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BOSTON HARBOR MASSACHUSETTS DEEP DRAFT NAVIGATION IMPROVEMENT PROJECT

COMMUNICATION

FROM

THE ASSISTANT SECRETARY, CIVIL WORKS, THE DEPARTMENT OF DEFENSE

TRANSMITTING

THE FINAL FEASIBILITY REPORT AND FINAL SUPPLEMENTAL ENVIRONMENTAL IMPACT STATEMENT

PART 3 OF 3

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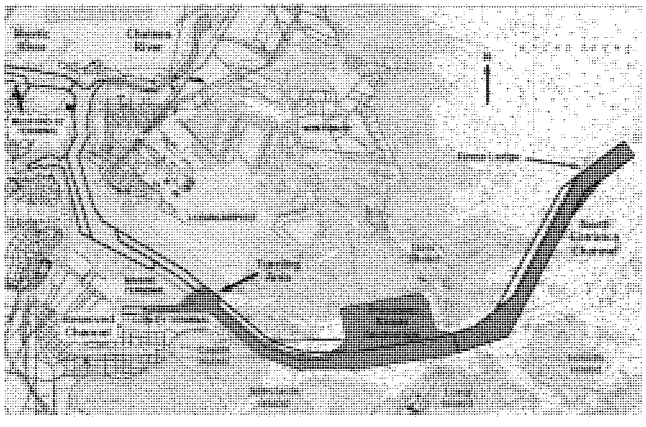
Final Feasibility Report and
Final Supplemental Environmental Impact Statement/
Massachusetts Final Environmental Impact Report
for Deep Draft Navigation Improvement (MA EOEEA #12958)

Volume 2 – Supplemental Technical Appendices F to Z

Boston Harbor
Boston, Chelsea and Revere
Massachusetts



MASSACHUSETTS
PORT AUTHORITY

US ARMY CORPS
OF ENGINEERS
New England District

April 2013

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DEPARTMENT OF THE ARMY
NEW ENGLAND DISTRICT
696 VIRGINIA ROAD
CONCORD, MASSACHUSETTS 01742-2751

REPLY TO
ATTENTION OF

BOSTON HARBOR, MASSACHUSETTS NAVIGATION IMPROVEMENT PROJECT

FINAL FEASIBILITY REPORT AND FINAL SUPPLEMENTAL ENVIRONMENTAL IMPACT STATEMENT AND MASSACHUSETTS FINAL ENVIRONMENTAL IMPACT REPORT (EOEA #12958)

VOLUME 2
SUPPLEMENTAL TECHNICAL APPENDICES F TO Z

APRIL 2013

BOSTON HARBOR
MASSACHUSETTS

NAVIGATION IMPROVEMENT STUDY

FINAL FEASIBILITY REPORT
AND FINAL SUPPLEMENTAL
ENVIRONMENTAL IMPACT STATEMENT
AND MASSACHUSETTS FINAL
ENVIRONMENTAL IMPACT REPORT

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HYDRODYNAMIC FIELD DATA
COLLECTION REPORT

(This Appendix Not Revised Since 2008 Draft)

U.S. ARMY CORPS OF ENGINEERS
ENGINEERING RESEARCH AND
DEVELOPMENT CENTER
VICKSBURG, MISSISSIPPI

Coastal and Hydraulics Laboratory

ERDC/CHL TR-07-3

APPENDIX F

HYDRODYNAMIC FIELD DATA COLLECTION REPORT

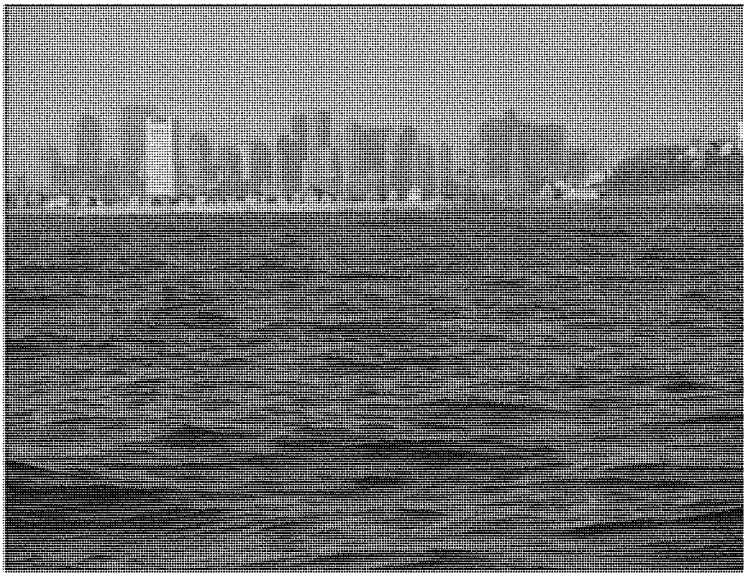
US Army Corps of Engineers®
Engineer Research and Development Center

Boston Harbor Navigation Channel Improvement Project

Field Data Collection Program Final Report

Michael W. Tubman

June 2007



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ERDC/CHL TR-07-3
June 2007

Boston Harbor Navigation Channel Improvement Project

Field Data Collection Program Final Report

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Final report

Approved for public release; distribution is unlimited.

Prepared for U.S. Army Engineer District, New England
696 Virginia Road, Concord, MA 01742-2751

Abstract: A field data collection program in Boston Harbor, MA, was conducted for the U.S. Army Engineer District, New England, during the late fall and winter of 2004/2005. The purpose of the program was to obtain data needed to validate a numerical hydrodynamic model (ADvanced CIRCulation (ADCIRC) model) of Boston Harbor and adjacent areas. The currents calculated by the verified model were input to a ship simulator used to assess the design of the Boston Harbor navigation improvement project.

A total of four water-level recorders and two acoustic profiling current meters were deployed on 10 November 2004. The water-level recorders were located adjacent to a bridge between Chelsea and East Boston in Boston's inner harbor, at the seaward end of Boston North Channel, at Gallops Island, and at the Hull Yacht Club in Allerton Harbor. The current meters were located at the seaward end of Boston North Channel and near the location where Boston's main navigation channel enters the inner harbor. Data from these instruments were supplemented by tide data from a National Oceanic and Atmospheric Administration (NOAA) tide gage in the inner harbor, and NOAA wind measurements at Logan Airport. In addition, daylight current transect surveys using a downward looking acoustic profiling current meter attached to a survey vessel were conducted on 11 November 2004 and 8 February 2005. Five transect survey lines across the main navigation channel were surveyed. All instrumentation was recovered on 7 and 8 February 2005.

Maximum-measured ebb tidal currents in the harbor were 0.9 to 3.84 ft/sec. Maximum-measured flood currents were 0.77 to 3.61 ft/sec. In general, the ebb currents were stronger than the flood currents. The data from the current meter deployed at the seaward end of Boston North Channel were analyzed to evaluate the importance of the wind-driven and tide-induced residual currents. The results of the analysis were that combined, these currents are small (5 to 22 percent of the ebb currents and 6 to 26 percent of the flood currents) compared to the maximum-measured tidal currents within the harbor. The tide-induced residual current at the seaward end of the navigation channel was estimated to be 0.07 ft/sec. The technical literature shows that tide-induced residual currents within the harbor, in the vicinity of the navigation channel, are stronger than they are at that location, with speeds of about 0.33 ft/sec.

The largest currents at the seaward end of the navigation channel resulting from the action of the wind during major storms were associated with outflow of the storm surge from within the harbor. The analyses showed that during a major storm in December 2004, the currents were 0.54 ft/sec toward 70 deg, and during one of the worst storms (in terms of wind speed) in recent history, which occurred in January 2005, they were 0.56 ft/sec toward 69 deg (both speeds include an estimated tide-induced residual vector of 0.07 ft/sec toward 90 deg).

The maximum water-level range is defined as the largest change in elevation from high-water to the low-water immediately following, that was recorded at a gage location. The maximum water-level range includes wind effects, as well as the astronomical tide. The range was 13.9 ft at the bridge between Chelsea and East Boston, 13.5 ft at Gallops Island, 14.1 ft at the Hull Yacht Club, and 13.9 ft at the NOAA gage.

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Preface

The field data collection program of Boston Harbor, MA, documented in this report was performed for the U.S. Army Engineer District, New England (CENAE). John H. Winkelman was the CENAE liaison during the study.

The program was conducted by the U.S. Army Engineer Research and Development Center (ERDC), Coastal and Hydraulics Laboratory (CHL), from November 2004 to June 2005, under the direct supervision of Thomas W. Richardson, Director, CHL, Bruce A. Ebersole, Chief, Flood and Storm Protection Division, and William Birkemeier, Chief, Field Data Collection and Analysis Branch. The work was performed by John R. Bull, Christopher J. Callegan, John M. Kirklin, Thad C. Pratt, and Michael W. Tubman. This report was written by Mr. Tubman.

At the time of the study, COL Richard B. Jenkins was Commander and Executive Director of ERDC. Dr. James R. Houston was Director.

1 Introduction

Purpose

A field data collection program in Boston Harbor, MA, was conducted for the U.S. Army Engineer District, New England (hereafter New England District), during the late fall and winter of 2004/2005. The purpose of the program was to obtain data needed to validate a numerical hydrodynamic model (ADvanced CIRCulation (ADCIRC) model) of Boston Harbor and adjacent areas. The currents calculated by the verified model were input to a ship simulator used to assess the design of the Boston Harbor navigation improvement project. The proposed effort (see the original Scope of Work (SOW) in Appendix A) was for water-level measurements at two locations, current and wind measurements, each at one location, for a 1- to 2-month period. In addition, transects of current measurements across the navigation channel were proposed for two spring tidal cycles.

During planning of the first field effort, it was realized that the field program could be improved. It was found that wind data are available from a meteorological station at Logan International Airport, and the proposed wind-measurement station was eliminated from the program. This made it possible to collect additional current and water-level data without exceeding the proposed budget. Two additional water-level recorders (for a total of four), and two current-meter moorings, instead of the one proposed, were deployed.

As specified in the SOW, the deliverables of the field data collection program are:

- Time series of water-level measurements and interpolation at all benchmarked locations in the harbor.
- Vectorized current velocity data from the transect data entered into a GIS database.
- Time series of currents at the current-meter mooring.
- Correlations between mooring and transect current data.
- Correlations between wind data and filtered mooring current data.
- Summary of wind statistics for the deployment period.
- Correlations between current and water-level data.

Funding for the program was provided by the New England District of the U.S. Army Corps of Engineers (Point of Contact (POC): John H. Winkelman, CENAE-EP-EW, telephone: 978-318-8615) to the U.S. Army Engineer Research and Development Center (ERDC), Coastal and Hydraulics Laboratory (CHL). Two previous reports on the field data collection program have been sent to the New England District. One report was submitted after the instruments were deployed and the first transect current survey was conducted on 10 and 11 November 2004, and the second was submitted after the instruments were recovered and the second current survey was conducted on 7 and 8 February 2005. This is the final report for the project. The work was conducted by ERDC personnel Thad C. Pratt (POC: ERDC-CHL-HF-HM, telephone: 601-634-2959), John Bull, Chris Callegan, John Kirklin, and Michael W. Tubman.

Study Area

Boston Harbor and adjacent areas, and the areas of the navigation channel improvement project are shown in Figure 1. Typical navigationally significant currents in the harbor are primarily the result of tidal forcing. The semi-diurnal M_2 tidal component, which has a 12.42-hr period, is the most navigationally significant current. However, the M_2 tidal currents are modulated by the S_2 and N_2 components, resulting in spring tidal currents that are 33 percent stronger than average currents. The spring tidal currents occur every 15 days. There is relatively little freshwater input to the harbor, and density-driven currents are not significant in terms of their effect on ship navigation. Water-level differences over the harbor (at any one time) are small in the absence of wind. Without wind-driven effects, water levels in the harbor are controlled by the astronomical tides, and the magnitudes and timing of their variations are nearly the same over the entire harbor.

The instrument mooring locations and the location of the wind station at Logan Airport are shown in Figure 2.

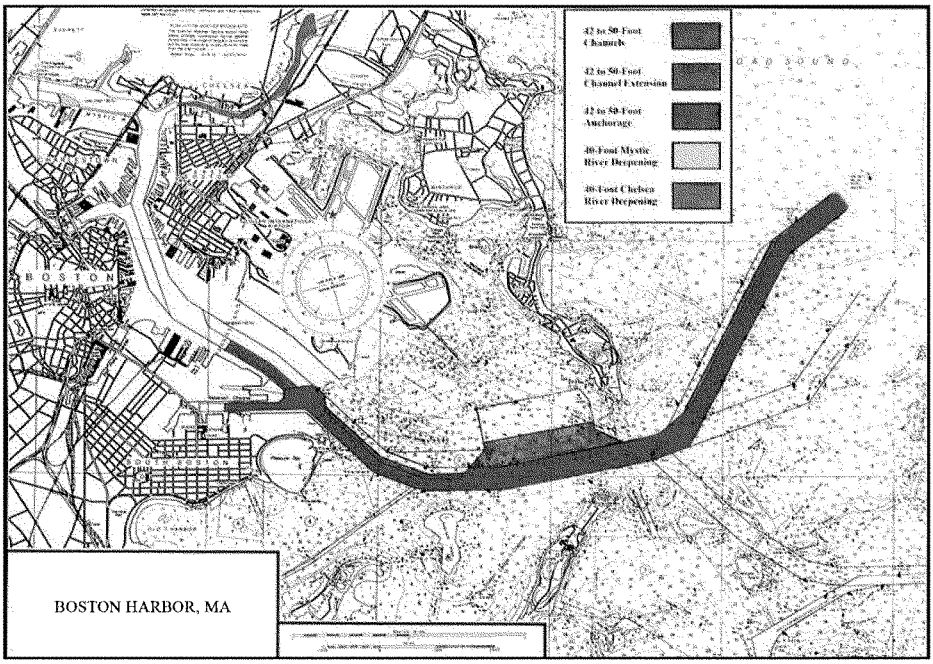

Figure 1. Boston Harbor and adjacent areas, and proposed channel deepening project.

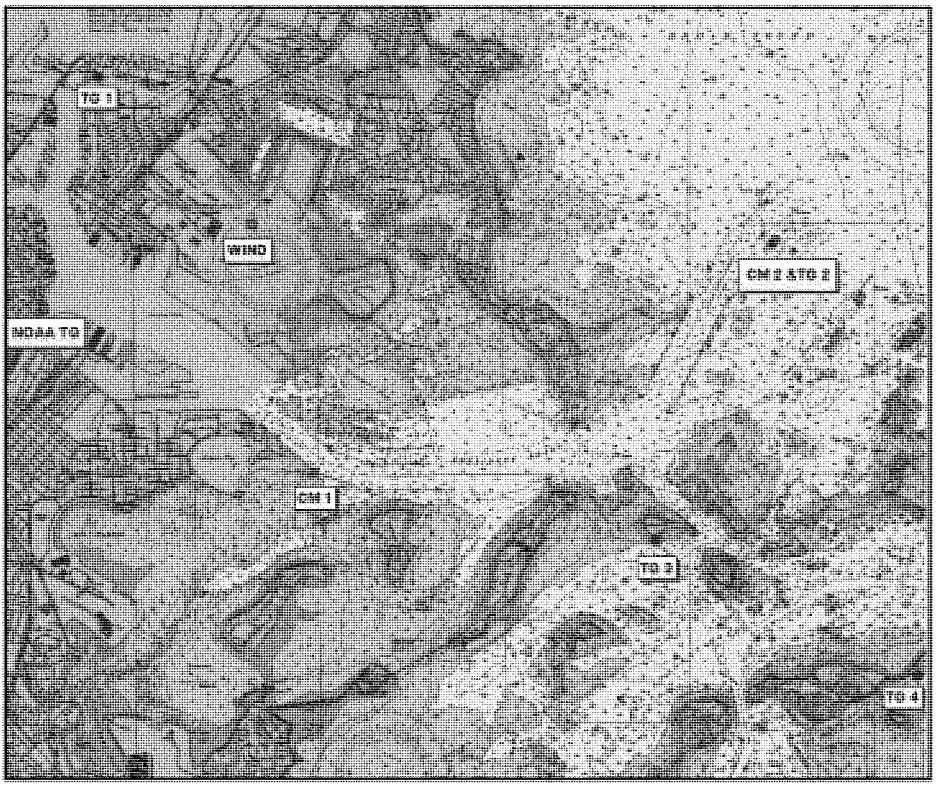

Figure 2. Locations of ERDC instrumentation (water-level recorders TG 1, TG 2, TG 3, TG 4 and current meters CM 1 and CM 2), NOAA tide gage (NOAA TG), and NOAA wind station (WIND).

2 Approach

Design of Data Collection Program

The National Oceanographic and Atmospheric Administration (NOAA) maintains a tide-measuring station in Boston's inner harbor. This station is referenced to a vertical datum. To verify ADCIRC, time series water elevation changes referenced to the record mean, as opposed to a verified datum, are adequate. Thus, the approach was to supplement the data from the NOAA station with water-level data from the four ERDC gages that were not surveyed to an established vertical datum.

Current information for the ship simulator studies was needed along the navigation channel. Producing this information was ADCIRC's primary role, and the focus of the field data collection program was to obtain current data for verification of the model along the channel. Therefore, two current transect surveys were undertaken at different locations along the navigation channel over two tidal cycles. For the purposes of the study, the strongest currents were thought to be the most significant, and the program plan was to make these surveys during spring tides. The importance of wind-driven currents was expected to be greatest near the seaward end of the navigation channel, which is basically in open-ocean waters. To record wind-driven currents, a mooring was deployed in this area. Wind measurements needed to correlate the wind-driven currents with the wind velocity were to come from the NOAA station at Logan Airport. Tidal asymmetry in the harbor can potentially result in residual tidal currents. To measure tidal currents in the vicinity of the navigation channel, a second current meter mooring was deployed near the entrance to the inner harbor.

Instrumentation

Water-level measurements were made using Coastal Leasing Microtides systems. The Microtides is a self-contained, internally recording, microprocessor controlled system (Figure 3). The instrument determines the elevation of the water column above it by measuring the pressure. A Foxboro Pressure Sensor having an accuracy of 0.1 percent of full scale is used to make these measurements. The 30-psia systems that were deployed have an elevation accuracy of approximately 0.07 ft of seawater.

Before deployment, the water-level gages were programmed to record a measurement every second for 1 min, and record the average pressure over the 1-min interval. These water-level (pressure) measurements were repeated every 6 min. A short bench-test run was made, and the measured pressures were compared to atmospheric pressure.

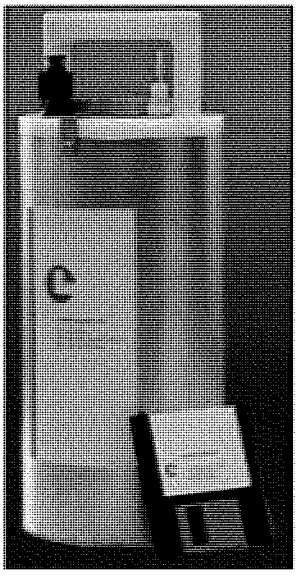

Figure 3. Microtides self-contained, internally recording, microprocessor controlled, water-level gage.

The water-level recorders are well suited to the Boston Harbor environment. They were deployed well below the surface (approximately 6 ft) so that they were not visible from the surface, even at low tide. This helped avoid interference with them in this heavily populated area, and it kept them below a level where ice could damage them. The pressure sensors recorded water-level changes even during times when extensive ice cover was present in the harbor.

The two current meters that were placed in bottom moorings (Figures 4 and 5), and the current meter used to perform the tidal-current survey, are acoustic profiling systems. An acoustic profiling current meter transmits sound bursts into the water column that are scattered back to the instrument by particulate matter suspended in the flowing water. The

current meter "listens" for the returning signals and assigns depths to the received signals based on speed of sound and the time-after-transmit that the signals are received. The current speeds at those depths are determined on the basis of the change in frequency caused by the moving particles. This change in frequency is called Doppler shift. The bottom-moored current meters transmit their signals up toward the surface, whereas the survey current meter is mounted to the side of a survey vessel (Figure 6) and transmits its signals down toward the bottom as the vessel navigates along the survey line.

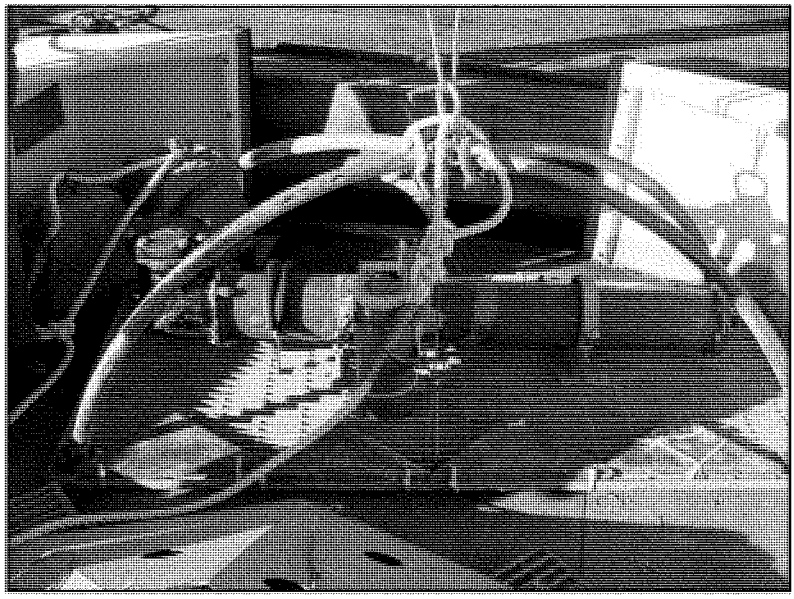

Figure 4. RDI ADCP and water-level gage mounted in mooring frame that was deployed near seaward end of navigation channel.

The survey acoustic current meter was a 1,200 kHz broadband Acoustic Doppler Current Profiler (ADCP) manufactured by RD Instruments, Inc. (RDI). During data collection, the ADCP is capable of measuring vessel velocity, water velocity, water temperature, and bottom bathymetry. The measurement of the velocity of the vessel over the bottom allows the current velocity data to be corrected for the movement of the survey vessel. The current meter near the seaward end of the navigation channel (the Boston North Channel) was also an RDI 1,200 kHz ADCP. For that instrument when in a mooring, the manufacture specifies accuracies of

+/- 0.00656 ft/sec (0.2 cm/sec) for current speed and +/- 2 deg for current direction. The current meter deployed near the inner harbor was a 1,500 kHz Acoustic Doppler Profiler (ADP) manufactured by SonTek. For that instrument SonTek specifies accuracies of +/- 0.0164 ft/sec (0.5 cm/sec) for speed and +/- 2 deg for direction when the current meter is in a mooring.

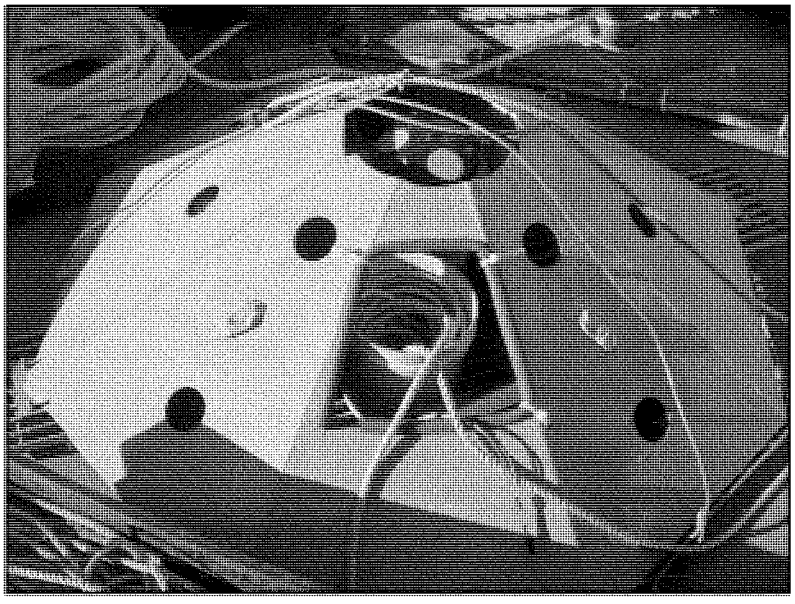

Figure 5. SonTek ADP mounted in mooring frame that was deployed near entrance to inner harbor.

The moored instruments were powered by batteries and recorded data internally. The survey instrument was externally powered and transmitted data over a cable to a computer onboard the survey vessel.

Before deployment, a program called BBTEST was run on a computer connected to the RDI current meter that was to be placed in the mooring. The program runs a series of diagnostic tests that establish that the ADCP is working properly and within specifications. To set the ADCP for deployment, the internally stored commands that the ADCP would use when started were displayed, reviewed, and changed where needed. The ADCP was set to average 170 pings, transmitted at the rate of approximately one every 0.7 sec, every 15 min, and recorded data in

1.641 ft (50 cm) vertical bins. According to RDI, this reduces the short-term random error of the acoustic measurements to near the long-term system bias of 0.007 ft/sec (standard deviation). A 120-sec averaging period was adopted to average out the wave-induced velocities.

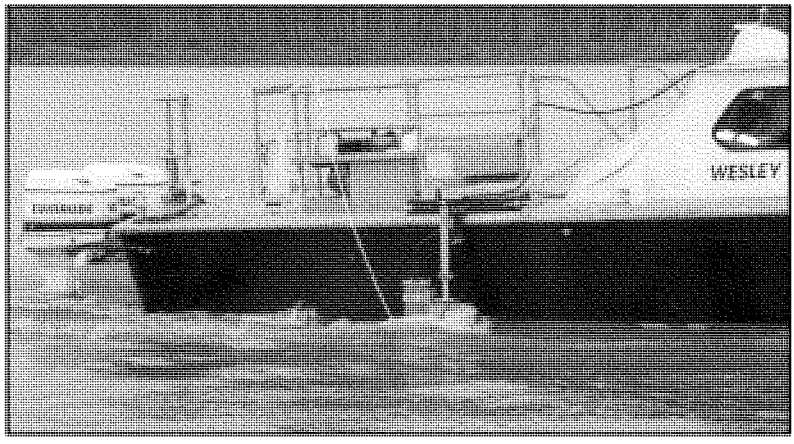

Figure 6. Typical mounting for current transect ADCP on side of survey vessel.

The SonTek ADP used for the mooring near the entrance to the inner harbor does not have a diagnostic program. However, the compass operation was checked as recommended by SonTek, and a short bench-test run was made to verify operation of the system. As with the RDI current meter, the internal commands were displayed, reviewed, and changed where needed. The ADP transmitted nine pings per second, and was set to average the measurements from the pings over a 120-sec interval (again, to average out the wave-induced velocities) every 15 min. Data were recorded in 0.984 ft (30 cm) vertical bins. According to SonTek, this results in a standard deviation in the random error of the acoustic measurements of about 0.05 ft/sec.

The fact that the acoustic current meters can be mounted on the bottom, out of the way of vessel traffic, and can record the vertical current profile from that position means they are particularly well suited for harbor deployments. Care was taken not to deploy these meters at locations where large ships might be able to damage them in high sea states; locations were selected so that water was deep enough that boat traffic could not affect them.

Just prior to beginning the transect current surveys, a magnetic deviation correction was made by navigating pairs of back-and-forth lines along fixed headings and determining the differences between the bottom-track output headings (determined by the system compass) and the headings from GPS (true direction). The compass calibrations were verified by driving the survey vessel in a circle, starting and ending at the same spot. The bottom-track data also showed that the vessel had completed the circle and returned to the same point.

Mooring and Instrument Deployments

With the exception of the water-level gage that was mounted on the current meter mooring frame deployed near the seaward end of the navigation channel (Figures 2 and 4), each gage was placed on a horizontal pedestal that was welded at a 90-deg angle to one end of an 8-ft-long aluminum angle iron (Figure 7). The gage was then strapped to the angle iron. Each gage was deployed by bolting the end of the angle iron opposite the gage to a wooden piling. A water-level recorder dedicated to recording atmospheric pressure was placed on land in Hull, MA. The atmospheric pressure measurements were made so that atmospheric effects on changing the water level could be removed from the water-level data.

The current meter deployed near the entrance to the inner harbor was placed next to a navigation channel marker (Figure 8) at a depth of approximately 15 ft mean low water (MLW). The other current meter was deployed near the seaward end of Boston North Channel at a depth of approximately 35 ft mean sea level (MSL). The exact location for this mooring deployment was selected primarily based on markers in the vicinity that showed fishing trawling lanes, as it was crucial to avoid trawling activity that could damage the instrumentation. Both moorings had sloped metal structures around them to help deflect anchors and other objects that might snag them. They also both had pop-up buoys (Figure 9) that released following activation by an acoustic signal from the surface. The buoys were held close to the bottom during the deployment. When released, they brought lines to the surface that were used to recover the moorings.

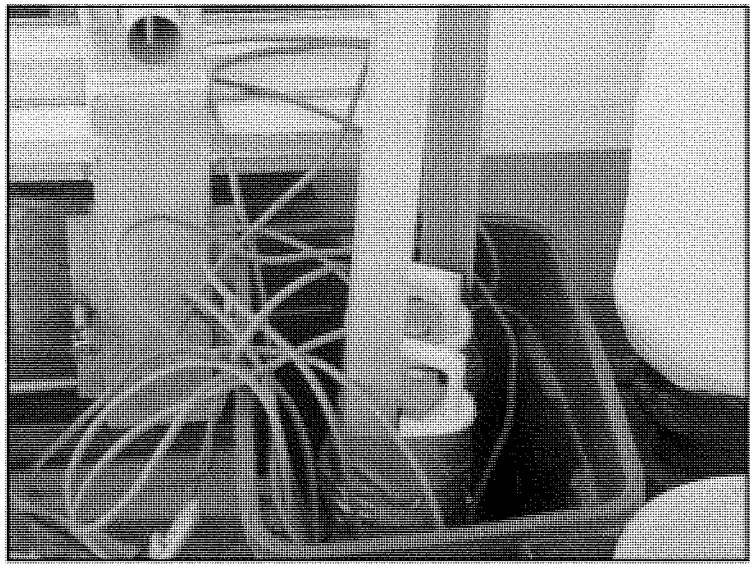

Figure 7. Water-level gage mounted on angle iron.

Figure 8. Navigation channel marker next to current meter deployed near entrance to inner harbor.

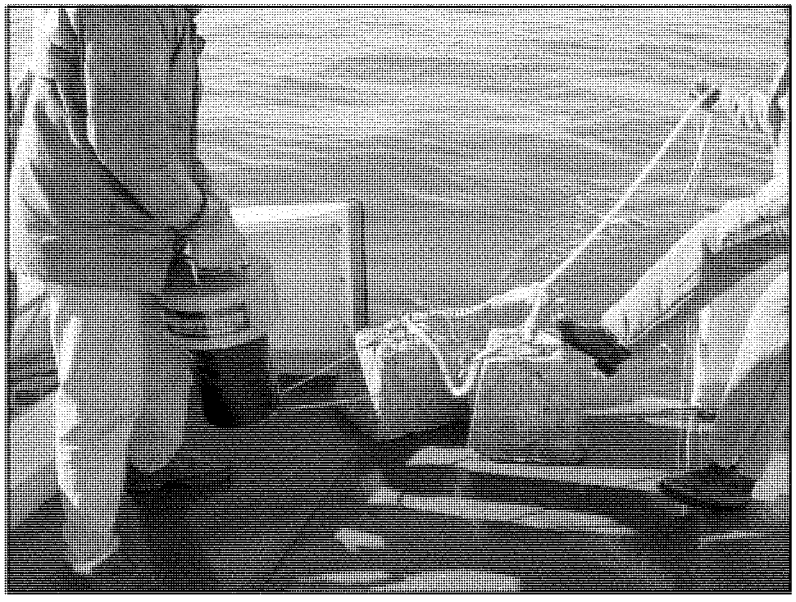

Figure 9. Deployment of pop-up buoy attached to mooring near seaward end of navigation channel.

The instrument deployments and recoveries were accomplished using the 35-ft fiberglass research vessel *Sakonnet,* based in Hull, MA (Figure 10). The *Sakonnet* has a 2,000-lb, 12-ft-high hydraulic A-frame that was used for deployment and recovery operations (Figure 11).

The *Sakonnet* was also used to conduct the current transect surveys. Waves were a problem for the surveys. In rough conditions, the movement of the ADCP can be such that it will lose track of the bottom and be unable to determine the speed of the survey vessel over the bottom. Vessel speed is an important measurement essential to obtaining good quality data. Certain transect lines that were planned to be run, were not, because the waves along them were too high. The waves that were encountered also required deviating from the ideal survey direction (which is perpendicular to the flow) for some lines, to more oblique angles. The survey lines are shown in Figure 12.

Figure 10. Research vessel *Sakonnet* based in Hull, MA, used for all operations.

Figure 11. A-frame on *Sakonnet* used to deploy current-meter moorings.

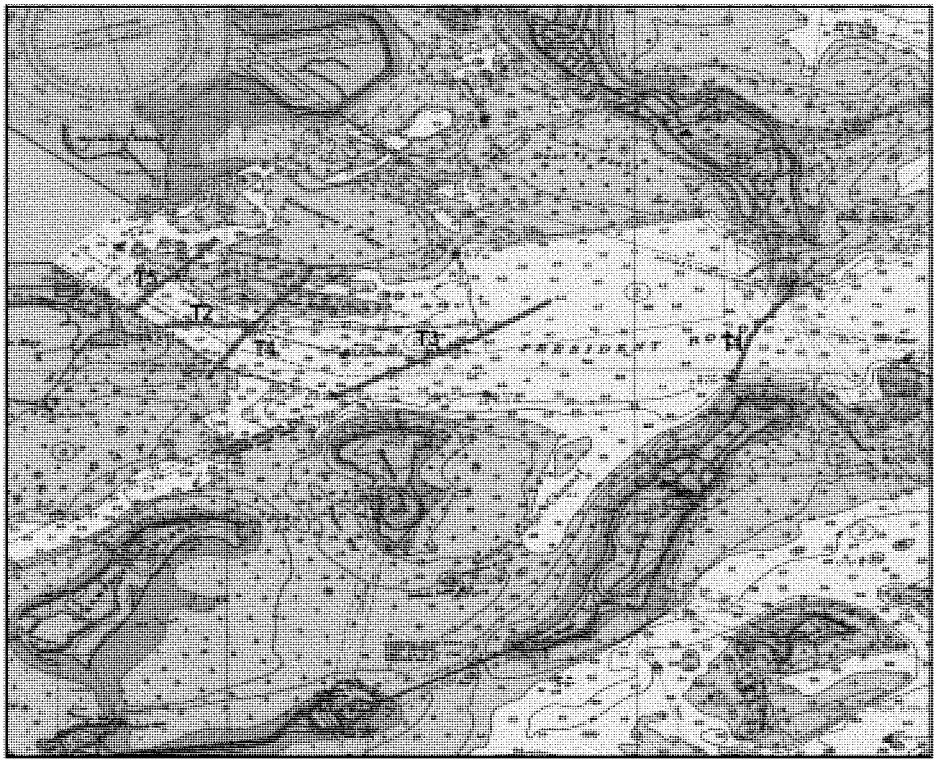

Figure 12. Current transect survey lines.

3 Chronology of Events

Preparations, Field and Post-Retrieval Activities

The first field effort was conducted from 8 to 12 November 2004. Instruments were deployed and the first current transect survey was conducted. The instruments were recovered and the second current transect survey was conducted during the 6 to 9 February 2005 effort. Detailed chronologies of the program during these times are listed in Tables 1 and 2.

Discussion

CHL responded quickly after receiving funding to begin the program on 5 November 2004. All instrumentation was deployed 5 days later on 10 November. The SOW called for 1 to 2 months of data collection. However, 3 months of data were collected, primarily because one of the worst storms in the area in 50 years occurred on 23 January 2005. The winter storm resulted in the harbor freezing and made operations impossible until the week beginning 8 February when there were both favorable wave conditions and an open passage to the survey area.

After returning from the instrument deployment and first current transect survey on 12 November 2004, a report of the field activities and a preliminary analysis of the current transect data was prepared and transmitted to the New England District approximately 2 weeks later. The recovered instrumentation at the end of the project was returned to CHL on 10 February 2005 and processing of the data from the moored instrumentation was completed by the middle of April. The ADCIRC modeling effort was preformed by the New England District with assistance from CHL personnel, and the requested data from the field collection program were provided for the modeling effort in May. A report on the second current transect survey and instrument retrieval was sent to the New England District in June 2005.

Table 1. Summary of activities for first field effort, 3-12 November 2004.

Date	Time (local)	Activities
11/3-11/5	Day	Planning, arranging logistics, instrument preparation, packing equipment.
11/7-11/8	Day	Kirklin and Bull transported equipment to Boston in truck. Pratt and Tubman flew to Boston, MA, on 11/8.
11/9	Day	Mobilized survey vessel, started tide gages and current meters, purchased supplies, prepared ADCP mount for *Sakonnet*.
	1445	Deployed TG4 on pier at Hull Yacht Club.
11/10	1015	Deployed TG2 and CM2.
	1055	Deployed CM1.
	1245	Deployed TG1.
	1351	Deployed TG3.
	1430-1645	Mounted ADCP on survey vessel and attempted calibration (ferrous metal in mount prevented calibration).
	Night	Replaced ferrous metal in ADCP mount.
11/11	0430	Kirklin and Bull started back to Vicksburg, MS, in truck.
	0600	Calibrated ADCP.
	0630-1600	Current transect survey along T3, T4, and T5.
	1630-1830	Demobilized survey vessel.
11/12	Day	Pratt and Tubman returned to Vicksburg, MS, by plane, Kirklin and Bull arrived in Vicksburg in truck.

Table 2. Summary of activities for second field effort, 5-10 February 2005.

Date	Time (local)	Activities
2/5-2/6	Day	Kirklin, Bull, and Callegan transported equipment to Boston, MA, in truck.
2/7	Morning	Mounted ADCP on survey vessel and calibrated it.
	1355	Recovered TG1.
	1527	Recovered CM1.
	1646	Recovered CM2.
2/8	0800-1500	Current transect survey along T1, T2, and T3.
	1616	Recovered TG3.
	1645	Recovered TG4.
	Evening	Demobilized survey vessel.
2/9-2/10	Day	Returned equipment to Vicksburg, MS, in truck.

An unknown problem with the current meter deployed near the entrance to the inner harbor (CM1) resulted in it not recording data. The current meter deployed at the seaward end of the navigation channel (CM2) recorded data during the entire deployment period, which included the time of the winter storm on 23 January 2005.

All of ERDC's water-level gages functioned throughout the storm and through the period where large areas of the harbor were ice covered. As a result of the requirement to stay out of trawling lanes, the water depth where the water-level recorder attached to the mooring on the seaward end of the navigation channel was deployed (TG2) ended up being approximately 5 ft deeper at high tide than the maximum range of the water-level gage. Thus, the tidal variations in water level were accurately recorded over about 60 percent of the total tidal range (missing a portion of high tide).

The NOAA tide gage in Boston's inner harbor failed at the beginning of the 23 January 2005 storm, and did not become operational again until near the beginning of 5 February 2005. The NOAA anemometer at Logan Airport provided data for the entire program with only a few invalid measurements.

4 Data Processing and Analysis

Processing Steps

Verified NOAA wind data from Logan Airport were downloaded from their Web site (*http://cdo.ncdc.noaa.gov/CDO/dataproduct*) as an ASCII file, and time series plots were made using in-house software. The data from the Microtides water-level recorders were down-loaded from the systems using software supplied by the manufacturer. The data were checked to verify that the atmospheric pressures recorded before and after deployment were correct. Using the atmospheric pressure, values recorded by the water-level recorder kept on land in Hull, MA, the atmospheric pressures were subtracted from the field data, and the pressures were converted to water-level values using a representative density of sea water (1.025 times the density of fresh water). The depths recorded just after deployment, and just prior to recovery, were then checked to verify that they agreed with the field observations at those times. The water levels were then referenced to the record means and stored in ASCII files.

The acoustic current meter that did not record data was manufactured by SonTek and there was no need to process data from it. The other moored current meter was the RDI ADCP deployed near the seaward end of the navigation channel (CM2). RDI supplies utility software for recovering and processing data. Newer versions of the software allow Windows®-based use of the software. However, the original DOS software supplied with the moored instrument was used for processing the recorded data. The RDI program BBSC was used to download the binary data file from the ADCP's memory and store it on the computer in binary form. An RDI program called BBLIST was used to convert the binary data into ASCII files. Three data-quality parameters were recorded by the current meter: correlation magnitude, percentage of good pings, and backscatter intensity. Correlation magnitude is a measure of the pulse-to-pulse correlation in a ping for each depth cell. Percentage of good pings is a data qualifier representing the percentage of pings having good data based on the signal-to-noise threshold. Backscatter intensity is a measure of the strength of the acoustic signal that is returned to the current meter in each depth cell. A low value can indicate an electronic failure or depth cells at the furthest ranges that are too far away from the instrument. At the approximately 35-ft deployment depth, all depth cells were well within range. However,

the recorded backscatter intensity plays an important role in determining were the sea surface is. The acoustic signal transmitted by the ADCP will be reflected by the surface and make it appear that the instrument is still measuring valid velocities at greater ranges than the actual depth. However, the backscatter strength from the surface is relatively strong, and indicates the range at which to terminate the velocity measurements in the data processing.

The correlation magnitudes and the percentage of good pings were reviewed for each ADCP measurement. An in-house extraction program was used to create files with only the parameters needed for further processing. These parameters are the time of the measurement, the vertical orientation and heading of the instrument, the water temperature, and the backscatter intensity. The current-meter orientation and heading, at this stage in the processing, are data-quality indicators. If the current meter is tilted more than 20 deg from the vertical, it will not operate correctly. The orientation and heading can also show if the mooring was snagged by an anchor or trawl, and, if it was, when it happened.

Using an in-house analysis program, the inflection point in the backscatter intensity within the depth range of 29 to 45 ft was located in each ADCP vertical profile. The depth was calculated for the depth cell that was one cell above the one in which the inflection occurred, and new files were produced that kept all the depth cells up to one cell less than the inflection cell. The calculated depth was plotted and compared to the time series record of the water-level recorder attached to the mooring. An in-house program used these files of processed vertical current profiles to calculate vertical vector averages of the current from the first cell, at a depth of approximately 3 ft above the sea floor, to the last cell in the processed profile. These vector averages were stored in an ASCII file and plotted in time series plots.

The first step in processing the current transect survey data was to compare the survey field notes with the ASCII files of GPS navigation data recorded for each transect. There were two objectives in the process. The first was to verify that the field notes matched the file numbers to the correct survey transect lines. The times and locations in the GPS navigation files provided this information. The second objective was to determine the exact time when each survey line was acquired and started by the survey vessel, and when the line was complete. By matching these

times to the times of the measurements recorded in the ADCP data files, data not along the transect line were eliminated from further processing.

The Windows®-based software package supplied by RDI used to acquire the current transect data (WinRiver) was used for the next step in processing the transect data. WinRiver converted the binary data recorded by the ADCP to ASCII output files. Two data-quality indicators are given in these files. They are percentage of good pings and backscatter intensity. These two parameters were reviewed for data quality. Correlation magnitudes are not shown in these files, as they are for the moored current meter, because unacceptable correlation magnitudes during the survey would have been shown on the transect survey output computer display, and the survey would have been stopped until the problem was corrected. In addition to the current speeds and directions in the depth cells, the WinRiver ASCII output files also contain the times of measurements, total depths, latitudes and longitudes at the locations of the measurements (from the GPS), and the total volume transport across the transect line from the current. From these files, an in-house program created files that contained the times, latitudes and longitudes, and depths for the measurements, and the current speeds and directions in the cells down to a level equal to 94 percent of the total depth. In the final 6 percent of the depth, acoustic side-lobe interference adversely affects the measurements. Using these files, an in-house program calculated the vector current average over the water column from the first depth cell, at a depth of approximately 3 ft below the surface, to the last depth cell in the processed profile. These vector averages were stored in ASCII files and plotted in time series plots.

Data Return and Assessment of Data Quality

NOAA tide data were available from the station in Boston's inner harbor for the deployment period, except from 22 January to 4 February 2005. There is no information on the NOAA Web site that explains why the data are missing for this period. However, the NOAA gage measures the distance to the sea surface inside a stilling well with an acoustic sensor positioned above the sea surface, and it may be affected by ice in the stilling well. Based on information supplied by the owner of the survey vessel (the *Sakonnet*) about conditions during this period, there is a good chance that the data loss was due to ice. At all other times during the field deployment period, NOAA has verified their data as being good.

Unlike the NOAA gage, the ERDC gages measure the water pressure above the gages without a stilling well. The effect of ice on these measurements is difficult to determine, especially without specific knowledge of the ice conditions right at the sensors. However, there are no obvious differences in the data from these gages during times when it was known that there was no ice, and during times when there may have been ice present. All indications are that at three of the gage locations, 100 percent good-data were obtained for the entire deployment period. As already noted, the fourth gage (TG2), on the current-meter mooring near the seaward end of the navigation channel, recorded water level during the entire deployment period, but the data are good only about 60 percent of the time.

As discussed earlier, the moored current meter near the entrance to the inner harbor recorded no data. For the other moored current meter (CM2), all data-quality indicators showed that it acquired 100 percent good-data for the entire deployment period and that the current meter was not disturbed at any time.

During the first transect current survey, the data quality indicators show that all the data are good. However, the wind and rough sea state on 11 November 2004 were such that the transect lines had to be confined to the western extent of the navigation channel between Spectacle and Castle Islands (lines T3, T4, and T5 in Figure 12). A failure of the shipboard generator during this survey ended the survey after 9.5 hr, instead of the planned 12 hr.

During the second transect current survey in February, the eastern extent of the navigation channel was surveyed out to a line from Deer Island to Long Island (line T1 in Figure 12). The data-quality indicators for the second survey show that on two of the lines surveyed, all the recorded data are good. As a result of the slower sound speed in the colder winter waters, the ADCP was unable to measure currents at all depths on the deepest transect line (i.e., T1 between Deer Island and Long Island). Failure to record data began at a depth of about 60 ft, and in the deepest places along this line, there are no data for the near-bottom portion of the water column. During this survey, the survey vessel had to return to the dock during daylight to avoid ice present in the harbor. As a result, the survey lasted 7.5 hr instead of the planned 12 hr.

There are verified NOAA wind data for all of the deployment period, with 3.9 percent observations labeled invalid. The longest period of invalid data is 11 hr, and the second longest is 5 hr.

The extent of the good-data coverage is shown in Figure 13. In reference to the original SOW, water elevation data were obtained for 3 months at four sites, instead of the 1 to 2 months of data at two sites, as originally proposed. Moored current data were obtained at one site for 3 months, instead of the 1 to 2 months at one site that was in the original SOW. Two transect current surveys were performed, as proposed. Wind data were obtained for nearly the entire deployment period, as proposed.

Analysis

The NOAA anemometer at Logan Airport is placed at an obstruction-free location near the center of the runway area. The sensor is 20 ft above the ground. The wind speeds and directions from the measurements at this location during the deployment period, with the gaps for invalid data filled by linear interpolations, were sorted into 30-degree direction categories. The directions are the directions the wind is blowing from in degrees true north. The speeds in each direction category were sorted into 5-ft/sec speed categories. Table 3 shows the percentage of the total number of observations in each category. There were two major storms during the 10 November 2004 to 8 February 2005 deployment period. One occurred on 27 December 2004, when a maximum wind speed of 47 ft/sec from 50 deg was measured at Logan Airport. The other one, on 23 January 2005, had a maximum wind speed and direction at Logan Airport of 57 ft/sec from 60 deg. The wind speed during the January storm is the maximum value observed during the deployment period. Table 3 is a statistical summary of the wind observations from Logan Airport; it shows that the strongest winds were from 345 to 15 deg and 45 to 75 deg. A majority of the winds were from the northwest quadrant, and almost half (47.71 percent) were 10 to 20 ft/sec. Overall, the statistics show a sustained period of strong winds, with two major storms.

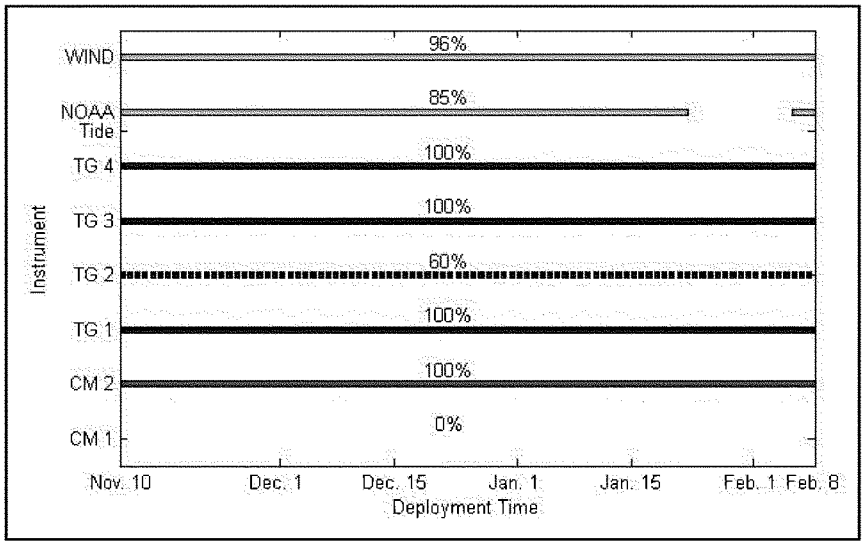

Figure 13. Summary of data return for deployment period. TG's are water-level recorders and CM's are moored current meters (see Figure 2 for instrument locations).

Table 3. Summary of wind observations made at Logan Airport during the deployment period (10 November 2004 – 8 February 2005).

		Wind Direction (deg T)												
		345-015	015-045	045-075	075-105	105-135	135-165	165-195	195-225	225-255	255-285	285-315	315-345	Total %
Wind Speed (ft/sec)	0-5	0.46	0.27	0.27	0.23	0.32	0.69	0.41	0.32	0.18	0.14	0.18	0.27	3.75
	5-10	2.61	0.96	0.46	0.91	1.37	1.37	1.01	1.74	0.78	0.73	1.23	1.37	14.53
	10-15	3.98	1.01	0.37	0.96	0.91	1.23	2.51	1.69	1.65	2.61	3.56	5.16	25.64
	15-20	3.02	1.65	0.27	0.46	0.69	0.59	0.55	2.24	2.33	3.24	3.06	3.98	22.07
	20-25	1.51	0.64	0.18	0.41	0.50	0.37	0.37	1.87	1.69	2.19	2.74	3.11	15.59
	25-30	1.42	0.18	0.14	1.10	0.27	0.14	0.14	1.10	0.96	1.28	1.92	1.23	9.87
	30-35	0.69	0.09	0.41	0.64	0.27	0.05	0.18	0.37	0.23	0.69	1.51	0.91	6.03
	35-40	0.09	0.00	0.09	0.05	0.05	0.00	0.09	0.18	0.00	0.32	0.18	0.00	1.05
	40-45	0.23	0.05	0.00	0.00	0.05	0.00	0.09	0.05	0.00	0.09	0.00	0.00	0.55
	45-50	0.23	0.00	0.18	0.05	0.00	0.00	0.05	0.09	0.05	0.05	0.00	0.00	0.69
	50-55	0.05	0.00	0.09	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.14
	>55	0.00	0.00	0.09	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.09
Total %		14.26	4.84	2.56	4.80	4.43	4.43	5.39	9.64	7.86	11.33	14.40	16.04	100.00

To evaluate the wind-driven currents generated near the seaward end of the navigation channel, the depth-averaged (east-west and north-south) components of the current velocities measured by the moored ADCP were put through a low-pass Butterworth filter with a cutoff frequency (0.7) of 1/26 hr^{-1} to remove the tidal signal. During the 23 January 2005 storm, the winds increased from above 32 ft/sec at 2354 (GMT) on 22 January, when they were blowing from 90 deg, to a maximum speed of 57 ft/sec (GMT) from 60 deg at 0554 (GMT) on 23 January. The wind direction then (later on 23 January) moved toward blowing from the north, and dropped below 32 ft/sec at 2100 (GMT) on the same day. During this time, the water-level records show the mean tide level in the harbor increased as the wind drove water into the harbor. The 26-hr (period) low-pass filter catches the contribution of the storm surge outflow from the harbor to the currents as a residual 0.56 ft/sec current toward 69 deg that enhanced the ebb currents near the end of the day on 23 January when the wind stress relaxed. The events during the 27 December 2004 storm repeated this pattern. The wind speed increased from 18.7 ft/sec to 45.6 ft/sec from 60 deg at 2254 (GMT) on 26 December, reached the maximum of 47.2 ft/sec from 50 deg on 27 December, and decreased below 18.7 ft/sec at 0554 (GMT) on 28 December. The filtered residual current showed a 0.54 ft/sec current toward 70 deg that enhanced the ebb currents near the end of the day on 27 December.

Other than during these two storms, the maximum current speeds after filtering were all less then 0.36 ft/sec, and there are nine periods in the record where the residual current speeds were greater than 0.30 ft/sec. During these periods, there is no obvious consistent pattern to their occurrence and wind speed and directions. Since there is very little freshwater input into Boston Harbor, density-driven currents are not likely to be contributing to the residual currents after filtering. Two other possible contributors are tide-induced residual currents and wind-driven currents.

To see if some statistical relationship between the winds and the currents might exist, power spectral estimates of the filtered velocity components were made using an in-house MATLAB program. The program uses a Fast Fourier Transform (FFT), with trend removal and a Blackman-Harris window. The resulting spectra are shown in Figure 14. The east-west filtered current components have a peak at a period of 3.489 days. The hourly wind speed and direction data from Logan Airport were broken into

their east-west and north-south components and power spectra were made. The resulting spectra are shown in Figure 15. The east-west components of the wind also have a peak at a period of 3.489 days. The north-south components of the wind have a smaller peak at 3.012 days. Cross spectra between the wind components and the current components were made and correlations between the current and wind components were performed. It was found that at a period of 3.012 days, the correlation coefficient between the north-south component of the wind and the north-south component of the current was 0.92. However, there is insignificant energy in the current band centered on that period. At a period of 3.489 ft/sec, the correlation between the north-south component of the wind and the east-west component of the current is only 0.65. At that period, the correlation between the east-west component of the wind and the east-west component of the current is 0.93. These results indicate that east-west wind-driven currents from east-west winds are likely contributing to the residual currents after filtering. The tide-induced residual current is expected to persist throughout the record, and its strength at the CM2 location can be estimated by taking the mean of the filtered record. The tide-induced residual current was calculated to be 0.07 ft/sec toward 19 deg.

Two of the correlation analyses in the SOW were specifically designed to evaluate the importance of the residual tidal currents in the harbor. The analyses are the correlations between the mooring and transect current data, and the correlations between the current and water-level data. These analyses were to utilize current data from the mooring near the entrance to the inner harbor (CM1) where wind-driven currents were expected to be very small in comparison to the tide-induced residual currents. The analyses were not performed because there were no data from this mooring. According to Signell and Butman (1992)[1] the tide-induced residual circulation inside the harbor near the navigation channel has maximum speeds of about 0.33 ft/sec. In the vicinity of CM2, Signell and Butman reported tidal-induced residuals of 0.11 to 0.19 ft/sec toward 90 deg. Considering that their observations are only somewhere in the vicinity of CM2 (the paper does not give exact locations), the comparison of the analysis of the CM2 observations and their observations is reasonably good.

[1] Signell, R. P., and B. Butman. 1992. Modeling tidal exchange and dispersion in Boston Harbor. *Journal of Geophysical Research* 97:15,592-16,606.

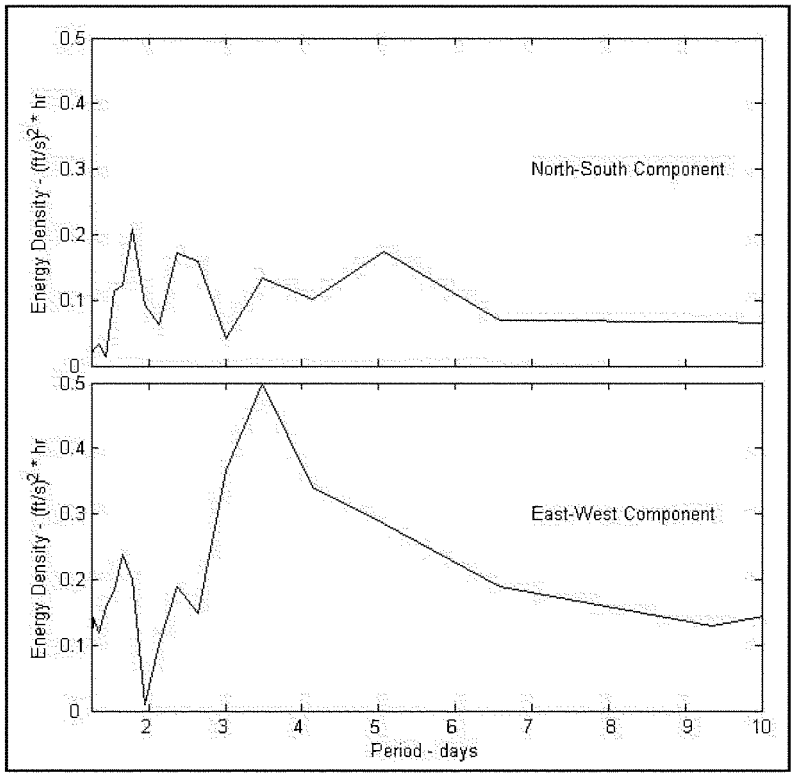

Figure 14. Power spectra of low-pass filtered (26-hr cutoff) current components of currents measured by ADCP mooring located near seaward end of navigation channel.

During the first transect current survey on 11 November 2004, the filtered residual currents at CM2 were about 0.2 ft/sec toward the west. Transects were surveyed at different times, when the survey vessel could get to them, so measurements were made at various stages in the tidal cycle. During that day, the maximum-measured tidal currents along the transects were 1.82 ft/sec along T3, 0.9 ft/sec along T4, and 1.37 ft/sec along T5 (all at ebb tide), therefore the filtered residual was 11 to 22 percent of the maximum-measured ebb speeds in November. The maximum-measured flood speeds on 11 November were 1.42 ft/sec along T3, 0.86 ft/sec along T4, and 0.77 ft/sec along T5, so the filtered residual was 14 to 26 percent of the maximum-measured flood speeds. Current meter CM2 was recovered before the second transect current survey on 8 February 2005. The maximum-measured currents at that time were 3.84 ft/sec along T1,

and 1.72 ft/sec along T3 (both at ebb). Transect T2 was not sampled at any time near peak ebb. During flood tide, the maximum-measured currents were 3.61 ft/sec along T1, 0.98 ft/sec along T2, and 1.27 ft/sec along T3. Using the same residual current speed, it was 5 to 12 percent of the measured-maximum ebb currents, and 6 to 20 percent of the measured-maximum flood currents.

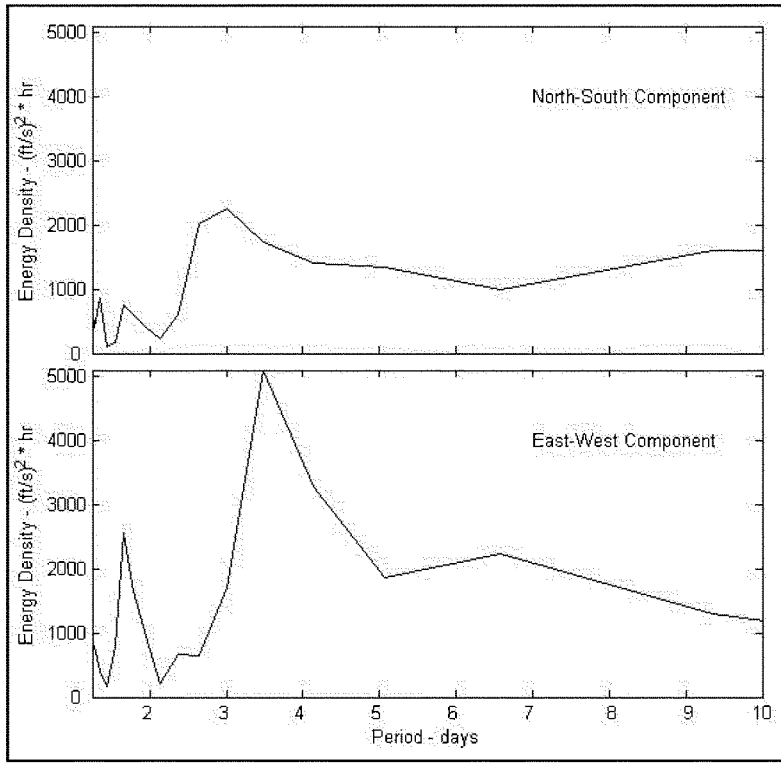

Figure 15. Power spectra of components of wind measured at Logan Airport over same period of time that currents were measured.

The maximum water-level range is defined as the largest change in elevation from high water to the low water immediately following, that was recorded at a gage location. The maximum water-level range includes wind effects, as well as the astronomical tide. Excluding TG2, which hit full scale at high tide, the range was 13.9 ft at TG1, 13.5 ft at TG3, 14.1 ft at TG4, and 13.9 ft at the NOAA gage.

Deliverables

Plots of all data in Appendices B, C, D, E, and F are in electronic form on the project DVD as ".jpeg" files. They include:

1. Water levels referenced to the record mean levels at four locations (TG1, TG 2, TG3, TG4) and tide data referenced to established mean lower low water (MLLW) at the NOAA gage in the inner harbor (Appendix B).
2. Depth-averaged current velocities from the CM2 (Appendix C).
3. Depth-averaged currents for the transect current surveys (Appendix D).
4. Horizontal cross sections of current velocities from the transect current surveys (Appendix E).
5. NOAA wind data from Logan Airport (Appendix F).

The data are on the project DVD which was sent to the New England District as ASCII text files. The folder structure of the project DVD is in Appendix G. The formats for ASCII data files are in Appendix H and are explained in "readme" files on the project DVD.

Transect current data were put in vectorized form. This makes it possible to display the current vectors in a GIS system on the transect lines along with the bathymetry and shoreline position. An ArcView project was built to make these displays. The ArcView project and the necessary files to run it are on the project DVD.

The statistical summaries and correlations are present in this report. An electronic copy of this report is on the project DVD as a "Word" document.

5 Summary and Conclusions

A field data collection program in Boston Harbor, MA, was conducted from 10 November 2004 to 8 February 2005. Four water-level gages and two moored current meters were deployed for this period. In addition, daylight current transect surveys were conducted on 11 November and 8 February. One of the moored current meters failed to collect data. The other recorded good quality data for the entire deployment period. The four tide gages recorded data for the entire deployment period; however, one gage recorded full scale readings around high tide, and thus, recorded accurate water levels for approximately 60 percent of the tidal cycle. The other three gages recorded 100 percent good data. NOAA tide and wind data were obtained for the study. Probably due to ice in the harbor, there are no NOAA tide gage data 15 percent of the time. There are some minor gaps in the NOAA wind data from Logan airport that total 3.9 percent of the deployment period.

Maximum-measured ebb tidal currents in the harbor were 0.9 to 3.84 ft/sec. Maximum-measured flood currents were 0.77 to 3.61 ft/sec. In general the ebb currents were stronger than the flood currents. The data at CM2 were analyzed to evaluate the importance of the wind-driven and tide-induced residual currents. The results of the analysis were that combined, these currents are small (5 to 22 percent of the ebb currents and 6 to 26 percent of the flood currents) compared to the maximum-measured tidal currents within the harbor. The tide-induced residual current at CM2 was estimated to be 0.07 ft/sec. The technical literature shows that tide-induced residual currents within the harbor, in the vicinity of the navigation channel, are stronger then they are at CM2, with speeds of about 0.33 ft/sec.

The strongest currents at CM2 resulting from the action of the wind during major storms were associated with outflow of the storm surge from within the harbor. The analyses showed that during a major storm in December 2004, the currents were 0.54 ft/sec toward 70 deg, and during one of the worst storms (in terms of wind speed) in recent history, which occurred in January, they were 0.56 ft/sec toward 69 deg (both speeds include an estimated tide-induced residual vector of 0.07 ft/sec toward 90 deg).

Appendix A: Scope of Work (SOW)

Field Data Collection to Validate Hydrodynamic Model Supporting Ship Simulator Studies, Boston Harbor, MA

Purpose

The purpose of the field data collection program is to obtain data needed to validate a hydrodynamic model of Boston Harbor and adjacent areas (Figure A1). The currents calculated by the verified model will be input to a ship simulator, which will be used to access the design of a navigation channel improvement project for Boston. The hydrodynamic model requires simultaneous measurements of water elevations, currents, and wind speed and direction for verification of model driving forces and calculated results.

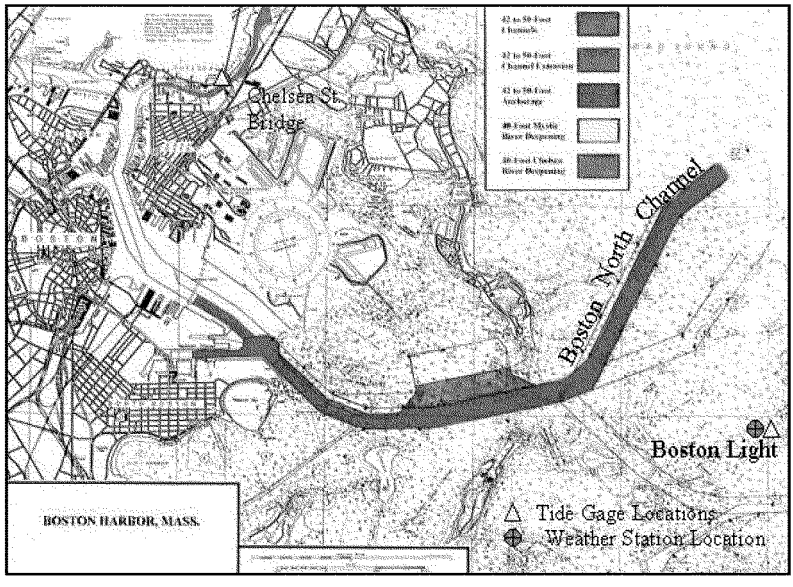

Figure A1. Boston Harbor and adjacent areas.

Approach

Typical navigationally significant currents in Boston Harbor are primarily the result of tidal forcing. The M_2 tidal component, which has a 12.42-hr period, is the most significant component. However, the currents are modulated by the S_2 and N_2 components, resulting in spring tidal currents that are 33 percent stronger than average currents. The spring tidal currents occur every 15 days. The wind also drives currents that can interact with, and modify the tidal-driven currents. There is relatively little freshwater input to the harbor, and resulting density-driven currents are not significant in terms of their effect on ship navigation. Water-level differences over the harbor (at any one time) are reported to be small in the absence of wind. Without wind-driven effects, water levels in the harbor are controlled by the astronomical tides, and the magnitudes and timing of their variations are nearly the same over the entire harbor. For this reason, the technical approach of the field data collection program emphasizes obtaining needed current information, and relies on minimal water-level measurements to provide elevation data.

NOAA maintains a tide measuring station in Boston's inner harbor, and has established five tidal benchmarks at various locations around the harbor. Thus the approach is to make additional tide measurements at only two locations in the harbor during the field data collection program and to use the existing NOAA tide station and benchmarks to provide the needed tidal elevation information throughout the harbor.

Current information for the ship simulator studies is needed along the navigation channel. Producing this information is the numerical model's primary role, and the focus of the field-data collection program is to obtain current data for verification of the model along the channel. The times of maximum tidal currents are predictable and can be measured by collecting data using a ship-mounted profiling current meter along transects across the navigation channel. It is proposed to do this over a tidal cycle during two separate times of spring tides. The importance of wind-driven currents is expected to be most significant in the channel in the vicinity of Boston North Channel and President Roads. Unlike tidal currents, the times and durations of strong wind-driven currents cannot be reliably predicted. Therefore, the proposed study has a current meter moored in, or very close to, Boston North Channel to collect current data every 15 min during the data collection program. The mooring will be deployed at the

beginning of the program and recovered at the end, thereby internally recording data for a 1- to 2-month period.

During this data collection program, it is proposed that wind speed and direction be collected at a site established in the harbor.

Data Collection Program

The proposed field effort, as stated above, will include measuring water levels at two locations, and currents and winds, each at one location, for a 1- to 2-month period, and measuring transects of currents across the navigation channel during two spring tidal cycles. Each tidal-cycle measurement period will be approximately 13 hr long. The locations of the two proposed tide stations are Boston Light and Chelsea St. Bridge. These two locations, shown in Figure A1, have established NOAA benchmarks. Boston Light is also the location for the proposed wind-measuring station. Choosing the exact location for the Boston North Channel current meter mooring, and the locations of the tidal current transects requires further study. Time is included in the proposal to conduct the study needed for determining these locations.

Current Measurements

Tidal-current transect measurements will be performed using a 1,200 or 600 kHz ADCP mounted on a boat. RDI instruments of San Diego manufacture the proposed instrument. The current meter is mounted over the side of the boat, with the acoustic transducers submerged and data are collected while the vessel is underway (Figure A2). All transect lines will be referenced to differential GPS locations through a navigation software package, HYPACK, to insure repeatability.

The ADCP transmits sound bursts into the water column, which are scattered back to the instrument by particulate matter suspended in the flowing water. The ADCP "listens" for the returning signal and assigns depths and velocity to the received signal based on techniques used in correlation sonar. The ADCP is also capable of measuring vessel velocity during collection and bottom bathymetry. Communication with the instrument for set-up, and data recording, are performed with a portable computer and manufacturer-supplied software, hardware, and communication cables.

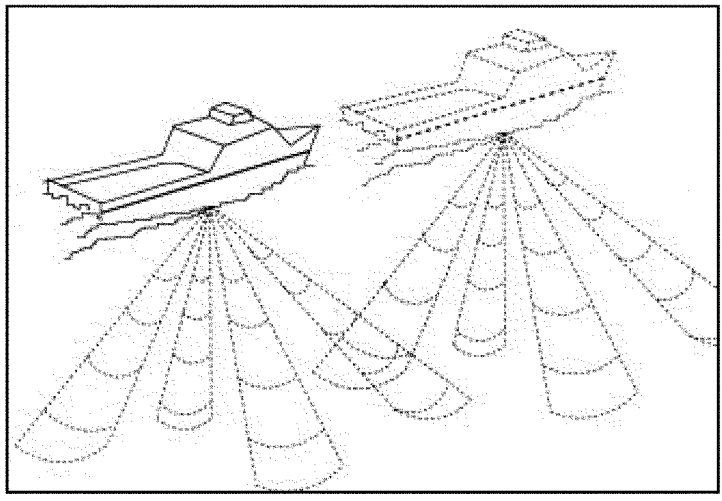

Figure A2. Typical ADCP collection operations.

Current measurements at the current-meter mooring will be made using an RDI instruments Work Horse current meter. The Work Horse is also a profiling current meter, and uses the same measurement techniques as the broadband ADCP. It will be mounted in a mooring similar to the one shown in Figure A3, and will record data internally. The mooring will be placed on the seafloor using a "slip-line," which makes it possible to deploy it without the assistance of divers. The meter will include an acoustic release that will release a buoy in response to an acoustic signal sent through the water from the boat used for the recovery operation. During deployment the buoy is attached to the mooring, and located near the seafloor. When it is released, it floats to the surface and brings with it a line attached to the mooring. This line is used to pull the mooring to the surface, thereby making it possible to recover the mooring without divers. After recovery, internally recorded data are downloaded to a portable computer.

Figure A3. Current-meter mooring.

Water-Level Measurements

The Coastal Leasing Microtides system is the instrument proposed for making the water-level measurements. It uses an absolute pressure gage and records data internally. The instrument is deployed below the surface, thereby reducing site security risks. The deployed position of each instrument will be surveyed to determine its location relative to the NOAA tidal benchmark at each site. A barometric pressure gage will be also deployed at each site for use in correcting water-level measurements for atmospheric pressure changes.

Wind Measurements

Wind speed and direction measurements will be made at the Boston Light location using a Young Anemometer. The system uses a propeller and vane assembly to make the measurements and records data internally. It will be mounted at an open location on a 3-meter aluminum tower. The position of the tower will be surveyed using a portable GPS receiver.

Data Reporting

Processing and reporting of data is focused on providing information to verify ADCIRC. This requires several steps. The first is to check the data

for quality to insure its accuracy. After the quality assurance step, data products are prepared that relate to demonstrating that certain assumptions inherent in the hydrodynamic model are valid for the study area, and that provide measures for verifying model current simulations. This requires that the processed and analyzed data be formatted to facilitate comparisons with ADCIRC output. The final step is documenting and storing the information for future reference. The proposed data products include:

- Time series of tides from measurements and interpolation at all benchmarked locations in the harbor.
- Vectorized current velocity data from the transect data entered into a GIS database.
- Time series of currents at the current-meter mooring.
- Correlations between the mooring and transect current data.
- Correlations between wind data and filtered mooring current data.
- Summary of wind statistics for the deployment period.
- Correlations between current and water-level data.

Appendix B: Water-Level Measurement Plots

NOAA TG Water-Level Measurement Plots

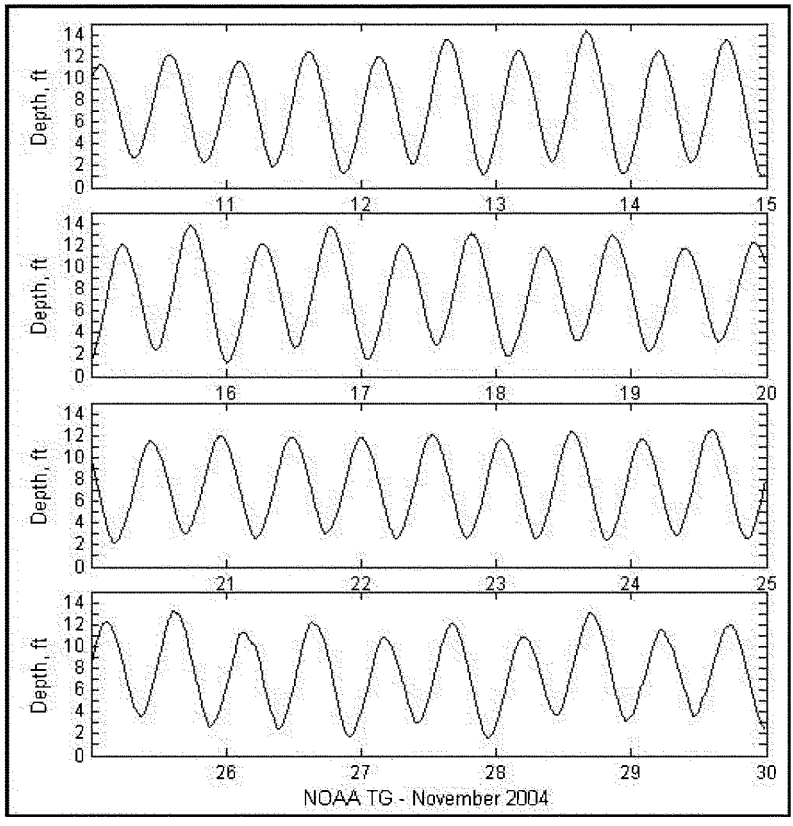

Figure B1. NOAA TG water-level measurement plot, November 2004.

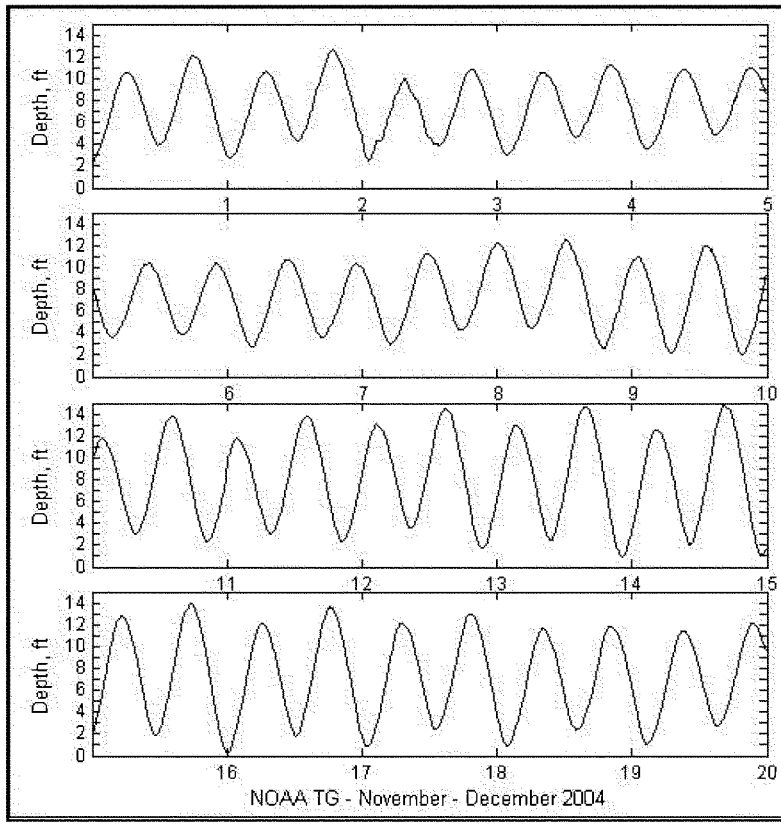

Figure B2. NOAA TG water-level measurement plot, November-December 2004.

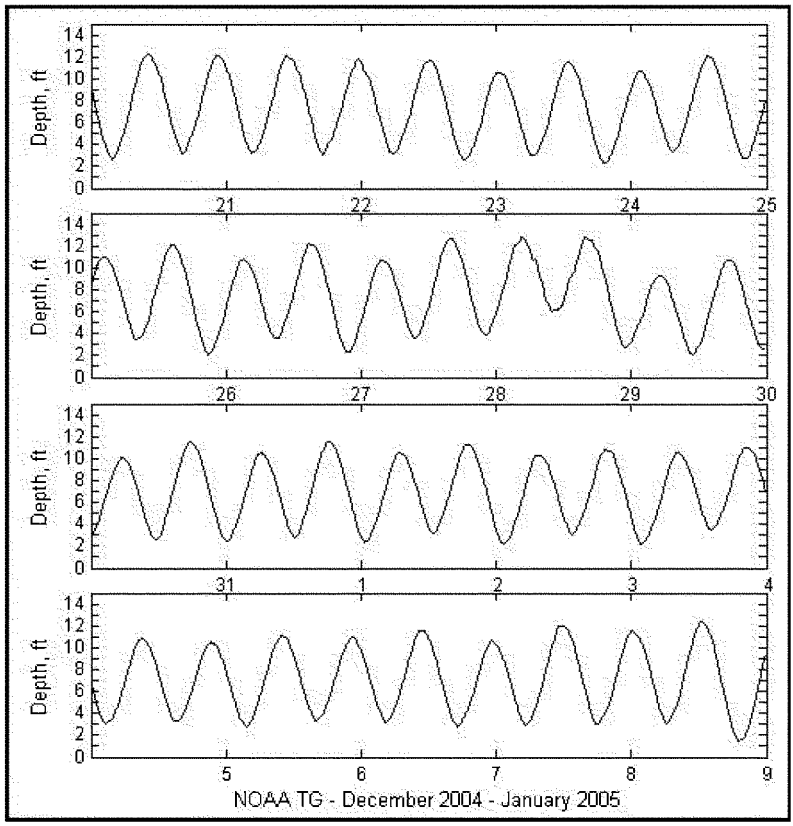

Figure B3. NOAA TG water-level measurement plot, December 2004-January 2005.

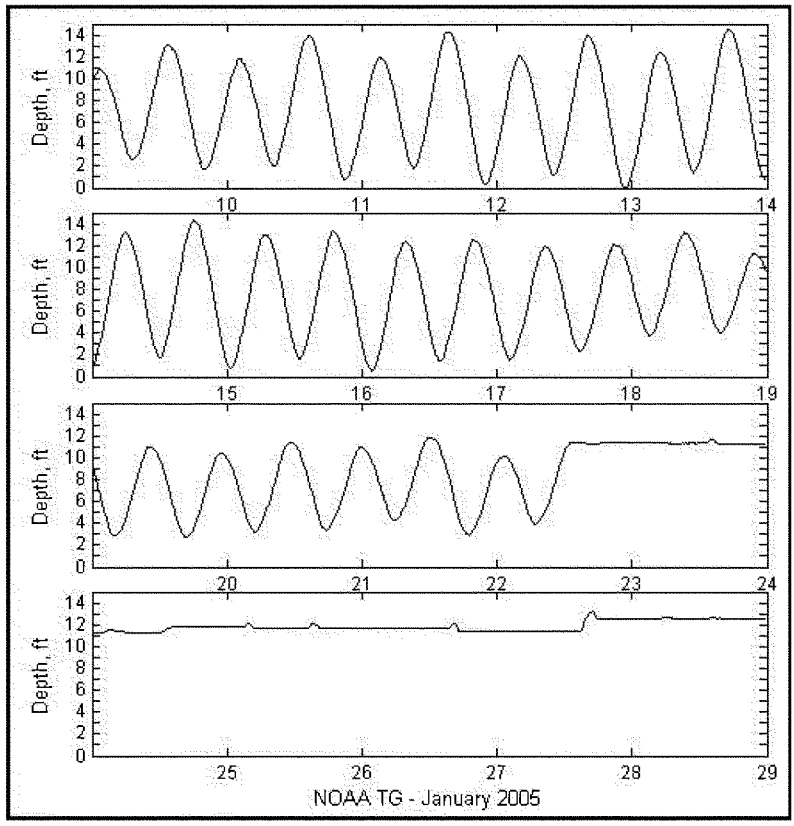

Figure B4. NOAA TG water-level measurement plot, January 2005.

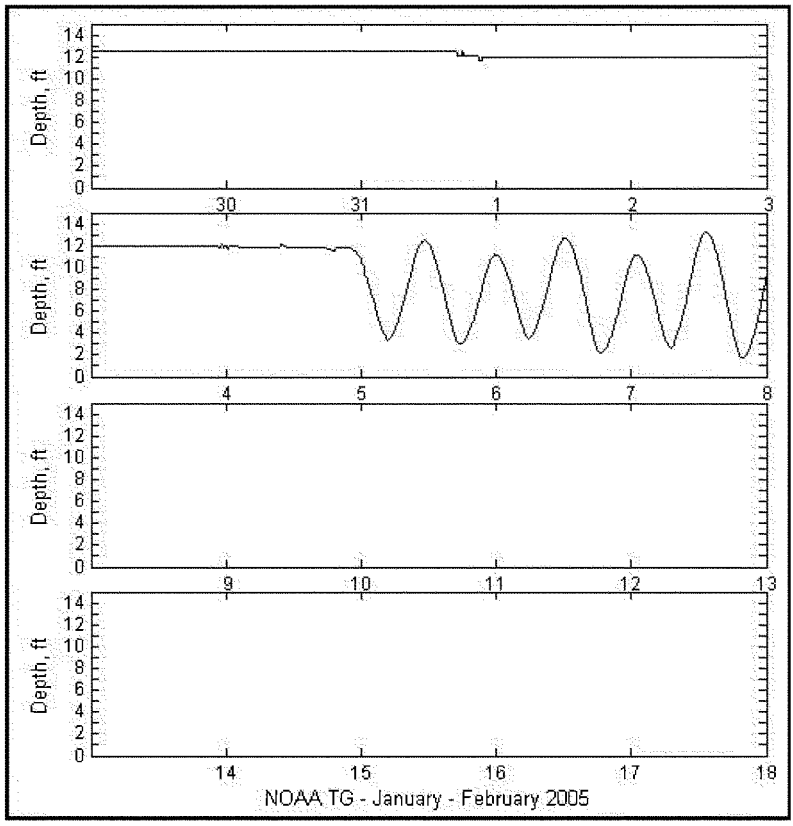

Figure B5. NOAA TG water-level measurement plot, January-February 2005.

TG1 Water-Level Measurement Plots

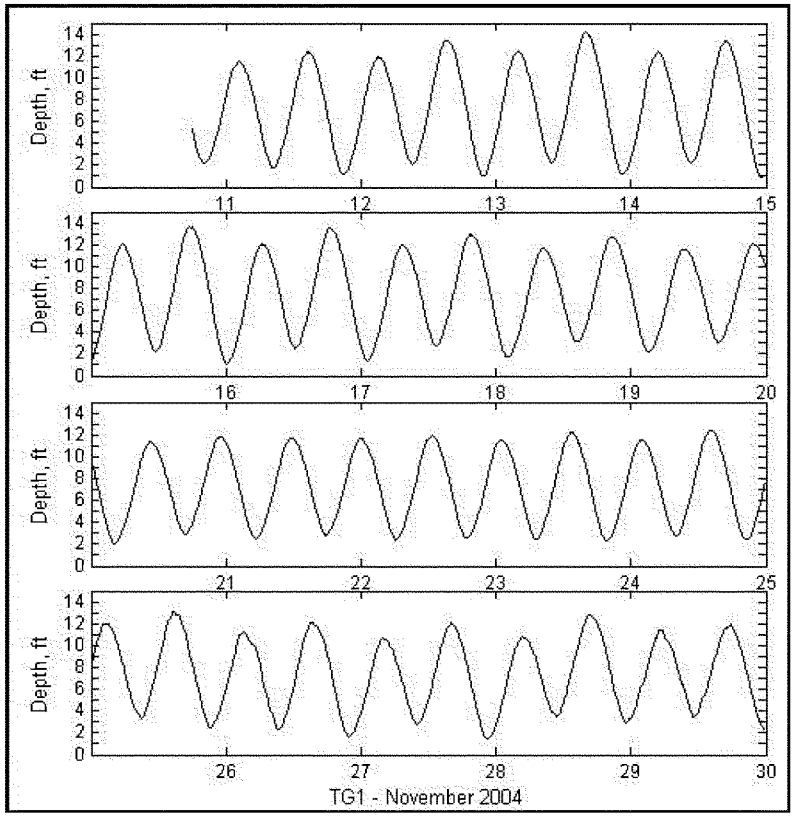

Figure B6. TG1 water-level measurement plot, November 2004.

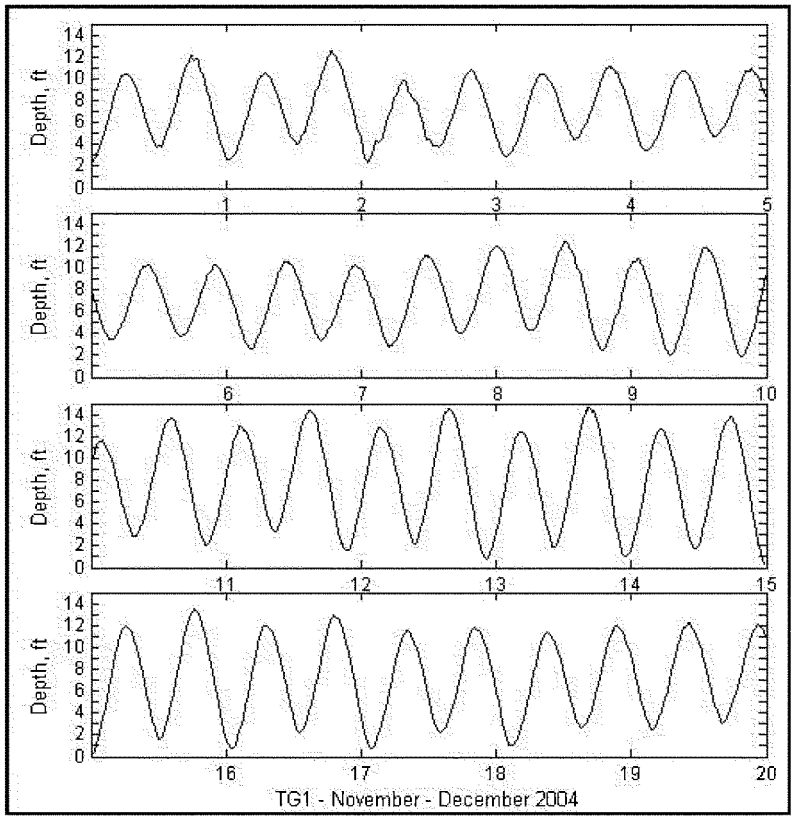

Figure B7. TG1 water-level measurement plot, November-December 2004.

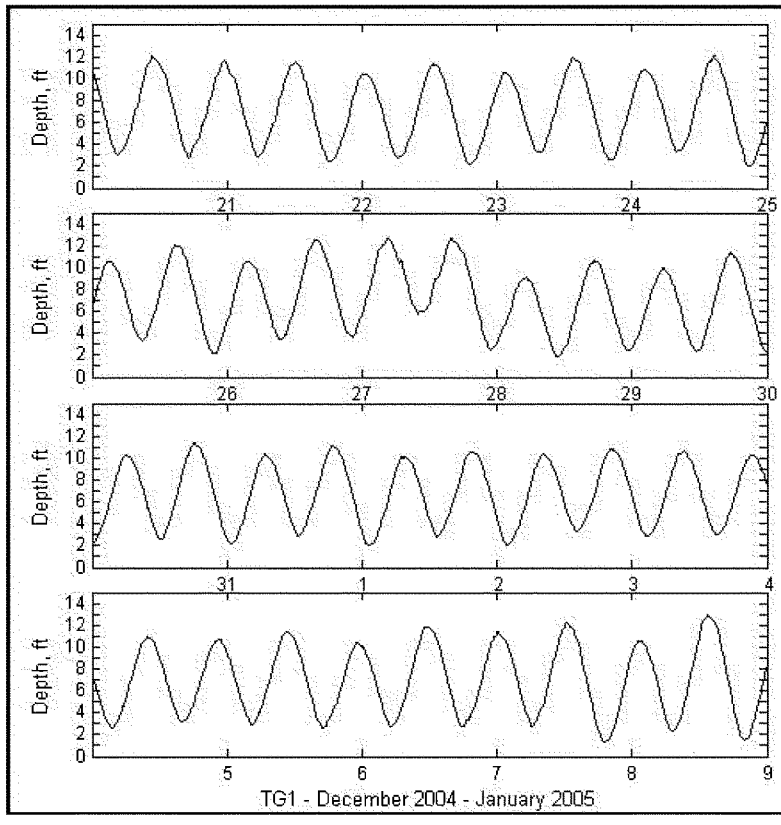

Figure B8. TG1 water-level measurement plot, December 2004-January 2005.

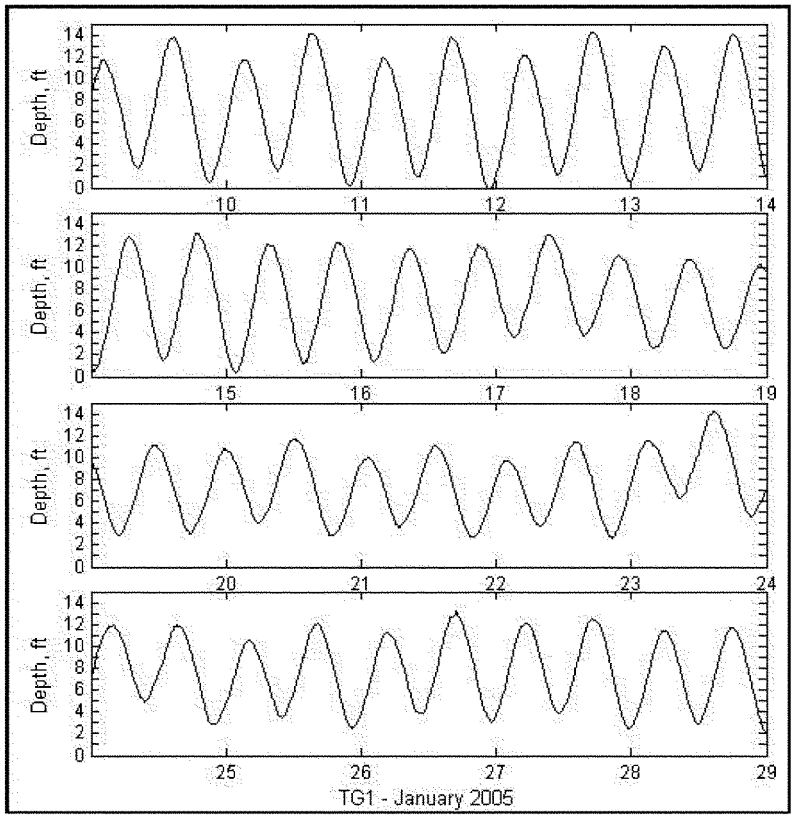

Figure B9. TG1 water-level measurement plot, January 2005.

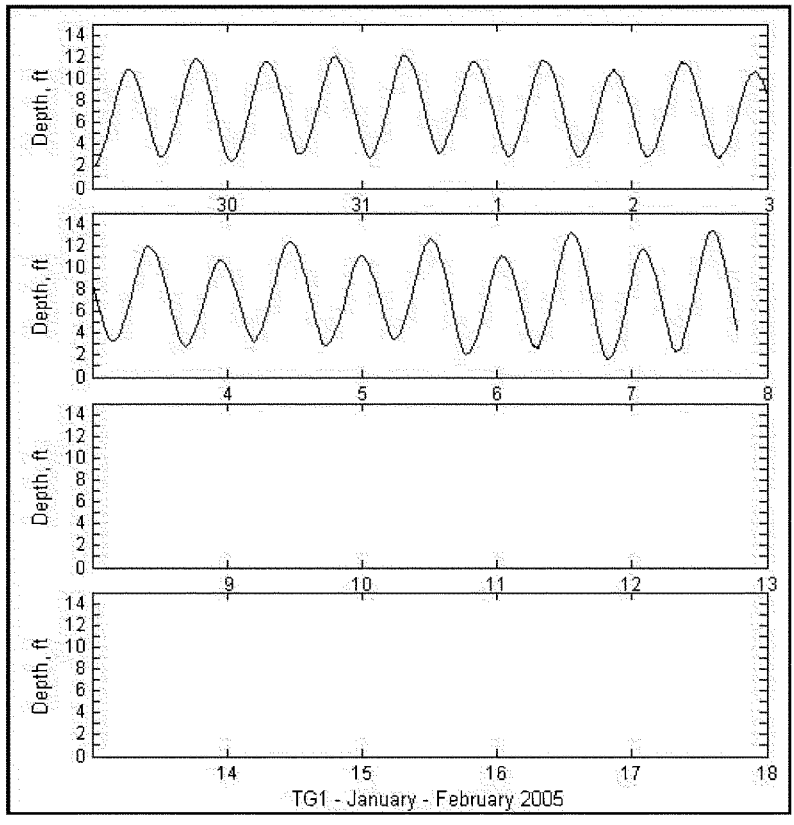

Figure B10. TG1 water-level measurement plot, January-February 2005.

TG2 Water-Level Measurement Plots

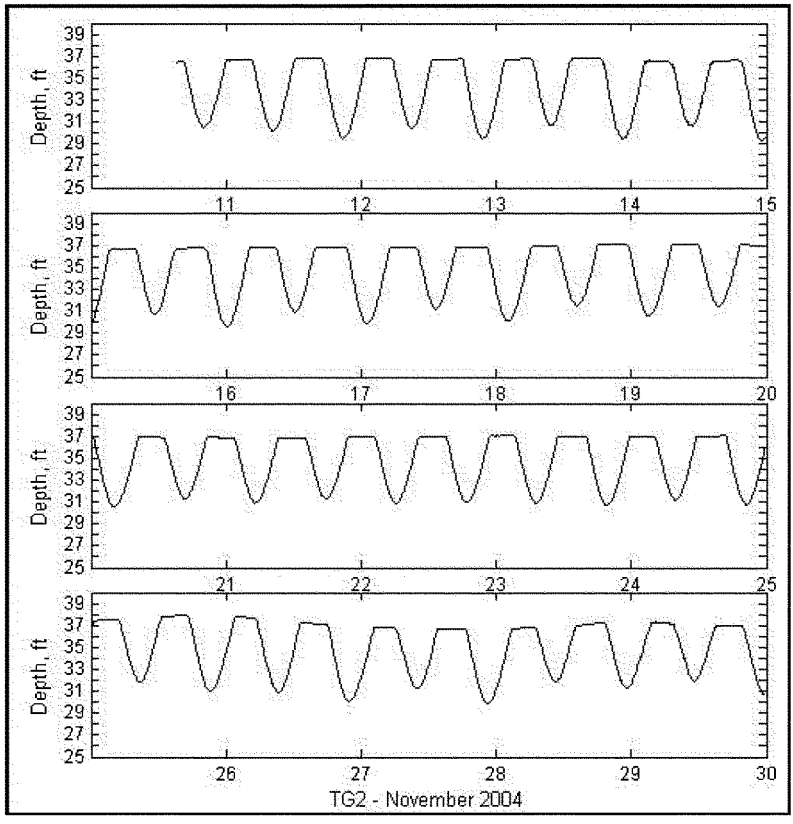

Figure B11. TG2 water-level measurement plot, November 2004.

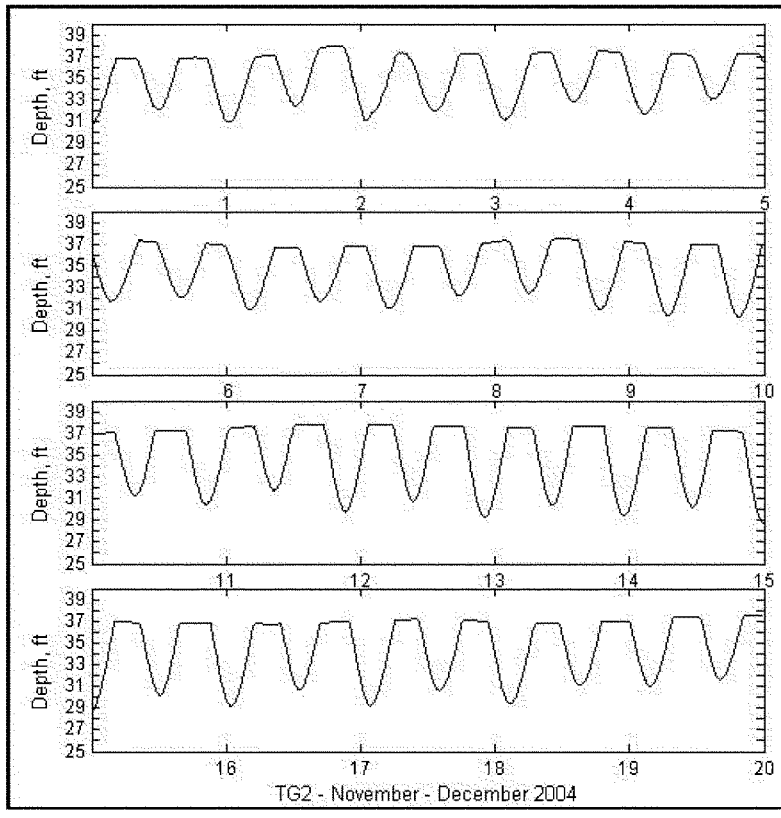

Figure B12. TG2 water-level measurement plot, November-December 2004.

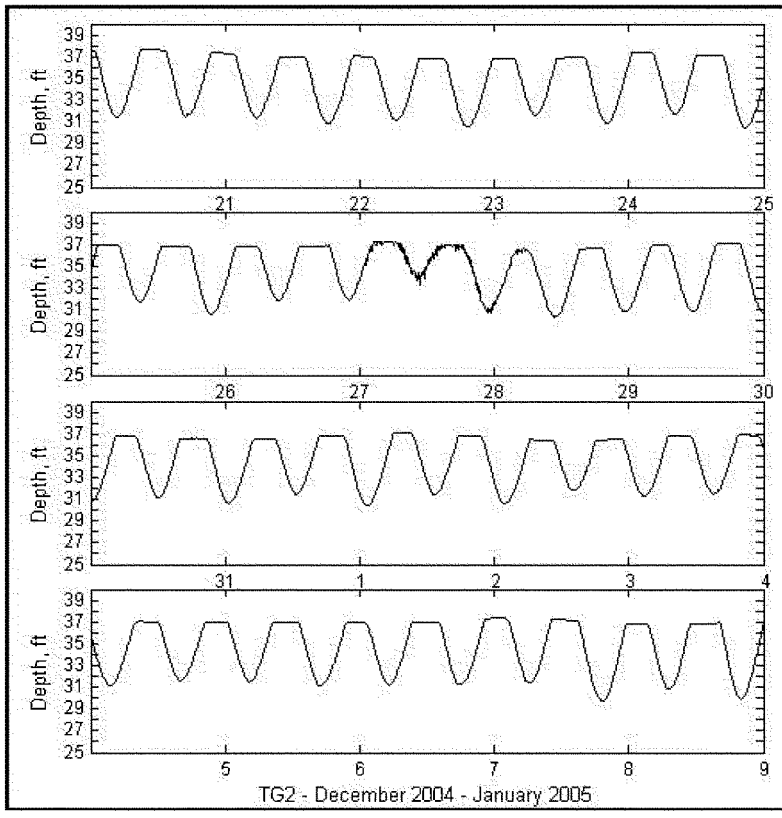

Figure B13. TG2 water-level measurement plot, November-December 2004–January 2005.

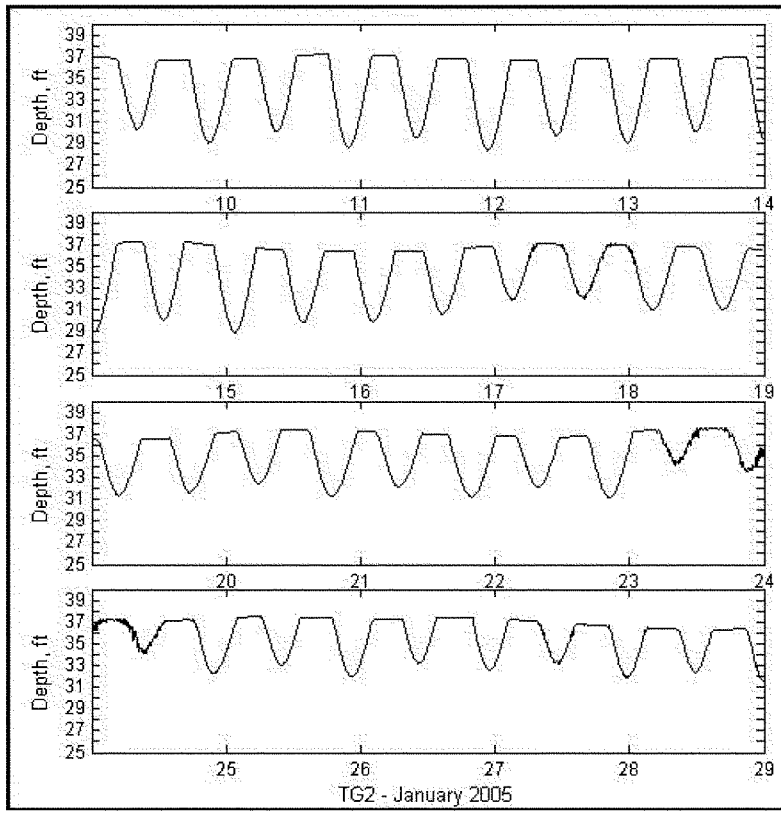

Figure B14. TG2 water-level measurement plot, January 2005.

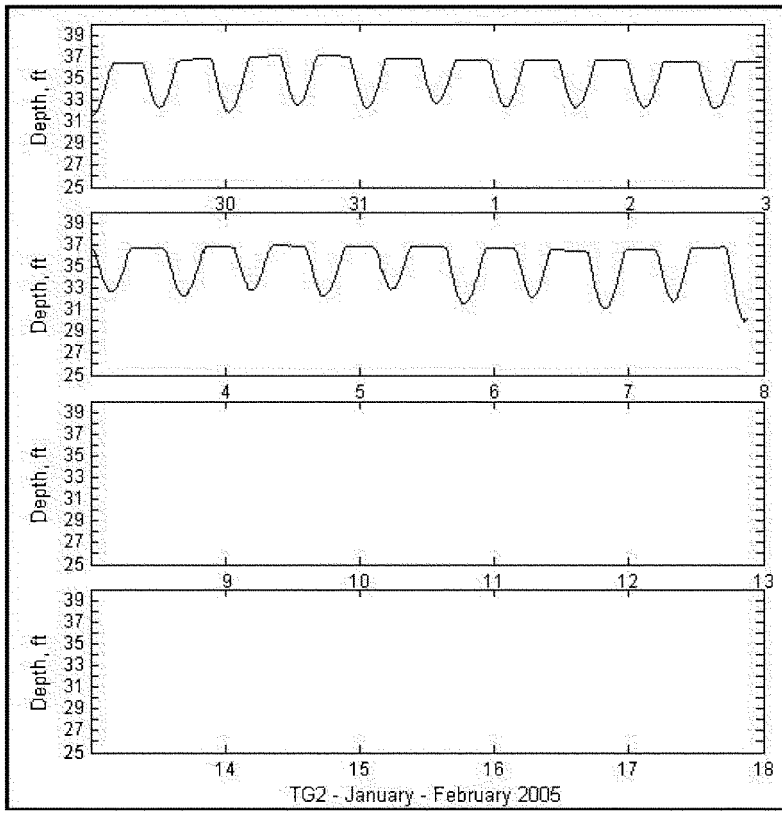

Figure B15. TG2 water-level measurement plot, January–February 2005.

TG3 Water-Level Measurement Plots

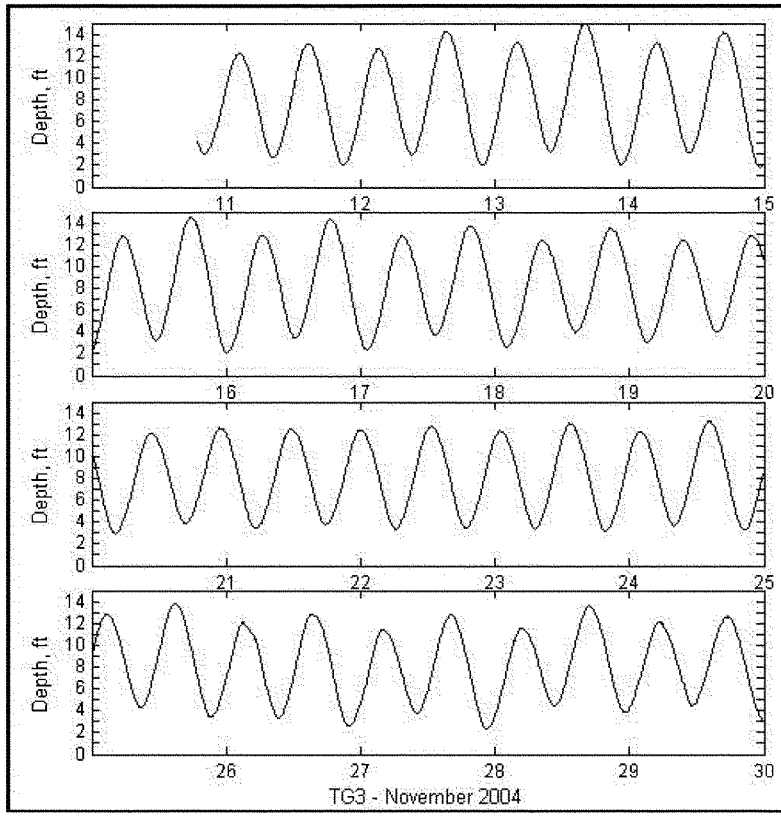

Figure B16. TG3 water-level measurement plot, November 2004.

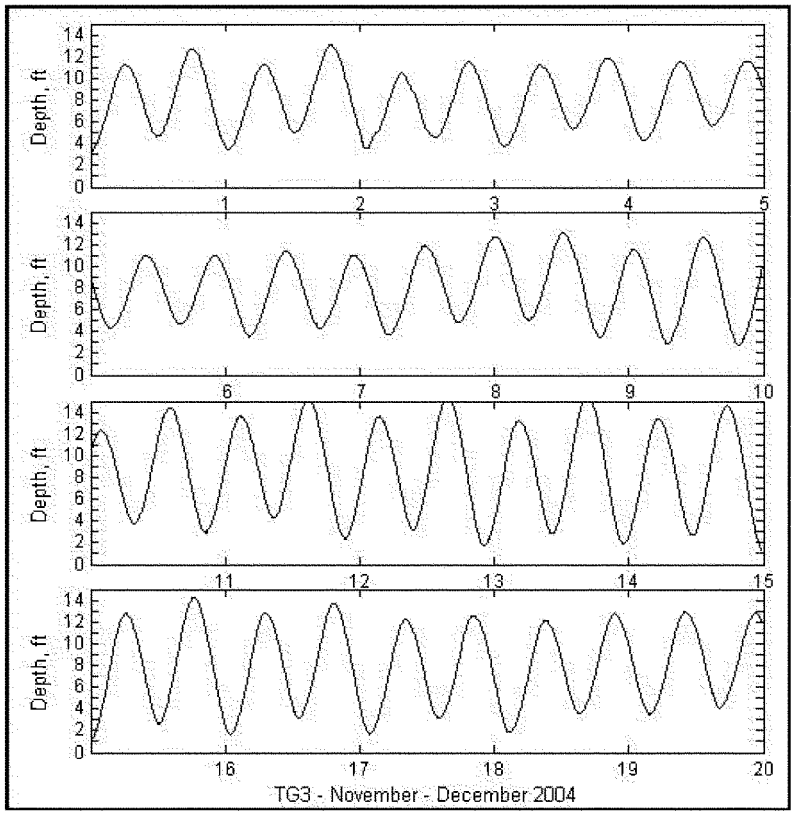

Figure B17. TG3 water-level measurement plot, November-December 2004.

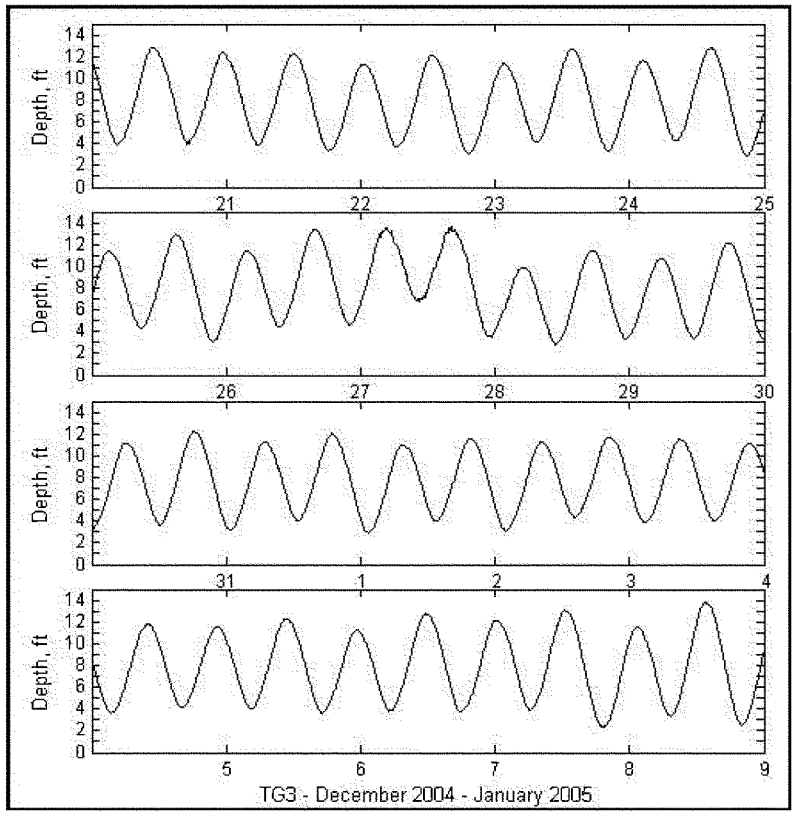

Figure B18. TG3 water-level measurement plot, December 2004–January 2005.

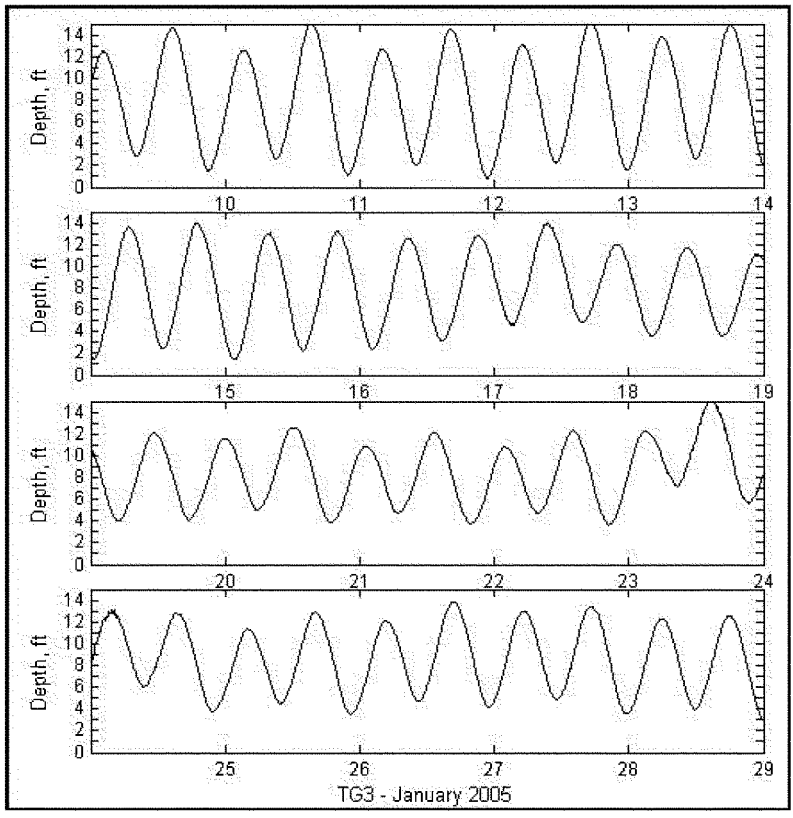

Figure B19. TG3 water-level measurement plot, January 2005.

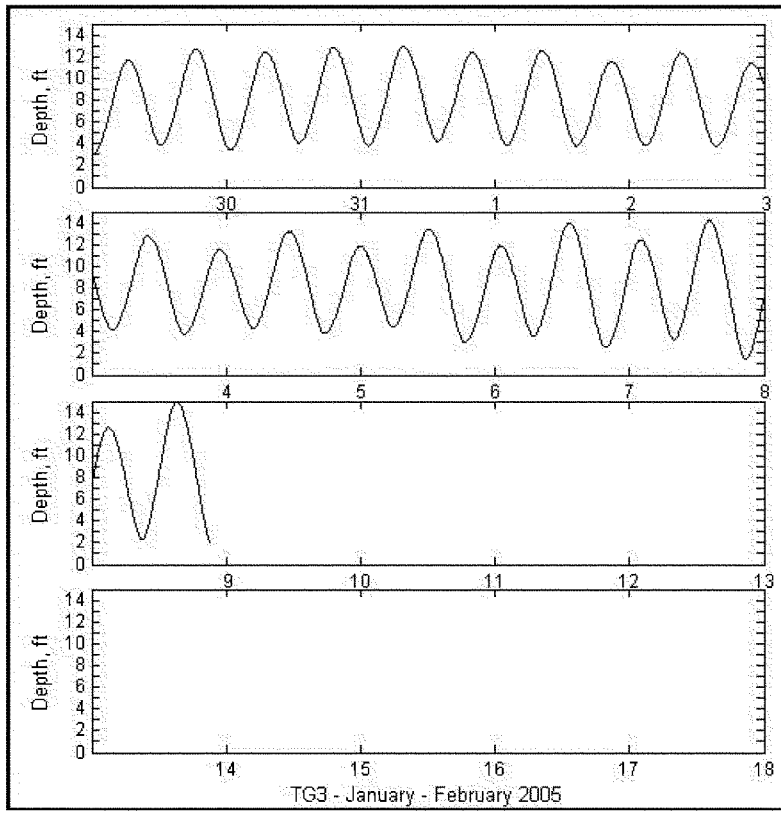

Figure B20. TG3 water-level measurement plot, January-February 2005.

TG4 Water-Level Measurement Plots

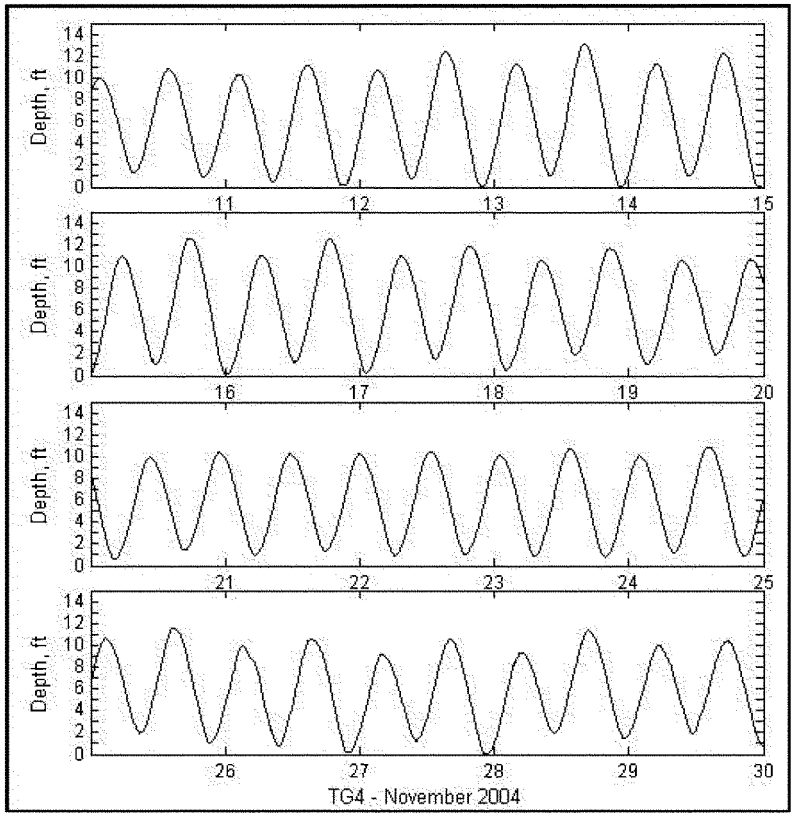

Figure B21. TG4 water-level measurement plot, November 2004.

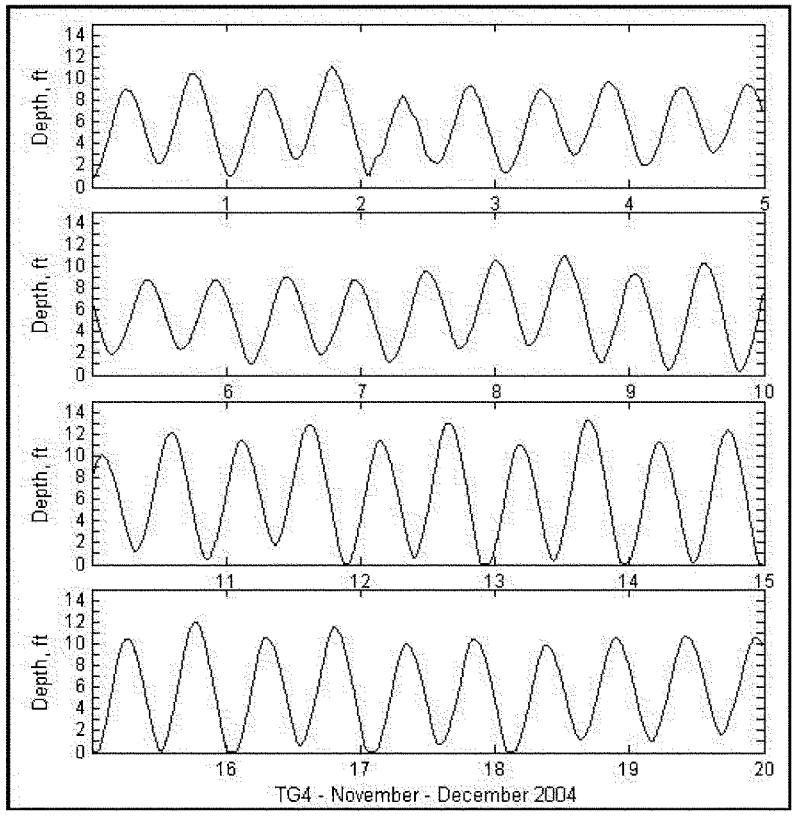

Figure B22. TG4 water-level measurement plot, November-December 2004.

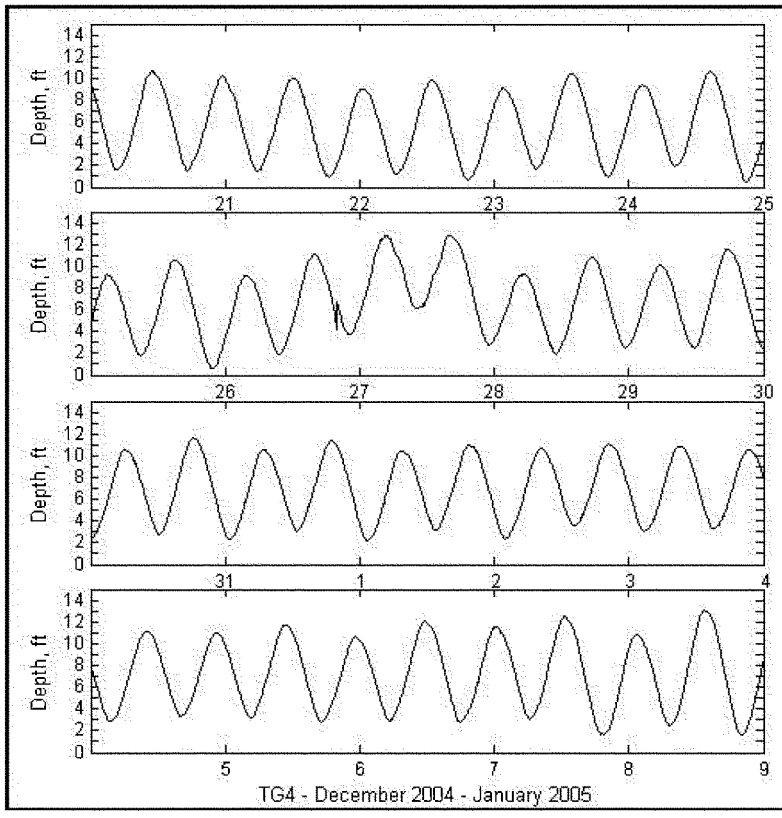

Figure B23. TG4 water-level measurement plot, December 2004–January 2005.

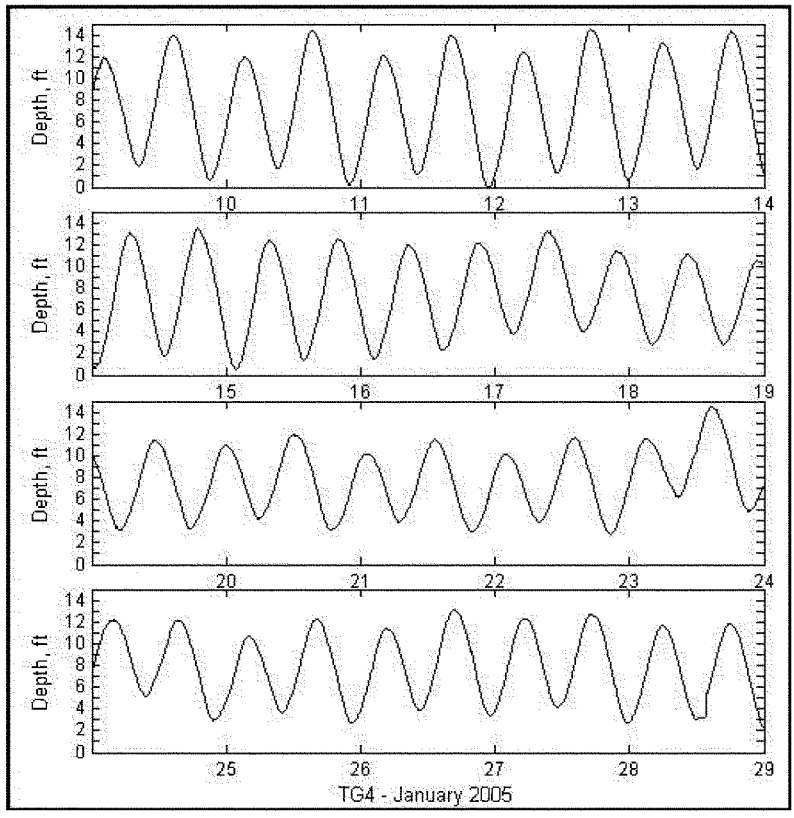

Figure B24. TG4 water-level measurement plot, January 2005.

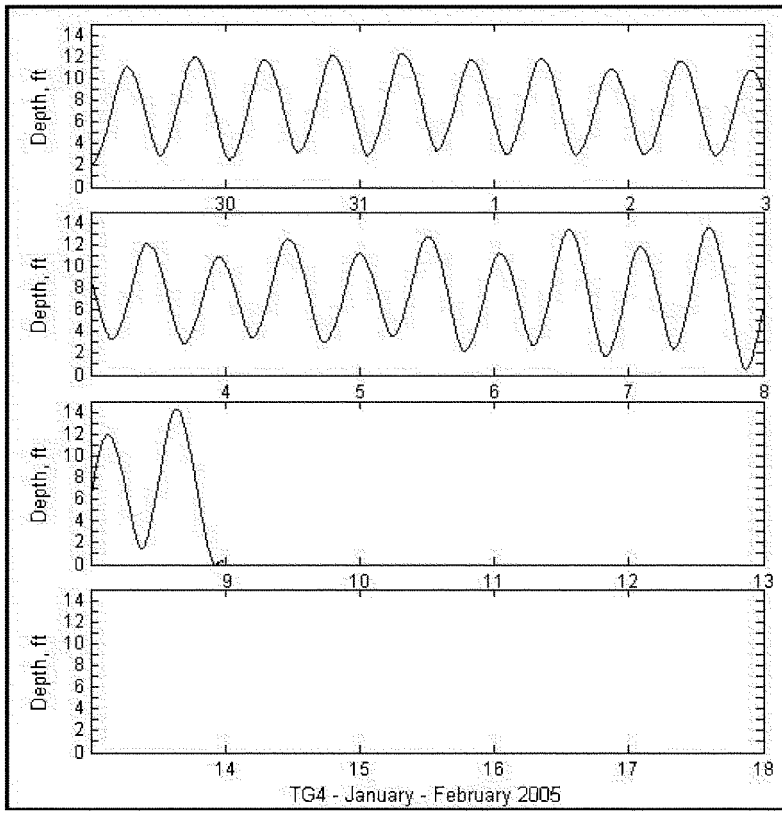

Figure B25. TG4 water-level measurement plot, January-February 2005.

Appendix C: Moored Current Measurement Plots

CM2 Moored Current Measurement Plots

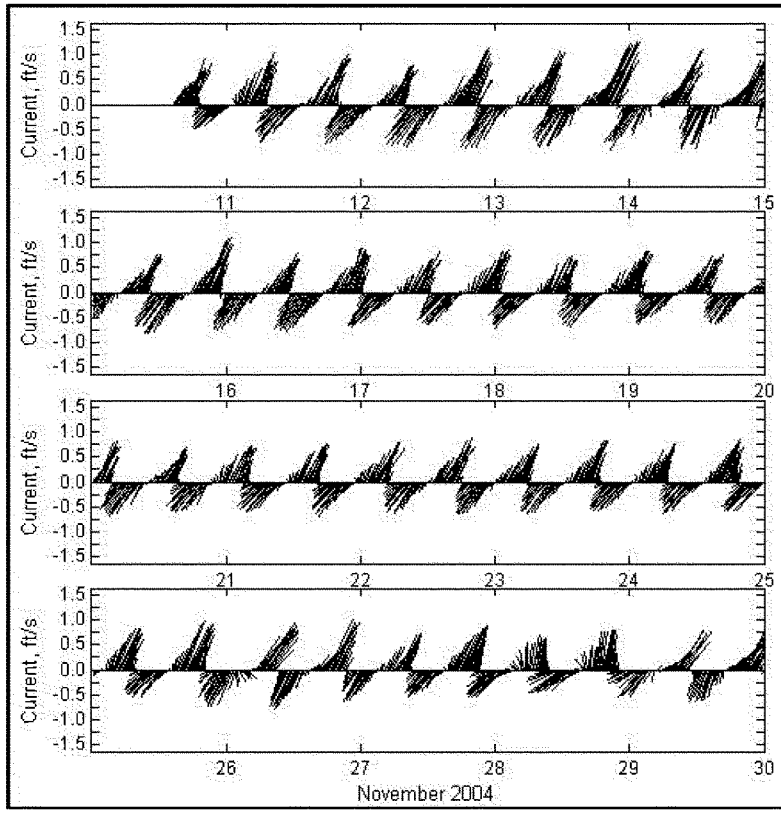

Figure C1. CM2 moored current measurement plots, November 2004.

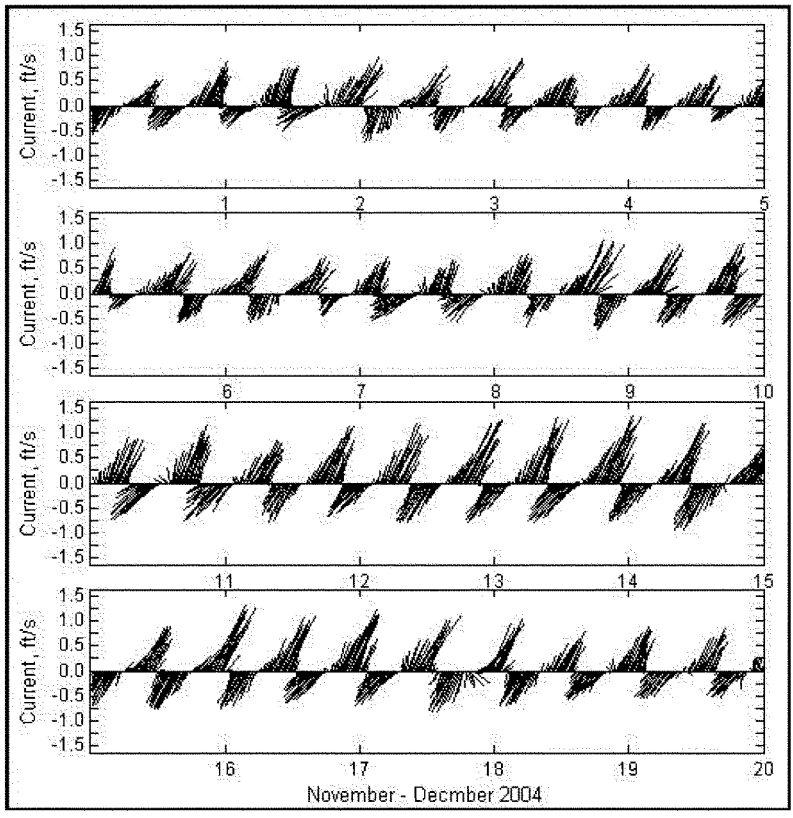

Figure C2. CM2 moored current measurement plots, November-December 2004.

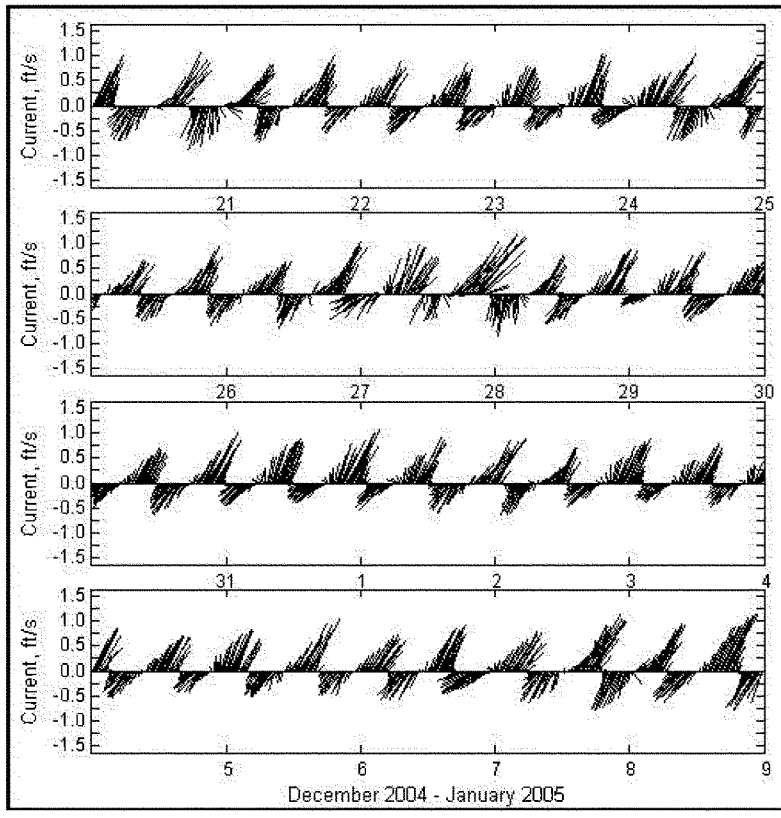

Figure C3. CM2 moored current measurement plots, December 2004–January 2005.

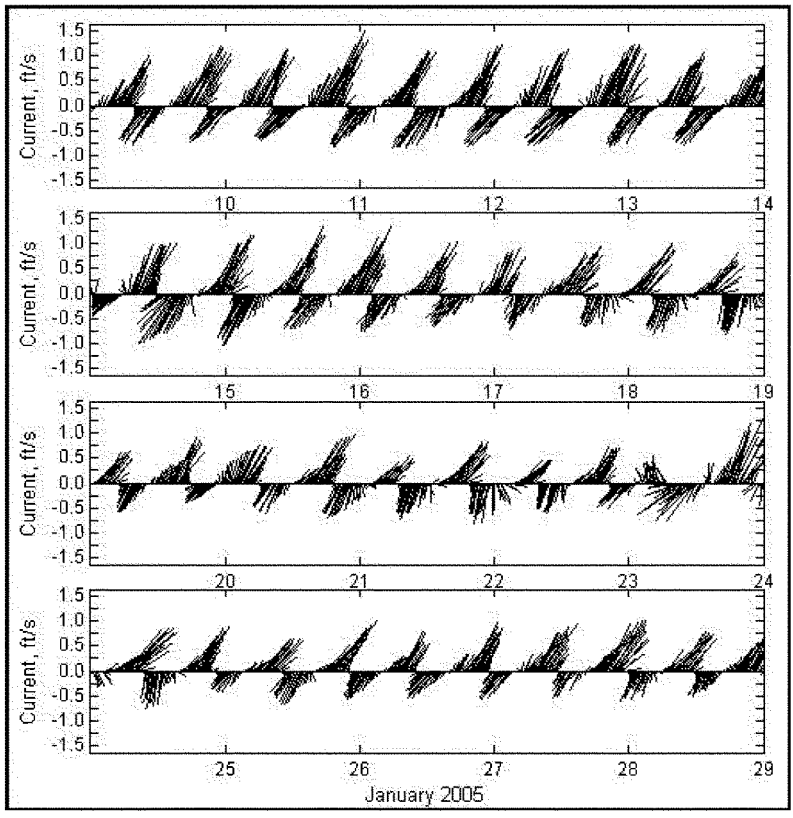

Figure C4. CM2 moored current measurement plots, January 2005.

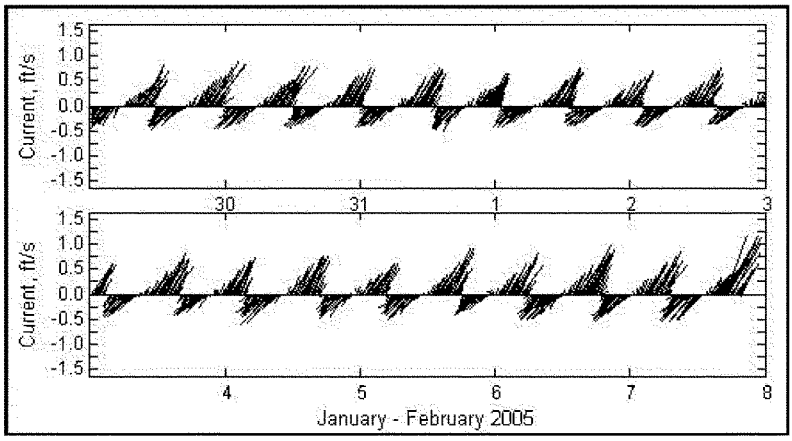

Figure C5. CM2 moored current measurement plots, January-February 2005.

Appendix D: Transect Current Surveys, Depth-Averaged Current Plots

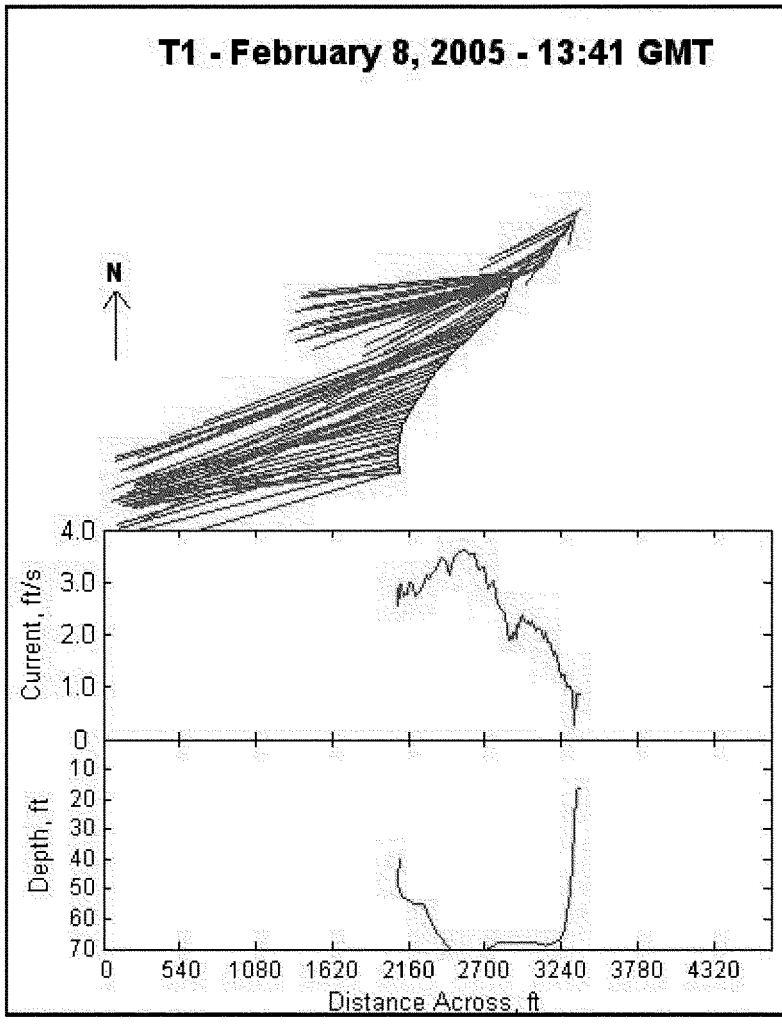

Figure D1. Transect 1 depth-averaged current plots, 8 February 2005, 1341 GMT.

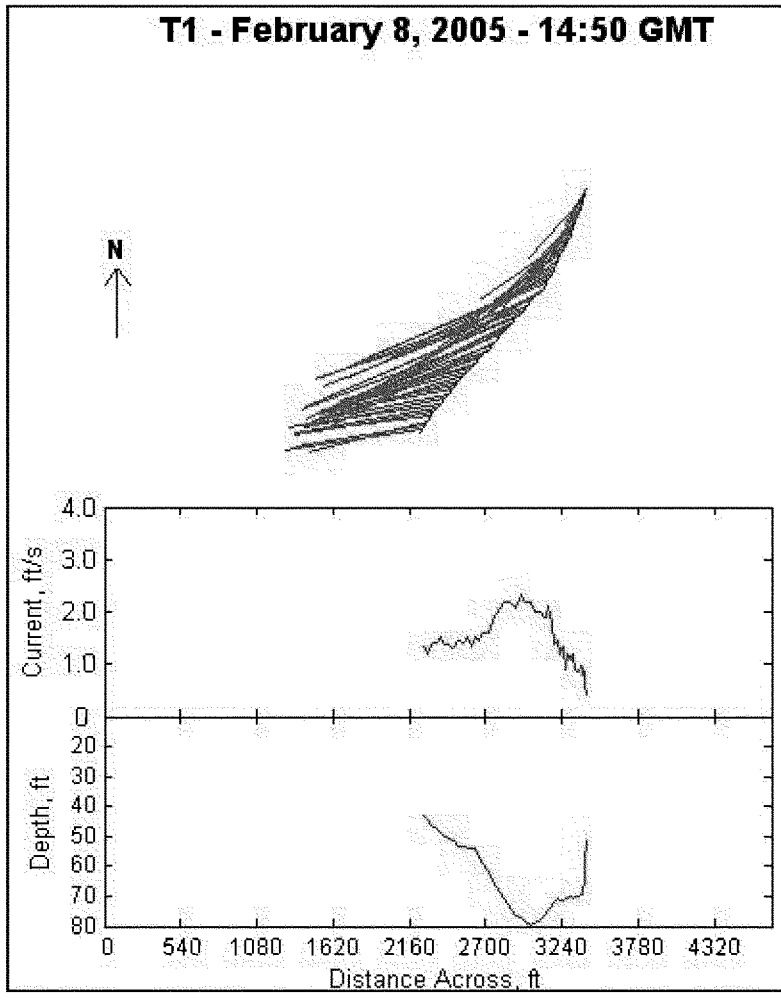

Figure D2. Transect 1 depth-averaged current plots, 8 February 2005, 1450 GMT.

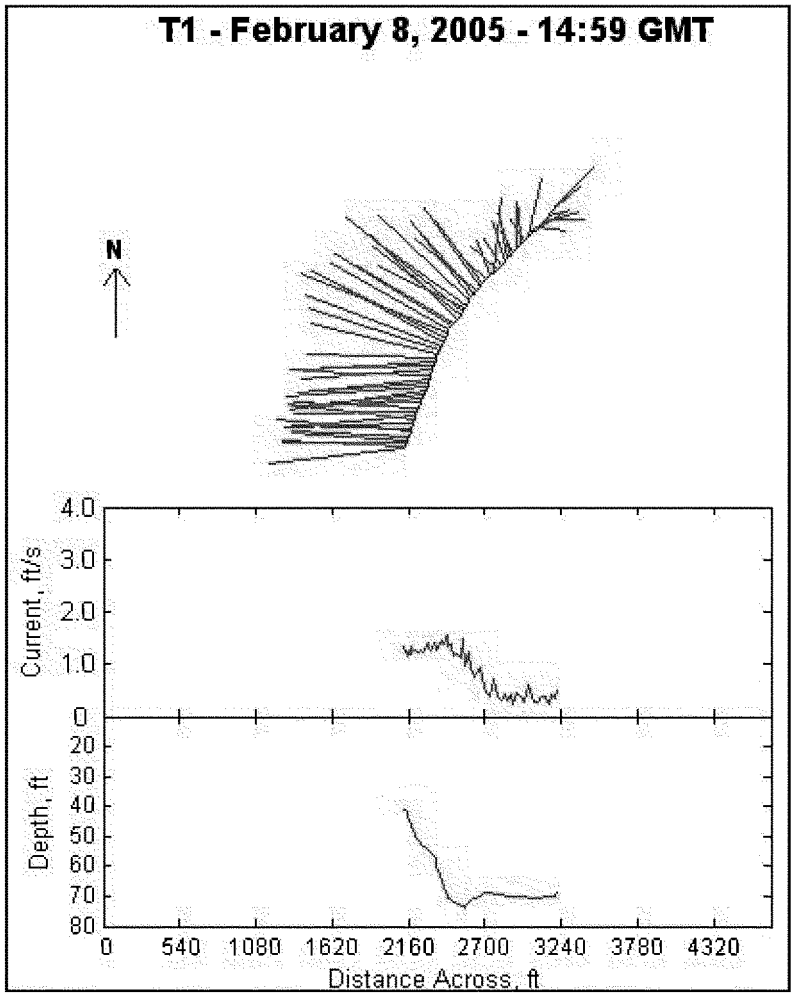

Figure D3. Transect 1 depth-averaged current plots, 8 February 2005, 1459 GMT.

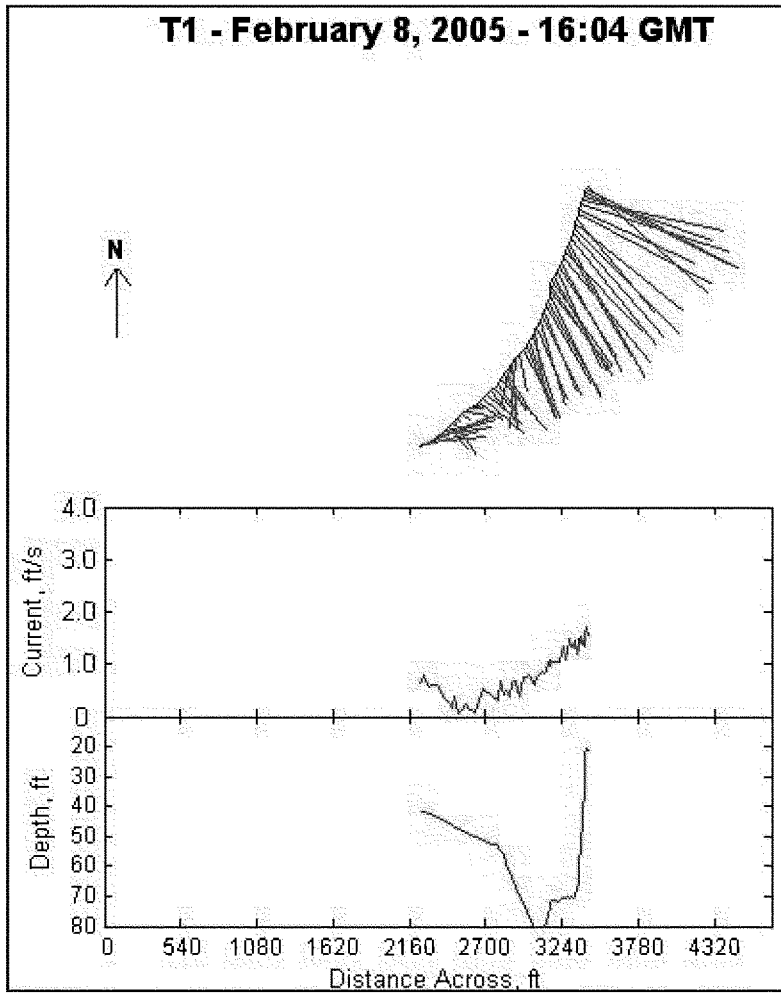

Figure D4. Transect 1 depth-averaged current plots, 8 February 2005, 1604 GMT.

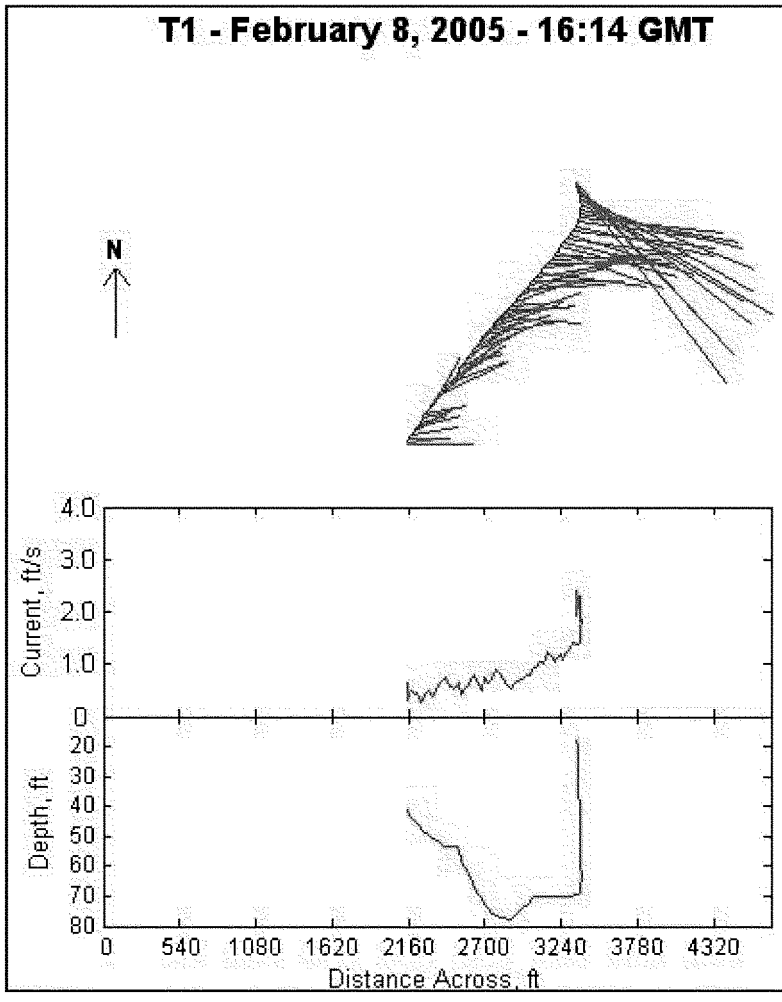

Figure D5. Transect 1 depth-averaged current plots, 8 February 2005, 1614 GMT.

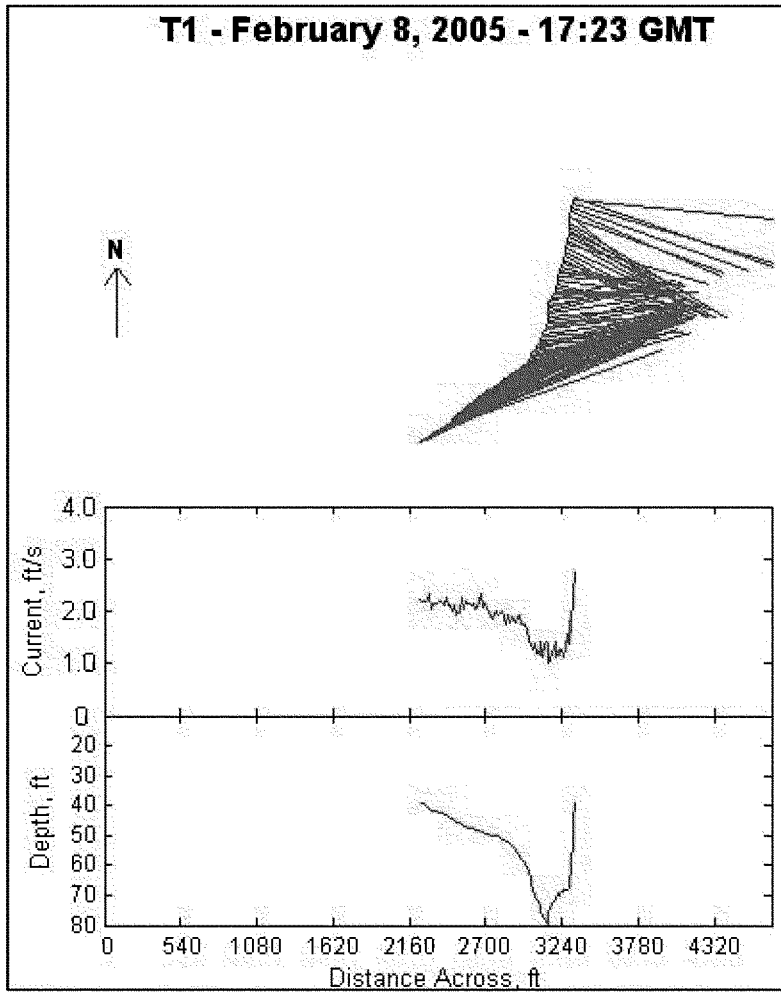

Figure D6. Transect 1 depth-averaged current plots, 8 February 2005, 1723 GMT.

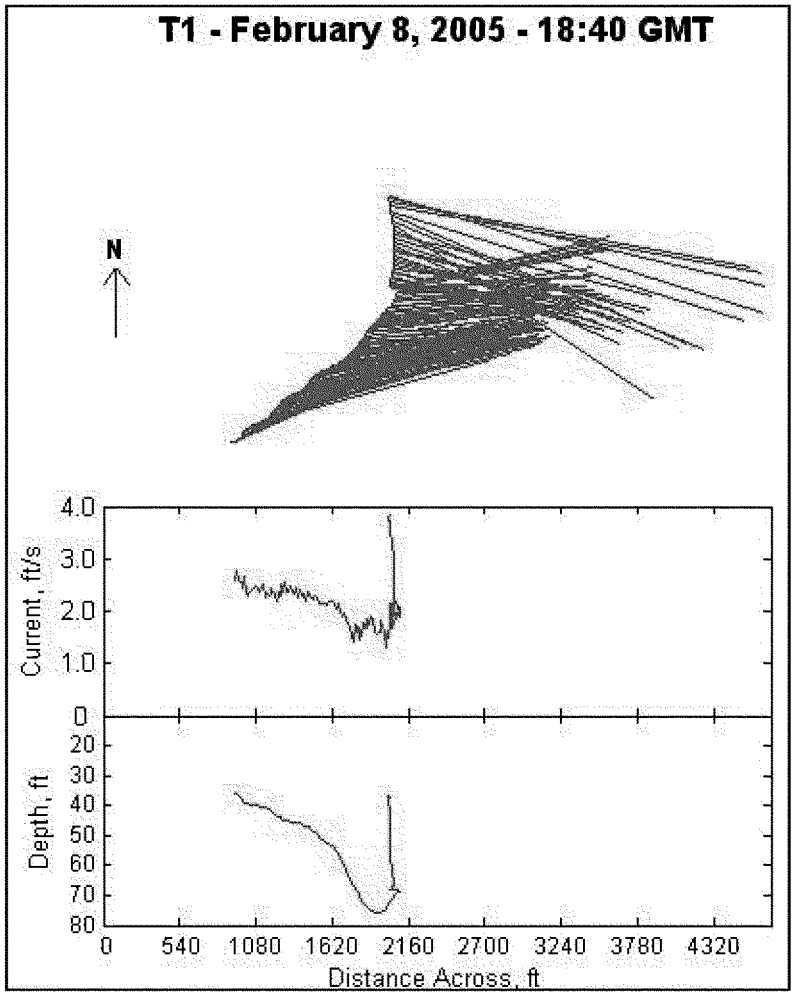

Figure D7. Transect 1 depth-averaged current plots, 8 February 2005, 1840 GMT.

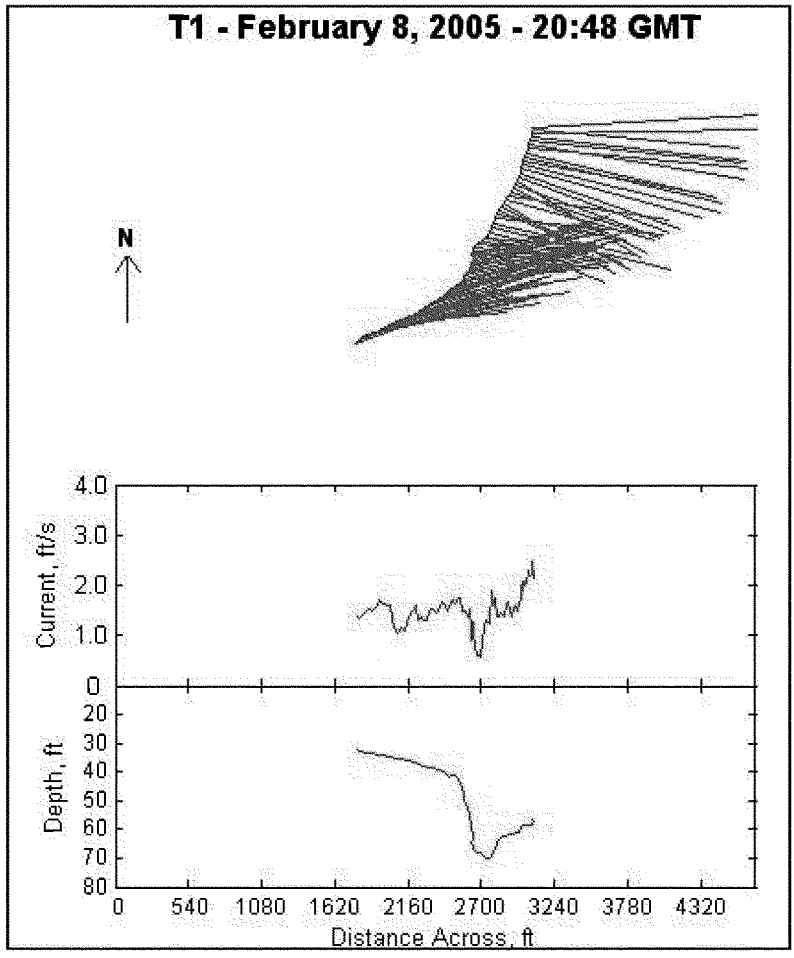

Figure D8. Transect 1 depth-averaged current plots, 8 February 2005, 2048 GMT.

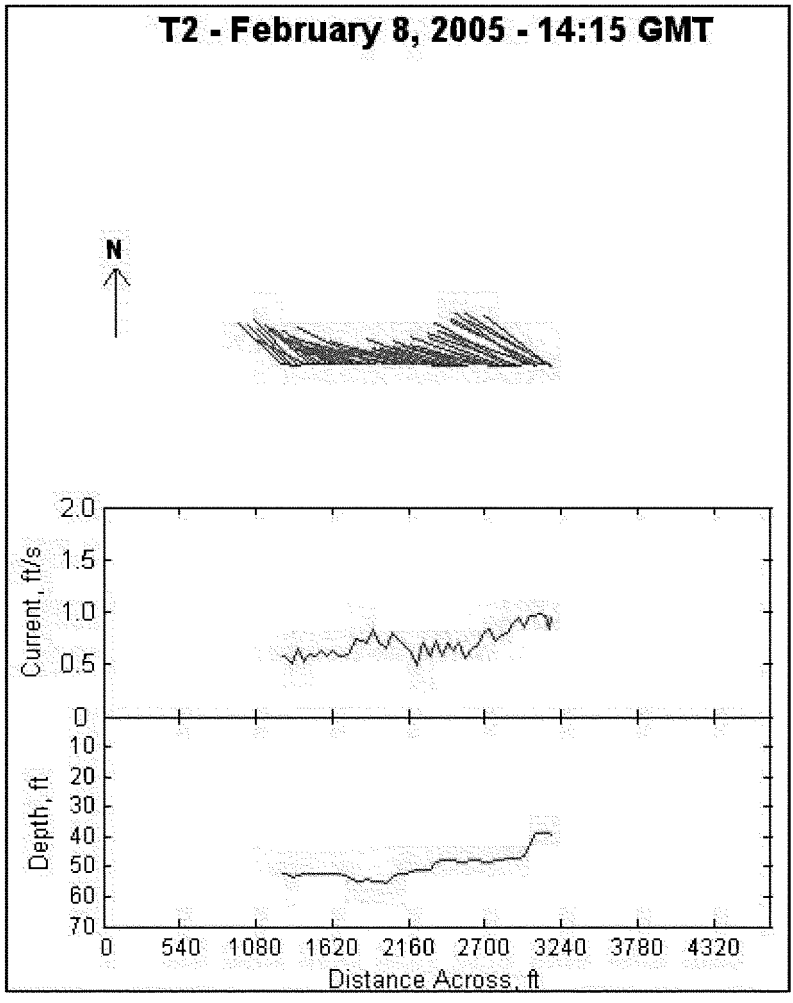

Figure D9. Transect 2 depth-averaged current plots, 8 February 2005, 1415 GMT.

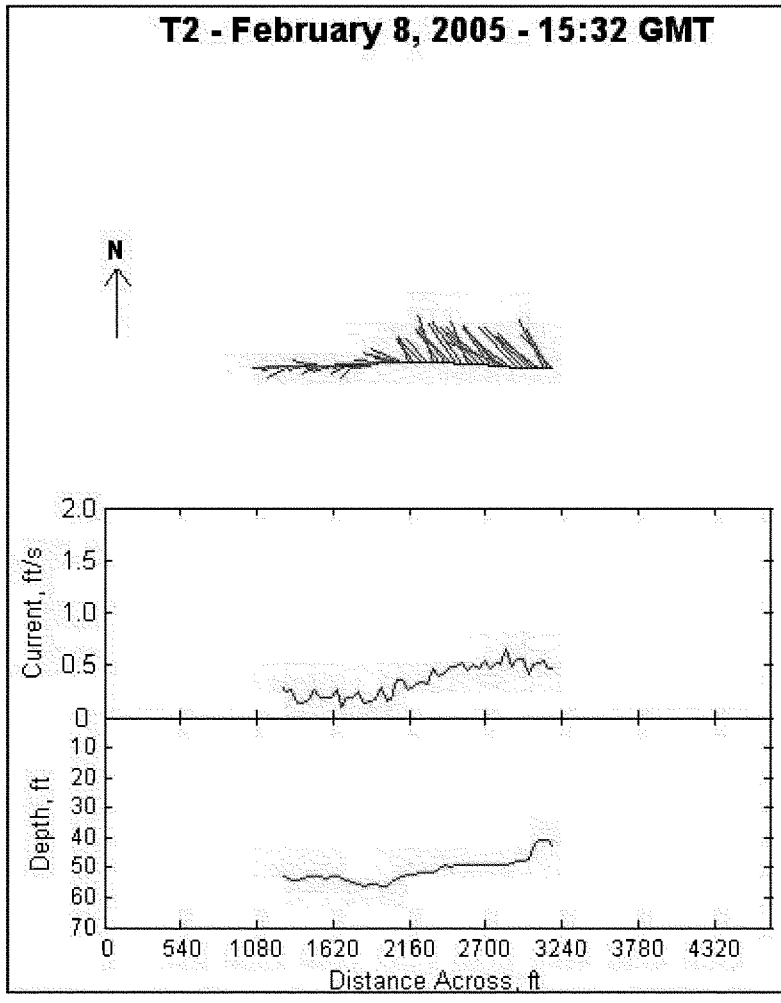

Figure D10. Transect 2 depth-averaged current plots, 8 February 2005, 1532 GMT.

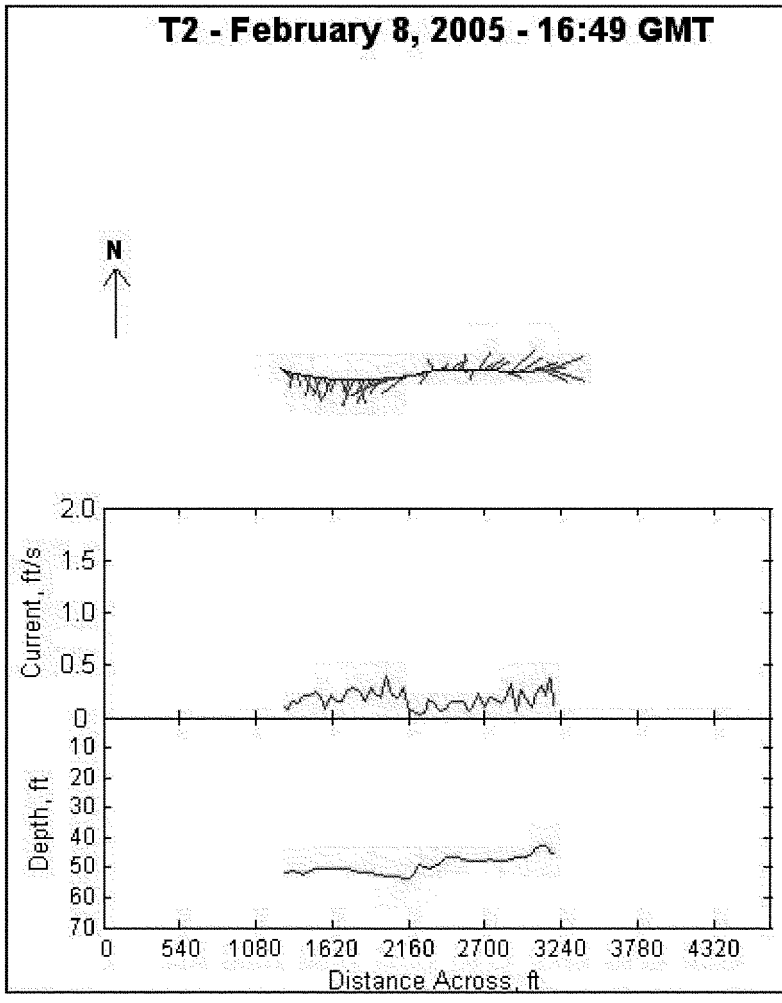

Figure D11. Transect 2 depth-averaged current plots, 8 February 2005, 1649 GMT.

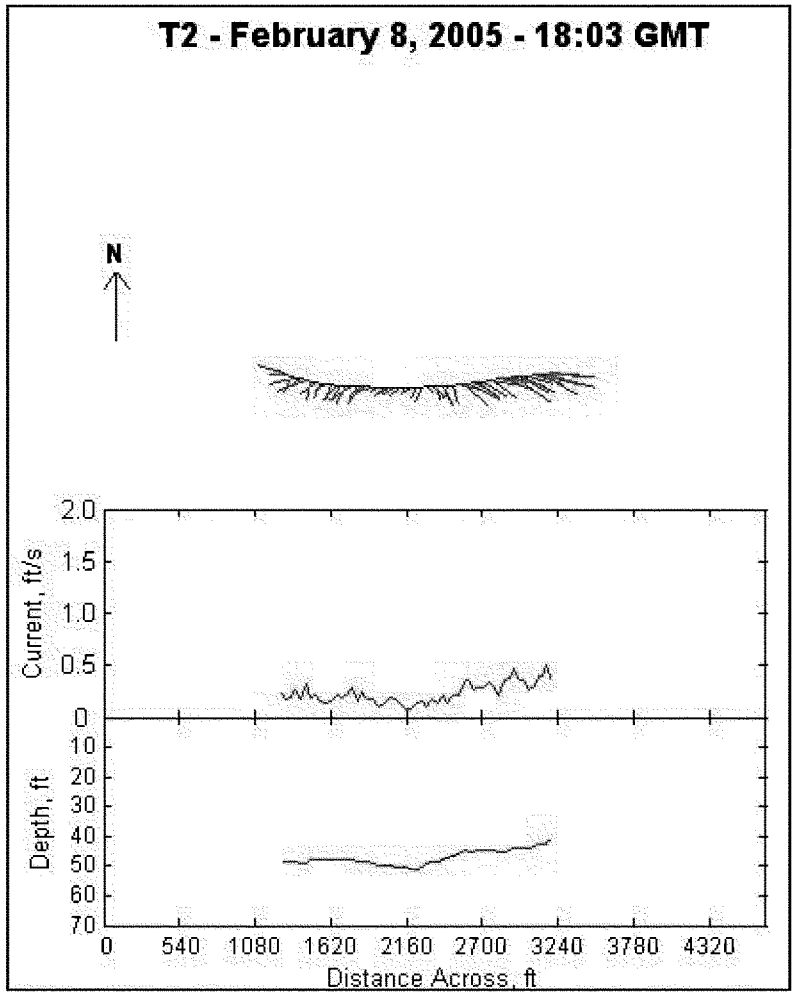

Figure D12. Transect 2 depth-averaged current plots, 8 February 2005, 1803 GMT.

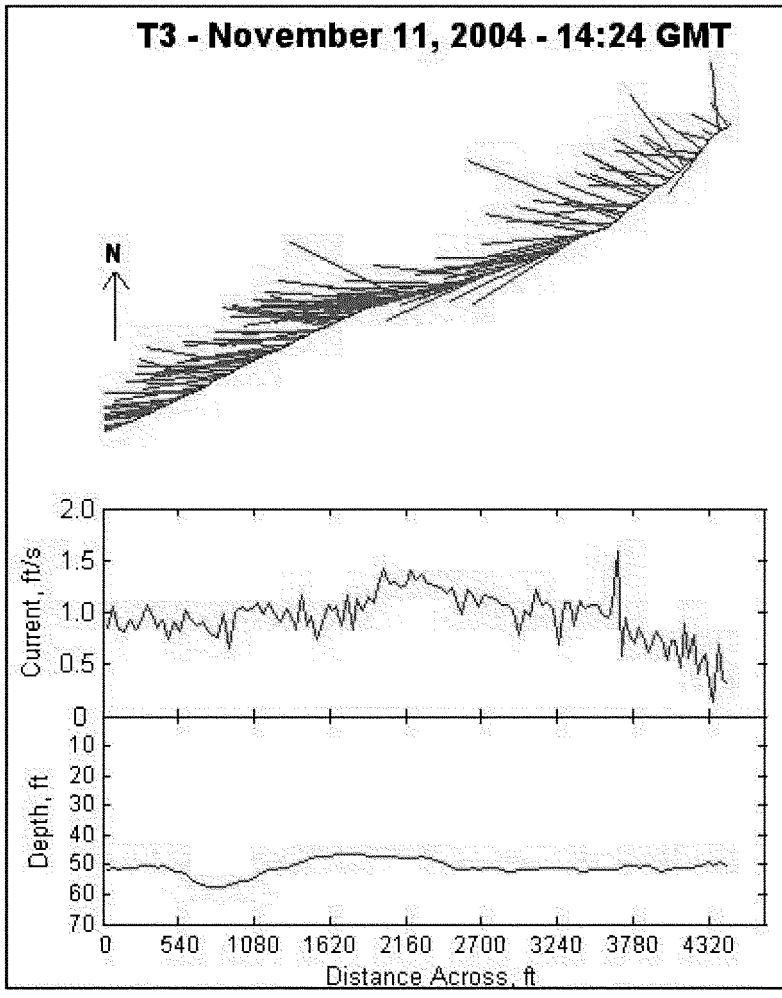

Figure D13. Transect 3 depth-averaged current plots, 11 November 2004, 1424 GMT.

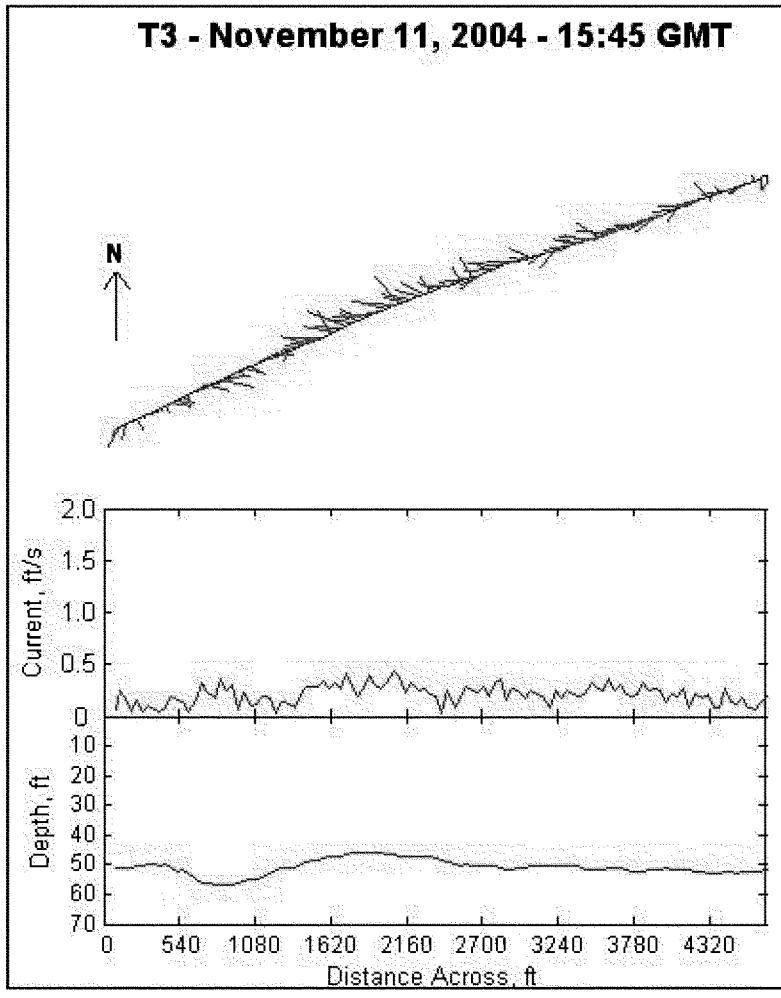

Figure D14. Transect 3 depth-averaged current plots, 11 November 2004, 1545 GMT.

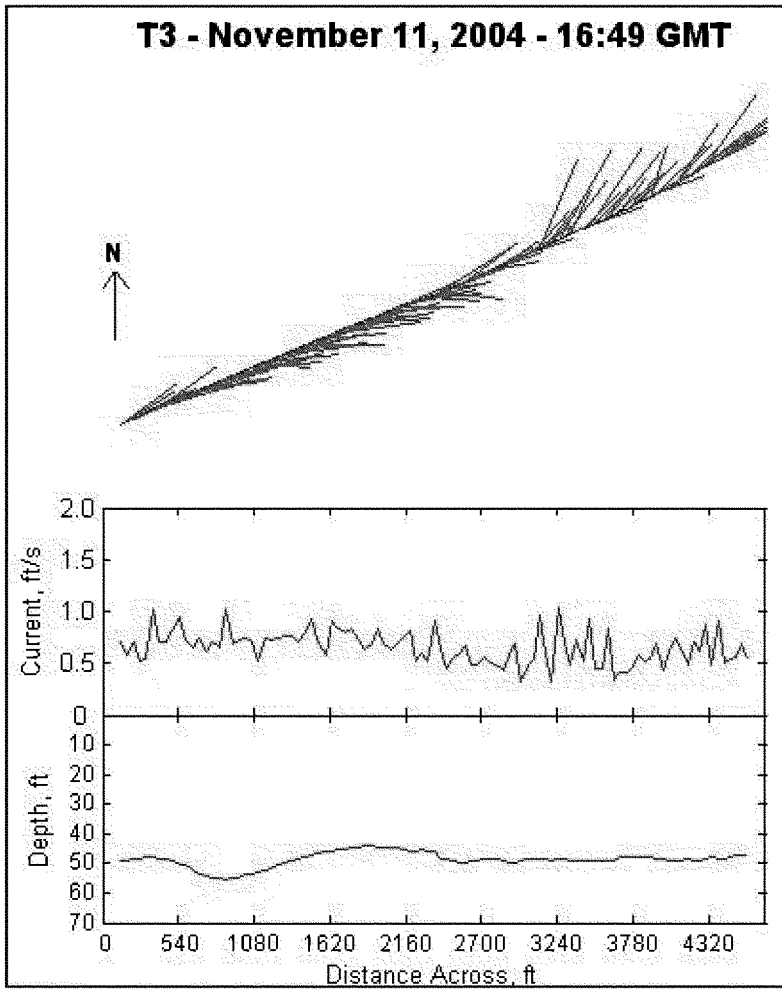

Figure D15. Transect 3 depth-averaged current plots, 11 November 2004, 1649 GMT.

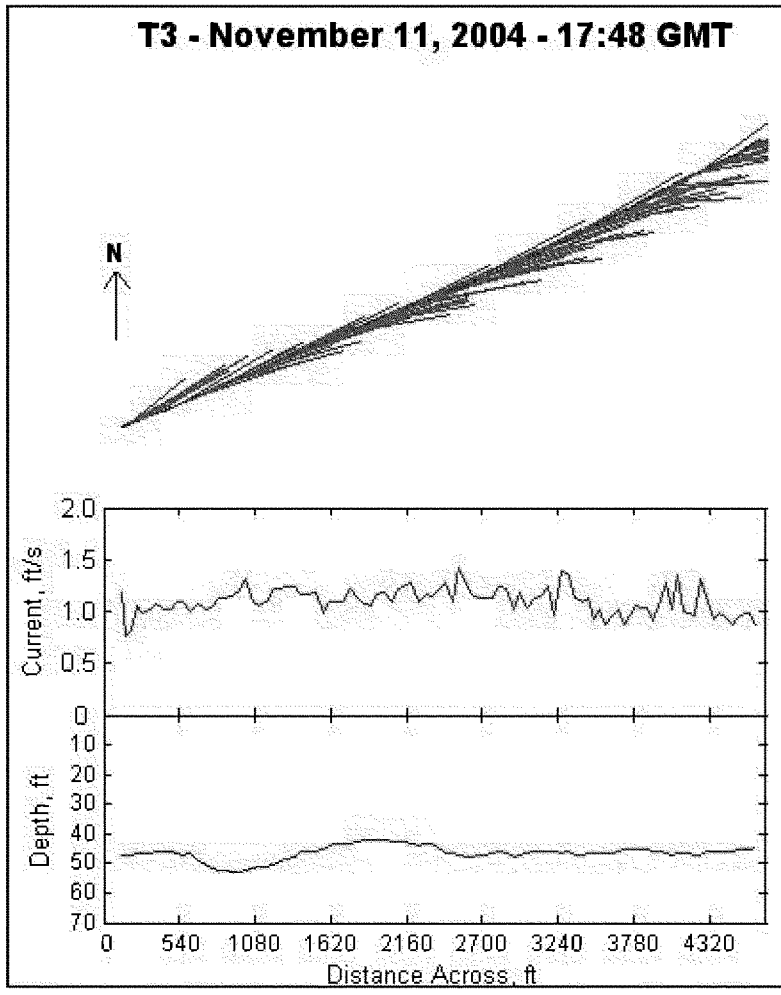

Figure D16. Transect 3 depth-averaged current plots, 11 November 2004, 1748 GMT.

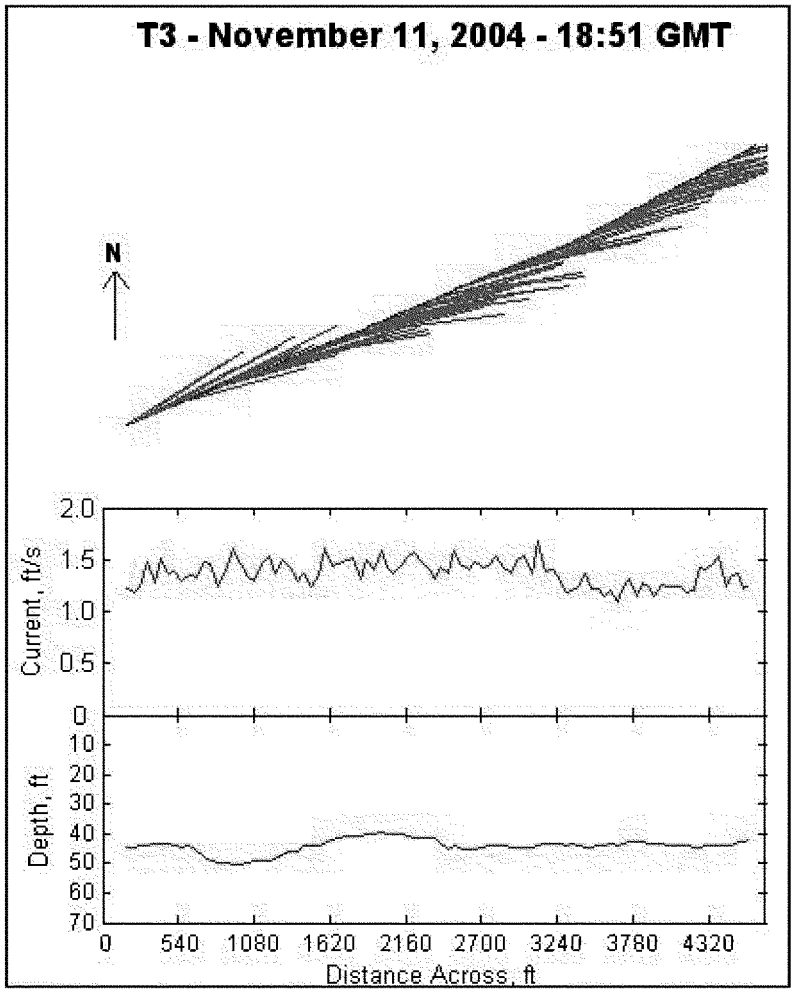

Figure D17. Transect 3 depth-averaged current plots, 11 November 2004, 1851 GMT.

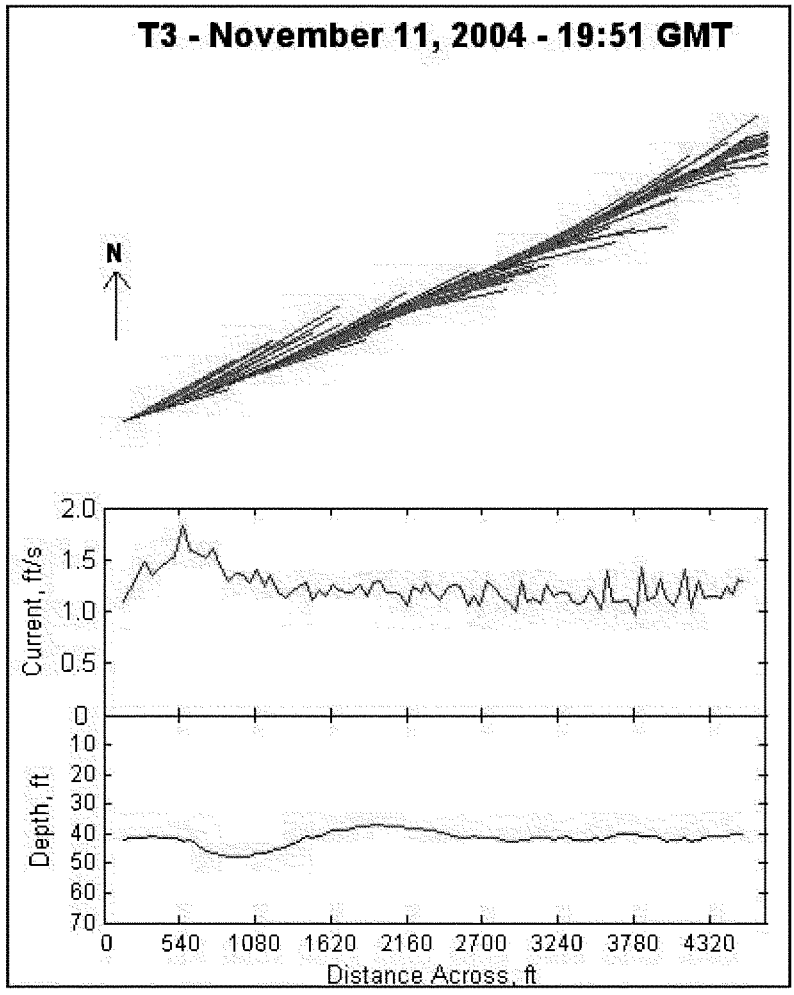

Figure D18. Transect 3 depth-averaged current plots, 11 November 2004, 1951 GMT.

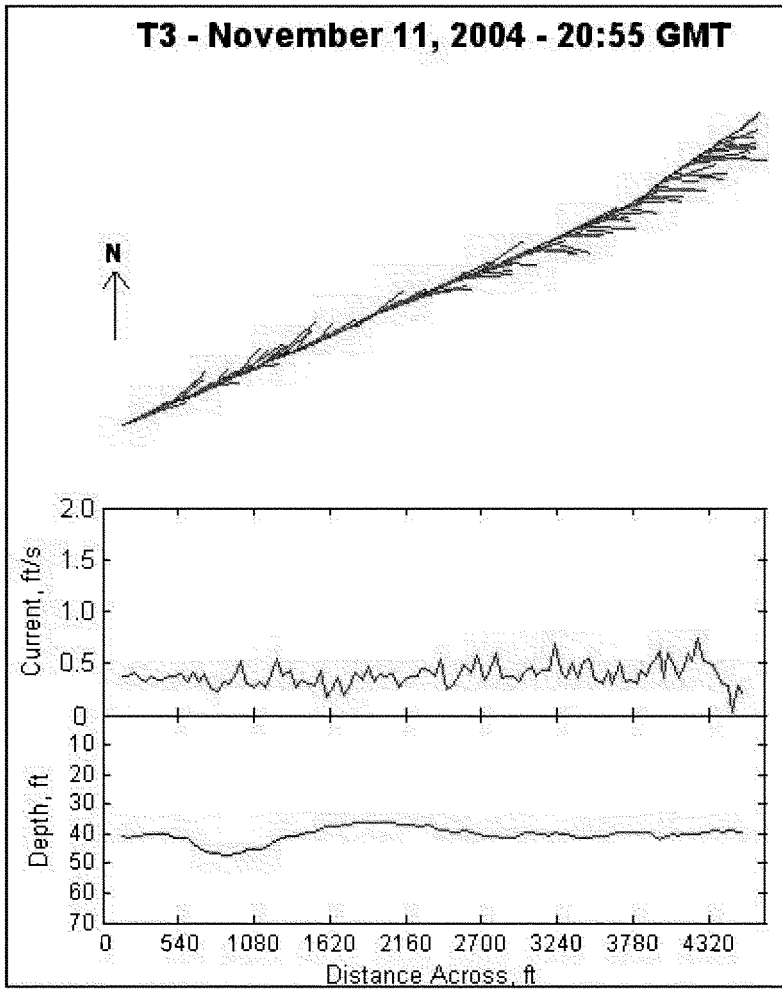

Figure D19. Transect 3 depth-averaged current plots, 11 November 2004, 2055 GMT.

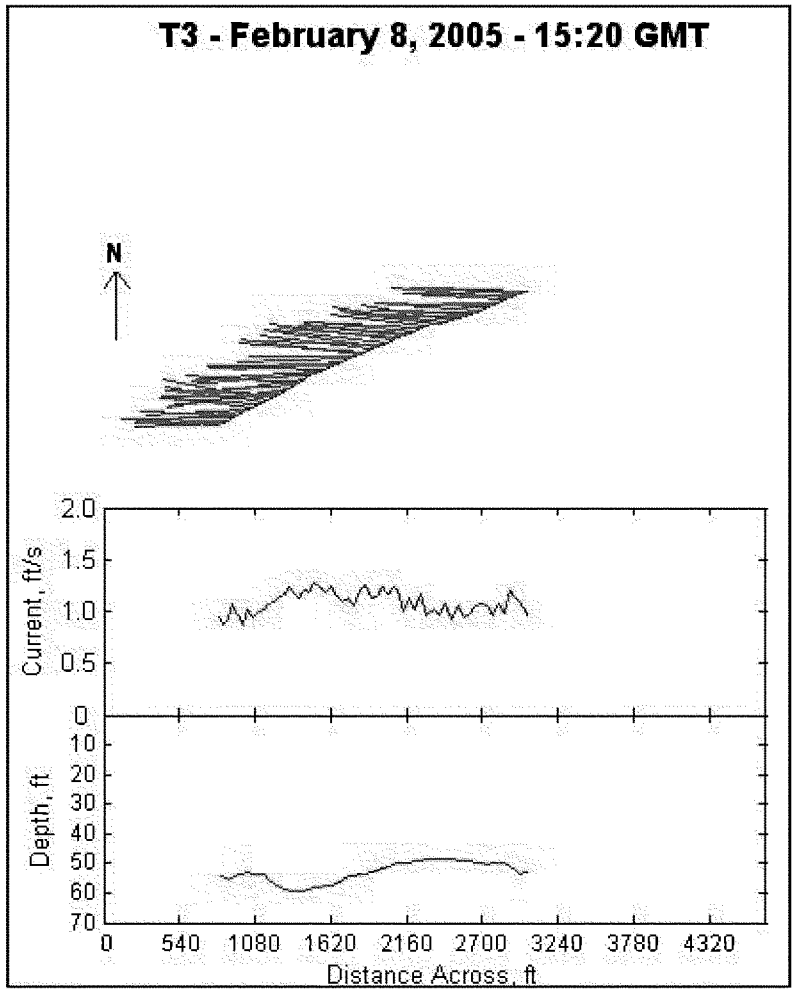

Figure D20. Transect 3 depth-averaged current plots, 8 February 2005, 1520 GMT.

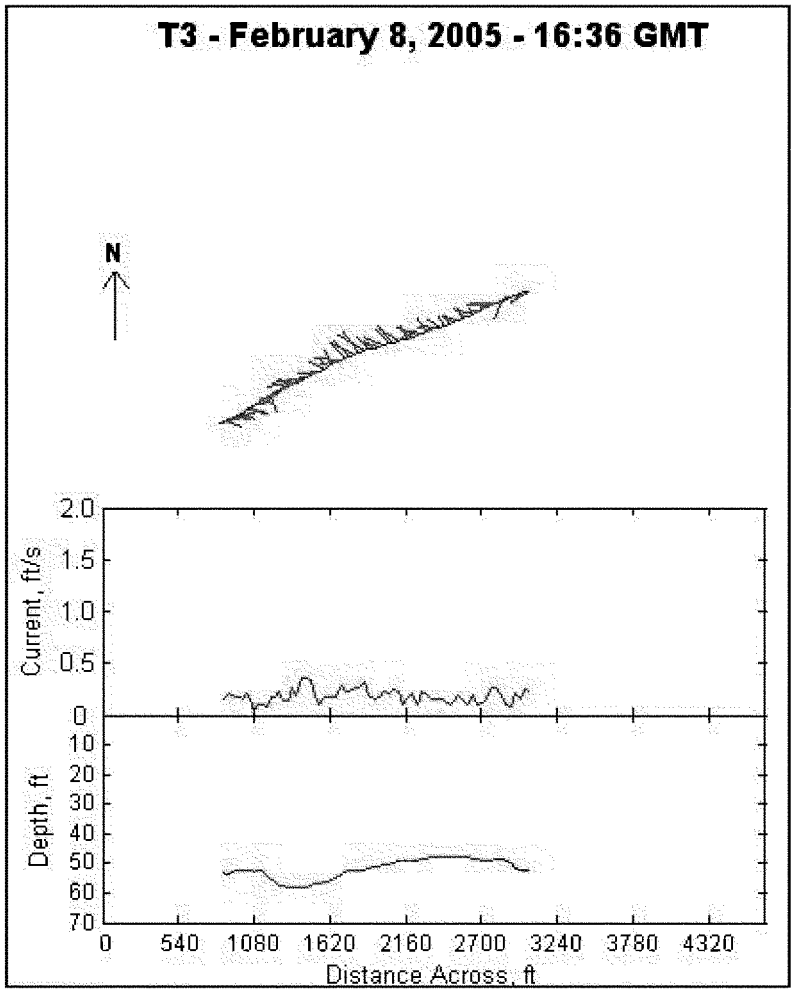

Figure D21. Transect 3 depth-averaged current plots, 8 February 2005, 1636 GMT.

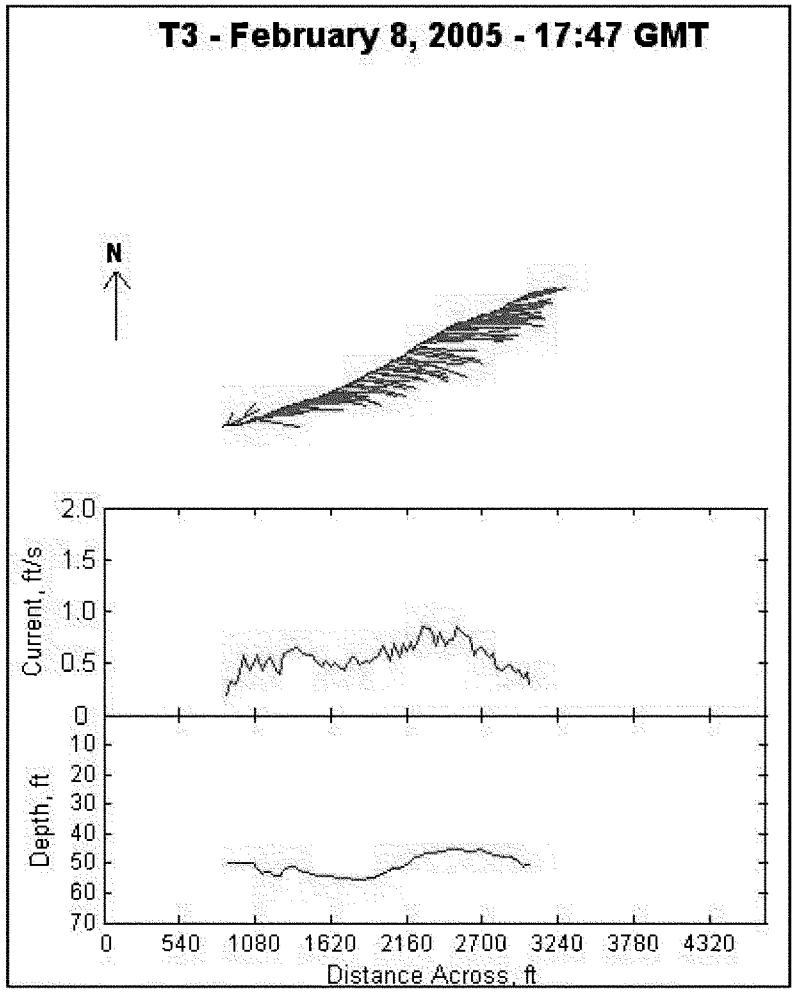

Figure D22. Transect 3 depth-averaged current plots, 8 February 2005, 1747 GMT.

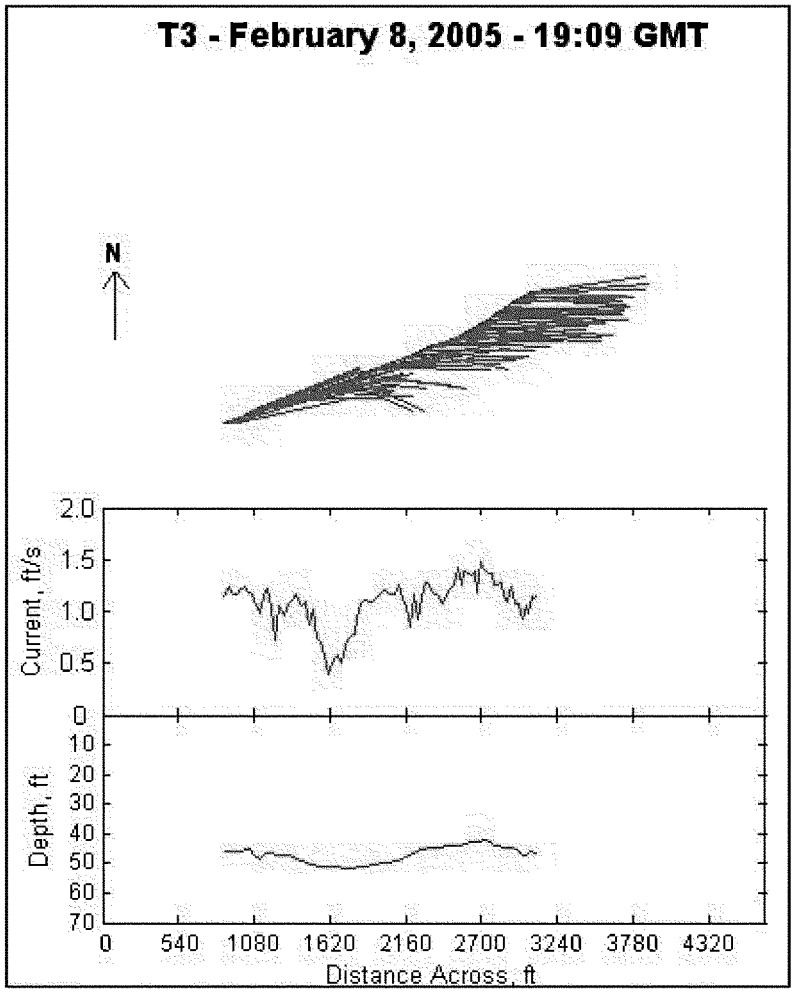

Figure D23. Transect 3 depth-averaged current plots, 8 February 2005, 1909 GMT.

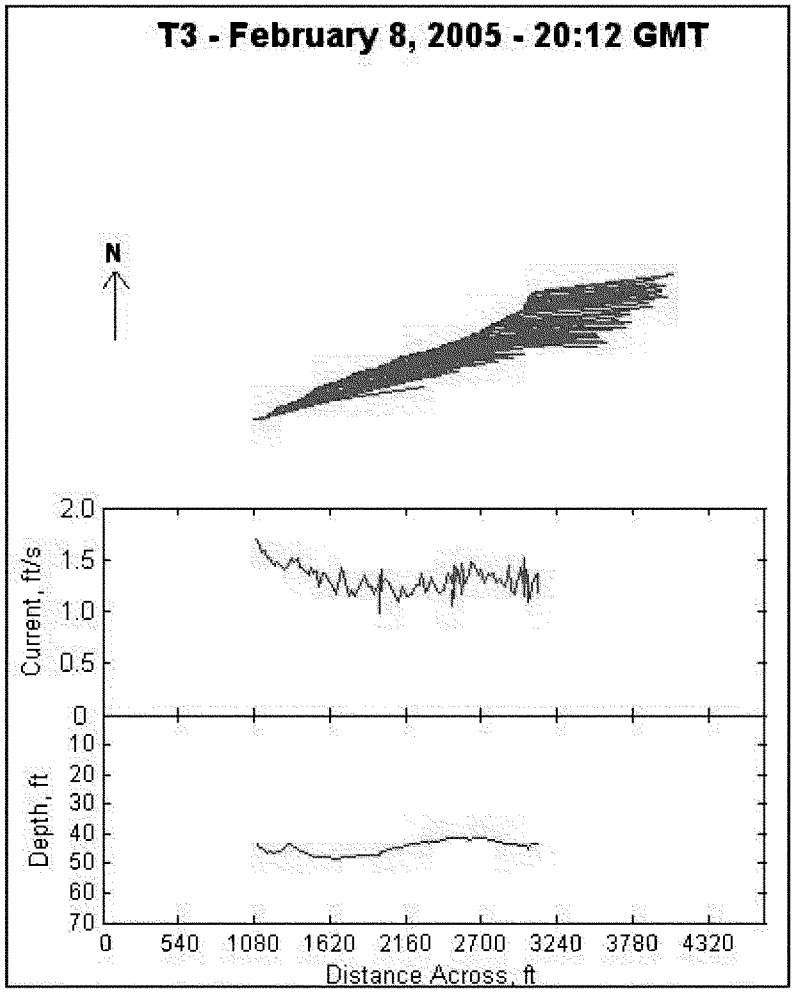

Figure D24. Transect 3 depth-averaged current plots, 8 February 2005, 2012 GMT.

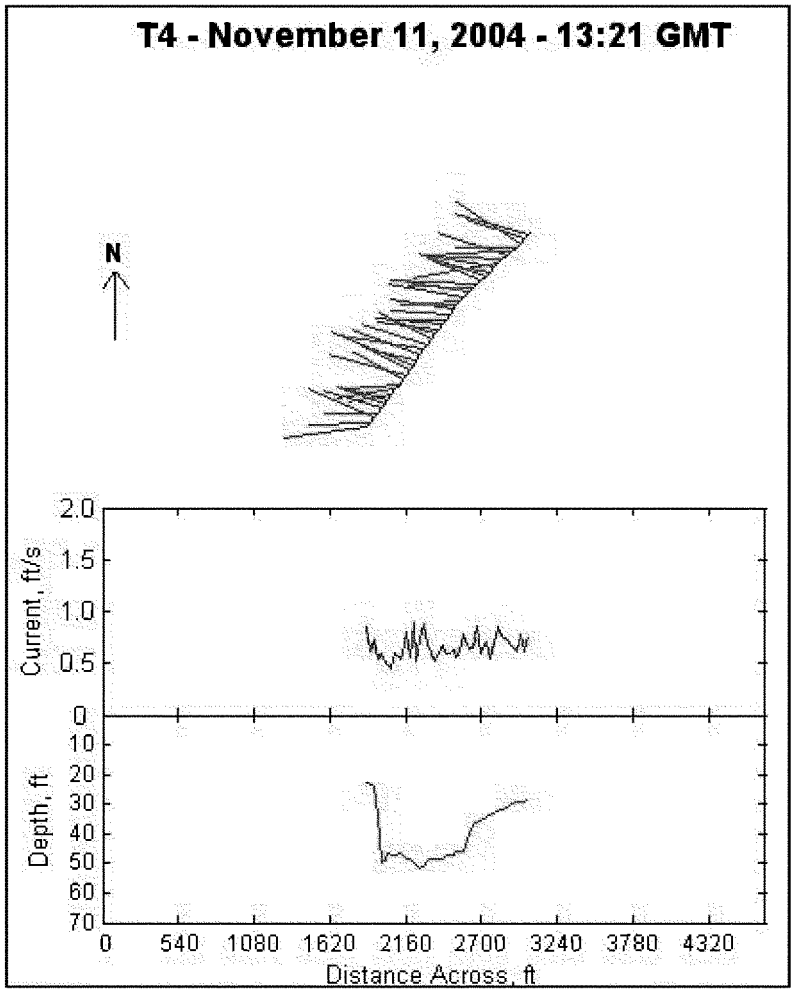

Figure D25. Transect 4 depth-averaged current plots, 11 November 2004, 1321 GMT.

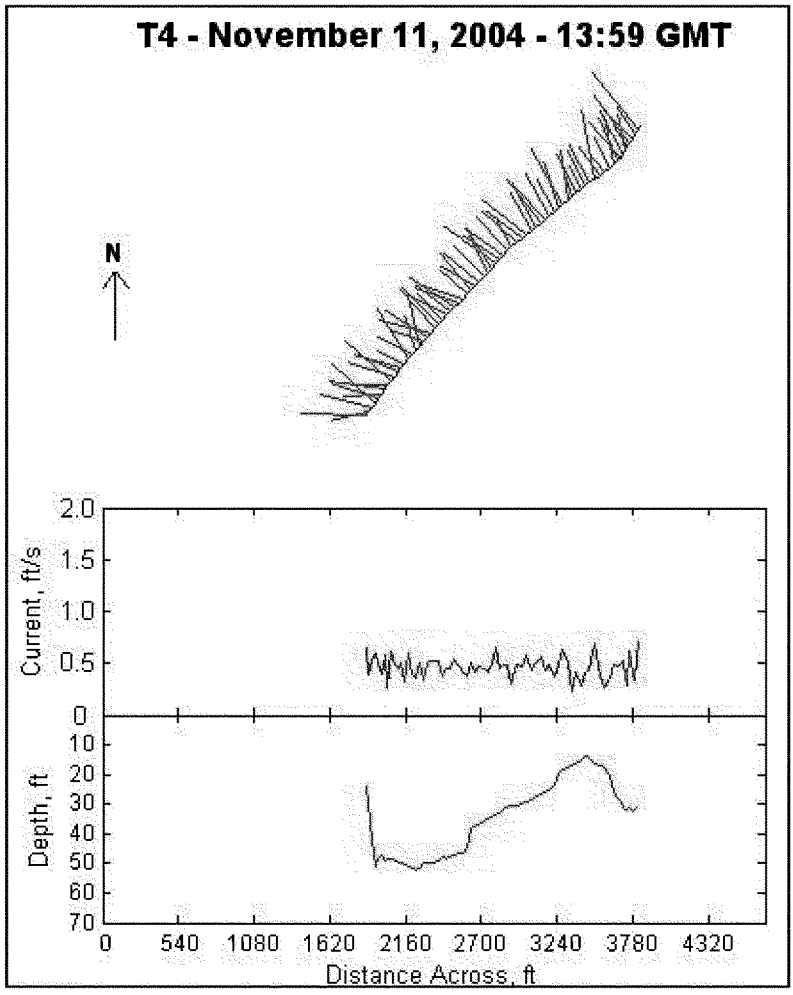

Figure D26. Transect 4 depth-averaged current plots, 11 November 2004, 1359 GMT.

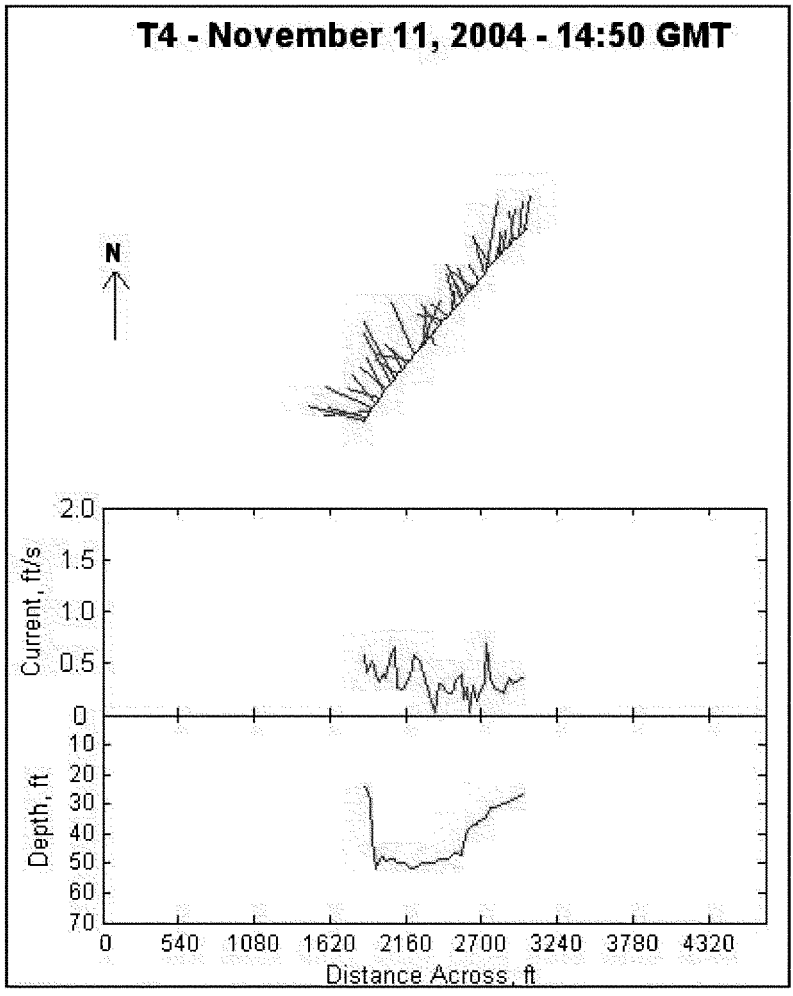

Figure D27. Transect 4 depth-averaged current plots, 11 November 2004, 1450 GMT.

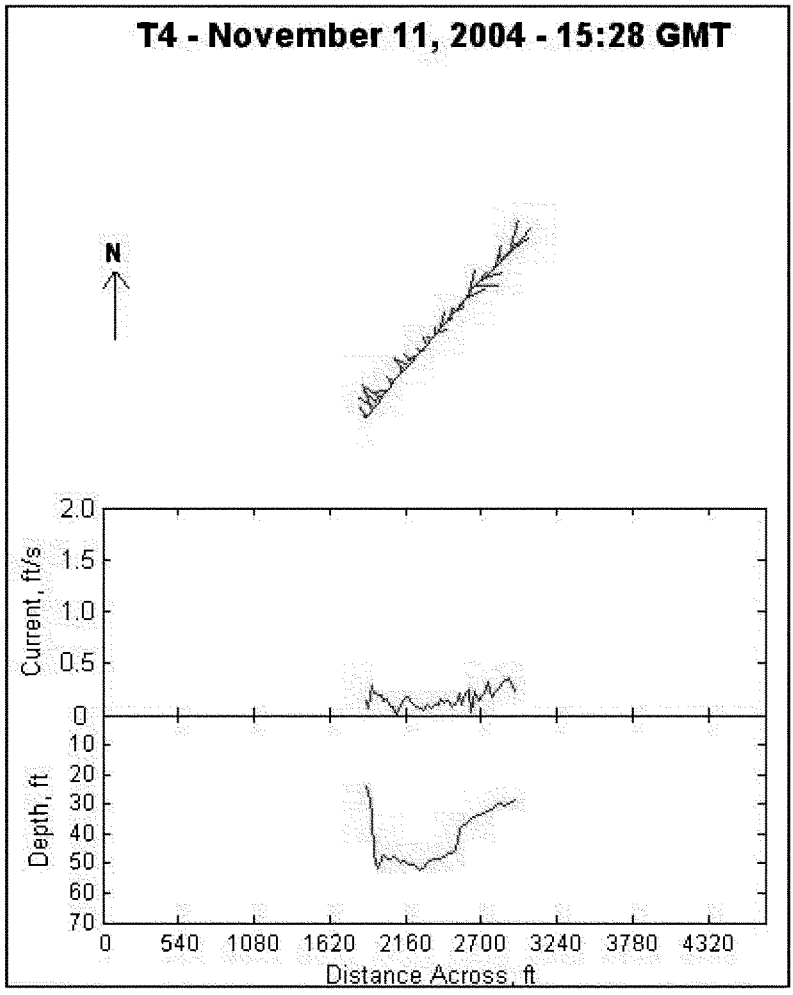

Figure D28. Transect 4 depth-averaged current plots, 11 November 2004, 1528 GMT.

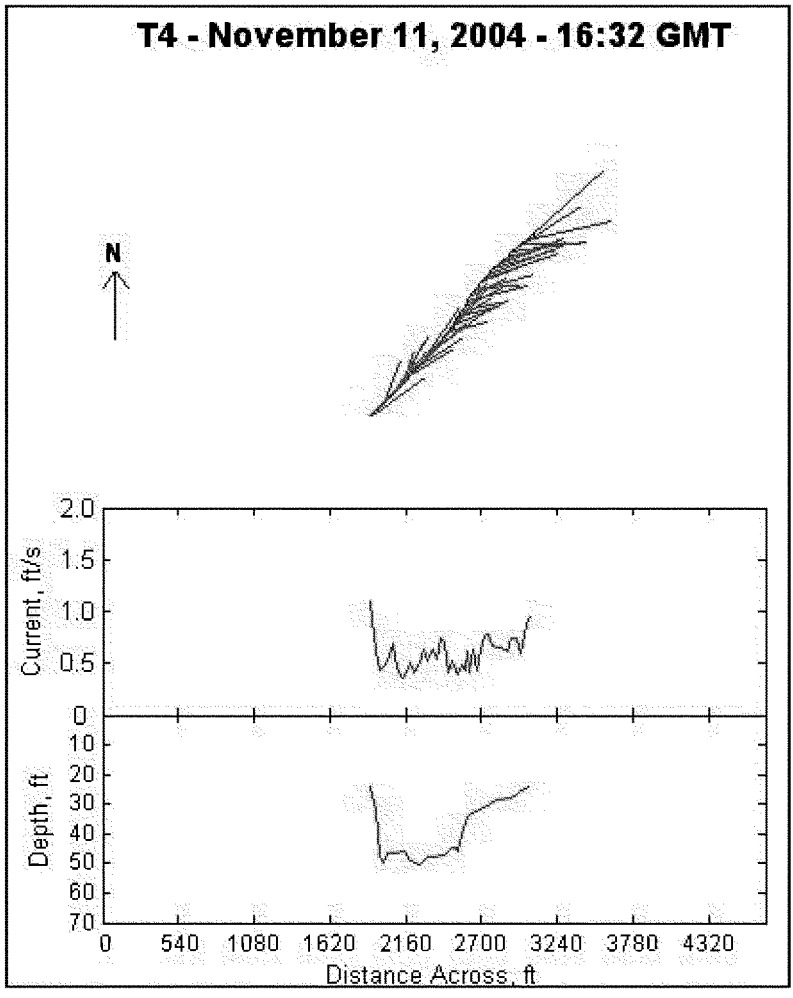

Figure D29. Transect 4 depth-averaged current plots, 11 November 2004, 1632 GMT.

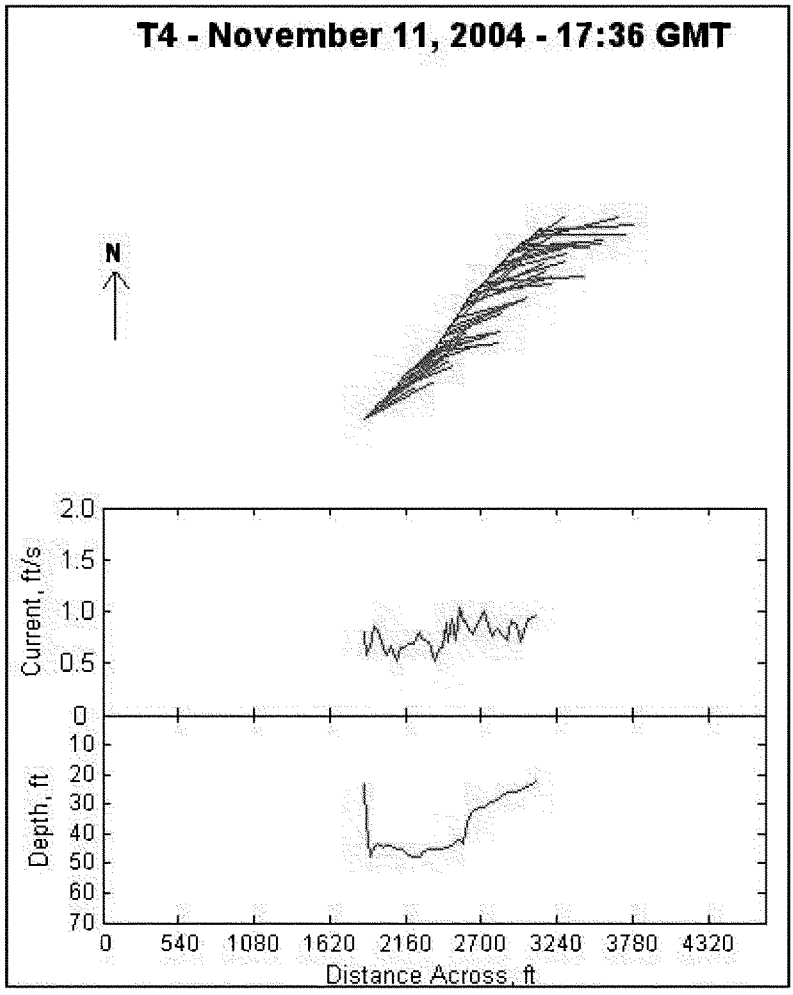

Figure D30. Transect 4 depth-averaged current plots, 11 November 2004, 1736 GMT.

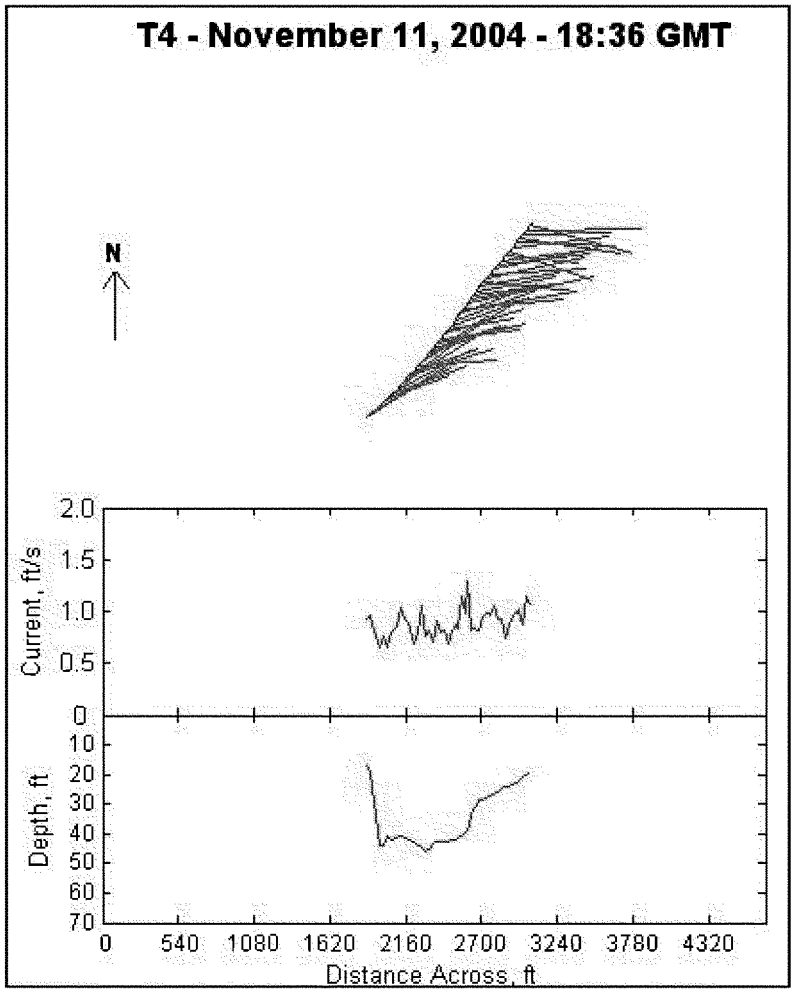

Figure D31. Transect 4 depth-averaged current plots, 11 November 2004, 1836 GMT.

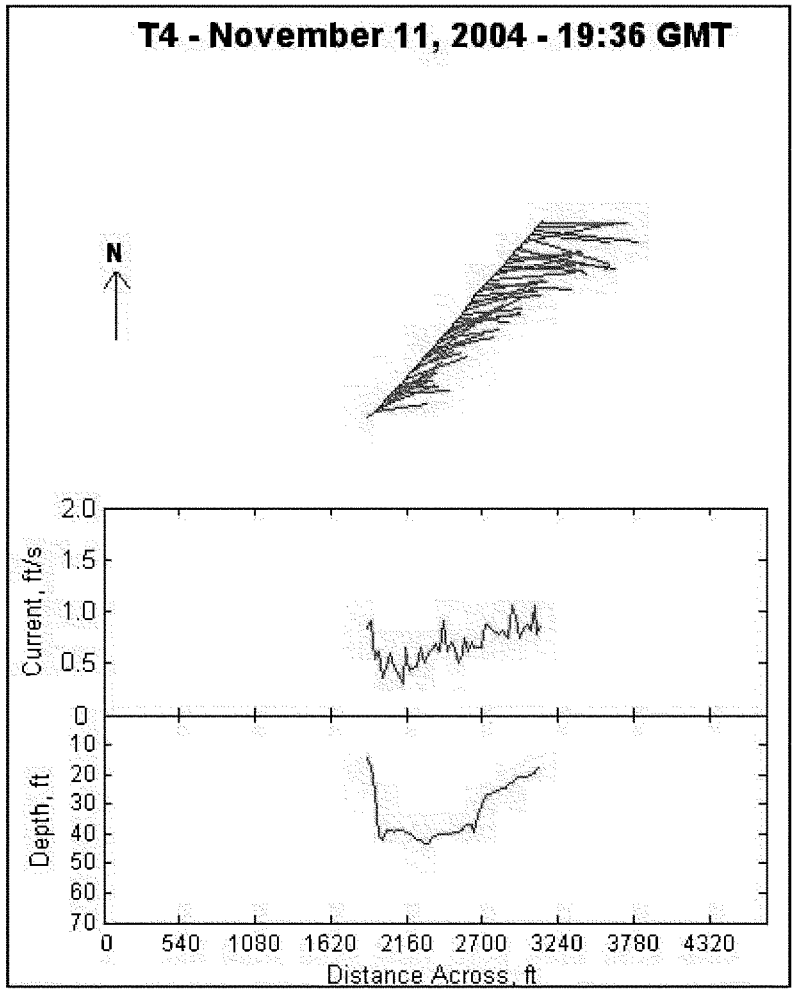

Figure D32. Transect 4 depth-averaged current plots, 11 November 2004, 1936 GMT.

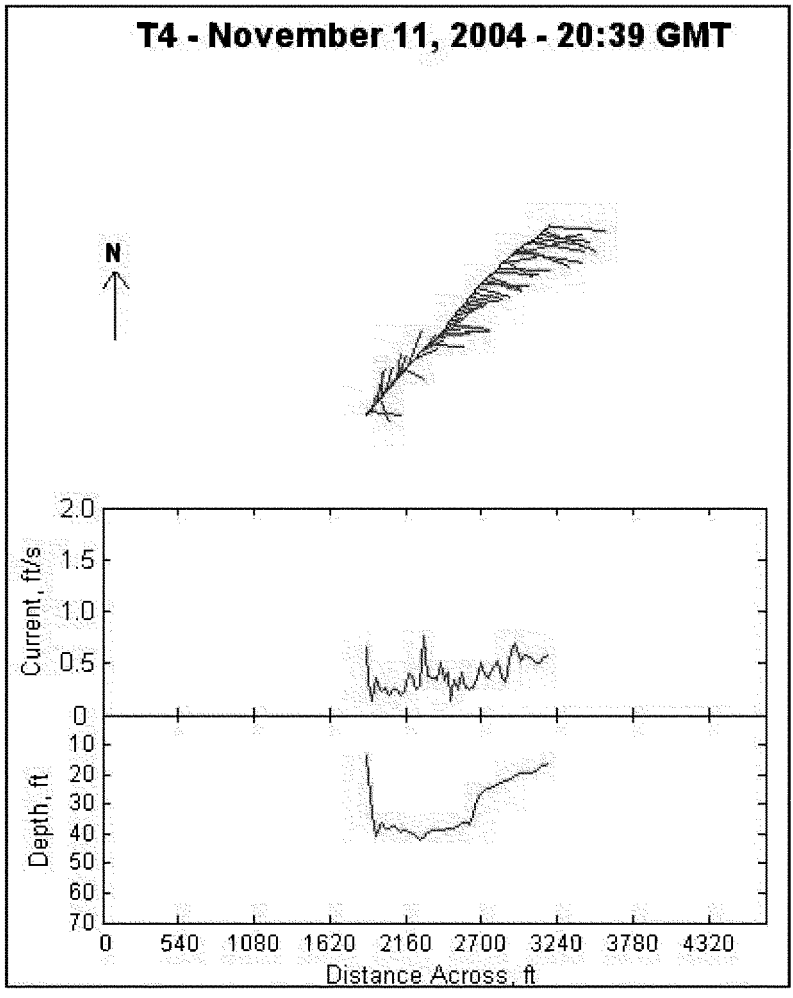

Figure D33. Transect 4 depth-averaged current plots, 11 November 2004, 2039 GMT.

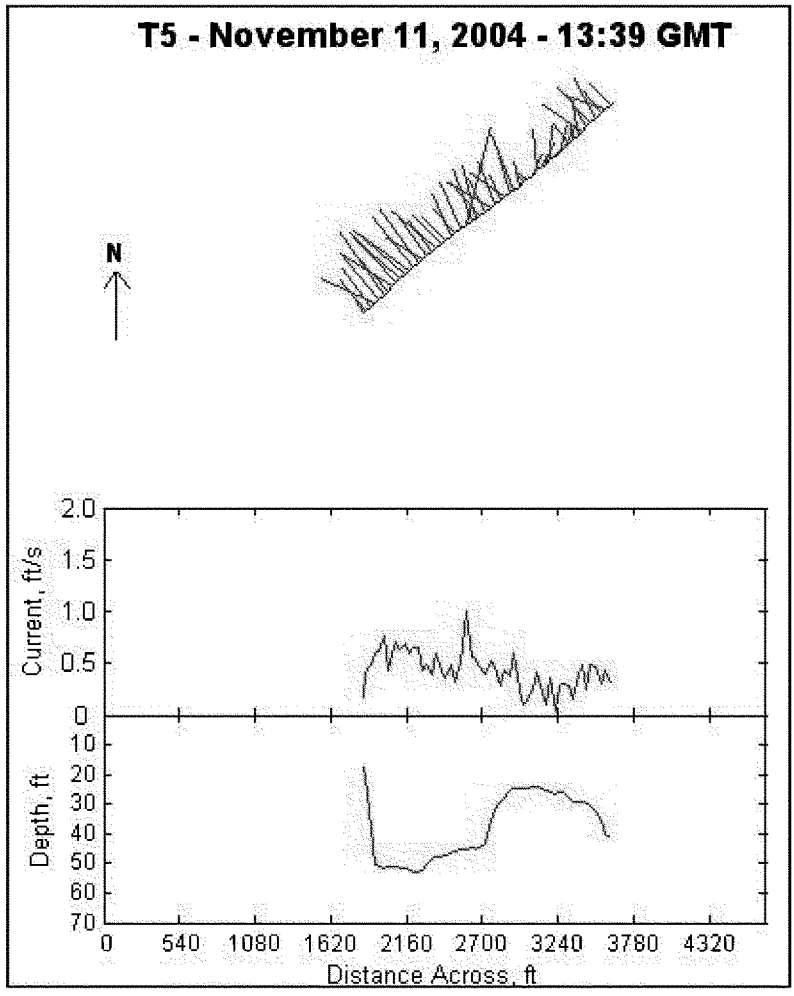

Figure D34. Transect 5 depth-averaged current plots, 11 November 2004, 1339 GMT.

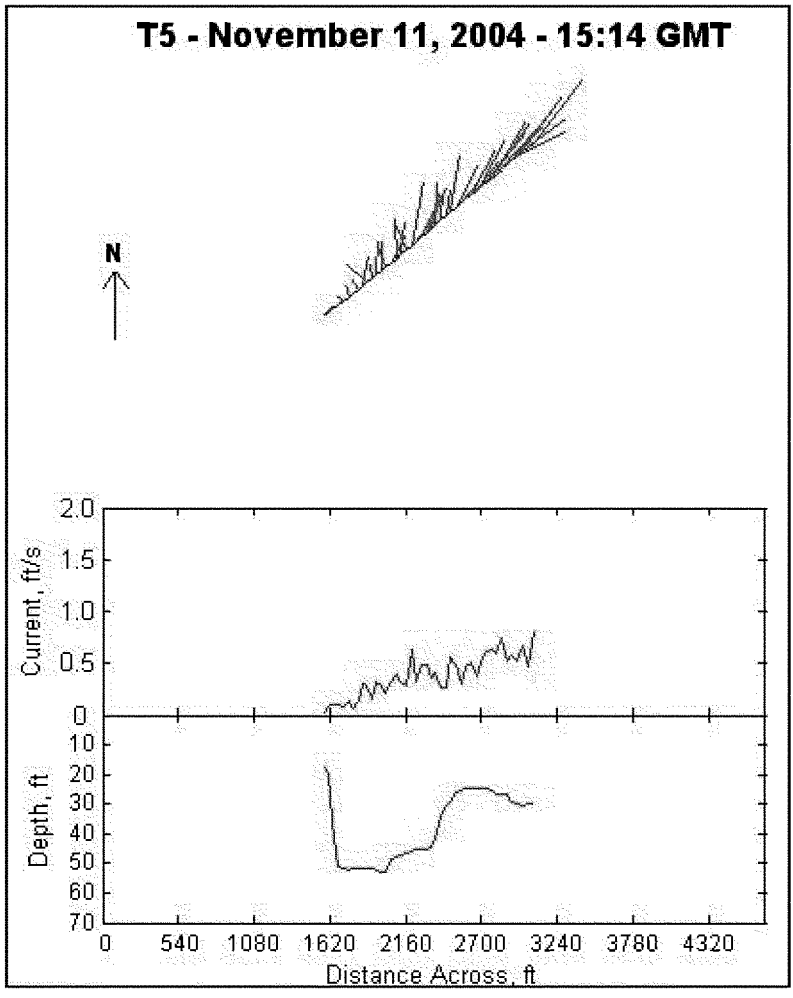

Figure D35. Transect 5 depth-averaged current plots, 11 November 2004, 1514 GMT.

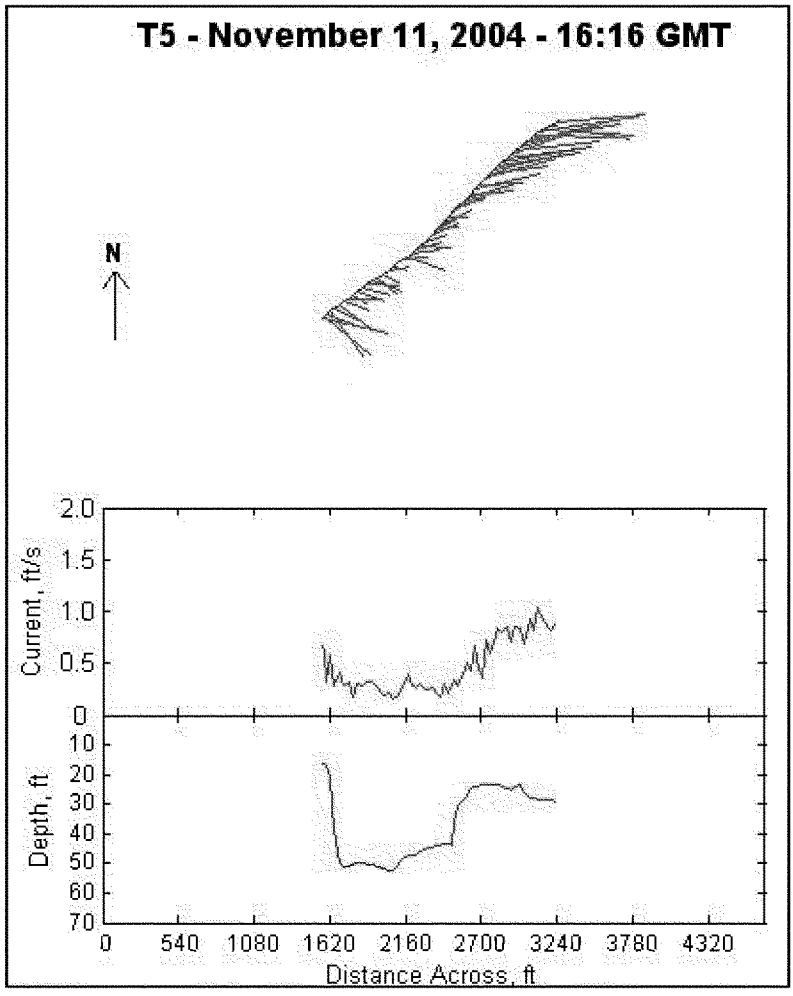

Figure D36. Transect 5 depth-averaged current plots, 11 November 2004, 1616 GMT.

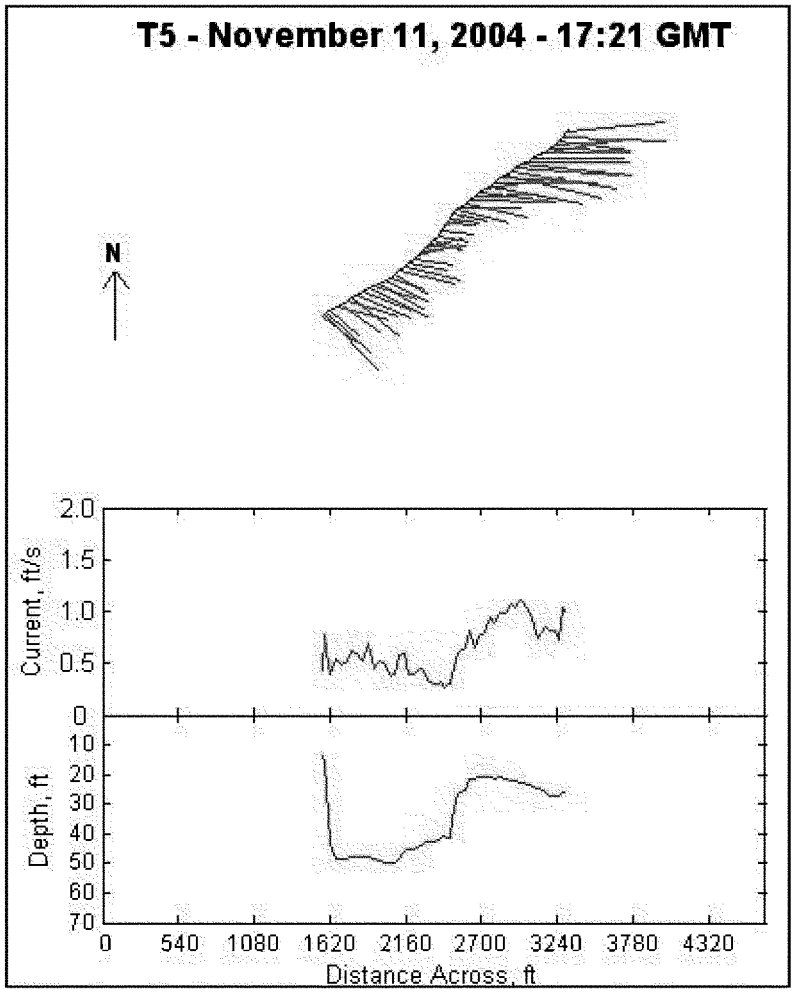

Figure D37. Transect 5 depth-averaged current plots, 11 November 2004, 1721 GMT.

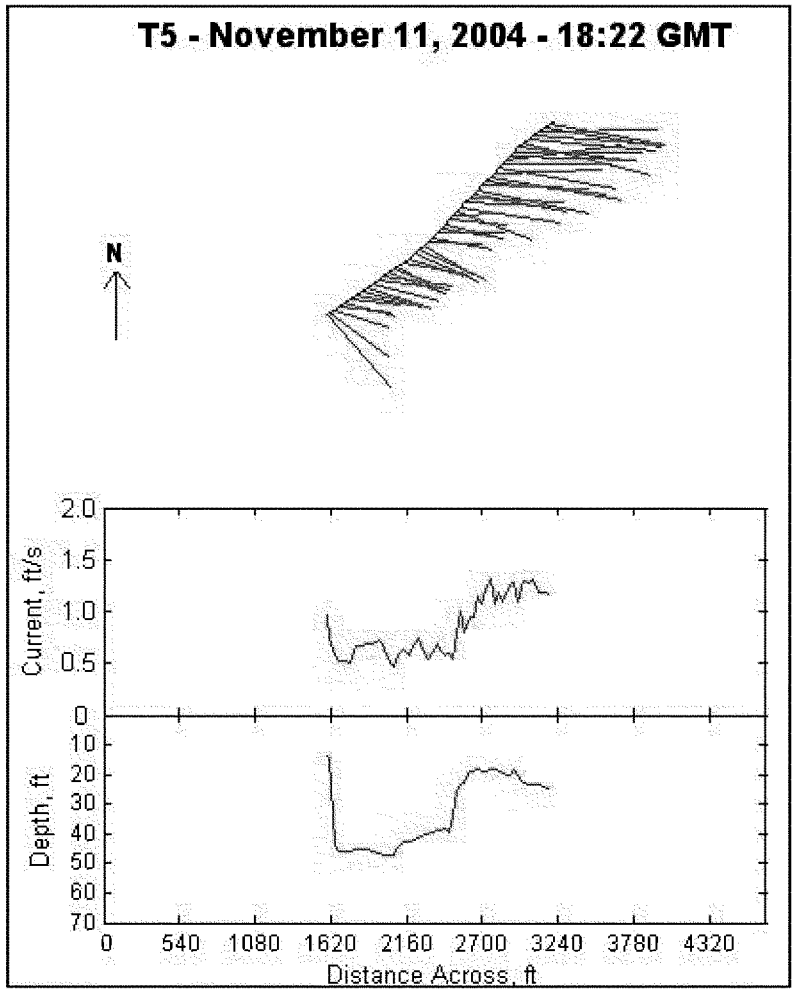

Figure D38. Transect 5 depth-averaged current plots, 11 November 2004, 1822 GMT.

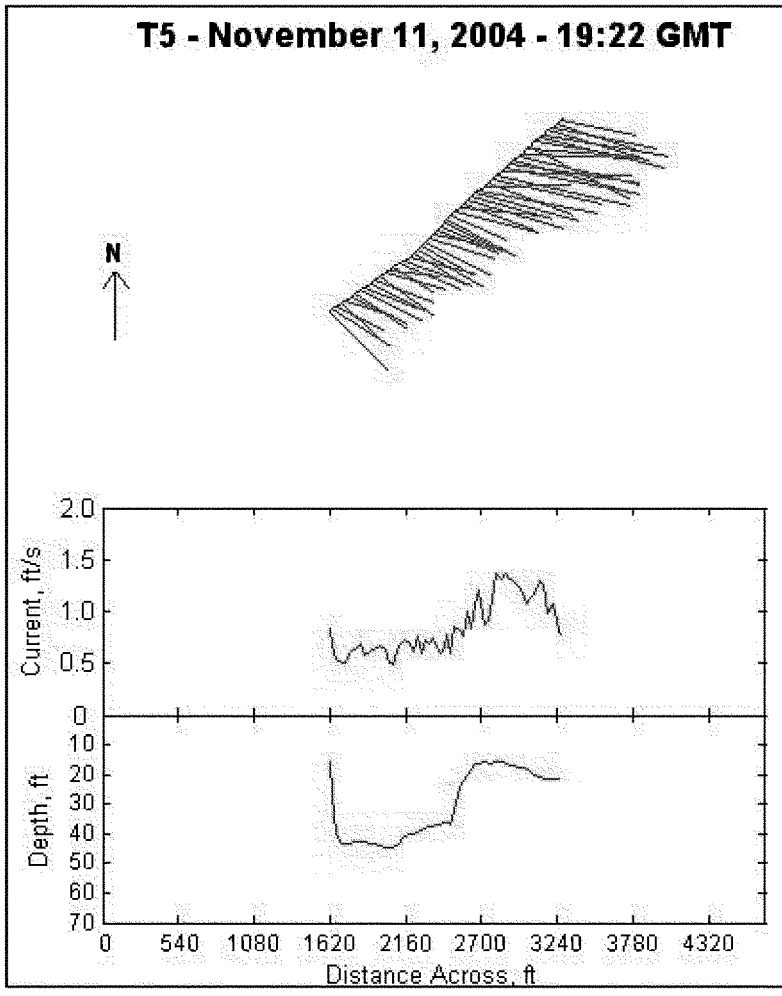

Figure D39. Transect 5 depth-averaged current plots, 11 November 2004, 1922 GMT.

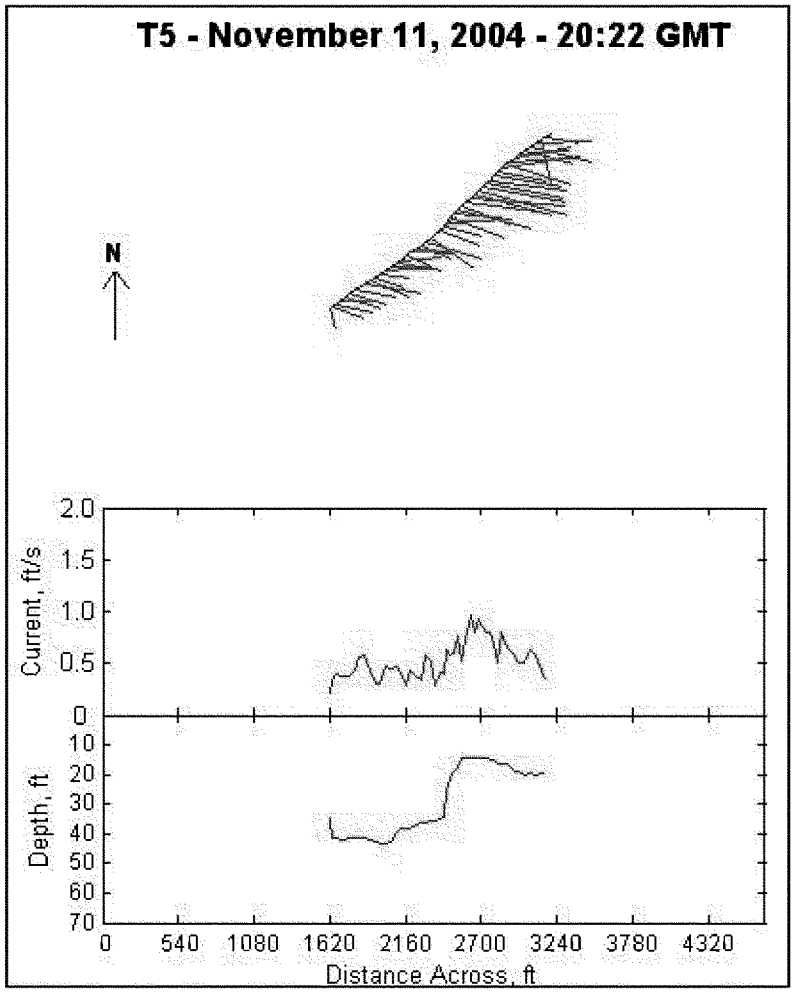

Figure D40. Transect 5 depth-averaged current plots, 11 November 2004, 2022 GMT.

Appendix E: Transect Current Surveys, Current Velocity Cross Sections

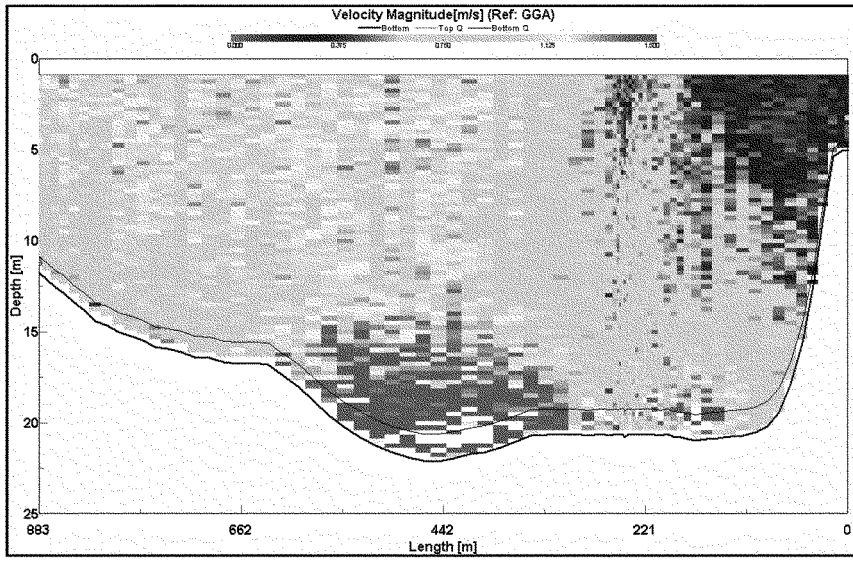

Figure E1. Transect 1 current velocity cross sections, 8 February 2005, 1341 GMT.

