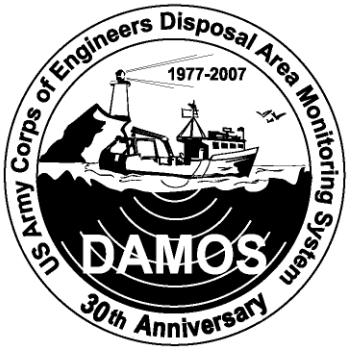
Monitoring Survey at the Boston Harbor CAD Cells
August 2004

Disposal Area Monitoring System DAMOS



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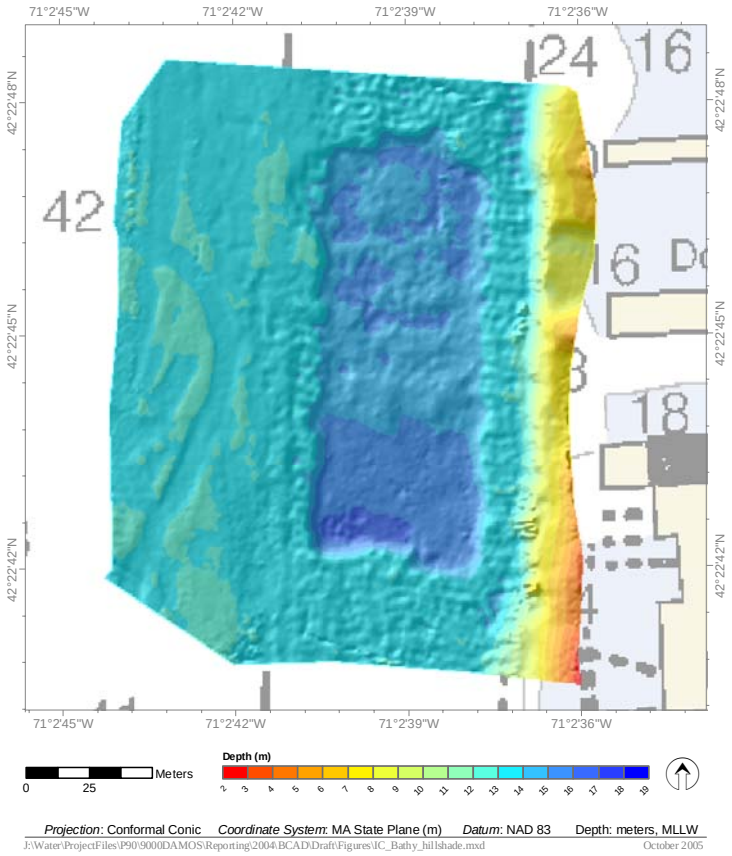

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13. ABSTRACT

A survey was performed at the confined aquatic disposal (CAD) cells in Boston Harbor in August 2004 as part of the Disposal Area Monitoring System (DAMOS), and included bathymetry, side-scan sonar, video sled and sediment-profile imaging. The CAD cells were constructed beneath the navigable channel as part of the Boston Harbor Navigation Improvement Project (BHNIP) carried out between 1997 and 2000. Under the BHNIP, the CAD cells received dredged harbor sediments that were identified as unsuitable for unconfined open water disposal. Following completion of disposal into the CAD cells, they were capped with a layer of sand to further isolate the dredged material from the overlying waters. The use of CAD cells within the footprint of a navigable channel was a relatively new technique at the time of the BHNIP; as a result, a series of investigations were performed during and following completion of the project to assess the effectiveness of dredged material disposal into the cells and cap placement. The August 2004 investigation was performed as a longer term follow-up as a requirement of the Water Quality Certification (WQC), four to seven years following completion of individual CAD cells.

The 2004 surveys confirmed that the surface sediment layers of the cells remain physically stable, with moderate amounts of sediment accumulating in the rectangular depressions formed by the cells. Consolidation of the material within the cells had also taken place, causing the surface topography to follow that of the underlying cell floor. Some collapse of the exposed sidewalls of the cells that rise steeply above the cell surface had also occurred. The towed video footage revealed numerous small fish and crustaceans at the bottom over the CAD cells, however, sediment-profile images revealed general benthic habitat conditions indicative of a consistently stressed environment, due to the urban harbor setting. This monitoring survey appears to meets the five-year post-construction monitoring requirements of the WQC. The CAD cells were stable, and no further monitoring is recommended for compliance with the WQC.

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EXECUTIVE SUMMARY

An investigation of nine previously constructed confined aquatic disposal (CAD) cells in Boston Harbor was performed in August 2004 as part of the U.S. Army Corps of Engineers (USACE) New England District Disposal Area Monitoring System (DAMOS). The CAD cells were constructed beneath the navigable channel as part of the Boston Harbor Navigation Improvement Project (BHNIP) carried out between 1997 and 2000. Under the BHNIP, the CAD cells received dredged harbor sediments that were identified as unsuitable for unconfined open water disposal. Following completion of disposal into the CAD cells, they were capped with a layer of sand to further isolate the dredged material from the overlying waters.

The use of CAD cells within the footprint of a navigable channel was a relatively new technique at the time of the BHNIP; as a result, a series of investigations were performed during and following completion of the project to assess the effectiveness of dredged material disposal into the cells and cap placement. The August 2004 investigation was performed as a longer term follow-up as a requirement of the Water Quality Certification (WQC), four to seven years following completion of individual CAD cells. The 2004 survey included bathymetric, side-scan sonar, underwater video and sediment-profile imaging surveys. The investigation was designed to 1) assess the general physical status of the surface of each CAD cell to evaluate cell stability, with a more detailed assessment of one cell (M19) where a linear depression in the capped surface of the cell had been identified in 2002; 2) characterize bathymetry over the CAD cells and surrounding channel; and 3) assess the benthic recolonization status of each of the nine CAD cells.

The high resolution swath bathymetry and side-scan sonar data collected as part of the August 2004 survey revealed that all nine CAD cells remained as stable structures with no evidence of significant cap disturbance or scour. As expected, additional consolidation of the material within the cells had taken place and some of the surface topography within the cells reflected cell bottom topography. Some collapse of the exposed sidewalls of the cells that rise steeply above the cell surface had also occurred. Both of these processes are expected to continue into the future, but without effect on the overall structure or integrity of the cells. The linear depression previously identified over cell M19 was clearly visible in 2004. Review of the pre-filling bathymetry of cell M19 revealed a similar feature on the bottom of the cell, and it is believed that the surface depression was the result of consolidation of material within the cell causing the surface topography to follow that of the underlying cell floor. The depression appeared stable over time.

follow-up surveys, as the cells, depressed below the surrounding harbor bottom, continued to receive sediments transported in runoff or resuspended from other areas of the harbor. Accretion of material within the cells was not identified in comparing the 2004 bathymetry data with data collected 2 to 7 years prior, indicating that the continuing consolidation of the dredged material within the cells likely masked the deposition. Large scale debris (timbers, piles, tires, etc.) were also identified on the surface of some of the cells in 2004. Deposition of fine material (as well as larger debris) is expected to continue into the future, helping to further sequester the material deeper within the cell.

The towed video footage collected in 2004 revealed numerous small fish and crustaceans at the bottom over the CAD cells indicating that the area was providing epibenthic habitat. However, sediment-profile images taken in 2004 from the cells and reference areas revealed general benthic habitat conditions indicative of a consistently stressed environment. The presence in the urban harbor of frequent ship traffic, high organic loading and periods of low dissolved oxygen in the bottom waters creates this stressed habitat. The continual exposure to stressful conditions limited the recolonization and successional status of both the CAD cells and associated reference areas, resulting in an environment in a perpetual state of early succession. This was expected given periodic episodes of poor water quality and physical disturbance associated with a working harbor.

The 2004 monitoring survey was designed to meet the five-year post-construction monitoring requirements of the WQC for the BHNIP CAD cells. As the structure of the CAD cells was found to be stable, no further monitoring is recommended for compliance with the WQC.

1.0 INTRODUCTION

An investigation of nine previously constructed confined aquatic disposal (CAD) cells in Boston Harbor was performed in August 2004 as part of the U.S. Army Corps of Engineers (USACE) New England District Disposal Area Monitoring System (DAMOS). The CAD cells were constructed beneath the navigable channel as part of the Boston Harbor Navigation Improvement Project (BHNIP) carried out between 1997 and 2000. Under the BHNIP, the CAD cells received dredged harbor sediments that were identified as unsuitable for unconfined open water disposal. Following completion of disposal into the CAD cells, they were capped with a layer of sand to further isolate the dredged material from the overlying waters.

Given that use of CAD cells within the footprint of a navigable channel was a relatively new technique at the time of the BHNIP, a series of investigations were performed during and following completion of the project to assess the effectiveness of dredged material disposal into the cells and cap placement. The August 2004 investigation was performed as a longer term follow-up as a requirement of the Water Quality Certification (WQC), four to seven years following completion of individual CAD cells. An introduction to the DAMOS Program under which this investigation was performed is provided below as well as background information on the construction, previous studies of the CAD cells, and the five-year monitoring requirements of the WQC.

1.1 Overview of the DAMOS Program

DAMOS is a comprehensive monitoring and management program designed and conducted to address environmental concerns associated with the use of open-water disposal sites throughout the New England region. For over 25 years, the DAMOS Program has collected and evaluated disposal site data throughout New England. Based on these data, patterns of physical, chemical, and biological responses of seafloor environments to dredged material disposal activity have been documented. The Program features a tiered approach to monitoring that is designed to allow for assessment of compliance with disposal permit regulations, for verification of the validity of model predictions and assumptions that are the foundation of the sampling design, and for identification of long-term environmental trends that could be related to disposal activity (Fredette and French 2004). The tiered approach provides recommendations for monitoring techniques and guidelines for defining when additional, more intensive monitoring is warranted (Germano et al. 1994).

Disposal site monitoring surveys are designed to collect data that will allow evaluation of the environmental status of each disposal site relative to conditions after recent disposal of dredged material and to conditions in nearby reference areas unaffected by disposal activities. The results of the monitoring surveys are evaluated to determine the next step in the management process of each specific disposal site. Focused studies are periodically undertaken within the DAMOS Program to evaluate inactive/historic disposal sites. The August 2004 investigation of the Boston Harbor CAD (BHCAD) cells represents a combination of a more standard survey to track recovery at the CAD cell disposal site and a focused investigation to evaluate the status of caps over the CAD cells.

1.2 Background on the Boston Harbor Confined Aquatic Disposal Cells

The Boston Harbor Navigation Improvement Project (BHNIP) was a joint project between the USACE and the Massachusetts Port Authority (Massport) that consisted of maintenance and improvement dredging in channels and berths within Boston Inner Harbor (Figure 1-1). The project included removal of a top layer of approximately 800,000 m^3 (1,000,000 yd^3) of silty maintenance material and 800,000 m^3 (1,000,000 yd^3) of underlying improvement or parent material, composed primarily of Boston Blue Clay (a highly consolidated glacio-marine deposit (Rosen et al. 1993)). The improvement material was disposed offshore at the designated Massachusetts Bay Disposal Site (MBDS). Because of adverse biological testing results, likely caused by elevated concentrations of metals and organic compounds, the maintenance material was disposed into CAD cells located within the dredging project footprint in the Federal navigation channels (USACE and Massport 1995) (Figure 1-2). The WQC for the project called for capping the cells with a 1 m (3.3 ft) layer of sand after completion of disposal (MADEP 1998). Nine cells were constructed during the project, located in the channel area of the Mystic and Chelsea Rivers and the Inner Confluence at the junction of the two rivers (Figure 1-3).

The BHNIP was completed in two phases. Phase 1 was performed from June through August 1997 by Weeks Marine, Inc. and included berth dredging at Conley Terminal on the Reserved Channel and the construction of a single CAD cell (IC2 in Figure 1-4). Phase 2 of the project was performed from August 1998 through September 2000 by Great Lakes Dredge and Dock Company and included the majority of the dredging work and construction of eight additional CAD cells. These cells were constructed, filled, and capped within three groups (Figure 1-4), with increasing consolidation time prior to capping and refinements to the capping technique of successive groups to increase capping performance. Chelsea River Cell C12 (Figure 1-4) had excess capacity at the completion of the project and was left uncapped for use in future projects.

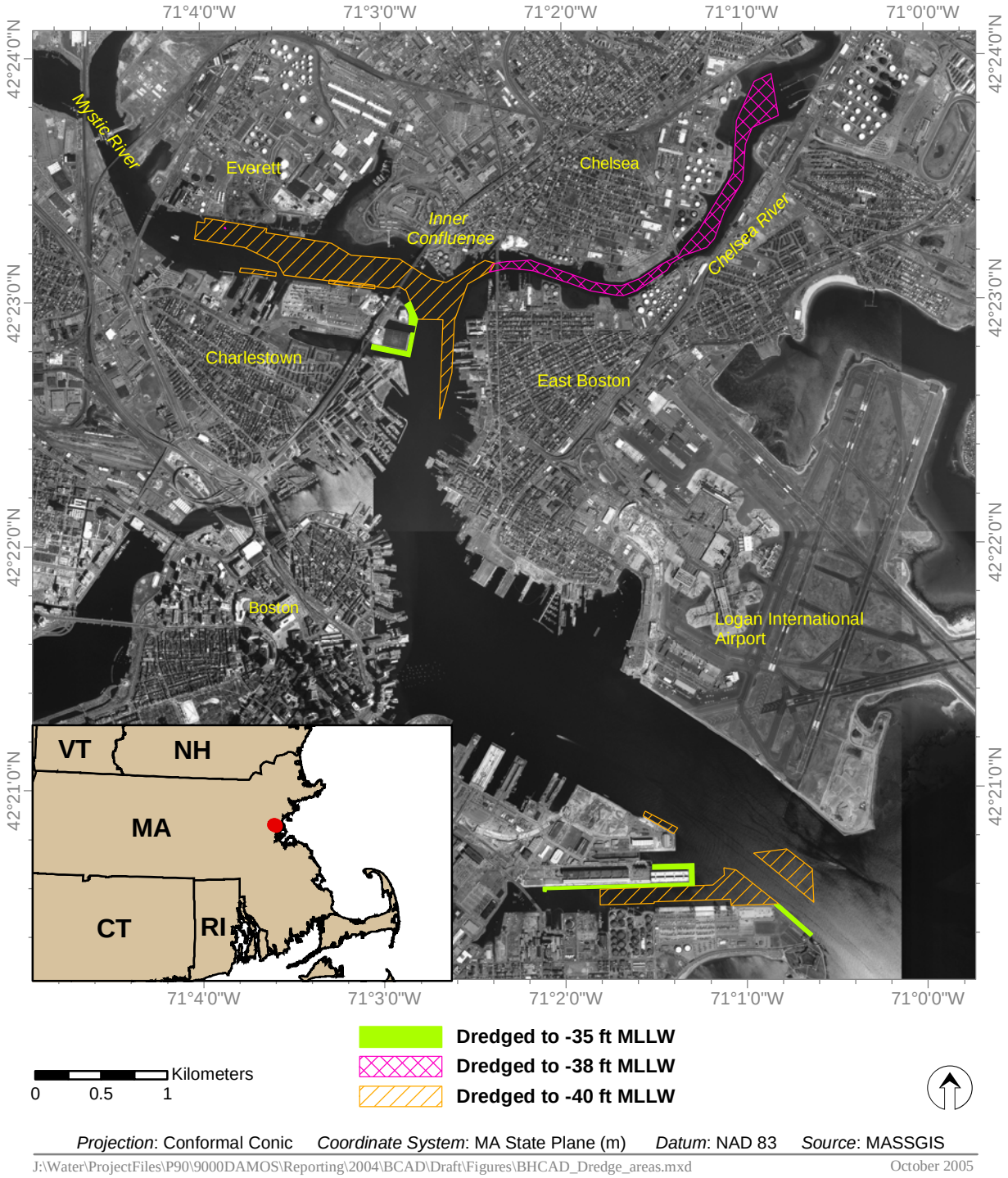

Figure 1-1. Boston Harbor Navigation Improvement Project dredged areas.

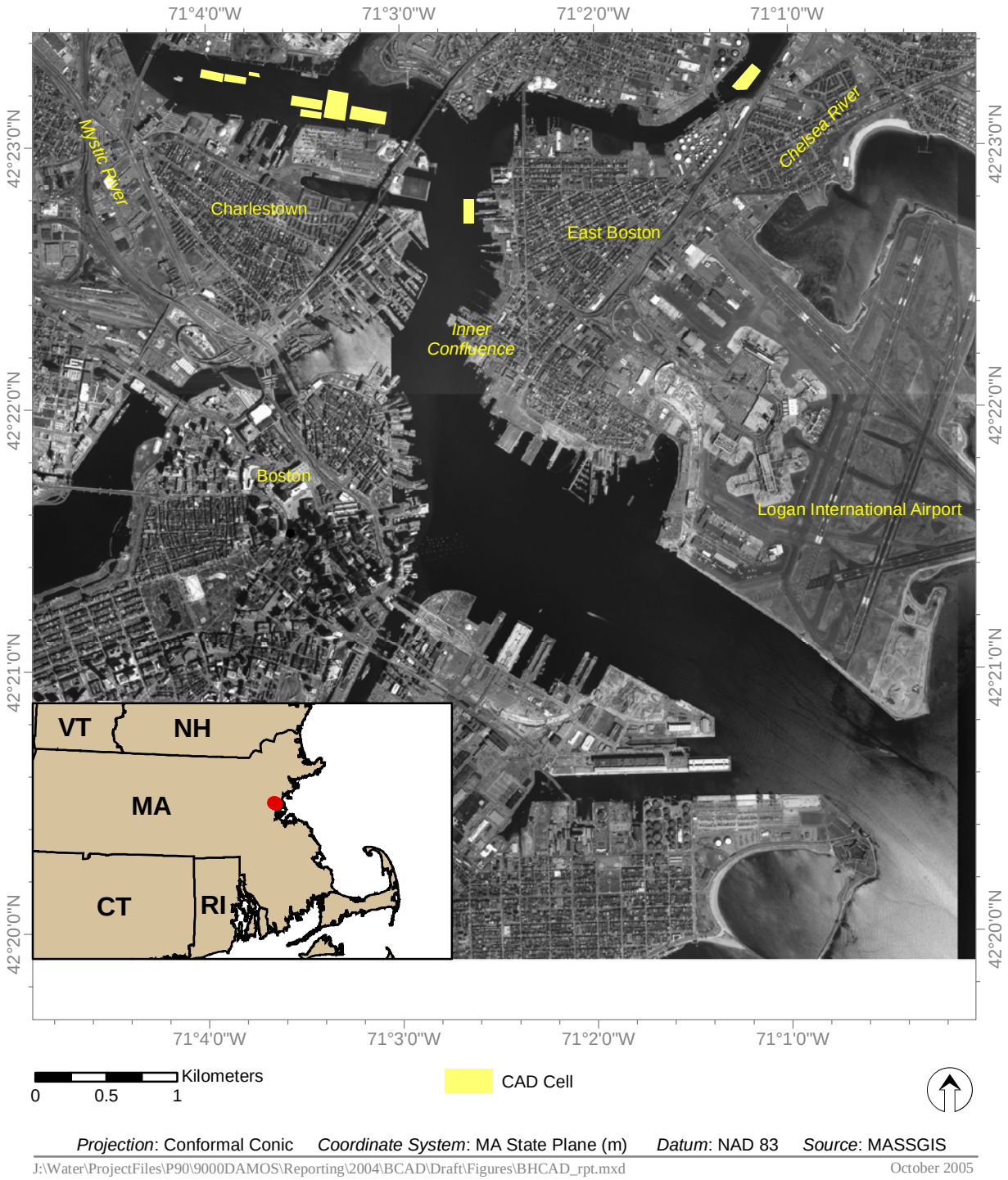

Figure 1-2. Location of the CAD cells in Boston Inner Harbor, Massachusetts

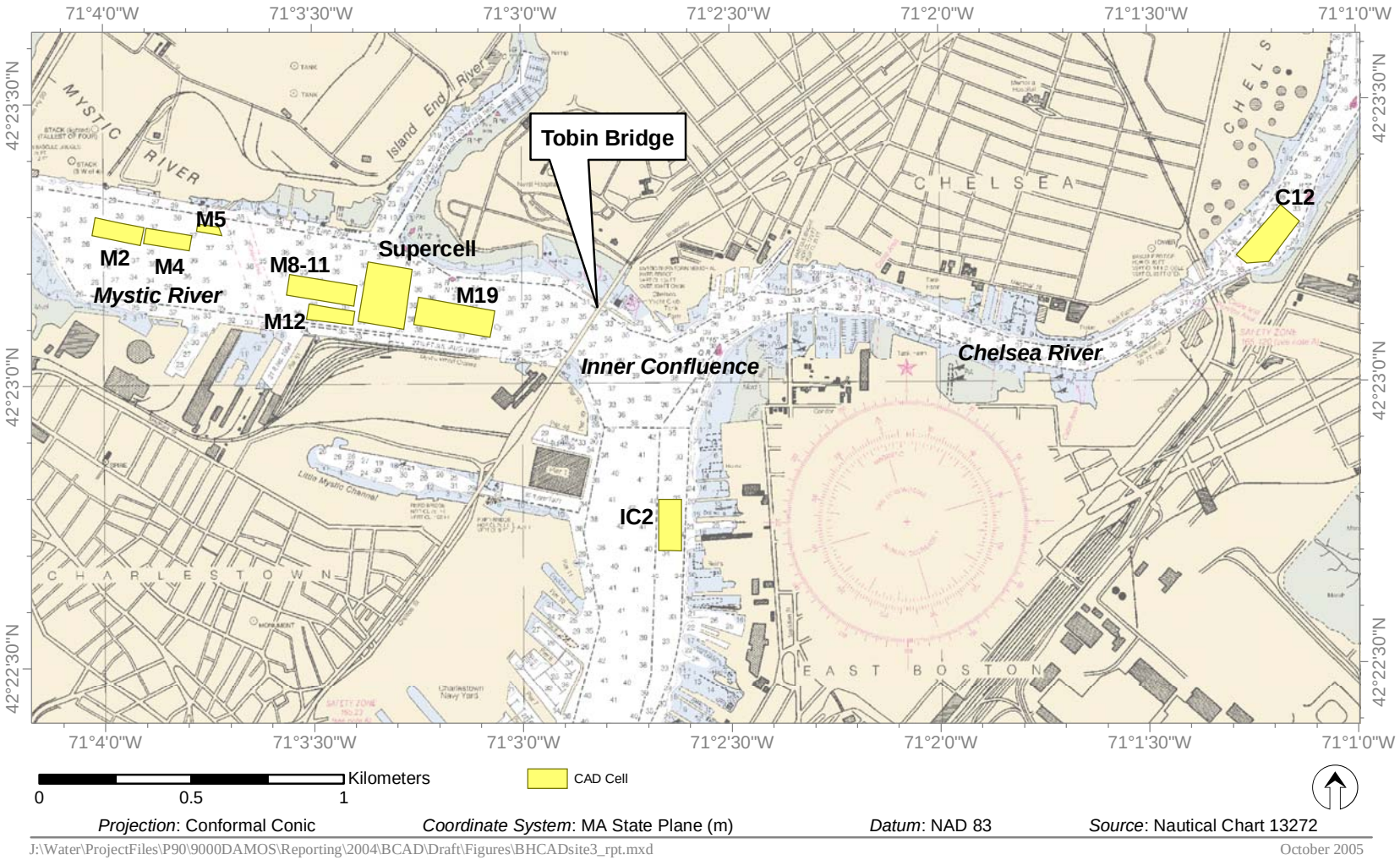

Figure 1-3. CAD cells used in the BHNIP

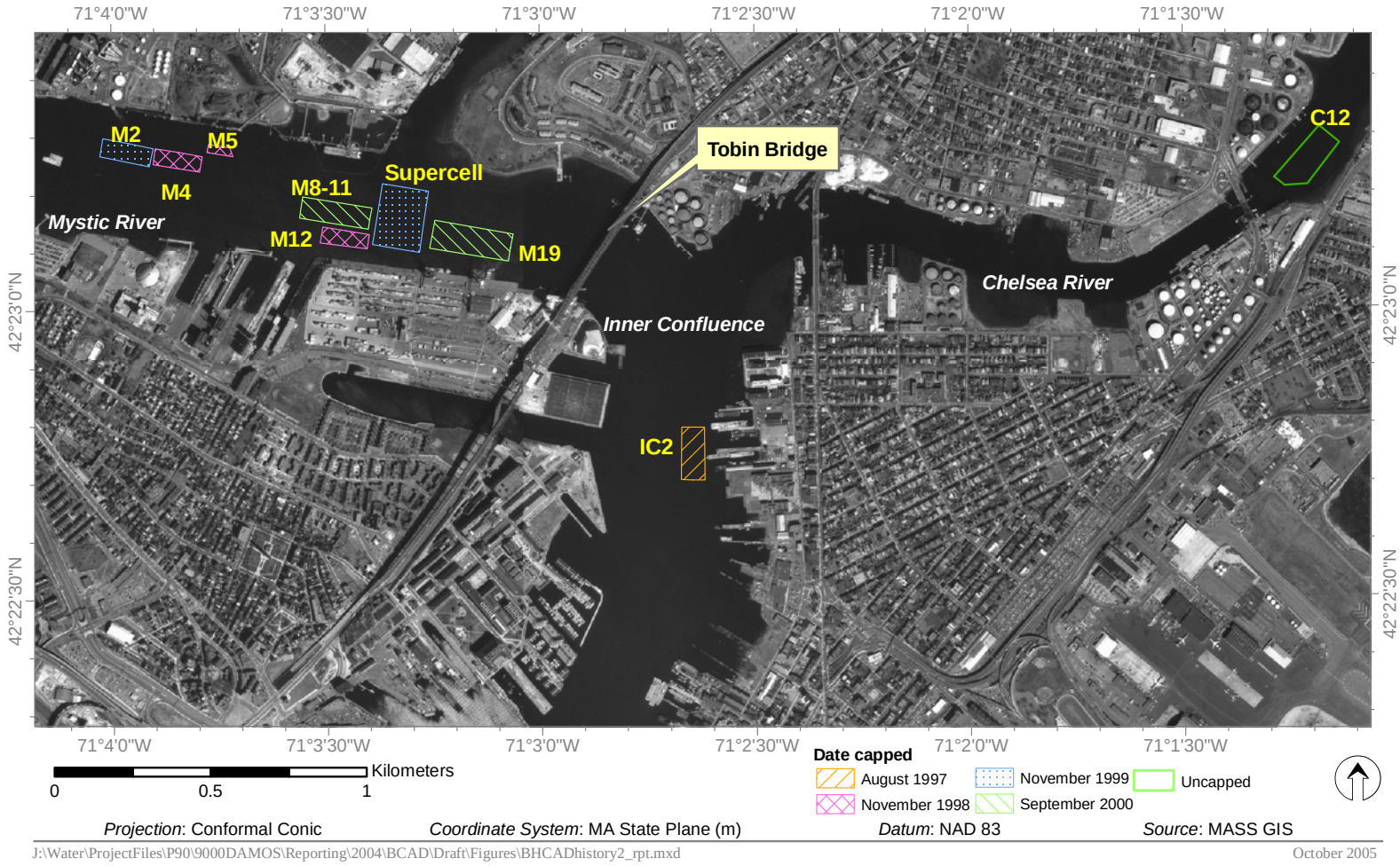

Figure 1-4. History of BHNIP CAD cell capping

Construction of the CAD cells began with removal of the unsuitable maintenance material over the cell footprint. This material was stored in scows for the first cell of each project phase or disposed into other open cells for the later Phase 2 cells. Once the cell footprint was uncovered, native parent material was excavated to construct the cell. The parent material was disposed offshore at MBDS. The original project plans called for construction of up to 52 smaller cells to a depth of approximately 6 m (20 ft) below the surrounding harbor bottom. However, given the highly consolidated nature of the native Boston Blue Clay, cells were constructed with relatively steep side slopes to depths up to 20 m (66 ft) below the surrounding harbor bottom. This allowed the use of much larger and fewer cells. Following construction, dredged maintenance material was placed into the cells using split-hulled scows, and regular bathymetric surveys were performed to track the level and evenness of the filling of the cells. Following completion of disposal activities, the material within the cells was allowed to consolidate for varying periods of time prior to capping.

The length of the consolidation period was found to be a key element in increasing the success of capping (Fredette et al. 2000). The maintenance material dredged from the harbor as part of the project had a high initial water content that was further increased by the dredging and disposal process. Once in the confines of the cell, self-consolidation of the material took place, but excess water could only be expressed upward to the surface of the cell as the highly consolidated Boston Blue Clay into which the cells were cut formed a hydraulic barrier. With a short consolidation period, the high water content of the upper layer of material within the cell caused the capping sand to displace and mix into the disposed material. With increased consolidation period, the surface of the material within the cell had sufficient strength to support the capping sand, but higher water content and more fluid material deeper within the cell was likely forced to the surface in some areas because of the increased pressure within the cell. Still later in the consolidation period, the strength of the disposed material within the cell had increased to a point that would fully support the sand cap without displacing material deeper within the cell.

A chronology of BHNIP activities and investigations is provided in Table 1-1, and a summary of CAD cell completion is provided below and in Table 1-2. Additional details on the BHNIP can be found in ENSR (1997) for Phase 1 and ENSR (2002) for Phase 2.

Cell IC2 - This cell was capped within two weeks of completion of disposal activities. Capping was performed with sand deposited from split-hulled scows positioned at a series of fixed locations over the cell. Post-cap investigations

Table 1-1
Chronology of BHNIP Activities and Investigations

Activity	Date	Details	Reference
Phase 1 of BHNIP	July – August 1997	Dredging of Conley Terminal berth area; Construction, filling, and capping of IC2	ENSR 1997
Bathymetric surveys of IC2	1997	Pre-construction, post-construction, post-fill and post-cap bathymetry	unpublished
Water quality monitoring of IC2	1997	Evaluation of water column impacts during dredging and disposal	ENSR 1997
Post-cap monitoring of IC2	1997	Coring, bathymetry, sub-bottom profiling	SAIC 1997
Phase 2 of BHNIP	1998 – 2000	Channel and berth dredging; construction of remaining 8 cells	ENSR 2002
Dredge bucket comparison	August 1999	Comparison of water column impacts of different dredge bucket types	Welp et al. 2001
Resuspension investigation	March 2000	Investigation of potential resuspension of cell material from vessel passage	Hales 2001; SAIC 2000
Benthic survey	June 2000	SPI and benthic infauna assessment of cells IC2, M2, M4, M8-11	ENSR 2001
Capping impact investigation	September 2000	Evaluation of water column impacts during capping of cells M8-11, M19	Battelle 2001 (in press)
Bathymetric surveys of Phase 2 cells	1998-2000	Pre-construction, post-construction, post-fill and post-cap bathymetry	unpublished
Water quality monitoring of Phase 2 cells	1998-2000	Evaluation of water column impacts during dredging and disposal	ENSR 2002
One-year monitoring survey	Summer 2001	Coring, SPI, bathymetry and benthic infauna assessment over all cells	SAIC 2001
Monitoring over BHCAD cell M19	Summer 2002	Bathymetry, side-scan sonar, and video sled for cell M19	SAIC 2003a
Sediment transport investigation	Summer-Fall 2002	Pilot scale study of sediment transport in Mystic River area using fluorescent tracers	SAIC 2003b

Table 1-2
History of CAD cell Filling and Capping

Cell	Filled	Capped
IC2	June-July 1997	July 1997
M4, M5, M12	August – October 1998	November 1998
M2	October 1998 – June 1999	November 1999
Supercell	December 1998 – August 1999	November 1999
M8-11	August 1999 – December 1999	September 2000
M19	November 1999 – January 2000	September 2000
C12	April 1999 – September 1999	Not Capped

revealed that this technique resulted in cap coverage of variable thickness over the majority of the cell with an area in the southern portion of the cell receiving little to no cap material (SAIC 1999).

Cells M4, M5, M12 – Following the review of the initial capping effort for IC2, the WQC was modified to allow additional consolidation time prior to capping. Cells M4, M5, and M12 were capped in November 1998 following 30 to 52 days of consolidation. The capping technique was also modified, with sand deposited from a hopper dredge, maneuvered over the cell under its own propulsion. Post-cap investigations revealed that the sand had been well distributed over the cell, but that mixing with the cell contents and/or settling beneath the surface of the cell material had occurred (Ocean Surveys 1999a, 1999b).

Cells M2 and Supercell – Following the review of capping results for the first set of Phase 2 cells, the consolidation time and capping technique were further modified. Cells M2 and Supercell were capped in November 1999 following approximately five months of consolidation. A hopper dredge was again used for capping, but in addition to using its main propulsion for maneuvering, a tugboat was used to push the hopper dredge sideways across the cell during sand placement. Post-cap investigations identified a distinct sand cap at the surface over the majority of both cells. Isolated areas were identified with silty material at the surface, considered to be more fluid material from within the cells that was displaced during capping (USACE 2000).

Follow-up surveys at M2 revealed that the sand cap was no longer located at the surface, but was observed below a layer of fine-grained material. In June 2000, SPI images indicated that the sand cap was 7 to 18 cm (2.8 to 7.1 in) below the surface (ENSR 2001). In July 2001, sand was not observed in the SPI images, and the top of the sand cap was observed in sediment cores at depths ranging from 8 to 20 cm (3.1 to 7.8 in) below the surface (SAIC 2001). In the Supercell, a narrow layer of sand (3 to 5 cm [1.2 to 2 in]) was observed in the SPI images at three stations, and the top of a more contiguous sand layer was observed in the cores at 7 to 36 cm (2.8 to 14.2 in) below the surface (SAIC 2001).

Cells M8-11 and M19 – Consolidation time was further extended for the last set of cells, M8-11 and M19, capped in September 2000, after approximately eight months of consolidation. Cells M8-11 and M19 were capped with the same methodology as cells M2 and SC. Post-cap investigations identified a distinct sand cap at the surface of both cells with limited mixing into the underlying silt and no

significant accumulation of silty material above the sand cap (Ocean Surveys 2000).

During the one-year follow-up survey, the sand cap at cell M8-11 was identified in both the SPI images and the cores. The SPI images indicated 0 to 2 cm (0.8 in) of silt overlying sand, which extended beyond penetration depth. The sand cap observed in the cores averaged 95 cm (3.2 ft) in thickness (SAIC 2001). In cell M19, SPI images and cores indicated a sand cap extending from the surface (where sands were mixed with shell fragments and fine-grained sediments) to depths of 22 to 117 cm (9 to 46 inches).

Additional investigations were performed during and following completion of the project to assess the effectiveness of the CAD cells at sequestering contaminated sediments and to meet the one-year requirements of the WQC. The WQC for the project had originally set a relatively short consolidation period between completion of disposal and initiation of capping because of concerns of potential material loss from open cells within the navigable channel and exposure for marine organisms. Because the consolidation time was extended as the project progressed to improve cap placement, an investigation was performed to evaluate resuspension of sediments over an uncapped cell in March 2000 (USACE 2001). The investigation tracked the passage of a deep-draft, 275-m (900-ft) vessel over cell M8-11, approximately two months into its eight-month consolidation period. Resuspension was found to be limited in extent and duration, and the loss of material from the cell was not considered to be significant.

A geotechnical investigation performed in 2001 included the collection of deep cores, extending through the cap layer of each cell into the underlying silty material as part of the one-year WQC monitoring requirement (SAIC 2001). This investigation determined that consolidation of the silty material was continuing, but the cells had maintained their original stratigraphy. Benthic recolonization of the cells was also investigated. Sediment-profile imaging was performed over four cells in 2000 (ENSR 2001) and over all nine cells in 2001 with supplemental grab sampling for benthic community analysis (SAIC 2001). These investigations revealed rapid recolonization of the cell surfaces with similar benthic characteristics to reference areas (consisting primarily of Stage I fauna) in the highly industrialized Boston Harbor.

Additional research studies included an evaluation of water column impacts during capping (Battelle 2001), a pilot investigation on sediment dynamics in the vicinity of the Mystic River CAD cells using fluorescent tracers performed in 2002 (SAIC 2003b), and an investigation of methane production within capped sediments in cell M19 performed

by EPA in 2001-02. The methane investigation was not completed due to loss of deployed gas collection chambers, but did include dive operations to install/retrieve the chambers. Divers conducting these operations noted a sharp vertical relief along the surface of cell M19 that could have indicated disturbance of the cap. As a result, a follow-up investigation was performed at cell M19 in June-August 2002 including bathymetry, side-scan sonar, towed video, and benthic grab sampling (SAIC 2003a). The investigation identified some surficial depressions within the CAD cell that were attributed to continued consolidation of the underlying silty material within the cell. The cap appeared intact over the southern portion of the cell, where some additional dredged clay (highly consolidated Boston Blue Clay) had been placed on top of the cap early in 2002. The investigation also identified a linear depression extending approximately 110 m (360 ft) along an east-west orientation near the center of the cell with a width of 10 to 25 m (33 to 82 ft) and a depth of 1.5 to 2.5 m (5 to 8 ft) below the surrounding cell surface. Given that the origin of the depression was not fully understood, additional studies were recommended for further characterization.

1.3 Project Objectives

The August 2004 BHCAD survey was designed to satisfy the five-year post-construction monitoring requirements of the WQC and address the following objectives, four to seven years following completion of the individual CAD cells:

- Assess the general physical status of the surface of each of the nine CAD cells to evaluate cell stability and long term integrity and thickness of the cap and overlying silts, with a more detailed assessment performed over cell M19.
- Determine bathymetry by performing a multi-beam bathymetric condition survey over the cells.
- Assess the benthic recolonization status of each of the nine CAD cells.

2.0 METHODS

A team of investigators from ENSR International, CR Environmental, and Diaz & Daughters performed the August 2004 survey at the Boston Harbor CAD cells (BHCAD). A swath bathymetry survey was conducted over all nine cells on 10 August 2004 and a side-scan sonar survey was conducted over all cells on 11 August 2004; both were performed to assess the physical status of the cells. A towed sled underwater video survey was performed on 12 August 2004 over a subset of the cells, focusing on Mystic River cell M19. A sediment-profile imaging survey was conducted 26-27 August 2004 to assess the benthic recolonization status of the CAD cells. Field activities are summarized in Table 2-1, and an overview of the methods used to collect, process, and analyze the survey data is provided below. A more detailed description of methodology and the related terminology can be found in ENSR (2004).

2.1 Navigation and On-Board Data Acquisition

Positional data, comprised of horizontal positioning (x- and y-dimensional data) and time (t-dimensional data), were collected using a Trimble® AG 132 Differential Global Position System (DGPS). This system received and processed GPS satellite and land-based U.S. Coast Guard beacon data and provided real-time vessel position to sub-meter accuracy. Coastal Oceanographics, Inc. HYPACK® hydrographic survey software was used to acquire, integrate, and store all positional data from the DGPS as well as bathymetric and station data. The HYPACK® software also displayed real-time vessel position, bathymetric data, and SPI stations over a background electronic chart of the study area, thus enabling survey scientists to review and evaluate survey data on a real-time basis.

2.2 Bathymetry

The bathymetric survey provided measurements of water depth that, when processed, were used to map the harbor bottom topography. The processed data were also compared with available previous survey data to track changes in depth and CAD cell features. This technique is the primary tool in the DAMOS Program for mapping the distribution of dredged material at disposal sites and tracking the stability of disposed deposits over time.

Table 2-1
August 2004 Field Activities Summary

Survey Type	Date	Summary
Bathymetry	10 August 2004	23 lanes covering all cells: Mystic River – 12 lanes Inner Confluence – 6 lanes Chelsea – 5 lanes
Side-Scan Sonar	11 August 2004	12 lanes covering all cells: Mystic River – 6 lanes Inner Confluence – 4 lanes Chelsea – 2 lanes
Underwater Video	12 August 2004	M19, Supercell, M8-11, M12, M4, IC2
Sediment-Profile Imaging	26-27 August 2004	60 stations: M2 – 4 stations M4 – 4 stations M5 – 4 stations M8-11 – 5 stations M12 – 4 stations Supercell – 7 stations M19 – 8 stations IC2 – 6 stations C12 – 6 stations Mystic River Reference – 6 stations Inner Confluence Reference – 3 stations Chelsea River Reference – 3 stations

2.2.1 Bathymetric Data Collection

The 2004 bathymetric survey was performed on 10 August 2004 aboard the R/V *Cyprinodon*. The bathymetric survey was designed to cover each CAD cell with survey lines preset 25 to 50 meters (82 to 164 ft) apart to ensure 100% data overlap between lines (Figure 2-1). The bathymetric survey was conducted using GeoAcoustics, Inc. 250-kHz GeoSwath® Shallow Water Bathymetry System. The Geoswath® system was a boom-mounted interferometric system that collected phase-measurement swath bathymetric data coupled with single channel echo sounder data, to deliver maximal across-track depth resolution and maximal vertical resolution beneath the survey vessel. Swath bathymetry provides similar data and equivalent resolution as that of multibeam bathymetry. The GeoSwath® system also generated preliminary side-scan sonar imagery, facilitating bottom classification and target identification. Swath data were gathered at up to 22,000 data points per second, regardless of depth. The system included an integral TSS motion reference unit, an integral altimeter and sound-velocity probe, and was interfaced with a precision S.G. Brown® gyrocompass and Trimble® DGPS.

Calibration procedures were conducted on site prior to data collection. The average speed of sound through the water column was obtained from a full depth cast of a Yellow Springs Instruments multi-meter. Additional standard calibration procedures were also conducted to stabilize the gyro compass prior to the start of the survey. Calibration lines were run with the multi-beam prior to the actual collection of survey data to facilitate the correction of field data for latency errors and any misalignment between the axis of the gyro compass and that of the transducers. Pitch and roll calibrations between the port and starboard channels of the multi-beam were also performed prior to the start of the survey.

Water depths were recorded in meters and referenced to mean lower low water (MLLW) based on the National Oceanic and Atmospheric Administration (NOAA) Tide Station located in Boston Harbor. A MiniTroll logger was deployed in the Mystic River as a local tide gauge, serving as a back-up record of tidal information in the event of an interruption in information available from the NOAA station.

2.2.2 Bathymetric Data Processing

The bathymetric data were processed using the GeoAcoustics, Inc. GS32® software package to include correction for local tidal conditions, local speed of sound, and spurious data points. Tidal correction consisted of transforming the raw measurements of depth below the transducer to seafloor elevation measurements relative to MLLW using

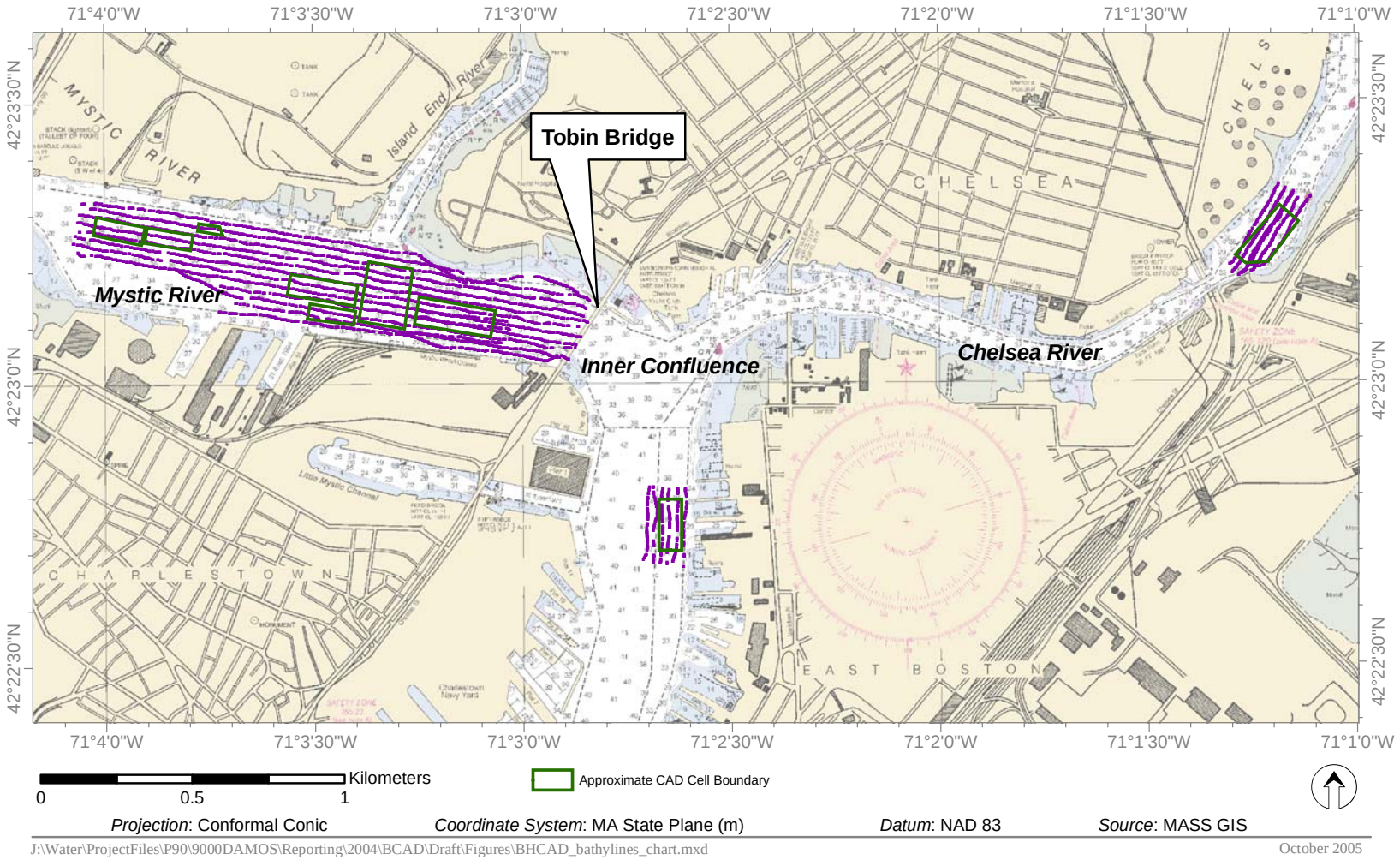

Figure 2-1. BHCAD bathymetry survey track lines, August 2004

the locally collected tidal elevation data. Heave data supplied by the vessel's motion reference unit were incorporated into the raw data to minimize the effects of vessel motion. The bathymetric data were also reviewed for spurious data points (clearly unrealistic measurements resulting from signal interference), and these points were removed.

2.2.3 Bathymetric Data Analysis

The processed bathymetric data were converted to the Massachusetts Mainland, NAD83 metric grid using USACE TEC Corpscon software and then analyzed using a combination of the contouring and surface plotting software program, Surfer® 8.0 and the GIS-based software package ArcView® 9.1. Using Surfer®, the processed BHCAD data were gridded to a cell size of 0.5 x 0.5 m (1.6 x 1.6 ft). Once gridded, bathymetric contour lines were generated and displayed using ArcView®.

Surfer® was also used to calculate depth-difference grids based on available historic bathymetric data sets supplied by the USACE, Great Lakes Dredge and Dock, and SAIC. Depth-difference grids were generated by comparing the August 2004 data with May 2001 data for the following cells: C12, M2, M4, M5, M8-11, and M19. For the Supercell the depth-difference grid was generated by comparing the August 2004 data with June 2002 data. The depth difference grid for the Inner Confluence cell IC2 was generated by comparing the August 2004 data with October 1997 data. No comparable historical data were available for the Mystic River cell M12. The grids were calculated by subtracting the August 2004 interpolated depth estimates from the previous depth estimates at each point throughout the grid. The resulting depth differences were contoured and displayed using ArcView®.

2.3 Side-Scan Sonar

Side-scan sonar measurements characterize the reflective acoustic properties of the seafloor beneath and to each side of the transiting survey vessel. Following processing, a map of seafloor acoustic reflectivity can be generated to help infer seafloor topography and surficial sediment characteristics. This technique is used in the DAMOS Program to help identify seafloor features and provide reconnaissance-level characterization of near-surface sediments.

2.3.1 Side-Scan Sonar Data Acquisition

The 2004 side-scan sonar survey was designed to cover each CAD cell (Figure 2-2). The survey was performed on 11 August 2004 aboard the R/V *Cyprinodon*. Side-scan sonar measurements were collected using an Edgetech, Inc. TD272 dual-frequency towfish (i.e., transducer array) with the following settings: 1° signal horizontal beam angle, 30° tilt angle, and 50° beam width angle. A sonar frequency of 500 kHz was used with range settings between 25 and 50 m (82 and 164 ft), resulting in a total swath width of 50 to 100 m (164 and 328 ft). Side-scan survey transects were spaced to ensure 100% overlap between adjacent passes.

