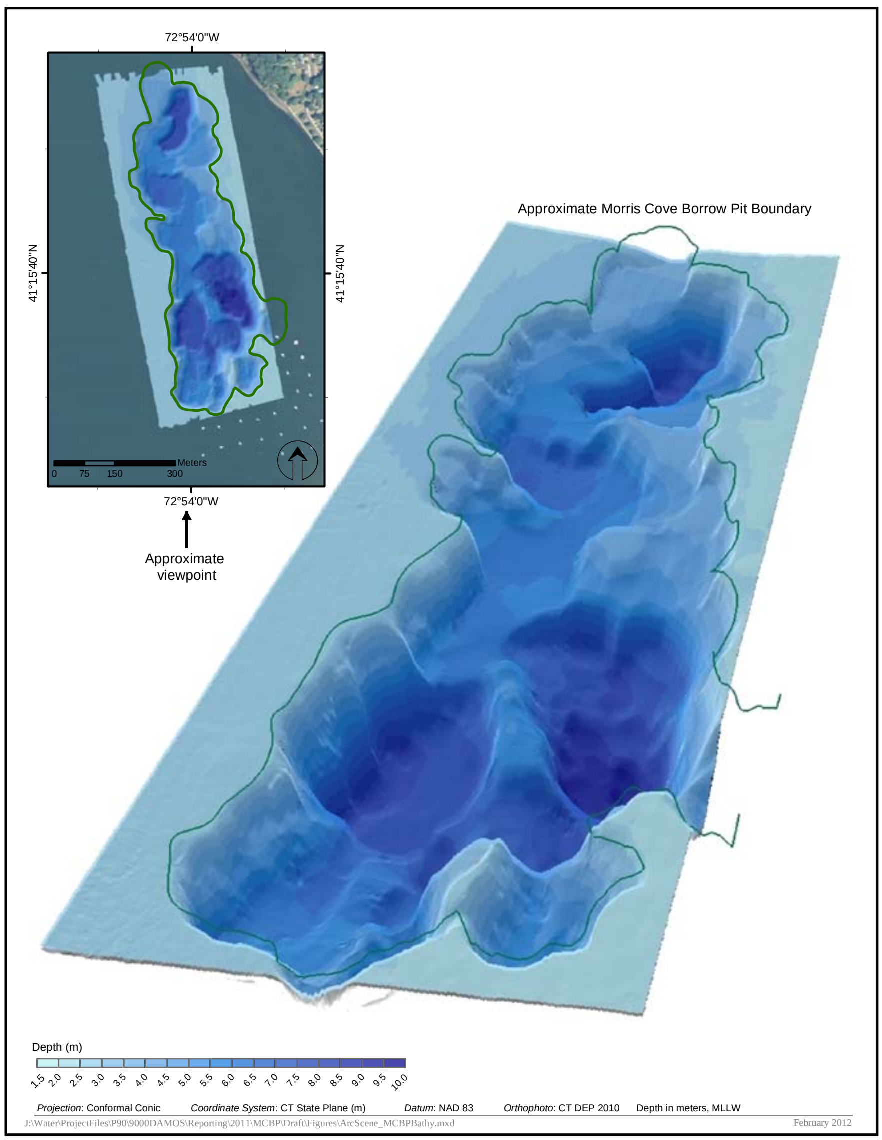
Monitoring Survey of the Morris Cove Borrow Pit
September-October 2011

Disposal Area Monitoring System DAMOS



DISPOSAL AREA MONITORING SYSTEM

Contribution 190
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AECOM, Germano & Associates, CR Environmental, Inc., CoastalVision

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
AECOM
250 Apollo Drive
Chelmsford, MA 01824

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13. ABSTRACT
A monitoring survey was conducted in September and October 2011 at the Morris Cove Borrow Pit (MCBP) in New Haven Harbor, Connecticut as part of the U.S. Army Corps of Engineers New England District's Disposal Area Monitoring System (DAMOS) Program. The 200 x 750 m pit was created in the 1950's by the removal of approximately 765,000 m^3 of material for use as road base. The excavation left an irregularly shaped depression up to 7 m deeper than the uniform bottom of the surrounding cove. The protected nature of Morris Cove and New Haven Harbor resulted in the preservation of the pit with little change over six decades. A previous study indicated the potential for the deeper, less flushed waters within the borrow pit to become anoxic during the late summer months.

The MCBP was investigated because the man-made depression has been considered for potential dredged material placement and coupled habitat restoration through elimination of the deeper, potentially stagnant zone. The 2011 investigation consisted of bathymetric and sediment-profile imaging (SPI) surveys designed to characterize the seafloor topography of the borrow pit and characterize benthic habitat conditions.

The multibeam bathymetric survey was performed over a 300 x 800 m area that encompassed the entire borrow pit site. Ambient seafloor depths averaged 2 m on the eastern side of the pit and 3.5 m to the west. The maximum depth observed was approximately 9.5 m in the southeastern portion of the borrow pit. The general features of the borrow pit remained consistent with previous surveys (e.g., isolated deep depressions, steeply sloped walls, and a 4 m rise in the middle of the pit) with no significant changes in its overall configuration since the last survey in 2002.

The 2011 sediment-profile imaging survey was performed along 5 transects perpendicular to the long axis of the borrow pit and extending onto ambient bottom on each side. The stations on the west side of the borrow pit were typically fine grained sand over silt and clay, with advanced Stage 3 biological communities present at every station. The SPI stations on the eastern side of the borrow pit consisted of coarse sand and shell covered substratum with low to moderate penetration and generally indeterminate aRPD depths. Within the pit, the sediments were typically soft and unconsolidated in nature with methane gas present at many stations. The stations within the borrow pit indicated both deposition and a stressed biological community.

A limited amount of dredged material was placed into the borrow pit in 2002 as part of a pilot study of larger scale dredged material disposal. This material was still visible in the 2011 survey as well as evidence of deposition of 6-10 cm of organic rich sediment over much of the borrow pit. There was also a visual signature in the sediment of episodic anoxic events. The results of the 2011 survey indicate that the degraded biological conditions within the borrow pit will likely persist for the foreseeable future and that there is opportunity for habitat restoration if the pit were filled in and returned to its pre-excavation contours eliminating the potential for site specific anoxic conditions. Restoration of the borrow pit area would increase available shellfish habitat and potentially provide additional winter flounder spawning and nursery grounds.

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New England District
U.S. Army Corps of Engineers
696 Virginia Road
Concord, MA 01742-2751

Prepared by:
AECOM, Germano & Associates,
CR Environmental, Inc., and CoastalVision

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

US Army Corps of Engineers®
New England District

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

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EXECUTIVE SUMMARY

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1.0 INTRODUCTION

A monitoring survey was conducted at the Morris Cove Borrow Pit (MCBP) in September-October 2011 as part of the U.S. Army Corps of Engineers (USACE), New England District (NAE) Disposal Area Monitoring System (DAMOS) Program. DAMOS is a comprehensive monitoring and management program designed and conducted to address environmental concerns associated with use of aquatic disposal sites throughout the New England region. The MCBP was investigated by DAMOS because the man-made depression has been considered for potential beneficial use of dredged material in restoring the depression to ambient water depths. An introduction to the DAMOS Program and the history of the MCBP are provided below.

1.1 Overview of the DAMOS Program

For 35 years, the DAMOS Program has conducted monitoring surveys at aquatic disposal sites throughout New England and evaluated the patterns of physical, chemical, and biological responses of seafloor environments to dredged material disposal activity. The DAMOS Program features a tiered disposal site management protocol designed to ensure that any potential adverse environmental impacts associated with dredged material disposal are promptly identified and addressed (Fredette and French 2004; Germano et al. 1994).

DAMOS monitoring surveys fall into two general categories, confirmatory and focused. 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. These surveys typically involve collection of both bathymetry and imaging data. Sequential bathymetric measurements are made to characterize the height and spread of discrete dredged material deposits or mounds created at open water sites as well as the accumulation/consolidation of dredged material into confined aquatic disposal (CAD) cells. Sediment-profile imaging (SPI) surveys are performed to provide additional physical characterization of sediments and to support evaluation of seafloor (benthic) habitat conditions and recovery over time. The data collected during these studies provide confirmation of the recovery of the benthic community following cessation of disposal at active sites and provide input for the longer term management of individual sites.

Focused studies are periodically undertaken within the DAMOS Program to evaluate inactive/historic disposal sites as well as to contribute to the development of dredged material placement, capping, and monitoring techniques. Focused studies may consist solely of records and literature review, involve comparison of analytical techniques, or include field surveys using sediment collection and other imaging and geophysical measurements in addition to standard confirmatory tools. The 2011 Morris Cove Borrow Pit survey is considered a focused investigation because the study area has not received dredged material since 2000, and there is ongoing interest regarding the potential beneficial use of dredged material for infilling the borrow pit.

1.2 Background on the Morris Cove Borrow Pit

Morris Cove is an approximately 1.5 x 1.5 km (0.8 nmi x 0.8 nmi) area in the southeastern portion of New Haven Harbor, Connecticut (Figure 1-1). The cove is bordered by shoreline to the east, much of the north and south, and a Federal navigation channel marks the western boundary. Depths within the cove slope gradually westward from the shoreline (except for the borrow pit) to a depth of approximately 4 m (13 ft) MLLW and then drop steeply into the navigation channel (maintained to approximately 10 m [34 ft] MLLW) (Figure 1-2). The overall New Haven Harbor opens to Long Island Sound to the south-southwest and is protected by three outlying breakwaters (Figure 1-1). The mean tidal range within the harbor is 2 m (6.6 ft). Historically, New Haven Harbor was one of the most valuable oyster fisheries on the East Coast. Although the oyster industry is not as robust as it once was, the harbor is considered good habitat for winter flounder spawning (Schultz et al 2007) and contains State-leased shellfish beds (including in Morris Cove) (CTDOAG 2010, Poppe et al 2001).

The Morris Cove Borrow Pit is an oblong 200 x 750 m (660 x 2500 ft) depression oriented north-south in the shallower eastern portion of the cove (Figure 1-2). It was formed in the 1950's by the removal of approximately 765,000 m^3 (1,000,000 yd^3) of sand and gravel that was used in the construction of Interstate Highway 95 through New Haven (O'Leary 2011). The outer boundary of the borrow pit is irregular as noted on navigational charts (Figure 1-3) and defined by the 3.5 m (11 ft) contour in Figure 1-4. The bottom topography within the borrow pit is also irregular, with several separate depressions, the deepest reaching nearly 10 m (33 ft).

Following its excavation, the borrow pit remained inactive for the next 40 years with no additional material removed or placed into it. Depths within the borrow pit did not significantly change over that period, indicating limited natural deposition of sediment. With an interest in re-establishing the uniform bottom topography of the surrounding cove, a pilot project was performed in 2000 to evaluate the feasibility of MCBP as a dredged material disposal site with input from USACE, U.S. Environmental Protection Agency, Connecticut Department of the Environment, and the National Marine Fisheries Service. A site marker buoy was placed in the southern portion of the borrow pit, and approximately 14,200 m^3 (18,600 yd^3) of fine-grained sediment dredged from the

U.S. Coast Guard base in New Haven Harbor (deemed suitable for open-water placement) was placed around the marker buoy from January to May 2000. No additional material has been placed at MCBP since that time.

1.3 Previous Investigations at the Morris Cove Borrow Pit

An initial investigation characterizing MCBP as a potential disposal site for dredged material was performed in 1983 and included a bathymetry survey and performance of a dye tracer study to evaluate current patterns around the borrow pit. The bathymetry survey identified the persistence of the irregular boundary and topography characterized in earlier charting of the harbor. The dye study supported the expected north-south trending tidal currents within the cove and MCBP (SAIC, 1984), but did not supply adequate data to evaluate the potential for regular flushing and sediment mobilization and transport (see results of later National Marine Fisheries Service and Woods Hole Group studies below).

In conjunction with the pilot dredged material disposal into MCBP in 2000, follow up monitoring was performed four months following cessation of disposal in 2000 and two years later in 2002, both as part of the DAMOS Program. The late September/early October 2000 monitoring survey consisted of SPI, side-scan sonar, limited single-beam bathymetry, and towed underwater video (SAIC 2001). The survey identified a small disposed sediment deposit that extended up to 150 m (490 ft) from the target buoy location and ranged up to 1.5 m (4.9 ft) in thickness in the vicinity of the buoy. Benthic recolonization had progressed as expected a short time following cessation of disposal. Methane gas was observed at three stations, indicative of relatively high organic loading in the material placed at the site and/or already existing within the borrow pit. Sediments appeared well-oxygenated at all stations, as expected given the fall conditions.

A follow up DAMOS monitoring survey was performed in May 2002 to document the continued recovery of the benthic habitat within the borrow pit and provide a comprehensive bathymetric map from which the remaining capacity of the MCBP could be estimated (SAIC 2003). The survey included single-beam bathymetry, side-scan sonar, SPI, and sediment grab sampling with benthic community analysis. Benthic recolonization had continued to progress as expected with advanced successional stage present at the majority of stations and relatively deep oxygen penetration of the surficial sediment during the late spring conditions. However, degraded benthic habitat conditions were observed at two stations on the southeastern margin of the borrow pit, and methane was observed at these and other stations. The potential capacity of the borrow pit (if filled to the 3.5 m [11 ft] MLLW contour) was estimated at approximately 460,000 m^3 (602,000 yd^3) (SAIC 2003).

The National Marine Fisheries Service (NMFS) identified Morris Cove as an important spawning and nursery area for a variety of commercially important fish species, including winter flounder (Pereira et al. 1994). NMFS had expressed concern regarding the presence of the borrow pit within the cove because of the potential for trapping of organic matter within the pit and reduced water exchange in the deeper portions. NMFS suggested that as organic material decayed within the borrow pit, the quality of near-bottom waters (dissolved oxygen [DO] in particular) could be negatively impacted. They noted that the potential for these conditions to occur increased during the late summer when more organic material was present and water temperatures were at their warmest (with coupled lowest DO saturation levels).

In the summer and fall of 2002, NMFS scientists deployed recording water quality monitoring instrumentation within Morris Cove to monitor DO concentrations and determine if juvenile fish could potentially be impacted. One instrument mooring was placed in the deepest, southern portion of the borrow pit, and a second was placed in the ambient water depths just west of the pit (Figure 1-2). The monitoring revealed that DO concentrations were generally lower within the deeper portion of MCBP relative to the shallower, adjacent ambient area, indicating reduced mixing and tidal flushing of the borrow pit. The monitoring also identified the absence of any temperature refuge for fish (i.e., cooler waters at depth typically with high DO levels) in the warmer months. The study concluded that the borrow pit could potentially become anoxic for periods of time during the late summer and early fall when water quality can be stressed throughout the region.

Under contract to the USACE, Woods Hole Group, Inc. recently performed monitoring to determine if there was potential for combined wave and tidal near-bottom currents to suspend and transport sediments in the area of the borrow pit under normal or more extreme storm conditions. Previous work had characterized New Haven Harbor as a relatively low energy environment with a mean current speed of 0.06 m/s (0.20ft/s) but with relatively high suspended solids loading in the water column (Bohlen et al. 1996). The high suspended solids load was attributed to wind wave action on shallow areas and the overall urbanized area.

Woods Hole Group deployed an acoustic Doppler current profiler (ADCP) array recording wave, current, and water surface elevation data just outside the western edge of borrow pit for a three month period in the fall of 2011 (Figure 1-2). The currents observed during the deployment were tidally dominated, aligning closely with typical ebb and flood tidal currents and were consistent with historical current data (Bohlen et al. 1996). The two dominant current bands were found on the east-northeast (flood) and south-southwest (ebb) axes with a mean current velocity of 0.09 m/s (0.30 ft/s). This pattern is consistent with typical tidal flow in and out of Morris Cove. Maximum current velocity (approximately 0.34 m/s [1.12 ft/sec]) occurred during the ebb tide with an increased freshwater discharge in a south-southwest direction consistent with the protected configuration of the harbor.

1.4 Survey Objectives

An interest in the ten-year, post-disposal physical and biological habitat conditions within the MCBP coupled with concerns regarding the previously observed dissolved oxygen concentrations within the borrow pit and an interest in potential long-term habitat restoration provided the basis for the September-October 2011 survey at the site. Specific objectives included:

- Use multibeam bathymetry to provide complete coverage of the seafloor topography of MCBP and to evaluate the stability of the borrow pit and the material previously placed into it; and

- Use SPI techniques to characterize benthic habitat conditions and assess the benthic recolonization status of MCBP compared to ambient sediments.

In addition, water quality measurements were performed during both surveys to supplement previously collected data.

Table 1-1.

Summary of Dredged Material Placement at MCBP

Permittee/Project	Disposal Dates	Volume (m^3)	Volume (yd^3)
U.S. Coast Guard - Channel and Dock Area	1/2000–2/2000	10,400	13,600
U.S. Coast Guard - Channel and Dock Area	5/2000	3,800	5,000
Total		14,200	18,600

Table 1-2.

Previous Monitoring Surveys at MCBP

Date	Survey Type	Bathymetric Survey Area (meters)	Side-scan	Number of SPI Stations	Other	Reference
March 1983	Monitoring	Site: 300x800	-	-	Tracer dye	SAIC 1984
September-October 2000	Post-disposal	Site: 300x800	√	Site: 22 Ref: 5	Video transects	SAIC 2001
May/ June 2002	Monitoring	Site: 300x800		Site: 22 Ref: 5	Benthic grab sampling	SAIC 2003
August/ October 2002	Monitoring	-	-	-	Water quality	SAIC (NMFS) 2003
September-December 2012	Monitoring	-	-	-	Current study (ADCP)	WHG, 2011

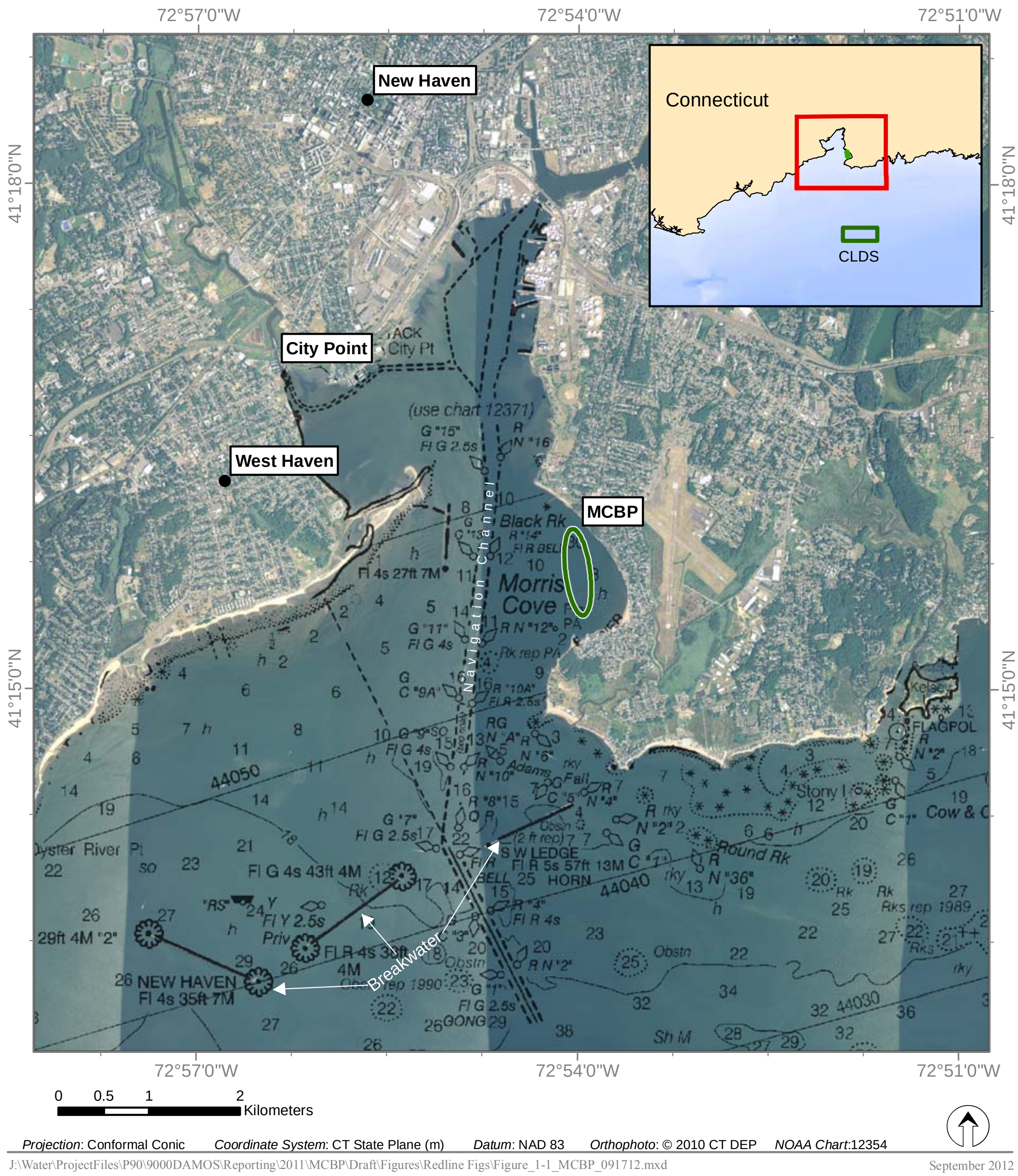


Figure 1-1. Location of the Morris Cove Borrow Pit (MCBP) within New Haven Harbor. Because of its irregular boundary, the approximate location of the pit is displayed as a green oval on the Section 1 and 2 figures.

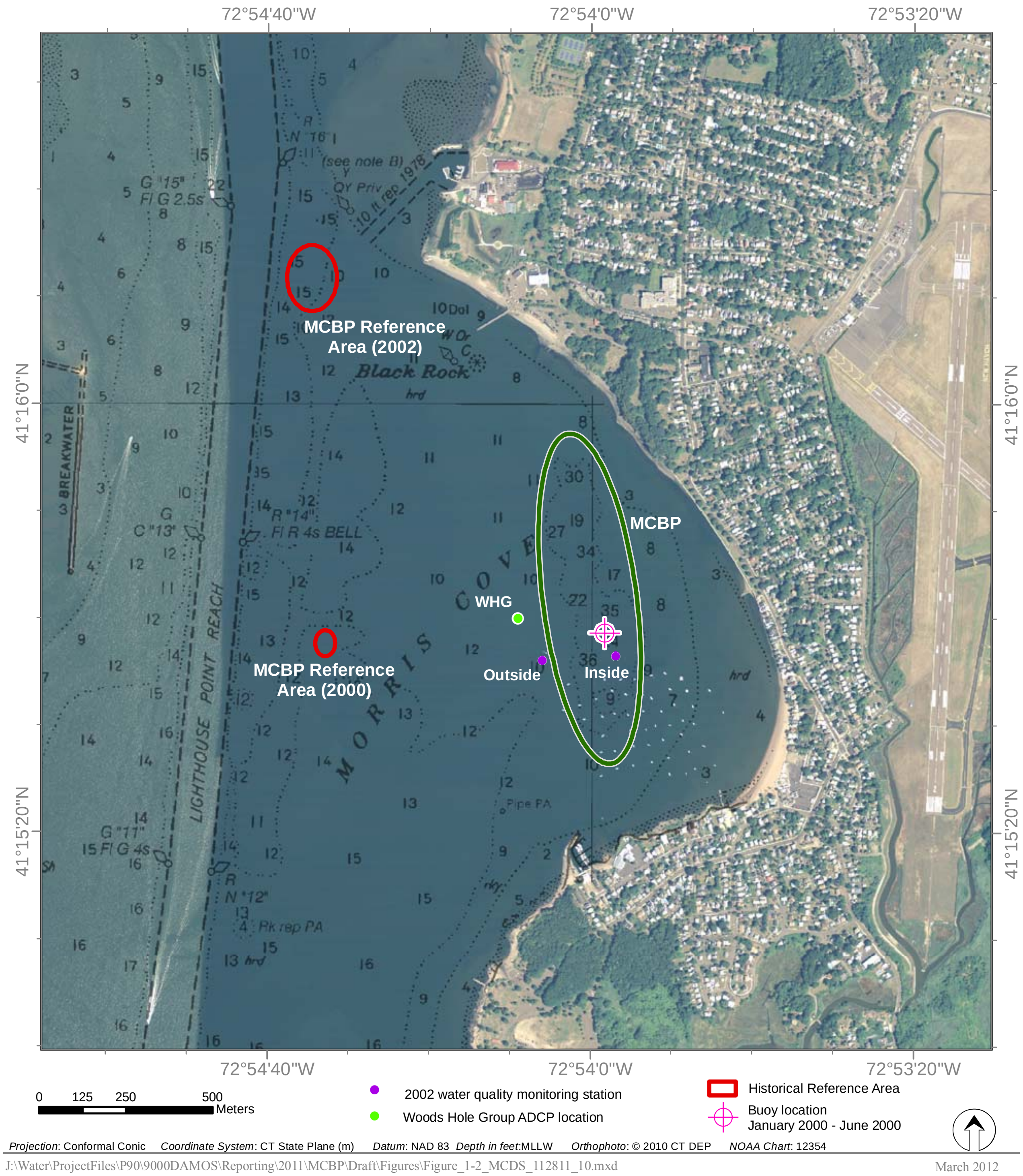


Figure 1-2. MCBP with study area boundary, pilot study buoy location, NMFS water quality stations, and WHG ADCP station indicated

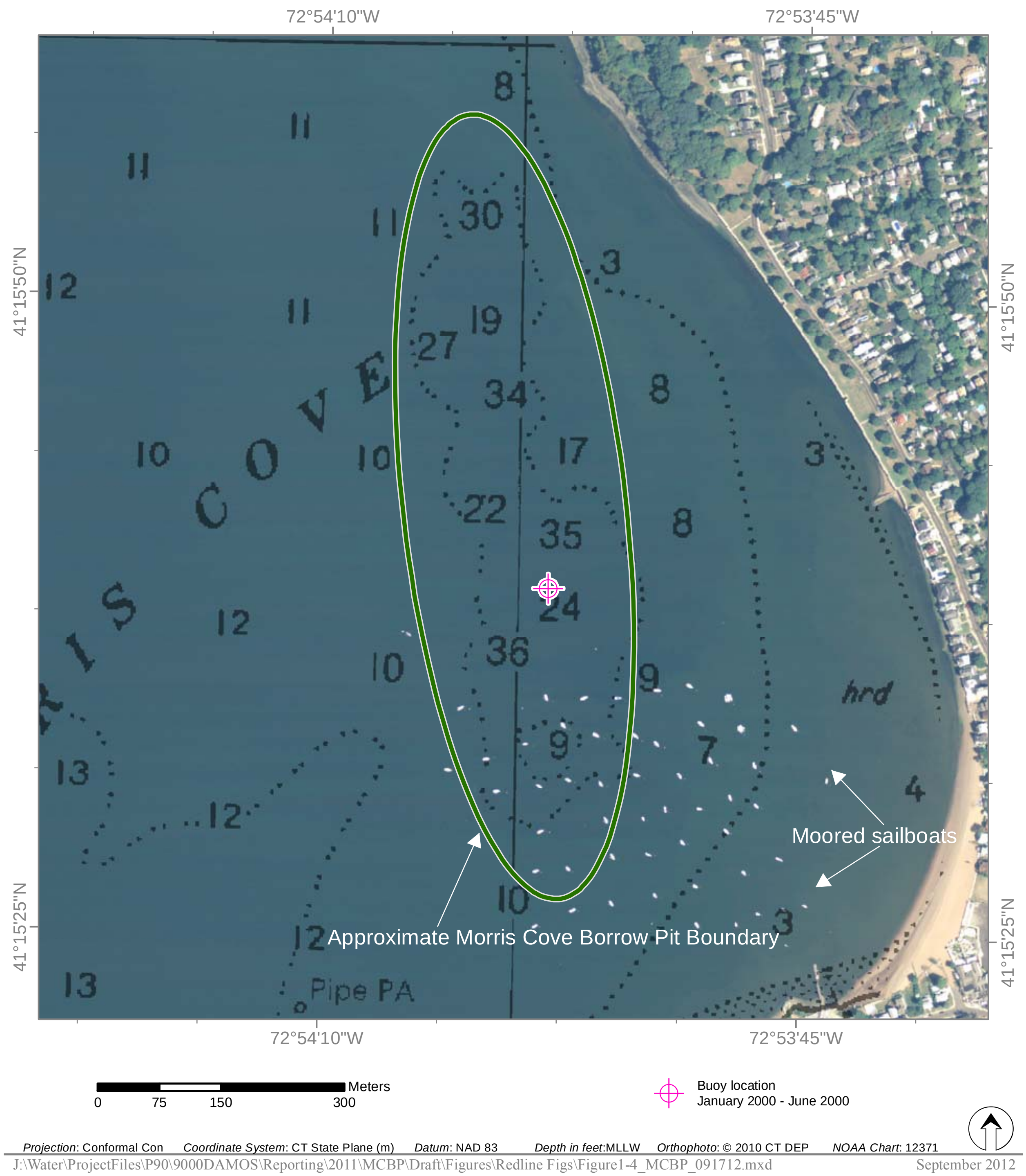


Figure 1-3. Close-up of MCBP on combined nautical chart and aerial photo basemap

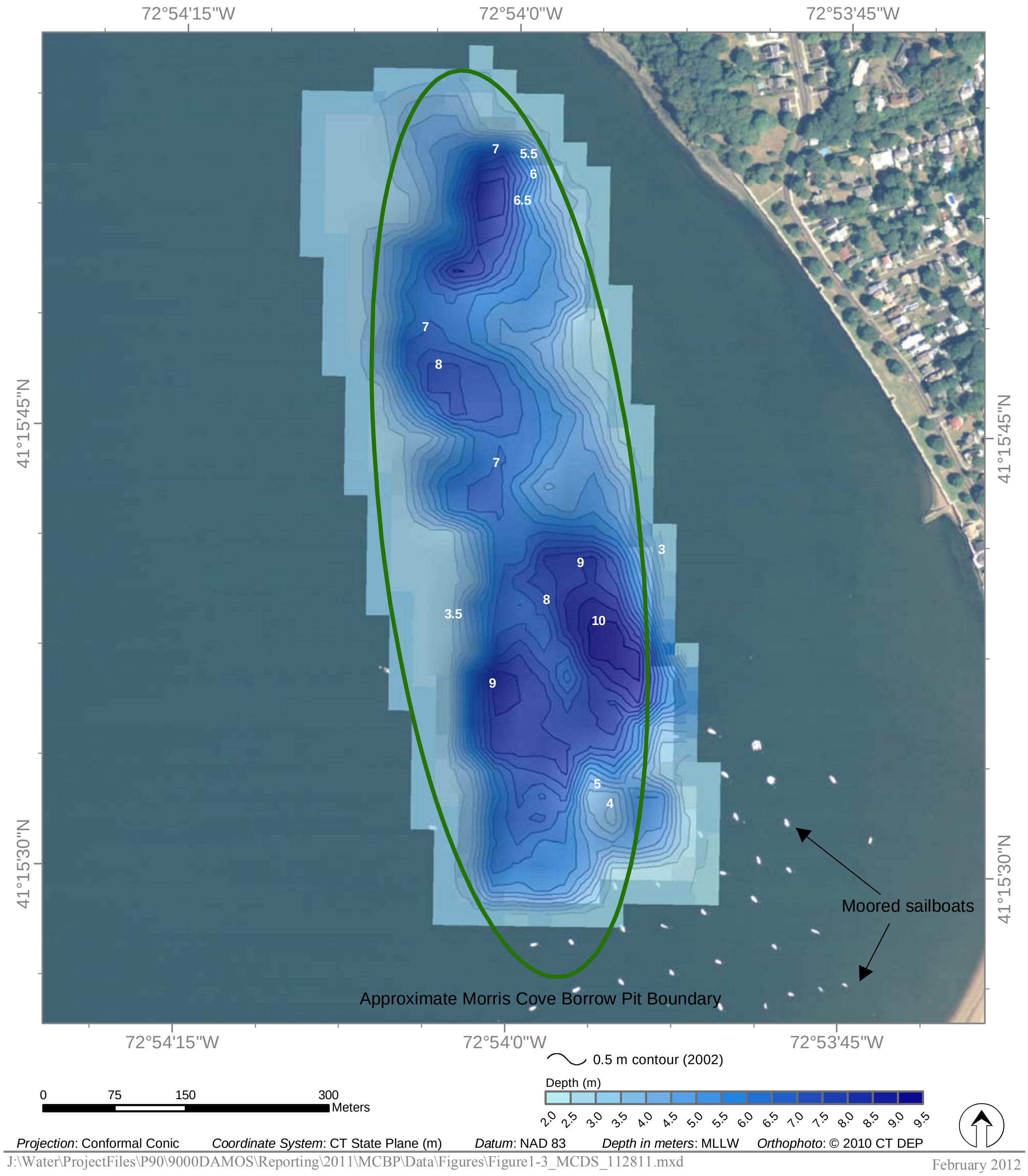


Figure 1-4. Bathymetry of MCBP, May 2002

2.0 METHODS

AECOM, CR Environmental, Inc., and Germano and Associates conducted the field surveys at MCBP in the fall of 2011. The bathymetric survey was conducted 28 September 2011 to document depths in and around the site. The SPI survey was conducted 4 October 2011 to further assess the physical characteristics of surficial sediment and to assess benthic recolonization within the borrow pit compared to ambient conditions. Water quality profiles were collected over various tidal events during both the bathymetric and SPI surveys. Field activities are summarized in Table 2-1, and an overview of the methods used to collect and process the survey data is provided below.

