of these disposal traces in the historical sequence available in this survey (disposal from 2005-2008) help to clarify the association of types of traces with disposal processes.

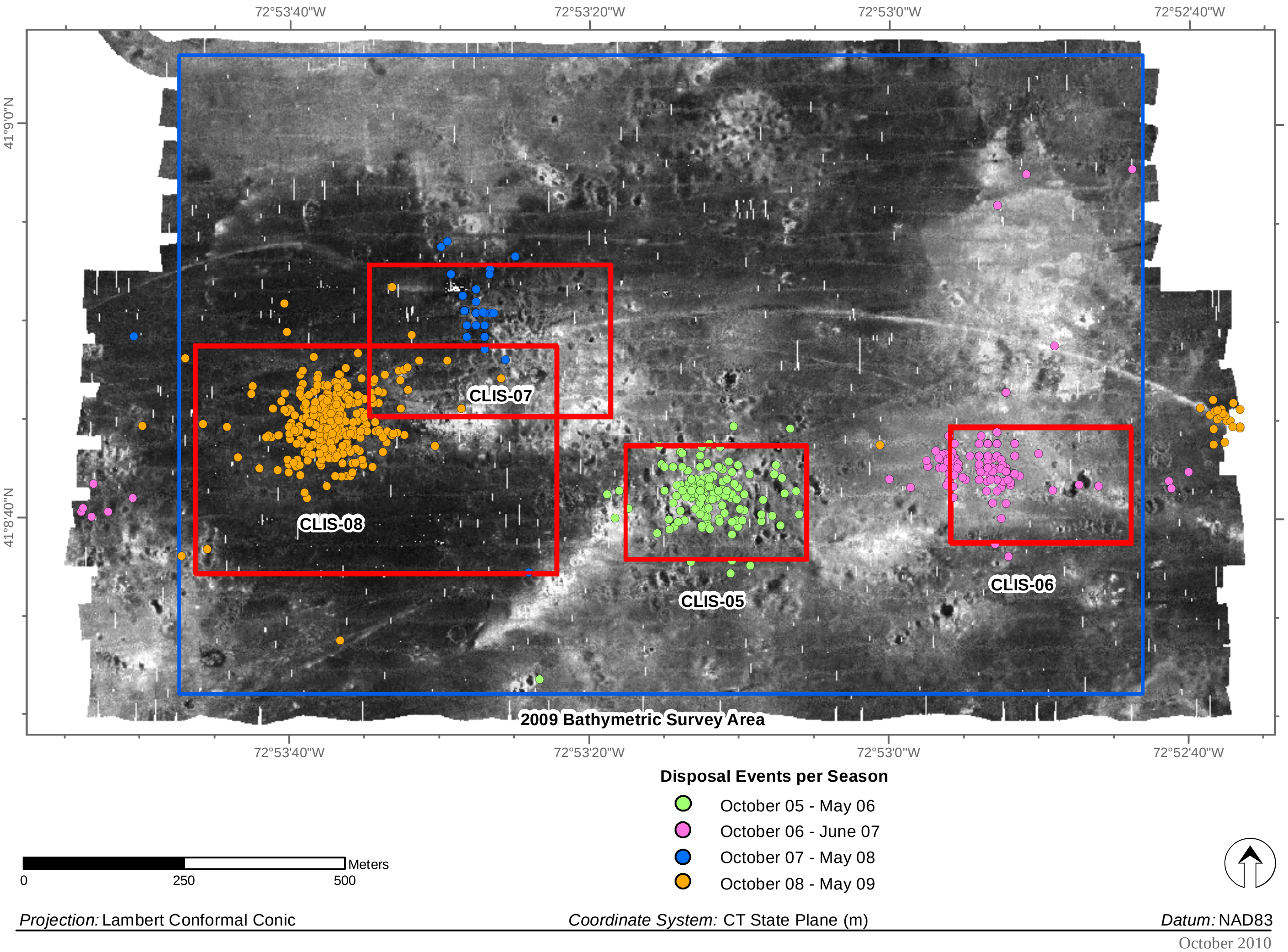


Figure 4-2. Backscatter mosaic at CLDS (2009) with disposal events per season. Insets indicate hillshaded bathymetry of individual mounds shown (from top) in Figures 4-3, 4-4, 4-5, and 4-6.

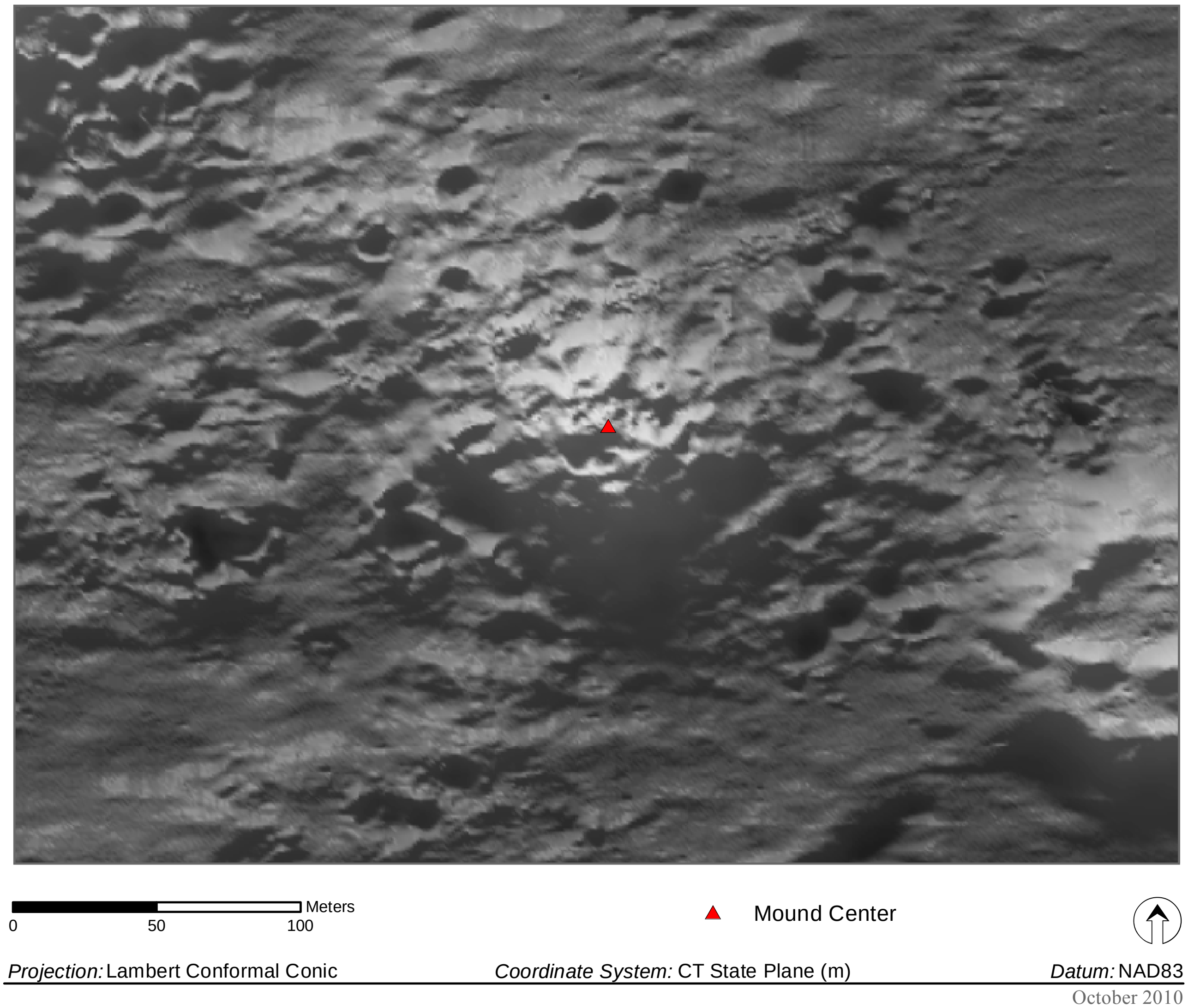


Figure 4-3. Multibeam bathymetric data collected at CLDS in September 2009. The hillshading highlights microtopographic features at the CLIS 2005 mound.

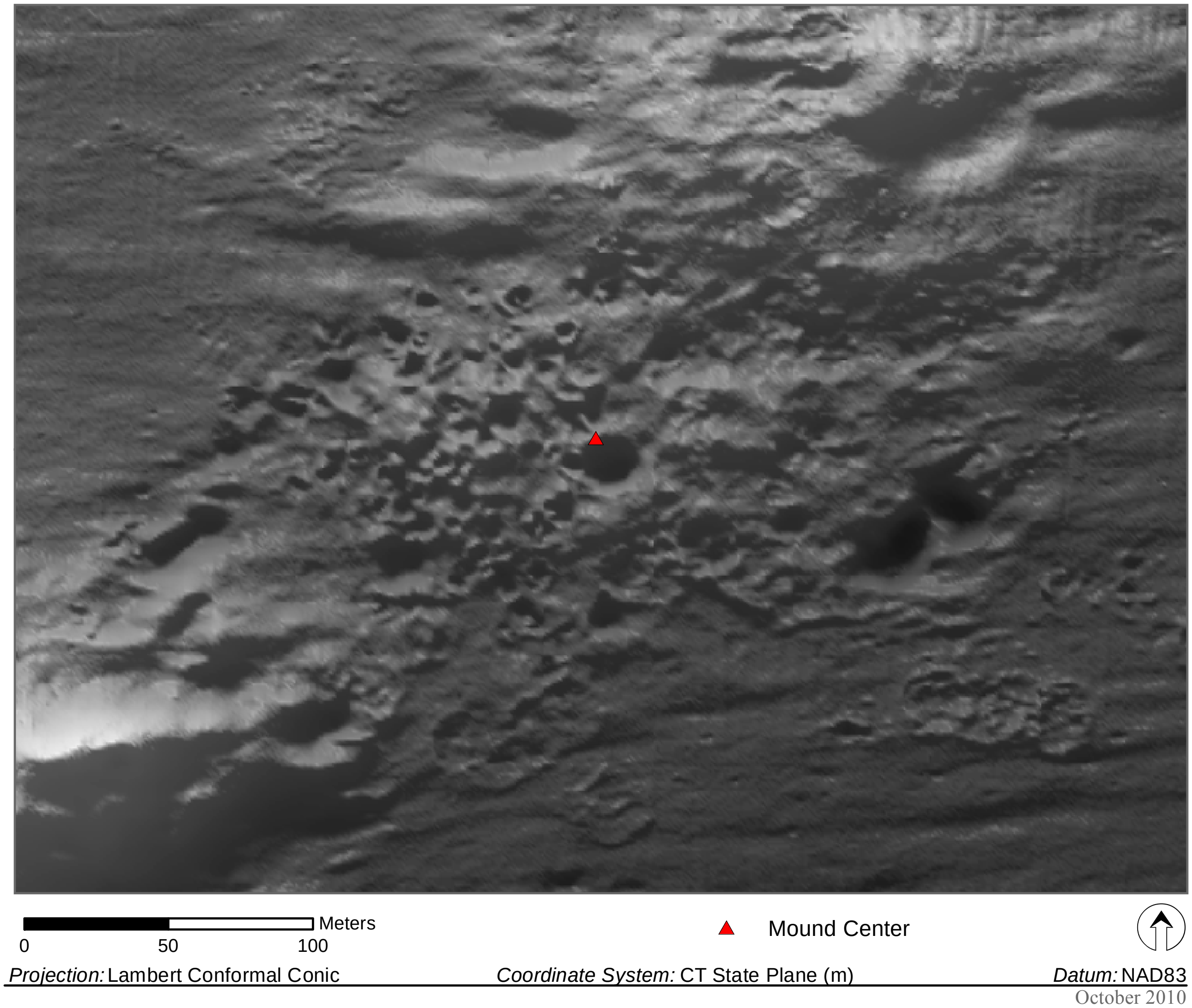


Figure 4-4. Multibeam bathymetric data collected at CLDS in September 2009. The hillshading highlights microtopographic features at the CLIS 2006 mound.

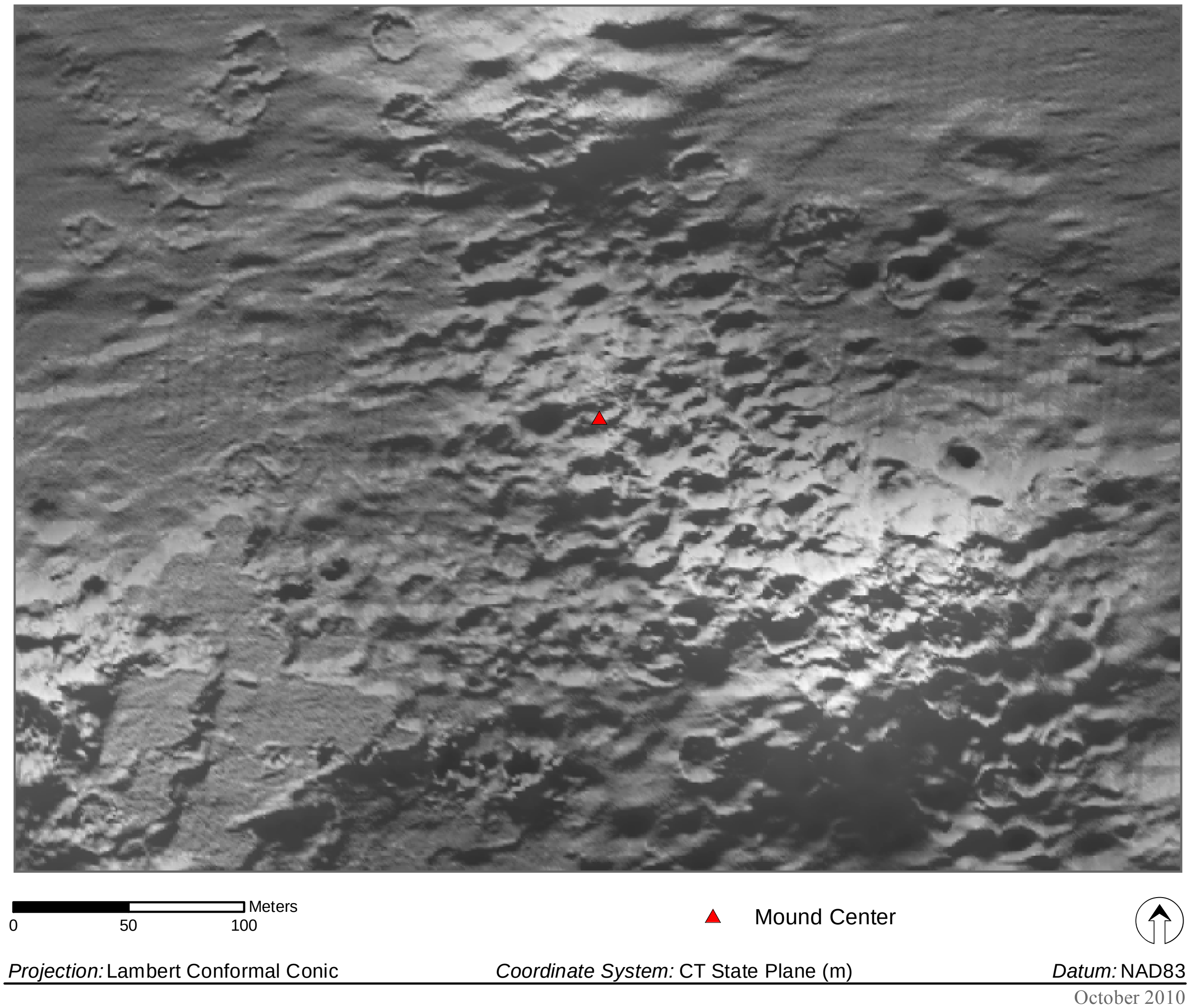


Figure 4-5. Multibeam bathymetric data collected at CLDS in September 2009. The hillshading highlights microtopographic features at the CLIS 2007 mound.

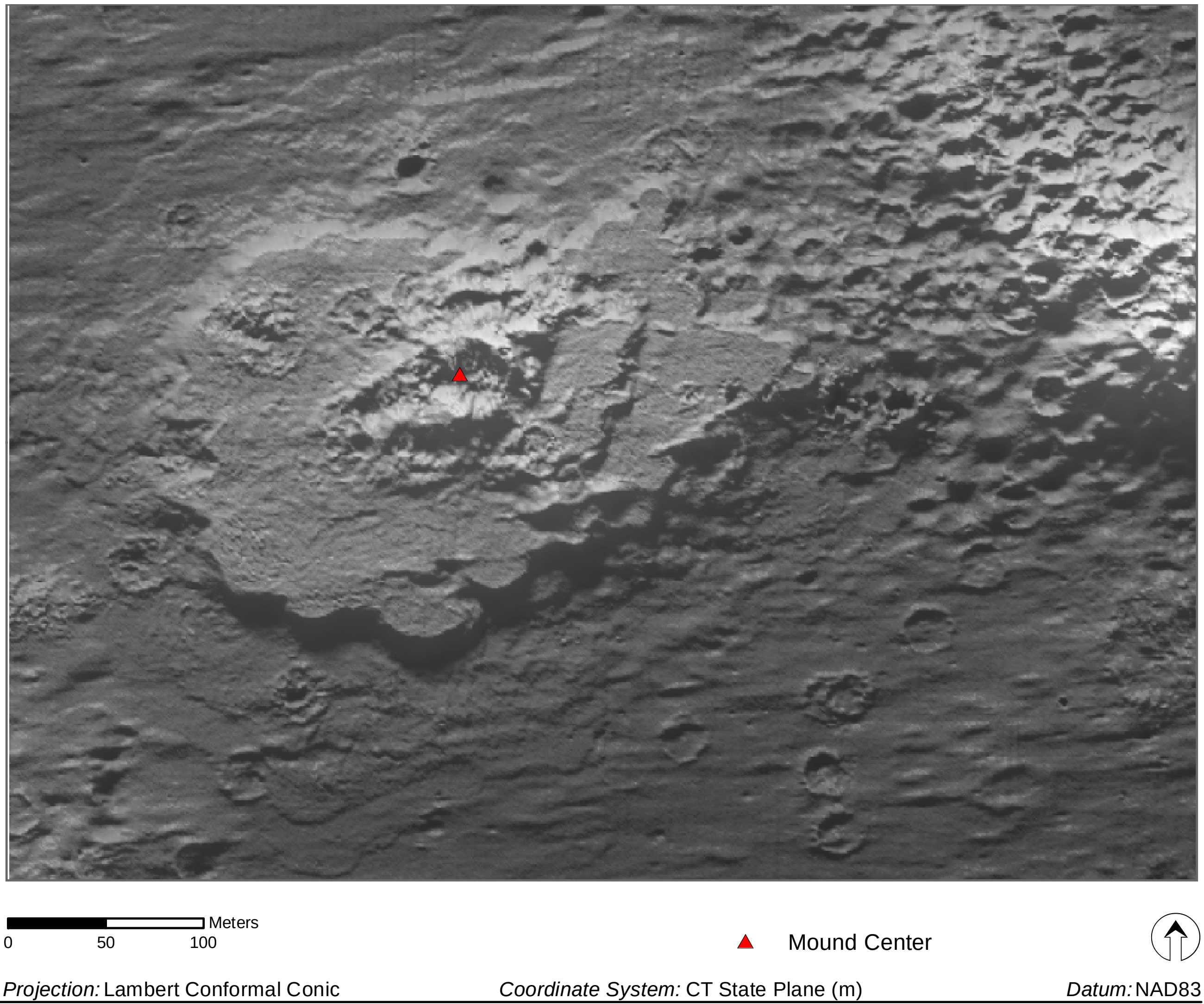


Figure 4-6. Multibeam bathymetric data collected at CLDS in September 2009. The hillshading highlights microtopographic features at the CLIS 2008 mound.