The towfish was deployed using a hydraulic oceanographic winch. The incoming acoustic returns arrived as analog sonar signals ("pings") and were converted to digital data using an Analog Control Interface board within an Edgetech Model 560 on-board data acquisition package. These digital signals were recorded and displayed in real-time using Chesapeake Technology, Inc.'s SonarWiz data acquisition software. The length of cable deployed during the survey was measured along with an estimate of the wire angle to allow for calculation of towfish layback (offset) from the DGPS antenna on the vessel.

2.3.2 Side-Scan Sonar Data Processing

Raw side-scan sonar data were processed to correct for layback, correct for signal attenuation related to swath width, and to georeference sonar imagery (i.e., project the sonar data into real-space coordinates). First, water column portions of the acoustic returns were removed through review and processing of each survey transect. The raw data were then corrected by calculating and applying accurate layback and catenary coefficients to each of the data files. Data processing also included corrections for variations of the sonar beam angle of incidence relative to the seafloor (beam angle corrections) and signal attenuation with distance (time varied gain corrections). These corrections were made through an iterative review of survey lane data.

The side-scan sonar data were processed using Chesapeake Technology, Inc.'s SonarWeb software. Once corrected, data from each survey lane were merged to create a single georeferenced mosaic of the survey area (in JPG format) with a resolution of 0.10-meters per pixel. Data were saved in several forms: georeferenced JPG files, high-resolution annotated "waterfall" imagery (uncorrected raw data) of each survey lane, and navigation overview plots. Also, a set of HTML files for the project was created, allowing Web-browser (i.e., Internet Explorer or Netscape) access to all survey data and imagery.

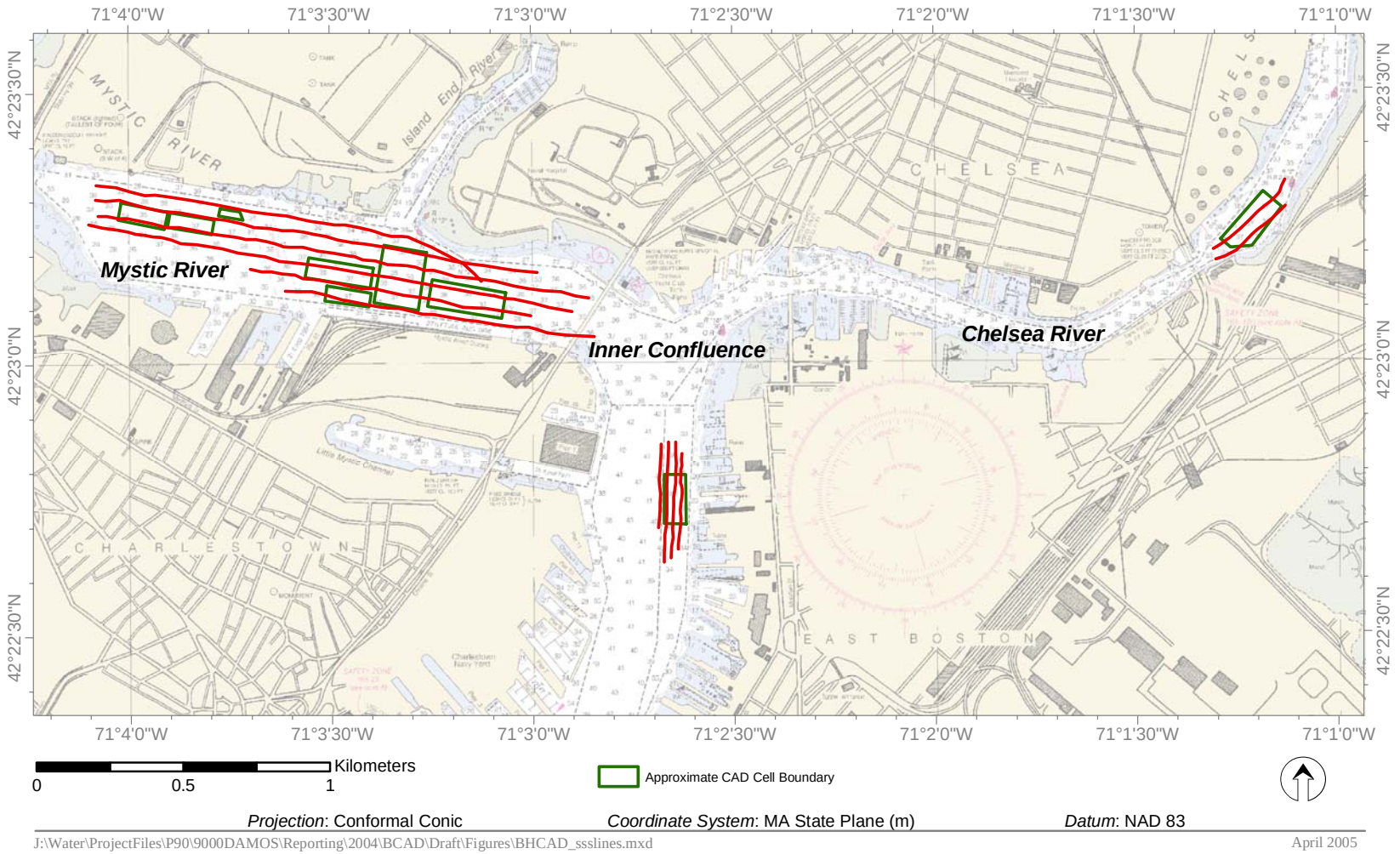

Figure 2-2. BHCAD side-scan sonar survey track lines, August 2004

2.3.3 Side-Scan Sonar Data Analysis

Side-scan sonar data were analyzed to identify features within and surrounding the CAD cells. Side-scan sonar results were presented as a mosaic of gray or color shaded information. In general, weak signal returns were assumed to correspond to smooth seafloor substrates (e.g., fine sediments with little micro-topography), soft materials that absorb the signal, or seabed sloping away from the signal source (towfish). These features appeared lighter gray on the sonar record. Strong signal returns were assumed to correspond to rough seabed substrates (e.g., gravel, cobble), highly reflective materials, or to a seabed sloping towards the signal source. These features appeared as dark gray to black on the sonar record. Features that rose above the harbor bottom (e.g., CAD cell wall rising above the cell interior) reflected more of the sonar energy than the surrounding substrate resulting in strong signal returns due to decreased angle of incidence. These features can prevent insonification (irradiation with sound) of the area opposite the signal source, resulting in a sonar "shadow" (white portion of the record).

2.4 Underwater Video

The underwater video survey provided real time video output that was used to characterize the geophysical and biological properties of the seafloor within and outside of each of the BHCAD cells. The underwater video was used to create representative video clips and representative screen captures throughout the survey area.

2.4.1 Video Data Acquisition

The 2004 video sled survey focused on Mystic River cell M19, with additional coverage of cells Supercell, M8-11, M12, M4, and IC2 (Figure 2-3). The survey was performed on 12 August 2004 aboard the R/V *Cyprinodon*. Video imagery was recorded using a Deep Sea Power and Light Multi-Sea Cam (Figure 2-4). This high resolution color video camera was mounted to a lightweight aluminum frame equipped with two 250 watt underwater flood lights. The frame was lowered to the bottom and slowly dragged along the full length of the survey transect. Real-time imagery from the frame was displayed topside on a color computer monitor while simultaneously being recorded. The viewing area of the sled in the towed configuration is approximately one square meter. Vessel position during the survey was recorded using the HYPACK® software.

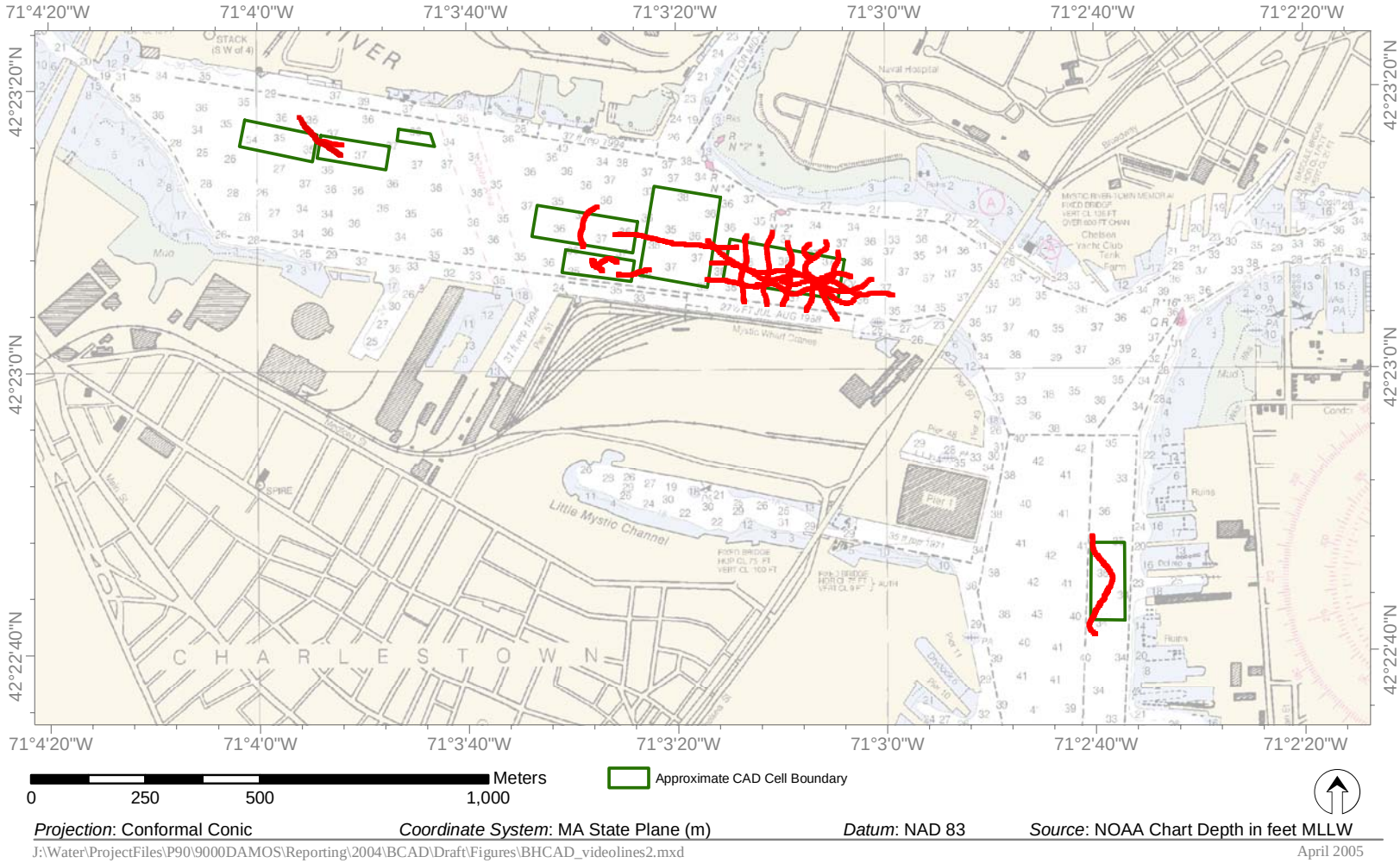

Figure 2-3. BHCAD towed video survey track lines, August 2004

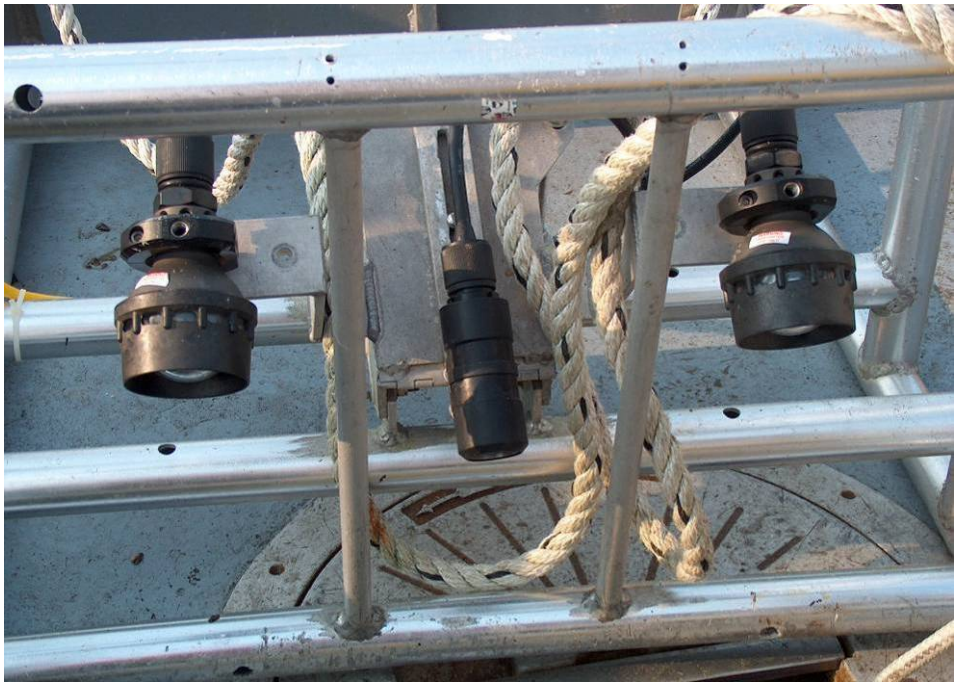

Figure 2-4. Towed video sled and camera setup

2.4.2 Video Data Analysis

Position data were imported into GIS-based software for plotting of track lines (Figure 2-4). The underwater video footage was reviewed and representative sequences illustrating some of the most interesting features were selected for creation of short clips or screen captures. In addition, the complete clips were reviewed and annotated, with references to sediment characteristics, observed fauna and debris.

2.5 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. The technique involves deploying an underwater camera system that photographs a cross section of the sediment-water interface. Computer-aided analysis of the resulting images provides a set of standard measurements that can be compared between different locations and different surveys. The DAMOS Program has successfully used this technique for over 20 years to map the distribution of disposed dredged material and to monitor benthic recolonization at disposal sites. For a detailed discussion of SPI methodology, see ENSR (2004).

2.5.1 SPI Data Acquisition

The 2004 BHCAD sediment-profile imaging (SPI) survey design included 60 stations distributed among the nine CAD cells and three associated reference areas (Table 2-2; Figures 2-5 and 2-6). Four stations each were located within CAD cells M2, M4, M5, and M12. CAD cell M8-11 contained five stations, C12 and IC2 each had six stations, the Supercell had seven stations, and M19 had eight stations. The reference areas were located adjacent to the cells and within the channel boundaries to provide characterization of ambient conditions in the active channel areas. Reference areas were selected to represent ambient conditions in both dredged and undredged channel areas. (Figure 2-7). Reference stations included six stations in the Mystic River (MREF), three stations in the Chelsea River upstream from CAD cell C12 (CREF), and three stations west of Inner Confluence CAD cell IC2 (ICREF). Target locations for all stations except C12-6 and SC-7 were determined prior to the survey. Stations C12-6 and SC-7 were selected while on site.

The SPI survey was conducted 26-27 August 2004 aboard the F/V *Cyprinodon*. At each station, the vessel was positioned at the target coordinates, and the camera was deployed within a defined station tolerance of 10 m (33 ft). Three replicate images were collected at each of the 60 stations for characterization of small-scale variability. In some

Table 2-2
BHCAD Sediment-Profile Image Target Sampling Locations

Area	Station	Latitude (N)	Longitude (W)	Area	Station	Latitude (N)	Longitude (W)
C12	C12-1	42° 23.246'	71° 01.234'	M5	M5-1	42° 23.279'	71° 03.768'
	C12-2	42° 23.282'	71° 01.174'		M5-2	42° 23.278'	71° 03.737'
	C12-3	42° 23.272'	71° 01.203'		M5-3	42° 23.273'	71° 03.721'
	C12-4	42° 23.232'	71° 01.218'		M5-4	42° 23.280'	71° 03.751'
	C12-5	42° 23.254'	71° 01.189'	M8-11	M8-11-1	42° 23.184'	71° 03.532'
	C12-6*	42° 23.232'	71° 01.254'		M8-11-2	42° 23.170'	71° 03.528'
IC2	IC2-1	42° 22.721'	71° 02.653'		M8-11-3	42° 23.164'	71° 03.480'
	IC2-2	42° 22.717'	71° 02.634'		M8-11-4	42° 23.173'	71° 03.457'
	IC2-3	42° 22.730'	71° 02.641'		M8-11-5	42° 23.160'	71° 03.418'
	IC2-4	42° 22.756'	71° 02.651'	Supercell	SC-1	42° 23.188'	71° 03.341'
	IC2-5	42° 22.780'	71° 02.647'		SC-2	42° 23.161'	71° 03.334'
	IC2-6	42° 22.769'	71° 02.632'		SC-3	42° 23.162'	71° 03.301'
M12	M12-1	42° 23.128'	71° 03.478'		SC-4	42° 23.188'	71° 03.289'
	M12-2	42° 23.128'	71° 03.449'		SC-5	42° 23.138'	71° 03.352'
	M12-3	42° 23.120'	71° 03.420'		SC-6	42° 23.113'	71° 03.312'
	M12-4	42° 23.127'	71° 03.496'		SC-7*	42° 23.143'	71° 03.303'
M19	M19-1	42° 23.119'	71° 03.217'	CREF	CREF-1	42° 23.417'	71° 01.083'
	M19-2	42° 23.123'	71° 03.188'		CREF-2	42° 23.442'	71° 01.066'
	M19-3	42° 23.106'	71° 03.117'		CREF-3	42° 23.417'	71° 01.028'
	M19-4	42° 23.106'	71° 03.132'	ICREF	ICREF-1	42° 22.784'	71° 02.733'
	M19-5	42° 23.110'	71° 03.143'		ICREF-2	42° 22.756'	71° 02.736'
	M19-6	42° 23.122'	71° 03.101'		ICREF-3	42° 22.721'	71° 02.733'
	M19-7	42° 23.124'	71° 03.139'	MREF	MREF-1	42° 23.228'	71° 03.981'
	M19-8	42° 23.134'	71° 03.213'		MREF-2	42° 23.211'	71° 03.837'
M2	M2-1	42° 23.277'	71° 03.935'		MREF-3	42° 23.194'	71° 03.718'
	M2-2	42° 23.263'	71° 03.931'		MREF-4	42° 23.232'	71° 03.643'
	M2-3	42° 23.282'	71° 03.965'		MREF-5	42° 23.244'	71° 03.720'
	M2-4	42° 23.286'	71° 04.006'		MREF-6	42° 23.218'	71° 03.569'
M4	M4-1	42° 23.261'	71° 03.887'				
	M4-2	42° 23.263'	71° 03.856'				
	M4-3	42° 23.257'	71° 03.829'				
	M4-4	42° 23.258'	71° 03.806'				

Notes: Coordinate system NAD83
***Positioned on-site**

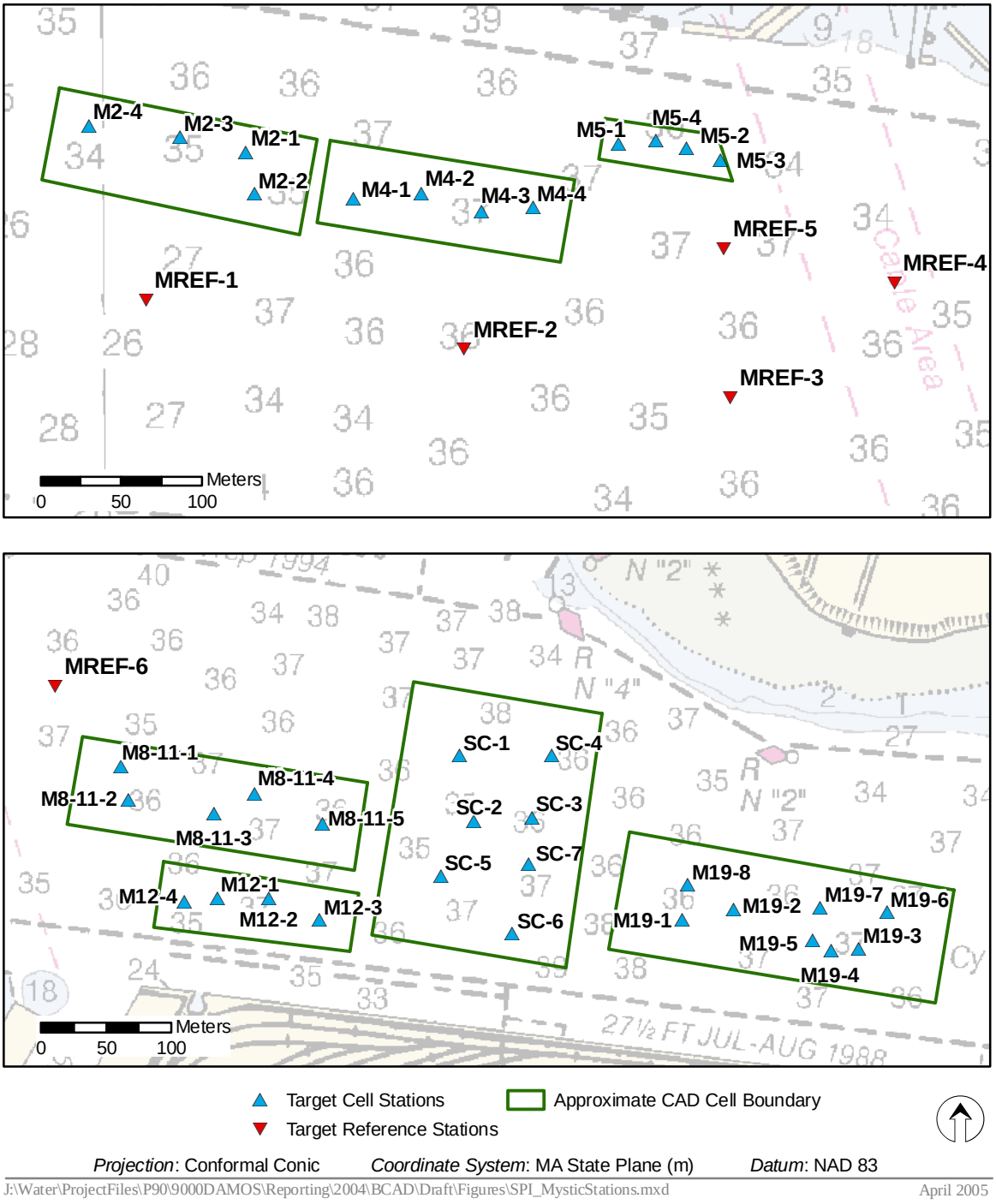

Figure 2-5. Mystic River target SPI sampling stations, August 2004

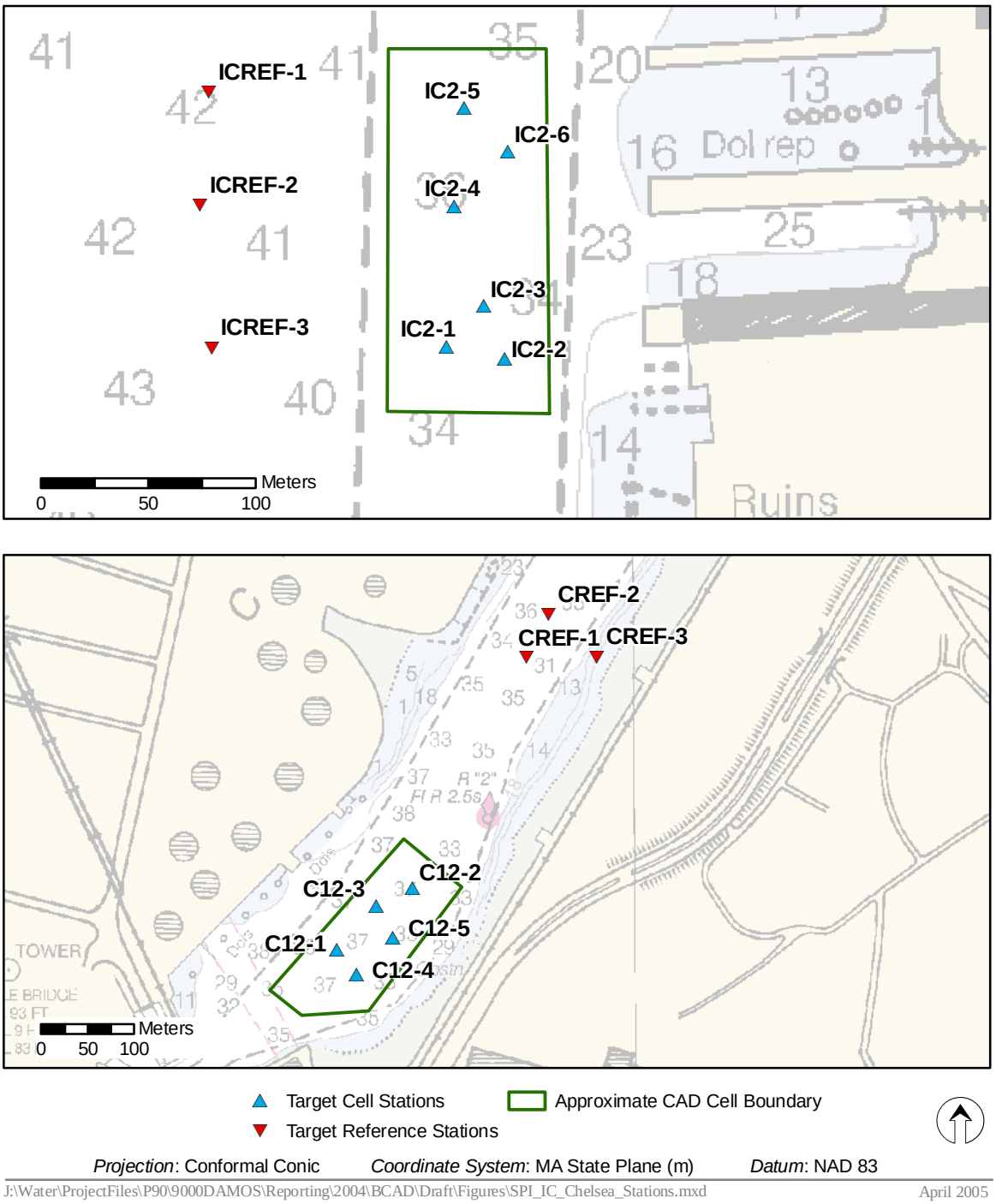

Figure 2-6. Inner Confluence (upper) and Chelsea River (lower) target SPI sampling stations, August 2004

Figure 2-7. Target SPI sampling stations relative to areas dredged during the BHNIP

instances more than three images were collected, but only the three highest quality images were analyzed.

SPI images were collected using a modified Hulcher SPI system outfitted with a Minolta Dimage 7i, 5.2-megapixal digital camera recording to a 1-gigabyte IBM Microdrive. The camera frame also supported a video-plan camera mounted to view the surface of the seabed. At each station, the camera unit was lowered to the seafloor using a hydraulic winch. The camera remained on the seafloor for at least 12 seconds, allowing for multiple pictures to be taken. The digital camera was also equipped with a video-feed used to send images to the surface so that camera location and prism penetration could be monitored in real-time.

A wiring problem prevented the onboard trigger from signaling the camera to take a picture, and instead, a magnet was used to trigger the camera upon impact on the seafloor. In this mode, the strobe and camera worked in synchrony so that pictures were taken every 1.5 seconds until the camera frame was lifted off of the seabed. This allowed a number of sediment-profile images, generally 6 to 12, to be taken as the camera penetrated the seabed. The video signal from the video camera showing the surface of the seafloor was recorded on 8-mm videotape for later review, permitting additional evaluation of the benthic habitat type.

The camera housing was opened several times during each survey day to replace the strobe and camera batteries and to exchange the Microdrive. Images were downloaded from the Microdrive to the laptop whenever the camera pressure case was opened.

A demonstration project was also conducted in which the SPI frame was outfitted with a modified camera housing designed to permit deeper penetration into the sediment. The modified pressure housing featured a slimmer profile that presented less resistance as it penetrated the sediment and was capable of penetrating to depths up to 30 cm (1 ft). Rather than a still image, a video camera was used to record the sediment profile. For this demonstration, the sediment profile was observed live on the video monitor during penetration until it was apparent that the camera had stopped penetrating the sediment. Images were collected from 12 previously occupied stations, and the video for the entire event was recorded on 8-mm videotape.

2.5.2 SPI Data Analysis

Computer-aided analysis of each 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.
- *Penetration Depth*—The depth to which the camera penetrates 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 (0 in) (i.e., no penetration on hard substrates) to a maximum of 24 cm (9.4 in) (full penetration on very soft substrates). Replicate images that were over-penetrated were assigned a value of >24 cm (9.4 in) for prism penetration and were not used in calculation of average station prism penetration.
- *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) may be related to physical structures (e.g., ripples, rip-up structures, mud clasts) or biogenic features (e.g., burrow openings, fecal mounds, foraging depressions).
- *Apparent Redox Potential Discontinuity (RPD) Depth*— RPD provides a measure of the oxygen conditions within the sediment pore waters. Sediment particles exposed to oxygenated waters oxidize and lighten in color to brown or light grey. As the particles are moved downwards by biological activity or buried, they are exposed to reduced oxygen concentrations in subsurface pore waters and their oxic coating slowly reduces, changing the color to dark grey or black. When biological activity is high the RPD depth increases; when it is low or absent, the RPD depth decreases. The RPD 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 or CAD cell capping), and this sequence has been divided subjectively into three stages

(Rhoads and Germano 1982, 1986). Successional stage was assigned by assessing which types of species or organism-related activities were apparent in the images.

- *Organism-Sediment Index (OSI)*—OSI is a summary parameter incorporating the apparent mean RPD depth, successional stage, and presence of methane or low oxygen (Revelas et al. 1987; Table 2-3). An OSI threshold of +6 is used to evaluate the degree of benthic habitat disturbance along the continuum from highly disturbed (OSI value of -10) to undisturbed (OSI value of +11). In general, OSI values of +6 and below are indicative of a moderately to highly disturbed habitat.

When the apparent RPD depth was indeterminate, the organism sediment index (OSI) was also considered to be indeterminate. When successional stage could not be determined or was questionable, the OSI score for successional stage was given a 1, and the OSI was flagged as ">". None of the flagged OSI values were included in station average calculations.

For the demonstration of the deeper penetrating camera, composite sediment-profile images from three of the twelve stations were constructed for review and evaluation for utility in characterization of sediment horizons. A cursory review of other images was performed to identify potential transitions in sediment horizons.

Table 2-3
Organism-Sediment Index (OSI) Terms and Formulation

Parameter	Index Value
A. Mean RPD Depth (choose one)	
0.00 cm	0
0.01 – 0.75 cm	1
0.76 – 1.50 cm	2
1.51 – 2.25 cm	3
2.26 – 3.00 cm	4
3.01 – 3.75 cm	5
> 3.75 cm	6
B. Successional Stage (choose one)	
Azoic	-4
Stage I	1
Stage I – II	2
Stage II	3
Stage II – III	4
Stage III	5
Stage I on III	5
Stage II on III	5
C. Chemical Parameters (choose all that apply)	
Methane Present	-2
No/Low Dissolved Oxygen	-4
Calculation of Organism-Sediment Index (OSI)	
OSI = Total of above indices (A+B+C)	
Range of possible OSI values is -10 to +11	

3.0 RESULTS

3.1 Bathymetry

The 2004 swath bathymetry survey was conducted on 10 August 2004 and provided detailed topographic data of the nine CAD cells. The 2004 bathymetric data were compared to historic data available for each cell to characterize changes that have occurred between subsequent surveys. Historic bathymetric data sets used to generate depth-difference maps are summarized in Table 3-1. All data are presented as depths relative to mean lower low water (MLLW).

3.1.1 Inner Confluence

Inner Confluence cell IC2 remained a distinct bathymetric feature on the harbor bottom with the cell margins steeply sloped and dropping 1 to 2 m (3.3 to 6.6 ft) into the cell (Figures 3-1 and 3-2). In the northern half of the cell, water depths were approximately 14 to 15 m (45.9 to 49.2 ft) MLLW and indicated a very irregular bottom (Figures 3-1 and 3-2). The bottom was more uniform in the southern half of the cell, sloping from approximately 14 m (45.9 ft) MLLW near the center of the cell to just over 16 m (52.5 ft) MLLW in the southwest corner. Outside of the cell, water depths generally ranged from 13 to 14 m (42.7 to 45.9 ft) MLLW (Figure 3-1). The immediate area surrounding the cell had a very irregular bottom (Figure 3-2) indicative of the clamshell dredging that was performed as part of the BHNIP. Farther to the west within the main portion of the channel, the bottom was more uniform, but still showed evidence of disturbance in the form of longer linear features (Figure 3-2).

A depth-difference map was generated using the August 2004 survey data and the bathymetric data collected in October 1997, several months following capping of the cell (Figure 3-3). The depth-difference data should be interpreted with caution, as the relatively steep bathymetric gradients at the cell margins can accentuate differences in survey technique (swath in 2004 vs. single-beam in 1997). The depth-difference map indicated an increase in depth of up to 3 m (9.8 ft) in the southwestern corner of the cell, with lesser increases along the southwestern and northeastern cell margins. More limited areas of depth decrease up to 1.5 m (4.9 ft) (i.e., shallower) were identified over the central portion of the cell and southeastern and northwestern cell margins.

Table 3-1
Summary of Historic Bathymetric Surveys Compared to the August 2004 Data

Cell	Date of Survey	Reference
IC2	October 1997	SAIC 1997
M2, M4, M5, M8-11, M19	May 2001	SAIC 2001
M12	No Data Available	
Supercell	June 2002	SAIC 2003a
C12	May 2001	SAIC 2001

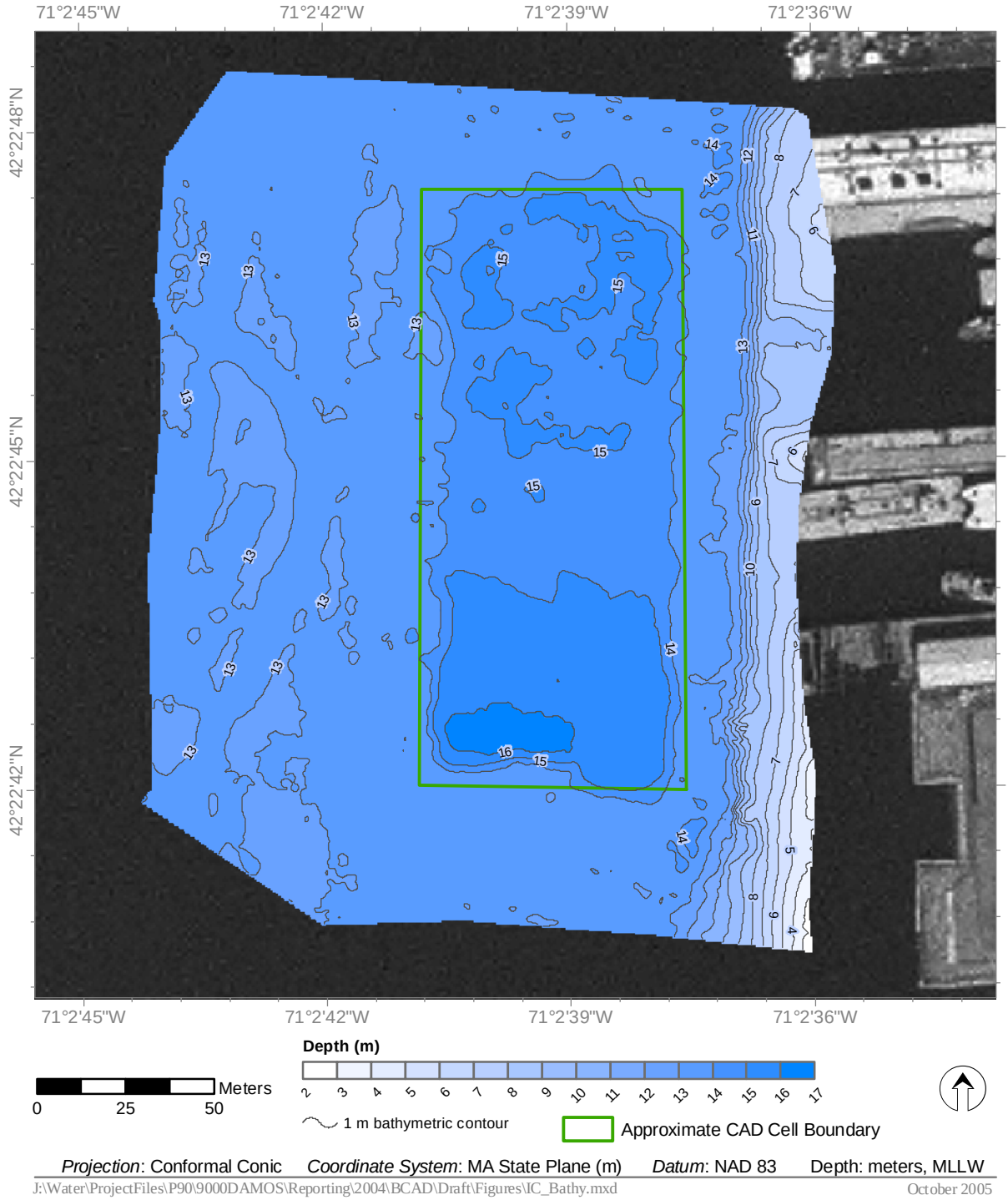

Figure 3-1. Bathymetric contour map of Inner Confluence cell IC2, August 2004 (1-m contour interval)

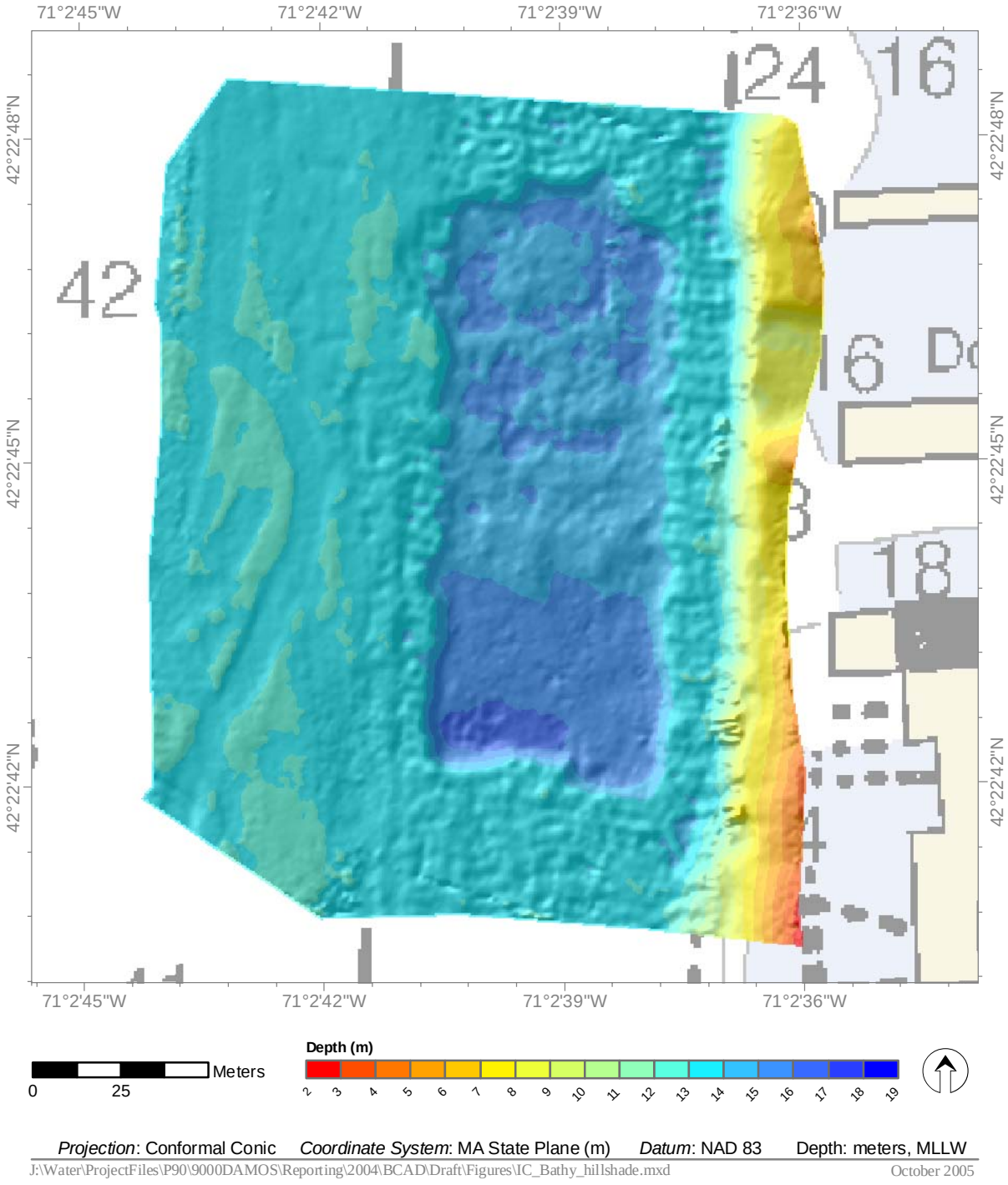

Figure 3-2. Bathymetric relief map of Inner Confluence cell IC2, August 2004

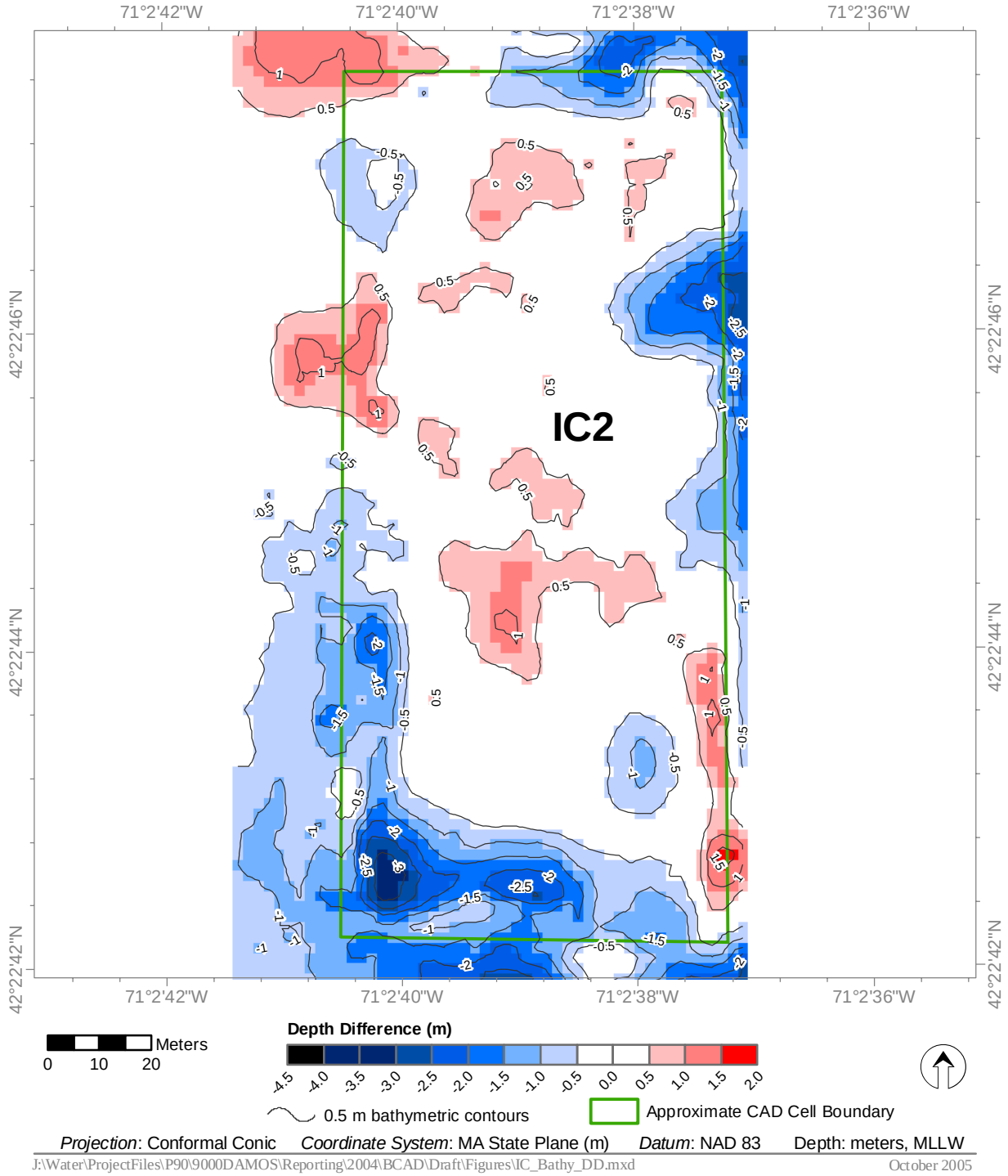

Figure 3-3. Depth difference map of Inner Confluence cell IC2, August 2004 and October 1997 surveys (0.5-m contour interval)

3.1.2 Mystic River

The seven Mystic River CAD cells were all apparent as distinct bathymetric features, depressed below the surrounding harbor bottom (Figures 3-4 and 3-5). Harbor bottom depths generally ranged from 13 to 14 m (42.7 to 45.9 ft) MLLW in the main portion of the channel, dropping steeply 2 to 4 m (6.7 to 13.1 ft) into the cells. Evidence of the BHNIP dredging was still quite apparent in the irregular bottom of the main channel with numerous low relief ridges and troughs (Figure 3-5). Two depressions of unknown origin approximately 1 m (3.3 ft) in depth and with somewhat rectangular dimensions were identified to the north of cell M8-11 (Figure 3-4). Depths ranged from 10 to 12 m (32.8 to 39.4 ft) MLLW in the southwestern portion of the survey area. The bottom was smoother in this area (part of the channel, but not dredged as part of the BHNIP), but did show evidence of disturbance in the form of longer, linear features (Figure 3-5) that may be from anchoring activities. The bathymetric features of the individual Mystic River CAD cells are described below.

Cell M2 – Cell M2 lies farthest west on the Mystic River and was capped in November 1999. Depths within the cell in the 2004 survey ranged from 15 m (49.2 ft) MLLW across the center of the cell to 17 m (55.8 ft) MLLW on both ends (Figure 3-6). The surface of the cell was generally smooth, except for a linear set of small, shallow depressions oriented east-west and limited irregular topography in the eastern portion of the cell and along the northwestern margin (Figure 3-7). A depth-difference map was generated using the August 2004 survey data and bathymetric data collected in May 2001, approximately 1½ years following capping of cell M2 (Figure 3-8). The depth-difference map indicated limited depth increase over the interior of the cell, generally less than 0.5 m (1.6 ft).

Cell M4 – Cell M4 lies in the western portion of the Mystic River channel and was capped in November 1998. Depths within the cell in the 2004 survey were fairly uniform at approximately 17 m (55.8 ft) MLLW (Figure 3-6), and the surface of the cell was smooth (Figure 3-7). A depth-difference map was generated using the August 2004 survey data and bathymetric data collected in May 2001, approximately 2½ years following capping of cell M4 (Figure 3-8). Very limited areas of depth increase up to 1 m (3.3 ft) were identified, all occurring along the margins of the cell.

