STABILITY AND RECOVERY OF CAPPED IN-CHANNEL CAD CELLS: BOSTON HARBOR, MASSACHUSETTS

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ABSTRACT

The Boston Harbor Navigation Improvement Project involved dredging within the Inner Harbor and construction of nine confined aquatic disposal (CAD) cells beneath the navigable channel from 1997 to 2000. The cells received dredged sediments that were unsuitable for unconfined open water disposal, and were capped with sand to further isolate the dredged material. Given that the use of CAD cells directly beneath the channel was a relatively new technique, investigations were required to assess the effectiveness of disposal into the cells, cap placement, and longer term stability and benthic recovery of the cells. The longer term follow-up investigation was performed in August 2004, four to seven years after completion of individual CAD cells and included bathymetry, side-scan sonar, underwater video, and sediment profile imaging.

The bathymetry and side-scan sonar data revealed that all nine CAD cells remained as stable structures with no evidence of significant cap disturbance. As expected, limited further consolidation of the material within the cells had taken place. While many of the cells had sand exposed at the surface at the completion of the project, silt-clay was identified as the predominant surficial sediment in 2004. This shift was expected as natural deposition takes place over the cells. Sediment profile images taken in 2004 revealed that the benthic habitat conditions within the cells and reference areas were similar, but both were indicative of a stressed environment, not unexpected given periodic episodes of poor water quality and disturbance associated with a working harbor. The towed video footage revealed an environment teeming with small fish and crustaceans, both over the CAD cells and reference areas.

Keywords: Dredging, dredged material disposal, confined aquatic disposal, benthos, contaminated sediment.

INTRODUCTION

An investigation of 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 as part of the Boston Harbor Navigation Improvement Project (BHNIP), a joint project between the USACE and the Massachusetts Port Authority carried out between 1997 and 2000. The BHNIP 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)), from the upper reaches of Boston Harbor (Figure 1). 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 the CAD cells located within the dredging project footprint in the Federal navigation channels (USACE and Massport 1995) (Figure 1). The State Water Quality Certification for the project called for capping the cells with a 1 m (3.3 ft) layer of sand after completion of disposal (MADEP 1998).

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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 2). 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 and a consolidation period, eight of the CAD cells were capped with a layer of sand, while the ninth cell remained open with excess capacity. Four rounds of capping were performed over the course of the project. For the first cell capped, sand was deposited from split-hulled scows positioned at a series of fixed locations over the cell. For the remaining three rounds of capping, sand was deposited using a hopper dredge partially split, maneuvered over the cell under its own propulsion or pushed sideways by tugboat in the later rounds. The consolidation periods for the different capping events ranged from two weeks for the first round to eight months for the last round, with the length of the consolidation period 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. With a longer 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.

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 (Table 1). The August 2004 investigation was performed as a longer term follow-up to meet a requirement of the Water Quality Certification (WQC), four to seven years following completion of individual CAD cells. A summary of methods and results are presented below.

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Table 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