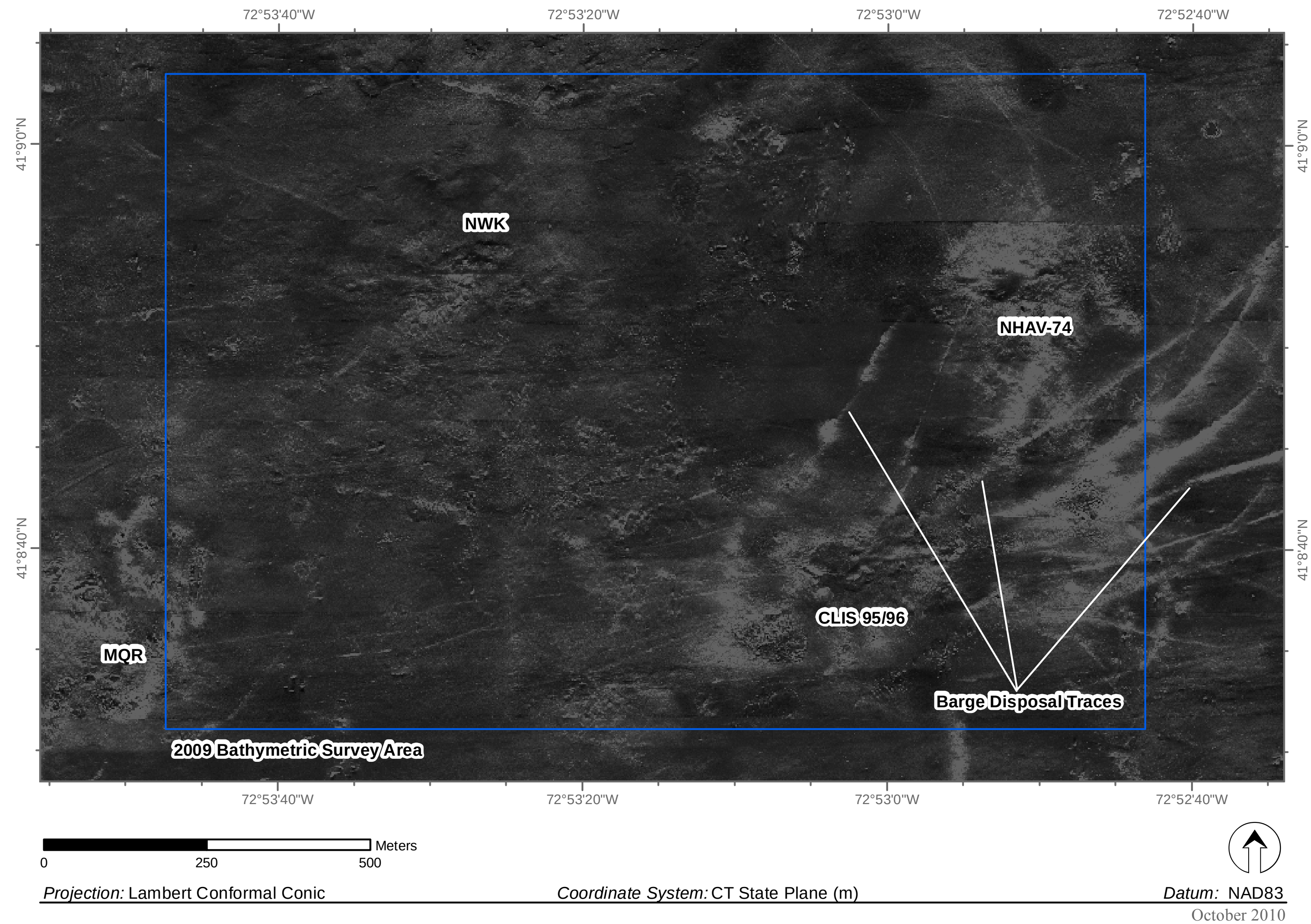


Figure 4-7. Side-scan sonar data from the 1997 survey of CLDS (from Poppe et al. 2001)

The CLIS 05 mound, which was placed on the edge of the CLIS 97 mound, had a distinct pattern of impact craters visible in the backscatter and multibeam bathymetric images (Figures 4-3 and 4-8 A, B). The impact craters resembled soft rings with deep depressions 10–12 m in diameter, similar to Type II Pits (ENSR, Table 4-1). These deep pits appear to be associated with disposal on soft material. The mound surface was comprised of silt/clay material but with some fine sand (Figure 3-15). Although numerous pits and rings were present in 2005, the placement of over 136,000 m^3 of dredged material at this location appears to have covered the disposal traces visible in 2005 (Figure 4-4 C). Only a few isolated ring traces were visible at this location in 1997 (Figure 4-8 D).

The CLIS 06 mound, which was placed in a saddle between the CLIS 95/96 and NHAV-74 mounds, had many small soft impact craters (4–12 m diameter) scattered around a single large crater (18 m diameter; Figure 4-4). The mound was formed from 59,654 m^3 of dredged material and was noticeably flatter than CLIS 2005. There were also groups of three and four raised rings (18–20 m diameter) with flat centers located away from the mound on flat seafloor (Figure 4-4) and two large pits (30 m diameter) on the eastern margin of the mound. These “ring” traces were not present in 2005 (Figure 4-9 C) but were similar to Type I craters found at CLDS on ambient seafloor or consolidated dredged material (ENSR 2007). The large pits were present in 2005, and there was a visible accumulation of material in the 1997 backscatter (Figure 4-9 C, D). This material and the pits were likely formed during the placement of CLIS 95/96. The mound surface was comprised of fine and very fine sand (Figure 3-15), and the presence of this coarser material is visible in the higher backscatter intensity (Figure 4-9 B).

The CLIS 07 mound, which was placed between CLIS 97/98 and NWK, had many overlapping ring traces (16–20 m in diameter) with some pits with sharp rims (13–16 m in diameter; Figure 4-5). The rings and pits were more difficult to distinguish in the backscatter than in the multibeam images (compare Figure 4-10 A with B). The backscatter results suggested soft, finer grained sediment with weak backscatter and poor definition of traces (Figure 4-10 B). These results were consistent with SPI results from the mound surface indicating silt/clay composition (Figure 3-15). Many of the pits to the south were visible in 2005 and are part of CLIS 97/98, but most of the ring traces were not visible in 2005 (Figure 4-10 C). The ring traces were consistent with Type I traces from CLDS on ambient or consolidated dredged material and the pits were consistent with Type II traces on mounds (ENSR 2007). Only a small amount of dredged material was visible in the 1997 backscatter images at this location (Figure 4-10 D). It appears that the ring traces were formed by placement of dredged material on ambient bottom around the margins of CLIS 97/98 and NWK, and the pits were formed on dredged material deposited during the 2007 disposal season.

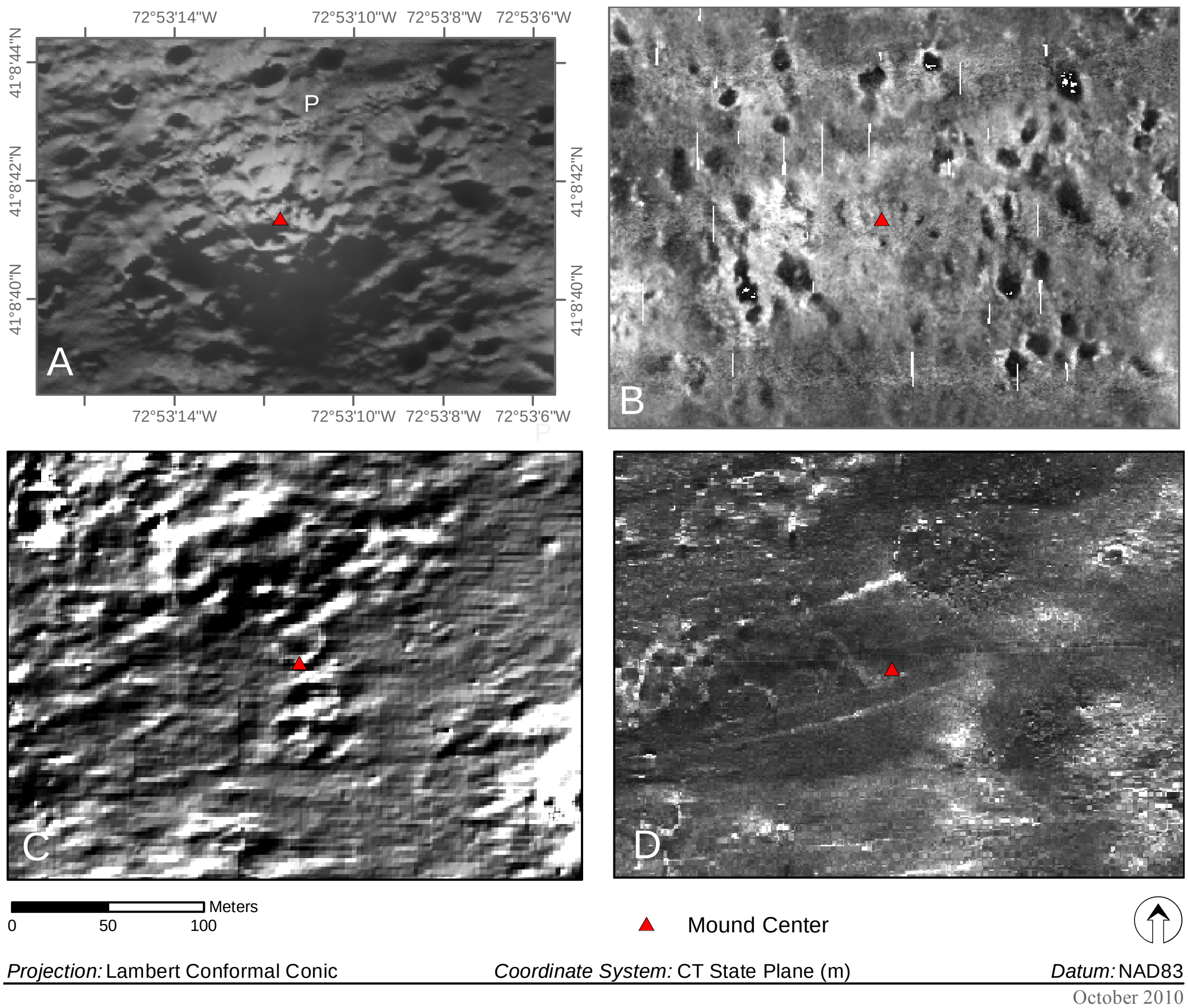


Figure 4-8. Acoustic results from CLIS 05 mound. A. Hillshaded multibeam bathymetry 2009 B. Backscatter mosaic 2009 C. Hillshaded multibeam bathymetry 2005 D. Side-scan sonar mosaic 1997 (from Poppe et al. 2001). P = pit

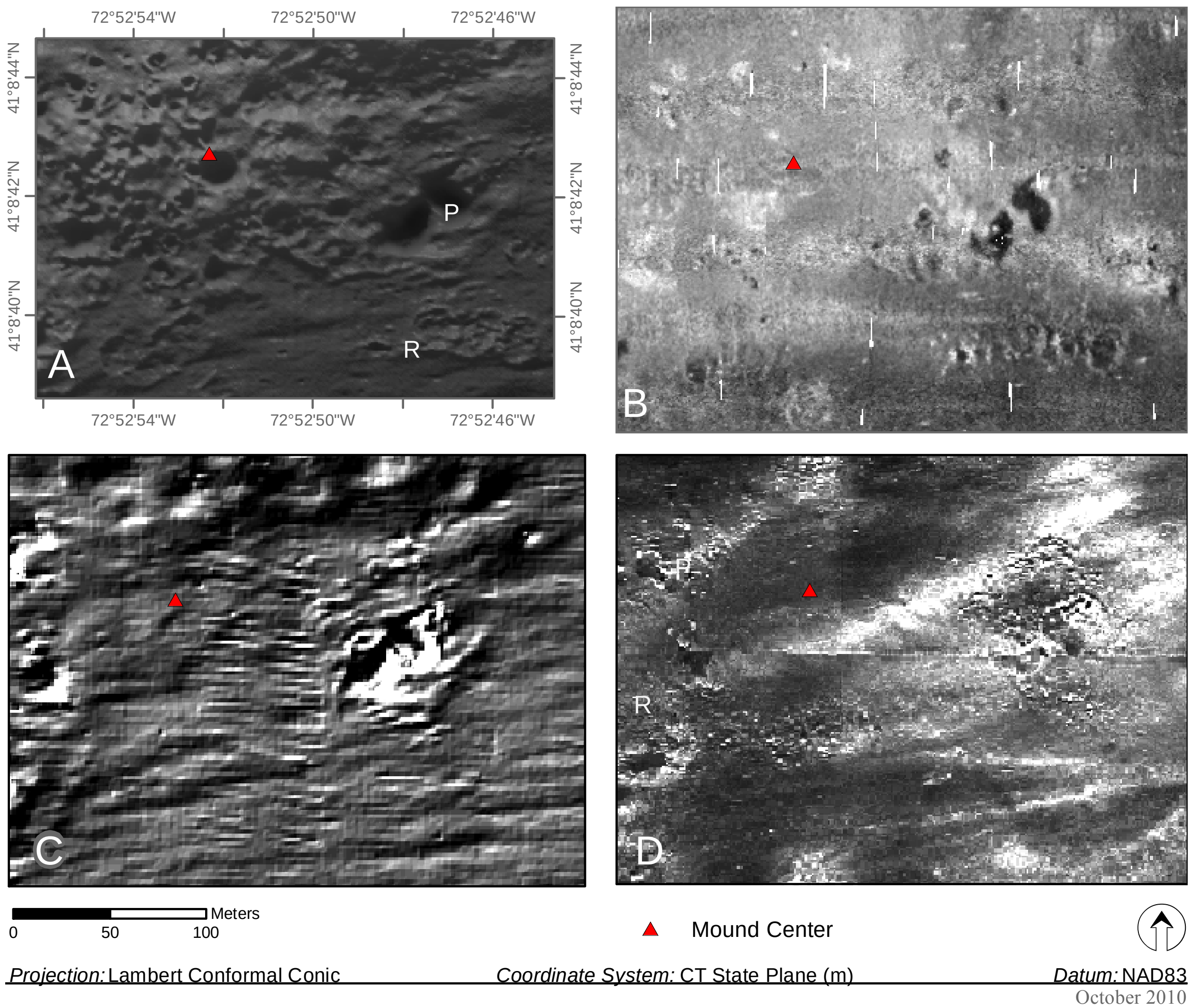


Figure 4-9. Acoustic results from CLIS 06 mound. A. Hillshaded multibeam bathymetry 2009 B. Backscatter mosaic 2009 C. Hillshaded multibeam bathymetry 2005 D. Side-scan sonar mosaic 1997 (from Poppe et al. 2001). P=pit, R=ring.