Cell M5 – Cell M5 lies along the northern boundary of the Mystic River channel and was capped in November 1998. Depths within the cell in the 2004 survey were uniform at approximately 15 m (49.2 ft) MLLW (Figure 3-6), and the surface of the cell was smooth (Figure 3-7). A depth-difference map was generated using the August 2004

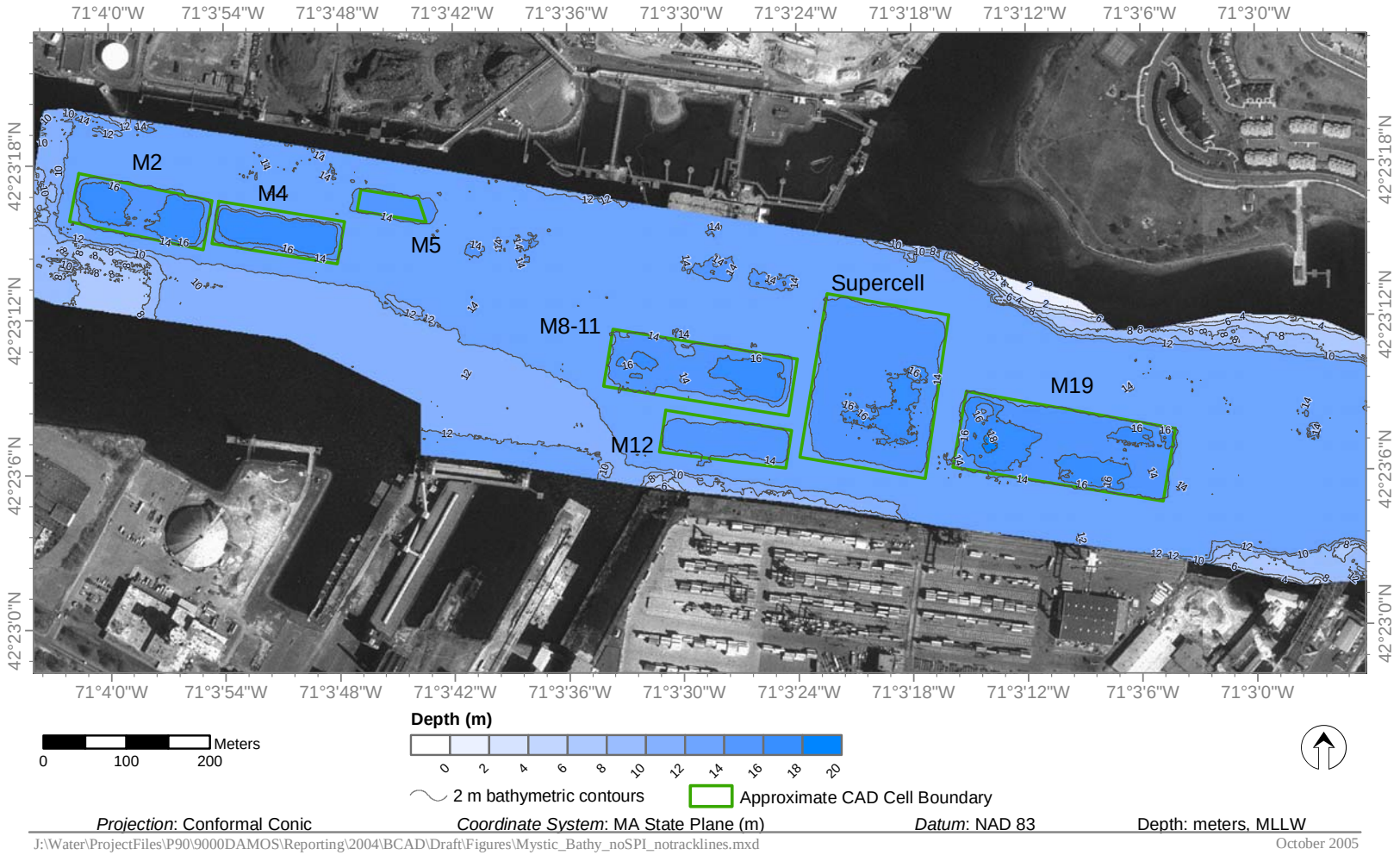

Figure 3-4. Bathymetric contour map of Mystic River, August 2004 (2-m contour interval)

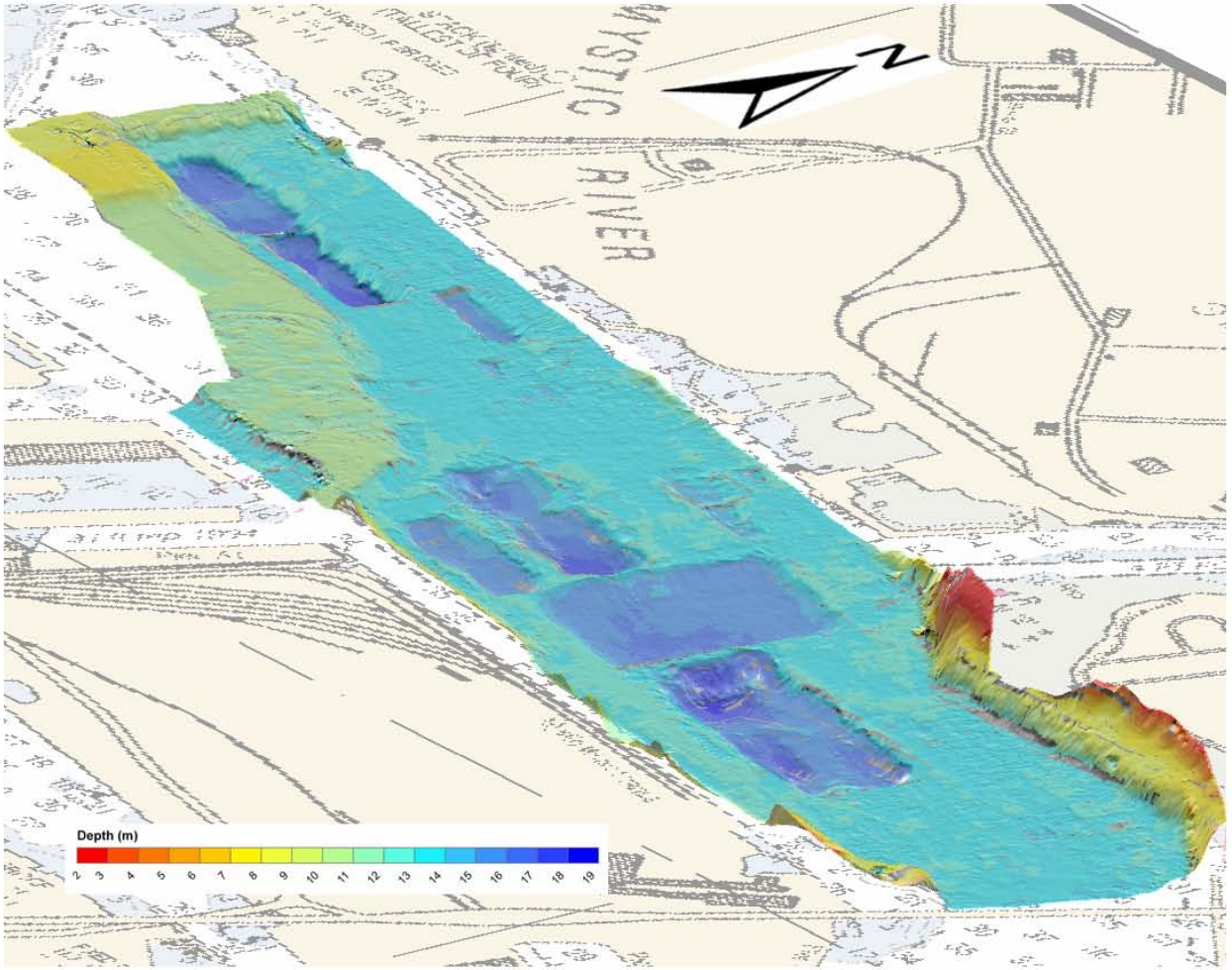

Figure 3-5. Bathymetric relief map of Mystic River, August 2004

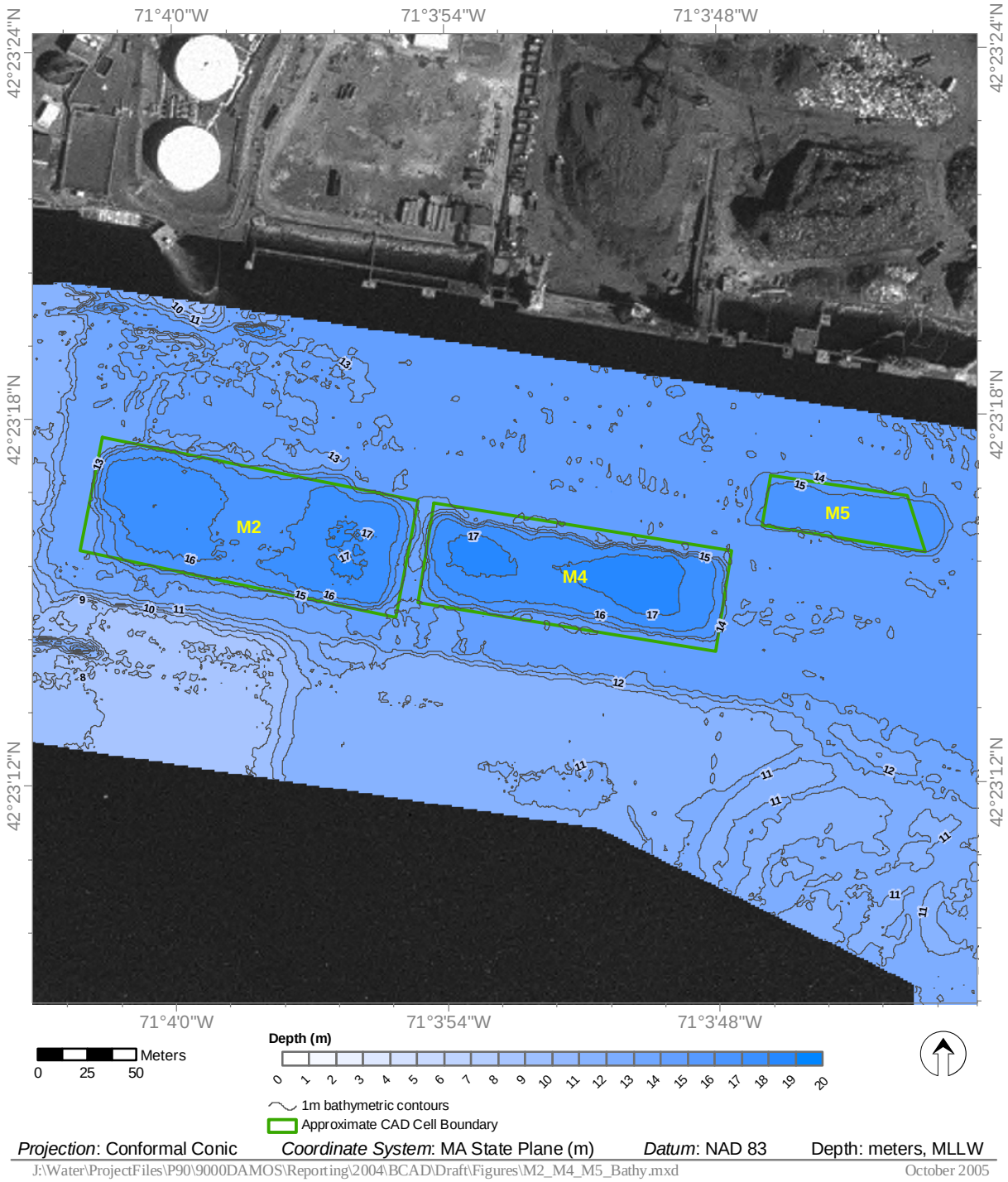

Figure 3-6. Bathymetric contour map of Mystic River cells M2, M4, and M5, August 2004 (1-m contour interval)

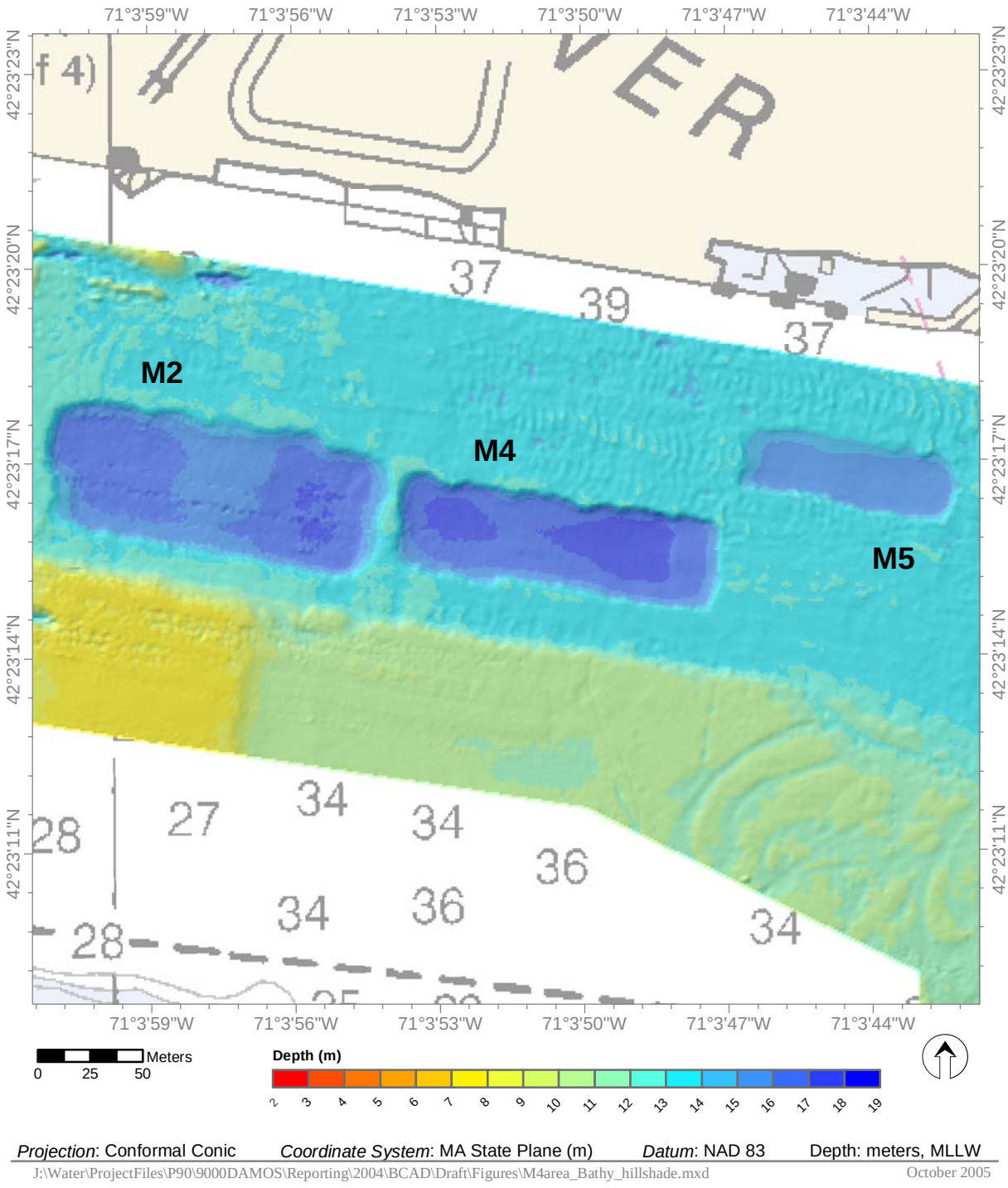

Figure 3-7. Bathymetric relief map of Mystic River cells M2, M4, and M5, August 2004

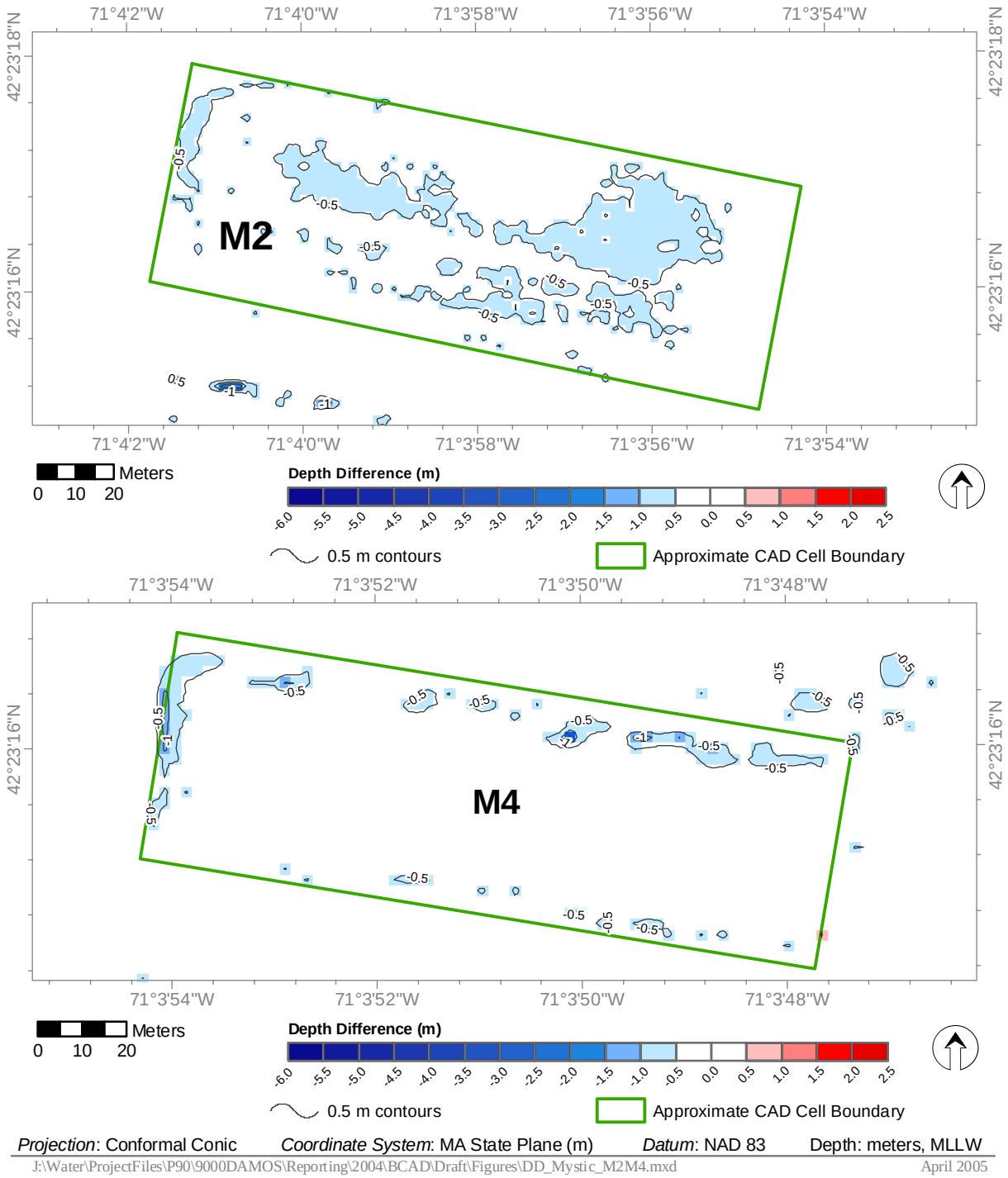

Figure 3-8. Depth difference contour map of Mystic River cells M2 and M4, August 2004 and May 2001 surveys (0.5-m contour interval)

survey data and bathymetric data collected in May 2001, approximately 2½ years following capping of cell M5 (Figure 3-9). Very limited areas of depth increase up to 1 m (3.3 ft) were identified, all occurring along the southern margin of the cell.

Cell M8-11 - Cell M8-11 lies in the central portion of the Mystic River channel and was capped in September 2000. Follow-up dredging of isolated shoals in the channel area surrounding some of cell M8-11 was performed early in fall 2001 (Mike Keegan, USACE NAE, pers. comm.), with the dredged material (consolidated Boston Blue Clay) bucketed directly into the cell. Depths within the cell in the 2004 survey ranged from 14 m (45.9 ft) MLLW along the southern margin and a portion of the northern margin to nearly 17 m (55.8 ft) MLLW in the western portion of the cell and nearly 18 m (59.1 ft) MLLW in the eastern portion of the cell (Figure 3-10). The surface of the cell was very irregular along the southern margin and along portions of the northern margin where additional dredged material had been placed, but was much smoother over the interior of the cell (Figure 3-11). A depth-difference map was generated using the August 2004 survey data and bathymetric data collected in May 2001, approximately nine months following capping of cell M8-11 but prior to the additional dredging around the cell margin (Figure 3-9). The depth-difference map indicated a broad area of depth increase up to 1 m (3.3 ft) over the eastern portion of the cell. The follow-up dredging around the perimeter of the cell and placement of the material into the cell in 2001 were clearly visible in the depth-difference map as areas with depth increase up to 2 m (6.6 ft) along the cell margins and areas of depth decrease up to 1.5 m (4.9 ft) within the cell, paralleling the margins. It should be noted that the original planned cell boundary for cell M8-11 shown in Figure 3-9 does not exactly align with the actual constructed cell margin.

Cell M12 - Cell M12 lies along the southern boundary of the Mystic River channel and was capped in November 1998. Depths within the cell in the 2004 survey were fairly uniform at approximately 15 to 16 m (49.2 to 52.5 ft) MLLW (Figure 3-10), and the surface of the cell was generally smooth (Figure 3-11). No previous bathymetry data set was available for cell M12, and a depth-difference assessment could not be performed. However, the uniform surface and depth identified in 2004 was similar to that reported in the original compliance submittal for cell M12 (USACE 1999).

Supercell - The Supercell was the largest cell of the BHNIP, cutting across most of the Mystic River channel. This cell was capped in November 1999. Depths within the cell in the 2004 survey ranged from approximately 15 m (49.2 ft) MLLW across the northern and western portions of the cell to nearly 17 m (55.8 ft) MLLW in the southeastern portion of the cell (Figure 3-10). The surface of the cell was generally

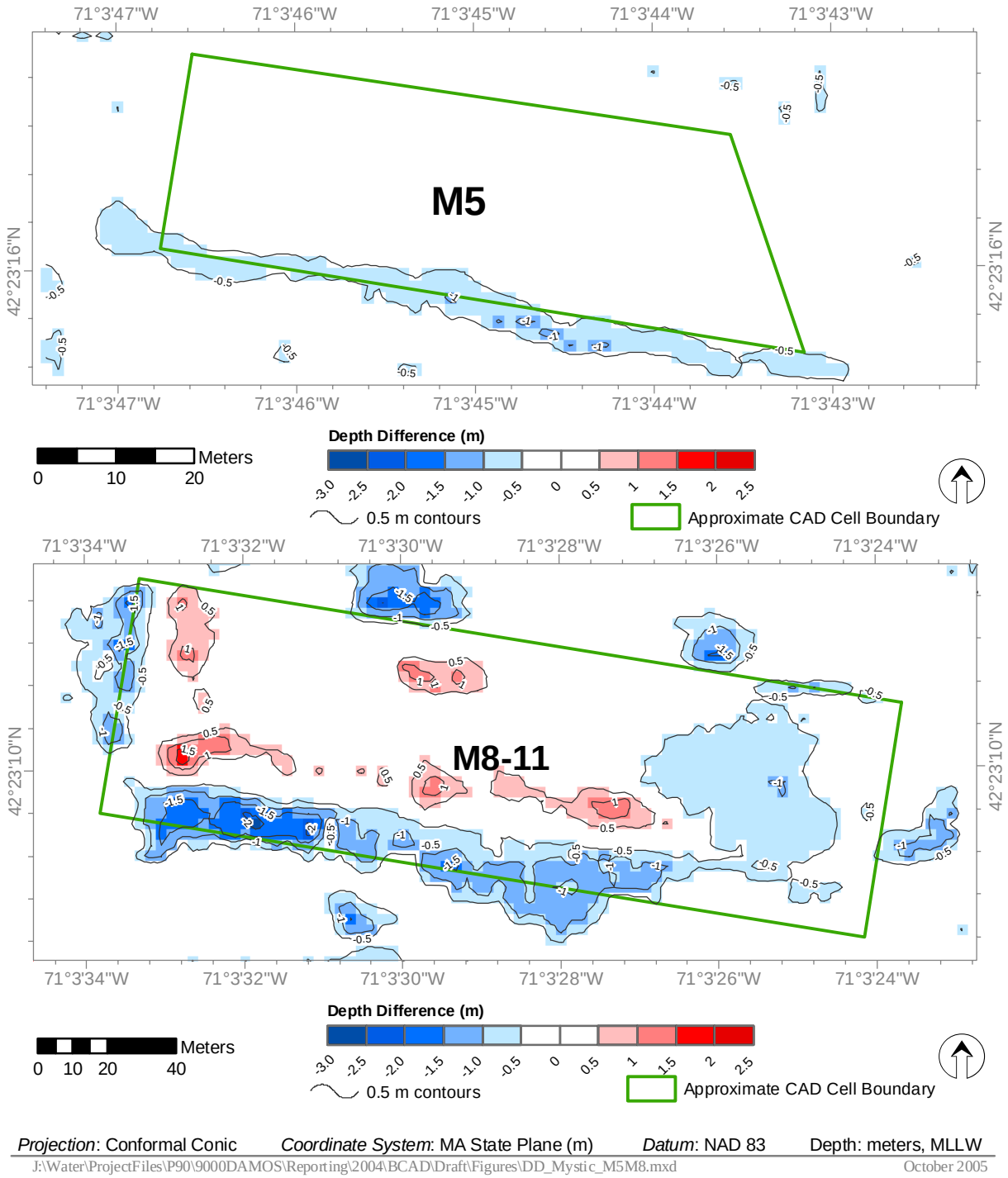

Figure 3-9. Depth difference contour map of Mystic River cells M5 and M8-11, August 2004 and May 2001 surveys (0.5-m contour interval)

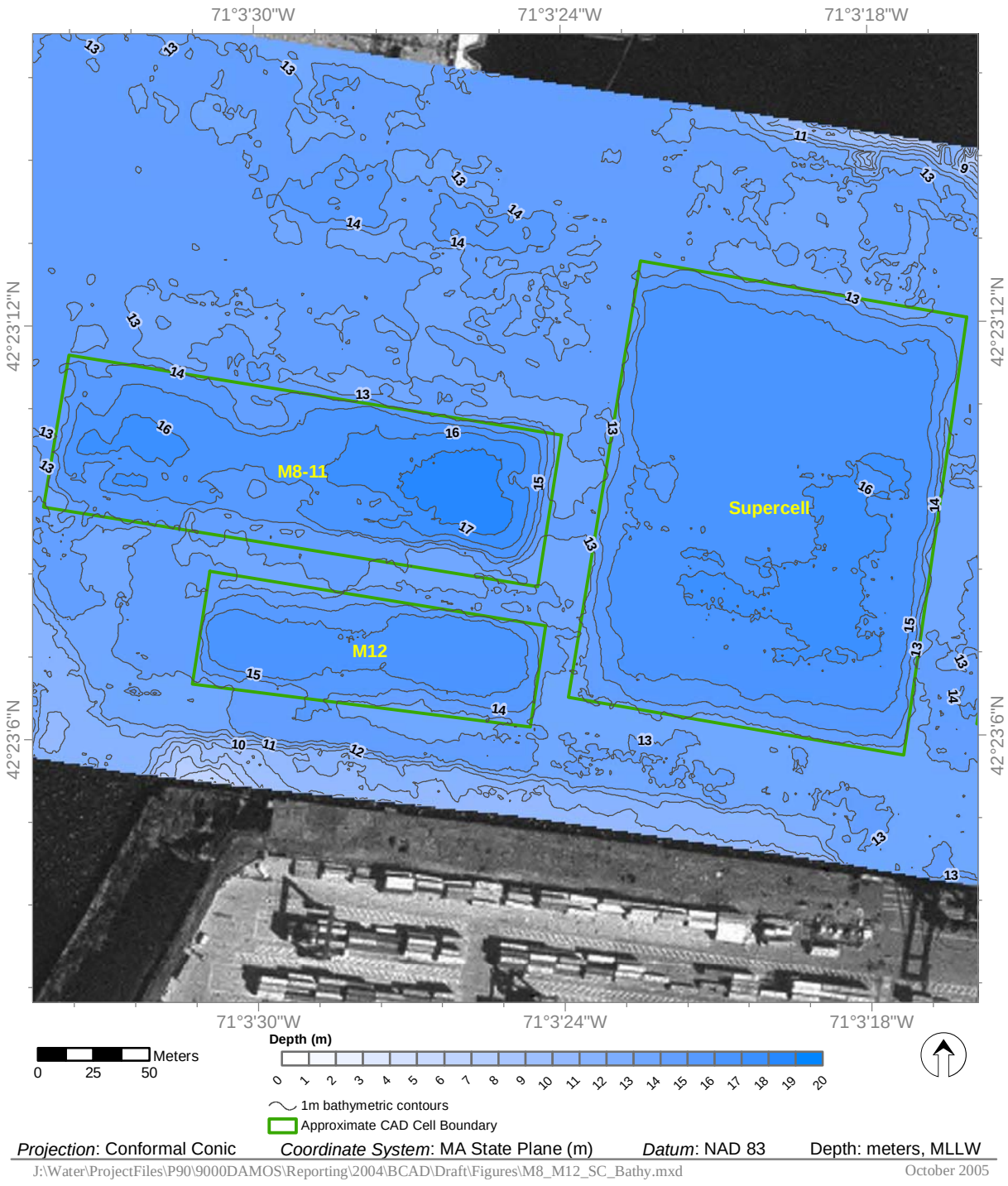

Figure 3-10. Bathymetric contour map of Mystic River cells M8-11, M12 and Supercell, August 2004 (1-m contour interval)

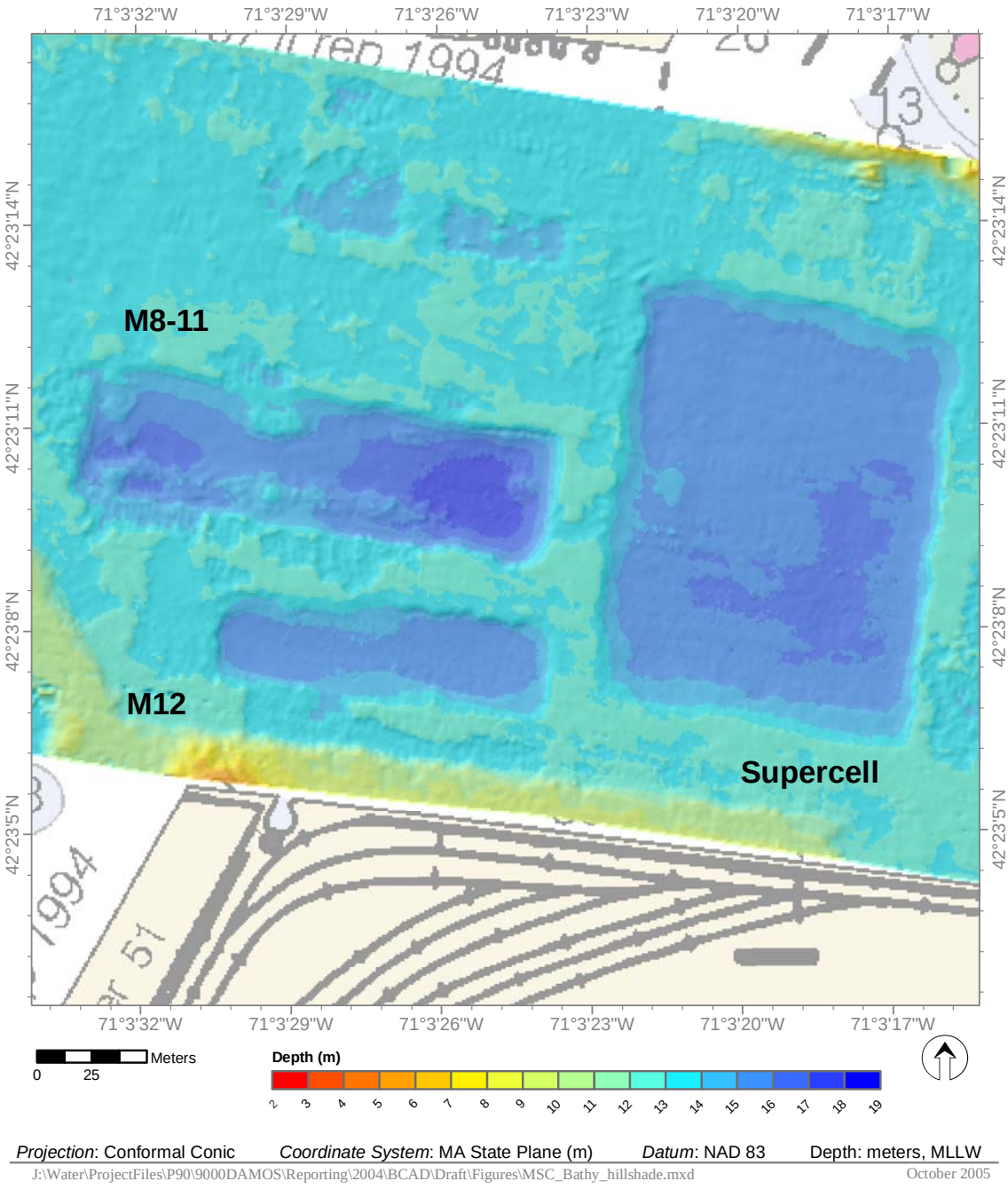

Figure 3-11. Bathymetric relief map of Mystic River cells, M8-11, M12, and Supercell, August 2004

smooth, with limited areas of irregular topography (Figure 3-11). A depth-difference map was generated using the August 2004 survey data and bathymetric data collected in June 2002, approximately 2½ years following capping of the Supercell (Figure 3-12). The depth-difference map indicated a limited depth increase of approximately 0.5 m (1.6 ft) over portions of the cell. The larger depth decreases around the cell margin are considered artifacts of the difference in bathymetric data collection (swath in 2004 vs. single beam with 50 m (164 ft) line spacing in 2002).

Cell M19 - Cell M19 lies in the eastern portion of the Mystic River channel and was capped in September 2000. Follow-up dredging of the channel area surrounding some of cell M19 was performed in fall 2001, with the dredged material (consolidated Boston Blue Clay) bucketed directly into the cell. The 2004 bathymetry of cell M19 was quite varied with depths ranging from 14 to over 18 m (45.6 to over 59 ft) MLLW (Figures 3-13 and 3-14). Shallowest areas were found along the cell margins and in the central portion of the cell. Deepest areas were found in the western portion of the cell and as a linear feature previously identified in the eastern portion of the cell. The irregular topography associated with the follow-up dredging and material placement into the cell in 2001 was apparent both outside and inside the cell, particularly along the southern and western margins (Figure 3-14). A depth-difference map was generated using the August 2004 survey data and bathymetric data collected in May 2001, approximately nine months following capping of cell M19 but prior to the additional dredging around the cell margin (Figure 3-15). The follow-up dredging around the cell in 2001 was clearly apparent in the depth-difference map, with a depth increase up to 1.5 m (4.9 ft) along the cell margins and areas of depth decrease up to 2 m (6.6 ft) within the cell, paralleling the dredged areas along the margins.

3.1.3 Chelsea River

Cell C12 was the only CAD cell constructed in the Chelsea River and remained uncapped with additional capacity at the end of the BHNIP. No additional disposal had taken place prior to the August 2004 survey, and cell C12 remained a distinct bathymetric feature on the harbor bottom with the cell margins steeply sloped and dropping approximately 4 to 5 m (13.1 to 16.4 ft) into the cell (Figures 3-16 and 3-17). Depths within the cell were fairly uniform at 17 to 18 m (55.8 to 59.1 ft) MLLW, and depths outside the cell were approximately 13 m (42.7 ft) MLLW. The surface of the cell appeared somewhat rougher than that of the capped cells. A depth-difference map was generated using the August 2004 survey data and the bathymetric data collected in May 2001, following completion of disposal into the cell (Figure 3-18). The depth-difference data showed limited depth increase (generally less than 0.5 m [1.6 ft]) over portions of

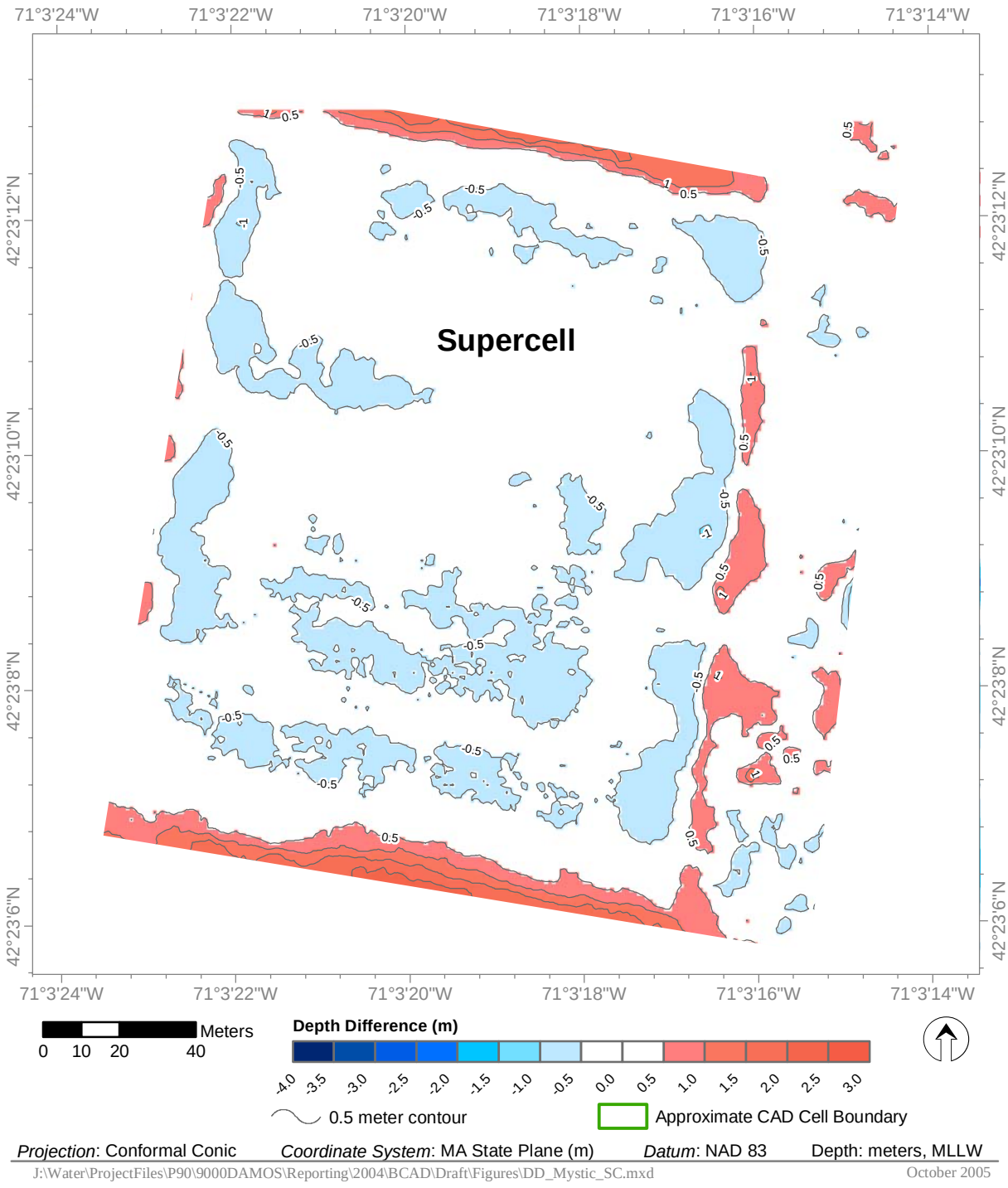

Figure 3-12. Depth difference contour map of Mystic River Supercell, August 2004 and June 2002 surveys (0.5-m contour interval)

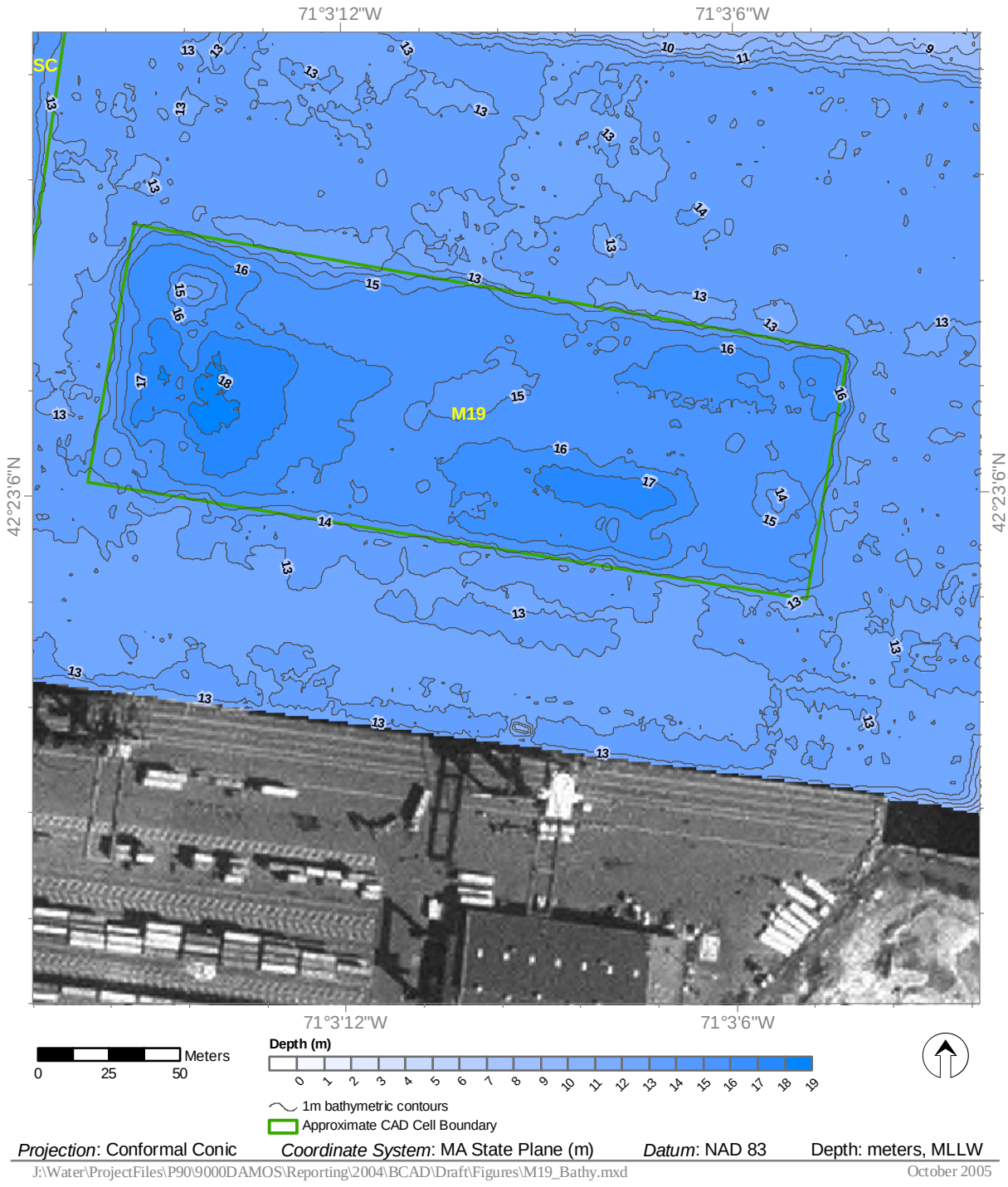

Figure 3-13. Bathymetric contour map of M19, August 2004 (1-m contour interval)

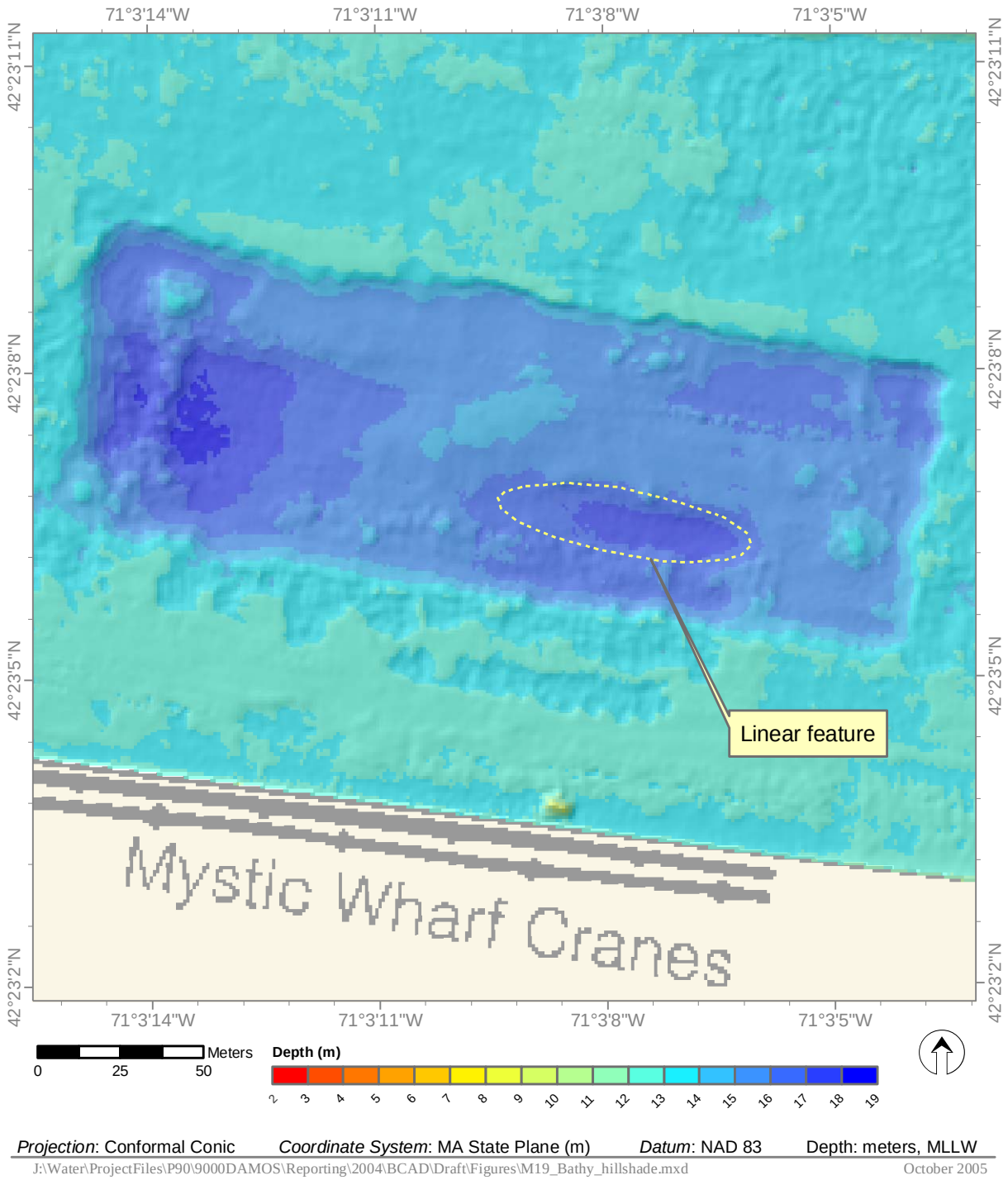

Figure 3-14. Bathymetric relief map of Cell M19, August 2004

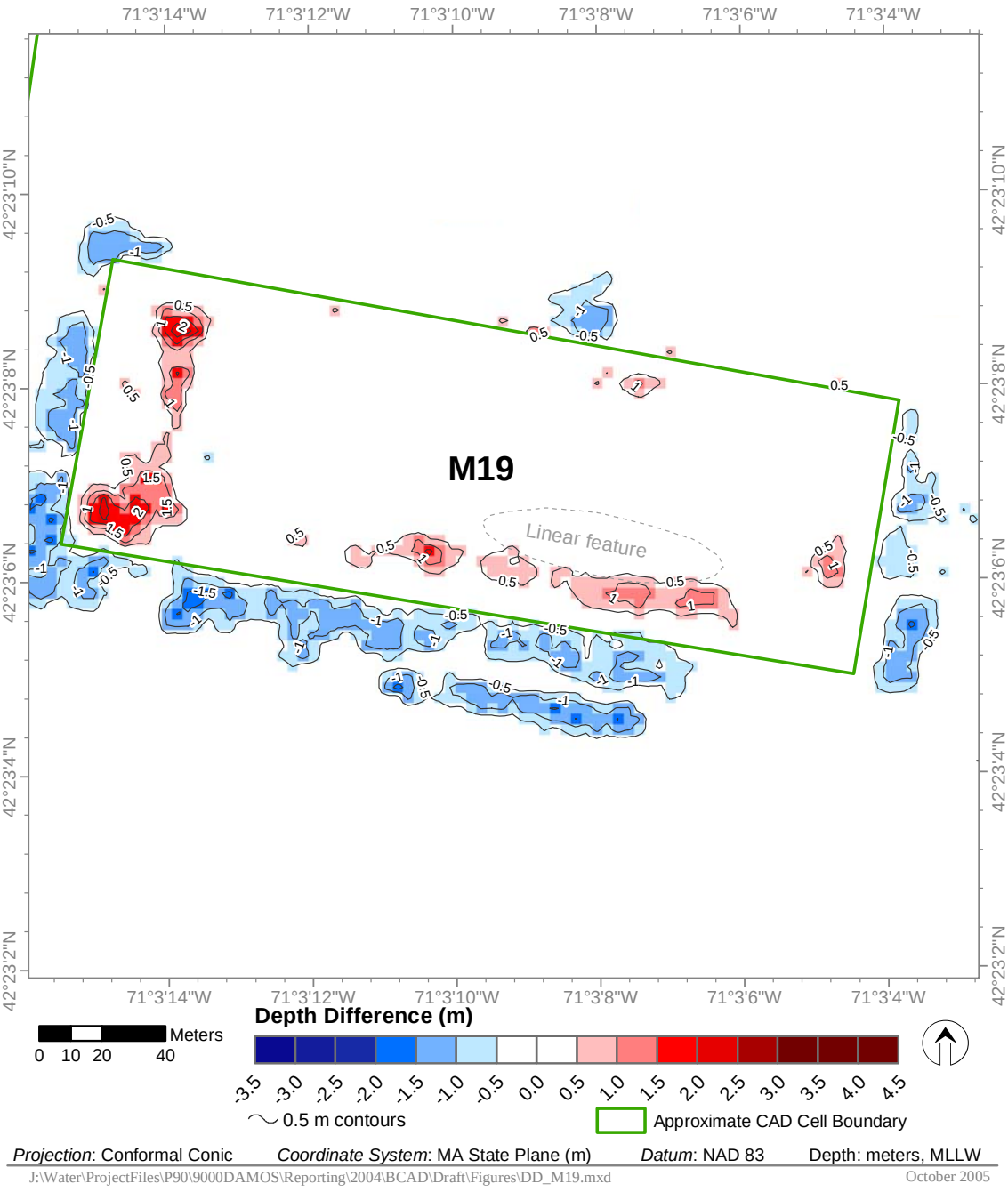

Figure 3-15. Depth difference contour map of M19, August 2004 and May 2001 surveys (0.5-m contour interval)