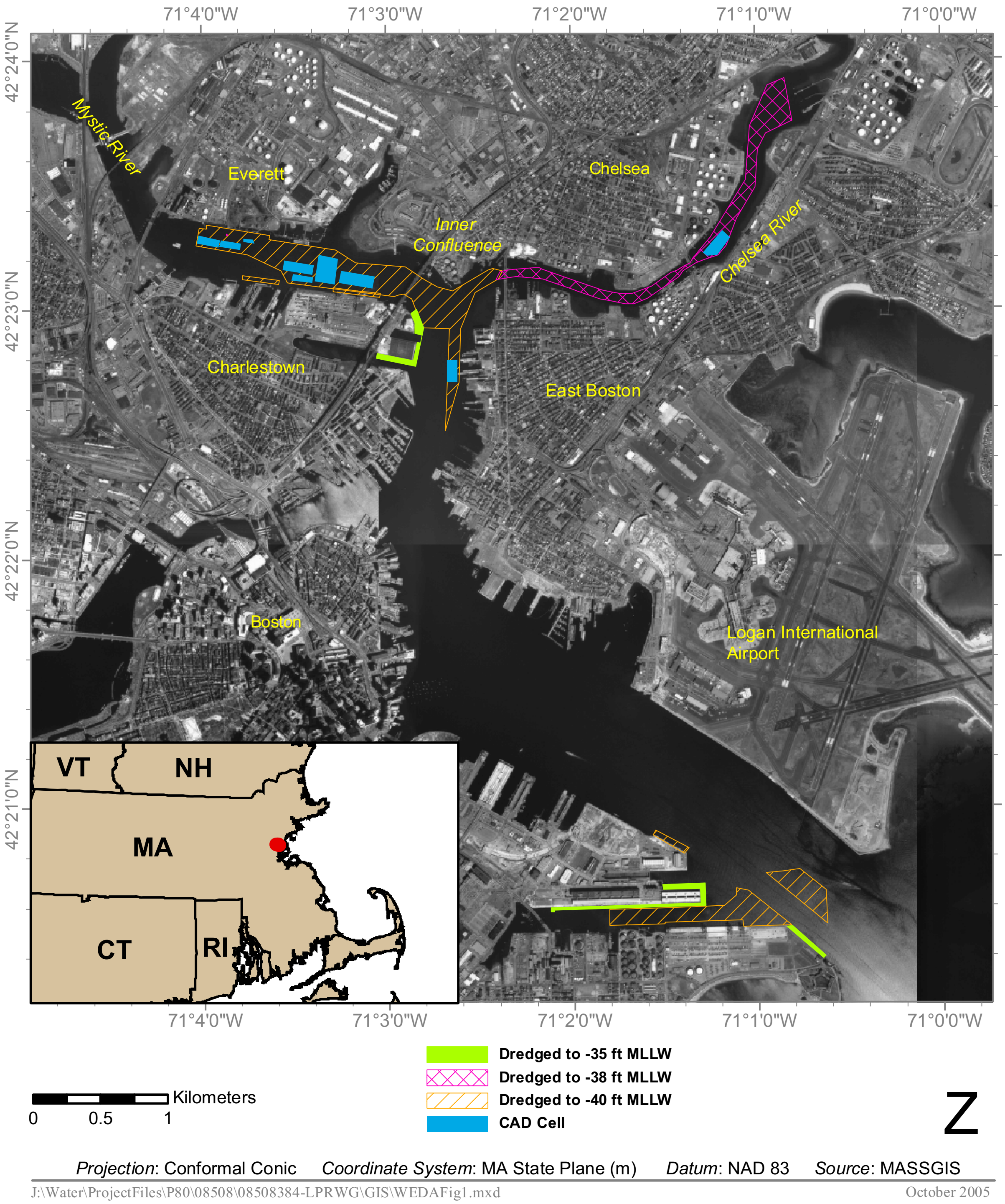

Figure 1. Boston Harbor Navigation Improvement Project dredged areas and CAD cells.

