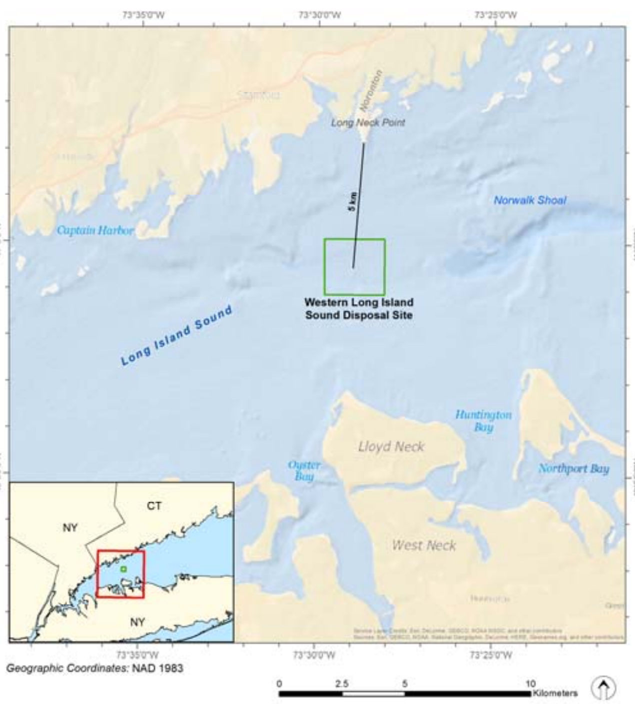
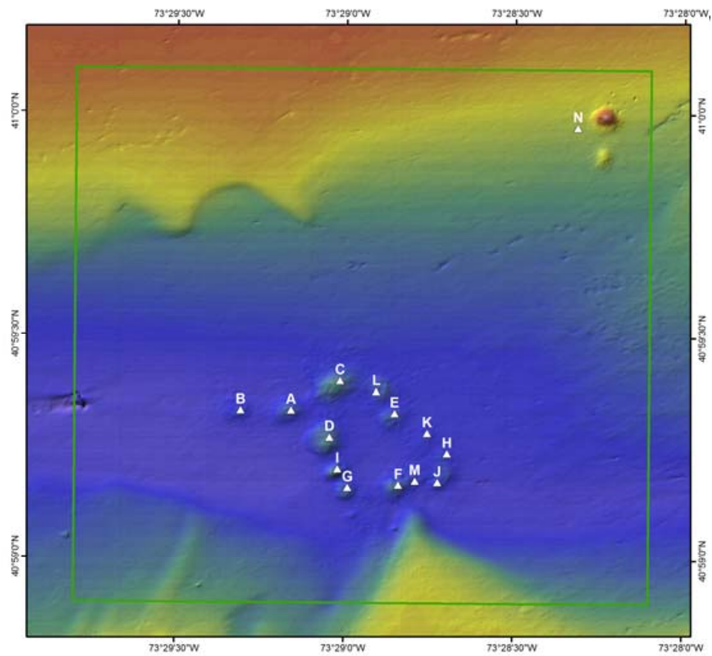
Monitoring Survey at the Western Long Island Sound Disposal Site
August 2014

Disposal Area Monitoring System DAMOS

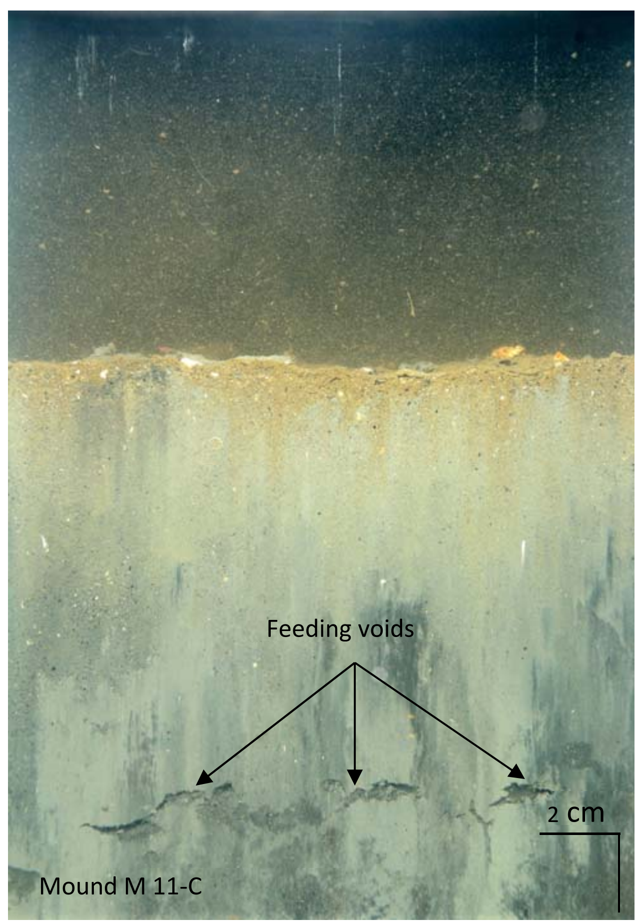




D A M O S

DISPOSAL AREA MONITORING SYSTEM

Contribution 199
April 2017



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13. ABSTRACT

In August 2014, a survey of the Western Long Island Sound Disposal Site (WLDS) was conducted to characterize seafloor topography at the disposal site, to document the condition and distribution of dredged material at recent and historic disposal target locations, and to assess the status of benthic community recolonization at recently formed disposal mounds (WLDS Mounds M and N). In order to meet these objectives, acoustic and imaging data were collected and conditions at disposal mounds were compared to three established reference areas. Additional data were collected for the purpose of revising the WLDS Site Management and Monitoring Plan, a periodic requirement for the U.S. Environmental Protection Agency for designated offshore dredged material disposal sites.

Specifically, acoustic measurements (bathymetric, backscatter, and side-scan sonar) were collected to characterize the shape of disposal mounds and other features on the seafloor influenced by placement of these materials. Sediment-profile imaging (SPI) and plan-view (PV) imaging were used to capture images that reveal further details about the physical conditions of the sediment, as well as important indicators of seafloor (benthic) biological habitat and post-disposal recovery. Benthic grab samples provided sediment that was analyzed for grain size composition (e.g., silt, sand, gravel, etc.), total organic carbon content, and for the identification of species found living within the sediment. These grab samples provided data that will be used to inform the revision of the Site Management and Monitoring Plan for WLDS.

Acoustic results show that dredged material has accumulated at the two northeast placement locations. For the most part, depths have not changed in other regions of the site since last surveyed in 2005. However, a small area of recent deposits of dredged material were found between Mounds G and F and were most likely placed during the 2009-2010 season. Results show features consistent with dredged material disposal throughout the site in addition to disposal mounds, including traces of barge deposition and lines of disposal craters and ring features of pits or craters around disposal target locations.

SPI images show the presence of dredged material at disposal mound locations, as well as evidence of benthic recovery. Benthic recovery is indicated by the presence of a subsurface infaunal community that reworks the sediment in characteristic ways that are discernable in the images. PV images show the opening of the burrows created by this community, in addition to tracks made by a mobile epifaunal community. The depth of the oxidized sediment [i.e., apparent redox potential discontinuity (aRPD)] was significantly less deep at disposal mounds than at reference areas. However, there was no difference between the successional stages of the respective benthic communities at reference and disposal mound areas. These differences indicate that benthic recolonization is progressing at Mounds M and N but is not complete as of this 2014 survey.

Results from the grab samples support SPI/PV results confirming a benthic community consisting of polychaetes, bivalves, gastropods, and nemerteans. Diverse infaunal communities occupied both reference and disposal mound locations with the two dominant taxa being the polychaete Nephtys incisa and the bivalve Nucula proxima. Diversity and abundance varied somewhat between locations, but both show signs of a robust benthic community. Based on the findings of the 2014 WLDS survey, our recommendations are:

R1. The presence of stable mounds and normal benthic recolonization indicate no need for remediation actions or change in dredged material placement approach;

R2. Continue monitoring efforts consistent with Tiered Monitoring Protocols based on volume placed at site;

R3. Future monitoring efforts should be scheduled earlier in the summer (i.e., June) due to the frequency of hypoxia in Long Island Sound, usually reaching its peak late in the summer.

14. SUBJECT TERMS DAMOS, dredged material, WLDS, Western Long Island Sound, acoustic, multibeam, SPI, PV, benthic, infauna

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

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LIST OF ACRONYMS

aRPD	Apparent redox potential discontinuity
ASCII	American Standard Code for Information Interchange
DAMOS	Disposal Area Monitoring System
BTS	Beam time-series
CLT	Central limit theorem
CT DEEP	Connecticut Department of Energy and Environmental Protection
CTD	Conductivity-temperature-depth
DAMOS	Disposal Area Monitoring System
DGPS	Differential GPS
DO	Dissolved oxygen
GIS	Geographic Information System
GPS	Global Positioning System
LUX	Unit of measure. The amount of light that falls on a surface is measured in lux. One lux is the light obtained from a source of one lumen over an area of one square meter.
MBES	Multibeam echo sounder
MLLW	Mean Lower Low Water
MPRSA	Marine Protection, Research and Sanctuaries Act
MRU	Motion reference unit
NAD83	North American Datum of 1983
NAE	USACE New England District
NEF	Nikon Electronic Format
NOAA	National Oceanic and Atmospheric Administration
NOS	National Ocean Service

PPS	Pulse-per-second
PV	Plan-View
RTK	Real time kinematic GPS
R/V	Research vessel
SBAS	Satellite-based differential corrections
SMMP	Site Management and Monitoring Plan
SOPs	Standard Operating Procedures
SPI	Sediment-Profile Imaging
SVP	Sound velocity profile
TIF	Tagged image file
TOC	Total organic carbon
TOST	Two one-sided tests
UNH/NOAA CCOM	University of New Hampshire's NOAA Center for Coastal and Ocean Mapping
USACE	U.S. Army Corps of Engineers
USCG	U.S. Coast Guard
USEPA	U.S. Environmental Protection Agency
VRS	Virtual Reference Station System
WLDS	Western Long Island Sound Disposal Site
WLIS	Western Long Island Sound

In August 2014, a survey of the Western Long Island Sound Disposal Site (WLDS) was conducted to characterize seafloor topography at the disposal site, to document the condition and distribution of dredged material at recent and historic disposal target locations, and to assess the status of benthic community recolonization at recently formed disposal mounds (WLDS Mounds M and N). In order to meet these objectives, acoustic and imaging data were collected and conditions at disposal mounds were compared to three established reference areas. Additional data were collected for the purpose of revising the WLDS Site Management and Monitoring Plan, a periodic requirement for the U.S. Environmental Protection Agency for designated offshore dredged material disposal sites.

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1.0 INTRODUCTION

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

1.1 Overview of the DAMOS Program

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

DAMOS monitoring surveys fall into two general categories: confirmatory studies and focused studies. Confirmatory studies are designed to test hypotheses related to expected physical and ecological response patterns following placement of dredged material on the seafloor at established, active disposal sites. The data collected and evaluated during these studies provide answers to strategic management questions in the disposal site management process. Focused studies are periodically undertaken within the DAMOS Program to evaluate inactive or historical disposal sites and contribute to the development of dredged material techniques and management planning. The 2014 WLDS survey was both a confirmatory study and a focused study. The survey featured confirmatory monitoring of areas that had recently received dredged material. Additional focused data collection was conducted to support revision of the WLDS Site Management and Monitoring Plan (SMMP), a periodic requirement for U.S. Environmental Protection Agency (USEPA) for designated offshore dredged material disposal sites.

Two primary goals of DAMOS confirmatory monitoring surveys are to document the physical location and stability of dredged material placed into the aquatic environment and to evaluate the biological recovery of the benthic community following placement of the dredged material. Several survey techniques are employed in order to characterize these responses to dredged material placement. Sequential acoustic monitoring surveys (including bathymetric, acoustic backscatter, and side-scan sonar measurements) are conducted to characterize the height and spread of discrete dredged material deposits or mounds created at open water sites.

Sediment-profile imaging (SPI) and plan-view underwater camera photography (referred to as plan-view [PV] imaging) surveys are performed to provide further physical characterization of the material and to support evaluation of seafloor (benthic) habitat conditions and recovery over time. Each type of data collection activity is conducted periodically at disposal sites and the conditions found after a defined period of disposal activity are compared with the long-term data set at specific sites to determine the next step in the disposal site management process (Germano et al. 1994). Focused DAMOS monitoring surveys may also feature additional types of data collection activities as deemed appropriate to achieve specific survey objectives, such as grab sampling of sediment for physical and biological analysis, sub-bottom profiling, or sediment coring.

1.2 Introduction to the Western Long Island Sound Disposal Site

WLDS is located approximately 5 km (2.7 nmi) south of Long Neck Point, Noroton, Connecticut and occupies a 5.3 km^2 (2 mi^2) rectangular area centered at 40° 59.50' N, 73° 28.95' W (NAD 83) (Figure 1-1). WLDS was opened in 1982 and formally designated as an Ocean Dredged Material Disposal Site under the Marine Protection, Research and Sanctuaries Act (MPRSA, also known as the Ocean Dumping Act) in June 2005. WLDS is situated in the vicinity of three historic dredged material disposal sites (Stamford, South Norwalk, and Easton's Neck; Figure 1-2).

The management strategy at WLDS has featured the controlled placement of dredged material to form individual disposal mounds arranged in a ring on the seafloor. The ring of disposal mounds was designed to form a containment cell that could subsequently be used for large-scale confined aquatic disposal. Such containment cells have proven useful at confining the lateral spread of dredged material deposits at the Central Long Island Sound Disposal Site and other disposal sites (ENSR 2005).

Water depths in WLDS range from 23 to 35 m (75 to 114 ft) with a relatively uniform slope from shallower in the north to deeper toward the south (Figure 1-3). A ridge feature rises up along the southern border of the site bringing water depths to approximately 33 to 27 meters. In the south-central region of the site, a set of dredged material mounds are visible that rise as much as 3 m above the seafloor. The majority of historic disposal activity at WLDS has been confined to the south-central basin of the site where thirteen dredged material disposal mounds (denoted as mounds WLIS-A through WLIS-M) have been placed in a ring-shaped arrangement (Figure 1-4). The letter designation is preceded by the prefix WLIS (Western Long Island Sound) in order to retain the naming convention used in previous DAMOS reports.

1.3 Historic Dredged Material Disposal Activity

WLDS was used regularly as a regional disposal site from 1982 through 2005, receiving a total of 875,000 m^3 (1.14 million yd^3) of dredged material. Thirteen distinct mounds (A through M, Figure 1-4) were developed on the seafloor in the south-central quadrant of WLDS. Table 1-1 provides the season the mounds were created, estimated volume disposed, and report reference for each WLDS mound. Mounds A and B were formed first, prior to the management decision to form a ring of mounds. Placement of dredged material at WLDS between 1986 and 1996 resulted in the formation of a ring of six disposal mounds (C, D, E, F, G, H, and I) partially enclosing a containment cell approximately 0.3 km^2 (0.1 mi^2) in the south-central region of WLDS (SAIC 2002) (Figure 1-4). Between 1997 and 2004, Mounds J, K, and L were formed in an effort to refine and complete the structure of the containment cell (SAIC 2002). During the 2004-2005 season, Mound M was formed to further enhance the ring-shaped containment formation.

1.4 Previous Monitoring Events

A summary of all WLDS monitoring events which occurred 1990 through 2005 is presented in Table 1-2. The last confirmatory survey was performed in 2004 (DAMOS Contribution #161, ENSR 2005) and a focused detailed baseline bathymetry survey of the entire site was conducted following formal site designation in 2005 (DAMOS Contribution #177, ENSR 2007).

In June 2004, a bathymetric survey was performed over a 1200 m × 1200 m [1.44 km^2 (0.55 mi^2)] area in the south-central portion of WLDS. The results of the 2004 survey indicated that 70,000 m^3 (91,557 yd^3) of dredged material was placed at WLDS between 2001 and 2004 near the WLIS J Mound which spread and settled onto the nearby WLIS H Mound, causing the two small mounds to coalesce into one oblong-shaped mound. The height of the resulting WLIS J/H Mound Complex was approximately 1.5 m (5 ft) above the surrounding seafloor (ENSR 2007).

The July 2005 focused WLDS survey was the first site-wide (2600 × 2800 m) high-resolution bathymetric survey performed. The survey provided baseline bathymetry of the entire site following its formal designation in 2005.

1.5 Recent Dredged Material Disposal Activity

Since the July 2005 survey, WLDS has typically received intermittent dredged material placement, with annual volumes averaging less than 32,500 m^3 (42,500 yd^3) in recent years (Table 1-3, Figure 1-5). The disposal mounds examined in this survey, M and N, were targets for these placements. Mound M was formed in 2004/2005 with ~78,500 m^3 (103,000 yd^3) as part of a mound complex with F and J. An additional 30,600 m^3 (40,000 yd^3) of dredged material was placed in the vicinity of Mound M during disposal seasons 2005-2006, 2006-2007, 2007-2008, and 2009-2010 (Figure 1-5). The material from season 2005-2006 and 2007-2008 [19,867 m^3 (25,985 yd^3)] were placed east of the Mound F/M/J complex. In 2009-2010, 7,998 m^3 (10,461 yd^3) of material was placed southeast of the Mound F/M/J complex (Figure 1-5). The material from season 2006-2007 [2,752 m^3 (3,600 yd^3)] was placed at Mound K just north of Mound M.

Beginning in 2010, placement of dredged material was targeted to the northeast corner of WLDS closer to dredging projects. Mound N was formed in the 2010-2011 season with close to 20,000 m^3 (26,000 yd^3) and received additional materials in the 2011-2012, 2012-2013, and 2013-2014 disposal seasons totaling 65,000 m^3 (85,000 yd^3). Complete disposal log data is provided in Appendix B.

1.6 2014 Survey Objectives

The August 2014 survey was designed to meet the following confirmatory and focused study objectives:

- Determine the physical stability of the seafloor sediments at the disposal site
- Assess the benthic habitat quality of recently placed dredged material compared to reference area conditions
- Evaluate the benthic infaunal community and sediment characteristics of the disposal site compared to reference conditions and 2005 conditions to provide additional information in support of the revision of the SMMP.

The following tasks were defined to meet the survey objectives:

- Characterize seafloor topography and surficial features of the full WLDS by completing an acoustic survey (bathymetry, backscatter, and side-scan sonar);
- Further define the physical characteristics of surficial sediment and to assess the benthic recolonization status (community recovery of the bottom-dwelling animals) of areas of the site with recent disposal activity using SPI and PV imaging; and
- Augment the imaging survey with sediment collection and analysis of grain size, total organic carbon, and benthic community structure.

Table 1-1.

Estimated Volume of Dredged Material Placed at WLDS by Mound through 2005

Mound Name	Season(s) Created	Volume Disposed (m^3)	Volume Disposed [a] (yd^3)	Data Source (DAMOS Contribution No.)
A	1982	40,000 [a]	52,300	27
B	1986-1988	73,800 [a]	96,500	55
C	1985-1986	73,230 [a]	95,800	61
D	1989-1990	185,000 [a]	242,000	138
E	1990-1991	86,462 [a]	113,000	99
F	1991-1994	80,300 [a]	105,000	119
G	1994-1995	52,500 [a]	68,700	119
H	1995-1996	15,300 [a]	20,000	125
I	1996-1997	35,000 [a]	45,800	125
J	1997-1998,	10,700 [a]	14,000	161
	2001-2004	70,000	91,500	161
K	1998-1999	33,500 [a]	43,800	161
L	1999-2000	40,000 [a]	52,300	161
M	2004-2005	78,500	103,000	177
Total Estimated Volume		**874,292**	**1,143,700**	

a. Barge disposal volumes reference from ENSR 2007

Table 1-2.

Previous Monitoring Events at WLDS, 1990 to 2005

Date	Purpose of Survey	Acoustic Surveys (m × m)	# SPI Stations	Additional Studies	Sediment Grabs (#)	Contribution # Reference
July 1990	Monitoring	800 × 800 3000 × 2500	77	CTD, DO	Chemical, Grain size (4)	85 Germano et al. 1993
July 1991	Monitoring	1200 × 800	77	CTD, DO	Grain size, TOC, Metals, PAH (3)	99 Williams 1995
July 1992	Monitoring, reference area investigation	1200 × 1000	64	CTD, DO, Toxicity	Grain size, TOC, Metals, PAH, Pesticides, PCBs (2)	102 Eller and Williams 1996
July 1996	Monitoring, reference area investigation	1400 × 1000	41	-	-	119 Morris 1998
Sept 1997	Monitoring	800 × 800	39	Side-scan	-	125 Murray and Saffert 1999
March 1998	Reference area investigation	1500 × 4000	60	Side-scan	Grain size, TOC, Metals, PAH, Pesticides, PCBs (10)	125 Murray and Saffert 1999
June 2001	Monitoring	1000 × 1000	47	-	-	138 SAIC 2002
June 2004	Monitoring	1200 × 1200	60	-	-	161 ENSR 2005
July 2005	Monitoring	2600 × 2800	-	-	-	177 ENSR 2007

Table 1-3.

Disposal Activity at WLDS since 2005 (per Scow Logs provided by USACE, October 2015)

Permit number	Permittee (if known)	Permittee Total (m^3)	Permittee Total (yd^3)
NAE2004500	Richard Delbello	300	229
NAE20041830	Long Neck Point Owners Assoc	300	229
200201805	Riverside Yacht Club	10,800	8,257
200202244	Wyncote Yacht Club	4,450	3,402
2005-2006 Disposal Season		**12,118**	**15,850**
NAE20044179	Stephen Freidheim	1,500	1,147
200201805	Riverside Yacht Club	2,100	1,606
2006-2007 Disposal Season		**2,752**	**3,600**
NAE20071196	Shore and Country Club	1,950	1,491
NAE20041828	Harbor Point Homeowners Assoc.	8,185	6,258
2007-2008 Disposal Season		**7,749**	**10,135**
NAE20072071		697	533
NAE20091660		1,668	1,275
NAE20072071		1,736	1,327
NAE-2004-4225	Yacht Club	1,364	1,043
NAE20072071		4,996	3,820
2009-2010 Disposal Season		**7,998**	**10,461**
NAE20042076		17,393	13,298
NAE20100058		8,464	6,471
2010-2011 Disposal Season		**19,769**	**25,857**

Table 1-3. (continued)

Disposal Activity at WLDS since 2005 (per Scow Logs provided by USACE, October 2015)

Permit number	Permittee (if known)	Permittee Total (m³)	Permittee Total (yd³)
NAE2005100		4,500	3,440
NAE2001183		9,500	7,263
200002513	Mianus River & Yacht Club	6,000	4,587
2011-2012 Disposal Season		**15,291**	**20,000**
NAE-2006-1764	City of Rye	19,995	15,287
NAE-2012-74	Greenfield	700	535
NAE-2011-1740	Greenwich	15,680	11,988
NAE-2004-4225	Yacht Club	5,001	3,824
2012-2013 Disposal Season		**31,634**	**41,376**
NAE-2006-2342	Wilson Cove Marina	7,584	5,798
NAE-2007-1762	South Norwalk Boat Club	12,174	9,308
NAE-2004-4225	Black Rock Yacht Club	3,900	2,982
2013-2014 Disposal Season		**18,088**	**23,658**
TOTAL Disposal Volumes 2005 through 2014		**115,400**	**150,937**

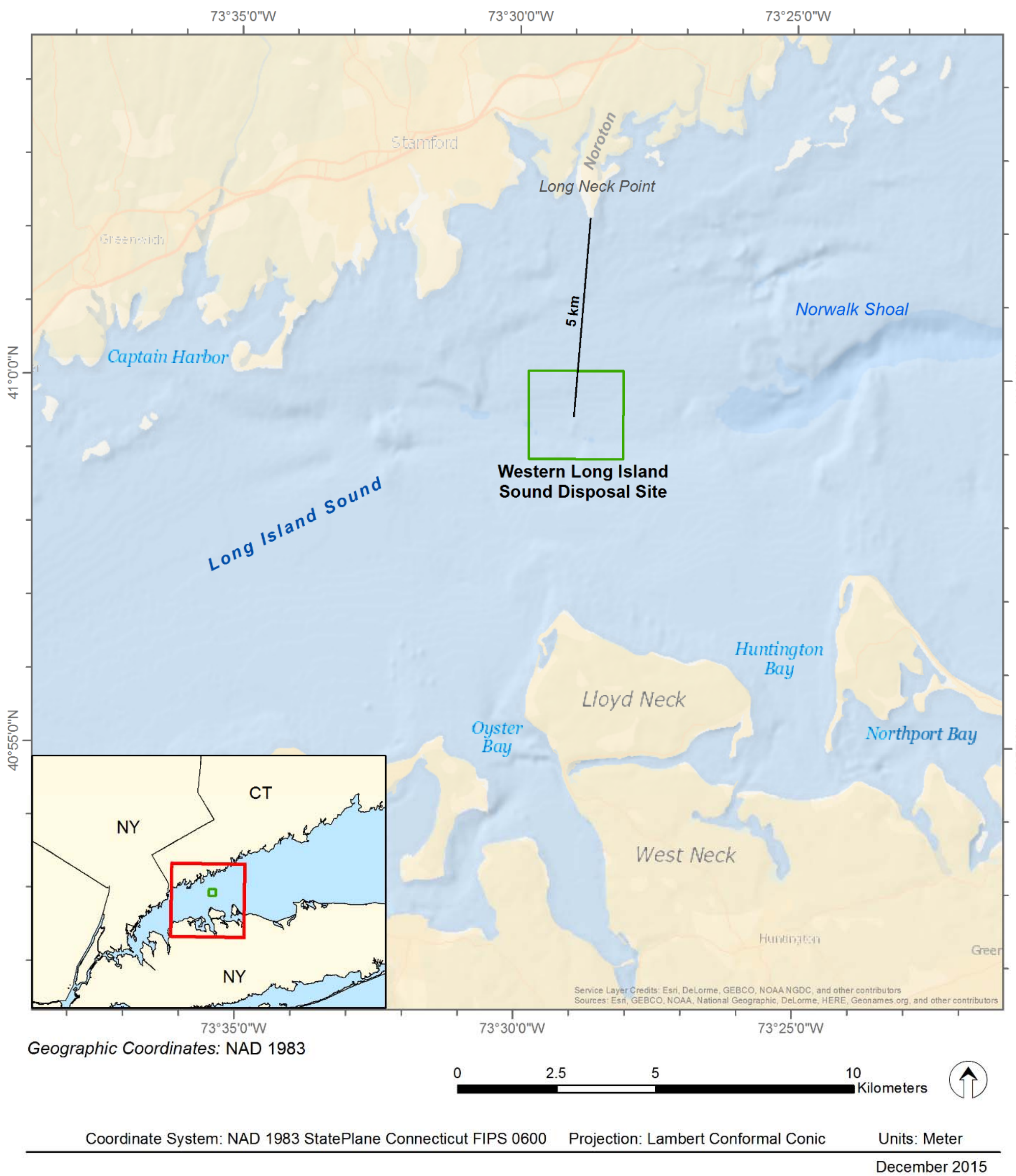

Figure 1-1. Location of the Western Long Island Sound Disposal Site (WLDS)

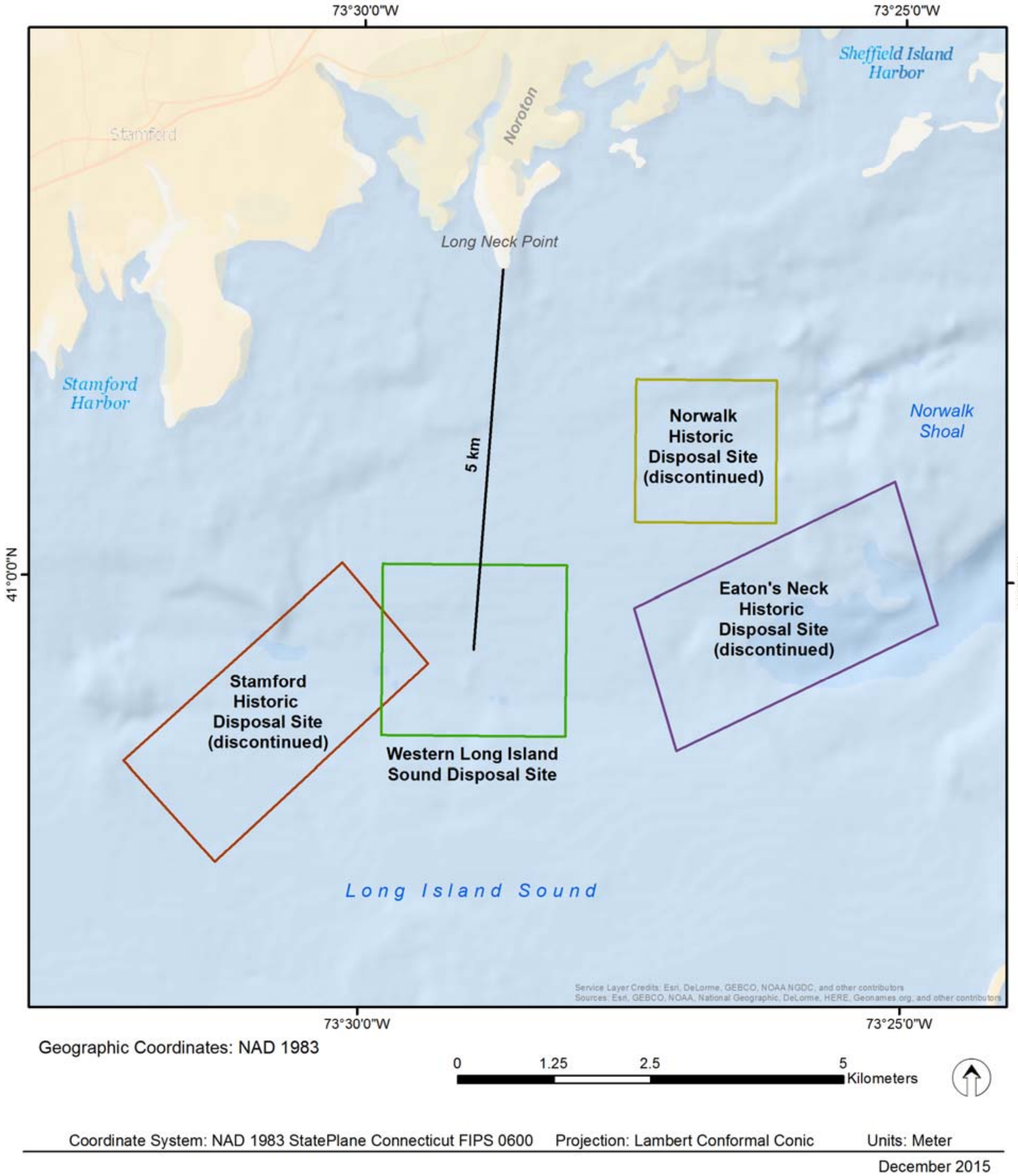

Figure 1-2. Location of WLDS relative to three historic dredged material disposal sites (Stamford, South Norwalk, and Easton's Neck)

