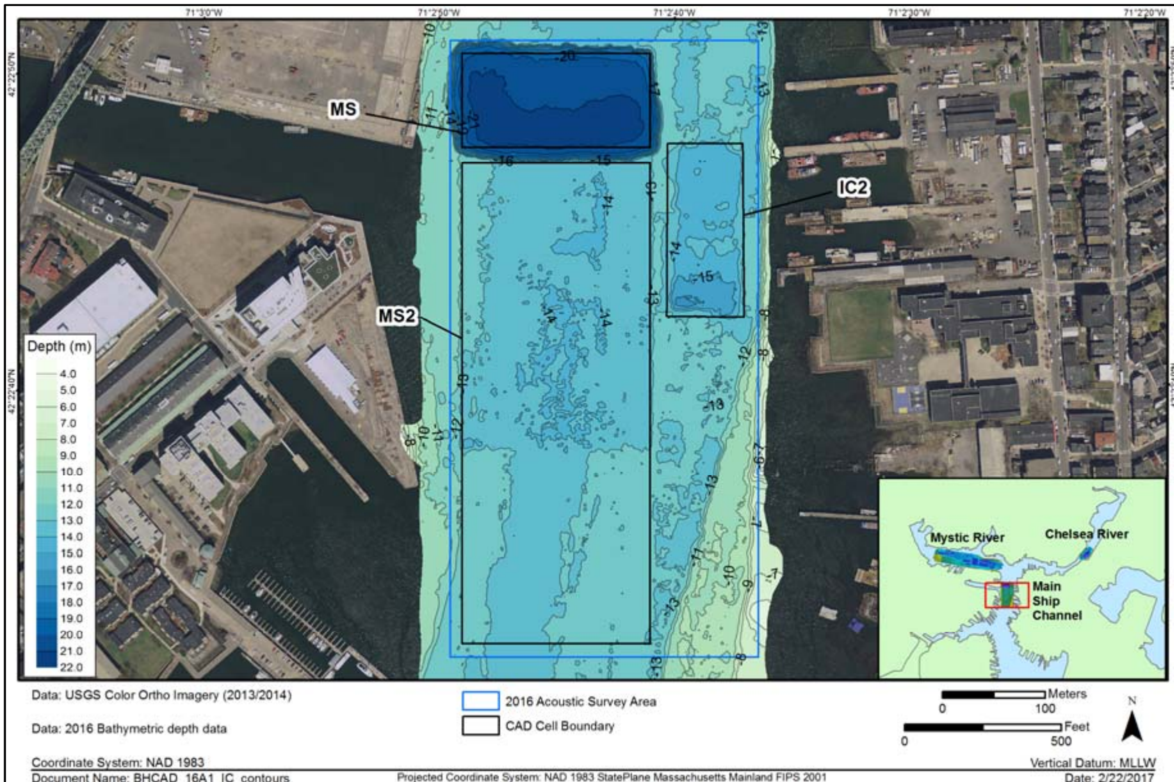
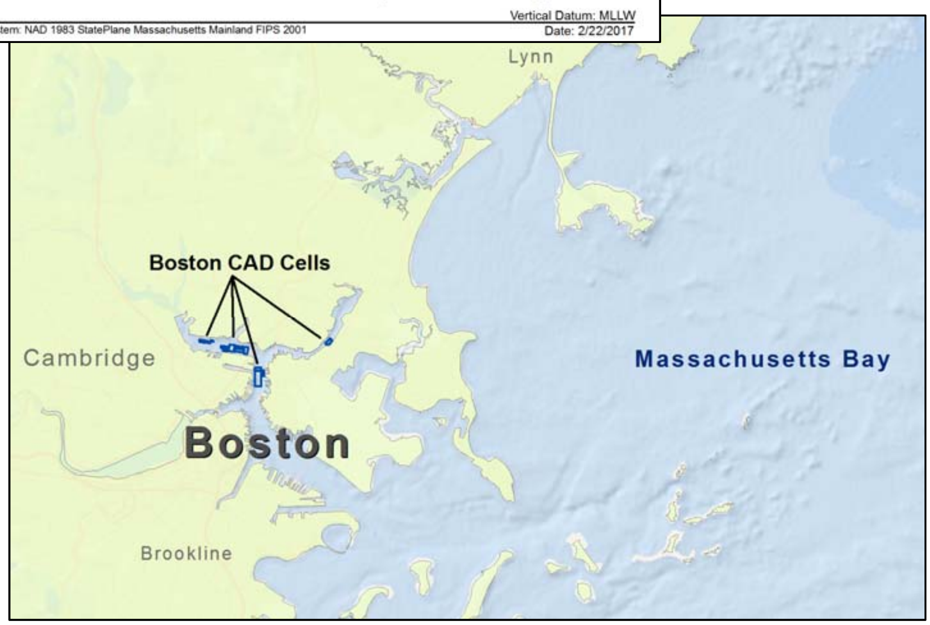
Data Summary Report for the Monitoring Survey at the Boston Harbor Confined Aquatic Disposal Cell Site – November 2016

Disposal Area Monitoring System DAMOS





D A M O S

DISPOSAL AREA MONITORING SYSTEM

Data Summary Report
DR 2016-01
October 2017

US Army Corps of Engineers®
New England District

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

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LIST OF ACRONYMS

ASCII	American Standard Code for Information Interchange
BHCAD	Boston Harbor CAD Cell Site
BHNIP	Boston Harbor Navigation Improvement Project
CAD	Confined Aquatic Disposal
CCOM	Center for Coastal and Ocean Mapping
DAMOS	Disposal Area Monitoring System
FIPS	Federal Information Processing Standard
GIS	Graphic information system
GPS	Global positioning system
MBES	Multibeam echo sounder
MLLW	Mean lower low water
NAE	New England District
NOAA	National Oceanic and Atmospheric Administration
NOS	National Ocean Service
NTRIP	Network transport of RTCM data over IP
PV	Plan-view
RTCM	Radio Technical Commission for Maritime Services
RTK	Real time kinematic GPS
SHP	Shapefile or geospatial data file
SOP	Standard Operating Procedures
SPI	Sediment-profile Imaging
TIF	Tagged image file
TIN	Triangulated irregular network
USACE	U.S. Army Corps of Engineers

1.0 INTRODUCTION

A monitoring survey was conducted at the Boston Harbor Confined Aquatic Disposal (BHCAD) Cell Site in November 2016 as part of the U.S. Army Corps of Engineers (USACE) New England District (NAE) Disposal Area Monitoring System (DAMOS) Program. DAMOS is a comprehensive monitoring and management program designed and conducted to address environmental concerns surrounding the placement of dredged material at aquatic disposal sites throughout the New England region. An overview of the DAMOS Program and the BHCAD Cell Site is provided below.

1.1 Overview of the DAMOS Program

The DAMOS Program features a tiered management protocol designed to ensure that any potential adverse environmental impacts associated with dredged material disposal are promptly identified and addressed (Germano et al. 1994). For over 39 years, the DAMOS Program has collected and evaluated disposal site data throughout New England. Based on these data, patterns of physical, chemical, and biological responses of seafloor environments to dredged material disposal activity have been documented (Fredette and French 2004).

DAMOS monitoring surveys fall into two general categories: confirmatory studies and focused studies. The data collected and evaluated during these studies provide answers to strategic management questions in determining the next step in the disposal site management process to guide the management of disposal activities at existing sites, plan for use of future sites, and evaluate the long-term status of historic sites.

Confirmatory studies are designed to test hypotheses related to expected physical and ecological response patterns following placement of dredged material on the seafloor at established, active disposal sites. Two primary goals of DAMOS confirmatory monitoring surveys are to document the physical location and stability of dredged material placed into the aquatic environment and to evaluate the biological recovery of the benthic community following placement of dredged material. Several survey techniques are employed in order to characterize these responses to dredged material placement. Sequential acoustic monitoring surveys (including bathymetric, acoustic backscatter, and side-scan sonar data collection) are performed to characterize the height and spread of discrete dredged material deposits or mounds created at open water sites as well as the accumulation/consolidation of dredged material into confined aquatic disposal cells.

Sediment-profile (SPI) and plan-view (PV) imaging surveys are often performed in both confirmatory and focused studies to provide further physical characterization of the material and to support evaluation of seafloor (benthic) habitat conditions and recovery over time. Each type of data collection activity is conducted periodically at disposal sites and the conditions found after a defined period of disposal activity are compared with the long-term data set at specific sites to determine the next step in the disposal site management process (Germano et al. 1994).

Focused studies are periodically undertaken within the DAMOS Program to evaluate inactive or historical disposal sites and contribute to the development of dredged material placement and capping techniques. Focused DAMOS monitoring surveys may also feature additional types of data collection activities as deemed appropriate to achieve specific survey objectives, such as sub-bottom profiling, towed video, sediment coring, or grab sampling.

The objective of the 2016 BHCAD Cell Site investigation was considered part of a focused study to track long-term stability of the confined aquatic disposal (CAD) cells given their location within a working harbor and as a baseline prior to the anticipated creation of a twelfth CAD cell (MS2) in the Main Ship Channel.

1.2 Introduction to the Boston Harbor Confined Aquatic Disposal Cell Site

The BHCAD Cell Site is one of several CAD Cell Sites in New England. The site is a series of 11 CAD cells in Boston Inner Harbor, Boston, Massachusetts (Figure 1-1). The construction of the BHCAD Cell Site began in 1997 to support the Boston Harbor Navigation Improvement Project (BHNIP) which marked the first major use of CAD cells in the United States (USACE 2012). The site includes two CAD cells in the Inner Confluence/ Main Ship Channel (MS and IC2), eight CAD cells in the Mystic River (M4, M5, M12, M2, Supercell, M8-11, M19, and Mystic CAD), and one CAD cell in the Chelsea River (C12) (Figure 1-2). The construction of a twelfth CAD cell is anticipated in the Main Ship Channel (MS2).

In the acoustic survey areas at the BHCAD Cell Site (Figure 1-2) water depths ranged from 2 m (6 ft) to 21 m (63 m) (Figures 1-3 through 1-6). The BHCAD Cell Site was last surveyed under the DAMOS Program in 2009 (USACE 2012).

1.3 Boston Harbor CAD Cell Construction Sequence

Nine of the BHCAD cells were constructed between 1997 and 2000 in support of the BHNIP, and two additional cells, one in the Mystic River (Mystic CAD) and one in the Main Ship Channel (MS), were constructed as part of a separate maintenance dredging project in 2008 (USACE 2012; Table 1-1). A portion of the footprint of the expected twelfth cell was constructed during the creation of the MS Cell in 2008, represented by dredging scars from the removal of surface material from the original planned footprint of the MS Cell which was modified based on capacity needs (Figure 1-3) (USACE 2012).

1.4 Previous Monitoring Events at Boston Harbor CAD Cell Site

Previous monitoring events have included pre- and post-cap monitoring by conducting bathymetric, sediment-profile and plan-view imaging, benthic, and coring surveys, water quality monitoring, resuspension investigations, and sub-bottom profiling (Table 1-2).

1.5 2016 Survey Objectives

The 2016 survey was designed as a focused survey to track long-term stability of the cells given their location within a working harbor and as a baseline prior to the anticipated creation of a twelfth cell (MS2) in the Main Ship Channel. The objectives of the survey were to:

- Characterize the harbor topography and surficial features over the 11 existing cells and the footprint of the expected twelfth cell by completing a multibeam bathymetric survey, and

- Calculate any remaining capacity of the cells if assumed filled to with 1 m (~3 ft) of the surrounding harbor bottom

Table 1-1. Boston Harbor CAD Cell Construction Sequence (USACE 2012)

Location	Cell	Date Constructed	Date Filled	Capping Status	Consolidation Period (months) Prior to Capping
Inner Confluence/ Main Ship Channel	IC2	June 1997	June-July 1997	July 1997	0
	MS	July-August 2008	September-November 2008	January 2010 [a]	13
Mystic River	M4	September 1998	September-October 1998	November 1998	1
	M5	August 1998	August-October 1998	November 1998	2
	M12	August-September 1998	September-October 1998	November 1998	2
	M2	October 1998	October 1998-June 1999	November 1999	5
	Supercell	October-December 1998	January-August 1999	November 1999	5
	M8-11	March-April 1999	August 1999-December 1999	September 2000	8
	M19	July-August 1999	November 1999-January 2000	September 2000	8
	Mystic	May-June 2008	September-November 2008	January 2010 [a]	13
Chelsea River	C12	February-March 1999	April-September 1999, May-August 2008 March-April 2012 [b]	Not Capped	--

[a] Capping was performed after completion of the 2009 survey
[b] Personal communication (A. Hopkins, USACE, Jan. 2017)

Table 1-2. Previous Investigations of the Boston Harbor CAD Cells

Activity	Date	Details	Reference
Phase 1 of BHNIP	July-August 1997	Dredging of Conley Terminal berth area; Construction, filling, and capping of IC2	
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
Sub-bottom profiling	1999	Sub-bottom survey of Mystic River cells	OSI 2000
Resuspension investigation	March 2000	Investigation of potential resuspension of cell material from vessel passage	Hales 2001; SAIC 2000
Benthic survey	June 2000	Benthic assessment of 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
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
Post-cap Monitoring			
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	SAIC 2003a
Sediment transport investigation	Summer-Fall 2002	Pilot scale study of sediment transport in Mystic River area using fluorescent tracers	SAIC 2003b
Monitoring Survey	August 2004	Bathymetry, side-scan sonar, video sled, SPI (incl. deep penetrating). Five-year post-construction monitoring requirement of Water Quality Certification	ENSR 2007
Monitoring Survey	Nov 2009	Bathymetry, sub-bottom, sediment coring	USACE 2012
Monitoring Survey	Feb 2010	Post-cap bathymetric survey	Personal communication [a]

[a] Personal communication (A. Hopkins, USACE, Jan. 2017)

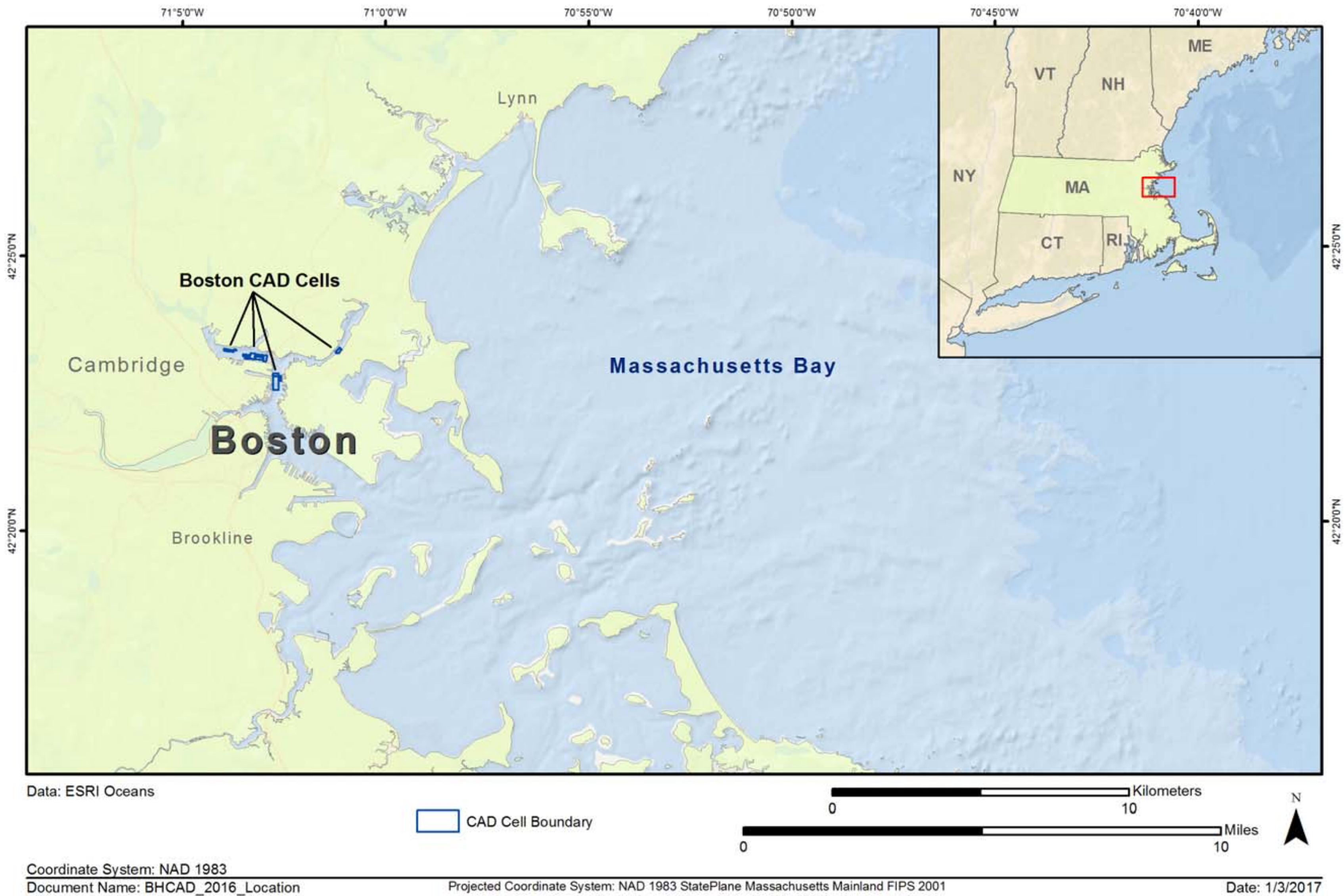

Figure 1-1. Location of the Boston Harbor CAD Cell Site (BHCAD)