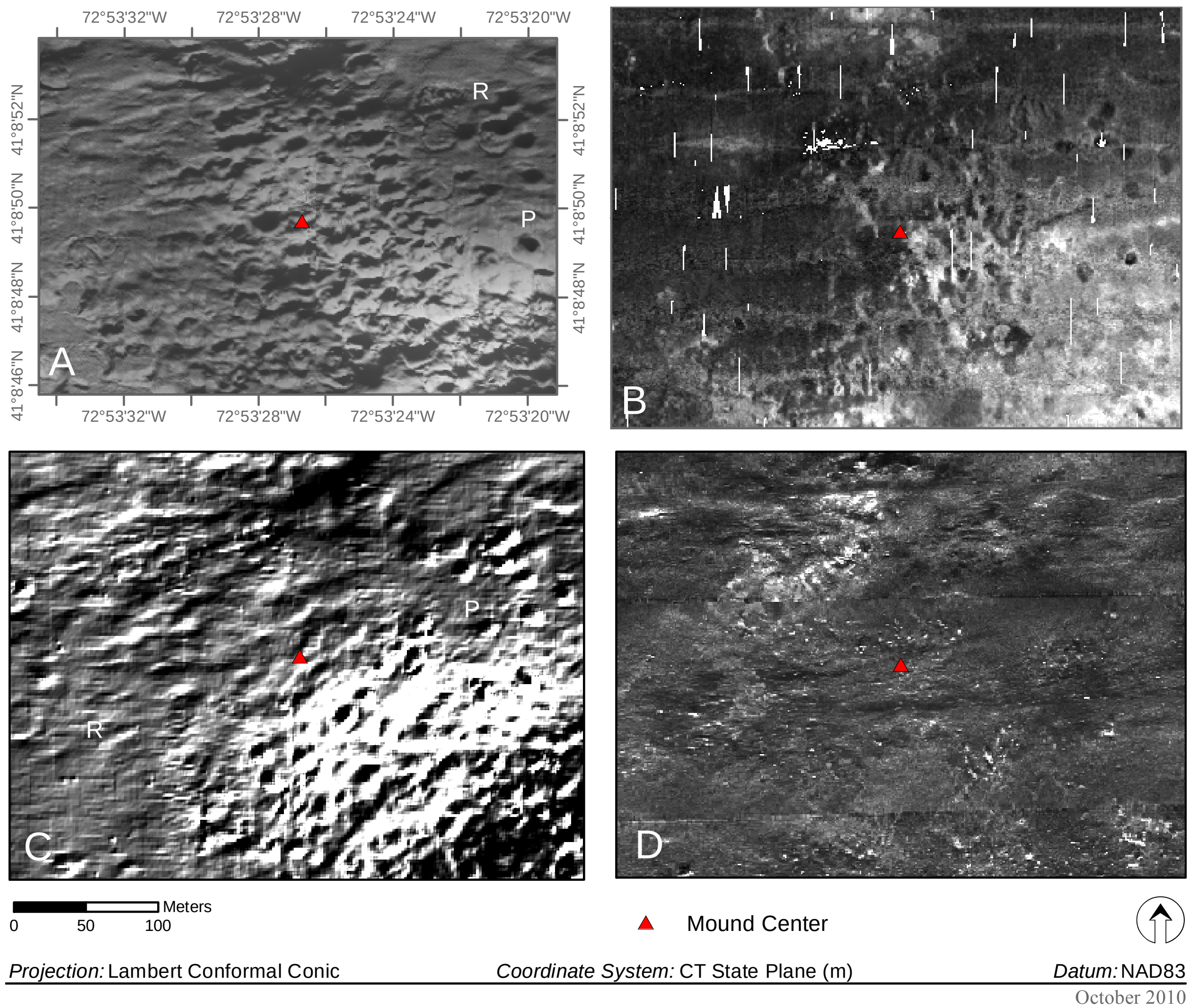


Figure 4-10. Acoustic results from CLIS 07 mound. A. Hillshaded multibeam bathymetry 2009 B. Backscatter mosaic 2009 C. Hillshaded multi-beam bathymetry 2005 D. Side-scan sonar mosaic 1997 (from Poppe et al. 2001). P = pit, R = ring.

The CLIS 08 mound, which was placed outside of the CAD cell berm on ambient seafloor, had very few disposal traces on a remarkably flat semicircular plateau with a small mound on top (Figure 4-6). The backscatter results were consistent with very soft, finer grained material that appeared to have deformed into a flat mound with distinct edges (Figure 4-11 A,B). The flat mound had a sharply defined, scalloped edge and at the toe of the slope a margin, or apron, of material that extended 50–100 m in a smoother scalloped shape (Figure 4-6). There were rings (14–21 m in diameter) around the margin of the mound and on the flat portion of the mound (Figure 4-6). There were pits (13–31 m in diameter) on the small mound on the plateau and to the east of the mound. In 2005 and 1997, there were a few scattered rings at this location but no accumulation of dredged material (Figure 4-11 C, D). Most of the older rings have been covered, but a few were still visible with very soft outlines in 2009 (Figure 4-11A). The mound surface was comprised of silt/clay (Figure 3-15) and also appeared to still have high water content consistent with fresh dredged material and high prism penetration depths (Table 3-3, Figure 3-16). The shape of the CLIS 08 mound (flat with distinct edges) was similar to CLIS 02 and 03 (Figure 1-2). These mounds were likely formed rapidly from dredged material with high water content that deformed after placement into a flat surface, as is also seen in CAD cells (ENSR 2008). If additional material is placed on the mound after some consolidation has occurred, a small mound and craters or rings can likely be formed (Figures 1-2 and 4-6).

4.3 Benthic Recolonization

The second objective of the 2009 survey was to assess the benthic recolonization status of the four mounds created over the 2005 through 2008 disposal seasons. In general, the extent of recolonization was related to the age of each mound. The two older mounds (CLIS 05 and CLIS 06) were characterized by an advanced successional status; almost all of the replicate images showed abundant evidence that deeper dwelling, Stage 3 organisms were widespread across the surface of each mound. In contrast, the two newer mounds (CLIS 07 and CLIS 08) were 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.

From a qualitative perspective, these results were consistent with the successional theory which predicts that the different stages will appear sequentially over time (Rhoads and Germano 1982, 1986). It was not surprising, therefore, that the older mounds had more advanced succession and the newer mounds, comprised of relatively fresh dredged material, were characterized by a transitional, intermediate successional status at the time of the survey.

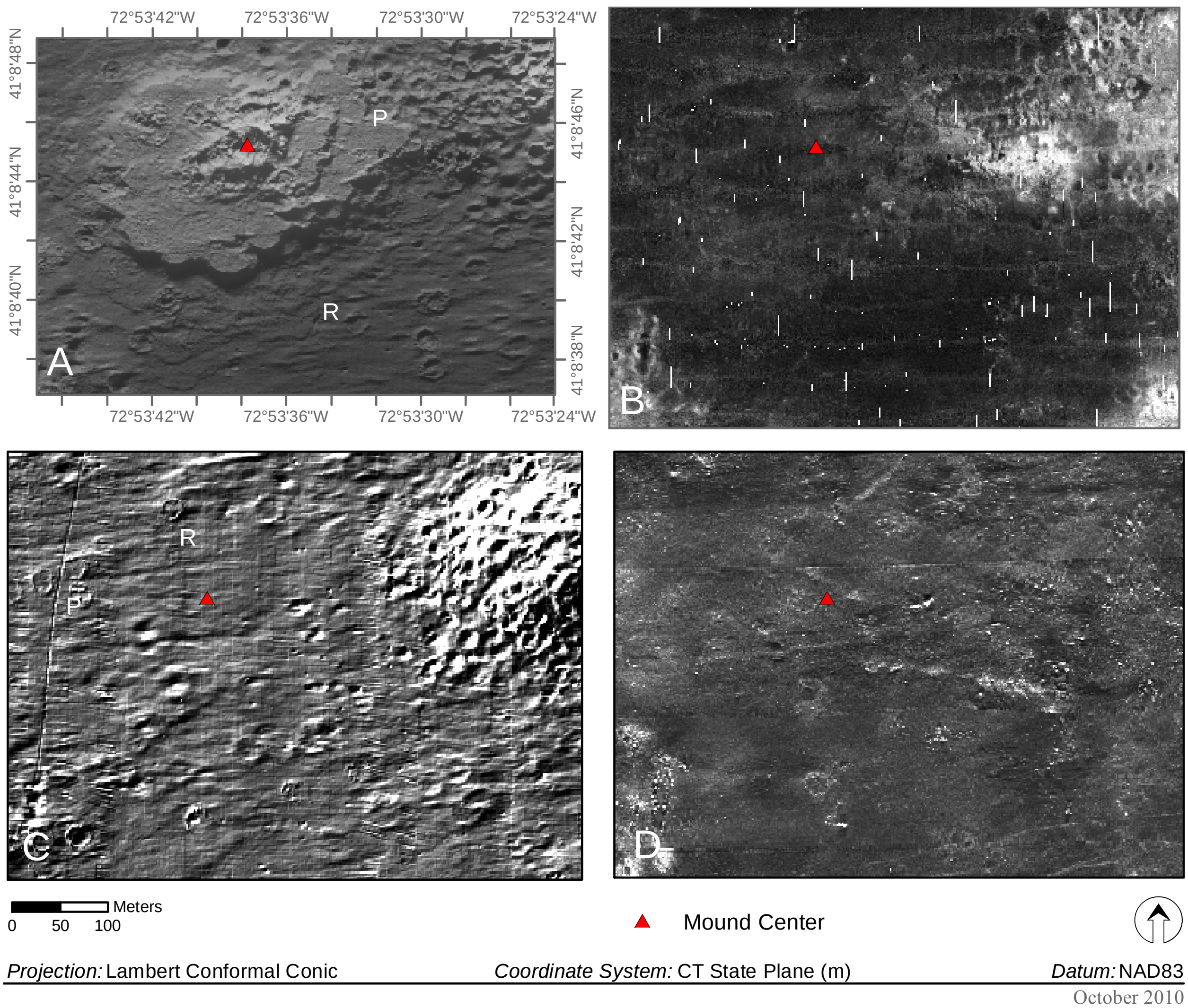


Figure 4-11. Acoustic results from CLIS 08 mound. A. Hillshaded multibeam bathymetry 2009 B. Backscatter mosaic 2009 C. Hillshaded multibeam bathymetry 2005 D. Side-scan sonar mosaic 1997 (from Poppe et al. 2001). P = pit, R = ring.

The mound-versus-reference statistical comparisons provided further insights into the successional dynamics. The average aRPD depths at the older CLIS 05 and CLIS 06 mounds were deeper than those at the CLIS 07 and CLIS 08 mounds. The average aRPD value of the CLIS 06 mound was not significantly different from reference, while the average aRPD values of other three mounds did differ significantly. The deeper aRPD depths at the two older mounds can be attributed to the widespread presence of Stage 3 infauna. 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.

At the two newer mounds (CLIS 07 and CLIS 08), the fine-grained dredged material was characterized by both high apparent water content (as evidenced by deep prism penetration depths) and a dark grey/black appearance at depth (suggesting a high residual inventory of labile organic matter and sulfides) at the time of the October 2009 survey (Figure 3-16). In addition, although there was some evidence that Stage 3 organisms were present, many of the profile images showed a transitional, less-advanced successional status. Because the relatively fresh dredged material at these mounds was still consolidating and was not yet fully recolonized by an extensive population of Stage 3 organisms, bioturbation rates were lower, and average aRPD depths were significantly less than those at the reference areas.

The statistical comparisons of infaunal successional ranks confirmed that the two older mounds had achieved a level of succession not significantly different from the reference areas, while the intermediate successional status at the two newer mounds differed significantly from reference conditions (Figure 3-24). As succession proceeds over time at these the two newer mounds, it is expected that they will converge both with reference conditions and with conditions observed at the two older mounds.

5.0 CONCLUSIONS

The multibeam bathymetric survey, performed as a standard confirmatory survey as part of the 2009 monitoring at CLDS, revealed that four discrete mounds of dredged material had been created on the seafloor as a result of disposal activities during the previous four years. The size of each mound was generally related to the volume of dredged material placed in each location.

Three of the new mounds (CLIS 05, CLIS 06, and CLIS 07) represented additions of dredged material to an existing, crescent-shaped line of mounds that are coalescing into a berm on the seafloor. The berm represents the southern wall of a large CAD area being formed in this part of the disposal site. The lowest points of the berm occur on either side of the existing CLIS 95/96 mound, and if there is a desire to make the height of the berm more uniform, then it is recommended that additional disposal activities be directed to these low points in the future.

The CLIS 08 mound was located outside and to the west of the existing crescent-shaped berm that includes the CLIS 05, CLIS 06, and CLIS 07 mounds. The intention of placing the CLIS 08 mound in this location was to begin creating another berm feature by connecting the CLIS 97/98, CLIS 04, MQR, and NHAV83 mounds.

Over the four new mounds, there was generally good agreement between backscatter intensity and sediment type as determined from analysis of sediment profile images. High backscatter intensity was associated with the presence of fine to very fine sand at the CLIS 06 mound and low backscatter intensity was associated with soft mud at the CLIS 07 and CLIS 08 mounds. Comparison of hillshaded multibeam images and backscatter mosaics from 2009, 2005, and 1997 clarified the development of disposal traces previously observed at CLDS (ENSR 2007). Flat ring structures were formed on ambient material on the margins of disposal mounds, and craters with pits in the center were formed on fresh disposal mounds.

The 2009 monitoring effort also included a SPI survey to assess the benthic recolonization status of the four mounds created over the 2005 through 2008 disposal seasons. The extent of recolonization was found to be related to the age of each mound, consistent with expectations based on the standard theory of infaunal succession. The two older mounds (CLIS 05 and CLIS 06) 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, the two newer mounds (CLIS 07 and CLIS 08) were 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. As succession proceeds over time at these the two newer mounds, they will converge both with reference conditions and with conditions observed at the two older mounds. .

Based on the findings of the 2009 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 south and east of CLIS 08 mound to complete the CAD area south of CLIS 98 mound.

R3) Benthic recolonization should be monitored with SPI surveys at CLIS 07, CLIS 08 and any future mounds formed as a result of disposal activity.

R4) 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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INDEX

APPENDIX A

GRAIN SIZE SCALE FOR SEDIMENTS

APPENDIX A

Grain Size Scale for Sediments

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

APPENDIX B

NONPARAMETRIC BOOTSTRAPPED CONFIDENCE LIMITS

APPENDIX B

Nonparametric Bootstrapped Confidence Limits

Bootstrapping is a statistical resampling procedure that uses the sample data to represent the entire population in order to construct confidence limits around population parameters. Bootstrapping assumes only that the sample data are representative of the underlying population, so random sampling is a prerequisite for appropriate application of this method.

Bootstrapping procedures entail resampling, with replacement, from the observed sample of size n. Each time the sample is resampled, a summary statistic (e.g., mean or standard deviation) of the bootstrapped sample is computed and stored. After repeating this procedure many times, a summary of the bootstrapped statistics is used to construct the confidence limit. For the bootstrap-*t* method (e.g., Manly 1997, pp. 56–59; or Lunneborg 2000, pp. 129–131), the bootstrapped statistic (T) is a pivotal statistic, which means that the distribution of T is the same for all values of the true mean (θ). The bootstrap-*t* is essentially the "Studentized" version (i.e., subtract the mean and divide by the standard error, as is done to obtain Student's *t*-distribution for the sample mean) of the statistic of interest. This approach is quite versatile, and can be applied to construct a confidence interval around any linear combination of means (Lunneborg 2000, p. 364).

For the purpose of constructing a confidence interval around the true value for the linear combination of means (e.g., $\theta = \mu_{Ref} - \mu_{Mound}$) the pivotal statistic T for the true difference is defined as

$$T = \frac{d - \theta}{SE(d)} \qquad \text{(Eq. A-1)}$$

where

θ is the true value for the linear combination of means (unknown), the "difference equation" we wish to test;

d is the linear combination of group means for the observed samples; and

$SE(d)$ is the standard error of d.

We assume that this is adequately approximated by the bootstrap sampling distribution of T, denoted T*:

$$T^* = \frac{d^* - \hat{\theta}}{SE(d^*)} \qquad \text{(Eq. A-2)}$$

Here,

$\hat{\theta}$ is the linear combination of group means from the original samples;

d^* is the linear combination of group means for a bootstrapped sample; and

$SE(d^*)$ is the estimated standard error of the linear contrast, derived from the bootstrap samples.

This distribution is comprised of the Studentized statistic (T^*) computed from a large number (B) of randomly chosen bootstrapped samples from each of our k group populations. The 5th and the 95th quantiles of the T^* distribution ($T^*_{0.05}$ and $T^*_{0.95}$, respectively) satisfy the equations:

$$\Pr[\frac{\theta - d}{SE(d)} > T^*_{0.05}] = 0.95 \quad \text{(Eq. A-3a)}$$

$$\Pr[\frac{\theta - d}{SE(d)} < T^*_{0.95}] = 0.95 \quad \text{(Eq. A-3b)}$$

Rearranging these equations yields 95% confidence in each of the following two inequalities:

$$\Pr[d + T^*_{0.05}\, SE(d) < \theta] = 0.95 \quad \text{(Eq. A-4a)}$$

$$\Pr[d + T^*_{0.95}\, SE(d) > \theta] = 0.95 \quad \text{(Eq. A-4b)}$$

Bootstrapping is used to estimate the values $T^*_{0.05}$, $T^*_{0.95}$, and $SE(d)$. The left side of equation A-4a represents the 95% lower confidence limit on the difference equation θ; the left side of equation A-4b is the 95% upper confidence limit on the difference equation. Based on the two one-sided testing (TOST) approach presented in McBride (1999), if the bounds computed by Equations A-4a and A-4b are fully contained within the interval [–δ , +δ], then we conclude equivalence within δ units.

The specific steps used to compute the 95% upper and 95% lower confidence limits on any linear combination of means using the bootstrap-*t* method are described below.

1. Bootstrap (sample with replacement from the original sample) B = 10,000 samples of size n_j (j=1 to k) from each of the k populations separately.
2. Compute the T^*_B statistic for each bootstrapped set of independent samples. T^*_i is the bootstrapped-*t* statistic computed from the i^{th} bootstrap sample, defined by the following equation

$$T^*_i = \frac{\sum_{j=1}^{k} c_j \bar{y}^*_{ji} - \sum_{j=1}^{k} c_j \bar{y}_j}{SE\left(\sum_{j=1}^{k} c_j \bar{y}^*_{ji}\right)} = \frac{\sum_{j=1}^{k} c_j \bar{y}^*_{ji} - \sum_{j=1}^{k} c_j \bar{y}_j}{\sqrt{\sum_{j=1}^{k} s^2_{y^*ji} c_j^2 / n_j}} \quad \text{(Eq. A-5)}$$

where

c_j are the coefficients for the j^{th} group (j=1 to k) that define the linear contrast (e.g., see Equation 1);

$\bar{y}*_{ji}$ is the mean for the i^{th} bootstrapped sample from the j^{th} group (j=1 to k);

$s^2_{y*_{ji}}$ is the variance for the i^{th} bootstrapped sample from the j^{th} group (j=1 to k);

$\bar{y}_j$ is the observed mean for the j^{th} group; and

n_j is the sample size for the j^{th} group.

