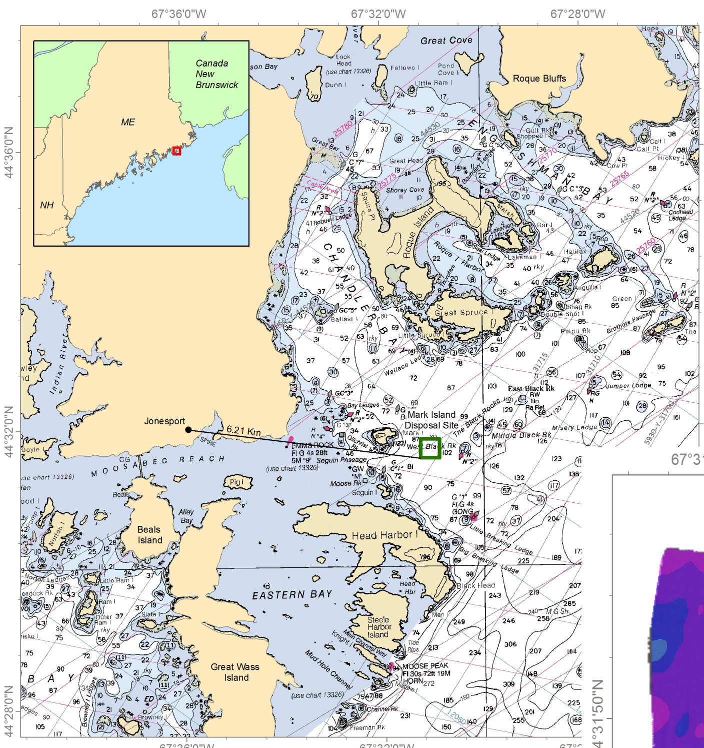
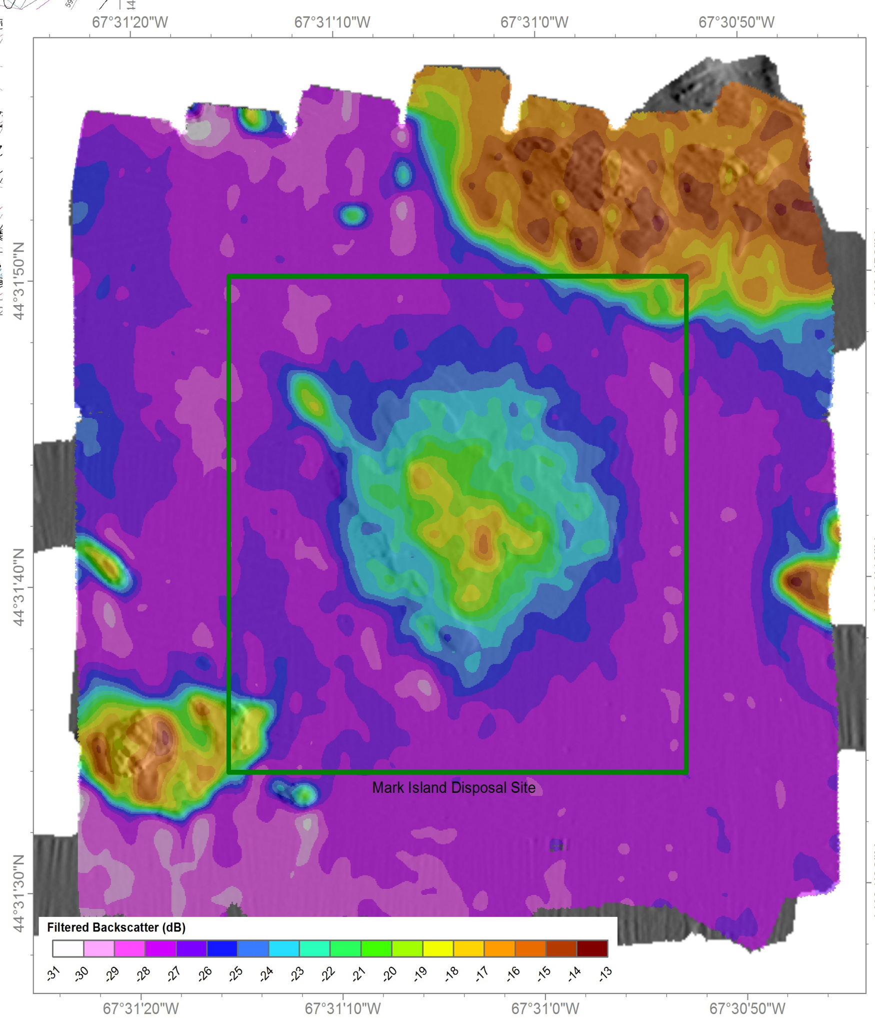
Monitoring Survey of the Mark Island Disposal Site - November 2017

Disposal Area Monitoring System DAMOS





D A M O S

DISPOSAL AREA MONITORING SYSTEM

Monitoring Survey
Contribution #207
November 2018

US Army Corps of Engineers®
New England District

MONITORING SURVEY OF THE MARK ISLAND DISPOSAL SITE NOVEMBER 2017

CONTRIBUTION # 207
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13. ABSTRACT

A confirmatory survey was conducted in November 2017 at the Mark Island Disposal Site (MIDS) as part of the Disposal Area Monitoring System (DAMOS) Program. The 2017 survey effort consisted of a multibeam acoustic survey to characterize seafloor topography and dredged material distribution as well as sediment profile imaging (SPI) and plan-view imaging surveys to provide additional physical characterization and to assess benthic recolonization. The results of the 2017 surveys were used to document changes at MIDS (the site) since the previous survey in 2002 following the initial placement of dredged material at the site, and the subsequent placement of approximately 5,400 m^3 of material during the 2011-2012 dredging season and 83,300 m^3 of material during the 2016-2017 season.

The multibeam acoustic survey was conducted over a 700 m x 700 m square area encompassing the entire extent of MIDS and documented a mound in the central portion of the site where sediment accumulation from dredged material disposal has occurred. The height of the mound within MIDS ranged from 0.2 m to 2.0 m above the ambient seafloor. The acoustic survey identified hard bottom areas to the southwest, northeast, and east of the site. In addition, the acoustic survey included characterization of the two reference areas for the site, NE REF and S REF.

SPI and plan-view images were collected from MIDS and the two reference areas. With the survey performed just 10 months following cessation of placement of dredged material at MIDS, the benthic community had shown significant recovery to a productive system.

In summary, the distributed disposal of approximately 88,700 m^3 of material over the two disposal episodes generated a mound within the central portion of the site. The infaunal benthic communities at the disposal site appear to have recovered within the 10-month period since the latest disposals. Given the current state of the site, it is predicted that the effects from future disposal operations at MIDS would allow for the site to fully recover in less than a year. Additional material placement should continue to target the central portion of the site to avoid rocky outcrops located within and near the survey area. Future survey work at MIDS should be conditional on the placement of additional dredged material and should include the collection of sediment samples for benthic community assessment, and analysis of total organic carbon. These additional data will allow for further comparison of the disposal site to the reference areas.

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EXECUTIVE SUMMARY

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LIST OF ACRONYMS

ANOVA	Analysis of Variance
aRPD	apparent Redox Potential Discontinuity
ASCII	American Standard Code for Information Interchange
CI	confidence interval
CLT	Central Limit Theorem
cm	centimeters
DAMOS	Disposal Area Monitoring System
dB	decibel
FNP	Federal Navigation Project
FOV	field of view
ft	foot/feet
GIS	geographic information system
GPS	Global Positioning System
GRD	gridded file format
kHz	kilohertz
km	kilometer
MBES	multibeam echosounder
ME	Maine
MIDS	Mark Island Disposal Site
MLLW	Mean Lower Low Water
MRU	motion reference unit
msec	millisecond
NAE	USACE, New England District
nmi	nautical miles
NOAA	National Oceanic and Atmospheric Administration
NOS	National Ocean Service
NTRIP	Networked Transport of Radio Technical Commission for Maritime Services (RTCM) via Internet Protocol
PPS	pulse-per-second

PV	plan-view
QAPP	Quality Assurance Project Plan
ROV	remotely operated vehicle
RTK GPS	real time kinematic Global Positioning System
SAIC	Science Applications International Corporation
SPI	sediment-profile imaging
SVP	sound velocity profile
TIF	tagged image file
TOST	two one-sided tests
UNH/NOAA CCOM	University of New Hampshire's NOAA Center for Coastal and Ocean Mapping
U.S.	United States
USACE	U.S. Army Corps of Engineers
USCG	U.S. Coast Guard
VDATUM	Vertical Datum Transformation

1.0 INTRODUCTION

A monitoring survey was conducted at the Mark Island Disposal Site (MIDS) in November 2017 as part of the United States (U.S.) Army Corps of Engineers (USACE) New England District (NAE) Disposal Area Monitoring System (DAMOS) Program. DAMOS is a comprehensive monitoring and management program designed and conducted to address environmental concerns surrounding the placement of dredged material at aquatic disposal sites throughout the New England region. An introduction to the DAMOS Program and MIDS, including a brief description of previous dredged material disposal and site monitoring activities, is provided below.

1.1 Overview of the DAMOS Program

The DAMOS Program features a tiered management protocol designed to ensure that any potential adverse environmental impacts associated with dredged material disposal are promptly identified and addressed (Germano et al., 1994). For over 40 years, the DAMOS Program has collected and evaluated dredged material disposal site data throughout New England. Based on these data, patterns of physical, chemical, and biological responses of seafloor environments to dredged material placement activity have been documented along with evaluation of any impacts to water quality (Fredette and French, 2004).

DAMOS monitoring surveys fall into two general categories: confirmatory studies and focused studies. The data collected and evaluated during these studies provide answers to strategic questions in determining next steps in the disposal site management process. DAMOS monitoring results guide the management of disposal activities at existing sites, support planning for use of future sites, and evaluate the long-term status of historical sites (Wolf et al. 2012).

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. Two primary goals of DAMOS confirmatory 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 and acoustic backscatter measurements and side-scan sonar) are made to characterize the height and spread of discrete dredged material deposits or mounds created at open water sites as well as the accumulation/consolidation of dredged material into confined aquatic disposal cells.

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 the evaluation of seafloor (benthic) habitat conditions and recovery over time. Each type of data collection activity is conducted periodically at disposal sites, and the conditions found after a defined period of disposal activity are compared with the long-term data set at a specific site to determine the next step in the disposal site management process (Germano et al., 1994).

Focused studies are periodically undertaken within the DAMOS Program to evaluate candidate sites, as baseline surveys at new sites, to evaluate inactive/historical disposal sites and to contribute to the development of dredged material placement and capping techniques. Focused DAMOS monitoring surveys often 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, sediment coring, towed video, or video collection via a remotely operated vehicle (ROV).

1.2 MIDS Background

MIDS is a small 500 meters (m) x 500 m (1,640 ft x 1,640 ft) site that covers an area of approximately 0.25 square kilometers (km^2) (61.8 acres) and is square in shape. The site is situated in the mouth of Chandler Bay, east of Mark Island and 6.2 km (3.3 nautical miles [nmi]) from Jonesport in eastern Maine (Figure 1-1). The MIDS is relatively sheltered due to the presence of large islands/land masses to the west and north and a number of shallow rocks and ledges to the east and south (e.g., The Black Rocks and Little Breaking Ledge) (Figure 1-2). Average water depths at the site range from approximately 27 to 31 m (88 to 102 ft) Mean Lower Low Water (MLLW) (Figure 1-3), and the site experiences an approximately 4 m (13 ft) tidal range.

A baseline survey was conducted in March 2000 at the originally proposed location of MIDS. This survey, which had a northern boundary that was 250 m (820 ft) to the north of the current boundary of the disposal site, revealed a large rock outcrop in the northern portion of the site. This finding prompted the entire site to be shifted 250 m (820 ft) to the south of the originally proposed boundary. The existing MIDS boundary is centered at 44°31.698' N, 67°31.070' W (NAD83) (Figure 1-2). The site was identified as a potential placement site for the disposal of small volumes of sediment planned to be dredged from marine facilities in Moosabec Reach and other nearby harbors.

1.3 Previous Disposal Activity at MIDS

Disposal activities at MIDS have occurred infrequently over the past 16 years. Recent disposal activities are shown in Table 1-1, and Appendix A. During the 2001/2002 dredging season, material from the U.S. Coast Guard (USCG) Base in Jonesport, Maine (ME) was dredged and an estimated dredged material disposal volume of 4,300 m^3 (5,620 yd^3) was placed within MIDS. Prior to this disposal, the last known use of the site was in 1966 when dredged material placement occurred from the Pig Island Gut Federal Navigation Project (FNP). An additional 5,400 m^3 (7,000 yd^3) of dredged material from the USCG Base was placed at MIDS during the 2011/2012 dredging season. Maintenance dredging of the

Beals Harbor (Barney's Cove) and Pig Island Gut channel and anchorages resulted in an additional 83,300 m^3 (109,000 yd^3) of dredged material placed at the site during the 2016/2017 season. Figure 1-4 displays the disposal log locations generated by the scows and also highlights the centrally focused targeted placement within the Site (also available in Appendix A).

1.4 Previous Surveys at MIDS

In 2000, a pre-disposal bathymetric survey was conducted at MIDS which documented water depths at the site ranging from approximately 27 to 30 m (88 to 98 ft) (Science Applications International Corporation [SAIC], 2000). In 2002, a post-disposal bathymetric survey of the site was conducted after the placement of dredged material to document distribution of dredged material and disposal mound morphology. Results of the post-disposal bathymetric survey indicated that water depths at the site ranged from approximately 27 to 31 m (88 to 102 ft) (Figure 1-3). A depth difference comparison of the pre- and post-disposal bathymetric survey results indicated no detectable changes in seafloor topography between the 2000 and 2002 surveys (SAIC, 2003), i.e., the extent of the limited amount of dredged material that had been placed at the site could not be identified using bathymetry.

In 2002, a post-disposal confirmatory SPI survey was conducted to assess the distribution of dredged material and to monitor the benthic recolonization status of MIDS after the placement of dredged material in 2001/2002. The 2002 SPI results indicated that dredged material was present in images taken at 5 of the 25 inner stations and appeared to be concentrated in the central and southwestern portions of the site. Benthic recovery at the disposal site was relatively advanced with successional Stage III organisms present at the majority of the stations (17 of the 25 inner stations) within the disposal site, including most of the stations with evidence of dredged material (SAIC, 2003).

1.5 Study Objectives

Two maintenance dredging projects have resulted in the placement of approximately 88,700 m^3 (116,000 yd^3) of dredged material at MIDS since the 2002 surveys. The 2017 survey was designed as a confirmatory DAMOS survey to document the distribution of recently placed dredged material, characterize the seafloor topography at MIDS, and evaluate the benthic recolonization status of the site compared to nearby references areas and previous surveys.

Specific objectives of the November 2017 survey were to:

- Characterize the seafloor topography and surficial features indicating the placement of dredged material at MIDS and to characterize the two reference areas by completing a high resolution acoustic survey, inclusive of bathymetry, backscatter and side-scan sonar; and

- Use SPI/PV imaging to assess the benthic recolonization status of MIDS compared to the previous survey and to further define the physical characteristics of surficial sediments across the site and the two reference areas.

Additionally, the locations of fishing marker floats within the MIDS and reference areas were logged during the bathymetric survey to better understand the use of the area for fishing.

Table 1-1.

Summary of Recent Disposals at MIDS

Project	Permittee	Disposal Date	Volume (m^3)	Volume (yd^3)
Moosabec Reach	US Coast Guard	1/2012	5,400	7,000
Beal's Harbor and Pig Island Gut FNP	USACE	12/2016 – 2/2017	83,300	109,000
	Total		88,700	116,000

Table 1-2.

Previous Surveys at MIDS

Year	Survey Type	Bathymetric Survey Area (m x m)	No. SPI Stations	Other	Citation
2000	Baseline Assessment/Pre-Disposal	500 x 500	17	Grab samples for chemistry and benthos/current meter	SAIC, 2000
2002	Post-disposal	1000 x 1000	Site: 25 Ref: 10		SAIC, 2003

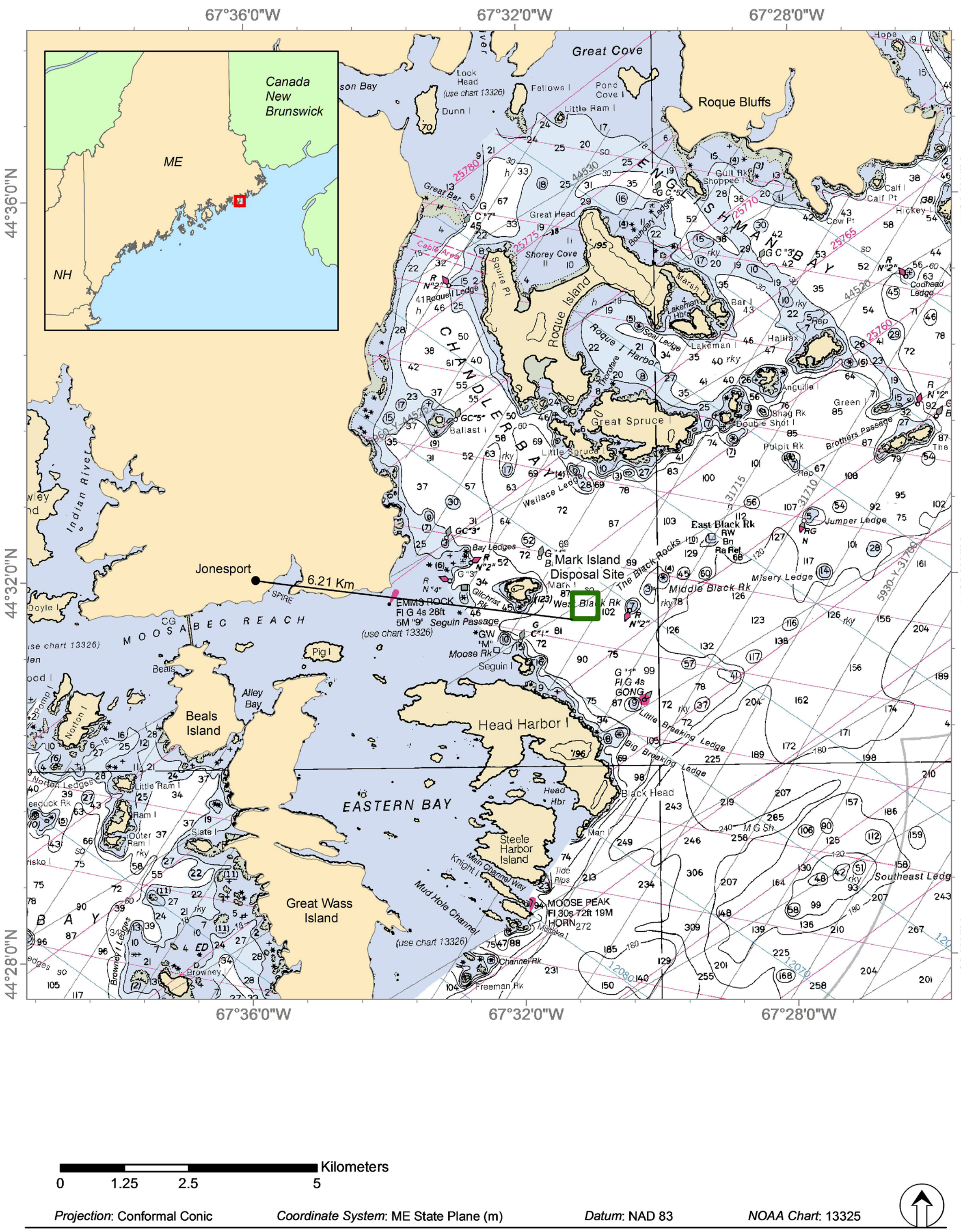

Figure 1-1. Location of MIDS in Chandler Bay, Maine.

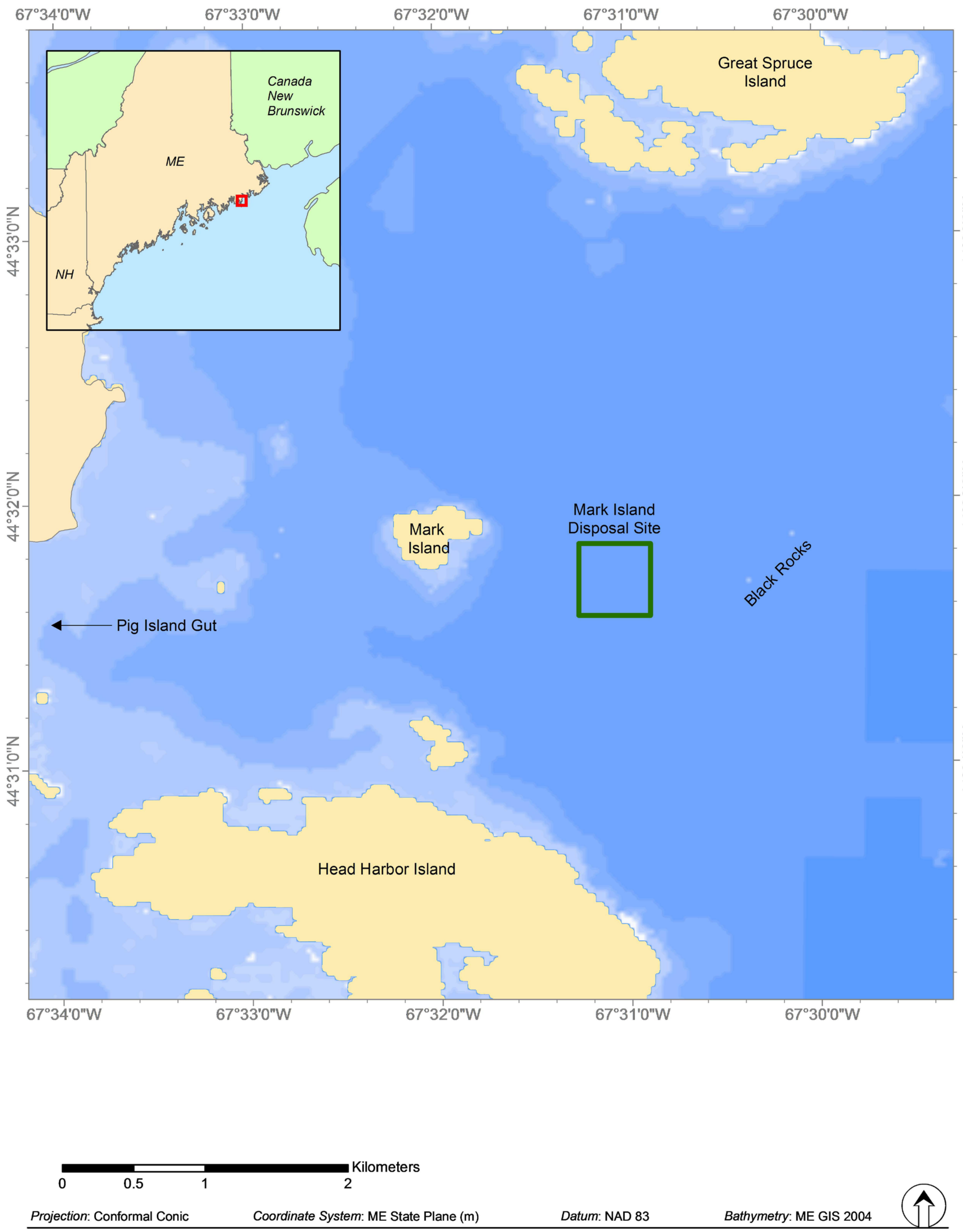

Figure 1-2. Disposal site boundary and nearby features.

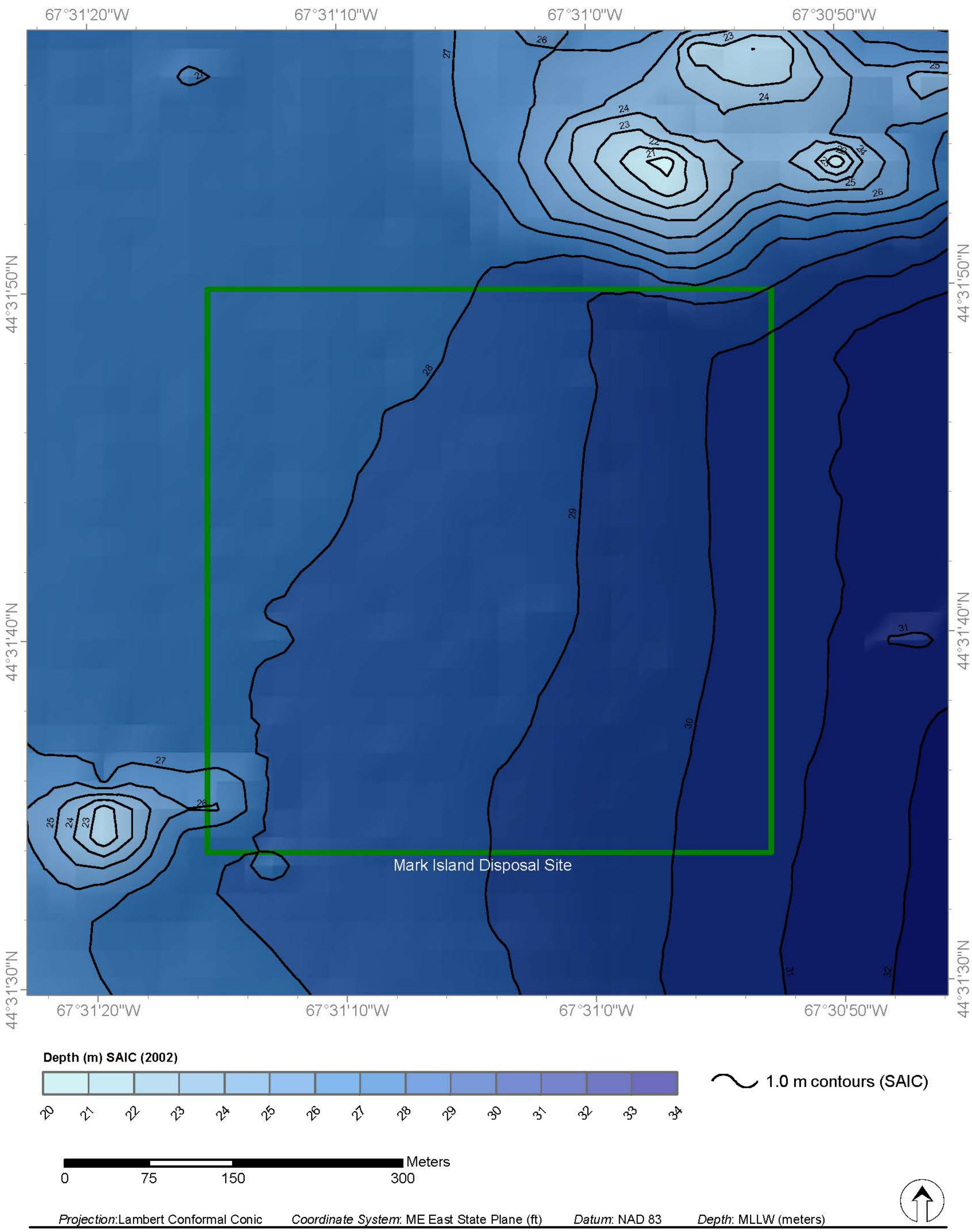

Figure 1-3. Bathymetric contour map of MIDS, July 2002 post-disposal.