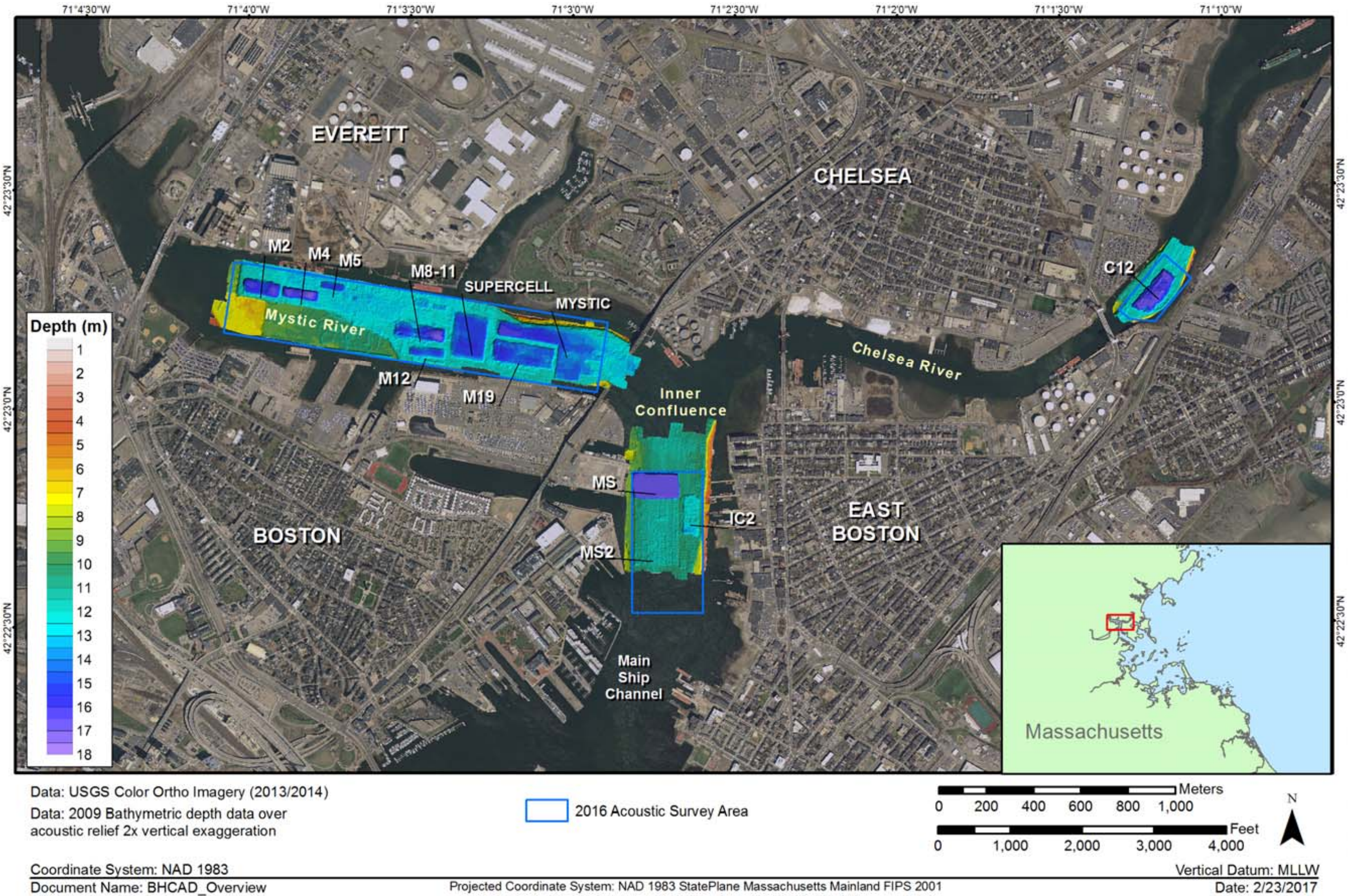

Figure 1-2. BHCAD overview and 2016 acoustic survey area

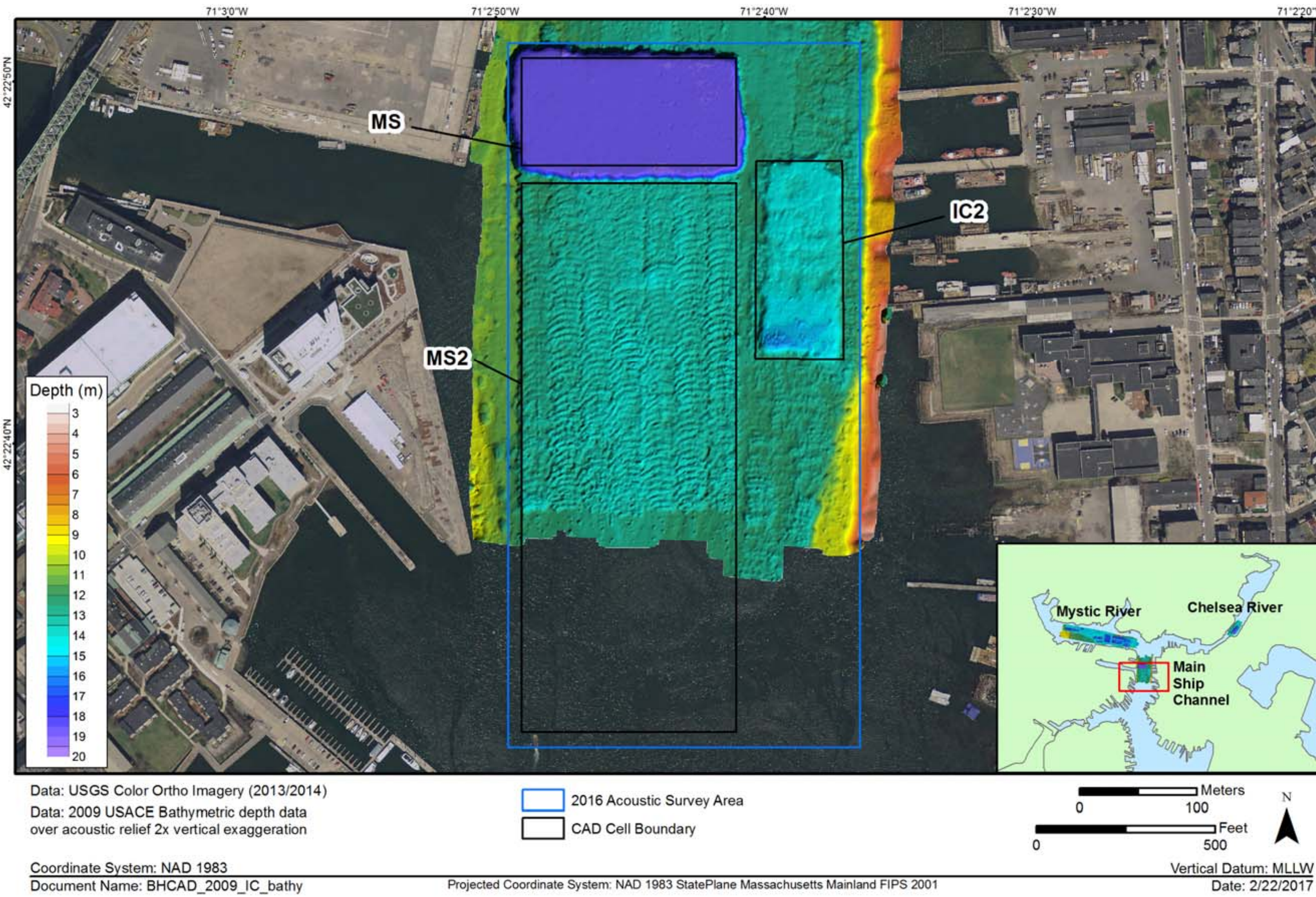

Figure 1-3. Bathymetric depth data over acoustic relief model of BHCAD Main Ship Channel cells – November 2009

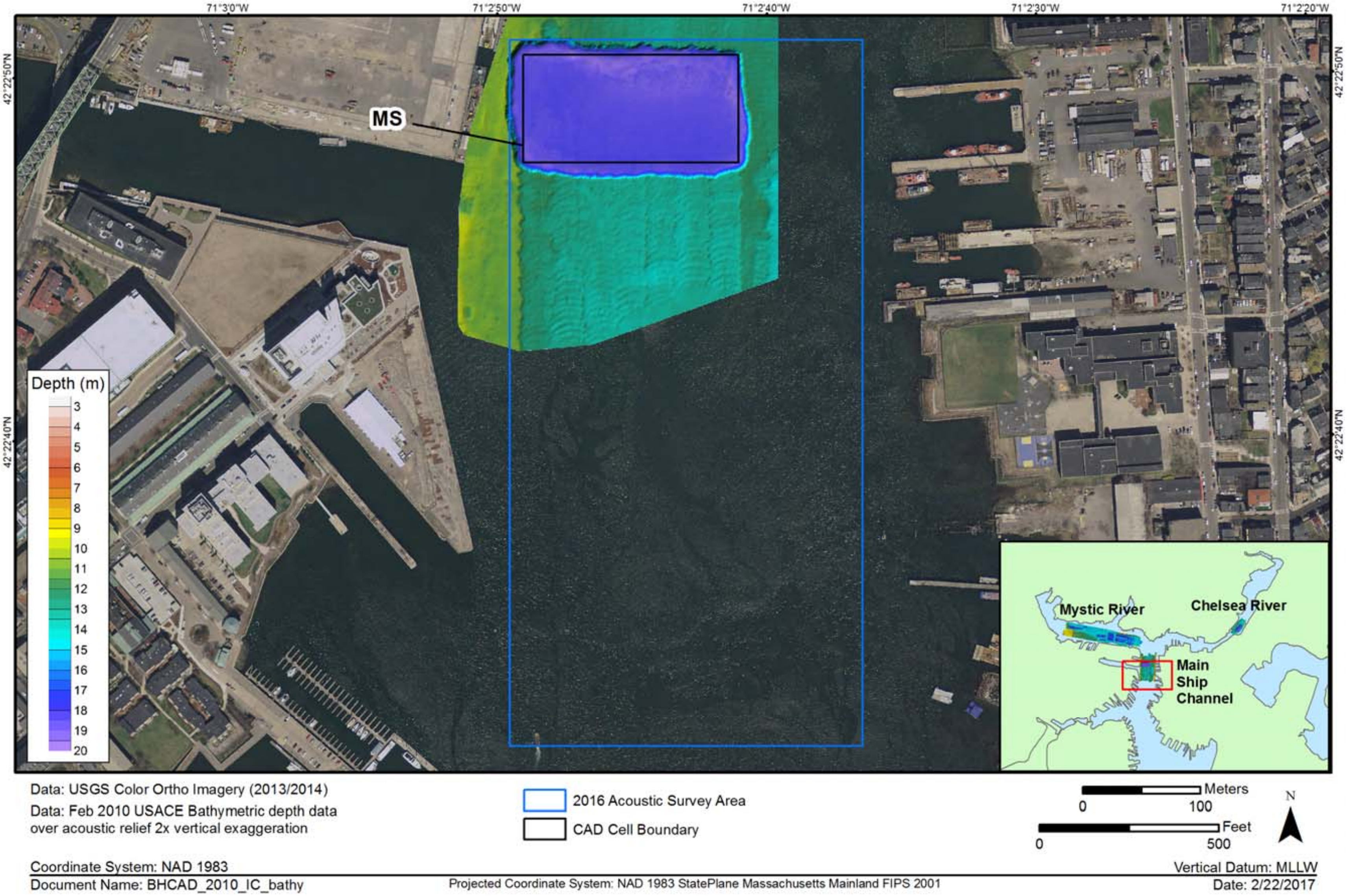

Figure 1-4. Bathymetric depth data over acoustic relief model of BHCAD Main Ship Channel cells – February 2010

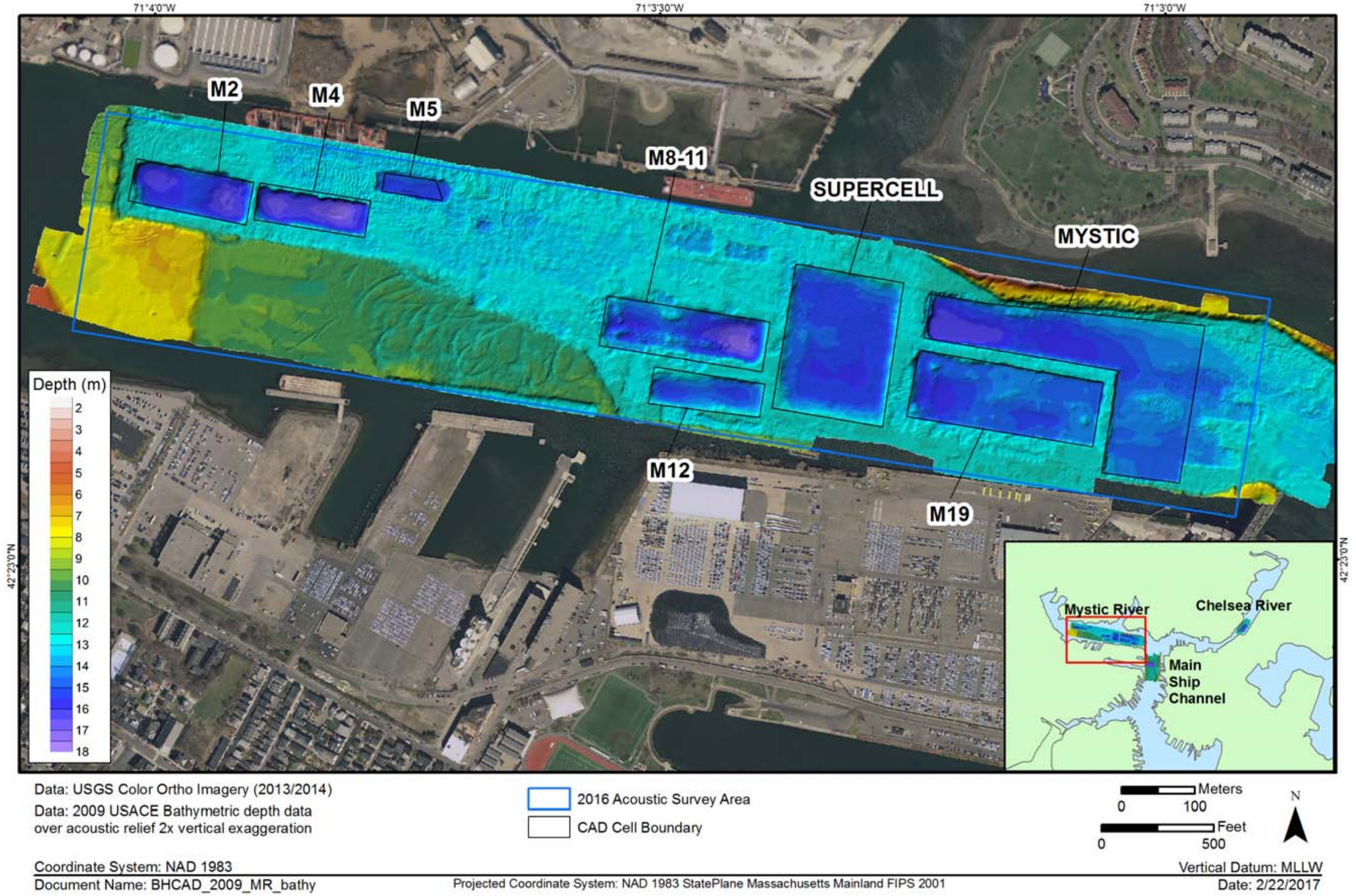

Figure 1-5. Bathymetric depth data over acoustic relief model of BHCAD Mystic River cells – November 2009

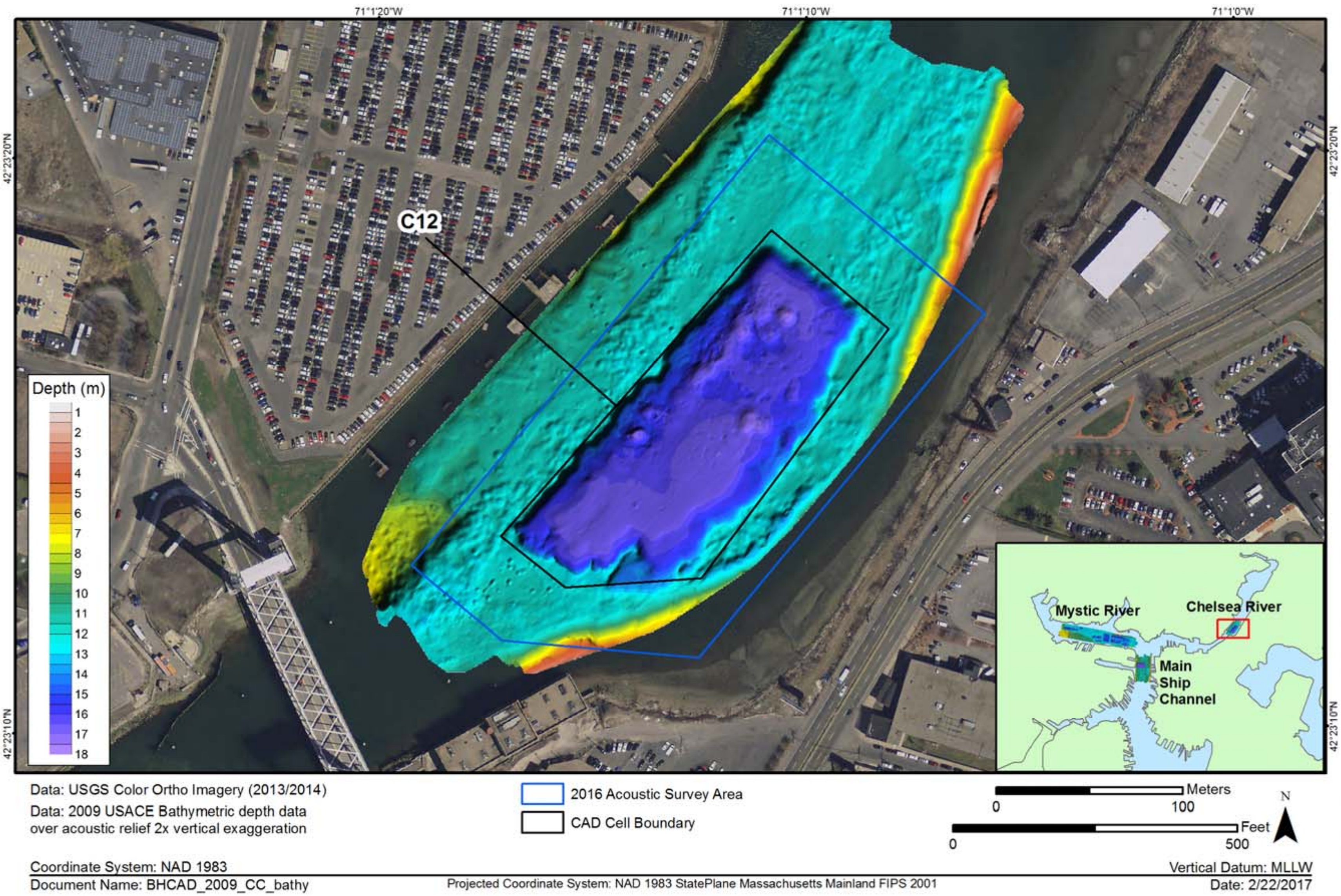

Figure 1-6. Bathymetric depth data over acoustic relief model of BHCAD Chelsea River cells – November 2009

2.0 METHODS

The November 2016 survey at the BHCAD Cell Site was conducted by a team of investigators from INSPIRE Environmental and CR Environmental including certified hydrographer Christopher Wright aboard the 25-foot *R/V Cyprinodon*. The acoustic survey was conducted 9-10 November 2016. An overview of the methods used to collect, process, and analyze the survey data is provided below. Detailed Standard Operating Procedures (SOPs) for data collection and processing are available in the Quality Assurance Project Plan for the DAMOS Program (Battelle 2015).

2.1 Navigation and On-Board Data Acquisition

Navigation for the acoustic survey was accomplished using a Hemisphere VS-330 RTK GPS which received base station correction through the Keynet NTRIP broadcast. Horizontal position accuracy in fixed RTK mode was approximately 1 cm, vertical (tidal) accuracy was approximately 2 cm. The GPS system was interfaced to a laptop computer running HYPACK MAX® hydrographic survey software. HYPACK MAX® recorded vessel position and GPS satellite quality and provided a steering display for the vessel captain to accurately maintain the position of the vessel along pre-established survey transects.

On the *Cyprinodon*, vessel heading measurements were provided by an IxBlue Octans III fiber optic gyrocompass. A dual-antenna Hemisphere VS-110 Crescent Digital compass was mobilized as a backup.

2.2 Acoustic Survey

The acoustic survey included bathymetric, backscatter, and side-scan sonar data collection. The bathymetric data provided measurements of water depth that, when processed, were used to map the seafloor topography. Backscatter and side-scan sonar data provided images that supported the characterization of surface sediment texture and roughness. Each of these acoustic data types is useful for assessing dredged material placement and surface sediment features.

2.2.1 Acoustic Survey Planning

The acoustic survey featured a high spatial resolution survey of all 11 CAD cells and the proposed twelfth CAD cell, approximately 300 × 600 m in the Inner Confluence/Main Ship Channel, 350 × 1600 m in the Mystic River, and 150 × 300 m in the upper Chelsea River (Figure 1-2). INSPIRE hydrographers obtained site coordinates, imported them to graphic information system (GIS) software, and created maps to aid planning. Base bathymetric data from previous DAMOS surveys were used to calculate the transect separation required to obtain full bottom coverage using an assumed beam angle limit of 90-degrees (45 degrees to port, 45 degrees to starboard). Transects spaced 15-20 m apart and cross-lines spaced 100-150 m apart were created to meet conservative beam angle constraints (Figure 2-1). The proposed survey area and design were then reviewed and approved by NAE scientists.

2.2.2 Acoustic Data Collection

Data layers generated by the survey included bathymetric, acoustic backscatter, and side-scan sonar and were collected using an R2Sonic 2022 broadband multibeam echo sounder (MBES). This 200-400 kHz system forms up to 256 1-2° beams (frequency dependent) distributed equiangularly or equidistantly across a 10 - 160° swath. The MBES system was operated using a transmit frequency of 200 kHz to facilitate comparisons with previous DAMOS survey data while maximizing bathymetric resolution. The MBES transducer was mounted amidships to the port rail of the survey vessel using a high strength adjustable boom. The primary GPS antenna was mounted on the transducer boom. The transducer depth below the water surface (draft) and antenna height were checked and recorded at the beginning and end of data acquisition, and the draft was confirmed using the "bar check" method.

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

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

2.2.3 Bathymetric Data Processing

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

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

Tidal adjustments were accomplished using RTK GPS. Water surface elevations derived using RTK were adjusted to Mean Lower Low Water (MLLW) elevations using NOAA's VDATUM Model. Processed RTK tide data were successfully ground-truthed against a data series acquired at NOAA's Boston Tide Station (#8443970).

Correction of sounding depth and position (range and azimuth) for refraction due to water column stratification was conducted using a series of nine sound-velocity profiles acquired by the survey team. Data artifacts associated with refraction remain in the bathymetric surface model at a relatively fine scale (generally less than 5 cm) relative to the survey depth.

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

The R2Sonics 2022 MBES system was operated at 200 kHz. At this frequency the system has a published beam width of 2.0°. Assuming a mean depth of 12 m and a maximum beam angle of 60°, the maximum diameter of the beam footprint was calculated at approximately 1.7 × 0.8 m (1.4 m^2). Mid-swath data would have a resolution of 0.3 m^2. Data were reduced to a cell (grid) size of 0.5 × 0.5 m, acknowledging the system's fine range resolution while accommodating beam position uncertainty. This data reduction was accomplished by calculating and exporting the average elevation for each cell in accordance with USACE recommendations (USACE 2013).

Statistical analysis of data as summarized on Table 2-1 showed negligible tide bias and vertical uncertainty substantially lower than values recommended by USACE (2013) or NOAA (2015). Note that the most stringent National Ocean Service (NOS) standard for this project depth (Special Order 1A) would call for a 95th percentile confidence interval (95% CI) of 0.30 m at the maximum site depth (21.8 m) and 0.27 m at the average site depth (12.5 m).

Reduced data were exported in ASCII text format with fields for Easting, Northing, and MLLW Elevation (meters). All data were projected to the Massachusetts State Plane FIPS 2001, NAD83 (metric). A variety of data visualizations were generated using a combination of ESRI ArcMap (V.10.1) and Golden Software Surfer (V.13). Visualizations and data products included:

- ASCII data files of all processed soundings including MLLW depths and elevations
- Contours of seabed elevation (25-cm, 50-cm and 1.0-m intervals) in a geospatial data file (SHP) format suitable for plotting using GIS and computer-aided design software
- 3-dimensional surface maps of the seabed created using 2× vertical exaggeration and artificial illumination to highlight fine-scale features not visible on contour layers delivered in grid and tagged image file (TIF) formats, and
- An acoustic relief map of the survey area created using 2× vertical exaggeration, delivered in georeferenced TIF format.

2.2.4 Backscatter Data Processing

Backscatter data were extracted from cleaned MBES TruePix formatted files then used to provide an estimation of surface sediment texture based on seabed surface roughness. Mosaics of backscatter data were created using HYPACK®'s implementation of GeoCoder software developed by scientists at the University of New Hampshire's NOAA Center for Coastal and Ocean Mapping (UNH/NOAA CCOM). Seamless mosaics of unfiltered backscatter data were developed and exported in grayscale TIF format. Backscatter data were also exported in ASCII format with fields for Easting, Northing, and backscatter (dB). A Gaussian filter was applied to backscatter data to minimize nadir artifacts and the filtered data were used to develop backscatter values on a 0.5-m grid. The grid was exported to an ESRI binary GRD format to facilitate comparison with other data layers.