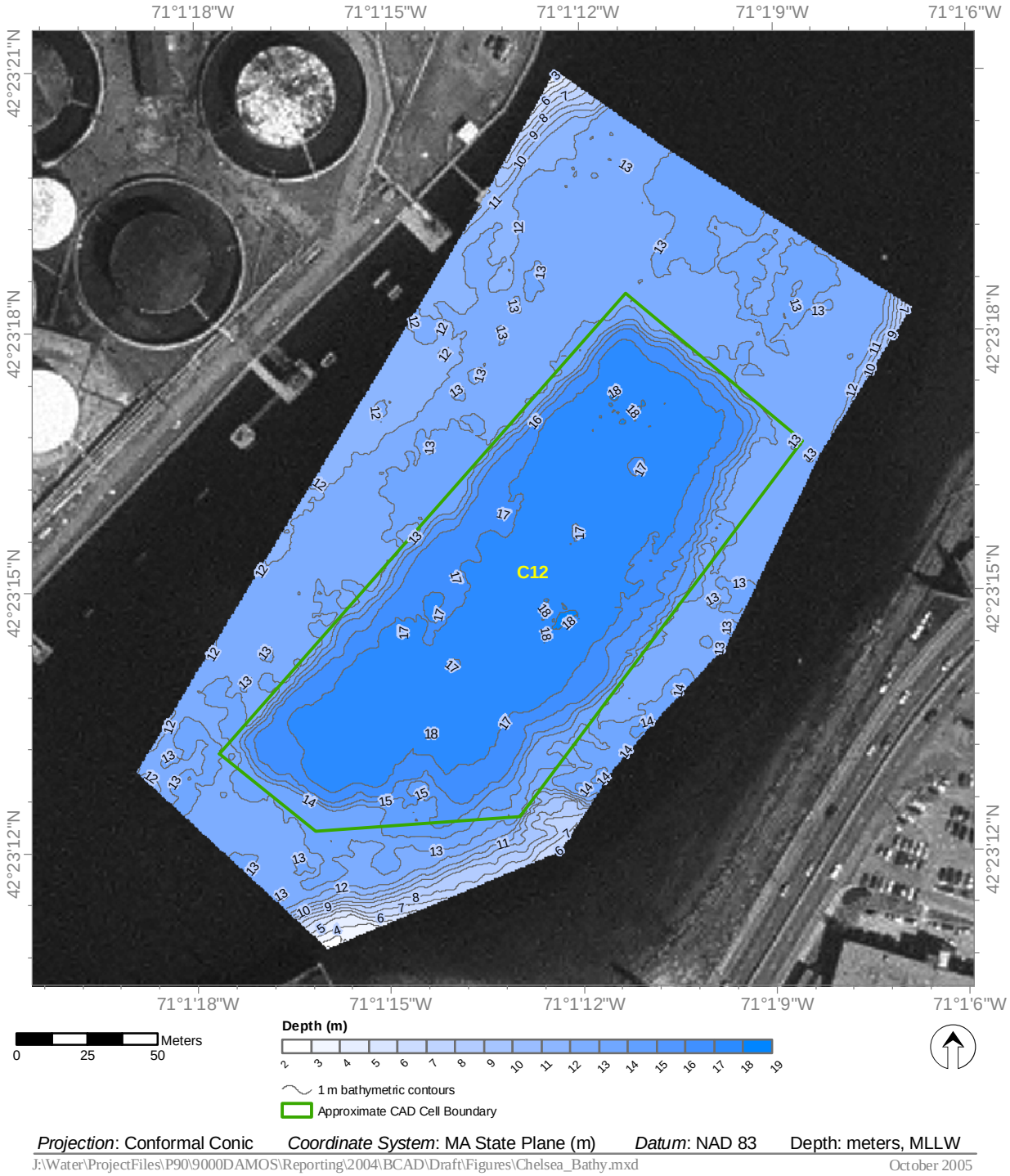

Figure 3-16. Bathymetric contour map of Chelsea cell C12, August 2004 (1-m contour interval)

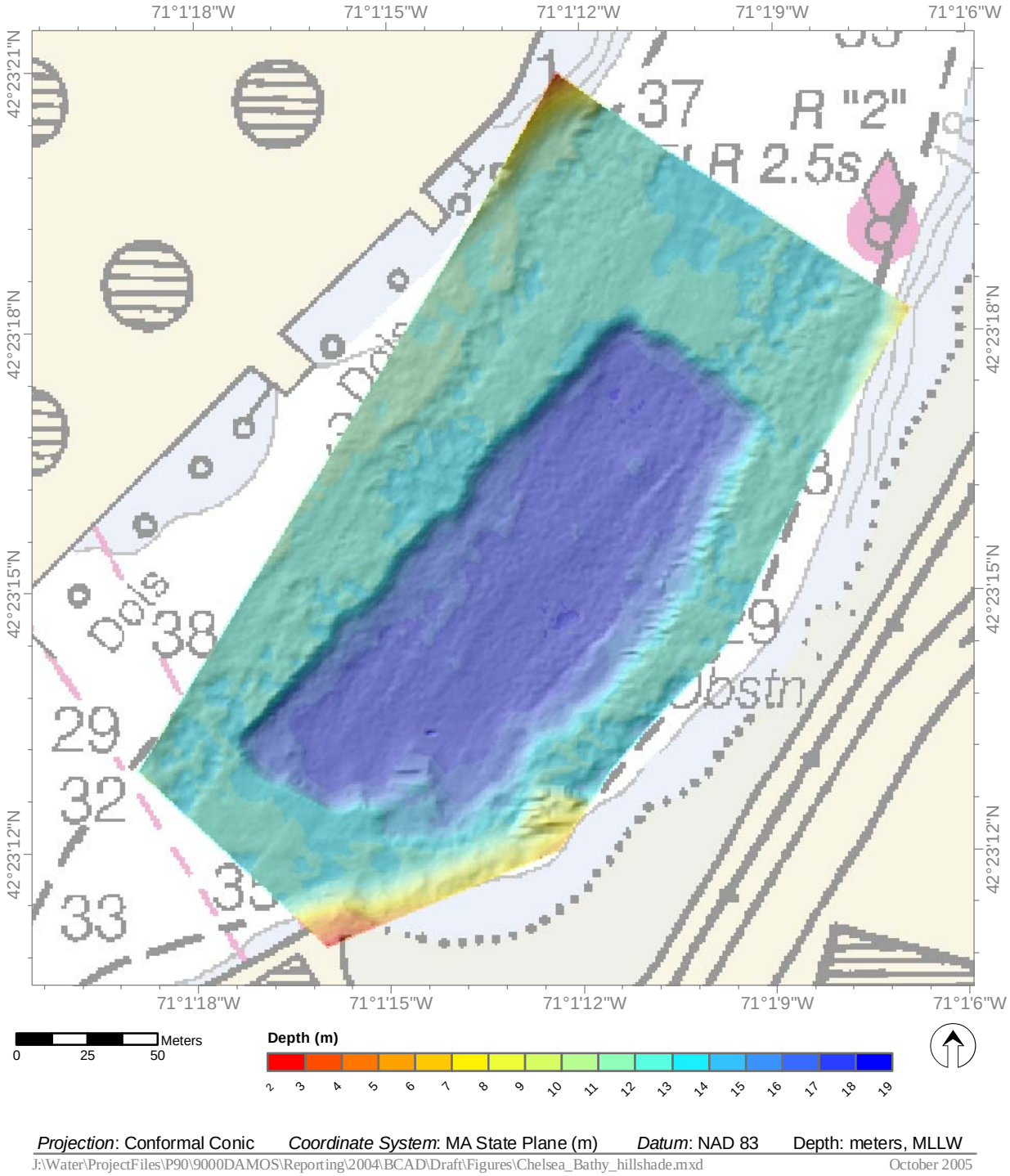

Figure 3-17. Bathymetric relief map of Chelsea cell C12, August 2004

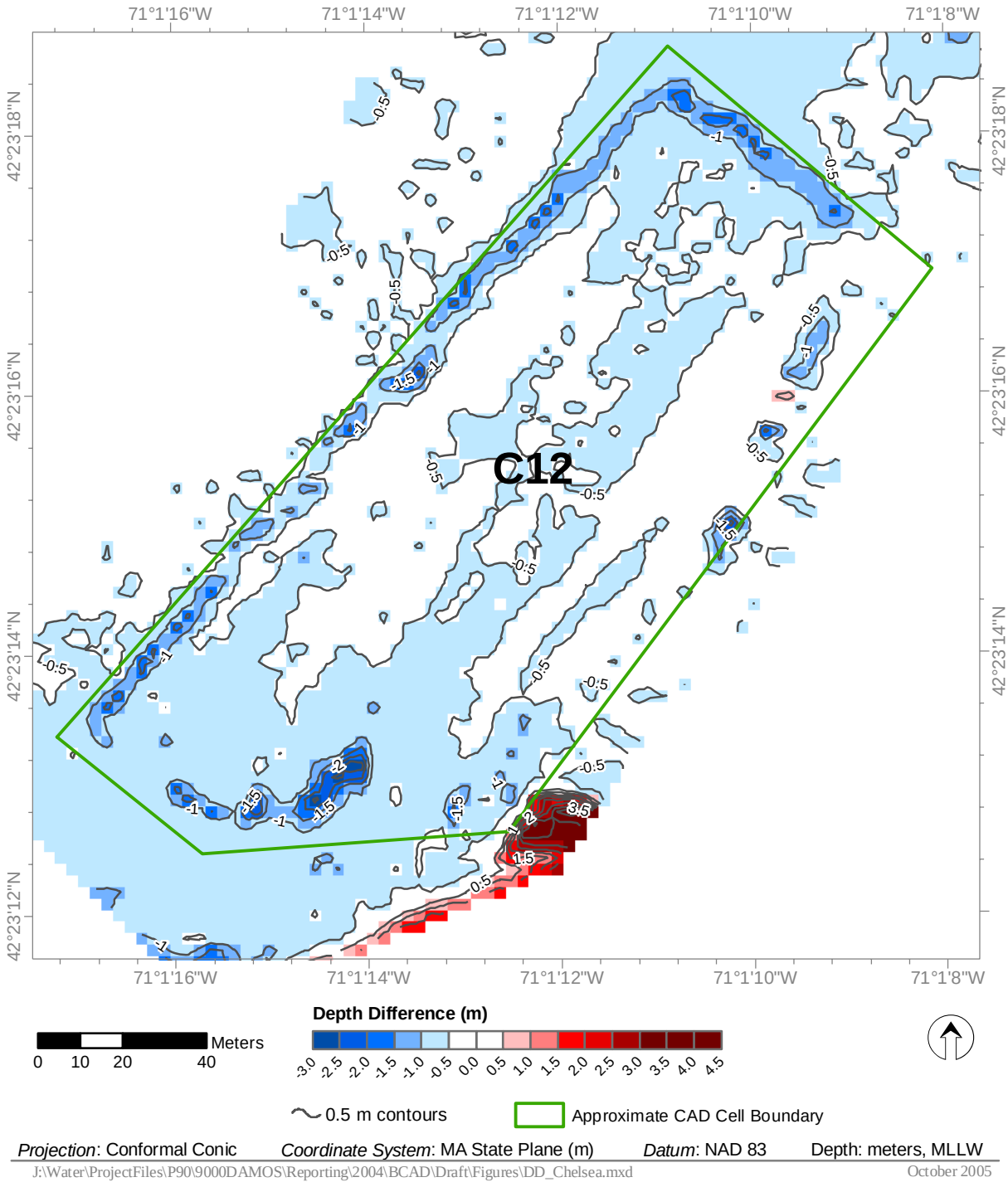

Figure 3-18. Depth difference map of Chelsea cell, C12, August 2004 and May 2001 surveys (0.5-m contour interval)

the cell and surrounding the cell and greater depth increases (up to 2 m [6.6 ft]) along the cell margins. The area of depth decrease along the southeast portion of the survey area could indicate deposition or could be an artifact as it lies along a steep slope and shoal area.

3.2 Side-Scan Sonar

A side-scan sonar survey was performed over all nine of the CAD cells on 11 August 2004. The side-scan imagery was used to supplement the bathymetric data in interpreting topographic features and bottom roughness/texture.

3.2.1 Inner Confluence

Inner Confluence cell IC2 appeared as a relatively smooth surface as compared to the surrounding area where dredge bucket and spud marks were still clearly visible seven years after completion of work in this area (Figure 3-19). Although slightly more texture and topography were visible in the northern portion of the cell relative to the southern portion, it was far less apparent than in the 1997 survey following completion of the cell (SAIC 1999). The channel area to the west of cell IC2, not dredged as part of the BHNIP, appeared more uniform than the dredged area with a somewhat rougher surface than within the cell. Linear features indicative of past/ongoing disturbance to the bottom were also apparent over the channel area.

3.2.2 Mystic River

Cell M2 - The boundary of cell M2 was only partially distinguished against the harbor bottom in the side-scan imagery (Figure 3-20). A number of smaller, low features were apparent in the western portion of the cell that appeared to be debris based on closer inspection of the image. The cell surface was more uniform in the eastern portion.

Cell M4 – The boundary of cell M4 was more apparent against the harbor bottom in the side-scan imagery given the approximate 3 m (9.8 ft) drop into the cell, and the surface of this cell appeared uniform and relatively featureless (Figure 3-20).

Cell M5 – The boundary of cell M5 was only partially distinguished against the harbor bottom in the side-scan imagery, but it was apparent that the cell had been constructed as a rectangle rather than the original planned trapezoidal shape (Figure 3--20). The cell surface appeared uniform over much of the cell, with some irregular topography apparent in the southwestern portion.

Figure 3-19. Side-scan sonar image of Inner Confluence cell IC2, August 2004

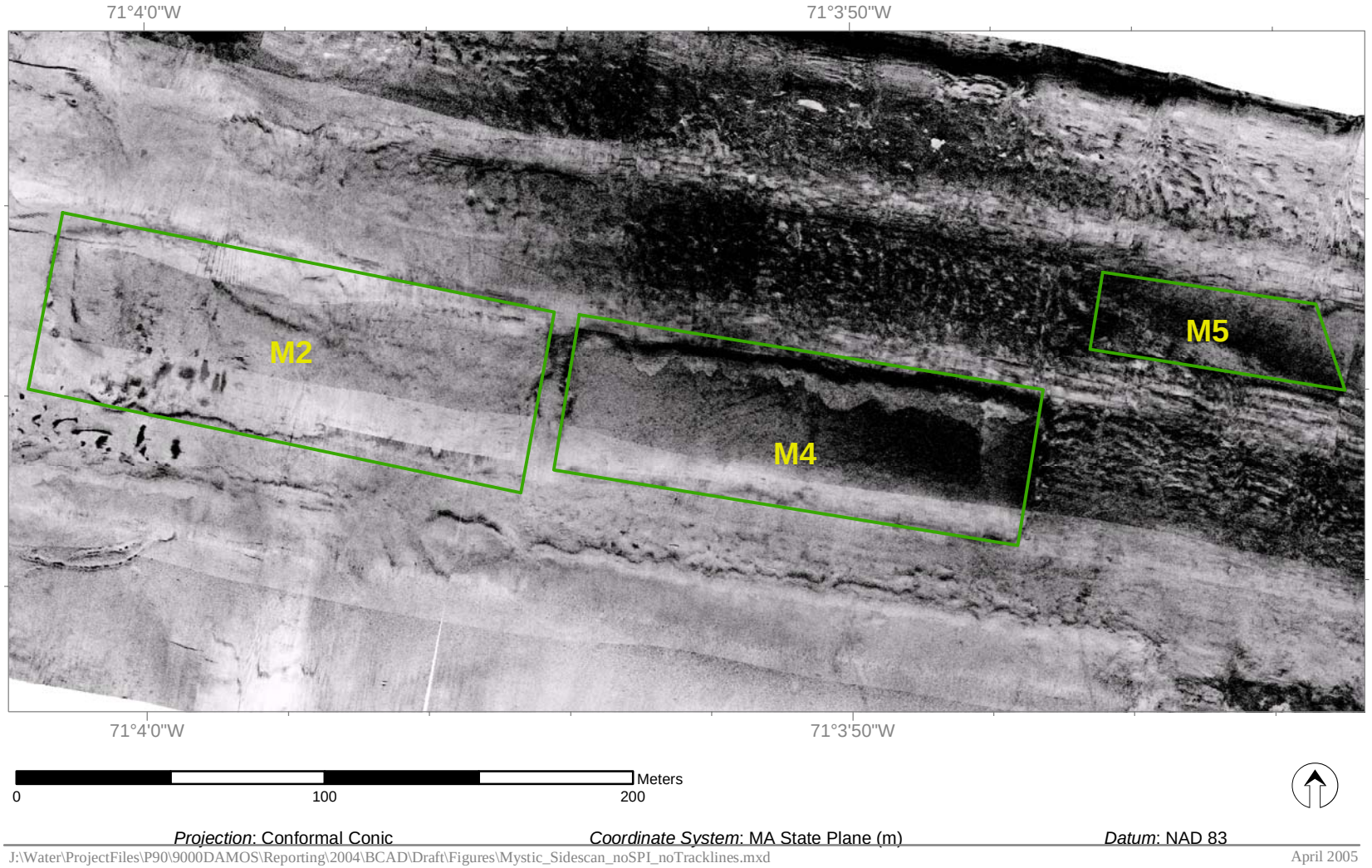

Figure 3-20. Side-scan sonar image of Mystic River cells, M2, M4, and M5, August 2004

Cell M8-11 – The most apparent feature in the side-scan imagery of cell M8-11 was related to the follow-up dredging and material placement that took place in fall 2001. Bucket marks were visible along the majority of the southern cell boundary and portions of the other boundaries (Figure 3-21). Mounds of the material were visible rising above the cell surface and paralleling the dredged areas. The remaining portion of the cell appeared relatively uniform and smooth with a limited amount of debris. A timber or pile was visible in the eastern portion of the cell.

Cell M12 – The boundary of cell M12 was only partially distinguished against the harbor bottom in the side-scan imagery (Figure 3-21). The surface of the cell was relatively uniform and smooth, and several timbers or piles were visible within the cell.

Supercell – The boundary of the Supercell was only partially distinguished against the harbor bottom in the side-scan imagery (Figure 3-21). The surface of the cell was relatively uniform and smooth, and there were no noteworthy features other than a limited amount of debris and several timbers or piles.

Cell M19 – The boundary around much of cell M19 was readily apparent against the harbor bottom in the side-scan imagery (Figure 3-22). Similar to cell M8-11, the dredging around the perimeter of cell M19 that took place in 2001 was still readily apparent in the 2004 survey, and the dredged material that was placed into the cell was visible as mounded clusters on the cell surface. Timbers or piles, a tire, and other debris were also visible within the cell. The linear depression identified in previous investigations and in the 2004 bathymetry was less apparent in the side-scan imagery as a topographic feature. However, the bright return over the area was suggestive of softer material as compared to the darker grey return over much of the rest of the cell.

The side-scan sonar imagery was superimposed on the swath bathymetric surface model of cell M19 with vertical exaggeration to better highlight topographic features within the cell (Figure 3-23). The dredged material that was placed into the cell in 2001 was clearly mounded above the cell surface. The linear depression in the eastern portion of the cell was quite visible in this view as was a ridge across the center of the cell.

3.2.3 Chelsea River

The boundary of cell C12 was quite apparent against the harbor bottom in the side-scan imagery given the 4 to 5 m (13.1 to 16.4 ft) drop into the cell highlighting the irregular boundary along the southern edge of the cell (Figure 3-24). The surface of the

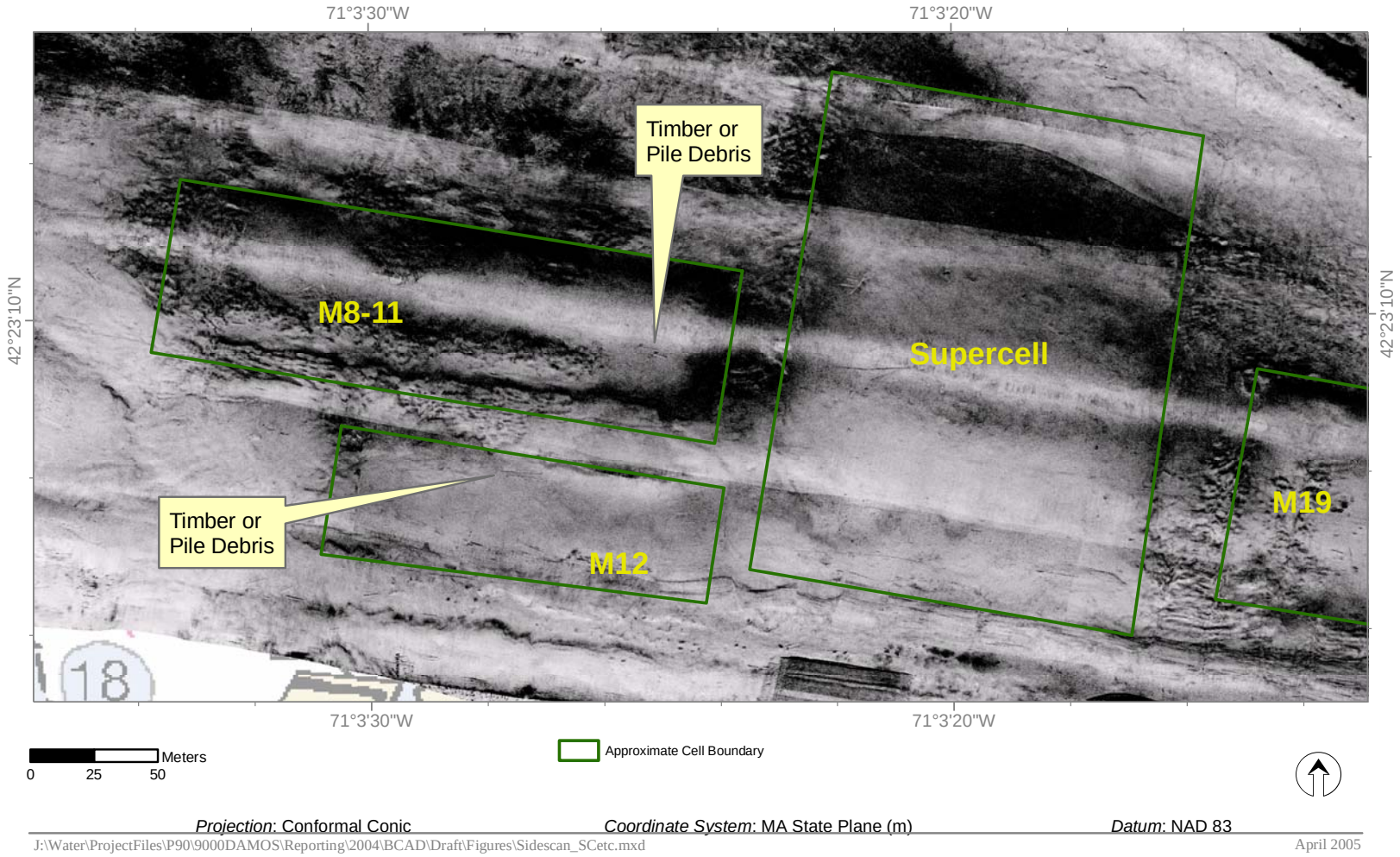

Figure 3-21. Side-scan sonar image of Mystic River cells, M8-11, M12, and Supercell, August 2004

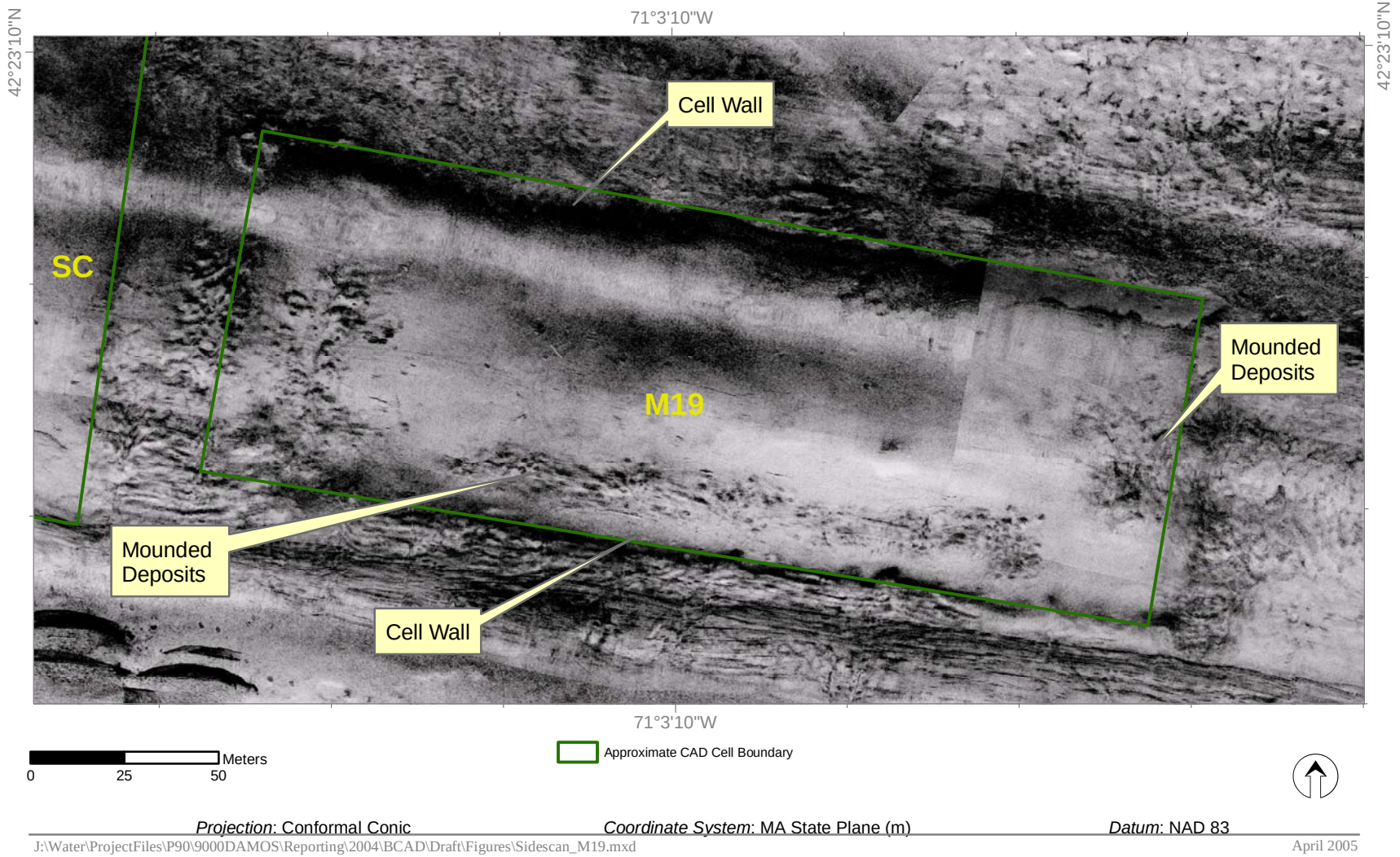

Figure 3-22. Side-scan sonar image of Mystic River Cell M19, August 2004

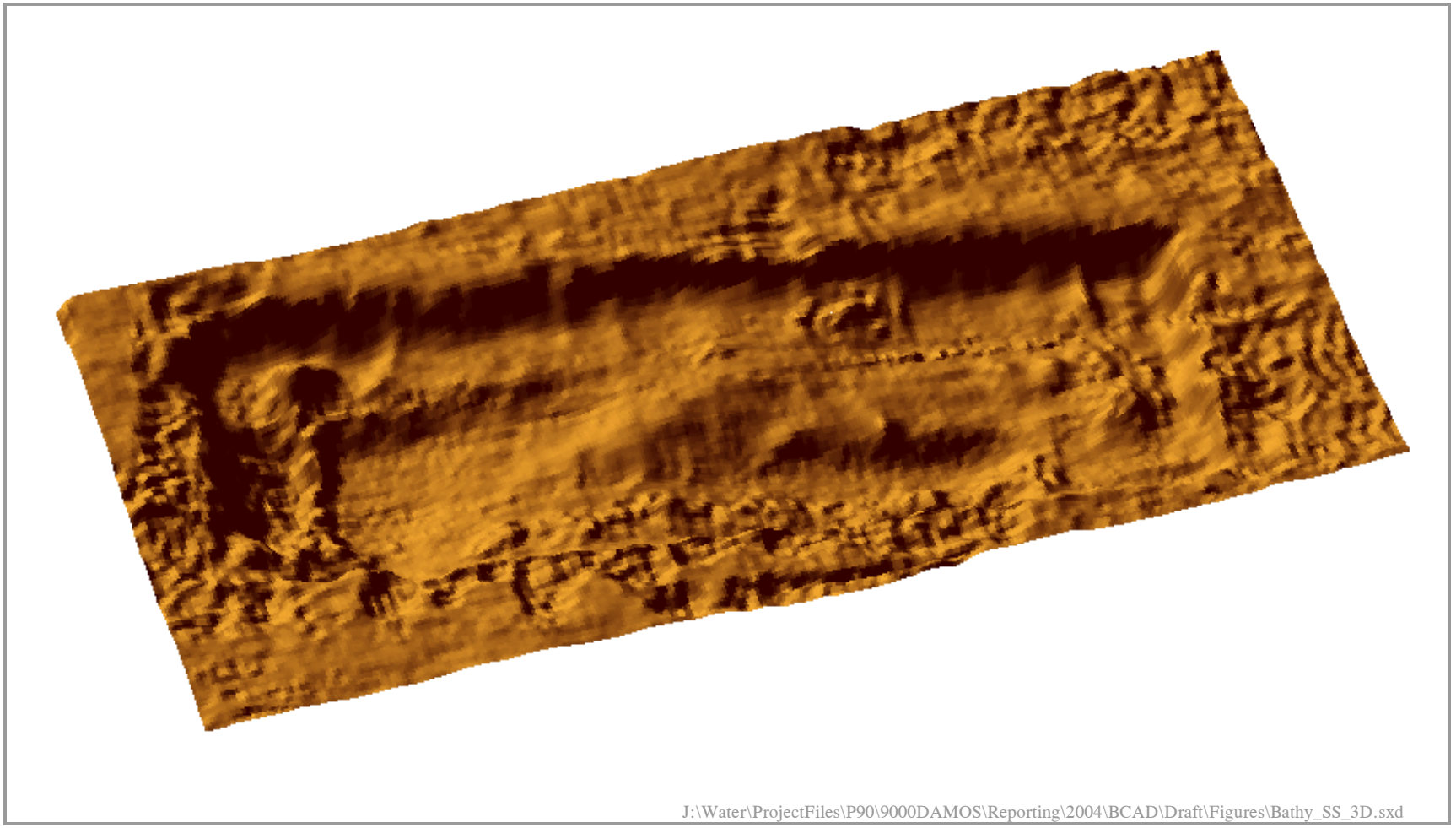

Figure 3-23. Side-scan sonar mosaic superimposed on swath bathymetric surface model of Mystic River cell M19 (5x vertical exaggeration), August 2004

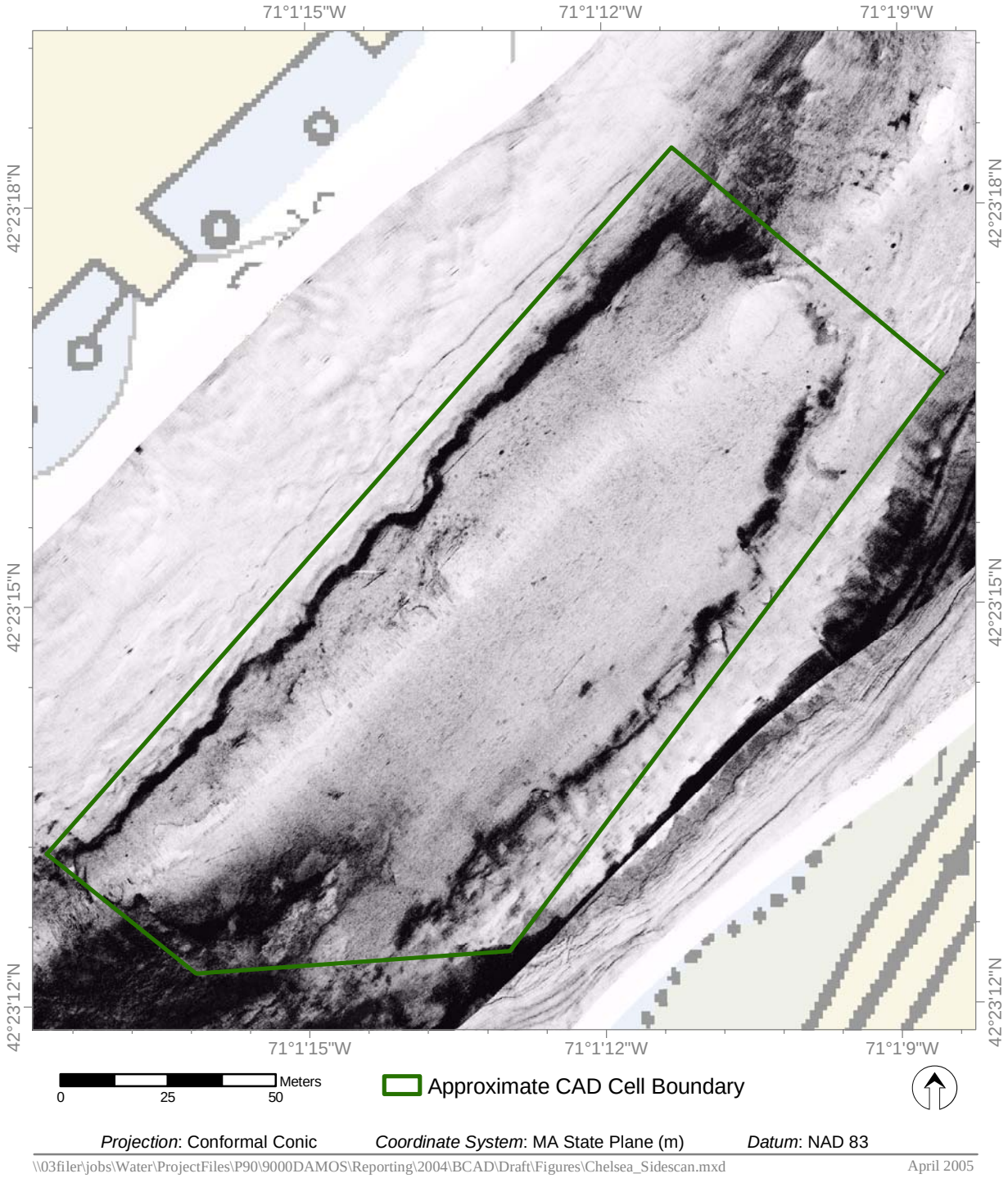

Figure 3-24. Side-scan sonar image of Chelsea River cell C12, August 2004

cell appeared relatively uniform and smooth with some debris visible, particularly along the northwestern boundary.

3.3 Underwater Video

The towed video sled survey was performed to aid in the physical and biological characterization of the surface of the CAD cells, focusing on cell M19 but with additional footage recorded over cells IC2, M4, M8-11, M12, and the Supercell. The survey was performed on 12 August 2004. The water clarity was poor, typical for late summer conditions within the inner reaches of the harbor. Visibility was further reduced following the midday passage of a large vessel through the area. Nevertheless, the acquired video footage provided insight into surficial sediment type and biological conditions. Representative clips of the video from each of the surveyed cells are provided electronically, with the location and video link provided in Figure 3-25. A description of each of these segments is provided below. An annotated transcript of the complete video clips is provided in Appendix A.

IC2 – The video clip for cell IC2 has three segments. The first segment was from the surrounding harbor bottom just to the southwest of the cell. Numerous small fish and shrimp were visible darting in front of the camera. Based on the wave of suspended sediment in front of the sled, fine material (silt/clay) dominated the surficial sediments. The second segment was from the south-central portion of the cell and looked very similar to that outside of the cell, except that there appeared to be more fine surficial sediment. A flounder was visible moving in front of the sled as were other small fish and shrimp. The third segment was from the southwest portion of the cell closer to the cell margin. Small pieces of consolidated clay were apparent, likely weathered from the exposed cell wall that was cut into Boston Blue Clay.

M4 – The video clip for cell M4 has two segments. The first segment was on the surrounding harbor bottom to the northwest of the cell, and the second clip was from the west-central portion of the cell. The water clarity was very poor in both segments, but the two segments appeared very similar with a predominance of fine surficial sediment, debris and algae visible on the bottom, and small fish or shrimp (more noticeable by the trails of suspended sediment that they left). Clasts of clay were also apparent on the sediment surface in the segment from within the cell.

M8-11 – The video clip for cell M8-11 has three segments. The first segment was just north of the cell on the surrounding harbor bottom. Surficial sediments appeared coarse with sections of exposed, weathered clay. The sled passed over a large crab.

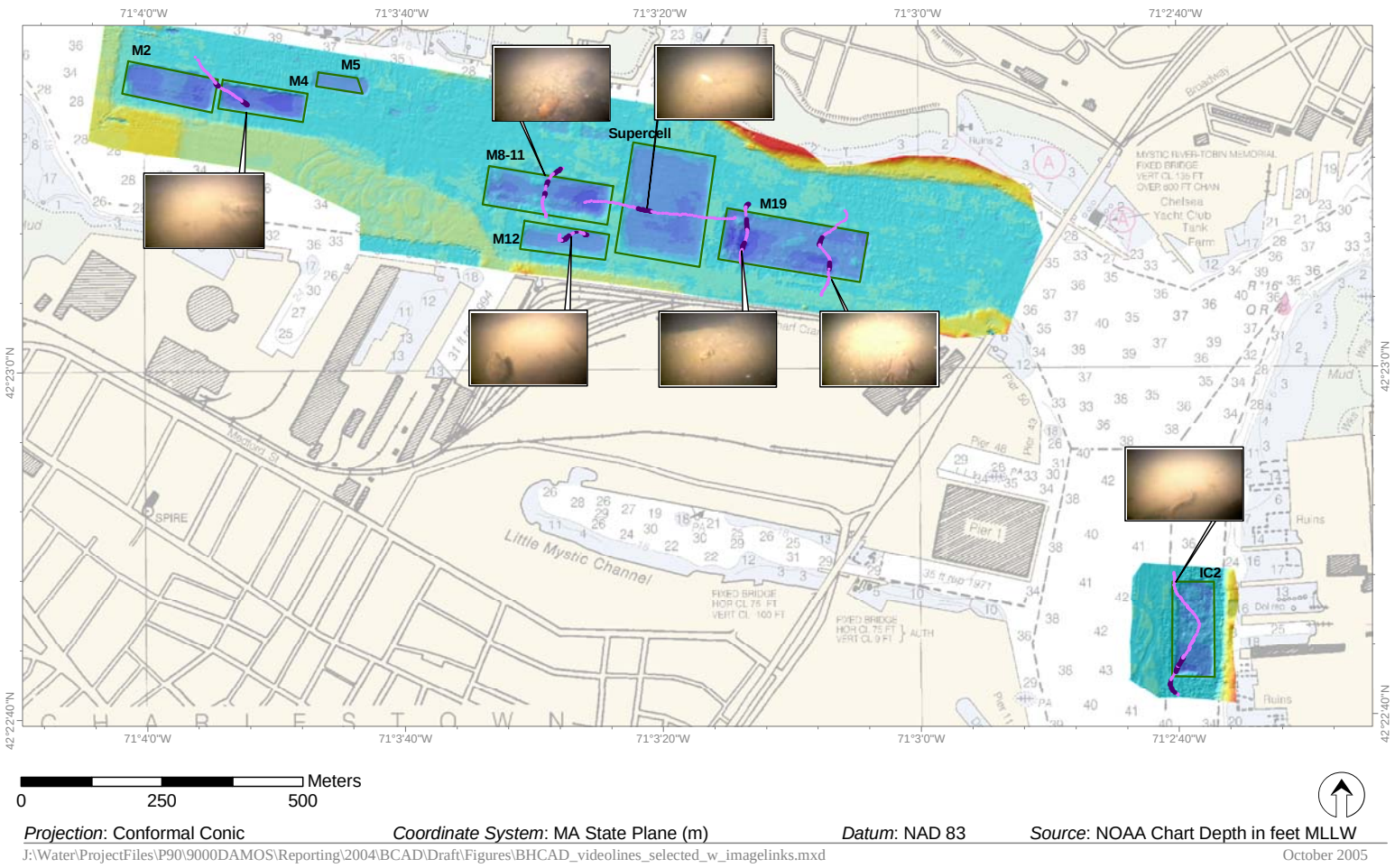

Figure 3-25. Location of towed video sled clips described in the text

Coarse surficial sediment was also apparent in the central portion of the cell in the second segment, as were clay clasts, debris, and numerous fish and shrimp. The third segment was from the south-central portion of the cell. Surficial sediments in this area appeared somewhat finer. Numerous fish and shrimp were visible, and the sled crossed a line on the bottom, potentially part of a lobster trap set.

M12 – The video clip for cell M12 has three short segments, all from the north-central portion of the cell. The segments were similar with a predominance of fine surficial sediments and numerous small fish (including several flounder) and shrimp.

Supercell – The video clip for the Supercell has one segment from the west-central portion of the cell. Surficial sediments appeared relatively fine with numerous small fish and shrimp apparent as well as suspended sediment trails from larger fish or lobster. The sled impacted a large piece of encrusted debris at the end of the clip.

M19 – There are two video clips for cell M19. The clip from the western portion of the cell has three segments. The first segment was from the surrounding harbor bottom on the northwest margin of the cell. Surficial sediments appeared coarse with exposed sections of weathered clay. Surficial sediments were quite similar in the second segment from the northwest portion of the cell where additional dredged Boston Blue Clay was placed in 2002. The topography was quite irregular. Numerous small fish and shrimp were visible as was a crab. The third segment was from the deeper area in the west-central portion of the cell. Surficial sediments appeared finer in this area with numerous small fish and shrimp visible. The second clip from cell M19 has two segments from the eastern portion of the cell. In the first segment the sled started on the surrounding harbor bottom to the north of the cell, dropped down the cell wall, and began a transit across the northeastern portion of the cell. Surficial sediments appeared coarse and were similar outside and inside the cell. Numerous small fish and shrimp were visible. The second segment was within the linear depression in the southeastern portion of the cell. Surficial sediments appeared much finer in this area. Numerous small fish and shrimp were visible as was the trail from a larger fish.

3.4 Sediment-Profile Imaging

The objectives of the August 2004 sediment-profile imaging (SPI) survey were to assess the recolonization status of the BHCAD cells and provide additional insight into the physical characterization of the surface of the cells. During the survey, sediment-profile images were collected at the nine CAD cells located in the Inner Confluence (IC2), the Chelsea River (C12), and the Mystic River (M2, M4, M5, M8-11, M12, M19,

and the Supercell) and their associated reference areas (IC-REF, CREF, and MREF). A total of 60 stations were sampled with three replicates per station. Detailed SPI data for all replicate images are presented in Appendix B.

3.4.1 Inner Confluence

Sediment Physical Characteristics

The predominant sediment type throughout the Inner Confluence area was silt-clay (>4 phi) (Table 3-2). Silty material was present in all replicates at the six IC2 stations and at the three IC-REF stations (Figure 3-26). Overall, stations within the IC-REF reference area were slightly sandier than the stations within the IC2 cell (Figure 3-26). Boundary roughness or surface relief appeared to be related to physical processes in all sediment-profile images collected at the Inner Confluence. The average boundary roughness for the six Inner Confluence stations was 0.9 cm (0.4 in), while for the three IC reference stations boundary roughness was 0.6 cm (0.2 in) (Table 3-3).

Obvious sedimentary features in the SPI images included the muddy texture and clay content of the sediments, as well as color layering (Figure 3-26). Layers alternated between light-gray and dark-gray, and were likely generated by resuspension/deposition events.

Biological Conditions

The predominant biogenic features present in the images from the Inner Confluence were small tubes at the sediment surface and burrow structures below the sediment surface. Tubes were present in low numbers at all stations sampled. The average number of tubes present per image at IC2 stations was 4.8, while the average number of tubes present per image at IC-REF stations was 6.0 (Table 3-2). Four of the six IC2 stations and all IC-REF stations had some burrow structures, which appeared to belong to small, successional Stage I polychaetes. Small infaunal organisms (<1 mm [0.04 in] diameter) were observed at five of the six IC2 stations and all IC-REF stations. The mean number of infauna was 0.8 per image at IC2 stations and 0.9 per image at IC-REF stations (Table 3-3).

Anaerobic voids, water-filled inclusions that did not appear to be oxic, were observed at both the IC2 stations and the IC-REF stations. The average number of anaerobic voids per image for the IC2 stations was 1.5 and for the IC-REF stations 0.8 voids per image (Table 3-2). Few oxic voids, presumed to be active feeding structures,

Table 3-2
Summary of SPI Results for BHCAD Inner Confluence Stations, August 2004

Area	Station	Mean Prism Penetration Depth (cm)	Mean Boundary Roughness (cm)	Mean RPD Depth (cm)	Grain Size Major Mode (phi)	Mean No. Tubes (#/image)	Mean No. Infauna (#/image)	Mean No. Oxic Voids (#/image)	Average No. Anaerobic Voids (#/image)	Successional Stages present (No. replicates)	Mean OSI
Inner Confluence	IC2-1	20.9	0.7	0.7	>4	1.0	0.0	0.0	2.0	I (3)	3.0
	IC2-2	13.9	0.7	0.8	>4	1.3	0.3	0.0	2.7	I (3)	2.7
	IC2-3	15.0	1.0	0.7	>4	5.3	2.0	0.0	1.0	I (3)	2.3
	IC2-4	19.8	1.1	1.0	>4	6.0	0.7	0.0	1.0	I (3)	3.0
	IC2-5	20.8	0.8	0.9	>4	11.3	1.7	0.0	1.0	I (3)	3.0
	IC2-6	18.2	1.0	0.9	>4	3.7	0.3	0.0	1.3	I (3)	3.0
	IC-REF-1	12.2	0.4	0.7	>4	6.3	2.0	1.7	1.3	I (1), I - III (2)	5.0
	IC-REF-2	12.1	0.7	0.7	>4	0.7	0.3	0.0	0.3	I (3)	2.3
	IC-REF-3	10.3	0.6	0.7	>4	11.0	0.3	0.0	0.7	I (3)	2.3
IC2 Average		18.1	0.9	0.8		4.8	0.8	0.0	1.5		2.8
IC REF Average		11.5	0.6	0.7		6.0	0.9	0.6	0.8		3.2

Table 3-3
Summary of SPI Results for BHCAD, August 2004

Area		Mean Boundary Roughness (cm)	Mean RPD Depth (cm)	Mean No. Infauna (#/image)	Mean OSI
IC2	Average	0.9	0.8	0.8	2.8
	Minimum	0.7	0.7	0.0	2.3
	Maximum	1.1	1.0	2.0	3.0
ICREF	Average	0.6	0.7	0.9	3.2
	Minimum	0.4	0.7	0.3	2.3
	Maximum	0.7	0.7	2.0	5.0
M2	Average	0.9	1.1	0.2	2.9
	Minimum	0.5	0.9	0.0	2.7
	Maximum	1.3	1.3	0.3	3.0
M4	Average	1.1	0.8	0.2	3.0
	Minimum	0.7	0.7	0.0	1.3
	Maximum	1.9	0.8	0.7	4.5
M5	Average	0.7	0.5	0.4	1.9
	Minimum	0.4	0.2	0.0	1.0
	Maximum	1.1	0.7	1.3	2.3
M8-11	Average	0.7	0.6	0.5	3.3
	Minimum	0.5	0.5	0.0	2.0
	Maximum	1.0	0.8	1.0	4.7
M12	Average	0.8	1.0	0.7	2.9
	Minimum	0.4	0.9	0.0	2.3
	Maximum	1.2	1.3	1.3	4.0
M19	Average	1.2	1.0	0.3	3.1
	Minimum	0.9	0.5	0.0	2.0
	Maximum	1.8	1.3	1.0	5.0
Supercell	Average	0.8	0.8	0.6	2.7
	Minimum	0.6	0.6	0.0	2.0
	Maximum	1.0	1.1	1.3	4.3
MREF	Average	2.2	0.8	0.1	2.5
	Minimum	0.8	0.6	0.0	2.0
	Maximum	3.8	0.9	0.3	3.0

Table 3-3 (continued)
Summary of SPI Results for BHCAD, August 2004

Area		Mean Boundary Roughness (cm)	Mean RPD Depth (cm)	Mean No. Infauna (#/image)	Mean OSI
C12	Average	1.6	1.5	0.9	3.8
	Minimum	1.1	1.3	0.0	2.7
	Maximum	2.8	1.9	2.0	5.0
CREF	Average	1.2	1.0	0.3	2.9
	Minimum	0.6	0.8	0.0	2.5
	Maximum	1.6	1.3	1.0	3.7

were evident and were only observed at station IC-REF-01. Gas voids, an indication of high rates of methanogenesis most likely associated with high levels of sedimentary organic carbon, were not observed in images collected from IC2 or IC-REF stations.