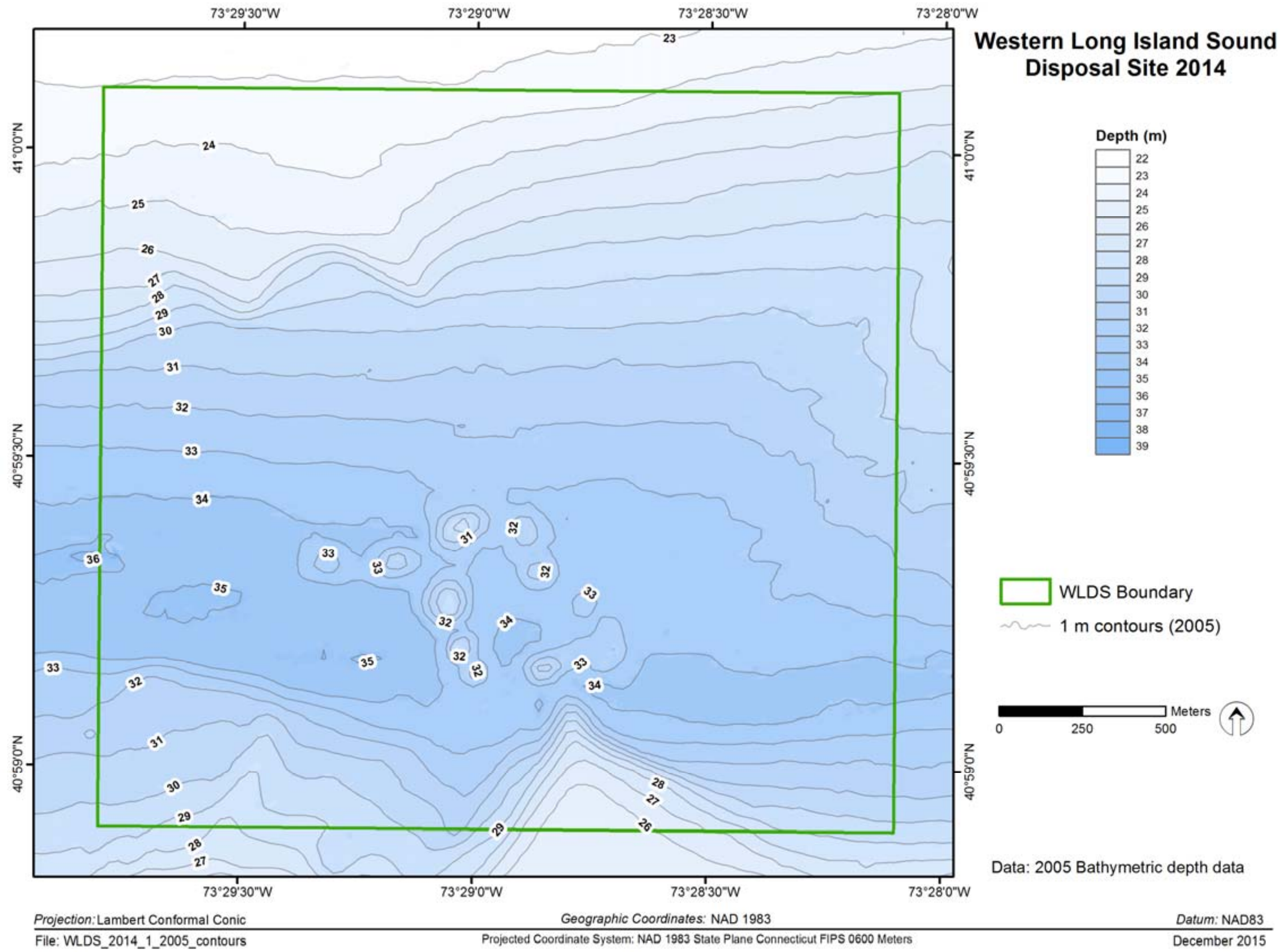

Figure 1-3. Bathymetric contour map of WLDS survey area, July 2005 (1-m contour interval)

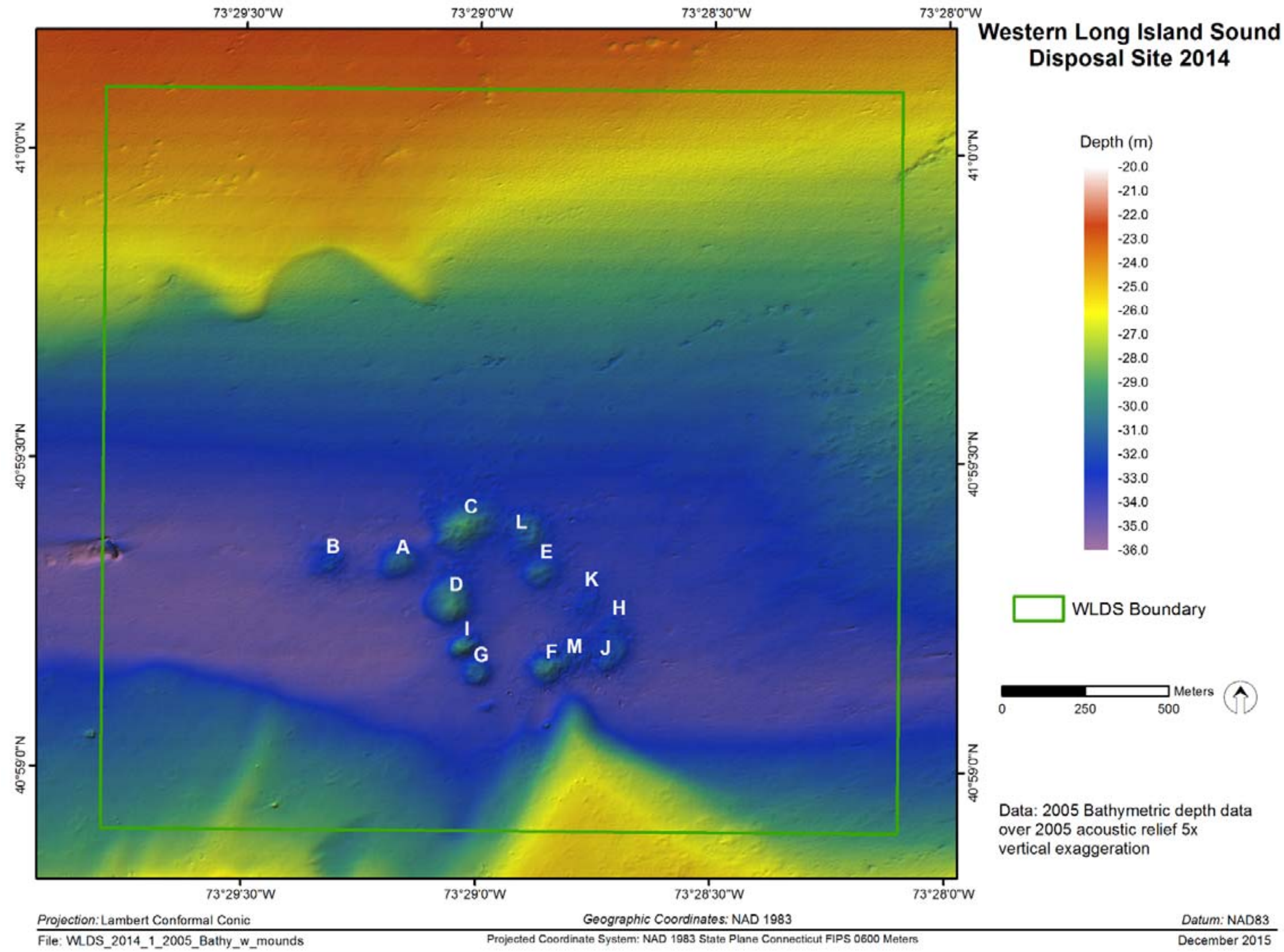

Figure 1-4. Bathymetric relief map of WLDS, July 2005 (ENSR 2007)

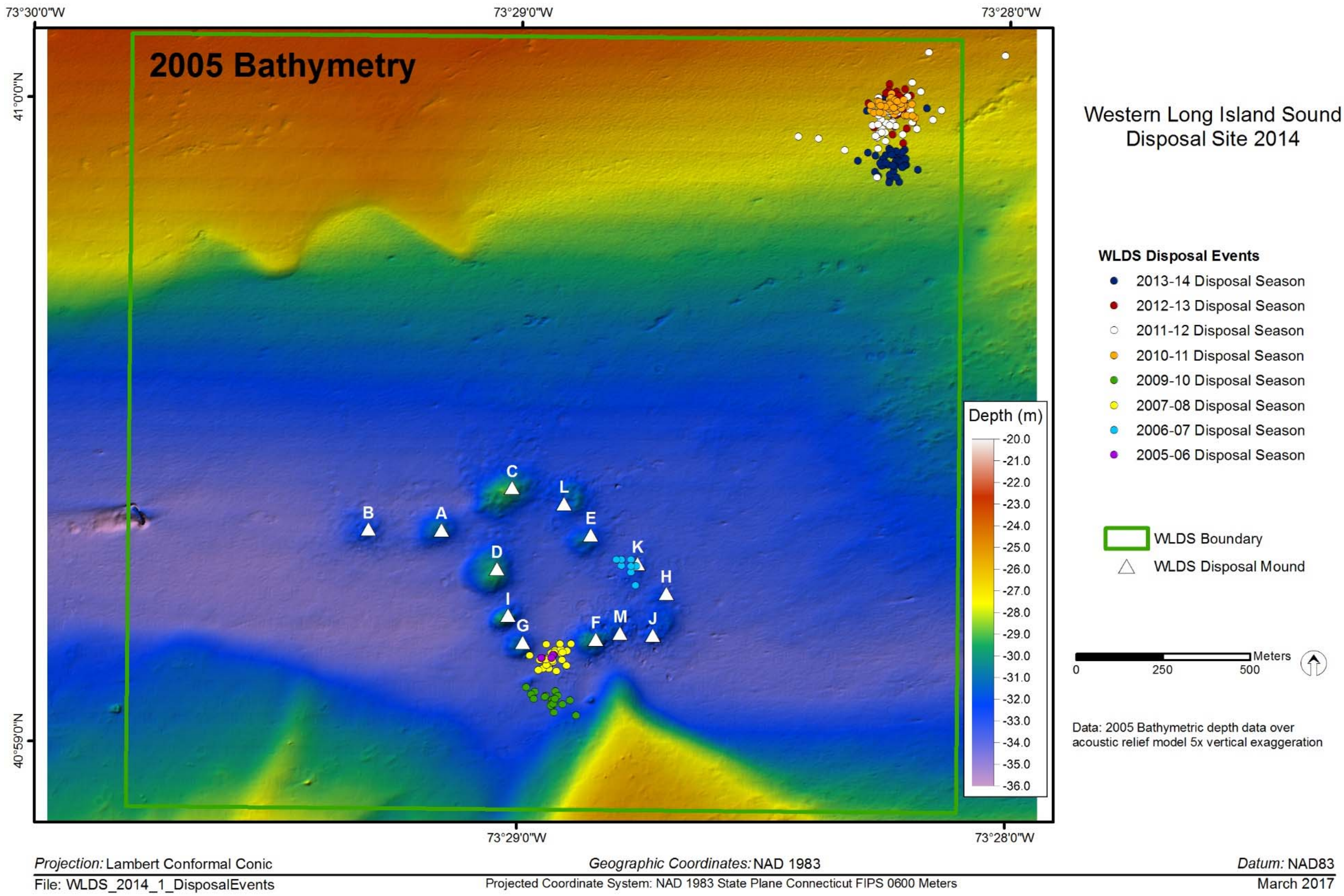

Figure 1-5. Location of reported disposal events at WLDS by disposal seasons between 2005 and 2014

2.0 METHODS

The August 2014 survey at WLDS was conducted by a team of investigators from DAMOSVision (CoastalVision, CR Environmental and Germano & Associates) and Battelle aboard the 55-foot R/V Jamie Hanna. The sediment-profile/plan-view (SPI/PV) imaging survey was conducted on 17 August, the acoustic survey was conducted from 19 to 21 August, and the benthic grab survey was conducted on 22 August. Detailed Standard Operating Procedures (SOPs) for data collection and processing are available in Carey et al. (2013).

2.1 Acoustic Survey

The acoustic survey in this study included bathymetric, backscatter, and side-scan sonar data collection. The bathymetric data provided measurements of water depth that, when processed, were used to map the seafloor topography. The processed data were also compared with previous surveys to track changes in the size and location of seafloor features. This technique is the primary tool of the DAMOS Program for mapping the distribution of dredged material at disposal sites. Backscatter and side-scan sonar data provided images that supported characterization of surficial topography, sediment texture, and bottom roughness. Backscatter data can be processed into a seamless mosaic image that is corrected for the effect of changing seafloor slope. Side-scan sonar data retains a higher resolution but correction for seafloor slope changes is not possible. The comparison of synoptic acoustic data types has the greatest utility for assessment of dredged material placement because it allows for evaluation and comparison of multiple properties of the seafloor.

2.1.1 Acoustic Survey Planning

The acoustic survey featured a high spatial resolution survey of WLDS. DAMOSVision hydrographers coordinated with USACE NAE scientists and reviewed alternative survey designs. For WLDS, a 2,700 × 2,900 m area was selected with a series of survey lines spaced 45 m apart and cross-tie lines spaced 400 m apart (Figure 2-1). The survey was designed to cover WLDS entirely and provide greater than 100 percent coverage of the seafloor within the survey area. Hydrographers obtained site coordinates, imported them to ESRI geographic information system (GIS) software, and created planning maps. The proposed survey area encompassing the entire site was then reviewed and approved by NAE scientists.

2.1.2 Navigation and On-Board Data Acquisition

Navigation for the survey was accomplished using a Hemisphere VS-330 270-channel Real-Time Kinematic Global Positioning System (RTK GPS) and Digital Compass system which received on-the-fly corrections from the KeyNet GPS, Inc. Trimble Virtual Reference Station System (VRS). Trimble and Hemisphere differential GPS (DGPS) systems capable of receiving satellite-based differential corrections (SBAS) and U.S. Coast Guard (USCG) Beacon corrections were available as backups. The RTK GPS system is capable of subdecimeter horizontal and vertical position accuracy. The RTK GPS system was interfaced to a laptop computer running HYPACK MAX® hydrographic survey software. HYPACK MAX® continually recorded vessel position and RTK GPS satellite quality and provided a steering display for the vessel captain to accurately maintain the position of the vessel along pre-established survey transects and relative to intended targets. The pulse-per-second (PPS) signals from the RTK GPS system were hardware interfaced to the multibeam echo sounder (MBES) topside processor and provided microsecond level accuracy of data stream time-tagging from each sensor. Vessel heading measurements were provided by a dual-antenna Hemisphere VS-110 Crescent Digital compass accurate to within 0.05° up to 20 times per second.

Navigation for the SPI survey was accomplished using a Hemisphere R110 differential GPS (DGPS) capable of sub-meter horizontal accuracy. Navigation data were recorded using HYPACK software.

2.1.3 Acoustic Data Collection

Bathymetric, acoustic backscatter, and side-scan sonar data were collected using an Odom MB1 MBES. This 200-kHz system forms up to 512 3° beams distributed equiangularly or equidistantly across a 120° swath. The MBES transducer was mounted amidships to the port rail of the survey vessel using a high strength adjustable boom, and offsets between the primary RTK GPS antenna and the sonar were precisely measured and entered into HYPACK. The transducer depth below the water surface (draft) was checked and recorded at the beginning and end of data acquisition, and confirmed using the “bar check” method.

A TSS DMS 3-05 motion reference unit (MRU) and the Hemisphere compass system were interfaced to the MBES topside processor. Depth, motion, heading, side-scan and backscatter data were PPS time-stamped and transmitted to the HYPACK MAX® acquisition computer via Ethernet communications. Several patch tests were conducted during the surveys to allow computation of angular offsets between the MBES system components. The system was calibrated for local water mass speed-of-sound by performing sound velocity profiles (SVP) and conductivity-temperature-depth (CTD) casts at frequent intervals throughout the survey day with an Odom Digibar sound velocity profiler and a Seabird SBE-19 Seacat CTD profiler. Additional confirmations of proper calibration, including static draft, were obtained using the “bar check” method, in which a metal plate was lowered beneath the MBES transducer to a known depth (e.g., 5.0 m) below the water surface. “Bar-check” calibrations were accurate to within 0.02 m in tests conducted at the beginning and end of each survey day.

2.1.4 Bathymetric Data Processing

Bathymetric data were processed using HYPACK HYSWEEP® software. Processing components are described below and included:

- Adjustment of data for tidal elevation changes
- Correction of acoustic ray bending (refraction) due to density variation of the water column
- Removal of spurious points associated with water column interference or system errors
- Development of a grid surface representing depth solutions
- Statistical estimation of sounding solution uncertainty
- Generation of data visualization products

Tidal adjustments for the winter 2013/2014 surveys were accomplished using data recorded at the National Oceanic and Atmospheric Administration's (NOAA) Bridgeport (Station 8467150). Tide adjustments for the August 2014 survey were accomplished using RTK GPS data merged with NOAA New Haven tide data when RTK fixes were compromised.

Correction of sounding depth and position errors associated with refraction due to water column stratification were conducted using a series of twenty-five SVPs acquired by the survey team. Data artifacts associated with refraction remain in the bathymetric surface model at a relatively fine scale (generally less than 5 to 10 cm) relative to the survey depth.

Data were filtered to accept only beams falling within an angular limit of 50° to minimize refraction artifacts while ensuring meaningful overlap between adjacent swaths. Spurious sounding solutions were flagged or rejected based on the careful examination of data on a sweep-specific basis.

The 219 kHz Odom MB1 MBES system has a published nadir beam width of 3°. The range precision of the MB1 is 3.8 cm with a sounding resolution of 1 cm. The MB1 uses a combination of electronic beam forming and interferometric beam forming methods. Both amplitude and phase bottom detection algorithms are used for each beam when calculating ranges (soundings), with a bias towards phase detection occurring very near nadir. Without consideration of interferometric capabilities, the theoretical spatial resolution of the MB1 would be entirely dependent upon the acoustic beam footprint, which is an ellipse formed by a 3 x 5-degree beam with semi-major axis orientation athwart ship. However, interferometric beam forming allows the system to maintain a static footprint across-track equal to the widest portion of the nadir beam ellipse. Thus, data collected at the WLDS mean depth of 29.1 m would retain footprint widths of approximately 2.5 meters across the full swath width.

Data were reduced to a cell (grid) size of 2.0 × 2.0 m, acknowledging the system's fine range resolution and approximately 39 m depth range while accommodating beam position uncertainty. This data reduction was accomplished by calculating and exporting the average elevation for each cell in accordance with USACE recommendations (USACE 2013).

Statistical analysis of data showed negligible tide bias and vertical uncertainty substantially lower than values recommended by USACE (2013) or NOAA (2015). The National Ocean Service (NOS) standard for the WLDS project depth (Order 1A/1B) would call for a 95th percentile confidence interval (95% CI) of 0.71 m at the maximum site depth (38.9 m) and 0.63 m at the mean site depth (29.1 m). Ninety-five percent of 2014 survey cell uncertainty values were less than 0.12 m. Areas and cells with uncertainty higher than performance standards were limited to higher relief seabed where slopes skewed statistical analysis. The evaluation suggests that elevation comparisons between surveys should be accurate to approximately 70 cm at the 95^{th} percentile uncertainty level (Table 2-1).

Reduced data were exported in ASCII text format with fields for Easting, Northing, and Mean Lower Low Water (MLLW) Elevation (meters). All data were projected to the Connecticut State Plane, NAD83 (metric) coordinate system. A variety of data visualizations were generated using a combination of IVS3D Fledermaus (V.7), ESRI ArcMap (V.10.2.1), and Golden Software Surfer (V.12). Visualizations and data products included:

- ASCII data files of all processed soundings including MLLW depths and elevations
- Contours of seabed elevation (25-cm, 50-cm, and 1.0-m intervals) in a geospatial data file (SHP) format suitable for plotting using GIS and computer-aided design software
- 3-dimensional surface maps of the seabed created using 5× vertical exaggeration and artificial illumination to highlight fine-scale features not visible on contour layers delivered in grid and tagged image file (TIF) formats, and
- Raster grid files for the bathymetric and uncertainty surfaces.

2.1.5 Backscatter Data Processing

Backscatter were extracted from cleaned files then used to provide an estimation of surficial sediment texture based on sediment surface roughness. Mosaics of beam time-series (BTS) backscatter data were created using HYPACK®'s implementation of GeoCoder software developed by scientists at the University of New Hampshire's NOAA Center for Coastal and Ocean Mapping (UNH/NOAA CCOM). A seamless mosaic of unfiltered BTS data was developed and exported in grayscale 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 backscatter values on a 2-m grid. The backscatter grid was delivered in ESRI binary GRID format to facilitate comparison with other data layers.

2.1.6 Side-Scan Sonar Data Processing

The side-scan sonar data were processed using Chesapeake Technology SonarWiz software. A seamless mosaic of unfiltered side-scan sonar data was developed and exported in grayscale TIF format using a resolution of 0.1 m per pixel.

2.1.7 Acoustic Data Analysis

The processed bathymetric grids were converted to rasters. Bathymetric contour lines and acoustic relief models were generated and displayed using GIS. The backscatter mosaics and filtered backscatter grid were combined with acoustic relief models in GIS to facilitate visualization of relationships between acoustic datasets. This is done by rendering images and color-coded grids with sufficient transparency to allow three-dimensional acoustic relief model to be visible underneath.

2.2 Sediment-Profile and Plan-View Imaging Survey

SPI and PV imaging are monitoring techniques used to provide data on the physical characteristics of the seafloor and the status of the benthic biological community.

2.2.1 SPI and PV Survey Planning

For the WLDS August 2014 survey, a total of 45 SPI/PV stations were surveyed; 30 stations within WLDS focused on two disposal mounds (M and N): and five randomly located stations in each of three reference areas (SW-REF, S-REF, and SE-REF; Figures 2-2 and 2-3). SPI/PV target station locations are provided in Table 2-2 and actual SPI/PV station replicate locations are provided in Appendix C.

2.2.2 Sediment-Profile Imaging

The SPI technique involves deploying an underwater camera system to photograph a cross-section of the sediment-water interface. In the 2014 survey at WLDS, high-resolution SPI images were acquired using a Nikon® D7100 digital single-lens reflex camera mounted inside an Ocean Imaging® Model 3731 pressure housing. The pressure housing sat atop a wedge-shaped steel 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 2-4).

The camera remained on the seafloor for approximately 20 seconds to ensure that a successful image had been obtained. Details of the camera settings for each digital image are available in the associated parameters file embedded in each electronic image file. For this survey, the ISO-equivalent was set at 635, shutter speed was 1/250, f-stop was f9, and storage was in compressed raw Nikon Electronic Format (NEF) files (approximately 30 MB each). Electronic files were converted to high-resolution JPEG (8-bit) format files (4000 × 6000 pixels) using Nikon Capture® NX2 software (Version 2.4.7).

Test exposures of the Kodak® Color Separation Guide (Publication No. Q-13) were made on deck at the beginning and end of the 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. Number of prism weights and frame stop collar positions were recorded for each replicate image and are available in Appendix D.

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 names immediately after downloading as a further quality assurance step.

2.2.3 Plan-View Imaging

An Ocean Imaging® Model DSC16000 PV underwater camera system with two Ocean Imaging® Model 400-37 Deep Sea Scaling lasers was attached to the sediment-profile camera frame and used to collect plan-view photographs of the seafloor surface; both SPI and PV images were collected during each "drop" of the system. The PV system consisted of a Nikon D-7000 encased in an aluminum housing, a 24 VDC autonomous power pack, a 500 W strobe, and a bounce trigger. A weight was attached to the bounce trigger with a stainless-steel cable so that the weight hung below the camera frame; the scaling lasers projected two red dots that are separated by a constant distance (26 cm) regardless of the field-of-view of the PV system. The field of view can be varied by increasing or decreasing the length of the trigger wire, and thereby the camera height above the bottom when the picture is taken. As the camera apparatus was lowered to the seafloor, the weight attached to the bounce trigger contacted the seafloor prior to the camera frame hitting the bottom and triggered the PV camera (Figure 2-4). Details of the camera settings for each digital image are available in the associated parameters file embedded in each electronic image file; for this survey, the ISO-equivalent was set at 500. The additional camera settings used were as follows: shutter speed 1/20, f14, white balance set to flash, color mode set to Adobe RGB, sharpening set to none, noise reduction off, and storage in compressed raw NEF files (approximately 20 MB each). Electronic files were converted to high-resolution JPEG (8-bit) format files (3264 × 4928 pixels) using Nikon Capture® NX2 software.

Prior to field operations, the internal clock in the digital PV system was synchronized with the GPS navigation system and the SPI camera. Each PV image acquired was assigned a time stamp in the digital file and redundant notations in the field and navigation logs. Throughout the survey, PV images were downloaded at the same time as the SPI images after collection and evaluated for successful image acquisition and image clarity.

The ability of the PV system to collect usable images was dependent on the clarity of the water column. Water conditions at WLDS allowed use of a ½-m trigger wire, resulting in an area of bottom visualization approximately 0.5 × 0.3 m in size.

2.2.4 SPI and PV Data Collection

The SPI/PV survey was conducted at WLDS on 17 August 2014 aboard the R/V Jamie Hanna. At each station, the vessel was positioned at the target coordinates and the camera was deployed within a defined station tolerance of 10 m. Four replicate SPI and PV images were collected at each of the stations (Figures 2-2 and 2-3; Appendix C). The three replicates with the best quality images from each station were chosen for analysis (Appendix D).

The DGPS described above was interfaced to HYPACK® software via laptop serial ports to provide a method to locate and record sampling locations. Throughout the survey, the HYPACK® data acquisition system received DGPS data. The incoming data stream was digitally integrated and stored on the PC's hard drive. The system provided a steering display to enable the vessel captain to navigate to the pre-established survey target locations. The navigator electronically recorded the vessel's position when the equipment contacted the seafloor and the winch wire went slack. Each replicate SPI/PV position was recorded and time stamped. Actual SPI/PV sampling locations were recorded using this system.

2.2.5 SPI and PV Data Analysis

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 30 years to map the distribution of disposed dredged material and to monitor benthic recolonization at disposal sites (Germano et al. 2011).

Following completion of data collection, the digital images were analyzed using Adobe Photoshop® CC 2014 Version 15.0. Images were first adjusted in Adobe Photoshop® to expand the available pixels to their maximum light and dark threshold range. Linear and areal measurements were recorded as number of pixels and converted to scientific units using the Kodak® Color Separation Guide for measurement calibration. Detailed results of all SPI and PV image analyses are presented in Appendix D.

2.2.5.1 SPI Data Analysis

Analysis of each SPI image was performed to provide measurement of the following standard set of parameters:

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

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

Apparent Redox Potential Discontinuity (aRPD) Depth– The aRPD depth provides a measure of the integrated time history of the balance between near-surface oxygen conditions and biological reworking of sediments. Sediment particles exposed to oxygenated waters oxidize and lighten in color to brown or light gray. As the particles are buried or moved down by biological activity, they are exposed to reduced oxygen concentrations in subsurface pore waters and their oxic coating slowly reduces, changing color to dark gray or black. When biological activity is high, the aRPD depth increases; when it is low or absent, the aRPD depth decreases. The mean aRPD depth was determined for each image by assessing color and reflectance differences visible in the sediment matrix and measuring the discernable area that indicates the apparent depth of oxidized sediments.

Low Dissolved Oxygen– Under conditions of high organic loading and hypoxia or anoxia in the water column, dark gray or black reduced sediments are in contact with the sediment water interface.

Sedimentary Methane– If organic loading is extremely high, porewater sulfate is depleted and methanogenesis occurs. The process of methanogenesis is indicated by the appearance of methane bubbles in the sediment column. These gas-filled voids are readily discernable in SPI images because of their irregular, generally circular aspect and glassy texture (due to the reflection of the strobe off the gas bubble).

Infaunal Successional Stage– Infaunal successional stage is a measure of the biological community inhabiting the seafloor. Current theory holds that organism-sediment interactions in fine-grained sediments follow a predictable sequence of development after a major disturbance (such as dredged material disposal), and this sequence has been divided subjectively into four stages (Rhoads and Germano 1982, 1986). Successional stage was assigned by assessing which types of species or organism-related activities were apparent in the images (Figure 2-5).

Additional components of the SPI analysis included calculation of means and ranges for the parameters listed above and mapping of means of replicate values from each station. Station means were calculated from three replicates from each station and used in statistical analysis.

2.2.5.2 PV Data Analysis

The PV images provided a much larger field-of-view than the SPI images and provided valuable information about seascape ecology and sediment topography in the area where the pinpoint "optical core" of the sediment profile was taken. Unusual surface sediment layers, textures, or structures detected in any of the sediment-profile images can be interpreted in light of the larger context of surface sediment features; i.e., is a surface layer or topographic feature a regularly occurring feature and typical of the bottom in this general vicinity or just an isolated anomaly? The scale information provided by the underwater lasers allows for accurate density counts (number per square meter) of attached epifaunal colonies, sediment burrow openings, or larger macrofauna or fish which may have been missed in the sediment-profile cross section. Information on sediment transport dynamics and bedform wavelength were also available from PV image analysis. Analysts calculated the image size and field-of-view and noted sediment type; recorded the presence of bedforms, burrows, tubes, tracks, trails, epifauna, mud clasts, and debris; and included descriptive comments (Appendix D).

2.2.6 Statistical Methods

In order to meet the objective of this survey to assess the baseline status of benthic community at the proposed disposal site relative to reference area conditions, statistical analyses were conducted to compare key SPI variables between sampled disposal locations (Mound M and N) and reference areas (S-REF, SE-REF, and SW-REF). The aRPD depth and successional stage measured in each image are the best indicators of infaunal activity measured by SPI and were, therefore, used in this comparative analysis. Standard boxplots were generated for visual assessment of the central tendency and variation in each of these variables within each disposal area and each reference area. Tests rejecting the inequivalence between the reference and disposal areas were conducted, as described in detail below.

The objective to look for differences is conventionally addressed using a point null hypothesis of the form, "There is no significant difference in benthic conditions between the reference area and the disposal target areas." However, there is always some difference (perhaps only to a very small decimal place) between groups, but the statistical significance of this difference may or may not be ecologically meaningful. On the other hand, differences may not be detected due to insufficient statistical power. Without a power analysis and specification of what constitutes an ecologically meaningful difference, the results of conventional point null hypothesis testing often provide inadequate information for ecological assessments (Germano 1999). An approach using an inequivalence null hypothesis will identify when groups are statistically similar, within a specified interval, which is more suited to the objectives of the DAMOS monitoring program.

For an inequivalence test, the null hypothesis presumes the difference is great; this is recognized as a "proof of safety" approach because rejection of the inequivalence null hypothesis requires sufficient proof that the difference was actually small (e.g., McBride 1999). The null and alternative hypotheses for the inequivalence hypothesis test are:

H_0: $d < -\delta$ or $d > \delta$ (presumes the difference is great)

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

where d is the difference between a reference mean and a site mean. If the inequivalence null hypothesis is rejected, then it is 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 and is therefore not ecologically meaningful. Primarily differences greater than δ are of ecological interest. Previously established δ values of 1 cm for aRPD depth, and 0.5 for successional stage rank (on the 0–3 scale) were used.

The test of this inequivalence (interval) hypothesis can be broken down into two one-sided tests (TOST) (McBride 1999, Schuirmann 1987). Assuming a symmetric distribution, the inequivalence hypothesis is rejected at α of 0.05 if the 90% confidence interval for the measured difference (or, equivalently, the 95% upper limit <u>and</u> the 95% lower limit for the difference) is wholly contained within the equivalence interval $[-\delta, +\delta]$. The statistics used to test the interval hypotheses shown here are based on the Central Limit Theorem (CLT) and basic statistical properties of random variables. A simplification of the CLT states 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 survey, five distinct locations were sampled, three were categorized as reference areas (S-REF, SE-REF, and SW-REF) and two were disposal locations (Mound M and Mound N). The difference equations of interest were the linear contrasts of each disposal area mean minus the average of the three reference means, or

$$\hat{d} = [1/3 \times (\text{Mean}_{\text{S-REF}} + \text{Mean}_{\text{SE-REF}} + \text{Mean}_{\text{SW-REF}}) - (\text{Mean}_{\text{Disposal}})] \qquad \text{[Eq.1]}$$

where $\text{Mean}_{\text{Disposal}}$ was the mean for one of the disposal areas (Mound M, or Mound N). The three reference areas collectively represented ambient conditions, but if the means were different among these three areas, then pooling them into a single reference group would inflate the variance estimate because it would include the variability between areas, rather than only the variability between stations within each single homogeneous area. The effect of keeping the three reference areas separate has no effect on the grand reference mean when sample size is equal among these areas, but it ensures that the variance is truly the residual variance within a single population with a constant mean.

The difference equation, $\hat{d}$, for the comparison of interest was specified in Eq. 1 and the standard error of each difference equation uses 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 were 1/3 for each of the 3 reference areas, and -1 for the disposal area).

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

n_j = number of stations for the jth area.