2.2.5 Side-Scan Sonar Data Processing

Side-scan sonar data were processed using Chesapeake Technology, Inc. SonarWiz software. Seamless mosaics of side-scan sonar data were developed and exported in grayscale TIF format using a resolution of 0.1 m per pixel.

2.2.6 Acoustic Data Analysis

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

2.3 Remaining Cell Capacity Calculation

CAD cell volumes and remaining capacities were calculated by constructing triangulated irregular network (TIN) surface models for each cell using processed ASCII point data (binned as described in Section 2.2.3), then computing the volumes and planar areas above and below discreet 20-cm elevation intervals within vertical prisms. Prism geometry was defined by digital polygons provided by USACE and, where applicable, alternate boundaries digitized based on the observed footprint of each cell's excavation. TIN-based volume calculations are recommended by EM 1110-2-1003 (30 Nov 13, 10-30(d)).

TIN models honor each sounding solution without introducing minor uncertainties associated with grid interpolations. A TIN model consists of a series of triangles constructed between corrected sounding points that exactly honors the elevation and position of each point.

Table 2-1. Accuracy and Uncertainty Analysis of Bathymetric Data

		Results (m)		
Survey Date	**Quality Control Metric**	**Mean**	**95% Uncertainty**	**Range**
11/9-10/2016	Cross-Line Swath Comparisons	0.01	0.15	
	Within Cell Uncertainty	0.05	0.14	0.00 - 5.14 (pilings)
	Beam Angle Uncertainty (0 – 60°)	0.01	0.15	0.10 - 0.60

Notes:
1. The mean of cross-line nadir and full swath comparisons are indicators of tide bias.
2. 95% uncertainty values were calculated using the sums of mean differences and standard deviations expressed at the 2-sigma level.
3. Within cell uncertainty values include biases and random errors.
4. Beam angle uncertainty was assessed by comparing cross-line data (60-degree swath limit) with a reference surface created using mainstay transect data.
5. Swath and cell based comparisons were conducted using 0.5 m x 0.5 m cell averages. These analyses do not exclude sounding variability associated with terrain slopes and objects (e.g., pilings).

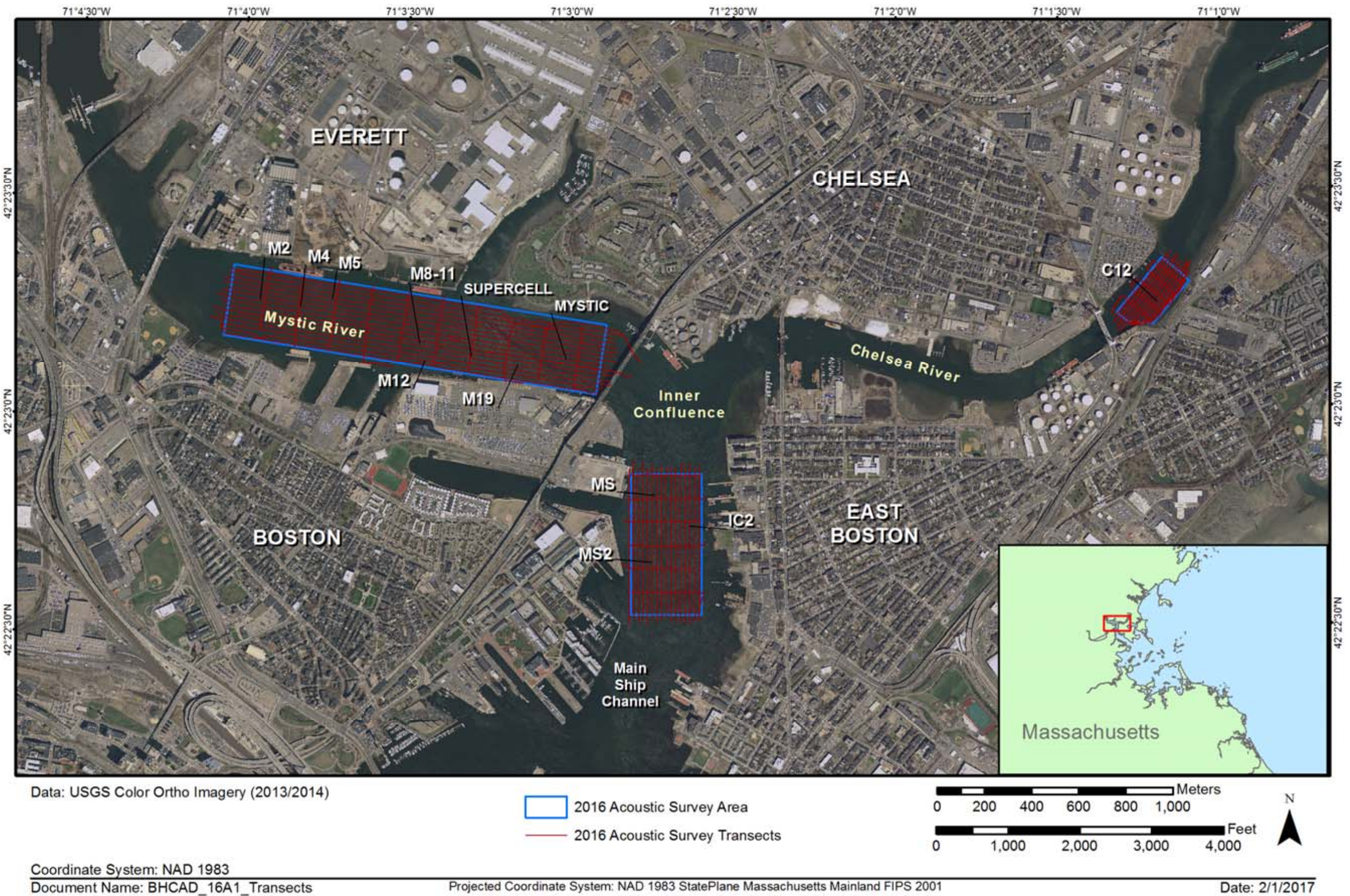

Figure 2-1. BHCAD 2016 acoustic survey area and tracklines

3.0 ACOUSTIC RESULTS

The results of the acoustic survey conducted in November 2016 to characterize seafloor topography and sediment surface features over the entire BHCAD Cell Site are presented in this section.

3.1 Main Ship Channel CAD Cells

The Main Ship Channel survey area was located south of the confluence of the Mystic River and Chelsea River. Two existing cells (MS and IC2) and one potential new cell (MS2) are in the Main Ship Channel survey area.

3.1.1 Main Ship Channel Bathymetry

Water depths in the Main Ship Channel at BHCAD varied from 7 m to 21 m throughout the survey area (Figure 3-1). The channel floor sloped from 7 m in the southeast to 11 m on the margin of the dredged channel towards the west. The dredged channel was a roughly rectangular area in the center of the survey area with depths from 10 m to 14 m outside the deepest cell. The MS Cell which lies in the north of the survey area is a large deep rectangular cell with distinct boundaries. Depths in this cell ranged from 15 m to 21 m. To the southeast of MS, IC2 was a small rectangular cell with depths of 14 m and 15 m. To the south of MS, the area proposed for a twelfth cell, MS2, had depths of 13 m and 14 m and showed regular surface cuts between 0.5 - 1.0 m deep, extending approximately 280 m to the south of the MS Cell. These depressions are likely dredging scars from the removal of surface material from the original planned footprint of the MS Cell in 2008 which was modified based on capacity needs (USACE 2012). Depths of 13 m continued to the south down the Main Ship Channel. Multibeam bathymetric data rendered as an acoustic relief model provided a more detailed representation of the fine-scale topography of the cells and of the entire Main Ship Channel survey area (Figure 3-2). The acoustic relief model revealed circular pockmarks in the channel as well as arcuate drag marks consistent with dredging in the northern 60% of the proposed twelfth cell (MS2).

Multibeam bathymetric data rendered as a color scale by depth over an acoustic relief model (grayscale with hill-shading) provided additional representation of cell topographic lows and of the entire Main Ship Channel survey area (Figure 3-3). In the Main Ship Channel these data confirmed a deep rectangular cell in the northwest with steep sides (MS) and a shallower rectangular cell in the northeast (IC2). South of the deep cell in the northwest, a large rectangular cell with scour marks consistent with artifacts from dredging was observed (MS2).

3.1.2 Main Ship Channel Acoustic Backscatter and Side-Scan Sonar

Acoustic backscatter data provided an estimate of surface sediment texture (hard, soft, rough, and smooth). Side-scan sonar data are higher resolution and more responsive to minor surface textural features and slope than backscatter results and can reveal additional information about topographic and textural properties of the seafloor.

A mosaic of unfiltered backscatter data for the Main Ship Channel at BHCAD (Figure 3-4) generally revealed rougher surfaces having a stronger acoustic return (lighter gray) running from the southwestern corner up towards the northern-central of the survey area. Finer sediment with a weaker acoustic return (darker gray) was found along the east and west banks of the Main Ship Channel. Weaker returns were also seen in cell MS with a surrounding border of strong returns. Filtered backscatter results were processed into a grid file and presented in a quantitative form where backscatter intensity values were assigned a color (Figure 3-5). In this filtered and gridded display, the finer-scale details were less visible, but the relative intensity of backscatter returns were easier to discern. Side-scan sonar results provided a high-resolution acoustic representation of the seafloor surface in a mosaic of the site (Figure 3-6).

3.1.3 Comparison with Previous Bathymetry

The 2016 bathymetric elevation surface was used as a baseline for comparison with data from previous surveys. Negative elevation differences computed between surveys indicate depth increases, positive elevation differences indicate depth decreases (shoaling). The multibeam data from the 2016 survey were compared with multibeam data collected in November of 2009 (Figure 3-7). Subtraction of the bottom elevations in the 2009 survey from the 2016 elevations captured the apparent changes in bathymetry since the 2009 survey. Depths increased approximately 0.5 m to 2 m within the MS cell, likely due to the consolidation of material in the cell. A mixture of relatively small positive and negative differences occurred south of the cell. Depth increases to the south of the cell coincided with higher backscatter values, suggesting that shipping activities may have disturbed fine bottom sediments.

The multibeam data from the 2016 survey were also compared to multibeam data collected by USACE as part of a "post cap" survey in February of 2010 (Figure 3-8). This survey did not cover the entire survey area but did cover MS. Subtraction of the bottom elevations in the 2010 survey from the 2016 elevations captured the apparent changes in bathymetry since the 2010 survey. Over the cell, depth increases ranged from 1.1 m to 3.5 m. The depth increases were greater than those observed in 2009 and record the potential placement of cap material from the Cape Cod Canal in the cell prior to the February 2010 survey (A. Hopkins pers. comm., 2 March 2017).

3.1.4 Cell Capacity

The Main Ship Channel CAD cell MS has a remaining capacity of approximately 190,350 m^3 (Table 3-1) if filled to within one meter of the surrounding harbor bottom. A complete capacity report is presented in Appendix B.

3.2 Mystic River CAD Cells

The Mystic River survey area was located west of the confluence of the Mystic River and Chelsea River. Eight cells are in the Mystic River survey area.

3.2.1 Mystic River Bathymetry

Water depths in the Mystic River at BHCAD varied from 6 m to 17 m throughout the survey area (Figure 3-9). The river channel had depths ranging from 8 m to 13 m. Eight cells with distinct boundaries were observed distinct from the river channel. Three small rectangular cells (M2, M4, and M5) were in the northwest, with depths ranging from 14 m to 16 m. Three rectangular cells in the center of the survey area, two small cells to the west (M8-11 and M12) and one large cell to the east (Supercell), had depths ranging from 13 m to 16 m. Mystic and M19 cells were visible in the east of the survey area. Of these two cells, the M12 cell was rectangular with distinct boundaries and depths ranging from 14 m to 16 m. The furthest east cell (Mystic) was large and "L" shaped with distinct boundaries to the west and gradually shoaling bathymetry to the east. All cells were deeper than depths observed in the river channel. Multibeam bathymetric data rendered as an acoustic relief model provided a more detailed representation of the fine-scale topography of the cells and of the entire site (Figure 3-10). Arcuate drag marks consistent with the removal of native material were revealed in the north of M4 and in the vicinity surrounding M5. All Mystic River CAD cells, except for M5, were smooth with small pockmarks inside the cells representing the deposition of dredged material.

Multibeam bathymetric data rendered as a color scale by depth over an acoustic relief model (grayscale with hill-shading) provided additional representation of cell topographic lows and of the entire site (Figure 3-11). In the Mystic River, these data also revealed consistent depths in the survey area away from the distinct cells. In the lower western corner of the survey area shallow depths of 7 m were present. To the east of this area depths were consistently in the 8 m to 10 m range. Scour marks were present in towards the east of this area. Additional scour marks consistent with artifacts from dredging were observed surrounding the three cells in the northwest of the survey area.

3.2.2 Mystic River Acoustic Backscatter and Side-Scan Sonar

A mosaic of unfiltered backscatter data for the Mystic River at BHCAD (Figure 3-12) generally revealed the cells as finer surfaces having a weaker acoustic return (darker gray) and areas around the cells as rougher surfaces (coarser sediment) having a stronger acoustic return (lighter gray) around the cells. The strongest returns are in the center and east of the survey area. M4, M5, M8-11, M19, and parts of the Mystic cell had the strongest returns, while M2, M12 and Supercell had the weakest returns. The strong returns may be associated with the placement of sand caps or shipping activities. A circular feature with a strong return was observed in the southeast. An area with mixed strong and weak returns coincided with scour marks in the southern-central portion of the survey area. Filtered backscatter results were processed into a grid file and presented in a quantitative form where backscatter intensity values were assigned a color (Figure 3-13). In this filtered and gridded display, the finer-scale details were less visible, but the relative intensity of backscatter returns were easier to discern. Side-scan sonar results provided a high-resolution acoustic representation of the seafloor surface in a mosaic of the site (Figure 3-14).

3.2.3 Mystic River Comparison with Previous Bathymetry

The multibeam data from the 2016 survey were compared with multibeam data collected in November of 2009 (Figure 3-15). A subtraction of the bottom elevations in the 2009 survey from the 2016 elevations captured the apparent changes in bathymetry since the 2009 survey. Negative elevation differences of 0.5 m to 1 m were seen in the southern-central portion of the Mystic cell where scour marks were observed in the 2016 bathymetry. The most notable positive elevation differences of 1 to 1.5 m were in the Mystic cell. Slight negative elevation differences of 0.5 m were also seen north of M8-11 and in and around M4 and M5. Small trace elevation increases were also seen around M2.

3.2.4 Cell Capacity

The Mystic River CAD cells combined have a remaining capacity of approximately 291,000 to 352,000 m³ (Table 3-1) if filled to within one meter of the surrounding harbor bottom. Complete capacity reports for all Mystic River CAD cells are presented in Appendix B. The 'Mystic' cell has a diffuse eastern morphologic boundary, so two alternatives on capacity are provided; Alternate 1 mirrors the shapefile file boundary, and Alternate 2 follows the limits of excavation.

3.3 Chelsea River CAD Cells

The Chelsea River survey area was located east of the confluence of the Mystic River and Chelsea River. One cell is in the Mystic River survey area.

3.3.1 Chelsea River Bathymetry

Water depths in the Chelsea River at BHCAD varied from 1 m to 17 m throughout the survey area (Figure 3-16). The river channel had depths ranging from 10 m to 13 m. A steep slope on the southwestern boundary of the survey area deepened from 1 m to river channel depths. C12, a deep large rectangular cell with distinct boundaries was in the center of the survey area. Depths in this cell range from 12 m to 17 m. The cell was deeper than depths observed in the river channel. Multibeam bathymetric data rendered as an acoustic relief model provided a more detailed representation of the fine-scale topography (tens of cm relief) of the cells and of the entire site (Figure 3-17). Towards the center of the northwest cell boundary large circular depressions were seen. Small accumulations and pockmarks were in the eastern portion of the cell.

Multibeam bathymetric data rendered as a color scale by depth over an acoustic relief model (grayscale with hill-shading) provided additional representation of cell topographic lows and of the entire site (Figure 3-18). In the Chelsea River, these data confirmed a large distinct cell in the center of the survey area.

3.3.2 Chelsea River Acoustic Backscatter and Side-Scan Sonar

A mosaic of unfiltered backscatter data for the Chelsea River at BHCAD (Figure 3-19) generally revealed the cell as a finer surface with a weaker acoustic return (darker gray) and areas around the cell as rougher seabed with a stronger acoustic return (lighter gray) around the cell. Filtered backscatter results were processed into a grid file and presented in a quantitative form where backscatter intensity values were assigned a color (Figure 3-20). In this filtered and gridded display, the finer-scale details were less visible, but the relative intensity of backscatter returns were easier to discern. A weaker return and softer surface was seen between the northwest boundary of the cell and northwest west boundary of the survey area. Side-scan sonar results provided a high-resolution acoustic representation of the seafloor surface in a mosaic of the (Figure 3-21). The results showed a definitive slope on the southern bank of the river and a sharp ridge along the northeast corner of the cell.

3.3.3 Chelsea River Comparison with Previous Bathymetry

The multibeam data from the 2016 survey were compared with multibeam data collected in November of 2009 (Figure 3-22). A subtraction of the bottom elevations in the 2009 survey from the 2016 elevations captured the apparent changes in bathymetry since the 2009 survey. Over the cell area elevations increased by 0.5 m to 1.5, suggesting sedimentation. Negative elevation differences of 1 m to 3 m run parallel to the southern half of the western boundary of the survey area, suggesting scour associated with shipping activities.

3.3.4 Cell Capacity

The Chelsea River CAD cell C12 has a remaining capacity of approximately 56,000 m^3 (Table 3-1) if filled to within one meter of the surrounding harbor bottom. A complete capacity report is presented in Appendix B.

Table 3-1. Remaining Capacity of Boston Harbor CAD Cells

<table>
<tr><th>CAD Cell Area</th><th colspan="2">Cell ID</th><th colspan="2">Depth of Surrounding Harbor Bottom (m) below MLLW</th><th colspan="2">Remaining Capacity if Filled to within 1 m of Surrounding Harbor Bottom (m³)</th></tr>
<tr><td>Main Ship Channel</td><td colspan="2">MS</td><td colspan="2">10.8</td><td colspan="2">190,357</td></tr>
<tr><td colspan="7"></td></tr>
<tr><td rowspan="8">Mystic</td><td colspan="2">M2</td><td colspan="2">11.8</td><td colspan="2">27,405</td></tr>
<tr><td colspan="2">M4</td><td colspan="2">12.6</td><td colspan="2">18,046</td></tr>
<tr><td colspan="2">M5</td><td colspan="2">13</td><td colspan="2">4,122</td></tr>
<tr><td colspan="2">M8-11</td><td colspan="2">12.4</td><td colspan="2">25,778</td></tr>
<tr><td colspan="2">M12</td><td colspan="2">12.2</td><td colspan="2">9,019</td></tr>
<tr><td colspan="2">M19</td><td colspan="2">12.4</td><td colspan="2">36,074</td></tr>
<tr><td colspan="2">Supercell</td><td colspan="2">12.2</td><td colspan="2">53,949</td></tr>
<tr><td>Mystic Alt1</td><td>Mystic Alt2</td><td>10.8</td><td>10.2</td><td>116,631</td><td>177,623</td></tr>
<tr><td></td><td colspan="2"></td><td colspan="2">Mystic River Cells Sub-total</td><td>291,024</td><td>352,016</td></tr>
<tr><td colspan="7"></td></tr>
<tr><td>Chelsea</td><td colspan="2">C12</td><td colspan="2">11.2</td><td colspan="2">56,081</td></tr>
</table>

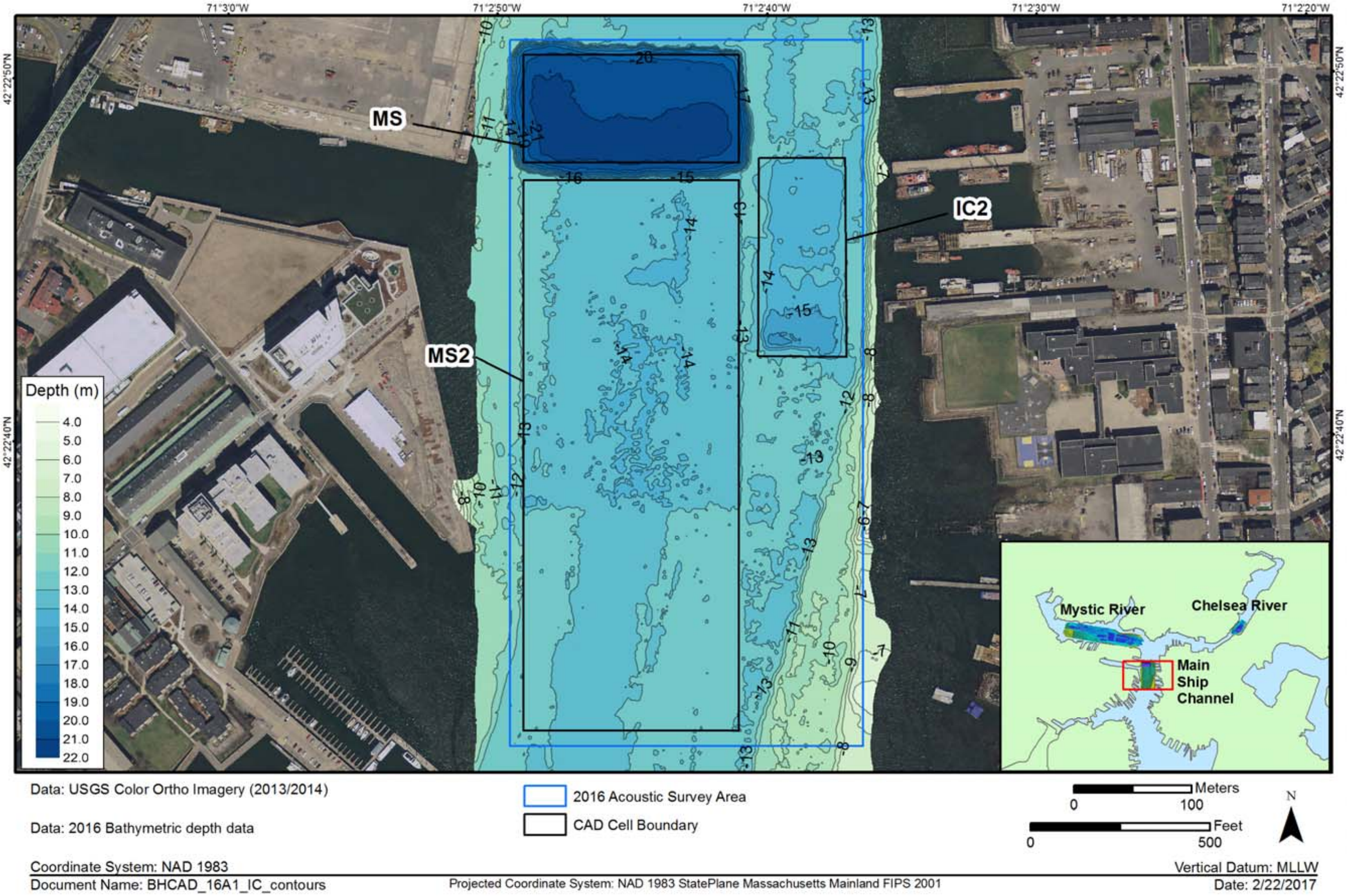

Figure 3-1. Bathymetric contour map of BHCAD Inner Confluence cells – November 2016