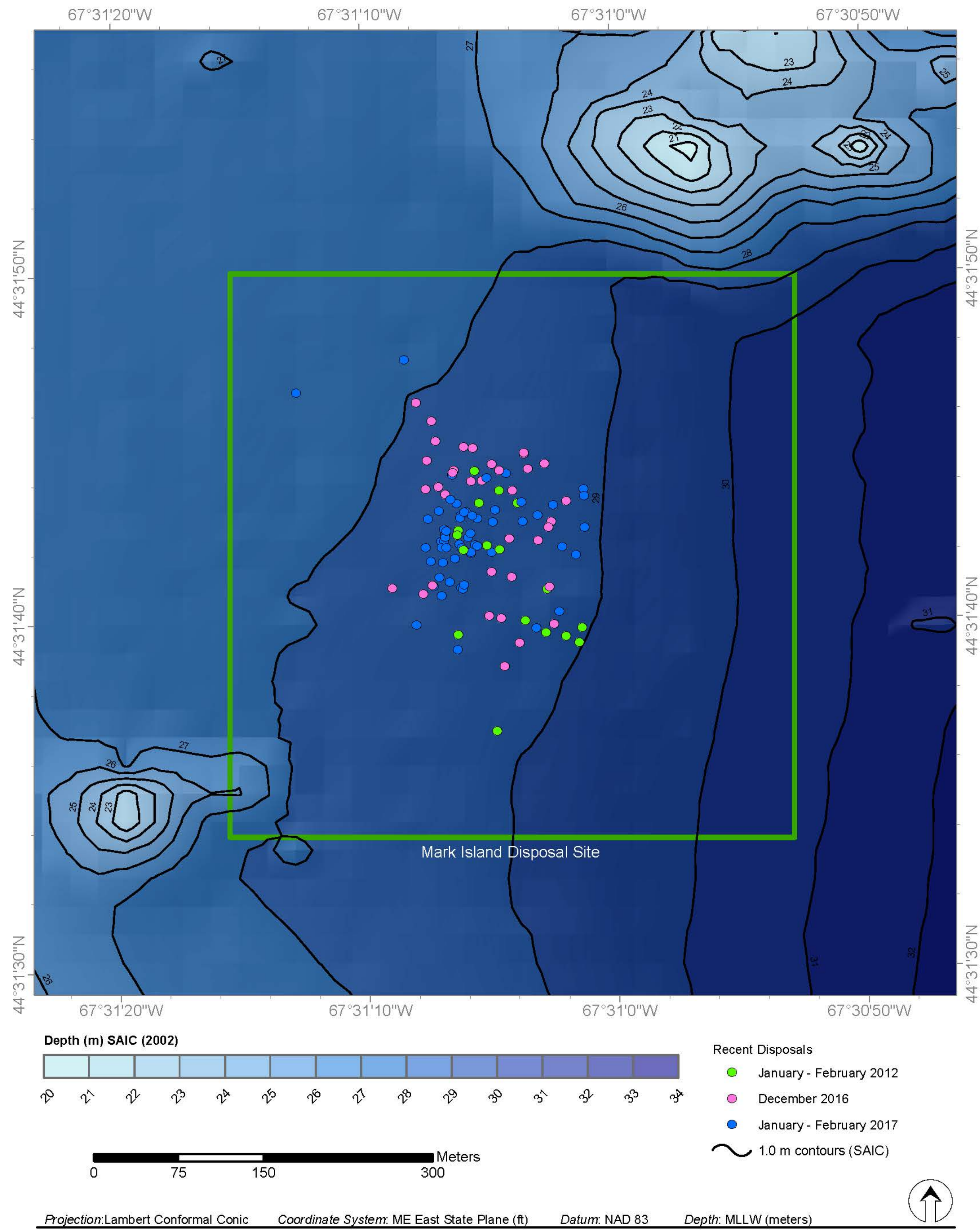

Figure 1-4. Recent disposal history at MIDS (2012 – 2017).

2.0 METHODS

The November 2017 surveys conducted at MIDS were performed by a scientific team from AECOM, CR Environmental, Inc., and Diaz and Daughters. The acoustic survey was conducted on 8 November 2017 to document post-disposal depths in and around the disposal site. The SPI survey was conducted on 9 November 2017 to provide additional data on the physical characteristics of the site and to assess post-disposal benthic recolonization within the disposal site as compared to the reference areas. A fishing gear assessment was performed during the bathymetry survey by marking the Global Positioning System (GPS) location of all buoys that were observed visually within the survey boundaries of MIDS and the reference areas. The assessment of fishing gear (color of buoy and location) provides an idea of commercial fishing density at/near the site and potential bottom disturbances from anchored buoys. The surveys were conducted aboard the 55-foot R/V *Jamie Hannah*. Field activities are summarized in Table 2-1 and an overview of the methods used to collect and analyze the survey data is provided below. Detailed Standard Operating Procedures (SOPs) for data collection and processing are presented in the program Quality Assurance Project Plan (QAPP) (AECOM, 2017).

2.1 Navigation and On-Board Data Acquisition

Navigation for the acoustic, fishing buoy, and SPI surveys was accomplished using a Hemisphere VS-330 real time kinematic GPS which received base station corrections through the Keynet (Networked Transport of Radio Technical Commission for Maritime Services (RTCM) via Internet Protocol) (NTRIP) broadcast. Horizontal position accuracy in fixed RTK mode was approximately 2 centimeters (cm). The GPS system was interfaced to a laptop computer running HYPACK® hydrographic survey software. HYPACK® continually recorded vessel position and GPS satellite quality, and provided a steering display for the vessel captain to accurately maintain the position of the vessel along pre-established bathymetric survey transects and at SPI station targets. Vessel heading measurements were provided by an IxBlue Octans III fiber optic gyrocompass.

2.2 Acoustic Surveys

Bathymetric surveys provide measurements of water depth that, when processed, can be used to map the seafloor topography. The processed data can also be compared with previous surveys to track changes in the size and location of seafloor features. This technique is the primary tool in the DAMOS Program for mapping the distribution of dredged material at disposal sites. Backscatter intensity is a measure of acoustic return from the seafloor from the multibeam system, which can be exploited for bottom classification purposes (USACE, 2002). Examples of seafloor properties that these data are able to estimate remotely include the grain size and roughness of the near-surface sediments

(Fonseca and Mayer, 2007). Side-scan sonar data allows for interpretation of surficial features, like rocks, shipwrecks, or other seafloor anomalies.

2.2.1 Bathymetry, Backscatter, and Side-Scan Data Collection

The 2017 acoustic survey of MIDS was conducted on 8 November 2017 aboard the R/V *Jamie Hannah*. The bathymetric survey was conducted within a 700 x 700 m square area encompassing the entire MIDS site and two 500 x 500 m squares covering the associated reference areas for MIDS (Figure 2-1). Sediment acoustic backscatter data (beam time-series) and side-scan sonar imagery were collected in conjunction with the bathymetric survey. The acoustic survey included a total of 16 survey lines, spaced approximately 60 m apart and oriented in a north-south direction. Four cross-tie lines were collected perpendicular to the survey lines to assess data quality and the accuracy of tidal corrections (Figure 2-1).

Bathymetric and acoustic backscatter data and side-scan sonar imagery were collected using a R2Sonic 2022 broadband multibeam echo sounder (MBES). This 200-400 kilohertz (kHz) system forms up to 256 1- to 2-degree beams (frequency dependent) distributed equiangularly or equidistantly across a 10- to 160-degree swath. For this survey, a frequency of 200 kHz and pulse length of 0.070 milliseconds (msec) was selected to maximize the resolution of bathymetric data without compromising the quality of acoustic backscatter data. The MBES transducer was mounted amidships to the port rail of the survey vessel using a high-strength adjustable boom. The primary GPS antenna was mounted atop the transducer boom. The transducer depth below the water surface (draft) and antenna height were checked and recorded at the beginning and end of data acquisition, and draft was confirmed using the “bar check” method.

An IxBlue Octans III motion reference unit (MRU) was interfaced to the MBES topside processor and to the acquisition computer. Precise linear offsets between the MRU and MBES were recorded and applied during acquisition. Depth and backscatter data were synchronized using pulse per second (PPS) timing and transmitted to the HYPACK MAX® acquisition computer via Ethernet communications. Several patch tests were conducted during the survey to allow for computation of angular offsets between the MBES system components.

The system was calibrated for local water mass speed of sound by performing sound velocity profile (SVP) casts at frequent intervals throughout each survey day using an AML, Inc. MinosX sound velocity profiler.

2.2.2 Bathymetric Data Processing

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

- Adjustment of data for tidal elevation fluctuations
- Correction of ray bending (refraction) due to density variations in 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 were accomplished using RTK GPS. Water surface elevations derived using RTK were adjusted to MLLW elevations using the National Oceanic and Atmospheric Administration's (NOAA's) Vertical Datum Transformation (VDATUM) Model. Correction of sounding depth and position (range and azimuth) for refraction due to water column stratification was conducted using a series of four sound-velocity profiles 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.

Bathymetric data were filtered to accept only beams falling within an angular limit of 60° to minimize refraction artifacts. Spurious sounding solutions were rejected based on the careful examination of data on a sweep-specific basis.

The R2Sonics 2022 MBES system was operated at 200 kHz. At this frequency, the system has a published beam width of 2.0°. Assuming an average MIDS depth of 29 m and a maximum beam angle of 60°, the average diameter of the beam footprint mid-swath was calculated at approximately 1.5 × 1.2 m (~1.9 m^2). Data were reduced to a cell (grid) size of 2.0 × 2.0 m, acknowledging the system's fine range resolution 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 bathymetric data, as summarized in Table 2-2, showed negligible tide bias and vertical uncertainty substantially lower than values recommended by USACE (2013) or NOAA (2015). Note that the most stringent National Ocean Service (NOS) standard for this project depth (Special Order 1A) would call for a 95^{th} percentile confidence interval (95% CI) of 0.36 m at the maximum survey depth (34.1 m) and 0.33 m at the average site depth (28.9 m).

Reduced data were exported in American Standard Code for Information Interchange (ASCII) text format with fields for Easting, Northing, and MLLW elevation (meters). All data were projected to the Maine State Plane (East), North American Datum of 1983 (NAD83) (metric). A variety of data visualizations were generated using a combination of

ESRI ArcMap and Golden Software Surfer programs. Visualizations and data products included:

- ASCII data files of all processed soundings including MLLW depths and elevations
- Contours of seabed elevation (20-cm, 50-cm, and 1.0-m intervals) in a geospatial data file format suitable for plotting using geographic information system (GIS) and computer-aided design software
- 3-dimensional surface maps of the seabed created using 2× vertical exaggeration and artificial illumination to highlight fine-scale features not visible on contour layers delivered in grid and tagged image file (TIF) formats
- An acoustic relief map of the survey area created using 2× vertical exaggeration, delivered in georeferenced TIF format

2.2.3 Backscatter Data Processing

Backscatter data were extracted from cleaned MBES TruePix formatted files then used to provide an estimation of surface sediment texture based on seabed surface roughness. Mosaics of 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 backscatter data was developed and exported in grayscale TIF format using a 1 m x 1 m pixel resolution. Backscatter data were also exported in ASCII format with MIDS for Easting, Northing, and backscatter (decibels [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 1m x 1m grid. The grid was exported in ESRI binary gridded (GRD) file format to facilitate comparison with other data layers.

2.2.4 Side-Scan Sonar Data Processing

Side-scan sonar data were processed using Chesapeake Technology, Inc. Sonar Wiz software and GeoCoder software to generate a database of images that maximized both textural information and structural detail.

Seamless mosaics of side-scan sonar data were developed using SonarWiz and exported in grayscale TIF format using a resolution of 0.20 m per pixel. Data were processed using gain adjustment methods to minimize nadir artifacts and facilitate visualization of fine seabed structures.

2.2.5 Acoustic Data Analysis

Bathymetric data were analyzed to document the distribution of dredged material at MIDS and to evaluate changes in seafloor topography in comparison with previous surveys.

The processed bathymetric grids were converted to rasters and bathymetric contour lines were generated and displayed using GIS.

GIS was also used to calculate depth difference grids between the previous 2002 survey and the 2017 bathymetric dataset. The depth difference grid was calculated by subtracting the 2002 survey depth estimates from the 2017 survey depth estimates at each point throughout the grid. The resulting depth differences were contoured and displayed using GIS. However, there were several factors associated with the 2002 dataset that limited the resolution of the depth difference model. For example, the 2002 bathymetric data were collected using a single beam system while the 2017 survey utilized a multibeam system. The resulting depth difference calculations were limited to an estimated uncertainty between the 2017 and 2002 surveys.

The backscatter mosaics and filtered backscatter grids were combined with acoustic relief models in GIS to facilitate visualization of relationships between acoustic datasets. This was done by rendering images and color-coded grids with sufficient transparency to allow the three-dimensional acoustic relief model to be visible underneath.

2.3 Sediment-Profile and Plan-View Imaging

2.3.1 Sediment-Profile Imaging

SPI is a monitoring technique used to provide data on the physical characteristics of the seafloor as well as the status of the benthic biological community. This technique involves deploying an underwater camera system that penetrates several cm into the seabed to photograph a cross section of the sediment-water interface.

Acquisition of high-resolution sediment-profile images was accomplished using a Canon® 7D digital single-lens reflex camera mounted inside a pressure-resistant housing. The sediment profile camera system consisted of an 18-megapixel digital camera, a 45° prism, and a mirror that reflected an image of the sediment through the camera lens (Figure 2-2). A strobe light mounted inside the prism was used to illuminate the sediment. The digital camera was also equipped with a video feed that was used to send images to the surface via cable so that prism penetration was monitored in real time. The camera was triggered from the surface about one second after bottom contact and after the prism stopped penetrating the sediment. The camera/prism system was mounted in a cradle that was secured to a larger frame, which ensured that the prism penetrated the sediment at a 90° angle.

The profile camera prism window was 15.5 cm wide and 30 cm tall. One hundred and seventy five (175) pounds of lead weights were added to the camera frame to increase prism penetration. 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 ISOequivalent was set at 400, shutter speed was 1/160, f-stop was f5, and storage was on the camera's internal memory card using Canon®'s raw image format.

2.3.2 Plan-View Imaging

A GoPro® HERO4 camera in a shockproof, underwater housing was mounted on the profile camera frame at an oblique angle of approximately 35° to the seafloor and used to collect plan-view images of the seafloor surface. The HERO4 had 4K video resolution and an ultra-wide field of view (FOV). To illuminate the seafloor during video collection, a Bigblue™ 3500 Lumen underwater video light was mounted on the camera frame. The GoPro® camera was turned on at the start of deployment and continuously recorded video footage during the survey. The ability of the PV system to collect usable images was dependent on the clarity of the water column. The HERO4 camera imaged an approximate 0.1 m^2 (40 cm x 25 cm) area in front of the prism.

2.3.3 SPI and PV Data Collection

The sediment-profile and plan-view imaging survey at MIDS was conducted on 9 November 2017 aboard the R/V *Jamie Hannah*. At each SPI station, the vessel was positioned at the target coordinates and the camera was deployed within a defined station tolerance of 10 m (AECOM, 2017). Three replicate SPI and plan-view images were collected at each of the stations.

The 2017 SPI and PV survey included the collection of sediment-profile and plan-view images at twenty-eight (28) stations (Table 2-3, Figure 2-3). Eighteen (18) stations were positioned within the recorded positions of dredged material disposals in the central portion of MIDS. Five (5) reference area SPI stations were randomly distributed throughout each of the two reference sites. The reference areas were selected and surveyed to compare the MIDS, which has received dredged materials, to the reference areas, which have not received dredged material and which represent ambient seafloor conditions.

2.3.4 SPI and PV Data Analysis

Computer-aided analysis of images provided a set of standard measurements that enabled comparison between different locations and different surveys. All SPI images were evaluated visually with data of all features recorded in a pre-formatted spreadsheet file. Images were digitally processed using histogram equalization and 0.1 to 1% histogram clipping to enhance contrast and color for determination of the apparent Redox Potential Discontinuity (aRPD) layer depth with Adobe PhotoShop®. Data from each image were sequentially saved to a spreadsheet file for later analysis.

SPI Data Analysis

Analysis of each SPI image was performed to provide measurement of the following standard set of parameters (Diaz and Schaffer, 1988; Rhoads and Germano, 1986):

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

Penetration Depth - The depth to which the camera penetrated into the seafloor was measured to provide an indication of the sediment density or bearing capacity. The penetration depth can range from a minimum of 0 cm (i.e., no penetration on hard substrates) to a maximum of 30 cm (full penetration on very soft substrates).

Surface Boundary Roughness - Surface boundary roughness is a measure of the vertical relief of features at the sediment-water interface in the sediment-profile image. Surface boundary roughness was determined by measuring the vertical distance between the highest and lowest points of the sediment-water interface. The surface boundary roughness (sediment surface relief) measured over the width of sediment-profile images typically ranges from 0 to 4 cm, and may be related to physical structures (e.g., ripples, rip-up structures, mudclasts) or biogenic features (e.g., burrow openings, fecal mounds, foraging depressions). Biogenic roughness typically changes seasonally and is related to the interaction of bottom turbulence and bioturbational activities.

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

Infaunal Successional Stage - Infaunal successional stage is a measure of the biological community inhabiting the seafloor. Current theory holds that organism-sediment interactions in fine-grained sediments follow a predictable sequence of development after a major disturbance (such as dredged material disposal), and this sequence has been subjectively divided into four stages (Germano et al., 2011). Successional stage was assigned by assessing which types of species or organism-related activities were apparent in the images.

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

PV Image Data Analysis

Analysis of each PV image was performed to provide a larger field of view of the sediment surface in the area where the SPI image was taken. The PV images provide additional information about large-scale sedimentary features, density and patch size of surface fauna, density of infaunal burrowers, and occurrences and density of epifaunal foraging patterns on the seafloor within the disposal site and reference areas. Still plan-view images were extracted from the 4K video using GoPro Studio® and scaled to the 40 x 25 cm area in front of the prism using Adobe PhotoShop®. Plan-view images were also digitally processed using histogram equalization to enhance contrast and sharpened to reduce the effects of bottom turbidity.

2.3.5 Statistical Methods

One of the objectives of the 2017 SPI survey at MIDS was to assess the benthic recolonization status of the site relative to reference conditions. The two SPI parameters which are most indicative of recolonization status, and which also lend themselves to quantitative analysis, are the depth of the aRPD (an indirect measure of the degree of biological reworking of surface sediments) and the infaunal successional stage. For the statistical analysis, the mean value for aRPD (based on n=3 replicate images) was utilized, while the maximum value among the three replicates was used as the successional stage rank for each station. The successional stage ranks had possible values between 0 (no fauna present) and 3 (Stage III); half ranks were also possible for the "in-between" stages (e.g., Stage I going to II had a value of 1.5).

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

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

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 the reference site and disposal mound means.

If the null hypothesis is rejected, then it is concluded that the two means are equivalent to one another within ±δ units. The size of δ should be determined from historical data and/or best professional judgment to identify a maximum difference that is within background variability/noise and is therefore not ecologically meaningful. Based on historical DAMOS data, δ values of 1 for aRPD and 0.5 for successional stage rank (on the 0–3 scale) have been established.

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

In the sampling design utilized in the 2017 SPI survey at MIDS, there were three distinct areas (the disposal site and two reference areas; NE REF and S REF), and the difference equations of interest are the linear contrasts of the disposal site mean minus the average of the two reference means, or:

$[{}^1/_2(\mathrm{Mean}_{\mathrm{NE\ REF}} + \mathrm{Mean}_{\mathrm{S\ REF}}) - (\mathrm{Mean}_{\mathrm{MIDS}})]$

where $\mathrm{Mean}_{\mathrm{NE\ REF}}$ and $\mathrm{Mean}_{\mathrm{S\ REF}}$ were the means for the two reference areas and $\mathrm{Mean}_{\mathrm{MIDS}}$ was the mean for the disposal site.

The two reference areas collectively represented ambient conditions, but if there were mean differences between these two areas, pooling them into a single reference group would increase the variance beyond true background variability. The effect of keeping the two reference areas separate has little effect on the grand reference mean [when n (number of sampling locations) is equal among these areas], but it maintains the variance as a true background variance for each individual population with a constant mean.

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

$[^1/_2(\text{Mean}_{NE\ REF} + \text{Mean}_{S\ REF}) - (\text{Mean}_{MIDS})]$ [Eq.1]

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

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

where:

C^2j = coefficients for the j means in the difference equation, $\hat{d}$ [Eq. 1] (i.e., for equation 1 shown above, the coefficients were 1/2 for each of the 2 reference areas, and -1 for the site).

S_j^2 = variance for the j^{th} area. If equal variances are assumed, a single pooled residual variance estimate can be substituted for each group, equal to the mean square error from an Analysis of Variance (ANOVA) based on all four groups.

n_j = number of replicate observations for the j^{th} area.

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

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

where:

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

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

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

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

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

Table 2-1.

2017 Field Activities at MIDS

Survey	Date	Summary
Bathymetry	8 November 2017	Square area with sides of: 700 x 700 m Lines: 16 Spacing: 60 m
SPI and PV	9 November 2017	Stations: 28 MIDS: 18 Reference Areas: 10

Table 2-2.

Acoustic Cross-Line Comparison Results

+/- Beam Angle Limit	Max Outlier	Mean Diff	Std Dev	95% Confidence
0 (vertical)	1.01	0.01	0.05	0.11
5	1.01	0.01	0.06	0.12
10	0.98	0.01	0.06	0.11
15	0.77	0	0.06	0.11
20	0.8	0	0.06	0.12
25	0.87	-0.01	0.06	0.12
30	1.03	-0.01	0.07	0.13
35	1.36	-0.01	0.07	0.14
40	1.36	-0.01	0.07	0.14
45	1.2	-0.01	0.08	0.15
50	1.22	-0.02	0.08	0.16
55	0.94	-0.04	0.09	0.18
60	0.98	-0.04	0.1	0.2

Notes:

1. Data from November 8, 2017 survey represented in meters.
2. Comparisons made between cross-line swaths and a reference surface created using mainstay data to +/- 60 degrees from nadir using 2m x 2m cell average elevations.
3. 95th percentile uncertainty calculated as 2x root mean square per Army Corps of Engineers recommendations (USACE date).

Table 2-3.

SPI and PV Stations

Station	Latitude (N)	Longitude (W)	Station	Latitude (N)	Longitude (W)
Mark Island Disposal Site			**Reference Areas**		
MIDS26	44° 31.766'	67° 31.135'	NEREF05	44° 32.348'	67° 30.676'
MIDS27	44° 31.766'	67° 31.073'	NEREF06	44° 32.350'	67° 30.455'
MIDS28	44° 31.767'	67° 31.011'	NEREF07	44° 32.271'	67° 30.320'
MIDS29	44° 31.747'	67° 31.142'	NEREF08	44° 32.171'	67° 30.387'
MIDS30	44° 31.746'	67° 31.084'	NEREF09	44° 32.167'	67° 30.511'
MIDS31	44° 31.751'	67° 31.019'	SREF05	44° 31.292'	67° 31.129'
MIDS32	44° 31.721'	67° 31.135'	SREF06	44° 31.307'	67° 31.045'
MIDS33	44° 31.722'	67° 31.074'	SREF07	44° 31.166'	67° 31.233'
MIDS34	44° 31.723'	67° 31.025'	SREF08X	44° 31.151'	67° 31.055'
MIDS35	44° 31.693'	67° 31.134'	SREF09	44° 31.088'	67° 30.995'
MIDS36	44° 31.696'	67° 31.071'			
MIDS37	44° 31.699'	67° 31.017'			
MIDS38	44° 31.677'	67° 31.138'			
MIDS39	44° 31.672'	67° 31.077'			
MIDS40	44° 31.670'	67° 31.022'			
MIDS41	44° 31.652'	67° 31.142'			
MIDS42	44° 31.652'	67° 31.074'			
MIDS43	44° 31.649'	67° 31.026'			

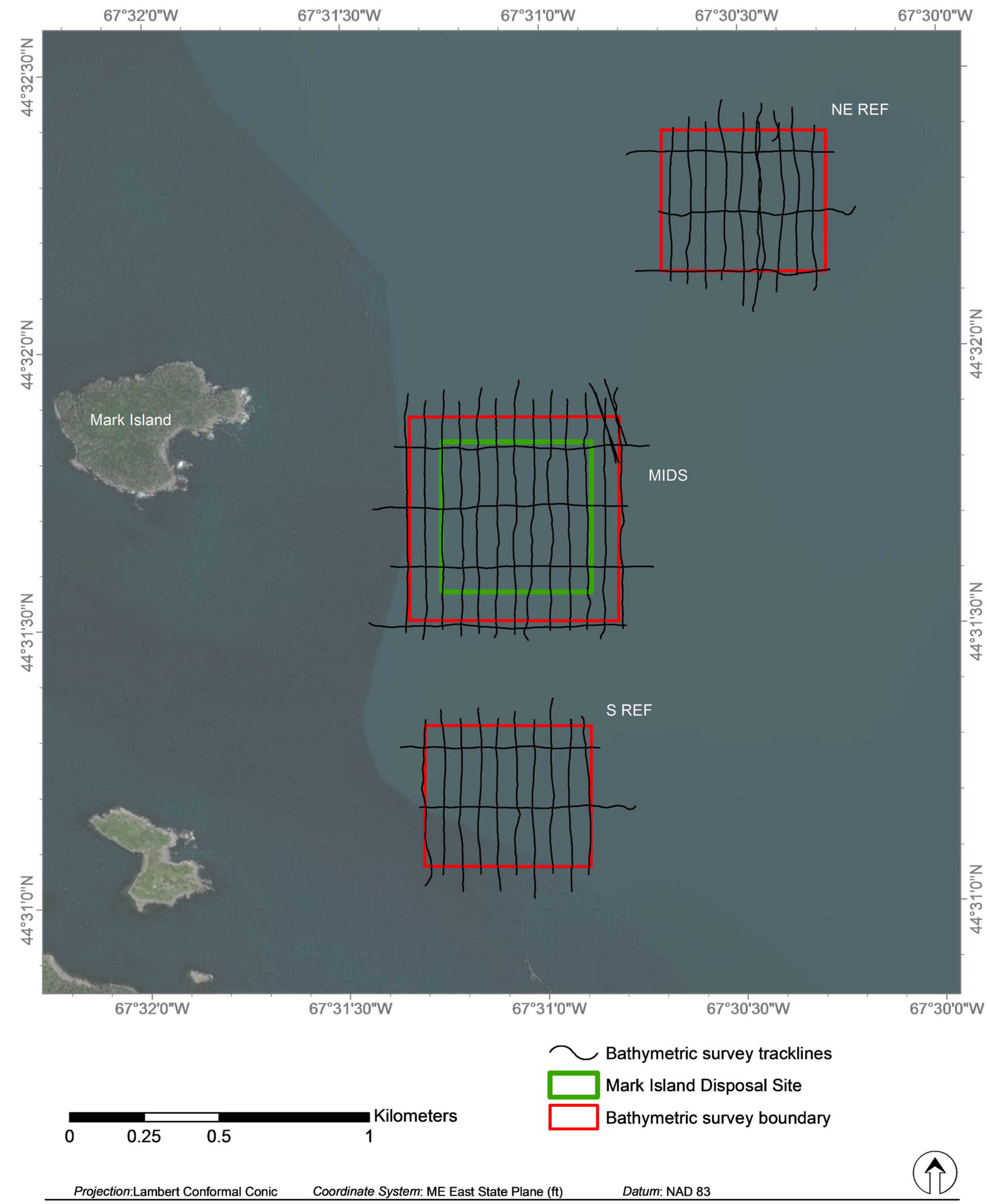

Figure 2-1. MIDS and Reference Areas bathymetric survey boundaries and tracklines, November 2017.