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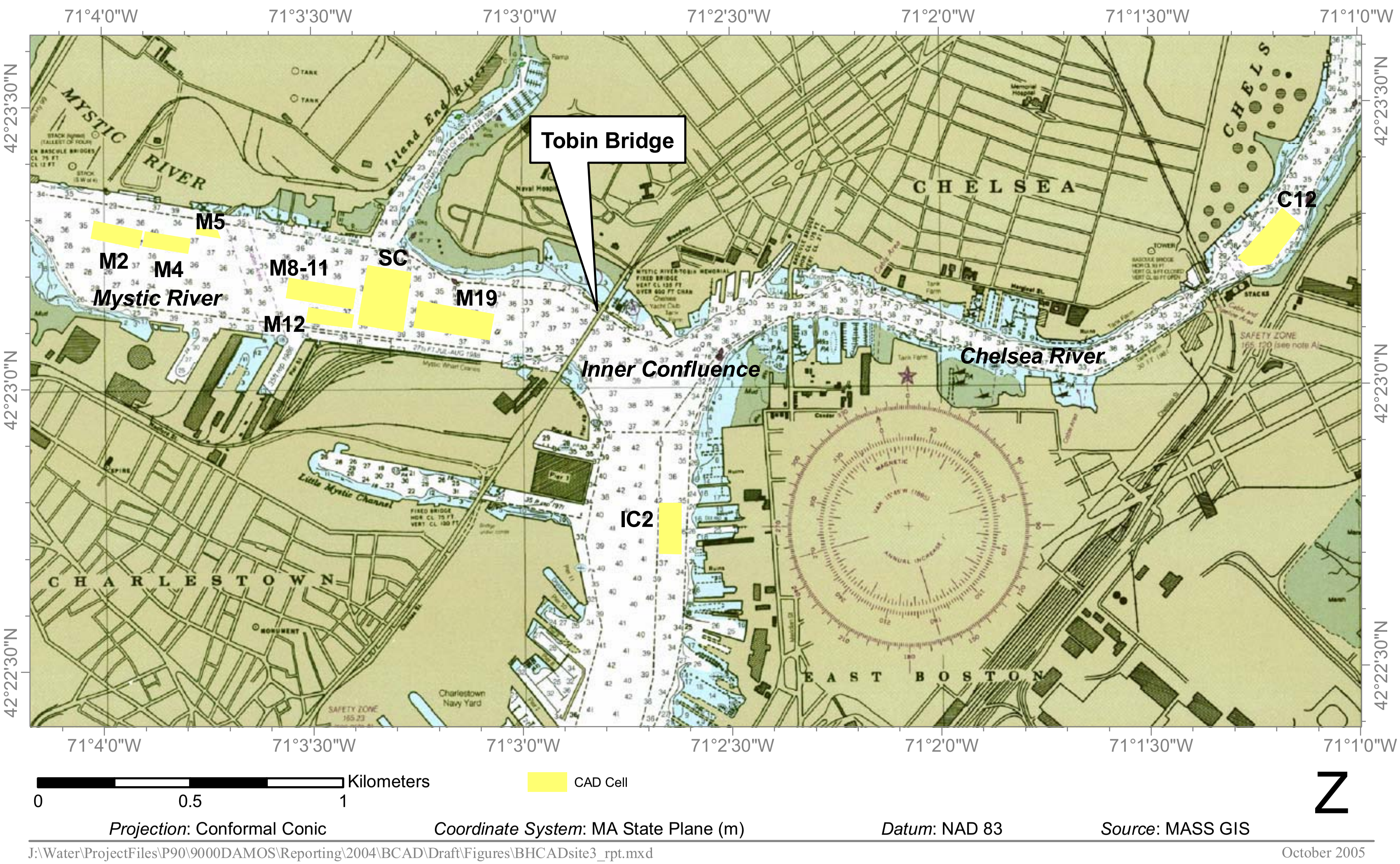

Figure 2. CAD cells used in the BHNIP.

METHODS

A team of investigators from ENSR International, CR Environmental, and Diaz & Daughters performed the August 2004 survey at the Boston Harbor CAD cells. The survey included bathymetry, side-scan sonar, sediment profile imaging (SPI), and underwater video components. The bathymetry survey was performed over all nine cells and surrounding area using a 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. 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. Side-scan sonar measurements were collected using an Edgetech, Inc. TD272 transducer array incorporating a sonar frequency of 500 kHz 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, covering all nine cells.

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 sediment profile imaging was performed at a total of 60 stations distributed among the nine CAD cells and three associated reference areas within the harbor. Additional underwater video imagery was recorded along transects across a subset of the cells using a Deep Sea Power and Light Multi-Sea Cam. The 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 towed across the bottom along each transect. The video survey focused on Mystic River Cell M19, but also included transects across five other cells. Additional details on data acquisition, processing, and analysis for all survey components can be found in ENSR (2006).

RESULTS AND DISCUSSION

Physical Conditions

The August 2004 survey identified all nine CAD cells as distinct topographic features on the harbor bottom (Mystic River cells are shown in Figure 3), with the cells depressed up to several meters below the surrounding harbor bottom. The swath bathymetry and side-scan sonar were able to resolve relatively fine scale structures within and around the cells, as shown in Figure 4. 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 2003b).