2.1 Navigation and On-Board Data Acquisition

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

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

2.2 Bathymetry

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

2.2.1 Bathymetric Data Collection

The 2011 multibeam bathymetric survey of MCBP was conducted 28 October 2011 aboard the F/V *First Light.* The bathymetric survey was conducted over a 300 x 800 m area, capturing the entirety of the borrow pit and a portion of the surrounding ambient seafloor (Figure 2-1). The survey area overlapped with a large field of approximately 40 moored sailboats in the southern portion of the borrow pit, which required the planned survey track lines to be adjusted. Full coverage of the borrow pit was still obtained during survey activities. Sediment acoustic backscatter data, in the form of side-scan imagery, were also collected. The bathymetric survey included a total of 45 survey lines, spaced 7 m apart and oriented in an approximately north-south direction. Multiple cross-tie lines were completed to assess data quality and the accuracy of tidal corrections (Figure 2-1). The summed length of occupied survey transects was approximately 42.5 km.

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

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

Water depths over the survey area were recorded in meters and referenced to mean lower low water (MLLW) based on water levels recorded at the NOAA New

Haven Tide Station #8465705, located approximately 2 km north of the survey area. A tide gage was also installed at the marina in Branford, CT to serve as a backup to the NOAA data. HYPACK MAX® software was used to manage data acquisition and storage of data from the echosounder and the navigation system. HYPACK MAX® also recorded depth, vessel heave, heading, position, and time along each survey transect line.

2.2.2 Bathymetric Data Processing

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

The cleaned and adjusted data were further processed to calculate seafloor elevations based on evaluation of overlapping swath data. Based on the combined estimated average acoustic footprint of the MBES system (~0.1–0.3 m diameter), the accuracy of the DGPS (<1.0 m) and anticipated beam steering errors, the average sounding solutions present within 2 x 2 m grid cells were accepted as seafloor elevations and exported in delimited ASCII text format for mapping in ArcGIS®10.1 (GIS). The vertical uncertainty of soundings within each of these cells was calculated and exported in ASCII format to aid statistical assessment of data quality.

MBES backscatter data were processed using HYPACK®'s implementation of GeoCoder software developed by NOAA's Center for Coastal and Ocean Mapping Joint Hydrographic Center. GeoCoder was used to create a mosaic best suited for substratum characterization through the use of innovative beam-angle correction algorithms.

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

2.2.3 Bathymetric Data Analysis

Bathymetric data were analyzed to evaluate changes in seafloor topography in comparison with previous surveys at MCBP, and to a lesser extent, document the distribution of the limited amount of dredged material placed in the borrow pit. The processed bathymetric grids were converted to rasters, and bathymetric contour lines were generated and displayed using GIS.

GIS was also used to calculate depth difference grids between previous surveys and the 2011 bathymetric dataset. The depth difference grids were calculated by subtracting the 2002 survey depth estimates from the 2011 survey depth estimates at each point throughout the grid. A limitation of this comparison is that the 2002 bathymetry was collected using a single beam system, while the 2011 survey utilized a multibeam system. The resulting depth difference calculations were limited to the accuracy of the 2002 grid surface (25 x 25 m), further impacting the resolution. Therefore, a limited amount of reprocessing of the 2002 single beam bathymetry data was conducted in order to produce representative profile view comparisons of the 2002 and 2011 data sets.

2.3 Sediment-Profile Imaging

Sediment-profile imaging (SPI) is a monitoring technique used to provide data on the physical characteristics of the seafloor as well as the status of the benthic biological community. This technique involves deploying an underwater camera system to photograph a cross section of the sediment-water interface. Acquisition of high-resolution sediment-profile images was accomplished using a Nikon D7000 digital single-lens reflex camera mounted inside an Ocean Imaging Model 3731 pressure housing system. The pressure housing sat atop a wedge-shaped prism with a front faceplate and back mirror. The mirror was mounted at a 45º angle to reflect the profile of the sediment-water interface. As the prism penetrated the seafloor, a trigger activated a time-delay circuit that fired an internal strobe to obtain a cross-sectional image of the upper 15–20 cm of the sediment column (Figure 2-2). The camera remained on the seafloor for approximately 20 seconds to ensure that a successful image had been obtained.

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

Each image was assigned a unique time stamp in the digital file attributes by the camera's data logger and cross-checked with the time stamp in the navigational system's computer data file. In addition, the field crew kept redundant written sample logs. Images were downloaded periodically to verify successful sample acquisition and/or to assess what type of sediment/depositional layer was present at a particular station. Digital image files were re-named with the appropriate station name immediately after downloading as a further quality assurance step.

Details of the camera settings for each digital image are available in the associated parameters file embedded in each electronic image file. For this survey, the ISO-equivalent was set at 800, shutter speed was 1/30, f16, white balance set to flash, color mode to Adobe RGB, sharpening to none, noise reduction off, and storage in compressed raw Nikon Electronic Format (NEF) files (approximately 10.5 MB each). Electronic files were converted to high-resolution jpeg (8-bit) format files (2850 x 4300 pixels) using Nikon Capture® NX2 software (Version 2.2.7).

2.3.1 SPI Data Collection

The sediment-profile imaging survey at MCBP was completed on 4 October 2011 aboard the F/V *First Light*. At each station, the vessel was positioned at the target coordinates, and the camera was deployed within a defined station tolerance of 10 m. Three sediment-profile images were collected at each of the stations.

The 2011 SPI survey design included the collection of sediment-profile images at 35 stations distributed across five transects located in an east-west orientation perpendicular to the axis of the borrow pit and extending onto the ambient seafloor in each direction (Table 2-2 & Figure 2-3). The ambient sediments were surveyed to provide a basis of comparison between MCBP sediments within the pit and the surrounding seafloor.

2.3.2 SPI Data Analysis

Computer-aided analysis of the resulting images provided a set of standard measurements that enabled comparison between different locations and different surveys.

Following completion of data collection, the digital images were analyzed using Bersoft Image Measurement© software version 3.06 (Bersoft, Inc.). Images were first adjusted in Adobe Photoshop® to expand the available pixels to their maximum light and dark threshold range. Linear and areal measurements were recorded as number of pixels and converted to scientific units using the Kodak® Color Separation Guide for measurement calibration. Detailed records of all SPI results are included in Appendix A.

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

Sediment Type—The sediment grain size major mode and range were estimated visually from the images using a grain-size comparator at a similar scale. Results were reported using the phi scale. Conversion to other grain-size scales is provided in Appendix B. The presence and thickness of disposed dredged material were also assessed by inspection of the images. Identifying dredged material is based on a number of differences, ranging from obvious to subtle, in a variety of characteristics that serve to distinguish the disposed sediments from those comprising the ambient seafloor in and around the disposal site (Germano et al. 2011). Among these characteristics are sediment color, particle size, texture, small-scale surface roughness, apparent water content, and degree of cohesiveness (Figure 9 in Germano et al. 2011). In addition to its unique optical or textural properties, dredged material will often form single or multiple depositional layers on the seafloor, and these are often visible as distinct sedimentary horizons in profile images.

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

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

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

Infaunal Successional Stage—Infaunal successional stage is a measure of the biological community inhabiting the seafloor. Current theory holds that organism-sediment interactions in fine-grained sediments follow a predictable sequence of development after a major disturbance (such as dredged material disposal), and this sequence has been divided subjectively into 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.

Methane gas and *Beggiatoa* bacteria presence were also noted during the image analysis. *Beggiatoa* sp. is a sulfur-oxidizing bacteria that flourishes in anoxic conditions. The presence of these bacteria is not uncommon in the waters of Long Island Sound. *Beggiatoa* filaments are micrometers in size, and recent advances in digital camera resolution have allowed for the accurate identification of these bacteria in the images. Additional components of the SPI analysis included calculation of means and ranges for the parameters listed above and mapping of station-averaged values.

2.3.3 Comparative Approach

The objectives of the 2011 SPI survey at MCBP were to characterize benthic habitat conditions and to assess the benthic recolonization status inside the borrow pit compared to the areas outside the pit. The results of the SPI survey were examined relative to the location of the station within or outside the borrow pit. Basic summary statistics (mean, standard deviation) were calculated for the three distinct sample populations (inside the pit, outside the pit west, and outside the pit east) and compared. Transect figures plotting the sediment-profile images along the bathymetric profile were also created, in order to qualitatively evaluate the SPI results against the water depths in and around the borrow pit. The SPI data also allowed for an evaluation of the physical composition of the sediments within the borrow pit and provided a dataset to ground truth the backscatter data.

2.4 Water Quality Profile Data Collection

Water quality profiles were collected at MCBP on 28 September 2011 and 4 October 2011, during the bathymetric and SPI surveys, aboard the F/V *First Light*. Three stations were selected for collection of water quality profiles, two within MCBP and one adjacent to the borrow pit (Figure 2-4). At each station, the vessel was positioned at the pre-determined target coordinates. Two stations (MCDS-Out and MCDS-In-1) were coincident with the 2002 NMFS water quality sampling stations. A minimum of two profiles were collected at each station during each survey day over two tidal events (high tide and low tide) (Table 2-3).

Real-time water quality measurements (temperature, pH, conductivity, salinity, and dissolved oxygen) were collected using a YSI 6920 multi-parameter meter integrated with a HYPACK® enabled laptop. The meter was calibrated each day before deployment. At each station, the depth measurement and tidal stage were recorded and the meter was lowered to approximately 0.5 m off the bottom. Data logging began after the meter was allowed to equilibrate. The meter was then slowly retrieved upward through the water column until it reached the surface, thereby allowing for collection of a complete profile of the water column. All water quality data were recorded electronically and downloaded at the conclusion of the survey.

Table 2-1.

Summary of Field Activities at MCBP, September-October 2011

Survey Type	Date	Summary
Bathymetry	28 September 2011	Area: 300 x 850m Lines: 45 Spacing: 70m
Sediment-Profile Imaging	4 October 2011	Stations: 35 Within Pit: 20 Outside Pit: 15
Water Quality Profiles	28 September/ 4 October 2011	Stations: 3 Within Pit: 2 Outside Pit: 1

Table 2-2.

MCBP SPI Target Locations

Station	Latitude (N)	Longitude (W)	Station	Latitude (N)	Longitude (W)
	Within Pit			Outside of Pit	
MCDS-3	41° 15.836'	72° 54.082'	MCDS-1	41° 15.820'	72° 54.197'
MCDS-4	41° 15.841'	72° 54.049'	MCDS-2	41° 15.828'	72° 54.143'
MCDS-5	41° 15.845'	72° 54.020'	MCDS-7	41° 15.866'	72° 53.859'
MCDS-6	41° 15.850'	72° 53.977'	MCDS-8	41° 15.759'	72° 54.174'
MCDS-10	41° 15.775'	72° 54.061'	MCDS-9	41° 15.768'	72° 54.105'
MCDS-11	41° 15.779’	72° 54.022'	MCDS-13	41° 15.794'	72° 53.913'
MCDS-12	41° 15.786'	72° 53.973'	MCDS-14	41° 15.805'	72° 53.835'
MCDS-17	41° 15.711'	72° 54.044'	MCDS-15	41° 15.696'	72° 54.154'
MCDS-18	41° 15.717'	72° 54.000'	MCDS-16	41° 15.704'	72° 54.098'
MCDS-19	41° 15.724'	72° 53.952'	MCDS-20	41° 15.730'	72° 53.903'
MCDS-23	41° 15.610'	72° 54.018'	MCDS-21	41° 15.741'	72° 53.822'
MCDS-24	41° 15.616'	72° 53.983'	MCDS-22	41° 15.598'	72° 54.116'
MCDS-25	41° 15.618'	72° 53.962'	MCDS-28	41° 15.638'	72° 53.813'
MCDS-26	41° 15.622'	72° 53.939'	MCDS-29	41° 15.524'	72° 54.085'
MCDS-27	41° 15.628'	72° 53.891'	MCDS-35	41° 15.562'	72° 53.795'
MCDS-30	41° 15.634'	72° 53.998'			
MCDS-31	41° 15.539'	72° 53.964'			
MCDS-32	41° 15.544'	72° 53.935'			
MCDS-33	41° 15.546'	72° 53.908'			
MCDS-34	41° 15.550'	72° 53.883'			

Note: Coordinate system NAD83

Table 2-3.

MCBP Water Quality Profile Locations

Station	Latitude (N)	Longitude (W)	Approximate water depth (m MLLW)
Within Pit			
MCDS-In-1	41° 15.608'	72° 53.948'	5.7
MCDS-In-2	41° 15.587'	72° 53.990'	7.7
Outside of Pit			
MCDS-Out	41° 15.601'	72° 54.100'	2.7

Note: Coordinate system NAD83

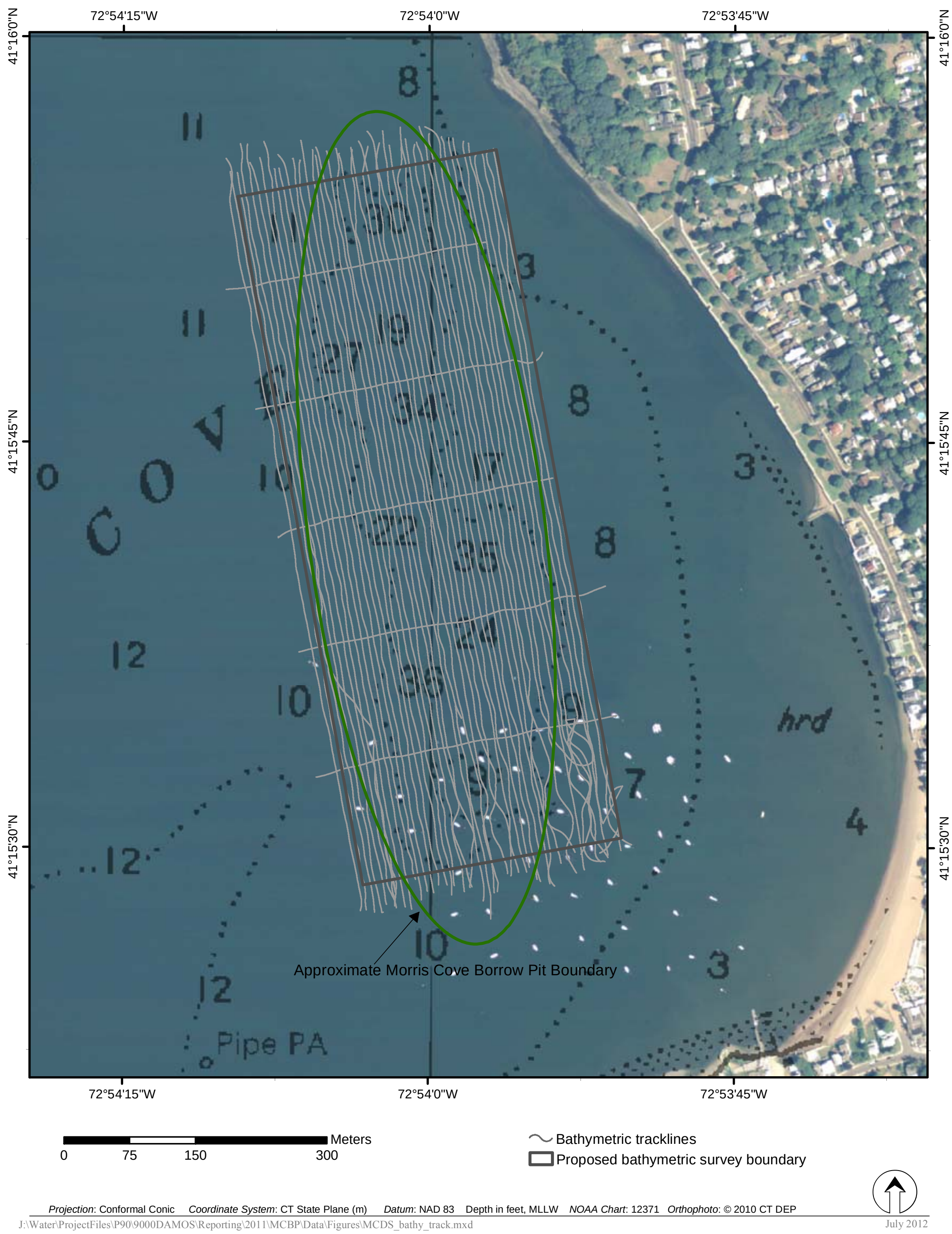


Figure 2-1. MCBP bathymetry survey boundary and tracklines (note adjustments around moored vessels in southern portion)

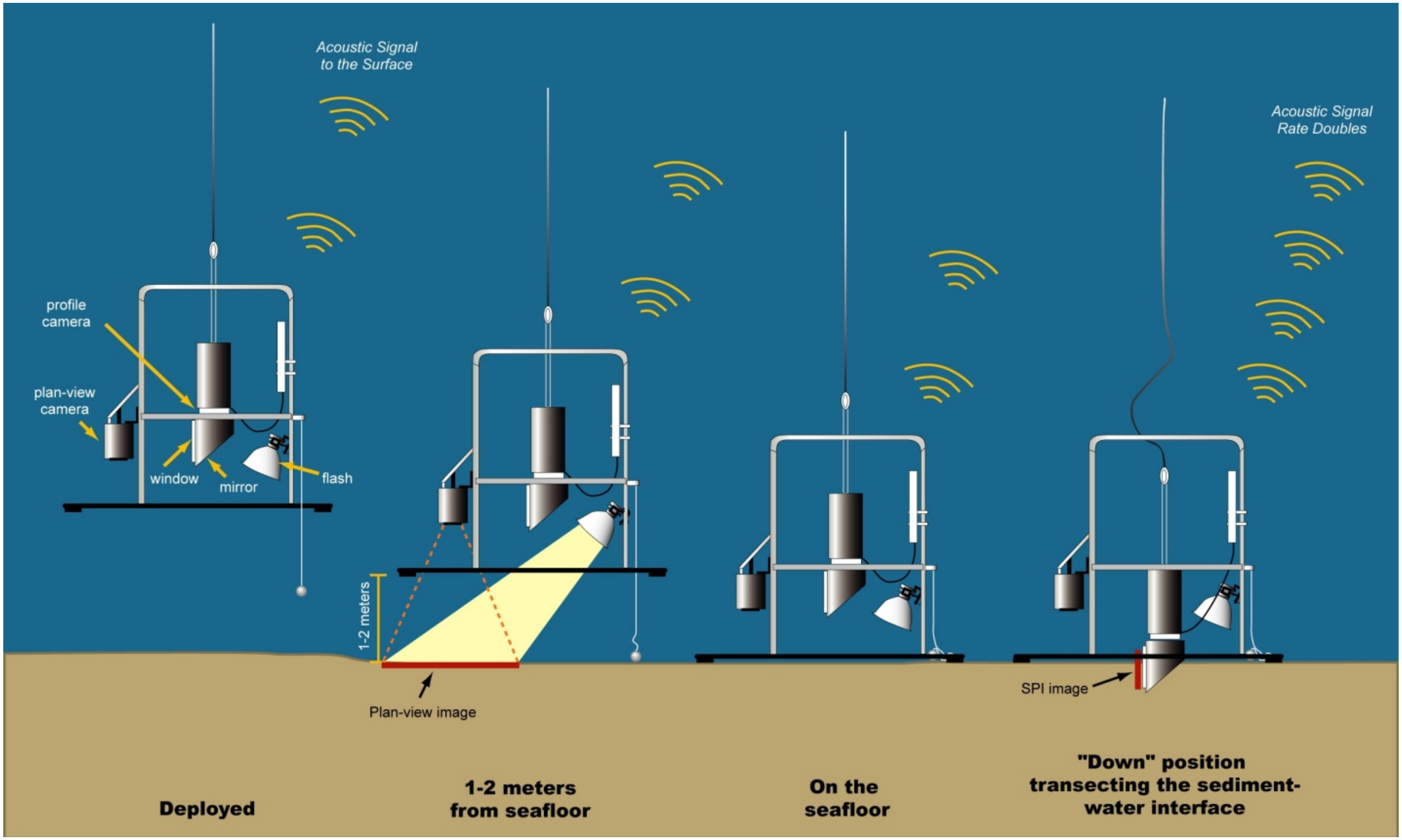


Figure 2-2. Operation of the Ocean Imaging Model 3731 sediment-profile camera (note that the plan view camera was not used at MCBP)

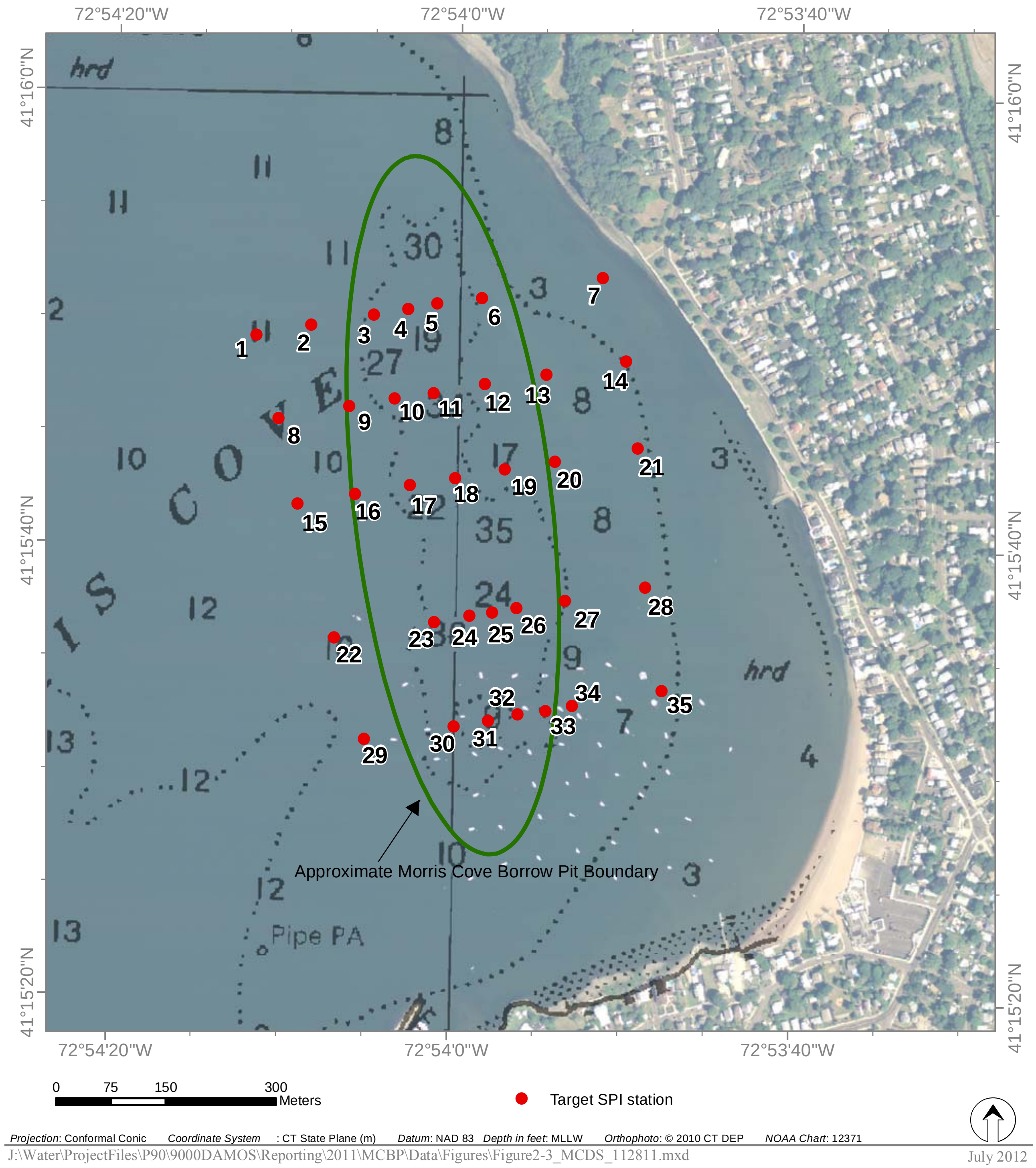


Figure 2-3. MCBP SPI target locations

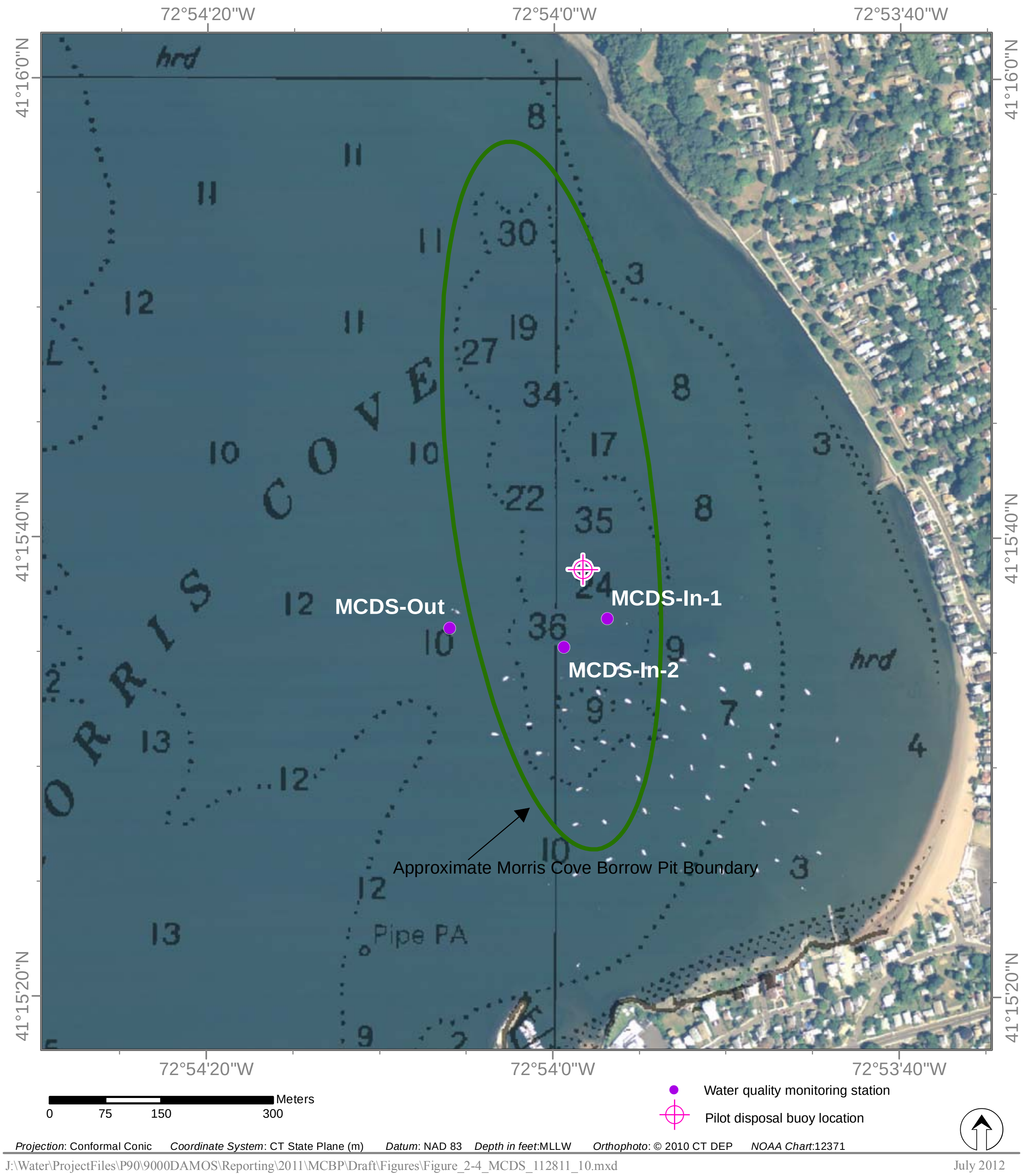


Figure 2-4. MCBP water quality profile locations

3.0 RESULTS

3.1 Bathymetry and Backscatter

A bathymetric survey was performed at the MCBP to document seafloor topography in and around the site. Results of this survey, including a bathymetric contour map and a depth difference figure are presented below.

3.1.1 Bathymetric Data Quality

In order to assess data quality across the MBES swath, within cell (2m x 2m) depth variations were mapped and statistically evaluated. The median 95% Confidence Interval (C.I.) uncertainty within bathymetric grid cells was 15 cm. The upper confidence limit of uncertainty distribution at the 95% C.I. for the entire data set was approximately 55 cm. USACE Guidance for Hydrographic Surveying (EM 1110-2-1003) provides performance standards for data acquired in depths of up to 80 feet (24 meters). The performance standard for data accuracy in this depth range was 30 cm at the 95% C.I.. The majority of data conform to this performance standard. Non-compliant outliers were universally confined to the slopes of seabed features where the sounding range within 2.0 m cells was constrained by morphology rather than accuracy.

3.1.2 Bathymetric Results

Water depths within the bathymetric survey area established over the ambient seafloor adjacent to the MCBP ranged from approximately 2.0 m on the eastern side of the borrow pit to a maximum depth of approximately 4.0 m on the western side (Figure 3-1). The surrounding area was characterized by a uniform bottom that displayed little topographic relief. Consistent with previous surveys and available nautical charts, the seafloor sloped gently from east to west.

The borrow pit boundary displayed in previous reports and in the figures within this report generally follows the 3.0 m bathymetric contour, with the exception of the northwest quadrant of the borrow pit, where it follows the 3.5 m contour. Typically this boundary marks a break to steeper slopes that descend into the borrow pit itself. This irregular boundary defines an area of approximately 800 m x 200 m. In general, the borrow pit has an uneven floor, apparently related to the topography of the initial excavation. The bathymetric data showed the borrow pit to be comprised of a series of depressions separated by saddle areas of varying width. The deepest and largest of the depressions in the borrow pit was found in the southeastern quadrant of the pit, with a maximum depth of 9.5 m. The second deepest depression was located in the southwest portion of the borrow pit, with an approximate depth of 8.0 m. A third significant depression was located in the northern extent of the borrow pit, with a maximum depth of 8.0 m.