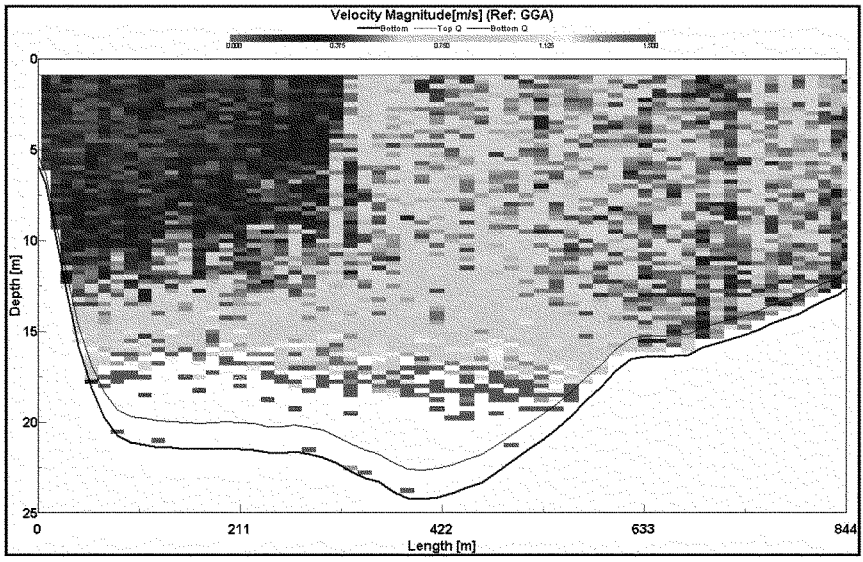

Figure E2. Transect 1 current velocity cross sections, 8 February 2005, 1450 GMT.

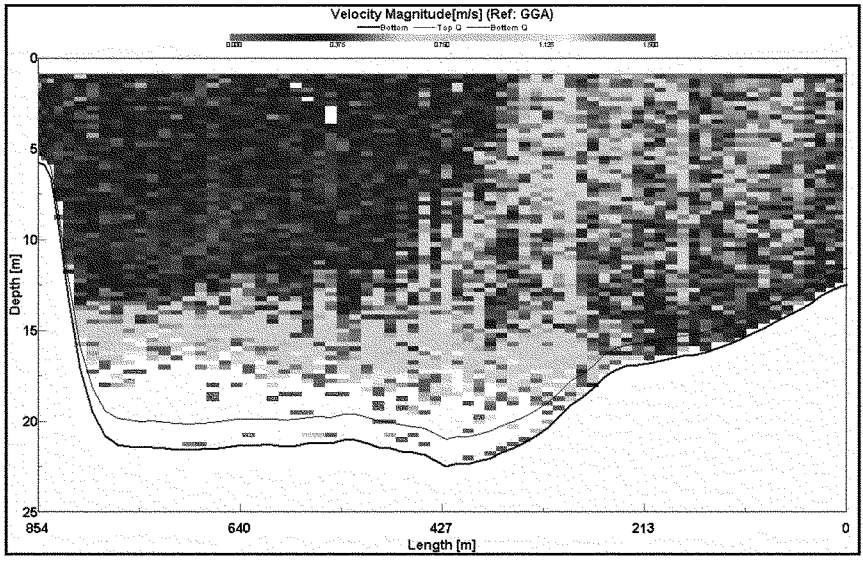

Figure E3. Transect 1 current velocity cross sections, 8 February 2005, 1459 GMT.

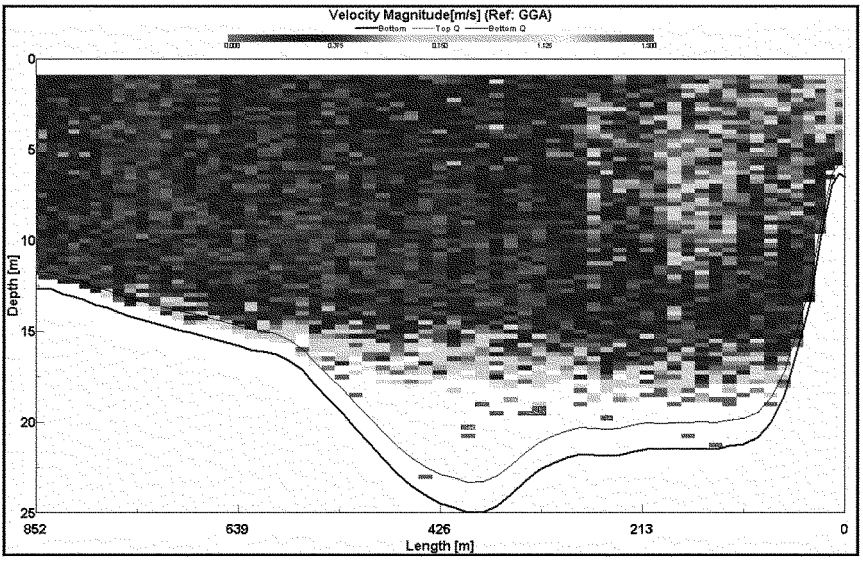

Figure E4. Transect 1 current velocity cross sections, 8 February 2005, 1604 GMT.

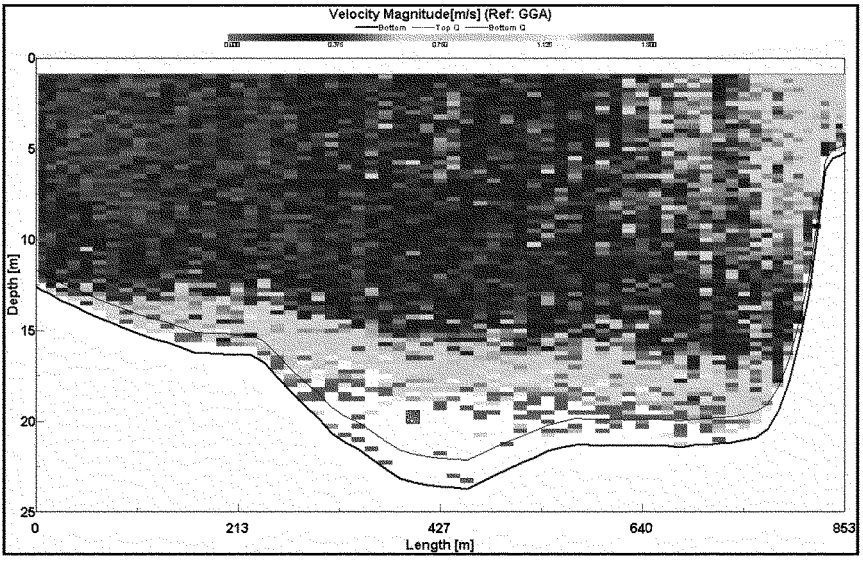

Figure E5. Transect 1 current velocity cross sections, 8 February 2005, 1614 GMT.

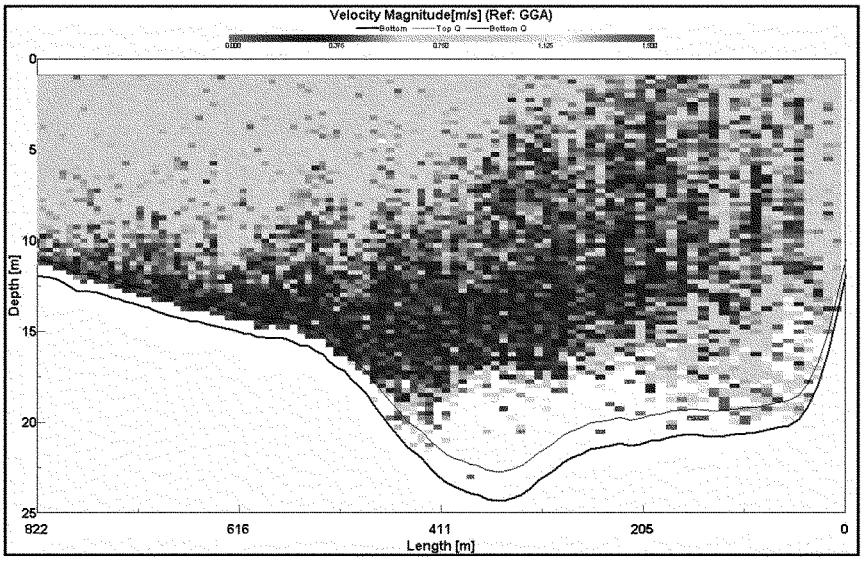

Figure E6. Transect 1 current velocity cross sections, 8 February 2005, 1723 GMT.

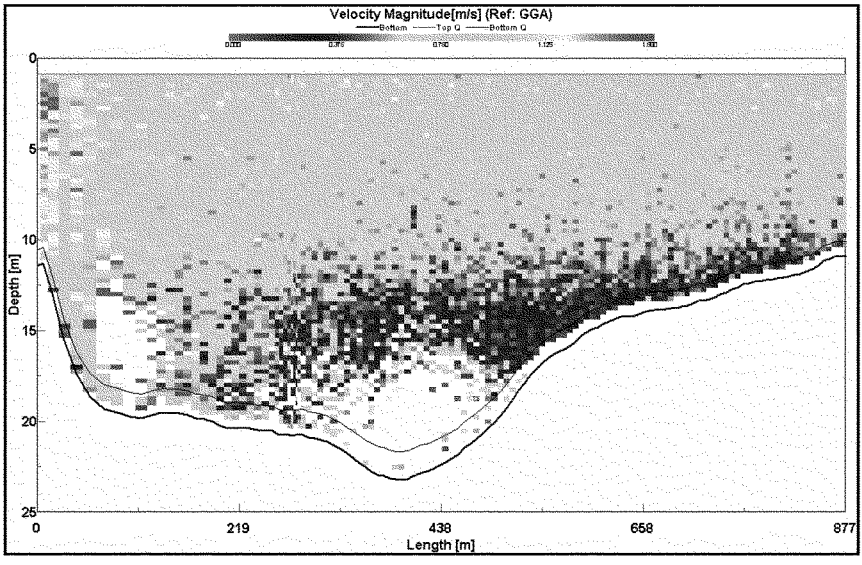

Figure E7. Transect 1 current velocity cross sections, 8 February 2005, 1840 GMT.

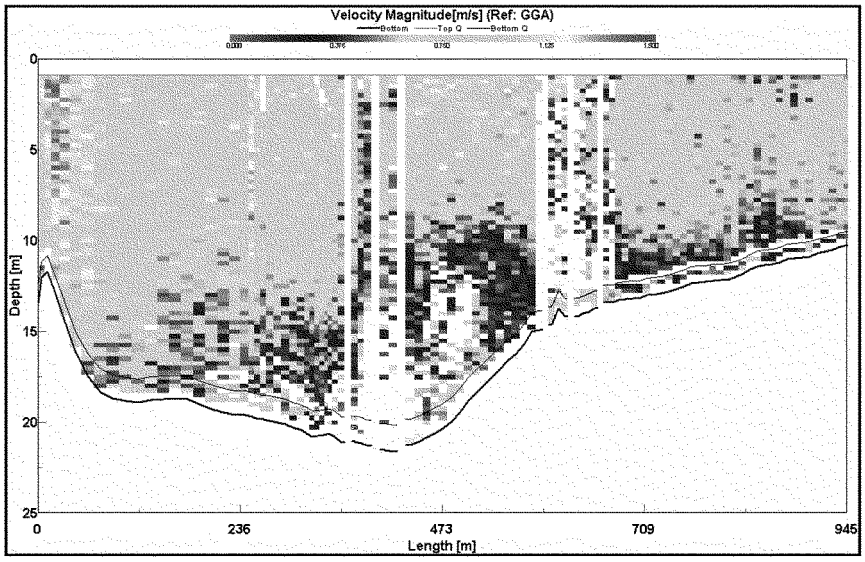

Figure E8. Transect 1 current velocity cross sections, 8 February 2005, 2048 GMT.

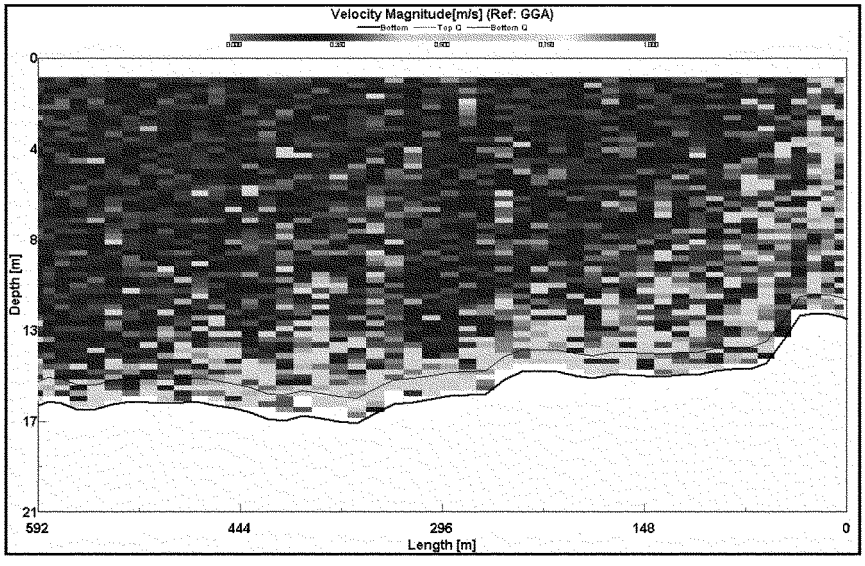

Figure E9. Transect 2 current velocity cross sections, 8 February 2005, 1415 GMT.

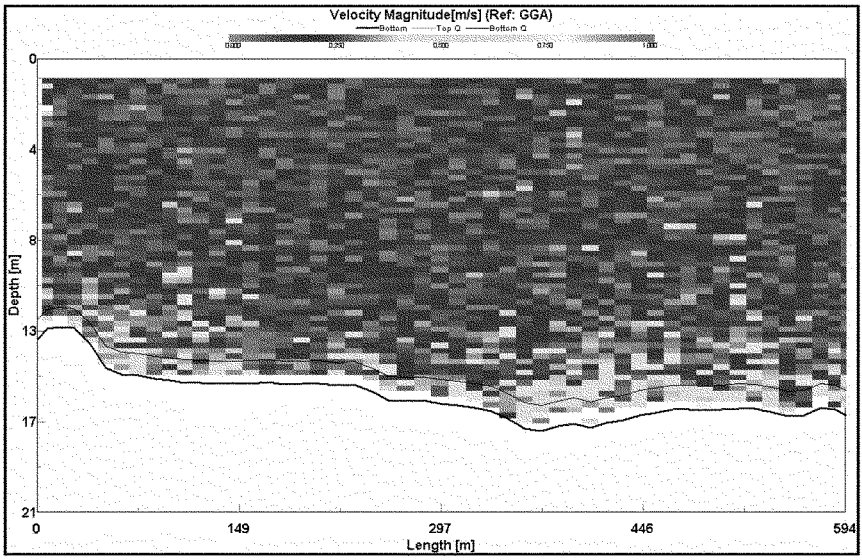

Figure E10. Transect 2 current velocity cross sections, 8 February 2005, 1532 GMT.

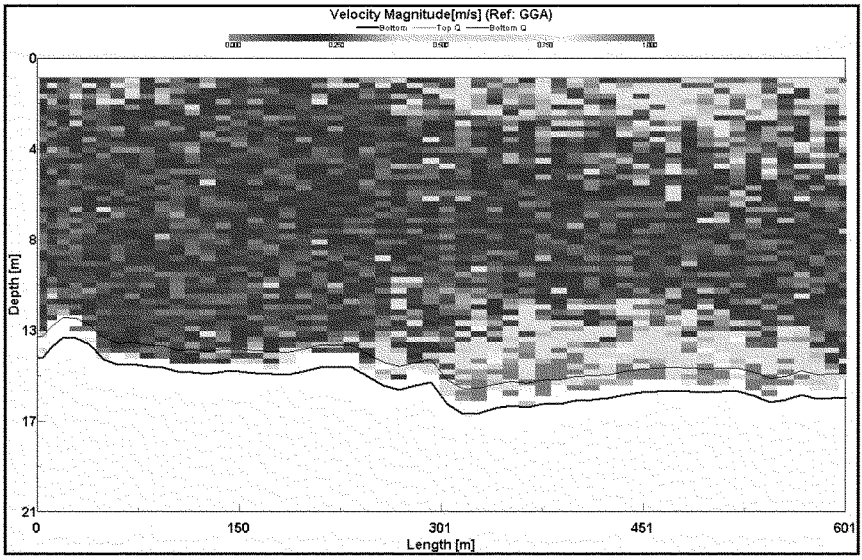

Figure E11. Transect 2 current velocity cross sections, 8 February 2005, 1649 GMT.

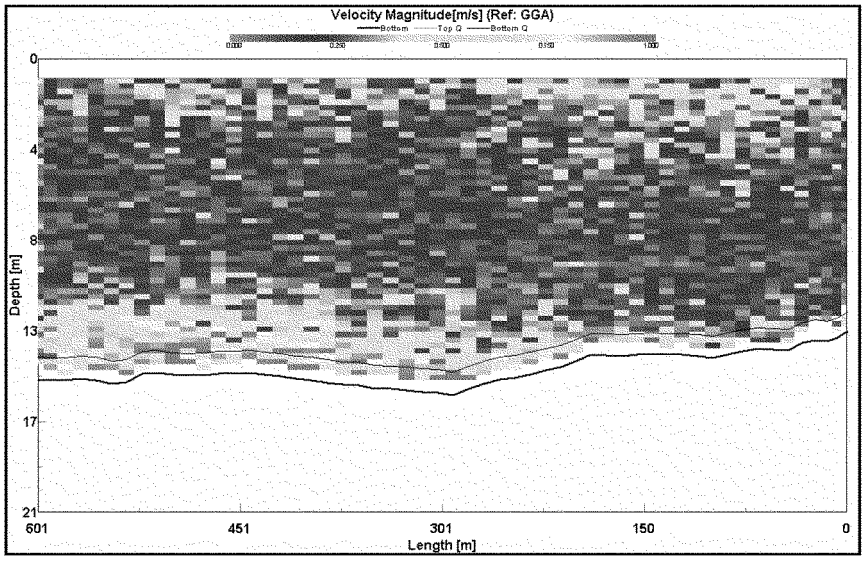

Figure E12. Transect 2 current velocity cross sections, 8 February 2005, 1803 GMT.

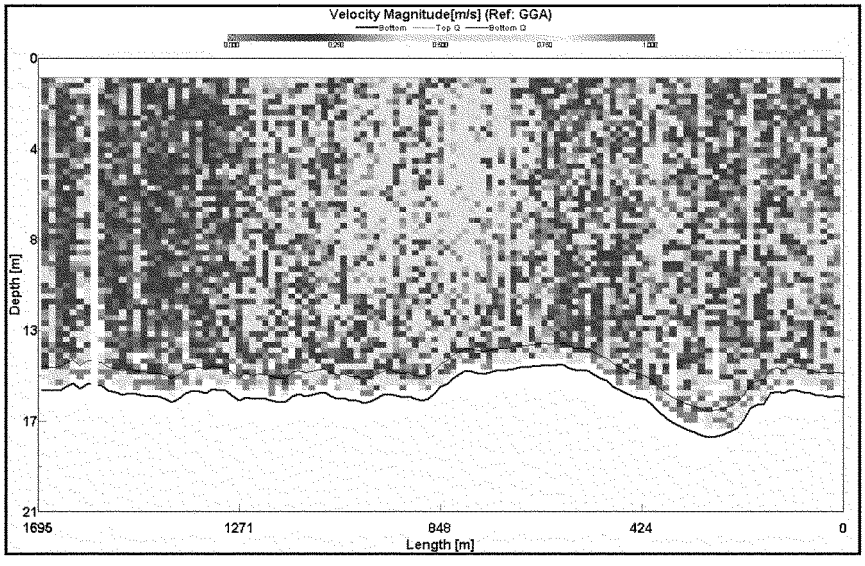

Figure E13. Transect 3 current velocity cross sections, 11 November 2004, 1424 GMT.

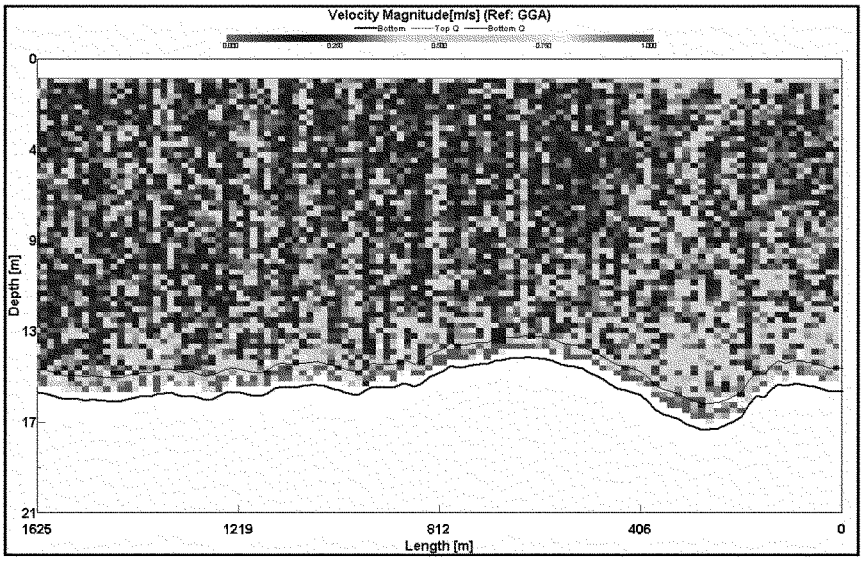

Figure E14. Transect 3 current velocity cross sections, 11 November 2004, 1545 GMT.

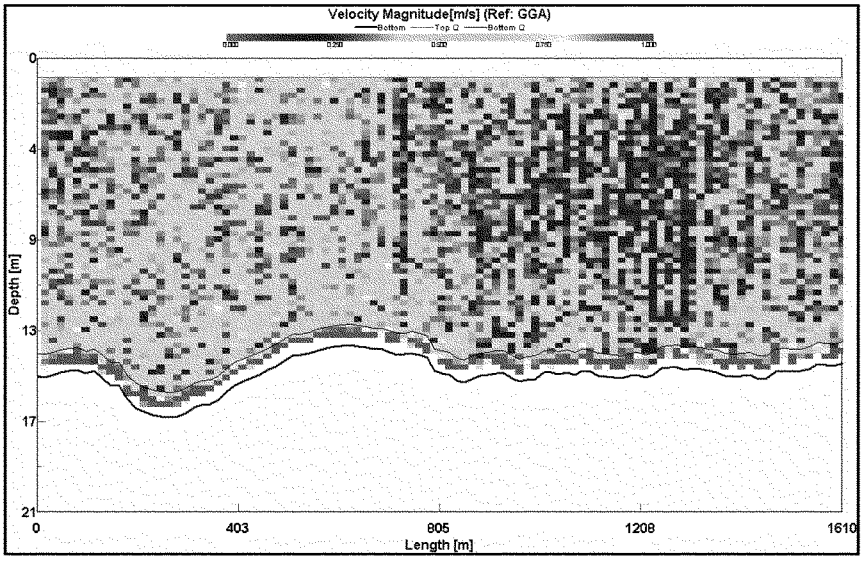

Figure E15. Transect 3 current velocity cross sections, 11 November 2004, 1649 GMT.

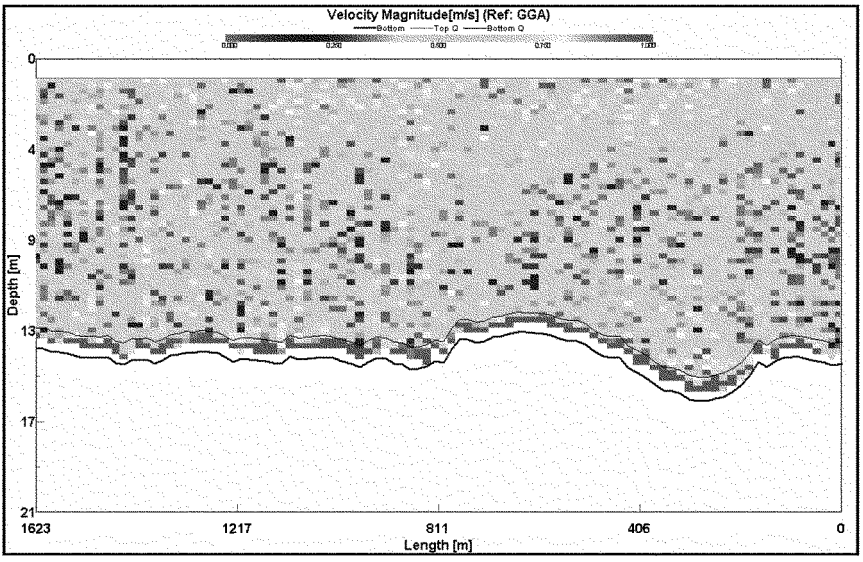

Figure E16. Transect 3 current velocity cross sections, 11 November 2004, 1748 GMT.

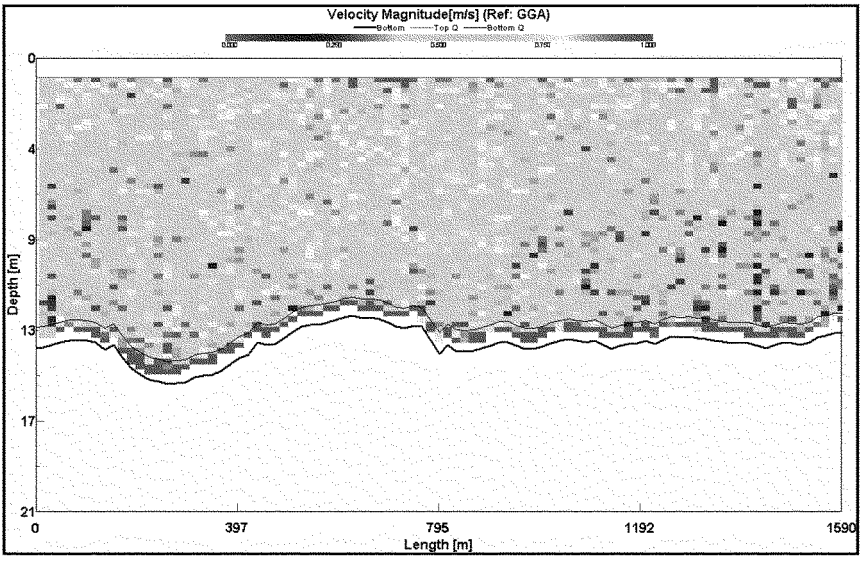

Figure E17. Transect 3 current velocity cross sections, 11 November 2004, 1851 GMT.

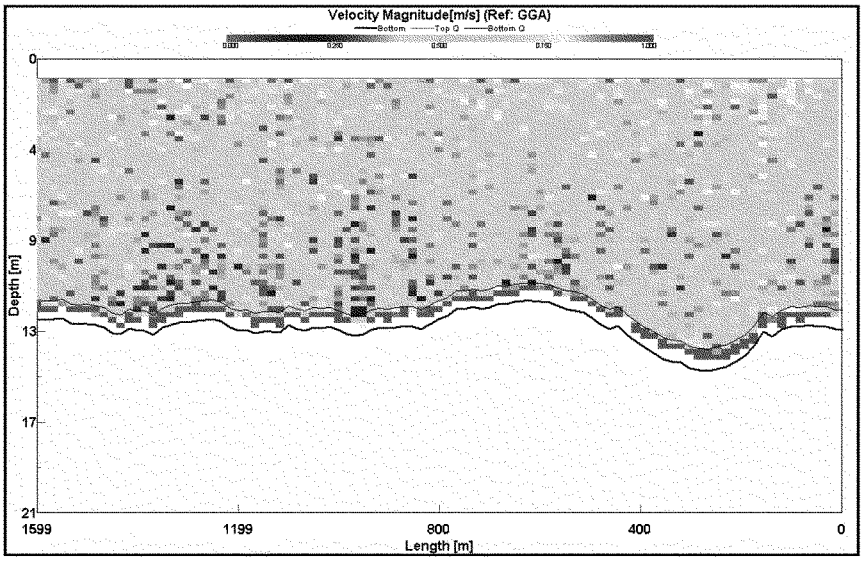

Figure E18. Transect 3 current velocity cross sections, 11 November 2004, 1951 GMT.

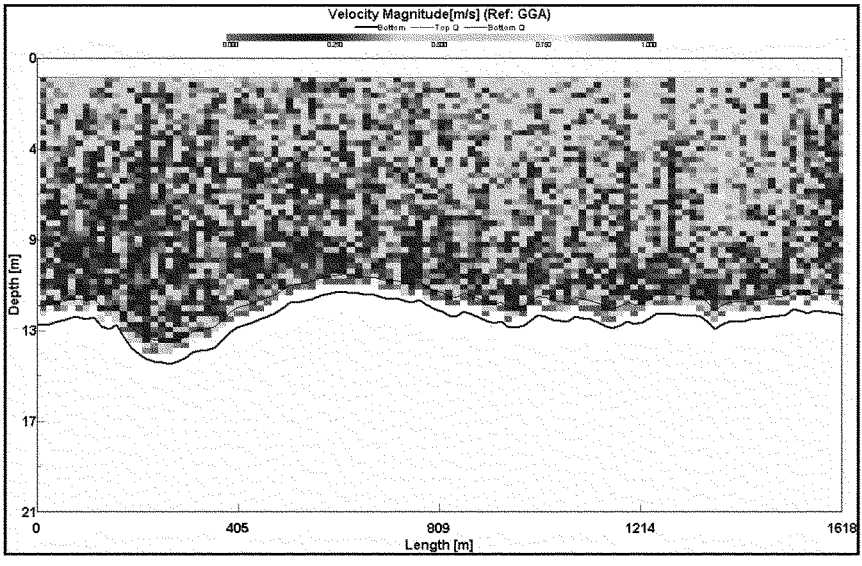

Figure E19. Transect 3 current velocity cross sections, 11 November 2004, 2055 GMT.

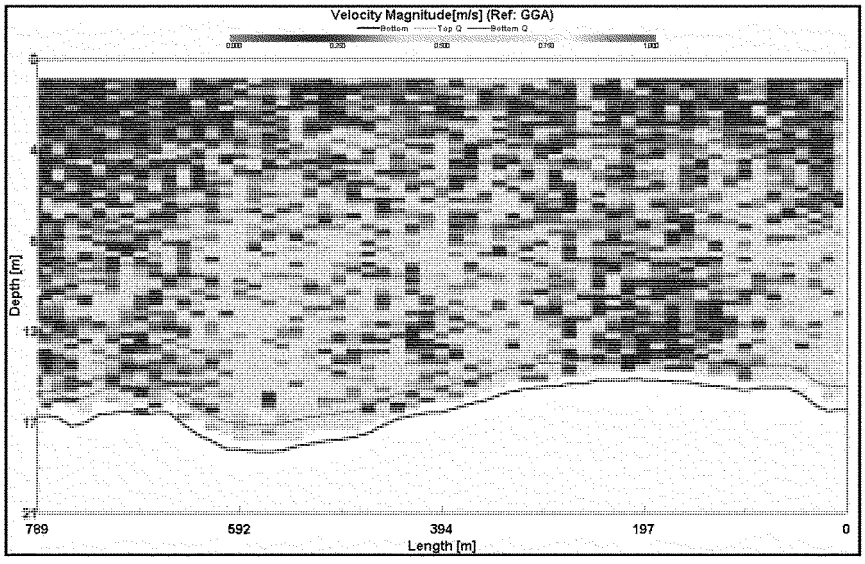

Figure E20. Transect 3 current velocity cross sections, 8 February 2005, 1520 GMT.

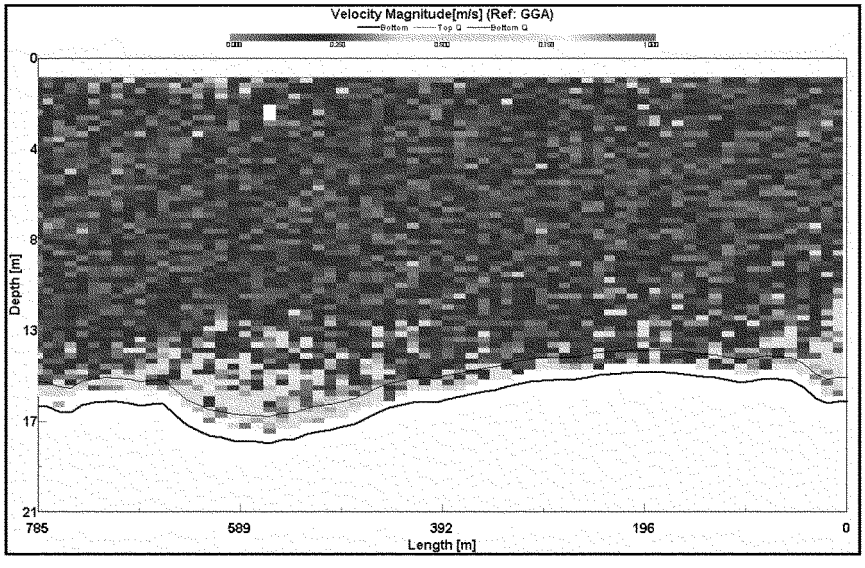

Figure E21. Transect 3 current velocity cross sections, 8 February 2005, 1636 GMT.

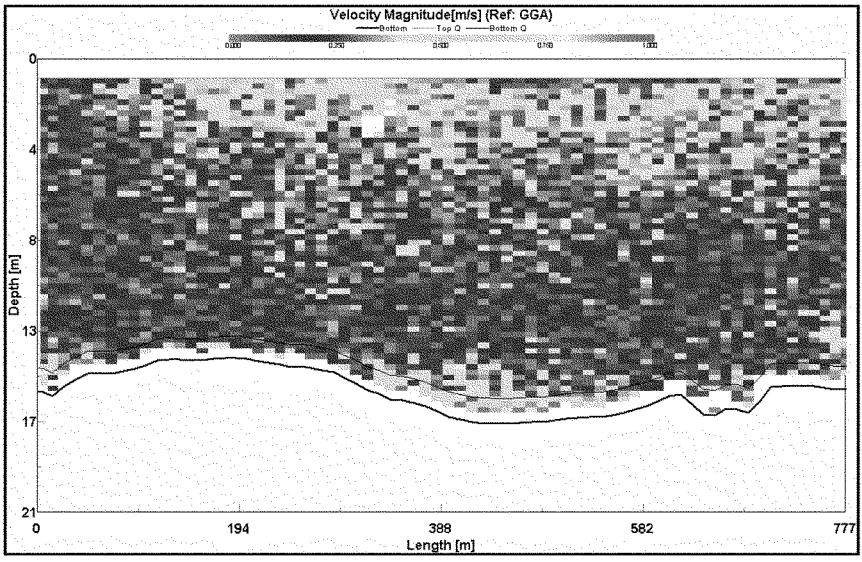

Figure E22. Transect 3 current velocity cross sections, 8 February 2005, 1747 GMT.

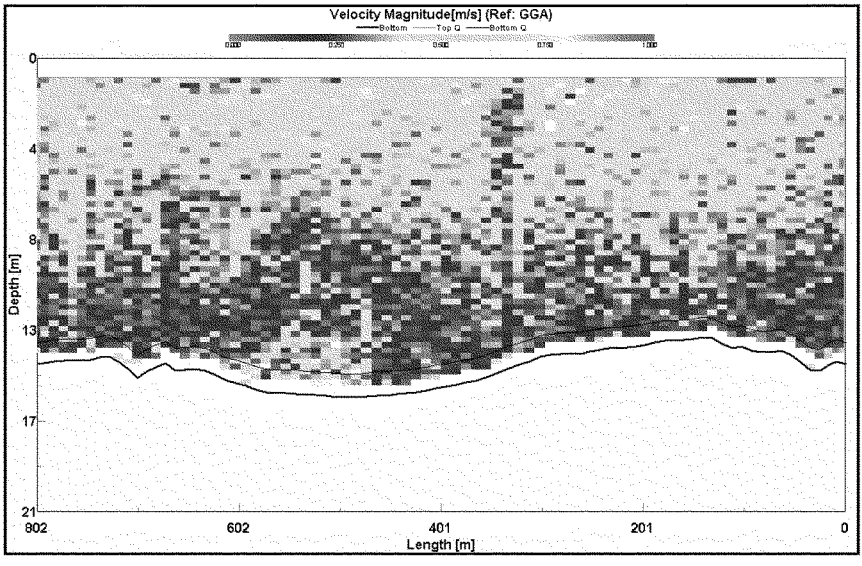

Figure E23. Transect 3 current velocity cross sections, 8 February 2005, 1909 GMT.

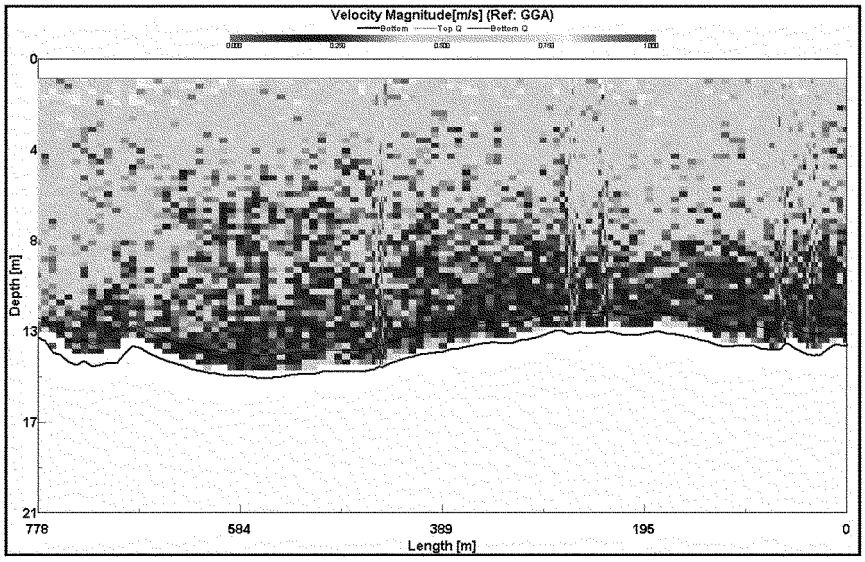

Figure E24. Transect 3 current velocity cross sections, 8 February 2005, 2012 GMT.

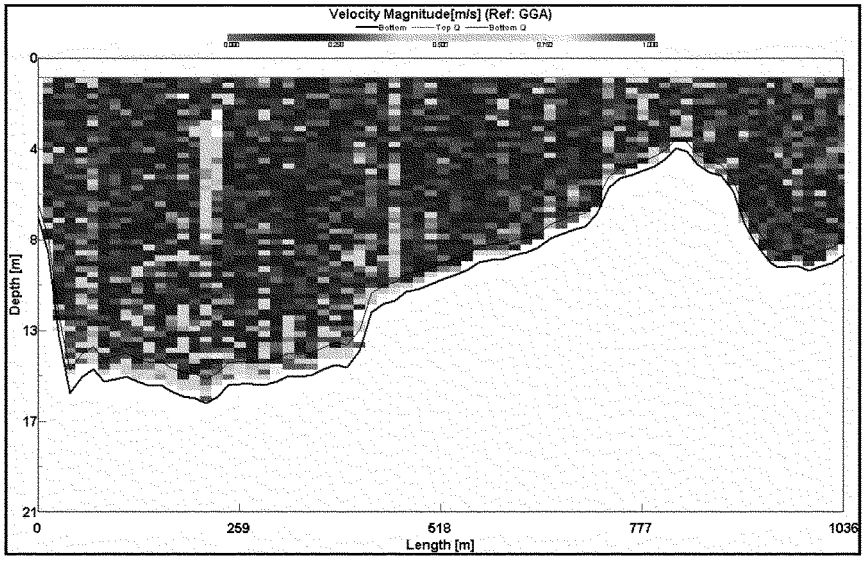

Figure E25. Transect 4 current velocity cross sections, 11 November 2004, 1359 GMT.

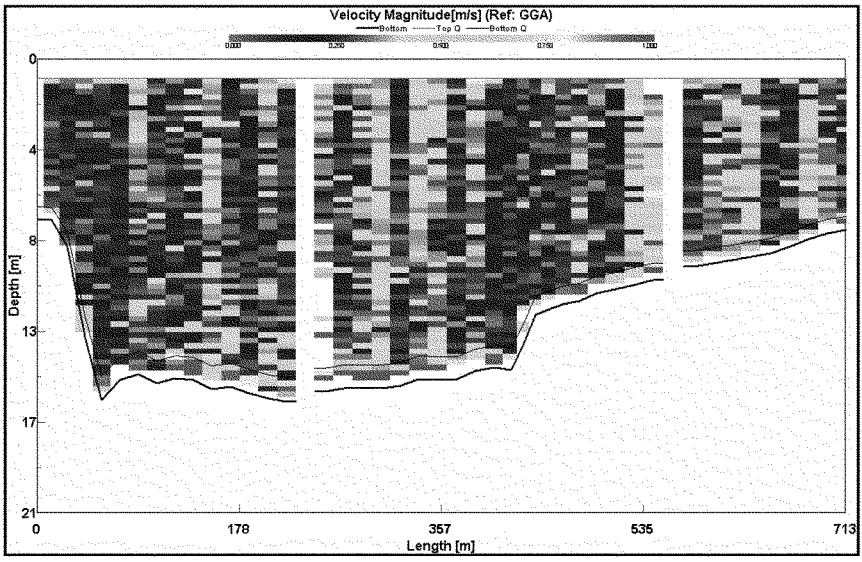

Figure E26. Transect 4 current velocity cross sections, 11 November 2004, 1450 GMT.

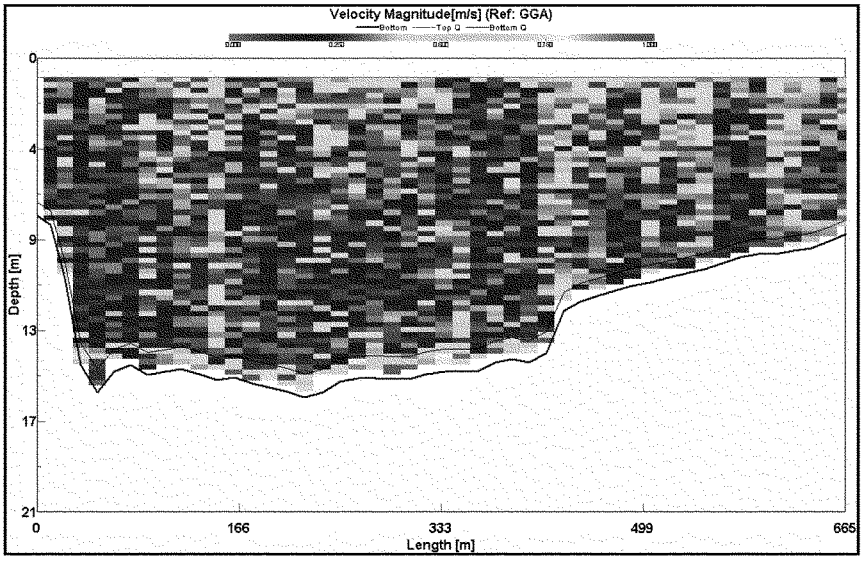

Figure E27. Transect 4 current velocity cross sections, 11 November 2004, 1528 GMT.

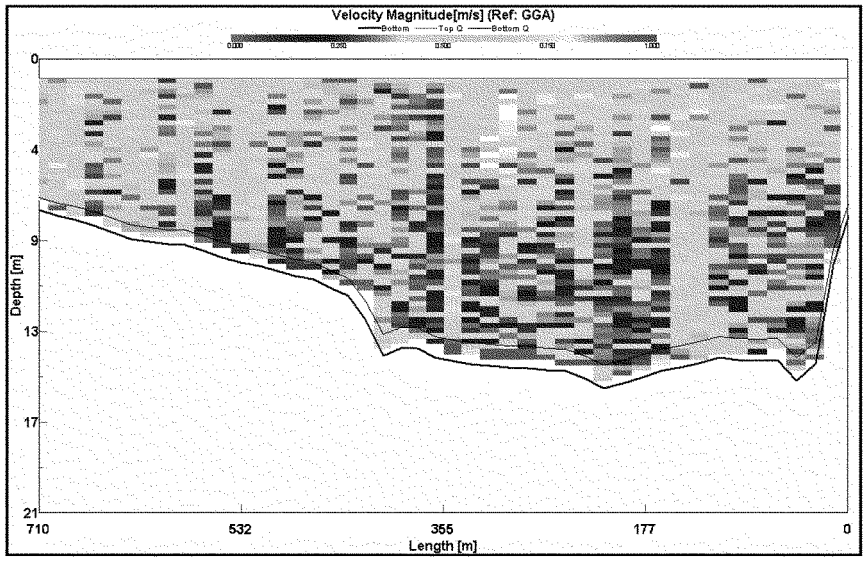

Figure E28. Transect 4 current velocity cross sections, 11 November 2004, 1632 GMT.

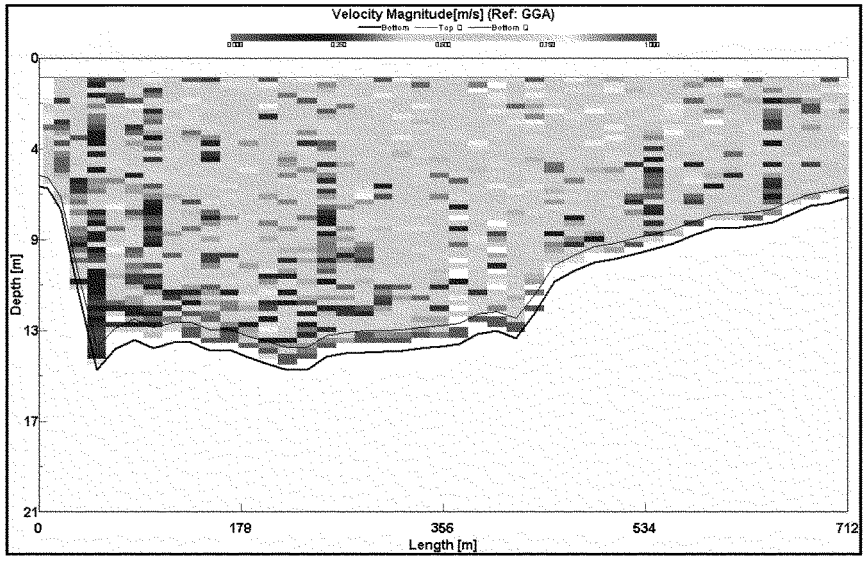

Figure E29. Transect 4 current velocity cross sections, 11 November 2004, 1736 GMT.

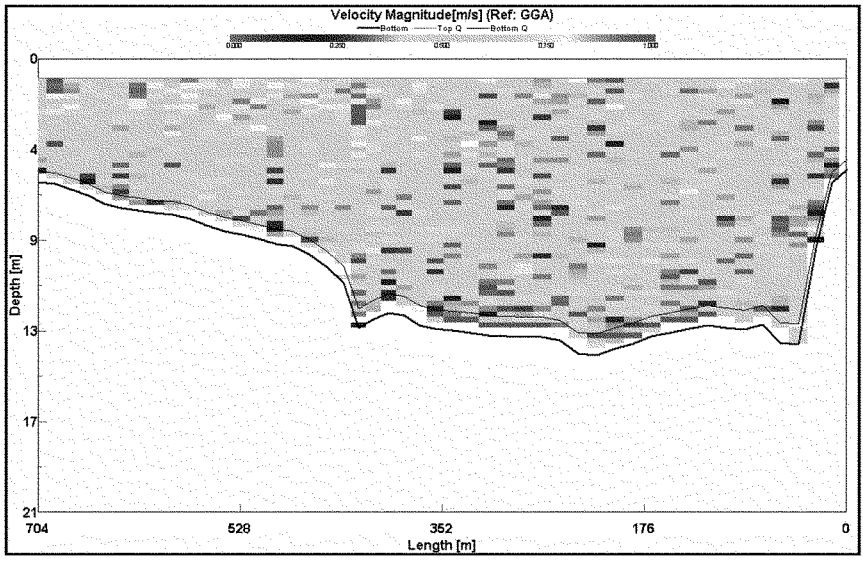

Figure E30. Transect 4 current velocity cross sections, 11 November 2004, 1836 GMT.

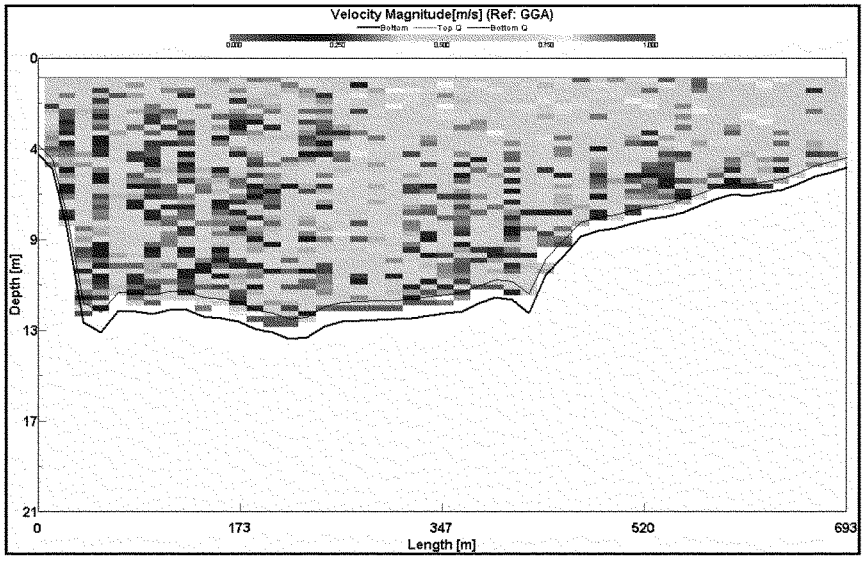

Figure E31. Transect 4 current velocity cross sections, 11 November 2004, 1936 GMT.

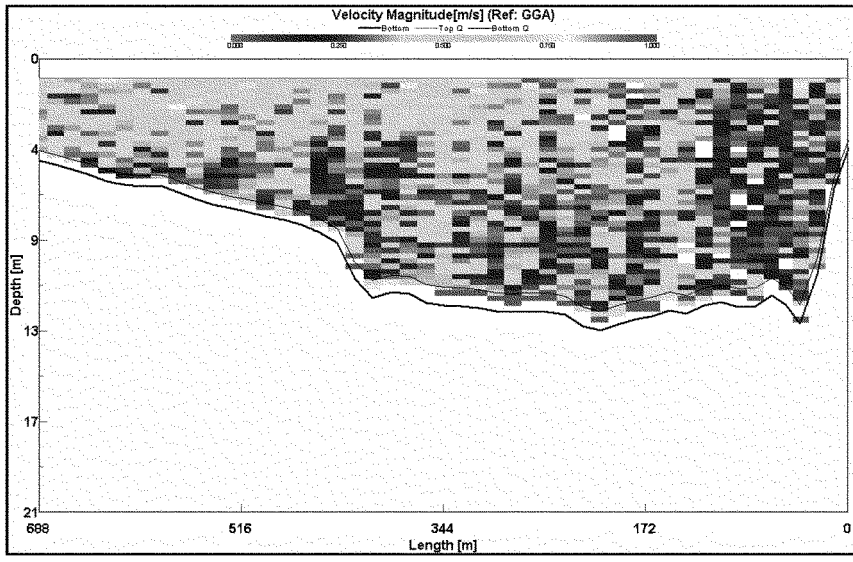

Figure E32. Transect 4 current velocity cross sections, 11 November 2004, 2039 GMT.

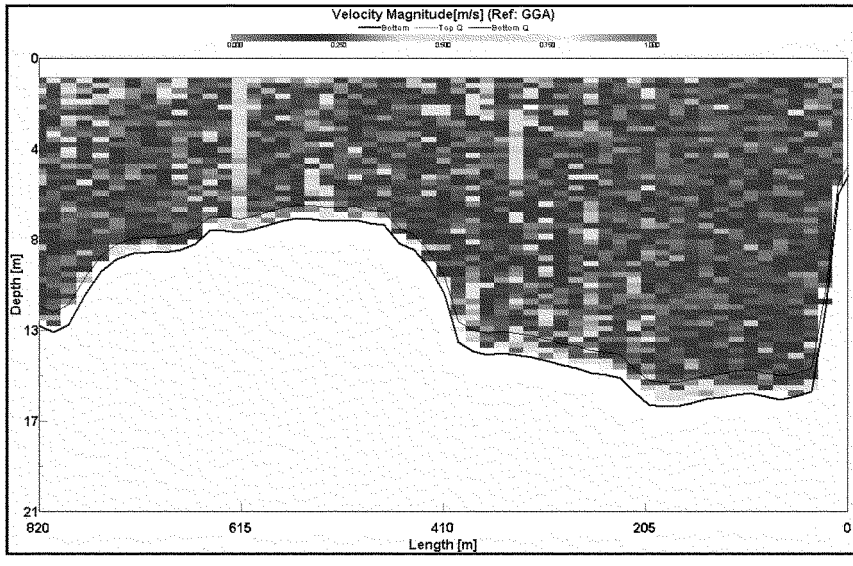

Figure E33. Transect 5 current velocity cross sections, 11 November 2004, 1339 GMT.

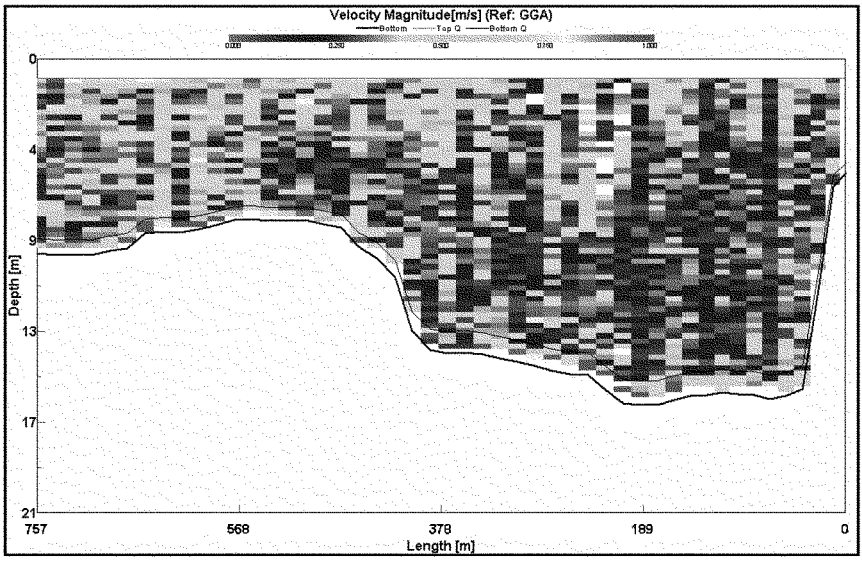

Figure E34. Transect 5 current velocity cross sections, 11 November 2004, 1514 GMT.

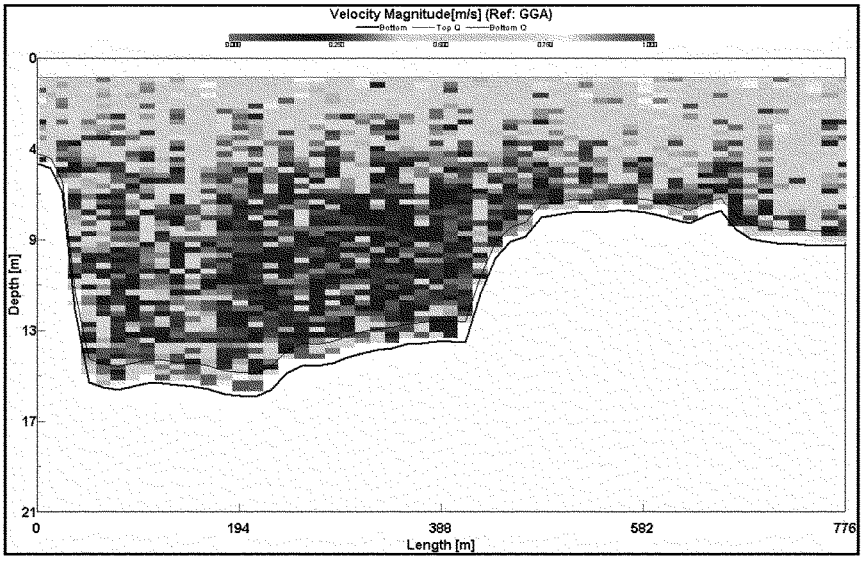

Figure E35. Transect 5 current velocity cross sections, 11 November 2004, 1616 GMT.

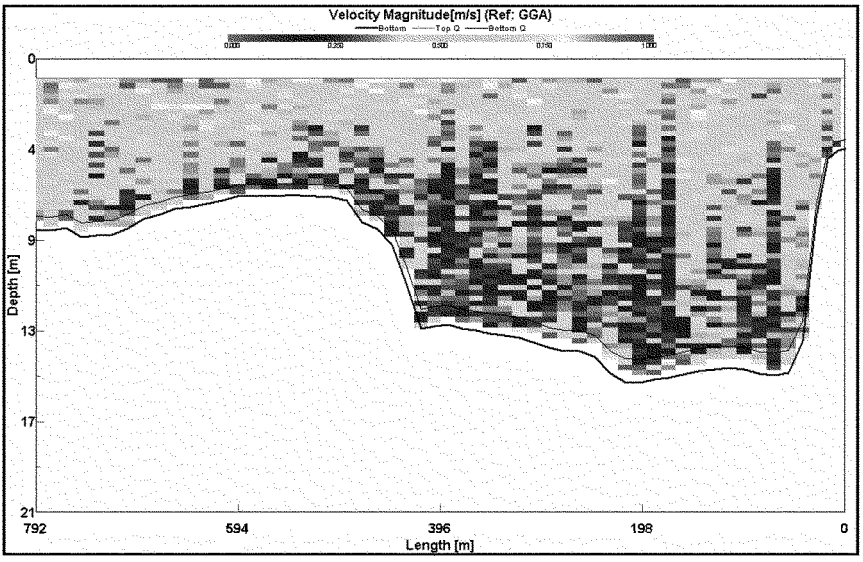

Figure E36. Transect 5 current velocity cross sections, 11 November 2004, 1721 GMT.

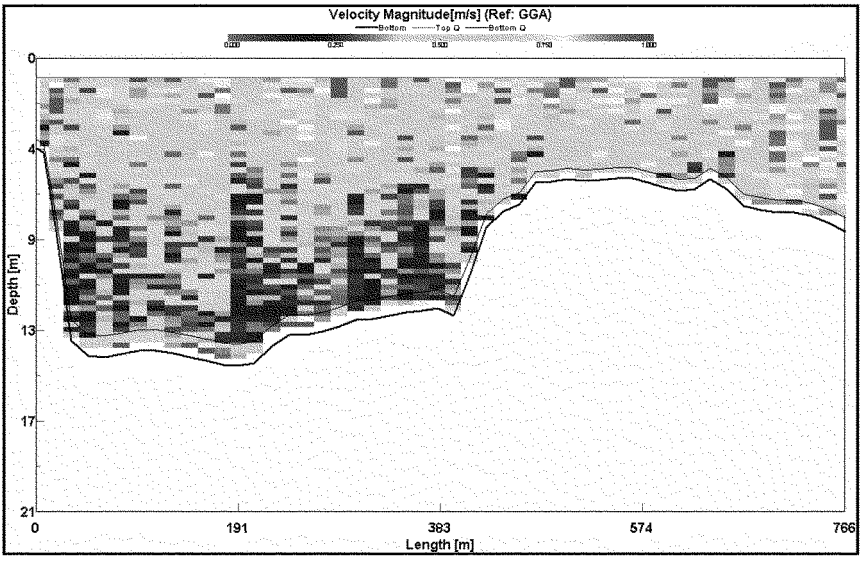

Figure E37. Transect 5 current velocity cross sections, 11 November 2004, 1822 GMT.

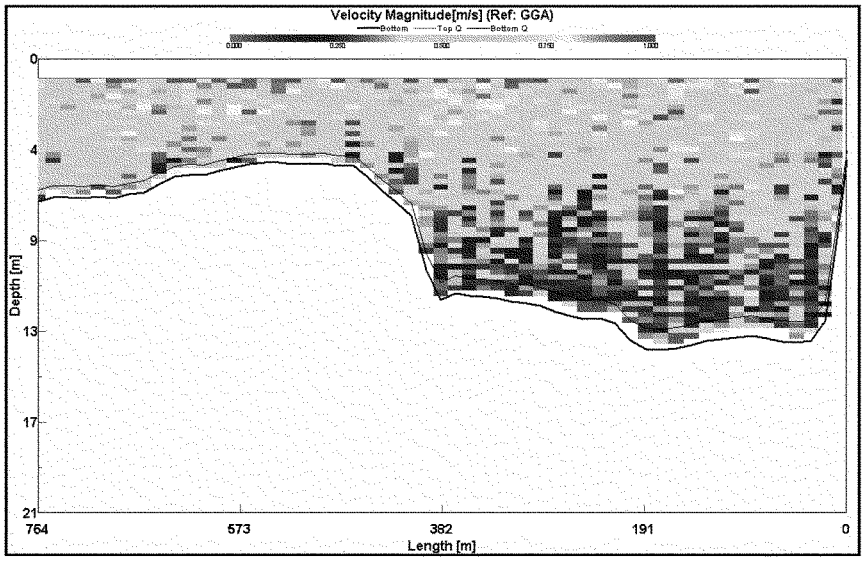

Figure E38. Transect 5 current velocity cross sections, 11 November 2004, 1922 GMT.

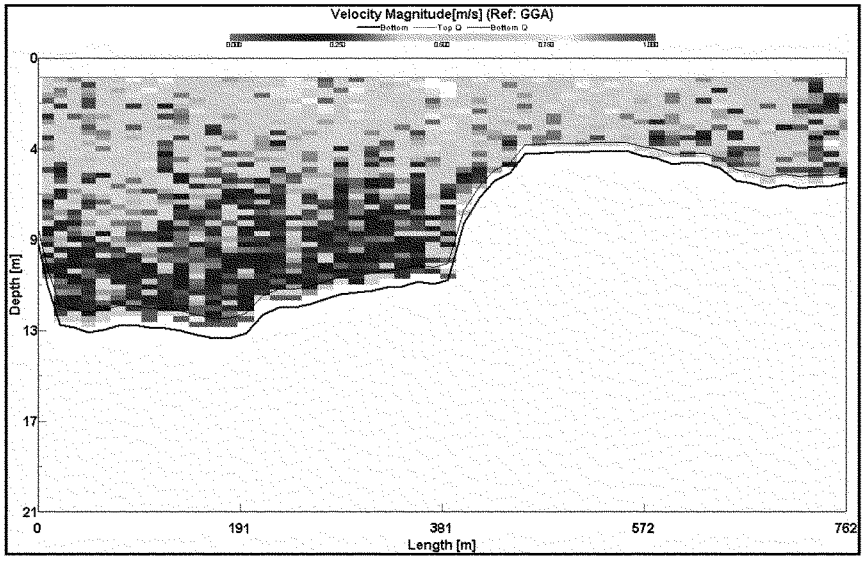

Figure E39. Transect 5 current velocity cross sections, 11 November 2004, 2022 GMT.

Appendix F: Wind Measurement Plots

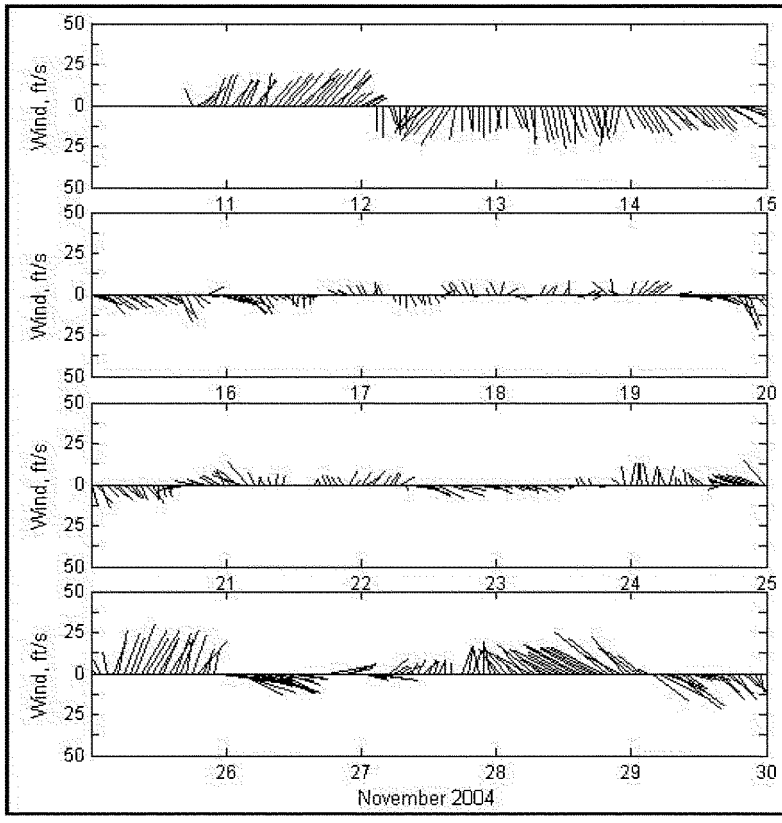

Figure F1. Wind measurement plots at Logan Airport, November 2004.

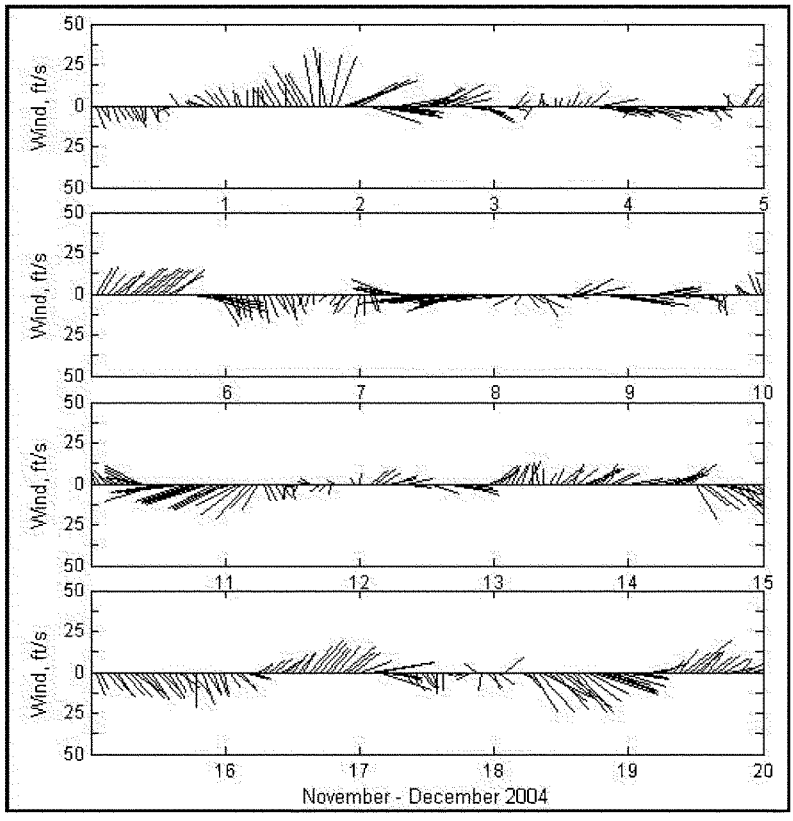

Figure F2. Wind measurement plots at Logan Airport, November-December 2004.

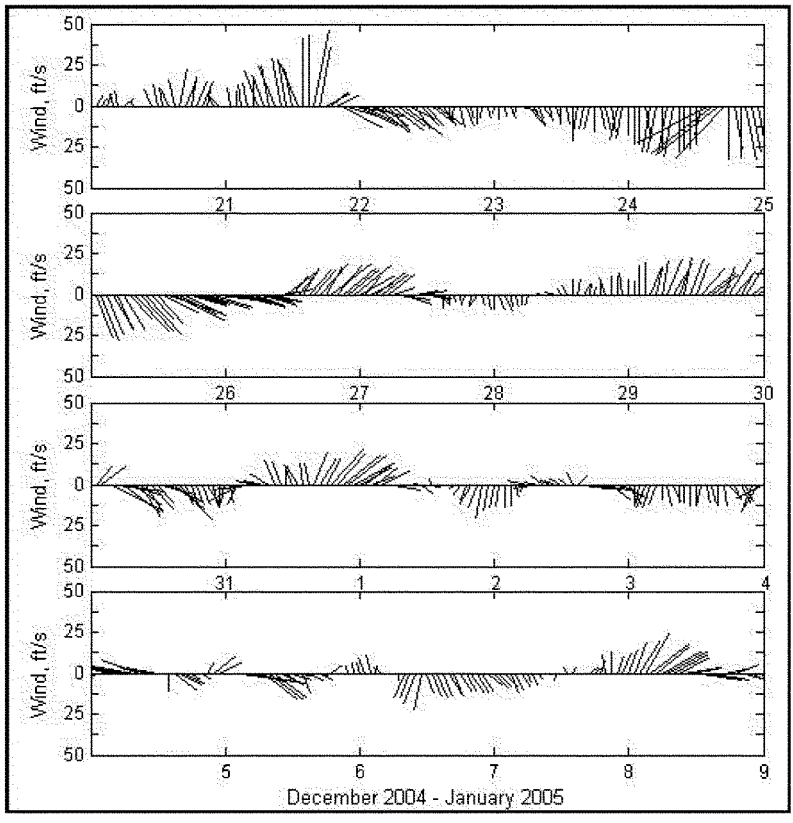

Figure F3. Wind measurement plots at Logan Airport, December 2004–January 2005.

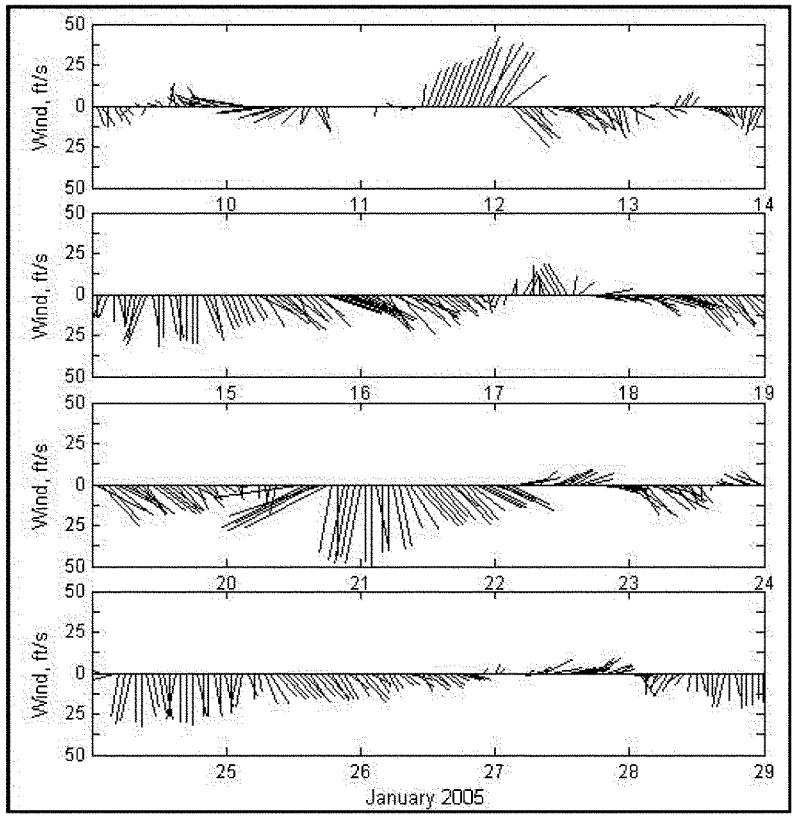

Figure F4. Wind measurement plots at Logan Airport, January 2005.

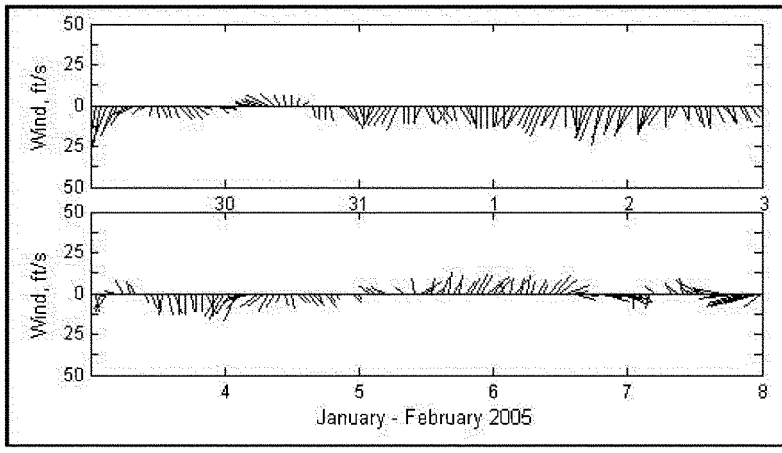

Figure F5. Wind measurement plots at Logan Airport, January-February 2005.

Appendix G: Folder Structure of Project DVD

Table G1. Folder structure of project DVD.

Boston Harbor Field Data Collection Program
Readme.txt (Table G1)
Documents
Report Contents .doc (report table of contents)
Report.doc (the final report without the appendices)
Appendix A.doc (Scope of Work)
Appendix B.doc (Water-level Measurements Plots))
Appendix C.doc (Moored Current Measurements Plots)
Appendix D.doc (Transect Current Surveys, Depth-averaged Current Plots)
Appendix E.doc (Transect Current Surveys, Current Velocity Cross-sections Plots)
Appendix F.doc (Wind Measurements Plots)
Appendix G.doc (Folder Structure on Project DVD)
Appendix E.doc (Data File Formats)
First Field Report.doc ("Instrumentation Deployment and Tidal-Current Survey – 8–12 November 2004")
Second Field Report.doc ("Instrumentation Recovery and Tidal-Current Transect Survey – 6–9 February 2005")
Plots
Readme.txt (Figures 2 and 12, showing the instrument locations and designations, and the transect locations)
Water-Level Measurements
TG1_1.jpeg (time series plot of water levels from TG1 – 10– 30 November 2004)
TG1_2.jpeg (time series plot of water levels from TG1 – 30 November 30 – 20 December 2004)
TG1_3.jpeg (time series plot of water levels from TG1 – 20 December 2004 – 9 January 2005)
TG1_4.jpeg (time series plot of water levels from TG1 – 9–29 January 2005)
TG1_5.jpeg (time series plot of water levels from TG1 – 29 January – 8 February 2005)
TG2_1.jpeg (time series plot of water levels from TG2 – 10–30 November 2004)
TG2_2.jpeg (time series plot of water levels from TG2 – 30 November – 20 December 2004)
TG2_3.jpeg (time series plot of water levels from TG2 – 20 December 2004 – 9 January 2005)
TG2_4.jpeg (time series plot of water levels from TG2 – 9–29 January 2005)
(Sheet 1 of 7)

Table G1. (Continued)

Water-Level Measurements (continued)
TG2_5.jpeg (time series plot of water levels from TG2 – 29 January – 8 February 2005)
TG3_1.jpeg (time series plot of water levels from TG3 – 10–30 November 2004)
TG3_2.jpeg (time series plot of water levels from TG3 – 30 November – 20 December 2004)
TG3_3.jpeg (time series plot of water levels from TG3 – 20 December 2004 – 9 January 2005)
TG3_4.jpeg (time series plot of water levels from TG3 – 9–29 January 2005)
TG3_5.jpeg (time series plot of water levels from TG3 – 29 January – 8 February 2005)
TG4_1.jpeg (time series plot of water levels from TG4 – 10–30 November 2004)
TG4_2.jpeg (time series plot of water levels from TG4 – 30 November – 20 December 2004)
TG4_3.jpeg (time series plot of water levels from TG4 – 20 December 2004 – 9 January 2005)
TG4_4.jpeg (time series plot of water levels from TG4 – 9–29 January 2005)
TG4_5.jpeg (time series plot of water levels from TG4 – 29 January – 8 February 2005)
NOAA_1.jpeg (time series plot of water levels from the NOAA tide gage – 10–30 November 2004)
NOAA_2.jpeg (time series plot of water levels from the NOAA tide gage – 30 November – 20 December 2004)
NOAA_3.jpeg (time series plot of water levels from the NOAA tide gage – 20 December 2004 – 9 January 2005)
NOAA_4.jpeg (time series plot of water levels from the NOAA tide gage – 9–29 January 2005)
NOAA_5.jpeg (time series plot of water levels from the NOAA tide gage – 29 January – 8 February 2005)
Moored Current Measurements
CM2_1.jpeg (time series plot of depth-averaged currents from CM2 – 10–30 November 2004)
CM2_2.jpeg (time series plot of depth-averaged currents from CM2 – 30 November – 20 December 2004)
CM2_3.jpeg (time series plot of depth-averaged currents from CM2 – 20 December 2004 – 9 January 2005)
CM2_4.jpeg (time series plot of depth-averaged currents from CM2 – 9–29 January 2005)
CM2_5.jpeg (time series plot of depth-averaged currents from CM2 – 29 January – 8 February 2005)
(Sheet 2 of 7)

Table G1. (Continued)

Logan Airport Wind Measurements
LA_1.jpeg (time series plot of winds from Logan Airport – 10–30 November 2004)
LA_2.jpeg (time series plot of winds from Logan Airport – 30 November – 20 December 2004)
LA_3.jpeg (time series plot of winds from Logan Airport – 20 December 2004 – 9 January 2005)
LA_4.jpeg (time series plot of winds from Logan Airport – 9–29 January 2005)
LA_5.jpeg (time series plot of winds from Logan Airport – 29 January – 8 February 2005)
Current Transect Measurements
Current Cross-Sections.doc (vertical profiles of current speed across each transect)
T4_11_11_1321.jpeg (depth-averaged current velocities across transect T4 at 1321 (GMT) on 11 November 2004)
T5_11_11_1339.jpeg (depth-averaged current velocities across transect T5 at 1339 (GMT) on 11 November 2004)
T4_11_11_1359.jpeg (depth-averaged current velocities across transect T4 at 1359 (GMT) on 11 November 2004)
T3_11_11_1424.jpeg (depth-averaged current velocities across transect T3 at 1424 (GMT) on 11 November 2004)
T4_11_11_1450.jpeg (depth-averaged current velocities across transect T4 at 1450 (GMT) on 11 November 2004)
T5_11_11_1514.jpeg (depth-averaged current velocities across transect T5 at 1514 (GMT) on 11 November 2004)
T4_11_11_1528.jpeg (depth-averaged current velocities across transect T4 at 1528 (GMT) on 11 November 2004)
T3_11_11_1545.jpeg (depth-averaged current velocities across transect T3 at 1545 (GMT) on 11 November 2004)
T5_11_11_1616.jpeg (depth-averaged current velocities across transect T5 at 1616 (GMT) on 11 November 2004)
T4_11_11_1632.jpeg (depth-averaged current velocities across transect T4 at 1632 (GMT) on 11 November 2004)
T3_11_11_1649.jpeg (depth-averaged current velocities across transect T3 at 1649 (GMT) on 11 November 2004)
T5_11_11_1721.jpeg (depth-averaged current velocities across transect T5 at 1721 (GMT) on 11 November 2004)
T4_11_11_1736.jpeg (depth-averaged current velocities across transect T4 at 1736 (GMT) on 11 November 2004)
T3_11_11_1748.jpeg (depth-averaged current velocities across transect T3 at 1748 (GMT) on 11 November 2004)
T5_11_11_1822.jpeg (depth-averaged current velocities across transect T5 at 1822 (GMT) on 11 November 2004)
(Sheet 3 of 7)

Table G1. (Continued)

Current Transect Measurements (continued)
T4_11_11_1836.jpeg (depth-averaged current velocities across transect T4 at 1836 (GMT) on 11 November 2004)
T3_11_11_1851.jpeg (depth-averaged current velocities across transect T3 at 1851 (GMT) on 11 November 2004)
T5_11_11_1922.jpeg (depth-averaged current velocities across transect T5 at 1922 (GMT) on 11 November 2004)
T4_11_11_1936.jpeg (depth-averaged current velocities across transect T4 at 1936 (GMT) on 11 November 2004)
T3_11_11_1951.jpeg (depth-averaged current velocities across transect T3 at 1951 (GMT) on 11 November 2004)
T5_11_11_2022.jpeg (depth-averaged current velocities across transect T5 at 2022 (GMT) on 11 November 2004)
T4_11_11_2039.jpeg (depth-averaged current velocities across transect T4 at 2039 (GMT) on 11 November 2004)
T3_11_11_2055.jpeg (depth-averaged current velocities across transect T3 at 2055 (GMT) on 11 November 2004)
T1_2_8_1341.jpeg (depth-averaged current velocities across transect T1 at 1341 (GMT) on 8 February 2005)
T2_2_8_1415.jpeg (depth-averaged current velocities across transect T2 at 1415 (GMT) on 8 February 2005)
T1_2_8_1450.jpeg (depth-averaged current velocities across transect T1 at 1450 (GMT) on 8 February 2005)
T1_2_8_1459.jpeg (depth-averaged current velocities across transect T1 at 1459 (GMT) on 8 February 2005)
T3_2_8_1520.jpeg (depth-averaged current velocities across transect T3 at 1520 (GMT) on 8 February 2005)
T2_2_8_1532.jpeg (depth-averaged current velocities across transect T2 at 1532 (GMT) on 8 February 2005)
T1_2_8_1604.jpeg (depth-averaged current velocities across transect T1 at 1604 (GMT) on 8 February 2005)
T1_2_8_1614.jpeg (depth-averaged current velocities across transect T1 at 1614 (GMT) on 8 February 2005)
T3_2_8_1636.jpeg (depth-averaged current velocities across transect T3 at 1636 (GMT) on 8 February 2005)
T2_2_8_1649.jpeg (depth-averaged current velocities across transect T2 at 1649 (GMT) on 8 February 2005)
T1_2_8_1723.jpeg (depth-averaged current velocities across transect T1 at 1723 (GMT) on 8 February 2005)
T3_2_8_1747.jpeg (depth-averaged current velocities across transect T3 at 1747 (GMT) on 8 February 2005)
T2_2_8_1803.jpeg (depth-averaged current velocities across transect T2 at 1803 (GMT) on 8 February 2005)
(Sheet 4 of 7)

Table G1. (Continued)

Current Transect Measurements (continued)
T1_2_8_1840.jpeg (depth-averaged current velocities across transect T1 at 1840 (GMT) on 8 February 2005)
T3_2_8_1909.jpeg (depth-averaged current velocities across transect T3 at 1909 (GMT) on 8 February 2005)
T3_2_8_2012.jpeg (depth-averaged current velocities across transect T3 at 2012 (GMT) on 8 February 2005)
T1_2_8_2048.jpeg (depth-averaged current velocities across transect T1 at 2048 (GMT) on 8 February 2005)
Data Files
Water-Level Measurements
Readme.txt (Table H1)
TG1.txt (water levels measured from TG1)
TG2.txt (water levels measures from TG2)
TG3.txt (water levels measured from TG3)
TG3.txt (water levels measured from TG4)
NOAA.txt (water levels measured from the NOAA tide gage)
Moored Current Measurements
Readme.txt (Table H2)
CM2.txt (depth-averaged current velocities from CM2)
Logan Airport Wind Measurements
Readme.txt (Table H3)
Wind.txt (wind speed and direction measured at Logan Airport)
Current Transect Measurements
Readme.txt (Table H4)
T4_11_11_1321.txt (depth-averaged current velocities across transect T4 at 1321 (GMT) on 11 November 2004)
T5_11_11_1339.txt (depth-averaged current velocities across transect T5 at 1339 (GMT) on 11 November 2004)
T4_11_11_1359.txt (depth-averaged current velocities across transect T4 at 1359 (GMT) on 11 November 2004)
T3_11_11_1424.txt (depth-averaged current velocities across transect T3 at 1424 (GMT) on 11 November 2004)
T4_11_11_1450.txt (depth-averaged current velocities across transect T4 at 1450 (GMT) on 11 November 2004)
T5_11_11_1514.TXT (depth-averaged current velocities across transect T5 at 1514 (GMT) on 11 November 2004)
T4_11_11_1528.txt (depth-averaged current velocities across transect T4 at 1528 (GMT) on 11 November 2004)
T3_11_11_1545.txt (depth-averaged current velocities across transect T3 at 1545 (GMT) on 11 November 2004)
T5_11_11_1616.txt (depth-averaged current velocities across transect T5 at 1616 (GMT) on 11 November 2004)
T4_11_11_1632.txt (depth-averaged current velocities across transect T4 at 1632 (GMT) on 11 November 2004)
(Sheet 5 of 7)

Table G1. (Continued)

Current Transect Measurements (continued)
T3_11_11_1649.txt (depth-averaged current velocities across transect T3 at 1649 (GMT) on 11 November 2004)
T5_11_11_1721.txt (depth-averaged current velocities across transect T5 at 1721 (GMT) on 11 November 2004)
T4_11_11_1736.txt (depth-averaged current velocities across transect T4 at 1736 (GMT) on 11 November 2004)
T3_11_11_1748.txt (depth-averaged current velocities across transect T3 at 1748 (GMT) on 11 November 2004)
T5_11_11_1822.txt (depth-averaged current velocities across transect T5 at 1822 (GMT) on 11 November 2004)
T4_11_11_1836.txt (depth-averaged current velocities across transect T4 at 1836 (GMT) on 11 November 2004)
T3_11_11_1851.txt (depth-averaged current velocities across transect T3 at 1851 (GMT) on 11 November 2004)
T5_11_11_1922.txt (depth-averaged current velocities across transect T5 at 1922 (GMT) on 11 November 2004)
T4_11_11_1936.txt (depth-averaged current velocities across transect T4 at 1936 (GMT) on 11 November 2004)
T3_11_11_1951.txt (depth-averaged current velocities across transect T3 at 1951 (GMT) on 11 November 2004)
T5_11_11_2022.txt (depth-averaged current velocities across transect T5 at 2022 (GMT) on 11 November 2004)
T4_11_11_2039.txt (depth-averaged current velocities across transect T4 at 2039 (GMT) on 11 November 2004)
T3_11_11_2055.txt (depth-averaged current velocities across transect T3 at 2055 (GMT) on 11 November 2004)
T1_2_8_1341.txt (depth-averaged current velocities across transect T1 at 1341 (GMT) on 8 February 2005)
T2_2_8_1415.txt (depth-averaged current velocities across transect T2 at 1415 (GMT) on 8 February 2005)
T1_2_8_1450.txt (depth-averaged current velocities across transect T1 at 1450 (GMT) on 8 February 2005)
T1_2_8_1459.txt (depth-averaged current velocities across transect T1 at 1459 (GMT) on 8 February 2005)
T3_2_8_1520.txt (depth-averaged current velocities across transect T3 at 1520 (GMT) on 8 February 2005)
T2_2_8_1532.txt (depth-averaged current velocities across transect T2 at 1532 (GMT) on 8 February 2005)
T1_2_8_1604.txt (depth-averaged current velocities across transect T1 at 1604 (GMT) on 8 February 2005)
T1_2_8_1614.txt (depth-averaged current velocities across transect T1 at 1614 (GMT) on 8 February 2005)
(Sheet 6 of 7)

Table G1. (Concluded)

Current Transect Measurements
T3_2_8_1636.txt (depth-averaged current velocities across transect T3 at 1636 (GMT) on 8 February 2005)
T2_2_8_1649.txt (depth-averaged current velocities across transect T2 at 1649 (GMT) on 8 February 2005)
T1_2_8_1723.txt (depth-averaged current velocities across transect T1 at 1723 (GMT) on 8 February 2005)
T3_2_8_1747.txt (depth-averaged current velocities across transect T3 at 1747 (GMT) on 8 February 2005)
T2_2_8_1803.txt (depth-averaged current velocities across transect T2 at 1803 (GMT) on 8 February 2005)
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T1_2_8_2048.txt (depth-averaged current velocities across transect T1 at 2048 (GMT) on 8 February 2005)
Project GIS
Boston.apr (ArcView project file for displaying the vectorized current transect data)
GIS files
Vectorized data files and GIS geospacial information needed for the GIS project)
(Sheet 7 of 7)

Appendix H: Data File Formats

Table H1. Format of water-level measurement files on project DVD.

Water-level measurement files TG1.txt, TG2.txt, TG3.txt, TG4.txt, NOAA.txt		
Row	**Field**	**Description**
1	1	Instrument designation
	2	Geographic location description
2	1	Latitude, degrees north
	2	Longitude, degrees west
3	1	Hour of first data value in record (GMT)
	2	Minute of first data value in record (GMT)
	3	Month of first data value in record (GMT)
	4	Day of first data value in record (GMT)
	5	Year of first data value in record (GMT)
4 – end of record	1	Time in hours from first data value in record
	2	Water level in feet relative to the record mean for TG1, TG2, TG3, and TG4, and relative to mean lower low water (MLLW) for NOAA

Example: First 6 rows of TG1.txt.

```
TG1 Chelsea Bridge
42.386556 71.039917
18 00 11 10 2004
 0.00 5.27
 0.10 5.09
 0.20 4.84
```

Table H2. Format of moored current meter measurement file on project DVD.

Moored current meter measurements file CM2.txt		
Row	**Field**	**Description**
1	1	Instrument designation
	2	Geographic location description
2	1	Latitude, degrees north
	2	Longitude, degrees west
3	1	Hour of first data value in record (GMT)
	2	Minute of first data value in record (GMT)
	3	Month of first data value in record (GMT)
	4	Day of first data value in record (GMT)
	5	Year of first data value in record (GMT)
4	1	Time in hours from first data value in record
	2	Depth-averaged current speed in feet per second
	3	Depth-averaged direction current is going to in degrees true

Example: First 6 rows of CM2.txt.

```
CM2 Near the seaward end of the navigation channel
42.363833 70.918000
14 21 11 10 2004
 0.00 0.42 47
 0.25 0.52 43
 0.50 0.63 44
```

Table H3. Format of Logan Airport wind measurement file on project DVD.

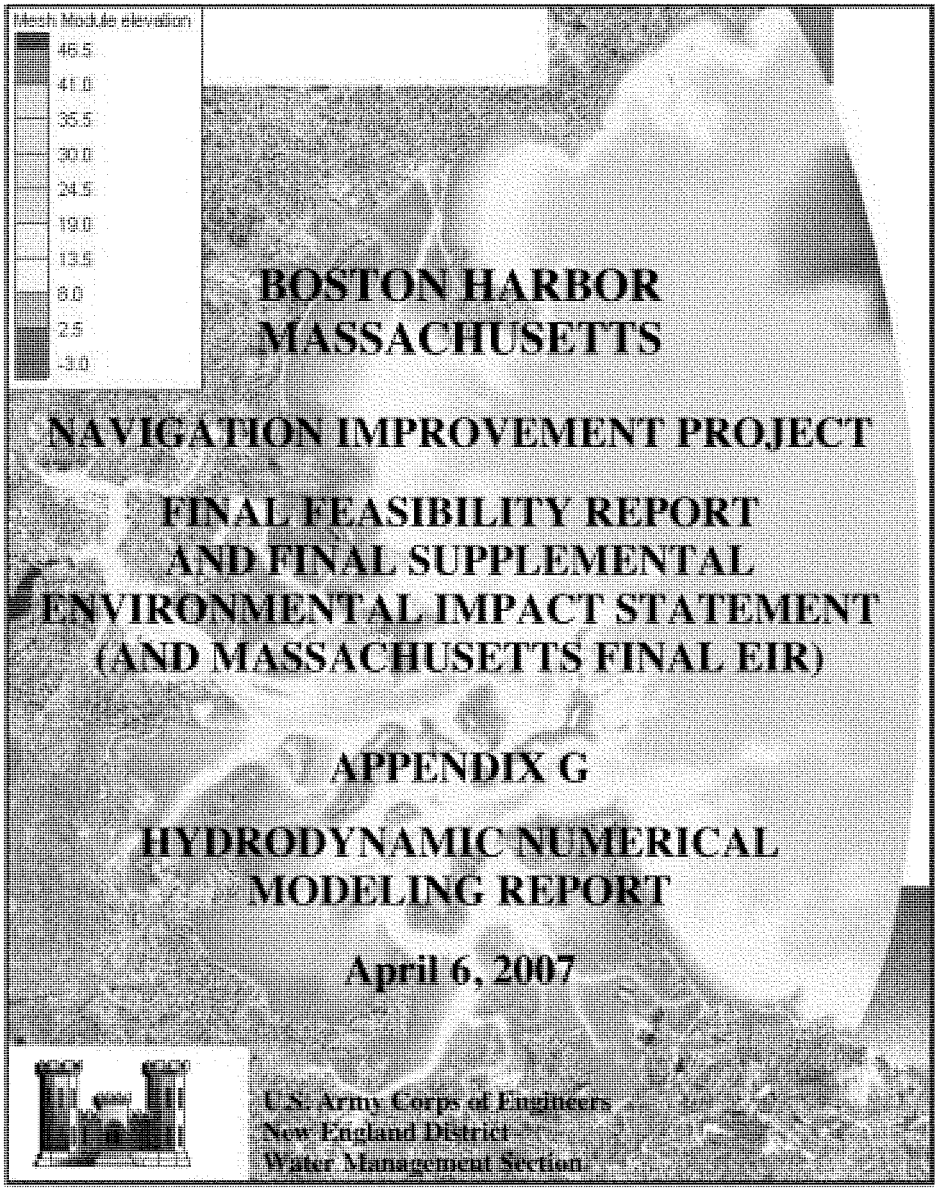
Logan Airport wind measurements file Wind.txt		
Row	**Field**	**Description**
1	1	Month and day of measurement (GMT)
	2	Time of measurement (GMT)
	3	Wind speed in meters per second
	4	Direction the wind is blowing from in degrees true
Example: First 6 rows of Wind.txt. Note that the first 6 rows have 4 invalid directions (i.e., 999) and 3 invalid speeds or no wind (i.e., 0.0). 1110 1454 0.0 999 1110 1554 0.0 999 1110 1654 1.5 999 1110 1754 3.6 160 1110 1854 3.6 240 1110 1954 3.6 220		

Table H4. Format of current transect measurement file on project DVD.

Current transect measurements files - name format: transect_month_day_time.txt Example: T5_11_11_1721.txt		
Row	**Field**	**Description**
1	1	Year of measurement in 2000 (i.e., either a 4 or a 5) (local)
	2	Month of measurement (local)
	3	Day of measurement (local)
	4	Hour of measurement (local)
	5	Minute of measurement (local)
	6	Second of measurement (local)
	7	Hundredth of a second of measurement (local)
	8	Depth in feet
2	1	Latitude, degrees north
	2	Longitude, degrees west
3	1	Depth-averaged current speed in feet per second
	2	Depth-averaged direction current going to in degrees true

Example: First 6 rows of T5_11_11_1721.txt.

```
4 11 11 12 17 43 32 13.84
 42.3381006 -71.0081996
 0.36 302
 4 11 11 12 17 49 71 14.09
 42.3381592 -71.0081658
 0.43 127
```



BOSTON HARBOR MASSACHUSETTS

NAVIGATION IMPROVEMENT PROJECT

FINAL FEASIBILITY REPORT AND FINAL SUPPLEMENTAL ENVIRONMENTAL IMPACT STATEMENT (AND MASSACHUSETTS FINAL EIR)

APPENDIX G

HYDRODYNAMIC NUMERICAL MODELING REPORT

April 6, 2007

U.S. Army Corps of Engineers
New England District
Water Management Section

This Appendix Unchanged Since 2008 Draft Final Report

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Boston Harbor Data Collection Report – See Appendix F

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1.0 Introduction

As part of the Boston Harbor Deep Draft Navigation Improvement project, a ship simulation model was needed to determine the effectiveness and potential hazards associated with various channel depths and configurations. The ship simulation effort was completed by the Engineering Research Development Center (ERDC) ship simulation section in Vicksburg, MS during the summer of 2005. Mr. Dennis Webb was the lead investigator for the modeling effort. An important component of the ship simulation effort was having correct water velocity information in the simulation so that the ship handling behavior would be realistic. The velocity data was needed along the channel for both the existing and proposed conditions. In order to provide this information a 2-D hydrodynamic model was used. This report will provide an overview of the hydrodynamic modeling effort and the field data collection effort that supported the validation of the model.

2.0 Model Study Approach

The hydrodynamic regime of Boston Harbor has been provided below in a passage taken from the ERDC Data Collection report (discussed in Section 4.0 and provided as Attachment 3)

> *"Boston Harbor and adjacent areas, and the areas of the navigation channel improvement project are shown in Figure 1. Typical navigationally-significant currents in the Harbor are primarily the result of tidal forcing. The semi-diurnal M_2 tidal component, which has a 12.42-hr period, is the most significant. However, these are modulated by the S_2 and N_2 components, resulting in spring tidal currents that are 33 percent stronger than average. The spring tidal currents occur every 15 days. There is relatively little fresh-water input to the Harbor, and density-driven currents are not significant in terms of their effect on ship navigation. Water-level differences over the Harbor (at any one time) are small in the absence of wind. Without wind-driven effects, water levels in the Harbor are controlled by the astronomical tides, and the magnitudes and timing of their variations are nearly the same over the entire Harbor."*

The channel area under consideration for improvement can be seen in Figure 1. The length of channel improvement was nearly 8 miles long. Due to the size of the area being investigated the model domain was large. Considering the size of the model domain and the complexities of the bathymetry a finite element model was chosen for this project.

The ADCIRC model was chosen after looking at both RMA2 and ADCIRC. Through several discussions with users of both models, including modelers from the Engineering Research and Development Centers (ERDC) Waterways Experiment Station (WES), it was clear that either model could perform the task equally well. However, ADCIRC was chosen due to the easier model setup and calibration/validation. The impression was also given that the ADCIRC model was an easier model to learn and less difficult to run.

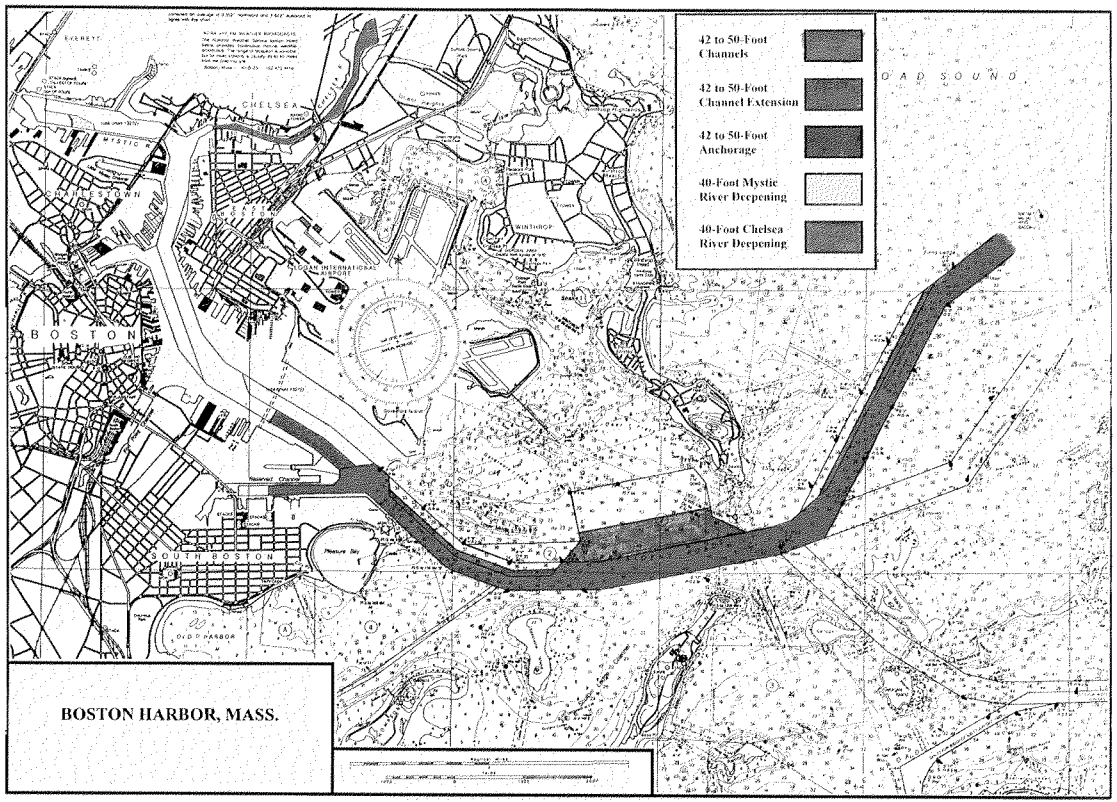


Figure 1. Proposed Channel Improvement Areas

The modeling effort was budgeted and scheduled to be mostly conducted within the New England district. The model budget for set up, validation, and alternative runs was $140,000 with $25,000 of this money earmarked for technical assistance from WES. However, due to a late federal budget approval, funding was not available until later in the fiscal year than anticipated, which shifted the schedule. This required that more of the modeling effort be shifted to WES. Dr. Zeki Demirbilek and Dr. Lihwa Lin from WES provided significant support for this effort. Additionally, three channel alternatives were run in the New York District by Dr. Jennifer Irish due to last minute changes that were necessary to address issues raised by the Massachusetts Port Authority (MASSPort). The NY District had significantly more computing power available to handle the three alternatives and was able to meet the tight time line that was set due to the ship simulator schedule and Boston Harbor Pilot availability. Due to Hurricane Katrina work WES personnel were not available to run the adjusted model alternatives. Additionally, a final set of runs was performed in February of 2007 by WES to provide consistent run lengths and uniform model output in the outer fringes of the model. When the model alternatives were run at the two different locations, different computing platforms were used, which necessitated the alteration of frictional values near the model fringes. This impacted model output away from the channel and did not impact the ship simulation study. The runs were completed for uniformity and to allow for easy comparison between alternative runs, without the interference of model differences on the fringes. All model results have been kept and can be found in digital storage. At the time of this report all files were stored on a set of DVDs. The model results being displayed in this report were from the 02/2007 model runs.

3.0 ADCIRC Model Background

ADCIRC is an acronym for Advanced Circulation Midel and is a widely used and accepted model. A description of the model and its features has been provided below (taken from the ERDC ADCIRC Fact Sheet dated September 24, 2004).

> *"ADCIRC is a finite element hydrodynamic circulation numerical model for water level and current over an unstructured grided domain. ADCIRC can be run as either a two-dimensional depth integrated (2DDI) model or as a three-dimensional model. ADCIRC can be used for modeling tidal and wind- and wave-driven currents in coastal waters; forecasting hurricane storm surge and flooding; inlet sediment transport/morphology change studies, and dredging/material disposal studies. The model has been certified by FEMA for use in performing storm surge analyses.*
>
> *ADCIRC simulates tidal circulation and storm surge propagation over large computational domains, eliminating the need for imposing approximate open-water boundary conditions that can create inaccuracies in model results, while simultaneously providing high resolution in areas of complex shoreline and bathymetry where it is needed to maximize simulation accuracy. The targeted areas for ADCIRC application include continental shelves, near shore coastal areas, inlets, and estuaries.*

Features available in ADCIRC include: wetting/drying of low-lying areas, overflow and through flow barriers, bridge piers, wave radiation stresses, sediment transport, and morphology change. Planned enhancements include modeling salinity, contaminant transport, three-dimensional sediment transport/morphology change modeling, and additional sediment transport algorithms. The model can be run as a single processor code or in parallel mode running efficiently on hundreds of processors."

4.0 Data Collection Effort

In order to provide calibration/validation data, a fairly comprehensive data collection effort was conducted. A team from ERDC in Vicksburg, MS was used to perform the data collection effort with the effort being lead by Mr. Thad Pratt.

The data collection effort consisted of five stationary tide gauges (including NOAA's Boston tide station), two stationary bottom mounted acoustic Doppler current meters, and two boat mounted ADCP data collection efforts. Figures 2 and 3 illustrate the location of the various data collection areas. The boat mounted ADCP data was collected along five transects on 11/11/04 and 02/08/05. The data collection report has been included as Attachment 3.

Three types of data were collected and they were water surface elevation, current velocity data, and wind velocity data. The water surface elevation was recorded using three gages, which actually recorded total pressure. In order to determine tide elevation the pressure transducers were surveyed into NAVD88 and the atmospheric pressure changes were recorded with an un-submersed tide gage/pressure transducer. With the elevation of the pressure transducer known, and the atmospheric pressure changes removed from the recorded signal, the remaining pressure signal was that of the water elevation. The pressure signal was converted to water surface elevation using typical ocean water density. The NOAA Boston Harbor Benchmark/tide collection gage was also used in this study to provide data at a fourth location. The location is also shown on Figure 2.

Since ADCIRC can incorporate wind data, wind was included in this effort. Originally, a meteorological station (MET) was going to be placed on one of the exterior islands outside of the harbor but it was ultimately decided to use the MET station at Boston Logan Airport (Figure 2). Given the exposed condition of this station it was thought that the data would be more than adequate for the purposes of this effort.

Current velocity data was collected using Acoustic Doppler Current Profilers using to different methods. The first was a permanently stationed, bottom mounted, upwards looking, ADCP and the other was using a boat mounted ADCP which was used to run repetitive channel cross sections. The location of the bottom mounted profiler and the boat transects can be seen in Figure 3.

Data collection return was fairly good with only one gage failing. The bottom mounted ADCP at CM1 failed and did not provide any data. The other gages provided data return rates of 85% to 100%. The return rate for each gage can be seen in Figure 4.

As mentioned earlier a complete description of the data collection effort can be found in Attachment 3, along with the formatted data. Only examples of the data will be provided of each data set in the body of this report. The graphical displays of the data can be seen in Figures 5 through 9. In addition to the hard copy data report and data graphics, at the time of this report, the entire set of data resided at the New England District with Mr. John Winkelman in the Water Management Section on a DVD.

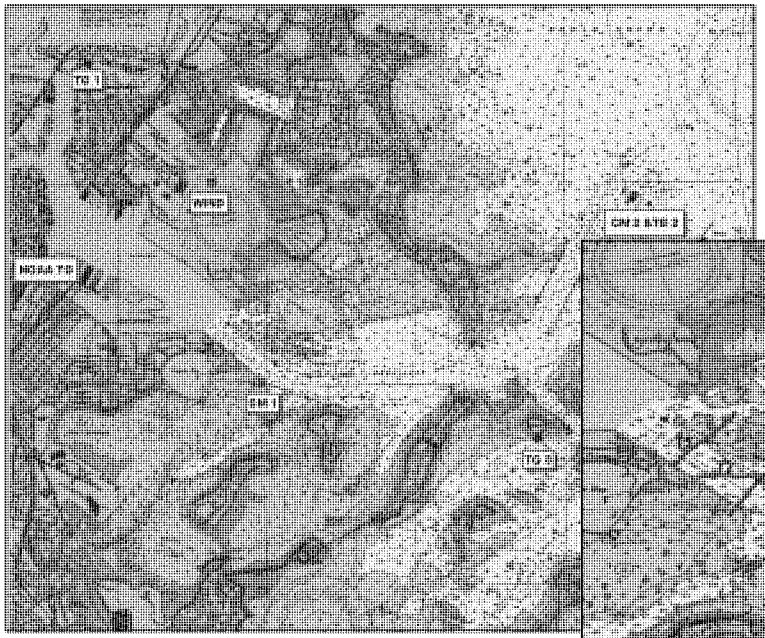


Figure 2. Data collection stations (TG=tide gage and CM= current meter)

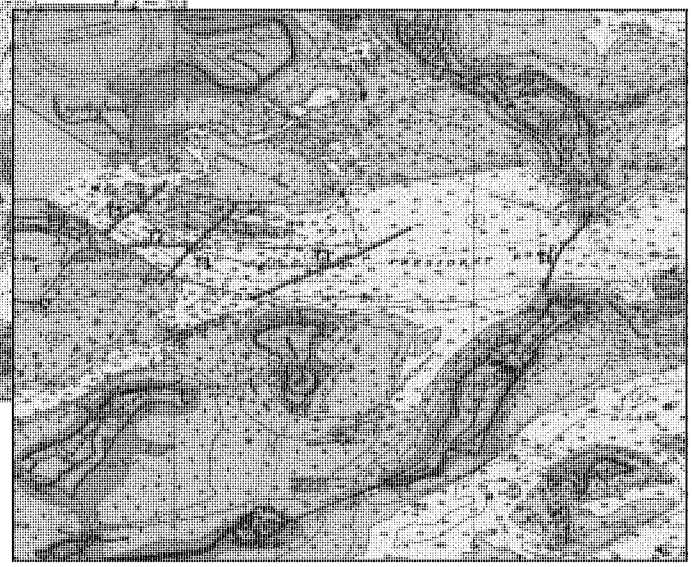


Figure 3. Boat mounted ADCP current profile transects

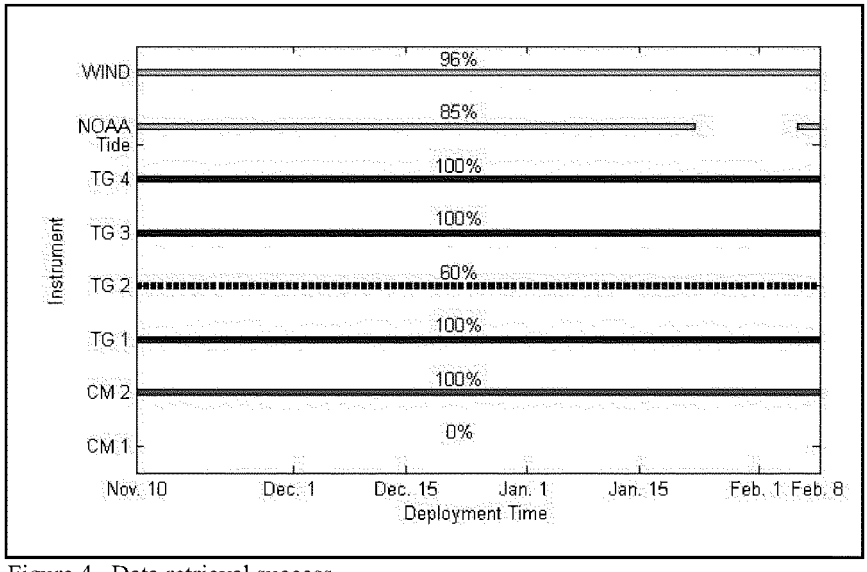


Figure 4. Data retrieval success.

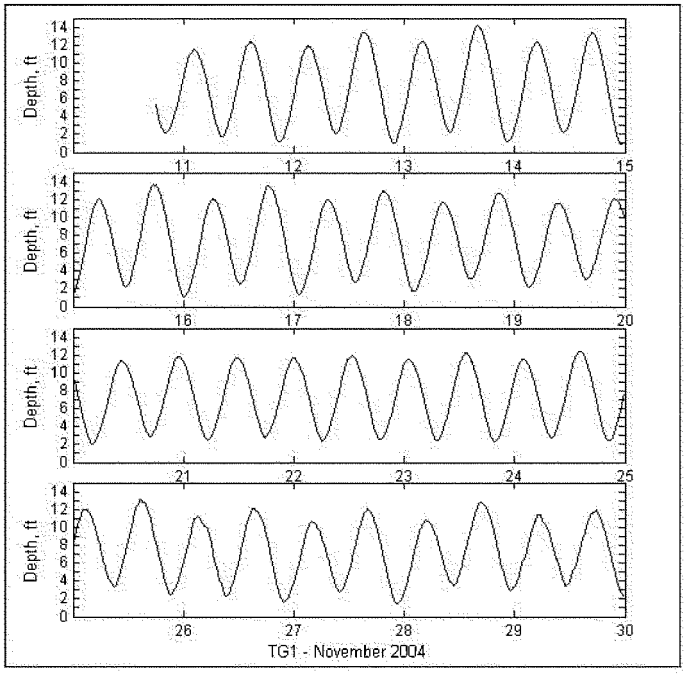


Figure 5. Sample tide data collected at tide gage 1.

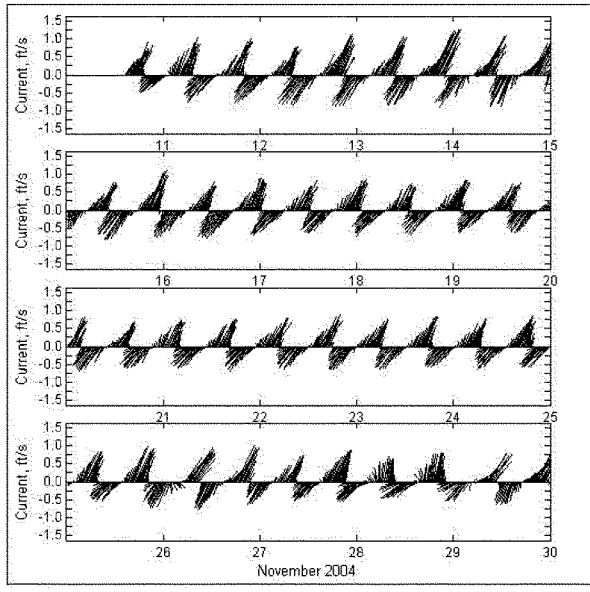


Figure 6. Sample of bottom mounted ADCP current measurements (CM2).

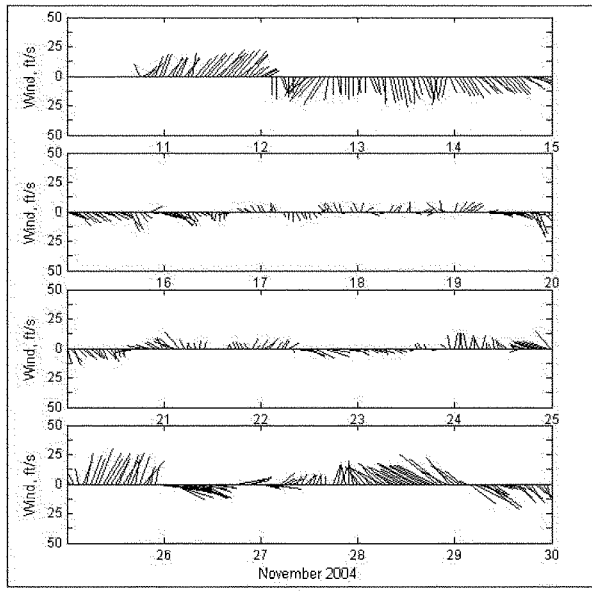


Figure 7. Sample of wind data from Boston Logan International Airport.

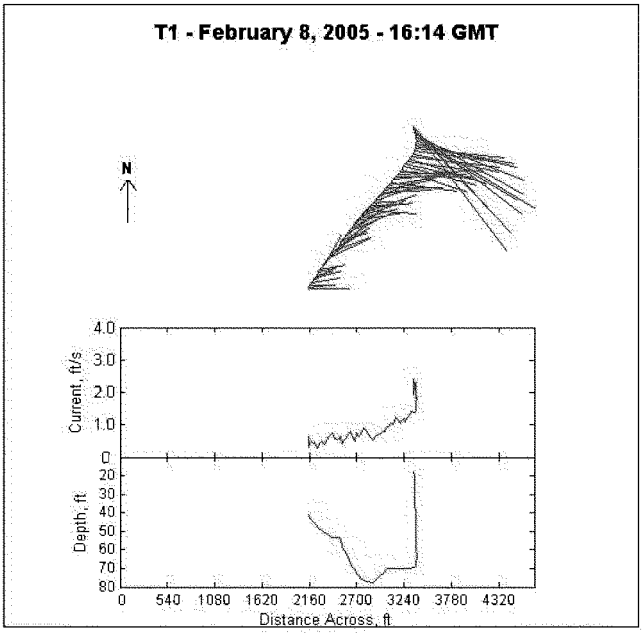


Figure 8. Sample boat mounted ADCP current data transect (depth averaged).

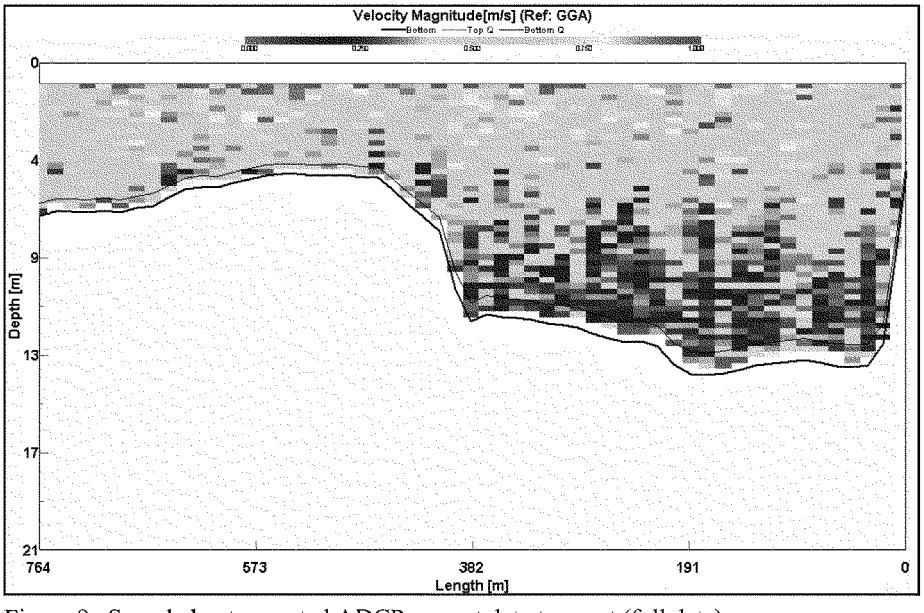


Figure 9. Sample boat mounted ADCP current data transect (full data).

5.0 Model Setup

The modeling effort was basically broken up into three steps which included model setup, model validation, and alternative analysis. The model setup up was performed using both the Surface Modeling System (SMS) and ArcMap GIS software.

The model input files, along with the running of the model was done through the SMS 9.0 interface. The grid and mesh files were generated using the model boundaries discussed in Section 5.2 and the bathymetry data discussed in Section 5.1. The boundaries were converted into densely spaced XYZ point files. The bathymetry data was too dense as provided and it was thinned in SMS. The data within Boston Harbor was kept at a more dense level than further off shore.

5.1 Model Bathymetry

The first step in the model setup was determining the extent of the model necessary to avoid having the ocean/tidal driven boundary conditions too close to the navigation channel. As discussed in Section 5.2.2 it was decided to extend the ocean boundary out to Marble Head, MA on the north side and near Cohasset Harbor on the south side. These two areas were connected by a semicircular/arc and which is shown in Figure 23 (in Section 5.2.2). In order to obtain bathymetry data for such a large area, data was obtained from NOAA's GEODAS data portal, which can be found at the following web site http://map.ngdc.noaa.gov/website/mgg/nos_hydro/viewer.htm. For the more immediate project area, specifically the federal navigation channels, the most recent available bathymetric survey data from the New England District Survey Section was used.

5.1.1 NOAA GEODAS Data

The GEODAS data files contain the digital point data that is used by NOAA to generate the NOAA navigational charts. The advantage of using GEODAS data is that the point density is higher than from digital charts or from digitizing navigational charts and it is already in a digital format. When using the GEODAS interactive viewer, large areas can be selected to retrieve data from. However, it must be realized by the user (at least at the time of this study) that the data was compiled from numerous surveys and individual files that were recorded in two different vertical datums. For the area in this study portions of the data were delivered in the vertical datums of MLW and MLLW. This meant that the entire area could not simply be highlighted and delivered as one large file. Instead the data was sent as individual files and the data was corrected using the proper adjustments from MLLW or MLW to MSL. The corrections were obtained from the Boston Harbor Benchmark Station # 8443970 which can be seen in Table 1. The Boston Harbor station is the control station for all of the prediction tide stations in the area to be modeled. The corrections to the various tide prediction stations within the model domain were checked against the Boston station and the vertical differences between MSL and MLW/MLLW were insignificant. Additionally the bathymetry data was converted from feet to meters.

Table 1. Boston Harbor Benchmark Data – Station # 8443970

Datum	MLLW feet	MTL feet	NGVD29 feet	NAVD88 feet
MEAN HIGHER HIGH WATER (MHHW)	10.27	5.18	5.57	4.77
MEAN HIGH WATER (MHW)	9.83	4.74	5.13	4.32
NORTH AMERICAN VERTICAL DATUM-1988 (NAVD)	5.51	0.42	0.81	0.00
Mean Sea Level (MSL)	5.20	0.11	0.50	-0.31
MEAN TIDE LEVEL (MTL)	5.09	0.00	0.39	-0.42
NGVD29	4.70	-0.39	0.00	-0.81
Mean Low Water (MLW)	0.45	-4.64	-4.25	-5.06
Mean Lower Low Water (MLLW)	0.00	-5.09	-4.70	-5.51

LENGTH OF SERIES: 19 Years
TIME PERIOD: January 1983 - December 2001
TIDAL EPOCH: 1983-2001

The map showing the various NOAA surveys can be seen in Figure 10 and the list of the survey identification numbers is provided in Attachment 1. The data was requested from the GEODAS interactive server in MA State Planes NAD 83 Meters in order to match the State of MA 2001/2003 aerial photography used as a background layer in the SMS interface and ArcMap GIS.

Figures 11 and 12 and have been included to provide the reader an idea of the point density provided by the GEODAS data. The figures show the entire model domain, and include one showing just the inner harbor of Boston.

5.1.2 New England District Survey Data

Since much of the GEODAS data from NOAA was not taken very recently, with several of the surveys being conducted in the 1940's, the more recent survey data collected by the New England District Survey Section was used for the navigation channel bathymetry. The surveys used can be seen in Figure 13. In addition to the data being more recent it was collected at a much higher density, which was necessary to pick of the features of the federal channel and the areas within the Inner Harbor.

The data from the Corps Survey was converted into the horizontal datum of Massachusetts State Plane NAD83 meters in ArcMap GIS/Arc Catalog. This datum was chosen to match the datum of the most recent set of aerial photography taken by MA. These photos were used as a background layer, but more importantly to provide the model shoreline boundary.

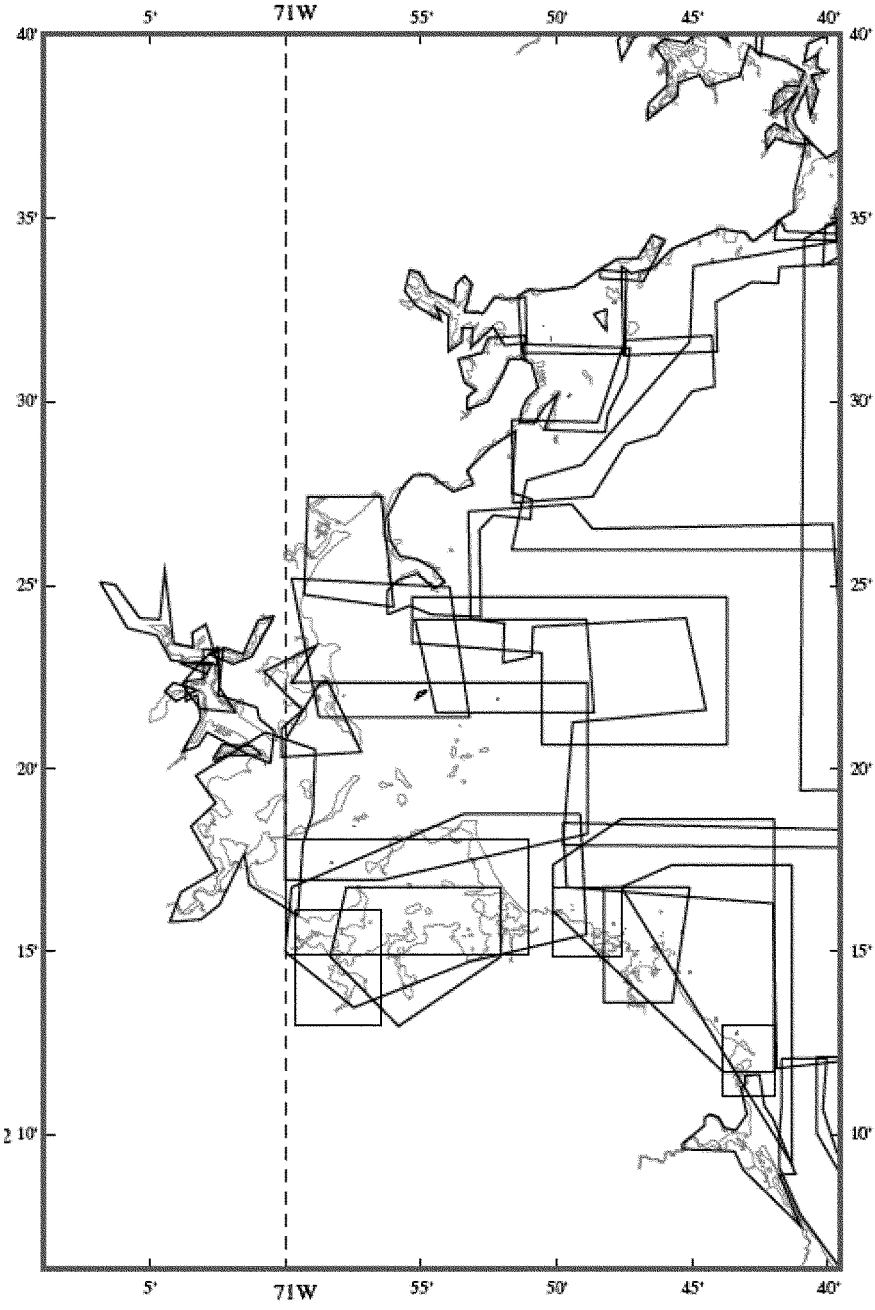


Figure 10. GEODAS surveys used.

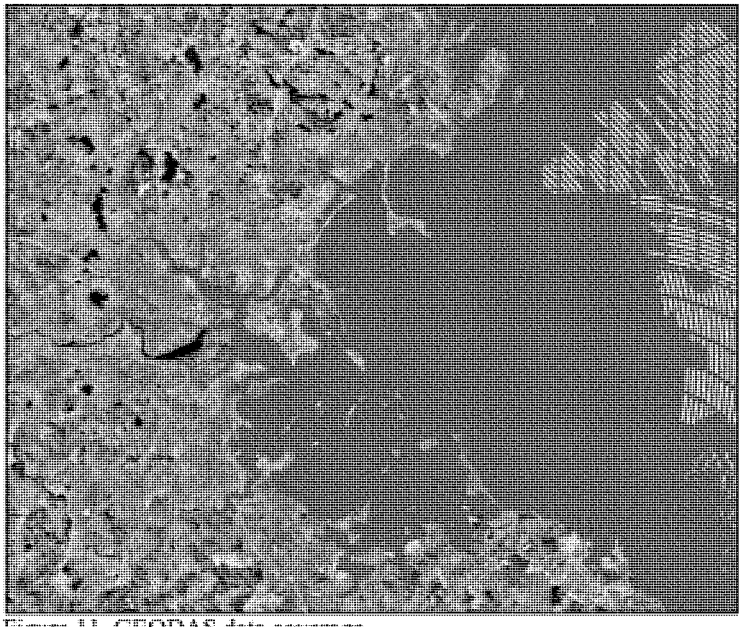


Figure 11. GEODAS data coverage

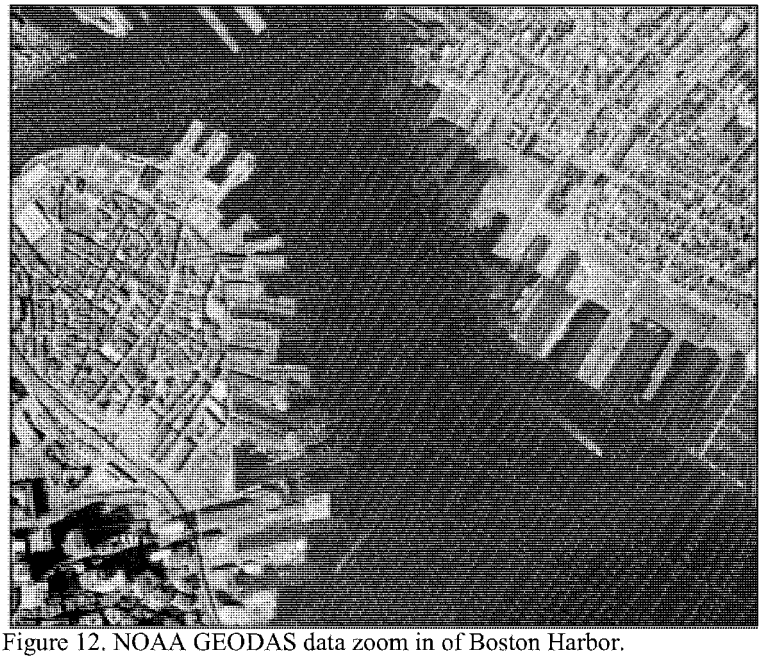


Figure 12. NOAA GEODAS data zoom in of Boston Harbor.

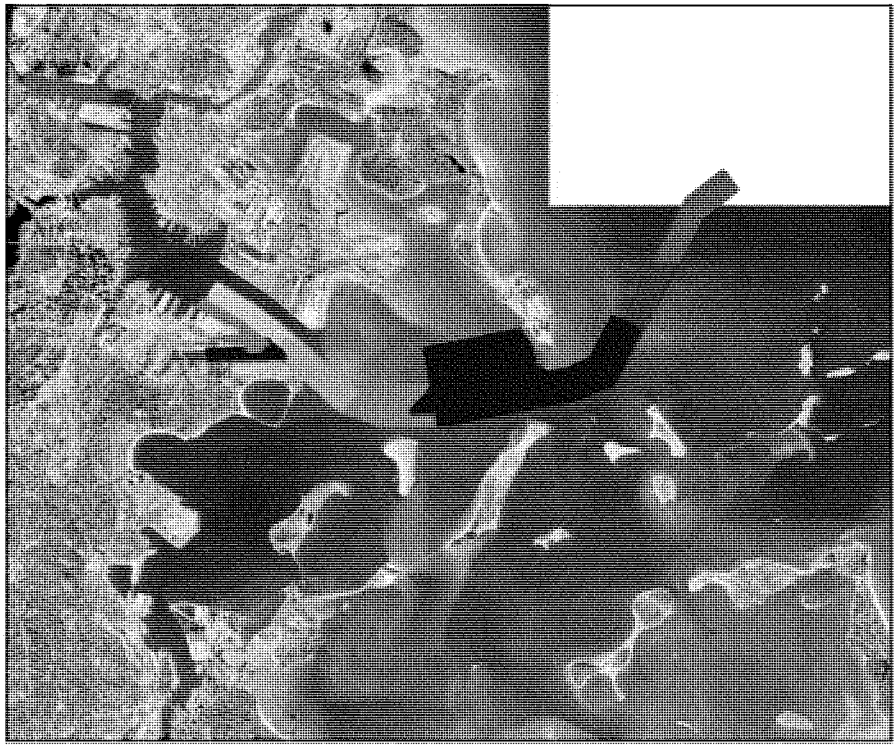


Figure 13. New England District-USACE Survey Data

5.1.3 Existing Condition Model Grid and Model Bathymetry Used

The bathymetry data from both NOAA GEODAS and the New England District were brought into the Corps Surface Modeling System (SMS) version 9.0 to generate the model grid. As previously mentioned, ADCIRC is a finite element model, which allows the grid element size to vary, without grid nesting. The model grid/mesh element sizes can be varied in size depending on the level of accuracy needed in a particular area or for model stability issues (fast current, sharply changing bathymetry, etc.). Due the scale of the model domain, the detailed nature of the Boston Harbor shoreline, and the numerous tidal marsh/channel areas, this was an important feature of the model. The model grid (elements can be seen in Figures 14, 15, and 16. Figure 14 shows the entire model domain, while Figures 15 and 16 provide zoomed in views of the grid to demonstrate the detail of the grid. The largest grid cell size (in deep water) is 518 meters wide, while the finer grid cells are on the order of several meters wide. Figures 17 and 18 show the resultant bathymetry used for the modeling effort and Figure 19 is a zoomed in view of Boston Harbor's Reserve Channel/Turning Basin area. Take note that the vertical scale is different from figure to figure due to the varying elevation ranges in each figure. The shoreline used to define the model grid will be discussed in the next section.

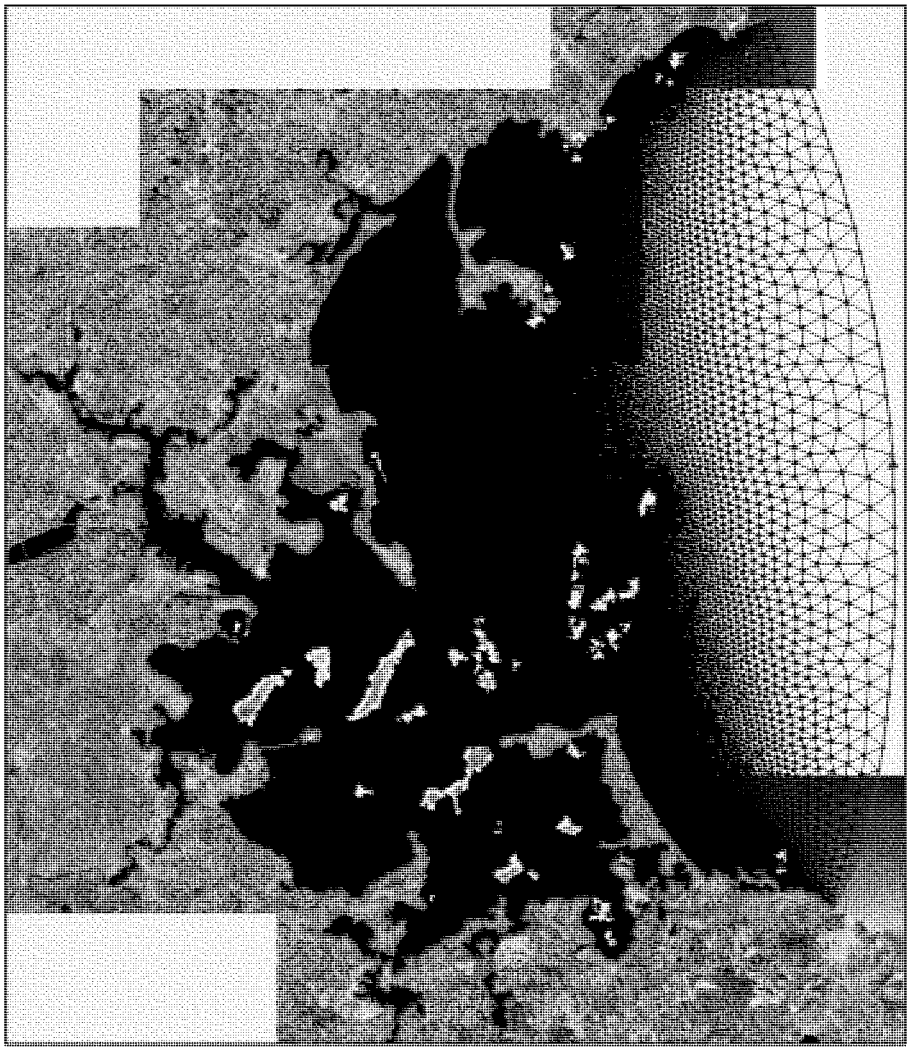


Figure 14. Full mesh for Boston Harbor ADCIRC model.

Figure 15. Model mesh zoomed in view.

Figure 16. Boston Harbor model mesh – example of mesh detail

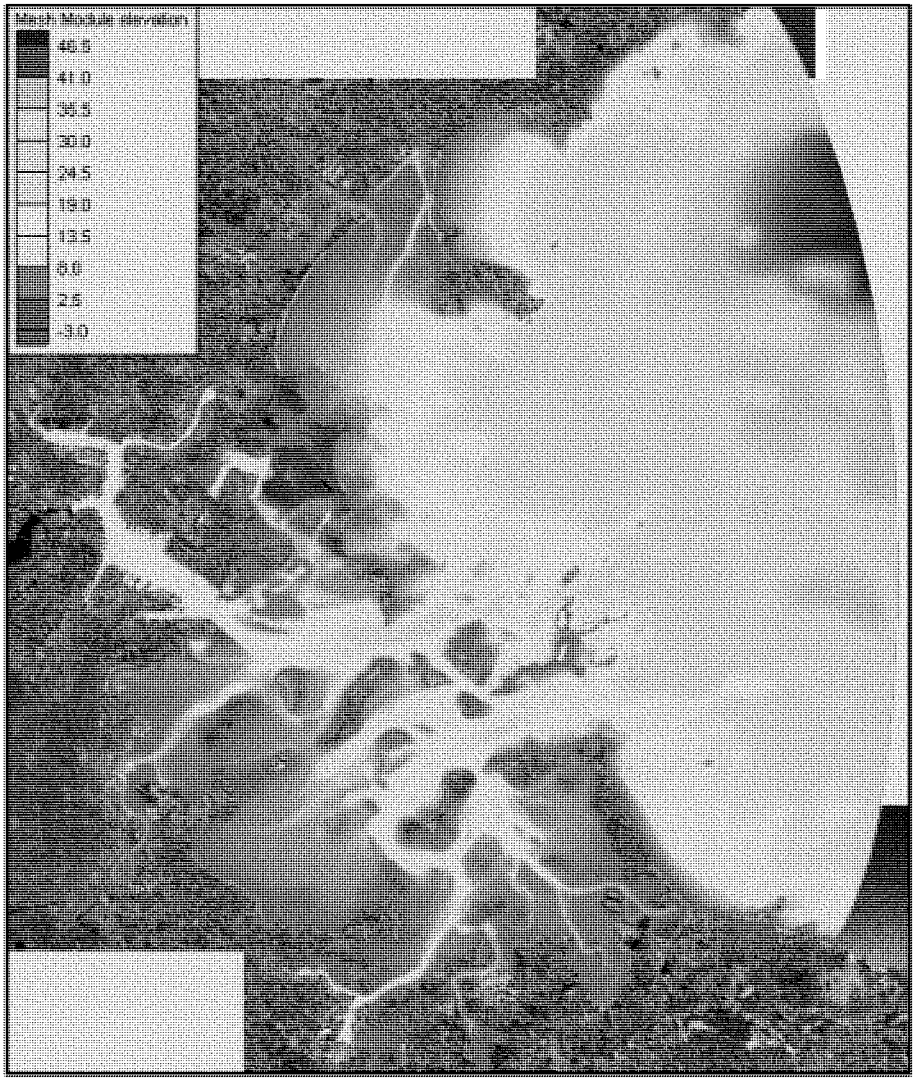


Figure 17. Bathymetry used for existing conditions model (Meters-MSL).

Figure 18. Bathymetry of Boston Inner Harbor used for existing model (Meters-MSL).

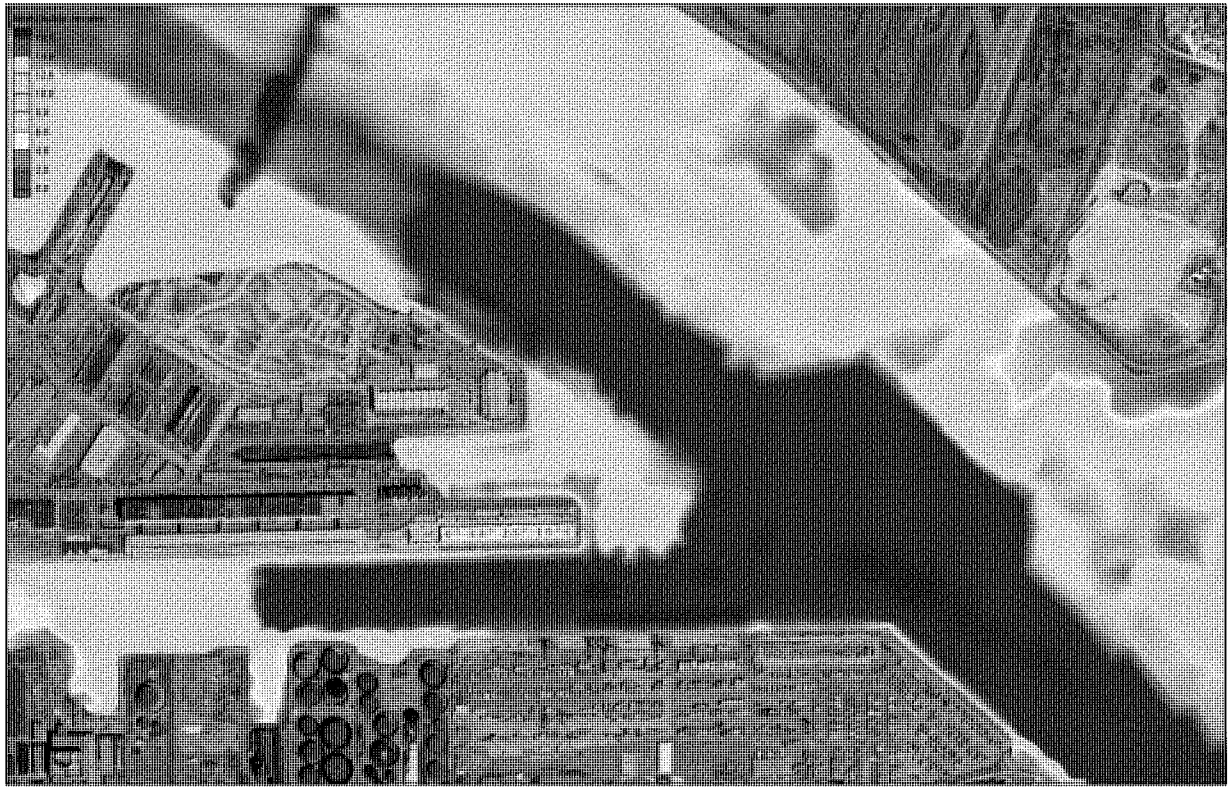


Figure 19. Boston Harbor Reserve Channel and Turning Basin bathymetry for existing conditions model (Meters-MSL)

5.2 Model Boundaries

5.2.1 Model Shoreline Boundary

The shoreline data for the model domain was obtained by meticulously tracing the shoreline from the State of MA 2001/2003 ortho-photos. Both the MA shoreline GIS layer and the NOAA shoreline from the Coastal Services Center were initially planned to be used but after attempting to correct numerous large scale discrepancies it was decided to invest the time and create an accurate shoreline for this modeling effort. From the aerial photos, the shoreline was mapped in ArcMap GIS using approximate beach/shoreline markers such as wetted bound, rock coloration, vegetation lines, channel boundaries in marshes, and hard vertical features such as piers. These features could result in errors on the scale of several meters, but considering the large model domain and the intended purpose of the model it was determined that these errors were insignificant. It is also expected that there are some errors within the inner harbor of Boston Harbor. The pier structures were not ground truthed so it was difficult in some instances to determine if these features were pile mounted features or filled or bulkhead type features. Once again considering the model domain it was anticipated that these issues would not impact the model. The shoreline has been provided in Figures 20 and 21, which show the entire domain shoreline, and a close up to show the reader how it compares to the aerial photos used. In order to use the shoreline in the model the ArcMap based shoreline was converted to a fairly dense point file. The spacing between shoreline points was less than ten meters and can be seen in Figure 22.

5.2.2 Ocean Boundary

The ocean boundary was defined fairly far out from the project area to keep the influences of the boundary condition away from the area of interest. As mentioned the models ocean boundary swept from Marble Head, MA to near Cohasset Harbor, MA on an arc with a roughly 12.5 mile radius from the turning basin at the end of the Reserve Channel in Boston Harbor (Figure 23). The tidal conditions or model driving conditions at the ocean boundary were taken from the Portland, ME tidal recording station. The NOAA tidal station at Portland ME, records and reports tidal elevations every 6 minutes. The data was easy to acquire from NOAA's web page. At first this choice for boundary condition elevations may seem inappropriate, but comparing the Portland, ME Benchmark Station # 8418150 (provided as Table 2) to the Boston Benchmark (Table 1 Section 5.1.1) it can be seen the tidal regimes are very similar. Looking at predicted tidal information from NOAA it can be seen that at the northern end of the ocean boundary the low tides occur at identical times and high tide is only separated by five minutes. At the southern end of the model boundary the discrepancy in time is slightly larger with high tide occurring 12 minutes later than at Portland only 11 minutes later for low tide. The tidal range is only 0.30 feet different as well.

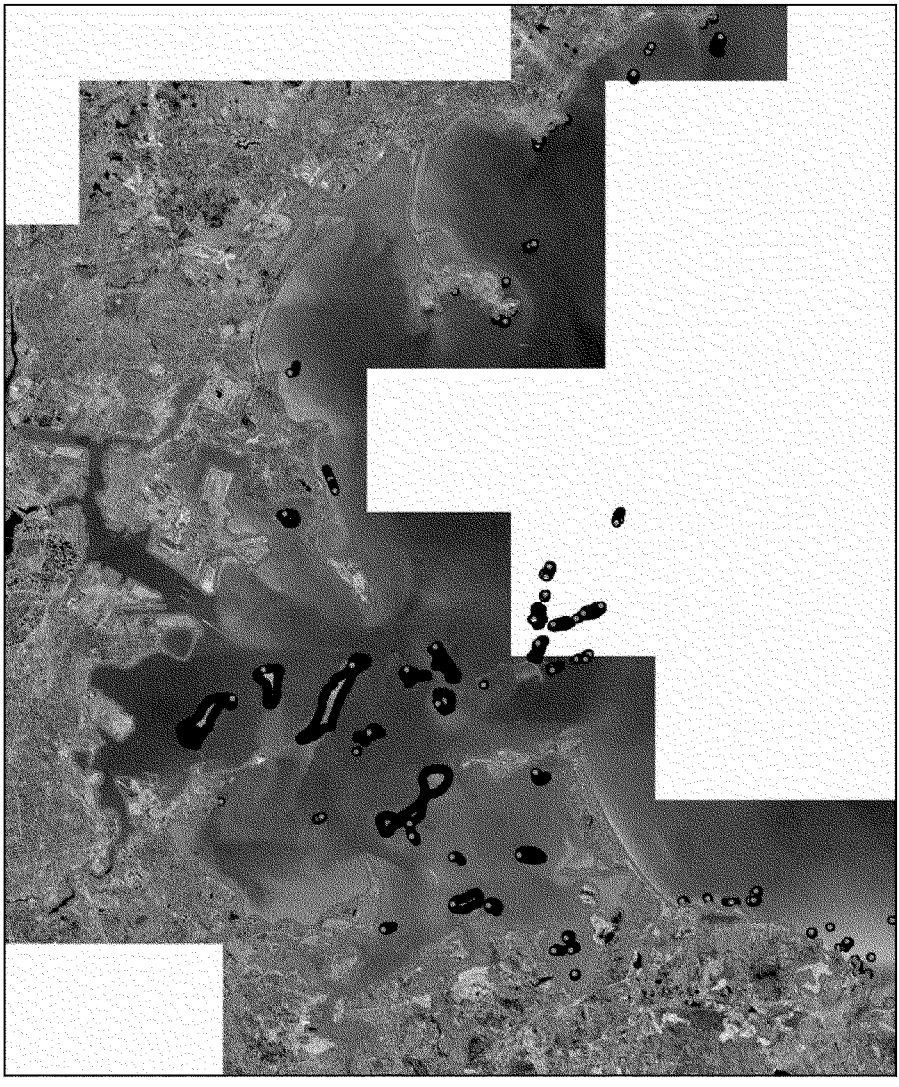


Figure 20. Boston Harbor shoreline map for model domain.

Figure 21. Zoomed in view of Boston Harbor shoreline map.

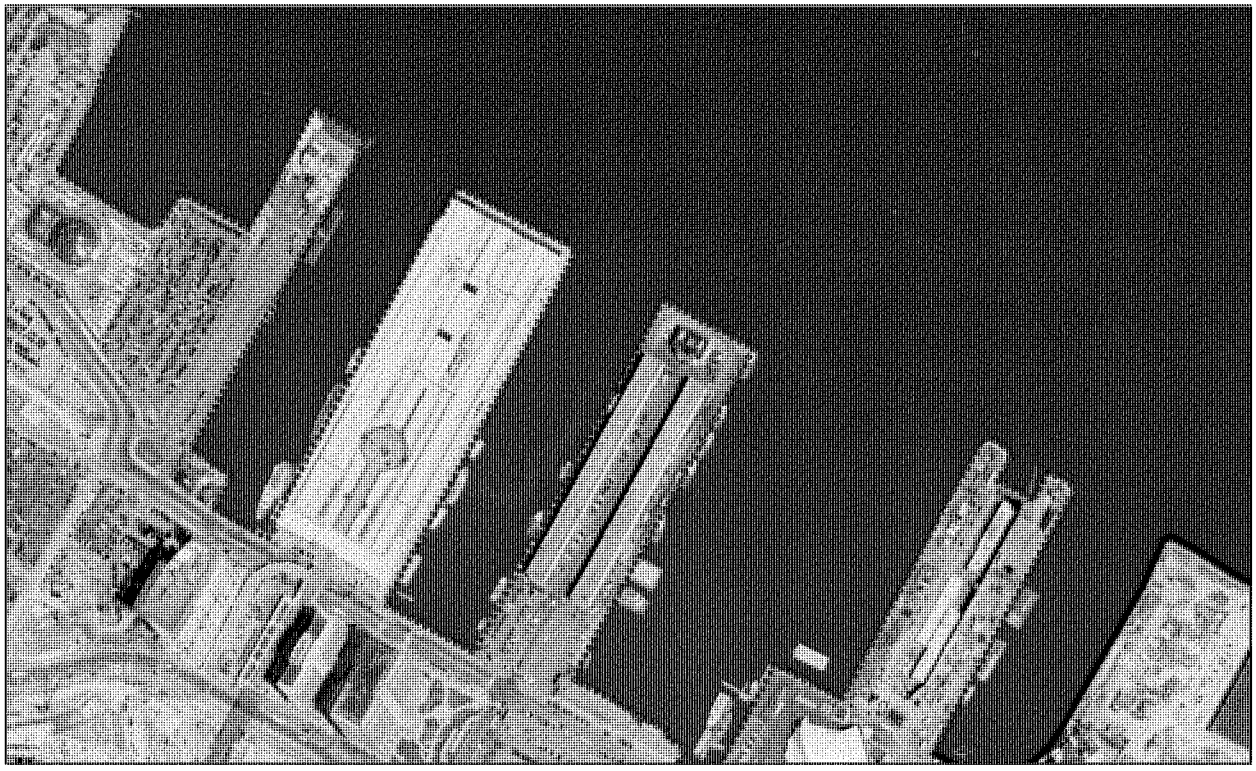


Figure 22. Boston Harbor shoreline converted to points to use in SMS/model mesh

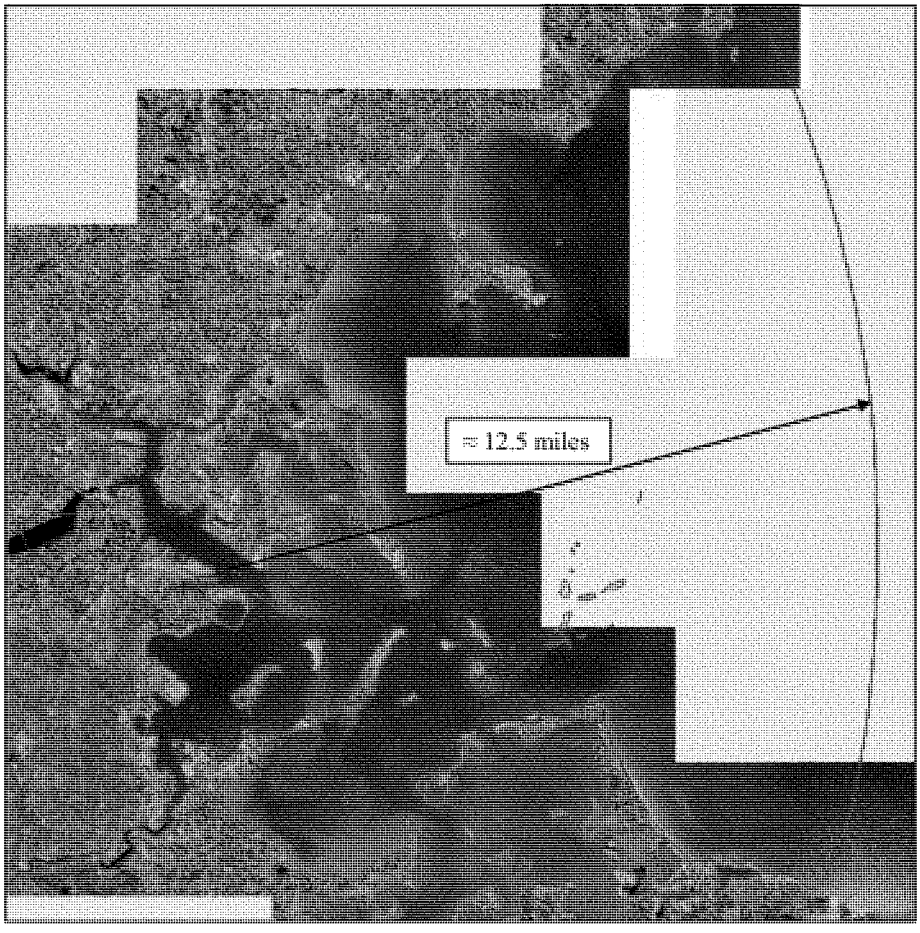


Figure 23. Model boundaries.

Table 2. Portland, ME Benchmark – Station # 8418150

Datum	MLLW feet	MTL feet	NGVD29 feet	NAVD88 feet
MEAN HIGHER HIGH WATER (MHHW)	9.91	5.00	5.39	4.66
MEAN HIGH WATER (MHW)	9.47	4.56	4.95	4.22
NORTH AMERICAN VERTICAL DATUM-1988 (NAVD)	5.25	0.34	0.73	0.00
Mean Sea Level (MSL)	4.94	0.03	0.42	-0.31
MEAN TIDE LEVEL (MTL)	4.91	0.00	0.39	-0.34
NGVD29	4.52	-0.39	0.00	-0.73
Mean Low Water (MLW)	0.34	-4.57	-4.18	-4.91
Mean Lower Low Water (MLLW)	0.00	-4.91	-4.52	-5.25

LENGTH OF SERIES: 19 Years
TIME PERIOD: January 1983 - December 2001
TIDAL EPOCH: 1983-2001

5.3 Frictional Information

The bottom friction, or Manning's "n", coefficients used across the model domain are shown in Figure 24. The main intent of the higher frictional values shown in the figure was to provide model stability. Exact care was not given in these areas and model results in these areas are likely not accurate. The main concern of this effort was the deeper navigation channel areas. If this model is to be used in the future to investigate the wetlands and smaller basins included in this model domain the model will need to be calibrated/validated for these areas.

6.0 Model Validation

In order to validate the ADCIRC model, an extensive field data collection effort was undertaken during the winter of 2004/2005. This effort was discussed in Section 4.0 with the detailed data collection being provided in Attachment 3.

For this effort calibration was not really performed, instead only model validation. Due to the ADIRC model code, there are not many variables to adjust. The model was run for two ten day simulations that covered the dates of February 1st to 10th, of 2005. The first run included wind while the second one did not. Significant differences were not noticed between the two runs. The model validation results can be seen below in three sets of information. The first set (shown in Figure 25), shows the comparison of the water elevation at various locations across the model domain. The points are located at the tide data recording stations from the data collection effort (locations shown in Figure 2). The second type of data used for validation was the current velocity information collected at the CM2 current meter location. This current meter was the eastern most bottom mounted ADCP current meter (location shown in Figure 2). As discussed in Section 4.0 the bottom mounted ADCP located in the inner harbor (CM 1) failed and no data was collected. The depth averaged current velocity data was compared directly to the model data at the ADCP gage coordinates. The results of the comparison are provided graphically in Figure 26. The third set of data/information that was used to validate the model was the boat mounted ADCP transect current data. The comparison between

transect data and the model was not as straight forward as comparing the model data to the in situ gage data since the transects were not instantaneous snap shots of the channel current profile. The model output, which was in one hour time steps, was used by using the time step data that straddled the transect time for comparison. SMS and ArcMap GIS were used for the comparison and the results can be seen in Figures 27 to 32.

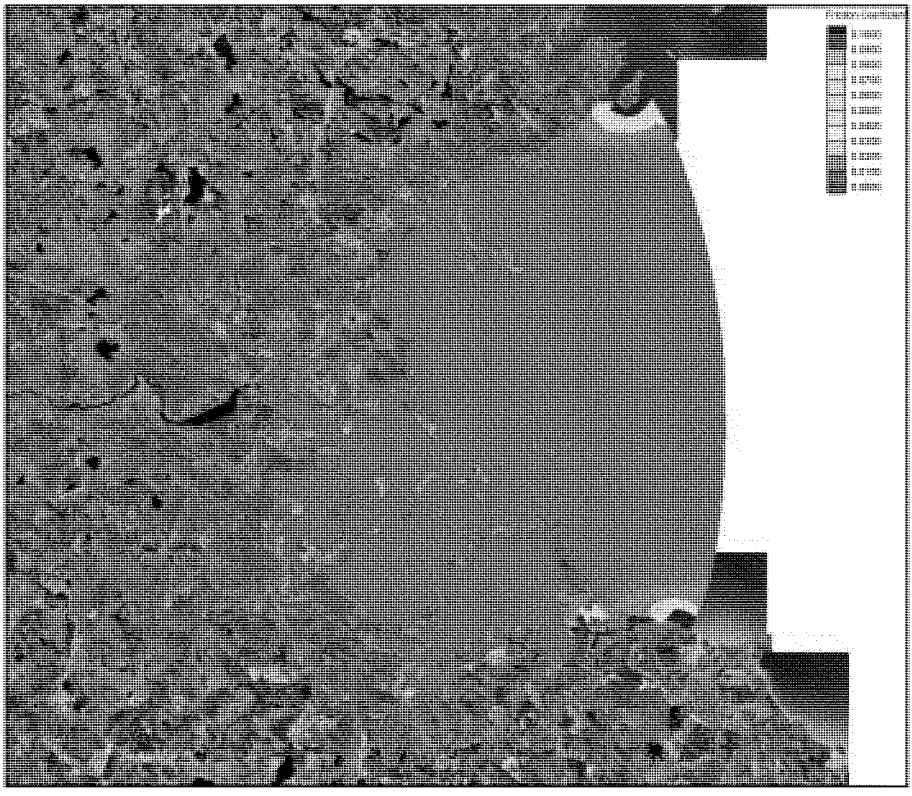


Figure 24. Map of bottom friction values used across model domain.

6.1 Model Validation Discussion

As shown in Figures 25 through 32 the validation run compares very well to the data that was collected. As provided in Attachment 3 the numerical information used to generate the graphics is provided. This information shows that the elevation data is nearly identical and along with the current data at the in situ station with a few exceptions. As shown in Figure 25, later in the 10 day simulation, the tidal phase output from the model elevation data at both CHL3 and 4 begins to lead the recorded data. The elevations are still very close, and the impacts to the model and ship simulator are not important but it is worth noting. Also, as shown in Figure 26, the current magnitude in the East/West

direction slightly overestimates the ebb tide speed and slightly underestimates the flood tide speed.

As discussed, due to the issues of comparing the boat mounted ADCP data to model data, comparisons between the two was more difficult. However it can be seen in Figures 27 and 32 that the model output matches the ADCP fairly well. The only exception is shown in Figure 32 in which the two sets of data do not match. It is uncertain what caused this large discrepancy, but based on the quality of the model validation shown in all other figures this was written off as an error in time stamping data, a processing error, or some other type of procedural error.

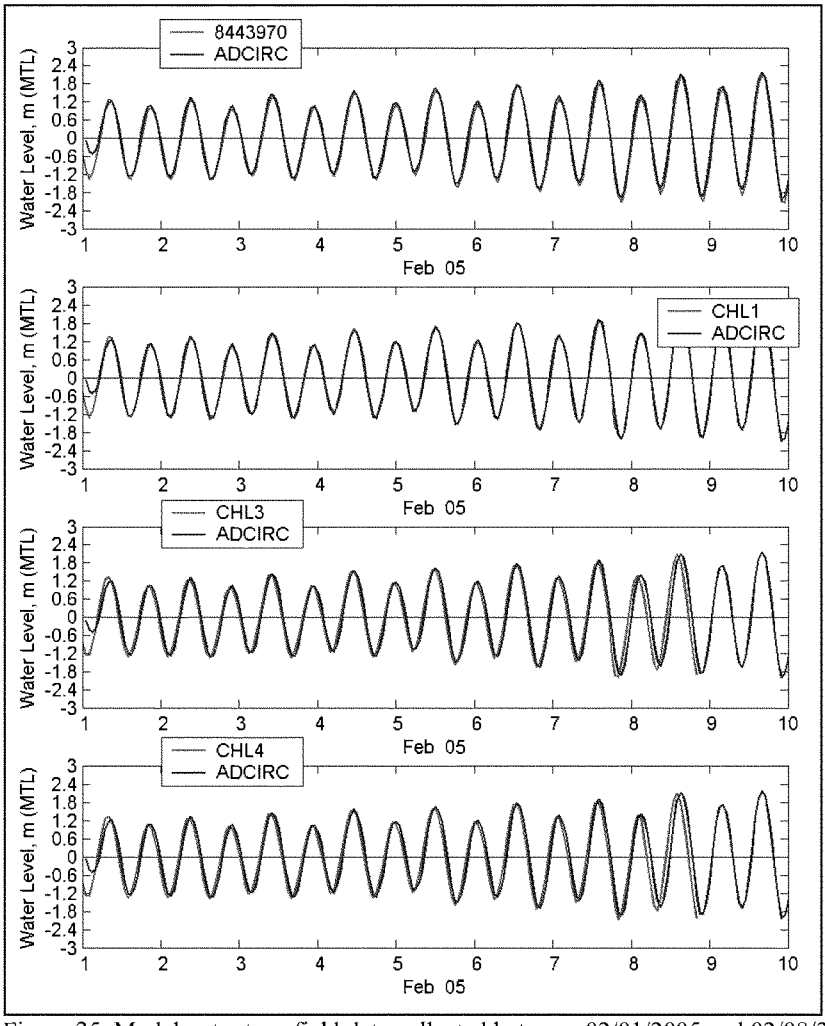


Figure 25. Model output vs. field data collected between 02/01/2005 and 02/08/2005

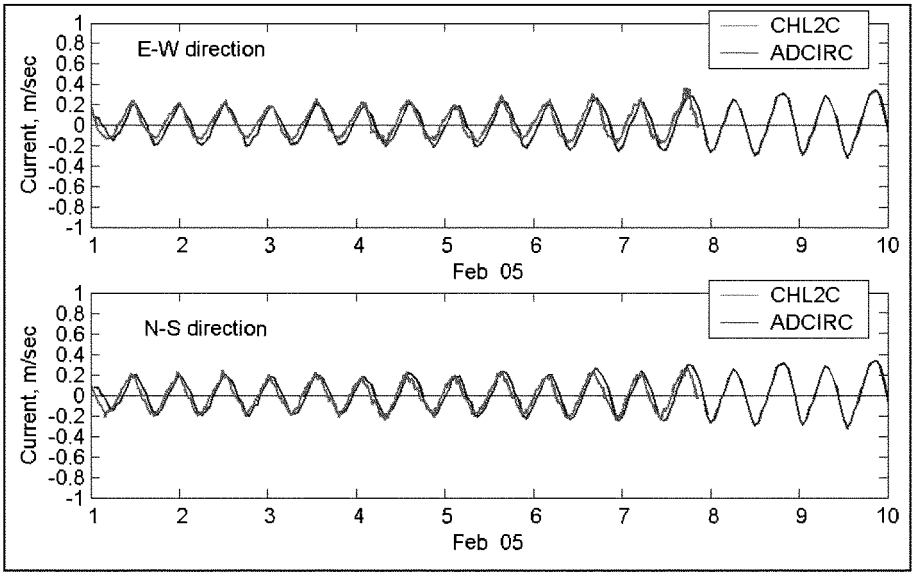
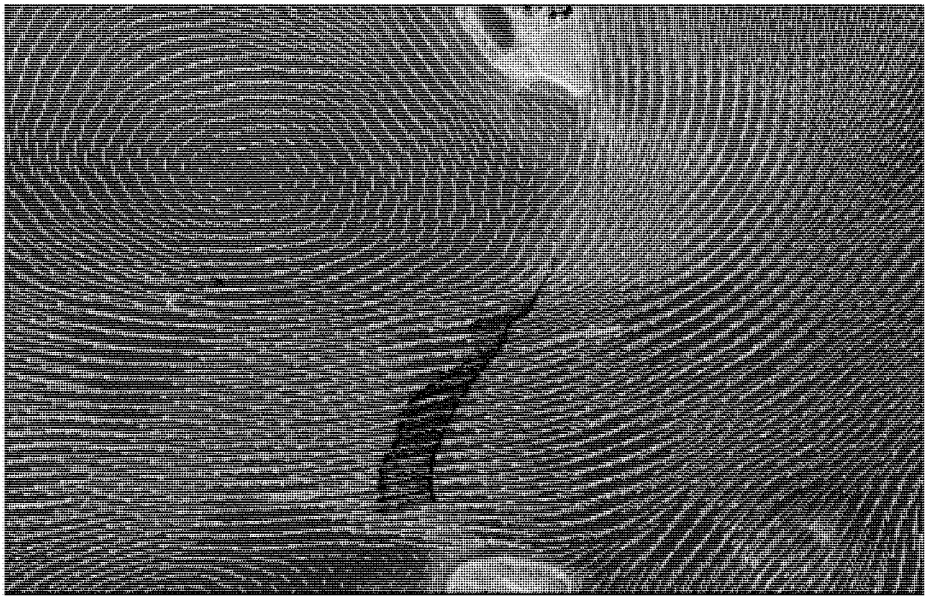


Figure 26. Model output vs. field data collected between 02/01/2005 and 02/08/2005



Figures 27. Boat ADCP data Transect 1 02-08-05 13:41 compared to model data at 14:00.

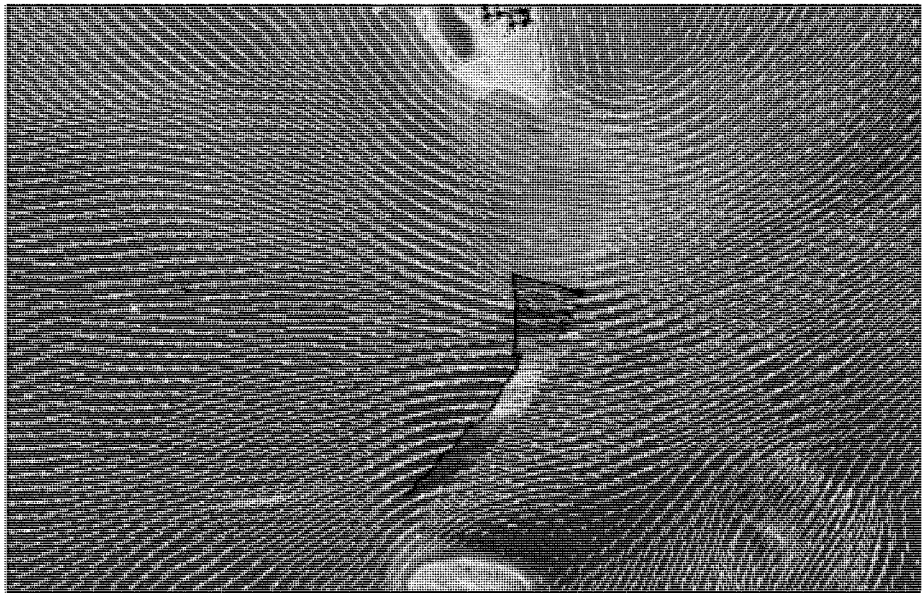


Figure 28. Boat ADCP data Transect 1 02/08/05 18:40 compared to model data at 19:00

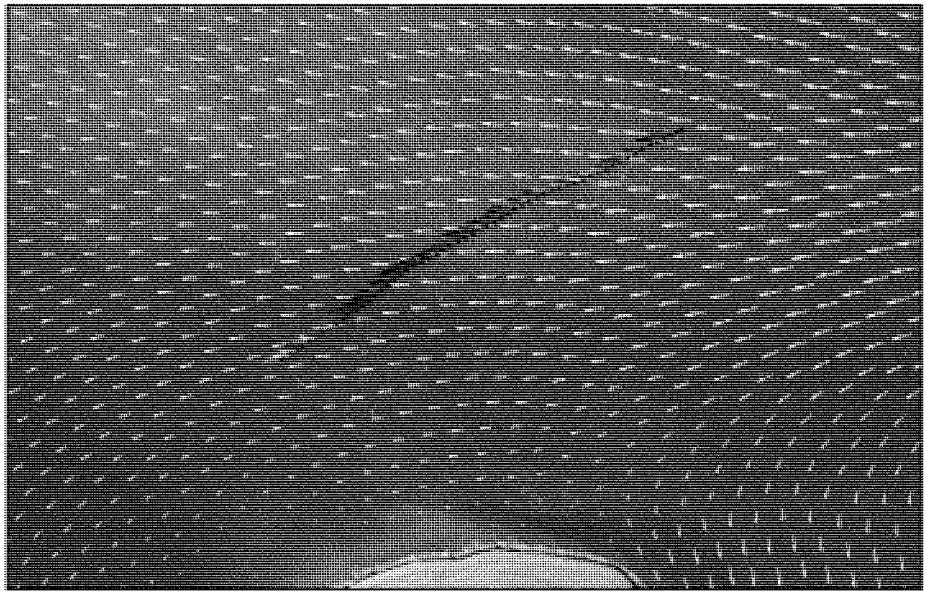


Figure 29. Boat ADCP data Transect 3 02/08/05 15:20 compared to model data at 15:00

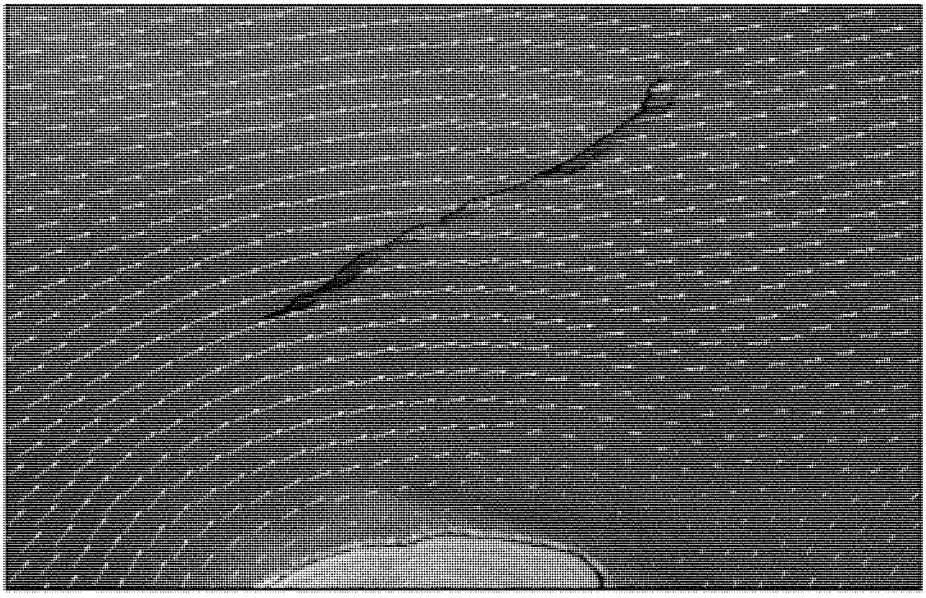


Figure 30. Boat ADCP data Transect 3 02/08/05 20:12 compared to model data at 20:00

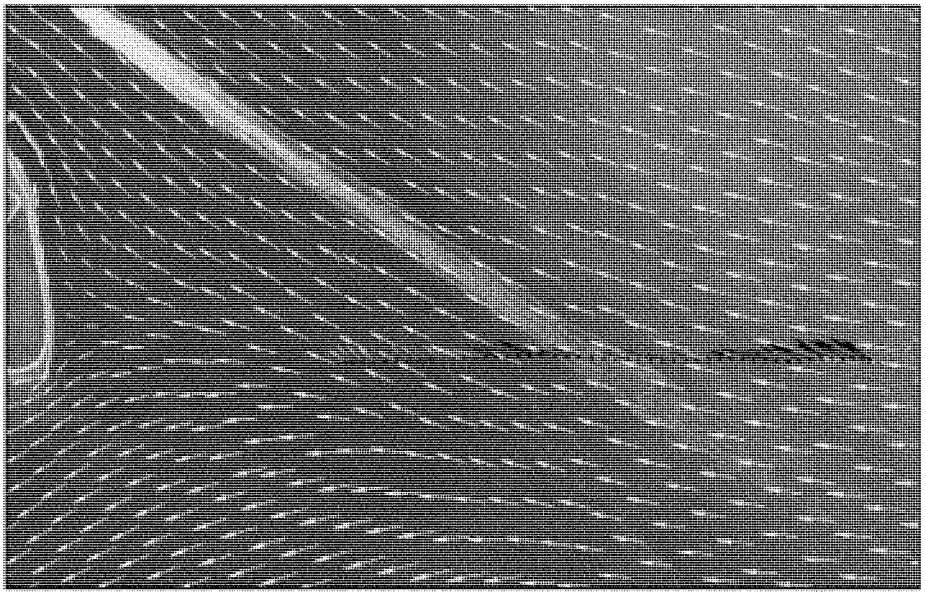


Figure 31. Boat ADCP data Transect 2 02/08/05 14:15 compared to model data at 14:00

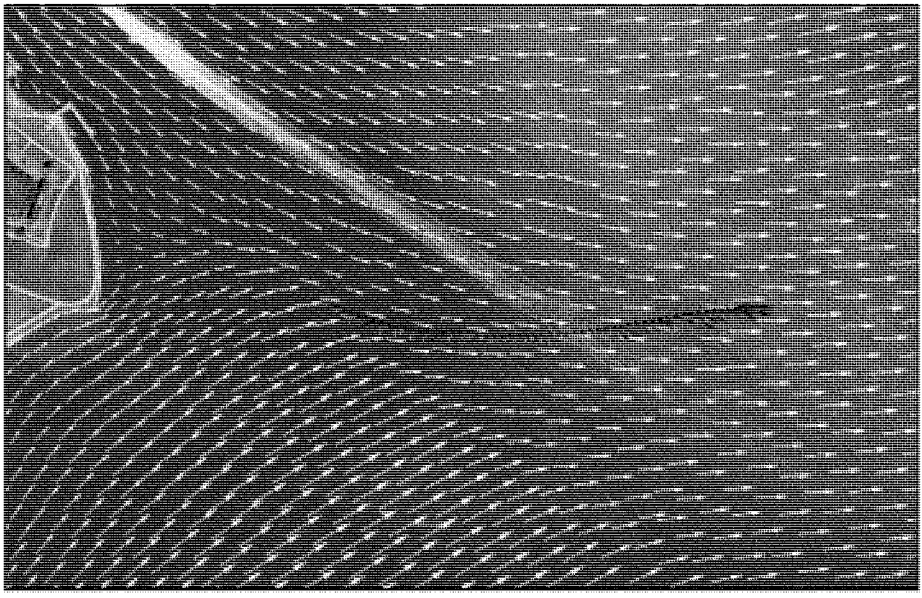


Figure 32. Boat ADCP data Transect 2 02/08/05 18:03 compared to model data at 18:00

7.0 Model Run – Existing Conditions

The existing conditions run is the same as the validation run. The highest current velocity magnitudes occur near the very end of the simulation since this time period was a Spring Tide condition. The peak ebb and flood currents have been provided in Figures 33 through 36. The highest current speeds that occur in the navigation channel are between Long Island and Deer Island. In this area the current speeds exceed 1.25 m/s or 3 mph. Along the rest of the navigation channel current speeds are less than 1.0 m/s or 2.25 mph. These maximum current speed fields were converted to the proper format for the Ship Simulator and provided to Mr. Dennis Webb of ERDC in Vicksburg, MS. Maximum current speed fields were used since these would impact ship handling the most. It was important to have the existing conditions modeled so that it could be verified by the Boston Harbor Bar Pilots that the ship simulator was reasonably representing real world conditions.

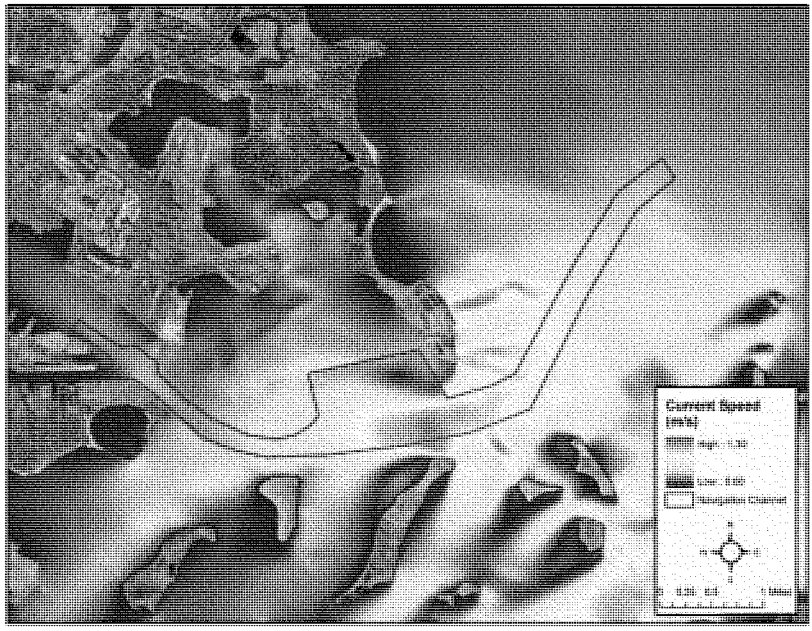


Figure 33. Maximum flood current (hour 123 of simulation)

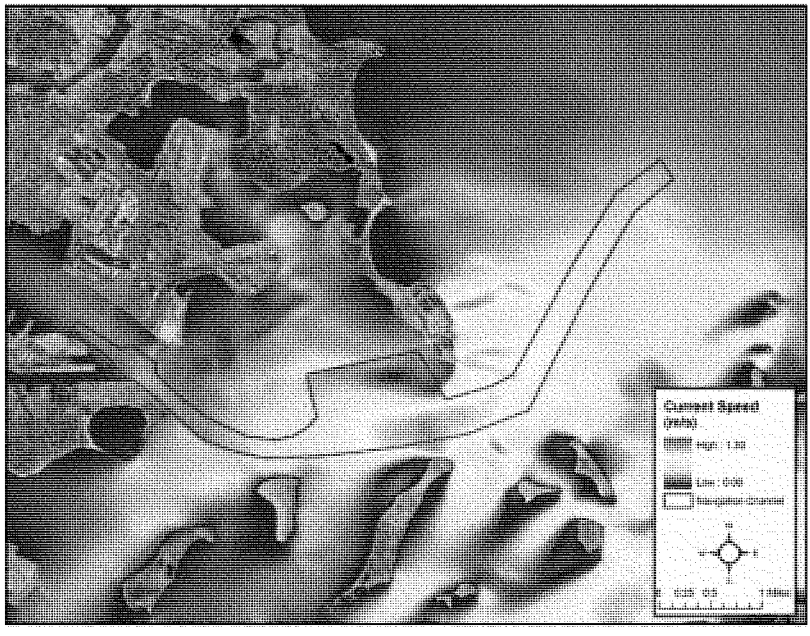


Figure 34. Maximum flood current (hour 135 of simulation)

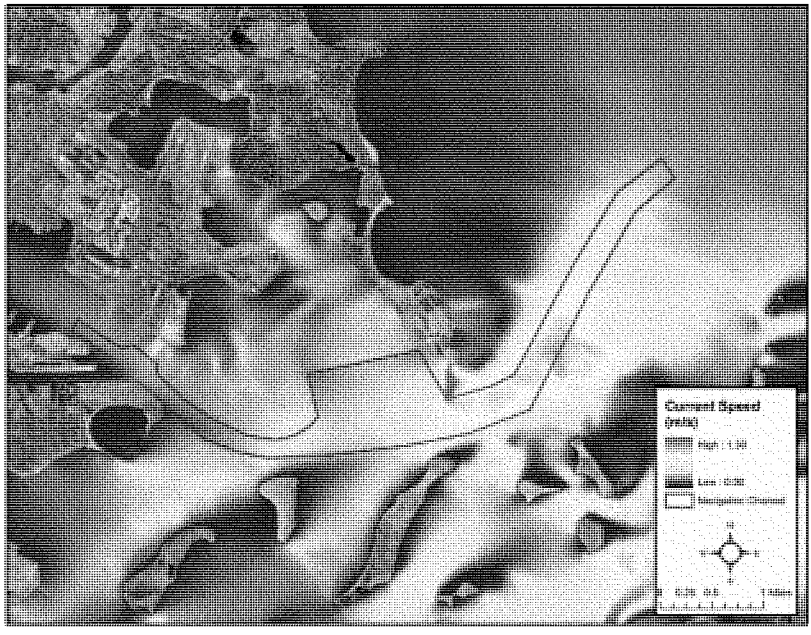


Figure 35. Maximum ebb current (hour 129 of simulation)

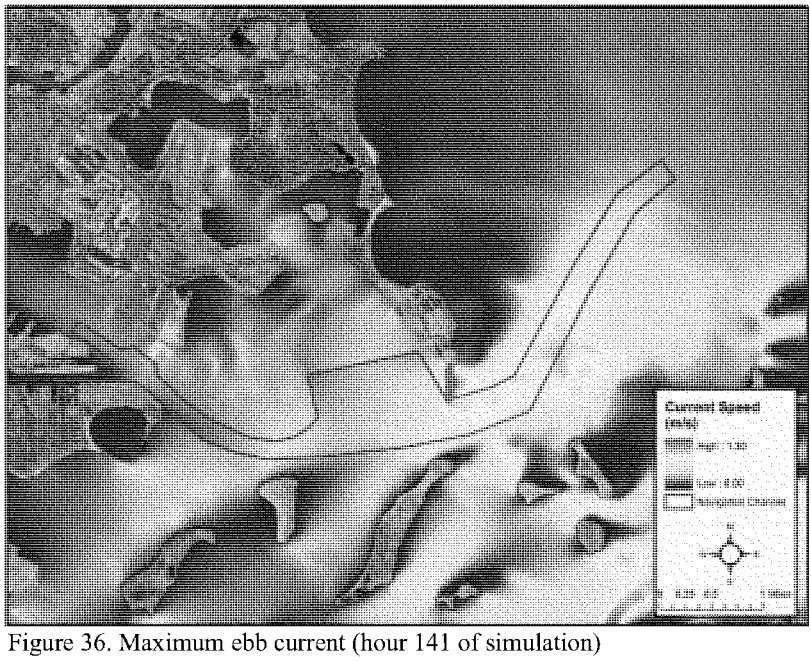


Figure 36. Maximum ebb current (hour 141 of simulation)

8.0 Alternative Model Runs

Alternative model runs were conducted for three different navigation channel depths which were, -44, -45, and -48 feet-MLLW. The existing conditions model mesh was altered by highlighting the nodes in the model that fell within the "deepening" area and changing the depths to the alternative depths. Depths that were already below the alternative depth were not altered. The model mesh was not altered except for the depth. The differences in elevation for alternatives -45 feet and -48 feet compared to the existing condition are shown in Figures 37, 38.

The resulting maximums for the spring flood and ebb currents have been provided below for the -45 foot and -48 foot alternatives (Figures 39, 41, 43, and 45). Also provided in Figures 40, 42, and 44 are the differences between the -45 foot and -48 foot alternatives and the existing condition currents. It can be seen that in the navigation channel area the changes are relatively small with the maximum current speed increase of 0.04 m/s or 0.09 mph for both the -45 foot and -48 foot alternatives. This is less than a 5% increase in current speed.

An additional alternative was looked at during the feasibility study outside of the three alternatives that were modeled. A -50 feet-MLLW channel option was looked at. Based on the very small increase in current speeds seen for the -45 and -48 foot alternatives, it was concluded that the -50 foot alternative would not cause a significant change in current velocity either.

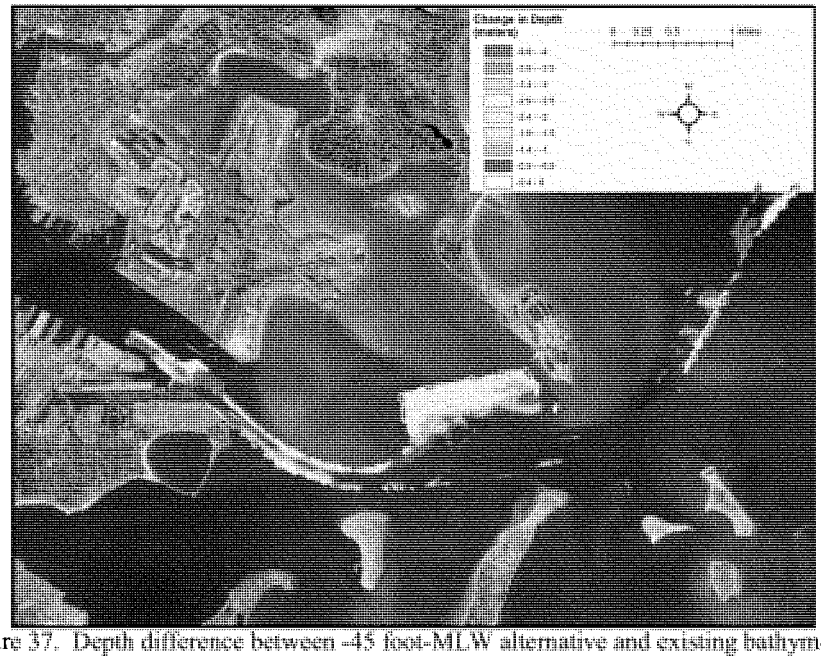


Figure 37. Depth difference between -45 foot-MLW alternative and existing bathymetry.

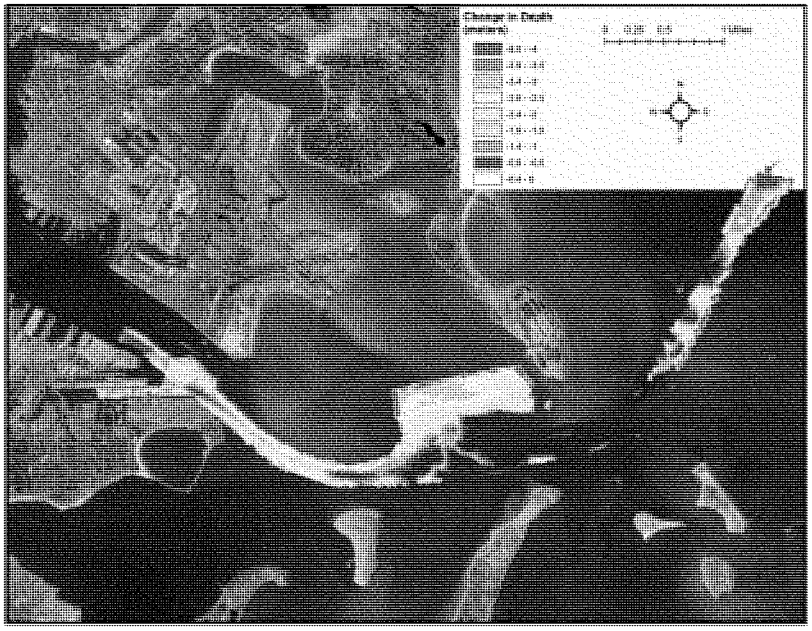


Figure 38. Depth difference between -48 foot-MLW alternative and existing bathymetry.

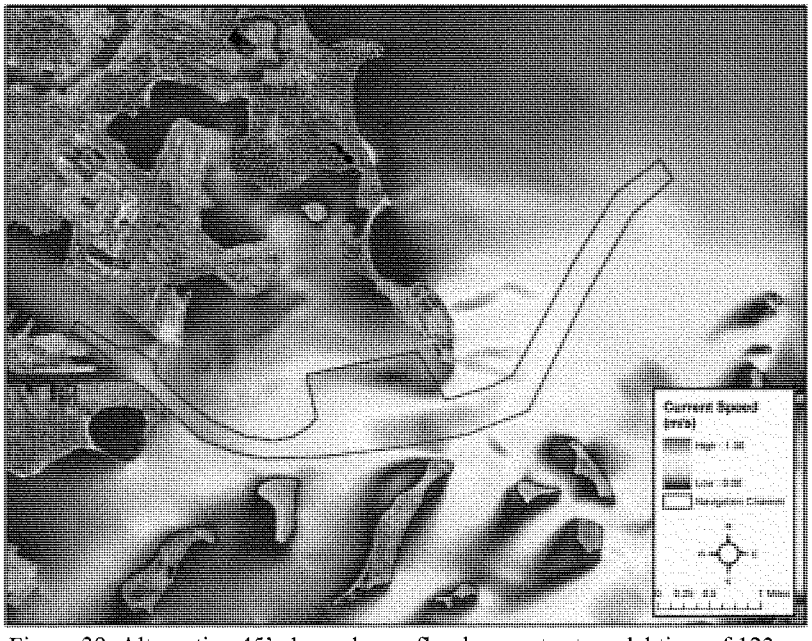


Figure 39. Alternative 45' channel max flood currents at model time of 123.

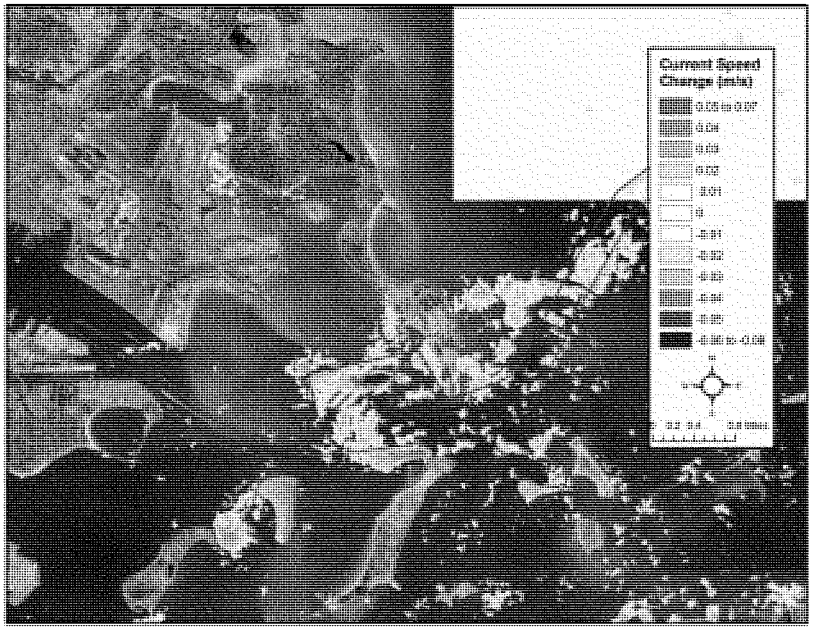


Figure 40. Alternative 45' channel minus existing conditions currents at model time 123.

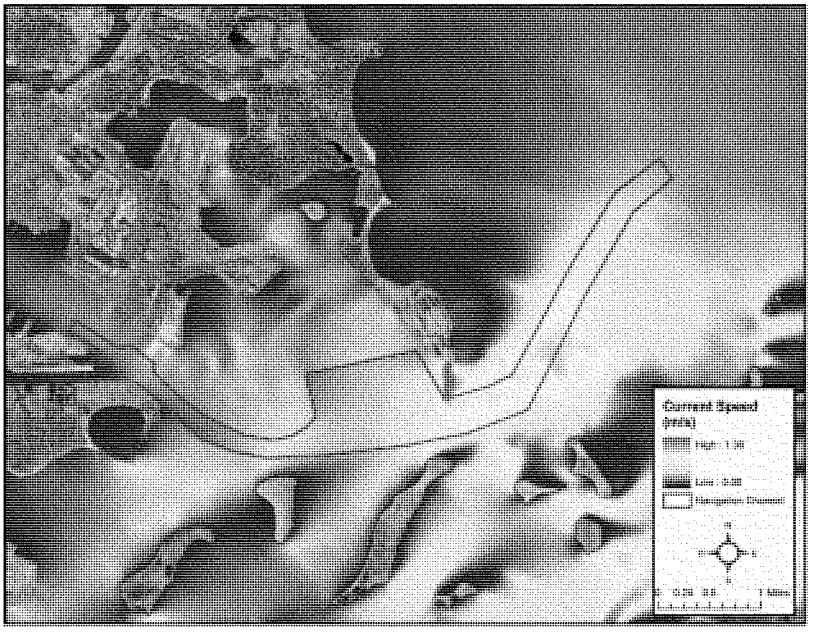


Figure 41. Alternative 45 max ebb currents at model time of 141.

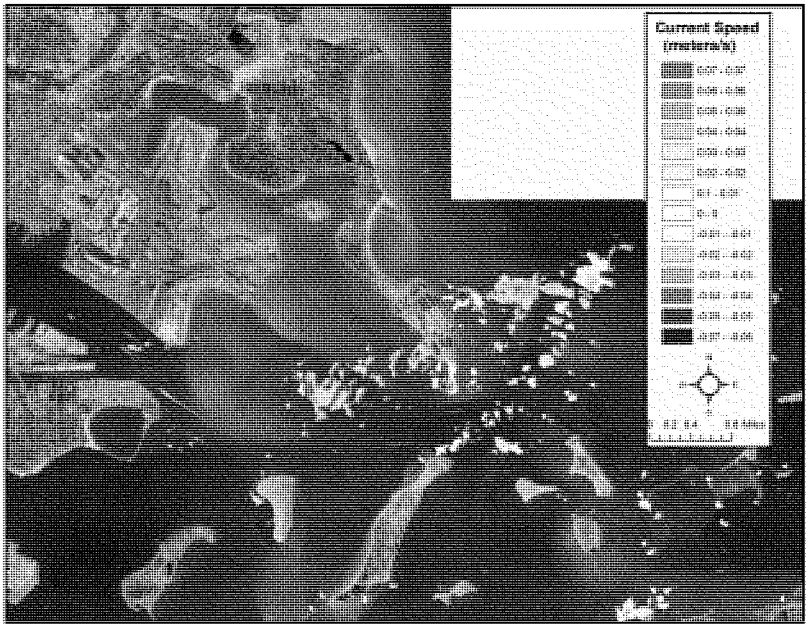


Figure 42. Alternative 45' channel minus existing conditions currents at model time 141.

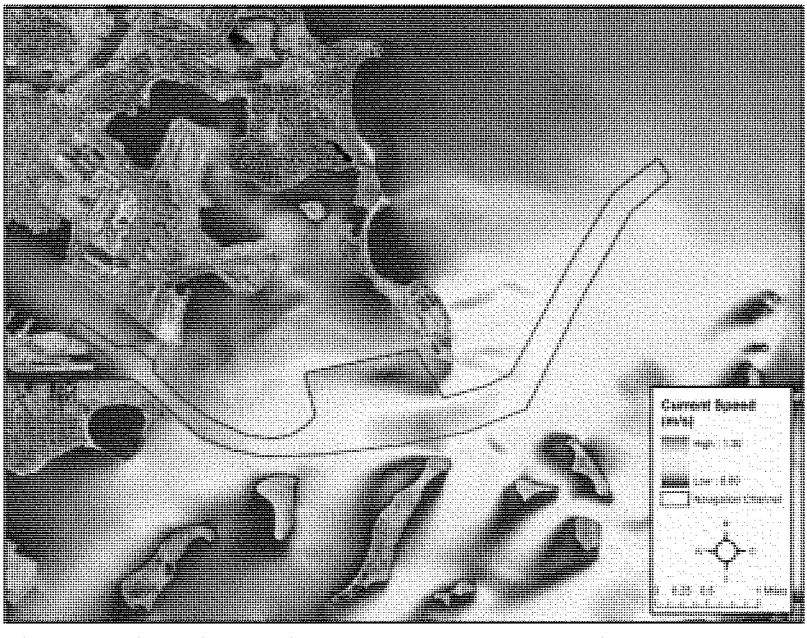


Figure 43. Alternative 48' channel max flood currents model time step 123

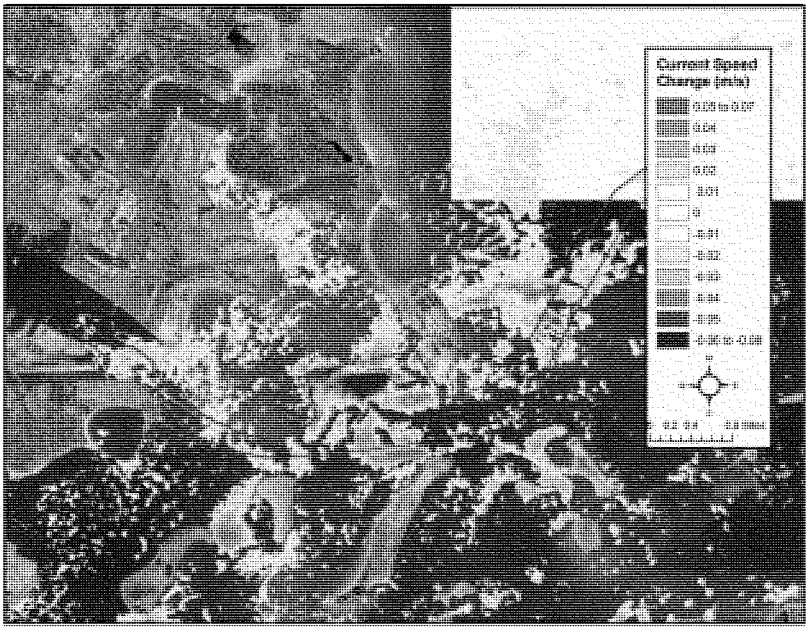


Figure 44. Alternative 48' channel minus existing conditions currents at model time 123

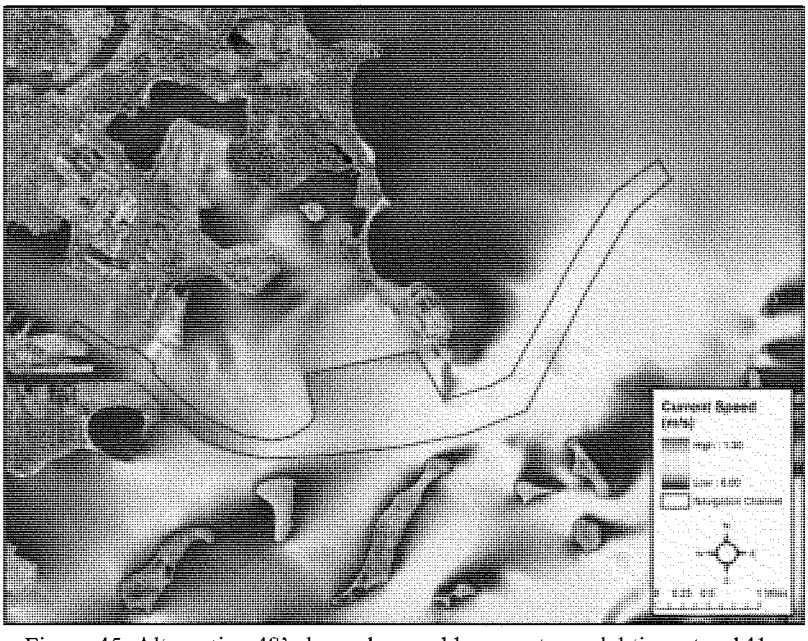


Figure 45. Alternative 48' channel max ebb currents model time step 141

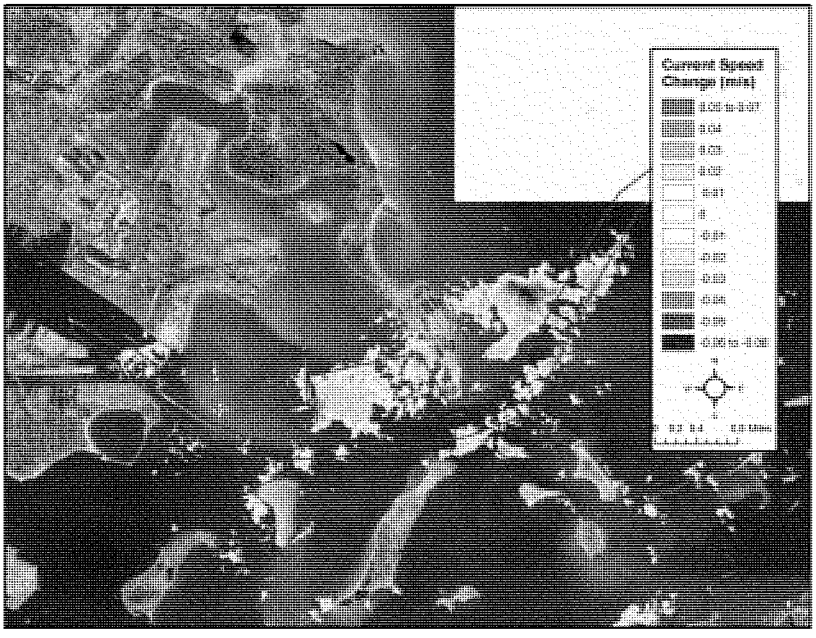


Figure 46. Alternative 48' channel minus existing conditions currents at model time 141

8.1 Alternative Model Runs – Adjusted Reserve Channel Turning Basin

Due to the discovery that the proposed improvements to the turning basin at the end of the reserve channel were directly in line with the flight path of airplanes from Boston Logan Airport, and from the input provided by the Boston Harbor Bar Pilot ship simulation runs, an alternative turning basin layout was designed. Figures 47 to 49 show the different layout of the turning basin. Since the altered turning basin would require significant removal of bank material at the north edge (Figure 49), it was determined that the new bathymetries would have to be modeled. It was thought that the bathymetric changes were significant enough to change the current field in the local area of the turning basin. The altered turning basin alternative was run for the -44 foot, -45 foot, and -48 foot channel depths. The model mesh was changed in the same fashion as the first set of alternatives. Due to the high mesh density the mesh elements did not need to be altered in the turning basin area and only the elevations were changed. The current speed differences between the -45 foot and -48 foot channel alternatives with the altered turning basin were compared to the original -45 foot and -48 foot alternatives. These difference plots are shown in Figures 50 to 53. As shown in the figures the current speed increased where the bathymetry was returned to the existing depth, and dropped where the bathymetry was deepend. The maximum increase was 0.05 m/s or 0.11 mph and the maximum decrease was 0.08 m/s or 0.18 mph. Comparisons to the existing conditions were not made since it was shown in Section 8.0 that the current speed change in this area was very small.

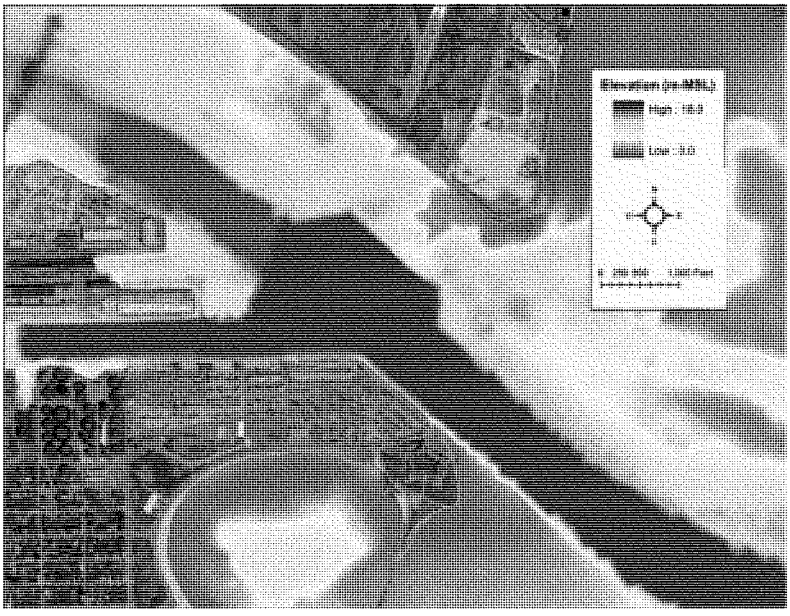


Figure 47. Original Turning Basin

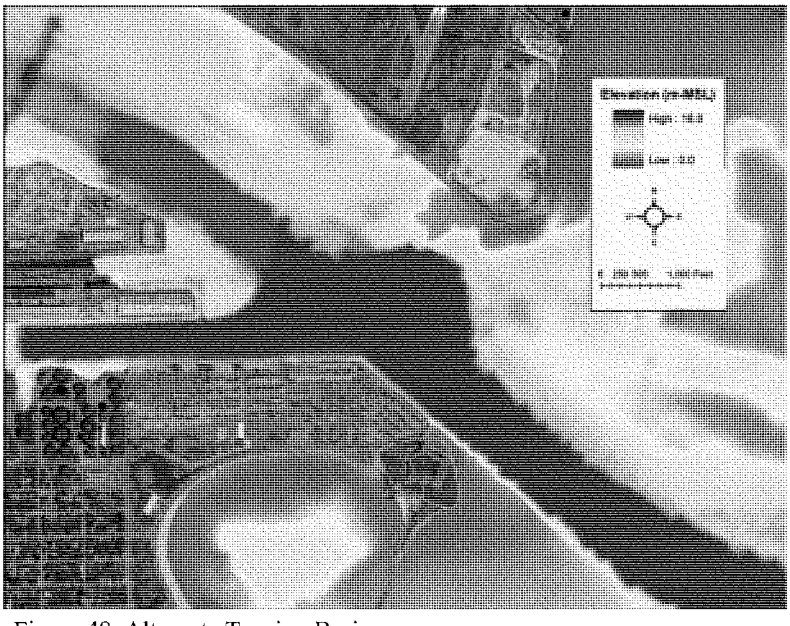


Figure 48. Alternate Turning Basin

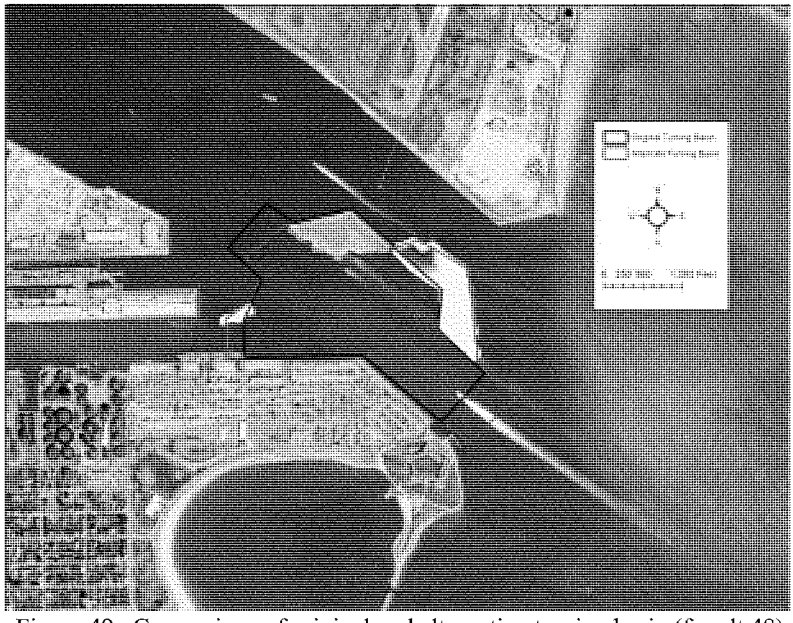


Figure 49. Comparison of original and alternative turning basin (for alt 48).

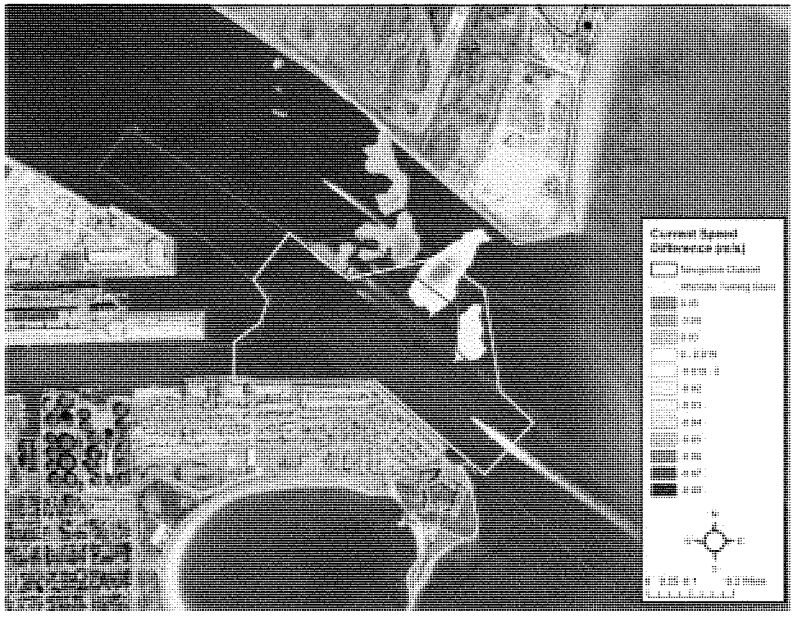


Figure 50. Comparison of original and alternate turning basin model time 123 alt 45.

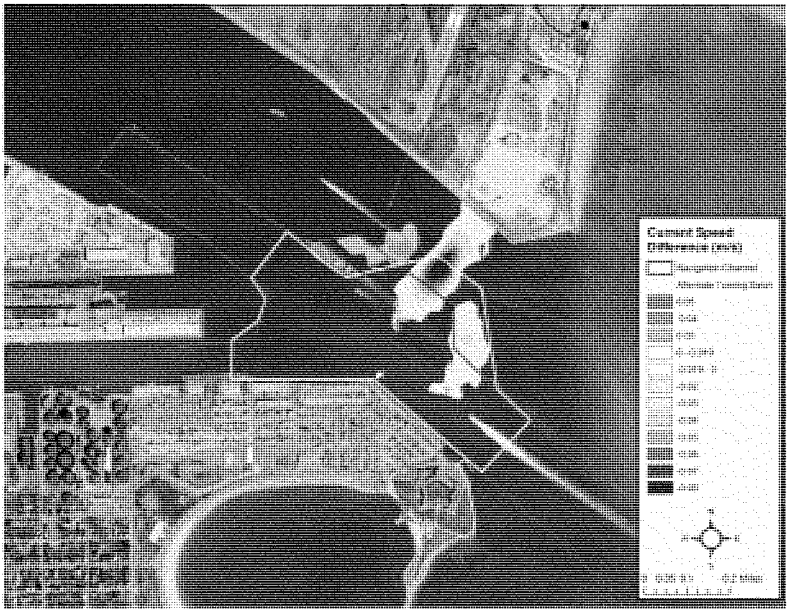


Figure 51. Comparison of original and alternate turning basin model time 141 alt 45.

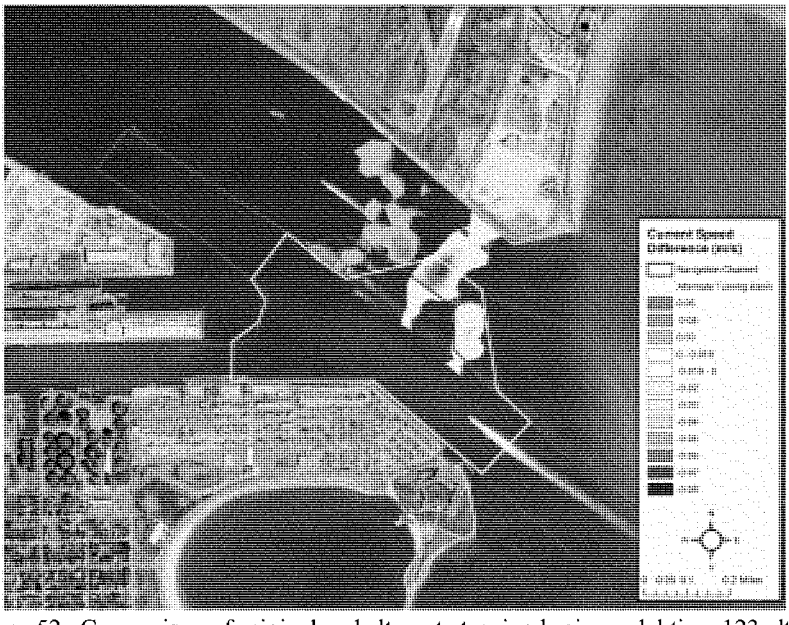


Figure 52. Comparison of original and alternate turning basin model time 123 alt 48.

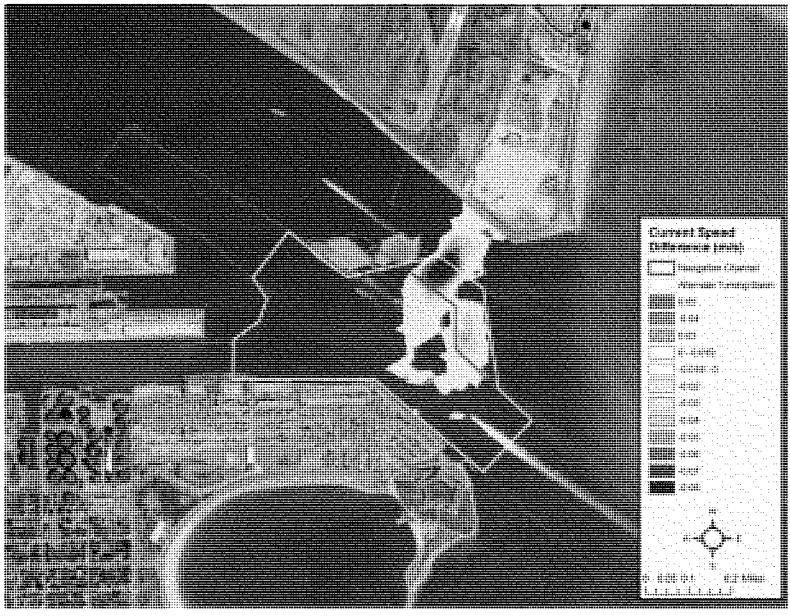


Figure 53. Comparison of original and alternate turning basin model time 141 alt 48

9.0 Conclusions

Based on the validated numerical model and the deepening alternatives modeled, current speeds will not change significantly in the Boston Harbor Navigation Channel and that it is likely that changes in channel layout would have more of an impact on ship handling. The maximum increases were found to be less than 5% which likely falls within modeling error and/or the natural variation in real life currents due to spring and neap tide cycles and wind generated current impacts. While not modeled, the additional alternative of -50 feet-MLLW would not be expected to be noticeably different from the -48 feet-MLLW channel alternative.

10.0 Summary

As part of the Boston Harbor Deep Draft Navigation Study a highly detailed 2-D, depth averaged, hydrodynamic numerical modeling effort was completed. Based on a review of available models, the Corps supported ADCIRC numerical model was chosen. The modeling effort was completed by the New England District, the CHL at ERDC, and the New York District in order to meet schedule deadlines.

Both ArcMap GIS and the SMS 9.0 package were used to develop the model and to run the model. Bathymetric data was taken from the NOAA GEODAS database and from previous navigation channel surveys conducted by USACE New England. The shoreline boundary was mapped using the 2003 Massachusetts aerial photographs and the ocean

boundary was set at over a 12 mile radius from the center of the project site in order to avoid model boundary affects in the study area.

A field data collection effort was undertaken in order to provide model validation data. The data collection effort consisted of both collecting both water surface elevation data and current velocity data. Water surface elevation was recorded using submerged pressure transducers and current velocity was collected using acoustic Doppler current profilers (ADCP). The ADCP gages were mounted on the bottom along the navigation channel and also on a boat in order to provide cross channel current velocity transects. Data return was fairly good with only one bottom mounted ADCP gage failing completely. The complete data report has been included as Attachment 3.

The model output compared very well to the collected data and showed the hydrodynamic model data very usable as input for the ship simulator study. The ADCIRC model output was converted into the necessary format for use in the ERDC ship simulator. The validated model's bathymetry was altered to model three different deepening alternatives, and the results showed current speeds only increased by a maximum of 5% over existing current speeds. In addition to the first three alternatives, the turning basin at the end of the Reserve Channel was altered. The model was rerun for the three depth alternatives with the altered turning basin. Once again the change in current speeds was relatively minor with the maximum change between the original alternative and turning basin alternative being 0.08 m/s or 0.18 mph.

Attachment 1
NOAA GEODAS Surveys Used

NGDC-Num	Survey	Navigation	Soundings	Features
03001010	H07724	2177	2087	90
03001030	H07715	17425	16568	857
03001043	F00256	7	7	0
03041028	H06642	12072	11076	996
03041029	H06643	37295	36784	511
03041030	H06644	3647	3632	15
03061204	H08938	17088	17088	0
03061205	H08939	8164	8164	0
03061206	H08940	15137	15137	0
03061207	H08941	8658	8658	0
03061208	H08942	8040	8040	0
03061209	H08943	7952	7952	0
03141004	H09009	6725	6725	0
03141005	H09010	4938	4938	0
03141007	H09012	17207	17207	0
03141010	H09046	15947	15947	0
03141011	H09063	8303	8303	0
03141012	H09064	4346	4346	0
03141013	H09090	8658	8658	0
03141014	H09094	12026	12026	0
03141015	H09095	2931	2931	0
03141071	H09133	9511	9511	0
03141072	H09134	6849	6849	0
03141073	H09150	11412	11412	0
03141074	H09151	6808	6808	0
03141075	H09152	4485	4485	0
03361081	F00465	1076	1075	1
03711002	H07159	2862	2840	22
03A11948	H06995	12401	12385	16
03F11572	H07066	11969	11649	320
03F11683	H07060	4466	4447	19
03F11684	H07061	2105	2057	48
03F11685	H07063	1483	1454	29
03F11740	H06862	4900	4900	0
03F11741	H06863	13383	13223	160
03F11744	H08005	4743	4479	264
03F11745	H08006	1870	1815	55
03F11746	H08007	1686	1652	34
03F11747	H08008	16897	16736	161
03F11748	H08009	8159	7993	166
03F11749	H08010	1619	1506	113
03F11750	H08063	13896	13896	0
03F11753	H08898	2742	2645	97

Attachment 2
ADCIRC Model Control file (Fort 19)

```
Boston Harbor                ! 32 CHARACTER ALPHANUMERIC RUN DESCRIPTION
ADCIRC Run                   ! 24 CHARACTER ALPHANUMERIC RUN IDENTIFICATION
1                          ! NFOVER - NONFATAL ERROR OVERRIDE OPTION
1                          ! NABOUT - ABREVIATED OUTPUT OPTION PARAMETER
1                          ! NSCREEN - OUTPUT TO UNIT 6 PARAMETER
0                          ! IHOT - HOT START OPTION PARAMETER
I                          ! ICS - COORDINATE SYSTEM OPTION PARAMETER
0                          ! IM - MODEL RUN TYPE: 0=2DDI, 1=3DL(VS), 2=3DL(DSS)
1                          ! NOLIBF - NONLINEAR BOTTOM FRICTION OPTION
2                          ! NOLIFA - OPTION TO INCLUDE FINITE AMPLITUDE TERMS
1                          ! NOLICA - OPTION TO INCLUDE CONVECTIVE ACCELERATION TERMS
1                          ! NOLICAT - OPTION TO CONSIDER TIME DERIVATIVE OF CONV ACC TERMS
0                          ! NWP - VARIABLE BOTTOM FRICTION AND LATERAL VISCOSITY OPTION PARAMETER
0                          ! NCOR - VARIABLE CORIOLIS IN SPACE OPTION PARAMETER
0                          ! NTIP - TIDAL POTENTIAL OPTION PARAMETER
0                          ! NWS - WIND STRESS AND BAROMETRIC PRESSURE OPTION PARAMETER
1                          ! NRAMP - RAMP FUNCTION OPTION
9.81000000                   ! G - ACCELERATION DUE TO GRAVITY - DETERMINES UNITS
0.0100                     ! TAU0 - WEIGHTING FACTOR IN GWCE
0.500000                   ! DT - TIME STEP (IN SECONDS)
0.000000                   ! STATIM - STARTING SIMULATION TIME IN DAYS
0.000                      ! REFTIME - REFERENCE TIME (IN DAYS) FOR NODAL FACTORS AND EQUILIBRIUM ARGS
10.000000                  ! RNDAY - TOTAL LENGTH OF SIMULATION (IN DAYS)
0.500                      ! DRAMP - DURATION OF RAMP FUNCTION (IN DAYS)
0.350 0.300 0.350            ! TIME WEIGHTING FACTORS FOR THE GWCE EQUATION
0.05 12 12 0.05            ! H0 - MINIMUM CUTOFF DEPTH
249512.81 901287.25          ! SLAM0,SFEA0 - CENTER OF CPP PROJECTION (NOT USED IF ICS=1, NTIP=0, NCOR=0)
0.0025                     ! FFACTOR - HOMOGENEOUS LINEAR OR NONLINEAR BOTTOM FRICTION COEFFICIENT
5.000                      ! ESL - LATERAL EDDY VISCOSITY COEFFICIENT; IGNORED IF NWP =1
0.00001                    ! CORI - CORIOLIS PARAMETER - IGNORED IF NCOR = 1
0                          ! NTIF - TOTAL NUMBER OF TIDAL POTENTIAL CONSTITUENTS BEING FORCED
0                          ! NBFR - TOTAL NUMBER OF FORCING FREQUENCIES ON OPEN BOUNDARIES
90.000                     ! ANGINN : INNER ANGLE THRESHOLD
0 0.000 0.000 0              ! NOUTE,TOUTSE,TOUTFE,NSPOOLE:ELEV STATION OUTPUT INFO (UNIT 61)
0                          ! TOTAL NUMBER OF ELEVATION RECORDING STATIONS
0 0.000 0.000 0              ! NOUTV,TOUTSV,TOUTFV,NSPOOLV:VEL STATION OUTPUT INFO (UNIT 62)
0                          ! NSTAV - TOTAL NUMBER OF VELOCITY RECORDING STATIONS
```

```
-1 0.000 10.000 7200              ! NOUTGE,TOUTSGE,TOUTFGE,NSPOOLGE : GLOBAL ELEVATION OUTPUT INFO (UNIT 63)
-1 0.000 10.000 7200              ! NOUTGV,TOUTSGV,TOUTFGV,NSPOOLGV : GLOBAL VELOCITY OUTPUT INFO (UNIT 64)
0                              ! NHARF - NUMBER OF FREQENCIES IN HARMONIC ANALYSIS
0.000 0.000 0 0.000               ! THAS,THAF,NHAINC,FMV - HARMONIC ANALYSIS PARAMETERS
0 0 0 0                        ! NHASE,NHASV,NHAGE,NHAGV - CONTROL HARMONIC ANALYSIS AND OUTPUT TO UNITS 51,52,53,54
1 144000                       ! NHSTAR,NHSINC - HOT START FILE GENERATION PARAMETERS
1 0 1.000000000E-005 25              ! ITITER, ISLDIA, CONVCR, ITMAX - ALGEBRAIC SOLUTION PARAMETERS
```

BOSTON HARBOR
MASSACHUSETTS

NAVIGATION IMPROVEMENT STUDY

FINAL FEASIBILITY REPORT
AND FINAL SUPPLEMENTAL
ENVIRONMENTAL IMPACT STATEMENT
(AND MASSACHUSETTS FINAL EIR)

APPENDIX H

SHIP SIMULATION STUDY

U.S. ARMY CORPS OF ENGINEERS
ENGINEERING RESEARCH AND
DEVELOPMENT CENTER
VICKSBURG, MISSISSIPPI

This Appendix Unchanged Since 2008 Draft Final Report

ERDC/CHL TR-06-11

Coastal and Hydraulics Laboratory

US Army Corps
of Engineers®
Engineer Research and
Development Center

Boston Harbor, Massachusetts, Deep-Draft Navigation Improvement Project Feasibility Study

Channel Improvement Investigations

Dennis W. Webb and Mark L. Habel

August 2006

APPENDIX H

SHIP SIMULATION STUDY

Approved for public release; distribution is unlimited.

ERDC/CHL TR-06-11
August 2006

Boston Harbor, Massachusetts, Deep-Draft Navigation Improvement Project Feasibility Study

Channel Improvement Investigations

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Final report

Approved for public release; distribution is unlimited.

Prepared for U.S. Army Engineer District, New England
Concord, MA 01742-2751

Abstract: Boston Harbor is located on the eastern shore of the Commonwealth of Massachusetts, on Massachusetts Bay. The Corps of Engineers and the Massachusetts Port Authority (Massport) are evaluating a number of improvements to Boston Harbor. These improvements include deepening and widening portions of the Broad Sound North Entrance Channel, Main Ship Channel, and lower Reserved Channel and its turning area for the benefit of larger container vessels calling on Massport's Conley Terminal. To assist in evaluating these improvements, the U.S. Army Engineer Research and Development Center (ERDC) conducted a ship-simulator-based navigation study. Data for the simulation models were obtained during a site visit to ride ships in the project area. Currents for both the existing and proposed channels were calculated using the ADCIRC computer model in a joint effort between ERDC and the U.S. Army Engineer District, New England. Harbor pilots traveled from Boston to validate and operate the simulations in September 2005.

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Preface

The model investigation described herein was conducted for the U.S. Army Engineer District, New England, by the U.S. Army Engineer Research and Development Center (ERDC), Vicksburg MS. The simulator experiments were performed during September 2005 by personnel of the Coastal and Hydraulics Laboratory (CHL).

The New England District was informed of the progress of the simulator study through monthly progress reports. Mark Habel, New England District, was in charge of project oversight for the District. The simulation models for the *Cosco Hamburg* and *Delaware Bridge* were developed by Designers and Planners, Inc.

The principal investigator in immediate charge of the navigation portion of the simulator study was Dennis W. Webb, assisted by Peggy Van Norman, Donna Derrick, Danny Marshall, and Gary Lynch, all of the Navigation Branch, CHL, and Ms. Sally Harrison, contractor for Analytical Services, Inc. Mr. Webb and Mr. Habel prepared this report , under the general supervision of Dr. Margaret Rose Kress, Chief, Navigation Division; Dr. William D. Martin, Deputy Director, CHL; and Mr. Thomas W. Richardson, Director, CHL.

Commander and Executive Director of ERDC was COL Richard B. Jenkins. Director was Dr. James R. Houston.

Unit Conversion Factors

Multiply	By	To Obtain
feet	0.3048	meters
knots	0.5144444	meters per second

1 Introduction

Background

Boston Harbor is located on the eastern shore of the Commonwealth of Massachusetts, on Massachusetts Bay (Figure 1). The layout of the existing Federal Navigation Project for Boston Harbor is shown in Figure 2. Deeply loaded commercial traffic uses the Broad Sound North Entrance Channel to access the harbor. Use of the other two entrance channels, the 30-ft Broad Sound South Channel and the 27-ft Narrow Channel, is limited to smaller ships and barges, mainly those in transit between the Port and the Cape Cod Canal to the south. Ships that presently call at Boston Harbor include petroleum tankers, bulk product carriers, containerships, and liquefied natural gas (LNG) tankers. The principal dry bulk cargos include salt and cement imports, and scrap and newsprint exports.

The existing Federal Navigation Project for Boston Harbor consists of the three entrance channels described above, a Main Ship Channel connecting the confluence of the three entrance channels off Deer Island with the lower and upper harbor areas, a deep-draft anchorage in President Roads, and several commercial tributary channels (the Reserved Channel, Fort Point Channel, Charles River, lower Mystic River, and Chelsea River).

Prior to 1930 the North Entrance Channel and Main Ship Channel had depths of –35 ft and widths of 1500 and 1200 ft, respectively. From 1930 to the mid-1950s, a 40-ft channel was constructed from the sea to the inner confluence of the Mystic and Chelsea Rivers, but not to the full channel width. In the North Entrance Channel and the lower reaches of the Main Ship Channel, the deeper 40-ft lane was dredged along the south limit of the channel, 900 ft wide in the entrance and 600 ft wide in the lower main ship channel. Above Commonwealth Pier in South Boston, the 40-ft lane shifted to the north side of the Main Ship Channel, and then shifted back to the northwest side above the Charles River. The intent seems to have been to ensure that the 40-ft depth accessed the several U.S. Navy facilities located on both sides of the harbor. The result today is an asymmetrical layout for the deep-draft channels, as shown in Figure 2.

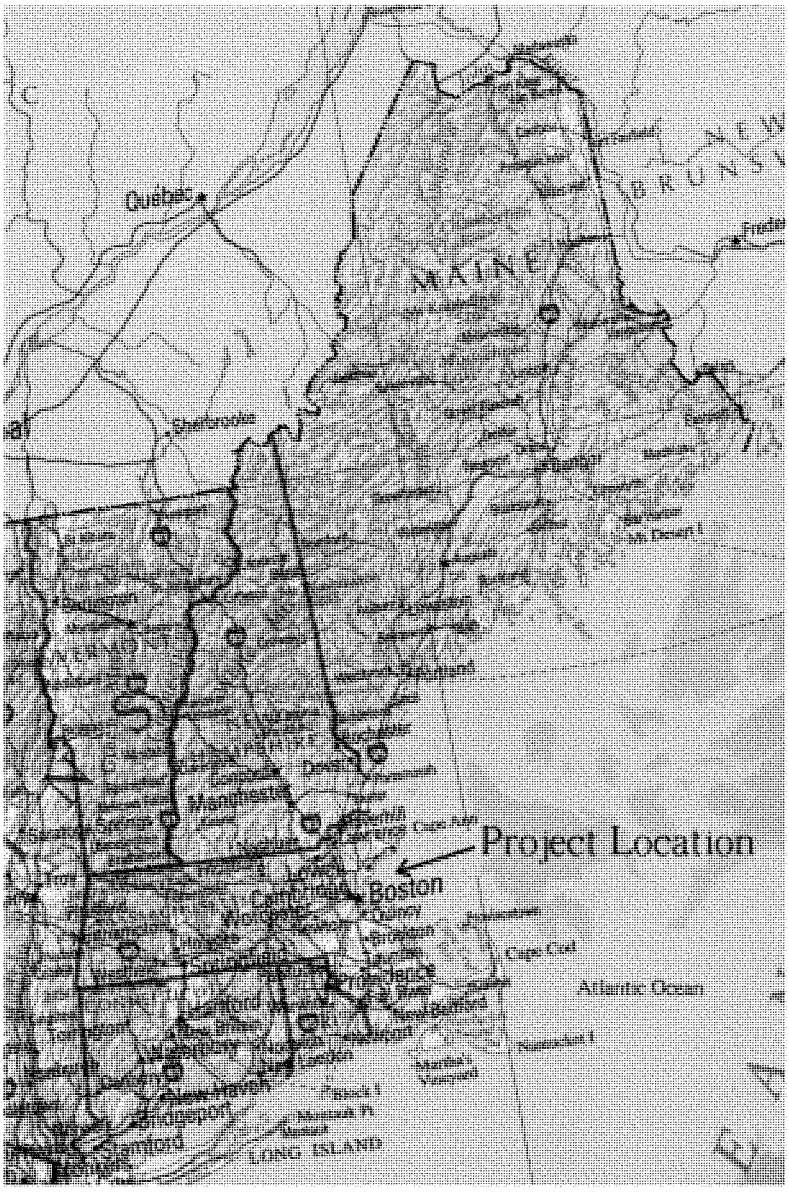


Figure 1. Boston Harbor location map.

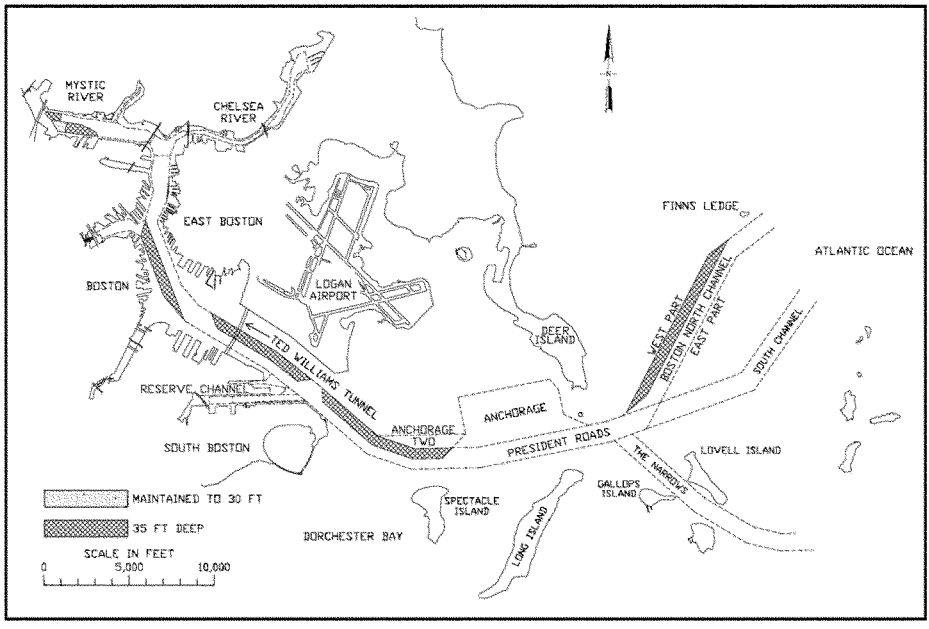


Figure 2. Boston Harbor, existing conditions.

The U.S. Coast Guard marks only the outer limits of the channels, and not the division between the 35- and 40-ft lanes. Consequently, safe navigation of larger vessels relies on the expert knowledge and experience of the harbor pilots and docking masters. Rules of the road regarding the passing of larger vessels rely on local knowledge and communication so that the deeper draft vessel can travel in the 40-ft lane.

The Reserved Channel in South Boston is 40 ft deep in its lower two-thirds along the Conley Terminal on the south shore and the former Army Base, now a dry bulk (cement) terminal on the north shore. Above this area the channel depth is 35 ft to access the upper berths of the Black Falcon Cruise Ship Terminal. The Main Ship Channel, at its confluence with the Reserved Channel, has been deepened to 40 ft for its full 1200-ft width to provide a turning basin for vessels accessing the Reserved Channel.

The 23-ft Fort Point Channel and 35-ft lower Charles River Channel are not included in this study as project dimensions are at least adequate for prospective commerce. The U.S. Coast Guard (USCG) Group Boston is located on the 35-ft Charles River Channel. Smaller visiting U.S. and NATO

warships are berthed at the former Navy Yard on the Charles River Channel. Deeper draft vessels such as carriers are berthed at the World Trade Center on the 40-ft Main Ship Channel during port visits.

The deep-draft reaches of the Mystic River Channel between the Tobin and Malden Bridges are divided into 40-, 35-, and 30-ft areas. Most of the channel was deepened to 40 ft under the project of 1990 between 1998 and 2001. The full width of the lower, eastern end of the channel is at 40 ft to access the Boston Autoport and Exxon Terminals. The northern half of most of the upper length of the channel along the Everett shore is also 40 ft. The remaining areas are authorized to 35 ft, with the far upper end of the channel along the southern (Charlestown) shore only maintained to -30 ft. At the time of the 1990 authorization and 1996 design memorandum, the Massachusetts Port Authority (Massport) plans for its Medford Street Terminal, located immediately upstream of the Boston Autoport along the southern shore, were not far enough advanced to permit a favorable economic justification for deepening this area of the channel to 40 ft.

The Chelsea River Channel, from the inner confluence to the head of navigation in Revere, has an authorized depth of 38 ft under the project of 1990. The 38-ft depth was the limit that could be economically justified with increased vessel drafts and capacities without replacement of the Chelsea Street Bridge. With the exception of a small area near the Chelsea Street Bridge that is awaiting utility relocation, the 38-ft deepening project was completed in 2002. As the USCG and City of Boston are proceeding with plans to replace the bridge, deepening this channel to 40 ft is once again being considered.

The Port's only container facility, the Conley Terminal, is located on the 40-ft lower reach of the Reserved Channel in South Boston. This is the Port's seaward most commercial terminal. The Port's only LNG facility, Distrigas, is located on the north side of the 40-ft Mystic River Channel near its head of deep-draft navigation. The Port's major petroleum terminals are located along the 38-ft Chelsea River Channel, with the sole exception of the Exxon Terminal on the Mystic River, below the Distrigas LNG Terminal. Boston Harbor has a mean tidal range of approximately 10 ft and a spring range of about 13.5 ft.

Purpose

The U. S. Army Engineer District, New England, is presently evaluating channel designs to deepen portions of Boston Harbor and widen some of the turns. The primary purpose of these improvements is to allow larger containerships to call at the docks at the Conley Terminal on the Reserved Channel.

The U. S. Army Engineer Research and Development Center (ERDC) conducted a navigation study utilizing real-time ship simulation modeling to evaluate the proposed improvements to Boston Harbor. Model development and online testing occurred at the ERDC Waterways Experiment Station in Vicksburg, MS, during the period April to September 2005.

2 Proposed Improvements

The New England District and Massport are evaluating a number of improvements to Boston Harbor's system of channels and anchorage area. The proposed improvements for Boston Harbor are shown in Figure 3.

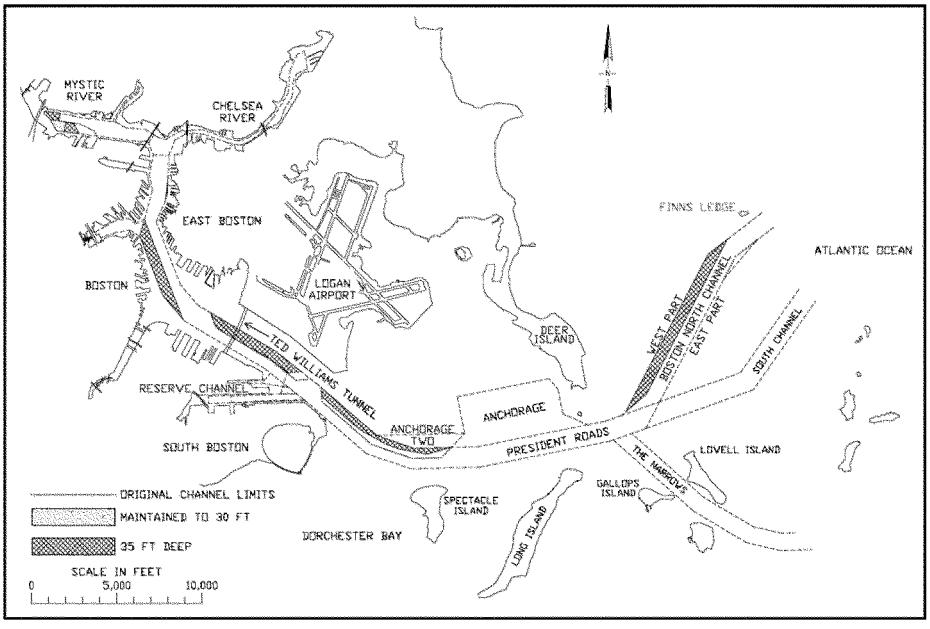


Figure 3. Boston Harbor, proposed conditions.

Entrance and main channel deepening

The first improvement plan would deepen the Broad Sound North Entrance Channel, Main Ship Channel, and the lower Reserved Channel and its turning area for the benefit of larger container vessels calling on Massport's Conley Terminal. A channel depth of –45 ft mean lower low water (MLLW) in the harbor is being considered, with incremental optimization between 42 and 50 ft. This plan includes (1) deepening the 40-ft lane of the Broad Sound North Entrance Channel from Massachusetts Bay to the outer confluence to a depth of –47 ft MLLW (the additional 2 ft in depth to compensate for increased wave and wind action), (2) deepening the Main

Ship Channel from the outer confluence through President Roads and up-harbor to the Reserved Channel to –45 ft, (3) deepening the 40-ft lower reach of the Reserved Channel to 45 ft, (4) deepening the Reserved Channel turning area to 45 ft and expanding it northwesterly up the main channel to accommodate larger vessels, and (5) deepening all or a portion of the President Roads Anchorage to 45 ft.

The deepened entrance channel will retain its 1100-ft entrance reach width and its 900-ft width in its remaining length. The current 35-ft-deep lane would remain unchanged. A bend widener is proposed at the turn where the 1100- and 900-ft-wide reaches join in response to pilots' concerns to have additional maneuvering width opposite Finns Ledge. A closeup of the widener is shown in Figure 4.

The portion of the Main Ship Channel along the south side of President Roads would retain its current 1200-ft width to facilitate safe access and egress from the anchorage and permit recovery of vessel course before entering the turns at Spectacle Island. The deepened channel would be widened to 800 ft by incorporating portions of the existing 35-ft lane. In the turns at Spectacle Island the channel would be widened further to 880 ft to increase the width available for vessel maneuvering through the turns, easing a difficult bend, especially for the larger containerships that are expected to call at Reserved Channel. The transition from the anchorage and the 1200-foot channel width in President Roads into the narrower lower Main Ship Channel would also be flared into the 35-ft lane to ease the approach up-harbor. These improvements are shown in Figure 5.

Main Ship Channel deepening extension to Ted Williams Tunnel

In order to accommodate plans by Massport to develop a new dry bulk terminal at the Massport Marine Terminal in South Boston, extending the proposed deepening of the Main Ship Channel above the Reserved Channel to below the Ted Williams Tunnel is also being considered. Massport's plans for this facility include leases for the receipt or export of cement, aggregates, newsprint, steel, and other bulk products. The clearances over the Ted Williams Tunnel above this terminal limit channel depths in the upper harbor areas to the 40 ft already provided. The reach of the Main Ship Channel to be deepened to 45 ft under this plan would be widened to 650 ft by including a 50-ft-wide strip of the current 35-ft lane.