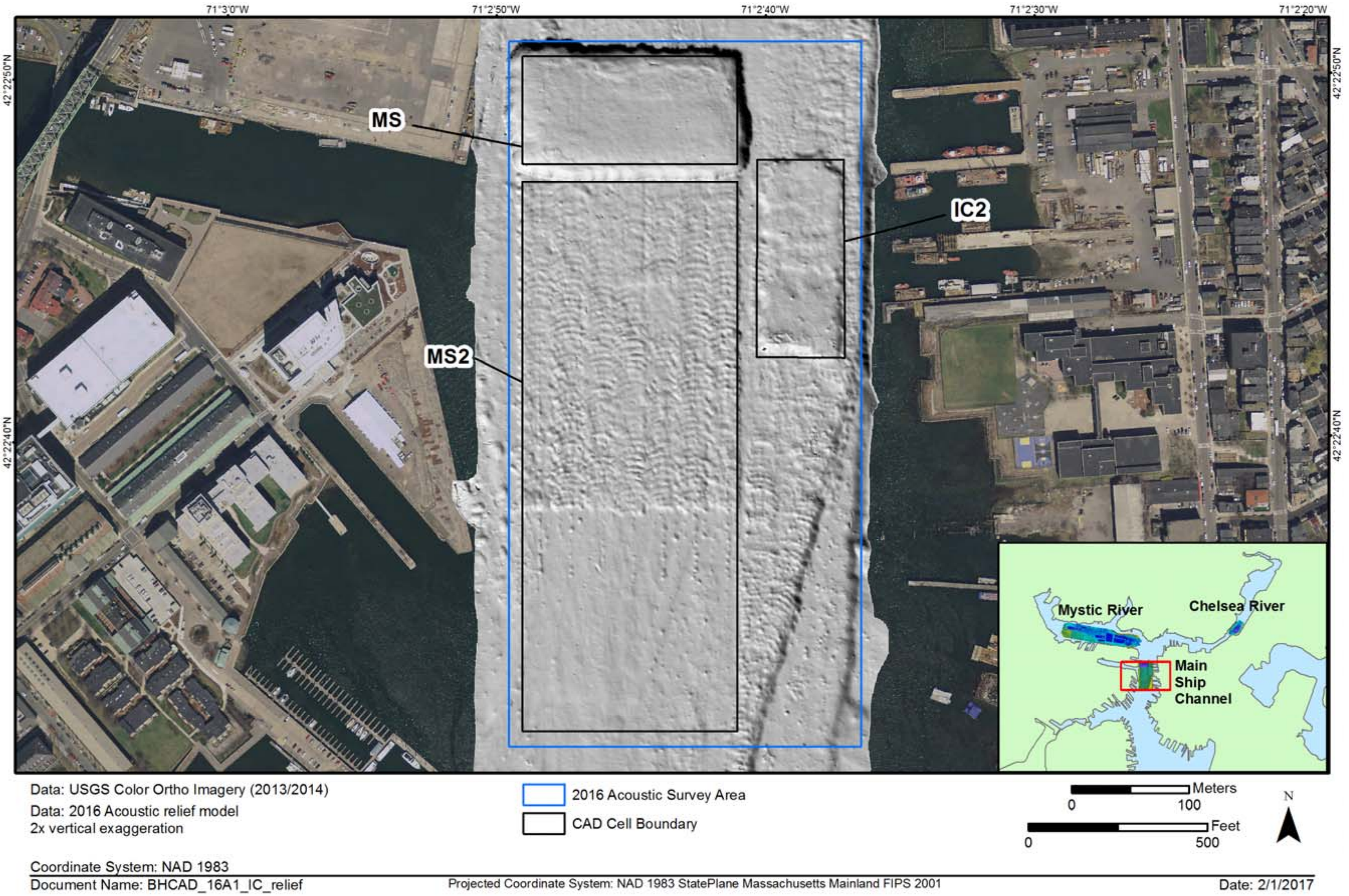

Figure 3-2. Acoustic relief map (hill-shaded) of BHCAD Inner Confluence cells – November 2016

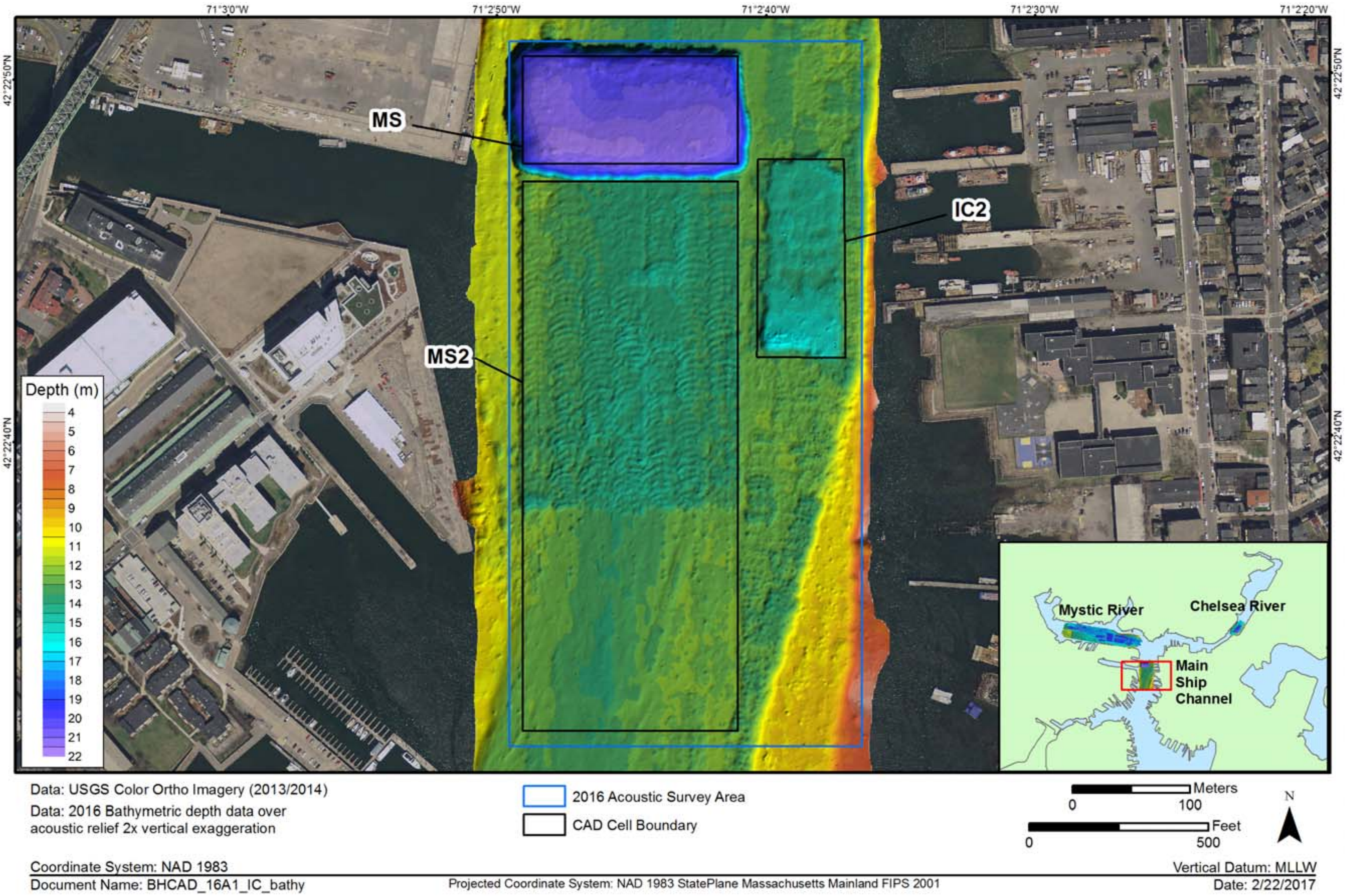

Figure 3-3. Bathymetric depth data over acoustic relief model of BHCAD Inner Confluence cells – November 2016

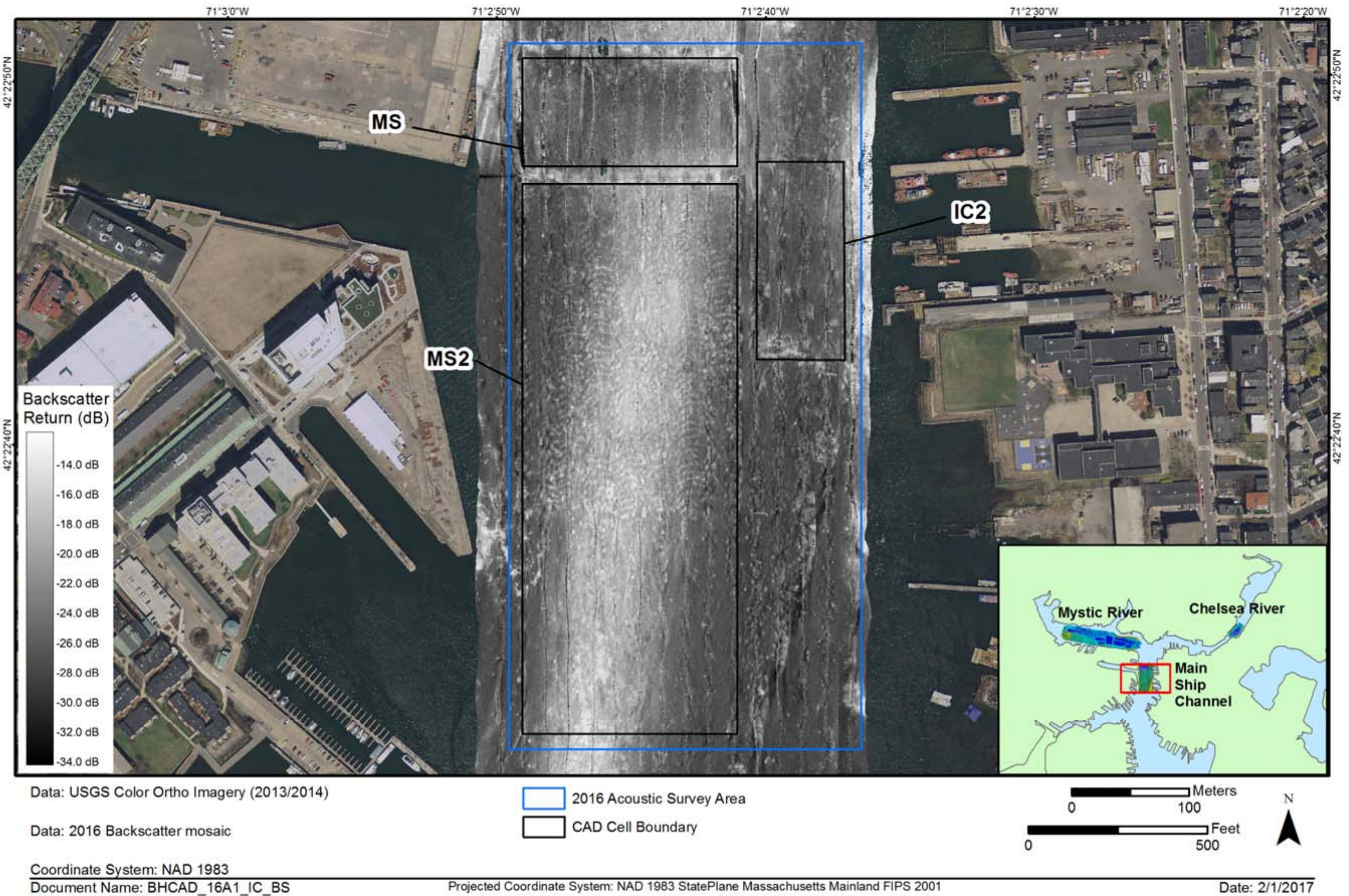

Figure 3-4. Mosaic of unfiltered backscatter data of BHCAD Main Ship Channel cells – November 2016

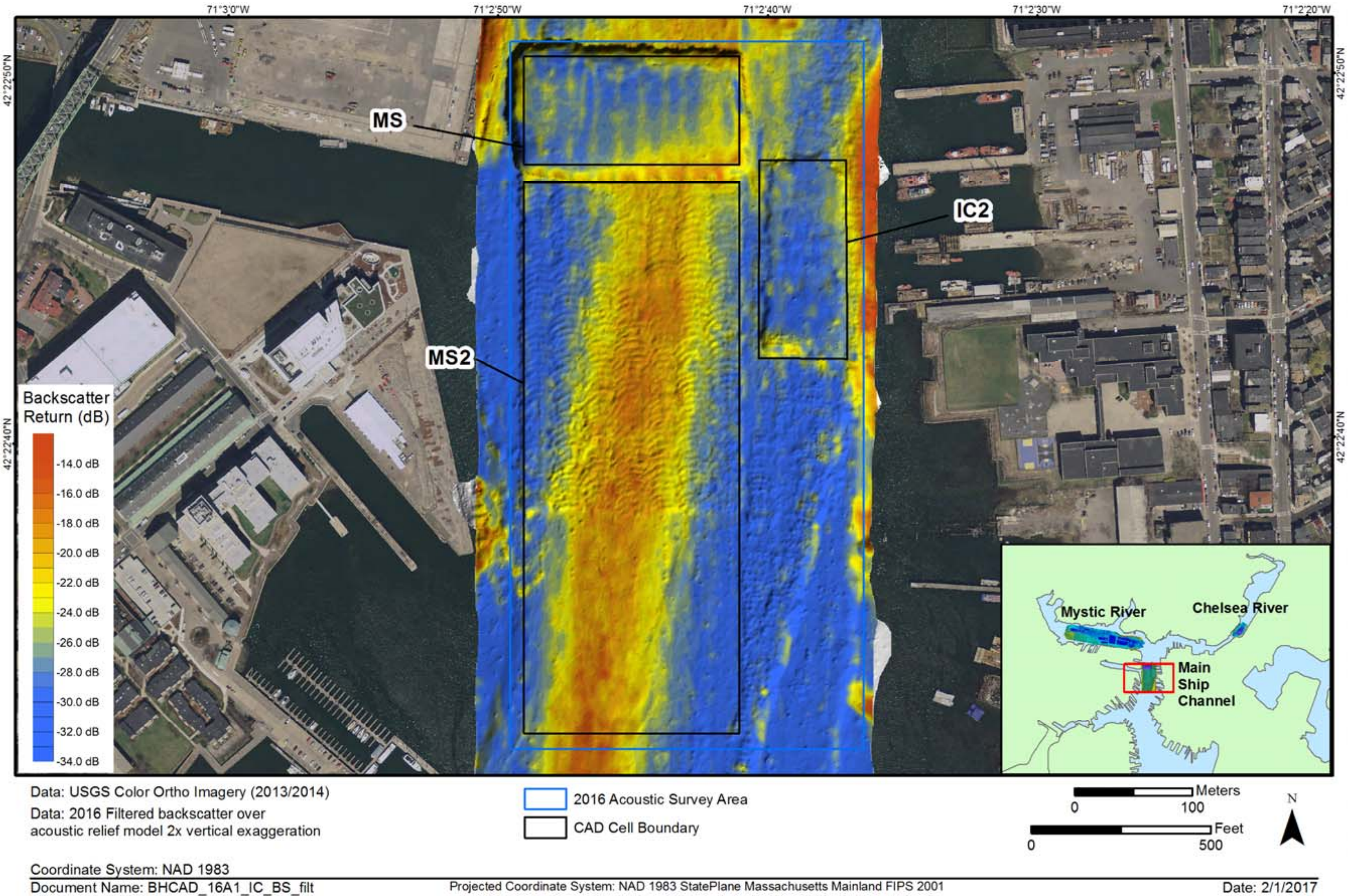

Figure 3-5. Filtered backscatter over acoustic relief model of BHCAD Main Ship Channel cells – November 2016