Thus we have calculated values for the difference equation we wish to test (Equation 1) for each bootstrap sample. This step produces 10,000 values of the bootstrapped-*t* statistic which together comprise the "bootstrap-*t* distribution."

3. Compute the standard deviation of the 10,000 bootstrapped linear combinations, $\sum_{j=1}^{k} c_j \bar{y}*_{ji}$ and save it as *SE(d)*. This is the bootstrap estimate of the true standard error.
4. Find $T*_{0.05}$ and $T*_{0.95,}$ the 5th and 95th quantiles of the bootstrap-*t* distribution generated in Step 2. These values satisfy Equations A- 3a and A-3b.
5. Applying Equations A-4a and A-4b using the values $T*_{0.05}$ and $T*_{0.95}$ found in Step 4 gives the bootstrap-*t* estimate of the 95% lower and upper confidence limits on the difference equation, i.e.,

$$95\%\ \text{LCL} = \sum_{j=1}^{k} c_j \bar{y}_j + T*_{0.05}\ SE(d) \qquad \text{(Eq. A-6a)}$$

$$95\%\ \text{UCL} = \sum_{j=1}^{k} c_j \bar{y}_j + T*_{0.95}\ SE(d) \qquad \text{(Eq. A-6b)}$$

where

$(\sum_{j=1}^{k} c_j \bar{y}_j)$ is the linear combination of means we wish to test (e.g., Equation 1) based on the original sample observations; and

SE(d) is the standard deviation of the bootstrapped differences computed in Step 3.

<u>References</u>

Lunneborg, C. E. 2000. Data analysis by resampling: Concepts and applications. Pacific Grove, CA: Duxbury Press.

Manly, B. F. J. 1997. Randomization, bootstrap and Monte Carlo methods in biology. Second edition. London: Chapman & Hall.

APPENDIX C

SEDIMENT-PROFILE IMAGE RESULTS FOR CLDS
OCTOBER 2009

APPENDIX C

Sediment-Profile Image Results for CLDS October 2009

Station	Replicate	Date	Time	Stop Collar Setting (in)	# of Lead Weights per Carriage	Calibration Constant	Grain Size Major Mode (phi)	Grain Size Maximum (phi)	Grain Size Minimum (phi)	Grain Size Range	Penetration Area (sq.cm)	Penetration Mean (cm)	Penetration Minimum (cm)	Penetration Maximum (cm)	Boundary Roughness (cm)	Boundary Roughness Type	aRPD Area (sq.cm)	Mean aRPD (cm)	Mud Clast Number	Mud Clast State	Methane	Total DM Area	Total DM Mean		Total DM Min		Total DM Max		Low DO?
1	A	10/1/2009	7:34	14	1	14.6	>4	>4	2	>4 to 2	291.5	20.0	19.5	20.5	1.0	Biological	24	1.6	2	Reduced	n	291.5	>	20.0	>	19.5	>	20.5	n
1	B	10/1/2009	7:35	14	1	14.6	>4	>4	2	>4 to 2	294.4	20.2	19.7	20.5	0.8	Biological	14.1	1.0	0		n	294.4	>	20.2	>	19.7	>	20.5	n
1	C	10/1/2009	7:36	14	1	14.6	>4	>4	2	>4 to 2	276.8	19.0	18.6	19.2	0.6	Biological	25.2	1.7	0		n	276.8	>	19.0	>	18.6	>	19.2	n
2	A	10/1/2009	7:47	13	1	14.6	>4	>4	2	>4 to 2	225	15.4	15	16	1.0	Biological	28.4	1.9	0		n	225	>	15.4	>	15	>	16	n
2	B	10/1/2009	7:48	13	1	14.6	>4	>4	2	>4 to 2	247.2	16.9	16.7	17.1	0.4	Biological	23.5	1.6	0		n	247.2	>	16.9	>	16.7	>	17.1	n
2	C	10/1/2009	7:48	13	1	14.6	>4	>4	2	>4 to 2	279.7	19.2	18.8	19.6	0.8	Biological	17.6	1.2	4	Both	n	279.7	>	19.2	>	18.8	>	19.6	n
3	A	10/1/2009	7:51	13	1	14.6	>4	>4	2	>4 to 2	264.7	18.1	17.7	18.4	0.7	Biological	46	3.2	0		n	264.7	>	18.1	>	17.7	>	18.4	n
3	B	10/1/2009	7:52	13	1	14.5	>4	>4	2	>4 to 2	315.5	21.8	>21.7	>21.8	ind	ind	ind	ind	ind		n	>315.5	>	21.8	>	21.7	>	21.8	n
3	C	10/1/2009	7:53	13	1	14.6	>4	>4	2	>4 to 2	226.2	15.5	15.1	15.7	0.6	Biological	34	2.3	0		n	226.2	>	15.5	>	15.1	>	15.7	n
4	A	10/1/2009	7:56	13	1	14.6	>4	>4	2	>4 to 2	262.5	18.0	17.6	18.4	0.8	Biological	39.9	2.7	0		n	262.5	>	18.0	>	17.6	>	18.4	n
4	B	10/1/2009	7:57	13	1	14.6	>4	>4	2	>4 to 2	201.1	13.8	13.5	14.2	0.7	Biological	44.4	3.0	0		n	201.1	>	13.8	>	13.5	>	14.2	n
4	C	10/1/2009	7:57	13	1	14.6	>4	>4	2	>4 to 2	257.1	17.6	17.4	17.9	0.5	Biological	32.5	2.2	0		n	257.1	>	17.6	>	17.4	>	17.9	n
5	A	10/1/2009	8:00	13	1	14.6	>4	>4	2	>4 to 2	228.3	15.6	15.6	15.9	0.3	Biological	36	2.5	8	Both	n	228.3	>	15.6	>	15.6	>	15.9	n
5	B	10/1/2009	8:01	13	1	14.6	>4	>4	2	>4 to 2	184.3	12.6	11.9	13.4	1.5	Physical	40.6	2.8	>20	Both	n	184.3	>	12.6	>	11.9	>	13.4	n
5	C	10/1/2009	8:02	13	1	14.6	>4	>4	2	>4 to 2	234.7	16.1	15.6	17.1	1.5	Biological	36.9	2.5	0		n	234.7	>	16.1	>	15.6	>	17.1	n
6	C	10/1/2009	8:09	13	1	14.6	>4	>4	2	>4 to 2	220.3	15.1	14.5	15.7	1.2	Physical	45	3.1	0		n	220.3	>	15.1	>	14.5	>	15.7	n

Sediment-Profile Image Results for CLDS October 2009

Station	Replicate	Date	Time	Stop Collar Setting (in)	# of Lead Weights per Carriage	Calibration Constant	Grain Size Major Mode (phi)	Grain Size Maximum (phi)	Grain Size Minimum (phi)	Grain Size Range	Penetration Area (sq.cm)	Penetration Mean (cm)	Penetration Minimum (cm)	Penetration Maximum (cm)	Boundary Roughness (cm)	Boundary Roughness Type	aRPD Area (sq.cm)	Mean aRPD (cm)	Mud Clast Number	Mud Clast State	Methane	Total DM Area	Total DM Mean		Total DM Min		Total DM Max		Low DO?
6	D	10/1/2009	9:05	12.5	1	14.6	>4	>4	2	>4 to 2	256.6	17.6	17	19.2	2.2	Physical	38.7	2.7	>20	Reduced	n	256.6	>	17.6	>	17	>	19.2	n
6	E	10/1/2009	9:06	12.5	1	14.6	>4	>4	2	>4 to 2	280.6	19.2	19.1	19.4	0.3	Biological	39.1	2.7	>20	Both	n	280.6	>	19.2	>	19.1	>	19.4	n
7	A	10/1/2009	8:39	13	1	14.6	>4	>4	2	>4 to 2	198.5	13.6	13.2	14.1	0.9	Physical	32.1	2.2	0		n	198.5	>	13.6	>	13.2	>	14.1	n
7	B	10/1/2009	8:40	13	1	14.6	>4	>4	2	>4 to 2	306.2	21.0	20.5	21.5	1.0	Biological	35.9	2.5	0		n	306.2	>	21.0	>	20.5	>	21.5	n
7	D	10/1/2009	8:42	13	1	14.6	>4	>4	2	>4 to 2	273	18.7	18.4	19.3	0.9	Physical	4.5	0.3	0		n	273	>	18.7	>	18.4	>	19.3	n
8	A	10/1/2009	8:11	13	1	14.6	>4	>4	2	>4 to 2	271.2	18.6	18.1	18.9	0.8	Biological	31.1	2.1	0		n	271.2	>	18.6	>	18.1	>	18.9	n
8	B	10/1/2009	8:12	13	1	14.6	>4	>4	2	>4 to 2	301.2	20.6	20.2	21	0.8	Physical	9.5	0.7	5	Both	n	301.2	>	20.6	>	20.2	>	21	n
8	C	10/1/2009	8:13	13	1	14.6	>4	>4	2	>4 to 2	239.7	16.4	16.2	16.6	0.4	Biological	0.4	0.0	2	Both	n	239.7	>	16.4	>	16.2	>	16.6	n
9	A	10/1/2009	8:19	13	1	14.6	>4	>4	2	>4 to 2	211.4	14.5	13.1	15.6	2.5	Physical	26.9	1.8	0		n	211.4	>	14.5	>	13.1	>	15.6	n
9	B	10/1/2009	8:20	13	1	14.6	>4	>4	2	>4 to 2	258	17.7	17	18	1.0	Biological	26.8	1.8	0		n	258	>	17.7	>	17	>	18	n
9	C	10/1/2009	8:20	13	1	14.6	>4	>4	2	>4 to 2	315.2	21.6	21.4	21.7	0.3	Biological	ind	2.5	0		n	>317.2	>	21.7	>	21.4	>	21.6	n
10	A	10/1/2009	8:30	13	1	14.6	>4	>4	2	>4 to 2	256.8	17.6	17.2	18.2	1.0	Biological	30.3	2.1	0		n	256.8	>	17.6	>	17.2	>	18.2	n
10	D	10/1/2009	9:00	12.5	1	14.5	>4	>4	2	>4 to 2	192.4	13.3	13.1	13.5	0.4	Biological	35.3	2.4	0		n	192.4	>	13.3	>	13.1	>	13.5	n
10	E	10/1/2009	9:00	12.5	1	14.6	3 to 2/>4	>4	-1	>4 to -1	227.8	15.6	14.9	15.9	1.0	Biological	30.7	2.1	4	Both	n	227.8	>	15.6	>	14.9	>	15.9	n
11	A	10/1/2009	8:35	13	1	14.6	>4	>4	0	>4 to 0	260.2	17.8	17.3	18.3	1.0	Biological	44.6	3.1	0		n	260.2	>	17.8	>	17.3	>	18.3	n
11	B	10/1/2009	8:36	13	1	14.6	>4	>4	2	>4 to 2	250.5	17.2	17.1	17.3	0.2	Biological	22.7	1.6	5	Reduced	n	250.5	>	17.2	>	17.1	>	17.3	n

APPENDIX C – (CONTINUED)

Sediment-Profile Image Results for CLDS October 2009

Station	Replicate	Date	Time	Stop Collar Setting (in)	# of Lead Weights per Carriage	Calibration Constant	Grain Size Major Mode (phi)	Grain Size Maximum (phi)	Grain Size Minimum (phi)	Grain Size Range	Penetration Area (sq.cm)	Penetration Mean (cm)	Penetration Minimum (cm)	Penetration Maximum (cm)	Boundary Roughness (cm)	Boundary Roughness Type	aRPD Area (sq.cm)	Mean aRPD (cm)	Mud Clast Number	Mud Clast State	Methane	Total DM Area	Total DM Mean		Total DM Min		Total DM Max		Low DO?
11	C	10/1/2009	8:37	13	1	14.6	>4	>4	2	>4 to 2	233.6	16.0	16.1	16.3	0.2	Biological	40.9	2.8	0		n	233.6	>	16.0	>	16.1	>	16.3	n
12	A	10/1/2009	8:15	13	1	14.6	>4	>4	2	>4 to 2	225.4	15.4	14.9	16.2	1.3	Physical	30.6	2.1	0		n	225.4	>	15.4	>	14.9	>	16.2	n
12	B	10/1/2009	8:16	13	1	14.6	>4	>4	2	>4 to 2	224.1	15.3	15.1	15.6	0.5	Biological	30	2.1	0		n	224.1	>	15.3	>	15.1	>	15.6	n
12	C	10/1/2009	8:17	13	1	14.6	>4	>4	2	>4 to 2	220.7	15.1	11.3	15.7	4.4	Biological	30.3	2.1	0		n	220.7	>	15.1	>	11.3	>	15.7	n
13	A	10/1/2009	8:23	13	1	14.6	>4	>4	2	>4 to 2	241.1	16.5	16.2	16.8	0.6	Biological	36.1	2.5	0		n	241.1	>	16.5	>	16.2	>	16.8	n
13	B	10/1/2009	8:23	13	1	14.6	>4	>4	2	>4 to 2	261.7	17.9	17.3	18.3	1.0	Physical	23.3	1.6	5	Both	n	261.7	>	17.9	>	17.3	>	18.3	n
13	C	10/1/2009	8:25	13	1	14.6	>4	>4	1	>4 to 1	253.5	17.4	17.1	17.6	0.5	Biological	29.4	2.0	0		n	253.5	>	17.4	>	17.1	>	17.6	n
14	A	10/1/2009	8:27	13	1	14.6	>4	>4	2	>4 to 2	258.3	17.7	17.4	18.2	0.8	Biological	23.7	1.6	0		n	258.3	>	17.7	>	17.4	>	18.2	n
14	B	10/1/2009	8:27	13	1	14.6	>4	>4	2	>4 to 2	247.2	16.9	16.8	17.1	0.3	Biological	23.5	1.6	0		n	247.2	>	16.9	>	16.8	>	17.1	n
14	C	10/1/2009	8:28	13	1	14.6	>4	>4	2	>4 to 2	240.5	16.5	16.1	16.8	0.7	Biological	20.2	1.4	0		n	240.5	>	16.5	>	16.1	>	16.8	n
15	A	10/1/2009	9:27	12.5	1	14.6	>4	>4	2	>4 to 2	225.4	15.4	15	15.9	0.9	Biological	14.5	1.0	0		n	225.4	>	15.4	>	15	>	15.9	n
15	B	10/1/2009	9:27	12.5	1	14.6	>4	>4	2	>4 to 2	230.4	15.8	11.4	17.6	6.2	Physical	16.2	1.1	0		n	230.4	>	15.8	>	11.4	>	17.6	n
15	C	10/1/2009	9:28	12.5	1	14.6	>4	>4	2	>4 to 2	309.4	21.2	20.9	21.8	0.9	Biological	26.5	1.8	0		n	309.4	>	21.2	>	20.9	>	21.8	n
16	A	10/1/2009	9:30	12.5	1	14.6	>4	>4	2	>4 to 2	224.9	15.4	15	15.9	0.9	Biological	15.4	1.1	0		n	224.9	>	15.4	>	15	>	15.9	n
16	B	10/1/2009	9:31	12.5	1	14.6	>4	>4	2	>4 to 2	94.8	6.5	5.3	6.9	1.6	Physical	9.4	0.6	5	Reduced	n	94.8	>	6.5	>	5.3	>	6.9	n

APPENDIX C – (CONTINUED)