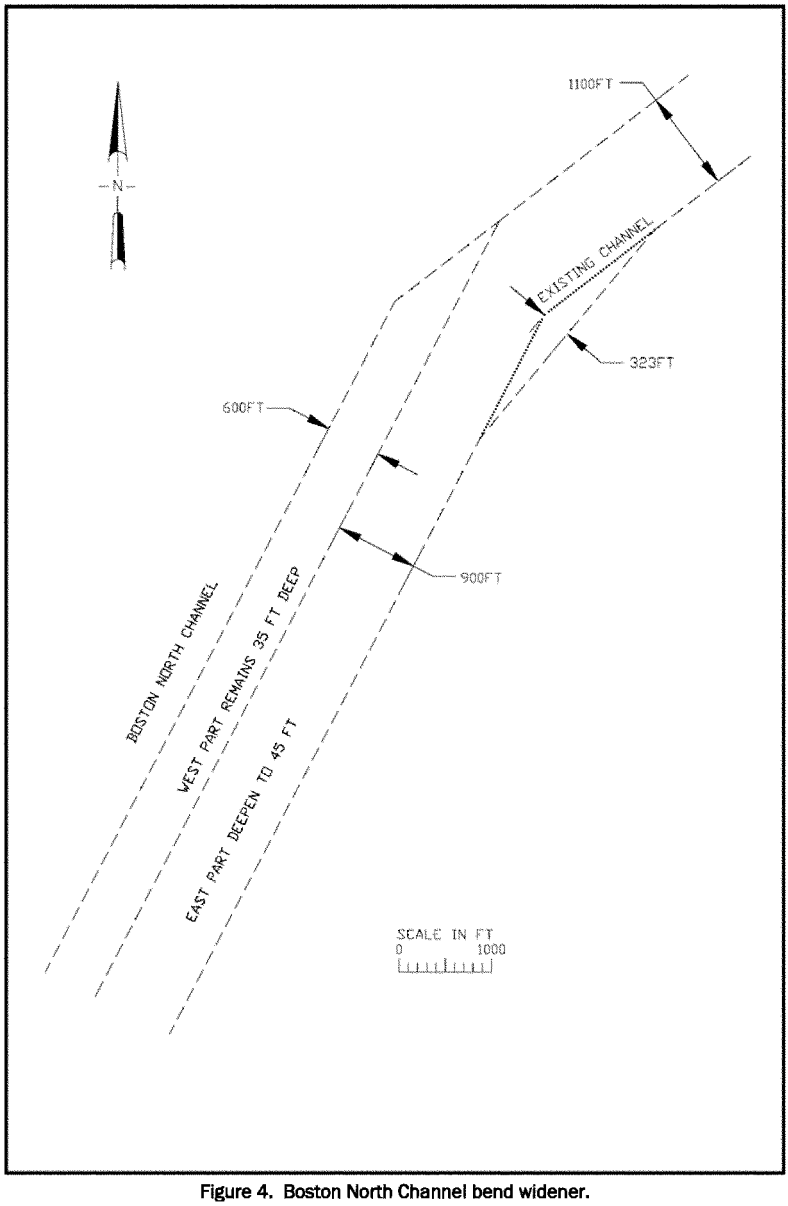


Figure 4. Boston North Channel bend widener.

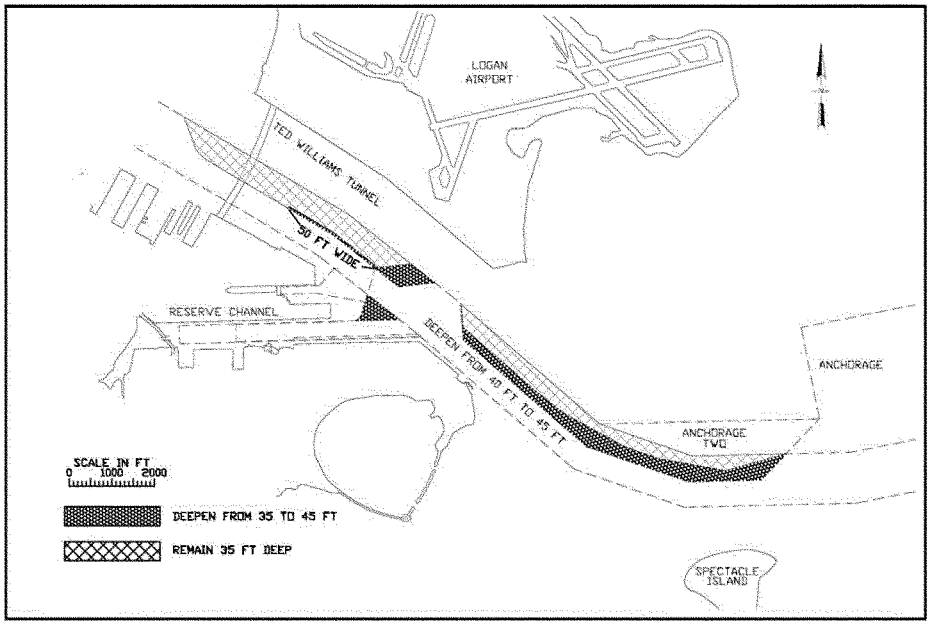


Figure 5. Widening near Reserve Channel.

Ted Williams Tunnel to confluence of Mystic and Chelsea Rivers

No channel improvements are proposed for this section of the harbor, including the Fort Point and Charles River Channel tributaries.

Mystic River

A portion of the existing 35-ft channel will be deepened to 40 ft to permit deeper access to Massport's Medford Street Terminal for bulk cargo vessels. This is shown in Figure 3. This area is located about midway along the southern half of the Mystic Channel above the Boston Autoport. This area was not included in the 1990 project authorization, as plans for this terminal had not yet progressed to the point of decisions on its future use. Massport plans to develop the property as another dry bulk terminal and has already deepened the berths to –40 ft. This will allow large bulk carriers to call without having to wait for tidal advantage. Since there will be no increase in ship size over those now plying this waterway, and currents are negligible throughout the tidal cycle, this improvement did not require being included in this navigation study.

Chelsea River

The Chelsea River is being considered for deepening from 38 ft to 40 ft. The 1990 project only recommended a 38-ft depth for this waterway because the Chelsea Street Bridge limited design vessel dimensions, particularly beam, so greater improvements were impractical with bridge replacement. With the USCG and the City of Boston now pursuing funds for a new bridge, a 40-ft improvement is being reconsidered. This area was included in the 1992 ship simulation study that examined vessels of the classes that would be expected to use the waterway under the 38-ft improvement and also considered a 40-ft improvement without the bridge. That study showed that larger tank ships that would require the 40-ft depth would also require bridge replacement and bend easing. Therefore, Chelsea River is not included in this navigation study.

3 Reconnaissance Trip

The reconnaissance trip for the Boston Harbor study was conducted November 15-19, 2004. The purpose of the trip was to meet with New England District representatives and the Boston Pilots. These meetings primarily took place upon ships transiting the study area so navigation practices could be observed. In addition, ERDC representatives took photographs and video, which was later used for simulation model development. ERDC was represented by Dennis Webb and Peggy Van Norman who traveled to Boston on November 15. Upon arrival in Boston, they contacted Capt. Gregg Farmer of the Boston Pilots and Mr. John Winkelman of the New England District to coordinate.

November 16

Capt. Farmer, Mr. Webb, Ms. Van Norman, and Mr. Winkelman boarded the *MV Allegiance* in the Atlantic Ocean. The *MV Allegiance* is a 612-ft-long Length-Over-All (LOA) tanker with a beam of 90 ft. The *MV Allegiance* was loaded to a draft of 34 ft and was heading inbound to the Global Terminal on Chelsea Creek. During the transit, Capt. Farmer listed several navigation concerns of the existing and future Boston Harbor:

- A wrecked barge was discovered a few years ago. The wreck was marked by a can buoy (Figure 6) and avoided by the pilots. This obstruction has since been removed by New England District under the last contract for maintenance dredging of the outer harbor channels in 2005. Therefore, this is no longer a concern.
- Swell is a serious issue for the approach channels to Boston Harbor. The channels are operational in up to 18-ft swells with tidal assistance.
- Boston Harbor presently has two asymmetric channels, i.e., two lanes of different depths. Capt. Farmer expressed concern that as the one lane was deepened to 50 ft, they would have problems with bank effects caused by the 35-ft lane.
- Flood currents into Dorchester Bay cause the ship to be set to the green buoys in the turns above Spectacle Island.
- There is also a ledge in this area where the channel is not 40 ft MLLW. This ledge is scheduled for removal to at least -42 ft as part of the upcoming inner harbor maintenance operation.

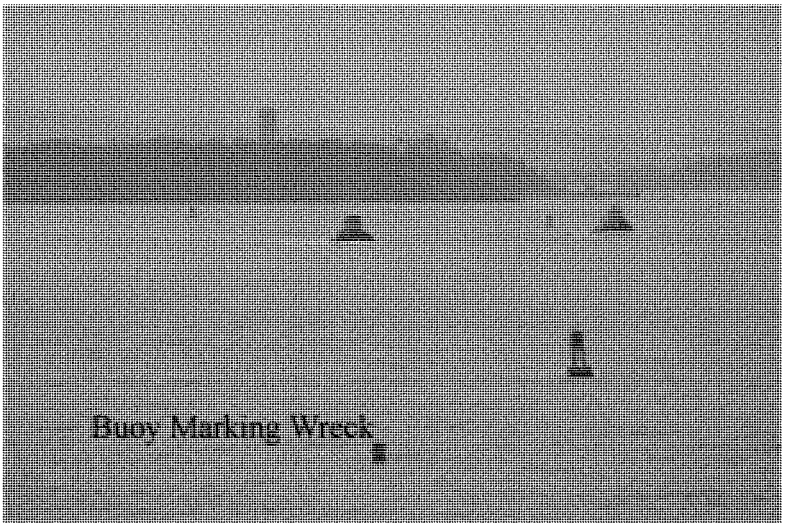


Figure 6. Buoy marking wreck.

Corps employees disembarked the ship onto the pilot boat in downtown Boston. The *MV Allegiance* and Capt. Farmer continued on to the Global Terminal. Corps representatives disembarked early, at Capt. Farmer's recommendation, so they could ride an inbound containership.

The Corps representatives boarded the *MV MSC Jeanne* in the Atlantic Ocean. The pilot was Capt. Frank Morten. The *MV MSC Jeanne* is a 767-ft-long (LOA) containership with a beam of 106 ft. The inbound draft was 41 ft. The *MV MSC Jeanne* was inbound to the container docks on the Reserved Channel. Capt. Morten reiterated Capt. Farmer's concerns about navigation in Boston Harbor. Figure 7 shows the *MV MSC Jeanne* turning into the Reserved Channel.

The Corps representatives boarded the *MV Zephyros* in the President Roads Anchorage. The *MV Zephyros* is a 538-ft-long (LOA) scrap metal ship with a beam of 75 ft. The *MV Zephyros* was loaded to a draft of 25 ft and was inbound to the Prolerized scrap metal dock on the Mystic River. The pilot for this movement was Capt. Richard Stover.

Figure 7. *MV MSC Jeanne* approaching Reserve Channel.

November 17

Mr. Webb and Ms. Van Norman boarded the *MV Delphina*, Capt. Marty McCabe, pilot. During the ride on the pilot boat, Captains McCabe and Chris Hoyt discussed their desired modifications to the President Roads Anchorage (USCG Anchorage #2). They stated that the anchorage was often crowded with three ships and that flood currents pushed the ships toward the northern end of the anchorage. Both pilots felt that angling the western end of the anchorage to incorporate portions of the 35-ft barge anchorage and areas between the two would make it more effective. The pilots' proposed angle is shown in Figure 8.

The *MV Delphina* is a 610-ft-long (LOA) tanker with a beam of 90 ft. The *MV Delphina* was loaded to a draft of 36 ft. During the transit to the Gulf Oil Dock, the 90-ft-wide *MV Delphina* passed through the 93-ft-wide Chelsea Street Bridge (Figure 9). Corps representatives rode back to the pilot station on a tractor tug, which gave them the opportunity to photograph Chelsea Creek from an outbound viewpoint.

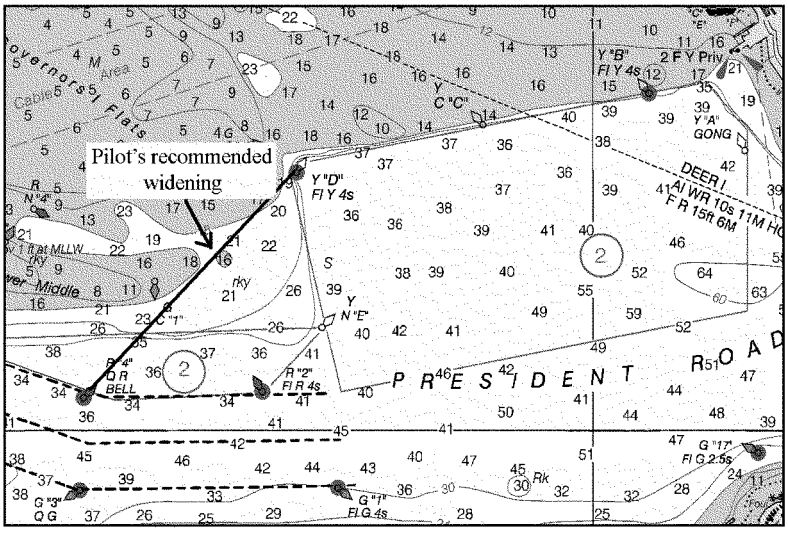


Figure 8. Pilot's recommended widening for anchorage.

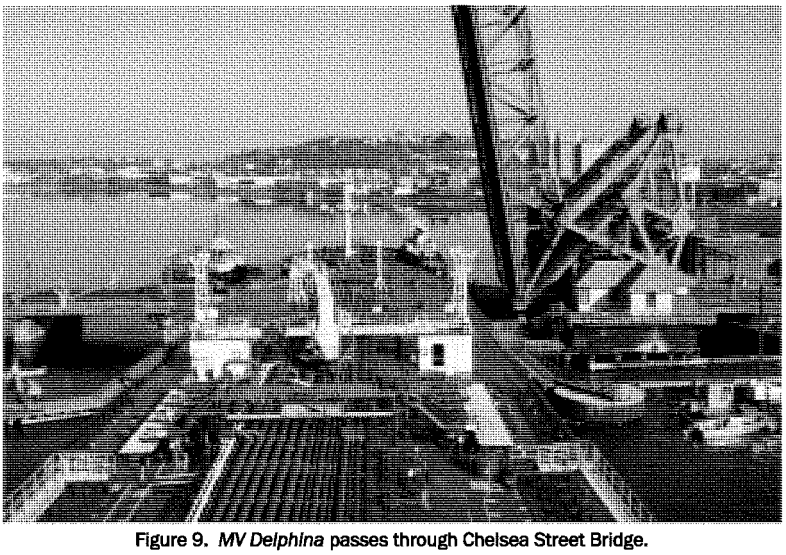


Figure 9. *MV Delphina* passes through Chelsea Street Bridge.

November 18

Mr. Webb and Ms. Van Norman boarded the *MV Hoegh Galleon,* Capt. Gregg Farmer, pilot. The *MV Hoegh Galleon* is an 818-ft-long (LOA) LNG

ship with a beam of 131 ft. The ship's draft was approximately 33 ft. The *MV Hoegh Galleon* docked at the Distrigas LNG terminal on the Mystic River, which concluded the reconnaissance trip.

4 Database Development and Validation

Database development

Currents for both the existing and proposed channels were calculated using the ADCIRC model in a joint New England District/ERDC effort (Wilkelman et al., in preparation). Current data for the maximum strength of both the ebb and flood tides were extracted and converted into the format required by the ERDC Ship/Tow Simulator.

Two ship models were developed for the Boston Harbor Navigation Study by Designers & Planners, Inc. (Ankudinov 2005):

- Ship 1. The *COSCO Hamburg*, a 918-ft-long (LOA), 5,618-TEU (TEU = twenty-foot equivalent unit) containership. The ship's beam is 131.2 ft, and the ship is fully loaded to a draft of 45.9 ft.
- Ship 2. The *Delaware Bridge*, a 871.8-ft-long (LOA), 4,713-TEU containership. The ship's beam is 105.6 ft, and the ship is fully loaded to a draft of 43.3 ft.

Both containership models were equipped with bow thrusters.

The visual scene was modified using the photos taken during the reconnaissance trip. Figure 10 shows the visual scene as one of the Boston Pilots operates the simulator. The only adjustment required to the visual scene for the proposed alternative channels was new aids to navigation (ATONS) for the Boston North Channel Bend widener. The buoy marking the wreck was removed, as was buoy G "3". The two new buoys that marked the ends of the widener are shown in Figure 11. The wrecked barge was removed from the approach to Boston Harbor during maintenance dredging during the spring/summer of 2005.

The Electronic Chart Display and Information System (ECDIS) was modified to reflect proposed changes to the channel footprints. Figure 12 shows an ECDIS chart modified to reflect changes at the mouth of the Reserved Channel. It should be noted that the ECDIS editing software does not allow removal of ATONS or modifying contour lines. However, the pilots felt the display showing the proposed channel was adequate.

Figure 10. Boston Ship Pilot turning containership near mouth of Reserve Channel.

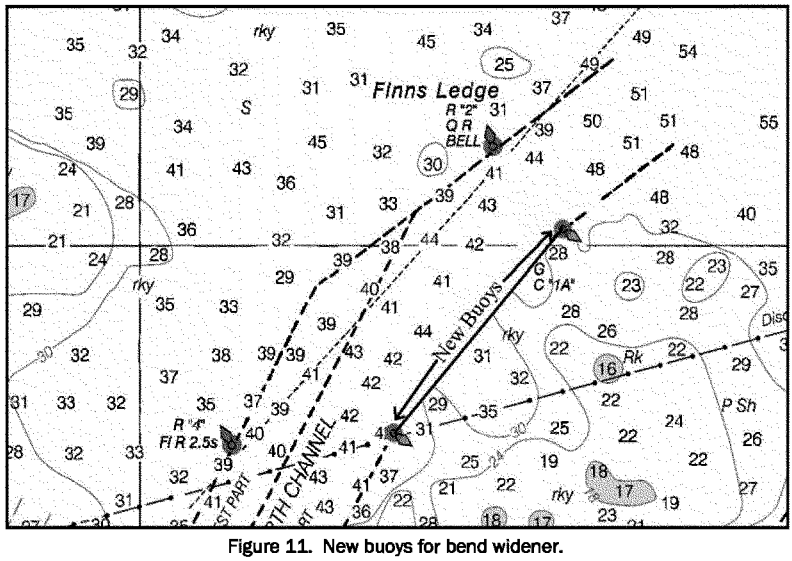


Figure 11. New buoys for bend widener.

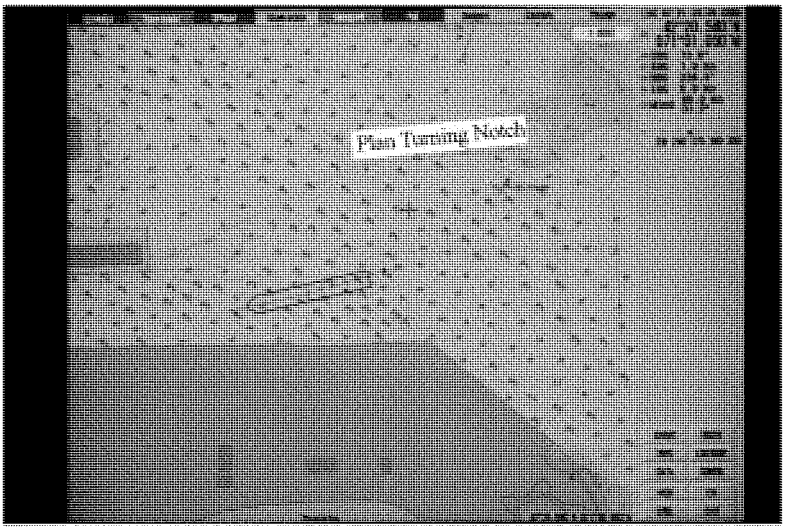


Figure 12. ECDIS display modified to show improved turning notch at mouth of Reserve Channel.

Validation

Validation for Boston Harbor was conducted September 6-9, 2005. Two Boston Harbor Pilots participated in the validation effort. A Massport representative also attended. Validation originally scheduled for August 29 – September 2, 2005, was delayed a week due to Hurricane Katrina. Representatives for New England District were scheduled to attend the original validation week but were unable to reschedule.

During validation, the Massport representative voiced concerns over the location of the improved turning notch. He stated that the improvements were directly in line with the low approach runway for Logan Airport. Representatives from New England District, New York District, ERDC, Massport, and the pilots worked together to formulate an alternative turning area configuration. This turning area, Plan 2, is shown in Figure 13. The ADCIRC model was modified to reflect the channel geometry of Plan 2 and currents were calculated. Simulations of the Plan 2 channel were conducted in the final days of the formal testing program.

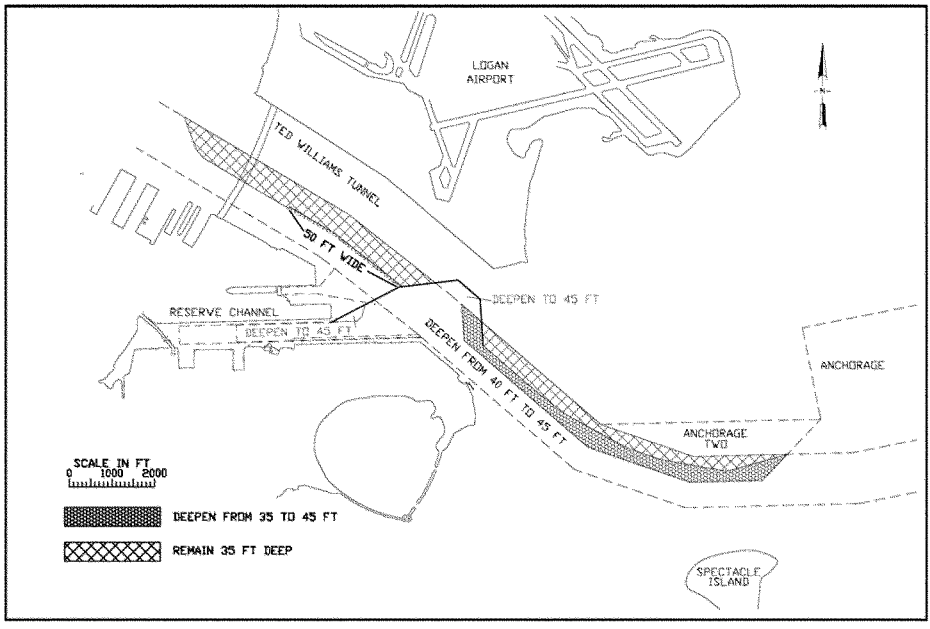


Figure 13. Plan 2 turning notch.

5 Tug Usage

Both containerships were equipped with bow thrusters for the simulations. All but one of the runs were completed with two tractor tugs. That one run used two tractor tugs and one conventional tug.

Tractor tugs are a generation beyond normal harbor tugs. Utilizing propulsion such as the Z Drive, the tractor tug can push or pull with little to no loss of thrust efficiency, eliminating most of the need to change position during the job.

Tug usage in the simulator is accomplished by radio communication between the pilot and the simulator operator. Different pilots use the tugs differently, but for the Boston transits, full ahead and astern commands were common. These commands are not unusual and do not necessarily indicate that changes need to be made.

During inbound runs, as the containerships came through Dorchester Bay (20-30 min before getting to Conley Terminal) the pilot would call the tugs alongside. From this point on the tugs were hooked up in order to be in position to work when needed. This position was typically one tug each on the ship's port bow and stern. Once the vessel started its turn for the backing maneuver into Reserve Channel, the tugs worked almost continuously until the transit and initial docking maneuvers were completed. Tug usage during the inbound runs was about 20–25 min (remembering that the transit stopped before the vessel was fully docked). For outbound runs, usage time increased closer to 40 min since the containerships were maneuvering off the terminal face to enter the federal channel.

6 Results

Testing was conducted September 12–16 and 17–21, 2005. Four Boston Harbor Pilots participated in the testing program. Simulations of the Plan 2 turning notch were conducted only during the last 3 days of the second session. After each test, the pilot was given a chance to provide written comment on the simulation. At the end of each week of testing, the pilots were given a final questionnaire to complete. These questionnaires are included in Appendix A.

Results are presented in the form of composite track plots. Results will be presented first for the Main Ship Channel and Reserved Channel turning notch improvements. These will be followed by the results for the Boston North Channel bend widener.

Main Ship Channel improvements and Plan 1 turning notch

Inbound, flood tide, 30 knots northeast wind, backing into Reserved Channel

Results of the *COSCO Hamburg* inbound through the Main Ship Channel and backing into the Reserved Channel with flood tide and 30 knots of wind from the northeast are shown in Plate 1. Four pilots completed this exercise, with one leaving the northeast end of the turning notch by nearly 260 ft. The other three pilots were able to turn within the notch. Several of the runs left the northeast end of the Reserved Channel. All ships successfully transited the improved Main Ship Channel. One of the four pilots used three tugs to back into the Reserved Channel. The pilot that used three tugs was one of the successful runs.

Results of the *Delaware Bridge* inbound through the Main Ship Channel and backing into the Reserved Channel with flood tide and 30 knots of wind from the northeast are shown in Plate 2. Four pilots completed this scenario. All ships successfully transited the improved Main Ship Channel and successfully turned in the improved notch. One of the runs left the northeast end of the Reserved Channel.

Inbound, flood tide, 30 knots northwest wind, backing into Reserved Channel

Results of the *COSCO Hamburg* inbound through the Main Ship Channel and backing into the Reserved Channel with flood tide and 30 knots of wind from the northwest are shown in Plate 3. Four pilots completed this scenario. All ships successfully transited the improved Main Ship Channel and successfully turned in the improved notch. One of the runs left the northeast end of the Reserved Channel.

Results of the *Delaware Bridge* inbound through the Main Ship Channel and backing into the Reserved Channel with flood tide and 30 knots of wind from the northwest are shown in Plate 4. Four pilots completed this scenario. All ships successfully transited the improved Main Ship Channel and successfully turned in the improved notch.

Inbound, ebb tide, 30 knots northeast wind, backing into Reserved Channel

Results of the *COSCO Hamburg* inbound through the Main Ship Channel and backing into the Reserved Channel with ebb tide and 30 knots of wind from the northeast are shown in Plate 5. Four pilots tested this scenario. One pilot was unable to stop his ship in time to turn in the notch and could not complete the maneuver. Another ship left the northeast side of the turning notch by nearly 260 ft. A third vessel just crossed the channel limits on the north end of the notch. All ships successfully transited the improved Main Ship Channel.

Results of the *Delaware Bridge* inbound through the Main Ship Channel and backing into the Reserved Channel with ebb tide and 30 knots of wind from the northeast are shown in Plate 6. Four pilots completed this scenario. All ships successfully transited the improved Main Ship Channel. One ship left the turning notch by slightly more than 10 ft.

Inbound, ebb tide, 30 knots northwest wind, backing into Reserved Channel

Results of the *COSCO Hamburg* inbound through the Main Ship Channel and backing into the Reserved Channel with ebb tide and 30 knots of wind from the northwest are shown in Plate 7. Four pilots completed this scenario. All ships successfully transited the improved Main Ship Channel.

Two ships left the northeast side of the turning notch, one by approximately 80 ft and the other by approximately 15 ft.

Results of the *Delaware Bridge* inbound through the Main Ship Channel and backing into the Reserved Channel with ebb tide and 30 knots of wind from the northwest are shown in Plate 8. Two pilots successfully completed this scenario. Pilots for the second week of testing did not attempt this exercise in order to complete some scenarios for the Plan 2 notch.

Outbound, flood tide, 30 knots northeast wind, backing out of Reserved Channel

Results of the *COSCO Hamburg* backing out of the Reserved Channel and heading outbound through the Main Ship Channel with flood tide and 30 knots of wind from the northeast are shown in Plate 9. Four pilots completed this exercise. All successfully turned in the improved notch. One ship did leave the southern edge of the improved Main Ship Channel by approximately 75 ft.

Results of the *Delaware Bridge* backing out of the Reserved Channel and heading outbound through the Main Ship Channel with flood tide and 30 knots of wind from the northeast are shown in Plate 10. Four pilots completed this exercise. All successfully turned in the improved notch. One ship did leave the southern edge of the improved Main Ship Channel by approximately 75 ft. The same pilot that left the southern edge of the improved Main Ship Channel with the *COSCO Hamburg* also left the channel with the *Delaware Bridge*, by approximately 60 ft.

Outbound, flood tide, 30 knots northwest wind, backing out of Reserved Channel

Results of the *COSCO Hamburg* backing out of the Reserved Channel and heading outbound through the Main Ship Channel with flood tide and 30 knots of wind from the northwest are shown in Plate 11. Four pilots completed this exercise. All successfully turned in the improved notch. One ship left the northeast corner of the Reserved Channel by about 15 ft.

Results of the *Delaware Bridge* backing out of the Reserved Channel and heading outbound through the Main Ship Channel with flood tide and 30 knots of wind from the northeast are shown in Plate 12. Four pilots successfully completed this exercise.

Outbound, ebb tide, 30 knots northeast wind, backing out of Reserved Channel

Results of the *COSCO Hamburg* backing out of the Reserved Channel and heading outbound through the Main Ship Channel with ebb tide and 30 knots of wind from the northeast are shown in Plate 13. Four pilots completed this exercise. One ship crossed the northeast end of the Reserved Channel while backing into the notch. All ships turned in the improved notch and transited the improved Main Ship Channel successfully.

Results of the *Delaware Bridge* backing out of the Reserved Channel and heading outbound through the Main Ship Channel with ebb tide and 30 knots of wind from the northeast are shown in Plate 14. Four pilots completed this exercise. One ship crossed the northeast end of the Reserved Channel while backing into the notch. All ships turned in the improved notch and transited the improved Main Ship Channel successfully.

Outbound, ebb tide, 30 knots northwest wind, backing out of Reserved Channel

Results of the *COSCO Hamburg* backing out of the Reserved Channel and heading outbound through the Main Ship Channel with ebb tide and 30 knots of wind from the northwest are shown in Plate 15. Two pilots completed this exercise. Both ships turned in the improved notch and transited the improved Main Ship Channel successfully.

Results of the *Delaware Bridge* backing out of the Reserved Channel and heading outbound through the Main Ship Channel with ebb tide and 30 knots of wind from the northwest are shown in Plate 16. Two pilots completed this exercise. One ship crossed the northeast end of the Reserved Channel while backing into the notch. Both ships turned in the improved notch and transited the improved Main Ship Channel successfully.

Inbound, ebb tide, 30 knots northwest wind, backing out of Reserved Channel

At a pilot's request, a scenario of a ship turning bow-in to Reserved Channel was undertaken. The scenario included a ship docked at the outer berth. Results of this exercise with the *COSCO Hamburg* are shown in Plate 17. Only one pilot completed this exercise. The ship entered the 35-ft-deep portion of the Main Ship Channel by about 20 ft while swinging

his ship to port. The pilot used two tugs and felt that three would be required in real life.

Plan 2 turning notch

Inbound, ebb tide, 30 knots northwest wind, backing into Reserved Channel

Results of the *COSCO Hamburg* inbound through the Main Ship Channel and backing into the Reserved Channel, using the Plan 2 turning notch, with ebb tide and 30 knots of wind from the northwest are shown in Plate 18. Two pilots completed this scenario. However, both pilots did a repeat run on the scenario. One pilot left the north side of the notch by about 170 ft on his first attempt. The other three runs were successful.

Outbound, ebb tide, 30 knots northwest wind, backing out of Reserved Channel

Results of the *COSCO Hamburg* backing out of the Reserved Channel, turning in the Plan 2 turning notch, and heading outbound through the Main Ship Channel with ebb tide and 30 knots of wind from the northwest are shown in Plate 19. Only one pilot attempted this exercise. It was successfully completed.

Outbound, ebb tide, 30 knots northeast wind, backing out of Reserved Channel

Results of the *COSCO Hamburg* backing out of the Reserved Channel, turning in the Plan 2 turning notch, and heading outbound through the Main Ship Channel with ebb tide and 30 knots of wind from the northeast are shown in Plate 20. Two pilots attempted this exercise, both successfully.

Inbound, flood tide, 30 knots northeast wind, backing into Reserved Channel

Results of the *COSCO Hamburg* inbound through the Main Ship Channel and backing into the Reserved Channel, using the Plan 2 turning notch, with flood tide and 30 knots of wind from the northeast are shown in Plate 21. Two pilots completed this scenario. However, one pilot brought his ship approximately 100 ft out of the north side of the Plan 2 turning notch. Both ships left the northeast end of the Reserved Channel.

Boston North Channel bend widener

Inbound, flood tide, 30 knots northeast wind

Results of the *COSCO Hamburg* inbound through the Boston North Channel bend widener with flood tide and 30 knots of wind from the northeast are shown in Plate 22. Four pilots completed this exercise, all successfully using the bend widener.

Results of the *Delaware Bridge* inbound through the Boston North Channel bend widener with flood tide and 30 knots of wind from the northeast are shown in Plate 23. Four pilots completed this exercise, all successfully using the bend widener.

Outbound, flood tide, 30 knots northeast wind

Results of the *COSCO Hamburg* outbound through the Boston North Channel bend widener with flood tide and 30 knots of wind from the northeast are shown in Plate 24. Four pilots completed this exercise, all successfully using the bend widener.

Results of the *Delaware Bridge* outbound through the Boston North Channel bend widener with flood tide and 30 knots of wind from the northeast are shown in Plate 25. Four pilots completed this exercise, all successfully using the bend widener.

Inbound, flood tide, 30 knots northwest wind

Results of the *COSCO Hamburg* inbound through the Boston North Channel bend widener with flood tide and 30 knots of wind from the northwest are shown in Plate 26. Two pilots completed this exercise, both successfully using the bend widener.

Outbound, flood tide, 30 knots northwest wind

Results of the *COSCO Hamburg* outbound through the Boston North Channel bend widener with flood tide and 30 knots of wind from the northwest are shown in Plate 27. Two pilots completed this exercise, both successfully using the bend widener.

Final questionnaire

At the end of their simulator testing session, the pilots completed a final questionnaire (included as Appendix A). In the questionnaire, the pilots stated their support for the improvements to the both Plans 1 and 2 turning notches, the Main Ship Channel, and the bend widener for the Boston North Channel. The two pilots that had the opportunity to simulate the Plan 2 turning notch felt it was adequate and even superior to the Plan 1 notch.

7 Recommendations

Based upon the simulator results and the pilot's final questionnaires, the following recommendations are made for the Boston Harbor Channel improvements:

a. The Boston North Channel bend widener is recommended without any modifications.

b. The widening of the Main Ship Channel is recommended without any modifications.

c. The Plan 1 turning notch is recommended with the modifications shown in Figure 14. A number of ships left the northeastern edge of the turning notch. This edge should be extended 100 ft. A number of ships also left the northeast end of the Reserved Channel. Modifying the Plan 1 notch to resemble the Plan 2 notch in this area is recommended.

d. The Plan 2 turning notch is recommended without any modifications. Only two pilots were able to test the Plan 2 notch, and they felt the notch was adequate. It is recommended that two additional pilots participate in a 2- or 3-day simulation program to verify these results. The modified Plan 1 turning notch could also be simulated at this time. However, this is not a requirement.

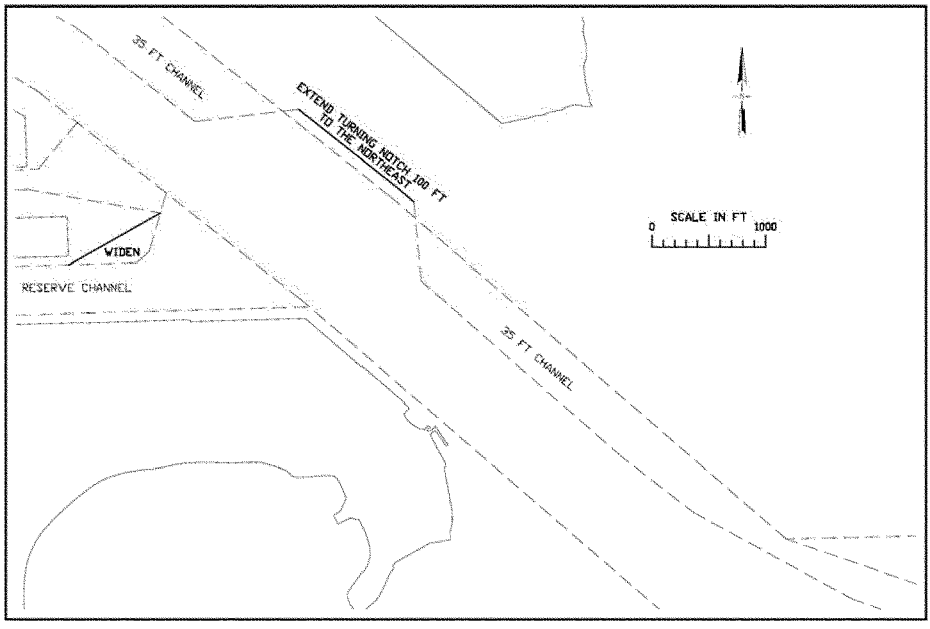
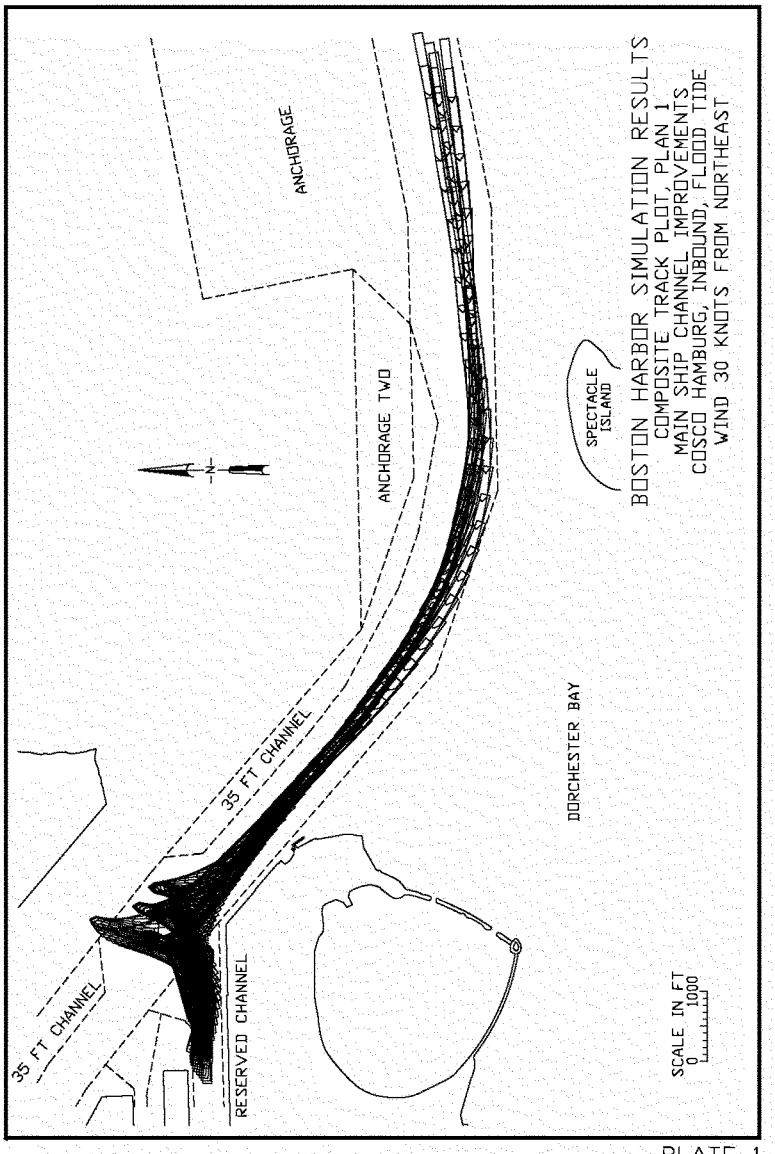


Figure 14. Recommended modifications to the Plan 1 turning notch.

References

Ankudinov, V. 2005. Development of two hi-fidelity ship models for a ship simulation study of Boston Harbor: "*COSCO Hamburg*", and "*Delaware Bridge*." Arlington, VA: BTM Designers & Planners, Inc.

Wilkelman, J., Z. Demirbilek, and L. Lin. *Boston Harbor Deep Draft Navigation Channel Improvement: 2-D Hydraulic Modeling*. In preparation.


BOSTON HARBOR SIMULATION RESULTS
COMPOSITE TRACK PLOT, PLAN 1
MAIN SHIP CHANNEL IMPROVEMENTS
COSCO HAMBURG, INBOUND, FLOOD TIDE
WIND 30 KNOTS FROM NORTHEAST
SPECTACLE ISLAND
DORCHESTER BAY
ANCHORAGE
ANCHORAGE TWO
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35 FT CHANNEL
RESERVED CHANNEL
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PLATE 1

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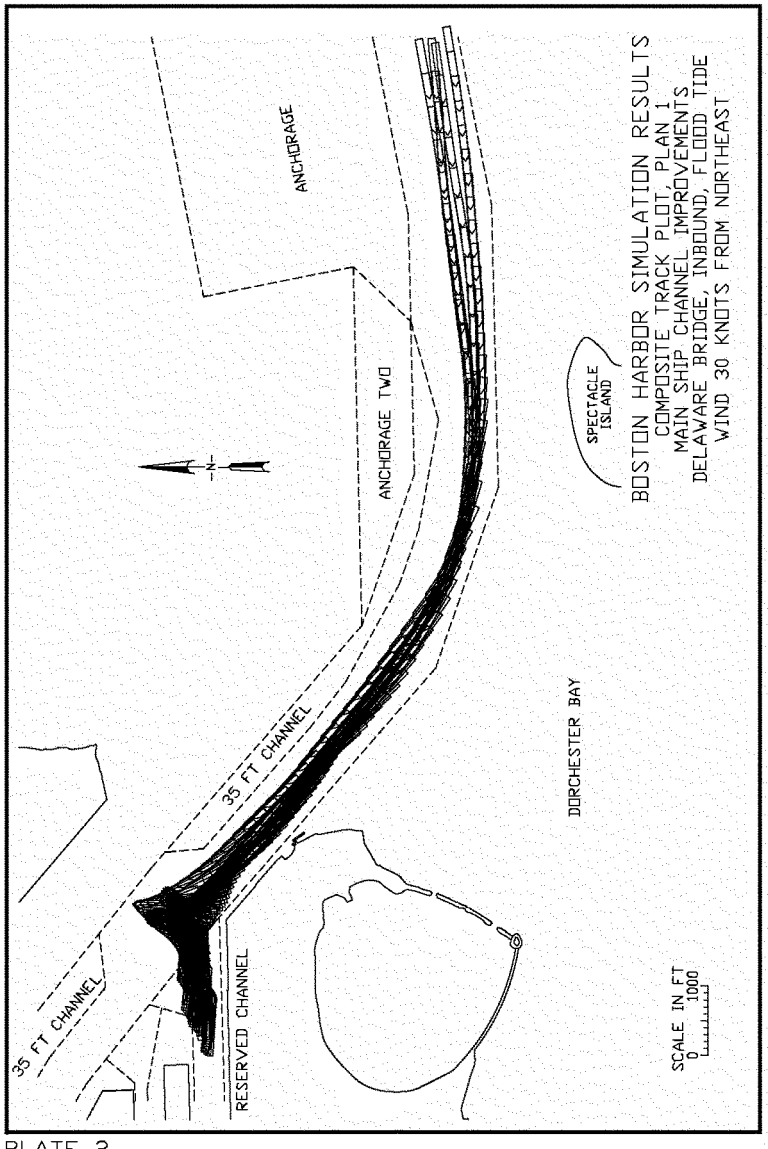
BOSTON HARBOR SIMULATION RESULTS
COMPOSITE TRACK PLOT, PLAN 1
MAIN SHIP CHANNEL IMPROVEMENTS
DELAWARE BRIDGE, INBOUND, FLOOD TIDE
WIND 30 KNOTS FROM NORTHEAST
SPECTACLE ISLAND
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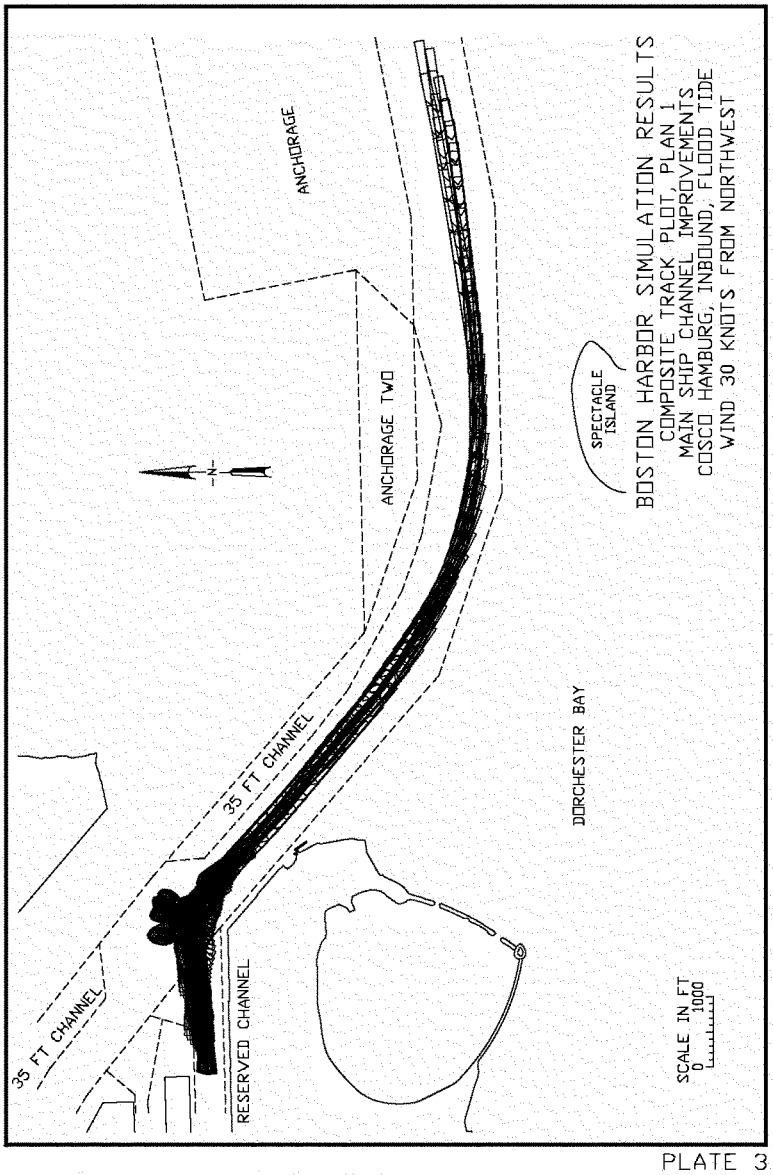
PLATE 2


ANCHORAGE
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BOSTON HARBOR SIMULATION RESULTS
COMPOSITE TRACK PLOT, PLAN 1
MAIN SHIP CHANNEL IMPROVEMENTS
COSCO HAMBURG, INBOUND, FLOOD TIDE
WIND 30 KNOTS FROM NORTHWEST

PLATE 3

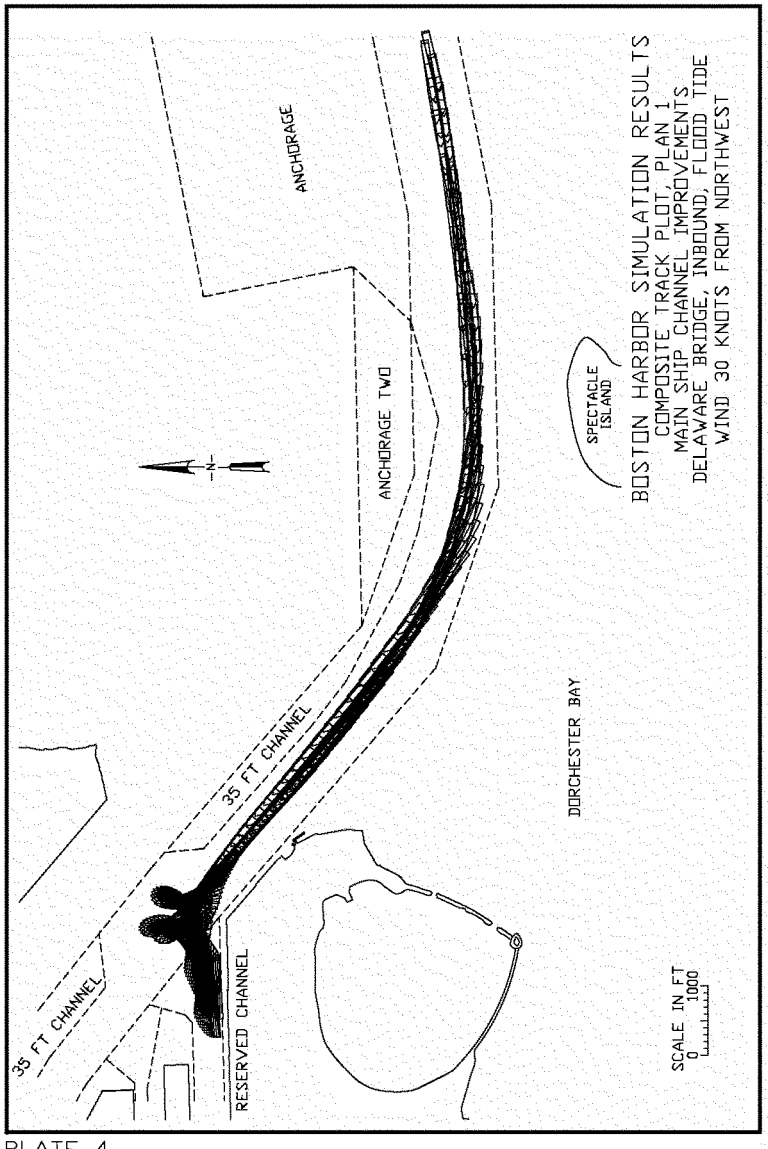
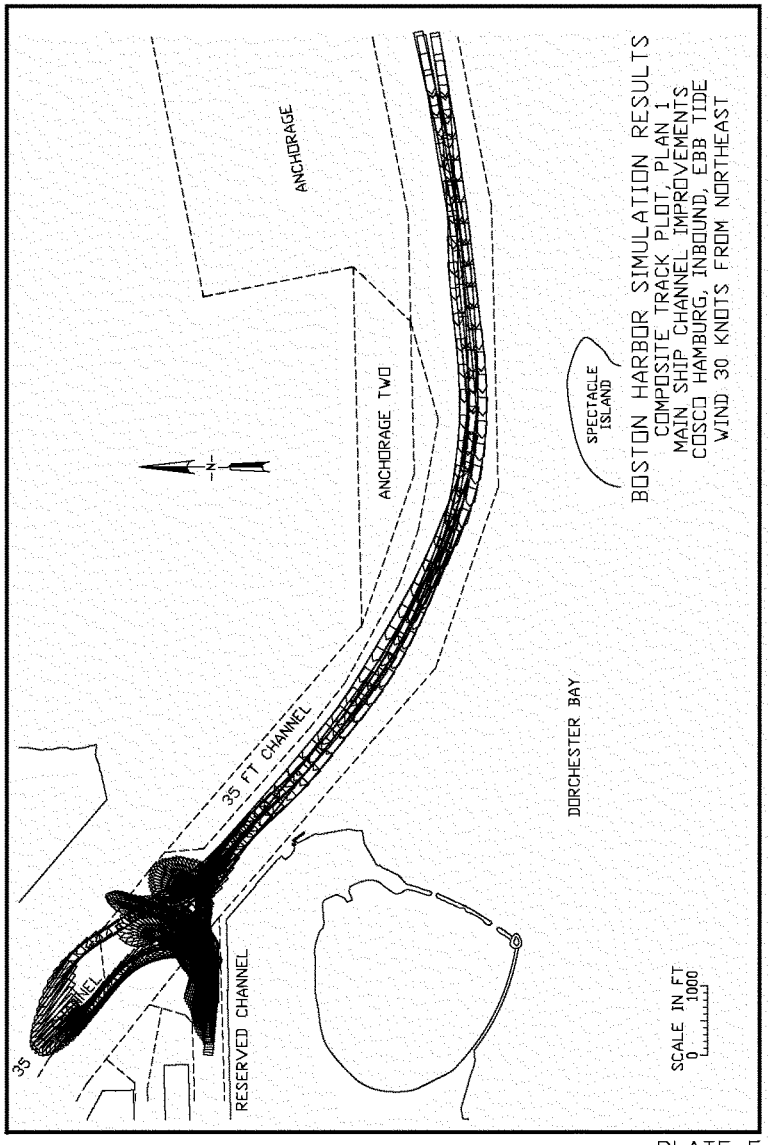

BOSTON HARBOR SIMULATION RESULTS
COMPOSITE TRACK PLOT, PLAN 1
MAIN SHIP CHANNEL IMPROVEMENTS
DELAWARE BRIDGE, INBOUND, FLOOD TIDE
WIND 30 KNOTS FROM NORTHWEST
SPECTACLE ISLAND
DORCHESTER BAY
ANCHORAGE
ANCHORAGE TWO
35 FT CHANNEL
35 FT CHANNEL
RESERVED CHANNEL
N
SCALE IN FT
0 1000

PLATE 4


ANCHORAGE
ANCHORAGE TWO
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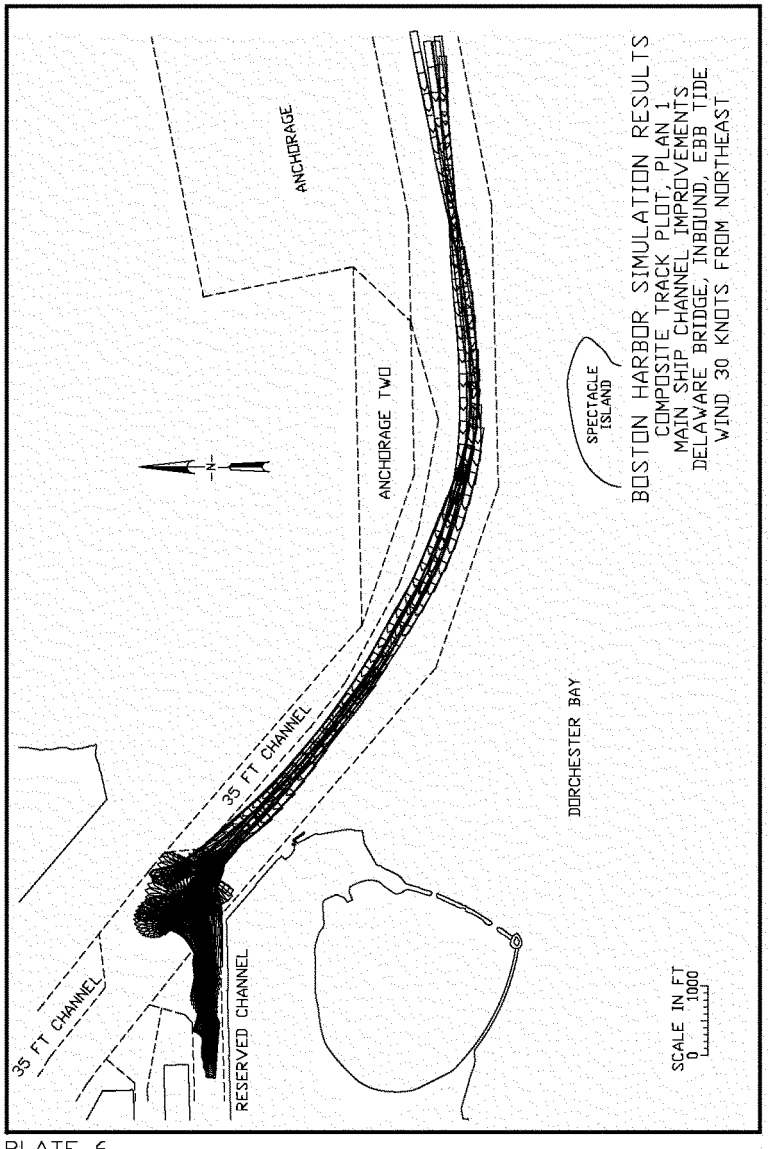
RESERVED CHANNEL
35
DORCHESTER BAY
SPECTACLE ISLAND
BOSTON HARBOR SIMULATION RESULTS
COMPOSITE TRACK PLOT, PLAN 1
MAIN SHIP CHANNEL IMPROVEMENTS
COSCO HAMBURG, INBOUND, EBB TIDE
WIND 30 KNOTS FROM NORTHEAST
SCALE IN FT
0
1000

PLATE 5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ANCHORAGE TWO
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35 FT CHANNEL
RESERVED CHANNEL
DORCHESTER BAY
SPECTACLE ISLAND
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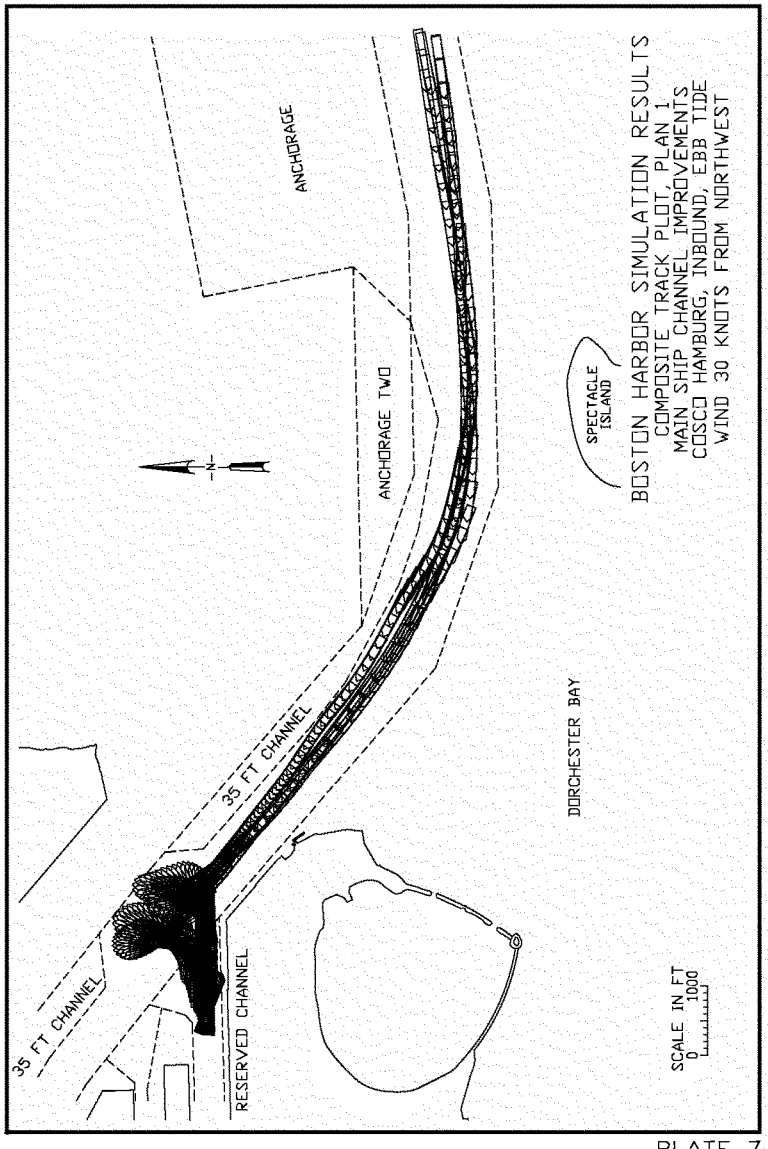
BOSTON HARBOR SIMULATION RESULTS
COMPOSITE TRACK PLOT, PLAN 1
MAIN SHIP CHANNEL IMPROVEMENTS
DELAWARE BRIDGE, INBOUND, EBB TIDE
WIND 30 KNOTS FROM NORTHEAST
SCALE IN FT
0
1000

PLATE 6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35 FT CHANNEL
RESERVED CHANNEL
DORCHESTER BAY
SPECTACLE ISLAND
BOSTON HARBOR SIMULATION RESULTS
COMPOSITE TRACK PLOT, PLAN 1
MAIN SHIP CHANNEL IMPROVEMENTS
COSCO HAMBURG, INBOUND, EBB TIDE
WIND 30 KNOTS FROM NORTHWEST
SCALE IN FT
0 1000
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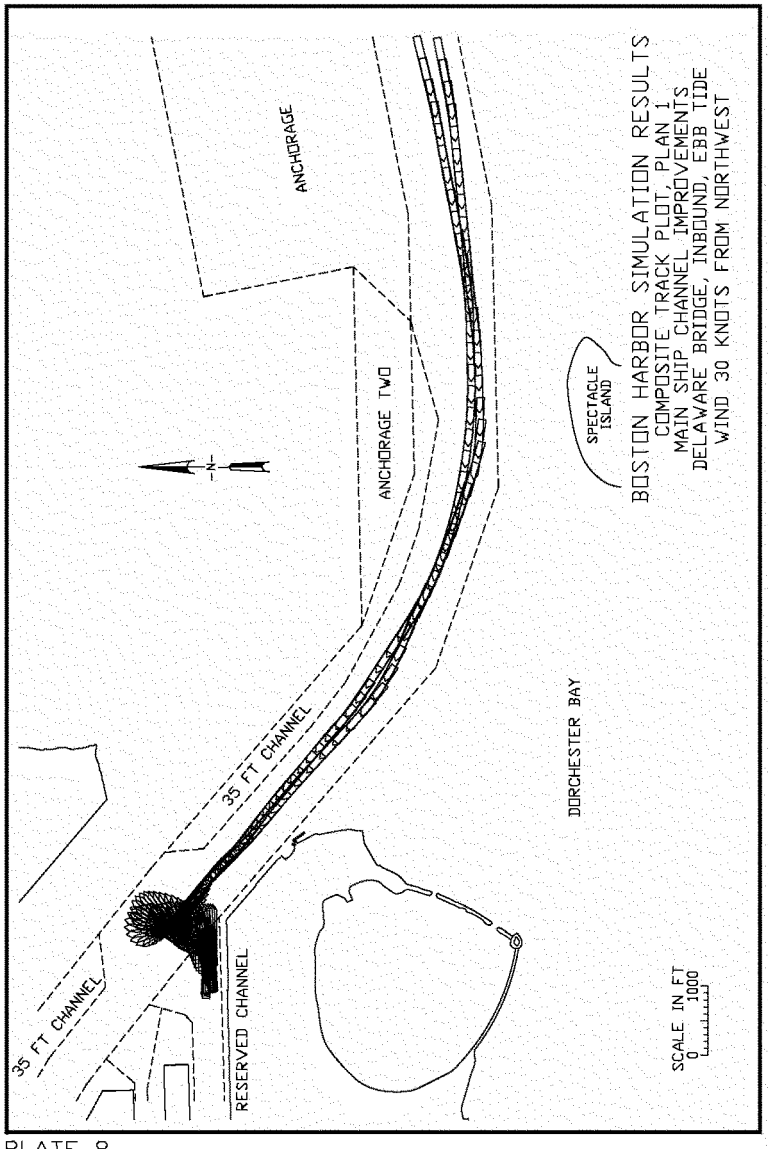
PLATE 7


BOSTON HARBOR SIMULATION RESULTS
COMPOSITE TRACK PLOT, PLAN 1
MAIN SHIP CHANNEL IMPROVEMENTS
DELAWARE BRIDGE, INBOUND, EBB TIDE
WIND 30 KNOTS FROM NORTHWEST
SCALE IN FT
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ANCHORAGE
ANCHORAGE TWO
35 FT CHANNEL
35 FT CHANNEL
RESERVED CHANNEL
DORCHESTER BAY
SPECTACLE ISLAND
N

PLATE 8

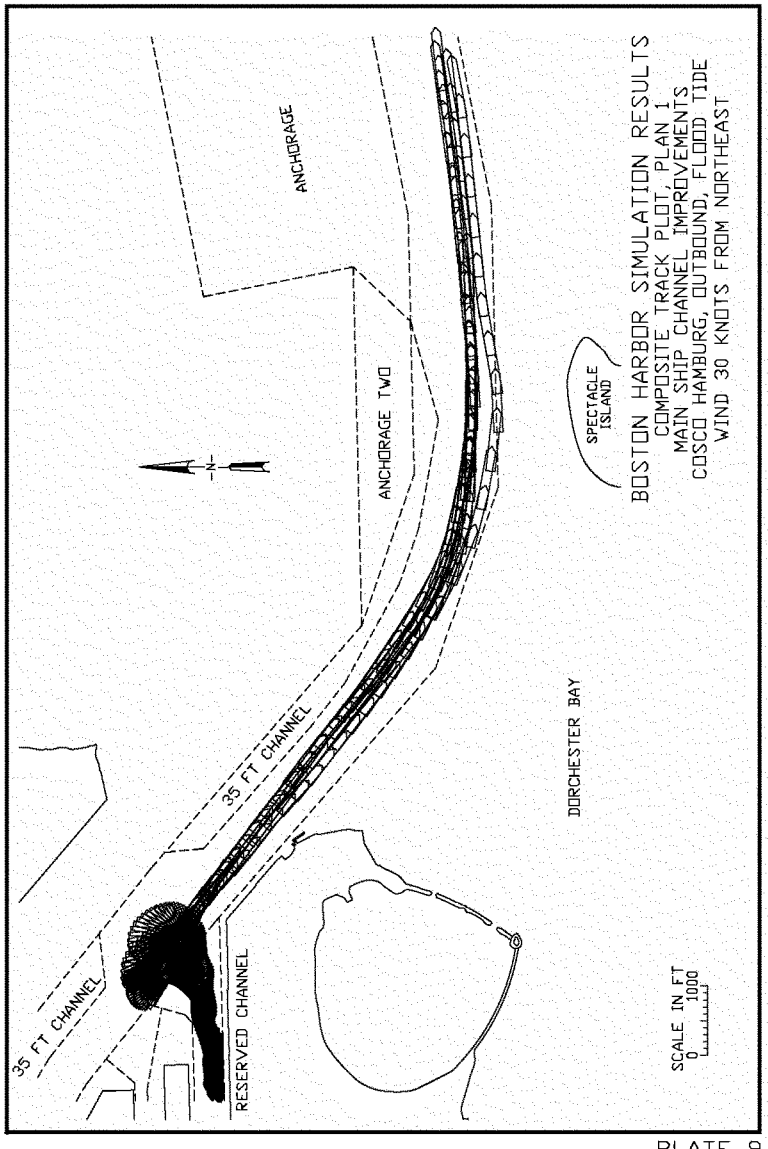

BOSTON HARBOR SIMULATION RESULTS
COMPOSITE TRACK PLOT, PLAN 1
MAIN SHIP CHANNEL IMPROVEMENTS
COSCO HAMBURG, OUTBOUND, FLOOD TIDE
WIND 30 KNOTS FROM NORTHEAST
SPECTACLE ISLAND
DORCHESTER BAY
ANCHORAGE
ANCHORAGE TWO
35 FT CHANNEL
35 FT CHANNEL
RESERVED CHANNEL
N
SCALE IN FT
0 1000

PLATE 9

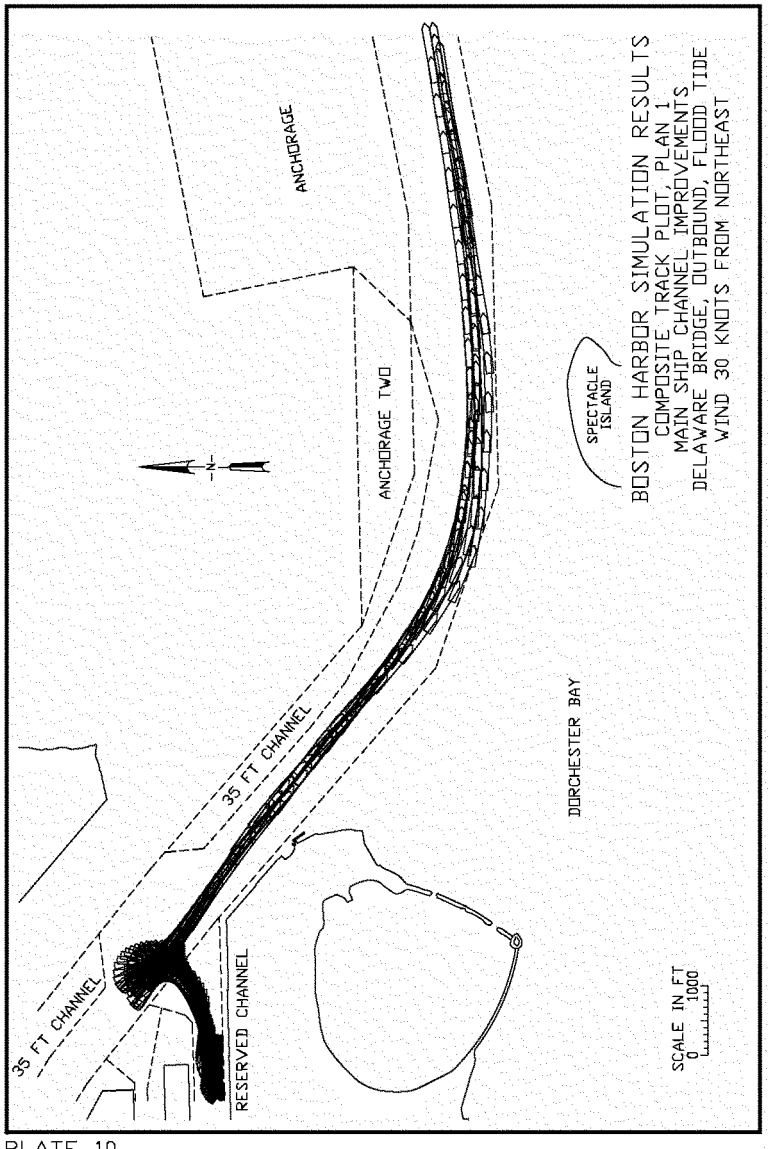
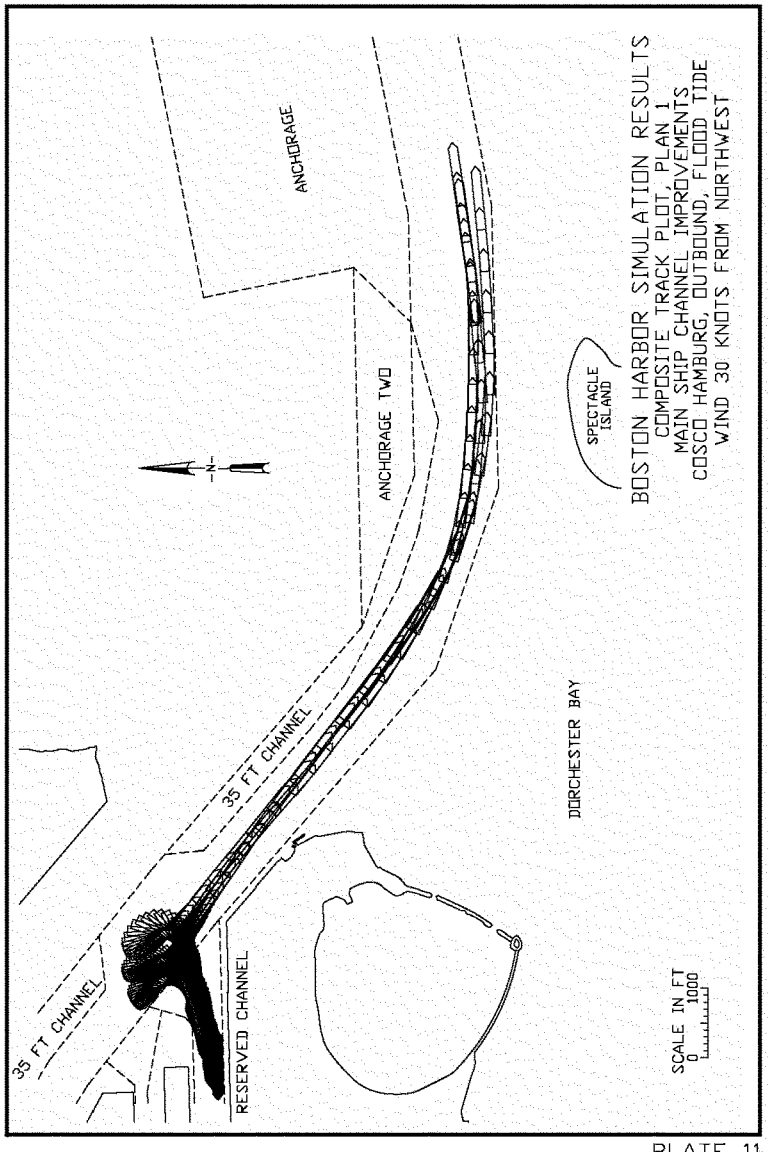

BOSTON HARBOR SIMULATION RESULTS
COMPOSITE TRACK PLOT, PLAN 1
MAIN SHIP CHANNEL IMPROVEMENTS
DELAWARE BRIDGE, OUTBOUND, FLOOD TIDE
WIND 30 KNOTS FROM NORTHEAST
SPECTACLE ISLAND
DORCHESTER BAY
ANCHORAGE
ANCHORAGE TWO
35 FT CHANNEL
35 FT CHANNEL
RESERVED CHANNEL
SCALE IN FT
0 1000
N

PLATE 10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35 FT CHANNEL
RESERVED CHANNEL
DORCHESTER BAY
SPECTACLE ISLAND
N
BOSTON HARBOR SIMULATION RESULTS
COMPOSITE TRACK PLOT, PLAN 1
MAIN SHIP CHANNEL IMPROVEMENTS
COSCO HAMBURG, OUTBOUND, FLOOD TIDE
WIND 30 KNOTS FROM NORTHWEST
SCALE IN FT
0 1000

PLATE 11

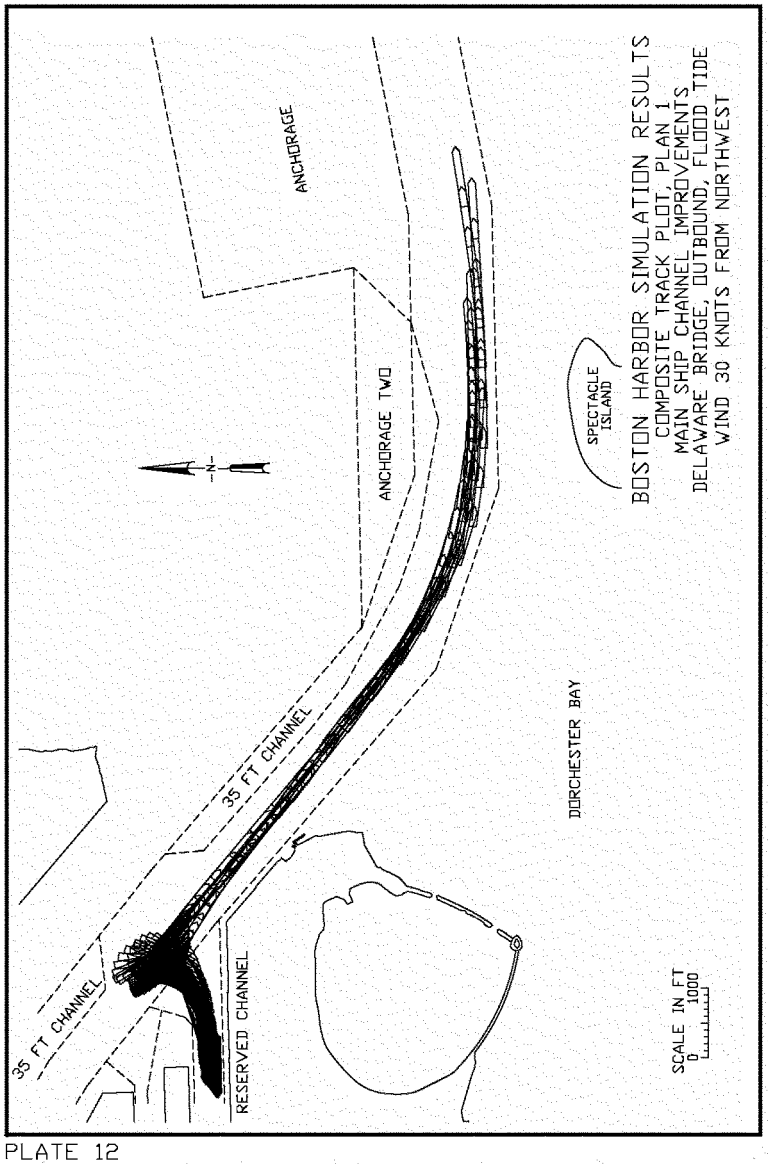

BOSTON HARBOR SIMULATION RESULTS
COMPOSITE TRACK PLOT, PLAN 1
MAIN SHIP CHANNEL IMPROVEMENTS
DELAWARE BRIDGE, OUTBOUND, FLOOD TIDE
WIND 30 KNOTS FROM NORTHWEST
ANCHORAGE
ANCHORAGE TWO
35 FT CHANNEL
35 FT CHANNEL
RESERVED CHANNEL
DORCHESTER BAY
SPECTACLE ISLAND
N
SCALE IN FT
0
1000

PLATE 12

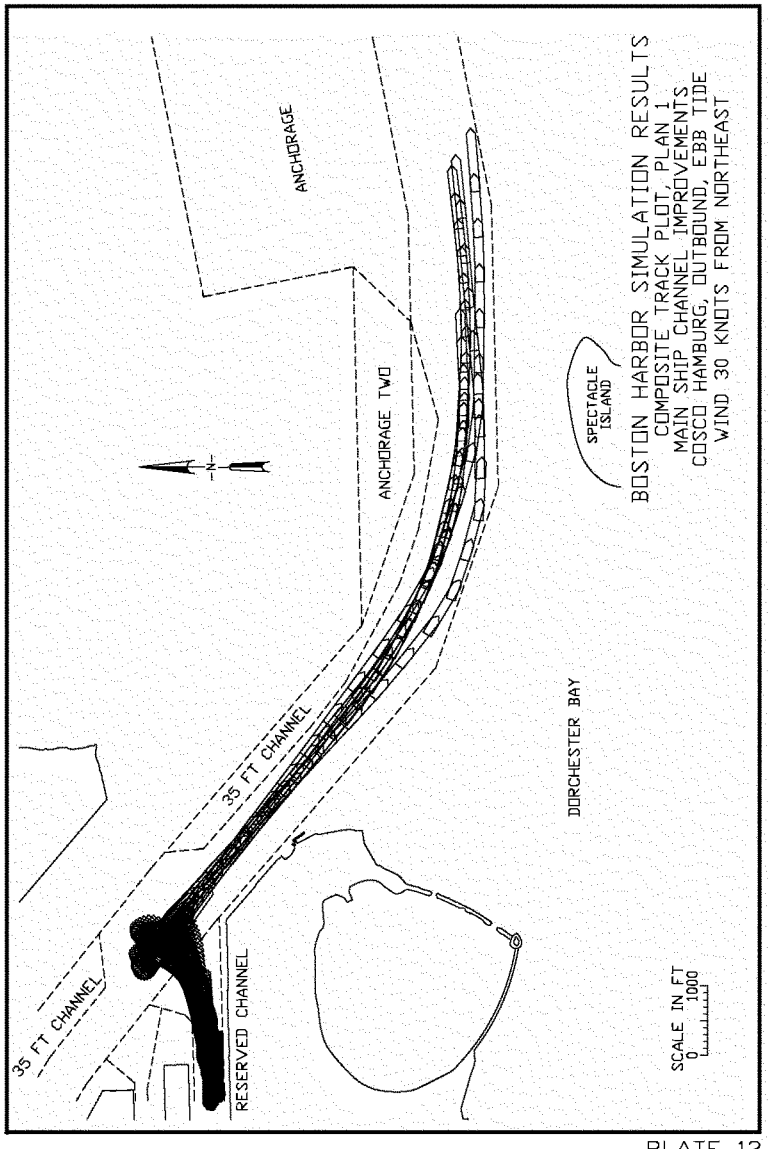

ANCHORAGE
ANCHORAGE TWO
35 FT CHANNEL
35 FT CHANNEL
RESERVED CHANNEL
DORCHESTER BAY
SPECTACLE ISLAND
N
BOSTON HARBOR SIMULATION RESULTS
COMPOSITE TRACK PLOT, PLAN 1
MAIN SHIP CHANNEL IMPROVEMENTS
COSCO HAMBURG, OUTBOUND, EBB TIDE
WIND 30 KNOTS FROM NORTHEAST
SCALE IN FT
0
1000

PLATE 13

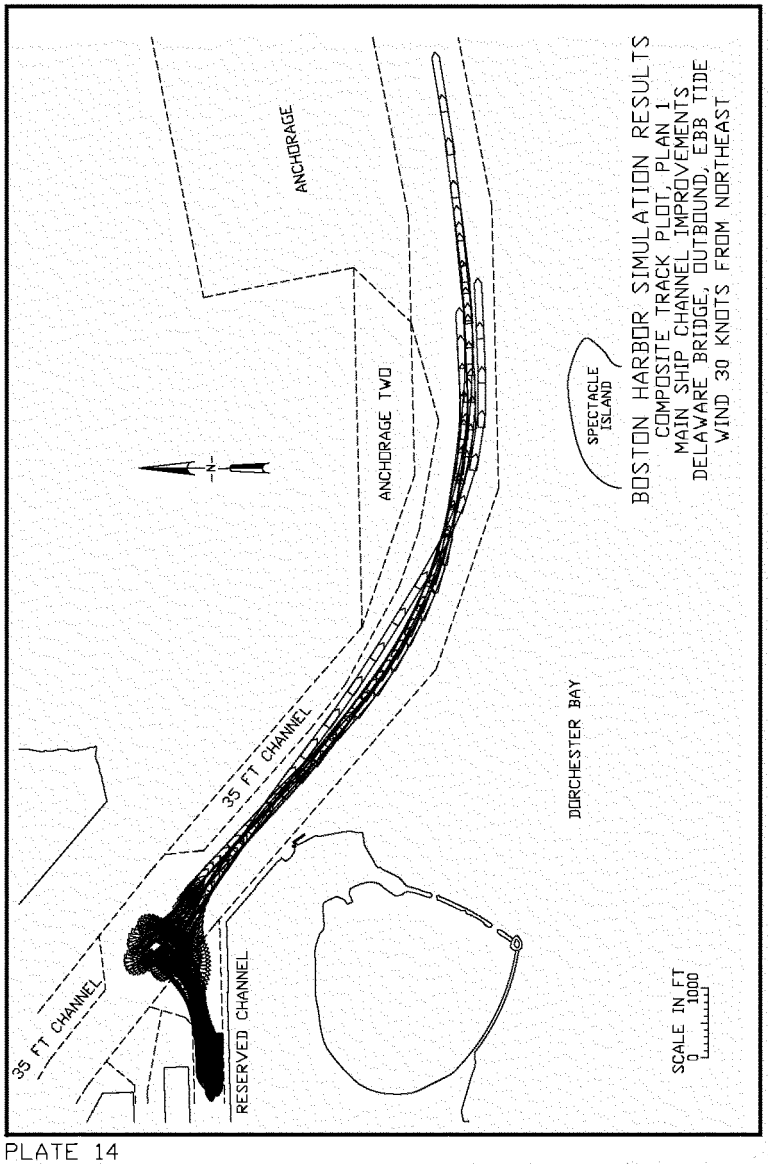
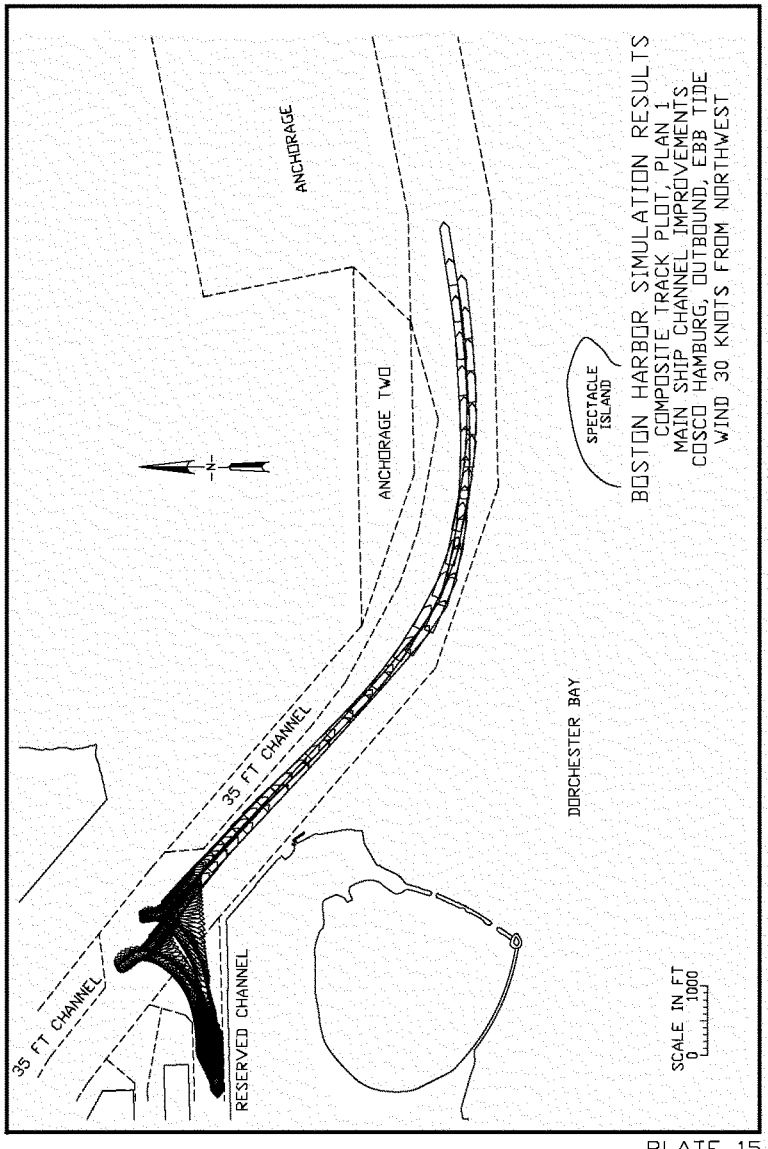

BOSTON HARBOR SIMULATION RESULTS
COMPOSITE TRACK PLOT, PLAN 1
MAIN SHIP CHANNEL IMPROVEMENTS
DELAWARE BRIDGE, OUTBOUND, EBB TIDE
WIND 30 KNOTS FROM NORTHEAST
SCALE IN FT
0 1000
ANCHORAGE
ANCHORAGE TWO
35 FT CHANNEL
35 FT CHANNEL
RESERVED CHANNEL
DORCHESTER BAY
SPECTACLE ISLAND
N

PLATE 14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ANCHORAGE TWO
35 FT CHANNEL
35 FT CHANNEL
RESERVED CHANNEL
DORCHESTER BAY
SPECTACLE ISLAND
N
BOSTON HARBOR SIMULATION RESULTS
COMPOSITE TRACK PLOT, PLAN 1
MAIN SHIP CHANNEL IMPROVEMENTS
COSCO HAMBURG, OUTBOUND, EBB TIDE
WIND 30 KNOTS FROM NORTHWEST
SCALE IN FT
0
1000

PLATE 15

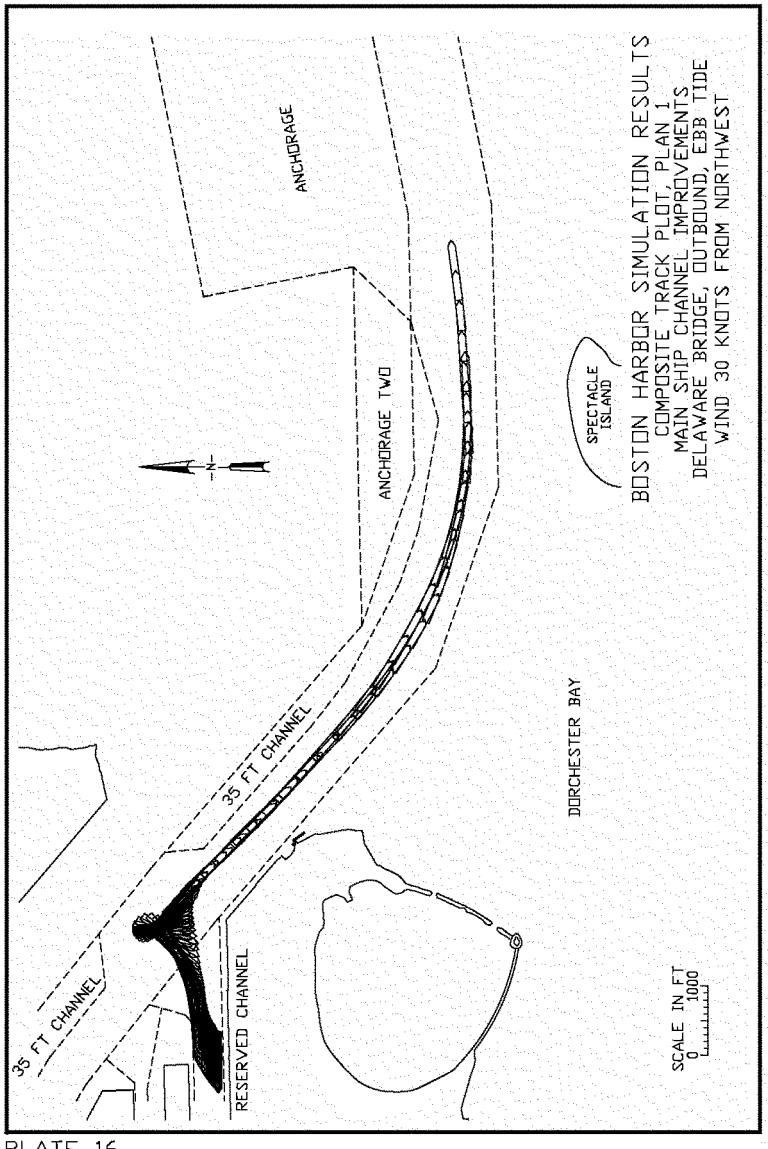
BOSTON HARBOR SIMULATION RESULTS
COMPOSITE TRACK PLOT, PLAN 1
MAIN SHIP CHANNEL IMPROVEMENTS
DELAWARE BRIDGE, OUTBOUND, EBB TIDE
WIND 30 KNOTS FROM NORTHWEST
SCALE IN FT
0 1000
ANCHORAGE
ANCHORAGE TWO
35 FT CHANNEL
35 FT CHANNEL
RESERVED CHANNEL
DORCHESTER BAY
SPECTACLE ISLAND
N

PLATE 16

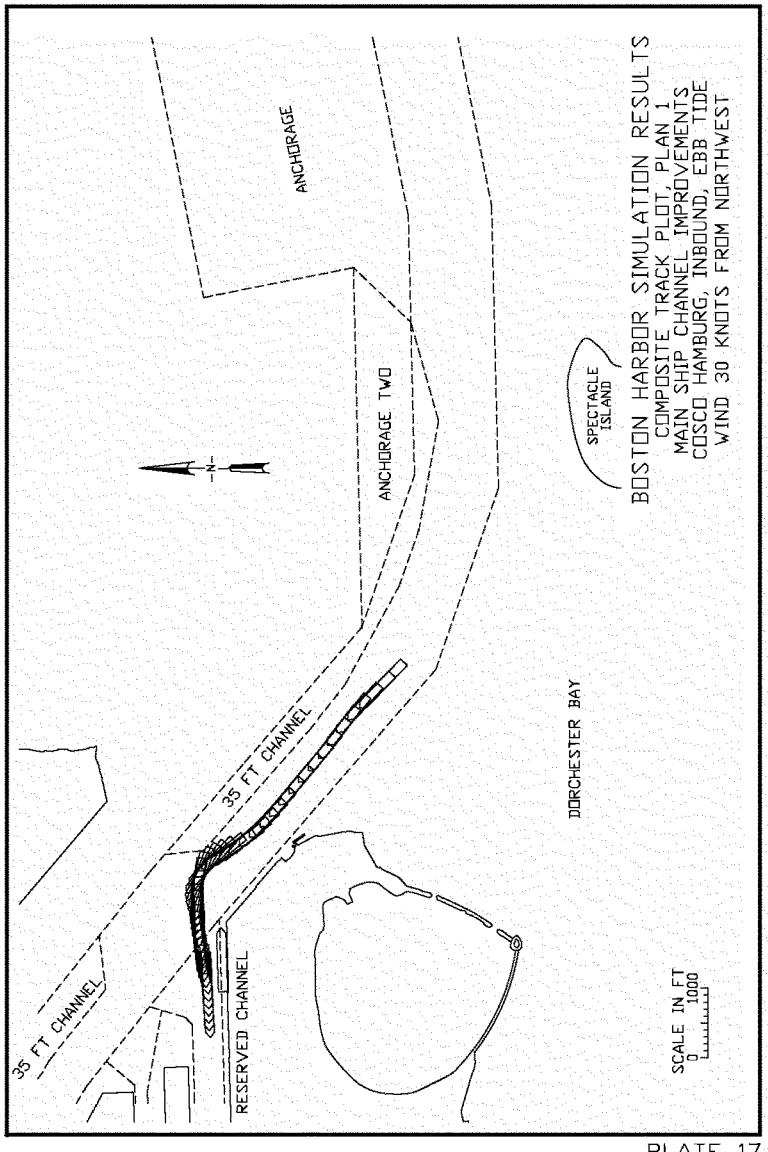
BOSTON HARBOR SIMULATION RESULTS
COMPOSITE TRACK PLOT, PLAN 1
MAIN SHIP CHANNEL IMPROVEMENTS
COSCO HAMBURG, INBOUND, EBB TIDE
WIND 30 KNOTS FROM NORTHWEST
SPECTACLE ISLAND
ANCHORAGE
ANCHORAGE TWO
35 FT CHANNEL
35 FT CHANNEL
RESERVED CHANNEL
DORCHESTER BAY
N
SCALE IN FT
0
1000

PLATE 17

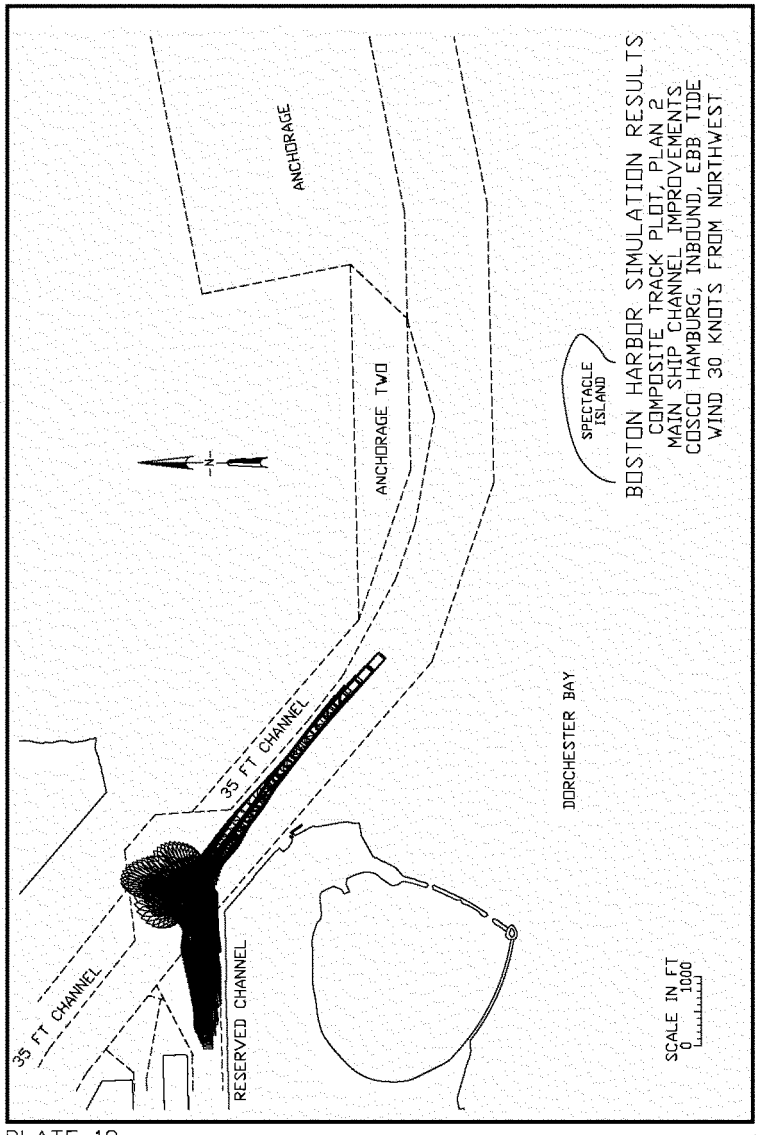
BOSTON HARBOR SIMULATION RESULTS
COMPOSITE TRACK PLOT, PLAN 2
MAIN SHIP CHANNEL IMPROVEMENTS
COSCO HAMBURG, INBOUND, EBB TIDE
WIND 30 KNOTS FROM NORTHWEST
SPECTACLE ISLAND
DORCHESTER BAY
ANCHORAGE
ANCHORAGE TWO
35 FT CHANNEL
35 FT CHANNEL
RESERVED CHANNEL
SCALE IN FT
0 1000

PLATE 18

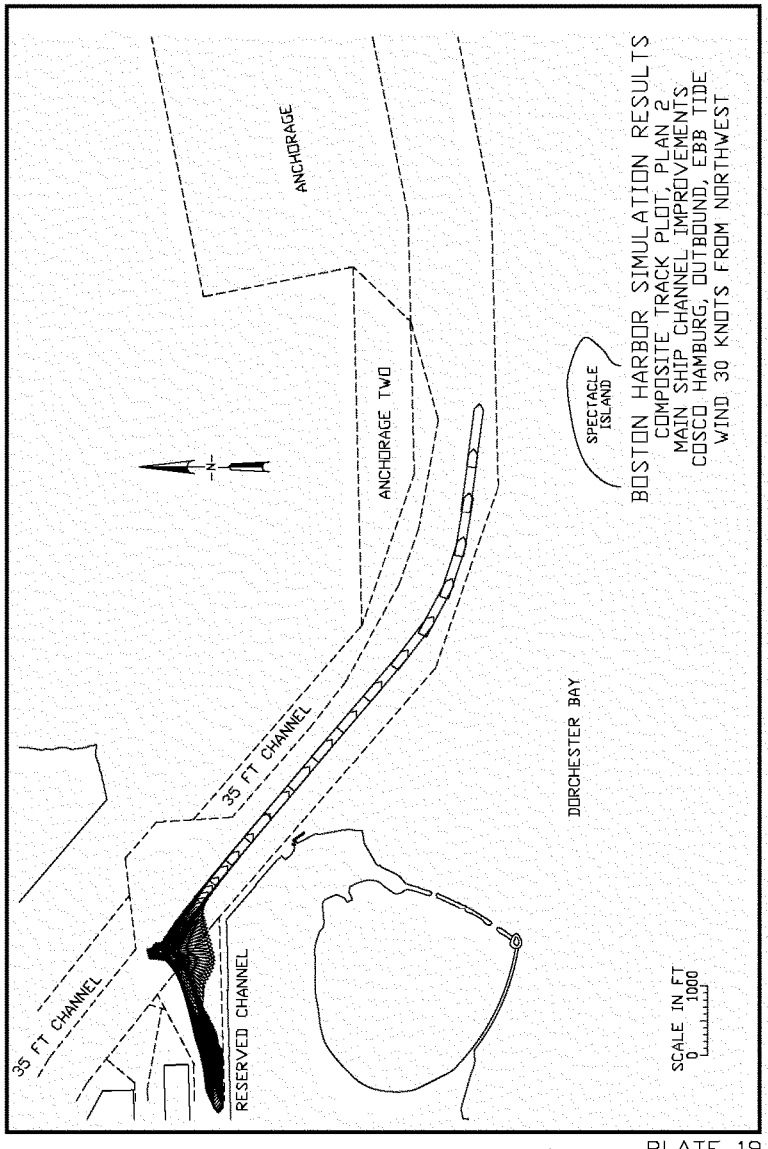
BOSTON HARBOR SIMULATION RESULTS
COMPOSITE TRACK PLOT, PLAN 2
MAIN SHIP CHANNEL IMPROVEMENTS
COSCO HAMBURG, OUTBOUND, EBB TIDE
WIND 30 KNOTS FROM NORTHWEST
SPECTACLE ISLAND
ANCHORAGE
ANCHORAGE TWO
35 FT CHANNEL
35 FT CHANNEL
RESERVED CHANNEL
DORCHESTER BAY
SCALE IN FT
0 1000
N

PLATE 19

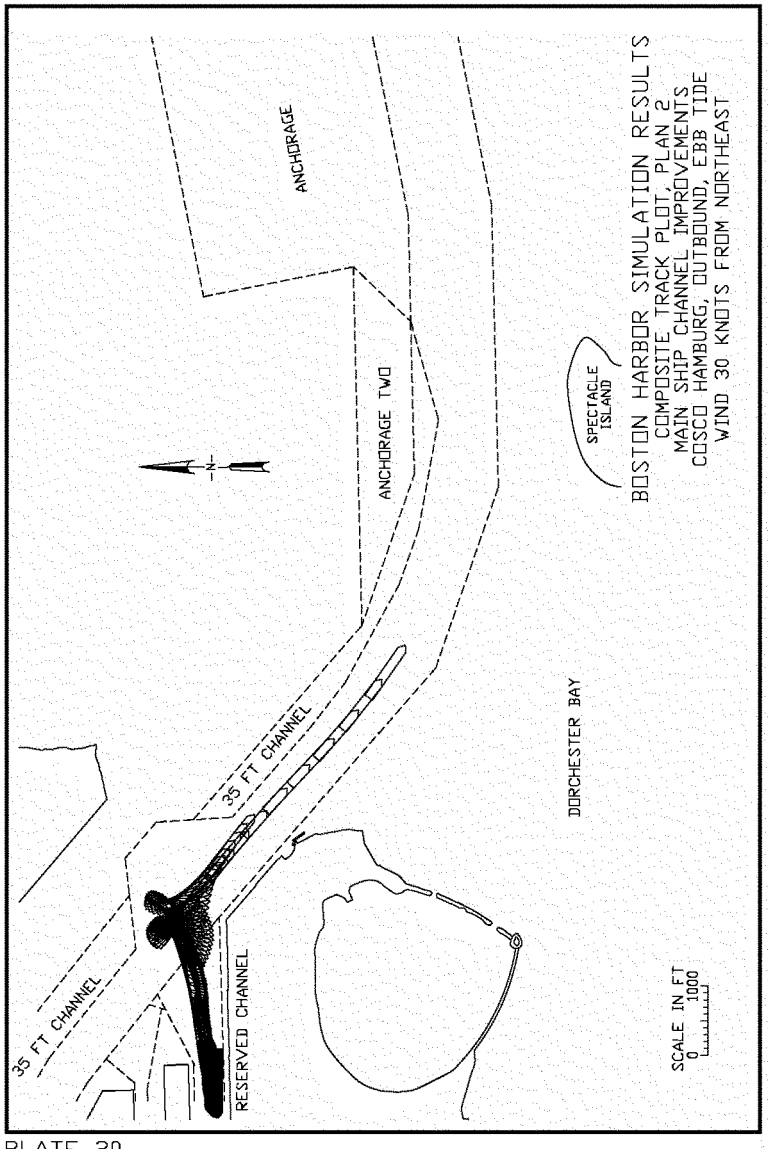
BOSTON HARBOR SIMULATION RESULTS
COMPOSITE TRACK PLOT, PLAN 2
MAIN SHIP CHANNEL IMPROVEMENTS
COSCO HAMBURG, OUTBOUND, EBB TIDE
WIND 30 KNOTS FROM NORTHEAST
SPECTACLE ISLAND
DORCHESTER BAY
ANCHORAGE
ANCHORAGE TWO
35 FT CHANNEL
35 FT CHANNEL
RESERVED CHANNEL
N
SCALE IN FT
0 1000

PLATE 20

H-50

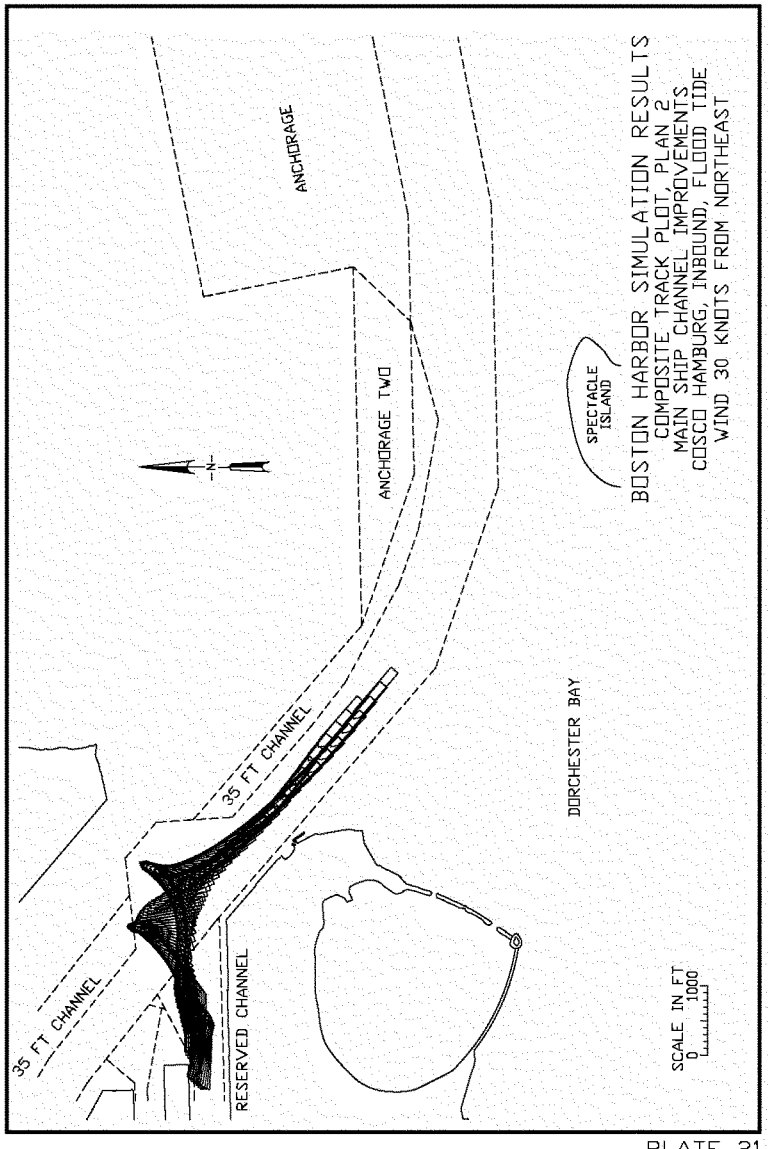
ANCHORAGE
ANCHORAGE TWO
35 FT CHANNEL
35 FT CHANNEL
RESERVED CHANNEL
DORCHESTER BAY
SPECTACLE ISLAND
BOSTON HARBOR SIMULATION RESULTS
COMPOSITE TRACK PLOT, PLAN 2
MAIN SHIP CHANNEL IMPROVEMENTS
COSCO HAMBURG, INBOUND, FLOOD TIDE
WIND 30 KNOTS FROM NORTHEAST
SCALE IN FT
0
1000
N

PLATE 21

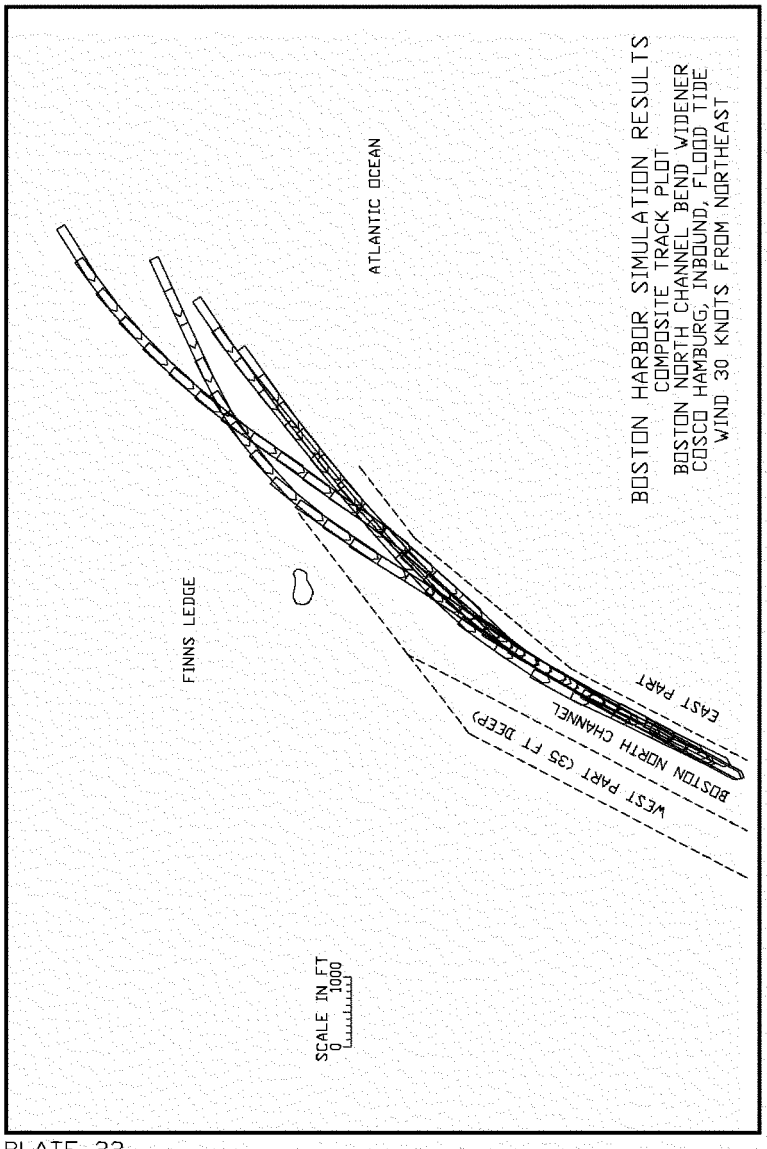
BOSTON HARBOR SIMULATION RESULTS
COMPOSITE TRACK PLOT
BOSTON NORTH CHANNEL BEND WIDENER
COSCO HAMBURG, INBOUND, FLOOD TIDE
WIND 30 KNOTS FROM NORTHEAST
ATLANTIC OCEAN
FINNS LEDGE
EAST PART
BOSTON NORTH CHANNEL
WEST PART (35 FT DEEP)
SCALE IN FT
0
1000

PLATE 22

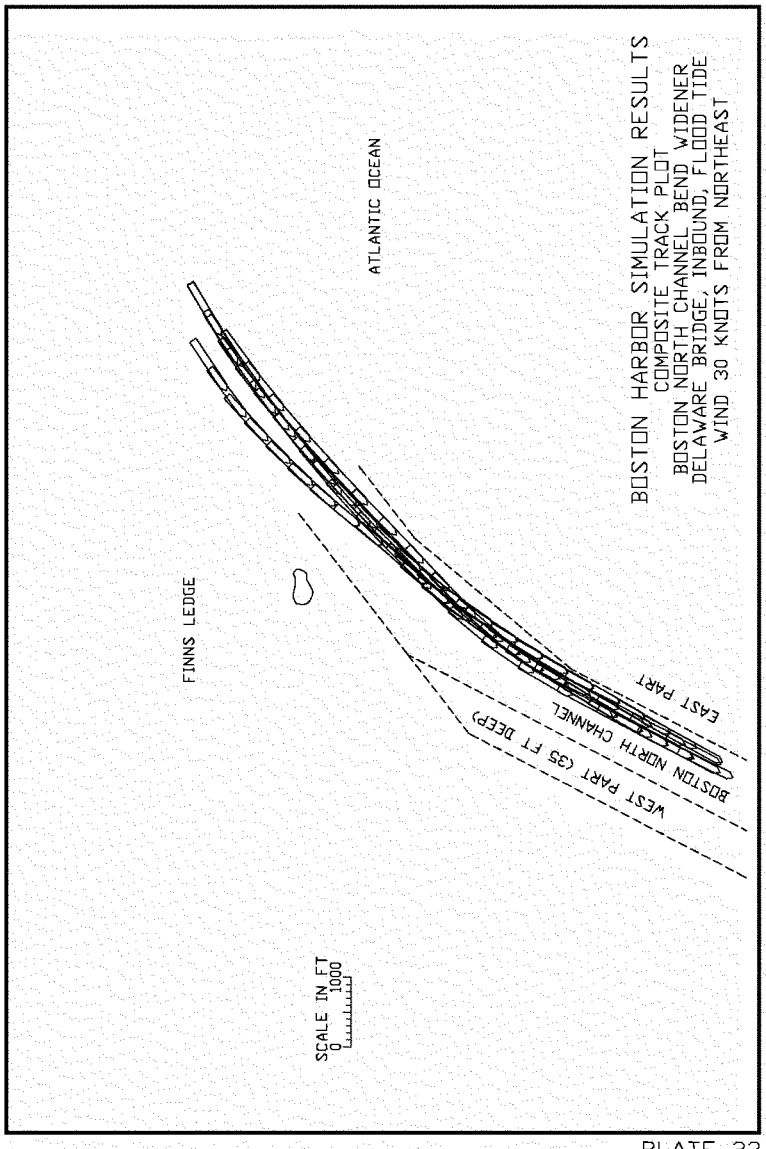
BOSTON HARBOR SIMULATION RESULTS
COMPOSITE TRACK PLOT
BOSTON NORTH CHANNEL BEND WIDENER
DELAWARE BRIDGE, INBOUND, FLOOD TIDE
WIND 30 KNOTS FROM NORTHEAST
ATLANTIC OCEAN
FINNS LEDGE
EAST PART
BOSTON NORTH CHANNEL
WEST PART (35 FT DEEP)
SCALE IN FT
0
1000

PLATE 23

H-53

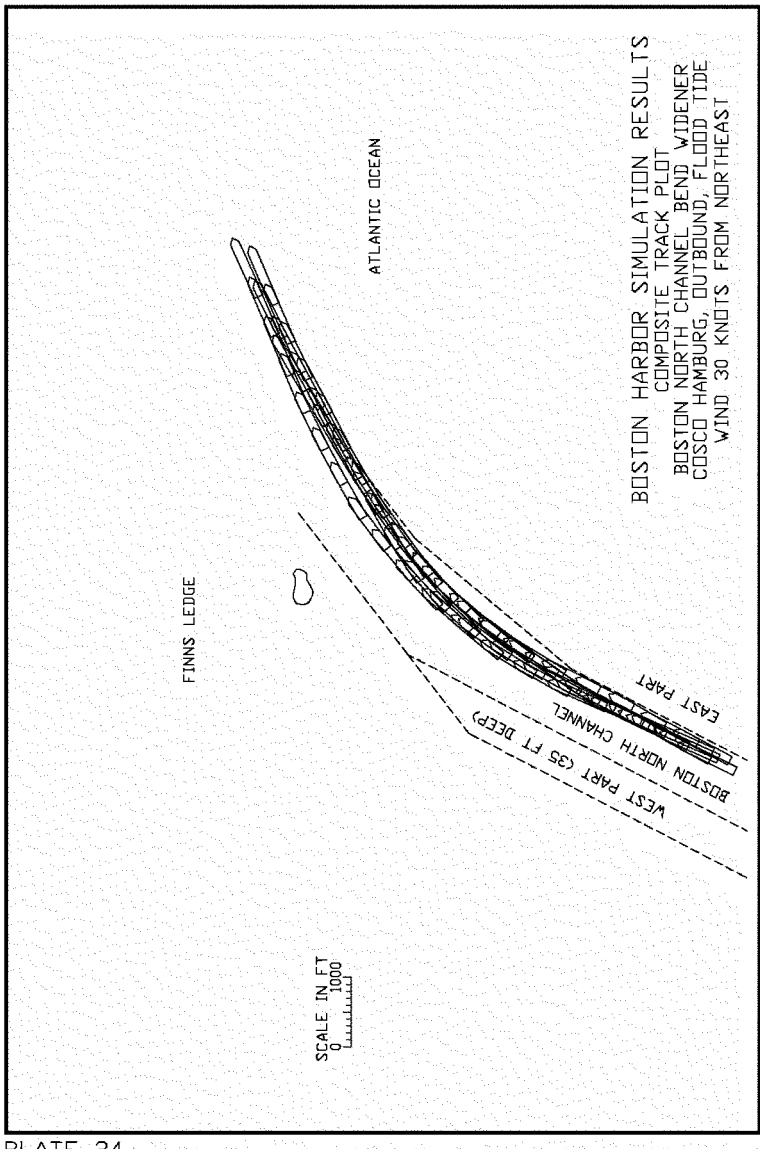
BOSTON HARBOR SIMULATION RESULTS
COMPOSITE TRACK PLOT
BOSTON NORTH CHANNEL BEND WIDENER
COSCO HAMBURG, OUTBOUND, FLOOD TIDE
WIND 30 KNOTS FROM NORTHEAST
ATLANTIC OCEAN
FINNS LEDGE
EAST PART
BOSTON NORTH CHANNEL
WEST PART (35 FT DEEP)
SCALE IN FT
0
1000

PLATE 24

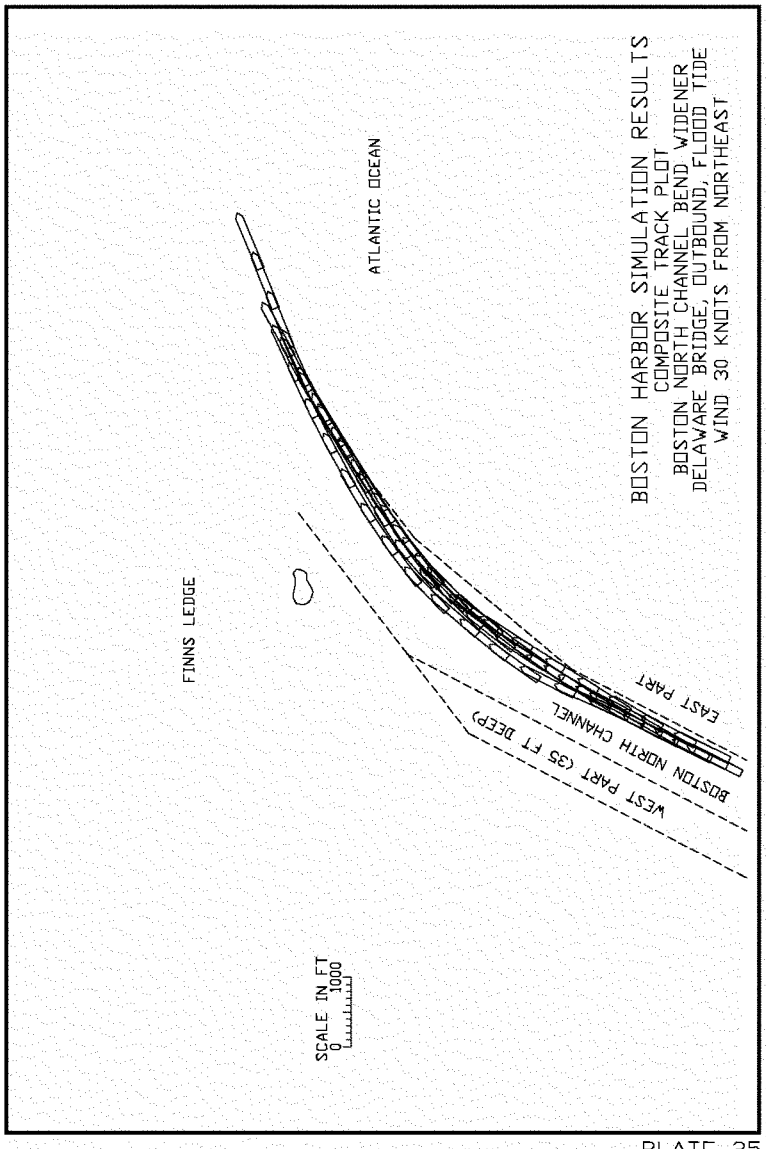
BOSTON HARBOR SIMULATION RESULTS
COMPOSITE TRACK PLOT
BOSTON NORTH CHANNEL BEND WIDENER
DELAWARE BRIDGE, OUTBOUND, FLOOD TIDE
WIND 30 KNOTS FROM NORTHEAST
ATLANTIC OCEAN
FINNS LEDGE
EAST PART
BOSTON NORTH CHANNEL
WEST PART (35 FT DEEP)
SCALE IN FT
0
1000

PLATE 25

H-55

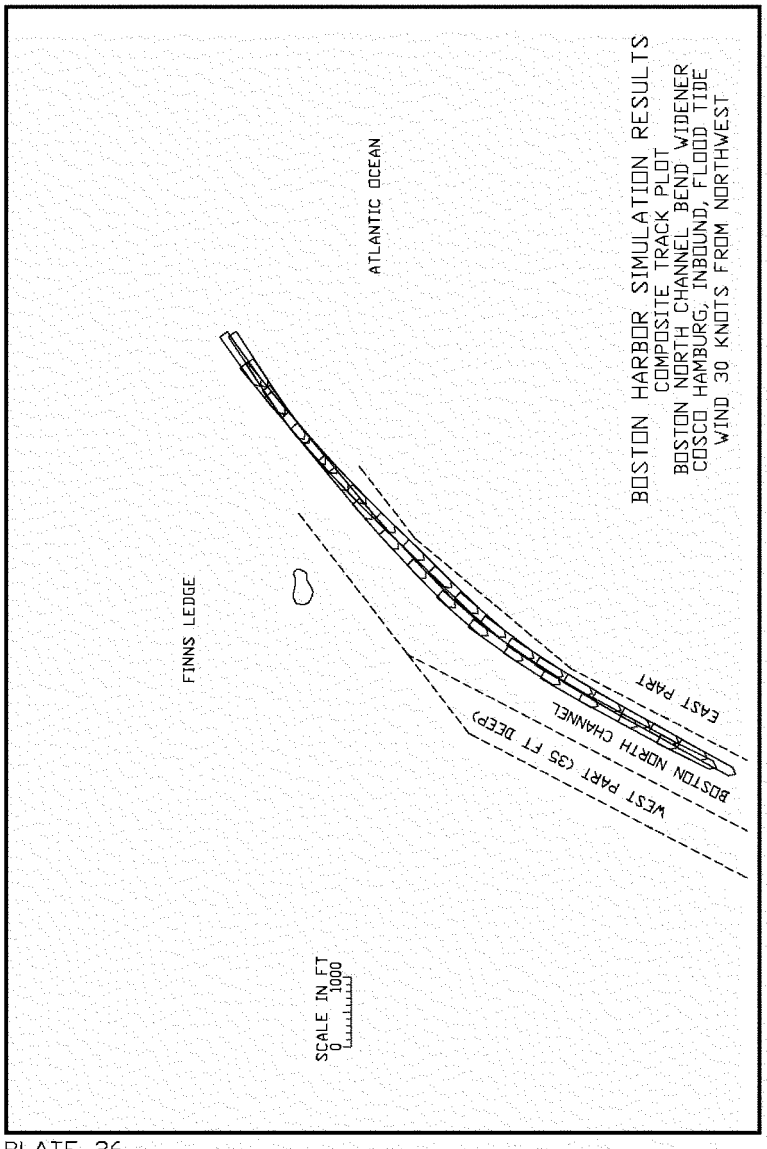
BOSTON HARBOR SIMULATION RESULTS
COMPOSITE TRACK PLOT
BOSTON NORTH CHANNEL BEND WIDENER
COSCO HAMBURG, INBOUND, FLOOD TIDE
WIND 30 KNOTS FROM NORTHWEST
ATLANTIC OCEAN
FINNS LEDGE
EAST PART
BOSTON NORTH CHANNEL
WEST PART (35 FT DEEP)
SCALE IN FT
0
1000

PLATE 26

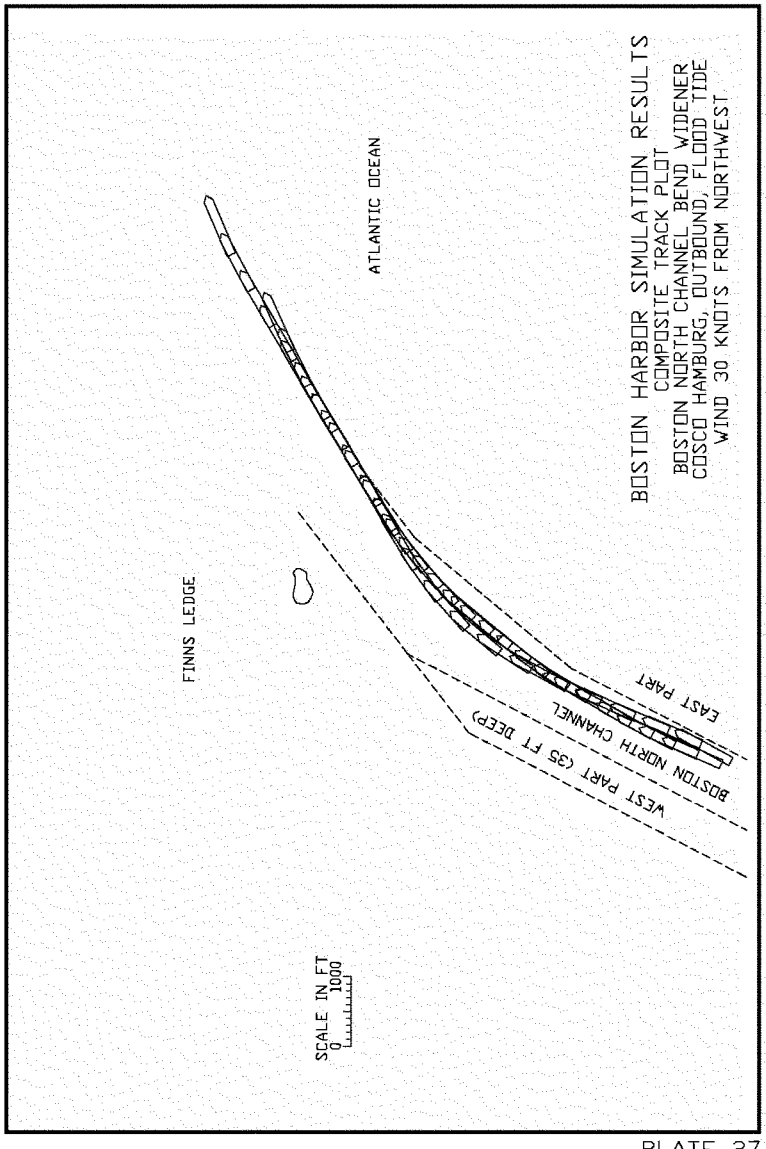
BOSTON HARBOR SIMULATION RESULTS
COMPOSITE TRACK PLOT
BOSTON NORTH CHANNEL BEND WIDENER
COSCO HAMBURG, OUTBOUND, FLOOD TIDE
WIND 30 KNOTS FROM NORTHWEST
ATLANTIC OCEAN
FINNS LEDGE
EAST PART
BOSTON NORTH CHANNEL
WEST PART (35 FT DEEP)
SCALE IN FT
0
1000

PLATE 27

H-57

Appendix A: Pilot Questionnaires

Boston Harbor Channel Improvements
Final Questionnaire

Captain Dirk Coffman

Ships

The *COSCO Hamburg* – 918 - x 131- x –46-ft containership.

The *Delaware Bridge* - 871.8 – 106 – x 43 ft containership.

1. A bend widener (Figure 1) is proposed for the East Part of the Boston North Channel. The purpose of the widener was to provide additional maneuvering room near Finns Ledge.

a. Based upon your simulation runs, do you feel that the widener provided adequate room for both the *COSCO Hamburg* and the *Delaware Bridge*?

Yes

b. Based upon your simulation runs, do you feel that the widener is necessary to bring the *COSCO Hamburg* and the *Delaware Bridge* into and out of Boston Harbor?

Both ships could be brought in with existing Channel but the widener would make a hard turn easier and safer. It would also make meeting other ships in to area easier.

c. Will the widener benefit other vessels calling at Boston Harbor? If so, which vessels and in what manner would they benefit.

All ships would benefit as turn could be negociated easier and safer.

d. Should the widener be modified? Feel free to sketch on Figure 1.

Configuration is good. I believe buoys are planned for corners.

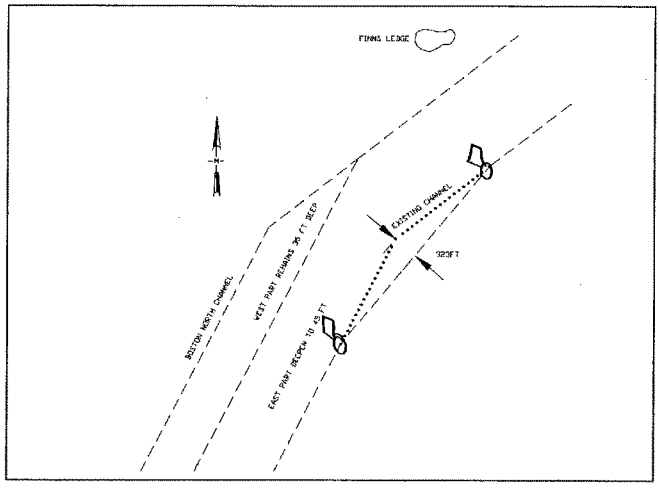

Figure 1. Boston North Channel Bend Widener

2. Widening of the deepened 45 ft channel near Spectacle Island is proposed. The widening will be accomplished by deepening on the south side of the 35 ft channel. The channel width would be increased to 800 feet with 880 feet through the turns. The widening is shown in Figure 2. The purpose of the additional width is permit passage of these larger vessels through this reach of the harbor's Main Ship Channel and to ease passage in the two turns above Spectacle Island.

   a. Based upon your simulation runs, do you feel that the additional width provided adequate room for both the *COSCO Hamburg* and the *Delaware Bridge*?

   yes

   b. Based upon your simulation runs, do you feel that the additional width is necessary to bring the *COSCO Hamburg* and the *Delaware Bridge* to make the turn near Spectacle Island?

   Yes, to bring in vessels of this size in challenging conditions of wind and current at slow speeds required the widening is necessary for safe transit.

   c. Will the widener benefit other vessels calling at Boston Harbor? If so, which vessels and in what manner would they benefit.

   Other deep draft vessels (tankers, bulk scrap or salt, etc) will also benefit greatly.

   d. Should the channel width in the straight sections or in the two turns be modified? Feel free to sketch on Figure 2.

   The proposed wider would be a great improvement. Additional improvements are noted on sketch.

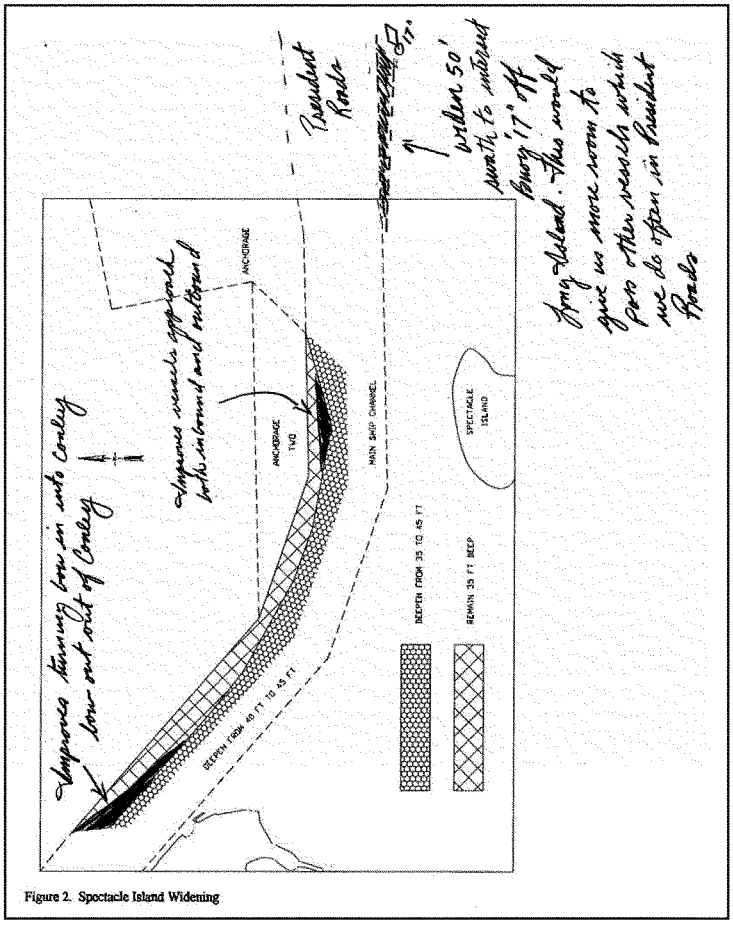

Figure 2. Spoctacle Island Widening

3. Widening near the mouth of the Reserved Channel is proposed. The widening will increase the size of the turning area from a radius of 1200 feet to a radius of 1500 feet. and also provide 50 ft additional width for the 45 ft channel north of the turning area. The widening is shown in Figure 3. The turning area is being increased to allow larger containerships access to the Reserve Channel. The additional 50 ft width is to allow more maneuvering room for larger bulk carriers expected to call on the Massport marine Terminal just north of the Reserve Channel.

   a. Based upon your simulation runs, do you feel that the enlarged turning area provided adequate room for both the *COSCO Hamburg* and the *Delaware Bridge*?

   - It can be done, but would benefit from larger area off Army Base

   b. Based upon your simulation runs, do you feel that the enlarged turning area is necessary to bring the *COSCO Hamburg* and the *Delaware Bridge* to enter and leave the Reserve Channel?

   As mentioned above enlarging the proposed turning basin of the Army Base make it possible to negociate the turn in and out, bow in and bow out or around another ship at dock

   c. Should the enlarged turning area be modified? Feel free to sketch on Figure 3.

   Yes, see sketch

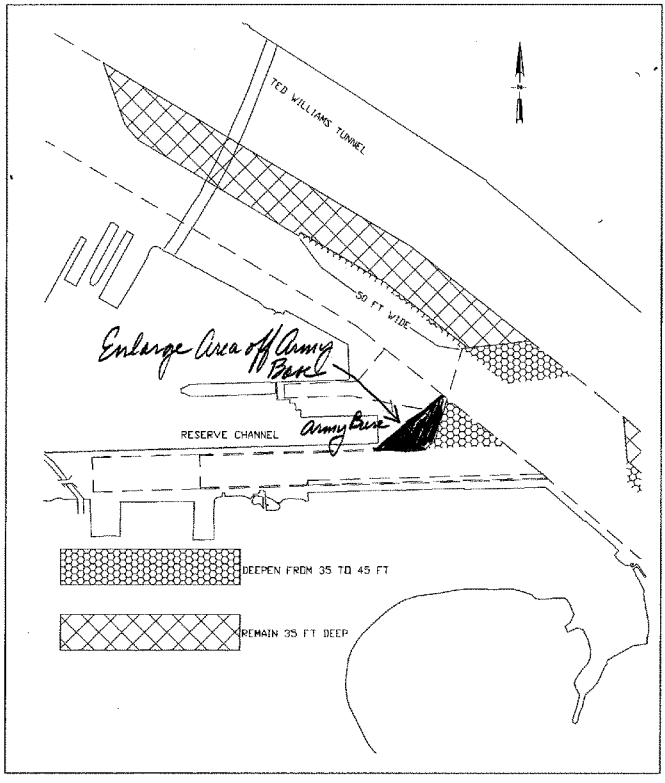

Figure 3. Widening near mouth of Reserve Channel

4. The following questions concern the simulation modeling of Boston Harbor.

   a. Was the visual scene realistic, accurate, and adequate for the study?

   Yes

   b. Do you feel the ships responded correctly to the currents?

   In most cases

   c. Do you feel the ships responded correctly to the bank forces?

   Yes

   d. Do you feel the ships responded correctly to the wind?

   In most cases

   e. Any additional comments regarding the simulation model?

   Overall, I had a great experience. The staff administrated the simulations in a competent professional manner. Thank You for your hard work on this project.

Boston Harbor Channel Improvements
Final Questionnaire

Captain Robert G. Cordes

Ships

The *COSCO Hamburg* – 918 - x 131- x –46-ft containership.

The *Delaware Bridge* - 871.8 – 106 – x 43 ft containership.

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a. Based upon your simulation runs, do you feel that the widener provided adequate room for both the *COSCO Hamburg* and the *Delaware Bridge*?

Yes

b. Based upon your simulation runs, do you feel that the widener is necessary to bring the *COSCO Hamburg* and the *Delaware Bridge* into and out of Boston Harbor?

No, But It Gives You The Extra Room Needed In The Event You Meet Another Vessel At This Juncture. It Also Reduces The Degree Of Turn To Maintain Ability To Remain On Green Side Of Channel (Deep Side).

c. Will the widener benefit other vessels calling at Boston Harbor? If so, which vessels and in what manner would they benefit.

Yes, LNG Tankers. It Allows For A Less Radical Turn To Port To Keep On Green (Deep) Side Of North Channel.

d. Should the widener be modified? Feel free to sketch on Figure 1.

See Sketch!

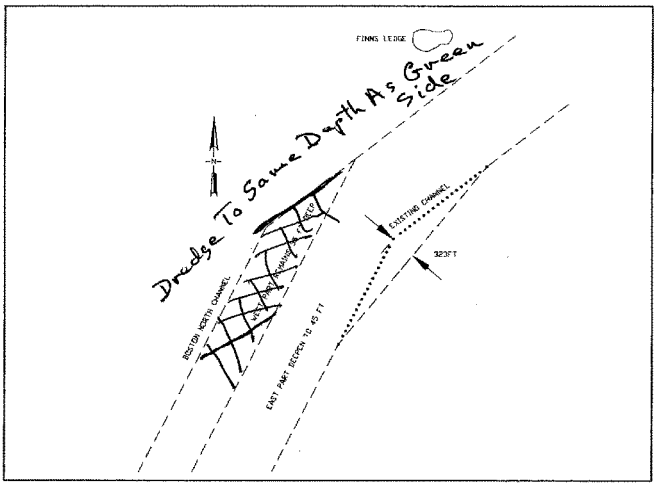


Figure 1. Boston North Channel Bend Widener

2. Widening of the deepened 45 ft channel near Spectacle Island is proposed. The widening will be accomplished by deepening on the south side of the 35 ft channel. The channel width would be increased to 800 feet with 880 feet through the turns. The widening is shown in Figure 2. The purpose of the additional width is permit passage of these larger vessels through this reach of the harbor's Main Ship Channel and to ease passage in the two turns above Spectacle Island.

   a. Based upon your simulation runs, do you feel that the additional width provided adequate room for both the *COSCO Hamburg* and the *Delaware Bridge*?

      Yes

   b. Based upon your simulation runs, do you feel that the additional width is necessary to bring the *COSCO Hamburg* and the *Delaware Bridge* to make the turn near Spectacle Island?

      Yes

   c. Will the widener benefit other vessels calling at Boston Harbor? If so, which vessels and in what manner would they benefit.

      Yes, LNG Tankers, In Sudden High Wind Gusts, And Would Also Allow For Larger LNG's. ie: Longer & Wider

   d. Should the channel width in the straight sections or in the two turns be modified? Feel free to sketch on Figure 2.

      See Note On Sketch.

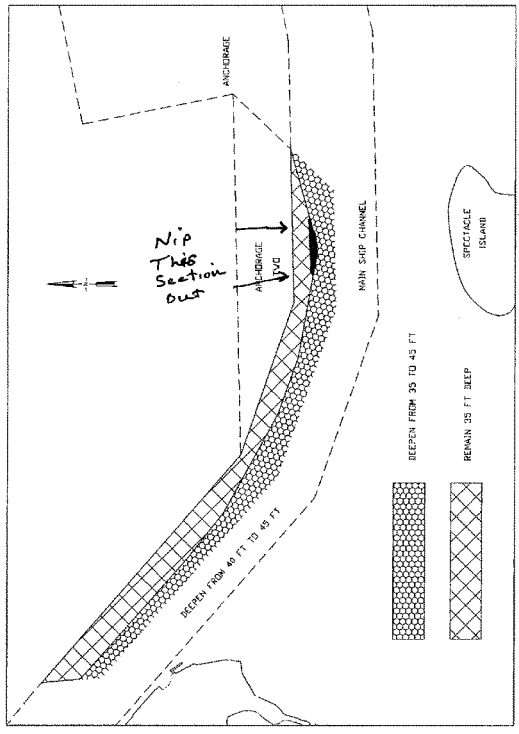


Figure 2. Spectacle Island Widening

H-68

3. Widening near the mouth of the Reserved Channel is proposed. The widening will increase the size of the turning area from a radius of 1200 feet to a radius of 1500 feet. and also provide 50 ft additional width for the 45 ft channel north of the turning area. The widening is shown in Figure 3. The turning area is being increased to allow larger containerships access to the Reserve Channel. The additional 50 ft width is to allow more maneuvering room for larger bulk carriers expected to call on the Massport marine Terminal just north of the Reserve Channel.

   a. Based upon your simulation runs, do you feel that the enlarged turning area provided adequate room for both the *COSCO Hamburg* and the *Delaware Bridge*?

      Yes

   b. Based upon your simulation runs, do you feel that the enlarged turning area is necessary to bring the *COSCO Hamburg* and the *Delaware Bridge* to enter and leave the Reserve Channel?

      Yes

   c. Should the enlarged turning area be modified? Feel free to sketch on Figure 3.

      Yes (See Note On Sketch.)

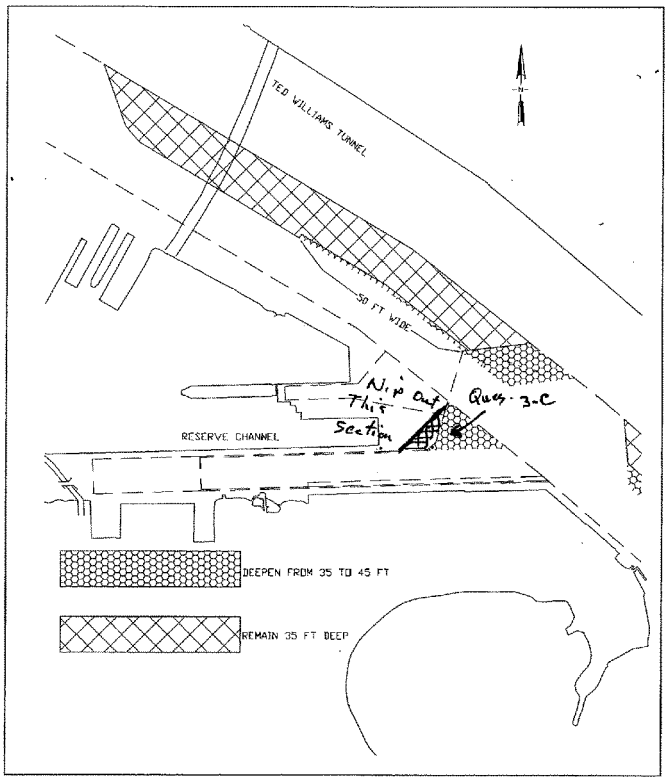


Figure 3. Widening near mouth of Reserve Channel

4. The following questions concern the simulation modeling of Boston Harbor.

   a. Was the visual scene realistic, accurate, and adequate for the study?

   Yes

   b. Do you feel the ships responded correctly to the currents?

   Yes

   c. Do you feel the ships responded correctly to the bank forces?

   Yes

   d. Do you feel the ships responded correctly to the wind?

   Yes

   e. Any additional comments regarding the simulation model?

   No, It Was Quite Satisfactory!

Boston Harbor Channel Improvements
Final Questionnaire

Captain F.R. MORTON

Ships

The *COSCO Hamburg* – 918 - x 131- x –46-ft containership.

The *Delaware Bridge* - 871.8 – 106 – x 43 ft containership.

1. A bend widener (Figure 1) is proposed for the East Part of the Boston North Channel. The purpose of the widener was to provide additional maneuvering room near Finns Ledge.

a. Based upon your simulation runs, do you feel that the widener provided adequate room for both the *COSCO Hamburg* and the *Delaware Bridge*? YES. THE ADDITIONAL ROOM WILL BE A BIG HELP WHEN SHIPS ARE MEETING.

b. Based upon your simulation runs, do you feel that the widener is necessary to bring the *COSCO Hamburg* and the *Delaware Bridge* into and out of Boston Harbor?

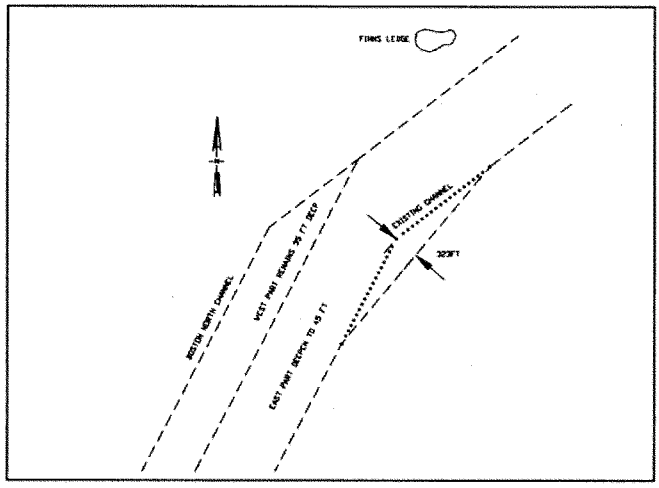
YES.

c. Will the widener benefit other vessels calling at Boston Harbor? If so, which vessels and in what manner would they benefit.

THE WIDENER WILL BENEFIT THE TRANSIT OF LNG TANKERS AND CRUISE SHIPS. THESE ARE BOTH GENERALLY BIG VESSELS THAT NEED LONGER TURNING AREAS

d. Should the widener be modified? Feel free to sketch on Figure 1.

NO. IT IS FINE AS PROPOSED.



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2. Widening of the deepened 45 ft channel near Spectacle Island is proposed. The widening will be accomplished by deepening on the south side of the 35 ft channel. The channel width would be increased to 800 feet with 880 feet through the turns. The widening is shown in Figure 2. The purpose of the additional width is permit passage of these larger vessels through this reach of the harbor's Main Ship Channel and to ease passage in the two turns above Spectacle Island.

   a. Based upon your simulation runs, do you feel that the additional width provided adequate room for both the *COSCO Hamburg* and the *Delaware Bridge*? YES.

   b. Based upon your simulation runs, do you feel that the additional width is necessary to bring the *COSCO Hamburg* and the *Delaware Bridge* to make the turn near Spectacle Island? YES

   c. Will the widener benefit other vessels calling at Boston Harbor? If so, which vessels and inwhat manner would they benefit. LNG TANKERS, CRUISE SHIPS, AIRCRAFT CARRIES. ALSO LOADED INBOUND TANKERS WITH A FLOOD TIDE NEED ADDITIONAL ROOM TO MAKE TURNS.

   c. Should the channel width in the straight sections or in the two turns be modified? Feel free to sketch on Figure 2.

   NO. IT IS WELL PLANNED AS IS.

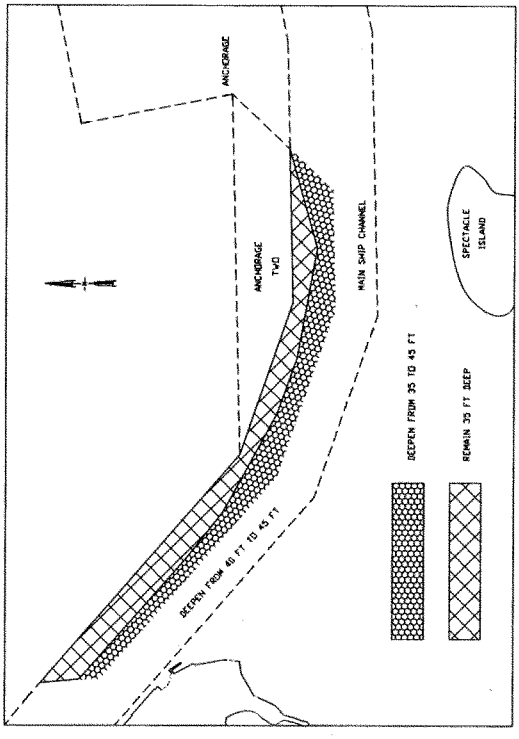


Figure 2. Spectacle Island Widening

3. Widening near the mouth of the Reserved Channel is proposed. The widening will increase the size of the turning area from a radius of 1200 feet to a radius of 1500 feet. and also provide 50 ft additional width for the 45 ft channel north of the turning area. The widening is shown in Figure 3. The turning area is being increased to allow larger containerships access to the Reserve Channel. The additional 50 ft width is to allow more maneuvering room for larger bulk carriers expected to call on the Massport marine Terminal just north of the Reserve Channel.

   a. Based upon your simulation runs, do you feel that the enlarged turning area provided adequate room for both the *COSCO Hamburg* and the *Delaware Bridge*?

      YES.

   b. Based upon your simulation runs, do you feel that the enlarged turning area is necessary to bring the *COSCO Hamburg* and the *Delaware Bridge* to enter and leave the Reserve Channel?

      YES

   c. Should the enlarged turning area be modified? Feel free to sketch on Figure 3.

      YES. I PREFER THE ALTERNATIVE TURNING NOTCH AS SHOWN IN FIGURE 4. THIS PROVIDED FOR AN EASIER TURN AROUND BOTH INBOUND AND OUTBOUND. IT ALSO KEEPS THE SHIPS AWAY FROM THE AIRPORT RUNWAY.

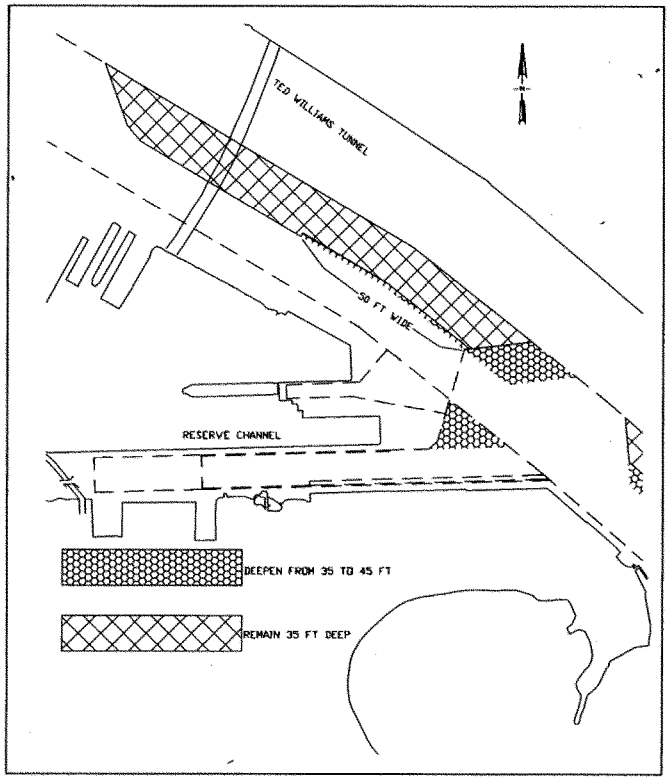


Figure 3. Widening near mouth of Reserve Channel

4. An alternative turning notch was simulated during the final days of the second week of simulations. It is shown in Figure 4.

   a. Based upon your simulation runs, do you feel that the enlarged turning area provided adequate room for both the *COSCO Hamburg* and the *Delaware Bridge*?

   YES.

   b. Based upon your simulation runs, do you feel that the enlarged turning area is necessary to bring the *COSCO Hamburg* and the *Delaware Bridge* to enter and leave the Reserve Channel?

   YES.

   c. Should the enlarged turning area be modified? Feel free to sketch on Figure 4.

   NO. I PREFER THIS TURNING AREA OVER THE OTHER PROPOSAL. IT MAKES FOR MUCH EASIER TURNS.

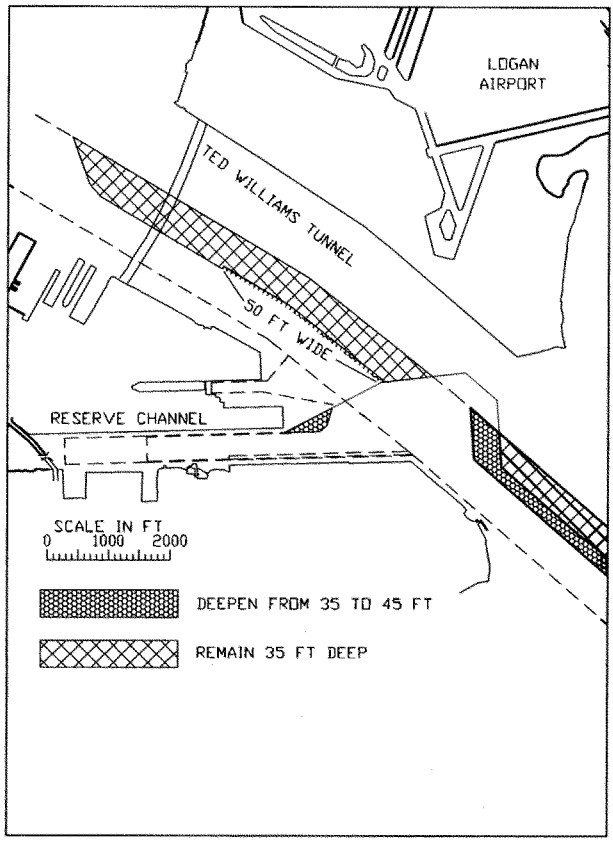


Figure 4. Plan 2 turning notch

5. The following questions concern the simulation modeling of Boston Harbor.

a. Was the visual scene realistic, accurate, and adequate for the study?

YES, VERY MUCH SO.

b. Do you feel the ships responded correctly to the currents?

YES ON THE FLOOD CURRENT. BUT NOT ON THE EBB. THE EBB CURRENT REALLY SLOWS THE SHIPS DOWN IN THE MAIN CHANNEL OF CONLEY TERMINAL.

c. Do you feel the ships responded correctly to the bank forces?

YES.

d. Do you feel the ships responded correctly to the wind?

YES

e. Any additional comments regarding the simulation model?

VERY GOOD SIMULATOR. I ENJOYED WORKING ON IT AND LEARNED A LOT. AN EXCELLENT STAFF TO WORK WITH.

Boston Harbor Channel Improvements
Final Questionnaire

Captain MIKE PEDDLE

Ships

The *COSCO Hamburg* – 918 - x 131- x –46-ft containership.

The *Delaware Bridge* - 871.8 – 106 – x 43 ft containership.

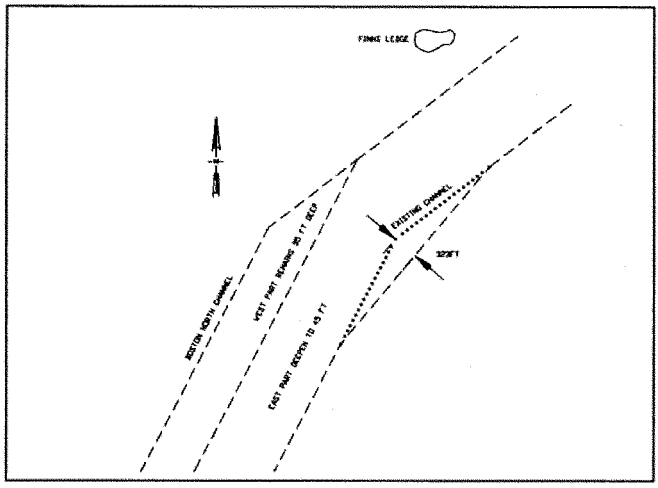
1. A bend widener (Figure 1) is proposed for the East Part of the Boston North Channel. The purpose of the widener was to provide additional maneuvering room near Finns Ledge.

a. Based upon your simulation runs, do you feel that the widener provided adequate room for both the *COSCO Hamburg* and the *Delaware Bridge*? YES. LONGER VESSELS WOULD HAVE NO DIFFICULTY MAKING THAT TURN. TWO WAY TRAFFIC AT CHANNEL ENTRANCE WOULD BE POSSIBLE

b. Based upon your simulation runs, do you feel that the widener is necessary to bring the *COSCO Hamburg* and the *Delaware Bridge* into and out of Boston Harbor? WITH THE DRAFT & U.K.C. OF THE COSCO HAMBURG, THE WIDENER PROVIDES A GREATER MARGIN OF SAFETY IN ADVERSE CONDITIONS.

c. Will the widener benefit other vessels calling at Boston Harbor? If so, which vessels and in what manner would they benefit. TWO WAY PASSING OR OVERTAKING COULD BE DONE SAFELY WITH 99% OF VESSELS CALLING. CURRENTLY ONLY ONE WAY PASSAGE AT FINN'S.

d. Should the widener be modified? Feel free to sketch on Figure 1. DON'T SEE NEED TO EXPAND CURRENT PROPOSAL.



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   a. Based upon your simulation runs, do you feel that the additional width provided adequate room for both the *COSCO Hamburg* and the *Delaware Bridge*?

      DEFINITELY

   b. Based upon your simulation runs, do you feel that the additional width is necessary to bring the *COSCO Hamburg* and the *Delaware Bridge* to make the turn near Spectacle Island?

      YES

   c. Will the widener benefit other vessels calling at Boston Harbor? If so, which vessels and inwhat manner would they benefit.

      TANKER (DEEP DRAFT), BULKER'S (SALT + SCRAP).
      WOULD BE RESTRICTED ONLY BY DEPTH AT BERTH NOT
      CHANNEL DEPTH.

   c. Should the channel width in the straight sections or in the two turns be modified? Feel free to sketch on Figure 2.

      PROPOSAL WORKED FINE.
      CHANGES/MODIFICATIONS WOULD BE NIT PICKING.

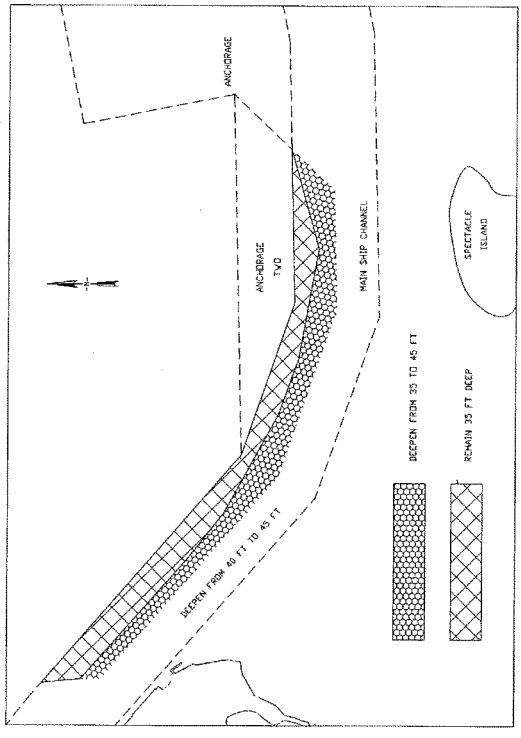

Figure 2. Spectacle Island Widening

3. Widening near the mouth of the Reserved Channel is proposed. The widening will increase the size of the turning area from a radius of 1200 feet to a radius of 1500 feet. and also provide 50 ft additional width for the 45 ft channel north of the turning area. The widening is shown in Figure 3. The turning area is being increased to allow larger containerships access to the Reserve Channel. The additional 50 ft width is to allow more maneuvering room for larger bulk carriers expected to call on the Massport marine Terminal just north of the Reserve Channel.

   a. Based upon your simulation runs, do you feel that the enlarged turning area provided adequate room for both the *COSCO Hamburg* and the *Delaware Bridge*?

      DEFINITELY

   b. Based upon your simulation runs, do you feel that the enlarged turning area is necessary to bring the *COSCO Hamburg* and the *Delaware Bridge* to enter and leave the Reserve Channel?

      YES

   c. Should the enlarged turning area be modified? Feel free to sketch on Figure 3.

      SEE PROPOSAL #2

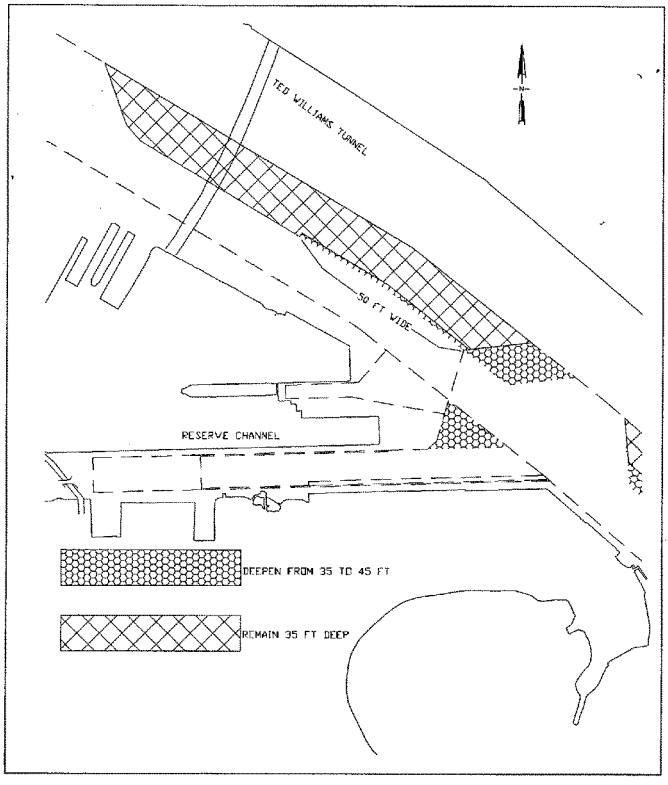

Figure 3. Widening near mouth of Reserve Channel

4. An alternative turning notch was simulated during the final days of the second week of simulations. It is shown in Figure 4.

   a. Based upon your simulation runs, do you feel that the enlarged turning area provided adequate room for both the *COSCO Hamburg* and the *Delaware Bridge*?

      YES

   b. Based upon your simulation runs, do you feel that the enlarged turning area is necessary to bring the *COSCO Hamburg* and the *Delaware Bridge* to enter and leave the Reserve Channel?

      IF INTENT IS TO MINIMIZE IMPACT TO AIR TRAFFIC. THE ALTERNATIVE NOTCH WORKED WELL.

   c. Should the enlarged turning area be modified? Feel free to sketch on Figure 4.

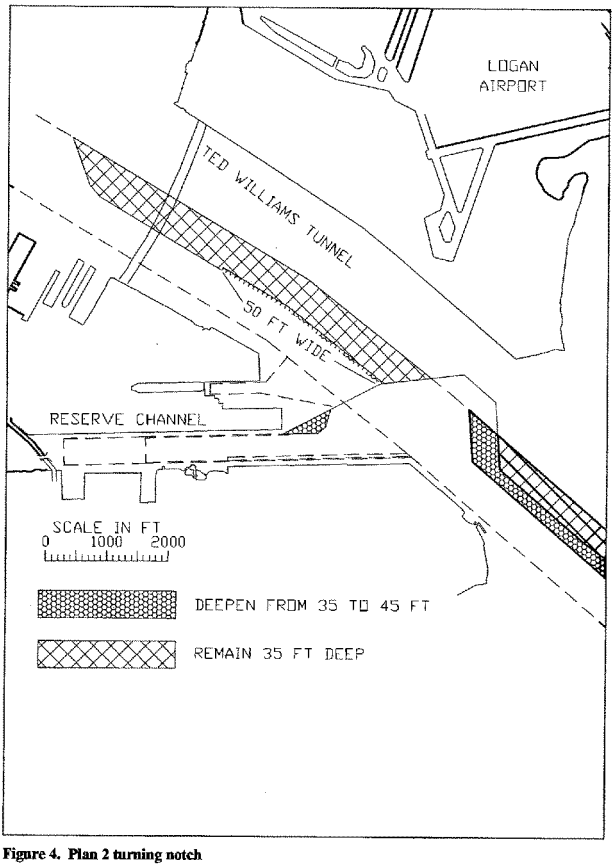

Figure 4. Plan 2 turning notch

5. The following questions concern the simulation modeling of Boston Harbor.

a. Was the visual scene realistic, accurate, and adequate for the study?

YES

b. Do you feel the ships responded correctly to the currents?

YES

c. Do you feel the ships responded correctly to the bank forces?

AS MODELED, THE PROGRAM RESPONDED AS DESIGNED. HOWEVER, SUCTION OCCURED WHERE IT NORMALLY WOULDN'T.

d. Do you feel the ships responded correctly to the wind?

GENERALLY, YES

e. Any additional comments regarding the simulation model?

TUGS SEEMED A LITTLE WEAKER THAN EXPECTED

REPORT DOCUMENTATION PAGE

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14. ABSTRACT

Boston Harbor is located on the eastern shore of the Commonwealth of Massachusetts, on Massachusetts Bay. The Corps of Engineers and the Massachusetts Port Authority (Massport) are evaluating a number of improvements to Boston Harbor. These improvements include deepening and widening portions of the Broad Sound North Entrance Channel, Main Ship Channel, and lower Reserved Channel and its turning area for the benefit of larger container vessels calling on Massport's Conley Terminal. To assist in evaluating these improvements, the U.S. Army Engineer Research and Development Center (ERDC) conducted a ship-simulator-based navigation study. Data for the simulation models were obtained during a site visit to ride ships in the project area. Currents for both the existing and proposed channels were calculated using the ADCIRC computer model in a joint effort between ERDC and the U.S. Army Engineer District, New England. Harbor pilots traveled from Boston to validate and operate the simulations in September 2005.

15. SUBJECT TERMS

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Navigation
Reserved Channel

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BOSTON HARBOR
MASSACHUSETTS

NAVIGATION IMPROVEMENT STUDY

FINAL FEASIBILITY REPORT
AND FINAL SUPPLEMENTAL
ENVIRONMENTAL IMPACT STATEMENT
(AND MASSACHUSETTS FEIR)

APPENDIX I

GEOLOGY AND GEOTECHNICAL
INVESTIGATIONS

(THIS APPENDIX UNCHANGED FROM 2008 DRAFT)

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BOSTON HARBOR FEASIBILITY STUDY
GEOLOGY AND GEOTECHNICAL STUDIES

INTRODUCTION

Feasibility Study investigations to support proposed navigational improvements of the Boston Harbor Channels were initiated in 2002 and are scheduled for completion in 2008. Explorations have consisted of marine geophysics and subsurface probes and borings for determining sea floor and bedrock topography and composition prior to deepening the channels. This appendix presents the results of current and previous studies and aims to provide sufficient description of the material to be dredged, to support Feasibility-level studies, as well as make recommendations for design phase investigations.

Since the early 1800's navigation in Boston Harbor and its tributaries has been facilitated by constant maintenance and periodic deepening. The current study aims to evaluate the feasibility of various deepening alternatives to allow larger container ships and other marine traffic easier access to Boston Harbor. Since the early 1900's, investigations concerning the surface of the seafloor and the underlying materials have been conducted. As the channels have been deepened, areas of shallow bedrock and dense sediment have taken on larger footprints. With the cost of removing hard material so high, and the scope of the project so large, marine geophysical surveys combined with subsurface explorations provide a cost-effective approach for obtaining information over large areas. This appendix serves to present these results, in context of past findings, and make recommendations for design-phase studies.

Marine geophysical surveys were performed in 2002, followed by probes and borings in 2003 to further confirm and delineate areas having shallow bedrock, and to predict the topography of the bedrock surface, for use in quantifying the required rock removal volumes for the various deepening alternatives. Shallow ledge was confirmed by probes in the Entrance Channel, consistent with historic probe information. Bedrock is not as extensive as predicted by marine geophysics in this area, as a dense till layer may be present, and getting picked up by the seismic survey methods above the actual bedrock surface. While shallow ledge was known to exist in the Entrance Channel, two previously unknown large bands of shallow bedrock were discovered crossing the North Channel off Great and Little Faun Shoals. These ledges were first identified by geophysical surveys, and then confirmed by probes. The existence of another ledge was also confirmed in the western end of the 40-foot President Roads Anchorage and in the 35-foot Anchorage No. 2 (barge anchorage), perhaps an extension of the Lower Middle Ground shoal. Consistent with the historic ledges identified in the 1940s deepening projects, bedrock was determined to be present under large portions of the Reserved Channel and Main Ship Channel, which were cut through areas of shallow bedrock and till, with an undulating bedrock surface and multiple shallow ledges to the east of Castle Island and along the South Boston shore. Smaller areas of rock were also found in sections of the Mystic and Chelsea Rivers. The Cambridge Argillite forms the bedrock underlying most of Boston Harbor and, while rippable in the past using heavy excavators, could be more difficult to remove if encountered in a harder, unweathered state at depth. Granite was encountered in the upper Chelsea River, and has required blasting in the past.

Despite these explorations, data gaps still remain. Seismic data are not available for areas where gaseous organic sediment or coarse bottom sediments prevented signal penetration. Chelsea River and the northern half of the President Roads Anchorage were not included in the geophysical surveys from this study. The topography of the bedrock surface will need to be further refined in the design phase to more accurately predict ledge volumes and rock types, and to distinguish ledge from other hard materials. A series of investigations is recommended to support design, starting with the collection of additional geophysical data; re-processing all geophysical data collected to date using probe data to ground-truth the seismic model; subsurface explorations to probe bedrock elevations and collect physical samples of sediment and rock core for mechanical analysis and strength testing to assess rippability, and a final re-processing of the geophysical data using the new subsurface data.

GEOLOGIC SETTING

Boston Harbor lies within the Boston Basin, a coastal depression bound by east-west trending thrust faults and composed of Proterozoic sedimentary rocks and Cenozoic glacial and marine deposits (see Figure I-1). A few major events led to the creation of the current basin topography. Reactivated fault movement in the late Paleozoic to Mesozoic folded the clastic rocks deposited in the Proterozoic, resulting in a series of easterly plunging anticlines and synclines. Uplift during this period is thought to have eroded a large part of the basin away. In the Tertiary, sea levels fell up to 65 feet (20 meters) and valleys were cut into the bedrock by rivers seeking equilibrium with the coast. Glacial activity in the Pleistocene scoured the bedrock surface and deposited more sediment. Most recently the prehistoric landscape of the basin was flooded as sea levels rose to their present state. The oldest bedrock formation in what remains of the Boston Basin is known as the Boston Bay Group.

The Boston Bay Group is a clastic wedge believed to have formed by a retrograding coastal sequence. Ages for the Boston Bay Group vary, but recent studies have established an estimated Proterozoic age from between 620 and 570 million years ago (mya) (Kaye and Zartman, 1980; Zartman and Naylor, 1984; Thompson and Bowring, 2000). The different units within the group are interconnected facies of the coastal environment and represent changing conditions across time and space (Billings and Tierney, 1964). As the basin subsided the coastline migrated inward towards the south-southwest and became deeper towards the north due to increased subsidence in the basin center (Billings, 1976). The higher basement rock to the south served as source material which was carried into the basin by rivers flowing north and east. This basement rock is composed of felsic volcanics and granites. Overlying the suite of basement rocks is the Cambridge and Roxbury Formations of the Boston Bay Group. The Cambridge Formation and the more recent sediments above it are most likely to be encountered in future dredging operations.

The Cambridge Formation, or Cambridge Argillite, represents the upper and more distal (deposited distant from shore) segment of the Boston Bay Group. The unit is almost exclusively comprised of gray argillite, a typically hard and well indurated siltstone, and has only 2-3% sandstone with little-to-no conglomerate (Billings, 1976). A possible member of

the Cambridge Formation is the Milton Quartzite, a coarse white quartzite found near the southern edge of the harbor (Billings, 1976). Deposition of the Cambridge Argillite occurred in the deeper portion of the basin where mainly finer grained silt and clay particles would be carried. Common sedimentary structures include very thin bedding, ripples, slumps, and folds. There are also numerous storm beds, or turbidites, that carried some coarser grained sand and silt further into the basin.

The Cambridge Argillite forms the bedrock under most of the harbor and associated rivers and channels involved in this improvement project. In other previous studies by the Corps, where limited probe and boring explorations were implemented, argillite was shown to form several significant high points (USACE, 1996). In earlier dredging the argillite had exhibited a highly weathered and broken up surface which proved to be rippable by heavy excavators. Even if the current surface has been cleared down to fresh exposures the higher clay content of the rock may still allow for separation along the bedding; a point confirmed during the excavation of the Main Drainage Tunnel in 1957-58. At depths of over 300 feet the argillite in the tunnel still had in many cases a "flaggy parting" associated with bedding and laminations (Rahm, 1962). However, new explorations into the condition of the bedrock surface should be done to confirm this. Also mentioned in the tunnel investigations are numerous dikes and sills of fresh to weathered diabase. Weathered diabase could make rock removal easier, but is potentially harder than the argillite in an unweathered state. Although most are smaller the largest diabase structure is 120 feet thick, and could pose a problem if the surface is fresh. Covering much of this bedrock surface is a series of Quaternary sedimentary deposits.

The majority of material overlying the Boston Bay Group is the result of Pleistocene glacial activity. Directly atop the Cambridge Argillite, and forming much of the harbor islands, is the drumlin till. Thought to be pre-Wisconsinan in age it is made of dense, highly weathered, surface-oxidized till with lesser amounts of stratified silt, sand, and gravel. The highly compacted nature of the till and its coarse texture, including boulders, sometimes results in the till surface being identified as the dominant reflector in marine seismic surveys, rather than the underlying bedrock. The next unit, known as the surface till, was formed during the retreat of the Wisconsin glacier. It is separated from the underlying drumlin till by an unconformity and consists of various till, outwash, and ice-contact sediments. A thick sequence of marine silts and clays called the Boston Blue Clay is the last of the glacial deposits. Meltwater released from the continuing glacial withdrawal is believed to have carried fine particles trapped beneath the ice out into the sea, and ice rafting may explain the few lenses of coarser sediment. Deposition also appears to have been quick and undisturbed, a theory supported by the clay's layered and draping nature (Ocean Surveys, 2003).

Of particular interest to dredging is the compact drumlin till found on the harbor islands. The islands are considered to be submerged drumlins, and it is possible that more of these hills have been eroded down or covered by the ocean (Mulholland, et al., 2003). Geophysical surveys of the Mystic and Chelsea Rivers, and the Inner Confluence discovered till formed the bottom surface in some areas (WES, 1994), such as the vicinity of the Chelsea Street Bridge. More of the sea floor, especially in areas not already dredged or blasted for channel deepening, may be formed by this till.

Younger Holocene sediments form the remaining part of the harbor stratigraphy. The soils contain unconsolidated alluvial and estuarine sand and silt deposits. The most recent of these is rich in organic matter, so much so that the breakdown of organics has produced enough methane gas for portions of the sea bed to be masked in seismic surveys of the harbor due to poor signal penetration (Ocean Surveys, 2003).

Past geophysical surveys and explorations by the Corps and its contractors have identified the likely presence of ledge within the proposed dredge limits, but limited sampling has been performed to date. In order to determine the necessary rock removal methods, additional sampling to characterize the rock type and strength properties is required. Strength data can be used indirectly to assess rippability. As discussed above the material largely defining the topography of Boston Harbor's sea floor, is the Cambridge Argillite and glacial till. In the event that dredging will take place in very hard argillites, diabase dikes, or compact tills, blasting may be required. However, these areas are likely to be limited, and scoop or shovel operations should be sufficient if the current surface is weathered and rippable as it was in the past.

PREVIOUS INVESTIGATIONS

The US Army Corps of Engineers (USACE) carried out several studies exploring the sea floor and underlying bedrock of Boston Harbor for previous channel improvements dating back to the late 1930's. These investigations serve as good background information regarding the location and identity of materials beneath the harbor. The data is sometimes insufficient because explorations for past improvements were concerned only with material at dredge depths required for those projects. However, in some cases the extent of sample gathering covered much more area than more recent studies could allow.

ARCHIVES

In 1936 and 1937 the 40-foot Boston Harbor Channel was surveyed from President Roads to Commonwealth Pier No. 1. The probes and soundings taken of the channel were for the purpose of future dredging and, in all, 19 areas of ledge were identified (see Figure I-2). In maps based off this information separate 40-foot contours for the ledge surface and the overlying sediments were labeled. Focus was placed only upon the depth and placement of these ledges, however, and no data concerning the underlying materials was recorded.

A second set of depth measurements was made, along with 26 borings, between 1944 and 1945. This series of explorations dealt with the proposed 35 and 40-foot anchorage areas that were to be created at President Roads. Most of the borings show silt or sand over blue clays and only two encountered refusals. One boring along the western edge of the 40-foot President Roads Anchorage encountered shallow refusal at – 44 feet Mean Low Water (MLW) in cemented sand, gravel, and clay. The other boring, situated on the northwestern edge of the 35-foot anchorage, encountered refusal at -38.9 feet MLW in hard sand. Most, if not all, of these borings are now less relevant given that they do not extend deep enough for the requirements of the future project.

USACE NAVIGATION IMPROVEMENT STUDY, GENERAL DESIGN MEMORANDUM, 1996

Plans from the 1996 Corps General Design Memorandum represent the most recent phase of channel deepening and improvement. Rock removal in the Reserved and Chelsea River resulting from this previous design phase is roughly mapped in Figures I-3 and I-4. Most areas were dredged to -40 feet Mean Lower Low Water (MLLW), and down to -43 feet MLLW for overdepth.

In 1992 the US Army Engineer Waterways Experiment Station (WES) carried out seismic reflection and side scan sonar surveys of the Mystic and Chelsea Rivers, Reserved Channel, and the Inner Confluence. Results were published as a separate document in 1994 and in the 1996 General Design Memo. Information gathered determined density and soil type of the sea bed to a depth of -42 feet MLLW and was used to support investigations into deepening the major tributaries of Boston Harbor. Survey lines varied from 1,000 to 6,000 feet in length and were spaced 150 to 200 feet apart. Analysis of 15 borings from the USACE, detailed in the 1996 Navigation Improvement Study, Design Memorandum, and an additional 6 borings made by WES, was used in comparison with the subbottom sediment surveys. The WES study allowed for some interpretation of the location of ledges in this portion of the harbor channel, finding 9 areas of rock, gravel, or till outcrops in the survey area. A number of these ledges within the Reserved Channel and Chelsea River, along with trackline and boring locations, can be seen in Figures 5 and 6. However, spacing was not close enough to provide sufficient detail of these structures for future projects.

In addition to the WES survey 54 machine probes and 15 borings, including drive samples and rock cores, were drilled in 1993. These investigations were used to better characterize the materials in areas where no prior dredging had occurred or where hard rock and till existed within the desired dredge depth. Although the 1993 sampling excluded President Roads and the North Channel it provided some of the only data that accurately describes bedrock near the surface. Bedrock is noted as having been discovered at dredge depth in and around the Reserved Channel and Mystic River. The graphic logs show argillite was collected at -42 to -42.5 feet MLLW in the Reserved Channel area and up to -45.3 feet MLLW in the Mystic River Channel.

CURRENT INVESTIGATIONS

Investigations in support of the Feasibility Study of proposed navigation improvements have been carried out between 2002 and 2003, and consist of marine geophysics (2002) and driven probes and borings (2003). Based on proposed improvements, -55 feet Mean Lower Low Water (MLLW) was considered the maximum depth of interest for these studies.

2002 GEOPHYSICS

Introduction

Between September 2002 and February 2003 marine geophysical surveys were conducted in Boston Harbor for the US Army Corps of Engineers. The investigation was performed by Ocean Surveys, Inc. (OSI) and the University of Massachusetts (UMass) Archaeological Services, under a joint contract to Battelle Memorial Institute. The areas analyzed included a portion of the Mystic River as well as the channel and anchorages from Pier 6 just west of the Reserved Channel to the eastern end of the North Channel at Finns Ledge. Side scan sonar, subbottom profiles, and marine magnetometer surveys were combined with sediment grab samples to map surface and underlying sediments and materials of Boston Harbor.

The purpose of the marine geophysics was twofold. Of primary concern was the determination of where removal of rock will be required. A second concern was the identification of any potential archaeological resources that may be present in areas of the seafloor that have never been dredged, but would be encountered during deepening. UMass used the marine geophysics data to provide an assessment of the potential for archeological discoveries in Boston Harbor's seabed, which was released in 2003 with the title "Remote Sensing Archaeological Survey and Geological Interpretation" under the Boston Harbor Navigation Improvement Study. Further discussion of the archaeological investigations and findings is provided in the Cultural Resources Appendix.

Methods

For the 2002 OSI geophysical survey approximately 200 nautical miles of trackline at 50-foot spacing was traveled with quality control cross tie lines every 2,000 feet. Data was collected on every line for magnetic intensity and along every cross tie and third line for side scan sonar imagery and subbottom profiles.

Ground truthing for the side scan sonar data was based on grab samples taken of the bottom sediments. Only 4 samples were collected spread across the survey area to provide a limited control.

Horizontal control was established using a Trimble DMS 212 Differential Global Positioning System. This equipment is capable of providing coordinates referenced to WGS-84 and NAD 83. Using Coastal Oceanographic's HYPACK navigation computer and software crew could record and convert these coordinates, which were ultimately provided in the Massachusetts State Plane Coordinate System, NAD 27 within the OSI report. Navigation checks with the Trimble GPS were taken every day from point OSI "NAV" on a floating dock at Crystal Cove Marina in Winthrop, MA.

- **Subbottom Profiles**

Subbottom profiles are made with seismic reflection. It is a method which uses acoustic waves emitted by a tow vehicle. As this equipment is dragged through the water the acoustic waves travel down and are bounced back by any objects they encounter, such as shipwrecks,

rocks, and sediment. Materials of different densities reflect these waves differently. Hard rock or bedding planes more easily reflect the acoustic waves, while soft sediment will let it pass through. The method is not perfect, however, as different materials can sometimes return the same kind of reflection. Compact till may return as strong a reflection as solid argillite because an abundance of dense cobbles and boulders is present. Images of trackline profiles are created as the reflected waves are measured by the tow vehicle and are electronically processed on ship.

Subbottom profiles were created by using an EdgeTech GeoStar "Chirp" Profiler recording on every third trackline (150-foot line spacing) and every cross tie line. The EdgeTech has a frequency range between 2-16 kHz and can penetrate subbottom sediments, such as clays, up to 260 feet (80 meters). The high-frequency "Chirp" system was considered most appropriate, in that it provides greater resolution, while low frequency profilers provide greater depth penetration, but less detailed resolution. Since the depth of interest was relatively shallow, the "Chirp" profiler was selected.

- **Side Scan Sonar**

Side scan sonar is another method of seismic reflection, which also uses reflecting acoustic waves to create an image. Generally in side scan very few waves penetrate into the subbottom sediments. The reflected signals produce a high resolution "picture" of the sea floor, detailing objects and topography across the surface.

Sonar imagery was collected by a DataSonics SIS1500 along every third trackline (150-foot line spacing) and all cross tie lines, using a 164-foot sweep range, and operating at a swept frequency of 200 kHz.

- **Marine Magnetometer**

Marine magnetometers, when involved in geophysical surveys, are utilized to detect metals on and beneath the sea floor. The magnetometer in the OSI survey used cesium vapor to operate. A photon emitter calibrates the instrument by exciting the electrons in the cesium atoms to specific energy levels. At this point any outside emissions or magnetic activity impacting the cesium atoms can affect their energy state. It is this change that is recorded by a photon detector and translated into a visual readout.

A Geometrics G-881 Magnetometer was used for the survey. Its range of operation is 20,000-100,000 nT and has a sensitivity of <0.01 nT/$\sqrt{Hz}$ RMS.

The marine magnetometer surveys were carried out primarily for the archaeological portion of the study. Readings showing the presence of ferrous metals taken with the instrument were compared with side scan sonar imagery to better evaluate objects with potential historical significance, particularly shipwrecks. However, there is geologic value as bedrock and till with high ferrous content could also create a positive reading. Accurate detection of underwater power cables and tunnels also serves an important purpose when considering the safety of dredging operations.

- **Sediment Grab Samples**

Grab samples are simply samples of material collected from the sea bed. A WildCo Ponor 9-inch grab sampler was used to collect unconsolidated marine sediments from the study area. The instrument has a bucket that is split in half and opened on either side of a set of cables. When the trigger mechanism hits bottom the two halves close together providing a relatively undisturbed sample. The grab sampler bucket has a sampling area of 9 in x 12 in x 6 in.

Results

Subbottom profiles provide an estimate of where till and bedrock may be present at depths above -55 feet MLLW. This methodology identifies the depth at which there is a sharp change in density (acoustic velocity) of subsurface materials, resulting in a well-defined reflection observed in the subbottom profiles. This reflector represents a material change in acoustic properties, and is referred to as the "acoustic basement." Signal penetration below this depth is weak and reflection imaging is negligible. Based on prior experience in the Boston area, the acoustic basement usually represents the contact between marine/glacial deposits and the underlying bedrock. However, strong contrasts in density within glacial till deposits can also generate a strong reflection. Therefore, the acoustic basement topography should not be interpreted definitively as bedrock surface topography without additional ground truthing efforts (outcrop observations, boring data).

OSI interpreted the data and generated a preliminary figure showing the areas where acoustic basement was detected above -55 feet MLLW (see Figures I-7 and I-8). Results are presented in the "Final Report – Geophysical Explorations: Remote Sensing Archaeological Survey and Geologic Interpretation, Boston Harbor Navigation Improvement Study, Boston, MA," prepared by Ocean Surveys, Inc., dated 21 May 2003 (OSI Report No. 02ES066).

OSI also plotted the areas where reflectors could not be identified, and the depth to the acoustic basement could not be determined. The lack of reflectors could be due to either a lack of signal penetration (typically caused by gas bubbles entrained in organic sediments, but also sometimes related to coarse textured material – cobbles and gravel – on the seafloor), or the presence of very deep bedrock, beyond the depth of signal penetration.

USACE subsequently tasked OSI with developing additional figures, contouring the acoustic basement (1-foot contour interval) where it was identified at depths shallower than – 55 feet MLLW. The results of this effort are documented in the "Addendum to Final Report," dated May 2003 (OSI Report No. 02ES066-A). The additional figures are provided in Attachment E-1. The contouring is subject to numerous uncertainties, both geological (variability in seismic velocity) as well as inherent in the data collection program (data density, spacing of cross tie lines, depth variability of the towed sonde, survey accuracy, tidal effects), ultimately affecting the accuracy of the elevations shown. For example, a constant seismic velocity of 5,200 foot per second (fps) was used in all profiles to convert return time data into depth data. Based on a sensitivity analysis of the seismic velocity used in interpretation, velocity variations in subsurface materials may account for as much as a 2-foot difference, plus or minus, in the actual acoustic basement surface. However, the general shape of the acoustic basement is likely valid.

The side scan sonar and magnetic intensity provided less information about the bedrock surface than the subbottom profiling. However, the sonar images gave a detailed view of sediment at the immediate surface, which is often missing or poorly detected in the deeper penetrating subbottom profiles. Shore structures in the inner channel, as well as fishing gear, lobster pots, and other anthropogenic influences clouded much of the magnetic survey, although some areas of shallow bedrock and till may have been detected. OSI included a discussion of how the geophysical data may possibly be used to identify man made objects (such as utilities, tunnels, and debris) that could be hazardous to dredging operations.

Results are divided by area, including: the North Entrance Channel, President Roads, Main Ship Channel, Reserved Channel, the Mystic River, and the Chelsea River. See figures in Attachment 1.

- **Road Sound North Entrance Channel**

The subbottom profiles showed shallow acoustic basement in two main areas of the North Entrance Channel, associated with Finn's Ledge at the outermost mouth of the entrance channel, and east-northeast of Great and Little Faun Shoals. Almost the entire southern half of the channel in this area had poor signal penetration, which was likely related to the coarse textured sediment on the seafloor bottom. As a result, however, there is a large area where subbottom profile data are not available.

The topography of the acoustic basement near Finn's Ledge is highly irregular, with interspersed peaks and valleys. Shallow bedrock would be anticipated near Finn's Ledge, based on historic probes conducted in this area (see Figure 9). However, the topography of the acoustic basement does not corroborate very well with the historic probe refusals. Shallow acoustic basement is indicated where historic probes have extended to depths greater than -55 feet MLLW.

The acoustic basement surface off Great and Little Faun Shoals manifests itself as two broad bands crossing the navigation channel. Ledge removal has not been required in this area in the past, but based on geophysical data, bedrock likely occurs at or just below the seafloor surface in this area. The bathymetry of the seafloor as shown on the nautical charts also hints at the east-northeast extension of these rocky shoals towards the navigation channel.

Side scan imagery revealed areas of coarse sediments at the surface in the section of the North Channel from Finns Ledge to Deer Island Light, just east of President Roads. Strong currents around Deer Island Light and shallow bedrock shoals identified in subbottom profiles are said to be likely reasons for a hard, rocky seafloor.

- **President Roads Anchorage and Channel Reach**

The majority of the subbottom material within the channel and anchorage that is above dredge depth is composed of unconsolidated sediment. A poorly sorted sample of clay, sand, gravel, and cobble was retrieved from some of this sediment in the middle of the President Roads Anchorage. Only several relatively small areas in President Roads showed evidence of acoustic basement above -55 feet MLLW.

The OSI surveys only investigated the southern half of the President Roads Anchorage. The northern half may still have significant sections of shallow bedrock and should be included in future explorations. During maintenance dredging operations in 2004-2005 six small areas of ledge with top elevations shallower than -40 feet MLLW were discovered near the western boundary of the northern part of the Anchorage. These ledge areas were removed in December 2007 as part of the Inner Harbor maintenance operation. The presence of these small ledges will require further exploration.

Side scan sonar showed limited areas of coarse sediment on the sea floor in the anchorages and channels east of Castle Island, which may be attributed to highs of bedrock and till as seen in the subbottom profiles.

- **Reserved Channel, Turning Area and Main Ship Channel**

The channel between Castle Island and President Roads has significant areas of acoustic basement within the proposed dredge depth. Bedrock and/or till form an undulating surface that becomes shallower towards Castle Island. Gaseous organic materials limited the collection of data along the southwestern edge of the channel. This was confirmed by the presence of odorous black silt and clay in grab samples.

Subbottom profiles show acoustic basement sloping up to less than -55 ft MLLW from the mouth of the Reserved Channel to the east and northeast. Much of this basement is formed by an undulating surface. However, most of the Reserved Channel appears to have been previously dredged down into the basement. Black clay with a strong odor, similar to that found near Castle Island, was collected from a location in the Main Ship Channel which corresponds with small area of poor sea floor penetration by the sonar.

Side scan images show coarse sediments forming the sea bed in addition to organic clays, till, and bedrock.

- **Lower Mystic River**

Only a small part of the lower Mystic River Channel is being considered for deepening, and therefore the geophysical surveys were limited to this area. Nearly this entire small portion that was surveyed had no seismic penetration. Undredged organic clays and petroleum byproducts are believed to have blocked the acoustic waves. An acoustics basement reflector was detected, sloping up to the riverbed in the northeast corner of the survey area. However, the shallowest estimated bedrock elevation was -45 feet in this area, below the maximum dredge depth of -42 feet for the Mystic River.

- **Chelsea River Channel**

No subsurface profile data was collected for the Chelsea River Channel. Reliance on prior subsurface exploration programs performed for the 38-foot deepening project of 1998-2001 was determined sufficient to define conditions.

2003 EXPLORATIONS

Introduction

In late 2003 GEI Consultants, Inc. (GEI) was tasked with conducting subsurface explorations for the Boston Harbor Navigation Improvement Study, including the Chelsea River. The work carried out included 97 machine probes, 1 bedrock boring, and 10 vibracores. Geologic–Earth Explorations, Inc. (Geologic) and TG&B Marine Services, Inc. were sub-contracted by GEI to perform the probes and boring, and vibracores, respectively. The areas covered by these explorations included the North Channel and President Roads to the Reserved Channel in the west, as well as portions of the Mystic and Chelsea Rivers. USACE selected probe and boring locations based on the 2002 geophysical data collected by OSI, as well as other existing historical information. Probe and boring locations are also plotted on the figures in Attachment I-1. Generally, probes were located along geophysical (subbottom profile) tracklines, and at the intersection of tracklines with cross tie lines when possible.

The purpose of these explorations was to determine where refusal (assumed to represent either bedrock or very dense glacial till deposits) occurs above -55 feet MLLW, and obtain general information regarding the density of overlying sediments. Due to funding constraints, with the exception of one core boring in Chelsea River to characterize rock type, no samples were collected as part of this program, which consisted entirely of probes. As a result, material types can not be characterized definitively. The rock core at Chelsea River was collected in order to classify the rock type present in that area, where ledge removal has been necessary as part of prior dredging operations (see Figure I-4).

Vibracore samples of soft sediments were sent to UMass Archaeological Services for analysis of potential cultural sites or artifacts, but played little role in determining bedrock surface. Results from the UMass study were presented in the 2004 document, "Archaeological Subsurface Testing for the Boston Harbor Navigation Improvement Study," and are discussed in more detail in the Cultural Resources Appendix.

Methods

The field work for the GEI explorations consisted of on-water barge based drilling. A skid-mounted drilling rig was loaded onto an approximately 40-foot by 110-foot spud barge owned by Boston Towing and Transport (BT&T). The barge was moved onto locations by a 55-foot tugboat tied to the barge. A 23-foot scow was also used. Once on position, the barge's three spuds were lowered by the barge crane. Drilling was conducted in water depths ranging from about 33 feet to 53 feet, depending on the tide. To accommodate drilling in these water depths, the spuds had to be lengthened prior to start of work.

To account for fluctuating sea level and tides the contractors needed a way to establish proper vertical controls. Field measurements were made using the tide gauges installed by its survey subcontractor (BSC) at Castle Island, South Boston and Shrafft's Center, Charlestown. Geologic established a barge reference point as the steel plate on the drill rig wash tub, located 7.5 feet above the water line. The elevation of the reference point was determined in

the field by taking a water level measurement from the closest tide gauge. Prior to drilling each location, they driller measured the distance from the reference point to the mudline, using a 6-inch diameter flat plate at the end of a ¾-inch steel rod. All measurements during drilling were referenced to the barge reference point. Ultimately, GEI determined that NOAA water level data for the various Boston and Boston Light water level stations were more accurate for the Inner and Outer Harbors, and so these elevations were used in calculating the final elevations of the probes and borings.

The majority of locations were drilled within 25 feet of the specified coordinate locations; due to barge movements, three locations were actually drilled 31 feet from the proposed locations. Horizontal surveying was controlled by Differential Global Positioning Systems (DGPS). A Trimble GeoXT GPS CE handheld unit was used to record probe, boring, and probe positions in the Massachusetts State Plane Coordinate System, NAD 27 datum. Corrections were made using Federal Aviation Administration (FAA) Wide Area Augmentation (WAA) satellites.

Probes and borings were numbered based on their location within the harbor:

Reach:	Number	Series	Probe Numbers
Finn's Ledge	10	100-Series	FP-03-101 through FP-03-110
Faun Ledges	8	200-Series	FP-03-201 through FP-03-208
President Roads	8	300-Series	FP-03-301 through FP-03-308
Main Ship Channel	40	400-Series	FP-03-401 through FP-03-440
Reserved Channel	8	500-Series	FP-03-501 through FP-03-508
Mystic River	8	600-Series	FP-03-601 through FP-03-608
Chelsea River	16	700-Series	Boring FD-03-701 Probes FP-03-702 through FP-03-716

- **Probes**

Gathering data using probes involves recording the number of blows it takes to drive a drill rod through a foot of sediment. Some assumptions about the type of sediment the rod is in can be made depending on how many times a hammer must be dropped for it to advance. Various size rods and hammers can be used, which can affect the interpretation of the underlying soils based on these numbers. When the probe cannot be advanced any further, or exceeds a specified number of hammer drops per depth of penetration, it has reached refusal. Refusal may indicate that the probe has reached bedrock, but can also be caused by encountering boulders (glacial erratics) or some other densely compacted sediment.

Probes were driven using open-ended NW drill rods and a 300-lb hammer falling from a height of 30 inches. Probes were driven to -45 feet MLLW in the Mystic and Chelsea Rivers and to -55 feet MLLW in the rest of the harbor, or to refusal, whichever was shallower. Refusal was established as 20 blows for less than an inch of penetration, or bouncing refusal.

- **Borings**

Borings provide a means for collecting physical samples of sediments and rock from beneath the sea floor. Many different methods are used for borings. In one way or another borings

consist of a hollow pipe that is driven or drilled into the subsurface to retrieve samples through the opening. To sample rocks special hollow casings with cutting edges at the end can be used to allow a core to be retrieved from the borehole.

Geologic, the drilling subcontractor, actually drilled two separate locations to collect the required rock core from the Chelsea River location. In their first attempt, they drilled using the drive-and-wash technique, using a 300-lb hammer to advance the casing (4-inch diameter). Drive samples were collected with a 2.5-inch inside diameter split spoon sampler and blows per foot recorded (300-lb hammer). They collected a 5-foot rock core on their second attempt, after roller-bitting to refusal

- **Vibracores**

TG&B Marine Services, Inc. used a pneumatically-driven vibratory core system to collect the 10-ft long vibracores. This method can carefully retrieve soft sediment samples by using high frequency, low amplitude vibrations to advance a hollow casing into the subsurface. A 6-in diameter vibrating pneumatic piston, actuated with a 125 cubic feet per minute air compressor, was driven into a core pipe. Within the core pipe the piston would impact a 10-ft long, 2 5/8in inner diameter polycarbonate core tube. The cores were not opened in the field, but were transported to GEI's office for evaluation in concert with the UMass archaeology staff.

Results

Of the explorations performed or administered by GEI the probes and borings are of most value to this study. Vibracores were done specifically for the 2004 UMass archaeology study, and are of little use because of their shallow penetration. GEI probe and boring results are summarized in Tables I-1 and I-2.

Data gathered during probing is not always accurate, and conditions between sample points may vary considerably. However, adding probe refusals to the acoustic basement mapped in geophysical surveys provides a great deal of information for estimating the composition and contouring of sediments and bedrock. Probe data relative to the acoustic basement at each location is summarized in Table I-3.

- **Broad Sound North Entrance Channel**

Two portions of the North Entrance Channel were specifically targeted for probing explorations, including Finn's ledge at the mouth of the Entrance Channel and the two broad bands of acoustic basement crossing the North Channel off Great and Little Faun Shoals.

Finn's Ledge: A total of 10 probes were drilled at Finn's Ledge, primarily focusing on peaks in the acoustic basement surface. Of these probes, only 3 encountered refusal above -55 feet MLLW. The location with the shallowest refusal, FP-03-102 (refusal at -46.3 feet MLLW) is located on one of the geophysical peaks, and is located near a finger of ledge that was interpreted to exist based in historic probes. The other refusal locations, FP-03-101 (-52.8) and FP-03-103 (-52.6), are also located near this finger, although actual refusals were

significantly deeper than predicted by the acoustic basement. The remainder of the probes in this area showed poor correlation with the geophysical acoustic basement surface; in all cases the probes extended deeper than the interpreted acoustic basement surface. Based on drilling observations, overburden materials likely consisted of cobbles and boulders, with clayey sand and gravel.

Faun Ledges: A total of 8 probes were drilled at the Faun Ledges, 5 at or near the northern band and 3 at the southern band. Three probes were drilled on the northern area to confirm elevations on the large flat plateau areas (FP-03-201, FP-03-204 and FP-03-205); all 3 encountered shallow refusal (-43.5 to -46.3 feet MLLW). The 3 probes on the southern band (FP-03-206 through FP-03-207) also encountered shallow refusal (-43.3 to –49.8 feet MLLW), again confirming the likely presence of shallow ledge within proposed dredge depths.

The purpose of the other two probes at the northern area was to determine whether shallow bedrock was present in an area of poor signal penetration (FP-03-202), and to investigate the possibility of shallow ledge along the south side of the channel, approximately 1,000 feet downstream of the north plateau (FP-03-203). Although historic probes showed some shallow ledge in this area, just outside the navigation channel, probe FP-03-203 extended to -58 feet MLLW without encountering refusal. Probe FP-03-02 encountered refusal at -53 feet MLLW, consistent with the shape of the suspected ledge in that area.

Based on drilling observations, the soils at the Faun ledges were interpreted to be predominantly clayey sand and sandy gravel.

- **President Roads Anchorage and Channel Reach**

The northern portion of the anchorage was not included in the 2002 subbottom profiling effort, as it was not being considered for deepening at that time. No probes were done in this area as part of the 2003 program. Without geophysical data, the likelihood of identifying ledge areas through a limited number of probes in this area is exceedingly small. Given the cost of marine explorations, a phase of geophysics prior to collecting probe data in this area is warranted. Historic borings (circa 1945) conducted in the northern anchorage extended to elevations of -46 to -49 feet MLLW without encountering refusal.

Very few areas were identified by subbottom profiling in the southern portion of the Anchorage and President Roads as having the potential for shallow bedrock above -55 feet MLLW. As a result, only 8 probes were drilled in this area. Three probes (FP-03-301 through FP-03-303) were located in the vicinity of historic boring No. 21 (circa 1945) at the far west edge of the anchorage where refusal was reported at elevation -44 feet MLW in "cemented sand, gravel and clay." Of these 3 probes, FP-03-302 (located approximately 100 feet east of Boring 21) was the only probe to encounter shallow refusal (-43.2 feet MLLW). The presence of ledge in this area may be related to the Lower Middle Ground shoal (ledge) area, which is located just north of the Main Ship Channel, and extends roughly east-west. The tip of this shoal may extend into the anchorage area. While the recent probe data confirms presence of ledge in this area, additional phases of work will be required to delineate ledge in this area for more accurate estimates of rock removal. The subbottom profiler (using

the high resolution "Chirp" high frequency source) was unable to get signal penetration here, and based on drilling observations by GEI, there appears to be a thick layer of organic sediment in this area. Other geophysical methods may be required in this area.

The remaining 7 probes were located where potentially shallow ledge was indicated, and driven to elevations deeper than -55 feet MLLW without encountering refusal.

- **Main Ship Channel**

Ledge areas were identified in the Main Ship Channel during design work for the 1940s deepening project. These historic ledge areas are shown in Figure I-2. The 2002 subbottom profiling also identified large sections of the Main Ship Channel, particularly east of Castle Island and North of the Reserved Channel, having bedrock and/or till within dredging depths. A total of 40 probes were drilled in the Main Ship Channel. Most of the probes confirmed the presence of shallow ledges, although at somewhat deeper elevations typically than what was indicated by the acoustic basement surface. Along the western side of the channel, to the southeast of Castle Island, probes were also able to detect shallow rock and sediment beneath gaseous organics that had masked previous seismic surveys by OSI.

Many different soil types were encountered in the Main Ship Channel including cobbles and boulders, clayey gravel, clay, and organic sediment. Twenty-nine of 40 probes were driven to refusal, and in several cases hard bottom was at or near the surface. Probes reached depths ranging from -36.1 feet to -57.8 feet MLLW.

- **Reserved Channel**

Seven out of the 8 probes drilled in the Reserved Channel encountered shallow refusal, with half of them reaching refusal shallower than -50 feet MLLW. The probe results help verify what prior seismic surveys had shown, that most of the channel has shallow acoustic basement. Ledge removal has been conducted in the Reserved Channel, and near the Notch, as part of recent improvements (reference Figure I-3). Based on drilling observations, sediment was largely organic, with occasional gravel or cobbles.

- **Lower Mystic River**

Probes were driven through gaseous organic sediment in the Mystic River Channel that seismic surveys by OSI could not penetrate. All 8 probes reached a depth of about -48 feet MLLW without encountering refusal. Organic sediment was the only soil type noted according to the blows per foot on the probes and descriptions made from material captured in the open-ended drill rods.

- **Chelsea River Channel**

Past channel dredging in the Chelsea River has required blasting in certain areas to get through the underlying material (reference Figure I-4). While it is know that bedrock is likely to be present in portions of Chelsea River, samples of the rock were not collected previously for geologic examination. One boring was specified in the area of prior rock removal in order to retrieve a core sample of the bedrock. The sediment overlying the bedrock surface

included a thin layer of organic sediment and 5 feet of glacial till. A 5-foot rock core was collected and identified as a very hard, slightly weathered to unweathered, pink granite. It is possible that this is a high point in the bedrock surface on which the Boston Bay Group was subsequently deposited, that has been re-exposed since the basin uplifted and eroded.

A total of 15 probes were drilled in Chelsea River, in addition to the boring, but none of them encountered refusal above the -45 feet MLLW dredge depth of interest. Three of the probes were driven to refusal, 2 of which were near the boring location.

BEDROCK SURFACE

Based on the results of subsurface explorations, a crude ground-truthing of the geophysical acoustic basement was performed by USACE staff, and the elevation of the surface adjusted as deemed appropriate, based on the assumption that the general shape of the acoustic basement is likely valid, but the elevation may need to be adjusted to more closely reflect conditions encountered in the probes. In general, most of the surfaces were dropped down. This move is supported by the fact that in many cases, the acoustic basement included elevations above the known mudline elevation of the harbor bottom. A more rigorous re-interpretation and re-processing of the subbottom profile datasets (modifying seismic velocities) is recommended as part of the design phase.

Once it was determined how to adjust the acoustic basement surface, an arithmetic function was applied to the xyz file, to reduce the z elevation by the specified amount. The adjusted xyz file was then provided to the project team for use in estimating ledge volumes for the various proposed navigation improvement plans. A discussion of the adjustments determined for each area is provided below.

- **Broad Sound North Entrance Channel**

Finn's Ledge: Because of the lack of correlation between the acoustic basement and probe data, the acoustic basement surface was not modified or used in estimating ledge removal volumes. Rather, the combination of historical probes and recent probes provide the best data currently to estimate the bedrock surface.

Faun Ledges: The 3 probes targeting the northern plateau all encountered shallow refusal, but somewhat deeper (-43.5 to -46.3 feet MLLW) than predicted by the acoustic basement. As a result, the acoustic basement surface was lowered 5.0 feet. The three probes targeting the southern plateau also confirmed presence of shallow bedrock, but again somewhat deeper than predicted by geophysics (-43.3 to –49.8 feet MLLW), and so the acoustic basement surface in this area was dropped 5.5 feet.

- **President Roads Anchorage and Channel Reach**

There is an area of shallow ledge indicated at the western edge of the anchorage, near the tip of the Lower Middle Ground shoal (ledge), based on historic boring No. 21 and probe FP-03-302. However, subbottom profiling was unable to generate an acoustic basement surface in this area due to organic sediments blocking signal penetration. With only two data points in

this area, it is difficult to generate a bedrock surface or predict rock removal quantities with any accuracy. Additional explorations will be needed in this area, as well as the entire northern portion of the anchorage that was not included in the 2002 geophysics program. Recent USACE surveys have identified isolated outcrops of what appears to be ledge in the western portion of the anchorage, and are scheduled to be removed in 2006. Information from this removal program should also be considered in the development of design phase exploration programs.

- **Main Ship Channel**

Comparison of probe data to the acoustic basement contours resulted in lowering the acoustic basement surface by varying values, depending on the area. With the exception of the area just off the Army Base and Turning Basin ("Notch") where the acoustic basement was lowered by 18 feet, the acoustic basement was lowered by 2 feet to 8 feet, and in most cases on the order of 2 to 5 feet. Areas where signal penetration was prevented by organic-rich sediments have been determined to have some shallow bedrock, based on probe data. Additional investigations will be required to estimate required rock removal volumes in these areas.

- **Reserved Channel**

Probes FP-03-501 through 503 encountered refusal significantly deeper than predicted by geophysics. Therefore the acoustic basement was lowered 12 feet at the west end of the Reserved Channel. The remaining probes encountered refusal somewhat deeper than predicted by geophysics, and so the acoustic basement in the remainder of the Reserved Channel was lowered 6 feet.

- **Lower Mystic River Channel**

Geophysical results were inconclusive due to lack of signal penetration (organic sediments), and probes extended to depths of -48 feet MLLW without reaching refusal. While it appears that a large mass of shallow bedrock is unlikely to be present, isolated bedrock highs cannot be ruled out. Additional investigations would improve the confidence level.

- **Chelsea River Channel**

Although shallow bedrock was not encountered during these investigations, its presence cannot be ruled out, given that rock removal has been required in certain areas during past deepening activities. Bedrock may occur as isolated pinnacles that will be more difficult to detect using either geophysics (limited by line spacing) or probes. It may be more difficult to identify and quantify the amount of rock requiring removal if it occurs as irregular and isolated pinnacles. Based on the granitic rock type, though, it will more likely require blasting to remove it.

DESIGN PHASE RECOMMENDATIONS

During the design phase it is recommended that further analysis of the conditions within the Boston Harbor Channel be performed. The need for continued study is evident in examining the existing data for the channel. Dated sources originating from previous channel deepening were mostly concerned with depths shallower than in the current project, and provide little information on the materials making up the ledges. Although more recent explorations have helped to expand USACE knowledge of subsurface conditions, data gaps still exist.

In most cases, probes confirmed the likely presence of bedrock where it has been identified historically and by recent geophysical investigations. There are still several areas with significant data gaps concerning bedrock elevation and characteristics:

- Areas where the acoustic signal was unable to penetrate the subsurface, either due to organics or coarse-grained surface sediments (President Roads, near historic boring No. 21 and probe FP-03-302; several areas in the Main Ship Channel, and Mystic River).
- The northern portion of President Roads Anchorage. A limited number of explorations were made here as part of the 2003 explorations, given that this area was not included as part of the 2002 geophysical work, as it was not being considered for deepening at that time.
- The nature of the overburden sediments and rock type has not been characterized, as the 2003 exploration program did not include sampling.

The elevation of the bedrock surface will also need to be further refined to more accurately predict ledge volumes in design phase. The following activities are recommended for design phase work:

- Collect additional subbottom profiling data where it is lacking, and to fill in the current subbottom dataset with lines at a 50-foot line spacing in areas where ledge is indicated. Where the high-resolution high-frequency CHIRP profiling system was unable to get signal penetration, the low frequency "Boomer" source should be tried.
- Re-process the previous subbottom profiling dataset and additional data collected, using the 2003 probe data to ground-truth the seismic velocity model and re-generate the acoustic basement surface.
- Employ resistivity methods where seismic methods have provided inconclusive results.
- Conduct explorations (probes and borings) to further characterize both the bedrock surface elevation and nature of subsurface materials. Collect samples of soil and rock
- Test rock core samples to evaluate strength and, indirectly, rippability.
- Test soil samples to characterize grain size distribution as needed to support re-use or disposal.
- Re-process the geophysical data again, using new subsurface exploration data, to update the acoustic basement surface.

A combination of geophysics and intrusive explorations is considered the most cost-effective method of characterizing the bedrock surface. While probes and borings provide very accurate elevations and actual material samples, they reflect the conditions only at that location, and they are very expensive. Geophysical methods allow for cost-effective data collection over large areas. However, as a remote sensing technique, geophysics requires interpretation and ground-truthing.

STEP 1: COLLECT ADDITIONAL GEOPHYSICAL DATA

To aid in the analysis and refinement of existing geophysical data, and prior to conducting additional subsurface explorations, another phase of marine geophysical surveys (sidescan sonar, magnetometer, and subbottom profiling) is recommended. Prior seismic surveys encountered difficulties when attempting to penetrate through gaseous organic materials or get reflections from deep bedrock. Another seismic technique, called the boomer method, could potentially obtain suitable data in this environment. The boomer method uses a lower frequency acoustic source, resulting in greater penetration than the high-frequency "Chirp" source used in the previous investigation. The signal could potentially penetrate the organics and allow imaging of the acoustic basement surface. The disadvantage of the boomer method is a loss of resolution, which may or may not matter for this study. In the event that the boomer method fails to penetrate organics, the seismic surveys could still be useful for resurveying areas with poor detail, or no previous data.

- Data should be collected in the following areas where marine geophysical data were not collected previously:
    - Northern portion of the President Roads Anchorage
    - Chelsea River Channel

- In addition, where shallow bedrock has been identified in the project areas in the past, recommend filling in the line spacing, such that a 50-foot line spacing results. Given that the dominant bedrock structure in the Main Ship Channel is oriented east-west, recommend that lines in this area be run primarily north-south (perpendicular to structure, and to the channel).

- Both the high-resolution "Chirp" source and the "boomer" source (capable of deeper penetration) should be mobilized. The lower frequency "boomer" source should be tried at new areas where signal penetration is affected by organics or surface sediment type, as well as at areas from the 2002 investigation where signal penetration was blocked:
    - Finn's Ledge Area
    - Faun Ledges
    - President Roads Anchorage, west end
    - Main Ship Channel
    - Mystic River

- As part of this mobilization, a boat reconnaissance should be made of any bedrock areas associated with Finn's Ledge and Great and Little Faun Shoals that are exposed and accessible during low tide. Such observations could provide supplemental information regarding rock types present in the area.

If seismic results are still inconclusive for large areas, and significant data gaps remain, then a third method could be used, that would not be affected by gaseous sediments. This alternative method analyzes resistivity, and could be used to survey both previous and additional areas. Resistivity measures not acoustic waves, but electrical conductivity of the subbottom sediments. Salt water, being highly conductive, may skew results which could complicate

interpretation. Additional literature searches and consultation would need to be conducted before making any recommendation on the applicability of this method to this site.

STEP 2: REPROCESS GEOPHYSICAL DATA

The newly collected geophysical data plus the prior geophysical datasets from seismic surveys carried out by OSI should be reprocessed, using subsurface exploration data to ground-truth the seismic velocity models used to generate the acoustic basement surface. Changing the velocities the acoustic waves are assumed to have been traveling at through sediments would adjust the bedrock surface plot. If the assumed wave velocities were too fast or too slow, the depth of the acoustic basement and other reflectors in the subsurface may have been incorrectly interpreted. The current acoustic basement determined from seismic data does not match up exactly with probes taken in the same areas, and in general the acoustic basement surfaces appeared to be on the order of about 5 feet higher than the bedrock surface, as identified in probes. Figures showing revised acoustic basement contouring would be the final product of this effort, and could be used in selecting the next phase of exploration locations. This re-processing effort could also identify areas where there is greater uncertainty in the interpretation, where additional explorations would be most helpful in resolving the interpretation. Re-contouring would also show more detail of the ledges and high points throughout the channel.

STEP 3: EXPLORATIONS

A final round of probes and borings is recommended to identify the materials likely to be encountered during dredging of hard material within the project boundaries. Subsurface explorations would be used to further delineate the extent of shallow bedrock and to collect physical samples of the overburden soil and bedrock for testing to characterize overburden material for re-use or disposal, and to assess rippability of the bedrock. These new explorations should be done after the above geophysical tasks are complete, and the extent and topography of ledges will be more defined. Placement of probes and borings carried out after reprocessing of the geophysics would be based on an up-to-date map of the acoustic basement contours.

Laboratory tests that should be performed on samples from these explorations include grain size for the overburden soils, and unconfined compressive strength (qu), point load, acoustic velocity, and resistivity for rock cores. Qu, point load tests and seismic velocity can be used to assess rippability, and evaluate the need for blasting. Resistivity and acoustic velocity values can be used to refine results from geophysics.

STEP 4: FINAL GEOPHYSICS REPROCESSING

A final stage of data re-processing (ground-truthing) is recommended to integrate the new exploration data with the prior geophysical datasets, to generate a final, improved contouring of the acoustic basement surface that can be used in calculating estimated rock removal quantities required for the selected alternative, and to determine the likely best methods of rock removal for various areas for cost-estimating, work sequencing and specifications purposes.

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TABLE I-1
BOSTON HARBOR FEASIBILITY STUDY
Geotechnical Probes and Borings in Boston Harbor and the Mystic River
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Taken from GEI Consultants, Inc. 2003 Geophysics Report

	Exploration ID	As-Drilled Location		Date	Start Time	End Time	Tide Gage Reading Time	Initial Water Level Elevation[2]	Barge Reference[3] Elevation[2]	Final Water Level Elevation[2]	Barge Reference[3] Elevation[2]	Mud Line		Bottom of Probe		Probe Penetration (feet)	Blows Per Foot[5] [6]	Comments[7]
		Northing (feet)[1]	Easting (feet)[1]									Depth[4] (feet)	Elevation[2]	Depth[4] (feet)	Elevation[2]			
Finn's Ledge	FP03-101	499,229.10	756,928.00	09/10/03	0922	0950	NA	5.6	13.1	6.7	14.2	57.7	-44.6	67.0	-52.8	8.2	WOR/1.4'-13/1.9'-10-27-17-14-<10-20/<1"	*Cobbles/Boulders at bottom;* Drill rods bouncing, REFUSAL
	FP03-102	499,050.04	757,147.66	09/10/03	1024	1036	NA	7.9	15.4	8.2	15.7	59.0	-43.6	62.0	-46.3	2.7	10/1.5'-12-55/0.5'-20/<1"	*Cobbles/Boulders at bottom;* Irregular bottom; Drill rods bouncing, REFUSAL
	FP03-103	498,767.87	757,510.33	09/10/03	1110	1136	NA	8.9	16.4	9.2	16.7	58.3	-41.9	69.3	-52.6	10.7	WOR/2.3'-9/0.4'-19-27-33-40-24-24-32-40-13/0.3'-20/<1"	*Cobbles/Boulders at bottom;* Drill rods bouncing, REFUSAL
	FP03-104	498,079.19	756,850.49	09/10/03	1218	1252	NA	9.3	16.8	8.9	16.4	50.1	-33.3	75.2	-58.8	25.5	WOR/0.9'-14-17-23-26-20-25-37-31-14-24-23-22-21-28-42-23-40-36-30-24-22-28-25-35/1.3'	*Hard bottom*
	FP03-105	497,849.04	756,607.51	09/10/03	1315	1340	NA	8.4	15.9	7.7	15.2	51.7	-35.9	73.5	-58.3	22.5	WOR/0.1'-15/2.2'-72-35-40-38-26-23-22-19-19-18-20-16-26-37-25-36-48-42-36-29/0.5'	*Hard bottom*
	FP03-106	497,968.76	756,499.63	09/10/03	1417	1433	NA	6.5	14.0	6.0	13.5	56.5	-42.5	71.9	-58.4	16.0	1/1.5'-23-15-19-13-16-10-17-16-21-23-19-21-19-25/0.9'	*Hard bottom*
	FP03-107	498,479.46	755,676.56	09/11/03	0940	1011	NA	5.0	12.5	6.3	13.8	53.2	-40.7	72.0	-58.2	17.6	WOH/1.4'-5-7-10-8-10-11-14-20-19-18-16-15-16-17-20-26-23-14	*Clayey sand and gravel" hard bottom;* Irregular bottom
	FP03-108	498,337.51	755,996.46	09/11/03	0842	0900	NA	2.8	10.3	3.5	11.0	54.6	-44.3	68.5	-57.5	13.3	WOR/0.4'-10-7-14-19-13-18-17-12-15-10-12-17-10-10/0.5'	*Clayey sand and gravel hard bottom*
	FP03-109	498,776.73	756,098.27	09/10/03	1641	1658	NA	1.1	8.6	0.6	8.1	52.5	-43.9	65.8	-57.7	13.8	17/0.5'-20-20-31-14-16-10-11-10-15-10-19-19-18-15/0.8'	*Clayey sand and gravel hard bottom; Cobbles/Boulders;* Irregular bottom
	FP03-110	498,502.57	756,432.43	09/10/03	1529	1548	NA	3.7	11.2	3.0	10.5	55.6	-44.4	69.3	-58.9	14.5	WOR/2'-8/2.4'-17-15-25-23-37-60-42-47-66/1.3'	*Hard bottom*
Faun Ledges	FP03-201	494,081.26	753,320.99	09/11/03	1400	1413	NA	8.7	16.2	8.3	15.8	55.6	-39.4	60.8	-45.0	5.6	2/0.4'-34-39-50-50-30/0.8'-20/<1"	*Clayey sand and gravel hard bottom;* Drill rods bouncing, REFUSAL
	FP03-202	494,272.11	753,830.93	09/11/03	1256	1317	NA	9.8	17.3	9.6	17.1	60.1	-42.8	70.1	-53.0	10.2	WOR/0.9'-2-12/2'-7-12-42-19-28-52-51-37/0.1'-20/<1"	*Clayey sand and gravel hard bottom ;* Drill rods bouncing, REFUSAL
	FP03-203	495,230.79	755,045.93	09/11/03	1125	1146	NA	8.8	16.3	9.3	16.8	59.1	-42.8	74.8	-58.0	15.2	WOR/1.5'-7/1.4'-5-7-9-9-14-10-7-7-18-20-25-22-14/0.9'	*Clayey sand and gravel hard bottom*
	FP03-204	493,729.45	754,049.18	09/15/03	0823	0833	NA	1.1	8.6	1.0	8.5	51.5	-43.0	52.0	-43.5	0.5	23/0.5'-20/<1"	*Clayey bottom; Sandy gravel;* Drill rods bouncing, REFUSAL
	FP03-205	493,127.38	753,916.84	09/15/03	0856	0902	NA	1.0	8.5	1.0	8.5	50.8	-42.3	54.8	-46.3	4.0	WOR/1.2'WOH/0.3'-9/0.7'-29-20/0.8'-20/<1"	*Clayey bottom; Sandy gravel;* Drill rods bouncing, REFUSAL
	FP03-206	491,970.97	753,127.54	09/15/03	0933	0948	NA	1.3	8.8	1.5	9.0	50.5	-41.5	58.8	-49.8	8.3	WOR/0.5'-WOH/0.1'-13/0.9'-26-17-55-36-105-85-113/0.8'-20/<1"	*Sandy gravel* Drill rods bouncing, REFUSAL
	FP03-207	492,510.25	752,603.34	09/15/03	1014	1023	NA	2.1	9.6	2.3	9.8	50.0	-40.2	53.1	-43.3	3.1	WOR/0.5'-28/1.5'-35-10/0.1'-20/<1"	*Clayey bottom; Sandy gravel* Drill rods bouncing, REFUSAL
	FP03-208	493,223.40	752,942.55	09/15/03	1058	1108	NA	3.2	10.7	3.5	11.0	55.5	-44.5	59.2	-48.2	3.7	25/0.5'-50-45-50-5/0.2'-20/<1"	*Hard bottom;* Drill rods bouncing, REFUSAL
President Roads & Anchorage Area	FP03-301	488,259.57	740,562.75	09/15/03	1302	1316	NA	7.4	14.9	7.9	15.4	53.7	-38.8	73.0	-57.6	18.8	WOR/4.3'-WOH-6-12-15-17-17-18-19-21-19-21-23-21-18-20	*Clay; Organic Sediment*
	FP03-302	488,207.98	740,690.37	09/15/03	1236	1243	NA	6.6	14.1	6.8	14.3	53.6	-39.5	57.5	-43.2	3.7	WOR-3.5'-WOH/0.2'-15/0.2'-20/<1"	*Clay; Organic Sediment;* Drill rods bouncing, REFUSAL
	FP03-303	488,052.38	740,569.71	09/15/03	1200	1210	NA	5.4	12.9	5.7	13.2	52.6	-39.7	70.9	-57.7	18.0	WOR/3.7'-WOH/1.5'-6/1.2'-5-7-8-14-10-13-12-16-19-20-19-21-18/0.9'	*Clay; Organic Sediment*
	FP03-304	487,745.10	741,086.65	09/12/03	1326	1337	NA	9.9	17.4	9.8	17.3	59.8	-42.4	74.5	-57.2	14.8	WOH/4.8'-18/1.4'-25-20-24-20-23-25-21-19-15/0.5'	*Clay**
	FP03-305	487,813.55	741,518.58	09/12/03	1238	1255	NA	9.7	17.2	9.8	17.3	59.9	-42.7	75.4	-58.1	15.4	WOR/1.9'-WOH/1.9'-7/1.3'-11-13-18-14-18-18-22-22-23-33/1.4'	*Clay*
	FP03-306	487,970.39	741,642.51	09/11/03	1512	1522	NA	6.8	14.3	6.5	14.0	55.6	-41.3	71.1	-57.1	15.9	WOR/2.5'-WOH/1.9'-10-10-10-10-9-10-16-15-16-17-19/1.1'	*Organic Sediment*
	FP03-307	488,923.86	745,543.16	09/12/03	1034	1045	NA	5.8	13.3	6.2	13.7	54.1	-40.8	71.5	-57.8	17.0	WOR/1.4'-WOH/2.2'-7/1.3'-5-9-12-10-9-9-8-10-14-16-19-23-8/0.5	*Clay; Organic Sediment*
	FP03-308	489,059.55	746,130.41	09/12/03	0958	1010	NA	4.4	11.9	4.9	12.4	52.5	-40.6	70.2	-57.8	17.2	WOR/1.3'-WOH/5.7'-6/2.5'-14-15-13-13-8-13-10-14-14/1.3'	*Clay; Organic Sediment*

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Taken from GEI Consultants, Inc. 2003 Geophysics Report

	Exploration ID	As-Drilled Location		Date	Start Time	End Time	Tide Gage Reading Time	Initial Water Level Elevation[2]	Barge Reference[3] Elevation[2]	Final Water Level Elevation[2]	Barge Reference[3] Elevation[2]	Mud Line		Bottom of Probe		Probe Penetration (feet)	Blows Per Foot[5][6]	Comments[7]
		Northing (feet)[1]	Easting (feet)[1]									Depth[4] (feet)	Elevation[2]	Depth[4] (feet)	Elevation[2]			
Main Ship Channel	FP03-401	493,121.12	727,593.63	09/17/03	0733	0738	NA	5.1	12.6	5.0	12.5	48.3	-35.7	51.8	-39.4	3.6	WOR/3.1'-2/0.4'-20/<1"	*Organic sediment;* Drill rods bouncing, REFUSAL
	FP03-402	492,018.65	727,403.32	09/17/03	0821	0829	NA	3.8	11.3	3.6	11.1	40.1	-28.8	47.2	-36.1	7.3	WOR/6.5'-22/0.4'-5/0.2'-20/<1"	*Organic sediment:* Drill rods bouncing, REFUSAL
	FP03-403	492,031.17	728,113.07	09/17/03	0900	0905	NA	2.8	10.3	2.7	10.2	52.4	-42.1	55.8	-45.6	3.5	WOR/1.5'-WOH/0.1'-29-11/0.8'-20/<1"	*Organic sediment;* Drill rods bouncing, REFUSAL
	FP03-404	491,829.64	728,832.79	09/17/03	0945	0953	NA	2.2	9.7	2.1	9.6	52.5	-42.8	59.6	-50.0	7.2	WOR/0.8'-3/0.7'-2-4-10-24-15-26/0.6'-20/<1"	*Cobbles/Boulders at bottom;* Drill rods bouncing, REFUSAL
	FP03-405	491,702.32	729,568.18	09/17/03	1028	1033	NA	2.2	9.7	2.2	9.7	44.8	-35.2	49.7	-40.0	4.9	WOR/4.6'-6/0.3'-20/<1"	*Organic sediment:* Spud penetrated harbor bottom ~5' after barge was stationed; Irregular bottom; Drill rods bouncing, REFUSAL
	FP03-406	491,076.27	730,002.21	09/12/03	0822	0831	NA	1.1	8.6	1.3	8.8	50.8	-42.2	54.6	-45.8	3.6	WOR/1.2'-10-22-30/0.8'-20/<1"	*Clay; Organic Sediment;* Drill rods bouncing, REFUSAL
	FP03-407	490,597.57	729,885.80	09/08/03	0813	0831	NA	7.0	14.5	7.7	15.2	54.3	-39.8	71.8	-56.6	16.8	WOR/3.7'-WOH-5-4-6-8-8-10-11-11-16-10-8-9-5/0.8'	*Organic Sediment to Clay*
	FP03-408	490,876.85	729,292.73	09/08/03	1244	1300	NA	6.9	14.4	6.4	13.9	50.5	-36.1	65.5	-51.6	15.5	WOR/9.2'-6/1.3'-45-66-44-35-66-26/0.5'-20/<1"	*Organic Sediment;* Drill rods bouncing, REFUSAL
	FP03-409	490,709.02	729,547.64	09/08/03	1153	1214	NA	8.5	16.0	7.9	15.4	51.8	-35.8	73.0	-57.6	21.8	WOR/6'-WOH-10/1.2'-8-8-6-8-8-8-13-17-25-29-17-25-80-20/<1"	*Organic Sediment;* Drill rods bouncing, REFUSAL
	FP03-410	490,497.43	729,725.20	09/08/03	0903	0920	NA	8.8	16.3	9.2	16.7	53.6	-37.3	73.1	-56.4	19.1	WOR/6.3'-WOH/1.1'-9/2'-7-10-10-8-15-14-17-12-15-26/1.1'	*Organic Sediment*
	FP03-411	490,535.93	729,285.07	09/08/03	1053	1108	NA	9.6	17.1	9.4	16.9	50.1	-33.0	74.1	-57.2	24.2	WOR/13'-WOH/1.9'-5-6-9-11-11-15-15-18-19/1.1"	*Organic Sediment*
	FP03-412	490,182.09	729,330.50	09/08/03	0950	1012	NA	9.7	17.2	9.8	17.3	44.2	-27.0	68.7	-51.4	24.4	WOR/19.1'-WOH/0.5'-9/1.2'-10-9-16-9-10-27-30-29-33-39-36-46-17/0.7'-20/<1"	*Organic Sediment;* Drill rods bouncing, REFUSAL
	FP03-413	490,196.06	729,623.52	09/08/03	1342	1405	NA	5.0	12.5	4.1	11.6	41.5	-29.0	66.5	-54.9	25.9	WOR/6.5'-5-7-6-8-6-9-8-13-12-12-16-30-50-32-43-19-35-50-66/0.5'-20/<1"	*Organic Sediment;* Drill rods bouncing, REFUSAL
	FP03-414	490,052.47	730,183.38	09/18/03	1008	1017	NA	2.8	10.3	2.7	10.2	53.1	-42.8	57.6	-47.4	4.5	WOR/0.3'-WOH/0.8'-3/0.8'-16-26-16/0.8'-20/<1"	*Cobbles/Boulders at bottom;* Drill rods bouncing, REFUSAL
	FP03-415	490,523.34	730,475.08	09/15/03	1400	1408	NA	9.1	16.6	9.3	16.8	59.8	-43.2	64.7	-47.9	4.8	WOR/1.2'-WOH/0.8'-7/0.2'-40-62-40/0.7'-20/<1"	*Clayey Gravel*[4]; Drill rods bouncing, REFUSAL
	FP03-416	490,584.25	730,809.94	09/09/03	0817	0845	NA	5.3	12.8	6.5	14.0	55.5	-42.7	66.5	-54.6	11.8	WOR/0.2'-12/1.2'-12-14-15-29-31-54-20-20-71-135-110-50/0.5'-20/<1"	*Cobbles/Boulders at bottom;* Drill rods bouncing, REFUSAL
	FP03-417	490,442.57	731,042.30	09/04/03	1355	1425	NA	3.3	10.8	4.2	11.7	54.0	-43.2	67.5	-55.8	12.7	WOR/0.2'-WOH/0.3'-7/0.5'-26-35-24-29-27-41-45-29-54-71-60-82-33/0.5'	*Clay bottom; Organic Sediment;* Terminated to protect drill rods
	FP03-418	490,476.29	731,182.93	09/04/03	1255	1320	NA	1.8	9.3	2.5	10.0	54.1	-44.8	62.4	-52.5	7.7	WOR/0.8'-WOH-11/1.1'-15-12-33/2'-29-23/0.3'-20/<1"	*Clay bottom; Organic Sediment;* Drill rods bouncing, REFUSAL
	FP03-419	490,550.18	731,558.25	09/04/03	1200	1225	NA	1.2	8.7	1.3	8.8	52.0	-43.3	59.4	-50.6	7.3	WOR-WOH/1.2'-6/0.8'-23-13-21-44-5/0.4'-20/<1"	*Clay bottom; Organic Sediment;* Drill rods bouncing, REFUSAL
	FP03-420	489,313.78	732,443.56	09/18/03	0912	0920	NA	3.8	11.3	3.6	11.1	49.0	-37.7	51.7	-40.6	2.9	WOR/0.4'-WOH/1.1'-24/0.5'-40/0.7'-20/<1"	*Cobbles/Boulders at bottom;* Drill rods bouncing, REFUSAL

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	Exploration ID	As-Drilled Location		Date	Start Time	End Time	Tide Gage Reading Time	Initial Water Level Elevation[2]	Barge Reference[3] Elevation[2]	Final Water Level Elevation[3]	Barge Reference[3] Elevation[2]	Mud Line		Bottom of Probe		Probe Penetration (feet)	Blows Per Foot[5] [6]	Comments[7]
		Northing (feet)[1]	Easting (feet)[1]									Depth[4] (feet)	Elevation[2]	Depth[4] (feet)	Elevation[2]			
Main Ship Channel (Cont.)	FP03-421	469,289.74	732,630.76	09/17/03	1314	1320	NA	5.4	12.9	5.6	13.1	51.3	-38.4	52.7	-39.7	1.2	WOR/0.9'-4/0.5'-20/<1"	*Cobbles/Boulders at bottom;* Drill rods bouncing, REFUSAL
	FP03-422	468,829.90	732,768.95	09/17/03	1248	1252	NA	4.6	12.1	4.7	12.2	50.9	-38.8	54.4	-42.2	3.4	WOR/3.1'-2/0.4'-20/<1"	*Cobbles/Boulders at bottom;* Irregular bottom; Drill rods bouncing, REFUSAL
	FP03-423	468,157.06	734,087.22	08/29/03	0835	0910	NA	1.6	9.1	2.8	10.3	48.9	-39.8	51.1	-40.8	1.0	WOR-3/1.1'-25/<1"	*Clay initially;* Drill rods bouncing, REFUSAL
	FP03-424	467,787.76	734,418.04	09/02/03	0835	0840	NA	2.0	9.5	1.8	9.3	48.2	-38.8	50.5	-41.2	2.5	3/0.6'-4-13-25/<1"	*Hard bottom; Clayey Gravel;* Drill rods bouncing, REFUSAL
	FP03-425	467,449.75	734,798.30	09/02/03	0910	0915	NA	0.9	8.4	0.8	8.3	45.2	-36.8	45.9	-37.6	0.8	3/0.6'-20/<1"	*Hard bottom; Clayey Gravel;* Drill rods bouncing, REFUSAL
	FP03-426	468,157.02	732,648.71	09/03/03	1405	1415	NA	5.3	12.8	5.6	13.1	54.6	-42.0	59.1	-46.0	4.0	WOR/3.2'-85-20/<1"	*Clay bottom;* Drill rods bouncing, REFUSAL
	FP03-427	467,676.71	733,655.25	09/03/03	1330	1340	NA	4.1	11.6	4.5	12.0	52.0	-40.4	61.6	-49.6	9.2	WOR/3.5'-WOH/6.2'-3/0.8'-8-35-23-24-28-20/<1"	*Clay bottom;* Drill rods bouncing, REFUSAL
	FP03-428	467,551.83	733,985.67	09/03/03	1130	1150	NA	0.9	8.4	1.1	8.6	50.4	-42.0	63.1	-54.8	12.7	WOR/2'-7-4-4-7-17-21-38-29-44-36-23-20/<1"	*Clay bottom;* Drill rods bouncing, REFUSAL
	FP03-429	467,457.86	733,815.41	09/03/03	1230	1250	NA	2.2	9.7	2.8	10.3	51.7	-42.0	64.3	-54.1	12.0	WOR/2.1'-WOH/1.7'-2/0.5'-2-4-5-7-6-8-9-10-20/0.3'	*Clay bottom;* Hard driving at end
	FP03-430	467,402.36	734,067.00	09/03/03	1045	1100	NA	0.8	8.3	0.8	8.3	49.6	-41.3	64.3	-56.0	14.8	WOR/3.9'-WOH/1.7'-3/0.8'-2-7-8-10-8-12-14-10-9/0.3'	*Clay bottom*
	FP03-431	467,422.28	734,227.83	09/03/03	1015	1030	NA	1.3	8.8	1.0	8.5	51.2	-42.5	52.0	-43.5	1.1	WOR/0.3'-5/0.4'-20/<1"	*Cobbles/Boulders at bottom;* Drill rods bouncing, REFUSAL
	FP03-432	467,399.46	734,427.06	09/03/03	0905	0935	NA	3.4	10.9	2.3	9.8	53.4	-42.6	53.5	-43.7	1.2	20/<1"	*Hard bottom;* Drill rods bouncing, REFUSAL
	FP03-433	467,238.07	733,916.27	09/04/03	1100	1110	NA	2.3	9.8	2.1	9.6	52.4	-42.6	66.8	-57.2	14.6	WOR/3.5'-WOH/0.8'-4/1.3'-4-9-7-10-13-14-16-17-8/0.8'	*Clay; Organic Sediment*
	FP03-434	466,944.45	734,613.43	09/03/03	0820	0840	NA	5.0	12.5	4.3	11.8	52.1	-39.6	57.0	-45.2	5.6	WOR/4.5'-18/0.3'-20/<1"	*Organic Sediment;* Drill rods bouncing, REFUSAL
	FP03-435	466,942.59	735,088.89	09/02/03	0950	1000	NA	0.3	7.8	0.2	7.7	50.3	-42.5	56.8	-49.1	6.6	WOR/0.7'-WOR-WOR-WOH/1.5'-1/0.5'-2-4/0.7'-20/<1"	*Clay bottom; Clayey Gravel*
	FP03-436	466,387.63	734,826.82	09/04/03	1000	1020	NA	4.0	11.5	3.3	10.8	54.9	-43.4	67.0	-56.3	12.8	WOR/3.8'-WOH/1.3'-6-4-4-13-8-12-12	*Clay; Organic Sediment*
	FP03-437	466,662.38	735,228.93	09/02/03	1215	1225	NA	3.0	10.5	3.3	10.8	51.2	-40.7	54.7	-43.9	3.2	WOR/0.5'-WOR-WOR-WOR-8/0.3'-20/<1"	*Clay; Organic Sediment;* Drill rods bouncing, REFUSAL
	FP03-438	466,758.81	735,472.16	09/02/03	1040	1050	NA	0.4	7.9	0.5	8.0	52.1	-44.2	56.5	-48.5	4.3	WOR/0.6'-WOR-WOH/0.7'-11-8-20/<1"	*Clay bottom; Clayey Gravel;* Drill rods bouncing, REFUSAL
	FP03-439	466,504.84	736,518.10	09/04/03	0855	0920	NA	6.3	13.8	5.5	13.0	54.5	-40.7	69.8	-56.8	16.1	WOR/1.2'-WOH/0.3'-17-16-27-23-40-48-86/3'-49-67-72-67-67/0.8'	*Clay; Organic Sediment*
	FP03-440	467,154.55	734,342.42	09/17/03	1158	1208	NA	3.4	10.9	3.6	11.1	50.8	-39.9	68.9	-57.8	17.9	WOR/4.9'-WOH-6/1.3'-5-6-6-11-9-11-10-11-15-14-12/0.9'	*Organic sediment*

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	Exploration ID	As-Drilled Location		Date	Start Time	End Time	Tide Gage Reading Time	Initial Water Level Elevation[2]	Barge Reference[3] Elevation[2]	Final Water Level Elevation[2]	Barge Reference[3] Elevation[2]	Mud Line		Bottom of Probe		Probe Penetration (feet)	Blows Per Foot[5][6]	Comments[7]
		Northing (feet)[1]	Easting (feet)[1]									Depth[4] (feet)	Elevation[2]	Depth[4] (feet)	Elevation[2]			
Reserved Channel	FP03-501	489,739.31	727,158.30	09/25/03	0951	1007	NA	9.3	16.8	9.8	17.3	59.8	-43.0	74.4	-57.2	14.2	WOR/0.2'-6-8-16-10-11-13-29-22-21-27-54-69-71-77-26/0.4'	*Organic sediment with gravel*
	FP03-502	489,650.35	727,316.64	09/22/03	1247	1301	NA	4.2	11.7	3.8	11.3	55.7	-44.0	67.3	-56.0	12.0	WOR/0.9'-WOH/0.2'-1/0.2'-5-15-9-6-12-12-13-16-20-64-29/0.3'-20/<1"	*Organic sediment;* Drill rods bouncing, REFUSAL
	FP03-503	489,743.61	727,517.67	09/25/03	0904	0925	NA	7.5	15.0	8.4	15.9	59.0	-44.0	72.3	-56.4	12.4	WOR/1.6'-WOH/0.9'-4/0.5'-15-14-17-48-100-84-117-58-66-125-68/0.3'-20/<1"	*Organic sediment with gravel;* Drill rods bouncing, REFUSAL
	FP03-504	489,682.28	728,003.95	09/22/03	1157	1205	NA	5.7	13.2	5.5	13.0	57.0	-43.8	61.0	-48.1	4.3	WOR/1.7'-7/0.3'-52-86-23/<1"	*Organic sediment;* Drill rods bouncing, REFUSAL
	FP03-505	489,830.70	728,233.31	09/25/03	0817	0837	NA	5.5	13.0	6.5	14.0	49.4	-36.4	57.1	-43.1	6.7	WOR/0.6'-10-35-39-36-28-37-80/1.1'-20/<1"	*Cobbles;* Drill rods bouncing, REFUSAL
	FP03-506	489,681.84	728,242.05	09/22/03	1042	1054	NA	7.6	15.1	7.3	14.8	56.9	-41.8	63.6	-48.8	7.0	WOR/0.7'-WOH/0.4'-12-30-35-62-41-40/0.6'-26/<1"	*Organic sediment;* Drill rods bouncing, REFUSAL
	FP03-507	489,718.13	728,709.60	09/22/03	0945	1007	NA	8.6	16.1	8.2	15.7	58.7	-42.6	73.6	-57.9	15.2	WOR/1.2'-WOH/0.1'-5/2'-25-24-25-41-47-20-45-82-57-42-56-18/0.6'-20/>1"	*Organic sediment;* Drill rods bouncing, REFUSAL
	FP03-508	489,857.09	729,008.94	09/22/03	0853	0907	NA	8.9	16.4	8.9	16.4	55.8	-39.4	60.6	-44.2	4.8	WOR/1.8'-WOH/0.4'-7-14-7/0.6'-28/<1"	*Organic sediment;* Drill rods bouncing, REFUSAL
Mystic River	FP03-601	505,457.47	718,223.84	09/16/03	0954	1002	0942	1.7	9.2	NA	NA	45.1	-35.9	57.2	-48.0	12.1	WOR/4.6'-WOH/0.9'-8/1.4'-4-5-5-7-6/1.2'	*Organic Sediment"*
	FP03-602	505,426.35	718,454.13	09/16/03	1024	1029	1018	2.0	9.5	NA	NA	46.4	-36.9	57.5	-48.0	11.1	WOR/4.4'-WOH-5/1.2'-5-6-6-7-3/0.5'	*Organic Sediment"*
	FP03-603	505,296.89	718,353.02	09/16/03	1128	1133	1125	3.5	11.0	NA	NA	46.0	-35.0	59.0	-48.0	13.0	WOR/5'-WOH-3-4-4-5-6-9-9	*Organic Sediment"*
	FP03-604	505,305.36	718,492.71	09/16/03	1105	1111	1100	2.9	10.4	NA	NA	46.1	-35.7	58.4	-48.0	12.3	WOR/3.9'-WOH-5-5-7-8-7-8-4/0.4'	*Organic Sediment"*
	FP03-605	505,277.49	718,795.52	09/16/03	1355	1359	1350	7.9	15.4	NA	NA	51.0	-35.6	63.4	-48.0	12.4	WOR/6.7'-WOH/1.3'-3-4-4-5-3/0.4'	*Organic Sediment"*
	FP03-606	505,152.98	718,566.41	09/16/03	1339	1343	1334	7.3	14.8	NA	NA	50.4	-35.6	62.8	-48.0	12.4	WOR/5.5'-WOH/1.7'-4/1.4'-2-4-4-5/0.8'	*Organic Sediment"*
	FP03-607	505,140.04	718,841.93	09/16/03	1412	1417	1411	8.3	15.8	NA	NA	50.3	-34.5	63.8	-48.0	13.5	WOR/7.3'-WOH/1.4'-2-3-6-5-4/0.8'	*Organic Sediment"*
	FP03-608	505,163.16	718,211.92	09/16/03	1316	1323	1310	6.5	14.0	NA	NA	48.8	-34.8	62.1	-48.1	13.3	WOR/6'-WOH/0.7'-5/1.5'-4-6-6-7-10/1.1'	*Organic Sediment"*

Notes:
(1) Coordinates are given in U.S. State Plane, Massachusetts Mainland 2001, NAD 1927, U.S. Survey foot.
(2) Elevations are in feet referenced to Mean Lower Low Water (MLLW).
Boston Light Station was referenced for Series 100 and 200 explorations & VC03-101 through 104.
Boston Harbor U.S. Coast Guard Station was referenced for Series 300, 400, and 500 explorations & VC03-105 through 109.
Shratft's Center tide gage was referenced for Series 600 explorations.
(3) Freeboard is about 7.5 feet (Distance from water to Barge Reference Point).
(4) Probe and Boring depths are measured from the Barge Reference Point.
(5) Example: 10-18-20/<1" corresponds to 10 blows for the first foot of penetration, 18 blows for the second foot of penetration, and 20 blows for the next 1 inch or less of penetration.
(6) WOR = weight of rods for 1 foot of penetration or other depth as noted by "/"; WOH = weight of hammer with rods for 1 foot of penetration or other depth as noted by "/".
(7) Driller's observations are italicized.
"NA" - Not Applicable.
"*" - Indicates a soil description made from soils directly observed in the open-end of drill rod.
GPS coordinates were post-processed and differentially corrected using the Acushnet, Massachusetts CORS.