A standard depth difference comparison between the 2002 single beam and 2011 multibeam datasets was limited by inconsistencies apparent in the 2002 bathymetric data. A consistent offset of approximately 20–30 cm was identified between the 2002 and 2011 datasets that could not be accounted for by standard datum or tidal corrections. Based on available sediment transport data for New Haven Harbor (Bohlen et al. 1996; Poppe et al. 2001) and a qualitative comparison of the previously collected bathymetric data (1983, 2000, and 2002), there is no historic evidence to support such significant deposition over both the cove and borrow pit area from 2002 to 2011. Furthermore, apparent deposition on the steeper side slopes is an indicator of an operational or processing offset between the two data sets.

Due to this variability, a standard depth difference model was not evaluated. Rather, using GIS, a cross-sectional representation of transects coincident to both bathymetric data sets was developed in order to evaluate any changes in the borrow pit topography. The ambient depths outside the borrow pit were adjusted to be equal by applying an offset of -25 cm to the 2002 dataset before developing the profile view (Figure 3-2). This approach assumed that there was not any major sediment deposition or scour of the seafloor that surrounded the borrow pit in the ten years since the previous survey.

Based on the results of the comparison, the general configuration and features within the borrow pit remained consistent, including the isolated deep depressions, steeply sloped walls, and a 4.0 m rise in the central portion of the pit (Figure 3-1). The selected profile matched depths outside the borrow pit but suggested deposition of sediment up to as much as 1 m within the northern depression outside of the area of direct dredged material placement in 2000.

3.1.3 Acoustic Backscatter

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 grainsize and roughness of the near-surface sediments (Fonseca and Mayer 2007). Typically, high backscatter intensity is related to rock or coarse-grained sediment (e.g., gravel, coarse sand), and low backscatter intensity is indicative of fine grained sediments (e.g., silt, clay).

Sonar imagery and modeled backscatter (measured in dB) outside of the borrow pit suggested that coarser sediments dominated the eastern (inshore) seafloor while finer sediments dominated the western seafloor (Figure 3-3). In general, there appeared to be some relationship between depth of the borrow pit and the backscatter intensity. Backscatter along the eastern boundary of the borrow pit (depth < 3.0 m) ranged from approximately -29 to -36 dB, while values to the west of the borrow pit (depth < 3.5 m) ranged from approximately -30 to -39 db. Within the borrow pit, the lowest backscatter values (i.e., the smoothest seafloor or least consolidated sediment) were observed near the eastern slope of the borrow pit and across an approximately 230 m x 70 m area in the northeastern portion of the pit (Figure 3-3). Backscatter within this area ranged from approximately -43 to -46 dB, typically at a depth of 4.0–7.0 m. Backscatter within the deeper areas of the borrow pit (> 7.0 m) suggested the presence of firmer, coarse deposits, with typical backscatter values ranging from -34 to -40 dB.

3.2 Sediment-Profile Imaging

A SPI survey was performed to aid in the physical and biological characterization of the borrow pit and surrounding area. The 2011 SPI survey design included the collection of sediment-profile images at 35 stations distributed across five transects. Each transect was oriented perpendicular to the long axis of the borrow pit and extended onto the ambient seafloor on both sides of the pit. Detailed image analysis results are provided in Appendix A. The following sections summarize and compare the results for the SPI stations outside and inside the borrow pit.

3.2.1 Ambient Seafloor

<u>Physical Sediment Characteristics</u>

The long axis of the borrow pit roughly falls along the break from the more uniform depths of the cove to the slope leading up to the shoreline (Figure 1-3), and the SPI results highlighted the physical differences in the ambient sediments in these two areas. The area sampled east of the borrow pit ranged in depth from 2.4–3.0 m while the area sampled west of the borrow pit ranged in depth from 3.0–3.4 m. The stations east of the borrow pit were firmer, sandier, and contained more shells/fragments than stations to the west of the borrow pit (Table 3-1). The major grain size mode at stations east of the borrow pit ranged from very fine sand (4-3 phi) to medium sand (2-1 phi). Stations west of the borrow pit had more fine-grained sediments, consisting of silt/clay (>4 phi) and very fine sand (4-3 phi) (Figure 3-4).

Differences in the mean station prism penetration depths reflected the same spatial distribution as the differences in sediment grain-size: the firmer sand substratum east of the borrow pit had shallower camera penetration depths, while the softer silt substratum west of the borrow pit allowed for greater camera prism penetration (Figure 3-5). Mean station prism penetration depth ranged from 1.7–5.2 cm east of the borrow pit and 12.2–17.6 cm west of the borrow pit (Table 3-1, Figure 3-6).

Although the magnitude of the boundary roughness was similar between the two areas, it was attributed to different sources (Figure 3-7, Table 3-1). Biological roughness due to the presence of small-scale biogenic features at the sediment surface (e.g., small tubes, burrows and mounds) resulting from the surface and subsurface feeding and foraging activities of benthic organisms was dominant in stations west of the borrow pit, while physical roughness due to the presence of physical sediment features (e.g. broken shells and sand ripples) was dominant east of the borrow pit (Figure 3-8). Dredged material was not detected in any of the 15 locations outside of the borrow pit (Figure 3-9).

Biological Conditions

Given the differences in substratum and water depth between the east and west areas outside the borrow pit, the biological conditions were subtly different (Figure 3-10). The mean aRPD depth ranged from 1.6–2.3 cm in the eastern area and 0.9–2.6 cm in the western area. Shallow aRPDs were measured at three western stations (Stations 9, 15, and 16) (Figure 3-11, Table 3-1). Four stations in the east (Stations 7, 13, 14, and 20) had indeterminate aRPD values due to limited prism penetration (Figure 3-10), but in the three other eastern stations aRPD values were fairly deep (Figure 3-11, Table 3-1).

Evidence of Stage 2 succession was present at one station (Station 21), and Stage 3 infauna was observed at the two southern stations (Stations 28 and 35) on the eastern side of the borrow pit (Figures 3-11, 3-12). There were no subsurface feeding voids visible in any of the eastern stations. Successional stage was indeterminate in all replicates at four stations located in the east (Stations 7, 13, 14, and 20; Figure 3-13). All of the western stations had evidence of Stage 3 succession in at least one replicate (Figure 3-12). All of the western stations also had an average of one feeding void present at each station, with the exception of Station 8 (Figure 3-13, Table 3-1). Methane was present in only one replicate from Stations 8 and 29, located west of the borrow pit (Figure 3-14). Evidence of *Beggiatoa* was not identified in any replicate images outside of the borrow pit (Figure 3-15).

3.2.2 Within Borrow Pit

Physical Sediment Characteristics

Although the SPI stations within the borrow pit ranged in depth from 3 m to over 8 m, the physical characteristics of the sediment were quite uniform (Table 3-2). All of the stations within the borrow pit had a grain size major mode of >4 phi (silt/clay, Figure 3-4). The mean prism penetration depths reflected the soft, unconsolidated texture of the sediment inside the borrow pit, and were comparable to, but in many cases less than, the measurements outside the borrow pit to the west (Figure 3-5). Mean station penetration depths ranged from 13.3–19.2 cm with an overall mean of 15 cm (Table 3-2).

Mean station boundary roughness within the borrow pit was variable, ranging from 0.4 to 3.1 cm, but most of the stations with high boundary roughness had a disturbed sediment-water interface classified as a camera artifact (Table 3-2; Figure 3-7, Appendix A). These stations also tended to have a high abundance of methane bubbles and unconsolidated sediment (Figure 3-16). Although methane was present in almost every station, stations with low biological boundary roughness (e.g., Station 10) generally had more consolidated silt and less methane (Figure 3-16). However, even stations that had well-developed layers of tubes (e.g., Station 31) could have substantial amounts of methane and moderate boundary roughness (Figure 3-17).

Dredged material was identified in the sediment-profile images collected from 11 of the 20 stations located within the borrow pit, exceeding the penetration depth of the camera prism in at least one replicate at seven of those stations (Figure 3-9). The dredged material observed within the borrow pit was found primarily at stations located within the southern or central portion of the borrow pit (near the pilot study buoy location). Generally, the physical composition of the dredged material did not appear dissimilar from the sediments in other portions of the borrow pit (unconsolidated silt/clay).

SPI data indicated that an anoxic event had taken place across the floor of the borrow pit. Evidence of its occurrence is typically identified in the sediment-profile images as a thin black layer between the new deposition and the underlying sediments (Figure 3-18). The material above this signal looks to be comprised of more recently deposited sediments.

3.2.2.1 Biological Conditions

The SPI data indicated poor biological conditions and a stressed community within the borrow pit. The mean aRPD depth (0.8 cm; Figure 3-10, Table 3-1) was less than half that of stations outside the borrow pit, and 15 stations had mean aRPD depths less than 1 cm, indicating limited oxygen penetration into the sediment (Figure 3-19, Figure 3-20).

Successional stage distribution inside the borrow pit was variable, but generally showed less advanced succession than stations outside the pit (Figure 3-12). In general, Stage 2 organisms (tube-building ampeliscid amphipods) dominated the biological assemblages inside the borrow pit (Figures 3-18, 3-19). Eighteen of the 20 borrow pit stations had at least one replicate with Stage 2 or 1->2 successional assemblages, whereas only six of the stations in the borrow pit had evidence of Stage 3 successional stages, including feeding voids (Figure 3-13).

Methane was present in all but three stations inside the borrow pit (Stations 12, 32 and 34) (Figure 3-14). Evidence of *Beggiatoa* sp. colonies was present in five stations inside the borrow pit (Stations 3, 6, 27, 30, and 33) (Figure 3-15).

3.3 Water Quality Profiles

The complete suite of water quality data collected outside and inside of the borrow pit is provided in Appendix C. The dates, times, depths, and tidal stage associated with each of the profiles are included in Table 3-4, as well as a brief summary of water quality data.

For the September and October surveys, temperatures were similar inside and outside the borrow pit and were slightly warmer near the bottom than at the surface at all stations. Water temperatures cooled slightly (approximately -1.5 °C) between surveys. Dissolved oxygen decreased with depth at both locations and was consistent across both surveys, with all values above 6 mg/L.

Table 3-1.

Summary SPI Results (station averages) outside the MCBP

Location	Station	Depth (m)	Grain Size Major Mode (phi)	Mean Prism Penetration Depth (cm)	Mean Boundary Roughness (cm)	Dominant Type of Boundary Roughness	Mean aRPD Depth (cm)	Mean # of Subsurface Feeding Voids	Methane Present?	Mean Dredged Material Thickness (cm)	Successional Stages Present (3 replicates)		
West of Pit	1	3.0	4-3/>4	16.9	1.2	Biological	2.6	4	No	0	1 on 3	2 on 3	2 on 3
	2	3.4	4-3/>4	16.1	1.5	Biological	2.3	3	No	0	1 on 3	2 on 3	2 on 3
	8	3.0	4-3/>4	16.8	0.6	Biological	2.4	0	Yes	0	1 on 3	1 on 3	1 on 3
	9	3.0	4-3/>4	12.2	1.1	Biological	1.4	1	No	0	1 on 3	2 on 3	2 on 3
	15	3.0	>4	17.6	0.9	Biological	0.9	2	No	0	1 on 3	1 on 3	2
	16	3.4	>4	17.6	1.0	Biological	0.9	2	No	0	1 on 3	1 on 3	1 on 3
	22	3.0	>4	16.3	0.6	Biological	2.1	1	No	0	1 on 3	1 on 3	2 on 3
	29	3.0	4-3/>4	14.3	1.4	Biological	2.6	1	Yes	0	1 on 3	1 on 3	2 on 3
East of Pit	7	2.4	2-1	3.2	1.1	Physical	IND	0	No	0	IND	IND	IND
	13	2.7	4-2	1.7	0.8	Physical	IND	0	No	0	IND	IND	IND
	14	2.7	3-2/2-1	3.0	1.5	Physical	IND	0	No	0	IND	IND	IND
	20	3.0	4-3	3.2	1.4	Physical	IND	0	No	0	IND	IND	IND
	21	2.7	3-2/2-1	3.0	0.7	Physical	2.3	0	No	0	2	2	IND
	28	2.7	3-2	4.6	1.1	Physical	1.6	0	No	0	1 on 3	1 on 3	1 on 3
	35	2.4	3-2	5.2	1.6	Physical	2.1	0	No	0	1 on 3	1 on 3	1 on 3

Note: IND = Indeterminate

Table 3-2.

Summary SPI Results (station averages) inside MCBP

Station	Depth (m)	Grain Size Major Mode (phi)	Mean Prism Penetration Depth (cm)	Mean Boundary Roughness (cm)	Dominant Type of Boundary Roughness	Mean aRPD Depth (cm)	Mean # of Subsurface Feeding Voids	Methane Present?	Mean Dredged Material Thickness (cm)	Successional Stages Present (3 replicates)		
3	5.2	>4	14.1	0.7	Biological	0.5	0	Yes	0	1 - 2	2	2
4	7.6	>4	14.0	1.0	Biological	0.5	0	Yes	0	1 - 2	2	0 (Azoic)
5	7.6	>4	14.9	0.7	Biological	0.6	0	Yes	0	2	2	2-3
6	4.9	>4	15.0	0.6	Biological	0.6	0	Yes	0	1	2	2
10	6.7	>4	15.0	0.4	Biological	0.8	1	Yes	0	1 - 2	2 on 3	2
11	6.7	>4	14.7	0.8	Biological	0.9	0	Yes	0	2	2	2
12	4.0	>4	14.3	0.9	Physical	0.6	1	No	0	2 on 3	2	2
17	5.8	>4	14.0	0.6	Biological	1.2	0	Yes	0	2	2	2-3
18	5.8	>4	13.3	2.0	Physical	1.2	0	Yes	0.7	1	2	2-3
19	4.6	>4	14.6	1.2	Physical	0.5	1	Yes	2.3	1	2	IND
23	7.9	>4	13.7	0.7	Biological	1.0	0	Yes	3.5	2	2	2
24	7.6	>4	15.7	1.3	Biological	1.6	0	Yes	3.6	2	2	3
25	5.2	>4	15.1	1.4	Physical	0.0	1	Yes	6.0	2	2	2
26	8.5	>4	14.0	1.0	Physical	0.2	0	Yes	3.0	1	1	2
27	5.2	>4	19.2	3.1	Physical	0.0	0	Yes	4.3	1	0 (Azoic)	0 (Azoic)
30	6.1	>4	15.0	0.6	Biological	1.1	0	Yes	4.6	1 - 2	2	2
31	6.4	>4	15.0	0.8	Biological	1.5	0	Yes	4.2	2	2	2
32	3.4	>4	19.1	1.0	Biological	0.9	0	No	0.5	1 on 3	2-3	2-3
33	5.2	>4	14.3	0.8	Biological	0.9	0	Yes	4.0	1 - 2	2	2
34	3.1	>4	16.0	1.2	Biological	0.8	0	No	0	1 - 2	1	1

Note: IND = Indeterminate

Table 3-3.

Summary of Station Means by Sampling Location

	Mean aRPD (cm)			Mean Prism Penetration (cm)		
Site	**N**	**Mean**	**Standard Deviation**	**N**	**Mean**	**Standard Deviation**
Outside Pit						
East	7	2.0	0.37	7	3.4	1.62
West	8	1.9	0.74	8	16	1.84
East+West	15	1.9	0.64	15	10.1	6.7
Within Pit	20	0.8	0.35	20	15	1.54

Table 3-4.

MCBP Water Quality Profile Events

Station	Date/ Time	Depth (m)	Tide	Temperature (°C) surface/ bottom	DO (mg/L) surface/ bottom
MCDS-Out					
	9/28/2011 12:27	5.7	High (ebb)	19.9 / 21.1	8.2 / 6.9
	9/28/2011 16:37	2.9	Low	21.1 / 21.2	7.5 / 7.0
	10/4/2011 07:45	4.7	High (ebb)	16.4 / 19.77	9.1 / 7.0
	10/4/2011 12:12	3.4	Low (slack)	19.2 / 19.8	10.6 / 6.2
	10/4/2011 13:55	4.0	Low (flood)	19.2 / 19.5	7.2 / 7.0
MCDS-In-1					
	9/28/2011 12:18	7.9	High (ebb)	21.0 / 21.2	7.2 / 6.5
	9/28/2011 16:29	5.9	Low	20.8 / 21.2	7.6 / 6.9
	10/4/2011 07:49	8.7	High (ebb)	18.4 / 19.9	7.7 / 6.6
	10/4/2011 12:04	6.1	Low (slack)	19.0 / 19.9	7.0 / 6.2
	10/4/2011 13:42	6.6	Low (flood)	18.9 / 19.8	7.6 / 6.8
MCDS-In-2					
	9/28/2011 12:22	9.8	High (ebb)	20.6 / 21.1	7.7 / 6.4
	9/28/2011 16:33	7.9	Low	21.1 / 21.2	7.5 / 6.8
	10/4/2011 07:55	9.5	High (ebb)	18.5 / 19.6	7.5 / 6.1
	10/4/2011 12:12	3.4	Low (slack)	18.7 / 19.6	7.3 / 6.5

Figure 3-1. Bathymetric contour map of MCBP, September 2011 (0.5 m contour intervals) over a hillshaded relief layer

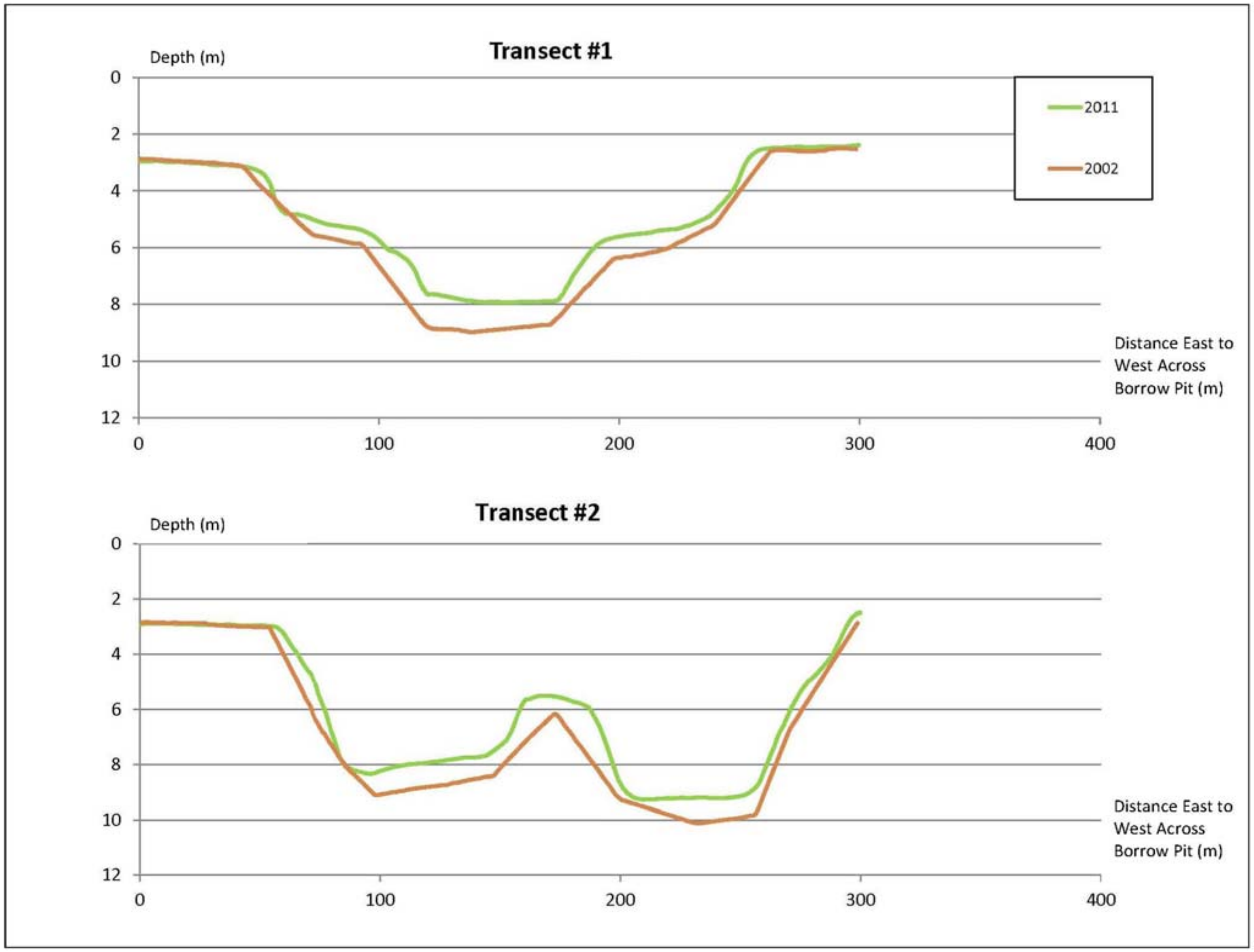


Figure 3-2. Depth difference profile map of MCBP survey area, May 2002 vs. September 2011. 2002 results have been corrected by a -0.25 m offset.

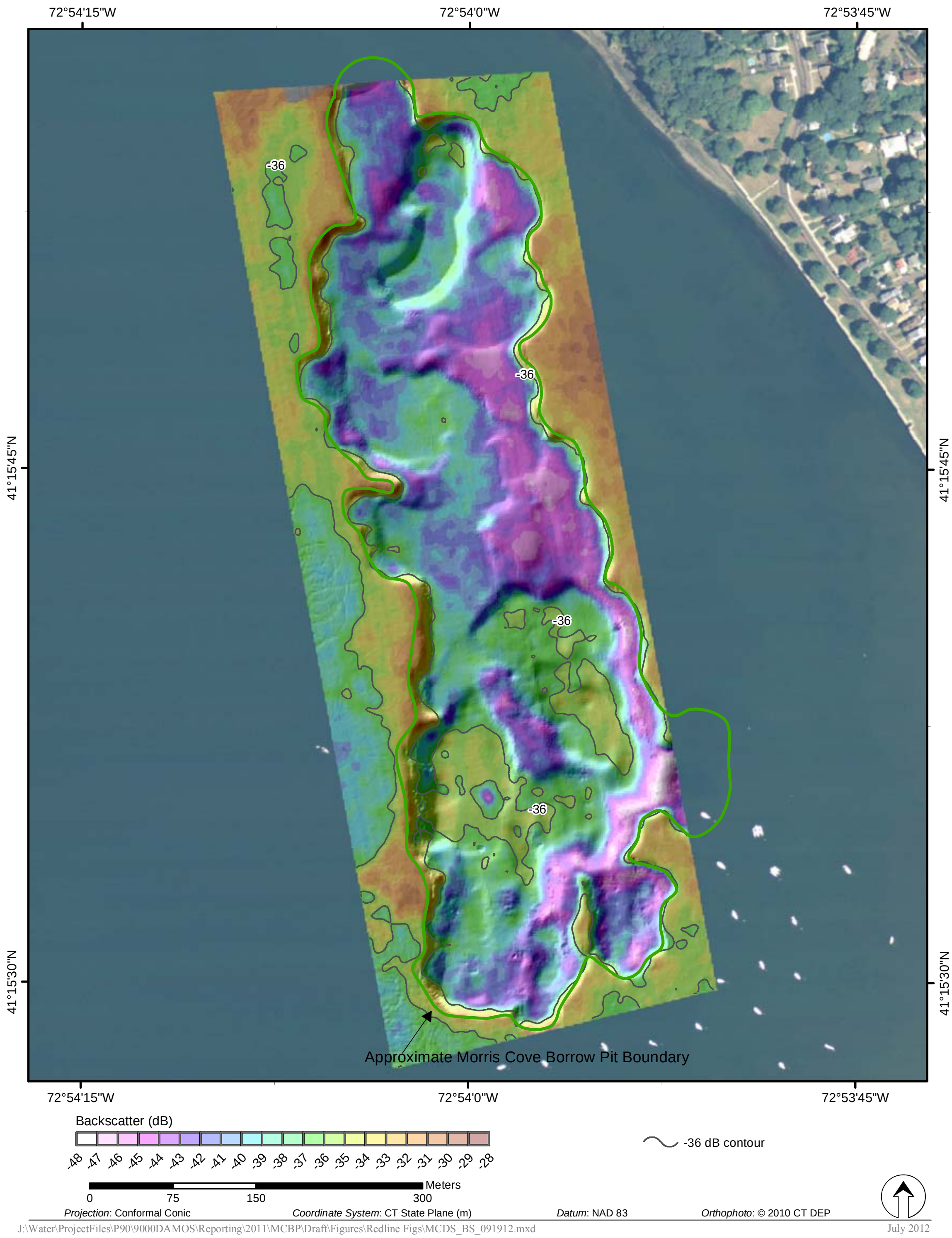


Figure 3-3. Backscatter intensity (dB) at MCBP, September 2011, over hillshaded bathymetry