The mean depth of the apparent color redox potential discontinuity (RPD) layer for IC2 was 0.8 cm (0.3 in) with a range between 0.7 and 1.0 cm (0.3 and 0.4 in). The mean depth of the RPD layer for IC-REF was 0.7 cm (0.3 in) with a narrow range of values between (0.7 to– 0.8 cm [0.28 to 0.31 in]) (Table 3-3; Figure 3-27).

The low degree of biogenic sediment reworking observed at most stations was consistent with Stage I fauna. The apparent modal successional stage indicated that the infaunal communities were overwhelmingly pioneering Stage I at all IC2 stations and at two of the three IC-REF stations (Table 3-2). Only one station, IC-REF-1, was designated as successional Stage I to III based on the assumption that the apparent oxic voids were active feeding structures.

The average Organism Sediment Index (OSI) was 2.8 with a range between 2.3 and 3.0 for IC2 stations and 3.2 with a range between 2.3 and 5.0 for IC-REF stations (Table 3-3; Figure 3-28). Station IC-REF-1 was one of only three stations sampled during this survey having an average OSI as high as 5.0 (Table 3-2), with two replicates at this station having an OSI of 6.0 (Appendix B).

3.4.2 Mystic River

Sediment Physical Characteristics

The most common sediment type present within the Mystic River cells and at the MREF reference area was silt-clay (>4 phi) (Table 3-4, Figure 3-29). Slightly coarser material was present at station M8-11-1 and at several stations within the Supercell (Figure 3-30).

Physical processes dominated the sediment surface at all Mystic River stations. Average boundary roughness ranged from 0.7 cm (0.3 in) at cells M5 and M8-11 to 1.2 cm (0.5 in) at M19, and the overall average boundary roughness for all seven cells was 0.9 cm (0.4 in) (Tables 3-3 and 3-4). It was not possible to determine the boundary roughness at Station MREF-1 as the prism over-penetrated the sediment in all three replicates. However, for the remaining five MREF stations, the boundary roughness ranged from 0.8 cm (0.3 in) at MREF-2 to 3.8 cm (1.5 in) at MREF-6 with an overall average of 2.2 cm (0.9 in) (Tables 3-3 and 3-4).

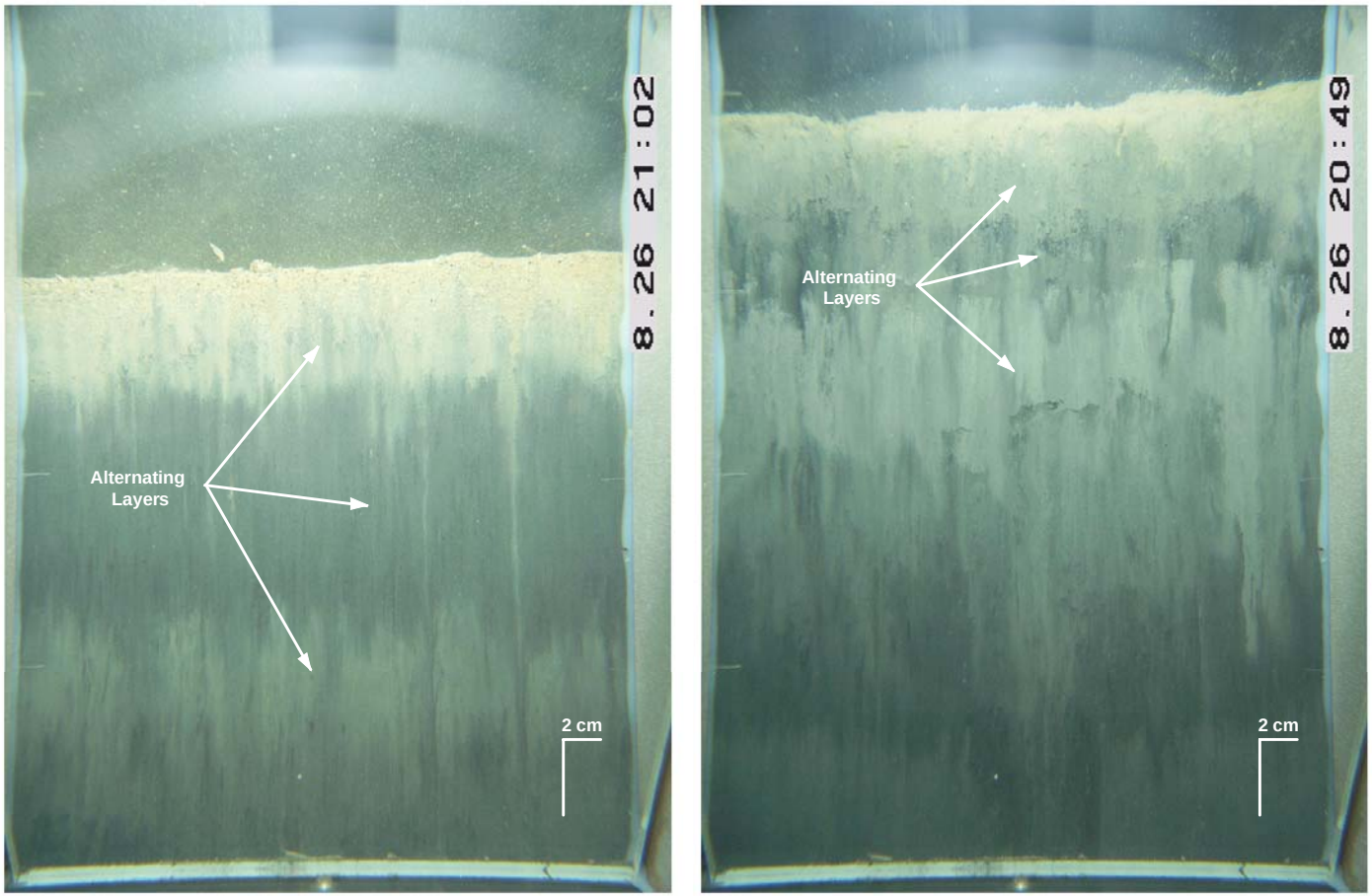

Figure 3-26. Representative SPI images from the Inner Confluence. Stations at the IC-REF reference area (IC-REF-2, left) were sandier than the stations within the IC2 cell (IC2-5, right). Both images show alternating light and dark gray layers, indicative of resuspension/deposition events. Tubes were present in low numbers at all stations.

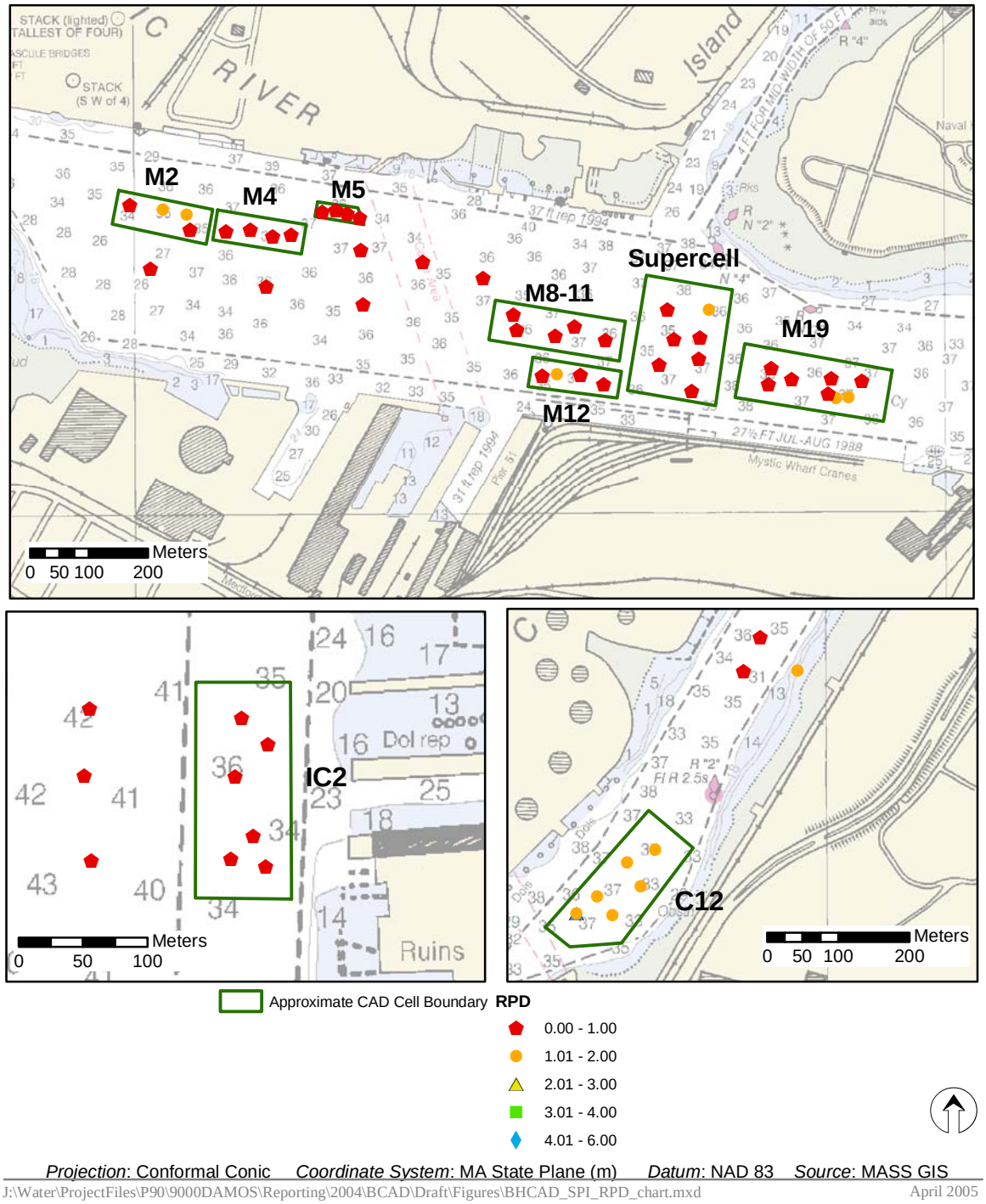

Figure 3-27. Distribution of mean apparent RPD depths (cm) at BHCAD, August 2004

Table 3-4
Summary of SPI Results for BHCAD Mystic River Stations, August 2004

Area	Station	Mean Prism Penetration Depth (cm)	Mean Boundary Roughness (cm)	Mean RPD Depth (cm)	Grain Size Major Mode (phi)	Mean No. Tubes (#/image)	Mean No. Infauna (#/image)	Mean No. Oxic Voids (#/image)	Average No. Anaerobic Voids (#/image)	Successional Stages present (No. replicates)	Mean OSI
Mystic River	M2-1	20.9	1.3	1.2	>4	0.3	0.0	0.0	0.3	I (3)	3.0
	M2-2	21.9	1.2	1.0	>4	0.0	0.3	0.0	0.0	I (3)	3.0
	M2-3	22.3	0.5	1.3	>4	0.0	0.3	0.0	1.0	I (3)	3.0
	M2-4	21.4	0.7	0.9	>4	1.5	0.0	0.0	0.0	I (3)	2.7
	M4-1	21.3	1.0	0.8	>4	1.0	0.0	0.0	1.3	I (3)	3.0
	M4-2	19.2	0.7	0.8	>4	0.5	0.0	0.0	1.7	I (3)	3.0
	M4-3	15.9	1.9	0.7	>4	0.5	0.0	0.5	0.5	I (1), I-III (1), ind (1)	4.5
	M4-4	13.9	0.7	0.7	>4	0.0	0.7	0.0	2.3	I (3)	1.3
	M5-1	11.4	1.1	0.2	>4	3.7	0.0	0.0	1.0	I (3)	2.0
	M5-2	12.5	0.5	0.7	>4	0.3	0.3	0.0	1.3	I (3)	2.3
	M5-3	16.5	0.4	0.5	>4	0.0	0.0	0.0	1.0	I (3)	1.0
	M5-4	14.2	0.6	0.6	>4	0.3	1.3	0.0	0.3	I (3)	2.3
	M8-11-1	10.8	1.0	0.5	>4	3.3	0.7	0.0	0.7	I (3)	2.0
	M8-11-2	16.5	1.0	0.7	>4	1.7	0.7	0.3	0.7	I (2), I-III (1)	3.7
	M8-11-3	14.7	0.6	0.8	>4	0.0	0.3	0.7	0.3	I (2), I-III (1)	4.0
	M8-11-4	11.7	0.5	0.6	>4	2.7	1.0	0.0	1.3	I (3)	2.0
	M8-11-5	14.0	0.5	0.5	>4	1.3	0.0	0.7	1.0	I (1), I-III (2)	4.7
	M12-1	21.2	1.2	1.3	>4	0.0	0.0	0.0	0.7	I (3)	3.0

Table 3-4 (continued)
Summary of SPI Results for BHCAD Mystic River Stations, August 2004

Area	Station	Mean Prism Penetration Depth (cm)	Mean Boundary Roughness (cm)	Mean RPD Depth (cm)	Grain Size Major Mode (phi)	Mean No. Tubes (#/image)	Mean No. Infauna (#/image)	Mean No. Oxic Voids (#/image)	Average No. Anaerobic Voids (#/image)	Successional Stages present (No. replicates)	Mean OSI
Mystic River	M12-2	21.6	0.4	0.9	>4	0.0	1.3	0.0	1.7	I (3)	2.3
	M12-3	19.3	0.8	0.9	>4	0.0	1.0	0.7	1.0	I (2), I–III (1)	4.0
	M12-4	17.8	1.0	1.0	>4	0.3	0.3	0.0	1.7	I (3)	2.3
	M19-1	13.7	1.8	0.7	>4	0.0	0.0	0.0	1.7	I (3)	2.7
	M19-2	11.2	1.0	0.5	>4	2.7	0.3	0.0	0.3	I (3)	2.0
	M19-3	15.3	1.2	1.2	>4	2.5	0.3	0.3	0.7	I (2), I-III (1)	5.0
	M19-4	17.2	1.0	1.3	>4	0.0	1.0	0.0	0.3	I (3)	3.3
	M19-5	18.2	0.9	1.0	>4	0.0	0.3	0.0	0.7	I (3)	3.0
	M19-6	14.8	1.5	1.0	>4	5.5	0.0	0.0	0.7	I (3)	3.0
	M19-7	11.0	1.2	1.0	>4	0.0	0.0	0.0	0.3	I (3)	3.0
	M19-8	14.7	1.4	1.0	>4	0.0	0.0	0.0	1.0	I (3)	3.0
	SC-1	7.2	0.7	0.9	>4	1.7	0.7	0.3	0.7	I (2), I-III (1)	4.3
	SC-2	11.0	0.6	0.8	>4	2.7	0.3	0.3?	1.0	I (2), >I (1)	2.5
	SC-3	11.6	1.0	0.6	>4	3.3	0.7	0.0	0.3	I (3)	2.0
	SC-4	4.8	1.0	1.1	>4	0.0	0.7	0.0	0.0	I (3)	2.7
	SC-5	21.3	0.6	0.7	>4	0.5	0.3	0.0	3.0	I (3)	2.5
	SC-6	21.8	0.9	0.9	>4	2.3	0.0	0.0	0.0	I (3)	2.7
	SC-7	18.2	1.0	0.6	>4	2.3	1.3	0.0	1.3	I (3)	2.0

Table 3-4 (continued)
Summary of SPI Results for BHCAD Mystic River Stations, August 2004

Area	Station	Mean Prism Penetration Depth (cm)	Mean Boundary Roughness (cm)	Mean RPD Depth (cm)	Grain Size Major Mode (phi)	Mean No. Tubes (#/image)	Mean No. Infauna (#/image)	Mean No. Oxic Voids (#/image)	Average No. Anaerobic Voids (#/image)	Successional Stages present (No. replicates)	Mean OSI
Mystic River	MREF-1	>24.0	IND	IND	>4	IND	0.0	0.0	0.0	I (3)	IND
	MREF-2	21.5	0.8	0.9	>4	0.0	0.3	0.0	0.7	I (3)	3.0
	MREF-3	13.3	1.1	0.7	>4	1.7	0.0	0.0	0.3	I (3)	2.0
	MREF-4	7.0	1.9	0.6	>4	23.3	0.0	0.0	0.0	I (3)	2.0
	MREF-5	5.8	3.3	0.9	>4	13.3	0.0	0.0	0.0	I (3)	3.0
	MREF-6	7.0	3.8	0.9	>4	5.0	0.0	0.0	0.3	I (3)	2.7
M2 Average		21.6	0.9	1.1		0.5	0.2	0.0	0.3		2.9
M4 Average		17.6	1.1	0.8		0.5	0.2	0.1	1.5		3.0
M5 Average		13.7	0.7	0.5		1.1	0.4	0.0	0.9		1.9
M8-11 Average		13.5	0.7	0.6		1.8	0.5	0.3	0.8		3.3
M12 Average		20.0	0.8	1.0		0.1	0.7	0.2	1.3		2.9
M19 Average		14.5	1.2	1.0		1.3	0.3	0.0	0.7		3.1
Supercell Average		13.7	0.8	0.8		1.8	0.6	0.1	0.9		2.7
Mystic Average		15.9	0.9	0.8		1.1	0.4	0.1	0.9		2.9
MREF Average		13.1	2.2	0.8		8.7	0.1	0.0	0.2		2.5

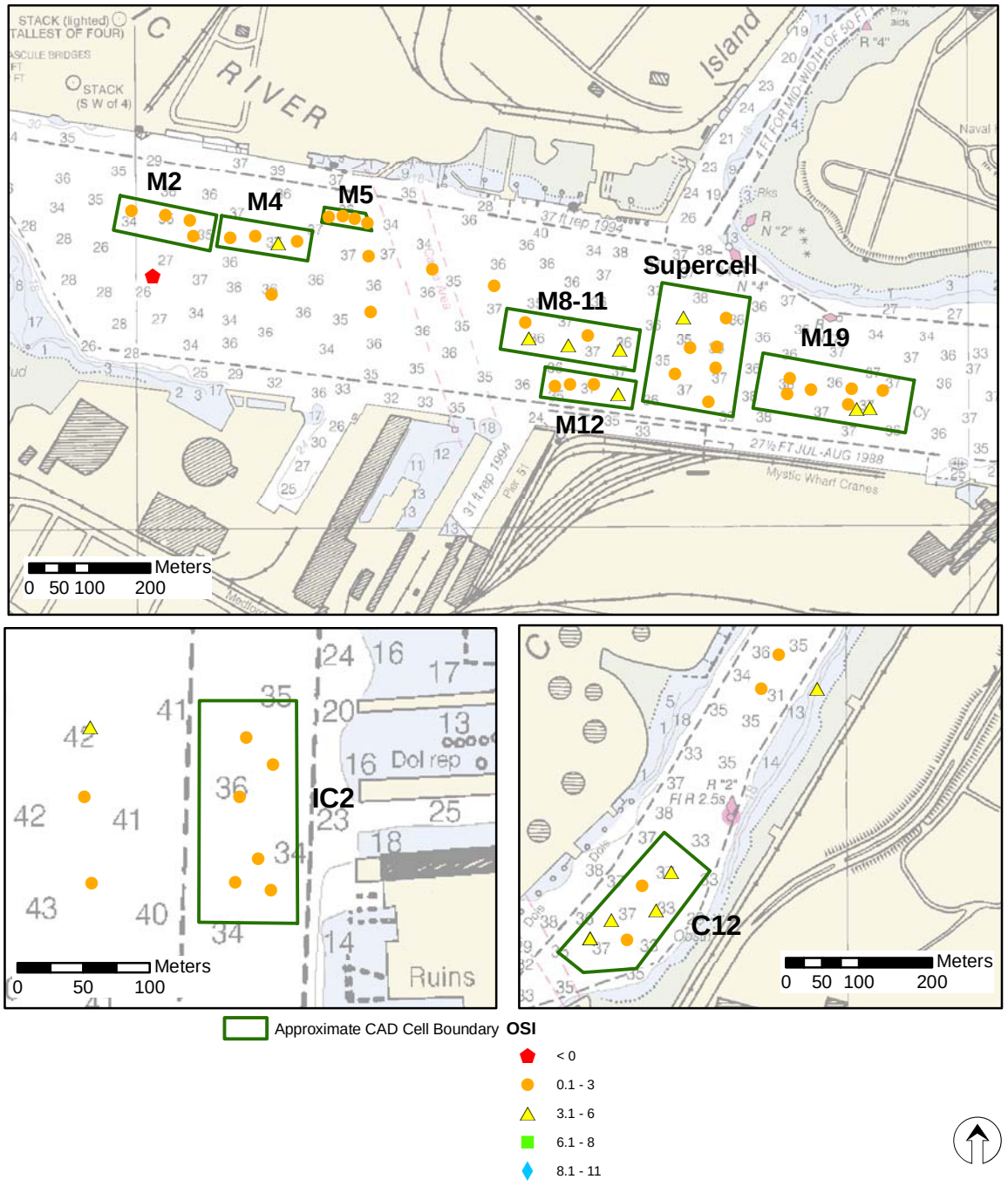

Figure 3-28. Distribution of mean OSI values at BHCAD, August 2004

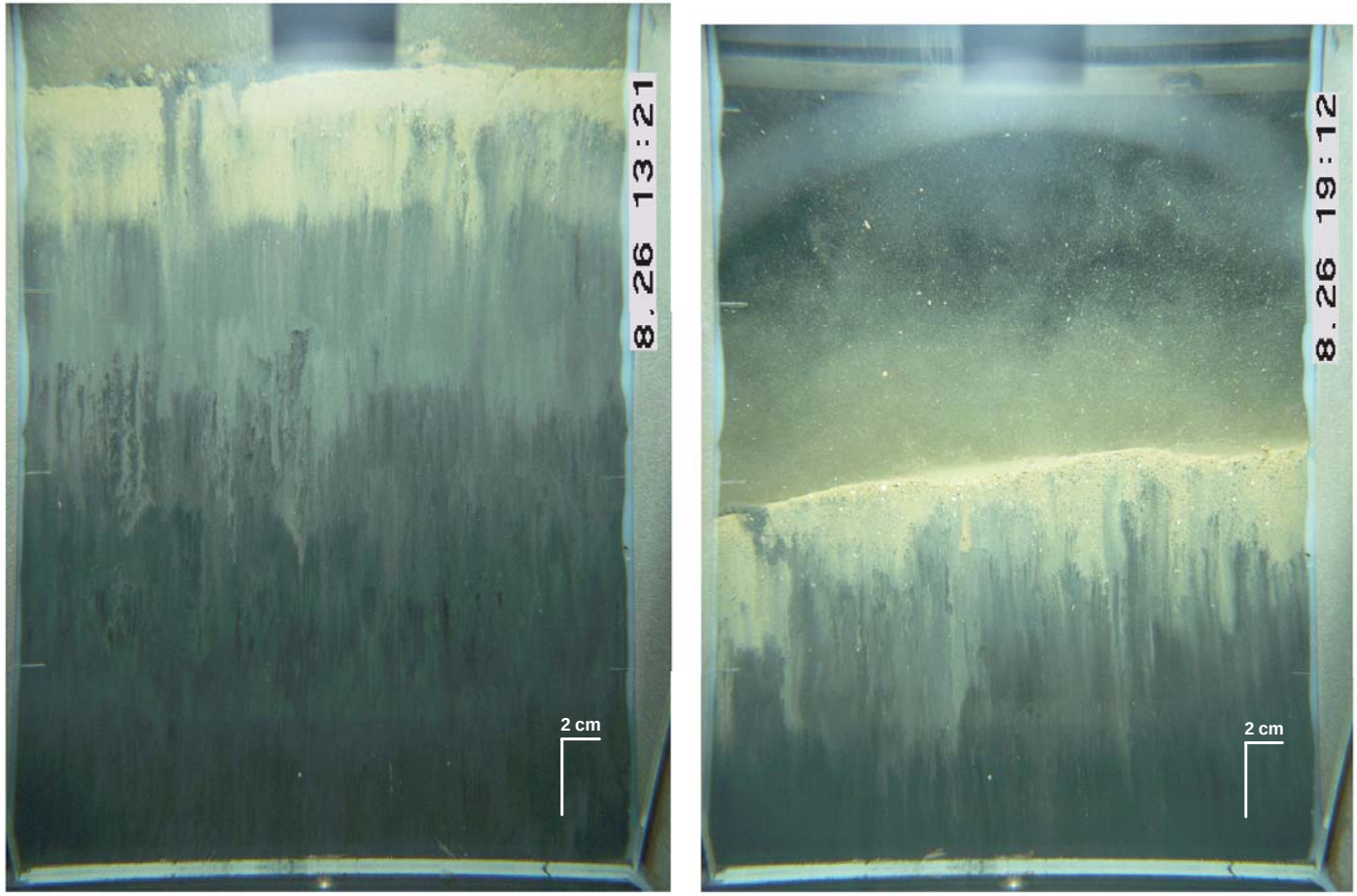

Figure 3-29. Representative SPI images from Mystic River, cell M2 and reference. The most common sediment type was silty-clay, as shown at Mystic River station, M2-1(left), and Mystic reference area, MREF-6 (right). Alternating light and dark gray layers were also evident, possibly indicative of resuspension/deposition events.

Obvious sedimentary features in the Mystic River SPI images included the muddy texture and clay content of the sediments, as well as color layering (Figure 3-29). Layers alternated between light-gray and dark-gray, likely generated by resuspension/deposition events. Light-gray clay, assumed Boston Blue Clay, appeared to be present in the form of gravel to cobble-sized clasts. Boston Blue Clay was observed at 10 stations within cells M4, M5, M8-11, and MREF in the Mystic River (Figure 3-31). These clay clasts occurred both at the sediment surface and subsurface in cell M5, but were all subsurface in cells M4 and M8-11. At the MREF stations the clasts were all at the surface. No Boston Blue Clay was observed in images taken in cells M2, M12, M19, or the Supercell.

Biological Conditions

Images taken at the Mystic River cells showed a very low level of biogenic activity. The predominant biogenic features present in the images from the Mystic River were small tubes at the sediment surface and burrow structures below the sediment surface. Tubes were present in low numbers within all areas sampled. On average, images from stations within the Mystic River cells tended to have few tubes, <2 tubes/image, but images from the Mystic River reference stations had the highest numbers of tubes, >8 tubes/image (Table 3-4, Figure 3-32). Evidence of burrow structures was observed within all areas sampled except cell M5. Of the six MREF stations, images from two of the stations showed burrows. These burrow structures appeared to belong to small successional Stage I polychaetes. Small infaunal organisms (<1 mm [0.04 in] diameter) were observed within all cells sampled; the range in infaunal numbers was 0.2 infaunal organisms per image at cells M2 and M4 to 0.7 infaunal organisms per image at M12 (Table 3-4). MREF had the fewest infaunal organisms present of any of the areas sampled during the 2004 BHCAD SPI survey; only one infaunal organism was seen in all 18 replicate images. One larger infaunal organism (possible *Nephtys* sp.) was observed at station M12-2 and multiple sand shrimp (*Crangon septemspinosa*) were observed at the sediment surface in four of the Mystic River cells (M4, M5, M8-11, and the Supercell) (Figure 3-33). The occurrence of sand shrimp is typically an indicator of reasonably good water quality.

Although there was no previous evidence of advanced successional stage fauna capable of making oxic voids (ENSR 2001, SAIC 2001), there appeared to be oxic voids present at seven or possibly eight of the Mystic River CAD cell stations, specifically stations from cells M4, M8-11, M12, M19, and the Supercell (Table 3-4). No oxic voids were seen in any of the six MREF stations (Table 3-4). All oxic voids were small and within 5 cm (2 in) of the sediment surface. Anaerobic voids were seen in images

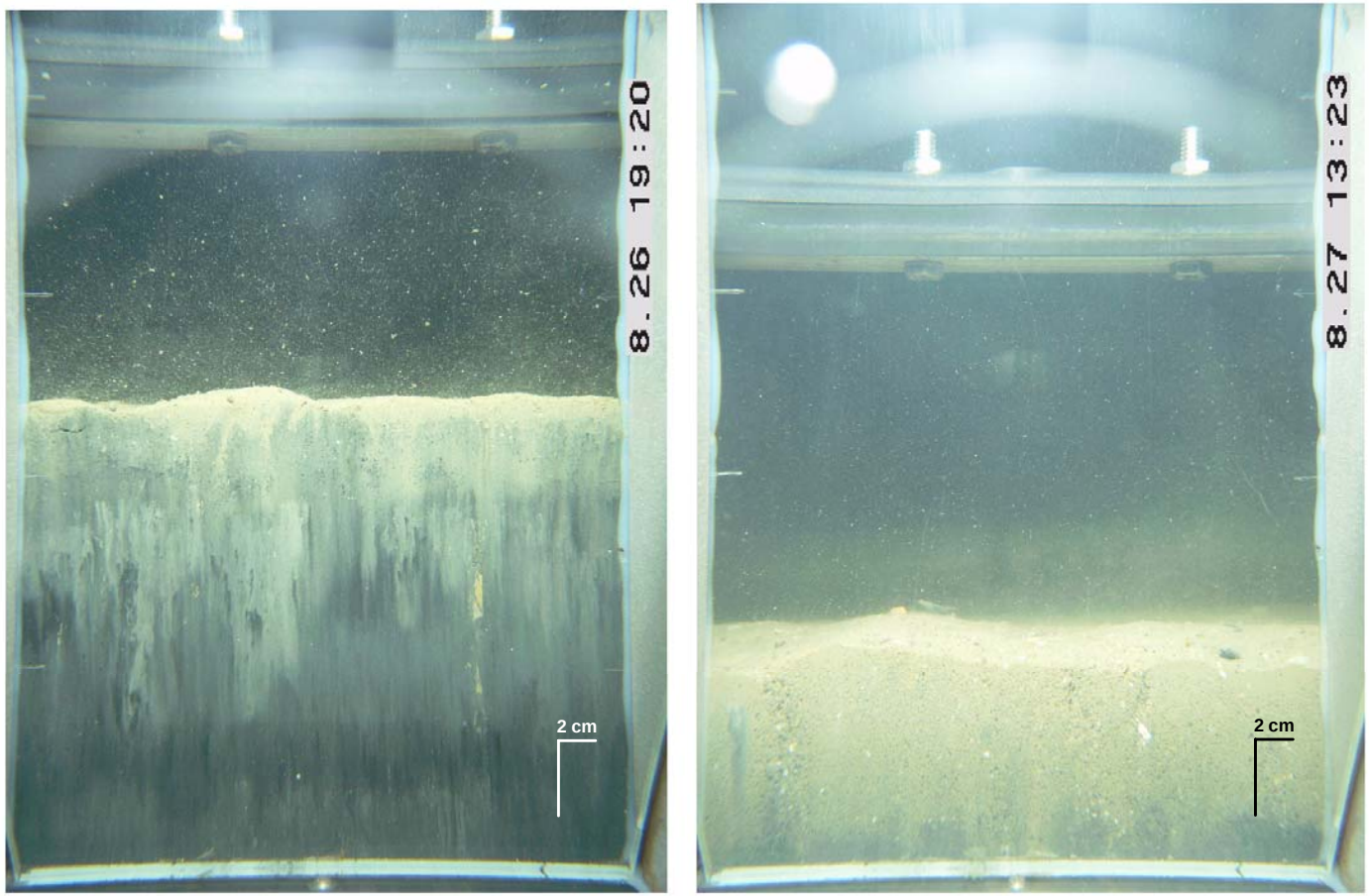

Figure 3-30. Representative SPI images from Mystic River, cells M8-11 and Supercell, Mystic River station, M8-11-1 (left), was dominated by coarser material, consisting of silty-fine-sand. A significant sand component was also present in Supercell stations (SC-4, right).

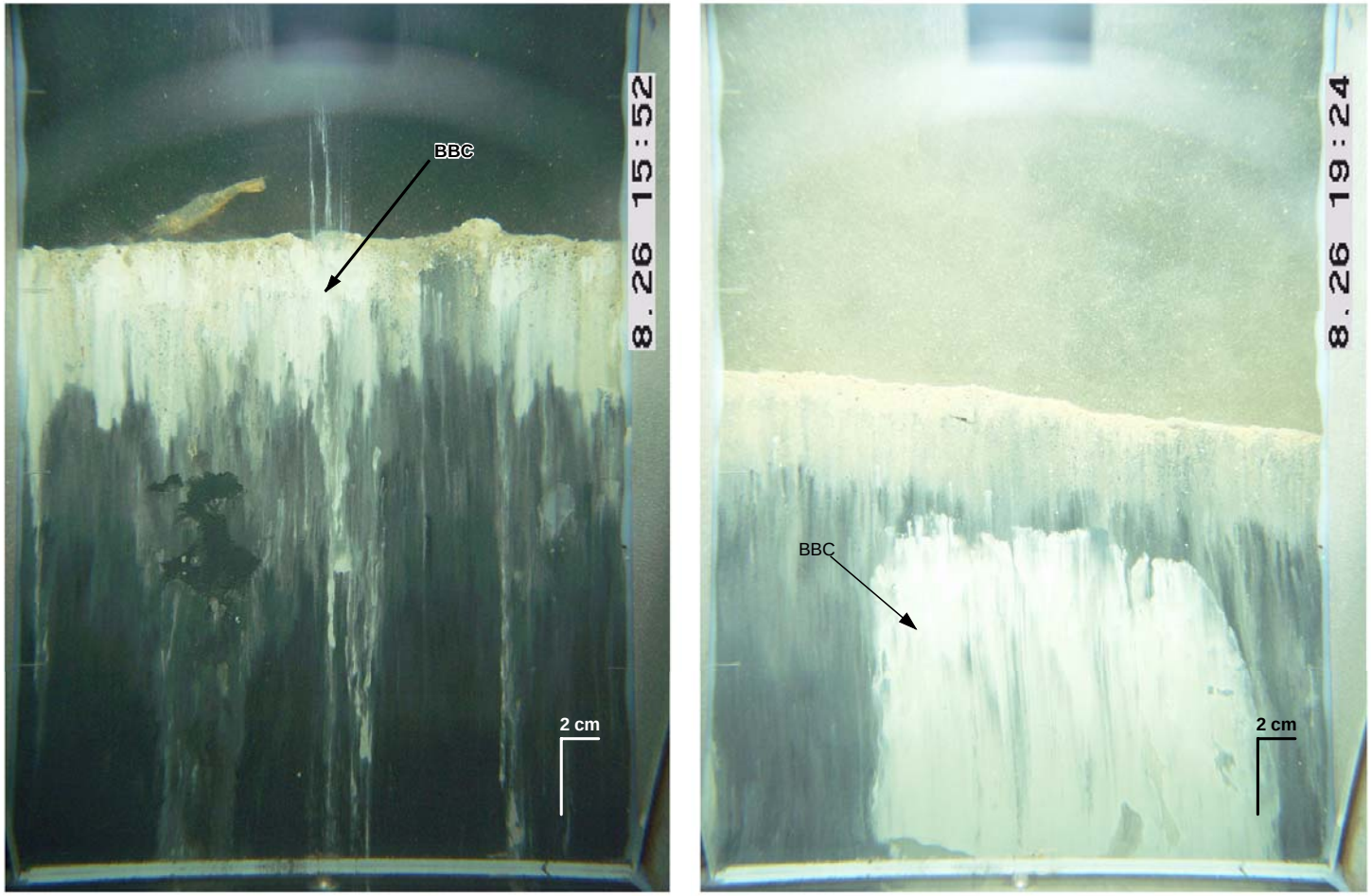

Figure 3-31. Representative SPI images from Mystic River with Boston Blue Clay (BBC) present at both the sediment surface (M5-4, left) and subsurface (right, M8-11-2).

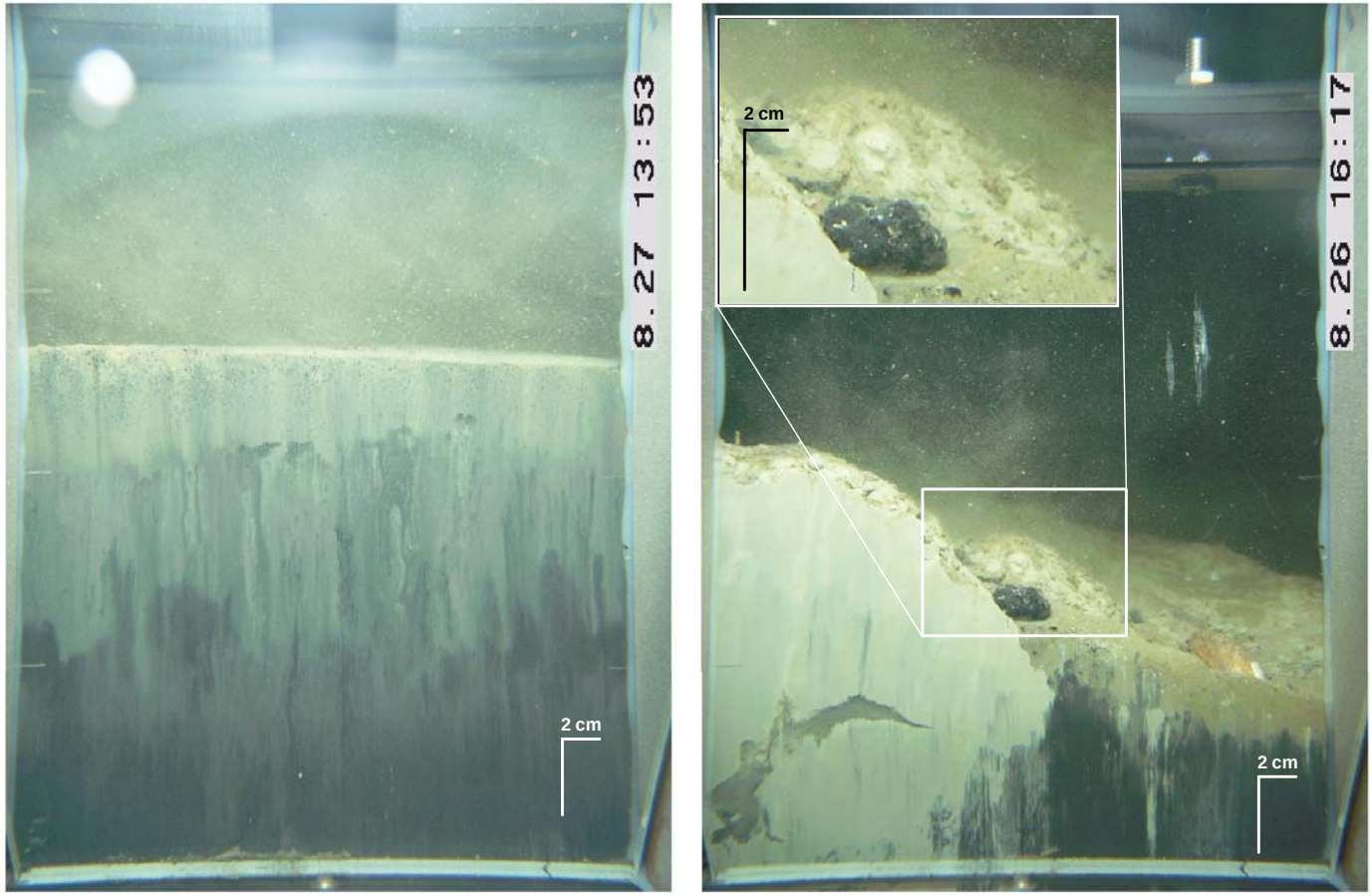

Figure 3-32. Representative SPI images from Mystic River showing variation in biological conditions as measured by the number of tubes present. On average, images from stations within the Mystic River cells (M19-1, left) tended to have fewer tubes than images from the Mystic River reference stations (MREF-5, right).

collected at all Mystic River cell stations and MREF stations. MREF had the lowest number of anaerobic voids per image. Gas voids were observed in three Mystic River CAD cells, ranging in number per image from 0.2 (M5) to 1.7 (M4). Gas voids were also observed at MREF stations (0.5 voids/image) (Appendix B).

The mean RPD depth for Mystic River cells ranged from 0.5 cm (0.2 in) at M5 (the shallowest RPD layer depth in the entire CAD cell survey) to 1.1 cm (0.4 in) at M2 (Table 3-4; Figure 3-27). The overall mean depth of the RPD layer at all seven Mystic River cells was 0.8 cm (0.3 in) (Table 3-4). For cell MREF-1, it was not possible to determine the depth of the RPD layer since the prism over-penetrated the sediment during all three replicate samples. However, for the remaining five MREF stations, the mean depth of the RPD layer was 0.8 cm (0.3 in), ranging from 0.6 to 0.9 cm (0.2 to 0.4 in) (Table 3-3).

The apparent modal successional stage indicated that the infaunal community was overwhelmingly dominated by pioneering Stage I at all Mystic River CAD cell stations and MREF stations. Eight replicate images were designated as successional Stage I to III based on the assumption that the oxic voids were active feeding structures; four of these were from cell M8-11. Stage I to III communities were also observed in images from stations M4-3, M12-3, M19-3, and SC-1 (Table 3-4).

The station averaged OSI for the Mystic River CAD cells ranged from 1.9 (M5) to 3.3 (M8-11), with an overall average of 2.9 (Tables 3-2 and 3-4; Figure 3-28). Eight station replicates had OSI values of 6.0 or 7.0 (Appendix B). The highest OSI values were associated with stations that had oxic voids and had a successional stage designation greater than Stage I. The lowest OSI values were associated with stations that had gas voids (Table 3-4). MREF stations (MREF-1 excluded because of an indeterminate OSI) had average OSI indices that ranged from 2.0 to 3.0 with an overall average of 2.5 (Table 3-3).

3.4.3 Chelsea

Sediment Physical Characteristics

The predominant sediment type within CAD cell C12 was silt-clay (>4 phi) (Table 3-5). In contrast, sediments from the three CREF reference stations, located upstream from the CAD cell, consisted of coarser material (Figure 3-34). Station CREF-3 had the coarsest sediment, in which grain size ranged from 4 to 1 phi (Table 3-5).

Table 3-5
Summary of SPI Results for BHCAD Chelsea River Stations, August 2004

Area	Station	Mean Prism Penetration Depth (cm)	Mean Boundary Roughness (cm)	Mean RPD Depth (cm)	Grain Size Major Mode (phi)	Mean No. Tubes (#/image)	Mean No. Infauna (#/image)	Mean No. Oxic Voids (#/image)	Average No. Anaerobic Voids (#/image)	Successional Stages present (No. replicates)	Mean OSI
Chelsea River	C12-1	14.1	2.2	1.6	>4	6.3	1.0	0.0	2.0	I (3)	3.7
	C12-2	18.0	2.8	1.9	>4	1.3	0.0	0.0	0.0	I (3)	4.5
	C12-3	14.8	1.1	1.3	>4	1.0	0.0	0.0	1.7	I (3)	2.7
	C12-4	17.2	1.1	1.3	>4	2.0	2.0	0.0	1.3	I (3)	2.7
	C12-5	21.5	1.1	1.5	>4	2.0	0.3	1.0	1.7	I (1), >I (2)	4.0
	C12-6	13.7	1.4	1.3	>4	3.3	2.0	0.5	1.0	I (1), >I (1), I-III (1)	5.0
	CREF-1	10.6	1.5	0.9	>4	1.0	1.0	0.3	0.3	I (2), >I (1)	2.5
	CREF-2	8.5	1.6	0.8	>4	6.7	0.0	0.3	0.0	I (2), >I (1)	2.5
	CREF-3	3.4	0.6	1.3	4 to1	0.0	0.0	0.0	0.0	I (3)	3.7
C12 Average		16.5	1.6	1.5		2.7	0.9	0.3	1.3		3.8
CREF Average		7.5	1.2	1.0		2.6	0.3	0.2	0.1		2.9

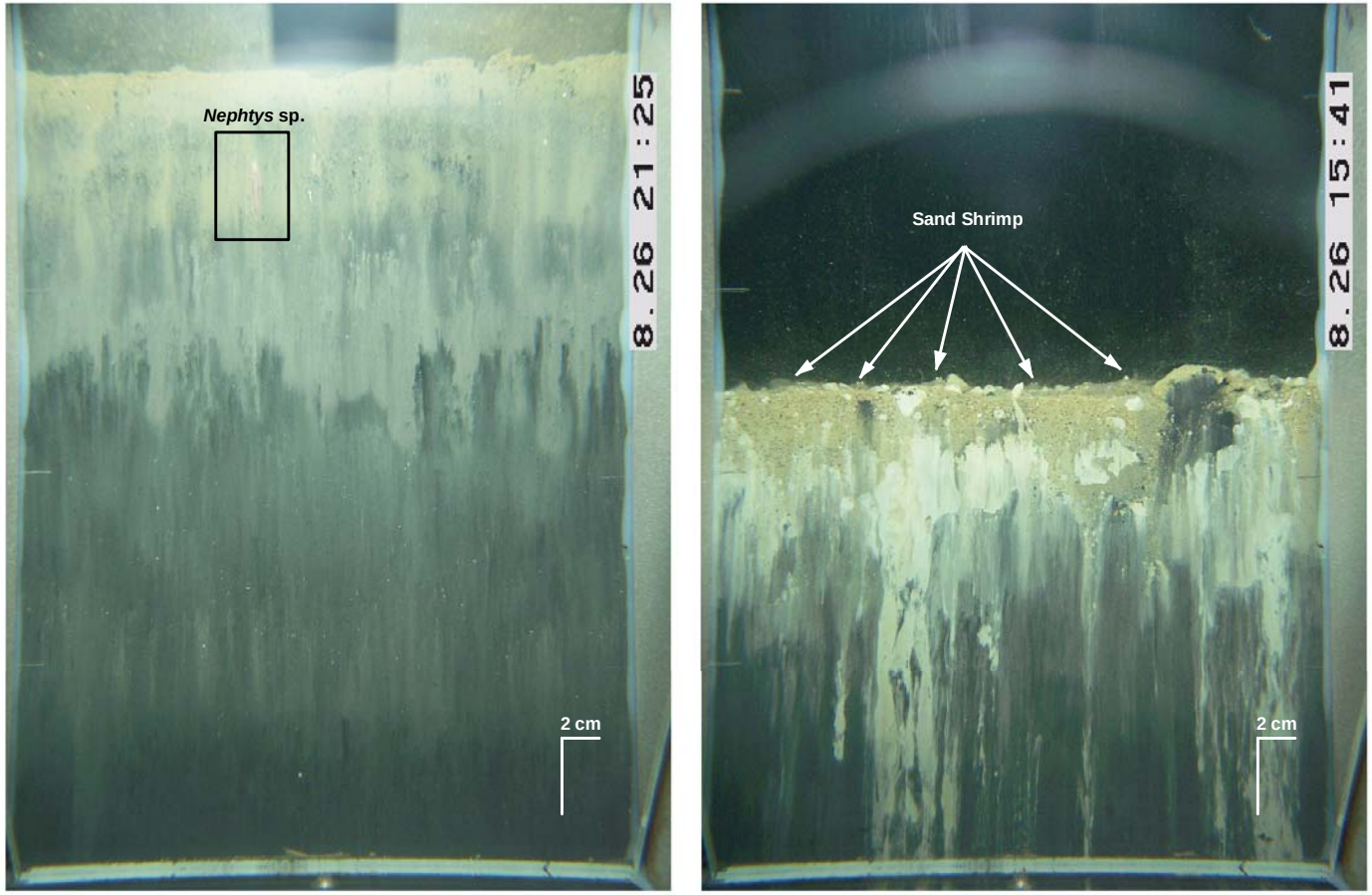

Figure 3-33. Representative SPI images from Mystic River cells M12 and M5. All of the infaunal organisms observed were small, except for the *Nephtys* sp. worm present at station M12-2 (left). Sand shrimp, *Crangon septemspinosa*, were also observed on the sediment surface at many Mystic River stations (M5-2, right).