Legend:
100 Series - Finn's Ledge
200 Series - Faun Ledges
300 Series - President Roads
400 Series - Main Ship Channel
500 Series - Reserved Channel
600 Series - Mystic River

TABLE I-2
BOSTON HARBOR FASIBILITY STUDY
Geotechnical Probes and Borings in the Chelsea River
Page 1 of 1

Taken from GEI Consultants, Inc. 2003 Geophysics Report

	Exploration ID	As-Drilled Location		Date	Start Time	End Time	Tide Gage Reading Time	Initial Water Level Elevation[2]	Barge Reference[3] Elevation[2]	Mud Line		Bottom of Probe/Boring		Probe/Boring Penetration (feet)	Blows Per Foot[5][6]	Comments[7]
		Northing (feet)[1]	Easting (feet)[1]							Depth[4] (feet)	Elevation[2]	Depth[4] (feet)	Elevation[2]			
Borings	FD03-701	508,552.13	730,601.03	09/24/03	1150	1312	1150	8.8	16.3	59.8	-43.5	65.0	-48.7	5.2		*Hard bottom*; Borehole; Sample REFUSAL at ; Gravelly Clay, Till
	FD03-701A	508,562.69	730,597.26	09/25/03	1203	1432	1206	10.3	17.8	61.6	-43.8	74.7	-56.9	13.1		*Hard bottom*; Borehole; Roller-bit REFUSAL at El -51.9 MLLW; 5-foot rock core run of Pink Granite
Probes	FP03-702	507,762.44	730,485.19	09/26/03	0910	0916	0903	5.9	13.4	54.0	-40.6	61.5	-48.1	7.5	WOR-WOH/0.7'-3/1.3'-4-5-6-8-4/0.5'	*Organic sediment; Gravelly Clay" in drill rod tip, Till*
	FP03-703	508,283.39	730,302.80	09/26/03	0833	0842	0825	4.3	11.8	52.2	-40.4	59.5	-47.7	7.3	WOR/0.5'-WOH/0.2'-25/0.7'-45-38-51-38-52-22/0.5'	*Organic sediment; Gravelly Clay" in drill rod tip, Till*
	FP03-704	508,258.63	730,542.45	09/26/03	0740	0809	0732	2.1	9.6	49.3	-39.7	58.0	-48.4	8.7	WOR/1.5'-WOH/0.2'-30-31-40-54-88-Tide/0.5'-82/0.5'-27	*Organic sediment; Gravelly Clay" in drill rod tip, Till*
	FP03-705	508,340.65	730,487.20	09/24/03	1005	1018	0957	9.6	17.3	56.4	-39.1	65.0	-47.7	8.6	WOR/0.6'-WOH/0.1'-52/0.9'-69-62-25-37-41-32-42	*Organic sediment"*
	FP03-706	508,447.52	730,507.96	09/23/03	1356	1408	1345	4.0	11.5	51.8	-40.3	59.2	-47.7	7.4	WOR-2/0.2'-34-50-45-105-66-46-6/0.2'	*Hard bottom, Cobbles/Boulders; Clayey Gravel", Till*
	FP03-707	508,507.01	730,503.99	09/23/03	1311	1328	1300	5.6	13.1	52.6	-39.5	59.6	-46.5	7.0	WOR/0.4'-17-21-33-64-98-174-45/0.5'-20/<1"	*Hard bottom, Cobbles/Boulders* Drill rods bouncing, REFUSAL
	FP03-708	508,694.87	730,565.02	09/24/03	0832	0843	0823	7.2	14.7	58.0	-43.3	63.0	-48.3	5.0	WOR/1.3'-14/0.7'-36-96-51	*Cobbles/Boulders at bottom;* Drill rods dropped 57.6' to 58.9' to 59.3' under WOR; Irregular bottom; Drill rods bouncing, REFUSAL
	FP03-709	508,749.14	730,617.77	09/24/03	0750	0806	0735	5.5	13.0	52.9	-39.9	60.7	-47.7	7.8	WOR/0.5'-WOH/0.1'-17/0.5'-43-30-35-32-46-45-67/0.7'	*Organic sediment*
	FP03-710	508,776.70	730,511.03	09/23/03	1227	1239	1217	6.9	14.4	54.6	-40.2	62.2	-47.8	7.6	WOR/0.2'-WOH/0.2'-24-33-21-13-24-36-47/1.2'	*Hard bottom, Cobbles/Boulders*
	FP03-711	508,773.83	730,885.37	09/23/03	1102	1115	1050	9.0	16.5	56.6	-40.1	64.2	-47.7	7.6	WOR/1.4'-WOH/0.3'-30/0.7'-39-36-41-47-62/1.2'	*Organic sediment*
	FP03-712	508,907.88	730,921.57	09/23/03	1017	1029	1008	9.6	17.1	56.9	-39.8	63.4	-46.3	6.5	WOR/1.1'-WOH/0.1'-60/0.9'-50-28-42-63-20/0.4'-20/<1"	*Organic sediment* Drill rods bouncing, REFUSAL
	FP03-713	509,490.28	730,898.16	09/23/03	0901	0907	0855	9.2	16.7	56.8	-40.1	65.0	-48.3	8.2	WOR/3.1'-WOH/0.1'-11-18-9-14-9	*Organic sediment*
	FP03-714	509,481.55	731,031.22	09/23/03	0832	0837	0824	8.6	16.1	56.3	-40.2	64.0	-47.9	7.7	WOR/2.2'-WOH/0.1'-2/0.4'-6-11-12-7-8	*Organic sediment*
	FP03-715	509,071.58	731,239.31	09/23/03	0941	0947	0932	9.6	17.1	57.6	-40.5	65.0	-47.9	7.4	WOR/1.4'-WOH/0.2'-6/0.8'-9-13-15-14-14	*Organic sediment*
	FP03-716	509,579.57	731,192.39	09/23/03	0757	0809	0748	7.6	15.1	55.8	-40.7	63.0	-47.9	7.2	WOR/1.2'-WOH/0.2'-57/0.8'-8-8-4-5-5	*Organic sediment* Obstruction from 57.2' to 58.0'

Notes:
(1) Coordinates are given in U.S. State Plane, Massachusetts Mainland 2001, NAD 1927, U.S. Survey foot.
(2) Elevations are in feet referenced to Mean Lower Low Water (MLLW).
Chelsea Street Bridge tide gage was referenced for Series 700 explorations.
(3) Freeboard is about 7.5 feet (Distance from water to Barge Reference Point).
(4) Probe and Boring depths are measured from the Barge Reference Point.
(5) Example: 10-18-20/<1" corresponds to 10 blows for the first foot of penetration, 18 blows for the second foot of penetration, and 20 blows for the next 1 inch or less of penetration.
(6) WOR = weight of rods for 1 foot of penetration or other depth as noted by "/"; WOH = weight of hammer with rods for 1 foot of penetration or other depth as noted by "/".
(7) Driller's observations are italicized.
"NA" - Not Applicable.
"*" - Indicates a soil description made from soils directly observed in the open-end of drill rod.
GPS coordinates were post-processed and differentially corrected using the Acushnet, Massachusetts CORS.
Tide gage readings for 700-series probes and borings are corrected based on the NOAA 10/07/2003 published change in the Chelsea Street Bridge Tidal Benchmark (2.7-foot difference).

Legend:
100 Series - Finn's Ledge
200 Series - Faun Ledges
300 Series - President Roads
400 Series - Main Ship Channel
500 Series - Reserved Channel
600 Series - Mystic River
700 Series - Chelsea River

Table I-3
BOSTON HARBOR FEASIBILITY STUDY
Probes vs. Geophysical Acoustic Basement
Page 1 of 2

Sample ID	Easting	Northing	Estimated Harbor Bottom Elevation (FT MLLW)	Acoustic Basement Elevation (FT MLLW)	Estimated Depth to Basement	Probe Data: Hard Zone Elevation	Probe Data: Refusal Elevation	Comments
FP03-101	756928	499229	-42.1	-41.7	-0.4	-51.9	-52.8	Bouncing refusal
FP03-102	757148	499050	-41.0	-41.8	0.9	-46.1	-46.3	Bouncing refusal
FP03-103	757510	498768	-41.6	Organic Material	NA	-46.6	-52.6	Bouncing refusal
FP03-104	756850	498079	-32.4	-33.7	1.3	-40	<-58.8	Refusal not reached
FP03-105	756608	497849	-34.5	-36.5	2.0	-38	<-58.3	Refusal not reached
FP03-106	756500	497989	-39.5	Organic Material	NA	NA	<-58.4	Refusal not reached
FP03-107	755677	498479	-38.4	-38.4	0.0	NA	<-58.2	Refusal not reached
FP03-108	755996	498338	-41.7	-41.7	0.0	NA	<-57.5	Refusal not reached
FP03-109	756098	498777	-40.7	-40.4	-0.3	NA	<-57.7	Refusal not reached
FP03-110	756432	498503	-42.1	-42.0	-0.1	-52.8	<-58.9	Refusal not reached
FP03-201	753321	494081	-38.3	-38.7	0.4	-39.8	-45	Bouncing refusal
FP03-202	753831	494272	-41.5	Organic Material	NA	-48.7	-53	Bouncing refusal
FP03-203	755046	495231	-42.3	Organic Material	NA	NA	<-58.0	Refusal not reached
FP03-204	754049	493729	-40.6	-40.2	-0.4	NA	-43.5	Bouncing refusal
FP03-205	753917	493127	-40.8	-41.0	0.2	NA	-46.3	Bouncing refusal
FP03-206	753128	491971	-40.3	-40.7	0.5	-45	-49.8	Bouncing refusal
FP03-207	752603	492510	-39.5	-38.7	-0.7	-42.2	-43.3	Bouncing refusal
FP03-208	752943	493223	-41.1	-41.7	0.6	-45	-48.2	Bouncing refusal
FP03-301	740563	488260	-38.1	No Data	NA	<-57.6	<-57.6	Soft organics -38.3 to -44
FP03-302	740690	488208	-38.8	Organic Material	NA	-43.2	-43.2	Soft organics -39.5 to -43, bouncing refusal
FP03-303	740590	488052	-38.8	Organic Material	NA	<-57.7	<-57.7	Soft organics -39.7 to -45
FP03-304	741087	487745	-41.5	-40.7	-0.9	<-57.2	<-57.2	Soft organics -42.4 to -47
FP03-305	741519	487814	-42.2	-42.5	0.3	<-58.1	<-58.1	Soft organics -42.7 to -46.5
FP03-306	741643	487970	-40.3	-41.6	1.3	<-57.1	<-57.1	Soft organics -41.3 to -45.7
FP03-307	745543	488924	-40.0	No Data	NA	<-57.8	<-57.8	Soft organics -40.8 to -44
FP03-308	746130	489060	-40.2	-43.7	3.4	<-57.8	<-57.8	Soft organics -40.6 to -47.6
FP03-401	727594	493121	-34.7	-37.7	2.9	NA	-39.4	Bouncing refusal
FP03-402	727403	492019	-28.5	-29.3	0.8	NA	-36.1	Bouncing refusal
FP03-403	728113	492031	-41.4	-41.4	-0.1	NA	-45.6	Bouncing refusal
FP03-404	728833	491830	-41.7	-56.9	15.2	NA	-50	Bouncing refusal
FP03-405	729568	491702	-34.4	-43.0	8.5	NA	-40	Bouncing refusal
FP03-406	730002	491076	-40.4	-42.6	2.1	NA	-45.8	Bouncing refusal
FP03-407	729886	490598	-38.4	-39.2	0.8	NA	<-56.6	Refusal not reached
FP03-408	729293	490877	-35.3	-37.2	1.9	-45.6	-51.6	Bouncing refusal
FP03-409	729548	490709	-35.3	Organic Material	NA	-56.5	-57.6	Bouncing refusal
FP03-410	729725	490497	-35.9	Organic Material	NA	NA	<-56.4	Refusal not reached
FP03-411	729285	490536	No Data	Organic Material	NA	NA	<-57.2	Refusal not reached
FP03-412	729331	490182	No Data	-35.9	NA	-45	-51.4	Bouncing refusal
FP03-413	729624	490196	-28.4	-28.8	0.4	-46.5	-54.9	Bouncing refusal
FP03-414	730183	490052	-41.1	-42.9	1.8	NA	-47.4	Bouncing refusal
FP03-415	730475	490523	-41.6	-41.7	0.1	-45.4	-47.9	Bouncing refusal
FP03-416	730810	490584	-40.7	-42.0	1.3	-47.1	-54.6	Bouncing refusal
FP03-417	731042	490443	-42.2	-42.3	0.2	-45	<-55.8	Refusal not reached
FP03-418	731183	490476	-41.5	-42.5	1.0	NA	-52.5	Bouncing refusal
FP03-419	731558	490550	-41.7	-44.2	2.5	-45.5	-50.6	Bouncing refusal
FP03-420	732444	489314	-37.5	-38.1	0.6	-40	-40.6	Bouncing refusal
FP03-421	732631	489270	-37.1	-37.0	0.0	NA	-39.7	Bouncing refusal
FP03-422	732769	488830	-42.9	-46.7	3.8	NA	-42.2	Bouncing refusal
FP03-423	734087	488157	-36.4	-40.2	3.8	NA	-40.8	Bouncing refusal
FP03-424	734418	487788	-36.8	-36.6	-0.1	NA	-41.2	Bouncing refusal
FP03-425	734798	487450	-36.0	-36.0	0.1	NA	-37.6	Bouncing refusal
FP03-426	732849	488157	-37.1	-38.7	1.6	-45	-46	Bouncing refusal
FP03-427	733655	487677	-40.0	-41.7	1.7	na	-49.6	Bouncing refusal
FP03-428	733986	487552	-40.9	-43.5	2.6	-50	-54.8	Bouncing refusal
FP03-429	733815	487458	-41.7	Organic Material	NA	-54.1	<-54.1	Refusal not reached
FP03-430	734067	487402	-41.0	Organic Material	NA	NA	<-56.0	Refusal not reached
FP03-431	734228	487422	-41.1	Organic Material	NA	NA	-43.5	Bouncing refusal
FP03-432	734427	487399	-40.6	-40.4	-0.3	NA	-43.7	Bouncing refusal
FP03-433	733916	487238	-42.2	-55.0	12.8	NA	<-57.2	Refusal not reached
FP03-434	734613	486944	-38.6	Organic Material	NA	NA	-45.2	Bouncing refusal
FP03-435	735089	486943	-41.0	-42.9	2.0	NA	-49.1	Refusal not reached
FP03-436	734827	486388	-39.8	Organic Material	NA	NA	<-56.3	Refusal not reached
FP03-437	735229	486662	-39.4	Organic Material	NA	NA	-43.9	Bouncing refusal

Table I-3
BOSTON HARBOR FEASIBILITY STUDY
Probes vs. Geophysical Acoustic Basement
Page 2 of 2

Sample ID	Easting	Northing	Estimated Harbor Bottom Elevation (FT MLLW)	Acoustic Basement Elevation (FT MLLW)	Estimated Depth to Basement	Probe Data: Hard Zone Elevation	Probe Data: Refusal Elevation	Comments
FP03-438	735472	486759	-39.6	-41.0	1.4	NA	-48.5	Bouncing refusal
FP03-439	736518	486505	-38.8	-40.5	1.7	-46	<-56.8	Refusal not reached
FP03-440	734342	487155	-40.0	Organic Material	NA	NA	< -57.8	Refusal not reached
FP03-501	727158	489739	-40.8	-43.2	2.3	-53.2	<-53.2	Refusal not reached
FP03-502	727317	489650	-41.4	-44.6	3.2	-54	-56	Bouncing refusal
FP03-503	727518	489744	-41.5	-41.7	0.2	-50	-56.4	Bouncing refusal
FP03-504	728004	489682	-42.1	-42.3	0.2	-45.8	-48.1	Bouncing refusal
FP03-505	728233	489831	-36.2	-36.8	0.7	-38	-43.1	Bouncing refusal
FP03-506	728242	489682	-41.5	-42.4	1.0	-44	-48.8	Bouncing refusal
FP03-507	728710	489718	-41.8	-42.2	0.4	-48.9	-57.9	Bouncing refusal
FP03-508	729010	489857	-37.6	-38.6	0.9	NA	-44.2	Bouncing refusal
FP03-601	718224	505457	-34.4	Organic Material	NA	NA	<-48	Refusal not reached
FP03-602	718454	505428	-34.5	Organic Material	NA	NA	<-48	Refusal not reached
FP03-603	718353	505297	No Data	Organic Material	NA	NA	<-48	Refusal not reached
FP03-604	718493	505305	-34.6	Organic Material	NA	NA	<-47	Refusal not reached
FP03-605	718796	505277	-35.1	Organic Material	NA	NA	<-48	Refusal not reached
FP03-606	718566	505153	No Data	Organic Material	NA	NA	<-48	Refusal not reached
FP03-607	718842	505140	-34.1	Organic Material	NA	NA	<-48	Refusal not reached
FP03-608	718212	505163	No Data	Organic Material	NA	NA	<-48.1	Refusal not reached
FD03-701	730597	508563	-41.1	No Data	NA		-51.9	Refusal, 5ft rock core retrieved
FP03-702	730485	507762	-38.5	No Data	NA	NA	<-48.1	Refusal not reached
FP03-703	730303	508283	-37.5	No Data	NA	NA	<-47.7	Refusal not reached
FP03-704	730542	508259	-37.9	No Data	NA	NA	<-47.9	Refusal not reached
FP03-705	730487	508341	-37.8	No Data	NA	NA	<-47.7	Refusal not reached
FP03-706	730508	508448	-38.0	No Data	NA	NA	<-47.7	Refusal not reached
FP03-707	730504	508507	-38.7	No Data	NA	NA	-46.6	Bouncing refusal
FP03-708	730565	508695	-38.6	No Data	NA	NA	-48.3	Bouncing refusal
FP03-709	730618	508749	-38.7	No Data	NA	NA	<-47.7	Refusal not reached
FP03-710	730511	508777	-38.2	No Data	NA	NA	<-47.8	Refusal not reached
FP03-711	730885	508774	-39.2	No Data	NA	NA	<-47.7	Refusal not reached
FP03-712	730922	508908	-38.0	No Data	NA	NA	-46.4	Bouncing refusal
FP03-713	730898	509490	-38.7	No Data	NA	NA	<-48.3	Refusal not reached
FP03-714	731031	509482	-38.6	No Data	NA	NA	<-47.9	Refusal not reached
FP03-715	731239	509072	-38.6	No Data	NA	NA	<-47.9	Refusal not reached
FP03-716	731192	509580	-38.7	No Data	NA	NA	<-47.9	Refusal not reached
VC03-101	754894	497921	-40.0	Organic Material	NA	NA	NA	
VC03-102	754062	496058	-45.6	Organic Material	NA	NA	NA	
VC03-103	751829	491289	-41.5	No Data	NA	NA	NA	
VC03-104	751335	490266	-42.0	No Data	NA	NA	NA	
VC03-105	736917	486390	-39.7	No Data	NA	NA	NA	
VC03-106	733473	488496	-38.5	No Data	NA	NA	NA	
VC03-107	728693	492352	-35.5	No Data	NA	NA	NA	
VC03-108	718915	505081	-34.7	Organic Material	NA	NA	NA	
VC03-109	718102	505362	No Data	No Data	NA	NA	NA	

Note: Northing and Easting are in NAD 27
NA = Not Applicable
All elevations are relative to Mean Lower Low Water (MLLW)
"Hard" implies > 30 blows per foot

*Figure I-1.
STRATIGRAPHIC UNITS
IN AND AROUND THE BOSON BASIN

* Geologic map from Goldsmith (1991)

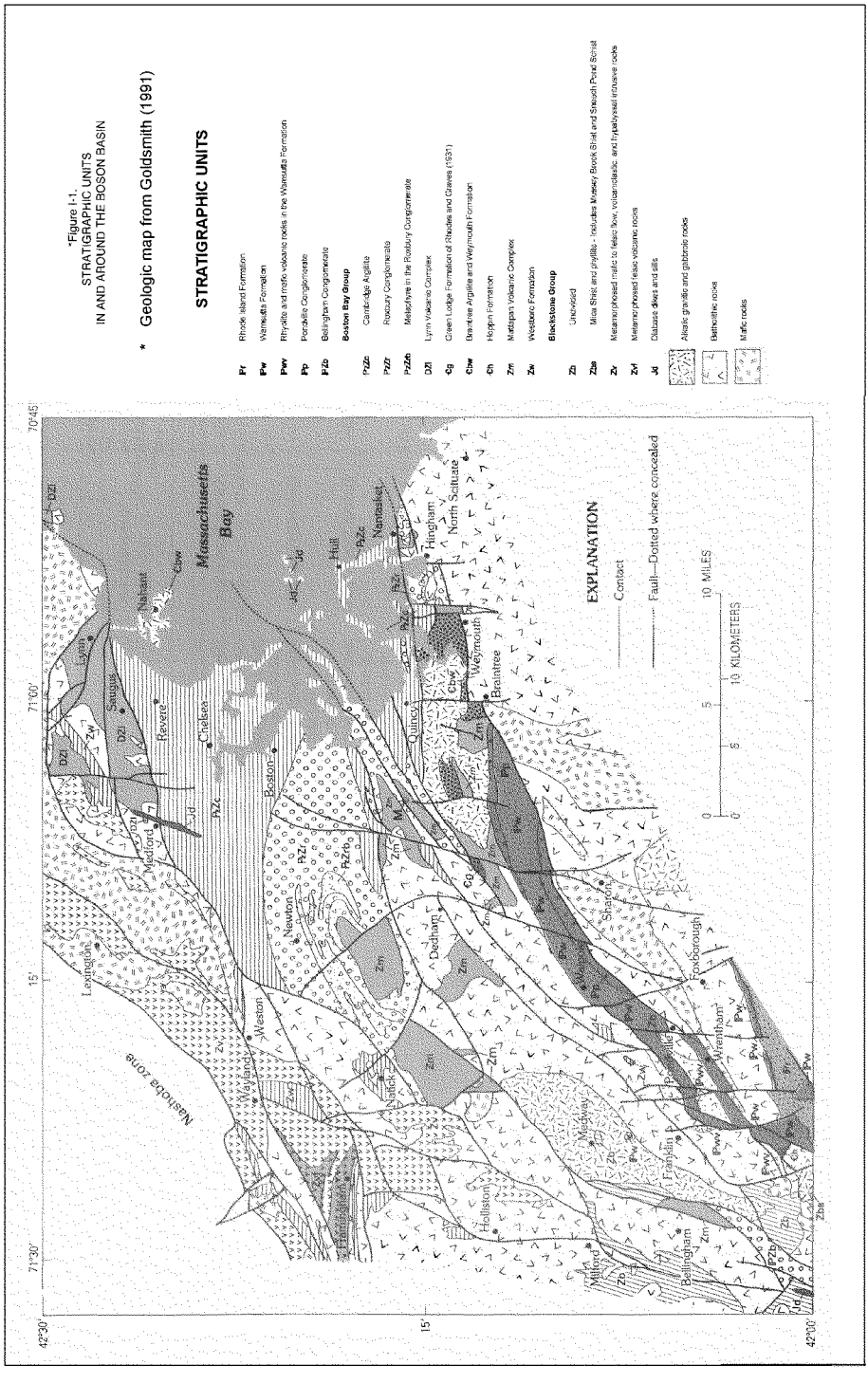
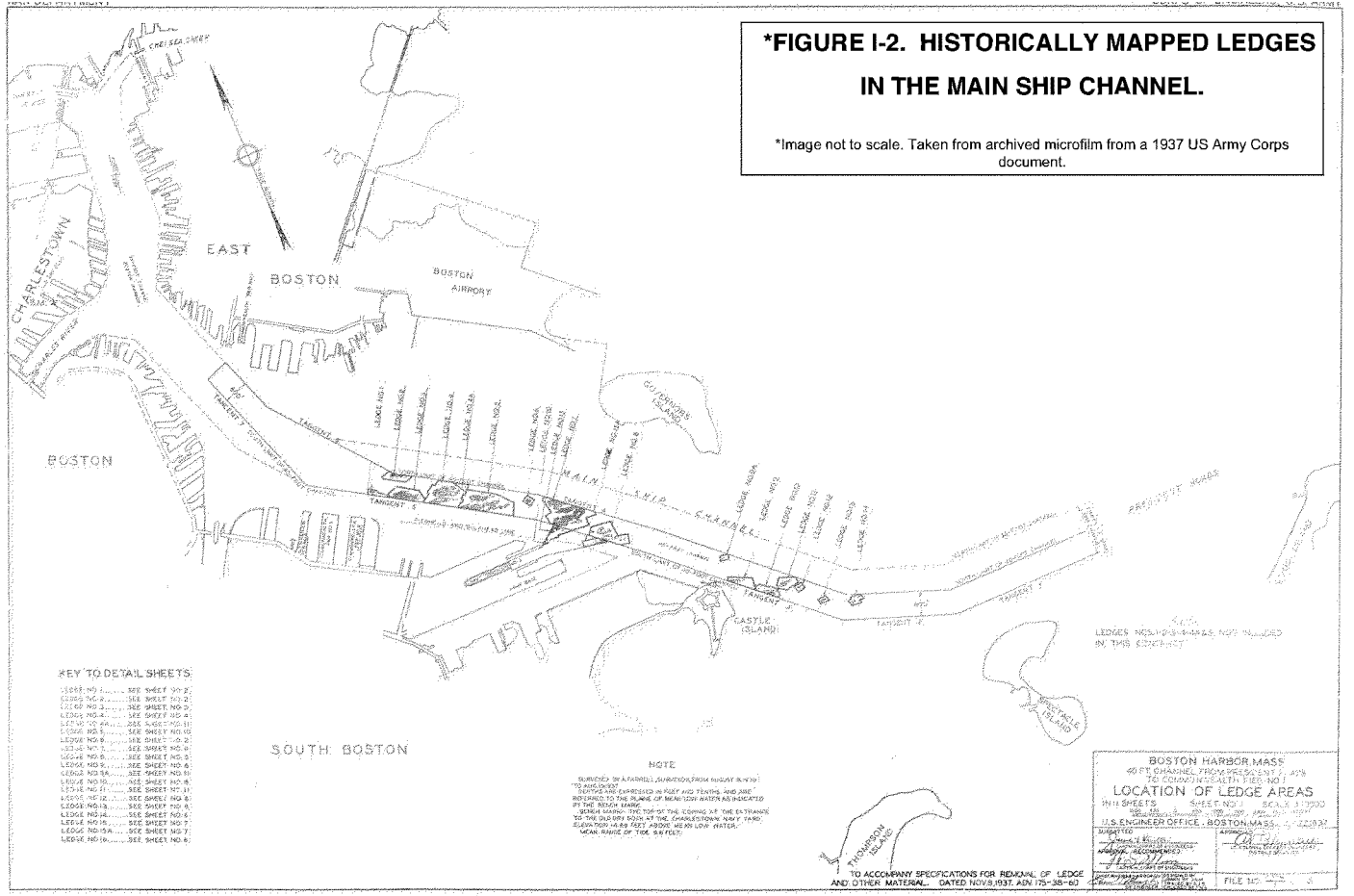


***FIGURE I-2. HISTORICALLY MAPPED LEDGES IN THE MAIN SHIP CHANNEL.**

*Image not to scale. Taken from archived microfilm from a 1937 US Army Corps document.



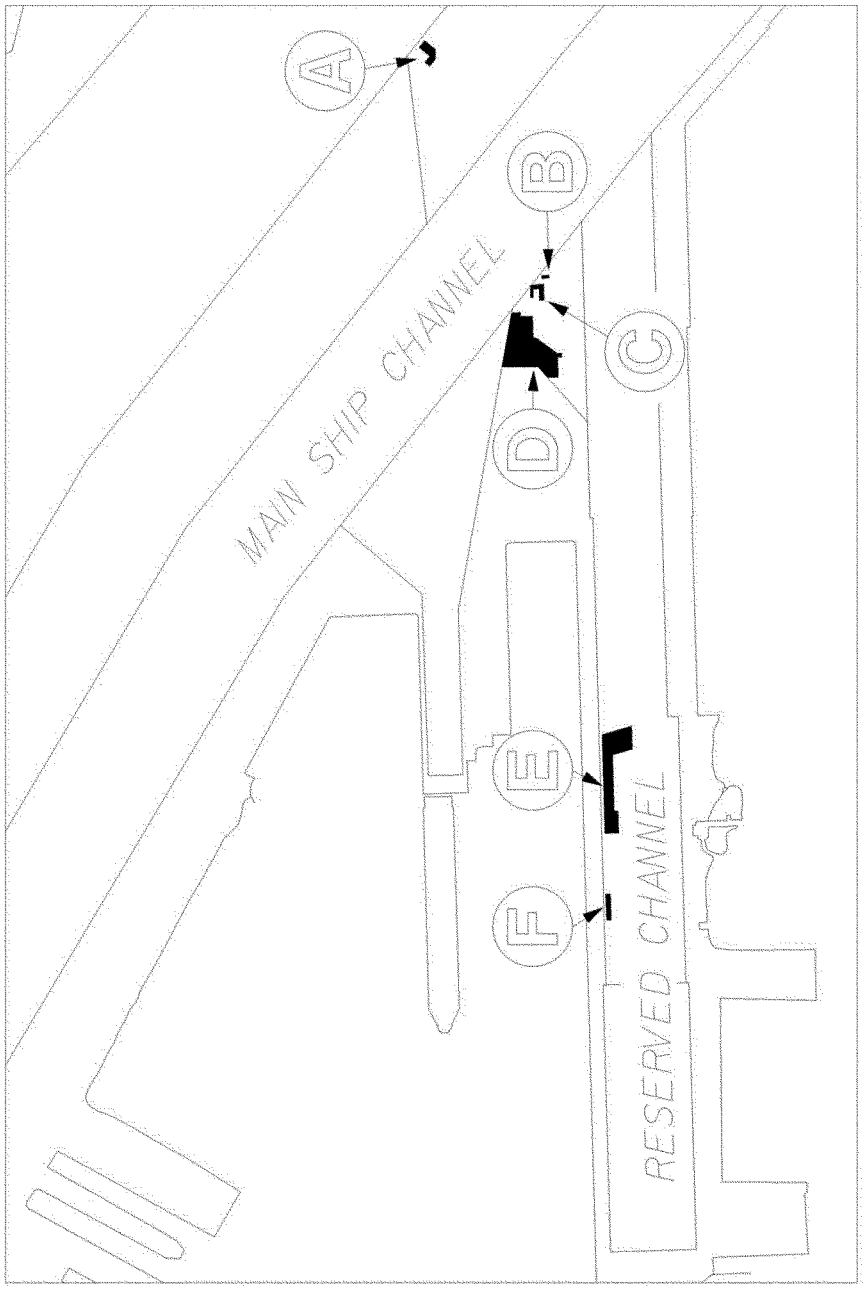


FIGURE I-3. PRIOR ROCK REMOVAL IN THE RESERVED AND MAIN SHIP CHANNEL. Image not to scale.

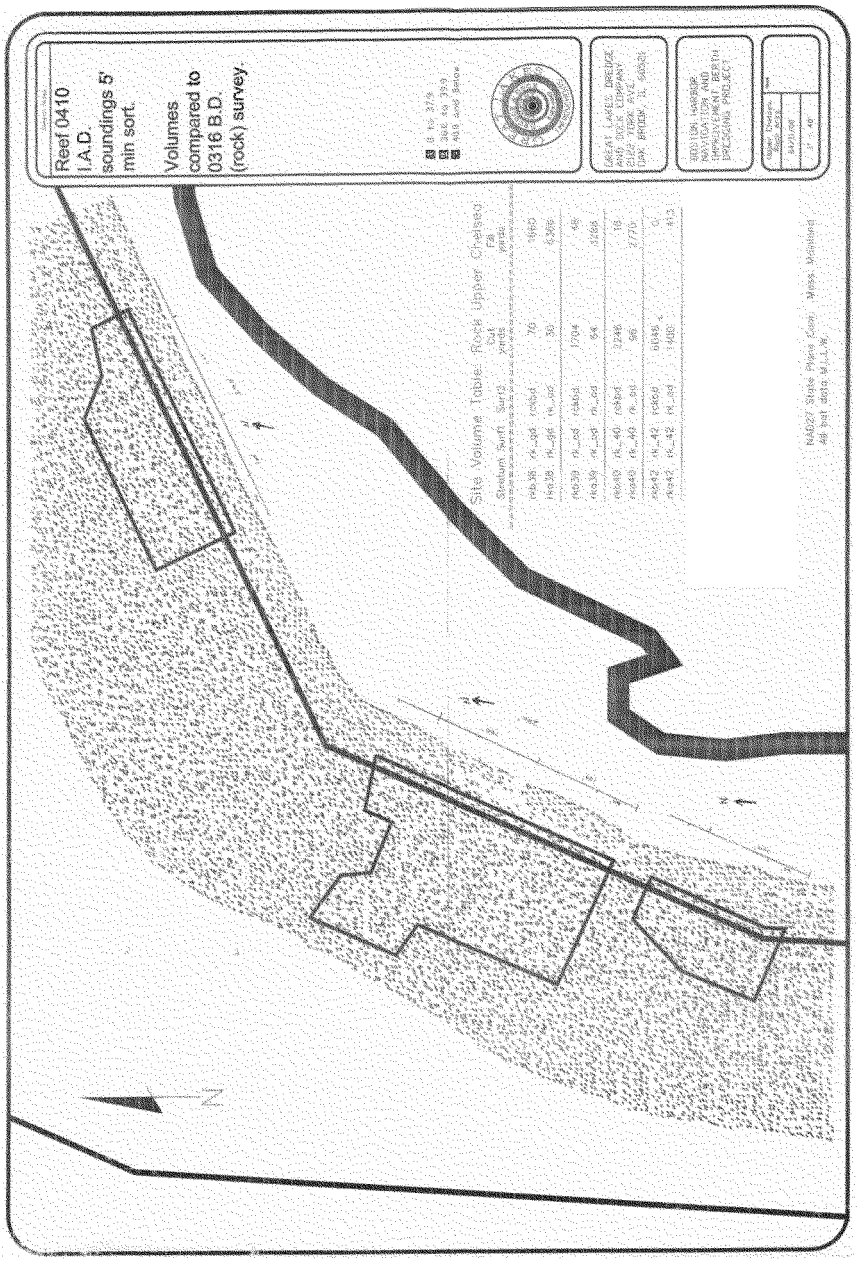


FIGURE I-4. PRIOR ROCK REMOVAL IN THE CHELSEA RIVER. Project dated to the year 2000.

Image not to scale. Taken from Great Lakes Dredge and Dock Company Figure.

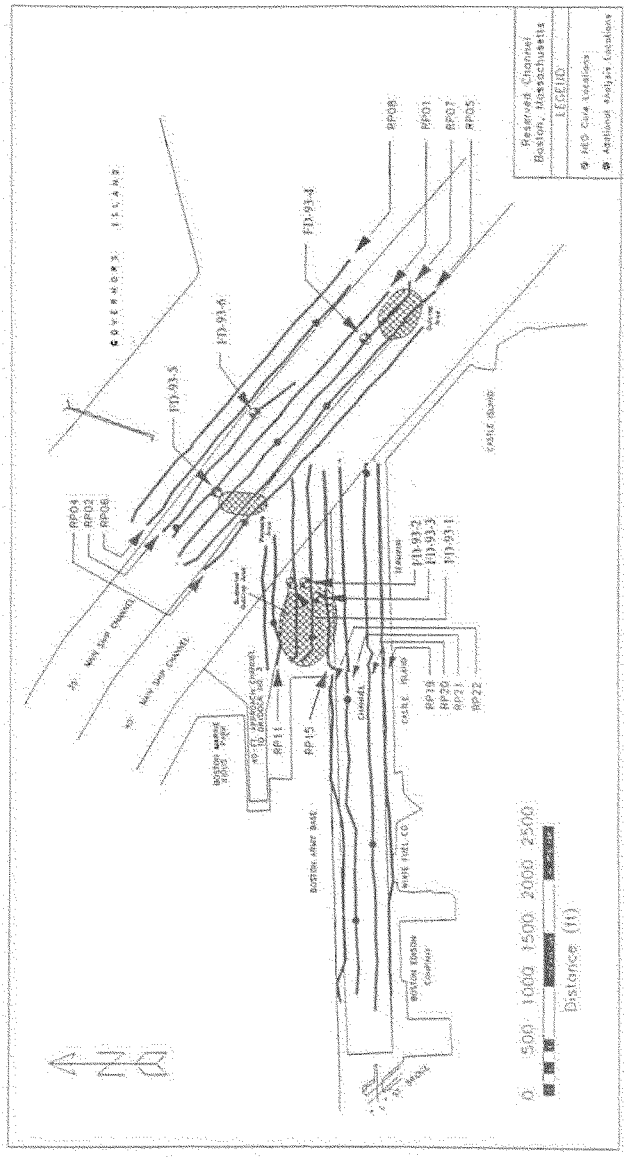


FIGURE I-5. RESERVED CHANNEL AND PORTION OF MAIN SHIP CHANNEL SEISMIC SURVEY AND LOCATIONS OF POSSIBLE ROCK. Crosshatched locations indicate possible outcrop area. (Adapted from WES 1994 Report)

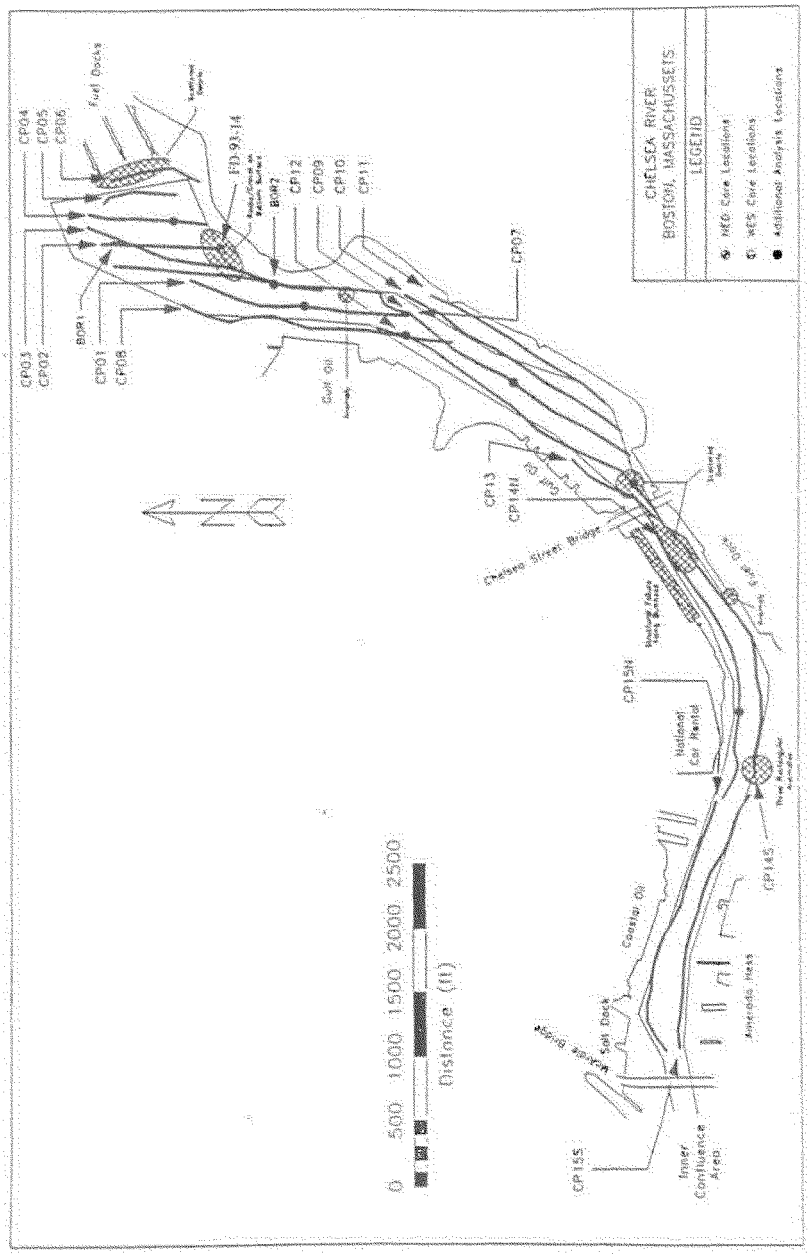


FIGURE I-6. CHELSEA RIVER SEISMIC SURVEY AND LOCATIONS OF POSSIBLE ROCK.
Crosshatched locations indicate possible outcrop area. (Adapted from WES 1994 Report)

FIGURE I-7. BOSTON HARBOR GEOPHYSICAL INTERPRETATION. Map of the main survey area showing region with water depths greater than 55 ft (cyan hatch), areas where acoustic basement is less than 55 ft (brown), and areas of no signal penetration (yellow). Map from Ocean Surveys, Inc. Geophysics Report (2003).

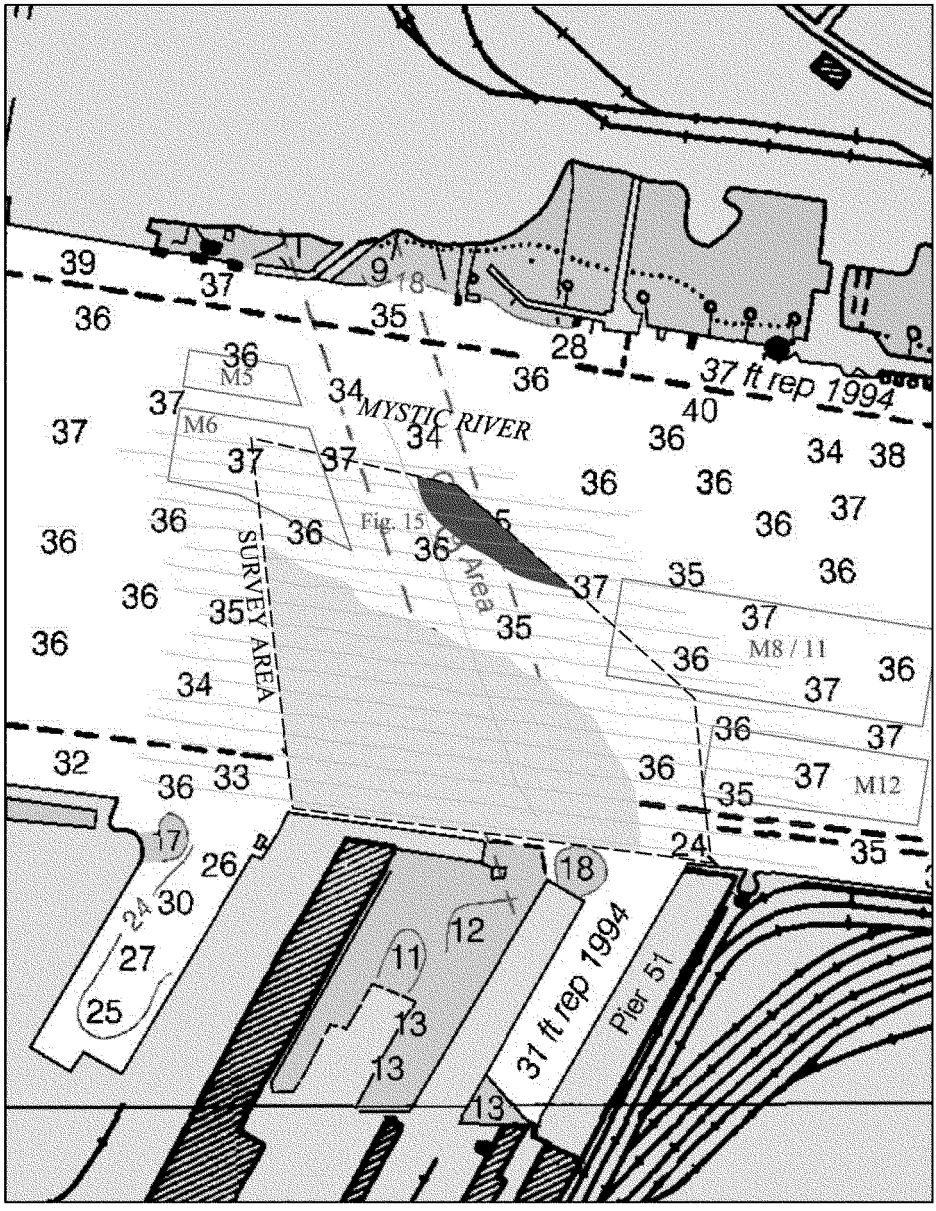


FIGURE I-8. MYSTIC RIVER GEOPHYSICAL INTERPRETATION. Figure shows areas where acoustic basement is less than 55 ft (brown), and areas of no signal penetration (yellow). Map from Ocean Surveys, Inc. Geophysics Report (2003).

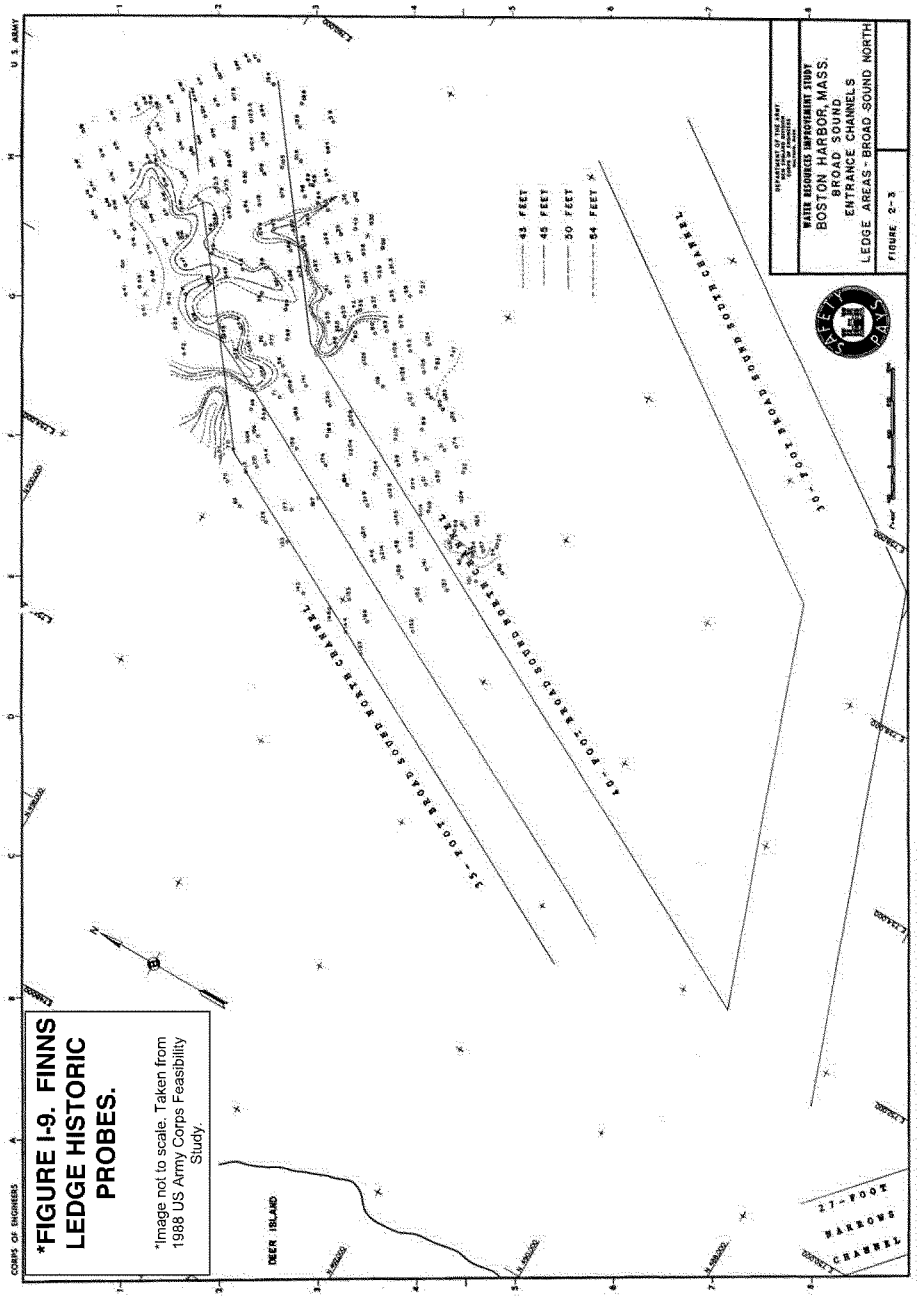


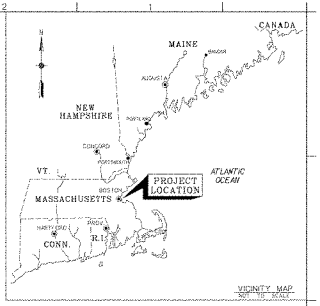
***FIGURE I-9. FINNS LEDGE HISTORIC PROBES.**

*Image not to scale. Taken from 1988 US Army Corps Feasibility Study.

US Army Corps
of Engineers
New England District

BOSTON HARBOR
BORING AND PROBE LOCATIONS

BOSTON
MASSACHUSETTS



VICINITY MAP
NOT TO SCALE

WATER RESOURCES DEVELOPMENT PROJECT
BOSTON HARBOR
MASSACHUSETTS
BORING AND PROBE LOCATIONS
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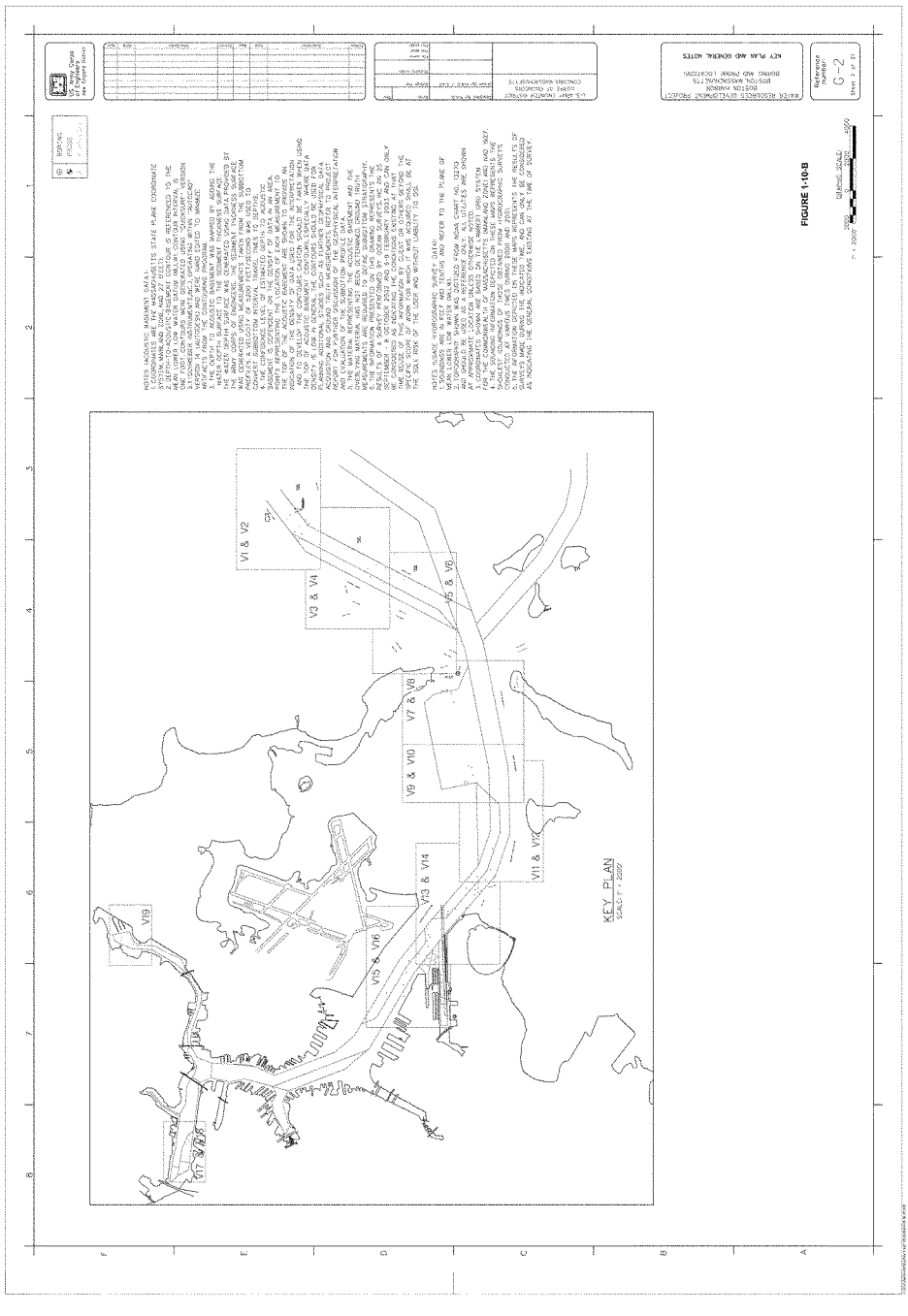
G-1
Sheet 1 of 21

FIGURE 1-10-A


KEY PLAN
V1 & V2
V3 & V4
V5 & V6
V7 & V8
V9 & V10
V11 & V12
V13 & V14
V15 & V16
V17
V18
V19
NOTES: HYDROSTATIC SURVEY DATA:
1. SOUNDINGS ARE IN FEET AND TENTHS AND REFER TO THE PLANE OF MEAN LOWER LOW WATER.
2. ELEVATIONS ARE REFERRED TO MEAN LOWER LOW WATER AS DETERMINED FROM NOAA CHART NO. 13233 AND ARE SHOWN IN FEET AND TENTHS.
3. COORDINATES SHOWN ARE BASED ON THE LAMBERT 1983 SYSTEM AND ARE REFERRED TO A REFERENCE ONLY: X=1,111,111.5 AND Y=222,222.5.
4. THE SOUNDING INFORMATION DEPICTED ON THESE BOARD REPRESENTS THE RESULTS OF A HYDROSTATIC SURVEY PERFORMED BY [illegible] AND CAN BE CONSIDERED CONDUCTED AT VARIOUS TIMES DURING 2000 AND 2001.
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108. THE SOUNDING INFORMATION DEPICTED ON THESE BOARDS REPRESENTS THE RESULTS OF A HYDROSTATIC SURVEY PERFORMED BY [illegible] AND CAN BE CONSIDERED CONDUCTED AT VARIOUS TIMES DURING 2000 AND 2001.
109. THE SOUNDING INFORMATION DEPICTED ON THESE BOARDS REPRESENTS THE RESULTS OF A HYDROSTATIC SURVEY PERFORMED BY [illegible] AND CAN BE CONSIDERED CONDUCTED AT VARIOUS TIMES DURING 2000 AND 2001.
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112. THE SOUNDING INFORMATION DEPICTED ON THESE BOARDS REPRESENTS THE RESULTS OF A HYDROSTATIC SURVEY PERFORMED BY [illegible] AND CAN BE CONSIDERED CONDUCTED AT VARIOUS TIMES DURING 2000 AND 2001.
113. THE SOUNDING INFORMATION DEPICTED ON THESE BOARDS REPRESENTS THE RESULTS OF A HYDROSTATIC SURVEY PERFORMED BY [illegible] AND CAN BE CONSIDERED CONDUCTED AT VARIOUS TIMES DURING 2000 AND 2001.
114. THE SOUNDING INFORMATION DEPICTED ON THESE BOARDS REPRESENTS THE RESULTS OF A HYDROSTATIC SURVEY PERFORMED BY [illegible] AND CAN BE CONSIDERED CONDUCTED AT VARIOUS TIMES DURING 2000 AND 2001.
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124. THE SOUNDING INFORMATION DEPICTED ON THESE BOARDS REPRESENTS THE RESULTS OF A HYDROSTATIC SURVEY PERFORMED BY [illegible] AND CAN BE CONSIDERED CONDUCTED AT VARIOUS TIMES DURING 2000 AND 2001.
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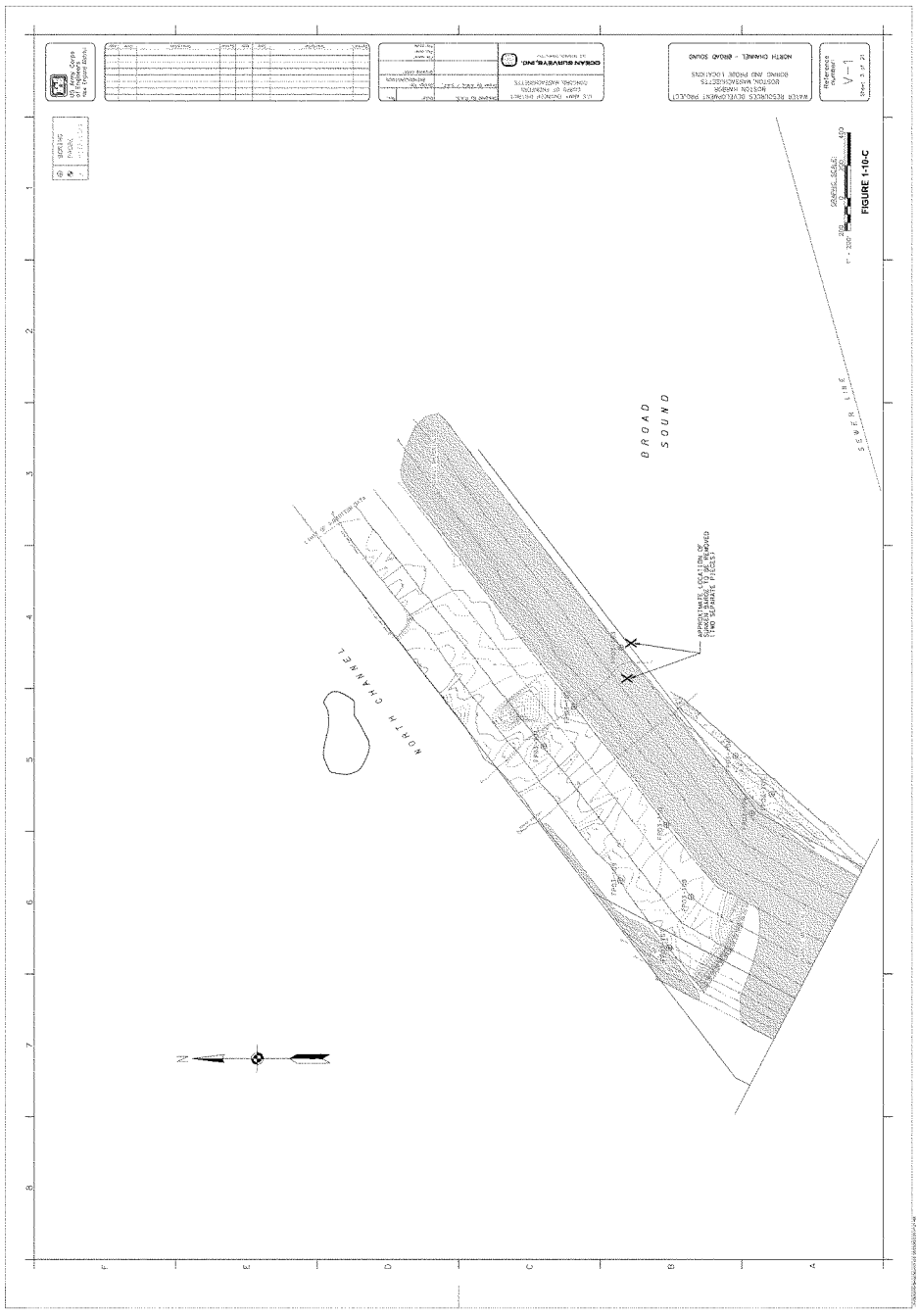
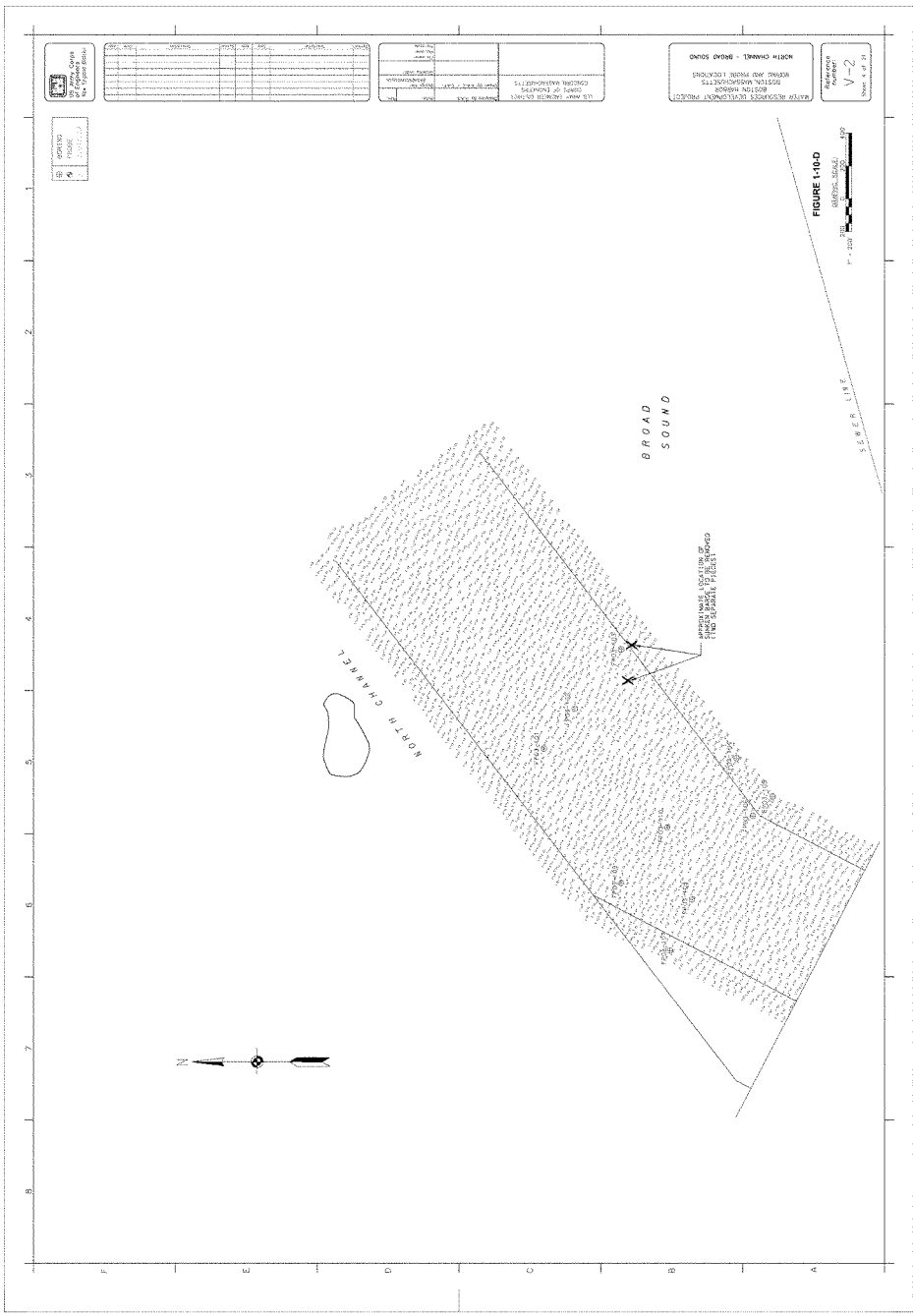
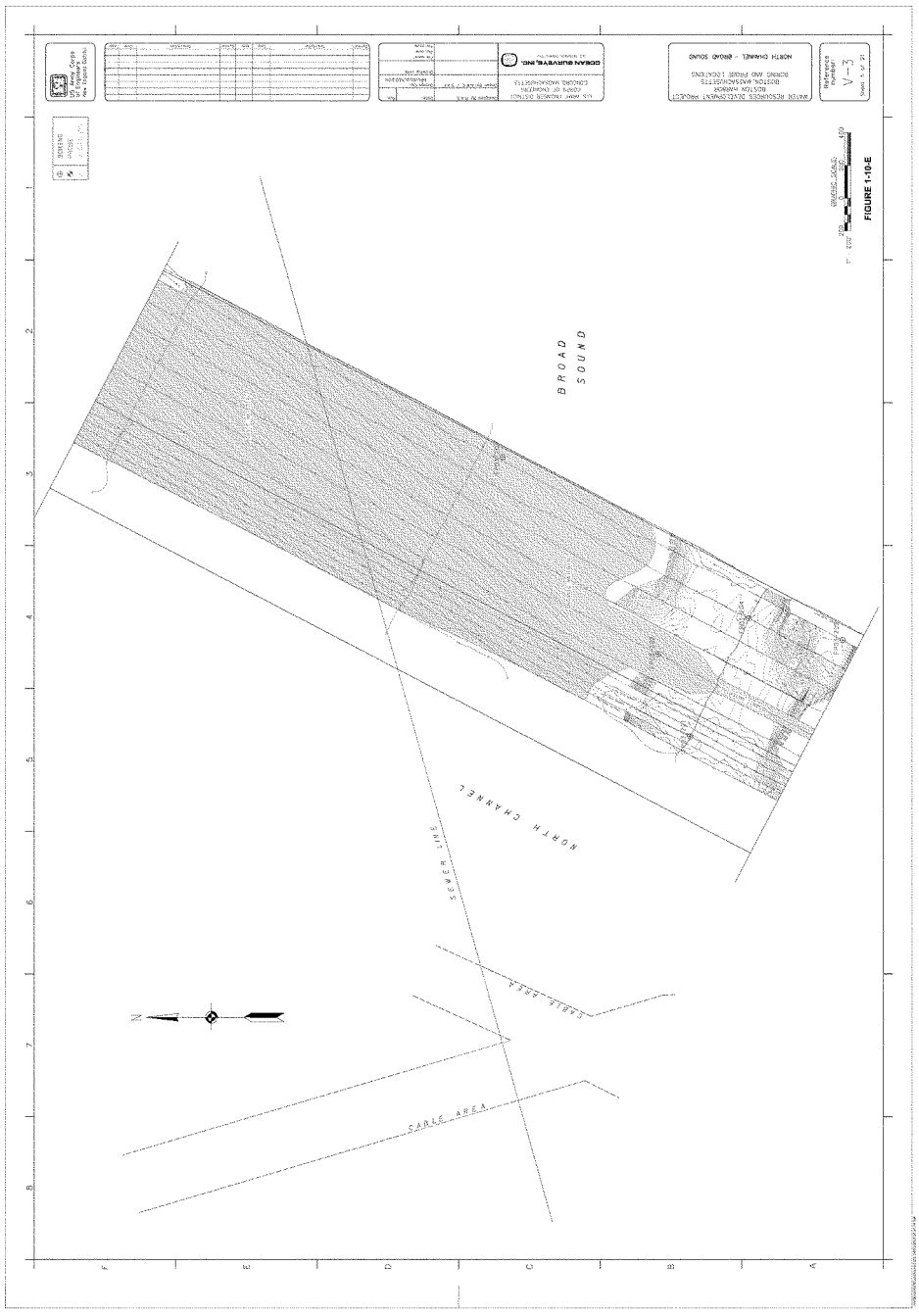
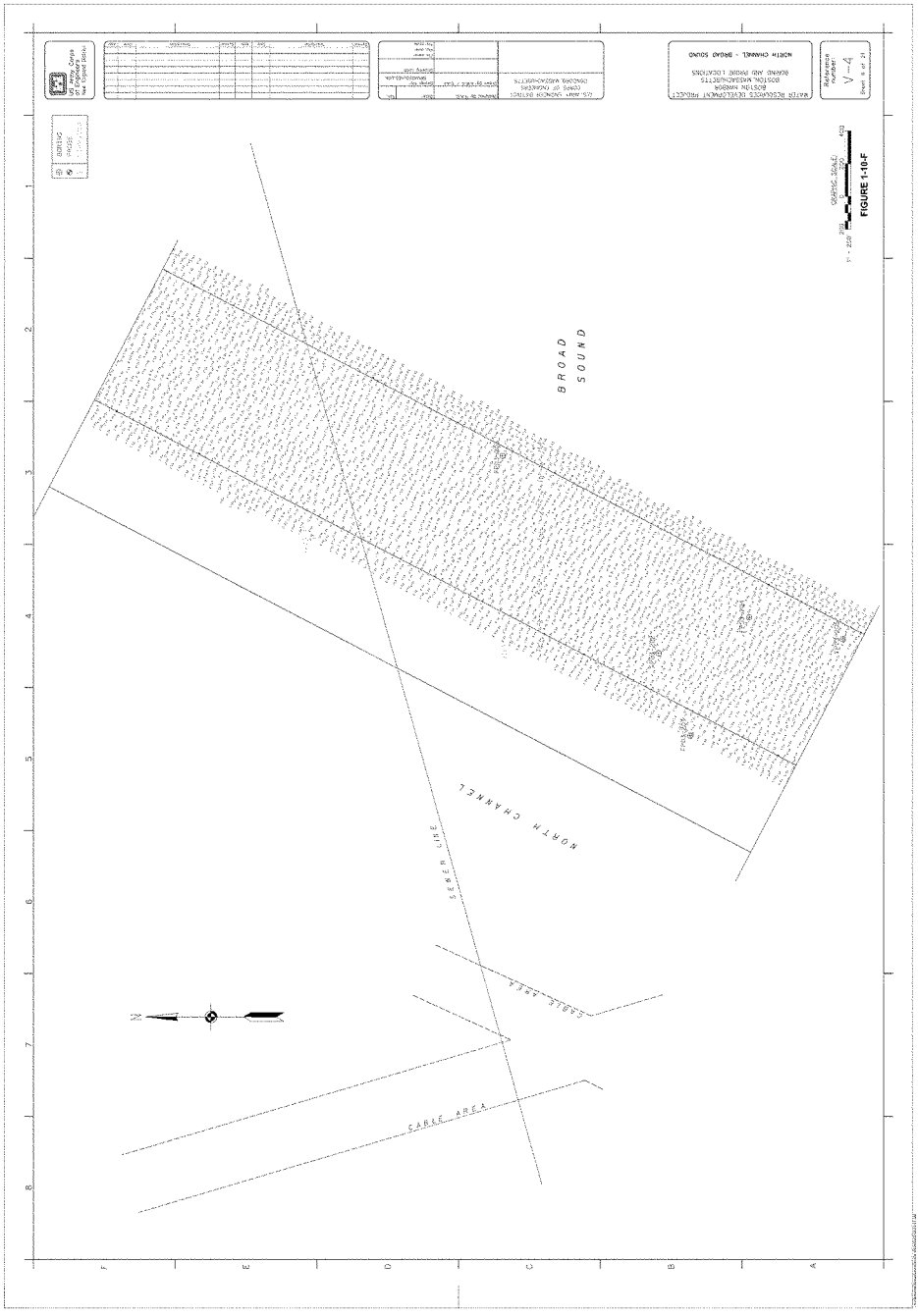
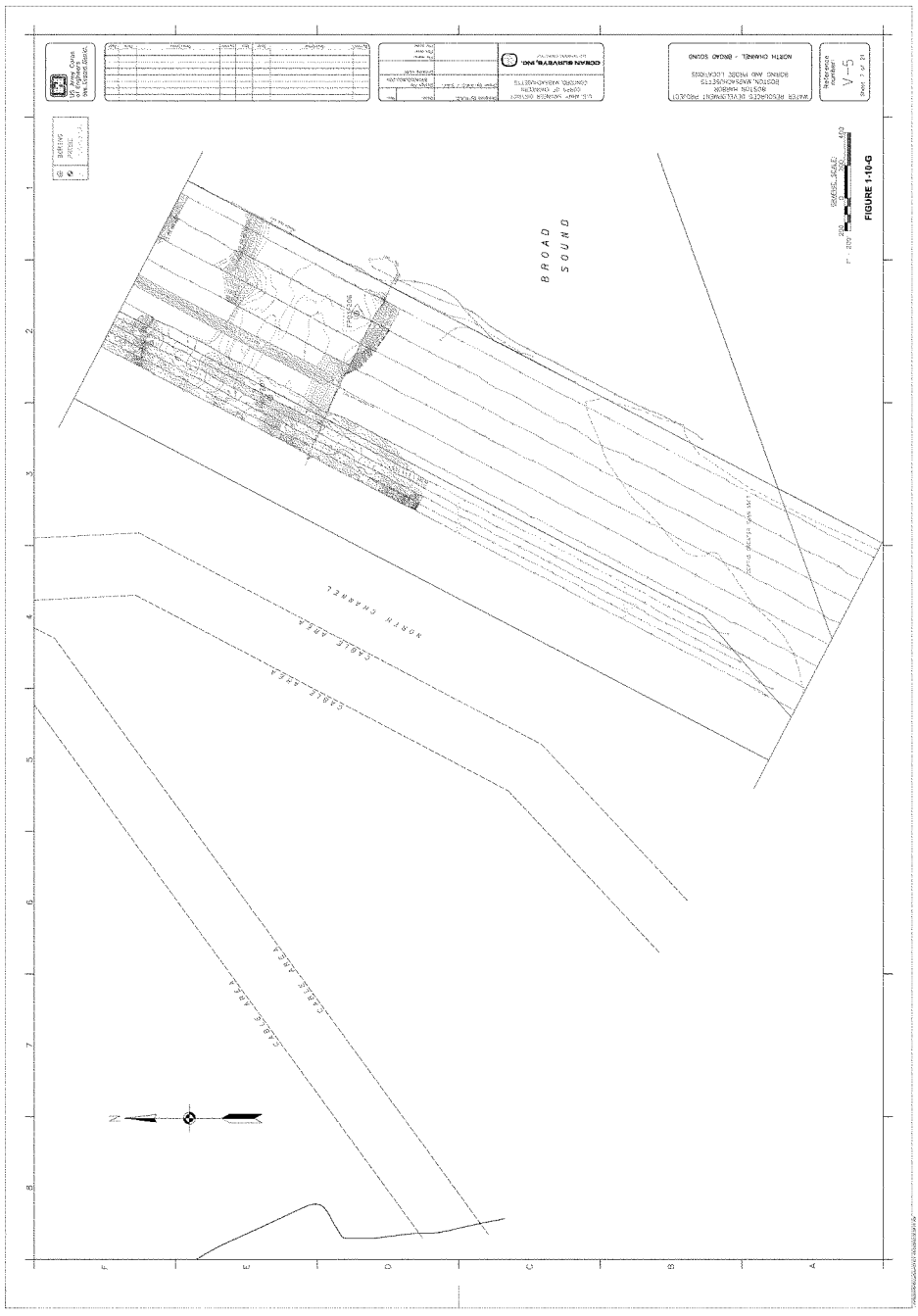
129. THE SOUNDING INFORMATION DEPICTED ON THESE BOARDS REPRESENTS THE RESULTS OF A HYDROSTATIC SURVEY PERFORMED BY [illegible] AND CAN BE CONSIDERED CONDUCTED AT VARIOUS TIMES DURING 2000 AND 2001.
130. THE SOUNDING INFORMATION DEPICTED ON THESE BOARDS REPRESENTS THE RESULTS OF A HYDROSTATIC SURVEY PERFORMED BY [illegible] AND CAN BE CONSIDERED CONDUCTED AT VARI

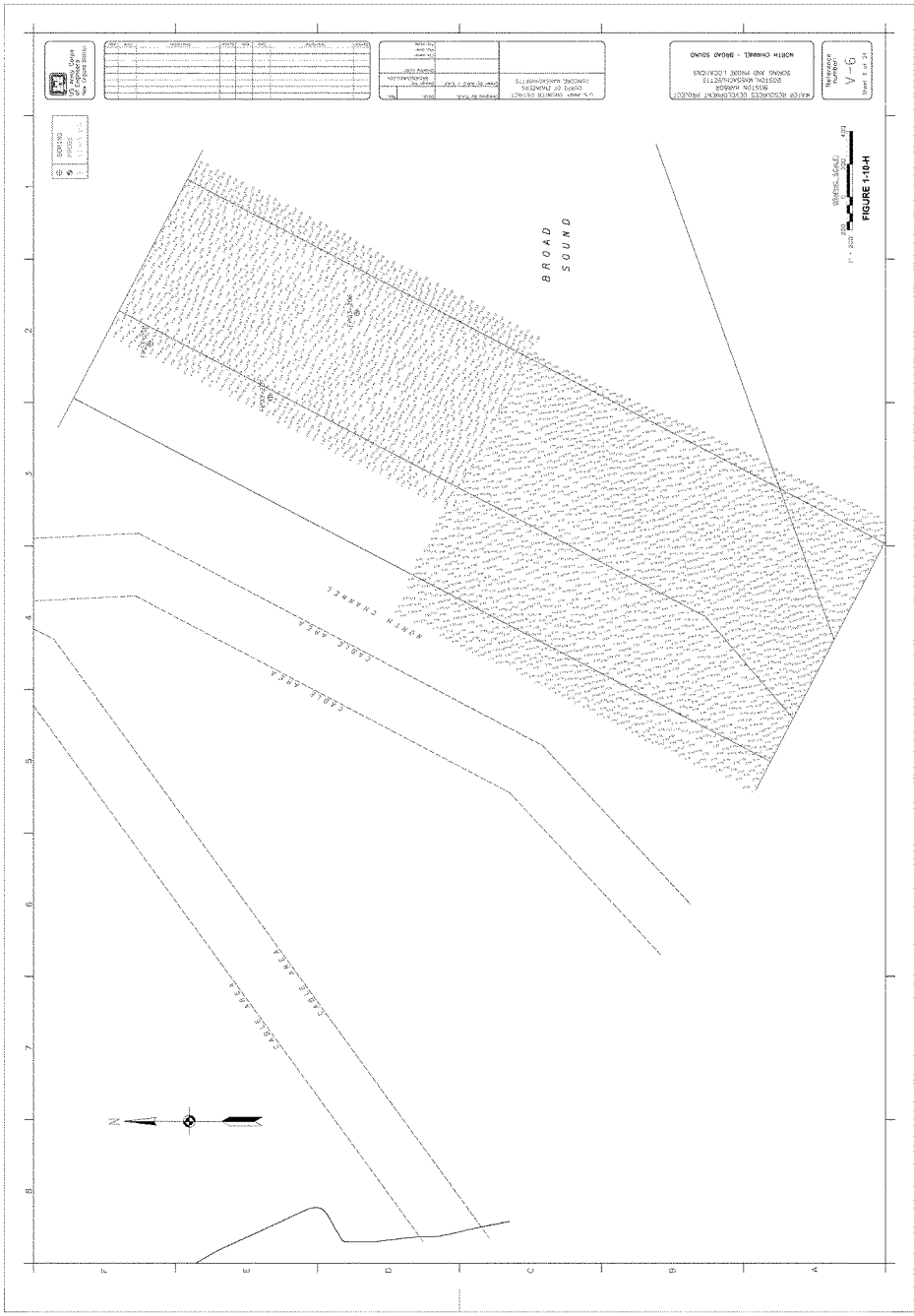

BROAD SOUND
NORTH CHANNEL
FIGURE 1-1b-C

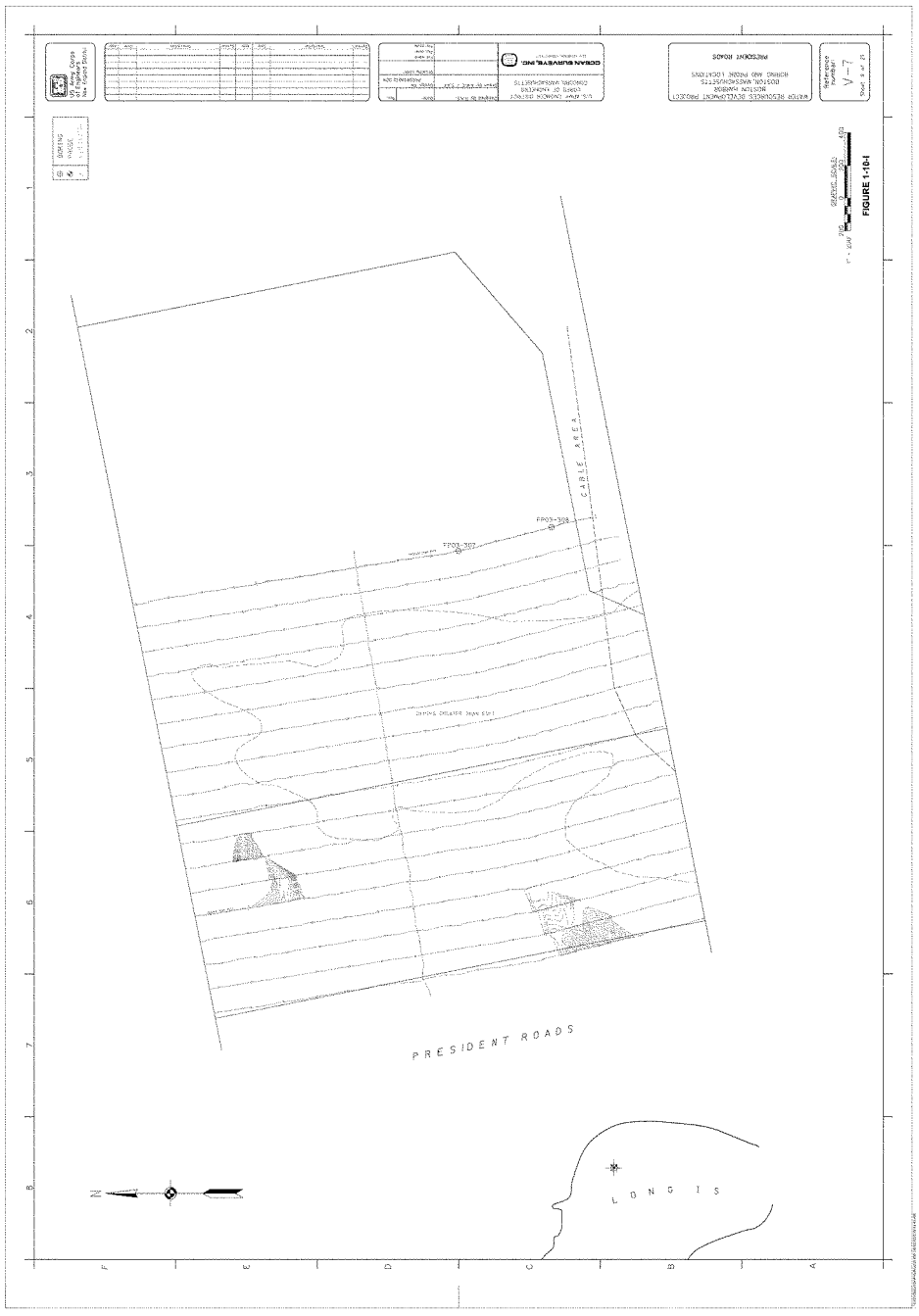

BROAD
SOUND
NORTH CHANNEL
SEWER LINE
FIGURE 1-10-D
NORTH CHANNEL - BROAD SOUND
BOSTON HARBOR
N

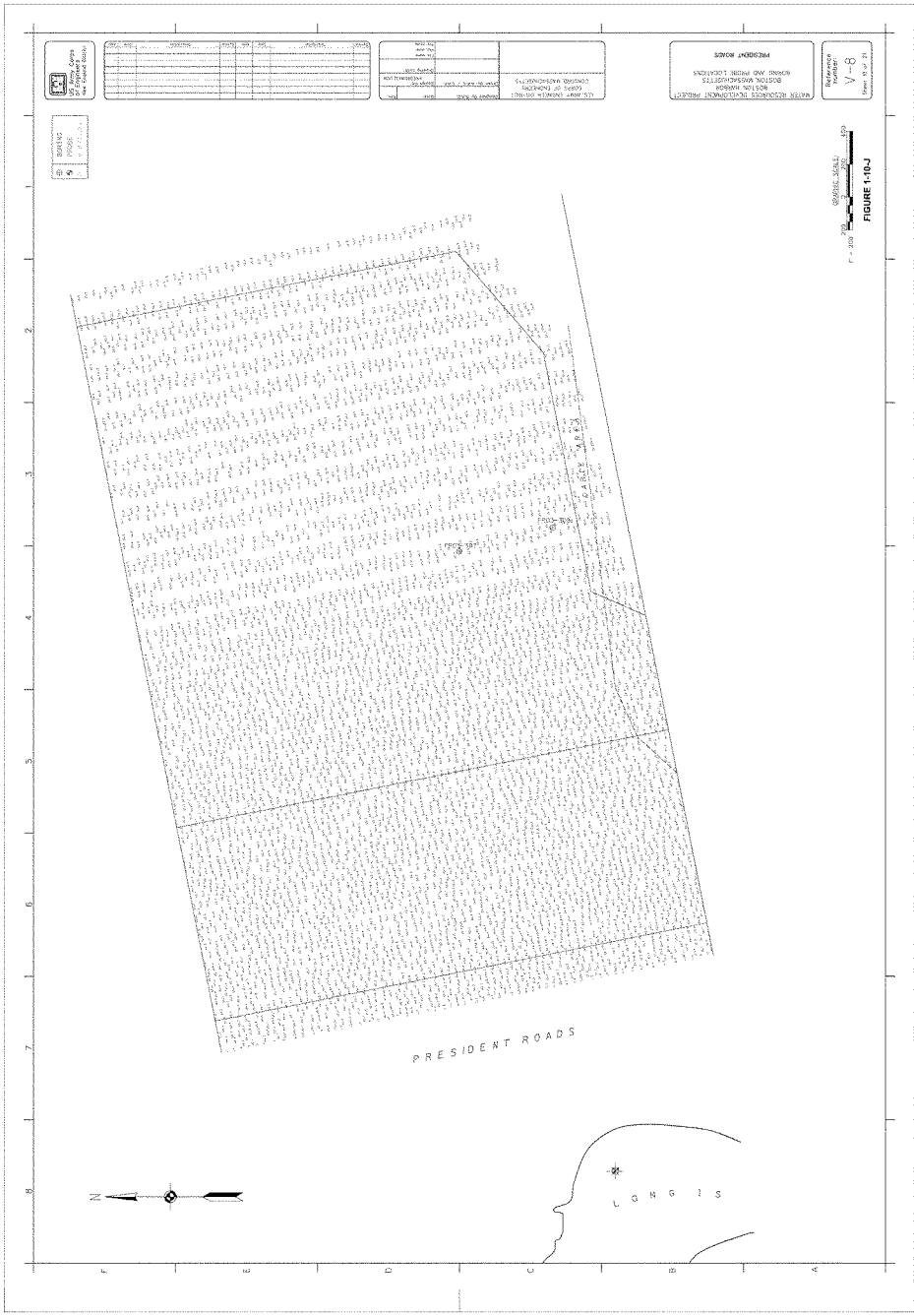

BROAD SOUND
NORTH CHANNEL
SEWER LINE
CABLE AREA
ANCHORAGE AREA
NORTH CHANNEL - BROAD SOUND
OCEAN SURVEYS, INC.
FIGURE 1-10-E

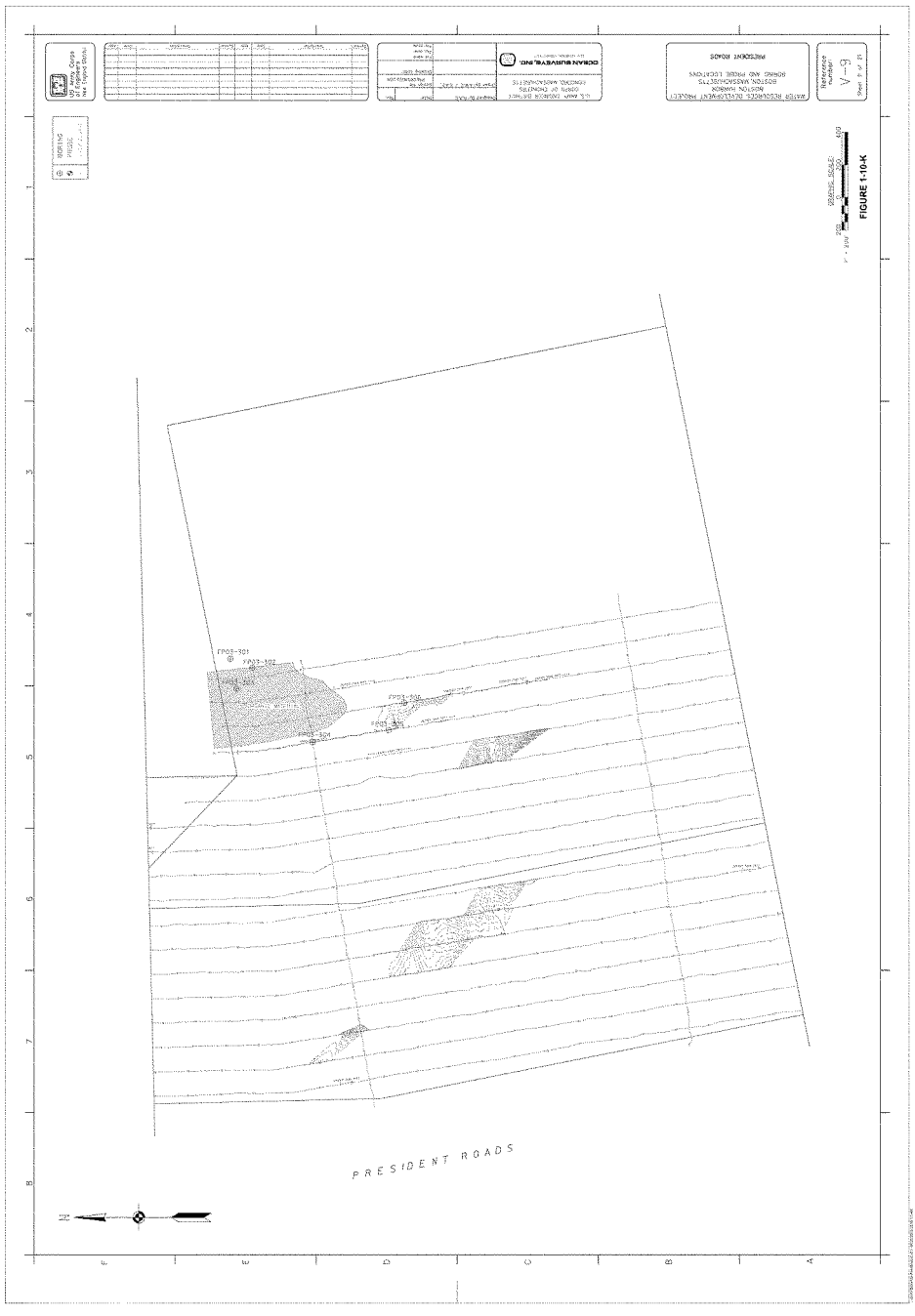

BROAD
SOUND
NORTH CHANNEL
CABLE AREA
CABLE AREA
FIGURE 1-10-F

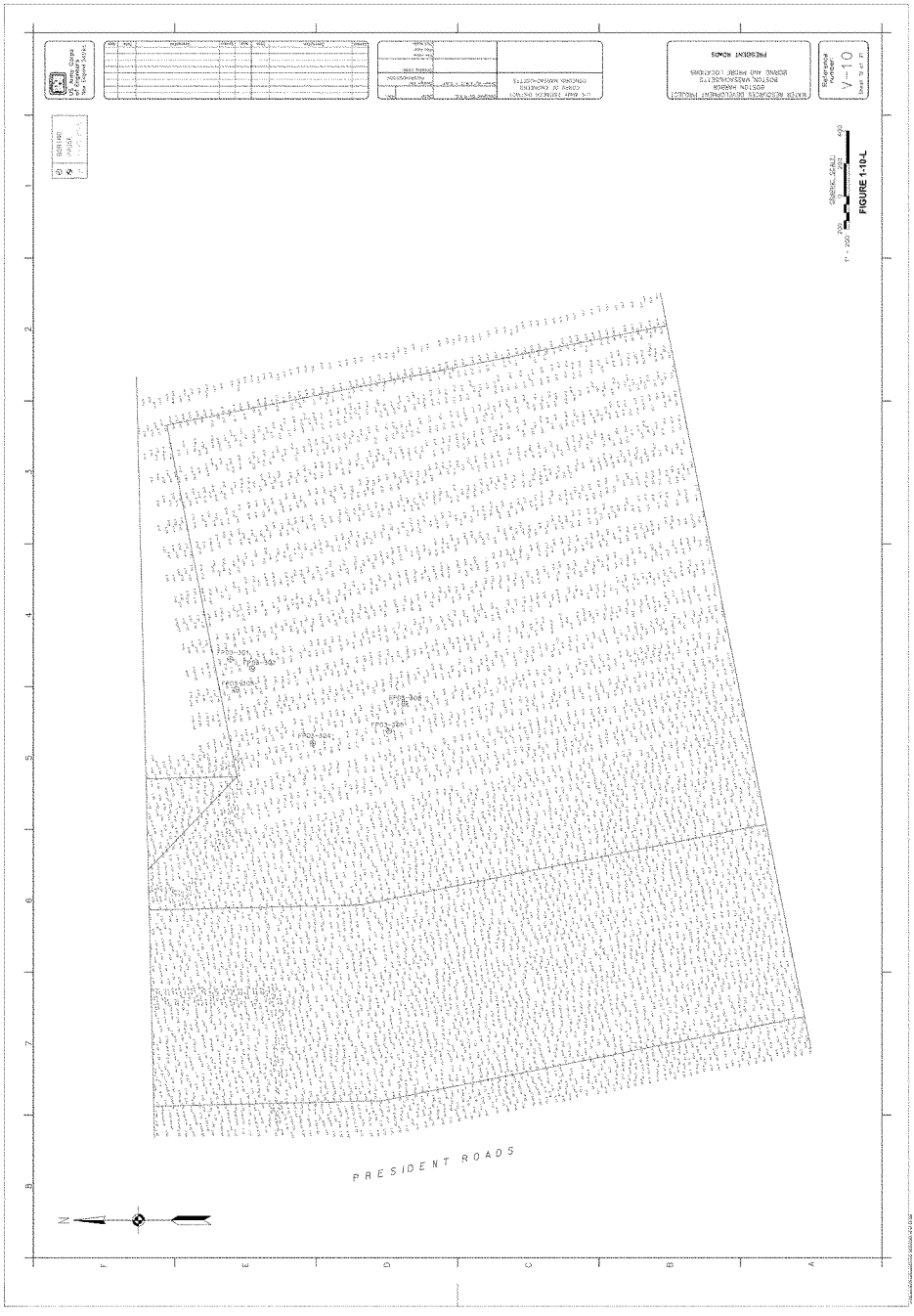

BROAD SOUND
NORTH CHANNEL
CABLE AREA
CABLE AREA
CABLE AREA
CABLE AREA
N
NORTH CHANNEL - BROAD SOUND
OCEAN SURVEYS, INC.
Old Saybrook, Connecticut
Reference
V-5
Sheet 1 of 1
FIGURE 1-10-G

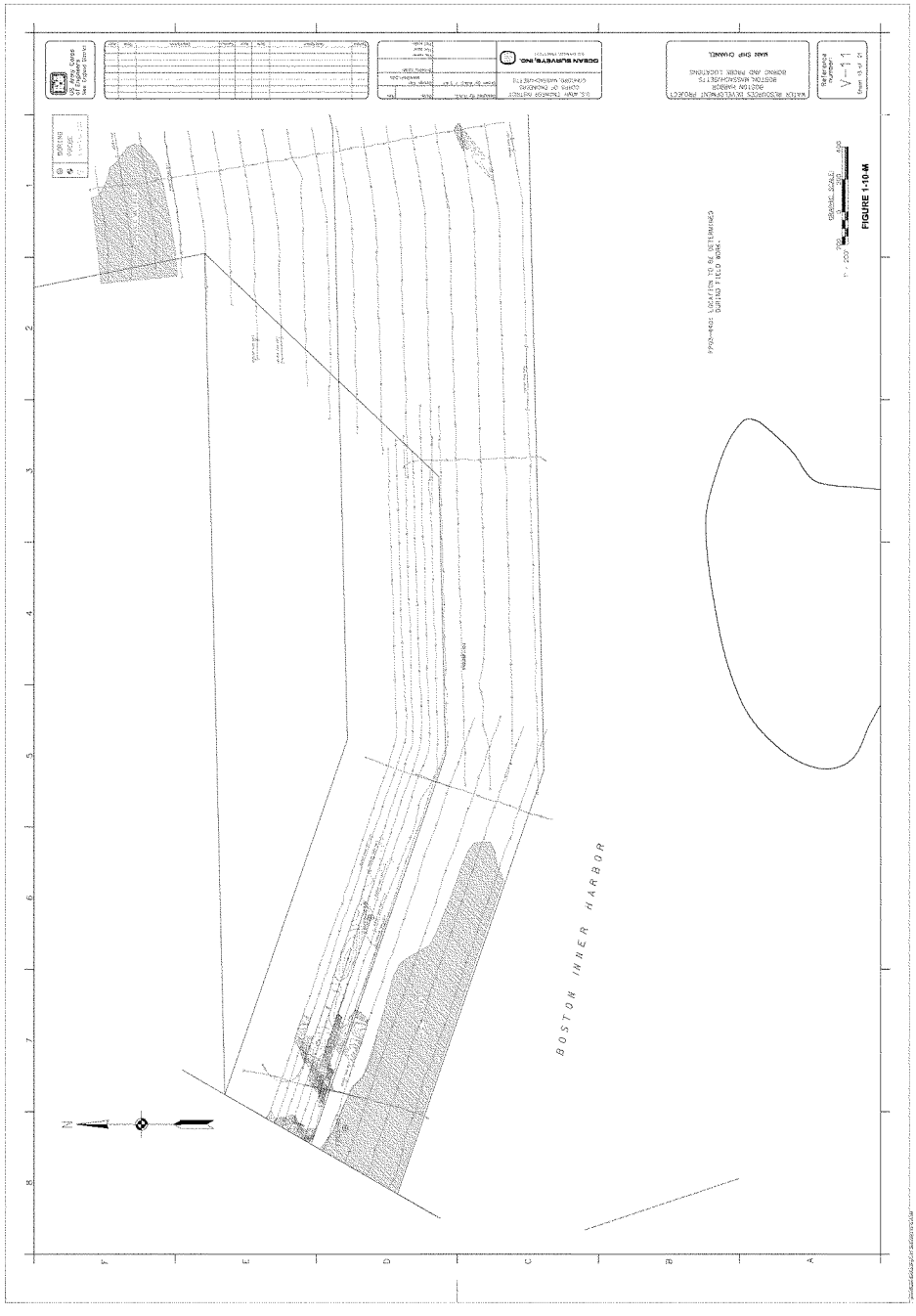

BROAD SOUND
NORTH CHANNEL
CABLE AREA
CABLE AREA
CABLE AREA
NORTH CHANNEL - BROAD SOUND
FIGURE 1-10-H

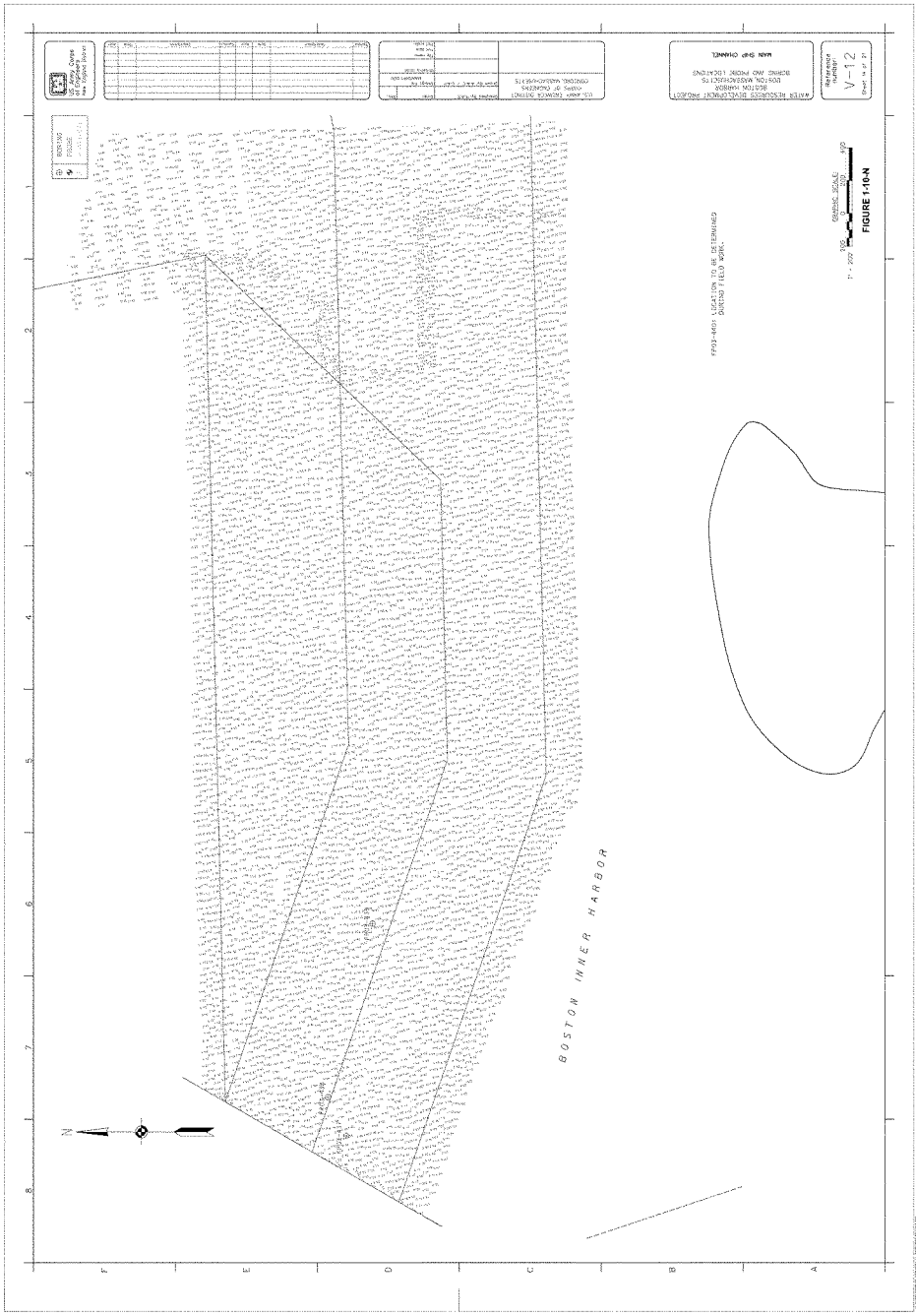

CABLE AREA
FPO1-302
FPO1-303
PRESIDENT ROADS
LONGIS
FIGURE 1-16-1


PRESIDENT ROADS
LONGIS
FIGURE 1-10-J


PRESIDENT ROADS
FIGURE 1-10-K


PRESIDENT ROADS
FIGURE 1-10-L


BOSTON INNER HARBOR
FIGURE 1-10-M


BOSTON INNER HARBOR
FIGURE 1-10-N

BOSTON INNER HARBOR
CABLE AREA
CABLE AREA
FIGURE 1-10-0

BOSTON INNER HARBOR
CABLE AREA
CABLE AREA
SPUD ZONE
ANCHORAGE
FIGURE 1-10-P

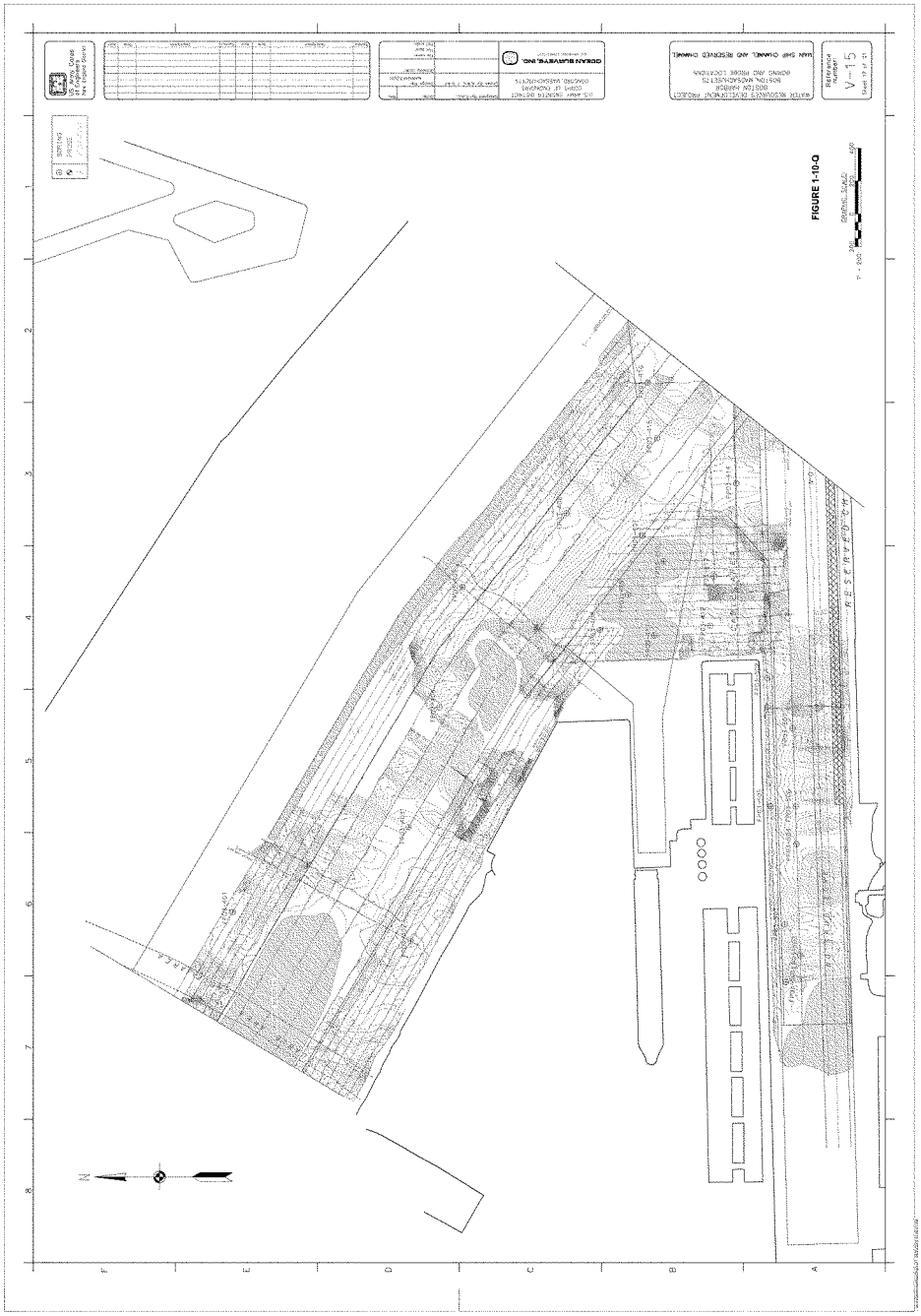


FIGURE 1-10-Q
OCEAN SURVEYS, INC.
U.S. Army Corps of Engineers New England District
Reference
V-15
Sheet 15 of 17
BOSTON HARBOR
MASSACHUSETTS
OCEAN SURVEYS, INC.
U.S. ARMY CORPS OF ENGINEERS
NEW ENGLAND DISTRICT
SOUNDING
SURVEY
SCALE 1" = 400'
Nautical Scale
1" = 400'
400
200
0
400
800
1200
1600
2000
2400
2800
3200
3600
4000
4400
4800
5200
5600
6000
6400
6800
7200
7600
8000
8400
8800
9200
9600
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14400
14800
15200
15600

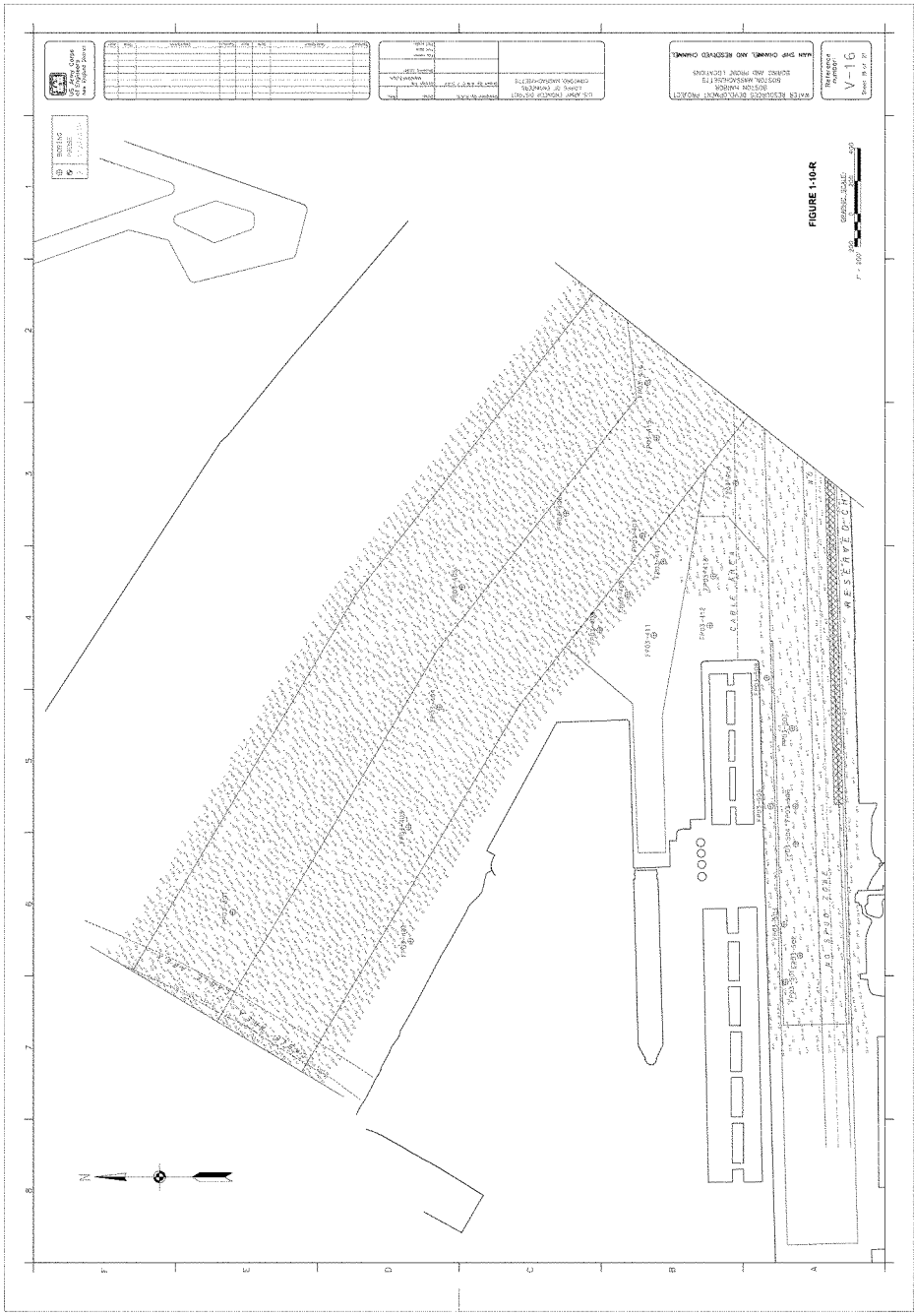
FIGURE 1-16-R
MAIN SHIP CHANNEL AND RESERVED CHANNEL
BOSTON HARBOR
BOSTON, MASSACHUSETTS
BOSTON HARBOR PROJECT
BOSTON MAP PROJECT LOCATIONS
U.S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
V-16
GRAPHIC SCALE
1" = 1000'
RESERVED CHANNEL
CABLE AREA
MAIN SHIP CHANNEL
ANCHORAGE AREA
FIXED BUOY
FIXED LIGHT
FIXED BEACON
FIXED DAYBEACON
FIXED LIGHT AND BELL
FIXED LIGHT AND HORN
FIXED LIGHT AND WHISTLE
FIXED LIGHT AND RACON
FIXED LIGHT AND FOG SIGNAL
FIXED LIGHT AND RADIO BEACON
FIXED LIGHT AND SIREN
FIXED LIGHT AND SIREN AND RACON
FIXED LIGHT AND SIREN AND FOG SIGNAL
FIXED LIGHT AND SIREN AND RADIO BEACON
FIXED LIGHT AND SIREN AND RACON AND FOG SIGNAL
FIXED LIGHT AND SIREN AND RACON AND RADIO BEACON
FIXED LIGHT AND SIREN AND RACON AND FOG SIGNAL AND RADIO BEACON
FIXED LIGHT AND SIREN AND RACON AND FOG SIGNAL AND RADIO BEACON AND HORN
FIXED LIGHT AND SIREN AND RACON AND FOG SIGNAL AND RADIO BEACON AND HORN AND WHISTLE
FIXED LIGHT AND SIREN AND RACON AND FOG SIGNAL AND RADIO BEACON AND HORN AND WHISTLE AND BELL
FIXED LIGHT AND SIREN AND RACON AND FOG SIGNAL AND RADIO BEACON AND HORN AND WHISTLE AND BELL AND SIREN
FIXED LIGHT AND SIREN AND RACON AND FOG SIGNAL AND RADIO BEACON AND HORN AND WHISTLE AND BELL AND SIREN AND RACON
FIXED LIGHT AND SIREN AND RACON AND FOG SIGNAL AND RADIO BEACON AND HORN AND WHISTLE AND BELL AND SIREN AND RACON AND FOG SIGNAL
FIXED LIGHT AND SIREN AND RACON AND FOG SIGNAL AND RADIO BEACON AND HORN AND WHISTLE AND BELL AND SIREN AND RACON AND FOG SIGNAL AND RADIO BEACON
FIXED LIGHT AND SIREN AND RACON AND FOG SIGNAL AND RADIO BEACON AND HORN AND WHISTLE AND BELL AND SIREN AND RACON AND FOG SIGNAL AND RADIO BEACON AND HORN
FIXED LIGHT AND SIREN AND RACON AND FOG SIGNAL AND RADIO BEACON AND HORN AND WHISTLE AND BELL AND SIREN AND RACON AND FOG SIGNAL AND RADIO BEACON AND HORN AND WHISTLE
FIXED LIGHT AND SIREN AND RACON AND FOG SIGNAL AND RADIO BEACON AND HORN AND WHISTLE AND BELL AND SIREN AND RACON AND FOG SIGNAL AND RADIO BEACON AND HORN AND WHISTLE AND BELL
FIXED LIGHT AND SIREN AND RACON AND FOG SIGNAL AND RADIO BEACON AND HORN AND WHISTLE AND BELL AND SIREN AND RACON AND FOG SIGNAL AND RADIO BEACON AND HORN AND WHISTLE AND BELL AND SIREN
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FIXED LIGHT AND SIREN AND RACON AND FOG SIGNAL AND RADIO BEACON AND HORN AND WHISTLE AND BELL AND SIREN AND RACON AND FOG SIGNAL AND RADIO BEACON AND HORN AND WHISTLE AND BELL AND SIREN AND RACON AND FOG SIGNAL
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FIXED LIGHT AND SIREN AND RACON AND FOG SIGNAL AND RADIO BEACON AND HORN AND WHISTLE AND BELL AND SIREN AND RACON AND FOG SIGNAL AND RADIO BEACON AND HORN AND WHISTLE AND BELL AND SIREN AND RACON AND FOG SIGNAL AND RADIO BEACON AND HORN
FIXED LIGHT AND SIREN AND RACON AND FOG SIGNAL AND RADIO BEACON AND HORN AND WHISTLE AND BELL AND SIREN AND RACON AND FOG SIGNAL AND RADIO BEACON AND HORN AND WHISTLE AND BELL AND SIREN AND RACON AND FOG SIGNAL AND RADIO BEACON AND HORN AND WHISTLE
FIXED LIGHT AND SIREN AND RACON AND FOG SIGNAL AND RADIO BEACON AND HORN AND WHISTLE AND BELL AND SIREN AND RACON AND FOG SIGNAL AND RADIO BEACON AND HORN AND WHISTLE AND BELL AND SIREN AND RACON AND FOG SIGNAL AND RADIO BEACON AND HORN AND WHISTLE AND BELL
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FIXED LIGHT AND SIREN AND RACON AND FOG SIGNAL AND RADIO BEACON AND HORN AND WHISTLE AND BELL AND SIREN AND RACON AND FOG SIGNAL AND RADIO BEACON AND HORN AND WHISTLE AND BELL AND SIREN AND RACON AND FOG SIGNAL AND RADIO BEACON AND HORN AND WHISTLE AND BELL AND SIREN AND RACON
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FIXED LIGHT AND SIREN AND RACON AND FOG SIGNAL AND RADIO BEACON AND HORN AND WHISTLE AND BELL AND SIREN AND RACON AND FOG SIGNAL AND RADIO BEACON AND HORN AND WHISTLE AND BELL AND SIREN AND RACON AND FOG SIGNAL AND RADIO BEACON AND HORN AND WHISTLE AND BELL AND SIREN AND RACON AND FOG SIGNAL AND RADIO BEACON

FIGURE 1-10-S
GRAPHIC SCALE
1" = 600'
0
300
600
1200
OCEAN SURVEYS, INC.
Old Saybrook, Connecticut
U.S. NAVY SONDAR SURVEY
CHARLES RIVER
BOSTON HARBOR
MASSACHUSETTS
SHOWING AREA FROM LOCATIONS
WATER RIVER
Reference
Plan
V-1-7
Sheet 8 of 31
Approved
Date
Scale
Drawn
Checked
Traced
Date
Revised
Description
By
Check

FIGURE 1-10-T
GRAPHIC SCALE
1" = 100'
0
100
200
MYSTIC RIVER
V-18
BORING
PIPE
FP03-602
FP03-603
FP03-604
FP03-605
FP03-606
FP03-607
FP03-608
FP03-609
F
E
D
C
B
A

FIGURE 1-10-U
CHELSEA RIVER
EXISTING PIERS
1" = 200'
GRAPHIC SCALE
200
0
400

GEI Consultants, Inc. 1021 Main Street Winchester, MA 01890	Project: Boston Harbor Feasibility Study Location: Boston, MA	Boring No.: FD03-701

Client:	U.S. Army Corp of Engineers	**Boring Location:**	N 508,555.77 ft E 730,602.45 ft	**Drilling Method:**	CWB
Driller:	Geologic	**Mud Line Elevation (ft.):**	-43.5	**Casing ID/OD:**	HW 4"/4.5"
Operator:	T. Tucker	**Datum:**	MLLW	**Sampler:**	2-1/2" I.D. Split Spoon
Logged By:	S. DiBartolo	**Total Depth (ft.):**	5.2	**Hammer Wt./Fall:**	300#/ 30"
Date Start/Finish:	9/24/03-9/24/03	**Water Level:**	Standing Water		

ABBREVIATIONS:
S = Split Spoon Sample; A = Auger Sample; U = Thin Wall Tube Sample; C = Rock Core Sample; NX,BX = Rock Coring; n/a,n/m = not Applicable, not Measured
HSA = Hollow Stem Auger Boring; SSA = Solid Stem Auger Boring; CWB = Cased Wash Boring; Open = Open Hole Boring; Pen. = Penetration length; Rec. = Recovery Length
WOC = weight of casing; WOR = weight of rods; WOH = weight of 300lb. hammer; RQD = Rock Quality Designation
S_u = Insitu Field Vane Shear Strength (psf); $S_{u(lab)}$ = Lab Vane Shear Strength (psf); S_v = Pocket Torvane Shear Strength (tsf); Q_p = Pocket Penetrometer Unconfined Compressive Strength (tsf)

Elevation (ft.)	Casing Blows (/1 ft.)	Depth (ft.)	Sample No.	Pen./Rec. (in.)	Sample Depth (ft.)	Blows (/6 in.) Shear Strength (psf) or ROD (%)	N-value	Top Elevation (ft.)	Water Level*	Graphic Log	USCS Visual Descriptions and Remarks	Stratum
		0										
-45	24		S1	24/14	0.0 - 2.0	8-12-16-20	30				S1 (0-2") - ORGANIC SEDIMENT (OL); mostly homogeneous, nonplastic, organic fines; <5% fine sand; slight organic odor; black to dark gray.	ORGANIC SEDIMENT
	26										---0.3 FEET/ EL -43.8 FEET---	
			S2	24/21	2.0 - 4.0	15-15-21-25	36	-45.5			S1 (2-14") - GRAVELLY CLAY (CL); mostly medium plastic clay; ≅30-35% fine to coarse, subangular to angular gravel, max size ≅2"; ≅5-10% fine to coarse sand; gray. S2 - GRAVELLY CLAY (CL); Similar to S1 (2-14"); except finer gravel @ 12-21".	GLACIAL TILL
		5	S3	14/12	4.0 - 5.2	11-35-100/2"	135/8"	-47.5			S3 - GRAVELLY CLAY (CL); Similar to S1 (2-14"); except max size ≅1-1/4".	
-50								-48.7			BOTTOM OF BOREHOLE, 5.2 FEET/ EL. -48.7 FEET.	
		10										
-55												
		15										
-60												
		20										
-65												
		25										
-70												

Remarks:

US State Plane, NAD27, Massachusetts Mainland Zone.
11.5' Tide Gage Reading @ 1150 hrs(-2.7' Tidal Bench-Mark difference).
7.5' Freeboard with 59.8' to Mud Line.

Stratification lines represent approximate boundaries between soil types; transitions may be gradual.

Page 1 of 1

Project No.: 03176-0

GEI Consultants, Inc. 1021 Main Street Winchester, MA 01890	Project:	Boston Harbor Feasibility Study	Boring No.:	FD03-701A
	Location:	Boston, MA		

Client:	U.S. Army Corp of Engineers	Boring Location:	N 508,562.69 ft E 730,597.26 ft	Drilling Method:	CWB
Driller:	Geologic	Mud Line Elevation (ft.):	-43.8	Casing ID/OD:	HW 4"/4.5"
Operator:	T. Tucker	Datum:	MLLW	Sampler:	N/A
Logged By:	S. DiBartolo	Total Depth (ft.):	13.1	Hammer Wt./Fall:	300#/ 30"
Date Start/Finish:	9/25/03-9/24/03	Water Level:	Standing Water		

ABBREVIATIONS:
S = Split Spoon Sample; A = Auger Sample; U = Thin Wall Tube Sample; C = Rock Core Sample; NX,BX = Rock Coring; n/a,n/m = not Applicable, not Measured
HSA = Hollow Stem Auger Boring; SSA = Solid Stem Auger Boring; CWB = Cased Wash Boring; Open = Open Hole Boring; Pen. = Penetration length; Rec. = Recovery Length
WOC = weight of casing; WOR = weight of rods; WOH = weight of 300lb. hammer; RQD = Rock Quality Designation
S_u = Insitu Field Vane Shear Strength (psf); $S_{u(lab)}$ = Lab Vane Shear Strength (psf); S_v = Pocket Torvane Shear Strength (tsf); Q_p = Pocket Penetrometer Unconfined Compressive Strength (tsf)

Elevation (ft.)	Casing Blows (/1 ft.)	Depth (ft.)	Sample Information: Sample No.	Pen./Rec. (in.)	Sample Depth (ft.)	Blows (/6 in.) Shear Strength (psf) or RQD (%)	N-value	Top Elevation (ft.)	Water Level*	Graphic Log	USCS Visual Descriptions and Remarks	Stratum
-45	WOC/	0									Note: No Sampling 0-8.1 ft. Casing to 8.1 ft. Roller-bit to Refusal @ 8.1 ft.	
	PUSH											
	PUSH											
	PUSH											
	PUSH											
	PUSH	5										
-50	27											
	30											
	40											
	80/0.1'		C1	60/60	8.1 - 13.1	RQD = 25%	25%	-51.9			**8.1 FEET/ El. -51.9 FEET** C1 - PINK GRANITE; very hard; igneous; slightly weathered to unweathered; fractured throughout @ close spacing, with rust-coloring in most joints; pink with rust-coloring, some spots with green coloring; RQD = 25%.	BEDROCK
-55		10										
								-56.9			BOTTOM OF BOREHOLE, 13.1 FEET/ EL. -56.9 FEET.	
		15										
-60												
		20										
-65												
		25										
-70												

Remarks:

US State Plane, NAD27, Massachusetts Mainland Zone.
13.0' Tide Gage Reading @ 1206 hrs(-2.7' Tidal Bench-Mark difference).
7.5' Freeboard with 61.6' to Mud Line.

Stratification lines represent approximate boundaries between soil types; transitions may be gradual.

Page 1 of 1

Project No.: 03176-0

BOSTON HARBOR
MASSACHUSETTS

NAVIGATION IMPROVEMENT STUDY
FINAL FEASIBILITY REPORT
AND FINAL SUPPLEMENTAL
ENVIRONMENTAL IMPACT STATEMENT
(AND MASSACHUSETTS FINAL EIR)

APPENDIX J

GEOPHYSICAL INVESTIGATIONS

(THIS APPENDIX UNCHANGED FROM 2008 DRAFT)

Battelle
. . . Putting Technology To Work

Duxbury Operations
397 Washington Street
Duxbury, Massachusetts 02332
Telephone 781-934-0571
Fax: 781-934-2124

June 9, 2003

Mark Habel
Chief Engineering/Planning Division
U.S. Army Corps of Engineers
New England District
696 Virginia Rd.
Concord, MA 01742-2751

CONTRACT NO. DACW33-01-D-0004
DELIVERY ORDER: 20
SUBMITTAL OF FINAL DELIVERABLE – Geophysical Explorations: Remote Sensing Archaeological Survey and Geologic Interpretation Boston Harbor Navigation Improvement Study Boston, Massachusetts.

Dear Mr. Habel:

Enclosed please find twelve (12) copies of the Final Report for Delivery Order 20, the ***Geophysical Explorations: Remote Sensing Archaeological Survey and Geologic Interpretation Boston Harbor Navigation Improvement Study Boston, Massachusetts.*** The Geologic Interpretation and Archaeological Findings are bound separately (12 copies each). Also enclosed are separate CDs containing electronic versions of the geophysical and archaeological reports, 45 CDs containing all raw data from the surveys, and 4 full-scale charts of acoustic basement contouring. This is the final deliverable to be submitted under Delivery Order 20. This document has been reviewed by a Battelle senior scientist for technical accuracy.

Please call Alex Mansfield at (781) 934-0571 if you have any technical questions regarding this submittal. Refer all contractual questions to Mr. David Sullivan at the same number.

Sincerely,

Alex Mansfield
Project Leader

Karen Foster
Program Manager

Encl
- 12 copies Final Geophysical Report
- 1 CD containing electronic copies of the Final Geophysical Report
- 45 CDs containing the raw survey data
- 4 Full size contouring maps
- 12 copies Final Archaeology Report
- 1 CD containing electronic copies of the Final Archaeology Report

FINAL REPORT

Geophysical Explorations:
Remote Sensing Archaeological Survey
and Geologic Interpretation
Boston Harbor Navigation Improvement Study
Boston, Massachusetts

OSI REPORT NO. 02ES066

Prepared For: Battelle Memorial Institute
397 Washington Street
Duxbury, MA 02322

Prepared By: Ocean Surveys, Inc.
91 Sheffield St.
Old Saybrook, CT 06475

21 May 2003

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Addendum

Subbottom Interpretation and Acoustic Basement Contours

FIGURES

Figure #	Title
1	Location Map of Survey Areas
2	Idealized Stratigraphic Column Underlying Boston Harbor
3	Main Survey Area and Tracklines
4	Mystic River Survey Area and Tracklines
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FINAL REPORT

GEOPHYSICAL EXPLORATIONS: REMOTE SENSING ARCHAEOLOGICAL SURVEY AND GEOLOGIC INTERPRETATIONS BOSTON HARBOR NAVIGATION IMPROVEMENT STUDY BOSTON, MASSACHUSETTS

1.0 INTRODUCTION

During the periods 24 September to 8 October 2002 and 6-9 February 2003, Ocean Surveys, Inc. (OSI) conducted marine remote sensing investigations in Boston Harbor (Figure 1). Survey operations were performed within the federal channel limits from approximately Pier 6 just west of the Reserve Channel out to the easternmost end of the North Channel near Finns Ledge. The survey area included the Reserve Channel and its turning area, as well as Anchorage No. 2 in President Roads. A small site in the Mystic River was also surveyed. The investigation was undertaken as part of the proposed Navigation Improvement Study for Boston Harbor, with intentions of deepening the main shipping channel. The survey was conducted in conjunction with UMass Archaeological Services, the group responsible for the marine archaeological assessments for the project.

Objectives of the investigation include (1) the identification of acoustic targets and magnetic anomalies in support of a marine archaeological assessment and (2) the delineation of areas possibly containing shallow bedrock and coarse glacial till that might adversely affect dredging operations. The surveys were performed under contract to Battelle Memorial Institute (BMI) for the U.S. Army Corps of Engineers, New England District (NED).

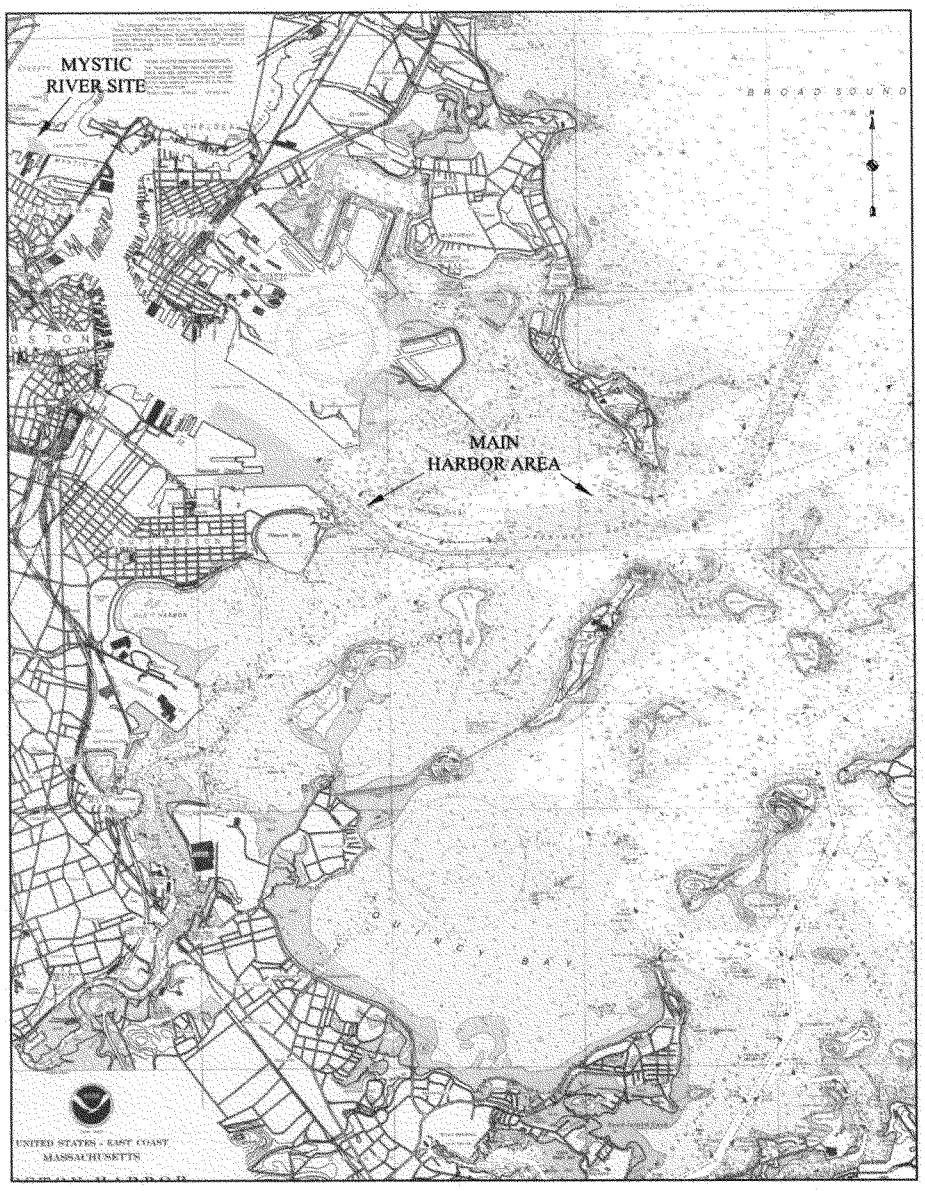

Figure 1. Location map.

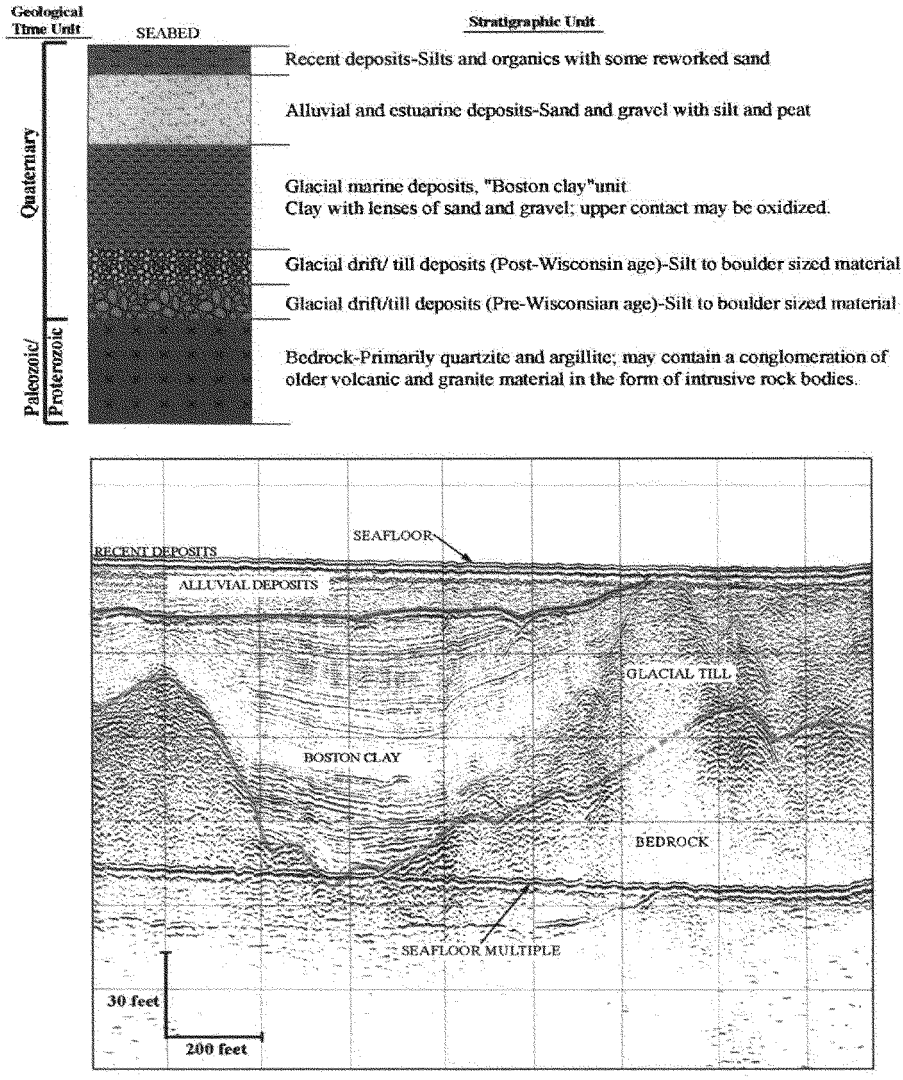

Figure 2. Idealized geologic cross section representing the marine stratigraphic framework that exists in the Boston Harbor area (upper), and the corresponding seismic returns that characterize each of the stratigraphic units (lower).

1.1 Project Tasks

The following tasks were completed to meet the objectives listed above. The NED provided tide corrected water depths throughout the areas so OSI was not required to collect hydrographic data, therefore no additional vertical control or tide recording was required for this project.

- **Side Scan Sonar Surveys** to identify geomorphologic variations and natural and man made objects on the bottom
- **Subbottom Profile Surveys** to delineate subsurface stratigraphy and estimate depth to bedrock within 10-20 feet of the channel bottom
- **Marine Magnetometer Surveys** to map the overall magnetic field gradient caused by the earth and local ferrous materials on or below the bottom
- **Sediment Grab Samples** to acquire representative samples of bottom sediments for ground truthing acoustic data

2.0 REGIONAL GEOLOGY

Boston Harbor, with its associated islands, is a glacially carved estuary that lies within a fault-bounded structural basin known as the Boston basin. The bedrock, which forms the foundation of the harbor, is a complex suite of granites and volcanic and sedimentary rocks formed primarily during the Proterozoic (late PreCambrian) nearly 570 million years BP (before present). The Cambridge Argillite (gray argillite and minor quartzite, rare sandstone and conglomerate) forms the uppermost rock unit in the area covered by this investigation.

Block faulting and volcanism which occurred during the Proterozoic, created the Boston Basin into which non-marine clastic type sediments, eroded from the surrounding highland areas, were deposited. Additional deformation of the area occurred during late Paleozoic and Mesozoic time as faults in the basin were reactivated. The Cretaceous and early Tertiary were

marked by deposition of nearshore coastal plain type materials into the basin. During the late Tertiary, in response to a worldwide low stand of sea level, the area was subaerially exposed and eroded. This period of erosion may have cut unconformities atop the bedrock and coastal plain deposits.

The Quaternary history of the Boston Harbor has involved multiple glaciations, isostatic crustal movement, and sea level change. During the Pleistocene, glaciers scoured the bedrock in the study area and deposited drift of two different ages. The older drift sequence, pre-Wisconsin in age and locally known as drumlin till, unconformably overlies most all of the scoured and eroded bedrock in the harbor and forms the majority of the harbor islands. Deeply weathered with occasional boulders, this sequence primarily consists of a compact, surface-oxidized till with locally stratified deposits of gravel, sand, and silt. In some places the top of the drumlin till forms the acoustic basement (maximum depth of subbottom penetration) due to the abundance of coarse material in these deposits.

Unconformably overlying the older drumlin till drift sequence is a younger post-Wisconsin drift sequence. The younger till sequence varies greatly in degree of sorting and stratification and is composed primarily of till, subaqueous outwash, ice-contact sand and gravel. In the Boston area, ice retreat and marine submergence occurred simultaneously following the period of Wisconsin glaciation and this younger drift sequence was deposited directly into the sea as eustatic sea level rose.

Immediately overlying the younger drift sequence is a glacial-marine unit composed primarily of stiff, bluish-gray to olive gray silty-clay, commonly referred to as "Boston Clay". The source of the fine grained sediments which comprise the Boston Clay unit are believed to be rock-flour-laden meltwater that was discharged directly into the sea via the retreating Wisconsin glacier and subaerial streams fed by the melting glacier. The layered and draped character of the unit suggests that it was deposited rapidly with little disturbance from physical or biological processes. Scattered lenses of sand, gravelly sediments, and pebbles (generally <

4 inches thick) are common within the unit and are believed to be the result of ice rafting. In many areas, the unit may be oxidized at the top of its section (upper 3-6 feet) due to subsequent subaerial exposure. Further discussion of the recent geological changes, including sea level change is included in theArcheological report submitted under separate cover.

Figure 2, an idealized geological section of the Boston Harbor area, has been constructed to exemplify the stratigraphic framework which has been described above. Included on this figure is a section of seismic reflection profile obtained in Boston Harbor which illustrates the acoustic returns that characterize each of the stratigraphic units described.

3.0 SURVEY AREAS AND CONTROL INFORMATION

3.1 Survey Areas and Tracklines

The main survey area designated for this investigation covers a 6.8 nautical mile length of the federal channel, with varying widths, from Pier 6 eastward past Finns ledge. A total of approximately 200 nautical miles of trackline at a 50 foot spacing were surveyed for this project to cover all the areas including the main shipping channel, Reserve Channel and turning area, Anchorage No. 2 in President Roads (Figure 3), and the Mystic River area (Figure 4). Cross tie lines were also surveyed approximately every 2000 feet through the areas for quality control. Magnetic intensity data were collected on every line while side scan sonar imagery (164 foot sweep range) and subbottom profiles were obtained on every third longitudinal line and the cross tie lines.

Samples of bottom sediments were designated for collection at only 4 locations. These stations were chosen to provide limited ground truthing of different surficial material types interpreted from the side scan sonar data. No geotechnical program was included as part of this investigation, thus there is no verification of subbottom lithologies and depths determined from geophysical interpretation.

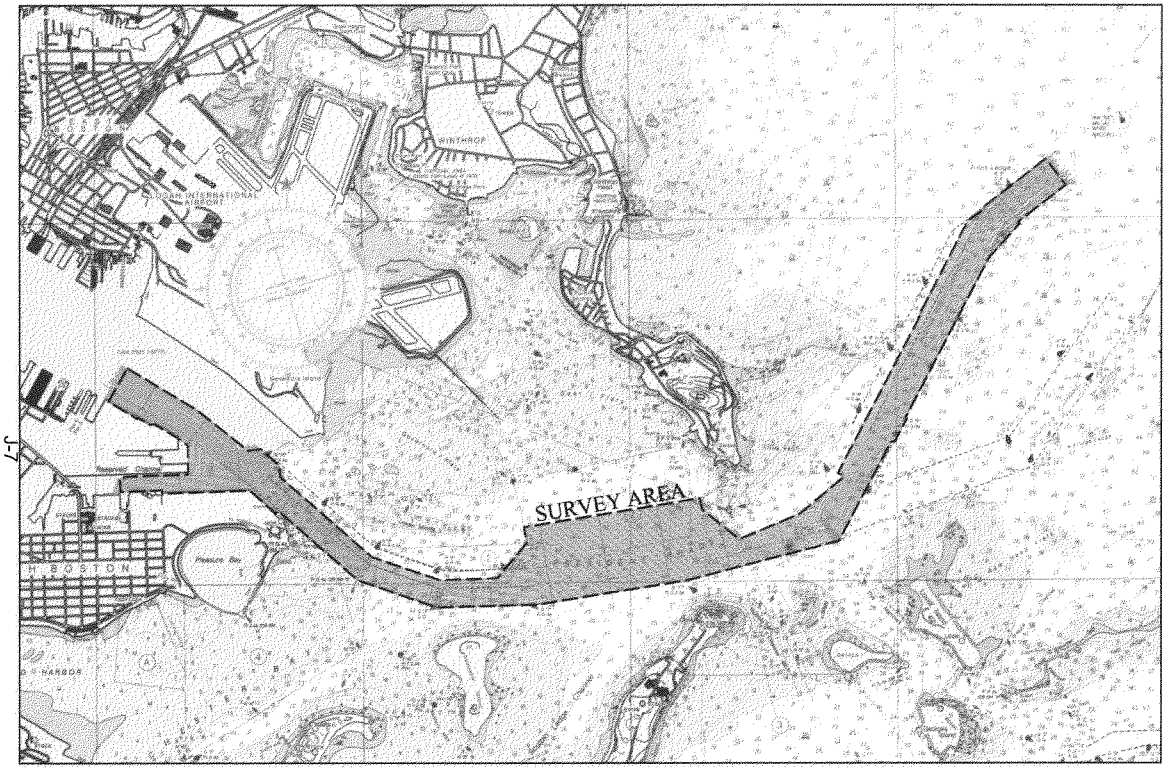

Figure 3. Main harbor tracklines.

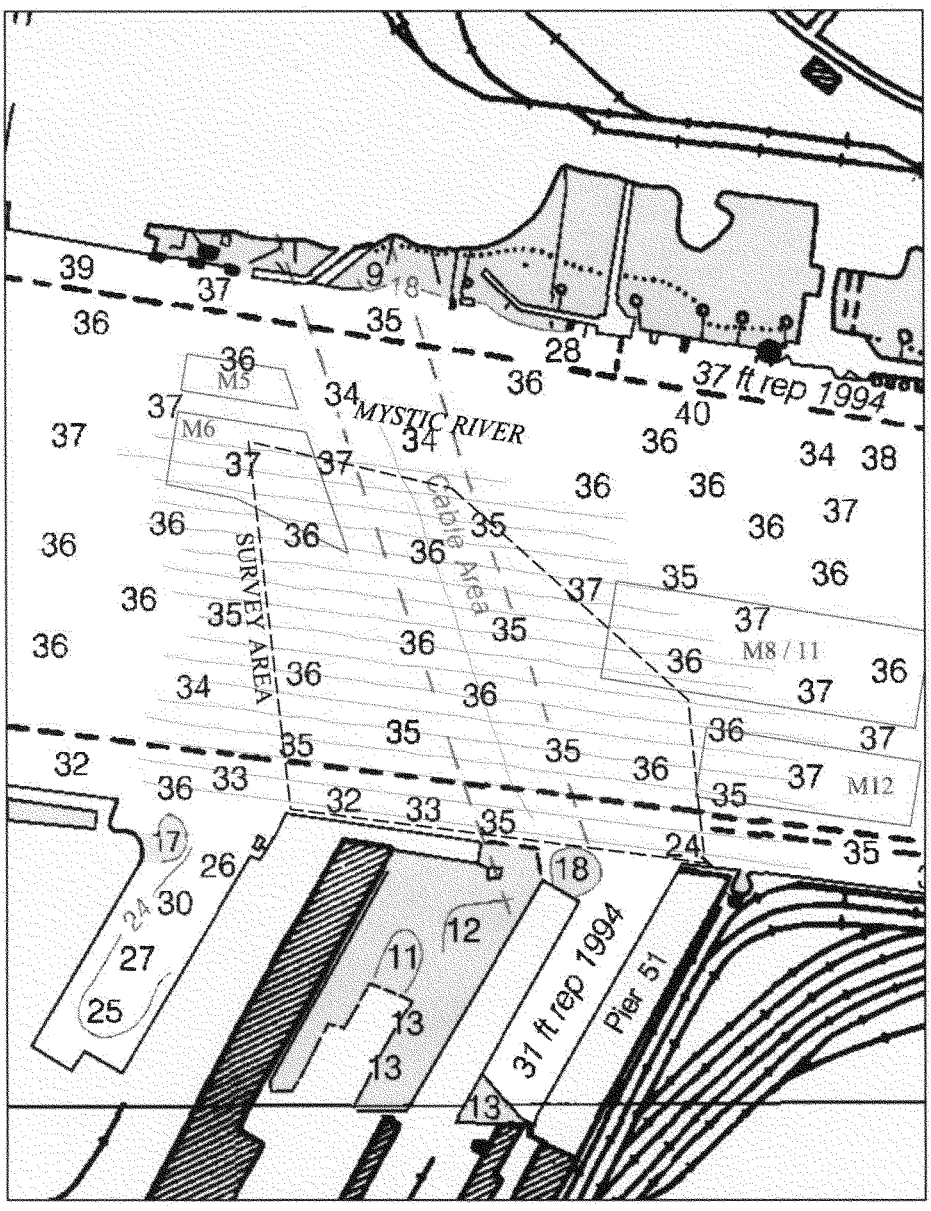

Figure 4. Mystic River site and tracklines (green).

3.2 Horizontal Control

Horizontal positioning of the survey vessel was accomplished by utilizing a Trimble DMS 212 Differential Global Positioning System (DGPS) which calculates geodetic coordinates referenced to the WGS-84 datum (World Geodetic System established in 1984), and equivalent to NAD 83 (North American Datum established in 1983). Differential corrections were received from the U.S. Coast Guard reference beacon at Chatham, Massachusetts (325 kHz @ 200 bps) with good reliability and signal strength. The computer and navigation software utilized aboard the survey vessel converts the geodetic coordinates (latitude-longitude) to state plane coordinates (easting-northing) for navigation while logging these position data at 1 second intervals along survey tracklines. The survey was conducted in the Massachusetts State Plane Coordinate System (Mainland Zone 2001), referenced to NAD 83 with all coordinates in feet. Horizontal coordinates were then converted to Massachusetts State Plane Coordinate System (Mainland Zone 2001), NAD 27. The NAD 27 coordinates are provided in this report and shown on project drawings.

Prior to commencement of the field survey, a navigation check was performed on a known horizontal control point. A survey point located near the Winthrop town boat ramp (on Shirley Street) was recovered and used for this purpose. The Trimble GPS antenna is placed directly over the point to compare measured coordinates on the GPS receiver with the expected coordinates published for the point. Details of the point are listed in the table below. Subsequently, a point was installed at the marina dock that was used to verify system accuracy each day of the survey. These checks show that the positioning equipment was operating properly and delivering the horizontal position accuracy required for this investigation.

Horizontal Control Points

Point	Position *	Description
"500059"	N 498604.29 E 742525.94	PK nail flush with patch of asphalt positioned in the grass surrounding the boat ramp parking lot; point located adjacent to north shore facing the Winthrop Yacht Club.
OSI "NAV"	N 499673 E 742608	Galvanized cleat on the marina dock located directly under GPS antenna; point is located on floating dock at the Crystal Cove Marina in Winthrop, MA

* Coordinates referenced to the Massachusetts State Grid System, Mainland Zone 2001, NAD 27 in feet.

4.0 EQUIPMENT OPERATIONS AND PROCEDURES

The major equipment systems utilized for this investigation are listed below. A complete discussion of this equipment along with the operational procedures employed to collect the data for this project can be found in Appendix D. Specification sheets for all the equipment used can be found in Appendix E.

- Trimble Model DSM 212 Differential Global Positioning System
- Coastal Oceanographic's HYPACK Navigation Software
- EdgeTech GeoStar "Chirp" Subbottom Profiler
- DataSonics SIS1500 Side Scan Sonar System
- Geometrics G-881 Marine Cesium Magnetometer
- WildCo Ponor 9 inch Grab Sampler

Summary of Survey Equipment Operations

Equipment System	Description
Trimble DSM 212 DGPS system	Global positioning system receiver capable of tracking up to 9 satellites simultaneously; contains internal USCG beacon receiver for enhanced positioning accuracy
Coastal Oceanographic's HYPACK navigation computer and software	HYPACK software runs on a Pentium notebook computer providing real time trackline control, digital data logging, and many survey utility functions; this package allows the efficient simultaneous acquisition of data from multiple systems
EdgeTech GeoStar "Chirp" Subbottom Profiler	High frequency 2-16 kHz "Chirp" profiler used for high resolution of nearsurface sediment layering and identification of lithologic structures
DataSonics SIS1500 Side Scan Sonar System	Side scan sonar system providing acoustic imagery of the bottom out to either side of the survey trackline; 200 kHz "chirp" technology provides high resolution images over extended sweep ranges out to 200 meters
Geometrics G-881 Marine Magnetometer	Marine cesium magnetometer used to detect ferrous metal on and below the bottom
WildCo Ponor 9 inch Grab Sampler	Bottom grab sampler for collecting unconsolidated marine sediments

5.0 SUMMARY OF FIELD INVESTIGATIONS

Field investigations for the project took place between the hours of 0700-1700 hours from 24 September to 8 October 2002, and 6-9 February 2003. Seasonable weather conditions with low to moderate sea states were encountered during this time with only one weather day realized during the survey period. Survey production was reduced due to the position of the areas entirely within the main shipping channel of the harbor. Commercial vessel traffic during the week, including complete work stoppages required by the Coast Guard during inbound and outbound LNG tanker transits, as well as increased recreational vessel traffic on the weekends, resulted in reduced survey time on most days. The following table details the work completed during these periods with individual daily logsheets included in Appendix B.

Remote Sensing Investigation

Task	Date	Description
Mobilization	22-23 September 2002	Outfit survey vessel with geophysical equipment
Operations	24 September	Transit from Old Saybrook, CT to Winthrop, MA; launch vessel, check navigation, test gear
	25 September to 4 October	Conduct remote sensing surveys
	5 October	Weather Day
	6 to 7 October	Continue remote sensing surveys
	8 October	Conduct "holiday" fill in lines and collect grab samples; pull vessel out of the water and return travel to Old Saybrook, CT
Demobilization	9 to 10 October	Offload geophysical equipment
Mobilization	3-4 February 2003	Outfit survey vessel with geophysical gear
Operations	5 February	Transit from Old Saybrook, CT to Boston, MA; launch vessel, check navigation, test gear
	6-9 February	Fill in additional areas of the channel requested by NED and BMI
	10 February	Pull vessel out of water and return travel to Old Saybrook, CT
Demobilization	11 February	Offload geophysical equipment

Geophysical Survey Crew:

Jeffrey D. Gardner	Geophysical & Oceanographic Project Manager
Justin M. Bailey	Geophysical Project Manager
John G. Wetmur	Geophysical Technician
G. Matt Slusher	Geophysical Technician

The R/V Parker Sport (26 ft Parker with dual 150 Hp outboard engines) was outfitted with the necessary survey equipment to complete this geophysical investigation. Figure 5 illustrates the survey vessel layout and equipment configuration during operations. The vessel is outfitted with an enclosed cabin and full suite of electronic navigation devices to ensure safe operations under a wide range of weather conditions.

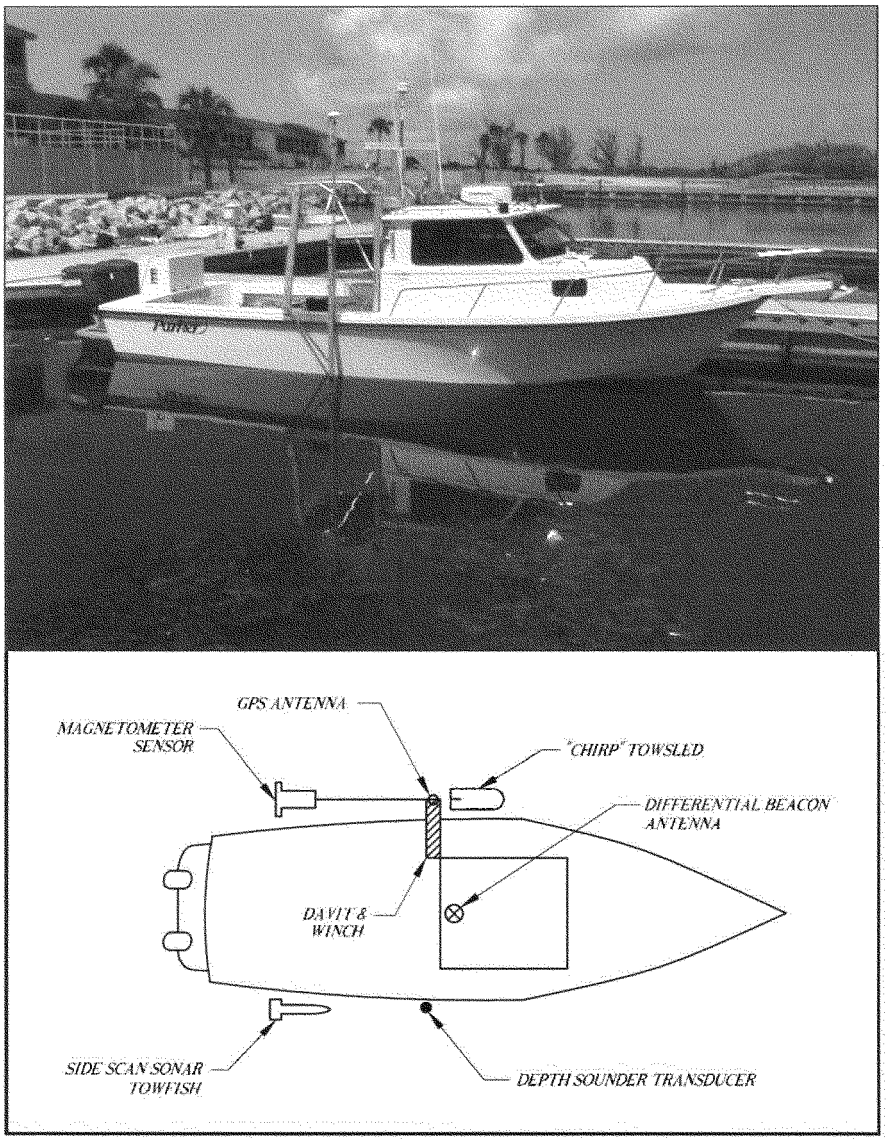

Figure 5. Equipment configuration aboard the survey vessel RV Parker Sport.

The Maritimes Safety Division of the United States Coast Guard (USCG) Group Boston was notified of survey operations prior to commencement of the investigation and each morning of the field work. The USCG Group Boston then transmitted a security broadcast on VHF channel 22 each day to warn mariners of the remote sensing operations and reduced manueverability of the survey vessel.

An archaeologist accompanied the remote sensing crew each day of the field survey to perform a preliminary assessment of geophysical data. Dr. Warren Riess and Keri Lynch, associated with UMass Archaeological Services, were the observers. Near the completion of the field investigation, the field team conducted a preliminary data review and interpretation of the "holidays" (gaps) in survey data coverage where the vessel was forced to maneuver around lobster pot buoys and other objects. Of approximately 45 total "holidays" of significance (greater than 75 foot wide gap in line spacing), only two were deemed appropriate for filling in based on review of the remote sensing data and subsequent recommendation of the project archaeologist.

6.0 DATA PROCESSING AND DELIVERABLES

Data processing techniques and the methods used for analysis of the subbottom profiles, side scan sonar, and magnetic data are described in Appendix F. Figures presenting the results from the OSI investigations have been included in the body of this report at various scales. Appendix G contains the drawings developed from the geological interpretation and results to this date (Main Area in Boston Harbor, 24x36 inches; Mystic River site, 11x17 inches). All data have been referenced to the Massachusetts State Plane Coordinate System (Mainland Zone 2001), NAD 27 in feet.

A separate data package was delivered to the project archaeologist prior to this submission for his/her assessment. That package included a side scan sonar mosaic of the survey areas, side scan sonar paper records, survey trackline plot, magnetic intensity profiles along every line, and

access to the subbottom profiles if necessary. Results from the archaeological review of the remote sensing results can be found in a separate report prepared by UMass Archaeological Services.

The following list details the data products, in addition to this report, that have been generated for this project.

Working Drawings	(generated for archaeological review)
No. 1	Side scan sonar mosaic covering all survey areas with survey tracklines superimposed
No. 2	Magnetic intensity profiles along all survey tracklines
Final Drawings	(generated for the NED)
Drawing 02ES066.1	Geophysical survey results showing areas of shallow acoustic basement, Boston Harbor area; 24x36" size, 1000 feet per inch (revised to include contours)
Drawing 02ES066.2	Geophysical survey results showing areas of shallow acoustic basement, Mystic River site; 11x17" size, 1000 feet per inch (revised to include contours)

7.0 SURVEY RESULTS

The survey areas designated for investigation have been subdivided, for the sake of discussion, into four zones; the Inner Harbor (Pier 6 at west end to Spectacle Island), President Roads (Spectacle Island to Deer Island Light), the North Channel (Deer Island Light to Finns Ledge), and the Mystic River site. Geological characteristics are generally similar within each of these zones as discussed below.

The project depth of interest was defined as 55 feet below MLLW (Mean Lower Low Water datum) by the NED. Figure 6 shows the boundary of the 55 foot contour within the main survey area where water depths reached over 90 feet. Data collected within this portion of the harbor has generally not been processed, interpreted, reviewed, or discussed in this report.

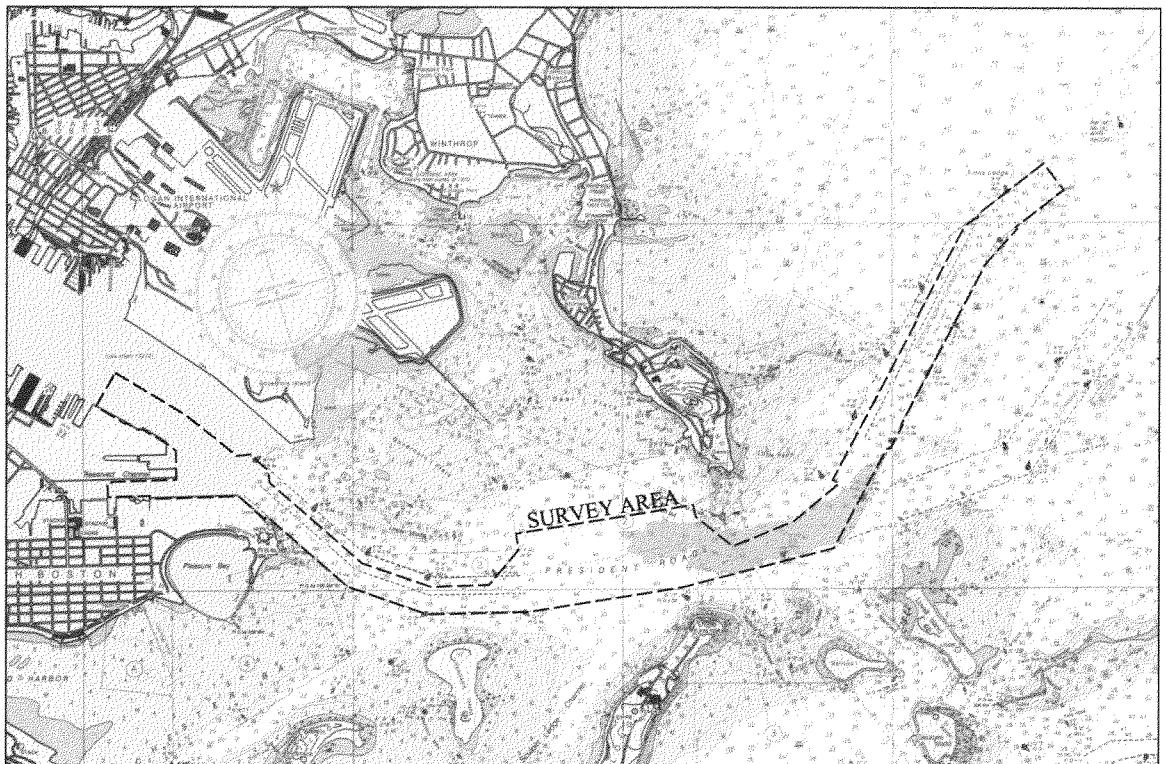

Figure 6. 55 Foot water depth limits (cyan).

7.1 Side Scan Sonar Imagery

Surficial acoustic reflectivity data obtained using a side scan sonar system revealed general geomorphologic trends in the Harbor and identified individual targets on the bottom representing possible man made and natural objects.

In general, surficial sediments in the channel east of Deer Island Light appear to be coarse (sand, gravel, and larger) whereas bottom materials west of this point are predominantly finer. The close proximity of the North Channel to adjacent shoals comprised of bedrock and the funneling of tidal currents around Deer Island Light and these shoals are factors which likely maintain a relatively hard, resistant seabed along the harbor approach. Although apparently localized, coarser sediments do exist in President Roads as demonstrated by the material retrieved in Grab sample No. 2. Some of these areas are patches of coarse glacial till associated with shallow bedrock while some may be material discarded or overflow from vessels transiting the harbor. Figure 7 shows photographs of the four samples collected and their location in the harbor.

Proceeding farther west into the harbor, sediments remain primarily fine grained except where coarse till and bedrock persist close to or on the bottom. Surficial fine grained sediments thin westward past navigation buoys Green #3 and Red #4 as bedrock and till slope upward near the bottom of the channel. In many places, a veneer of highly aqueous, fine grained sediments may exist over the harder substrate. Coarse sediments and rock persist near the bottom particularly east of Castle Island, in the Reserve Channel, and northwest of the Reserve Channel and turning area.

Sonar images of the bottom in the Mystic River site revealed generally fine grained sediments with very low reflectivity (Figure 8). Some coarser materials (possibly sand and/or gravel) are

Figure 7. Grab sample locations and photographs of recovered sediments positioned on the side scan sonar mosaic.

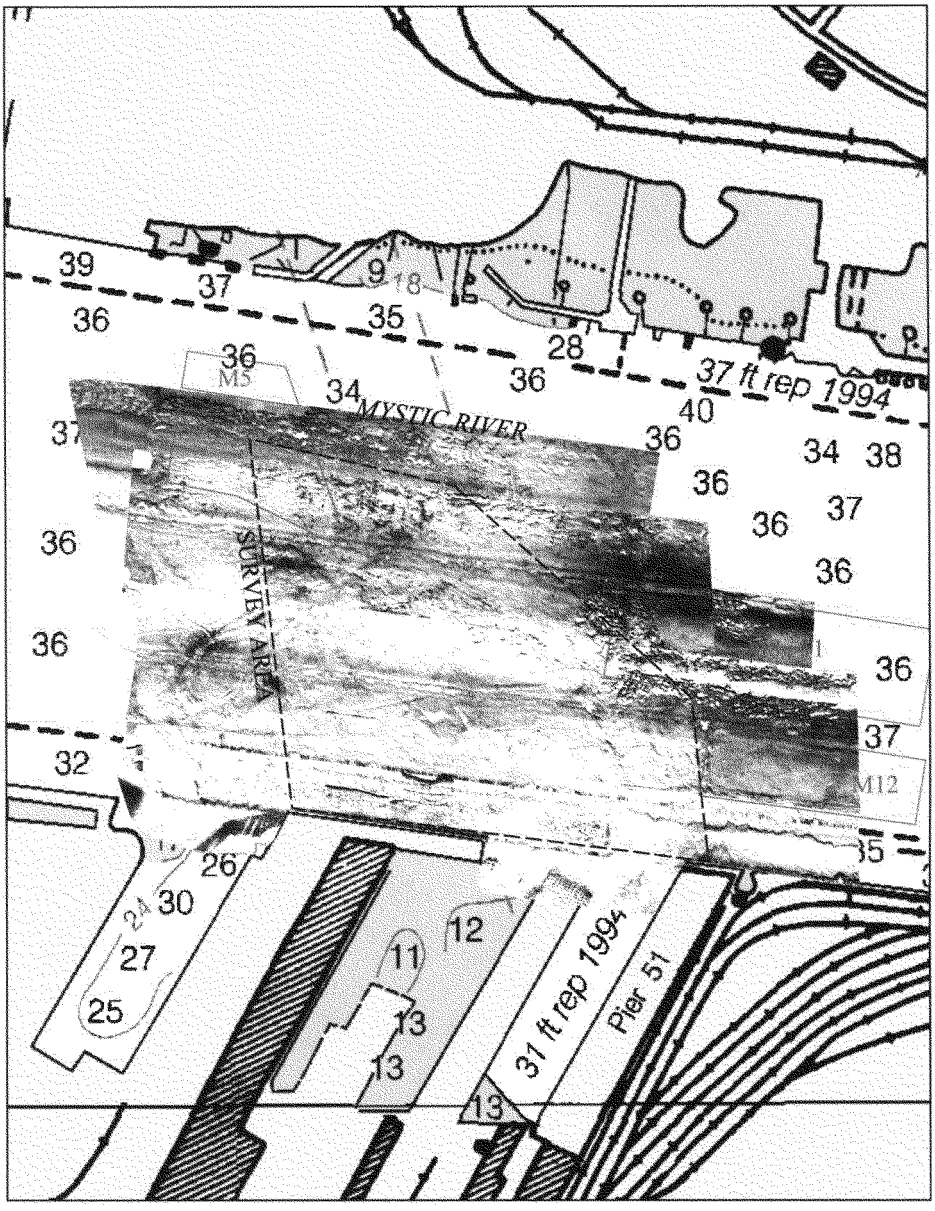

Figure 8. Side scan sonar mosaic in Mystic River site.

evident in the northeast corner of the site. No verification of these surficial materials could be performed during this investigation.

Review and interpretation of the sonar images to assess the historical significance of targets on the bottom was performed by the project archaeolgist. A comprehensive list of all sonar targets was not required by the scope of work; it was only necessary to analyze targets to make a determination of their potential significance as cultural resources. Please refer to the UMass Archaeological Services final report for this information.

7.2 Magnetic Intensity Measurements

Magnetic anomalies detected throughout the survey area suggest an abundance of ferrous material on or below the bottom. Many of these anomalies may represent man made ferrous objects, while some may be generated by the local geology where coarse glacial till and bedrock exists just below or outcrop on the bottom. Some of the anomalies are likely associated with fishing gear (lobster pots mainly) found near the edges of the channel, primarily east of Spectacle Island. Large background gradients from shore structures may mask smaller anomalies along the shoreline, particularly in the Reserve Channel, along the shoreline northwest of Castle Island, and in the Mystic River site. In addition, anomalies were detected in the vicinity of large man made features within the survey area such as the third harbor tunnel at the west end of the main survey area near Pier 6 and the cable crossing area just south of the reserve channel, north of Castle Island (Figure 9). Complex anomalies may be the result of a combination of ferrous objects including charted features (i.e. underwater cables) and uncharted features, possibly including potential obstructions and cultural resources. Refer to OSI drawing 02ES066.1,"Top of Acoustic Basement" which shows NOAA chart 13270 in the background, for the locations of charted features relative to the survey area.

The magnetic intensity data were reviewed and analyzed by the project archaeologist, then compared to side scan sonar targets for correlation. This is the typical process followed when

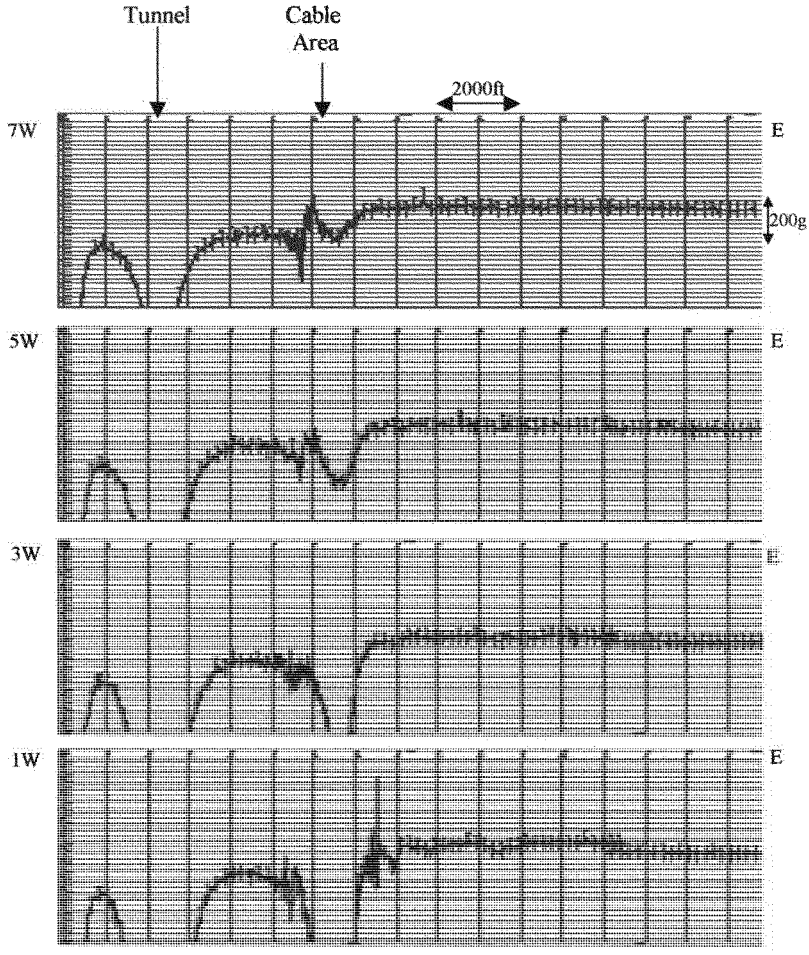

Figure 9. Magnetic intensity profiles along adjacent tracklines illustrating the anomalies in the vicinity of the third harbor tunnel and cable crossing area just south of the Reserve Channel. The profile lengths shown above are approximately 17000ft, starting at the northwestern end of the survey route, south of Logan Airport (see NOAA charts 13272, 13270)

examining remote sensing data to determine the potential for historical significance of submerged objects. No comprehensive list of magnetic anomalies was required by the scope of work and thus has not been developed by OSI. Please refer to the UMass Archaeological Services final report for results from the magnetometer data analysis and comparison with the side scan sonar targets.

7.3 Subbottom Profiles

Subsurface information was obtained by conducting reconnaissance level seismic reflection (subbottom) profiling throughout the survey areas (150 foot data spacing). The initial phase of analysis included identifying areas where the acoustic basement reflector, presumably representing coarse glacial till (cobbles and boulders) or bedrock, may be present at elevations above 55 feet MLLW. Areas where gaseous, organic material present in the shallow subsurface inhibit penetration of the seismic signal were also identified during this process. The following paragraphs qualitatively discuss the results of this analysis. Figure 10 depicts the regions where the acoustic basement may be above 55 feet (colored brown) in the main survey area of Boston Harbor while Figure 11 shows the interpretation for the Mystic River site. These figures were previously delivered as preliminary drawings at a scale of 1000 feet per inch; the Boston Harbor main area (24x36 inches) and the Mystic River site (11x17 inches).

Further processing of the subbottom profiles and subsurface mapping were completed as a later task, authorized after preparation of the main report. Refer to the addendum to this report (attached) for a detailed description of processing and mapping methodologies and results. The project drawing, 02ES066.1 has also been revised to show the contouring results in place of the more generalized identification of areas where acoustic basement may be above 55 ft. The revised drawing is included at the back of this report (Appendix G).

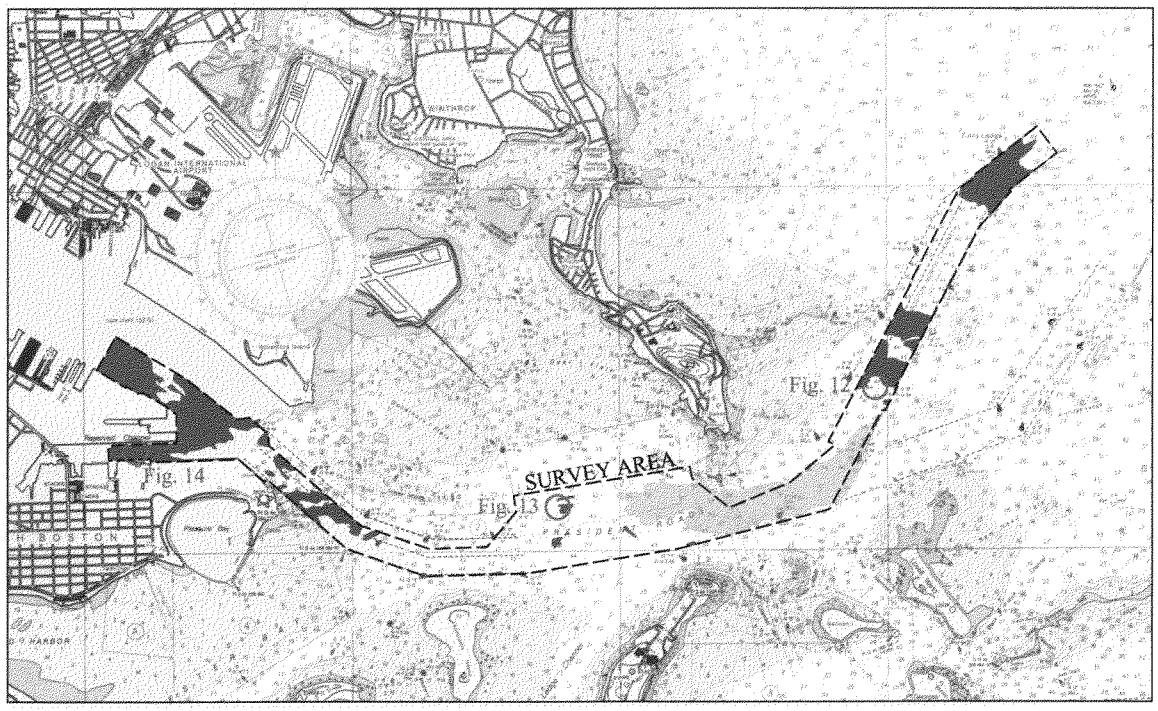

Figure 10. Map of the main survey area showing region with water depths greater than 55 ft (cyan), areas where acoustic basement is Less than 55 ft (brown), and areas containing organic-rich sediments (yellow). Locations of seismic profiles shown in other report figures are also included.

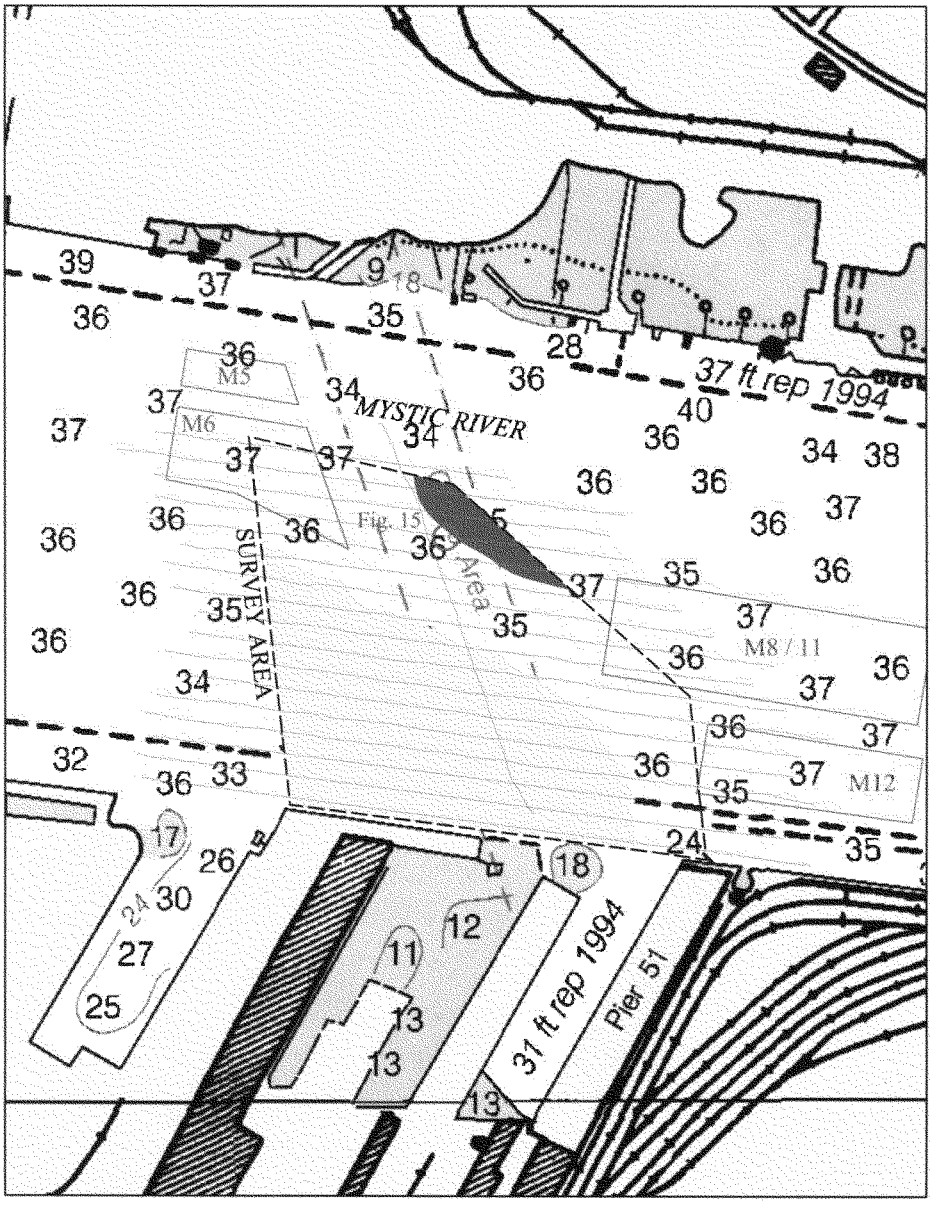

Figure 11. Mystic River geophysical interpretation.

7.3.1 North Channel

There are two primary regions where the acoustic basement exists just below or at the seafloor in the North Channel; east-northeast of the Great Faun and Little Faun Shoals and near the offshore end of the channel at Finns Ledge. The southern area shows coarse material and possibly bedrock from just north of navigation buoy pair Red #8/Green #9 to north of the next buoy set Red #6/Green #7. A review of the nautical chart hints at the general trend of the bedrock extending east-northeast off these rocky shoals. Figure 12 shows the character of the acoustic basement reflector in this section of the channel. East of the channel rocky shoals remain prominent with sharp depth contours along the eastern limit of the channel, indicative of a dredged hard substrate.

The same bedrock high continues to the northeast where the channel again cuts through the rock and/or till unit at Finns Ledge. The profiles show the acoustic basement is evident at the seafloor over much of this portion of the channel.

7.3.2 President Roads and Anchorage No. 2

The majority of the upper portion of the stratigraphic column underlying President Roads and Anchorage No. 2 does not include the acoustic basement reflector. For the most part, the top of rock and coarse glacial till units can be distinguished on the records below the project depth of interest. Figure 13 demonstrates the thick sequence of unconsolidated sediments overlying the basement unit in much of President Roads. There are, however, localized acoustic reflector peaks just below the bottom at elevations shallower than 55 feet MLLW. These isolated locations are of limited areal extent compared to the overall size of the President Roads section of the harbor, defined here as the region between Spectacle Island and Deer Island Light.

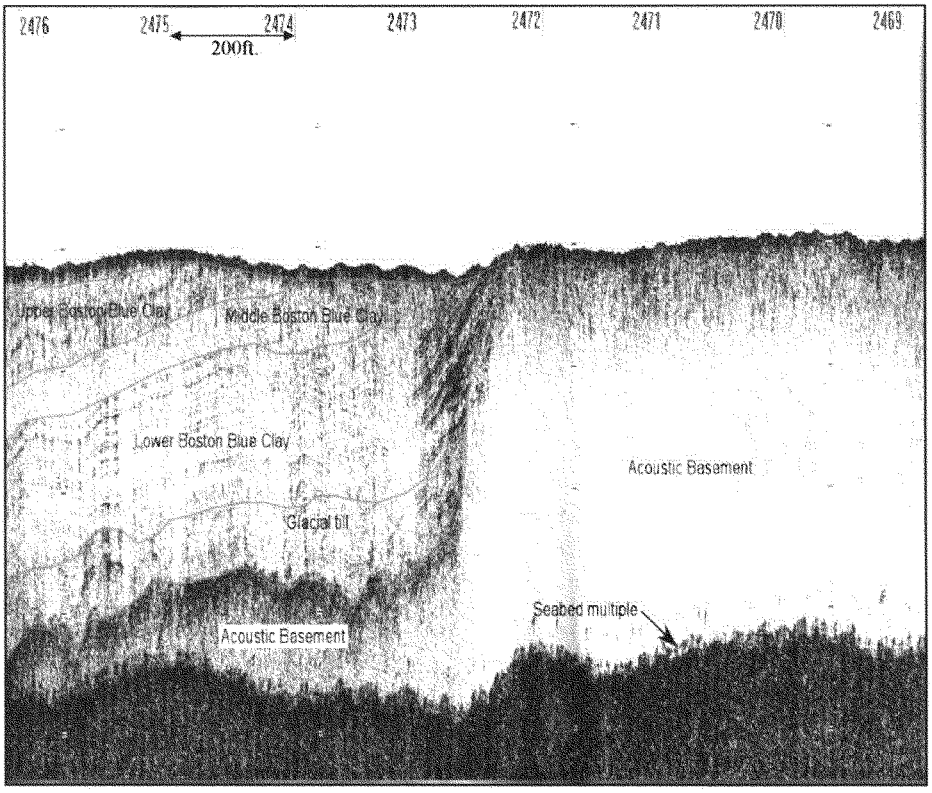

Figure 12. This profile shows an example of the rapid transition from finer unconsolidated material (mainly sand with some gravel on left side of image) to coarse glacial till with bedrock outcrop at the surface (right side of image). This is due to the steeply sloping (? degrees) metamorphic rock which rises to the seafloor, exhibiting a vertical change of ?? feet over only ?? feet laterally. The profile was collected in the North Channel due east of Deer Island and just north of green Buoy #9.

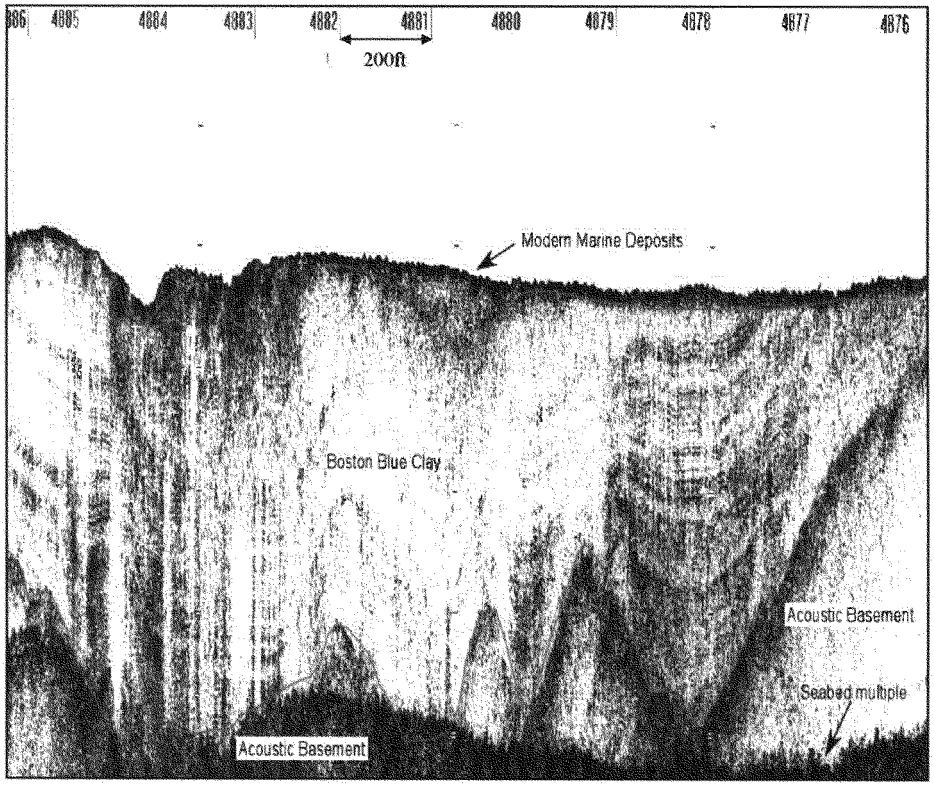

Figure 13. Subbottom profile collected in Anchorage No. 2 in President Roads revealing a relatively thick sediment sequence over acoustic basement / bedrock. The acoustic basement approaches the project depth of interest on the right side of the image.

7.3.3 Inner Harbor Section and Reserve Channel

Continuing west from navigation buoy Green #3, an area of limited subbottom data was encountered as a result of organic-rich, gaseous sediments in the nearsurface. This was verified by Grab Sample #3 which revealed black silt/clay with a very strong odor typical of anoxic sediments immediately below the surface. This area of reduced seismic penetration extends west almost to Green buoy #5A along the southern half of the channel. In the center of the channel beginning midway between Green buoys #3 and #5, the acoustic basement reflector is apparent just below the bottom. The reflector suggests an undulating bedrock or coarse till surface exists with small highs jutting above the 55 foot MLLW elevation, then rises closer to the channel bottom becoming more prominent directly east of Castle Island.

Near the entrance to the Reserve Channel and the southernmost portion of the turning area to the east, the acoustic basement reflector is not apparent within the depth of interest. However, the basement unit slopes up to the west into the Reserve Channel and toward the northwest below the main shipping channel. Much of the Reserve Channel appears to have been dredged into the acoustic basement or to its surface, similar to areas of the federal channel northwest toward Pier 6. Figure 14 shows a section of a Chirp profile which reveals the acoustic basement reflector undulating at or just below the bottom.

7.3.4 Mystic River Site

This site is situated over a cable area which crosses the waterway from the northwest shore to the southeast, and is also located along a dredge cut or slope which runs through the site in a generally similar orientation. The shallower, possibly undredged portion of the bottom covers over 60% of the southwest corner of the site. The survey area also encroaches on existing CAD cell M12 in the southeast corner and overlaps portions of CAD cell M8/M11 along the eastern limits and cell M6 in the northwest corner.

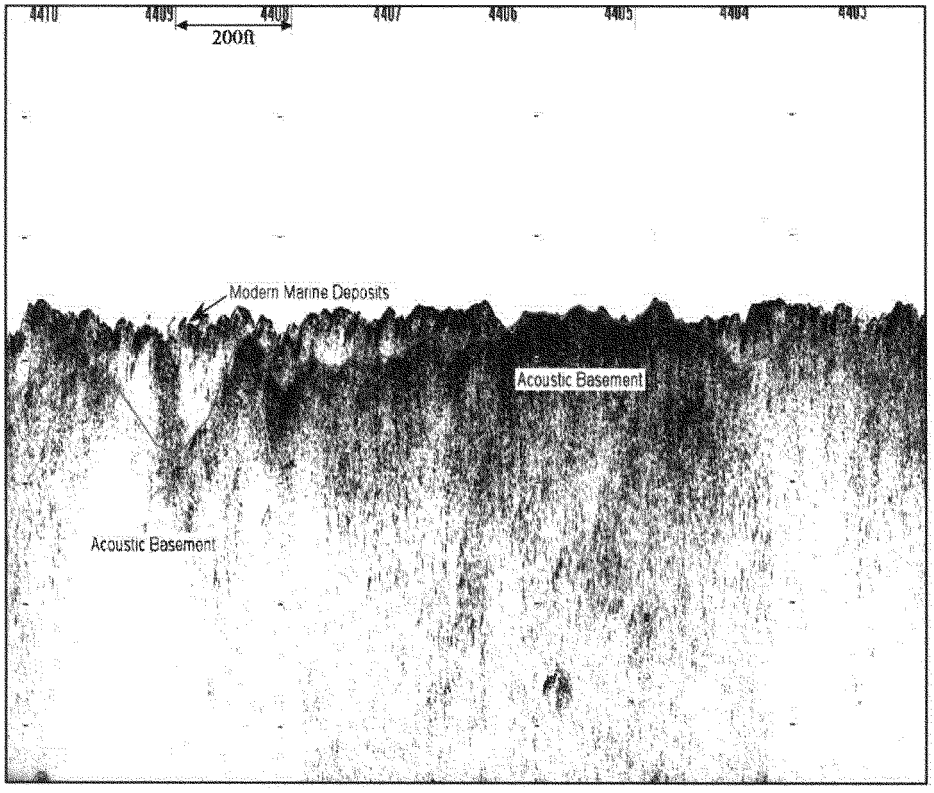

Figure 14. Section of a subbottom profile collected in the Reserve Channel showing the close proximity of the acoustic basement reflector to the bottom. The irregular bottom surface is likely the result of dredging and the constant reworking of surficial sediments from the large ships inbound and outbound from the Reserve Channel.

As expected, no seismic penetration was achieved in the undredged, shallower portion of the site due to the likely presence of gaseous, organic sediments and petroleum by-products from years of commercial activity in the river. In the northeast portion of the site, subsurface information was attainable and revealed an acoustic basement reflector sloping up to the bottom within the depth of interest (Figure 15).

8.0 CONCLUSIONS AND RECOMMENDATIONS

The geophysical explorations conducted by OSI in Boston Harbor for the Navigation Improvement Study acquired high quality remote sensing data for archaeological assessment and identification of potential areas of shallow bedrock.

A high concentration of man made objects and debris was identified in the channel, as one might expect in a major port where centuries of intensive commercial activity has occurred. If necessary, inspection of targets deemed potentially significant by the project archaeologists can be supported by OSI via diving operations or remotely operated vehicles (ROV). Refer to the UMass Archaeological Services final report for results on their determination of potential historically significant sites and recommendations for further studies.

Prior to the commencement of any dredging, complete documentation of the side scan sonar and magnetic intensity data may be warranted to develop a list of obstructions which could pose a hazard to those operations. To date, these remote sensing data have only been reviewed with respect to the archaeological requirements for the project. Tabulation of all anomalies and targets detected on this data set may provide insight in designing more detailed pre-dredge surveys.

In addition, a detailed geotechnical program is necessary to ground truth the subbottom profile data and develop a better understanding of the material comprising the acoustic basement

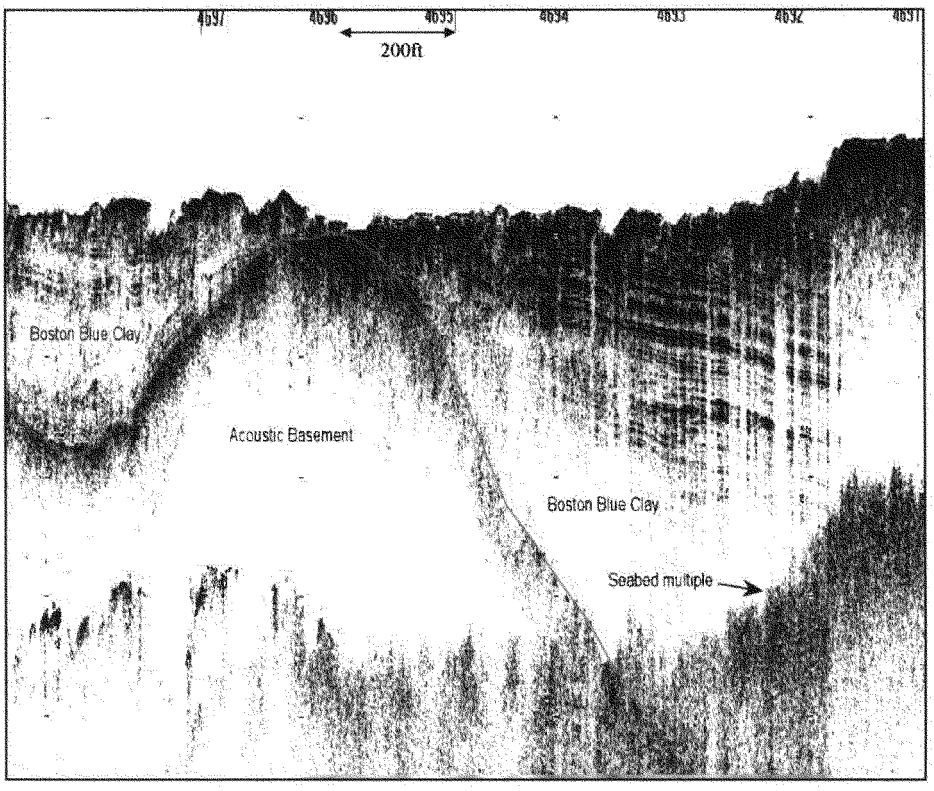

Figure 15. Image of the subbottom stratigraphy that exists below the Mystic River survey site. The acoustic basement reflector slopes up to the riverbed in the northeast corner of the survey area. The thinly laminated sediments visible throughout Boston Harbor mark the presence of the Boston blue clay. The small holes in the bottom surface are remnants from dredging activity associated with other existing CAD cells that surround this site.

surface (coarse glacial till versus rock). This would provide a more accurate picture of the depth to bedrock in critical areas. This is important throughout the project area but even more so in regions where gaseous, organic sediments prevented the acquisition of subsurface seismic information. This includes a good portion of the Mystic River site as well as the southern half of the federal channel southeast of Castle Island between Green buoys #3 and #5A. It is also highly recommended that this program be supplemented by filling in the current subbottom dataset with lines at a 50 foot spacing, since the subbottom line spacing of 150 feet is not believed adequate for a pre-dredge assessment of rock or other material quantities.

9.0 REFERENCES

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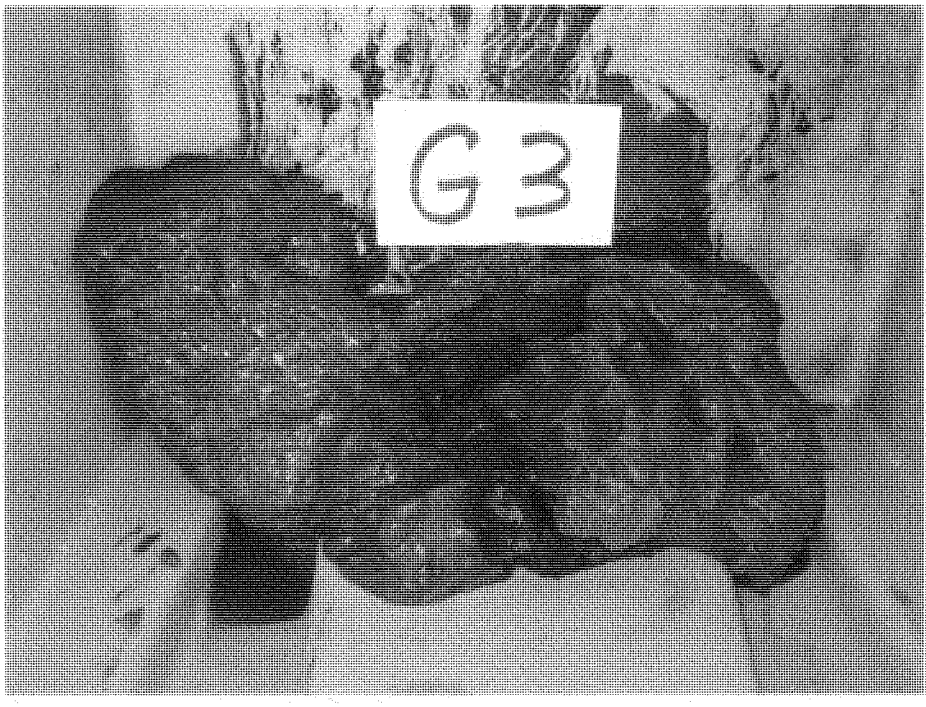
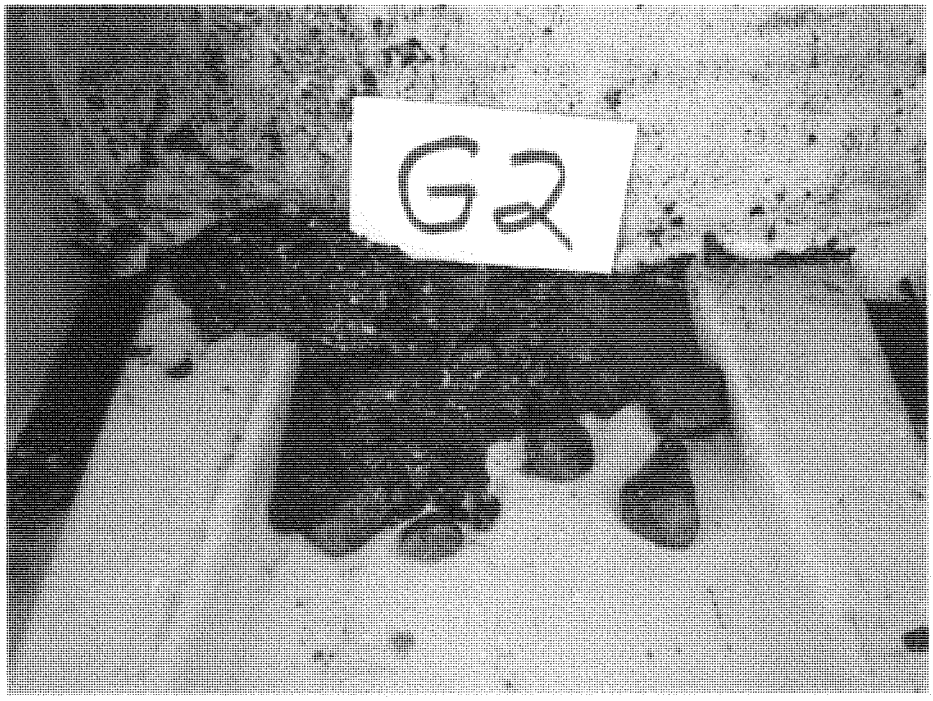


GRAB #3 Thin gray-brown silt layer (<1/4 inch) over black silt-clay; strong odor; possible amphipod tubes on surface; ~5/6 of bucket recovered.

Collection Date: 8 October 2002
Location: N 486561, E 735115
Water Depth: 41 feet
Sampler Type: Ponor Dredge

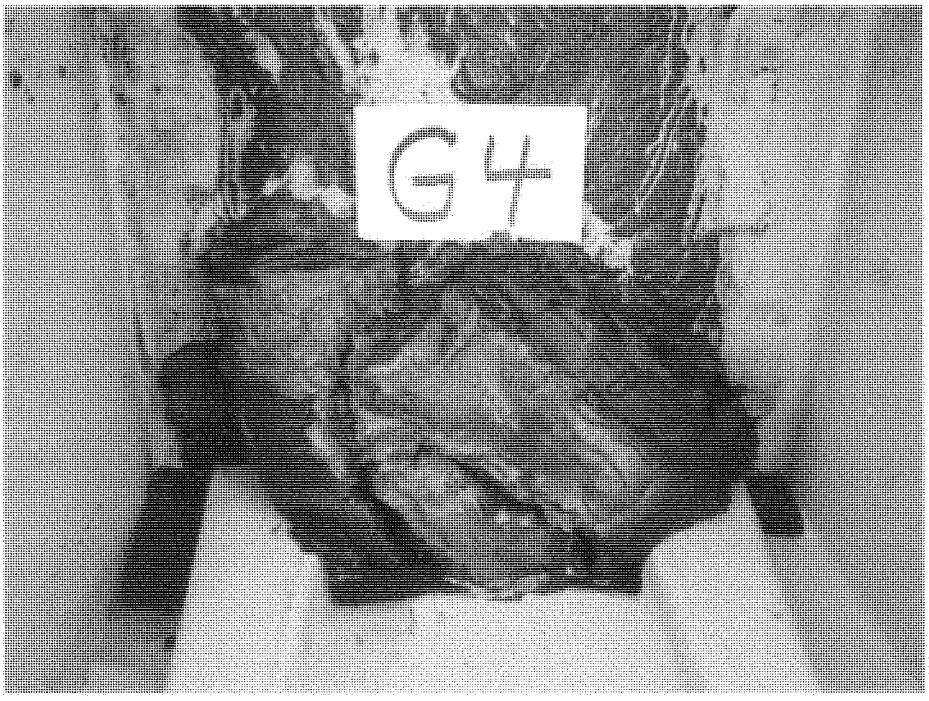


GRAB #2 Poorly sorted sample consisting of clay, sand, gravel, and cobble size material with shell hash; ~1/8 of bucket recovered.

Collection Date: 8 October 2002
Location: N 486916, E 743000
Water Depth: 45 feet
Sampler Type: Ponor Dredge

GRAB #1 Gravel and cobble size material with one blue mussel shell fragment recovered on second attempt; no recovery on first attempt; only ~1/15 of bucket recovered.

Collection Date: 8 October 2002
Location: N 493921, E 753890
Water Depth: 41 feet
Sampler Type: Ponor Dredge



GRAB #4 Thin gray-brown silt layer (<1/4 inch) over black silt-clay; strong odor; ~3/4 of bucket recovered.

Collection Date: 8 October 2002
Location: N 491551, E 729050
Water Depth: 42 feet
Sampler Type: Ponor Dredge

APPENDIX F

Data Processing and Analysis Methods

Navigation Data
Subbottom Profile Data
Side Scan Sonar Images
Magnetometer Data
Grab Sample Information

DATA PROCESSING AND ANALYSIS METHODS

Navigation Data

Upon completion of the field work, the digital files of vessel position were processed using the HYPACK software to plot survey tracklines for remote sensing data interpretation. Sensor laybacks and offsets can be applied to develop precise positions of all sensors during the survey. The processing program inputs raw data files into an editor and allows the data to be exported for plotting in a variety of formats.

Subbottom Profile Data

Digital seismic data was imported to the seismic processing program REFLEXW (Sendmeier Software) Version 2.5 for analysis, interpretation, final data formatting. REFLEXW is a 32 bit software package running in a Windows 2000 environment. Since a raw seismic profile is measured in time travel of the acoustic signals, a time to distance/depth conversion is required. Acoustic velocities for subsurface layers can be obtained directly from seismic refraction methods or assumed from physical sampling of materials. Historical research shows most marine sediment types and compositions fall into certain velocity ranges (eg. Hamilton, 1972). The subbottom profiles were reviewed to delineate areas where the acoustic basement reflector (possible bedrock or coarse glacial till) was present within the project depth of interest for dredging.

Interpretation and mapping of the acoustic basement reflector was completed to develop a three dimensional surface of the acoustic basement. This surface was then combined with a water depth surface generated from the tide corrected hydrographic data to obtain a plan view contoured surface referenced to the MLLW datum. The digital terrain modeling (DTM) software QuickSurf Pro Version 5.2 (Schreiber Instruments, Inc.) operating within AutoCad Version 14 was used for these procedures.

Side Scan Sonar Images

During interpretation of the side scan sonar records, areas on the bottom exhibiting different acoustical properties were identified. The variation in acoustical characteristics on the bottom represents changes in surficial lithology and/or the presence of benthic communities and foreign material. Areas of large natural seabed features were identified by the increased topographic relief and morphologic variations observed on the records. Acoustic targets are also evident as isolated reflections representing possible man made objects.

A digital side scan sonar mosaic was developed to allow a detailed examination of the acoustic imagery in comparison to the magnetic intensity data. During sonar image processing, layback of the side scan towfish behind the GPS antenna was applied. The project archaeologist performed the analysis of side scan sonar targets using the plan view mosaic and the raw paper records.

Magnetometer Data

Digital records of the magnetic data were processed and plotted for review to determine the presence of ferrous material in the survey areas. Layback from the GPS antenna to the magnetic sensor is applied to obtain the true sensor positions along each survey track. Anomalous readings above the regional geologic background gradient represent potential ferrous objects. The project archaeologist performed the interpretation of the magnetic intensity data and any subsequent correlation between sonar targets and magnetic anomalies.

Grab Sample Information

Surficial ground truthing of the side scan sonar data was accomplished through use of the WildCo Ponor grab sampler which provided direct visual identification of bottom sediments. Samples were photographed and described onboard the survey vessel. The sediment descriptions were then used to correlate the reflectivity coefficient of the acoustic data.

ADDENDUM
TO
FINAL REPORT

Geophysical Explorations:
Remote Sensing Archaelogical Survey
and Geologic Interpretation
Boston Harbor Navigation Improvement Study
Boston, Massachusetts

OSI REPORT NO. 02ES066-A

OSI REPORT NO. 02ES066-A

ACOUSTIC BASEMENT CONTOURS
BOSTON HARBOR NAVIGATION IMPROVEMENT STUDY
BOSTON HARBOR, BOSTON, MASSACHUSETTS

1.0 INTRODUCTION

This report describes the methodology applied to the interpretation and mapping of the Acoustic Basement in Boston Harbor based on high-resolution CHIRP subbottom seismic data acquired by OSI on Sept.-Oct, 2002, and Feb. 2003. The field investigation was conducted under subcontract to Battelle Memorial Institute for the U.S. Army Corps of Engineers, New England District (NED). The purpose of this additional task (requested after completion of the original report) is to provide further support for planning and design of the proposed Navigation Improvement Project.

The archaelogical investigation consisted of acquiring magnetometer data along tracklines at a 50 foot spacing throughout the survey area. In general, subbottom profile data were acquired along every third line (150 ft. spacing) and along cross lines. Additional subbottom data were acquired, based on a preliminary review of the data. Further discussion of survey procedures is included in the project report. To complete the present task of mapping the acoustic basement, all subbottom profile data collected during the two survey periods were processed and analyzed.

In this report, the "acoustic basement" corresponds to a high-amplitude, well-defined reflection observed on subbottom profiles. It represents a seismic boundary beyond which acoustic penetration is weak and reflection imaging is negligible (Figures 1 and 2). In the majority of cases, we believe, based on prior work in the Boston areas, this acoustic basement represents the contact between the glacial/marine sedimentary section and the underlying metamorphic/igneous bedrock. In some cases strong acoustic impedance contrasts can occur within glacial till deposits and can account for the strong character of the recorded reflection. It is therefore advisable not to interpret the acoustic basement as a straightforward

indication of bedrock occurrence without having additional and independent supporting evidence, such as outcrop, side scan sonar, grab samples, and/or boring data.

A description of the software and methods used for data interpretation and mapping is presented below. Limitations in the dataset and the margin of error in the mapping of the acoustic basement are also discussed as well as factors affecting those margins of error and additional sources of uncertainty. Finally recommendations are made for additional subsurface exploration activities to improve the level of contouring confidence and help ground-truthing the acoustic basement data.

2.0 SOFTWARE AND METHODS USED

2.1 Software Used

TASK	ReflexW Ver. 3.0	Corpscon Ver. 5.11	Quicksurf Ver. 5.1	AutoCAD Ver. 14	MicroStationSE
Subbottom Reflection Analysis	X				
XYZ ASCII Coordinate Conversion		X			
Contouring			X	X	
Drawing & Data Integration				X	X

- ReflexW 3.0. (Sandmeier Software)
- Corpscon 5.11 (U.S. Army Corps of Engineers)
- Quicksurf, Version 5.1. (Schreiber Instruments, Inc.)
- AutoCAD Release 14 (Autodesk, Inc.)
- MicroStationSE. (Bentley Systems)

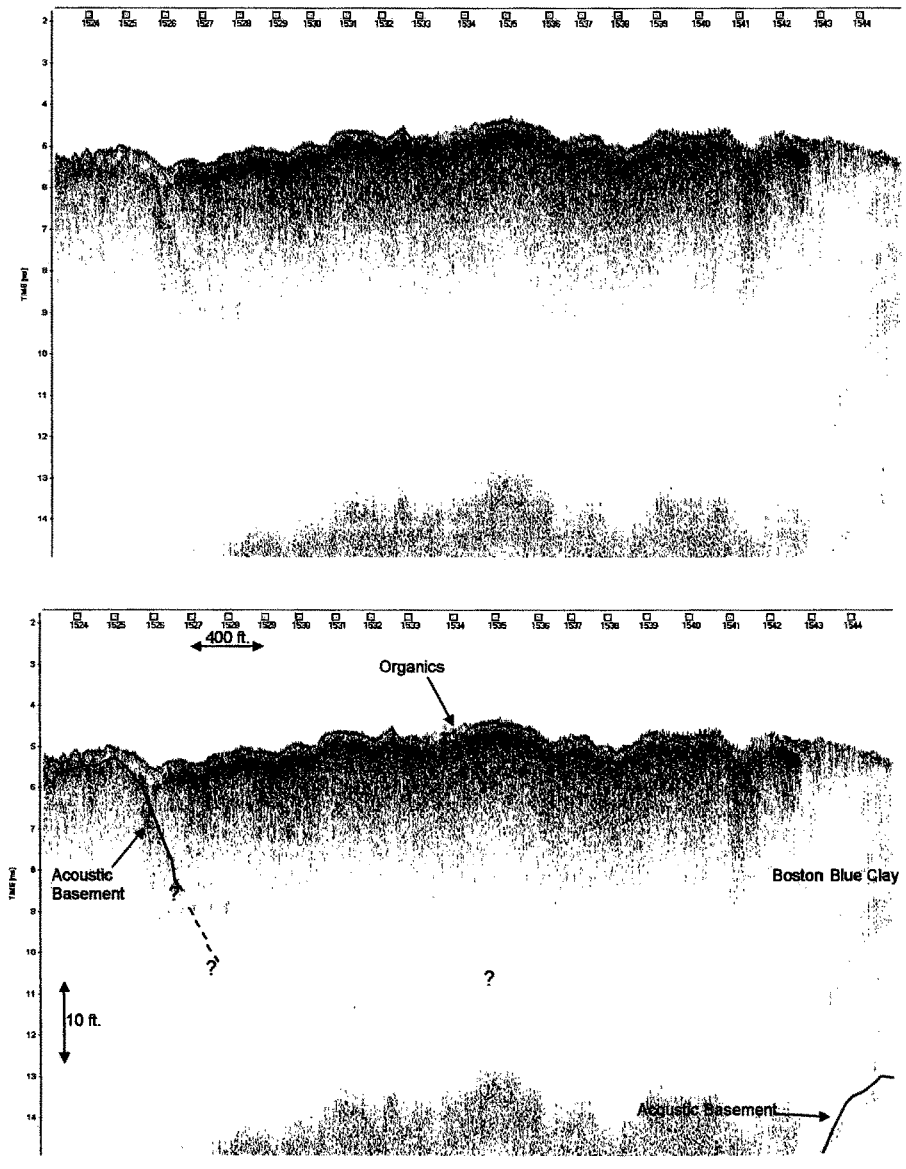


Figure 1. Subbottom profiler record (above) and the same record annotated (below) showing subsurface returns typical of the area.

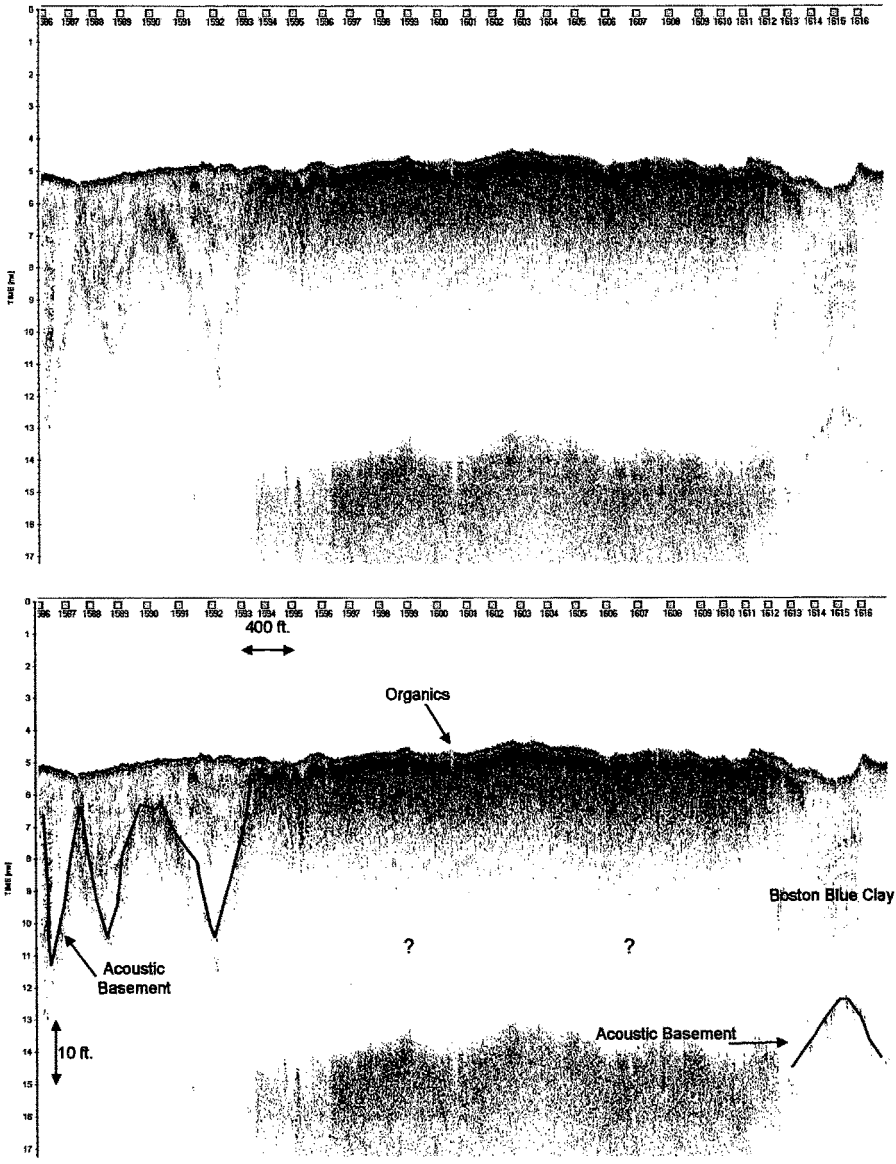


Figure 2. Subbottom profiler record (above) and the same record annotated (below) showing types of returns typical in the area.

2.2 Subbottom Mapping Procedure

A. Tide-corrected water depth values provided by the NED and referenced to Mean Lower Low Water (MLLW), were contoured and contours were overlaid on a basemap containing all subbottom tracklines.

B. Areas with water depth greater than 55 ft were delimited on the basemap. Subbottom profiles were not mapped within these areas.

C. Subbottom profiles in areas with water depth shallower than 55 ft were analyzed as follows:

   a. All digital CHIRP seismic data files originally in SEGY file format were imported into ReflexW seismic data processing software

   b. All seismic time sections were adjusted for delays, offsets, and static variations and some sections were filtered to improved the signal/noise ratio.

   c. The first reflection return corresponding to the water bottom interface was picked along each digital subbottom profile using ReflexW 3.0 2D data analysis module.

   d. Each water bottom pick was flattened and shifted to zero time.

   e. Reflections corresponding to the interpreted acoustic basement were picked along each profile down to 5 ms TWTT (two-way-travel-time).

   f. Picked data were cross-checked by loop-tying along tie lines.

   g. To calculate the depth from the sea bottom to the acoustic basement the time difference between the water bottom pick and the acoustic basement pick was computed at every CHIRP ping location along each one of the profiles.

   h. A seismic velocity of 5,200 ft/sec, representative of the type of sediments present within the Boston Harbor (mainly sands and muds), was used for time-depth conversion.

   i. All computed values were saved into an XYZ ASCII file containing Latitude, Longitude, and Depth to acoustic basement for each subbottom trace along each profile.

D. All Longitude and Latitude values in the XYZ ASCII were converted from Geographic Coordinates (NAD 83), into State Plane, Massachusetts Mainland (NAD 27) coordinate system values using Corpscon 5.11 conversion software.

E. The final XYZ ASCII file was imported into QuickSurf 5.1 running inside of AutoCAD Release 14.

F. A total of 37,395 sets of ternary values were modeled with QuickSurf and converted into a surface representing the 3D distribution of the acoustic basement in the subsurface.

G. Using QuickSurf 5.1 the newly modeled acoustic basement surface was added to the surface representing water depth referenced to MLLW (produced in Step A, above).

H. The new surface data were saved into a final XYZ ASCII file and then converted into a Triangulated Irregular Network (TIN) and computer contoured using QuickSurf and a 1-foot contouring interval.

I. When necessary some contour lines were manually modified to fix artifacts created by applying an automatic, computer-based contouring method to a non-uniformly distributed data set.

J. Contours were imported into Microstation and placed on US Army Corps of Engineers 1"=200' and 1"=100' basemaps.

3.0 DATA LIMITATIONS AND MARGIN OF ERRORS

There are several factors affecting the accurate mapping of the acoustic basement. Chiefly among them and by far the most important factor is the irregular distribution in subsurface seismic data coverage within the study area. Geological factors such as the presence of organic material and gaseous sediments in some surveyed areas provided another source of localized uncertainty by precluding imaging and detection of the acoustic basement in the subsurface. Another factor contributing to the margin of error in acoustic basement mapping was the seismic velocity used for time–depth conversion.

3.1 Incomplete subsurface seismic data coverage

The main limitation for an accurate mapping and contouring of the interpreted acoustic basement is the irregular and uneven distribution of data points. As can be seen in the provided digital drawings, data points along each surveyed line are separated between 2 and 5 feet but the distance between data points on parallel adjacent lines varies between 50 and 150 feet. This produces a set of points where the separation between points in one direction is up to 30 times greater than the distance of adjacent points in the orthogonal direction. This uneven distribution of data points decreases our ability to model the acoustic basement surface accurately and creates errors and artifacts when contouring this surface.

3.2 Geological Uncertainty

In addition to the limited line spacing, another factor decreasing the amount of available data points is the presence of acoustically opaque areas attributed to gas-charged sediments. Decaying organic matter in sediments produces methane gas, which act as a shield to the propagation of the seismic signal. Areas with abundant organic matter, and therefore a high sediment gas constituent, are virtually impenetrable to compressional acoustic CHIRP waves, usually resulting in a "no-data" area. Figures 1 and 2 show two examples where the acoustic basement cannot be imaged because of organic matter in the upper sedimentary layers. On the final drawings, areas containing organic material have been outlined.

In the Presidents Roads and the North Channel – Broad Sound areas site conditions, other than organic material occasionally inhibit the penetration of the seismic signal. This is the case in the outer reaches of Broad Channel, where an area tentatively identified as having acoustic basement present above 55 feet on the preliminary drawings (submitted with the main report) has now been identified as "no acoustic basement reflector". In this area, subbottom data from nearby lines and side scan sonar imagery suggest there may be coarse material at the surface however the acoustic basement reflector was not present on the lines running through the area. At the outermost end of the survey area, just beyond the above

described area, a mappable acoustic basement reflector was also not present, however side scan sonar imagery doesn't indicate coarse material at the surface. These distinctions are noted on the drawings. For future project design purposes, the area labeled "no acoustic basement reflector" in the vicinity of areas where acoustic basement was mapped above 55 ft. should be considered as possibly having the acoustic basement present above 55 feet. Further surveying and ground truth sampling will be required to fully determine the nature of the subsurface in the area.

3.3 Velocity Uncertainty

A constant seismic velocity value of 5200 ft/s was used in all seismic profiles to convert time data into depth data. This value was selected because it represents an average seismic velocity for the sedimentary section, which is locally composed mainly of a mixture of marine and glacial sands and muds. Because of the direct proportional relationship between velocity and depth and to evaluate the effect of velocity in depth calculation several profiles were depth converted using different seismic velocities. First a low velocity of 4,600 ft/s was used and then a higher velocity of 6,000 ft/s was applied, to bracket the velocity field 800 ft/s below and above the average velocity of 5200 ft/s. The procedure was done for six subbottom profiles and it was found that a decrease and/or increase in 800 ft/s in the seismic velocity used for depth calculation accounted for just a +/- 2 ft difference in calculated depths. It is advisable then to take into consideration when interpreting the 1 ft interval contour map that velocity variations in the subsurface might account for a +/- 2 ft difference in the acoustic basement depth shown in the map.

4.0 IDENTIFICATION AND DESCRIPTION OF CONTOURED AREAS WITH DIFFERENT LEVELS OF CONFIDENCE

Because of the nature of the mapped data set characterized by an uneven distribution of data points, the level of confidence associated with each contour line varies at different sites of the surveyed area. Areas with high spatial density in data points and high number of tie lines will

produce more representative contour lines than those areas with just points along a few parallel lines and no tie lines. Considering these facts the surveyed area was divided into four different kind of zones, each of of them characterized by a qualitatively assigned level of uncertainty in the data contouring. Each area was color coded and are included in the provided Microstation digital drawings on level 60. From high to low confidence, the levels are defined as follows:

1) Red, those areas with contiguous parallel lines and crossed by "more than two" tie lines (Figure 3)
2) Blue, areas with contiguous parallel lines and "two or less" tie lines" (Figures 3-4)
3) Magenta, areas with "no tie lines" and contiguous parallel lines separated 50 ft apart (Figures 3-4)
4) Green, areas with "no tie lines" and distant parallel lines separated 150 ft apart (Figure 4)

5.0 RECOMMENDATIONS FOR ADDITIONAL SUBSURFACE EXPLORATIONS

The acoustic basement mapping presented in this report is the first phase in identifying and mapping top of rock in the survey area. These results should be used to plan future work. Other items to consider in further mapping the rock surface include:

- Additional subbottom data acquisition
- Vibratory Cores
- Borings

After each additional work phase, a reanalysis of all data should be completed to modify the interpretation as needed to achieve the final goal of mapping the top of rock.

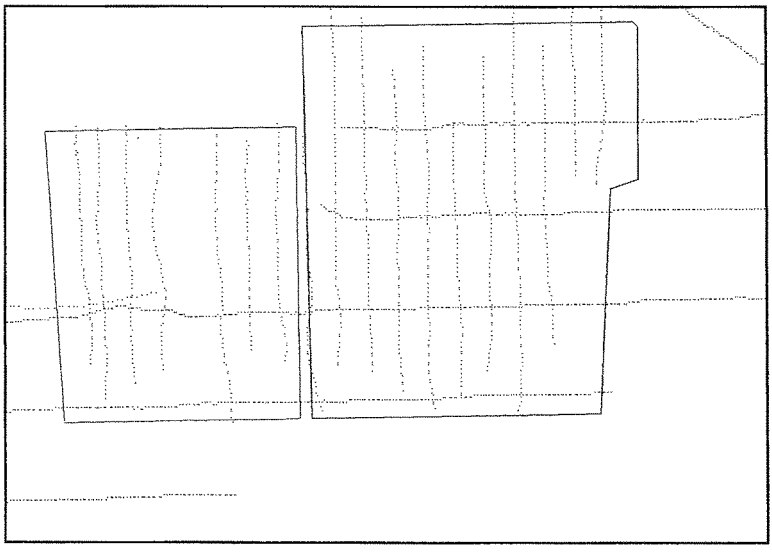


Figure 3. Example of boundaries for Red and Blue Confidence Levels.

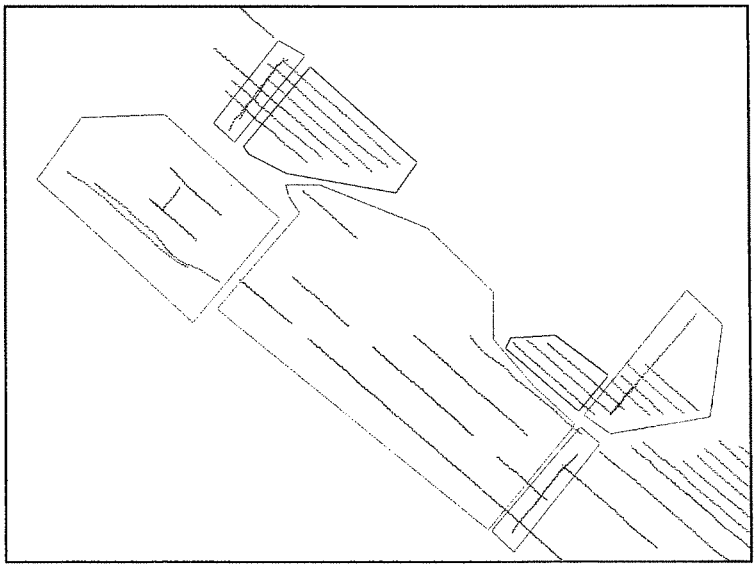


Figure 4. Example of boundaries for Green, Blue and Magenta Confidence Levels.

BOSTON HARBOR
MASSACHUSETTS

NAVIGATION IMPROVEMENT STUDY

FINAL FEASIBILITY REPORT
AND FINAL SUPPLEMENTAL
ENVIRONMENTAL IMPACT STATEMENT
(AND MASSACHUSETTS FINAL EIR)

APPENDIX K
SEDIMENT SAMPLING AND TESTING

(THIS APPENDIX UNCHANGED FROM 2008 DRAFT)

APPENDIX K
SEDIMENT SAMPLING AND TESTING

Introduction

Sampling and testing of materials proposed for dredging was made to determine the nature of the materials at depth for engineering design and dredging cost estimating purposes, and to determine the suitability of dredged materials for various methods of dredging and disposal. In order to minimize study costs, sampling and testing activities were coordinated with similar efforts for characterization of maintenance material during studies in preparation for the major maintenance cycle for the harbor in 2004 to 2009.

Additional sources of information on the nature of the dredged materials included:

- Core sample results conducted for the 1995 EIS for the maintenance and improvement work accomplished in 1998-2001,
- Sediment sampling operations for this project and the two maintenance operations in August 2002 by the Woods Hole Laboratories and CR Environmental
- The seismic surveys conducted in 2002-2003 (see Appendix I)
- Subsurface borings and probes from 2004 (see Appendices I and J)
- Vibracores made for the cultural resource investigation in 2003 (see Appendix M-3)
- Sediment sampling operations made for this project and the two maintenance operations in 2004 by the Woods Hole Laboratories
- Sediment sampling operations made for this project and for maintenance of the lower Main Ship Channel and outer harbor areas in 2005 by Battelle

These sampling operations, and the data collected on the materials to be removed by the proposed improvement dredging project, are described in the following sections.

BOSTON HARBOR

2002 SAMPLING AND TESTING PROGRAM

August 2002 Sampling Program

Initial sampling for the Boston Harbor Navigation Improvement Study was undertaken in 8 to 15 August of 2002 in conjunction with sampling for the inner and outer harbor maintenance dredging projects. A total of 51 sites were sampled in support of both maintenance and proposed improvement. In areas being considered for project deepening, penetration of cores into the parent material underlying the softer shoal material was attempted. Where possible, core samples were taken with a vibracore device. Where surface refusal was encountered a Ted Young grab sampler was used. Grain size analysis was run on the samples. The sampling locations are shown in Figures K-1 to K-6. Where possible, cores of up to 8 feet were taken. The grain size data from the 2002 core composites is provided following the location maps.

The stations would be used for all subsequent sediment characterization sampling and testing (2003, 2004 and 2005), with minor variations. Chemical and biological testing data relative to the maintenance dredging projects is not reproduced in this improvement dredging documentation. The contractor's full reports are available for review at the New England District offices.