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

$t_{\alpha,\upsilon}$ = upper (1-α)*100th percentile of a Student's t-distribution with υ degrees of freedom (α = 0.05)

$SE(\hat{d})$ = standard error of the difference ([Eq. 2])

υ = degrees of freedom for the standard error. If a pooled residual variance estimate was used, this was the residual degrees of freedom from an ANOVA on all groups (total number of stations minus the number of groups); if separate variance estimates were used, degrees of freedom were calculated based on the Welch-Sattherthwaite estimation (Satterthwaite 1946, Welch 1947, with the results nicely summarized on the Wikipedia page for 'Welch-Satterthwaite equation'; a two-sample example is found in Zar 1996).

Validity of normality and equal variance assumptions was tested using Shapiro-Wilk's test for normality on the area residuals (α = 0.05) and Levene's test for equality of variances among the five areas (α =0.05). If normality was not rejected but equality of variances was, then normal parametric confidence bounds were calculated, using separate variance estimates for each group. If normality was rejected, then non-parametric bootstrapped estimates of the confidence bounds were calculated.

2.3 Benthic Grab Collection and Analysis

Sediment grab samples were collected from 12 stations on 22 August 2014 for analysis of grain size, total organic carbon (TOC) and benthic community structure (infaunal analysis; sorting into major taxonomic categories and identification/ enumeration to the lowest taxonomic category practicable). Grab samples were collected at co-located SPI stations—four near Mound M (Stations 1, 4, 5, and 6; Figure 2-6) and four near Mound N (Stations 3, 4, 9, and 11; Figure 2-6); one at each of two reference areas, SW-REF and S-REF and two at SE-REF (Figure 2-7). The sediment grab samples were obtained and processed as detailed in the DAMOS Quality Assurance Project Plan (QAPP) for grain size (ASTM D422), Total Organic Carbon (EPA Method 9060), and benthic community structure (Battelle 2015).

Sediment grab samples were collected using a 0.04-m^2 Ted Young-modified Van Veen grab sampler. At each station, the vessel was positioned at the target coordinates and grab samples were collected within a defined station tolerance of 30 m. The samples were checked for penetration depth (10 cm maximum and 6 cm minimum acceptable penetration depth), depth of the aRPD layer, sediment texture, odor, and observed biota.

Two grab samples were collected at each station. One grab sample was processed for TOC and grain size analyses, and the other grab sample was processed for infaunal community analysis. For grain size and TOC, grab samples were collected and the overlying water was first removed with a siphon. Next, the entire contents of the grab sample were homogenized until a consistent color and texture was achieved. Aliquots of sediment were then placed into two 125-ml clear glass jars, one for TOC analysis and one for grain size analysis. The samples were stored on ice and shipped priority overnight to Katahdin Analytical Services for analysis. Sediment sample containers for TOC (4-oz jars) and grain size (8-oz jars) were provided by the lab.

The sediment grab sample for benthic community analysis was washed into a clean 10-liter plastic bucket and sieved through a 0.5 mm mesh screen. The material retained on the sieve was then placed in an appropriate sample container (1 liter or 500 ml) and preserved with 10% formalin and half a tablespoon of borax to buffer the solution. The samples for benthic infaunal analysis were sent to New England District, US Army Corps of Engineers, 696 Virginia Avenue, Concord, MA for analysis.

Table 2-1.

Accuracy and Uncertainty Analysis of Bathymetric Data

		Results (m)		
Survey Date(s)	**Quality Control Metric**	**Mean**	**95% Uncertainty**	**Range**
8/19-8/21/2014	Cross-Line Nadir Comparisons	-0.05	0.22	-0.34 - 0.31
	Cross-Line Swath Comparisons	0.07	0.17	
	Within Cell Uncertainty	0.07	0.14	0.00 - 2.97
	Beam Angle Uncertainty (0 - 50d)	0.08	0.24	0.00 - 0.94

Notes:
1. The mean of cross-line nadir and full swath comparisons are indicators of tide bias.
2. 95% uncertainty values were calculated using the sums of mean differences and standard deviations expressed at the 2-sigma level.
3. Within cell uncertainty values include biases and random errors.
4. Beam angle uncertainty was assessed by comparing cross-line data (50-degree swath limit) with a reference surface created using mainstay transect data.
5. Swath and cell based comparisons were conducted using 3 m x 3 m cell averages. These analyses do not exclude sounding variability associated with extreme (near vertical) terrain slopes. Uncertainties associated with slope are depicted on maps within the report.

Table 2-2.

WLDS 2014 Survey Target SPI/PV and Sediment Grab Station Locations

WLDS August 2014 SPI Target Station Locations					
Station	**Latitude (N)**	**Longitude (W)**	**Station**	**Latitude (N)**	**Longitude (W)**
MoundN-01	40° 59.963'	73° 28.199'	SW-REF-01	40° 58.629'	73° 29.885'
MoundN-02	40° 59.984'	73° 28.198'	SW-REF-02	40° 58.402'	73° 30.006'
MoundN-03	40° 59.920'	73° 28.309'	SW-REF-03	40° 58.531'	73° 29.726'
MoundN-04	40° 0.022'	73° 28.263'	SW-REF-04	40° 58.487'	73° 29.851'
MoundN-05	40° 59.934'	73° 28.171'	SW-REF-05	40° 58.490'	73° 30.004'
MoundN-06	40° 59.913'	73° 28.258'	S-REF-01	40° 58.694'	73° 29.015'
MoundN-07	40° 59.963'	73° 28.340'	S-REF-02	40° 58.832'	73° 29.159'
MoundN-08	40° 59.857'	73° 28.256'	S-REF-03	40° 58.608'	73° 29.300'
MoundN-09	40° 59.943'	73° 28.253'	S-REF-04	40° 58.680'	73° 29.282'
MoundN-10	40° 59.898'	73° 28.284'	S-REF-05	40° 58.682'	73° 29.132'
MoundN-11	40° 59.986'	73° 28.253'	SE-REF-01	40° 58.407'	73° 27.705'
MoundN-12	40° 59.878'	73° 28.235'	SE-REF-02	40° 58.295'	73° 27.802'
MoundN-13	40° 59.914'	73° 28.338'	SE-REF-03	40° 58.216'	73° 27.809'
MoundN-14	40° 59.918'	73° 28.206'	SE-REF-04	40° 58.297'	73° 27.572'
MoundN-15	40° 59.983'	73° 28.341'	SE-REF-05	40° 58.306'	73° 27.664'
MoundM-01	40° 59.170'	73° 28.779'			
MoundM-02	40° 59.155'	73° 28.752'			
MoundM-03	40° 59.191'	73° 28.804'			
MoundM-04	40° 59.132'	73° 28.784'			
MoundM-05	40° 59.180'	73° 28.750'			
MoundM-06	40° 59.137'	73° 28.806'			
MoundM-07	40° 59.149'	73° 28.803'			
MoundM-08	40° 59.194'	73° 28.757'			
MoundM-09	40° 59.194'	73° 28.829'			
MoundM-10	40° 59.192'	73° 28.784'			
MoundM-11	40° 59.179'	73° 28.805'			
MoundM-12	40° 59.156'	73° 28.831'			
MoundM-13	40° 59.180'	73° 28.834'			
MoundM-14	40° 59.157'	73° 28.775'			
MoundM-15	40° 59.137'	73° 28.756'			

Note: Coordinate system NAD83

Table 2-2. (continued)

WLDS 2014 Survey Target SPI/PV and Sediment Grab Station Locations

WLDS August 2014 Target Benthic Grab Locations		
Station	**Latitude (N)**	**Longitude (W)**
MoundM-01	40° 59.170'	73° 28.779'
MoundM-04	40° 59.132'	73° 28.784'
MoundM-05	40° 59.180'	73° 28.750'
MoundM-09	40° 59.194'	73° 28.829'
MoundN-03	40° 59.920'	73° 28.309'
MoundN-04	41° 0.022'	73° 28.263'
MoundN-09	40° 59.943'	73° 28.253'
MoundN-11	40° 59.986'	73° 28.253'
SE-REF-02	40° 58.295'	73° 27.802'
SE-REF-05	40° 58.306'	73° 27.664'
S-REF-05	40° 58.682'	73° 29.132'
SW-REF-05	40° 58.490'	73° 30.004'

Note: Coordinate system NAD83

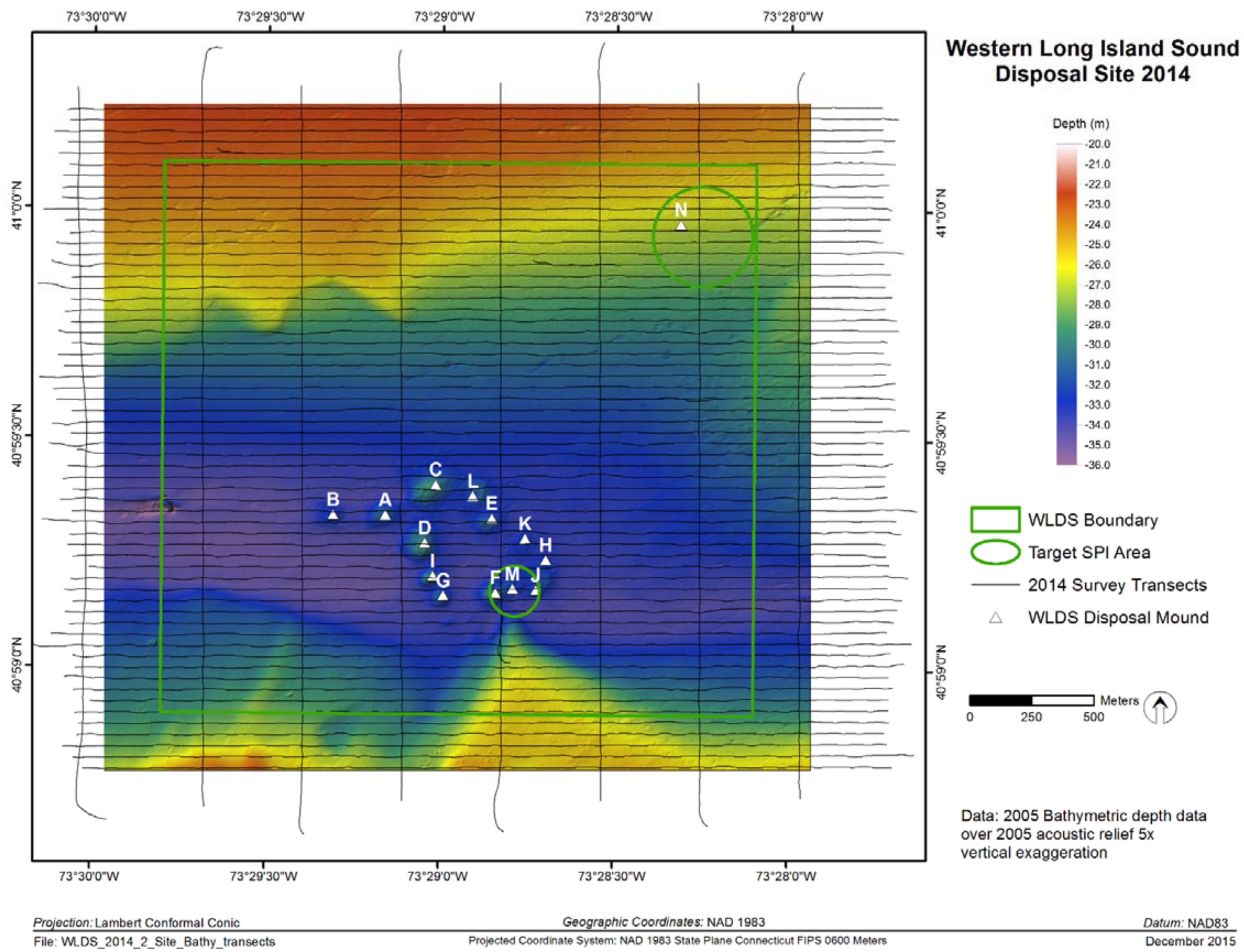

Figure 2-1. WLDS bathymetric survey area and tracklines

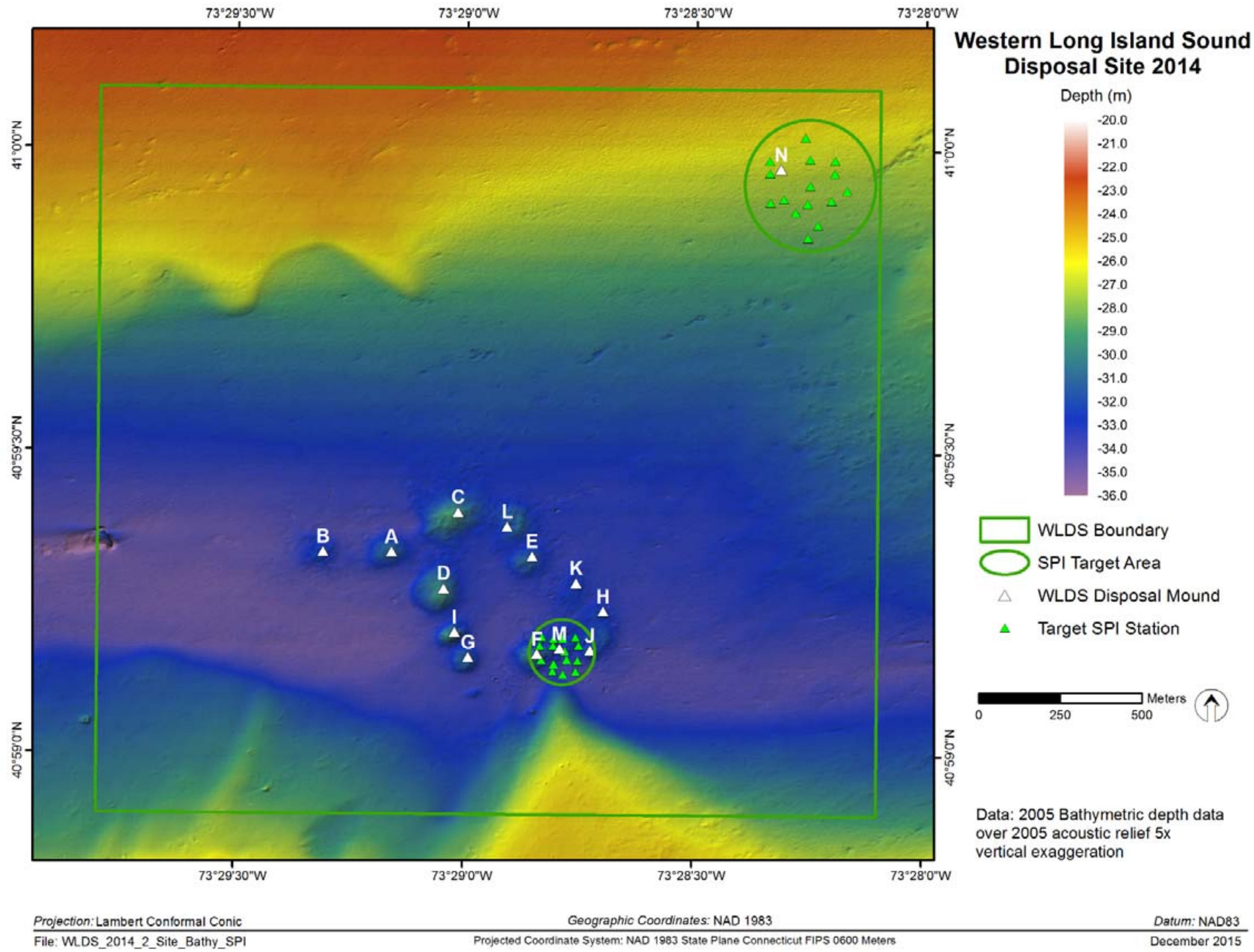

Figure 2-2. WLDS disposal mounds with target SPI/PV stations indicated

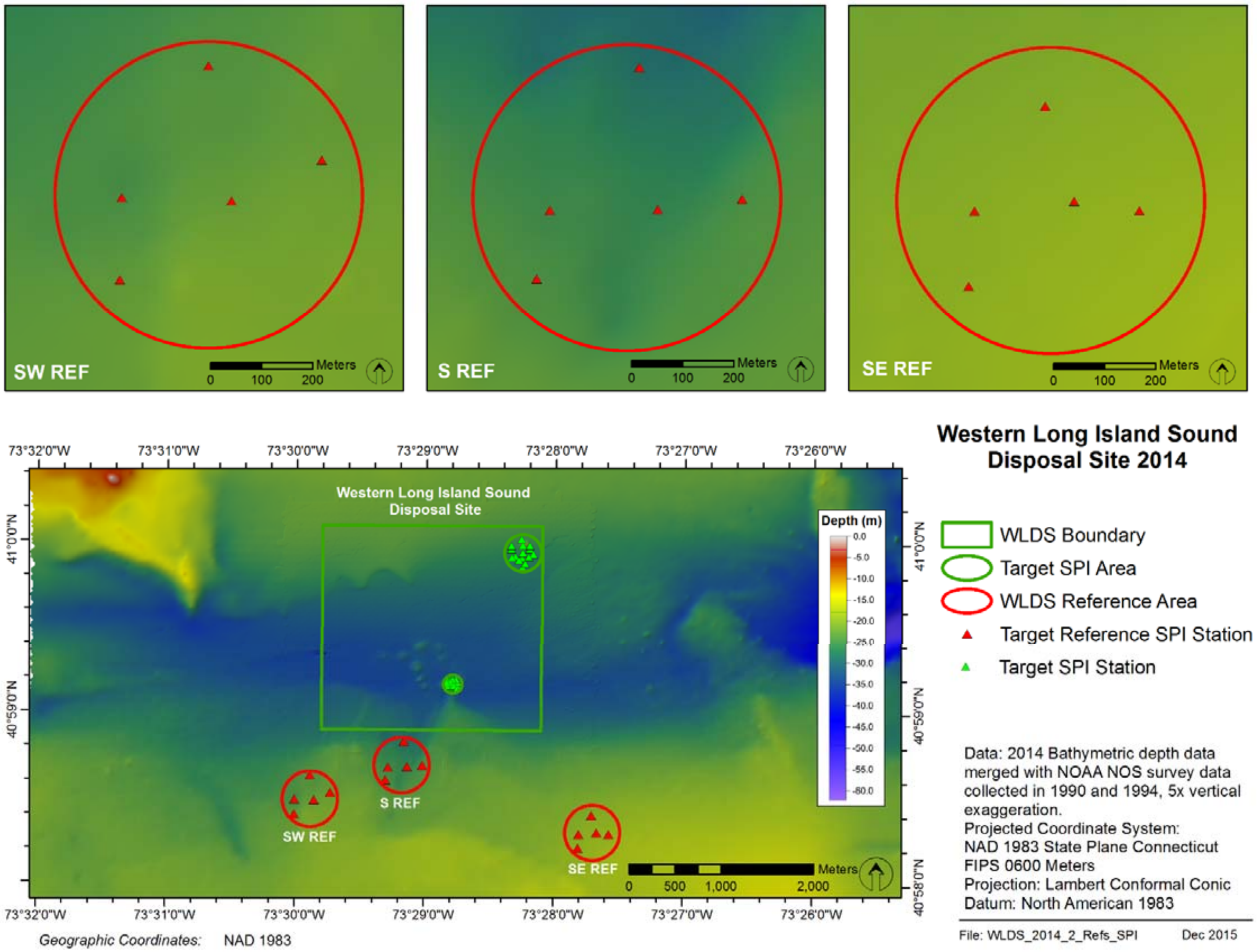

Figure 2-3. WLDS reference areas with target SPI/PV stations indicated

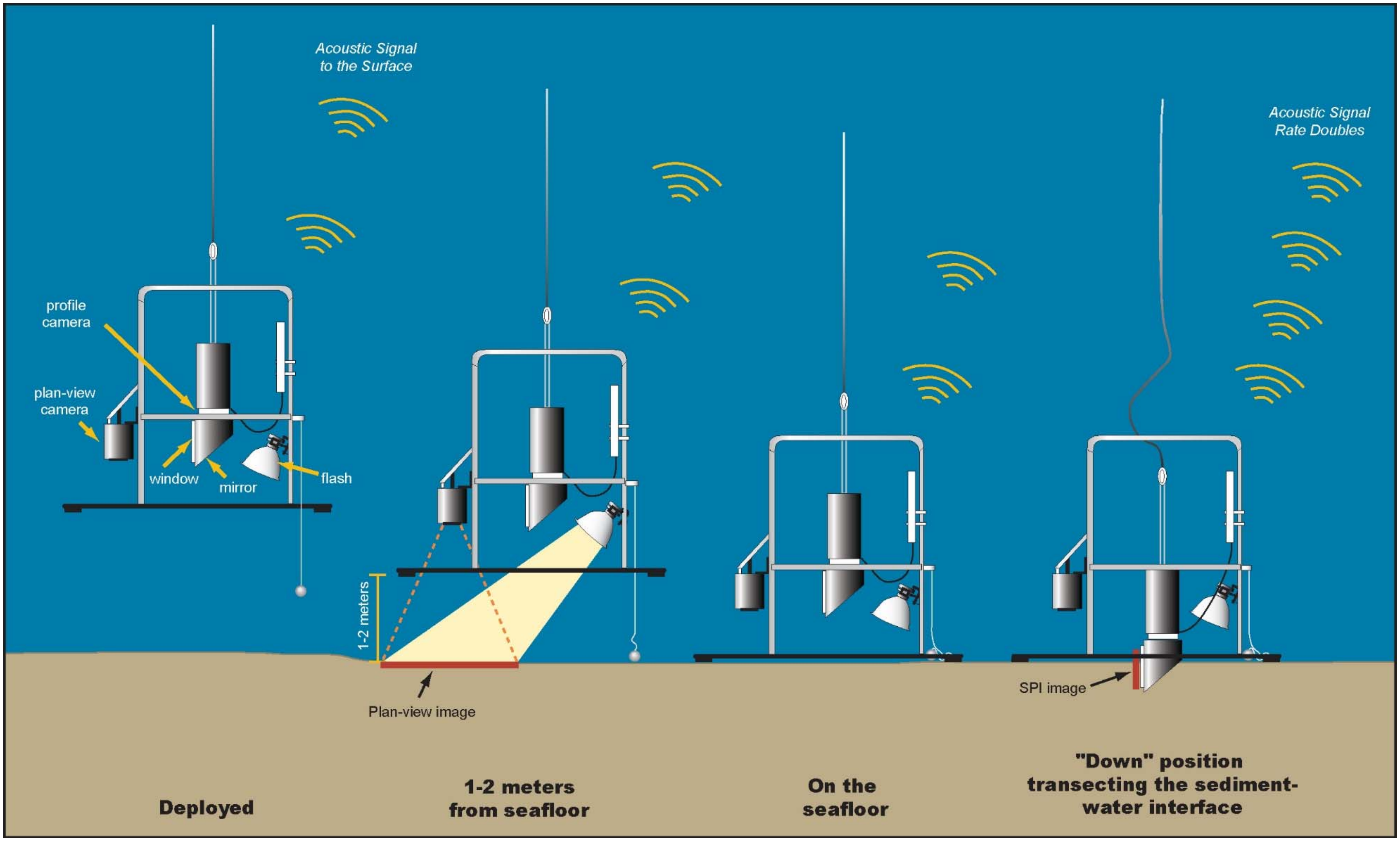

Figure 2-4. Schematic diagram of the SPI/PV camera deployment

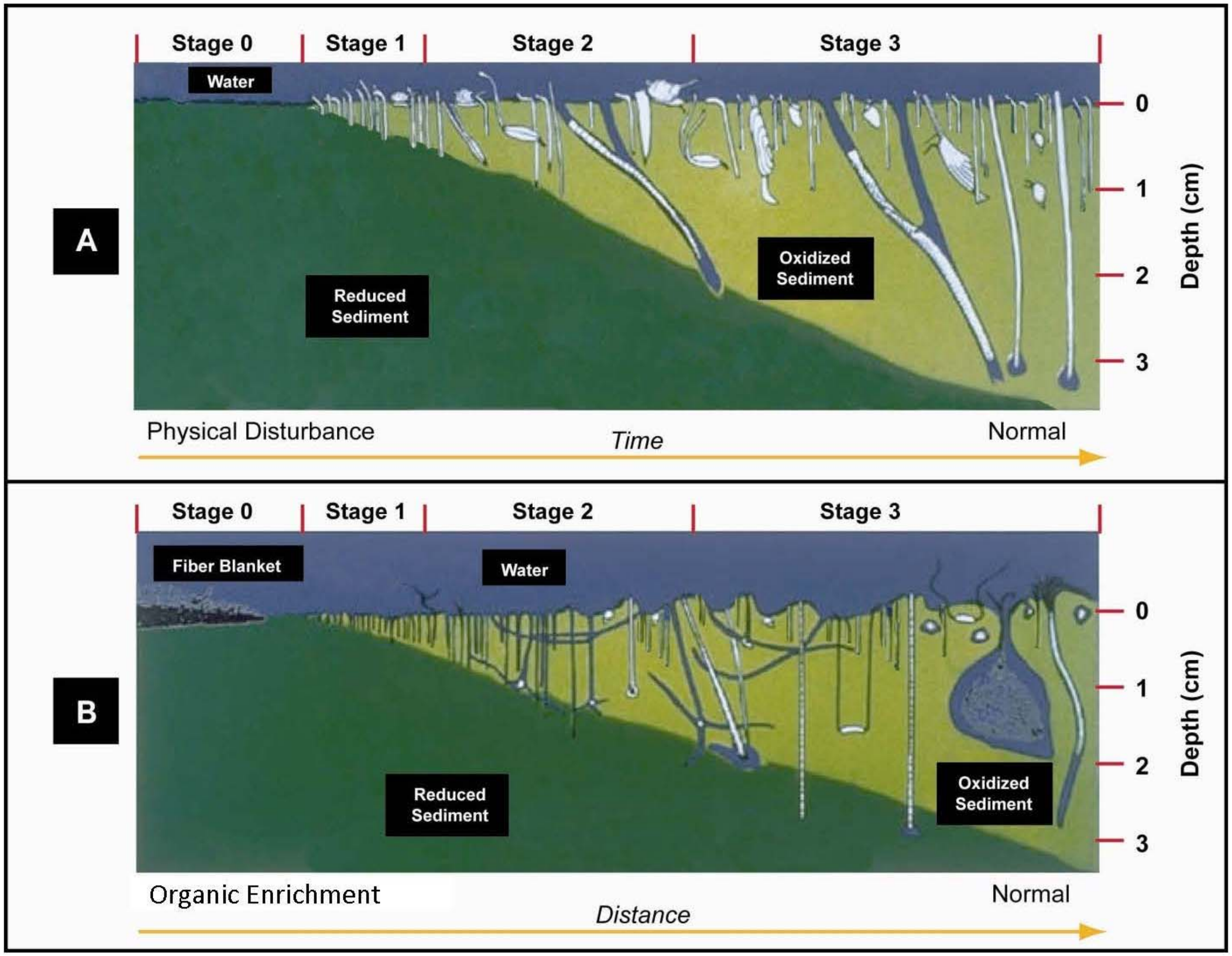

Figure 2-5. Stages of infaunal succession as a response of soft-bottom benthic communities to (A) physical disturbance or (B) organic enrichment, from Rhoads and Germano (1982)

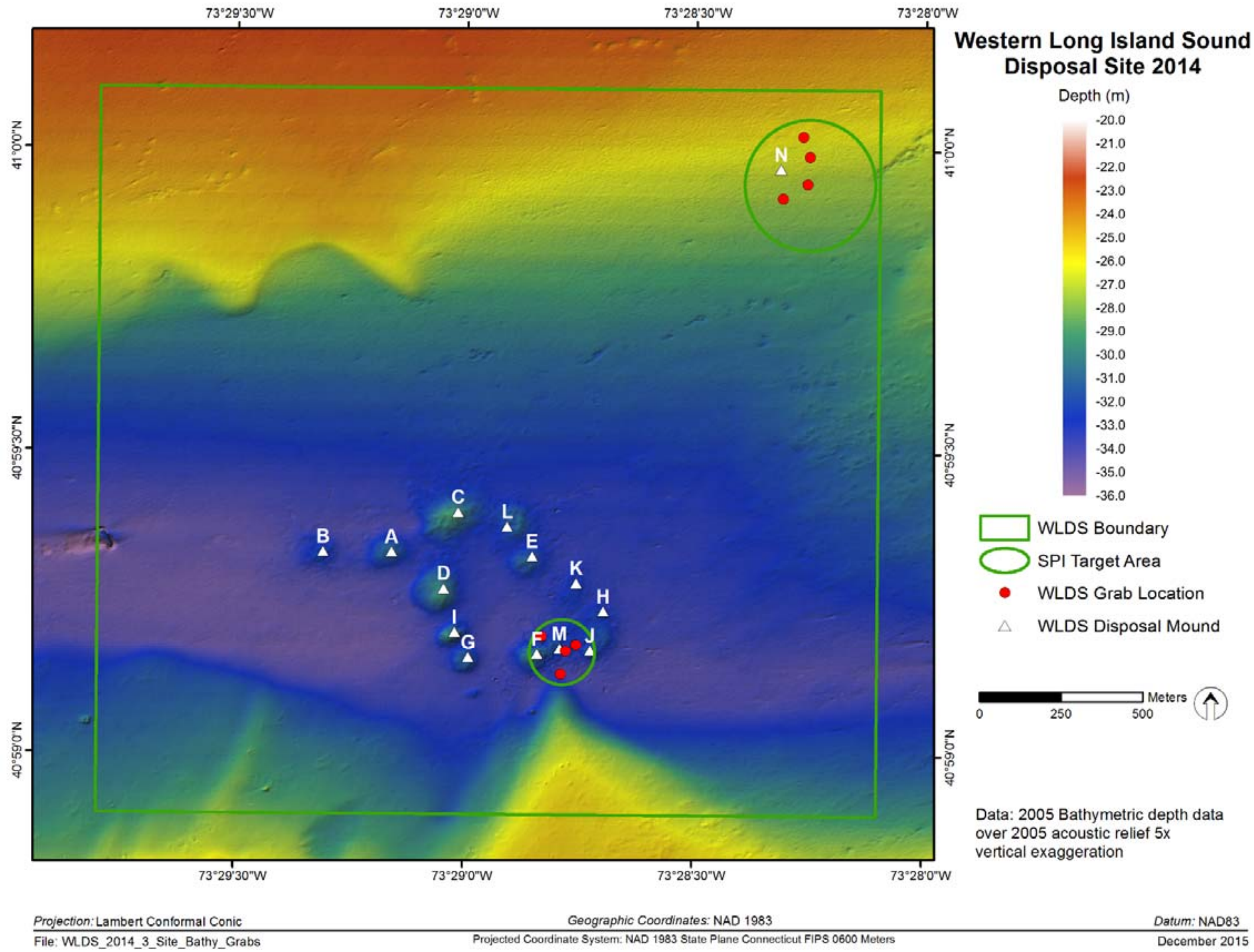

Figure 2-6. WLDS target benthic grab stations indicated

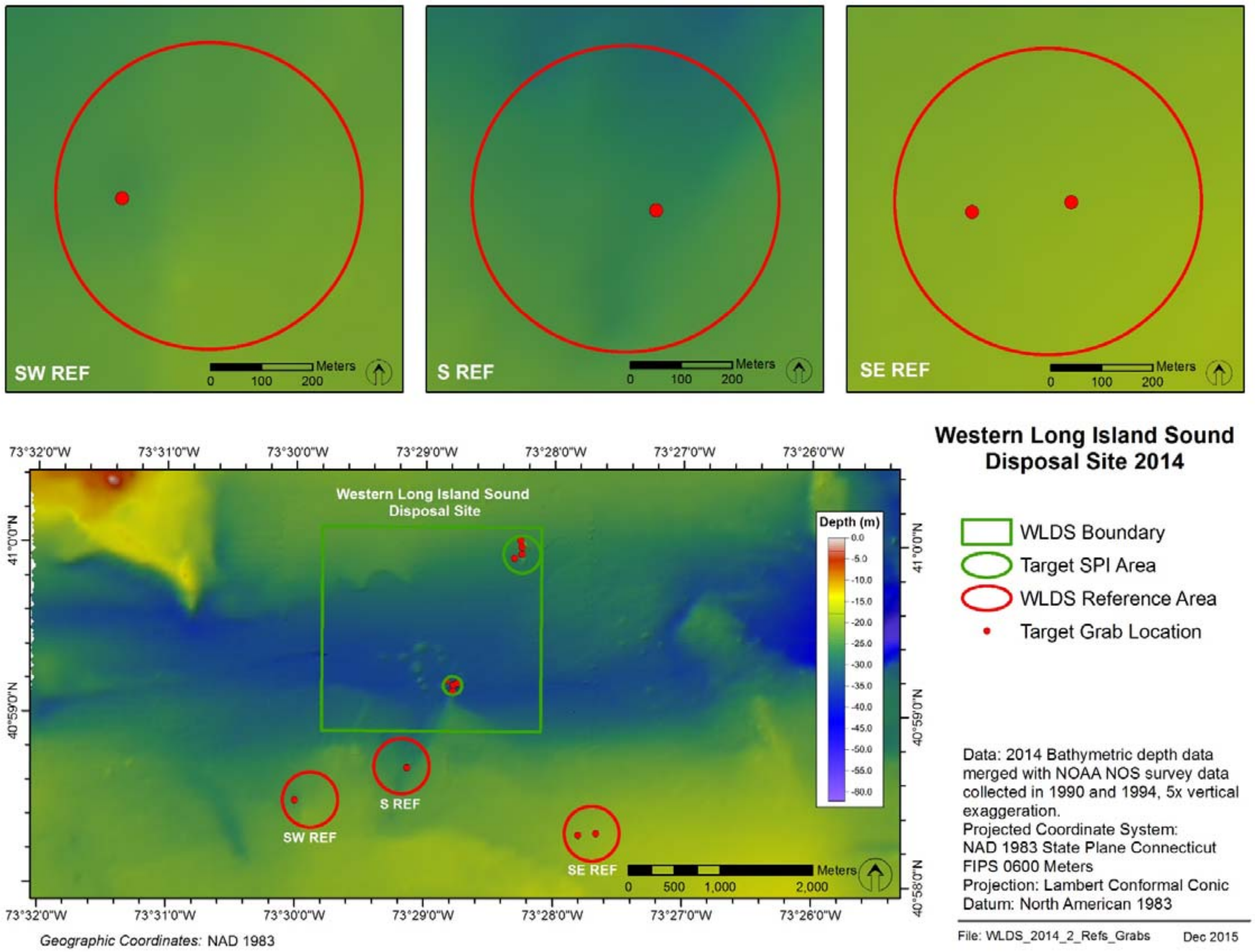

Figure 2-7. WLDS reference areas with target benthic grab stations indicated

3.0 RESULTS

3.1 Existing Bathymetry

The August 2014 bathymetric survey was consistent with previous surveys in characterizing existing topographic features in the area. These surveys reveal that the site was centered over a broad trough trending east-west and narrowing to the east (Figure 3-1). This trough had an average depth of 33 m (MLLW) and was bounded on the northern side by the edge of a plateau with a scalloped edge and on the southern side by the edge of an incised platform. These platforms on the margin of the trough are eroded margins of pre-glacial, glacial, and post-glacial deposits (Lewis and DiGiacomo-Cohen 2000). The western region of Long Island Sound is marked by the presence of the Norwalk Shoal, a shallow area east of WLDS composed of two promontories mantled with deltaic fan deposits and later marine sediments (Figure 1-1). These promontories on Norwalk Shoal have been shown to be bedrock on the north, and coastal plain deposits in the south. The eroded margins of the trough adjacent to WLDS are likely to be similar but less dramatic expressions of these underlying geologic formations now mantled by fine-grained deposits (Knebel and Poppe 2000, Poppe et al. 2000).