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 comparison of the 2004 bathymetry data with data collected two to seven 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.

A linear depression had been previously identified over cell M19 (SAIC 2003a), and had raised concerns over cell/cap stability. This feature was clearly visible in 2004 (Figure 4), but appeared to be stable over time when compared with earlier surveys. Review of the pre-filling bathymetry of this cell revealed a similar feature on the bottom of the cell (i.e., the cell bottom was not level), 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.

Biological Conditions

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 (Figure 5 presents SPI images from M8, M12 Supercell, M19 and MREF). The low level of biogenic activity indicated that the physical processes of diffusion and resuspension were the primary factors controlling the boundary roughness and apparent Redox Potential Discontinuity (RPD) layer thickness (rather than biological activity). 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.

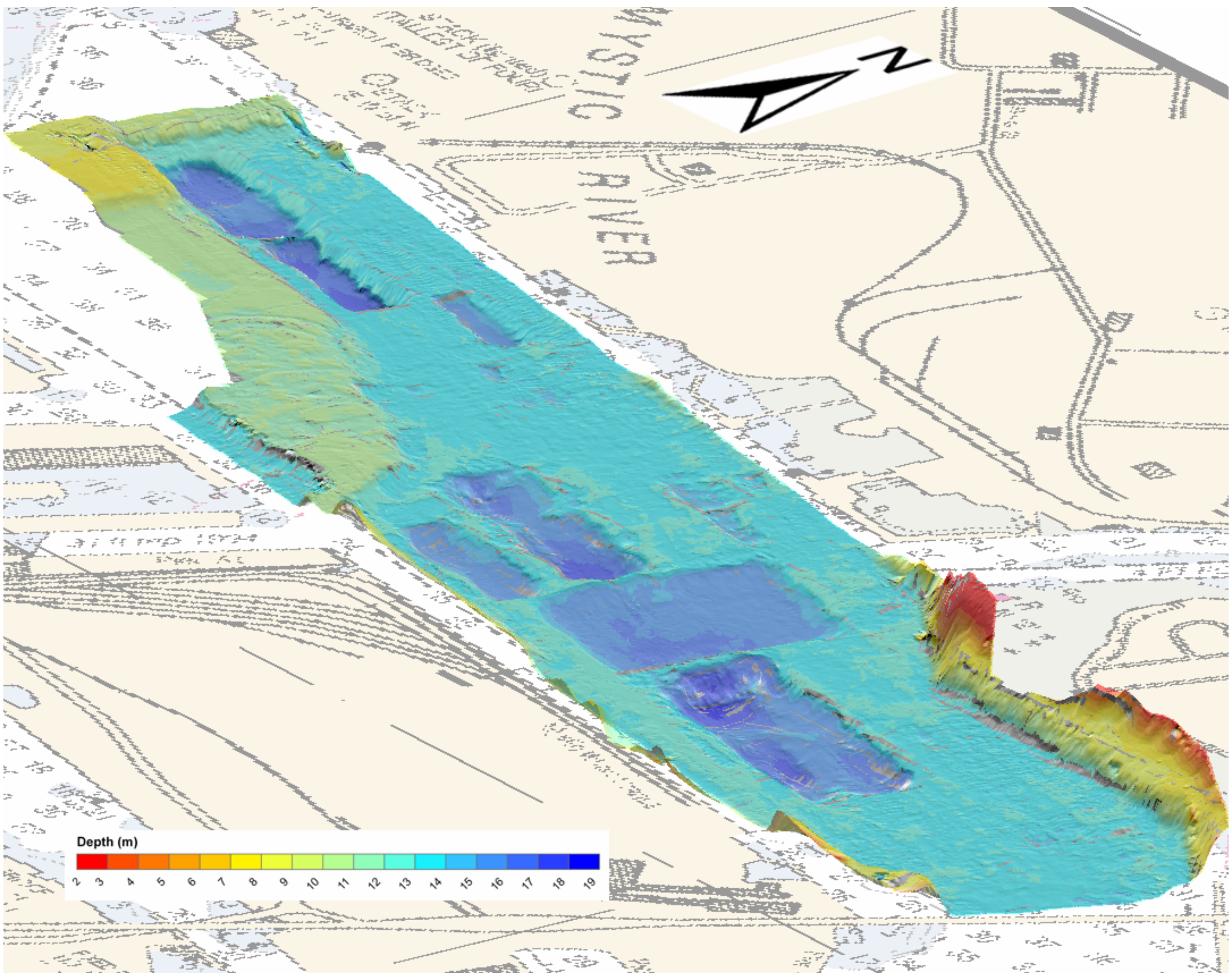

Figure 3. Bathymetric map of Mystic River CAD cells.