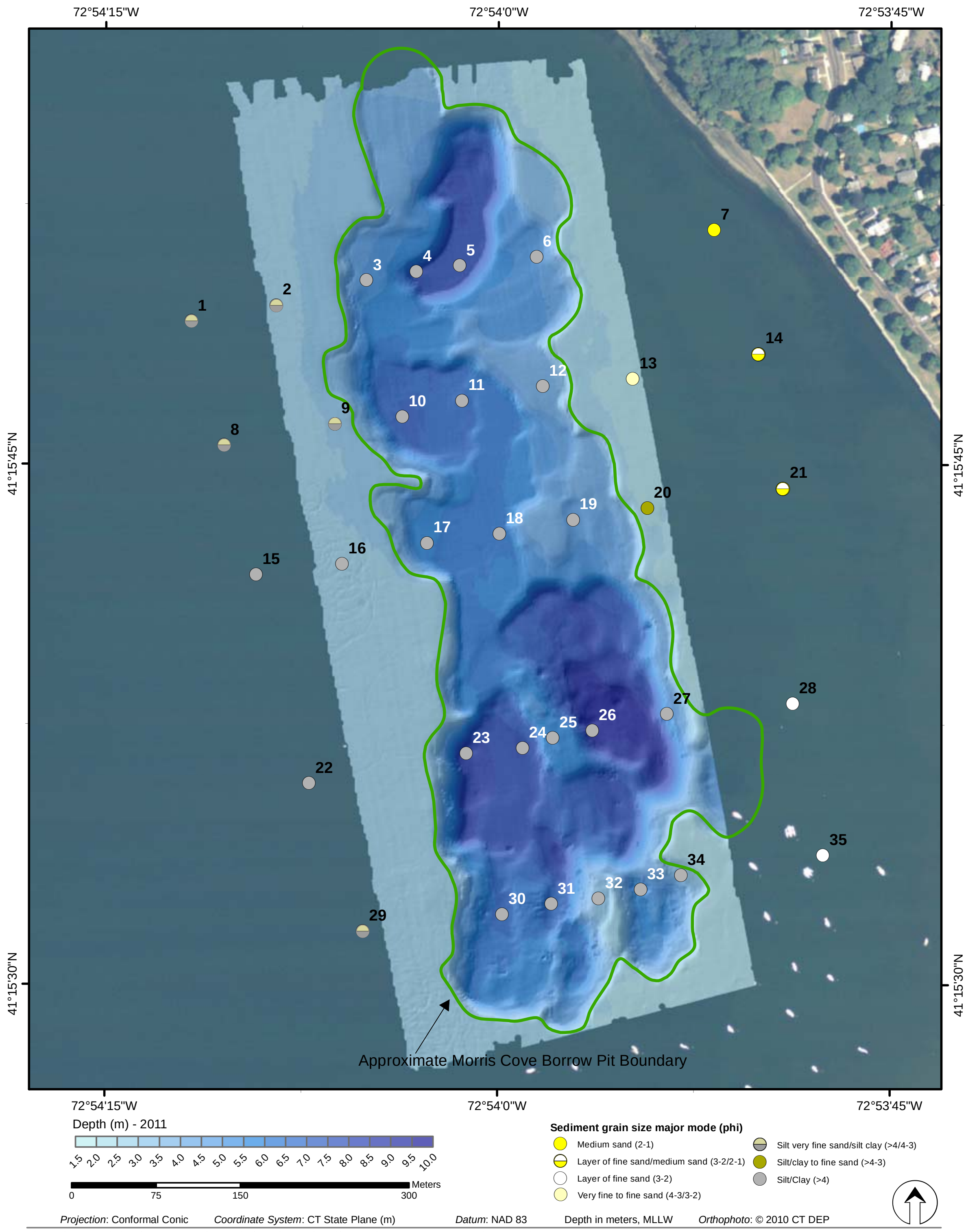


Figure 3-4. Map of mean replicate grain-size major-mode (phi units) at MCBP

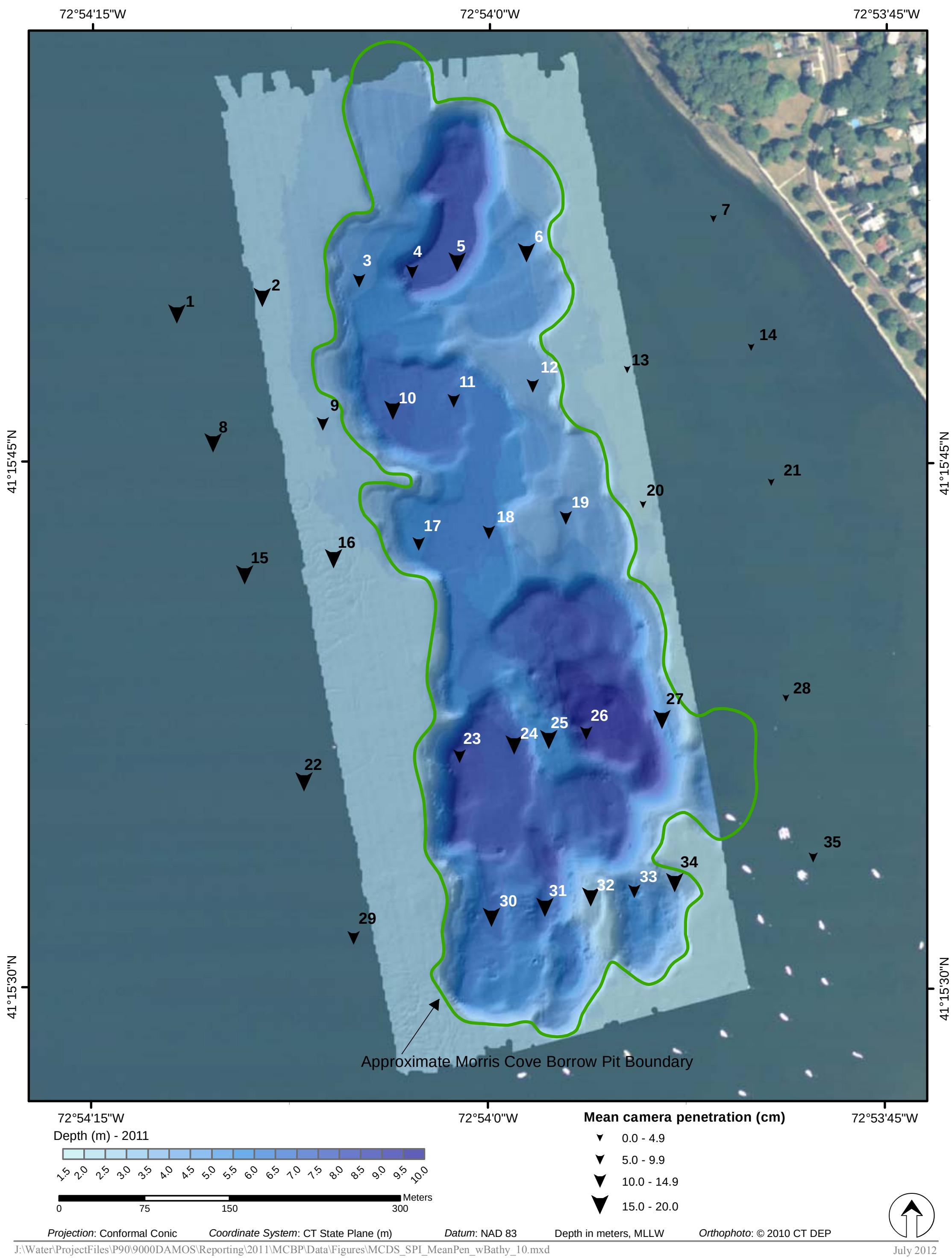


Figure 3-5. Map of mean replicate prism penetration depths (cm) at MCBP

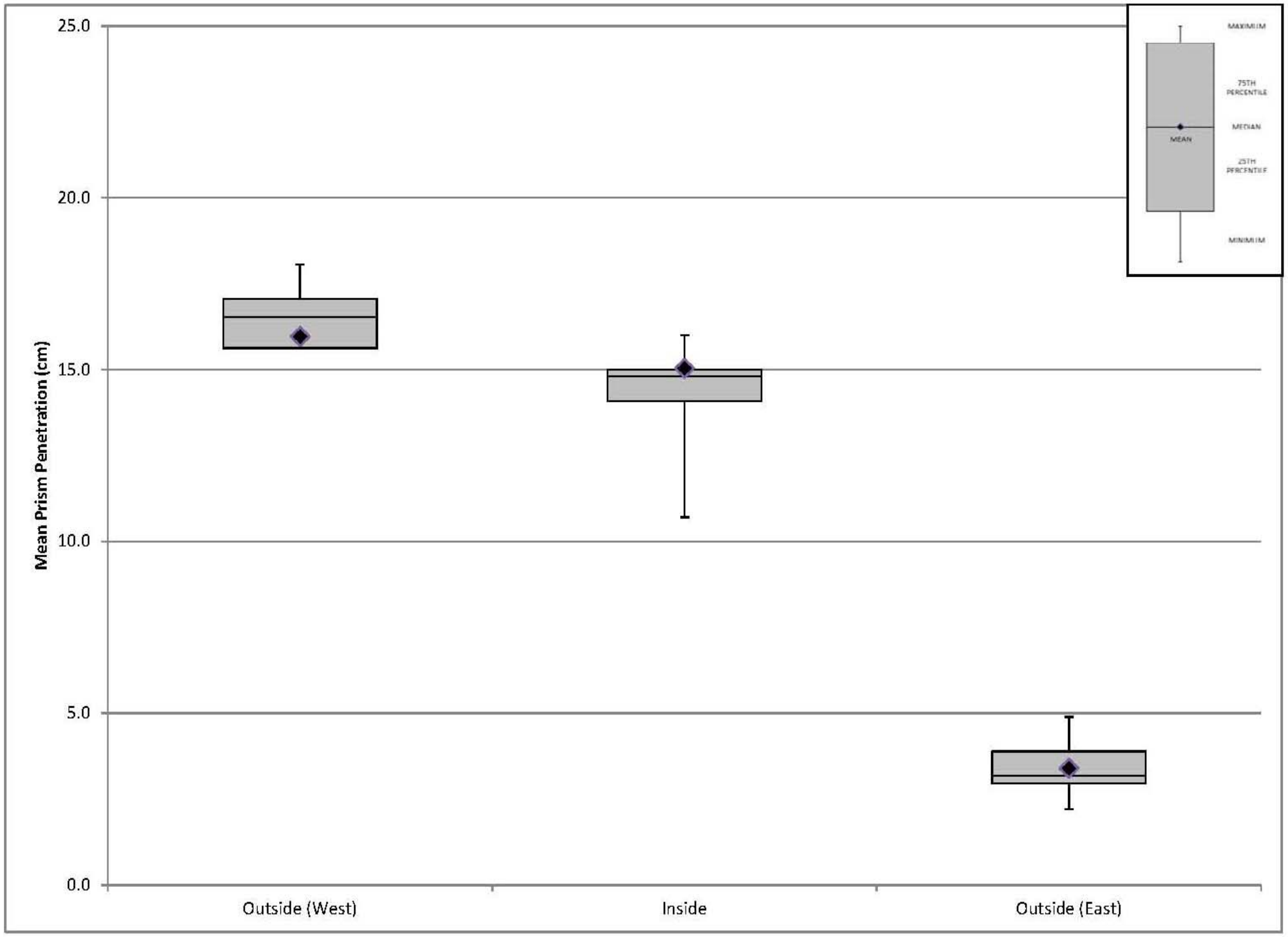


Figure 3-6. Box plots showing the distribution of mean prism penetration depths in the stations located within and outside the borrow pit.

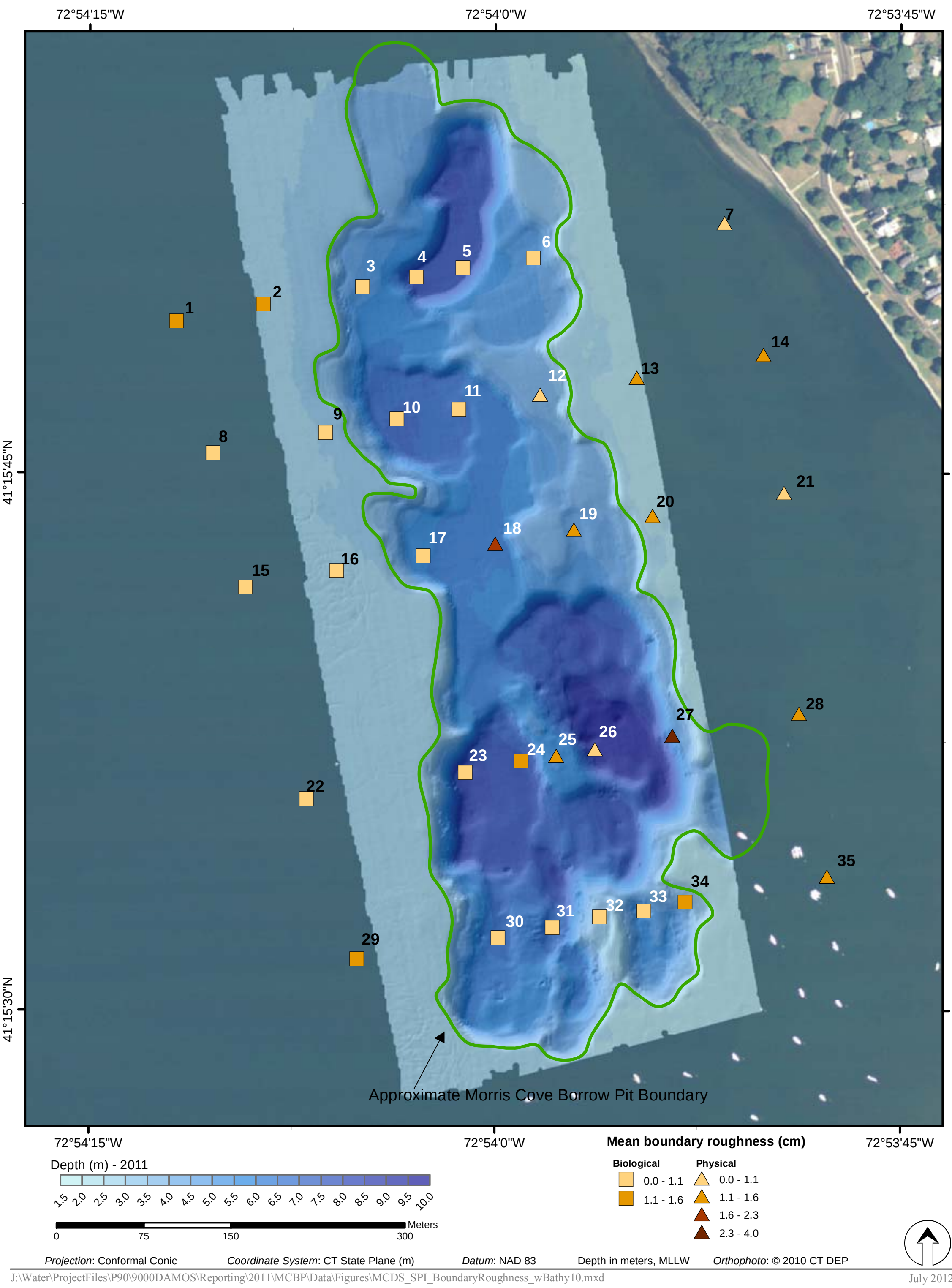
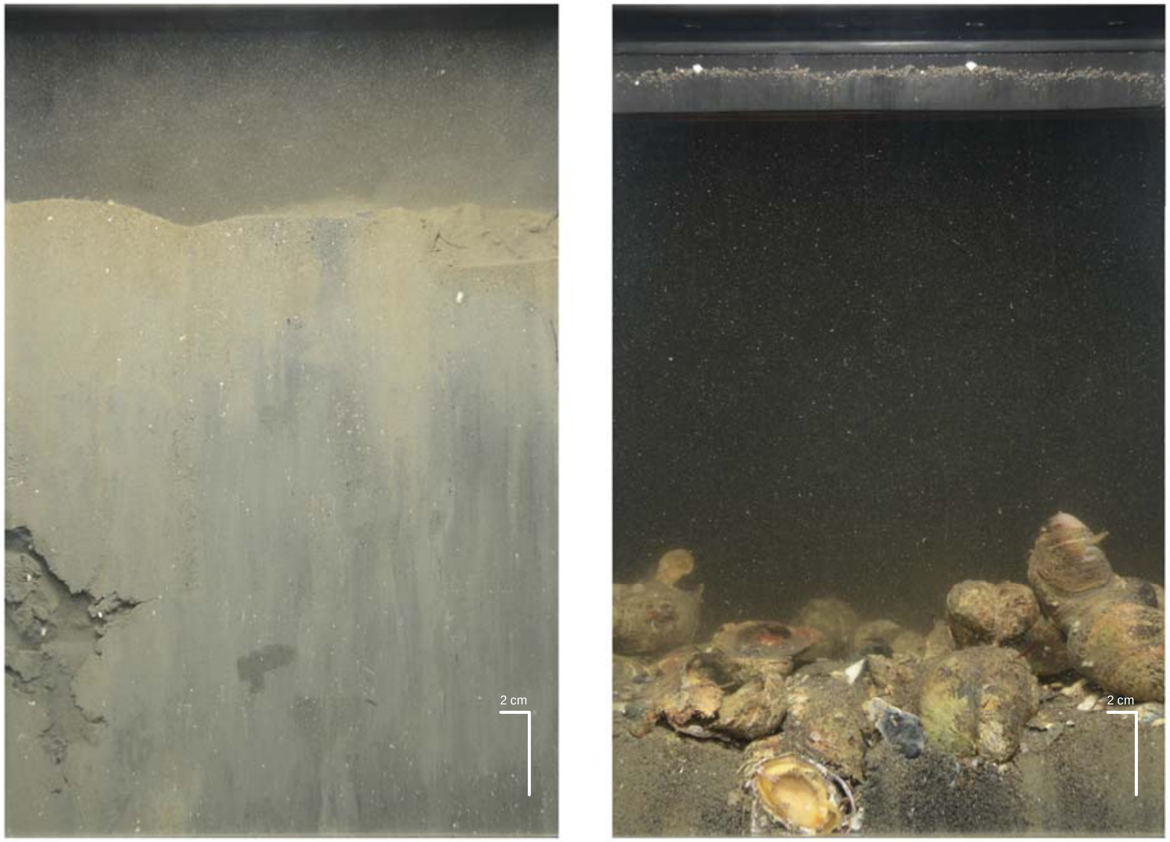


Figure 3-7. Map of mean replicate surface boundary roughness (cm) at MCBP



Station1b Station 14d

Figure 3-8. Comparison of sediment physical characteristics west of the borrow pit (Station 1) and east of the borrow pit (Station 14). Station 1b (left) had a layer of very fine sand over silt/clay and a surface largely formed by biological activities (tubes, burrows) with deep prism penetration (16.3 cm). Station 14d (right) had a layer of fine sand over medium sand, shallow prism penetration (2.3 cm) and a surface largely formed by the presence of live shells and fragments (*Crepidula* sp.).

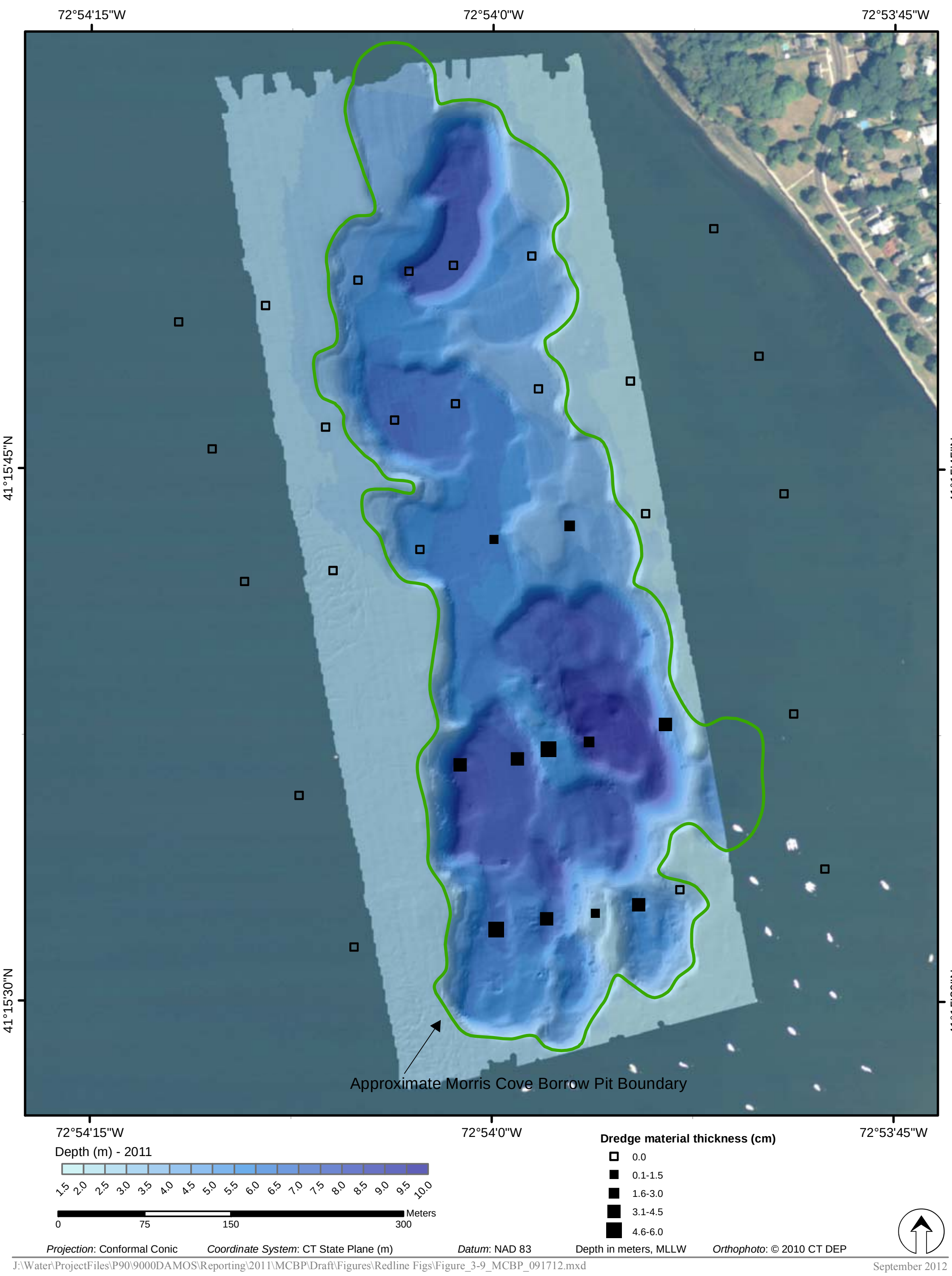


Figure 3-9. Thickness of dredged material identified in SPI images

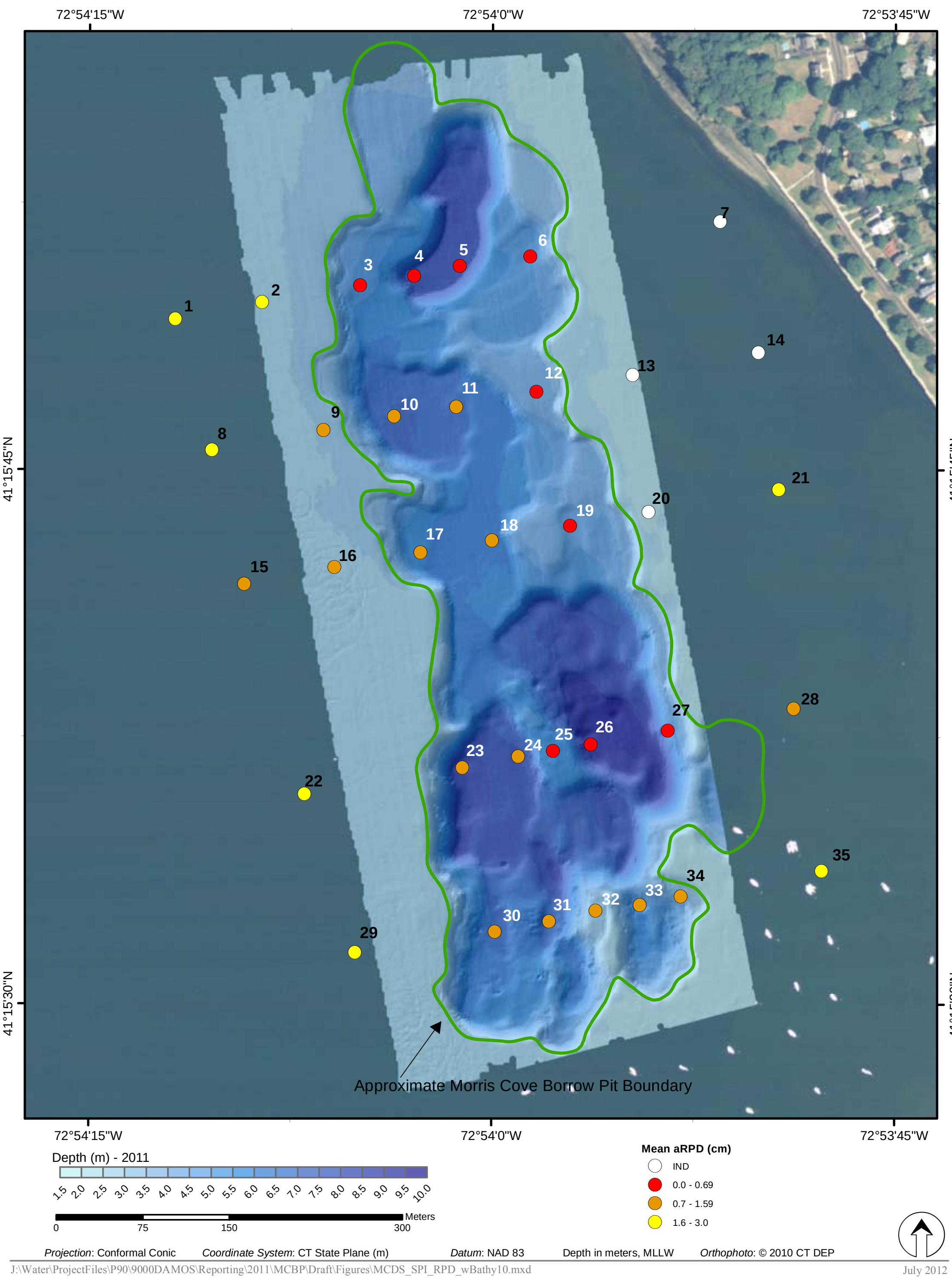


Figure 3-10. Map of mean replicate aRPD depths (cm) at MCBP

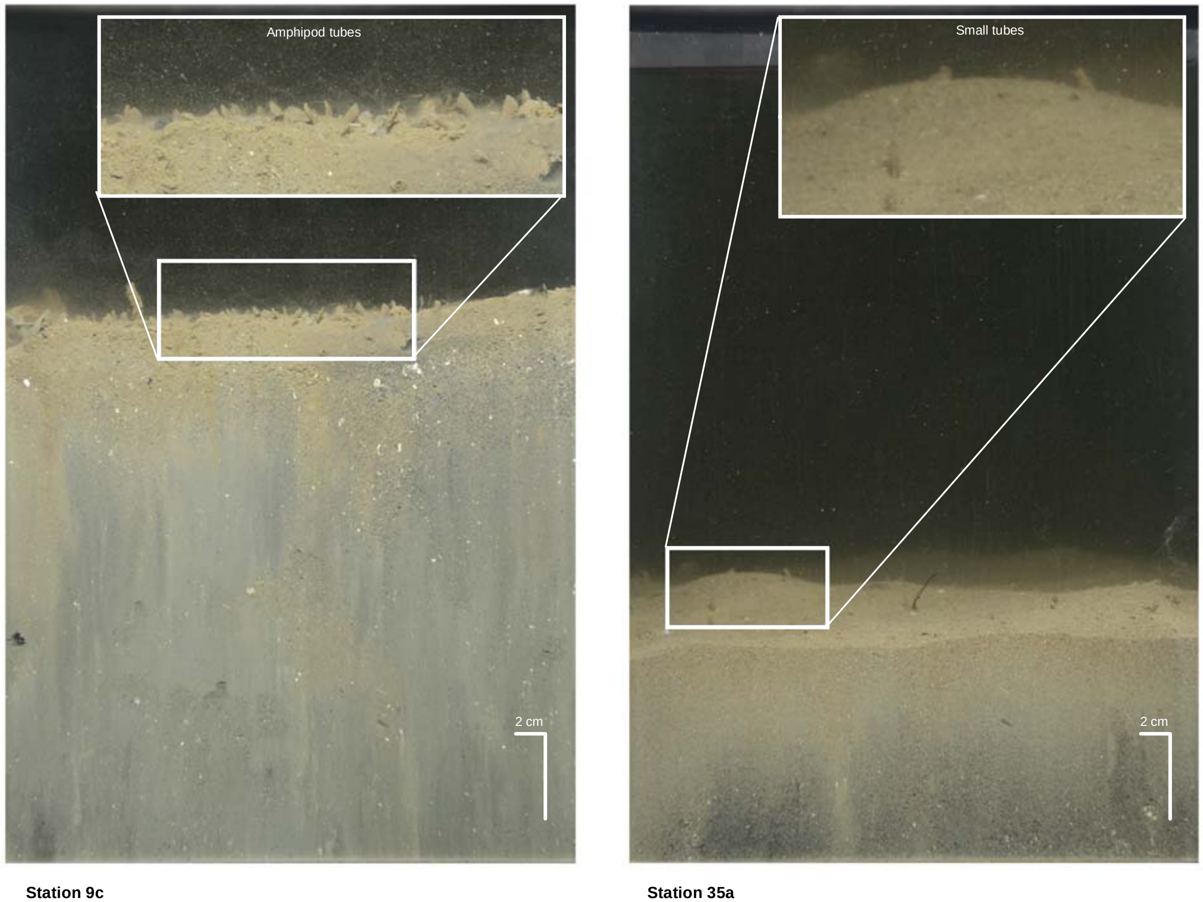


Figure 3-11. Comparison of biological characteristics west of the borrow pit (Station 9) and east of the borrow pit (Station 35). Station 9d had a Stage 2 (amphipod tubes) over Stage 3 (large burrows, feeding voids) successional classification and a shallow aRPD (0.9 cm). Station 35a had a Stage 1 (small tubes) over Stage 3 (large burrows) successional classification and a deep aRPD (2.3 cm).

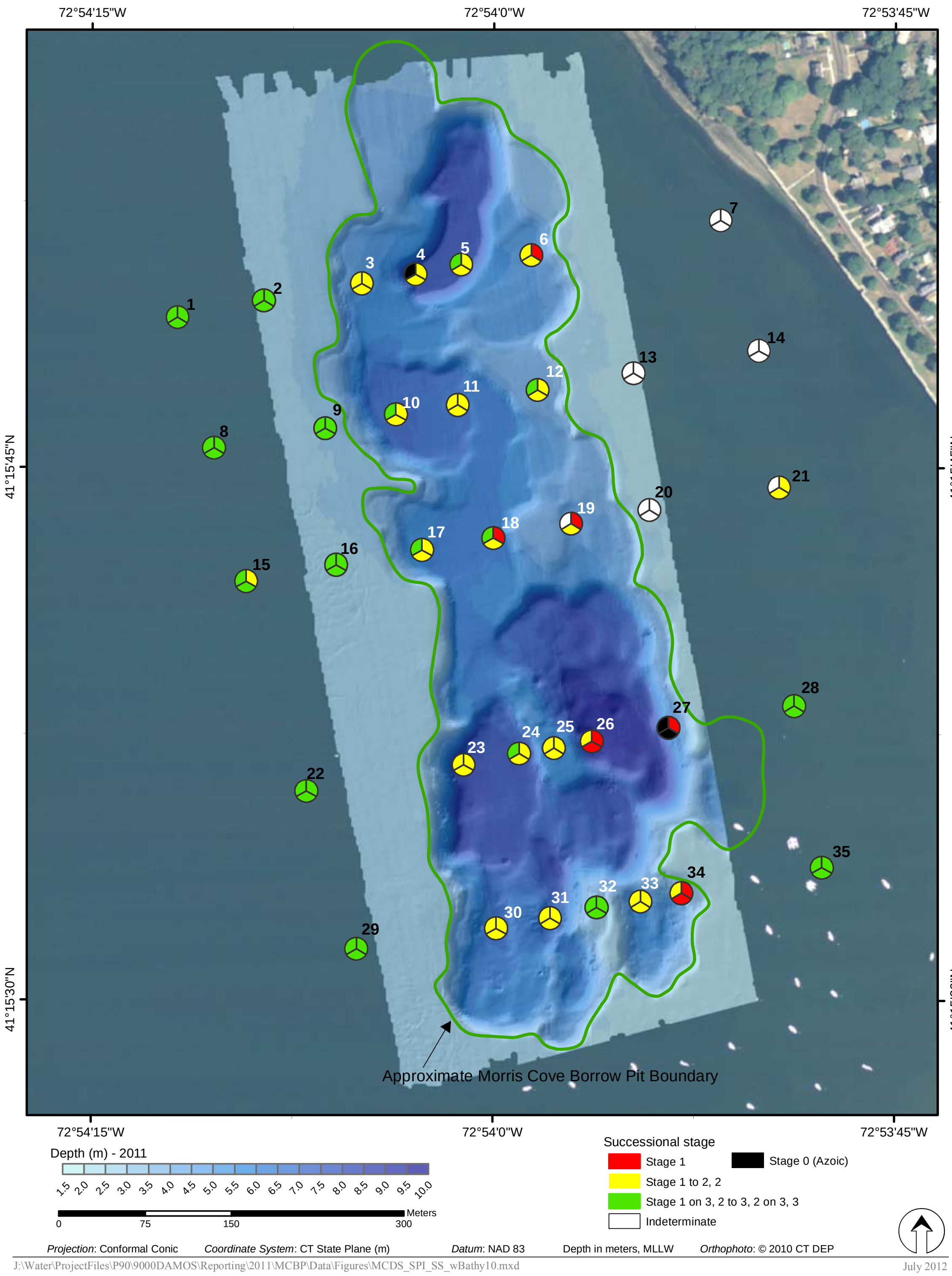
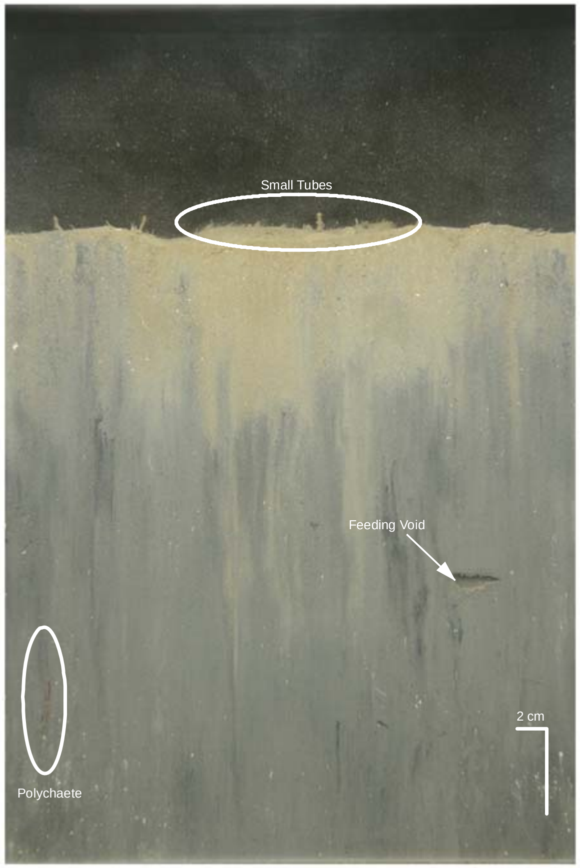


Figure 3-12. Map of replicate infaunal successional stages found at MCBP



Station 22a

Station 20d

Figure 3-13. Comparison of biological characteristics west of the borrow pit (Station 22) and east of the borrow pit (Station 20). Station 22a had a Stage 1 (very small tubes) over Stage 3 (large polychaete and feeding voids) successional classification and a deep aRPD (2.3 cm). Station 20d had an indeterminate successional stage and aRPD due to coarse sediment and limited prism penetration.