Multibeam bathymetric data rendered as an acoustic relief model (color scale with hillshading) provided a more detailed representation of the site topography (Figure 3-2). The central portion of the site was relatively smooth, ranging in depth from 30 to 38.5 m. Patterns consistent with placement of dredged material were visible as raised isolated mounds or as small circular features (pits with raised rims ~20 m in diameter). Disposal mounds were located in two groups: a circular arrangement of 12 mounds (A, C-M) with one mound to the west (B); and two mounds in the northeast corner of the site (N and unnamed). The surfaces of the eastern and southern margins of the trough inside WLDS were covered with circular patterns consistent with dredged material placement as noted in 2005 (ENSR 2007). Along the western margin of WLDS, a large object and an associated scour pattern were observed protruding above the seafloor (Figure 3-2).

The mounds in the northeast corner were distinct: Mound N was a circular mound that rose approximately 6 m above the surrounding seafloor with five very small (8 m) craters to the northeast; the unnamed mound just south of Mound N was an oval feature about 2 m high with a rough surface (Figure 3-2).

3.1.1 Acoustic Backscatter and Side-Scan Sonar

Unfiltered backscatter imagery of the disposal site revealed several areas throughout the site with patterns of dredged material disposal. Each of these areas is associated with ring features, pits or craters (Figure 3-3). Strong backscatter returns with diffuse outlines that indicate rougher or coarse grain sediments were evident adjacent to dredged material mounds, along the plateau to the north and the incised platform to the south (light areas in

Figure 3-3). Weaker returns were found in the trough and to the northeast indicating finer-grained sediment typical of ambient conditions (dark areas in Figure 3-3). One distinct area of weaker returns surrounded the unnamed mound in the northeast. There were several linear patterns (appearing as long white lines in Figure 3-3) consistent with release of material while barges were under transport within the site.

Filtered backscatter (Figure 3-4), which presents a quantitative assessment of surface characteristics independent of slope effects, showed that the strongest backscatter returns (-33 to -27 dB) occurred along the leading edge of the plateau to the north, the shallowest portions of the incised platform and Mounds A, B, C, D, G, I and N. The weakest backscatter returns (-45 to -38 dB) were measured in the southeast corner and the northeast around the margins of Mound N and on the surface of the unnamed mound (Figure 3-4). An area of elevated backscatter was measured along the eastern margin of the site with apparent historical dredged material deposits (pits and craters).

Side-scan sonar results also provide a clear representation of disposal activity over the central and eastern portions of the site. Side-scan results confirmed observations from the backscatter results, but with additional detail (Figure 3-5). The side-scan sonar results have a higher resolution and are more responsive to minor surface textural features and slope than backscatter results. The edges of the plateau and platform were apparent as were numerous lines of disposal features including traces of barge deposition and lines of impact craters. Details of smaller features were more apparent in the detailed images from side-scan sonar results including scour around an apparent sunken barge and more recent placement features (Figure 3-6).

3.1.2 Comparison with Previous Bathymetry

The bathymetric results in August 2014 were consistent with earlier survey results for WLDS (Table 1-2, Myre and Saffert 1999, SAIC 2002, ENSR 2005, ENSR 2007). An elevation difference comparison between elevations measured in 2005 and 2014 demonstrated that dredged material accumulated at the two northeastern placement locations and a small area between Mounds F and G with no net change in the rest of the site (Figure 3-7). Minor changes in elevation (10-50 cm) on slopes are considered artifacts resulting from slight differences in positioning of survey instruments (for example along the NE edge slope of the southern incised platform).

3.2 Sediment-Profile and Plan-View Imaging

Detailed SPI and PV image analysis results are provided in Appendix D. The following sections summarize the results for the reference areas (S-REF, SE-REF, SW-REF) and for each of the disposal mounds surveyed (M and N). Comparisons between reference areas and disposal mounds, as well as to surveys from 2001 and 2005 are also provided below. Key ecological measures (aRPD and successional stage) were also evaluated for statistical equivalence between reference and disposal areas sampled during the 2014 survey effort. All locations were surveyed 17 August 2014. SPI and PV images were collected at 15 stations per mound and 5 per reference area (Figures 2-2 and 2-3). The area of seafloor captured in the PV images ranged from 0.7 to 0.25 m².

3.2.1 Reference Area Stations

Physical Sediment Characteristics

The majority of all three reference areas were characterized by relatively soft mud (i.e., silt/clay), with most stations having a grain size major mode of >4 phi and mean camera prism penetration depths per reference area greater than 12 cm (Table 3-1, Figures 3-8 and 3-9). However, two stations at SW-REF (3 and 4) had a layer of coarse to fine sand overlaying this soft mud (e.g., 2 to 1/>4 phi) (Figure 3-10). Both of these stations are in the eastern portion of the SW-REF sampling area. There was no evidence of dredged material at any of the stations sampled in the reference areas, and no evidence of low dissolved oxygen (DO) or sedimentary methane.

Mean replicate camera prism penetration values among the reference area stations ranged from 8.9 to 20.1 cm (Table 3-1, Figure 3-9). All stations at SE-REF were softer than each of the other reference locations with deeper average penetration depths (Figure 3-11) and an overall average penetration depth of 17.7 cm compared to 12.9 cm at S-REF and 12.4 cm at SW-REF (Table 3-1). The SE reference area is located in shallower waters (19.5 – 20.4 m) than the other two (21.9 – 28.0 m) areas. Each of the SE and S reference areas had one station averaging less than 10 cm for camera penetration depth (S-REF-1 and SW-REF-3) (Table 3-1, Figure 3-9), indicating coarser and/or more compact sediment grains.

Means of replicate small-scale boundary roughness ranged from 0.5 to 2.3 cm at the reference stations (Table 3-1, Figure 3-12); all this small-scale topography can be attributed to the surface and sub-surface activity of benthic organisms evidenced as small burrowing openings, pits, mounds, etc. (e.g., Figure 3-13). Mean boundary roughness was higher at SE-REF, 1.5 cm, compared to 1.0 cm and 0.9 cm at S-REF and SW-REF (Table 3-1, Figure 3-12), respectively; this result is likely due to the greater prevalence of soft-sediment and apparent absence of coarse sediment, at this reference area. PV images support the SPI findings; in all images that could be classified the sediment was identified as oxidized silt with no bedforms resulting from physical disturbance.

Biological Conditions

The means of replicate aRPD depths ranged from 3.5 to 10.5 cm (Table 3-1, Figures 3-14 and 3-15) and averaged 6.2 cm across all reference area stations. The mean aRPD depths at S-REF and SW-REF were identical at 5.5 cm and were deeper on average at SE-REF at 7.5 cm. At S-REF and SW-REF the average aRPD was less than 6.5 cm at all stations, while at SE-REF only one station (3) was below 6.5 cm (Table 3-1). This difference is consistent with the somewhat softer sediment and higher boundary roughness values in the latter reference area.

Stage 3 infauna were present across all three reference areas. Most images classified as Stage 3 or Stage 1 on 3 (Table 3-1, Figure 3-16). Evidence for the presence of Stage 3 fauna includes large-bodied infauna, subsurface burrows, and/or feeding voids (Figures 3-17 and 3-18), and opportunistic Stage 1 taxa are indicated by the presence of small tubes at the sediment water interface (Figure 3-18). Three images each at SE-REF and SW-REF were classified as Stage 2 on 3 (Table 3-1), and the successional stage could not be determined for two images at S-REF (Table 3-1, Figure 3-16). Stage 2 fauna are smaller than Stage 3 taxa and are active in the zone 2 - 4 cm below the sediment surface. The number of subsurface feeding voids, indicating Stage 3 fauna, ranged from 0 - 5 across all reference stations, and the mean number of voids per reference station ranged from 0.3 to 2 (Table 3-1).

Further indications of subsurface faunal activity from Stage 2 and 3 taxa are seen in the PV images as the presence of burrows, ranging from sparse at S-REF to present at all three reference areas (Figure 3-19). The presence of tubes ranged from present to abundant at all three reference areas. Tracks across the seafloor often created by epifauna (e.g. crabs, gastropods) were seen at SE-REF and SW-REF (Figure 3-19). Fish were noted in a few images. Additionally, shell fragments were seen in two PV images at SW-REF. No flora were present in the PV images across reference areas (Appendix D).

3.2.2 Disposal Site Stations

Physical Sediment Characteristics

Both Mound M and Mound N occupy similar depth ranges; Mound M stations had a mean depth of 32.6 m and ranged from 30.5 to 33.5 m and Mound N stations had a mean depth of 27.6 m and ranged from 23.8 to 29.3 m (Table 3-2). Sediments at both mounds were generally soft mud (i.e., silt/clay), with most stations having a grain size major mode of >4 phi. One station each at Mound M (12) and at Mound N (11) had a thin layer of medium to fine sand overlaying this soft mud (Table 3-2, Figure 3-10, and Figure 3-20). Mean camera prism penetration values at each mound were very similar, 14.7 cm at Mound M and 14.2 cm at Mound N. Mean replicate camera prism penetration values ranged from 8.8 to 16.9 cm at Mound M and 12.1 to 16.4 cm at Mound N (Table 3-2, Figure 3-21). Not surprisingly, the stations mentioned above as having sand overlaying the soft mud also represent the minimum end of these penetration values at each mound. All stations exhibited dredged material within the silt/clay portion of the sediment with the presence of dredged material extending below the camera penetration depth. There was no evidence of low DO or sedimentary methane at either disposal mound.

The two mounds were also similar in small-scale boundary roughness values, with means of 0.9 cm at Mound M and 1.1 at Mound N. Means of replicate small-scale boundary roughness ranged from 0.5 to 1.6 cm at Mound M and 0.7 to 2.2 cm at Mound N (Table 3-2, Figure 3-22); 95% of this small-scale topography can be attributed to the surface and sub-surface activity of benthic organisms evidenced as small burrowing openings, pits, mounds, etc. (Figure 3-13). PV images support the SPI findings; in all images that could be classified the sediment was identified as oxidized silt with no bedforms resulting from physical disturbance.

Biological Conditions

The mean of replicate aRPD depths ranged from 1.2 to 3.8 cm at Mound M and from 2.1 to 7.7 cm at Mound N (Table 3-2, Figures 3-23 and 3-24). All stations at Mound N averaged aRPD depths of over 3.0 cm whereas 40% of those at Mound M did (Table 3-2, Figure 3-24). Physical characteristics at both mounds were very similar, thus difference in aRPD depth can be attributed primarily to a difference in the activity level of infaunal communities at these two locations.

All images at Mound M had evidence of Stage 3 fauna, except for one at M-13, which was classified as Stage 1 on 2 (Table 3-2, Figure 3-25). Similarly, all images at Mound N had evidence of Stage 3 fauna, with the exception of one image at N-8 from which the successional stage could not be determined (Table 3-2, Figure 3-25). Evidence for the presence of Stage 3 fauna includes large-bodied infauna, large subsurface burrows, and/or feeding voids (Figures 3-17 and 3-18), and opportunistic Stage 1 taxa are indicated by the presence of small tubes at the sediment water interface (Figure 3-18). Stage 2 fauna are smaller than Stage 3 taxa and are active in the zone 2-4 cm below the sediment surface. Most images at Mounds M and N were classified as Stage 1 on 3 (Table 3-2, Figure 3-25). The number of subsurface feeding voids, indicating Stage 3 fauna, ranged from 0 to 5 across all Mound stations and the mean number of voids ranged from 0 to 3.3 at Mound M and from 0.7 to 2.3 at Mound N (Table 3-2).

PV images indicated more biological activity present at Mound N compared to Mound M. Burrows, indicating subsurface activity by Stage 2 and 3 fauna, were sparse and present at Mound M and sparse to abundant at Mound N with 69% of the images containing abundant burrows (Figure 3-19). No tubes were seen in PV images at Mound M and were present to abundant at several stations at Mound N. Tracks across the seafloor often created by epifauna (crabs, gastropods) were seen at a several stations at each Mound (Figure 3-19). Fish were noted in a few images at Mound N. Additionally, shell fragments were seen in at M-11 and M-12. No flora were present in the PV images across both mounds (Appendix D).

3.2.3 Comparison to Reference Areas

Mean aRPD Variable

Area mean aRPD depths were lower at both mounds compared to the grand mean of the reference areas. Depths at Mound N were closer to reference area means than values at Mound M (Table 3-3). The standard deviation among stations for aRPD depths across all sampling areas ranged from 0.56 to 2.20 cm (Table 3-3). Median aRPD values were deeper at SE-REF compared to S-REF and SW-REF (7.7 compared to 5.7 and 6.0, respectively). Values for the aRPD also ranged more widely at SE-REF, from 4.5 to 10.5 (Table 3-1).

A test was performed to determine whether or not the differences observed in mean aRPD values between the three reference areas and two mounds were statistically significant. The station mean aRPD data from all five locations were combined to assess normality and estimate pooled variance. Results for the normality test indicated that the area residuals (i.e., each observation minus the area mean) were not significantly different from a normal distribution (Shapiro-Wilk's test p-value = 0.095, with alpha = 0.05). Levene's test for equality for variances was rejected (p-value = 0.037, with alpha = 0.05). The confidence interval for the difference equation was constructed using normal theory equations with separate variance estimates for the five groups and the appropriate Welch-Satterthwaite degrees of freedom.

The confidence region for the difference between the reference areas versus disposal mound means was not contained within the interval [-1, +1] (Table 3-4). The conclusion was that the three reference and two mound areas did not have significantly equivalent aRPD values in the 2014 survey, with a difference in means of approximately 2.5 cm, with reference areas having deeper aRPD values than disposal mound locations (Table 3-4).

<u>Successional Stage Rank Variable</u>

Across the reference areas and both mounds examined, Stage 3 fauna were consistently found, often along with Stage 1 fauna (Table 3-1, Table 3-2, Figure 3-16, Figure 3-25). To evaluate these successional stages numerically, a successional stage rank variable was applied to each image. A value of 3 was assigned to Stage 3, 2 on 3, or 1 on 3 designations; a value of 2 was applied to Stage 2 or 1 on 2; a value of 1 was applied to Stage 1; and images from which the stage could not be determined were excluded from calculations. The maximum successional stage rank among replicates was used to represent the station value.

The successional stage rank variable was uniformly 3 across all three reference areas and both mounds; no statistics are required to conclude that these areas are equivalent.

<u>Number of Feeding Voids Variable</u>

Mean numbers of feeding voids were higher at both disposal mounds compared to reference areas, which were somewhat more variable. Median values of feeding voids at disposal mounds were very similar (1.7 at M, 1.7 at N) (Table 3-2), whereas median values at reference areas ranged from 0.3 at S-REF and SW-REF to 1.3 at SE-REF (Table 3-1) (Table 3-1). Values ranged widely at all locations except S-REF where the minimum count was equivalent to the median (Table 3-1).

3.2.4 Comparison to 2005 and 2004

Neither Mound M nor Mound N has been surveyed for benthic ecological status in the past. The previous SPI survey at WLDS was conducted in June 2004, prior to initial disposal of dredged materials at Mound M in the 2004-2005 season, when the mound was formed by the placement of approximately 78,500 m^3 of disposal materials. A detailed high resolution bathymetric survey of WLDS was conducted in July 2005 and observed the height of Mound M to be 1.5 m above the seafloor and that it formed a mound complex with Mounds F and J. Ring features (akin to impact craters) from recent disposal activity were also detected at Mound M. Results from the 2005 survey also indicated that the mounds at WLDS were generally stable and exhibited expected benthic recovery trajectories. Since that time, Mound M received an additional 30,600 m^3 of disposal materials. The Mound N location was initially targeted with disposal materials in the 2010-2011 season and received additional materials in 2011-2012, 2012-2013, and 2013-2014, with materials totaling close to 65,000 m^3.

Results of the 2014 SPI survey revealed physical and some biological characteristics at the 3 reference areas that were consistent with results of the SPI survey conducted in 2004. Both surveys, in addition to previous surveys, showed that S-REF and SW-REF had thin layers of fine sand and mud overlaying predominantly silt/clay (mud) sediment whereas sediments found at SE-REF were soft muds with deeper aRPDs. The 2004 SPI survey sampled Mounds H, J, K, and L. This survey found relatively high aRPD values given the timing of disposal activity and no significant ecological difference between these mounds and the reference areas.

Given that Mound M formed a mound complex with Mounds F and J and was found at a similar depth range and area of the disposal site as previous mounds (A-L), we would expect to have observed similar rates of benthic recovery as those recorded during prior SPI surveys. Indeed, we did observe a mature benthic infaunal community (Stage 3 fauna present at most sites). However, aRPD means were lower than at reference areas and Mound N (Table 3-3). Mound N, on the other hand, was positioned in the NE corner of the disposal area in shallower depths, and SPI surveys have not been conducted in this location prior to 2014. Here we also found a mature community, in addition to aRPD levels close to those seen at the reference areas (Table 3-3). Statistical results showed disposal mound aRPD values to be significantly less than, and successional stage to be ecologically equivalent to, reference areas (Table 3-4). Therefore, compared to 2004 when there was no significant ecological difference between mounds and reference areas, there are some ecologically meaningful differences in 2014 indicating that benthic recolonization is progressing at Mounds M and N but is not yet complete.

3.3 Sediment Grab Samples

Sediment grab samples were collected from 12 stations on 22 August 2014 for analysis of grain size, total organic carbon (TOC) and benthic community structure (Figures 2-5 and 2-6).

3.3.1 Grain Size and Total Organic Carbon

All samples were dominated by silt, clay, and fine sand with smaller proportions of medium to coarse sand and gravel (Table 3-5). As evidenced in the SPI results, SE-REF stations were more fine-grained than other reference areas, classified as 'clayey silt' in the Shepard classification scheme. Samples collected at S-REF and SW-REF had more sand and were classified as 'clayey sand.' All grabs at Mound M were classified as 'sand silt clay', as did stations 9 and 4 at Mound N. Station N-3 had more fines and was classified as 'clayey silt' and N-11 had lower fines and higher sand and was classified as 'silty sand.' N-11 is also the station that had a layer of medium sand over silt/clay, as identified in the SPI images; this station is on the side of a disposal mound (Figure 3-20).

TOC provides a specific value for the amount of organic matter in the surface sediments (TOC includes some carbon that may not be digestible and does not include some forms of organic matter). This value reflects organic loading to the sediments and is also affected by the metabolic activity of the infaunal community. Across all samples, TOC values ranged from 0.9 to 2.4% and there was a general trend of increasing TOC values with increasing percent fine grains, an expected pattern as high TOC values typically are found in areas with high proportions of fine grained sediment. At reference areas, TOC was above 2% at the 'clayey silt' stations (both at SE-REF) and below 2% at the 'clayey sand' stations. TOC values at disposal mounds ranged from 0.9 to 2.3% with 'silty sand' and 'clayey silt' at the low and high end of the range, respectively, and all other stations classifying as 'sand silt clay.' These patterns area as expected with higher TOC values in more finely grained sediment.

3.3.2 Benthic Community Analysis

Benthic community characterization results provide additional insight into the recovery of the benthic system. Species richness, abundance, density, and diversity metrics are provided along with a list of dominant taxa in Tables 3-6 and 3-7 for 1) each sampled station, 2) each mound and reference area evaluated separately, and 3) disposal mounds and reference areas evaluated in aggregate. Total species richness was measured as the number of unique taxa identified, abundance was measured as the total number of individuals found at each location, density as the number of individuals per meter squared, and the Shannon-Wiener Diversity Index (H') and the Pielou Evenness Index (J') were used to assess overall diversity. Dominant taxa are those found in the highest abundance in each location.

A total of 55 species were found over all stations (reference + site) with a mean species richness of 14.17 species per station. Total abundance overall was 963, with a mean of 80 individuals per station. Mean density was 1822 ind/m^2, diversity 2.9, and evenness 0.8. The top ten dominant taxa overall included polychaetes (three species; *Nephtys incisa, Mediomastus ambiseta,* and *Levinsenia gracilis*), bivalves (five species; *Nucula proxima, Yoldia sapotilla, Mulinia lateralis, Pitar morrhuanus*, and *Macoma tenta*), and gastropods (two species; *Turbonilla interrupta* and *Haminoea solitaria*) (Table 3-7).

3.3.2.1 Reference Areas Stations

Thirty-seven species were found at all sampled reference areas, and site level species richness ranged from 14 to 21, with a mean of 19 species per station. Total abundance at reference areas was 398 individuals and ranged from 70 to 147 at sampled stations, with a mean of 100 individuals per station. Densities ranged from 1,589 to 3,337 ind/m^2, with a mean of 2,259. Diversity ranged from 2.9 to 3.6, with a mean of 3.3. Evenness ranged from 0.7 to 0.8, with a mean of 0.8 (Table 3-6).

The dominant taxon found across all reference samples was *Nephtys incisa*, a predatory polychaete of the family Nephtyidae in the class Polychaeta. This polychaete dominated all samples with the exception of SE-REF-2, which was dominated by the Nuculid bivalve *Nucula proxima* (Table 3-6). The top ten dominant taxa at the reference stations included polychaetes (3; *Nephtys incisa, Mediomastus ambiseta,* and *Levinsenia gracilis*), bivalves (3; *Nucula proxima, Yoldia sapotilla,* and *Pitar morrhuanus*), and gastropods (4; *Turbonilla interrupta, Haminoea solitaria, Nassarius trivittatus,* and *Acteocina canaliculata*) (Table 3-7).

3.3.2.2 Disposal Site Stations

A total of 44 species were found at sampled disposal mound sites, and site level species richness ranged from 5 to 20, with a mean of 12 species. Species richness at Mound M ranged from 10 to 20 with a mean of 15 species. Species richness at Mound N ranged from 5 to 13 with a mean of 9 species per station. Total abundance was 565 and ranged from 26 to 183 at sampled stations, with a mean of 71 individuals per station. Abundance at Mound M ranged from 52 to 183 with a mean of 113 individuals per station. Abundance at Mound N ranged from 15 to 39 with a mean of 28 individuals per station. Densities ranged from 341 to 4,154 ind/m^2, with a mean of 3.29. Densities at Mound M ranged from 1180 to 4154 ind/m^2, with a mean of 2565. Densities at Mound N ranged from 341 to 885 ind/m^2. Diversity ranged from 1.4 to 3.4, with a mean of 2.7. Diversity at Mound M ranged from 2.0 to 3.4, with a mean of 2.9. Diversity at Mound N ranged from 1.4 to 2.9, with a mean of 2.4. Evenness ranged from 0.6 to 0.9, with a mean of 0.8. Evenness at Mound M ranged from 0.6 to 0.8, with a mean of 0.8. Evenness at Mound N ranged from 0.6 to 0.9, with a mean of 0.8 (Table 3-6).

The dominant taxon found across all samples from disposal mounds was *Nephtys incisa*, a predatory polychaete of the family Nephtyidae in the class Polychaeta. This polychaete dominated all samples with the exception of Mound M-5, which was dominated by the Nuculid bivalve *Nucula proxima* (Table 3-6). The top ten dominant taxa at disposal mound stations included polychaetes (3; *Nephtys incisa, Mediomastus ambiseta,* and *Levinsenia gracilis*), bivalves (5; *Nucula proxima, Mulinia lateralis, Yoldia sapotilla, Pitar morrhuanus, Macoma tenta*), and gastropods (1; *Nassarius trivittatus*), and nemerteans (1; *Tubulanus pellucidus*) (Table 3-7).

3.3.2.3 Comparison to Reference Areas

Results indicated that reference area infaunal communities were more diverse and slightly less skewed by presence of overly abundant taxa than those at disposal mound stations (Table 3-6). However, overall benthic infaunal community composition found at reference and disposal mound locations were very similar, with the same top two dominant taxa, *Nephtys incisa* and *Nucula proxima* (Table 3-7). The upper range of species richness at disposal mounds and reference areas was similar at 21 and 20, respectively, indicating that diverse communities do occupy both areas. Reference areas had higher mean abundance (100 vs. 71) and densities (2,259 vs. 1,603 ind/m^2) than at mound locations. Additionally, Mound M had higher mean abundance (113 vs. 28), density (2,565 vs 641 ind/m^2), and diversity (2.9 vs. 2.4) than Mound N (Table 3-6). The differences between abundance and densities at mound locations were largely driven by high numbers of *Nucula proxima* at Mound M-5 and by *Mediomastus ambiesta* and *Mulinia lateralis* at Mound M-4 (Appendix F).

The small opportunistic polychaete *Mediomastus ambiesta* and the surf clam *Mulinia lateralis* were found at both reference and disposal areas and are indicative of Stage 1 infauna (Table 3-7, Appendix F). Prevalence of *Nephtys incisa* at all sampling stations (ranging from 4 to 41 in abundance, Appendix F) indicates and confirms the presence of Stage 3 taxa at reference and disposal mound locations.

Table 3-1.

Summary of WLDS Reference Station Sediment-Profile Imaging Results (station means), August 2014

Area	Station	Depth (m)	Grain Size Major Mode (phi)	Mean Prism Penetration Depth (cm)	Mean Boundary Roughness (cm)	Dominant Type of Boundary Roughness	Mean aRPD Depth (cm)	Mean # of Subsurface Feeding Voids	Methane Present?	Successional Stages Present		
S REF	1	24.4	>4	8.9	0.5	Biological	3.9	0.3	No	3	3	Ind
	2	28.0	>4	14.8	1.5	Biological	5.6	2.0	No	1 on 3	3	1 on 3
	3	24.1	>4	12.9	1.5	Biological	5.9	0.3	No	1 on 3	1 on 3	Ind
	4	24.7	>4	13.8	0.9	Biological	5.7	0.3	No	1 on 3	1 on 3	1 on 3
	5	25.9	>4	14.2	0.7	Biological	6.5	0.7	No	1 on 3	1 on 3	1 on 3
	Mean	25.4		12.9	1.0		5.5	0.7				
SE REF	1	20.4	>4	20.1	1.5	Biological	10.5	1.7	No	1 on 3	1 on 3	1 on 3
	2	20.1	>4	17.0	0.8	Biological	6.8	0.7	No	1 on 3	3	2 on 3
	3	19.5	>4	16.1	1.9	Biological	4.5	0.7	No	2 on 3	1 on 3	1 on 3
	4	19.5	>4	17.9	2.3	Biological	8.3	1.3	No	1 on 3	1 on 3	2 on 3
	5	19.8	>4	17.5	0.9	Biological	7.7	1.7	No	1 on 3	1 on 3	1 on 3
	Mean	19.9		17.7	1.5		7.5	1.2				
SW REF	1	23.8	>4	10.1	0.8	Biological	6.1	0.3	No	1 on 3	1 on 3	3
	2	22.6	>4	15.1	1.2	Biological	6.3	2.0	No	1 on 3	1 on 3	1 on 3
	3	21.9	2 to 1/>4	9.4	0.7	Biological	3.5	0.3	No	2 on 3	1 on 3	2 on 3
	4	21.9	2/>4	11.8	1.1	Biological	5.9	0.3	No	2 on 3	1 on 3	1 on 3
	5	23.8	>4	15.8	0.9	Biological	6.0	1.7	No	1 on 3	1 on 3	1 on 3
	Mean	22.8		12.4	0.9		5.5	0.9				
	Max	28.0		20.8	3.0		10.8	5.0				
	Min	19.5		7.5	0.2		3.8	0.0				
	Mean	22.7		14.4	1.2		6.2	1.0				

Ind = Indeterminate

a Grain Size: "/" indicates layer of one phi size range over another (see Appendix E)

b Successional Stage: "on" indicates one Stage is found on top of another Stage (i.e., 1 on 3);"→" indicates one Stage is progressing to another Stage (i.e., 2→3)

Table 3-2.