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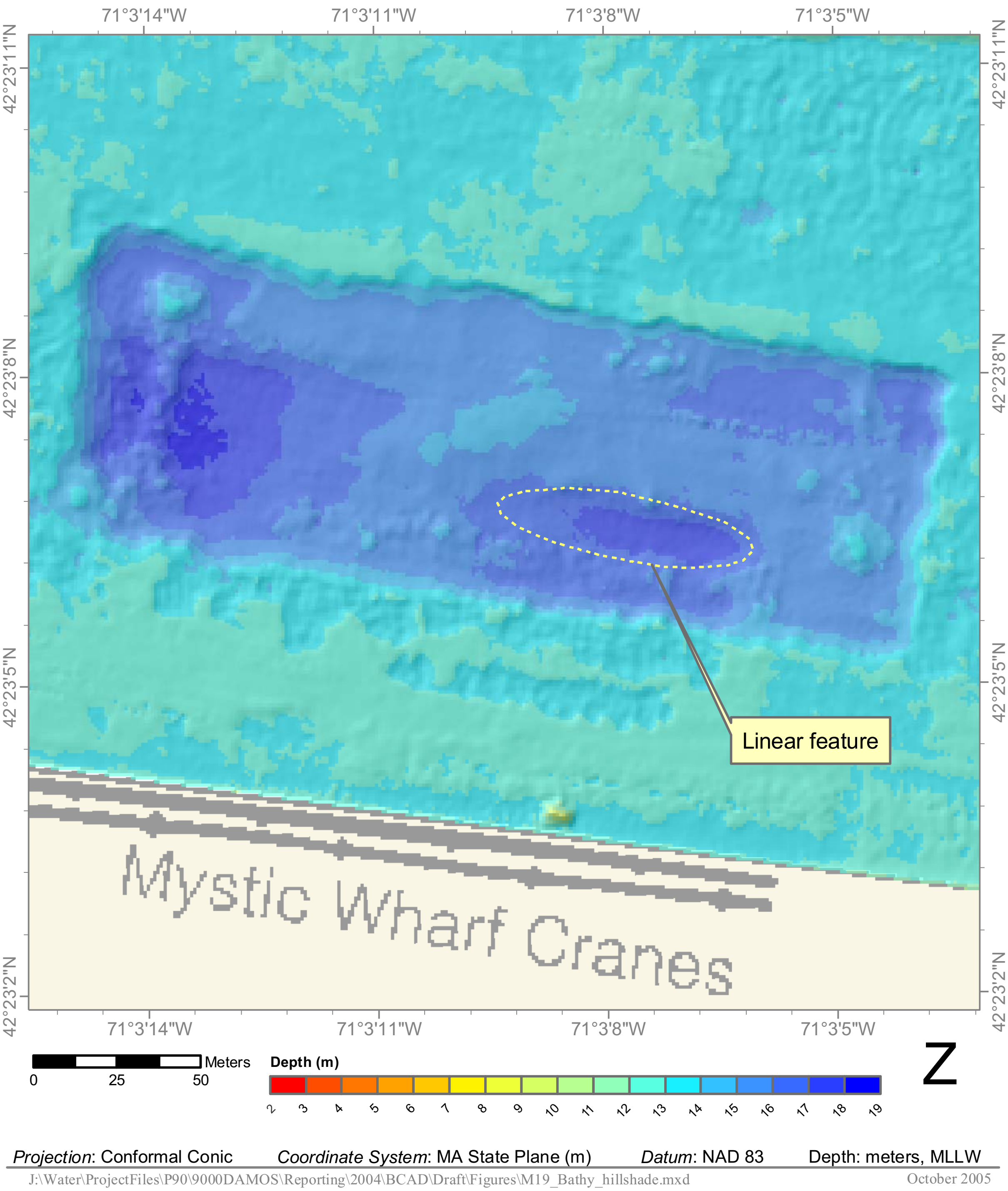

Figure 4. Bathymetric map of Mystic River Cell M19.