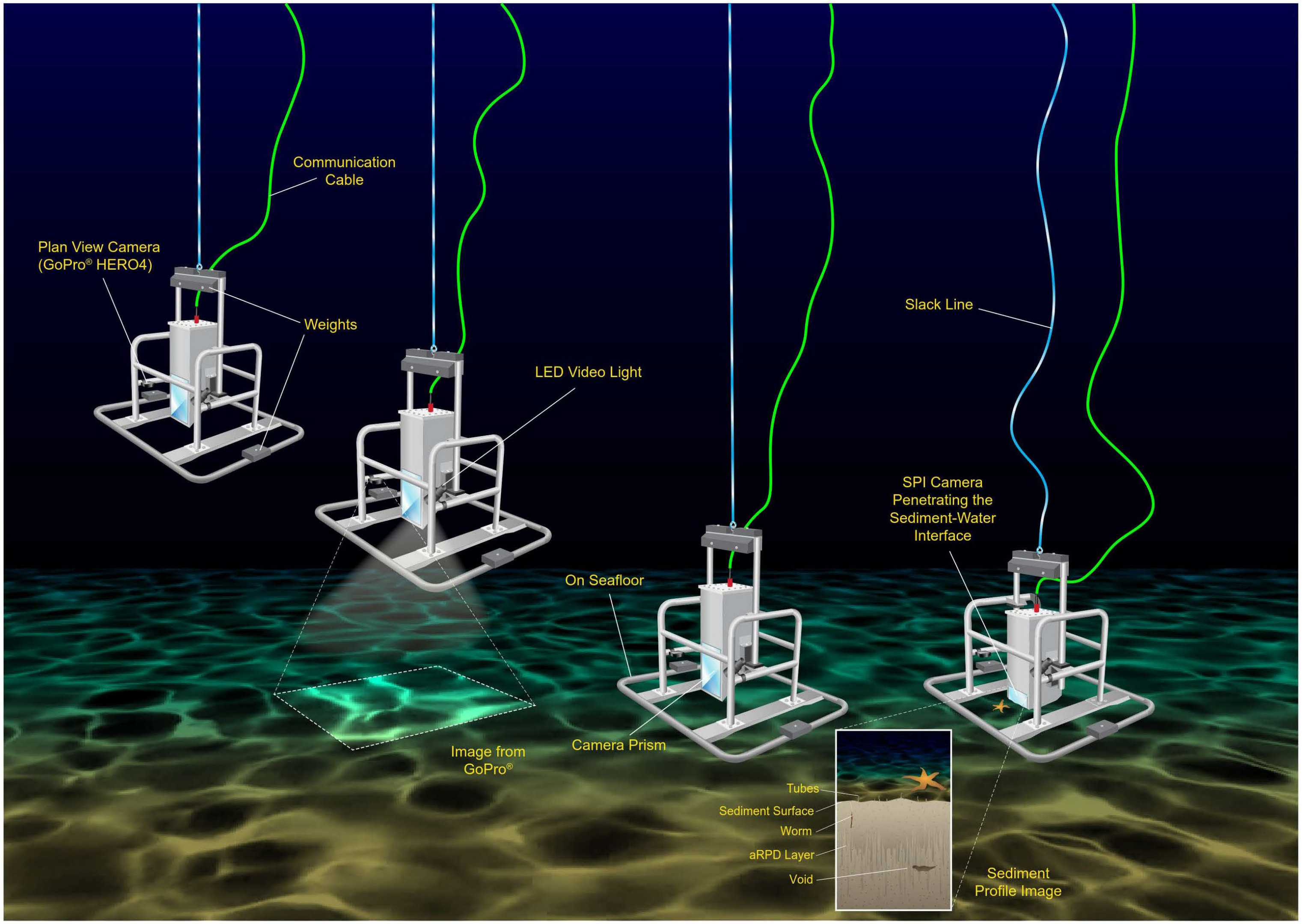

Figure 2-2. Schematic diagram of the SPI and plan-view camera deployment.

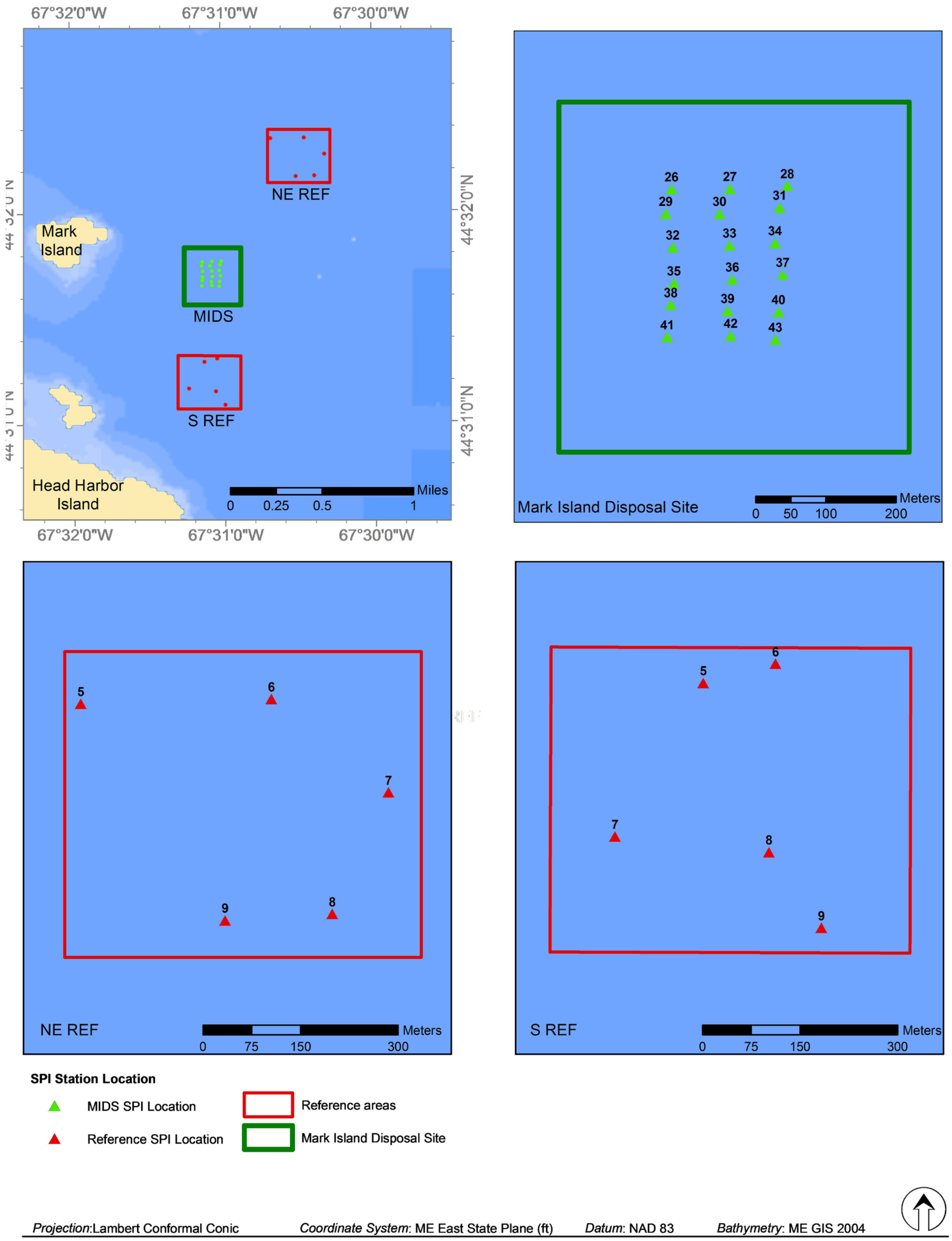

Figure 2-3. MIDS and Reference Areas SPI locations, November 2017.

3.0 RESULTS

The 2017 acoustic surveys of MIDS covered an area of 700 x 700 m over the site, and areas of 500 x 500 m over the two reference areas (NE REF and S REF). The acoustic survey was completed on 8 November 2017. During the acoustic survey, a fishing gear assessment was also conducted. SPI and plan view images were collected at MIDS and the two reference areas on 9 November 2017. Data from these investigations are presented below and in the subsequent tables and figures.

3.1 Bathymetry Backscatter and Side-Scan

3.1.1 Bathymetric Results

The Mark Island Disposal Site naturally slopes from its western boundary, at a depth of approximately 27 m MLLW, to its eastern boundary, at a depth of approximately 30 m MLLW. A disposal mound was apparent in the central portion of the site; water depths over the mound were the shallowest at approximately 26 m MLLW (Figure 3-1). The disposal mound appeared as an irregularly shaped feature rising from the ambient seafloor in the central portion of the site. The mound spanned approximately 325 m in diameter at its widest point and rose approximately two meters above the surrounding seafloor. Three rocky areas were identified in the acoustic survey – these were located just outside of the MIDS to the northeast and east and straddling the boundary of the site in the southwest corner.

Bathymetric surveys were conducted over the two reference areas (Figure 3-2) (NE REF and S REF). Water depths within NE REF ranged from 28-32 m, with the site gradually gaining depth from the northwest corner to the southeast corner. Water depths within S REF were at their shallowest at a depth of 24 m over an apparent rocky area along the eastern-central border; the overall site sloped downward from west to east with depths ranging from 25-32 m.

Depth difference calculations were performed using the 2002 and 2017 bathymetric datasets. An estimated uncertainty of -0.2 to 0.2 m was assumed to capture the range of uncertainty between the 2002 and 2017 surveys. Depth difference results clearly displayed the disposal mound that had been formed in the central portion of the site, rising approximately 2.0 m above the ambient seafloor. The results of the depth difference comparison show a mound with a footprint covering approximately 25% of the site (Figure 3-3).

Volume estimates generated from subtracting the difference between the 2002 and 2017 bathymetric surveys resulted in a measured volume of 84,900 m^3 of material being added to the mound since it was last surveyed in 2002. This volume is very consistent with the estimated volume of dredged material (88,700 m^3) placed at MIDS since the 2002 survey considering the consolidation of mound material expected over time and the uncertainty in volume estimates considering the use of different bathymetric techniques (single beam vs. multi beam).

3.1.2 Backscatter and Side-Scan Results

Backscatter and side-scan sonar data provide images that display changes in seafloor sediment texture and roughness. These tools also aid in the analysis of topographic changes between the ambient seafloor and areas that have received dredged material. Typically, high backscatter intensity is related to the presence of rock or coarse-grained sediment (e.g., gravel, coarse sand), and low backscatter intensity is indicative of fine-grained sediments (e.g., silt, clay). Side-scan sonar also provides an image of seafloor texture and bottom features.

The MIDS backscatter survey results (measured in dB) display the difference in sediments over the disposal mound, in the central portion of the site (Figures 3-4 and 3-5). In general, backscatter signals over the disposal mound ranged from to -24 to -15 dB. Ambient, softer sediments in the areas surrounding the disposal mound emitted a weaker backscatter signal ranging from -24 to -29 dB. An apparent extension of the mound on the northwest side was present on the backscatter results and correlates with the location of placement of material made in that area in 2016 as shown by the reported disposal locations shown in Figure 1-4.

A side-scan sonar mosaic of the survey area allowed for interpretation of surficial features of the site. This mosaic highlighted the disposal mound and extension located in the central portion of MIDS as well as the rocky outcrops to the northeast, southwest, and east (Figure 3-6). No individual disposal features were identified from the side-scan images, but a clear depiction of the mound was apparent.

Backscatter signals over the NE REF area ranged from -14 to -29 dB with coarser materials located towards the southeastern corner, transitioning to softer sediment towards the northwest (Figures 3-7 and 3-8). Side-scan sonar results displayed a similar transition of coarse to soft sediment within the NE REF area (Figure 3-9). Backscatter signals over the S REF area ranged from -14 to -30 dB; a majority of the S REF area is comprised of softer sediments with an apparent rocky area located along the central eastern boarder (Figures 3-7 and 3-8). Side-scan sonar results also display the softer sediments throughout this area and the apparent rocky outcrop (Figure 3-9).

3.2 Sediment-Profile and Plan-View Imaging

The SPI and PV data were assessed to aid in the physical and biological characterization of the disposal site and the two reference areas. Three replicate images from the SPI/PV camera system were analyzed at each station. The data from three replicates for aRPD depth, prism penetration depth, and boundary roughness were averaged to get a mean value per station. Successional stage for each station replicate was displayed as a pie chart in the figures depicting each of the three replicates. Detailed image analysis results are provided in Appendix C (Sediment Profile Imaging Results) and Appendix D (Plan View Imaging Results). The following sections summarize the results for the reference areas and the disposal site. Statistical comparisons between the reference area and site SPI results are also presented.

3.2.1 Disposal Site SPI and Plan-View Results

Physical Sediment Characteristics

Surface sediments at SPI stations located within the disposal site were primarily sand and silt over dredged material. The grain size major mode throughout the disposal site was 4 to 3 phi over the central portion and northeast corner of the disposal area, and > 4 phi around the edge of the existing dredged material disposal mound (Table 3-1, Figure 3-10). The presence of dredged material was noted at stations sampled within the disposal area footprint, with thickness ranging from 1.0 cm to the depth of the camera penetration (Figure 3-11).

Mean camera penetration throughout the disposal site ranged from 7.4 to 16.1 cm with an overall disposal site camera penetration depth mean of 10.8 cm (Figure 3-12), identical to the disposal site camera penetration depth mean observed from the results of the 2002 survey. These results indicate that sediments were moderately firm with coarser sand particles mixed with finer silt and clay. Areas where the sediment grain size was categorized as predominantly fine sand showed the shallowest penetration depths (MIDS 33 and MIDS 37, at penetration depths of 8.5 and 7.4 cm, respectively). The stations with silty sediment (>4 phi) generally had deeper penetrations, with values greater than 10 cm (Figure 3-13).

Small-scale surface boundary roughness ranged from 0.7 to 2.3 cm with a disposal site mean of 1.3 cm (Table 3-1, Figure 3-14). The boundary roughness characteristics at the site were attributed to both physical and biological processes and consisted of small-scale sand waves as well as feeding mounds, burrows, and pits (Appendices C and D).

Biological Sediment Characteristics

Disposal area aRPD mean values ranged from 0.9 to 5.3 cm, with an overall disposal site mean aRPD depth of 3.0 cm, similar to the 2002 survey mean aRPD depth of 2.9 cm (Table 3-1, Figure 3-15). Stations within the 2017 mapped disposal site boundary showed no evidence of anoxia or hypoxia (low or no oxygenated sediment) and did not show the presence of methane gas bubbles. Evidence of infaunal organism tubes was noted from the stations analyzed within the disposal site; burrows were present at 10 of the 18 disposal site stations. Oxic feeding voids were present at 13 of the 18 disposal site stations ranging from depths of 0.5 cm to 8.2 cm below the sediment surface (Figure 3-16). Stage I, I to II, and III organisms were present at the disposal site, with an apparent increased infaunal presence within the northern portion of the site and a decreased presence over the central portion of the mound and the southeastern stations (Figure 3-17). A plan-view image taken at MIDS 27 displayed a thin silt layer over fine sand with invertebrate trails, tubes, and burrows present within the disposal site (Figure 3-18, Appendix D)

3.2.2 Reference Area SPI and Plan-View Results

3.2.2.1 Physical Sediment Characteristics

Sediments at the reference areas were classified as very fine sand (4 to 3 phi), with areas of surficial shell hash noted at two locations within NE REF (Table 3-1, Figure 3-19). Dredged material was not observed from images analyzed from the reference locations (NE REF and S REF). As noted during the 2002 SPI survey, small flecks of light-colored clay were apparent within images taken at NE REF (Figure 3-20). Camera penetration ranged from 1.1 to 13.9 cm with an overall reference area mean penetration of 7.8 cm (Table 3-1, Figure 3-21). Small-scale surface boundary roughness values ranged from 0.5 to 4.6 cm with an overall reference area mean of 1.4 cm (Table 3-1); surface boundary roughness was characterized as both physical and biological, consisting of small surface sand waves and biological activity such as feeding pit mounds. The reference area stations (NE REF and S REF) did not exhibit evidence of hypoxia or anoxia in the overlying water or within the sediment, and methane was not observed in the subsurface sediments.

3.2.2.2 Biological Conditions

Mean aRPD depths at the reference stations ranged from 3.6 to 12.1 cm, with some values being affected by the camera penetration depth (Table 3-1, Figure 3-22). Recorded aRPD depths within the reference areas were deeper than those observed within the disposal site, potentially due to a difference in grain size. Evidence of Stage I to II communities was observed at each of the reference stations (Figure 3-23). Surface tubes were evident within each image replicate and burrows were noted within three stations at NE REF, but were absent from all stations within S REF. Oxic Feeding voids were apparent at 6 of the 10 reference locations, and at a maximum depth of 6.8 cm at SREF08X. There were also extensive organism tracks, pits, and burrow openings visible in the plan-view images from the reference area stations (Figure 3-24, Appendix D).

3.2.3 Statistical Comparisons of Disposal Site and Reference Stations

A summary of the mean aRPD and successional stage rank values by sampling location are shown in Tables 3-3 and 3-4 and Figures 3-25 and 3-26. The statistical comparisons results for each variable follow.

Mean aRPD Variable

At each of the stations, there were results for three replicate drops of the SPI/PV camera. The mean aRPD depth for a station, based on the three replicate observations, was used in the statistical inequivalence testing. For three stations in the NE REF area and three stations in the S REF area the aRPD was indeterminate because the aRPD depth appeared to be deeper than camera penetration — for these six stations, the maximum camera penetration depth was used in the analysis.

The two reference areas had different mean aRPD depths with the NE REF area having a lower mean, but more variance than the S REF area **(**Table 3-2, Figure 3-25**)**. The mean aRPD depths for both reference areas were greater than the mean depth for the MIDS. A statistical inequivalence test was performed to determine whether the differences observed in mean aRPD depths between the two reference areas and the MIDS were significantly similar. Normality and pooled variance were tested using the Shapiro-Wilk's normality test and Levene's test for equality of variances, respectively. Results for the Shapiro-Wilk's normality tests indicated that each area was normally distributed (alpha = 0.05). The resulting p-values from the Shapiro-Wilks' tests were 0.54 (MIDS), 0.48 (NE REF), and 0.56 (S REF).

The resulting p-value from the Levene's test was 0.004. Levene's test for equality of variances was rejected (alpha = 0.05), so a single pooled variance estimate for mean aRPD depths from the MIDS and the two reference areas could not be used in calculations of the confidence interval on the difference of means.

The confidence interval for the difference of mean aRPD depths was constructed using parametric estimates. Results are provided in Table 3-3. The difference in mean aRPD depths between the MIDS and the reference areas was 5.39 cm (with a confidence range of 3.56 to 7.23 cm). The confidence range for the difference between mean aRPD depths is not within the interval of [-1 cm, +1 cm] that would be expected from background variability/ noise. The conclusion is that the aRPD depths from the MIDS and the reference areas are statistically inequivalent.

3.2.3.1 Successional Stage Rank Variable

Successional stage ranks had possible values between 0 and 3 with half ranks assigned to in-between stages. The maximum successional stage rank for a station was used in the statistical inequivalence testing.

The two reference areas had maximum successional stage ranks of 1.5 at all stations **(**Table 3-2, Figure 3-26). The maximum successional stage ranks for stations in the MIDS ranged from 1 to 3 with an average of 2.2. A statistical inequivalence test was performed to determine whether the differences observed in maximum successional stage ranks between the two reference areas and the MIDS were significantly similar. Normality and pooled variance were tested using the Shapiro-Wilk's normality test and Levene's test for equality of variances, respectively. The Shapiro-Wilk's normality test was applied to the maximum successional stage ranks from the MIDS, but not to the reference areas where all stations had the same maximum rank. Results for the Shapiro-Wilk's normality test with an alpha of 0.05

indicated that maximum successional stage ranks from the MIDS are normally distributed (p value = 0.99).

The resulting p-value from the Levene's test was 0. Levene's test for equality of variances was rejected (alpha = 0.05), so a single pooled variance estimate for maximum successional stage ranks from the MIDS and two reference areas could not be used in calculations of the confidence interval on the difference of ranks.

The confidence interval for the difference of maximum successional stage ranks was constructed using parametric estimates. Results are provided in Table 3-4. The difference in maximum successional stage ranks between the MIDS and the reference areas was -0.64 (with a confidence range of -0.97 to -0.31). The confidence range for the difference between maximum successional stage ranks is not within the interval of [-0.5, 0.5] that would be expected from background variability/noise. The conclusion is that the maximum successional stage ranks from the MIDS and the reference areas are statistically inequivalent.

3.3 Fishing Gear Assessment

The fishing gear assessment resulted in identification of 22 fishing marker buoys (buoys) within the footprint of MIDS and 11 buoys located just outside of the MIDS footprint, but within the survey area (Appendix E and Figure 3-27). Fishing gear was also surveyed within the reference areas resulting in the identification of 29 buoys within the NE REF survey area, and 19 within the S REF survey area. The 81 identified buoys had a total of 26 separate coloration schemes, indicating that multiple fisherman utilize the area.

Table 3-1.

Summary SPI Results (station means) at MIDS and Reference Stations

Area	Station	Grain Size Major Mode (phi)	Mean Prism Penetration Depth (cm)	Mean Boundary Roughness (cm)	Mean aRPD Depth (cm)	Maximum Void Depth (cm)	Mean Dredged Material Thickness (cm)	Successional Stages Present (3 Replicates)		
MIDS	MIDS26	>4	14.9	1.4	2.9	6.3	3.0	III	III	I to II
	MIDS27	>4	16.1	1.1	3.1	2.0	3.5	I to II	III	III
	MIDS28	4-3	12.9	0.9	4.7	8.1	2.2	I to II	I to II	III
	MIDS29	>4	12.4	1.9	4.8	4.2	2.7	III	I to II	I to II
	MIDS30	>4	14.6	1.8	3.1	N/A	3.2	III	III	I to II
	MIDS31	>4	15.4	1.4	0.9	3.0	6.2	I to II	I to II	III
	MIDS32	4-3	12.9	1.0	1.6	2.3	7.1	III	I to II	I to II
	MIDS33	3	8.5	2.3	2.8	4.5	8.5	I	I	I
	MIDS34	>4	14.4	0.9	4.1	3.5	4.5	I to II	I to II	III
	MIDS35	>4	13.8	1.3	3.2	4.8	3.2	I to II	I to II	I to II
	MIDS36	4-3	10.0	1.6	3.1	2.6	10.0	I to II	I to II	I to II
	MIDS37	4-3	7.4	1.1	1.9	N/A	7.4	I to II	I to II	I
	MIDS38	>4	15.0	1.1	2.3	N/A	9.2	I to II	I to II	I to II
	MIDS39	>4	11.7	1.1	1.7	N/A	11.7	I to II	I to II	I
	MIDS40	>4	12.2	1.5	4.5	8.2	12.2	I to II	I to II	I to II
	MIDS41	>4	14.0	1.1	5.3	N/A	8.4	I to II	I to II	I to II
	MIDS42	>4	10.5	1.2	1.0	2.1	10.5	I	I	I to II
	MIDS43	>4	9.8	0.7	2.9	2.3	9.7	I to II	I	I to II

Table 3-1 (continued).

Summary SPI Results (station means) at MIDS and Reference Stations

Area	Station	Grain Size Major Mode (phi)	Mean Prism Penetration Depth (cm)	Mean Boundary Roughness (cm)	Mean aRPD Depth (cm)	Maximum Void Depth (cm)	Mean Dredged Material Thickness (cm)	Successional Stages Present (3 Replicates)		
NE REF	NEREF05	4-3	10.1	1.1	12.1	3.3	N/A	I to II	I to II	I to II
	NEREF06	4-3	8.9	0.7	8.4	1.2	N/A	I to II	I to II	I to II
	NEREF07	4-3	2.8	1.8	3.6*	N/A	N/A	I to II	I to II	I to II
	NEREF08	4-3	3.1	1.2	3.6*	N/A	N/A	I to II	I to II	I to II
	NEREF09	4-3	6.4	0.9	6.8*	1.1	N/A	I to II	I to II	I to II
S REF	SREF05	4-3	6.7	2.3	10.4*	NA	N/A	I to II	I to II	I to II
	SREF06	4-3	8.7	1.9	9.8*	3.8	N/A	I to II	I to II	I to II
	SREF07	4-3	12.6	1.8	10.3	N/A	N/A	I to II	I to II	I to II
	SREF08X	4-3	9.6	1.2	9.8	6.9	N/A	I to II	I to II	I to II
	SREF09	4-3	8.8	0.8	9.1*	1.9	N/A	I to II	I to II	I to II

Table 3-2.