Physical processes dominated the sediment surface at all Chelsea River stations. Bedforms were observed at the sediment surface of station CREF-3 while the sediment surfaces at all other C12 and CREF stations consisted of uniform, unconsolidated mud (Figure 3-34). Average boundary roughness was 1.6 cm (0.6 in) for the six Chelsea C12 stations and 1.2 cm (0.5 in) for the three Chelsea reference stations (Table 3-5).

Color layering was an obvious feature in the SPI images from the Chelsea River. Layers alternated between light-gray and dark-gray, and were likely generated by resuspension and deposition events.

Biological Conditions

The predominant biogenic features in the images from the Chelsea River stations were small tubes at the sediment surface and burrow structures below the sediment surface. Tubes were present in low numbers both in cell C12, with 2.7 tubes per image, and CREF, with 2.6 tubes per image (Table 3-5). Three of the six C12 stations and one of the three CREF stations had burrow structures, which appeared to belong to small successional Stage I polychaetes. Small infaunal organisms (< 1 mm [0.04 in] diameter) were observed at four C12 stations and one CREF station. The mean number of infauna per image was 0.9 for C12 stations and 0.3 for CREF stations (Table 3-5). The sand shrimp, *Crangon septemspinosa*, was observed on the sediment surface at two Chelsea River stations C12-3 and C12-6 (Figure 3-35).

Oxic voids were observed in images from C12 cell stations C12-5 and C12-6 as well as stations CREF-1 and CREF-2 (Table 3-5). All oxic voids were small and within 5 cm (2 in) of the sediment surface. Anaerobic voids were also observed at five of six C12 stations and one of three CREF stations (Table 3-5). Gas voids were observed at three C12 stations but not at any of the CREF stations (Appendix B).

The mean RPD depth for C12 stations was 1.5 cm (0.6 in), the deepest seen in any of the CAD cells sampled during the 2004 survey (Table 3-5). The deepest RPD layer was observed at station C12-2 with an average RPD of 1.9 cm (0.7 in) (Table 3-3; Figure 3-27). The average RPD at the CREF stations was 1.0 cm, (0.4 in) the deepest seen in any of the three reference areas sampled (Table 3-5; Figure 3-27).

The apparent modal successional stage indicated that the infaunal communities were dominated by pioneering Stage I organisms at four of the six C12 stations and at all three CREF stations. The low degree of biogenic sediment reworking observed at most stations was consistent with Stage I fauna. Two replicate images at stations, C12-5 and

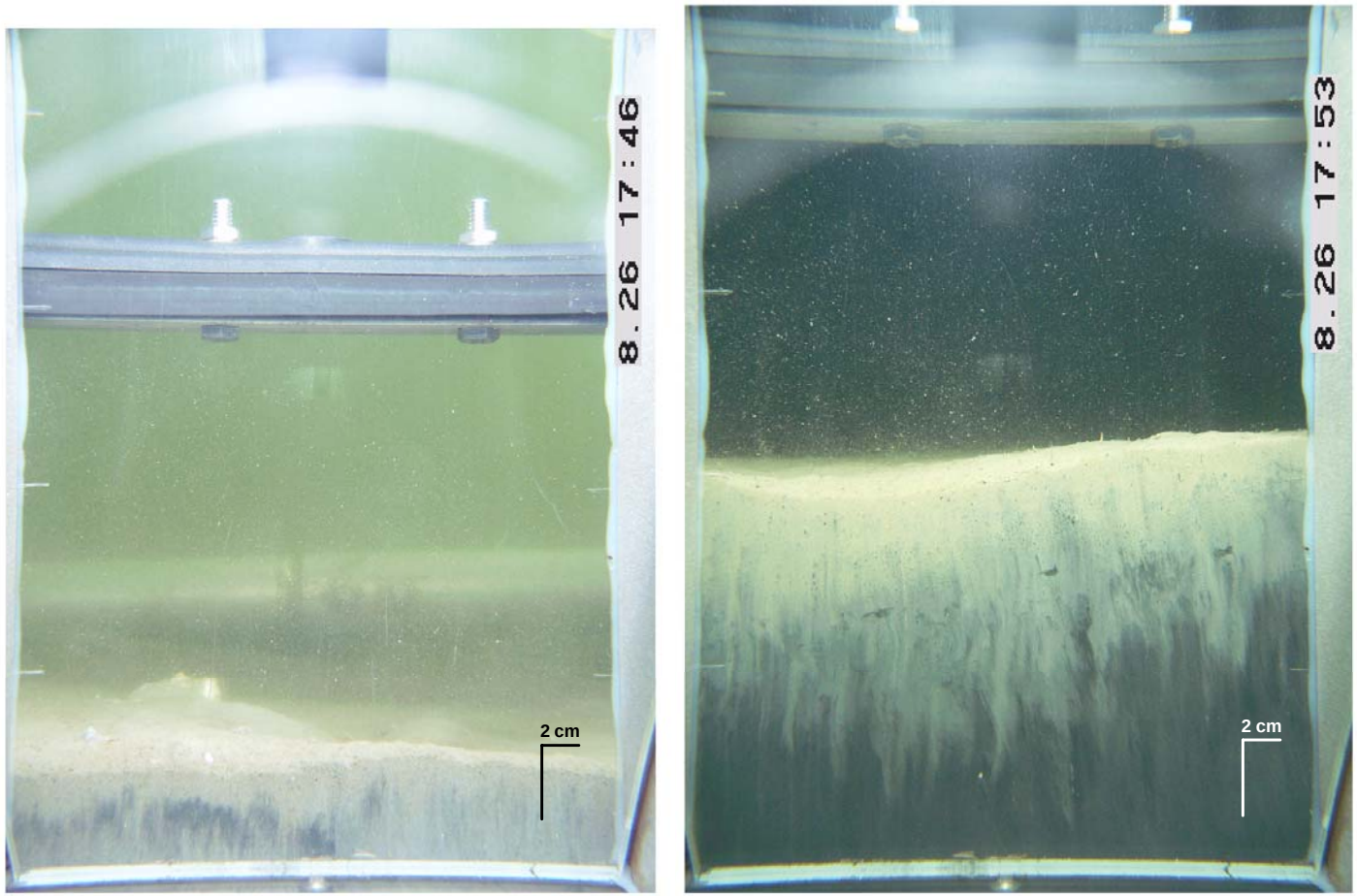

Figure 3-34. Representative SPI images from Chelsea River stations. Coarse, sandy material and bedforms were observed at station CREF-3 (left) while all other C12 and CREF stations consisted of uniform, unconsolidated mud (right, C12-1).

C12-6, showed structures considered to be oxic voids (Appendix B), and were designated as successional Stage I to >I, based on the assumption that these voids were active feeding structures. Two of five stations sampled at the C12 cell showed evidence of having some advanced successional stage fauna.

The average OSI was 3.8 for C12 stations and 2.9 for CREF stations (Table 3-3). Station-averaged OSI values ranged from 2.7 (C12-3 and C12-4) to 5.0 (C12-6) at C12 stations and 2.5 (CREF-1 and CREF-2) to 3.7 (CREF-3) at Chelsea reference stations (Table 3-5; Figure 3-28). One station replicate (C12-6) had an OSI of 7.0 (Appendix B).

3.4.4 Comparison of 2004 Results with Previous SPI results

The first SPI survey of the CAD cells was conducted over Inner Confluence cell IC2 and Mystic River cells M2, M4, and M8-11 in June 2000 (ENSR 2001). All nine BHCAD cells were sampled again in August 2001 (SAIC 2001). SPI results from June 2000, September 2001, and August 2004 are summarized in Table 3-6.

Sediment Physical Characteristics

The August 2004 SPI substrate characterization was different from that reported in June 2000 (ENSR 2001) and September 2001 (SAIC 2001). In 2000 and 2001 there was more variation in sediment grain-size and texture within and between cells than in 2004. The general substrate conditions were more similar between the CAD cells and reference areas in August 2004. Surface sediments down to about 20 cm (8 in) were uniform silt-clay in the majority of the CAD cells. The only CAD cell stations that appeared to contain significant quantities of sand were M8-11-1, SC-1, and SC-4. Sand was also a more prominent component of the sediment at the reference areas, CREF and IC-REF. This is in contrast to previous surveys that found significant quantities of sand near the sediment surface in many of the cells.

In June 2000, four CAD cells and reference areas were sampled with surficial sediments containing sand in cells M2, M4, and M8-11, and little to no sand in cell IC2. At the time of the first SPI survey in June 2000 (ENSR 2001), cell M8-11 had not yet been capped, and no coarse capping sand was seen in the SPI images.

In September 2001, nine CAD cells and reference areas were sampled for a second time (SAIC 2001). By September 2001, grain size of the surficial sediments in both the CAD cells and reference areas was finer relative to that seen in June 2000.

Table 3-6
Summary of June 2000, August 2001, and August 2004 SPI results

Cell/Area	Year	No. of samples	Mean RPD (cm)	Grain Size Major Mode (phi)	Min Successional Stage	Max Successional Stage	Mean OSI
IC2	2000	8	0.7	>4	I	I	2.3
IC2	2001	6	1.3	>4	I	III	5.5
IC2	2004	6	0.8	>4	I	I	2.8
IC-REF	2000	4	1.2	>4	I	I-II	3.3
IC-REF	2001	1	1.3	>4	I	III	6.3
IC-REF	2004	3	0.7	>4	I	I to III	3.2
M2	2000	8	0.1	>4	Azoic	I	-4.4
M2	2001	6	0.7	>4	Azoic	III	2.4
M2	2004	4	1.1	>4	I	I	2.9
M4	2000	8	0.4	>4	I	I	1.5
M4	2001	6	1.0	>4	I	III	3.2
M4	2004	4	0.8	>4	I	I to III	3.0
M5	2001	6	2.1	>4	Azoic	I	4.0
M5	2004	4	0.5	>4	I	I	1.9
M8-11	2000	8	0.6	>4	I	I-II	2.5
M8-11	2001	6	1.4	4 to 3	I	I	3.4
M8-11	2004	5	0.6	>4	I	I to III	3.3
M12	2001	6	1.5	>4	I	III	4.4
M12	2004	4	1.0	>4	I	I	2.9

June 2000 data from ENSR(2001), September 2001 data from SAIC (2001)

Table 3-6 (continued)
Summary of June 2000, August 2001, and August 2004 SPI results

Cell/Area	Year	No. of samples	Mean RPD (cm)	Grain Size Major Mode (phi)	Min Successional Stage	Max Successional Stage	Mean OSI
M19	2001	6	1.0	>4	I	III	3.6
M19	2004	8	1.0	>4	I	I	3.1
Supercell	2001	6	2.0	>4	I	III	4.4
Supercell	2004	7	0.8	>4	I	I	2.7
MREF	2000	9	0.5	>4	I	I	1.8
MREF	2001	1	1.7	>4	I	I	4.0
MREF	2004	6	0.8	>4	I	I	2.5
CR	2001	6	1.6	>4	I	III	4.4
C12	2004	6	1.5	>4	I	>I	3.8
CREF	2004	3	1.0	>4	I	I	2.9

June 2000 data from ENSR (2001), September 2001 data from SAIC (2001)

Biological Conditions

OSI results indicated that the general benthic habitat conditions have been consistently stressed since the initial SPI survey in June 2000. Most of the areas sampled had average OSI values <6; the only exception was IC-REF in September 2001 when SAIC (2001) reported the area to have an average OSI of 6.3 (Table 3-6).

Opportunistic or pioneering successional Stage I species appeared to dominate the community in all three surveys. There was little evidence of advanced successional Stage III organisms in the SPI images from August 2004 or previous surveys (Table 3-6). Large, deep-burrowing species characteristic of an equilibrium successional stage were absent at all locations.

3.4.5 Plan Video and Deep Penetrating SPI Camera

The video footage from the plan-view camera attached to the frame of SPI array was reviewed. Given the poor water clarity, the bottom was visible for only a short segment just prior to camera frame impact on the bottom. However, the video footage provided further support of the physical and biological data presented above; the predominance of fine surficial sediment was apparent, and biota were observed within the cells and reference areas (including one juvenile lobster).

For the demonstration of the deep-penetrating SPI camera, penetration depths varied at the 12 stations, with many reaching the full depth of 30 cm (1 ft). Composite sediment-profile images were constructed from the video footage at three stations (Figure 3-36). The resolution of the composite image is much less than that of a standard SPI camera, but changes in sediment type can be resolved. At Stations IC2-1 and M12-1 alternating bands of light and dark sediment bands are visible over the length of the images. At Station M4-3 Boston Blue Clay could be identified within the darker sediment matrix. Observations from the video image at Station M8-11-3 indicated possible sand cap material at 23 cm (9 in), the extent of the penetration, evidenced by a change in sediment consistency. At Station SC-2, there was no evidence of a sand cap layer over the 26 cm (10 in) of penetration. At Station M19-8, a crunchy sound was heard at the penetration depth of 16 cm (6 in), potentially indicative of a sand pocket.

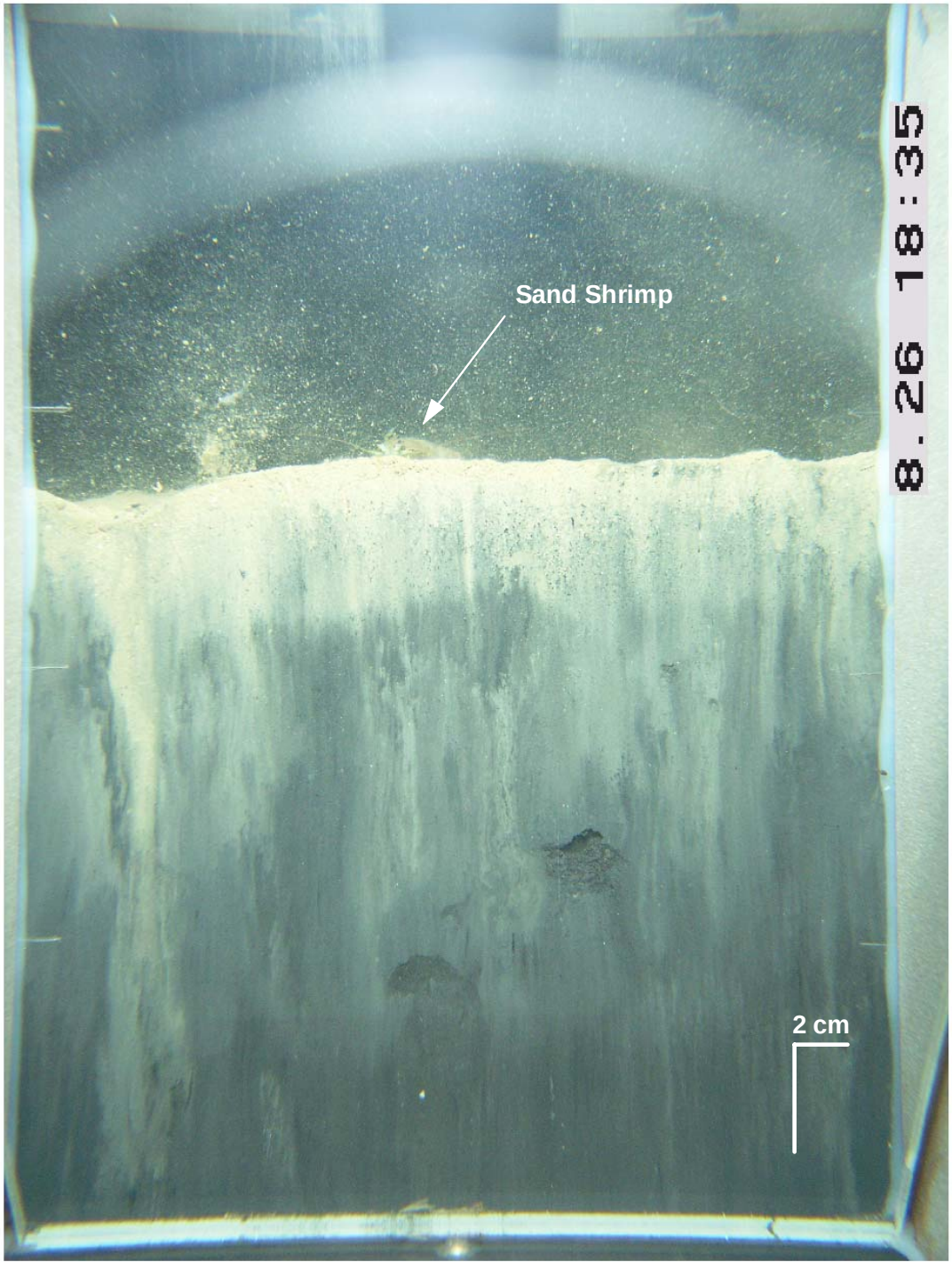

Figure 3-35. SPI image from Chelsea River station, C12-6. Sand shrimp, *Crangon septemspinosa*, typically indicate reasonable water quality.

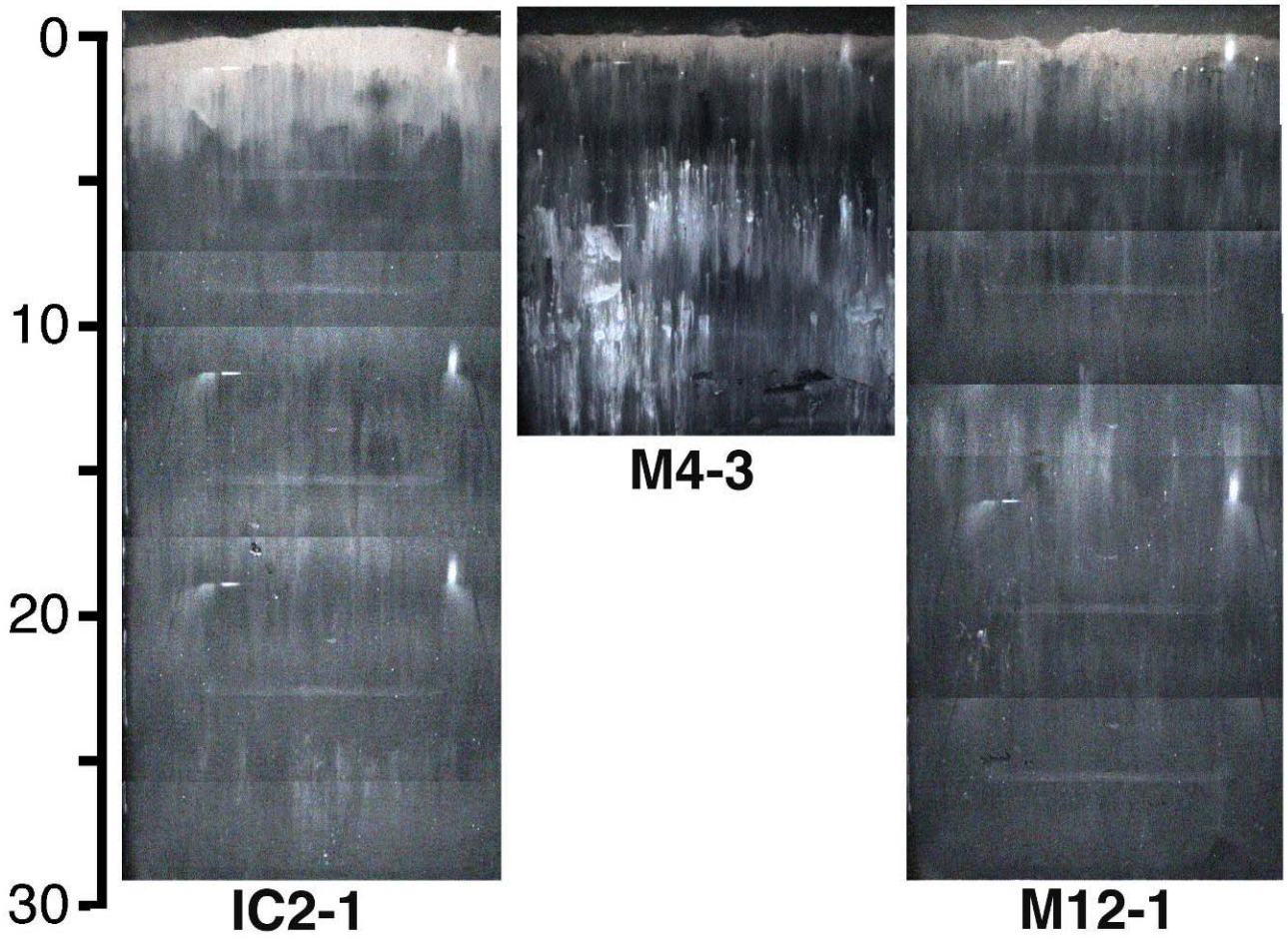

Figure 3-36. Composite images from video footage collected using the deep-penetrating SPI camera

4.0 DISCUSSION

Confined aquatic disposal (CAD) was developed as a practical alternative for sediments deemed unsuitable for unconfined open water disposal (Fredette and French 2004). The technique involves isolating contaminated sediments within depressions or cells cut into the bottom and optionally capped with a layer of clean material. The Boston Harbor Navigation Improvement Project (BHNIP), carried out between 1997 and 2000 (with minor work performed in fall 2001), represented the first large scale use of CAD cells cut directly into the footprint of the navigable channel. As such, a series of investigations were performed during and following completion of the project to assess the effectiveness of dredged material disposal into the cells and cap placement as well as the long term stability and benthic recovery of the cells.

A total of nine CAD cells were constructed as part of the overall project. Eight of the cells were capped with sand, and the ninth remained uncapped at the end of the project with excess capacity. Four rounds of capping were performed over the course of the project (one cell in 1997, three cells in 1998, two cells in 1999, and two cells in 2000). Based on cell/cap investigations performed following capping, the consolidation time prior to capping (the length of time the material disposed into the cells was allowed to settle) and the capping technique were modified during each subsequent capping round to improve performance (Fredette et al. 2000).

A survey of all of the CAD cells was performed in 2001, approximately one year following completion of the overall BHNIP, and one to four years after completion of individual cells (SAIC 2001). The survey included coring, sediment-profile imaging (SPI), and benthic community assessment, and found that the cells were maintaining their original stratigraphy and that the surface of the cells had been recolonized to a similar community structure as the surrounding harbor bottom (pioneering Stage I species). The cells continued to be the focus of study, and during a spring 2002 investigation of potential methane gas production within one cell, divers installing equipment noted a steep vertical relief of 1 to 2 m (3.3 to 6.6 ft) within cell M19. Limited dredging of the harbor bottom immediately around the perimeter of this cell had been performed earlier in 2002, with the material (primarily Boston Blue Clay) placed directly into cell M19. Because of concerns that the vertical relief noted by the divers could indicate a change in the cap structure (potentially caused by the additional material placement), follow-up investigations were performed over cell M19 in summer 2002 including bathymetry, side-scan sonar, towed video sled, and sediment grab sampling for physical characterization (SAIC 2003a). These investigations indicated that the cap did not appear to be affected in the immediate area of the additional dredged material placement. The 2002 investigations

also identified other areas where consolidation of M19 cell material had likely occurred as well as a linear depression (approximately 110 m [360 ft] long, 10 to 25 m [32.8 to 82.0 ft] wide, and 1.5 to 2.5 m [4.9 to 8.8 ft] deep) of unknown origin. The August 2004 investigation was performed as a long term follow-up as a requirement of the WQC, four to seven years after completion of individual CAD cells, to address the following objectives:

- Assess the general physical status of the surface of each of the nine CAD cells to evaluate cell stability and long term integrity and thickness of the cap and overlying silts, with a more detailed assessment performed over cell M19.
- Determine bathymetry by performing a multi-beam bathymetric condition survey over the cells.
- Assess the benthic recolonization status of each of the nine CAD cells.

4.1 Physical Condition of CAD Cells

The August 2004 survey identified all nine CAD cells as distinct topographic features on the harbor bottom. The physical condition of the surface of each cell is discussed individually below and collectively in Section 4.1.4 based on the combined results of all survey components (swath bathymetry, side-scan sonar, and SPI (outfitted with a plan-view video camera) on all cells; towed video on six cells).

4.1.1 Inner Confluence Cell IC2

The August 2004 survey was performed seven years following the capping of cell IC2. The only cell constructed in the first phase of the BHNIP, cell IC2 was relatively shallow (cut approximately 6 m [20 ft] below the harbor bottom) and had a short consolidation time (nine days). The topography of the cell in 2004 appeared similar to that immediately after capping, more disturbed in the northern portion where the sand placement resulted in mounds that were redistributed with the dredge bucket and smoother in the southern portion where little or no capping sand had been placed (SAIC 1999). The depth-difference assessment for this cell compared August 2004 swath bathymetry with October 1997 single beam bathymetry, potentially resulting in some artifacts due to the differing techniques. The depth difference identified likely consolidation in the uncapped southern portion of the cell. Potential collapse of the exposed eastern margin (the 1 to 2 m [3.3 to 6.7 ft] of steep cell wall that rose above the cell surface) was expected given its close proximity to finger piers that are heavily used by tugboats/barges (see Figure 3-2). The accretion that was identified in several areas by the depth-difference was likely due to infilling of smaller depressions within and around

the cell that were apparent in the October 1997 survey soon after capping (SAIC 1999). The potential collapse of sidewalls and redistribution of material over the cell was consistent with the shift in surficial sediments between 1997 and 2004; the northern and central portions of the cell had sand cap exposed at the surface in 1997 whereas silt/clay was the dominant surficial material identified in the 2004 survey.

4.1.2 Mystic River Cells

The Mystic River cells were capped in three rounds during Phase 2 of the BHNIP. The capping technique was modified in the first and second round, and the consolidation time was extended for each subsequent round to improve capping performance (Fredette et al. 2000).

Cells Capped in November 1998

Cell M4 – Cell M4 was capped following a 33-day consolidation period. The investigations performed immediately following the capping revealed that given the short consolidation period, the material within the cell was still quite fluid, allowing the capping sand to sink into and mix with the cell contents, leaving a uniform surface composed predominantly of fine material (Ocean Surveys 1999a). The surface of the cell appeared quite similar in the 2004 survey. Comparison of the 2004 bathymetry data with June 2001 data indicated that the contents of the cell were stable with no appreciable change in depth. The depth difference indicated that cell wall collapse of up to 1 m (3.3 ft) had occurred along the cell margin. This was expected given the approximately 3 m (10 ft) of exposed face and steepness of the cell sidewalls cut into the Boston Blue Clay and was further supported by the weathered clay clasts identified on the surface of the cell in 2004.

Cell M5 - Cell M5 was capped following a 52-day consolidation period. The investigations performed immediately following the capping revealed that the sand cap remained as a distinct layer, but that more fluid material from within the cell was displaced to the surface over the sand cap, leaving a uniform surface similar to cell M4 composed predominantly of fine material (Ocean Surveys 1999a). Also similar to cell M4, the surface of the cell M5 appeared unchanged in the 2004 survey, and comparison of the 2004 bathymetry data with June 2001 data indicated that the contents of the cell were stable with no appreciable change in depth. The depth difference indicated that erosion of up to 1 m (3.3 ft) had occurred along the southern cell margin. Although there was less of the cell wall exposed in M5 (it was filled to a depth closer to the harbor

bottom), erosion of the steep face was expected over time, especially given the location of cell M5 directly adjacent to a large ship terminal (see Figure 3-7).

Cell M12 - Cell M12 was capped following a 49-day consolidation period with limited additional disposal taking place partway through the period. The investigations performed immediately following the capping revealed a very heterogeneous cell surface with areas of sand, sand mixed with dredged material, and solely dredged material exposed at the surface. This was attributed to the relatively short consolidation period and the thickness of the dredged material layer (M12 was one of the deeper cells extending to over 20 m [66 ft] below the surrounding harbor bottom). During the 2004 survey, silt-clay was identified as the predominant surficial material. Although an earlier dataset was not available for a depth-difference assessment, the relatively smooth surface of the cell and the uniform depth that was comparable with post-cap measurements (USACE 1999) suggests that no significant cap disturbance had taken place.

Cells Capped in November 1999

Cell M2 – Cell M2 was capped following a five-month consolidation period. The investigations performed immediately following the capping revealed that sand was exposed at the surface over much of the cell with only limited areas of silty material (Ocean Surveys 1999b; USACE 2000). Subsequent investigations revealed that the sand cap was located at depth, below a layer of fine-grained material (ENSR 2001; SAIC 2001). The 2004 survey identified silt-clay as the predominant surficial sediment, attributed to ongoing deposition over the cell. The absence of sand observed in the 2004 survey in neither the SPI nor the deep-penetrating images indicated a sedimentation rate (including redeposition and cell wall collapse) of at least 7 cm/yr. The 2004 survey revealed no change in surface topography indicative of cap disturbance, and comparison of the 2004 bathymetry data with June 2001 data indicated that only limited net consolidation ($\sim$0.5 m [1.6 ft]) had occurred over portions of the cell.

Supercell - The Supercell was capped following a five-month consolidation period. The investigations performed immediately following the capping revealed that sand was exposed at the surface over much of the cell with only limited areas of silty material (Ocean Surveys 1999b; USACE 2000). The one–year follow-up survey indicated that the sand layer was 7 to 36 cm (0.3 to 1.2 ft) below the surface (SAIC 2001). Although some coarse material was identified at the surface in the 2004 survey, silt-clay was identified as the predominant surficial sediment and was attributed to ongoing deposition over the cell. The absence of sand observed in the 2004 survey in neither the SPI nor the deep-penetrating images indicated a sedimentation rate (including redeposition and cell wall

collapse) of at least 7 cm/yr. The 2004 survey revealed no change in surface topography indicative of cap disturbance, and comparison of the 2004 bathymetry data with June 2002 data indicated that only limited net consolidation (~ 0.5 m [1.64 ft]) had occurred over portions of the cell.

Cells Capped in September 2000

Cell M8-11 - Cell M8-11 was capped following a consolidation period of approximately eight months with limited additional disposal taking place partway through the period. The investigations performed following the capping revealed that the sand cap remained exposed at the surface across the entire cell (Ocean Surveys 2000; SAIC 2001). Some coarser material was visible in the towed video and sediment-profile images for cell M8-11 during the 2004 survey, and a change in sediment consistency at the bottom of the deep-penetrating image may be indicative of the top of the cap. However, silt-clay was identified as the dominant fraction in 2004 indicating ongoing deposition over the cell. A limited amount of project follow-up dredging was performed around the perimeter of cell M8-11 in fall 2001, with the dredged Boston Blue Clay placed directly into the cell. This material was quite distinct in the 2004 survey, mounded above the cell surface, demonstrating the strength of the underlying capped cell at supporting the highly consolidated Boston Blue Clay. The absence of sand observed in the 2004 survey in neither the SPI nor the deep-penetrating images indicated that at least 30 cm (the depth of the deep-penetrating camera image) of sediment had accumulated since the cell was capped in 2000, suggesting a sedimentation rate (including redeposition, dredged material placement, and cell wall collapse) of at least 7.5 cm/yr. Comparison of the 2004 bathymetry data with June 2001 data clearly identified the dredging around the cell perimeter and placement of material into the cell. A limited amount of net consolidation (up to 1 m [3.3 ft]) was identified over the eastern portion of the cell.

Cell M19 - Cell M19 was capped following a consolidation period of approximately eight months. The investigations performed immediately following the capping revealed that the sand cap was present at the surface across the entire cell (Ocean Surveys 2000). The one-year follow-up survey indicated that the sand cap was present 23 to 117 cm (0.8 to 3.8 ft) below the surface (SAIC 2001). Although some coarser material was visible in the towed video and sediment-profile images for cell M19 during the 2004 survey, silt-clay was identified as the dominant fraction in 2004 indicating ongoing deposition over the cell. Similar to cell M8-11, a limited amount of project follow-up dredging was performed around the perimeter of cell M19 in fall 2001, with the dredged Boston Blue Clay placed directly into the cell. Also similar to cell M8-11, this material was quite distinct in the 2004 survey, mounded above the cell surface,

demonstrating the strength of the underlying capped cell at supporting the highly consolidated clay. The absence of sand observed in the 2004 survey in neither the SPI nor the deep-penetrating images indicated that at least 30 cm (the depth of the deep-penetrating camera image) of sediment had accumulated since the cell was capped in 2000, suggesting a sedimentation rate (including redeposition, dredged material placement, and cell wall collapse) of at least 7.5 cm/yr.

Comparison of the 2004 bathymetry data with June 2001 data clearly identified the dredging around the cell perimeter and placement of material into the cell. Distinctly absent from the depth-difference plot (see Figure 3-15) were any depth changes in the vicinity of the linear depression in the eastern portion of the cell first identified in the spring of 2002. Hence, the depression existed at the time of the June 2001 survey and was not the result of loading the surface of the cell with placement of the dredged clay that occurred in fall 2001.

Limited October 1999 bathymetric data from the constructed (but unfilled) M19 cell were retrieved from Great Lake Dredge and Dock Company and reviewed. The data consisted of a series of north-south transects across the cell. One transect passed through the area of the linear depression, and depths along the transect were compared with the 2004 survey data (Figure 4-1). A deep trough was apparent in the October 1999 data, directly aligned with the linear depression. Hence, it appears that the depression formed as the result of consolidation of the disposed material within the cell that caused the cell surface to mimic the topography of the underlying floor of the cell. Although a map of bathymetry was not available from the time period immediately following capping, a review of sub-bottom profile data from that time indicated that the depression was already at least partially formed in October 2000 (Ocean Surveys 2000).

Based on discussions with Great Lake Dredge and Dock, a large portion of cell M19 was planned to be cut to the 24 m (79 ft) MLLW depth of the trough noted in Figure 4-1. However, partway through construction, projections of the remaining amount of maintenance dredging were revised, and less capacity was required for cell M19. As a result, construction of the cell was terminated, leaving the steep-walled trough as shown in Figure 4-1.

4.1.3 Chelsea River Cell

Cell C12 was the only cell constructed in the Chelsea River and remained uncapped at the end of the BHNIP with additional capacity for use in future projects. Following completion of dredging/disposal operations in 2000, the level of material in the

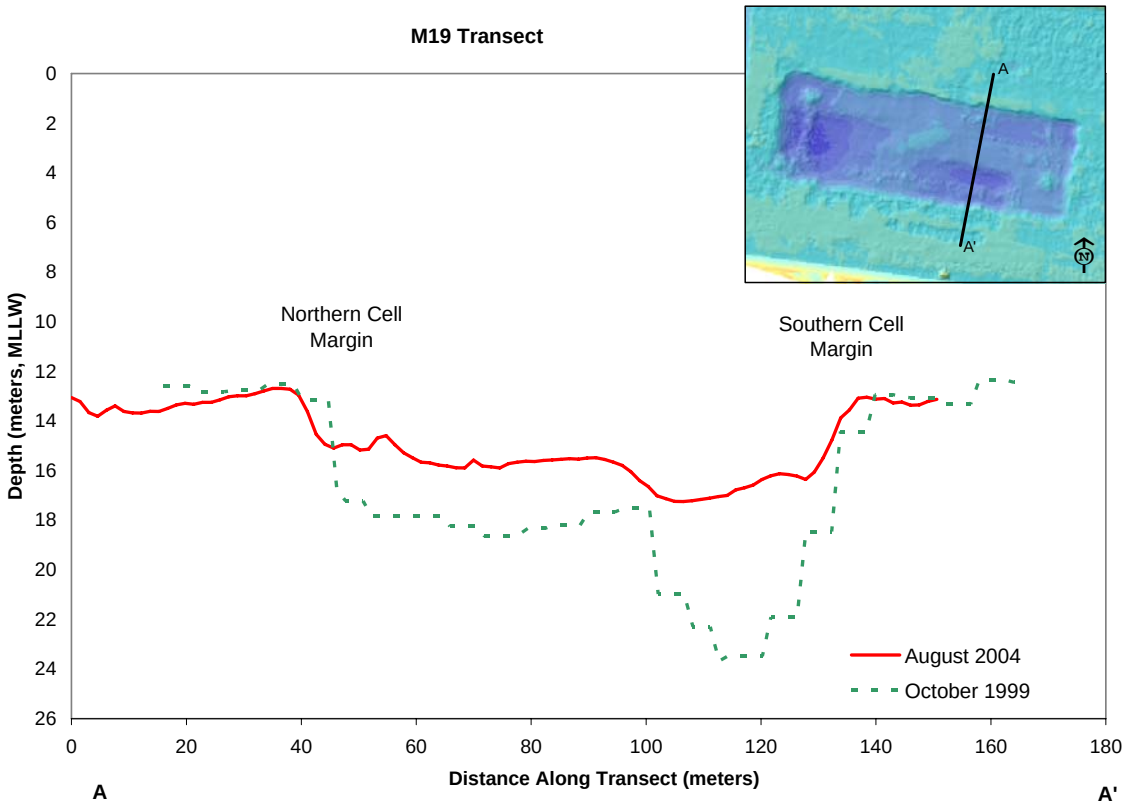

Figure 4-1. Comparison of Cell M19 bathymetry: post-construction (pre-filling) and August 2004

cell was approximately 5 m (16.4 ft) below the surrounding harbor bottom. The 2004 survey revealed no change in surface topography that would be indicative of surface disturbance, and comparison of the 2004 bathymetry data with June 2001 data indicated that only limited consolidation (~0.5 m [1.64 ft]) had occurred over portions of the cell. The depth-difference assessment also indicated collapse of portions of the exposed cell wall. This was expected given the height of the exposed, steep wall and the vessel traffic over the cell (C12 occupies most of the width of the channel – see Figure 3-17).

4.1.4 Physical Condition Overview

The high resolution swath bathymetry and side-scan sonar data collected as part of the 2004 survey revealed that all nine BHNIP CAD cells remained as stable structures four to seven years following completion of individual cells with no evidence of significant cap disturbance or scour. As expected, limited consolidation of the material within the cells had taken place, and some erosion of the exposed sidewalls of the cells that rise steeply above the cell surface had also occurred. Both of these processes are expected to continue into the future, but without effect on the overall structure or integrity of the cells.

Prior to performance of the BHNIP, it was anticipated that the sand-capped cells depressed below the harbor bottom would fill in over time, and the surfaces of the cells would take on the physical characteristics of the surrounding harbor area, i.e., there would be a return to a fine-grained sediment surface similar to that present prior to cell construction (Fredette et al., 2000). The coring, SPI, and benthic sampling performed in 2001 identified a layer of soft, fine material of variable thickness over most of the surface of the cells (SAIC 2001). A pilot-scale sediment transport study was performed over the area of the Mystic River cells in 2002 and identified both upriver and downriver transport of fine material with deposition into the Supercell (SAIC 2003). Although coarse material was still present over the surface of some cells in the 2004 survey, silt-clay was identified as the predominant surficial material over all of the cells. Accretion of material within the cells was not identified in comparing the 2004 bathymetry data with data collected 2 to 7 years prior, indicating that continuing consolidation of the dredged material within the cells likely masked the deposition. Large scale debris (timbers, piles, tires, etc.) were also identified on the surface of some of the cells in 2004. Deposition of fine material (as well as larger debris) is expected to continue into the future, helping to further sequester the material deeper within the cell.

4.2 Biological Conditions

Overall, the biological conditions observed in the SPI images collected in 2004 from the Inner Confluence, Mystic River, and Chelsea River were very similar and were representative of a stressed benthic environment. The low level of biogenic activity indicated that the physical processes of diffusion and resuspension were the primary factors controlling the boundary roughness and RPD layer thickness. The low degree of biogenic sediment reworking observed at most stations was also consistent with the presence of pioneering Stage I fauna. Evidence of successional Stage III organisms in the SPI images was rare. The average Organism Sediment Index (OSI) values for the nine individual CAD cells and the three reference areas ranged from 1.9 to 3.8, indicating that environmental conditions likely had a major effect on infaunal community development. The highest OSI values were associated with stations that had oxic voids and were consequently scored as having successional Stage I to III. Lowest OSI values were typically associated with stations that had gas voids. Despite the SPI assessment of all of the cell and reference stations as representative of a stressed environment, abundant small and medium-sized fish, including juvenile flounder, and shrimp and crabs were evident in the video images. Areas both within and outside of the CAD cells appear to be providing comparable epibenthic habitat.

4.2.1 Inner Confluence Cell IC2

Post cap investigations performed in 1997 revealed that the northern and central portions of the cell had a thick layer of sand at the surface while the southern portion received no cap material (SAIC 1999). Comparison of the 2004 SPI data from the two areas of the cell revealed that seven years following capping of cell IC2 these two areas were nearly identical from both a physical and biological perspective. Fine-grained sediments were observed across the cell throughout the video, with no detectable differences between the northern and southern areas.

4.2.2 Mystic River Cells

The seven cells Mystic River cells were capped in three stages from 1998 to 2000, with the performance of the capping operation improving with each set of cells. Hence, at the time of the 2004 survey, it had been four to six years since these cells were capped. The SPI data were quite similar for all of the cells, despite the differences in the initial physical conditions on the cell surface and the varied time since capping took place. In all cells, numerous fish, crabs, and shrimp were observed in the video images.

In addition, biological conditions over the cells appeared similar to or slightly better than those at the associated reference stations.

4.2.3 Chelsea River Cell

Cell C12 was the only cell constructed in the Chelsea River and remained uncapped at the end of the BHNIP with additional capacity for use in future projects. Overall, biological conditions at the uncapped cell C12 appeared better than those at the associated reference station or any of the other cells or reference stations surveyed in 2004.

4.2.4 Biological Condition Overview

The general benthic habitat conditions observed both within the CAD cells and the associated reference areas in 2004 were indicative of a consistently stressed environment. All of the areas sampled had average OSI values <5, which indicated that the infaunal communities were under some form of stress, possibly related to organic loading or physical disturbance of the bottom (Rhoads and Germano 1986). In silt-clay sediments, such as those found in the CAD cells, simple physical diffusion limits oxygen penetration to <1 cm (0.4 in) (Jørgensen and Revsbech 1985), but upon resuspension, sediments become oxidized and form oxic layers upon redeposition. As a result, the shallow RPD layers (<2 cm [0.8 in]) coupled with very few burrow structures indicated that biogenic activity was low and physical processes, most likely cycles of resuspension/re-deposition, were responsible for the thickness of the RPD layer and the presence of oxic voids.

Initial recolonization of the CAD cells after completion depended on the re-establishment of the basic physical (density, particle size) and geochemical (redox potential) properties of the dredged material (Bolam et al. 2004), and overlying water quality (Diaz and Rosenberg 1995). While the benthos had recolonized the CAD cells since they were capped, the communities still appeared to be in the early stages of development. This is typical of low-diversity assemblages dominated by opportunistic species (Levin 1984, Trueblook et al. 1994) since multiple stressors act to keep the benthos in a perpetual state of early succession (Rhoads et al. 1977, 1978). For example, in June 2001, it appeared that the bottom water at cell M2 became hypoxic and bacterial mats were observed at the sediment surface (Figure 4-2; ENSR 2001). In addition, the 2004 bathymetry and side-scan sonar data depicted a harbor bottom that undergoes periodic disturbance.

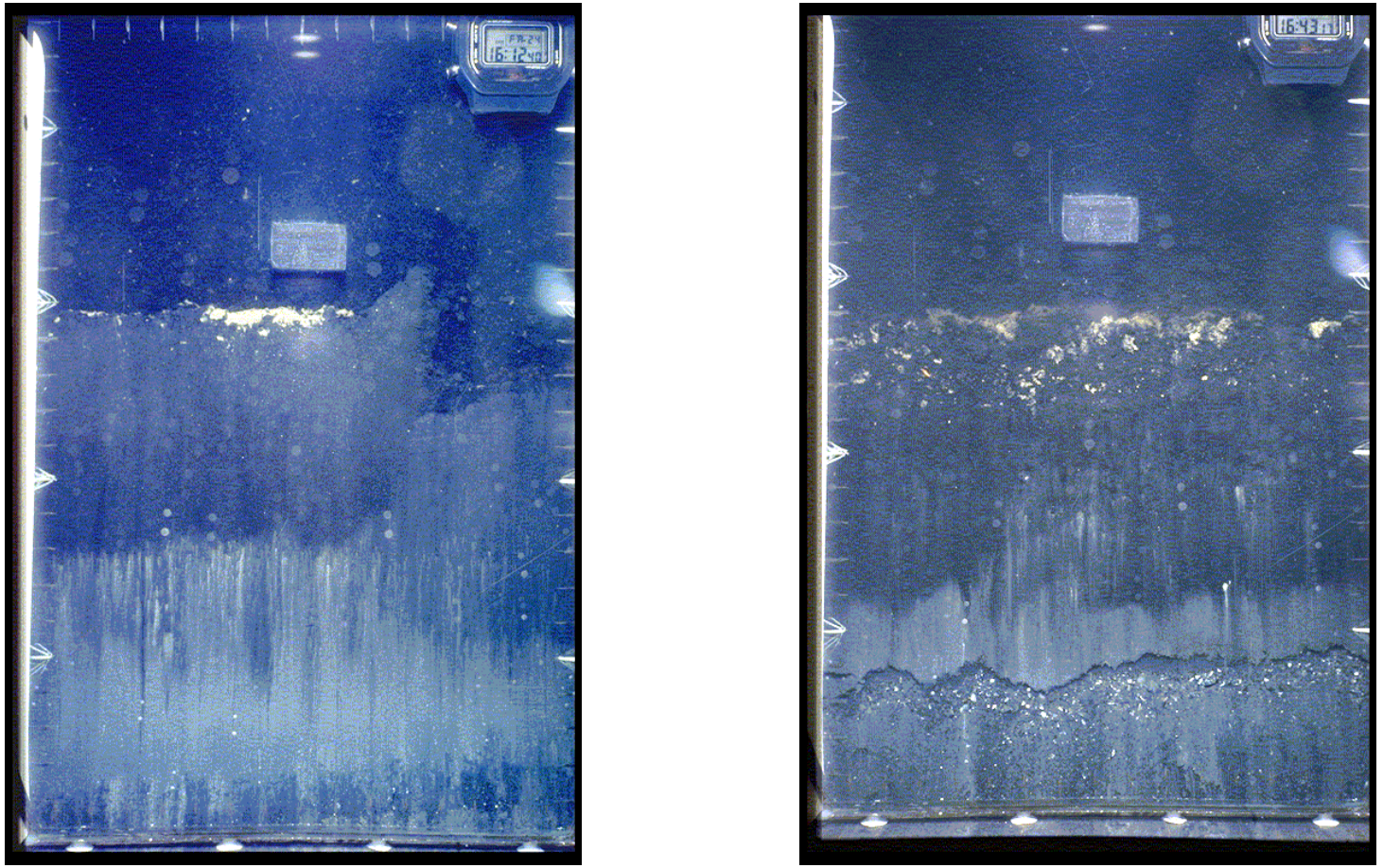

Figure 4-2. SPI images of cell M2 from June 2000 survey. Both images show evidence of bacterial mats on the sediment surface.

However, immediately above the harbor bottom, the 2004 towed video sled footage revealed the presence of numerous small fish and crustaceans. These appeared equally plentiful over both the surface of the cells and the reference areas, indicative of at least reasonably good water quality and food supply.

4.3 Plan-View and Deep Penetrating Cameras Technologies

The plan-view camera attached to the SPI camera frame provided a real-time video feed of the approach to and contact with the bottom. Although the viewing perspective was not as good as the towed video sled (directly downward for the plan-view vs. oblique for the sled), review of the footage allowed for some confirmatory assessment of physical and biological conditions. With adjustments to the lighting supply for the camera, it could supply data to supplement the sediment-profile images and in some cases could potentially replace a dedicated towed video survey.

The deep penetrating camera was able to record a sediment-profile image to approximately 30 cm (1 ft) depth in the trial demonstration performed at BHCAD. Although the quality of the image was much reduced over traditional SPI (it is a composite generated from video), it was sufficient to discern textural and shading changes along the profile. This technique has promise as a preliminary survey, supplement or replacement for more traditional coring in the evaluation of cap placement, depending on the expected depth of the sand cap.