Summary of WLDS Disposal Mounds M and N Sediment-Profile Imaging Results (station means), August 2014

Mound	Station	Depth (m)	Grain Size Major Mode (phi)	Mean Prism Penetration Depth (cm)	Mean Boundary Roughness (cm)	Dominant Type of Boundary Roughness	Mean aRPD Depth (cm)	Mean # of Subsurface Feeding Voids	Methane Present?	Successional Stages Present		
M	1	32.3	>4	14.7	0.8	Biological	2.2	1.7	No	1 on 3	1 on 3	1 on 3
	2	32.9	>4	14.2	0.5	Biological	2.4	2.0	No	1 on 3	1 on 3	1 on 3
	3	32.3	>4	16.4	0.9	Biological	3.5	0.3	No	1 on 3	1 on 3	1 on 3
	4	33.5	>4	15.5	0.6	Biological	2.7	1.7	No	1 on 3	1 on 3	1 on 3
	5	33.2	>4	16.9	1.3	Biological	3.2	3.3	No	1 on 3	1 on 3	1 on 3
	6	33.5	>4	15.3	0.7	Biological	3.3	0.7	No	1 on 3	1 on 3	1 on 3
	7	32.6	>4	16.0	0.7	Physical	3.8	3.3	No	1 on 3	1 on 3	1 on 3
	8	32.3	>4	14.7	0.9	Biological	2.8	2.3	No	1 on 3	1 on 3	1 on 3
	9	32.9	>4	12.4	0.8	Biological	2.4	3.0	No	1 on 3	1 on 3	3
	10	32.3	>4	15.9	0.7	Biological	3.0	2.7	No	2 on 3	3	3
	11	31.7	>4	13.2	1.0	Biological	2.0	2.0	No	1 on 3	3	2 on 3
	12	30.5	2/>4	8.8	1.6	Biological	2.0	0.0	No	1 on 3	1 on 3	1 on 3
	13	31.7	>4	14.8	1.2	Biological	2.9	0.7	No	1 on 2	1 on 3	1 on 3
	14	32.9	>4	16.2	1.0	Biological	2.8	1.3	No	1 on 3	1 on 3	3
	15	33.5	>4	16.0	0.9	Biological	3.4	1.0	No	1 on 3	1 on 3	1 on 3
	Max	33.5		19.0	2.5		4.6	5.0				
	Min	30.5		7.8	0.3		1.5	0.0				
	Mean	32.6		14.7	0.9		2.8	1.7				

Ind = Indeterminate
a Grain Size: "/" indicates layer of one phi size range over another (see Appendix E)
b Successional Stage: "on" indicates one Stage is found on top of another Stage (i.e., 1 on 3);"→" indicates one Stage is progressing to another Stage (i.e., 2→3)

Table 3-2. (continued)

Summary of WLDS Disposal Mounds M and N Sediment-Profile Imaging Results (station means), August 2014

Mound	Station	Depth (m)	Grain Size Major Mode (phi)	Mean Prism Penetration Depth (cm)	Mean Boundary Roughness (cm)	Dominant Type of Boundary Roughness	Mean aRPD Depth (cm)	Mean # of Subsurface Feeding Voids	Methane Present?	Successional Stages Present		
N	1	27.7	>4	13.6	0.9	Biological	7.7	1.7	No	1 on 3	1 on 3	1 on 3
	2	25.9	>4	12.7	1.2	Biological	2.1	2.3	No	1 on 3	1 on 3	1 on 3
	3	28.0	>4	14.3	1.6	Biological	3.8	1.7	No	1 on 3	1 on 3	1 on 3
	4	25.9	>4	13.8	1.5	Biological	4.1	1.7	No	1 on 3	1 on 3	1 on 3
	5	28.0	>4	14.3	0.8	Biological	5.9	2.0	No	1 on 3	1 on 3	1 on 3
	6	27.4	>4	16.1	1.2	Biological	4.3	2.0	No	1 on 3	1 on 3	1 on 3
	7	28.7	>4	13.8	0.9	Biological	5.1	1.0	No	1 on 3	1 on 3	1 on 3
	8	29.3	>4	15.2	0.7	Biological	4.4	2.3	No	Ind	1 on 3	3
	9	28.0	>4	14.5	2.2	Biological	3.4	2.0	No	1 on 3	1 on 3	1 on 3
	10	28.3	>4	14.3	0.7	Biological	2.5	0.7	No	1 on 3	1 on 3	1 on 3
	11	23.8	2 to 1/>4	12.1	0.9	Physical	4.2	1.3	No	3	3	3
	12	28.7	>4	15.0	0.7	Biological	4.2	1.3	No	1 on 3	1 on 3	1 on 3
	13	29.0	>4	12.7	1.0	Biological	6.3	1.7	No	1 on 3	1 on 3	1 on 3
	14	27.4	>4	16.4	1.1	Biological	7.3	1.0	No	1 on 3	1 on 3	1 on 3
	15	27.1	>4	14.6	1.3	Biological	3.8	2.3	No	1 on 3	1 on 3	1 on 3
	Max	29.3		17.4	4.7		9.7	5.0				
	Min	23.8		9.8	0.3		2.2	0.0				
	Mean	27.6		14.2	1.1		4.6	1.7				

Ind = Indeterminate
a Grain Size: "/" indicates layer of one phi size range over another (see Appendix E)
b Successional Stage: "on" indicates one Stage is found on top of another Stage (i.e., 1 on 3);"→" indicates one Stage is progressing to another Stage (i.e., 2→3)

Table 3-3.

Summary of Station Means for aRPD, Successional Stage, and Feeding Voids by Sampling Location

Site	N	Mean aRPD (cm)		Successional Stage Rank		Number of Feeding Voids	
		Mean	**Standard Deviation**	**Mean**	**Standard Deviation**	**Mean**	**Standard Deviation**
Reference Areas							
S REF	5	5.5	1.0	3.0	0.0	0.7	0.7
SE REF	5	7.5	2.2	3.0	0.0	1.2	0.5
SW REF	5	5.5	1.2	3.0	0.0	0.9	0.8
Mean		6.2		3.0		0.9	
Disposal Mounds							
M	15	2.8	0.6	3.0	0.1	1.7	1.1
N	15	4.6	1.6	3.0	0.0	1.7	0.5
Mean		3.7		3.0		1.7	

Table 3-4.

Summary Statistics and Results of Inequivalence Hypothesis Testing for aRPD Values

Variable	Difference Equation	Observed Difference ($\hat{d}$)	SE ($\hat{d}$)	df for SE ($\hat{d}$)	95% Confidence Bounds (lower–upper)
aRPD	$Mean_{REF} - Mean_{DISP}$	2.5	0.5	12.7	1.7 – 3.3

Table 3-5.

WLDS 2014 Results of Sediment Grain Size Analysis and Percent Total Organic Carbon (TOC)

Location	**Station No.**	**Lab ID No.**	**Total Organic Carbon (%)**	**Fines (%)**	*Silt (%)*	*Clay (%)*	**Total Sand (%)**	*Fine Sand (%)*	*Medium Sand (%)*	*Coarse Sand (9%)*	**Gravel (%)**	**Shepard Classification**
Mound M	1	PAN-007	1.1	44.9	*23.5*	*21.4*	50.0	*25.4*	*19.5*	*5.1*	5.1	sand silt clay
Mound M	4	PAN-008	1.6	58.8	*33.1*	*25.7*	40.7	*35.2*	*4.9*	*0.6*	0.5	sand silt clay
Mound M	5	PAN-006	2.0	61.6	*36.8*	*24.8*	38.1	*31.9*	*5.2*	*1.0*	0.3	sand silt clay
Mound M	9	PAN-005	1.3	46.6	*25.7*	*20.9*	50.5	*42.3*	*7.1*	*1.1*	2.9	sand silt clay
Mound N	3	PAN-004	2.3	81.6	*51.4*	*30.2*	12.4	*3.8*	*4.8*	*3.8*	6.0	clayey silt
Mound N	4	PAN-001	2.2	78.9	*44.2*	*34.7*	21.1	*17.5*	*2.9*	*0.7*	0.0	sand silt clay
Mound N	9	PAN-003	2.1	69.3	*40.7*	*28.6*	29.9	*21.1*	*7.2*	*1.6*	0.8	sand silt clay
Mound N	11	PAN-002	0.9	28.1	*19.6*	*8.5*	63.9	*53.0*	*10.2*	*0.7*	8.0	silty sand
S REF	5	PAN-011	1.1	38.3	*16.4*	*21.9*	60.4	*47.5*	*11.9*	*1.0*	1.3	clayey sand
SE REF	2	PAN-010	2.4	87.3	*50.5*	*36.8*	12.7	*10.4*	*1.7*	*0.6*	0.0	clayey silt
SE REF	5	PAN-009	2.2	85.9	*49.7*	*36.2*	14.1	*11.2*	*2.1*	*0.8*	0.0	clayey silt
SW REF	5	PAN-012	1.8	35.9	*15.8*	*20.1*	61.7	*49.4*	*11.3*	*1.0*	2.4	clayey sand

Table 3-6.

Species Richness, Abundance, Density, Diversity, and Evenness of Species at WLDS Stations

Listed by Station at WLDS

Station	Richness (S)	Abundance (N)	Density (ind/m^2)	Diversity (H')	Evenness (J')	Dominant Taxon	Class, Family of Dominant Taxon
MoundM-1	15	67	1521	3.3	0.8	*Nephtys incisa*	Polychaeta, Nephtyidae
MoundM-4	20	150	3405	3.4	0.8	*Nephtys incisa*	Polychaeta, Nephtyidae
MoundM-5	10	183	4154	2.0	0.6	*Nucula proxima*	Bivalvia, Nuculidae
MoundM-9	15	52	1180	3.0	0.8	*Nephtys incisa*	Polychaeta, Nephtyidae
MoundN-3	10	33	749	2.6	0.8	*Nephtys incisa*	Polychaeta, Nephtyidae
MoundN-4	13	39	885	2.9	0.8	*Nephtys incisa*	Polychaeta, Nephtyidae
MoundN-9	5	26	590	1.4	0.6	*Nephtys incisa*	Polychaeta, Nephtyidae
MoundN-11	8	15	340	2.8	0.9	*Nephtys incisa*	Polychaeta, Nephtyidae
S-REF-5	20	70	1589	3.5	0.8	*Nephtys incisa*	Polychaeta, Nephtyidae
SE-REF-2	19	147	3337	3.1	0.7	*Nucula proxima*	Bivalvia, Nuculidae
SE-REF-5	14	100	2270	2.9	0.8	*Nephtys incisa*	Polychaeta, Nephtyidae
SW-REF-5	21	81	1839	3.6	0.8	*Nephtys incisa*	Polychaeta, Nephtyidae
Total	55	963					
Mean	14.2	80.3	1822	2.9	0.8		

Table 3-6. (continued)

Species Richness, Abundance, Density, Diversity, and Evenness of Species at WLDS Sampling Areas

Listed by Location at WLDS

Location	Richness (S)	Abundance (N)	Station Mean Density (ind/m^2)	Station Mean Diversity (H')	Station Mean Evenness (J')	Dominant Taxon	Class, Family of Dominant Taxon
Mound M	29	452	2565	2.9	0.8	*Nucula proxima*	Bivalvia, Nuculidae
Mound N	28	113	641	2.4	0.8	*Nephtys incisa*	Polychaeta, Nephtyidae
S-REF	20	70	1589	3.5	0.8	*Nephtys incisa*	Polychaeta, Nephtyidae
SE-REF	23	247	2804	3.0	0.8	*Nucula proxima*	Bivalvia, Nuculidae
SW-REF	21	81	1839	3.6	0.8	*Nephtys incisa*	Polychaeta, Nephtyidae

Listed by Type at WLDS

Type	Richness (S)	Abundance (N)	Station Mean Density (ind/m^2)	Station Mean Diversity (H')	Station Mean Evennes s (J')	Dominant Taxon	Class, Family of Dominant Taxon
Disposal Mound	44	565	1603	2.7	0.7	*Nephtys incisa*	Polychaeta, Nephtyidae
Reference	37	398	2258	3.3	0.8	*Nephtys incisa*	Polychaeta, Nephtyidae

Table 3-7.

Top Ten Dominant Species by Abundance at WLDS, at Reference Areas, and Overall

Rank	Top Ten Dominant at Disposal Site	Top Ten Dominant at Reference Areas	Top Ten Dominant Overall
1.	*Nephtys incisa*	*Nephtys incisa*	*Nephtys incisa*
2.	*Nucula proxima*	*Nucula proxima*	*Nucula proxima*
3.	*Mulinia lateralis*	*Turbonilla interrupta*	*Mediomastus ambiseta*
4.	*Mediomastus ambiseta*	*Mediomastus ambiseta*	*Yoldia sapotilla*
5.	*Yoldia sapotilla*	*Yoldia sapotilla*	*Turbonilla interrupta*
6.	*Pitar morrhuanus*	*Pitar morrhuanus*	*Mulinia lateralis*
7.	*Levinsenia gracilis*	*Haminoea solitaria*	*Pitar morrhuanus*
8.	*Macoma tenta*	*Levinsenia gracilis*	*Levinsenia gracilis*
9.	*Tubulanus pellucidus*	*Nassarius trivittatus*	*Haminoea solitaria*
10.	*Nassarius trivittatus*	*Acteocina canaliculata*	*Macoma tenta*

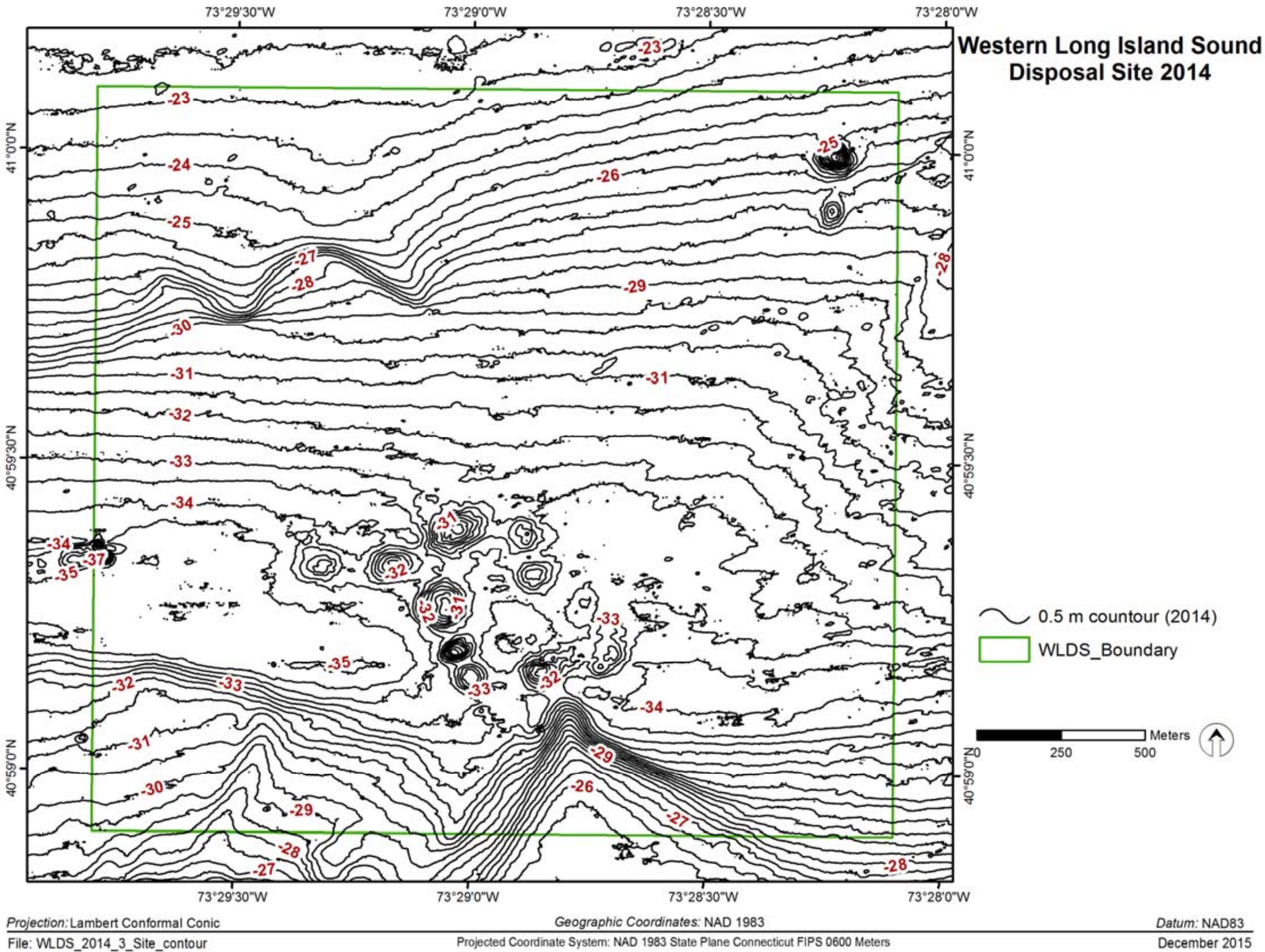

Figure 3-1. Bathymetric contour map of WLDS – August 2014

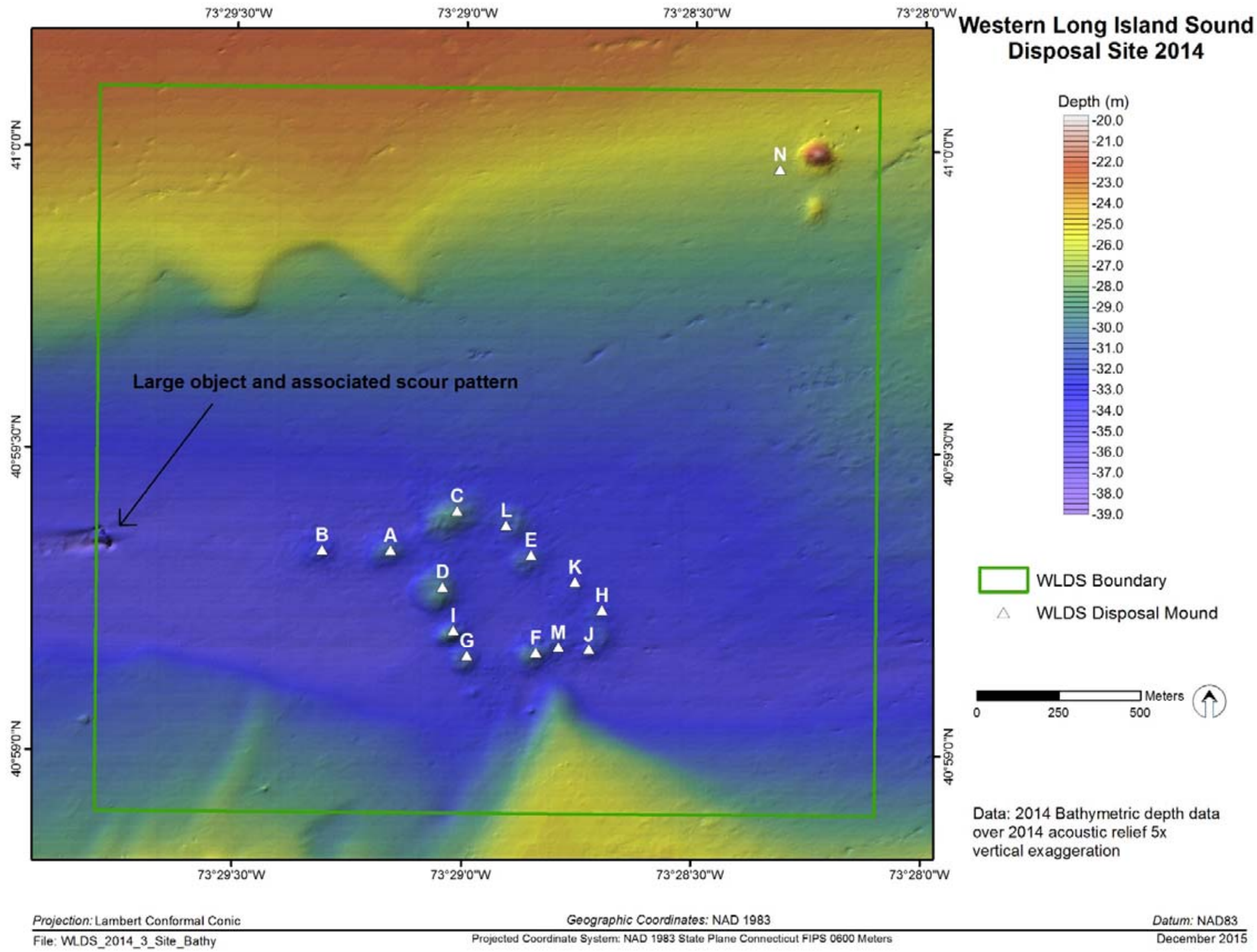

Figure 3-2. Bathymetric depth data over acoustic relief model of WLDS – August 2014