Summary of Station Means by Sampling Location

Area	N	Mean aRPD (cm)*		Successional Stage Rank	
		Mean	Standard Deviation	Mean	Standard Deviation
Reference Locations					
NE REF	5	6.9	3.2	1.5	0
S REF	5	9.9	0.5	1.5	0
Mean		8.4		1.5	
Disposal Site					
MIDS	18	3.0	1.3	2.1	0.78

*Includes aRPD values that were not recorded because the redox line was below the camera penetration line. In these cases the max penetration value was used.

Table 3-3.

Summary of Statistics and Results of Inequivalence Hypothesis Testing for aRPD Values

Difference Equation	Observed Difference ($\hat{d}$)	SE ($\hat{d}$)	df for SE ($\hat{d}$)	95% Confidence Bounds (lower–upper)	Results
*$Mean_{NEREF\&SREF}$ – $Mean_{MIDS}$	5.4	0.86	4	3.56–7.23	d

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

*= Includes aRPD values that were not recorded because the redox line was below the camera penetration line. In these cases the max penetration value was used.

Table 3-4.

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

Difference Equation	**Observed Difference ($\hat{d}$)**	**SE ($\hat{d}$)**	**df for SE ($\hat{d}$)**	**95% Confidence Bounds (lower–upper)**	**Results**
$Mean_{NEREF\&SREF}$ – $Mean_{MIDS}$	-0.64	0.2	17	-0.97– -0.31	d

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

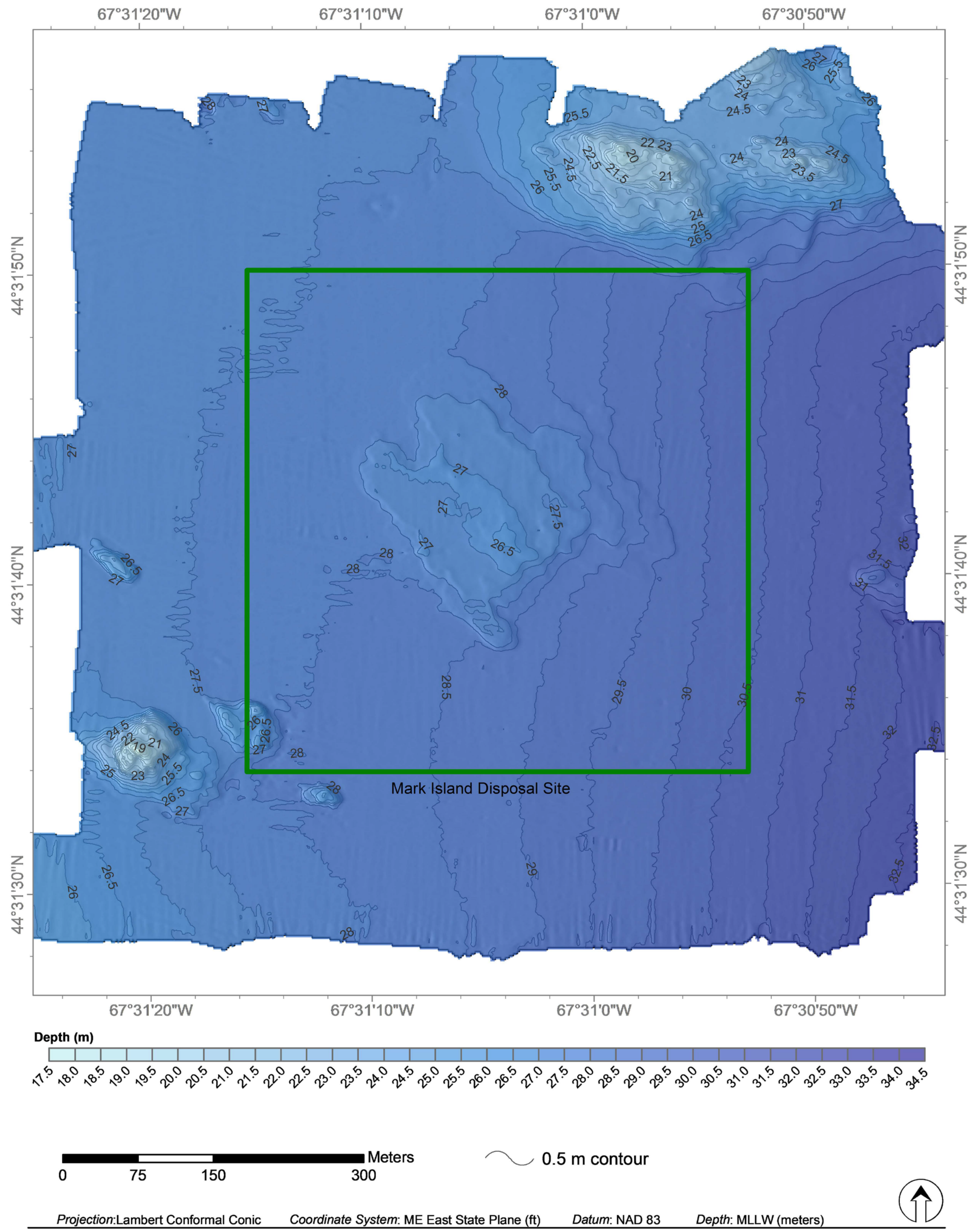

Figure 3-1. Bathymetry of MIDS over 2x vertical relief model, November 2017.

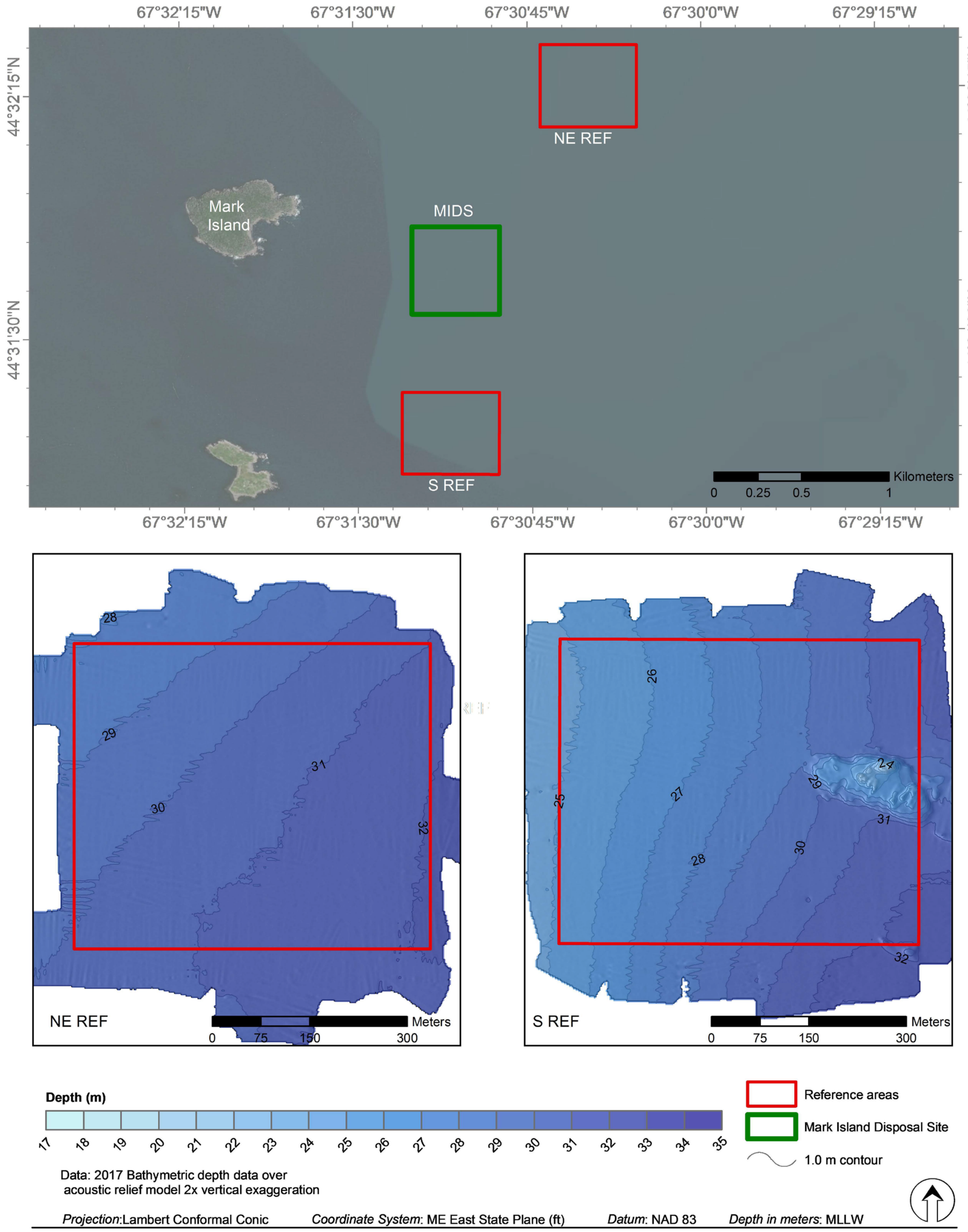

Figure 3-2. Bathymetry of NE REF and S REF over 2x vertical relief model, November 2017.

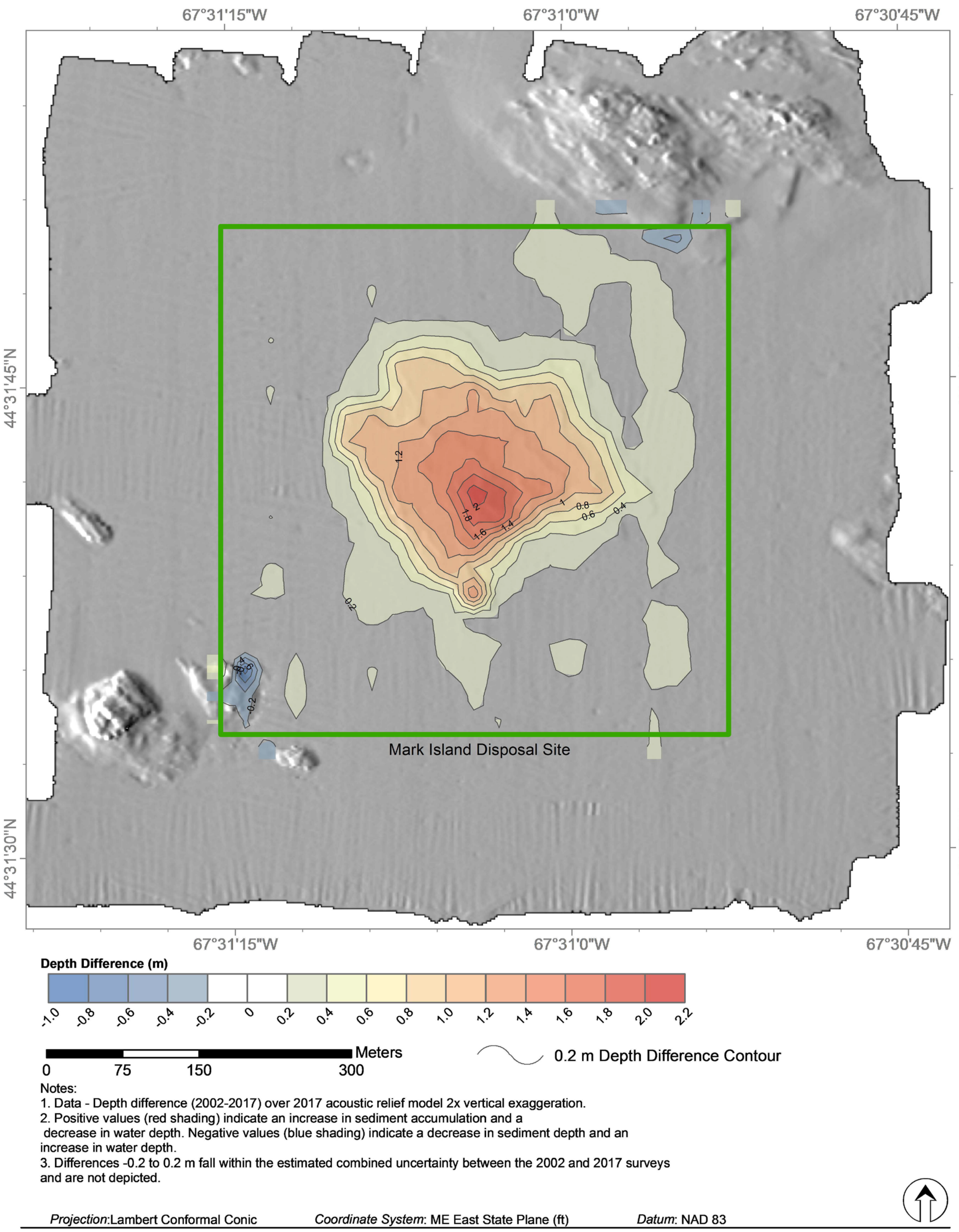

Figure 3-3. Depth differencing (2002 – 2017) of MIDS over 2x vertical relief model, 2017.

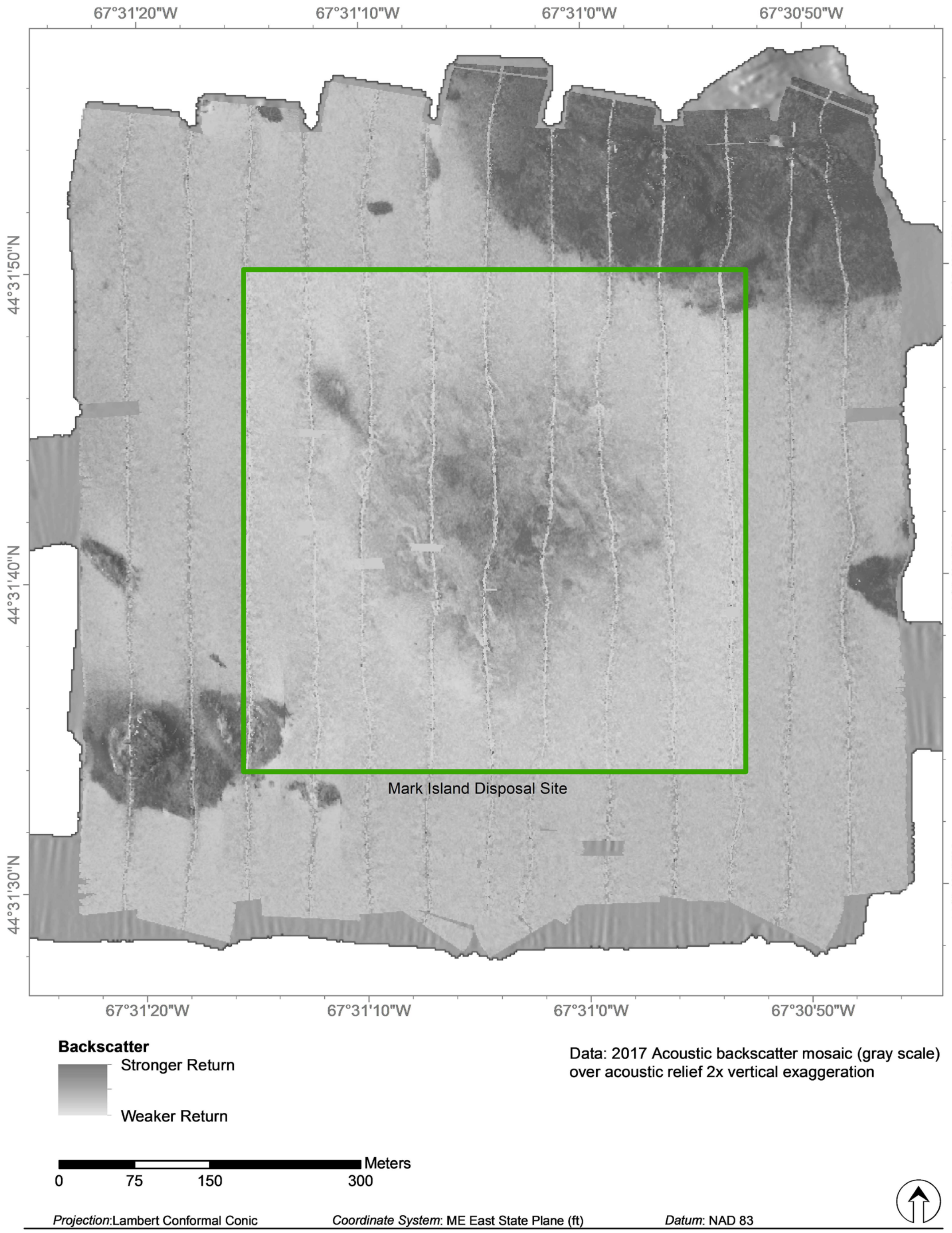

Figure 3-4. Backscatter intensity (dB) at MIDS, over 2x vertical relief model, 2017.

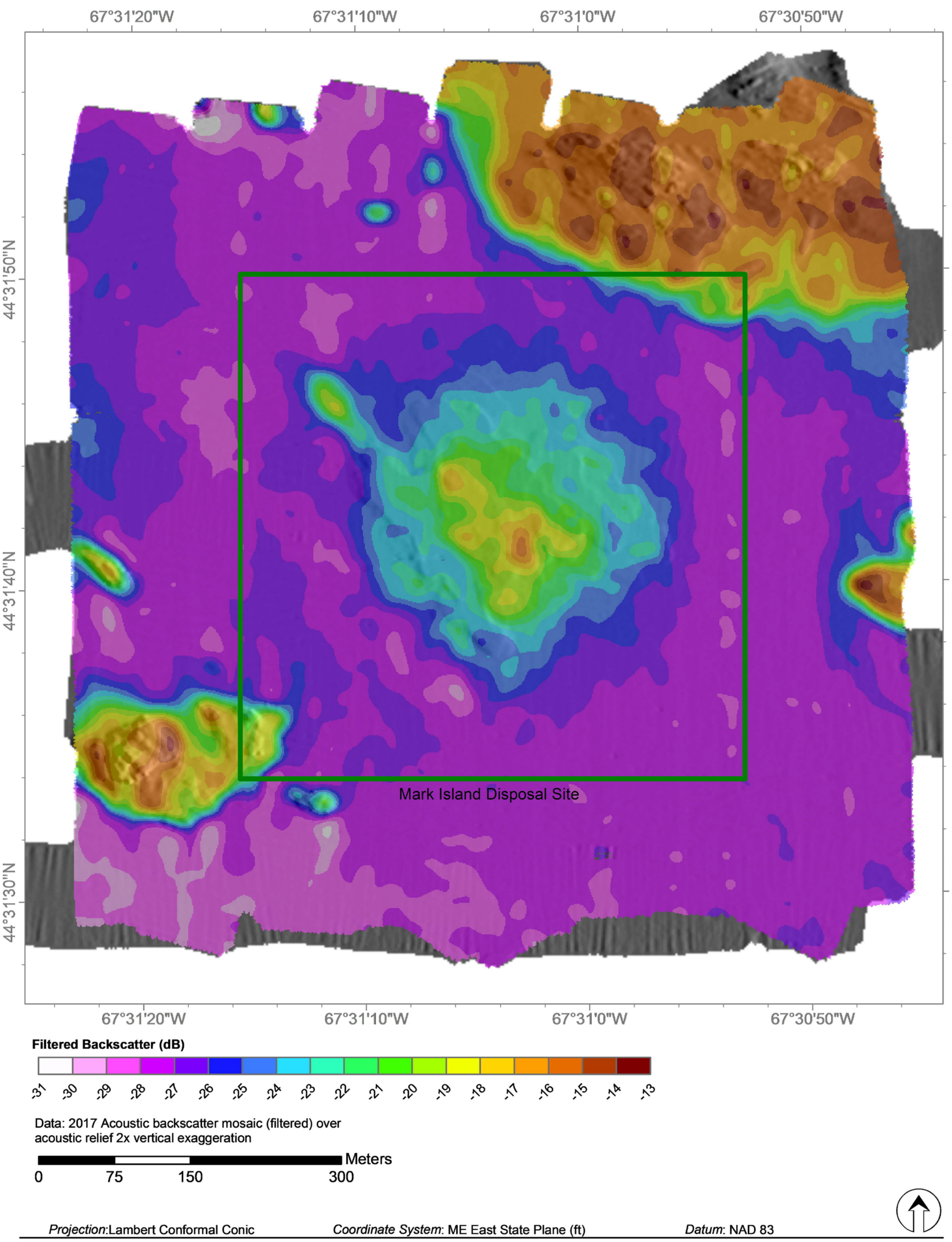

Figure 3-5. Filtered backscatter intensity (dB) at MIDS, over 2x vertical relief model, 2017.

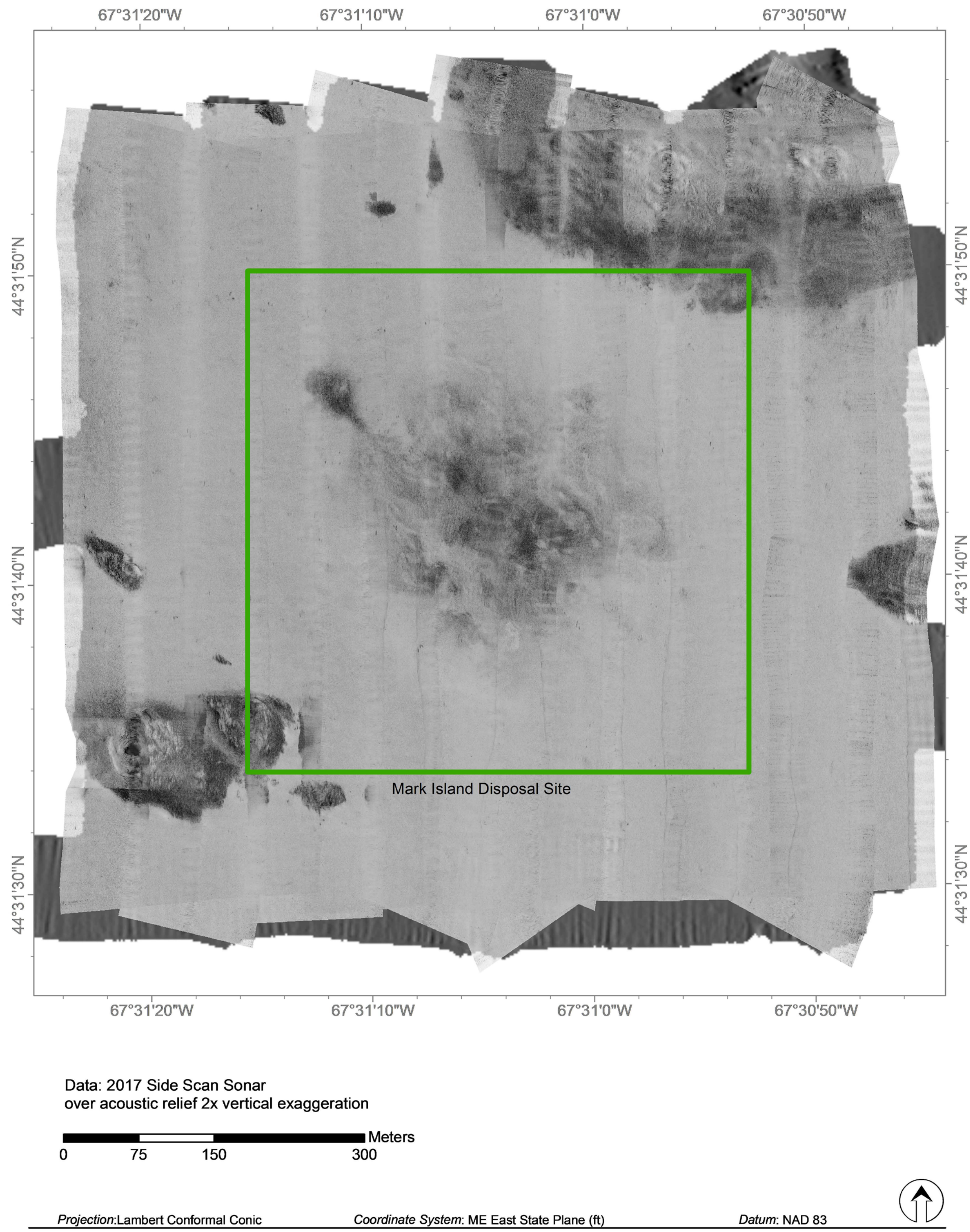

Figure 3-6. Side-scan sonar at MIDS, over 2x vertical relief model, 2017.