5.0 CONCLUSIONS

The Boston Harbor Navigation Improvement Project, carried out between 1997 and 2000 (with minor additional work in fall 2001), represented the first large scale use of confined aquatic disposal (CAD) cells cut directly into the footprint of a navigable channel. A total of nine CAD cells were constructed as part of the overall project. Eight of the cells were capped with sand over the course of the project, and one cell was left uncapped with additional capacity for future projects. A series of investigations were performed during and following completion of the project to assess the effectiveness of dredged material disposal into the CAD cells and cap placement as well as the stability and benthic recovery of the cells. The August 2004 DAMOS survey was performed as a long term follow-up, as a requirement of the five-year WQC monitoring, four to seven years after completion of individual CAD cells, to address the following objectives:

- Assess the general physical status of the surface of each of the nine CAD cells to evaluate cell stability and long term integrity and thickness of the cap and overlying silts, with a more detailed assessment performed over cell M19.
- Determine bathymetry by performing a multi-beam bathymetric condition survey over the cells.
- Assess the benthic recolonization status of each of the nine CAD cells.

The high resolution swath bathymetry and side-scan sonar data collected as part of the August 2004 survey revealed that all nine CAD cells remained as stable structures four to seven years following completion of individual cells with no evidence of significant cap disturbance or scour. As expected, limited consolidation of the material within the cells had taken place, and some collapse of the exposed sidewalls of the cells that rise steeply above the cell surface had also occurred. Both of these processes are expected to continue into the future, but without effect on the overall structure or integrity of the cells. The linear depression previously identified over cell M19 was clearly visible in 2004. Review of the pre-filling bathymetry of cell M19 revealed a similar feature on the bottom of the cell, and it is believed that the surface depression was the result of consolidation of material within the cell causing the surface topography to mimic that of the underlying cell floor. The depression appeared stable over time.

While many of the cells had sand cap exposed at the surface at the completion of the project, follow-up surveys prior to the 2004 survey indicated that fine-grained materials were being deposited on top of the sand cap, and the sand caps were observed at depths increasing with time following the capping. Silt-clay was identified as the

receive sediments transported in runoff or resuspended from other areas of the harbor. Accretion of material within the cells was not identified in comparing the 2004 bathymetry data with data collected 2 to 7 years prior, indicating that continuing consolidation of the dredged material within the cells likely masked the deposition. Large-scale debris (timbers, piles, tires, etc.) were also identified on the surface of some of the cells in 2004. Deposition of fine material (as well as larger debris) is expected to continue into the future, helping to further sequester the material deeper within the cell.

The towed video footage collected in 2004 revealed numerous small fish and crustaceans at the bottom over both the CAD cells and surrounding channel areas. However, based on sediment-profile images taken in 2004, the general benthic habitat conditions observed within the cells and reference areas were indicative of a consistently stressed environment. The continual exposure to harbor-wide stressful conditions limited the recolonization and successional status of both the CAD cells and associated reference areas. The result was a benthic environment in a perpetual state of early succession. This was expected given periodic episodes of poor water quality and physical disturbance associated with a working harbor.

The 2004 monitoring survey was designed to meet the five-year post-construction monitoring requirements of the WQC for the BHNIP CAD cells. As the objectives of this study were fully met and the structure of the cells was found to be stable, no specific follow-up investigations are proposed. However, given the long-term interest in CAD cells as a management tool for contaminated sediment, the following recommendations are proposed for continued scientific understanding:

- For future assessment of the physical integrity/biological recolonization of the CAD cells, the use of swath bathymetry and SPI (outfitted with plan video camera) with supplemental collection of grabs or short cores for physical inspection are expected to be sufficient to meet the monitoring objectives.
- For construction of future CAD cells, a detailed as-built (pre-filling) bathymetric survey should become part of the project record to aid in interpreting potential consolidation/changes to the completed cell over time. For cells where continuous cap coverage is desired at the surface, project specifications should include provisions for required minimal slopes within the excavated cell.

6.0 REFERENCES

Battelle. 2001. Evaluation of Sediment Agitation and Mixing into the Surrounding Water Column from Capping Activities – Boston Harbor. USEPA, National Risk Management Research Laboratory, Cinicinnati, OH.

Boesch, D. F.; Rosenberg, R. 1981. Response to stress in marine benthic communities. In: Barrett, G.W., Rosenberg, R. (Eds.), Stress Effects on Natural Ecosystems. John Wiley and Sons, New York, pp. 179–198.

Bolam, S. G.; Whomersley, P. 2005. Development of macrofaunal communities on dredged material used for mudflat enhancement: a comparison of three beneficial use schemes after one year. Mar. Pollut. Bull. 50:40-47.

Bolam, S. G., Schratzberger, M.; Whomersley, P. 2004. Macrofaunal recolonization in intertidal mudflats: the effect of organic content and particle size. J. Exp. Mar. Biol. Ecol. 306:157-180.

Cloern, J.E. 2001. Our evolving conceptual model of the coastal eutrophication problem. Marine Ecol-Prog. Ser. 210:223-253.

Diaz, R. J.; Rosenberg, R. 1995. Marine benthic hypoxia: A review of its ecological effects and the behavioural responses of benthic macrofauna. Oceanogr. Mar. Biol. 33:245-303.

ENSR. 1997. Summary Report of the Independent Observer Phase I - Boston Harbor Navigation Improvement Project. Final Report submitted Massachusetts Coastal Zone Management. Boston MA.

ENSR 2001. June 2000 Benthic Survey of Boston Harbor Navigational Improvement Project Confined Aquatic Disposal (CAD) Cells. Report submitted to Massachusetts Coastal Zone Management, Boston MA.

ENSR. 2002. Boston Harbor Navigation Improvement Project Phase 2 Summary Report. Final Report submitted to U.S. Army Corps of Engineers, New England District, Concord, MA and Massachusetts Port Authority, Boston MA.

ENSR. 2004. Monitoring Survey at the Rockland Disposal Site, September 2003. DAMOS Contribution No. 156. U.S. Army Corps of Engineers, New England District, Concord, MA, p. 66.

Fredette, T. J. 1994. Disposal Site Capping Management: New Haven Harbor. In: McNair, E.C. ed. Dredging '94, Proceedings of the Second International Conference on Dredging and Dredged Material Placement (Vol. 2). , New York: American Society of Civil Engineers. pp. 1142–1151

Fredette, T. J.; Jackson, P. E.; Demos, C. J.; Hadden, D. A.; Wolf, S. W.; Nowak Jr., T. A.; DeAngelo, E. 2000. The Boston Harbor Navigation Improvement Project CAD cells: recommendations for future projects based on field experience and monitoring. Proceedings of the Western Dredging Association, 20th Technical Conference and 22nd Texas A&M Dredging Seminar, Warwick, RI, pp. 291-302.

Fredette, T. J.; French, G. T . 2004. Understanding the physical and environmental consequences of dredged material disposal: history in New England and current perspectives. Mar. Pollut. Bull. 49:93-102.

Germano, J. D.; Rhoads, D. C.; Lunz, J. D. 1994. An integrated, tiered approach to monitoring and management of dredged material sites in the New England region. DAMOS Contribution No. 87 (SAIC Report No. 90/7575&234). US Army Corps of Engineers, New England Division, Waltham, MA.

Hales, L.Z. 2001. Monitoring of the Boston Harbor Confined Aquatic Disposal Cells. ERD/CHL TR-01-27. Coastal and Hydraulics Laboratory, U.S. Army Engineer Research and Development Center, Vicksburg, MS.

Hubbard, W. H. U.S. Army Corps of Engineers (USACE). 1999. Correspondence to Lois Bruinooge of Massachusetts Department of Environmental Protection regarding Disposal Cell Caps Completion.

Jørgensen, N.; Revsbech, N. P. 1985. Diffusive boundary layers and the oxygen uptake of sediments and detritus. Limnol. Oceanogr. 30:111-122.

Levin, L.A. 1984. Life history and dispersal patterns in a dense infaunal polychaete assemblage: community structure and response to disturbance. Ecology 65:1185-1200.

Massachusetts Department of Environmental Protection (MADEP). 1998. Amended Water Quality Certification Boston Harbor Navigation Improvement and Berth Dredging Project. MADEP Transmittal Number 114030.

Ocean Surveys, Inc. 1999a. Vibratory Coring Bathymetric and subbottom Profiling Survey - Confined Disposal Facilities Mystic River, Boston Harbor. Submitted to Great Lakes Dock and Dredge Company, Oakbrook, IL.

Ocean Surveys, Inc. 1999b. Subbottom Profiling Survey - Confined Disposal Facilities Mystic River, Boston Harbor. Submitted to Great Lakes Dock and Dredge Company, Oakbrook, IL.

Ocean Surveys, Inc. 2000. Final Report – Hydrographic and subbottom profiling status survey, Confined Disposal Facilities (CDF), Mystic River, Boston, Massachusetts. Submitted to Great Lakes Dock and Dredge Company, Oakbrook, IL.

Revelas, E. C.; Germano, J. D.; Rhoads, D. C. 1987. REMOTS® Reconnaissance of benthic environments. Coastal Zone '87: Proceedings of the Conference, WW DIV/ASCE/May 26-29, Seattle, WA, pp. 2069–2083.

Rhoads, D. C.; Boyer, L. F. 1982. The effects of marine benthos on physical properties of sediments: a successional perspective. In: McCall, P.L., Tevesz, M.J.S. (Eds.), Animal-Sediment Relations. Plenum Press, New York, pp. 3-52.

Rhoads, D. C., McCall, P. L.; Yingst, J. Y. 1978. Disturbance and production on the estuarine seafloor. Am. Sci. 66:577–586.

Rhoads, D. C., Aller, R. C.; Goldhaber, M. B. 1977. The influence of colonizing benthos on physical properties and chemical diagenesis of the estuarine seafloor. In: Coull, B.C. (Ed.), Ecology of Marine Benthos. University of South Carolina Press, Columbia, pp. 113–138.

Rhoads, D. C.; Germano, J. D. 1982. Characterization of organism-sediment relations using sediment profile imaging: an efficient method of Remote Ecological Monitoring of the Seafloor (REMOTS System). Mar. Ecol. Prog. Ser. 8:115-128.

Rosen, P.S., Brenninkmeyer, B. M.; Maybury, L. M. 1993. Holocene evolution of Boston inner harbor, Massachusetts. J. Coastal Res. 9:363-377.

SAIC. 1997. Postcap Monitoring of Boston Harbor Navigation Improvement Project (BHNIP) Phase 1: Assessment of Inner Confluence CAD Cell. SAIC Report No. 413. Final report submitted to the US Army Corps of Engineers, New England District, Concord, MA.

SAIC. 1999. Monitoring Results from the First Boston Harbor Navigation Improvement Project Confined Aquatic Disposal Cell. DAMOS Contribution No. 124. US Army Corps of Engineers, New England District, Concord, MA.

SAIC. 2000. Boston Harbor Water Quality Monitoring – Vessel Passage Over Confined Aquatic Disposal Cells; Monitoring in Wake of LNG Carrier Matthew on March 31, 2000. SAIC Report No. 491. Final Report submitted to US Army Corps of Engineers, New England District, Concord, MA.

SAIC. 2001. One-Year Monitoring Report for the Boston Harbor CAD Cells Summer 2001. SAIC Report No. 561. Final report submitted to the US Army Corps of Engineers, New England District, Concord, MA.

SAIC. 2003a. Monitoring Survey Over Boston Harbor CAD Cell M19. DAMOS Contribution No. 148. US Army Corps of Engineers, New England District, Concord, MA.

SAIC. 2003b. An Investigation of Sediment Dynamics in the Vicinity of Mystic River CAD Cells Utilizing Artificial Sediment Tracers. DAMOS Contribution No. 150. US Army Corps of Engineers, New England District, Concord, MA.

Trueblood, D. D., Gallagher, E. D.; Gould, D. M. 1994. Three stages of seasonal succession on the Savin Hill Cove mudflat, Boston Harbour. Limnol. Oceanogr. 39:440–1454.

U.S. Army Corps of Engineers (USACE). 1999. Correspondence to Ms. Lois Bruinooge, Division of Watershed Management, Massachusetts Department of Environmental Protection.

U.S. Army Corps of Engineers (USACE) and Massachusetts Port Authority (MassPort). 1995. Final Environmental Impact Report (EOEA File Number 8695) and Final Environmental Impact Statement – Boston Harbor, MA, Navigation Improvement Project and Berth Dredging Project.

Wilcox, J. R.; Jeffries, H. P. 1974. Feeding habits of the sand shrimp *Crangon septemspinosa*. Biological Bulletin (Woods Hole) 146:424–434.

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Appendix A

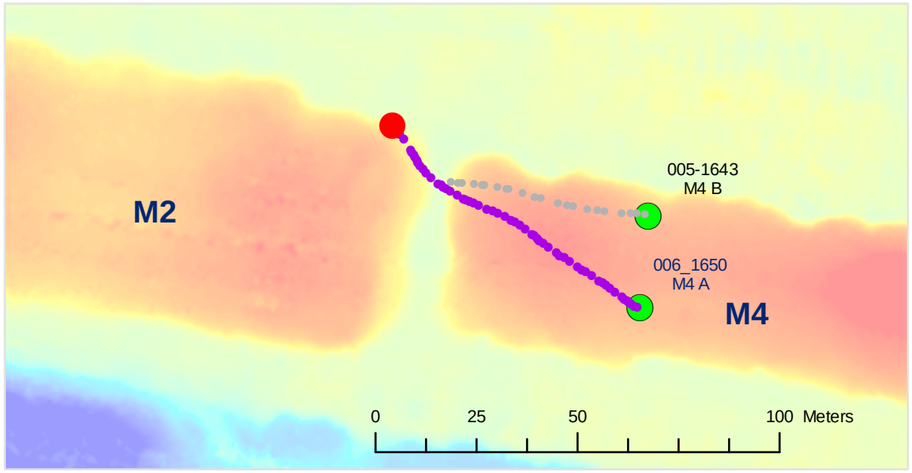
Underwater Video Annotation for BHCAD Cells – August 2004 Survey

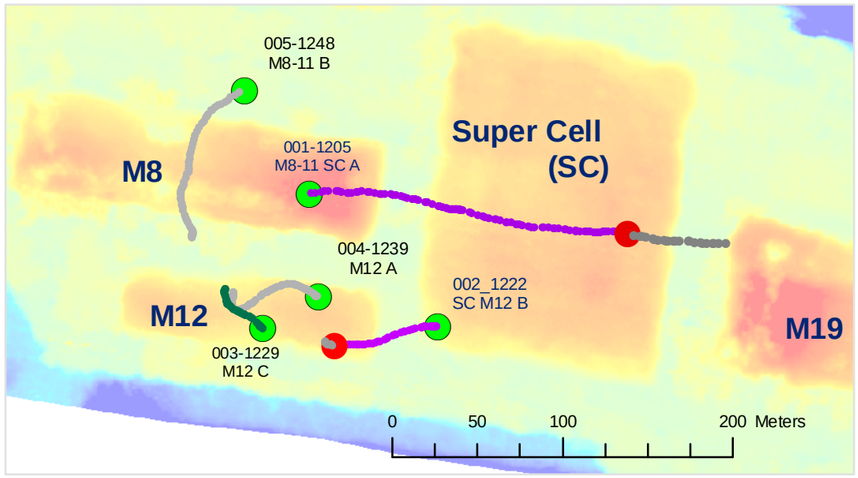
VIDEO INDEX

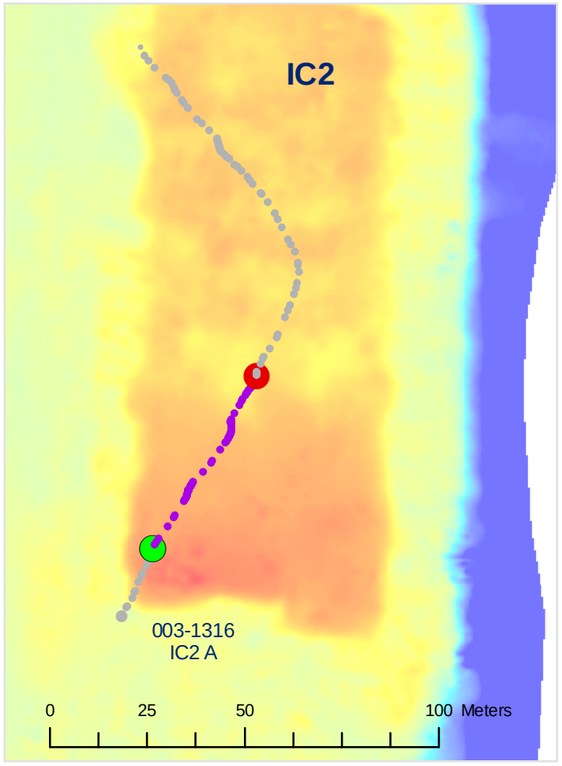
Monitoring Survey at the
Boston CAD Cell Site
August 2004

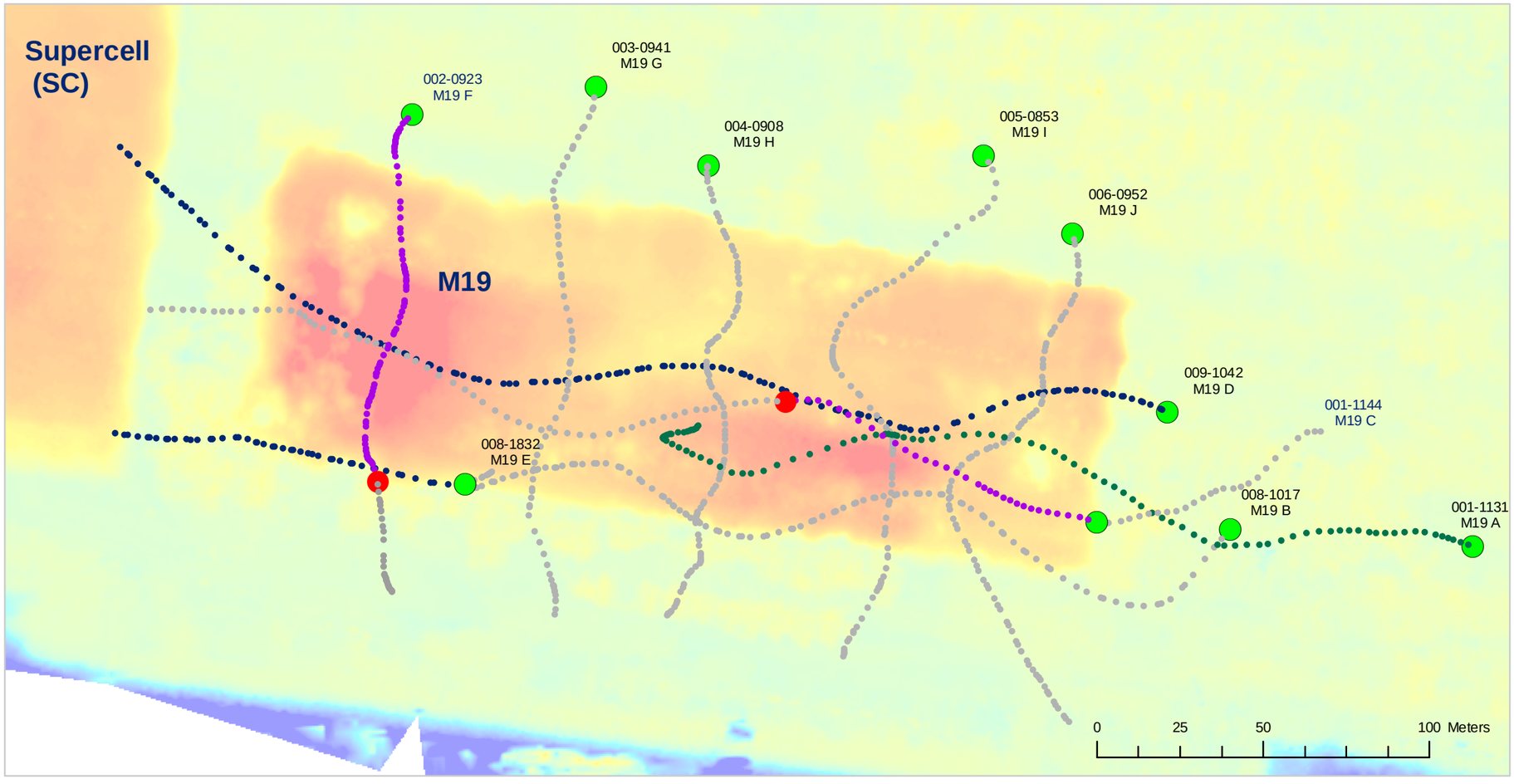
Track	Hypack ID	Video	Annotation
IC2 A*	003-1316	IC2 A (003-1316).mpg	IC2 A (003-1316).pdf
M4 A*	006-1650	M4 A (006-1650).mpg	M4 A (006-1650).pdf
M4 B	005-1643	M4 B (005-1643).mpg	M4 B (005-1643).pdf
M8-11 B	005-1428	M8-11 B (005-1428).mpg	M8-11 B (005-1428).pdf
M8-11 SC A*	001-1205	M8-11 SC A (001-1205).mpg	M8-11 SC A (001-1205).pdf
M12 A	004-1239	M12 A (004-1239).mpg	M12 A (004-1239).pdf
M12 C	003-1229	M12 C (003-1229).mpg	M12 C (003-1229).pdf
M19 A	001-1131	M19 A (001-1131).mpg	M19 A (001-1131).pdf
M19 B	008-1017	M19 B (008-1017).mpg	M19 B (008-1017).pdf
M19 C*	001-1144	M19 C (001-1144).mpg	M19 C (001-1144).pdf
M19 D	009-1042	M19 D (009-1042).mpg	M19 D (009-1042).pdf
M19 E	008-1832	M19 E (008-1832).mpg	M19 E (008-1832).pdf
M19 F*	002-0923	M19 F (002-0923).mpg	M19 F (002-0923).pdf
M19 G	003-0941	M19 G (003-0941).mpg	M19 G (003-0941).pdf
M19 H	004-0908	M19 H (004-0908).mpg	M19 H (004-0908).pdf
M19 I	005-0853	M19 I (005-0853).mpg	M19 I (005-0853).pdf
M19 J	006-0952	M19 J (006-0952).mpg	M19 J (006-0952).pdf
SC M12 B*	002-1222	SC M12 B (002-1222).mpg	SC M12 B (002-1222).pdf

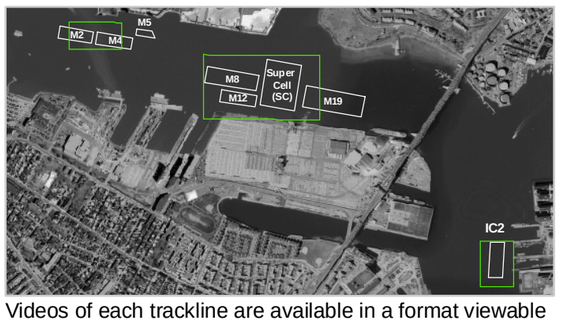
*Video selections include a narrated segment of this full-length track.











Videos of each trackline are available in a format viewable on any personal computer.

The beginning of trackline videos are indicated by the icons.

Tracklines with narrated selections are indicated by the the colored tracking points and the icon, which indicates the end of the narrated segment.

Transcripts of the narrations are available in Appendix A.

IC2_A (003_1316) Video Transect
Total Time: 11:04
The transect begins on the channel bottom to the south of IC2, proceeds north descending into the southwest corner of the cell, traverses the length of the cell, exiting at the northwest corner and ending on the channel bottom to the north of the cell.

Running Time (m:s)	Biological Characteristics	Physical Characteristics
0:00-0:10		Very soft sediment, elevated turbidity
0:05		Video cable visible
0:10-0:20	Small fish and shrimp	Visibility improves. Numerous clay clasts, irregular bottom.
0:20-0:57	Occasional fish and algae	Camera directed upward periodically (bottom not always visible). Occasional debris.
0:58-1:13	Occasional fish and algae	Fine-grained sediment and occasional debris. Sled movement causes elevated turbidity.
1:13-1:20	Small fish and shrimp	Irregular bottom with clay clasts, debris, shell hash
1:20-1:35		Poor visibility
1:35		Irregular bottom feature
1:36-1:54	Numerous small fish and shrimp	Relatively smooth bottom, occasional debris
1:54-2:01	Larger fish trail	
*2:02-2:18	Flounder and other fish	Very fine sediment. Elevated turbidity from sled and fish.
2:13-2:28	Few small fish	Sled descends into cell. Numerous clay clasts and irregular surface.
2:28-3:26	Some algae	Cell bottom consists of clay clasts, shell hash and debris.
3:26-3:50	Several flounder and small fish	Bottom appears smoother with fewer clay clasts and shell hash
3:50-until end of transect	Occasional small fish and shrimp	Very fine-grained sediment. Sled interaction with bottom causes periodic elevated turbidity, poor visibility.
*5:35-5:50	Several flounder	
6:12-7:07		Camera directed upward with limited bottom view.
7:09-7:39	Small fish, shrimp	Elevated turbidity

Running Time (m:s)	Biological Characteristics	Physical Characteristics
7:09		Possible algae, debris
7:12	Large fish	
7:27	Algae	Possible algae, debris
7:40-8:00	Numerous small fish	
8:00-9:03	Several larger fish, including flounder, algae	Very fine-grained sediment. Sled causes elevated turbidity.
9:04-9:30	Several small fish, algae	Elevated turbidity. Debris.
9:30-10:00	Several flounder and some smaller fish	Very fine-grained sediment, elevated turbidity
9:32		Bottle
9:39	Flounder	
10:00-10:04		Sled ascends cell wall and exits IC2.
10:05-11:00	Several flounder and similar-sized fish, as well as small fish and shrimp	Fine-grained sediment. Elevated turbidity. Debris.
10:42	Crab	Debris, possible encrusted line.

*A narration of this full-length video, between time 2:00 and 6:00, is available.

M4_A (006_1650) Video Transect
Total Time: 4:59
The transect begins in the south-central portion of cell M4, proceeds northwest, exits the northwest corner of the cell, and ends on the channel bottom adjacent to cell M2.

Running Time (m:s)	Biological Characteristics	Physical Characteristics
*0:00-0:20	Algae	Fine-grained material, clay clasts, intermittent debris. Visibility is poor throughout the entire transect due to high ambient suspended solids within the water column.
0:20-1:20	Some small fish, visible mostly as turbidity trails	Small and medium clay clasts, some debris
1:18		Tire
1:20-1:31		Camera directed upward, no bottom view.
1:32		Camera view of bottom returns.
1:33-2:40	Some small fish, visible mostly as turbidity trails Some algae and larger fish	Very fine-grained sediment, occasional debris, and clay clasts
1:56	Flounder	
2:50-3:24	More fish trails, occasional algae	Very fine-grained material. Elevated turbidity from sled.
3:25-4:16	Algae, fish	Some small clay clasts, debris
3:49	Mussel clump on right	
4:16		Sled ascends cell wall and exits M4.
4:17-4:40	Flounder, other fish	Large clay clasts. Irregular bottom.
4:40-end		Channel bottom adjacent to cell M2, fine material, some small clay clasts, shell hash
4:48-4:59*		Camera directed upward as sled begin ascent through water column.

* A narration of this entire video is available

M4 B (005-1643) Video Transect
Total Time: 1:32
Sled begins inside and moves along parallel to the northern edge of Cell M4 in a northwesterly direction towards cell M2

Running Time (m:s)	Biological Characteristics	Physical Characteristics
0:00-0:10		A lot of consolidated clay, small clay clasts, shell hash, some debris, lots of turbidity. Visibility is poor.
0:10-1:16		Sled keeps bouncing off bottom. Bottom not visible for much of transect. Timber. Several large clay clasts. Small clay clasts no longer visible
1:10	Small fish and shrimp when bottom is visible	
1:12		Large piece of debris
1:16-1:32		Sled ascends in the water column and exits cell M4 in a northwesterly direction. The walls of the cell are not captured in this video recording.
Overall	Not many fish visible (probably due to poor visibility)	Visibility is very poor. Sediment is fine-grained. Fair amount of debris

M8-11 B (005-1428) Video Transect
Total Time: 4:29
Sled begins north of Cell M8 and travels southward through the cell.

Running Time (m:s)	Biological Characteristics	Physical Characteristics
0:00-0:04		Sled descends through water column
0:04-1:05	Several flounder, shrimp and small fish, crab	Fairly coarse-grained sediment, shell hash, weathered clay. Good visibility
0:21	Crab	
1:06		Sled descends cell wall into Cell M8
1:07-1:41	Increased number of fish	Similar material as channel bottom, but slightly finer-grained
1:30-1:42		Sled bounces off bottom
1:43-2:07	Small fish more numerous, crab, shrimp	Increased turbidity – slightly finer-grained material, less shell hash
2:08		Line, possibly from lobster trap set
2:09-2:27	Several flounder and numerous small to medium-sized fish	Large clay clasts, irregular bottom
2:28-4:29	Numerous small and medium-sized fish and shrimp	Sediment becomes finer-grained from here until end of transect, little shell hash. Turbidity plumes from camera and fish contact with bottom. Visibility is poor. Still a lot of debris and rocks/clay, irregular bottom, several large clay clasts. Video cable or piece of rope at end
3:54		Large piece of debris – plank?

M8-11_SC_A (001_1205) Video Transect - Total Time: 6:59
The transect begins in the eastern portion of cell M8-11, proceeds east exiting cell M8-11, crosses the Supercell (SC) from west to east, and ends on the channel bottom to the east of the Supercell.

Running Time (m:s)	Biological Characteristics	Physical Characteristics
*0:00-1:25	Few small fish	Sled descends, bounces off bottom repeatedly. Soft bottom, fine-grained material, poor visibility.
0:15	Crab	Large clay clast or debris
0:23		Lobster pot
0:53		Large flat debris
1:26	Occasional small fish and flounder	Irregular bottom, large clay clasts, occasional debris, shell hash. Visibility improves.
~ 1:00-1:28		Sled gradually ascends out of M8-11 to the channel bottom (not readily apparent in video).
1:28-2:06	Few small fish	Possible edge of M8-11. Relatively smooth bottom with shell hash.
1:48		Flat debris
2:07-2:39	Numerous small fish	Finer-grained sediment, occasional debris and algae. Shell hash less dense. Elevated turbidity from sled and fish.
~2:00-2:30		Sled gradually descends into the Supercell (not readily apparent in video).
2:40-2:49		Very irregular bottom, large clay clasts
2:50-3:18	Some small and medium-sized fish, flounder	Coarser-grained sediment, clay clasts, poor visibility
3:19-3:30	Numerous small and medium-sized fish	Soft bottom, occasional clay clasts, debris and algae, poor visibility
4:29-4:38		Sled collides with large piece of encrusted debris

Running Time (m:s)	Biological Characteristics	Physical Characteristics
4:39-5:01	Numerous small fish	Very soft bottom, fine-grained sediment. Elevated turbidity.
*5:02		Encrusted debris
5:03-6:35	Numerous small fish, including flounder	Less turbidity, slightly coarser-grained sediment, algae, some debris
5:58		Line, possibly from lobster trap set
6:04		Clay clasts
6:35-6:44		Clay clasts, shell hash. Sled ascends wall of Supercell (not readily apparent in video).
6:45-6:59		Surface becomes smoother with less shell hash.

* A narration of this video, between minutes 0:00 and 5:02, is available.

M12 A (004-1239) Video Transect
Total Time: 4:17
Sled begins in cell M12 and travels northwest along the northern cell boundary.

Running Time (m:s)	Biological Characteristics	Physical Characteristics
0:00-0:34		Very turbid, sled descends to bottom, bounces off bottom
0:35-1:29	Occasional fish, flounder and algae	Soft, silty bottom with apparent clay clasts or debris. Visibility is generally poor
1:30-2:06	Flounder, small fish and shrimp, algae	Visibility improves somewhat
1:30-1:38	Burrows?	
2:07-2:10		Exposed clay, uneven surface
2:11-2:19		Bottom is smooth and soft again
2:20-3:44	Numerous small fish and shrimp	Smooth bottom, some debris and shell hash, sled causes turbidity plume
3:41	Crab	
3:45-4:17		High turbidity, sled bounces through water column

M12 C (003-1229) Video Transect
Total Time: 2:39
Sled begins in Cell M12 and travels northwest through the center of M12.

Running Time (m:s)	Biological Characteristics	Physical Characteristics
0:00-0:40	Some algae	Sled descends through water column. Soft bottom covered in oxidized silty clay. Lots of turbidity
0:13	What is that crawling orange thing? Crab?	
0:40-0:45		Sediment becomes slightly coarser-grained. Debris, BBC nodules, shell hash
0:41	Seastars	
0:45	Lobster/Crab?	
0:46-0:52		Lots of turbidity. Sled bounces off bottom
0:52-1:10	Occasional small fish and shrimp	Water clears up. Not much shell hash or clay clasts from here until end of transect. Smooth bottom and slightly coarser-grained material.
1:11-2:10	Numerous small fish, flounder and shrimp. Some algae	Sediment becomes finer. Sled and fish frequently cause turbidity plumes. Occasional debris
1:44		Aluminum can?
2:10		Encrusted line, possibly from lobster trap set
2:17		Sled becomes caught on rope. Sled rises through water column
2:37		Camera breaks surface

M19 A (001-1131) Video Transect
Total Time: 8:13
Sled begins to the east of Cell M19 and travels westward descending into the cell. Towards the end of the video, the sled passes through the linear depression in the southeastern region of the cell.

Running Time (m:s)	Biological Characteristics	Physical Characteristics
0:00-0:17	Occasional fish, flounder	Soft, smooth, silty bottom. Very poor visibility
0:18-0:28	More numerous fish, flounder	Soft, smooth, silty bottom. Very poor visibility
0:29-0:36		Sled bounces off bottom, only water column visible
0:37-	Some fish, flounder, some algae	Very poor visibility. Silty bottom
1:20		Some shell hash and/or small clay clasts
1:32-1:42		Sled descending
1:43-2:09	Some fish, flounder	Very poor visibility. Silty bottom.
2:10-2:16	Increased fish activity	Silty material. Poor visibility. Numerous sediment trails
2:17-3:21	Some fish, flounder	Poor visibility. Smooth surface, silty material. Occasional debris
2:55-2:57		Parallel lines, possibly a lobster trap set
3:22-3:25		Sled makes a short descent into Cell M19
3:26		Debris – concrete block?
3:27-3:35	Some fish	Smooth surface, silty material
3:36-3:41		2 medium sized clasts. Ridge. Sled makes short descent from the mounded area located in the south east corner of Cell M19.
3:42-3:57	Increased fish activity	Slightly uneven surface. Small clay clasts, shell hash
3:58-4:08		Smooth bottom. Silty material. Less shell hash and clay clasts.

Running Time (m:s)	Biological Characteristics	Physical Characteristics
4:09-4:20		Sled descends into a low trench-like area located just south east of the center of Cell M19.
4:21-4:29		Irregular bottom with some exposed clay
4:30-4:48		Sled makes ascent out of low trench-like area, with exposed clay
4:49-4:56		Exposed clay, irregular surface, sled makes short descent
4:57-6:05	Numerous fish, some algae, shrimp	Smooth, silty bottom. Turbidity plumes, poor visibility. Some debris
5:14		Rope?
5:33		Rope, chain, or mussel bed?
6:06-7:32		Camera becomes entangled in debris (plastic garbage bag and plastic cup). View is obscured
7:33		Camera breaks water surface
7:40-7:50		Field crew removes debris
7:51-8:13		Intermittent views of stern of research vessel and harbor, and water column
Overall		Difficult to identify much due to very poor visibility

M19 B (008-1017) Video Transect
Total Time: 7:30
Sled begins to the East of Cell M19 and travels westward descending into and remaining close to the southern boundary of the cell. This video transect continues and contains the video capture of the continuation, also known as video transect 008_1832.

Running Time (m:s)	Biological Characteristics	Physical Characteristics
0:00-0:11	Occasional fish, some algae	Poor visibility. Smooth, silty bottom
0:12		Ridge of exposed clay
0:13-0:24	More numerous fish	Poor visibility. Smooth, silty bottom
0:25-0:57	Algae, occasional fish, flounder	Sled appears to make a series of short descents. Smooth silty bottom. Poor visibility.
0:58-1:28	More numerous fish, some flounder	Poor visibility, lots of sediment trails from fish, very silty
1:29-1:38	Occasional fish	Sled descends into M19 along a slope of moderate grade with some exposed clay
1:39-1:49		A lot of exposed clay, uneven bottom, a lot of turbidity from sled bouncing off bottom
1:46		Ridge of exposed clay
1:50-2:51	Numerous fish, flounder, some algae	Bottom is smoother, still very silty and soft. Poor visibility
2:52		Line, possibly from lobster trap set
2:53		Another line, parallel to first
2:54-3:04	Some fish	Some clay clasts. Sediment trails from fish. Poor visibility
3:05-3:09		Sled climbs wall with exposed clay
3:10-3:39	Some algae, numerous fish	Very poor visibility. Soft, smooth, silty bottom, occasional clay clast
3:35		Soda can

Running Time (m:s)	Biological Characteristics	Physical Characteristics
3:40		Line (from lobster trap set?)
3:41-4:40	Numerous fish, some flounder, some algae	Soft, silty bottom. Poor visibility. Occasional debris
4:41-4:49		Sled appears to be descending
4:50-5:01	Numerous fish	Soft, silty bottom. Poor visibility
5:02		Debris – aluminum can and rope?
5:03-5:08		Turbidity plume
5:09		Piece of debris
5:10-5:35	Numerous fish, including flounder. Some algae	Very soft, silty bottom. Sediment trails. Very poor visibility
5:36-5:45		Sled catches on large piece of debris, passes over several other pieces of debris
5:46-7:03		Sled ascending. View of water column only
7:04-7:30		Camera breaks water surface, view of stern of research vessel and Boston Harbor

M19_C (001_1144) Video Transect
Total Time: 9:54
The transect begins on the channel bottom to the east of cell M19, proceeds westward across the length of the cell, rises out of the western end of the cell, and ends on the harbor bottom between cell M19 and Supercell.

Running Time (m:s)	Biological Characteristics	Physical Characteristics
0:00- 1:04	Some fish, flounder, some algae	Smooth bottom. Very soft, silty material. Sled generates elevated turbidity and poor visibility.
1:05- 1:15		Exposed clay (large clast). Sled makes 2 short descents.
1:16- 1:56	More numerous fish, flounder, shrimp	Slightly irregular bottom
* 1:57- 2:01		Sled makes short descent
2:02- 2:24	Some fish, flounder	Soft, silty material. Smooth bottom, some exposed clay.
2:08	Crab	
2:19	Flounder	
2:25		Clay clasts, algae, likely debris
2:28		Thin, linear debris
2:30- 2:33		Sled makes short descent into Cell M19.
2:34- 2:44		Silty material. Sled generates elevated turbidity.
2:40	Likely kelp	
2:45- 2:50		Sled appears to ascend wall with exposed clay.
2:51- 2:54		Very soft, silty bottom. Small and medium sized clay clasts. Sled generates elevated turbidity.
2:55- 3:00		Ridge visible. Uneven bottom.
3:01- 3:07		Very soft, silty material. Smooth bottom. Elevated turbidity.
3:08- 3:10	Some fish, flounder	Visibility improves. Small clay clasts, shell hash visible.
3:11- 7:23	Some to numerous fish, flounder, shrimp, some algae	Very soft, silty material. Smooth bottom. Some debris. Sled generates elevated turbidity.
3:19		Linear debris – stick?
4:20		Lines – possible lobster trap set
* 4:56		Lines – possible lobster trap set
6:05		Debris

Running Time (m:s)	Biological Characteristics	Physical Characteristics
6:28		Lines – possible lobster trap set
7:24- 8:12	Numerous fish	Slight descent due to irregular bottom. Very soft, silty material. Turbidity wave in front of sled.
7:47		Lines – possible lobster trap set
8:13- 8:30		Only water column is visible.
8:31		Bottom view returns.
8:32- 9:08	Numerous fish, visible mostly as sediment trails	Very soft, silty bottom, with some clay clasts. Elevated turbidity.
8:56	Crab?	
9:09- 9:40		Sled ascends western edge of cell and exits M19. Exposed clay indicates near-vertical cell wall. Some debris.
9:44		Plastic cup
9:41- 9:54	Some fish	Very soft, silty material. Smooth bottom. Elevated turbidity.

*A narration of this full-length video, between time 1:57 and 4:56, is available.

M19 D (009-1042) Video Transect
Total Time: 7:46
Sled starts to the east of Cell M19 and travels westward through M19 entering a deep trench-like area at the western edge of the cell. The sled ascends and exits the cell and travels along the channel bottom towards the Supercell.

Running Time (m:s)	Biological Characteristics	Physical Characteristics
0:00-0:28		Sled descends to seafloor
0:28-0:32		Sled reaches bottom. Bottom is fairly smooth, medium-grained
0:33-0:49		Sled descends into Cell M19
0:37-0:41		Smooth surface, medium-grained sediment
0:50-1:04	Some fish, mostly visible as suspended sediment trails	Bottom is slightly more fine-grained. Lots of debris and small clay clasts. Uneven surface
1:05-1:23		Sled continues to descend into Cell M19, hits plateau, and descends again in a long drop. Exposed, irregular clay surface, shell hash.
1:24-1:47	Few fish	Sled hits bottom. Surface is fine-grained, with some medium clay clasts. Visibility is poor.
1:48		Bottom drops off slightly. Surface is irregular, with small and large clay clasts
1:49-2:02	Numerous small fish, shrimp	Visibility is poor. Very fine-grained sediment.
2:03-2:35	Numerous small fish	Bottom is very irregular, with large clay clasts. Sled often creates turbidity plumes. Some debris, including timber
2:03-2:05		Irregular surface, large clay clasts
2:06-2:17		Smooth surface, fine material. Sled creates plume. Piece of timber (2:17)
2:18-2:20		Irregular bottom, clay clasts

Running Time (m:s)	Biological Characteristics	Physical Characteristics
2:21	Numerous small fish and shrimp	Smooth, fine material, poor visibility
2:36-4:34	Numerous small fish	Bottom becomes mostly smooth with occasional clay clasts and debris
3:11		Bottle
3:14		Timber
3:30		Piece of wood stuck under sled
4:30-4:32		Piece of timber or rope?
4:35-6:50	Occasional algae, numerous small fish	Occasional clay clasts, debris, some timber. Sediment is still fine-grained. Lots of turbidity
6:40		Line, possibly from lobster trap set
6:51-7:05		Sled ascends cell wall
7:05-7:46	Occasional fish	Irregular clay bottom, high turbidity, poor visibility
7:06-7:18		Sled descends cell wall
7:19-7:46		Sled hits bottom, irregular clay surface

M19 E (008-1832) Video Transect
Total Time: 2:28
Traveling westward inside cell M19 along southern boundary towards the Supercell.

Running Time (m:s)	Biological Characteristics	Physical Characteristics
0:00-0:11		Sled descends through water column
0:12-1:00	Occasional fish and fish trails, some algae	Sled hits bottom. Visibility is poor. Soft, silty bottom
1:01-1:16	Fish are more numerous	Some clay clasts and debris, timber
1:17-1:20		Medium-sized clay clasts, larger clay pieces
1:21-1:40	Occasional fish and fish trails	Sled climbs, then descends, along the cell wall. The cell wall consists of large clay clasts with a very irregular surface.
1:41-2:04	Fish are more numerous	Surface is smoother, occasional debris
2:05-2:16		Sled creates turbidity plume, obscures view
2:17-2:28		Very poor visibility, something stuck on left side of frame

M19_F (002_0923) Video Transect
Total Time: 6:42
The transect begins on the channel bottom to the north of cell M19, proceeds south across the depression identified in the western portion of the cell, rises out of the southern edge of the cell, and ends on the harbor bottom between cell M19 and the southern edge of the Mystic River Channel.

Running Time (m:s)	Biological Characteristics	Physical Characteristics
*0:00- 0:24	Occasional fish and shrimp	Small clay clasts, one medium-sized clay clast, shell hash, some debris. Good visibility.
0:25 - 1:15	More numerous fish and shrimp, several flounder, algae	Smoother surface, finer material, small clay clasts, less shell hash, including mussel shells. Good visibility.
1:26 - 1:32		Sled descends cell wall in M19.
1:28	Crab	
1:33 - 1:36		Coarse material. Dense shell hash.
1:37 - 3:17	Numerous fish and shrimp, several flounder, algae	Material appears similar to channel bottom, but finer-grained with less shell hash. Elevated turbidity from sled and fish, reducing visibility. Possible debris.
2:14 - 2:16		Elevated turbidity due to sled movement.
2:41	Possible burrows in succession on either side of camera	
3:02		Possible debris
3:14		Bottle
3:18 - 4:07	Numerous small and medium size fish, including flounder	Fine material. Sled bouncing off bottom creates elevated turbidity plumes, reducing visibility.
3:26 - 3:32		Elevated turbidity
3:35	Several flounder	
3:50		Bucket or other debris

Running Time (m:s)	Biological Characteristics	Physical Characteristics
3:56		Bottle
*4:08 - 4:10		Sled appears to be ascending
4:11 - 4:16	Numerous small fish	Fine material
4:17 - 4:18		Log
4:21 - 4:39	Many fish, visible mostly as turbidity trails	Slightly coarser material. Some shell hash and clay clasts. Elevated turbidity limits visibility.
4:40	Many fish	Visibility improves momentarily, clay clast apparent.
4:46 - 4:55		Sled appears to be ascending out of M19 with limited view of the cell wall.
4:56 - 5:20	Several fish	Surface is smoother, few clay clasts, very silty, with poor visibility. Sled transits uneven bottom.
5:04	Crab	
5:21		Stick or other debris
5:22 - 6:00	Numerous fish (as turbidity trails), some flounder	Elevated turbidity from sled
6:01		Large clay clast, uneven bottom, visibility is still very poor.
6:02		Elevated turbidity from sled
6:15 - 6:23		Exposed clay. Sled appears to climb a ledge
6:24 - 6:42	Several fish	Very fine material, resulting in elevated turbidity

*A narration of this full-length video, between time 0:00 and 4:10, is available.

M19_G (003-0941) Video Transect
Total Time: 4:47
Sled begins north of Cell M19 and travels southward descending into and ascending out of the cell.

Running Time (m:s)	Biological Characteristics	Physical Characteristics
0:00-0:21	Occasional fish, flounder	Very soft bottom, small clay clasts and shell hash
0:22-0:34	Occasional fish	Soft, uneven bottom. Sled makes 2 short descents (Descent into cell?). Poor visibility
0:34		Large hole in clay
0:35-0:47	Occasional fish	Uneven, soft bottom, small clay clasts and shell hash
0:48-1:20		Sled makes gradual descent into M19
0:51-1:29	Occasional small fish and flounder	Uneven bottom, small clay clasts and shell hash, including mussel shells. Less silt, improved visibility
1:30-1:44	Numerous fish, including flounder	Coarse material. Shell hash and clay clasts
1:45-2:00		Uneven bottom, clay clasts, shell hash. Camera appears to bounce up and down
2:01-4:07	Numerous small fish, shrimp, some flounder, some algae	Smoother bottom. Fine, silty material. Some small clay clasts and shell hash, occasional small debris. Sediment trails
2:33	Crab	
4:13		Encrusted rope
4:08-4:18		Sled collides with large clay clast. Increased turbidity. Sled gradually ascends the soft cell wall.
4:19-4:47	Numerous fish	Poor visibility, exposed clay, uneven surface. Sled ascending
4:26		Stick?
4:43		Camera is hoisted and loses visual contact with the seafloor.

M19_H (004-0908) Video Transect
Total Time: 6:06
Traveling Southward
Sled begins north of Cell M19 and travels southward entering and exiting the cell through the approximate center.