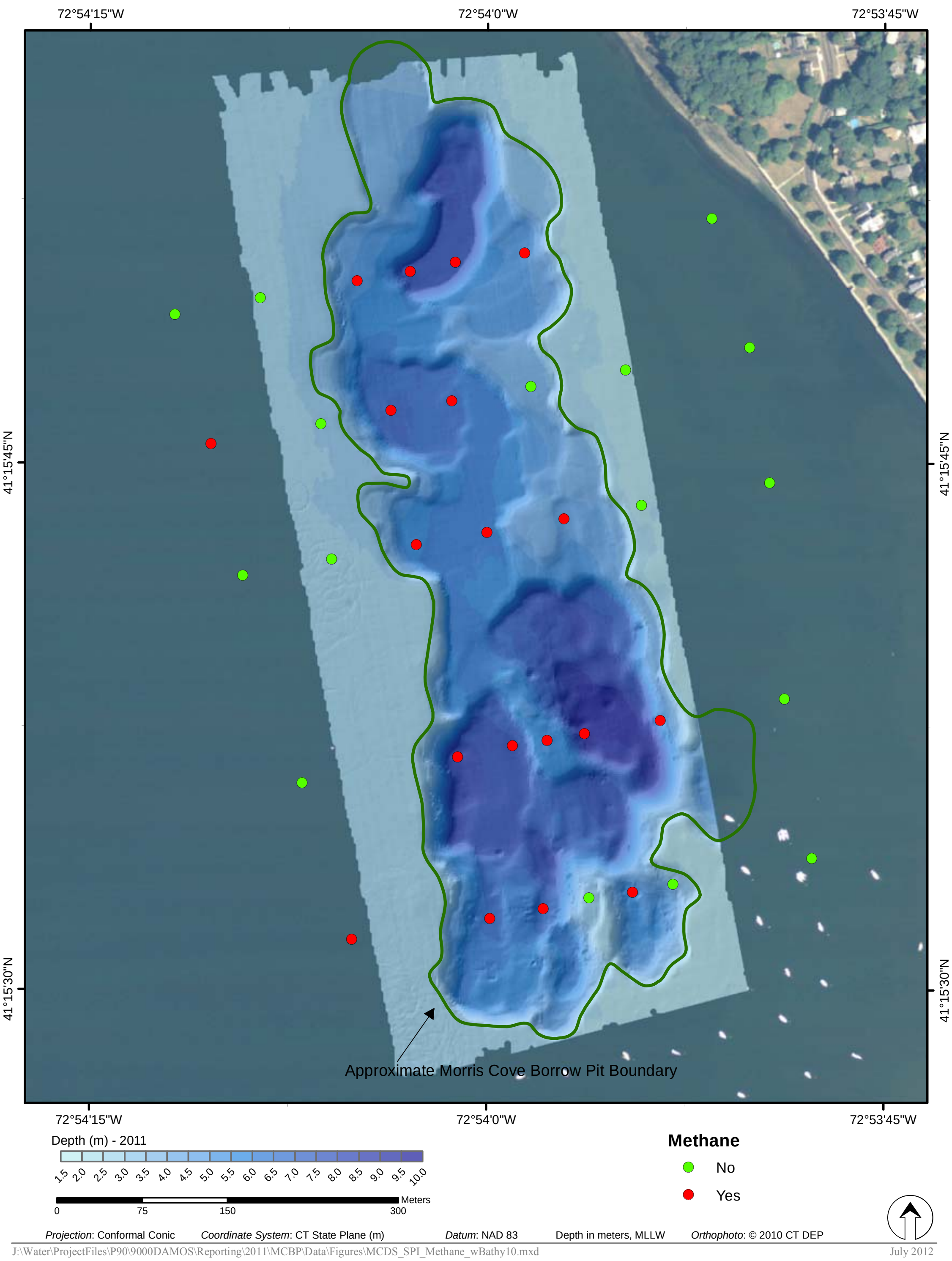


Figure 3-14. Map of methane gas presence at MCBP

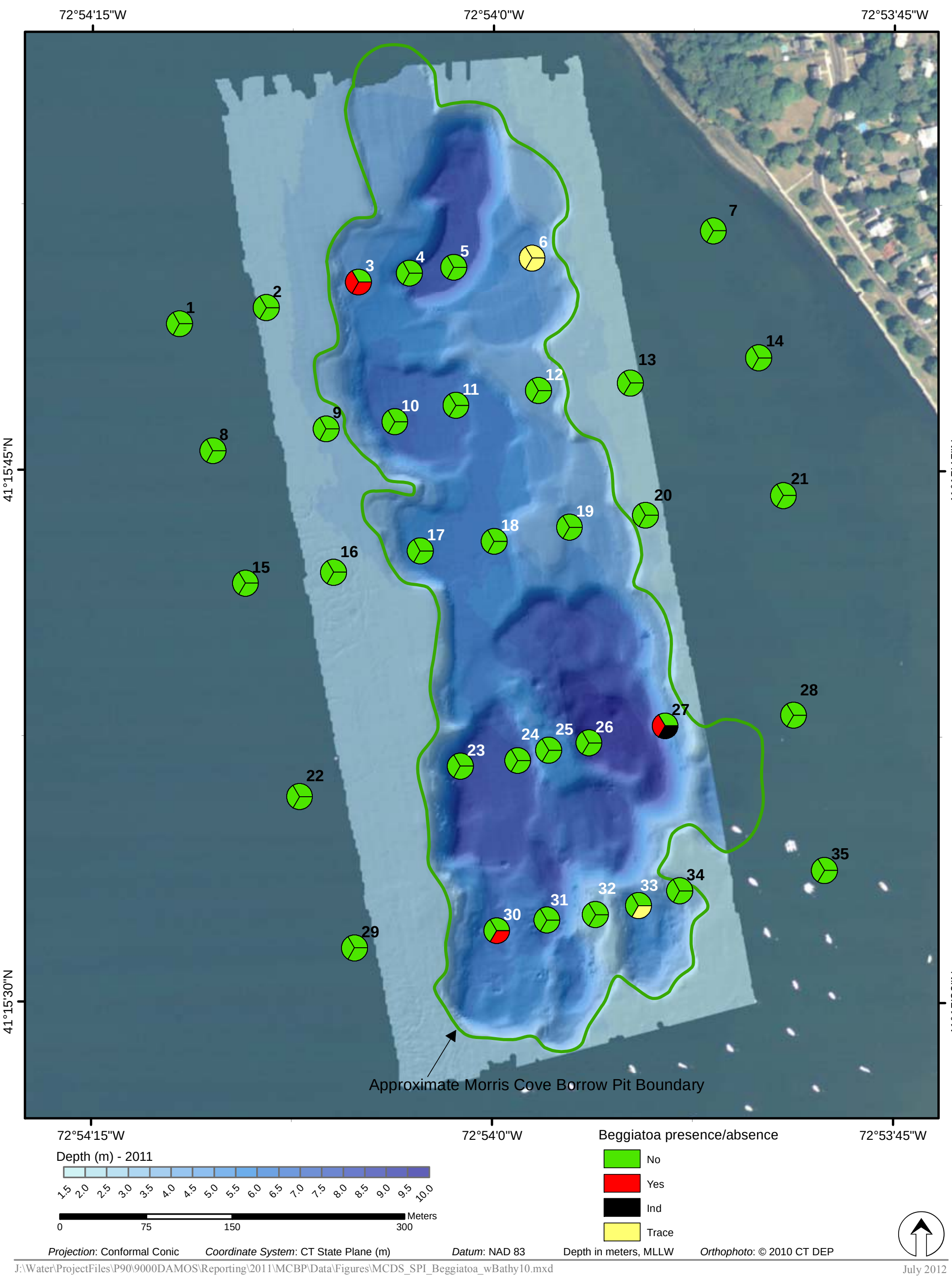
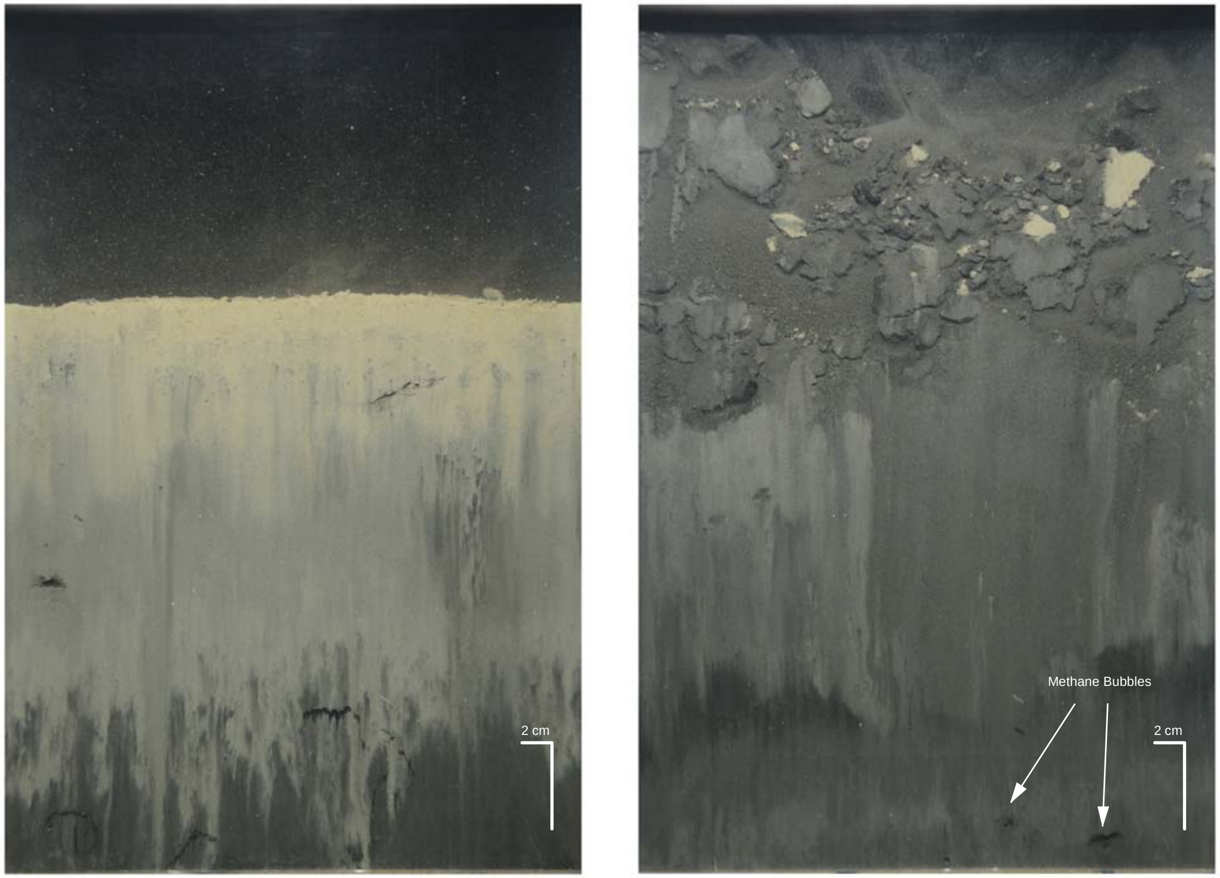


Figure 3-15. Map of *Beggiatoa* sp. presence at MCBP



Station 10c **Station 27c**

Figure 3-16. Comparison of physical characteristics of stations within MCBP (Stations 10 and 27). Station 10c (left) had low biological boundary roughness (0.4 cm) in partially consolidated silt. Station 27c (right) had high physical boundary roughness (3.5 cm) due to disturbance of the loose unconsolidated sediment surface by the camera.

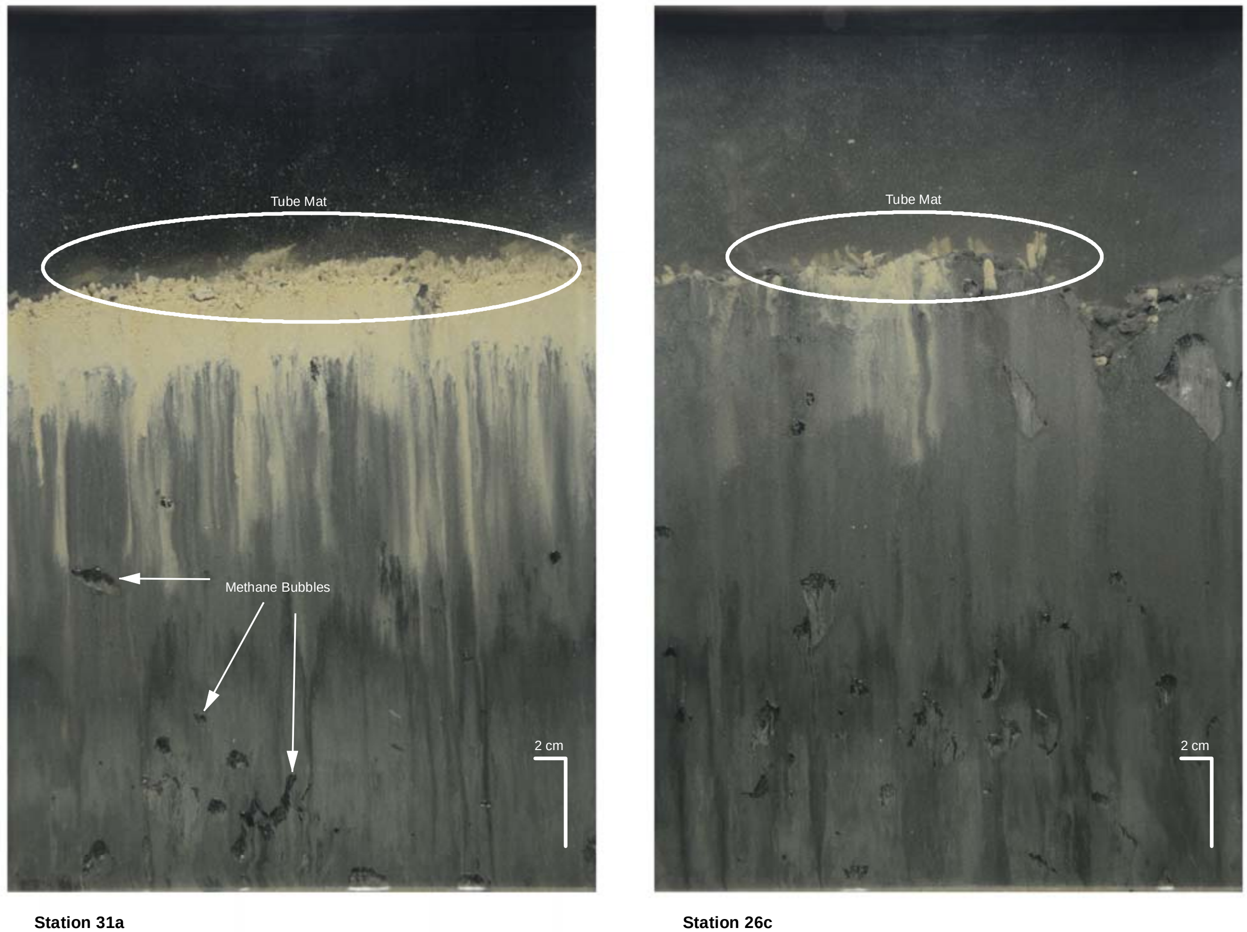


Figure 3-17. Comparison of physical characteristics of stations within MCBP (Stations 31 and 26). Station 31a had distinctive layering of oxidized and reduced sediments with methane bubbles and moderate biological roughness from a tube mat (1.0 cm). Station 26c also had distinctive layering of reduced sediments and a high physical boundary roughness from the collapse of loose sediments around a tube mat (1.7 cm).

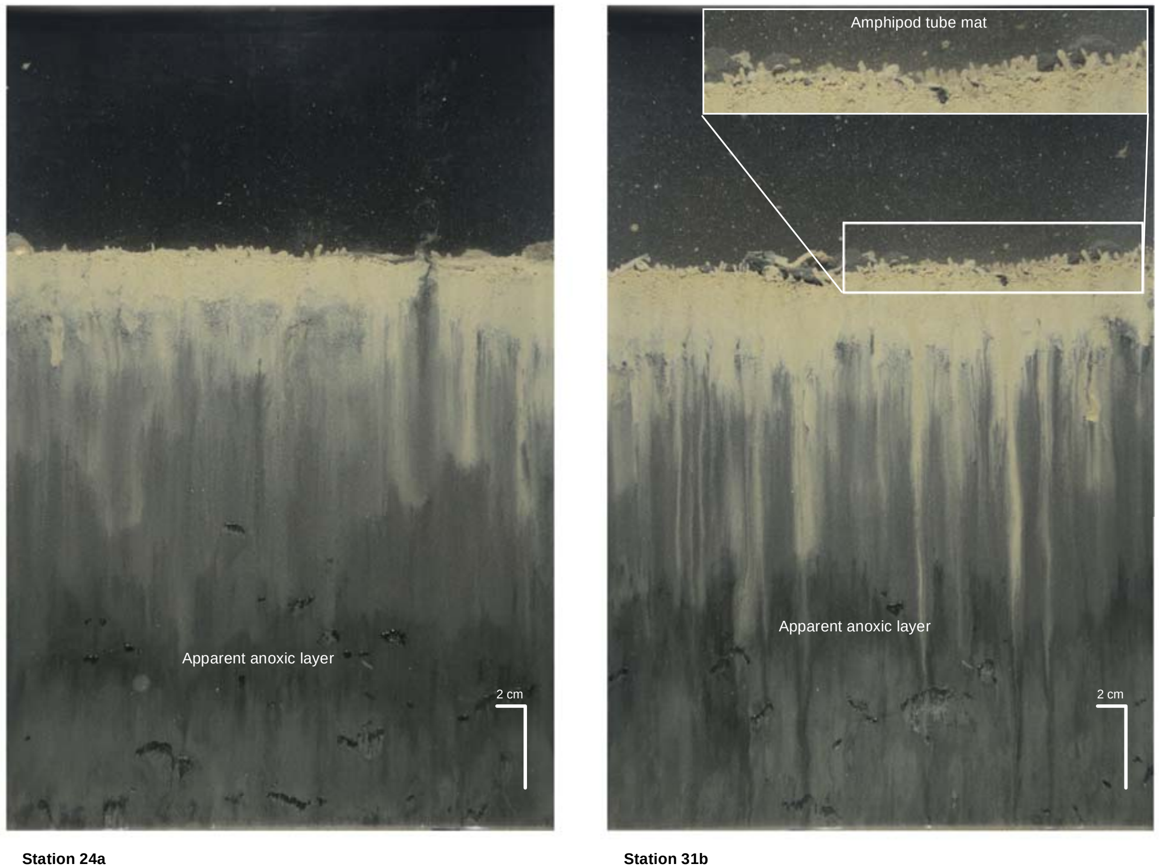
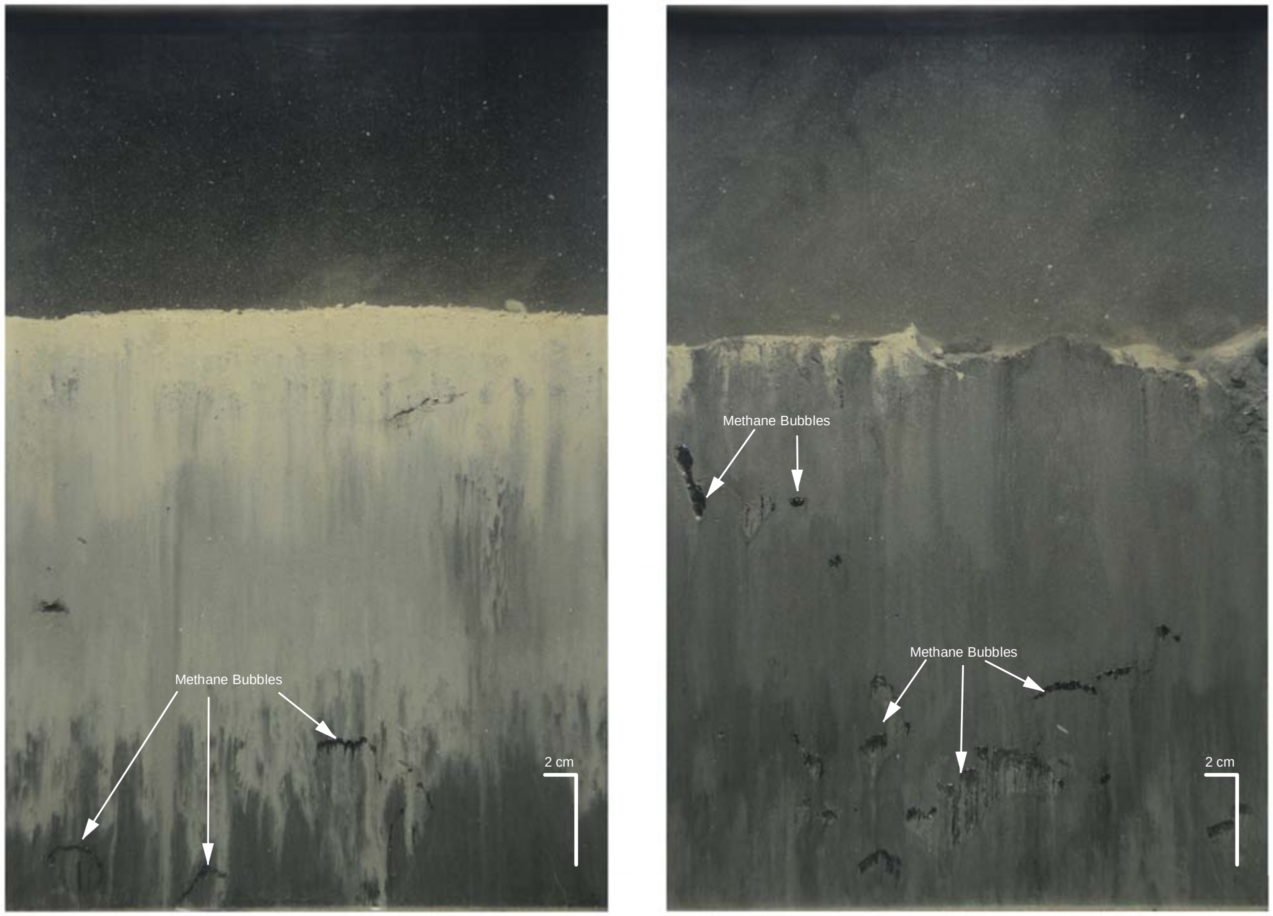


Figure 3-18. Comparison of SPI stations displaying dredged material and anoxic layer (Stations 24 and 31). Station 24a (left) displayed an anoxic layer approximately 9.0 cm below the sediment-water interface overlying apparent dredged material from 2000. Station 31b (right) displayed a similar anoxic layer over dredged material and an amphipod tube mat visible at the surface. This anoxic layer indicates a potential pit-wide anoxic event.



Station 10c Station 26b

Figure 3-19. Comparison of biological condition of stations within MCBP (Stations 10 and 26). Evidence of Stage 2 -> 3 succession at Station 10c (left) with a relatively shallow aRPD (0.8 cm) and very little methane. Evidence of Stage 1 succession at Station 26b (right) with very shallow aRPD (0.1 cm) and numerous methane bubbles.

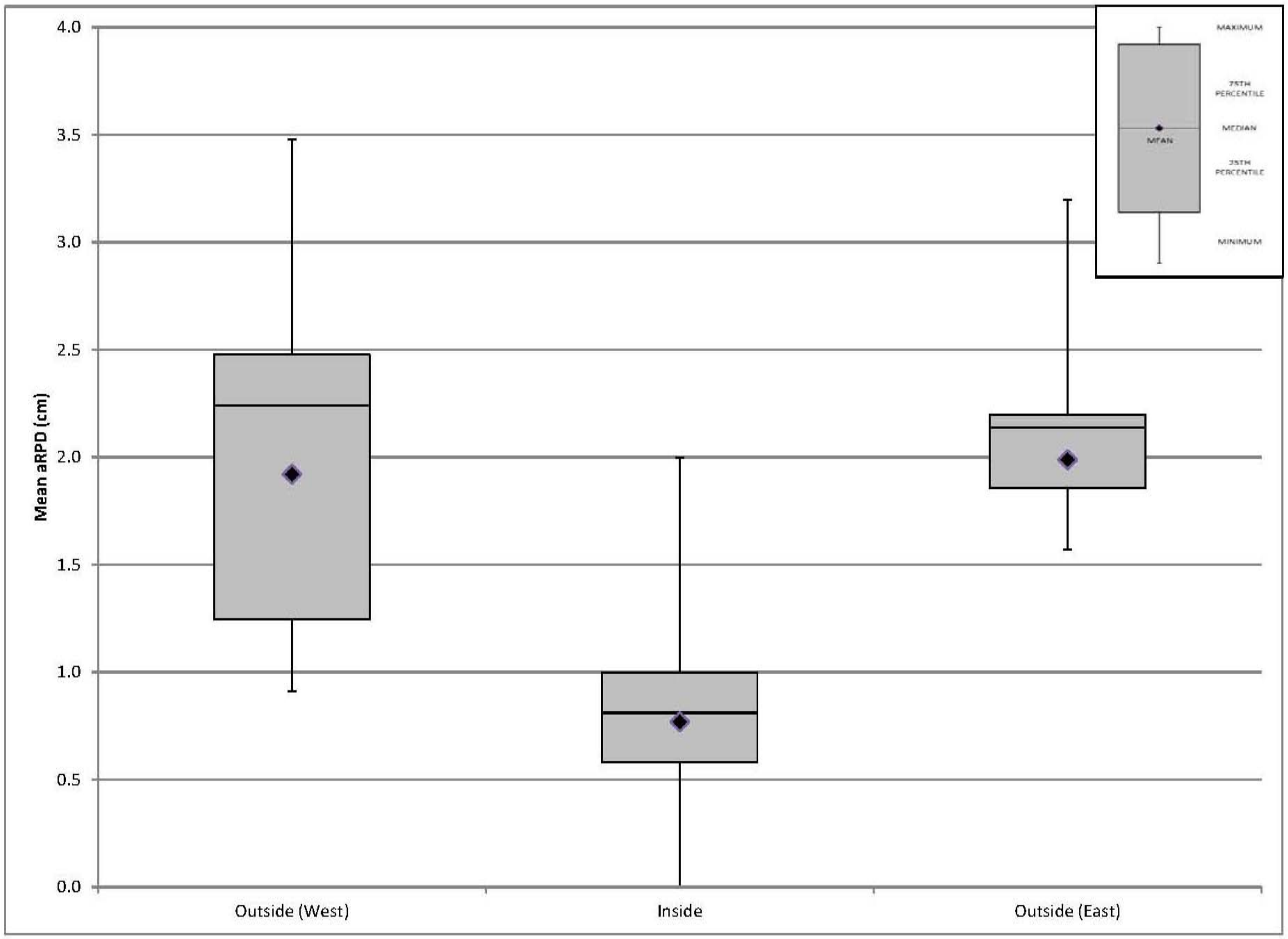


Figure 3-20. Box distribution of mean aRPD depths in the stations located within and outside the borrow pit

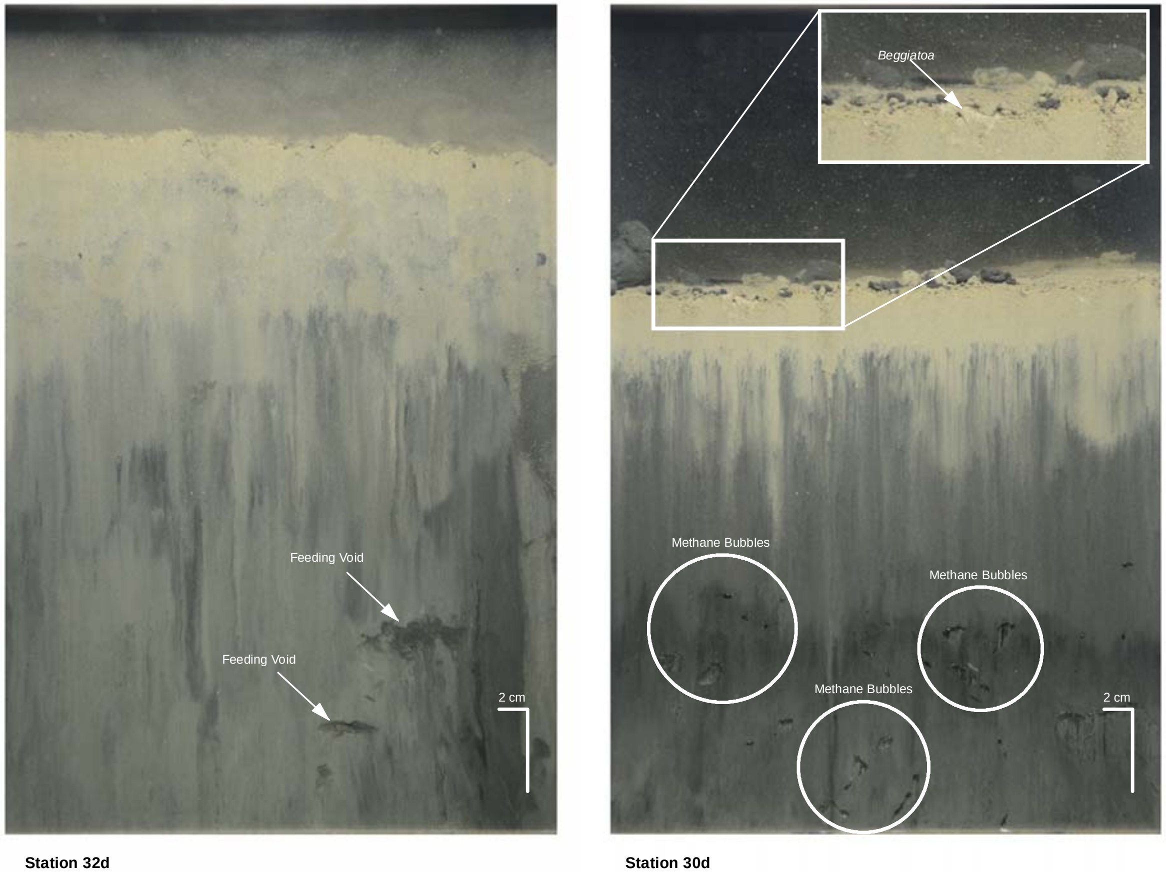


Figure 3-21. Comparison of biological condition of stations within MCBP (Stations 32 and 30). Station 32d (left) displayed evidence of Stage 2 -> 3 succession with deep feeding voids, a relatively deep aRPD (1.1 cm), and no methane bubbles. Station 30d (right) displayed evidence of Stage 1 ->2 succession, a relatively deep aRPD (1.3 cm), abundant methane bubbles, distinctive layering of reduced sediments, and a bloom of *Beggiatoa* sp. at the sediment-water interface.

4.0 DISCUSSION

The Morris Cove Borrow Pit (MCBP) has been a feature of New Haven Harbor for over 60 years. At the time of its construction, plausible future scenarios for the borrow pit could have included: 1) The borrow pit filling in naturally back to its pre-excavation contours given sufficient tidal currents and wave action, 2) The borrow pit remaining as a deeper feature, providing a diversified habitat within the fairly uniform harbor bottom of Morris Cove, and 3) The pit becoming a long term trap for detritus and fine grained sediments from the urban harbor, ultimately diminishing the water quality and habitat within the pit. While the first two scenarios may have been possible with sufficient energy and tidal flushing, the data collected at the site over multiple surveys indicate the development of the third outcome, with the borrow pit remaining as a subregion of poor habitat quality in the midst of shellfish beds, demersal fish spawning habitat, and an extensively used recreational area.

4.1 Current Regime

Morris Cove has been characterized as a relatively calm environment that does not experience strong tidal current velocities (WHG 2011). These current dynamics are commonly associated with depositional environments, i.e., current velocities of this magnitude do not have sufficient energy to suspend and transport sand-sized sediments (e.g. Miller et al. 1977). Although there are no direct near-bottom current measurements for the deeper portions of the borrow pit, all available data indicate that resuspension and transport of sediment out of the borrow pit is not occurring. A recent study of man-made depressions within New England harbors (including two along the Connecticut shore of Long Island Sound) concluded that these features are largely depositional environments, with no evidence of material loss over the long term (USACE 2012).

4.2 Physical Condition

The borrow pit appears to be a stable environment; significant changes to the major physical features within the pit (steep walls, isolated deep depressions) were not observed (Figure 4-1). Based on the measured thickness of fine-grained material observed in the sediment-profile images (SPI) overlaying the previously placed dredged material, it is estimated that the borrow pit receives approximately 0.5–0.8 cm of new material per year. There was not any evidence of coarse-grained sediments at the surface within the borrow pit, indicating the absence of erosional processes in the immediate area (Figure 4-2). Considering the functional history of the borrow pit (source of sand and gravel), the presence of soft, fine-grained material within the depths of the borrow pit provides further evidence that the borrow pit is a depositional area and receives naturally deposited material (Figure 4-3).