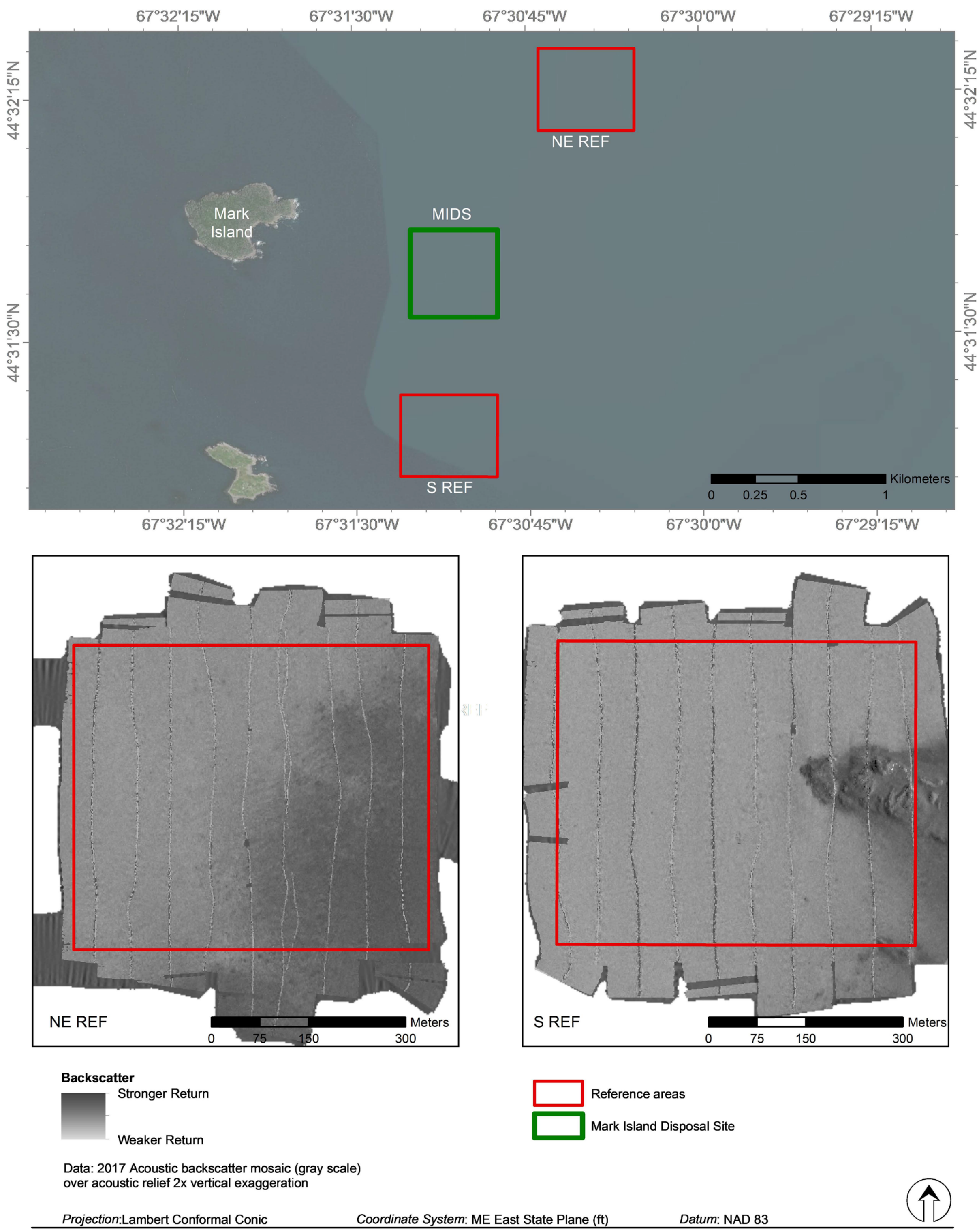

Figure 3-7. Backscatter intensity (dB) at NE REF and S REF, over 2x vertical relief model, November 2017.

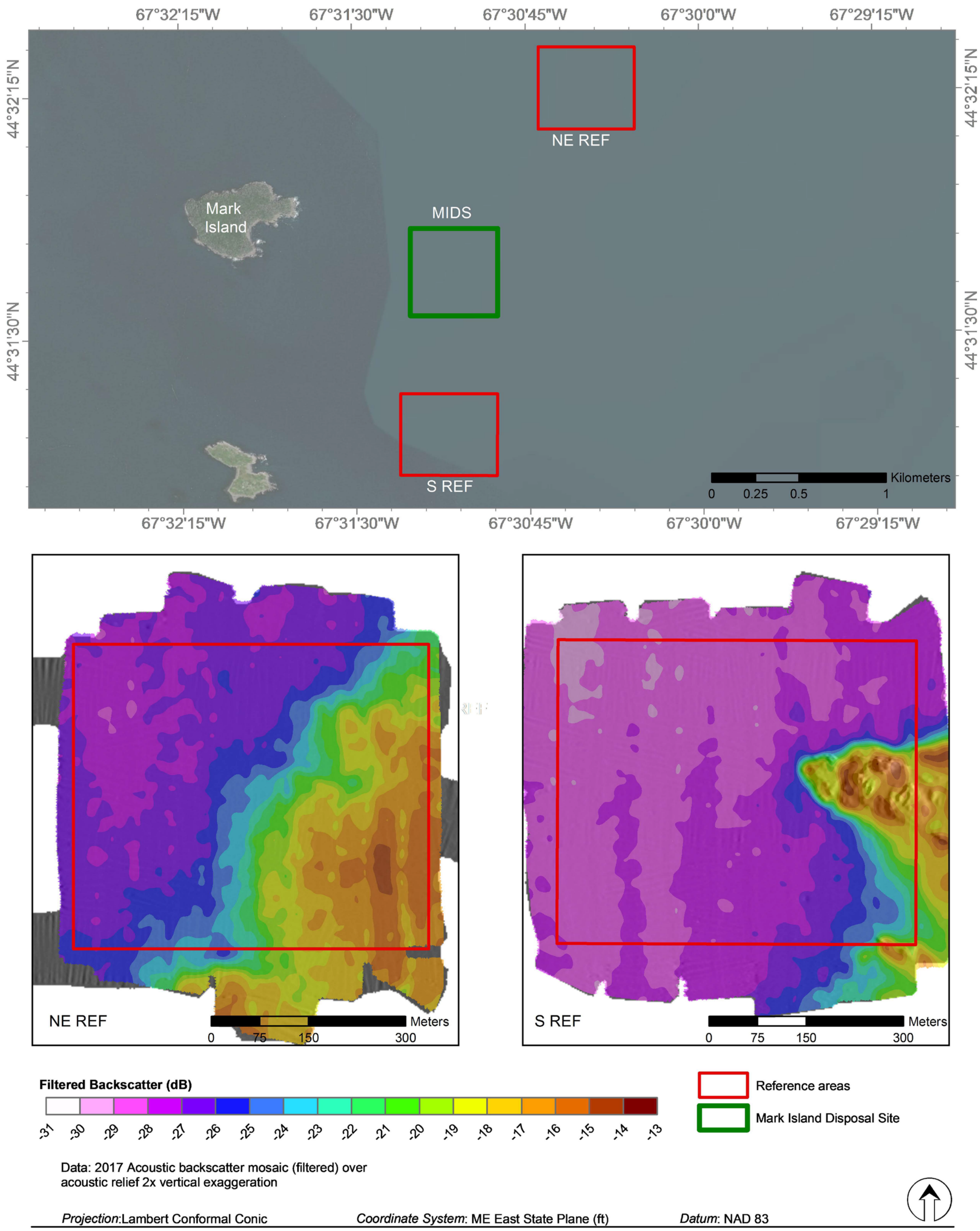

Figure 3-8. Filtered backscatter intensity (dB) at NE REF and S REF, over 2x vertical relief model, November 2017.

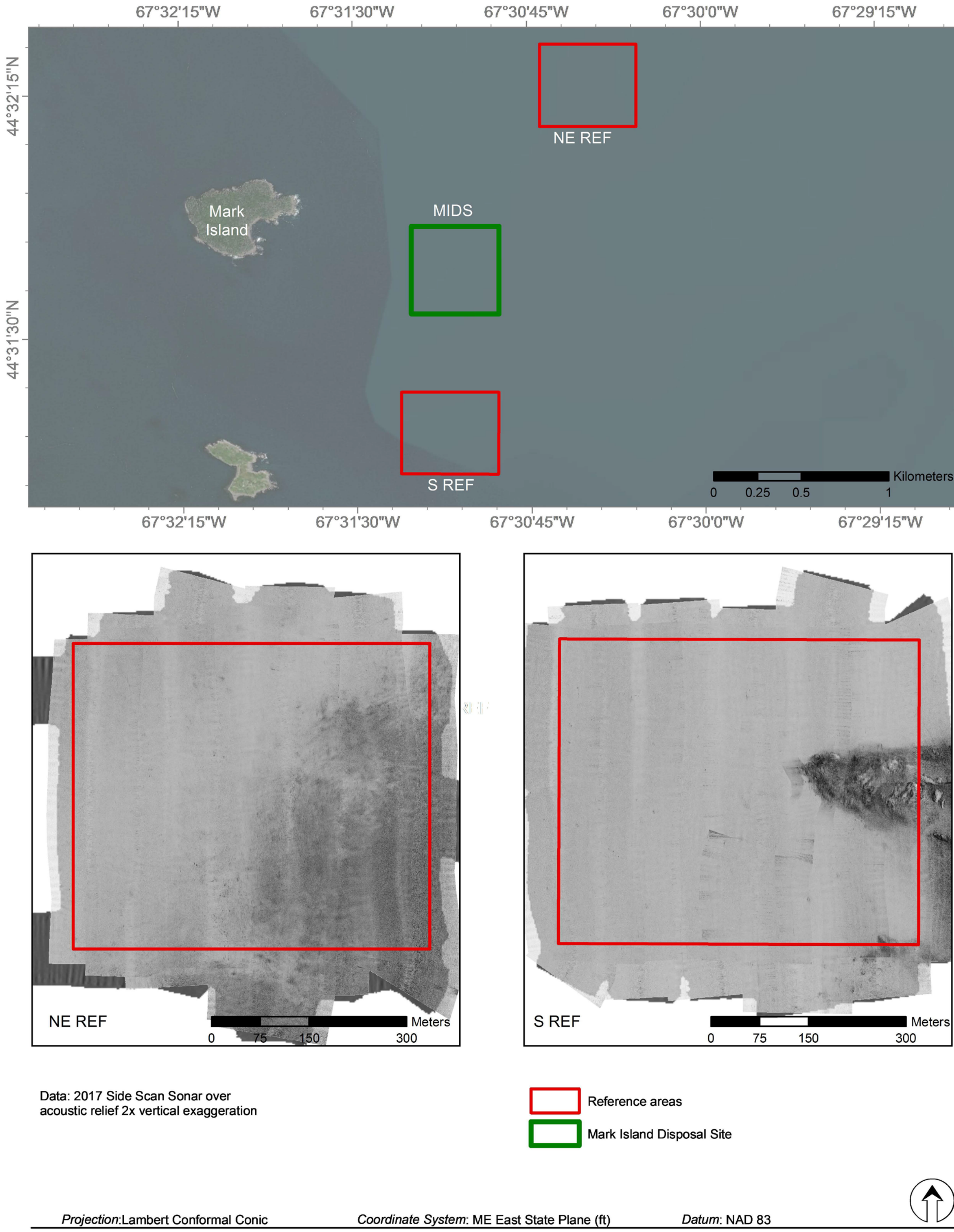

Figure 3-9. Side-scan sonar at NE REF and S REF, over 2x vertical relief model, November 2017.

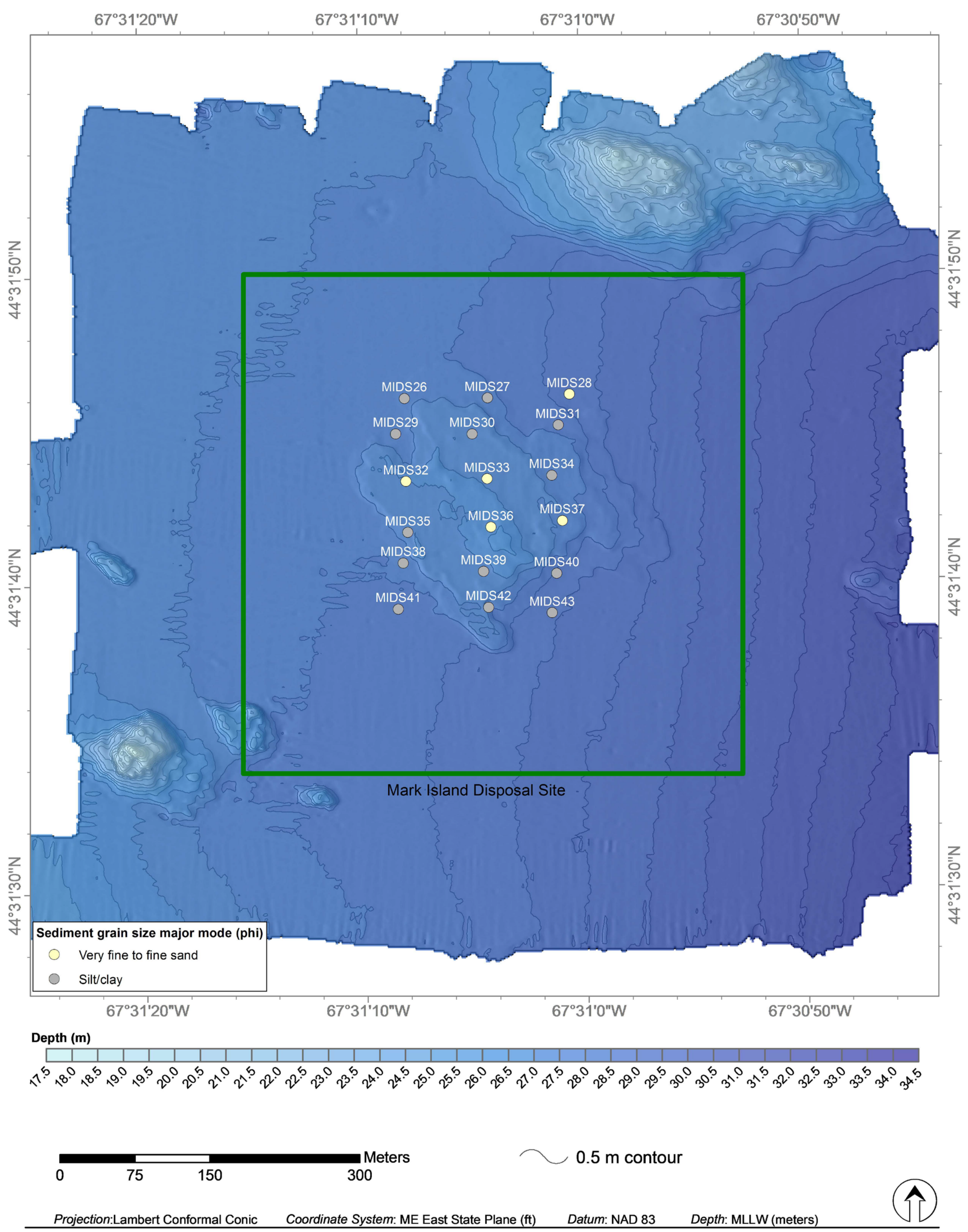

Figure 3-10. Mean grain size (phi) at MIDS over bathymetric data and 2x vertical relief model.

Figure 3-11. Sediment Profile Image (MIDS 40) of layered dredged material and dredged material to the depth of the camera penetration (12.9 cm). Surface feeding void is also present on image.

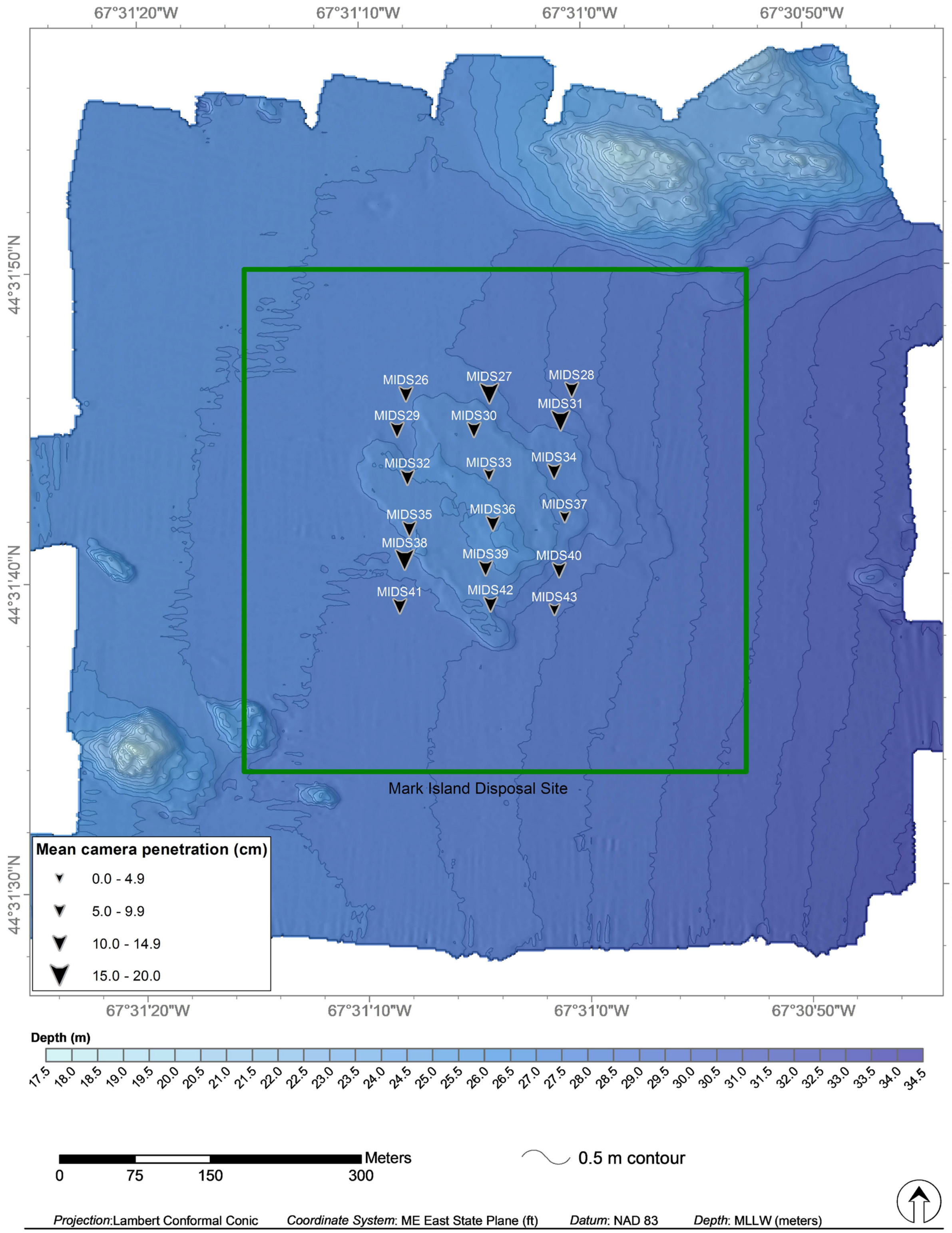

Figure 3-12. Mean replicate camera penetration depths (cm) at MIDS over bathymetric data and 2x vertical relief model.

Figure 3-13. Sediment Profile Image of MIDS-33 (left) displays course grain size (3-2 phi) and reduced camera penetration (5.8 cm). MIDS-27 (right) displays finer grain size (>4 phi) and deeper camera penetration (15.1 cm).

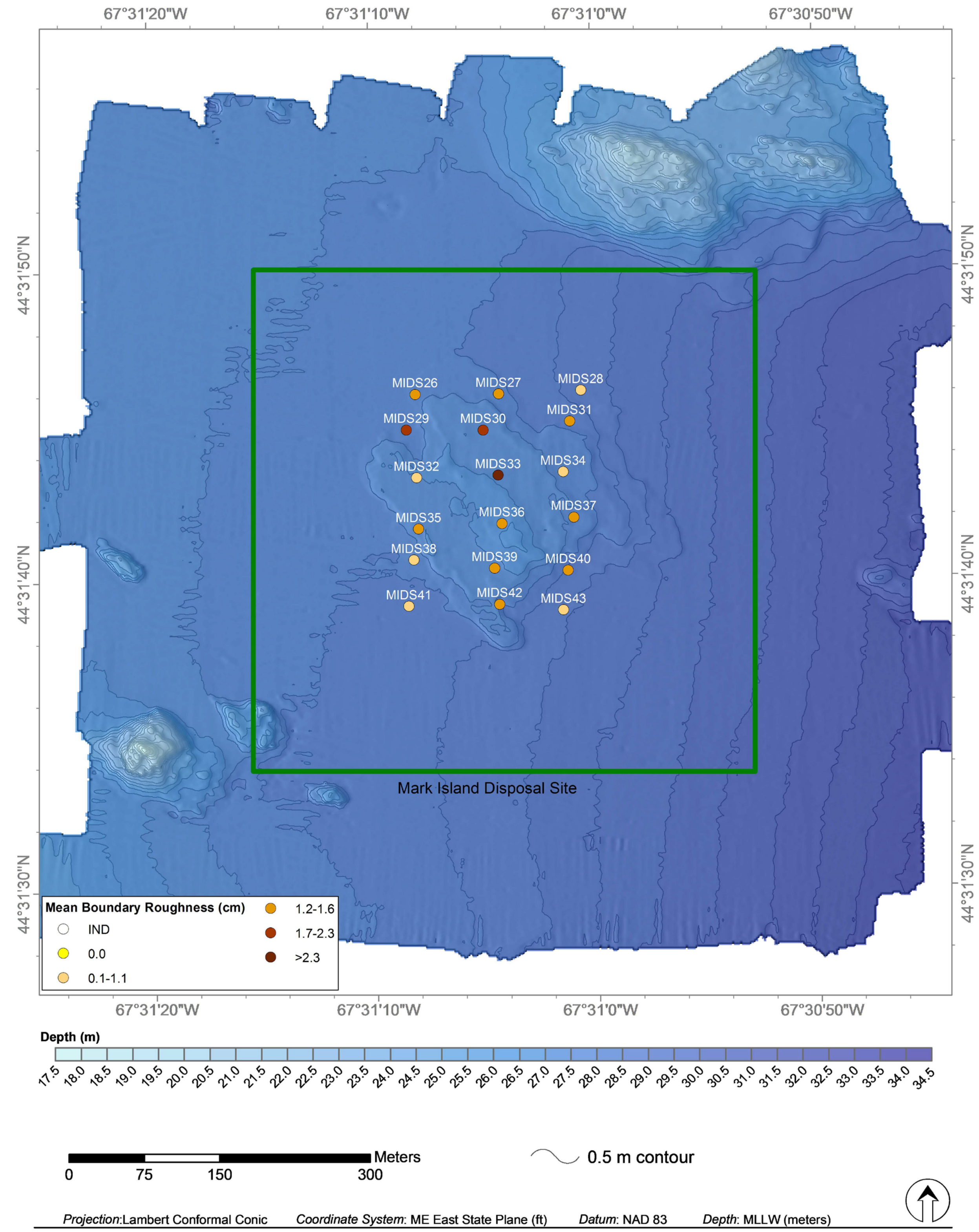

Figure 3-14. Fishing gear assessment within MIDS survey area, 2017.

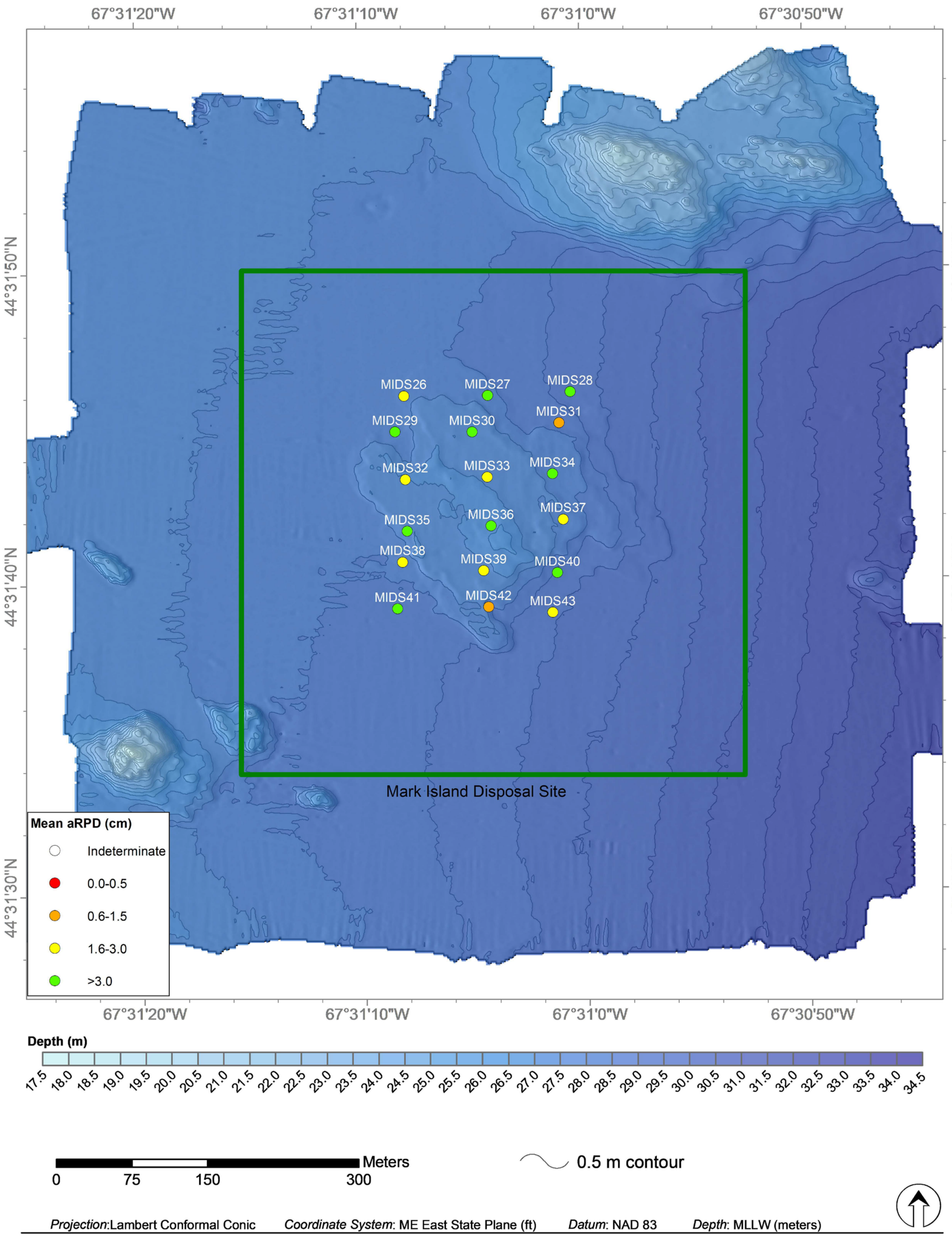

Figure 3-15. Map of mean replicate boundary roughness depths (cm) at MIDS over bathymetric data and 2x vertical relief model.