Running Time (m:s)	Biological Characteristics	Physical Characteristics
0:00-0:58	Several small fish	Bottom is fairly coarse-grained, small clay clasts, shell hash
0:11-0:15		Video cable visible
0:59-1:15		Bottom becomes more uneven, slightly finer-grained
1:16-1:35		Sled appears to descend into cell
1:36-1:57	More frequent small fish and shrimp	Bottom becomes finer-grained, small clay clasts, less shell hash, few rocks
1:58-2:13		Visibility is obscured by turbidity plume
2:14-2:17		Larger clay clasts, uneven bottom
2:17-2:24	Something crawling in lower left corner	Low visibility
2:25-2:27	Flounder	
2:28-2:37		Visibility is obscured by turbidity plume
2:38-2:50	Few small fish	Bottom is smoother, visibility is poor
2:44-2:47		Bottom becomes slightly uneven, small clay clasts
2:45	Crab	
2:48-2:51		Smooth bottom, visibility is poor
2:51-2:53		Turbidity plume
2:54-3:16	Few small fish, fish trails visible	Visibility is poor
3:08		Rope/line
3:16-3:19	Several fish, including a large fish	
3:20-4:30	Numerous small and medium fish and shrimp, occasional flounder	Bottom is soft and fairly smooth, visibility is poor

Running Time (m:s)	Biological Characteristics	Physical Characteristics
4:10-4:30		Camera occasionally hits bottom, camera dragged along bottom creating turbidity plume
4:30-4:39		Video transmission problem
4:39		Rope/line
4:40-4:59		Poor visibility, camera occasionally plowing along bottom creating turbidity plume. Sled ascends and exits Cell M19.
4:45		Debris
4:59		Encrusted debris
5:00-5:30	Small fish	Smooth bottom, poor visibility
5:12-5:15		Turbidity obscures view
5:26		Cup
5:31-5:36	Fish activity increases, flounder	More clay clasts
5:37-5:44		Sled ascends over some exposed clay on the channel bottom.
5:45-6:06	Occasional small fish, one flounder	Channel bottom is soft, fairly smooth. Turbidity plumes

M19_I (005-0853) Video Transect
Total Time: 6:42
Sled begins north of Cell M19 and travels southward descending into and exiting out of the cell. The sled passes through two deep trench-like areas in the north and south of the cell.

Running Time (m:s)	Biological Characteristics	Physical Characteristics
0:00-0:03	Medium-sized fish (flounder?)	Fairly coarse-grained sediment, small clay clasts, shell hash
0:03-0:06		Camera freezes
0:10-0:20		Water column
0:21-0:24	Numerous fish and shrimp, flounder	Soft, silty bottom, clay clasts, shell hash, fish leave sediment trails, occasional debris. Visibility is poor. Bottom appears slightly uneven, with sled bouncing off it several times.
1:08		Sled descends into Cell M19.
1:15-2:02	Not as many fish	Visibility improves, bottom appears more coarse-grained, but still contains small clay clasts, shell hash
1:22	Flounder	
1:42-1:49		Video transmission problem
1:55	Crab	
2:03-2:10		Sled descends into first trench-like area, uneven surface, exposed clay
2:11-2:29	Numerous small fish, flounder, few crabs, and shrimp	Bottom is similar to outside cell, coarse material, shells, debris, visibility is good
2:30-2:38		Bottom is smoother, finer grained material, some shell hash
2:39-2:45		Turbidity plume obscures view

2:46-4:00	Numerous small fish and shrimp	Sediment is soft and silty. Turbidity in front of sled. Bottom is uneven. Sled ascends out of the first trench 2:50)
3:19-3:59		Line, possibly from lobster pot set
4:00-4:09		Sled appears to lift off bottom, only water column is visible
4:10-4:39	Numerous fish	A lot of turbidity when sled lands. Visibility is poor. Bottom is very soft and silty
4:40-4:44		Sled appears to lift off bottom, only water column is visible
4:45-4:50		A lot of turbidity when sled lands
4:51-5:02		Sled ascends out of the cell, As the sled is hoisted, the video captures images of the water column
5:03-5:09		A lot of turbidity when sled lands
5:10		Debris
5:11-6:01	Occasional fish visible	Very soft, silty sediment. Turbidity in front of sled. Poor visibility. Occasional debris
6:02-6:20		Sled appears to ascend over an uneven surface, much turbidity
6:21-6:42	Some small fish	Soft, silty sediment, much turbidity. Uneven bottom

M19_J (006-0952) Video Transect
Total Time: 4:51
Sled begins north of Cell M19 and travels southward descending into and exiting out from the cell.

Running Time (m:s)	Biological Characteristics	Physical Characteristics
0:00-0:03		Silty bottom, some shell hash or small clay clasts
0:12-0:14		Silty bottom, some shell hash or small clay clasts
0:15	Flounder	
0:16-0:34	Some small fish and shrimp	Silty bottom with shell hash
0:22-0:25		Abundant shell hash
0:35-1:20	Numerous small fish and shrimp, some flounder, some algae	Silty bottom with abundant shell hash, small clay clasts? Slightly irregular bottom
1:21-1:25		Sled makes descent over exposed clay wall
1:26-1:27		Very abundant shell hash, small clay clasts? Silty – sled creates turbidity plume when it lands
1:28-1:28		Sled makes a short descent
1:29-1:38	Some fish	Abundant shell hash
1:39		Line, possibly from lobster trap set
1:40-1:54	Numerous small fish and shrimp, some flounder	Shell hash, weathered clay
1:55-2:02	Numerous small fish and shrimp, some flounder	Less shell hash
2:03-2:04		Sled passes over clay ridge – slight descent
2:05-3:18	Numerous small fish and flounder, some shrimp and algae	Smooth, silty bottom, turbidity plumes caused by fish
2:52	Large piece of algae gets caught on sled	
3:19-3:23		Sled appears to make descent
3:24-4:13	Numerous small fish and flounder, some algae	Smooth, silty bottom, turbidity plumes caused by fish
3:35	Medium-sized fish creating turbidity plume	

Running Time (m:s)	Biological Characteristics	Physical Characteristics
4:14-4:34	Numerous small fish	Sled appears to ascend exposed clay wall – sled exits M19
4:35-4:51	Numerous small fish and flounder, some algae	Smooth, silty bottom, turbidity plumes caused by fish
4:49	Medium-sized fish (flounder?) passes directly in front of camera	
5:20		

SC_M12_B (022_1222) Video Transect
Total Time: 4:08
The transect begins in the southwestern corner of the Supercell (SC), proceeds southwest out of cell SC, across the channel bottom, enters cell M12 at its southeast corner, and ends within cell M12 along its southern boundary.

Running Time (m:s)	Biological Characteristics	Physical Characteristics
0:00-0:10		Sled descends through water column. Very poor visibility through most of the transect due to high ambient suspended material and turbidity generated by sled.
0:11	Occasional fish and fish trails	Very soft sediment, some algae
0:11-0:30		Sled gradually ascends Supercell wall (not apparent in video).
1:31	Possible lobster	
1:31-2:20	Numerous small fish, flounder	Channel bottom appears somewhat irregular with fine-grained sediment. Some debris
2:20-2:40	Numerous small fish, flounder	Sled gradually descends into cell M12 (not apparent in video). Some debris.
2:48-2:50		Soft bottom with very fine-grained sediment. Sled creates elevated turbidity limiting visibility.
2:51- 3:02	Several small fish	Continued very fine-grained sediment
3:03		Can
3:04	Small fish and shrimp	
3:15-4:08		Continued very fine-grained sediment. Sled creates elevated turbidity.

*A narration of this full-length video, between time 0:00 and 3:30, is available.

Appendix B

Sediment-Profile Images Results for BHCAD Cells – August 2004 Survey

Table B-1
Grain Size Scale for Sediments

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

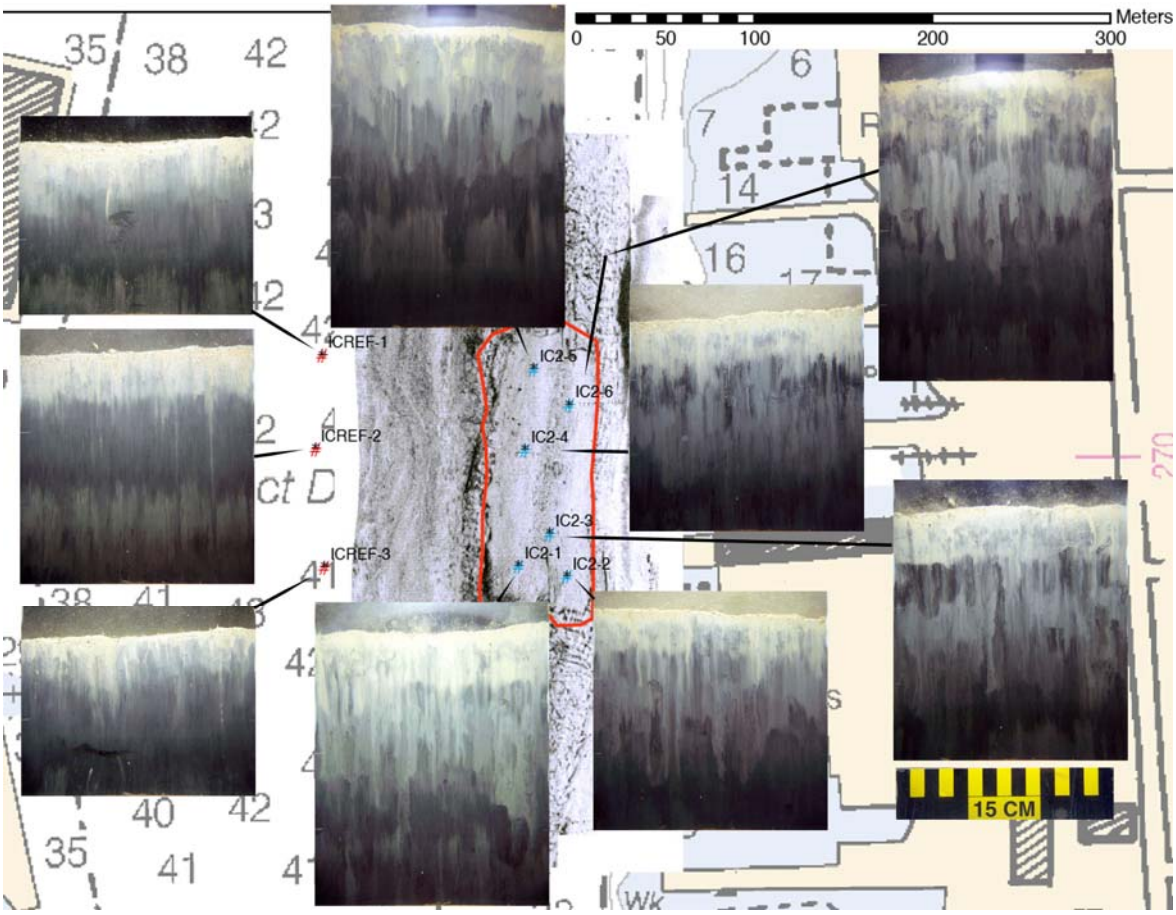


Figure B-1. SPI images from IC2 and IC-REF station, August 2004

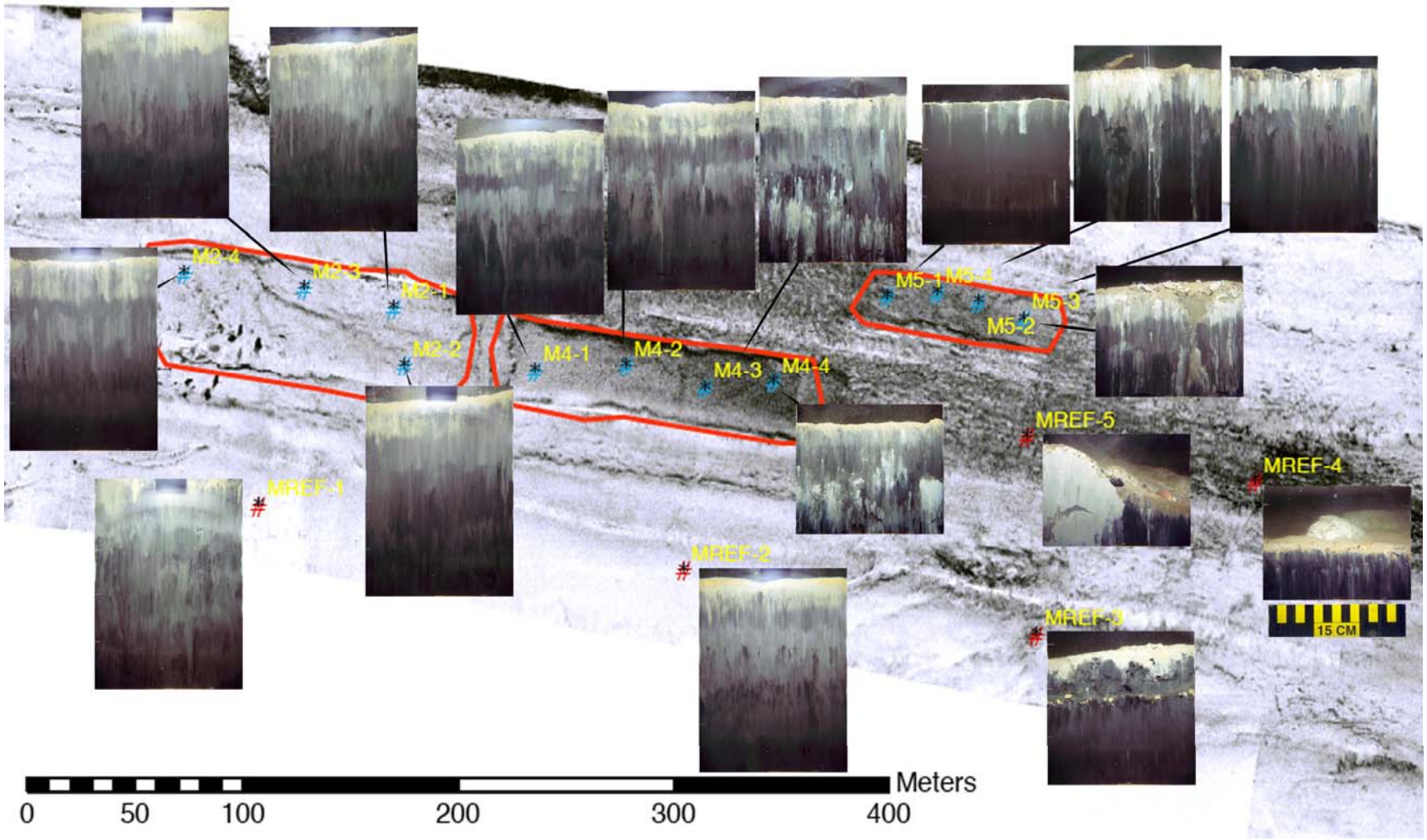


Figure B-2. SPI images from M2, M4, M5 and five MREF stations, August 2004.

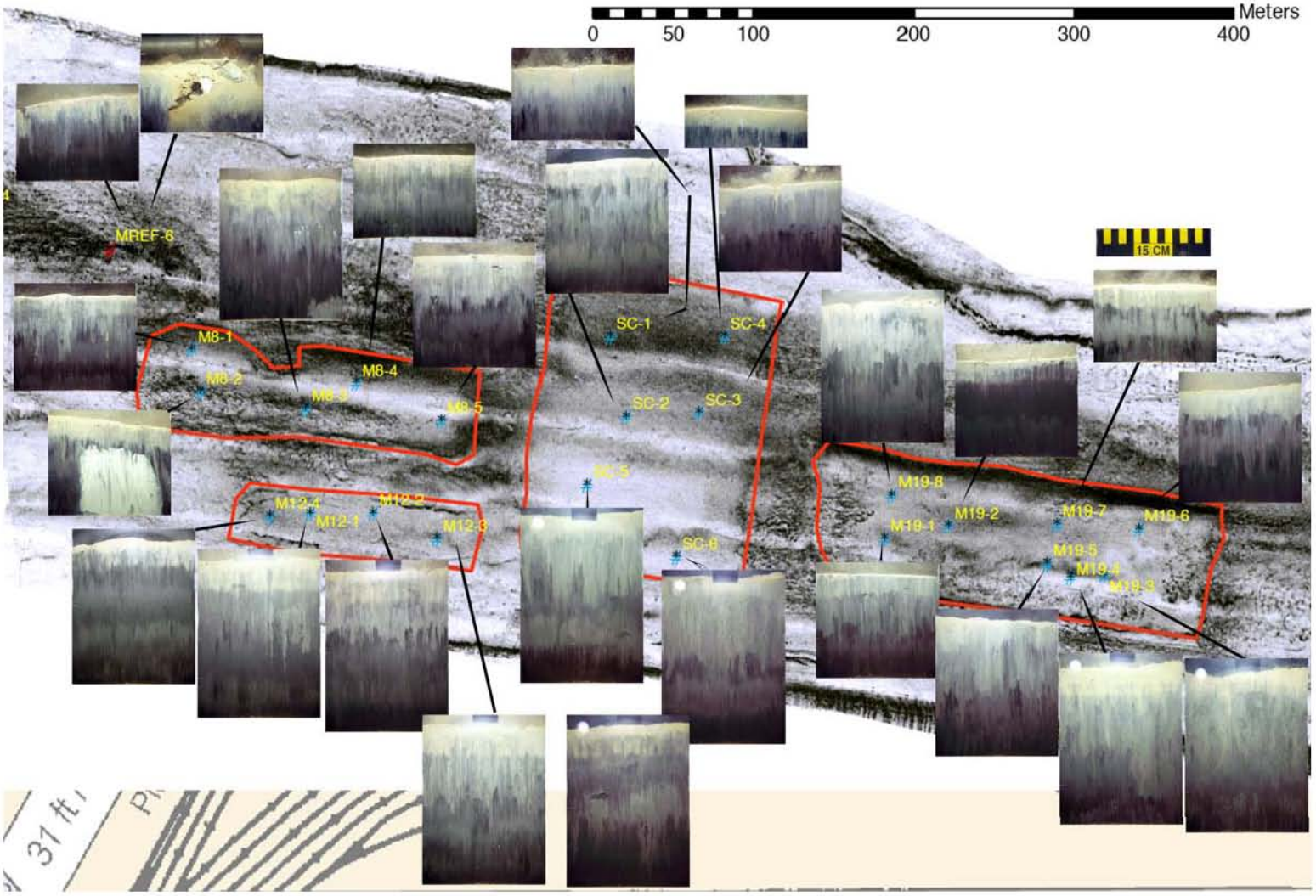


Figure B-3. SPI images from M8, M12, M19, MREF-6, and SC stations, August 2004.

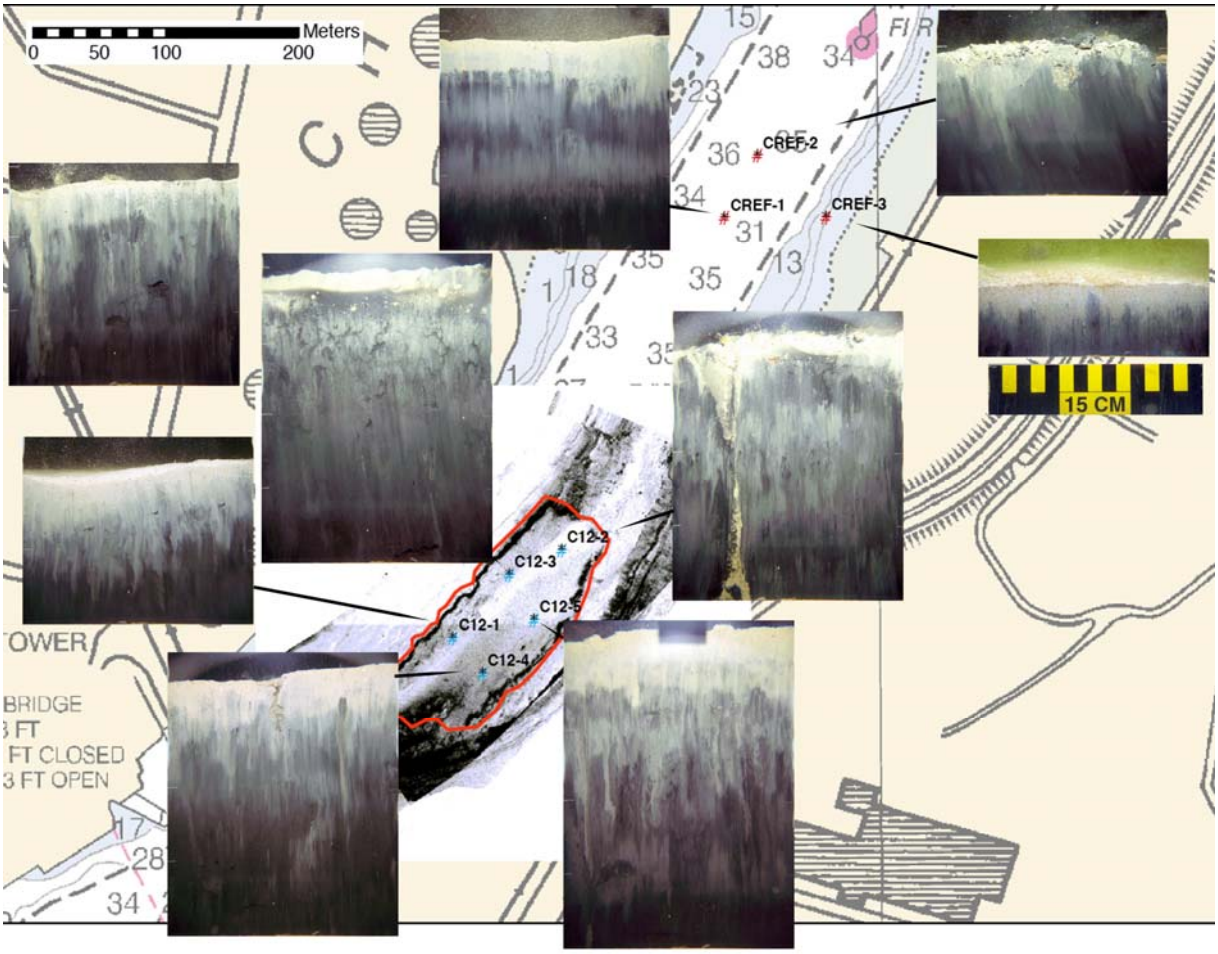


Figure B-4. SPI images from C12 and CREF stations, August 2004.

Table B-2 Sediment-Profile Image Results for Stations at BHCAD

Station ID	Replicate	Penetration Depth Mean (cm)	Boundary Roughness (cm)	Boundary Roughness Type	RPD Depth Mean (cm) (IND - Indeterminate)	RPD Qual (DI - Disturbed Image, OP Over Penetrated)	Grain Size (Mode PHI)	Maximum PHI	Grain Size Mode Category	Maximum Category	Grain Size Comment	Clay Clast	Tubes (# image)	Burrow	Infauna (# image)	Oxic Voids (# image)	Anaero. Voids (# image)	Methane/Gas Voids (# image)	Succ. Stage	Epifauna/Infauna
C12-1	1	10.5	1.5	Physical	1.6		>6	>4	SICL	SI			15	+	3	0	3	0	I	
C12-1	2	14.0	0.8	Physical	1.4	DI	>6	>4	SICL	SI			1	+	0	0	1	0	I	
C12-1	3	17.8	4.1	Physical	1.9		>6	>4	SICL	SI			3	+	0	0	2	0	I	
C12-2	1	17.7	4.4	Physical	2.4	DI	>6	>4	SICL	SI			0	-	0	0	0	0	I	
C12-2	2	18.0	1.3	Physical	1.5		>6	>4	SICL	SI			4	+	0	0	0	0	I	Hydroids
C12-2	3	18.2	2.8	Physical	IND	DI	>6	>4	SICL	SI			0	-	0	0	0	0	I	
C12-3	1	20.3	0.0	Physical	1.1		>6	>4	SICL	SI	mixed sedi layer		0	-	0	0	4	1	I	
C12-3	2	16.6	0.7	Physical	1.5	DI	>6	>4	SICL	SI			1	-	0	0	0	0	I	Shrimp
C12-3	3	7.4	2.5	Physical	1.3		>6	>4	SICL	SI			2	-	0	0	1	0	I	
C12-4	1	18.3	1.3	Physical	1.3		>6	>4	SICL	SI			0	+	3	0	3	3	I	
C12-4	2	15.5	0.9	Physical	1.5		>6	>4	SICL	SI	Whole shell		2	-	3	0	1	0	I	tentacles in sedi?
C12-4	3	17.8	1.0	Physical	1.0		>6	>4	SICL	SI			4	-	0	0	0	0	I	
C12-5	1	22.0	1.4	Physical	2.1		>6	>4	SICL	SI			1	-	0	0	2	0	I	
C12-5	2	20.8	0.8	Physical	1.1		>6	>4	SICL	SI			4	+	0	1?	2	0	I to >I	
C12-5	3	21.8	1.1	Physical	1.4		>6	>4	SICL	SI			1	+	1	1?	1	1	I to >I	
C12-6	1	13.9	1.0	Physical	1.3		>6	>4	SICL	SI			0	+	2	1?	2	0	I to >I	Hermit crab
C12-6	2	11.9	1.1	Physical	1.3		>6	>4	SICL	SI			8	+	2	0	0	0	I	Hydroids
C12-6	3	15.4	1.9	Physical	1.2		>6	>4	SICL	SI			2	+	2	1	1	0	I to III	Shrimp, tentacles in sedi?
CREF-1	1	14.8	0.8	Physical	1.0		>6	>4	SICL	SI			1	-	2	0	1	0	I	
CREF-1	2	7.8	1.3	Physical	1.1	DI	>4	4-2	SIFS	FS			2	-	1	1?	0	0	I to >I	
CREF-1	3	9.4	2.5	Physical	0.4		>4	4-2	SIFS	FS			0	-	0	0	0	0	I	
CREF-2	1	11.5	1.3	Physical	0.5		>4	-1--2	SIFS	GR			15	+	0	1?	0	0	I to >I	
CREF-2	2	4.3	2.2	Physical	1.1		>4	-2--6	SIFS	PB			2	+	0	0	0	0	I	
CREF-2	3	9.7	1.3	Physical	0.7		>4	-1--2	SIFS	GR	Cap material layer?		3	-	0	0	0	0	I	large tubes
CREF-3	1	2.6	0.6	Physical	0.9		4-1	2-1	FSMS	MS	bedforms		0	-	0	0	0	0	I	
CREF-3	2	5.0	0.3	Physical	1.5		4-1	2-1	FSMS	MS	bedforms		0	+	0	0	0	0	I	microalgae
CREF-3	3	2.6	0.8	Physical	1.6		4-1	2-1	FSMS	MS	bedforms		0	-	0	0	0	0	I	microalgae
IC2-1	1	22.6	0.5	Physical	0.9		>6	>4	SICL	SI			0	-	0	0	1	0	I	
IC2-1	2	21.2	0.5	Physical	0.2	DI	>6	>4	SICL	SI			1	-	0	0	3	0	I	
IC2-1	3	18.8	1.0	Physical	1.0		>6	>4	SICL	SI			2	-	0	0	2	0	I	
IC2-2	1	14.6	0.8	Physical	0.8		>6	>4	SICL	SI			1	-	1	0	1	0	I	
IC2-2	2	13.1	1.0	Physical	0.7		>6	>4	SICL	SI			1	-	0	0	3	0	I	
IC2-2	3	14.0	0.5	Physical	1.0		>6	>4	SICL	SI			2	-	0	0	4	0	I	
IC2-3	1	13.7	1.1	Physical	0.5		>6	>4	SICL	SI			3	+	2	0	2	0	I	
IC2-3	2	14.3	0.8	Physical	0.9		>6	>4	SICL	SI			3	+	4	0	1	0	I	
IC2-3	3	16.9	0.9	Physical	0.7		>6	>4	SICL	SI			10	+	0	0	0	0	I	
IC2-4	1	14.8	1.3	Physical	0.9		>6	>4	SICL	SI			18	+	2	0	1	0	I	
IC2-4	2	22.3	1.1	Physical	1.1	DI	>6	>4	SICL	SI			0	-	0	0	1	0	I	
IC2-4	3	22.4	0.8	Physical	1.2	DI	>6	>4	SICL	SI			0	-	0	0	1	0	I	2 SNAILS
IC2-5	1	21.8	0.5	Physical	1.1		>6	>4	SICL	SI			8	+	2	0	1	0	I	
IC2-5	2	20.5	0.7	Physical	0.8		>6	>4	SICL	SI			1	+	1	0	1	0	I	
IC2-5	3	20.2	1.3	Physical	0.8		>6	>4	SICL	SI			25	+	2	0	1	0	I	

Table B-2 Sediment-Profile Image Results for Stations at BHCAD

Station ID	Replicate	Penetration Depth Mean (cm)	Boundary Roughness (cm)	Boundary Roughness Type	RPD Depth Mean (cm) (IND - Indeterminate)	RPD Qual (DI - Disturbed Image, OP Over Penetrated)	Grain Size (Mode PHI)	Maximum PHI	Grain Size Mode Category	Maximum Category	Grain Size Comment	Clay Clast	Tubes (# image)	Burrow	Infauna (# image)	Oxic Voids (# image)	Anaero. Voids (# image)	Methane/Gas Voids (# image)	Succ. Stage	Epifauna/Infauna
IC2-6	1	12.5	0.4	Physical	0.8		>6	>4	SICL	SI			10	+	0	0	1	0	I	
IC2-6	2	21.8	1.5	Physical	0.9		>6	>4	SICL	SI			0	-	1	0	2	0	I	
IC2-6	3	20.4	1.1	Physical	1.0		>6	>4	SICL	SI			1	+	0	0	1	0	I	
IC-REF-1	1	16.8	0.2	Physical	0.6		>6	>4	SICL	SI			15	+	3	1	3	0	I to III	
IC-REF-1	2	11.9	0.4	Physical	0.9		>6	>4	SICL	SI			2	+	1	0	1	0	I	
IC-REF-1	3	8.0	0.6	Physical	0.5		>6	>4	SICL	SI			2	-	2	4	0	0	I to III	Hydroids
IC-REF-2	1	9.2	0.8	Physical	0.4		>4	4-2	SIFS	FS			0	+	0	0	1	0	I	
IC-REF-2	2	15.9	0.8	Physical	0.7		>4	4-2	SIFS	FS			2	+	0	0	0	0	I	Hermit crab in shell, Mysic
IC-REF-2	3	11.3	0.4	Physical	1.0		>4	4-2	SIFS	FS			0	+	1	0	0	0	I	
IC-REF-3	1	11.0	0.8	Physical	0.7		>6	>4	SICL	SI			15	+	0	0	1	0	I	
IC-REF-3	2	9.3	0.7	Physical	0.7		>4	4-2	SIFS	FS			10	+	1	0	0	0	I	
IC-REF-3	3	10.6	0.4	Physical	0.9		>4	4-2	SIFS	FS			8	+	0	0	1	0	I	
M12-1	1	21.2	1.7	Physical	1.2		>6	>4	SICL	SI			0	-	0	0	1	0	I	
M12-1	2	20.5	0.7	Physical	1.2		>6	>4	SICL	SI			0	+	0	0	0	0	I	
M12-1	3	21.8	1.1	Physical	1.3		>6	>4	SICL	SI			0	-	0	0	1	0	I	
M12-2	1	22.2	0.3	Physical	1.0		>6	>4	SICL	SI			0	+	0	0	2	3	I	
M12-2	2	21.6	0.1	Physical	0.8		>6	>4	SICL	SI			0	-	0	0	3	0	I	
M12-2	3	21.1	0.8	Physical	0.9		>6	>4	SICL	SI			0	+	4	0	0	0	I	large worm
M12-3	1	20.6	0.7	Physical	0.9		>6	>4	SICL	SI			0	-	0	0	2	0	I	
M12-3	2	20.4	0.7	Physical	1.0		>6	>4	SICL	SI			0	-	0	0	0	0	I	
M12-3	3	16.8	1.0	Physical	0.7		>6	>4	SICL	SI			0	-	3	2	1	0	I to III	
M12-4	1	18.4	1.3	Physical	1.0		>6	>4	SICL	SI			0	-	0	0	0	5	I	
M12-4	2	14.6	0.6	Physical	0.9		>6	>4	SICL	SI			1	+	0	0	2	0	I	
M12-4	3	20.2	1.0	Physical	1.1		>6	>4	SICL	SI			0	-	1	0	3	0	I	
M19-1	1	13.4	0.6	Physical	0.3		>6	>4	SICL	SI			0	-	0	0	4	0	I	
M19-1	2	12.3	3.4	Physical	0.4		>6	>4	SICL	SI			0	-	0	0	1	0	I	
M19-1	3	15.4	1.4	Physical	1.6	DI	>6	>4	SICL	SI			0	-	0	0	0	0	I	
M19-2	1	10.5	0.8	Physical	0.5		>6	>4	SICL	SI			5	+	0	0	0	0	I	
M19-2	2	12.5	1.0	Physical	0.6		>6	>4	SICL	SI			0	-	1	0	0	0	I	
M19-2	3	10.6	1.1	Physical	0.5		>6	>4	SICL	SI			3	+	0	0	1	0	I	
M19-3	1	20.9	1.5	Physical	1.4		>6	>4	SICL	SI			4	-	0	1	1	0	I to III	
M19-3	2	10.9	1.0	Physical	0.9		>6	>4	SICL	SI			1	-	1	0	0	0	I	
M19-3	3	14.1	1.0	Physical	IND	DI	>6	>4	SICL	SI			IND	-	0	0	1	0	I	
M19-4	1	21.0	1.0	Physical	1.7		>6	>4	SICL	SI			0	-	1	0	0	0	I	
M19-4	2	14.5	0.4	Physical	1.4		>6	>4	SICL	SI			0	-	2	0	0	0	I	
M19-4	3	16.2	1.6	Physical	0.8		>6	>4	SICL	SI			0	-	0	0	1	0	I	
M19-5	1	17.6	1.3	Physical	1.1		>6	>4	SICL	SI			0	-	0	0	0	0	I	
M19-5	2	17.9	0.9	Physical	0.9		>6	>4	SICL	SI			0	+	1	0	2	0	I	
M19-5	3	19.0	0.4	Physical	IND	DI	>6	>4	SICL	SI			IND	-	0	0	0	0	I	
M19-6	1	15.0	1.3	Physical	0.9		>6	>4	SICL	SI			1	+	0	0	0	0	I	
M19-6	2	14.9	1.8	Physical	IND	DI	>6	>4	SICL	SI			IND	-	0	0	0	0	I	
M19-6	3	14.4	1.5	Physical	1.1		>6	>4	SICL	SI			10	-	0	0	2	0	I	

Table B-2 Sediment-Profile Image Results for Stations at BHCAD

Station ID	Replicate	Penetration Depth Mean (cm)	Boundary Roughness (cm)	Boundary Roughness Type	RPD Depth Mean (cm) (IND - Indeterminate)	RPD Qual (DI - Disturbed Image, OP Over Penetrated)	Grain Size (Mode PHI)	Maximum PHI	Grain Size Mode Category	Maximum Category	Grain Size Comment	Clay Clast	Tubes (# image)	Burrow	Infauna (# image)	Oxic Voids (# image)	Anaero. Voids (# image)	Methane/Gas Voids (# image)	Succ. Stage	Epifauna/Infauna
M19-7	1	10.1	0.4	Physical	1.0		>6	>4	SICL	SI			0	-	0	0	0	0	I	
M19-7	2	11.2	2.4	Physical	IND	DI	>6	>4	SICL	SI			0	-	0	0	0	0	I	
M19-7	3	11.6	0.7	Physical	0.9		>6	>4	SICL	SI			0	-	0	0	1	0	I	
M19-8	1	14.7	1.3	Physical	IND	DI	>6	>4	SICL	SI			0	-	0	0	1	0	I	
M19-8	2	18.3	1.2	Physical	1.0		>6	>4	SICL	SI			0	-	0	0	0	0	I	
M19-8	3	11.1	1.6	Physical	0.9		>6	>4	SICL	SI			0	+	0	0	2	0	I	
M2-1	1	20.7	1.4	Physical	1.0		>6	>4	SICL	SI			0	+	0	0	0	0	I	
M2-1	2	20.5	0.6	Physical	1.3		>6	>4	SICL	SI			0	+	0	0	1	0	I	
M2-1	3	21.3	1.8	Physical	IND	DI	>6	>4	SICL	SI			1	+	0	0	0	0	I	
M2-2	1	22.1	0.7	Physical	1.1		>6	>4	SICL	SI			0	-	1	0	0	0	I	
M2-2	2	>24		Physical	IND	OP	>6	>4	SICL	SI			IND	-	0	0	0	0	I	
M2-2	3	21.6	1.7	Physical	1.0		>6	>4	SICL	SI			0	-	0	0	0	0	I	
M2-3	1	22.3	0.5	Physical	1.3		>6	>4	SICL	SI			0	-	1	0	1	0	I	
M2-3	2	>24		Physical	IND		>6	>4	SICL	SI			IND	-	0	0	0	0	I	
M2-3	3	>24		Physical	IND		>6	>4	SICL	SI			IND	-	0	0	2	0	I	
M2-4	1	22.1	0.7	Physical	1.2		>6	>4	SICL	SI			1	+	0	0	0	0	I	
M2-4	2	>24		Physical	0.9		>6	>4	SICL	SI			IND	+	0	0	0	0	I	
M2-4	3	20.7	0.6	Physical	0.6		>6	>4	SICL	SI			2	+	0	0	0	0	I	
M4-1	1	22.3	0.3	Physical	0.9		>6	>4	SICL	SI			0	+	0	0	2	0	I	
M4-1	2	19.5	1.2	Physical	0.8		>6	>4	SICL	SI			3	+	0	0	2	0	I	
M4-1	3	22.1	1.4	Physical	IND	DI	>6	>4	SICL	SI			0	-	0	0	0	0	I	
M4-2	1	20.1	0.8	Physical	0.9		>6	>4	SICL	SI			1	-	0	0	2	0	I	
M4-2	2	18.2	0.7	Physical	0.8		>6	>4	SICL	SI			0	-	0	0	2	0	I	
M4-2	4	>24		Physical	IND	DI	>6	>4	SICL	SI			IND	+	0	0	1	0	I	
M4-3	1	18.2		Physical	IND	DI	>6	>4	SICL	SI	Plastic Bag?		IND	IND	IND	IND	IND	IND	IND	Plastic Bag?
M4-3	2	17.8	0.4	Physical	0.7		>7	>4	CLSI	SI	light gray clay	+	1	+	0	1	0	0	I to III	Hydroids
M4-3	3	11.7	3.3	Physical	0.8		>7	>4	CLSI	SI	light gray clay	+	0	+	0	0	1	0	I	Shrimp
M4-4	1	12.2	0.6	Physical	0.6		>7	>4	CLSI	SI	light gray clay	+	0	+	1	0	2	0	I	
M4-4	2	10.8	0.9	Physical	0.7		>7	>4	CLSI	SI	light gray clay	+	0	-	0	0	4	10	I	
M4-4	3	18.7	0.6	Physical	0.6		>6	>4	SICL	SI	light gray clay	+	0	+	1	0	1	0	I	
M5-1	1	15.6	0.3	Physical	0.2		>6	>4	SICL	SI			5	-	0	0	0	0	I	
M5-1	2	5.6	2.2	Physical	IND	DI	>7	-2--6	CLSI	PB	light gray clay	+	0	-	0	0	2	0	I	Hermit crab
M5-1	3	13.1	0.9	Physical	IND		>4	1--1	SIFS	CS			6	-	0	0	1	0	I	
M5-2	1	12.6	0.9	Physical	0.9		>7	1--1	CLSI	CS	light gray clay	+	0	-	0	0	1	0	I	4 Crangon shrimp
M5-2	2	11.8	0.2	Physical	0.7		>7	1--1	CLSI	CS	light gray clay	+	1	-	1	0	3	0	I	
M5-2	3	13.3	0.5	Physical	0.7		>7	1--1	CLSI	CS	light gray clay	+	0	-	0	0	0	0	I	
M5-3	1	15.8	0.3	Physical	IND	DI	>7	1--1	CLSI	CS	light gray clay	+	0	-	0	0	0	0	I	
M5-3	2	16.3	0.3	Physical	0.6		>7	1--1	CLSI	CS	light gray clay	+	0	-	0	0	2	0	I	
M5-3	3	17.6	0.7	Physical	0.3		>7	1--1	CLSI	CS	light gray clay	+	0	-	0	0	1	1	I	
M5-4	1	16.7	0.4	Physical	0.4		>7	1--1	CLSI	CS	light gray clay	+	0	-	1	0	1	0	I	Crangon
M5-4	2	14.9	0.3	Physical	0.4		>7	-1--2	CLSI	GR	light gray clay	+	0	-	1	0	0	0	I	
M5-4	3	11.1	1.1	Physical	1.1		>7	-1--2	CLSI	GR	light gray clay	+	1	-	2	0	0	0	I	

Table B-2 Sediment-Profile Image Results for Stations at BHCAD

Station ID	Replicate	Penetration Depth Mean (cm)	Boundary Roughness (cm)	Boundary Roughness Type	RPD Depth Mean (cm) (IND - Indeterminate)	RPD Qual (DI - Disturbed Image, OP Over Penetrated)	Grain Size (Mode PHI)	Maximum PHI	Grain Size Mode Category	Maximum Category	Grain Size Comment	Clay Clast	Tubes (# image)	Burrow	Infauna (# image)	Oxic Voids (# image)	Anaero. Voids (# image)	Methane/Gas Voids (# image)	Succ. Stage	Epifauna/Infauna
M8-1	1	8.5	0.9	Physical	0.5		>4	4-2	SIFS	FS			2	+	0	0	0	0	I	
M8-1	2	12.3	0.8	Physical	0.4		>4	4-2	SIFS	FS			3	+	1	0	0	0	I	
M8-1	3	11.5	1.2	Physical	0.4		>4	4-2	SIFS	FS			5	+	1	0	2	0	I	
M8-2	1	12.2	1.8	Physical	0.6		>7	>4	CLSI	SI	light gray clay	+	0	-	0	0	0	0	I	
M8-2	2	16.9	0.8	Physical	0.7		>7	>4	CLSI	SI	light gray clay	+	2	-	1	1	1	0	I to III	
M8-2	3	20.4	0.5	Physical	0.9		>6	4-2	SICL	FS			3	-	1	0	1	0	I	
M8-3	2	18.1	0.4	Physical	1.1		>7	>4	CLSI	SI	light gray clay	+	0	-	0	0	0	0	I	
M8-3	3	12.8	0.5	Physical	0.8		>6	>4	SICL	SI	light gray clay	+	0	+	0	2	1	0	I to III	
M8-3	4	13.1	0.8	Physical	0.6		>7	>4	CLSI	SI	light gray clay	+	0	+	1	0	0	0	I	
M8-4	1	13.3	0.7	Physical	0.7		>6	>4	SICL	SI			3	+	1	0	1	0	I	
M8-4	2	11.2	0.5	Physical	0.5		>6	>4	SICL	SI			2	+	2	0	3	0	I	
M8-4	3	10.7	0.3	Physical	0.7		>6	>4	SICL	SI			3	+	0	0	0	0	I	
M8-5	1	14.7	0.5	Physical	0.5		>6	>4	SICL	SI			2	+	0	1	2	0	I to III	
M8-5	2	13.7	0.3	Physical	0.6		>6	>4	SICL	SI			2	+	0	1	1	0	I to III	
M8-5	3	13.6	0.8	Physical	0.5		>6	>4	SICL	SI			0	+	0	0	0	0	I	Shrimp
MREF-1	1	>24		Physical	IND	OP	>6	>4	SICL	SI			IND	-	0	0	0	0	I	
MREF-1	2	>24		Physical	IND	OP	>6	>4	SICL	SI			IND	-	0	0	0	0	I	
MREF-1	3	>24		Physical	IND	OP	>6	>4	SICL	SI			IND	-	0	0	0	4	I	
MREF-2	1	20.9	0.7	Physical	0.8		>6	>4	SICL	SI			0	+	0	0	0	0	I	
MREF-2	2	22.1	0.9	Physical	1.0		>6	>4	SICL	SI			0	+	1	0	1	0	I	
MREF-2	3	21.5	0.8	Physical	0.9		>6	>4	SICL	SI			0	-	0	0	1	0	I	
MREF-3	1	14.0	0.7	Physical	IND	DI	>7	>4	CLSI	SI	light gray clay	+	2	-	0	0	1	0	I	
MREF-3	2	11.6	0.7	Physical	IND	DI	>7	>4	CLSI	SI	light gray clay	+	0	-	0	0	0	0	I	
MREF-3	3	14.4	1.7	Physical	0.7	DI	>7	>4	CLSI	SI	light gray clay	+	3	-	0	0	0	0	I	
MREF-4	1	6.7	1.2	Physical	0.7		>7	-2--6	CLSI	PB	light gray clay	+	25	-	0	0	0	0	I	Tubes on Clay clast
MREF-4	4	5.6	0.9	Physical	0.4		>7	-2--6	CLSI	PB	light gray clay	+	25	+	0	0	0	0	I	Tubes on Clay clast
MREF-4	5	8.6	3.6	Physical	IND	DI	>7	-2--6	CLSI	PB	light gray clay	+	20	-	0	0	0	0	I	Tubes on Clay clast
MREF-5	1	3.5	1.7	Physical	0.8		>7	>4	CLSI	SI	light gray clay	+	5	-	0	0	0	0	I	Tubes on Clay clast
MREF-5	2	7.6	6.8	Physical	0.9		>7	>4	CLSI	SI	light gray clay	+	30	-	0	0	0	0	I	Tubes on Clay clast
MREF-5	3	6.2	1.5	Physical	IND		>7	>4	CLSI	SI	light gray clay	+	5	-	0	0	0	0	I	Tubes on Clay clast
MREF-6	1	10.4	1.7	Physical	0.5		>6	>4	SICL	SI			2	+	0	0	1	0	I	
MREF-6	2	3.3	6.5	Physical	0.7		>6	>4	SICL	SI			3	+	0	0	0	0	I	
MREF-6	3	7.3	3.0	Physical	1.5		>7	-2--6	CLSI	PB	light gray clay	+	10	-	0	0	0	0	I	Tubes on Clay clast
SC-1	1	9.5	0.8	Physical	0.8		>4	4-2	SIFS	FS			2	-	1	0	1	0	I	
SC-1	2	4.6	0.5	Physical	0.9		>4	4-2	SIFS	FS			3	+	0	1	0	0	I to III	
SC-1	3	7.4	0.6	Physical	0.9		>4	4-2	SIFS	FS			0	+	1	0	1	0	I	
SC-2	1	9.7	0.6	Physical	0.9		>6	>4	SICL	SI			1	+	1	1?	0	0	I to >I	
SC-2	2	6.2	0.5	Physical	0.7		>4	4-2	SIFS	FS			3	+	0	0	0	0	I	
SC-2	3	17.2	0.8	Physical	0.9		>6	>4	SICL	SI			4	+	0	0	3	0	I	
SC-3	1	12.3	0.8	Physical	0.7		>6	>4	SICL	SI			10	+	1	0	1	0	I	
SC-3	2	11.2	1.0	Physical	IND		>6	>4	SICL	SI			0	-	0	0	0	0	I	
SC-3	3	11.2	1.3	Physical	0.5		>6	>4	SICL	SI			0	-	1	0	0	0	I	

Table B-2 Sediment-Profile Image Results for Stations at BHCAD

Station ID	Replicate	Penetration Depth Mean (cm)	Boundary Roughness (cm)	Boundary Roughness Type	RPD Depth Mean (cm) (IND - Indeterminate)	RPD Qual (DI - Disturbed Image, OP Over Penetrated)	Grain Size (Mode PHI)	Maximum PHI	Grain Size Mode Category	Maximum Category	Grain Size Comment	Clay Clast	Tubes (# image)	Burrow	Infauna (# image)	Oxic Voids (# image)	Anaero. Voids (# image)	Methane/Gas Voids (# image)	Succ. Stage	Epifauna/Infauna
SC-4	1	4.0	1.4	Physical	1.0		>4	1--1	SIFS	CS			0	+	0	0	0	0	I	
SC-4	2	5.4	0.8	Physical	1.5		>4	1--1	SIFS	GR			0	-	1	0	0	0	I	Shrimp
SC-4	3	4.9	0.8	Physical	0.7		>4	4-2	SIFS	FS			0	+	1	0	0	0	I	
SC-5	1	22.0	0.7	Physical	0.7		>6	>4	SICL	SI			1	+	1	0	5	0	I	
SC-5	2	20.5	0.6	Physical	0.8		>6	-2--6	SICL	PB	Red Brick?		0	+	0	0	2	0	I	Brick? With Hydroid
SC-5	3	>24		Physical	IND	DI	>6	>4	SICL	SI			IND	-	0	0	2	0	I	
SC-6	1	22.0	0.6	Physical	1.2		>6	>4	SICL	SI			4	+	0	0	0	0	I	
SC-6	2	21.4	1.3	Physical	1.0		>6	>4	SICL	SI			3	-	0	0	0	0	I	
SC-6	3	22.1	0.9	Physical	0.5		>6	>4	SICL	SI			0	-	0	0	0	0	I	
SC-7	1	15.6	1.9	Physical	0.7		>6	>4	SICL	SI			5	+	3	0	2	0	I	
SC-7	2	20.9	0.9	Physical	0.7		>6	>4	SICL	SI			2	+	0	0	2	0	I	
SC-7	3	18.2	0.4	Physical	0.4		>6	>4	SICL	SI			0	+	1	0	0	0	I	