Sediment-Profile Image Results for CLDS October 2009

Station	Replicate	Date	Time	Stop Collar Setting (in)	# of Lead Weights per Carriage	Calibration Constant	Grain Size Major Mode (phi)	Grain Size Maximum (phi)	Grain Size Minimum (phi)	Grain Size Range	Penetration Area (sq.cm)	Penetration Mean (cm)	Penetration Minimum (cm)	Penetration Maximum (cm)	Boundary Roughness (cm)	Boundary Roughness Type	aRPD Area (sq.cm)	Mean aRPD (cm)	Mud Clast Number	Mud Clast State	Methane	Total DM Area		Total DM Mean		Total DM Min		Total DM Max	Low DO?
16	C	10/1/2009	9:31	12.5	1	14.6	>4	>4	2	>4 to 2	247.5	17.0	16.6	17.4	0.8	Physical	33.9	2.3	8	Both	n	247.5	>	17.0	>	16.6	>	17.4	n
17	C	10/1/2009	9:24	12.5	1	14.6	>4	>4	2	>4 to 2	276.7	19.0	18.7	19.6	0.9	Physical	31.3	2.1	1	Oxidized	n	276.7	>	19.0	>	18.7	>	19.6	n
17	D	10/1/2009	9:43	12.5	1	14.6	>4	>4	2	>4 to 2	290.9	19.9	19.5	20.4	0.9	Physical	26	1.8	0		n	290.9	>	19.9	>	19.5	>	20.4	n
17	F	10/1/2009	9:45	12.5	1	14.6	>4	>4	2	>4 to 2	268.9	18.4	18.3	19	0.7	Biological	34.4	2.4	10	Both	n	268.9	>	18.4	>	18.3	>	19	n
18	A	10/1/2009	9:18	12.5	1	14.6	>4	>4	2	>4 to 2	281.5	19.3	19	19.7	0.7	Physical	25.9	1.8	8	Reduced	n	281.5	>	19.3	>	19	>	19.7	n
18	B	10/1/2009	9:19	12.5	1	14.6	>4	>4	2	>4 to 2	234.8	16.1	15.4	16.4	1.0	Physical	18.6	1.3	4	Both	n	234.8	>	16.1	>	15.4	>	16.4	n
18	D	10/1/2009	9:20	12.5	1	14.6	>4	>4	2	>4 to 2	218.6	15.0	14.8	15.2	0.4	Biological	22.6	1.5	7	Both	n	218.6	>	15.0	>	14.8	>	15.2	n
19	A	10/1/2009	9:11	12.5	1	14.6	>4	>4	2	>4 to 2	303.1	20.8	20.7	20.9	0.2	Biological	38.7	2.7	0		n	303.1	>	20.8	>	20.7	>	20.9	n
19	B	10/1/2009	9:12	12.5	1	14.6	>4	>4	2	>4 to 2	296.3	20.3	20.1	20.8	0.7	Physical	19.2	1.3	13	Both	n	296.3	>	20.3	>	20.1	>	20.8	n
19	C	10/1/2009	9:13	12.5	1	14.6	>4	>4	2	>4 to 2	315	21.6	>21.8	>21.8	ind	ind	ind	ind	ind		n	>315	>	21.6	>	21.8	>	21.8	n
20	A	10/1/2009	9:15	12.5	1	14.6	>4	>4	2	>4 to 2	214.8	14.7	14.6	14.9	0.3	Biological	32.8	2.2	0		n	214.8	>	14.7	>	14.6	>	14.9	n
20	B	10/1/2009	9:15	12.5	1	14.6	>4	>4	2	>4 to 2	237.4	16.3	16.1	16.7	0.6	Biological	31.6	2.2	0		n	237.4	>	16.3	>	16.1	>	16.7	n
20	C	10/1/2009	9:16	12.5	1	14.6	>4	>4	0	>4 to 0	135.1	9.3	8.9	9.5	0.6	Physical	9	0.6	0		n	135.1	>	9.3	>	8.9	>	9.5	n
21	A	10/1/2009	11:47	12.5	1	14.6	4 to 3	>4	0	>4 to 0	138.1	9.5	8.6	10.2	1.6	Physical	62.1	4.3	0		n	138.1	>	9.5	>	8.6	>	10.2	n
21	B	10/1/2009	11:48	12.5	1	14.6	3 to 2	>4	0	>4 to 0	134.5	9.2	8.7	9.8	1.1	Biological	52.0	3.6	0		n	134.5	>	9.2	>	8.7	>	9.8	n
21	D	10/1/2009	11:50	12.5	1	14.6	4 to 3	>4	1	>4 to 1	145.6	10.0	9.6	10.4	0.8	Physical	59.3	4.1	0		n	145.6	>	10.0	>	9.6	>	10.4	n
22	A	10/1/2009	11:25	12.5	1	14.6	3 to 2	>4	1	>4 to 1	162.7	11.1	10.8	11.8	1.0	Physical	83.0	5.7	0		n	162.7	>	11.1	>	10.8	>	11.8	n
22	B	10/1/2009	11:26	12.5	1	14.6	>4 to 3	>4	1	>4 to 1	147.9	10.1	9.7	11.1	1.4	Biological	93.1	6.4	0		n	147.9	>	10.1	>	9.7	>	11.1	n
22	C	10/1/2009	11:26	12.5	1	14.6	3 to 2	>4	1	>4 to 1	134	9.2	8.6	9.9	1.3	Biological	58.4	4.0	0		n	134	>	9.2	>	8.6	>	9.9	n

Sediment-Profile Image Results for CLDS October 2009

Station	Replicate	Date	Time	Stop Collar Setting (in)	# of Lead Weights per Carriage	Calibration Constant	Grain Size Major Mode (phi)	Grain Size Maximum (phi)	Grain Size Minimum (phi)	Grain Size Range	Penetration Area (sq.cm)	Penetration Mean (cm)	Penetration Minimum (cm)	Penetration Maximum (cm)	Boundary Roughness (cm)	Boundary Roughness Type	aRPD Area (sq.cm)	Mean aRPD (cm)	Mud Clast Number	Mud Clast State	Methane	Total DM Area		Total DM Mean		Total DM Min		Total DM Max	Low DO?
23	E	10/1/2009	12:20	14	2	14.6	3 to 2	>4	1	>4 to 1	100.7	6.9	6.3	7.5	1.2	Biological	49.3	3.4	0		n	100.7	>	6.9	>	6.3	>	7.5	n
23	F	10/1/2009	12:21	14	2	14.6	3 to 2	>4	1	>4 to 1	99.8	6.8	6.3	7.4	1.1	Biological	71.2	4.9	0		n	99.8	>	6.8	>	6.3	>	7.4	n
23	G	10/1/2009	12:22	14	2	14.6	3 to 2	>4	1	>4 to 1	79.4	5.4	5	6	1.0	Biological	79.4	5.4	0		n	79.4	>	5.4	>	5	>	6	n
24	A	10/1/2009	11:19	12.5	1	14.6	4 to 3	>4	1	>4 to 1	150.9	10.3	9.7	11.3	1.6	Biological	72.3	5.0	0		n	150.9	>	10.3	>	9.7	>	11.3	n
24	C	10/1/2009	11:21	12.5	1	14.6	4 to 3	>4	1	>4 to 1	172.1	11.8	11.3	12.2	0.9	Biological	72.1	4.9	0		n	172.1	>	11.8	>	11.3	>	12.2	n
24	D	10/1/2009	11:22	12.5	1	14.6	3 to 2	>4	1	>4 to 1	142.6	9.8	8.9	11.3	2.4	Physical	66.6	4.6	0		n	142.6	>	9.8	>	8.9	>	11.3	n
25	B	10/1/2009	11:38	12.5	1	14.6	3 to 2	>4	1	>4 to 1	82.8	5.7	5.1	6.4	1.3	Physical	34.7	2.4	0		n	82.8	>	5.7	>	5.1	>	6.4	n
25	E	10/1/2009	12:08	14	2	14.6	3 to 2	>4	1	>4 to 1	93.1	6.4	6	6.7	0.7	Physical	56.5	3.9	0		n	93.1	>	6.4	>	6	>	6.7	n
25	F	10/1/2009	12:09	14	2	14.6	3 to 2	>4	1	>4 to 1	118.1	8.1	7.4	8.8	1.4	Physical	52	3.6	0		n	118.1	>	8.1	>	7.4	>	8.8	n
26	C	10/1/2009	11:33	12.5	1	14.6	4 to 3	>4	1	>4 to 1	104.3	7.1	6.7	7.6	0.9	Physical	33.5	2.3	0		n	104.3	>	7.1	>	6.7	>	7.6	n
26	E	10/1/2009	12:14	14	2	14.6	4 to 3	>4	1	>4 to 1	121.2	8.3	6.7	9.4	2.7	Biological	49.2	3.4	0		n	121.2	>	8.3	>	6.7	>	9.4	n
26	G	10/1/2009	12:16	14	2	14.6	4 to 3	>4	1	>4 to 1	119.3	8.2	8.1	8.4	0.3	Biological	57.9	4.0	0		n	119.3	>	8.2	>	8.1	>	8.4	n
27	B	10/1/2009	11:15	12.5	1	14.6	4 to 3	>4	1	>4 to 1	147.9	10.1	9.8	10.4	0.6	Biological	42.5	2.9	0		n	147.9	>	10.1	>	9.8	>	10.4	n
27	C	10/1/2009	11:16	12.5	1	14.6	4 to 3	>4	1	>4 to 1	163.7	11.2	9.9	11.9	2.0	Physical	46.1	3.2	0		n	163.7	>	11.2	>	9.9	>	11.9	n
27	D	10/1/2009	11:17	12.5	1	14.6	4 to 3	>4	1	>4 to 1	146	10.0	9.1	10.6	1.5	Physical	55.7	3.8	0		n	146	>	10.0	>	9.1	>	10.6	n
28	A	10/1/2009	11:06	12.5	1	14.6	3 to 2	>4	1	>4 to 1	143.1	9.8	9.5	10	0.5	Physical	61.2	4.2	0		n	143.1	>	9.8	>	9.5	>	10	n
28	B	10/1/2009	11:07	12.5	1	14.6	3 to 2	>4	1	>4 to 1	166.4	11.4	10.9	12	1.1	Biological	42.2	2.9	0		n	166.4	>	11.4	>	10.9	>	12	n

Sediment-Profile Image Results for CLDS October 2009

Station	Replicate	Date	Time	Stop Collar Setting (in)	# of Lead Weights per Carriage	Calibration Constant	Grain Size Major Mode (phi)	Grain Size Maximum (phi)	Grain Size Minimum (phi)	Grain Size Range	Penetration Area (sq.cm)	Penetration Mean (cm)	Penetration Minimum (cm)	Penetration Maximum (cm)	Boundary Roughness (cm)	Boundary Roughness Type	aRPD Area (sq.cm)	Mean aRPD (cm)	Mud Clast Number	Mud Clast State	Methane	Total DM Area	Total DM Mean		Total DM Min		Total DM Max		Low DO?
28	C	10/1/2009	11:08	12.5	1	14.6	3 to 2	>4	1	>4 to 1	154.1	10.6	9.9	11.4	1.5	Biological	55.1	3.8	0		n	154.1	>	10.6	>	9.9	>	11.4	n
29	A	10/1/2009	11:10	12.5	1	14.6	3 to 2	>4	1	>4 to 1	136.2	9.3	8.7	10.8	2.1	Physical	71.2	4.9	0		n	136.2	>	9.3	>	8.7	>	10.8	n
29	B	10/1/2009	11:11	12.5	1	14.6	3 to 2/>4	>4	1	>4 to 1	190.8	13.1	12.5	13.4	0.9	Physical	38.9	2.7	0		n	190.8	>	13.1	>	12.5	>	13.4	n
29	C	10/1/2009	11:12	12.5	1	14.6	3 to 2	>4	1	>4 to 1	143.8	9.8	9.5	10.4	0.9	Physical	49.3	3.4	0		n	143.8	>	9.8	>	9.5	>	10.4	n
30	A	10/1/2009	10:24	12.5	1	14.6	3 to 2/>4	>4	-2	>4 to -2	173.8	11.9	11.5	12.7	1.2	Biological	25.1	1.7	0		n	173.8	>	11.9	>	11.5	>	12.7	n
30	C	10/1/2009	10:25	12.5	1	14.6	>4	>4	2	>4 to 2	165.6	11.3	10.8	11.8	1.0	Biological	27.6	1.9	0		n	165.6	>	11.3	>	10.8	>	11.8	n
30	E	10/1/2009	10:27	12.5	1	14.6	>4	>4	2	>4 to 2	131.5	9.0	8.3	9.4	1.1	Biological	32.9	2.3	>20	Reduced	n	131.5	>	9.0	>	8.3	>	9.4	n
31	B	10/1/2009	10:46	12.5	1	14.6	>4	>4	2	>4 to 2	249.8	17.1	16.7	17.5	0.8	Biological	59	4.0	0		n	249.8	>	17.1	>	16.7	>	17.5	n
31	C	10/1/2009	10:47	12.5	1	14.6	>4	>4	1	>4 to 1	276.1	18.9	18.8	19.3	0.5	Biological	43.1	3.0	0		n	276.1	>	18.9	>	18.8	>	19.3	n
31	D	10/1/2009	10:48	12.5	1	14.6	>4	>4	2	>4 to 2	302.2	20.7	20.6	20.8	0.2	Biological	51.1	3.5	0		n	302.2	>	20.7	>	20.6	>	20.8	n
32	B	10/1/2009	10:31	12.5	1	14.6	>4	>4	2	>4 to 2	167.9	11.5	11	13	2.0	Biological	30.9	2.1	10	Reduced	n	167.9	>	11.5	>	11	>	13	n
32	C	10/1/2009	10:31	12.5	1	14.6	>4	>4	2	>4 to 2	170.3	11.7	11.2	12.2	1.0	Biological	34.7	2.4	4	Oxidized	n	170.3	>	11.7	>	11.2	>	12.2	n
32	D	10/1/2009	10:32	12.5	1	14.6	>4	>4	1	>4 to 1	166.2	11.4	11.1	12	0.9	Physical	30.4	2.1	8	Oxidized	n	166.2	>	11.4	>	11.1	>	12	n
33	A	10/1/2009	10:36	12.5	1	14.5	3 to 2	>4	1	>4 to 1	141.9	9.8	9.2	10.1	0.9	Biological	36.5	2.5	3	Both	n	141.9	>	9.8	>	9.2	>	10.1	n
33	C	10/1/2009	10:38	12.5	1	14.6	3 to 2	>4	-2	>4 to -2	47.3	3.2	1.7	4.1	2.4	Physical	>pen	3.2	ind	Oxidized	n	47.3	>	3.2	>	1.7	>	4.1	n
33	D	10/1/2009	10:38	12.5	1	14.6	3 to 2	>4	-2	>4 to -2	49.3	3.4	1.6	5.5	3.9	Physical	>pen	3.4	0		n	49.3	>	3.4	>	1.6	>	5.5	n
34	A	10/1/2009	10:18	12.5	1	14.6	>4	>4	1	>4 to 1	139.2	9.5	6.3	11.4	5.1	Physical	25.2	1.7	0		n	139.2	>	9.5	>	6.3	>	11.4	n

APPENDIX C – (CONTINUED)

Sediment-Profile Image Results for CLDS October 2009

Station	Replicate	Date	Time	Stop Collar Setting (in)	# of Lead Weights per Carriage	Calibration Constant	Grain Size Major Mode (phi)	Grain Size Maximum (phi)	Grain Size Minimum (phi)	Grain Size Range	Penetration Area (sq.cm)	Penetration Mean (cm)	Penetration Minimum (cm)	Penetration Maximum (cm)	Boundary Roughness (cm)	Boundary Roughness Type	aRPD Area (sq.cm)	Mean aRPD (cm)	Mud Clast Number	Mud Clast State	Methane	Total DM Area	Total DM Mean		Total DM Min		Total DM Max		Low DO?
34	B	10/1/2009	10:19	12.5	1	14.6	>4	>4	1	>4 to 1	231.9	15.9	15.6	16	0.4	Biological	13	0.9	6	Reduced	n	231.9	>	15.9	>	15.6	>	16	n
34	D	10/1/2009	10:21	12.5	1	14.6	>4	>4	-1	>4 to -1	100.2	6.9	3.4	9.7	6.3	Biological	23.3	1.6	1	Reduced	n	100.2	>	6.9	>	3.4	>	9.7	n
35	B	10/1/2009	10:14	12.5	1	14.6	>4	>4	2	>4 to 2	182.9	12.5	12.2	12.7	0.5	Biological	34.5	2.4	3	Oxidized	n	182.9	>	12.5	>	12.2	>	12.7	n
35	C	10/1/2009	10:15	12.5	1	14.6	>4	>4	2	>4 to 2	196.2	13.4	12.9	13.8	0.9	Biological	39.8	2.7	5	Oxidized	n	196.2	>	13.4	>	12.9	>	13.8	n
35	D	10/1/2009	10:16	12.5	1	14.6	>4	>4	2	>4 to 2	163.8	11.2	10.8	11.4	0.6	Biological	40.4	2.8	5	Both	n	163.8	>	11.2	>	10.8	>	11.4	n
36	A	10/1/2009	10:41	12.5	1	14.6	3 to 2/>4	>4	-1	>4 to -1	186.9	12.8	12.5	13.2	0.7	Biological	49.7	3.4	0		n	186.9	>	12.8	>	12.5	>	13.2	n
36	C	10/1/2009	10:43	12.5	1	14.6	3 to 2/>4	>4	-1	>4 to -1	218.3	15.0	14.3	15.2	0.9	Physical	29.2	2.0	7	Both	n	218.3	>	15.0	>	14.3	>	15.2	n
36	D	10/1/2009	10:44	12.5	1	14.6	3 to 2/>4	>4	0	>4 to 0	203.4	13.9	13.5	14.3	0.8	Biological	38.9	2.7	20	Both	y	203.4	>	13.9	>	13.5	>	14.3	n
37	A	10/1/2009	10:09	12.5	1	14.6	>4	>4	2	>4 to 2	265.1	18.2	17.7	18.5	0.8	Biological	62.3	4.3	8	Both	n	265.1	>	18.2	>	17.7	>	18.5	n
37	B	10/1/2009	10:10	12.5	1	14.6	>4	>4	2	>4 to 2	213.4	14.6	14.1	15.1	1.0	Biological	46.2	3.2	10	Both	n	213.4	>	14.6	>	14.1	>	15.1	n
37	D	10/1/2009	10:11	12.5	1	14.6	>4	>4	2	>4 to 2	162.8	11.2	9.1	12.9	3.8	Biological	68.8	4.7	0		n	162.8	>	11.2	>	9.1	>	12.9	n
38	A	10/1/2009	10:00	12.5	1	14.6	>4	>4	2	>4 to 2	202.9	13.9	13.6	14.2	0.6	Biological	63	4.3	0		n	202.9	>	13.9	>	13.6	>	14.2	n
38	B	10/1/2009	10:01	12.5	1	14.6	>4	>4	2	>4 to 2	232.9	16.0	15.4	16.3	0.9	Biological	49.2	3.4	>20	Both	n	232.9	>	16.0	>	15.4	>	16.3	n
38	C	10/1/2009	10:02	12.5	1	14.6	>4	>4	2	>4 to 2	257	17.6	17.1	18	0.9	Biological	67.7	4.6	1	Reduced	n	257	>	17.6	>	17.1	>	18	n
39	A	10/1/2009	10:05	12.5	1	14.6	>4	>4	2	>4 to 2	220.2	15.1	14.6	15.6	1.0	Biological	30.6	2.1	0		y	220.2	>	15.1	>	14.6	>	15.6	n
39	B	10/1/2009	10:06	12.5	1	14.6	>4	>4	2	>4 to 2	186.1	12.7	10.7	13.4	2.7	Biological	37.4	2.6	4	Reduced	n	186.1	>	12.7	>	10.7	>	13.4	n
39	C	10/1/2009	10:06	12.5	1	14.6	>4	>4	2	>4 to 2	210.8	14.4	14.3	14.7	0.4	Biological	28.3	1.9	0		n	210.8	>	14.4	>	14.3	>	14.7	n

APPENDIX C – (CONTINUED)