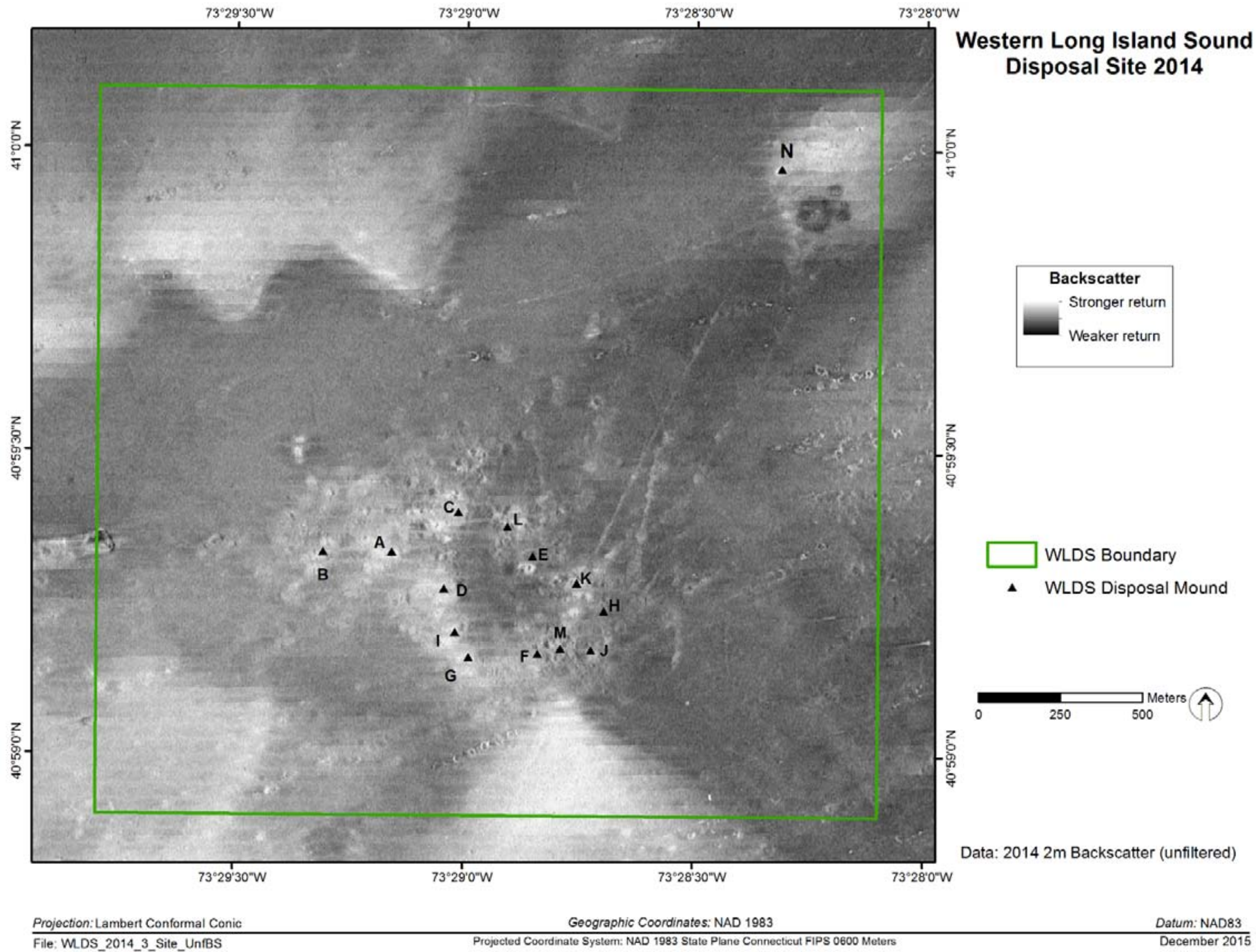

Figure 3-3. Mosaic of unfiltered backscatter data of WLDS – August 2013

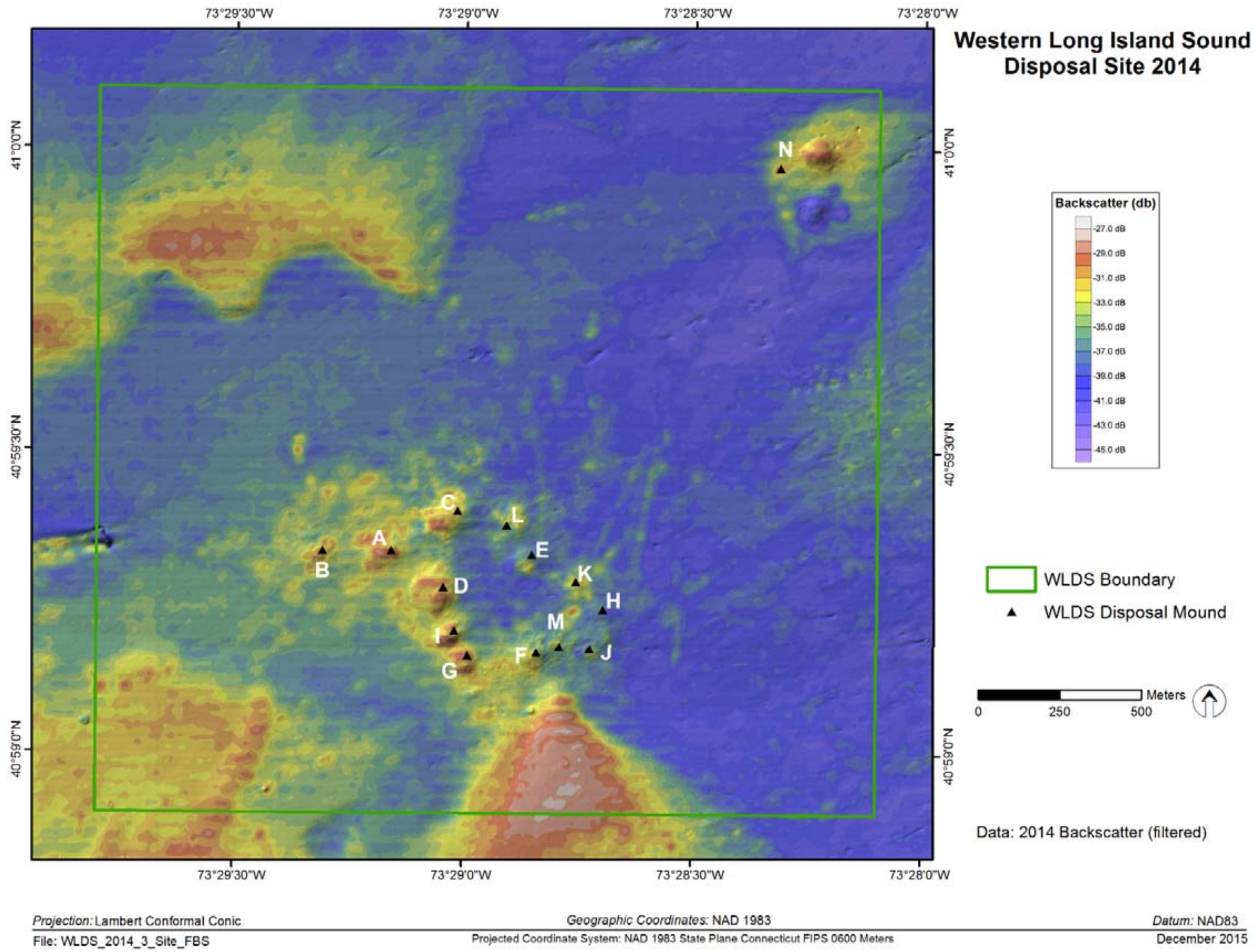

Figure 3-4. Filtered backscatter of WLDS – August 2014

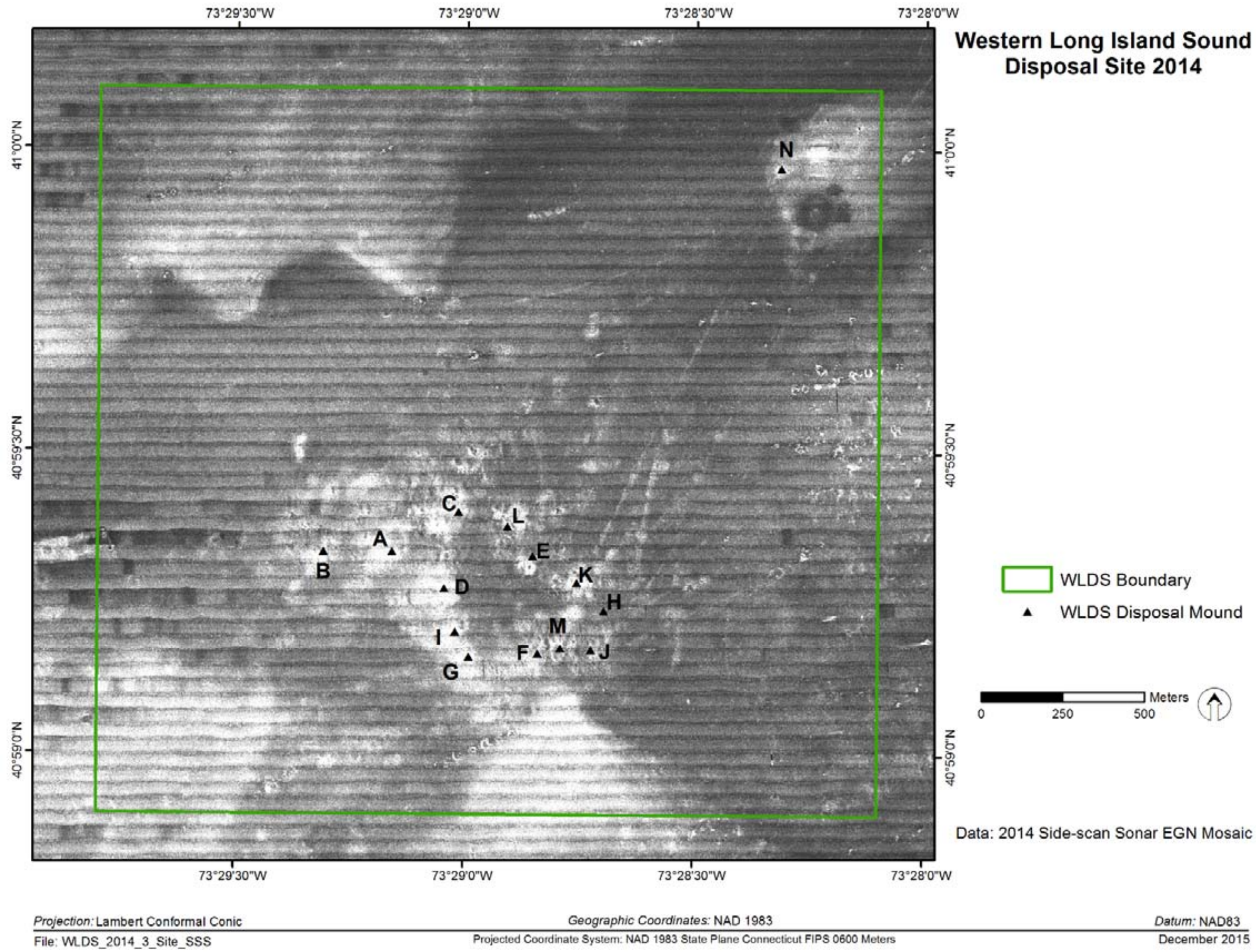

Figure 3-5. Side-scan mosaic of WLDS with feature close-ups – August 2014

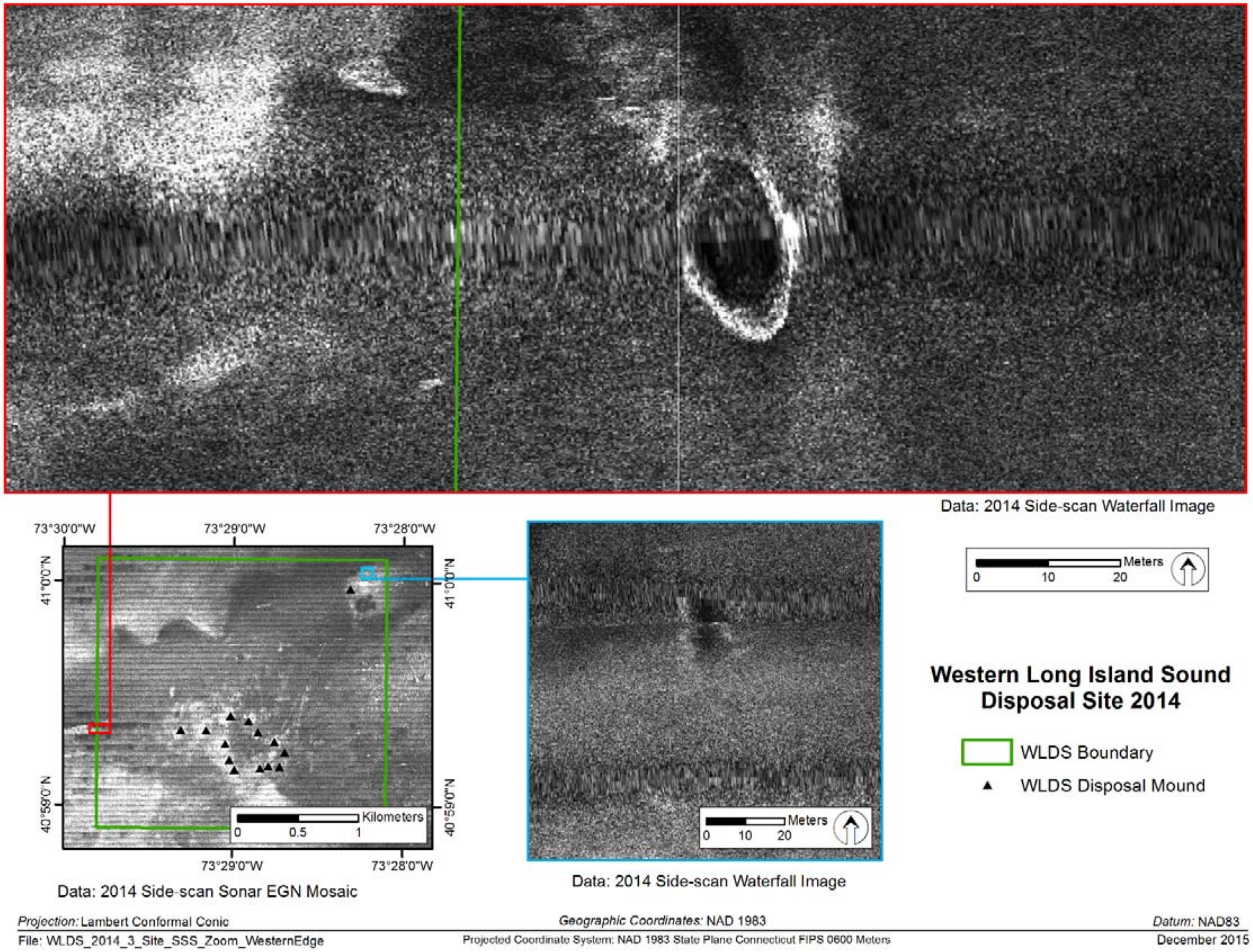

Figure 3-6. Details of small features represented in side-scan mosaic

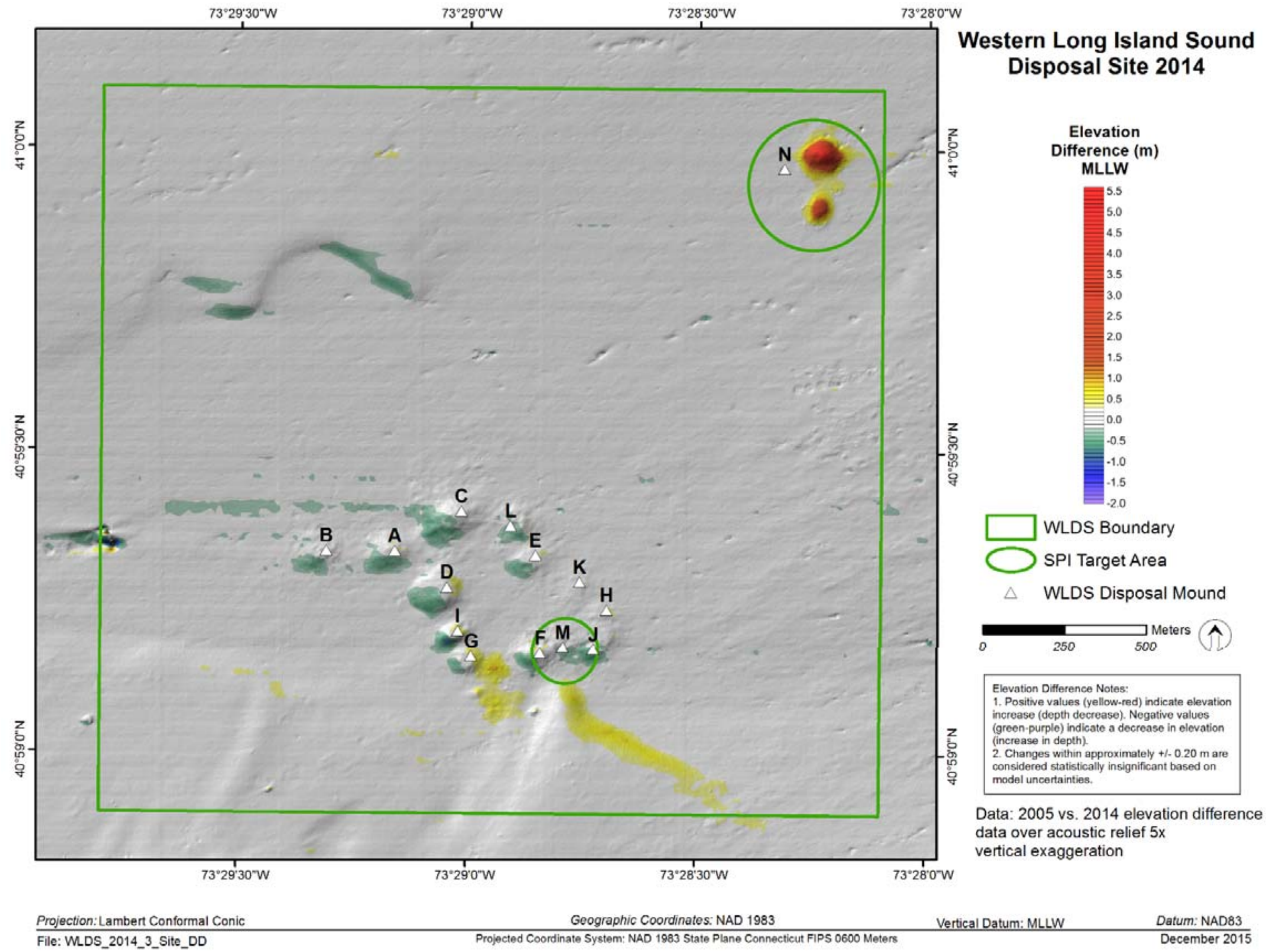

Figure 3-7. WLDS elevation difference: 2005 vs. 2014

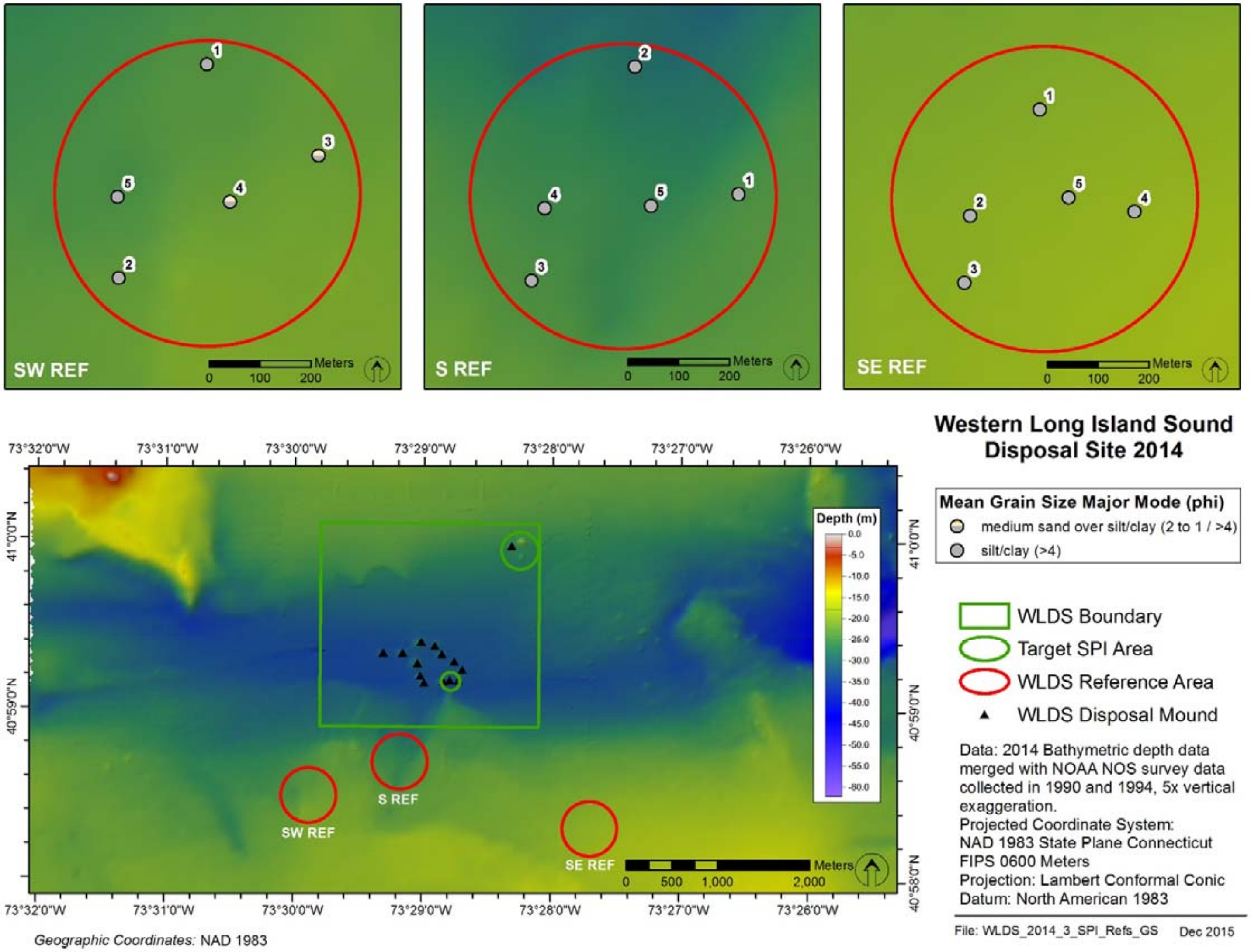

Figure 3-8. Sediment grain size major mode (phi units) at the WLDS reference areas

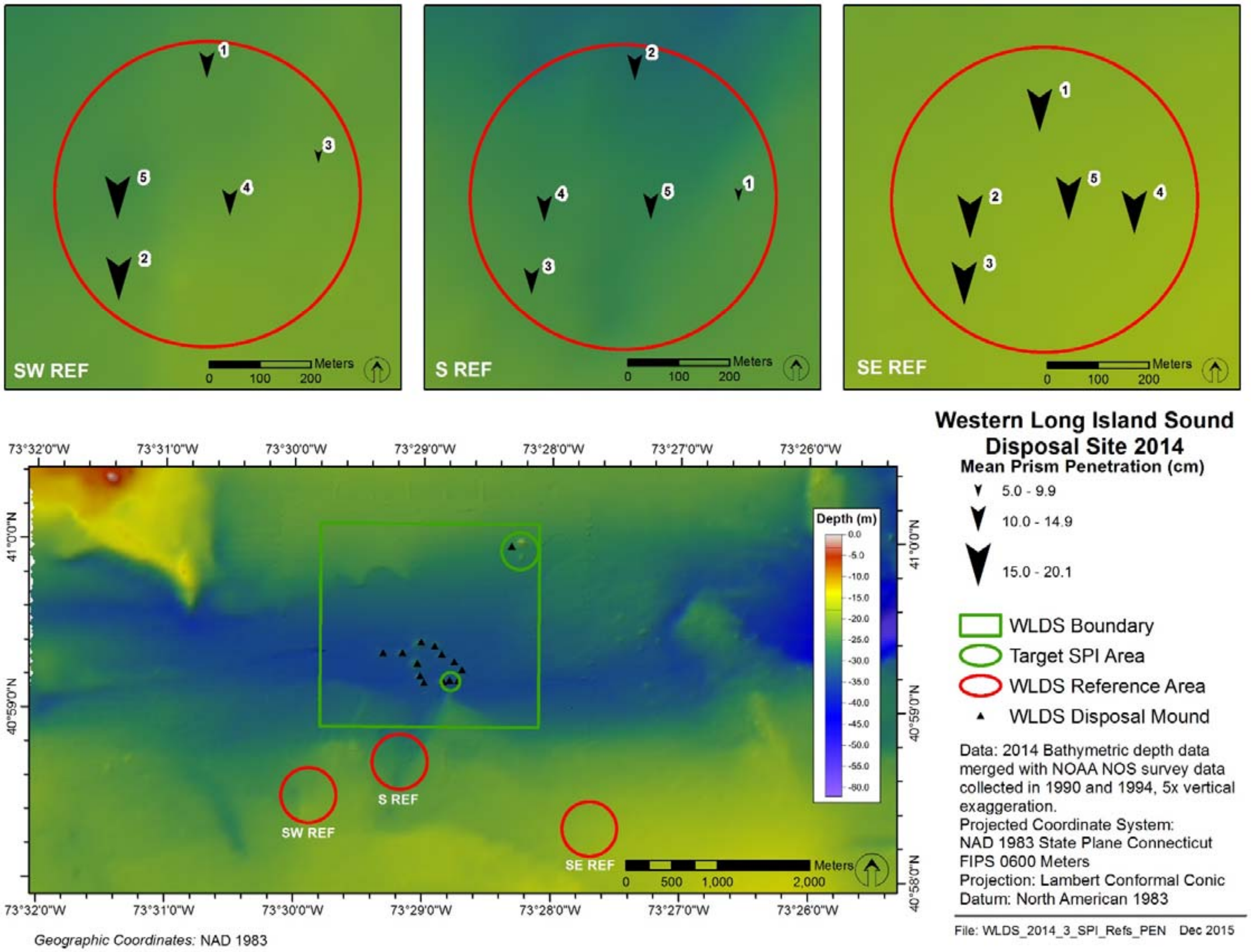

Figure 3-9. Mean station camera prism penetration depths (cm) at the WLDS reference areas

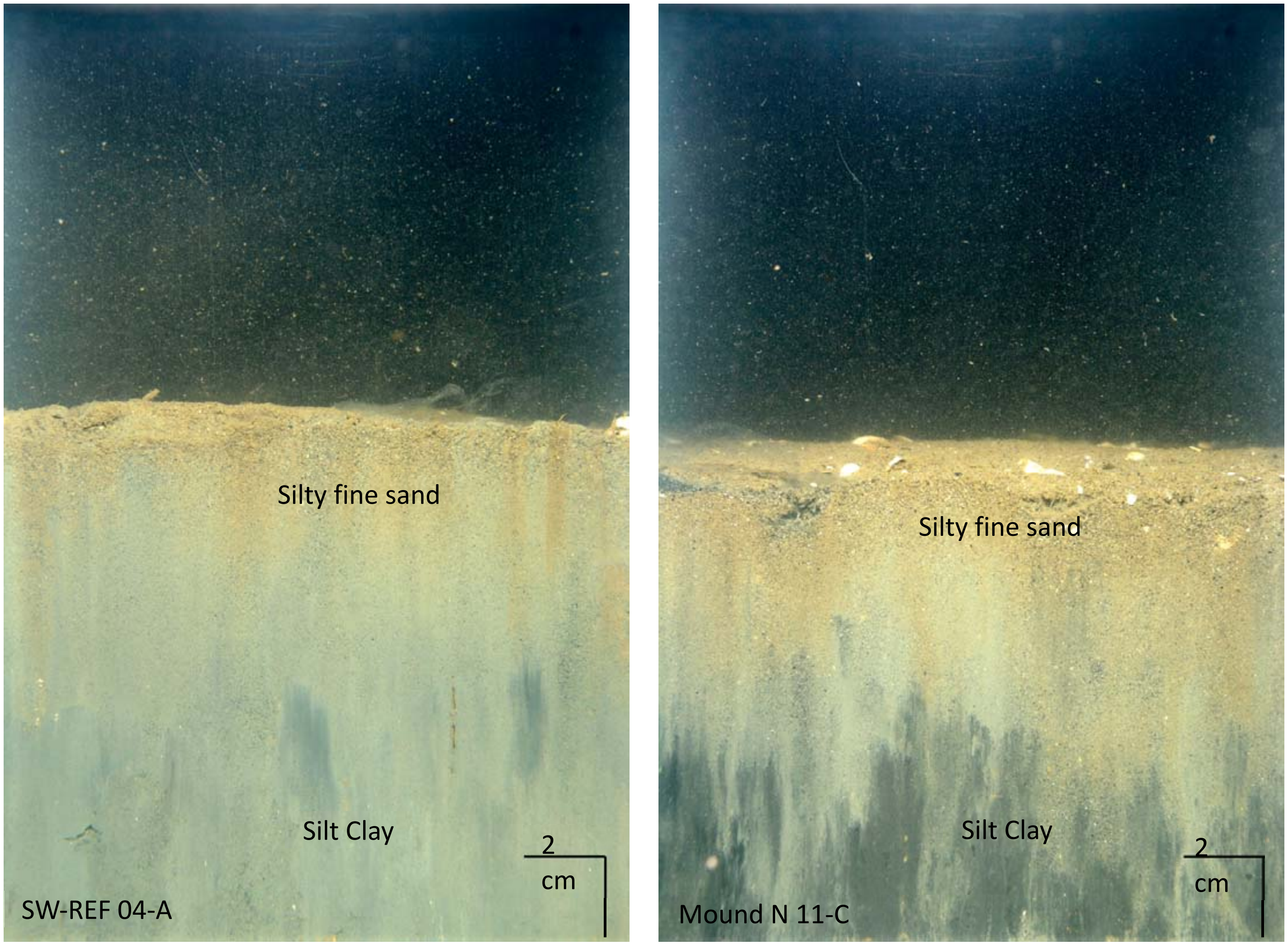

Figure 3-10. Station 4 at SW-REF and Station 11 at Mound N exhibit a thin layer of silty fine sand overlaying silt clay sediments

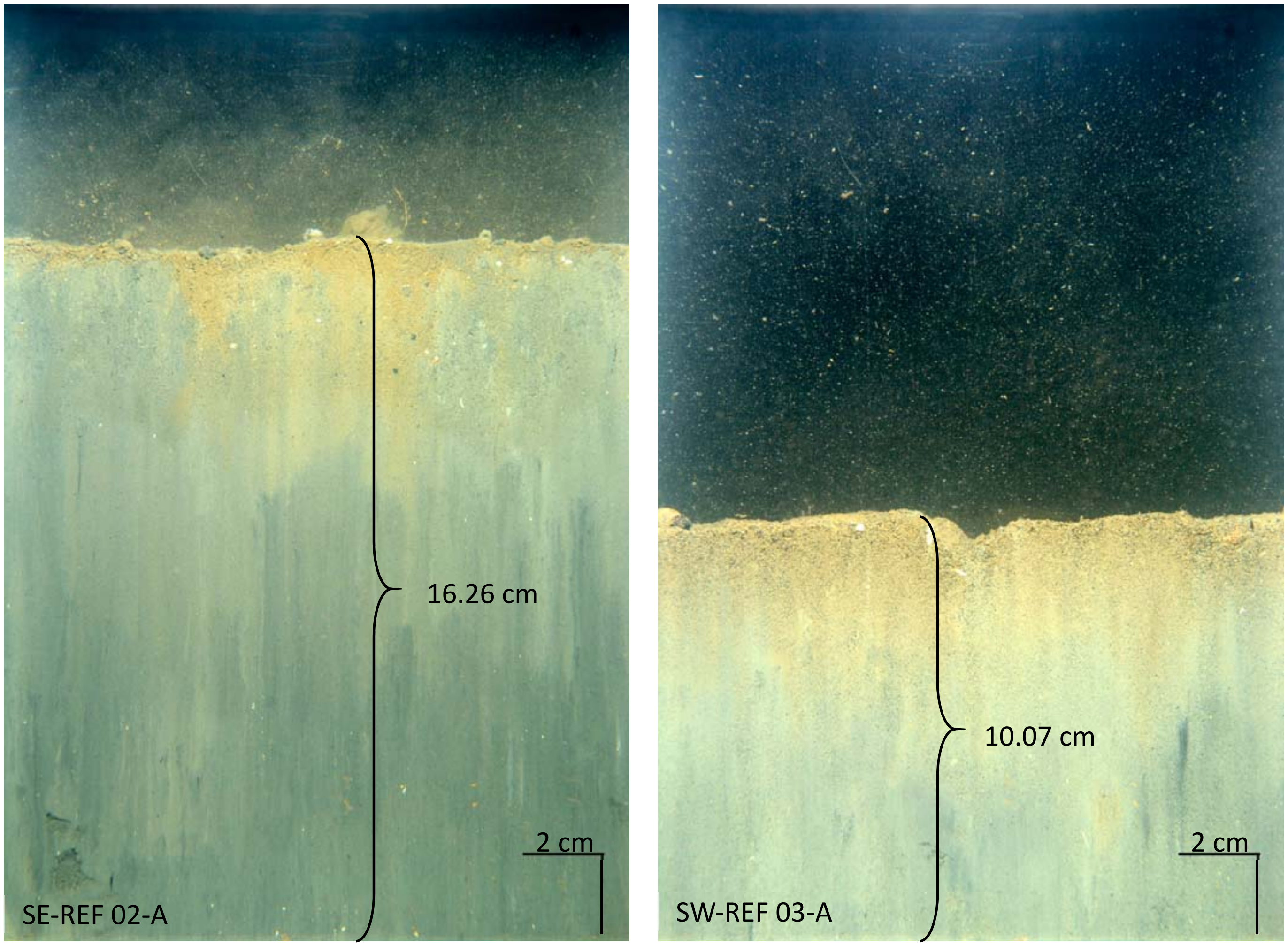

Figure 3-11. Representative images demonstrating the soft silt clay sediments found at SE-REF compared to the other reference area stations as indicated by deeper penetration of the camera prism. Maximum penetration depths are noted.

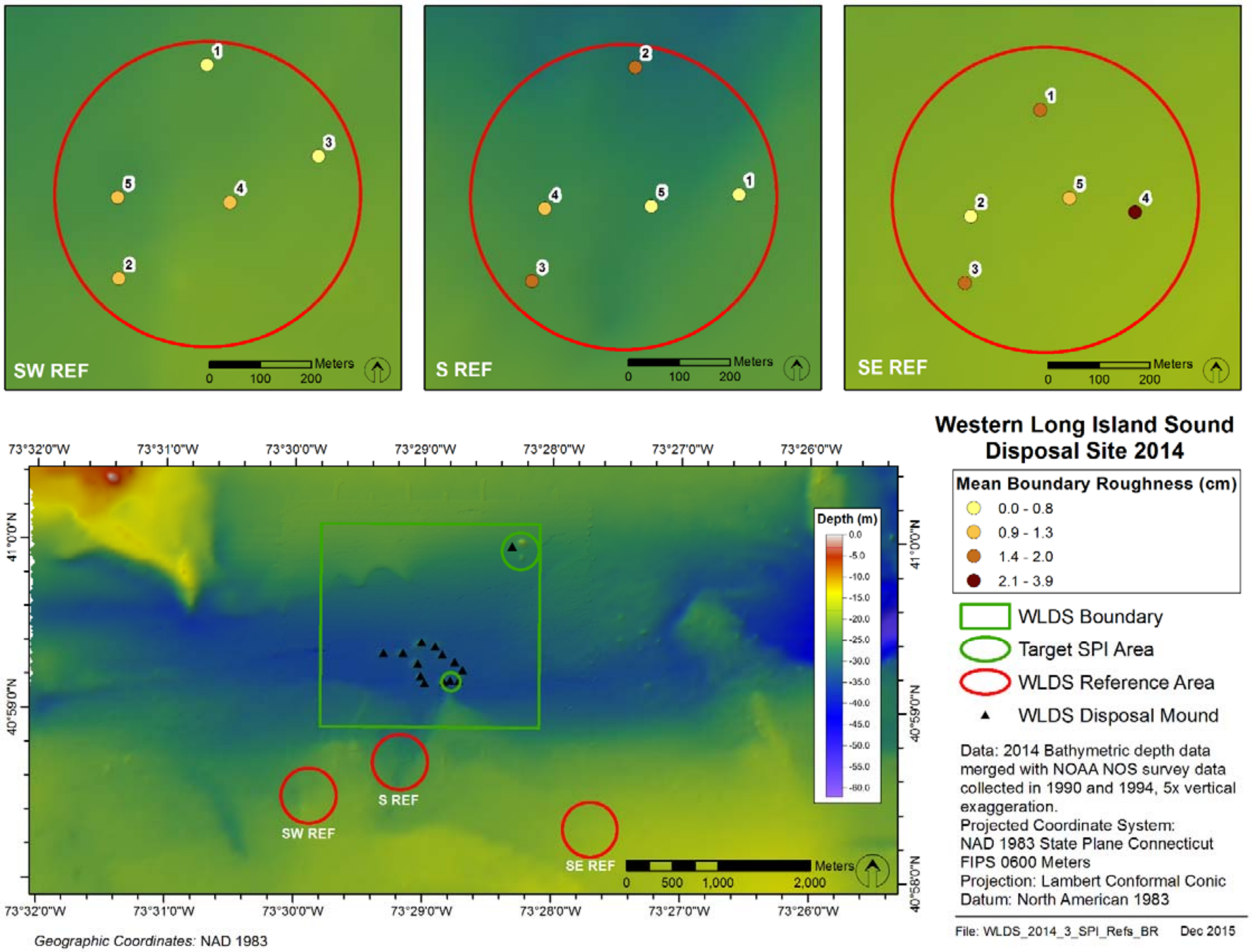

Figure 3-12. Mean station small-scale boundary roughness values (cm) at the WLDS reference areas

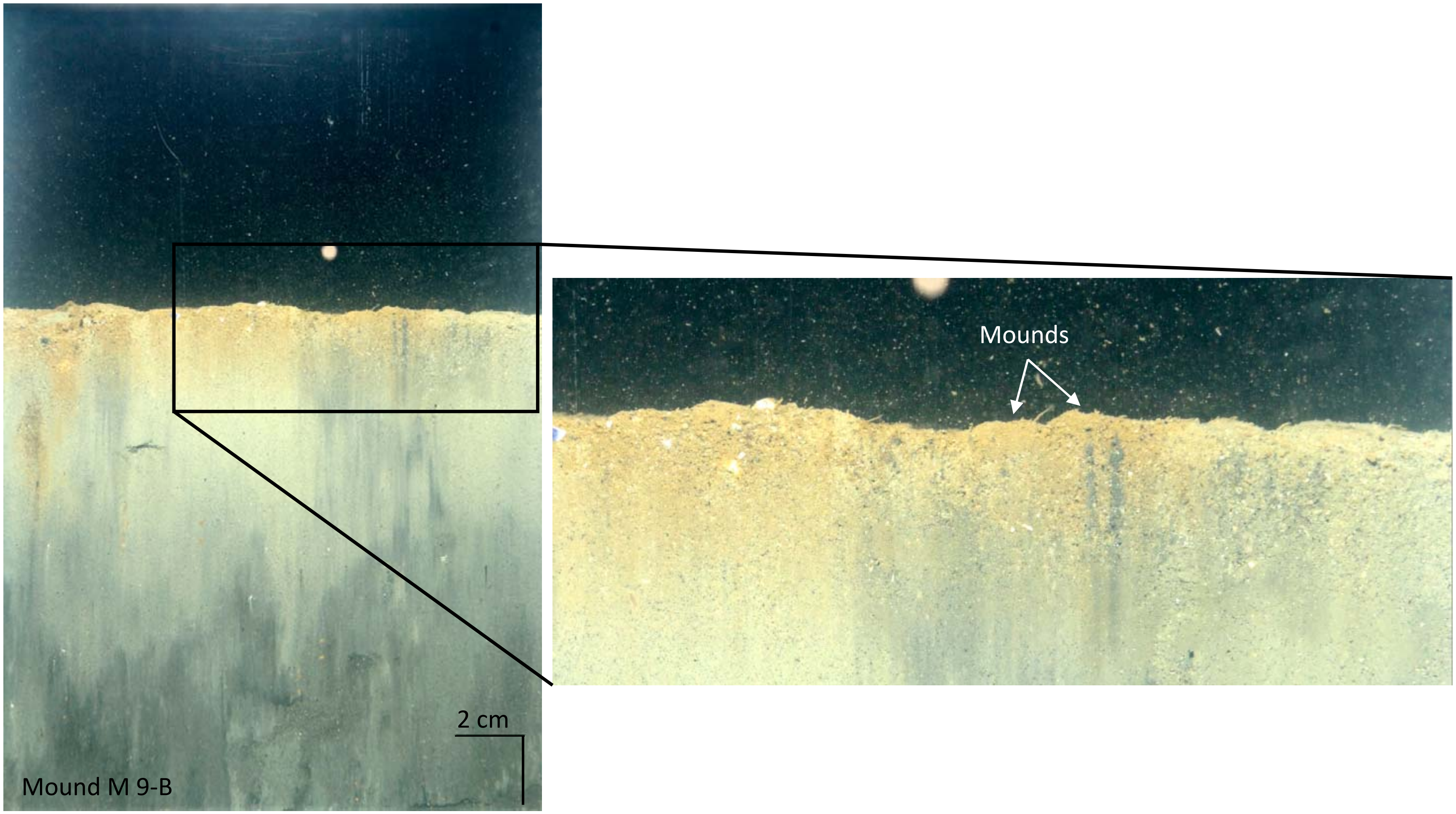

Figure 3-13. Small scale topography (i.e., boundary roughness) resulting in burrowing and feeding activity of small soft-sediment infauna