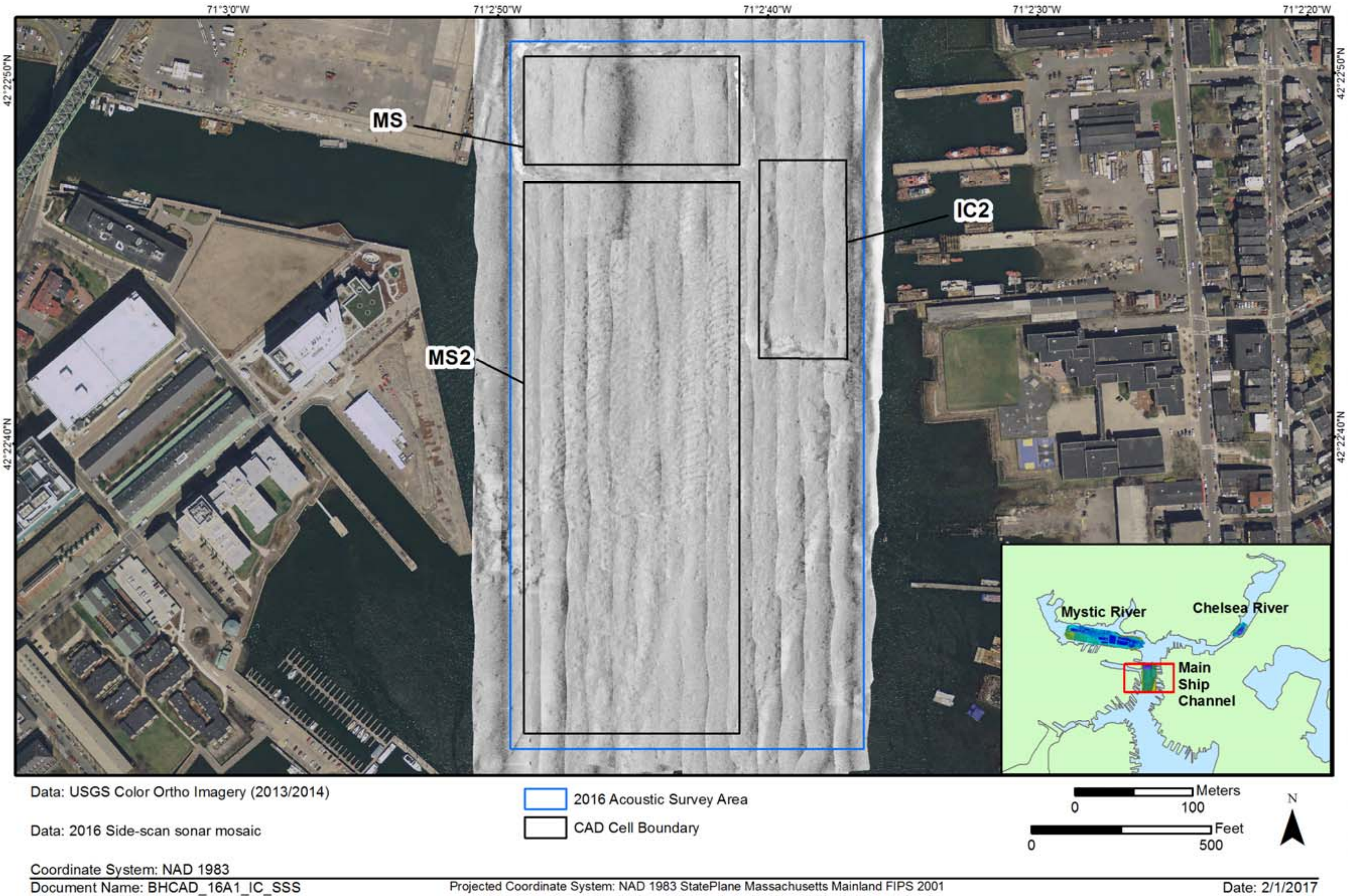

Figure 3-6. Side-scan mosaic of BHCAD Main Ship Channel cells – November 2016

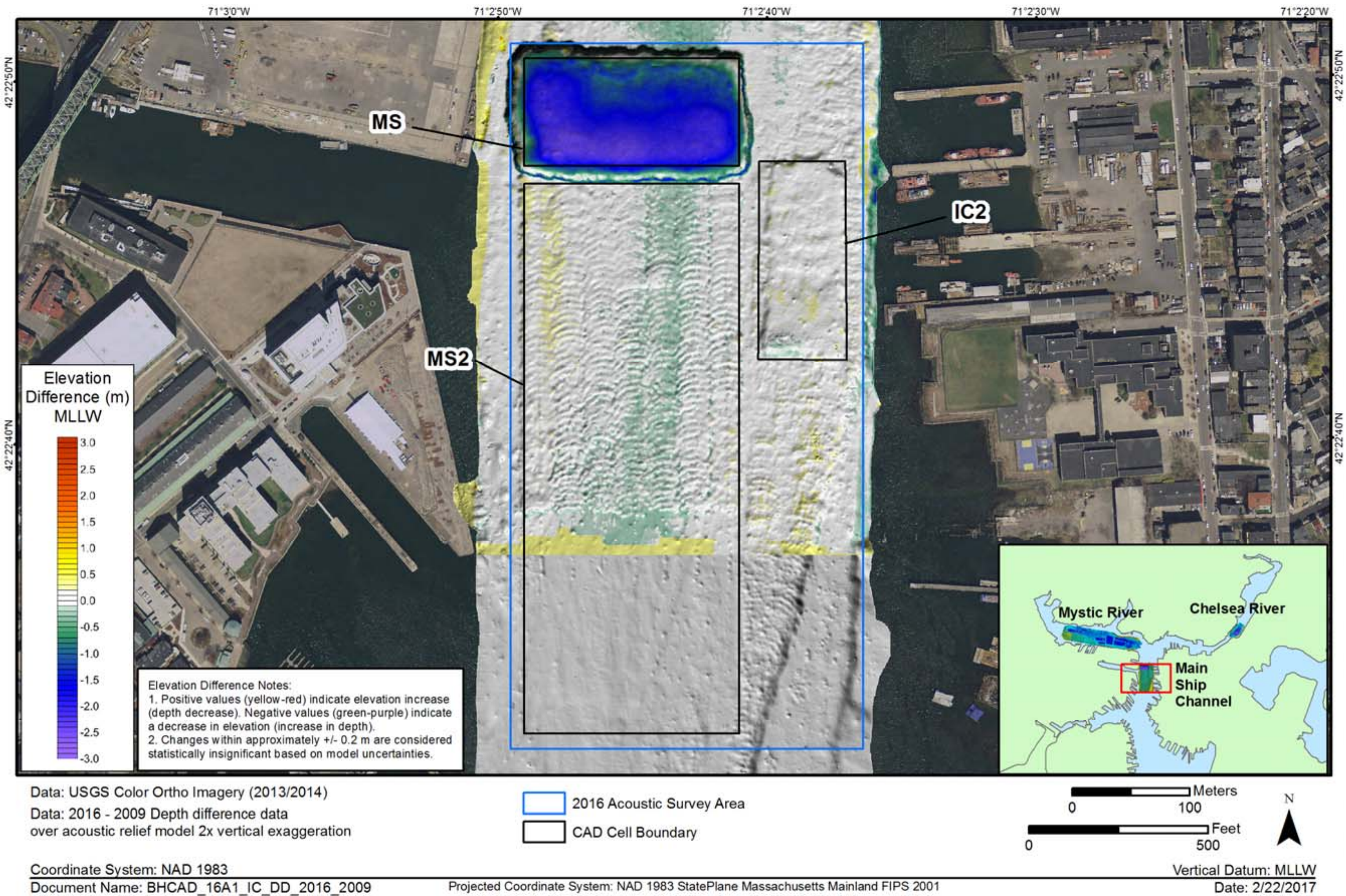

Figure 3-7. BHCAD Main Ship Channel cells elevation difference: 2016 vs. 2009

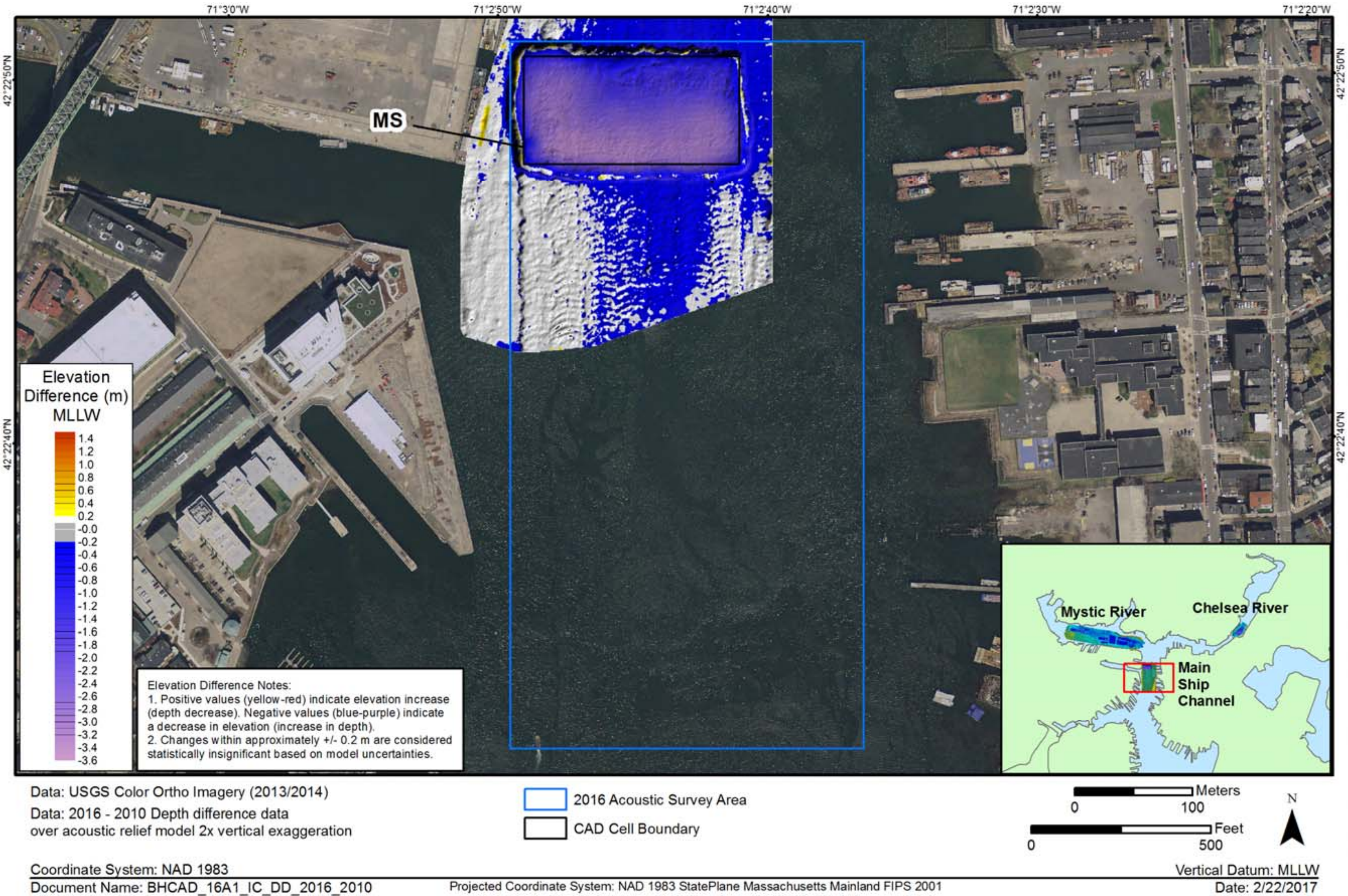

Figure 3-8. BHCAD Main Ship Channel cells elevation difference: 2016 vs. 2010

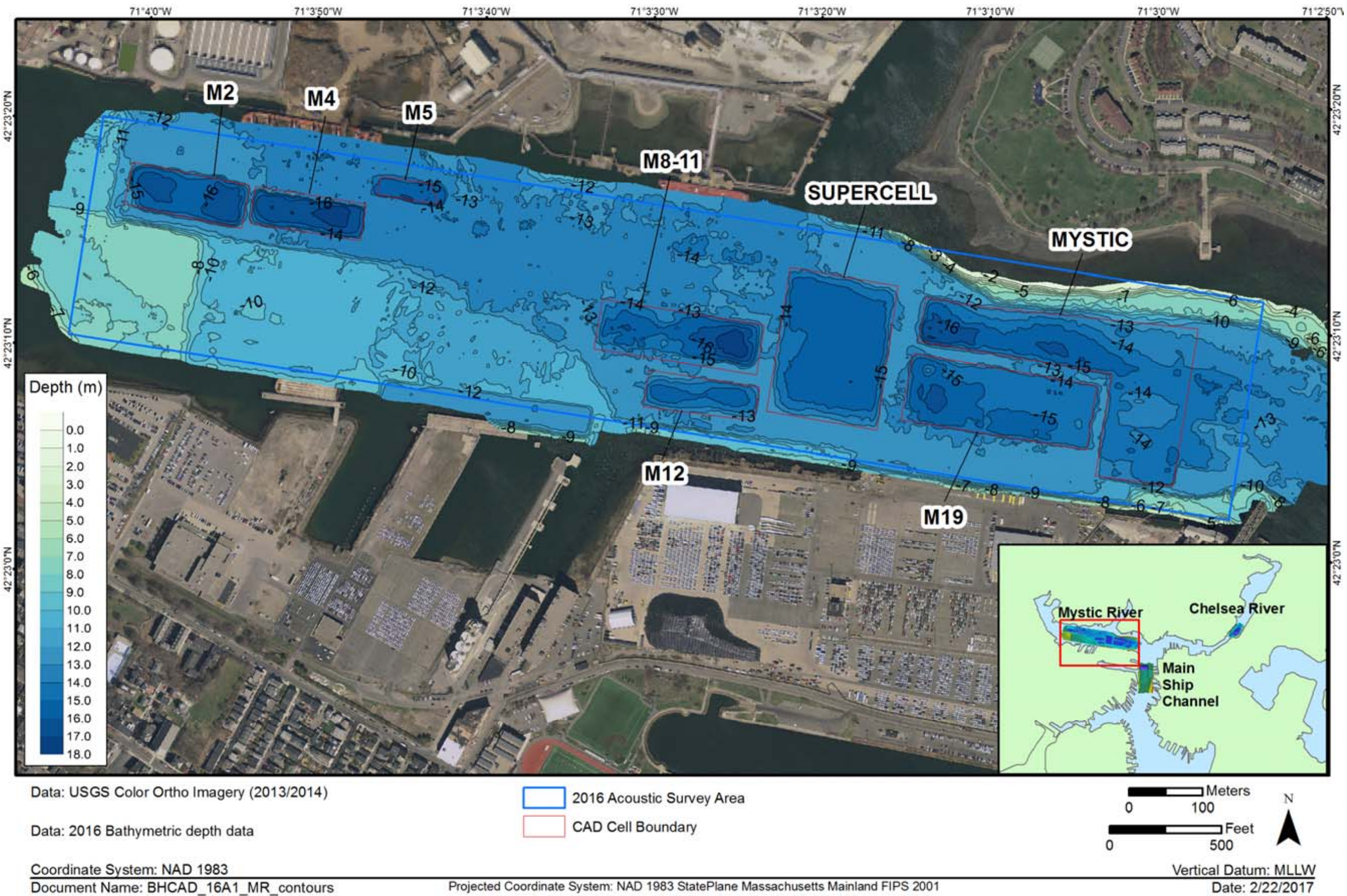

Figure 3-9. Bathymetric contour map of BHCAD Mystic River cells – November 2016

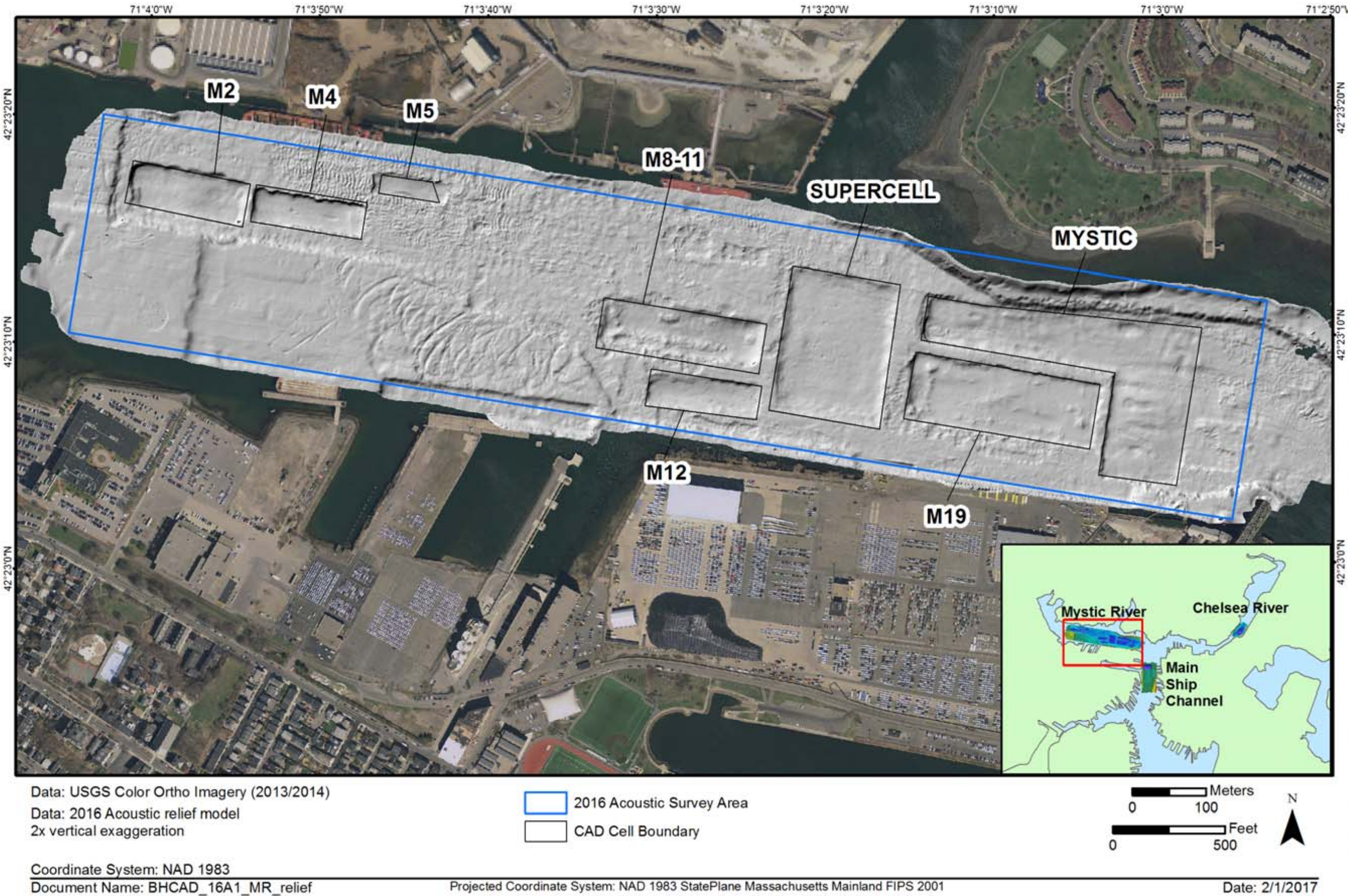

Figure 3-10. Acoustic relief map (hill-shaded) of BHCAD Mystic River cells – November 2016

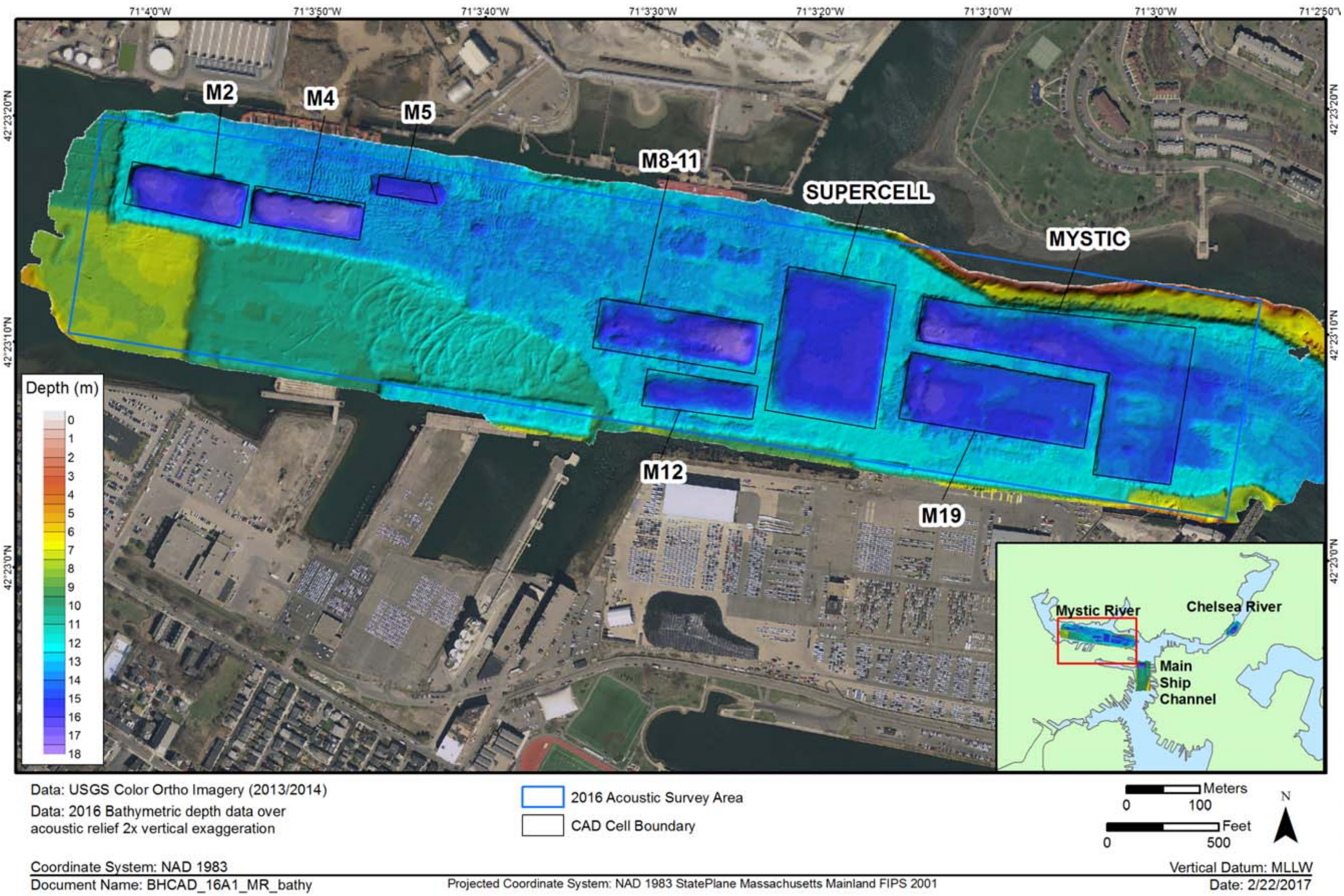

Figure 3-11. Bathymetric depth data over acoustic relief model of BHCAD Mystic River cells – November 2016

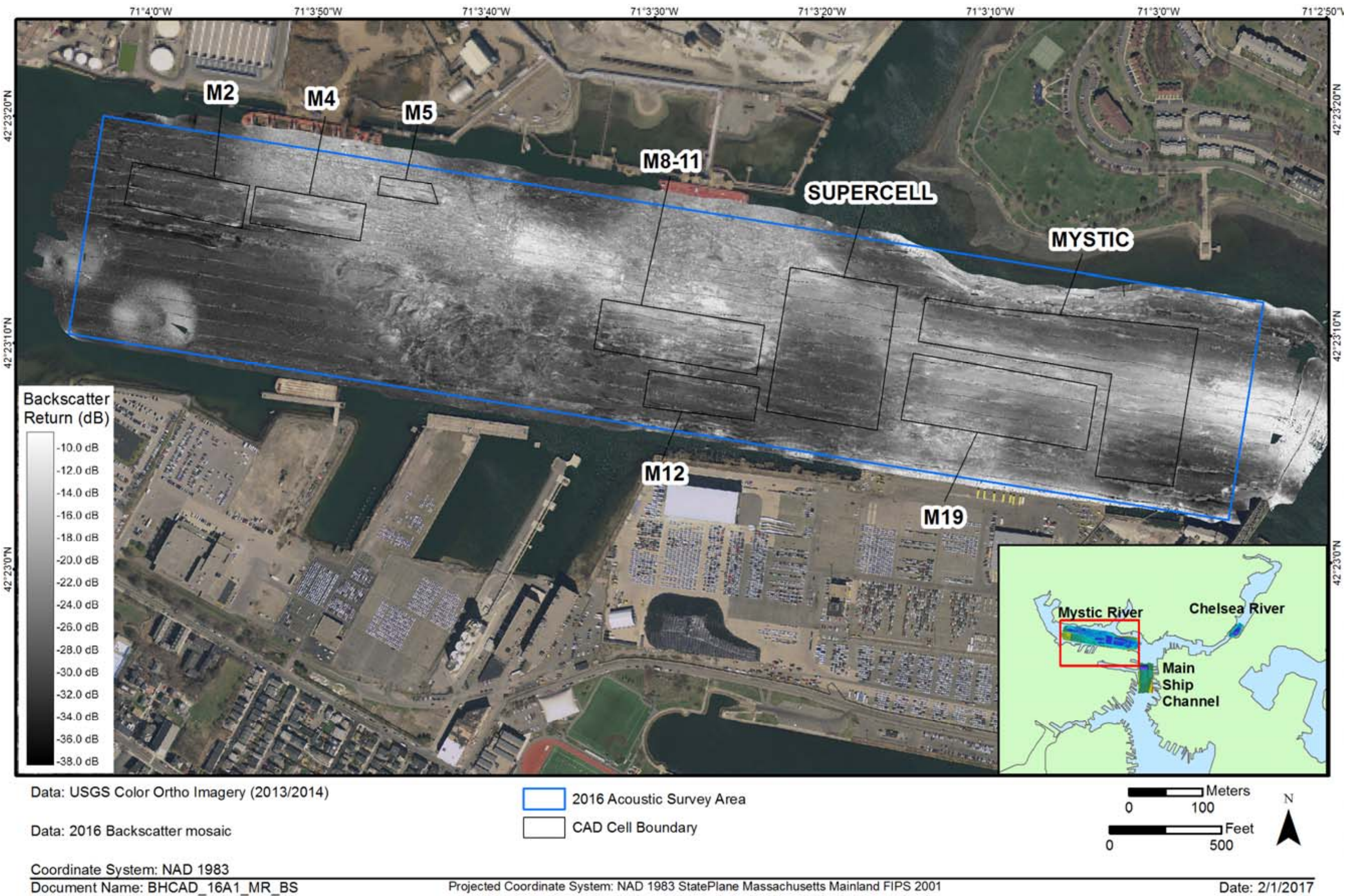

Figure 3-12. Mosaic of unfiltered backscatter data of BHCAD Mystic River cells – November 2016