Sediment-Profile Image Results for CLDS October 2009

Station	Replicate	Date	Time	Stop Collar Setting (in)	# of Lead Weights per Carriage	Calibration Constant	Grain Size Major Mode (phi)	Grain Size Maximum (phi)	Grain Size Minimum (phi)	Grain Size Range	Penetration Area (sq.cm)	Penetration Mean (cm)	Penetration Minimum (cm)	Penetration Maximum (cm)	Boundary Roughness (cm)	Boundary Roughness Type	aRPD Area (sq.cm)	Mean aRPD (cm)	Mud Clast Number	Mud Clast State	Methane	Total DM Area		Total DM Mean		Total DM Min		Total DM Max	Low DO?
40	B	10/1/2009	9:57	12.5	1	14.6	>4	>4	1	>4 to 1	202	13.8	13.6	14.3	0.7	Biological	53.4	3.7	4	Oxidized	n	202	>	13.8	>	13.6	>	14.3	n
40	C	10/1/2009	9:57	12.5	1	14.6	>4	>4	1	>4 to 1	196.7	13.5	13.1	13.9	0.8	Biological	39	2.7	7	Reduced	n	196.7	>	13.5	>	13.1	>	13.9	n
40	D	10/1/2009	9:59	12.5	1	14.6	>4	>4	1	>4 to 1	184.6	12.6	12.3	13.1	0.8	Biological	58.3	4.0	6	Both	n	184.6	>	12.6	>	12.3	>	13.1	n
4500 E REF 1	A	10/1/2009	14:24	12.5	1	14.6	>4	>4	2	>4 to 2	277.9	19.0	18.2	19.7	1.5	Biological	62.8	4.3	4	Oxidized	n								n
4500 E REF 1	C	10/1/2009	14:26	12.5	1	14.6	>4	>4	2	>4 to 2	218.2	14.9	14	15.6	1.6	Biological	65.2	4.5	0		n								n
4500 E REF 1	D	10/1/2009	14:27	12.5	1	14.6	>4	>4	2	>4 to 2	256.8	17.6	16.8	18.2	1.4	Biological	52.4	3.6	0		n								n
4500 E REF 2	A	10/1/2009	14:28	12.5	1	14.6	>4	>4	2	>4 to 2	223	15.3	15	15.8	0.8	Biological	55.7	3.8	20	Both	n								n
4500 E REF 2	B	10/1/2009	14:29	12.5	1	14.6	>4	>4	2	>4 to 2	219.4	15.0	14.9	15.3	0.4	Biological	60.2	4.1	7	Both	n								n
4500 E REF 2	C	10/1/2009	14:30	12.5	1	14.6	>4	>4	2	>4 to 2	243.7	16.7	16.4	17.1	0.7	Biological	61.4	4.2	0		n								n
4500 E REF 3	C	10/1/2009	14:40	12.5	1	14.6	>4	>4	2	>4 to 2	261.3	17.9	17.7	18.2	0.5	Biological	58.2	4.0	0		n								n
4500 E REF 3	D	10/1/2009	14:41	12.5	1	14.6	>4	>4	2	>4 to 2	256.1	17.5	17.3	17.9	0.6	Biological	51.2	3.5	3	Reduced	n								n
4500 E REF 4	B	10/1/2009	14:45	12.5	1	14.6	>4	>4	2	>4 to 2	207	14.2	14	14.5	0.5	Biological	58.1	4.0	3	Both	n								n
4500 E REF 4	C	10/1/2009	14:47	12.5	1	14.6	>4	>4	2	>4 to 2	199.8	13.7	13.4	14.2	0.8	Biological	55.7	3.8	0		n								n
4500 E REF 4	D	10/1/2009	14:48	12.5	1	14.6	>4	>4	2	>4 to 2	228.1	15.6	15.1	16	0.9	Biological	66.5	4.6	20	Both	n								n
4500 E REF 5	A	10/1/2009	14:53	12.5	1	14.6	>4	>4	2	>4 to 2	193.4	13.2	12.9	13.4	0.5	Biological	50.2	3.4	0		n								n
4500 E REF 5	C	10/1/2009	14:54	12.5	1	14.6	>4	>4	2	>4 to 2	217.5	14.9	14.6	15	0.4	Biological	52.1	3.6	0		n								n
4500 E REF 5	D	10/1/2009	14:56	12.5	1	14.6	>4	>4	2	>4 to 2	221.8	15.2	14.9	15.6	0.7	Biological	51.8	3.5	0		n								n
CLIS REF 1	A	10/2/2009	7:37	12.5	1	14.6	>4	>4	2	>4 to 2	211.5	14.5	14.3	14.7	0.4	Biological	49.4	3.4	0		n								n

APPENDIX C – (CONTINUED)

Sediment-Profile Image Results for CLDS October 2009

Station	Replicate	Date	Time	Stop Collar Setting (in)	# of Lead Weights per Carriage	Calibration Constant	Grain Size Major Mode (phi)	Grain Size Maximum (phi)	Grain Size Minimum (phi)	Grain Size Range	Penetration Area (sq.cm)	Penetration Mean (cm)	Penetration Minimum (cm)	Penetration Maximum (cm)	Boundary Roughness (cm)	Boundary Roughness Type	aRPD Area (sq.cm)	Mean aRPD (cm)	Mud Clast Number	Mud Clast State	Methane	Total DM Area	Total DM Mean	Total DM Min	Total DM Max	Low DO?
CLIS REF 1	B	10/2/2009	7:38	12.5	1	14.6	>4	>4	2	>4 to 2	192.2	13.2	12.9	13.5	0.6	Biological	58	4.0	0		n					n
CLIS REF 1	D	10/2/2009	7:39	12.5	1	14.6	>4	>4	0	>4 to 0	208.6	14.3	14.1	14.6	0.5	Biological	46.6	3.2	0		n					n
CLIS REF 2	A	10/2/2009	7:42	12.5	1	14.6	>4	>4	0	>4 to 0	211.1	14.5	14.4	14.8	0.4	Biological	68.6	4.7	5	Both	n					n
CLIS REF 2	B	10/2/2009	7:43	12.5	1	14.6	>4	>4	2	>4 to 2	212	14.5	14.2	15	0.8	Biological	86.9	6.0	5	Reduced	n					n
CLIS REF 2	C	10/2/2009	7:44	12.5	1	14.6	>4	>4	0	>4 to 2	215.3	14.7	14.7	15	0.3	Biological	76.7	5.3	5	Reduced	n					n
CLIS REF 3	A	10/2/2009	7:47	12.5	1	14.6	>4	>4	2	>4 to 2	217.1	14.9	14.5	15.3	0.8	Biological	58.7	4.0	0		n					n
CLIS REF 3	B	10/2/2009	7:48	12.5	1	14.6	>4	>4	2	>4 to 2	214.4	14.7	14.4	15.2	0.8	Biological	70.2	4.8	4	Both	n					n
CLIS REF 3	C	10/2/2009	7:48	12.5	1	14.6	>4	>4	2	>4 to 2	200.5	13.7	13.6	14	0.4	Biological	68	4.7	0		n					n
CLIS REF 4	B	10/2/2009	7:52	12.5	1	14.6	>4	>4	2	>4 to 2	206.2	14.1	14	14.5	0.5	Biological	62.3	4.3	0		n					n
CLIS REF 4	C	10/2/2009	7:53	12.5	1	14.6	>4	>4	2	>4 to 2	199.4	13.7	13.4	14.2	0.8	Biological	53.5	3.7	2	Both	n					n
CLIS REF 4	D	10/2/2009	7:54	12.5	1	14.6	>4	>4	2	>4 to 2	206	14.1	13.9	14.4	0.5	Biological	74.1	5.1	0		n					n
CLIS REF 5	A	10/2/2009	7:55	12.5	1	14.6	>4	>4	2	>4 to 2	192.4	13.2	13.1	13.4	0.3	Biological	50	3.4	0		n					n
CLIS REF 5	B	10/2/2009	7:56	12.5	1	14.6	>4	>4	2	>4 to 2	225.4	15.4	15.3	15.6	0.3	Biological	48.7	3.3	1	Reduced	n					n
CLIS REF 5	C	10/2/2009	7:57	12.5	1	14.6	>4	>4	2	>4 to 2	203.8	14.0	13.7	14.2	0.5	Biological	49.1	3.4	0		n					n
2500 W REF 1	B	10/1/2009	13:05	14	2	14.6	>4	>4	2	>4 to 2	308.7	21.1	20.6	21.5	0.9	Biological	86	5.9	0		n					n
2500 W REF 1	C	10/1/2009	13:06	14	2	14.6	>4	>4	2	>4 to 2	>312.1	21.5	>21.5	>21.5	ind	ind	ind	ind	0		n					n

APPENDIX C – (CONTINUED)

Sediment-Profile Image Results for CLDS October 2009

Station	Replicate	Date	Time	Stop Collar Setting (in)	# of Lead Weights per Carriage	Calibration Constant	Grain Size Major Mode (phi)	Grain Size Maximum (phi)	Grain Size Minimum (phi)	Grain Size Range	Penetration Area (sq.cm)	Penetration Mean (cm)	Penetration Minimum (cm)	Penetration Maximum (cm)	Boundary Roughness (cm)	Boundary Roughness Type	aRPD Area (sq.cm)	Mean aRPD (cm)	Mud Clast Number	Mud Clast State	Methane	Total DM Area	Total DM Mean	Total DM Min	Total DM Max	Low DO?
2500 W REF 1	D	10/1/2009	13:07	14	2	14.6	>4	>4	2	>4 to 2	278	19.0	18.9	19.4	0.5	Biological	65.4	4.5	0		n					n
2500 W REF 2	A	10/1/2009	13:10	14	2	14.6	>4	>4	2	>4 to 2	286.9	19.7	19	20.6	1.6	Biological	85.1	5.8	0		n					n
2500 W REF 2	B	10/1/2009	13:11	14	2	14.6	>4	>4	2	>4 to 2	303	20.8	20.1	21.2	1.1	Biological	47.9	3.3	8	Reduced	n					n
2500 W REF 2	D	10/1/2009	13:13	14	2	14.6	>4	>4	2	>4 to 2	283.3	19.4	19.3	19.6	0.3	Biological	56.9	3.9	0		n					n
2500 W REF 3	A	10/1/2009	13:16	14	2	14.6	>4	>4	2	>4 to 2	309.3	21.2	21.1	21.3	0.2	Biological	80.3	5.5	0		n					n
2500 W REF 3	B	10/1/2009	13:17	14	2	14.6	>4	>4	2	>4 to 2	>312.1	21.5	>21.5	>21.5	ind	ind	ind	ind	ind		n					n
2500 W REF 3	D	10/1/2009	13:19	14	2	14.6	>4	>4	2	>4 to 2	>312.1	21.5	>21.5	>21.5	ind	ind	ind	ind	ind		n					n
2500 W REF 4	A	10/1/2009	13:22	14	2	14.6	>4	>4	2	>4 to 2	300.8	20.6	19.9	21.4	1.5	Physical	85.1	5.8	6	Both	n					n
2500 W REF 4	C	10/1/2009	13:24	14	2	14.6	>4	>4	2	>4 to 2	>312.1	21.5	>21.5	>21.5	ind	ind	ind	ind	ind		n					n
2500 W REF 4	D	10/1/2009	13:25	14	2	14.6	>4	>4	2	>4 to 2	>312.1	21.5	>21.5	>21.5	ind	ind	ind	ind	ind		n					n
2500 W REF 5	A	10/1/2009	13:28	14	2	14.6	>4	>4	2	>4 to 2	307.9	21.1	20.9	21.2	0.3	Biological	66.9	4.6	0		n					n
2500 W REF 5	B	10/1/2009	13:29	14	2	14.6	>4	>4	2	>4 to 2	>312.1	21.5	>21.5	>21.5	ind	ind	ind	ind	ind		n					n
2500 W REF 5	C	10/1/2009	13:30	14	2	14.6	>4	>4	2	>4 to 2	>312.1	21.5	>21.5	>21.5	ind	ind	ind	ind	ind		n					n
2500 W REF 6	B	10/1/2009	13:46	12.5	1	14.6	>4	>4	2	>4 to 2	246.9	16.9	16.4	17.3	0.9	Biological	63.6	4.4	8	Oxidized	n					n
2500 W REF 6	C	10/1/2009	13:47	12.5	1	14.5	>4	>4	2	>4 to 2	261	18.0	17	18.7	1.7	Biological	80.5	5.6	5	Oxidized	n					n
2500 W REF 6	D	10/1/2009	13:48	12.5	1	14.6	>4	>4	2	>4 to 2	254.4	17.4	17.1	17.7	0.6	Biological	44	3.0	10	Both	n					n
2500 W REF 7	B	10/1/2009	13:52	12.5	1	14.5	>4	>4	2	>4 to 2	283.5	19.6	19	19.7	0.7	Biological	76.4	5.3	0		n					n

APPENDIX C – (CONTINUED)

Sediment-Profile Image Results for CLDS October 2009

Station	Replicate	Date	Time	Stop Collar Setting (in)	# of Lead Weights per Carriage	Calibration Constant	Grain Size Major Mode (phi)	Grain Size Maximum (phi)	Grain Size Minimum (phi)	Grain Size Range	Penetration Area (sq.cm)	Penetration Mean (cm)	Penetration Minimum (cm)	Penetration Maximum (cm)	Boundary Roughness (cm)	Boundary Roughness Type	aRPD Area (sq.cm)	Mean aRPD (cm)	Mud Clast Number	Mud Clast State	Methane	Total DM Area	Total DM Mean	Total DM Min	Total DM Max	Low DO?
2500 W REF 7	C	10/1/2009	13:53	12.5	1	14.6	>4	>4	2	>4 to 2	226.6	15.5	15.4	15.9	0.5	Biological	76.1	5.2	0		n					n
2500 W REF 7	D	10/1/2009	13:54	12.5	1	14.5	>4	>4	2	>4 to 2	240.7	16.6	16.4	16.6	0.2	Biological	52	3.6	10	Both	n					n
2500 W REF 8	A	10/1/2009	13:59	12.5	1	14.6	>4	>4	2	>4 to 2	262.8	18.0	17.7	18.4	0.7	Biological	61.7	4.2	20	Both	n					n
2500 W REF 8	B	10/1/2009	14:00	12.5	1	14.6	>4	>4	2	>4 to 2	248.8	17.0	16.4	17.5	1.1	Biological	65.8	4.5	8	Both	n					n
2500 W REF 8	C	10/1/2009	14:02	12.5	1	14.6	>4	>4	2	>4 to 2	259.1	17.7	17.5	18.2	0.7	Biological	79.6	5.5	4	Both	n					n

APPENDIX C – (CONTINUED)

Sediment-Profile Image Results for CLDS October 2009

Station	Rep	Comment	Feeding Void #	Void Minimum Depth (cm)	Void Maximum Depth (cm)	Void Average Depth (cm)	Successional Stage
1	A	Moderately reduced soft muddy DM>penetration; moderate RPD contrast; 1 small void + a few small subsurface organisms; amphipod tube at surface farfield	1	13.1	13.3	13.2	2 -> 3
1	B	Moderately reduced soft muddy DM>penetration; moderate RPD contrast; 1 void + dense surface tubes; a few amphipod tubes at surface	1	6.2	6.5	6.35	2 on 3
1	C	Moderately reduced soft muddy DM>penetration; moderate RPD contrast; 1 large-bodied polychaete at depth; assorted large + small surface tubes	0				2 -> 3
2	A	Moderately reduced soft muddy DM>penetration; moderate RPD contrast; 1 large-bodied polychaete at depth sliced in half horizontally; assorted large + small surface tubes; sediment surface partly pelletized	0				2 -> 3
2	B	Moderately reduced soft muddy DM>penetration; moderate RPD contrast; 2 shallow voids at left; small surface tubes; vertical oxygenated tubes/burrows	2	2.3	3	2.65	2 -> 3
2	C	Moderately reduced soft muddy DM>penetration; moderate RPD contrast; several partial or small voids; numerous surface tubes	3	5.1	8.2	6.65	1 on 3
3	A	Moderately reduced soft muddy DM>penetration; moderate RPD contrast; a few surface tubes, shallow subsurface burrows	0				2
3	B	Overpenetration=moderately reduced soft muddy DM>penetration; very little subsurface biological activity	IND				IND
3	C	Moderately reduced soft muddy DM>penetration; moderate RPD contrast; 1 void/vertical oxygenated burrow; numerous surface tubes	1	2.8	3.1	2.95	1 on 3
4	A	Moderately reduced soft muddy DM>penetration; moderate RPD contrast; several voids; surface tubes	4	8.4	3.1	5.75	2 -> 3
4	B	Moderately reduced soft muddy DM>penetration; moderate RPD contrast; relatively fresh dm?=surface tubes + shallow burrows= transitional stage infaunalization; organic detritus at surface	1	1.4	1.6	1.5	2
4	C	Moderately reduced soft muddy DM>penetration; moderate RPD contrast; relatively fresh dm?=surface tubes + shallow burrows=transitional stage infaunalization	0				2
5	A	Moderately reduced soft muddy DM>penetration; moderate RPD contrast; relatively fresh dm?=surface tubes + shallow burrows/voids=transitional stage infaunalization; patches of reddish brown clay	2	1.3	3.8	2.55	2
5	B	Moderately reduced soft muddy DM>penetration; moderate RPD contrast; relatively fresh DM?=much surf debris (clasts + shells + organic detritus) + a few surface tubes + shallow burrows/voids=early stage infaunalization; patches of reddish brown clay	0				1 -> 2
5	C	Moderately reduced soft muddy DM>penetration; moderate RPD contrast; relatively fresh DM? surface debris; 1 prominent void; oxygenated vertical burrows/tubes; surface tubes	1	2.9	3.5	3.2	2 -> 3
6	C	Moderately reduced soft muddy DM>penetration; moderate RPD contrast; relatively fresh DM? small subsurface voids but not biogenic; 1 vertical shallow burrow/void; transitional recolonization	0				2
6	D	Moderately reduced soft muddy DM>penetration; moderate RPD contrast; relatively fresh DM? reduced wiper clasts at sediment surface; burrows transected at depth	0				2 -> 3
6	E	Moderately reduced soft muddy DM>penetration; moderate RPD contrast; relatively fresh DM? many small wiper clasts at sediment-water interface; 2 shallow subsurface voids=early Stage 3 colonization	2	4.1	5.3	4.7	2 -> 3
7	A	Moderately reduced soft muddy DM>penetration; moderate RPD contrast; relatively fresh DM? small surface tubes, evidence of shallow subsurface activity	0				2
7	B	Partial overpenetration=Moderately reduced soft muddy DM>penetration; moderate RPD contrast; relatively fresh DM; surface tubes and 1 prominent void/burrow	1	8.5	11	9.75	1 on 3
7	D	Moderately to strongly reduced soft muddy DM>penetration; moderate to strong RPD contrast; very shallow RPD w/ reduced sediment at sediment-water interface; very fresh DM, small surface tubes but little/no evidence of subsurface activity	0				1
8	A	Moderately to strongly reduced soft muddy DM>penetration; moderate to strong RPD contrast; very fresh DM, numerous small surface tubes with one vertical oxidized burrow halo	0				1 -> 2
8	B	Soft moderately reduced muddy DM>penetration; thin RPD w/ moderate contrast; small surface tubes but little/no evidence of subsurface activity=relatively fresh DM	0				1
8	C	Moderately reduced soft muddy DM>penetration; shallow RPD w/ moderate contrast; dense surface tubes with cluster of amphipod tubes in farfield; relatively fresh DM	0				2
9	A	Moderately reduced soft muddy DM>penetration; moderate RPD contrast; dense surface tubes and shallow small burrows; leaf fragment + other plant detritus; relatively fresh DM	0				1 -> 2