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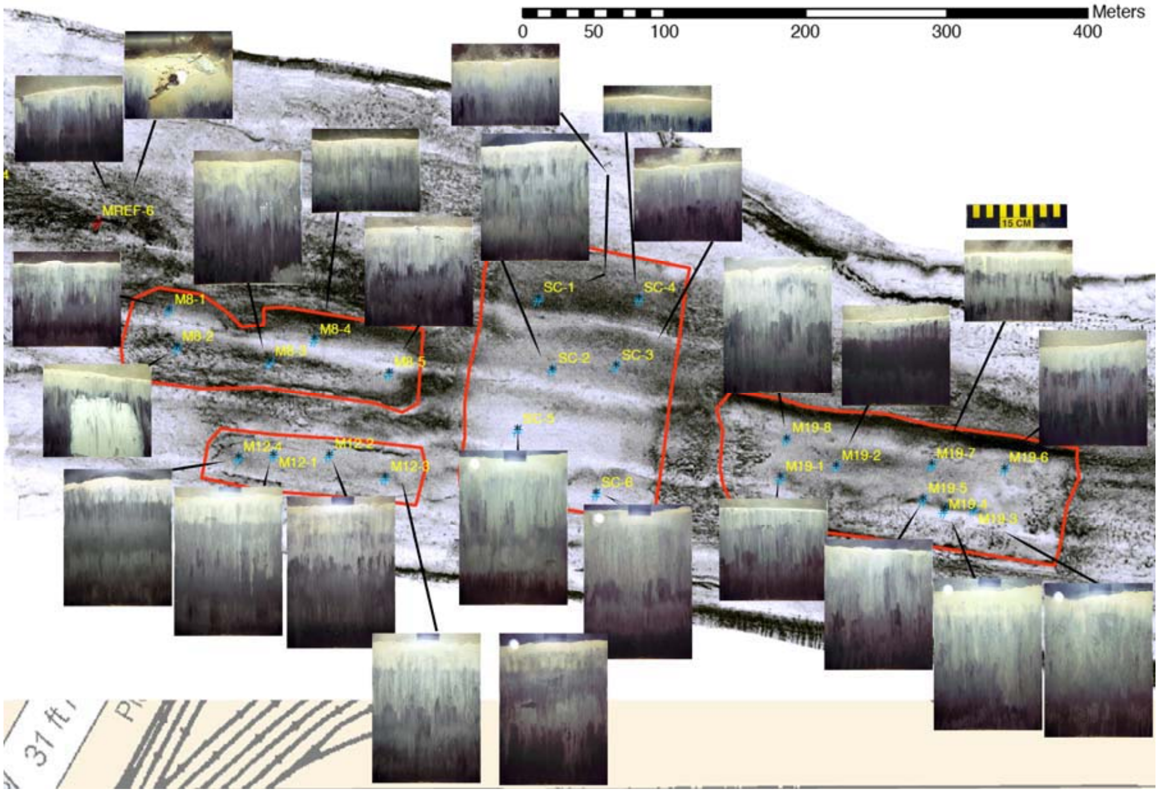

Figure 5. Representative sediment profile images.

CONCLUSIONS

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.

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 predominant surficial sediment in 2004 (based on SPI, video, and side-scan). This was consistent with earlier 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 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.

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.

In summary, the 2004 survey data reveal that the in-channel CAD cells remained stable four to seven years following completion and were biologically similar to the surrounding harbor bottom. With the depositional characteristics of the channel area and the depressed footprint of the CAD cells, fine-grained material is expected to continue accumulating over the cells, further sequestering the material within the cells over time.

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