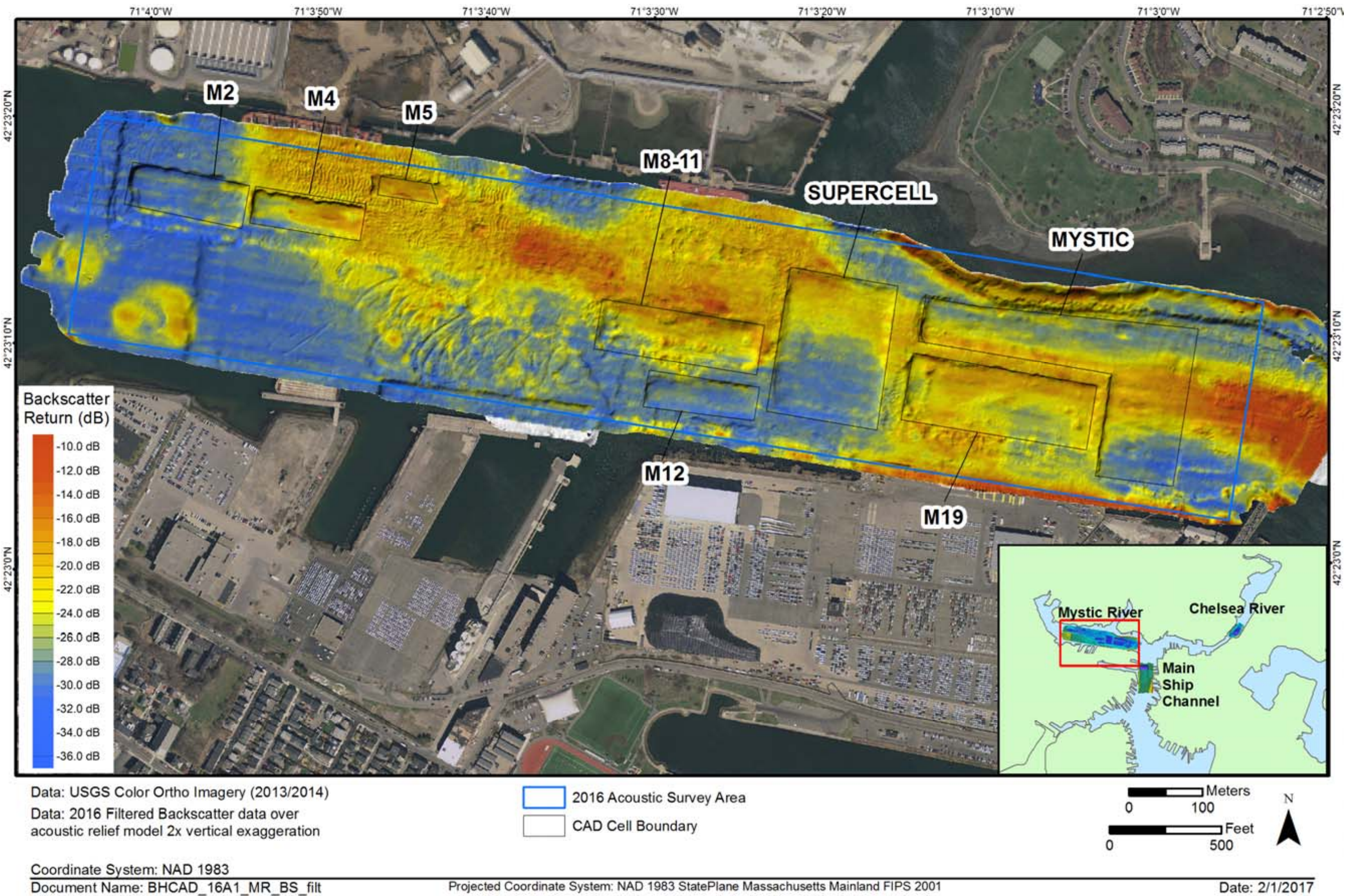

Figure 3-13. Filtered backscatter over acoustic relief model of BHCAD Mystic River cells – November 2016

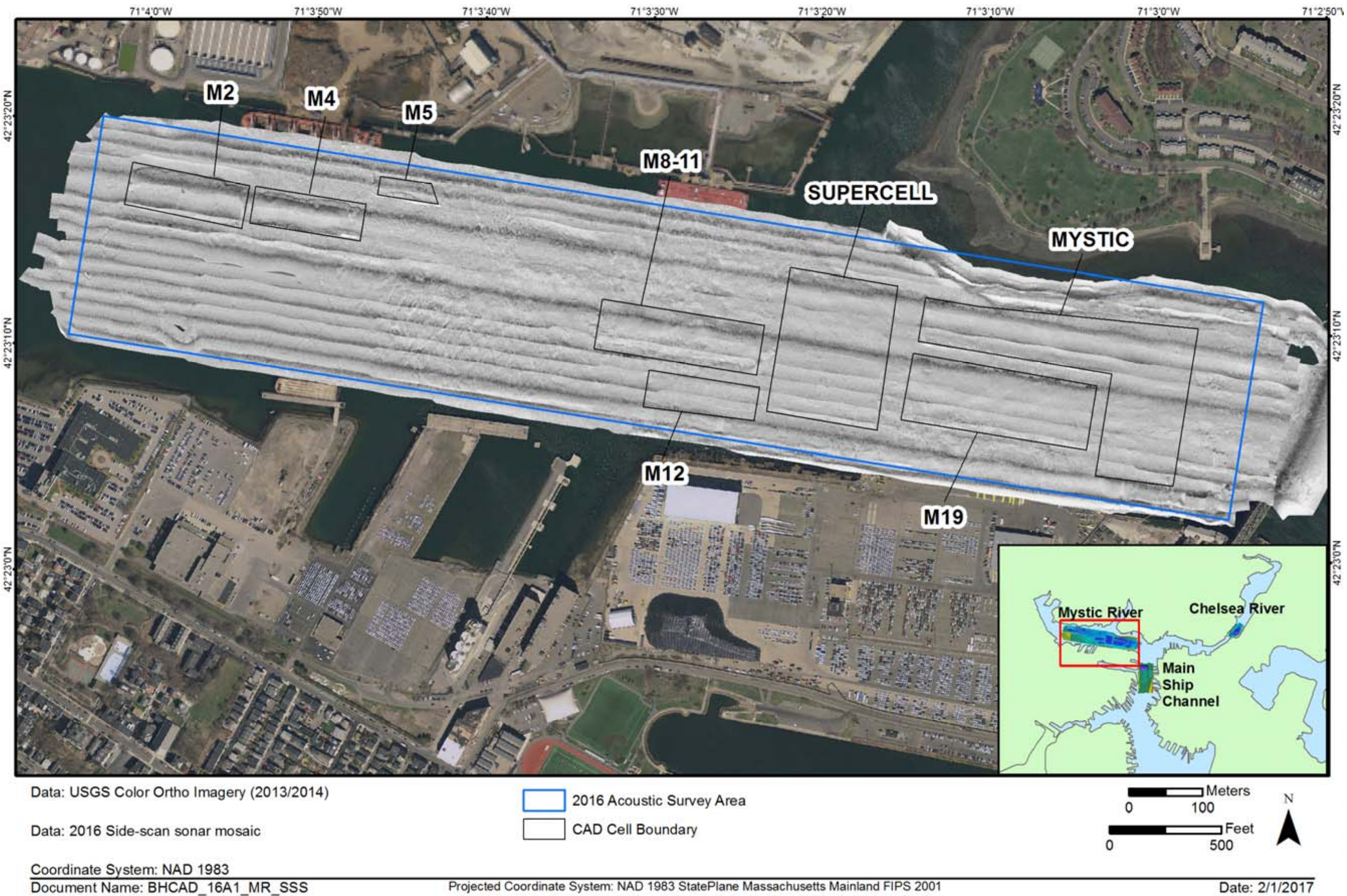

Figure 3-14. Side-scan mosaic of BHCAD Mystic River cells – November 2016

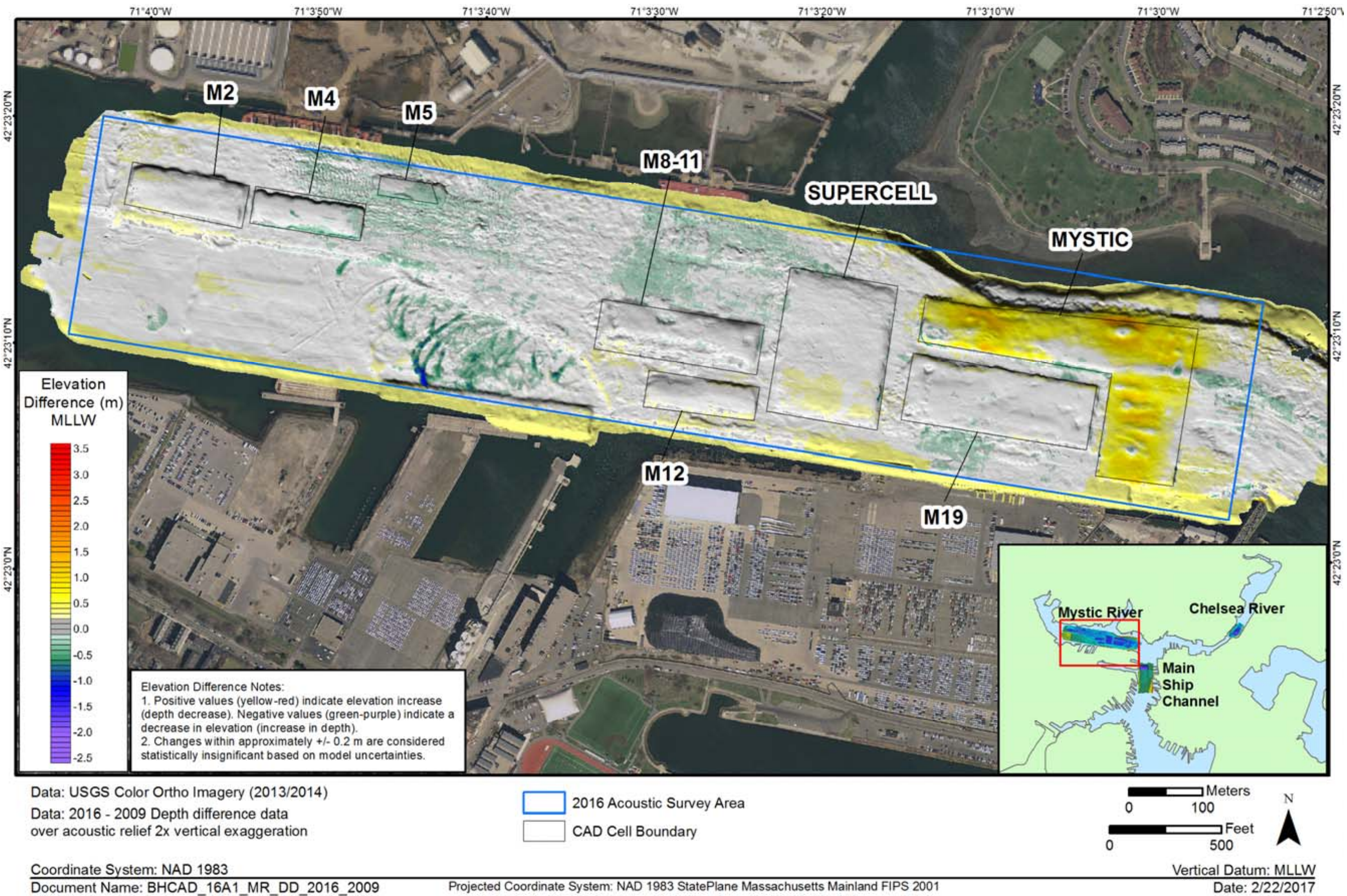

Figure 3-15. BHCAD Mystic River cells elevation difference: 2016 vs. 2009

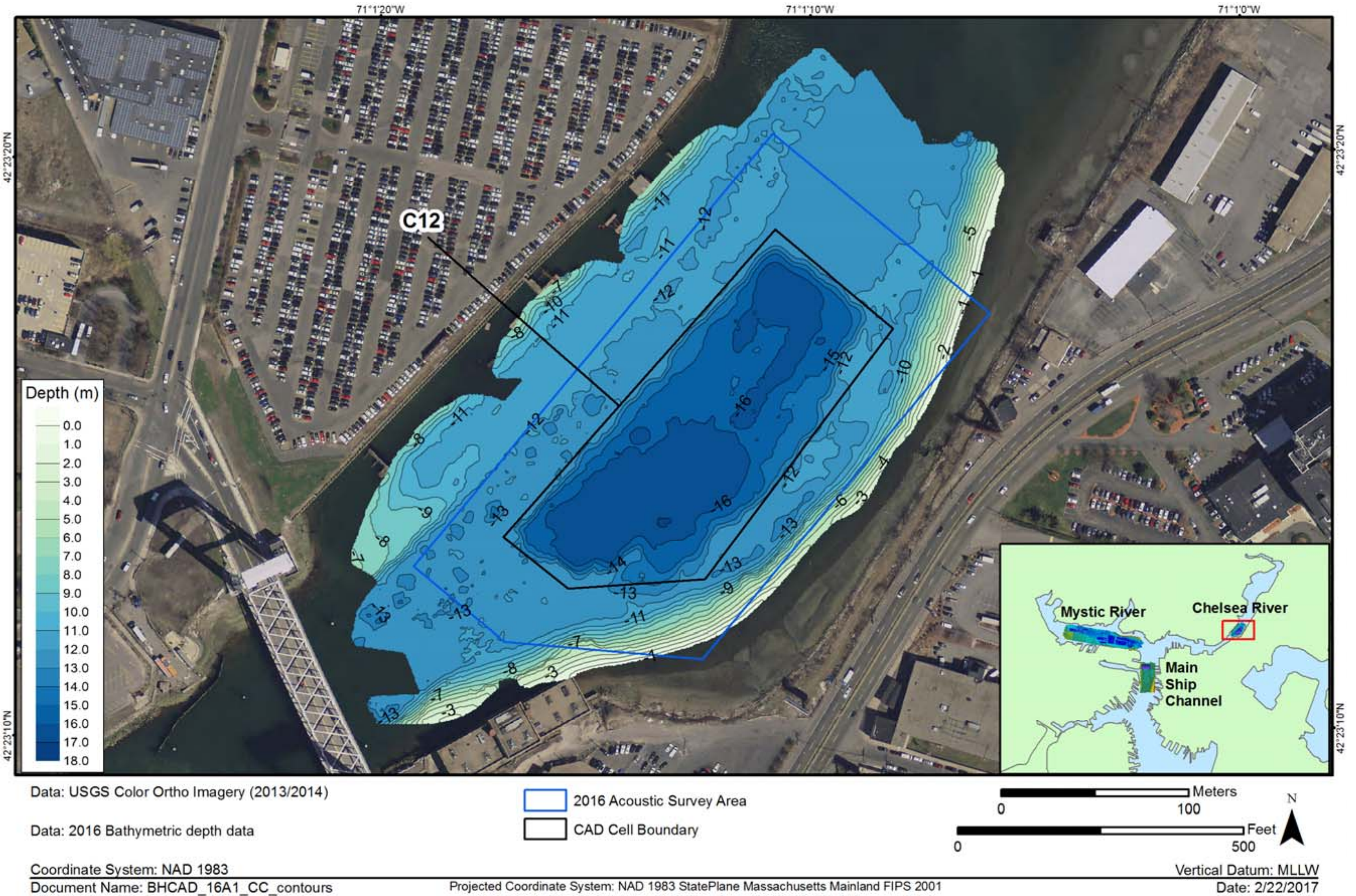

Figure 3-16. Bathymetric contour map of BHCAD Chelsea River cells – November 2016

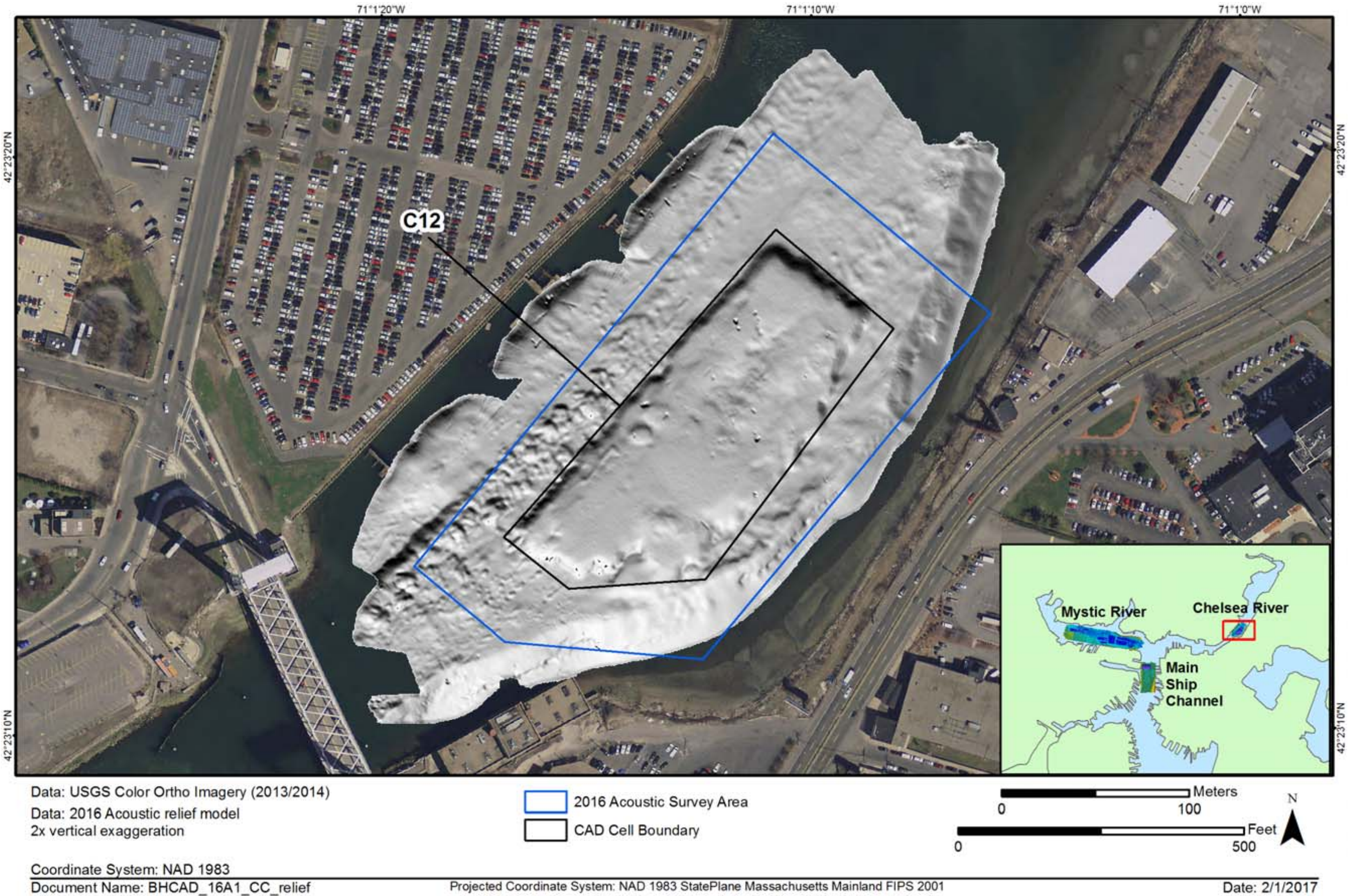

Figure 3-17. Acoustic relief map (hill-shaded) of BHCAD Chelsea River cells – November 2016