APPENDIX C – (CONTINUED)

Sediment-Profile Image Results for CLDS October 2009

Station	Rep	Comment	Feeding Void #	Void Minimum Depth (cm)	Void Maximum Depth (cm)	Void Average Depth (cm)	Successional Stage
9	B	Moderately reduced soft muddy DM>penetration; moderate RPD contrast; surface tubes and extensive shallow small burrows/voids; relatively fresh DM with early to midstage colonization	1	4.1	5.2	4.65	2
9	C	Overpenetration at left third of image, moderately reduced soft muddy DM>penetration; aRPD linear measure from right half of image; relatively fresh DM in early colonization	0				1 -> 2
10	A	Moderately reduced soft muddy DM>penetration; moderate RPD contrast; dense Stage 1 surface tubes; relatively fresh DM with early colonization	0				1 -> 2
10	D	Moderately reduced soft muddy DM with very fine sandy silt at surface; DM > penetration. Stage 1 surface tubes and 1–2 small voids/burrows=relatively fresh DM with early colonization and low Stage 3 density	2	7.9	8.6	8.25	2 -> 3
10	E	DM>penetration; Sand/Mud=upper 3–4 cm is fine to medium sand w/ shell fragments over silt/clay reduced DM; fresh DM; 2 shallow voids/burrows in sand layer	2	1.4	3.2	2.3	2 -> 3
11	A	DM>penetration; Sand/Mud=upper 4 cm is fine shell fragments over reduced silt/clay DM; deep voids; moderate to strong RPD contrast	3	11.3	15.4	13.35	1 on 3
11	B	Moderately reduced soft muddy DM>penetration; moderate RPD contrast; reduced wiper clasts at sediment-water interface; a few Stage 1 surface tubes but little subsurface activity=relatively fresh DM	0				1 -> 2
11	C	Moderately reduced soft muddy DM>penetration; moderate RPD contrast; a few Stage 1 surface tubes and moderate shallow subsurface activity. Relatively fresh DM; a few small voids/burrows, possibly juvenile Stage 3 taxa	0				1 -> 2
12	A	Moderately reduced soft muddy DM>penetration; moderate RPD contrast; a few small Stage 1 surface tubes, some shallow subsurface burrows	0				1 -> 2
12	B	Moderately reduced soft muddy DM>penetration; moderate RPD contrast; dense Stage 1 surface tubes, possible 1 or 2 amphipod tubes, shallow meiofaunal burrowing	0				1 -> 2
12	C	Moderately reduced soft muddy DM>penetration; moderate RPD contrast; vertical oxygenated burrow/void complex with white worm-like organism; dense surface tubes w/ 1–2 capreliids; biological boundary roughness due to burrow	4	3.7	7.8	5.75	1 on 3
13	A	Moderately reduced soft muddy DM>penetration; moderate RPD contrast; dense surface tubes, possible capreliids and/or podocerid whip, some *Ampelisca* tubes in background.	0				1 -> 2
13	B	Moderately reduced soft muddy DM>penetration; moderate RPD contrast; dense surface tubes, 1 very small and possibly inactive void at left with some *Ampelisca* tubes in background	1	4	4.1	4.05	1 -> 2
13	C	Moderately reduced soft muddy DM>penetration; moderate RPD contrast; dense surface tubes, with some *Ampelisca* tubes; dragdown of oxygenated surface tube at depth; 1 small subsurface void at left=early Stage 3	1	12	12.1	12.05	2 -> 3
14	A	Moderately reduced soft muddy DM>penetration; distinct DM layering (new DM on older DM); surface tubes, 2 polychaetes against faceplate at depth (one at very bottom edge of image), most likely adults migrating upward from former sediment-water interface	0				2 -> 3
14	B	Moderately reduced soft muddy DM>penetration; distinct DM layering (new DM on older DM); dense surface tubes, not much evidence of subsurface biological activity	0				1
14	C	Moderately reduced soft muddy DM>penetration; distinct DM layering (new DM on older DM); some surface tubes, 1 small void at bottom of RPD at right=early Stage 3	1	4.3	4.5	4.4	2 -> 3
15	A	Moderately reduced soft muddy DM>penetration; grey clay at depth; dense surface tubes; 2 void-like excavations at depth from upward migrating adults, but otherwise little evidence of subsurface deposit feeders	2?	12	15.4	13.7	1 -> 2
15	B	Moderately reduced DM>penetration with high clay fraction; consolidated grey clay at depth; surface tubes; physical disturbance/artifact disturbing sediment-water interface at left (most likely from previous camera image); white shell fragments	3	4.7	13.8	9.25	2 -> 3
15	C	Partial overpenetration; moderately reduced very soft muddy DM>penetration; moderate RPD contrast; streaky grey clay at depth; little evidence of subsurface biological activity	0				1
16	A	Moderately reduced soft muddy DM>penetration; thin RPD w/ moderate contrast; Stage 1 surface tubes, some evidence of subsurface biological activity	0				1 -> 2
16	B	Firm consolidated grey clay DM>penetration; low penetration; thin veneer of oxygenated silt at surface w/ dense Stage 1 tubes; shallow worm-like organisms; small reduced wiper clasts	0				1 -> 2
16	C	Moderately reduced soft muddy DM>penetration; moderate RPD contrast; some surface tubes; several subsurface voids; numerous mud clasts at sediment-water interface=wiper clasts	4	6.3	14.8	10.55	1 on 3

APPENDIX C – (CONTINUED)

Sediment-Profile Image Results for CLDS October 2009

Station	Rep	Comment	Feeding Void #	Void Minimum Depth (cm)	Void Maximum Depth (cm)	Void Average Depth (cm)	Successional Stage
17	C	Moderately reduced soft muddy DM>penetration; moderate RPD contrast; a few surface tubes and edge of burrow halo transected at depth on left	0				1 -> 2
17	D	Moderately reduced soft muddy DM>penetration; moderate RPD contrast; a few surface tubes; partial void/burrow at RPD in center=early infaunalization	1	2.6	3	2.8	1 -> 2
17	F	Moderately reduced soft muddy DM>penetration; moderate RPD contrast; a few surface tubes; prominent void at bottom of RPD; biogenic mound; plan-view would have been useful here	1	3.3	4.1	3.7	1 on 3
18	A	Moderately reduced soft muddy DM>penetration; moderate RPD contrast; cohesive streaky grey clay at depth; a few surface tubes + hydroid; small void at depth, most likely from adults migrating upward; reduced wiper clasts	1	13.7	14	13.85	1 on 3
18	B	Moderately reduced soft muddy DM>penetration; moderate RPD contrast; grey clay streaks at depth; a few surface tubes; small shallow void; reduced wiper clasts	1	2.5	2.7	2.6	2
18	D	Moderately reduced soft muddy DM>penetration; moderate RPD contrast; 1 small shallow burrow w/ opening at surface=early infaunalization	0				2
19	A	Moderately reduced soft muddy DM>penetration; moderate RPD contrast; faint sulfidic horizon at depth=old DM layer; evidence of shallow subsurface activity	0				1 -> 2
19	B	Moderately reduced soft muddy DM>penetration; low to moderate RPD contrast; old DM layer horizon at depth; wiper clasts at sediment-water interface	0				1
19	C	Overpenetration; very soft muddy DM>penetration; 1 void-like opening at lower right with oxidized burrow halo above and below	1	IND	IND		IND
20	A	Moderately reduced soft muddy DM>penetration; moderate RPD contrast; prominent void/burrow; surface tubes	2	4.5	5.2	4.85	1 on 3
20	B	Moderately reduced soft muddy DM>penetration; moderate RPD contrast; small surface tubes; 2 voids at far right, oxidized burrow on left.	2	3.6	9.7	6.65	1 on 3
20	C	Somewhat firm slightly sandy streaky clay DM>penetration; sandy surface over consolidated grey clay at depth; clay clasts at sediment-water interface in farfield; 1 large-bodied worm-like organism at depth at right; sediments in this image very different than in reps A & B	0				1 on 3
21	A	Silty very fine sand; very weak RPD contrast; surface tubes; burrow opening in background	0				3
21	B	Silty fine sand DM>penetration; surface tubes; several subsurface voids	3	1.1	8.1	4.6	1 on 3
21	D	Silty very fine sand DM>penetration; one small cryptic void/burrow; edge of oxidized burrow halos transected	1	8.5	8.7	8.6	1 on 3
22	A	Silty fine to very fine sand; weak RPD contrast; surface tubes; oxidized halos at depth from subsurface burrowing	0				1 on 3
22	B	Silty fine to very fine sand; shallow feeding void; 1 organism at depth in lower left corner; reduced flocculant/mud clasts at sediment-water interface=artifact; fecal castings on surface	1	0.8	1.3	1.05	1 on 3
22	C	Silty fine to very fine sand w/ clay patches/streaks; weak RPD contrast; subsurface voids + organism; thick surface tubes; amphipod at sediment-water interface at left	3	3.8	7.7	5.75	1 on 3
23	E	Silty fine to very fine sand; hermit crab at sediment-water interface; several thick tubes (Stage 3); weak RPD contrast	0				3
23	F	Silty fine to very fine sand; upright white tube-like biological structures in farfield; worm-like organism in far left bottom corner; weak RPD contrast	0				3
23	G	Silty fine to very fine sand; white tube-like structure in farfield; other surface tubes as well; weak RPD contrast & aRPD > penetration	0				3
24	A	Sandy DM>penetration; fine sand w/ some silt/clay; numerous prominent maldanid tubes w/ extensive subsurface void/burrow gallery	6	5.2	11.1	8.15	3
24	C	Sandy DM>penetration; fine sand w/ silt; cohesive clay at depth=possible S/M layering; numerous voids + burrows; weak RPD contrast	5	2.5	11.4	6.95	3
24	D	Sandy DM>penetration; weak RPD contrast; significant silt/clay content w/ small burrow/voids at depth; surface tubes	3	4.8	8.8	6.8	1 on 3
25	B	Somewhat firm sandy DM>penetration; patchy RPD w/ weak contrast; faint sulfide patches; long polychaete tubes in background	0				1 on 3
25	E	Firm sandy DM>penetration; slightly muddy/silty; weak RPD contrast; thick short worm tubes + oxygenated rust halo at depth; 1 small void at right	1				3
25	F	Sandy DM>penetration; fine sand w/ some silty mud; shell fragments; weak RPD contrast; 1 subsurface void/burrow	1	7.8	8.1	8.0	3

Sediment-Profile Image Results for CLDS October 2009

Station	Rep	Comment	Feeding Void #	Void Minimum Depth (cm)	Void Maximum Depth (cm)	Void Average Depth (cm)	Successional Stage
26	C	Sandy DM>penetration; very fine sand w/ significant silt/clay; slightly reduced at depth; weak to moderate RPD contrast; 2 voids/burrows	2	3.1	7.1	5.1	1 on 3
26	E	Sandy DM>penetration; fine to very fine sand w/ significant silt/clay; weak RPD contrast; thick surface worm tubes=maldanids; hermit crab at left; shell fragments	0				3
26	G	Sandy DM>penetration; fine to very fine muddy sand; weak RPD contrast; vertical oxygenated burrow + 2 voids/burrows; shell in farfield	2	5.3	6.5	5.9	1 on 3
27	B	Sandy DM>penetration; very fine sand w/ significant silt/clay; weak RPD contrast; 2 small voids/burrows at depth	2	9.6	10.1	9.9	3
27	C	Sandy DM>penetration; fine to very fine sand w/ significant silt/clay; patchy RPD w/ weak contrast; small void at far left	1	4.6	4.7	4.7	3
27	D	Sandy DM>penetration; fine to very fine muddy sand; deep RPD w/ weak contrast; 1 subsurface void; numerous short thick surface tubes	1	3.6	3.7	3.7	1 on 3
28	A	Sandy DM>penetration; fine to very fine muddy sand; patchy RPD w/ weak contrast; several subsurface voids/burrows; subtle S/M layering=moderately reduced patch of silt/clay at depth	4	8.6	9.6	9.1	1 on 3
28	B	Sandy DM>penetration; fine to very fine muddy sand; subtle S/M layering; weak RPD contrast; numerous surface tubes; tube at right on biogenic mound w/ attached hydroid; several subsurface voids/burrows	4	2.9	10.3	6.6	1 on 3
28	C	Sandy DM>penetration; fine to very fine muddy sand; subtle S/M layering; weak RPD contrast; several thick surf tubes + fecal coil; subtle voids	2	8.8	9.5	9.2	3
29	A	Sandy DM>penetration; fine to very fine muddy sand; 1 subsurface void + worm-like organism; weak RPD contrast; worm tubes	1	7.5	7.7	7.6	1 on 3
29	B	Distinct S/M layering; fine sand over reduced silt/clay DM at depth; voids/burrows in silt/clay layer; small surface tubes; weak RPD contrast	3	7.7	12.2	10.0	1 on 3
29	C	Sandy DM>penetration; fine to very fine sand w/ minor brown silt/clay; patchy RPD w/ weak contrast; thick surface tubes + subtle voids/burrows at depth; vertical oxygenated tube halo at far left	2	6.1	7	6.6	3
30	A	S/M layering with chaotic fabric=mixed sand and clay layers (grey clay + patch of red clay at depth); numerous subsurface voids; pebble sediment-water interface; small surface tubes; moderate RPD contrast	7	5.1	10.5	7.8	1 on 3
30	C	DM>penetration=thin oxygenated layer of brown silt over cohesive grey silt/clay at depth; cluster of hydroids at sediment-water interface; surface tubes; 1 prominent subsurface void + 1 partial void at depth	2	4.1	10.1	7.1	1 on 3
30	E	DM>penetration=thin surface layer of oxygenated brown silt over cohesive grey clay at depth; numerous cohesive grey clay clasts are sampling artifacts; hydroid cluster at sediment-water interface; several prominent subsurface feeding voids	4	5.1	8.5	6.8	1 on 3
31	B	DM>penetration; soft muddy sulfidic DM>penetration; distinct layering=new DM layer over older sandy DM; several deep voids; deep RPD w/ strong contrast; intense biological reworking at sediment-water interface	5	12.9	16.8	14.9	1 on 3
31	C	DM>penetration; several layers of soft muddy-clayey moderately reduced DM; deep RPD w/ moderate contrast; several subsurface voids	4	3.1	18.9	11.0	1 on 3
31	D	DM>penetration; soft muddy moderately reduced DM; deep RPD w/ moderate contrast; sediment is more reduced at depth; surface reworking; several voids	3	5.4	15.3	10.4	1 on 3
32	B	DM>penetration; consolidated but relatively soft grey clay; weak to moderate RPD contrast; prominent vertical oxygenated burrow w/ surface opening; orange/red worms visible in sediment; hydroids; amphipod tubes at right	4	2.2	9.3	5.8	2 on 3
32	C	DM>penetration; consolidated but relatively soft grey clay w/ silty surface; several small hydroids and several caprellids at sediment-water interface; several subsurface voids	4	1.6	3.7	2.7	1 on 3
32	D	DM>penetration; consolidated moderately soft grey clay w/ sandy-silty surface; moderate RPD contrast, more reduced at depth; small voids; surface tubes + hydroids in farfield	5	2.4	9.2	5.8	1 on 3
33	A	Sandy DM>penetration; fine sand mixed w/ significant greyish silt/clay; numerous subsurface voids/burrow complex; surface tubes; fecal mound in farfield	10	3.5	9.5	6.5	1 on 3
33	C	Underpenetration=firm sandy DM>penetration; sediment-water interface partly obscured by turbidity; RPD>penetration: thick surface tubes are visible; shallow subsurface burrow	IND	IND	IND		3
33	D	Underpenetration=firm sandy DM>penetration; several large thick surface tubes against faceplate at sediment-water interface; hydroid + shells (appear to be mussels) in farfield; subsurface biogenic voids/burrows	1	1.7	2.2	2.0	1 on 3

APPENDIX C – (CONTINUED)