August 2002 Sampling Program			
Project Segment	Number of Samples	Sample Stations	Sample Type
North Entrance Channel	10	Stations A thru J (Sta. C – no recovery)	Mostly Grab Samples
President Roads Anchorage	3	Stations OO, PP and QQ	Grab Samples
Main Ship Channel – President Roads	9	Stations K thru R	Mostly Grab Samples
Main Ship Channel – Roads to RTA	10	Stations S thru CC	Core Samples
Lower Reserved Channel	8	Stations DD thru KK	Core Samples
Main Ship Channel along Marine Terminal	3	Stations LL thru NN	Core Samples
Mystic River	8	Stations RR thru YY	Core Samples
Chelsea River		Stations 1 thru 12	

Figure 3. Overview of Sampling Locations within the Mystic River During the Original Sampling Effort (August 2002)

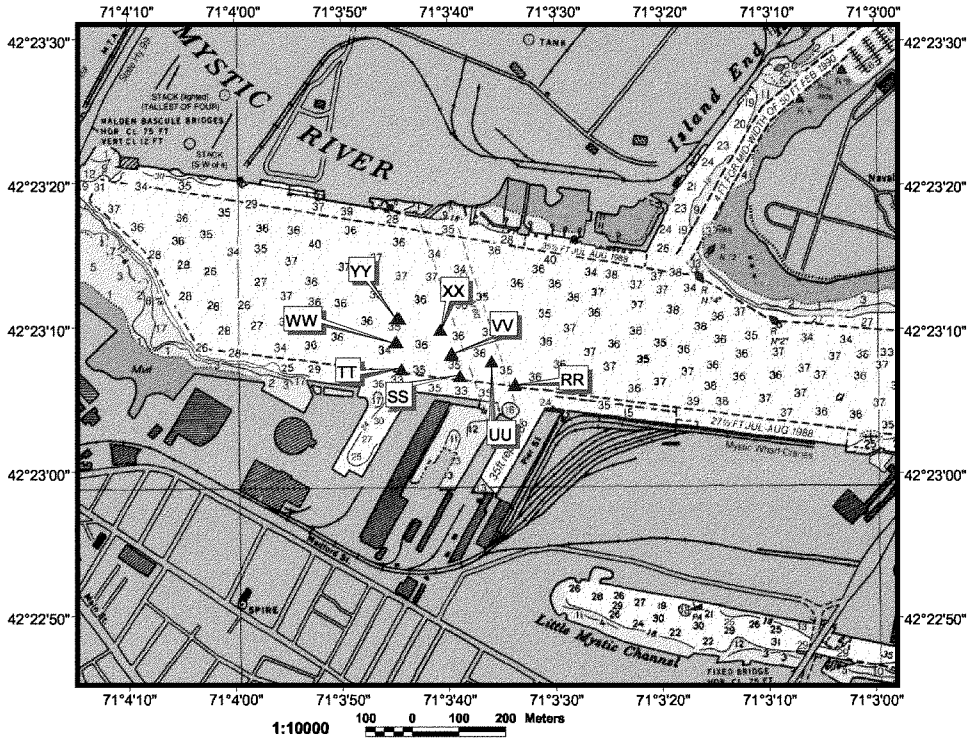


FIGURE K-3

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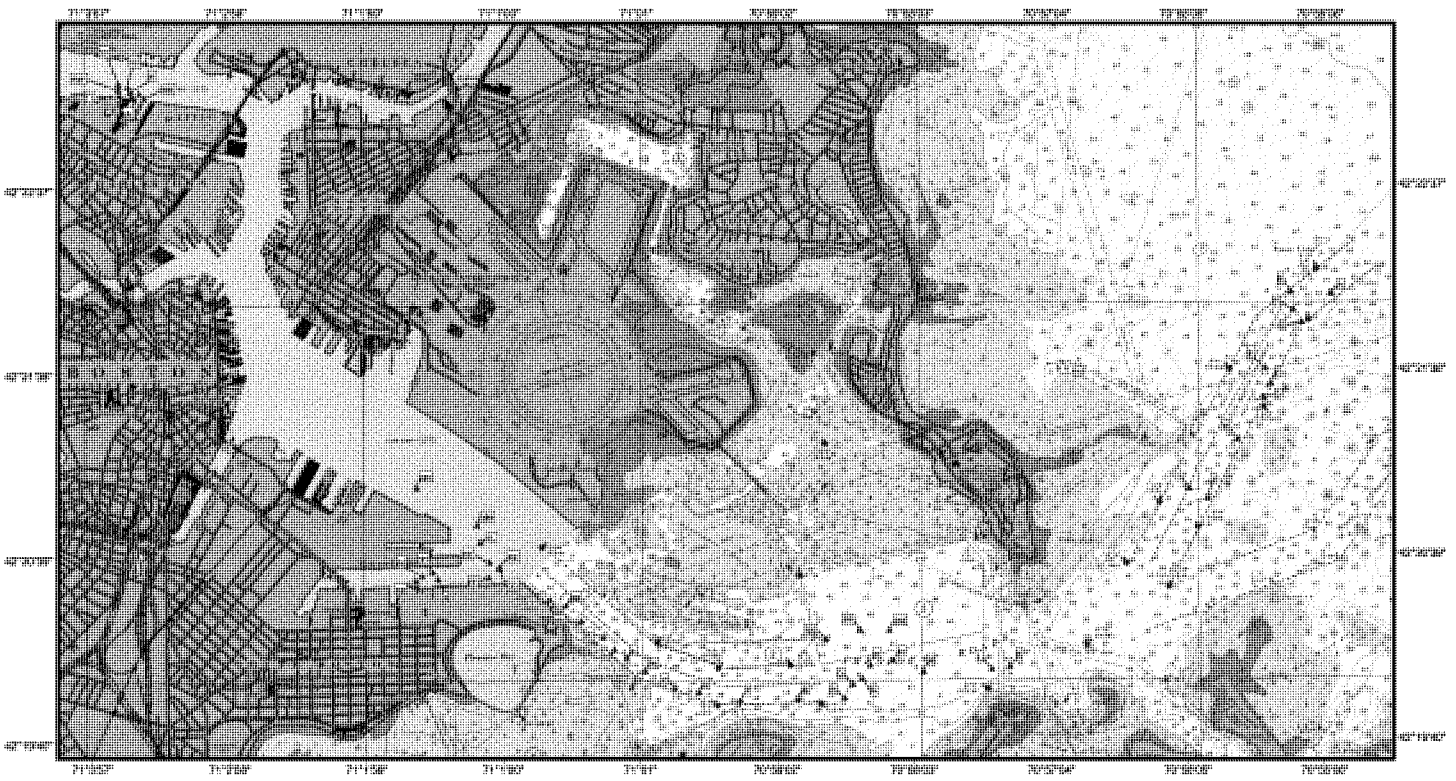
East Falmouth, Massachusetts 02536

Figure 1. Overview of Sampling Locations within Boston Harbor (August 2002)



1000 0 1000 2000 Meters

1:35000

FIGURE K-1

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Figure 4. Locations of Sediment Sampling Stations in the Reserved Channel and Adjacent Shipping Channel Collected During the Original Sampling Effort (August 2002)

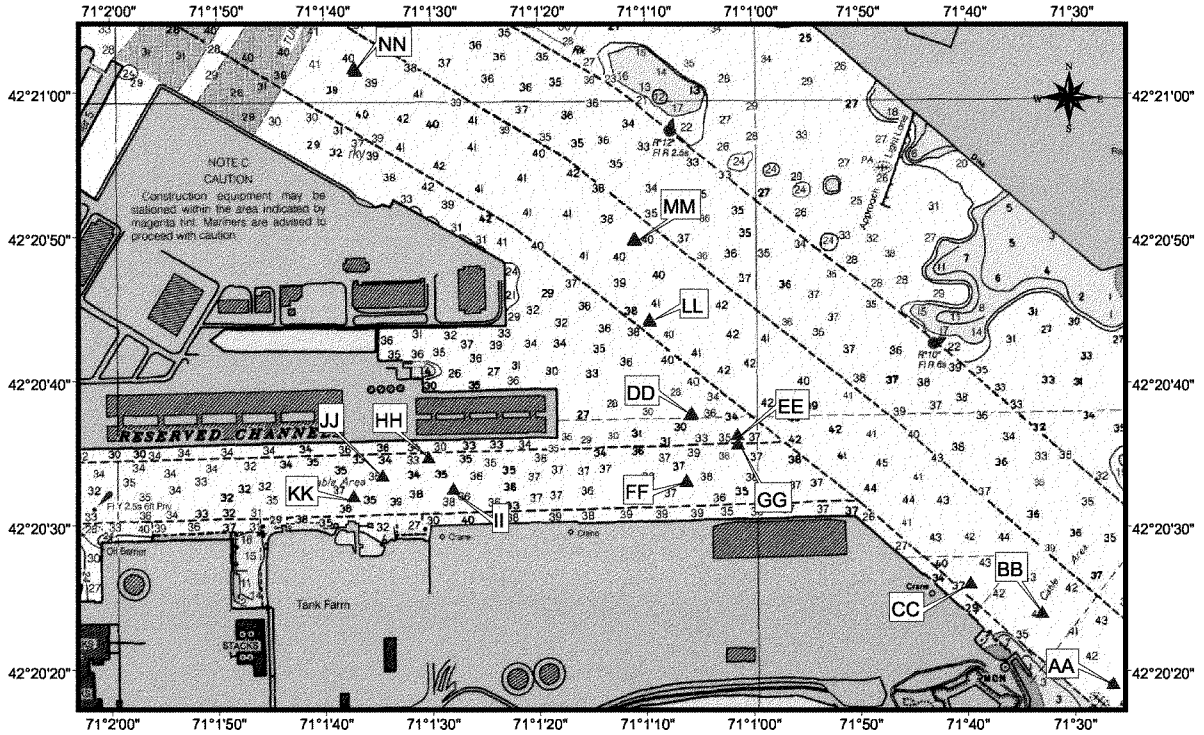

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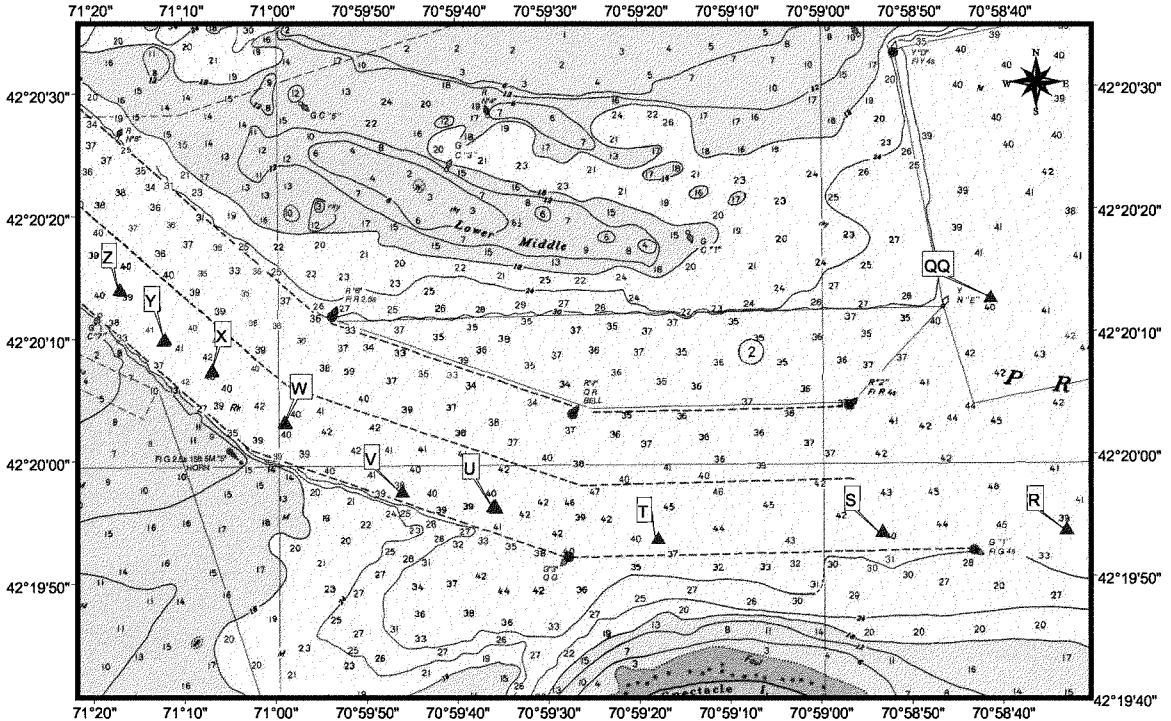
FIGURE K-4

Figure 5. Locations of Sediment Sampling Stations in the President Roads (West) Area Collected During the Original Sampling Effort (August 2002)



Ecological and Oceanographic Consultants
ENVIRONMENTAL, INC.
639 Boxberry Hill Road
East Falmouth, Massachusetts 02536

FIGURE K-5

Figure 6. Locations of Sediment Sampling Stations in the President Roads Area Collected During the Original Sampling Effort (August 2002)

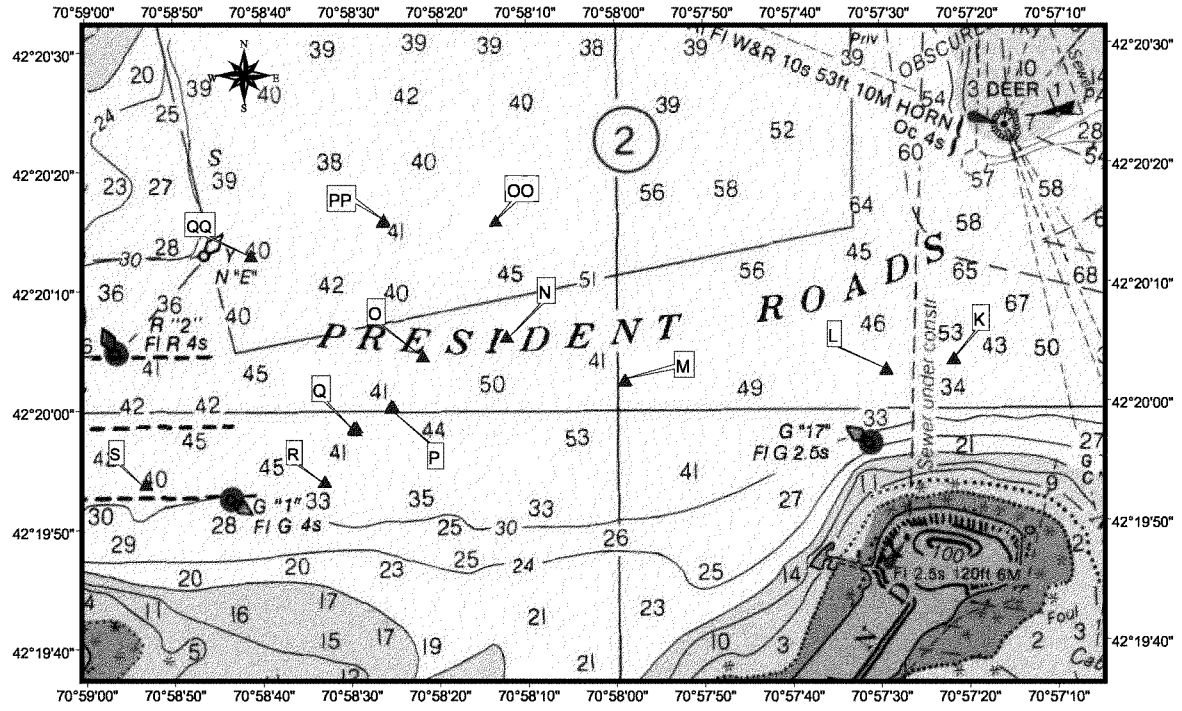


FIGURE K-6

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East Falmouth, Massachusetts 02536

Figure 7. Locations of Sediment Sampling Stations in the North Channel Collected During the Original Sampling Effort (August 2002)

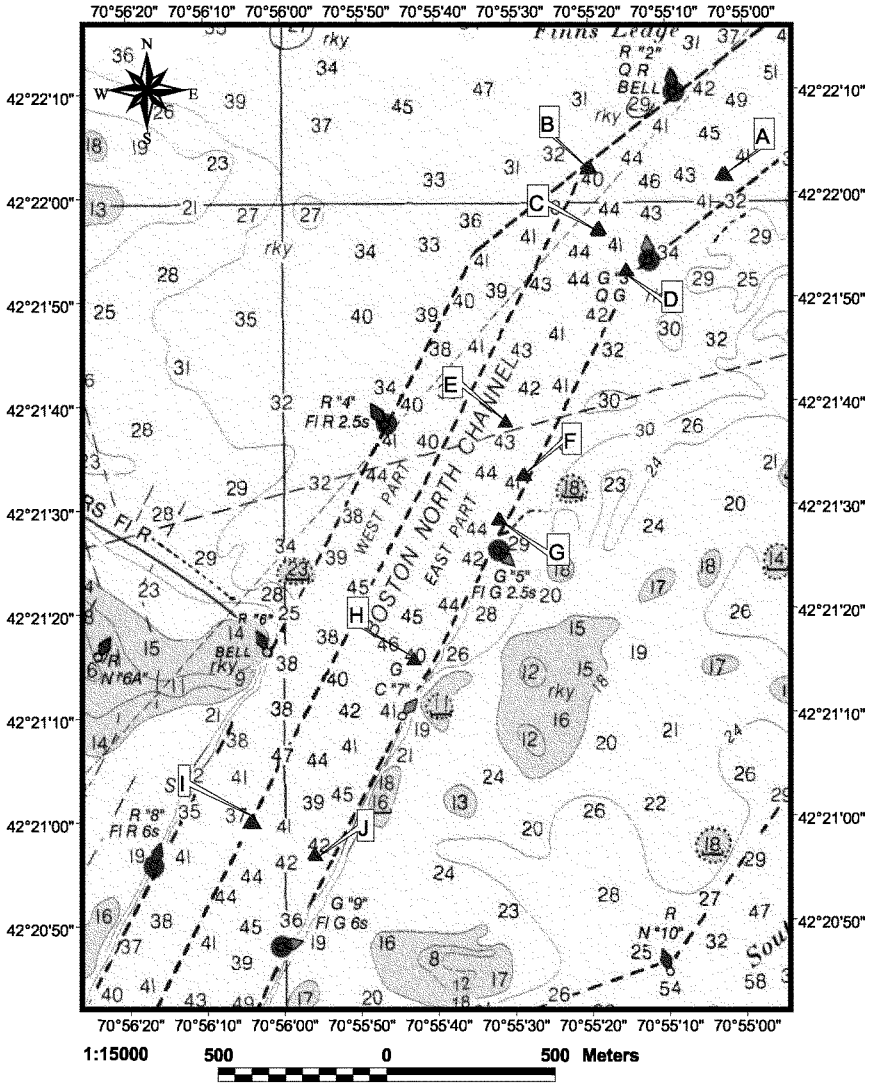

FIGURE K-7

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East Falmouth, Massachusetts 02536

Task 0002 Boston Harbor Improvement Project

STA F	STA G	STA H	STA I	STA J	STA K	STA L	STA M	STA N	STA O	STA P	STA Q	STA R	STA S	STA T	STA U	STA V
%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%
7.88	91.47	53.19	81.94	19.78	84.36	42.28	82.87	10.23	8.60	61.81	0.86	0.17	0.12	0.92	0.30	9.78
6.91	1.19	7.71	3.01	7.94	3.42	5.18	3.52	5.89	6.54	5.90	0.86	0.94	0.51	0.52	0.97	5.94
3.30	1.08	5.50	1.96	7.37	1.56	6.50	2.44	7.88	6.89	3.24	6.40	1.26	1.28	0.49	6.50	4.77
4.19	2.17	9.13	1.80	16.95	1.85	10.46	3.95	19.66	14.17	3.94	7.78	2.17	2.04	0.90	9.15	5.59
9.73	2.36	10.83	3.10	22.72	2.73	7.86	3.72	18.56	25.03	7.22	8.93	6.39	4.44	1.18	9.26	7.08
5.15	0.84	7.59	4.18	4.98	0.97	1.35	0.94	6.52	11.85	4.08	10.89	4.84	14.07	2.47	15.36	12.74
0.61	0.23	1.33	1.42	1.42	0.63	0.63	0.46	5.13	4.32	1.38	13.05	2.10	11.37	1.77	17.05	18.90
2.16	0.59	4.72	2.53	18.78	4.36	25.56	2.07	26.05	22.48	12.21	51.21	82.11	66.13	91.79	41.36	35.23
%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%
13	12	15	12	19	2.5	29	18	30	32	30	31	77	58	38	51	40

Task 0002 Boston Harbor Improvement Project

STA Y2 #2	STA Z	STA AA	STA BB	STA CC	STA DD	STA EE	STA FF	STA GG	STA HH	STA II	STA JJ	STA KK	STA LL	STA MM	STA NN	STA OO
%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%
0.00	1.87	0.41	0.56	0.00	16.25	0.08	0.00	0.10	14.41	31.01	35.7	17.45	0.07	0.11	0.00	10.21
0.00	0.74	0.45	0.30	0.43	2.61	0.02	0.02	0.24	7.79	8.25	9.94	3.36	0.05	0.16	0.00	4.35
0.03	0.42	0.42	0.22	0.62	2.95	0.11	0.05	0.32	5.66	11.81	6.69	2.15	0.15	0.25	0.03	6.54
0.10	0.44	0.51	0.43	0.97	4.49	0.18	0.06	0.40	5.32	10.57	6.1	1.80	0.38	0.32	0.08	12.29
0.11	0.47	0.67	0.64	1.34	8.95	0.80	0.09	0.80	4.67	6.06	9.09	2.03	1.08	1.16	0.13	17.52
0.19	0.95	1.10	0.45	2.16	15.91	4.80	1.86	1.13	4.06	4.29	11.35	2.50	2.44	3.21	0.30	12.19
0.35	4.02	5.64	1.32	6.11	20.33	14.16	9.85	1.90	5.41	3.01	8.94	3.09	3.69	5.84	1.48	7.96
9.07	90.88	90.77	96.31	88.34	28.48	79.77	88.00	95.13	52.64	24.97	12	67.64	92.01	88.82	97.91	28.89
%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%
43	96	45	40	51	18	27	31	30	29	22	22	28	61	89	56	29

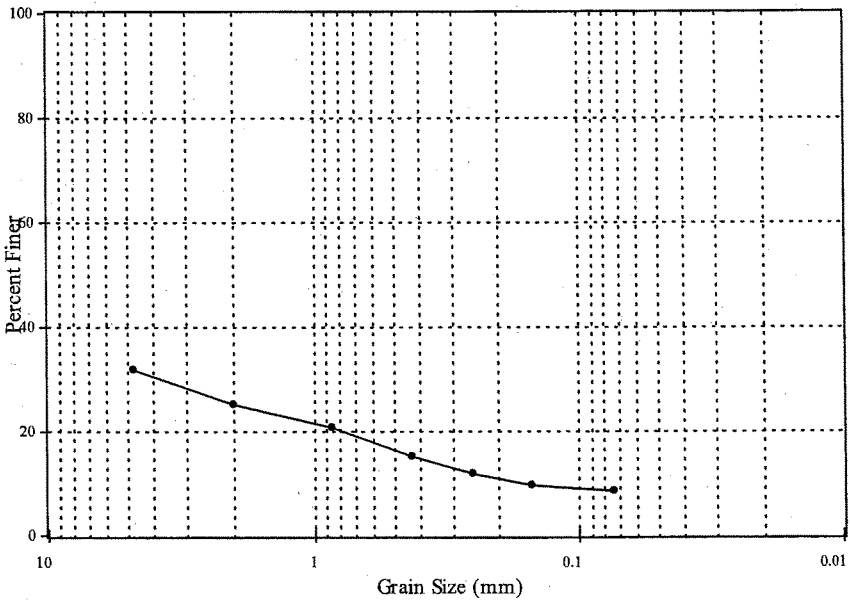
Task 0002 Boston Harbor Improvement Project

STA SS	STA TT #1	STA TT #2	STA UU #1	STA UU #2	STA VV	STA WW	STA XX #1	STA XX #2	STA YY	STA CC2 #1	STA CC2 #2	STA MM2	STA NN2 #1	STA NN2 #2
%	%	%	%	%	%	%	%	%	%	%	%	%	%	%
0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	3.01	0.00	0.00	0.00	1.23	0.00
0.00	0.03	0.00	0.00	0.00	0.02	0.01	0.02	0.00	0.80	0.18	0.00	0.00	0.14	0.00
0.02	0.17	0.00	0.01	0.00	0.22	0.08	0.08	0.04	1.96	0.62	0.01	0.40	0.38	0.02
0.02	0.66	0.13	0.56	0.00	0.34	0.30	0.14	0.04	4.05	1.62	0.03	0.70	0.71	0.01
0.04	1.27	0.32	0.83	0.00	0.73	0.32	0.27	0.03	4.46	2.04	0.06	1.07	0.73	0.02
0.69	2.52	0.13	1.85	0.07	1.38	0.62	1.21	0.23	4.17	5.03	0.16	2.34	0.74	0.07
4.09	9.04	0.76	8.22	0.86	7.85	8.82	5.74	3.56	16.87	18.57	0.58	4.51	5.07	0.18
95.14	86.02	98.89	88.49	99.06	89.37	89.91	92.50	96.08	64.63	70.94	99.17	91.02	90.97	99.70
%	%	%	%	%	%	%	%	%	%	%	%	%	%	%
37	85	40	99	38	79	55	105	37	75	73	34	82	58	32

Wet Sieve Analysis

Client: **Army Corps of Engineers**
Project: **Boston Harbor Improvement Project**
Case: N/A SDG: N/A
Client ID: **STA A**
Matrix: **Sediment**
Collection Date: **8/13/2002**

Lab Code: **M-MA030**
ETR: **0208086**
Lab ID: **0208086-09**
Concentration Units: **%**
Received Date: **8/13/2002**
Analysis Date: **8/19/2002**



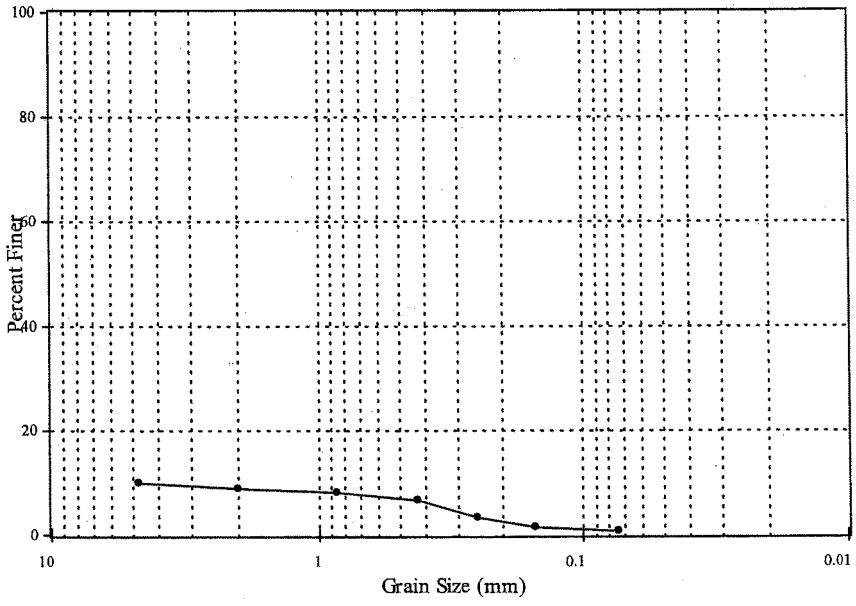
Sieve Number	Diameter Range	Percent Retained	Description
#4	>4.76 mm	68.29	Gravel
#10	<4.76 mm - 2.00 mm	6.38	Coarse Sand
#20	<2.00 mm - 0.85 mm	4.75	Medium Sand
#40	<0.85 mm - 0.425 mm	5.23	Medium Sand
#60	<0.425 mm - 0.25 mm	3.56	Fine Sand
#100	<0.25 mm - 0.15 mm	2.08	Fine Sand
#200	<0.15 mm - 0.074 mm	1.36	Fine Sand
Passing #200	<0.074 mm	8.25	Silt/Clay

N/A - Not Applicable

Wet Sieve Analysis

Client: **Army Corps of Engineers**
Project: **Boston Harbor Improvement Project**
Case: **N/A** SDG: **N/A**
Client ID: **STA B**
Matrix: **Sediment**
Collection Date: **8/13/2002**

Lab Code: **M-MA030**
ETR: **0208086**
Lab ID: **0208086-08**
Concentration Units: **%**
Received Date: **8/13/2002**
Analysis Date: **8/19/2002**



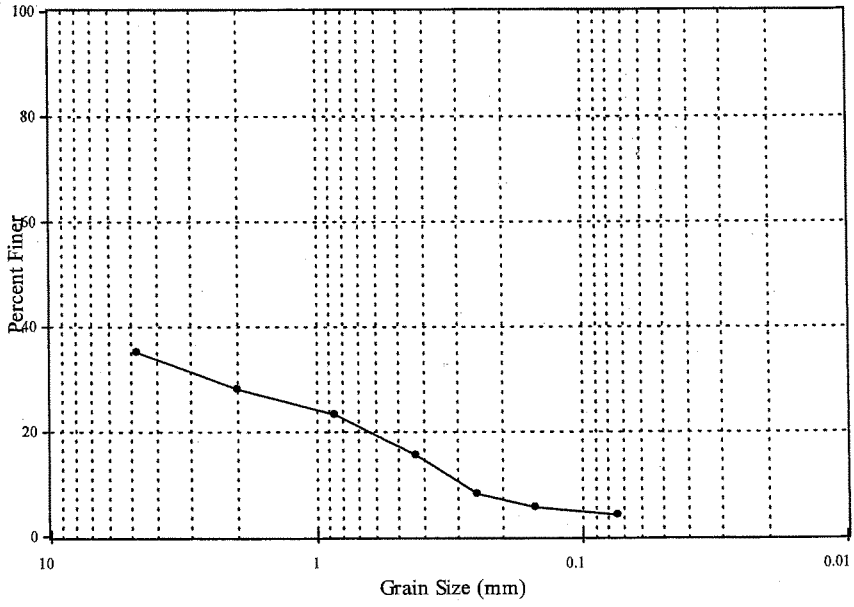
Sieve Number	Diameter Range	Percent Retained	Description
#4	>4.76 mm	90.11	Gravel
#10	<4.76 mm - 2.00 mm	1.12	Coarse Sand
#20	<2.00 mm - 0.85 mm	0.69	Medium Sand
#40	<0.85 mm - 0.425 mm	1.31	Medium Sand
#60	<0.425 mm - 0.25 mm	3.48	Fine Sand
#100	<0.25 mm - 0.15 mm	1.97	Fine Sand
#200	<0.15 mm - 0.074 mm	0.58	Fine Sand
Passing #200	<0.074 mm	0.72	Silt/Clay

N/A - Not Applicable

Wet Sieve Analysis

Client: **Army Corps of Engineers**
Project: **Boston Harbor Improvement Project**
Case: N/A SDG: N/A
Client ID: **STA D**
Matrix: **Sediment**
Collection Date: **8/13/2002**

Lab Code: **M-MA030**
ETR: **0208086**
Lab ID: **0208086-07**
Concentration Units: **%**
Received Date: **8/13/2002**
Analysis Date: **8/19/2002**



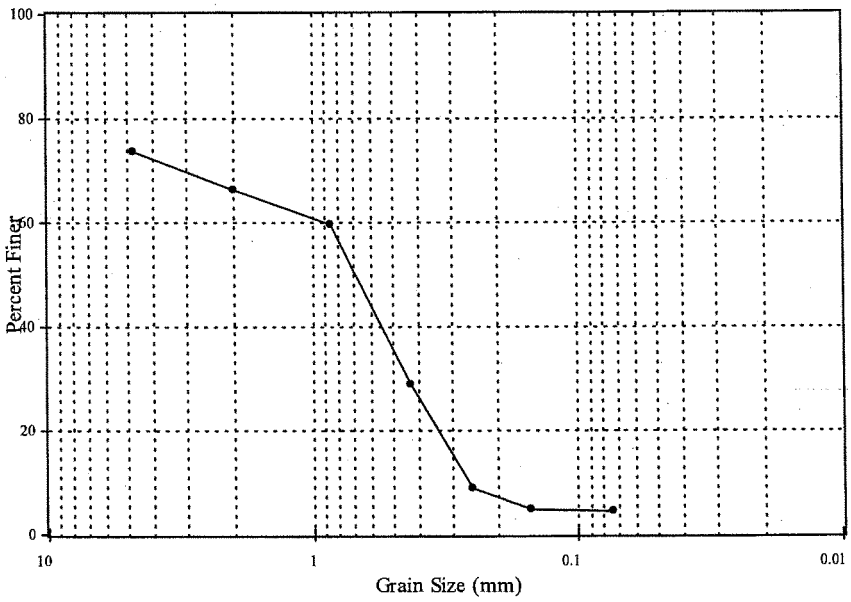
Sieve Number	Diameter Range	Percent Retained	Description
#4	>4.76 mm	64.82	Gravel
#10	<4.76 mm - 2.00 mm	6.98	Coarse Sand
#20	<2.00 mm - 0.85 mm	4.95	Medium Sand
#40	<0.85 mm - 0.425 mm	7.64	Medium Sand
#60	<0.425 mm - 0.25 mm	7.34	Fine Sand
#100	<0.25 mm - 0.15 mm	2.71	Fine Sand
#200	<0.15 mm - 0.074 mm	1.30	Fine Sand
Passing #200	<0.074 mm	4.18	Silt/Clay

N/A - Not Applicable

Wet Sieve Analysis

Client: **Army Corps of Engineers**
Project: **Boston Harbor Improvement Project**
Case: **N/A** SDG: **N/A**
Client ID: **STA E**
Matrix: **Sediment**
Collection Date: **8/13/2002**

Lab Code: **M-MA030**
ETR: **0208086**
Lab ID: **0208086-06**
Concentration Units: **%**
Received Date: **8/13/2002**
Analysis Date: **8/17/2002**



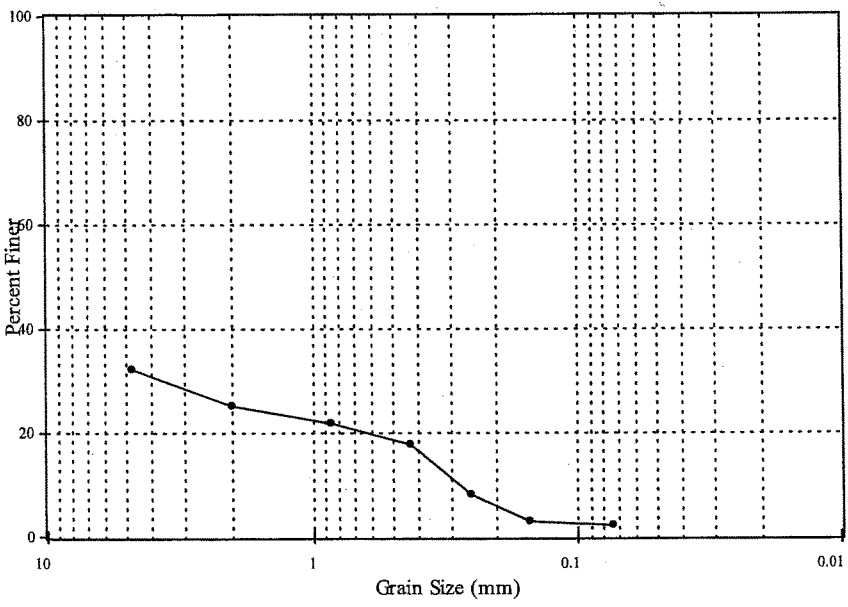
Sieve Number	Diameter Range	Percent Retained	Description
#4	>4.76 mm	26.40	Gravel
#10	<4.76 mm - 2.00 mm	7.20	Coarse Sand
#20	<2.00 mm - 0.85 mm	6.79	Medium Sand
#40	<0.85 mm - 0.425 mm	30.58	Medium Sand
#60	<0.425 mm - 0.25 mm	19.98	Fine Sand
#100	<0.25 mm - 0.15 mm	4.33	Fine Sand
#200	<0.15 mm - 0.074 mm	0.44	Fine Sand
Passing #200	<0.074 mm	4.10	Silt/Clay

N/A - Not Applicable

Wet Sieve Analysis

Client: **Army Corps of Engineers**
Project: **Boston Harbor Improvement Project**
Case: **N/A** SDG: **N/A**
Client ID: **STA F**
Matrix: **Sediment**
Collection Date: **8/13/2002**

Lab Code: **M-MA030**
ETR: **0208086**
Lab ID: **0208086-05**
Concentration Units: **%**
Received Date: **8/13/2002**
Analysis Date: **8/17/2002**



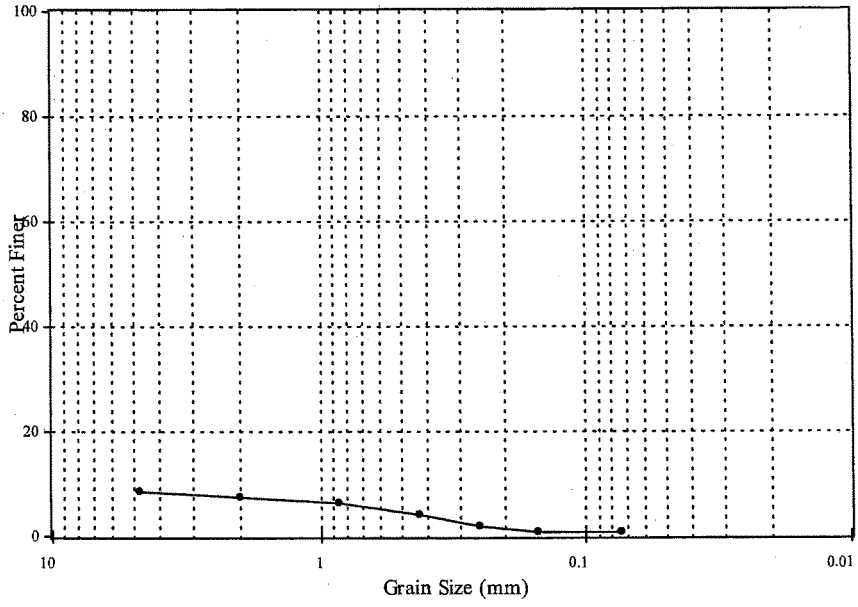
Sieve Number	Diameter Range	Percent Retained	Description
#4	>4.76 mm	67.88	Gravel
#10	<4.76 mm - 2.00 mm	6.91	Coarse Sand
#20	<2.00 mm - 0.85 mm	3.30	Medium Sand
#40	<0.85 mm - 0.425 mm	4.19	Medium Sand
#60	<0.425 mm - 0.25 mm	9.73	Fine Sand
#100	<0.25 mm - 0.15 mm	5.15	Fine Sand
#200	<0.15 mm - 0.074 mm	0.61	Fine Sand
Passing #200	<0.074 mm	2.16	Silt/Clay

N/A - Not Applicable

Wet Sieve Analysis

Client: **Army Corps of Engineers**
Project: **Boston Harbor Improvement Project**
Case: **N/A** SDG: **N/A**
Client ID: **STA G**
Matrix: **Sediment**
Collection Date: **8/13/2002**

Lab Code: **M-MA030**
ETR: **0208086**
Lab ID: **0208086-04**
Concentration Units: **%**
Received Date: **8/13/2002**
Analysis Date: **8/17/2002**



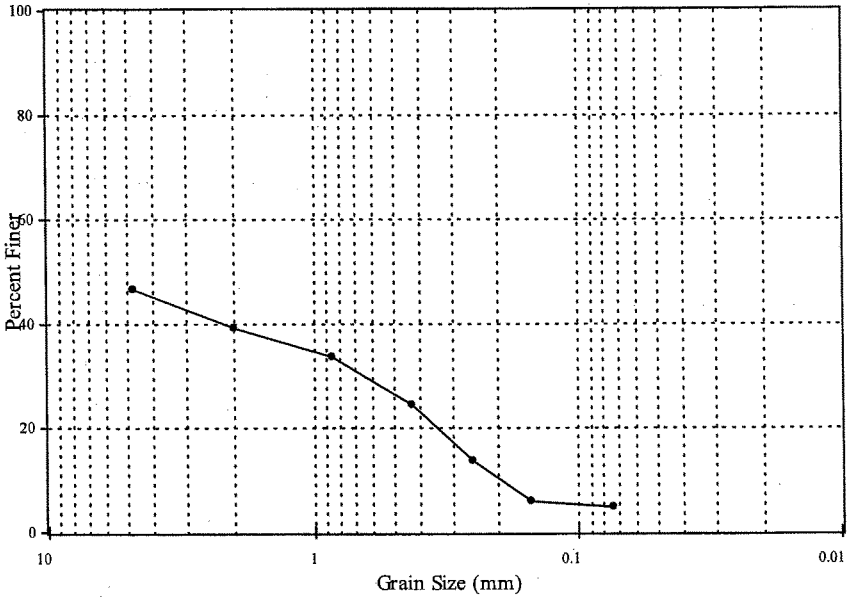
Sieve Number	Diameter Range	Percent Retained	Description
#4	>4.76 mm	91.47	Gravel
#10	<4.76 mm - 2.00 mm	1.19	Coarse Sand
#20	<2.00 mm - 0.85 mm	1.08	Medium Sand
#40	<0.85 mm - 0.425 mm	2.17	Medium Sand
#60	<0.425 mm - 0.25 mm	2.36	Fine Sand
#100	<0.25 mm - 0.15 mm	0.84	Fine Sand
#200	<0.15 mm - 0.074 mm	0.23	Fine Sand
Passing #200	<0.074 mm	0.59	Silt/Clay

N/A - Not Applicable

Wet Sieve Analysis

Client: **Army Corps of Engineers**
Project: **Boston Harbor Improvement Project**
Case: **N/A** SDG: **N/A**
Client ID: **STA H**
Matrix: **Sediment**
Collection Date: **8/13/2002**

Lab Code: **M-MA030**
ETR: **0208086**
Lab ID: **0208086-03**
Concentration Units: **%**
Received Date: **8/13/2002**
Analysis Date: **8/17/2002**



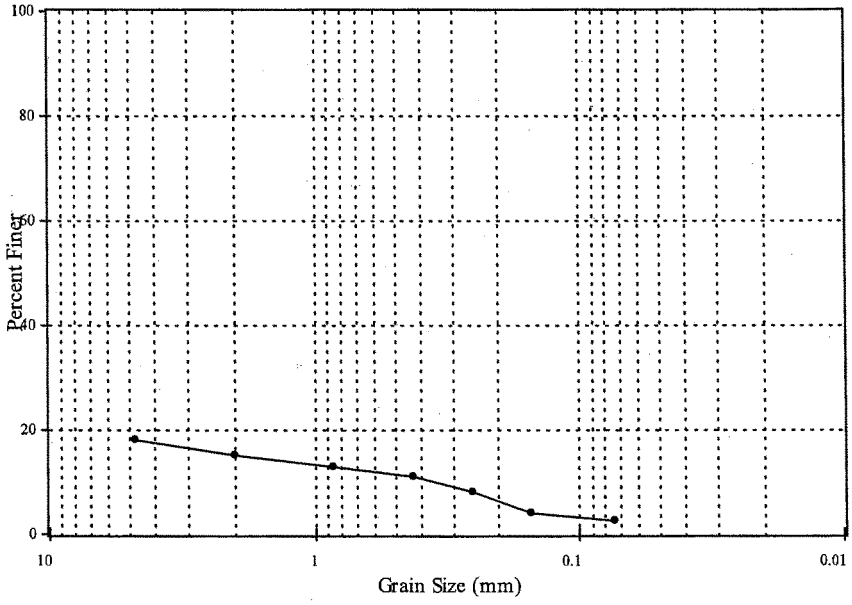
Sieve Number	Diameter Range	Percent Retained	Description
#4	>4.76 mm	53.19	Gravel
#10	<4.76 mm - 2.00 mm	7.71	Coarse Sand
#20	<2.00 mm - 0.85 mm	5.50	Medium Sand
#40	<0.85 mm - 0.425 mm	9.13	Medium Sand
#60	<0.425 mm - 0.25 mm	10.83	Fine Sand
#100	<0.25 mm - 0.15 mm	7.59	Fine Sand
#200	<0.15 mm - 0.074 mm	1.33	Fine Sand
Passing #200	<0.074 mm	4.72	Silt/Clay

N/A - Not Applicable

Wet Sieve Analysis

Client: **Army Corps of Engineers**
Project: **Boston Harbor Improvement Project**
Case: **N/A** SDG: **N/A**
Client ID: **STA I**
Matrix: **Sediment**
Collection Date: **8/13/2002**

Lab Code: **M-MA030**
ETR: **0208086**
Lab ID: **0208086-02**
Concentration Units: **%**
Received Date: **8/13/2002**
Analysis Date: **8/17/2002**



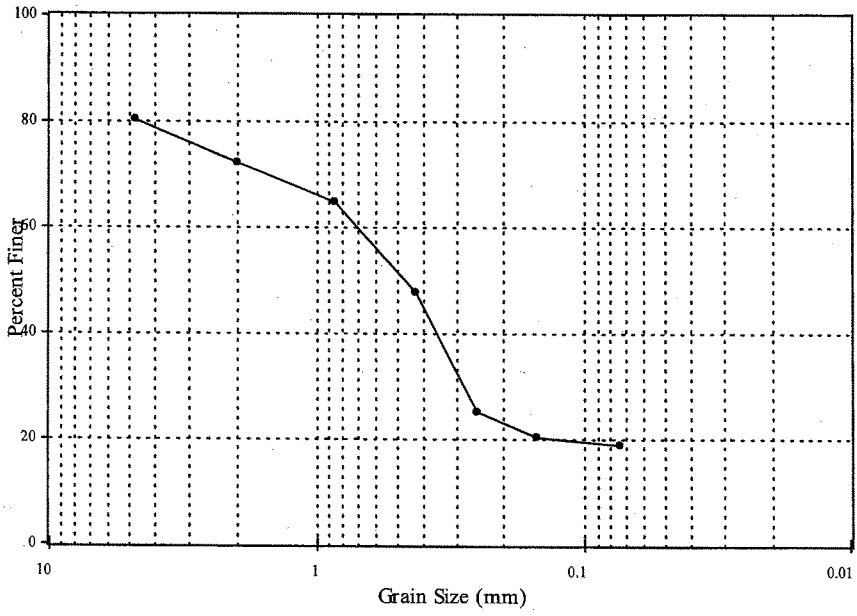
Sieve Number	Diameter Range	Percent Retained	Description
#4	>4.76 mm	81.94	Gravel
#10	<4.76 mm - 2.00 mm	3.01	Coarse Sand
#20	<2.00 mm - 0.85 mm	1.96	Medium Sand
#40	<0.85 mm - 0.425 mm	1.80	Medium Sand
#60	<0.425 mm - 0.25 mm	3.10	Fine Sand
#100	<0.25 mm - 0.15 mm	4.18	Fine Sand
#200	<0.15 mm - 0.074 mm	1.42	Fine Sand
Passing #200	<0.074 mm	2.53	Silt/Clay

N/A - Not Applicable

Wet Sieve Analysis

Client: **Army Corps of Engineers**
Project: **Boston Harbor Improvement Project**
Case: **N/A** SDG: **N/A**
Client ID: **STA J**
Matrix: **Sediment**
Collection Date: **8/13/2002**

Lab Code: **M-MA030**
ETR: **0208086**
Lab ID: **0208086-01**
Concentration Units: **%**
Received Date: **8/13/2002**
Analysis Date: **8/17/2002**



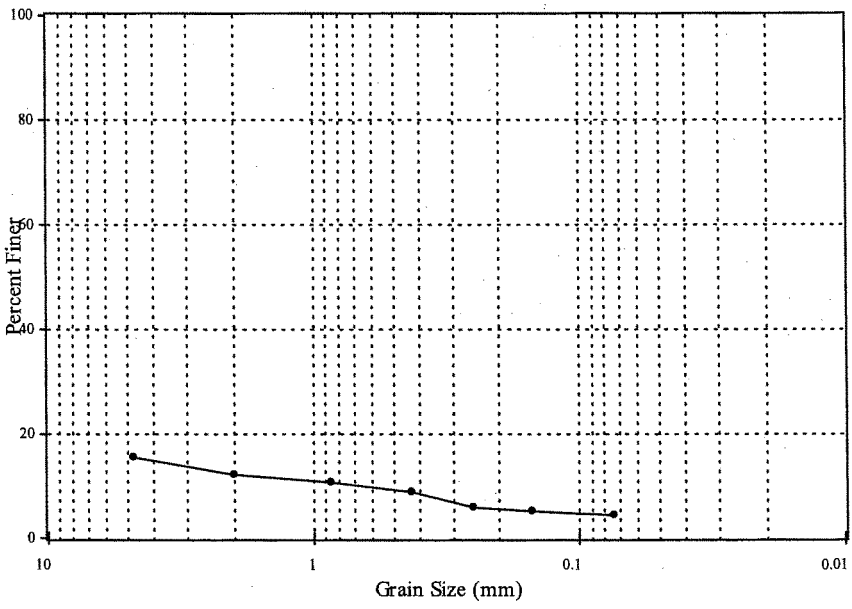
Sieve Number	Diameter Range	Percent Retained	Description
#4	>4.76 mm	19.78	Gravel
#10	<4.76 mm - 2.00 mm	7.94	Coarse Sand
#20	<2.00 mm - 0.85 mm	7.37	Medium Sand
#40	<0.85 mm - 0.425 mm	16.95	Medium Sand
#60	<0.425 mm - 0.25 mm	22.72	Fine Sand
#100	<0.25 mm - 0.15 mm	4.98	Fine Sand
#200	<0.15 mm - 0.074 mm	1.42	Fine Sand
Passing #200	<0.074 mm	18.78	Silt/Clay

N/A - Not Applicable

Wet Sieve Analysis

Client: **Army Corps of Engineers**
Project: **Boston Harbor Improvement Project**
Case: **N/A** SDG: **N/A**
Client ID: **STA K**
Matrix: **Sediment**
Collection Date: **8/13/2002**

Lab Code: **M-MA030**
ETR: **0208086**
Lab ID: **0208086-10**
Concentration Units: **%**
Received Date: **8/13/2002**
Analysis Date: **8/19/2002**



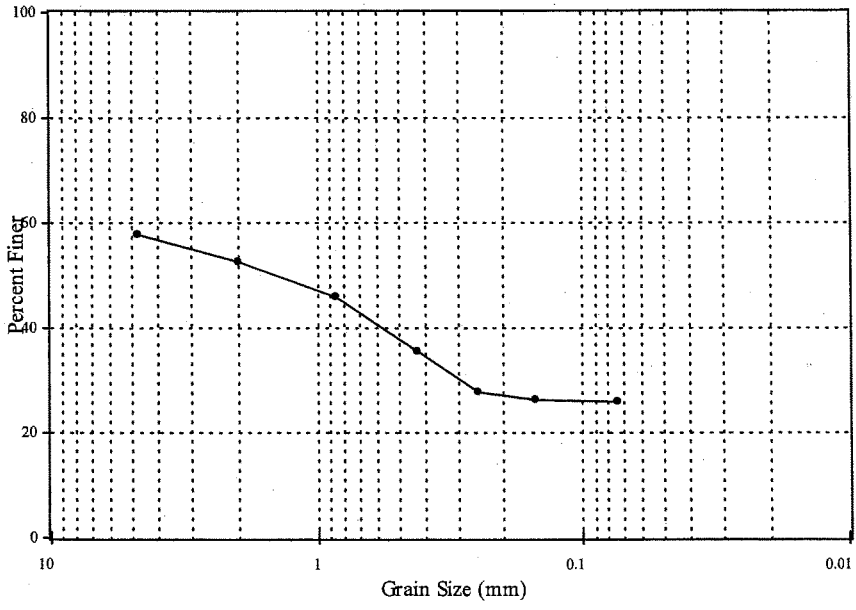
Sieve Number	Diameter Range	Percent Retained	Description
#4	>4.76 mm	84.36	Gravel
#10	<4.76 mm - 2.00 mm	3.42	Coarse Sand
#20	<2.00 mm - 0.85 mm	1.56	Medium Sand
#40	<0.85 mm - 0.425 mm	1.85	Medium Sand
#60	<0.425 mm - 0.25 mm	2.73	Fine Sand
#100	<0.25 mm - 0.15 mm	0.97	Fine Sand
#200	<0.15 mm - 0.074 mm	0.63	Fine Sand
Passing #200	<0.074 mm	4.36	Silt/Clay

N/A - Not Applicable

Wet Sieve Analysis

Client: **Army Corps of Engineers**
Project: **Boston Harbor Improvement Project**
Case: **N/A** SDG: **N/A**
Client ID: **STA L**
Matrix: **Sediment**
Collection Date: **8/13/2002**

Lab Code: **M-MA030**
ETR: **0208086**
Lab ID: **0208086-11**
Concentration Units: **%**
Received Date: **8/13/2002**
Analysis Date: **8/19/2002**



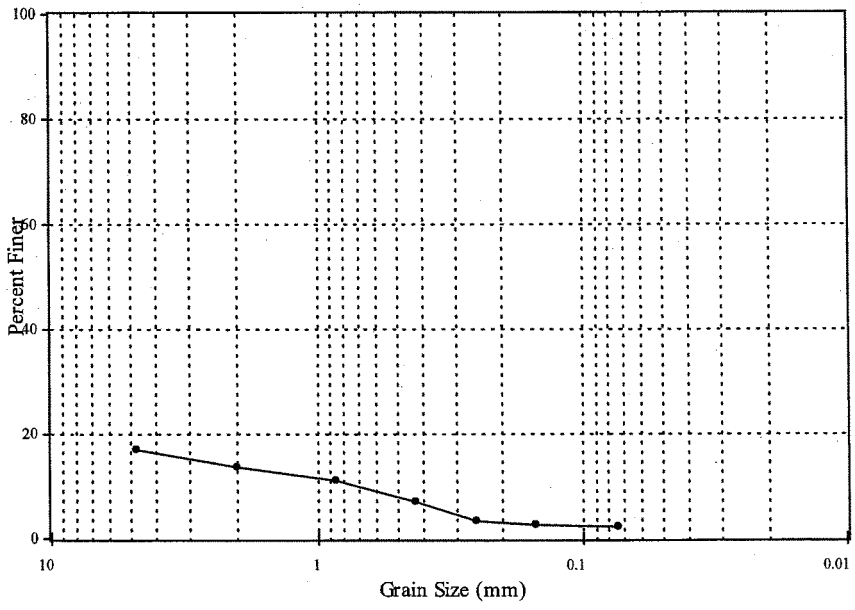
Sieve Number	Diameter Range	Percent Retained	Description
#4	>4.76 mm	42.28	Gravel
#10	<4.76 mm - 2.00 mm	5.18	Coarse Sand
#20	<2.00 mm - 0.85 mm	6.50	Medium Sand
#40	<0.85 mm - 0.425 mm	10.46	Medium Sand
#60	<0.425 mm - 0.25 mm	7.86	Fine Sand
#100	<0.25 mm - 0.15 mm	1.35	Fine Sand
#200	<0.15 mm - 0.074 mm	0.63	Fine Sand
Passing #200	<0.074 mm	25.56	Silt/Clay

N/A - Not Applicable

Wet Sieve Analysis

Client: **Army Corps of Engineers**
Project: **Boston Harbor Improvement Project**
Case: **N/A** SDG: **N/A**
Client ID: **STA M**
Matrix: **Sediment**
Collection Date: **8/14/2002**

Lab Code: **M-MA030**
ETR: **0208094**
Lab ID: **0208094-09**
Concentration Units: **%**
Received Date: **8/15/2002**
Analysis Date: **8/20/2002**



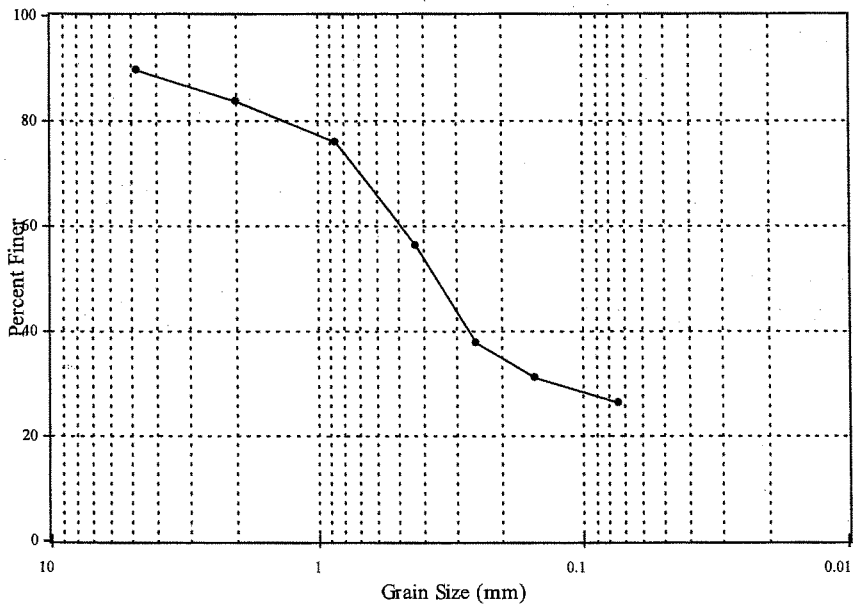
Sieve Number	Diameter Range	Percent Retained	Description
#4	>4.76 mm	82.87	Gravel
#10	<4.76 mm - 2.00 mm	3.52	Coarse Sand
#20	<2.00 mm - 0.85 mm	2.44	Medium Sand
#40	<0.85 mm - 0.425 mm	3.95	Medium Sand
#60	<0.425 mm - 0.25 mm	3.72	Fine Sand
#100	<0.25 mm - 0.15 mm	0.94	Fine Sand
#200	<0.15 mm - 0.074 mm	0.46	Fine Sand
Passing #200	<0.074 mm	2.07	Silt/Clay

N/A - Not Applicable

Wet Sieve Analysis

Client: **Army Corps of Engineers**
Project: **Boston Harbor Improvement Project**
Case: N/A SDG: N/A
Client ID: **STA N**
Matrix: **Sediment**
Collection Date: **8/14/2002**

Lab Code: **M-MA030**
ETR: **0208094**
Lab ID: **0208094-08**
Concentration Units: **%**
Received Date: **8/15/2002**
Analysis Date: **8/20/2002**



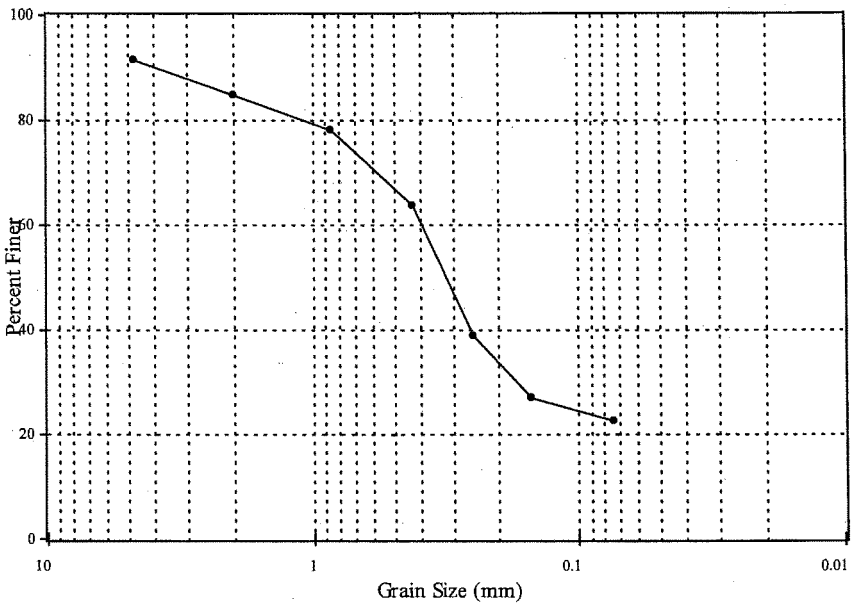
Sieve Number	Diameter Range	Percent Retained	Description
#4	>4.76 mm	10.23	Gravel
#10	<4.76 mm - 2.00 mm	5.89	Coarse Sand
#20	<2.00 mm - 0.85 mm	7.88	Medium Sand
#40	<0.85 mm - 0.425 mm	19.66	Medium Sand
#60	<0.425 mm - 0.25 mm	18.56	Fine Sand
#100	<0.25 mm - 0.15 mm	6.52	Fine Sand
#200	<0.15 mm - 0.074 mm	5.13	Fine Sand
Passing #200	<0.074 mm	26.05	Silt/Clay

N/A - Not Applicable

Wet Sieve Analysis

Client: **Army Corps of Engineers**
Project: **Boston Harbor Improvement Project**
Case: **N/A** SDG: **N/A**
Client ID: **STA O**
Matrix: **Sediment**
Collection Date: **8/14/2002**

Lab Code: **M-MA030**
ETR: **0208094**
Lab ID: **0208094-07**
Concentration Units: **%**
Received Date: **8/15/2002**
Analysis Date: **8/20/2002**



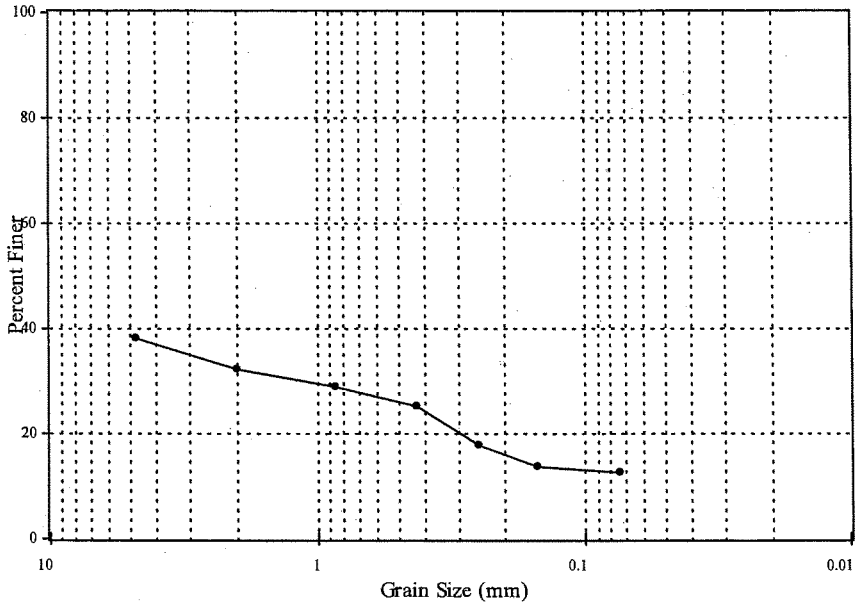
Sieve Number	Diameter Range	Percent Retained	Description
#4	>4.76 mm	8.60	Gravel
#10	<4.76 mm - 2.00 mm	6.54	Coarse Sand
#20	<2.00 mm - 0.85 mm	6.89	Medium Sand
#40	<0.85 mm - 0.425 mm	14.17	Medium Sand
#60	<0.425 mm - 0.25 mm	25.03	Fine Sand
#100	<0.25 mm - 0.15 mm	11.85	Fine Sand
#200	<0.15 mm - 0.074 mm	4.32	Fine Sand
Passing #200	<0.074 mm	22.48	Silt/Clay

N/A - Not Applicable

Wet Sieve Analysis

Client: **Army Corps of Engineers**
Project: **Boston Harbor Improvement Project**
Case: **N/A** SDG: **N/A**
Client ID: **STA P**
Matrix: **Sediment**
Collection Date: **8/14/2002**

Lab Code: **M-MA030**
ETR: **0208094**
Lab ID: **0208094-06**
Concentration Units: **%**
Received Date: **8/15/2002**
Analysis Date: **8/20/2002**



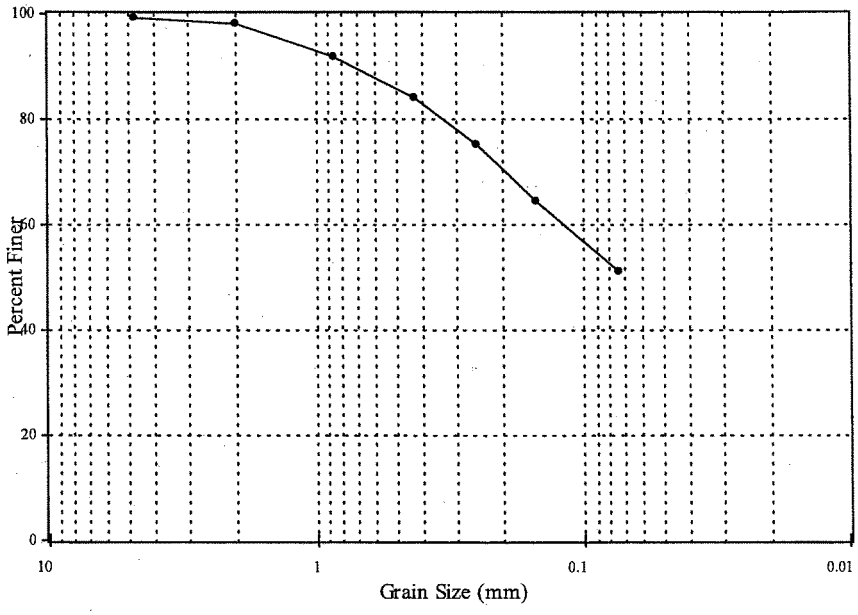
Sieve Number	Diameter Range	Percent Retained	Description
#4	>4.76 mm	61.81	Gravel
#10	<4.76 mm - 2.00 mm	5.90	Coarse Sand
#20	<2.00 mm - 0.85 mm	3.24	Medium Sand
#40	<0.85 mm - 0.425 mm	3.94	Medium Sand
#60	<0.425 mm - 0.25 mm	7.22	Fine Sand
#100	<0.25 mm - 0.15 mm	4.08	Fine Sand
#200	<0.15 mm - 0.074 mm	1.38	Fine Sand
Passing #200	<0.074 mm	12.21	Silt/Clay

N/A - Not Applicable

Wet Sieve Analysis

Client: **Army Corps of Engineers**
Project: **Boston Harbor Improvement Project**
Case: **N/A** SDG: **N/A**
Client ID: **STA Q**
Matrix: **Sediment**
Collection Date: **8/9/2002**

Lab Code: **M-MA030**
ETR: **0208080**
Lab ID: **0208080-10**
Concentration Units: **%**
Received Date: **8/9/2002**
Analysis Date: **8/12/2002**



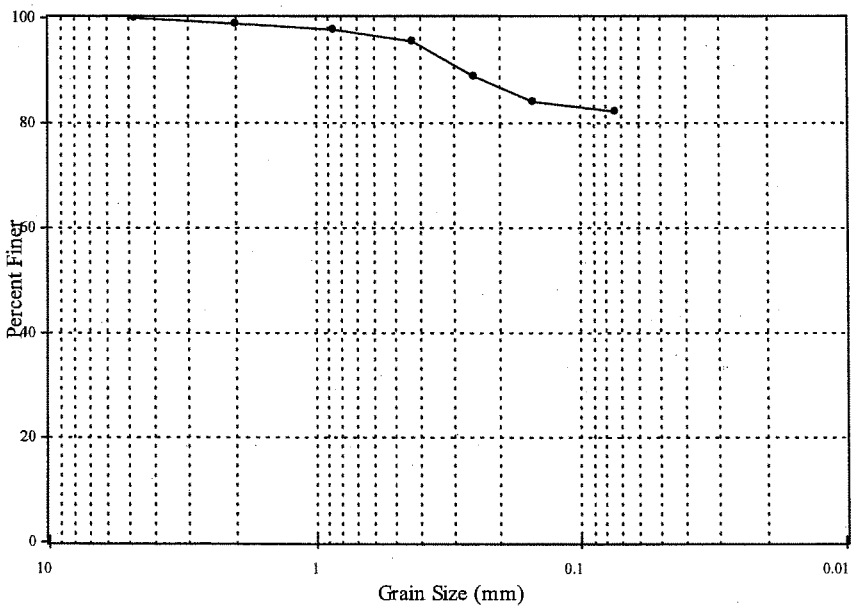
Sieve Number	Diameter Range	Percent Retained	Description
#4	>4.76 mm	0.86	Gravel
#10	<4.76 mm - 2.00 mm	0.86	Coarse Sand
#20	<2.00 mm - 0.85 mm	6.40	Medium Sand
#40	<0.85 mm - 0.425 mm	7.78	Medium Sand
#60	<0.425 mm - 0.25 mm	8.93	Fine Sand
#100	<0.25 mm - 0.15 mm	10.89	Fine Sand
#200	<0.15 mm - 0.074 mm	13.05	Fine Sand
Passing #200	<0.074 mm	51.21	Silt/Clay

N/A - Not Applicable

Wet Sieve Analysis

Client: **Army Corps of Engineers**
Project: **Boston Harbor Improvement Project**
Case: **N/A** SDG: **N/A**
Client ID: **STA R**
Matrix: **Sediment**
Collection Date: **8/14/2002**

Lab Code: **M-MA030**
ETR: **0208094**
Lab ID: **0208094-05**
Concentration Units: **%**
Received Date: **8/15/2002**
Analysis Date: **8/19/2002**



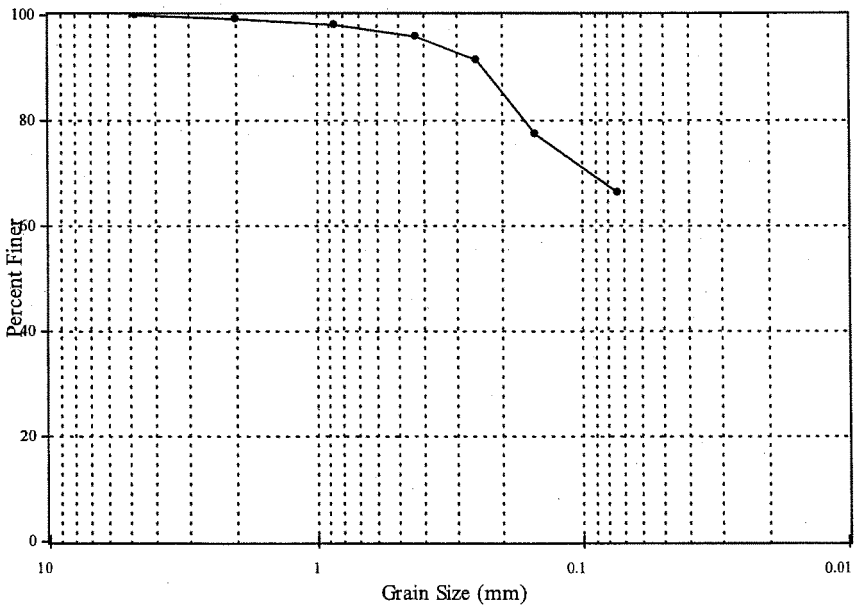
Sieve Number	Diameter Range	Percent Retained	Description
#4	>4.76 mm	0.17	Gravel
#10	<4.76 mm - 2.00 mm	0.94	Coarse Sand
#20	<2.00 mm - 0.85 mm	1.26	Medium Sand
#40	<0.85 mm - 0.425 mm	2.17	Medium Sand
#60	<0.425 mm - 0.25 mm	6.39	Fine Sand
#100	<0.25 mm - 0.15 mm	4.84	Fine Sand
#200	<0.15 mm - 0.074 mm	2.10	Fine Sand
Passing #200	<0.074 mm	82.11	Silt/Clay

N/A - Not Applicable

Wet Sieve Analysis

Client: **Army Corps of Engineers**
Project: **Boston Harbor Improvement Project**
Case: **N/A** SDG: **N/A**
Client ID: **STA S**
Matrix: **Sediment**
Collection Date: **8/14/2002**

Lab Code: **M-MA030**
ETR: **0208094**
Lab ID: **0208094-04**
Concentration Units: **%**
Received Date: **8/15/2002**
Analysis Date: **8/20/2002**



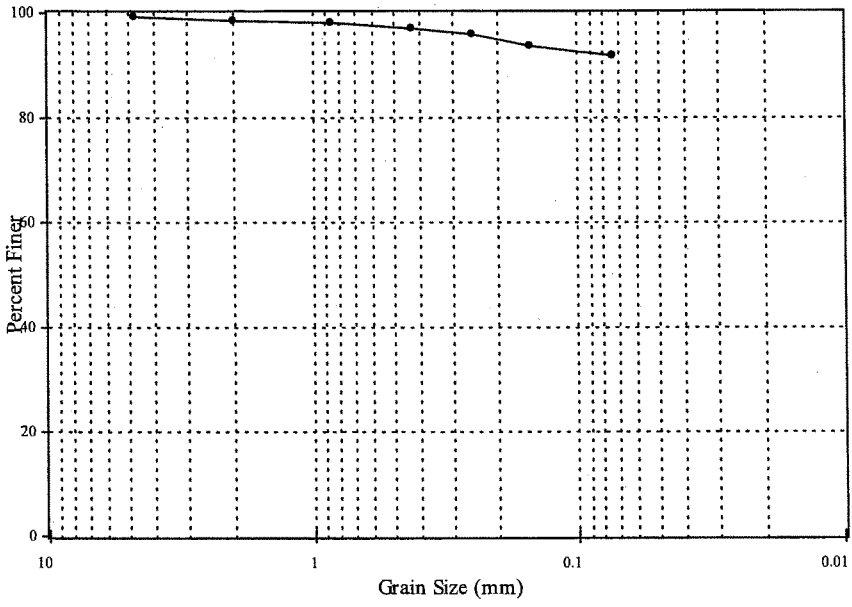
Sieve Number	Diameter Range	Percent Retained	Description
#4	>4.76 mm	0.12	Gravel
#10	<4.76 mm - 2.00 mm	0.51	Coarse Sand
#20	<2.00 mm - 0.85 mm	1.28	Medium Sand
#40	<0.85 mm - 0.425 mm	2.04	Medium Sand
#60	<0.425 mm - 0.25 mm	4.44	Fine Sand
#100	<0.25 mm - 0.15 mm	14.07	Fine Sand
#200	<0.15 mm - 0.074 mm	11.37	Fine Sand
Passing #200	<0.074 mm	66.13	Silt/Clay

N/A - Not Applicable

Wet Sieve Analysis

Client: **Army Corps of Engineers**
Project: **Boston Harbor Improvement Project**
Case: **N/A** SDG: **N/A**
Client ID: **STA T**
Matrix: **Sediment**
Collection Date: **8/14/2002**

Lab Code: **M-MA030**
ETR: **0208094**
Lab ID: **0208094-03**
Concentration Units: **%**
Received Date: **8/15/2002**
Analysis Date: **8/20/2002**



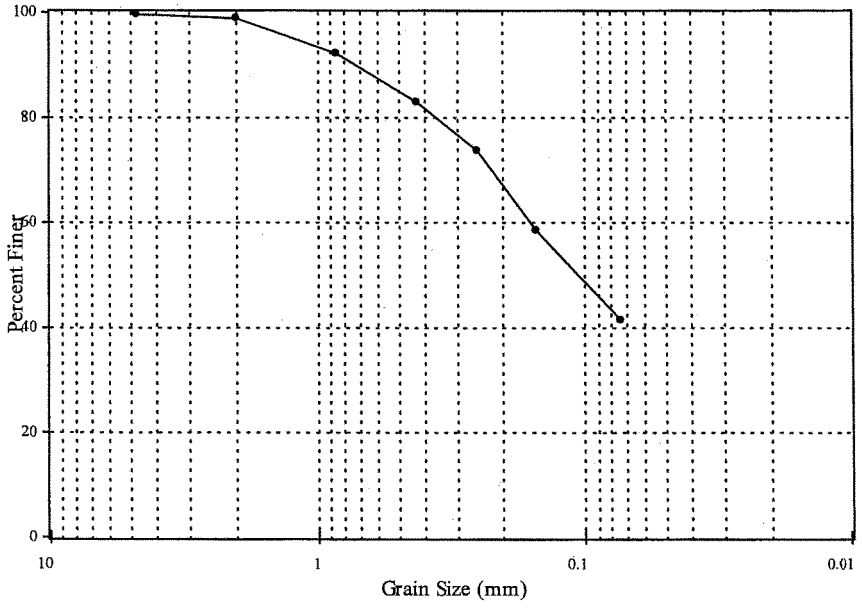
Sieve Number	Diameter Range	Percent Retained	Description
#4	>4.76 mm	0.92	Gravel
#10	<4.76 mm - 2.00 mm	0.52	Coarse Sand
#20	<2.00 mm - 0.85 mm	0.49	Medium Sand
#40	<0.85 mm - 0.425 mm	0.90	Medium Sand
#60	<0.425 mm - 0.25 mm	1.18	Fine Sand
#100	<0.25 mm - 0.15 mm	2.47	Fine Sand
#200	<0.15 mm - 0.074 mm	1.77	Fine Sand
Passing #200	<0.074 mm	91.79	Silt/Clay

N/A - Not Applicable

Wet Sieve Analysis

Client: **Army Corps of Engineers**
Project: **Boston Harbor Improvement Project**
Case: N/A SDG: N/A
Client ID: **STA U**
Matrix: **Sediment**
Collection Date: **8/9/2002**

Lab Code: **M-MA030**
ETR: **0208080**
Lab ID: **0208080-08**
Concentration Units: **%**
Received Date: **8/9/2002**
Analysis Date: **8/12/2002**



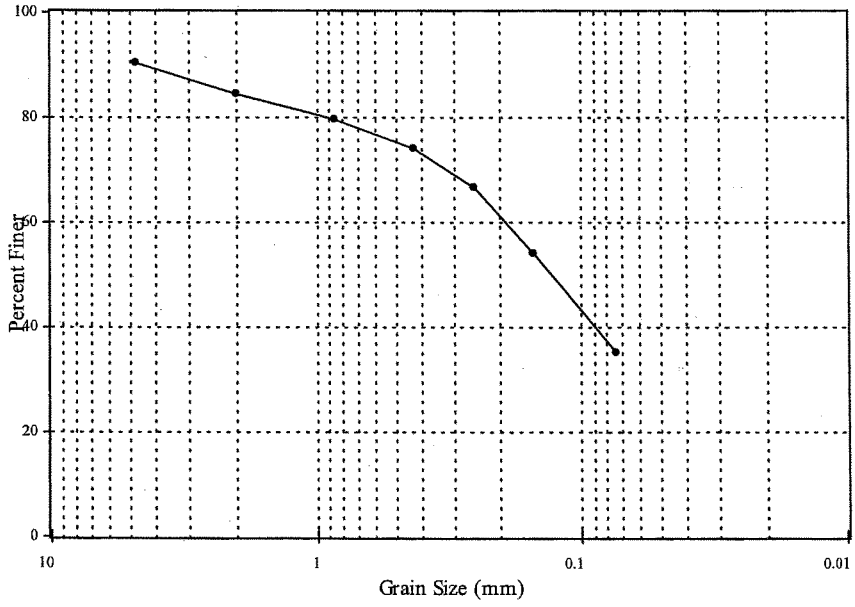
Sieve Number	Diameter Range	Percent Retained	Description
#4	>4.76 mm	0.30	Gravel
#10	<4.76 mm - 2.00 mm	0.97	Coarse Sand
#20	<2.00 mm - 0.85 mm	6.50	Medium Sand
#40	<0.85 mm - 0.425 mm	9.15	Medium Sand
#60	<0.425 mm - 0.25 mm	9.26	Fine Sand
#100	<0.25 mm - 0.15 mm	15.36	Fine Sand
#200	<0.15 mm - 0.074 mm	17.05	Fine Sand
Passing #200	<0.074 mm	41.36	Silt/Clay

N/A - Not Applicable

Wet Sieve Analysis

Client: **Army Corps of Engineers**
Project: **Boston Harbor Improvement Project**
Case: N/A SDG: N/A
Client ID: **STA V**
Matrix: **Sediment**
Collection Date: **8/9/2002**

Lab Code: **M-MA030**
ETR: **0208080**
Lab ID: **0208080-09**
Concentration Units: **%**
Received Date: **8/9/2002**
Analysis Date: **8/12/2002**



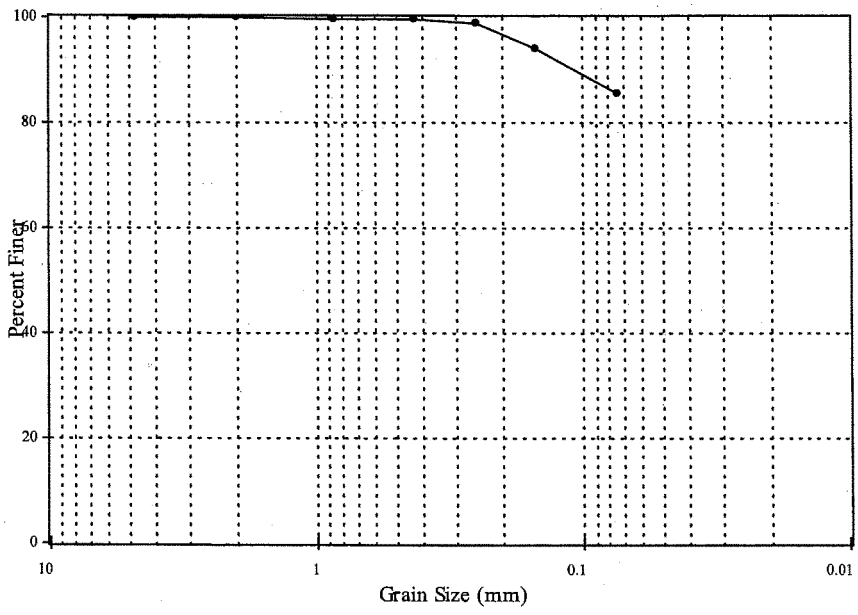
Sieve Number	Diameter Range	Percent Retained	Description
#4	>4.76 mm	9.78	Gravel
#10	<4.76 mm - 2.00 mm	5.94	Coarse Sand
#20	<2.00 mm - 0.85 mm	4.77	Medium Sand
#40	<0.85 mm - 0.425 mm	5.59	Medium Sand
#60	<0.425 mm - 0.25 mm	7.08	Fine Sand
#100	<0.25 mm - 0.15 mm	12.74	Fine Sand
#200	<0.15 mm - 0.074 mm	18.90	Fine Sand
Passing #200	<0.074 mm	35.23	Silt/Clay

N/A - Not Applicable

Wet Sieve Analysis

Client: **Army Corps of Engineers**
Project: **Boston Harbor Improvement Project**
Case: N/A SDG: N/A
Client ID: **STA X**
Matrix: **Sediment**
Collection Date: **8/14/2002**

Lab Code: **M-MA030**
ETR: **0208094**
Lab ID: **0208094-02**
Concentration Units: **%**
Received Date: **8/15/2002**
Analysis Date: **8/21/2002**



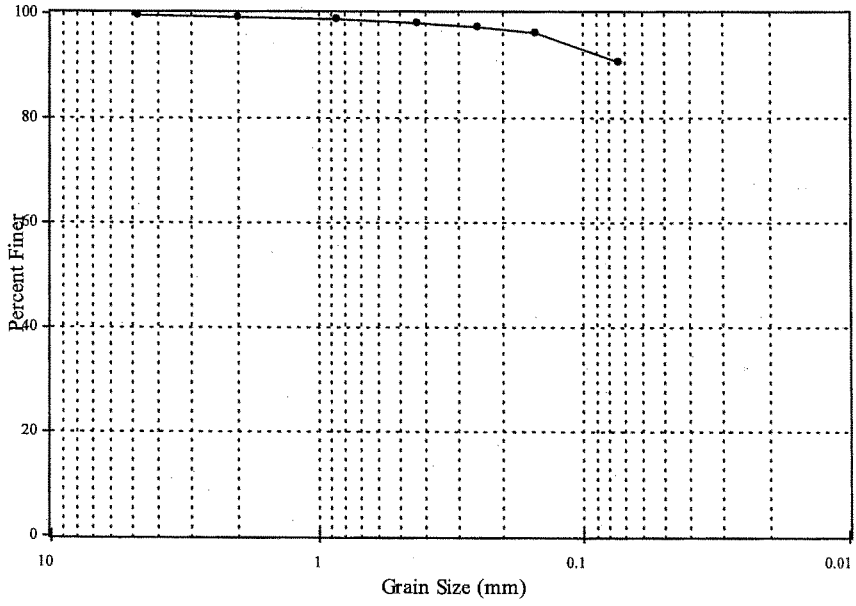
Sieve Number	Diameter Range	Percent Retained	Description
#4	>4.76 mm	0.00	Gravel
#10	<4.76 mm - 2.00 mm	0.00	Coarse Sand
#20	<2.00 mm - 0.85 mm	0.27	Medium Sand
#40	<0.85 mm - 0.425 mm	0.23	Medium Sand
#60	<0.425 mm - 0.25 mm	0.65	Fine Sand
#100	<0.25 mm - 0.15 mm	4.76	Fine Sand
#200	<0.15 mm - 0.074 mm	8.68	Fine Sand
Passing #200	<0.074 mm	85.33	Silt/Clay

N/A - Not Applicable

Wet Sieve Analysis

Client: **Army Corps of Engineers**
Project: **Boston Harbor Improvement Project**
Case: N/A SDG: N/A
Client ID: **STA AA**
Matrix: **Sediment**
Collection Date: **8/12/2002**

Lab Code: **M-MA030**
ETR: **0208085**
Lab ID: **0208085-10**
Concentration Units: **%**
Received Date: **8/13/2002**
Analysis Date: **8/16/2002**



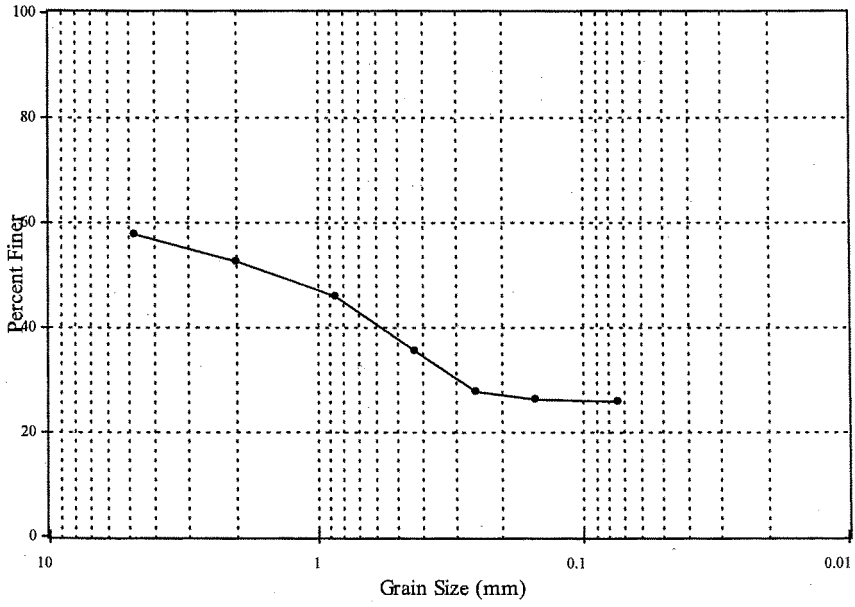
Sieve Number	Diameter Range	Percent Retained	Description
#4	>4.76 mm	0.41	Gravel
#10	<4.76 mm - 2.00 mm	0.45	Coarse Sand
#20	<2.00 mm - 0.85 mm	0.42	Medium Sand
#40	<0.85 mm - 0.425 mm	0.51	Medium Sand
#60	<0.425 mm - 0.25 mm	0.67	Fine Sand
#100	<0.25 mm - 0.15 mm	1.10	Fine Sand
#200	<0.15 mm - 0.074 mm	5.64	Fine Sand
Passing #200	<0.074 mm	90.77	Silt/Clay

N/A - Not Applicable

Wet Sieve Analysis

Client: **Army Corps of Engineers**
Project: **Boston Harbor Improvement Project**
Case: **N/A** SDG: **N/A**
Client ID: **STA Z**
Matrix: **Sediment**
Collection Date: **8/14/2002**

Lab Code: **M-MA030**
ETR: **0208094**
Lab ID: **0208094-01 DUP**
Concentration Units: **%**
Received Date: **8/15/2002**
Analysis Date: **8/19/2002**



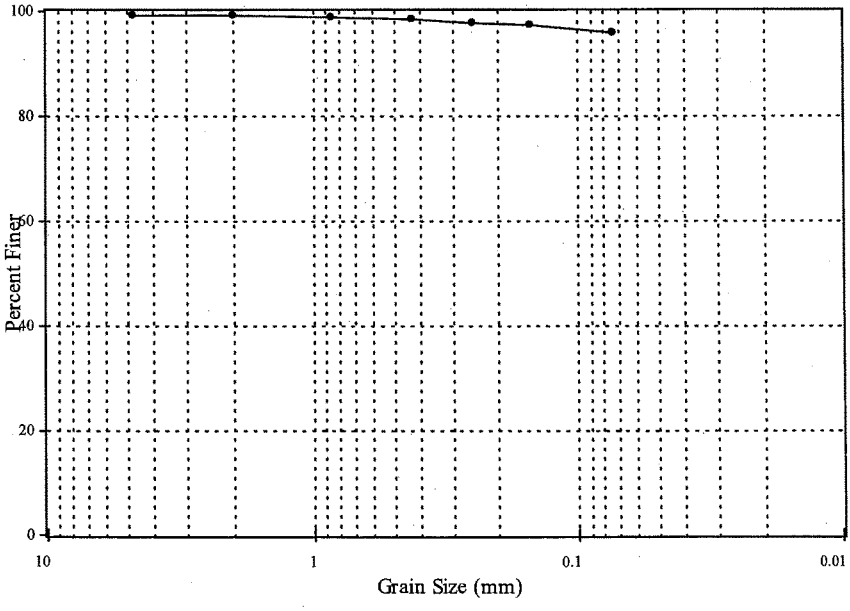
Sieve Number	Diameter Range	Percent Retained	Description
#4	>4.76 mm	42.28	Gravel
#10	<4.76 mm - 2.00 mm	5.18	Coarse Sand
#20	<2.00 mm - 0.85 mm	6.50	Medium Sand
#40	<0.85 mm - 0.425 mm	10.46	Medium Sand
#60	<0.425 mm - 0.25 mm	7.86	Fine Sand
#100	<0.25 mm - 0.15 mm	1.35	Fine Sand
#200	<0.15 mm - 0.074 mm	0.63	Fine Sand
Passing #200	<0.074 mm	25.56	Silt/Clay

N/A - Not Applicable

Wet Sieve Analysis

Client: **Army Corps of Engineers**
Project: **Boston Harbor Improvement Project**
Case: **N/A** SDG: **N/A**
Client ID: **STA BB**
Matrix: **Sediment**
Collection Date: **8/12/2002**

Lab Code: **M-MA030**
ETR: **0208085**
Lab ID: **0208085-09**
Concentration Units: **%**
Received Date: **8/13/2002**
Analysis Date: **8/16/2002**



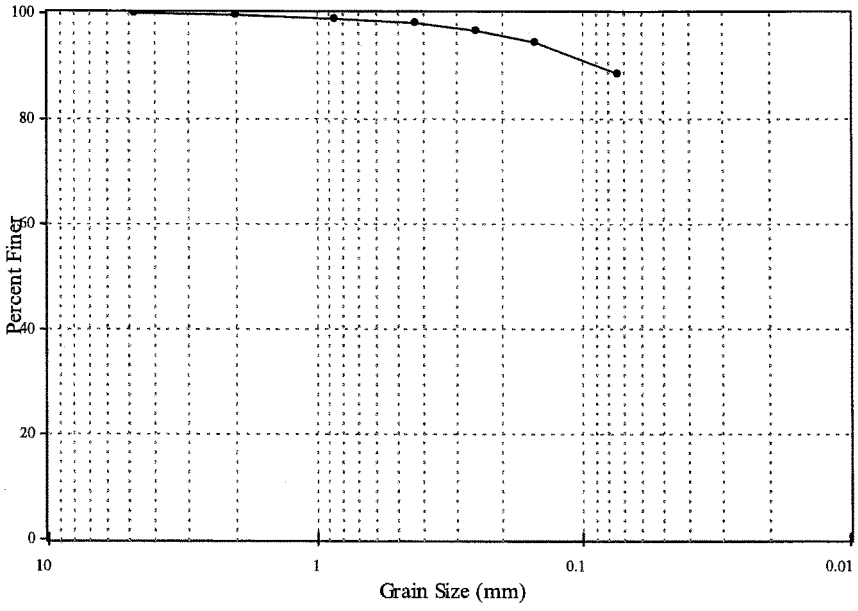
Sieve Number	Diameter Range	Percent Retained	Description
#4	>4.76 mm	0.56	Gravel
#10	<4.76 mm - 2.00 mm	0.30	Coarse Sand
#20	<2.00 mm - 0.85 mm	0.22	Medium Sand
#40	<0.85 mm - 0.425 mm	0.43	Medium Sand
#60	<0.425 mm - 0.25 mm	0.64	Fine Sand
#100	<0.25 mm - 0.15 mm	0.45	Fine Sand
#200	<0.15 mm - 0.074 mm	1.32	Fine Sand
Passing #200	<0.074 mm	96.31	Silt/Clay

N/A - Not Applicable

Wet Sieve Analysis

Client: **Army Corps of Engineers**
Project: **Boston Harbor Improvement Project**
Case: **N/A** SDG: **N/A**
Client ID: **STA CC**
Matrix: **Sediment**
Collection Date: **8/12/2002**

Lab Code: **MA00030**
ETR: **0208085**
Lab ID: **0208085-08**
Concentration Units: **%**
Received Date: **8/13/2002**
Analysis Date: **8/16/2002**



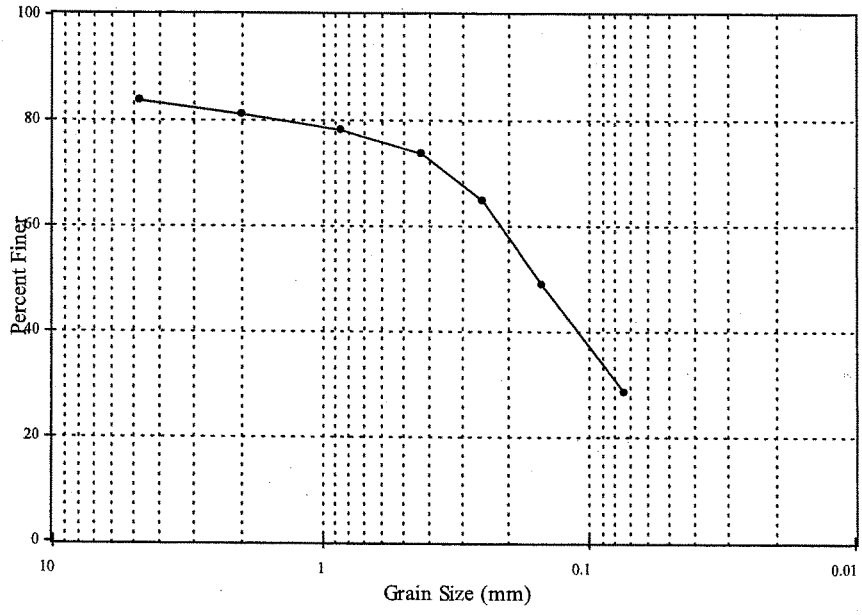
Sieve Number	Diameter Range	Percent Retained	Description
#4	>4.76 mm	0.00	Gravel
#10	<4.76 mm - 2.00 mm	0.43	Coarse Sand
#20	<2.00 mm - 0.85 mm	0.62	Medium Sand
#40	<0.85 mm - 0.425 mm	0.97	Medium Sand
#60	<0.425 mm - 0.25 mm	1.34	Fine Sand
#100	<0.25 mm - 0.15 mm	2.16	Fine Sand
#200	<0.15 mm - 0.074 mm	6.11	Fine Sand
Passing #200	<0.074 mm	88.34	Silt/Clay

N/A - Not Applicable

Wet Sieve Analysis

Client: **Army Corps of Engineers**
Project: **Boston Harbor Improvement Project**
Case: **N/A** SDG: **N/A**
Client ID: **STA DD**
Matrix: **Sediment**
Collection Date: **8/12/2002**

Lab Code: **M-MA030**
ETR: **0208085**
Lab ID: **0208085-04**
Concentration Units: **%**
Received Date: **8/13/2002**
Analysis Date: **8/16/2002**



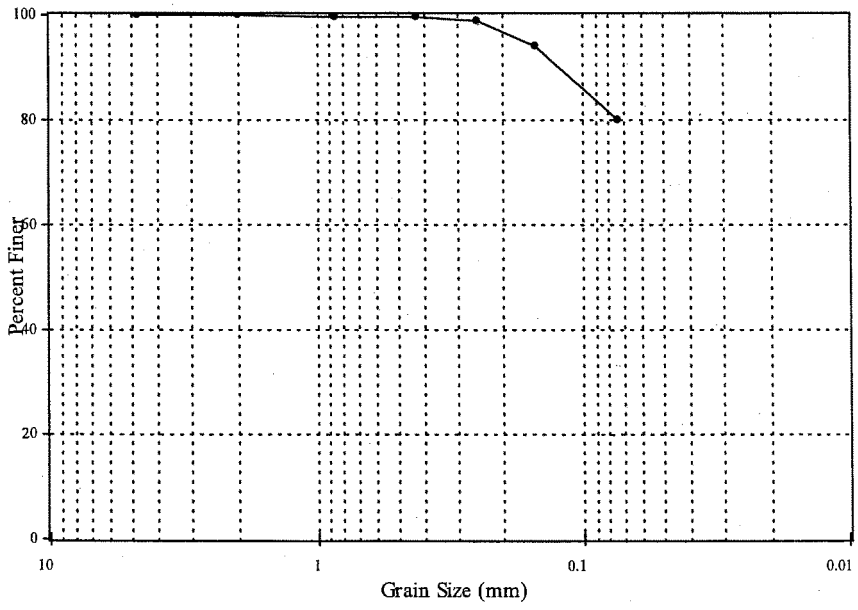
Sieve Number	Diameter Range	Percent Retained	Description
#4	>4.76 mm	16.25	Gravel
#10	<4.76 mm - 2.00 mm	2.61	Coarse Sand
#20	<2.00 mm - 0.85 mm	2.95	Medium Sand
#40	<0.85 mm - 0.425 mm	4.49	Medium Sand
#60	<0.425 mm - 0.25 mm	8.95	Fine Sand
#100	<0.25 mm - 0.15 mm	15.91	Fine Sand
#200	<0.15 mm - 0.074 mm	20.33	Fine Sand
Passing #200	<0.074 mm	28.48	Silt/Clay

N/A - Not Applicable

Wet Sieve Analysis

Client: **Army Corps of Engineers**
Project: **Boston Harbor Improvement Project**
Case: N/A SDG: N/A
Client ID: **STA EE**
Matrix: **Sediment**
Collection Date: **8/12/2002**

Lab Code: **M-MA030**
ETR: **0208085**
Lab ID: **0208085-05**
Concentration Units: **%**
Received Date: **8/13/2002**
Analysis Date: **8/16/2002**



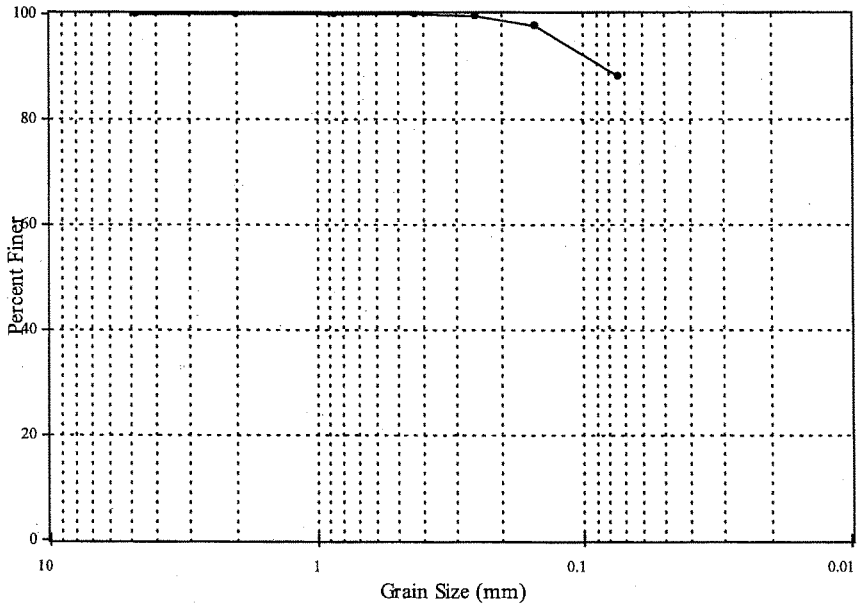
Sieve Number	Diameter Range	Percent Retained	Description
#4	>4.76 mm	0.08	Gravel
#10	<4.76 mm - 2.00 mm	0.02	Coarse Sand
#20	<2.00 mm - 0.85 mm	0.11	Medium Sand
#40	<0.85 mm - 0.425 mm	0.18	Medium Sand
#60	<0.425 mm - 0.25 mm	0.80	Fine Sand
#100	<0.25 mm - 0.15 mm	4.80	Fine Sand
#200	<0.15 mm - 0.074 mm	14.16	Fine Sand
Passing #200	<0.074 mm	79.77	Silt/Clay

N/A - Not Applicable

Wet Sieve Analysis

Client: **Army Corps of Engineers**
Project: **Boston Harbor Improvement Project**
Case: **N/A** SDG: **N/A**
Client ID: **STA FF**
Matrix: **Sediment**
Collection Date: **8/12/2002**

Lab Code: **M-MA030**
ETR: **0208085**
Lab ID: **0208085-07**
Concentration Units: **%**
Received Date: **8/13/2002**
Analysis Date: **8/16/2002**



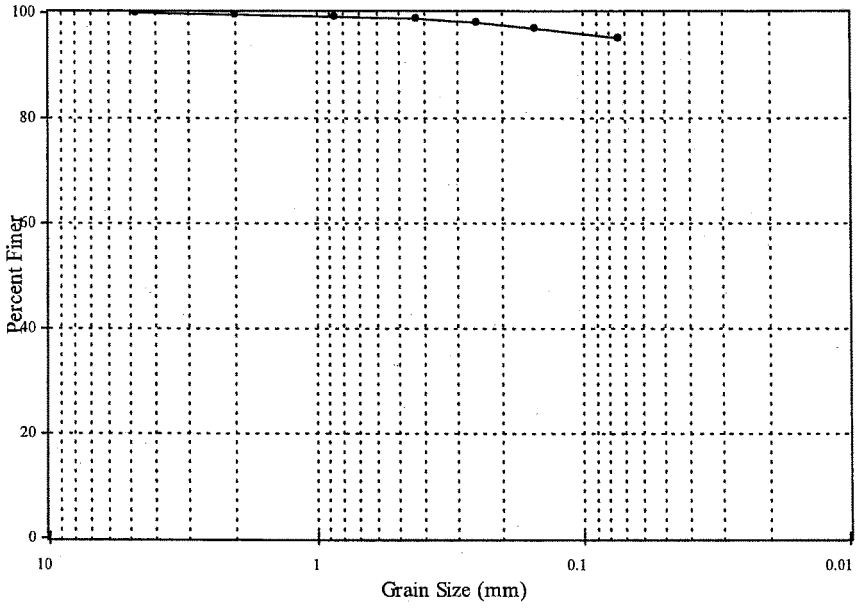
Sieve Number	Diameter Range	Percent Retained	Description
#4	>4.76 mm	0.00	Gravel
#10	<4.76 mm - 2.00 mm	0.02	Coarse Sand
#20	<2.00 mm - 0.85 mm	0.05	Medium Sand
#40	<0.85 mm - 0.425 mm	0.06	Medium Sand
#60	<0.425 mm - 0.25 mm	0.09	Fine Sand
#100	<0.25 mm - 0.15 mm	1.86	Fine Sand
#200	<0.15 mm - 0.074 mm	9.85	Fine Sand
Passing #200	<0.074 mm	88.00	Silt/Clay

N/A - Not Applicable

Wet Sieve Analysis

Client: **Army Corps of Engineers**
Project: **Boston Harbor Improvement Project**
Case: N/A SDG: N/A
Client ID: **STA GG**
Matrix: **Sediment**
Collection Date: **8/12/2002**

Lab Code: **M-MA030**
ETR: **0208085**
Lab ID: **0208085-06**
Concentration Units: **%**
Received Date: **8/13/2002**
Analysis Date: **8/16/2002**



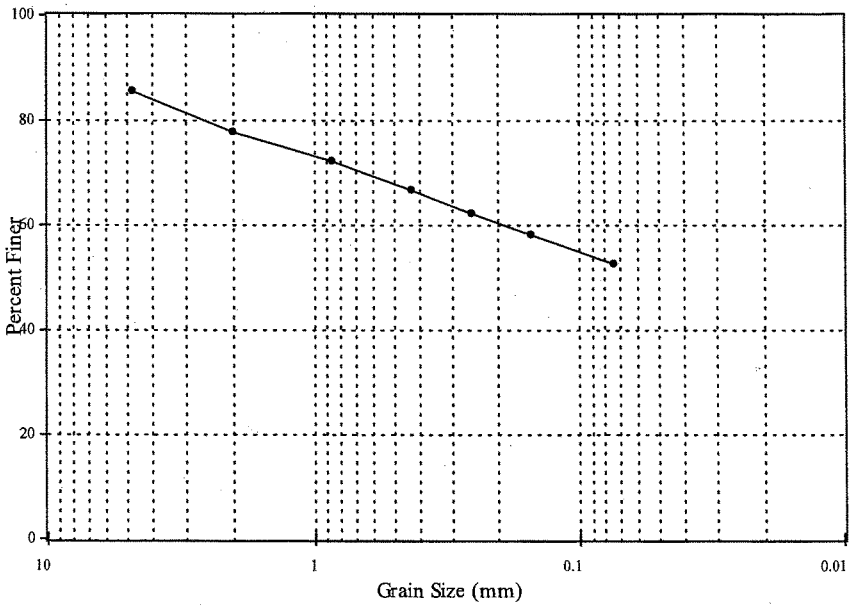
Sieve Number	Diameter Range	Percent Retained	Description
#4	>4.76 mm	0.10	Gravel
#10	<4.76 mm - 2.00 mm	0.24	Coarse Sand
#20	<2.00 mm - 0.85 mm	0.32	Medium Sand
#40	<0.85 mm - 0.425 mm	0.40	Medium Sand
#60	<0.425 mm - 0.25 mm	0.80	Fine Sand
#100	<0.25 mm - 0.15 mm	1.13	Fine Sand
#200	<0.15 mm - 0.074 mm	1.90	Fine Sand
Passing #200	<0.074 mm	95.13	Silt/Clay

N/A - Not Applicable

Wet Sieve Analysis

Client: **Army Corps of Engineers**
Project: **Boston Harbor Improvement Project**
Case: **N/A** SDG: **N/A**
Client ID: **STA HH**
Matrix: **Sediment**
Collection Date: **8/8/2002**

Lab Code: **M-MA030**
ETR: **0208080**
Lab ID: **0208080-03**
Concentration Units: **%**
Received Date: **8/9/2002**
Analysis Date: **8/12/2002**



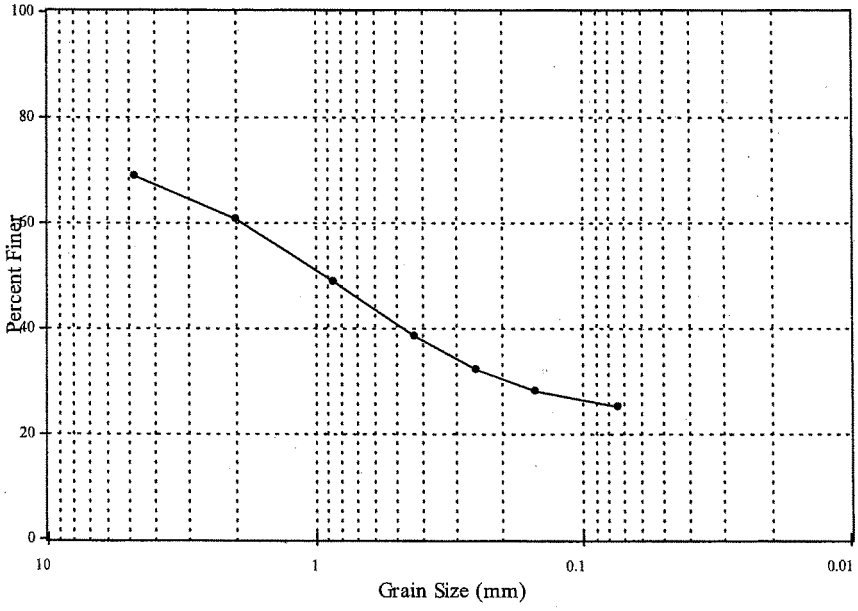
Sieve Number	Diameter Range	Percent Retained	Description
#4	>4.76 mm	14.41	Gravel
#10	<4.76 mm - 2.00 mm	7.79	Coarse Sand
#20	<2.00 mm - 0.85 mm	5.66	Medium Sand
#40	<0.85 mm - 0.425 mm	5.32	Medium Sand
#60	<0.425 mm - 0.25 mm	4.67	Fine Sand
#100	<0.25 mm - 0.15 mm	4.06	Fine Sand
#200	<0.15 mm - 0.074 mm	5.41	Fine Sand
Passing #200	<0.074 mm	52.64	Silt/Clay

N/A - Not Applicable

Wet Sieve Analysis

Client: **Army Corps of Engineers**
Project: **Boston Harbor Improvement Project**
Case: N/A SDG: N/A
Client ID: **STA II**
Matrix: **Sediment**
Collection Date: **8/8/2002**

Lab Code: **M-MA030**
ETR: **0208080**
Lab ID: **0208080-04**
Concentration Units: **%**
Received Date: **8/9/2002**
Analysis Date: **8/12/2002**



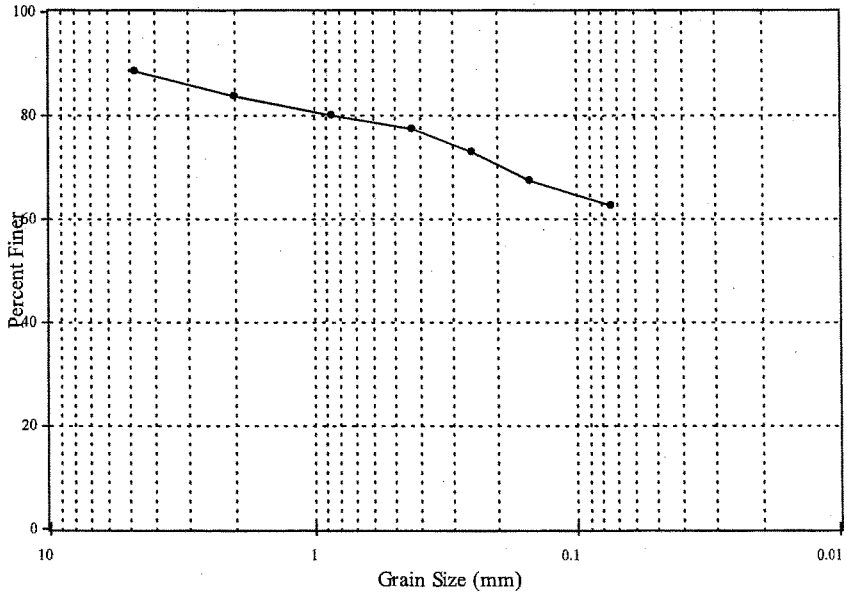
Sieve Number	Diameter Range	Percent Retained	Description
#4	>4.76 mm	31.01	Gravel
#10	<4.76 mm - 2.00 mm	8.25	Coarse Sand
#20	<2.00 mm - 0.85 mm	11.81	Medium Sand
#40	<0.85 mm - 0.425 mm	10.57	Medium Sand
#60	<0.425 mm - 0.25 mm	6.06	Fine Sand
#100	<0.25 mm - 0.15 mm	4.29	Fine Sand
#200	<0.15 mm - 0.074 mm	3.01	Fine Sand
Passing #200	<0.074 mm	24.97	Silt/Clay

N/A - Not Applicable

Wet Sieve Analysis

Client: **Army Corps of Engineers**
Project: **Boston Harbor Improvement Project**
Case: **N/A** SDG: **N/A**
Client ID: **STA JJ**
Matrix: **Sediment**
Collection Date: **8/8/2002**

Lab Code: **M-MA030**
ETR: **0208080**
Lab ID: **0208080-02 DUP**
Concentration Units: **%**
Received Date: **8/9/2002**
Analysis Date: **8/12/2002**



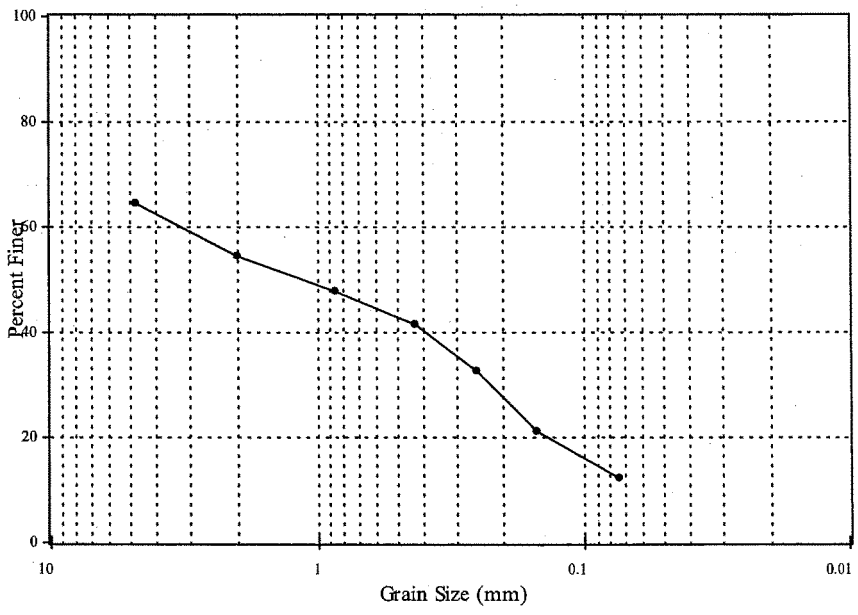
Sieve Number	Diameter Range	Percent Retained	Description
#4	>4.76 mm	11.58	Gravel
#10	<4.76 mm - 2.00 mm	4.78	Coarse Sand
#20	<2.00 mm - 0.85 mm	3.49	Medium Sand
#40	<0.85 mm - 0.425 mm	2.87	Medium Sand
#60	<0.425 mm - 0.25 mm	4.31	Fine Sand
#100	<0.25 mm - 0.15 mm	5.73	Fine Sand
#200	<0.15 mm - 0.074 mm	4.70	Fine Sand
Passing #200	<0.074 mm	10.11	Silt/Clay

N/A - Not Applicable

Wet Sieve Analysis

Client: **Army Corps of Engineers**
Project: **Boston Harbor Improvement Project**
Case: **N/A** SDG: **N/A**
Client ID: **STA JJ**
Matrix: **Sediment**
Collection Date: **8/8/2002**

Lab Code: **M-MA030**
ETR: **0208080**
Lab ID: **0208080-02**
Concentration Units: **%**
Received Date: **8/9/2002**
Analysis Date: **8/12/2002**



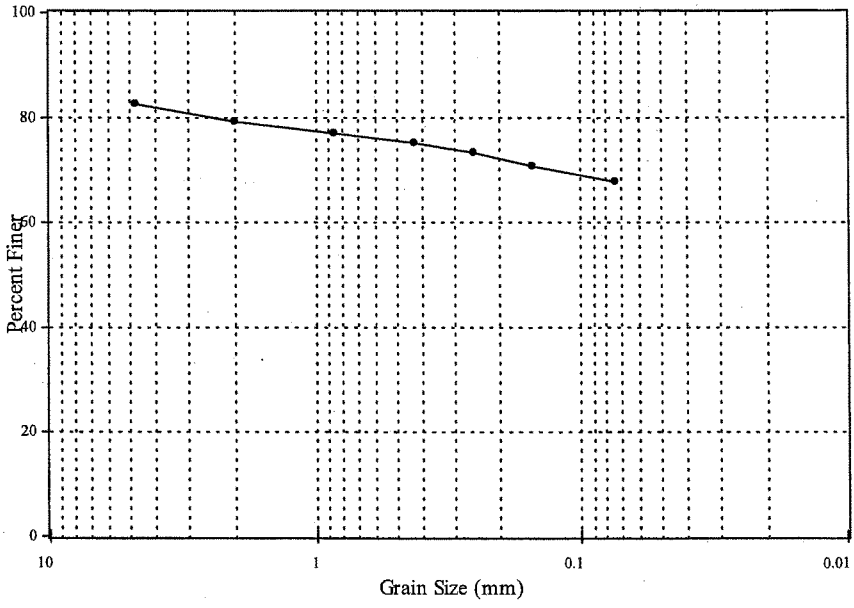
Sieve Number	Diameter Range	Percent Retained	Description
#4	>4.76 mm	35.67	Gravel
#10	<4.76 mm - 2.00 mm	9.94	Coarse Sand
#20	<2.00 mm - 0.85 mm	6.69	Medium Sand
#40	<0.85 mm - 0.425 mm	6.05	Medium Sand
#60	<0.425 mm - 0.25 mm	9.09	Fine Sand
#100	<0.25 mm - 0.15 mm	11.35	Fine Sand
#200	<0.15 mm - 0.074 mm	8.94	Fine Sand
Passing #200	<0.074 mm	12.33	Silt/Clay

N/A - Not Applicable

Wet Sieve Analysis

Client: **Army Corps of Engineers**
Project: **Boston Harbor Improvement Project**
Case: **N/A** SDG: **N/A**
Client ID: **STA KK**
Matrix: **Sediment**
Collection Date: **8/8/2002**

Lab Code: **M-MA030**
ETR: **0208080**
Lab ID: **0208080-01**
Concentration Units: **%**
Received Date: **8/9/2002**
Analysis Date: **8/12/2002**



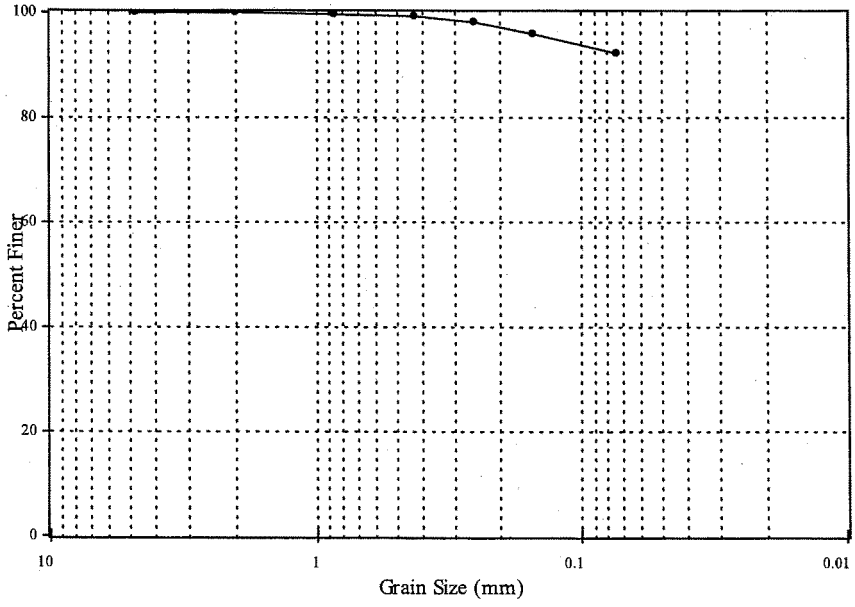
Sieve Number	Diameter Range	Percent Retained	Description
#4	>4.76 mm	17.45	Gravel
#10	<4.76 mm - 2.00 mm	3.36	Coarse Sand
#20	<2.00 mm - 0.85 mm	2.15	Medium Sand
#40	<0.85 mm - 0.425 mm	1.80	Medium Sand
#60	<0.425 mm - 0.25 mm	2.03	Fine Sand
#100	<0.25 mm - 0.15 mm	2.50	Fine Sand
#200	<0.15 mm - 0.074 mm	3.09	Fine Sand
Passing #200	<0.074 mm	67.64	Silt/Clay

N/A - Not Applicable

Wet Sieve Analysis

Client: **Army Corps of Engineers**
Project: **Boston Harbor Improvement Project**
Case: **N/A** SDG: **N/A**
Client ID: **STA LL**
Matrix: **Sediment**
Collection Date: **8/12/2002**

Lab Code: **M-MA030**
ETR: **0208085**
Lab ID: **0208085-03**
Concentration Units: **%**
Received Date: **8/13/2002**
Analysis Date: **8/16/2002**



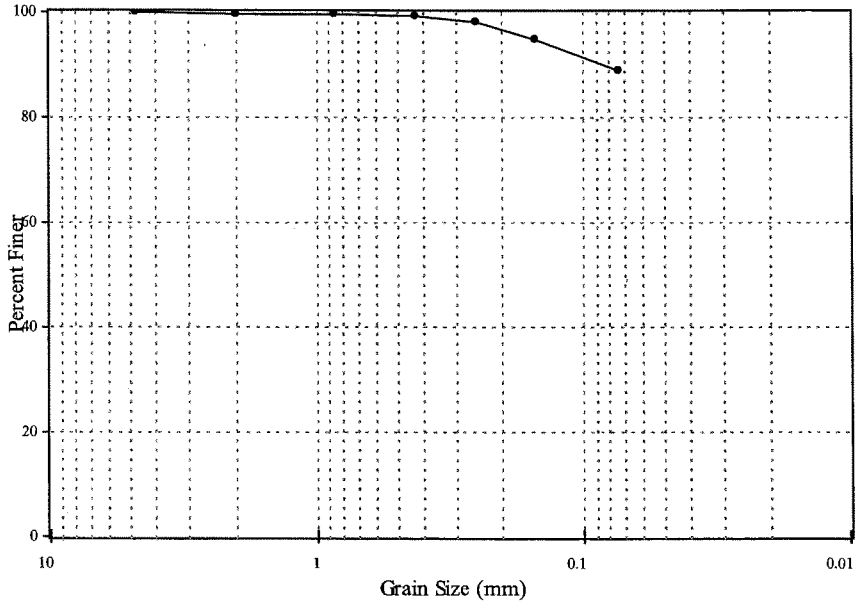
Sieve Number	Diameter Range	Percent Retained	Description
#4	>4.76 mm	0.07	Gravel
#10	<4.76 mm - 2.00 mm	0.05	Coarse Sand
#20	<2.00 mm - 0.85 mm	0.15	Medium Sand
#40	<0.85 mm - 0.425 mm	0.38	Medium Sand
#60	<0.425 mm - 0.25 mm	1.08	Fine Sand
#100	<0.25 mm - 0.15 mm	2.44	Fine Sand
#200	<0.15 mm - 0.074 mm	3.69	Fine Sand
Passing #200	<0.074 mm	92.01	Silt/Clay

N/A - Not Applicable

Wet Sieve Analysis

Client: **Army Corps of Engineers**
Project: **Boston Harbor Improvement Project**
Case: **N/A** SDG: **N/A**
Client ID: **STA MM**
Matrix: **Sediment**
Collection Date: **8/12/2002**

Lab Code: **MA00030**
ETR: **0208085**
Lab ID: **0208085-02**
Concentration Units: **%**
Received Date: **8/13/2002**
Analysis Date: **8/16/2002**



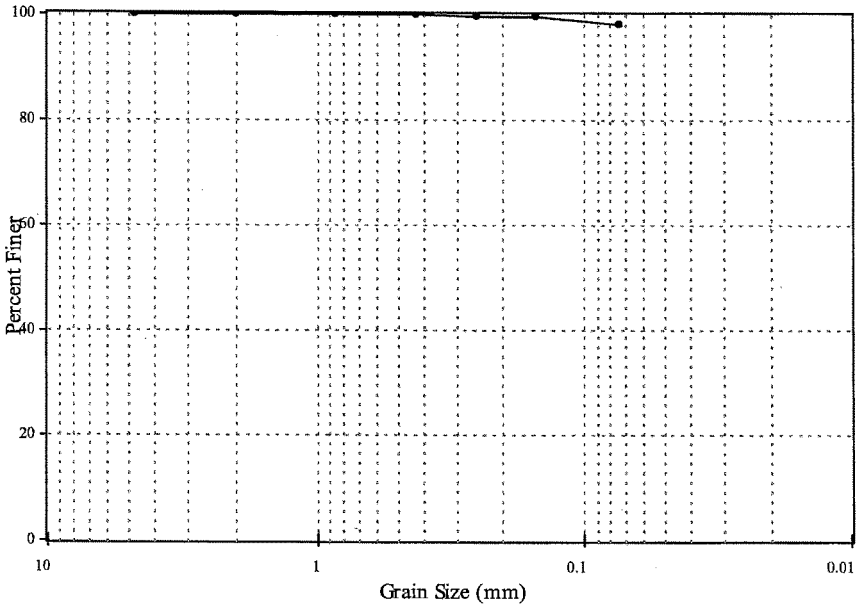
Sieve Number	Diameter Range	Percent Retained	Description
#4	>4.76 mm	0.11	Gravel
#10	<4.76 mm - 2.00 mm	0.16	Coarse Sand
#20	<2.00 mm - 0.85 mm	0.25	Medium Sand
#40	<0.85 mm - 0.425 mm	0.32	Medium Sand
#60	<0.425 mm - 0.25 mm	1.18	Fine Sand
#100	<0.25 mm - 0.15 mm	3.21	Fine Sand
#200	<0.15 mm - 0.074 mm	5.84	Fine Sand
Passing #200	<0.074 mm	88.82	Silt/Clay

N/A - Not Applicable

Wet Sieve Analysis

Client: **Army Corps of Engineers**
Project: **Boston Harbor Improvement Project**
Case: **N/A** SDG: **N/A**
Client ID: **STA NN**
Matrix: **Sediment**
Collection Date: **8/12/2002**

Lab Code: **MA00030**
ETR: **0208085**
Lab ID: **0208085-01**
Concentration Units: **%**
Received Date: **8/13/2002**
Analysis Date: **8/12/2002**



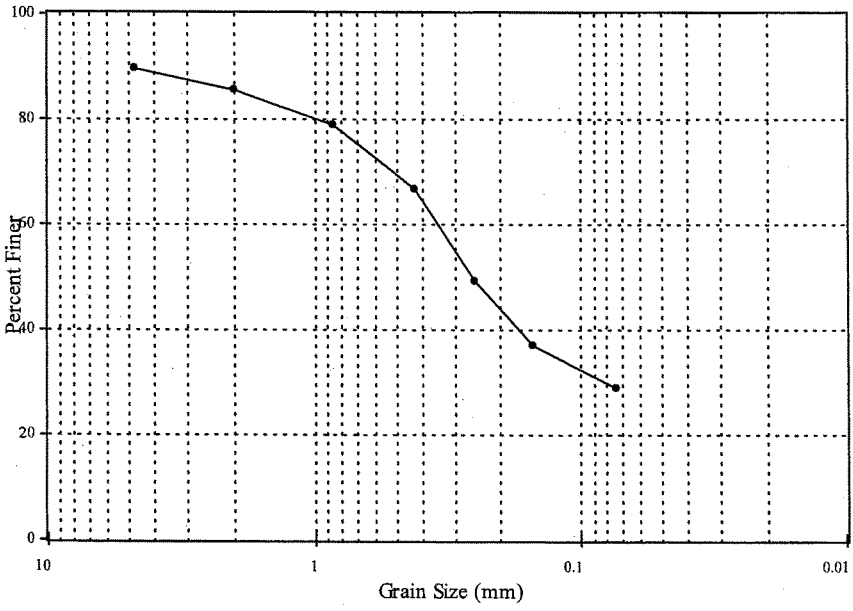
Sieve Number	Diameter Range	Percent Retained	Description
#4	>4.76 mm	0.00	Gravel
#10	<4.76 mm - 2.00 mm	0.00	Coarse Sand
#20	<2.00 mm - 0.85 mm	0.03	Medium Sand
#40	<0.85 mm - 0.425 mm	0.08	Medium Sand
#60	<0.425 mm - 0.25 mm	0.13	Fine Sand
#100	<0.25 mm - 0.15 mm	0.30	Fine Sand
#200	<0.15 mm - 0.074 mm	1.48	Fine Sand
Passing #200	<0.074 mm	97.91	Silt/Clay

N/A - Not Applicable

Wet Sieve Analysis

Client: **Army Corps of Engineers**
Project: **Boston Harbor Improvement Project**
Case: **N/A** SDG: **N/A**
Client ID: **STA OO**
Matrix: **Sediment**
Collection Date: **8/9/2002**

Lab Code: **M-MA030**
ETR: **0208080**
Lab ID: **0208080-05**
Concentration Units: **%**
Received Date: **8/9/2002**
Analysis Date: **8/12/2002**



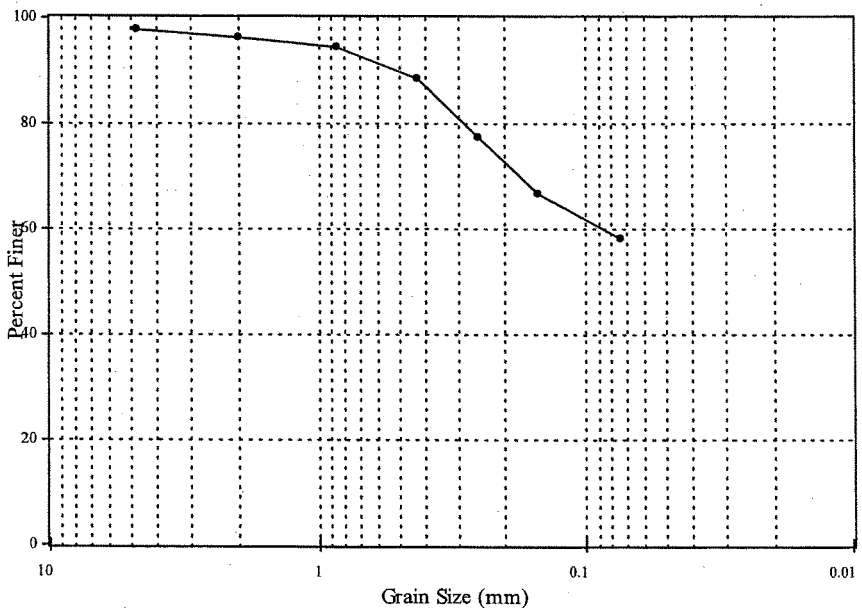
Sieve Number	Diameter Range	Percent Retained	Description
#4	>4.76 mm	10.21	Gravel
#10	<4.76 mm - 2.00 mm	4.35	Coarse Sand
#20	<2.00 mm - 0.85 mm	6.54	Medium Sand
#40	<0.85 mm - 0.425 mm	12.29	Medium Sand
#60	<0.425 mm - 0.25 mm	17.52	Fine Sand
#100	<0.25 mm - 0.15 mm	12.19	Fine Sand
#200	<0.15 mm - 0.074 mm	7.96	Fine Sand
Passing #200	<0.074 mm	28.89	Silt/Clay

N/A - Not Applicable

Wet Sieve Analysis

Client: **Army Corps of Engineers**
Project: **Boston Harbor Improvement Project**
Case: **N/A** SDG: **N/A**
Client ID: **STA PP**
Matrix: **Sediment**
Collection Date: **8/9/2002**

Lab Code: **M-MA030**
ETR: **0208080**
Lab ID: **0208080-06**
Concentration Units: **%**
Received Date: **8/9/2002**
Analysis Date: **8/12/2002**



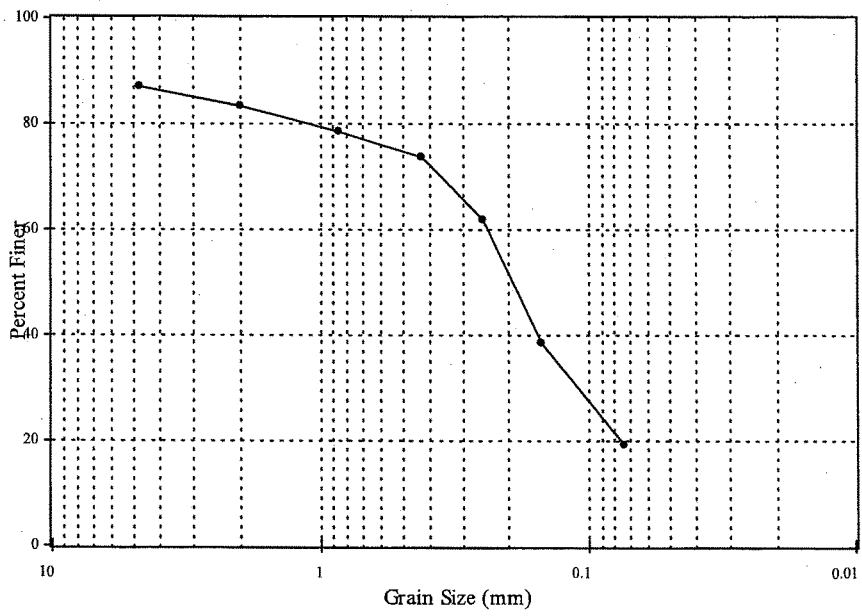
Sieve Number	Diameter Range	Percent Retained	Description
#4	>4.76 mm	2.30	Gravel
#10	<4.76 mm - 2.00 mm	1.38	Coarse Sand
#20	<2.00 mm - 0.85 mm	2.04	Medium Sand
#40	<0.85 mm - 0.425 mm	5.72	Medium Sand
#60	<0.425 mm - 0.25 mm	11.27	Fine Sand
#100	<0.25 mm - 0.15 mm	10.50	Fine Sand
#200	<0.15 mm - 0.074 mm	8.55	Fine Sand
Passing #200	<0.074 mm	58.21	Silt/Clay

N/A - Not Applicable

Wet Sieve Analysis

Client: **Army Corps of Engineers**
Project: **Boston Harbor Improvement Project**
Case: **N/A** SDG: **N/A**
Client ID: **STA QQ**
Matrix: **Sediment**
Collection Date: **8/9/2002**

Lab Code: **M-MA030**
ETR: **0208080**
Lab ID: **0208080-07**
Concentration Units: **%**
Received Date: **8/9/2002**
Analysis Date: **8/12/2002**



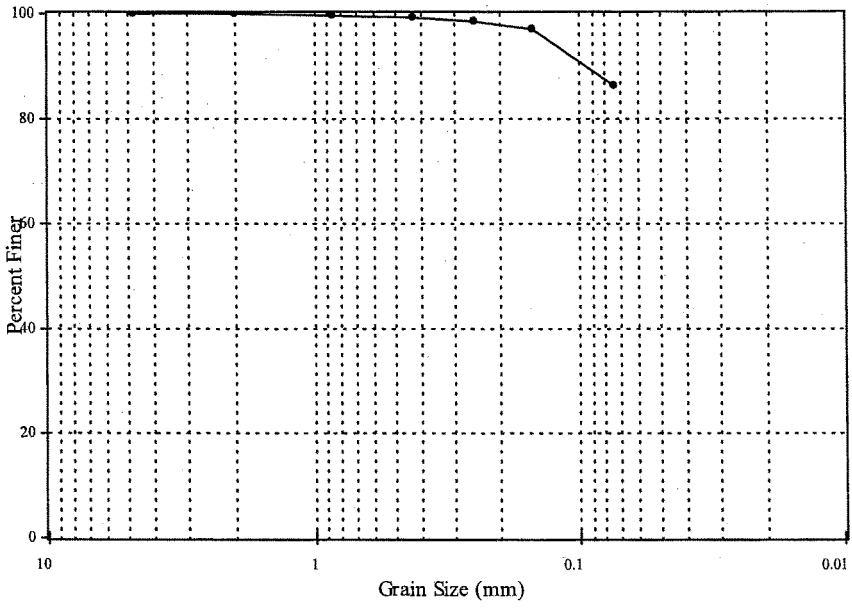
Sieve Number	Diameter Range	Percent Retained	Description
#4	>4.76 mm	12.95	Gravel
#10	<4.76 mm - 2.00 mm	3.75	Coarse Sand
#20	<2.00 mm - 0.85 mm	4.74	Medium Sand
#40	<0.85 mm - 0.425 mm	4.95	Medium Sand
#60	<0.425 mm - 0.25 mm	11.83	Fine Sand
#100	<0.25 mm - 0.15 mm	23.13	Fine Sand
#200	<0.15 mm - 0.074 mm	19.54	Fine Sand
Passing #200	<0.074 mm	19.12	Silt/Clay

N/A - Not Applicable

Wet Sieve Analysis

Client: **Army Corps of Engineers**
Project: **Boston Harbor Improvement Project**
Case: N/A SDG: N/A
Client ID: **STA RR #1**
Matrix: **Sediment**
Collection Date: **8/15/2002**

Lab Code: **M-MA030**
ETR: **0208095**
Lab ID: **0208095-05**
Concentration Units: **%**
Received Date: **8/15/2002**
Analysis Date: **8/21/2002**



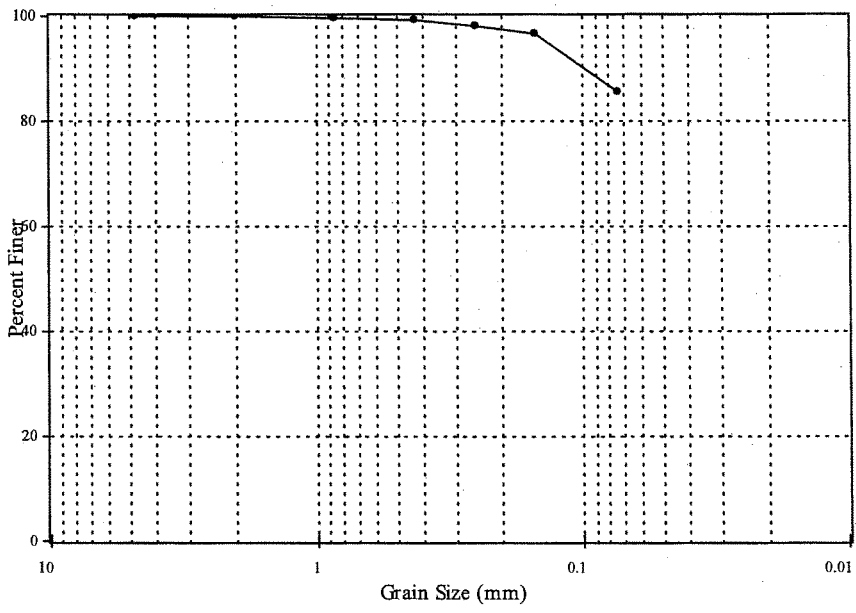
Sieve Number	Diameter Range	Percent Retained	Description
#4	>4.76 mm	0.00	Gravel
#10	<4.76 mm - 2.00 mm	0.07	Coarse Sand
#20	<2.00 mm - 0.85 mm	0.13	Medium Sand
#40	<0.85 mm - 0.425 mm	0.47	Medium Sand
#60	<0.425 mm - 0.25 mm	0.89	Fine Sand
#100	<0.25 mm - 0.15 mm	1.56	Fine Sand
#200	<0.15 mm - 0.074 mm	10.63	Fine Sand
Passing #200	<0.074 mm	86.27	Silt/Clay

N/A - Not Applicable

Wet Sieve Analysis

Client: **Army Corps of Engineers**
Project: **Boston Harbor Improvement Project**
Case: **N/A** SDG: **N/A**
Client ID: **STA RR #1**
Matrix: **Sediment**
Collection Date: **8/15/2002**

Lab Code: **M-MA030**
ETR: **0208095**
Lab ID: **0208095-05 DUP**
Concentration Units: **%**
Received Date: **8/15/2002**
Analysis Date: **8/21/2002**



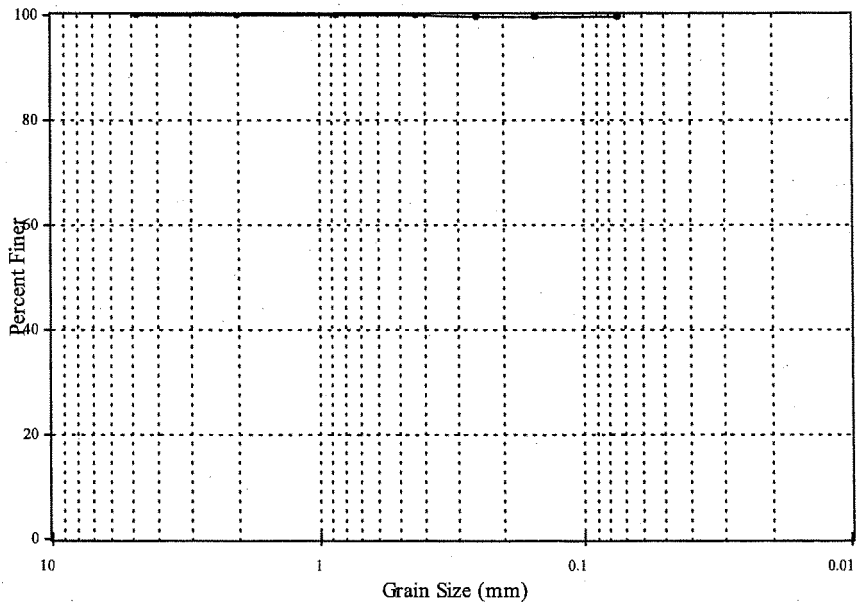
Sieve Number	Diameter Range	Percent Retained	Description
#4	>4.76 mm	0.00	Gravel
#10	<4.76 mm - 2.00 mm	0.17	Coarse Sand
#20	<2.00 mm - 0.85 mm	0.18	Medium Sand
#40	<0.85 mm - 0.425 mm	0.50	Medium Sand
#60	<0.425 mm - 0.25 mm	0.87	Fine Sand
#100	<0.25 mm - 0.15 mm	1.62	Fine Sand
#200	<0.15 mm - 0.074 mm	11.01	Fine Sand
Passing #200	<0.074 mm	82.58	Silt/Clay

N/A - Not Applicable

Wet Sieve Analysis

Client: **Army Corps of Engineers**
Project: **Boston Harbor Improvement Project**
Case: **N/A** SDG: **N/A**
Client ID: **STA RR #2**
Matrix: **Sediment**
Collection Date: **8/15/2002**

Lab Code: **M-MA030**
ETR: **0208095**
Lab ID: **0208095-06**
Concentration Units: **%**
Received Date: **8/15/2002**
Analysis Date: **8/20/2002**



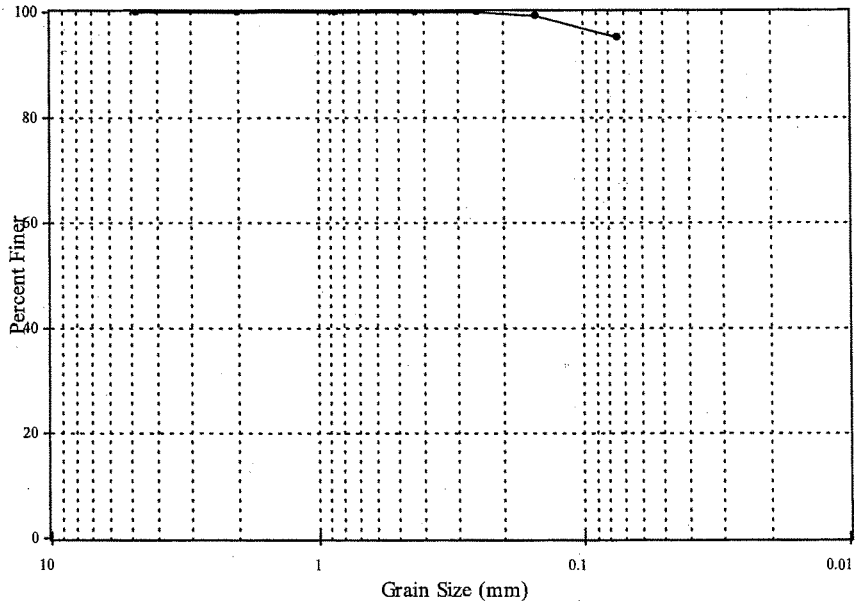
Sieve Number	Diameter Range	Percent Retained	Description
#4	>4.76 mm	0.00	Gravel
#10	<4.76 mm - 2.00 mm	0.00	Coarse Sand
#20	<2.00 mm - 0.85 mm	0.00	Medium Sand
#40	<0.85 mm - 0.425 mm	0.01	Medium Sand
#60	<0.425 mm - 0.25 mm	0.24	Fine Sand
#100	<0.25 mm - 0.15 mm	0.09	Fine Sand
#200	<0.15 mm - 0.074 mm	0.14	Fine Sand
Passing #200	<0.074 mm	99.52	Silt/Clay

N/A - Not Applicable

Wet Sieve Analysis

Client: **Army Corps of Engineers**
Project: **Boston Harbor Improvement Project**
Case: N/A SDG: N/A
Client ID: **STA SS**
Matrix: **Sediment**
Collection Date: **8/15/2002**

Lab Code: **M-MA030**
ETR: **0208095**
Lab ID: **0208095-07**
Concentration Units: **%**
Received Date: **8/15/2002**
Analysis Date: **8/20/2002**



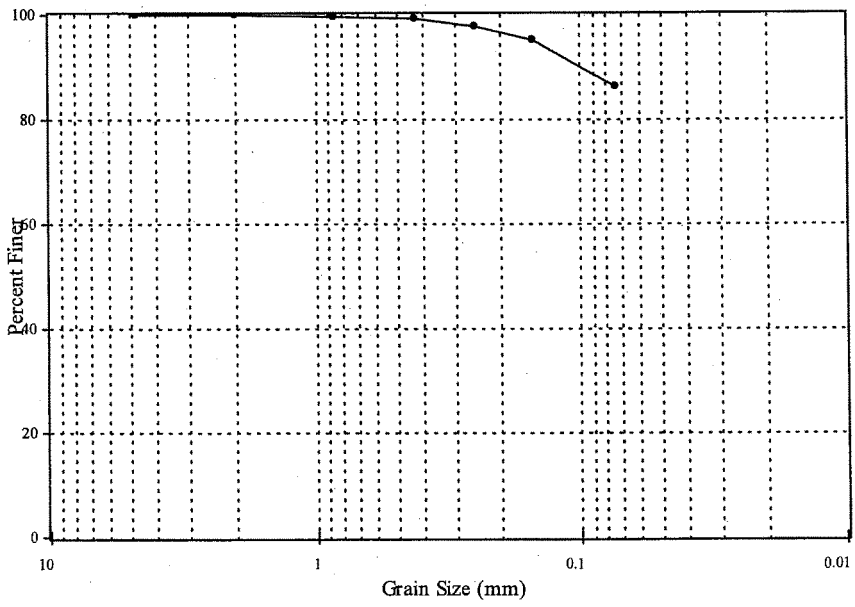
Sieve Number	Diameter Range	Percent Retained	Description
#4	>4.76 mm	0.00	Gravel
#10	<4.76 mm - 2.00 mm	0.00	Coarse Sand
#20	<2.00 mm - 0.85 mm	0.02	Medium Sand
#40	<0.85 mm - 0.425 mm	0.02	Medium Sand
#60	<0.425 mm - 0.25 mm	0.04	Fine Sand
#100	<0.25 mm - 0.15 mm	0.69	Fine Sand
#200	<0.15 mm - 0.074 mm	4.09	Fine Sand
Passing #200	<0.074 mm	95.14	Silt/Clay

N/A - Not Applicable

Wet Sieve Analysis

Client: **Army Corps of Engineers**
Project: **Boston Harbor Improvement Project**
Case: **N/A** SDG: **N/A**
Client ID: **STA TT #1**
Matrix: **Sediment**
Collection Date: **8/15/2002**

Lab Code: **M-MA030**
ETR: **0208095**
Lab ID: **0208095-01**
Concentration Units: **%**
Received Date: **8/15/2002**
Analysis Date: **8/19/2002**



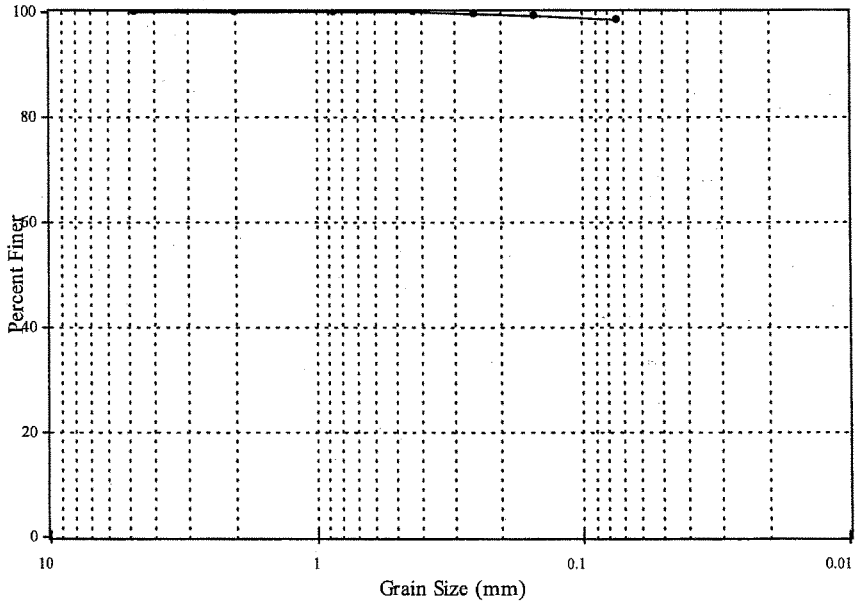
Sieve Number	Diameter Range	Percent Retained	Description
#4	>4.76 mm	0.00	Gravel
#10	<4.76 mm - 2.00 mm	0.03	Coarse Sand
#20	<2.00 mm - 0.85 mm	0.17	Medium Sand
#40	<0.85 mm - 0.425 mm	0.66	Medium Sand
#60	<0.425 mm - 0.25 mm	1.27	Fine Sand
#100	<0.25 mm - 0.15 mm	2.52	Fine Sand
#200	<0.15 mm - 0.074 mm	9.04	Fine Sand
Passing #200	<0.074 mm	86.02	Silt/Clay

N/A - Not Applicable

Wet Sieve Analysis

Client: **Army Corps of Engineers**
Project: **Boston Harbor Improvement Project**
Case: **N/A** SDG: **N/A**
Client ID: **STA TT #2**
Matrix: **Sediment**
Collection Date: **8/15/2002**

Lab Code: **M-MA030**
ETR: **0208095**
Lab ID: **0208095-02**
Concentration Units: **%**
Received Date: **8/15/2002**
Analysis Date: **8/21/2002**



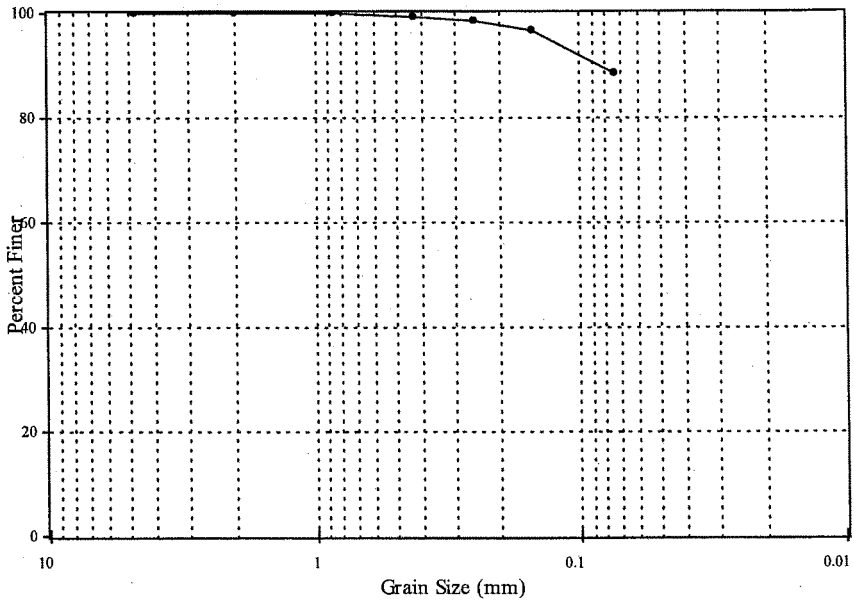
Sieve Number	Diameter Range	Percent Retained	Description
#4	>4.76 mm	0.00	Gravel
#10	<4.76 mm - 2.00 mm	0.00	Coarse Sand
#20	<2.00 mm - 0.85 mm	0.00	Medium Sand
#40	<0.85 mm - 0.425 mm	0.13	Medium Sand
#60	<0.425 mm - 0.25 mm	0.32	Fine Sand
#100	<0.25 mm - 0.15 mm	0.13	Fine Sand
#200	<0.15 mm - 0.074 mm	0.76	Fine Sand
Passing #200	<0.074 mm	98.89	Silt/Clay

N/A - Not Applicable

Wet Sieve Analysis

Client: **Army Corps of Engineers**
Project: **Boston Harbor Improvement Project**
Case: N/A SDG: N/A
Client ID: **STA UU #1**
Matrix: **Sediment**
Collection Date: **8/15/2002**

Lab Code: **M-MA030**
ETR: **0208095**
Lab ID: **0208095-11**
Concentration Units: **%**
Received Date: **8/15/2002**
Analysis Date: **8/20/2002**



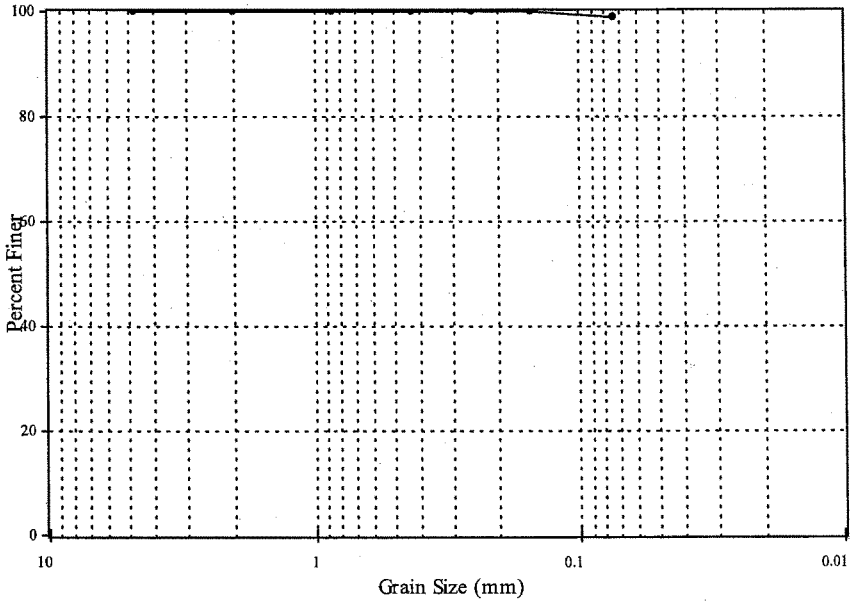
Sieve Number	Diameter Range	Percent Retained	Description
#4	>4.76 mm	0.01	Gravel
#10	<4.76 mm - 2.00 mm	0.00	Coarse Sand
#20	<2.00 mm - 0.85 mm	0.01	Medium Sand
#40	<0.85 mm - 0.425 mm	0.56	Medium Sand
#60	<0.425 mm - 0.25 mm	0.83	Fine Sand
#100	<0.25 mm - 0.15 mm	1.85	Fine Sand
#200	<0.15 mm - 0.074 mm	8.22	Fine Sand
Passing #200	<0.074 mm	88.49	Silt/Clay

N/A - Not Applicable

Wet Sieve Analysis

Client: **Army Corps of Engineers**
Project: **Boston Harbor Improvement Project**
Case: **N/A** SDG: **N/A**
Client ID: **STA UU #2**
Matrix: **Sediment**
Collection Date: **8/15/2002**

Lab Code: **M-MA030**
ETR: **0208095**
Lab ID: **0208095-12**
Concentration Units: **%**
Received Date: **8/15/2002**
Analysis Date: **8/20/2002**



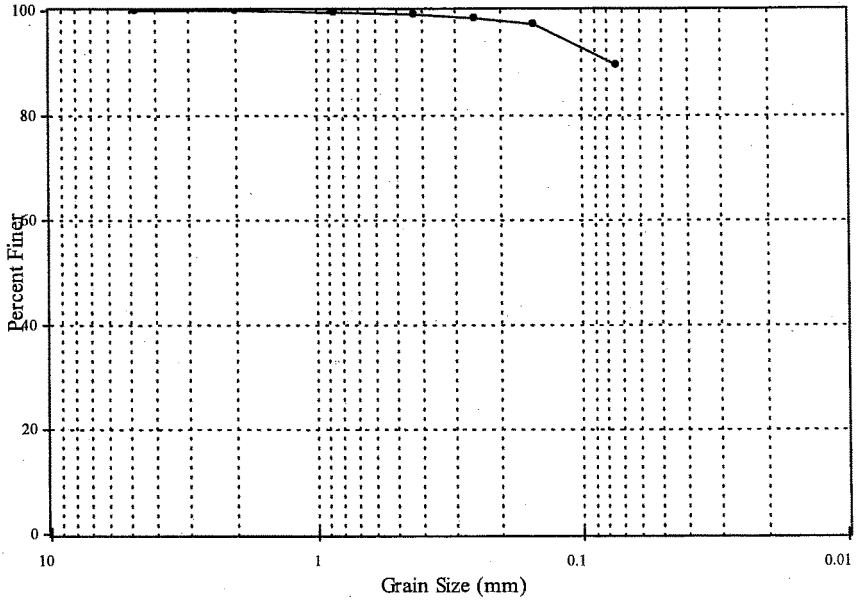
Sieve Number	Diameter Range	Percent Retained	Description
#4	>4.76 mm	0.00	Gravel
#10	<4.76 mm - 2.00 mm	0.00	Coarse Sand
#20	<2.00 mm - 0.85 mm	0.00	Medium Sand
#40	<0.85 mm - 0.425 mm	0.00	Medium Sand
#60	<0.425 mm - 0.25 mm	0.00	Fine Sand
#100	<0.25 mm - 0.15 mm	0.07	Fine Sand
#200	<0.15 mm - 0.074 mm	0.86	Fine Sand
Passing #200	<0.074 mm	99.06	Silt/Clay

N/A - Not Applicable

Wet Sieve Analysis

Client: **Army Corps of Engineers**
Project: **Boston Harbor Improvement Project**
Case: N/A SDG: N/A
Client ID: **STA VV**
Matrix: **Sediment**
Collection Date: **8/15/2002**

Lab Code: **M-MA030**
ETR: **0208095**
Lab ID: **0208095-08**
Concentration Units: **%**
Received Date: **8/15/2002**
Analysis Date: **8/21/2002**



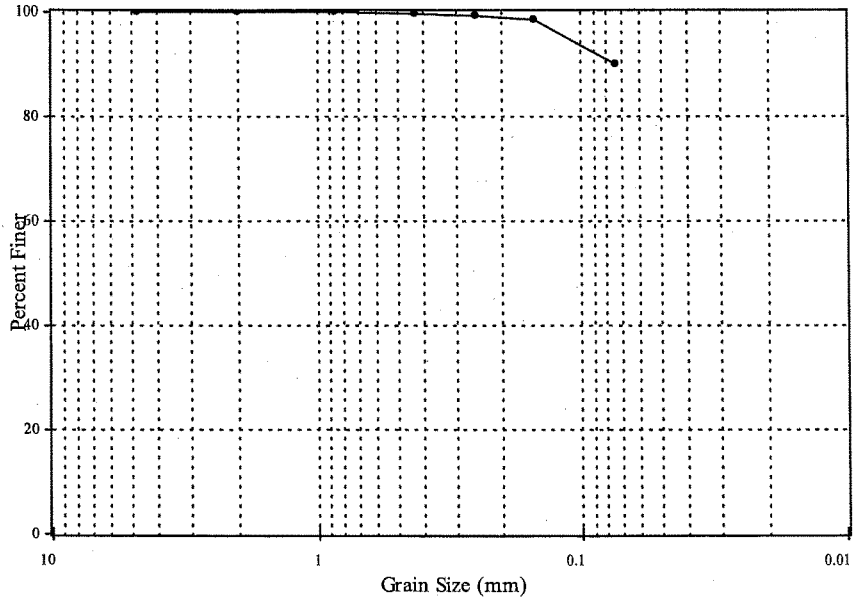
Sieve Number	Diameter Range	Percent Retained	Description
#4	>4.76 mm	0.00	Gravel
#10	<4.76 mm - 2.00 mm	0.02	Coarse Sand
#20	<2.00 mm - 0.85 mm	0.22	Medium Sand
#40	<0.85 mm - 0.425 mm	0.34	Medium Sand
#60	<0.425 mm - 0.25 mm	0.73	Fine Sand
#100	<0.25 mm - 0.15 mm	1.38	Fine Sand
#200	<0.15 mm - 0.074 mm	7.85	Fine Sand
Passing #200	<0.074 mm	89.37	Silt/Clay

N/A - Not Applicable

Wet Sieve Analysis

Client: **Army Corps of Engineers**
Project: **Boston Harbor Improvement Project**
Case: **N/A** SDG: **N/A**
Client ID: **STA WW**
Matrix: **Sediment**
Collection Date: **8/15/2002**

Lab Code: **M-MA030**
ETR: **0208095**
Lab ID: **0208095-03**
Concentration Units: **%**
Received Date: **8/15/2002**
Analysis Date: **8/21/2002**



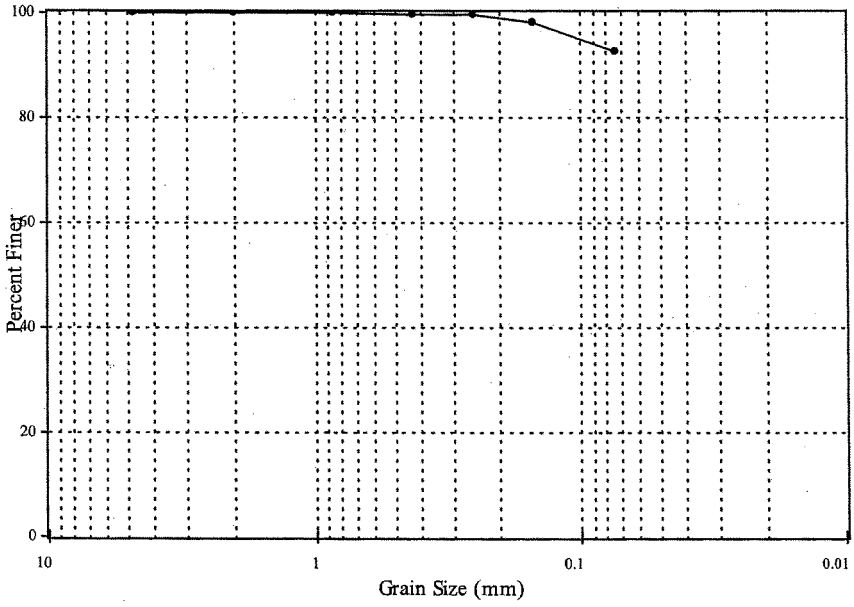
Sieve Number	Diameter Range	Percent Retained	Description
#4	>4.76 mm	0.00	Gravel
#10	<4.76 mm - 2.00 mm	0.01	Coarse Sand
#20	<2.00 mm - 0.85 mm	0.08	Medium Sand
#40	<0.85 mm - 0.425 mm	0.30	Medium Sand
#60	<0.425 mm - 0.25 mm	0.32	Fine Sand
#100	<0.25 mm - 0.15 mm	0.62	Fine Sand
#200	<0.15 mm - 0.074 mm	8.82	Fine Sand
Passing #200	<0.074 mm	89.91	Silt/Clay

N/A - Not Applicable

Wet Sieve Analysis

Client: **Army Corps of Engineers**
Project: **Boston Harbor Improvement Project**
Case: N/A SDG: N/A
Client ID: **STA XX #1**
Matrix: **Sediment**
Collection Date: **8/15/2002**

Lab Code: **M-MA030**
ETR: **0208095**
Lab ID: **0208095-09**
Concentration Units: **%**
Received Date: **8/15/2002**
Analysis Date: **8/20/2002**



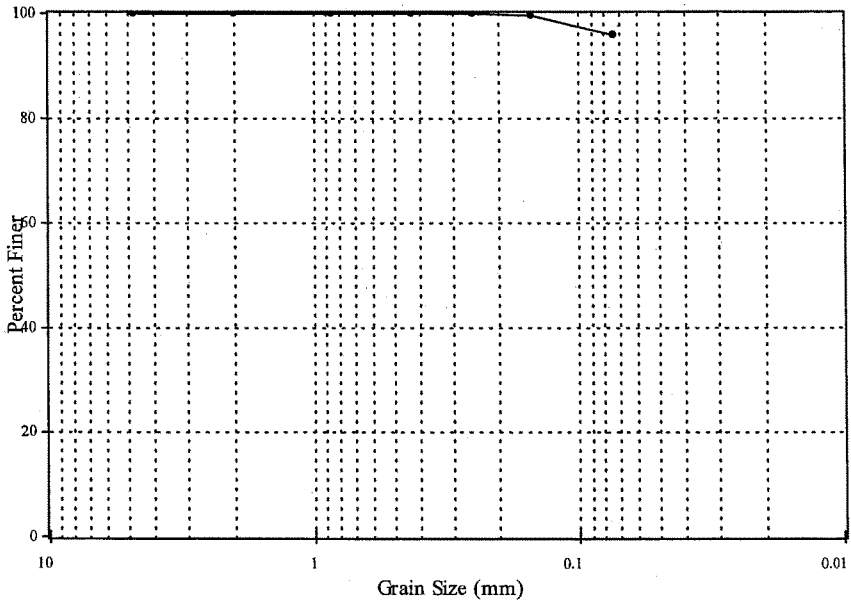
Sieve Number	Diameter Range	Percent Retained	Description
#4	>4.76 mm	0.00	Gravel
#10	<4.76 mm - 2.00 mm	0.02	Coarse Sand
#20	<2.00 mm - 0.85 mm	0.08	Medium Sand
#40	<0.85 mm - 0.425 mm	0.14	Medium Sand
#60	<0.425 mm - 0.25 mm	0.27	Fine Sand
#100	<0.25 mm - 0.15 mm	1.21	Fine Sand
#200	<0.15 mm - 0.074 mm	5.74	Fine Sand
Passing #200	<0.074 mm	92.50	Silt/Clay

N/A - Not Applicable

Wet Sieve Analysis

Client: **Army Corps of Engineers**
Project: **Boston Harbor Improvement Project**
Case: **N/A** SDG: **N/A**
Client ID: **STA XX #2**
Matrix: **Sediment**
Collection Date: **8/15/2002**

Lab Code: **M-MA030**
ETR: **0208095**
Lab ID: **0208095-10**
Concentration Units: **%**
Received Date: **8/15/2002**
Analysis Date: **8/20/2002**



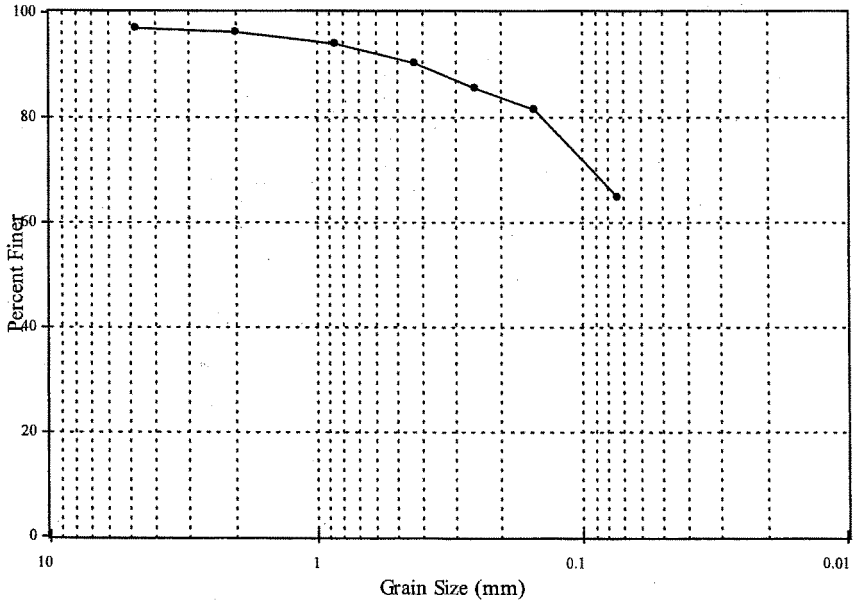
Sieve Number	Diameter Range	Percent Retained	Description
#4	>4.76 mm	0.00	Gravel
#10	<4.76 mm - 2.00 mm	0.00	Coarse Sand
#20	<2.00 mm - 0.85 mm	0.04	Medium Sand
#40	<0.85 mm - 0.425 mm	0.04	Medium Sand
#60	<0.425 mm - 0.25 mm	0.03	Fine Sand
#100	<0.25 mm - 0.15 mm	0.23	Fine Sand
#200	<0.15 mm - 0.074 mm	3.56	Fine Sand
Passing #200	<0.074 mm	96.08	Silt/Clay

N/A - Not Applicable

Wet Sieve Analysis

Client: **Army Corps of Engineers**
Project: **Boston Harbor Improvement Project**
Case: **N/A** SDG: **N/A**
Client ID: **STA YY**
Matrix: **Sediment**
Collection Date: **8/15/2002**

Lab Code: **M-MA030**
ETR: **0208095**
Lab ID: **0208095-04**
Concentration Units: **%**
Received Date: **8/15/2002**
Analysis Date: **8/21/2002**



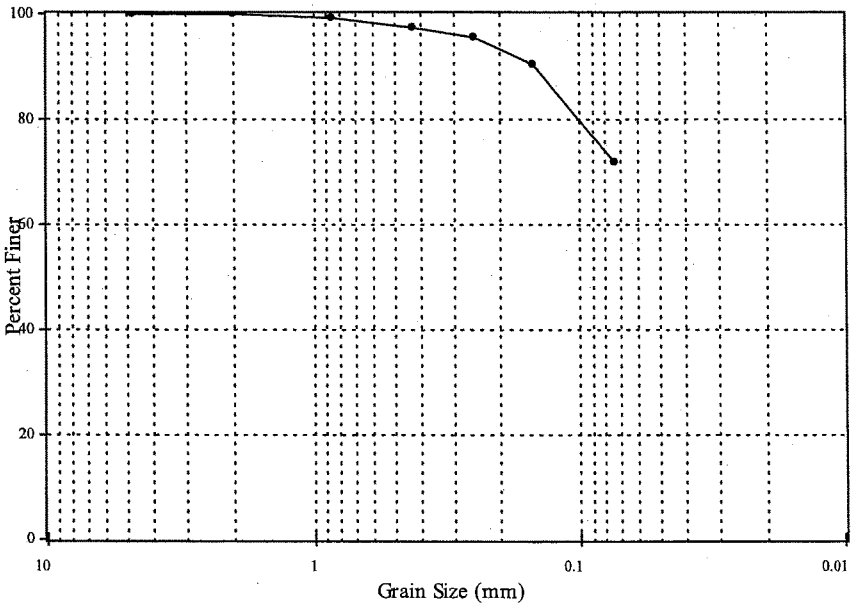
Sieve Number	Diameter Range	Percent Retained	Description
#4	>4.76 mm	3.01	Gravel
#10	<4.76 mm - 2.00 mm	0.80	Coarse Sand
#20	<2.00 mm - 0.85 mm	1.96	Medium Sand
#40	<0.85 mm - 0.425 mm	4.05	Medium Sand
#60	<0.425 mm - 0.25 mm	4.46	Fine Sand
#100	<0.25 mm - 0.15 mm	4.17	Fine Sand
#200	<0.15 mm - 0.074 mm	16.87	Fine Sand
Passing #200	<0.074 mm	64.63	Silt/Clay

N/A - Not Applicable

Wet Sieve Analysis

Client: **Army Corps of Engineers**
Project: **Boston Harbor Improvement Project**
Case: N/A SDG: N/A
Client ID: **STA CC2 #1**
Matrix: **Sediment**
Collection Date: **8/15/2002**

Lab Code: **M-MA030**
ETR: **0208095**
Lab ID: **0208095-16**
Concentration Units: **%**
Received Date: **8/15/2002**
Analysis Date: **8/21/2002**



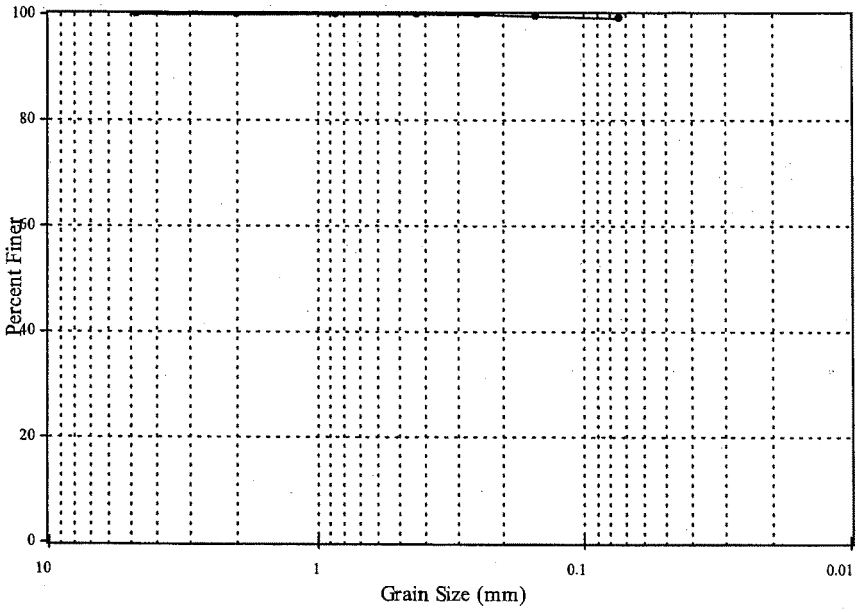
Sieve Number	Diameter Range	Percent Retained	Description
#4	>4.76 mm	0.00	Gravel
#10	<4.76 mm - 2.00 mm	0.18	Coarse Sand
#20	<2.00 mm - 0.85 mm	0.62	Medium Sand
#40	<0.85 mm - 0.425 mm	1.62	Medium Sand
#60	<0.425 mm - 0.25 mm	2.04	Fine Sand
#100	<0.25 mm - 0.15 mm	5.03	Fine Sand
#200	<0.15 mm - 0.074 mm	18.57	Fine Sand
Passing #200	<0.074 mm	70.94	Silt/Clay

N/A - Not Applicable

Wet Sieve Analysis

Client: **Army Corps of Engineers**
Project: **Boston Harbor Improvement Project**
Case: N/A SDG: N/A
Client ID: **STA CC2 #2**
Matrix: **Sediment**
Collection Date: **8/15/2002**

Lab Code: **M-MA030**
ETR: **0208095**
Lab ID: **0208095-17**
Concentration Units: **%**
Received Date: **8/15/2002**
Analysis Date: **8/20/2002**



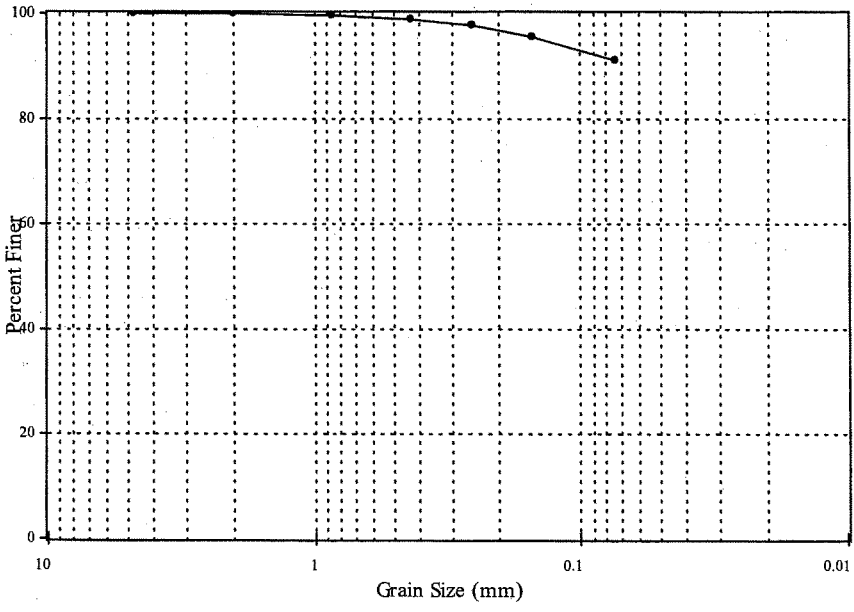
Sieve Number	Diameter Range	Percent Retained	Description
#4	>4.76 mm	0.00	Gravel
#10	<4.76 mm - 2.00 mm	0.00	Coarse Sand
#20	<2.00 mm - 0.85 mm	0.01	Medium Sand
#40	<0.85 mm - 0.425 mm	0.03	Medium Sand
#60	<0.425 mm - 0.25 mm	0.06	Fine Sand
#100	<0.25 mm - 0.15 mm	0.16	Fine Sand
#200	<0.15 mm - 0.074 mm	0.58	Fine Sand
Passing #200	<0.074 mm	99.17	Silt/Clay

N/A - Not Applicable

Wet Sieve Analysis

Client: **Army Corps of Engineers**
Project: **Boston Harbor Improvement Project**
Case: N/A SDG: N/A
Client ID: **STA MM2**
Matrix: **Sediment**
Collection Date: **8/15/2002**

Lab Code: **M-MA030**
ETR: **0208095**
Lab ID: **0208095-15**
Concentration Units: **%**
Received Date: **8/15/2002**
Analysis Date: **8/21/2002**



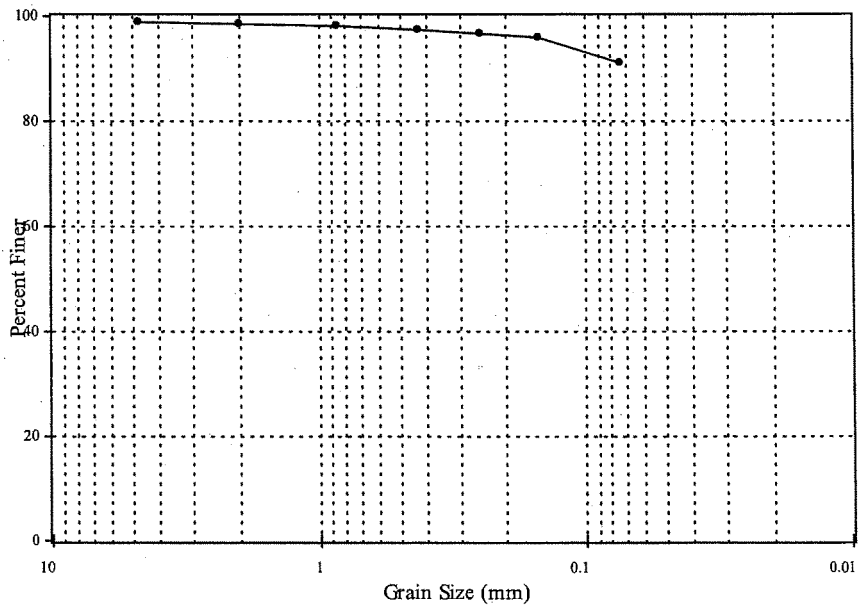
Sieve Number	Diameter Range	Percent Retained	Description
#4	>4.76 mm	0.00	Gravel
#10	<4.76 mm - 2.00 mm	0.00	Coarse Sand
#20	<2.00 mm - 0.85 mm	0.40	Medium Sand
#40	<0.85 mm - 0.425 mm	0.70	Medium Sand
#60	<0.425 mm - 0.25 mm	1.07	Fine Sand
#100	<0.25 mm - 0.15 mm	2.34	Fine Sand
#200	<0.15 mm - 0.074 mm	4.51	Fine Sand
Passing #200	<0.074 mm	91.02	Silt/Clay

N/A - Not Applicable

Wet Sieve Analysis

Client: **Army Corps of Engineers**
Project: **Boston Harbor Improvement Project**
Case: N/A SDG: N/A
Client ID: **STA NN2 #1**
Matrix: **Sediment**
Collection Date: **8/15/2002**

Lab Code: **M-MA030**
ETR: **0208095**
Lab ID: **0208095-13**
Concentration Units: **%**
Received Date: **8/15/2002**
Analysis Date: **8/21/2002**



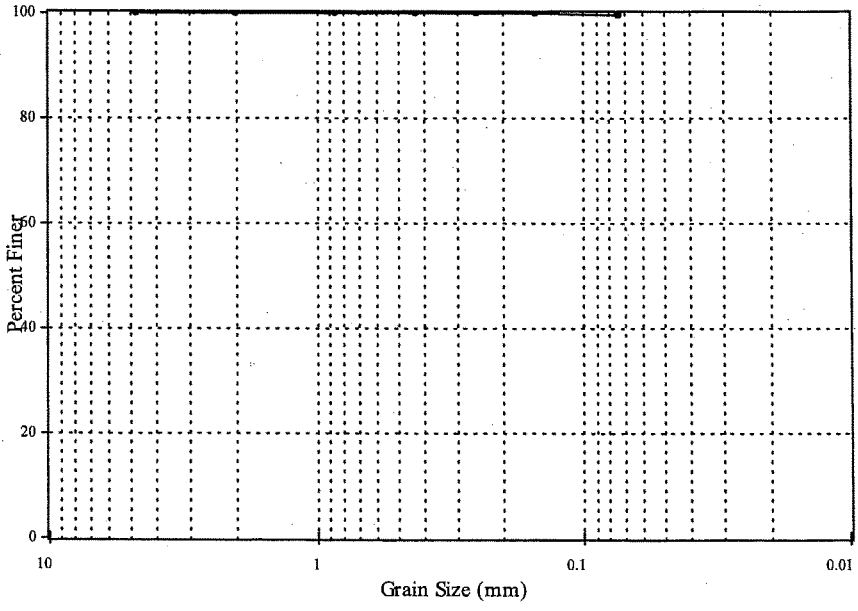
Sieve Number	Diameter Range	Percent Retained	Description
#4	>4.76 mm	1.23	Gravel
#10	<4.76 mm - 2.00 mm	0.14	Coarse Sand
#20	<2.00 mm - 0.85 mm	0.38	Medium Sand
#40	<0.85 mm - 0.425 mm	0.71	Medium Sand
#60	<0.425 mm - 0.25 mm	0.73	Fine Sand
#100	<0.25 mm - 0.15 mm	0.74	Fine Sand
#200	<0.15 mm - 0.074 mm	5.07	Fine Sand
Passing #200	<0.074 mm	90.97	Silt/Clay

N/A - Not Applicable

Wet Sieve Analysis

Client: **Army Corps of Engineers**
Project: **Boston Harbor Improvement Project**
Case: N/A SDG: N/A
Client ID: **STA NN2 #2**
Matrix: **Sediment**
Collection Date: **8/15/2002**

Lab Code: **M-MA030**
ETR: **0208095**
Lab ID: **0208095-14**
Concentration Units: **%**
Received Date: **8/15/2002**
Analysis Date: **8/20/2002**



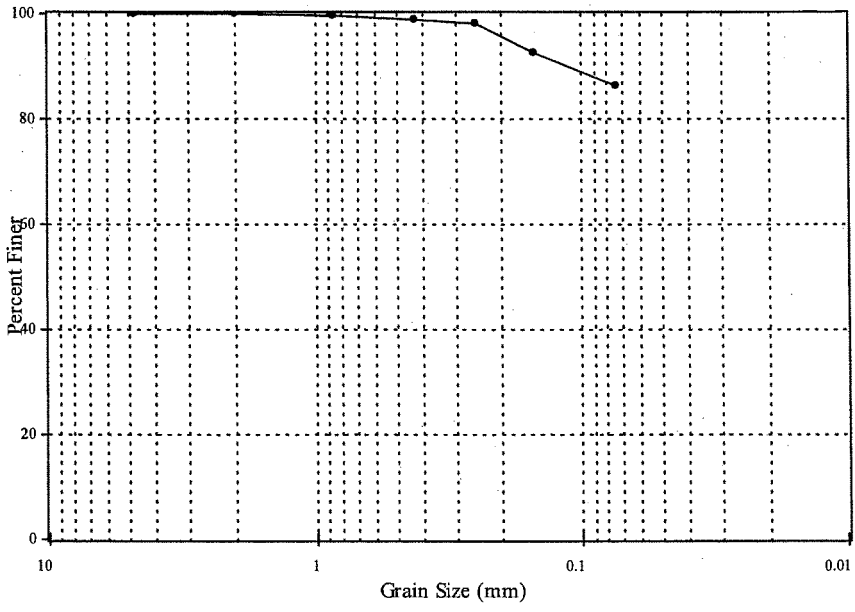
Sieve Number	Diameter Range	Percent Retained	Description
#4	>4.76 mm	0.00	Gravel
#10	<4.76 mm - 2.00 mm	0.00	Coarse Sand
#20	<2.00 mm - 0.85 mm	0.02	Medium Sand
#40	<0.85 mm - 0.425 mm	0.01	Medium Sand
#60	<0.425 mm - 0.25 mm	0.02	Fine Sand
#100	<0.25 mm - 0.15 mm	0.07	Fine Sand
#200	<0.15 mm - 0.074 mm	0.18	Fine Sand
Passing #200	<0.074 mm	99.70	Silt/Clay

N/A - Not Applicable

Wet Sieve Analysis

Client: **Army Corps of Engineers**
Project: **Boston Harbor Improvement Project**
Case: N/A SDG: N/A
Client ID: **STA W2 #1**
Matrix: **Sediment**
Collection Date: **8/15/2002**

Lab Code: **M-MA030**
ETR: **0208095**
Lab ID: **0208095-20**
Concentration Units: **%**
Received Date: **8/15/2002**
Analysis Date: **8/20/2002**



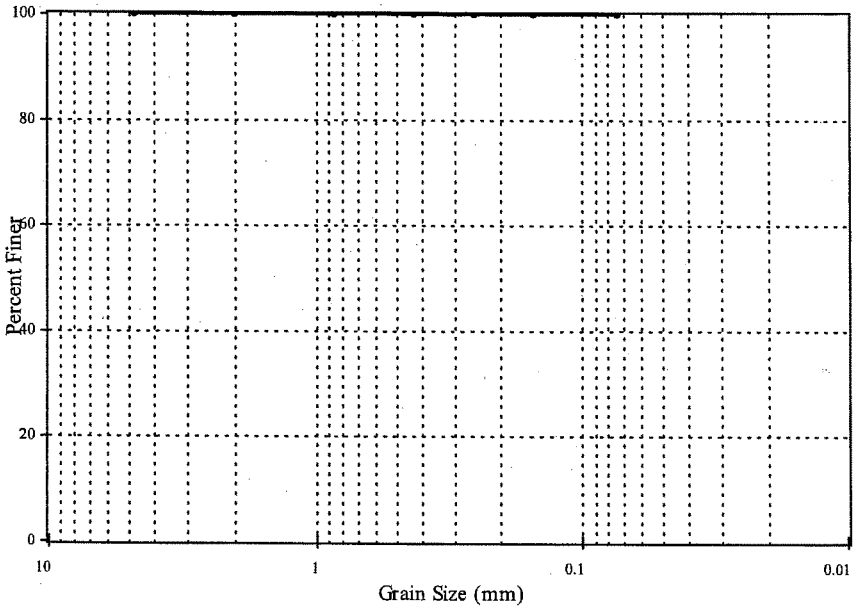
Sieve Number	Diameter Range	Percent Retained	Description
#4	>4.76 mm	0.00	Gravel
#10	<4.76 mm - 2.00 mm	0.01	Coarse Sand
#20	<2.00 mm - 0.85 mm	0.25	Medium Sand
#40	<0.85 mm - 0.425 mm	0.73	Medium Sand
#60	<0.425 mm - 0.25 mm	0.89	Fine Sand
#100	<0.25 mm - 0.15 mm	5.42	Fine Sand
#200	<0.15 mm - 0.074 mm	6.57	Fine Sand
Passing #200	<0.074 mm	86.10	Silt/Clay

N/A - Not Applicable

Wet Sieve Analysis

Client: **Army Corps of Engineers**
Project: **Boston Harbor Improvement Project**
Case: N/A SDG: N/A
Client ID: **STA W2 #2**
Matrix: **Sediment**
Collection Date: **8/15/2002**

Lab Code: **M-MA030**
ETR: **0208095**
Lab ID: **0208095-21**
Concentration Units: **%**
Received Date: **8/15/2002**
Analysis Date: **8/20/2002**



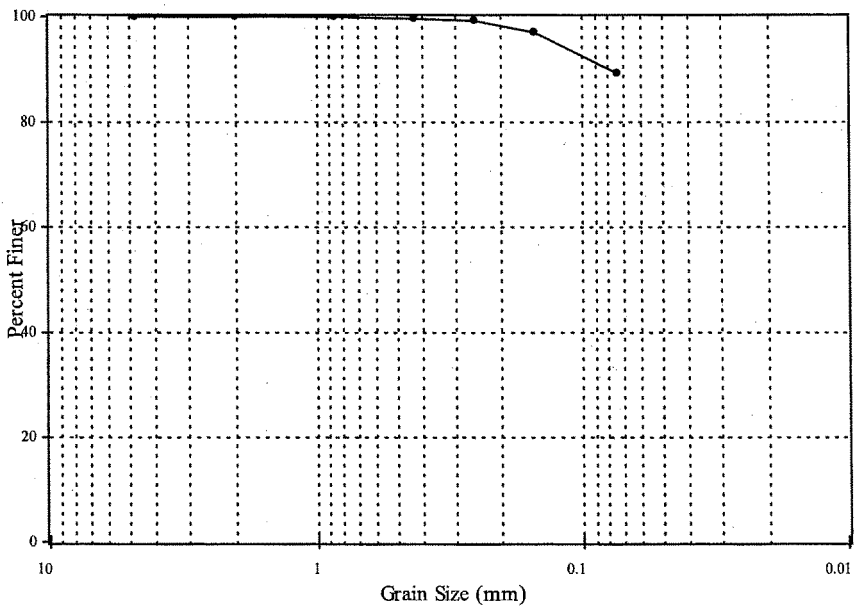
Sieve Number	Diameter Range	Percent Retained	Description
#4	>4.76 mm	0.00	Gravel
#10	<4.76 mm - 2.00 mm	0.00	Coarse Sand
#20	<2.00 mm - 0.85 mm	0.00	Medium Sand
#40	<0.85 mm - 0.425 mm	0.00	Medium Sand
#60	<0.425 mm - 0.25 mm	0.01	Fine Sand
#100	<0.25 mm - 0.15 mm	0.02	Fine Sand
#200	<0.15 mm - 0.074 mm	0.07	Fine Sand
Passing #200	<0.074 mm	99.89	Silt/Clay

N/A - Not Applicable

Wet Sieve Analysis

Client: **Army Corps of Engineers**
Project: **Boston Harbor Improvement Project**
Case: N/A SDG: N/A
Client ID: **STA Y2 #1**
Matrix: **Sediment**
Collection Date: **8/15/2002**

Lab Code: **M-MA030**
ETR: **0208095**
Lab ID: **0208095-18**
Concentration Units: **%**
Received Date: **8/15/2002**
Analysis Date: **8/21/2002**



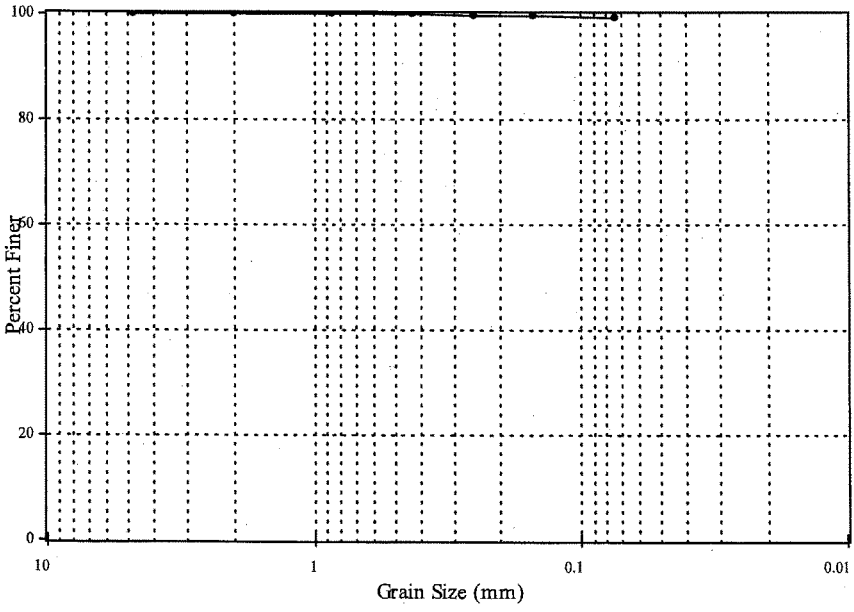
Sieve Number	Diameter Range	Percent Retained	Description
#4	>4.76 mm	0.00	Gravel
#10	<4.76 mm - 2.00 mm	0.00	Coarse Sand
#20	<2.00 mm - 0.85 mm	0.10	Medium Sand
#40	<0.85 mm - 0.425 mm	0.19	Medium Sand
#60	<0.425 mm - 0.25 mm	0.31	Fine Sand
#100	<0.25 mm - 0.15 mm	2.45	Fine Sand
#200	<0.15 mm - 0.074 mm	7.53	Fine Sand
Passing #200	<0.074 mm	89.34	Silt/Clay

N/A - Not Applicable

Wet Sieve Analysis

Client: **Army Corps of Engineers**
Project: **Boston Harbor Improvement Project**
Case: N/A SDG: N/A
Client ID: **STA Y2 #2**
Matrix: **Sediment**
Collection Date: **8/15/2002**

Lab Code: **M-MA030**
ETR: **0208095**
Lab ID: **0208095-19**
Concentration Units: **%**
Received Date: **8/15/2002**
Analysis Date: **8/20/2002**



Sieve Number	Diameter Range	Percent Retained	Description
#4	>4.76 mm	0.00	Gravel
#10	<4.76 mm - 2.00 mm	0.00	Coarse Sand
#20	<2.00 mm - 0.85 mm	0.03	Medium Sand
#40	<0.85 mm - 0.425 mm	0.10	Medium Sand
#60	<0.425 mm - 0.25 mm	0.11	Fine Sand
#100	<0.25 mm - 0.15 mm	0.19	Fine Sand
#200	<0.15 mm - 0.074 mm	0.35	Fine Sand
Passing #200	<0.074 mm	99.07	Silt/Clay

N/A - Not Applicable

BOSTON HARBOR

SEPTEMBER 2003 VIBRACORE SAMPLING FOR CULTURAL RESOURCE INVESTIGATION

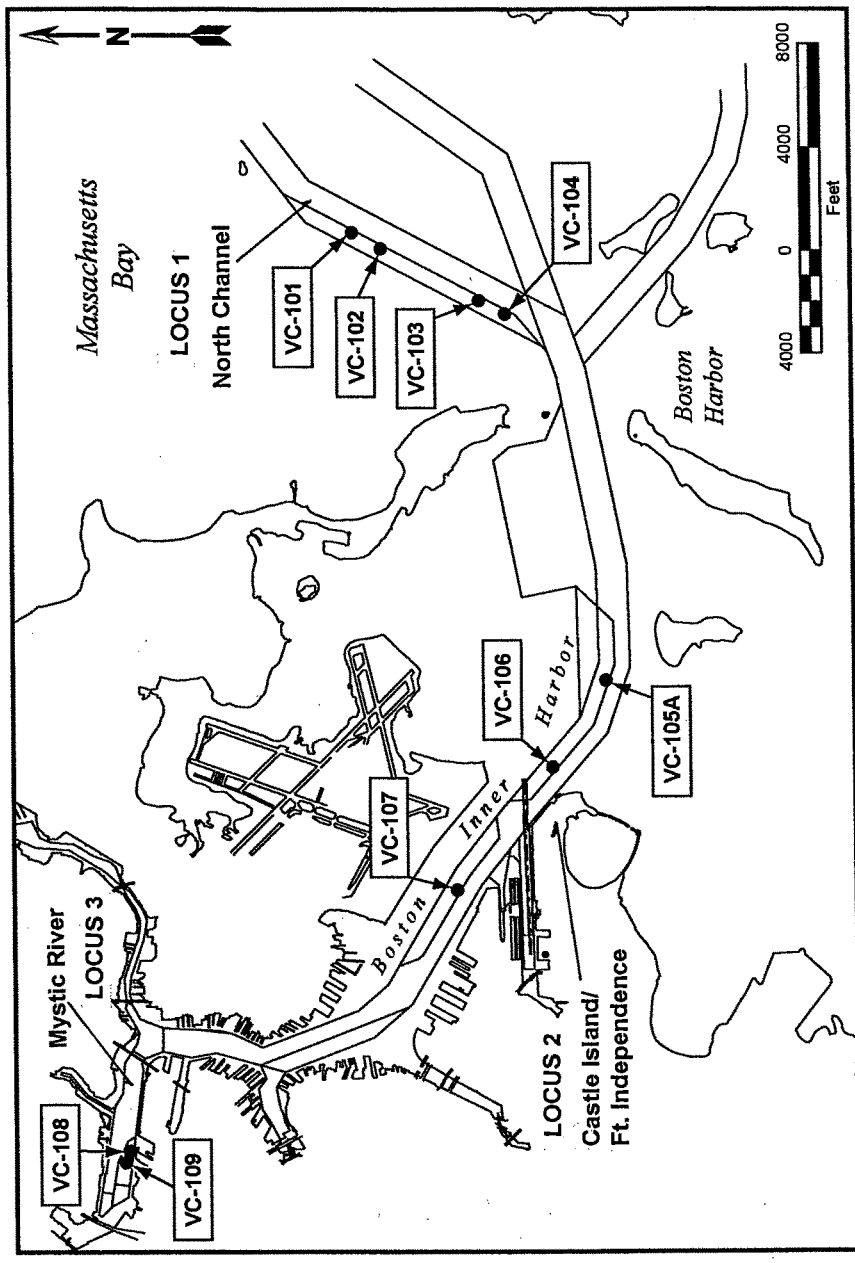


Figure 3. Map indicating the location of vibratory cores in Boston Harbor.

Table 2. Actual core locations and coring information.

VIBRACORE ID	DATE	TIME	NORTHING COORDINATE (feet)[1]	EASTING COORDINATE (feet)[1]	LATITUDE[2]	LONGITUDE[2]	WATER DEPTH (feet)[3]	SEDIMENT LENGTH (cm)
VC 101	9/11/2003	1:55pm	497,920.55	754,894.26	42° 21.9054'	70° 55.5814'	50.2	228
VC 102	9/11/2003	10:59am	496,058.31	754,061.68	42° 21.59972'	70° 55.7690'	48.2	232
VC 103	9/12/2003	9:35am	491,289.36	751,828.54	42° 20.8170'	70° 56.2717'	42.8	270
VC 104	9/12/2003	11:07am	490,265.71	751,334.68	42° 20.6490'	70° 56.3828'	48.6	270
VC 105	9/10/2003	N/A	486,381.22	736,890.52	N/A	N/A	40.2	vibracore refusal
VC 105A	9/11/2003	3:42pm	486,389.88	736,916.60	42° 20.0257'	70° 59.5878'	40.2	88
VC 106	9/10/2003	2:54pm	488,495.55	733,472.72	42° 20.3757'	71° 00.3493'	47	287
VC 107	9/10/2003	12:50pm	492,352.02	728,692.79	42° 21.0151'	71° 01.4053'	44.3	287
VC 108	9/12/2003	12:47pm	505,080.78	718,915.08	42° 23.1194'	71° 03.5610'	42.8	287
VC 109	9/12/2003	2:12pm	505,362.08	718,102.23	42° 23.1664'	71° 03.7412'	42.3	287

(1) U.S. State Plane, Massachusetts Mainland 2001, NAD 1927, U.S. Survey feet.

(2) Datum WGS-84. Coordinates recorded by TG & B Marine Services using real-time differential GPS.

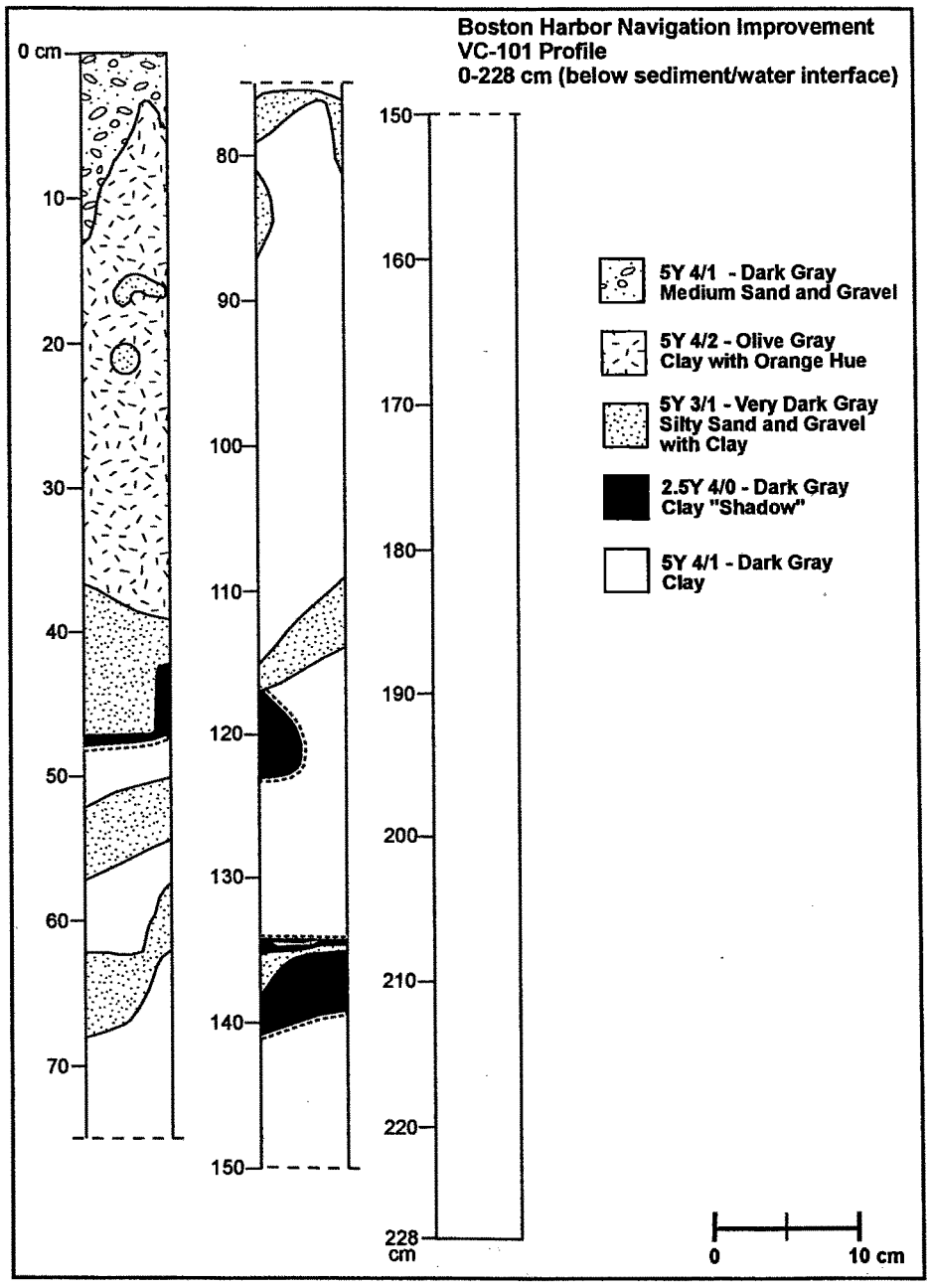


Figure 9. Profile of Vibratory Core VC-101 taken in the North Channel.

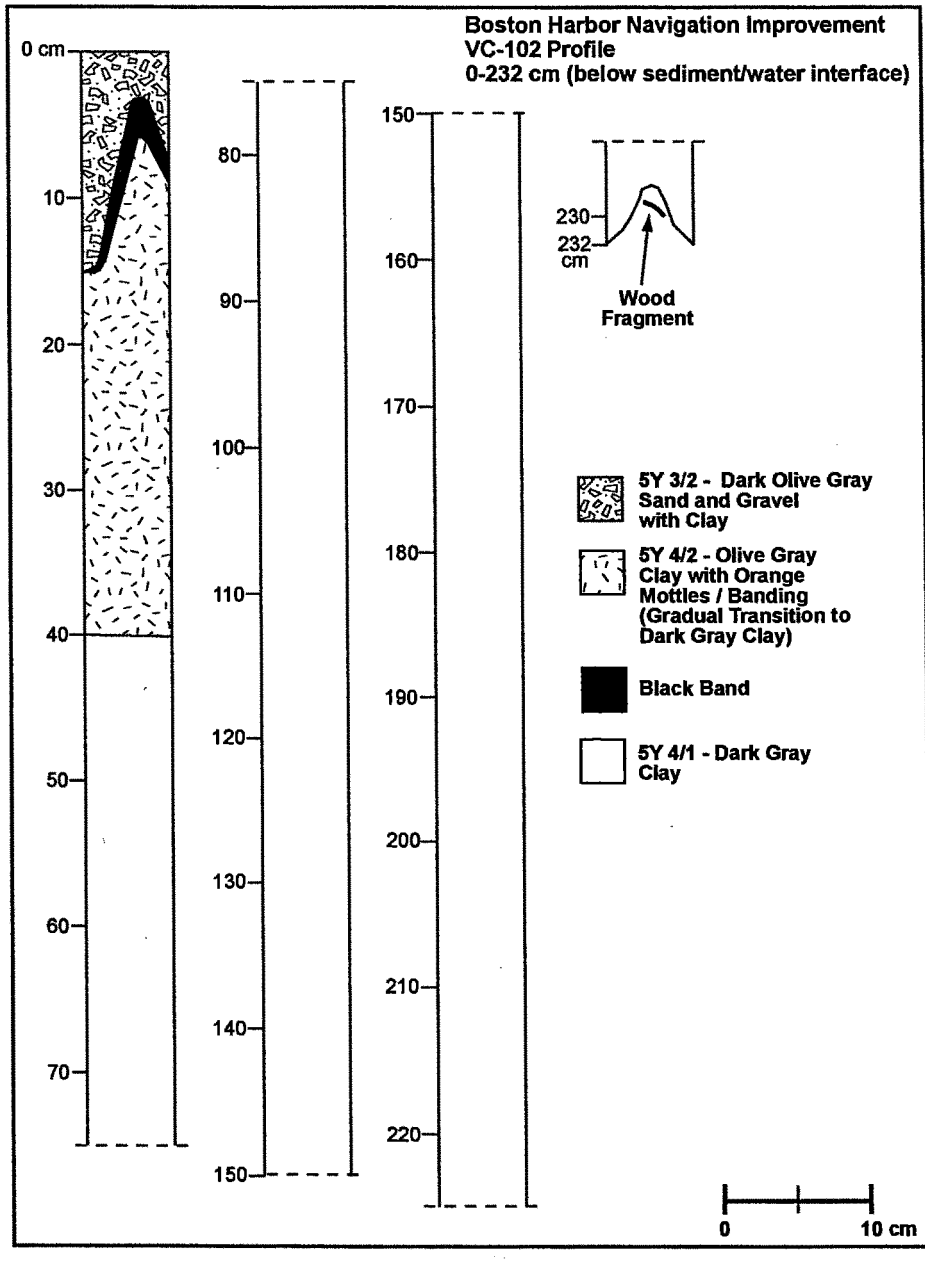


Figure 11. Profile of Vibratory Core VC-102 taken in the North Channel.

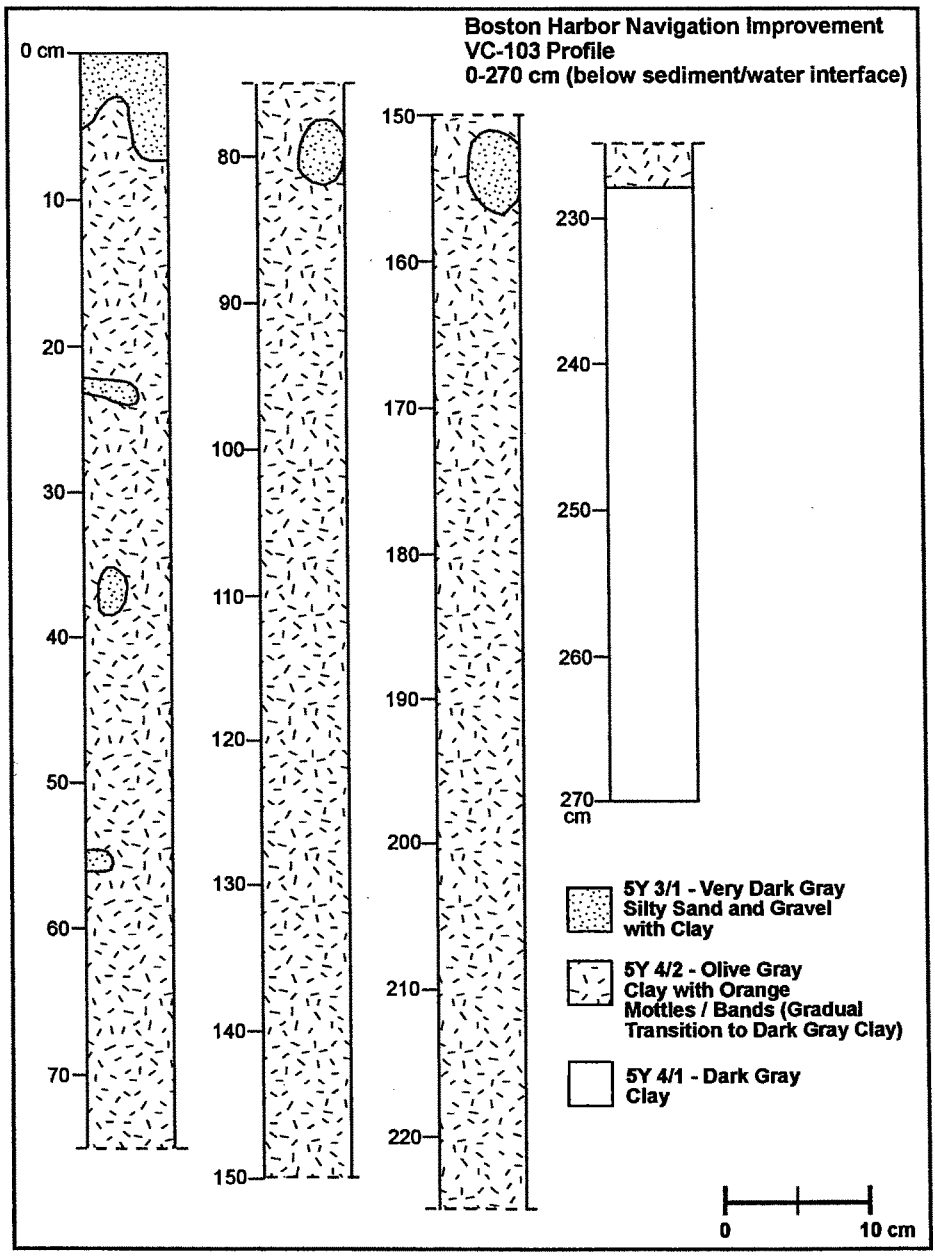


Figure 13. Profile of Vibratory Core VC-103 taken in the North Channel.

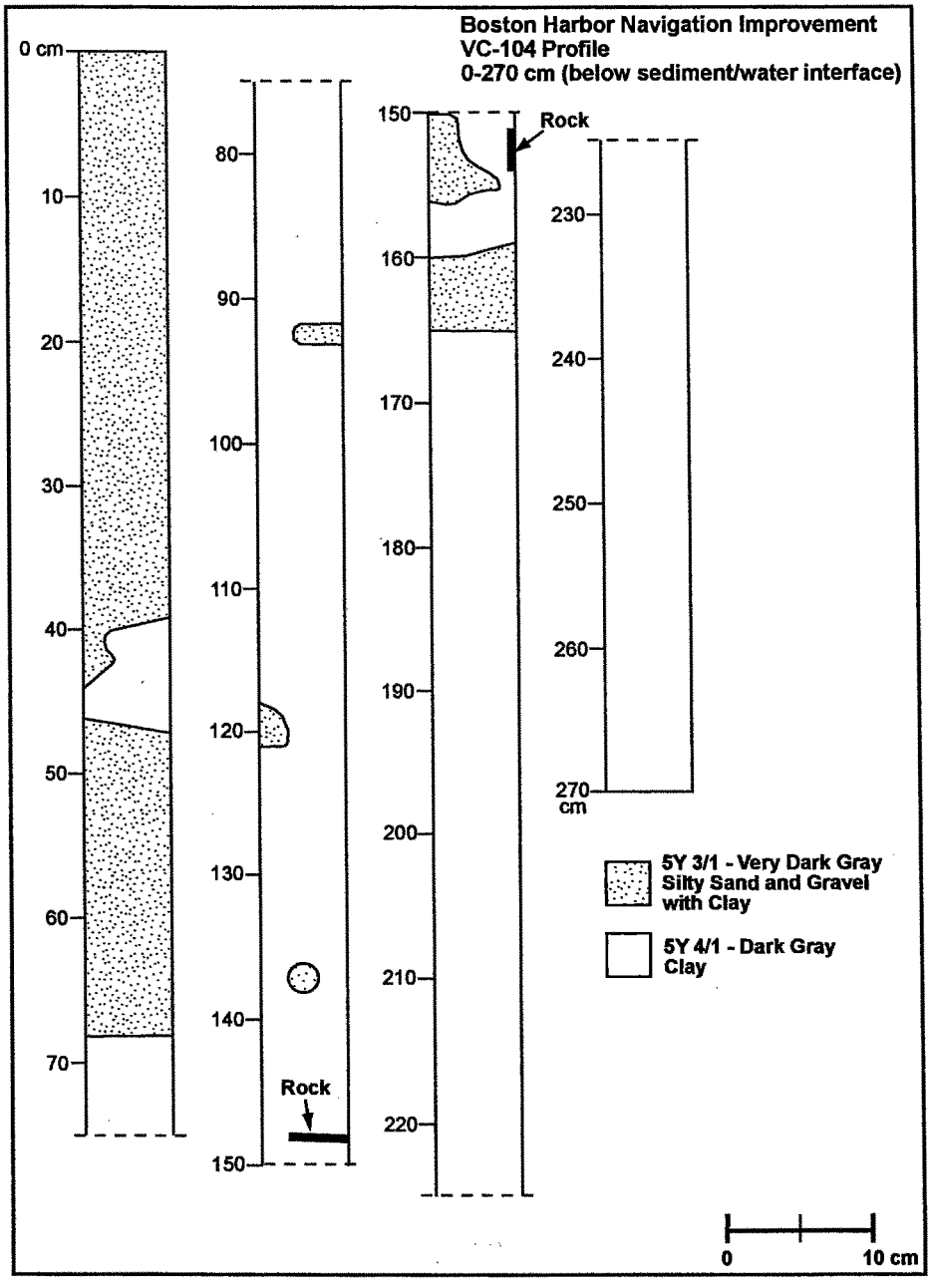


Figure 15. Profile of Vibratory Core VC-104 taken in the North Channel.

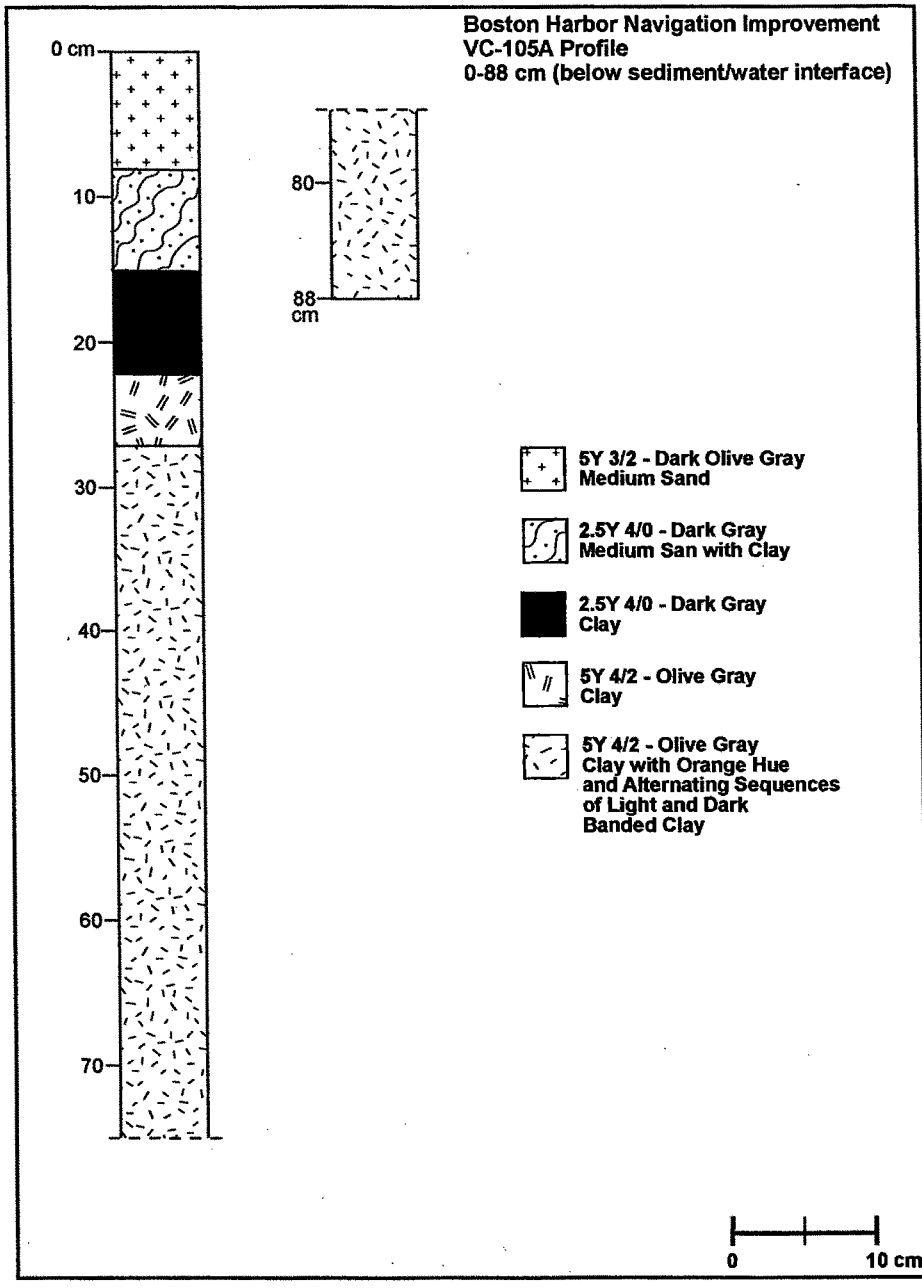


Figure 17. Profile of Vibratory Core VC-105A taken in the channel east of Castle Island.

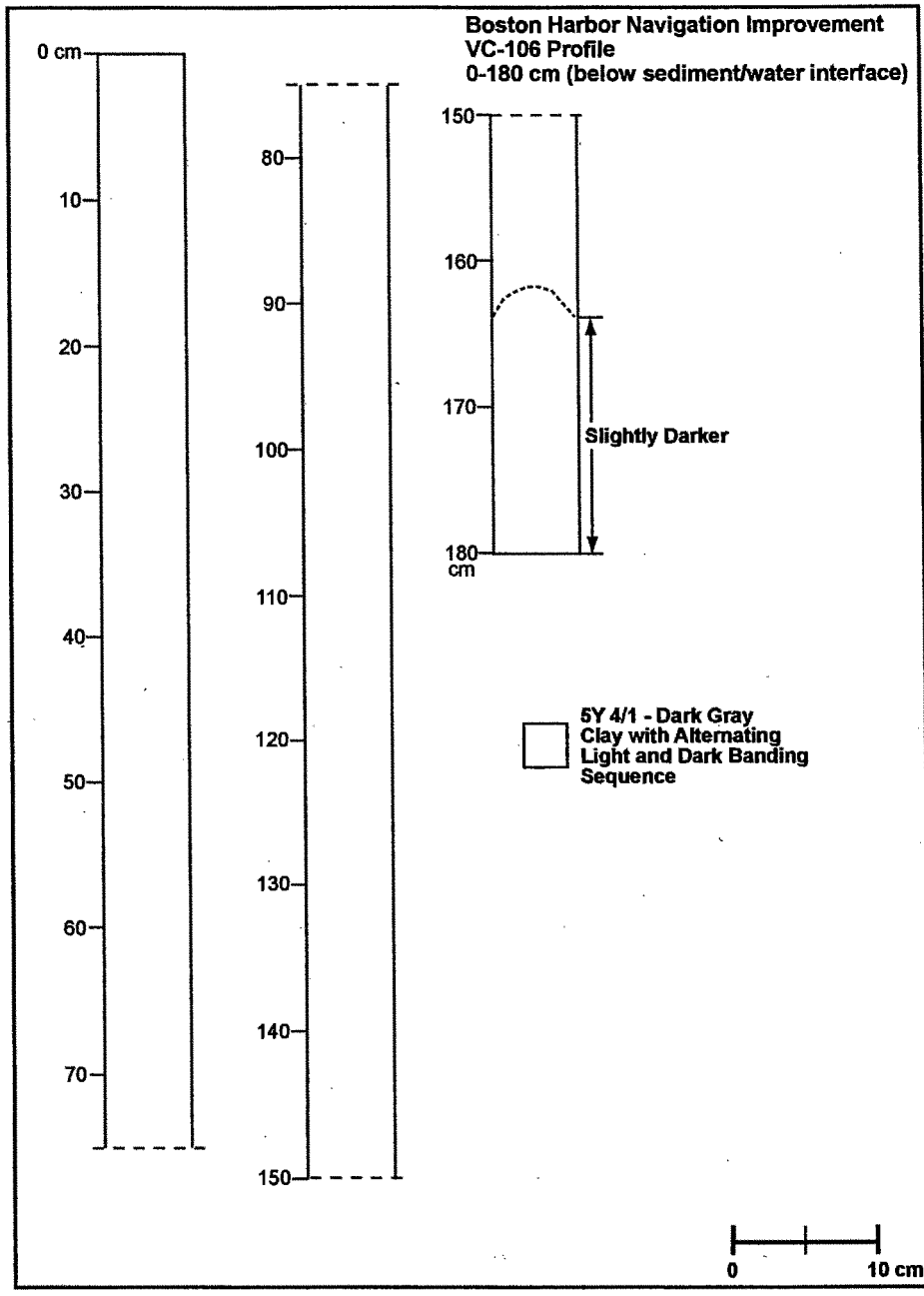


Figure 19. Profile of Vibratory Core VC-106 taken in the channel east of Castle Island.

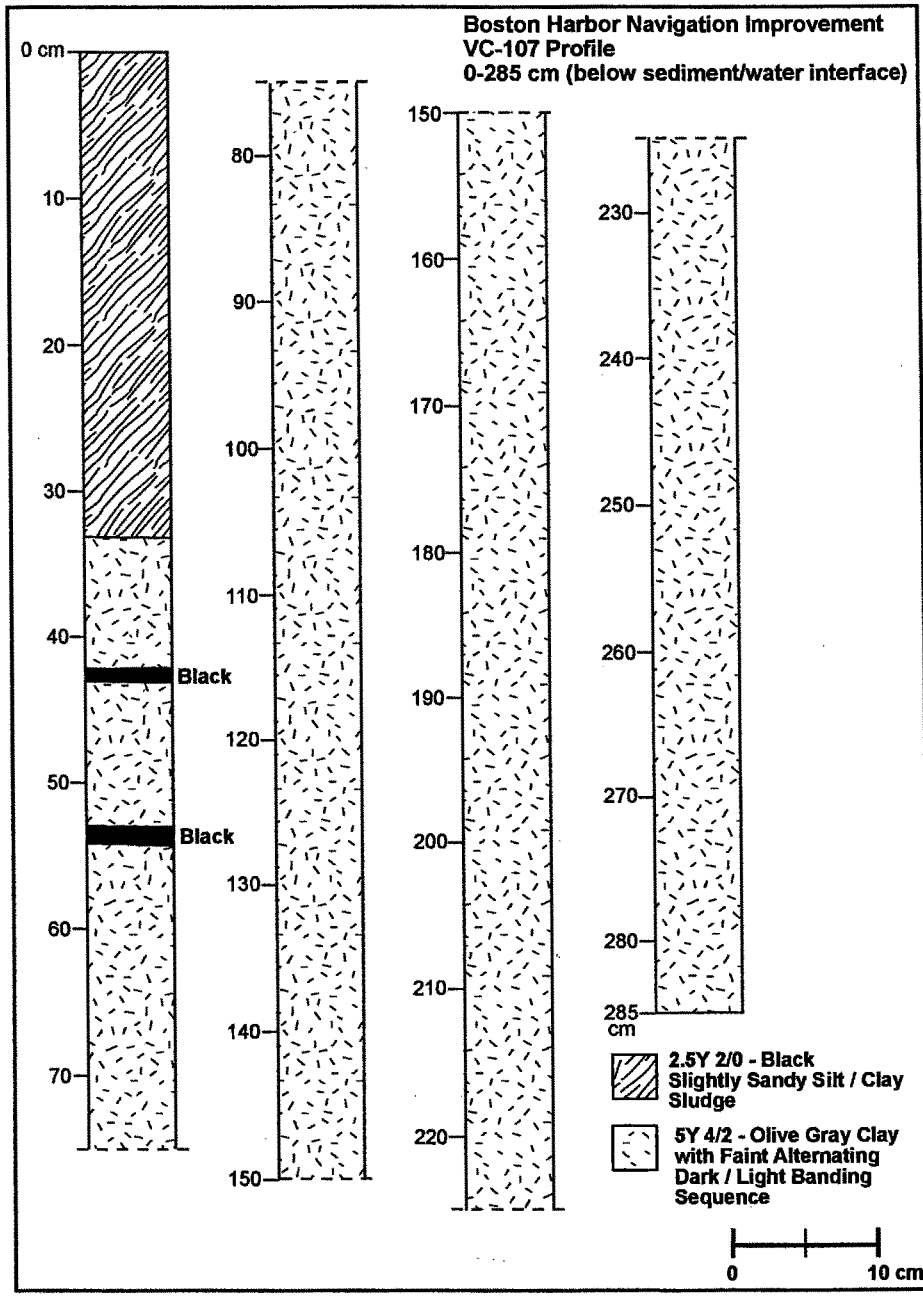


Figure 20. Profile of Vibratory Core VC-107 taken in the channel north of Castle Island.

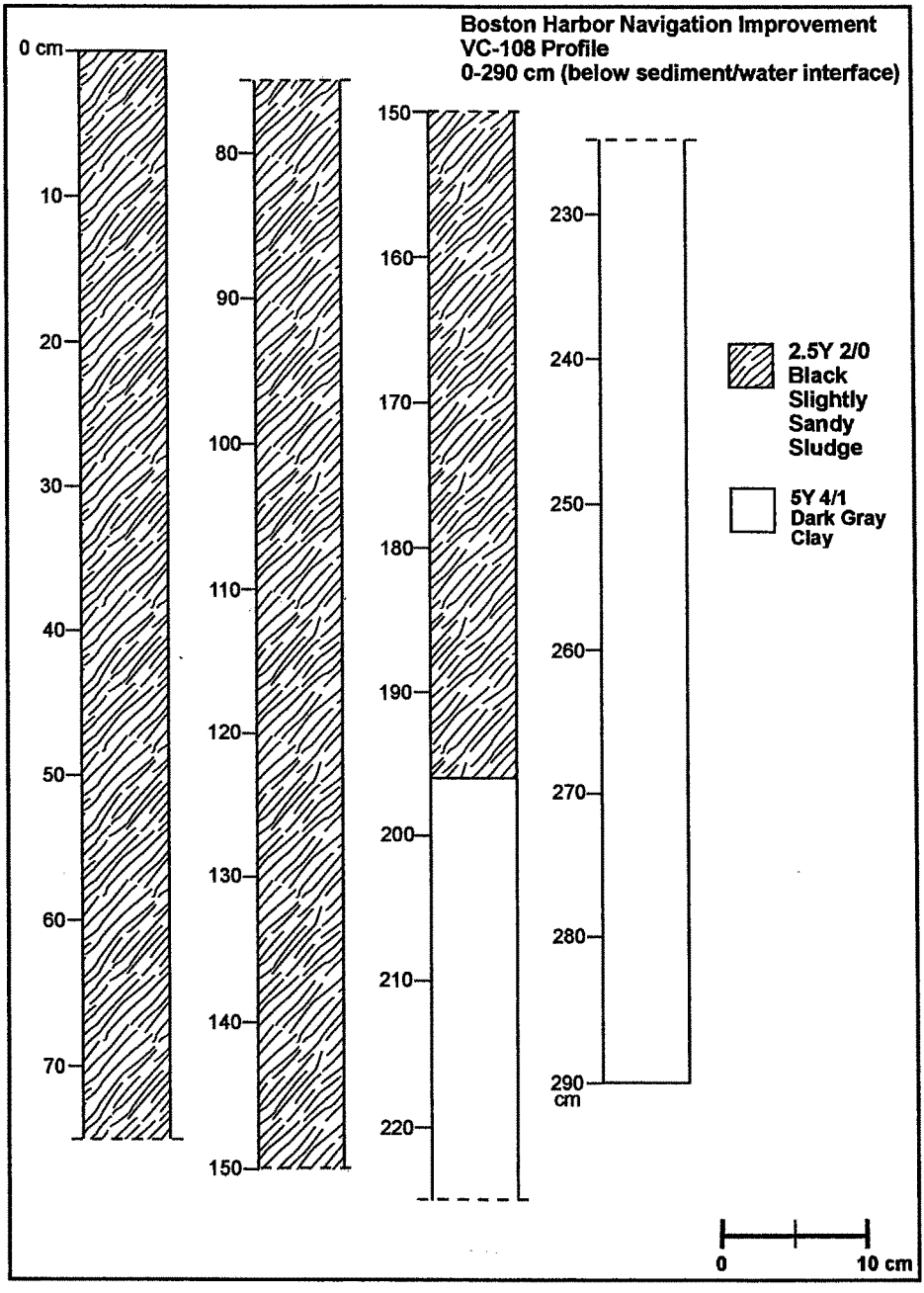


Figure 21. Profile of Vibratory Core VC-108 taken in the Mystic River.

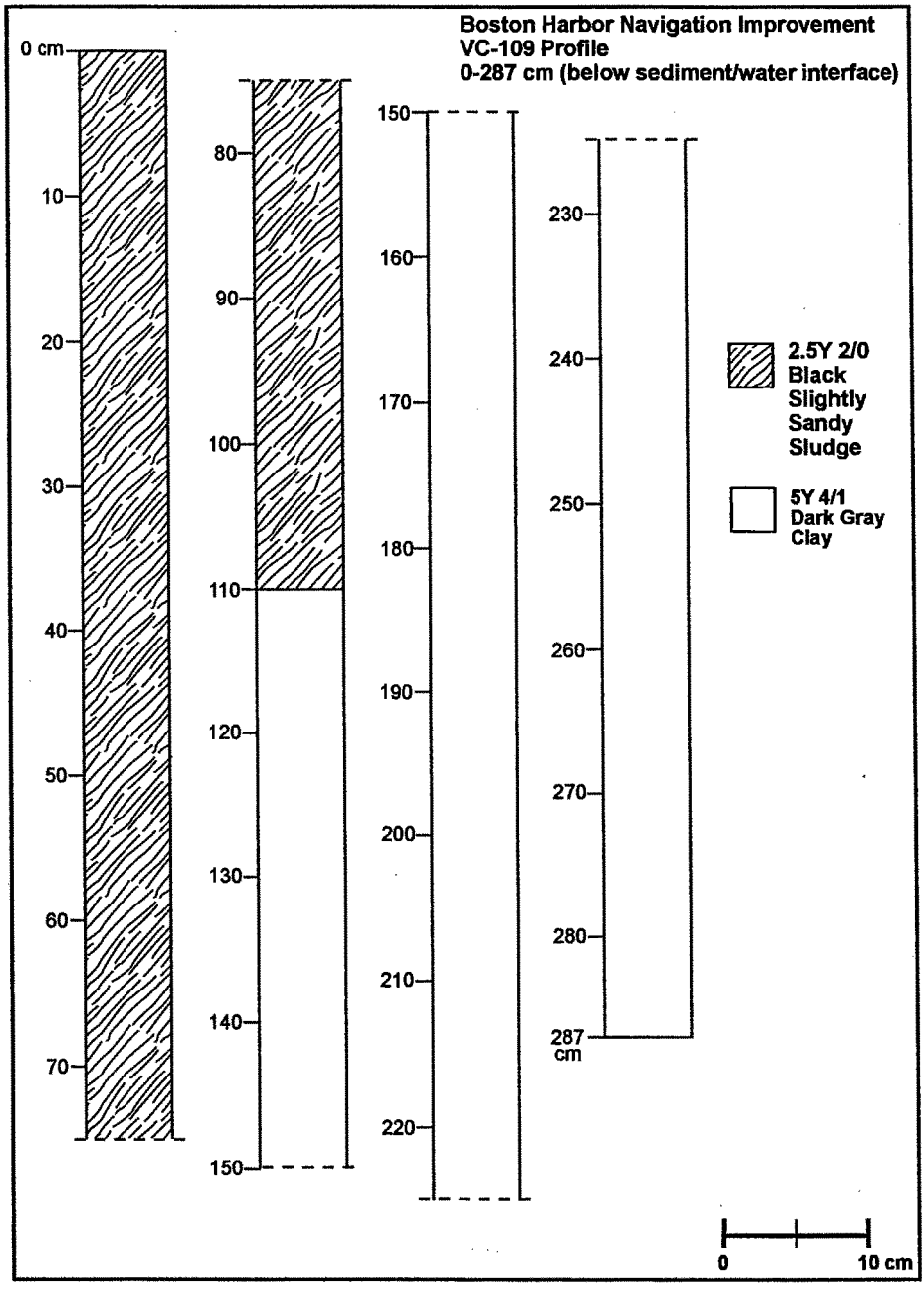


Figure 22. Profile of Vibratory Core VC-109 taken in the Mystic River.

BOSTON HARBOR

AUGUST 2003 AND APRIL 2004 SAMPLING PROGRAMS

August 2003 Sampling Program

The second field sampling effort was conducted from August 18 through September 3, 2003 by Woods Hole Group Environmental Laboratories and CR Environmental. This effort included collection of sediment and seawater samples to support physical, chemical, and biological testing. Samples were collected from 38 sampling locations (37 harbor locations, including the Mystic River, plus the MBDS Reference Site). The stations sampled were stations N through YY plus the disposal site reference. Fourteen of the 51 stations originally sampled in 2002 were not included in the biological sampling and testing since the sediments from those locations (Stations A-M and DD) were determined to be exempt from additional testing under the Ocean Dumping Act (40 CFR 227.13(b)) based on the 2002 results. The Broad Sound North Entrance Channel materials were thus excluded from further testing for both the maintenance or improvement dredging projects.

Sediment samples were collected from the improvement dredging horizon via a pneumatic vibracoring device, box corer, or Ted Young Grab sampler, depending on the water depth at the sampling site. Where maintenance materials were encountered, cores were used to reach the underlying improvement materials. Samples collected with the pneumatic vibracoring device were taken to the proposed depth of penetration or core refusal, with a maximum penetration of 10 feet. The Ted Young grab sampler collected surface samples with a maximum depth of six inches. The box corer achieved a maximum depth of 18 inches.

Unfortunately due to an error in the sampling plan, all 2003 collected materials were composited for testing. This homogenized both the maintenance shoal material, largely silts, with the underlying parent improvement materials, largely sands and clays. This rendered the improvement results unusable for purposes of sediment classification or analysis of results. After consultation with US EPA and other agencies, the results were discarded, and a new sampling plan devised that would separate the maintenance and improvement materials. None of the 2003 program results are pertinent to this project.

April 2004 Sampling Program

In March and April 2004 a third sampling and testing program was undertaken for the maintenance and improvement projects. Selected areas were identified by US EPA and the Corps for re-sampling based on the results obtained in the prior two sediment characterization programs. Areas where a determination as to suitability for ocean disposal could not be made from the existing data were re-sampled, with the core samples split to segregate maintenance shoal material and parent improvement materials.

Sampling was conducted by GEI Consultants, Inc., and TG&B Marine Services between 30 March and 8 April in the lower harbor, and on 17 April at the MBDS reference area. Stations sampled were W, X, Y, Z, LL, MM and NN. At each site at least one sample was taken to the target improvement elevation for physical characterization of the parent improvement material. GEI's field sampling data is shown in the following table.

Physical testing of the sediment samples was accomplished by Applied marine Sciences, Inc., under contract to Battelle. The grain size curves and TOC data are shown following the log table.

Table 1 - Field Sediment Sampling Data
Field Sampling in Support of Environmental Assessment
Navigation Improvement - Feability Study Boston Harbor
Boston, Massachusetts
July 2004

Location ID	Proposed Location		As-Sampled Location		Date	Time	Initial Water Level Elevation[2]	Mud Line		Bottom of Recon Vibracore		Sample IDs[4]	Comments[5]
	Northing (feet)[1]	Easting (feet)[1]	Northing (feet)[1]	Easting (feet)[1]				Depth[3] (feet)	Elevation[2] (feet)	Penetration (feet)	Elevation[2] (feet)		
W	486,547.2	735,143.6	486,516.5	735,184.7	04/07/04	0830	0.0	38.7	-38.7	13.0	-51.7	B-RC04-W, VC04-W-1-A, VC04-W-1-B, VC04-W-2-A, VC04-W-2-B, VC04-W-3-A, VC04-W-3-B, VC04-W-4-A, VC04-W-4-B, VC04-W-5-A, VC04-W-5-B, VC04-W-6-A, VC04-W-6-B	~ 0-4.6' Maintenance Layer ~ 4.8-13' Improvement Layer
X	486,978.0	734,542.3	487,006.4	734,527.5	04/07/04	1130	8.0	48.8	-40.8	5.0	-45.8	VC04-X-1-A, VC04-X-1-B, VC04-X-2-A, VC04-X-2-B, VC04-X-3-A, VC04-X-3-B, VC04-X-4-A, VC04-X-4-B, VC04-X-5-A, VC04-X-5-B, B-VC04-X-6-A	0-5' Maintenance Layer Refusal @ 5'
Y	487,228.8	734,143.7	487,228.9	734,145.4	03/30/04	0911	4.9	46.4	-41.5	10.0	-51.5	B-RC04-Y, B-VC04-Y-A, B-VC04-Y-B, B-VC04-Y-C, B-VC04-Y-D, B-VC04-Y-E, B-VC04-Y-F	~ 0-5.5' Maintenance Layer ~ 5.5-10' Improvement Layer
Z	487,640.8	733,774.8	487,637.4	733,787.0	04/07/04	1600	7.0	49.9	-42.9	7.0	-49.9	VC04-Z-1-A, VC04-Z-1-B, VC04-Z-2-A, VC04-Z-2-B, VC04-Z-3-A, VC04-Z-3-B, VC04-Z-4-A, VC04-Z-4-B, VC04-Z-5-A, VC04-Z-5-B, VC04-Z-6-A, VC04-Z-6-B	0-7' Maintenance Layer Refusal @ 7'
LL	490,705.7	729,803.7	490,686.7	729,798.0	03/31/04	0900	7.2	46.9	-39.7	12.0	-51.7	B-RC04-LL, B-VC04-LL-A, B-VC04-LL-B, B-VC04-LL-C, B-VC04-LL-D, B-VC04-LL-E, B-VC04-LL-F	~ 0-7.8' Maintenance Layer ~ 7.8-12' Improvement Layer
~~MM~~ MM-80	491,267.9	729,703.8	491,249.9	729,715.6	03/31/04	1630	4.6	44.6	-40.0	4.5	-44.5	VC04-MM-1-A, VC04-MM-1-B, VC04-MM-2-A, VC04-MM-2-B, VC04-MM-3-A, VC04-MM-3-B, VC04-MM-4-A, VC04-MM-4-B, VC04-MM-5-A, VC04-MM-5-B	~ 0-4.5' Maintenance Layer Refusal @ 4.5'
NN	492,461.7	727,727.6	492,505.3	727,750.0	04/08/04	0900	-0.3	42.5	-42.8	10.0	-52.8	B-RC04-NN, B-VC04-NN-1, VC04-NN-2-A, VC04-NN-2-B, VC04-NN-3-A, VC04-NN-3-B, VC04-NN-4-A, VC04-NN-4-B, VC04-NN-5-A, VC04-NN-5-B, VC04-NN-6-A, VC04-NN-6-B, VC04-NN-7-A, VC04-NN-7-B	~ 0-1.4' Maintenance Layer ~ 1.4-10' Improvement Layer
MBDS Reference Location	42°22.7' N	70°30.3' W	42°22.79' N	70°30.30' W	04/17/04	0915						B-MBDS04-A, B-MBDS04-B, B-MBDS04-C, B-MBDS04-D, B-MBDS04-E, B-MBDS04-F, B-MBDS04-G, B-MBDS04-H	Grab Sample

Notes:
(1) Coordinates are given in U.S. State Plane, Massachusetts Mainland 2001, NAD 1927, U.S. Survey foot, except MBDS Reference Location which is reported in Latitude and Longitude, World Geodetic System 1984.
(2) Elevations are in feet referenced to Mean Lower Low Water (MLLW) referenced from the Boston Harbor U.S. Coast Guard Station.
(3) Depth soundings made with a survey fathometer.
(4) Sample designations given to bucket and tube samples.
(5) Comments pertain to observations from recon cores.

Table 1. Summary of Sediment Composite Samples Analyzed for Physical and Chemical Parameters (a).

Composite ID	Description	Laboratory ID					
		Atterburg Limits	Grain Size	TOC	PCB/ Pesticide	PAH	Metals
Composite Y	Improvement	19504	19504	19504 (a)			
Composite LL	Improvement	19505	19505	19505 (a)			
Composite W	Improvement	19506	19506	19506 (a)			
Composite NN	Improvement	19507	19507	19507 (a)			
Composite Y	Maintenance		19508	19508	S1645	S1645	2191-2
Composite LL	Maintenance		19509	19509	S1640	S1640	2191-3
Composite MM	Maintenance		19510	19510	S1641	S1641	2191-4
Composite Z	Maintenance		19511	19511	S1646	S1646	2191-5
Composite X	Maintenance		19512	19512	S1644	S1644	2191-6
Composite W	Maintenance		19513	19513	S1643	S1643	2191-7
Composite NN	Maintenance		19514	19514	S1642	S1642	2191-8
MBDS	Reference		19563	19563	S1861	S1861	2191-9
EB-1	Metals Field Blank						2191-1
EB-2	Organics Field Blank				S1534	S1534	

(a) Analysis not required, but samples inadvertently analyzed for TOC.
Not required.

Table 5. Grain Size and TOC Summary Data (%).

Composite ID	Description	Gravel	Coarse Sand	Medium Sand	Fine Sand	Silt	Clay	TOC (a)
Composite Y	Improvement	0.00	0.03	0.03	0.21	38.30	61.43	0.11
Composite LL	Improvement	0.00	0.12	0.01	0.05	35.99	63.84	0.12
Composite W	Improvement	0.00	0.00	0.17	0.14	23.27	76.42	0.13
Composite NN	Improvement	0.00	0.09	0.05	0.23	26.60	73.03	0.11
Composite Y	Maintenance	0.00	0.16	0.24	11.81	41.37	46.42	3.20
Composite LL	Maintenance	0.00	0.00	0.36	13.11	39.40	47.13	2.69
Composite MM	Maintenance	0.00	0.05	0.36	7.34	33.51	58.75	2.41
Composite Z	Maintenance	0.07	0.60	0.67	7.67	37.01	53.98	2.77
Composite X	Maintenance	0.00	0.13	0.11	12.22	41.30	46.23	3.37
Composite W	Maintenance	0.00	0.00	0.13	11.13	41.71	47.03	3.31
Composite NN	Maintenance	0.69	0.50	1.76	8.59	32.31	56.15	2.19
MBDS	Reference	0.00	0.00	0.07	1.04	46.99	51.90	2.42

(a) Each sample analyzed in duplicate; results from replicate one reported.

VIBRACORE LOCATION:	Boston Harbor W	DRILL DATE(S):	4/7/04 - 4/7/04
COORDINATES:	N 486,516.5 ft , E 735,184.7ft NAD83	DRILLED BY:	TG&B / Mark Avakian
WATER DEPTH:	38.7 ft at 0830 hrs	LOGGED BY:	B. Sawa
MUD LINE ELEVATION (MLLW):	-38.7 ft	NUMBER OF PENETRATIONS:	1

VIBRACORE LOG — PAGE 1 of 1 — RC04-W

PEN. OF TUBE FT.	SAMPLE TYPE & NO.	SAMPLE PEN FT.	SAMPLE REC FT.	REMARKS	GRAPHIC LOG	SOIL AND ROCK DESCRIPTIONS
0					Maintenance Layer	(0-4.8'): **ORGANIC SOIL (OL)**; Organic Silt; homogeneous; organic odor; roots fibers; black.
2.5						
5					Improvement Layer	(4.8-12.5') **LEAN CLAY (CL)**; Homogeneous; medium plasticity; gray.
7.5	P1	13	12.5	Only Improvement Layer collected		
10				[B-RC04-W]		
12.5						Bottom of Vibracore, 13.0 ft (EL -51.7ft MLLW).
15						
17.5						
20						
22.5						
25						
27.5						
30						

N/A -- NOT APPLICABLE
PEN -- PENETRATION LENGTH OF VIBRACORE TUBE
REC -- RECOVERY LENGTH OF VIBRACORE TUBE

NOTES:
VIBRACORE ID =2 5/8"
"[ ]"--INDICATES SAMPLE IDENTIFICATION

Boston Harbor Sediment Sampling
Project 03176-2

GEI Consultants, Inc.

VIBRACORE LOCATION:	Boston Harbor X	DRILL DATE(S):	4/7/04 - 4/7/04
COORDINATES:	N 487,006.4 , E 734,527.5 NAD83	DRILLED BY:	TG&B / Mark Avakian
WATER DEPTH:	48.8 ft at 1130 hrs	LOGGED BY:	B. Sawa
MUD LINE ELEVATION (MLLW):	-40.8 ft	NUMBER OF PENETRATIONS:	1

VIBRACORE LOG | PAGE 1 of 1 | RC04-X

PEN. OF TUBE FT.	SAMPLE TYPE & NO.	SAMPLE PEN FT.	SAMPLE REC FT.	REMARKS	GRAPHIC LOG	SOIL AND ROCK DESCRIPTIONS
0	P1	5	4.5	No Improvement Layer collected Refusal at 5.0 ft	Maintenance Layer	(0-4.0'): **ORGANIC SOIL (OL)**; Organic Silt; homogeneous; organic odor; root fibers; black. (4.0-4.5'): **LEAN CLAY (CL)**; Angular gravel up to 1", grayish-black. Bottom of Vibracore, 5ft (EL -45.8 ft MLLW).
2.5						
5						
7.5						
10						
12.5						
15						
17.5						
20						
22.5						
25						
27.5						
30						

N/A -- NOT APPLICABLE
PEN -- PENETRATION LENGTH OF VIBRACORE TUBE
REC -- RECOVERY LENGTH OF VIBRACORE TUBE

NOTES:
VIBRACORE ID =2 5/8"
"[ ]"--INDICATES SAMPLE IDENTIFICATION

Boston Harbor Sediment Sampling
Project 03176-2

GEI Consultants, Inc.

VIBRACORE LOCATION:	Boston Harbor Y	DRILL DATE(S):	3/30/04 - 3/30/04	VIBRACORE LOG	
COORDINATES:	N 487,228.9 , E 734,145.4 NAD 83	DRILLED BY:	TG&B / Mark Avakian		
WATER DEPTH:	46.4 ft at 0911hrs	LOGGED BY:	B. Sawa	PAGE 1 of 1	RC04-Y
MUD LINE ELEVATION (MLLW):	-41.5 ft	NUMBER OF PENETRATIONS:	1		

PEN. OF TUBE FT.	SAMPLE TYPE & NO.	SAMPLE PEN FT.	SAMPLE REC FT.	REMARKS	GRAPHIC LOG	SOIL AND ROCK DESCRIPTIONS
0				Only Improvement Layer collected	Maintenance Layer	(0-0.5'): **ORGANIC SOIL (OL)**; Organic Silt; homogeneous; organic odor; < 5% sand; black.
2.5				[B-RC04-Y]		
5	P1	10	5	-5.5'	Improvement Layer	(0.5-5.0') **LEAN CLAY (CL)**; Homogeneous; low plasticity; gray.
7.5						
10						Bottom of Vibracore, 10.0 ft (EL -51.5 ft MLLW).
12.5						
15						
17.5						
20						
22.5						
25						
27.5						
30						

N/A -- NOT APPLICABLE
PEN -- PENETRATION LENGTH OF VIBRACORE TUBE
REC -- RECOVERY LENGTH OF VIBRACORE

NOTES:
VIBRACORE ID = 2 5/8"
"[]"--INDICATES SAMPLE IDENTIFICATION

Boston Harbor Sediment Sampling
Project 03176-2

GEI Consultants, Inc.

VIBRACORE LOCATION:	Boston Harbor Z	DRILL DATE(S):	4/7/04 - 4/7/04	VIBRACORE LOG	
COORDINATES:	N 487,637.4 ft , E 733,787.0 ft NAD83	DRILLED BY:	TG&B / Mark Avakian		
WATER DEPTH:	49.9 ft at 1600 hrs	LOGGED BY:	B. Sawa	PAGE 1 of 1	RC04-Z
MUD LINE ELEVATION (MLLW):	-42.9 ft	NUMBER OF PENETRATIONS:	1		

PEN. OF TUBE FT.	SAMPLE TYPE & NO.	SAMPLE PEN FT.	SAMPLE REC FT.	REMARKS	GRAPHIC LOG	SOIL AND ROCK DESCRIPTIONS
0	P1	7	6.5	No Improvement Layer collected Refusal at 7.0 ft	Maintenance Layer	(0-6.5'): **ORGANIC SOIL (OL)**; Organic Silt; homogeneous; organic odor; gravel up to 1"; black. Bottom of Vibracore 7.0ft (EL -49.9ft MLLW).
2.5						
5						
7.5						
10						
12.5						
15						
17.5						
20						
22.5						
25						
27.5						
30						

N/A -- NOT APPLICABLE
PEN -- PENETRATION LENGTH OF VIBRACORE TUBE
REC -- RECOVERY LENGTH OF VIBRACORE TUBE

NOTES:
VIBRACORE ID =2 5/8"
"[ ]"--INDICATES SAMPLE IDENTIFICATION

Boston Harbor Sediment Sampling
Project 03176-2

GEI Consultants, Inc.