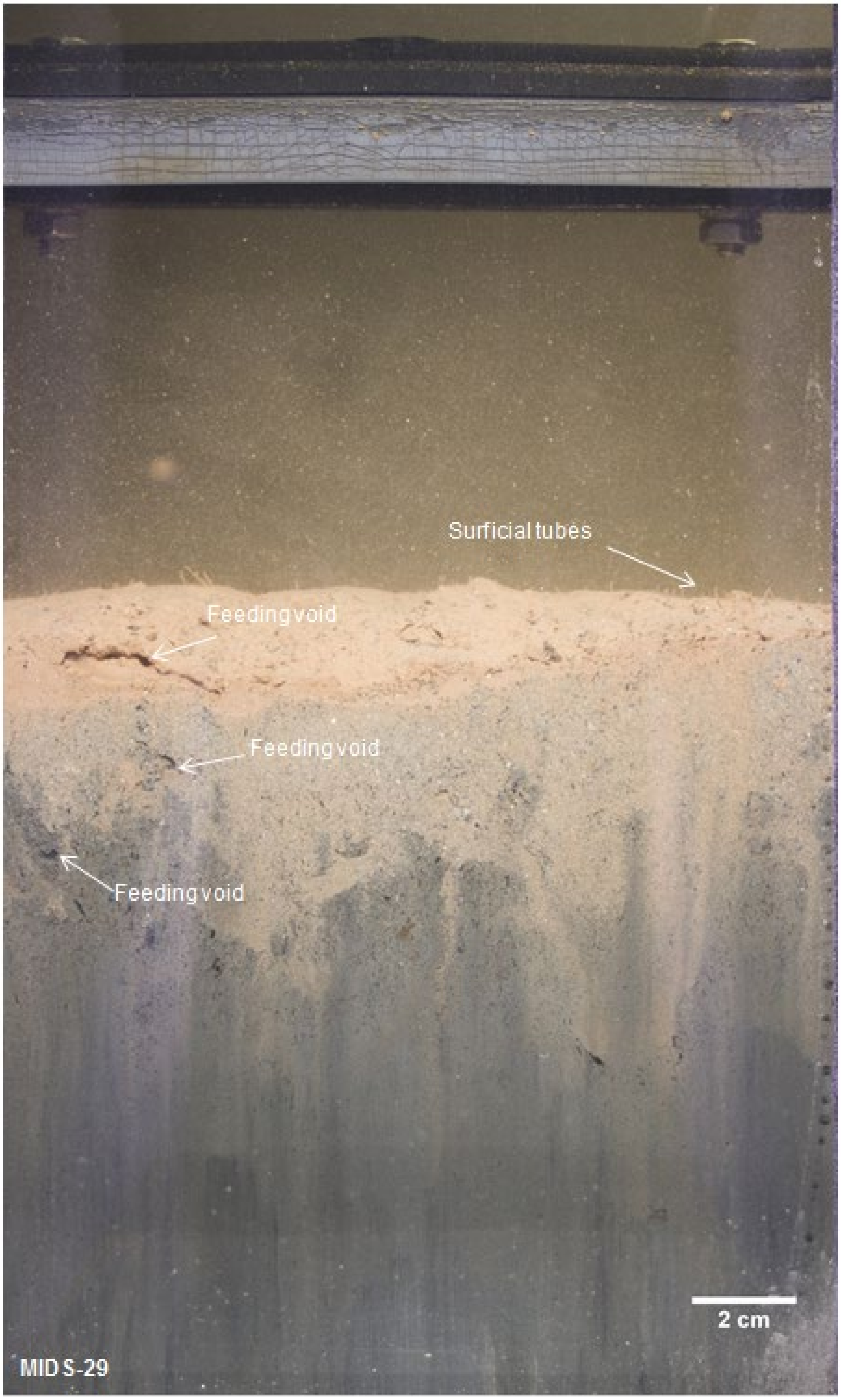

Figure 3-16. Mean of replicate aRPD depths (cm) at MIDS over bathymetric data and 2x vertical relief model.

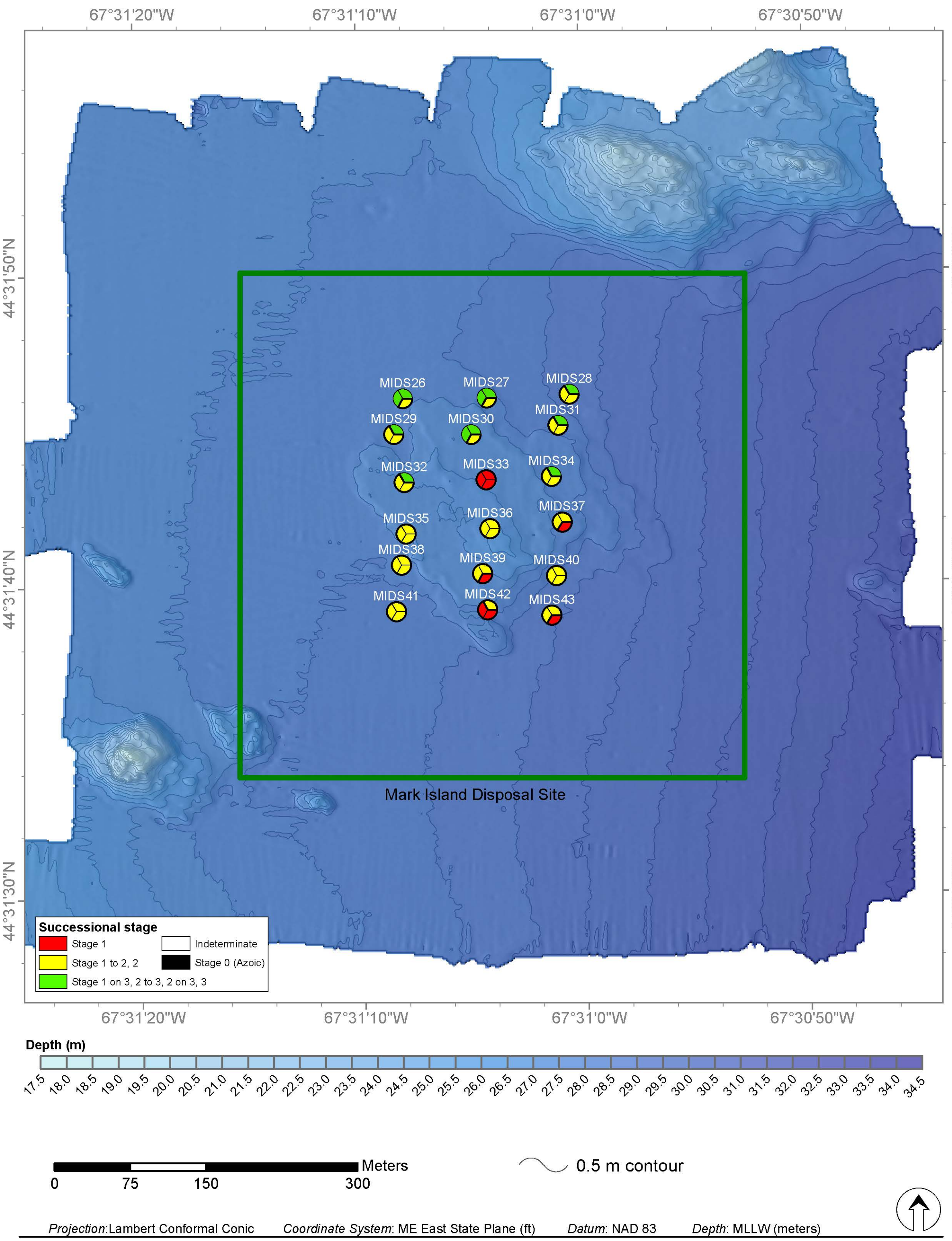

Figure 3-17. Sediment Profile Image of MIDS-29 displays feeding voids and surficial tubes.

Figure 3-18. Plan-view image from MIDS-27. Thin silt layer over sand and shell fragments. Invertebrate trail, tubes and small burrow openings are displayed on the sediment surface

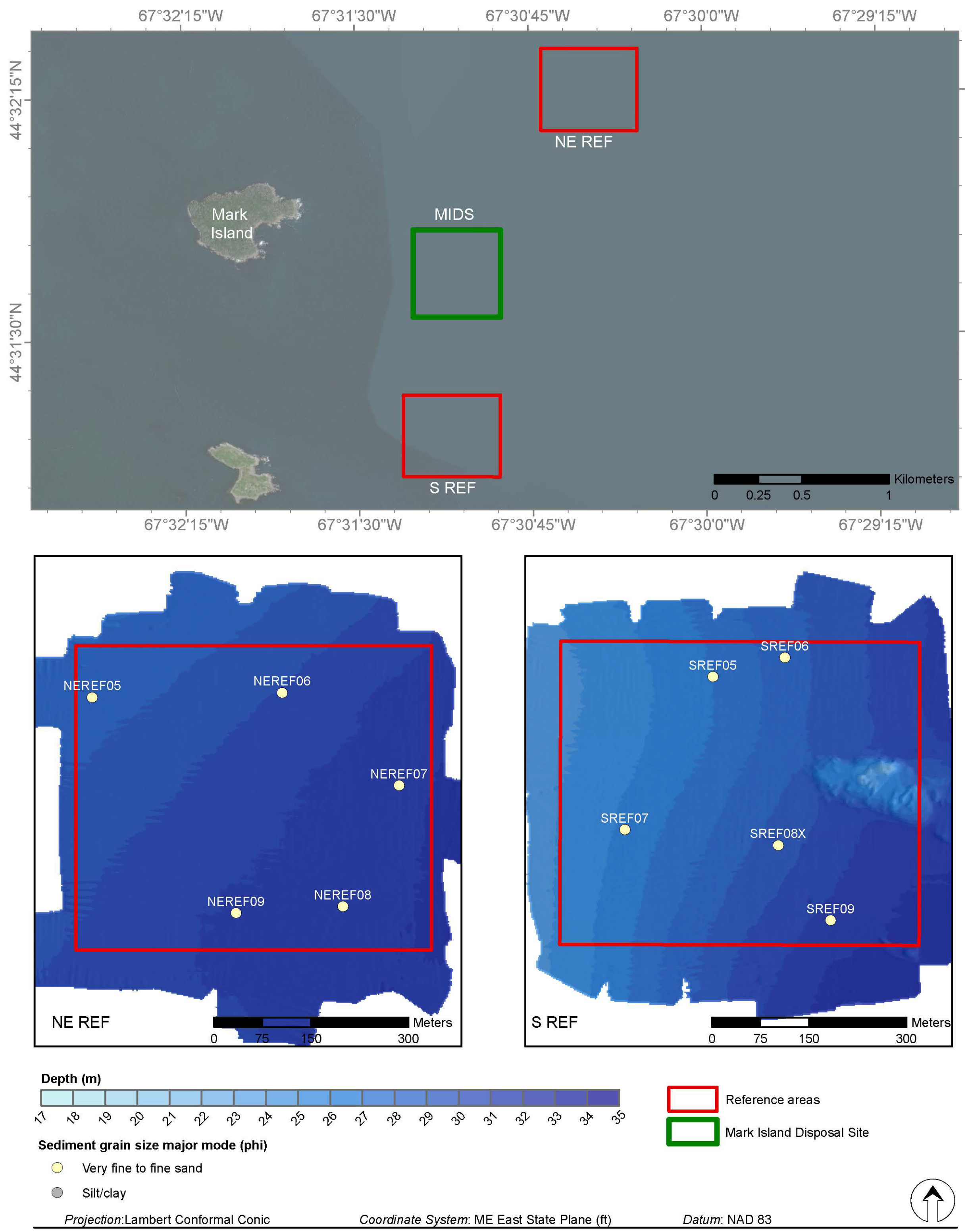

Figure 3-19. Mean of replicate grain size (phi) data at the reference stations over bathymetric data and 2x vertical relief model.

Figure 3-20. Sediment Profile Image of NEREF-05 displaying light-colored clay flecks, also noted during 2002 survey.

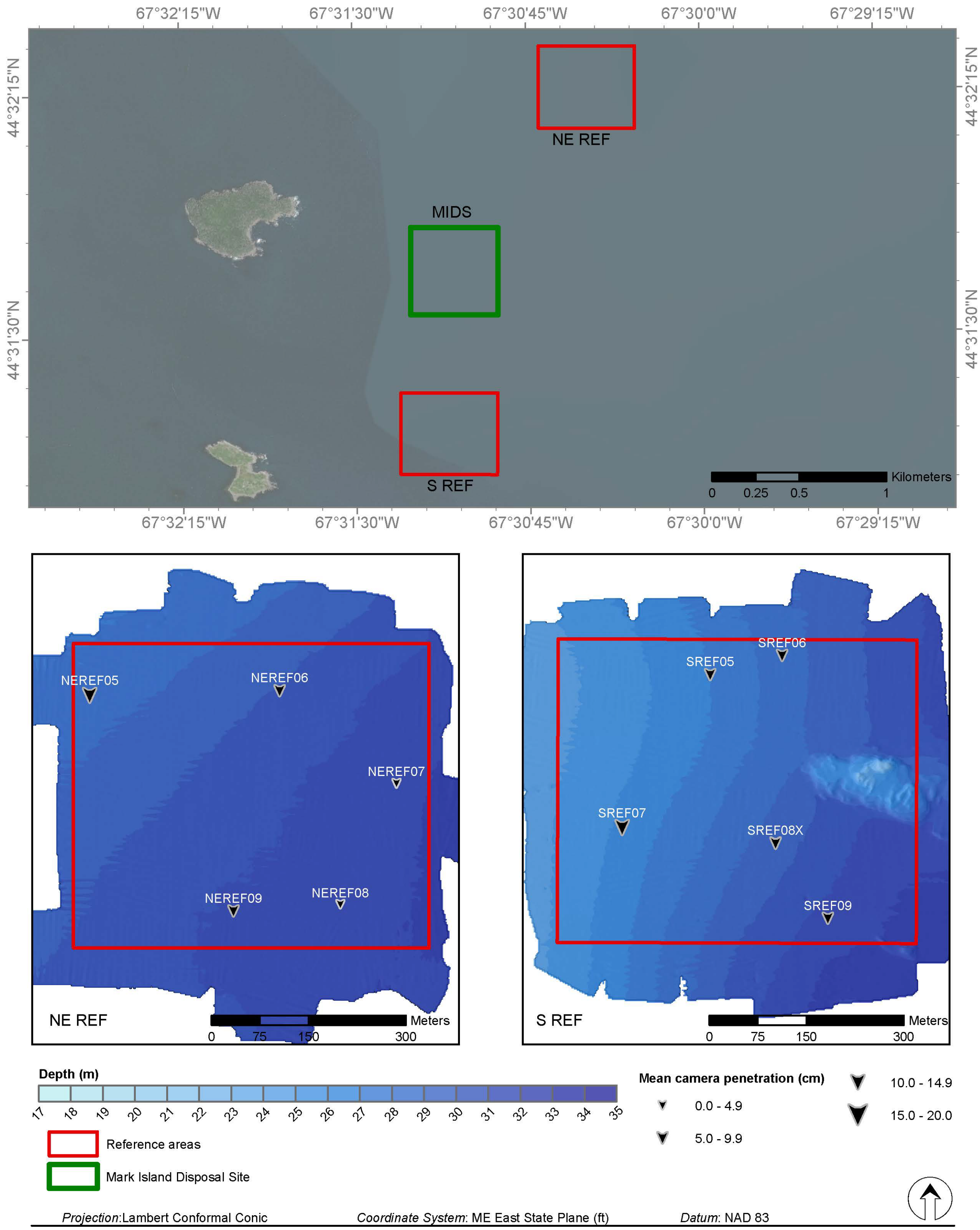

Figure 3-21. Mean of replicate camera penetration depths (cm) at the reference stations over bathymetric data and 2x vertical relief model.

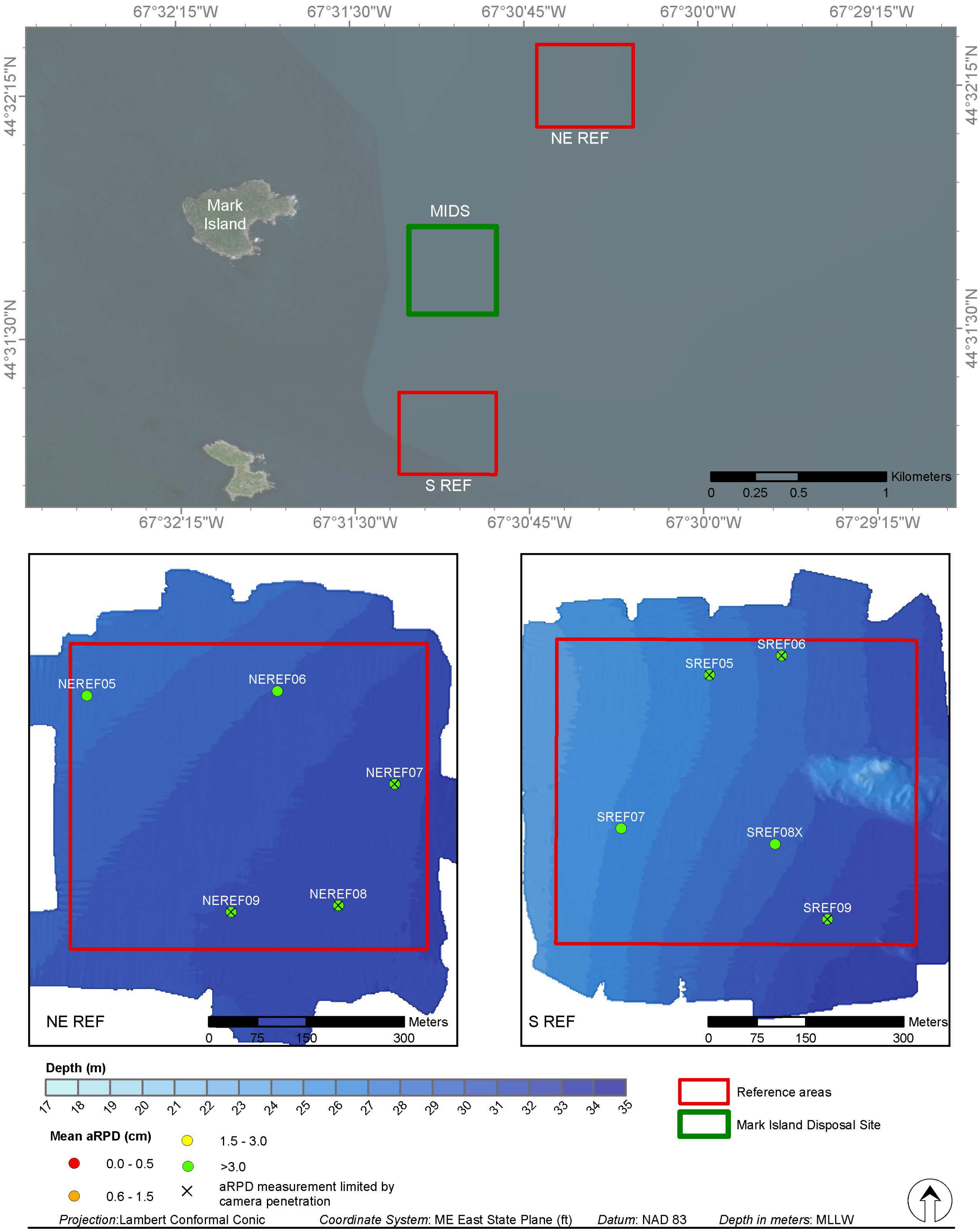

Figure 3-22. Mean of replicate aRPD depths (cm) at the reference stations over bathymetric data and 2x vertical relief model.

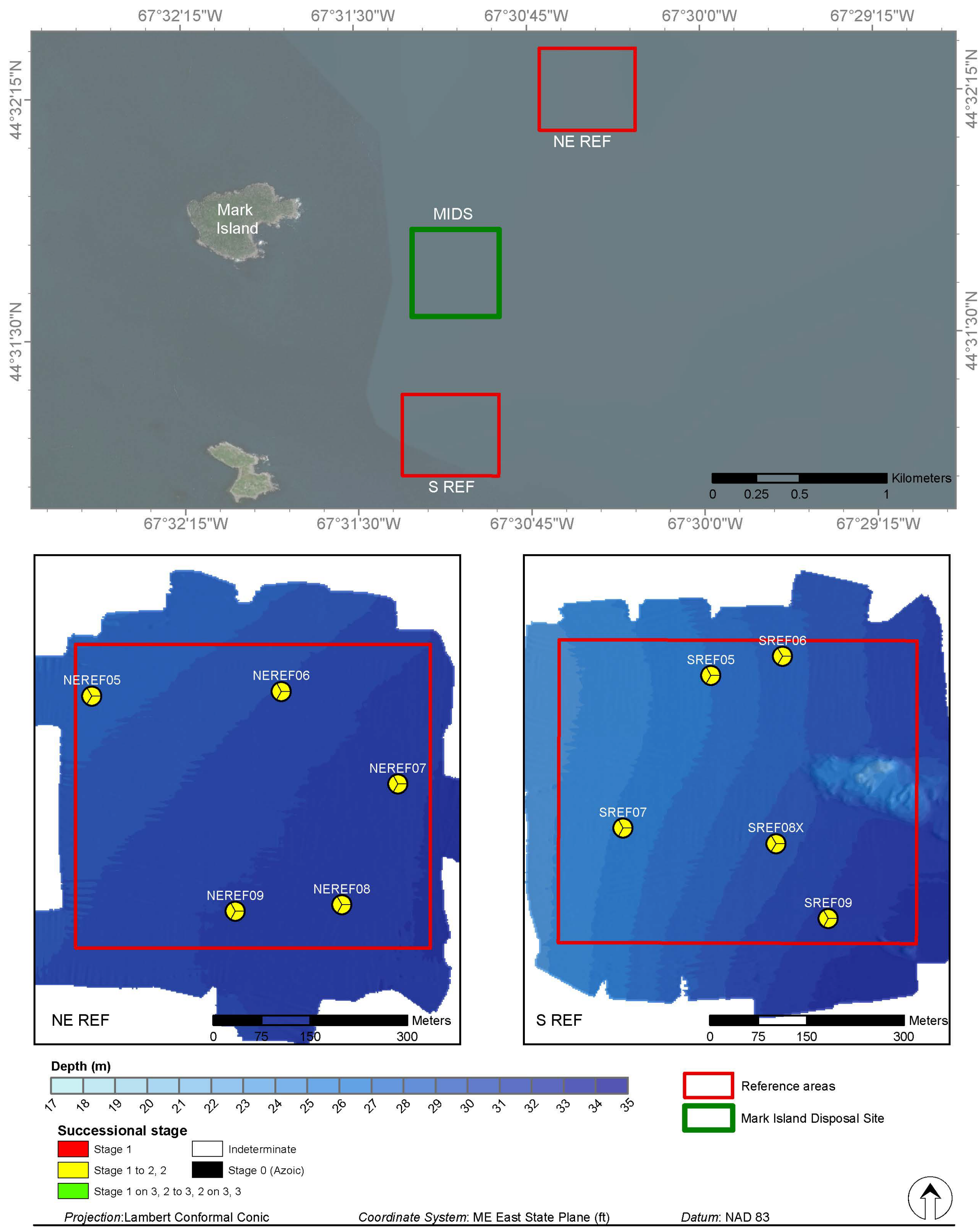

Figure 3-23. Successional stage observed in each replicate image at the reference stations over bathymetric data and 2x vertical relief model.

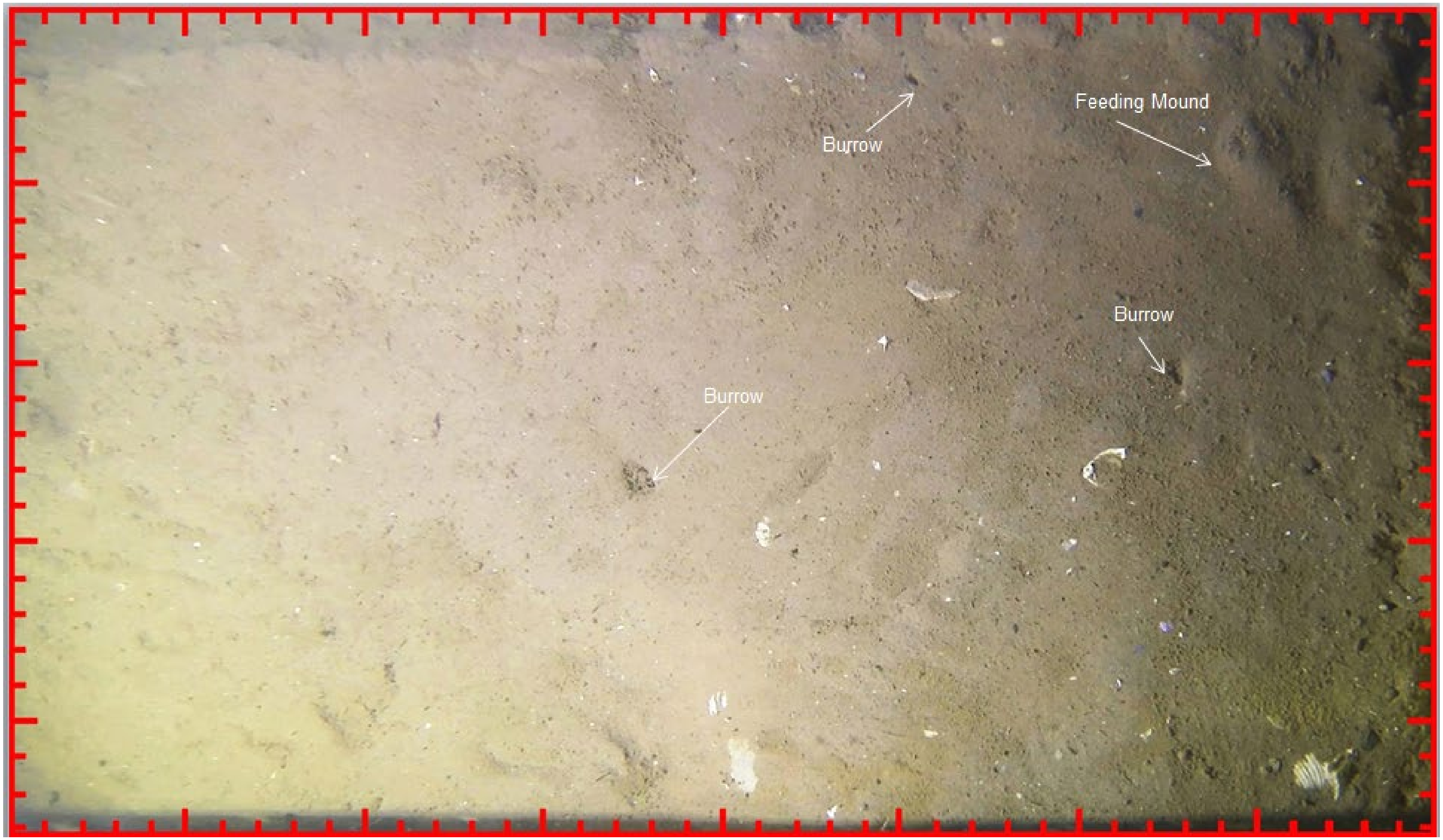

Figure 3-24. Plan-view image from SREF-06. Thin silt layer over sand and shell fragments. Burrow openings and feeding mounds are displayed on the sediment surface.