4.3 Water Quality Conditions and Impairment of the Pit

The borrow pit's steeply sloped walls, coupled with the relatively low currents measured in the vicinity of the borrow pit (WHG 2011), appear to control the frequency and volume of water that is flushed from the borrow pit. This has resulted in episodic hypoxic conditions in the borrow pit, as shown in the data from the August 2002 NMFS instrument deployment (SAIC 2002). According to CTDEP, hypoxic conditions in 2011 were present in Long Island Sound from 6 July through 28 August (CTDEP 2012). Therefore, it is very likely that hypoxic conditions could have occurred in MCBP during the summer, but were not observed due to the timing of the fall 2011 survey.

Dissolved oxygen (DO) levels below 5.0 mg/l are known to cause significant adverse ecological effects in the bottom water habitats of the Sound, including reducing the abundance and diversity of adult finfish, reducing the growth rate of juvenile winter flounder, and diminishing habitat value (LISS 1994). Sustained DO concentrations below this threshold were observed for several days during the summer 2002 NMFS survey (SAIC 2002). In 2010, the USEPA listed the overall status of the water body in the vicinity of the borrow pit as "Impaired" with regard to its viability as habitat for fish, shellfish, and other aquatic life (USEPA 2012). In addition to other anthropogenic impacts, depleted DO concentrations were listed as a cause of the impairment (USEPA 2012).

The sediments in the borrow pit also showed evidence of fluctuations between anoxic and oxygenated conditions in the overlying water, as indicated by the SPI images highlighting the band of highly reduced sediments and less reduced sediments (Figure 4-4). However, even under oxygenated conditions, the high organic content of the fine sediments deposited in the borrow pit would still produce substantial sediment oxygen demand, potentially depleting available oxygen from the immediate overlying water. These cyclical anoxic events are likely to persist as organic material continues to accumulate within the confines of the borrow pit.

4.4 Habitat Potential

The organic sediments and depleted dissolved oxygen environment that exists within the borrow pit do not provide productive habitat for the local biological community (Figure 4-5). If the conditions were more favorable in the area in and around the borrow pit, there would be an opportunity to support other marine species such as winter flounder (*Pseudopleuronectes americanus*) and oysters (*Crasssotaea virginica*), which have similar habitat requirements (Castonguay and Visel 1988).

Within Long Island Sound, New Haven Harbor has been identified as an estuary where winter flounder are known to spawn. Morris Cove in particular has been identified as spawning habitat (SAIC 1996) for this commercially and recreationally important species. Winter flounder prefer shallow water for spawning (Schultz et al 2007), and prefer a flat, hard, and clean bottom protected from waves and currents (Castonguay and Visel 1988), making Morris Cove valuable potential nursery habitat. The low current velocities observed in the WHG study also suggest that the cove would have a current regime supportive of winter flounder eggs and juveniles (Schultz et al 2007). However, the deeper depths, fine organic sediment substrate, and degraded dissolved oxygen environment within the borrow pit are not suitable as flounder habitat (Figure 4-6).

Presently, there is a large density of state leased shellfish beds in Morris Cove in the immediate vicinity of the borrow pit (Figure 4-7). A substantial number of oyster shells were observed in the SPI images collected from the eastern side of the borrow pit. The water depths (3.0–4.0 m) and substratum of Morris Cove (sandy, oyster shells) outside of the borrow pit are ideal for oyster larvae development and oyster bed production. However, the greater water depths and fine, organic substratum within the borrow pit are not suitable for oyster habitat and, as a consequence, no shellfish beds are located within the borrow pit.

4.5 Management

As currently constituted, the borrow pit could remain in its present condition for the foreseeable future. The physical features (walls, slopes, and rises) within the borrow pit are expected to remain structurally stable. Given the rising water temperatures in LIS (CTDEP 2012), the decreased concentrations of dissolved oxygen in the bottom waters of the borrow pit will likely continue to cause detrimental effects on the local biological communities. Prolonged periods of decreased DO have been documented in the borrow pit, and it is evident when evaluating the benthic communities that these conditions have impacted recolonization and the biological assemblages present (e.g., low percentage of Stage 3 communities in the borrow pit [Table 4-1]). The presence of organic rich sediment and ongoing deposition of additional organic material into the borrow pit will continue to drive sediment oxygen demand and cause the low DO conditions in the bottom waters to persist. In addition, the fine organic substrate will continue to be a limiting factor in the re-establishment of a more diverse benthic community.

In order to return the borrow pit to a fully functioning benthic habitat, restorative efforts should be focused on attaining conditions similar to those outside the western edge of the borrow pit. The sediments west of the borrow pit are in 3.0–3.5 m of water and receive sufficient flushing to maintain a healthy benthic community. Filling the borrow pit and restoring the average depth to approximately 3.5 m would provide an additional 172,500 m^2 (42.6 acre) of productive benthic habitat to Morris Cove and would eliminate the conditions for site-specific DO depletion. Based on calculations utilizing GIS software and using the boundary definition described previously, the volume of the borrow pit is approximately 460,000 m^3 (Figure 4-1). The final sediments placed in the borrow pit (those forming the surficial layer) should consist of fine sandy silt-clay material to mimic the sediment grain size composition to the west. Because of the unconsolidated and high organic content of some of the sediments in the borrow pit, the filling of the borrow pit may need to be phased to allow for consolidation, ebullition of methane, and even distribution.

Table 4-1.

SPI Stations with Stage 3 Organisms Present

		SS Rank
Site	**N**	**% of Replicates with Stage 3**
Outside Pit		
East*	3	67%
West	8	96%
Total	11	82%
Within Pit	20	15%

Note: There were seven stations sampled east of the borrow pit, however four of these stations were hard bottomed and did not allow substantive penetration to determine successional stage.

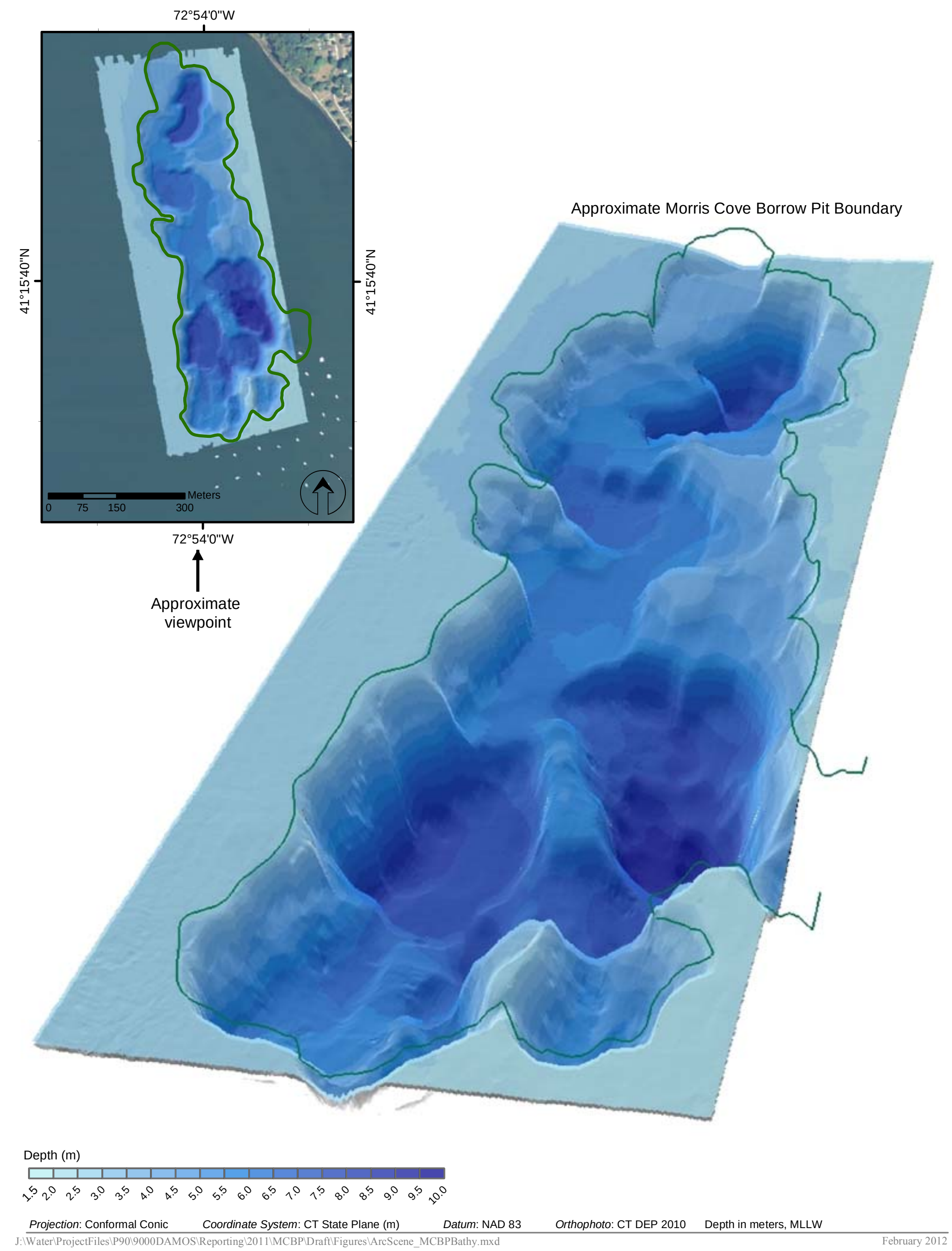


Figure 4-1. Three-dimensional representation of MCBP based on multibeam bathymetry used to calculate volumetric capacity. Actual side slopes ranged from approximately 1:5 on the eastern side of the borrow pit to 1:17 on the western side. The appearance of steep borrow pit walls are accentuated by the image aspect.

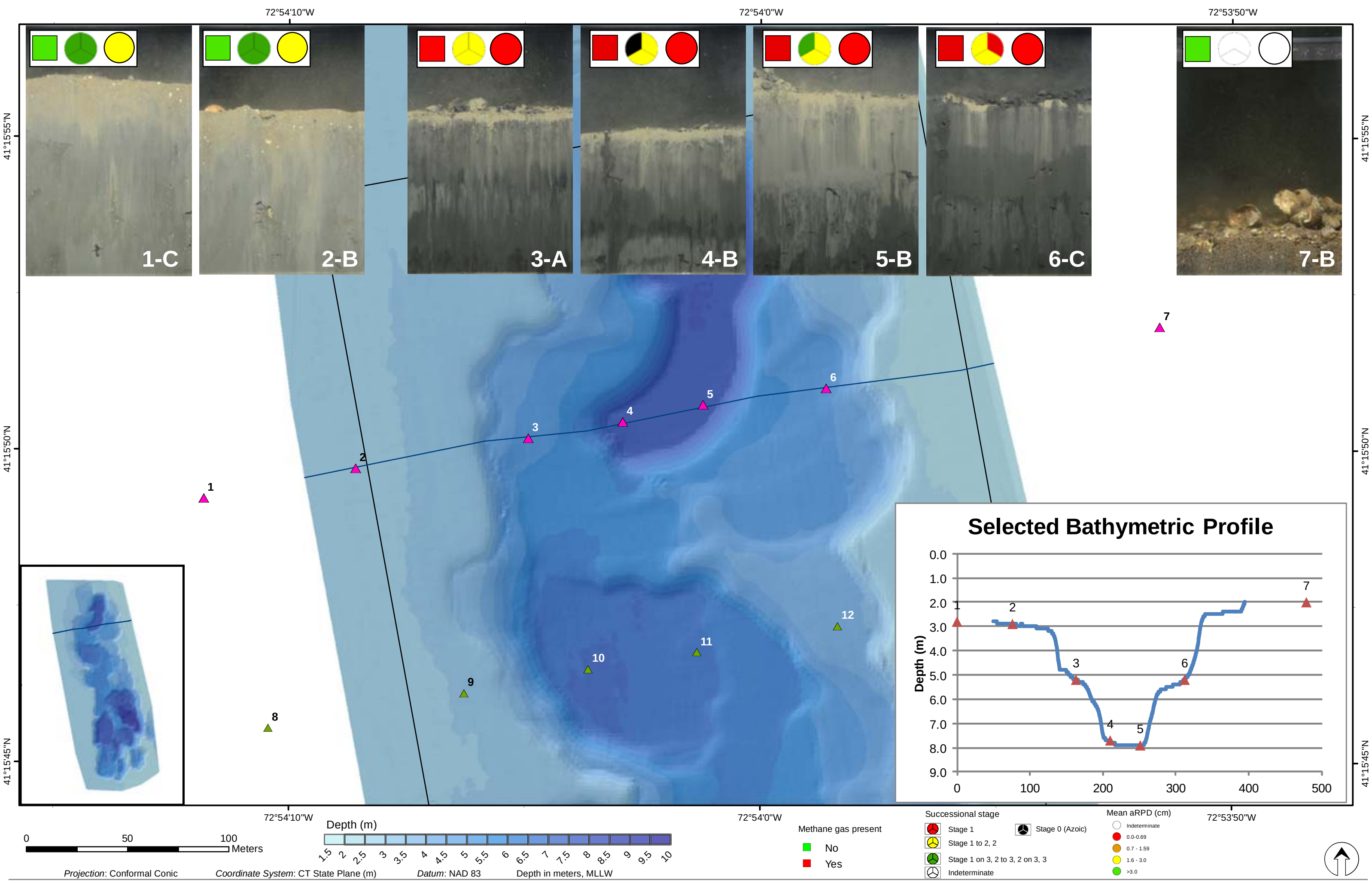


Figure 4-2. Sediment-profile image transect #1 across the northernmost depression within MCBP

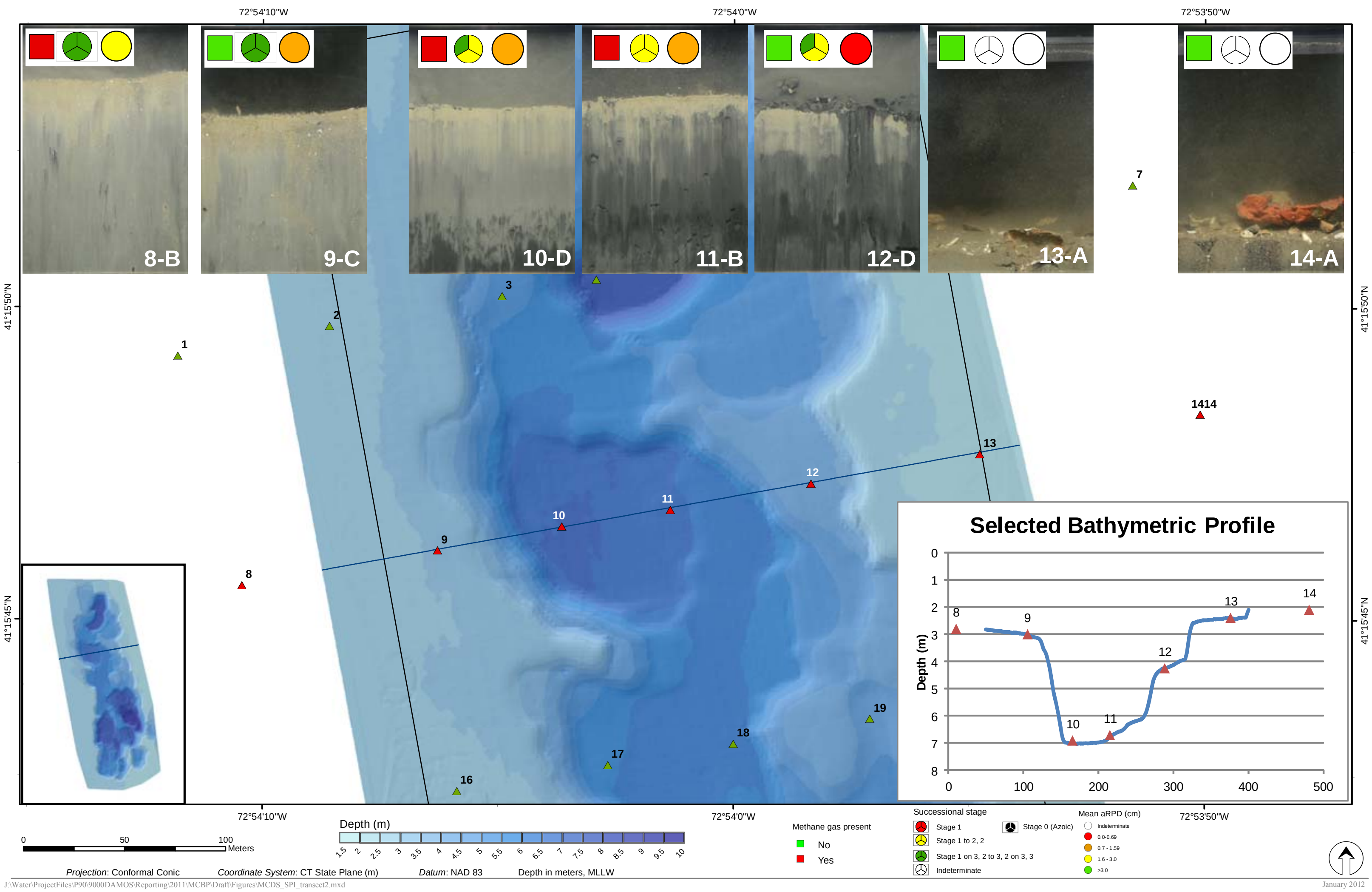


Figure 4-3. Sediment-profile image transect #2 across the northern MCBP

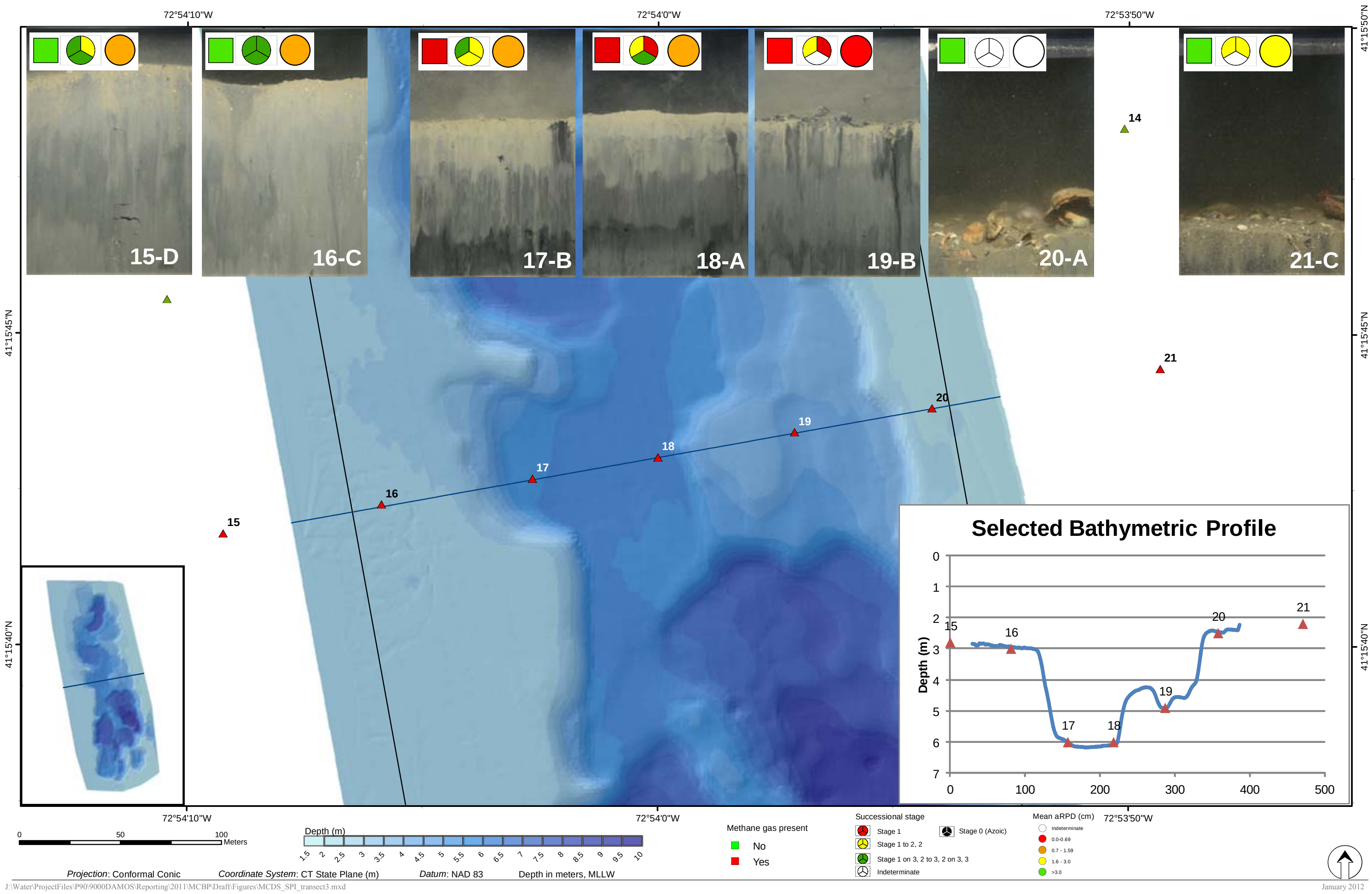


Figure 4-4. Sediment-profile image transect #3 across the central MCBP

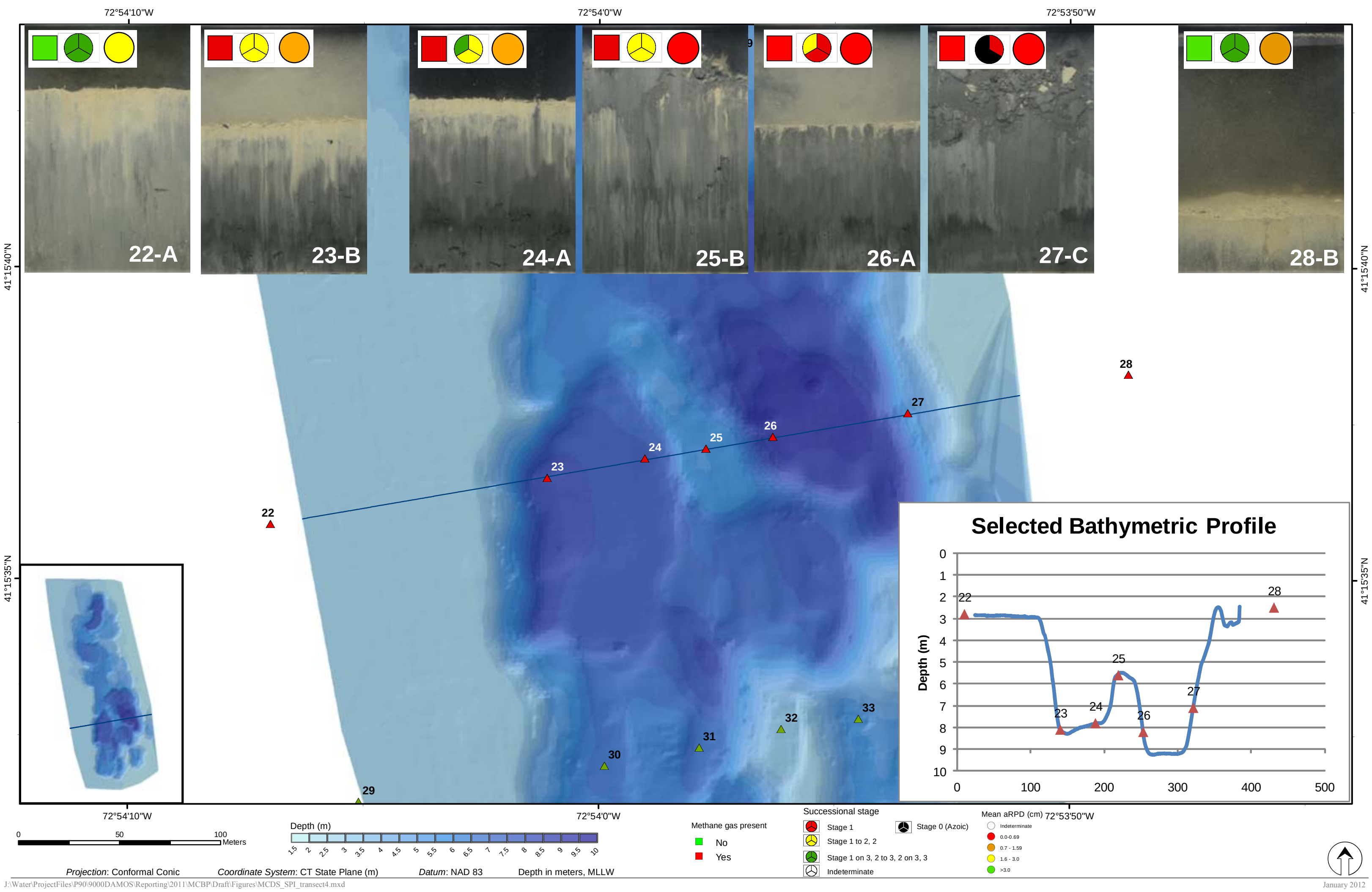


Figure 4-5. Sediment-profile image transect #4 across the two deepest depressions in the southern MCBP

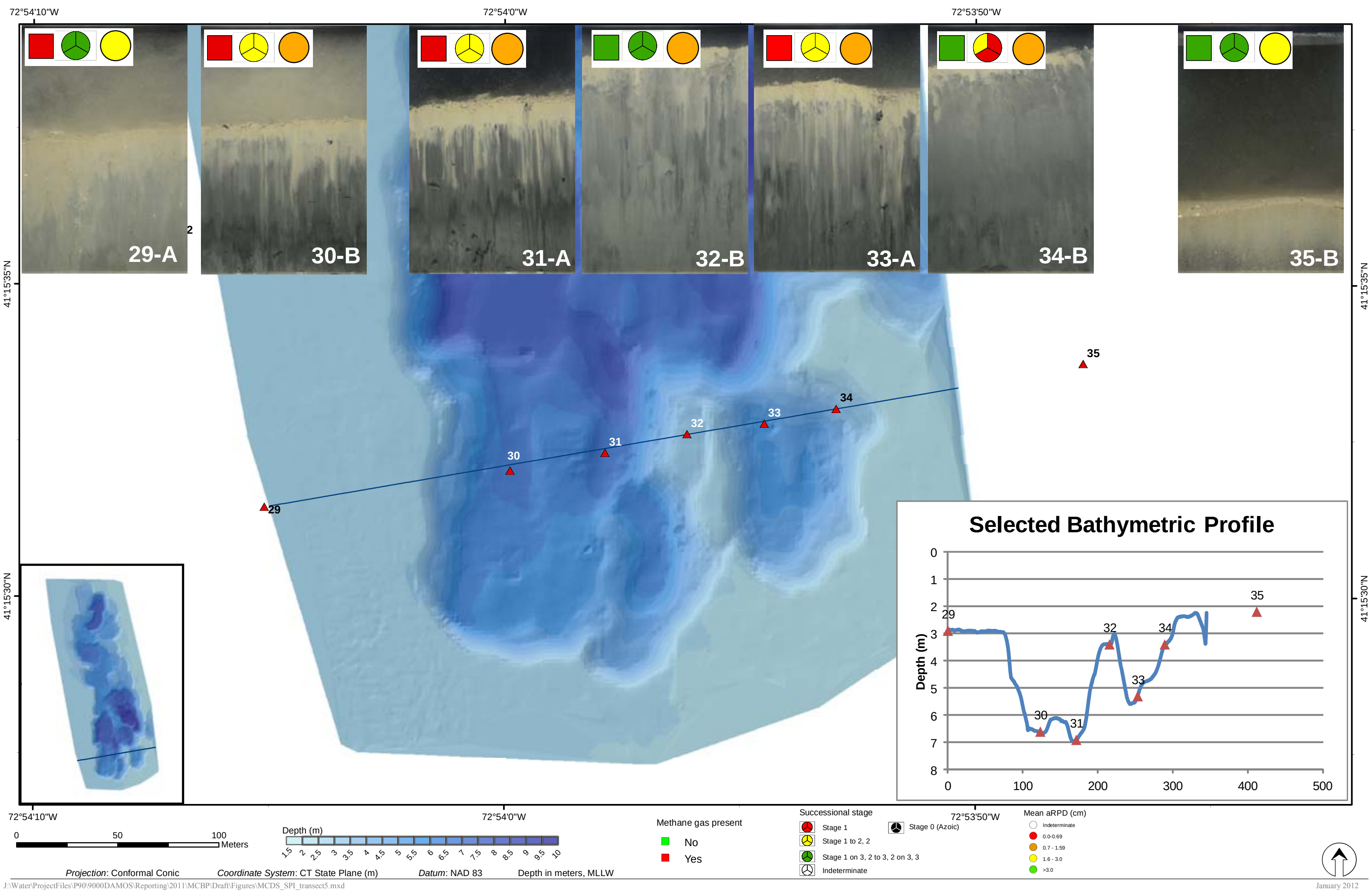


Figure 4-6. Sediment-profile image transect #5 across the southern margin of MCBP

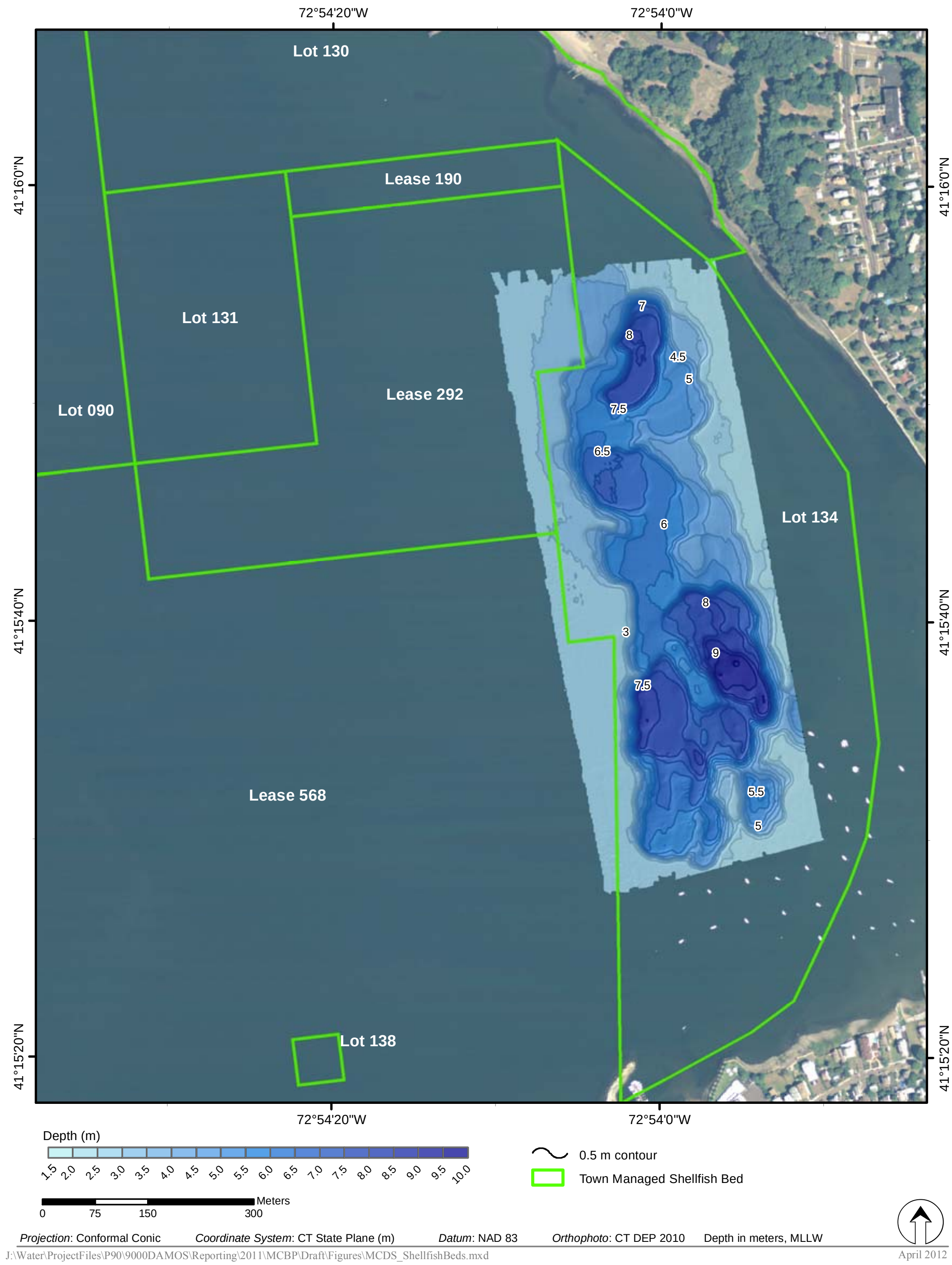


Figure 4-7. Location of Connecticut leased shellfish beds in the vicinity of MCBP

5.0 CONCLUSIONS

The September and October 2011 surveys at MCBP were performed to collect bathymetric and backscatter data over the entire borrow pit along with SPI images alongside and within the borrow pit. The survey was designed to characterize the physical stability of the borrow pit and assess the benthic habitat and recolonization status of the borrow pit relative to surrounding conditions since it was last surveyed in 2002. These data allow an assessment of management options for the borrow pit.