VIBRACORE LOCATION:	Boston Harbor LL	DRILL DATE(S):	3/31/04 - 3/31/04
COORDINATES:	N 490,686.7 ft , E 729,798.0 ft NAD 83	DRILLED BY:	TG&B / Mark Avakian
WATER DEPTH:	46.9 ft at 0900 hrs	LOGGED BY:	B. Sawa
MUD LINE ELEVATION (MLLW):	-39.7 ft	NUMBER OF PENETRATIONS:	1

VIBRACORE LOG — PAGE 1 of 1 — RC04-LL

PEN. OF TUBE FT.	SAMPLE TYPE & NO.	SAMPLE PEN FT.	SAMPLE REC FT.	REMARKS	GRAPHIC LOG	SOIL AND ROCK DESCRIPTIONS
0	P1	12	10.3	[B-RC04-LL] Only Improvement Layer collected	Maintenance Layer	(0-7.8'): **ORGANIC SOIL (OL)**; Organic Silt; homogeneous; organic odor; molluscs; black.
7.5					Improvement Layer	(7.8-10.3') **LEAN CLAY (CL)**; Homogeneous; medium plasticity; gray.
						Bottom of Vibracore, 12.0 ft (EL -51.7ft MLLW).

N/A -- NOT APPLICABLE
PEN -- PENETRATION LENGTH OF VIBRACORE TUBE
REC -- RECOVERY LENGTH OF VIBRACORE TUBE

NOTES:
VIBRACORE ID = 2 5/8"
"[ ]"--INDICATES SAMPLE IDENTIFICATION

Boston Harbor Sediment Sampling
Project 03176-2

GEI Consultants, Inc.

VIBRACORE LOCATION:	Boston Harbor MM	DRILL DATE(S):	3/31/04 - 3/31/04	VIBRACORE LOG	
COORDINATES:	N 491,249.9 ft , E 729,715.6 ft NAD83	DRILLED BY:	TG&B / Mark Avakian		
WATER DEPTH:	44.6 ft at 1630 hrs	LOGGED BY:	B. Sawa	PAGE 1 of 1	RC04-MM
MUD LINE ELEVATION (MLLW):	-40.0 ft	NUMBER OF PENETRATIONS:	1		

PEN. OF TUBE FT.	SAMPLE TYPE & NO.	SAMPLE PEN FT.	SAMPLE REC FT.	REMARKS	GRAPHIC LOG	SOIL AND ROCK DESCRIPTIONS
0	P1	4.5	4.5	No Improvement Layer collected Refusal at 4.5 ft	Maintenance Layer	(0-4.5'): **ORGANIC SOIL (OL)**: Organic Silt; homogeneous; organic odor; large gravel up to 1 inch; black.
2.5						Bottom of Vibracore, 4.5 ft (EL -45.5 ft MLLW).
5						
7.5						
10						
12.5						
15						
17.5						
20						
22.5						
25						
27.5						
30						

N/A -- NOT APPLICABLE
PEN -- PENETRATION LENGTH OF VIBRACORE TUBE
REC -- RECOVERY LENGTH OF VIBRACORE TUBE

NOTES:
VIBRACORE ID = 2 5/8"
"[ ]"--INDICATES SAMPLE IDENTIFICATION

Boston Harbor Sediment Sampling
Project 03176-2

GEI Consultants, Inc.

VIBRACORE LOCATION:	Boston Harbor NN	DRILL DATE(S):	4/8/04 - 4/8/04
COORDINATES:	N 492,505.3 ft, E 727,750.0 ft NAD83	DRILLED BY:	TG&B / Mark Avakian
WATER DEPTH:	42.5 ft at 0900 hrs	LOGGED BY:	B. Sawa
MUD LINE ELEVATION (MLLW):	-42.8 ft	NUMBER OF PENETRATIONS:	1

VIBRACORE LOG — PAGE 1 of 1 — RC04-NN

PEN. OF TUBE FT.	SAMPLE TYPE & NO.	SAMPLE PEN FT.	SAMPLE REC FT.	REMARKS	GRAPHIC LOG	SOIL AND ROCK DESCRIPTIONS
0					M. Layer	(0-1.4'): **ORGANIC SOIL (OL)**; Organic Silt; homogeneous; organic odor; molluscs; black.
				~1.4'		
2.5						(0.4-0.8'): **LEAN CLAY (CL)**; Homogeneous; low plasticity; olive-gray.
5	P1	10	6.7	Only Improvement Layer collected [B-RC04-NN]	Improvement Layer	(0.8-1.4'): **ORGANIC SOIL (OL)**; Organic Silt; homogeneous; organic odor; molluscs; roots; worm; black.
7.5						(1.4-6.7'): **LEAN CLAY (CL)**; Homogeneous; stiff; medium plasticity; greenish-gray.
10						Bottom of Vibracore, 10.0 ft (EL -52.8 ft MLLW).
12.5						
15						
17.5						
20						
22.5						
25						
27.5						
30						

N/A – NOT APPLICABLE
PEN – PENETRATION LENGTH OF VIBRACORE TUBE
REC – RECOVERY LENGTH OF VIBRACORE TUBE

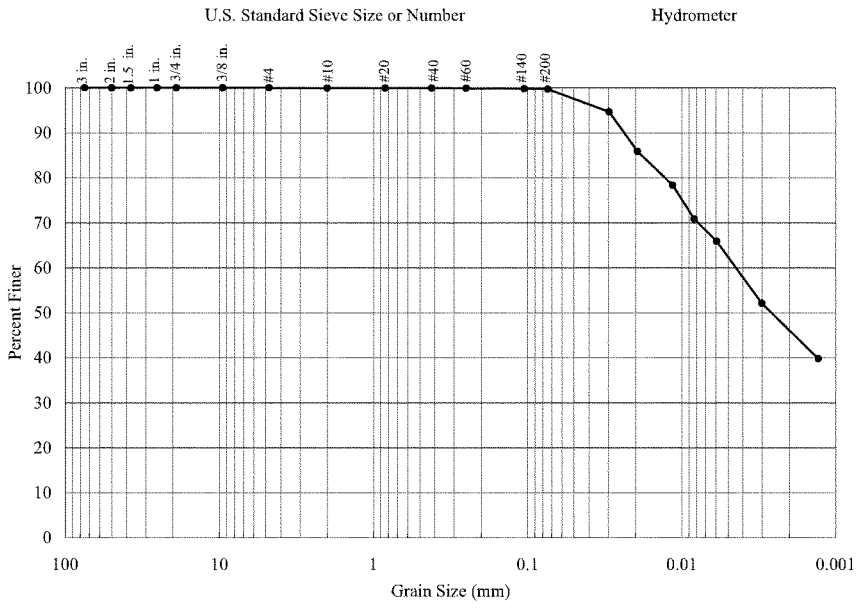
NOTES:
VIBRACORE ID =2 5/8"
"[ ]"--INDICATES SAMPLE IDENTIFICATION

Boston Harbor Sediment Sampling
Project 03176-2

GEI Consultants, Inc.

Applied Marine Sciences, Inc.

502 N. Hwy 3, Suite B, League City, TX 77573, (281) 554-7272 Fax (281) 554-6356



ASTM D422 (Particle-Size Analysis of Soils)

% Cobble	% Gravel	% Sand			% Fines	
		Coarse	Medium	Fine	Silt	Clay
>3"	<3" - #4	#10	#20-#40	#60-#200	0.074-0.005 mm	<0.005 mm
0.00	0.00	0.03	0.03	0.21	38.30	61.43

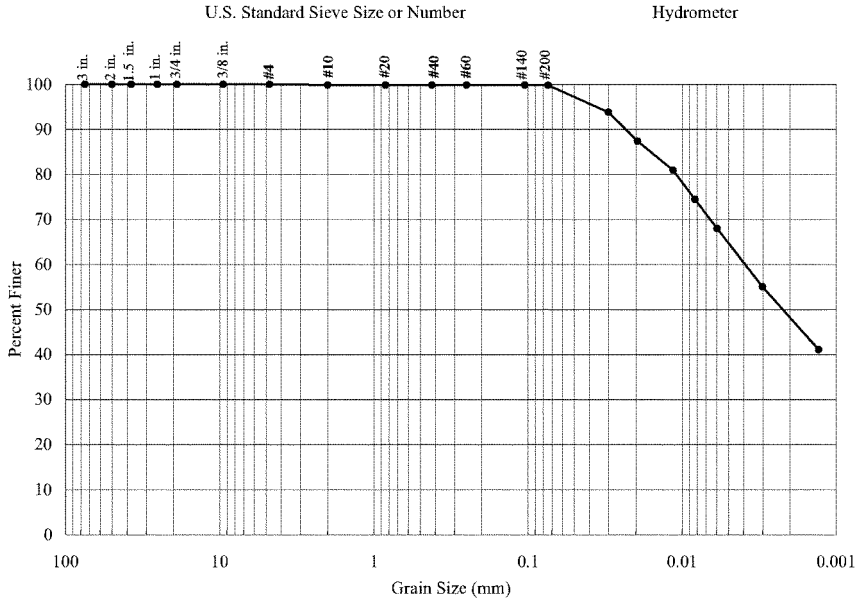
Water Cont. (%)	Tot. Solids (%)	LL	PL	D_{85}	D_{60}	D_{50}	D_{30}	D_{15}	D_{10}	C_c	C_u

Material Description	USCS
Fat Clay, Greenish Gray (5Y 6/1)	CH

Project Description	
Boston Harbor	Client P/N: G606405
	AMS P/N: 2004-03-18
	Client ID: Recon-Y-D
	AMS ID: 19504
AMS, Inc. Project Manager:	Date Analyzed: 4/20/2004

Applied Marine Sciences, Inc.

502 N. Hwy 3, Suite B, League City, TX 77573, (281) 554-7272 Fax (281) 554-6356



ASTM D422 (Particle-Size Analysis of Soils)

% Cobble	% Gravel	% Sand			% Fines	
		Coarse	Medium	Fine	Silt	Clay
>3"	<3" - #4	#10	#20-#40	#60-#200	0.074-0.005 mm	<0.005 mm
0.00	0.00	0.12	0.01	0.05	35.99	63.84

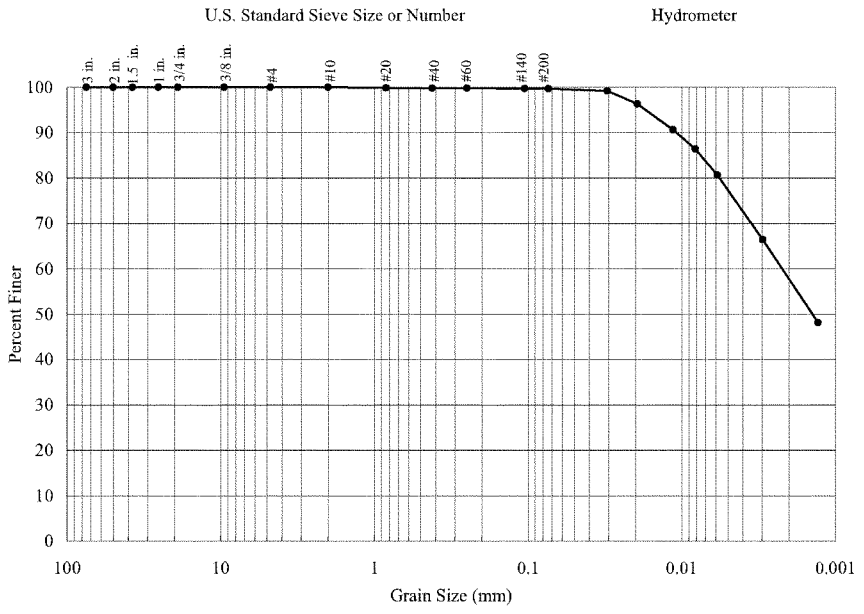
Water Cont. (%)	Tot. Solids (%)	LL	PL	D_{85}	D_{60}	D_{50}	D_{30}	D_{15}	D_{10}	C_c	C_u

Material Description	USCS
Fat Clay, Greenish Gray (5Y 6/1)	CH

Project Description	
Boston Harbor	Client P/N: G606405
	AMS P/N: 2004-03-18
	Client ID: Recon-LL-D
	AMS ID: 19505
AMS, Inc. Project Manager:	Date Analyzed: 4/20/2004

Applied Marine Sciences, Inc.

502 N. Hwy 3, Suite B, League City, TX 77573, (281) 554-7272 Fax (281) 554-6356



ASTM D422 (Particle-Size Analysis of Soils)

% Cobble	% Gravel	% Sand			% Fines	
		Coarse	Medium	Fine	Silt	Clay
>3"	<3" - #4	#10	#20-#40	#60-#200	0.074-0.005 mm	<0.005 mm
0.00	0.00	0.00	0.17	0.14	23.27	76.42

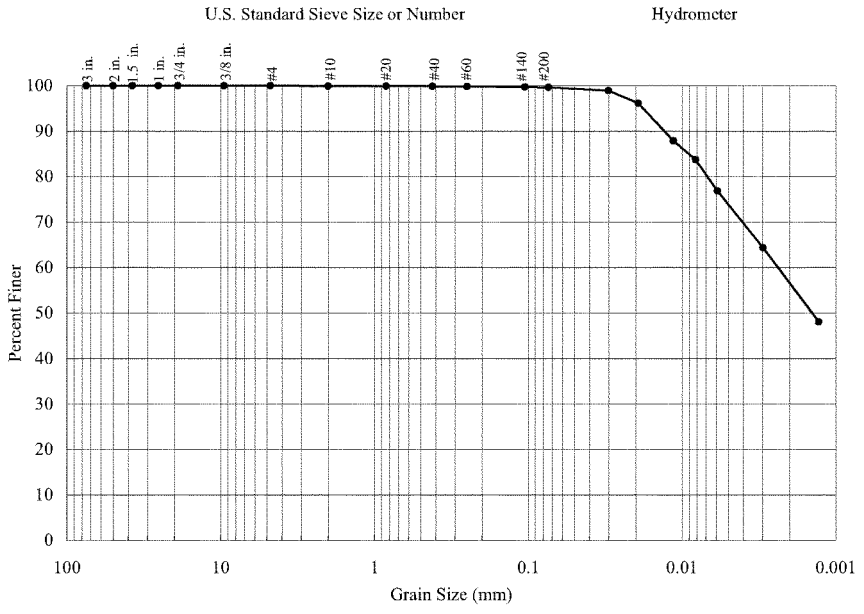
Water Cont. (%)	Tot. Solids (%)	LL	PL	D_{85}	D_{60}	D_{50}	D_{30}	D_{15}	D_{10}	C_c	C_u

Material Description	USCS
Fat Clay, Greenish Gray (5Y 6/1)	CH

Project Description	
Boston Harbor	Client P/N: G606405
	AMS P/N: 2004-03-18
	Client ID: Recon-W-D
	AMS ID: 19506
AMS, Inc. Project Manager:	Date Analyzed: 4/20/2004

Applied Marine Sciences, Inc.

502 N. Hwy 3, Suite B, League City, TX 77573, (281) 554-7272 Fax (281) 554-6356



ASTM D422 (Particle-Size Analysis of Soils)

% Cobble	% Gravel	% Sand			% Fines	
		Coarse	Medium	Fine	Silt	Clay
>3"	<3" - #4	#10	#20-#40	#60-#200	0.074-0.005 mm	<0.005 mm
0.00	0.00	0.09	0.05	0.23	26.60	73.03

Water Cont. (%)	Tot. Solids (%)	LL	PL	D_{85}	D_{60}	D_{50}	D_{30}	D_{15}	D_{10}	C_c	C_u

Material Description	USCS
Fat Clay, Greenish Gray (5Y 6/1)	CH

Project Description	
Boston Harbor	Client P/N: G606405
	AMS P/N: 2004-03-18
	Client ID: Recon-NN-D
	AMS ID: 19507
AMS, Inc. Project Manager:	Date Analyzed: 4/20/2004

BOSTON HARBOR
MASSACHUSETTS

DEEP DRAFT
NAVIGATION IMPROVEMENT STUDY

FINAL FEASIBILITY REPORT
AND FINAL SUPPLEMENTAL
ENVIRONMENTAL IMPACT STATEMENT
AND MASSACHUSETTS
FINAL ENVIRONMENTAL IMPACT REPORT

APPENDIX L

SUITABILITY DETERMINATION
FOR DREDGED MATERIAL DISPOSAL

(THIS APPENDIX UNCHANGED FROM 2008 DRAFT)

APPENDIX L
SUITABILITY DETERMINATION
FOR DREDGED MATERIAL DISPOSAL
BOSTON HARBOR NAVIGATION IMPROVEMENT STUDY

The following Suitability Determination and US EPA Region I concurrence, both dated 8 December 2006 cover disposal of dredged material from the Federal Navigation Improvement Project for Boston Harbor at the Massachusetts Bay Disposal Site. The Massachusetts Bay Disposal Site (MBDS) is located beyond the territorial sea (3 mile limit) in waters regulated by the US EPA under the provisions of the Marine Protection Research and Sanctuaries Act of 1972, as amended (MPRSA).

The project covered by this suitability determination includes the deepening of the main project features connecting the Conley Terminal to the sea; the Broad Sound North Entrance Channel, President Roads Anchorage, Main Ship Channel from the Roads to the Reserved Channel, the Reserved Channel Turning Area, and the lower Reserved Channel, all to depths of up to 50 feet MLLW, including widening of the channel bends and the turning area, with an additional two feet in the entrance channel, and additional required two feet of excavation in rock and hard bottom materials, and two feet of allowable overdepth throughout the project area. The project also includes three additional minor improvements to the Federal Navigation Project: extending the deepening of the Main Ship Channel above the Reserved Channel Turning Area to below the Ted Williams Tunnel to depths of up to 45 feet; deepening a small portion of the 35-foot Mystic River Channel area in the approach to the Medford Street Terminal to up to -40 feet; and deepening the 38-foot Chelsea River Channel and its turning basin to -40 feet, with widening in the bridge approaches and turns and through the new bridge opening at Chelsea Street once that bridge has been replaced.

Disposal of any maintenance material remaining in the channel areas to be deepened under this project would be carried out in accordance with prior NEPA/MEPA documents for that maintenance work and suitability determinations for that work.

Habel, Mark L NAE

Subject: FW: FW: SD for Boston Harbor Deep Draft Improvement (UNCLASSIFIED)

Attachments: 200102368 SD2.doc

200102368
SD2.doc (318 KB)

-----Original Message-----
From: Guza.Olga@epamail.epa.gov [mailto:Guza.Olga@epamail.epa.gov]
Sent: Friday, December 08, 2006 11:53 AM
To: Nimeskern, Phillip W NAE
Cc: Habel, Mark L NAE
Subject: Re: FW: SD for Boston Harbor Deep Draft Improvement (UNCLASSIFIED)

I concur with the SD for Boston Harbor Deep Draft Improvement Project as written. The project has gone through multiple reviews and meets the conditions as written in the SD.

Olga Guza
Environmental Scientist
USEPA Region 1
Boston, MA
Telephone - 617-918-1542
Fax 617-918-0542

-----"Nimeskern, Phillip W NAE" <Phillip.W.Nimeskern@nae02.usace.army.mil> wrote: -----

To: Olga Guza/R1/USEPA/US@EPA
From: "Nimeskern, Phillip W NAE"
<Phillip.W.Nimeskern@nae02.usace.army.mil>
Date: 12/05/2006 05:43PM
cc: "Habel, Mark L NAE" <Mark.L.Habel@nae02.usace.army.mil>
Subject: FW: SD for Boston Harbor Deep Draft Improvement (UNCLASSIFIED)

Classification: UNCLASSIFIED
Caveats: NONE

Hello Olga,

I am forwarding another copy of the draft suitability determination (SD) for the Boston Harbor Deep Draft Improvement project. As you see, it is the same as was sent to you in October. Mark Habel has asked that we have EPA's concurrence in writing before I finalize the SD for this project, even though we can assume concurrance based on our MOA. Would you please refresh your memory on this document and send me a note that you concur?

Thank you,

Phillip W. Nimeskern
US Army, Corps of Engineers
696 Virginia Road
Concord, MA 01742-2751
(978) 318-8660
FAX: (978) 318-8303

-----Original Message-----
From: Nimeskern, Phillip W NAE
Sent: Monday, October 02, 2006 3:53 PM
To: Olga Guza; William_Neidermyer@fws.gov; Peter.colosi@noaa.gov;
Ken Chin(Ken.Chin@State.MA.US)
Subject: SD for Boston Harbor Deep Draft Improvement

INTERAGENCY COORDINATION

DATE: 2 October 2006

PROPONENT: CENAE & Massport

APPLICATION NUMBER: 2001-02386

NOTIFICATION SENT TO:

EPA Olga Guza (617) 918-1505
Guza.Olga@epamail.epa.gov <mailto:Guza.Olga@epamail.epa.gov>

NMFS Peter Colosi (978) 281-9301
Peter.Colosi@noaa.gov <mailto:Peter.Colosi@noaa.gov>

F&WS William Neidermeyer (603) 223-0104
William_Neidermyer@fws.gov <mailto:William_Neidermyer@fws.gov>

cc: Ken Chin (617) 292-5696
Ken.Chin@state.ma.us <mailto:Ken.Chin@state.ma.us>

This draft is being transmitted in accordance with our agreement on interagency technical coordination procedures for projects involving open water disposal of dredged materials. The proponents are proposing to dredge between 5,460,000 and 15,323,000 CY of ordinary material and between 399,000 and 1,495,000 CY of rock from Boston Harbor in Boston, Massachusetts, and dispose of it at the MBDS.

Please respond to me within 10 working days of the above date at(978) 318-8871 if you have comments or concerns. If you have technicalquestions, you can contact Phillip Nimeskern at (978) 318-8660.

__Phill Nimeskern for_____
MARK HABEL
Project Manager

Classification: UNCLASSIFIED
Caveats: NONE

CENAE-R-PT 8 December 2006

MEMORANDUM THRU:

Ruth M. Ladd, Chief, Policy Analysis and Technical Support Branch

FOR: Mark Habel, Project Manager, CENAE-EP-PN

SUBJECT: Suitability Determination for Boston Harbor Deep Draft Improvement, Boston, Massachusetts, Application Number 200102386.

1. **Project Description:**

The **CENAE** is proposing to deepen portions of the Boston Harbor Federal Navigation Project. The proposed disposal site is Massachusetts Bay Disposal Site (**MBDS**). This work will be done according to a base plan, Plan B, and three additional incremental improvements, Plans C, D and E. The base plan, the incremental plans, and their estimated volumes of dredged materials are as follows:

Plan B - Outer and Lower Harbor Improvements: The CENAE is proposing to deepen the follow project components:

Broad Sound North Entrance Channel;
President Roads Anchorage;
Main Ship Channel, through President Roads and up to the Reserved Channel in South Boston;
the Reserved Channel Turning Area; and
the lower (currently 40-foot) reach of the Reserved Channel.

These would all be deepened to provide a channel depth of between -44 and -50 feet MLLW, with an additional two feet of depth in the entrance channel (-46 to -52 feet MLLW), and a further two feet (-48 to -54 feet MLLW) provided in areas of rock or hard bottom materials (cobble or glacial till).

In addition, the bend in the entrance channel opposite Finn's Ledge would be widened at its apex by approximately 300 feet, and the deep lane of the Main Ship Channel between President Roads and the Reserved Channel Turning Area would be widened to 800 feet, and up to 900 feet in sections, by incorporating a portion of the existing 35-foot channel lane into the deeper channel. The Reserved Channel Turning Area would also be widened within, and northwest of, the existing channel limits.

Deepening these project areas to between -44 and -46 feet or to between -50 and -52 feet would require removal of between 5,041,000 and 14,755,000

Subject: Suitability Determination for Boston Harbor Deep Draft Improvement, Boston, Massachusetts, Application Number 200102386.

CY of ordinary material and between 355,000 and 1,385,000 CY of rock. The distribution of this material by channel reach is shown below.

Plan B – At 44-46 Foot Depth		
FNP Area	Volume of sediment	Volume of rock
North Entrance Channel (46 Feet)	1,597,000 cy	258,000 cy
Main Ship Channel (44 Feet)		
President Roads Reach	233,000 cy	0 cy
President Roads to Reserved Channel	1,157,000 cy	41,000 cy
Lower Reserved Channel (44 Feet)	371,000 cy	14,000 cy
Reserved Channel Turning Area (44 Feet)	202,000 cy	10,000 cy
Presidential Roads Anchorage (44 Feet)	1,481,000 cy	32,000 cy
Total	5,041,000 cy	355,000 cy

Plan B – At 50-52 Foot Depth		
FNP Area	Volume of sediment	Volume of rock
North Entrance Channel (52 Feet)	3,924,000 cy	883,000 cy
Main Ship Channel (50 Feet)		
President Roads Reach	1,496,000 cy	1,000 cy
President Roads to Reserved Channel	2,947,000 cy	153,000 cy
Lower Reserved Channel (50 Feet)	572,000 cy	123,000 cy
Reserved Channel Turning Area (50 Feet)	906,000 cy	137,000 cy
Presidential Roads Anchorage (50 Feet)	4,910,000 cy	88,000 cy
Total	14,755,000 cy	1,385,000 cy

Plan C - Main Ship Channel Deepening Extension:
Extending the deepened portion of the Main Ship Channel above the Reserved Channel Turning Area to a point below the Ted Williams Tunnel (I-90) is also being examined, with channel depths of between -42 and -45 feet under consideration (with an additional two feet in rock or hard bottom areas). The deepened channel would include the entire width of the existing 40-foot channel lane in this area plus a 50- to 100-foot width of the existing 35-foot channel lane. Deepening the channel to between -42 and -45 feet MLLW would require the removal of between 119,000 and 268,000 CY of ordinary material and between 39,000 and 105,000 CY of rock.

Plan D - Mystic River Channel Improvements:
A small area of the 35-foot portion of the Mystic River Channel that was not deepened to -40 feet during the improvement project of 1998-2002 is now being considered for deepening to -40 feet MLLW. This improvement would allow deeper draft access to Massport's Medford Street Terminal for proposed bulk cargo operations. The area to be dredged will be an approximately 800' by 450' area in the 35' Channel along the Charlestown shore of the Mystic River. Deepening this small area of the 35-foot channel to -40 feet MLLW would require the removal of about 83,000 CY of ordinary material.

Subject: Suitability Determination for Boston Harbor Deep Draft Improvement, Boston, Massachusetts, Application Number 200102386.

Plan E - Chelsea River Channel Improvements:
The existing 38-foot Chelsea River Channel and Turning Basin would be deepened to -40 feet MLLW if other parties proceed with plans to replace the Chelsea Street Bridge. The channel would be widened to conform to the new bridge opening and would be widened slightly in its turns approaching the bridge. Deepening the channel to -40 feet MLLW would require the removal of about 217,000 CY of ordinary material and 5,000 CY of rock.

Summing up:
These improvements would involve removal of a total of **between 5,460,000 and 15,323,000 CY** of **ordinary material** and **between 399,000 and 1,495,000 CY** of **rock**, depending on the final channel depths supported by economic analysis in the feasibility and design phase investigations. The ordinary material removed under this project is proposed to be mechanically dredged and disposed of at the MBDS. Rock removed under this project is also proposed for disposal at MBDS, unless some suitable beneficial use, for habitat enhancement or other purposes, is identified and approved.

This improvement work will be performed after the proposed maintenance dredging of the existing Boston Harbor Project has been completed and has removed the overlying sediments. The Main Ship Channel above Spectacle Island and the small portion of the Mystic River at the Medford Street Terminal is intended to be accomplished in 2006-2008. In addition, the final improvement dredging of the Chelsea River Channel to -38 feet under the project of 1990, in the vicinity of the Chelsea Street Bridge, is intended to be accomplished at the same time.

A sampling plan was developed on 8 November 2001 for the analysis of physical, chemical and biological characteristics of the sediments proposed to be dredged for the improvement dredging. The federal agencies concurred with this plan. The project has since been modified by increasing the project depth and adding a new area, Chelsea River. Except for this new area, the project area remains the same. The sediment data report was dated September 30, 2006.

2. **Summary:**

This memorandum addresses compliance with the regulatory evaluation and testing requirements of 40 CFR 227.13 for unconfined open water disposal at an open ocean disposal site. This evaluation confirms that sufficient information was obtained to properly evaluate the suitability of this material for open water disposal under the guidelines and finds the sediments suitable for disposal at MBDS.

3. **Ocean Dumping Act Regulatory Requirements:**

The disposal of sediments below mean low water in Massachusetts Bay is

Subject: Suitability Determination for Boston Harbor Deep Draft Improvement, Boston, Massachusetts, Application Number 200102386.

regulated according to both Section 103 of the Ocean Disposal Act and Section 404 of the Clean Water Act.

§227.13 Dredged Materials.

(a) This paragraph defines dredged materials and does not give any criteria for the evaluation of sediments.

(b) This paragraph states that proposed dredged material which meets the criteria in one of the following three paragraphs is environmentally acceptable for ocean disposal without further testing.

(b)(1) Dredged material that is predominately sand, gravel, rock, or any other naturally occurring bottom material with particle size greater than silt and is found in areas of high current or wave energy can be disposed of in a 103 site without further testing. The material from the fourteen samples in the North Channel, Presidents Roads, and Reserved Channel Turning Basin (Samples A through M and Sample DD) had high proportions of gravel and sand. The fines in these samples ranged from 0.59% to 28.48%. The sediments from these areas meet this exclusion and are suitable for unconfined open water disposal at MBDS without further testing.

(b)(2) Dredged material that is proposed for beach nourishment and is predominantly sand, gravel or shell with grain sizes similar to the receiving beaches can be disposed of without further testing. As the material from this project is not proposed for beach disposal, it does not meet this exclusion.

(b)(3) When the dredged material is substantially the same as that at the disposal site and the dredged material is taken from a site far removed from known sources of pollution, it can be disposed of without further testing. This project's material does meet this exclusion. The sediment to be removed is parent material (mostly silts and clays) underlying the contaminated surficial material, which is being removed by the ongoing maintenance dredging. It is far removed from known sources of contamination, having been laid down by glaciers before the Industrial Revolution and insulated from industrial contaminants by soon-to-be-removed surficial material. It is the same type of material as at the disposal site, as the same glaciers laid sediments at both areas.

(c) This paragraph states that if the dredged material does not meet the criteria of paragraph b above, it must undergo further testing of the liquid, suspended particulate and solid phases before it can be considered acceptable for ocean disposal. This section does not apply to this project, as the dredge materials meet the criteria in paragraphs b(1) or b(3) above.

Subject: Suitability Determination for Boston Harbor Deep Draft Improvement, Boston, Massachusetts, Application Number 200102386.

(d) This subsection discusses the choice of the liquid phase analytes and does not give any criteria for the evaluation of sediments.

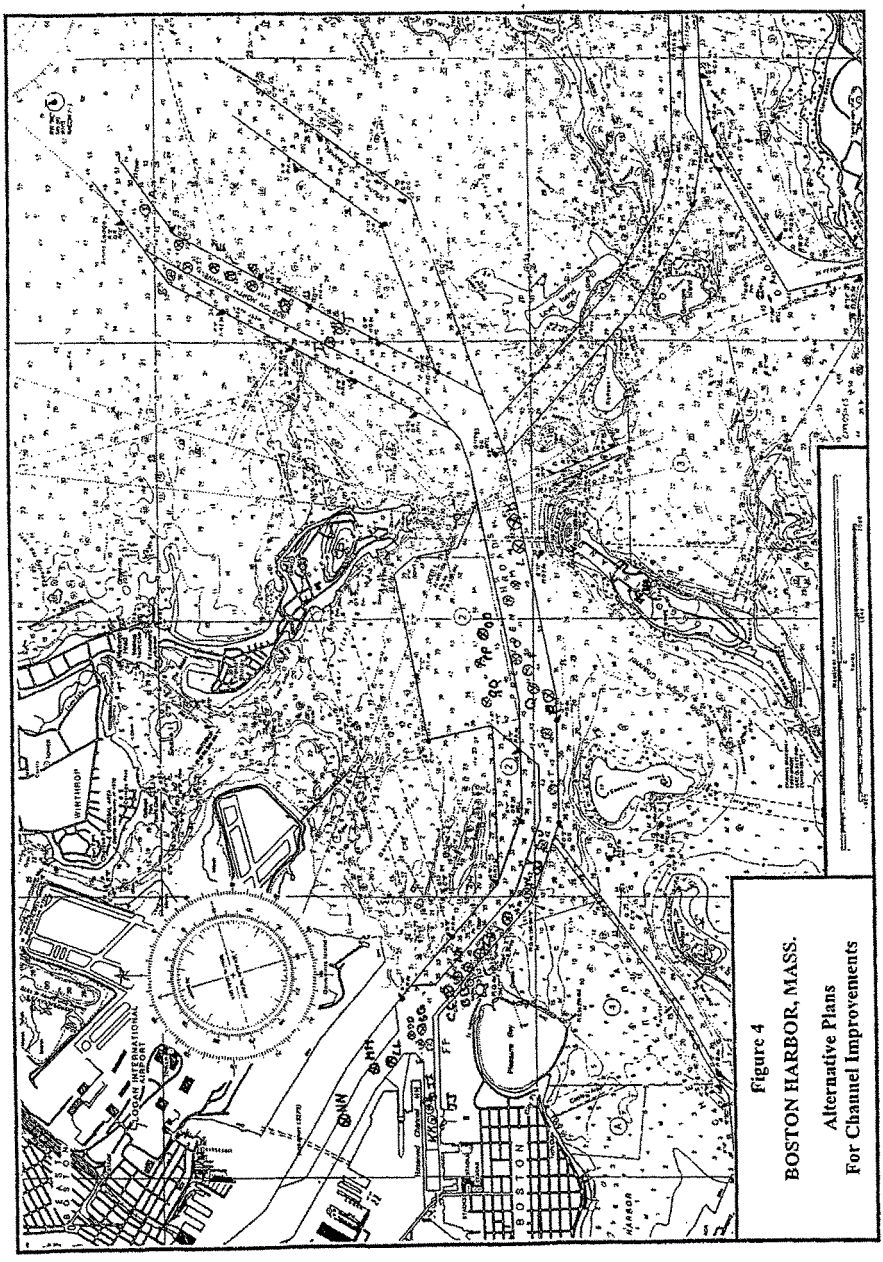
5. Copies of the above mentioned data and of the draft suitability determination were sent to the State DEP, US EPA, US F&WS and US NMFS for their review. The US EPA responded to say that they concur with the determination. No response was received from the other Federal agencies within the 10-day response period.

6. If you have any questions, please contact me at extension 660.

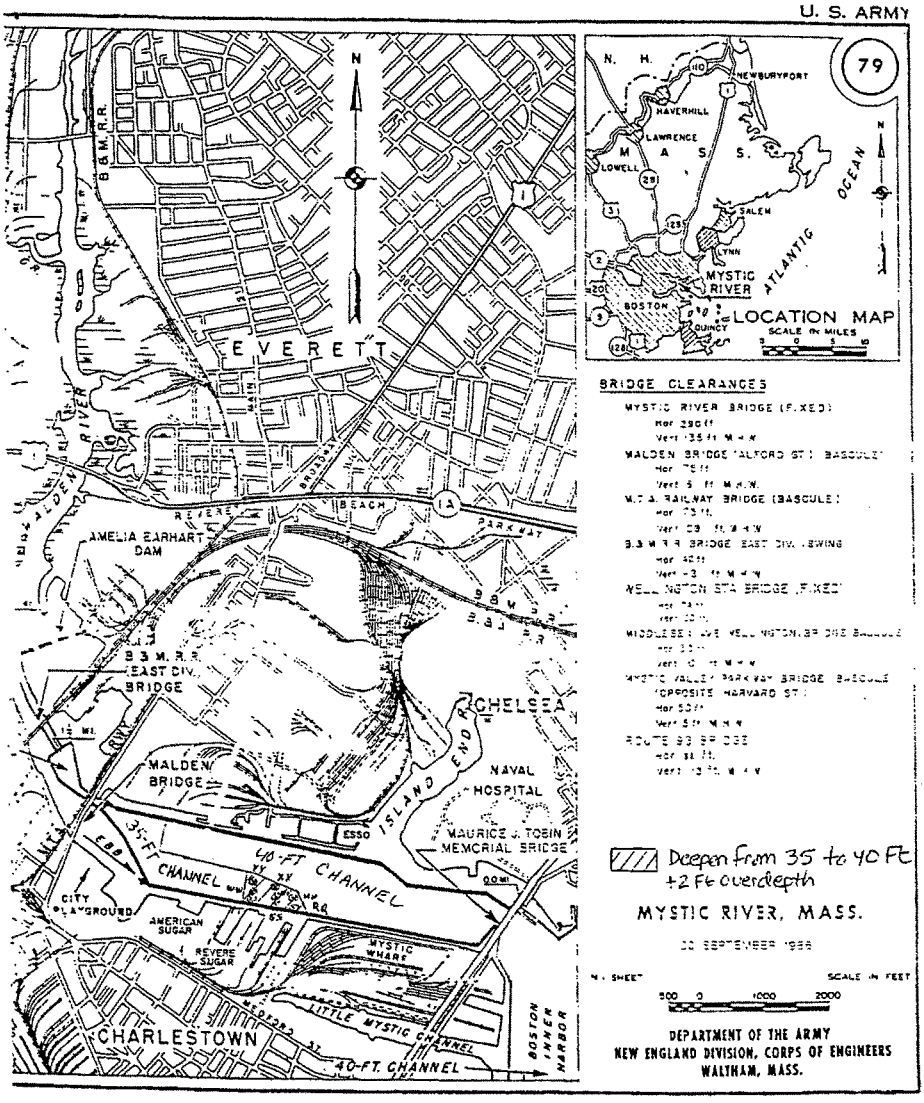
Phillip Nimeskern

PHILLIP NIMESKERN
Project Manager,
Marine Analysis Section

Subject: Suitability Determination for Boston Harbor Deep Draft Improvement, Boston, Massachusetts, Application Number 200102386.



Subject: Suitability Determination for Boston Harbor Deep Draft Improvement, Boston, Massachusetts, Application Number 200102386.



BOSTON HARBOR
MASSACHUSETTS

DEEP DRAFT
NAVIGATION IMPROVEMENT STUDY

FINAL FEASIBILITY REPORT
AND FINAL SUPPLEMENTAL
ENVIRONMENTAL IMPACT STATEMENT
AND MASSACHUSETTS
FINAL ENVIRONMENTAL IMPACT REPORT

APPENDIX M

CULTURAL RESOURCES INVESTIGATIONS
AND COORDINATION

(THIS APPENDIX UNCHANGED FROM AUGUST 2008 DRAFT)

BOSTON HARBOR, MASSACHUSETTS NAVIGATION IMPROVEMENT STUDY

APPENDIX M CULTURAL RESOURCE INVESTIGATIONS AND COORDINATION

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Remote Sensing Archaeological Survey and Geologic Interpretation, Boston Harbor Navigation Improvement Study, May 30, 2003, University of Massachusetts Amherst Archaeological Services (Mulholland, Riess, Donnelly, Donta and Buynevich). Under contract to Battelle.

Archaeological Subsurface Testing for the Boston Harbor Navigation Improvement Study, May 19, 2004, University of Massachusetts Amherst Archaeological Services (Lynch, Mulholland and Donnelly). Under Contract to GEI Consultants, Inc.

Inspection of Magnetic Anomalies, Remote Sensing Archaeological Survey, Boston Harbor Deep Draft Navigation Improvement Study, Public Archaeology Laboratory Inc. (PAL), Pawtucket, RI. (Robinson, David S. and Ben Ford)

BOSTON HARBOR DEEP DRAFT NAVIGATION IMPROVEMENT STUDY
APPENDIX J
CULTURAL RESOURCE INVESTIGATIONS AND COORDINATION

HISTORICAL AND ARCHAEOLOGICAL RESOURCES SETTING

The following narrative is culled from several investigations conducted on behalf of the Corps during planning for the Boston Harbor Deep Draft Navigation Improvement Study Environmental Impact Statement. The subject studies include the following: *Remote Sensing Archaeological Survey and Geologic Interpretation, Boston Harbor Navigation Improvement Study, Boston Harbor, Boston, Massachusetts* prepared by the University of Massachusetts Archaeological Services (UMAS) (Mulholland *et al.*, 2003); *Inspection of Magnetic Anomalies, Remote Sensing Archaeological Survey, Boston Harbor Deep Draft Navigation Improvement Study* prepared by the Public Archaeology Laboratory Inc. (PAL) (Robinson and Ford, 2003); and *Archaeological Subsurface Testing for the Boston Harbor Navigation Improvement Study, Boston Harbor, Boston, Massachusetts* prepared by UMAS (Lynch *et al.*, 2004). More detailed information is available in these references. For purposes of this SEIS, a brief summation of the pre-Contact context and Historic Period Shipwreck background for the project area is included.

Pre-Contact Context

The Mystic, Neponset, and Charles Rivers of southeastern Massachusetts, which feed into the Massachusetts Bay Basin, were focal points for Native American occupation for more than 9,000 years. Dena Dincauze's survey of the archaeological resources in the greater Boston area, conducted in 1967-8, included the Boston Harbor islands and revealed the potential for significant archaeological data from sites within the harbor district. A later investigation of the 12 Harbor Islands by Luedtke resulted in the Boston Harbor Islands being nominated as a National Register Historic District. Luedtke's studies confirmed that the harbor islands contained the best-preserved concentration of Native American archaeological sites in the metropolitan Boston area. Currently, 60 documented sites spanning the Early Archaic to the Late Woodland Periods are distributed among 21 islands within the district (Robinson and Ford, 2003).

The Boston Basin area included two core areas of Native American settlement during the Contact Period: the Neponset core situated in the southern part of Massachusetts Bay and the Mystic core situated in the northern portion of the Bay. The Mystic River area included several smaller adjacent coastal river drainages such as the Malden, Pines, and Saugus Rivers. Larger lakes and ponds including Fresh and Spy Pond near the estuary, and Spot Pond and Crystal Lake in the Middlesex Fells formed part of the inland section of the Mystic core area. Contact era sites in the Boston Basin include isolated burial and cemetery locations. Contact Period burials from the Mystic River area are known from West Medford, Winthrop, Revere Beach, and Nahant (Robinson and Ford, 2003).

Historic Period Shipwreck Context

Many historic period shipwreck sites are known to exist in Boston Harbor, with a large number of probable sites within the study area. State and Federal Government compilations of vessel losses date only from the late 1800s and most of these are incomplete (Mulholland *et al.*, 2003).

In addition to any recorded vessel losses, many more were likely lost in Boston Harbor and simply not recorded. Many lost vessels are simply recorded as missing at sea, whether they had just left the harbor, were returning from a long voyage, or were blown in while trying to sail past the shore. In these cases, their actual fate can only be revealed through the efforts of underwater archaeologists. Such vessels would include small and large fishing boats, coasters, transoceanic merchantmen, and warships (Mulholland *et al.*, 2003).

Because little is known of the early vessels, how they were made and used, and life aboard the early merchant vessels, the remains of any historic ship or boat would be archaeologically and historically significant on a local, regional, and national level. Historic shipwreck sites in New England are sources that provide archaeologists with information about shipping, vessel construction, lifeways of mariners, and also about early terrestrial life in New England (Mulholland *et al.*, 2003).

Major changes took place in shipping during the latter 19th and early 20th Centuries that would affect the number and size of boats and ships lost throughout the United States and especially the Boston Harbor region. During this time, the introduction of important technical and safety innovations allowed seamen to keep their vessels afloat. Engine power, rather than sail and oar, made near shore voyages much safer. First, tugboats, and then internal engines could move a vessel away from danger. Navigation aids along the sides of channels, buoys and beacons, on-shore ranges, and electric navigation lights all assisted small and large vessels navigate through the harbor. Wireless telegraphy and later radio communications helped crews call for assistance and communicate with other vessels. Federal agencies such as the U.S. Life Saving Service and eventually the Coast Guard were established to search for and assist vessels in distress (Mulholland *et al.*, 2003).

All of the potentially significant historic period sites that might be found in the study area would likely be water vessels and their contents. Since Boston Harbor has attracted almost all types of ships, boats, and barges throughout the centuries, the remains of any type of vessel used in the Atlantic during the last four centuries could conceivably be found. There is no complete listing of shipwreck files for the Boston region; however, even incomplete records or compilations suggest a plethora of types, sizes, and cargoes lost in Boston Harbor (Mulholland *et al.*, 2003).

Most recorded shipwrecks are large, transoceanic and coastal ships because until the late 19th Century researchers and the media were primarily interested in larger vessels. Therefore, the potential for other, unknown smaller vessels in a larger, urban harbor is usually high. The remains of pre-20th Century small oceanic and coastal vessels would be particularly significant due to their archaeologically important cargoes and hulls. However, since these vessels typically did not carry large amounts of iron, they are more difficult to discern through only the use of a marine magnetometer. Additional remote sensing data, including side scan

sonar records, would need to be utilized in conjunction with magnetic anomalies to determine the existence of cultural resources (Mulholland *et al.*, 2003).

PREVIOUS CULTURAL RESOURCE STUDIES

The Corps has conducted remote sensing and underwater archaeological investigations in the Boston Harbor area for previous dredging activities. In 2003, as part of our compliance responsibilities for the Boston Harbor Deep Draft Navigation Improvement Study, a remote sensing archaeological survey of the Boston Harbor shipping channel was conducted by University of Massachusetts Archaeological Services (UMAS) (Mulholland *et al.*, 2003). Utilizing site location characteristics, sea level curves, and reconstructed past landforms, the study found that there was a potential for inundated Native American sites to be located within portions of the project area. Subsurface testing through the use of vibratory cores was recommended. The historic period background indicated that at least 93 vessels were lost in the general area of the harbor channel, but none were known to be specifically within the study area. Analysis of the remote sensing data produced 187 targets that required further consideration; however, only 3 appeared to be potentially significant historic shipwrecks. Dive investigations were recommended for these 3 targets. In addition, one sunken barge was located in two sections in the outer (east) entrance to the North Channel. This barge was removed during the maintenance dredging in 2004-2005.

In September 2003, the Public Archaeology Laboratory, Inc. (PAL) conducted an inspection of magnetic anomalies survey to determine the nature of the 3 anomalies identified during the UMAS study (Robinson and Ford 2003). Due to the depth of the channel, the survey was conducted with the use of a remotely operated vehicle (ROV). The systematic and visual ROV survey consisted of 21 survey lines spaced at 10-foot intervals, with the collection of visual and magnetic data along each line. Limited excavation using the ROV thruster-wash deflector was also conducted at the locations of the three magnetic anomalies.

No pre-Contact Period cultural materials or archaeological features were identified during the 2003 ROV survey. The survey only noted lobster pots and modern debris. Lobster pots and/or magnetic rock outcrops or boulders likely caused the magnetic anomalies. Additionally, archaeological subsurface testing through the use of nine vibratory cores was completed in September 2003 by UMAS (Lynch *et al.*, 2004). Testing was concentrated within three separate areas: the north channel; the western portion of the project area including the Reserved Channel and Mystic River confluence; and the Mystic River area. Cores were collected and then analyzed for stratigraphic integrity and evidence of inundated archaeological resources. Both visual means and magnetic susceptibility techniques were used to attempt to detect buried soil horizons. Likely sediments were also screened for artifacts. Profiles of visible stratigraphy were recorded and the magnetic susceptibility was plotted and graphically reproduced. The magnetic susceptibility graphs reliably detected changes in stratigraphy. For the Boston Harbor channel area, potentially preserved cultural resources are well below the maximum depth of proposed dredging. Preserved sites, if they exist, will not be impacted by the dredging. No further survey was recommended.

As a result of the preceding investigations, no significant resources were expected during the original Boston Harbor Deep Draft Navigation Improvement Study. The remains of the now removed sunken barge were that of a modern 20th Century steel vessel and were not considered historically significant. Coordination with the Massachusetts State Historic Preservation Officer (MA SHPO), the MA Board of Underwater Archaeological Resources (MA BUAR) and the Naval Historical Center (pertaining to the sunken barge only) ensued and resulted in concurrence with this determination. No further investigations were required for the Deep Draft Navigation Improvement Study as relates to the main channels improvements and the Mystic River Channel. However, additions of the Chelsea River Channel deepening and potential beneficial use sites in Massachusetts Bay may require additional investigation during the design phase as discussed below.

CULTURAL RESOUCE IMPACTS

Main Channels and Mystic River Improvements

The proposed project described in this Supplemental EIS consists of four separate improvement projects: (1) deepening areas of the Federal navigation channels providing access from Broad Sound to the Conley container terminal in South Boston, including the lower Main Ship Channel, the lower Reserved Channel and its Turning Area, and the President Roads Channel Reach and Anchorage, and the North Entrance Channel (widened at the Finns Ledge bend); (2) extending the deepening of the Main Ship Channel above the Reserved Channel to access Massport's Marine Terminal in South Boston at a depth of up to 45 feet; (3) deepening a small 35-foot portion of the Mystic River Channel to 40 feet to access Massport's Medford Street Terminal in Charlestown, and (4) deepening the 38-foot Chelsea River Channel and its turning basin to 40 feet, with minor widening in the bridge approaches and the channel bend between the bridges.

The improvement of the main channels up to the Conley Terminal is being examined to provide a depth of between 45 and 50 feet, with an additional two feet in the entrance channel under all plans. Economic optimization currently indicates that a channel depth of 48 feet (MLLW) with 50 feet in the entrance channel will result in the highest net annual benefit. All the project areas to be deepened under the main channels plan are presently part of the existing 40-foot and 35-foot deep Federal navigation project features, with the exception of small ledge areas that would be removed to widen the outer approach turn in the entrance channel opposite Finns Ledge and enlargement of the Reserved Channel Turning Area.

The main ship channel deepening extension to the Marine Terminal, the deepening of the Mystic River at Medford Street, and the deepening of the Chelsea River, all involve dredging to deepen the existing project limits, except for three small areas along the Chelsea River Channel. The area immediately upstream of the A.P. McArdle Bridge along, and the area of the bend between the bridges just downstream of the Conoco-Philips Terminal, both along the East Boston side of the channel, would be widened by no more than 50 feet. At the Chelsea Street Bridge, scheduled for replacement in 2007-2008 by the City and US Coast Guard, the Federal channel would be widened to conform to the new fender opening as part of the next maintenance dredging operation. This widened bridge opening would also be deepened under the improvement project.

All of the material to be removed by the deep draft improvement project consists of parent glacial material and rock determined suitable for disposal at the Massachusetts Bay Disposal Site (MBDS) by the Corps and US EPA. The main channels improvement plan (at 48 feet) and the three additional plans (main ship channel extension, Mystic River and Chelsea River) would together generate about 12 million cubic yards of ordinary unconsolidated material and 1.1 million cubic yards of blasted rock. This rock would either be used for beneficial purposes as described below, made available for use upland as structural fill by other parties, or placed at the Mass Bay Disposal Site.

Based upon the aforementioned remote sensing survey (Mulholland et al. 2003) and follow-up inspection of magnetic anomalies (Robinson and Ford 2003), significant cultural resources should not be impacted by the proposed improvement dredging of the Federal navigation channel including the Main Ship Channel, the Reserved Channel and its Turning Area, the President Road Channel Reach and Anchorage, and the North Entrance Channel from Broad Sound. The only magnetic anomalies identified during the survey were located near Castle Island and turned out to be modern debris and lobster pots. Vibracore sampling (Lynch et al. 2004) of the most potentially sensitive areas of the navigation channel determined that intact land surfaces, if present, are well below the depth of dredging. Additionally, the creation of CAD cells within the channel, for possible disposal of unsuitable material, will not impact cultural resources due to the extensive modifications of the shipping channel and prior dredging. Suitable material from the dredging will be deposited at the Massachusetts Bay Disposal Site, a previously utilized disposal area for prior dredging activities.

Mystic River and Chelsea River Dredging

If proposals to deepen both the Mystic River Channel from 35 to 40 feet to access Massport's Medford Street Terminal in Charlestown and the entire Chelsea River Channel, including its upstream turning basin from its current depth of –38 feet to –40 feet MLLW are implemented, a remote sensing archaeological survey will be recommended in order to identify the presence of submerged archaeological resources including shipwrecks in these areas. The original remote sensing survey of the Federal navigation channel (Mulholland et al. 2003) did not include the Chelsea River portion of the inner harbor. This area is sensitive for historic archaeological resources including recorded shipwrecks. Vibracore samples were taken from the Mystic River area (including the vicinity of the Medford Street terminal) during the navigation improvement study; however similar sampling for the presence of buried land surfaces and pre-Contact archaeological sites was not conducted for the Chelsea River portion of the study. Vibracores of this area should be incorporated into the design for a remote sensing archaeological survey if improvement of the Chelsea River Channel is recommended.

Areas proposed for widening were not subject to remote sensing survey during the SEIS and, due to the extensive number of charted wrecks in the area, should be considered sensitive for underwater archaeological resources including shipwrecks. Further evaluation of these areas should be completed by the proponent prior to widening of new areas.

Beneficial Use Sites

Beneficial use of the dredged material at several sites for hard-bottom habitat creation were investigated at five sites: offshore of Magnolia, in Nahant Bay, in Broad Sound south of Nahant, in Massachusetts Bay east of the Brewster Islands, and Nantasket Roads. Two of these areas show potential for development of new hard bottom habitat. Since these areas were not included in the original field investigations, a remote sensing archaeological survey may be conducted as part of further evaluation of these beneficial use sites, in coordination with the MA BUAR and the MA SHPO.

Industrial Waste Site and Massachusetts Bay Disposal Site

The Massachusetts Bay Disposal Site is the Federal base plan for disposal of all dredged material from the deep draft navigation improvement project. The former Industrial Waste Site (IWS) is located north of and overlaps the northern portion of the MBDS. The IWS was used from the 1940s to 1970s for disposal of chemical, medical and low level radiological waste. The site was also used for general disposal of dredged material, construction debris and other materials before and during that time. Remains of waste barrels are located throughout the site and most are concentrated in several areas. The Corps and US EPA are investigating the potential to use the improvement project's millions of cubic yards of unconsolidated dredged materials to form a cap over these barrel "fields". A side scan sonar survey of the Industrial Waste Site (IWS) and portions of the MBDS was conducted by US EPA Region I in July 2006. A number shipwrecks were identified within the IWS and the MBDS and the area where those two sites overlap. These locations should be avoided, if possible, by any MBDS disposal or IWS capping operation.

The MBDS and IWS are located seaward of the territorial sea (three-mile limit) in Federally regulated waters. If the IWS is ultimately recommended for capping via beneficial use of the dredged material from the improvement project, further data on the significance of the wrecks may be required if the capping plan were determined to have an impact on those resources. If impacts are unavoidable, a Phase II site examination level survey of the wrecks may be needed to determine the boundaries of these potentially significant resources and determine whether any are eligible for listing on the National Register of Historic Places. The scope of any studies and results would be coordinated with EPA.

The preceding comments are offered in partial compliance with Section 106 of the National Historic Preservation Act of 1966, as amended and implementing regulations 36 CFR 800. The MA BUAR and SHPO are expected to concur with these recommendations.

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Lynch, Kerry, Mitchell Mulholland, and Jeffrey Donnelly
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Mulholland, Mitch, Warren Riess, Jeffrey Donnelly, Christopher Donta, and Ilya Buynevich
2003 *Remote Sensing Archaeological Survey and Geologic Interpretation, Boston Harbor Navigation Improvement Study, Boston Harbor, Boston, Massachusetts.* Presented by: UMass Archaeological Services, Amherst, MA. Presented to: Alex Mansfield, Battelle Ocean Sciences, Inc., Duxbury, MA.

Robinson, David S. and Ben Ford
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Archaeological Services

Contract Number DACW33-01-D-0004

REMOTE SENSING ARCHAEOLOGICAL SURVEY AND GEOLOGIC INTERPRETATION BOSTON HARBOR NAVIGATION IMPROVEMENT STUDY BOSTON HARBOR, BOSTON, MASSACHUSETTS

APPENDIX M

ATTACHMENT 1

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Contract Number DACW33-01-D-0004

REMOTE SENSING ARCHAEOLOGICAL SURVEY AND GEOLOGIC INTERPRETATION BOSTON HARBOR NAVIGATION IMPROVEMENT STUDY BOSTON HARBOR, BOSTON, MASSACHUSETTS

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May 30, 2003

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Figure 18. Map of the main survey area indicating areas recommended for core testing for cultural resources. Dark areas indicate acoustic basement of less than 55 feet (bedrock or glacial till). Stippled areas represent former estuarine deposits; hatchured areas recommended testing. Map provided by Ocean Surveys, Inc.OSI Report 02ES066-D.

Figure 19. Map of the Mystic River area indicating areas recommended for core testing for cultural resources. Dark areas indicate acoustic basement of less than 55 feet (bedrock or glacial till). Stippled areas represent former estuarine deposits; hatchured areas recommended testing. Map provided by Ocean Surveys, Inc. OSI Report 02ES066-D.

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Table 1. Native American Sites in Boston Harbor.

Table 2. Magnetometer data for Targets 1, 2, and 3 near Castle Island.

ABSTRACT

A remote sensing study and archaeological reconnaissance survey was conducted for the proposed improvements of the Boston Harbor Shipping Channel. Using site locational characteristics, sea level curves and reconstructed past landforms, the study found that there is a potential for inundated Native American sites to be located within portions of the project area. Subsurface testing through the use of vibratory cores or split spoon borings is recommended. The historic period background study indicated that at least 93 vessels were lost in the general area of the dredging project, but none are known to be specifically in the route. Analysis of the remote sensing data produced 187 targets that required further consideration; however only 3 appear to be potential historically significant shipwrecks. In addition, one obvious sunken barge rests in two sections near the outer (east) entrance to the North Channel. Dive inspections are recommended for the three targets.

MANAGEMENT SUMMARY

This report discusses an evaluation of the archaeological sensitivity of offshore areas in the Boston Harbor shipping channel. The project area extends from the Mystic River in the west, to the eastern end of North Channel. This project has included a reconnaissance level archaeological background survey; historical background research to detect shipwrecks; and a remote sensing survey of the project area. Background is provided for potential Native American occupation of the project area; methods used in locating underwater Native American sites; a summary of inundated sites found throughout the eastern seaboard of the United States; a discussion of the processes of oceanic transgression following sea level rise that can protect or destroy sites; a review of the results of the remote sensing survey; a recommendations for further survey.

Native American Sites Study. Using site locational characteristics, sea level curves and reconstructed past landforms, the study determined that there is a potential for inundated Native American sites to be located within portions of the project area. Subsurface testing through the use of vibratory cores or split spoon borings is recommended on the north side of the North Channel, in the vicinity of Castle Island/Fort Independence and in the Mystic River area.

Historic Period Background Study and Remote Sensing Survey. The historic-period background study indicated that at least 93 vessels were lost in the general area of the dredging project. However, none are known to be specifically in the route. Analysis of the remote sensing data produced 187 targets that required further consideration; however only three were considered to be possible shipwrecks. In addition, one obvious sunken barge rests in two sections near the outer (east) entrance to the North Channel. The New England USACOE is aware that this is a modern steel wreck. Therefore, it is recommended that the three targets be physically inspected to determine if they are significant cultural resources. This will require an underwater archaeological team. If desired, the same team could record the barge during the same operation.

INTRODUCTION

UMass Archaeological Services (Archaeological Services) has conducted a remote sensing archaeological survey (magnetometer, sidescan sonar, and sub-bottom profiler) and archaeological reconnaissance of several areas within Boston Harbor and adjacent locations (Figures 1-3) that will be subject to modifications by dredging and the disposal of dredged material. Archaeological Services conducted the project for Battelle Ocean Sciences, Inc. of Duxbury on behalf of the U.S. Army Corps of Engineers (USACE). Prior to the remote sensing survey, historic and archaeological background research was conducted. The project follows the scope of work issued by the U.S. Army Corps of Engineers.

The purpose of the remote sensing survey has been to locate objects or magnetic anomalies representing historic period shipwrecks or other historic-period resources. The archaeological reconnaissance survey used a predictive model to identify areas in the project that may contain submerged Native American sites. The combined study makes recommendations for future studies at the intensive survey level.

The Archaeological Services team utilized a systematic, interdisciplinary approach in conducting the study. Specialized knowledge and skills were used during the course of the study and included expertise in the disciplines of maritime archaeology, coastal geology, history and geophysics. Techniques and methodologies used for the study are representative of the state of current professional knowledge and development.

Archaeological Services has conducted the background research for historic-European and Native American resources, including submerged shipwrecks and other features. Key personnel on the Archaeological Services team consisted of Maritime/Underwater Archaeologist Warren Riess, Project Archaeologists Mitchell Mulholland and Christopher Donta, and Coastal Geologists Jeffrey Donnelly and Ilya Buynevich. It was assumed that with the exception of shipwrecks, submerged historic sites (buildings, foundations, etc.) will not be impacted by the proposed project. Therefore, a Project Historical Archaeologist specializing in terrestrial historical archaeology was not included in this project. The remote sensing survey vessel, it's operation and remote sensing equipment were provided by Ocean Surveys, Inc. (OSI) in a direct contract with Battelle Ocean Sciences. OSI also provided an accident prevention plan (APP), prior to the initiation of field work.

The proposed project area is the Boston Harbor Navigation Channel and a small area in the Mystic River, Boston, Massachusetts. Research tasks for this project were as follows:

Task 1. A remote sensing survey, including precise navigation, magnetometer, side scan sonar, and subbottom profiler of all possible impact areas.

Task 2. Analysis of data collected in Task 1. In addition, a literature search to determine what is known about possible significant Native American or historic sites in the proposed impact area.

Task 3. Reporting. Preparation and submission a report covering the results of Tasks 1 and 2.

In addition, potential contingency days were handled contractually as Tasks 4 and 5:

Task 4 (Option). Weather Days.

Task 5 (Option) - Contingency Work Days.

Task 1 - Marine Geophysics and Remote Sensing Archaeological Survey.

This task included a remote sensing survey, including precise navigation, magnetometer, side scan sonar, and subbottom profiler covering all possible impact areas. The purpose was to locate any historic archaeological resources, as well as provide information on bottom conditions of importance to the engineering effort. Environmental conditions included the presence of bedrock, cobbles, mud/fines, and areas that would preclude excavating within the channel.

The distance between remote sensing transects surveyed by OSI was determined through background research and a prediction of the types of wrecks and other archaeological features likely to be encountered. Parallel lanes did not exceed 50-foot intervals resulting in a total of approximately 180 nautical miles of testing. Sidescan sonar and subbottom profiling were conducted over every third magnetometer transect (with spacing of 150 feet). This resulted in a coverage of 60 nautical miles. It was assumed that bottom elevations would range between 25 and 60 MLLW and target dredge depths would range between 35 and 52 feet MLLW.

A precise archaeological remote sensing survey of the sites was run in a series of 50-foot (15-m) tracklines. The marine magnetometer was used on each track line, while the subbottom profiler and sidescan sonar were used on at least every third trackline. The project's maritime archaeologist, in conjunction with OSI's geophysicist, planned and supervised the field work, analysis, and report.

The marine magnetometer was capable of reading 1-gamma differences in the magnetic field. Magnetic data collected included date, time, navigation events, heading, depth of sensor, and strength of field.

A 200 KHz side scan sonar unit was used to survey the project area to locate possible cultural resources that do not have a significant amount of iron in them and that are located near the water/sediment interface.

A high-resolution subbottom profiler provided detailed information about the sediment and bedrock on the sea bottom. This provided important contextual information for analysis of the side scan and magnetometer data. Occasionally such data indicates possible Native American sites (based on landform and stratigraphy) or vessel timbers buried in the sediment.

In order to accurately locate the transects, and to consolidate the remote sensing data, a precise DGPS navigation system was employed on the survey boat. The magnetometer, side scan sonar, and subbottom profiler were synchronized with the navigation system in the field.

As in all Archaeological Services underwater surveys, all work accomplished was conducted in accordance with the Secretary of the Interior's Standards and Guidelines for Archaeology and Historic Preservation (48 FR 44716, September 29, 1983) and the Advisory Council on Historic Preservation's Handbook "Treatment of Archaeological Properties" (1980). Massachusetts legislation dealing with the protection of underwater archaeological resources includes the Underwater Archaeology Act (Chapter 989, Acts of 1973). The qualifications for conducting a historic shipwrecks study were met, as specified by the National Park Service in the

Abandoned Shipwreck Guidelines published in the Federal Register, Volume 50, Number 233, on December 4, 1990.

Task 2 - Technical Evaluation, Literature Review and Assessment, and Presentation of Findings.

This task included the preliminary analysis and interpretation of data collected under Task 1; technical evaluation of the results as they pertain to the project's objectives; identification of areas that are questionable CADD locations (such as bedrock or shallow depth to bedrock, cobbles, mud/fines, etc.) or areas of archaeological sensitivity.

Initial processing of the survey data was conducted by OSI, who provided post-plot tracklines, magnetic data contour charts, and all original data. The OSI geophysicist and the archaeologist systematically inspected and analyzed the data for possible cultural resources. The archaeologist developed a pre-draft presentation of the results of the survey and analysis, which became the basis for a determination of which targets should be inspected by an underwater archaeology team.

A literature search and review of archaeological site files also took place under this task. Background research consisted of the collection of data concerning known historic and Native American sites in the Boston Harbor area. There are numerous Native American sites along the shores of the harbor. The Boston Harbor Islands (a National and State Register site) contain many Native American and European American sites. Many of the islands contain military resources dating to the American Revolution through the twentieth century. Several sites were occupied during the two World Wars and were dedicated to harbor defense. In this study, at the recommendation of the USCAE, only the Native American archaeological record and shipwrecks were researched.

At the outset of the project it was known that sea level has changed dramatically over the past 14,000 years following the retreat of glacial ice from the region. Sea levels have risen approximately 300 feet, inundating many Native American occupation sites. The study thus attempted to determine the changing patterns of Native settlement locations over time, as reflected in the land-based archaeological record in immediate proximity of Boston Harbor's islands and shoreline. This research revealed selective choice of certain landforms, wetlands and islands that were useful in predicting the location of submerged archaeological sites.

Information concerning previously recorded sites was obtained by reviewing the site Inventory of Archaeological Assets at the Massachusetts Historical Commission (MHC); the archival resources at the University of Massachusetts (Amherst campus); the Massachusetts Archives; the Boston Public Library; Woods Hole Oceanographic Institute; the U.S. Army Corps of Engineers; the W.E.B. DuBois Library at the University of Massachusetts, and its Special Collections Department; local historical commissions and societies; town and regional libraries, and other repositories of archaeological and historical site data.

The effort included a thorough review of the published and unpublished archaeological literature and reports, theses, journals, manuscripts and dissertations. Also studied were early USGS Topographic Quadrangles and other appropriate historic maps. Names of local collectors of Native American artifacts were sought from the Massachusetts Archaeological Society and

MHC, local historical society files, and local historical commissions. Interviews were conducted with librarians, project personnel and other maritime archaeologists. Professional archaeologists, historians, geologists, palynologists, collectors and local historians were interviewed for their knowledge of sites in the project area.

Local research included the acquisition of information from published and unpublished material at the local libraries and historical societies. The researchers also interviewed fishermen, divers, and harbor personnel. The Underwater Archaeologist conducted research at the U.S. Army Corps of Engineers Archives in Concord, Massachusetts, which has historic maps to be studied for indications of submerged cultural resources or former dredging and other disturbances. In addition, the Blunt White Library of the Mystic Seaport Museum in Connecticut has one of the best historic navigation chart collections in New England.

Environmental information was compiled to assist in the prediction of locations of archaeological sites and to facilitate later planning. The Archaeological Services team consulted first with project planners to obtain all information previously collected for the project. Information concerning geography, topography, geology, soils, climate and vegetation were gathered from existing published sources. The National and State Registers of Historic Places were researched for listed sites, structures, and properties within the study area.

Areas of potential to contain Native American sites, or sites that are recorded were identified on the basis of a review of the literature, archaeological site repositories, and stratification based on bottom topography, inundated streams and other water sources and terrain.

Following completion of the background research and fieldwork, a presentation was made to the USACE District Office in Concord, Massachusetts. The presentation focused on the results of the geological interpretation, and areas of potential archaeological resources were discussed. Also discussed were an assessment of the proposed project area, preliminary statements of resource potential and significance, the identification of anomalies and potential archaeological sites recommended for additional evaluation.

An assessment of the Native American potential of the project area was made by a qualified specialist in Native American archaeology familiar with the Boston area and the potential of the Harbor to contain inundated archaeological resources.

Task 3 (Option) - Reporting.

Archaeological Services has prepared this report in accordance with the USACE's requirements. The report describes the results of the survey, including archaeological resources identified, magnetic anomalies encountered and recommendations for further investigations.

1) The report includes a complete discussion of the background research, field work, analysis, results of magnetometer, subbottom profiler and sidescan sonar surveys, electronic data files, discussion of equipment and methods, etc.

2) The report includes a finalized interpretation of the geology, geophysical data, and technical evaluation and interpretation of results. Recommendations are provided for additional survey.

3) The report provides an archaeological assessment of the survey findings, including a discussion of the resources identified, magnetic anomalies encountered, and recommendations for further investigations.

4) The report includes a table of all possible submerged cultural resources that were recorded from the research, illustrations showing known and assumed positions of the cultural resources, a list of resources researched, and recommendations based on the study.

The report is designed to serve several functions. The report will assist Battelle Ocean Sciences and the USACE NAE in fulfilling legal obligations under Section 106 of the National Historic Preservation Act of 1966 as amended, and related regulations. The report also is a scholarly document that fulfills the mandated legal requirements, and serves as a scientific reference for future professional studies as well.

Task4 (Option). Weather Day.

This task includes all additional remote sensing survey days caused by inclement weather. The task includes time and expenses for the Maritime Archaeologist.

Task 5 (Option) - Contingency Work Day.

This task includes all additional remote sensing survey days caused by unanticipated delays. The task includes time and expenses for the Maritime Archaeologist.

GENERAL METHODOLOGY

The purpose of the archaeological research study is to assess the potential of the project area to contain submerged Native American archaeological resources and European historic resources. Native American sites are predicted using a site locational model that includes environmental variables detectable through remote sensing data and the literature. European American historic sites are located using site data bases, and remote sensing surveys (magnetometer, side-scan Sonar and sub-bottom profiler).

Background Research

In order to accomplish the background research for Native American sites, several methods were employed. These included:

1. Researching historical documents, state and federal records, cultural resource management reports and the archaeological literature to determine the location of reported contact period and pre-contact period Native American sites. The archaeological literature was researched to determine the characteristics of the types of sites that might be expected to occur within the project area. Sources consulted during background research are cited in the references section.

2. Researching archaeological site inventories maintained by the MHC to determine site locational patterns in the Boston Harbor environment.

3. Stratifying the project area using environmental factors known to be associated with aboriginal sites.

4. Conducting interviews with experts on underwater archaeology, coastal geologists, local informants, amateur archaeologists, and other individuals or offices knowledgeable about Native American history of the area of investigation.

5. Canvassing staff of the State Historic Preservation Offices and boards of underwater archaeology of all the states on the eastern coast of the United States for a history of finds of Native American sites in submerged contexts.

Criteria for Determining Archaeological Potential

For submerged Native American archaeological sites, there are several environmental attributes that can be considered in order to predict potential site locations. The usefulness of these attributes for site prediction depends upon the availability of data (such as wide-scale bathymetric contours), and subsurface conditions in aquatic environments (such as clear versus murky conditions). In an ideal situation, these site predictive variables may include:

1. Proximity to an ancient (but now inundated) water course or supply of fresh water (often detectable from bathymetric contours);

2. Topographic features (in many cases determined from bathymetric contours) such as slope, aspect, relative elevation, and barriers to prevailing winds and seas. Of particular interest are suitable land forms adjacent to relict stream beds, ancient shorelines, wetlands, peat deposits, etc.;

3. Ancient shorelines can be determined by comparing charts of sea level rise (Figure 4) with bathymetric data (Figures 5 through 9);

4. Proximity to areas where Native American artifacts have been recovered or sites reported (e.g., from fishing activities, dredging, actual archaeological surveys, etc.);

5. Proximity to now-inundated seasonal or perennial subsistence resources (inundated wetlands, ponds, estuaries, etc.) often detectable from bathymetric data or sub-bottom profiles);

6. Proximity to sources of raw materials (from geological data on bedrock outcrops, boulders, etc. (often detectable from sub-bottom profiles and possibly side-scan Sonar);

7. Depths beneath marine sediments that are below the depths of proposed impacts (detectable through coring, boring logs, sub-bottom profiles).

Geological data on oceanic transgression shows that during the earliest periods of human occupation in the region, sea levels were some 22m (72 feet) lower than they are today. The Continental Shelf includes relict stream channels, wetlands, lakes, terraces and hills that once were suitable as Native site locations. In some cases, as in deep alluviation, sites have been protected from the ravages of the rising sea and are preserved beneath deep sediments. On the basis of the background research, portions of the project area are considered to have a high potential to contain ancient Native American sites.

Native American Site Prediction Based on Land Models

Archaeological site inventories were researched at the MHC. The archaeological literature also was reviewed for site locations. Information was collected on sites recorded in the vicinity of the modern shorelines adjacent to the project area. Sites of particular interest were those in localities with environments similar to that of the now inundated project area. The assumption was made that site locational patterns of Native Americans observed on land for various periods, can be projected on offshore areas.

Historical Background Research for Shipwrecks

In order to determine the probability of there being shipwrecks in the project area, the location of any known remains, and information about previously investigated sites, the research team inspected mostly secondary and some primary archival material. Extensive primary documentary research was not required for this study because the USACE required a remote sensing survey. To research all available primary material would take many months of time without any guarantee of obtaining additional information.

The research team interviewed staff at the New England District of the USACE and the Massachusetts Board of Underwater Archaeological Resources, the staff of three local dive shops, and a local scientist/shipwreck diver (Appendix A). The team also reviewed the appropriate historic charts at the Mystic Seaport Museum Library and the USACE facility in Concord.

Histories of the Boston area and the New England region were studied for background historical information. In addition, published and unpublished lists of shipwrecks were inspected to determine how many ships were lost in the study area. The references included books, excerpts from a federal Bureau of Land Management study of primary sources, a list compiled by an amateur shipwreck historian, and NOAA's Automated Wrecks and Obstructions Information System Internet web site. No primary research was conducted, except for a study of historic charts and the interviews mentioned above.

Since most shipwreck locations cited in contemporary newspapers were quite general, such as "lost in Boston Harbor," and other sources gave specific locations, the team included all shipwrecks that were listed either at a specific location near the project, "off" a local location, or in the general project area.

When considering significance for each site we used the Department of the Interior's definition for eligibility to the National Register of Historic Places—generally sites over fifty years old could be eligible. However, most of the shipwrecks researched were more than one hundred years old. The team accepted the recorded locations and dates of the shipwrecks, without enough time to research each individual shipwreck in detail; therefore the recorded location information for any particular site could be rather general. However, the approximate number of significant shipwreck sites in the study area was accurate enough to justify conducting a remote sensing study.

Underwater Archaeological Survey Techniques.

Archaeological surveys to detect inundated Native American sites in salt-water have increased over the past decade. However, compared with the number of surveys in terrestrial environments they are few. Most underwater surveys have been highly successful in locating submerged shipwrecks and other large or metallic historic objects (e.g., shipping containers, ship parts, anchors, lobster pots, ordnance), but few have located intact submerged Native sites.

The location of historic-period archaeological sites in underwater contexts, requires sophisticated remote sensing techniques such as magnetometer, bathymetric recording, sub-bottom profiles and side-scan sonar. This section provides a general summary of the remote

sensing techniques used in this survey. More technical details are provided in the chapter on Remote Sensing Results.

A *magnetometer survey* is capable of detecting submerged iron and ferrous objects or varying sizes. A positive target is indicated as a high or low gamma reading that indicates the strength of the signal. The archaeologists must correlate the magnetometer results with results from the other remote sensing techniques, and especially visual observations on the surface of the water taken during data collection. In this manner, modern targets such as buoy anchors and lobster pots could be eliminated from further survey. Magnetometry is unlikely to detect submerged pre-Contact Native American sites. Historic period sites that contain iron conceivably could be detected, however, Native use of iron materials was limited. The amount of iron in a typical Contact-period Native American site would not be large enough to provide a detectable signature and because of the short time period of occupation, Contact/Historic period Native sites in offshore contexts should be rare. This technique was used in this project to detect historic sites, particularly shipwrecks.

The *sub-bottom profiler* (CHIRP) produces a stratigraphic image similar to that of a soil profile recorded on land by an archaeological survey team. The CHIRP penetrates the ocean floor and indicates changes in the density of sediments and is capable of detecting large, solid objects or changes in sediment. Theoretically, a large archaeological feature such as a deep shell midden, or hearth could be detected with this technique, especially in a sandy matrix. The sub-bottom profiler also reveals the amount and depths of overburden on the site. This information can be used to determine whether or not impact may occur to a submerged site from a proposed construction project. This technique was used in this project to detect historic sites and profiles of relict land surfaces and overburden.

Side-Scan Sonar is capable of detecting objects that protrude from the ocean floor. Shipwrecks and other large objects are detected using this technique. Shipwrecks, freight containers, and other obtrusive features are easily detected by this method. Small buried Native American archaeological features such as fire hearths, shell middens, etc. are not detectable. This technique was used in this project to detect protruding historic sites.

Bathymetric data are useful for plotting the depths of a project area, and provide information about topographic context. This is especially useful when compared with broad scale bathymetric data from the surrounding area. Broad scale topographic data can be derived from NOAA navigation charts and special surveys. In such a manner, relict stream courses, terraces and knolls may be detected. This information, when coupled with known site locations on land can then be used by the archaeologists to predict the location of Native American sites underwater. Bathymetric data was obtained during this project.

Dredging, through the use of a long arm bucket-excavator or induction dredge can be used to located Native American sites, but they damage soil context. Features are broken

up and destroyed. However, artifacts may be recovered intact. The trade-off is that artifacts have better preservation than on land adding a dimension of understanding of cultural lifeways not available in terrestrial sites. A portion of a site may be disturbed, but once identified, and integrity is assessed, more meticulous excavation may take place. This technique was not employed in this project, but has been employed in studies in other countries.

Coring with vibratory corers or split spoon borings may be used to test for Native American archaeological sites following the remote sensing data collection.

Library Research

Background research was conducted at the MHC in Boston, the USACE in Concord, and the Mystic Seaport Library. Other sources included the Special Collections Department and Map Library of the W.E.B. Du Bois Library in Amherst, Massachusetts; and the archaeological literature. Archaeologists specializing in the evaluation of underwater archaeological sites were interviewed as were the State Historic Preservation Offices (or State Underwater Archaeologists) of the 14 coastal states of the eastern United States. Archaeological site files at the state site repositories indicate that numerous sites are located in the coastal areas adjacent to the project area. In several instances Native American artifacts have been recovered from submerged salt-water contexts. In two instances, archaeological sites were evaluated by professional archaeologists in submerged salt-water contexts.

PROCESSES OF OCEANIC TRANSGRESSION – IMPACTS ON PRE-TRANSGRESSIONAL LAND SURFACES

Often in cultural resource management discussions, the question arises about the need to survey for Native American sites that may lie submerged in a project area. This chapter is intended to provide the reader with a summary of the oceanic processes that occur with sea-level rise. Many are highly destructive and result in the loss of archaeological sites. However, some processes may actually preserve sites. The chapter also discusses Native American sites that have been found in submerged contexts in the eastern United States and in other countries. The authors believe that the low frequency of inundated Native sites on record in the United States is a product of the dearth of effective archaeological surveys in submerged environments, rather than all sites having been destroyed through post-glacial oceanic transgression.

Transgression refers to a landward displacement of coastal environments and is commonly associated with rising sea level. However, in some areas depletion of sediment supply or land subsidence may result in marine transgression even during periods of stable or falling sea level (Curray, 1964). During a transgression, the erosional surface associated with landward translation of the surf zone represents a transgressive surface. Depending on the slope of the flooded surface and the rate of transgression, the underlying pre-transgressional deposits may be partially or completely reworked, or may escape the erosion where the surf zone passes quickly and high sedimentation rates prevail (Kraft, 1971; Belknap and Kraft, 1981; 1985; Davis and Clifton, 1987). Besides wave-induced erosion (wave ravinement) in areas with high tidal influence, bottom scour by tidal currents may produce regional tidal ravinement surfaces (Belknap and Kraft, 1981). During the transgression, sedimentary deposits formed in laterally-adjacent environments will become superimposed in a vertical sequence with offshore sediments overlying the shallow water, barrier, backbarrier, and upland deposits.

The marine transgression can occur as: 1) gradual landward movement of the shoreline (shoreface retreat), or 2) episodic rapid flooding of the inner continental shelf that may be accompanied by in-place drowning of coastal accumulation forms (stepwise retreat). Whereas slow shoreface retreat may be efficient in eroding or reworking the underlying marine, estuarine, or terrestrial deposits, stepwise retreat is more conducive to preservation of coastal lithosomes and associated archaeological sites.

Theory of Marine Profile Equilibrium

One of the responses to marine transgression is a re-establishment of the equilibrium profile, which refers to a condition where conservation of sand volume accompanies upward and landward translation of the nearshore profile in response to relative sea-level rise. Proposed by Bruun (1962), the nearshore profile equilibrium theory, known as *Bruun Rule*, states that in a two-dimensional system, the sediment eroded from the upper part of the profile (beach) is transported and deposited offshore in equal volume thus raising the seafloor by the amount equal to sea-level rise. Although the Bruun model did not include the third dimension of the coastal

system and was modified to address this issue (Bruun, 1988), it has been used to examine the landward migration of barrier islands (Dean and Maurmeyer, 1983). In addition to eroding glacial deposits, the continental shelf of Long Island has been shown to be the source of sediment for the nearshore and coastal accumulation forms, an observation that contradicts the Bruun Rule (Williams and Meisburger, 1987), but recently reinforced by Schwab et al. (2000).

Effects of Waves on Shorelines

The onshore-offshore movement of sediment by incident waves and erosional processes associated with breaking waves, superimposed on tidal cycles and long-term sea-level trends, are the major forces transforming a shoreline. The orbital motion within the waves continues downward toward the wave base (1/2 of the wave length) thereby extending the geological effect of the wave beyond the shoreline, often hundreds of meters offshore. The erosional power of the waves is concentrated in the surf zone, although during storms large parts of the upper beach and dune may be affected by elevated storm-surge levels. Because most waves move onshore at an angle, even after their refraction in shallow water a small angle may still remain, resulting in a longshore current.

Longshore Currents

A shore-parallel movement of water in the surf zone is called a *longshore current.* These currents are the result of the longshore component of the oblique wave approach and their magnitude is related to the height and the angle of the breaking waves. Onshore gradient (beach slope) is another important factor in determining the actual "thrust" for producing the current (Komar, 1998). Sediment suspended by breaking waves may be entrained by the longshore current resulting in the *longshore transport.* Over 90% of longshore movement of water and sediment occurs in the surf and breaker zone, with the remainder confined to the swash zone. Because wave energy is an important driving force, the longshore currents are strongest and the longshore transport is at its maximum during storm conditions. Studies by Vincent et al. (1981) showed a dominant net westerly transport of bottom sediments along the Long Island shelf (down to 30 m depth) with an onshore component in water depths shallower than 10 m. Where two longshore currents meet at the boundary of two nearshore circulation cells, a rip current is often generated.

Rip Currents

Rip current is a seaward-directed flow of water produced by wave set-up at the beach. The direction of the current may be perpendicular or at a slight angle to the shoreline, and its location commonly coincides with the zone of the smallest incoming waves (Cook, 1970; Davis, 1994). Rip currents are commonly produced along steep- or intermediate-slope beaches in the areas of local convergence of water moved along the shore by longshore currents or edge waves.

They also occur when the water trapped between the beach and nearshore bars escapes through the gaps between adjacent bars or where longshore current encounters a protruding shore-normal coastal structure (jetty or groin). The feeder current at the beach channels the water into the narrow rip current, which in turn grades into a dissipative rip head farther offshore (Komar, 1998). Some rip currents may extend for more than 500 m offshore and attain velocities sufficient enough to entrain and transport sediment (up to 1 m/sec; Davis, 1994). In this case, a net seaward movement of bottom sediments may take place in the surf zone, however the scouring capacity of rip currents is relatively insignificant.

Nearshore and Offshore Circulation Systems in the Boston Harbor Area

Although prevailing winds are from southwest to northwest, the dominant waves approach from the east and northeast during storm events. During storm events wave heights often exceed 2 m at the mouth of the harbor and cause extensive reworking of bottom sediments (Knebel et al., 1991). Lower wave heights are typically experienced within Boston Harbor during storm events (Knebel et al., 1991).

Tidal Currents and Waves

The mean tidal range in Boston Harbor today is 2.9 m (NOAA, 1993). Changes in basin geometry have altered the tidal range through time. Model results suggest that the tidal range in the vicinity of Boston Harbor may have been 1.1 m less 7 ka (Gehrels et al., 1995). Tidal currents in Boston Harbor today are highly variable as a result of the complex geometry of the system and the irregular bottom topography (Knebel et al., 1991). In channels near-bottom currents can exceed 50 cm/sec, while in sheltered areas bottom currents are generally between 15 and 30 cm/sec. Bottom currents over shallow subtidal flats are typically less than 15 cm/sec.

Effects of catastrophic events

Catastrophic events like intense hurricanes and tsunamis can significantly modify coastal landforms. Hurricanes have repeatedly impacted the northeastern United States. New England and Long Island, New York, protrude into the western Atlantic close to the warm Gulf Stream current and are often in the path of fast-moving tropical storms and hurricanes as they track north. Intense hurricanes are rare in New England, however. According to the National Oceanic and Atmospheric Administration (NOAA) "Best Track" data set, nine intense hurricanes threatened the northeastern United States and Maritime Canada in the last 149 years (Neumann et al., 1993). However, only three of these made landfall as intense hurricanes (1938-Long Island/New England, 1893-Nova Scotia, 1869-Long Island/New England). Two of these intense storms made landfall after weakening to Category 2 intensity (1896-Maine, 1969-New Brunswick); the remainder recurved to the east and did not make landfall.

The cool sea-surface temperatures immediately south of New England typically result in significant weakening of these systems as they move north. An acceleration in the forward motion of hurricanes as they move up the eastern seaboard of the United States (as much as 18-27 m s^{-1} or 40-60 mph) can make up for this loss of intensity as it enhances the winds on the right side of the hurricane. In addition the rapid forward motion shortens the length of time that a storm spends over cooler ocean waters, potentially preventing or slowing weakening.

Storm surge results from the strong winds driving ocean water onshore and, to a lesser degree, from the response of the sea surface to the extremely low atmospheric pressure of an intense storm (Redfield and Miller, 1957). In studies examining the patterns of water level change that result from hurricanes, storm surge is typically defined as the rise in water level, above the predicted astronomically-driven level of the tide, that results from strong onshore winds and low atmospheric pressure associated with a storm (Redfield and Miller, 1957). Tide-gauge measurements taken during hurricane strikes typically reveal a rapid but steady rise in water levels followed by an equally rapid fall in water levels (Redfield and Miller, 1957). However, first-hand historical accounts often describe storm surge accompanying hurricanes as coming in as a wave or series of waves (Tannehill, 1927; Allen, 1976). It is this wave energy in combination with coastal inundation that transports and deposits sediment in the coastal zone.

Hurricanes in the western Atlantic typically track northward along the eastern seaboard of the United States and, if they fail to recurve to the northeast, can strike New England or Long Island from the south. As a result, the strongest onshore southerly winds, and therefore maximum storm surge associated with hurricanes that make landfall in the northeastern United States, generally occur to the east of the storm track. Intense hurricane strikes in the northeastern United States have typically resulted in over 3 meters of storm surge (Donnelly et al., 2001a; 2001b). In addition, focusing of the storm surge occurring in south-facing embayments can result in significantly heightened storm surge (> 4 meters) at the head of these bays (Redfield and Miller, 1957).

Severe winter storms can also cause storm surge in the northeastern United States, although generally to considerably lower elevations than storm surge that occurs with intense-hurricane strikes. Storm wind directions are generally from the northeast (11). Winter storms in this region often produce strong northeast winds. As a result the highest storm-surge levels associated with winter storms typically occur on north- or east-facing coastlines. Many severe winter storms have battered southern New England since European settlement, with some of the most infamous occurring in 1723, 1888, 1944, 1953, 1962, 1978, 1991 and 1993. Historical accounts of these storms confirm that damage from their storm surges was generally most severe on coastlines exposed to northeasterly winds (Snow 1943; Dickson 1978; Fitzgerald et al., 1994). Records from tide gauges in the region show that storm-surge associated with severe winter storms in the 20th century typically reached heights of approximately 2 meters above mean sea level (Donnelly et al., 2001a; 2001b).

Hurricanes of the Twentieth Century

Hurricanes can be highly destructive to archaeological sites. Ten hurricanes made landfall in the northeastern United States in the 20th century. Hurricane Bob, which caused eight deaths and over 1.5 billion dollars in damage, was the last hurricane to come ashore. This Category 2 storm passed over eastern Rhode Island and southeastern Massachusetts on August 19, 1991.

Three hurricanes made landfall in the northeastern United States between 1955 and 1990 (Neumann et al., 1993). Hurricane Gloria made landfall as a Category 2 storm in western Long Island, NY and western Connecticut on September 27, 1985 and produced storm-surge heights of a meter or less above mean high water in southeastern New England. On August 10, 1976, Hurricane Belle, a category 1 storm, made landfall in western Long Island, NY and produced storm surge of less than 0.5 m above mean high water. Hurricane Donna made landfall on eastern Long Island, NY, eastern Connecticut, and Rhode Island on September 12, 1960 as a Category 2 storm, causing storm surge to rise roughly 1 m above mean high water in southeastern New England.

Hurricane Carol (August 31, 1954) caused significant storm surge in southern New England. Although technically not an intense hurricane at landfall, Hurricane Carol was a strong Category 2 storm at landfall with sustained winds of approximately 44 m s^{-1}. Carol made landfall on eastern Long Island and eastern Connecticut during a time of astronomical high tide and resulted in storm-surge of between 2 and 3 meters above mean high water on the open coast from eastern Connecticut to southeastern Massachusetts with lesser amounts to the west of the storm track (Redfield and Miller, 1957). Focusing of storm surge in the south-facing Narragansett and Buzzards Bays resulted in storm-surge heights of over 4 m above predicted tide levels at the heads of these bays (Redfield and Miller, 1957).

On September 14, 1944 a Category 1 hurricane made landfall on the eastern tip of Long Island, NY, and southeastern New England. Storm surge recorded by the tide gauges at Woods Hole, Newport, and New London ranged between 1.62 and 1.33 m above mean high water (MHW). This storm resulted in 26 deaths in New England and over 100 million dollars in damage.

The most recent intense (Category 3 or greater) hurricane to strike Long Island, NY and southern New England made landfall September 21, 1938 in central Long Island and tracked north into Connecticut, Massachusetts and Vermont (Minsinger, 1988; Brooks, 1939; Neumann et al., 1993). The 1938 hurricane was moving north at 22 to 28 m s^{-1} (50-60 mph). Wind speeds to the right of the storm's track exceeded 53 m s^{-1} and a maximum wind gust of 83 m s^{-1} was recorded at the Blue Hills Observatory in Milton, Massachusetts. The lowest recorded barometric pressure was 946 mb at the Coast Guard Station, Bellport, New York. Storm surge and an astronomical high tide combined to cause the water level to rise over 3 m above normal spring tide levels along the open coast, and focusing in Narragansett and Buzzards Bays resulted in over 4 m of storm surge in some areas (Paulsen, 1940; Redfield and Miller, 1957). Over 600 lives were lost and property damage was estimated at approximately 400 million dollars (Brooks, 1939). Significant coastal modification and erosion occurred from Long Island, NY to southeastern Massachusetts in 1938 as a result of the combined effect of storm surge and wave action (Wilby et al., 1939; Nichols and Marston, 1939). Extensive sheet-overwash fans were deposited in the backbarrier environment from central Long Island, NY to western Cape Cod, MA as storm surge washed over nearly every barrier beach in the region.

Hurricanes of the Nineteenth Century

The "Best Track" HURDAT data set has recently been extended back to 1851. It provides a relatively complete list of tropical cyclones in the North Atlantic Basin (Landsea et al.,

2003). The record, however, is incomplete before that, especially for less-intense tropical storms and Category 1 hurricanes that received considerably less attention than the more intense storms. At least seven hurricanes made landfall in the Northeast in the 19th century (Landsea et al., 2003; Neumann et al., 1993; Ludlum, 1963). Four of these storms (1893, 1869b, 1858, and 1804) may have been of Category 2 intensity, while three (1869a, 1821, and 1815) may have been of category 3 intensity (Landsea et al., 2003; Boose et al., 2001). The latter three hurricanes caused significant loss of life and damage and are well documented in the historic record.

On September 8, 1869 a compact but intense hurricane struck southeastern New England (Ludlum, 1963). The storm made landfall first at Montauk, Long Island, NY then again just to the west of Stonington, CT. The short duration of hurricane-force winds and the timing of landfall being coincident with a relatively low tide combined to lessen the level of storm surge. A storm surge of approximately 2 m above the normal high-tide level was noted at Bristol, RI.

The Great September Gale of 1815 struck Long Island and southern New England on the morning of September 23, 1815. Historians have frequently equated this storm to the 1938 Hurricane (Ludlum, 1963; Minsinger, 1988; Snow, 1943). Moving at close to 22 m s^{-1} (or 50 mph) it made landfall on Long Island, NY, near Center Moriches, less than 16 km to the east of the landfall location of the 1938 Hurricane, and resulted in a similar damage pattern (Boose et al., 2001). The height of the storm surge at Providence, RI was approximately 3.5 meters, nearly 70 cm below the level reached during the 1938 Hurricane (Snow, 1943). In Stonington, CT, near the Rhode Island border the storm surge reportedly exceeded 5 m above the normal high-tide level (Snow, 1943).

In the Colonial Period (1620-late 18th century), at least six hurricanes made landfall in the region between European settlement of the region (1620) and 1800. The most intense hurricane strike during this interval is the Great Colonial Hurricane of August 25, 1635. Occurring 15 years following the settlement of Plymouth Plantation and 5 years after the establishment of the Massachusetts Bay Colony, this hurricane was well documented in the journals of Governors William Bradford of Plymouth Plantation and John Winthrop of Massachusetts Bay Colony (Ludlum, 1963). John Winthrop wrote in his journal, "[t]he tide rose at Narragansett fourteen feet higher than ordinary, and drown [sic] eight Indians flying from their wigwams." Likewise, William Bradford recorded, "[i]t caused the sea to swell to the south wind of this place above 20 foot [sic] right up and down, and made many Indians to climb into trees for their safety." These accounts of significant storm surge and further accounts of extensive destruction of forests within the region indicate a storm of intensity similar to or greater than those of the hurricanes of 1815 and 1938 (Boose et al., 2001).

John Winthrop also makes note of a "very great tempest or hurricano" on August 13, 1638. It does not appear to have been nearly as intense as the storm 3 years earlier in Boston, but a storm surge of approximately 5 m was noted at Narragansett, RI. This and a wind direction from the southwest at Boston, as noted by Winthrop (Ludlum, 1963), suggests that this storm may have taken a track to the west of Rhode Island, similar to the 1938 hurricane, resulting in extremely high tides in Narragansett Bay and less damage in eastern Massachusetts. Boose et al. (2001) estimate the intensity of this storm at Category 2, but their estimate is based on only two reports. Given the sparseness of available historical data, areas of more extreme damage may have gone unreported. It is possible that this storm may have been more intense than a category 2, as the report of tremendous storm surge in Narragansett may indicate.

Storm Impacts

The high energy of intense storms reworks and erodes coastal sediments. In barrier systems, such as the one that exists in the northeastern United States, the combination of storm surge and waves can breach sandy barriers resulting in the formation of an inlet. Inlets can also form a result of breaching from the reversal of storm surge in the lagoon associated with a change from onshore to offshore winds as a storm passes (Pierce, 1970). Inlets can be significant conduits for transporting sediment from the marine side of the barrier into backbarrier environment. Strong currents through an inlet can quickly erode previously-deposited barrier and backbarrier sediments. Once an inlet forms it may close within a few days if there is 1) insufficient tidal flow to maintain an open inlet and 2) ample sediment supply. An inlet may remain open indefinitely if there is sufficient tidal flow. In this case the inlet may migrate laterally along the beach.

Effects of coastal processes on the preservation of archaeological sites

The translation of the coastline landward as sea-level has risen since the last glacial maximum has likely reworked most of the evidence of human habitation on the once exposed continental shelf. As a result the archaeological record of coastal human habitation is likely to be highly fragmented. This is especially true of any coastal sites that date to before approximately 6-7ka, as the high-energy shoreface has migrated past these locations. Pockets of potential pre-7ka coastal site preservation may exist however. For example, an early site may be preserved if it was inundated in a low-energy regime, such as a protected backbarrier estuarine environment, and was sufficiently low-lying as to be below the erosive level of the shoreface as it migrated past. In addition step wise retreat (rapid landward translation of the shoreface) associated with a rapid rise in sea level may contribute to site preservation as the landforms are subjected to much less erosion as the shoreface passes by relatively quickly. Several of these rapid sea-level rise events have been proposed for the latest Pleistocene. Fairbanks (1989) inferred two of these rapid jumps in sea level from coral data, occurring around 11.4 and 14ka. Emery and Edwards (1966) speculated that the best chance for the detection of older evidence of human habitation on the continental shelf would be in areas that have not been significantly covered by postglacial sediments and in areas where rivers once crossed the continental shelf.

By far the highest potential for the preservation of intact archaeological sites in the Boston Harbor is in areas that are extremely well-sheltered from storm waves from the east and northeast and are in regions not subject to extreme runoff or tidal currents. The two regions of the harbor that best meet these conditions are the extreme southeastern section of the harbor (Hingham Bay) and the embayment north of Deer and Governors Islands (Figure 11). Given that the coastline arrived at close to its current position between 5-7ka, any coastal sites likely to be preserved under these relatively low-energy sediments would date to the mid to late Holocene (see Stright, 1990). Intertidal or sub-tidal archaeological features such as fish weirs may also be

preserved in these estuarine environments (Kaye and Barghorn, 1964; Newby and Webb, 1994).

Known Native American Sites in Inundated Contexts

Surprisingly few inundated Native American sites are known in salt water in the eastern United States. To date, none have been found through cultural resources management surveys. This is more a product of the lack of surveys in the region than a lack of existing sites. When inundated Native sites are the focus of archaeological surveys, they generally are found provided that natural processes protected the sites prior inundation.

The presence of submerged archaeological sites is well-known in other parts of the world. In most cases, sites have been identified by the recovery of artifacts alone, and not features. In many sites, the degree of artifact preservation is stunning. In comparison with the United States, other countries spend considerably more time and effort on the location of offshore archaeological sites. These studies often are sponsored by governments, and conducted through the efforts of museums and academic institutions. Recent surveys in Denmark conducted by Jorgen Dencker of the National Museum of Denmark's Institute of Maritime Archaeology have recovered artifacts in spectacular condition (Dencker 2003). While features rarely are encountered because of the destructive survey methods employed, the artifacts provide information about styles and artistic inscription and carving that is seldom seen in terrestrial sites. Organic materials such as wooden canoes with elaborate carvings have been recovered. Carved bone and wood implements also have been recovered in excellent condition. Projectile points have not been pilfered by looters, a common malady in terrestrial sites. Even the condition of stone tools is remarkable with sharp edges of cutting tools intact. Such artifacts are recovered predominantly from contexts in which substantial amounts of overburden protects the materials from the ravages of oceanic transgression (Jorgen Dencker, personal communication).

Recent surveys and observations in southern New England have provided information that may suggest the presence of surviving Native American sites below the water surface. For example, in Hyannis Harbor on Cape Cod, peat deposits (some containing chips of wood) have been found off Dunbar Point at approximately 4.3 to 9.8 m (14 to 32 ft) below the present Harbor bottom (Riess et al. 1997). These deposits could represent drowned wetlands or estuaries. Instances of shell have also been noted from 2.1 to 5.5 m (7 to 18 ft) below the bottom surface, but it is unclear whether these are simply random natural occurrences, or deposits of shell that could be a cultural shell midden. Shell deposits have been observed when moorings have been removed from the harbor (Riess et al. 1997). A recent unpublished boring survey in Hyannis Harbor revealed a fragment of wood recovered from a depth of 6.7 m (22 ft; 4.5 m or 15 ft below the ground surface), and shells and wood fragments at 7.9 m (26 ft; 5.8 m or 19 ft below the ground surface) (Riess et al. 1997). All of this is significant, because the land surface of Dunbar Point itself is the location of a reported Native American site (19-BN-577), and it may be that the site extended to lower elevations on the terraces surrounding the point, now submerged. Similar circumstances may have prevailed at locations within Narragansett Bay (Riess et al., 2000).

Many other sites are known in other countries. Brian Williams has identified archaeological features in the intertidal zone of Ireland. Dortch has discussed submerged archaeological sites in the Lake Jasper area of Australia (Dortch 1997). A submerged prehistoric site (Atlit-Yam) in Israel was studied in 1993 (Galili et al., 1993). Finds of stone hand axes are

reported for Table Bay in South Africa (Werz and Fleming 2001).

Despite the number of underwater archaeological surveys conducted in the eastern United States, no Native American sites have been located physically in salt-water bodies through the efforts of cultural resource management surveys. The presence of sites in submerged contexts often is brought to the attention of the scientific community by sport divers, fishermen, dredging and construction crews, and beachcombers. More Native American sites are found accidentally during fishing or dredging activities than through archaeological survey. Unfortunately, artifacts generally are recovered in nets and in the spoils of dredges, and are removed from their archaeological contexts. As on terrestrial sites, inundated sites often are found because of surface disturbance.

Underwater archaeological surveys in the Northeast generally identify areas within a project that have the potential to contain inundated Native American sites on the basis of known settlement patterns derived from terrestrial sites (Public Archaeology Laboratory 2002; Robinson and Waller 2002; Riess, Mulholland and Donta 1997, Mulholland, Riess, Binzen and Donta 2000; Mulholland 1979 *inter alios*). Bathymetric data is coupled with curves of oceanic transgression to determine now-inundated areas that were dry land during the time of occupation.

In comparison with land survey techniques, underwater survey for Native American sites is difficult and extremely expensive. On land, typical survey techniques include the use of hand-excavated 50 cm wide test pits. Off shore deep-water techniques generally are limited to the use of 3.5-inch vibratory cores sometimes located a kilometer or more apart. Because of the expense, such cores must be limited in number. Archaeologists must combine their survey interests with those of the geological and engineering surveyors. In many cases vibratory cores can be directed by the archaeologist to test areas of high site potential in combination with the goals of the geological survey. Often core locations work well for both sciences. Following extraction, cores are examined by a qualified archaeologist and geologist to detect buried land surfaces and vegetational deposits. The possibility of intercepting a feature such as a fire hearth or post mold, or artifacts as small as a projectile point, is remote in deep water. Detection of relict land surfaces is more likely. Depending upon impacts, recommendations are made to conduct subsurface testing in areas of high site potential and project impact.

If sites are found in shallow water, testing may include the use of a backhoe in which the archaeologist directs the excavation, and screens excavated material to recover artifacts. Such techniques destroy the archaeological context of a small area of a site, but can be effective in the recovery of artifacts. Once a site has been identified in this manner, site examination is recommended. Such excavations are conducted by a dive team using the more conventional and exacting methods of underwater excavation.

Finds of Pleistocene megafauna have been known since at least the 1960s. Edwards and Emery reported finds of mammoth and other extinct fauna found in fishing nets (Emery and Edwards 1966). In 1977, these two scientists predicted that the area from Montauk Point, New York and Delaware Bay would be a prime area for proving the presence of archaeological sites in inundated contexts (Edwards and Emery 1977). There are numerous reports of mammoth and mastodon teeth recovered on the Continental Shelf. By 1950, more than 50 finds were reported in the Northeast (Edwards and Emery 1977:250; Whittemore et al., 1967). These specimens were predominantly recovered by sea-scallop- and surf-clam fishermen. Both fishing techniques employ metal dredges that scrape the sea floor to depths of up to 40 cm. It is significant that most

of the finds are large and would be trapped easily in the nets and dredges.

There have been occasional finds of Native American artifacts in Long Island Sound and other shallow water bodies, but few have been documented professionally. Generally, the finds are near shore where projectile points and other artifacts have eroded from the shoreline. The finds are few because professional survey designed to detect inundated Native American sites is a recent phenomenon. Survey methods to detect such sites are in their infancy, and those in use today are prohibitively expensive and cover woefully small areas per test unit.

Throughout the eastern coast of the United States, most inundated sites are brought to the attention of archaeologists by fishermen or scallopers. In few cases are the finds evaluated by a professional underwater archaeologist. In even fewer instances are intact Native American sites actually identified by professional archaeologists and subjected to subsurface testing. For the eastern United States there are only *two* instances in which Native American sites were physically identified through non-CRM survey. In Maine, after being informed of a site by scallopers, archaeologists of the Maine State Museum evaluated the site. In Florida, archaeological sites have been located through an academic program dedicated to the discovery and evaluation of inundated Native American sites. The following is a discussion of Native American sites and artifacts encountered in submerged salt-water contexts.

In Maine, the Lazygut Native American site was found on a submerged terrace with steep slopes on the sides. The site was found at a depth of 8m (26ft) in salt water on Lazygut Island, off Deer Isle (Cox 1991). The site was reported to the Maine State Museum by a local amateur from reports of scallop draggers having recovered artifacts in nets (Steven Cox, personal communication). The site was then investigated by professional underwater archaeologists who initially recovered lithic flakes and a flake core. Artifacts recovered from the site included an ulu, adze, two celts, mudstone bifaces, rhyolite flakes, a flake core, an abrader, a plummet, oyster shell and a ground slate *ulu*. A date of 6100+\-65 B.P. was derived from an oyster shell bed adjacent to the site, but approximately matches the time of submergence at this location. Intact features were not encountered. Researchers concluded that the site was destroyed during oceanic transgression, noting that subsidence along the Down East coast of Maine is very severe (Cox 1991:154). Daily tidal ranges in this area range up to 25 feet!

Evidence of other submerged sites has been found including a biface and plummet from eastern Blue Hill Bay in Maine (Crock et al, 1993). One site has been identified in Penobscot Bay north of Butter Island. Three axes of the Susquehanna Tradition (appx 4,000 to 3,000 years ago were also recovered by scallopers (Bruce Bourque, personal communication). Dr. David Sanger reported the find of two assymetrical pits in an inundated saltwater context near Penobscot (Sanger 1988). Numerous other sites are found in inundated contexts throughout the islands of the coast of Maine (Crock 2003).

In general, underwater archaeology of small Native sites is hampered in Maine by poor visibility and high tidal action (Steven Cox and Warren Riess, personal communication).

The most successful and largest survey for inundated Native sites in the eastern United States is being conducted in Florida. A large-scale underwater archaeological survey is currently in progress at Florida State University. Known as the PaleoAucilla Prehistory Project (PAPP), directed by Dr. Michael Faught of the Department of Anthropology, the project is conducted under the auspices of the Florida State University Program in Underwater Archaeology. The project is funded by a grant from the Florida Division of Historical Resources, graduate student

support and private sources (Faught 2002:1).The survey employs settlement locational models coupled with geological and geophysical information to locate relict landscapes, including shorelines, sink holes, oyster beds and old stream beds. In the process, at least 38 Native American sites have been identified (Faught and Latvis 1999; Faught 2002). The results have been spectacular, and indicate that site locational predictive models projected to offshore areas are valid and effective.

Sites that have been protected from oceanic transgression were covered by sediment long before sea levels rose. Tidal regimes in Florida are milder than in the northern part of the United States (e.g., Maine). In at least one site (the J & J Hunt site) artifacts were found *in situ*, but there is some question as to the integrity of the site (Christopher Horrell, personal communication). Fragments of a mastodon cranium and teeth were recovered associated with Native American lithic artifacts (Faught 2002:3). To-date only artifacts (no features) and the remains of Pleistocene megafauna have been recovered from the sites, but the primary effort has been on locating the sites. Sites have been found at depths of between 3 to 6 m (10-20 feet). The sites are situated adjacent to inundated river channels (Faught 2002:1). The prospects for significant advances in underwater archaeology from this project area are extremely promising.

Remote survey methods included sidescan sonar, bathymetric data and sub-bottom profiles to locate relict landforms. Survey locational methods include vibratory cores, four- and six-inch induction-dredge excavations, and in some cases hand-fan testing by divers. Once located, more exacting methods of excavation are employed, including hand-excavation of test pits. While the locational methods destroy any possible features at the test location, recovery of artifacts is effective and leads to more traditional methods of excavation. By 2002, the study had recovered 1,689 lithic artifacts from the J.& J. Hunt site alone. The site was located some 3.5 miles offshore.

Planned subsequent excavations include site evaluations that promise to determine the integrity, data potential and occupation activities from the sites. More intensive site evaluation is planned for the Ontolo site. Several temporally diagnostic artifacts have been recovered that date to the Middle Archaic (8,000-6,000 years ago), Early Archaic (10,000-8,000 years ago) and Paleoindian periods (12,000-10,000 years ago) (Faught 2002).

It should be noted that in contrast with New England, New York and New Jersey, Florida's environment provides distinct advantages to the underwater archaeologist. Depths are shallower than in the glaciated Northeast. Sites are found in shallow waters. The inundated shelf is gradual, waters are warm, tidal regimes are low, and underwater visibility is excellent.

In other states, numerous Native American sites have been reported by non-archaeologists. One survey identified ten archaeological sites extending from Cape Cod, Massachusetts to the Chesapeake Bay (Stright 1986a and b, 1990, 1995). In Massachusetts, a foreshaft and projectile point were recovered from a salt marsh bog in Wellfleet on Cape Cod (Frederick Dunford, personal communication).

In New York, Daniel Lynch, Daria Merwin and David Robinson (2003) cite as evidence for submerged archaeological sites in New York Harbor, the density of known archaeological sites on land, coupled with data on sea level rise. South of New York Harbor, east of Sandy Neck, New Jersey, a collection of Early, Middle and Late Archaic period artifacts (10,000 to 3,000 years old) was found following a beach replenishment dredging project. Dredged material (which included artifacts) was pumped from the offshore dredge site to a beach on Sandy Hook.

The dredge site is some three kilometers off shore and artifacts was excavated from 10 to 13 m (10-20 feet) (Lynch et al., 2003). A local resident, Mrs. Helen Corcione, discovered the artifacts when walking on the newly created beach and began to collect the materials (Merwin 2002:5). Now known as the Corcione collection, the materials were evaluated by underwater archaeologist Daria Merwin and were determined to date between the Early through Late Archaic period. The list of tools in the collection reads like a collection derived from an unlooted terrestrial site. In the collection are "24 Early, Middle and Late Archaic projectile points, 74 bifacially-worked tools, and 109 (lithic) flakes (or rhyolite and basalt)" (Lynch et al. 2003:5). Weathering on the projectile points is considerable, but does not obscure their styles. The authors estimate on the basis of artifact finds and sea level curves, that 10,000-year-old sites should be found at depths of 26m (85ft). It is significant that the site is located adjacent to the inundated Hudson River. As evidence for the possible integrity of inundated sites, Lynch et al., (2003:5) note that a core extracted from some 4.5 kilometers of the Moriches Inlet in which 1.2 m (4 feet) of marine deposits overlie buried terrestrial sediments was radiocarbon dated to 7,600 B.P.

Several finds have been reported in the state of Connecticut. Several sites were reported by McWeeney (1986) in her study of sea level rise and site submergence. Many, such as the Spruce Swamp Midden, are near shore and in estuarine environments (Powell 1965). Several sites are known in the intertidal zone of Rhode Island. Lynch (2001) identified several sites as a result of interviews with fisherman involved in shell fishing. In many of the sites artifacts were recovered from the Bay floor with the use of clamming tongs (Lynch 2001). Lynch's study resulted in the identification of more than 100 Native American artifacts from submerged contexts. The Grassy Island site dating to the Late Archaic period originally was identified in the 1920s and later studied by Johnson and Raup (1947). Kevin McBride of the Mashantucket Pequot Museum and the University of Connecticut recently has conducted archaeological surveys off Block Island, Rhode Island (McBride 2003). Using the U.S. Navy's nuclear research submarine, submerged landforms such as "barrier beaches, lagoons, rivers and wetlands" were identified and mapped. Future locational surveys are planned.

In Virginia and Maryland, several finds of Native American artifacts have occurred within the Chesapeake Bay and Atlantic Ocean (e.g., Blanton 1996). As in other areas, artifacts were recovered from disturbed and eroded contexts. Chesapeake Bay shellfishermen use tongs, some of which are 60 feet in length. No archaeological features or intact archaeological sites have been located. Within the inundated bed of the Susquehanna River in the northern portions of the Bay, eroded shell middens were found (Susan Langley, personal communication). Within the brackish water portions of the Patuxent River isolated artifact finds are known. Offshore dredging operations recently were conducted at Great Gull Shoal approximately 4 miles east of the Maryland shore with dredged material pumped to the shore. Within the dredge deposits, several Late Archaic period artifacts (3,000 to 6,000 years old) were found. Artifacts included grooved mauls and projectile points (Susan Langley, personal communication). An archaeological survey was not conducted at this location because the operation took place outside of the State of Maryland's three-mile limit, within which the State Underwater Archaeologist has jurisdiction (Susan Langley, personal communication).

In summary, evidence of sites in offshore areas is substantial. Most of the sites known have been found accidentally by non-archaeologists. Most have not been surveyed professionally. No sites have been identified in a cultural resource survey. Techniques used by the University of

Florida, and the Maine State Museum suggest that sites can be found in archaeological surveys. Evidence from other countries suggests that the information that can be derived from these sites greatly compliments the information derived from terrestrial sites.

SUMMARY OF ENVIRONMENTAL, NATIVE AMERICAN, AND HISTORIC CONTEXTS

Environmental Context of Boston Harbor

Boston is located in the Seaboard Lowland section of the New England Physiographic Province (Fenneman 1938:345). This section represents the gently sloping margin of the New England Upland, varying from 10 to 20 miles in width along the present shoreline. The topography in this section is not only lower than the upland, but more regular. Elevations of the lowland lie generally below 120 m (400 ft) (Fenneman 1938:370), but some monadnocks are present. Elevations in Boston range from sea level to a high point of 99 m (328 ft) in West Roxbury. Most of the city lies between 0 and 30 m (0 to 98 ft), with numerous small hills scattered about. Elevations are based on the National Geodetic Vertical Datum of 1929, field checked in 1979 (USGS 1984).

The islands of Boston Harbor lie at the eastern edge of the geologic formation known as the Boston Basin, which is a lowland consisting of volcanic and metamorphosed deposits of Late Paleozoic origin (see Dincauze 1974). The islands themselves are of Pleistocene glacial origin, part of a field of partially sunken drumlins. Most of the islands range from 0 to 30 m (0 to 98 ft) in elevation.

Soils on most of the Boston Harbor Islands are comprised of Newport silt loam, which is sandy and well drained, and is derived from glacial till (Peragallo 1989).

It is thought that the islands were covered with forests for most of the past few thousand years, prior to the beginning of horticulture practices by Native Americans of the Woodland period. After European settlement, many forests were cleared for wood, and/or for farming or pasturage. By the late seventeenth century, the islands are described as largely devoid of trees, consisting of open fields (Snow 1936).

Holocene Geological History

The present day morphology of Boston Harbor is a product of the last glaciation and the subsequent rise in sea level. Figure 12 shows the present geography of the harbor (Figure 12). The Laurentide Ice Sheet (LIS) reached its maximum extent about 23,000 years ago (Balco et al., 2002). At this time sea level was approximately 120 meters lower than present day (Fairbanks, 1989). Isostatic depression of the land surface due to ice loading resulted in the Gulf of Maine, Boston Harbor included, to be flooded by the sea as the LIS retreated away from the present coastline. For a brief time (<1000 years), around 15 ka, sea level was as much as 18 m higher than it is today in the vicinity of present day Boston, leaving sediments of marine origin on now-exposed upland. Isostatic rebound caused sea level to fall to a lowstand about 22 m below modern sea level by about 12 ka. This was followed by a continuous rise of sea level to the present day. This most recent marine incursion flooded the topography shaped by the LIS and previous glaciations and the earlier marine transgression, which consisted of till, drumlins,

glacio-marine deltas, and marine muds (up to 25 m thick in some places (Stone and Peper, 1982; Newman and Mickelson, 1994).

The modern-day Boston Harbor started to form in the early Holocene as continued sea-level rise began to flood the basin. Sea level in Northern Massachusetts has risen about 13 m in the last 7000 years (Donnelly, 2000; Figure 4). The rate of rise has been decelerating through time from between 2.2 and 5 mm/year between 5000 and 7000 years ago to approximately 0.5 mm/year in the last 2000 years. The rate of MHW rise decreased between 1000 and 1650 AD to close to 0.3 mm/year followed by an increase to over 1 mm/year between the 16th or 17th centuries and the early 20th century.

Combining this sea-level chronology with a detailed bathymetric survey of the region (Knebel et al., 1991), we have created a series of paleogeographic maps for the study area. In constructing these maps we assumed that the present day geometry of the basin was undisturbed by transgression processes. This assumption is surely not valid as significant erosion and deposition altered the landscape as the sea transgressed over it (Rendigs and Oldale, 1990). The resulting paleogeographic maps, therefore, are only a first-order approximation of shoreline position and the past. Detailed high-resolution seismic surveys are necessary in order to more accurately estimate past shorelines. About 9 ka sea level was close to 20 m below modern (Fairbanks, 1989), and all of what is now Boston Harbor was likely exposed (Figure 5). Sea level rose to about 16 m below modern sea level by roughly 8 ka, to a position just east of the outer Boston Harbor Islands (Figure 6). The northern part of the present Boston Harbor likely began to flood around 7 ka as sea level rose to about 12 m below modern sea level (Figure 7). By about 6 ka the sea began to also flood the deeper section of southern Boston Harbor as sea level reached approximately 8 m below modern sea level (Figure 8). At this time several large islands were likely separated from the mainland. Sea level continued to rise more gradually, and at about 4 ka it had reached a level of about 4 m below modern levels (Figure 9). At this stage most of the Charles River Estuary was flooded, including the Back Bay where ancient fish weir remains have been documented (Kaye and Barghorn, 1964; Newby and Webb, 1994). Relatively large (4-7 km^2) islands still existed within the embayment at this time. Sea level continued to rise over the next 4000 years, flooding the exposed land, until it reached its current position (Figure 10).

Native American Context in the Boston Harbor/Eastern Massachusetts Area

Eastern Massachusetts is known to have been inhabited for approximately the last 13,000 years. For the first few thousand years following deglaciation, the ocean levels were considerably lower than they are today because much of the world's water was locked up in glacial ice. Thus, the harbor islands would have been inland hills, rather than coastal for the first three periods of human occupation in the area. Coastlines would have been affected by slowly rising sea levels until stabilization approximately 5,000 years ago (see Dincauze and Mulholland 1977).

The Boston area is known to have been inhabited for at least the past 13,000 years. As is the case throughout the Northeast, evidence for **Paleoindian Period (13,000-10,000 B.P.** [Before

Present]) occupation in eastern Massachusetts is extremely rare. However, one of the most important Paleoindian sites in New England is located on the northern shore of Assawompset Pond in Middleborough, southwest of the project area. The Wapanucket site (19-PL-203) includes fluted projectile points, the hallmark artifact type of this time period, as well as scrapers, gravers, and debitage of chert and jasper from two different loci (Robbins 1980:272-285). Another important exception to this is the Bull Brook site, located in Ipswich, north of Boston (Byers 1954, 1955, 1956). No evidence of Paleoindian occupation has yet been recovered from the Boston Harbor Islands.

Evidence from the greater Northeast indicates that Paleoindians first settled in the area not long following the retreat of the Wisconsin glacier, which vacated New England by around 13,000 years ago. Recent calibration of radiocarbon dates based on ice cores, marine and lake varves, and sea coral indicate that the initial settlement of North America from Beringia is earlier than previously thought, clustering around 13,400-13,000 B.P. in the west, midwest, and southeast (Fiedel 1999). First settlement in the Northeast appears to be slightly later than in the western part of North America (Haynes et al. 1984), but certainly by 12,500 years ago. Claims for slightly earlier occupation of North America (as at the Meadowcroft Rockshelter in western Pennsylvania [Adovasio et al. 1978, 1980]) to much earlier inhabitation (see Meltzer 1989; Lynch 1990) remains unconvincing to most archaeologists.

A tundra environment succeeded the Wisconsin glacier, and was, in turn, replaced by a spruce-parkland community (Davis and Jacobsen 1985; Gaudreau 1986; Jacobsen et al. 1987). Paleoindians living in these post-glacial ecological contexts have traditionally been characterized as hunters and gatherers who subsisted primarily on several large species of animals known to herd in the Northeast, including the mastodon and mammoth. Little evidence of human interaction with these megafauna has been forthcoming, however, and more recent interpretations have focused on smaller species such as caribou and elk as primary food sources (Curran 1987; Curran and Dincauze 1977; Dincauze 1990; Dincauze and Curran 1984).

Little is known presently concerning the social structures, family life, and religion among Paleoindians. No house features, burials, or ceremonial objects have been recovered from Paleoindian sites in the Northeast. This lack of data is the product of 10,000 years of organic decay, geological forces, and urban development impacting the archaeological record. All that remains of this time, in most cases, are stone tools. Projectile points with a distinctive basal flute can be identified as originating from this time, as this style occurs across North America in the Paleoindian period. Little else is ever found in addition to fluted points and specialized stone tools, making interpretation of Paleoindian lifeways difficult.

Based on ethnographic analogy, it is assumed that peoples of this time were seasonally nomadic, following the movement of game with the changing weather conditions of the year. Similarities in artifact forms among Paleoindians all across North America argue for a generalized character of adaptation, with few specializations to local conditions evident (Haynes 1980:119). A correlate of this fact is that population densities among Paleoindians were almost certainly very low. Raw materials utilized by these first inhabitants come from only a few sources, often from relatively distant locations (Spiess and Wilson 1989). This may indicate a high degree of mobility, established trade networks and/or a high frequency of interaction among units of population.

The time period following Paleoindian occupation, but predating the use of pottery and horticulture, has been designated the Archaic period by North American archaeologists. The **Early Archaic Period (10,000-8000 B.P.)** is thought to be a time of environmental change with a generally low population density. Very few sites dating to this period have been discovered. Harsh conditions and rapidly evolving environments may have contributed to both a scarce occupation of the area during this time period, as well as to the destruction of existing sites through landscape changes. Poor recognition of sites of this early date may also contribute to the lack of information on Early Archaic artifacts and lifeways. Evidence from the greater Northeast indicates that large hilltop sites were no longer as important as in the preceding period. In fact, sites are generally smaller, probably indicating that large bands were not utilized as social units. Large herds of game were apparently gone by this time, explaining the lesser importance of hilltop sites. As in the preceding period, tool types are uniform across the Northeast, but by this time the tools were being more frequently made of local materials (Braun and Braun 1994:29-31). It is likely that a more localized population structure was developing.

There is, at present, no consensus as to how people of the Early Archaic period were related to those of the preceding Paleoindian period. Some researchers have argued that there is a "clear discontinuity" between Paleoindian and Early Archaic peoples, following some type of ecological over-exploitation (Ritchie 1969:16; Snow 1980:157-159). Others see important technological similarities that are interpreted as evidence of continued occupation by Paleoindian descendants during the Archaic period (Custer 1984). The present lack of data, whether due to environmental degradation, urban development, or simple scarcity of sites, prevents firm conclusions either way, despite arguments to that effect.

Bifurcate-base projectile points are the hallmark artifact of the Early Archaic period in southern New England. The distribution of surface finds of the bifurcate-base point type indicate that people were present throughout New England at this time (Dincauze and Mulholland 1977). In eastern Massachusetts, the greatest density of Early Archaic sites is located along large river drainages, such as the Merrimack and Taunton Rivers. Early Archaic manifestations typically occur as isolated bifurcate-based point findspots near rivers. A single bifurcated-base point was recovered from Long Island (Ritchie et al. 1984), representing the only documented find of this period to date. The Long Island site (19-SU-39) also contains midden material and features indicating that it was occupied into the Late Woodland era, documenting a range of occupation in the harbor of over 9,000 years.

During the **Middle Archaic Period (8000-6000 B.P.)** environmental conditions in the area began to approach those of today. The deciduous forest became established, providing a diverse array of plant and animal foods (Dincauze 1976; Dincauze and Mulholland 1977). Sites of this time period are more numerous than those of the Early Archaic, but still rare in comparison to subsequent stages. Archaeological materials from the area provide evidence of significant local populations by 7,000 years ago. Archaeological data from the greater southern New England area provide evidence that a substantial degree of population growth had occurred by the end of this period (Mulholland 1984).

A variety of site locations during the Middle Archaic indicate that a multi-site settlement system had become established. Supporting evidence for this rests in a variety of tool assemblages and recovered faunal material (Dincauze and Mulholland 1977; Barber 1979). It is

likely that this seasonal settlement system had begun during the preceding Early Archaic period (Ritchie 1984), though the scant evidence for this time hinders attaching any degree of certainty to this interpretation. Sites of this time are sometimes large, appear to be reused, and include sizable midden dumps, as at the Neville site in New Hampshire (Dincauze 1976). All of this seems to indicate that the settlement system included permanent or semi-permanent base camps to which social groups returned. Anadromous fish may have been an important resource, as is interpreted for the important Neville site in southeastern New Hampshire (Dincauze 1976). Also of note during this time is the continuation of a gradual shift from the use of non-local to local lithic sources from the Early to Middle Archaic period (Ritchie and Leveillee 1982). This may be a product of rising population levels and the establishment of more firm notions of territoriality.

The first evidence of religious beliefs becomes available at this time, though only from a few select sites. The most informative is L'Anse Amour, at the southeastern tip of Labrador. A Middle Archaic burial mound was excavated here, which included evidence of fire, the use of red ocher, and numerous grave goods (McGhee and Tuck 1975). This collection of materials may be interpreted as indicative of a belief in the afterlife. Closer to the project area, cremated human remains of the Middle Archaic period were found at Annasnappet Pond in southeastern Massachusetts (Cross and Doucette 1994). Projectile points, winged atlatls, red ocher, and other tools were found in association with the burnt bones, dated to 7570-150 B.P.

There are presently three major projectile point styles that are recognized as diagnostic of the Middle Archaic period. These were defined by Dincauze in her interpretation of the Neville site (Dincauze 1976). They are: the Neville and Neville Variant points, dating from approximately 8000-7000 B.P.; the Stark, from around 7700-7200 B.P.; and the Merrimack, from close to 7200 B.P. to the end of the period. Other artifacts used during this time include atlatls or throwing sticks, knives, perforators, axes, adzes, scrapers, abraders, ulus (semi-lunar ground stone knives), gouges, and harpoons.

Middle Archaic materials are more common in the harbor area, having been recovered from Spectacle Island (Edens and Kingsley 1998; Jones 1988; McHargue 1996), Peddocks Island, and Grape Island (Luedtke 1975).

Late Archaic Period (6000-3000 B.P.) sites in eastern Massachusetts are much more numerous than in previous periods. Peoples of southern New England at this time occupied a wide variety of environmental settings (Mulholland 1984:277-280), and there appears to be a significant diversity in site type and function. Modern environmental conditions were present and the wild resources available were the same as those observed by the early European settlers and explorers. Population densities may have been sufficient to result in the development of multiple ethnic groups in the Northeast (Dincauze 1974). Three cultural traditions have been identified based on artifactual materials: the Laurentian, Susquehanna, and Small-Stemmed, all of which are present in some form in southern New England, although Small-Stemmed materials are the most common. Along with the development of multiple traditions, increased specialization and the exploitation of a broad spectrum of resources are interpreted for this time period.

The relationship between the three recognized Late Archaic traditions remains unclear, after decades of debate (Ritchie 1971; Dincauze 1974, 1975). Laurentian materials are more numerous in the central and western parts of the state, raising the possibility that this tradition represents an interior, upland adaptation. An alternative interpretation is that the Laurentian, part

of the greater Lake Forest tradition which has a distribution that extends from New Brunswick to Wisconsin, represents some form of ethnic identity. Laurentian materials appearing approximately 4,500 years ago may be indications of some form of population movement, probably originating from the Great Lakes region.

The significance of the more common Susquehanna and Small-Stemmed traditions is not known. Dincauze has suggested that the two represent different populations, with the former consisting of an intrusive group, which peacefully coexisted with the latter people for some thousands of years (Dincauze 1974, 1975). Alternative explanations include the possibility that these traditions are somehow different in function, representing different types of tool kits. At present, there is some agreement that the technological precedents for Susquehanna tools are found in the southeastern United States, ultimately deriving from Middle Archaic stemmed biface types in this region. Small-Stemmed, or Narrow Point tradition artifacts, are widely viewed as a pan-Northeastern phenomenon, probably deriving from the indigenous people of the northeastern Middle Archaic. Analysis of local collections clearly indicates a predominance of Small-Stemmed materials over the other cultural traditions in the eastern part of the state (Dincauze 1975). It is likely that the presence of Small-Stemmed and Susquehanna artifacts in a single site represents some combination of technological exchange and population mixture, varying depending on the location (Ritchie 1969; Dincauze 1976; Snow 1980; Custer 1984; Bourque 1995).

Late Archaic sites are more common in eastern Massachusetts than in previous periods. In fact, throughout southern New England, sites dating from the fifth and fourth millennia (5000-3000 B.P.) are the greatest in number of any time period (Mulholland 1984). However, the large representation for this time period may be somewhat overstated, due to the over-reliance on certain projectile point styles as temporal markers of the Late Archaic. Small-Stemmed points are the most common artifact styles of this era, and they have traditionally been utilized as a diagnostic for the Late Archaic. But a closer examination of radiocarbon dates associated with this point style show a wider range, extending well past the 3000 B.P. end date for this period. It is likely that a substantial number of sites currently attributed to the Late Archaic actually postdate this period (Filios 1990).

It is thought that people of the Late Archaic period in southern New England developed a more locally focused subsistence economy than during previous times. This may be due to increasing population levels, requiring groups to remain in more confined territories to avoid encroaching on others. Some degree of sedentism is interpreted by at least the end of the period, based on changes in subsistence strategy. Shell middens begin to appear in some coastal locations, indicating increased use of shoreline resources (Bourque 1976). Extensive fish weirs have also been documented in the Boston area for this time, where large numbers of fish could be speared in an organized manner (Johnson 1949). Some limited experimenting with cultigens also occurred, the idea probably spreading from the southeastern and central part of the continent. Squash, gourds, and sunflowers grew wild in parts of the northeast, and a few Late Archaic people began to purposefully plant these species to supplement their diets.

There is also more information on the ceremonial life of Late Archaic times. Burial sites are much more commonly encountered in excavations, providing a glimpse at the religious beliefs of the era. The "Red Paint People" of Northern New England and the Canadian Maritimes are one example. These people used large quantities of red ocher and included decorated tools

and ornaments in the burials of some of their dead (Sanger 1973; Tuck 1976). Another burial site of note closer to the project area is the Wapanucket site (Robbins 1980), which also included tools and red ocher. Cremation burials of the Susquehanna tradition are present across New England, featuring stone and bone artifacts and faunal remains (Dincauze 1968). Susquehanna cremation burials have been excavated by amateur archaeologists on Cape Cod, at Orleans and Truro (Dincauze 1968:89; Mahlstedt 1987).

Late Archaic sites have been identified on Grape Island (Luedtke 1975), Spectacle Island (Jones 1988), Thompson Island (Luedtke, personal communication), Peddocks Island (Casjens 1976), and Long Island (Ritchie et al. 1984), and include Small-Stemmed and Susquehanna tradition materials. To date, no Laurentian style projectile points have been recorded from the islands. Of particular interest is a human burial documented by Dincauze on Peddocks Island that dates to the Late Archaic period, and yielded a radiocarbon date of 4135±225 years (Dincauze 1973:31). The site, known as West Head Shell Heap (19-PL-3), included Squibnocket triangular points in association with the burial, as well as fire-cracked rock, adzes, awls, and later material including pottery, a net sinker, and some possible Early Woodland projectile points.

The third major Native American era is referred to as the Woodland period. This period was originally defined to include a broad area of the Northeast, encompassing new technologies such as ceramics, the bow and arrow, and horticulture involving exotics such as corn. As with the Archaic period, archaeologists have divided the Woodland into three stages, used to demarcate changes in adaptation.

The **Early Woodland Period (3000-2000 B.P.)** has generally been considered a period of population decline following a cultural fluorescence during the Late Archaic. The quantity of sites is lower, and site locations are more frequently restricted to coastal lowlands and river valleys. These characterizations, however, are based on the traditional association of several widespread forms of projectile points with only the Late Archaic period. Recent research indicates that Small-Stemmed and Susquehanna point styles are found to frequently postdate the 3000 B.P. end date for the Late Archaic (Funk and Pfeiffer 1988; Filios 1989). The likely interpretation to be gleaned from this information is that the Early Woodland is merely under-represented in the existing corpus of site files, rather than in actual number of sites. Should a method of correcting this bias be established, it is probable that the Early Woodland would have to be recharacterized as continuing some trends of the Late Archaic, such as population increase, while new technologies became a part of life.

Some changes in subsistence strategy are apparent during this time, probably representing a continuation of the Late Archaic trend toward a more localized, semi-sedentary settlement system. The more permanent types of camps were established along the coast or inland watercourses, where waterfowl, fish, and sea mammals could be easily exploited. Shellfish were also taken, although it seems that these were not a major dietary component until the Middle Woodland. Despite an increasingly localized focus of subsistence, the pattern remained one of hunting and gathering, particularly along water bodies where fish could be included in the daily fare. Technological changes are an important component of how archaeologists understand the Early Woodland period. This millennium witnessed the first widespread use of ceramics across the Northeast. Traditionally, ceramics were thought to coincide with the appearance of horticultural practices, serving as a convenient means of storing the surplus foods obtained

through purposeful planting. It is now known that in most of New England, cultigens were not an important part of most people's subsistence routine for at least 1,500 years after ceramics became established in the area.

The rich burial ceremonialism of the Late Archaic continued into the Early Woodland, with exotic artifacts such as gorgets, birdstones, pottery pipes, copper beads, and red ocher placed in graves with human remains (Ritchie 1965; Ritchie and Funk 1973; Spence and Fox 1986). The significance of these religious practices is not known, but they do not appear to reflect any kind of hierarchical social relationships. The presence of exotic goods in sites provides evidence of established trade routes that extend to the Midwestern portion of the continent, where the Adena complex was well established.

Much remains to be understood about this time period. Hindered by confusion with the Late Archaic period, sites of the Early Woodland often go unrecognized, or are misinterpreted. Many of the sites reported along the coastline in the greater Massachusetts Bay area near Boston are typical of this problem. A number of sites were initially identified by shell middens, a trend that seems to coincide, in general, with the onset of the Woodland period. Without associated diagnostic stone tools, however, it is not possible to place these sites into a specific Woodland period.

Presently, only a few Early Woodland sites have been unequivocally identified in the harbor. One such site (19-SU-17) lies on Thompson Island (Luedtke 1996), while a second possible Early Woodland site (19-PL-3) has been reported for Peddocks Island (Casjens 1976), and a third on Grape Island (19-NF-3) (Dudek 2000). The Bass Point site on Long Island (19-SU-55) may also include Early Woodland material, but again documents the problematic nature of archaeologists' current understanding of the transition from the Archaic to Woodland (Ritchie et al. 1984).

The **Middle Woodland Period (2000-1000 B.P.)** witnessed a continuation of trends of the Early Woodland. Again, however, technological innovations provide evidence of change. This part of the Woodland period is differentiated from the preceding millennium by a change from simply decorated ceramics to widespread use of more elaborately decorated wares. No functional interpretation for this change appears accepted; rather, the increased decoration probably has to do more with style and ethnic identification, a traditional archaeological interpretation. Another new technology became important: the bow and arrow is thought to have become a part of regional technology at this time.

Subsistence trends of the Early Woodland continued. Large, semi-permanent, or perhaps even year-round settlements were utilized by this time (see McManamon 1984). These locations were supported by specialized subsistence foci, such as shellfish, fish, and sea mammals. The first large shell middens appear in the archaeological record at this time. The presence of shell middens may be related to the establishment of mature shellfish beds following the postglacial stabilization in sea levels. Continued experimentation with horticulture using local cultigens is inferred for this time, though evidence for such activity is rarely preserved.

The sometimes-elaborate burial ceremonialism of the Late Archaic and Early Woodland periods is rarely seen during this millennium. The reasons for this are not clear. Contacts with neighboring areas are still thought to be important, as exotic lithics are frequently used throughout most of the Northeast. In fact, a significant amount of non-local lithic materials were

utilized in the Middle Woodland, in contrast to the almost exclusive use of quartz and other locals in the preceding period. This may indicate an expanding trade network.

In Boston Harbor, Middle Woodland sites are recognized on Bumpkin (19-PL-6) and Grape Islands (19-NF-3, 4, 5) (Luedtke 1976), Long Island (19-SU-39, 55) (Ritchie et al. 1984), Spectacle Island (19-SU-38) (Edens and Kingsley 1998), Peddocks Island (19-PL-5) (Dincauze 1973), and at numerous sites on Thompson Island (Luedtke 1996).

The **Late Woodland Period (1000-450 B.P.)** represents the end of a period of at least 11-13,000 years in which Native Americans dominated the Boston landscape. It is during this and the preceding period that the pattern of settlement witnessed by the first European explorers became established. Also during this time, horticulture, including exotic domesticates such as corn and beans, became a widespread and occasionally important dietary element. There is more evidence of permanent settlements, or at least locations that were used for much of the year, especially on the coasts (Carlson 1986; Yesner 1988). It has traditionally been assumed, in part due to the early historic descriptions, that permanent settlement became widespread as a result of a dependence on corn. However, corn is infrequently found at sites in New England, despite all efforts to recover evidence for its use (Bumstead 1980; Thomas 1991). A more likely interpretation for the trend toward more permanent settlements is an increase in population, territoriality, and conflict.

In many parts of the Northeast, subsistence and settlement continued to be based on a hunting/gathering/fishing system with seasonally based camps. Corn remains are found at a number of Late Woodland sites, but in small amounts (as in Luedtke 1980; Dunford 1992). Deer, rabbit, birds, and sea mammals were hunted, while fish and shellfish were taken, and a wide variety of plants and vegetables were collected. The growing population levels may have in part prompted some to turn to horticulture to relieve a decreasing degree of flexibility in food sources. Other mechanisms adopted included using more marginal areas and expanding the variety of foods to include what had previously been considered less desirable resources (Luedtke 1980; Lightfoot 1985).

Less is known about Late Woodland religious beliefs than in the earlier phases of this period. While burials are still found from this time, the ceremonialism attached to human remains seems to have waned by about 1,000 years ago. Burials are often unadorned, and sometimes include many individuals. Grave goods are not commonly found, but sometimes do occur in small numbers. Why the decrease in burial ceremonialism occurred is unclear.

In Boston Harbor, the Late Woodland period is the most well-documented of any of the Native American cultural historical periods. Sites have been recorded for Gallops, Grape, Bumpkin, and Calf Islands (Luedtke 1975); Peddocks Island (Casjens 1976; Dincauze 1973; Braun 1972); Long Island (Luedtke 1987; Ritchie et al. 1984); Spectacle Island (Edens and Kingsley 1998); and Thompson Island (Luedtke 1996).

During the Late Woodland period, the ethnic identities encountered by European explorers came into full form. In New York state, the Iroquois and Mohawks established their territories and core areas of settlement, including some permanent villages. In southern New England, the Pawtuckets, Nipmucks, Massachusetts, Wampanoags, Pequots, Nehantics, Mahicans, and other groups came into form, with each group developing relationships with particular geographic areas. Most of these ethnic groups or nations were composed of smaller

tribal entities that were based around a permanent meeting place or village. Trade routes and patterns of conflict between these groups also became established.

The end of the pre-Contact Native American era is marked by the arrival of Europeans in the Northeast. The end of the Woodland period is thus somewhat varied, depending upon the exact area considered. European contacts with the area began at the very end of the fifteenth century, with Italian, Portuguese, and French explorers reaching coastal locations by the year 1500. In some cases, interior areas of New England were not contacted directly for many years following this date.

Native Americans of Southeastern New England in the Contact Period. The end of the Native American era (*Contact period*) is defined by the arrival (and domination) of Europeans along the eastern United States and their interaction and exploitation of Native American people. Contacts with Europeans began at the end of the fifteenth century. These poorly documented visits began with Portuguese, French, and Italian explorers reaching Northeast coastal locations by the year 1500. Most of the contacts were confined to the coast, with interior locations left unhindered for generations. Bringing with them the implements of new technologies, the Europeans unfortunately also brought diseases, against which the Native people had inadequate immunity.

At the time of the first European arrival in the area, the southeastern part of New England was inhabited by speakers of the Massachusett language. The Massachusetts included two major subgroups: the Massachusetts, who lived in the area around Boston Harbor; and the Wampanoags, who occupied most of the southeastern part of the state, including all of Plymouth County and Cape Cod (Simmons 1986; Bragdon 1996). To the north and northwest of the Massachusetts were the Pawtuckets (or Pennacooks) and Nipmucks, while to the west were the Narragansetts and Pequots. Divisions among and between these groupings, too, were fluid. All of these peoples, including the Massachusetts, were part of a larger group of tribes known as the Eastern Algonquians. All Algonquians spoke related languages, which differed from the Iroquoian languages prevalent in New York State and southern Canada (see Goddard 1978). The Massachusetts were most closely related to the Wampanoags, who were their traditional allies. The Massachusetts were reportedly in frequent conflict with the Narragansetts (Gookin 1972:9).

The Massachusetts were composed of a number of subgroups, all of which spoke a mutually intelligible language, although with some dialectical differences. The boundaries of the subgroups appear to have been indefinite, but were probably based on natural geographical boundaries. One of these subgroups was located at present-day Weymouth, which was known as Wessaguscus or Wessagusset (Kevitt 1981:1). Others were situated on the Mystic River, Nonantum (Newton), Shawmut (Boston), and Neponset (Grumet 1995:110). It is estimated that, prior to the influx of European diseases, the total Massachusetts population was in the tens of thousands (Grumet 1995:110). By the middle part of the seventeenth century, that number had certainly dropped by about 90 percent, due primarily to a number of devastating epidemics (Spiess and Spiess 1987; Carlson et al. 1992).

Massachusett subgroups were composed of a number of political units referred to by historic sources as sachemships. This comes from the word sachem, which was a standardization of the various dialectical versions (*sontim*, *sachim*, *saunchem*, *sagamore*) of the Proto-Algonquian *sa-kima-wa, meaning chief (Goddard and Bragdon 1988:2). The sachemship

consisted of the sachem and his family; the chief men, who formed a council, and their high-ranking families; common people; and others about which little is known (Bragdon 1996:140-143). The sachem was usually male, and a member of a privileged family or lineage. Early sources stress that social status was inherited, and the position of sachem was passed down along male lines, although not necessarily directly from father to son (Simmons and Aubin 1975:24). Personal ability certainly must have influenced the pattern of leadership, perhaps deciding to whom the title would pass among male family members. Chief men and their families also inherited their positions, which required them to advise the sachem, who in turn needed their consent to make his wishes binding (Goddard and Bragdon 1988:3). Common people also inherited their membership in the sachemship, naturally owing allegiance to their respective leaders, who represented their land and their ancestors, and who would make decisions affecting their descendants. The consent of the people was needed by the council and sachem regarding important matters, such as warfare and matters of the land (Simmons 1986:13).

There are some elements of Massachusett society that are not clearly understood. Slaves and servants were reportedly a part of the culture, but little is known about these people (Mayhew 1694:9; Williams 1936:5). Some specialized roles have also been identified, such as military leaders (Trumbull 1903:67) and tribute collectors (Winslow 1624:55,57), but little is known of these positions (Bragdon 1996:143).

Sachemships were associated with specific geographic locations, known to all area sachems and their followers, for which the individual sachemships were often named. Martha's Vineyard, for instance, was reportedly divided into four sachemships, located at Chappaquiddick, Gayhead, Nunnepog, and Takemmeh (Bragdon 1981:129). Nantucket consisted of two sachemships, one on the east side of the island and one on the west (Simmons 1986:12). Sachemships were, apparently, also subdivided into sub-sachemships, providing for three levels (subgroup, sachemship, sub-sachemship) of political organization within the Massachusett territory. Unfortunately, it is not clear how the different levels were coordinated politically. Descriptions of grand sachems, who claimed jurisdiction over several sachemships, probably corresponded to the subgroup category. Who led sub-sachemships, and how they were impacted by, and in turn affected, leadership at the full sachem level is unknown. The fluid nature of Massachusett territory and political leadership, undoubtedly exacerbated by the radical changes impacting Native communities in the seventeenth century, is the main source of confusion in the historic descriptions of Massachusett society and territories, with none of the Native political units conforming to the European concepts of bounded village lands.

The Massachusett were semi-sedentary horticulturalists, who relied heavily on cultigens such as corn, beans, and squash, as well as wild plants and game, and sea resources (see Bragdon 1996). Families lived in circular houses known as wigwams, constructed with poles bound inward and covered with bark or mats. People slept on platforms or on mats, blankets, or furs on the ground, next to the fire. Early historic reports indicate that the people spent part of each year, probably from late spring to early autumn, in dispersed settlements along the coast, growing and processing food that could be stored for the colder months. During the winter, people aggregated at protected inland locations where fishing and hunting could be profitable (see Little 1988 for discussion). Some permanent coastal settlements may have also existed (McManamon 1984:40). Several historic Contact period sites are recorded on the Boston Harbor Islands. Trade was well established along ancient routes, in manufactured goods such as steatite vessels and pipes,

wooden bowls and spoons, clothing, and raw materials like shell and copper (Bragdon 1981:2).

Previous Archaeological Research

The history of Boston and the islands of Boston Harbor have been well documented in the literature (for example, see Adams 1880; Mikal 1973; Shurtleff 1891; Snow 1936, 1941, 1944, 1971; Stark 1879; Whitehill and Kennedy 2000). The Boston Harbor Islands also have been the focus of archaeological research for the past two decades, particularly through the effort of Dr. Barbara Leudtke and Lawrence Kaplan of the University of Massachusetts in Boston. Recently cultural resource management efforts have increased in response to improvements of the islands for recreational and management purposes.

Dena Dincauze conducted a study of islands managed by DEM in 1969-1972, which included the salvage of a human burial and two cremations (Dincauze 1973). Another such survey was undertaken by Barbara Luedtke in 1974 (Luedtke 1975), which included an archaeological and paleobotanical analysis of twelve of the islands. Luedtke later produced more detailed analyses of Grape Island (Luedtke 1976), Calf Island (Luedtke 1980), Long Island (Luedtke 1987), and Thompson Island (Luedtke 1996), and summarized her work in the harbor (Luedtke 2000). One other project was conducted on Thompson Island (Cook 1993). Research on Peddocks Island has included a testing program (Braun 1972) and a survey (Casjens 1976). Excavations on Spectacle Island have focused on a shell midden site primarily dating to the Woodland Period (Jones 1988; McHargue 1996; Edens and Kingsley 98).

The construction of the Deer Island wastewater treatment facility led to the completion of six surveys (Randall 1981; Ritchie et al 1984; Ritchie and King 1986; King 1987a, 1987b; King and Miller 1994). Other proposed construction led to surveys on Gallops, Georges, Grape and Bumpkin Islands (Dudek 1996, 2000; Stokinger 1998; Donta 2001), and additional work on Long and Spectacle Islands (Pendery 1992; Hasenstab and Mohler 1999). Two archaeological projects were conducted on Georges Island (Fahey 1977, Donta 2001).

In 1985, a National Register nomination was accepted by the National Park Service. The nomination was based on archaeological research conducted by Dincauze, Braun, Luedtke, and others. The area is now listed as the Boston Harbor Archaeological District. The research for the nomination did not include archaeological excavation, but did summarize archaeological knowledge of the Harbor and its known resources at the time, which included 34 Native American sites (MHC site files).

More than 60 Native American sites are recorded on the Boston Harbor Islands (Luedtke 2000). These sites range in age over at least 8,000 years, from the Early Archaic through the Late Woodland Periods. Sites of the preceding Paleoindian Period have not yet been found on the islands, but may exist, considering such sites are known in several locations in eastern Massachusetts (Carty and Spiess 1992). During the Paleoindian period, Boston Harbor was a part of the coastal plain and the coastline was some 13 kilometers from Castle Island. Most sites in the Harbor date from the past 2,000 years. This is most likely the result of sea level changes, and the erosion of older sites, but is also partially a product of population growth. Most of the sites that pre-date 2,000 years ago are now inundated. Many sites on the islands include middens, but not all sites have middens. Sites on the islands probably were occupied as temporary camps,

where a wide variety of animals were taken, similar to sites on the mainland. More recent sites, after AD 1200, usually are located adjacent to soils suitable for horticulture, or are on the smaller outer islands (Luedtke 2000).

Archaeological surveys conducted to date have covered substantial portions of the large islands, but must still be considered incomplete. Most surveys have focused on identifying eroding shell middens, the most obvious types of sites, but have not systematically tested below the surface. As Luedtke has cautioned, many sites on the islands do not contain shell middens, and therefore many sites have likely not yet been found.

Historic archaeology is poorly represented in the Harbor, despite the presence of a wide variety of interesting and significant historic sites spanning a nearly 400-year period. Historic sites include farmsteads, military installations, hospitals, pest houses, estates and summer homes, yet only a small number of specifically historic projects have been conducted. Surveys include a small metal-detector survey on Georges Island (Fahey 1977), a more comprehensive survey of Thompson Island (Cook 1993), investigations at the Deer Island House of Corrections Cemetery (King 1987a, 1987b), a study of a military installation on Gallops Island, and a survey of Rainsford Island by the Boston Historic Landmarks Commission. Other projects have considered some of the abundant historic resources, but have completed only limited testing (see Donta 2001). Important research topics that should be addressed include the early settlement of the islands, the development of military fortifications, and the role of multiple ethnic groups in the history of the islands.

Potential for Native American Sites in the Proposed Project Corridor

During the Paleoindian and Early Archaic periods in the region, all of the harbor was land (Figure 5). This area would have been dotted with streams, wetlands and ponds bordered by well-drained terraces suitable for Native site location. Of particular interest would have been the ancestral Charles River drainage which roughly follows the modern Boston Harbor shipping channel. Earlier shipping channel improvement projects took advantage of this ancient stream channel. Dredging deepened and improved the channel for vessel use.

By the Middle Archaic period (8,000 to 6,000), the land mass was similar to that of earlier periods. The ancient river channel divided near the coastline near Great Brewster Island (Figures 6 and 7). At this time remnant Middle Archaic sites on the Islands were located on Spectacle Island, Long Island and Grape Island.

By 6,000 years ago (Figure 8), remnant island landforms existed adjacent to the eastern end of North Channel. The group of modern Islands known as Green, Little Calf, Calf, Middle Brewster, Great Brewster and Outer Brewster were all contained within a large landmass.

During the Late Archaic period (Figure 9) the harbor area was began to appear similar to its modern configuration, but with most of the islands much larger in size. Native American sites occupying the coastal portions of the islands are now inundated. Spectacle and Long Islands were much larger land masses that protruded north to the edge of the modern shipping channel. The highest density of sites from this period were located on Thompson and Peddocks Islands. Peddocks Island and the Hull peninsula were two to three times their modern size.

By the Woodland period (3,000 to 400 years ago) the landscape of the harbor and its islands was very similar to that of today. Most islands were slightly larger in size, and many such as Long Island and the Brewsters were connected by land bridges (Figure 10).

Native American sites that were in areas where they could be protected by wind (e.g. in the lee of islands and barrier beaches) or deeply buried in alluvium as along the ancient Charles River and smaller streams could have survived the ravages of a transgression post-glacial sea. It is predicted that many lie as yet undetected within the harbor.

Any portion of the project area in proximity to an ancient water body (rivers, lakes, streams, etc.); less than 22m (72 feet) in depth; on level to slightly sloping ground; on soils that would have been well-drained (especially glacial outwash soils); in the vicinity of sources of lithic raw materials; and that have not been destroyed by oceanic transgression; could have been the location of Native American sites.

Patterns of Known Native American Sites on Land Near the Project Area

Sites in the Vicinity of Boston Harbor. An examination of the archaeological site files was conducted at the Massachusetts Historical Commission in Boston and at the University of Massachusetts at Amherst. Several archaeological sites are recorded within the modern coastal margin and islands near the project area. No Native American archaeological sites are on record within the project area. This is more a product of the dearth of professional archaeological surveys in offshore areas, than a real low frequency Native presence. Numerous terrestrial sites are located in the vicinity that are in similar environmental conditions to the pre-transgressional project area.

In the coastal area of Boston Harbor near the project area, 52 Native American sites (comprised of 72 recorded temporal components) were reviewed in the literature and archaeological site records. Many of the sites could not be attributed to a time of occupation. Of the 72 components, 51 were attributed to a cultural historical time period (Table 1).

Middle Archaic Sites (8,000 to 6,000 years ago). The earliest sites in the area date to the Middle Archaic period (8,000 to 6,000 years ago). There are three sites of this period in the immediate vicinity of the project. Site 19-SU-038 is located on Spectacle Island and is a small shell midden. Site 19-NF-006 is in the town of Weymouth on Grape Island. A Neville projectile point was found. Components of other time periods were found at the site as well. Site 19-SU-017 was recorded at Thompson in Boston. Only temporal periods are on record. All three of the sites are associated with wetlands. Two of the Middle Archaic sites are on wetlands.

Late Archaic Period Sites (6,000 to 3,000 years ago). Ten sites are on record that date to the Late Archaic period. Site 19-PL-003 is a shell heap situated on a pond on Peddocks Island in Hingham. Artifacts include Squibnocket Triangle (4,000 to 5,400 years ago), Atlantic (2,700 to 3,900 years ago), Wading River (3,800 to 4,140 years ago) projectile points. Site 19-PL-005 is also located in Hingham on Peddocks Island. Situated on West Head Pond the site contained Atlantic points. Site 19-NF-006 is located in Weymouth on Grape Island. This multi-component site is situated on a wetland. Artifacts included small stemmed points. Site 19-NF-007 is situated on a wetland on adjacent to the Grape Island sandbar. Late Archaic artifacts included a small stemmed point. Sites 19-SU-051, 72 and 73 are located in Boston on Thompson Island and contained small stemmed points. Site 19-SU-017 is also located on Thompson. Only the cultural period is listed for this site. Site 19-NF-004 on Grape Island, Weymouth, contained small stemmed points, lithic flakes, pestles, hammerstones and faunal remains. Three Late Archaic sites are on ponds, four are on wetlands.

Early Woodland Period sites (3,000 to 2,000 years ago). Five Early Woodland sites are recorded near the project area. Site 19-PL-003 on Peddocks Island contained unspecified points from this time period. Site 19-PL-005 on Peddocks Island in Hingham is situated on West Head Pond. Unspecified Early Woodland points are recorded. Sites 19-SU-017, 069 and 075 are located in Boston on Thompson Island. Only the Early Woodland period is recorded. Two Early Woodland sites are on ponds, three are on wetlands.

Middle Woodland Period Sites (2,000 to 1,000 years ago). Nine Middle Woodland sites are on record near the project area. Site 19-PL-005 is situated on a pond on Peddocks Island. Site 19-NF-005 yielded a radiocarbon date of 950 BP and neighboring site 19-NF-006 contained a Jack's Reef component. The Sumac Grove site (19-NF-003) on Grape Island, Weymouth also contained a Jacks Reef component. Site 19-NF-006 on Grape Island contained a Jacks Reef component. Site 19-NF-006 is located on Bumpkin Island in Hingham and contained shell and grit tempered pottery. Sites 19-SU-075 on Thompson Island contained a Jacks Reef component. Sites 19-SU-033 and 069 contained grit and shell tempered pottery. Site 19-SU-017 is recorded as having been occupied during this period. Five Middle Woodland sites are associated with wetlands and one with a pond.

Late Woodland Period Sites (1,000 to 400 years ago). Fourteen Late Woodland sites are recorded near the project area. Site 19-SU-038 on Spectacle Island contained a small shell heap dating to the Late Woodland period. Site 19-SU-009 is a shell midden located on Gallops Island. From the midden; seeds; hickory shell; mammal, bird and fish bone, lithic flakes, a postmold, and ceramics were recovered from the site. Site 19-SU-008 on Calf Island, Boston, contained ground stone grooved axes, flakes, netsinkers, bifaces a perforator tip and ceramics. Radiocarbon dates dating to the Late Woodland period include 510+/-145, 685+/-135, 860+/-115 and 880+/-165. The Bass Point Site (19-SU-055), a shell midden, is located on Long Island, Boston. The site contained lithic cores, scrapers, a Levanna projectile point (400 to 1600 years ago), ceramics and a ground stone pestle. Site 19-SU-038 is a small shell heap recorded as a Late Woodland component, situated on Spectacle Island, Boston. Site 19-PL-004 on Peddocks Island, Hingham contained fire-cracked rock, jasper, quartz and rhyolite flakes, as well as a Levanna projectile point. On Grape Island, Weymouth, site 19-NF-005 contained a Levanna point, and site 19-NF-006 contained a large triangle. Unspecified Late Woodland materials are recorded for Grape Island sandbar site 19-NF-007. Site 19-PL-006 on Bumpkin Island contained Late Woodland shell and grit tempered pottery. Sites 19-SU-033, 069 and 075 on Thompson Island all contained Late Woodland ceramics. Site 19-SU-017 is recorded as having been occupied during the Late Woodland period.

General Woodland period (3,000 to 400 years ago). In ten sites unspecified ceramics are recorded. Ceramic technology was introduced to Northeast Native people in the Early Woodland period. Thus unspecified ceramics could date to any of the three Woodland period subdivisions. There are five sites near the project area that contained unspecified ceramics. Site 19-SU-010 dates to this period. The Hill site (19-SU-056) and the Marsh Locus #4 site (19-SU-053) contained lithic flakes, and shell-tempered incised pottery. Site 19-NF-004 on Grape Island, Weymouth, contained grit-tempered pottery, lithic flakes, pestles, hammerstones and faunal remains.Site 19-NF-008 on Grape Island is recorded as having been occupied during the period with no specified artifacts. Thompson Island sites 19-SU-074, 066, 067, 068 all contained

ceramics. Site 19-SU-031 on Thompson Island contained a side-notched point and ceramics. Seven Late Woodland sites abut wetlands.

Contact/Historic Period (400 years ago). Two Contact/Historic period sites are on record within the islands. They include 19-SU-010 on Long Island. Willoughby recorded documentary evidence that the Natick Indians lived at this site. A Contact Period human burial is recorded for site 19-SU-018, in Boston's Savin Hill Park. Water source associations are not available for these sites.

Undated Sites. There are fourteen undated sites in Boston Harbor. These sites are located on Grape, Calf, Great Brewster, Long, Bumpkin, Thompson Islands, Worlds End, Houghs Neck and Merrymount Park in Quincy, and Allerton Hill in Hull. Four sites abut wetlands and one abuts a pond.

Common Environmental Characteristics. Sites located along the coast and islands of Boston Harbor are predominantly located adjacent to small wetlands and ponds. No streams are indicated because most of the sites are on the islands where the common water sources (if any) are wetlands and seeps. Twenty sites in Boston Harbor are associated with wetlands as well as the harbor. Four are associated with ponds. Most of the sites are located on well-drained terrace soils adjacent to a water body. Thus, in offshore contexts, remnants of small ponds and wetlands, as well as small streams, especially those at confluences with bordering level terrain, have a high potential to contain Native American sites.

Pertinent Post-Contact Historic Context of the Region

In the late fifteenth and throughout the sixteenth centuries various European explorers sailed along the North American coast seeking a water passage to the Far East. Giovanni da Verrazanno first sailed through and described the study area to Europeans in 1524, but no Europeans permanently settled in the region until after John Smith carefully explored and mapped the area in 1614.

After Europeans settled in the study area in the 1620s, they quickly grew in number, thereby increasing the use of Massachusetts and Cape Cod Bays. By 1640, 35,000 people resided in Massachusetts. In the first half of the seventeenth century, settlers established fishing and timber businesses for regional and transatlantic commerce. The collection of natural harbors, such as Salem and Weymouth, provided havens for inshore and offshore fishing vessels. The crews fished for cod, mackerel, haddock and other species and brought their catch to port for processing and sale. They would split and store the cod on salt in the ship or salt-dry the cod on stages and flakes set up on the slopes at the villages' shores (Lawson, 1895, 111-115 and Reynolds, 1856). Many types of historic vessels were used for fishing in the study area, including 1600s and 1700s shallops, ketches, pinkies, and schooners, plus 1800s schooners, Chebacco boats, and jiggers (Lawson, 1895; Reynolds, 1856). In the early 1800s, Jefferson's Embargo, the War of 1812, and other economic factors hurt the area's fishing industry. Some area ports continued to be mainly fishing towns, yet others slowly changed their financial interests.

Development of the land varied within Boston Harbor. Early European explorers mapped the harbor with its many islands, and early English settlers lived on the islands or used them for

timber and animal grazing. As they were close to the channel into Boston, the islands and associated rocks were both a danger and help to mariners. Some ships inadvertently were driven onto the islands and ledges in poor visibility or adverse winds. Yet the islands were bases for lighthouses, channel markers, and rescue teams and they were dry refuges for shipwrecked mariners. The islands also served as bases for defense forts and observation posts during times of war.

When it was part of the English (British after 1707) Empire, Boston attracted shipping of small, medium, and large vessels. Inter-colonial trade brought in boats and ships from surrounding towns and other colonies. The use of Boston by the British military and government agencies (customs, mail, etc.) encouraged its use by most ships coming to the region (Figures 13 and 14). During the eighteenth century, the population, business, and therefore shipping in the Boston Harbor area increased slowly. Shipping data for 1770 show Boston in second place behind Philadelphia, its major shipping rival in America, and just ahead of Charleston and New York. In that year Boston's total shipping was 38,000 tons of cargo (Albion 1939:5).

Boston continued to be the focus of local, coastal, and oceanic shipping, especially as its inhabitants aggressively improved the waterfront. However, there were also many boats that shuttled between other local ports without radiating from Boston. Almost all people in early Massachusetts relied heavily on commercial salt-water transportation. With no practical coastal roads, most transportation of goods, supplies, people, live stock, and written communications between Massachusetts towns were conveyed by sail or oar-powered boats. Similarly, the only means of transportation and communications with England was by sailing ships through the study area. This condition continued through the mid-nineteenth century.

Boston also continued to be a large population center and an important commercial market for fish, though it was farther from the fishing grounds and its harbor entrance was more hazardous for sailing vessels than smaller towns like Salem and Provincetown. Railroad connections between these fishing towns and Boston reinforced the dispersed nature of the industry. However, when in the late 1800s and early 1900s engines were used for propulsion on many fishing boats and the new, safer channels were established in northern Boston Harbor, many fishermen began to shift their landings to Boston. Throughout the twentieth century the neighboring towns lost more of their fishing industry and Boston grew as one of the most important fish terminals in the region.

The 1800s saw a dramatic change in the settlement and business patterns of the Boston Harbor region. Because of a continued and increased competitive approach to trade, successful trade innovations, canals, the affects of federal immigration regulations, and a continued social flexibility, Boston quickly grew and continued to be not only the regional center, but also one of the largest and economically most successful cities in America. The surrounding counties of Massachusetts expanded along with Boston, though generally not as quickly. Population and industry, and therefore local shipping increased throughout the nineteenth century.

In the mid-eighteenth century water transportation patterns changed. Steam power changed the routes of many transoceanic and coastal vessels moving through Massachusetts Bay. Boston continued to be the commercial *entrepot* of New England with a general increase in shipping tons through the centuries; even when the new railroads and better wagon roads competed for coastal traffic. Telegraph wires, including underwater cables, began to carry additional communications, but much mail continued to move by ship.

Until the early twentieth century, many of these vessels were lost to storms, internal accidents, navigation errors, and winds and currents driving them ashore. The latter two situations were the cause of most of the vessel losses. With the twentieth century came more reliable power to move out of harm's way, better aids to navigation, onboard radios to call for assistance, and radio-dispatched tugs to help. The rate of losses therefore dropped significantly in the twentieth century.

Context for Historic Period Shipwrecks

Many historic shipwreck sites are known to exist in Boston Harbor. The number of vessel losses revealed in this historic background study is obviously smaller than the total losses that would be located with a more exhaustive study. However, the results are indicative of a large number of probable shipwreck sites in the study area. The lack of complete recorded evidence is typical for any locality along the New England shores. Until recently the loss of a vessel, even with the loss of life, was not considered newsworthy enough for the ubiquitous four-page weekly newspaper in the 1700s and 1800s. State and federal government compilations of vessel losses, which are incomplete, date only from the very late 1800s.

In addition to those vessels recorded in the historical records, we must assume many others were lost in Boston Harbor and not recorded. Before radios and radar, vessels were surely lost with all hands on the numerous ledges in the area during storms and fogs. Many lost vessels are simply recorded as missing at sea, whether they had just left the harbor, were returning after a long voyage, or were blown in while trying to sail past the shore. Their actual fate could be revealed only through efforts of underwater archaeologists. Such vessels would include small and large fishing boats, coasters, transoceanic merchantmen, and warships.

Because we know so little of the early vessels, the people who made and used them, the onboard fishing processes, and life aboard the early merchant vessels, the remains of any historic ship or boat would be archaeologically and historically significant on a local, regional, and national level. Historic shipwreck sites in New England are sources that provide archaeologists with information about shipping, vessel construction, lifeways of mariners, and about early terrestrial life in New England.

Locating the remains of small commercial and fishing vessels with remote sensing requires a precise survey. Many vessels lack the iron required for remote detection. Warships, and larger merchantmen sailing to dangerous places, typically carried many iron guns and a large quantity of iron shot. The iron disturbs the earth's magnetic field and usually can be detected with a magnetometer survey. Most of the vessels which might have been lost in the study area would have had few, if any, large guns or ammunition. However, many had iron anchors and sometimes small iron guns which produce smaller anomalies in the earth's magnetic field. Therefore, they can only be detected with a careful and precise remote sensing survey.

In the last half of the nineteenth and early twentieth century, major changes took place in shipping that would affect the number and size of boats and ships lost throughout the United States and especially the Boston Harbor region. This period saw the introduction of important technical and safety innovations that allowed seamen to keep their vessels afloat. Engine power rather than sail and oar, made near-shore voyages much safer. First tug boats, then internal

engines could move a vessel away from danger while a wind or current tried to move it toward destruction against rocks, shore, shallows, or other vessels. Navigation aids along the sides of channels, buoys and beacons at dangerous shoals, on-shore ranges to guide ships, dredging to improve channels, and electric navigation lights on vessels all helped small and large vessels navigate through the busy harbor. The use of wireless telegraphy and eventually radios helped crews call for assistance when out of sight and communicate among themselves to avoid collisions and pass information about dangers. Additional help came from the various federal agencies, such as U.S. Life Saving Service, Revenue Service, and eventually the Coast Guard that actively searched for and assisted vessels in distress.

Throughout modern history the average size and strength of vessels has increased. This was especially true in the last two centuries as iron and steel were used first to replace wood frames and knees, then almost every part of the vessels. Steel's strength, especially when used for a vessel's skin, allowed a higher percentage of boats and ships to survive accidents such as running aground. Steel construction and engines also allowed much larger ships to be safe and economical so that more tonnage from a port could be carried in fewer vessels. Even with an increase in population and trade, fewer and safer boats, barges, and ships have produced many fewer commercial shipwrecks in the past century. The amount of steel and iron on vessels make them easier to locate.

All of the potentially significant historic-period sites that might be found in the proposed dredging project are predicted to be water vessels and their contents. Because Boston Harbor has attracted almost all types of ships, boats, and barges through the centuries, the remains of any type of vessel used in the Atlantic in the past four centuries could be found. There is no complete listing of shipwreck sites for the Boston region; however, even incomplete compilations of shipwreck sites from historic records reveal a plethora of types, sizes, and cargoes lost in the Boston Harbor area.

Almost all recorded shipwrecks are large, transoceanic and coastal ships because until the late nineteenth century most news media, government personnel, and modern researchers have been primarily interested in larger vessels. Therefore, one must assume the area has the potential to include the remains of other, smaller vessels as well. The remains of pre-twentieth century small oceanic and coastal vessels would be particularly significant due to their archaeologically important cargoes and hulls. However, the vessels typically did not carry large amounts of iron armament, and some of these vessels may have carried no guns at all, thereby reducing the probability of locating the wrecks with a marine magnetometer. Therefore, when analyzing the remote sensing data, one must consider that even relatively small magnetic anomalies, especially ones with some side scan sonar signature, must be considered possible significant cultural remains unless one can eliminate them from consideration because there is good evidence they are modern debris.

Given the considerable historical activity in Boston Harbor, it was predicted at the outset of this study that the remains of ships and other vessels could be found in the project area.

RESULTS OF THE REMOTE SENSING AND RECONNAISSANCE SURVEY

Remote Sensing Methods

The number of historic shipwrecks found and implied by historical research indicated that there was a possibility that dredging operations would impact or come close to historic shipwreck sites. Thus, a remote sensing survey was requested by the USACE.

To accomplish the survey, Dr. Warren Riess conducted the field survey with an OSI crew that included a geophysicist and navigation/electrical technician (Appendix A). OSI provided a survey vessel, a DGPS horizontal positioning and navigation system, magnetometer, side scan sonar, subbottom profiler, and depth sounder. A full description of the planned survey, including description of vessel, equipment, procedures, planned tracklines, schedule, contingency plans, and personnel, is presented in OSI's Field Sampling Plan.

On site fieldwork was completed in two sessions: September 25-October 7, 2002 and February 6- 9, 2003.

Survey Vessel, Navigation, and Horizontal Control

Vessel and Navigation. Field operations were conducted off the survey vessel *Parker Sport*, a 26-foot OSI boat specifically built for geophysical and archaeological surveys (Figure 15). A Trimble DSM-212 Differential Global Positioning System (DGPS) interfaced with OSI's Maretrack II PC-based navigational software package was used to position the vessel during all data collection. Differential correctors, used to increase vessel position accuracy to ± 1 meter, were received via a radio link to a U.S. Coast Guard beacon transmitter. The geodetic positions derived from the DGPS system were converted to the Massachusetts Plane Coordinate system (NAD83) for survey operations and preparation of final products.

The Maretrack II navigation system was used for positioning directions to the helm. The navigation system received geodetic position data every second and converted these data into x-y grid coordinates in the specified plane coordinate system.

Remote Sensing Equipment

In addition to the navigation system, equipment installed on the survey vessel and used to complete the investigation included:

Innerspace Model 448 digital depth sounder (200 kHz.);

Benthos SIS-1500 high resolution chirp technology side scan sonar system, operating at a central "swept" frequency of 200 kHz;

Edgetech Geo-Star "CHIRP" subbottom profiling system (2-16 kHz.);

Geometrics Model G-881 Cesium Vapor Magnetometer;

TSS DMS2-05 Heave, Pitch, Roll Sensor;

KVH Digital Compass.

All instruments displayed and recorded data on each run. Tracklines were spaced 50 feet apart in all areas. This provided 100 percent coverage with the magnetometer, 200 percent coverage with side scan sonar, and sufficient coverage with the subbottom profiler. The field team completed all planned survey and tie lines.

In order to obtain the best data, the survey team attempted to keep the magnetometer sensor at an altitude of 25 feet above the bottom, with a maximum of 35 feet altitude.

Remote Sensing Data Analysis

After field acquisition, the navigational data were used to create post-plots of the actual track lines. The remote sensing data then were analyzed, adjusting for the magnetometer and side scan offset and layback. In order to determine the presence of any possible significant cultural resources that should be avoided or inspected, the geophysicist and archaeologist compared all original magnetic, side scan, and subbottom profiler data. Every possible magnetic anomaly or sonar target was cross-referenced with the other data for proper analysis, including field notes to eliminate modern targets such as shoreline debris, navigation buoys, and passing ships and boats.

In most areas the quality of the magnetic data allowed even small ferrous objects to be seen as anomalies in the field. Therefore, side scan targets without corresponding magnetic anomalies were not considered possible significant cultural remains, because even small colonial shipwreck sites would contain at least enough ferrous material to produce a small magnetic anomaly. Because the flux, measured in gammas, of an anomaly's field falls off with the cube of the distance from an object, it is important to set a standard strength at a standard distance. Using a most-significant example, a typical cannon, large anchor, or shot locker from a seventeenth-century shipwreck might set up a shift in the earth's magnetic field that at 25 feet would be sensed as a 10-gamma anomaly on a magnetometer. Therefore, to compile a list of targets, all magnetic anomalies of 10 gammas or more at a magnetometer altitude of 25 feet were considered to be possible cultural resources (PCR's). The expected strength of field was adjusted for the magnetometer's altitude, so that in shallow water, when the magnetometer would be close to any iron object on the sea floor, only larger anomalies were considered. For example, if the magnetometer sensor's altitude was 16 feet, only monopole anomalies of 20 gammas or greater, or dipole anomalies of 40 gammas or greater were considered. When the magnetometer was higher than 25 feet smaller anomalies were listed.

A first consideration of the magnetic data discerned 187 anomalies. Subsequently, at the location of each magnetic anomaly, the archaeological analysis team reviewed the nature of the magnetometer data, depth data, magnetometer data from adjacent tracklines, the side scan and subbottom data from the nearest two tracklines that included sonar, field notes, and chart information. The team was able to eliminate most of the anomalies from being PCR's because of

subbottom data showing geological changes that would cause such an anomaly in the magnetic field; side scan data showing probable fishing traps, scrap cable, modern building material, and navigation buoys; and field notes and chart information that include passing steel vessels, cable crossings, navigation buoys, etc. They eliminated other groups of anomalies that appeared to be cables or pipelines crossing the route.

When considering possible cultural resources within maintained channels, one must consider that in other areas of the United States a small number of shipwreck sites have been located in previously dredged areas. Archaeologists have assumed that in the past a dredging contractor may have left a found shipwreck in place without notifying authorities, rather than deal with its problems. When such a site has been located with remote sensing it not only causes a magnetic anomaly, but also includes a shallow mound that can be observed on the side scan records—the mound left after the surrounding area was dredged. Almost all segments of the project are within maintained channels, therefore many of the magnetometer anomalies were within maintained channels. During analysis, the side scan records were carefully scrutinized at each of these anomalies and those anomalies where the channel bottom was even, without any mound, were deemed caused by modern debris deposited after dredging operations. The only exceptions to this elimination process were those anomalies that were in naturally deep areas of a maintained channel that never had to be dredged, such as near President Roads, where the water is deeper than the required 45 feet.

Results of the Analysis for Shipwrecks

Background Research. The literature research for shipwrecks near the project areas yielded 93 shipwrecks that are, or could be, within a mile of the project. None of the wrecks had a location listed specifically in the proposed dredging areas, and many were listed in the general area, such as in "Boston Harbor." Some of the reported wrecks, especially those that ran ashore or on ledges, may have been refloated or completely salvaged shortly after their demise. Some or none of the reported wrecks' remains could be in the proposed project.

From the remote sensing data for the entire planned route, including the Mystic River area, the archaeology team identified only three targets that are interpreted as potential cultural resources (Table 2; Figure 16). All of the three targets produced magnetic anomalies, indicating the presence of ferrous objects, and they also have a corresponding side scan sonar image indicating shallow mounding above the channel bottom. The three anomalies are within 200 feet of each other, near Fort Independence on Castle Island, at the approximate location of a shipwreck symbol on NOAA navigation chart 13270.

None of the three targets is easily discernable as an obvious historically significant shipwreck or other significant site, however any of the anomalies could indicate the presence of significant cultural remains and cannot be eliminated at this stage. In the experience of the research team, more than ninety percent of such remote sensing targets are found to be modern debris when inspected.

In addition, Targets 4 and 5 appear to be two pieces of a barge near the eastern end of the North Channel (Table 2; Figure 17). New England USACOE engineers are aware of its existence and that it is a modern steel barge.

Recommendations for Historic Sites

At the time of this study, it is assumed that the USACE prefers to inspect, rather than avoid all possibly impacted targets that are deemed possible cultural resources from the remote sensing data. Therefore, archaeological inspections of the three PCR targets near Castle Island (Targets 1, 2, and 3) are recommended. These inspections can be accomplished in two days of diving operations. Inspection would include dropping an anchored buoy at each possible cultural resource and diving down to conduct a systematic search and recording of the target. Recording would be accomplished with drawings, still photography, or video. If the target cannot be located on the sea bottom surface, archaeologists will attempt to locate the target with a hand-held metal detector or gradiometer.

A qualified underwater archaeologist will conduct all underwater fieldwork following USACE regulations and American Academy of Underwater Sciences (AAUS) standards, per OSHA guidelines. Personnel and diving equipment will be chosen for specific climate, location, and safety considerations.

Since the side scan sonar data indicate that all three of the targets show relief, indicating that at least a portion of each object is above the surrounding sediment, the archaeology team should be able to successfully complete the inspections with a remotely controlled vehicle (ROV). As the sites are not in deep water, there is no safety advantage to using an remote operated vehicle (ROV); cost may be the determining factor.

If the USACE desires recordation of the two barge sections, targets 4 and 5 with still photography or video, the archaeology team can accomplish this while already mobilized in the field, by adding one field day. Detailed, measured mapping would take longer.

Results of Analysis for Native American Sites

Following a review of site distributions in coastal areas abutting the project area, an assessment of post-glacial transgressional processes; a re-creation of Boston Harbor landmass over 9,000 years; and the presence of known inundated Native sites in other parts of the Northeastern United States, the research team predicts that Native American archaeological sites may exist where they have been protected by natural barriers and through burial in alluvium. The latter is especially relevant given the shipping channel's route within or near the ancient Charles River channel and its estuaries.

Dredging has been conducted along the route and undoubtedly damaged or destroyed sites. However, in the North Channel (the easternmost part of the project area) only the Southern half has been dredged in the past. The proposed improvement project plans to widen the channel on the north side. Given the proximity to the ancient Charles River channel and its alluvial processes, Native American sites may lie deeply below the buried surface and could be impacted by proposed dredging.

The same may be true of the western part of the corridor. The water at this location is shallow. Past dredging operations have taken place here, but the extent of dredging is uncertain.

Recommendations for Native American Sites

It is recommended that areas in the westernmost part of the project area, the Mystic River, and the northeastern side of the North Channel be tested using selected vibratory cores or split-spoon borings. The areas recommended for further testing are as followed:

1. *The North Channel.* This is the northeast-southwest-oriented channel in the easternmost part of the project area. The northern (northwestern) side of the channel has not been dredged as deeply as the southern (southeastern) side. This channel follows the ancient Charles River channel. Despite impacts from storm winds, archaeological sites could lie buried beneath alluvium and may have survived damage from storms and transgressional processes. It is recommended that at least four vibratory cores (or other coring device) be extracted from this area to determine the presence of surviving buried A horizons. The general areas to be tested are those consisting of unconsolidated sand and gravels located in between coarse glacial till and bedrock (Figure 18). The presence of bedrock and coarse till upwind could have protected this area from storm and other currents.

2. *The western portion of the project area (Reserved Channel and Mystic River confluence).* This area is northwest and east of Castle Island and Fort Independence. It is not clear how much damage past dredging has caused in this area. Two loci may have a high potential to contain Native American sites. It is recommended that at least four vibratory cores (or other coring device) be extracted from this general area to determine the presence of surviving buried A horizons. The general areas to be tested are possible former land areas that border organic deposits that are remnants of former estuaries (Figure 18). Locus A is an area of high organic deposits intermittently bordered by till and glacial deposits, and unconsolidated sand and gravel. Locus B is a tiny organic area within the Mystic River channel bordered by till deposits and unconsolidated sand and gravels.

3. *Mystic River Area.* This area may have a high potential to contain Native American sites. The area of proposed impact within the Mystic River should be tested. It is recommended that at least two vibratory cores (or other coring device) be extracted from this area to determine the likelihood of surviving buried A horizons. The general areas to be tested are former land surfaces abutting organic deposits that are remnants of former estuaries (Figure 19).

4. *Random Cores.* In addition, two core locations should be selected randomly within the project area, at depths less than 55 feet. One core should be in the Anchorage No. 2 and one in the President Roads channel. The purpose of the cores will be to detect buried organic land surfaces.

Specific locations of cores should be selected by an archaeologist in collaboration with project engineers. At this time it is assumed that cores are planned for engineering and geophysical purposes. A qualified archaeologist should be a part of the decision-making process when the location of cores is chosen. Following collection of the cores, the archaeologists should review the records from all cores, and physically examine those cores that appear to contain evidence of early land surfaces.

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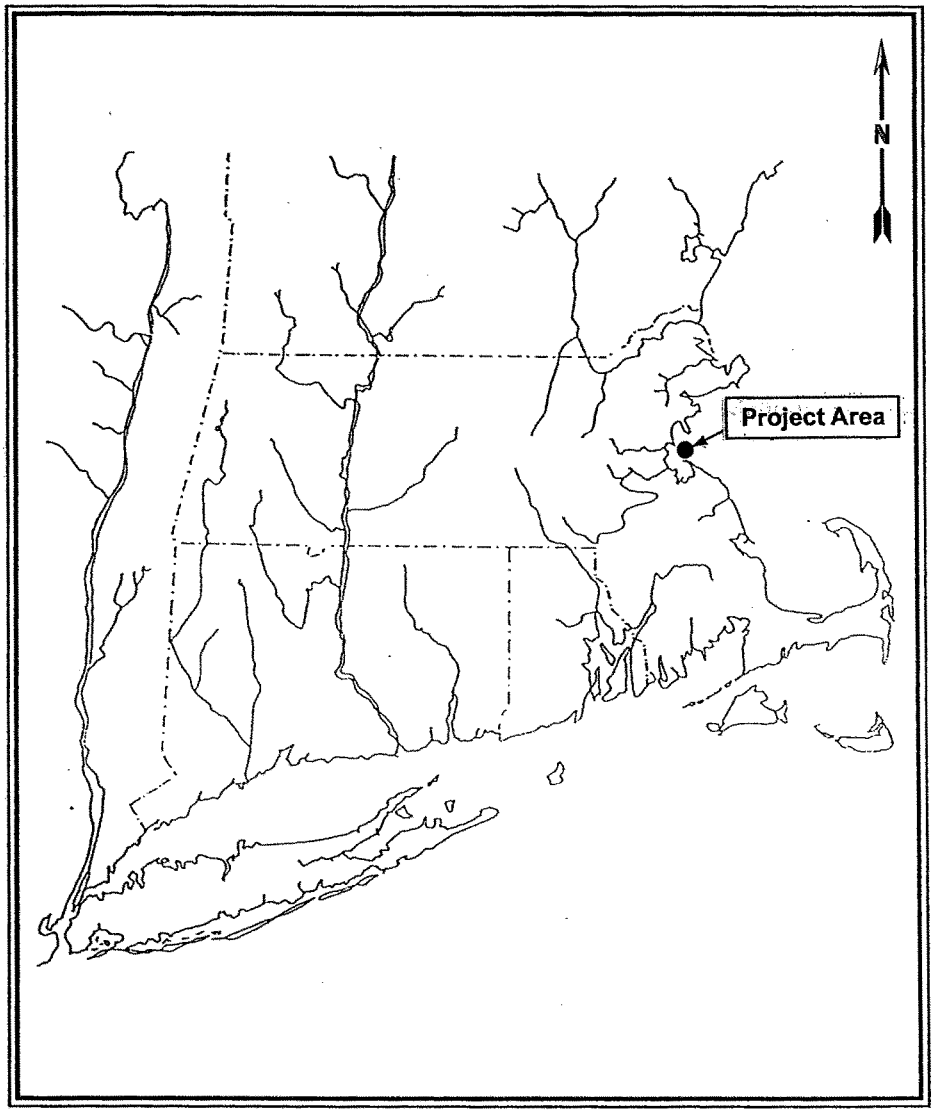

Figure 1. Project area location in the southern New England region.

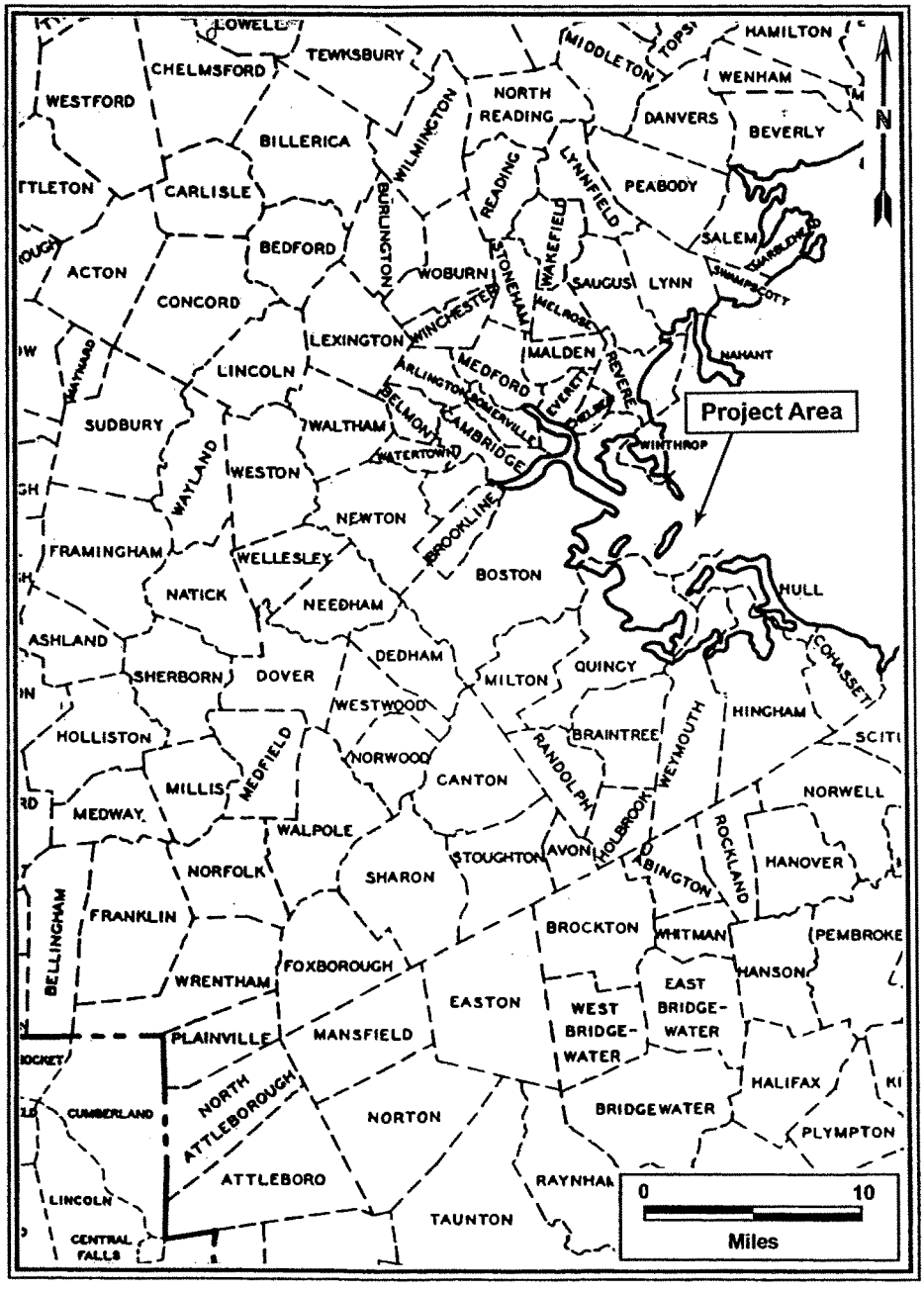

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Figure 2. Location of project area in Boston.

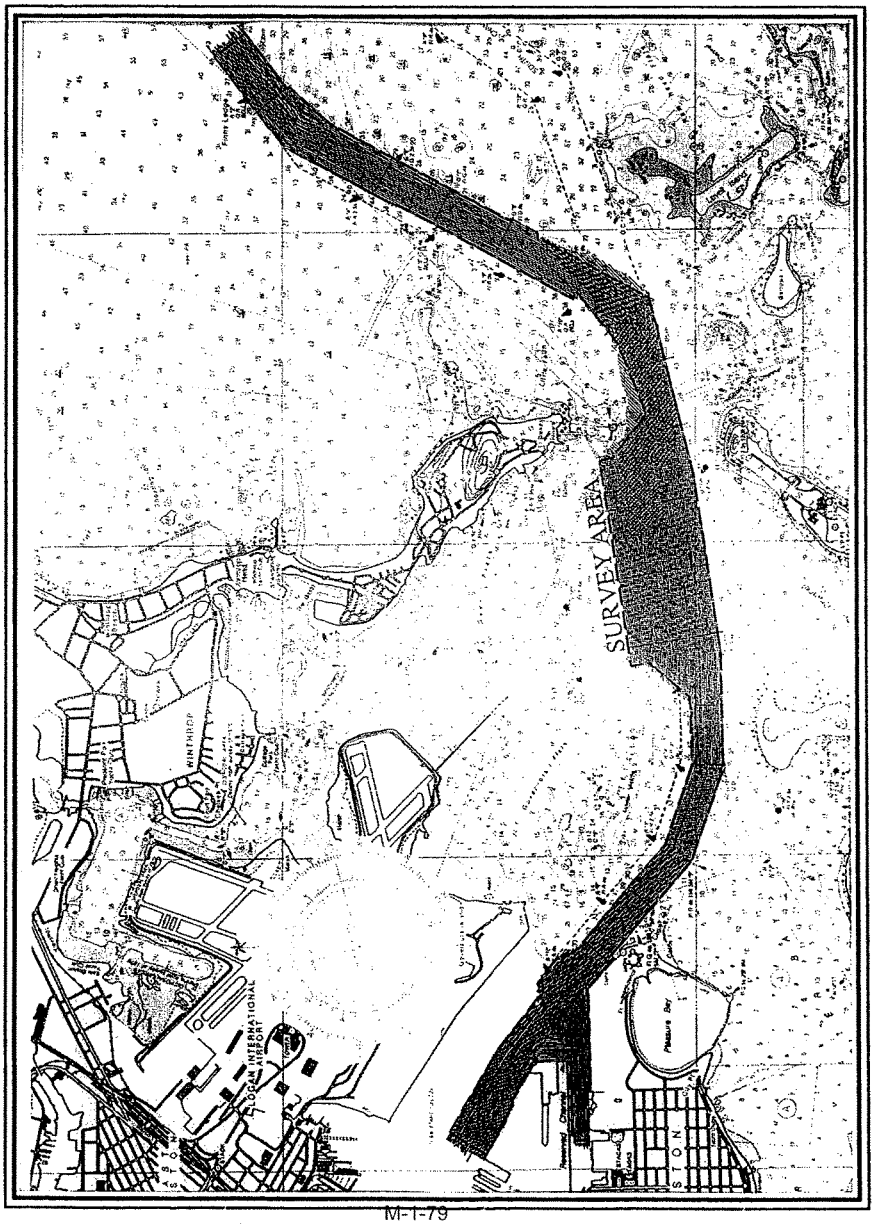


Figure 3. Map indicating the project area in Boston Harbor.

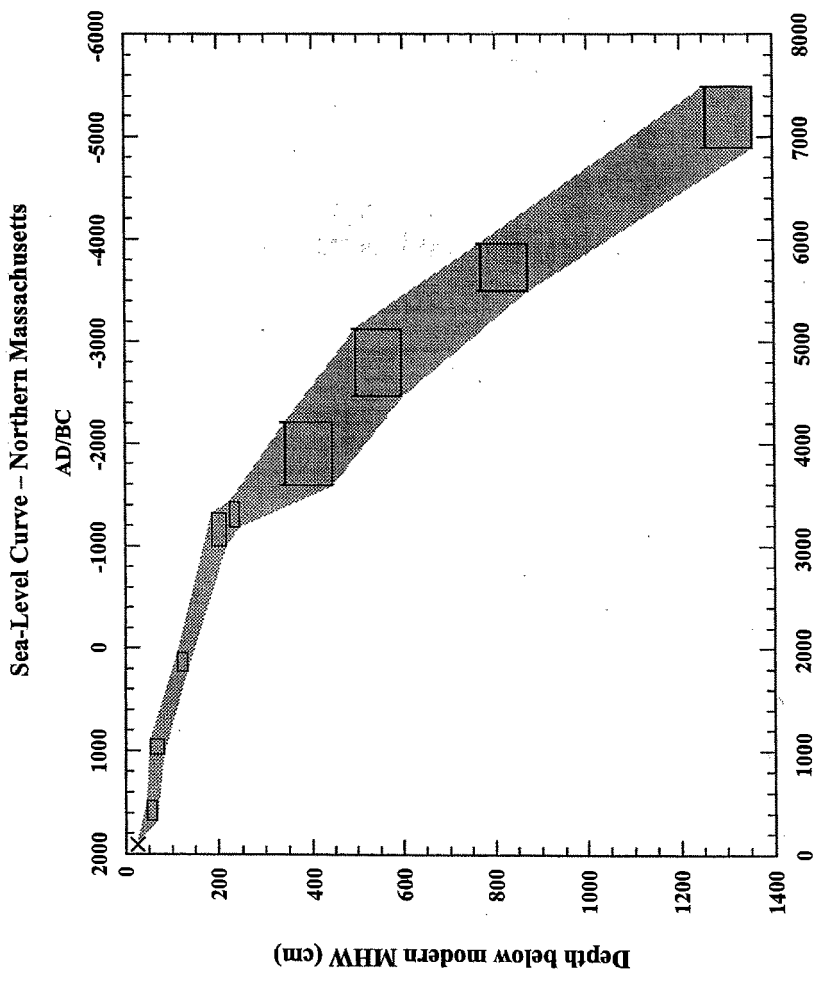


Figure 4. Composite sea-level curve for northern Massachusetts based on C-14 dated basal salt marsh remains (adapted from Donnelly, 2000)

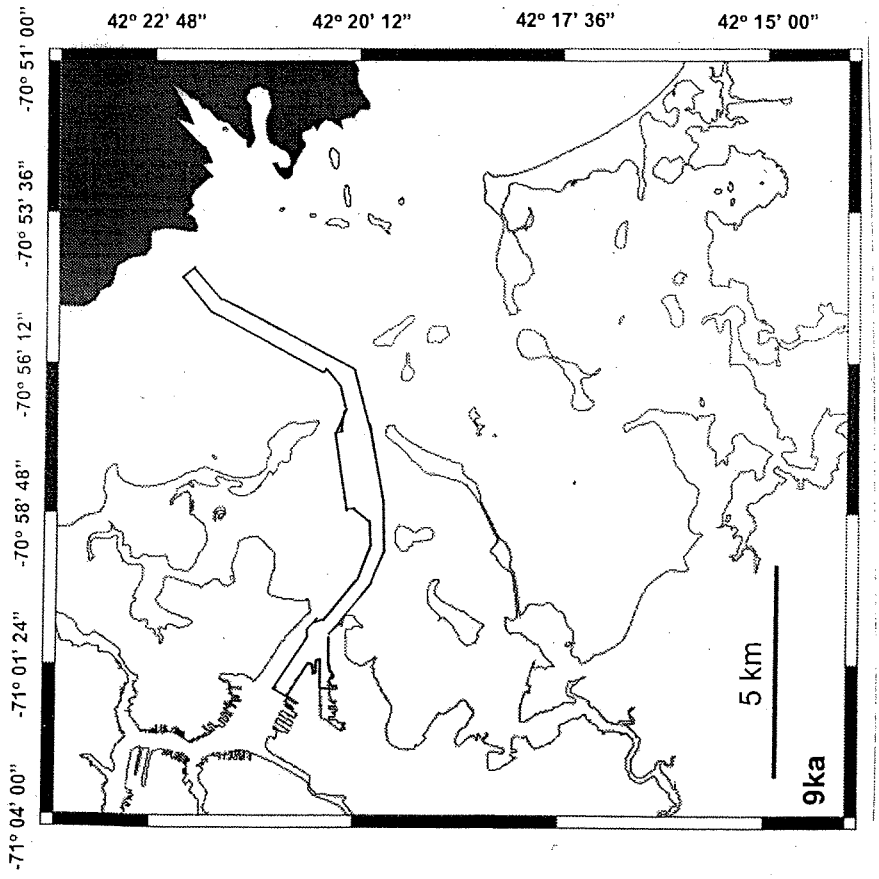


Figure 5. Paleogeography of the Boston Harbor at 9 ka when sea level was approximately 20 meters below modern sea level (marine waters are shown in blue).

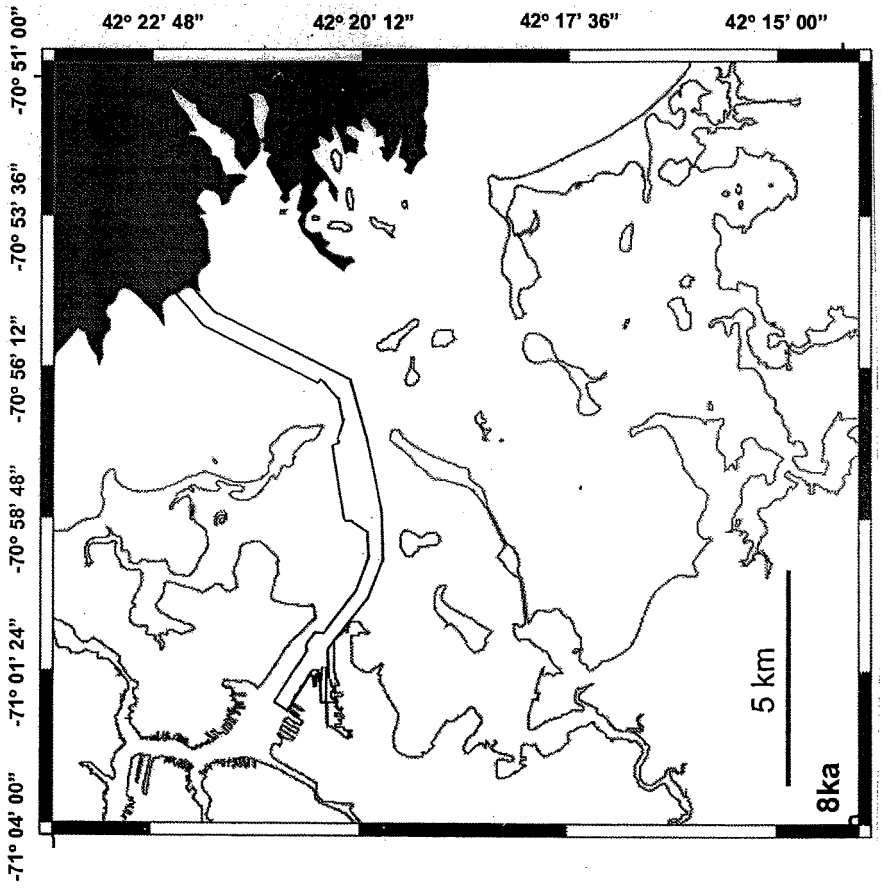


Figure 6. Paleogeography of the Boston Harbor at 8 ka when sea level was approximately 16 meters below modern sea level (marine waters are shown in blue).

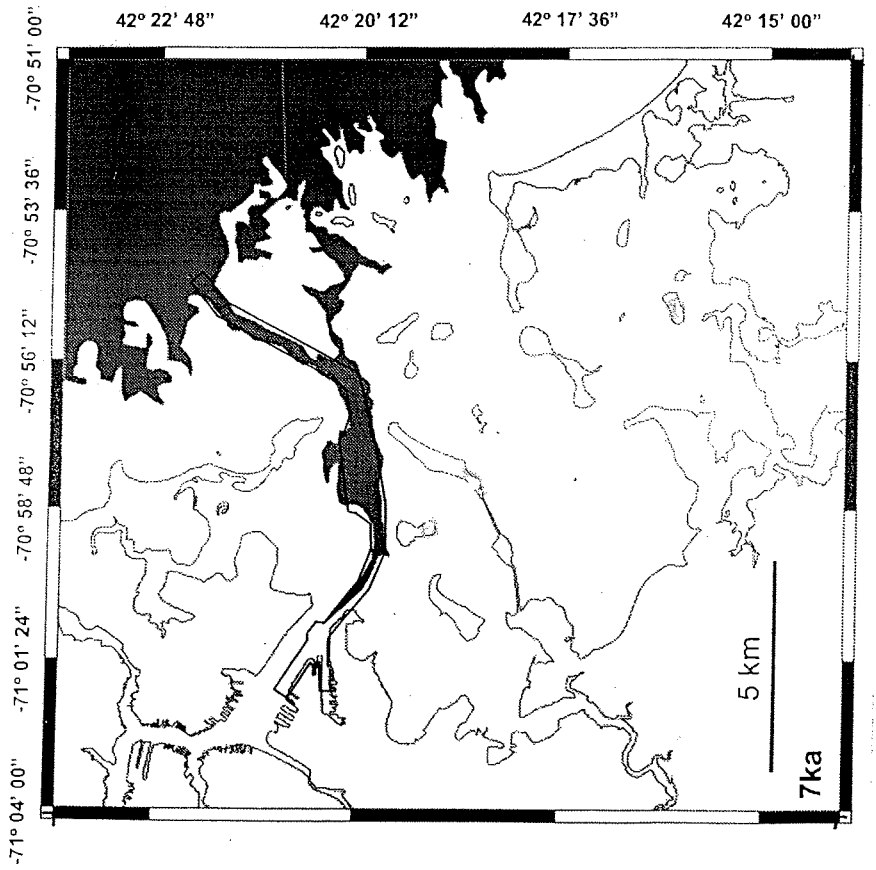


Figure 7. Paleogeography of the Boston Harbor at 7 ka when sea level was approximately 12 meters below modern sea level (marine waters are shown in blue).

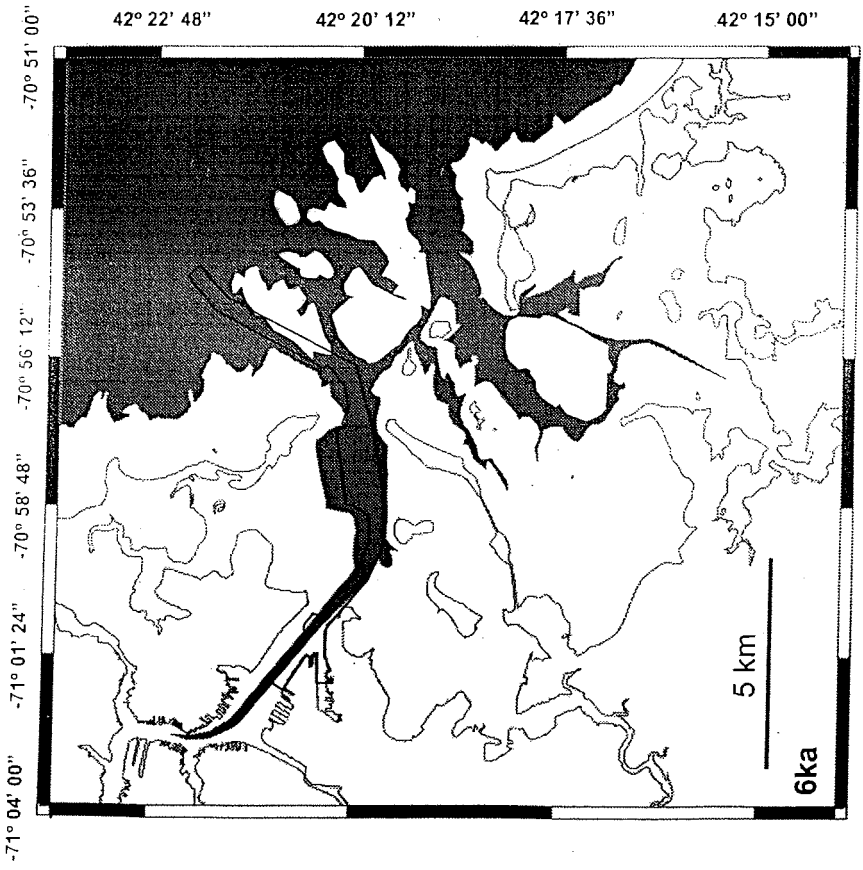


Figure 8. Paleogeography of the Boston Harbor at 6 ka when sea level was approximately 8 meters below modern sea level (marine waters are shown in blue).

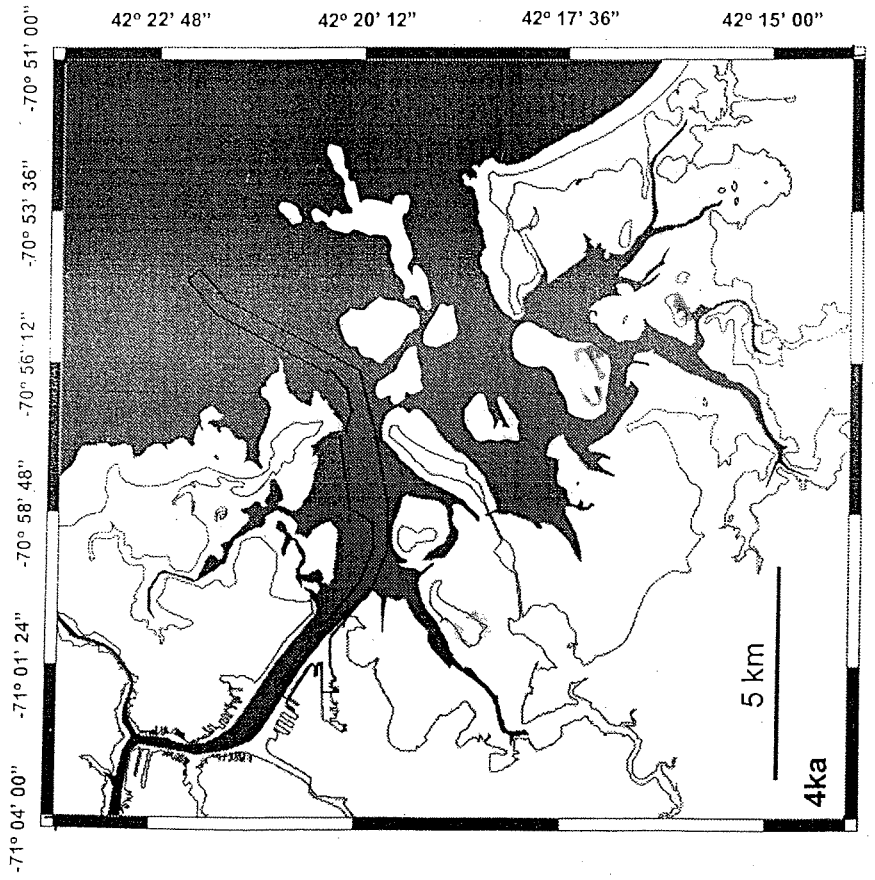


Figure 9. Paleogeography of the Boston Harbor at 4 ka when sea level was approximately 4 meters below modern sea level (marine waters are shown in blue).

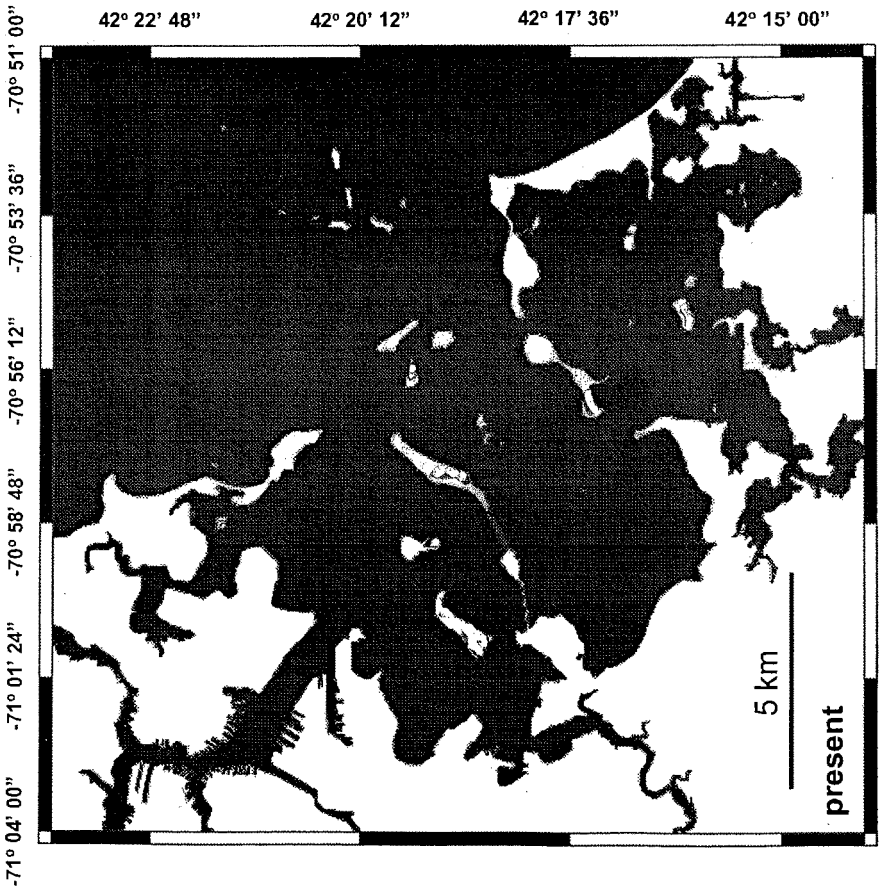


Figure 10. Paleogeography of the Boston Harbor at modern sea levels.

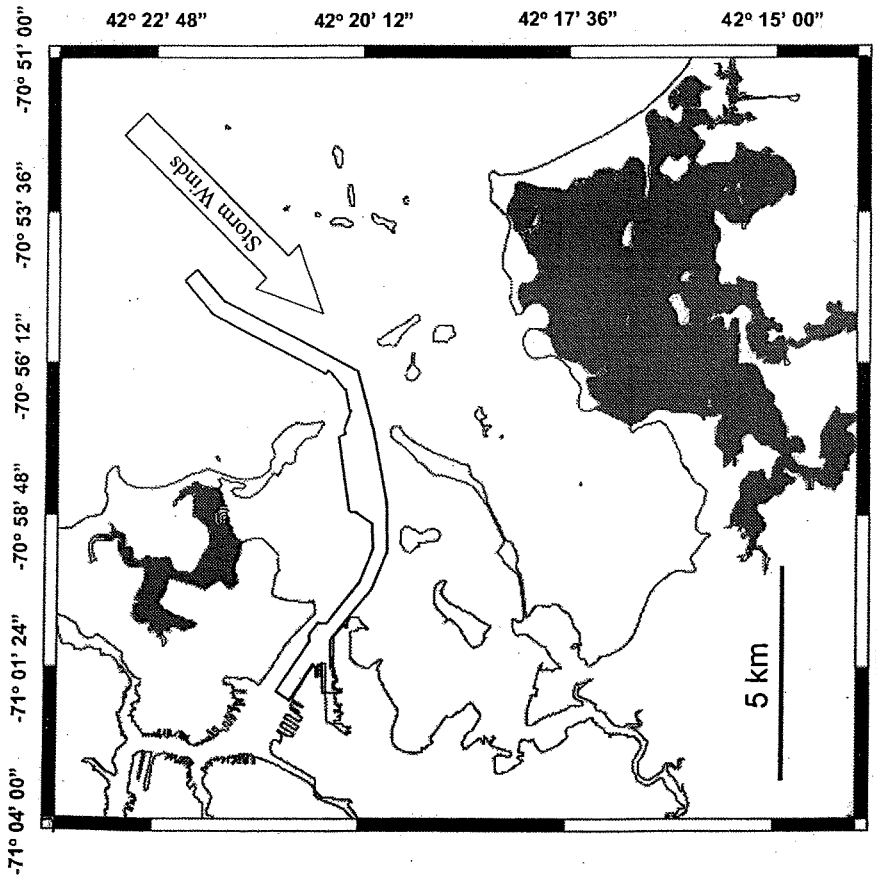


Figure 11. Areas of highest potential for intact archaeological sites (gray; areas most protected from storms waves and currents).

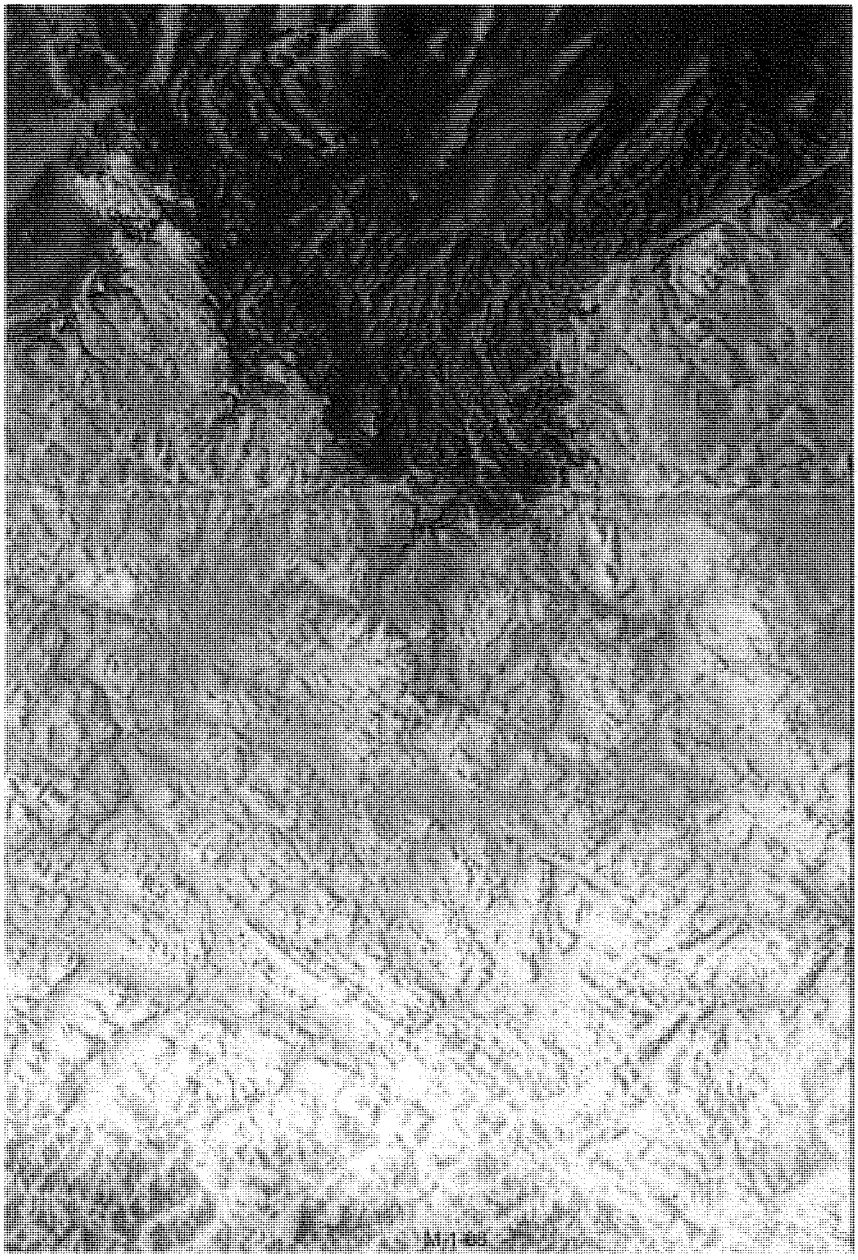


Figure 12. Present day geography of the Boston Harbor (marine waters are shown in blue).

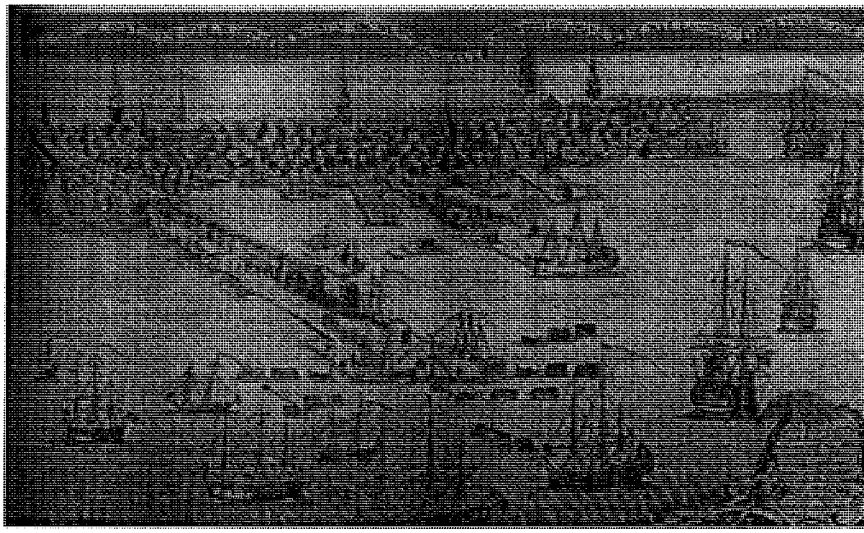


Figure 13. The Boston Waterfront in 1768. Engraving by Paul Revere. Winterthur Museum.

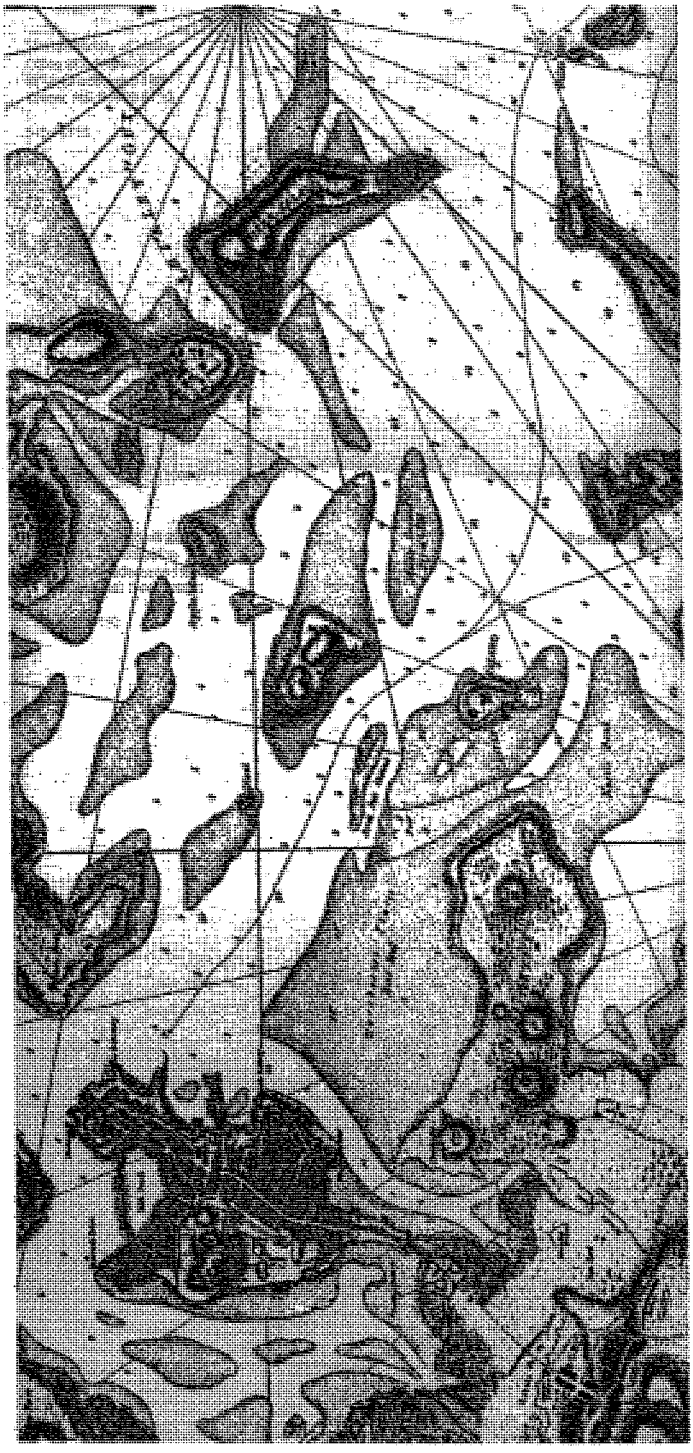
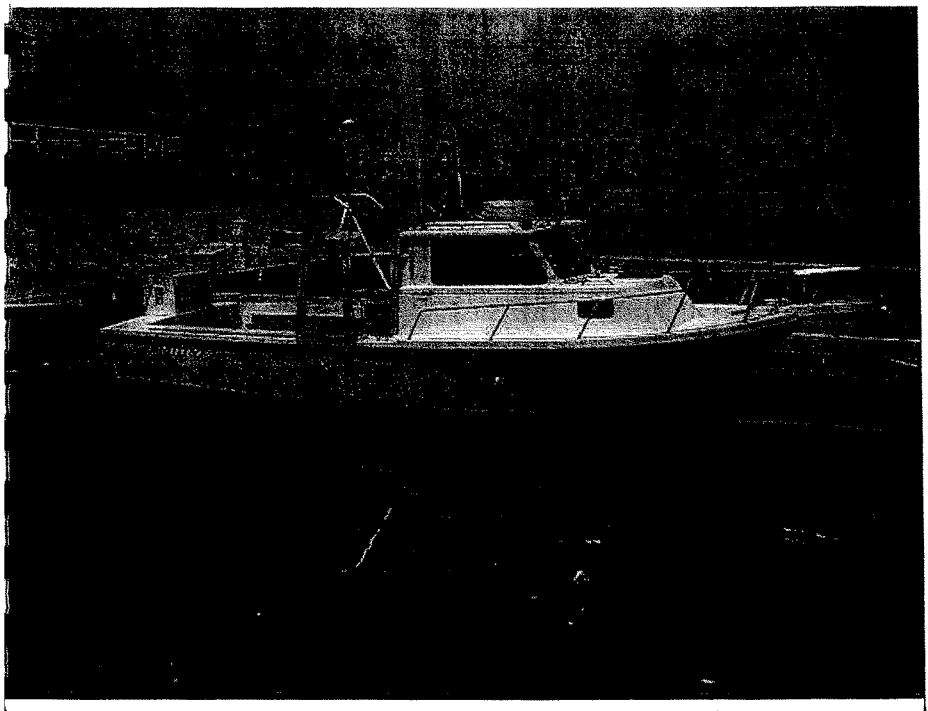


Figure 14. British Map of Boston Harbor, depths are in fathoms 1778.



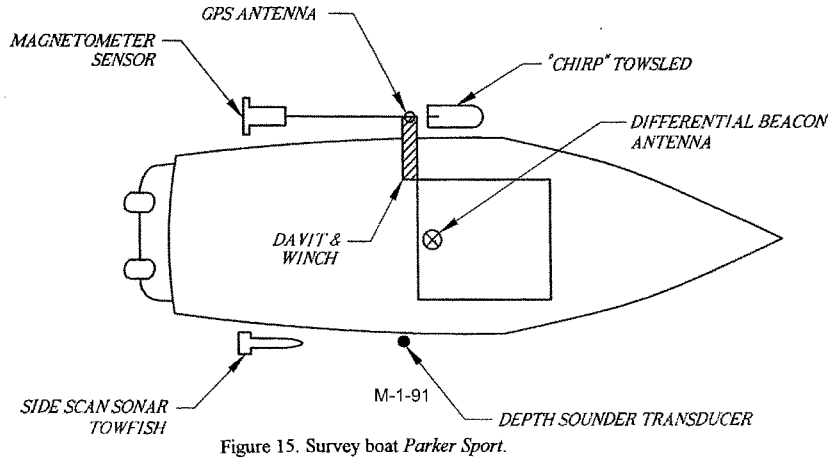


Figure 15. Survey boat *Parker Sport*.

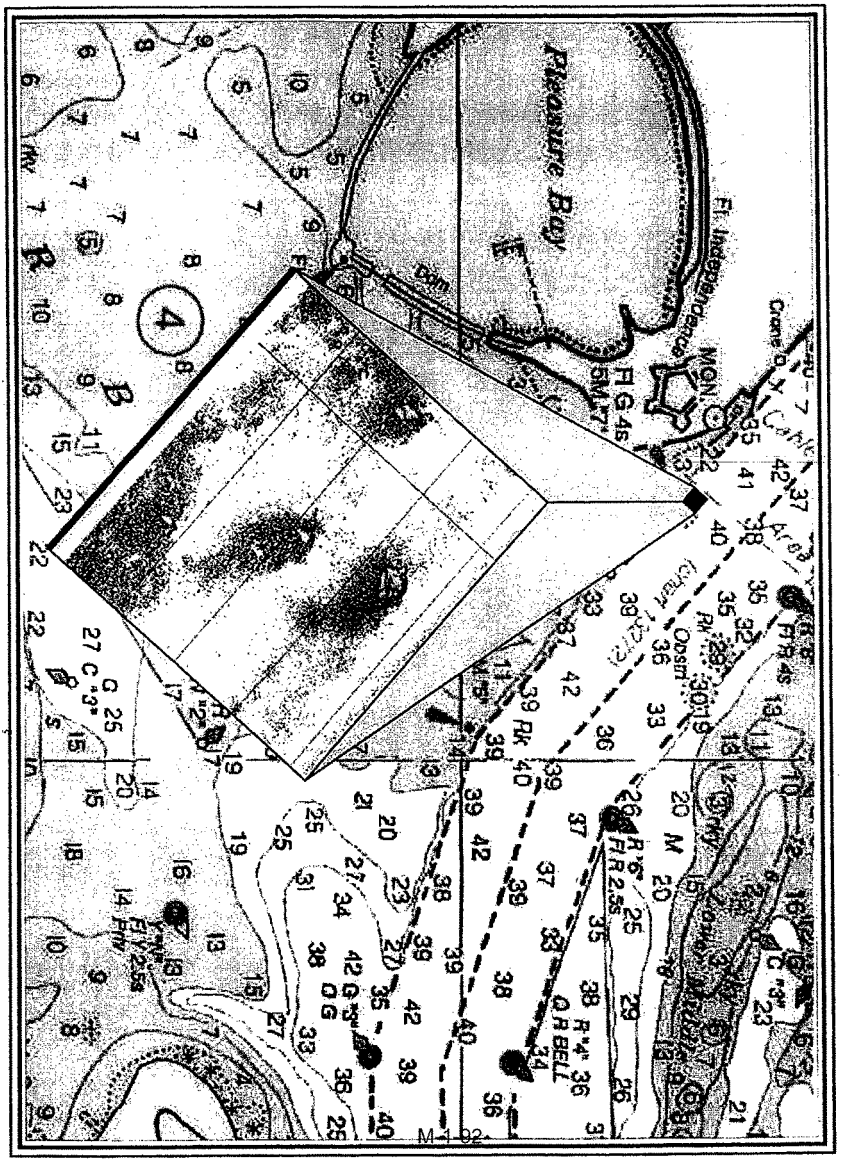


Figure 16. Side scan sonar images of Targets 1, 2, and 3 near Castle Island. Image by OSI.

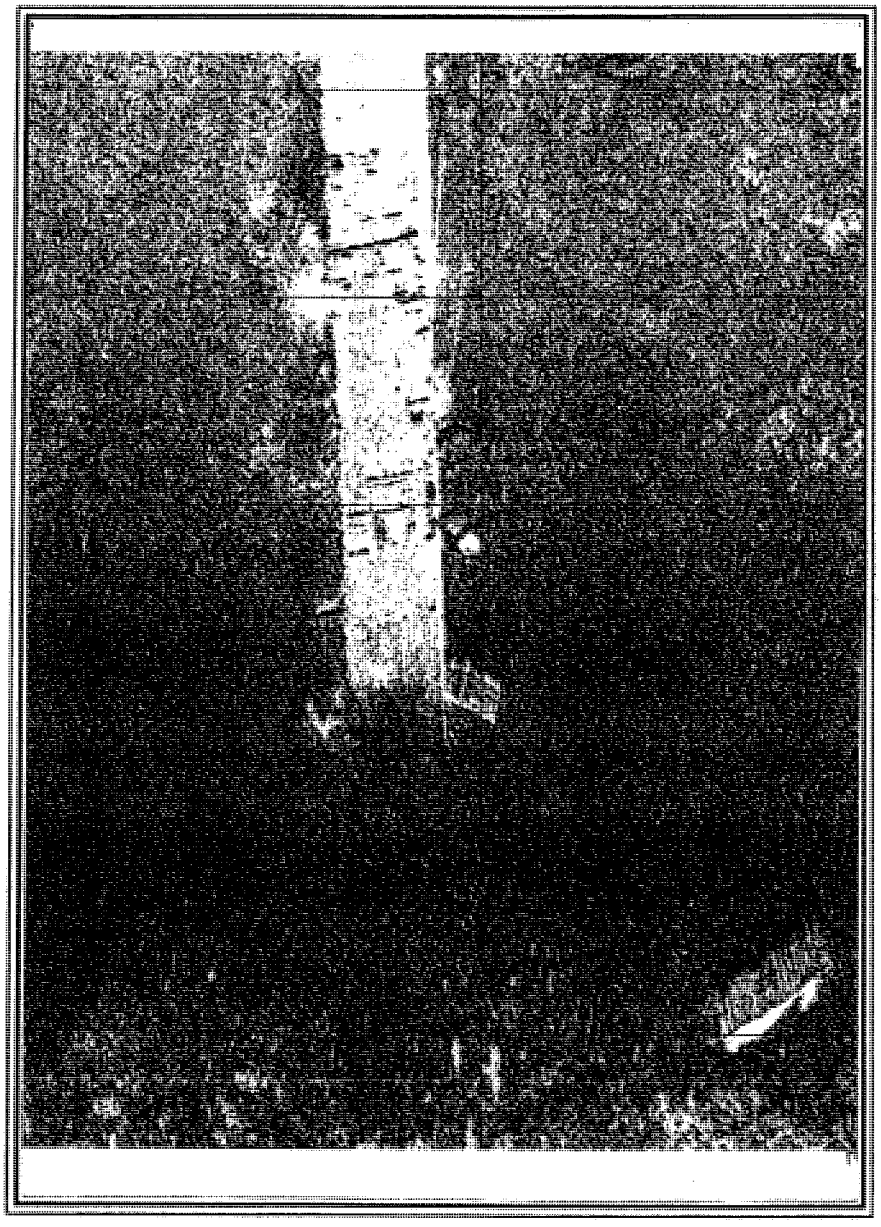


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Figure 17. Side scan sonar image of Targets 4 and 5: two sections of a barge.

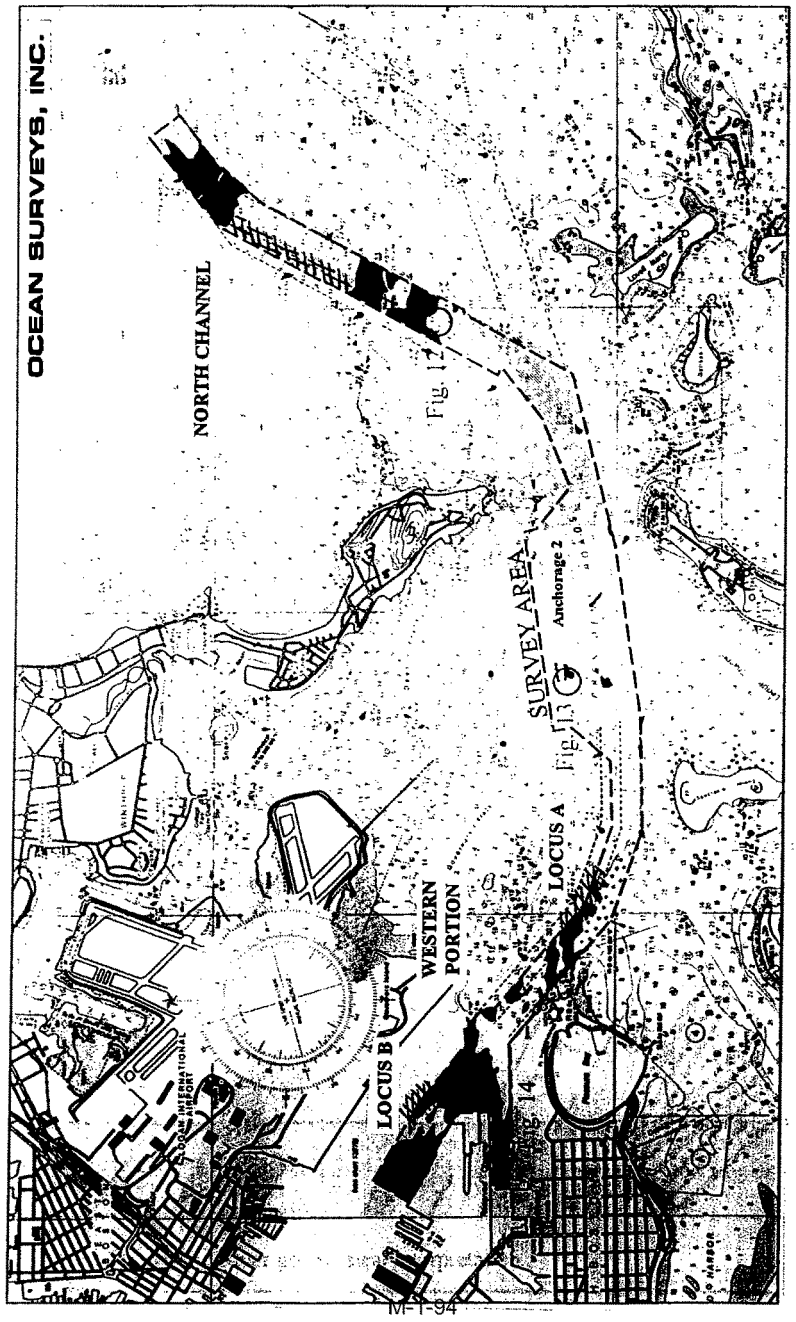

Figure 18. Map of the main survey area indicating areas recommended for core testing for cultural resources. Dark areas indicate acoustic basement of less than 55 feet (bedrock or glacial till). Stippled areas represent former estuarine deposits; hatchured areas recommended testing. Map provided by Ocean Surveys, Inc.OSI Report 02ES066-D.

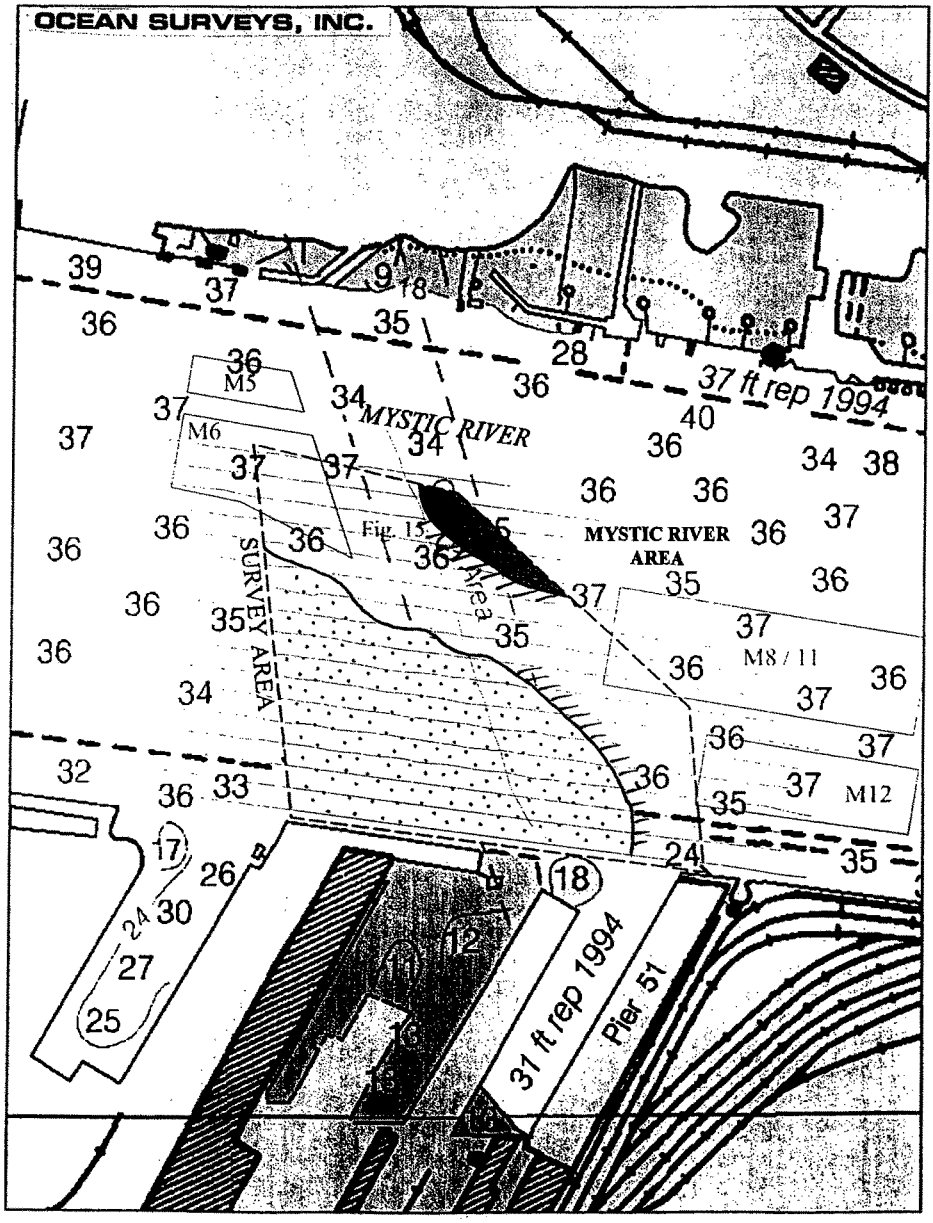

Figure 19. Map of the Mystic River area indicating areas recommended for core testing for cultural resources. Dark areas indicate acoustic basement of less than 55 feet (bedrock or glacial till). Stippled areas represent former estuarine deposits; hatchured areas recommended testing. Map provided by Ocean Surveys, Inc. OSI Report 02ES066-D.