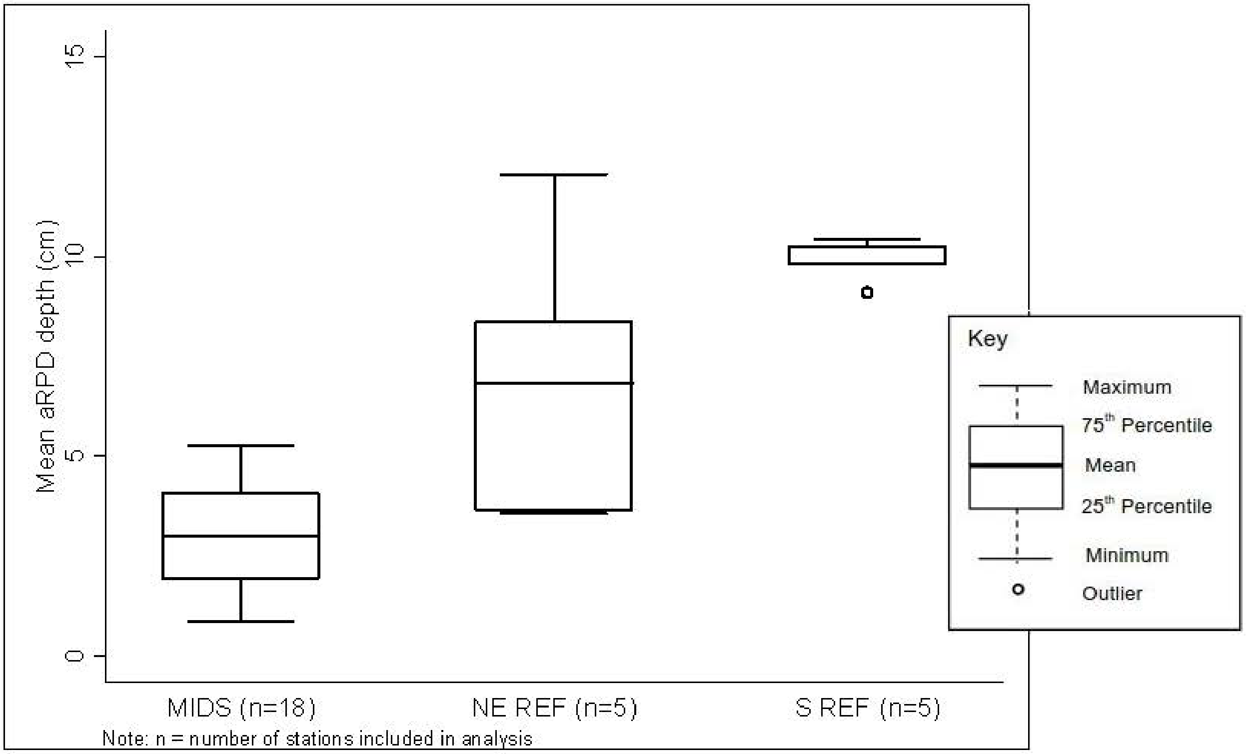

Figure 3-25. Boxplots with distribution of station mean aRPD values for MIDS and reference stations, November 2017 (Includes aRPD values that were not recorded because the redox line was below the camera penetration line. In these cases the max penetration value was used.).

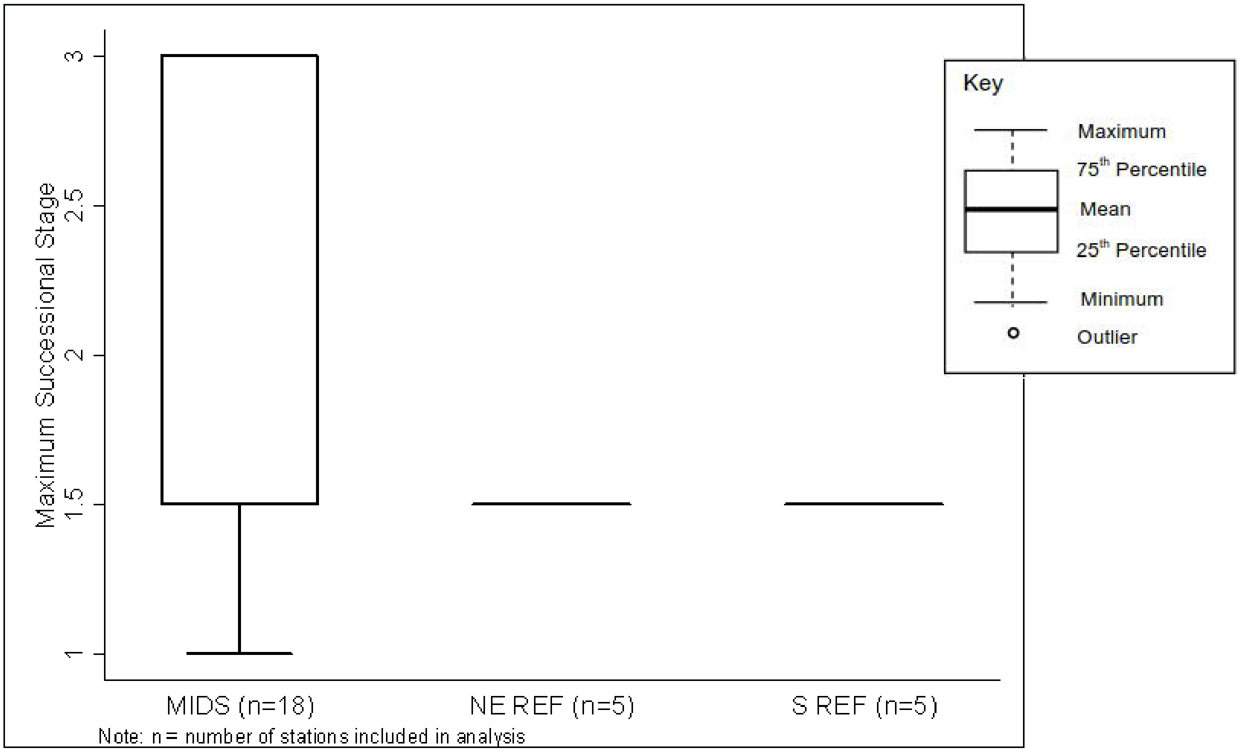

Figure 3-26. Boxplots with distribution of successional stage values for MIDS and reference stations, November 2017.

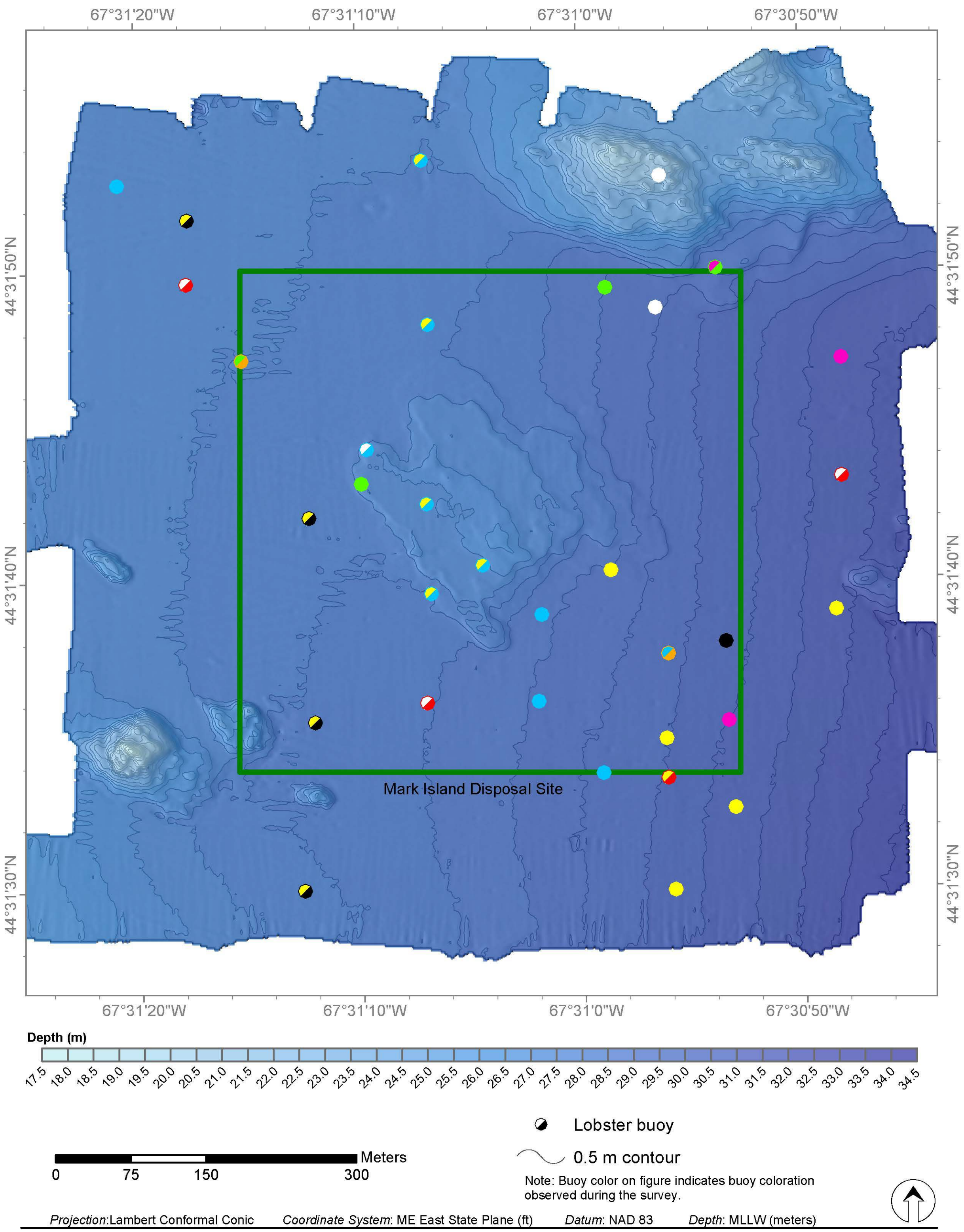

Figure 3-27. Fishing gear assessment within MIDS survey area, 2017.

4.0 DISCUSSION

The objectives of the November 2017 survey of the Mark Island Disposal Site (MIDS) were to document the distribution of dredged material and assess benthic recovery at the site after placement of approximately 88,700 m^3 of dredged material since 2002. Survey tools included an acoustic survey (multibeam bathymetry, backscatter, and side-scan sonar), sediment-profile imaging (SPI), and plan-view imaging.

4.1 Dredged Material Distribution

Dredged material placement at the MIDS was documented during the bathymetric surveys. The bathymetric survey identified a distinct mound formed within the central portion of the site. When compared to the 2002 bathymetric survey, it was apparent that the 88,700 m^3 of material that was placed at the MIDS formed a mound centered in the site that rises to a maximum height of 2 m above the ambient seafloor. The SPI images from the site displayed soft sand and silt overlying dredged material across the mound. Collectively, the bathymetric, backscatter, and image data revealed a the disposal mound as a discrete feature contained within the overall MIDS.

4.2 Benthic Recolonization

As expected, there was greater variability in the successional stage and aRPD depths across the site as compared to the reference areas, but the overall results of the 2017 SPI and PV survey indicated that benthic recolonization had occurred rapidly at the site in the short ten months since dredged material placement was completed in January of 2017. At some locations within MIDS, the successional stage was advanced compared to that of the reference areas as sometimes occurs with the placement of high quality material that may be enriched in organic content compared to the surrounding area. This can lead some disposal sites to become targeted areas for fishing as may be the case for MIDS. Fishing and dredged material disposal can be compatible activities for a site as long as ample notification is provided prior to the start of a dredging project.

4.3 Conclusions and Management Considerations

The results of the 2017 survey demonstrated that nearly 90,000 m^3 of dredged material could be accurately placed and contained within the boundaries of the MIDS. The survey also revealed that the benthic community had achieved nearly a full recovery in the relatively short period of time (10 months) since the cessation of dredged material placement at the site. Given these results, no additional monitoring is considered necessary until significant additional dredged material placement occurs at the site. The following management considerations are proposed:

- Placement of material should continue to target the center of this relatively small site. In particular, the northeast and southwest corners of MIDS should be avoided given the proximity to rocky outcrops identified in the 2017 survey.

- Any future surveys should include collection of sediment samples for benthic community assessment and analysis of total organic carbon to more fully characterize the reference areas as part of the comparison with the disposal site.

5.0 CONCLUSIONS

The November 2017 survey at MIDS was conducted to collect bathymetric data across the entire site and to collect SPI and plan-view imaging at the site and the two reference areas. The survey was designed to assess changes at the site after placement of 88,700 m^3 of dredged material since the previous surveys. The 2017 SPI and bathymetric surveys exhibited the following results:

- The disposal of 88,700 m^3 of dredged material during 2012, 2016, and 2017 created a disposal mound that was detected during the bathymetric survey. Additional bottom features, such as rock outcrops, were also visible during the bathymetric survey.
- Depth difference comparisons of the 2002 and 2017 bathymetric surveys displayed a disposal mound within the central portion of the site rising 2 m from the ambient seafloor.
- SPI images indicated that dredged material was present at all of the sampling stations within MIDS and dredged material was absent from all of the reference locations.
- The benthic community within MIDS has recolonized to reflect reference location conditions.

Additional monitoring of MIDS is only recommended if significant additional dredged material placement occurs at the site.

6.0 REFERENCES

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Appendix A

Disposal Barge Logs for MIDS

Appendix A.

Disposal Barge Logs

Project Name	Permitee	Placement Date	Volume (yd³)	Volume (m³)	Latitude (Degrees)	Longitude (Degrees)	Notes
Beal's Harbor and Pig Island Gut FNP	USACE	1/20/2017	1123	859	44.528	-67.518	excessive speed (>2 kts)
Beal's Harbor and Pig Island Gut FNP	USACE	1/27/2017	1123	859	44.529	-67.518	excessive speed (>2 kts)
Beal's Harbor and Pig Island Gut FNP	USACE	1/28/2017	1123	859	44.528	-67.518	excessive speed (>2 kts)
Beal's Harbor and Pig Island Gut FNP	USACE	1/28/2017	1123	859	44.528	-67.518	
Beal's Harbor and Pig Island Gut FNP	USACE	1/29/2017	1123	859	44.529	-67.517	excessive speed (>2 kts)
Beal's Harbor and Pig Island Gut FNP	USACE	1/31/2017	1123	859	44.528	-67.518	excessive speed (>2 kts)
Beal's Harbor and Pig Island Gut FNP	USACE	2/2/2017	1123	859	44.529	-67.518	
Beal's Harbor and Pig Island Gut FNP	USACE	2/4/2017	1123	859	44.529	-67.518	
Beal's Harbor and Pig Island Gut FNP	USACE	2/5/2017	1123	859	44.528	-67.519	
Beal's Harbor and Pig Island Gut FNP	USACE	2/6/2017	1123	859	44.528	-67.519	
Beal's Harbor and Pig Island Gut FNP	USACE	2/17/2017	1123	859	44.528	-67.519	
Beal's Harbor and Pig Island Gut FNP	USACE	2/20/2017	1123	859	44.528	-67.517	
Beal's Harbor and Pig Island Gut FNP	USACE	2/23/2017	1123	859	44.529	-67.517	
Beal's Harbor and Pig Island Gut FNP	USACE	2/24/2017	1123	859	44.529	-67.519	
Beal's Harbor and Pig Island Gut FNP	USACE	12/8/2016	1123	859	44.529	-67.519	placement outside of target area
Beal's Harbor and Pig Island Gut FNP	USACE	12/10/2016	1123	859	44.529	-67.519	placement outside of target area
Beal's Harbor and Pig Island Gut FNP	USACE	12/11/2016	1123	859	44.529	-67.518	
Beal's Harbor and Pig Island Gut FNP	USACE	1/6/2017	1123	859	44.528	-67.517	excessive speed (>2 kts)

Appendix A.

Disposal Barge Logs

Project Name	Permitee	Placement Date	Volume (yd³)	Volume (m³)	Latitude (Degrees)	Longitude (Degrees)	Notes
Beal’s Harbor and Pig Island Gut FNP	USACE	1/5/2017	1123	859	44.528	-67.519	excessive speed (>2 kts)
Beal’s Harbor and Pig Island Gut FNP	USACE	1/5/2017	1123	859	44.528	-67.519	excessive speed (>2 kts)
Beal’s Harbor and Pig Island Gut FNP	USACE	1/6/2017	1123	859	44.528	-67.519	excessive speed (>2 kts)
Beal’s Harbor and Pig Island Gut FNP	USACE	1/6/2017	1123	859	44.528	-67.518	excessive speed (>2 kts)
Beal’s Harbor and Pig Island Gut FNP	USACE	1/7/2017	1123	859	44.528	-67.519	excessive speed (>2 kts)
Beal’s Harbor and Pig Island Gut FNP	USACE	1/7/2017	1123	859	44.528	-67.518	excessive speed (>2 kts)
Beal’s Harbor and Pig Island Gut FNP	USACE	1/7/2017	1123	859	44.528	-67.519	excessive speed (>2 kts)
Beal’s Harbor and Pig Island Gut FNP	USACE	1/8/2017	1123	859	44.529	-67.518	excessive speed (>2 kts)
Beal’s Harbor and Pig Island Gut FNP	USACE	1/9/2017	1123	859	44.528	-67.519	excessive speed (>2 kts)
Beal’s Harbor and Pig Island Gut FNP	USACE	1/9/2017	1123	859	44.529	-67.519	excessive speed (>2 kts)
Beal’s Harbor and Pig Island Gut FNP	USACE	1/10/2017	1123	859	44.529	-67.518	excessive speed (>2 kts)
Beal’s Harbor and Pig Island Gut FNP	USACE	1/10/2017	1123	859	44.529	-67.518	excessive speed (>2 kts)
Beal’s Harbor and Pig Island Gut FNP	USACE	1/12/2017	1123	859	44.529	-67.518	excessive speed (>2 kts)
Beal’s Harbor and Pig Island Gut FNP	USACE	1/13/2017	1123	859	44.529	-67.517	
Beal’s Harbor and Pig Island Gut FNP	USACE	1/7/2017	1123	859	44.528	-67.518	excessive speed (>2 kts)
Beal’s Harbor and Pig Island Gut FNP	USACE	1/7/2017	1123	859	44.529	-67.519	excessive speed (>2 kts)
Beal’s Harbor and Pig Island Gut FNP	USACE	1/8/2017	1123	859	44.528	-67.518	excessive speed (>2 kts)
Beal’s Harbor and Pig Island Gut FNP	USACE	1/9/2017	1123	859	44.528	-67.519	excessive speed (>2 kts)

Appendix A.

Disposal Barge Logs

Project Name	Permitee	Placement Date	Volume (yd³)	Volume (m³)	Latitude (Degrees)	Longitude (Degrees)	Notes
Beal's Harbor and Pig Island Gut FNP	USACE	1/9/2017	1123	859	44.528	-67.519	excessive speed (>2 kts)
Beal's Harbor and Pig Island Gut FNP	USACE	1/10/2017	1123	859	44.528	-67.518	
Beal's Harbor and Pig Island Gut FNP	USACE	1/10/2017	1123	859	44.528	-67.518	excessive speed (>2 kts)
Beal's Harbor and Pig Island Gut FNP	USACE	1/10/2017	1123	859	44.528	-67.518	excessive speed (>2 kts)
Beal's Harbor and Pig Island Gut FNP	USACE	1/12/2017	1123	859	44.529	-67.519	excessive speed (>2 kts)
Beal's Harbor and Pig Island Gut FNP	USACE	12/20/2016	1123	859	44.529	-67.517	doors open extended period
Beal's Harbor and Pig Island Gut FNP	USACE	12/21/2016	1123	859	44.529	-67.518	
Beal's Harbor and Pig Island Gut FNP	USACE	12/21/2016	1123	859	44.529	-67.518	
Beal's Harbor and Pig Island Gut FNP	USACE	1/20/2017	1123	859	44.528	-67.519	doors open extended period
Beal's Harbor and Pig Island Gut FNP	USACE	1/21/2017	1123	859	44.528	-67.518	
Beal's Harbor and Pig Island Gut FNP	USACE	1/25/2017	1123	859	44.530	-67.520	placement outside of target area
Moosabec Reach	US Coast Guard	1/7/2012	500	382	44.527	-67.518	
Moosabec Reach	US Coast Guard	1/9/2012	500	382	44.528	-67.517	
Moosabec Reach	US Coast Guard	1/9/2012	500	382	44.528	-67.517	
Moosabec Reach	US Coast Guard	1/11/2012	500	382	44.528	-67.518	
Moosabec Reach	US Coast Guard	1/11/2012	500	382	44.528	-67.517	
Moosabec Reach	US Coast Guard	1/16/2012	500	382	44.528	-67.518	
Moosabec Reach	US Coast Guard	1/16/2012	500	382	44.528	-67.518	
Moosabec Reach	US Coast Guard	1/19/2012	500	382	44.528	-67.517	
Moosabec Reach	US Coast Guard	1/21/2012	500	382	44.528	-67.517	
Moosabec Reach	US Coast Guard	1/22/2012	500	382	44.528	-67.518	
Moosabec Reach	US Coast Guard	1/22/2012	500	382	44.528	-67.517	
Moosabec Reach	US Coast Guard	1/25/2012	500	382	44.529	-67.518	
Moosabec Reach	US Coast Guard	1/26/2012	500	382	44.529	-67.518	
Moosabec Reach	US Coast Guard	2/3/2012	500	382	44.529	-67.518	
Beal's Harbor and Pig Island Gut FNP	USACE	12/12/2016	1123	859	44.529	-67.518	

Appendix A.

Disposal Barge Logs

Project Name	Permitee	Placement Date	Volume (yd³)	Volume (m³)	Latitude (Degrees)	Longitude (Degrees)	Notes
Beal's Harbor and Pig Island Gut FNP	USACE	12/13/2016	1123	859	44.529	-67.518	
Beal's Harbor and Pig Island Gut FNP	USACE	12/14/2016	1123	859	44.529	-67.518	excessive speed (>2 kts)
Beal's Harbor and Pig Island Gut FNP	USACE	12/15/2016	1123	859	44.529	-67.519	
Beal's Harbor and Pig Island Gut FNP	USACE	12/8/2016	1123	859	44.529	-67.519	placement outside of target area
Beal's Harbor and Pig Island Gut FNP	USACE	12/9/2016	1123	859	44.529	-67.517	
Beal's Harbor and Pig Island Gut FNP	USACE	12/9/2016	1123	859	44.528	-67.517	
Beal's Harbor and Pig Island Gut FNP	USACE	12/10/2016	1123	859	44.528	-67.519	placement outside of target area
Beal's Harbor and Pig Island Gut FNP	USACE	12/11/2016	1123	859	44.528	-67.519	
Beal's Harbor and Pig Island Gut FNP	USACE	12/11/2016	1123	859	44.528	-67.518	sensor issue
Beal's Harbor and Pig Island Gut FNP	USACE	12/12/2016	1123	859	44.528	-67.518	sensor issue
Beal's Harbor and Pig Island Gut FNP	USACE	12/13/2016	1123	859	44.528	-67.518	sensor issue
Beal's Harbor and Pig Island Gut FNP	USACE	12/14/2016	1123	859	44.528	-67.519	sensor issue
Beal's Harbor and Pig Island Gut FNP	USACE	12/14/2016	1123	859	44.528	-67.518	sensor issue
Beal's Harbor and Pig Island Gut FNP	USACE	12/15/2016	1123	859	44.528	-67.518	
Beal's Harbor and Pig Island Gut FNP	USACE	12/18/2016	1123	859	44.529	-67.518	doors open extended period
Beal's Harbor and Pig Island Gut FNP	USACE	12/19/2016	1123	859	44.529	-67.518	excessive speed (>2 kts)
Beal's Harbor and Pig Island Gut FNP	USACE	12/19/2016	1123	859	44.529	-67.519	excessive speed (>2 kts)
Beal's Harbor and Pig Island Gut FNP	USACE	12/20/2016	1123	859	44.528	-67.518	
Beal's Harbor and Pig Island Gut FNP	USACE	12/21/2016	1123	859	44.529	-67.518	

Appendix A.

Disposal Barge Logs

Project Name	Permitee	Placement Date	Volume (yd^3)	Volume (m^3)	Latitude (Degrees)	Longitude (Degrees)	Notes
Beal's Harbor and Pig Island Gut FNP	USACE	12/21/2016	1123	859	44.529	-67.517	
Beal's Harbor and Pig Island Gut FNP	USACE	12/22/2016	1123	859	44.529	-67.518	
Beal's Harbor and Pig Island Gut FNP	USACE	12/22/2016	1123	859	44.529	-67.519	
Beal's Harbor and Pig Island Gut FNP	USACE	12/18/2016	1123	859	44.529	-67.517	
Beal's Harbor and Pig Island Gut FNP	USACE	12/20/2016	1123	859	44.529	-67.518	
Beal's Harbor and Pig Island Gut FNP	USACE	12/22/2016	1123	859	44.529	-67.518	sensor issue
Beal's Harbor and Pig Island Gut FNP	USACE	12/23/2016	1123	859	44.527	-67.518	sensor issue
Beal's Harbor and Pig Island Gut FNP	USACE	12/23/2016	1123	859	44.530	-67.519	placement outside of target area
Beal's Harbor and Pig Island Gut FNP	USACE	1/3/2017	1123	859	44.528	-67.519	excessive speed (>2 kts)
Beal's Harbor and Pig Island Gut FNP	USACE	1/3/2017	1123	859	44.528	-67.518	excessive speed (>2 kts)
Beal's Harbor and Pig Island Gut FNP	USACE	1/3/2017	1123	859	44.530	-67.519	placement outside of target area
Beal's Harbor and Pig Island Gut FNP	USACE	1/14/2017	1123	859	44.528	-67.518	excessive speed (>2 kts)
Beal's Harbor and Pig Island Gut FNP	USACE	1/15/2017	1123	859	44.528	-67.518	excessive speed (>2 kts)
Beal's Harbor and Pig Island Gut FNP	USACE	1/15/2017	1123	859	44.529	-67.518	excessive speed (>2 kts)
Beal's Harbor and Pig Island Gut FNP	USACE	1/15/2017	1123	859	44.529	-67.518	excessive speed (>2 kts)
Beal's Harbor and Pig Island Gut FNP	USACE	1/16/2017	1123	859	44.528	-67.517	
Beal's Harbor and Pig Island Gut FNP	USACE	1/17/2017	1123	859	44.529	-67.519	excessive speed (>2 kts)
Beal's Harbor and Pig Island Gut FNP	USACE	1/17/2017	1123	859	44.529	-67.518	excessive speed (>2 kts)
Beal's Harbor and Pig Island Gut FNP	USACE	1/20/2017	1123	859	44.529	-67.518	excessive speed (>2 kts)

Appendix A.