The overall topography of the borrow pit appears stable; there have not been any significant changes to the major features within the borrow pit (steep walls, isolated deep depressions). The borrow pit has not received any dredged material since the 2000 pilot study, and the sediment deposit observed in 2002 still appears intact. It does not appear that the dredged material has migrated outside of the borrow pit or even into other areas within the borrow pit. The biological community within the borrow pit continues to show evidence of limited recolonization compared to ambient sediments to the east and west, similar to results found in 2002. There is evidence of anoxic events present in the SPI images, indicating that oxygen-deprived conditions periodically occur within the depths of the borrow pit.

Low concentrations of dissolved oxygen (DO) in bottom waters are known to cause significant detrimental effects on marine benthic communities. Prolonged periods of decreased DO have been documented in the borrow pit, and it is evident when analyzing the benthic communities that these conditions have impacted recolonization and the biological assemblages present (e.g., low percentage of Stage 3 communities in the borrow pit). The presence of organic rich sediment and ongoing deposition of additional organic material into the borrow pit will continue to drive sediment oxygen demand and enable the periods of low DO conditions in the bottom waters to recur.

Based on the findings of the 2011 surveys, the approximately 43 acre borrow pit area is expected to be a more productive habitat if it were restored to its pre-excavation (pre-1950s) condition. Therefore, the following recommendations are proposed if the borrow pit is filled and restored to the elevation of the surrounding contours:

- To return the borrow pit area to a productive benthic habitat, the new habitat should be modeled after conditions on the western side of the borrow pit. These sediments receive regular flushing and maintain a healthy, well developed benthic community, but show no evidence of wind-wave resuspension and sediment transport.

- Suitable fill material for the surficial layer should consist of fine sandy silt-clay sediments, which comprise the majority of the sediments observed on the western side of the borrow pit.

- Filling of the borrow pit may need to take place in stages, depending on the type of fill and method of placement, to allow for consolidation of the existing and newly placed material.

A plan for monitoring during filling of the borrow pit and tracking the benthic recovery following placement should be developed once the design specifications for filling are defined.

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Appendix A

Sediment Profile Imaging Results

APPENDIX A
Sediment Profile Imaging Results

Station ID	Rep	Date	Time	DOORS USED: Stop Collar Settings (in.)	# of weights per chassis	Water Depth (ft)	Calibration Constant	GrnSzMajor Mode (phi)	GrnSz Max (phi)	GrnSz Min (phi)	GrnSz RANGE	Penetration Area (sq.cm)	Pen Mean (cm)	Pen Min (cm)	Pen Max (cm)	Boundary Roughness (cm)	Origin of Boundary Roughness	RPD Area (sq.cm)	Mean RPD (cm)	Mud Clast Number	Mud Clast State	Methane	Beggiatoa Present?	# of Feeding Voids	Void Minimum Depth (cm)	Void Maximum Depth (cm)	Void Average Depth (cm)	Successional Stage	Low DO?	Notes
MC-01	A	10/4/11	9:28	15	1	10	14.6	4-3/>4	2	>4	>4 to 2	251.3	17.25	16.7	17.6	0.9	bio	43.0	2.9	0	-	n	no	4	9.6	13.4	11.5	2 on 3	no	Silt, grading to very fine silty sand in upper cms. Shallow burrows in the upper cms. Several small tubes and clam siphons at SWI. Small shell fragments throughout sediment. Multiple voids.
MC-01	B	10/4/11	9:29	15	1	10	14.6	4-3/>4	2	>4	>4 to 2	236.7	16.25	15.1	16.9	1.8	bio	41.0	2.8	0	-	n	no	2	8.5	14.9	11.7	2 on 3	no	Silt, grading to very fine silty sand in upper cms. Multiple small thin tubes at SWI. Small burrows in upper cms with portions of small polychaetes near base of aRPD against faceplate, setae visible on one. Void is very large; smaller hints of former voids
MC-01	C	10/4/11	9:30	15	1	10	14.6	4-3/>4	2	>4	>4 to 2	250.6	17.20	16.8	17.7	0.9	bio	30.9	2.1	1	r	n	no	5	9.6	16.4	13.0	1 on 3	no	Silt, grading to very fine silty sand in upper cms. Multiple small thin tubes and few large ones at SWI. Mud clast is camera artifact. Few shell fragments in upper cm.
MC-02	A	10/4/11	8:56	16	5	11	14.6	4-3/>4	0	>4	>4 to 0	282.1	19.36	18.9	20.2	1.3	bio	37.7	2.6	1	r	n	no	1	12.9	16.8	14.8	1 on 3	no	Silt, grading to very fine silty sand in upper cms. Multiple small thin tubes at SWI. Many small burrows in upper 2 cms. Large void with worm tube visible
MC-02	B	10/4/11	9:01	14	1	11	14.6	4-3/>4	0	>4	>4 to 0	209.0	14.34	13.4	14.8	1.5	bio	34.1	2.3	0	-	n	no	5	7.6	14.1	10.8	2 on 3	no	Silt, grading to very fine silty sand in upper cms, some coarser grains and shell frag worked into upper cms. Small thin tubes at SWI. Burrowing bivalves visible and pit at center.
MC-02	C	10/4/11	9:02	14	1	11	14.6	4-3/>4	0	>4	>4 to 0	211.6	14.52	13.2	14.9	1.7	bio	30.4	2.1	0	-	n	no	2	7.1	9.5	8.3	2 on 3	no	Silt, grading to very fine silty sand in upper cms. Few bivalve shell fragments at SWI. Small thin and medium tubes at SWI. Small burrows in upper 2 cms.
MC-03	A	10/4/11	13:16	13	0	17	14.6	>4	2	>4	>4 to 2	208.8	14.33	14.2	14.5	0.2	bio	7.6	0.5	10+	b	n	no	0	-	-		1 -> 2	no	Very fine sandy silt, reduced at depth Small to large mud clasts at SWI. Polychaetes, amphipods & Mulinia in upper few cm.
MC-03	B	10/4/11	13:16	13	0	17	14.6	>4	2	>4	>4 to 2	223.6	15.35	14.9	15.6	0.8	bio	9.1	0.6	5	r	y	yes	0	-	-		2	no	Very fine sandy silt, reduced at depth. Polychaetes& Mulinia in upper few cm with traces of incipient Beggiatoa. Methane @ depth
MC-03	D	10/4/11	13:18	13	0	17	14.6	>4	2	>4	>4 to 2	184.1	12.63	12.1	13.1	1.0	bio	6.4	0.4	2	r	n	yes	0	-	-		2	no	Very fine sandy silt, reduced at depth. Few oxidized and reduced amphipod tubes at surface with Mulinia & traces of Beggiatoa. aRPD is discontinuous, only on right.
MC-04	A	10/4/11	13:21	13	0	25	14.6	>4	2	>4	>4 to 2	190.8	13.09	12.6	13.3	0.7	bio	13.7	0.9	3	b	y	no	0	-	-		2	no	Silt, with reduced sed at depth. Bio reworked surface, fecal pellets. Small burrows in upper cms. Small mud clasts on surface. Methane bubbles at depth.
MC-04	B	10/4/11	13:22	13	0	25	14.6	>4	2	>4	>4 to 2	185.6	12.74	12.3	13.0	0.7	bio	8.3	0.6	6	b	y	no	0	-	-		1 -> 2	no	Silt, gray high sed oxy demand sed at depth. Small to medium mud clasts on surface. Few amphipod tubes at surface. Methane bubbles at depth.

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Sediment Profile Imaging Results

Station ID	Rep	Date	Time	DOORS USED: Stop Collar Settings (in.)	# of weights per chassis	Water Depth (ft)	Calibration Constant	GrnSzMajor Mode (phi)	GrnSz Max (phi)	GrnSz Min (phi)	GrnSz RANGE	Penetration Area (sq.cm)	Pen Mean (cm)	Pen Min (cm)	Pen Max (cm)	Boundary Roughness (cm)	Origin of Boundary Roughness	RPD Area (sq.cm)	Mean RPD (cm)	Mud Clast Number	Mud Clast State	Methane	Beggiatoa Present?	# of Feeding Voids	Void Minimum Depth (cm)	Void Maximum Depth (cm)	Void Average Depth (cm)	Successional Stage	Low DO?	Notes
MC-04	C	10/4/11	13:22	13	0	25	14.6	>4	2	>4	>4 to 2	234.7	16.11	15.2	16.7	1.5	phys	0.0	0.0	10+	b	y	no	0	-	-		0	yes	Silt, gray high sed oxy demand sed at depth. Sed looks somewhat sandier at surface. No aRPD, few bits of oxy sed at surface. Lots of methane bubbles at depth.
MC-05	A	10/4/11	13:26	13	0	25	14.6	>4	2	>4	>4 to 2	208.2	14.29	14.0	14.5	0.6	bio	13.0	0.9	0	-	y	no	0	-	-		2	no	Very fine sandy silt-clay. Bed of amphipod tubes at surface. Shallow burrowing in upper cm. Gray high sed oxy demand sed at depth. Methane bubbles at depth.
MC-05	B	10/4/11	13:27	13	0	25	14.6	>4	1	>4	>4 to 1	234.0	16.06	15.6	16.4	0.8	bio	6.2	0.4	10+	b	y	no	0	-	-		2	no	Very fine sandy silt-clay. Lots of small to large mud clasts on surface, pile on left. Few amphipod tubes at SWI. Methane bubbles at depth.
MC-05	C	10/4/11	13:28	13	0	25	14.6	>4	1	>4	>4 to 1	209.4	14.37	14.0	14.7	0.7	bio	6.9	0.5	4	b	y	no	1	0.0	7.3	3.6	2 -> 3	no	Very fine sandy silt-clay; Small mud clasts at surface.Methane bubbles in burrow connecting void to SWI and at depth. Gray high sed oxy demand sed at depth.
MC-06	A	10/4/11	10:46	13	0	16	14.6	>4	2	>4	>4 to 2	226.4	15.54	15.3	15.6	0.3	bio	14.7	1.0	0	-	y	trace	0	-	-		2	no	Very fine sandy silt-clay with amphipod tubes at SWI. Many methane bubbles at depth. Traces of Beggiatoa visible at aRPD boundary
MC-06	C	10/4/11	10:48	13	0	16	14.6	>4	2	>4	>4 to 2	225.1	15.45	15.0	15.7	0.7	phys	2.0	0.1	10+	r	y	trace	0	-	-		1	yes	Silt-clay with minor very fine sand fraction. Many dark reduced mud clasts on surface (camera sled artifacts). aRPD is patchy and discontinuous. Gray high sed oxy demand sed. Methane bubbles mostly at depth.
MC-06	D	10/4/11	10:49	13	0	16	14.6	>4	2	>4	>4 to 2	202.5	13.89	13.2	14.1	0.9	bio	10.2	0.7	10+	r	y	trace	0	-	-		2	no	Silt-clay with minor very fine sand fraction. Dense amphipod tubeswith small to large mud clasts at surface. Highly reduced sediment at depth.
MC-07	B	10/4/11	8:11	16	5	8	14.6	2-1	-2	>4	>4 to -2	49.2	3.38	2.3	3.8	1.5	phys	ind	ind	0	-	n	no	0	-	-		ind	no	Poorly sorted silty to coarsesand and pebbles at SWI. Crepidula shells, other shell frag (some bivalve), and brick bits on surface.
MC-07	C	10/4/11	8:12	16	5	8	14.6	2-1	-2	>4	>4 to -2	43.3	2.97	2.4	3.3	0.8	phys	ind	ind	0	-	n	no	0	-	-		ind	no	Fine to medium sand, few pebbles at SWI. Few Crepidula shells at surface with more "urban lithics"
MC-07	D	10/4/11	8:12	16	5	8	14.6	0- (-1)	-2	>4	>4 to -2	46.4	3.19	2.7	3.6	0.9	phys	ind	ind	0	-	n	no	0	-	-		ind	no	Medium to coarse sand, pebbles at SWI. Surface covered with Crepidula shells.
MC-08	A	10/4/11	9:38	15	1	10	14.6	4-3/>4	1	>4	>4 to 1	243.8	16.73	16.3	16.8	0.5	bio	43.0	3.0	0	-	n	no	0	-	-		1 on 3	no	Silty, very fine sand over silt-clay; short thin tubes at SWI. Few shells on surface. Shallow burrowing. Edges of voids & burrows transected at depth.
MC-08	B	10/4/11	9:39	15	1	10	14.6	4-3/>4	1	>4	>4 to 1	251.6	17.27	17.0	17.9	1.0	bio	33.2	2.3	0	-	y	no	0	-	-		1 on 3	no	Silty very fine sand over silt clay; small tubes at SWI. Shallow burrowing. End of large burrow at depth, 1 methane bubble at bottom of frame

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MC-08	C	10/4/11	9:40	15	1	10	14.6	4-3/>4	1	>4	>4 to 1	236.8	16.25	16.0	16.4	0.4	bio	29.9	2.1	2	r	n	no	1	7.2	8.8	8.0	1 on 3	no	Silty very fine sand over silt-clay, shell fragments mixed in. Few bivalve shell fragments at SWI. Small thin and amphipod tubes at SWI. Shallow burrowing.
MC-09	A	10/4/11	9:15	15	1	10	14.6	4-3/>4	1	>4	>4 to 1	183.7	12.60	12.0	13.1	1.1	phys	28.7	2.0	0	-	n	no	0	-	-		1 on 3	no	Silty very fine sand, coarser in upper cm, overlying silt-clay base. Shell fragments on surface. Some sed slouging against faceplate. Many small thin tubes at SWI.
MC-09	C	10/4/11	9:16	15	1	10	14.6	4-3/>4	1	>4	>4 to 1	202.7	13.91	13.1	14.6	1.4	bio	13.6	0.9	0	-	n	no	1	7.0	7.4	7.2	2 on 3	no	Silt-clay, grading upwards to very fine sand, coarser in upper cm, few shell frag incorporated in upper cms. Bed of amphipod tubes covering most of surface.
MC-09	D	10/4/11	9:17	15	1	10	14.6	4-3/>4	1	>4	>4 to 1	148.6	10.20	9.8	10.4	0.6	bio	16.9	1.2	3	b	n	no	1	2.8	4.3	3.5	2 on 3	no	Silt-clay, grading upwards to very fine sand. Shell fragments and debris at surface. Few amphipod tubes in background. Shallow burrowing, deeper burrow/void thin below aRPD, amphipod tubes in background.
MC-10	B	10/4/11	13:05	13	0	22	14.6	>4	2	>4	>4 to 2	228.6	15.69	15.5	15.8	0.4	bio	13.0	0.9	7	b	y	no	0	-	-		1 -> 2	no	Silt-clay with minor fraction of very fine sand. Mud clasts on surface. Few amphipod tubes at surface. Highly-reduced sed & methane at depth.
MC-10	C	10/4/11	13:05	13	0	22	14.6	>4	2	>4	>4 to 2	211.5	14.51	14.4	14.7	0.4	bio	11.4	0.8	2	r	y	no	2	2.2	7.1	4.6	2 on 3	no	Silt-clay with minor fraction of very fine sand. Few amphipod tubes at SWI. All but one methane bubble at depth, one is at edge of upper burrow.
MC-10	D	10/4/11	13:06	13	0	22	14.6	>4	2	>4	>4 to 2	214.2	14.70	14.5	14.8	0.3	bio	11.4	0.8	10+	b	y	no	0	-	-		2	no	Silt-clay with small mud clasts across surface. Few tubes at SWI. Shallow burrowing, small bivalve on left.
MC-11	A	10/4/11	13:10	13	0	22	14.6	>4	2	>4	>4 to 2	222.8	15.29	14.8	15.5	0.7	bio	15.6	1.1	5	b	y	no	0	-	-		2	no	Silt-clay with mud clast artifacts on surface. Amphipod tubes at SWI. Methane bubbles and highly reduced sed at depth.
MC-11	B	10/4/11	13:10	13	0	22	14.6	>4	2	>4	>4 to 2	227.6	15.62	15.2	15.9	0.6	bio	10.8	0.7	8	b	y	no	0	-	-		2	no	Silt-clay with small mud clast artifacts on surface. Amphipod tubes at SWI. Methane bubbles and gray high sed oxy demand sed at depth.
MC-11	D	10/4/11	13:12	13	0	22	14.6	>4	3	>4	>4 to 3	192.1	13.18	12.6	13.8	1.2	phys	ind	Ind	10+	b	y	no	0	-	-		2	no	Silt-clay with multiple mud clast artifacts; surface disturbed by sampling so aRPD indeterminate. Few amphipod tubes collapsed on top of mud clasts. Methane bubble and gray high sed oxy demand sed at depth.
MC-12	A	10/4/11	10:52	13	0	13	14.6	4-3/>4	2	>4	>4 to 2	206.4	14.17	13.4	14.5	1.2	bio	10.5	0.7	0	-	n	no	1	11.0	11.2	11.1	2 -> 3	no	Silty very fine sand over silt-clay; some amphipod tubes. Shallow burrowing in aRPD.

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Station ID	Rep	Date	Time	DOORS USED: Stop Collar Settings (in.)	# of weights per chassis	Water Depth (ft)	Calibration Constant	GrnSzMajor Mode (phi)	GrnSz Max (phi)	GrnSz Min (phi)	GrnSz RANGE	Penetration Area (sq.cm)	Pen Mean (cm)	Pen Min (cm)	Pen Max (cm)	Boundary Roughness (cm)	Origin of Boundary Roughness	RPD Area (sq.cm)	Mean RPD (cm)	Mud Clast Number	Mud Clast State	Methane	Beggiatoa Present?	# of Feeding Voids	Void Minimum Depth (cm)	Void Maximum Depth (cm)	Void Average Depth (cm)	Successional Stage	Low DO?	Notes
MC-12	B	10/4/11	10:53	13	0	13	14.6	>4	2	>4	>4 to 2	205.9	14.13	13.7	14.6	0.9	phys	7.6	0.5	10+	r	n	no	0	-	-		2	no	Silt-clay with higher percentage of very fine sand in surface. Collapsed tubes on surface, disturbed by doors on camera
MC-12	D	10/4/11	10:55	13	0	13	14.6	>4	2	>4	>4 to 2	211.4	14.51	14.3	14.8	0.5	phys	8.6	0.6	10+	r	n	no	2	9.7	12.5	11.1	2	no	Silt-clay with higher percentage of very fine sand in surface. Collapsed tubes on surface, disturbed by doors on camera; voids appear to be relict.
MC-13	A	10/4/11	8:40	16	5	9	14.6	4-3	0	>4	>4 to 0	23.9	1.64	0.0	1.1	1.1	phys	ind	ind	0	-	n	no	0	-	-		ind	no	Silty very fine sand. Few shell fragments and Crepidula shells on surface. Few white calcareous worm tubes on one shell.
MC-13	B	10/4/11	8:41	16	5	9	14.6	IND	-	-	- to -	none	none	0.0	0.0	0.0	-	-	-	-	-	-	no	-	-	-		ind	-	No penetration. Crepidula & oyster shells. Sediment surface is not visible.
MC-13	D	10/4/11	8:43	16	5	9	14.6	3-2	0	>4	>4 to 0	25.0	1.72	1.1	2.3	1.1	phys	ind	ind	0	-	n	no	0	-	-		ind	no	Silty fine sand. Surface covered with shell fragments, few Crepidula shells. Lots of suspended sed.
MC-14	A	10/4/11	8:16	16	5	9	14.6	3-2/2-1	-1	>4	>4 to -1	46.1	3.16	2.2	3.4	1.3	phys	ind	ind	0	-	n	no	0	-	-		ind	no	Silty poorly sorted fine to medium sand, patchy in distribution. Shell fragments & hermit crab on surface.
MC-14	C	10/4/11	8:17	16	5	9	14.6	2-1	-1	>4	>4 to -1	48.8	3.35	2.5	4.0	1.5	phys	ind	ind	0	-	n	no	0	-	-		ind	no	Poorly sorted fine to medium sand, more coarse; few pebbles on surface. Few shell fragments and Crepidula shells - few upright- on surface. Bits of red.brown algae in background.
MC-14	D	10/4/11	8:18	16	5	9	14.6	3-2/2-1	-1	>4	>4 to -1	34.8	2.38	1.7	3.4	1.7	phys	ind	ind	0	-	n	no	0	-	-		ind	no	Poorly sorted fine to medium sand, patchy. Piles of Crepidula shells and some shell fragments.
MC-15	A	10/4/11	9:44	15	1	10	14.6	>4	0	>4	>4 to 0	266.0	18.26	17.9	18.5	0.5	bio	23.6	1.6	0	-	n	no	0	-	-		2	no	Silt-clay with shell fragments and minor fraction of very fine sand. Short thin tubes at SWI. Shallow burrowing. Small mud clasts on surface.
MC-15	C	10/4/11	9:45	15	1	10	14.6	>4	0	>4	>4 to 0	240.5	16.51	16.2	16.8	0.6	bio	9.6	0.7	0	-	n	no	1	10.1	10.6	10.3	1 on 3	no	Silt-clay with shellf fragments and minor fraction of very fine sand. Few amphipod tubes at surface. aRPD is thin at some points. Oxidized void at right..
MC-15	D	10/4/11	9:46	15	1	10	14.6	>4	0	>4	>4 to 0	263.6	18.09	17.1	18.6	1.4	bio	6.6	0.5	3	b	n	no	4	5.3	15.8	10.5	1 on 3	no	Silt-clay with shellf fragments and minor fraction of very fine sand. Short thin tubes at SWI.
MC-16	A	10/4/11	9:20	15	1	11	14.6	>4	0	>4	>4 to 0	283.4	19.45	18.7	20.0	1.2	bio	21.4	1.5	0	-	n	no	3	14.5	19.1	16.8	1 on 3	no	Sile-clay with minor fraction of very fine sand. Short thin tubes at SWI. Possible longer tube directly above large burrow that extends from SWI to 2.33cm. One void has reduced fecal pellets.
MC-16	B	10/4/11	9:21	15	1	11	14.6	>4	0	>4	>4 to 0	233.6	16.03	15.7	16.5	0.8	bio	8.6	0.6	0	-	n	no	1	15.8	16.3	16.0	1 on 3	no	Very fine sandy silt; long, thick tube collapsed on surace. Thin aRPD. Few small tubes and shallow burrows. Few shell fragments incorporated in sediment in upper cms.

APPENDIX A
Sediment Profile Imaging Results

Station ID	Rep	Date	Time	DOORS USED: Stop Collar Settings (in.)	# of weights per chassis	Water Depth (ft)	Calibration Constant	GrnSzMajor Mode (phi)	GrnSz Max (phi)	GrnSz Min (phi)	GrnSz RANGE	Penetration Area (sq.cm)	Pen Mean (cm)	Pen Min (cm)	Pen Max (cm)	Boundary Roughness (cm)	Origin of Boundary Roughness	RPD Area (sq.cm)	Mean RPD (cm)	Mud Clast Number	Mud Clast State	Methane	Beggiatoa Present?	# of Feeding Voids	Void Minimum Depth (cm)	Void Maximum Depth (cm)	Void Average Depth (cm)	Successional Stage	Low DO?	Notes
MC-16	C	10/4/11	9:22	15	1	11	14.6	>4	0	>4	>4 to 0	250.9	17.22	16.8	17.7	0.9	bio	10.3	0.7	0	-	n	no	1	16.8	17.4	17.1	1 on 3	no	Very fine sandy silt with pile of reduced pseudofeces on left. Lots of short thin tubes at SWI. Few shell frag on surface and incorporated in sed in upper cms.
MC-17	A	10/4/11	12:52	13	0	19	14.6	>4	2	>4	>4 to 2	201.3	13.82	13.6	14.1	0.5	bio	18.8	1.3	0	-	y	no	0	-	-		2	no	Silt-clay with minor fraction of very fine sand. Amphipod tubes & some Mulinia at surface. Methane bubbles and highly reduced sediment at depth.
MC-17	B	10/4/11	12:53	13	0	19	14.6	>4	1	>4	>4 to 1	202.0	13.86	13.7	14.2	0.6	bio	18.4	1.3	0	-	y	no	0	-	-		2	no	Silt-clay with minor fraction of very fine sand. Amphipod tubes & some Mulinia at surface. Methane bubbles and highly reduced sediment at depth.
MC-17	D	10/4/11	12:54	13	0	19	14.6	>4	1	>4	>4 to 1	209.3	14.37	14.0	14.7	0.7	bio	14.6	1.0	3	r	y	no	0	-	-		2 -> 3	no	Silt-clay with minor fraction of very fine sand. Amphipod tubes & some Mulinia at surface. Methane bubbles and highly reduced sediment at depth.
MC-18	A	10/4/11	12:57	13	0	19	14.6	>4	2	>4	>4 to 2	212.3	14.57	14.4	14.7	0.4	bio	16.1	1.1	6	b	y	no	0	-	-		2	no	Silt-clay with minor fraction of very fine sand. Amphipod tubes at surface. Methane bubbles and highly reduced sediment at depth.
MC-18	B	10/4/11	12:58	13	0	19	14.6	>4	2	>4	>4 to 2	198.5	13.62	12.9	14.1	1.1	phys	23.7	1.6	9	r	y	no	0	-	-		2 -> 3	no	Silt-clay with minor fraction of very fine sand. Shallow burrowing. Methane bubbles and highly reduced sed at depth. Small polychaete (may be Heteromastus) in aRPD on left.
MC-18	D	10/4/11	12:59	13	0	19	14.6	>4	1	>4	>4 to 1	172.0	11.80	8.9	13.5	4.6	phys	11.0	0.8	10+	b	y	no	0	-	-		1	no	Silt-clay with minor sand fraction but sediment profile disturbed by camera doors (interface is artifact); piles of mud clasts at surface, aRPD smeared. Methane bubbles and highly reduced sed at depth. No signs of burrowing.
MC-19	A	10/4/11	11:01	13	0	15	14.6	>4	2	>4	>4 to 2	188.1	12.91	12.5	13.3	0.7	bio	11.5	0.8	2	r	n	no	1	9.1	9.3	9.2	2	no	Silt-clay with minor fraction of very fine sand, small mud clasts at surface. Few amphipod tubes (couple reduced) at surface. Void appears relict
MC-19	B	10/4/11	11:02	13	0	15	14.6	>4	2	>4	>4 to 2	200.9	13.78	13.4	14.2	0.8	phys	4.9	0.3	10+	b	n	no	0	-	-		1	no	Surface disturbed by camera doors; silt-clay with very fine sand minor fraction. aRPD is patchy and discontinuous.
MC-19	C	10/4/11	11:03	13	0	15	14.6	>4	2	>4	>4 to 2	249.9	17.15	16.1	18.0	1.9	phys	5.1	0.4	10+	b	y	no	1	11.8	11.9	11.8	ind	no	Surface disturbed by camera doors; silt-clay with very fine sand minor fraction. aRPD is patchy and discontinuous.
MC-20	A	10/4/11	8:46	16	5	10	14.6	4-3	0	>4	>4 to 0	38.4	2.63	1.5	4.0	2.5	phys	ind	ind	0	-	n	no	0	-	-		ind	no	Compact, silty very fine sand, with some coarser grains. Large bivalve, Crepidula shells and shell fragments on surface.

APPENDIX A
Sediment Profile Imaging Results

Station ID	Rep	Date	Time	DOORS USED: Stop Collar Settings (in.)	# of weights per chassis	Water Depth (ft)	Calibration Constant	GrnSzMajor Mode (phi)	GrnSz Max (phi)	GrnSz Min (phi)	GrnSz RANGE	Penetration Area (sq.cm)	Pen Mean (cm)	Pen Min (cm)	Pen Max (cm)	Boundary Roughness (cm)	Origin of Boundary Roughness	RPD Area (sq.cm)	Mean RPD (cm)	Mud Clast Number	Mud Clast State	Methane	Beggiatoa Present?	# of Feeding Voids	Void Minimum Depth (cm)	Void Maximum Depth (cm)	Void Average Depth (cm)	Successional Stage	Low DO?	Notes
MC-20	C	10/4/11	8:47	16	5	10	14.6	4-3	0	>4	>4 to 0	58.6	4.02	3.4	4.5	1.1	phys	ind	ind	0	-	n	no	0	-	-		ind	no	Compact, silty fine sand, coarser at surface. Small shell fragments covering the surface. Few bivalve shells on surface.
MC-20	D	10/4/11	8:48	16	5	10	14.6	4-3	0	>4	>4 to 0	43.8	3.01	2.7	3.3	0.6	phys	ind	ind	0	-	n	no	0	-	-		ind	no	Compact, silty very fine sand, coarser grains at surface and along SWI. Pebbley coarse dark sand grains and small shell fragments covering surface. One larger thin shell.
MC-21	A	10/4/11	8:21	16	5	9	14.6	3-2/2-1	0	>4	>4 to 0	37.0	2.54	2.2	2.8	0.6	phys	ind	ind	0	-	n	no	0	-	-		2	no	Silty, poorly-sorted fine to medium sand, patchy in distribution. Bivalve shells and shell fragments on the surface. Active burrow transected at depth.
MC-21	C	10/4/11	8:22	16	5	9	14.6	3-2/2-1	0	>4	>4 to 0	55.1	3.78	3.6	4.1	0.5	phys	32.9	2.3	0	-	n	no	0	-	-		2	no	Silty fine to medium sand, patchy in distribution. Bivalve shells and shell fragments on surface. Some larger shells in background. Bit of red algae
MC-21	D	10/4/11	8:23	16	5	9	14.6	3-2/2-1	0	>4	>4 to 0	37.2	2.55	1.8	2.9	1.1	phys	ind	ind	0	-	n	no	0	-	-		ind	no	Silty fine to medium sand. Shell fragments on surface.
MC-22	A	10/4/11	9:50	15	1	10	14.6	>4	1	>4	>4 to 1	234.6	16.10	15.8	16.4	0.6	bio	34.1	2.3	0	-	n	no	1	8.8	9.2	9.0	1 on 3	no	Silt-clay with surface 3 cm having siltyvery fine sand. Multiple short thin tubes at SWI; some longer and thicker tubes. aRPD thickness is variable. Polychaete at ~11 cm on left.
MC-22	C	10/4/11	9:51	15	1	10	14.6	>4	1	>4	>4 to 1	232.1	15.93	15.5	16.2	0.7	bio	41.8	2.9	6	b	n	no	0	-	-		2 on 3	no	Silt-clay with surface layer enriched with very fine sand. Few tubes visible. Burrowing, including possible small bivalves, in upper cms.
MC-22	D	10/4/11	9:52	15	1	10	14.6	>4	1	>4	>4 to 1	246.0	16.88	16.6	17.0	0.4	bio	17.7	1.2	0	-	n	no	1	10.0	15.0	12.5	1 on 3	no	Silt-clay with very fine sand in upper 3 cm, shell fragments incorporated into sed. Few short tubes at SWI. Void is very large, extends ~2/3 the width of the image.
MC-23	A	10/4/11	12:35	13	0	26	14.6	>4	2	>4	>4 to 2	199.6	13.70	13.3	13.9	0.6	bio	13.0	0.9	8	b	y	no	0	-	-		2	no	Silt-clay with very fine sand in upper layer. Mud clasts on surface, some piled with collapsed amphipod tubes on right (artifact from disturbance from sled doors).
MC-23	B	10/4/11	12:36	13	0	26	14.6	>4	1	>4	>4 to 1	194.1	13.32	12.8	13.7	0.9	bio	13.3	0.9	2	b	y	no	0	-	-		2	no	Silt-clay with some very fine sand in upper layer. Mud clasts and amphipod tubes at SWI. Methane bubbles & highly reduced sed at depth.
MC-23	D	10/4/11	12:38	13	0	26	14.6	>4	1	>4	>4 to 1	205.4	14.09	13.7	14.3	0.5	bio	16.4	1.1	10+	b	y	no	0	-	-		2	no	Silt-clay with some very fine sand in upper layer. Mud clasts and amphipod tubes at SWI. Methane bubbles & highly reduced sed at depth.
MC-24	A	10/4/11	12:41	13	0	25	14.6	>4	2	>4	>4 to 2	223.6	15.35	15.1	15.5	0.5	bio	15.6	1.1	0	-	y	no	0	-	-		2	no	Silt-clay with some very fine sand in upper layer and amphipod tubes at SWI. Methane bubbles & highly reduced sed at depth.