Table 1.								
Native American Sites - Boston Harbor Islands and Shoreline								
Site Number	Town	Elev	Dist to Proj	Location	Comments	Age	Period	Water
19-SU-005	Boston	20-30'	830'/253m	Green Island	Seagull midden		n/a	
19-SU-006	Boston	0-40'	900'/274m	Calf Island	Flakes, Hammerstones		n/a	
19-SU-008	Boston	0-30'	960'/293m	Calf Island	Grooved axe, flakes, netsinkers, fish and bird bones, bifaces, drill tip, pottery, C14-1540+/110,510+/145, 880+-165, 685+-135, 860+-115, clam shell	1600-400	WL	
19-SU-051	Boston	0-10'	1100'/335m	Great Brewster Island	Gt. Brewster Site: 2 rhyolite flakes		n/a	wetland
19-SU-038	Boston	0-50'	380'/116m	Spectacle Island	Small shell heap		MA, LW	
19-SU-009	Boston		350'/107m	Gallops	Shell Midden, seeds, hickory, mammal, bird and fish bone, fcrk, flakes, postmold, pottery	1000-400	LW	
19-SU-010	Boston	0-30'	350'/107m	Long Island	Natick Indians lived here (Willoughby)	400	WL-CONT	
19-SU-056	Boston	0-30'	450'/137m	Long Island	Hill Site: Flakes, shell tempered incised pottery		n/a	
19-SU-039	Boston	0-40'	530'/162m	Long Island	Long Island Site: Shell midden, flakes, fcrk, red jasper point tip,			wetland
19-SU-055	Boston	0-40'	570'/174m	Long Island	Bass Point Site:Shell midden, cores, scrapers, Levanna, pottery, pestle	1000-400	LW	wetland

19-SU-054	Boston	0-20'	680'/207m	Long Island	Marsh Locus 1-2:Poss. Neville,flakes, fcrk, post molds	8000-7000	MA	wetland
19-SU-052	Boston	0-10'	670'/204m	Long Island	Marsh Locus 4:flakes, shell-tempered pottery	3000-1000	WL	wetland
19-SU-053	Boston	0-10'	730'/223m	Long Island	Marsh Locus 3: flakes, shells		n/a	wetland
19-PL-002	Hingham	0-30'	1550'/472	Peddocks Island	Harry's Rock:2 small pieces of shell		n/a	pond
19-PL-003a	Hingham	0-40'	1550'/472m	Peddocks Island	Walsh Workshop: Atlantic, brown porphoritic flakes and bifaces	3500-2500	LA	pond
19-PL-004	Hingham	0-30'	1480'/451m	Peddocks Island	Fcrk, jasper, quartz, rhyolite flakes, Levanna	1000-400	LW	
19-PL-003	Hingham	0-40'	1530'/466m	Peddocks Island	Shell heap, Squibnocket Tri, Atlantic, Wading River, Levanna points, Poss EW points, pottery, awl, adze	5000-400	LA,EW,LW	pond
19-PL-005	Hingham	0-30'	1550'/472m	Peddock's Island	West Head Pond: burial, oyster shell, Atlantic proj. pts, EW, LA, MW (Dincauze)	3500-1000	LA,EW, EW	pond
19-PL-264	Hingham	0-30'	1450'/442m	Peddocks Island	East Village: shell midden		n/a	
19-NF-003	Weymouth	10'	2350'/716m	Grape Island	Sumac Grove:grit, crushed rock and shell temp. pottery, Jack's Reef, extensive faunal collection C14-1185+/-100	1500	MW	

19-NF-004	Weymouth	0-20'	2350'/716m	Grape Island	Grit-tempered pottery, small stemmed points flakes, pestles, hammerstones, extensive faunal collection.	3000-1500	WL	wetland
19-NF-005	Weymouth	10'	2370'/722m	Grape Island	Grit tempered pottery, Levanna, small stemmed point, shell midden, C14 950BP	2000-400	MW,LW	wetland
19-NF-006	Weymouth	10'	2380'/725m	Grape Island	Drill tip, Neville, Triangular,stemmed Fox Creek, Jack's Reef, small stemmed point, pottery, extensive shell and faunal collection.	8000-400	MA, LA, MW, LW	wetland
19-NF007	Weymouth	10-20'	2390'/728m	Grape Island sandbar	shell tempered pottery, stemmed point, gr.slate at\ at\ weight, shell	5000-400	LA, LW	wetland
19-NF-008	Weymouth	10-40'	2380'/725m	Grape Island		3000-400	WL	
19-NF-006	Weymouth	20-40'	2230'/680m	Bumpkin Island	shell and grit temp. pottery,	2000-400	MW, LW	
19-PL-811	Hingham	45-60'	2230'/680m	Bumpkin Island	Bumpkin Island II:low density flake scatter		n/a	
19-SU-075	Boston	0-10'	830'/253m	Thompson Island	Small stem, Jacks Reef	4000-1500	LA, EW, MW, LW	wetland
19-SU-074	Boston	10-30'	800'/244m	Thompson Island	pottery	3000-400	WL	wetland
19-SU-073	Boston	0-20'	810'/247m	Thompson Island	Small stem points	4000-3000	LA	wetland
19-SU-072	Boston	0-20'	810'/247m	Thompson Island	Small stem points	4000-3000	LA	wetland
19-SU-069	Boston	10-30'	780'/238m	Thompson Island	Small stem points, grit and shell tempered pottery	4000-400	LA-LW	wetland
19-SU-068	Boston	0-10'	730'/223m	Thompson Island	shell tempered pottery	3000-400	WL	wetland
19-SU-067	Boston	0-10'	790'/241m	Thompson Island	Grit tempered pottery	3000-400	WL	wetland
19-SU-066	Boston	0-10'	670'/204m	Thompson Island	Shell tempered pottery	3000-400	WL	wetland

19-SU-065	Boston	0-10'	600'/183m	Thompson Island	Jacks Reef points	1500	MW	wetland
19-SU-048	Boston	0-10'	1400'/427m	Charlestown	C14: 1810+\-50, 2370+/-80, Fox Creek points	2300-1500	MW	
19-SU-037	Boston	0-5'	450'/137m	Thompson Island	Sandbar		n/a	
19-SU-033	Boston	0-40'	490'/149m	Thompson Island	Small stem points, pottery	2000-400	MW, LW	
19-SU-032	Boston	0-20'	720'/219m	Thompson Island			n/a	
19-SU-031	Boston	0-20'	720'/219m	Thompson Island	pottery, side notched point	3000-400	WL	
19-SU-034	Boston	0-40'	400'/122m	Thompson Island			n/a	
19-SU-018	Boston	30-100'	1430'/436m	Savin Hill Park	Contact Period burial	400	CONT	
19-SU-017	Boston	0-30'	820'/250m	Thompson Island	Only periods recorded	5000-400	LA, EW, MW, LW	wetland
19-PL-371	Hingham	0-30'	2660/811m	Worlds End	MHC			
19-PL-267	Hingham	0-40'	2750/838m	Worlds End	MHC			
19-PL-570	Hingham	0-30'	2830/863m	Worlds End	MHC			
19-PL-572	Hingham	0-30'	2850/869m	Worlds End	MHC			
19-NF-10	Quincy	10-20'	2250/686m	Houghs Neck	Pestle, plummet, burial		n/a	
10-NF-467	Quincy	0-10'	2200/671m	Merrymount Park	MHC			wetland
19-PL-265	Hull	0-100'	1600/488m	Allerton Hill	MHC			
19-PL-266	Hull	0-100'	1730/527m	Allerton Hill	MHC			

Table 2 . Coordinates of Targets

Target	Northing	Easting	Mag.Flux	Type	Comments
1	2,948,857	789,163	60	m+	sss: low object(s), near shipwreck symbol
2	2,948,816	789,233	50	d+	sss: low object(s), near shipwreck symbol
3	2,948,778	789,242	40	m-	sss: low object(s), near shipwreck symbol
4	498,723	757,326	> 600	d	sss: section of 20th C. barge
5	498,698	757,542	320	m-	sss: section of 20th C. barge

APPENDIX A

Persons Consulted for this Project

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Bruce Bourque, Archaeologist, Maine State Museum
Steven Cox, Archaeologist, Maine Historic Preservation Commission
John Crock, Archaeologist, University of Vermont
Jorgen Dencker, Archaeologist, National Museum of Denmar, Institute of Marine Archaeology
Charles Dill, Geophysicist, Alpine, Inc.
Christopher Donta, Archaeologist, UMASS Archaeological Services, Amherst
Michael Faught, Archaeologist, Florida State University
Edna Feighner, Review and Compliance Specialist, New Hampshire Division for Historical Resources, Concord
Jeffrey Gardner, Geophysicist, OSI
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Susan Langley, Maryland State Underwater Archaeologist, Maryland
Gregory Lattanzi, Archaeologist, New Jersey State Museum, Trenton.
Douglas Mackey, Archaeologist New York State Division of Parks, Recreation and Historic Preservation
Alex Mansfield, Scientist, Battelle Ocean Sciences, Duxbury
Victor Mastone, Department of Environmentaol Management, Boston, Massachusetts
Kate Marcopul, State Historic Preservation Office, Trenton, New Jersey.
Charles Mazel, Phycical Sciences, Inc. Andover, Massachusetts.
Kevin McBride, Archaeologist, University of Connecticut at Storrs, and Mashantucket Pequot Museum
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Marcus Paiva, Archaeologist, USACE, Concord.
David Robinson, Maritime archeologist, Public Archaeology Laboratory, Pawtucket, RI
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Charlotte Taylor, Maritime Archaeologist, Rhode Island Historic Preservation Commission
Wayne Trulli, Scientist, Battelle Ocean Sciences, Duxbury
Michael Volmar, Fruitlands Museum, Harvard, Massachusetts
John Wetmer, Navigation/Electrical Technician, OSI

Dive Shops:

Atlantic Divers, Lynn, MA
South Shore Skindivers, North Weymouth, MA
United Divers, Somerville, MA

APPENDIX M

ATTACHMENT 2

INSPECTION OF MAGNETIC ANOMALIES
REMOTE SENSING ARCHAEOLOGICAL SURVEY
BOSTON HARBOR DEEP DRAFT NAVIGATION
IMPROVEMENT STUDY

Boston, Massachusetts

CONTRACT NO. DACW33-03-D-0002

Public
Archaeology
Laboratory

PRESERVATION PLANNING

ARCHAEOLOGY

ARCHITECTURAL HISTORY

EDUCATION

DRAFT REPORT

INSPECTION OF MAGNETIC ANOMALIES REMOTE SENSING ARCHAEOLOGICAL SURVEY BOSTON HARBOR DEEP DRAFT NAVIGATION IMPROVEMENT STUDY

Boston, Massachusetts

CONTRACT NO. DACW33-03-D-0002

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EXECUTIVE SUMMARY

PAL has completed a remotely operated vehicle (ROV) survey of three magnetic anomalies within the Boston Harbor Deep Draft Navigation Improvement Study area. The goal of the survey was to identify and determine the nature of the three magnetic anomalies situated within the ship channel east of Castle Island.

The ROV survey included background research, a systematic visual and magnetic ROV survey, and limited subsurface testing. Background research indicated that the study area was within an area of ancient Native American coastal settlement and that the project area was exposed during the prehistoric period. Historically, the project area was within the heavily traveled main southern ship channel into Boston Harbor. One vessel was documented lost in close proximity to the project area in 1895, and NOAA navigation charts indicate a shipwreck within the project area beginning in 1975. Beginning in the last quarter of the nineteenth century dredging to improve and maintain the ship channel lowered the channel bottom within the project area 16 feet. The systematic and visual ROV survey consisted of 21 survey lines spaced at 10-foot intervals. Visual and magnetic data were collected along the survey lines. Limited excavation using the ROV thruster-wash deflector was also conducted at the three magnetic anomaly locations.

No pre-Contact Period cultural materials or archaeological features were identified during the ROV survey within the Boston Harbor Deep Draft Navigation Improvement Study area. The only cultural materials noted were lobster pots and modern debris. Lobster pots and/or magnetic rock outcrops or boulders caused the magnetic anomalies.

The proposed activities within the study area will not affect significant archaeological resources; therefore, no additional archaeological investigations of the Boston Harbor Deep Draft Navigation Improvement Project study area are recommended.

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CHAPTER ONE

INTRODUCTION

Scope and Authority

Scope

This report presents the results of the marine archaeological investigation of three targets identified as Targets 1, 2, and 3 during a 2002 remote sensing archaeological survey of the port of Boston's main shipping channel (Mulholland et al. 2003). The targets consist of 40–60-gamma magnetic anomalies associated with acoustic anomalies located in approximately 42 feet of water off the eastern shore of Castle Island, at the western edge of the channel, in Boston County, Massachusetts. The targets study area is situated within the Boston Harbor Deep Draft Navigation Improvements Project area, which extends the full length of the maintained main shipping channel, from Boston's Inner harbor out to a point just east of Finns Ledge (Figures 1-1 and 1-2). The U.S. Army Corps of Engineers-New England District (USACE-NED) and its project partner, the Massachusetts Port Authority (MPA), are proposing to make navigation improvements to the existing channel. Dredging of the existing channel to accommodate deep draft vessels is included among these improvements.

Historical and archaeological investigations conducted for this project focused on an approximately 200-x-300-foot (ft) rectangular study area encompassing the three targets. PAL, in cooperation with Ocean Surveys, Inc. (OSI) of Old Saybrook, Connecticut, conducted these investigations on behalf of the USACE-NED in support of the proposed project's permitting process. The goal of the current investigations was to determine the presence or absence of potentially significant submerged cultural resources associated with the remote sensing targets, and, if present, document, map, and draw visible

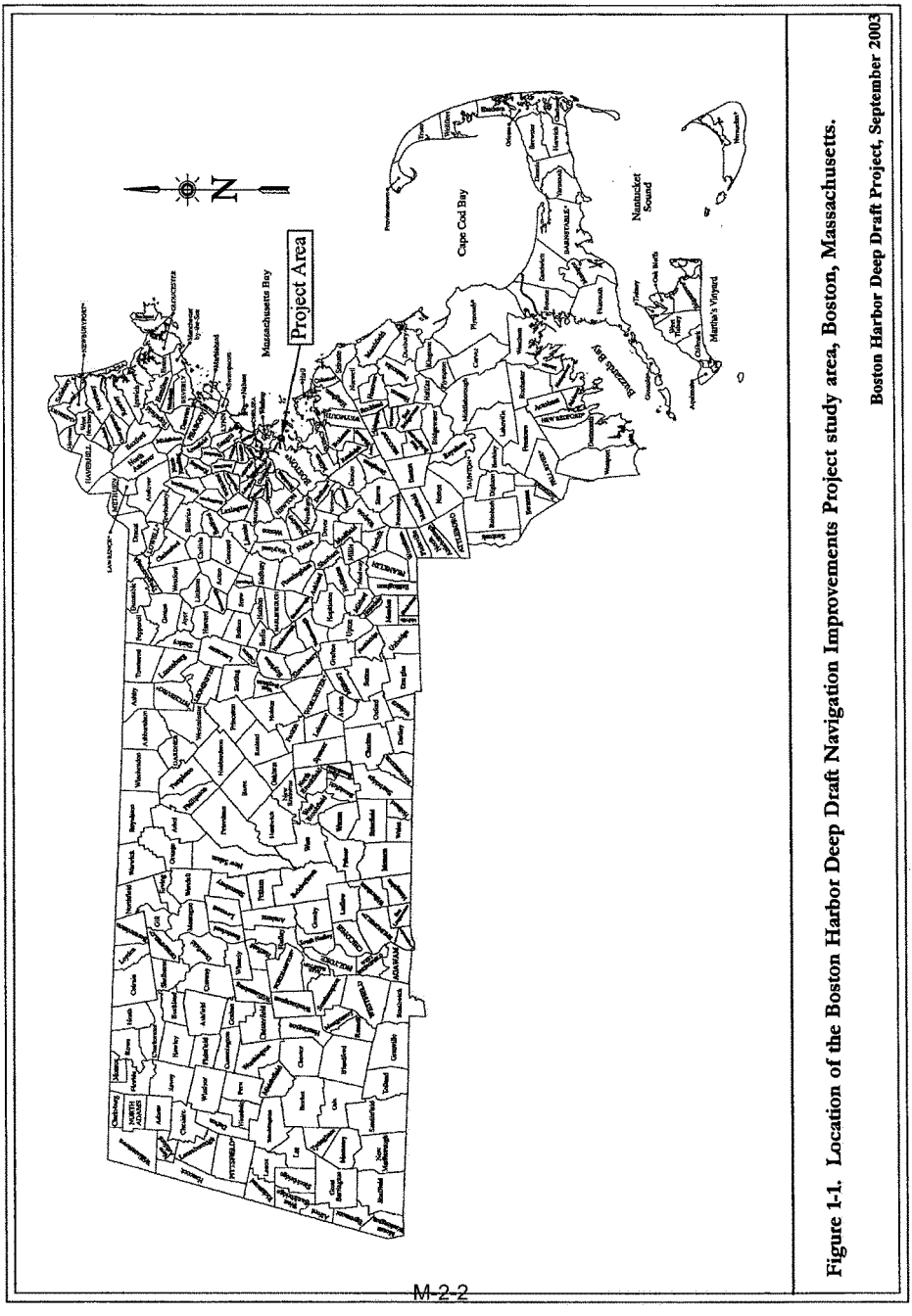

Figure 1-1. Location of the Boston Harbor Deep Draft Navigation Improvements Project study area, Boston, Massachusetts.

Boston Harbor Deep Draft Project, September 2003

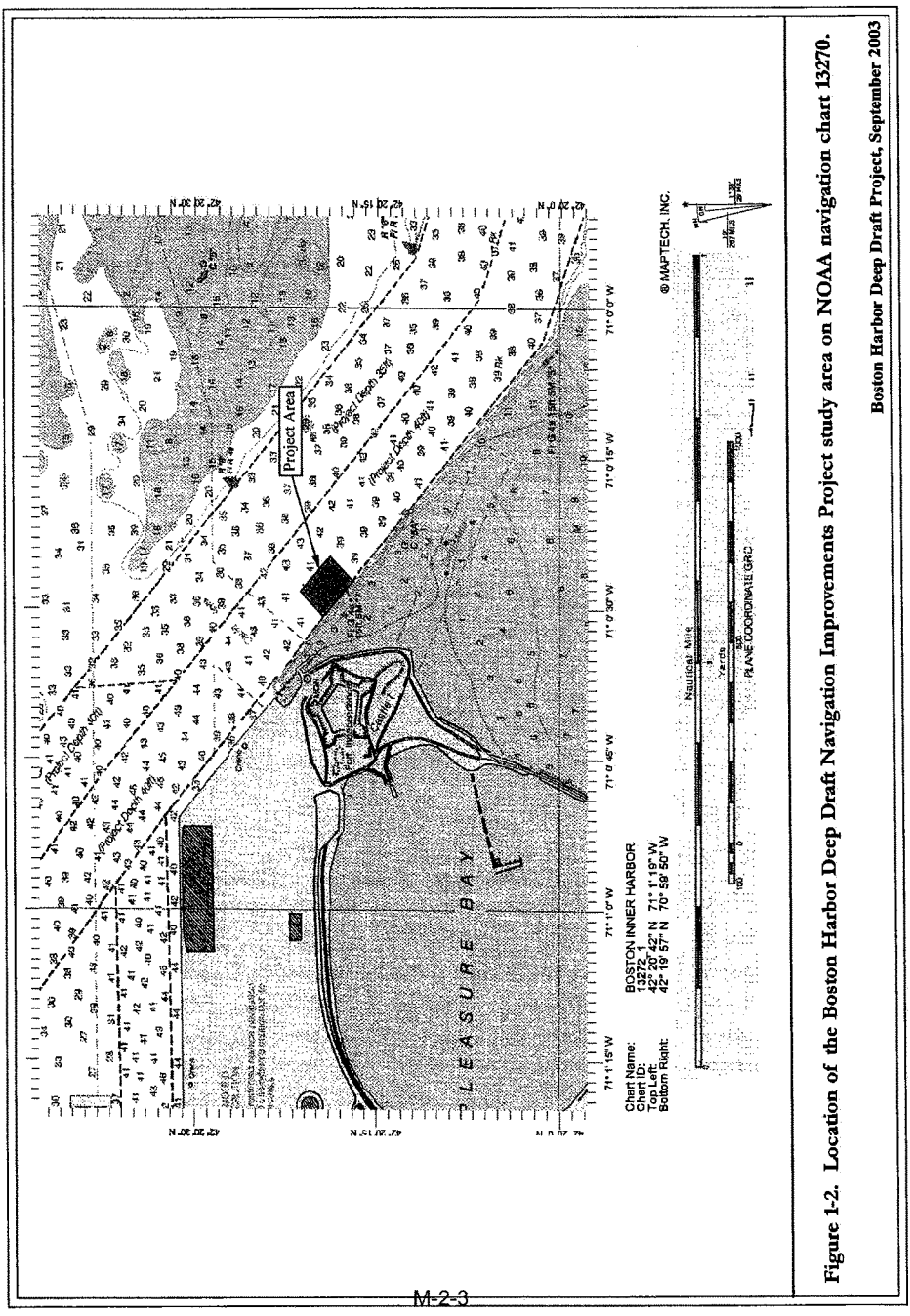

Figure 1-2. Location of the Boston Harbor Deep Draft Navigation Improvements Project study area on NOAA navigation chart 13270.

Boston Harbor Deep Draft Project, September 2003

associated features and artifacts, and preliminarily determine the target sources' potential historical significance.

Authority

The archaeological reconnaissance investigation was completed under Massachusetts Board of Underwater Archaeological Resources (MBUAR) permit (MBUAR Excavation Permit no. 03-003). The archaeological investigations were conducted under the authority of the National Historic Preservation Act of 1966, as amended (16 U.S.C. 470 et seq.) and the Advisory Council on Historic Preservation, Protection of Historic Properties (36 CFR 800). All archaeological survey work was undertaken in accordance with the *Secretary of the Interior's Standards and Guidelines for Archaeology and Historic Preservation* (48 FR 44716, 1983), the Advisory Council on Historic Preservation's *Treatment of Archaeological Properties* (1980), the National Park Service's *Abandoned Shipwreck Guidelines* (FR Vol. 50, Number 233, December 4, 1990), MBUAR regulations (312 CMR 200), and the Massachusetts Historical Commission's (MHC) *Historical Properties Survey Manual: Guidelines for the Identification of Historic and Archaeological Resources in Massachusetts* (1992).

Personnel

Background research and field investigations for the Boston Harbor Deep Draft Navigation Improvement Study target inspections were conducted in August 2003. PAL staff involved in the project included Deborah C. Cox (project manager), David S. Robinson (principal investigator and project archaeologist), and Ben Ford (project historian). OSI project staff included Thaddeus Nowak (geophysical surveys program manager), Jeffrey Gardner (project manager), John Wetmur (project manager and remotely

operated vehicle [ROV] pilot), Jeffrey Hall (project scientist), Christopher Reamer (project scientist), Kyle Toothaker (field technician), and George Main, II (vessel captain).

Acknowledgements

The authors would like to acknowledge the assistance of USACE-NED Project Manager Mark Habel, USACE-NED Archaeologist Marc Paiva, and USACE-NED Health and Safety Officer, Patricia Sumner, for their guidance and assistance throughout the project. The MBUAR is also acknowledged for their assistance in expediting the permitting process and sharing information with us from their shipwreck database. We also would like to acknowledge the USCG-Boston Group's Captain-of-the-Port, Brian Salerno, USCG-Boston Group Chief, Dan Duggary, and MASSPORT's Brad Wellock, for their support and assistance with logistical planning of the project regarding vessel traffic safety issues.

Disposition of Project Materials

All project information (i.e., correspondence, field notes, maps, videotapes, etc.) is currently on file at PAL, 210 Lonsdale Avenue, Pawtucket, Rhode Island. PAL serves as a *temporary* repository for project-related materials until such time that they are turned over to the USACE-NED for permanent archiving.

CHAPTER TWO

RESEARCH DESIGN AND FIELD WORK METHODOLOGIES

The goal of this investigation was to utilize a ROV system to conduct a systematic survey of an approximately 200-x-300-ft area encompassing remote sensing Targets 1, 2, and 3 to document the nature and extent of the three targets and preliminarily assess their potential historic significance. The methods used to collect the information necessary to accomplish this goal are discussed below.

Archaeological Significance and Historic Contexts

The different phases of any marine archaeological investigation (reconnaissance, identification survey, site examination, and data recovery) reflect preservation-planning standards for the identification, evaluation, registration, and treatment of terrestrial and submerged cultural resources alike (National Park Service [NPS] 1983). This planning structure centers on the eligibility of cultural resources for inclusion in the National Register of Historic Places (NRHP). The National Register is the official federal list of properties studied and found worthy of preservation. The results of a marine archaeological survey of this nature are used to make recommendations about the potential significance and eligibility of any cultural resource.

The standards for determining the potential significance of submerged cultural resources, a task required of federal agencies, are the guidelines provided by the NPS (36 CFR 60): the National Register Criteria for Evaluation. The following four criteria are given for determining if the "quality of significance in American history, architecture, archaeology, engineering, and culture is present in districts, sites, buildings, structures, and objects that possess integrity of location, design, setting, materials, workmanship, feeling and association" (36 CFR 60):

A. that are associated with events that have made a significant contribution to the broad patterns of our history, or;

B. that are associated with the lives of persons significant in our past, or;

C. that embody the distinctive characteristics of a type, period, or method of construction, or that represent the work of a master, or that possess high artistic values, or that represent a significant and distinguishable entity whose components may lack individual distinction, or;

D. that has yielded, or may be likely to yield, information important to prehistory or history.

Most archaeological sites listed in the NRHP have been determined eligible under criterion A or D. For eligibility under these criteria, a number of issues must be addressed, including the kind of data contained in the site, the relative importance of research topics suggested by the data, whether these data are unique or redundant, and the current state of knowledge relating to the research topic(s) (McManamon 1990). A defensible argument must establish that a site "has important legitimate associations and/or information value based upon existing knowledge and interpretations that have been made, evaluated, and accepted" (McManamon 1990).

The criteria used to evaluate the significance of cultural resources are applied in relation to the historical contexts of the resources. A historic context is defined as follows:

At a minimum, a historic context is a body of information about past events and historic processes organized by theme, place, and time. In a broader sense, an historic context is a unit of organized information about our prehistory and history according to the stages of development occurring at various times and places (NPS 1985).

Historic contexts provide an organizational format that groups information about related historical properties based on a theme, geographic limits, and chronological periods. A historic context may be developed for Native American, historic, and/or modern cultural resources. Each historical context is related to the developmental history of an area, region, or theme (e.g., trade, transportation, technology, military, waterpower), and identifies the significant patterns that a particular resource can represent. Historic contexts are developed by:

- identifying the concept, period, and geographic limits for the context
- collecting and assessing existing information about these limits;
- identifying locational patterns and current conditions of the associated property types;
- synthesizing the information in a written narrative, and;
- identifying information needs.

"Property types" are groupings of individual sites or properties based on common physical and associative characteristics. They serve to link the concepts presented in the historical contexts with properties illustrating those ideas (NPS 1983:44719).

Summarizing an area's cultural history may be accomplished through the development of a set of historic contexts for a particular locale or region. This formulation of contexts is a logical first step in the design of any cultural resources survey. It is also crucial to the evaluation of individual properties in the absence of a comprehensive survey of a region (NPS 1983:9).

The result is an approach that structures information collection and analyses. This approach further ties work tasks to the types and levels of information required to identify and evaluate potentially important cultural resources.

Research contexts were developed for this project to organize the data relating to the Native American and Euro-American cultural chronology and land and water use patterns in the Boston Harbor area. These research themes were developed to more fully understand the expected types and locational patterns of prehistoric and historic archaeological deposits potentially present on and/or immediately below the surface of the sea floor within the Boston Harbor Deep Draft Navigation Improvements Project study area. The potential research value of known and expected prehistoric and historic archaeological resources identified in the study area are evaluated in terms of these historical contexts. This evaluation, along with management recommendations, is presented in the summary and recommendations chapter at the end of this report.

Archival Background Research and Information Sources

The information necessary to develop environmental and historical contexts and assess the potential for archaeological resources to be present in the project Boston Harbor Deep Draft Navigation Improvements Project study area was gathered through an examination of primary and secondary documentary sources. These sources include written and cartographic documents relating to past and present environmental conditions and to known historic and prehistoric period resources in or within close proximity to the project area. A review of these background data assisted with the formulation of predictive models or statements about the project area. These data may be useful for any future archaeological work (i.e., intensive subsurface testing or site examinations) subsequently conducted in or near the project area. The following sources were reviewed as part of the background research for the study area:

State Site Files and Artifact Collection Reports

MBUAR maintains an inventory that includes submerged cultural resources listed or eligible for listing in the NRHP and a database of documented shipwrecks and obstructions located within Massachusetts waters. MHC staffs have also produced reports on a number of large artifact assemblages collected by avocational archaeologists. These reports include a record of site locations, catalogs of cultural material, and brief site summaries. In 1987, staff at the MHC prepared the nomination form for the Boston Harbor Islands Archaeological District, in which the results of 14 years of archaeological research on the area and island's prehistory were synthesized and described (MHC 1987). The targets that were the focus of this study were compared with the information contained in these databases to determine if there were any correlation.

Cultural Resource Management (CRM) Studies

Reports from previous CRM investigations conducted on land and offshore in and near the project study area, or those that contained information relevant to this investigation, were reviewed to further characterize the archaeological sensitivity of the project area of potential effect (APE) and identify any previously documented submerged cultural resources located within it. These reports included: *Remote Sensing Archaeological Survey and Geologic Interpretation, Boston Harbor Navigation Improvement Study, Boston Harbor, Boston, Massachusetts* (Mulholland et al. 2003); *Phase I Underwater Archaeological Reconnaissance Survey for Submerged Prehistoric Cultural Resources - Cultural Resources Investigations, Algonquin Gas Transmission Company, HubLine Mainline/Deer Island Lateral Offshore Gas Transmission Pipeline Project, FERC Docket No. CP01-5-000* (Robinson and Waller 2002) and; *Phase I Underwater Archaeological Reconnaissance and Intensive Survey for Submerged Historic Cultural Resources - HubLine Mainline and Deer Island Lateral Offshore Gas Transmission Pipeline Project, FERC Docket No. CP01-5-000* (Robinson et al. 2002).

Environmental Studies

A review of environmental studies provided information about Boston Harbor's physical structure and conditions in the Boston Harbor Deep Draft Navigation Improvements Project study area. Environmental factors, both present and historic, influence the formation processes of submerged cultural resources in numerous important ways and on multiple levels of scale. Environmental conditions on land strongly influence human settlement and land use patterns, the effects of which extend offshore and are strongly exhibited in the concentration, spatial distribution, and types of submerged cultural resources deposits that are preserved underwater. Natural variables, such as sea state, current velocity, light levels, sediment load, water depth, temperature, chemistry, marine biota, and anthropogenic agents of physical and chemical degradation, together act upon submerged cultural deposits and control rates of deterioration of different types of archaeological materials and features (Muckelroy 1978; Schiffer 1987).

Bedrock and surficial geology studies provide information about the region's physical structure and about geological resources near the magnetic anomalies study area. The United States Department of Agriculture (USDA) Soil Conservation Service soil survey (1969) supplied information about onshore soil types and surficial deposit comprising the islands in Boston Harbor in vicinity of the study area. The USDA survey also provided general information about the general categories of flora and fauna that these soil types support.

Supplemental environmental information pertaining specifically to the geomorphological history of Massachusetts Bay was obtained from sources such as: *Geomorphology of Spectacle Island and Boston Harbor, Massachusetts, 10,000 Years B.P.-Present* (Aubrey 1993); *Alluvial Geoarchaeology: Floodplain Archaeology and Environmental Change* (Brown 1997); *Massachusetts Bay/Stellwagon Bank Animated Sea Level Rise Model* (USGS URL http://crusty.er.usgs.gov/movies/fli/stellrise.flc 2000); *Contaminant Accumulation in the Boston Harbor-Massachusetts Bay Sedimentary System* (USGS URL

http://marine.usgs.gov/fact-sheets/fs172-97/accumulation.html 2000); *Maps and Diagrams Showing Acoustic and Textural Characteristics and Distribution of Bottom Sedimentary Environments, Boston Harbor and Massachusetts Bay, Massachusetts* (Knebel and Circe 1995); *Sedimentary Framework of Boston Harbor, Massachusetts* (Knebel et al 1992); *Archaeological Geology on Long Island, Boston Harbor* (Leudtke and Rosen 1991); *A Late Wisconsinan Marine Incursion into Cape Cod Bay, Massachusetts* (Oldale 1988); *Rapid Postglacial Shoreline Changes in the Western Gulf of Maine and the PaleoIndian Environment* (Oldale 1985a); *Late Quaternary Sea-Level History of New England: A Review of the Published Sea-Level Data* (Oldale 1985b); *Submerged and Eroded Drumlins off Northeastern Massachusetts* (Oldale et al. 1994); *Maps and Seismic Profiles Showing Geology of the Inner Continental Shelf, Massachusetts Bay, Massachusetts* (Oldale and Bick 1987); *New Radiocarbon Dates from the Inner Continental Shelf off Southeastern Massachusetts and a Local Sea-Level-Rise Curve for the Past 12,000 yr* (Oldale and O'Hara 1980); *Maps Showing the Results of Subbottom Acoustic Survey of Boston Harbor, Massachusetts* (Rendigs and Oldale 1990); *A Field Guide to Geology: Eastern North America* (Roberts 1996); and *Principles of Geoarchaeology: A North American Perspective* (Waters 1992).

NOAA Navigational Charts, AWOIS Database, and the Northern Shipwrecks Database

Navigational charts (National Oceanic and Atmospheric Administration [NOAA] Chart Nos. 13270 and 13272) and the Automated Wrecks and Obstructions Information System (AWOIS) produced and maintained by the NOAA were reviewed to determine if any shipwrecks or unidentified obstructions with the potential for being shipwrecks were charted or reported within the magnetic anomalies study area. NOAA's searchable online AWOIS database is a particularly useful research tool that is available to the public free of charge at the NOAA URL (http://anchor.ncd.noaa.gov/awois/SEARCH.CFM.). The database has a substantial volume of reported wrecks and obstructions that are considered navigational hazards within the waters of the United States. The Northern Shipwrecks Database is a CD-ROM

searchable database that includes locational and attribute data on shipwrecks in the Northeast (Northern Maritime Research 2002).

Target Identification/Documentation ROV Field Survey

Inspection of the three targets identified during the marine remote sensing archaeological survey of the Boston Harbor Deep Draft Navigation Improvements Project study area was performed using a Differential Global Positioning System- (DGPS) linked ROV system equipped with an underwater video camera and metal detector to examine and document the source of the magnetic and side-scan sonar targets. The inspection covered an area approximately 220-x-310-ft in size. This inspection was conducted over a three-day period from August 4–6, 2003.

Instrumentation employed for the inspections included:

- Trimble Differential Global Positioning System
- Coastal Oceanographic's HYPACK navigation software
- KVH magnetic, fluxgate compass
- DMS-05 Motion Sensor
- Deep Ocean Engineering Phantom HD2+2 ROV including (Figure 2-1):
    - underwater video camera
    - laser measuring device
    - underwater metal detector
    - thruster-wash deflector for limited excavation
- LinkQuest Tracklink 1500 underwater positioning system
- Ocean Tools video overlay system
- additional VCRs for simultaneous recording

Figure 2-1. Deep Ocean Engineering Phantom HD2 remotely operated vehicle (ROV) including underwater video camera, laser measuring device, and underwater metal detector.

Boston Harbor Deep Draft Project, September 2003

Target positions were reacquired using DGPS-corrected coordinates derived from the Mulholland et al. (2003) remote sensing archaeological survey report and entered into the on board navigation computer, which simultaneously displayed the locations of the survey vessel and ROV relative to the location of the targets. The survey vessel transited to the coordinates as indicated by the on board navigation system and the boat was anchored directly adjacent to the recorded position of the target using an unconstrained, single point, hydraulic anchoring system located at the stern of the survey vessel. Multiple anchor positions were used to cover the distance between targets and to provide high-quality underwater positioning.

The ROV was operationally tested at the surface and then deployed into the water from the stern of the survey vessel. The ROV was then steered to systematically survey the study area using Coastal Oceanographic's HYPACK navigation software and real-time video imaging as visual references to maintain consistent survey lines. The study area was surveyed using 21 track lines spaced apart at a 10-ft interval. Twenty-three track lines were originally proposed, but during the course of the field investigation, survey of lines 2 and 23 near the outside edges of the study area was deemed unnecessary by the project archaeologist, because of the absence of archaeological material on adjacent lines and their low probability for containing materials associated with the targets (Figure 2-2).

The seafloor was video-documented along each survey track line using a standard VHS videotape format for additional post-fieldwork analyses and future reference. The ROV's laser-indexed dimensional referencing system provided a 4.5-inch-long scale in the foreground of the camera's visual field to permit approximation of the size of a target's features. An underwater metal detector mounted to the forward end of the ROV was used to assist in the location of any metallic materials on or buried beneath the sediments. The LinkQuest Tracklink 1500 underwater positioning system permitted the exact position of the ROV to be recorded and correlated with the video so that all images and metal detector readings could be plotted in a geographically-referenced digital format.

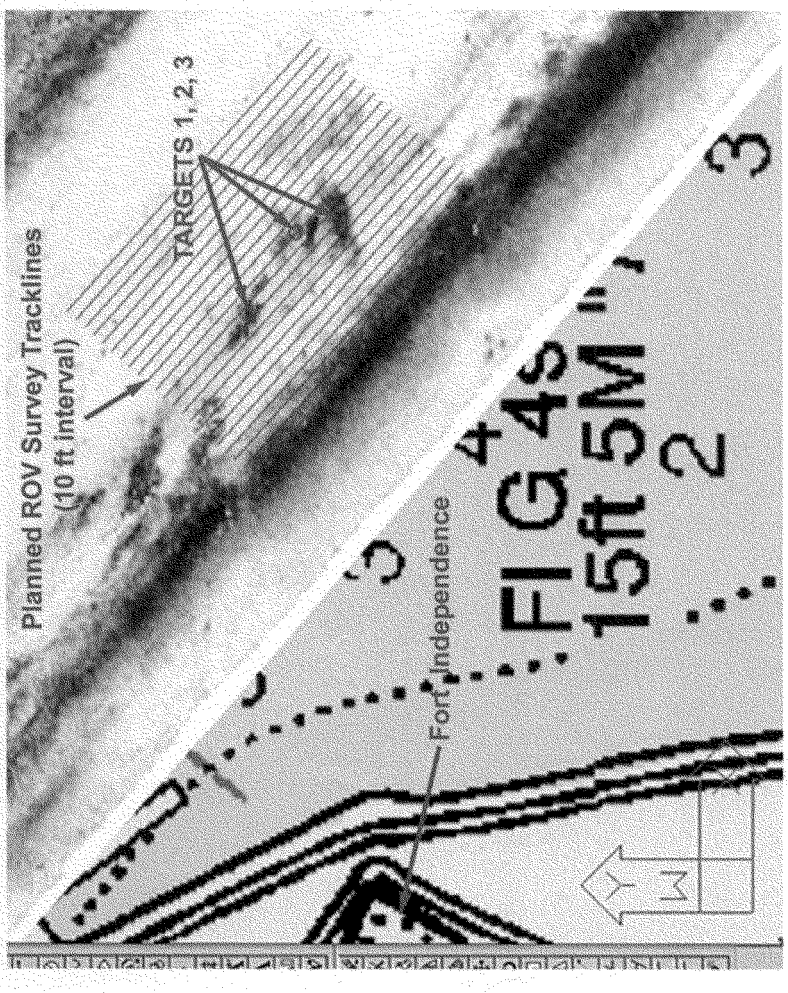

Figure 2-2. Planned remotely operated vehicle (ROV) survey lines displayed over sonar image of the three magnetic anomaly targets.

Boston Harbor Deep Draft Project, September 2003

After completion of the video and metal detector ROV survey, three loci of relatively concentrated metal detector "hits" located in proximity to the three original targets positions were partially excavated to permit a visual inspection of any potentially buried materials associated with the targets. Excavation was performed by redirecting the flow of water from one of the ROV's four-inch diameter thrusters with a fiberglass cowling attached over the thruster (Figure 2-3). Using this method, it was possible to excavate shallow (1 to 2 ft deep) test pits into the sediments at each target location.

Figure 2-3. Remotely operated vehicle (ROV) thruster (left) and thruster-wash deflector (right).

Boston Harbor Deep Draft Project, September 2003

CHAPTER THREE

ENVIRONMENTAL CONTEXT

Environmental settings, conditions, and natural resources are important factors to consider when assessing the potential for the presence of archaeological deposits, including prehistoric cultural resources that have been submerged by eustatic sea level rise. As Renfrew notes: "because archaeology recovers almost all of its basic data by excavation, every archaeological problem starts as a problem in geoarchaeology" (Renfrew 1976). The complexity and variability of geological processes make every site or region geologically unique, and sediments comprising the sea floor in Boston Harbor are no exception. Understanding the evolving and dynamic geomorphic landscape of the harbor, which was once exposed land available for habitation is essential for assessing the potential archaeological sensitivity of the Boston Harbor Deep Draft Navigation Improvements Project study area.

Geomorphology and Drainage Patterns

Geomorphology assists in reconstructing the paleoenvironment of an area and is particularly useful for early Holocene Period (i.e., PaleoIndian and Early Archaic Period) sites in areas that are different physically than they were 10,000 years ago, especially when they have been inundated by marine transgression. The submergence, and, thus, erosion and apparent obscurity of inundated landforms, can make it difficult to assess an area's original configuration and current archaeological potential (Hasenstab 1991).

The project study area lies in the western portion of Massachusetts Bay offshore of the Massachusetts Coastal River Drainage System encompassing the North Coastal (Essex, Danvers, Saugus, Pines, and Annisquam rivers), Boston Harbor (Mystic, Neponset, Weir, and the Weymouth rivers), and Charles

River drainage basins. The area's varied topography, fresh and salt water resources, and abundant floral and faunal species together comprise a wide range of onshore ecozones in the vicinity of the harbor and would have extended through the offshore study area when it was subaerially exposed prior to the last marine transgression of the Holocene epoch.

Bedrock Geology

Boston Harbor is a glacially carved estuary that lies within a fault-bounded structural basin known as the Boston Basin. The basin is a complex matrix of granite, volcanic, and sedimentary bedrock formed largely by block faulting and volcanism that occurred during the Proterozoic eon (i.e., the late Pre-Cambrian era approximately 570 million years B.P.).

Non-marine clastic erosional sediments from surrounding highlands were deposited within the basin, and additional faulting activity occurred during the late Paleozoic and Mesozoic eras. Current interpretation of geophysical data indicates that there are approximately seven geological features interpreted to be major faults that extend out into the harbor oriented on roughly east-west axes from previously identified longitudinal land-based faults (i.e., the Walden Pond Fault, the Northern Border Fault, and the Ponkapoag Fault). Movement of these faults, however, is undifferentiated and poorly understood at present (OSI 2000).

The bedrock within the Boston Harbor Deep Draft Navigation Improvements Project study area is Cambridge Argillite dating from the Proterozoic to Paleozoic period. The bedrock is a gray argillite that contains quartzite, acritarchs, and in some cases sandstone and conglomerates (Zen et al. 1983).

Surficial Geology

During the Cretaceous (about 146 to 65 million years B.P.) and Early-Tertiary (about 65 to 58 million years B.P.) periods, near-shore coastal plain-type sediments accumulated in the basin. At the time of a "low-stand" in global sea levels during the Late Tertiary period (5.5 to 3 million years B.P.), the basin was subaerially exposed and eroded. This erosion appears to have cut "unconformities" (i.e., eroded surfaces between two geological formations or surfaces onto which nothing was deposited for a significant time causing the two adjacent formations to not "conform" to each other) into the basin's bedrock and coastal plain sediment deposits (OSI 2000; Roberts 1996).

The Quaternary Period (about 2 million years B.P. to present) in the geological history of Boston Harbor is characterized by a complex interplay of multiple episodes of glaciation, isostatic crustal movement, and eustatic changes in sea level. At about 2.3 million years ago, the climate of the Northern Hemisphere cooled enough to cause mountain valley glaciers to grow and join continental glaciers that were also forming. These glaciations occurred at least 20 different times during the Pleistocene Epoch (about 2 million–10,000 years B.P.) of the early Quaternary Period (Waters 1992). The most recent of these periodic glacial episodes, the Wisconsinan glaciation, began about 30,000 years B.P., when large continental ice sheets developed in northern Europe and North America (i.e., the Cordilleran Ice Sheet in the northwest and the Laurentide Ice Sheet in the northeast) (Roberts 1996; Waters 1992). The Laurentide Ice Sheet spread outward from a point in eastern/central Canada and passed over the Boston Harbor area at around 21,000 years B.P. before reaching its terminal position on Martha's Vineyard and Nantucket at approximately 18,000 years B.P. (Brown 1997; Knebel et al 1992; Oldale 1988).

Tons of "clastic" or fragmented stone debris, including stone with magnetic properties, embedded and transported in the Laurentide glacial ice sheet eroded and polished the underlying bedrock of Boston Harbor over which it passed, scouring valleys and flat plains before being eventually deposited as glacial "drift" along the base, sides, and terminus of the glacier (Waters 1992). More specifically, the poorly sorted, unstratified deposits of boulders, cobbles, pebbles, sand, silt, and clay that were deposited directly

from the ice comprise till; while stratified drift consists of morphologically differentiated, well-sorted, glacial deposits of sand and gravel that form geological features termed "eskers" and "kames" (or "drumlins") (Oldale et al 1994).

During the Pleistocene epoch, drift dating from two different ages was deposited into Boston Harbor. An older "pre-Wisconsinan drift" sequence, known locally as "drumlin till," overlies most of the scoured and eroded bedrock in the harbor and forms a majority of the harbor's islands. This drumlin till sequence consists of deeply weathered stone and occasional boulders that form compact layers of surface-oxidized till with locally stratified deposits of gravel, sand, and silt. Overlying the older drumlin till pre-Wisconsinan drift sequence is a more recently deposited "post-Wisconsinan drift" sequence composed primarily of till, subaqueous outwash, ice-contact sand, and gravel that varies greatly in degree of sorting and stratification.

The glaciers took up significant amounts of water from the oceans, and lowered temperatures resulted in reduced runoff to the ocean basins from melting snow and ice. Consequently, sea levels fell worldwide and extensive portions of the North American continental shelf (the low, sloping platform extending seaward from the present coastline) were exposed. The peak of the Wisconsinan glacial episode (ca. 18,000 B.P.) corresponds with a period of "low stand" in sea level that in the Boston Harbor area is interpreted to have been about 300 feet below present sea level (Oldale 1985a, 1985b).

After reaching its apex at about 18,000 B.P., the Wisconsinan glaciation began receding, because of a climatic shift toward a cycle of global warming. Meltwater from the shrinking ice sheets was funneled into rivers and returned to the world's ocean basins. Sea level rose rapidly. As the Laurentide Ice Sheet retreated northward across Boston Harbor at about 16,000 years B.P., ice and sea were in contact (i.e., the ice's retreat and marine submergence occurred simultaneously) and the area was inundated by a marine transgression. At about 14,000 years B.P., local relative sea level rose to a point of about 60 feet above

present sea level (Knebel et al. 1992). As the ice melted, discontinuous ice-proximal glacial deposits and glaciomarine muds accumulated on the seabed in portions of the harbor. Large amounts of glacially pulverized rock fragments, known as "rock-flour," were discharged directly into the sea from the retreating Wisconsinan glacier and, later, into rock-flour-laden subaerial glacial meltwater streams. This glacial run-off produced deposits of a glacial-marine sedimentary unit composed primarily of stiff, bluish-gray to olive-gray silty clay referred to commonly as "Boston Blue Clay." The blue clay overlies the later of the two aforementioned post-Wisconsinan drift sequence deposits.

Deglaciation of the Boston Harbor area was followed by a rapid isostatic crustal rebound of the land between about 14,000 and 12,000 years B.P. This rebound produced a rapid concomitant regression in relative local sea level (Oldale et al. 1993). As isostatic rebound of the crust progressed, the relatively gently sloping seabed in Boston Harbor was exposed (horizontally) at a rate of 40 feet/year before sea level reached a low stand of approximately 150 feet below present sea level 12,000 years B.P. (i.e., start of the Holocene epoch) (Oldale 1985a, 1985b; Oldale et al. 1993; Oldale et al. 1994). During the regression and low stand, heterogeneous, texturally diverse, fluvial and estuarine sediments were deposited in small channels that were cut into the subaerially exposed upper drift and glacio-marine sediments. These deposits include fluvial, estuarine, and marine mud, sand, and gravel, and freshwater and saltwater peat (Redfield 1967; Oldale and Bick 1987; Knebel et al. 1992; Oldale et al. 1994).

Within about 1,000 years of reaching its postglacial low stand, isostatic rebound of the land appears to have slowed relative to the rate of eustatic sea level rise, which peaked at around this time, causing the resubmergence of much of the Boston Harbor area in the early Holocene Epoch (i.e., about 9000 to 8000 years B.P.) (Knebel et al. 1992). Initially, the late Wisconsinan and early Holocene local sea level rise in the harbor was rapid (an average of about 30 feet per 1,000 years between ca. 12,000 to 4,000 years B.P.) before slowing about 4,000 years B.P. to its present rate of less than 3 feet per 1,000 years (Oldale et al.

1993) (Figure 3-1). As the Boston Harbor area was resubmerged during the late Pleistocene and early Holocene epochs, sediments were eroded and redistributed.

Marine Transgression and Site Preservation

Where shorelines regress because of glacially related, or eustatic, marine transgression, as they did in Boston Harbor, the preservation of archaeological sites with undisturbed systemic contexts is unlikely (Waters 1992; Andersen, Dencker, Lewis personal communication 2002). Erosion associated with the swash and backwash processes on the beach face, erosion accompanying wave processes, rip and long shore currents in the surf and breaker zones of the shore face, and erosion caused by intensified waves and currents during storms will rework archaeological deposits on and in preexisting coastal landforms and sediments. When high-energy coastal processes come into contact with buried sites, the fine-grained fraction of the site matrix is winnowed and the artifacts and heavier archaeological debris are abraded and reworked into a "lag" deposit, consisting primarily of gravel and coarse sand, along the beach. If a number of sites of different ages are eroded and reworked by shoreline processes, the beach lag will be composed of a mixture of larger, heavier artifacts of different temporal ages (Waters 1992).

Two naturally occurring factors or conditions that influence the preservation of intact underwater prehistoric archaeological deposits and protect them or minimize damage from the erosive processes of transgression are the rate of sea level rise and the configuration of the pre-submergence topography (Belknap and Kraft 1981, 1985; Kraft 1971). If sea level rises rapidly, erosion will be of short duration and the underlying sediments will have a greater potential for preservation. Conversely, if the sea level rises slowly, then erosional conditions persist longer in a given location and result in greater erosion of the underlying substrate. If a site is located and later buried in a topographic position that will not be eroded during transgression, it will be preserved under what is referred to as the "ravinement" surface (Waters 1992).

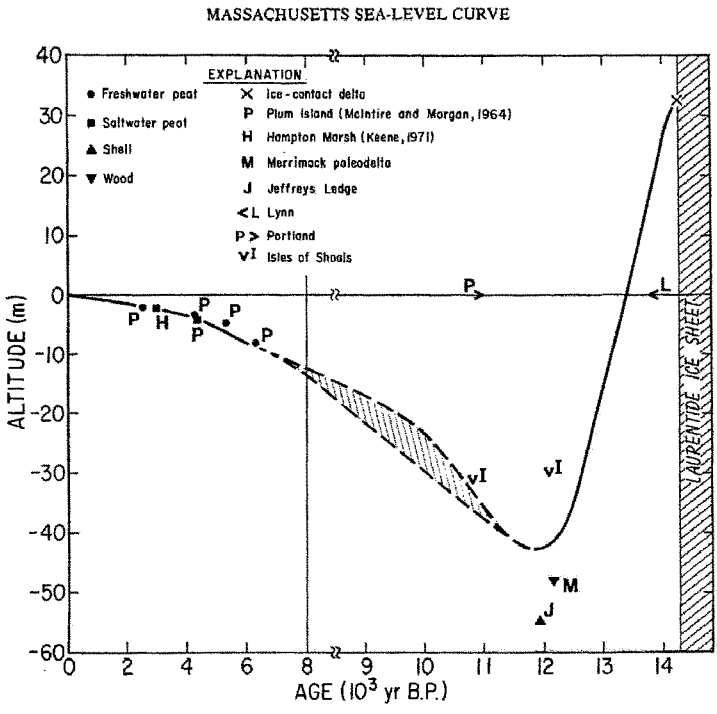

Figure 3-1. Relative sea level curve for northeastern Massachusetts and adjacent inner continental shelf, including Massachusetts Bay (source: Oldale et al. 1993).

The topographic situations that offer the best protection of relict sediments and sites are topographic low-points in the pre-submergence surface of the harbor floor. Additional factors influencing preservation of inundated prehistoric archaeological deposits include:

- pre-inundation post-depositional site transformation processes;
- the energy level of coastal processes and the depth of the wave base (i.e., the depth of effective erosion);
- the cohesiveness of sediments comprising the site matrix;
- the amount of subsidence prior to transgression;
- the gradient of the transgressed land;
- tidal range; and
- sediment import and export processes.

These and other variables effecting submerged prehistoric site preservation are discussed in Aten 1983; Belknap and Kraft 1981, 1985; Flemming 1983; Hoyt et al. 1990; Kraft 1971, 1985; Kraft et al. 1983; Masters and Flemming 1983; Pearson et al. 1986; Schiffer 1987; Stright 1986a, 1986b, 1990.

Submerged prehistoric archaeological deposits, particularly those dating from the PaleoIndian and Archaic periods that may be present on the sea floor of Boston Harbor have been most affected by the

coastal processes that occurred during the last marine transgression and the modern wave and tidal conditions to which they have been exposed the longest. During periods of lower sea level, terrestrial and coastal environments advanced seaward and occupied areas formerly covered by the oceans (Emery and Edwards 1966). In general, the types of geomorphic features and their spatial configuration in the formerly subaerially exposed portions of Boston Harbor would have been similar to those that exist today, only displaced seaward. Terrestrial environments such as river valleys, sand dunes, springs, and lakes, extended offshore into a coastal zone, perhaps characterized by a lagoon and barrier island, which extended out into deeper water marine environments. As transgression occurred, these adjacent terrestrial, coastal, and marine environments retreated landward in a sub-parallel fashion. Ideally, deposits associated with these laterally adjacent, coexisting environments should have overlapped each other and been superimposed vertically as the sea advanced landward through time. That is, as the shoreline rose, the area previously covered by terrestrial environments and sediments would have been covered by coastal sediments, while the area formerly occupied by the coastal environment would have been covered by marine sediments, and so on.

Present Conditions in the Project Area

Today, the modern geology of sea bed in Boston Harbor is characterized as irregular, with extensive subtidal flats (i.e., less than 15 feet deep) near shore, complex assemblages of irregular, discontinuous sands, gravel, boulder, and bedrock patches, ridges, and depressions under the harbor's relatively deeper waters, and a mosaic of hummocks across the approaches to Boston Harbor (Knebel et al. 1992). Waves in the progressively encroaching marine transgressive surf zone have beveled, reworked, and winnowed the upper levels of the older sedimentary substrata and, as a result, produced thin, discontinuous, shallow, marine sediment deposits that have accumulated on a widespread, underlying, time-transgressive marine unconformity (Knebel et al.. 1992). The locations and lithologic characteristics of these Holocene Epoch marine deposits appear to have been influenced by existing topography, wave energy, and the nature of

208 the eroded substrata before being drowned and preserved as water depth increased across the harbor
209 (Knebel et al. 1992). Researchers collecting seismic sub-bottom profiling data throughout Boston Harbor
210 and the Massachusetts Bay area have documented a marine sedimentary unit that ranges from moderately
211 layered to virtually transparent in the acoustic record present within depressions and on the flanks of sub-
212 bottom highs with a maximum thickness of approximately 17 feet (Knebel et al. 1992). Holocene
213 sediments composing the Boston Harbor marine unit are lithologically diverse with textures that range
214 from clayey silts to sands and include local concentrations of gravel. The unit also includes scattered
215 shells, layers of shell hash (typically less than 4 inches thick), plant fragments, beds of organic-rich
216 detritus (typically less than six inches thick), and at the base of the unit, clasts of glacio-marine mud
217 (Knebel et al. 1992). Geophysical data from the USGS, Knebel, Oldale, and others describing the modern
218 environmental conditions of the sea floor in Boston Harbor indicate that erosion from waves and currents
219 associated with shoreface retreat (beginning about 4,000 years B.P) has extensively eroded and reworked
220 most of the previously deposited sediments within the harbor. Channel maintenance undertaken since the
221 turn of the twentieth century, consisting primarily of dredging the channel to approximately 16 feet below
222 its natural depth, has also greatly disturbed natural sediments in the study area. All three targets are
223 situated within the dredged channel.
224
225 The U.S. Geological Survey (USGS) has mapped and interpreted the modern seabed geology of Boston
226 Harbor using an extensive inventory of side-scan sonagraphic data supplemented with available
227 bathymetric, sedimentary, sub-bottom, and bottom-current data adopted from the work of Knebel and
228 Circe (1995) and others. From these data, the USGS has identified three distinct seabed or "benthic"
229 environments characterized by erosion, sediment reworking, and sediment deposition that have developed
230 in the upper limits of the older sedimentary units within the harbor in response to the relatively modern
231 wave and current conditions (Knebel et al. 1992) (USGS 2000a). Inside the southwestern part of Boston
232 Harbor, shallow areas around the islands have been eroded by near-shore wave action that in many
233 instances has cut bluffs into the glacial till comprising the islands. Depositional environments in the

substrate occur in those areas where weak bottom currents predominate, such as over sub-tidal flats and within sheltered depressions between islands and away from the main tidal channels in the southwestern part of the harbor. Depositional environments are composed of naturally occurring gray-to-black silts, clayey-silts, and sandy-silts that contain relatively high concentrations of organic matter.

CHAPTER FOUR

PREHISTORIC CONTEXT

Prehistoric Cultural Chronology for Prehistoric Land Use and Settlement Patterns in Southern New England and the Massachusetts Bay Area

The study of prehistoric land use and settlement systems in southern New England has benefited substantially from the efforts of historians and avocational and professional archaeologists. The enactment of federal- and state-level regulations supportive of historic preservation has resulted in the execution of numerous CRM investigations that have identified and evaluated many Native American sites across the southern New England region. Information derived from these sources has been used to assemble a record of almost 12,500 years of human occupation in southern New England and Massachusetts.

Prehistoric culture history for southern New England may be divided into specific temporal periods (Table 4-1). These periods are distinguishable based on material culture, specific patterns of land use, and, occasionally, by additional indicators of social organization, such as mortuary/burial practices. The relatively large number of recorded Native American sites within the coastal zone of eastern Massachusetts attests to the importance of the natural resources and environmental settings that the coast afforded the region's human inhabitants during the ancient past.

Table 4-1. Native American Cultural Chronology for Southern New England.

Period	*Years*	*Identified Temporal Subdivisions*[1]	*Cultural Aspects*
PaleoIndian	12,500–10,000 B.P.[2] (10,500–8000 B.C.)	• Eastern Clovis • Plano	Exploitation of migratory game animals by highly mobile bands of hunter-gatherers with a specialized lithic technology.
Early Archaic	10,000–7500 B.P. (8000–5500 B.C.)	• Bifurcate-Base Point Assemblages	Few sites are known, possibly because of problems with archaeological recognition. This period represents a transition from specialized hunting strategies to the beginnings of more generalized and adaptable hunting and gathering, due in part to changing environmental circumstances.
Middle Archaic	7500–5000 B.P. (5500–3000 B.C.)	• Neville • Stark • Merrimack • Otter Creek • Vosburg	Regular harvesting of anadramous fish and various plant resources is combined with generalized hunting. Major sites are located at falls and rapids along river drainages. Ground-stone technology first utilized. There is a reliance on local lithic materials for a variety of bifacial and unifacial tools.
Late Archaic	5000–3000 B.P. (3000–1000 B.C.)	• Brewerton • Squibnocket • Small Stemmed Point Assemblage	Intensive hunting and gathering were the rule in diverse environments. Evidence for regularized shellfish exploitation is first seen during this period. Abundant sites suggest increasing populations, with specialized adaptations to particular resource zones. Notable differences between coastal and interior assemblages are seen.
Transitional	3600–2500 B.P. (1600–500 B.C.)	• Atlantic • Watertown • Orient • Coburn	Same economy as the earlier periods, but there may have been groups migrating into New England, or local groups developing technologies strikingly different from those previously used. Trade in soapstone became important. Evidence for complex mortuary rituals is frequently encountered.
Early Woodland	3000–1600 B.P. (1000 B.C.–A.D. 300)	• Meadowood • Lagoon	A scarcity of sites suggests population decline. Pottery was first made. Little is known of social organization or economy, although evidence for complex mortuary rituals is present. Influences from the midwestern Adena culture are seen in some areas.
Middle Woodland	1650–1000 B.P. (A.D. 300–950)	• Fox Creek • Jack's Reef	Economy focused on coastal resources. Horticulture may have appeared late in the period. Hunting and gathering were still important. Population may have increased from the previous low in the Early Woodland. Extensive interaction between groups throughout the Northeast is seen in the widespread distribution of exotic lithics and other materials.
Late Woodland	1000–450 B.P. (A.D. 950–1500)	• Levanna	Horticulture was established in some areas. Coastal areas seem to be preferred. Large groups sometimes lived in fortified villages, and may have been organized in complicated political alliances. Some groups may still have relied solely on hunting and gathering.
ProtoHistoric and Contact	450–300 B.P. (A.D. 1500–1650)	• Algonquian	Groups such as the Wampanoag, Narragansett, and Nipmuck were settled in the area. Political, social, and economic organizations were relatively complex, and underwent rapid change during European colonization.

[1] Termed Phases or Complexes
[2] Before Present

PaleoIndian Period (12,500–10,000 B.P.)

Following the retreat of thick glacial ice between 21,000 and 16,000 years ago, southern New England was populated by bands of migratory people collectively referred to as PaleoIndians. The earliest unequivocal evidence for the human occupation of the Northeast is associated with the Clovis Culture and dates to 11,120 ± 180 B.P. at the Vail Site in Maine (Gramly 1982). The presence of thick glacial ice in the Northeast until roughly 16,000 years B.P. precludes any discussion of pre-Clovis occupation of the region.

PaleoIndian settlement systems have traditionally been interpreted as bands of highly mobile hunters specialized in the exploitation of large game such as mastodon, bison, elk, and caribou (Dragoo 1976; Snow 1980). In southern New England, however, there is no clear evidence for an association between large extinct animal species and PaleoIndian artifacts (Dincauze 1993; Ogden 1977). During the time of initial settlement in the Northeast, glacial lake basins were widely distributed across the recently deglaciated landscape. The presence of resource-rich freshwater ponds and wetlands would have enticed transient PaleoIndians. These microenvironments likely supported a diversity of plant and animal species available for human exploitation. Consequently, southern New England PaleoIndians were likely generalized in their subsistence strategies, hunting available animal species and gathering various plant species for consumption and use.

Archaic Period (10,000–3,000 B.P.)

Current interpretation by archaeologists indicates that the Archaic Period was a time of colonizing and settlement of the Eastern Woodlands. The Archaic Period is subdivided into Early, Middle, and Late periods. The archaeological data attests to an increased diversification of food sources and the generalization in the exploitation of faunal and floral species throughout the period. In general, the

Archaic concept involves a primarily hunting and gathering subsistence economy with wandering or seasonal relocations in circumscribed territories that may have coincided with major river drainages.

Early Archaic Period (10,000–7500 B.P.)

The Early Archaic was marked by warmer and drier conditions that differentiate the present Holocene epoch from the preceding Pleistocene epoch. Early Archaic peoples were likely generalized in their subsistence regimes in a sense similar to the PaleoIndians (Dumont 1981; Kuehn 1998; Meltzer and Smith 1986; Nicholas 1987). Identifying Early Archaic archaeological deposits typically relies on recovery of characteristic bifurcate-based lithic projectile points. Early Archaic occupations have been identified around the perimeters of ponds, marshes, and wooded wetlands and at the headwaters of major rivers in southeastern Massachusetts. The proximity of Early Archaic sites to wetland locations may imply that plant resources were important, although hunting still appears to be the major subsistence strategy. The use of local or regional lithic materials (Blue Hills rhyolite, Sally Rock felsite, Lynn/Mattapan rhyolite) on sites in the Mystic, Shawsheen, Charles, and Neponset drainages was common during the Early Archaic Period.

Middle Archaic Period (7500–5000 B.P.)

An increase in the distribution and density of Middle Archaic sites in southern New England suggests that prehistoric peoples were firmly established in the region by 7,500 years B.P. Middle Archaic archaeological deposits are common around waterfalls, river rapids, major river drainages, wetlands, and even coastal settings (Bunker 1992; Dincauze 1976; Doucette and Cross 1997; Maymon and Bolian 1992). Subsistence activities likely included the harvesting of anadromous fish species, generalized hunting and foraging activities, as well as fishing and shellfish collection. An increase in the complexity of seasonal rounds is conjectured based upon a broad range of available resources (McBride 1984).

Middle Archaic components are identifiable in site assemblages through the presence of Neville, Neville-variant, Stark, and Merrimack style lithic projectile points (Dincauze 1976; Dincauze and Mulholland 1977). The Middle Archaic Period also coincides with the introduction of ground-stone tool technology (Dincauze 1976). A preference for locally available lithic raw materials such as quartzite, argillite, and rhyolite is reflected in the regional collective site database. A high density of local materials from Middle Archaic sites led Dincauze (1976) to theorize that Native American band or tribal territories might have been established within major river drainages by this time.

Late Archaic Period (5000–3000 B.P.)

The Late Archaic Period is among the most-represented archaeological periods in southern New England. Three archaeological traditions are identifiable in the regional archaeological record and include the Laurentian, Small Stemmed, and Susquehanna. Each tradition is a reflection of changing times, lithic technologies, and/or ceremonial or cultural practices. Seasonal and multicomponent campsites were used for the procurement of specific resources during the Late Archaic. Shellfish exploitation, for example, first observed during the Middle Archaic Period, intensified as the rate of coastal inundation decreased and estuaries, salt marshes, and tidal mud flats began to be established (Braun 1974; Lavin 1988).

The predominance of Late Archaic sites in the region suggests that settlement patterns and subsistence strategies began to shift to locations in or within very short distances of coastal and estuarine habitats. This is a major deviation from the preceding Middle Archaic Period, where resource procurement appears to have focused on the region's inland freshwater sources and wetland systems. This pattern likely relates to the stabilization of coastlines and the establishment of stable shellfish beds. The high density of Late Archaic sites in a wide range of habitats, coupled with the large number of artifacts attributed to the period, is suggestive of a large population exploiting an extremely broad spectrum of resources (Dincauze 1975).

Transitional/Terminal Archaic Period (3600–2500 B.P.)

The Transitional Archaic Period marks the interim from the Archaic Period to the Woodland Period and represents a time of changing culture dynamics. An extensive trade network, increased burial ceremonialism, and the development of technologies strikingly different from those of the antecedent Late Archaic traditions characterize the Transitional Archaic Period. Susquehanna Tradition sites are markers of the Transitional Archaic Period and are best known from cremation cemetery complexes (Dincauze 1968; Leveillee 1999). New technological developments associated with the Transitional Archaic Period include the manufacture of steatite vessels as well as a distinctive lithic flaking technology and diagnostic tool forms (Atlantic, Wayland Notched, Susquehanna Broad, and Orient Fishtail projectile points) that either developed out of the local populations or were introduced to the region by new groups immigrating into the New England area. Susquehanna Tradition chipped-stone tools were commonly manufactured from a variety of lithic materials including quartzite, rhyolite, and non-local chert.

Woodland Period (3000–450 B.P.)

The Woodland Period appears to have been a time of continued dynamic development for local indigenous peoples. The archaeological data suggests that during the Woodland Period a distinct but gradual diversification of food sources persisted, along with an increased reliance on shellfish, the refinement of pottery manufacturing, and, eventually, year-round coastal or riverine settlement. In general, the Woodland concept involves a cultural transformation from a foraging way of life toward a more sedentary existence associated with the introduction of domestic plant cultivation and the manufacture of ceramic vessels for storage and cooking. Like the Archaic Period, the Woodland Period can be subdivided into Early, Middle, and Late periods.

Early Woodland Period (3000–1600 B.P.)

The Early Woodland Period is generally underrepresented in southern New England's archaeological record. This has led some archaeologists to speculate that a population decline occurred in the region during this period (Dincauze 1974; Fiedel 2001; Lavin 1988). This apparent underrepresentation may possibly stem from the difficulty in determining what constitutes diagnostic artifact assemblages for the period. Identification of Early Woodland archaeological deposits has generally relied on the presence of Meadowood, Lagoon, and Rossville lithic projectile-point types, as well as grit-tempered, cord-marked Vinette I ceramic styles in the absence of radiocarbon assays. However, the positive identification of some Small Stemmed lithic projectile-point forms dating from the Woodland Period suggests that some Early Woodland archaeological assemblages are possibly being misidentified by archaeologists as older, Late Archaic materials.

Settlement patterns and land use during the Early Woodland Period apparently were characterized by limited use of upland areas, and more intensive use of coastal and estuarine resources and settlement locations. Numerous coastal habitation sites and shell midden deposits from Salem to Plymouth reflect the increasing dependence on shellfish and other marine resources.

Middle Woodland Period (1650–1000 B.P.)

Middle Woodland archaeological sites demonstrate an increasing focus on coastal resource adaptation. Artifacts diagnostic of the period include Jack's Reef Pentagonal and Jack's Reef Corner-Notched and Fox Creek lithic projectile points. Rocker and dentate-stamped decorations on Native American ceramics are also characteristic of the Middle Woodland Period. Middle Woodland occupations in many sections of eastern Massachusetts appear to be marked by a high occurrence of non-local chert and jasper, with varying amounts of hornfels from a source in the Blue Hills south of Boston (Luedtke 1987; Ritchie and

Gould 1985). The use of Boston Basin lithic materials is in contrast to the almost exclusive use of quartz and argillite in the Small Stemmed materials. The relative frequency of "exotic" raw materials from Middle Woodland sites implies the existence of long-distance exchange networks that extended from Pennsylvania to Labrador during this time (Dragoo 1976; Fitting 1978; Snow 1980). The late Middle Woodland Period is also marked by the addition of horticulture to the traditional subsistence practices of hunting and gathering. The earliest evidence of domesticated agricultural products in the region dates from around AD 1000 to the end of the period (Bendremer and Dewar 1993).

Late Woodland Period (1000–450 B.P.)

The Late Woodland Period is associated with an improvement in ceramic technology. Social complexity, the formation of political alliances, and the establishment of tribal territories all appear to have developed during the Late Woodland Period (Mulholland 1988). Traditional views hold that population growth, increased sedentism, and village formation followed the adoption of horticulture during the Late Woodland Period. Others argue, however, that increased sedentism and aggregated settlements could have occurred independently of the adoption of horticulture, especially in coastal or estuarine environments that support a rich and reliable fish and shellfish base (McBride and Dewar 1987). An argument has also been raised that village formation and intensive maize horticulture were essentially riverine developments during the Late Woodland (Bendremer 1993; Bendremer and Dewar 1993).

Late Woodland Period artifacts represented in the archaeological record include Madison and triangular Levanna lithic projectile points and ceramic vessels that are decorated with cord-wrapped, stick-impressed, and incised patterns. Diagnostic Levanna projectile points were most often manufactured from quartz and quartzite, with some use of Boston Basin-derived lithic materials. The distribution of Late Woodland Period archaeological deposits appears to be a continuation of the Middle Woodland pattern, but with a greater number of sites from the period represented. Clusters of Late Woodland Period

archaeological deposits are common within coastal environments, around interior freshwater ponds and wetlands, as well as adjacent to large tributary streams.

Contact Period (1500–1620 A.D.)

Native American settlement continued to be focused within traditional territories along major river drainages and coastal areas from Boston Harbor north to Cape Ann during the Contact Period. At the time of European-Native American Contact, the area of Boston Harbor was incorporated within the ancestral tribal territory of the Massachusett while north shore Massachusetts was the territorial boundary between the Massachusett and Pennacook-Pawtucket Indian groups (Grumet 1995; Leavenworth 1999; Stewart-Smith 1998). During the Contact Period, the Massachusett and Pennacook-Pawtucket Indian groups derived their subsistence needs from fishing, shellfishing, hunting, gathering of plant foods, and horticulture. Indigenous materials, such as pottery vessels and lithic artifacts, continued to be manufactured within traditional tribal territories that developed during the preceding Late Woodland Period. The subsistence patterns of the resident tribes eventually changed as a result of the increasing influence and partial adaptation of the European commodity-based economic system, with indigenous peoples selling off land as they became increasingly reliant upon items of European manufacture. Furthermore, effects of disease, isolated trade, and intertribal warfare significantly altered and reduced local Native populations.

The Boston Basin included two core areas of Native American settlement during the Contact Period: the Neponset core situated in the southern part of Massachusetts Bay and the Mystic core situated in the northern portion of the Bay (Figure 4-1). The Mystic River core area likely included several smaller adjacent coastal river drainages such as the Malden, Pines, and Saugus rivers. The larger lakes and ponds, including Fresh and Spy Pond near the estuary and Spot Pond and Crystal Lake in the Middlesex Fells, formed part of the inland section of the Mystic core (MHC 1982:29). Contact era sites in the

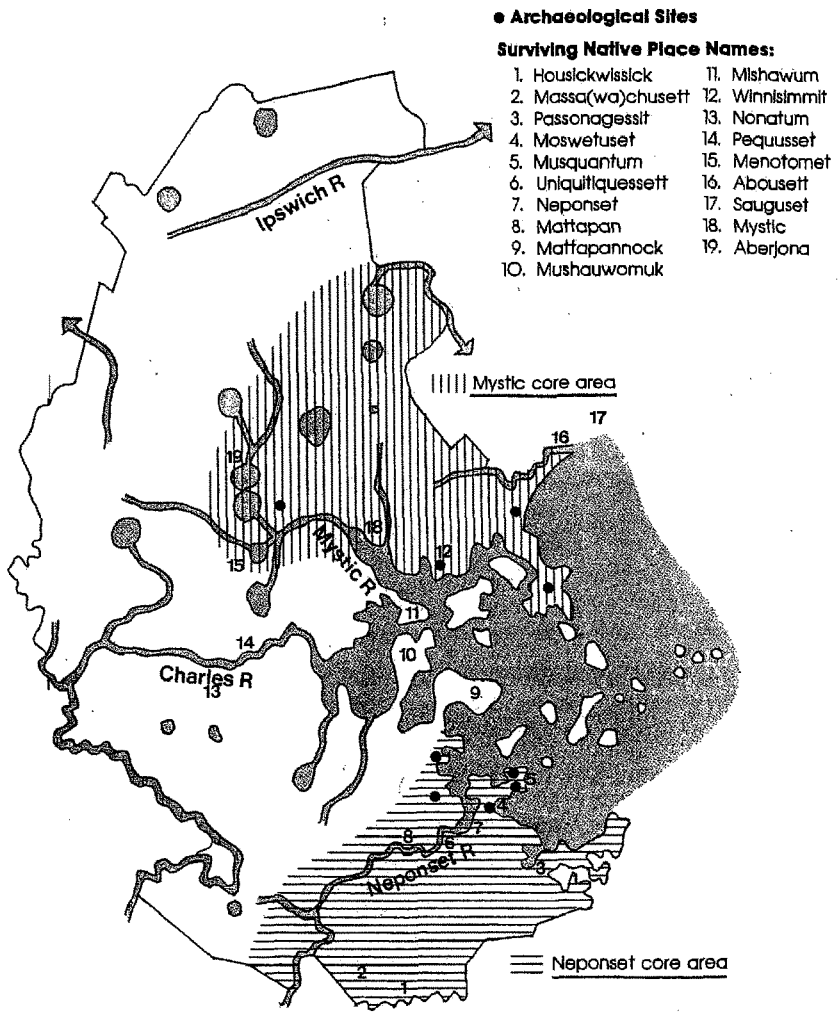

Figure 4-1. Contact Period Native American core areas within the Boston Harbor drainage (source MHC 1982).

Boston Basin include primarily isolated burial and cemetery locations. Cemeteries with Contact Period burials known from the Mystic River core-area include burials from present-day West Medford (Levin and Mahlstedt 1990), Winthrop (Willoughby 1924), and Revere Beach/Nahant sections of the Mystic River core area (Dincauze 1974).

A series of deadly epidemics between 1616 and 1620 and again between 1633 and 1634 resulted in the decimation of between 90 and 95 percent of the local Pennacook-Pawtucket population. These epidemics depopulated large portions of Native lands situated within the lower Merrimack River Drainage area (Leavenworth 1999), resulting in the appearance of "vacant" lands. An apparent absence of fifteenth/sixteenth-century or Contact Period archaeological deposits may be the result of a settlement shift to larger coastal river or estuary villages, or reuse and destruction of Native sites by subsequent settlement.

Archaeological Investigations of Prehistoric Sites in the Boston Harbor Drainage

Increased settlement and industrialization of the metropolitan Boston area throughout the seventeenth and into the twentieth centuries has resulted in major alterations to the natural landscape. Some of the known examples of landscape modification to the Boston area include filling in portions of the Back Bay estuary and other tidal mudflats or salt marsh environs along the Charles River and the grading of hills on the Shawmut peninsula. Coincident with the region's landscape modifications were the destruction of many sites. Artifact collections (e.g., J.W. Fewkes, G.B. Frazer, and F. Putnam) assembled in the late nineteenth century from sites along the lower Charles and Mystic River drainages have proven to be valuable sources of information for professional archaeologists about prehistoric sites long since destroyed by development. The G.B. Frazar Collection was compiled from numerous sites situated in the Arlington Plain area extending from Spy Pond to the confluence of Alewife Brook and the Mystic River.

The Tyzzer Collection includes Native American cultural materials from the towns of Saugus, Wakefield, and Melrose (Haynes 1886).

The Mystic, Neponset, and Charles rivers of southeastern Massachusetts, which feed into the Massachusetts Bay Basin, were focal points of Native American occupation for more than 9,000 years (Dincauze 1974). Dincauze's survey of archaeological resources in the greater Boston area, conducted in 1967–1968, included the Boston Harbor islands and revealed the research potential contained at sites located within the harbor district. A later investigation of the 12 harbor islands was the first archaeological survey focused specifically on them (Luedtke 1975, 1980). The Boston Harbor Islands National Register Historic District currently supports the best-preserved concentration of prehistoric archaeological sites in the metropolitan Boston area. The current inventory of 60 documented sites spanning the Early Archaic to Late Woodland Periods is distributed among 21 islands within the district (Luedtke 2000).

The earliest assemblages collected from the lower Boston Basin contained bifurcate-based and Stark-type lithic projectile points of Early and Middle Archaic period cultural affiliation (Dincauze 1974), although a single Eden-like Late PaleoIndian projectile is reported from along the Mystic River in Arlington (MHC 1982). Early Archaic Period archaeological sites have been reported from Arlington, Watertown, Wakefield, and Cambridge. Additionally, an Early Archaic archaeological deposit component identified on Long Island provides the first evidence for prehistoric occupation within the Boston Harbor District.

Although settlement in proximity to interior wetlands and water bodies appeared to have continued during the Middle Archaic Period, cultural materials recovered from Magazine Beach in Cambridge indicates the importance of estuaries to the Middle Archaic Period settlement system (MHC 1982). Documented Middle Archaic sites in the area include the Dillaway-Thomas House Site (Boston), Brooks Farm (West Medford) and the Spring Site (Medford/Winchester line), Goat Acre (Arlington), Watertown Arsenal

(Watertown), Cedar Hill (Wakefield), and the Small Site (Saugus). The Small Site was most likely used for fishing during spawning runs of anadromous fish species. Middle Archaic occupation of the Bay Islands is represented by spot finds from Long Island and Spectacle Island (Jones and Seasholes 1989).

With the establishment of estuaries by the Late Archaic Period, settlement appears to have concentrated increasingly around Boston Harbor. Cultural materials recovered from archaeological deposits dating from all three of the Late Archaic Period cultural traditions have been reported from the Boston Harbor drainage and are especially common along the Charles River estuary (Dincauze 1974; MHC 1982). Small Stemmed projectiles or Squibnocket Triangles affiliated with the Small Stemmed Point Tradition of southern New England were particularly frequent. The fall line of the Neponset River in Dorchester and Milton and the estuary below it were possibly focal points of Late Archaic Period activity. Late Archaic archaeological sites in the Boston Basin area include Craddock Field and Rock Hill (19-MD-366) sites in Medford and Stowell's Field Site in Wakefield. The Goat Acre, Spy Pond, and other large archaeological site deposits in the Arlington Plain and Alewife Brook may have been Small Stemmed Point base camps (MHC 1982). Site 19-SU-35, one of the nine known sites in the Neponset estuary, shows evidence of several Late Archaic Period Laurentian and Small Stemmed lithic material site components. Small, Late Archaic Period site components are suggested for the harbor islands at the Calf Island Site that produced a radiocarbon age of 3315 ± 140 years B.P. along with few Late Archaic Period artifacts (Luedtke 1980) and a date of 4135 ± 225 from a burial on Peddock's Island (Dincauze 1974). Additionally, a Small Stemmed site was identified on Spectacle Island in Boston Harbor (Jones and Seasholes 1989).

The Boylston Street Fishweir Site, discovered in downtown Boston in 1913 along the lower Charles River, represents a significant Late Archaic Period archaeological site. Multidisciplinary studies conducted at the site in 1939 and then again in 1946, represent one of the first paleoenvironmental reconstructions completed in southern New England outlining the process of marine inundation of the lower Charles River (Johnson 1942, 1949). Recent study of the site by Newby and Webb (1994)

283 established that the fishweir was utilized between about 4700 to 3700 years B.P. by people of the Small
284 Stemmed Lithic Tradition following establishment of the Boston estuary. Supplemental work in
285 proximity to the fishweir (Mrozowski et al. 1999, 2000) has resulted in a clearer understanding of the
286 filling of Boston's Back Bay and the potential for preservation of archaeological sites in an urban context.
287
288 Following about 4000 years B.P., the large pond side and riverine zone sites (Goat Acre, Spy Pond)
289 continued to be used as base camps by Susquehanna Tradition groups. A similar focus on the head of
290 tidal/estuarine section of the Saugus River was also likely. Diagnostic lithic projectile points (Atlantic
291 type) have also been found at a number of other smaller sites along the lower Mystic and Saugus rivers
292 suggesting that these coastal/estuarine environments were a focus of Susquehanna settlement. Rhyolite
293 lithic materials from the Wakefield section of the Lynn volcanic geological complex appear to have been
294 an important source of lithic materials for Susquehanna Tradition prehistoric groups settled in the
295 northern Boston Basin.
296
297 Settlement appears to have intensified in the coastal zone around Boston Harbor with decreased coastal
298 inundation and the stabilization of shorelines ca. 2,500 years ago (Dincauze 1974). At this time,
299 exploitation of various shellfish species by hunter-gatherer groups intensified. Many shell midden sites
300 were created at locations in the Boston Harbor district used for shellfish processing and temporary,
301 seasonal settlement. Few temporary camps (i.e., Water Street, Town Dock Pottery sites) occupied by
302 Early Woodland Period hunter-gatherers have been found buried under deposits of historic/modern period
303 fill near former salt marsh and shoreline locations between the mouths of the Charles and Mystic rivers in
304 Charlestown. Activities conducted at these sites included production of chipped-stone tools and limited
305 resource processing (Ritchie 1992; Shaw 1984). Early Woodland Period lithic materials, including
306 Meadowood-type projectile points, have also been recovered near the confluence of the Alewife Brook
307 and the Mystic River (Dincauze 1974). A recently unearthed hearth feature, which produced an
308 uncalibrated date of 2430 ± 80 radiocarbon years B.P., documents an Early Woodland presence in

Winthrop (Waller et al. 2000). Middle Woodland and Late Woodland materials have also been reported for many of these locations suggesting a continuity of occupation of the area.

Middle Woodland Period settlement in the northern Boston Basin appears to have been concentrated at the large estuary head and pond sites along the Mystic and lower Saugus rivers. Diagnostic lithic projectile points (i.e., Fox Creek, Jack's Reef, and Greene) found at the Goat Acre, Wyman Farm, and Spy Pond sites are evidence of continued occupation of the Arlington Plain area. Middle Woodland Period lithic projectile points found in and around the Saugus Ironworks National Historic Site indicate use of this tidal river/estuarine location about 1,600 to 1,000 years ago. A burial uncovered during construction at Revere Beach in the late nineteenth to early twentieth century contained a ceramic vessel, smoking pipe, and mica sheets typical of Middle Woodland Period grave good artifact assemblages in southern New England (Dincauze 1974). In the Saugus/Mill River area north of the Middlesex Fells, a few multicomponent archaeological sites (i.e., Ossini's Garden, Woodville district) have yielded evidence of human occupation there during the Middle Woodland Period. Middle Woodland Period sites are also represented in the coastal zone and offshore islands of Boston Harbor as documented by excavations at shell middens (Dincauze 1974) and on Spectacle Island (Aubrey et al. 1996). Middle Woodland artifacts have also been recovered from the heads of the Charles, Mystic, and Black rivers.

Late Woodland Period Archaeological deposits are more numerous than either Early or Middle Woodland Period cultural materials. The frequency of recovered Late Woodland Levanna-type lithic projectile points from the Boston Basin indicates intensive occupation of the Boston Harbor estuary and offshore islands during the Late Woodland Period. Many shell midden sites around the perimeter of Boston Harbor appear to exhibit evidence for Late Woodland Period occupation. Large settlements were located at the estuary head sites like those on the Mystic (Goat Acre, Wyman Farm) and Saugus (Saugus Ironworks) rivers (Dincauze 1974). A settlement focus concentrated in this area continued into the European Contact Period era as evidenced by the identification of Native American burial sites containing

Late Woodland or Contact Period burials in West Medford (Levin and Mahlstedt 1990), Winthrop (Willoughby 1924; MHC site files), Revere, and Nahant (MHC site files). The inner harbor islands such as Long Island, Peddock's Island, and Thompson Island were used for intensive shellfish processing and possibly farming during the Late Woodland Period (Luedtke 2000). Outer harbor islands, such as Calf Island and the Brewster Islands, were prime locations for exploiting marine resources such as fish, shellfish, and sea birds (Dincauze 1974; Luedtke 1980, 2000). A logboat recovered from Weymouth's Great Pond and believed to date from the Late Woodland - early European Contact time period provides an indication of the type of watercraft prehistoric peoples were manufacturing and traveling in across the inland and protected coastal waters of the Boston Drainage System (Kevitt 1968; Plane 1991).

CHAPTER FIVE

EURO-AMERICAN PERIOD CONTEXT AND WATERWAY DEVELOPMENT

Historic development in and around the Boston Harbor Deep Draft Improvement Project study area has been governed by a series of events and underlying processes. Some of these events and processes affected the entire region while others were unique to the Castle Island portion of Boston Harbor. This chapter presents a synopsis of the project vicinity's historic period development and provides a historical context for the study area.

Contact and Plantation Period (1500–1675)

The initial incursion of Europeans into the eastern Massachusetts region prior to 1620 followed the expansion of fur trapping, fishing, exploration, and limited trade in the region. In 1614 John Smith explored Cape Ann, Cape Cod, Massachusetts Bay, and other New England locations. Smith, upon his return to England and in conjunction with maps made by fishing captains and explorers, published *A Description of New England*, which helped open the region to more widespread European colonial settlement. The first significant and lasting influx of European settlers into southern New England began with the establishment of a Puritan settlement at Plymouth in 1620. Shortly after the founding of Plymouth, European settlements were also established at Salem (1629), Boston (1630), and Haverhill (1645).

The first Europeans to arrive in the area found Native American interconnected villages located along major river drainages. The immigration of Europeans and their endemic diseases to North America caused a precipitous and disastrous decline in the Native American population. Regional estimates indicate that between 80 and 90 percent of the native population was killed off through disease, with some

individual Native American populations suffering even higher mortality rates. Prior to European contact, an estimated 120,000 Native Americans inhabited the region. A century later, that number apparently plummeted to just 16,000 (Muir 2000:24). Conversely, by 1640 approximately 35,000 Europeans were estimated to reside in Massachusetts.

The first of the region's Euro-American entrepreneurs specialized in the fur and fish trades. Fish were obtained by European fishermen plying the coasts of Massachusetts and Maine, while furs, especially beaver, were bartered from inland European and Native American trappers. Euro-Americans quickly realized the benefits of reducing the region's natural resources close to the source and industries were founded. The three primary early industries in eastern Massachusetts were ironworks, cloth making, and shipbuilding. Bog iron was first exploited in the area at Saugus in 1642 (Weeden 1890:174), and Joseph Jenks began producing cast iron goods in Lynn shortly thereafter. Additional ironworks were erected in Saugus (ca. 1645) and Raynham (ca. 1656). By 1645, the ironworks at Lynn and Braintree were producing iron in the tons. In 1643, cloth, primarily woolens, began to be spun at Rowley. Throughout the period, production of wool and the spinning of cloth continued to increase. Additional industries, such as leather tanning, were also being established in the area at approximately the same time.

Shipbuilding was initiated with the July 4, 1631 launching of John Winthrop's first New England-built vessel, the 30- to 40-ton bark, *Blessing of the Bay* (Weeden 1890:123; Bauer 1988:30). Winthrop, the governor of the Massachusetts Bay Colony, was an early proponent of the settlement of trained shipwrights in the North American colonies. Capable shipbuilders were an asset to the colony, because early transportation was almost solely via water. Small vessels were built for fishing and coastal and inland trade, while larger vessels were constructed for trade with the Old World. Shipbuilding supplies were also exported from New England, especially pine for ships' masts, with the first shipment being delivered to Europe in 1634 (Bauer 1988:34). The ocean-going vessels of this period consisted primarily

of ships, barks, and pinks, while the most common coastal and riverine watercraft were pinnaces, shallops, ketches, and sloops (Lawson 1895:111–115). Most ocean going vessels of this period were approximately 60 feet in length, and seldom more than 100 feet, with a length to beam ration of 3:1. Coastal vessels were generally 30–40 feet in length (Bauer 1988:31).

Colonial Period (1675–1775)

During the Colonial Period, the Euro-American population of the region continued to expand through immigration and natural growth, which put further strain on relations with the indigenous peoples. These poor relationships and competition for land manifested themselves in a number of conflicts, most notably King Philip's War (1675–1676). Ultimately, the European colonists were successful in continuing the expansion of their settlements and displaced the Native American populations of the area.

The physical and material expression of this Euro-American expansion was apparent in the continuation of earlier social and economic patterns (MHC 1981:4). For example, roads and ferry service were expanded and improved. A dichotomy between urban centers, where most of the industry, crafts, and trade were centered, and the hinterlands where agriculture and extractive industries occurred, developed during this period.

In 1722, 15 different shipyards were operating in Boston and producing all manner of vessels, especially larger ships for the transoceanic export trade (Goldenberg 1976:33). The major classes of maritime occupations in eastern Massachusetts during this period were, commerce, fishing, whaling, the slave trade, and privateering/piracy. The increased differentiation of maritime trades led to a need for more adaptable vessel types. The schooner appeared in Boston in 1716 (Bauer 1988:31), the sloop surpassed the pinnace, shallop, and ketch, and the brigantine replaced the bark, but in general the sizes of ships and

the construction techniques were the same as during the previous period. (Goldenberg 1976:39). Boston was also a premier shipping port, because of its location, good harbor, and key political connections. By the second decade of the eighteenth century, important improvements to Boston's waterfront had been made. Included among them were the construction of Long Wharf and Boston Light (MHC 1981:5, 7).

The primary trade network engaged in by Massachusetts merchants during the period was the infamous "Triangle Trade," in which sugar and molasses, rum, and slaves were transported between Africa, the Caribbean Islands, and the North American colonies. Export of natural resources, such as pelts and lumber remained major sources of wealth as well. Following the same rationale applied by modern core nations to those of the periphery, England viewed their colonies as a source of raw materials that could be processed in England and sold back to the colonies as a finished product for the profit of English merchants. In exchange, the colonies were provided with established trade networks, financial support, and military protection. However, in an attempt to maintain control over the financial fortunes of their colonies, the British passed a series of new laws that included the Townshend Act (1767) and the Stamp Act (1770), which were aimed at restricting the economic growth of the colonies. Both the Boston Massacre (1770) and the Boston Tea Party (1773) were colonial revolts against the effects of these acts. Ultimately, the American Revolution resulted.

Federal Period (1775–1830)

This period began with the Revolutionary War, which effectively disrupted many of the traditional trades until the signing of the Treaty of Paris (1783). Maritime trades such as commerce and whaling were almost destroyed by British predation and raids, and agricultural pursuits saw some decline as men joined the Continental Army. However, merchants made substantial money by supplying the army with goods and food (Weeden 1890:821).

A number of important changes took place in transportation and communication during this period. Coastal and riverine routes remained important, but new, artificial networks were developed (MHC 1981:9). Canals were built to link the interior with the coast. For example the Middlesex Canal was built during the 1790s to link Boston and the Merrimack Valley. At the same time, the first turnpikes began to be constructed throughout New England (Muir 2000:111). Much of the labor for these undertakings was provided by immigrant workers as the slave trade in Massachusetts was legally ended in 1783 (Weeden 1890:834).

While the surrounding towns continued to be major shipbuilding centers, Boston had only four or five dockyards during this period, and these were used primarily for repairs. At the same time there were as many as 80 wharves in operation (MHC 1981), indicating the importance of commerce, rather than shipbuilding to the area's economy. Ships of this period were very similar to those from earlier periods with large vessels ranging from 95 to 120 feet in length. Trade during this period fluctuated depending on the political climate. During the last decades of the eighteenth century, Yankee merchants opened trade with the Orient (Weeden 1890:820). In addition to China, Americans found a number of willing markets for their raw materials and finished goods after the war. However, the Embargo Act (1807), The War of 1812 (1812 to 1815), and the Great Panic (1819) all caused depressions in trade.

Early Industrial Period (1830–1870)

The trends begun in the previous period continued to accelerate during this age. The development of the region's transportation infrastructure continued to develop, primarily in the form of railroads, which proliferated after circa 1835 (MHC 1981:14). Road networks continued to be important and saw improvements. The improvement of roads and railroads effectively opened up the interior of the country

to mass settlement. Coastal trading and transportation, however, continued to depend heavily on waterborne transportation.

The influx of European immigrants into the region, primarily Irish, driven across the ocean by the potato famine (1845–1846), and Germans, filled the labor needs of area mills and factories. While industrialization grew of its own accord, spurred on by increased mechanization, steam power, and refinements in machining parts, the Civil War (1861–1865) caused an enormous boom in production for the factories of the north. Major industries of this period included textiles, metalworking, machinery, and shoe and boot manufacture.

Trade continued to be a source of income for the region, as was fishing, although commercial fishing, especially whaling, saw a decline during this period as production of petroleum began to replace whale oil. Lobstering emerged a source of income for fishermen (Bauer 1988:225). Aggressive trade with Europe and the Orient, as well as the western Gold Rush provided ample opportunities for maritime trade.

Vessels of this period were built of both wood and iron and powered by both sail and steam. Large vessels of this period averaged 150 feet in length but many vessels were more than 300 feet in length. Side-paddlewheel steamers were the predominant steamship hull type throughout the period, although screw-propelled vessels became increasingly common after their introduction during in the early 1840s (Bauer 1988:100). Coastal fishing vessels of the era, like those of most of the preceding and subsequent periods, continued to be built with a low freeboard and transom, which permitted the haul to be brought aboard more easily.

Late Industrial Period (1870–1915)

The period prior to the First World War bore witness to a number of major technological developments including the widespread use of steam, electrification, and gas lighting. These advances resulted not only in more comforts at home, but also improved industrial production. Textile mills once again became the dominant form of industrial production, supplemented by metal products and other goods (Muir 2000). Increased technology also provided for increased urban sprawl. Urban and interurban mass transportation, street railways, and elevated lines were constructed during this period (MHC 1981:21). This expansion was in part possible because of the collapse of small-scale farming, which opened land up for subdivision. An anomalous, slight resurgence in agriculture did occur in eastern Massachusetts, however, in the form of cranberry cultivation.

Coastal Massachusetts began to see the development of summer and resort industries aimed at individuals wealthy enough to vacation. This transformation saw the beginnings of the shift from commercial to recreational fishing in towns like Beverly. Despite this shift, commercial fishing and maritime trades remained a major source of employment in the area.

Following the Civil War and the success of the iron-clads, most large-scale shipbuilding shifted to iron and steel construction. Metal-hulled ships of this period tended to be 260 feet or less in length with beams of 40 feet or less. While metal-hulled vessels were ascendant during this period they did not push wooden ships out of the market until World War II (Bass 1988: 248; Gould 2000:241). Sail continued to be used into the twentieth century (Bass 1988:248), but increasingly steam-driven propellers powered vessels. Most of the vessels of this period, both sail and steam powered, maintained hull forms that were very similar to those of the previous era.

In addition to oceangoing vessels large three- to seven-masted schooners, with displacements ranging from 500 to 900 tons, were used to transport inexpensive bulk cargoes of coal and ice to various points. Small 30–40 foot long vessels were still used for fishing. This period also saw the first widespread use of barges. Because they do not have their own source of power barges could not be widely used until the adoption of steam power to propel tug and push boats.

Modern Period (1915–present)

With the Great Depression (1930s) following World War I, the mill industry of Massachusetts experienced a general decline. World War II temporarily reversed this decline, but following the war, industry continued its downward slide. The textile and shoe industries of region were particularly hard hit. Much of the population displaced by the fall of industry in the area were absorbed into growing professional and service occupations, such as banking, computers, and defense industry contracting. Many of these service-based firms were established outside of Boston in more rural and suburban settings.

This period saw the near total extinction of large sailing wooden vessels. Instead, large vessels of this period were primarily those built of iron and steel, and were assembled initially with rivets, and later with arc-welded seams (Bauer 1988:295). Propulsion for these large vessels was initially in the form of reciprocating steam engines, but by World War II diesel and steam turbines had nearly replaced the older style engines. During the middle part of the century, turbo-electric and diesel-electric engines were installed in large vessels with varying degrees of success (Bauer 1988:293).

Small vessels underwent a number of developments during this period as well. Steel hulls became prevalent in small commercial vessel construction during the second half of the twentieth century. Hulls

fabricated from fiberglass became increasingly common during the past few decades. Today, 90 percent of dinghies, yachts, and small craft up to75 feet in length are made of fiberglass (Kemp 1976:300). Diesel and gasoline engines began to appear in the civilian market during the 1920s, but did not become widespread until after World War II. Sail persisted in small recreational vessels, and is generally used in conjunction with a wood or fiberglass hull and sometimes supported by a gasoline engine. By the end of World War II, steel- hulled barges began to become more common.

The twentieth century saw new safety regulations applied to the sea. Drastically improved navigational aides and the presence of radios combined with radio-dispatched tugs made it easier for mariners to stay out of or get out of harms way. With the addition of more reliable power sources to keep vessels off of rocks the mortality rate of the sea dropped significantly during this period.

Historic Development of Castle Island

Early English settlers lived on the Boston Harbor islands or used them for timber and animal grazing. As they were close to the channel into Boston, the islands and associated rocks were both a danger and help to mariners. Some ships inadvertently were driven onto the islands and ledges in poor visibility or adverse winds. Yet the islands were bases for lighthouses, channel markers, and rescue teams and they were dry refuges for shipwrecked mariners. The islands also served as bases for defense forts and observation posts during times of war (Mulholland et al. 2003:39–40).

Castle Island with Fort Independence (also known as Fort/Castle William and Fort/Castle William and Mary) was the second (after the defenses erected on Fort Hill at the southeast end of Boston) location fortified in the Massachusetts Bay Colony. The area was early on recognized as an important maritime defensive location because it controlled much of the southern approach to Boston. John Winthrop built a

fortification there in 1634. That structure burned in 1673 but was rebuilt shortly thereafter. Early in the 1700s a masonry fort was built on the site, at the order of King William who feared a French attack of the area. Stamps associated with the Stamp Act were stored at the fort, and after the British troops withdrew from the town following the Boston Massacre, they were garrisoned there. The British held the fort for the duration of the Siege of Boston, before partially destroying it by explosion on March 19, 1776 as they withdrew from the city. The fort, the sixth on the site, was rebuilt by the Americans under the direction of Richard Gridley and renamed Fort Independence. On September 6. 1776 Paul Revere became the Commandant of Fort Independence, and remained at that post until September 6, 1780. During this period the fort had a rubble stone wall, largely made from the remains of the previous structure, and was surrounded by a nine-foot palisade. The fort, mounting 30 guns by 1777, formed the backbone of the harbor defenses along with Fort Hill, Dorchester Point Fort, Charles Town Fort, and Noodles Island Fort. Following the Revolution the fort became a state prison in 1785 prior to being transferred to the federal government in 1798. In 1801 the seventh fort on the site was built. This fort, the most important fortification on the site, which stood from 1801 to 1836, was the most significant deterrent of a British invasion of the harbor and Boston that existed during the War of 1812. The present (eighth) fort was built in 1841 and was used to garrison troops during the Civil War (Figure 5-1). The fort was then inactive and owned by the state until it was used briefly by the Signal Corps and as a degaussing station during World War II. From 1892 to 1942 the island was used as a city park. Fort Independence was transferred back to the state of Massachusetts in the 1960s, renovated in the late 1970s, and reopened to the public as a park in 1981. (Reid 1995)

The first connection between the mainland and Castle Island was a bridge completed in 1892 that allowed the island to be used as a city park. Beginning in 1916 dredge spoils were dumped between the island and the mainland, and by the mid 1920s a dirt road had been formed. The dirt road was replaced by a

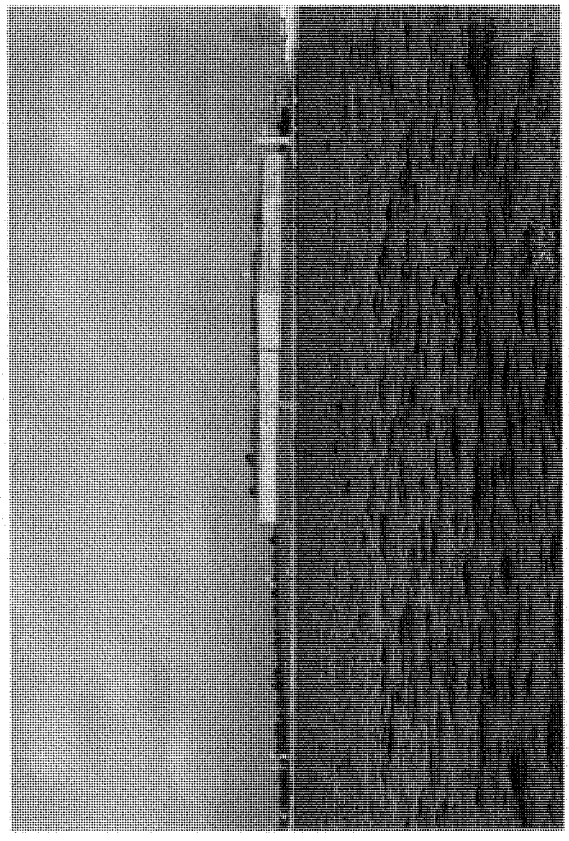

Figure 5-1. View of Fort Independence and Castle Island from the Boston Harbor Deep Draft Navigation Improvements Project study area.

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concrete walkway in 1928 and Castle Island Boulevard in 1931. Castle Island Boulevard eventually became part of William J. Day Boulevard. (Reid 1995:131, 139)

Recorded Wrecks within the Boston Harbor Deep Draft Navigation Improvements Project Study Area

Despite the treacherous nature of the entrance to Boston Harbor, especially prior to the installation of modern navigation aids and regular channel maintenance, only five ships have been recorded as wrecked or run-aground in close proximity to Castle Island. The earliest occurred in 1646 and was recorded in Winthrop's *Journal*. Two Hingham men formed a large raft of timber and attempted to float it to Boston in order to sell the wood. As the raft approached Castle Island a storm blew up, destroying the raft and forcing the men and much of the timber onto the island. After a second attempt staged from the island that ended with a similar storm, the men eventually reached Boston and sold most of the timber (Reid 1995:167). The only recorded vessel to actually be lost in the immediate vicinity of Castle Island was the *John F. Nickerson*. On October 25, 1895 the fishing schooner *John F. Nickerson* was returning to Boston with a load of halibut when it was struck by an unlit towed mud scow. The schooner sank so quickly that the crew had only enough time to jump into the schooner's small fishing dories as they were swept from their stowed position on the *Nickerson*'s deck by the rising water. The captain made his escape by scrambling up the rigging to the top of the mast, which remained a few feet above the water's surface as the ship settled to the bottom (Sullivan 1990:144). On November 4, 1907, the steamer *City of Birmingham* struck a submerged wreck (the *Nickerson*?) and began to sink. Before abandoning ship, the captain managed to steer the vessel onto the mud flats near the island where it sank to its upper deck. Divers patched the hull and the vessel was pumped out and towed to East Boston for repairs (Sullivan 1990:146). On August 20, 1974, the *Vineyard Queen* ran aground on the mud flats off of Castle Island in

a fog. The *Natascot* attempted to aid the *Vineyard Queen*, but also ran aground. Eventually both boats were freed (Reid 1995:167).

The shipwreck noted on NOAA navigation chart 13270 within the study area has not been identified (Mulholland et al. 2003:45). This wreck was first indicated on the NOAA charts in 1975, suggesting that the wreck either occurred or was reported between 1974 or 1975 (Figure 5-2).

Channel Maintenance within the Boston Harbor Deep Draft Navigation Improvements Project Study Area

The Boston Harbor Deep Draft Navigation Improvements Project study area location within the main, southern approach to Boston has been a busily traveled thoroughfare for local, regional, and international shipping since the earliest days of European colonization. Many of the vessel types discussed in the historic context sailed through the study area. This channel has been referred to as the "23-Foot Channel," the "35-Foot Channel," the "40-Foot Channel," and the "Main Ship Channel," as it developed and was deepened. From the late eighteenth through the late nineteenth centuries, water depth within the study area was approximately 24 feet deep at low tide (see Figure 5-2). In 1883, a spur shoal was removed off Castle Island to widen the 23-Foot Channel. Between 1903 and 1918 the channel within the study area was deepened further and was dredged to 35 feet below the mean low water mark. Finally, during the waning years of the 1930s, the channel was deepened to its current depth of approximately 40 feet. Periodic dredging to maintain the channel has continued through the 1980s (USACE-NED 2003). The channel has been dredged numerous times, and deepened by at least 16 feet since the *John F. Nickerson* sank off of Castle Island

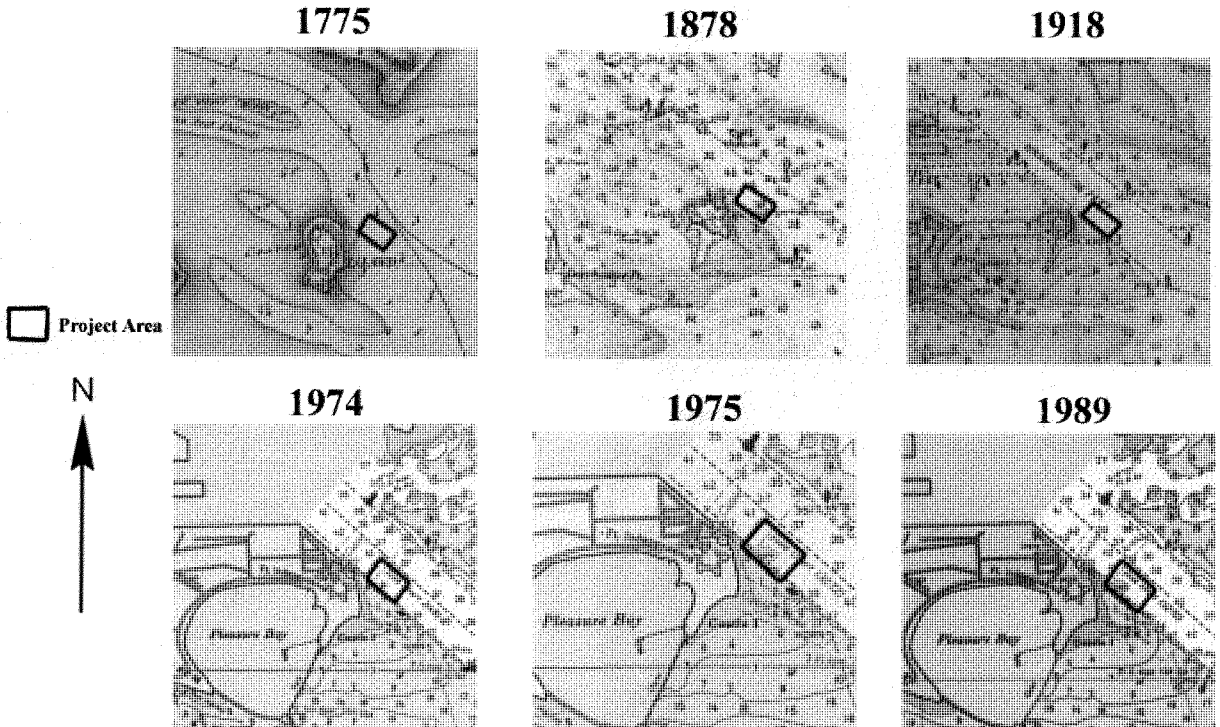

Figure 6-2. ROV video image of steel-wire mesh lobster traps and naturally occurring rock that are the sources of the magnetic and acoustic anomalies comprising Targets 1, 2, and 3.

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CHAPTER SIX

RESULTS AND RECOMMENDATIONS

Marine archaeological remote sensing survey conducted by Mulholland et al. (2003) resulted in the identification of three targets that were recommended for additional inspection to determine their source, extent, and potential significance. To accomplish these objectives, background research and an ROV survey were conducted. This chapter presents the results of these investigations and provides management recommendations for the study area.

Background Research

Background research indicated that prehistoric Native American populations extensively utilized the surrounding lands and islands within Boston Harbor prior to European contact. Thompson Island, for example, approximately 1 mile south of Castle Island, contains at least 17 recorded ancient Native archaeological sites. As discussed in Chapter 3, significantly lower ocean levels during the PaleoIndian and Archaic periods also suggested that archaeological evidence from these periods could be present within intact sediments comprising what is now the harbor floor, although such evidence has not yet been found and there are no known prehistoric sites within or in close proximity to the study area.

Background research also revealed that Castle Island had been the locus of extensive human activity during the post-Contact historic period, because of both its service as an important military outpost from the seventeenth century through the World War II era and its location adjacent to Boston Harbor's main shipping channel. As one of America's oldest and most active international ports, Boston has seen a steady stream of vessels of almost every description and nationality pass in and out of its harbor for more than 400 years. Among these countless vessels, only five were reported to have either sank near or run aground on Castle Island, and all but one, the fishing schooner *John F. Nickerson*, were repaired and re-

floated. The absence of documentation describing the *Nickerson*'s salvage suggested that the wreck depicted within the study area on NOAA navigational chart #13270 could be that of the schooner. However, shipwrecks have been depicted on navigational charts since at least 1898 (Steven Verry [director, NOAA AWOIS] electronic communication, 2003), and an obstruction present since 1895 in a heavily traveled shipping lane would likely have been recorded prior to the initial charting of the wreck in 1975.

Among the most important conclusions to be drawn from the background research conducted for this study was that the improvements and periodic maintenance dredging of the main shipping channel conducted to date have profoundly altered the natural bathymetry and sediments of the sea floor within the study area. In fact, approximately 16 vertical feet of sediments were removed from the area between 1883 and the mid-1930s (Appendix B). As a consequence of this extensive removal and disturbance, there was a low probability for encountering potentially significant submerged ancient Native American cultural resources, or potentially significant historic vessels, such as the *John F. Nickerson*, that were 50 or more years old.

ROV Survey of the Targets

ROV survey of the study area encompassing targets 1, 2, and 3 confirmed the disturbed nature of the study area, and determined the source of the targets to be a concentration of abandoned steel-wire mesh lobster trap trawls that were entangled in a naturally occurring rock deposit within the study area. This conclusion is based on the results from the survey of 21 of the 23 planned track lines covering the 220-x-310-ft study area encompassing targets 1, 2, and 3 (Table 6-1; Figure 6-1). Two of the 23 planned lines, located near the edges of the study area, were not surveyed because of the absence of any detectable evidence of target sources along adjacent lines and the low probability for lines two and 23 to contain anything of note.

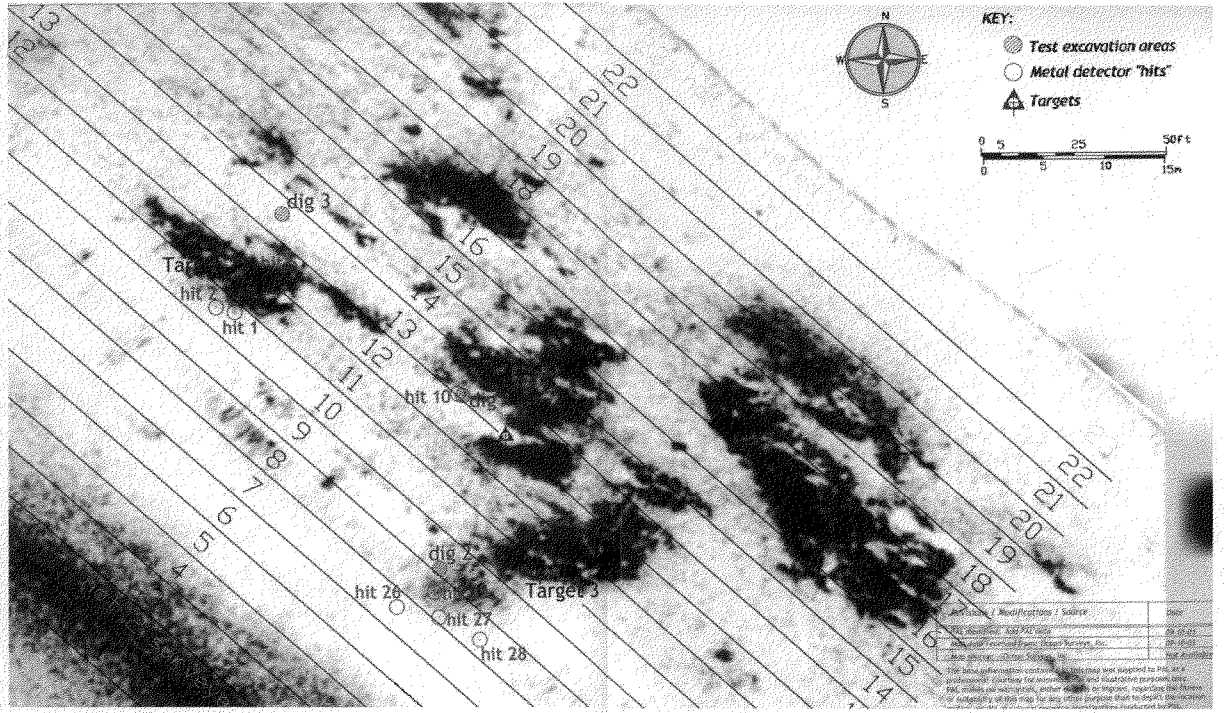

Figure 6-1. Remotely operated vehicle (ROV) survey lines, targets 1, 2, and 3, metal detector "hits", and test excavation areas displayed over composite NOAA chart and sonar image of the three magnetic anomaly targets.

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Table 6-1. Summary of Remotely Operated Vehicle (ROV) Survey Results.

Track Line	Number of Magnetic Anomalies	Isolate or Cluster	Cluster/Anomaly Excavated	Magnetometer Target	Notes
1	0	n/a	n/a	None	Edge of channel slope
2	Not surveyed	n/a	n/a	None	Low probability
3	1	Isolate	No	None	Shallow
4	1	Isolate	No	None	Rocky area with vegetation
5	1	Cluster	No	None	None
6	3	Cluster	No	None	Area of vegetation; modern bottles
7	2	Cluster	Yes	Target 3	None
8	2	Cluster	Yes	Target 3	Rocks
9	3	Cluster	Yes	Target 3	Rocks
10	1	Cluster	No	None	Area of vegetation
11	5	Cluster	Yes	Target 1	One lobster pot
12	2	Cluster	Yes	Target 1	Planking nearby
13	3	Isolate	Yes	Target 2	None
14	0	n/a	n/a	None	Rope
15	1	Isolate	No	None	Lobster pot
16	4	Isolate	No	None	Three lobster pots
17	1	Isolate	No	None	Lobster pot
18	2	Isolate	No	None	One lobster pot
19	1	Isolate	No	None	Lobster pot
20	2	Isolate	No	None	One Lobster pot
21	1	n/a	n/a	None	ROV Cable
22	0	n/a	n/a	None	None
23	Not surveyed	n/a	n/a	None	Low probability

Sediments within the study area consisted primarily of soft silty muds and sands interspersed by concentrations of naturally occurring cobble and small boulder-sized rocks. The only anthropogenic objects noted within the study area were the remains of the steel-wire mesh lobster traps and miscellaneous modern debris (e.g., polypropylene rope, glass bottles, and aluminum beverage cans) (Figure 6-2). A total of 36 metal detector "hits" were recorded. Hits associated with the three target locations tended to be clustered. A majority of the hits were isolated, indicating that they resulted from small or discrete sources with low probability to represent potentially significant cultural materials associated with the targets.

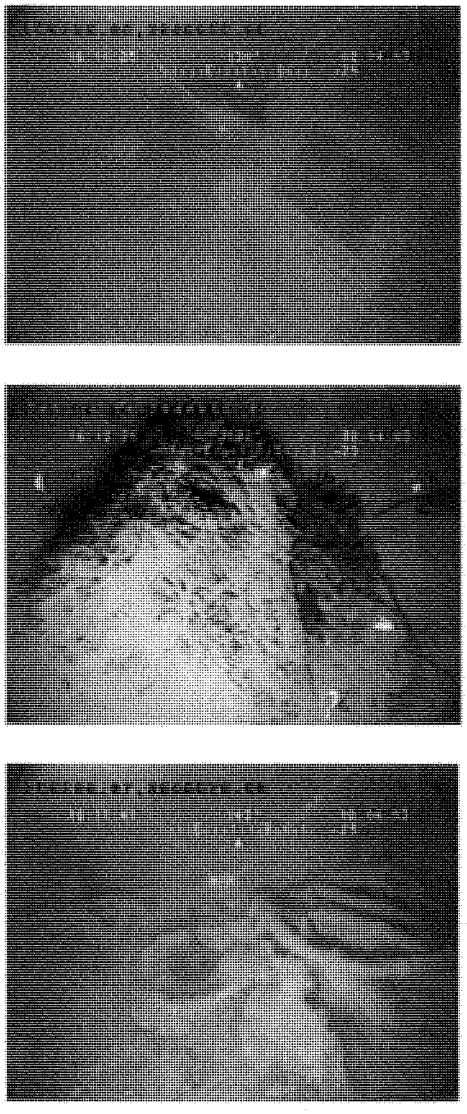

Figure 6-2. ROV video image of steel-wire mesh lobster traps and naturally occurring rock that are the sources of the magnetic and acoustic anomalies comprising Targets 1, 2, and 3.
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Although no evidence of cultural resources was observed on the sea floor within the study area, test excavations were performed in three areas where there were clusters of metal detector hits that corresponded with the magnetometer anomalies detected during the Mulholland et al. (2003) survey. These excavations were conducted to further confirm that the source of the targets was related to modern debris and naturally occurring rock. In two test excavation areas, solid rock was encountered within about 1 foot of the sea floor surface. In the third test excavation area, a depth of approximately 2 feet (the practical limit of excavation with the Deep Ocean Engineering Phantom HD 2+2 ROV) was attained without encountering any cultural materials or natural impediment.

Recommendations

No evidence of any potentially significant Native American or Euro-American submerged cultural resources was identified within the Boston Harbor Deep Draft Navigation Improvement Project study area encompassing remote sensing targets 1, 2, and 3. The only cultural materials encountered within the project area were steel-wire mesh lobster pots and modern debris. No evidence of the shipwreck depicted on NOAA navigation chart #13270 was found within the study area. The magnetometer and acoustic anomalies reported by Mulholland et al. (2003) appear to have resulted from abandoned lobster pots associated with a naturally occurring rock deposit. **Since the proposed improvement activities within the study area will not affect potentially significant submerged cultural resources, no additional archaeological investigation of remote sensing targets 1, 2, or 3 is recommended. NOAA should be notified that this survey found no evidence of a shipwreck at the charted location, so that they may revise their charting of the area**

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APPENDIX A

PROJECT CORRESPONDENCE

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July 18, 2003

Victor Mastone
Director
Board of Underwater Archaeological Resources
Executive Office of Environmental Affairs
251 Causeway Street, Suite 900
Boston, Massachusetts 02114-2119

Re: Inspection of Magnetic Anomalies, Remote Sensing Archaeological Survey, Boston Harbor Deep Draft Navigation Improvement Study, Boston, MA
USACE-NED DACW33-01-D-0004

Dear Mr. Mastone:

Enclosed please find for your review a completed MBUAR Excavation Permit application and check covering the application fee for the above-referenced project. Based on our recent conversations, it is our understanding that you will be convening a meeting of the MBUAR to review our application at the end of this month and that our attendance at this meeting will be required. The U.S. Army Corps of Engineers-New England District has indicated they need for us to complete the two-day field survey on or before August 15.

If there's anything we can do to assist the MBUAR in expediting the permitting process, or if you have any questions or require further information, please do not hesitate to contact Deborah Cox, President, or me at your convenience.

Sincerely,

David S. Robinson
Principal Investigator

/kt

Enclosure

cc: Marc Paiva, US Army Corps of Engineers-New England District (w/encl.)

210 Lonsdale Avenue
Pawtucket, RI 02860
TEL 401.728.8780
FAX 401.728.8784

July 31, 2003

The Commonwealth of Massachusetts

William Francis Galvin, Secretary of the Commonwealth
Massachusetts Historical Commission

David L. Dulong
Chief, Engineering/Planning Division
New England District
US Army Corps of Engineers
696 Virginia Road
Concord, MA 01742-2751

Attn.: Mark Paiva

RE: Boston Harbor Deep Draft Navigation Improvements Project, Boston, MA. MHC #RC.323.

Dear Mr. Dulong:

Staff of the Massachusetts Historical Commission have reviewed the report, *Remote Sensing Archaeological Survey and Geologic Interpretation, Boston Harbor Navigation Improvements Study, Boston Harbor, Boston, Massachusetts,* prepared by UMass Archaeological Services, received by the MHC on June 20, 2003.

MHC concurs with the report recommendations. MHC additionally recommends to include Targets 4 and 5 as part of the recommended assessment during the next phase of archaeological investigation. MHC has reviewed and concurs with the proposed methodology prepared for the inspection and assessment of the targets.

It will be especially important that the proposed methodology as suggested in the report be finalized for the assessment of those project areas determined to be sensitive for containing submerged ancient Native American resources. MHC looks forward to reviewing the proposed methodology and research design for identification of submerged ancient Native American sites in the project area.

MHC looks forward to reviewing and continuing to consult on the methodology and results of the archaeological investigations of the project.

These comments are provided to assist in compliance with Section 106 of the National Historic Preservation Act of 1966, as amended (36 CFR 800), the Secretary of Interior's Standards and Guidelines for Archeology and Historic Preservation (48 Fed. Reg. 190 (1983)), and 950 CMR 70. Should you have any questions, please feel free to contact Edward L. Bell of my staff.

Sincerely,

Brona Simon

Brona Simon
State Archaeologist
Deputy State Historic Preservation Officer
Massachusetts Historical Commission

xc:
Mitchell T. Mulholland, UMAS
Deborah C. Cox, PAL
Victor T. Mastone, BUAR
Ellen P. Berkland, Boston City Archaeologist

220 Morrissey Boulevard, Boston, Massachusetts 02125
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The Commonwealth of Massachusetts
Executive Office of Environmental Affairs
251 Causeway Street, Suite 900
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BOARD OF
UNDERWATER
ARCHAEOLOGICAL
RESOURCES

Tel. (617) 626-1000
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http://www.magnet.state.ma.us/envir

July 31, 2003

David S. Robinson
Senior Project Manager
PAL, Inc.
210 Lonsdale Avenue
Pawtucket, RI 02860

Dear Mr. Robinson,

This letter confirms the vote taken by the Massachusetts Board of Underwater Archaeological Resources on 31 July 2003 to grant Public Archaeology Laboratory, Inc. (PAL) an Excavation Permit (03-003) for the exploration, excavation and recovery of underwater archaeological resources at its Boston site as defined by the Boston Harbor Deep Draft Navigation Improvement Study (USACE-NED DACW33-01-D-0004) project area. The duration of this permit shall be one year from the date of issuance with its expiration date as 31 July 2004.

This permit is herein granted dependent upon the compliance of PAL with the Board's Regulations (312 CMR 2.00). This permit constitutes PAL's sole right to document, test and excavate underwater archaeological resources within the permit area for the permit's duration. All work must be conducted in accordance with Board directives and standard conditions with the further condition that any revisions or changes to the scope of work are subject to prior review and approval of the Board's staff.

This permit does not relieve the permittee or any other person of the necessity of complying with all other federal, state and local statutes, regulations, by-laws and ordinances.

If you should have any questions or need further assistance, do not hesitate to contact the Board at the address above or by telephone at (617) 626-1141.

The Board wishes you the best of luck and looks forward to working with you this year.

Sincerely,

Victor T. Mastone
Director

VTM/dwt

M-2-85

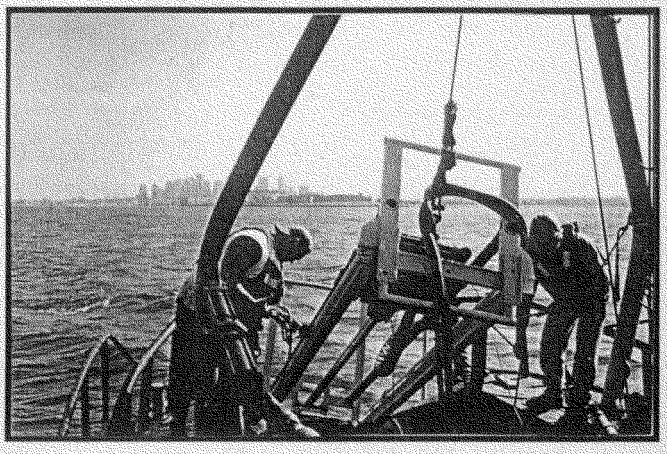
FILE
Boston Harbor
E-24
1237

APPENDIX B

BOSTON HARBOR CHANNEL DREDGING HISTORY

SEE APPENDIX B TO FEASIBILITY REPORT FOR PROJECT AUTHORIZATION, CONSTRUCTION AND MAINTENANCE HISTORY

Archaeological Services



ARCHAEOLOGICAL SUBSURFACE TESTING FOR THE BOSTON HARBOR NAVIGATION IMPROVEMENT STUDY BOSTON HARBOR, BOSTON, MASSACHUSETTS

APPENDIX M

ATTACHMENT 3

Kerry Lynch
Mitchell Mulholland
Jeffrey Donnelly

at the University of Massachusetts Amherst

USACE Contract Number DACW33-02-D-0007
Tasks 8 and 10
GEI Project Number 02176

ARCHAEOLOGICAL SUBSURFACE TESTING BOSTON HARBOR NAVIGATION IMPROVEMENT STUDY BOSTON HARBOR, BOSTON, MASSACHUSETTS

Kerry Lynch
Mitchell Mulholland
Jeffrey Donnelly

Presented by:
UMASS Archaeological Services
Blaisdell House
University of Massachusetts
Amherst, MA 01003

Presented to:
Lee Wooten
GEI Consultants, Inc.
1021 Main Street
Winchester, MA 01890-1970

May 19, 2004

Mitchell T. Mulholland, Ph.D.
Principal Investigator

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ABSTRACT

A remote sensing study and archaeological reconnaissance survey were conducted in 2002-2003 for the proposed improvements of the Boston Harbor Shipping Channel. Using a predictive model for site locational characteristics, sea level curves and reconstructed past land forms, the study predicted that there is a high potential for inundated Native American sites to be located within portions of the project area. Subsurface testing through the use of nine vibratory cores was completed in September, 2003. The cores were then analyzed for stratigraphic integrity and evidence of inundated archaeological resources. Both visual means and magnetic susceptibility were used to attempt to detect buried soil horizons. Likely sediments were screened for artifacts. Profiles of visible stratigraphy were recorded and the magnetic susceptibility was plotted and graphically reproduced. The magnetic susceptibility reliably detected changes in stratigraphy. The study proved that potentially preserved cultural resources are well below the maximum depth of the proposed dredging. Preserved sites, if they exist will not be impacted by the project. No further survey is recommended.

ANALYSIS AND REPORTING

Introduction

UMASS Archaeological Services (Archaeological Services) has conducted subsurface testing within Boston Harbor and the Mystic River (Figures 1-3). The survey area will be subject to modifications by dredging and the disposal of dredged material. Archaeological Services conducted the project for GEI Consultants, Inc. of Winchester on behalf of the U.S. Army Corps of Engineers (USACE). Prior to the remote sensing survey, historic and archaeological background research was conducted. The project follows the scope of work issued by the U.S. Army Corps of Engineers. State Underwater Archaeologist Victor Mastone was consulted.

Summary of Background Research

This report discusses research associated with Tasks 8 and 10 of the Boston Harbor Improvement Study, the final phase of an archaeological study that evaluated the archaeological sensitivity of offshore areas in the Boston Harbor shipping channel. The project area extends from the Mystic River in the west, to the eastern end of North Channel. In an earlier study under Task Orders 1-5, this project included a reconnaissance level archaeological background survey; historical background research to detect shipwrecks; and a remote sensing survey of the project area. Background is provided in a report on the first five tasks (Mulholland et al., 2003) for potential Native American occupation of the project area; methods used in locating underwater Native American sites; a summary of inundated sites found throughout the eastern seaboard of the United States; a discussion of the processes of oceanic transgression following sea level rise that can protect or destroy sites; a review of the results of the remote sensing survey; and recommendations for further survey. For background detail, the reader is referred to the earlier report (Mulholland et al., 2003) available from the U.S. Army Corps of Engineers.

Native American Sites Study. The reconnaissance survey used site locational characteristics, sea level curves and reconstructed past landforms, to determine that there is a potential for inundated Native American sites to be located within undisturbed portions of the project area. Subsurface testing through the use of vibratory cores was recommended on the north side of the North Channel, in the vicinity of Castle Island/Fort Independence and in the Mystic River area.

Historic Period Background Study and Remote Sensing Survey. The historic-period background study conducted by UMASS Archaeological Services under contract with Battelle Ocean Sciences, Inc., indicated that at least 93 vessels were lost in the general area of the dredging project. However, none were known to be specifically in the route. Analysis of the remote sensing data produced 187 targets that required further consideration; however only three were considered to be possible shipwrecks. In addition, one obvious sunken barge rests in two sections near the outer (east) entrance to the North Channel. The New England USACOE is aware that this is a modern steel wreck. Therefore, it was recommended that the three targets be physically inspected to determine if they are significant cultural resources. The inspection was

conducted by the Public Archaeology Laboratory, Inc (Robinson and Ford 2003).

Proposed Coring Locations for Detecting Native American Sites

The following are recommendations for testing for inundated Native American sites that were made in the earlier study (Mulholland et al., 2003). It was recommended that areas in the westernmost part of the project area, the Mystic River, an area off Castle Island, and the northeastern side of the North Channel be tested using selected vibratory cores or split-spoon borings. The areas recommended for further testing are as follows:

Locus 1. ***The North Channel.*** This is the northeast-southwest-oriented channel in the easternmost part of the project area (Figure 3). The northern (northwestern) side of the channel has not been dredged as deeply as the southern (southeastern) side. This channel follows the ancient Charles River channel. Despite impacts from storm winds, archaeological sites could lie buried beneath alluvium and may have survived damage from storms and transgressional processes. It is recommended that at least four vibratory cores (or other coring device) be extracted from this area to determine the presence of surviving buried A horizons. The general areas to be tested are those consisting of unconsolidated sand and gravels located in between coarse glacial till and bedrock. The presence of bedrock and coarse till upwind could have protected this area from storm and other currents.

Locus 2. ***The western portion of the project area*** *(Reserved Channel and Mystic River confluence).* This area is northwest and east of Castle Island and Fort Independence (Figure 3). It is not clear how much damage past dredging has caused in this area. Two loci may have a high potential to contain Native American sites. It is recommended that at least four vibratory cores (or other coring device) be extracted from this general area to determine the presence of surviving buried A horizons. The general areas to be tested are possible former land areas that border organic deposits that are remnants of former estuaries. Locus A is an area of high organic deposits intermittently bordered by till and glacial deposits, and unconsolidated sand and gravel. Locus B is a tiny organic area within the Mystic River channel bordered by till deposits and unconsolidated sand and gravels.

Locus 3. ***Mystic River Area.*** This area may have a high potential to contain Native American sites. The area of proposed impact within the Mystic River should be tested (Figure 3). It is recommended that at least two vibratory cores (or other coring device) be extracted from this area to determine the likelihood of surviving buried A horizons. The general areas to be tested are former land surfaces abutting organic deposits that are remnants of former estuaries.

The U.S. Army Corps of Engineers provided predetermined Ground Positioning System (GPS) coordinates to be used for coring locations by the GEI, Inc. coring team (Table 1). These coordinates fell within the boundaries of the areas of high archaeological potential and were necessary as guidelines given the lack of landscape features usually employed as reference points

when choosing test locations.

Nine vibratory cores were collected over a three-day period, from September 10 through 12, 2003. Vibratory cores numbered 101, 102, 103 and 104 (VC 101-104) were collected from the north side of the North Channel. VC 105, 106 and 107 were collected from the Castle Island/Fort Independence area, and VC 108 and 109 were collected from the Mystic River. The core coordinates were recorded by TG & B Marine Services using real-time differential GPS. Also recorded at the time of coring was water depth, time of day and the core recovery (length of the tube with visible sediment). During the analysis phase that followed, the cores were cut open lengthwise, measured and profiled. Table 2 indicates the vibratory core numbers, coordinates (in U.S. State Plane, Massachusetts Mainland 2001, NAD 1927, U.S. Survey feet and latitude/longitude), water depth, date and time of day and total sediment length (recorded during analysis).

Field Methodology – Vibratory Cores

The coring team consisted of TG & B Marine Services of Bourne, Massachusetts (Robert Reynolds, Mark Avakian, and Leonard Perry); the captain of the research vessel *Buoy Maker* (a chartered, mooring tender) (Figure 4), Jodi Mazzarino, an engineer with GEI Consultants Inc.; and Kerry Lynch, a marine archaeologist from University of Massachusetts Archaeological Services. A small tender vessel, owned by TG & B, also was used. This vessel was responsible for locating the GPS coordinates and dropping a marker buoy at that location. The *Buoy Maker* would then anchor so that the marker buoy was directly off the bow. The vibratory core mechanism (Figure 5) was encased in a metal frame which was suspended within a hydraulic A-frame (Figure 6).

Sediment cores were collected using a pneumatically-driven vibratory core system. The vibratory core system consists of a vibrating piston (6 inch diameter) that is mounted at the top of the core pipe (Figure 5). The entire "head" assembly weighs 500 lbs. The piston is actuated with air provided by a 125 cubic feet per minute (cfm) air compressor and fed to the piston via 1 1/2 inch hose. The head assembly and stainless steel core pipe are supported in the vertical position by a tripod-shaped frame with a 10 ft.x 10 ft. base mounted at the bow of the vessel (Figure 6). Guide pipes allow the unit to slide vertically down, driving the pipe into the bottom. Polycarbonate core tubes, 2 5/8 inch inner diameter, are encased in the core pipe (Figure 7). The continuous core is collected in the core tubes, nominally 10 feet long (Figure 8). A "finger" style core catcher helps retain the sample in the tube. In addition, a piston is positioned within the tube which starts at 1-2 inches above the bottom, and remains there because of a wire through the pipe secured to the top of the frame. This provides suction to assist penetration and recovery (retainage).

During operation the frame was lowered to the bottom with the vessel's winch. The air was turned on and coring proceeded until full penetration was achieved, or refusal. The pipe and frame then were pulled back to the deck of the *Buoy Maker* and the core tube is removed from the core pipe.

An overview of the coring methodology is as follows;

- Tender vessel placed a marker buoy at a GPS coordinate
- Research vessel anchored off both the bow and stern in order to remain stable during the coring process.
- The core housing was prepared by inserting a core puller (a plug device designed to aid in drawing sediment into the core and allowing it to stay in place while the core is being raised) into an acrylic tube. The tube then was inserted into a slightly larger stainless steel tube.
- The core tube was then clamped to the inside of the core housing frame.
- The frame was lowered into the water, using a hydraulic A-frame, until it was determined that the frame rested on the ocean floor.
- A generator fueled a vibrating, pneumatic hammer that forced the core tube into the bottom sediment.
- The hydraulics then raised the frame back to the bow of the vessel and the frame was re-secured.
- The stainless steel core housing was then removed from the frame and the inner acrylic tube was retrieved by hand.
- The core puller plug was removed and both ends were capped and taped securely.

The coring team began the survey on September 10, 2003. Three vibratory cores were attempted on that day, with only two being successful (VC 106 and 107). Difficulty was encountered at this time with core VC 105 which could not penetrate the bottom at the pre-selected location. Either rock or extremely compact clay were assumed to be the problem. Cores VC 106 and 107 were obtained from the Castle Island/Fort Independence area. On September 11 the marine archaeologist joined the team.

On September 11 the survey began in the North Channel. The area of highest archaeological potential in the North Channel was predicted using the analysis of the remote sensing data conducted for the remote sensing and archaeological reconnaissance phase of this project (Mulholland et.al. 2003)). Two ledges of bedrock or glacial till were identified that are perpendicular to the channel. The area between and leeward of the ledges were delineated as coring boundaries because it was hypothesized that the ledges would act to protect sediments from being eroded during oceanic transgression.

Cores VC 101 and 102 were designated for the area between the ledges. The *Buoy Maker* attempted anchorage at the coordinates for VC 102, but was unsuccessful due to soft bottom conditions. The vessel then drifted back along the channel until the anchor caught on hard sediments. At this point the vessel was approximately 152 m (500 ft), roughly southwest, from the proposed core coordinates, but it was estimated to still be within the boundaries of high

allowed for comparative analysis between sediments within each core, and between cores.

Magnetic susceptibility has been successfully applied to archaeological deposits in order to record buried, cultural features, anthropogenic soils that had been burned or heated, and even landscape modifying activity (Evans and Heller 2003). The application of magnetic susceptibility to the vibratory cores collected in Boston Harbor was an attempt to use this technology to determine if there were buried organic layers not visible to the naked eye. This was recommended following personal communication with geologist Dr. Julie Brigham-Grette, of the Geosciences Department at the University of Massachusetts. Dr. Brigham-Grette has used this technique in situations where relict land surfaces are indiscernible from surrounding sediment in marine cores. Such conditions may be caused by excessive leaching, long-term inundation, and organic or chemical pollutants. Because the technique is experimental and was not a part of the proposal for this project, use of the technique was not charged to the project. Rather the results offered at no cost as an aid to the visual analysis

Results of Analysis of Cores

The following are the results of the visual analysis of the cores, plus stated results of the magnetic susceptibility analysis. Magnetic susceptibility analysis was conducted only on cores VC101-105A. Cores VC106-109 were all clay, clearly non-cultural and, therefore, were not analyzed using this technique.

VC 101 – North Channel (Figure 9): The upper portion of this core from 1-13cm (.43 ft) was a dark gray medium sand and gravel (Munsell 5Y 4/1) that transitioned abruptly to the next layer. This was an olive gray clay with an orange hue (Munsell 5Y 4/2) that extended to 39cm (1.28 ft). This had a gradual transition into a dark gray clay (Munsell 5Y 4/1) with fine sand inclusions of Munsell 5Y 3/1, very dark gray and Munsell 2.5Y 4/0 dark gray clay with 228cm (7.5 ft)as the extent of the core. No cultural material was recovered.

Magnetic Susceptibility Results (Figure 10): This core was analyzed to a depth of 228 cm. In the upper portion of the core, some minor trends are apparent, such as an olive gray clay layer with an orange hue that extends to a depth of 40cm (Figure 9). The magnetic susceptibility (Figure 10) indicates considerably more variation in these sediments than is apparent visually (Figure 9). The sand and gravel inclusions from 0-160cm show more variation in fluctuation than the deeper clay without the inclusions (160-228cm). Three visible strata with dark gray clay shadow (Munsell 2.5Y 4/0) correlate with decreases in magnetic susceptibility at 50, 120 and 140cm (compare Figures 9 and 10) The fluctuations from 160-228cm are interpreted as numerous faint banding sequences in ancient, visually homogeneous dark gray clay (marine sediment). These strata are not cultural or other organic land surfaces. The banding sequences are barely visible. In this lower part of the core the results indicate many fluctuations between high and medium magnetic susceptibility in dark gray clay (Figure 10 - 1500 to 2000 mm) that were indiscernible during profiling. In this part of the core no major trends are present.

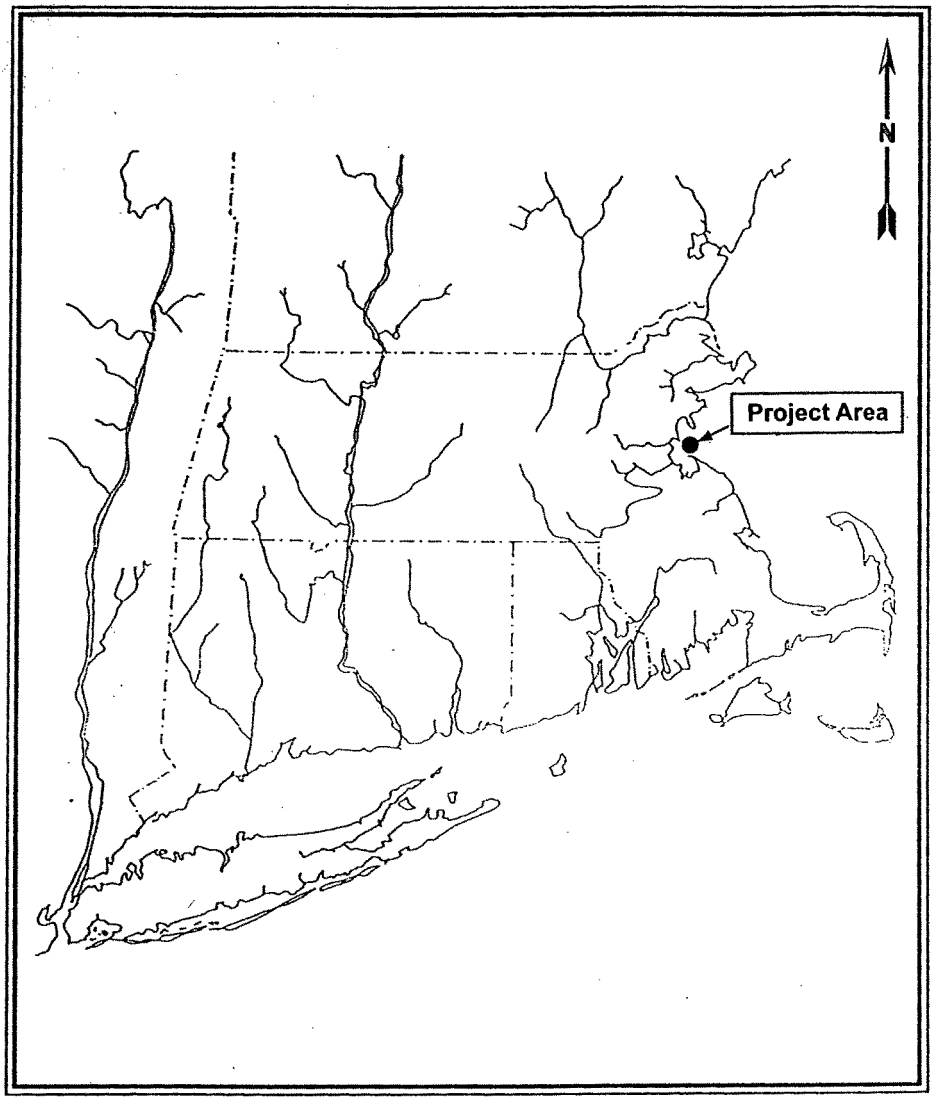

Figure 1. Project area location in the southern New England region.

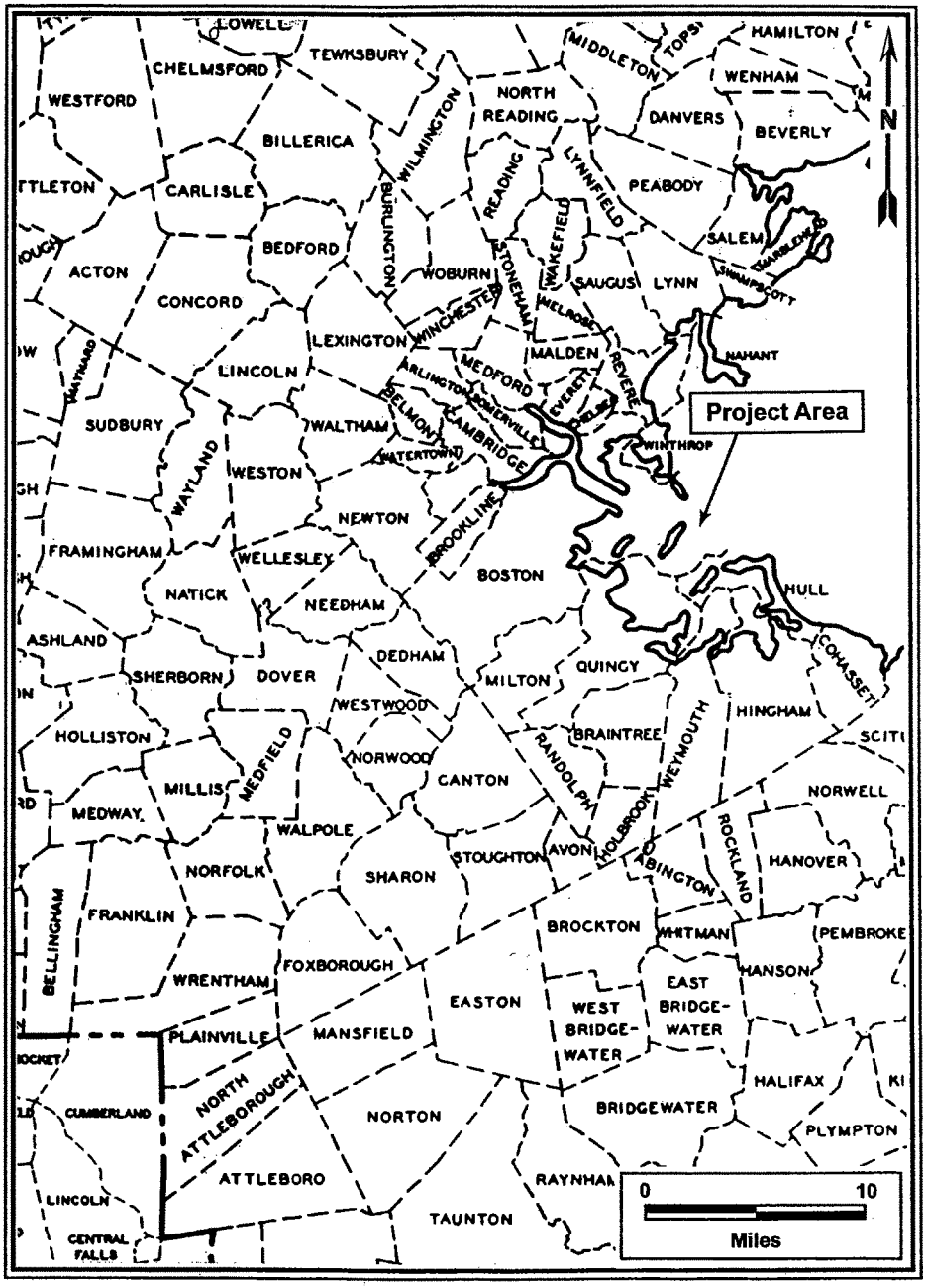

Figure 2. Location of project area in Boston.

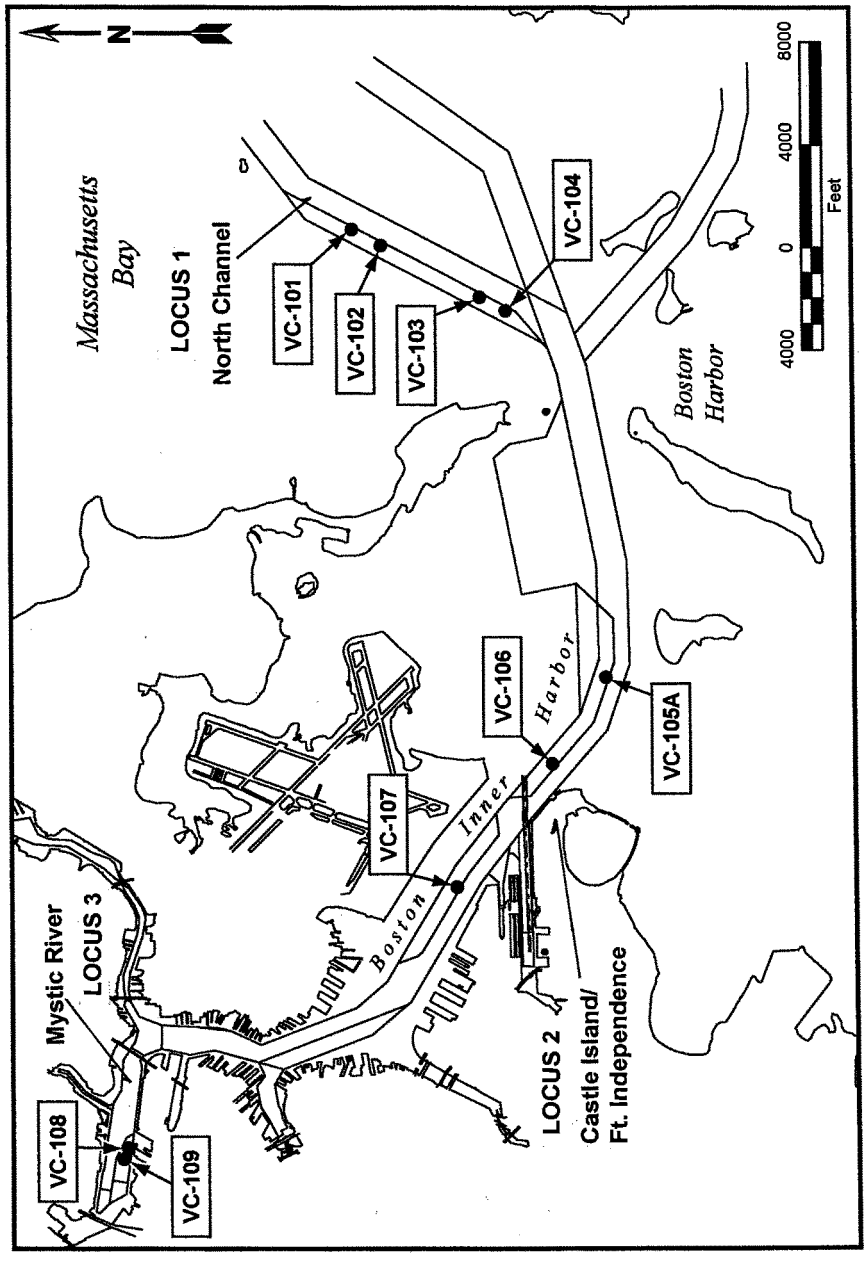

Figure 3. Map indicating the location of vibratory cores in Boston Harbor.

Figure 4. Survey Vessel *Buoy Maker* at the location of Core VC-103.

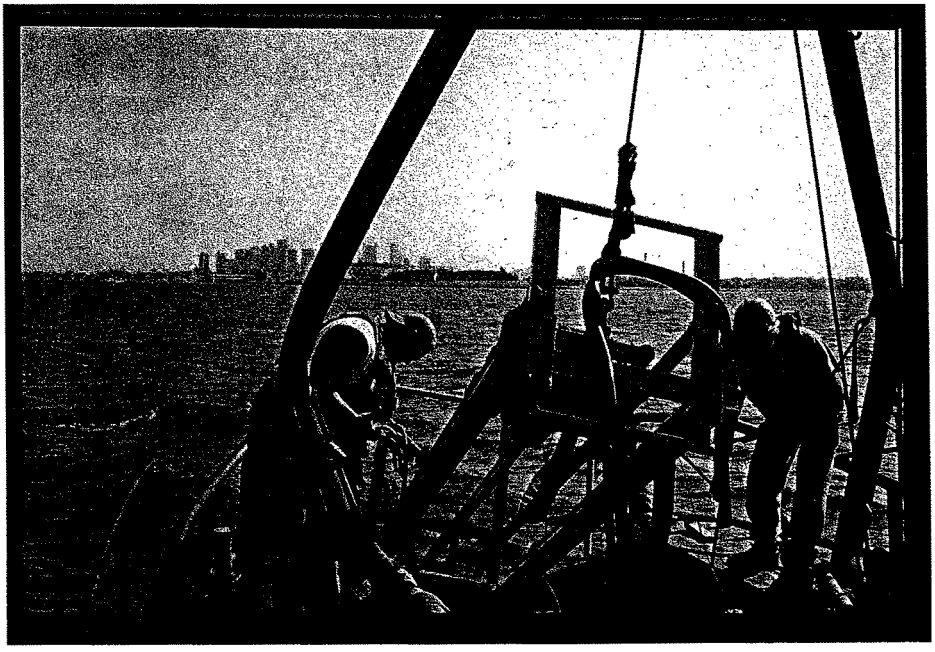

Figure 5. Vibratory core mechanism being raised. Boston skyline in background.

Figure 6. "A"-frame mounted on the bow of the *Bucoy Maker*, used to lower and retrieve vibratory cores.

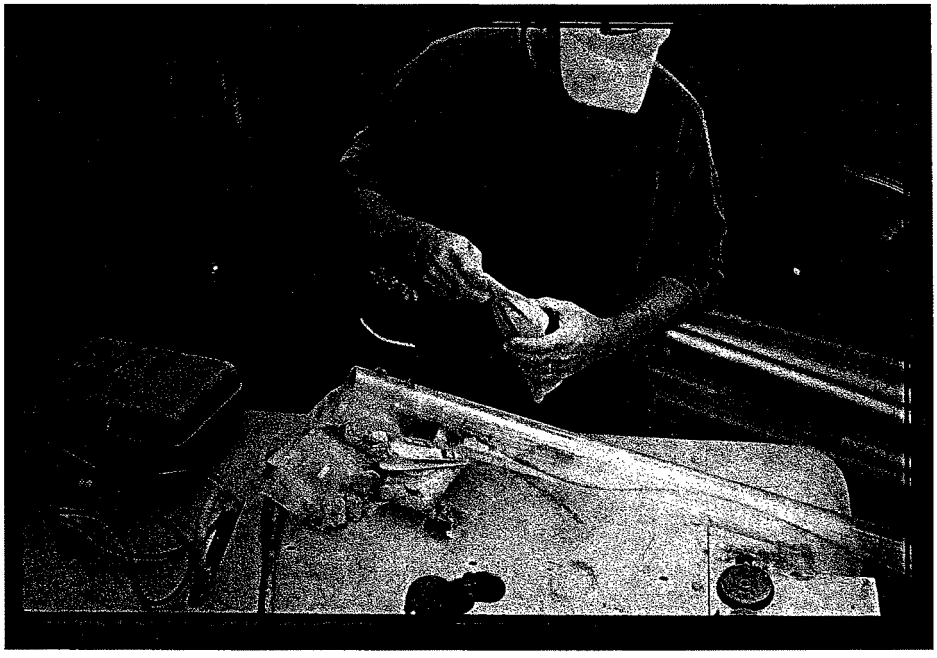

Figure 7. Preparation of polycarbonate cores prior to coring.

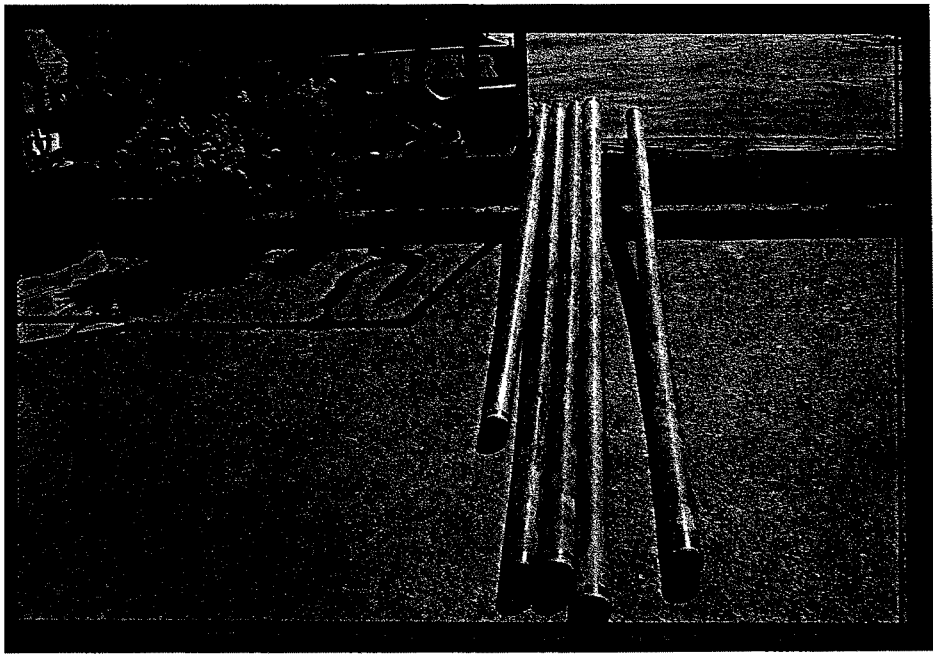

Figure 8. Polycarbonate cores awaiting shipment to lab.

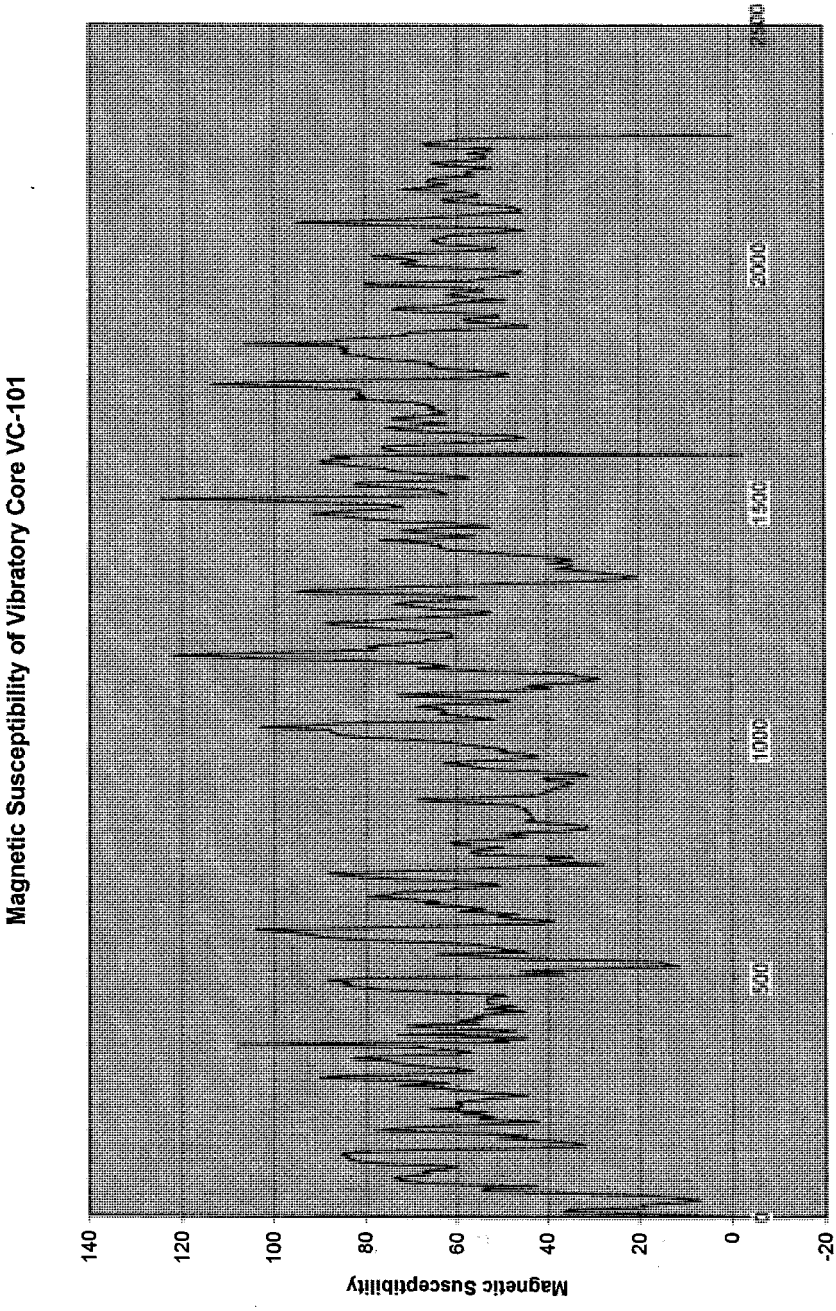

Figure 10. Magnetic Susceptibility of Core VC-101.

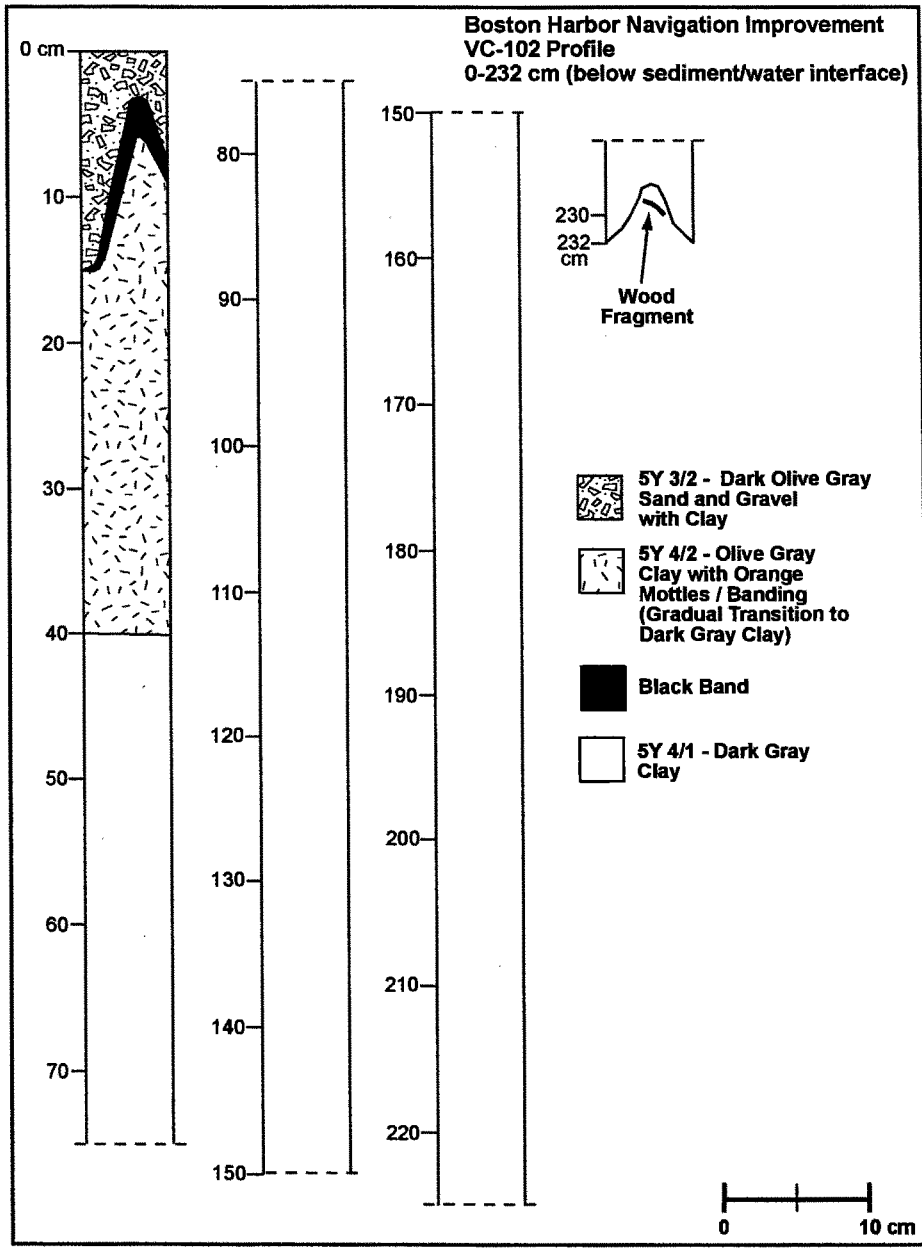

Figure 11. Profile of Vibratory Core VC-102 taken in the North Channel.

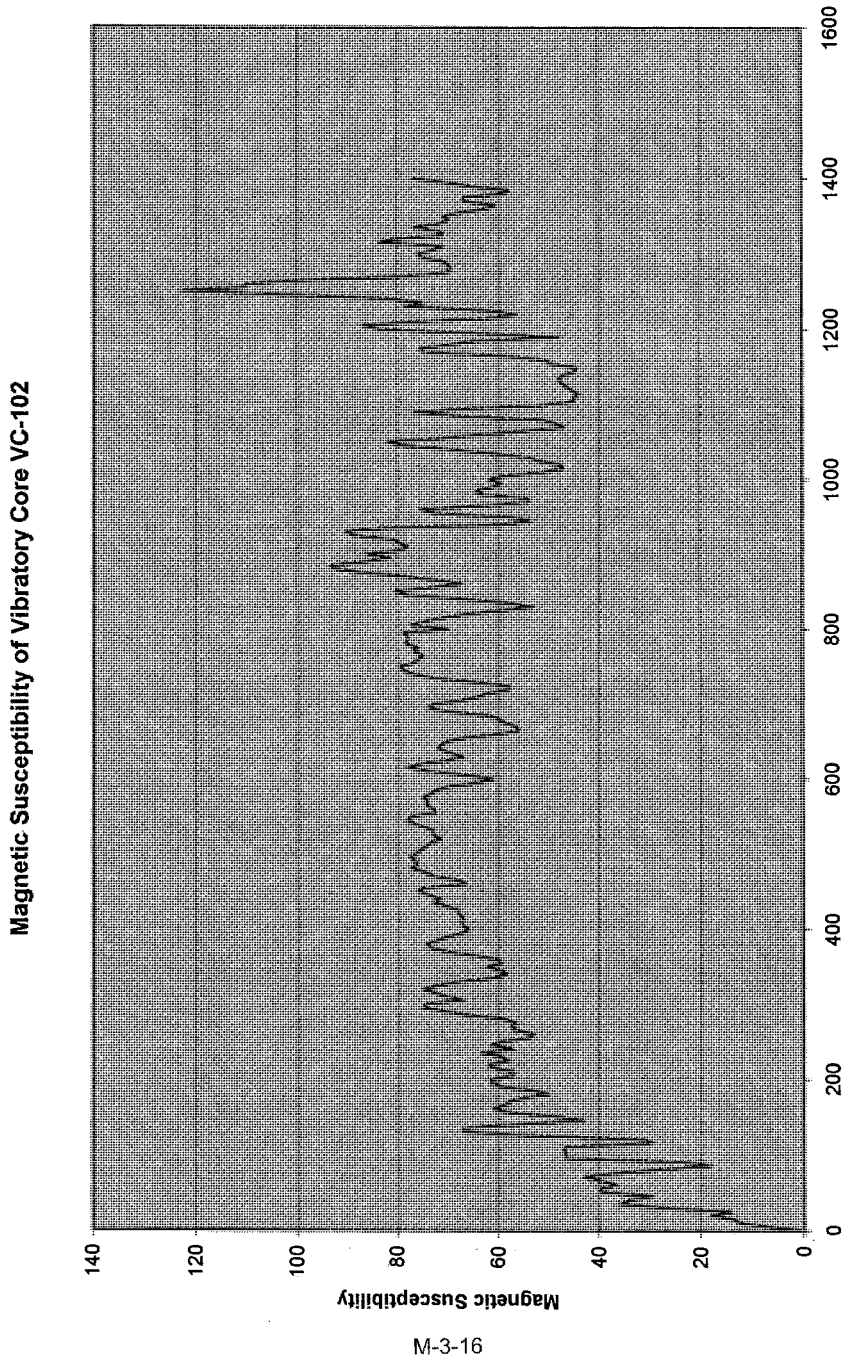

Figure 12. Magnetic Susceptibility of Core VC-102.

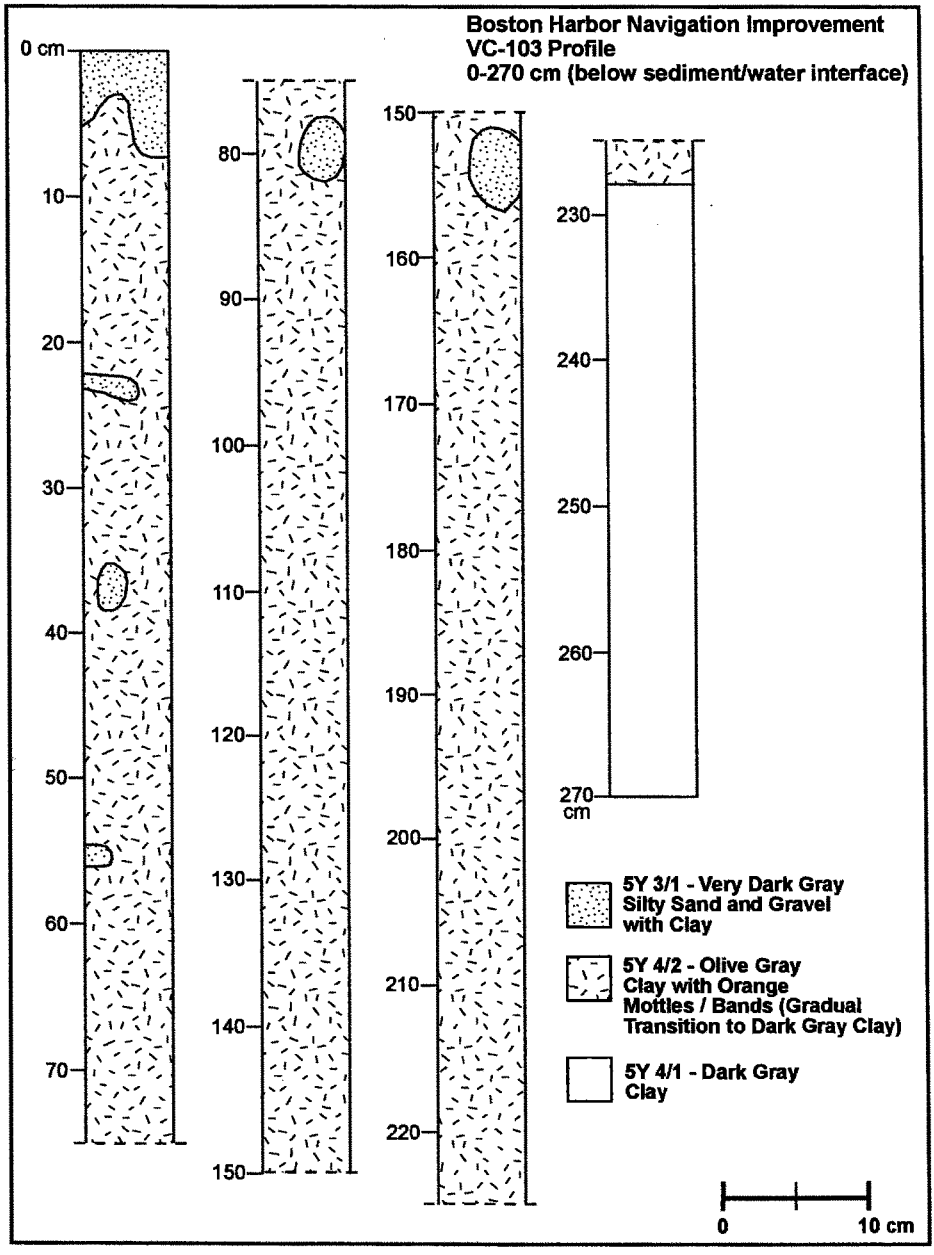

Figure 13. Profile of Vibratory Core VC-103 taken in the North Channel.

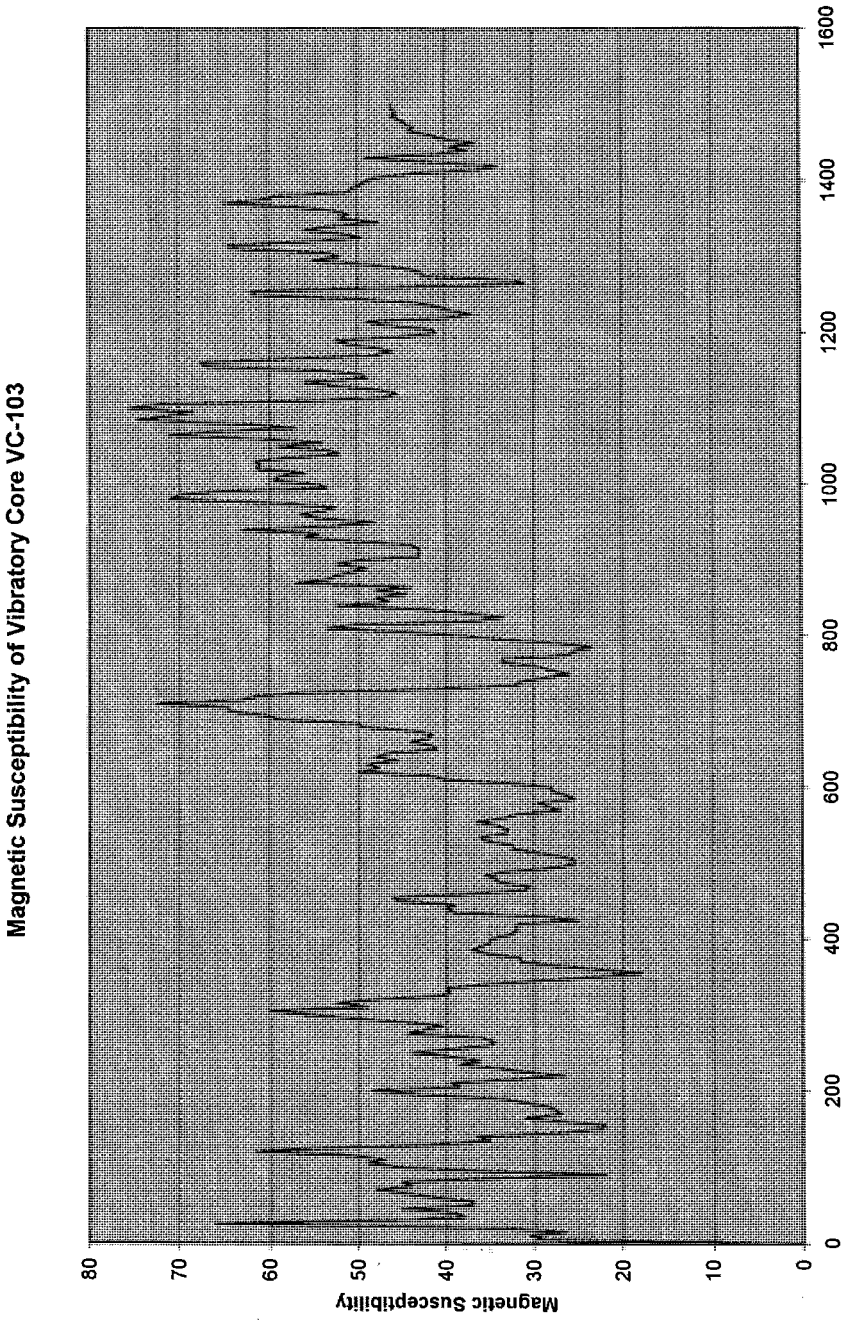

Figure 14. Magnetic Susceptibility of Core VC-103.

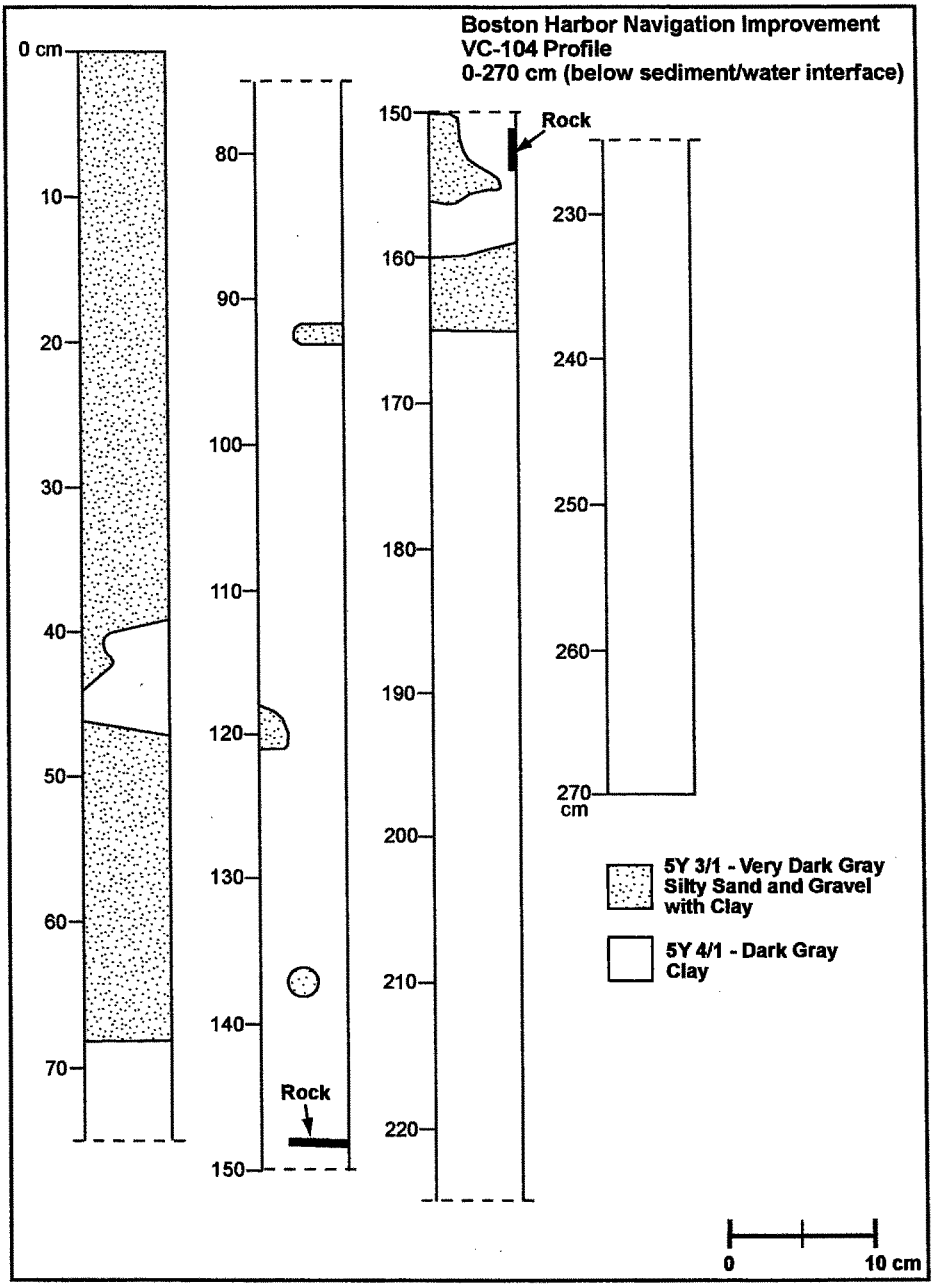

Figure 15. Profile of Vibratory Core VC-104 taken in the North Channel.

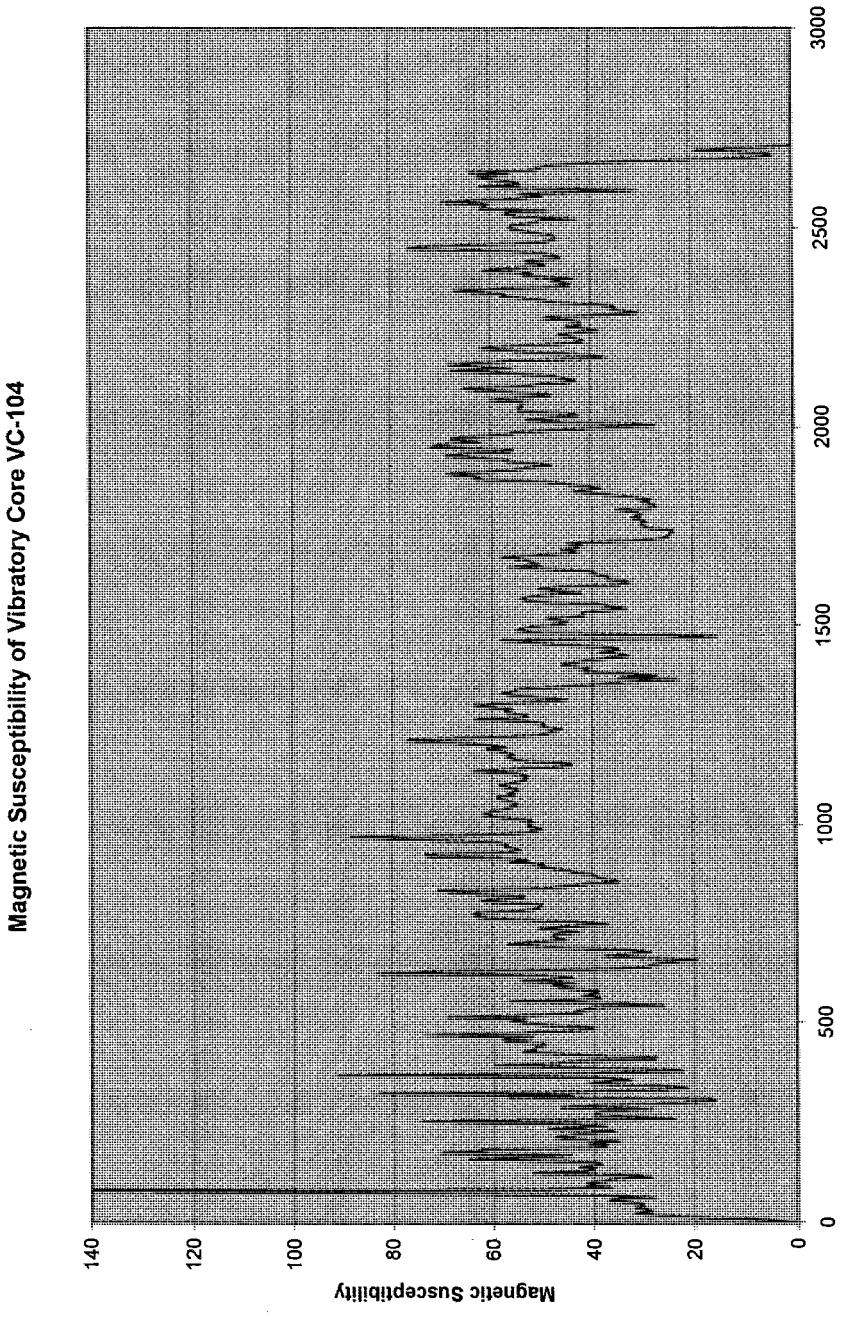

Figure 16. Magnetic Susceptibility of Core VC-104.

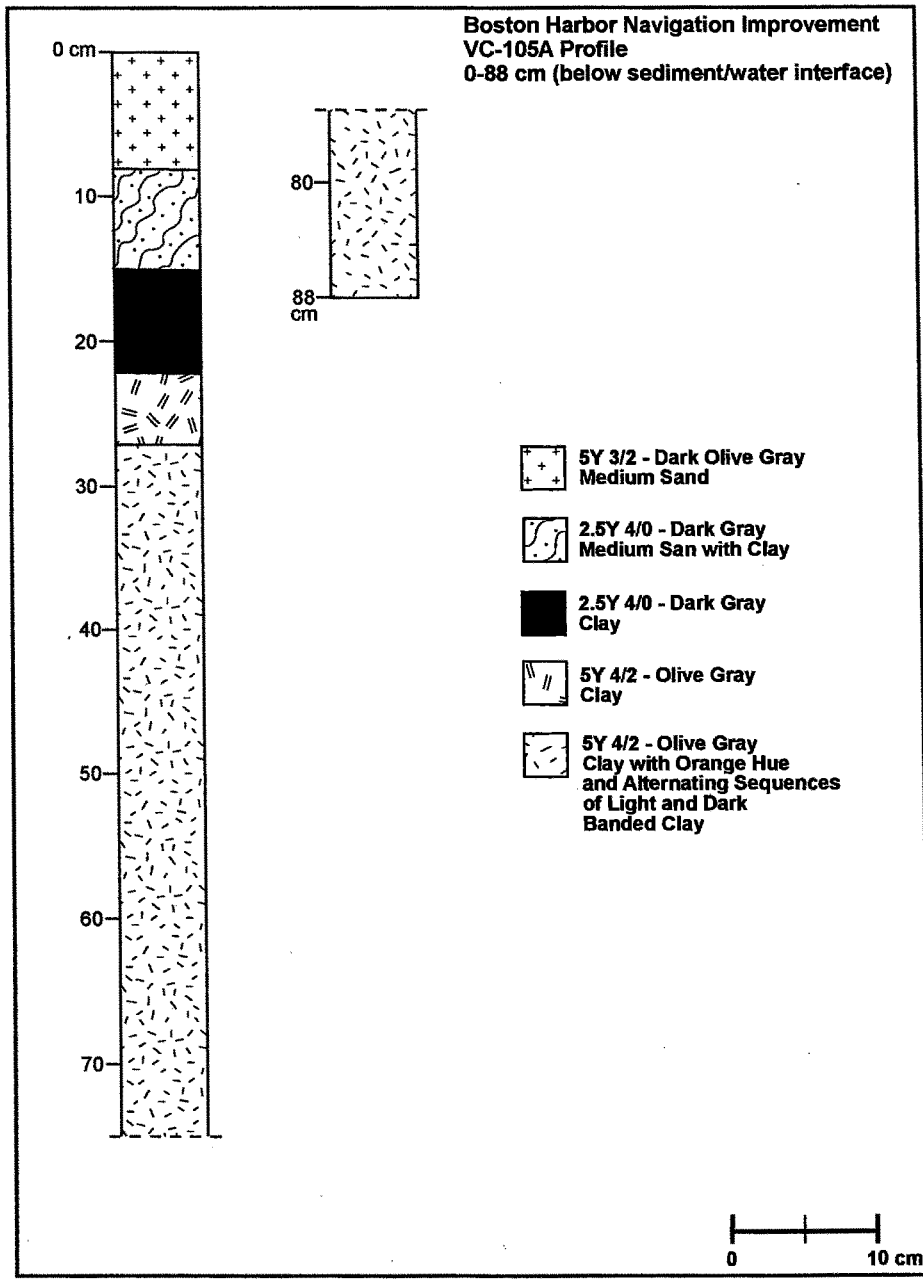

Figure 17. Profile of Vibratory Core VC-105A taken in the channel east of Castle Island.
M-3-21

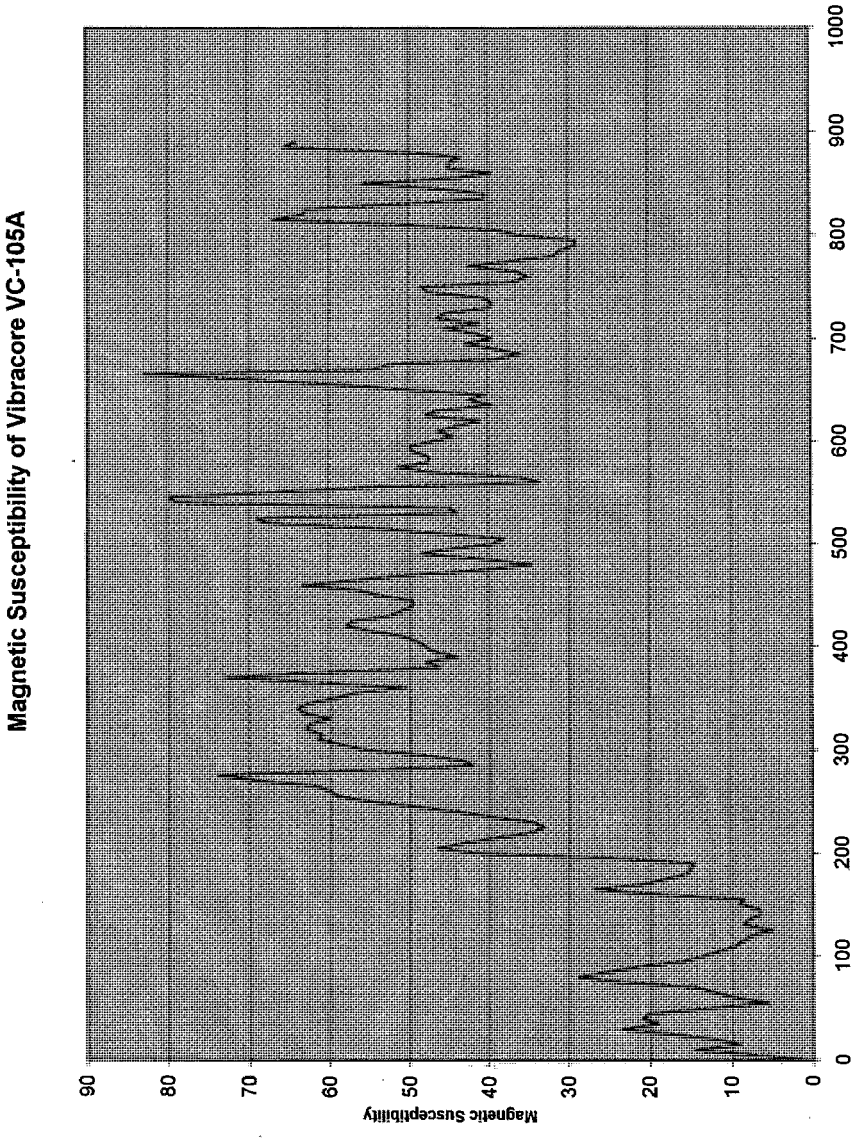

Figure 18. Magnetic Susceptibility of Core VC-105A.

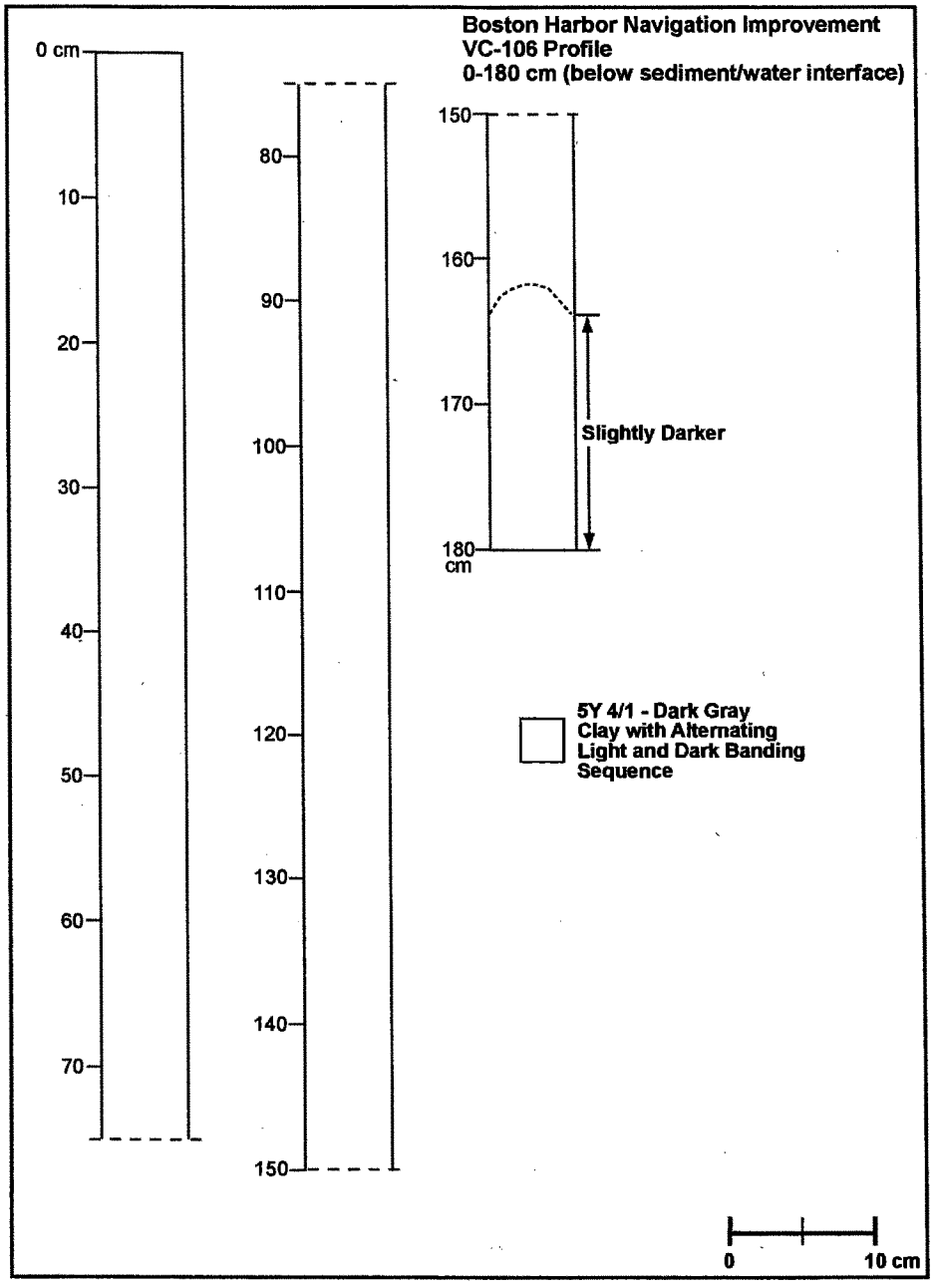

Figure 19. Profile of Vibratory Core VC-106 taken in the channel east of Castle Island.

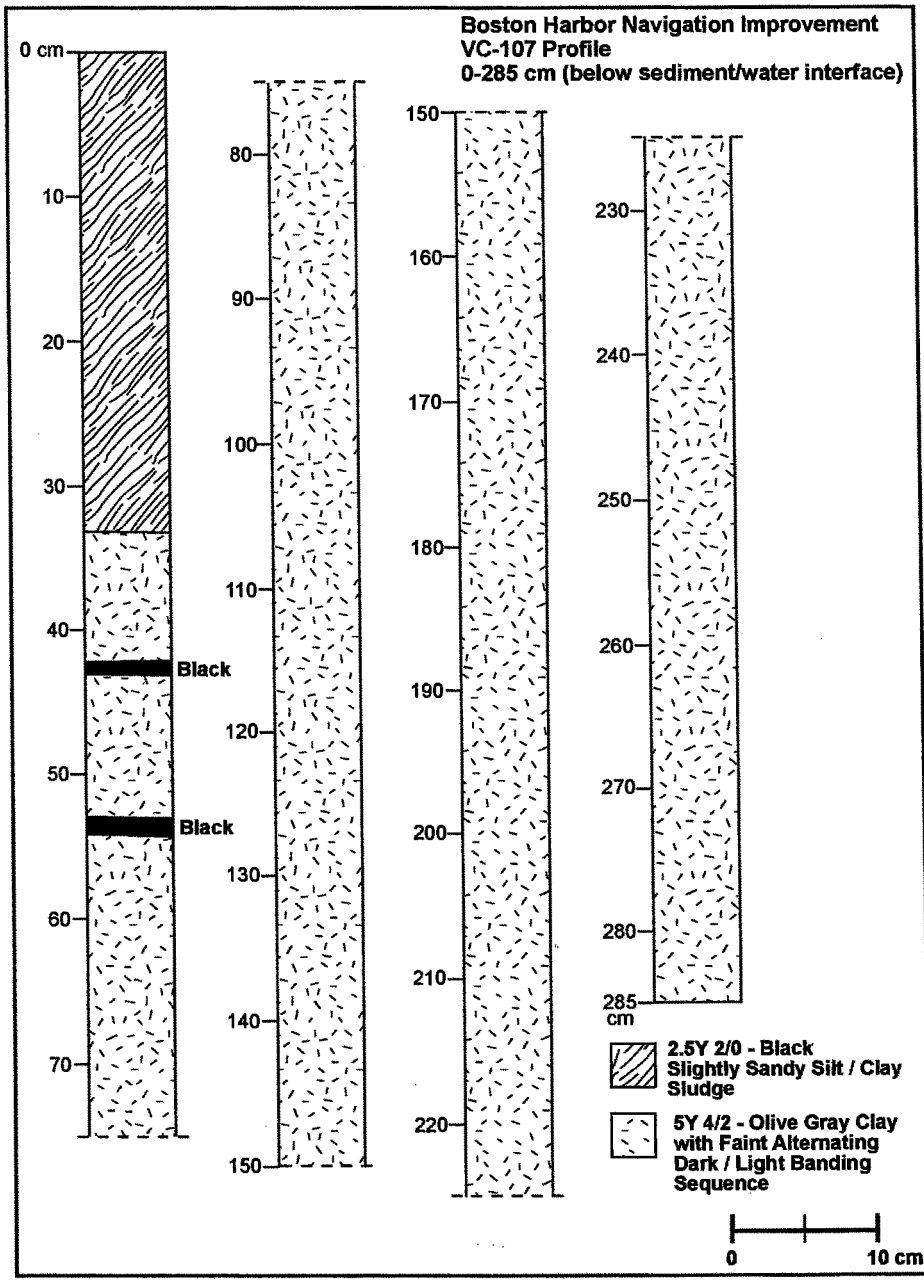

Figure 20. Profile of Vibratory Core VC-107 taken in the channel north of Castle Island.

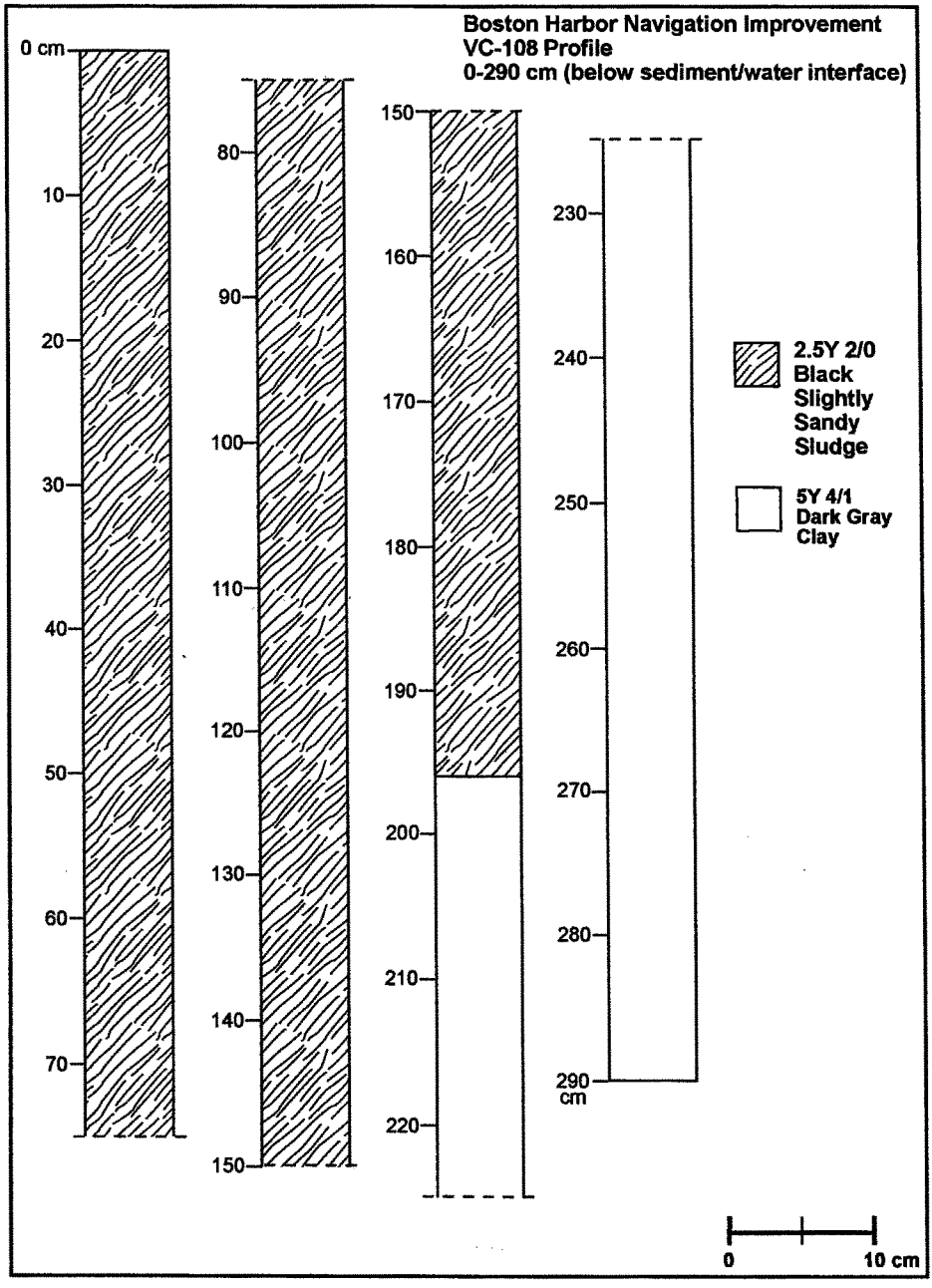

Figure 21. Profile of Vibratory Core VC-108 taken in the Mystic River.

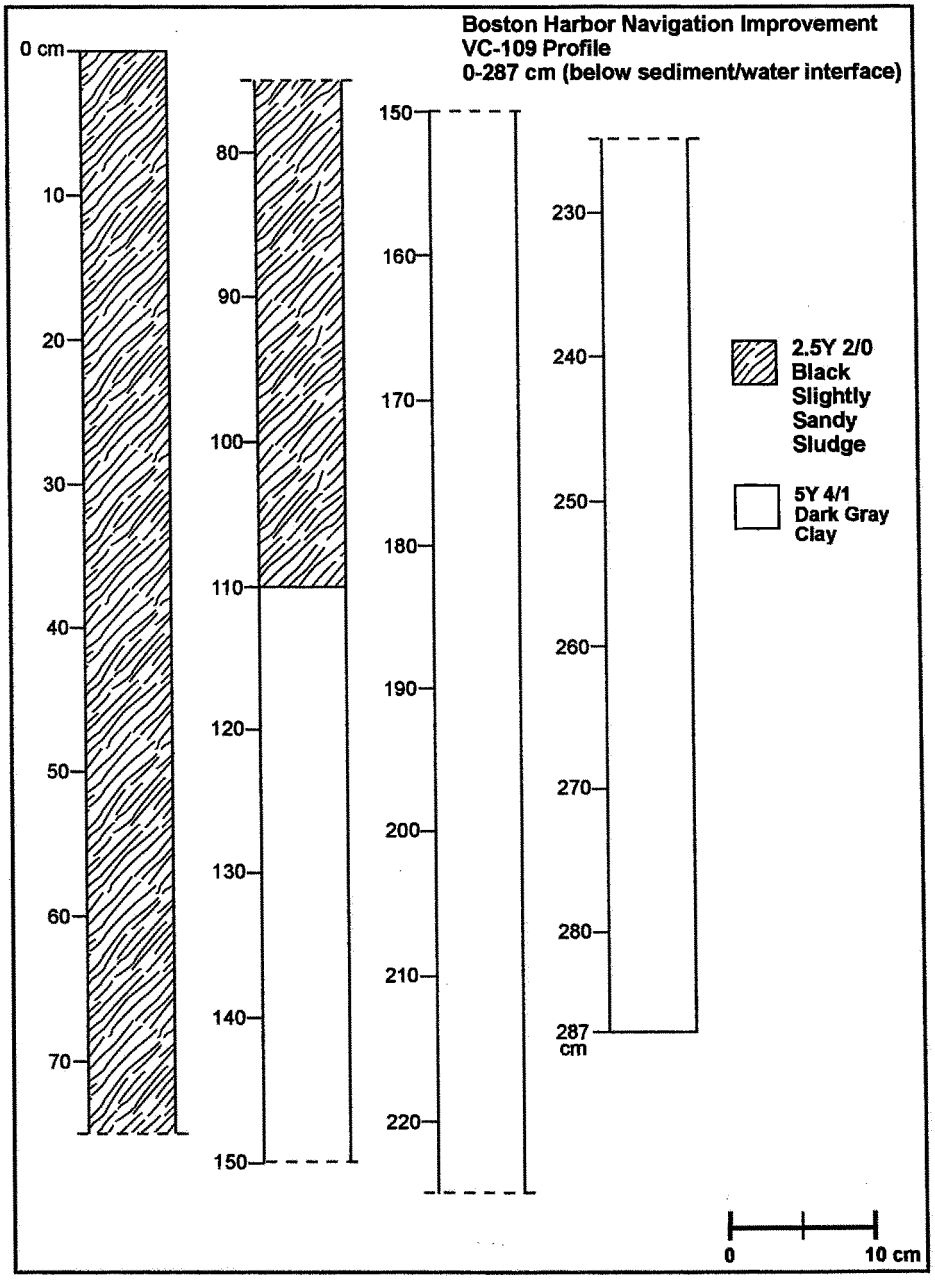

Figure 22. Profile of Vibratory Core VC-109 taken in the Mystic River.

Table 1. GPS coordinates
Boston Harbor Navigation Improvement - Targeted Vibracore Locations

VIBRACORE ID	NORTHING COORDINATE (feet)[1]	EASTING COORDINATE (feet)[1]	LATITUDE[2]	LONGITUDE[2]
VC 101	496,376.82	754,524.90	42° 21' 39.09906"	70° 55' 39.94178"
VC 102	495,159.12	753,888.93	42° 21' 27.11218"	70° 55' 48.52082"
VC 103	491,306.64	751,868.22	42° 20' 49.18821"	70° 56' 15.77210"
VC 104	490,287.87	751,342.01	42° 20' 39.15856"	70° 56' 22.86843"
VC 105	486,400.27	736,875.43	42° 20' 01.64720"	70° 59' 35.81535"
VC 106	488,524.66	733,462.96	42° 20' 22.83022"	71° 00' 21.08571"
VC 107	492,340.17	728,701.31	42° 21' 00.78858"	71° 03' 44.32993"
VC 108	505,067.18	505,067.18	42° 23' 07.03003"	71° 03' 44.32993"
VC 109	505,371.32	718,112.84	42° 23' 10.07488"	71° 03' 44.32993"

(1) U.S. State Plane, Massachusetts Mainland 2001, NAD 1927, U.S. Survey feet.

(2) NAD 1983

Table 2. Actual core locations and coring information.

VIBRACORE ID	DATE	TIME	NORTHING COORDINATE (feet)[1]	EASTING COORDINATE (feet)[1]	LATITUDE[2]	LONGITUDE[2]	WATER DEPTH (feet)[3]	SEDIMENT LENGTH (cm)
VC 101	9/11/2003	1:55pm	497,920.55	754,894.26	42° 21.9054'	70° 55.5814'	50.2	228
VC 102	9/11/2003	10:59am	496,058.31	754,061.68	42° 21.59972'	70° 55.7690'	48.2	232
VC 103	9/12/2003	9:35am	491,289.36	751,828.54	42° 20.8170'	70° 56.2717'	42.8	270
VC 104	9/12/2003	11:07am	490,265.71	751,334.68	42° 20.6490'	70° 56.3828'	48.6	270
VC 105	9/10/2003	N/A	486,381.22	736,890.52	N/A	N/A	40.2	vibracore refusal
VC 105A	9/11/2003	3:42pm	486,389.88	736,916.60	42° 20.0257'	70° 59.5878'	40.2	88
VC 106	9/10/2003	2:54pm	488,495.55	733,472.72	42° 20.3757'	71° 00.3493'	47	287
VC 107	9/10/2003	12:50pm	492,352.02	728,692.79	42° 21.0151'	71° 01.4053'	44.3	287
VC 108	9/12/2003	12:47pm	505,080.78	718,915.08	42° 23.1194'	71° 03.5610'	42.8	287
VC 109	9/12/2003	2:12pm	505,362.08	718,102.23	42° 23.1664'	71° 03.7412'	42.3	287

(1) U.S. State Plane, Massachusetts Mainland 2001, NAD 1927, U.S. Survey feet.

(2) Datum WGS-84. Coordinates recorded by TG & B Marine Services using real-time differential GPS.

APPENDIX A -Persons Consulted for this Project

Mark Besonen, Marine Geologist, Department of Geosciences, University of Massachusetts, Amherst.

Julie Brigham-Grette, Geologist, Department of Geosciences, University of Massachusetts, Amherst.

Eric Johnson, Staff Archaeologist, Massachusetts Historical Commission

Victor Mastone, State Underwater Archaeologist, Department of Environmental Management, Boston, Massachusetts

Jodi Mazzarino, Engineer, GEI Consultants, Inc.

Robert Reynolds, TG&B Marine Services, Bourne, Massachusetts

Lee Wooten, Scientist, GEI Consultants, Inc.

BOSTON HARBOR
MASSACHUSETTS

DEEP DRAFT
NAVIGATION IMPROVEMENT STUDY

FINAL FEASIBILITY REPORT
AND FINAL SUPPLEMENTAL
ENVIRONMENTAL IMPACT STATEMENT
AND MASSACHUSETTS
FINAL ENVIRONMENTAL IMPACT REPORT

APPENDIX N

EVALUATION OF LOBSTER
IN BOSTON HARBOR

THIS APPENDIX UNCHANGED FROM JULY 2008 REVISION

APPENDIX N
BOSTON HARBOR NAVIGATION IMPROVEMENT PROJECT

EVALUATION OF LOBSTER IN BOSTON HARBOR

FINAL REPORT

Contract Number DACW33-03-D-0004
Delivery Order No. 05

To:

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

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SEPTEMBER 2005

US ARMY CORPS
OF ENGINEERS
New England District

Battelle
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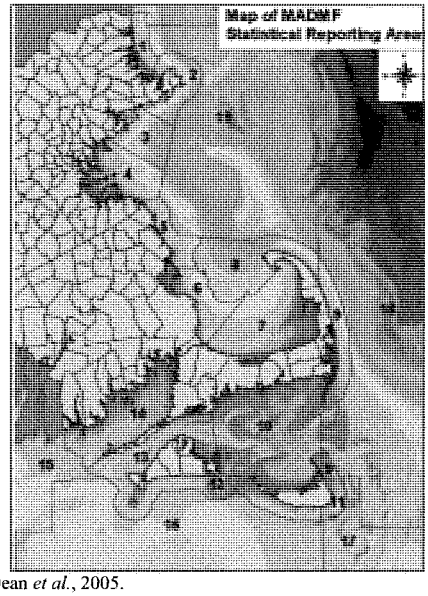
1.0 LOBSTER FISHERY DATA

With the decline of cod and other groundfish fisheries, the American lobster, *Homarus americanus*, has emerged as the most economically important fishery in Massachusetts State waters (Estrella and Glenn, 2001; Dean *et al.*, 2005). There has been a shift of commercial gear from the more common trawls in the 1950s to lobster pots in the late 1990s (Pol and Carr, 2000). In response to a need for a cohesive management plan for sustainable fisheries, the territorial waters of Massachusetts (within the 3-mile territorial limit) have been subdivided into 14 areas, while Federal waters have been subdivided into 12 additional areas, for a total of 26 State-managed areas (Dean *et al.*, 2005; Figure 1). These State-managed areas are used to issue lobster permits, which are divided into four classes: coastal commercial (within State territorial waters only), offshore commercial (within Federal territorial waters only), seasonal commercial (within both State and Federal waters, but limited to 25 traps total during the period June-September), and recreational (collected by SCUBA or via 10 traps, but catch cannot be sold) (Dean *et al.*, 2005). Commercial fishers are required to report the number and value of their fishing gear, which is used by the State to calculate effort by home port. Therefore, data referring to number of fishers, number of pots fished, and number of boats are presented by home port; otherwise, data are reported for the specific State-managed area where the fishing occurred (i.e., port of landing). The poundage of lobster landed is also reported by the port of landing (Dean *et al.*, 2005) and by the specific State-managed area where traps were hauled (Bob Glenn, personal communication). All data reported to the State as the actual number of lobsters landed, rather than poundage, is converted to weight by applying a conversion factor of 1.27 lbs per lobster (Dean *et al.*, 2005).

The area of interest related to the Boston Harbor Deep Draft Navigation Improvement Project and Inner Harbor Maintenance Dredging consists of a sub-region within the State-managed Area 4, which includes the Boston Harbor Federal Navigation Channel. This area is bounded to the east by the State territorial line, to the north by Red Rock, Lynn, and to the south by Strawberry Point, Cohasset (DMF Statistic Reporting Areas at http://www.mass.gov/dfwele/dmf/commercialfishing/inshoreareas.htm#map). Based on landing data collected by the State, the annual lobster catch in Area 4 (including Boston Harbor) has remained fairly steady from 2001 through 2003, but has recently decreased after a small peak in the late 1990s (Figure 2; Table 1). As of 2003, the catch is about one-half that of a decade ago, most likely due to a decrease in the number of fishers and thus effort, as well as a decrease in the resource (Table 1). The annual reported landings for Area 4 are presented in Table 1 for years 1990 through 2003 (2004 data are not yet available from the State). The data are divided into the following categories: total poundage landed in State territorial waters, poundage of lobsters landed in Area 4, percent of total territorial (i.e., coastal) landings in Area 4, and approximate number of lobsters landed in Area 4 using the inverse of the weight-to-lobster conversion factor (1.27 lbs per lobster) described above.



From Dean *et al.*, 2005.

Figure 1. Statistical Reporting Areas in Massachusetts.

Note: Coastal regions are outlined in red.

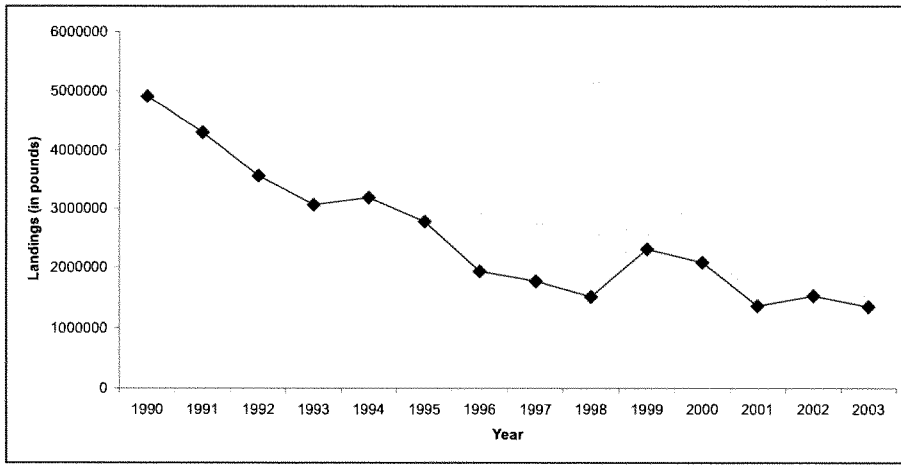


Figure 2. Annual landings in pounds for State-managed Area 4 which includes Boston Harbor and Massachusetts Bay. Data not yet available for 2004.

Data Source: Robert Glenn, Coastal Lobster Investigations Project, MADMF, Pocasset, MA.

Table 1. Area 4 Lobster Harvest Statistics.

Year	Total Territorial Harvest	Area 4 Lobsters Landed (pounds)[1]	Percentage of Total Territorial Harvest	Area 4 Number of Lobsters Landed
1990	12,260,805	4,908,821	40.04	3,865,213
1991	11,007,474	4,295,414	39.02	3,382,216
1992	9,658,545	3,564,716	36.91	2,806,863
1993	9,059,867	3,062,624	33.80	2,411,515
1994	10,412,422	3,176,607	30.51	2,501,266
1995	10,030,426	2,779,186	27.71	2,188,336
1996	9,109,902	1,928,590	21.17	1,518,575
1997	8,434,199	1,758,385	20.85	1,384,555
1998	7,660,274	1,506,212	19.66	1,185,994
1999	9,603,589	2,308,163	24.03	1,817,451
2000	9,855,003	2,082,547	21.13	1,639,801
2001	7,147,288	1,351,165	18.91	1,063,910
2002	8,172,984	1,529,639	18.70	1,204,440
2003	6,850,185	1,340,893	19.57	1,055,821

[1] Data on poundage landed from Robert Glenn, Coastal Lobster Investigations Project, MADMF, Pocasset, MA. Additional data compiled from Dean *et al.*, 2005; 2004; 2002; McBride *et al.*, 2001; McBride and Hoopes, 2000; Pava *et al.*, 1999; 1998; 1997; 1996; McCarron and Hoopes, 1995; 1994, 1993, 1992; Hoopes, 1991.

For the years 2001 through 2003, Area 4 ranked second in the State only to Area 2 (Gloucester/Cape Ann region) in terms of coastal harvest; it ranked third in the State from 2001-2002 for total territorial harvest[1] behind both Areas 2 and 6 (Plymouth region) (Dean *et al.*, 2005; 2004; 2002; Table 2). Prior to 2001, Area 4 ranked first in the State for coastal harvest and second to fourth for total territorial harvest. Between one-third (historically) and one-fifth (currently) of the State's entire coastal harvest comes from Area 4, making lobster an important and plentiful resource in this region.

Table 1 shows that there were approximately 1,000,000 marketable-sized lobsters in Area 4 in 2003 and around 1,200,000 lobsters in 2002. This number of marketable-sized lobsters is approximately one-quarter of the number landed in 1990. Although, the decline in landings (both poundage and numbers) began in 1990, landings have decreased substantially since 1996 compared to pre-1996 levels and have fluctuated between 1.8 to 1.0 million lobsters landed (Figure 2). Area 4 has shown the same trends in landings decline, as has the State overall—from 1990 to 2003, the total territorial harvest declined from 12,260,805 lbs to 6,850,185 lbs, or by nearly half. In Area 4, the current landings are approximately one-quarter of their 1990 levels.

[1] Total territorial harvest includes all poundage of lobster landed by both coastal commercial license holders and seasonal commercial license holders. See description of lobster permit types above.

Table 2. Area 4 Rankings for Poundage Landed.

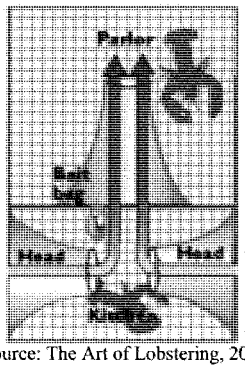
Year	Area 4 Ranking for Coastal Licenses	Area 4 Ranking for Seasonal License	Area 4 Ranking for Total Territorial Harvest
1990	1	4	1
1991	1	6	1
1992	1	9	2
1993	1	4	1
1994	1	8	1
1995	1	4	2
1996	1	7	2
1997	1	11	3
1998	1	Tied for 10	4
1999	1	6	2
2000	1	3	2
2001	2	7	3
2002	2	5	3
2003	2	No information	No information

Data compiled from Dean *et al.*, 2005; 2004; 2002; McBride *et al.*, 2001; McBride and Hoopes, 2000; Pava *et al.*, 1999; 1998; 1997; 1996; McCarron and Hoopes, 1995; 1994, 1993, 1992; Hoopes, 1991.

Commercial catches have been used to estimate lobster densities (Fogarty, 1995); however, they may not be the best predictor of actual populations because of a variety of factors involving the behavior of the targeted size-class of lobster (Addison, 1995; 1997; Fogarty and Addison, 1997). In naturalistic laboratory settings, only a small proportion of lobsters that encounter a trap actually enter it (11%), and of those, only 2% are retained (Karnofsky and Price, 1989). Analysis of lobster approaches to traps placed in the field and outfitted with video monitors indicate that, while a large number of lobsters approach a trap, only 4% enter (Jury *et al.*, 2001). Of those 4% entering, only 6% are retained—the remaining individuals escape through the kitchen[2] (72%) or the parlor[3] (28%) (Figure 3). Escaping lobsters include both sub-legal and legal-sized lobsters. Lobsters that remain in the trap for some time feeding on the bait are also observed to escape. Entry into the trap by an individual is dependent on the frequency of previous approaches (the greater number of approaches, the more likely an entry) (Karnofsky and Price, 1989) and presence and location of other lobsters in the trap (Jury *et al.*, 2001). For instance, if the kitchen is unoccupied, entry by other lobsters is higher: 69% fully enter, compared to only 11% when the kitchen is occupied. The daily timing of the placement of the trap is insignificant, as lobsters are as equally likely to approach and enter a trap during the day as during the night (Jury *et al.*, 2001).

[2] The kitchen of a trap is the end where the lobster enters, attracted by the bait bag secured within. The entrance, or door, is typically funnel-shaped, with the narrowest end of the funnel opening into the kitchen. This arrangement makes it difficult for the lobsters to fall out of the kitchen (and thus the trap) while the trap is being hauled to the surface (Figure 3).

[3] The parlor of a trap is the compartment at the other end of a single-door trap, or in the middle of a double-door/double-kitchen trap. Lobsters exit the kitchen via another funnel-like door into this compartment. Escape vents are present to allow undersized lobsters (sub-legals) the opportunity to exit the trap before it is hauled (Figure 3).



Source: The Art of Lobstering, 2003.

Figure 3. Parts of a Typical Lobster Trap.

These field and laboratory observations suggest that traps which rapidly become saturated with lobsters prevent additional lobsters from entering. Thus, lobster landing data are a poor reflection of the population density of lobsters in a particular area (Jury *et al.*, 2001). This means that population densities of lobsters based on catch-per-trap-haul or densities based on poundage landed or catch-per-unit-effort (CPUE) are likely gross underestimates of actual populations in the reporting region. Therefore, the landings and catch-per-trap-haul reported for Area 4 (Table 2, Figure 2) likely under-represents the actual population of lobsters in that area.

1.1 Massachusetts Division of Marine Fisheries Lobster Sea Sampling Program

The Massachusetts Division of Marine Fisheries (MADMF) conducts annual sampling aboard commercial vessels to assess various biological parameters of legal, sub-legal (i.e., undersized), and ovigerous (i.e., egg-bearing) lobsters in several of their management areas, including Area 4. This sampling program has been ongoing since 1981 for stock assessment purposes (Estrella and Glenn, 2001; 2002). Sampling occurs monthly in coastal waters during May through November aboard only a few commercial vessels conducting normal fishing operations in a designated region. Traps are not necessarily hauled in the same locations as in prior months within a year, or among different years. Thus, there is no standardized sampling protocol, other than to simply sample wherever participating fishers happen to be fishing at the time of the sample. While normal fishing traps are used in this program, the trap types and vent styles may vary among participating fishers. As a result, the data are highly dependent on the individual characteristics of the fishers[4] involved in the sampling, and could be skewed based on how "good" the participating fisher is at his or her trade or how well he or she selects a particular location during the sampling day. The data are also highly dependent on the type of trap used, as some fishers prefer double entry/double kitchen traps, while others prefer single-entry/single-kitchen traps. In addition, statistical robustness of the data is achieved only when it is pooled, because many

[4] The number of fishers participating year-to-year is typically small—about 2 to 3 individuals (Bob Glenn, MADMF, personal communication).

locations within an area are sampled only once during the more than 20 years of sampling (Bob Glenn, personal communication).

MAMDF sea samplers onboard commercial vessels record trap location by LORAN or GPS, carapace length (CL), sex, condition, the presence or absence of eggs on females, number of lobsters caught, number of trap hauls, and set-over days[5]. By statute, undersized lobsters cannot be landed and often escape from traps via vents prior to haul, or are returned to the ocean when captured. Likewise, legal-sized ovigerous females cannot be landed and must be returned immediately to the ocean when captured. Adult, marketable lobster catch rates are expressed as catch-per-trap-haul standardized to a three day set-over-day (Estrella and McKiernan, 1989). Undersized lobsters (sub-legals) or ovigerous females are not standardized to three day set-over days, but are standardized to the same number of set-over-days (i.e., if one set of hauls occurred after eight set-over-days, one occurred after twelve set-over-days, and another occurred after four set-over-days, all would be standardized to four set-over-days). Figure 4 represents the sea sampling locations in Area 4 for the past 10 years. Figure 5 shows that the overall catch-per-trap-haul in the Boston Harbor area (inclusive of all sampling locations in Boston Harbor) has been slowly decreasing from slightly more than one legal-sized lobster per trap for three set-over-days to between 0.4 and 0.8 legal-sized lobster per trap. A similar trend is seen for sub-legal lobsters in Figure 5; however, the larger variability of the sub-legal data likely relates to changes in the escape vent (both in terms of size and shape), which affects the number of sub-legal lobsters capable of escaping from the traps. The size of escape vents has changed three times in the last decade (1991, 1992, and 2001), increasing by a total of $^{3}/_{16}$", and currently stands at a size of $1^{15}/_{16}$". During the same time period, the size limit of marketable lobsters increased by 2 mm, from 81 mm CL in 1989 to 83 mm CL in 1991. It is thought that by increasing the size of the escape vent, juveniles that might enter the trap to feed will be able to leave, so as to not result in saturation of the trap by undersized individuals that cannot be legally landed. Thus, increases in the vent size should, theoretically, increase the likelihood of capturing marketable-sized lobsters.

Commercial landings (as well as sea sampling landings) from State territorial waters follow a seasonal trend, with the lowest landings in February (Figure 6). A steady increase occurs during the spring and summer months, with a peak occurring in September/October, followed by a steady decline through the winter months to February (Dean *et al.*, 2005; 2004; 2002; McBride *et al.*, 2001; McBride and Hoopes, 2000; Figure 6). This trend reflects the lobster's dependence on temperature for movements and feeding, both of which affect entrapment (Ennis, 1973; Miller, 1990; Cobb, 1995; Tremblay, 2000). Temperature affects the activity rate of lobsters, specifically their walking rate. Below 10°C, the walking rate is severely reduced (McLeese and Wilder, 1958) and lobsters are less likely to leave their shelters or depressions (Stewart, 1972), and are, therefore, unlikely to enter a trap. Similarly, their molt condition affects entrapment, with the lowest catches corresponding to the timing of ecdysis[6] or molting (Miller, 1990). The timing of ecdysis for adults and adolescent lobsters depends on the thermal regime in which they live. In areas with relatively high summer temperatures, there are usually two molting peaks, one in the spring and one in the autumn. In colder areas, or areas that experience less dramatic

[5] Set-over days refers to how many days the trap has been "set" in the water prior to being hauled.
[6] Ecdysis refers to the shedding of and escape from the old exoskeleton (shell). Recently molted lobsters are called "new shells" or "paper shells" to represent the thin, non-calcified exoskeleton immediately post-molt.

summer temperatures, ecdysis tends to occur in late summer (Templeman, 1936). In Boston Harbor, molting tends to occur in late summer (Feeney, President, Massachusetts Lobstermen's Association, personal communication).

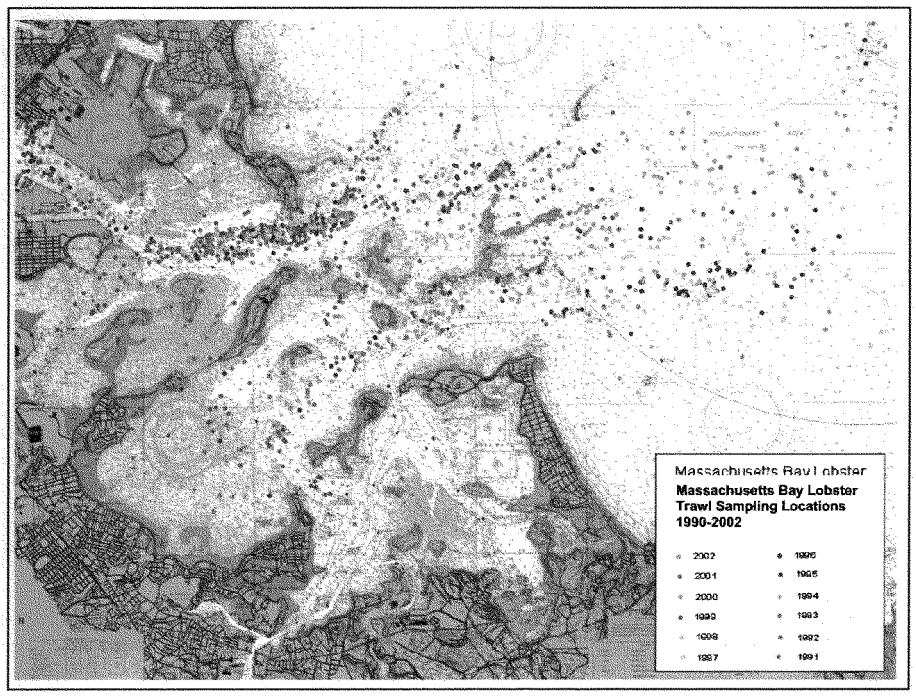


Figure 4. MADMF Boston Harbor and Massachusetts Bay sea sampling locations for the years 1991-2002.

Note: Sampling locations are not available for years 1984-1990, as their coordinates were not recorded until 1991.
Data Source: Robert Glenn, Coastal Lobster Investigations Project, MADMF, Pocasset, MA.

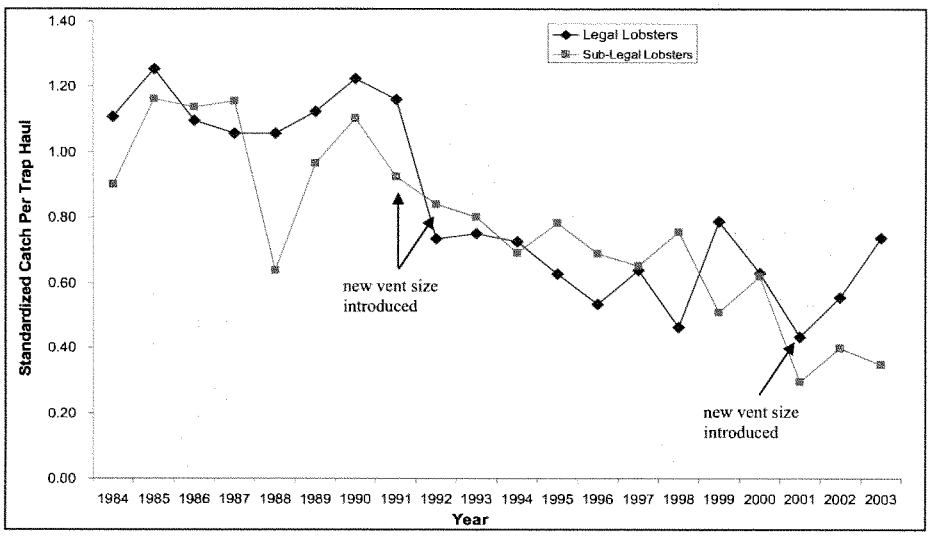


Figure 5. Catch per trap haul in Boston Harbor from the MADMF sea sampling program conducted for marketable (legal) lobsters, standardized to three set-over-days and non-marketable (sub-legal) lobsters, standardized to the same number of set-over-days.

Data Source: Robert Glenn, Coastal Lobster Investigations Project, MADMF, Pocasset, MA.

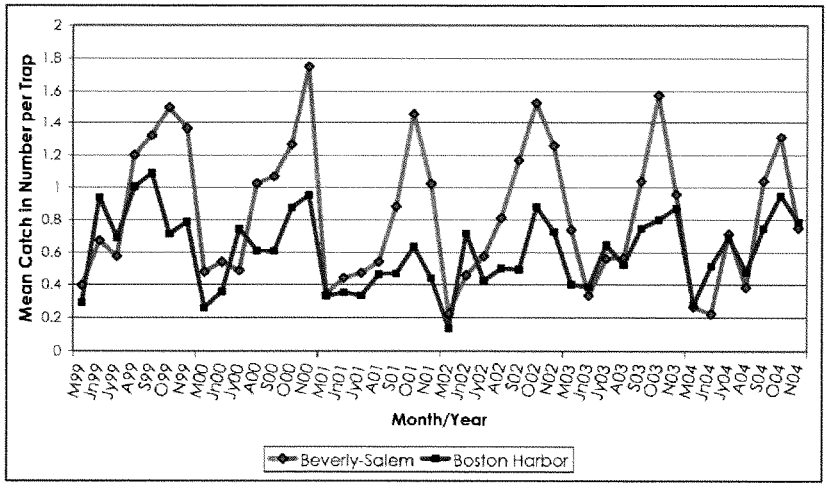


Figure 6. May-November sea sampling catch per trap haul standardized for three set-over days for Beverly-Salem and Boston Harbor for the years 1999-2004.

Data Source: Robert Glenn, MADMF, Pocasset, MA.

1.1.1 Ovigerous (Egg-Bearing) Females

While the overall catch-per-trap-haul has been decreasing in Boston Harbor, the percentage of ovigerous females per trap haul has been steadily increasing (Figure 7) from less than 2% in 1984 to ~12% in 2003. It is unknown whether these ovigerous females reside in the shallow coastal waters of the harbor throughout the year or migrate to deeper waters in the late fall/early winter months to subject their eggs to a more constant thermal regime. Large, sexually mature females have been described as employing several different strategies: 1) moving from deep to shallow waters to subject developing embryos to thermal regimes for optimal development ("seasonal migrators"); 2) moving long distances ("migrators"); or 3) remaining in a particular home location ("groundskeepers") (Pezzack and Duggan, 1986).

Historically, lobster researchers assumed that small, inshore ovigerous females moved into deeper waters to avoid subjecting their developing larvae to rapidly changing or more extreme water temperatures during the late fall/early winter and early spring/summer months (Lawton and Lavalli, 1995). In contrast, most large, sexually mature females were groundskeepers that did not undertake seasonal migrations (Campbell, 1986). More recently, however, others (Krouse, 1980; Cooper and Uzmann, 1980; Haakonsen and Anoruo, 1994; Lawton and Lavalli, 1995) have noted that inshore lobsters (both male and female) tend to restrict their movements locally, such that while they may change their home ranges ("street") every couple of days, they tend to remain in the same "neighborhood" (Watson, 2005).

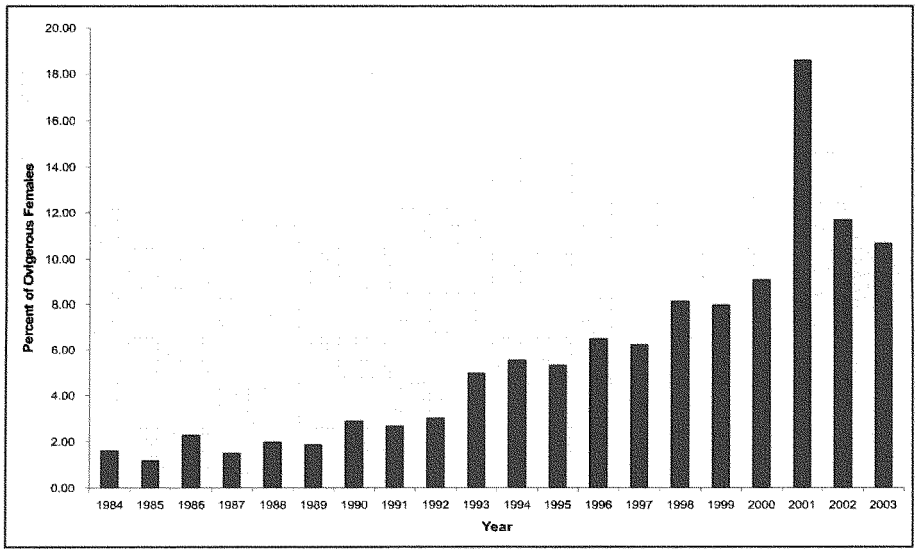


Figure 7. Percent of ovigerous females in the MADMF sea sampling program for Area 4 from 1984-2003.

Data Source: Robert Glenn, Coastal Lobster Investigations Project, MADMF, Pocasset, MA.

As previously mentioned, lobster movements are strongly influenced by temperature; however, it is unclear how females specifically react to changing temperatures. New, multi-seasonal data from a two-year study following sonar-tagged ovigerous females in Maine (Cowan *et al.*, 2005), suggests that differently sized ovigerous females employ different movement strategies. Small brooders (< 93 mm CL – the size at which 50% are mature in Maine waters) reside within coastal waters throughout their egg-bearing months, experiencing cold water temperatures from November through April and warm temperatures from mid-May through July. Large brooders (> 93 mm CL) travel greater distances and experience more moderate temperatures throughout the year, even if they brood and hatch their eggs near their spawning grounds. Both small and large brooders tend to hatch their eggs around the same time in the summer (Cowan, personal communication); thus, changes in thermal regimes do not necessarily exert major effects on developing embryos.

The average carapace length of ovigerous females sampled in the MADMF sea sampling program in Boston Harbor ranges between 72 and 78 mm CL (Figure 8), making them "small brooders[7]." These female lobsters are typically smaller in size than either sub-legal or legal lobsters, which is reflective of the fishing pressure put on the resource that selects for early maturation of females. These females, therefore, are likely to remain in Boston Harbor, spawning early, and brooding and hatching their eggs annually within the harbor. Thus, they likely provide a local recruitment source of benthic juveniles. Evidence of this is, in part, provided by the presence of early benthic phase lobsters (Stage IV to yearlings, ~5 to 15 mm CL) found in a number of locations in the Boston Harbor region, which are likely supplied, in part, by these resident females. If the females remain resident in the area throughout the year, they are likely to remain within their shelters and move very little during the winter months. Any physical disruption of their habitat in winter months could severely impact them and their brooding embryos because of their reduced ability to move quickly during cold temperatures.

[7] They are considered "small brooders" because their average carapace length is less than that previously determined for the size at 50% sexual maturity (~86 mm CL) in Boston Harbor (Estrella and McKiernan, 1985; Glenn and Pugh, 2005).

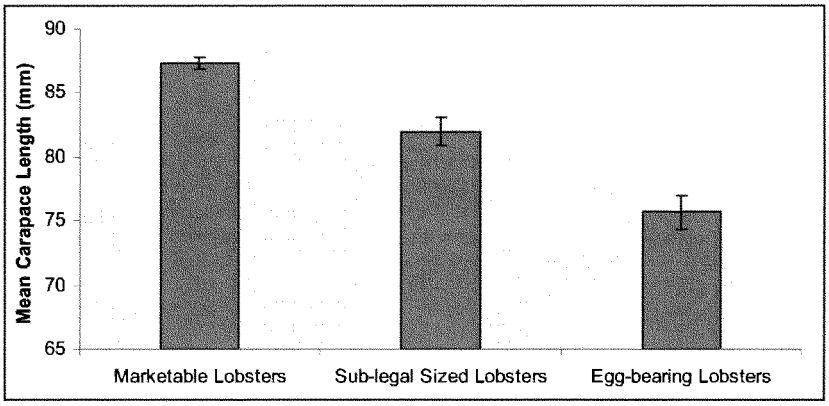


Figure 8. Mean carapace length of legal-sized (marketable), sub-legal sized, and ovigerous (egg-bearing) females represented in the MADMF sea sampling program for Area 4 from 1984 to 2003.

Error bars = standard deviation.
Data Source: Robert Glenn, Coastal Lobster Investigations Project, MADMF, Pocasset, MA.

1.1.2 Early Benthic Phase Lobsters

After hatching, lobsters begin a short, pelagic larval phase, which lasts for three molts over the span of approximately one month. These three molts include the molt at hatching (Stage I), the molt from Stage I to Stage II larvae, and the molt from Stage II to Stage III larvae. The larvae are primarily concentrated in surface waters and are subject to wind-driven currents (Harding *et al.*, 1987). Although Stage I lobster larvae are some of the largest members of the plankton community, they are clumsy (undirected) and fairly poor swimmers (Hadley, 1908). Their swimming ability improves as they pass from Stage I to Stage II and then Stage II to Stage III, at which time swimming can be accomplished by both the leg and mouthpart exopodites (feathery appendages) and the setose (hairy) pleopods (aka, "swimmerets") (Hadley, 1908; Herrick, 1909). Later-stage larvae are capable of maintaining position in the water column and migrating vertically to take advantage of sub-surface currents (Harding *et al.*, 1987). However, there are differences in larval behavior, depending on whether the larvae are located in offshore or coastal waters. Coastal larvae tend to concentrate in the upper 2-3 m of the water column. In contrast, offshore larvae exploit a greater range of depths, up to about 30 m (Harding *et al.*, 1987).

The molt between Stage III and Stage IV is considered a metamorphic molt, which results in a postlarva (Cobb, 1988). This stage resembles an adult lobster, which is only about 2.5 cm in length and has small, symmetrical claws. These postlarvae recruit into the benthic environment; thus, they are neither completely planktonic nor completely benthic (Lawton and Lavalli, 1995). The postlarvae settle sometime between the middle and end of the stage prior to molting, the timing of which is dependent upon environmental conditions (Scarratt, 1973; Cobb *et al.*, 1989). Environmental cues that may influence settlement choices include, but are not limited to, thermal gradients (Boudreau *et al.*, 1992), changes in light-seeking or light-avoiding behavior (Botero

and Atema, 1982; Hadley, 1908), chemical cues from previously settled benthic lobsters or substrates (Boudreau *et al.*, 1993; Hudon *et al.*, 1986), and reactions to predator odors (Boudreau *et al.*, 1993; Wahle, 1992). Of these factors, a thermal gradient of 4-5°C appears to be a significant barrier to postlarvae, because they are disinclined to swim from the warm surface waters through the thermocline[8] and into the cold waters below (Boudreau *et al.*, 1992). Because of this reluctance to move from warm surface waters to cold waters, postlarvae generally remain in warm, shallow, inshore waters where such gradients are absent (Boudreau and others 1992; Wahle and Steneck, 1991). This temperature avoidance behavior may explain the lack of recently settled juvenile lobsters in deep water Maine cobble habitats that are considered "prime habitats" for protection against predators (Wahle and Steneck, 1991; Wilson, 1998). Such a lack of postlarvae in deep cobble habitats led Wahle and Steneck (1991) to agree with the hypothesis that lower temperatures (<15°C) and thermal gradients may inhibit settlement, as originally proposed by Huntsman (1923).

Once settling is complete, the postlarva molts into the first juvenile stage. This stage, as well as subsequent stages within the first year, is commonly referred to as a young-of-the-year (YOY) lobster, or is included within the broader categorization of "early benthic phase (EBP) lobster," which typically extends past the first year and through the third year of the benthic lobster's life[9]. YOY lobsters (<15 mm CL) typically move very little. If movements do occur, they tend to be within contiguous cobble coverings (Lavalli and Lawton, 1996). Shallow, inshore populations of YOY lobsters benefit from warm coastal temperatures, which allow them to grow rapidly and attain larger sizes by the end of their first benthic season. Second year lobsters, also known as early benthic phase juveniles or vagile juveniles (Lavalli and Lawton, 1996), typically move about more frequently than YOY lobsters, but still remain localized within their settlement neighborhood, as evidenced by their residence in the same habitats as YOY (Wahle and Steneck, 1991). Here, they also benefit from shallow, warm waters in the spring and summer months, which permit rapid growth. Data from *in situ* predation studies indicate that lobsters that are larger than 30 mm CL are significantly less vulnerable to predation by inshore fish than those between either 5 to 7 mm CL or 15 to 20 mm CL (Wahle and Steneck 1992). When juveniles reach a size of 40 mm CL (the upper size limit of EBP lobsters) or larger, their movements tend to increase because the need for shelter-providing habitats is reduced (Lavalli and Lawton, 1996).