Sediment-Profile Image Results for CLDS October 2009

Station	Rep	Comment	Feeding Void #	Void Minimum Depth (cm)	Void Maximum Depth (cm)	Void Average Depth (cm)	Successional Stage
34	A	DM>penetration; cohesive yet moderately soft grey clay w/ brown silt at surface; dense surface tubes + hydroids; numerous small worm-like organisms at depth	0				1 on 3
34	B	DM>penetration; soft reduced muddy DM; moderate to strong RPD contrast; dense Stage 1 surface tubes; several subsurface voids; reduced wiper clasts	3	7.7	14.9	11.3	1 on 3
34	D	DM>penetration; cohesive grey clay w/ brown sandy silt w/ shell fragments at sediment surface; numerous hydroids; subsurface voids + burrows + worms at depth	4	2.7	9	5.9	1 on 3
35	B	DM>penetration; soft muddy moderately reduced DM w/ moderate to strong RPD contrast; surface tubes + biological reworking of sediment-water interface; partial void at right	1	4.9	5	5.0	2 -> 3
35	C	DM>penetration; soft muddy moderately reduced DM w/ moderate to strong RPD contrast; small surface tubes; 1 subsurface worm-like organism at right=early Stage 3 colonization; shallow bivalves (*Mulinia*?) in upper 1 cm	0				2 -> 3
35	D	DM>penetration; soft muddy moderately reduced DM w/ moderate RPD contrast; patches of cohesive grey clay; biological reworking of sediment-water interface (fecal pellets); 2 small voids and numerous very small worm-like organisms at depth	2	2.3	6.7	4.5	1 on 3
36	A	Distinct S/M layering=upper 4 cm is fine to medium sand w/ shell fragments over grey cohesive clay DM; several prominent subsurface voids; surface tubes; oyster shell fragments	4	2.3	9.3	5.8	1 on 3
36	C	Distinct S/M layering=upper 3–4 cm is fine to medium sand w/ shell fragments (cap material?) over grey reduced silt/clay DM; several prominent subsurface voids w/ surface sand incorporated; surface tubes; shell fragments; wiper clasts	8	3.3	9.7	6.5	1 on 3
36	D	Distinct S/M layering=upper 3–4 cm is fine to medium sand w/ shell fragments (cap material?) over grey reduced silt/clay DM; several prominent subsurface voids w/ surface sand incorporated; surface tubes; wiper clasts; one small methane bubble; 1 or 2 subsurface worm-like organisms	5	3	7.8	5.4	1 on 3
37	A	DM>penetration; soft reduced mud w/ well-developed RPD and advanced recolonization (surface tubes + multiple voids + worm-like organisms); hydroids at sediment-water interface (look like stick amphipods but see next rep)	5	9.9	12.6	11.3	1 on 3
37	B	DM>penetration; soft reduced mud w/ well-developed RPD and extensive biological activity (surface hydroids + vertical active burrow + multiple voids + large-bodied worms)	6	3.9	13.6	8.8	1 on 3
37	D	DM>penetration; soft reduced mud w/ well-developed RPD and extensive biological activity; voids, oxygenated burrow w/ opening, dense surface tubes, fecal casts + dense fecal pellets at sediment-water interface	3	3.5	9.7	6.6	1 on 3
38	A	DM>penetration; soft moderately reduced silt/clay w/ well-developed RPD; several subsurface voids/burrows; dense small surface tubes	4	3.6	13.8	8.7	1 on 3
38	B	DM>penetration; soft moderately reduced silt/clay w/ well-developed RPD; small clasts at sediment-water interface=camera artifact; small surface tubes, 2–3 small voids/burrows	3	7.8	9.3	8.6	1 on 3
38	C	DM>penetration; soft moderately reduced silt/clay w/ well-developed RPD; biogenic mound w/ shallow burrow; several voids	6	3	17.1	10.1	1 on 3
39	A	DM>penetration; soft reduced silt/clay w/ RPD that is shallower than other stations; 1 prominent methane bubble at left; decreased subsurface biological activity compared to other stations	0				2 -> 3
39	B	DM>penetration; soft reduced silt/clay w/ well-developed RPD; surface tubes, large vertical oxygenated burrow containing part of worm tube; 1 void; thick surface tube at burrow opening	1	9.1	9.4	9.3	1 on 3
39	C	DM>penetration; chunk of weathered consolidated grey clay w/ reduced soft silt/clay; surface of oxygenated brown silt; small surface tubes; subsurface voids and numerous small worm-like organisms; moderate RPD contrast	3	3.7	12.4	8.1	1 on 3
40	B	DM>penetration; soft moderately reduced silt/clay w/ a sandy horizon at depth; layering=sand is bottom of upper DM layer; several voids and worm-like organisms at depth; surface tubes; biological reworking of sediment-water interface	2	5.5	8.1	6.8	1 on 3
40	C	DM>penetration; soft moderately reduced silt/clay w/ some sandy patches at depth; grey clay at depth; numerous voids/burrows + 1 large-bodied worm-like organism at center left	6	4.8	13.5	9.2	1 on 3
40	D	DM>penetration; soft reduced silt/clay w/ significant sand at depth; mud over sand=DM layering; numerous subsurface voids/burrows; large mud clasts at sediment-water interface	8	4.3	12.4	8.4	1 on 3
4500 E REF 1	A	Very soft homogenous ambient silt/clay>penetration; at least 2 vertical burrows in upper 3–4 cm; weak to moderate RPD contrast=light color at depth=not sulfidic	0				3
4500 E REF 1	C	Soft homogenous ambient silt/clay>penetration; weak to moderate RPD contrast=not highly sulfidic at depth; biological reworking of surface; surface tubes; several subsurface voids	3	6.7	13.6	10.2	1 on 3

Sediment-Profile Image Results for CLDS October 2009

Station	Rep	Comment	Feeding Void #	Void Minimum Depth (cm)	Void Maximum Depth (cm)	Void Average Depth (cm)	Successional Stage
4500 E REF 1	D	Soft homogenous ambient silt/clay>penetration; partial camera smearing of RPD=measured deeper than it appears; weak RPD contrast; shallow + deep voids; surface tubes	6	1.5	14	7.8	1 on 3
4500 E REF 2	A	Soft homogenous ambient silt/clay>penetration; weak RPD contrast; multiple voids/burrow; slightly sulfidic horizon at depth; surface tubes	10	3.5	8.8	6.2	1 on 3
4500 E REF 2	B	Soft homogenous ambient silt/clay>penetration; weak RPD contrast; multiple voids/burrows; surface tubes + biogenic reworking of sediment surface	6	1.8	13.2	7.5	1 on 3
4500 E REF 2	C	Soft homogenous ambient silt/clay>penetration; weak RPD contrast; multiple voids/burrows; surface tubes + biogenic reworking of sediment surface	9	1.6	16.3	9.0	1 on 3
4500 E REF 3	C	Soft homogenous ambient silt/clay>penetration; weak RPD contrast=low sulfides; dense surface tubes; several small cryptic/partial voids	4	9.7	17.6	13.7	1 on 3
4500 E REF 3	D	Soft homogenous ambient silt/clay>penetration; weak RPD contrast=low sulfides; surface tubes; several voids	6	3.8	13.8	8.8	1 on 3
4500 E REF 4	B	Soft homogenous ambient silt/clay>penetration; weak RPD contrast=low sulfides; surface tubes; several voids	6	1.3	4.6	3.0	1 on 3
4500 E REF 4	C	Soft homogenous ambient silt/clay>penetration; weak RPD contrast=low sulfides; surface tubes; several voids; vertical oxygenated tube or burrow	3	3.9	10.1	7.0	1 on 3
4500 E REF 4	D	Soft homogenous ambient silt/clay>penetration; weak RPD contrast=low sulfides; surface tubes; multiple subsurface voids/burrows	11	2.7	15.4	9.1	1 on 3
4500 E REF 5	A	Soft homogenous ambient silt/clay>penetration; weak RPD contrast=low sulfides; small surface tubes + significant biological reworking of sediment-water interface; 2 active voids + worm-like organism in lower left corner	2	7.7	9.7	8.7	1 on 3
4500 E REF 5	C	Soft homogenous ambient silt/clay>penetration; weak RPD contrast=low sulfides; small surface tubes + significant biological reworking of sediment-water interface; several subsurface voids/burrows	6	2.8	14.5	8.7	1 on 3
4500 E REF 5	D	Soft homogenous ambient silt/clay>penetration; weak RPD contrast=low sulfides; small surface tubes + significant biological reworking of sediment-water interface; several subsurface voids/burrows	6	2.4	8.2	5.3	1 on 3
CLIS REF 1	A	Soft homogenous ambient silt/clay>penetration; weak RPD contrast=low sulfides; small surface tubes + significant biological reworking of sediment-water interface; several subsurface voids/burrows	2	5.7	9	7.4	1 on 3
CLIS REF 1	B	Soft homogenous ambient silt/clay>penetration; weak RPD contrast=low sulfides; small surface tubes + significant biological reworking of sediment-water interface; several subsurface voids/burrows; vertical oxygenated burrow; several subsurface worm-like organisms	3	1.5	7	4.3	1 on 3
CLIS REF 1	D	Soft homogenous ambient silt/clay>penetration; weak RPD contrast=low sulfides; small surface tubes + significant biological reworking of sediment-water interface; several subsurface voids/burrows	6	1.5	14	7.8	1 on 3
CLIS REF 2	A	Soft homogenous ambient silt/clay>penetration; weak RPD contrast=low sulfides; small surface tubes + significant biological reworking of sediment-water interface; several subsurface voids/burrows	8	2.7	14.1	8.4	1 on 3
CLIS REF 2	B	Soft homogenous ambient silt/clay>penetration; weak RPD contrast=low sulfides; small surface tubes + significant biological reworking of sediment-water interface; several subsurface voids/burrows; vertical burrows w/ openings at sediment-water interface	6	4.6	13.6	9.1	1 on 3
CLIS REF 2	C	Soft homogenous ambient silt/clay>penetration; weak RPD contrast=low sulfides; small surface tubes + significant biological reworking of sediment-water interface; several subsurface voids/burrows; subsurface worms; reduced wiper clasts	3	2	7.5	4.8	1 on 3
CLIS REF 3	A	Soft homogenous ambient silt/clay>penetration; weak RPD contrast=low sulfides; surface tubes + significant biological reworking of sediment-water interface; several subsurface voids	7	1.9	7.4	4.7	1 on 3
CLIS REF 3	B	Soft homogenous ambient silt/clay>penetration; weak RPD contrast=low sulfides; surface tubes + significant biological reworking of sediment-water interface; several small subsurface voids	3	6.9	10.7	8.8	1 on 3
CLIS REF 3	C	Soft homogenous ambient silt/clay>penetration; weak RPD contrast=low sulfides; surface tubes + significant biological reworking of sediment-water interface; several small subsurface voids	4	1.6	12.8	7.2	1 on 3
CLIS REF 4	B	Soft homogenous ambient silt/clay>penetration; weak RPD contrast=low sulfides; surface tubes + significant biological reworking of sediment-water interface; several small subsurface voids	6	1.4	4.7	3.1	1 on 3
CLIS REF 4	C	Soft homogenous ambient silt/clay>penetration; weak RPD contrast=low sulfides; surface tubes + significant biological reworking of sediment-water interface; several subsurface voids; vertical oxygenated burrow/tube; biogenic mound at left	3	4	10.6	7.3	1 on 3
CLIS REF 4	D	Soft homogenous ambient silt/clay>penetration; weak RPD contrast=low sulfides; surface tubes + significant biological reworking of sediment-water interface; several subsurface voids; large vertical oxygenated burrow	3	4.2	7.9	6.1	1 on 3

APPENDIX C – (CONTINUED)

Sediment-Profile Image Results for CLDS October 2009

Station	Rep	Comment	Feeding Void #	Void Minimum Depth (cm)	Void Maximum Depth (cm)	Void Average Depth (cm)	Successional Stage
CLIS REF 5	A	Soft homogenous ambient silt/clay>penetration; weak RPD contrast=low sulfides; surface tubes + significant biological reworking of sediment-water interface; several subsurface voids; worm-like organism at lower left; small biogenic mound at sediment-water interface at right	2	7.7	9.8	8.8	1 on 3
CLIS REF 5	B	Soft homogenous ambient silt/clay>penetration; weak RPD contrast=low sulfides; surface tubes + significant biological reworking of sediment-water interface; several subsurface voids; vertical oxygenated tube at center	6	1.6	11.3	6.5	1 on 3
CLIS REF 5	C	Soft homogenous ambient silt/clay>penetration; weak RPD contrast=low sulfides; surface tubes + significant biological reworking of sediment-water interface; several small subsurface voids	4	3.3	8.8	6.1	1 on 3
2500 W REF 1	B	Very soft homogenous ambient silt/clay>penetration; partial overpenetration in soft mud; weak RPD contrast=low sulfides; surface tubes; one small and one large burrow/void at depth	2	10.1	20.1	15.1	1 on 3
2500 W REF 1	C	Overpenetration=very soft homogenous ambient silt/clay>penetration; RPD and successional stage indeterminate	0				IND
2500 W REF 1	D	Soft homogenous ambient silt/clay>penetration; weak RPD contrast=low sulfides; surface tubes + significant biological reworking of sediment-water interface; several small subsurface voids; large-bodied infaunal organism	5	1.3	14.9	8.1	1 on 3
2500 W REF 2	A	Soft homogenous ambient silt/clay>penetration; weak RPD contrast=low sulfides; surface tubes + significant biological reworking of sediment-water interface; 1–2 small subsurface voids/burrows; vertical oxygenated tubes/burrows	3	2.4	13.2	7.8	1 on 3
2500 W REF 2	B	Soft homogenous ambient silt/clay>penetration; weak RPD contrast=low sulfides; surface tubes + significant biological reworking of sediment-water interface; dragdown of reduced sediment=camera smearing artifact; 1 large subsurface void/burrow; brownish worm at depth near bottom of image	1	13.2	16.7	15.0	1 on 3
2500 W REF 2	D	Soft homogenous ambient silt/clay>penetration; weak RPD contrast=low sulfides; surface tubes + significant biological reworking of sediment-water interface; several small shallow voids/burrows + one partial deeper subsurface void	4	1.3	9.7	5.5	1 on 3
2500 W REF 3	A	Partial overpenetration=very soft homogenous ambient silt/clay>penetration; surface tubes, 2 small cryptic voids	2	2.5	4.2	3.4	1 on 3
2500 W REF 3	B	Overpenetration=very soft homogenous ambient silt/clay>penetration; RPD and successional stage indeterminate	0				IND
2500 W REF 3	D	Overpenetration=very soft homogenous ambient silt/clay>penetration; vertical oxygenated burrow/void and subsurface voids=Stage 3	4	IND	IND	IND	1 on 3
2500 W REF 4	A	Soft homogenous ambient silt/clay>penetration; deep RPD w/ weak contrast=low sulfides; surface tubes + significant biological reworking of sediment-water interface; 2 small cryptic voids; wiper clasts	2	5.2	10.3	7.8	1 on 3
2500 W REF 4	C	Overpenetration=very soft homogenous ambient silt/clay>penetration; vertical oxygenated burrow/void and subsurface voids=Stage 3	2	IND	IND	IND	1 on 3
2500 W REF 4	D	Overpenetration=very soft homogenous ambient silt/clay>penetration; numerous subsurface voids + organisms=Stage 3	2	IND	IND		1 on 3
2500 W REF 5	A	Very soft homogenous ambient silt/clay>penetration; deep RPD w/ weak contrast=low sulfides; surface tubes + significant biological reworking of sediment-water interface; several subsurface voids; small wiper clasts	5	7.1	13.9	10.5	1 on 3
2500 W REF 5	B	Overpenetration=very soft homogenous ambient silt/clay>penetration; several subsurface voids + organisms=Stage 3	3	IND	IND	IND	1 on 3
2500 W REF 5	C	Overpenetration=very soft homogenous ambient silt/clay>penetration; subsurface voids + organisms=Stage 3	2	IND	IND	IND	1 on 3
2500 W REF 6	B	Soft homogenous ambient silt/clay>penetration; surface tubes + intense biological reworking of sediment-water interface; weak RPD contrast=low sulfides; numerous subsurface voids	9	0.7	14.4	7.6	1 on 3
2500 W REF 6	C	Soft homogenous ambient silt/clay>penetration; deep RPD w/ weak contrast=low sulfides; surface tubes + intense biological reworking of sediment-water interface; subsurface voids	4	6.1	16.6	11.4	1 on 3
2500 W REF 6	D	Soft homogenous ambient silt/clay>penetration; weak RPD contrast=low sulfides; surface tubes + intense biological reworking of sediment-water interface; 1 small cryptic subsurface void	1	5.6	5.7	5.7	1 on 3
2500 W REF 7	B	Soft homogenous ambient silt/clay>penetration; weak RPD contrast=low sulfides; surface tubes + intense biological reworking of sediment-water interface; several subsurface voids + organism	5	1.4	11.4	6.4	1 on 3
2500 W REF 7	C	Soft homogenous ambient silt/clay>penetration; weak RPD contrast=low sulfides; surface tubes + intense biological reworking of sediment-water interface; subsurface voids	3	3.1	13.8	8.5	1 on 3

APPENDIX C – (CONTINUED)

Sediment-Profile Image Results for CLDS October 2009

Station	Rep	Comment	Feeding Void #	Void Minimum Depth (cm)	Void Maximum Depth (cm)	Void Average Depth (cm)	Successional Stage
2500 W REF 7	D	Soft homogenous ambient silt/clay>penetration; weak RPD contrast=low sulfides; surface tubes + intense biological reworking of sediment-water interface; 1 subsurface void; vertical oxygenated tube/burrow; several subsurface organisms	1	5.6	5.7	5.7	1 on 3
2500 W REF 8	A	Soft homogenous ambient silt/clay>penetration; weak RPD contrast=low sulfides; surface tubes + intense biological reworking of sediment-water interface; 2 subsurface voids; small organisms	2	1.5	15.5	8.5	1 on 3
2500 W REF 8	B	Soft homogenous ambient silt/clay>penetration; weak RPD contrast=low sulfides; surface tubes + intense biological reworking of sediment-water interface; several subsurface voids; at least 2 vertical oxygenated burrows	6	11.3	16.8	14.1	1 on 3
2500 W REF 8	C	Soft homogenous ambient silt/clay>penetration; weak RPD contrast=low sulfides; surface tubes + intense biological reworking of sediment-water interface; several small subsurface voids; subsurface organisms	6	0.8	12.2	6.5	1 on 3