APPENDIX A
Sediment Profile Imaging Results

Station ID	Rep	Date	Time	DOORS USED: Stop Collar Settings (in.)	# of weights per chassis	Water Depth (ft)	Calibration Constant	GrnSzMajor Mode (phi)	GrnSz Max (phi)	GrnSz Min (phi)	GrnSz RANGE	Penetration Area (sq.cm)	Pen Mean (cm)	Pen Min (cm)	Pen Max (cm)	Boundary Roughness (cm)	Origin of Boundary Roughness	RPD Area (sq.cm)	Mean RPD (cm)	Mud Clast Number	Mud Clast State	Methane	Beggiatoa Present?	# of Feeding Voids	Void Minimum Depth (cm)	Void Maximum Depth (cm)	Void Average Depth (cm)	Successional Stage	Low DO?	Notes
MC-24	C	10/4/11	12:43	13	0	25	14.6	>4	2	>4	>4 to 2	221.1	15.18	14.6	15.9	1.3	bio	23.8	1.6	2	o	y	no	0	-	-		2	no	Silt-clay with some very fine sand in upper few cm; sparse amphipod tubes at SWI. Burrowing in upper 2 cm. High sed oxy demand sed below aRPD. Methane bubbles at depth.
MC-24	D	10/4/11	12:44	13	0	25	14.6	>4	2	>4	>4 to 2	240.8	16.53	15.6	17.6	2.0	phys	6.8	0.5	10+	r	y	no	1	2.5	3.7	3.1	2 -> 3	no	SWI disturbed by camera doors, multiple small to large mud clasts on surface. Silt clay with some very fine sand in upper 3-5 cm. High sed oxy demand sed. Methane bubbles at depth.
MC-25	A	10/4/11	12:46	13	0	17	14.6	>4	2	>4	>4 to 2	214.4	14.71	14.1	15.0	0.9	bio	11.7	0.8	0	-	n	no	0	-	-		2	no	Silt-clay with very fine sand in unpper 3-4 cm.. Multiple amphipod tubes at SWI. Burrowing polychaete below aRPD at right.
MC-25	B	10/4/11	12:47	13	0	17	14.6	>4	2	>4	>4 to 2	268.6	18.43	17.2	19.6	2.4	phys	ind	ind	10+	b	y	no	0	-	-		2	no	Surface disturbed by camera doors; silt-clay with very fine sand minor fraction. Appears to be dense amphipod mat at this location.
MC-25	C	10/4/11	12:48	13	0	17	14.6	>4	2	>4	>4 to 2	175.0	12.01	11.8	12.7	0.9	phys	5.8	0.4	8	b	n	no	4	8.0	11.9	10.0	2	no	Silt-clay, grading to very fine sand at surface. Few amphipod tubes at SWI and in background. Voids appear relict.
MC-26	A	10/4/11	10:33	13	0	28	14.6	>4	2	>4	>4 to 2	191.2	13.12	12.9	13.3	0.4	bio	3.0	0.2	2	o	y	no	0	-	-		1	no	Silt-clay with highly reduced sediment at depth and minor fraction of very fine sand in upper 3-4 cm. Methane bubbles at depth.
MC-26	B	10/4/11	10:34	13	0	28	14.6	>4	2	>4	>4 to 2	199.3	13.68	13.0	14.0	1.0	phys	1.8	0.1	4	b	y	no	0	-	-		1	yes	Silt-clay with highly reduced sediment at depth and minor fraction of very fine sand in upper 3-4 cm. Methane bubbles at depth; minimal faunal density.
MC-26	C	10/4/11	10:35	13	0	28	14.6	>4	2	>4	>4 to 2	222.3	15.26	14.2	16.0	1.7	phys	3.4	0.2	10+	b	y	no	0	-	-		2	yes	Silt-clay with highly reduced sediment & methane at depth, minimal O2 in boundary layer, surface somewhat distrubed by camera, Ampelisca tubes present.
MC-27	B	10/4/11	11:08	13	0	17	14.6	>4	3	>4	>4 to 3	251.0	17.22	15.4	18.0	2.6	phys	ind	ind	10+	b	y	no	0	-	-		1	yes	Interface disturbed by camera, profile is all artifact, evidence of Stage 1 worms present with methane and highly reduced sediment.
MC-27	C	10/4/11	11:08	13	0	17	14.6	>4	3	>4	>4 to 3	278.7	19.13	17.7	21.3	3.5	phys	0.0	0.0	10+	b	y	yes	0	-	-		0	yes	Interface disturbed by camera, profile is all artifact, evidence of Beggiatoa traces present with methane and highly reduced sediment.
MC-27	D	10/4/11	11:09	13	0	17	14.6	>4	2	>4	>4 to 2	309.3	21.23	20.8	>21.39	Ind	ind	0.0	0.0	ind	ind	y	Ind	0	-	-		0	yes	Over-penetration in all part a small part of the image. Dark and gray high sed oxy demand sed. Methane bubbles throughout, highly reduced, very soft sediment.

APPENDIX A
Sediment Profile Imaging Results

Station ID	Rep	Date	Time	DOORS USED: Stop Collar Settings (in.)	# of weights per chassis	Water Depth (ft)	Calibration Constant	GrnSzMajor Mode (phi)	GrnSz Max (phi)	GrnSz Min (phi)	GrnSz RANGE	Penetration Area (sq.cm)	Pen Mean (cm)	Pen Min (cm)	Pen Max (cm)	Boundary Roughness (cm)	Origin of Boundary Roughness	RPD Area (sq.cm)	Mean RPD (cm)	Mud Clast Number	Mud Clast State	Methane	Beggiatoa Present?	# of Feeding Voids	Void Minimum Depth (cm)	Void Maximum Depth (cm)	Void Average Depth (cm)	Successional Stage	Low DO?	Notes
MC-28	B	10/4/11	8:27	16	5	9	14.6	3-2	0	>4	>4 to 0	73.7	5.06	4.8	5.2	0.4	bio	24.6	1.7	0	-	n	no	0	-	-		1 on 3	no	Silty fine sand with bits of debris and shells on surface. Few thin burrows through aRPD, fecal pellet mound from deposit feeders in center of image.
MC-28	C	10/4/11	8:28	16	5	9	14.6	3-2	1	>4	>4 to 1	62.8	4.31	2.9	5.1	2.2	phys	18.4	1.3	0	-	n	no	0	-	-		1 on 3	no	Sitly fine sand with some shells on the surface. Few thin tubes on surface, Burrow/pit on right edge. Signs of burrowing through aRPD.
MC-28	D	10/4/11	8:29	16	5	9	14.6	3-2	0	>4	>4 to 0	62.4	4.28	3.7	4.5	0.8	phys	25.7	1.8	0	-	n	no	0	-	-		1 on 3	no	Silty fine sand. Larger shells and bits of debris on surface. Larger worm tubes visible above SWI just beyond faceplate contact.
MC-29	A	10/4/11	9:55	15	1	10	14.6	4-3/>4	1	>4	>4 to 1	177.5	12.18	11.6	12.8	1.2	bio	39.4	2.7	7	b	n	no	0	-	-		1 on 3	no	Silty very fine sand over silt-clay. Short thin tubes on surface. Burrows through aRPD as well as evidence of deeper burrowing.
MC-29	B	10/4/11	9:57	15	1	10	14.6	4-3/>4	0	>4	>4 to 0	209.7	14.39	13.3	14.8	1.5	bio	33.3	2.3	7	b	n	no	1	7.4	8.6	8.0	1 on 3	no	Silty very fine sand over silt-clay; shell fragments on surface and incorporated into sed. Few tubes at SWI. Evidence of burrowing through aRPD.
MC-29	D	10/4/11	9:58	15	1	10	14.6	4-3/>4	0	>4	>4 to 0	236.3	16.22	15.4	16.7	1.3	bio	42.9	2.9	9	b	n	no	1	2.7	4.6	3.7	2 on 3	no	Silty very fine sand over silt-clay with shell fragments on surface and at depth. Few amphipod tubes visible on surface. Few old/collapsed voids. Evidence of burrowing through aRPD.
MC-30	A	10/4/11	12:29	13	0	20	14.6	>4	2	>4	>4 to 2	223.6	15.35	15.0	15.5	0.6	bio	14.2	1.0	0	-	y	no	0	-	-		2	no	Silt-clay with minor fraction of very fine sand. Bed of amphipod tubes at SWI with organically enriched, highly reduced sediment at depth.
MC-30	B	10/4/11	12:30	13	0	20	14.6	>4	2	>4	>4 to 2	218.5	14.99	14.6	15.3	0.6	bio	16.3	1.1	6	b	y	no	1	7.3	7.7	7.5	2	no	Silt-clay with minor fraction of very fine sand in surface layer. Shallow burrowing. Methane bubbles at depth, evidence of low density of shallow-dwelling deposit feeders; contrast to previous rep with dense amphipod bed.
MC-30	D	10/4/11	12:32	13	0	20	14.6	>4	2	>4	>4 to 2	212.1	14.56	14.4	14.9	0.5	bio	19.2	1.3	10+	b	y	yes	0	-	-		1 -> 2	no	Silt-clay with minor fraction of very fine sand. Organically enriched sediment at depth, high density of methane, sparse to rare amphipods and patches of Beggiatoa blooms at SWI.
MC-31	A	10/4/11	11:18	13	0	21	14.6	>4	2	>4	>4 to 2	218.7	15.01	14.3	15.3	1.0	bio	21.5	1.5	8	b	y	no	0	-	-		2	no	Silt-clay with dense bed of amphipod tubes at SWI. Shallow burrowing. Organically enriched sediment at depth. Methane bubbles throughout image.
MC-31	B	10/4/11	11:19	13	0	21	14.6	>4	2	>4	>4 to 2	217.6	14.94	14.5	15.2	0.7	bio	21.5	1.5	9	b	y	no	0	-	-		2	no	Silt-clay with dense bed of amphipod tubes at SWI. Shallow burrowing. Organically enriched sediment at depth. Methane bubbles throughout image.

APPENDIX A
Sediment Profile Imaging Results

Station ID	Rep	Date	Time	DOORS USED: Stop Collar Settings (in.)	# of weights per chassis	Water Depth (ft)	Calibration Constant	GrnSzMajor Mode (phi)	GrnSz Max (phi)	GrnSz Min (phi)	GrnSz RANGE	Penetration Area (sq.cm)	Pen Mean (cm)	Pen Min (cm)	Pen Max (cm)	Boundary Roughness (cm)	Origin of Boundary Roughness	RPD Area (sq.cm)	Mean RPD (cm)	Mud Clast Number	Mud Clast State	Methane	Beggiatoa Present?	# of Feeding Voids	Void Minimum Depth (cm)	Void Maximum Depth (cm)	Void Average Depth (cm)	Successional Stage	Low DO?	Notes
MC-31	C	10/4/11	11:20	13	0	21	14.6	>4	2	>4	>4 to 2	218.5	14.99	14.6	15.1	0.5	bio	21.5	1.5	3	r	y	no	0	-	-		2	no	Silt-clay with slightly less dense bed of amphipod tubes at SWI compared to two previous replicates from this station. Shallow burrowing. Organically enriched sediment at depth. Methane bubbles throughout image.
MC-32	A	10/4/11	10:05	15	1	11	14.6	>4	2	>4	>4 to 2	277.2	19.02	18.6	19.5	0.9	bio	9.1	0.6	3	b	n	no	0	-	-		2 -> 3	no	Silt-clay with silty very fine sand in upper 3-5 cm. Few small tubes at surface with evidence of shallow burrowing.
MC-32	B	10/4/11	10:05	15	1	11	14.6	>4	2	>4	>4 to 2	287.8	19.75	19.2	20.2	1.0	bio	13.1	0.9	4	o	n	no	0	-	-		2 -> 3	no	Silt-clay with minor fraction of very fine sand in upper 3-5 cm. Few small tubes at surface. Shallow burrowing. Larger burrow/tunnel connected to SWI, reduced interior.
MC-32	D	10/4/11	10:07	15	1	11	14.6	>4	2	>4	>4 to 2	267.9	18.38	17.7	18.6	0.9	bio	15.4	1.1	8	b	n	no	1	15.4	15.8	15.6	1 on 3	no	Silt-clay with very fine sand in upper sediment layer; shallow burrowing.
MC-33	A	10/4/11	11:12	13	0	17	14.6	>4	2	>4	>4 to 2	238.1	16.34	15.7	16.9	1.2	bio	18.6	1.3	3	b	y	no	0	-	-		2	no	Silt-clay, organically enriched sediment with minor fraction of very fine sand. Amphipod tubes at SWI, some collapsed. Methane bubbles throughout image, one large one near SWI.
MC-33	C	10/4/11	11:14	13	0	17	14.6	>4	2	>4	>4 to 2	195.5	13.42	13.1	14.1	1.0	bio	12.2	0.8	7	b	y	no	0	-	-		1 -> 2	no	Silt-clay with minor fraction of very fine sand. Few reduced, collapsed amphipod tubes at surface. Medium to large mud clasts on surface. Methane bubbles throughout image, most just below aRPD.
MC-33	D	10/4/11	11:15	13	0	17	14.6	>4	2	>4	>4 to 2	192.2	13.19	13.1	13.3	0.2	bio	6.6	0.4	4	b	y	trace	0	-	-		2	no	Silt-clay with minor fraction of very fine sand. Some long amphipod tubes at surface. Methane bubbles at depth.
MC-34	B	10/4/11	10:11	15	1	11	14.6	>4	2	>4	>4 to 2	277.6	19.05	18.2	19.7	1.5	phys	11.1	0.8	4	b	n	no	1	18.0	18.5	18.3	1	no	Silt-clay with minor fraction of very fine sand. Few reduced amphipod tubes on surface. Shallow burrowing. Relict reduced void at base of image.
MC-34	E	10/4/11	10:26	13	0	10	14.6	>4	2	>4	>4 to 2	203.1	13.94	13.7	14.2	0.5	bio	15.4	1.1	5	b	n	no	0	-	-		1 -> 2	no	Silt-clay with some very fine sand in upper 3-5 cm. Few amphipod tubes in background. Shallow burrowing. Discontinuous aRPD. Evidence of former or collapsed voids (2) at depth.
MC-34	G	10/4/11	10:28	13	0	10	14.6	>4	2	>4	>4 to 2	217.8	14.95	14.1	15.6	1.5	bio	8.5	0.6	10+	b	n	no	0	-	-		1	no	Silt-clay with minor fraction of very fine sand. Small to medium mud clasts (artifacts) on surface. Shallow burrowing. Evidence of a former void at depth.
MC-35	A	10/4/11	8:32	16	5	8	14.6	3-2	0	>4	>4 to 0	83.5	5.73	5.2	6.0	0.8	phys	35.1	2.4	0	-	n	no	0	-	-		1 on 3	no	Compact silty fine sand, ripples, somewhat coarser at base of image. Bit of debris on surface. Some tubes at surface.

Station ID	Rep	Date	Time	DOORS USED: Stop Collar Settings (in.)	# of weights per chassis	Water Depth (ft)	Calibration Constant	GrnSzMajor Mode (phi)	GrnSz Max (phi)	GrnSz Min (phi)	GrnSz RANGE	Penetration Area (sq.cm)	Pen Mean (cm)	Pen Min (cm)	Pen Max (cm)	Boundary Roughness (cm)	Origin of Boundary Roughness	RPD Area (sq.cm)	Mean RPD (cm)	Mud Clast Number	Mud Clast State	Methane	Beggiatoa Present?	# of Feeding Voids	Void Minimum Depth (cm)	Void Maximum Depth (cm)	Void Average Depth (cm)	Successional Stage	Low DO?	Notes
MC-35	B	10/4/11	8:32	16	5	8	14.6	3-2	0	>4	>4 to 0	84.7	5.81	5.0	6.4	1.4	phys	30.0	2.1	0	-	n	no	0	-	-		1 on 3	no	Compact silty fine sand, ripples, somewhat coarser at base of image. Shell fragments and bits of debris on surface. Some tubes at surface.
MC-35	C	10/4/11	8:33	16	5	8	14.6	3-2	0	>4	>4 to 0	60.6	4.16	2.2	4.7	2.4	bio	28.4	1.9	0	-	n	no	0	-	-		1 on 3	no	Compact silty fine sand, ripples, somewhat coarser at base of image. Shell fragments and bits of debris on surface. Some tubes, small thin and medium tubes, few amphipod ones, at surface, eividence of deposit feeding fauna

Note: ind = indeterminate; Mud Clast State: 0 = oxidized; r = reduced; b = oxidized and reduced; Origin of Boundary Roughness: phys = physical; bio = biological; Methane: n = none; y = yes

Appendix B

Grain Size Scale Conversions

APPENDIX B
Grain Size Scale Conversions

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

APPENDIX C

Water Quality Profile Data

APPENDIX C
Water Quality Profile Data

Station MCDS-Out

9/28/11 12:27							9/28/11 16:37						
Depth (m)	Conductivity (μS)	Salinity (%)	DO (%)	DO (mg/L)	Temperature (°C)	Specific Conductance (μS/cm)	Depth (m)	Conductivity (μS)	Salinity (%)	DO (%)	DO (mg/L)	Temperature (°C)	Specific Conductance (μS/cm)
<0.5	11.50	7.90	93.96	8.19	19.95	12.49	<0.5	24.52	16.87	92.37	7.46	21.08	26.43
0.5 - 1.5	37.67	26.00	93.75	7.15	21.24	40.59	0.5 - 1.5	37.51	25.88	92.47	7.06	21.22	40.42
1.5 - 2.5	37.72	26.03	91.36	6.96	21.24	40.64	1.5 - 2.5	37.59	25.95	92.23	7.04	21.22	40.51
2.5 - 3.5	37.82	26.12	91.83	7.00	21.22	40.76	2.5 - 3.5	37.71	26.03	91.96	7.01	21.22	40.64
3.5 - 4.5	37.81	26.11	92.57	7.06	21.22	40.75	3.5 - 4.5	37.79	26.10	91.76	6.99	21.21	40.74
4.5 - 5.5	38.01	26.30	91.81	7.00	21.17	41.01	4.5 - 5.5						
5.5 - 6.5	38.08	26.38	90.25	6.88	21.13	41.12	5.5 - 6.5						
6.5 - 7.5							6.5 - 7.5						
7.5 - 8.5							7.5 - 8.5						
8.5 - 9.5							8.5 - 9.5						
>9.5							>9.5						

10/4/11 7:45							10/4/11 12:12							10/4/11 13:55						
Depth (m)	Conductivity (μS)	Salinity (%)	DO (%)	DO (mg/L)	Temperature (°C)	Specific Conductance (μS/cm)	Depth (m)	Conductivity (μS)	Salinity (%)	DO (%)	DO (mg/L)	Temperature (°C)	Specific Conductance (μS/cm)	Depth (m)	Conductivity (μS)	Salinity (%)	DO (%)	DO (mg/L)	Temperature (°C)	Specific Conductance (μS/cm)
<0.5	7.05	5.15	95.46	9.11	16.40	8.23	<0.5	0.22	0.13	101.45	10.62	13.29	0.28	<0.5	33.65	24.06	89.57	7.17	19.21	37.83
0.5 - 1.5	32.27	23.38	97.57	7.96	18.50	36.85	0.5 - 1.5	33.22	23.92	94.22	7.61	18.86	37.60	0.5 - 1.5	33.64	24.05	89.25	7.15	19.22	37.81
1.5 - 2.5	32.52	23.46	95.01	7.71	18.70	36.96	1.5 - 2.5	33.77	24.32	90.05	7.24	18.93	38.20	1.5 - 2.5	33.55	24.00	89.16	7.14	19.19	37.74
2.5 - 3.5	34.06	24.55	93.58	7.52	18.95	38.51	2.5 - 3.5	35.89	25.46	79.00	6.20	19.84	39.82	2.5 - 3.5	33.91	24.17	85.84	6.85	19.38	37.99
3.5 - 4.5	35.68	25.42	91.23	7.19	19.62	39.76	3.5 - 4.5	0.50	0.32	101.80	10.64	13.30	0.65	3.5 - 4.5	35.55	25.40	88.48	6.99	19.50	39.73
4.5 - 5.5	35.64	25.30	89.18	7.01	19.77	39.59	4.5 - 5.5							4.5 - 5.5						
5.5 - 6.5							5.5 - 6.5							5.5 - 6.5						
6.5 - 7.5							6.5 - 7.5							6.5 - 7.5						
7.5 - 8.5							7.5 - 8.5							7.5 - 8.5						
8.5 - 9.5							8.5 - 9.5							8.5 - 9.5						
>9.5							>9.5							>9.5						

Note: Data represents average for each horizon collected per profile.

APPENDIX C
Water Quality Profile Data

Station: MCDS-In

9/28/11 12:17							9/28/11 16:29						
Depth (m)	Conductivity (µS)	Salinity (%)	DO (%)	DO (mg/L)	Temperature (°C)	Specific Conductance (µS/cm)	Depth (m)	Conductivity (µS)	Salinity (%)	DO (%)	DO (mg/L)	Temperature (°C)	Specific Conductance (µS/cm)
<0.5	19.33	13.26	87.12	7.21	20.97	20.82	<0.5	20.09	13.84	91.59	7.59	20.77	21.68
0.5 - 1.5	37.71	26.01	89.08	6.78	21.27	40.60	0.5 - 1.5	38.00	26.28	91.52	6.97	21.18	40.99
1.5 - 2.5	37.74	26.04	88.50	6.74	21.26	40.65	1.5 - 2.5	38.03	26.31	90.68	6.91	21.18	41.02
2.5 - 3.5	37.78	26.09	87.95	6.70	21.23	40.71	2.5 - 3.5	38.04	26.32	91.24	6.95	21.19	41.03
3.5 - 4.5	37.83	26.13	88.30	6.73	21.23	40.77	3.5 - 4.5	38.10	26.35	90.70	6.91	21.19	41.09
4.5 - 5.5	37.93	26.21	87.46	6.66	21.20	40.90	4.5 - 5.5	38.14	26.39	90.54	6.89	21.19	41.14
5.5 - 6.5	37.96	26.25	87.53	6.67	21.18	40.95	5.5 - 6.5	38.17	26.41	90.58	6.89	21.18	41.17
6.5 - 7.5	37.97	26.27	85.82	6.54	21.17	40.97	6.5 - 7.5	38.17	26.42	90.55	6.89	21.17	41.18
7.5 - 8.5	37.98	26.27	85.61	6.52	21.17	40.98	7.5 - 8.5						
8.5 - 9.5	37.98	26.27	85.25	6.50	21.17	40.97	8.5 - 9.5						
>9.5							>9.5						

10/4/11 7:49							10/4/11 12:04							10/4/11 13:42						
Depth (m)	Conductivity (µS)	Salinity (%)	DO (%)	DO (mg/L)	Temperature (°C)	Specific Conductance (µS/cm)	Depth (m)	Conductivity (µS)	Salinity (%)	DO (%)	DO (mg/L)	Temperature (°C)	Specific Conductance (µS/cm)	Depth (m)	Conductivity (µS)	Salinity (%)	DO (%)	DO (mg/L)	Temperature (°C)	Specific Conductance (µS/cm)
<0.5	32.17	23.37	92.01	7.73	18.38	36.83	<0.5	33.58	24.11	86.97	6.99	19.03	37.90	<0.5	33.23	23.91	94.68	7.63	18.90	37.62
0.5 - 1.5	32.23	23.39	82.50	6.79	18.41	36.87	0.5 - 1.5	33.71	24.20	85.98	6.90	19.05	38.03	0.5 - 1.5	33.23	23.92	93.93	7.58	18.89	37.62
1.5 - 2.5	32.29	23.38	84.81	7.14	18.53	36.85	1.5 - 2.5	34.44	24.73	85.38	6.82	19.13	38.78	1.5 - 2.5	33.72	24.23	93.24	7.49	19.02	38.07
2.5 - 3.5	34.29	24.58	84.23	6.78	19.19	38.57	2.5 - 3.5	35.89	25.63	85.04	6.70	19.55	40.06	2.5 - 3.5	33.90	24.24	89.93	7.19	19.26	38.08
3.5 - 4.5	35.72	25.45	84.83	6.85	19.64	39.80	3.5 - 4.5	36.05	25.62	84.20	6.61	19.79	40.03	3.5 - 4.5	34.70	24.75	86.50	6.87	19.45	38.81
4.5 - 5.5	35.92	25.49	84.94	6.83	19.83	39.86	4.5 - 5.5	36.09	25.60	76.39	5.99	19.86	40.02	4.5 - 5.5	35.91	25.56	83.16	6.54	19.70	39.95
5.5 - 6.5	35.97	25.50	84.59	6.69	19.88	39.87	5.5 - 6.5	36.13	25.63	78.85	6.18	19.86	40.06	5.5 - 6.5	36.08	25.60	78.11	6.12	19.85	40.01
6.5 - 7.5	36.00	25.52	83.86	6.63	19.88	39.90	6.5 - 7.5							6.5 - 7.5	36.11	25.64	86.85	6.82	19.84	40.06
7.5 - 8.5	36.04	25.55	81.95	6.57	19.89	39.94	7.5 - 8.5							7.5 - 8.5						
8.5 - 9.5	36.07	25.57	74.15	6.57	19.90	39.97	8.5 - 9.5							8.5 - 9.5						
>9.5							>9.5							>9.5						

Note: Data represents average for each horizon collected per profile.

APPENDIX C
Water Quality Profile Data

Station MCDS-In2

9/28/11 12:22							9/28/11 16:33						
Depth (m)	Conductivity (μS)	Salinity (%)	DO (%)	DO (mg/L)	Temperature (°C)	Specific Conductance (μS/cm)	Depth (m)	Conductivity (μS)	Salinity (%)	DO (%)	DO (mg/L)	Temperature (°C)	Specific Conductance (μS/cm)
<0.5	5.98	2.38	87.78	7.72	20.60	6.46	<0.5	23.35	16.04	92.08	7.47	21.10	25.19
0.5 - 1.5	37.80	26.00	87.92	6.70	21.23	40.74	0.5 - 1.5	37.90	26.21	91.05	6.94	21.18	40.88
1.5 - 2.5	37.71	26.02	88.61	6.75	21.25	40.62	1.5 - 2.5	37.91	26.21	91.13	6.95	21.18	40.89
2.5 - 3.5	37.79	26.09	89.04	6.78	21.24	40.71	2.5 - 3.5	37.91	26.22	91.28	6.96	21.18	40.90
3.5 - 4.5	37.91	26.19	88.59	6.75	21.22	40.86	3.5 - 4.5	37.93	26.23	90.88	6.93	21.18	40.92
4.5 - 5.5	37.98	26.25	87.80	6.69	21.20	40.95	4.5 - 5.5	37.96	26.25	90.90	6.92	21.19	40.94
5.5 - 6.5	37.99	26.27	85.96	6.55	21.18	40.97	5.5 - 6.5	38.02	26.30	90.52	6.89	21.19	41.01
6.5 - 7.5	37.99	26.27	86.08	6.56	21.19	40.97	6.5 - 7.5	38.08	26.34	90.49	6.89	21.18	41.07
7.5 - 8.5	38.01	26.29	84.80	6.46	21.17	41.00	7.5 - 8.5	38.10	26.35	90.60	6.90	21.18	41.09
8.5 - 9.5	38.02	26.31	84.13	6.41	21.16	41.02	8.5 - 9.5	38.09	26.35	89.83	6.84	21.17	41.09
>9.5	38.03	26.33	83.54	6.37	21.14	41.06	>9.5						

10/4/11 7:55							10/4/11 12:08						
Depth (m)	Conductivity (μS)	Salinity (%)	DO (%)	DO (mg/L)	Temperature (°C)	Specific Conductance (μS/cm)	Depth (m)	Conductivity (μS)	Salinity (%)	DO (%)	DO (mg/L)	Temperature (°C)	Specific Conductance (μS/cm)
<0.5							<0.5	32.91	23.74	90.15	7.30	18.74	37.38
0.5 - 1.5	32.33	23.45	91.91	7.50	18.45	36.95	0.5 - 1.5	32.86	23.72	90.02	7.29	18.73	37.33
1.5 - 2.5	32.40	23.49	87.40	7.13	18.47	37.02	1.5 - 2.5	32.88	23.68	89.78	7.26	18.82	37.28
2.5 - 3.5	33.36	24.23	87.55	7.09	18.52	38.06	2.5 - 3.5	33.99	24.60	89.77	7.23	18.76	38.59
3.5 - 4.5	35.38	25.38	81.68	6.49	19.30	39.70	3.5 - 4.5	35.96	25.86	89.55	7.09	19.27	40.37
4.5 - 5.5	35.77	25.66	83.67	6.62	19.37	40.08	4.5 - 5.5	36.05	25.66	88.90	6.99	19.71	40.11
5.5 - 6.5	35.91	25.57	80.28	6.32	19.68	39.97	5.5 - 6.5	36.10	25.62	87.84	6.89	19.84	40.05
6.5 - 7.5	35.94	25.56	83.17	6.54	19.74	39.96	6.5 - 7.5	36.12	25.62	86.47	6.78	19.87	40.04
7.5 - 8.5	35.93	25.51	82.10	6.45	19.81	39.89	7.5 - 8.5	36.10	25.62	75.27	5.90	19.85	40.04
8.5 - 9.5	35.97	25.52	78.13	6.13	19.85	39.90	8.5 - 9.5	36.06	25.58	82.25	6.45	19.85	40.00
>9.5							>9.5						

Note: Data represents average for each horizon collected per profile.

APPENDIX D

Common Conversions

APPENDIX D
Common Conversions

Metric	English
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)
Velocity	
1 Meter per Second (m/s)	3.28 Feet Per Second