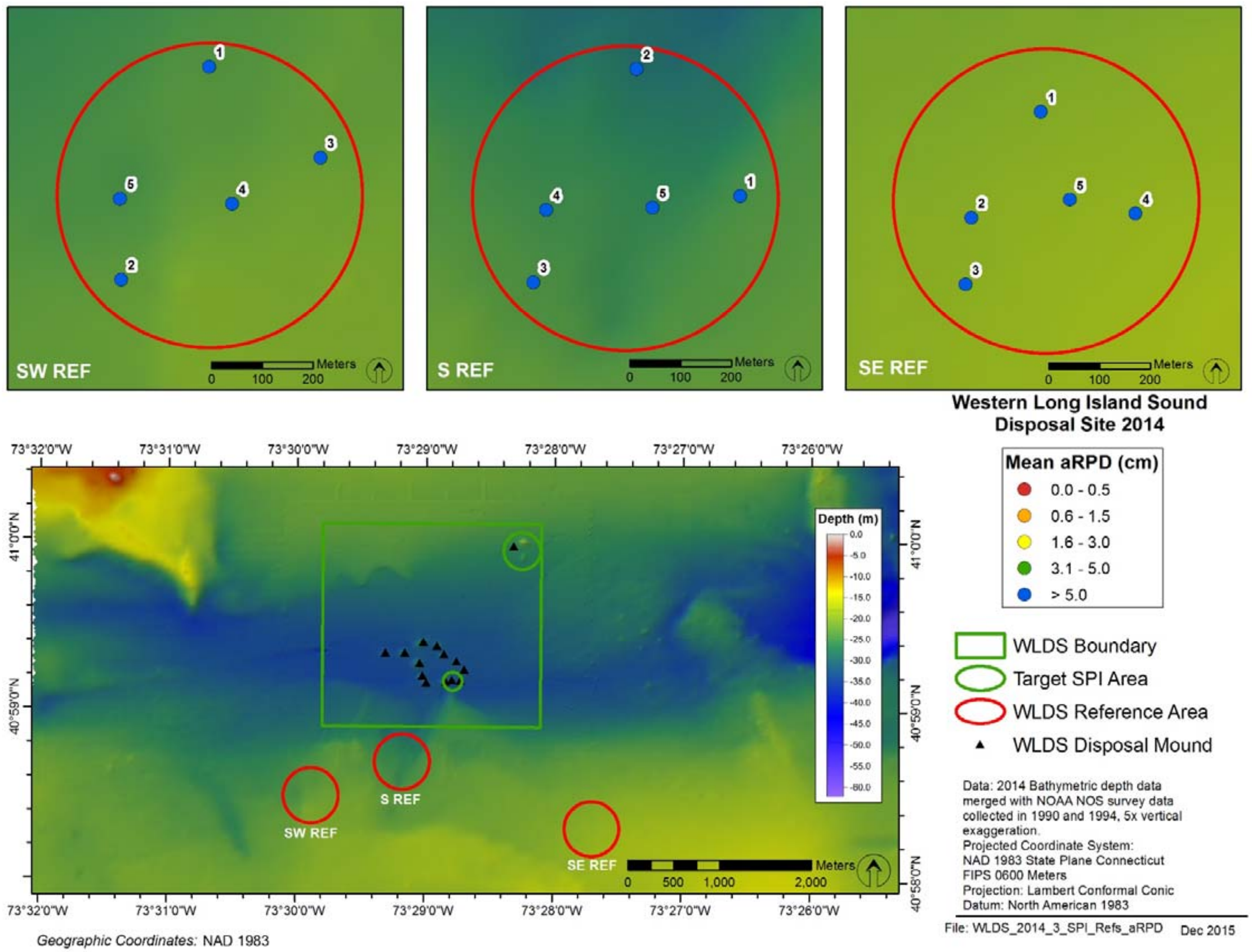

Figure 3-14. Mean station aRPD depth values (cm) at the WLDS reference areas

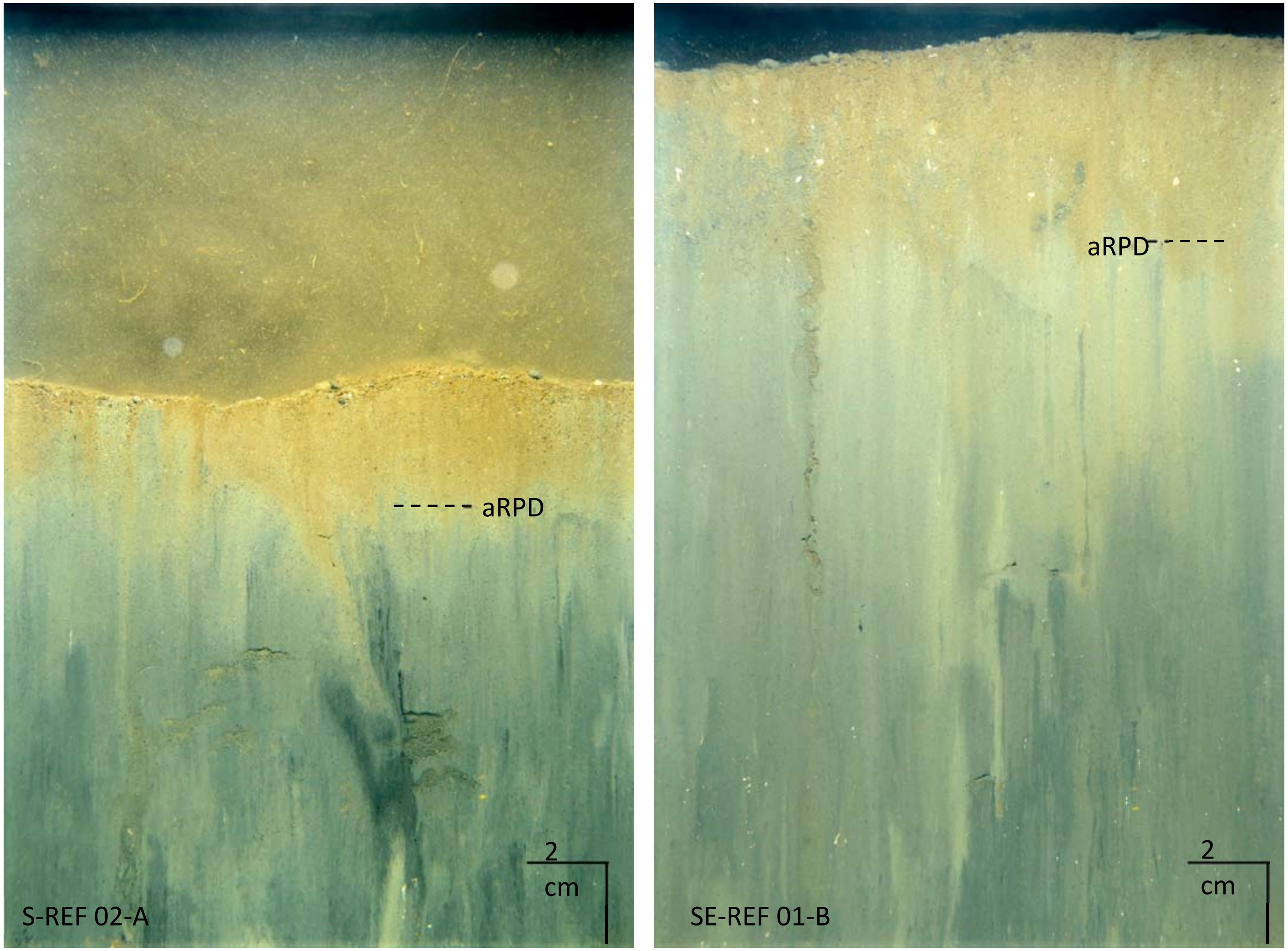

Figure 3-15. Profile images showing the minimum (left) and maximum (right) mean aRPD depths at reference stations. Dashed lines show the approximate depth of the aRPD on each image.

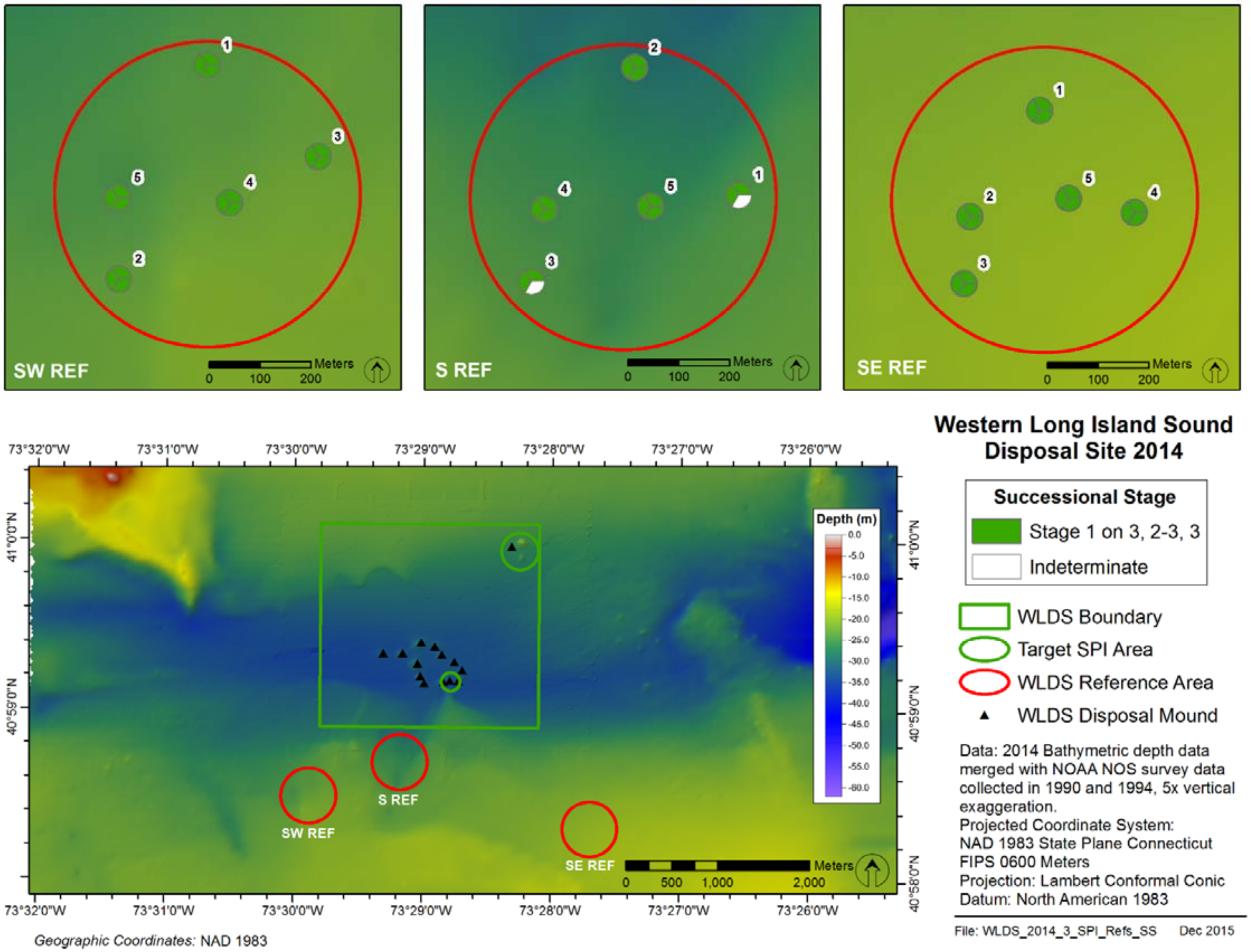

Figure 3-16. Infaunal successional stages found at the WLDS reference areas

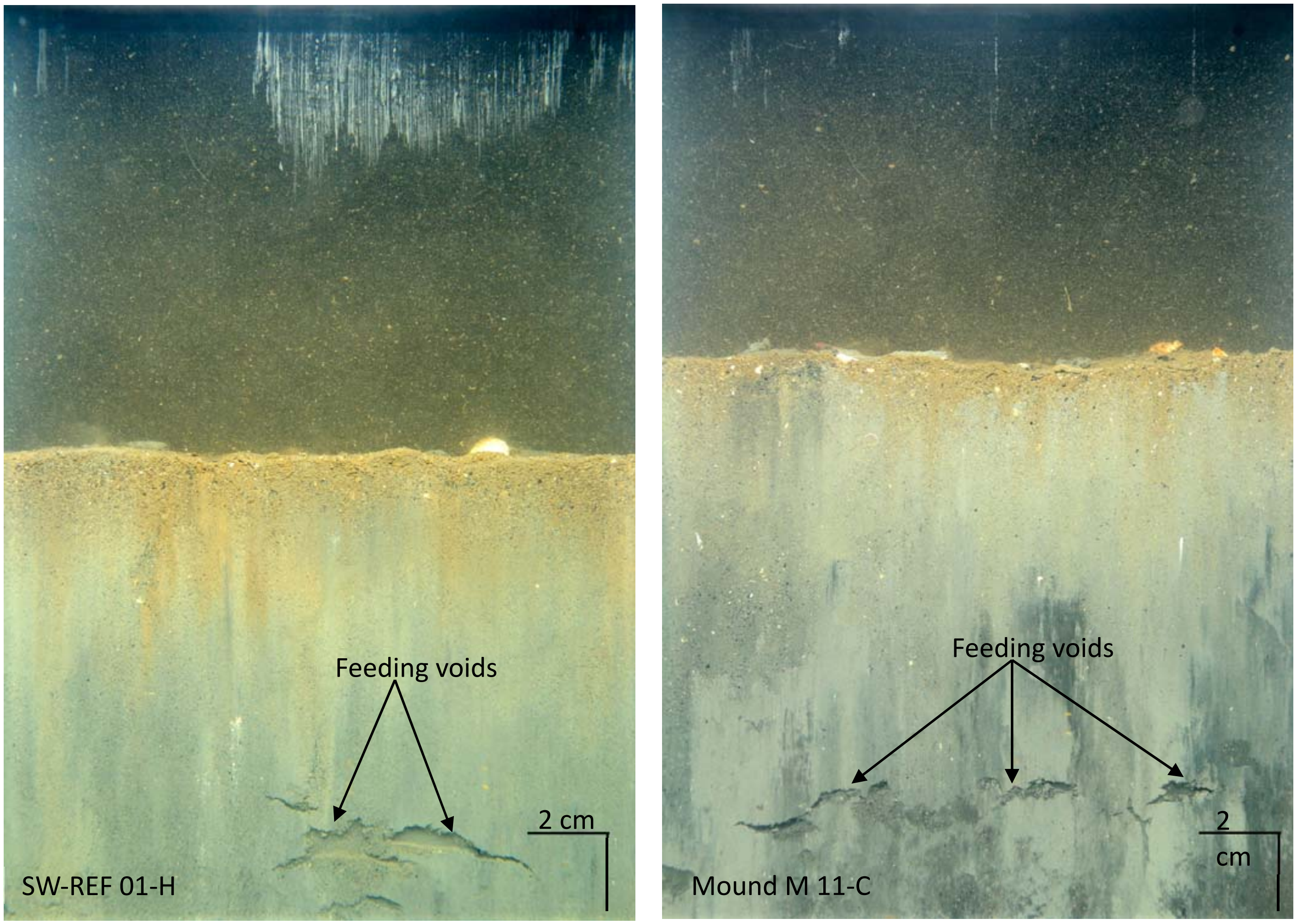

Figure 3-17. Representative images from reference areas and disposal mounds showing Stage 3 benthic infaunal activity, indicated by the presence of subsurface feeding voids. Note the light gray silt/clay dredge materials at depth in the image from Mound M.

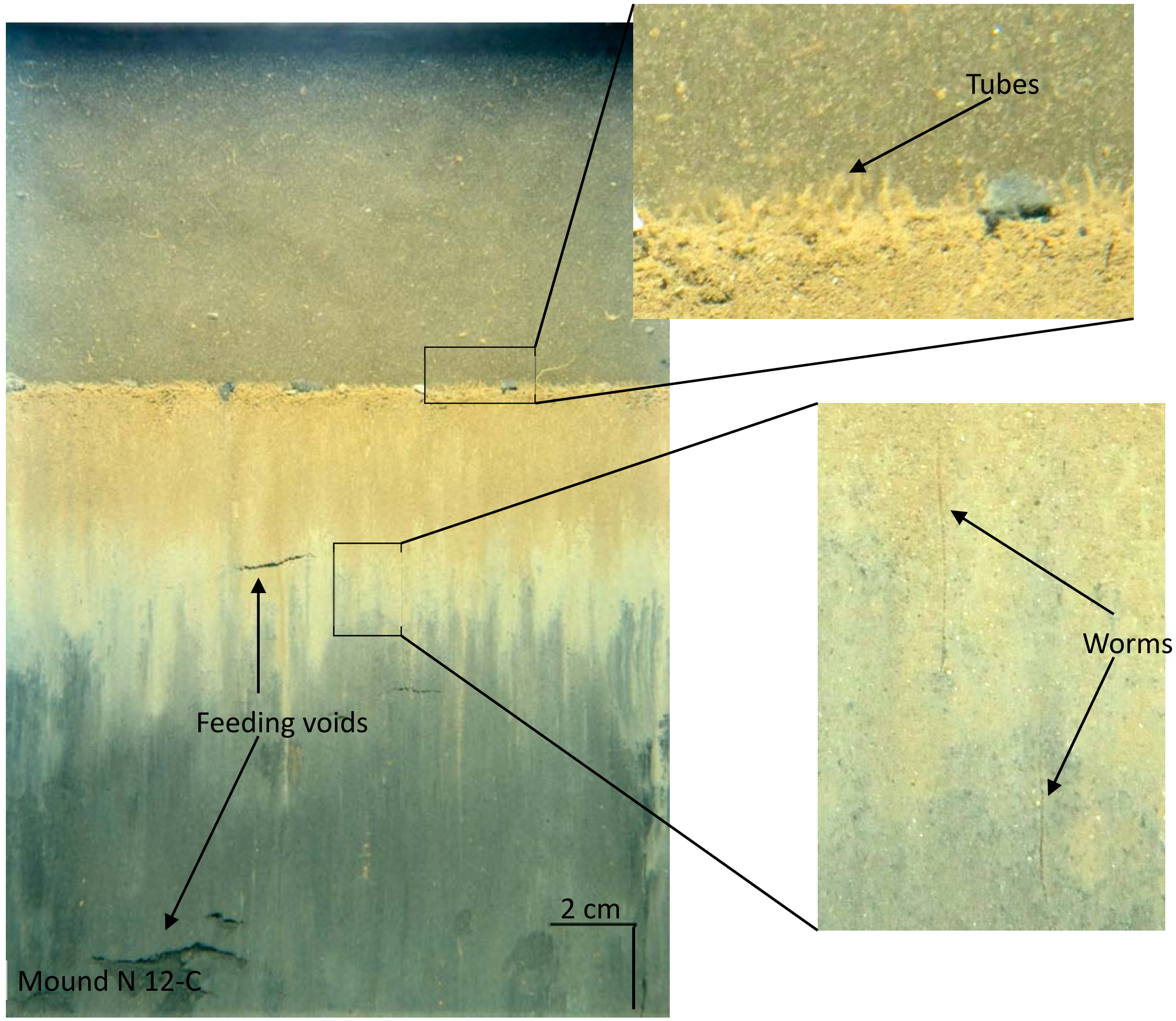

Figure 3-18. Representative image for a Stage 1 on 3 benthic community, indicated by the presence of small tubes at the SWI (Stage 1) and worms and feeding voids subsurface (Stage 3)

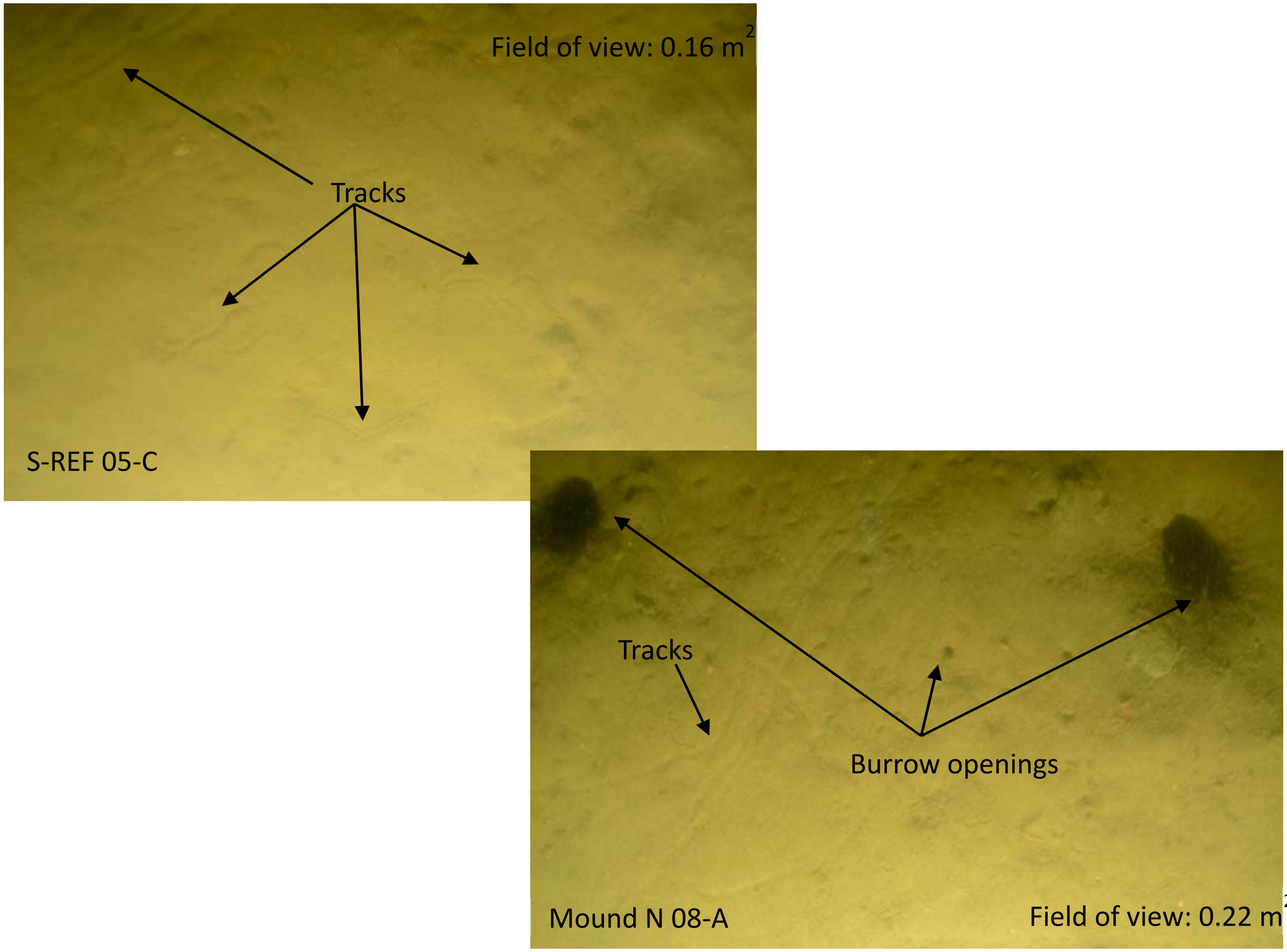

Figure 3-19. Representative images from reference areas and disposal mounds showing evidence of burrowing fauna (Stage 3), as well as a mobile epifaunal community (e.g., gastropods, crustaceans), as indicated by burrow openings and tracks, respectively

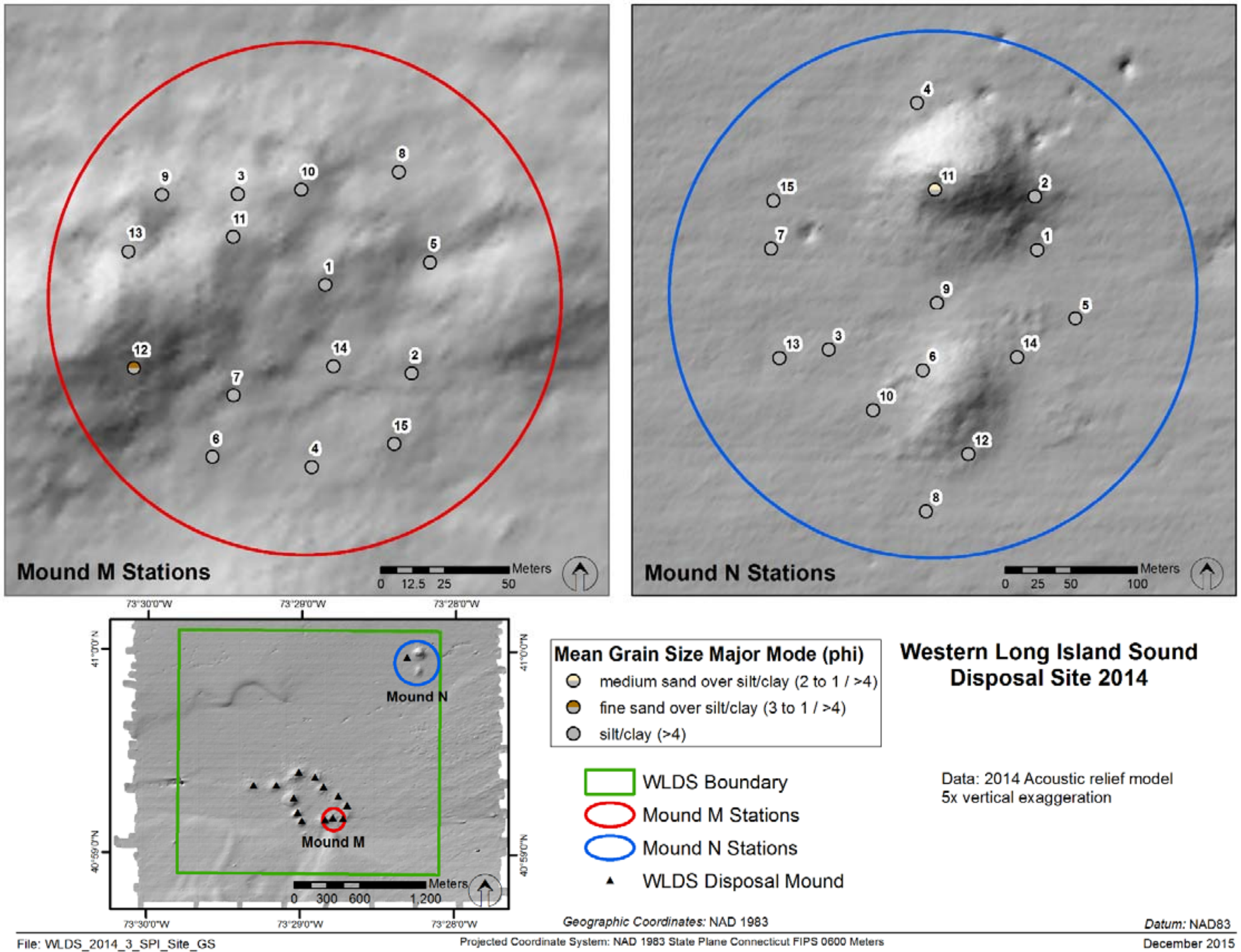

Figure 3-20. Sediment grain size major mode (phi units) at stations sampled within WLDS disposal target areas

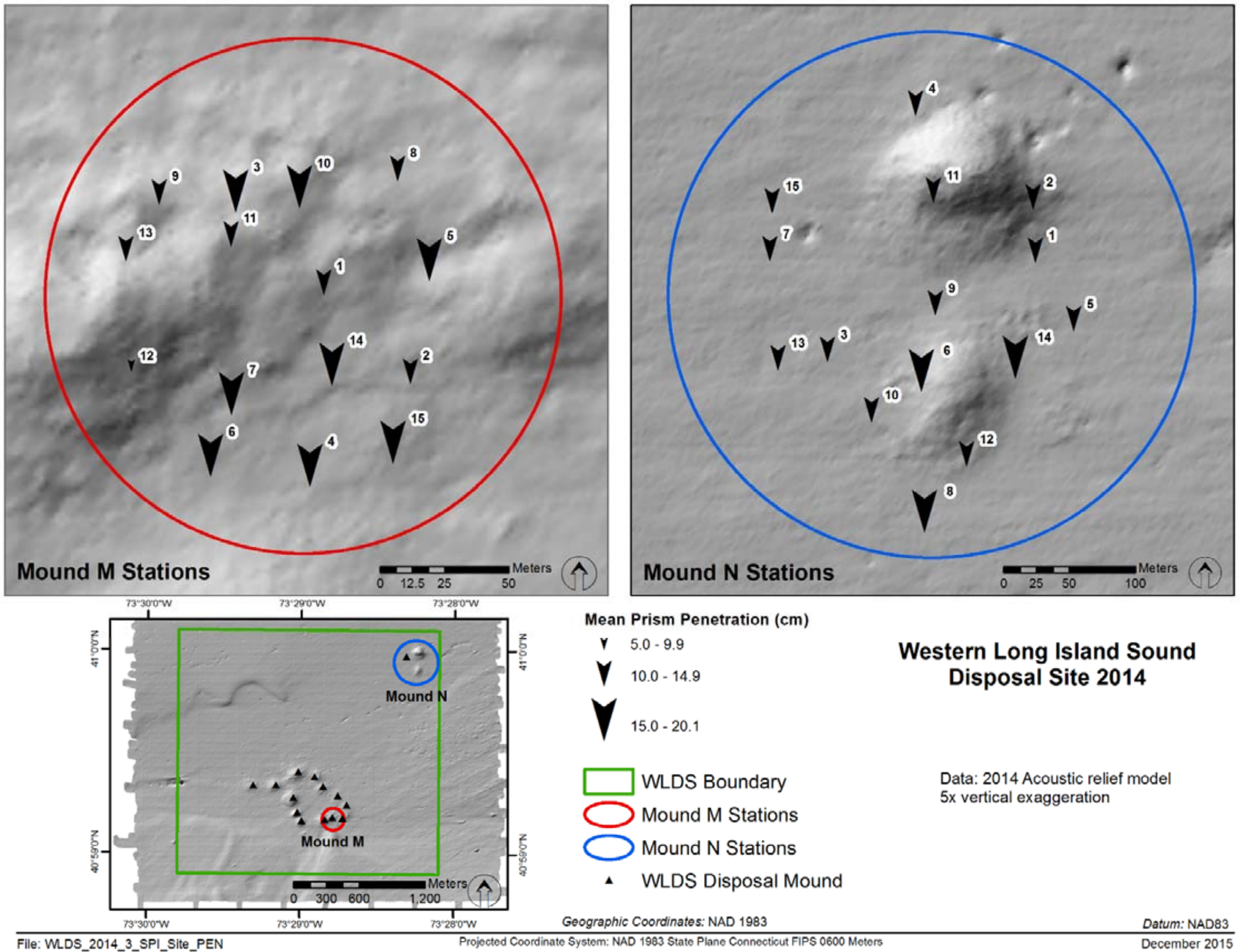

Figure 3-21. Mean station camera prism penetration depths (cm) at stations sampled within WLDS disposal target areas

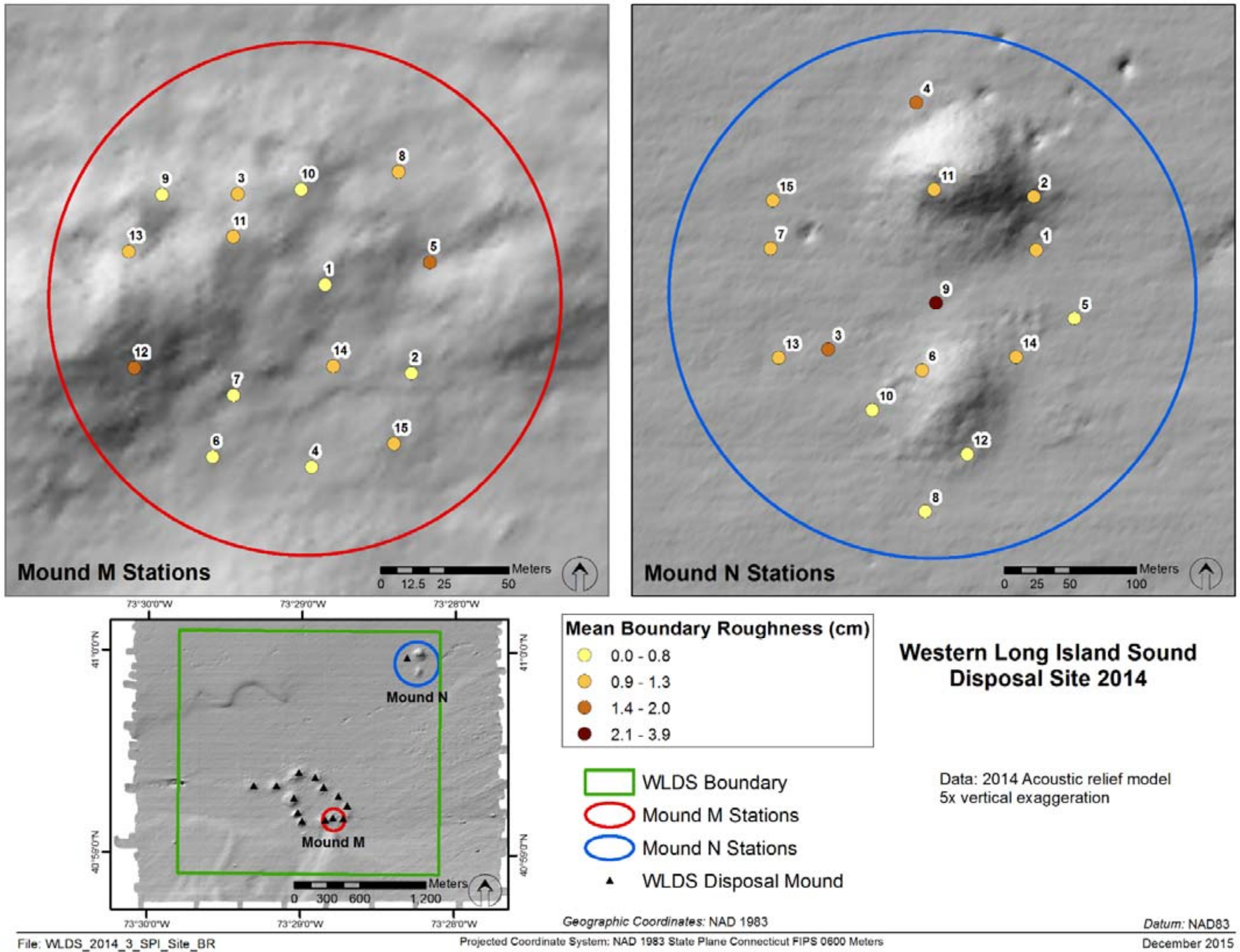

Figure 3-22. Mean station small-scale boundary roughness values (cm) at stations sampled within WLDS disposal target areas

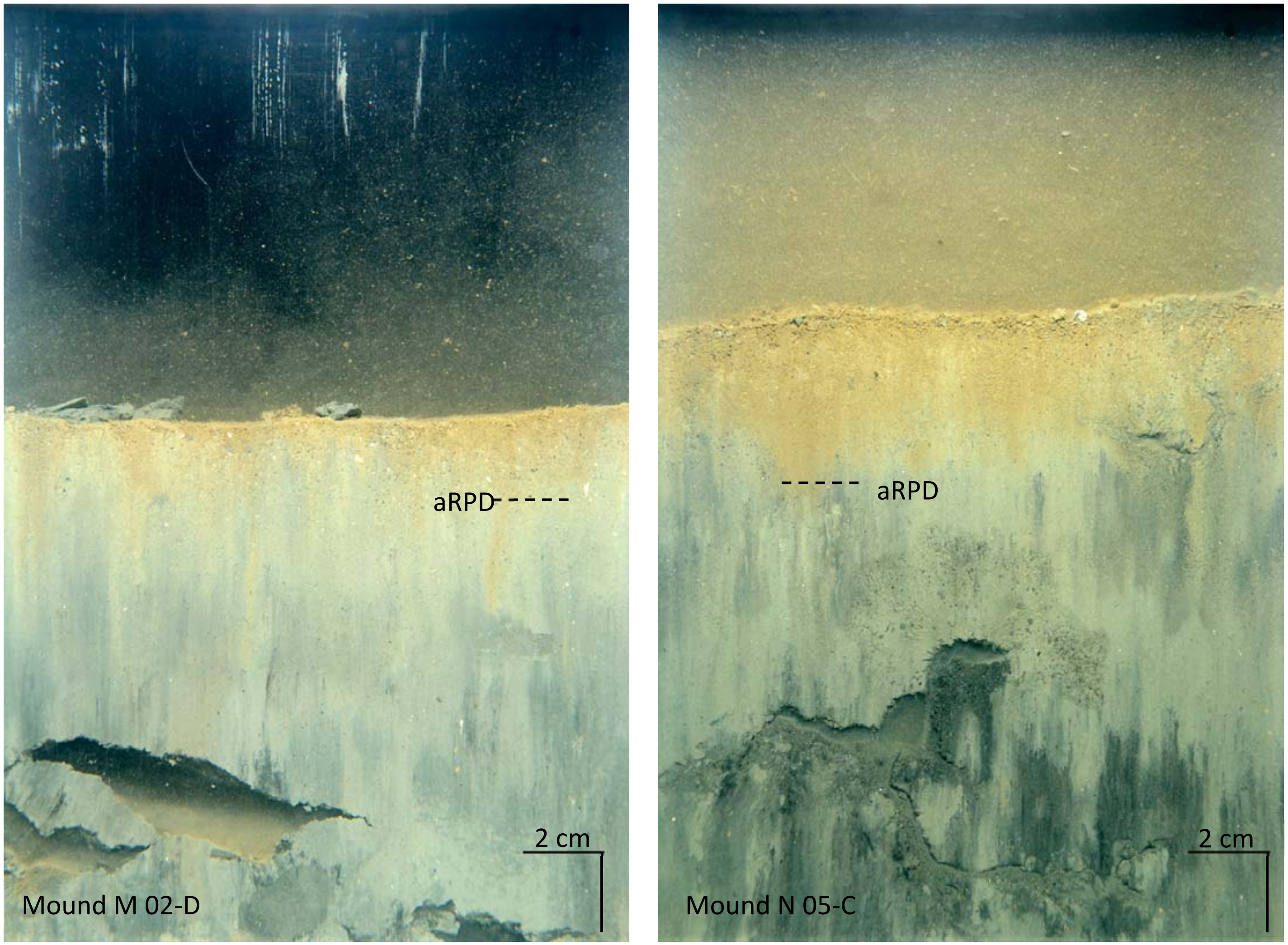

Figure 3-23. Profile images showing the minimum (left) and maximum (right) mean aRPD depths at disposal mounds. Dashed lines show the approximate depth of the aRPD on each image.