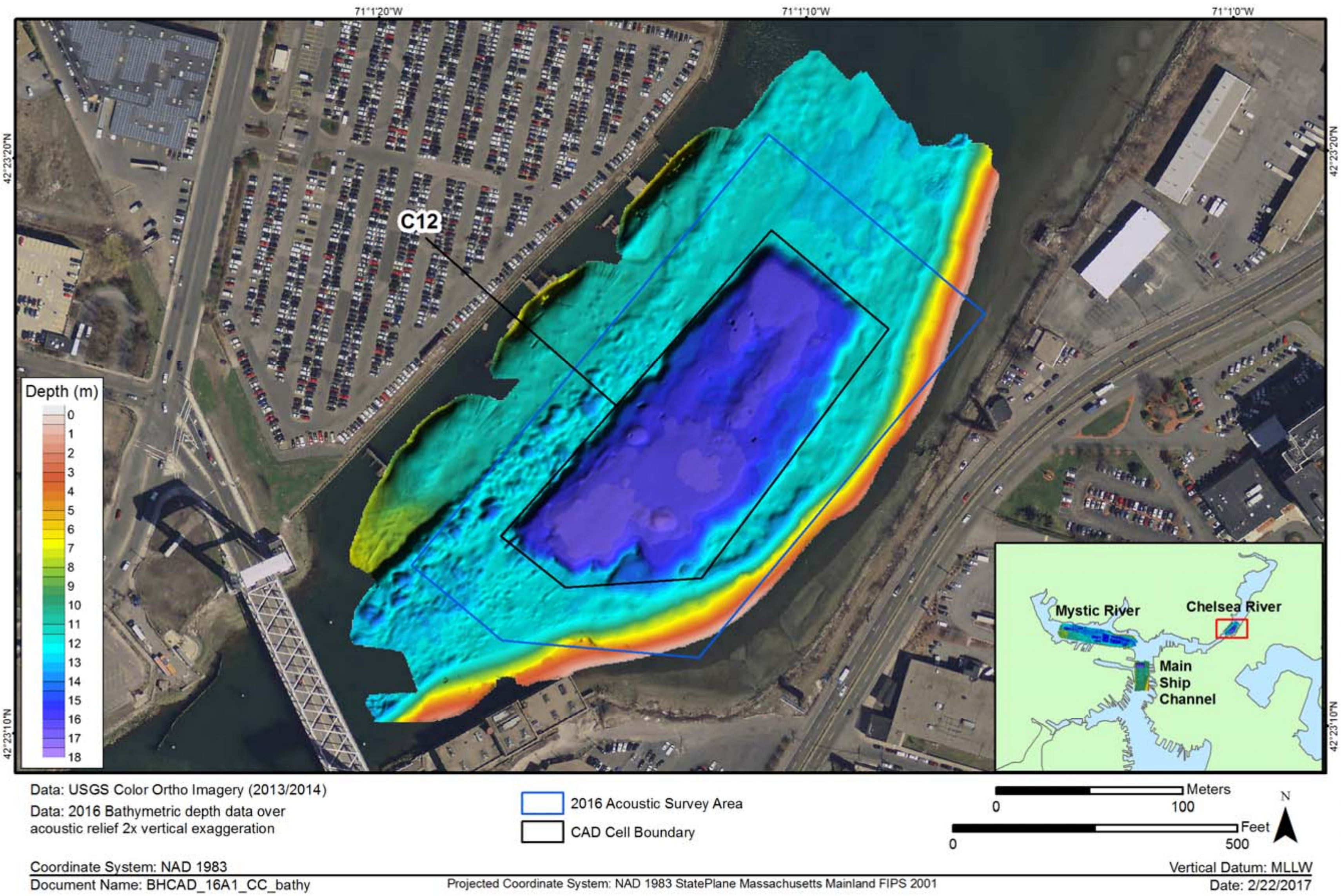

Figure 3-18. Bathymetric depth data over acoustic relief model of BHCAD Chelsea River cells – November 2016

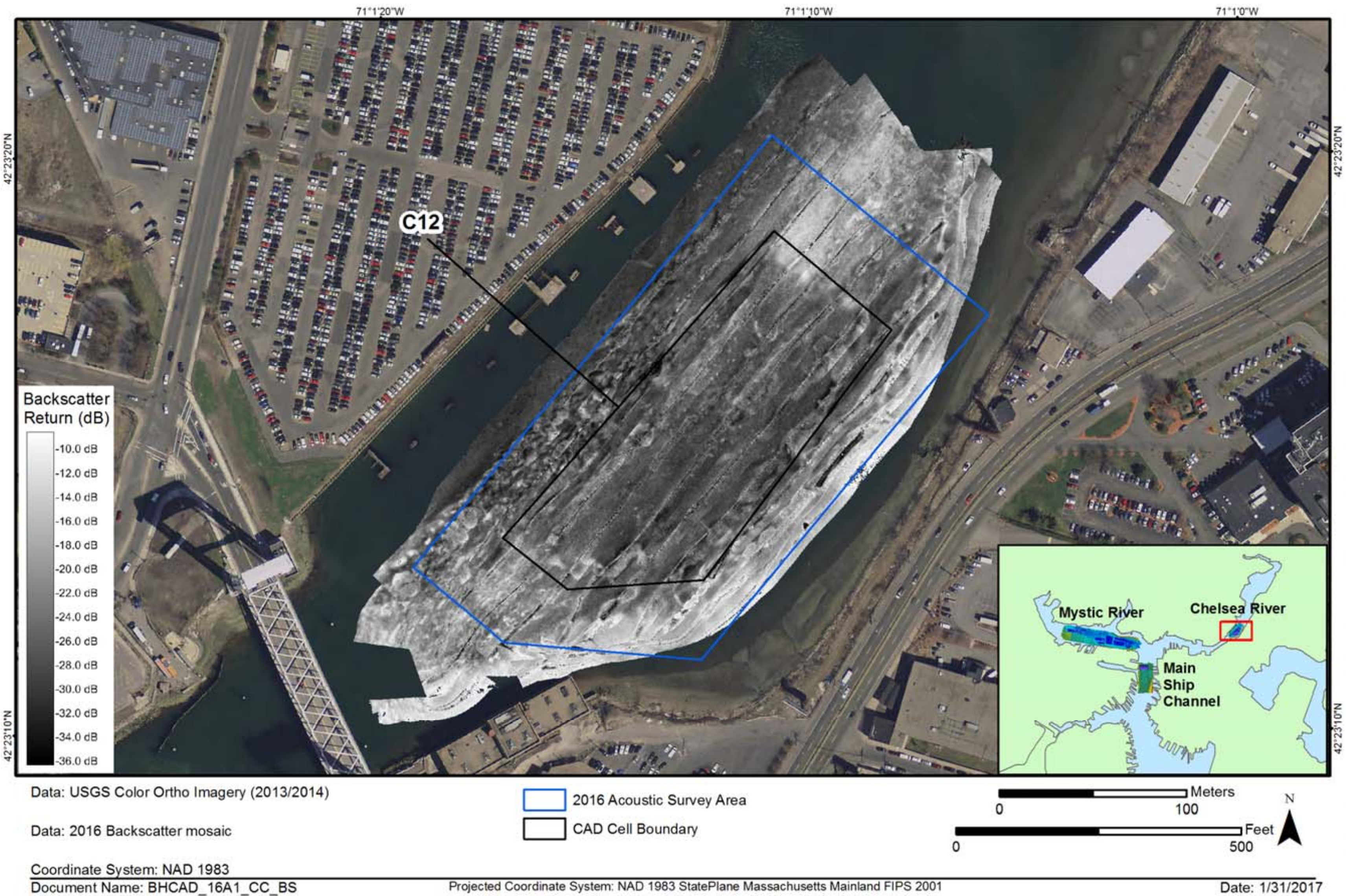

Figure 3-19. Mosaic of unfiltered backscatter data of BHCAD Chelsea River cells – November 2016

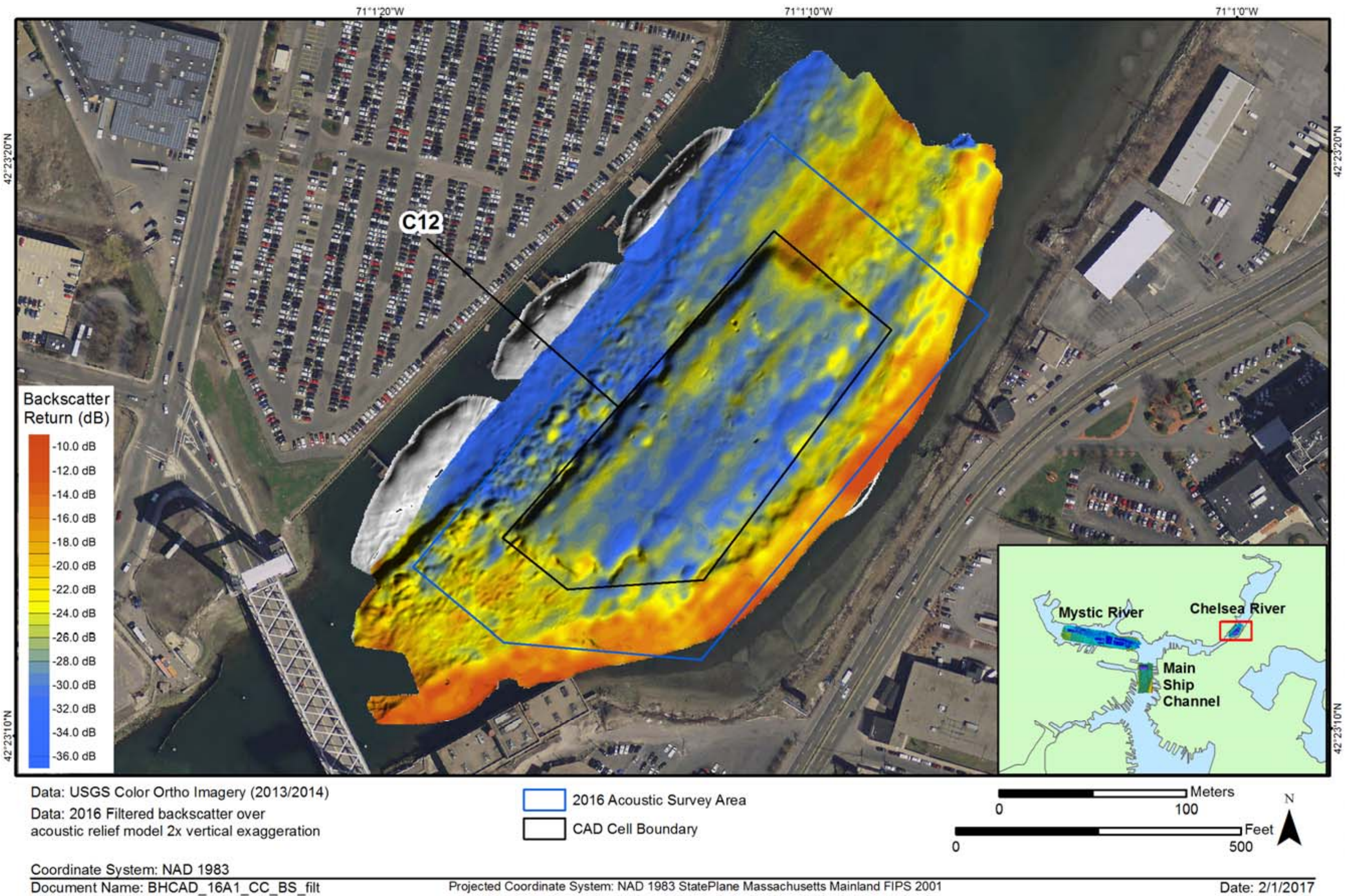

Figure 3-20. Filtered backscatter over acoustic relief model of BHCAD Chelsea River cells – November 2016

Figure 3-21. Side-scan mosaic of BHCAD Chelsea River cells – November 2016

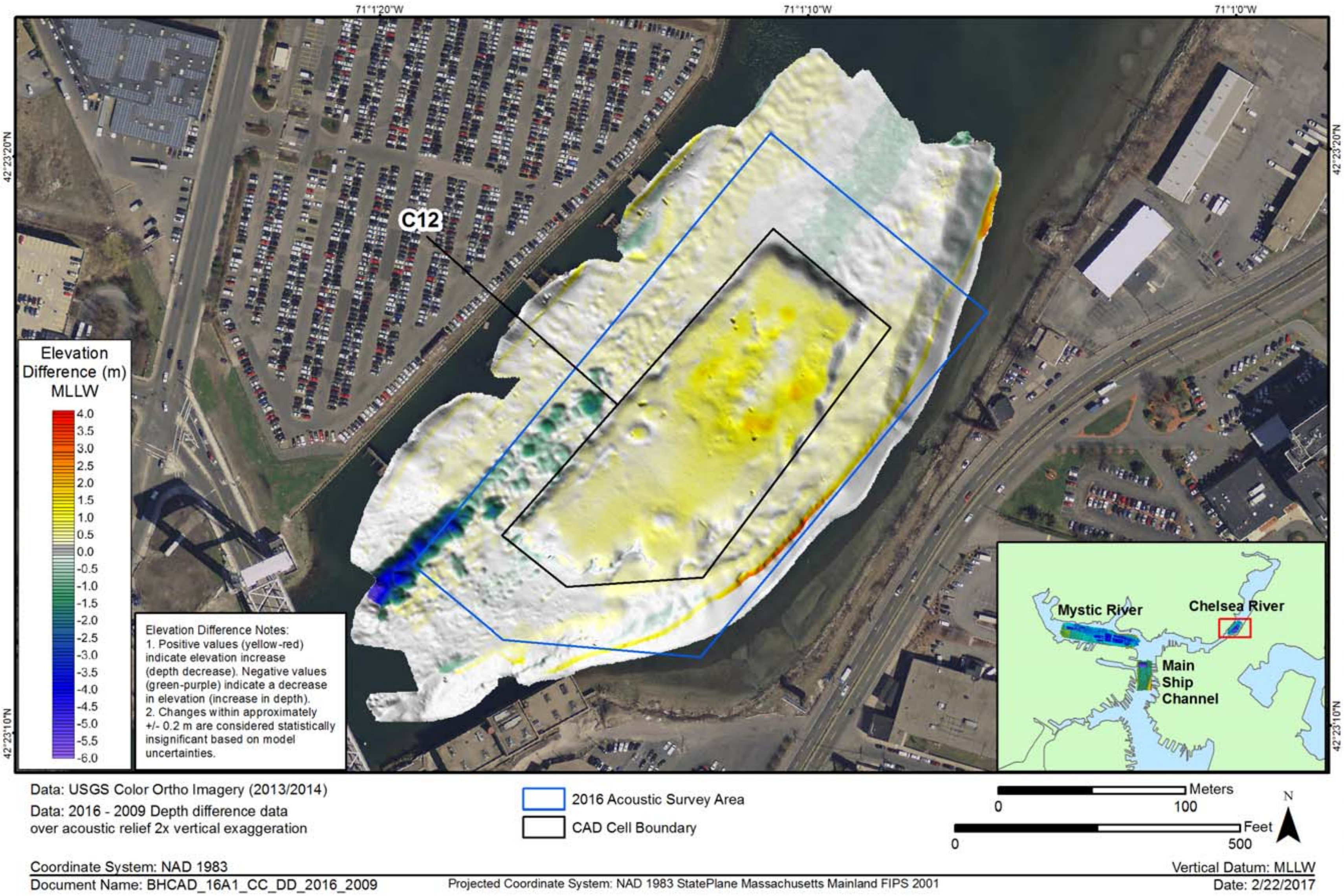

Figure 3-22. BHCAD Chelsea River cells elevation difference: 2016 vs. 2009

4.0 SUMMARY

The objectives of the survey were to:

- Characterize the harbor topography and surficial features over the 11 existing cells and the footprint of the expected twelfth cell by completing a multibeam bathymetric survey, and
- Calculate any remaining capacity of the cells if assumed filled to with 1 m (~3 ft) of the surrounding harbor bottom.

Observed surficial features in the survey areas were consistent with excavation of CAD cells with dredging equipment (arcuate scars or parallel marks) and filling of the cells with bottom release barges (smooth surfaces and circular depressions).

For each survey area, elevation differences were measured by subtracting survey data from 2009 or 2010 from the 2016 survey data. Dredged material placed in CAD cells is expected to initially reduce water depth and then dewater and consolidate over time with a resulting increase in water depth.

Main Ship Channel CAD Cells

- A negative elevation difference of 0.5 m to 2 m between 2009 and 2016 covered MS, likely due to the consolidation of material in the cell.
- Elevation differences between 2010 and 2016 were greater than those observed in 2009 and suggest that some additional consolidation occurred in the cell between November 2009 and February 2010.
- The Main Ship Channel CAD cell MS has a remaining capacity of approximately 190,350 m^3 if filled to within one meter of the surrounding harbor bottom.

Mystic River CAD Cells

- Negative elevation differences of 0.5 m to 1 m between 2009 and 2016 were seen in the southern-central portion of the survey area where scour marks were observed in the 2016 bathymetry.
- The most notable positive elevation differences of 1 to 1.5 m were in the Mystic cell.
- Slight negative elevation differences of 0.5 m were also seen north of M8-11 and in and around M4 and M5. Small trace elevation increases were also seen around M2.
- The Mystic River CAD cells combined have a remaining capacity of approximately 291,000 to 352,000 m^3 if filled to within one meter of the surrounding harbor bottom.

Chelsea River CAD Cells

- Over the cell area depth increased between 2009 and 2016 by 0.5 m to 1.5m.
- Negative elevation differences of 1 m to 3 m run parallel to the southern half of the western boundary of the survey area.
- The Chelsea River CAD cell C12 has a remaining capacity of approximately 56,000 m^3 (Table 3-1) if filled to within one meter of the surrounding harbor bottom.

5.0 DATA TRANSMITTAL

Data transmittal to support this data report will be provided as a separate deliverable for inclusion in a Technical Support Notebook. The data submittal will include:

- Scope of Work
- Raw and processed acoustic survey data
- Survey field logs
- Report figures and associated files, including an ArcGIS geo-database
- Electronic copies of all data and final products

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APPENDIX A

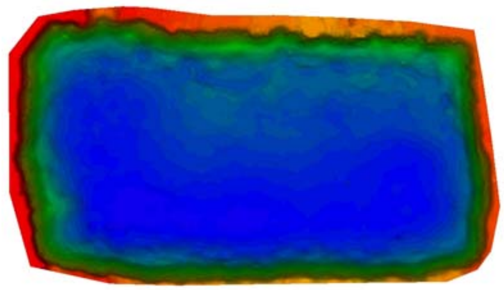
TABLE OF COMMON CONVERSIONS

Metric Unit Conversion to English Unit		English Unit Conversion to Metric Unit	
1 meter 1 m	3.2808 ft	1 foot 1 ft	0.3048 m
1 square meter 1 m^2	10.7639 ft^2	1 square foot 1 ft^2	0.0929 m^2
1 kilometer 1 km	0.6214 mi	1 mile 1 mi	1.6093 km
1 cubic meter 1 m^3	1.3080 yd^3	1 cubic yard 1 yd^3	0.7646 m^3
1 centimeter 1 cm	0.3937 in	1 inch 1 in	2.54 cm

APPENDIX B

CAPACITY REPORTS FOR BOSTON HARBOR CAD CELL SITE

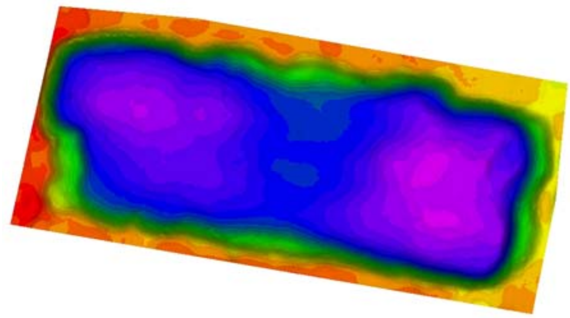
Main Ship Channel
CAD Cell Capacity Report
CAD Cell: MS
Level unit: Meter
Volume unit: Cubic Meter
TIN vs Level Volume Totals



Level (MLLW)	Volume Above	Area Above	Volume Below	Area Below
-10.8	0	1	215,683	25,689
-11.0	1	30	210,546	25,660
-11.2	27	232	205,434	25,458
-11.4	106	544	200,375	25,146
-11.6	227	654	195,358	25,035
-11.8	364	707	**190,357**	24,983
-12.0	509	747	185,365	24,942
-12.2	665	817	180,382	24,873
-12.4	842	964	175,421	24,726
-12.6	1,047	1,104	170,489	24,586
-12.8	1,300	1,436	165,604	24,254
-13.0	1,617	1,777	160,783	23,913
-13.2	2,000	2,038	156,027	23,652
-13.4	2,433	2,320	151,323	23,369
-13.6	2,927	2,614	146,679	23,076
-13.8	3,485	2,945	142,099	22,745
-14.0	4,097	3,170	137,573	22,520
-14.2	4,747	3,330	133,086	22,360
-14.4	5,427	3,458	128,627	22,232
-14.6	6,129	3,568	124,192	22,122
-14.8	6,853	3,672	119,778	22,018
-15.0	7,598	3,770	115,384	21,920
-15.2	8,361	3,867	111,010	21,823
-15.4	9,144	3,964	106,655	21,726
-15.6	9,947	4,063	102,320	21,626
-15.8	10,770	4,167	98,005	21,523
-16.0	11,614	4,276	93,711	21,413
-16.2	12,481	4,390	89,440	21,299
-16.4	13,371	4,510	85,192	21,180
-16.6	14,285	4,637	80,968	21,053
-16.8	15,226	4,770	76,771	20,919
-17.0	16,194	4,909	72,601	20,780
-17.2	17,190	5,055	68,459	20,635
-17.4	18,216	5,208	64,347	20,482
-17.6	19,274	5,367	60,267	20,323
-17.8	20,364	5,535	56,219	20,155
-18.0	21,488	5,711	52,205	19,979
-18.2	22,649	5,900	48,228	19,790
-18.4	23,849	6,104	44,291	19,586