Disposal Barge Logs

Project Name	Permitee	Placement Date	Volume (yd^3)	Volume (m^3)	Latitude (Degrees)	Longitude (Degrees)	Notes
Beal’s Harbor and Pig Island Gut FNP	USACE	1/13/2017	1123	859	44.529	-67.518	excessive speed (>2 kts)
Beal’s Harbor and Pig Island Gut FNP	USACE	1/14/2017	1123	859	44.529	-67.518	excessive speed (>2 kts)
Beal’s Harbor and Pig Island Gut FNP	USACE	1/14/2017	1123	859	44.529	-67.517	excessive speed (>2 kts)
Beal’s Harbor and Pig Island Gut FNP	USACE	1/15/2017	1123	859	44.528	-67.518	excessive speed (>2 kts)
Beal’s Harbor and Pig Island Gut FNP	USACE	1/16/2017	1123	859	44.529	-67.518	excessive speed (>2 kts)
Beal’s Harbor and Pig Island Gut FNP	USACE	1/17/2017	1123	859	44.528	-67.518	excessive speed (>2 kts)
Beal’s Harbor and Pig Island Gut FNP	USACE	1/17/2017	1123	859	44.529	-67.519	excessive speed (>2 kts)
Beal’s Harbor and Pig Island Gut FNP	USACE	1/18/2017	1123	859	44.529	-67.518	excessive speed (>2 kts)
Beal’s Harbor and Pig Island Gut FNP	USACE	1/18/2017	1123	859	44.528	-67.518	
Beal’s Harbor and Pig Island Gut FNP	USACE	1/19/2017	1123	859	44.529	-67.518	excessive speed (>2 kts)
Beal’s Harbor and Pig Island Gut FNP	USACE	1/20/2017	1192	911	44.528	-67.519	excessive speed (>2 kts)

Appendix B

Sediment Grain Size Scale

APPENDIX B.

Grain Size Scale Conversions

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

Appendix C

Sediment Profile Imaging Results

Appendix C.

SPI Results

		Penetration	Penetration	Penetration	Dredged Material Present	Dregde Material Thickness	Tubes	Infauna	Burrows	Oxic Voids	Oxic Voids	Anaerobic Voids	Gas Voids
MIDS26	A	16.526	15.734	14.863	Y	4	>20	0	<5	2	5.07,3.94	0	0
MIDS26	B	14.658	15.647	15.228	Y	2.5	>20	0	<5	1	6.3	0	0
MIDS26	C	13.753	15.326	14.554	Y	2.5	>20	0	0	0	0	0	0
MIDS27	A	14.700	15.484	15.083	Y	3.5	>20	0	0	0	0	0	0
MIDS27	B	15.479	16.589	16.160	Y	3.5	>20	0	<5	1	7.3	0	0
MIDS27	C	16.405	17.821	17.063	Y	3.5	>20	0	<5	2	2,1.5	0	0
MIDS28	A	10.595	11.663	11.204	Y	2.5	>20	0	<5	0	0	0	0
MIDS28	B	13.216	14.126	13.545	Y	1	>20	0	<5	0	0	0	0
MIDS28	C	13.437	14.284	14.014	Y	3	>20	0	>5	7	5.7,7.2,4.5,8.1,3.8,8.1,7.9	0	0
MIDS29	A	13.595	15.042	14.345	Y	1	>20	0	<5	4	1.2,4.2,0.5,3.1	0	0
MIDS29	C	12.237	13.053	12.564	Y	4	>20	0	>5	0	0	0	0
MIDS29	D	8.668	11.979	10.330	Y	3	6 to 20	1	<5	0	0	0	0
MIDS30	A	13.721	15.074	14.437	Y	5.5	6 to 20	0	<5	1	4.17	0	0
MIDS30	B	12.616	15.095	13.906	Y	1	>20	0	<5	1	3.01	0	0
MIDS30	C	14.826	16.305	15.518	Y	3	6 to 20	0	0	0	0	0	0
MIDS31	A	15.205	16.779	15.817	Y	7.5	6 to 20	1	0	0	0	0	0
MIDS31	B	14.732	15.705	15.110	Y	4.8	>20	0	<5	0	0	0	0
MIDS31	C	14.637	16.242	15.167	Y	6.3	<6	0	0	3	1, 1.5, 3	0	0
MIDS32	A	16.121	16.747	16.337	Y	5.2	6 to 20	0	<5	1	2.87	0	0
MIDS32	B	10.879	12.295	11.615	Y	4.8	6 to 20	1	<5	0	0	0	0
MIDS32	D	10.184	11.284	10.815	Y	To depth	6 to 20	0	<5	0	0	0	0
MIDS33	A	3.300	6.358	5.801	Y	To depth	6 to 20	0	<5	0	0	0	0
MIDS33	B	9.016	9.895	9.308	Y	To depth	<6	0	<5	0	0	0	0
MIDS33	C	8.100	11.189	10.400	Y	To depth	6 to 20	0	<5	1	4.5	0	0
MIDS34	A	12.553	13.621	13.234	Y	3.5	6 to 20	1	<5	0	0	0	0
MIDS34	B	13.026	13.495	13.251	Y	4.5	>20	1	<5	0	0	0	0
MIDS34	C	16.405	17.505	16.864	Y	5.5	>20	0	<5	1	3.5	0	0
MIDS35	A	13.311	13.874	13.597	Y	Trace	>20	0	<5	0	0	0	0
MIDS35	B	14.289	16.053	15.124	Y	3.2	>20	0	<5	0	0	0	0
MIDS35	C	11.889	13.432	12.729	Y	Trace	6 to 20	0	<5	1	4.81	0	0
MIDS36	A	13.247	14.253	13.809	Y	To depth	6 to 20	0	0	1	6.21	0	0
MIDS36	B	10.311	11.947	11.138	Y	To depth	<6	1	0	1	2.53	0	0
MIDS36	C	4.216	6.263	5.203	Y	To depth	6 to 20	0	0	1	2.56	0	0
MIDS37	A	11.826	12.579	12.084	Y	To depth	<6	0	0	0	0	0	0
MIDS37	B	8.605	9.453	8.997	Y	To depth	<6	0	0	1	0.33	0	0
MIDS37	C	0.000	1.779	1.142	Y	To depth	<6	0	0	0	0	0	0
MIDS38	A	15.742	16.337	16.086	Y	8.5	6 to 20	0	0	0	0	0	0
MIDS38	B	12.742	14.126	13.331	Y	3.7	6 to 20	0	0	0	0	0	0
MIDS38	C	15.047	16.274	15.461	Y	To depth	6 to 20	0	0	0	0	0	0
MIDS39	A	11.637	12.484	12.213	Y	To depth	<6	0	0	0	0	0	0
MIDS39	B	14.700	15.958	15.426	Y	To depth	<6	0	0	0	0	1	0
MIDS39	C	7.089	8.347	7.490	Y	To depth	<6	0	0	0	0	0	0
MIDS40	A	9.963	12.895	11.329	Y	To depth	6 to 20	0	0	0	0	0	0

Appendix C.

SPI Results

		Penetration	Penetration	Penetration	Dredged Material Present	Dregde Material Thickness	Tubes	Infauna	Burrows	Oxic Voids	Oxic Voids	Anaerobic Voids	Gas Voids
MIDS40	B	12.079	12.926	12.333	Y	To depth	<6	0	0	1	8.21	0	0
MIDS40	C	13.484	14.253	13.047	Y	To depth, good image	<6	1	<5	0	0	0	0
MIDS41	A	14.826	15.263	15.049	Y	6.3	6 to 20	0	0	0	0	0	0
MIDS41	B	14.163	14.979	14.603	Y	6.5	6 to 20	1	0	0	0	0	0
MIDS41	C	11.542	13.526	12.316	Y	To depth	6 to 20	0	0	0	0	0	0
MIDS42	A	5.289	6.516	5.798	Y	To depth	<6	0	0	0	0	0	0
MIDS42	B	10.216	11.821	11.345	Y	To depth	<6	0	0	0	0	0	0
MIDS42	C	13.911	14.600	14.221	Y	To depth	6 to 20	0	<5	0	0	0	0
MIDS43	A	12.047	12.389	12.272	Y	To depth	6 to 20	0	0	1	2.11	0	0
MIDS43	B	7.784	8.537	8.164	Y	To depth	<6	0	0	0	0	0	0
MIDS43	C	8.416	9.516	8.824	Y	To depth	6 to 20	0	0	1	2.34	0	0

Appendix C.

SPI Results

		Successional		Fauna		General Comment
MIDS26	A	I on III	III	Pit mound	11	
MIDS26	B	I on III	III	Numerous small tubes	9	
MIDS26	C	I on III	I to II		9	Possible organic material left side of image
MIDS27	A	I on III	I to II	III, possible void lower right, not clearly defined	10	
MIDS27	B	I on III	III		11	wiper smear
MIDS27	C	I on III	III		7	
MIDS28	A	I on III	I to II		11	
MIDS28	B	I on III	I to II		11	relict aRPD 5.5cm
MIDS28	C	I on III	III		11	
MIDS29	A	I on III	III		10	
MIDS29	C	I on III	I to II	Pit mound	11	
MIDS29	D	I on III	I to II		9	
MIDS30	A	I on III	III		11	
MIDS30	B	I on III	III		6	
MIDS30	C	I on III	I to II		8	
MIDS31	A	I on III	I to II		6	>15.2 Dredged material, relict aRPD?
MIDS31	B	I on III	I to II		8	>15.7 Dredged material
MIDS31	C	I on III	III		6	
MIDS32	A	I on III	III		8	trace at surface
MIDS32	B	I	I to II	gastropod shell and other large shell hash	2	clay clasts at surface
MIDS32	D	I on III	I to II		8	Dredged material >10
MIDS33	A	I	I	gastropod shell's and other shell hash	6	reddish color sediment, Dredged material >6
MIDS33	B	I	I		4	reddish color sediment, Dredged material >9
MIDS33	C	I	I		6	reddish color sediment, Dredged material >10
MIDS34	A	I on III	I to II	Polycheate @ 4.17cm	11	Dredged material >10
MIDS34	B	I on III	I to II	Polychaete @ 7.99cm	9	Dredged material >10
MIDS34	C	I on III	III		11	Dredged material >10
MIDS35	A	I on III	I to II	Fecal pellets present	8	Dredged material >13
MIDS35	B	I on III	I to II	Pit mound	11	drege material >13
MIDS35	C	I on III	I to II		9	Dredged material >13
MIDS36	A	I on III	I to II		8	Dredged material > 14
MIDS36	B	I on III	I to II	Gastropod shell	8	Dredged material > 11
MIDS36	C	I on III	I to II		11	Dredged material > 6
MIDS37	A	I on III	I to II		7	Dredged material >12
MIDS37	B	I on III	I to II		9	Dredged material >9
MIDS37	C	I	I	Shell hash at surface	IND	Shallow penetration, hard sediment, Dredged material >1.8
MIDS38	A	I on III	I to II		7	Relict aRPD at 8
MIDS38	B	I on III	I to II		8	Relict aRPD at 4
MIDS38	C	I on III	I to II		10	Relict aRPD at depth
MIDS39	A	I on III	I to II		8	drege material >12
MIDS39	B	I on III	I to II		6	Dredged material >15
MIDS39	C	I	I		6	Dredged material >7.5, large clay patch
MIDS40	A	I on III	I to II	*Mytilus edulis* shell, dead, few	9	Dredged material >12

Appendix C.

SPI Results

		Successional		Fauna		General Comment
MIDS40	B	I on III	I to II		11	Dredged material >12
MIDS40	C	I on III	I to II	Hermit crab and large burrow	11	Dredged material >14
MIDS41	A	I on III	I to II		11	trace at surface
MIDS41	B	I on III	I to II	Polycheate present @ 5.34cm	11	relict aRPD 6, Dredged material below 6 cm
MIDS41	C	I on III	I to II		7	Dredged material >8cm lsft side
MIDS42	A	I	I		3	Dredged material >6, anoxic Dredged material at surface and depth
MIDS42	B	I	I		2	Dredged material to depth, >11
MIDS42	C	I on III	I to II	large burrow	7	Dredged material to >14 cm
MIDS43	A	I on III	I to II	Dredged material to >12cm	11	Dredged >12
MIDS43	B	I	I		3	
MIDS43	C	I on III	I to II	Fecal pellets present	11	Dredged to 8 cm

Appendix D

Plan View Imaging Results

Appendix D.

Plan View Results

Location	Station	Replicate	Whole Image Area (m2)	Boundary Roughness Type	Surface Sediment Type	Shell Coverage	Bedforms	Feeding Pits/Mounds	Burrow Openings	Tubes	Snails or Hermit Crabs	Colonial Epifauna	Comment
Mark Island	MIDS26	**A**	0.1	Biological/Physical	Thin silt-clay layer over sand and shell fragments	<10%							marginally analyzable - image quality poor
Mark Island	MIDS27	**A**	0.1	Biological/Physical	Thin silt-clay layer over sand and shell fragments	<10%	Asymmetric	-	+	+	+	-	
Mark Island	MIDS27	**B**	0.1	Biological/Physical	Thin silt-clay layer over sand and shell fragments	<10%	Asymmetric	+	+	+	-	-	
Mark Island	MIDS27	**C**	0.1	Biological/Physical	Thin silt-clay layer over sand and shell fragments	<10%	Asymmetric	+	+	+	-	-	
Mark Island	MIDS28	**A**	0.1	Biological/Physical	Thin silt-clay layer over sand and shell fragments	<10%	-	+	+	+	-	+	Chaetopteridae tubes
Mark Island	MIDS28	**B**	0.1	Biological/Physical	Thin silt-clay layer over sand and shell fragments	<10%	-	+	+	+	-	-	
Mark Island	MIDS28	**C**	0.1	Biological/Physical	Thin silt-clay layer over sand and shell fragments	<10%							marginally analyzable - image quality poor
Mark Island	MIDS29	**A**	0.1	Biological/Physical	Medium-coarse sand with shell fragments	<10%	-	-	+	-	-	-	
Mark Island	MIDS29	**B**	0.1	Biological/Physical	Medium-coarse sand with shell fragments	<10%	-	+	+	+	-	+	
Mark Island	MIDS30	**A**	0.1	Biological/Physical	Thin silt-clay layer over sand and shell fragments	<10%							Unanalyzable-image poor quality
Mark Island	MIDS30	**B**	0.1	Biological/Physical	Thin silt-clay layer over sand and shell fragments	<10%							Unanalyzable-image poor quality
Mark Island	MIDS30	**C**	0.1	Biological/Physical	Thin silt-clay layer over sand and shell fragments	<10%							marginally analyzable - image quality poor
Mark Island	MIDS31	**A**	0.1	Biological/Physical	Thin silt-clay layer over sand and shell fragments	<10%	-	+	+	+	-	-	
Mark Island	MIDS31	**B**	0.1	Biological/Physical	Thin silt-clay layer over sand and shell fragments	<10%	-	-	+	+	-	-	
Mark Island	MIDS31	**C**	0.1	Biological/Physical	Thin silt-clay layer over sand and shell fragments	<10%							marginally analyzable - image quality poor
Mark Island	MIDS34	**A**	0.1	Biological/Physical	Medium-coarse sand with shell fragments	<10%	-	+	-	+	-	-	possible epifauna on right side, not colonial
Mark Island	MIDS34	**B**	0.1	Biological/Physical	Medium-coarse sand with shell fragments	<10%	-	-	-	+	-	-	
Mark Island	MIDS34	**C**	0.1	Biological/Physical	Medium-coarse sand with shell fragments	<10%	-	+	+	+	-	-	
Mark Island	MIDS37	**A**	0.1	Biological/Physical	Thin silt-clay layer over sand and shell hash	10-25%							marginally analyzable - image quality poor
Mark Island	MIDS40	**A**	0.1	Biological/Physical	Thin silt-clay layer over sand and shell fragments	<10%	Asymmetric	-	+	+	-	-	
Mark Island	MIDS40	**B**	0.1	Biological/Physical	Thin silt-clay layer over sand and shell fragments	<10%	Asymmetric	+	+	+	-	-	
Mark Island	MIDS40	**C**	0.1	Biological/Physical	Thin silt-clay layer over sand and shell fragments	<10%							Unanalyzable-image poor quality
Mark Island	MIDS43	**A**	0.1	Biological/Physical	Thin silt-clay layer over sand and shell fragments	<10%							Unanalyzable-image poor quality
Mark Island	MIDS43	**B**	0.1	Biological/Physical	Thin silt-clay layer over sand and shell fragments	<10%							Unanalyzable-image poor quality
Mark Island	MIDS43	**C**	0.1	Biological/Physical	Thin silt-clay layer over sand and shell fragments	<10%	-	+	+	+	-	-	
Mark Island	NER05	**E**	0.1	Biological/Physical	Thin silt-clay layer over sand and shell	<10%	-	+	+	-	-	-	
Mark Island	NER06	**A**	0.1	Biological/Physical	Medium-coarse sand with shell hash	<10%	-	-	-	-	-	-	marginally analyzable - image quality poor
Mark Island	NER07	**A**	0.1	Physical	Medium-coarse sand with shell hash	50-75%	-	+	-	+	-	+	
Mark Island	NER07	**B**	0.1	Physical	Medium-coarse sand with shell hash	25-50%	Asymmetric						marginally analyzable - image quality poor
Mark Island	NER08	**A**	0.1	Biological/Physical	Medium-coarse sand with shell hash	10-25%	-	+	+	+	-	-	
Mark Island	NER09	**A**	0.1	Physical	Thin silt-clay layer over sand and shell fragments	<10%							Unanalyzable-image poor quality
Mark Island	NER09	**B**	0.1	Biological/Physical	Thin silt-clay layer over sand and shell fragments	<10%	Asymmetric	+	+	+	-	-	
Mark Island	SF05	**A**	0.1	Physical	Thin silt-clay layer over sand and shell fragments	<10%	-	-	-	-	-	-	marginally analyzable - image quality poor
Mark Island	SF05	**C**	0.1	Biological/Physical	Thin silt-clay layer over sand and shell fragments	<10%	-	+	+	-	-	-	marginally analyzable - image quality poor
Mark Island	SF06	**A**	0.1	Biological/Physical	Thin silt-clay layer over sand and shell fragments	<10%	-	-	+	-	-	-	
Mark Island	SF07	**A**	0.1	Biological/Physical	Thin silt-clay layer over sand and shell fragments	<10%							Unanalyzable-image poor quality
Mark Island	SF07	**B**	0.1	Biological/Physical	Thin silt-clay layer over sand and shell fragments	<10%							Unanalyzable-image poor quality
Mark Island	SF07	**C**	0.1	Biological/Physical	Thin silt-clay layer over sand and shell fragments	<10%							Unanalyzable-image poor quality
Mark Island	SF08X	**A**	0.1	Biological/Physical	Thin silt-clay layer over sand and shell fragments	<10%							Unanalyzable-image poor quality
Mark Island	SF09	**A**	0.1	Biological/Physical	Thin silt-clay layer over sand and shell fragments	<10%	Asymmetric	+	+	+	-	-	
Mark Island	SF09	**B**	0.1	Biological/Physical	Thin silt-clay layer over sand and shell fragments	<10%	Asymmetric	+	+	+	-	-	
Mark Island	SF09	**C**	0.1	Biological/Physical	Thin silt-clay layer over sand and shell fragments	<10%							Unanalyzable-image poor quality

Appendix E

Surface Marker Buoys

Appendix E

Surface Buoy Markers

Buoy Description	Water Depth (m)	Latitude (N)	Longitude (W)	Location
Green/Pink	30.32	44° 31.8336	67° 30.8981	MIDS Site
Black	31.6	44° 31.6325	67° 30.8932	MIDS Site
Pink	31.89	44° 31.5898	67° 30.8914	MIDS Site
Red/Yellow	31.37	44° 31.5591	67° 30.9374	MIDS Site
Yellow	31.3	44° 31.5804	67° 30.9387	MIDS Site
Orange/Blue	31.31	44° 31.6259	67° 30.9368	MIDS Site
White	30.89	44° 31.8126	67° 30.9435	MIDS Site
Green	30.45	44° 31.8236	67° 30.9814	MIDS Site
Yellow	30.45	44° 31.6711	67° 30.9794	MIDS Site
Blue	31.21	44° 31.5620	67° 30.9864	MIDS Site
Blue	30.52	44° 31.6010	67° 31.0346	MIDS Site
Blue	30.27	44° 31.6476	67° 31.0320	MIDS Site
Blue/Yellow	28.92	44° 31.6745	67° 31.0761	MIDS Site
Large Red/White and Solid Green	30.33	44° 31.6007	67° 31.1188	MIDS Site
Yellow/Blue	29.55	44° 31.6594	67° 31.1149	MIDS Site
Yellow/Blue	28.74	44° 31.7078	67° 31.1176	MIDS Site
Blue/Yellow	29.37	44° 31.8045	67° 31.1155	MIDS Site
Blue/White	29.03	44° 31.7374	67° 31.1625	MIDS Site
Green	29.07	44° 31.7190	67° 31.1666	MIDS Site
Yellow/Black	30.11	44° 31.5906	67° 31.2035	MIDS Site
Yellow/Black	29.75	44° 31.7007	67° 31.2064	MIDS Site
Large Orange and Green	29.35	44° 31.7858	67° 31.2562	MIDS Site
Pink	32.01	44° 31.7847	67° 30.8042	MIDS Survey Area
Red/White	32.65	44° 31.7212	67° 30.8047	MIDS Survey Area
Yellow	32.4	44° 31.6491	67° 30.8097	MIDS Survey Area
Yellow	32.15	44° 31.5429	67° 30.8871	MIDS Survey Area
White	22.21	44° 31.8836	67° 30.9397	MIDS Survey Area
Blue/Yellow	29.28	44° 31.8931	67° 31.1193	MIDS Survey Area
Yellow/Black	29.75	44° 31.5000	67° 31.2125	MIDS Survey Area
Red/White	29.54	44° 31.8272	67° 31.2973	MIDS Survey Area
Yellow/Black	29.38	44° 31.8618	67° 31.2962	MIDS Survey Area
Blue	29.57	44° 31.8808	67° 31.3483	MIDS Survey Area
Yellow	32.53	44° 31.4987	67° 30.9331	MIDS Survey Area
Yellow	31.83	44° 32.2363	67° 30.3122	NE REF
Red/Green	31.73	44° 32.2609	67° 30.3120	NE REF
Blue/Yellow	31.58	44° 32.2880	67° 30.3103	NE REF
Blue/Pink	31.5	44° 32.3033	67° 30.3102	NE REF
Green	30.89	44° 32.3906	67° 30.3652	NE REF
Green	31.86	44° 32.1854	67° 30.3567	NE REF
Yellow	32.03	44° 32.1540	67° 30.4019	NE REF
Blue/Yellow	31.98	44° 32.2135	67° 30.3943	NE REF
Green/Pink	31.84	44° 32.2372	67° 30.3903	NE REF
Blue	31.79	44° 32.2528	67° 30.3873	NE REF

Appendix E

Surface Buoy Markers

Buoy Description	Water Depth (m)	Latitude (N)	Longitude (W)	Location
Green/Pink	31.78	44° 32.2771	67° 30.3872	NE REF
Orange/Yellow	29.56	44° 32.4156	67° 30.4478	NE REF
Yellow	31.52	44° 32.1742	67° 30.4911	NE REF
Green	31.73	44° 32.2202	67° 30.4946	NE REF
Green/Yellow	31.46	44° 32.2301	67° 30.4960	NE REF
Orange/Yellow	29.25	44° 32.4197	67° 30.5487	NE REF
Yellow/Pink White/Blue	31.32	44° 32.2002	67° 30.5859	NE REF
Green	30.58	44° 32.2836	67° 30.5838	NE REF
Blue	30.8	44° 32.1780	67° 30.6326	NE REF
Green/Pink	28.75	44° 32.3535	67° 30.7492	NE REF
Orange/Yellow	29	44° 32.3538	67° 30.7278	NE REF
Green	30.9	44° 32.3492	67° 30.4652	NE REF
Orange/White	31.49	44° 32.3510	67° 30.3889	NE REF
White/Blue	33.17	44° 32.2439	67° 30.2608	NE REF
Green/Yellow	32.69	44° 32.2426	67° 30.3308	NE REF
Orange	32.38	44° 32.1390	67° 30.4616	NE REF
Orange	32.16	44° 32.1380	67° 30.4546	NE REF
White/Blue	32.19	44° 32.1813	67° 30.4502	NE REF
Orange/White	31.83	44° 32.2923	67° 30.4436	NE REF
Blue	34.82	44° 31.0591	67° 30.9428	SREF
Blue	29.6	44° 31.2060	67° 30.9860	SREF
Blue	33.33	44° 31.1847	67° 30.9863	SREF
White	33.65	44° 31.1406	67° 30.9945	SREF
White/Blue	34.08	44° 31.1292	67° 30.9960	SREF
Red/Yellow	30.34	44° 31.2602	67° 31.1253	SREF
White/Blue	30.18	44° 31.2100	67° 31.1678	SREF
White/Blue	30.16	44° 31.1195	67° 31.2170	SREF
Yellow/Black	29.91	44° 31.1364	67° 31.2209	SREF
Yellow/Black	29.49	44° 31.2147	67° 31.2172	SREF
Yellow/Black	29.16	44° 31.2646	67° 31.2136	SREF
Yellow/Black	28.98	44° 31.2680	67° 31.2559	SREF
Yellow/Black	28.97	44° 31.2338	67° 31.2576	SREF
Pink/Black	29	44° 31.1483	67° 31.2613	SREF
Blue	29.49	44° 31.0892	67° 31.2618	SREF
Blue	28.41	44° 31.1486	67° 31.3080	SREF
White/Black; Orange	28.33	44° 31.1981	67° 31.3126	SREF
Blue	32.72	44° 31.2807	67° 30.9937	SREF
White	32.04	44° 31.1741	67° 31.0903	SREF

Notes:

1. Grid coordinates are NAD_1983_2011_StatePlane_Maine_East_FIPS_1801
2. Geographic coordinates are NAD83 degree decimal minute

Appendix F

Common Conversions

APPENDIX F.

Common Conversions

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