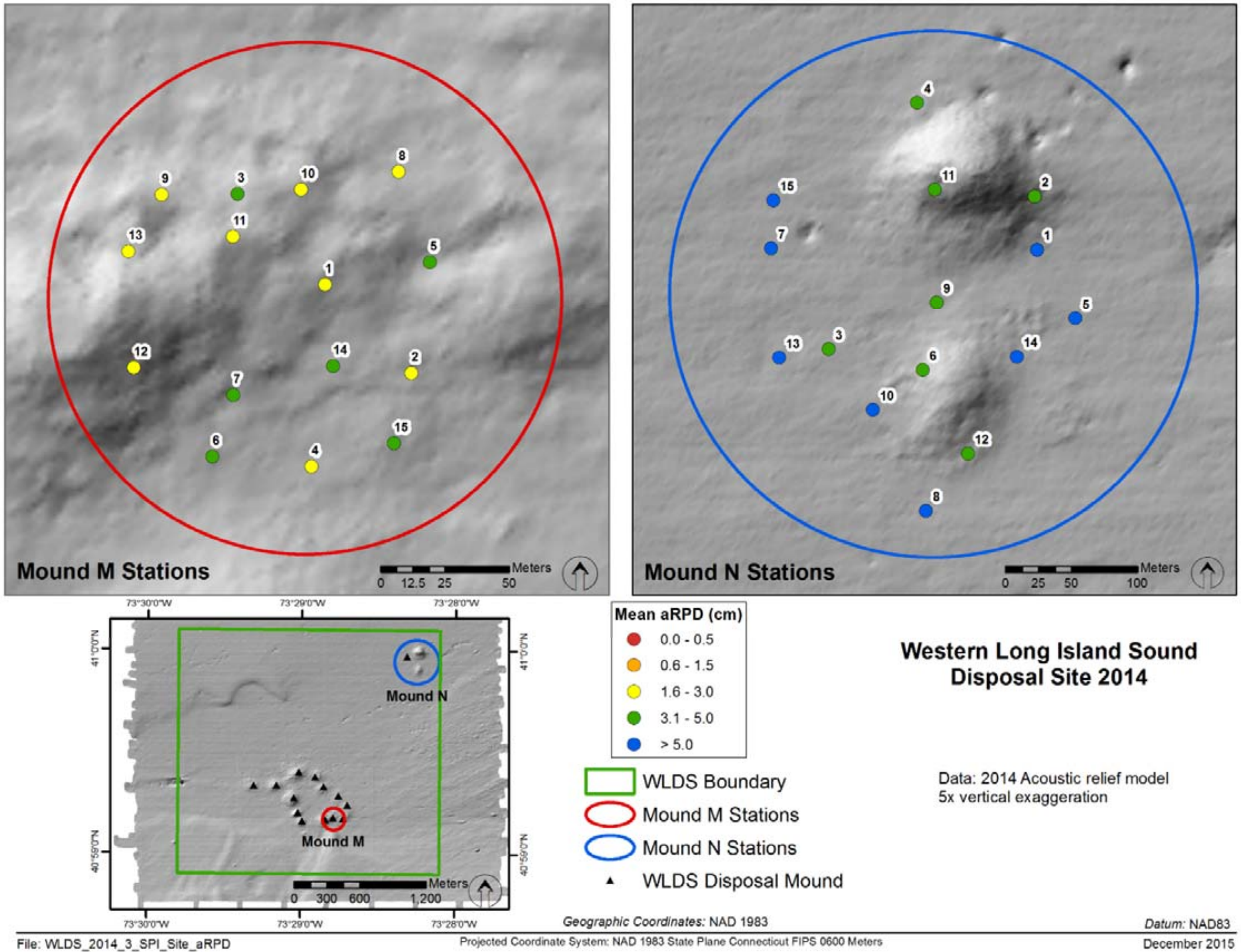

Figure 3-24. Mean station depth of the apparent RPD (cm) at stations sampled within WLDS disposal target areas

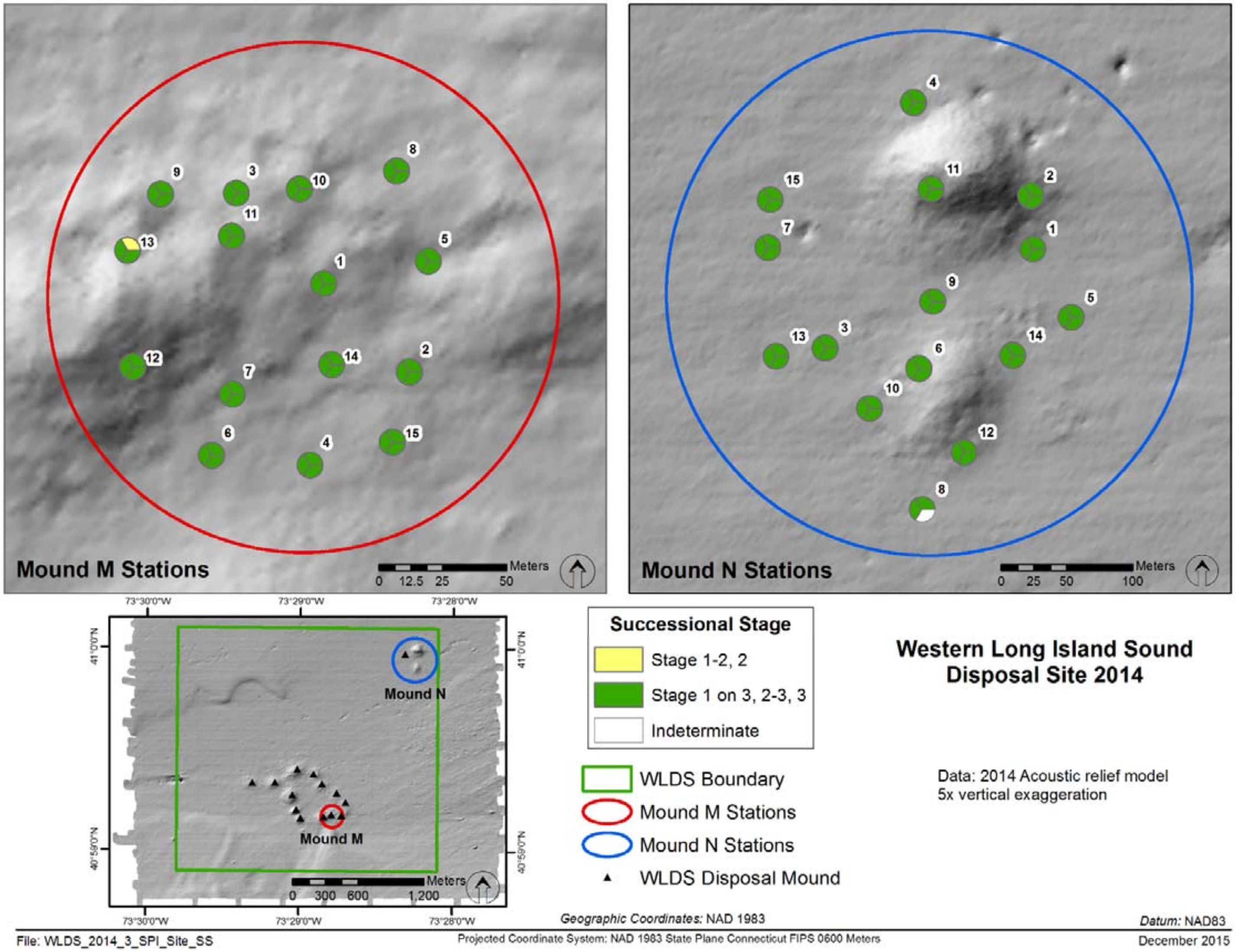

Figure 3-25. Infaunal successional at stations sampled within WLDS disposal target areas

4.0 DISCUSSION

The August 2014 survey was designed to meet the following objectives:

- Determine the physical stability of the seafloor sediments at the disposal site
- Assess the benthic habitat quality of recently placed dredged material compared to reference area conditions
- Evaluate the benthic infaunal community and sediment characteristics of the disposal site compared to reference conditions and 2005 conditions to support revision of the Site Management and Monitoring Plan

The following tasks were defined to meet the survey objectives:

- Characterize seafloor topography and surficial features of the full WLDS by completing an acoustic survey (bathymetry, backscatter, and side-scan sonar);
- Further define the physical characteristics of surficial sediment and to assess the benthic recolonization status (community recovery of the bottom-dwelling animals) of areas of the site with recent disposal activity using SPI and PV imaging; and
- Augment the imaging survey with sediment collection and analysis of grain size, total organic carbon, and benthic community structure.

4.1 Long Term Stability of Material Placed at WLDS

The area within and surrounding the current WLDS boundary has documented placement of dredged material dating back more than 40 years. The complete mapping of seafloor topography afforded by multibeam instrumentation provides a more accurate means for tracking the long-term stability of the multiple dredged material deposits on the seafloor at WLDS than the older single-beam technology that required interpolation between discrete survey lines. A multibeam survey of the entire site was first completed in 2005, and this area was re-surveyed in August 2014. The seafloor topography has been very consistent between the surveys with the addition of discrete deposits of dredged material, particularly disposal targets in the northeast corner of the site (Mound N and unnamed target) (Figures 4-1 and 4-2). An elevation difference of the two surveys clearly identified the accumulation of material from the placement activities as well as the expected consolidation of material placed just prior to the initial survey (Figure 4-2). The elevation difference also clearly demonstrated the long-term stability of the dredged material deposits on the seafloor. The majority of the defined mounds experienced the storm conditions of Hurricane Sandy in 2012 as well as a number of powerful nor'easters during the period between the surveys. Through multiple surveys spanning nearly four decades, there has been no documented significant loss of material from the site or redistribution of material within the site, i.e., once formed, the dredged material mounds become stable features at this site.

Dredged material has been placed in a ring structure in the central region of the site and in the northeast corner to begin formation of another ring. Acoustic characteristics of the seafloor revealed three distinct areas of dredged material: the ring formed by Mounds A-M; the new mound complex in the northeast corner (Mound N); and an area of historic dredged material disposal on the eastern boundary of the site (Figure 4-2).

Recent deposits of dredged material were found between Mounds F and G and were consistent with placement during the 2005-2006, 2007-2008 and 2009-2010 seasons. The largest deposits were located at Mound N and just south of Mound N in two small mounds that rose about 5 m off the bottom with a dredged material footprint at least 500 meters in diameter (Figure 4-3).

The lines of rings oriented NE-SW, located in the eastern quadrant of WLDS were likely historical dredged material deposits from Eaton's Neck Disposal Area, located to the east of WLDS (ENSR 2007). The Eaton's Neck Disposal Area has not been used for dredged material disposal since 1977, therefore the ring-like sedimentary features were likely formed over 30 years ago. The object that appeared as sharp relief along the western edge of the WLDS boundary is believed to be a sunken disposal barge (Figure 3-4).

The origin of the faint linear markings observed to the north-northeast of the disposal mounds in bathymetric data in 2005 (Figure 4-10 in ENSR 2007) is now clear. The collection of acoustic backscatter data in this survey revealed numerous linear features consistent with trace disposal by barges returning to the harbor of origin (Figures 3-3 and 4-3).

4.2 Biological Recovery of the Benthic Community

Since monitoring of the WLDS area began in 1978 and disposal activity began in 1982, the mound areas have been monitored for stability, dredged material cover, and benthic recolonization indicated by aRPD depth and successional stage. Slow benthic recovery was noted in the 1990s and was attributed to late summer hypoxia (low dissolved oxygen concentrations) and high rates of carbon cycling. The survey in June 2001 saw no signs of this slow recovery and the recommendation was made to conduct monitoring in June, if possible, before the potential occurrence of late summer hypoxia (typically at its maximum extent in mid-August in western Long Island Sound).

Monitoring data from the Connecticut Department of Energy and Environmental Protection (CT DEEP) shows that WLDS is located at the eastern edge of a portion of Long Island Sound that has experienced hypoxia 90-100% of the years between 1994 and 2014. The WLDS site is within an area that has ranged between 50-100% hypoxic during that time period (CTDEP 2014). Therefore, it is reasonable to presume that the benthic community at

WLDS is often at risk of experiencing summertime hypoxia. The 2014 survey was conducted in mid-August, potentially the peak of hypoxic conditions in the Sound. However, 2014 was a below average year for hypoxia area and duration compared to the previous 10 years. SPI results show a robust benthic community at reference areas and WLDS, indicating that these communities were not negatively affected by hypoxia at the end of the 2014 summer season, when hypoxia was recorded in parts of Long Island Sound (CTDEP 2014). However, the possibility for hypoxia and tracking of current year trends at this location should be considered in the future when planning the sampling time period at WLDS.

Ecological condition variables (i.e., aRPD and successional stage) compared between reference and disposal areas indicate that the benthic community at WLDS is well along the recovery trajectory with a robust benthic community, nearly ecologically equivalent to reference areas. The primary significant difference between reference and disposal areas was the depth of oxidized sediment, the aRPD, which was deeper at reference stations. These results suggest that while Stage 3 fauna are prevalent at disposal locations, bioturbation activity may be somewhat less than at reference areas. Differences in aRPD depths also could be more of a function of localized DO values over summer season rather than benthic sediment conditions at mound locations.

Grab samples provided further support for the finding that a robust benthic community is recolonizing the disposal mounds M and N at WLDS. The polychaete *Nephtys incisa* is common in Long Island Sound soft sediment communities and placement of disposal materials has been shown to eliminate populations of these polychaetes at some target disposal locations in shallow water (Zajac and Whitlatch 1988). These species return to abundance levels slowly after disturbance events, such as the placement of dredged materials. At disposal locations in Long Island Sound over one year was required for populations to return to natural densities and population structure characteristics (size-structure, reproduction, etc.) (Zajac and Whitlatch 1988). The presence and similar abundance levels of this species at reference and disposal locations during this 2014 survey indicate that benthic communities at WLDS disposal locations have recovered or are well along the expected recovery trajectory.

4.3 Management Considerations for WLDS

The comprehensive 2014 survey provided sufficient site-wide data for an overall assessment of the status of WLDS and the management approach for the site as described below.

- Reference Areas – The physical conditions of reference areas SW-REF, S-REF and SE-REF are very similar to those of WLDS. While slightly shallower and finer grained, SE-REF is still considered similar in habitat type to WLDS. All three reference areas displayed healthy, mature biological communities. All three areas are considered appropriate as reference for evaluation of conditions at WLDS. Inclusion of the reference areas in periodic multibeam surveys could provide additional characterization data and insight into benthic disturbances (such as trawling) relevant to interpreting imaging and sampling data.

- Monitoring Approach – The combined use of multibeam bathymetry and sediment-profile/plan view imaging has been an effective approach for initial screening level assessment of the physical and biological status of WLDS.

- Status of Overall Site Conditions – Prior to 1982, dredged material had been placed in the vicinity of the present WLDS, but without specific information on the quality of the placed material.
- General Management Approach – The established approach for disposal of dredged material at WLDS has been to focus placement at a specific target location for dredging seasons with low to moderate expected total annual volumes. This approach minimizes the area of the seafloor experiencing benthic impacts and builds up individual mounds which, when coalesced, can form a containment ring to limit the lateral spread of larger maintenance dredging projects. This approach also focuses post-placement monitoring to specific areas to track the expected biological recovery of the benthic system. Given the apparent success of this approach, no changes are proposed now.

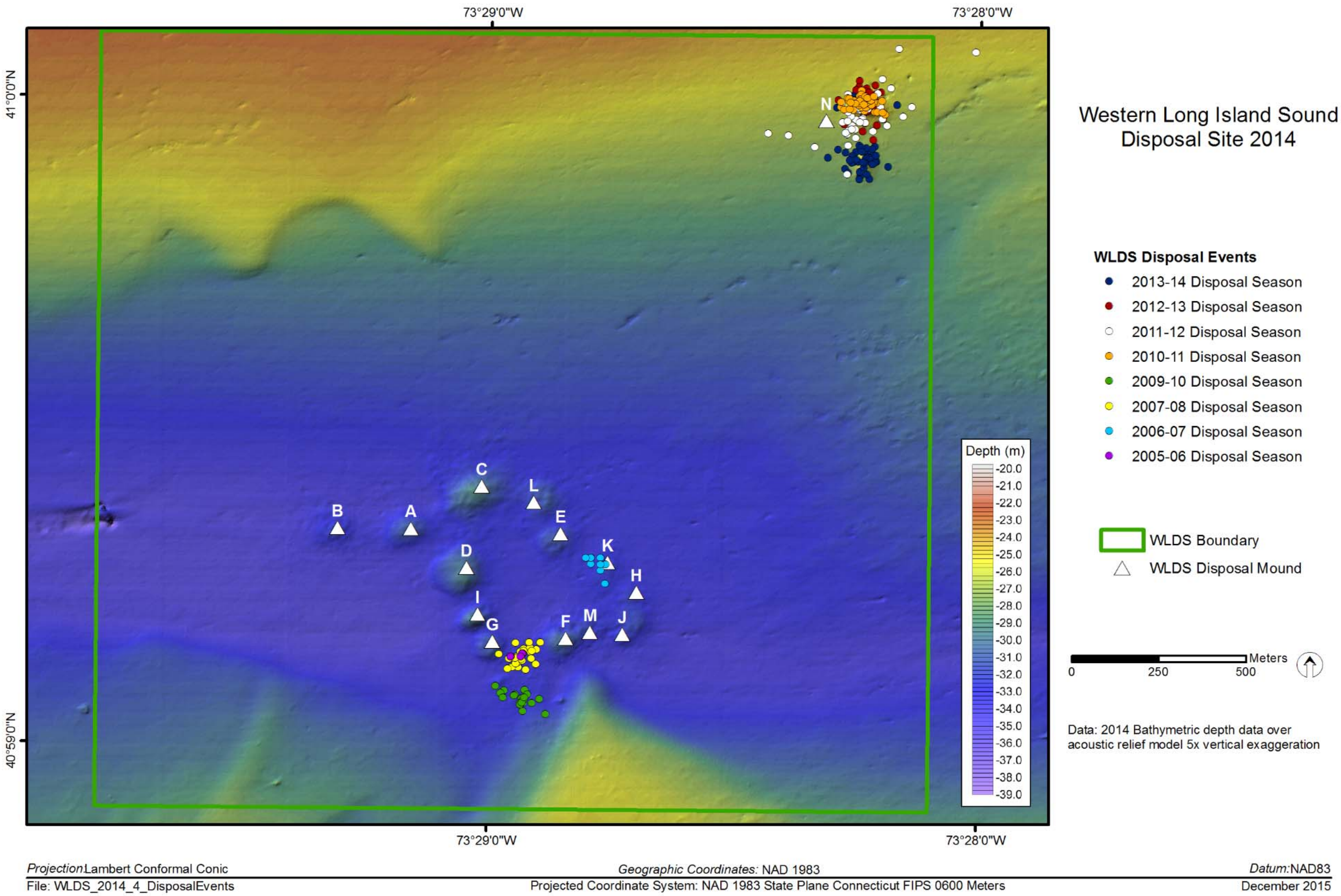

Figure 4-1. Location of reported disposal events at WLDS by disposal seasons between 2005 and 2014

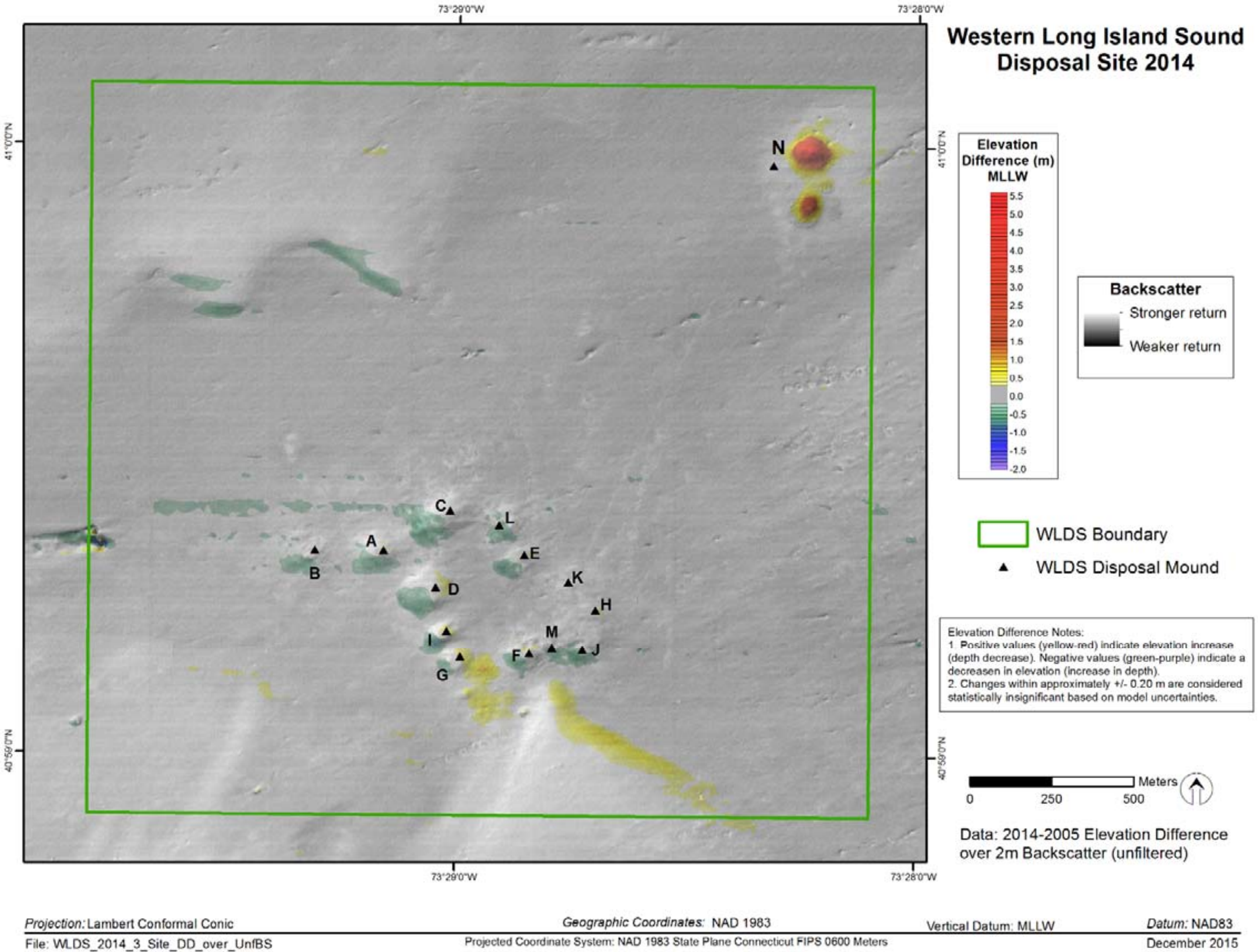

Figure 4-2. WLDS elevation difference 2005 vs. 2014 over unfiltered backscatter

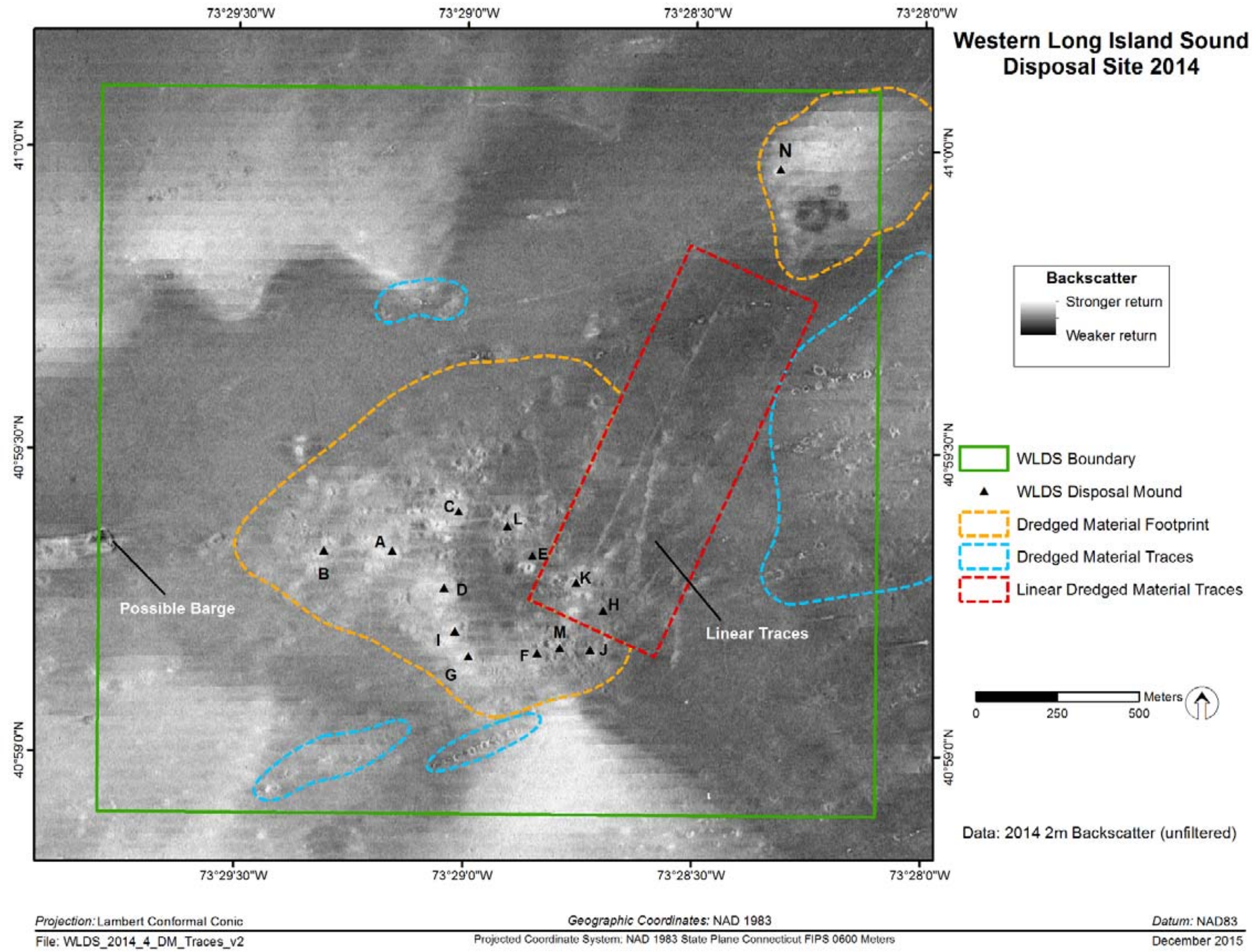

Figure 4-3. Dredged material traces and features

5.0 CONCLUSIONS AND RECOMMENDATIONS

Overall the 2014 survey at the WLDS site showed that existing disposal mounds were stable and that over time benthic communities recolonize these areas. Seafloor topography results showed three areas of disposal materials – 1) the containment ring created by Mounds A through M, 2) rings in the eastern quadrant of the site, likely historical dredged material deposits from Eaton’s Neck Disposal Area, and 3) recent disposals in the northeast corner of the site, Mound N and an unnamed target. Changes in depth at the site were consistent with the recent history of dredged material placement, with the greatest difference being at the newest mound, N. SPI/PV and infaunal grab results show a robust benthic community at reference and disposal mounds, indicating benthic recolonization and recovery of mounds, despite statistically significant differences (lower) in aRPD depth compared to reference areas.

Based on the findings of the 2014 WLDS survey, our recommendations are:

R1. The presence of stable mounds and normal benthic recolonization indicate no need for remediation actions or change in dredged material placement approach;

R2. Continue monitoring efforts consistent with Tiered Monitoring Protocols based on volume placed at site;

R3. Future monitoring efforts should be scheduled earlier in the summer (i.e., June) due to the frequency of hypoxia in Long Island Sound, usually reaching its peak late in the summer.

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