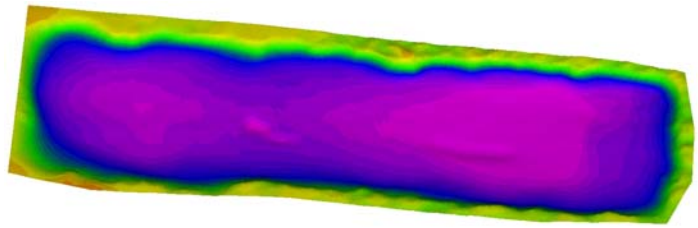
Level (MLLW)	Volume Above	Area Above	Volume Below	Area Below
-18.6	25,092	6,326	40,395	19,363
-18.8	26,382	6,577	36,547	19,113
-19.0	27,725	6,860	32,752	18,829
-19.2	29,129	7,189	29,019	18,500
-19.4	30,604	7,571	25,356	18,119
-19.6	32,161	8,006	21,774	17,684
-19.8	33,812	8,517	18,288	17,173
-20.0	35,572	9,116	14,910	16,574
-20.2	37,481	10,084	11,681	15,606
-20.4	39,681	12,094	8,744	13,596
-20.6	42,319	14,351	6,243	11,339
-20.8	45,394	16,312	4,180	9,378
-21.0	48,836	18,125	2,484	7,564
-21.2	52,664	20,275	1,174	5,414
-21.4	56,969	22,910	341	2,780
-21.6	61,799	24,980	34	710

Mystic River
CAD Cell Capacity Report
CAD Cell: M2
Level unit: Meter
Volume unit: Cubic Meter
TIN vs Level Volume Totals



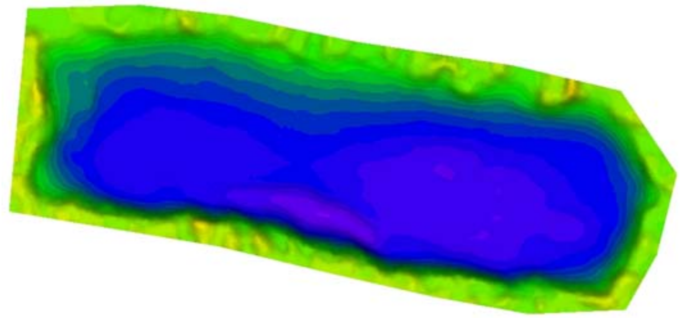
Level (MLLW)	Volume Above	Area Above	Volume Below	Area Below
-11.8	1	16	39,597	13,066
-12.0	10	116	36,990	12,966
-12.2	55	338	34,419	12,744
-12.4	167	898	31,914	12,184
-12.6	455	1,830	29,586	11,252
-12.8	890	2,499	**27,405**	10,583
-13.0	1,433	2,914	25,331	10,168
-13.2	2,042	3,154	23,323	9,928
-13.4	2,693	3,352	21,358	9,730
-13.6	3,382	3,541	19,431	9,542
-13.8	4,109	3,732	17,541	9,350
-14.0	4,876	3,941	15,692	9,142
-14.2	5,687	4,174	13,887	8,908
-14.4	6,547	4,426	12,130	8,656
-14.6	7,459	4,691	10,425	8,391
-14.8	8,424	4,970	8,774	8,112
-15.0	9,449	5,285	7,183	7,797
-15.2	10,544	5,685	5,661	7,397
-15.4	11,753	6,495	4,254	6,587
-15.6	13,175	7,694	3,060	5,388
-15.8	14,808	8,622	2,076	4,460
-16.0	16,628	9,592	1,280	3,490
-16.2	18,650	10,657	685	2,425
-16.4	20,881	11,631	300	1,451
-16.6	23,288	12,384	90	698
-16.8	25,823	12,935	9	147

Mystic River
CAD Cell Capacity Report
CAD Cell: M4
Level unit: Meter
Volume unit: Cubic Meter
TIN vs Level Volume Totals



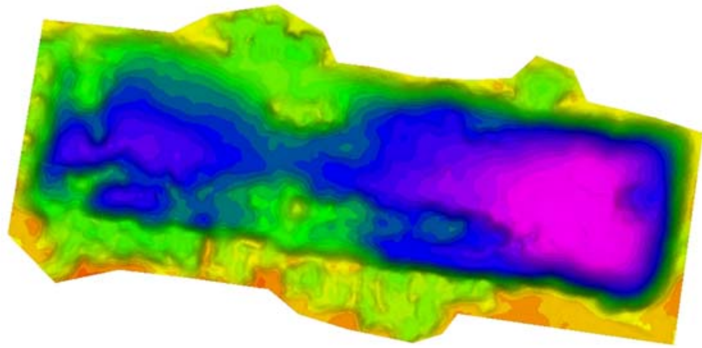
Level (MLLW)	Volume Above	Area Above	Volume Below	Area Below
-12.6	0	11	25,781	8,330
-12.8	10	85	24,122	8,256
-13.0	51	380	22,495	7,961
-13.2	163	747	20,939	7,594
-13.4	350	1,122	19,458	7,219
-13.6	606	1,412	**18,046**	6,929
-13.8	907	1,583	16,679	6,758
-14.0	1,237	1,706	15,340	6,635
-14.2	1,589	1,820	14,024	6,521
-14.4	1,965	1,937	12,732	6,404
-14.6	2,364	2,059	11,463	6,282
-14.8	2,789	2,194	10,220	6,147
-15.0	3,243	2,345	9,005	5,996
-15.2	3,729	2,520	7,823	5,821
-15.4	4,253	2,723	6,679	5,618
-15.6	4,820	2,956	5,578	5,385
-15.8	5,439	3,233	4,528	5,108
-16.0	6,117	3,561	3,538	4,780
-16.2	6,869	3,978	2,622	4,363
-16.4	7,721	4,573	1,805	3,768
-16.6	8,714	5,431	1,131	2,910
-16.8	9,911	6,519	660	1,822
-17.0	11,297	7,275	377	1,066
-17.2	12,788	7,613	200	728
-17.4	14,338	7,873	82	468
-17.6	15,938	8,156	14	188
-17.8	17,594	8,320	1	21
-18.0	19,261	8,341	0	0

Mystic River
CAD Cell Capacity Report
CAD Cell: M5
Level unit: Meter
Volume unit: Cubic Meter
TIN vs Level Volume Totals



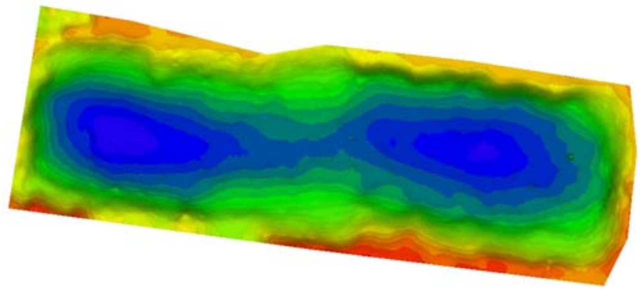
Level (MLLW)	Volume Above	Area Above	Volume Below	Area Below
-13.0	1	10	7,840	4,181
-13.2	7	69	7,008	4,122
-13.4	40	277	6,203	3,914
-13.6	124	574	5,449	3,617
-13.8	274	908	4,761	3,283
-14.0	473	1,073	**4,122**	3,118
-14.2	700	1,197	3,511	2,994
-14.4	952	1,325	2,924	2,866
-14.6	1,232	1,481	2,366	2,710
-14.8	1,547	1,667	1,842	2,524
-15.0	1,903	1,892	1,361	2,299
-15.2	2,305	2,141	925	2,050
-15.4	2,763	2,456	545	1,735
-15.6	3,302	2,969	245	1,222
-15.8	3,965	3,624	70	566
-16.0	4,739	4,130	6	61
-16.2	5,571	4,189	0	1

Mystic River
CAD Cell Capacity Report
CAD Cell: M8-11
Level unit: Meter
Volume unit: Cubic Meter
TIN vs Level Volume Totals



Level (MLLW)	Volume Above	Area Above	Volume Below	Area Below
-12.4	1	22	43,111	19,042
-12.6	28	375	39,325	18,689
-12.8	191	1,240	35,675	17,823
-13.0	516	2,039	32,188	17,025
-13.2	1,019	3,023	28,879	16,040
-13.4	1,732	4,119	**25,778**	14,945
-13.6	2,661	5,134	22,895	13,929
-13.8	3,781	6,137	20,202	12,927
-14.0	5,117	7,150	17,726	11,913
-14.2	6,617	7,830	15,413	11,234
-14.4	8,251	8,512	13,234	10,552
-14.6	10,026	9,245	11,196	9,818
-14.8	11,949	9,998	9,307	9,065
-15.0	14,038	10,932	7,583	8,132
-15.2	16,345	12,163	6,077	6,900
-15.4	18,890	13,272	4,809	5,791
-15.6	21,657	14,357	3,764	4,706
-15.8	24,624	15,291	2,918	3,772
-16.0	27,773	16,156	2,255	2,907
-16.2	31,057	16,630	1,726	2,433
-16.4	34,419	16,988	1,275	2,076
-16.6	37,854	17,330	897	1,734
-16.8	41,349	17,633	579	1,431
-17.0	44,908	17,961	326	1,102
-17.2	48,532	18,297	137	766
-17.4	52,233	18,725	26	339
-17.6	56,020	19,060	0	7

Mystic River
CAD Cell Capacity Report
CAD Cell: M12
Level unit: Meter
Volume unit: Cubic Meter
TIN vs Level Volume Totals



Level (MLLW)	Volume Above	Area Above	Volume Below	Area Below
-12.2	7	95	16,380	8,084
-12.4	43	275	14,780	7,905
-12.6	123	524	13,224	7,656
-12.8	267	959	11,732	7,220
-13.0	502	1,386	10,331	6,793
-13.2	826	1,834	**9,019**	6,346
-13.4	1,230	2,206	7,788	5,974
-13.6	1,710	2,578	6,631	5,602
-13.8	2,259	2,910	5,544	5,270
-14.0	2,872	3,225	4,522	4,954
-14.2	3,548	3,531	3,562	4,649
-14.4	4,289	3,894	2,667	4,285
-14.6	5,114	4,381	1,856	3,799
-14.8	6,053	5,054	1,159	3,126
-15.0	7,150	5,945	621	2,235
-15.2	8,437	6,876	272	1,303
-15.4	9,883	7,567	81	613
-15.6	11,447	8,030	9	149

Mystic River

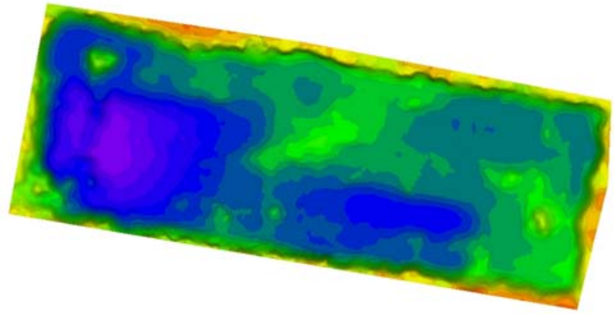
CAD Cell Capacity Report

CAD Cell: M19

Level unit: Meter

Volume unit: Cubic Meter

TIN vs Level Volume Totals



Level (MLLW)	Volume Above	Area Above	Volume Below	Area Below
-12.4	1	30	61,470	26,593
-12.6	33	312	56,177	26,311
-12.8	139	801	50,959	25,822
-13.0	367	1,520	45,863	25,103
-13.2	738	2,174	40,909	24,449
-13.4	1,228	2,724	**36,074**	23,899
-13.6	1,826	3,244	31,348	23,379
-13.8	2,525	3,748	26,721	22,876
-14.0	3,326	4,263	22,198	22,361
-14.2	4,238	4,912	17,785	21,712
-14.4	5,334	6,199	13,556	20,424
-14.6	6,803	8,748	9,701	17,876
-14.8	8,880	12,626	6,454	13,998
-15.0	11,895	17,281	4,143	9,342
-15.2	15,635	20,146	2,559	6,478
-15.4	19,913	22,418	1,512	4,206
-15.6	24,567	23,962	842	2,661
-15.8	29,450	24,859	400	1,764
-16.0	34,512	25,704	137	920
-16.2	39,715	26,298	15	325

Mystic River

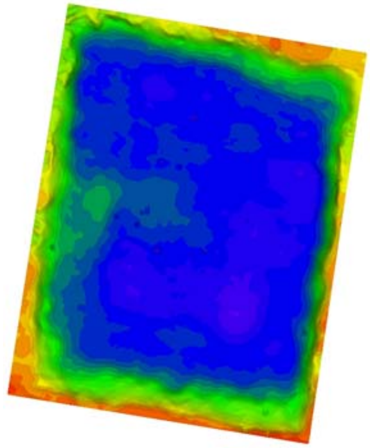
CAD Cell Capacity Report

CAD Cell: Supercell

Level unit: Meter

Volume unit: Cubic Meter

TIN vs Level Volume Totals



Level (MLLW)	Volume Above	Area Above	Volume Below	Area Below
-12.2	3	70	84,597	32,405
-12.4	58	531	78,157	31,944
-12.6	251	1,473	71,854	31,001
-12.8	633	2,321	65,742	30,153
-13.0	1,163	3,002	59,777	29,472
-13.2	1,830	3,678	**53,949**	28,797
-13.4	2,648	4,490	48,272	27,984
-13.6	3,625	5,292	42,754	27,183
-13.8	4,758	6,055	37,392	26,420
-14.0	6,049	6,855	32,189	25,620
-14.2	7,499	7,646	27,143	24,829
-14.4	9,108	8,443	22,257	24,032
-14.6	10,885	9,380	17,539	23,095
-14.8	12,897	10,853	13,057	21,622
-15.0	15,250	12,632	8,914	19,843
-15.2	18,000	15,032	5,170	17,443
-15.4	21,388	20,220	2,063	12,255
-15.6	26,300	28,113	479	4,362
-15.8	32,352	31,970	37	505
-16.0	38,810	32,469	0	6

Mystic River

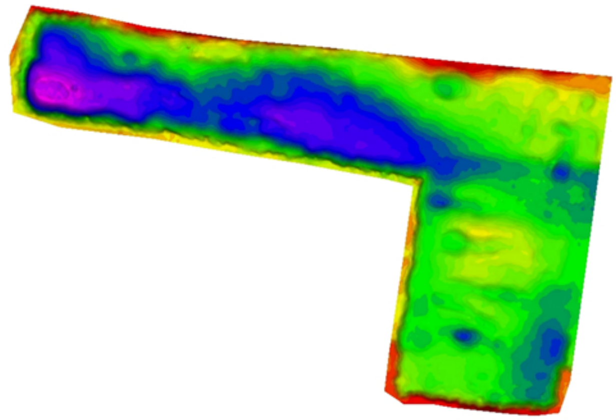
CAD Cell Capacity Report

CAD Cell: Mystic Cells-Alternate 1

Level unit: Meter

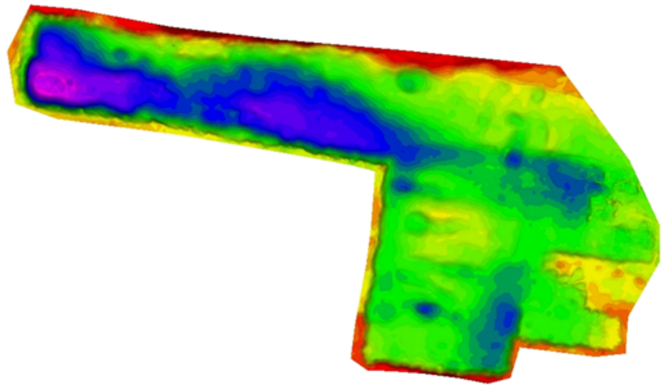
Volume unit: Cubic Meter

TIN vs Level Volume Totals



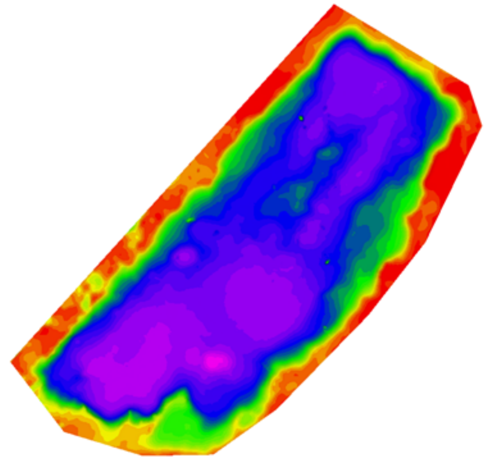
Level (MLLW)	Volume Above	Area Above	Volume Below	Area Below
-10.8	0	3	163,361	46,806
-11.0	1	6	154,000	46,803
-11.2	3	16	144,640	46,793
-11.4	9	49	135,284	46,760
-11.6	29	164	125,942	46,645
-11.8	79	368	**116,631**	46,442
-12.0	186	701	107,376	46,108
-12.2	371	1,202	98,199	45,607
-12.4	666	1,793	89,133	45,016
-12.6	1,108	2,620	80,212	44,189
-12.8	1,716	3,520	71,459	43,289
-13.0	2,544	4,788	62,924	42,021
-13.2	3,649	6,420	54,668	40,389
-13.4	5,179	8,935	46,836	37,874
-13.6	7,198	11,287	39,493	35,522
-13.8	9,746	14,274	32,679	32,536
-14.0	12,946	17,726	26,518	29,083
-14.2	16,857	21,419	21,067	25,390
-14.4	21,570	25,800	16,418	21,009
-14.6	27,161	29,913	12,647	16,896
-14.8	33,485	33,158	9,609	13,651
-15.0	40,372	35,648	7,134	11,161
-15.2	47,720	37,857	5,121	8,952
-15.4	55,516	39,954	3,555	6,855
-15.6	63,671	41,522	2,348	5,287
-15.8	72,117	43,009	1,432	3,800
-16.0	80,872	44,427	825	2,382
-16.2	89,867	45,436	458	1,373
-16.4	99,019	46,006	249	804
-16.6	108,247	46,250	115	559
-16.8	117,520	46,536	27	273
-17.0	126,857	46,772	2	37

Mystic River
CAD Cell Capacity Report
CAD Cell: Mystic Cells-Alternate 2
Level unit: Meter
Volume unit: Cubic Meter
TIN vs Level Volume Totals



Level (MLLW)	Volume Above	Area Above	Volume Below	Area Below
-10.2	0	2	238,460	60,895
-10.4	1	9	226,281	60,887
10.6	4	22	214,105	60,875
-10.8	11	54	201,933	60,843
-11.0	28	114	189,770	60,783
-11.2	60	230	**177,623**	60,667
-11.4	126	428	165,509	60,468
-11.6	236	693	153,440	60,204
-11.8	411	1,105	141,435	59,792
-12.0	690	1,672	129,535	59,225
-12.2	1,090	2,388	117,756	58,509
-12.4	1,659	3,386	106,145	57,511
-12.6	2,470	4,727	94,778	56,170
-12.8	3,558	6,260	83,686	54,637
-13.0	5,024	8,559	72,972	52,338
-13.2	6,977	11,016	62,746	49,881
-13.4	9,499	14,325	53,089	46,572
-13.6	12,693	17,631	44,104	43,265
-13.8	16,616	21,714	35,847	39,183
-14.0	21,454	26,717	28,506	34,180
-14.2	27,350	32,389	22,222	28,508
-14.4	34,425	38,128	17,118	22,769
-14.6	42,528	42,672	13,042	18,225
-14.8	51,440	46,312	9,775	14,584
-15.0	61,013	49,349	7,168	11,547
-15.2	71,146	51,929	5,122	8,967
-15.4	81,759	54,042	3,555	6,855
-15.6	92,731	55,610	2,348	5,287
-15.8	103,994	57,097	1,432	3,800
-16.0	115,567	58,515	825	2,382
-16.2	127,380	59,524	458	1,373
-16.4	139,349	60,093	249	804
-16.6	151,395	60,338	115	559
-16.8	163,486	60,624	27	273
-17.0	175,640	60,860	2	37

Chelsea River
CAD Cell Capacity Report
CAD Cell: C12
Level unit: Meter
Volume unit: Cubic Meter
TIN vs Level Volume Totals



Level (MLLW)	Volume Above	Area Above	Volume Below	Area Below
-11.2	0	0	76,641	20,937
-11.4	0	2	72,454	20,935
-11.6	6	66	68,273	20,871
-11.8	32	259	64,111	20,678
-12.0	134	779	60,026	20,158
-12.2	376	1,745	**56,081**	19,192
-12.4	824	2,694	52,341	18,243
-12.6	1,447	3,483	48,776	17,454
-12.8	2,204	4,067	45,346	16,870
-13.0	3,060	4,477	42,015	16,460
-13.2	3,988	4,799	38,756	16,138
-13.4	4,976	5,076	35,556	15,861
-13.6	6,020	5,362	32,413	15,575
-13.8	7,120	5,639	29,325	15,298
-14.0	8,278	5,952	26,295	14,985
-14.2	9,509	6,347	23,339	14,590
-14.4	10,813	6,701	20,456	14,236
-14.6	12,195	7,143	17,651	13,794
-14.8	13,681	7,729	14,949	13,208
-15.0	15,293	8,443	12,374	12,494
-15.2	17,067	9,316	9,960	11,622
-15.4	19,027	10,277	7,733	10,660
-15.6	21,180	11,298	5,698	9,639
-15.8	23,572	12,643	3,903	8,294
-16.0	26,241	14,132	2,385	6,805
-16.2	29,236	15,864	1,192	5,073
-16.4	32,641	18,281	409	2,656
-16.6	36,481	20,154	62	783
-16.8	40,617	20,872	11	66
-17.0	44,795	20,910	2	27