Although all benthic stages of lobsters are capable of modifying substrates, their distribution in the benthos is not random. Typically, postlarvae settle into shelter-providing habitats, and are found in the highest densities in cobble (Wahle and Steneck, 1991). EBP lobsters from 5 to 40 mm CL are most abundant on cobble-boulder habitats (Wahle and Steneck, 1991; Wahle, 1993; Hudon, 1987), salt marsh peat reefs (Able *et al.*, 1988), and the intertidal zone (Cowan *et al.*, 2002). Young-of-the-year (YOY) lobsters (<10 to 12 mm CL) are typically found in lower

[8] A layer below the warm surface water where there is a rapid change in temperature with depth. This layer provides a separation between warm surface waters and cold, deeper waters where temperatures change, but not as rapidly.

[9] EBP lobsters range in size from 5 to 40 mm CL and are subdivided into several different juvenile age ranges: YOY (between 5 to 12 or 15 mm CL, depending on researchers and location), second year or vagile juveniles (~15 to 20-25 mm CL) and emergent juveniles (between 20-25 and 40 mm CL). Sizes may be adjusted by researchers working in different regions, as colder waters (such as those found in Maine) may decrease growth rates compared to warmer water regions, such as southern Massachusetts, Rhode Island, and Connecticut.

densities than larger juveniles (>10 to 12 and < 40 mm CL) at most sites (Incze and Wahle, 1991; Wahle and Incze, 1997). Despite the higher density on cobble-boulder habitats of all EBP lobsters that are less than 40 mm CL, there is extreme variation in density from region to region (Cobb *et al.*, 1999; Incze and Wahle, 1991; Incze *et al.*, 1997; Wahle and Steneck, 1991; Wahle, 1993). The highest densities of EBPs were reported in cobble-boulder sites in Maine; much lower densities were reported from similar substrates in New Hampshire, northern and southern Massachusetts, and Rhode Island (Cobb *et al.*, 1999; Incze *et al.*, 1997; Wahle and Steneck, 1991; Wahle, 1993; Wahle and Incze, 1997). Lower densities of EBPs are also reported by depth gradient, with the highest densities being found between 5 and 10 m depths (Wilson, 1998). The smallest EBP juveniles (YOY) are only successfully sampled in large densities through the use of airlift sampling, which essentially vacuums up the sediments and captures the lobsters. Most researchers (including MADMF personnel) today use a suction device that consists of a 3" PVC lift tube supplied with air from a SCUBA tank. Samples are air-lifted into a 1.5 mm mesh nylon bag attached to the upper end of the suction tube. At each site, 0.5 m^2 quadrats are haphazardly placed on the substratum at least 2 m apart. Large boulders and large patches of sand are avoided. Sampling a quadrat in cobble habitat involves slowly moving the lift tube over the bottom while carefully moving rocks individually. Rocks are removed until no interstitial spaces remained. Twelve quadrats are sampled at each site. The samples were either sorted on the dive boat immediately following the dive, sorted at the lab later that day, or placed on ice and sorted the following day. All lobsters in the bag are counted and measured to the nearest 0.1 mm.

In 1995, MADMF began a suction-sampling program to monitor densities of newly settled postlarvae and subsequent YOY. The goals of this program are to document important nursery habitat and develop a lobster settlement index to better understand environmental factors influencing population trends. Currently 18 sites are sampled in Massachusetts, including seven within the Boston Harbor/Massachusetts Bay area, spanning from the Inner Harbor to the Outer Harbor and southwards towards Cohasset (Figure 9). In the Inner Harbor, Castle Island (located 50 m south of green can 5A, at a distance of 200 to 300 m from the shore) early benthic phase lobsters are sampled in cobble interspersed with kelp holdfasts, at a depth of 10–20 feet. The substrate at the Long Island site (located 75 m from shore off the southeast corner of the island) consists of cobble bottom with moderate kelp cover that changes to mud/gravel toward shore, at a depth of 12-20 feet. EBP lobsters at Sculpin Ledge Reef (located ¼ mile south of the Sculpin Ledge Channel) are found on substrate that consist of "man-made" rip-rap rock approximately 5 to 15 cm in diameter, stacked 3 to 4 layers deep. Those at Bumpkin Island are found on cobble mixed with loose shell rubble and sparse macroalgae at a depth ranging from 10 to 15 feet. At Grape Island (located 75 m from shore off the northwest corner of the island), the substratum sampled is mostly gravel/mussel shell rubble with small patches of cobble, at a depth of 10-15 feet. In the Outer Harbor, lobsters sampled at Greater Brewster Island (located 100 m from shore off the southeast portion of the island) are found in substrates of cobble interspersed with boulders and moderate macroalgae cover, at a depth of 15-20 feet. Those at Point Allerton (located 150 m from shore off the eastern-most portion of the point) are found on large boulder/sand substrates with moderate patches of cobble and heavy to moderate macroalgae cover, at a depth of 15-20 feet.

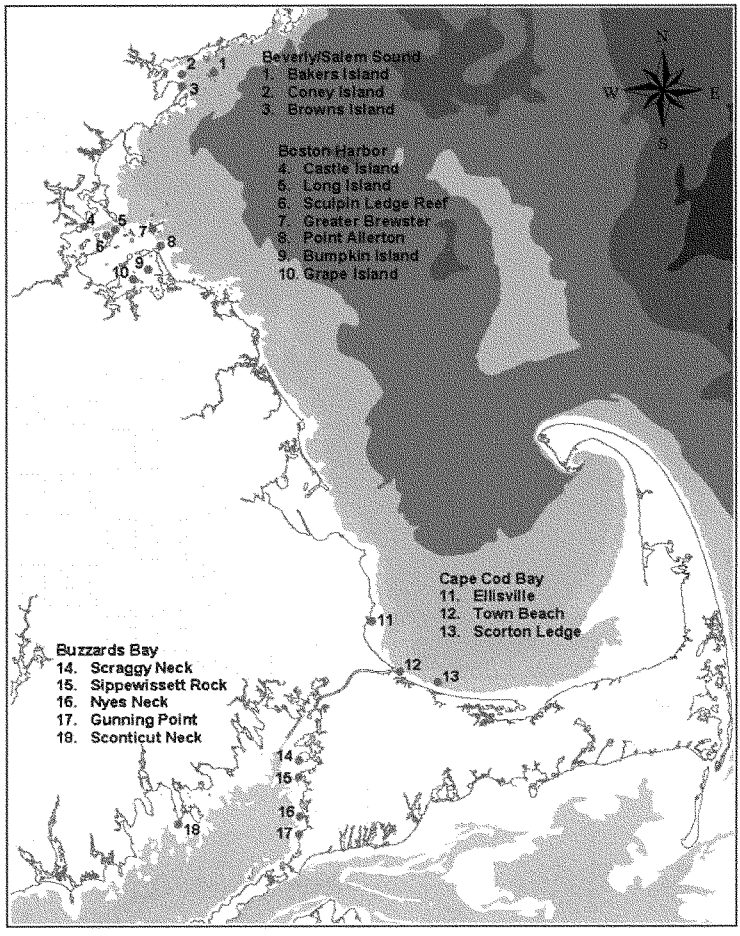


Figure 9. EBP sampling sites within Massachusetts State waters selected on the basis of the presence and quality of appropriate substrate at each location, as well as exposure to prevailing summer winds to ensure wind driven larval transport.

Data from Robert Glenn, Coastal Lobster Investigations Project, MADMF, Pocasset, MA.

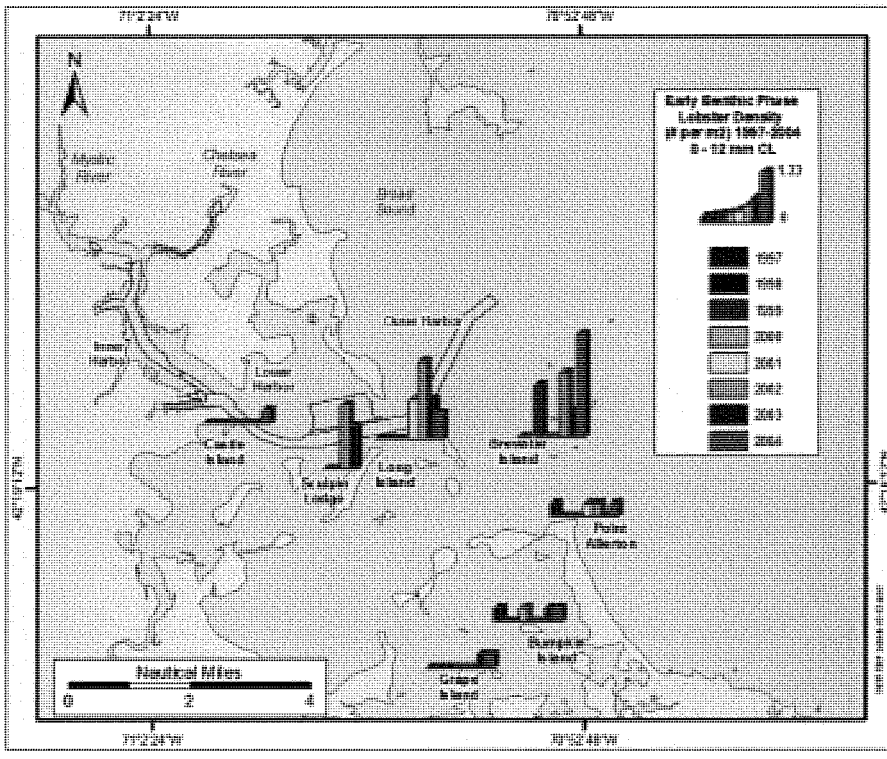


Figure 10. Average annual densities of EBP lobsters (0-12 mm CL) for sampling sites within Boston Harbor, 1997-2004.

Source: Robert Glenn, Coastal Lobster Investigations Project, MADMF, Pocasset, MA.

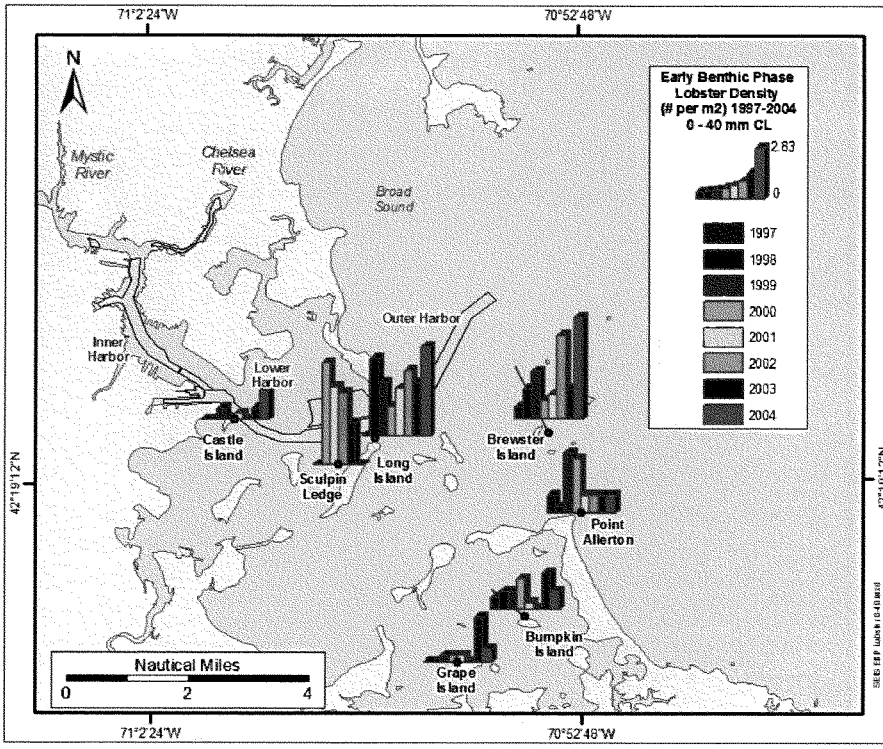


Figure 11. Average annual densities of EBP lobsters (0-40 mm CL) for sampling sites within Boston Harbor, 1997-2004.

Source: Robert Glenn, Coastal Lobster Investigations Project, MADMF, Pocasset, MA.

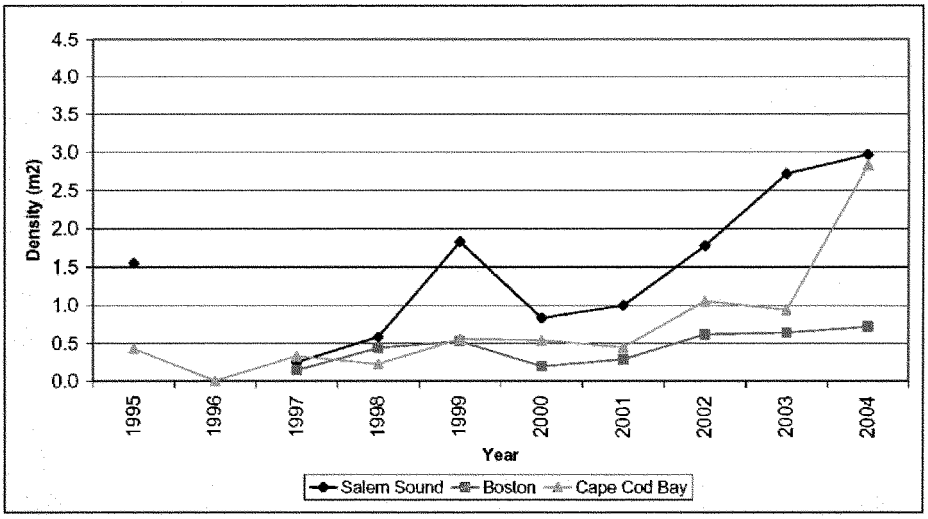


Figure 12. Densities of EBP lobsters (0-25 mm CL) in the Massachusetts portion of the Gulf of Maine.

Data Source: Robert Glenn, Coastal Lobster Investigations Project, MADMF, Pocasset, MA.

It should be noted that Sculpin Island was not sampled until 2000, and it was not sampled in 2004 due to inclement weather. Castle and Grape Islands were not sampled until 1999. While there is great interannual variability in densities of YOY (up to 12 mm CL) among the sites within Boston Harbor most sites have shown a stable (Bumpkin Island, Point Allerton, Grape Island) or increasing density (see, for example, Brewster Island in the outer harbor) (Figure 10).

The density of early benthic phase lobsters from 0 to 40 mm CL appears to increase at sites near the Boston Harbor navigation channel and decrease at sites south of the channel (Figure 11). Increases in the larger juveniles (12-40 mm CL) could be due to "walk-ins[10]" from other settlement sites, as well as from growth of settlers in the previous year. Although there are increases in average densities of EBPs within the harbor, the rate of increase is not as high as in Salem Sound and Cape Cod Bay (Figure 12). Harbor densities are likely dependent on surface currents during the months when larvae and postlarvae are present in the water column, and/or to the numbers of resident, ovigerous females within the harbor (which have also been slowly increasing during this same time period; see Figure 7). Such surface currents may affect the Boston Harbor region differently from Salem Sound and Cape Cod Bay and, thus, may impact EBP densities.

[10] The term "walk-in" refers to juvenile lobsters that are greater than 12-15 mm CL and more mobile; they tend to be more vagile in their movements and can move from site to site over short distances. Thus, if a particular settlement site becomes saturated, the larger juveniles can fan out from that site, immigrating to non-saturated sites. This movement pattern will result in different densities for YOY (0-12 mm CL) versus larger EBPs (12-40 mm CL), as is seen in the Boston Harbor sampling program.

1.2 Lobster Habitat

In general, lobster habitats are highly variable (Cooper and Uzmann, 1980). Inshore habitats used by populations of EBP juveniles, adolescents, and adults include mud, cobble, bedrock, peat reefs, eelgrass beds, sand, and for smaller individuals, the intertidal zone (Thomas, 1968; Cooper, 1970; Cobb, 1971; Cooper *et al.*, 1975; Hudon, 1987; Able *et al.*, 1988; Heck *et al.*, 1989; Wahle and Steneck, 1991; Lawton and Robichaud, 1992; Cowan *et al.*, 2002). YOY (EBPs, < 15 mm CL) are typically restricted to shelter-providing habitats that protect them from predators (Lavalli and Barshaw, 1986; Hudon, 1987; Johns and Mann, 1987; Barshaw and Lavalli, 1988; Able *et al.*, 1988; Wahle and Steneck, 1991; Wahle and Steneck, 1992). Larger juveniles may be less susceptible to inshore predators and, thus, are able to exploit a wider range of habitats, including those less likely to provide ready-made shelter, and habitat that allows them to build shelters (e.g., mud) (Cobb, 1971; Berrill and Stewart, 1973; and Botero and Atema, 1982). Adolescents (sub-legal lobsters) and adults (mostly legal-sized lobsters), particularly those that remain in shallow coastal waters, have fewer predators and are found in featureless substrates, such as sand and fine-grained mud (Cooper and Uzmann, 1980). While shelters are necessary for the purposes of molting and mating (Tremblay and Smith, 2001; Karnofsky *et al.*, 1989), these larger lobsters show little shelter fidelity within a home range over a period of several days, except during over-wintering months (Watson, 2005). Thus, there is a trend of increased ability to exploit all available habitats, both featureless and shelter-providing, as the size of a lobster increases.

The non-depositional sedimentary environments of Boston Harbor and Massachusetts Bay consist of subtidal, exposed bedrock, glacial drift, and mixed deposits from coastal–plains containing boulder fields to gravelly sand (USGS, 1999; Figure 13). These sediment types are found in areas of high energy and typically occur within the harbor near the mainland, along insular (isolated island) shorelines, harbor approaches, and over scattered knolls and ridges. Depositional sedimentary environments are fine-grained muddy sand or muds and are typical in weak bottom currents (USGS, 1999; Figure 13). Sediment reworking environments are characterized by sandy-gravels to muds and are common where bottom currents fluctuate to alternatively erode and deposit the sediments. The navigation channel passes through depositional areas (Inner Harbor, Mystic and Chelsea Rivers), sediment reworking areas (Lower Harbor in the eastern portion and the Outer Harbor), and erosional areas (Lower Harbor in the western portion). Sedimentary environments in all of these areas appear to consist predominantly of slit, clay, mud, sand, and gravel (Figure 13).

In an ongoing ventless trap study conducted by MADMF, efforts are underway to characterize the importance of substrate type and depth to lobster abundance and size distribution (Glenn *et al.*, 2005). Fixed stations within Massachusetts Bay (including several in Boston Harbor, Figure 14) were sampled during a pilot study in 2004 and are currently being sampled for a multi-year survey. Sampling occurs aboard commercial vessels, twice monthly from May through November, using a six-trap haul, in which vented and ventless traps are alternately strung on the trawl line. The sampling involves 80 randomly selected, but fixed (month-to-month and year-to-year) stations in Massachusetts Bay with each stratum (depth and substrate) represented by at least seven stations. No sampling is done directly in the Boston Harbor navigation channel

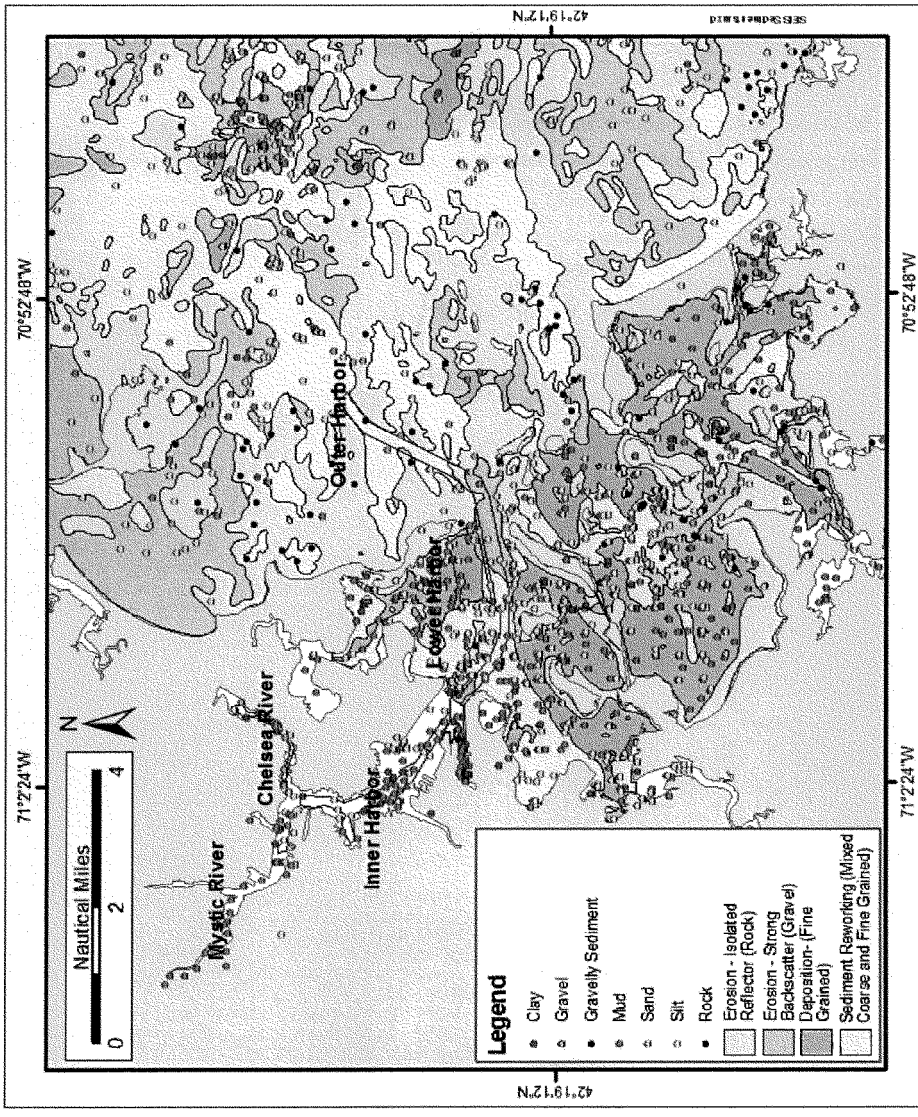


Figure 13. Sedimentary environments and sediment bottom type in Boston Harbor and Massachusetts Bay.

Note: Bottom type locations are approximate.
Data Source: USGS, 1999

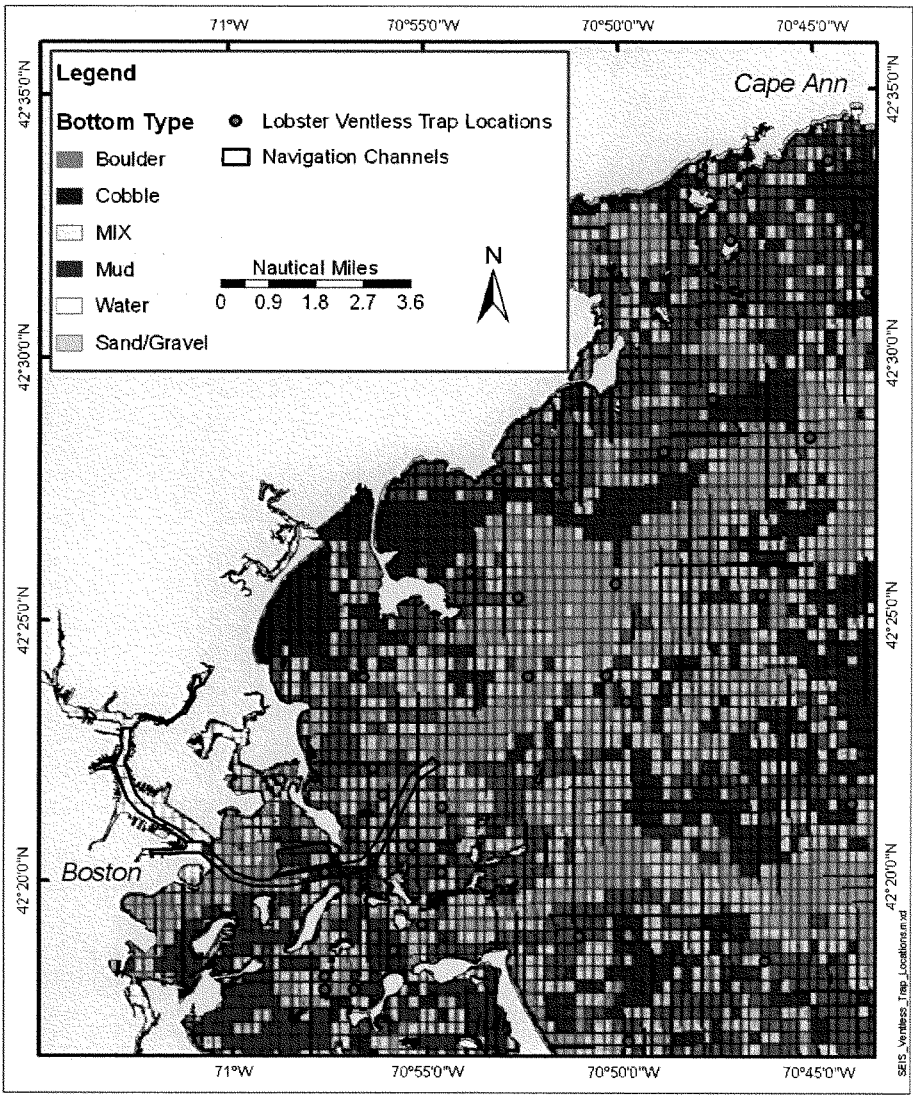


Figure 14. Map of the MADMF Massachusetts Bay ventless trap study area with the 2005 sample locations and strata.

Data Source: Glenn *et al.*, 2005.

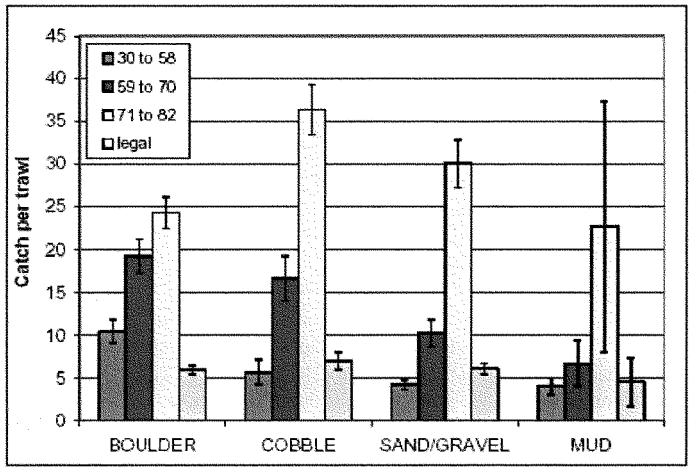


Figure 15. Catch-per-trawl during the ventless trap study of four size classes of lobster by sediment type: juveniles (30-58 mm CL), adolescents (59-70 mm CL), sub-legals (71-82 mm CL), and legal (>83 mm CL). Bars represent standard error.

Data Source: Glenn *et al.*, 2005.

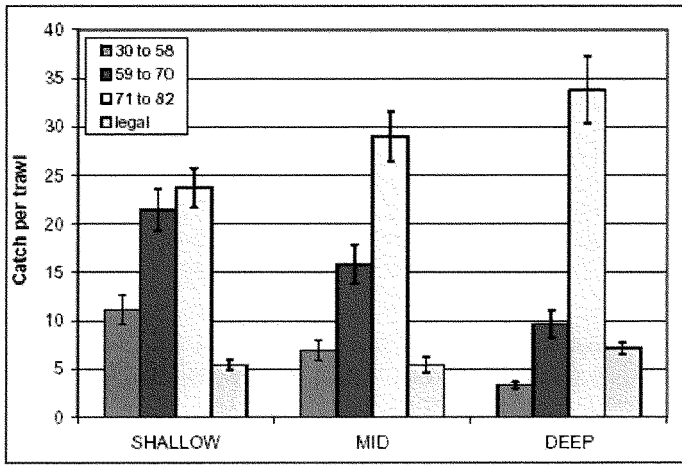


Figure 16. Catch-per-trawl during the ventless trap study of four size classes of lobster by depth: juveniles (30-58 mm CL), adolescents (59-70 mm CL), sub-legals (71-82 mm CL), and legal (>83 mm CL); Shallow, 0-15 m; Mid, 16-30 m; Deep, >30 m. Bars represent standard error.

Data Source: Glenn *et al.*, 2005.

because the traps are only recovered by grappling without buoys present to mark their location, and thus there is great potential for loss of these trawl lines and data. Instead, several stations that are in close proximity to the channel are sampled.

Data from the October through November 2004 pilot study (16 sampling trips, 40 stations, 3 depth strata, 4 substrate strata for 936 trap hauls) provided initial information on the size distribution of lobsters in various types of bottom habitats in the Massachusetts Bay/Boston Harbor area. As expected from previous studies, juvenile (30-58 mm CL) and adolescent (59-70 mm CL) lobsters were more common in the shelter-providing habitats of boulder and cobble than in sand/gravel or mud (Figure 15), and were more common in shallow waters (0-15 m depth) (Figure 16). Again, these data reflect the needs of smaller juveniles for shelter-providing habitats that offer protection against predators. In contrast, sub-legal sized adult lobsters (71-82 mm CL) were nearly equally distributed in all habitats at all depths sampled, and were more abundant than legal-sized adult lobsters (> 83 mm CL), indicative of the highly exploited nature of this resource (Glenn *et al.*, 2005). Both of these larger size classes of lobsters have fewer inshore predators than do the smaller class size lobsters and, thus, fewer restrictions in habitat usage.

1.3 Summary and Conclusions

Lobsters captured from Massachusetts State waters, including Boston Harbor, have been showing a slight decline in numbers for the past decade. Despite this, lobsters continue to be an important fishery in the State, and as such, are being carefully studied and managed. Recent studies have focused on lobster larval development and movement within Massachusetts Bay. Populations of EBP lobsters less than 12 mm CL are known to exist in high densities just outside of the navigation channel and along island coastlines. Here, they utilize cracks within the bedrock, boulders/cobble, and rocks within glacial drift for their shelter-providing habitat. The depth of the navigation channel may restrict habitat exploitation by EBPs, which prefer shallower, non-depositional habitats outside of the footprint. Thus, there would likely be minimal impact on these populations from activities within the navigational channel itself. However, if the deepening activities cause sedimentation in the water column which disperses via currents to outlying island areas, then some impact on these populations could arise because EBP lobsters may be less inclined to settle in cobble overlain with sediment (Botero and Atema, 1982).

Other size classes of lobsters, such as larger juveniles (>12 mm CL), sub-legal sized lobsters (> 30 mm CL), and adults capable of utilizing all of the described habitats in the navigation channel (Figure 13), as shown in the ventless trap study by MADMF, are found in all of these environments in Boston Harbor. Within the planned dredge footprint for the navigation channel, both non-depositional and depositional environments exist; therefore, lobsters of these larger class sizes are likely to exploit the habitats in the same manner as they are exploiting the habitats outside of the planned dredge footprint. Lobster populations in the channel, therefore, may potentially be affected by the proposed project.

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BOSTON HARBOR
MASSACHUSETTS

DEEP DRAFT
NAVIGATION IMPROVEMENT STUDY

FINAL FEASIBILITY REPORT
AND FINAL SUPPLEMENTAL
ENVIRONMENTAL IMPACT STATEMENT
AND MASSACHUSETTS
FINAL ENVIRONMENTAL IMPACT REPORT

APPENDIX O

AIR QUALITY CONFORMITY

(THIS APPENDIX UNCHANGED FROM 2008 DRAFT)

Appendix O
Air Quality General Conformity

O.1 Introduction

This technical appendix presents a comprehensive air quality impact analysis in support of the General Conformity applicability determination for the Boston Harbor Deep Draft Navigation Improvement Project (Project). The U.S. Army Corps of Engineers (ACE) is required to prepare air emissions inventories in support the Supplemental Environmental Impact Statement (SEIS)/Environmental Report (EIR) and General Conformity Determination for the Project. The Clean Air Act's general conformity rule requires that the ACE determine whether or not the total of direct plus indirect emissions associated with the Project would "conform" with the U.S. Environmental Protection Agency (EPA) – approved Massachusetts State Implementation Plan (SIP) and General Conformity rule.

This appendix summarizes the results of the air emissions inventories, the development and selection of an emissions reduction strategy to bring the Project in compliance with the General Conformity standards of the Clean Air Act.

The description of the Project and the purpose of the air quality impact analysis are presented below. A summary of the applicable federal air quality regulations including the General Conformity rule are presented in Section O.2. Section O.3 gives an overview of the air emissions estimation methodology and selection of the air emissions models used to estimate direct and indirect emissions. Section O.4 presents a summary of the emissions inventory modeling results and the results of the General Conformity applicability determination, and Section O.5 presents the conclusions and recommendations. The supporting documentation and detailed modeling results are presented in Attachments A and B.

O.1.1 Project

The General Conformity analysis was conducted for three potential alternatives:

- No-Project;
- Alternative 1 – 45-foot harbor depth, and
- Alternative 2 - 50-foot harbor depth.

Without channel improvements (No Project alternative), larger cargo ships now either delay (i.e., slow down) their arrival to ride the high tide into Boston Harbor, or wait in the anchorage area or outside the project area for high tide. The lack of depth in the navigation channel may also cause a ship to delay departure or leave early from Boston Harbor. In addition, larger cargo ships are diverted to the Port of New York &

New Jersey (PONYJ). The container boxes are then loaded on trucks for delivery to destinations in New England. The No Project alternative limits the number of container ships that can port into Boston Harbor causing economic and air quality impacts. The economic and air quality benefits of the "Project" alternatives would include newer deeper draft container ships as well as a decrease in truck miles traveled between the PONYJ and destinations for shipping container boxes in New England.

The project alternatives would include harbor deepening of channels and other areas seaward of the South Boston Reserved Channel for improved containership access to the Conley Terminal. ACE considered various depth increments; however, two deepening plans were selected by ACE. The minimum deepening plan is a 45-foot access improvement plan (Alternative 1) and the maximum deepening plan is a 50-foot access improvement plan (Alternative 2). Under Alternative 1, the areas to be deepened to 45 feet include the Main Ship Channel below the Reserved Channel, the lower two thirds of the Reserved Channel, the Reserved Channel Turning Area and the Presidents Roads anchorage. The Broad Sound North Entrance Channel would be deepened to 47 feet. The additional two feet in the entrance would be required to compensate for higher seas and their impact on effective draft of cargo ships. Alternative 1 would require removal of approximately 6,530,000 cubic yards (cy) of dredged material and approximately 512,000 cy of ledge material. This alternative would take approximately three years to complete. It is anticipated that Alternative 1 dredging operations would occur from 2011 through 2013.

Under Alternative 2, these same areas would be deepened to 50 feet, except for the Broad Sound North Entrance Channel which would be deepened to 52 feet. All depths are referenced to mean lower low water (MLLW). Other minor improvements are also proposed for the Main Ship Channel in the reach above the Reserved Channel and below the Ted Williams Tunnel and the Mystic and Chelsea Rivers. The improvements would consist of dredging unconsolidated material, and blasting and removal of ledge. Alternative 2 would require the removal of approximately 14,755,000 cy of dredge material and approximately 1,384,000 cy of ledge. This plan would take approximately fours years to complete. It is anticipated that Alternative 2 dredging operations would occur from 2011 through 2014.

The ACE is carrying two project alternatives in order to evaluate a range of potential air quality impacts since the final depth of the main harbor channel could be between 45-ft MLLW and 50-ft MLLW.

O.1.2 Purpose

The purpose of this appendix was to develop air emissions estimates for the different types of equipment that will be used to dredge the Boston Harbor Deep Draft Navigation Improvement Project, and from shipping activities associated with the No Project and With Project alternatives. The air pollutant emissions associated with the Project would be from two types of activities:

- Direct Emissions – from dredging equipment, barges and other vessels carrying equipment and dredged material; land-based equipment; and motor vehicles transporting workers, equipment and material.

- Indirect Emissions – from projected net changes in ship traffic volumes and vessel types enabled by the deeper channels.

Under the general conformity regulations, an air emissions analysis is required to determine the direct and indirect emissions for each criteria pollutant within the project study area. The General Conformity rule only requires a conformity general determination for the "proposed action." The ACE is carrying two project alternatives in order to evaluate a range of potential air quality impacts since the final depth of the main harbor channel could be between 45-ft MLLW and 50-ft MLLW. Therefore, CDM calculated air emissions estimated for the No-Project and With Project indirect emissions, and direct emissions for both Project Alternatives. Based on the results of the preliminary air emissions modeling analysis, an emission reduction strategy was developed to allow both Preferred Alternatives to comply with the General Conformity requirements of the Clean Air Act.

O.2 Regulatory Setting

O.2.1 Federal Regulations

O.2.1.1 Ambient Air Quality Standards and Attainment Status

Clean Air Act (Act) was passed in 1970 and amended three times afterward (including in 1990, 42 USC 7401 et seq.). The Act establishes the framework for modern air pollution control, and delegates primary responsibility for regulating air quality to the states, with oversight by the U.S. Environmental Protection Agency (EPA). EPA develops rules and regulations to preserve and improve air quality as minimum requirements of the Act, as well as delegating specific responsibilities to state and local agencies.

EPA has identified seven specific pollutants (called criteria pollutants) that are of concern with respect to the health and welfare of the general public. The criteria pollutants are carbon monoxide (CO), sulfur dioxide (SO_2), nitrogen dioxide (NO_2), ozone (O_3), particulate matter 10 micrometers or less in aerodynamic diameter (PM_{10}), particulate matter 2.5 micrometers or less in aerodynamic diameter ($PM_{2.5}$), and lead (Pb). EPA has established the National Ambient Air Quality Standards (NAAQS) for these pollutants. EPA recently approved changes to the O_3 and PM_{10}, and $PM_{2.5}$ NAAQS. In place of the 1-hour O_3 standard, EPA approved an 8-hour standard of 0.08 parts per million (ppm). In addition to the current PM_{10} standard, EPA approved standards for $PM_{2.5}$. Although these changes have been approved, implementation of the new standards and monitoring of ambient conditions relative to these new standards is an ongoing process.

Similarly, Massachusetts Department of Environmental Protection (MassDEP) has established Massachusetts Ambient Air Quality Standards (MAAQS), which are equal to the NAAQS. Currently, Massachusetts has not adopted the new eight-hour average O_3 standard or the 24-hour and annual average $PM_{2.5}$ standards. **Table O-1** lists the national and state standards for criteria pollutants. The standards are divided into primary and secondary standards; the former are set to protect the public (i.e., human) health with an adequate margin of safety, and the latter to protect the public welfare (e.g., environmental quality, such as plant and animal life).

Areas that do not meet the NAAQS are called nonattainment areas. For nonattainment areas, the Act requires states to develop and adopt State Implementation Plans (SIPs), which are air quality plans showing how air quality standards will be attained. SIPs, which are reviewed and approved by EPA, must demonstrate how the federal standards will be achieved. Failing to submit a plan or secure approval could lead to denial of federal funding and permits for such improvements as highway construction and sewage treatment plants. In cases in which a SIP is submitted by the state but fails to demonstrate achievement of the standards, EPA is directed to prepare a Federal Implementation Plan.

As stated above, the Project is located in the Metropolitan Boston Intrastate AQCR (40 CFR 81.19). As shown in **Table O-2**, the AQCR is considered to be in attainment with all NAAQS, with the exception of CO and O_3 for which it is designated as "maintenance" and "non-attainment," respectively[1] (40 CFR 81.322). On December 12, 1994, the MassDEP submitted a request to redesignate the Boston area CO nonattainment area to attainment for CO. As part of the redesignation request, MassDEP submitted a maintenance plan, which included a base year (1993 attainment year) emission inventory for CO and a demonstration of maintenance of the CO NAAQS with projected emissions inventories to the year 2010 (U.S. EPA, *Massachusetts; Boston Harbor Area Carbon Monoxide Redesignation to Attainment,* December 2005.

MassDEP submitted a revision to the SIP for ozone. This submittal was a supplement to the 1-hour ozone standard attainment submittal for Massachusetts submitted in July 1998. Massachusetts was designated non-attainment for ozone state-wide, with a classification of "serious." MassDEP was required to demonstrate attainment in Eastern Massachusetts. MassDEP proposed to attain the one-hour standard by an attainment date of December 2007 (MassDEP, Final Eastern Massachusetts 1-Hour Ozone NAAQS Attainment Demonstration SIP, September 2002). However, EPA revoked the 1-hour standard in 2005. Therefore, the revised ozone SIP will need to demonstrate attainment of the 8-hour ozone NAAQS by 2010. The update to the SIP is currently under development.

[1] Attainment means there are no recorded exceedances of the NAAQS in the area; non-attainment means exceedances of the NAAQS have occurred in the area; and maintenance means the area is in transition from non-attainment to attainment.

Table O-1
Ambient Air Quality Standards[1, 2]

Pollutant	*Averaging Period*	*Massachusetts Standard*	*National Primary Standard*	*Massachusetts & National Secondary Standard*
NO_2 (µg/m³)	Annual	100	100	100
SO_2 (µg/m³)	3-Hr	1300	-	1300
	24-Hr	365	365	-
	Annual	80	80	-
CO (ppm)	1-Hr	35	35	-
	8-Hr	9	9	-
Pb (µg/m³)	Qtr	1.5	1.5	1.5
O_3 (ppm)[3]	8-Hr	-	0.08	0.08
PM_{10} (µg/m³)	24-Hr	150	150	150
$PM_{2.5}$ (µg/m³)[4]	24-Hr	-	35	35
	Annual	-	15	15

Notes:

[1]All short-term (1-hour, 3-hour, and 24-hour) standards except ozone are not to be exceeded more than once per 12 month period.

[2]Annual standards are 12-month arithmetic means, never to be exceeded. Quarterly standards are also never to be exceeded.

[3]The 8-hour primary and secondary ozone standards are based on the fourth-highest daily maximum 8-hour average ozone concentration.

[4]Attainment of the 24-hour $PM_{2.5}$ standard is based on the 98th percentile of the 24-hour concentrations in a year, averaged over three years.

Conversion factors:

1 ppm NO_2 = 1887 µg/m³ NO_2

1 ppm CO = 1140 µg/m³ CO

1 ppm SO_2 = 2601 µg/m³ SO_2

1 ppm O_3 = 1961 µg/m³ O_3

Sources:
1 310 CMR 6.00, April 2002.
2 40 CFR 50.

Table O-2 Attainment/Non-Attainment Designations For Metropolitan Boston	
Pollutant	***Designation***
Carbon Monoxide	Maintenance
Lead	Attainment
Nitrogen Dioxide	Attainment
Ozone (8-hour)	Non-attainment
Particulate Matter (<10 microns)	Attainment
Particulate Matter (< 2.5 microns)	Attainment
Sulfur Dioxide	Attainment

Source: U.S. EPA, 2007.

O.2.1.2 General Conformity

Section 176 (c) of the Act requires any entity of the federal government that engages in, supports, or in any way provides financial support for, licenses or permits, or approves any activity to demonstrate that the action conforms to the applicable SIP required under the Act. In this context, conformity means that such federal actions must be consistent with a SIP's purpose of eliminating or reducing the severity and number of violations of NAAQS and achieving expeditious attainment of those standards. In 1993, the EPA promulgated regulations prescribing general criteria and procedures for analysis of both transportation and general conformity which apply in non-attainment and maintenance areas only. Since that date, most if not all state and local air pollution control agencies have adopted conformity requirements at least as stringent as the EPA regulations.

EPA promulgated two regulations to address the conformity requirements of the Act. On November 24, 1993, EPA issued final transportation conformity regulations at 40 CFR 93 Subpart A to address federally assisted transportation plans, programs, and projects. These regulations have been revised several times since they were first issued to clarify and simplify them. On November 30, 1993, EPA issued final general conformity regulations at 40 CFR 93 Subpart B for all federal activities except those covered under transportation conformity. The general conformity regulations apply to a federal action if the total of direct and indirect emissions for a criteria pollutant from the action equals or exceeds the de minimis thresholds. Regardless of the action's total of direct and indirect emissions, if this total represents 10 percent or more of a non-attainment or maintenance area's total emissions of that pollutant (i.e., is "regionally significant"), the federal agency must conduct a conformity analysis. By requiring an analysis of direct and indirect emissions, EPA intended the federal agency to make sure that only those emissions that the federal agency can practicably

control, and that are subject to that agency's continuing program responsibility, will be reasonably controlled.

The Project is subject to the General Conformity Rule since it is sponsored by (i.e., requires approval from) the ACE. For the Project, the de minimis thresholds for general conformity analysis and the 10 percent eastern Massachusetts area inventory levels are presented in **Table O-3**. The inventory levels were obtained from the latest O_3 and CO SIPs described earlier. The O_3 SIP includes both NO_x and VOC emissions projections made for 2007 in order to attain the one-hour O_3 standard. The CO emissions projections were made for 2010 for its maintenance demonstration.

Table O-3
General Conformity De Minimis and 10 Percent Area Inventory Levels for the Eastern Massachusetts Area

Pollutant	*Federal Status*	*De Minimis Value (tons/yr)*	*10 Percent of Area Inventory Level (tons/yr)*
Nitrogen Oxides (NO_x) (as an Ozone Precursor)	Non-attainment, moderate 8-hour Ozone	100	220,825
Carbon Monoxide (CO)	Attainment, Maintenance	100	161,697
Volatile Organic Compounds (VOCs) (as an Ozone Precursor)	Non-attainment, moderate 8-hour Ozone	50	179,179
Notes:			
1. The 10% Area Inventory Level represents projected emissions inventories prepared by the MassDEP and approved by EPA. The latest NO_x and VOC emissions inventory data represents 2007 and CO emission inventory represents 2010. Annual emissions were estimated based on daily summer for NO_x and VOC and daily winter projections for CO.			
Sources:			
U.S. EPA, Region I, Massachusetts; Boston Harbor Area Carbon Monoxide Redesignation to Attainment (http://www.epa.gov/region1/topics/air/sips/ne_sip_summaries.html), December 2005.			
MassDEP, Final Eastern Massachusetts 1-Hour Ozone NAAQS Attainment Demonstration SIP, September 2002.			

In addition to projects where the total of direct and indirect emissions of a pollutant are projected to be less than the de minimis levels, the following types of projects are also exempt from a conformity analysis:

- Actions which carry out plans which previously have been determined to conform to the SIP;
- Special actions where conformity is not required;

- Actions where the emissions are not reasonably foreseeable; and
- Actions which are presumed to conform (e.g., maintenance dredging).

In order for a federally supported action to conform to the SIP, the total of direct and indirect emissions associated with the action must be in compliance or consistent with all applicable requirements in the SIP. In addition, the action must meet certain criteria spelled out in the regulations, which include either having the emissions specifically identified and accounted for in the SIP's attainment or maintenance demonstration; fully offsetting the emissions within the non-attainment or maintenance area; including the emissions within the SIP's emissions budget; or conducting dispersion modeling analyses to demonstrate that the emissions do not cause or contribute to any new violation of the NAAQS and do not increase the frequency or severity of any existing violation of the NAAQS.

A conformity analysis must follow general procedures outlined in the regulations. For example, the federal agency must employ the latest planning assumptions, based on projections of population, employment, travel, and congestion, approved by the local metropolitan planning organization (MPO). Also, the federal agency must use the latest and most accurate emission estimation methods approved by EPA. Further, if the federal agency performs any dispersion modeling, it must be consistent with EPA modeling guidance. In addition, the federal agency must perform the analysis using the total of direct and indirect emissions from the action estimated for the mandated attainment year, the year of maximum emissions, and any year for which the SIP specifies an emissions budget.

General Conformity Thresholds Comparison

The direct and indirect emissions were determined for each piece of equipment. The direct and indirect emissions were then summed on an annual basis for all equipment. The general conformity regulations require that the total of direct and indirect emissions be evaluated for: (1) the year of maximum emissions; (2) the mandated attainment year (for non-attainment pollutants) or the year of farthest emissions projections in the SIP (for maintenance pollutants); and (3) any year with an emissions budget specified in the SIP. The annual emissions were compiled for each appropriate year for each project alternative, and each year's net emissions were then compared to the de minimis values and appropriate SIP emissions budgets (See Section O.2.1.1 for discussion on Massachusetts SIP emissions budgets).

O.3 Air Emissions Estimation Methodology

Air emissions were estimated for the No-Project alternative and each year for Alternatives 1 and 2. The total of the direct and indirect emissions (the net emissions increases) for a proposed project represents the difference between the build and the no-build scenarios. The general conformity regulations define "direct emissions" as those associated with the federal action and that occur at the same time and place as the action. "Indirect" emissions are defined as those that occur later in time or at distance from the federal action, and the federal agency can practicably control

through its continuing program responsibility. For the purposes of the General Conformity analysis, it was assumed that dredging and construction activities define direct emissions and the effects on cargo vessel operations including scheduling, volume of ship calls, fleet mix and associated trucking operations define indirect emissions. It is anticipated that changes in shipping operations for both project alternatives would occur after the dredging operations are complete. Therefore, there would be no overlapping of either Alternative 1 or 2 indirect emissions with the direct emissions from the dredging operations in any particular year.

Emissions of nitrogen oxides (NO_x), volatile organic compounds (VOCs) and carbon monoxide (CO) were estimated for the General Conformity applicability analysis and support of the SEIS/EIR. Emissions of sulfur dioxide (SO_2) and particulate matter (PM_{10} and $PM_{2.5}$) were only estimated in support of the SEIS/EIR air quality impact analysis. The emission sources for Alternatives 1 and 2 would consist of marine and land-based mobile sources that would be used during the 3 to 4 year dredging activities. The marine sources would include tugboats and barges, as well as support equipment, such as crew and drill boats, and anchor and dump scows). The land-based emissions would include both nonroad and on-road equipment. The nonroad equipment would consist of heavy equipment, such as clamshells, backhoe excavators, loaders, cranes, generators, pumps, etc. The on-road equipment would be made up of employee vehicles and any delivery trucks.

O.3.1 Direct Emissions

The ACE provided a dredging operations schedule for both project alternatives. The schedule included a breakout of the number of pieces of equipment, engine sizes, and power loadings for each major phase of dredging. These data were used to estimate emissions from marine vessels, nonroad (dredging) equipment and on-road vehicles. It was assumed that all equipment, except for on-road vehicles would use diesel fuel. The on-road vehicles were assumed to be a mix of both gasoline- and diesel-fuel engines. **Attachment A** presents ACE's dredging operations schedule.

Annual emissions calculated from all three emissions phases were summed to obtain the total direct emissions for each project alternative, which were compared to the General Conformity de minimis thresholds.

A detailed discussion of the methods used to estimate emissions from all three phases is provided below.

O.3.1.1 Marine Vessels

Marine vessel emissions were estimated using the latest EPA technical report for developing load factors and emissions factors for large compression-ignition marine diesel engines as prescribed in U.S. EPA, *Analysis of Commercial Marine Vessels Emissions and Fuel Consumption Data,* EPA420-R-00-002, February 2000. The technical report is a compilation of engine and fuel usage test data from various types of marine vessels including bulk carriers, container ships, dredges, tankers and tugboats. This report was used to determine the load factors and emissions factors for the various

ship types that would be used during the dredging operations. The load factors for the marine vessels are based on the suggested operating mode of the vessel. These load factors are based on different operating modes (cruise, slow cruise, maneuvering and hoteling) for different types of vessels.

The report contains emissions factors based on a regression analysis of representative test data for various marine vessels. Emission factor algorithms were derived for different pollutants and also for fuel consumption, which was used to determine the SO_2 emission factor. The sulfur content used to calculate the SO_2 emission factor was based on low sulfur diesel fuel (500 part per million (ppm)), which is currently being used by local tugboat operators and would be required by EPA as part of the proposed marine vessel emissions standards for 2007 and beyond (U.S. EPA, *Clean Diesel Program for Locomotives and Marine, EPA 420-F-04-041*, May 2004). Table 5-1 of the EPA technical report stated above presents the emission factor and fuel consumption rate algorithms, which are applicable to all engine sizes since the emissions data showed no statistically significant difference across engine sizes.

The marine engine emission factor and fuel consumption algorithms are derived from the following equation for all pollutants, except SO_2:

[Equation 1] $EF_{(SO2)} = a\ (\text{Fractional Load})^{-x} + b$

Where:

EF = emission factor (g/kW-hr)

Fractional Load = actual engine output divided by engine output

a= coefficient (Table 5-1)

x = exponent (Table 5-1)

b = intercept (Table 5-1)

The SO_2 emission factor algorithm is derived from Equation 2:

[Equation 2] $EF = a\ (FSF) + b$

Where:

$EF_{(SO2)}$ = emission factor (g/kW-hr)

FSF = fuel sulfur content (g/kW-hr) (See Equation 3 for calculation)

a= coefficient (Table 5-1)

b = intercept (Table 5-1)

[Equation 3] FSF = BSFC x FSC x 0.746 hp/kW x 454 g/lb x 10^4

Where:

FSF = fuel sulfur content (g/kW-hr)

BSFC = brake specific fuel consumption (lb/hr)

FSC = fuel sulfur content (ppm)

10^4 = conversion from ppm to % (unitless)

[Equation 4] ER = EF x EP x LF x hours/month x 0.0022046 x 1 tons/2000 lbs

Where:

ER = monthly emission rates (tons/month)

EF = emissions factor (g/kW-hr)

EP = engine power (kW)

LF = engine load factor (i.e., cruise, slow cruise, maneuvering)

0.0022046 = conversion factor from grams to pounds

The recommended number of tugboats and the size of the tugboat engines used for this size of a dredging project were used in the emissions calculations based on a conversation with a local tugboat company.[2] It was recommended that a single screw (2,150 horsepower) and a twin screw (3,000 horsepower) tugboat would be used to tow barges to and from the disposal sites for Alternative 1 and second twin screw tugboat was added for Alternative 2 due to increase amount material that would be disposed.

Monthly emissions (tons/month) were calculated based on the number of tugboats, survey boats and pushboats, their rated horsepower, average power load factor, and hours of operation per day. The emissions were summed for each month to calculate the annual emissions. The annual emissions are based on a maximum of 239 days per year of dredging operations. This number of days per year takes into account downtime associated with inclement weather and maintenance of equipment.

CDM developed a marine vessel MS Excel emissions calculations spreadsheets which is included in the CD-ROM disk provided in **Attachment B**.

[2] Kristin Lemaster, CDM telephone conversation with Dave Clarke, Boston Towing & Transportation, Company, November 11, 2005.

O.3.1.2 Nonroad Equipment

The nonroad equipment would consist of heavy equipment, such as clamshells, backhoe excavators, loaders, cranes, generators, pumps, etc. The nonroad equipment emissions were calculated using information from an EPA computer model NONROAD2.5. CDM developed a nonroad emissions calculation MS Excel Workbook to estimate non-road equipment emissions. The final emissions factors for each piece of equipment were estimated based on the equation presented below and unadjusted emission factors, transient adjustment and deterioration factors provided in the U.S. EPA, *Exhaust and Crankcase Emission Factors for Nonroad Engine Modeling – Compression-Ignition, EPA420-P-04-009*, April 2004. Information in this document is directly incorporated into NONROAD2.5 model.

Equation 5 was used to calculate VOC, CO and NO_x exhaust emissions factors for each piece of equipment.

[Equation 5] $EF_{adj(VOC, CO, NOx)} = EF_{SS} \times TAF \times DF$

Where:

$EF_{adj(VOC, CO, NOx)}$ = final emission factor, after adjustments to account for transient operation and deterioration (grams/horsepower-hour (g/hp-hr))

EF_{SS} = zero-hour, steady-state emission factor (g/hp-hr)

TAF = transient adjustment factor (unitless)

DF = deterioration factor (unitless)

The zero-hour, steady-state emission factors (EF_{SS}) are mainly a function of equipment model year and horsepower category, which defines the technology type and emissions standard. EPA established a tiered approach for setting emissions control standards for nonroad equipment starting with model year 1988 (Tier 0 emissions standards). Subsequently, EPA has established more stringent emissions standards as follows:

- Tier 1 emissions standards starting with model year 1996;
- Tier 2 emissions standards starting with model year 2001;
- Tier 3 emissions standards starting with model year 2006, and
- Tier 4 emissions standards starting with model year 2008.

NONROAD2.5 handles the effects of deterioration in the emissions calculations by multiplying a zero hour emission factor for each category of engine by a deterioration factor (DF). DF varies as a function of age of the equipment. The ACE provided a range of 8 to 18 years for the age of the equipment. A median age of 13 years was

used to calculate the deterioration factors for each pollutant for the uncontrolled emissions calculations. For the emissions reduction options, which are based on new equipment, the age of the equipment was set to zero for the first year of construction. The deterioration factors were increased for each subsequent year of construction for both old and new equipment.

The use of an equipment age of 13 years was also used to determine the EF_{SS} for each piece of equipment. Therefore, Tier 0 and Tier 1 EF_{SS} were used to calculate equipment emissions. For the emissions reduction options, which assumes the use of new, low emissions equipment, the appropriate Tier 3 and 4 emissions factors were used.

Since PM emissions are dependent on the sulfur content of the fuel, the equation used for PM is slightly modified from Equation 6, as follows:

[Equation 6] $EF_{adj\ (PM)} = EF_{SS} \times TAF \times DF - S_{PMadj}$

Where:

S_{PMadj} = adjustment to PM emission factor to account for variations in fuel sulfur content (g/hp-hr).

PM and SO_2 are the only diesel pollutants that are dependent on the fuel sulfur content. SO_2 emissions were estimated using Equation 7.

[Equation 7] $SO_2 = (BSFC * 453.6 * (1-soxcnv) - HC * 0.01 * soxdsl * 2$

Where:

SO_2 is in g/hp-hr

BSFC = in-use adjusted fuel consumption in lb/hp-hr

453.6 = conversion factor from pounds to grams

soxcnv = fraction of fuel sulfur converted to direct PM

HC = in-use adjusted hydrocarbon emissions in g/hp-hr

0.01 = conversion factor from weight percent to weight fraction

soxdsl = episodic weight percent of sulfur in nonroad diesel fuel

2 = grams of SO_2 formed from a gram of sulfur

It was assumed that ultra-low sulfur diesel (ULSD) would be used in all nonroad equipment. EPA would require the use of ULSD by 2007 and beyond (40 CFR 89). A sulfur content of 15 ppm was used in calculating SO_2 and PM emissions.

Similar to the marine vessels emissions calculations, monthly emissions (tons/month) were calculated for the dredging operations based on the number of pieces of equipment, rated horsepower, average power load factor, and hours of operation per day. The emissions were summed for each month to calculate the annual emissions.

The non-road emissions spreadsheets are included in the CD-ROM disk provided in **Attachment B**.

O.3.1.3 Onroad Vehicles

The on-road equipment would be made up of employee vehicles and any delivery trucks. The on-road vehicle emissions were calculated using the EPA model MOBILE6.2. It is an emission factor model that calculates emissions, in grams per mile, for different vehicle types under various operating conditions. Crew sizes and delivery truck sizes were provided by the ACE. Based on information provided by ACE, an average commute of 25 miles each way (1 round trip of 50 miles) at a default average speed of 27.6 miles per hour for arterial roadways in MOBILE6.2 was assumed for each vehicle[3]. The number of miles per trip was then multiplied by the total number of days per year to determine the total number of miles traveled. CDM obtained MOBILE6.2 input files representative of 2011 and beyond for eastern Massachusetts from MassDEP that would be representative of vehicles to be used on the project[4]. The results for the different emission quantities from the MOBILE6.2 model runs were multiplied by the number of vehicle miles traveled during each calendar year. Equation 8 was used to calculate employee vehicle and delivery trucks emissions.

[Equation 8] $ER = EF_{(MOBILE6.2)} \times VMT/yr / 907185$

Where:

ER = Vehicle emissions in tons/yr

$EF_{(MOBILE6.2)}$ = Emission Factor in grams/mile (g/mi)

VMT = Vehicle miles traveled

907185 = Conversion factor from grams to tons

CDM developed a MS Excel spreadsheet to calculate the on-road annual emissions, which is presented in **Attachment A**. The MOBILE6.2 model input and output files are also included on CD-ROM disk provided in **Attachment B**.

O.3.1.4 Total Direct Emissions

Monthly emissions (tons/month) were calculated for each phase of the dredging operation based on the number of pieces of equipment, rated horsepower, average

[3] M. Wallace, CDM, Conference Call meeting notes with the ACE on September 28, 2005.
[4] Email to Marc Wallace, CDM from Craig Woleader, MassDEP, December 5, 2005.

power load factor, and hours of operation per day. The emissions were summed for each month to calculate the annual emissions. The equation used to calculate marine and nonroad sources annual emissions is provided below:

[Equation 9] ER = Hp x PL x EF x hours/day x days/month x 0.0022046 x 1 ton/2000 lbs

Where:

ER = Monthly emission rate (tons/month)

Hp = Engine rated horsepower-hour

PL = Engine power load factor

EF = Emission factor in grams/horsepower (g/hp-hr)

0.0022046 = conversion factor from grams to pounds

Annual marine and non-road emissions were estimated by summing the monthly emissions for each construction year, and the annual emissions calculated for all three emissions phases were summed to obtain the total direct emissions for each dredging alternative.

O.3.2 Indirect Emissions

Under both project alternatives the main channel would be deepened to a depth greater than the currently authorized depth of 40 feet. Deeper channel depth would put Boston Harbor more in line with channel depths at other U.S. east coast and foreign container ports, which are mostly 48–50 feet deep. A deeper channel would allow larger vessels in an economically efficient manner; thereby, increasing the volume of twenty-foot equivalent units (TEU) loaded and unloaded at Boston Harbor while maintaining existing sailing schedules and port rotations[5]. For the purposes of evaluating the potential air quality impacts or benefits of the Project (Post-Construction) shipping and trucking operations, a 48-foot MLLW was selected based on guidance provided by ACE. This depth was selected because it represented the median depth between the two project alternative depths.

The No-Project and Project (Post-Construction) container, cargo and petroleum vessel operations including scheduling, volume of ship calls, fleet mix and associated trucking operations were obtained from the David Miller Associates, *Boston Harbor Channel Deepening Containerized Cargo Benefits Analysis,* August 2007. The shipping and trucking operations data were used to estimate indirect emissions for both scenarios. It was assumed that routine shipping operations would be the same under Alternatives 1 and 2 during dredging activities.

[5] David Miller Associates, Draft Boston Harbor Channel Deepening Project, Containerized Cargo Economic Benefits Analysis, August, 2007.

Annual emissions (tons/year) were calculated based on changes in sizes of ships (i.e., smaller to larger vessels), changes in ship mode operations (i.e., anchoring, cruising and hoteling) and the number of ship calls per year. The net reductions in trucking emissions for the Project were also calculated using MOBILE6.2 emissions model. The emissions were summed for each vessel type to calculate the annual emissions. The net change in trucking emissions were added from the total Project emissions.

A similar approach was also conducted to estimate the air quality benefit for the New England region because of the reduced truck miles due to cargo trucked from Boston Harbor instead of from the PONYJ. The results of this analysis would be discussed as part of the comparison between No-Project and the Project (Post Construction) scenarios.

O.3.2.1 Ship Emissions

No-Project and Post -Construction shipping emissions were calculated based on the effects on container, cargo and petroleum vessel operations including scheduling, volume of ship calls, fleet mix and associated trucking operations. No-Project and Project (Post-Construction) shipping emissions were also estimated using emissions factors presented in U.S. EPA, *Final Regulatory Support Document: Control of Emissions from New Marine Compression-Ignition Engines at or Above 30 Liters per Cylinder, EPA420-R-03-004,* January 2003. However, for new container ships, it was assumed they would comply with the International MARPOL Annex VI NO_x emissions standard. The international standard applies to engines installed on vessels constructed on or after January 1, 2000. EPA is adopting this standard under its Tier 1 standards for Category 3 marine diesel engines (engine sizes 3,000 to 100,000 horsepower). Engines meeting the Tier 1 standards have emission levels about 20 percent lower than uncontrolled levels (U.S. EPA, *Emission Standards Adopted for New Marine Diesel Engines, EPA420-F-03-001, January 2003*). Therefore, for newer container ships a NO_x emission factor of 23.60 g/kW-hr was used to calculate the Project (Post-Construction) emissions.

The ACE is projecting a shift in container ships with the Project from approximately 4,100 TEU class ships to 5,600 TEU class ships for 104 ship calls per year, and 5,100 TEU class ships to 5,600 TEU class ships for 52 ship calls per year. The larger class ships are also expected to be newer models (2002) than the current fleets (average model year of 1994). The No-Project bulk cargo shipments assume 24 bulk shipments/year on 40,000 dead weight tonnage (DWT) bulk carriers. The ACE estimates that the Project bulk cargo shipments would decrease to 16 bulk shipments/year, but the size of the ships would increase to 60,000 DWT bulk carriers. Finally, the net change in petroleum shipments between the No-Project and Project is projected to be a decrease of 19 ship calls per year. However, the Project would generate a net increase of 34 ship calls/year for larger petroleum tankers 35,000 DWT or greater. **Table O-4** presents a summary of the No-Project and Post-Construction shipping operations.

Table O-4 No-Project and Post-Construction Shipping Operations	
Ship Type	***Number of Ship Calls/Year***
No-Project	
Containership - 4,000 TEUs (Foreign)	104
Containership - 5,100 TEUs (Foreign)	52
Bulk Carrier - 40,000 DWT (Foreign)	24
Bulk Carrier - 25,000 DWT (Foreign)	12
Petroleum Ship - <20,000 DWT	305
Petroleum Ship - 20,000 DWT	14
Petroleum Ship - 25,000 DWT	49
Post-Construction	
Containership - 5,600 TEUs (Foreign)	156
Bulk Carrier - 60,000 DWT (Foreign)	16
Bulk Carrier - 40,000 DWT (Foreign)	8
Petroleum Ship - <20,000 DWT	291
Petroleum Ship - 20,000 DWT	14
Petroleum Ship - 25,000 DWT	43
Petroleum Ship - 35,000 DWT	54
Petroleum Ship - >35,000 DWT	82

Annual emissions were calculated based on the number of ship calls per year, engine load factors and anchoring, cruising and hoteling hours of operation per day. The shipping modes of operation (i.e., anchoring, cruising and hoteling) were based on information provided by ACE[6]. The deepening of the harbor would eliminate anchoring activities for petroleum ships and improve ship movement activities in the harbor. The power load factors were 0.1 for anchoring and hoteling modes and 0.25 for cruising mode within the reduced speed zone (RSZ) per guidance in U.S. EPA, *Final Regulatory Support Document: Control of Emissions from New Marine Compression-Ignition Engines at or Above 30 Liters per Cylinder, EPA420-R-03-004.*

O.3.2.2 Cargo Truck Emissions

The cargo truck emissions were calculated using the EPA model MOBILE6.2. It is an emission factor model that calculates emissions, in grams per mile. The same MOBILE6.2 input files used to calculate the on-road vehicles direct emissions one year

[6] Telephone conversation between Karen Umbrell, ACE and Marc Wallace, CDM based on information provided by Boston Pilots, January 24, 2007.

after dredging is expected to be complete were used. The pollutant emission factors from the MOBILE6.2 model runs were multiplied by the number of truck miles traveled. The net change in projected truck emissions were added to the net change in shipping emissions between the No-Project and Project (Post-Construction) scenarios. The MOBILE6.2 model input and output files are also included on CD-ROM disk provided in Attachment B.

O.4 Air Emissions Modeling Results

Because the Project requires federal funding and approvals, the Act's general conformity rule (40 CFR 93 Subpart B) requires that ACE determine whether or not the total of the direct plus indirect air emissions associated with the Project would "conform" with the Massachusetts State Implementation Plan (SIP) to attain the NAAQS. The Boston area is a nonattainment area for the eight-hour O_3 NAAQS, and a maintenance area for the one- and eight-hour CO NAAQS. So, the general conformity analysis was conducted for the pollutants that cause O_3 formation (VOC and NO_X) and for CO. A formal general conformity determination is **not** required for projects that are "de minimis": those that have net emissions increases less than the thresholds of 100 tons of NO_X/year, 50 tons of VOC/year, or 100 tons of CO/year. If, however, the maximum potential net emissions increases from the Project could exceed these thresholds, then the Project must demonstrate conformity with the SIP, or else the federal approvals and funding must be denied. Making a positive finding of general conformity can be difficult, because the regulations only allow prescribed approaches:

- showing that the proposed project and its associated net emissions increases are specifically identified in the SIP;
- showing that the net emissions increases from the proposed project, along with all other emissions in the non-attainment or maintenance area, would not exceed the emissions budgets in the SIP;
- showing that the net emissions increases from the proposed project are fully offset within the non-attainment or maintenance area;
- fully mitigating the net emissions increases from the proposed project to zero; or
- for CO, showing through either local or areawide dispersion modeling that the NAAQS are not threatened.

The objective for this analysis was to avoid having to do a formal general conformity determination, and to work with ACE and Massport to manage the Project's emissions rates to be below the de minimis values. The critical pollutant was NO_X. The uncontrolled emissions increase associated with the sum of direct and indirect emissions from the Boston Harbor Deep Draft Navigation Improvement Project would likely exceed the 100-ton/year de minimis threshold.

The general conformity applicability analysis was conducted by calculating NO_X, VOC and CO emission rates for both project alternatives and for changes in shipping and trucking operations after completion of the Project, based on likely equipment and operations data provided by ACE. If the resulting uncontrolled net emission increases exceeded any of the de minimis values, then emissions reduction measures were evaluated. These measures included modifying dredging methods, increasing the duration of dredging activities, and/or requiring the use of low emitting equipment. Such measures would also have to be adopted by ACE as part of the Project's design.

O.4.1 Direct Emissions

O.4.1.1 Alternative 1

The project dredging emissions represent the estimated total direct emissions that would occur with the proposed deepening of Boston Harbor to the 45-ft MLLW depth. The emissions for the marine, nonroad and on-road equipment were determined as discussed in Section O.3.1. The calculated direct emissions were then totaled on an annual basis for all equipment involved for Alternative 1. The direct emissions represent the net change in total emissions, since the indirect emissions would not occur during the three-year dredging schedule. Therefore, the total direct emissions were compared to the General Conformity de minimis thresholds.

The estimated emissions for Alternative 1 are summarized in **Table O-5**. This table presents a summary of each pollutant's emissions categorized by marine vessels, nonroad equipment and on-road employee and truck deliveries emissions.

The first set of emissions calculations identified as "uncontrolled" emissions represents preliminary estimates without making adjustments to the dredging operations, schedule or equipment. Table O-5 shows that the total emissions for the uncontrolled conditions for NO_x and CO exceed the General Conformity de minimis thresholds for all three years. The peak year emissions (Year 2) for NO_x and CO are 256 and 151 tons, respectively, which far exceed the 100 ton/yr de minimis thresholds for both pollutants. The major contributors to these exceedances are the marine vessels and in particular the tugboat operations and the nonroad equipment, specifically the clam shell and backhoe operations. The on-road vehicle emissions are a minor contributor to the total emissions (i.e., less than 5 percent of the total emissions). The tugboat NO_x emissions represent 92 percent of the total marine vessel NO_x emissions and 23 percent of the total direct NO_x emissions. The clamshell and backhoe NO_x emissions represent 86 percent of the total non-road NO_x emissions and 64 percent of the total direct NO_x emissions, respectively. Similarly, the tugboat CO emissions represent 95 percent of the total marine vessel CO emissions, but only represent approximately 5 percent of the total direct CO emissions. The clamshell and backhoe CO emissions represent 81 percent and 88 percent of the total non-road CO emissions and total direct CO emissions, respectively.

TABLE O-5
45-Foot MLLW Alternative - Summary of Dredging Operations Emissions

Year	Pollutant	Emissions (tons/yr)												General Conformity Thresholds (tons/yr)
		Uncontrolled Conditions				Emission Reduction Option # 1				Emission Reduction Option # 2				
		Marine	Non-Road	On-Road	Total	Marine	Non-Road	On-Road	Total	Marine	Non-Road	On-Road	Total	
1	$PM_{2.5}$	3	13	0.02	16	3	2	0.02	5	2	1	0.02	3	--
	PM_{10}	3	13	0.04	16	3	2	0.04	5	2	1	0.04	3	--
	SO_2	187	0.1	0.01	187	187	0.1	0.01	187	126	0.1	0.01	126	--
	NO_x	61	142	0.8	**203**	50	49	0.8	99	34	30	0.8	65	100
	CO	7	101	8.8	**117**	27	20	8.8	56	18	13	8.8	40	100
	VOC	1	16	0.4	17	1	5	0.4	6	0.5	3	0.4	4	50
2	$PM_{2.5}$	3	17	0.02	20	3	2	0.02	5	2	2	0.02	4	--
	PM_{10}	3	18	0.03	21	3	3	0.03	6	2	2	0.03	4	--
	SO_2	200	0.2	0.01	200	200	0.2	0.01	200	154	0.1	0.01	154	--
	NO_x	65	191	0.7	**256**	54	65	0.71	**119**	41	48	0.7	90	100
	CO	8	135	8.4	**151**	29	27	8.4	64	22	20	8.4	50	100
	VOC	1	21	0.3	22	1	7	0.34	8	1	5	0.3	6	50
3	$PM_{2.5}$	3	17	0.02	19	3	2	0.02	5	2	2	0.02	4	--
	PM_{10}	3	17	0.03	20	3	2	0.03	5	2	2	0.03	4	--
	SO_2	174	0.1	0.01	174	176	0.1	0.01	176	154	0.1	0.01	154	--
	NO_x	56	182	0.61	**239**	47	55	0.6	**103**	41	49	0.6	91	100
	CO	7	128	8.1	**143**	25	24	8.1	57	22	20	8.1	50	100
	VOC	1	20	0.3	21	1	6	0.3	7	1	5	0.3	6	50
4	$PM_{2.5}$	--	--	--	--	--	--	--	--	2	2	0.02	4	--
	PM_{10}	--	--	--	--	--	--	--	--	2	2	0.03	4	--
	SO_2	--	--	--	--	--	--	--	--	127	0.1	0.01	128	--
	NO_x	--	--	--	--	--	--	--	--	34	41	0.5	75	100
	CO	--	--	--	--	--	--	--	--	18	18	7.9	44	100
	VOC	--	--	--	--	--	--	--	--	0.5	4	0.3	5	50

Notes: 1. Values in bold print and box represent exceedances of the General Conformity de minimis thresholds.
2. Emission Reduction Option #1 is based on replacing older equipment with newer ones meeting EPA emissions standard, Emission Reduction Option #2 is based on lengthening the construction schedule from 36 months to 42 months and requiring the contractor to use new equipment meeting applicable EPA non-road emissions standards.

Since the uncontrolled direct emissions substantially exceeded the de minimis thresholds, two options were evaluated to reduce the net emissions increases. The first option would require replacing older, higher emitting equipment with newer and cleaner burning equipment that would be available by 2011 and beyond. The second option would require using new equipment and extending the proposed three-year dredging schedule. This approach would allow for spreading the peak year emissions over the entire dredging schedule.Emission Reduction Option 1 requires replacing all nonroad equipment with newer equipment that would meet EPA Tier 3 and 4 emissions standards that would be required for equipment model years 2011 and beyond. The clamshell and backhoe engines would need to meet Tier 4 emissions standards and support equipment would need to comply with Tier 3 and Tier 4 emissions standards, depending on the equipment category and engine size. In addition, the tugboats would also have to be equipped with engines that meet EPA's Tier 2 marine engine emissions standards (U.S. EPA, *Overview of EPA's Emission Standards for Marine Engines, EPA420-F-04-031,* August 2004). **Table O-6** presents the Tier 2 emissions standards for Category 2 marine diesel engines.

Table O-6
Tier 2 Standards for Category 2 Marine Diesel Engines

Displacement (liter/cylinder)	*Power (kW)*	*HC+ NOx (g/kW-hr)*	*PM (g/kW-hr)*	*CO (g/kW-hr)*
5.0</= disp. <15	--	7.8	0.27	5.0
15</= disp. <20	<3300	8.7	0.50	5.0
15</= disp. <20	>/= 3300	9.8	0.50	5.0
20</= disp. <25	--	9.8	0.50	5.0
25</= disp. <30	--	11.0	0.50	5.0

Source: U.S. EPA, Overview of EPA's Emission Standards for Marine Engines, EPA420-F-04-031, August 2004.

Table O-5 shows that the NO_x and VOC emissions for Emissions Reduction Option 1 were reduced significantly for each year. **Table O-7** shows that the replacement of older equipment with newer equipment would reduce total NO_x, CO and VOC emissions by 53, 57 and 63 percent, respectively. Both the marine vessel and non-road NO_x and CO emissions totals are below the 100 ton/yr threshold for all three years of dredging operations. However, the peak year total emissions (Year 2) for NO_x would be 119 tons, which would still exceed the 100 ton/yr de minimis threshold. The use of new equipment would reduce peak year CO emissions below the 100 ton/yr de minimis threshold; even though, tugboats equipped with Tier 2 engines were projected to increase CO by 279 percent (from 8 tons to 22 tons). This is because engine modifications to reduce NO_x emissions would cause CO emissions to increase.

Table O-7
Summary of Percent Emission Reductions

Pollutant	Emission Reduction Option # 1			Emission Reduction Option # 2		
	Marine	Non-Road	Total	Marine	Non-Road	Total
NO_x	-18%	-66%	-53%	-36%	-75%	-65%
CO	279%	-80%	-57%	186%	-85%	-67%
VOC	0%	-66%	-63%	-23%	-75%	-72%

Note:
1. CO emissions increased from tugboat operations

Emission Reduction Option 2 would include both the replacement of older equipment with newer equipment and increasing the dredging scheduling by 6 months (from 36 months to 42 months). The extension of the dredging schedule over four calendar years is based on 9 months of operation per year. Table O-5 shows that the peak year (Year 3) total NO_x and VOC emissions for Emissions Reduction Option 2 would be reduced to 91 tons and 56 tons, respectively. Table O-7 shows that the replacement of older equipment with newer equipment and stretching the dredging schedule to four years would reduce total NO_x and CO emissions by 65 and 67 percent, respectively. Emission Reduction Option 2 demonstrates dredging operations would avoid (i.e., be exempt from) the General Conformity rules.

Figures O-1 through O-3 presents graphs of the Uncontrolled and Emissions Reductions Options 1 and 2 NO_x, CO and VOC emissions.

O.4.1.2 Alternative 2

The project dredging emissions represent the estimated total direct emissions that would occur with the proposed deepening of Boston Harbor to the 50-ft MLLW depth. The estimated emissions for Alternative 2 are summarized in **Table O-8**. This table presents a summary of each pollutant's emissions categorized by marine vessels, nonroad equipment and on-road employee and truck deliveries emissions.

The first set of emissions calculations identified as "uncontrolled" emissions represents preliminary estimates without making adjustments to the dredging operations, schedule or equipment. Table O-8 shows that the total emissions for the uncontrolled conditions for NO_x and CO exceed the General Conformity de minimis thresholds for all four years. The peak year emissions (Year 2) for NO_x and VOCs would be 557 tons and 53 tons, respectively, which would far exceed the 100 tons/yr de minimis thresholds for NO_x and the 50 tons/yr de minimis threshold for VOCs. In addition, the peak year emissions (Year 3) for CO would be 395 tons, which also far exceeds the 100 tons/yr de minimis thresholds for CO. The major contributors to

Figure O-1
Alternative 1 (45-Ft MLLW)
Uncontrolled Conditions
Construction Total Emissions

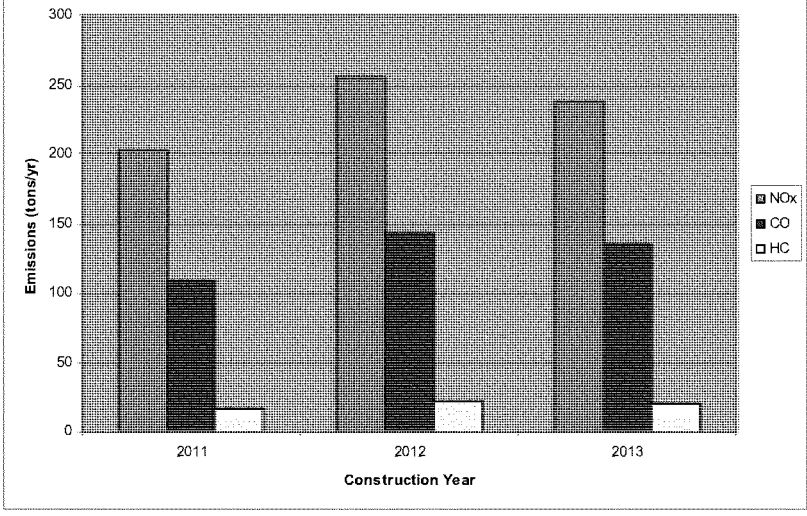
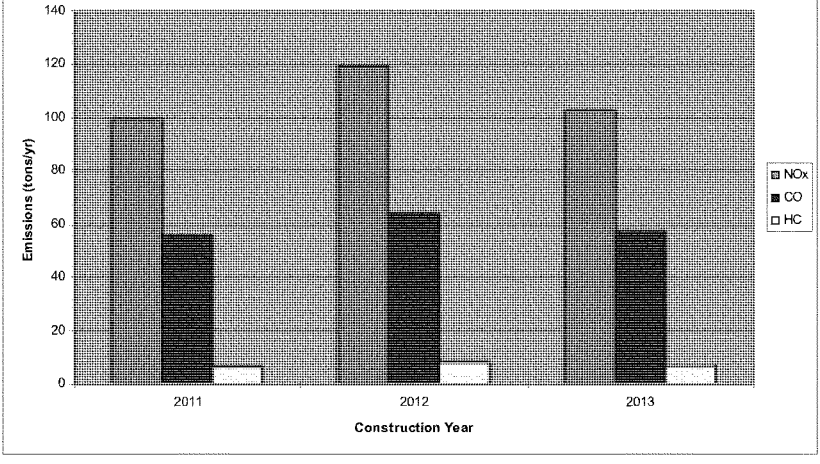
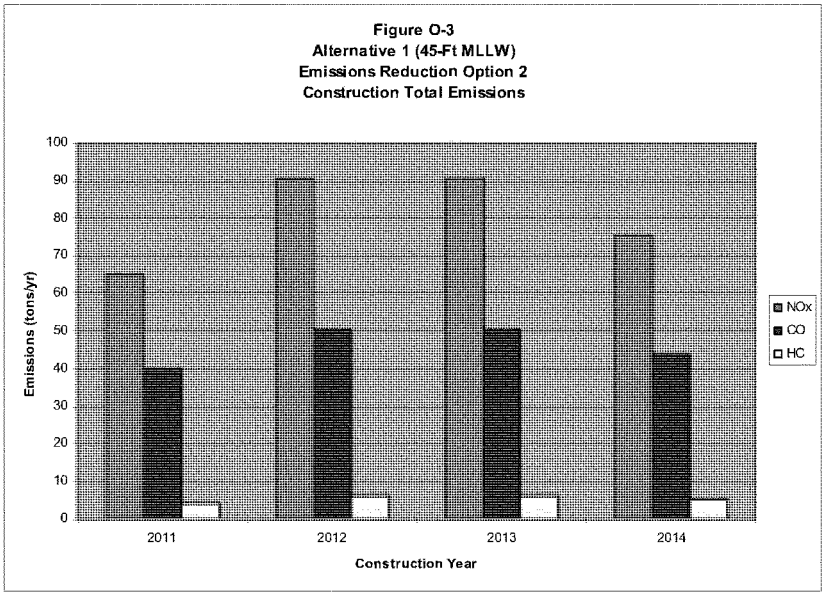


Figure O-2
Alternative 1 (45-Ft MLLW)
Emissions Reduction Option 1
Construction Total Emissions





these exceedances are the marine vessels and in particular the tugboat operations and the nonroad equipment, specifically the clamshells and backhoe operations. The on-road vehicle emissions are a minor contributor to the total emissions (i.e., less than 5 percent of the total emissions). The tugboat NO_x emissions represent 96 percent of the total marine vessel NO_x emissions and 46 percent of the total direct NO_x emissions. The clamshells and backhoe NO_x emissions represent 83 percent of the total non-road NO_x emissions and 60 percent of the total direct NO_x emissions, respectively.

Similarly the tugboat CO emissions represent 96 percent of the total marine vessel CO emissions, but only represent approximately 5 percent of the total direct CO emissions. The clamshells and backhoe CO emissions represent 76 percent and 70 percent of the total non-road CO emissions and total direct CO emissions, respectively.

Since the uncontrolled direct emissions substantially exceeded the de minimis thresholds, the two options that were evaluated to reduce the net emissions increases under Alternative 1 were also used to reduce net emissions increases under Alternative 2. Emission Reduction Option 1 would require replacing all nonroad equipment with newer equipment that would meet EPA Tier 2, 3 and 4 emissions standards that would be required for equipment model years 2011 and beyond.

Table O-8
50-Foot MLLW Alternative
Summary of Dredging Operations Emissions

Emissions (tons/yr)														
Year	*Pollutant*	*Uncontrolled Conditions*				*Emission Reduction Option # 1*				*Emission Reduction Option # 2*				*General Conformity Thresholds (tons/yr)*
		Marine	*Non-Road*	*On-Road*	*Total*	*Marine*	*Non-Road*	*On-Road*	*Total*	*Marine*	*Non-Road*	*On-Road*	*Total*	
1	$PM_{2.5}$	5	14	0.03	20	5	2	0.03	8	2	1	0.03	3	--
	PM_{10}	5	15	0.04	20	5	3	0.04	8	2	1	0.04	4	--
	SO_2	353	0.1	0.01	353	353	0.2	0.01	353	143	0.1	0.01	143	--
	NO_x	114	141	1.0	**257**	94	68	1.0	**163**	38	38	1.0	77	100
	CO	14	108	10	**131**	52	30	10	93	20	18	10	49	100
	VOC	1	16	0.4	18	1	8	0.4	9	1	4	0.4	5	50
2	$PM_{2.5}$	6	45	0.02	51	6	5	0.02	11	2	2	0.02	4	--
	PM_{10}	6	46	0.04	52	6	5	0.04	11	2	2	0.04	4	--
	SO_2	395	0.4	0.01	396	395	0.3	0.01	396	154	0.1	0.01	154	--
	NO_x	128	428	0.8	**557**	105	123	0.8	**230**	41	53	0.8	96	100
	CO	15	325	9.8	**350**	58	49	9.8	**117**	22	24	9.8	56	100
	VOC	1	51	0.4	**53**	1	14	0.4	16	1	6	0.4	7	50
3	$PM_{2.5}$	6	46	0.02	52	6	5	0.02	11	2	2	0.02	5	--
	PM_{10}	6	47	0.04	53	6	5	0.04	11	2	2	0.04	5	--
	SO_2	395	0.3	0.01	396	395	0.3	0.01	396	154	0.1	0.01	154	--
	NO_x	128	418	0.7	**547**	105	122	0.7	**228**	41	53	0.7	96	100
	CO	15	327	9.4	**352**	58	48	9.4	**116**	22	25	9.4	56	100
	VOC	1	51	0.4	**53**	1	14	0.4	16	1	6	0.4	7	50
4	$PM_{2.5}$	5	32	0.02	38	5	5	0.02	10	2	2	0.02	5	--
	PM_{10}	5	33	0.04	39	5	5	0.04	11	2	2	0.04	4	--
	SO_2	367	0.3	0.01	367	367	0.3	0.01	367	154	0.1	0.01	154	--
	NO_x	119	342	0.6	**461**	98	108	0.6	**206**	41	53	0.6	95	100
	CO	14	246	9.2	**269**	54	41	9.2	**105**	22	24	9.2	55	100
	VOC	1	36	0.3	37	1	12	0.3	14	1	6	0.3	7	50

Table O-8 (Continued)
50-Foot MLLW Alternative - Summary of Dredging Operations Emissions

Year	Pollutant	Emissions (tons/yr)												General Conformity Thresholds (tons/yr)
		Uncontrolled Conditions				Emission Reduction Option # 1				Emission Reduction Option # 2				
		Marine	Non-Road	On-Road	Total	Marine	Non-Road	On-Road	Total	Marine	Non-Road	On-Road	Total	
5	$PM_{2.5}$	--	--	--	--	--	--	--	--	2	2	0.02	5	--
	PM_{10}	--	--	--	--	--	--	--	--	2	2	0.03	4	--
	SO_2	--	--	--	--	--	--	--	--	154	0.1	0.01	154	--
	NO_x	--	--	--	--	--	--	--	--	41	53	0.5	95	100
	CO	--	--	--	--	--	--	--	--	22	25	8.9	55	100
	VOC	--	--	--	--	--	--	--	--	1	6	0.3	7	50
6	$PM_{2.5}$	--	--	--	--	--	--	--	--	2	2	0.02	5	--
	PM_{10}	--	--	--	--	--	--	--	--	2	2	0.03	4	--
	SO_2	--	--	--	--	--	--	--	--	154	0.1	0.01	154	--
	NO_x	--	--	--	--	--	--	--	--	41	53	0.5	95	100
	CO	--	--	--	--	--	--	--	--	22	24	8.8	55	100
	VOC	--	--	--	--	--	--	--	--	1	6	0.3	7	50
7	$PM_{2.5}$	--	--	--	--	--	--	--	--	2	2	0.02	5	--
	PM_{10}	--	--	--	--	--	--	--	--	2	2	0.03	4	--
	SO_2	--	--	--	--	--	--	--	--	154	0.1	0.01	154	--
	NO_x	--	--	--	--	--	--	--	--	41	53	0.4	95	100
	CO	--	--	--	--	--	--	--	--	22	25	8.6	55	100
	VOC	--	--	--	--	--	--	--	--	1	6	0.3	7	50
8	$PM_{2.5}$	--	--	--	--	--	--	--	--	2	2	0.02	4	--
	PM_{10}	--	--	--	--	--	--	--	--	2	2	0.03	4	--
	SO_2	--	--	--	--	--	--	--	--	140	0.1	0.01	140	--
	NO_x	--	--	--	--	--	--	--	--	38	44	0.3	82	100
	CO	--	--	--	--	--	--	--	--	20	20	8.5	49	100
	VOC	--	--	--	--	--	--	--	--	0.5	5	0.3	6	50

Notes: 1. Values in bold print and box represent exceedances of the General Conformity de minimis thresholds.

2. Emission Reduction Option #1is based on replacing older equipment with newer ones meeting EPA emissions standard, Emission Reduction Option #2 is based on lengthening the construction schedule from 48 months to 73 months, the same dredging equipment and operations as Alternative 1 (45-ft MLLW) and requiring the contractor to use new equipment meeting applicable EPA non-road emissions standards.

Table O-8 shows that the NO_x and VOC emissions for Emissions Reduction Option 1 were reduced significantly for each year. **Table O-9** shows that the replacement of older equipment with newer equipment would reduce total NO_x, CO and VOCs emissions by 59, 67 and 70 percent, respectively. Both the marine vessel and non-road NO_x and CO emissions totals are below the 100 ton/yr threshold for all three years of dredging operations. However, the peak year total emissions (Year 2) for NO_x would be 230 tons, which would still exceed the 100 ton/yr de minimis threshold. The use of new equipment would reduce peak year CO emissions below the 100 ton/yr de minimis threshold; even though, tugboats equipped with Tier 2 engines were projected to increase CO by 282 percent (from 15 tons to 58 tons). This is because engine modifications to reduce NO_x emissions would cause CO emissions to increase.

Table O-9
Summary of Percent Emission Reductions

Pollutant	*Emission Reduction Option # 1*			*Emission Reduction Option # 2*		
	Marine	*Non-Road*	*Total*	*Marine*	*Non-Road*	*Total*
NO_x	-18%	-71%	-59%	-68%	-88%	-83%
CO	282%	-85%	-67%	45%	-93%	-84%
VOC	0%	-73%	-70%	-61%	-89%	-87%

Note:
1. CO emissions increased from tugboat operations

Since the direct net emissions for NO_x would be significantly higher than the 100 ton/yr de miminis threshold that both the replacement of older equipment with newer equipment and extending the dredging schedule would not eliminate the peak year emissions exceedances. Therefore, the ACE revised the dredging operations to be the same as Alternative 1(i.e., two dredging plants rather than three) and extended the dredging schedule from by 48 months to 73 months over 8 calendar years. The extension of the dredging schedule an additional four calendar years is based on 10 months of operation in the first year and 9 months of operation for years 2 through 8. Table O-8 shows that the peak years (Years 2 and 3) total NO_x and CO emissions for Emissions Reduction Option 2 would be reduced to 96 tons and 56 tons, respectively. Table O-9 shows that the replacement of older equipment with newer equipment and stretching the dredging schedule to four years would reduce total NO_x and CO emissions by 83 and 84 percent, respectively. Emission Reduction Option 2 demonstrates dredging operations would avoid (i.e., be exempt from) the requirements of the General Conformity rule.

Figures O-4 through O-6 presents graphs of the Uncontrolled and Emissions Reductions Options 1 and 2 for the three pollutants.

Figure O-4
Alternative 2 (50-Ft MLLW)
Uncontrolled Construction Total Emissions

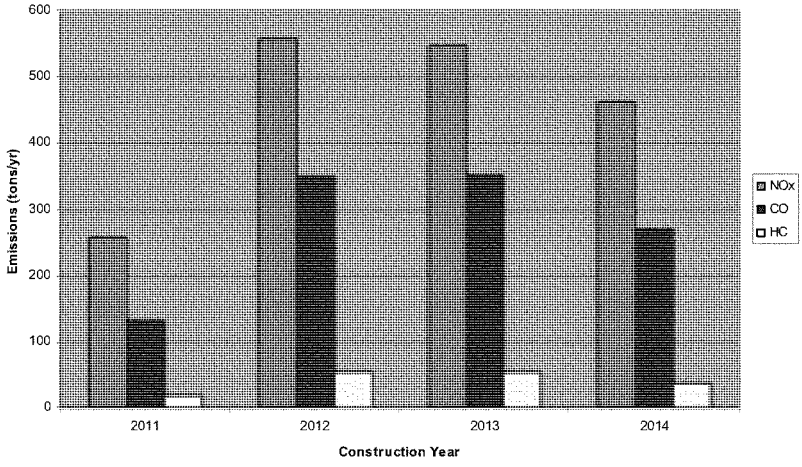


Figure O-5
Alternative 2 (50-Ft MLLW)
Emissions Reduction Option 1
Construction Total Emissions

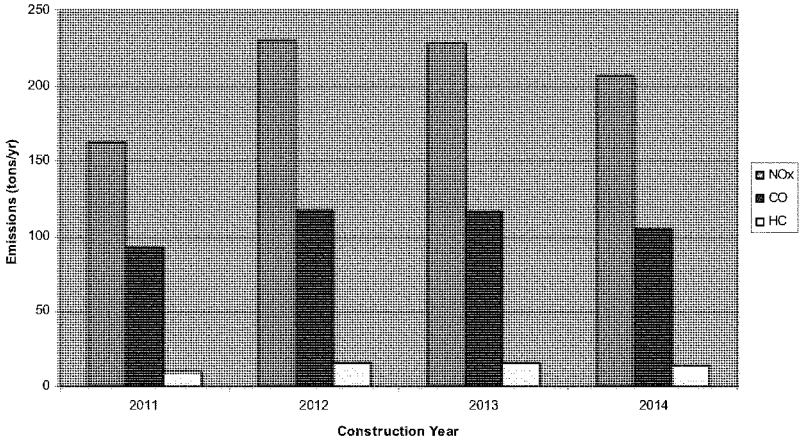
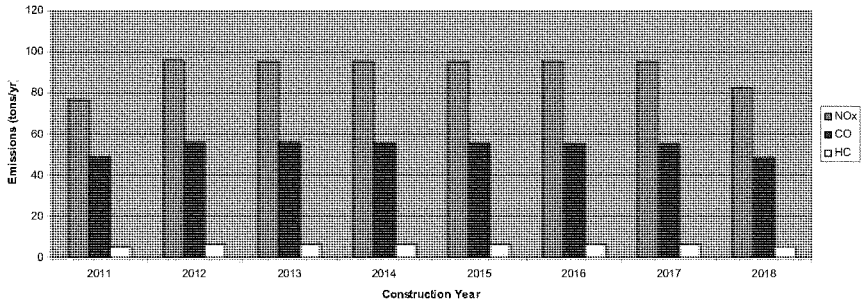


Figure O-6
Alternative 2 (50-Ft MLLW)
Emissions Reduction Option 2
Construction Total Emissions



O.4.2 Indirect Emissions

CDM calculated the Project indirect emissions based on the net effects on container, cargo and petroleum vessel operations including scheduling, volume of ship calls, fleet mix and associated cargo truck operations between No-Project and Project (Post-Construction) scenarios. **Table O-10** presents a summary of both the No-Project and Project indirect emissions and the net change in annual emissions.

The Project would reduce NO_x, CO and VOC emissions by 71, 28 and 17 tons, respectively. The reductions in pollutant emissions are primarily due to changes in fleet mix for all shipping operations (i.e., fewer, but larger ships), no anchoring activities for petroleum ships and less time for ships to move and in out of the harbor. However, the cargo trucking miles in Massachusetts would increase by 766,276 milesunder the Project (Post-Construction) shipping operations due to increased truck volumes departing from Conley Terminal[7,8]. An average travel speed of 27.6 miles per hour was assumed in the model. The estimated NO_x, CO and VOC emissions would increase by 1.91, 0.51 and 0.24 tons, respectively in the project area. These small increases in pollutant emissions would be more than offset by the emissions reductions estimated for the changes in shipping activities associated with the Project. Therefore, the Project indirect emissions would avoid (i.e., be exempt from) the requirements of the General Conformity rule.

[7] David Miller & Associates, Inc., Techical Memorandum to Karen Umbrell, July 13, 2006.
[8] Email from Karen Umbrell to Marc Wallace, CDM, Revised Truck Miles Saved Spreadsheet, October 13, 2007.

Table O-10
Shipping and Trucking Operations
Summary of Indirect Emissions

Pollutant	*No Project (tons)*	*Project, Post-Construction (tons)*	*Net Change (tons)*	*Net Change (%)*
$PM_{10}/PM_{2.5}$	96	91	-5	-5.2
SO_2	248	247	-0.6	-0.2
NO_x	634	563	-71	-11.2
CO	377	349	-28	-7.3
VOC	231	214	-17	-7.5

Notes:

1. Indirect emissions without project are associated with projected shipping operations in 2016 and beyond. It is assumed that the shipping operations would be constant during the dredging years.

2. Indirect emissions with project are associated with projected shipping operations one year after the dredging operations are completed. It is anticipated that there would be no overlap of indirect and direct emissions at the end of the project.

3. With project emissions includes emissions reductions associated with the projected reduction of truck traffic from the Port of New York/New Jersey.

Sources:

David Miller Associates, Boston Harbor Channel Deepening Containerized Cargo Benefits Analysis, August 2007.

O.4.3 General Conformity Applicability Results

The General Conformity regulations require that the total of direct and indirect emissions be evaluated for: (1) the year of maximum emissions; (2) the mandated attainment year (for non-attainment pollutants) or the year of farthest emissions projections in the SIP (for maintenance pollutants); and (3) any year with an emissions budget specified in the SIP. The annual emissions were compiled for each propriate year for the Project, and each year's net emissions were then compared to the de minimis values. The latest NO_x, CO and VOC emissions projections were obtained from MassDEP. The 10% Area Inventory Levels are based on projected SIP emissions inventories prepared by the MassDEP and approved by EPA. The latest NO_x and VOC emissions inventory data for 2007 represent the ozone attainment mandate year and the CO emissions inventory data for 2010 represents the year of farthest emissions projections in the SIP. Annual emissions were estimated based on daily summer projections for NO_x and VOC and daily winter projections for CO.

As stated above, it was assumed that dredging and construction activities define direct emissions and the effects on cargo vessel operations including scheduling, volume of ship calls, fleet mix and associated trucking operations define indirect

emissions. It is anticipated that changes in shipping operations for both project alternatives would occur after the dredging operations are complete. Therefore, there would be no overlapping of indirect emissions with the direct emissions from the dredging operations in any particular year for both project alternatives. **Table O-11** presents the results of the General Conformity Applicability Analysis.

This table shows that the maximum year emissions for Alternative 1 (2013) and Alternative 2 (2012) would not exceed the General Conformity de minimis thresholds and are also less than one percent of the MassDEP 10% Area Inventory Levels for NO_x and VOC, and CO in 2007 and 2010, respectively. Furthermore, the change in indirect emissions for NO_x, VOC and CO between the No-Project and Project scenarios would decrease, and thus, would also be less than the 10% Area Inventory Levels. Therefore, Alternative 1 and 2 emissions would avoid (i.e., be exempt from) the requirements of the General Conformity rule.

Table O-11
Summary of General Conformity Applicability Analysis

		Alternative 1 (45-Ft MLLW)			*Alternative 2 (50-Ft MLLW)*		
Indirect Emissions with No-Project	**Year**	**Pollutant**			**Pollutant**		
		NO_x	**CO**	**VOC**	**NO_x**	**CO**	**VOC**
	Year After Dredging Complete	634	377	231	634	377	231
Indirect Emissions with Project	**Year**	**Pollutant**			**Pollutant**		
		NO_x	**CO**	**VOC**	**NO_x**	**CO**	**VOC**
	Year After Dredging Complete	563	349	214	563	349	214
Direct Emissions	**Year**	**Pollutant**			**Pollutant**		
		NO_x	**CO**	**VOC**	**NO_x**	**CO**	**VOC**
	Year 1	65	40	4	77	49	5
	Year 2	90	50	6	**96**	**56**	**7**
	Year 3	**91**	**50**	**6**	96	56	7
	Year 4	75	44	5	95	55	7
	Years 5-7	--	--	--	95	55	7
	Year 8	--	--	--	82	49	6

Summary (tons, except where noted)		Pollutant			Pollutant		
		NO_x	CO	VOC	NO_x	CO	VOC
	Indirect Emissions Net Change	-71	-28	-17	-71	-28	-17
	Direct Emissions Net Change	91	50	6	96	56	7
	GC Threshold	100	100	50	100	100	50
	SIP Mandate Year	2007	2010	2007	2007	2010	2007
	10% Area Inventory Level	220,825	161,697	179,179	220,825	161,697	179,179
	Project % of Area Inventory Level	0.04%	0.03%	0.003%	0.04%	0.03%	0.004%

Notes:

1. Indirect emissions without project are associated with projected shipping operations in 2010 and beyond.

2 The net change in indirect emissions is based on comparing indirect emissions for the No-Project and Project scenarios.

3. Indirect emissions with project are associated with projected shipping operations one year after the dredging operations are completed. It is anticipated that there will be no overlap of indirect and direct emissions at the end of the project.

4. Values in bold print and box represent peak year direct emissions.

5. Direct emissions are based on stretching the construction schedule and requiring new equipment meeting EPA emissions standards.

6. GC Threshold represents the General Air Quality Conformity de minimis thresholds

7. The 10% Area Inventory Level represents projected emissions inventories prepared by the MassDEP and approved by EPA. The latest NOx and VOC emissions inventory data represents 2007 and CO emission inventory represents 2010. Annual emissions were estimated based on daily summer for NOx and VOC and daily winter projections for CO.

Sources:

U.S. Army Corps of Engineers, Boston Harbor, Massachusetts Navigation Improvement Study, Alternative Formulation Briefing Technical Memorandum, July 2005.

U.S. EPA, Region I, Massachusetts; Boston Harbor Area Carbon Monoxide Redesignation to Attainment (http://www.epa.gov/region1/topics/air/sips/ne_sip_summaries.html), December 2005.

MassDEP, Final Eastern Massachusetts 1-Hour Ozone NAAQS Attainment Demonstration SIP, September 2002.

O.5 Conclusions and Recommendations

The results of the General Conformity Applicability Analysis are shown in Table O-11 for all pollutants. Detailed modeling of the emissions resulting from the two project alternatives predicted that releases of direct and indirect emissions of NOx, CO and VOCs would be below the de minimis thresholds and would also be less than the 10% Area Inventory Levels. Therefore, Alternative 1 and 2 emissions would avoid (i.e., be exempt from) the requirements of the General Conformity rule. However, marine and nonroad engine pollutant releases during dredging operations would require that the ACE include in their designs specifications that new equipment meeting the more the stringent EPA emissions standards at the time of dredging operations be used on the project. In addition, the ACE would be required to lengthen the dredging schedule for both project alternatives. For Alternative 1, the dredging schedule would need to be increased by 6 months (from 36 months to 42 months). The extension of the dredging schedule over four calendar years is based on 9 months of operation per year. For Alternative 2, the revised the dredging operations would be the same as Alternative 1, but the dredging schedule would be extended from by 48 months to 73 months over 8 calendar years. The extension of the dredging schedule an additional four calendar years is based on 10 months of operation in the first year and 9 months of operation for years 2 through 8.

The ACE has made the following environmental commitment regarding air quality to avoid or minimize the effects of Alternatives 1 and 2:

Environmental Commitment A-1: Use of New Equipment Meeting More Stringent EPA Emissions Standards.

The ACE will include in its designs specifications that the Contractor use new equipment meeting the most stringent EPA emissions standards at the time of the project. This environmental commitment requires replacing all nonroad equipment with newer equipment that would meet EPA Tier 3 and 4 emissions standards that would be required for equipment model years 2011 and beyond. The clamshell and backhoe engines would need to meet Tier 4 emissions standards and support equipment would need to comply with Tier 3 and Tier 4 emissions standards, depending on the equipment category and engine size. **Table O-12** presents the Tier 3 and Tier 4 emissions limits based on engine size, in horsepower. In addition, the tugboats would also have to be equipped with engines that meet EPA's Tier 2 marine engine emissions standards presented in Table O-6.

Table O-12
Non-Road Emissions Limits

Engine Power (hp)	Tier 3 and 4 Technology Type Emission Limits * (g/hp-hr)				
	HC	CO	NO_x	PM	SO_2
0 - 11 (Tier4A)	0.55	4.11	4.3	0.28	0.006
12 - 25 (Tier 4A)	0.55	4.11	4.3	0.28	0.006
26 - 50 (Tier 4A)	0.28	1.53	4.7	0.2	0.006
51 - 75 (Tier 4A)	0.18	2.37	3.0	0.2	0.006
76 - 100 (Tier 3B)	0.18	2.37	3.0	0.3	0.006
101 - 175 (Tier 3)	0.18	0.87	2.5	0.22	0.006
176 - 300 (Tier 4 transitional)	0.13	0.075	1.39	0.009	0.006
301 - 600 (Tier 4 transitional)	0.13	0.084	1.39	0.009	0.006
601 - 750 (Tier 4 transitional)	0.13	0.13	1.39	0.009	0.006
>750 (Tier 4)	0.28	0.08	2.39	0.07	0.006

* Tier 3 and 4 emission factors are taken from Table A2 of the EPA Technical Document "Exhaust and Crankcase Emission Factors for Nonroad Engine Modeling --Compression-Ignition, 2004.

APPENDIX O

AIR QUALITY CONFORMITY

Attachment A
Emissions Modeling Summary Spreadsheets
And Supporting Documentation

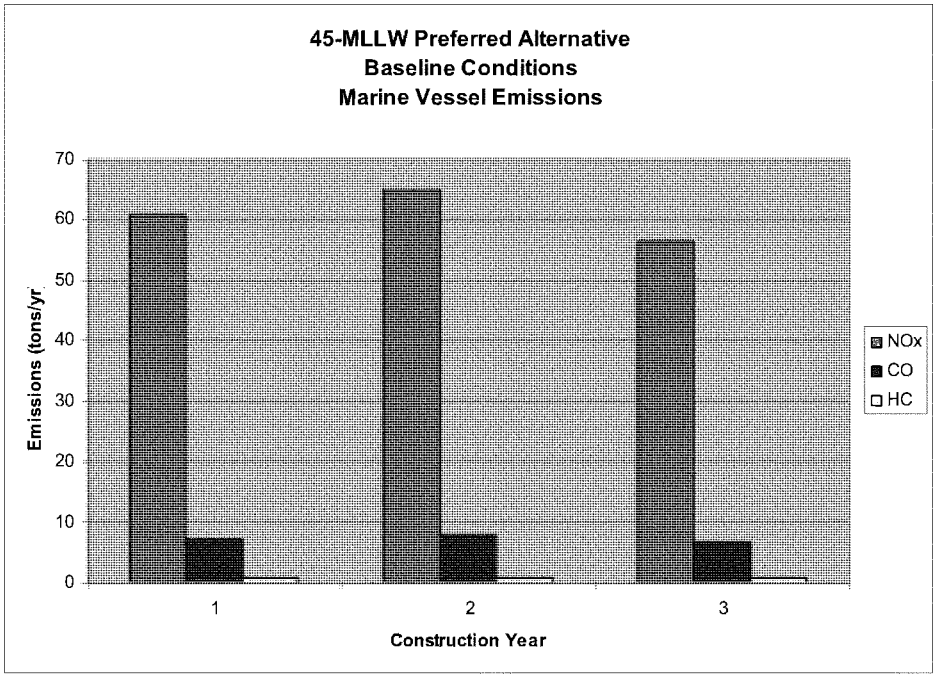
PART 1

DIRECT EMISSIONS CALCULATIONS

ALTERNATIVE 1

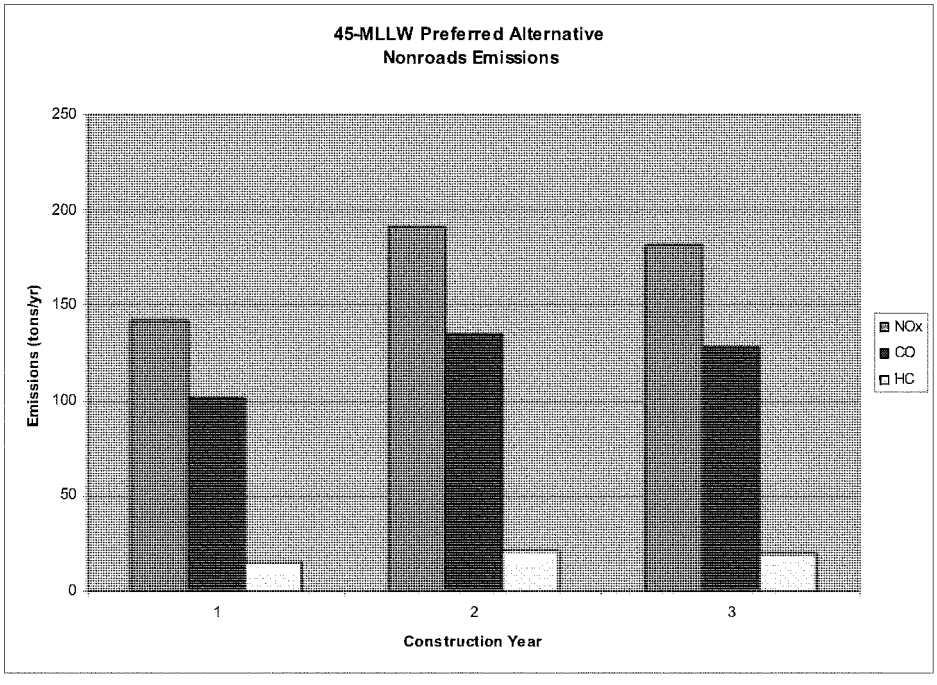
Boston Harbor, Massachusetts - Navigation Improvement Study
45-MLLW Depth Preferred Alternative
Uncontrolled Conditions
Marine Vessel Total Emissions

Pollutant	Year 1	Year 2	Year 3	Total
PM	3	**3**	3	8
SO_2	187	**200**	174	562
NOx	61	**65**	56	182
CO	7	**8**	7	22
HC	0.7	**0.8**	0.7	2



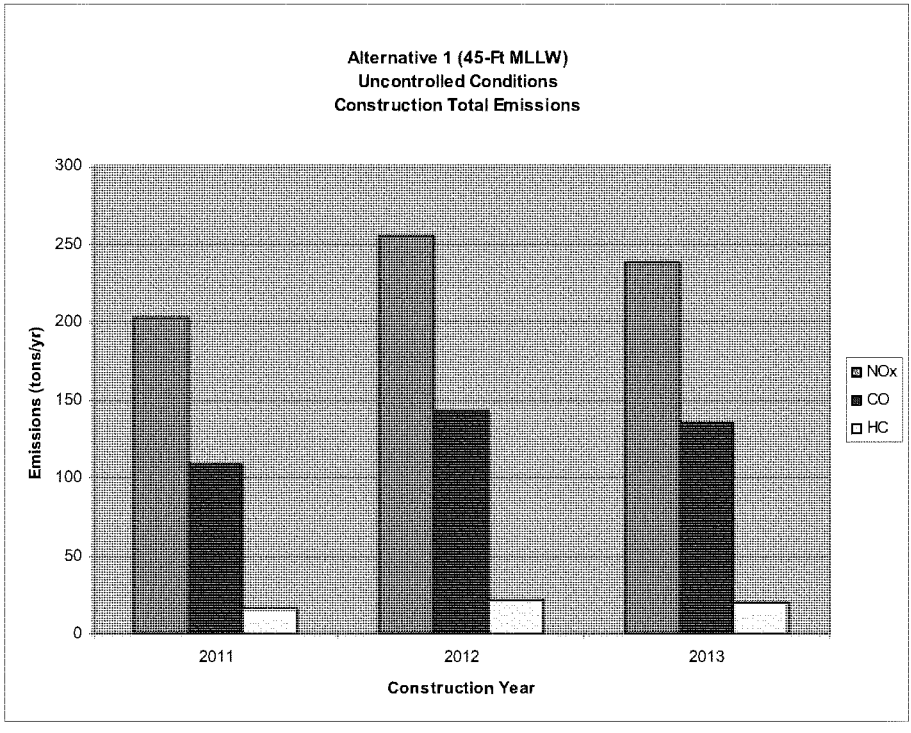
Boston Harbor, Massachusetts - Navigation Improvement Study
45-MLLW Preferred Alternative
Uncontrolled Conditions
Nonroads Equipment Total Emissions (tons/yr)

Pollutant	Year 1	Year 2	Year 3	Total
PM2.5	13	**17**	17	47
PM10	13	**18**	17	49
SO_2	0.1	**0.2**	0.1	0.4
NOx	142	**191**	182	514
CO	101	**135**	128	364
HC	16	**21**	20	56



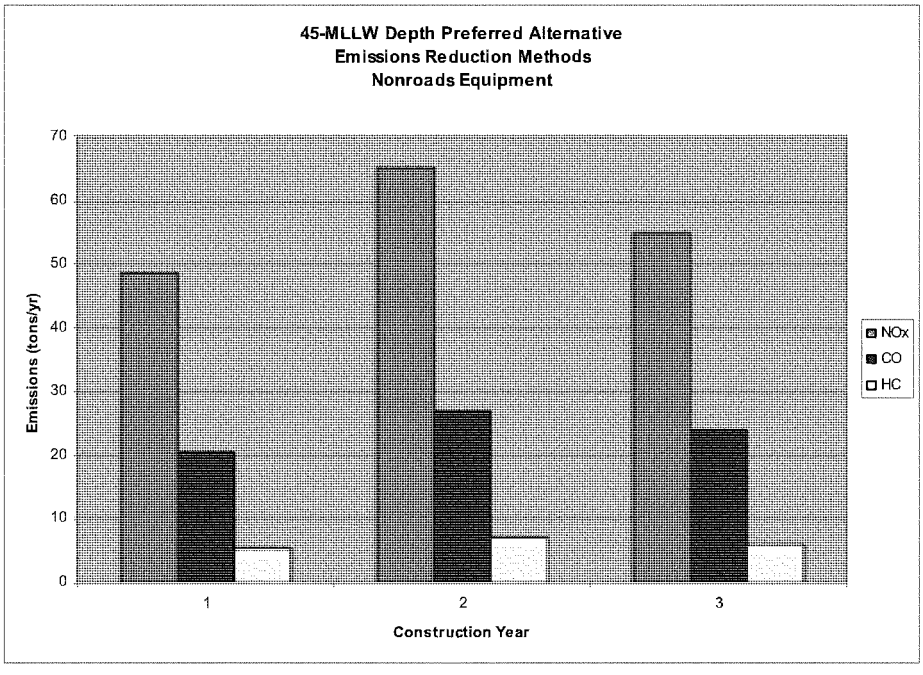
Boston Harbor, Massachusetts - Navigation Improvement Study
45-MLLW Preferred Alternative
Uncontrolled Conditions
Summary of Total Annual Emissions (tons/yr)

Pollutant	2011	2012	2013	Total
$PM_{2.5}$	16	20	19	56
PM_{10}	16	21	20	57
SO_2	187	200	174	562
NO_x	203	256	238	696
CO	108	142	135	386
HC	16	22	20	58



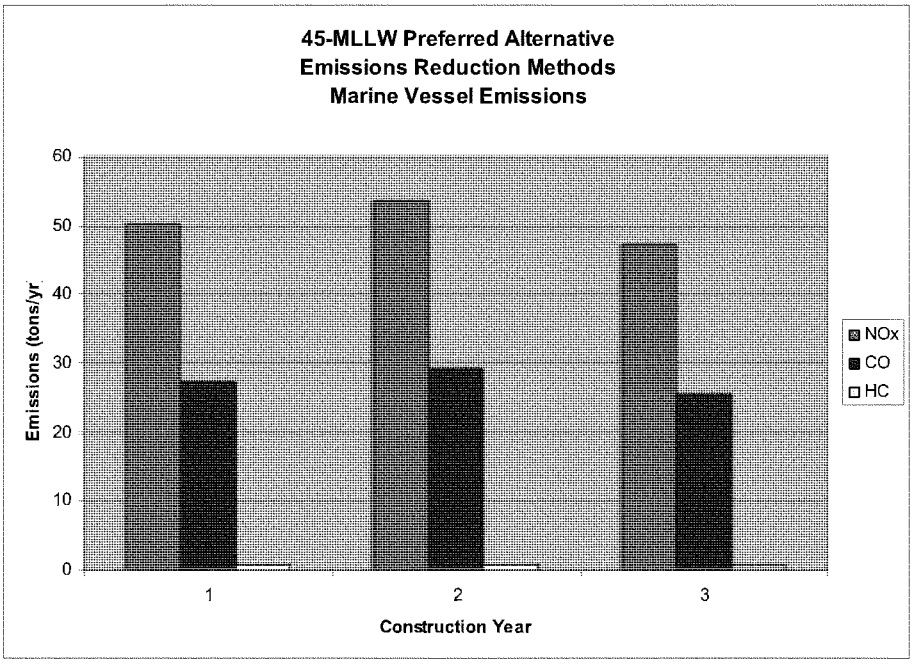
Boston Harbor, Massachusetts - Navigation Improvement Study
45-MLLW Depth Preferred Alternative
Emissions Reduction Methods
Nonroads Equipment Total Emissions (tons/yr)

Pollutant	Year 1	Year 2	Year 3	Total
PM2.5	2	2	2	6
PM10	2	3	2	7
SO_2	0.1	**0.2**	0.1	0.4
NOx	49	**65**	55	168
CO	20	**27**	24	71
HC	5	**7**	6	18



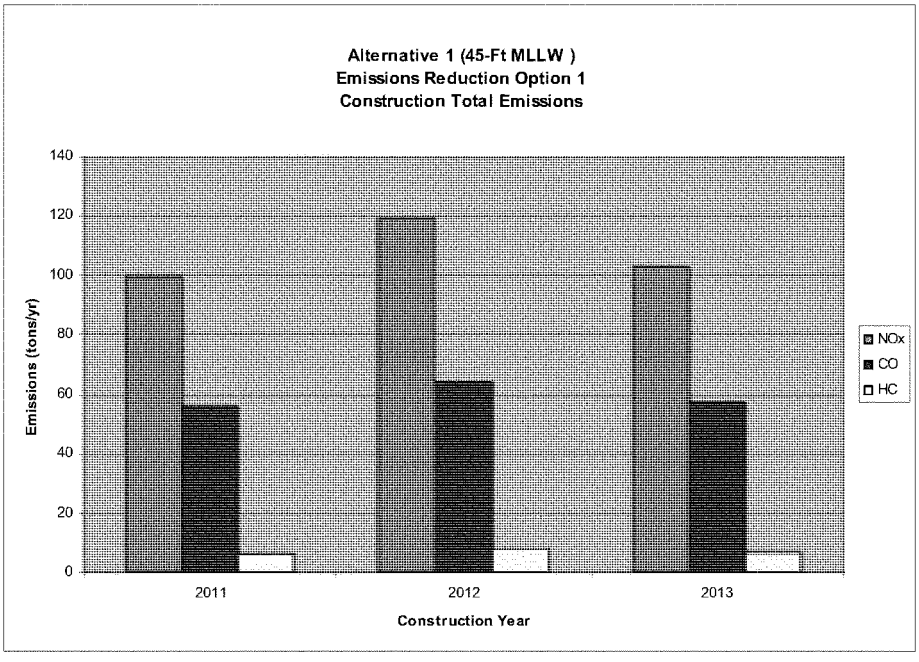
Boston Harbor, Massachusetts - Navigation Improvement Study
45-MLLW Depth Preferred Alternative
Emissions Reduction Methods
Marine Vessel Total Emissions

Pollutant	Year 1	Year 2	Year 3	Total
PM	3	**3**	3	8
SO_2	187	**200**	176	563
NOx	50	**54**	47	151
CO	27	**29**	25	82
HC	0.7	**0.8**	0.7	2



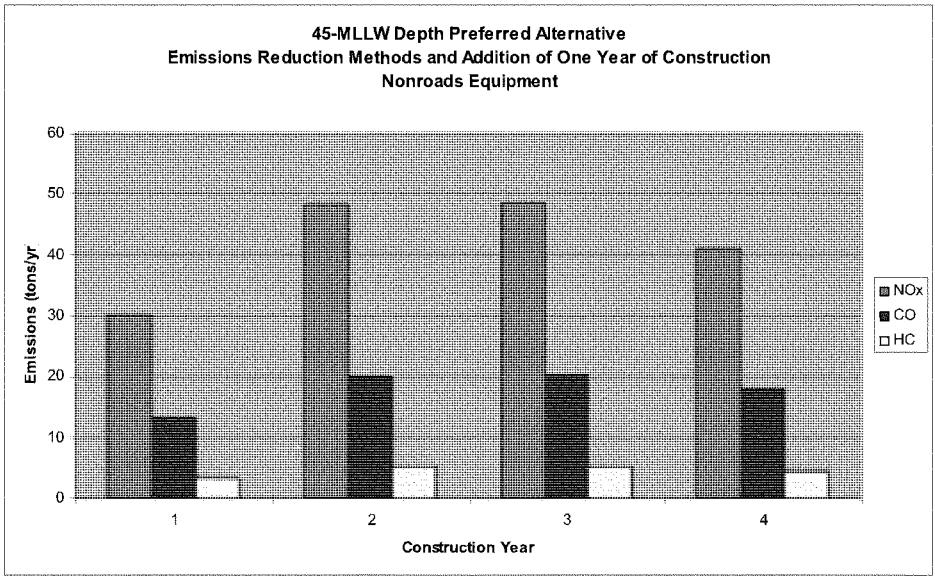
Boston Harbor, Massachusetts - Navigation Improvement Study
45-MLLW Depth Preferred Alternative
Emissions Reduction Methods
Summary of Total Annual Emissions (tons/yr)

Pollutant	2011	2012	2013	Total
$PM_{2.5}$	5	5	5	15
PM_{10}	5	6	5	15
SO_2	187	200	176	564
NO_x	99	119	102	321
CO	56	64	57	177
HC	6	8	7	21



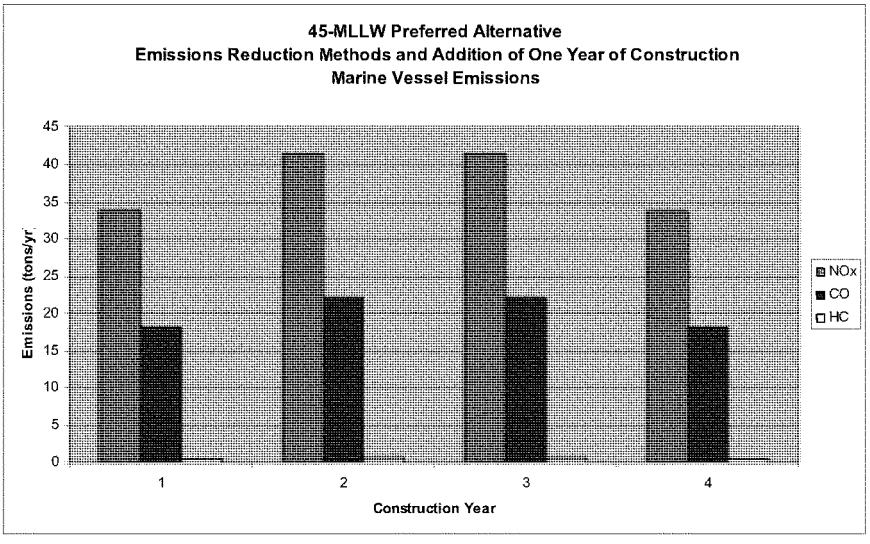
Boston Harbor, Massachusetts - Navigation Improvement Study
45-MLLW Depth Preferred Alternative
Emissions Reduction Methods and Addition of One Year of Construction
Nonroads Equipment Total Emissions (tons/yr)

Pollutant	Year 1	Year 2	Year 3	Year 4	Total
PM2.5	1	2	2	2	7
PM10	1	2	2	2	7
SO_2	0.1	0.1	0.1	0.1	0.4
NOx	30	48	49	41	168
CO	13	20	20	18	71
HC	3	5	5	4	18



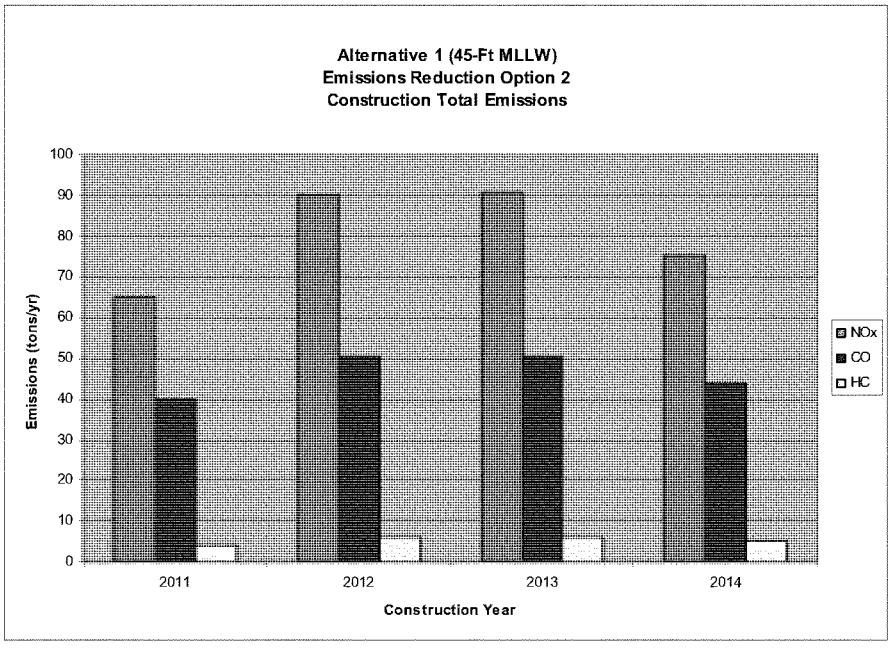
Boston Harbor, Massachusetts - Navigation Improvement Study
45-MLLW Depth Preferred Alternative
Emissions Reduction Methods and Addition of One Year of Construction
Marine Vessel Total Emissions

Pollutant	Year 1	Year 2	Year 3	Year 4	Total
PM	2	**2**	**2**	2	8
SO_2	126	**154**	**154**	127	562
NOx	34	**41**	**41**	34	151
CO	18	**22**	**22**	18	80
HC	0.5	**0.6**	**0.6**	0.5	2



Boston Harbor, Massachusetts - Navigation Improvement Study
45-MLLW Preferred Alternative
Emissions Reduction Methods and Addition of One Year of Construction
Summary of Total Annual Emissions (tons/yr)

Pollutant	2011	2012	2013	2014	Total
$PM_{2.5}$	3	4	4	4	15
PM_{10}	3	4	4	4	15
SO_2	126	154	154	128	563
NO_x	65	90	90	75	321
CO	40	50	50	44	184
HC	4	6	6	5	22



Boston Harbor Dredge Project
Onroads Mobile Source Modeling Analysis

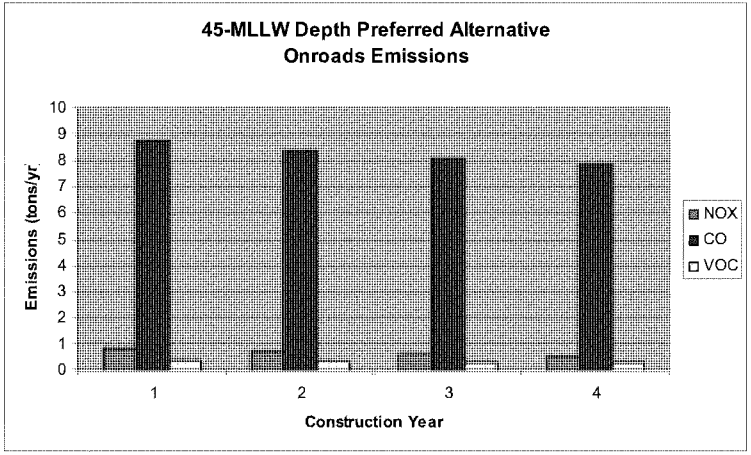
45-MLLW Depth Preferred Alternative Vehicle Trips Data

	Employee Per Major Piece of Equipment	Major Piece of Equipment	No. of Shifts	Number of Vehicles/Day	Roundtrip Distance (mi)	Vehicle-Miles Traveled (VMT)/yr
Employee Vehicle Trips	10	3	2	60	50	717,000
On-Road Truck Trips	--	--	2	12	50	143,400

45-MLLW Depth Preferred Alternative (3 to 4 Year Construction Period)

		MOBILE6.2 Emission Factor (g/mi)						Emissions (tons/yr)					
YEAR	VMT/YR	NOX	CO	VOC	PM10	PM2.5	SO2	NOX	CO	VOC	PM10	PM2.5	SO2
2011	860,400	0.882	9.260	0.391	0.0387	0.0230	0.0091	0.84	8.77	0.37	0.04	0.02	0.01
2012	860,400	0.754	8.863	0.354	0.0362	0.0207	0.0091	0.71	8.40	0.34	0.03	0.02	0.01
2013	860,400	0.645	8.540	0.324	0.0344	0.0192	0.0092	0.61	8.09	0.31	0.03	0.02	0.01
2014*	860,400	0.549	8.287	0.298	0.0328	0.0177	0.0092	0.52	7.85	0.28	0.03	0.02	0.01

Note:* Year 2014 only applies if the construction is extended one additional year.



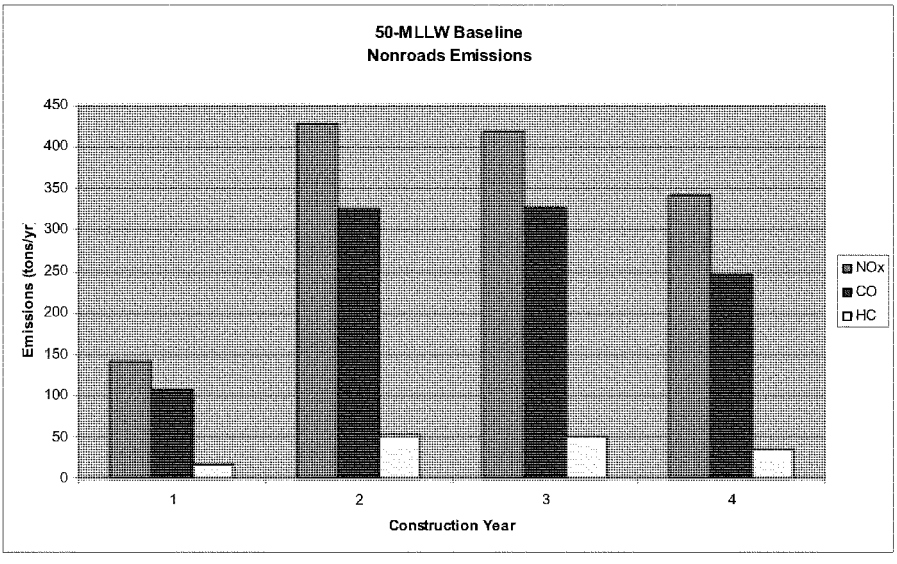
PART 2

DIRECT EMISSIONS CALCULATIONS

ALTERNATIVE 2

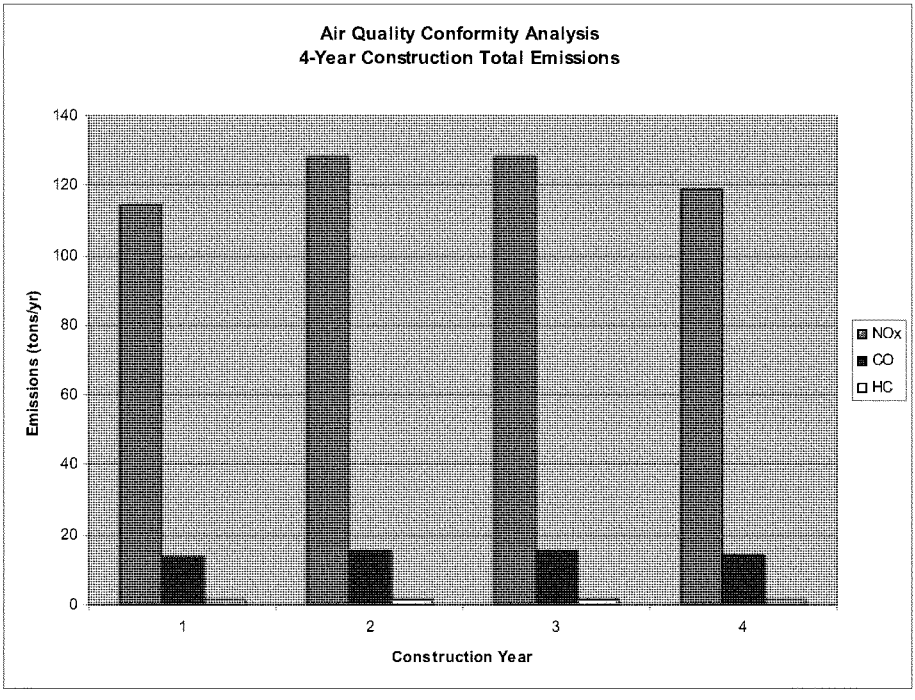
Boston Harbor, Massachusetts - Navigation Improvement Study
50-MLLW Uncontrolled
Nonroads Equipment Total Emissions (tons/yr)

Pollutant	Year 1	Year 2	Year 3	Year 4	Total
PM2.5	14	45	46	32	137
PM10	15	46	47	33	142
SO_2	0.1	0.4	0.3	0.3	1
NOx	141	428	418	342	1329
CO	108	325	327	246	1005
HC	16	51	51	36	154



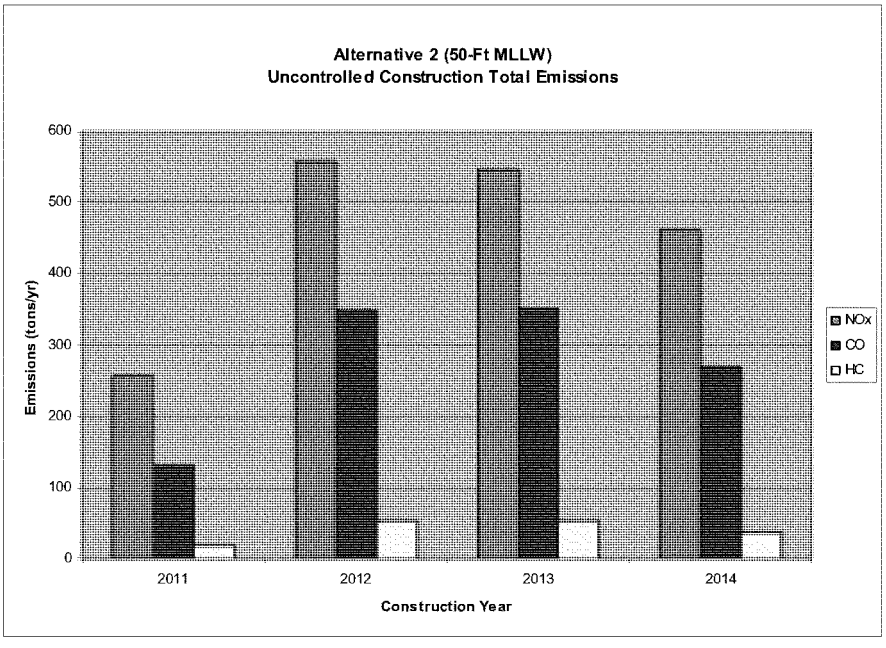
Boston Harbor, Massachusetts - Navigation Improvement Study
50-MLLW Uncontrolled
Marine Vessel Total Emissions (tons/yr)

Pollutant	Year 1	Year 2	Year 3	Year 4	Total
PM	5	6	6	5	**23**
SO_2	353	395	395	367	**1,511**
NOx	114	128	128	119	**490**
CO	14	15	15	14	**58**
HC	1	1	1	1	**6**



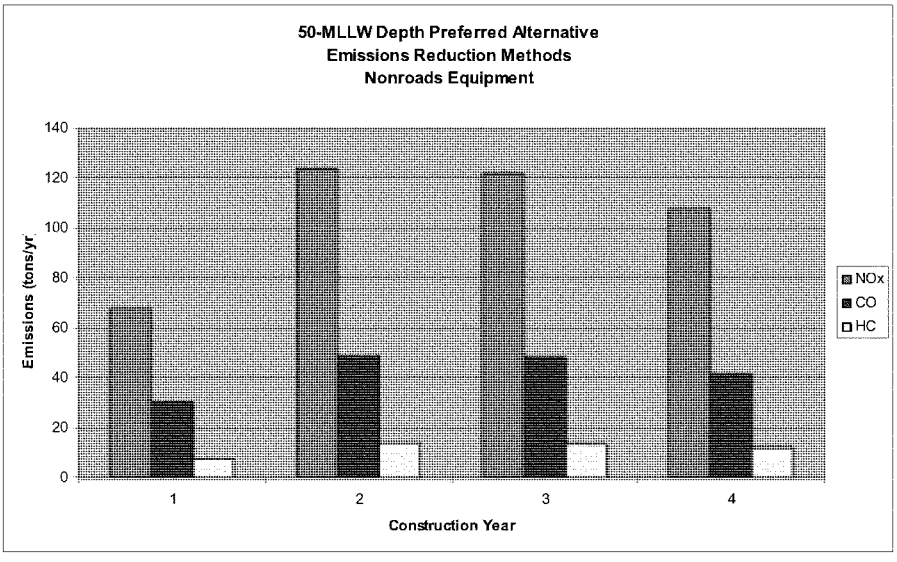
Boston Harbor, Massachusetts - Navigation Improvement Study
50-MLLW Uncontrolled
Summary of Total Annual Emissions (tons/yr)

Pollutant	2011	2012	2013	2014	Total
$PM_{2.5}$	20	51	52	38	160
PM_{10}	20	52	53	39	164
SO_2	353	396	396	367	1,512
NO_x	257	557	547	461	1,823
CO	131	350	352	269	1,102
HC	18	53	53	37	162



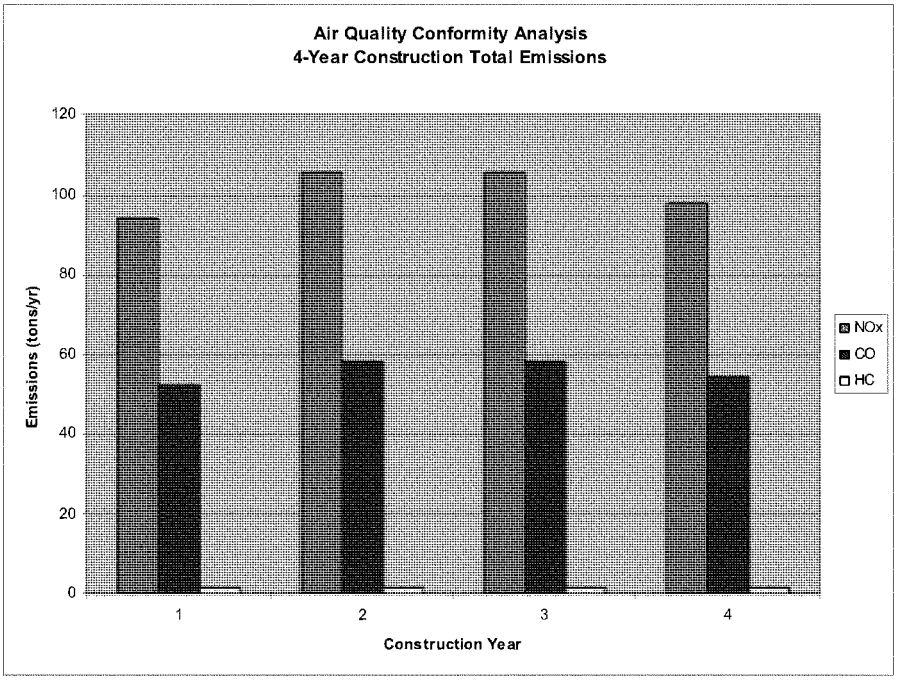
Boston Harbor, Massachusetts - Navigation Improvement Study
50-MLLW Depth Preferred Alternative
Emissions Reduction Methods
Nonroads Equipment Total Emissions (tons/yr)

Pollutant	Year 1	Year 2	Year 3	Year 4	Total
PM2.5	2	**5**	**5**	5	17
PM10	3	**5**	**5**	5	18
SO_2	0.2	**0.3**	**0.3**	0.3	1
NOx	68	**123**	**122**	108	421
CO	30	**49**	**48**	41	169
HC	8	**14**	**14**	12	48



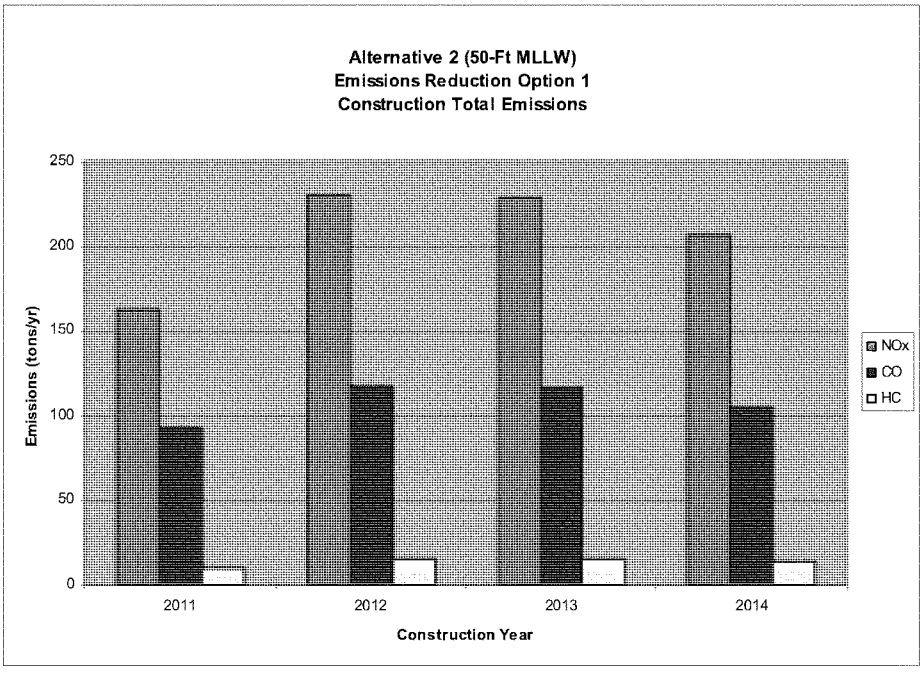
Boston Harbor, Massachusetts - Navigation Improvement Study
50-MLLW Depth Preferred Alternative
Emissions Reduction Methods
Marine Vessel Total Emissions (tons/yr)

Pollutant	Year 1	Year 2	Year 3	Year 4	Total
PM	5	6	6	5	**23**
SO_2	353	395	395	367	**1,511**
NOx	94	105	105	98	**403**
CO	52	58	58	54	**223**
HC	1	1	1	1	**6**



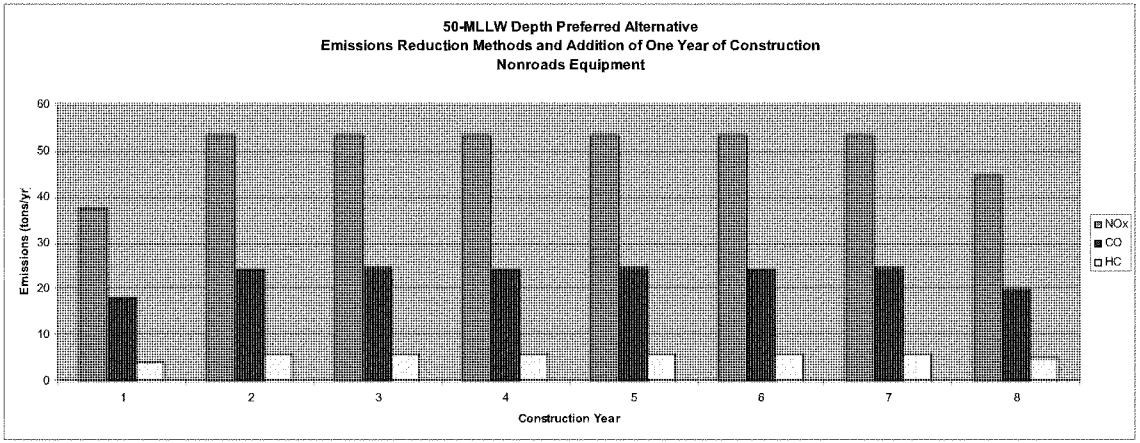
Boston Harbor, Massachusetts - Navigation Improvement Study
50-MLLW Preferred Alternative
Emissions Reduction Methods
Summary of Total Annual Emissions (tons/yr)

Pollutant	2011	2012	2013	2014	Total
$PM_{2.5}$	8	11	11	10	40
PM_{10}	8	11	11	11	40
SO_2	353	396	396	367	1,512
NO_x	163	230	228	206	826
CO	93	117	116	105	430
HC	9	16	16	14	55



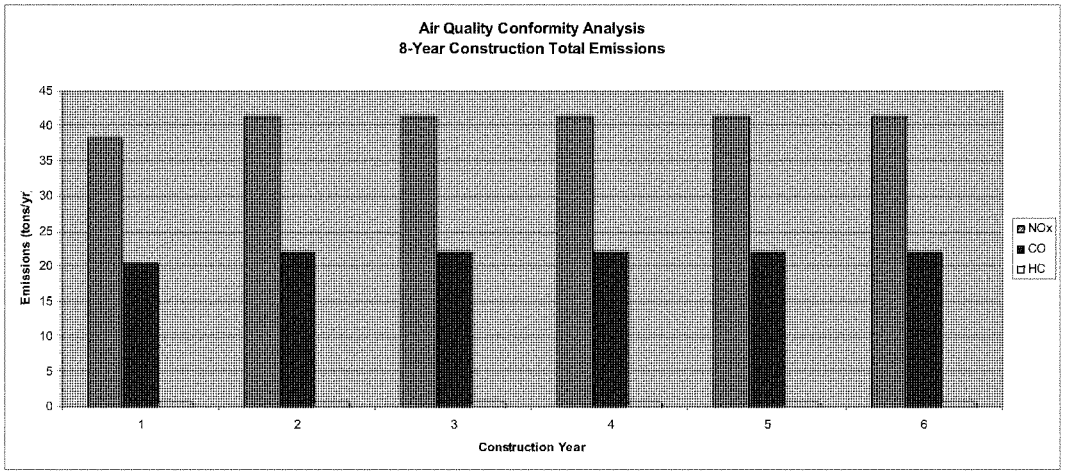
Boston Harbor, Massachusetts - Navigation Improvement Study
50-MLLW Depth Preferred Alternative
Emissions Reduction Methods and Addition of Four Years of Construction
Nonroads Equipment Total Emissions (tons/yr)

Pollutant	2011	2012	2013	2014	2015	2016	2017	2018	Total
PM2.5	1.3	2.1	2.3	2.2	2.3	2.2	2.3	2.0	17
PM10	1.4	2.1	2.2	2.2	2.2	2.2	2.2	2.1	17
SO_2	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	1
NOx	38	53	53	53	53	53	53	44	402
CO	18	24	25	24	25	24	25	20	185
HC	4	6	6	6	6	6	6	5	44



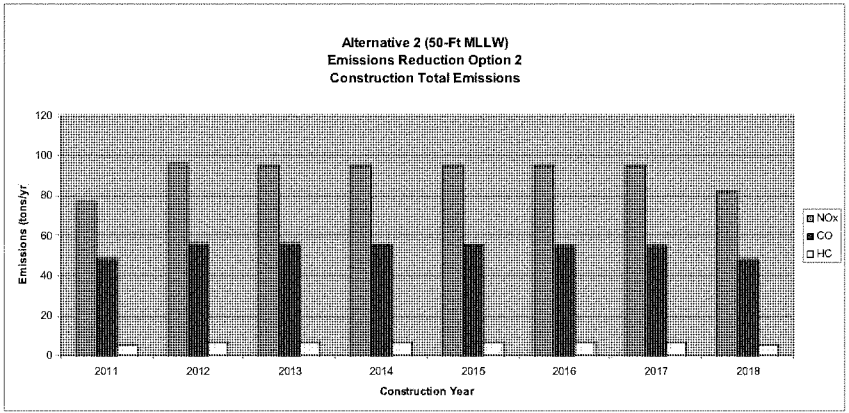
Boston Harbor, Massachusetts - Navigation Improvement Study
50-MLLW Depth Preferred Alternative
Emissions Reduction Methods and Addition of Four Years of Construction
Marine Vessel Total Emissions (tons/yr)

Pollutant	2011	2012	2013	2014	2015	2016	2017	2018	Total
PM	2	2	2	2	2	2	2	2	18
SO_2	143	154	154	154	154	154	154	140	1,208
NOx	38	41	41	41	41	41	41	38	325
CO	20	22	22	22	22	22	22	20	173
HC	1	1	1	1	1	1	1	1	5



Boston Harbor, Massachusetts - Navigation Improvement Study
50-MLLW Preferred Alternative
Emissions Reduction Methods and Addition of Four Years of Construction
Summary of Total Annual Emissions (tons/yr)

Pollutant	2011	2012	2013	2014	2015	2016	2017	2018	Total
$PM_{2.5}$	3	4	5	5	5	5	5	4	35
PM_{10}	4	4	5	4	4	4	4	4	34
SO_2	143	154	154	154	154	154	154	140	1,209
NO_x	77	96	96	95	95	95	95	82	732
CO	49	56	56	55	56	55	55	49	431
HC	5	7	7	7	7	7	7	6	51

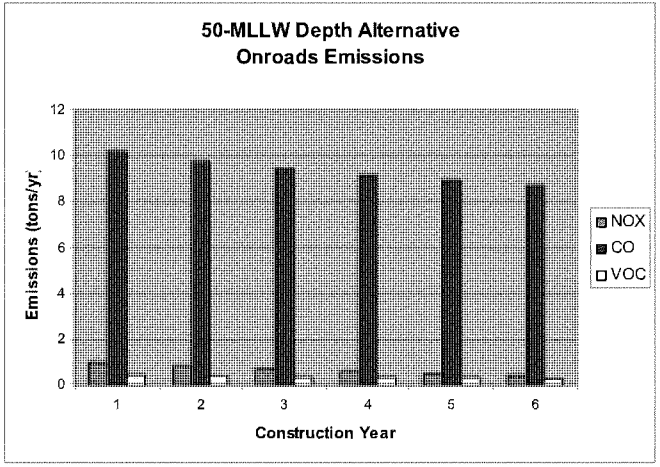


50-MLLW Depth Alternative Vehicle Trips Data

	Employee Per Major Piece of Equipment	Major Piece of Equipment	No. of Shifts	Number of Vehicles/Day	Roundtrip Distance (mi)	Vehicle-Miles Traveled (VMT)/yr
Employee Vehicle Trips	12	3	2	72	50	860,400
On-Road Truck Trips	--	--	2	12	50	143,400

50-MLLW Depth Alternative (4 to 6 Year Construction Period)

		MOBILE6.2 Emission Factor (g/mi)						Emissions (tons/yr)					
YEAR	VMT/YR	NOX	CO	VOC	PM10	PM2.5	SO2	NOX	CO	VOC	PM10	PM2.5	SO2
2011	1,003,800	0.882	9.260	0.391	0.0387	0.0230	0.0091	0.98	10.24	0.43	0.04	0.03	0.010
2012	1,003,800	0.754	8.863	0.354	0.0362	0.0207	0.0091	0.83	9.80	0.39	0.04	0.02	0.010
2013	1,003,800	0.645	8.540	0.324	0.0344	0.0192	0.0092	0.71	9.44	0.36	0.04	0.02	0.010
2014	1,003,800	0.549	8.283	0.298	0.0328	0.0177	0.0092	0.61	9.16	0.33	0.04	0.02	0.010
2015	1,003,800	0.468	8.085	0.277	0.0316	0.0166	0.0092	0.52	8.94	0.31	0.03	0.02	0.010
2016	1,003,800	0.408	7.916	0.261	0.0308	0.0160	0.0092	0.45	8.75	0.29	0.03	0.02	0.010
2017	1,003,800	0.358	7.786	0.249	0.0303	0.0154	0.0092	0.40	8.61	0.28	0.03	0.02	0.010
2018	1,003,800	0.315	7.672	0.240	0.0297	0.0148	0.0093	0.35	8.48	0.27	0.03	0.02	0.010



PART 3

INDIRECT EMISSIONS

Boston Harbor, Massachusetts - Navigation Improvement Study
Indirect/Secondary Air Emissions
Marine Vessel Air Emissions
Summary of Total Annual Emissions (tons)

WITHOUT PROJECT

Emission	Unit	MSC Containership 4,000 TEUs	COSCO Containership 5,100 TEUs	Bulk Carrier 25,000 DWT	Bulk Carrier 40,000 DWT	Petroleum Ship <20,000 DWT	Petroleum Ship 20,000 DWT	Petroleum Ship 25,000 DWT	Petroleum Ship 35,000 DWT	Petroleum Ship >35,000 DWT	Truck Trip Emissions	Total
PM	TPY	23	16	5.0	2.2	27.8	1.4	5.0	9.8	6.2	0.2	96
SO_2	TPY	65	45	7	3	71	3	13	25	16	0.03	248
NOx	TPY	169	117	13	6	179	9	32	63	40	5.8	634
CO	TPY	84	58	23.7	10.5	109.8	5.4	19.9	38.8	24.3	1.6	377
HC	TPY	51.7	35.8	14.7	6.5	67.5	3.3	12.2	23.8	14.9	0.7	231

POST-CONSTRUCTION

Emission	Unit	MSC Containership 5,600 TEUs	COSCO Containership 5,600 TEUs	Bulk Carrier 40,000 DWT	Bulk Carrier 60,000 DWT	Petroleum Ship <20,000 DWT	Petroleum Ship 20,000 DWT	Petroleum Ship 25,000 DWT	Petroleum Ship 35,000 DWT	Petroleum Ship >35,000 DWT	Truck Trip Emissions	Total
PM	TPY	17.4	35	3.8	1.7	18.0	0.9	3.0	4.1	7.1	0.2	91
SO_2	TPY	50	99	5	2	49	3	8	11	19	0.04	247
NOx	TPY	105	209	9	4	124	6	21	29	49	7.7	563
CO	TPY	65	130	18.1	7.9	68.7	3.6	11.5	15.8	27.2	2.1	349
HC	TPY	39.7	79.4	11.2	4.9	42.2	2.2	7.0	9.7	16.7	1.0	214

DIFFERENTIAL (POST-CONSTRUCTION MINUS WITHOUT PROJECT)

Emission	Unit	Without Project	Post Construction	Net Change	Percent Change
PM	TPY	96	91	-5	-5.2
SO_2	TPY	248	247	-0.6	-0.2
NOx	TPY	634	563	-71	-11.2
CO	TPY	377	349	-28	-7.3
HC	TPY	231	214	-17	-7.5

CDM	New England USACE	JOB NO. 48047-6149.008.102.EMISS	COMPUTED BY M. Wallace
PROJECT	B.H. Deep Draft Navigation	DATE CHECKED	DATE 10/18/06
DETAIL	Conformity Determination	CHECKED BY	PAGE NO. 1 of 1

Total Truck Miles Saved by State

New England Imports - 2005			
State	Total TEUs	Wt. Avg. Dist. Saved (miles)	Total Mileage Savings*
CT	19,253	34.9	383,960
ME	2,838	222.2	360,345
MA	68,809	182.0	7,156,136
NH	6,679	212.6	811,403
RI	16,206	128.3	1,188,131
VT	3,035	76.4	132,499
Totals	**116,820**	**150.3**	**10,032,475**

*Calculated using 1.75 TEU's per truck trip.

New England Exports - 2005			
State	Total TEUs	Wt. Avg. Dist. Saved (miles)	Total Mileage Savings*
CT	3,386	40.5	78,362
ME	678	222.2	86,087
MA	26,179	159.9	2,392,013
NH	1,833	184.4	193,146
RI	5,956	105.2	358,041
VT	74	139.6	5,903
Totals	**38,106**	**143.0**	**3,113,551**

*Calculated using 1.75 TEU's per truck trip.

New England Imports & Exports by State (except MA) - 2005			
State	Total TEUs	Total Mileage Savings	% of Total Mileage Savings
CT	22,639	462,322	12.85%
ME	3,516	446,432	12.41%
MA	0	0	0.00%
NH	8,512	1,004,549	27.92%
RI	22,162	1,546,172	42.97%
VT	3,109	138,403	3.85%
Totals	**59,938**	**3,597,877**	**100%**

New England Import & Export Totals - 2005			
	Total TEUs	Wt. Avg. Dist. Saved (miles)	Total Mileage Savings
Imports	116,820	150.3	10,032,475
Exports	38,106	143.0	3,113,551
Totals	**154,926**	**148.5**	**13,146,025**

Estimated Miles Saved by State

State	Total Boxes*	Total Mileage Savings
CT	50872	970,700
ME	50872	937,337
MA**	50872	0
NH	50872	2,109,171
RI	50872	3,246,374
VT	50872	290,593
Totals		7,554,174

* Total boxes shifted from PONYNJ to Boston based on project.

**Total mileage in MA would increase by 709,595.

CDM	CLIENT	New England USACE	JOB NO. 48047-6149.008.102.EMISS	COMPUTED BY M. Wallace
	PROJECT	B.H. Deep Draft Navigation	DATE CHECKED	DATE 10/08/07
	DETAIL	Conformity Determination	CHECKED BY	PAGE NO. 1 of 1

Heavy Duty Diesel Cargo Trucks Emissions Calculations

Massachusetts Only Emissions

Existing Emissions - Cargo from Boston Harbor

	HDD Truck	MOBILE6.2 Heavy Duty Diesel (HDD) Truck Emission Factor (g/mi)						Emissions (tons/yr)					
YEAR	VMT/YR	NOX	CO	VOC	PM10	PM2.5	SO2	NOX	CO	VOC	PM10	PM2.5	SO2
2007	3,100,278	10.033	2.615	0.482	0.2855	0.2401	0.0497	34.26	8.93	1.65	0.97	0.82	0.170

With Project Indirect Emissions - Cargo from Boston Harbor

	HDD Truck	MOBILE6.2 Heavy Duty Diesel (HDD) Truck Emission Factor (g/mi)						Emissions (tons/yr)					
YEAR	VMT/YR	NOX	CO	VOC	PM10	PM2.5	SO2	NOX	CO	VOC	PM10	PM2.5	SO2
2016	3,100,278	2.265	0.607	0.288	0.0905	0.0606	0.013	7.73	2.07	0.98	0.31	0.21	0.044

Without Project Indirect Emissions - Cargo from PONYNJ

	HDD Truck	MOBILE6.2 Heavy Duty Diesel (HDD) Truck Emission Factor (g/mi)						Emissions (tons/yr)					
YEAR	VMT/YR	NOX	CO	VOC	PM10	PM2.5	SO2	NOX	CO	VOC	PM10	PM2.5	SO2
2016	2,334,001	2.265	0.607	0.288	0.0905	0.0606	0.013	5.82	1.56	0.74	0.23	0.16	0.03

With Project Indirect Emissions - Net Change in Truck Emissions

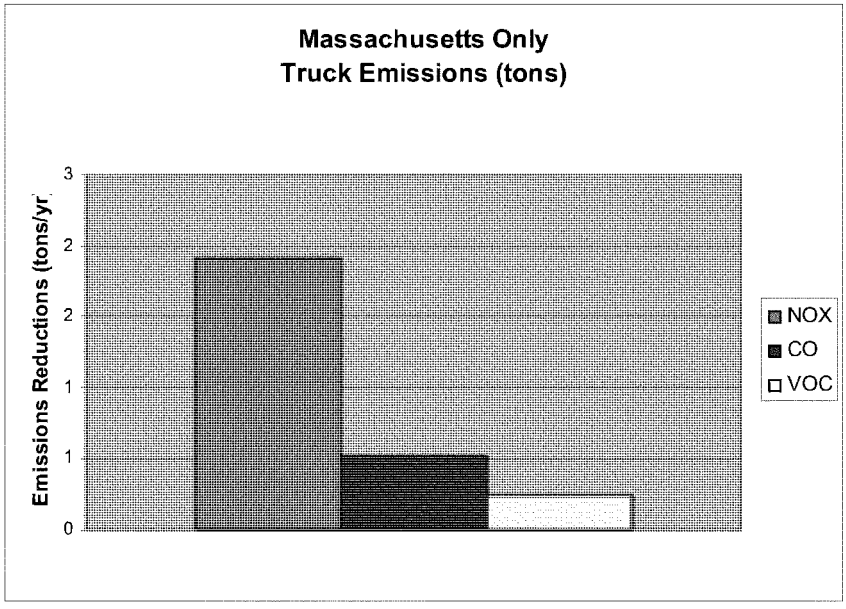
	HDD Truck	MOBILE6.2 Heavy Duty Diesel (HDD) Truck Emission Factor (g/mi)						Emissions (tons/yr)					
YEAR	VMT/YR	NOX	CO	VOC	PM10	PM2.5	SO2	NOX	CO	VOC	PM10	PM2.5	SO2
2016	766,276	2.265	0.607	0.288	0.0905	0.0606	0.013	1.91	0.51	0.24	0.08	0.05	0.01

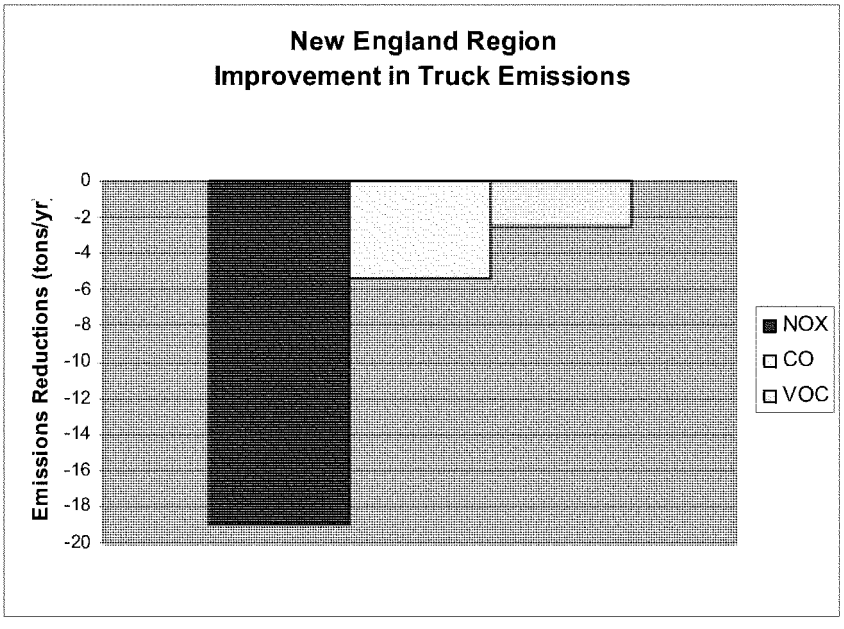
New England Region Emissions (2016)

With Project Indirect Emission - Net Change in Truck Vehicle Miles Traveled

	HDD Truck	MOBILE6.2 Heavy Duty Diesel (HDD) Truck Emission Factor (g/mi)						Emissions (tons/yr)					
STATE	VMT/YR	NOX	CO	VOC	PM10	PM2.5	SO2	NOX	CO	VOC	PM10	PM2.5	SO2
RI	-3,246,374	1.552	0.478	0.292	0.0840	0.0539	0.0131	-5.55	-1.71	-1.04	-0.30	-0.19	-0.05
CT	-970,700	2.822	0.726	0.310	0.1066	0.0746	0.0132	-3.02	-0.78	-0.33	-0.11	-0.08	-0.01
NH	-2,109,171	2.227	0.669	0.302	0.1018	0.0785	0.0132	-5.17	-1.55	-0.70	-0.24	-0.18	-0.03
ME	-937,337	4.130	1.053	0.353	0.1516	0.1160	0.0132	-4.26	-1.09	-0.36	-0.16	-0.12	-0.01
VT	-290,593	2.941	0.769	0.317	0.1063	0.0743	0.0132	-0.94	-0.25	-0.10	-0.03	-0.02	0.00
Total	**-7,554,174**							**-18.94**	**-5.37**	**-2.54**	**-0.84**	**-0.60**	**-0.11**

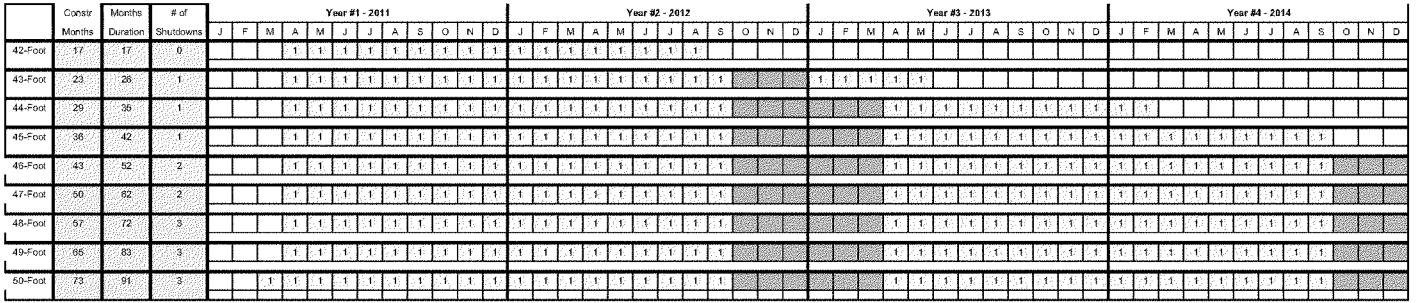
Yellow highlighted emission factors based on Massachusetts MOBILE6.2 model runs. Awaiting Maine and Vermont MOBILE6.2 input files.


Massachusetts Only
Truck Emissions (tons)
Emissions Reductions (tons/yr)
3
2
2
1
1
0
NOX
CO
VOC

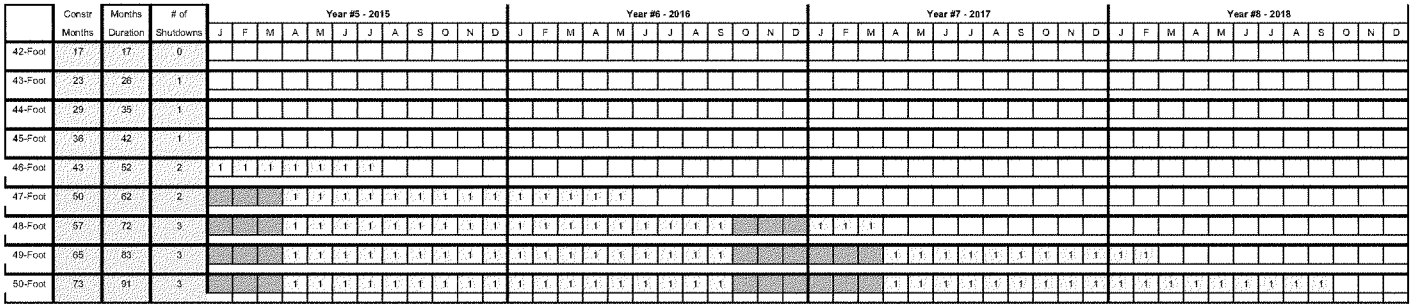

New England Region
Improvement in Truck Emissions
Emissions Reductions (tons/yr)
0
-2
-4
-6
-8
-10
-12
-14
-16
-18
-20
NOX
CO
VOC

PART 4

DREDGING SCHEDULE AND SUPPORT INFORMATION



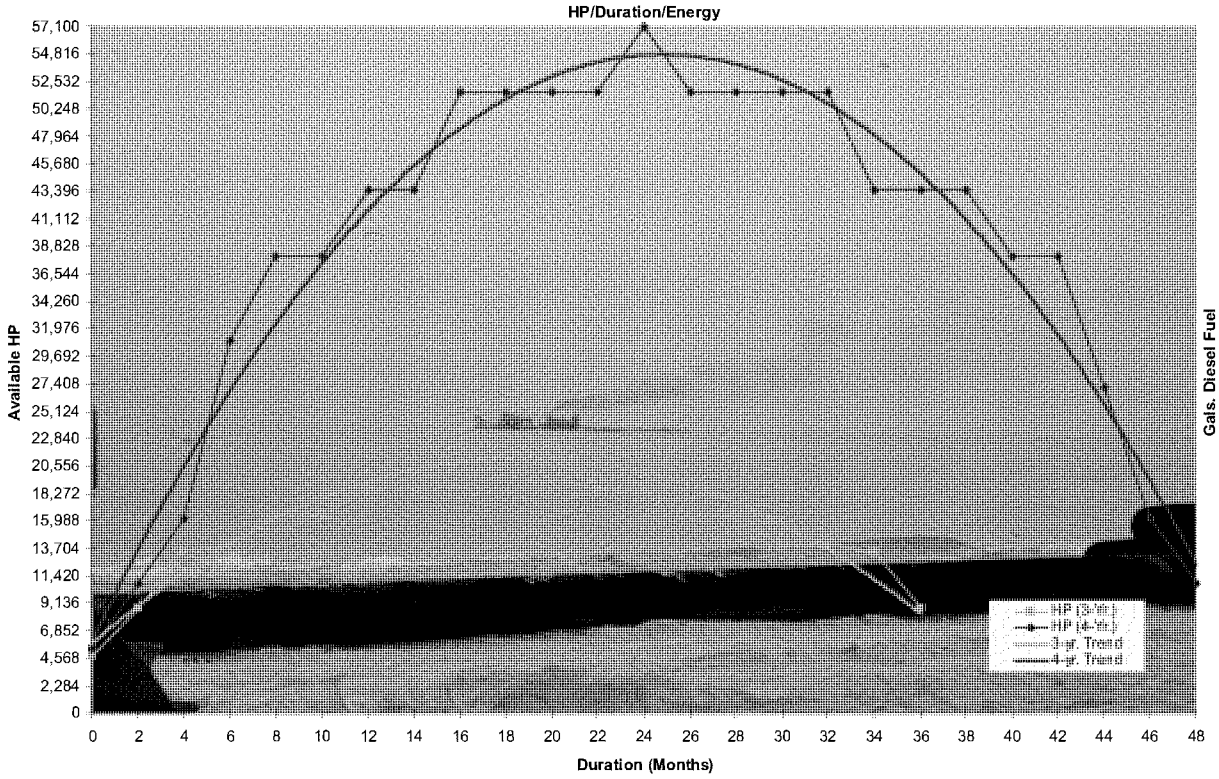
	Constr Months	Months Duration	# of Shutdowns	Year #1 - 2011												Year #2 - 2012												Year #3 - 2013												Year #4 - 2014											
				J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D
42-Foot	17	17	0				1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1																												
43-Foot	23	26	1				1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1				1	1	1	1	1																			
44-Foot	29	35	1				1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1							1	1	1	1	1	1	1	1	1	1									
45-Foot	36	42	1				1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1							1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1			
46-Foot	43	52	2				1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1							1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
47-Foot	50	62	2				1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1							1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
48-Foot	57	72	3				1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1							1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
49-Foot	65	83	3				1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1							1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
50-Foot	73	91	3				1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1							1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1



	Constr Months	Months Duration	# of Shutdowns	Year #5 - 2015												Year #6 - 2016												Year #7 - 2017												Year #8 - 2018											
				J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D
42-Foot	17	17	0																																															
43-Foot	23	26	1																																															
44-Foot	29	35	1																																														
45-Foot	36	42	1																																														
46-Foot	43	52	2	1	1	1	1	1	1	1																																								
47-Foot	50	62	2				1	1	1	1	1	1	1	1	1	1	1	1	1	1																														
48-Foot	57	72	3				1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1				1	1	1																					
49-Foot	65	83	3				1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1							1	1	1	1	1	1	1	1	1	1									
50-Foot	73	91	3				1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1							1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1

PLANT EQUIPMENT / PHASE / OPERATION (SF MLLW / 65,130,000 CY)	H-yr	0	2	4	6	8	10	12	14	16	18	20	22	24	26	28	30	32	34	36	38	40	42	44	46	48
Misc. Admin. Plant, x 12 laborers/vehicles			x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	
Technical and Support x 12 laborers/vehicles		x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Mob/Demob/Transportation 33.3% all waterborne self-propelled vessels		x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x		
Dredge Mechanical Clamshell CBR1 START (remove overburden)			x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x		
33.3% Scows, Misc. tugs self-propelled dredge-support barges/equipment			x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x		
Transportation/Mobilization 33.3% all waterborne self-propelled vessels			x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Dredge Mechanical Clamshell CBR2 START (remove overburden)				x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
33.3% Scows, Misc. tugs self-propelled dredge-support barges/equipment				x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
[illegible]																										
Transportation/Mobilization 33.3% all waterborne self-propelled vessels				x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Dredge Mechanical Backhoe BBH1 START (remove rock/bedrock and bottom)					x	x	x	x	x	x	x	x	x	x (1)	x	x	x	x	x	x	x	x	x	x	x	x
33.3% Scows, Misc. tugs self-propelled dredge-support barges/equipment					x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
See Additional Footnote Standard Factors																										

					45' MLLW / 3 Yrs.			50' MLLW / 4 Yrs.	
Available HP	DURATION	HP (4-Yr.)		HP (3-Yr.)	CY (overburden)	CY (rock)	GAL (diesel fuel)	CY (overburden)	CY (rock)
57,000	0	5,400		4,750	0	0	720,000	0	0
54,720	2	10,800		8,750			1,440,000		
52,440	4	16,200		13,500			2,160,000		
50,160	6	31,000		14,000			2,880,000		
47,880	8	38,000		16,500			3,600,000		
45,600	10	38,000		16,500			4,320,000		
43,320	12	43,535		18,675			5,040,000		
41,040	14	43,535		18,675			5,760,000		
38,760	16	51,700		22,480			6,480,000		
36,480	18	51,700		27,230			7,200,000		
34,200	20	51,700		22,480			7,920,000		
31,920	22	51,700		18,675			8,640,000		
29,640	24	57,100		18,675			9,360,000		
27,360	26	51,700		16,500			10,080,000		
25,080	28	51,700		16,500			10,800,000		
22,800	30	51,700		14,000			11,520,000		
20,520	32	51,700		14,000			12,240,000		
18,240	34	43,535		13,500			12,960,000		
15,960	36	43,535		8,750	6,530,000	512,000	13,680,000		
13,680	38	43,535					14,400,000		
11,400	40	38,000					15,120,000		
9,120	42	38,000					15,840,000		
6,840	44	27,100					16,560,000		
4,560	46	16,200					17,280,000		
2,280	48	10,800					18,000,000	14,755,000	1,384,000


HP/Duration/Energy
Available HP
Gals. Diesel Fuel
Duration (Months)
57,100
54,816
52,532
50,248
47,964
45,680
43,396
41,112
38,828
36,544
34,260
31,976
29,692
27,408
25,124
22,840
20,556
18,272
15,988
13,704
11,420
9,136
6,852
4,568
2,284
0
0 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38 40 42 44 46 48

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Floating Plant/Equipment Category/Material	# Vessels Floating Plants Probable	TOTAL Installed HP ea. (Including all aux. engines)	
		45+' MLLW / 3 years 7,042,000 CY	50+' MLLW / 4 years 16,139,000 CY
Transportation Vehicles (115 - 425 hp)	60 - 84	270 (16,200)	270 (22,680)
Hydrographic Survey Vessels	1 (2)	215	315 (630)
Launches, Crew/Dredge Assist/Push-Boats	2	700 (1,400)	1,500 (3,000)
Dredge Mechanical Calmshell CB #1 and /#2	2	2500 (5,000)	3,500 (7,000)
Ocean Towing Vessels	3 (5)	3,000 (9,000)	7,200 (25,000)
Split-Hull Dump Scows	5 (7)	60 (300)	165 (1,155)
Drill Towers/Blast Platform Barge #1 (rock/ledge)	1 (2)	2,000	2,500 (5,000)
Dredge Excavator/Backhoe BB #1	1 (2)	3,750	4,000 (8,000)
Explosives Barge	1	55	165
Service Barge (rigging/staging/floating workshop/floating storage)	1	500	750
Misc. Powered Machinery/Equipment (welders, light towers, etc.)	Varies	260	1,000
HP SUB - TOTALS		~22,500	~51,700
		(+ transportation/vehicles)	(+ transportation/vehicles)
USACE Survey vessel		(+ USACE survey)	(+ USACE survey)
See comments / Additional Emitters / Standard Factors			

STANDARD HP / EFFICIENCY FACTORS (Affecting optimum operating parameters and subsequent 'emissions') Include...

Drive train / HP losses
Power vs Transmission range matching ('throttle-up/power-down', 66-83 % rated power)
Fuel type/quality (petrol/bio/syn-diesel)/quality/conditioning (BTU content, energy density, cetane rating, etc.)

>/=500 PPM, 4.5% sulfur, marine-industrial residual diesel (#2)

Ambient/operating (air/fuel) temperatures (intake/exhaust)
Economizers (i.e. turbo-chargers, after treatment(s)/exhaust-fitted catalytic devices, air-box design/intake blowers)
2 vs 4-stroke/cycle
Idle limiting devices (ILD)
Operating modes/durations
Engine condition/age/configuration/usage/coolant-lubricant/temperature
Operator(s)
Ambient temperature/climate/sea conditions (including haul/transportation routes)
Lubrication (petro/bio/syn-products) / Coolant temperature / System (open/closed)
Maintenance/tuning/settings/mixtures (automated in-situ vs manual)
Drag/resistance (wind/water, fouling, hull-shape, steerage, ballast, speed, propulsion type, etc.)
Operating loads/factors
Auxiliary engines (pumps, generators, HPU's, light towers, etc.) and power draws (day/night, panel balancing, etc.)
Environmental resrtictions (whales, etc.)
Incentives/penalties (USCG/USACE/EPA requirements/regulations?!)
Refueling/venting/storage/bunkering (settlement/sediment, [in]-filtration, water content)
Overall efficiency

See comments

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SUMMARY DRAFT

ESTIMATED MINIMUM HP/'ENERGY' REQUIREMENTS/CONSUMPTION

NOTE: Does NOT include; additional/significant emission contributors affecting air/atmosphere quality/conditions, i.e. explosives, transportation vehicles, etc… (See list/worksheet attached)

Total installed HP range = 22,480 + 51,700 = 74,180 / 2 = ~37,090 HP

1-yr. 24/7 = 365 days x 24 hrs. = 8760 hrs. x % efficiency/time (est. xx%) factor(s) = xxxxx hrs.

#1. -45' MLLW… 3 yrs. duration… Production (CY)/Energy Consumption Rate:
6,530,000 CY overburden + 512,000 CY ledge = 7,042,000 CY required (? allowed-OD) dredge material = 6,431+ CY/day (min.)
3-yr. = 1095 days/26,280 hrs. x (1/3, .333) efficiency factor = 8,751 hrs.
22,480 max. HP x (2/3, .666) overlap factor x (2/3, .666) RPM/idle factor = 9,971 final adj. continuous/gross HP
9,971 HP x 8,760 hrs. x .456 SFC / 7.15 = 5,570,673 gals. diesel fuel (energy)

#2. -50' MLLW… 4 yrs. duration… Production (CY)/Energy Consumption Rate:
14,755,000 CY overburden + 1,384,000 CY ledge = 16,139,000 CY required (? allowed-OD) material = 11,054+ CY/day (min.)
4-yr. = 1460 days/35,040 hrs. x (1/3, .333) efficiency factor = 11,668 hrs.
51,700 max. HP x (2/3,.666) overlap factor x (2/3, .666) RPM/idle factor = 22,932 final adj. continuous/gross HP
22,932 max. HP x 11,668 hrs. x .456 SFC /7.15 = 17,064,525 gals. diesel fuel (energy)

NOTES:

Overlap HP and average RPM/idle factors = .666 (applied successively)
(3) / (4) yrs. x days x 24 hrs. x efficiency factor (.333… weather, maintenance, breakdown, etc.) = total effective hours (x adj. gross HP)
(Above definitely does NOT include 'out' and MAY not include all (?) 'required over-depth'… 1 ' in soft + 4' in hard, material)

Significantly less than 50% thermal efficiency is anticipated (As low as 25% not unusual)

SFC = lbs. / HP / hr. 'range'
26 -.38 = .32… .161 -.935 = .548… .40 -.60 = .50… / 3 = .456
Diesel fuel (energy) weighs 7.15 lbs./gal.

Total (equivalent) quantity low quality (sulfur = 500 ppm/4.5%) 'energy'/petrol-diesel fuel = 5,570,673 - 17,064,525 gals. min.
.791 - 1.057 gal./CY min. (high due to large amount of rock/blasting/surface area unknown major factor…)
1 barrel = 42 gals.

ADDITIONAL/SIGNIFICANT 'EMITTER' CONTRIBUTORS AFFECTING AIR/ATMOSPHERE QUALITY/CONDITIONS

Paints/solvents
Cleaners/detergents
Conditioners/additives
Leaks/spills/run-off/discharges/releases/waste/by-products
Miscellaneous lubricants/grease
Hydraulic and lube-oil
All auxiliary engines
Shore power
Fuel types (bio-diesel/petro-diesel/syn-crudes (non-petrol-derivative i.e. waste coal)
Evaporation/Convection
Non-ionizing radiation (radar/microwave/EMR/laser/radio transmitters/etc.)
Heat sources
Refrigerants
Noise
Welding/cutting torch (gasses, flux. etc.)
Sewerage/sludge treatment
Atmospheric conditions incident to the event/emission/discharge…
Explosives
'Other' support emitters… (vehicles/transportation, including aircraft/POV's/trucks, etc.)
Indirect/future/long-term effects of the overall improvement project (bigger ships, etc.)

MAJOR PHASES

(NOT adequately broken-down to satisfy contract-required 'CQC Definable Features of Work' or 'APP/SSHP, Job-Activity Hazard Analysis')

PROJECT DEVELOPMENT…Planning/Programming/Desigining/Engineering/Organization/Accounting…
ADMINISTRATION/MANAGEMENT/SUPERVISION…
BCOE Reviews, (Pre)-Solicitation, Bid/Qualify, Award, Pre-Con/MUM (ramp-up milestones)
TRANSPORTATION (land/water-borne/low-level aircraft)
Site Visits (survey/layout) / Stake Holder Meetings (coordination) / Submittals (submit/approve)
Establish Temporary Field Office(s) / Facilities / POC's / Controls (including begin on-site implementation of SSH requirements)
Mobilization (floating plants/equipment/support vessels/crew-labor/staff/technical support)
Rigging/Staging, Assembly, Preparatory Inspections/Testing/Certifications
Environmental (initial/existing/background) sampling/monitoring (personnel, air/terra, water/benthos)
Hydrographic/Aerial Survey(s) ('pre-dredge'… top of existing/overburden exposed rock/ledge)
Navigation/Positioning/Tracking/Recording/Telemetry/Inter-net-work (all floating plant/tugs-scows continuous)
START WORK (milestone)
Operational Trials (floating plants, equipment, support/assist vessels, etc.)
Monitoring… Environmental, Hydrographic Surveys (daily/routine), Technical Assist/QC-QA Support, etc.
Dredge (CB #1 and #2) (remove overburden…)
Hydrographic Survey(s) (bottom of overburden/top of rock)
Ocean Towing/Disposal (assuming no beneficial-use of overburden)
Drill/Blast rock/hard bottom
Excavate (BB)/remove rock
Ocean Towing/Disposal/Beneficial usage (ledge/rock/hard material) cont.
Hydrographic multi-beam (sweep) surveys cont. (final grade, acceptance areas, 30-day/progress payments, after-dredge) cont.
AMENDMENTS (milestone)
Adjusted Work Effort/Amended Schedule
Idle/Down-Time (weather/holiday/site-conditions/mech. failure, maint., safety, changes-mods-disputes, traffic, etc.)
COMPLETION / ACCEPTANCE (milestone)
De-Rig, Force Reduction, Demobilization
Site Restoration, Final as-built records/drawings, Completion documentation/summary reports

DREDGE RESOURCES Include:

Great Lakes Dredge & Dock
Weston-Bean
Weeks Marine
Norfolk Dredging
The Dutra Group
Manson Construction
Bean-Stuyvesant
Jay (Michael) Cashman, Inc.
DonJon Marine Co., Inc.

OEM REFERENCES Include;

Cummins
GM/Detroit Diesel/EMD/Daimler-Chrysler/Mercedes
Caterpillar
Kubota
John Deere
Liebherr
Perkins
Onan

E/PUBLICATIONS Include:

Google.com
WorkBoat (including 2005 Diesel Engine Directory/Power Guide)
World Dredging, Mining and Construction
Maritime Reporter

BOSTON HARBOR PROBABLE/POSSIBLE EQUIPMENT... 22,480 - 51,700 (grand total max./available) HP

1 - (2) Excavator/backhoe (BB) dredge (rock)... 3,750 - 4,000 (total installed) HP ea.

3 generators (50-150 kW) x 165-900 HP ea.
2-4 Winches x 100-900 HP ea.
1-2 HPU x ?HP
3 pumps x 6.5 - 15 HP ea.
1-2 main engines x 1,323-3,046 HP ea.

Examples include:

1 GLDD 'New York' BB, 60-83' reach/depth, 7-25 CY, 60,000 gal fuel... 3,434 HP
2 Dutra 'Antone' BB, Liebherr 996, 24 CY... ~4,000 HP
3 Cashman 'Captain A.J. Fournier' BB, 40-75' reach/depth, Liebherr 944 (1,323-1,523 HP), 7.5-18 CY, 34,000 gal. fuel/14,600 gal. lube oil, 3-spud winches/2-fleeting winches (HP?), 2 generators 100 kW, 1 HPU CAT 3456 ATAAC 500 HP... ~3,300 HP
4 Cashman 'Jay Cashman' BB, 66' reach/depth, Liebherr 995 (2,176 HP), 11.8-30 CY, 60,874 gal. fuel/5,949 gal. lube oil, 3-spud winches, 3-fleeting winches (2 x 200 HP), 3 generators (1) 350kW/(2) 900kW, 1 HPU 40 HP... ~3,750 HP
5 DonJon Marine Co. Inc., 'JP Boisseau' BB, Liebherr 996, 17-24 CY,

2 Mechanical 'clam-shell' (15-35 CY) dredges (CD) (overburden)... 2,500 - 3,500 (8,985 HP industry max) (total installed) HP ea.

3 generators (50-150 kW) x 25-165 HP ea.
2-4 Winches x 100-200 HP ea.
3 pumps x 6.5 - 15 hp ea.
1-2 main engines x 2,550 HP ea.

Examples include:

1 GLDD '#54' CB, 74' depth, 12-30 CY, 40,000 gal. fuel, 2340 HP...
2 GLDD '#53' CB, 60' depth, 12-26 CY, 100,000 gal. fuel, 2550 HP...
3 GLDD '#52' CB, 65' depth, 12-30 CY, 25,400 gal. fuel, 1745 HP...
4 Norfolk 'Atlantic' (aka Dutra 'Super Scoop') CB, 18-38 CY, 2000 HP
5 Norfolk 'Virginian' CB, 16-26 CY
6 Norfolk '#428' CB, 8-14 CY
7 Weeks '#550' CB, 25 CY, 2,100 HP
8 Weeks '#551' CB, 25 CY, 2,100 HP
9 Weeks '#506' CB, 13 CY, 2,200 HP
10 Dutra 'Paula Lee' CB, 17-24 CY, 1,050 HP
11 Dutra 'DB24' CB
12 Dutra 'DB5' CB
13 Manson 'Haakon' CB 24 CY, 1,500 HP
14 Manson 'Viking' CB 24 CY, 1,500 HP
15 Manson 'Njord' CB, 59 CY, 8,000 HP
16 Manson 'Vulcan' CB 24 CY, 1,200 HP
17 DonJon Marine 'Michigan' CB, 16 CY, 1,050 +~450 aux. = 1,500 HP

3 - (5) Tugs (twin screw)... 3,000 - 7,200 (total installed) HP ea.

2 main engines x 1,600-3,000 HP ea.
1-2 Winches x 100-200 HP ea.
2 generators (50-150 kW) x 25-165 HP ea.
Bow thruster
Fire pump 15 HP
Welding machine
Portable pumps (2) x 6.5 hp ea.

5 - (7) Split-Hull Dump Scows 3,300-7,000 CY... 60 - 165 (total installed) HP ea.

1 power-pack (hydraulics) x 45 HP ea.
1 generator x 15 HP ea.
Anchor winch
Portable pump

2 Crew/Work boats/launches/support (dredge assist) vessels... 700 - 1,500 (total installed) HP ea.

2 main engines x 165-545 HP ea.
1-2 winch engines x 100-200 HP ea.
2 generators (50-150 kW) x 25-165 HP ea.
1 pump x 6.5 HP ea.

1 - (2) Survey vessels (SV)... 215 - 315 (total installed) HP ea.

2 engines x 100 -150 HP ea.
1 generator x 15 HP ea.

1 - (2) Drill Towers / Blast Platform (DB)... 2,000 - 2,250 (total installed) HP ea.

1-2 power-packs (hydraulic/pneumatic) x 700 HP ea.
2 winch engines x 100-200 HP ea.
2 generators (50-200kW) x 50-165 HP ea. (CAT 3412S/CAT 342C/6-71 GM Detroit)
2 pumps x 6.5 - 15 HP ea.

Examples include:

1 GLDD 'Apache' DB, 85' depth, 2 x winches/2 x power packs/2 x generators = 2,250 HP, 10,000 gal. fuel...
2 GLDD '#8' DB, 85' depth, 2 x winches/2 x power packs/2 x generators = 2,000 HP, 5,000 gal. fuel...

1 Service/anchor/derrick-barge (floating storage/machine/work-shop,)... 500 - 750 (total installed) HP ea.

1 generator (50-150 kW) x 50-200 HP
1 pump x 6.5 - 15 HP
1-2 winch engines x 100-200 HP ea.
1 smaller crane/hydraulic boom/derrick x 325 HP

Miscellaneous Support Equipment:*Estimate* 300 - 1,000 (total installed) HP

3 Welding machines x 45 - 65 HP ea.

1 Explosives barge… 55-165 (total installed) HP
1 generator x 45 HP
1 pump x 6.5 HP

3 Light Towers x 35 HP ea.

50-60 Transportation vehicles x 115-425 HP ea.
12 crew members/laborers per definable/distinct major/7 'operations'…
Project scheduled 24/7… (probably 2 shifts/day)

INITIAL ENERGY / EMITTER METRICS

(Brake) Specific Fuel Consumption (SFC) (Fuel flow per horsepower… lbs. / HP / hr.)
SFC Range…
Excellent = .260-.278 lbs./HP/hr. exceeding 50% thermal efficiency (more than 50% of the energy in the fuel converted to 'work')
Average = .40-.60 lbs./HP/hr. @ 25-30% thermal efficiency
New engines = .161.lbs./HP/hr. vs Old = .935…
.28 - .36 4-stroke diesel
.32 - .38 2-stroke diesel
.26 - .34 large-industrial diesel
.40 - .48 fuel-injected 4-stroke gas (auto)

Efficiency = 'work' / energy
Power = work per time
Energy = Capacity to do work
Foot pound = work moving weight or force over a distance
Fuel = Energy… (NOTE: consumption/thermal efficiency equations may be outdated/inaccurate due to cleaner bio/syn-diesel fuels)
Diesel = 7.0 - 7.3 lbs./gal. (temp. Depending)
1 gal. diesel = 147,000 BTU… 1 gal. gas = 125,000 BTU
Up to 50% more efficient than gasoline
(Engine-out) Volatile exhaust hydrocarbon organic emissions
Marine/industrial diesel fuels = recycled residual/high sulfur diesel fuels
SO2, NO/X/2, CO/2, soot/particulates with sulfur levels 4.5 % / 500 PPM
NOTE: there are other (types of) air quality (emitter) impacts (See 'Other Considerations' below)
Emission = sub/sequential discharge/release

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BOSTON HARBOR, MASSACHUSETTS
NAVIGATION IMPROVEMENT STUDY

APPENDIX P
MASSACHUSETTS REGULATORY REVIEW DOCUMENTS

This appendix consists of several documents relative to the Commonwealth of Massachusetts' regulatory review requirements and process under the Massachusetts Environmental Policy Act (MEPA):

(1) Massport's April 2013 Draft Section 61 Water Quality Certification Findings, and correspondence with the State following selection of the final recommended plan and project depth optimization and re-initiation of agency coordination in October 2012.

(2) The Secretary of Energy and Environmental Affairs Certificate on the Draft Environmental Impact Report and attached state agency and public comment letters – for comment and response table please see Appendix A – Public Involvement

(3) The Secretary of Environmental Affairs Certificate on the ENF, including EIR Scoping requirements and attached state agency and public comment letters

(4) The MEPA Comment and Response Table listing comments received in response to publication of the Environmental Notification Form for the project at the beginning of the study, with annotated responses and references to the responsive sections of the SEIS/EIR and Feasibility Report.

(5) The Environmental Notification Form and attachments filed by Massport with the Executive Office of Environmental Affairs MEPA Office on 31 January 2003

Based on negotiations with the State, final State action on Water Quality Certification by the Massachusetts Department of Environmental Protection and Federal Consistency Review documents of the Massachusetts Office of Coastal Zone Management, as well as action by the three municipalities, the Cities of Boston, Chelsea and Revere, on local regulatory actions, have been deferred until the Design Phase of the project. The Design Phase includes several investigations and planning efforts critical to securing regulatory approvals for the project.

BOSTON HARBOR
MASSACHUSETTS

NAVIGATION IMPROVEMENT STUDY

FINAL FEASIBILITY REPORT
AND FINAL SUPPLEMENTAL
ENVIRONMENTAL IMPACT STATEMENT
AND MASSACHUSETTS
FINAL ENVIRONMENTAL IMPACT REPORT
(EOEA #12958)

APPENDIX P

MASSACHUSETTS REGULATORY REVIEW DOCUMENTS

THIS APPENDIX WAS UPDATED DECEMBER 2012

PART 1

CORRESPONDENCE WITH THE STATE FOLLOWING IDENTIFICATION OF FINAL RECOMMENDED PLAN OF IMPROVEMENT AND RE-INITIATION OF AGENCY COORDINATION IN OCTOBER 2012

The Commonwealth of Massachusetts
Executive Office of Energy and Environmental Affairs
100 Cambridge Street, Suite 900
Boston, MA 02114

Deval L. Patrick
GOVERNOR

Timothy P. Murray
LIEUTENANT GOVERNOR

Richard K. Sullivan, Jr.
SECRETARY

Tel: (617) 626-1000
Fax: (617) 626-1181
http://www.mass.gov/envir

December 12, 2012

Stewart Dalzell, Deputy Director
Environmental Planning and Permitting
Massachusetts Port Authority
One Harborside Drive, Suite 200S
East Boston, MA 02128-2909

Re: Request for Advisory Opinion
EEA #12958 Boston Harbor Deep Draft Navigation Improvement Project

Dear Mr. Dalzell:

I am writing in response to your letter of November 20, 2012 in which you requested an advisory opinion as to whether changes to the above-referenced project require revisions to the Scope of the Final EIR. A Certificate on the Draft Environmental Impact Report (DEIR) was issued on June 13, 2008 and included the Scope of the Final EIR.

According to your letter and attachment (Executive Summary Figure), the project change consists of a one-foot reduction in project depth in the inner harbor from the President Roads Channel and Main Ship Channel to Massport's Conley terminal. Project depth will be reduced from 48 feet to 47 feet at mean lower low water (MLLW). This change was proposed in response to additional economic studies conducted by the U.S. Army Corps of Engineers (ACOE). No other changes are proposed to project elements that were described and analyzed in the DEIR.

Based on the review of the information you presented, I concur that the project changes do not warrant filing of a Notice of Project Change (NPC) or revisions to the Scope for the FEIR. Please contact Deirdre Buckley, MEPA Analyst, at (617) 626-1040 if you have any questions concerning this matter.

Sincerely,

Maeve Vallely-Bartlett
Assistant Secretary

THE COMMONWEALTH OF MASSACHUSETTS
EXECUTIVE OFFICE OF ENERGY AND ENVIRONMENTAL AFFAIRS
OFFICE OF COASTAL ZONE MANAGEMENT
251 Causeway Street, Suite 800, Boston, MA 02114-2136
(617) 626-1200 FAX: (617) 626-1240

November 29, 2012

Mr. John R. Kennelly
Chief of Planning
Department of the Army
New England District, Corps of Engineers
696 Virginia Road
Concord, MA 01742-2751

Re: CZM Federal Consistency Review Boston Harbor Deep Draft Navigation Improvement Project – DEIR/DEIS; Boston.

Dear Mr. Kennelly:

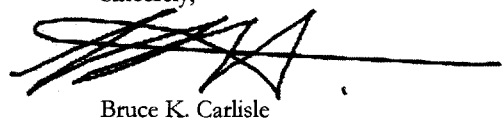
The Massachusetts Office of Coastal Zone Management (CZM) has completed its review of the Draft Environmental Impact Report/Draft Environmental Impact Statement (DEIR/DEIS) for the proposed port improvements in the City of Boston. The project includes improving access to the Conley Terminal for containerships by deepening the harbor's existing 40-foot channels, turning basin, and anchorage to a depth of -47 feet MLLW, with an additional three feet of depth in the Broad Sound North Entrance Channel (up to -50 feet MLLW). The Massachusetts Port Authority (MassPort) would also deepen the berths in the Conley Terminal to at least -50 feet MLLW. The 40-foot lane of the Main Ship Channel above the Reserved Channel and below the Ted Williams Tunnel would be deepened to -45 feet MLLW, access to MassPort's Medford Street Terminal on the Mystic River would be improved by deepening to -40 feet MLLW, and the existing -38 foot channel in the Chelsea River would be deepened to -40 feet MLLW.

Based upon our review of applicable information, we concur with your certification and find that the activity's effects on resources and uses in Massachusetts coastal zone as proposed in the DEIR/DEIS are consistent with the CZM enforceable program policies. We look forward to reviewing the Final Feasibility Report and the joint Final Supplemental Environmental Impact Statement/Final Environmental Impact Report for consistency with CZM's enforceable program policies, when released in 2013.

If the above-referenced project is modified in any manner, including any changes resulting from permit, license or certification revisions, including those ensuing from an appeal, or the project is noted to be having effects on coastal resources or uses that are different than originally proposed, it is incumbent upon the proponent to notify CZM, submit an explanation of the nature of the change pursuant to 15 CFR 930, and submit any modified state permits, licenses, or certifications. CZM will use this information to determine if further federal consistency review is required.

Thank you for your cooperation with CZM.

Sincerely,



Bruce K. Carlisle
Director

BKC/rlb/vg
CZM# 5376

The COMMONWEALTH OF MASSACHUSETTS
BOARD OF UNDERWATER ARCHAEOLOGICAL RESOURCES
EXECUTIVE OFFICE OF ENERGY AND ENVIRONMENTAL AFFAIRS
251 Causeway Street, Suite 800, Boston, MA 02114-2136
Tel. (617) 626-1200 Fax (617) 626-1240 Web Site: www.mass.gov/czm/buar/index.htm

November 27, 2012

John R. Kennelly
Chief of Planning
New England District
US Army Corps of Engineers
696 Virginia Road
Concord, MA 01742-2751

RE: *Boston Harbor, Massachusetts Navigation Improvement Project – Update of the Final Feasibility Report and Final Supplemental Environmental Impact Statement/Final Environmental Impact Report*

Dear Mr. Kennelly,

The staff of the Massachusetts Board of Underwater Archaeological Resources has completed its review of your letter of 11 October 2012 and attached chart regarding the final FR and FSIES/FEIR reports for the above referenced report. We offer the following comments.

The Board provided comments on the draft version of the above referenced report in its letter of 2 June 2008. Based on the information provided in your recent letter, the Board's original comments remain appropriate and applicable to the updated plan.

The Board notes the updated plan specifically calls for deepening access to the Chelsea River. This area is considered archaeological sensitive, particularly in relation to the 1775 Battle of Chelsea Creek and the loss of HMS *Diana*. The recommendation that a remote sensing archaeological survey should be conducted for the areas of potential affect in the Mystic River and Chelsea River Channels remains applicable. The Board looks forward to working with the Corps and its consultants in developing a successful surveying strategy for these areas.

Should you have any questions regarding this letter, please do not hesitate to contact me at the address above, by telephone at (617) 626-1141 or by email at victor.mastone@state.ma.us.

Sincerely,

Victor T. Mastone
Director

Cc: Brona Simon, MHC
Marc Paiva, USACE
Bob Boeri, MCZM
Stewart Dalzell, Massport

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MASSACHUSETTS WATER RESOURCES AUTHORITY
Charlestown Navy Yard
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Boston, MA 02129

Frederick A. Laskey
Executive Director

Telephone: (617) 242-6000
Fax: (617) 788-4899
TTY: (617) 788-4971

November 9, 2012

Mr. John R. Kennelly, Chief of Planning
Department of the Army
New England District, U.S. Army Corps of Engineers
696 Virginia Road
Concord, Massachusetts 01742-2751

Re: Boston Harbor Deep Draft Navigational Improvement Project
EOEEA #12958
Feasibility Report and Supplemental Environmental Impact Report

Dear Mr. Kennelly:

The Massachusetts Water Resources Authority (MWRA) appreciates your recent letter requesting confirmation that our previous comments on the above mentioned project are still valid and remain the same. MWRA reiterates our comments submitted on the Environmental Notification Form dated February 28, 2003 and on the Feasibility Report and Supplemental Environmental Impact Report dated June 2, 2008. MWRA's concerns continue to focus on the need to protect MWRA's infrastructure in two locations within the project area:

- Reserve Channel: where NSTAR's four-mile 115 Kv Submarine Cross Harbor Cable runs the entire length beneath the channel and continues across the Harbor to Deer Island.

- Chelsea Creek: where MWRA has an active 36-inch diameter water main that crosses the Creek supplying East Boston and Logan International Airport.

Reserved Channel: NSTAR Cable

NSTAR's Cross Harbor Cable originates at the K Street Substation in South Boston and services the Deer Island Treatment Plant that serves over 2.5 million people in the metropolitan Boston area. The proposed dredging plan now calls to deepen the harbor's main channels and the lower portion of the Reserved Channel at the Conley Terminal from their existing - 40 foot depth at mean lower low water (MLLW) to a depth of - 47 feet MLLW. In addition to this - 47 foot dredging level, standard procedures require adding an additional two feet (for over-dredge) and in this case, given the presence of ledge, an additional two feet must be factored into the final dredge depth. As a result of these standard dredging procedures, the actual proposed depth of dredge in the Reserve Channel is - 51 MLLW. Most recent underwater surveys have revealed that NSTAR's cable at the highest point is - 52.2, which places the cable at approximately 1.2 feet below the proposed dredging depth.

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As MWRA has said in the past, MWRA's primary concern is that any blasting and dredging as part of this proposal near the cable in the Reserved Channel cannot help but pose a direct threat of damage to the cable which would result in the long-term loss of a vital energy link to its Deer Island facility and, in the process, cause a release of insulating oil in the cable to the waters of Boston Harbor, the same waters which have seen dramatic improvement in quality precisely because of the contributions of that wastewater treatment facility.

The disruption of this primary source of power to the treatment plant servicing over 43 cities and towns in metropolitan Boston would be catastrophic for MWRA over the lengthy period which would be required to replace that cable. It should be noted that even in the short term, any disruption in the use of the cable would require that MWRA depend upon and use its own back-up generating capability, which given today's fuel costs, could result in millions of dollars in annual additional expenditures charged to MWRA's ratepayers, whose municipal budgets are already substantially over-burdened. Additionally, should MWRA's sole source of back-up power fail for any reason, the environmental impacts would be disastrous.

MWRA's National Pollutant Discharge Elimination System (NPDES) Permit, issued by the U.S. EPA and the Massachusetts Department of Environmental Protection, authorizing the discharge of wastewater from the Deer Island Treatment Plant requires two separate power sources to operate MWRA's wastewater treatment and pumping facilities. Any disruption or damage to the capable would eliminate one of MWRA's two existing power sources (the cross harbor cable and the on-island power plant) thereby violating MWRA's permit condition.

For these reasons, it is extremely important that the ACOE and Massport be satisfied that any plans which NSTAR may have to protect or to relocate the cable be sufficient to ensure its integrity. To date, NSTAR has not shared its plans with MWRA. MWRA remains very concerned about the protection of the cable which is a vital and non-expendable item of infrastructure upon which MWRA relies heavily.

Chelsea River: MWRA Section 38 Water Main Crossing

MWRA understands that some dredging has already occurred in Chelsea Creek as part of the Department of Transportation's (DOT) recently completed Chelsea Street Bridge project. MWRA staff worked closely with DOT staff during that project. Now that the Bridge is complete, the proposal calls for further dredging in the channel to a depth of - 40, which is actually - 42 to accommodate a two foot over-dredge. It appears that the proposed depth of - 42 will not impact MWRA's Section 38, a 36-inch water main crossing under the Chelsea River because Section 38 is located at elevation - 45 (top of pipe).

It appears that the proposed dredging width of 175 feet will also not impact the existing water main. The 36- inch main at its - 45 foot depth has a minimum perpendicular width across Chelsea Creek of 195 feet. Therefore there is sufficient "length" of 10 feet on either side of the pipe.

Any future dredging and/or blasting in the Reserve Channel or the Chelsea Creek area should be carefully coordinated with MWRA through the 8 (m) permitting process. The Proponents should contact Mr. Ralph Francesconi at (617) 305-5827 within MWRA's Water Field Operations Group.

Please contact me at (617) 788-1165 if you have questions or need additional information. Thank you for the opportunity to comment.

Sincerely,

Marianne Connolly

Marianne Connolly
Sr. Program Manager, Regulatory Compliance

cc: Mr. Frederick Laskey, MWRA Executive Director
Michael Hornbrook, MWRA COO
Steven Remsberg, MWRA, General Counsel
Kevin McCluskey, MWRA, Dir. Public Affairs
Mike McCarthy, Work Coordination Center Mgr, MWRA
Ralph Francesconi, MWRA Water Field Operations Permitting
Michael Keegan, Project Mgr., US Army Corps of Engineers
Deb Hadden, Massport, Acting Port Director, Massport
Stewart Dalzell, Massport, Deputy Director, Env. Planning & Permitting

C: 2012BosHarDredging 12958ArmyCorp2012Nov9final.doc

THE COMMONWEALTH OF MASSACHUSETTS
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October 24, 2012

John Kennelly
Chief, Planning Branch
New England Division
U.S. Army Corps of Engineers
696 Virginia Road
Concord, MA 01742

Mr. Kennelly,

This morning, the Corps and CZM participated in a conference call regarding the Boston Harbor Deep Draft Navigational Improvement Project. As you know, CZM is in the process of initiating a federal consistency review of the DEIR/DEIS for the project, which was released in 2008. CZM participated in the review of the project as part of the Massachusetts Environmental Policy Act review. At that time, CZM indicated our support for the project and also provided comments on several issues, including the continuation of the Technical Working Group/Technical Advisory Committee, documentation of outer and lower harbor resources (including a pre- and post-blasting/dredging monitoring program), the development of a comprehensive blast plan, and the evaluation of the beneficial reuse of rock material for shore protection and upland use.

In the letter prepared by the Corps on October 16, 2012 in response to these comments, a commitment was made to continue the Technical Working Group/Technical Advisory Committee, to conduct additional resource surveys of benthic and shellfish communities, develop a sequencing plan for the project, including a comprehensive blast plan, and develop a pre- and post construction monitoring program. CZM is requesting additional information on the commitment/planning by the Corps to pursue viable options regarding alternatives for beneficial reuse beyond the creation of rock reefs, including both shore protection and upland use. Several options were discussed during both the Massachusetts dredging Team meeting held on October 19, 2012 and today's conference call, including, but not limited to, use by the Department of Conservation and Recreation for the maintenance of shore protection structures, potential use by MassPort, and use by private aggregate companies.

CZM is preparing to initiate the federal consistency review, and once the additional information has been provided, a scheduling letter will be sent to the Corps. As always, we look forward to working with the Corps on enhancing the capabilities of the port of Boston.

Regards,

Robt L. Boeri

Bob Boeri
Project Review/Dredging Coordinator
Massachusetts Office of Coastal Zone Management

October 18, 2012

John R. Kennelly
Chief of Planning
New England District
US Army Corps of Engineers
696 Virginia Road
Concord, MA 01742-2751

The Commonwealth of Massachusetts
William Francis Galvin, Secretary of the Commonwealth
Massachusetts Historical Commission

Attn. Marc Paiva

RE: Boston Harbor Deep Draft Navigation Improvements Project. MHC #RC.323.

Dear Mr. Kennelly:

Thank you for your letter dated October 11, 2012, received by the Massachusetts Historical Commission (MHC) on October 17, 2012. Staff of the MHC have reviewed the information regarding the change in scope for the project referenced above, and the MHC's files.

Review of the MHC's files indicates that the MHC commented on May 5, 2008, in response to the Corps letter of April 10, 2008. A copy of the MHC's comments are enclosed.

The Corps, in a letter to Massachusetts Board of Underwater Archaeological Resources, dated October 4, 2007, proposed to conduct additional identification surveys for historic properties that may be affected by the project.

In regards to the project change, the MHC advises that the Corps should review the results of previous identification efforts for historic properties in the area of potential effect, and evaluate the potential of the currently proposed project to affect previously identified historic properties, or properties not yet identified that may be located in project area that have not yet been sufficiently surveyed for historic properties.

The MHC looks forward to review of scopes for any additional proposed archaeological identification and evaluation efforts, and the Corps findings and determinations in accordance with 36 CFR 800.

These comments are provided to assist in compliance with Section 106 of the National Historic Preservation Act of 1966, as amended (36 CFR 800). Should you have any questions, please contact me.

Sincerely,

Edward L. Bell
Deputy State Historic Preservation Officer
Massachusetts Historical Commission

Enclosure (MHC 5/5/2008)

xc w/enclosure:
Stewart Dalzell, Massport
Victor T. Mastone, BUAR
Joe Bagley, Boston City Archaeologist

220 Morrissey Boulevard, Boston, Massachusetts 02125
(617) 727-8470 • Fax: (617) 727-5128
www.sec.state.ma.us/mhc

PART 2

SECRETARY'S CERTIFICATION OF THE DRAFT FEASIBILITY REPORT AND SEIS/EIR

MASSACHUSETTS EXECUTIVE OFFICE OF ENERGY AND ENVIRONMENTAL AFFAIRS

WITH ATTACHMENTS

The Commonwealth of Massachusetts
Executive Office of Energy and Environmental Affairs
100 Cambridge Street, Suite 900
Boston, MA 02114

Deval L. Patrick
GOVERNOR

Timothy P. Murray
LIEUTENANT GOVERNOR

Ian A. Bowles
SECRETARY

Tel: (617) 626-1000
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June 13, 2008

CERTIFICATE OF THE SECRETARY OF ENERGY AND ENVIRONMENTAL AFFAIRS
ON THE
DRAFT SUPPLEMENTAL ENVIRONMENTAL IMPACT STATEMENT/
DRAFT ENVIRONMENTAL IMPACT REPORT

PROJECT NAME	: Boston Harbor Deep Draft Navigation Improvement Project (BHDDNIP)
PROJECT MUNICIPALITY	: Boston, Chelsea and Revere
PROJECT WATERSHED	: Boston Harbor
EOEA NUMBER	: 12958
PROJECT PROPONENT	: Massport
DATE NOTICED IN MONITOR	: April 23, 2008

Pursuant to the Massachusetts Environmental Policy Act (G. L. c. 30, ss. 61-62H) and Section 11.08 of the MEPA regulations (301 CMR 11.00), I hereby determine that the Draft Supplemental Environmental Impact Statement(SEIS)/Draft Environmental Impact Report (EIR) submitted on this project **adequately and properly complies** with MEPA and its implementing regulations. The proponent may prepare and submit the Final EIR for review.

The Boston Harbor Deep Draft Navigation Improvement Project (BHDDNIP) proposes navigation channel improvements within Boston Harbor to increase the commercial viability of this working port. The Port of Boston is the largest port in New England for bulk and container cargoes and an important economic engine within the local and regional economy. The Massachusetts Port Authority (Massport) indicates that the Port handles approximately 22 million tons of cargo worth approximately $2.4 billion annually to the regional economy. Its growth is limited due to existing channel depths. This $307 million dollar project will increase the ability of the port to attract larger, deeper draft vessels and thus ensure its continued use by the shipping industry. Comments from resource agencies reflect support for the selection of the

Preferred Alternative while emphasizing the significant amount of work required in the Final EIR to ensure that improvements are planned and implemented with adequate consideration and protection of other interests in the harbor, including fisheries and recreation.

As with the Boston Harbor Navigation Improvement and Berth Dredging Project (BHNIP) (#8695), the ACOE has formed a Technical Working Group (TWG) consisting of resource agencies, environmental advocates, scientists and others, to help advise the proponent through the design, permitting and construction phases of the project. The TWG will develop conditions for the Water Quality Certificate, evaluate disposal alternatives and modify construction and monitoring techniques as necessary to ensure adequate environmental protection.

Project Description

Massport is the local sponsor for this project that will be conducted by the US Army Corps of Engineers (ACOE). The purpose of the project is to meet shipping industry needs by providing access for deeper draft bulk and container vessels to enter the harbor without experiencing tidal delays. The primary goal of the project is to provide deeper access to the Massport Conley Container Terminal; however, additional port improvements in the Main Ship Channel, the Mystic River and Chelsea River are also under consideration. Based on the draft feasibility study included with the Draft SEIS/EIR, the Preferred Alternative includes the following elements:

- deepen the Broad Sound North Entrance Channel to -50 feet mean lower low water (MLLW);
- deepen the President Roads Anchorage and Main Ship Channel to -48 feet MLLW;
- deepen the Main Channel 2,600 feet above the Turning Basin to the Massport Marine Terminal to -45 feet MLLW;
- widen the Main Ship Channel to 900 feet between President Roads Anchorage and Castle Island;
- widen the Main Ship Channel to 800 feet above Castle Island to the Reserved Channel;
- widen the channel bends at Spectacle Island and Castle Island to 1,050 feet;
- widen the Reserved Channel Turning Area to a minimum of 1,500 feet;
- deepen the Mystic River Channel to the Medford Street Terminal to -40 feet MLLW;
- deepen the Chelsea River Channel and Turning Basin to -40 feet MLLW;[1]
- widen the Chelsea River Channel at the bridge approaches, the bend between the two bridges and the area through the Chelsea Street bridge opening;
- deepen the two existing deep berths at Conley Terminal to -42 MLLW to -45 MLLW to allow vessels to employ tidal assistance to enter the Terminal; and
- deepen the Massport Marine Terminal to -45 feet MLLW.

[1] Deepening project depends upon replacement of the Chelsea Street Bridge and removal and relocation of the Keyspan gas siphon.

In addition, channel and anchorage areas not maintained in the past dredging projects may be dredged during the improvement dredging to provide alternative routes for shallow-draft traffic. Areas under consideration include the Broad Sound South Entrance Channel, the 35-foot northern lane of the Broad Sound North Entrance Channel, the Nubble Channel, and the 35-foot West Anchorage at Presidents Road. Approximately 264,000 cubic yards (cy) of maintenance material would be dredged and disposed.

The project will alter approximately 22 acres of previously undisturbed Land Under the Ocean and it could convert approximately 1,100 to 1,300 acres of soft-bottom to hard substrate. The project will take two years to design and from three to five years to complete, with construction estimated to begin in 2011. The ACOE will conduct most of the actual dredging and related mitigation while Massport may implement discrete elements of it. Channel deepening associated with the Preferred Alternative will require blasting and use of a mechanical bucket dredge. It will require removal and disposal of approximately 1,032,000 cy of rock and 11.7 million cy of dredged spoils.[2] Dredged material will consist of glacial parent material and rock ledge that is suitable for disposal at the Massachusetts Bay Disposal Site (MBDS). The glacial materials are composed primarily of Boston blue clay and mixed tills with compacted sands, gravel and cobble. Any silty material not suitable for disposal at the MBDS site will be disposed of in one of the previously permitted Confined Aquatic Disposal (CAD) Cells developed as part of the Boston Harbor Navigation Improvement Project (BHNIP). Although the material may be disposed at the MBDS, the proponent has analyzed and proposed beneficial uses. ACOE proposes to create an extensive artificial reef with the rock material and to cap the EPA Industrial Waste Site (IWS), located adjacent to the MBDS, with the parent material.

Permits and Jurisdiction

The project is undergoing MEPA review and requires the preparation of an EIR pursuant to Section 11.03 (a)(1)(a) because it requires a state permit and will alter more than ten acres of wetlands. The project requires a 401 Water Quality Certification from the Department of Environmental Protection (DEP) and it may require an 8(m) permit from the Massachusetts Water Resources Authority (MWRA). It requires an Order of Conditions from the Boston, Chelsea and Revere Conservation Commissions. Also, it will require Federal Consistency Review by Coastal Zone Management (CZM).

The project requires review under the National Environmental Policy Act (NEPA). The proponent requested that the MEPA/NEPA review processes be coordinated. Accordingly, the proponent submitted a joint Draft SEIS/EIR review document and coordinated the comment period. Although the Draft SEIS/EIR addresses both the federal and state scopes, I am issuing a determination of adequacy only for those portions of the document required in the state scope.

[2] This estimate is based on Table 2-2. This estimate assumes a 2-foot overdepth allowance and a 1:3 side slope for ordinary material. It assumes an additional two feet where ledge is encountered and a 1:1 side slope for rock removal.

Because the proponent is a state agency and, under a cost sharing agreement, is responsible for providing a significant percentage of the project costs, MEPA jurisdiction extends to all aspects of the project that may cause significant Damage to the Environment including air quality, water quality, threatened and endangered species, marine habitat, fisheries and historic and archaeological resources.

Review of the Draft EIR

The Draft SEIS/EIR provides a thorough description of the project and all project elements. It provides a description of existing environmental conditions and resources, includes an alternatives analysis, identifies associated environmental impacts and identifies measures to avoid, minimize and mitigate project impacts.

Review of the BHNIP, the Inner Harbor Maintenance Dredging Project (IHMDP) and the Outer Harbor Maintenance Dredging Project (OHMDP)

As required, the Draft SEIS/EIR includes a section on the previous improvement dredging and maintenance dredging projects. The BHNIP included the maintenance and improvement dredging of the main shipping channels and berths within Boston's Inner Harbor. Over 784,850 cubic yards of dredged material deemed unsuitable for open-water disposal was placed within nine Confined Aquatic Disposal (CAD) cells constructed within the dredging footprint of navigation channels. The planning and permitting process for the BHNIP addressed a number of issues that are directly relevant to the design and implementation of this project. The BHNIP, which was completed in late 2002, provided a framework for creating an environmentally acceptable dredging and disposal plan. It furthered understanding of dredging operations and techniques, provided information about baseline conditions within Boston Harbor, and resulted in the development of guidelines for permitting and constructing CAD cells for disposal of contaminated materials. The recommendations included in the EIR, including water quality monitoring methodology, are informed by the experience developed during the BHNIP.

Although the BHNIP, the Inner Harbor Maintenance Project (IHMDP) and the Outer Harbor Maintenance Project (OHMDP) project provide useful framework for decision-making and baseline environmental information, this project differs from previous projects in two significant respects – the scale of the project and the type of material to be dredged. The improvement and maintenance dredging consisted primarily of dredging significant amounts of contaminated silty material for disposal at the MBDS or within CAD cells. These projects required only a relatively small amount of rock removal, the majority of which could be removed with an excavator, compared to this project. The amount of parent material to be dredged for the BHDDNIP is approximately 3 to 6 times greater than the BHNIP. The Draft SEIS/EIR identifies four fish kill events associated with 13 blasting events during the maintenance project. In light of these events, the amount of rock removal and the blasting associated with its removal is a significant concern.

Alternatives Analysis

The Draft SEIS/EIR includes a draft feasibility study and an alternatives analysis that addresses the Port of Boston's current and future role in maritime commerce and identifies potential levels of future vessel traffic and commerce. The analyses explore options for accommodating increased deep draft vessel traffic in Boston Harbor, including No Action, Non-Structural Alternatives, and Structural Alternatives/Navigational Channel Depths and it includes a cost-benefit analysis for the range of alternatives. In addition, it analyzes alternative dredging methods, dredged material disposal alternatives and beneficial use alternatives for dredged material.

Non-Structural Alternatives include measures that allow for greater unit-loading of vessels without deepening (e.g. use of tides, light-loading of vessels, and lightering), alternative sites for cargo transfer and alternative means of cargo transport. The analysis concludes that management measures are already being employed to the extent feasible and are not sufficient to support deeper draft vessels expected to be employed by the shipping industry. It indicates that there are no other ports within New England with sufficient facilities and depths to provide a viable alternative to Boston Harbor. The analysis indicates that alternative means of cargo transport consist of truck transportation of containers which increase the cost of shipping and add traffic to existing highways with associated increases in emissions of air pollutants.

Structural Alternatives examine channel deepening at a range of depths including deepening the Entrance Channel, Main Anchorage and Main Ship Channel from – 40 feet MLLW up to – 50 feet MLLW, the Mystic River Channel from –35 feet MLLW up to – 40 feet MLLW and the Chelsea River Channel from – 38 MLLW up to – 40 feet MLLW. Improvements were examined in one-foot increments. Three segments in the Main Ship Channel were selected for presentation of costs and impacts (Plan A – 45 foot, Plan B – 48 feet and Plan C – 50 feet). Improvements to support bulk cargo terminals and petroleum terminals were also examined and include: Plan D – extend Main Ship Channel above Reserved Channel to the Massport Marine Terminal to a depth of -45 feet MLLW; Plan E – deepen a small area of the Mystic River Channel up to – 40 feet MLLW to access the Massport Medford Street Terminal in Charlestown to divert smaller bulk cargo operations from the Marine Terminal; and Plan F-deepening the entire Chelsea River Channel to -40 feet to benefit the four active petroleum terminals along this waterway.

The Draft SEIS/EIR estimates dredge quantities associated with each alternative which will range from 6.4 to 15.0 million cy of parent material and 450,000 to 1.5 million cy of rock.[3] The Preferred Alternative, which is described in the introduction to this Certificate, is based on providing the highest net economic benefits while meeting the objectives of the ACOE and Massport. The Draft SEIS/EIR indicates that the Preferred Alternative will evolve based on Congressional authorizations, updated shipping trends and economic information and completion of related projects (e.g Chelsea River project is dependent upon replacement of the Chelsea Street Bridge and removal of the Keyspan gas siphon).

[3] This estimate is also based on Table 2-2.

The Draft SEIS/EIR indicates that use of a mechanical dredge is the only feasible dredging method for rock, tills, stiff clays and other glacial deposits. In addition, because low levels of turbidity are associated with dredging of hard pack Boston blue clay, the proponent asserts that water quality standards will be maintained. The Draft SEIS/EIR identified disposal alternatives evaluated during the BHNIP and indicates that MBDS was the only practical alternative for non-contaminated material and CAD cells for disposal of contaminated material. Consistent with the policy of the ACOE to use dredged material, where practicable, for beneficial use, the Draft SEIS/EIR, evaluates several alternatives to disposal at the MBDS including: use of parent material for lining landfills or capping of the EPA IWS and use of rock for creation of an artificial reef, shore protection or construction. The Draft SEIS/EIR asserts that costs and logistical challenges render use of material for lining landfills, shore protection and/or construction purposes infeasible.

The alternatives analysis is adequate for MEPA purposes. Comment letters from state agencies support the Preferred Alternative, acknowledge that the Preferred Alternative may be revised, and agree that the majority of material will be suitable for disposal at the MBDS. Although material is suitable for disposal in the MBDS, most commentors agree that evaluation of beneficial reuse alternatives for rock was not thorough and should be re-assessed prior to the filing of the Final EIR. I understand that CZM is developing an alternative for reuse of rock material by a materials handling company that would provide a beneficial reuse while minimizing project costs associated with transport and disposal of dredged material. In addition, the Final EIR should address whether any of the material would be appropriate for beach nourishment at Winthrop Beach. Although general support is expressed for habitat restoration through creation of an artificial reef, significant concern is expressed with the siting and scale of the proposed reef. If the artificial reef is intended to serve as a major mitigation commitment, the proponent will need to consult closely with state and federal agencies and, in particular, DMF and NMFS, to identify a site and develop a design that meet the project objectives.

Environmental Conditions and Impacts – Marine Resources

The Draft SEIS/EIR includes a section on existing environmental conditions and environmental impacts of dredging and dredged material disposal including water quality issues, biological resources, threatened and endangered species, and historic and archaeological resources. Information on benthic resources was compiled from data collected by ACOE, MWRA and Massport. Information on lobsters, fisheries and marine mammals is based on data collected by DMF, MWRA and from previous dredging projects. The document addresses resources and impacts related to the dredging sites, the MBDS/IWS and the artificial reef sites. In addition, it addresses the secondary impacts of the deepening project including increased ship traffic and an increase in the size of ships entering the harbor. Although the Draft SEIS/EIR generally characterizes impacts as insignificant and/or temporary in nature, it indicates that the dredging project will alter approximately 22 acres of previously undisturbed bottom and may convert more than 1,100 acres of soft-bottom to hard substrate. In addition, the project will follow over ten years of maintenance and improvement dredging in the harbor that were conducted from 1998 – 2002 (BHNIP), 2004 – 2005 (OHMDP) and the current IHMDP that will extend from 2008 to 2009. The Draft EIS/EIR indicates that, cumulatively, these dredging

projects will result in temporary and permanent impacts to approximately 3,600 acres (although portions of the projects overlap).

The proponent indicates that it will use dredging protocols developed during the BHNIP to minimize turbidity and migration of dredged sediments during dredging and disposal. Measures used during blasting to minimize impacts to fisheries included an independent fisheries observer, side scan sonar fish finder and fish startle system. The Draft SEIS/EIR identifies four fish kill events associated with 13 blasting events as part of the maintenance project (ledge pinnacle removal) that occurred despite implementation of protective measures. The Draft SEIS/EIR does not provide the "After Action Report" referenced in the ENF or identify revisions to protocols or additional mitigation necessary to avoid and minimize these impacts. Although blasting presents the most significant source of risk for impacts to marine resources, the Draft SEIS/EIR does not include an analysis of the location, timing and methods of proposed blasting and anticipated impacts on marine resources. It does indicate that the project will be sequenced to minimize impacts to fisheries but it does provide a schedule that supports this or indicate what factors will be considered for sequencing. Appendix D of the Draft SEIS/EIR provides a schedule (Table D2-30) that projects blasting for a 15-month period from May of 2011 to August 2012 within the Broad Sound North Entrance Channel. Additional blasting would occur in the Chelsea River in May, 2011, in the Presidents Road Anchorage from August to September of 2012, in the Lower Reserved Channel and Turning Basin from April to August of 2013, in the Main Ship Channel Roads to Reserved Channel from August to October 2013, and in the Main Ship Channel Extension to the Massport Marine Terminal from November to December, 2013. Further, the Draft SEIS/EIR indicates that, development of more detailed data, including more extensive borings to characterize the type and quantities of rock to be removed, will not be conducted until the final design phase.

To assist the permitting agencies in their evaluation of the potential impacts of this project within the context of a growing and active harbor, the Draft SEIS/EIR includes a qualitative cumulative impacts analysis that identifies completed, ongoing and planned projects within Boston Harbor and Massachusetts Bay, including the Hubline Submarine Natural Gas Pipeline project and Everett Extension (EEA #12355) and the use of an offshore borrow site (NOMES 1) by the Department of Conservation and Recreation (DCR) as a sand source for the Winthrop Shores Reservation and Restoration Program (EEA #10113). It includes a summary of the project impacts, individually and cumulatively, including the size of the impacted area, the resources impacted by the projects, and the duration of the impacts. In addition, it includes a timeline that shows when the projects are planned to occur in relation to the dredging project. This analysis underscores the amount of activity ongoing and planned within Boston Harbor with the potential to impact up to 18% of Boston Harbor. This analysis demonstrates that the BHDDNIP, HubLine and the the Winthrop Shores Reservation Restoration Program are associated with the vast majority of potential impacts (temporary and permanent).

Comment letters express significant concern with three issues – the timely development of additional data to adequately characterize sediment types and affected resources, development of mitigation to adequately avoid, minimize and mitigate impacts to fisheries, in particular from blasting impacts, and additional consideration of beneficial reuse opportunities. EPA comments indicate that the duration and magnitude of blasting described in the Draft SEIS/EIR is of a scope

that has the potential for serious and significant impacts to fish and marine mammals and is the most significant source of risk for impacts to marine resources associated with the project. Comments from DMF and NMFS stress the importance of this ecosystem to fisheries and indicate the grave status of some species within Boston Harbor. DMF identifies the importance of the project site to several species of shellfish and finfish, including lobster (*Homarus americanus*), soft shell clam (*Mya arenaria*), mussels and winter flounder (*Pseudopleuronectes americanus*). In addition, several diadromous species utilize the area including rainbow smelt (*Osmerus mordax*), Atlantic tomcod (*Microgadus tomcod*), white perch (*Morone Americana*), and river herring (*Alosa spp.*). Comments from NMFS also highlight the presence of alewife (*Alosa pseuodoharengus*) and blueback herring (*Alosa aestivalis*). Boston Harbor is classified as Essential Fish Habitat (EFH) for 23 federally managed species including winter flounder and Atlantic cod. DMF has banned fishing for river herring due to population concerns and rainbow smelt is listed as a "species of concern" by NMFS. Commentors indicate that the Final EIS/EIR should include a sequencing plan, blasting plan and pre- and post-monitoring plan to ensure adequate provisions are made to avoid, minimize and mitigate project impacts.

Environmental Impacts – Air Quality

The Draft SEIS/EIR includes an air quality analysis and discusses alternatives for establishing consistency with the federal Clean Air Act (CAA) General Conformity provisions (section 176(c)(1)). MassDEP's role in a general conformity determination under federal regulation is to review and provide comments on conformity determinations. Federal actions must support the goals of the Massachusetts State Implementation Plan (SIP) and be shown not to:

- Cause or contribute to new violations of any national ambient air quality standard (NAAQS) in any area;
- Increase the frequency or severity of any existing violation of any NAAQS or interim emission reductions;
- Delay timely attainment of any NAAQs or interim emission reductions.

The Draft SEIS/EIR includes an air quality analysis for the No Build, Plan A and Plan C. The analysis indicates that emissions associated with both alternatives would exceed the general conformity deminimis thresholds.

The proponent has identifies two approaches to address general conformity. It can structure the project to ensure its emissions are below identified thresholds or it can offset the total emissions of the projects through emission reductions projects or through the purchase of emission reduction credits. The Draft SEIS/EIR indicates that, without a work stoppage, the project will likely be subject to the General Conformity provisions of the CAA. The EIR indicates that sufficient emission reductions credits are available to offset project emissions and that the costs of this alternative are equivalent to those associated with the cost of one mobilization and demobilization of the project.

The EIR identifies two options (Alternatives 1 and 2) to reduce emissions below the general conformity review thresholds. Both alternatives propose the replacement of older, higher emitting equipment with newer and cleaner burning equipment in 2011 and beyond and extend the dredging schedule to reduce annual emissions associated with the project. Alternative 1 would increase the dredging schedule by 6 months and Alternative 2 would increase the dredging project by four years. Extension of the dredging schedule through work stoppages will not reduce actual emissions associated with the project. The use of cleaner burning equipment will provide a relatively small decrease in overall emissions. Nitrogen Oxide (NO_x) emissions associated with these alternatives would remain close to the deminimis level under the general conformity requirements.

Comments from MassDEP indicate that the proponent should explore additional mitigation strategies, including the use of emission reduction credits to offset emissions. MassDEP comments also express support of the use of lower emitting nonroad engines for the project and identify the need to verify how this strategy will be implemented and enforced. In addition, MassDEP notes that if the proponent chooses to delay the project schedule, it should consider targeting dredging operations in the pre-or post-ozone season.

Comments from EPA express concern with the approach to general conformity and, in particular, with the potential impacts to marine resources associated with an extended schedule which would increase the duration of impacts and therefore the recovery period. EPA indicates that the proponent should further consider the use of emission credits and/or offsets and that the approach to general conformity be fully vetted for public review as part of the environmental review document rather than addressed during the final design process. They note that a general conformity analysis requires a public review process and issuance of a final conformity determination prior to the issuance of the Record of Decision (ROD) and, therefore, draft conformity findings should be reviewed prior to the close of the NEPA process.

Impacts to Historic and Archaeological Resources

The Draft SEIS/EIR identifies potential impacts to historic and archaeological resources. It indicates that, based on remote sensing surveys and vibracore investigations, significant cultural resources are unlikely to be encountered in the Main Ship Channel, the extension of the Main Ship Channel above the Turning Basin and in the Mystic River. It indicates that borings and remote sensing surveys should be conducted for the widening of the Chelsea River Channel to assess the presence of cultural resources. The Draft EIS/EIR indicates that the proponent will continue its consultations with the Massachusetts Historical Commission (MHC) and the Massachusetts Board of Underwater Archaeological Resources (BUAR).

Conclusion

Review of the Draft SEIS/EIR, review of comment letters and consultation with state agencies indicate support for the proposed project. Although additional review of alternatives is not warranted, there are significant outstanding issues that must be resolved regarding development of measures to avoid, minimize and mitigate project impacts. These outstanding issues can be addressed in the Final EIR and the proponent may prepare and submit the Final

EIR for review. I expect that the proponent will fully address the issues identified in the Scope below. In particular, I note that failure to adequately characterize resources could lead to requirement of more conservative mitigation measures in state permits.

In the event that the Final EIS does not fully address issues, the comment letter from EPA has noted that a supplemental NEPA process may be necessary to provide to agencies and the public supplemental information during the design phase of the project. I note that the MEPA regulations allow the filing of a Notice of Project Change (NPC) subsequent to the review of the Final EIR that can be used to provide public review of significant changes to the project and/or development of additional information/analysis.

SCOPE

The Final EIR should follow Section 11.07 of the MEPA regulations for outline and content, as modified by this scope. It should include a copy of this Certificate and of each comment received.

Marine Resources

Regulatory Consistency

The Water Quality Certificate, issued by MassDEP, will be the vehicle for establishing enforceable mitigation commitments. Adequate resource characterization and development of mitigation commitments will be necessary for CZM to issue a federal consistency statement. The Final EIR should provide additional information on 401 Water Quality Certification standards and criteria and demonstrate how the project is being designed to ensure consistency with these requirements. MassDEP, as the permitting agency, will incorporate requirements for fisheries protection into the Water Quality Certificate based on consultation with DMF. As noted previously, provision of adequate resource characterization and mitigation developed in response to these findings will balance the need for more conservative mitigation approaches such as strict dredging windows. Best management practices will need to be developed based on available technology.

The ACOE has committed to convening an interagency underwater blasting technical working group with federal and state resource agencies to focus on construction sequencing for several areas of the harbor, constraints on work during certain tidal and weather conditions, operational changes and equipment changes. As noted previously, the Final EIR must provide more information on sequencing including the location, timing and methods of proposed blasting and anticipated impacts on marine resources. The Final EIR should further illustrate how much hard bottom is impacted, how much will be converted to other habitat and how much may be created within the project site. In addition, a pre- and post-monitoring plan must be developed for the project as a whole, including the artificial reef if that remains as a project component.

The Final EIR should identify total impacts (permanent and temporary) to Land Under the Ocean. It should include a timeline and plans that clearly illustrate where and when the BHNIP, IHMDP, OHMDP and the BHDDNIP overlap. It should provide a plan that clearly delineates areas that BHDDNIP will alter that have not been disturbed by the BHNIP, IHMDP and OHMDP. The Final EIR should include maps that clearly delineate resource areas including eelgrass beds and shellfish habitat. In addition, the Final EIR should assess noise impacts associated with the blasting, in particular, for blasting associated with the Mystic River and Chelsea River.

Monitoring Program

Resource agencies identify the need for an environmental monitoring plan to assess the recovery period of impacted areas. The monitoring plan should be included in the Final EIR. Its scope and duration should be developed in consultation with the working group. It should include pre- and post-monitoring, real-time information on the impacts of blasting and reporting protocols. The Final EIR should identify the extent of suspended sediment dispersion resulting from dredge operations and indicate how the plume is modeled and verified.

Resource Characterization

Comments from CZM and DMF indicate that additional information on shellfish, fish, benthic infauna and epifauna, and other species of decapod crustaceans is necessary to adequately evaluate baseline conditions and recovery. The lack of site specific data for the blast area is of particular concern due to potential impacts to relatively stable exposed bedrock seafloor habitat. A minimum of one year of fisheries data should be collected to support the development of a sequencing plan. The total amount of conversion of soft-bottom habitat to hard substrate should be identified and conversion should be identified on project plans.

In addition, CZM notes that the Draft SEIS/EIR identifies the presence of scallops in the outer and lower harbor, with areas of coarser-grain material and encourages the development of additional resource characterization and monitoring to further characterize these resources. DMF notes particular concern with softshell clam habitat that will be impacted by dredging in the Chelsea River, including permanent loss through habitat conversion. The Final EIR should include a clear delineation of the shellfish habitat potentially impacted by dredging and assess the functional loss to other species. The Final EIR should identify measures to avoid, minimize and mitigate impacts to these resources. In addition, the Final EIR should identify any elements of the project that are located within the Cod Conservation Zone.

The proponent should consult with MassDEP, as the permitting agency, DMF and CZM regarding further characterization of resources prior to the filing of the Final EIR.

Sequencing Plan

The sequencing plan should include a plan for sequencing the most disruptive and potentially damaging aspects of the project (e.g. blasting) to avoid sensitive locations during

critical times of year. Additional resource characterization, including a minimum of one year of biological surveys to assess fisheries resources and use of habitat, should be completed to support a rational sequencing plan. It should identify the volumes of material that will be dredged in what time periods and it should consider timing of disposal (i.e. dredge contaminated in early phases so that it can be capped with clean material dredged in subsequent phases). The Proponent should consult with DEP, as the permitting agency, and DMF to determine what additional data is necessary to support the sequencing plan and the monitoring plan. As noted previously, the proponent may choose to more fully characterize the resources affected by the project or may be subject to a more conservative management approach including time-of-year restrictions.

The proponent should establish plans for communication with the fishing and lobstering communities regarding construction activities and timing to avoid impacts and conflicts.

Blasting Plan

The blasting plan should be included in Final EIR to understand impacts and potential recovery of the area and plan for modifications that may be necessary as the project proceeds. ACOE has indicated it will provide an "After Action Report" to provide information and determine what lessons can be learned from 2007 fish kills. This report must be included in the Final EIR and will inform development of the blasting plan. The blasting plan should consider avoidance measures such as shifting of channel limits and, where feasible, removal of rock with a large toothed bucket mounted on an excavator. It should consider additional technological approaches, sequencing and time of year restrictions. Technological approaches could include use of additional acoustic fish exclusion devices and consideration of bubble curtains. The proponent should commit to provide an independent third party observer that will consult with the TWG and ensure procedures are followed or modified on a real-time basis.

Threatened and Endangered Species, Marine Mammals

Comments from NMFS indicate that its previous determination that the project is likely to have no adverse affect on marine mammals was based on removal of two to six cy of material and did not identify the need for blasting for rock removal. NMFS comments indicate the need to reinitiate consultation and provide additional information regarding the potential impacts of blasting on marine mammals.

EPA has indicated that ACOE should evaluate the potential for impacts of blasting on the recently installed buoy listening and monitoring system. This system was designed to reduce the likelihood of ships colliding with whales by providing close to real time information regarding the presence of whales in the shipping channel.

Disposal and Reuse of Dredged Materials

The Draft EIS/EIR proposes to use dredged materials to cap the EPA IWS and to create an artificial reef. The Draft EIS/EIR indicates that five sites were evaluated for creation of an

artificial reef based on ACOE siting criteria. These were narrowed to two sites - one site in Massachusetts Bay and one site in Broad Sound. The Draft EIS/EIR indicates that, dependent upon the final alternative selected and the reef design, the project would alter 220 to 530 acres of soft bottom habitat.

As noted previously, comment letters indicate the need to re-assess beneficial uses for the rock material. Comments urge the proponent to reconsider upland disposal options as a first priority and creation of the proposed reef as a secondary consideration. The proponent should consult with CZM regarding an upland disposal alternative that is being developed by its staff and address its viability in the Final EIS/EIR.

Comment letters indicate that, based on the information provided in the Draft EIS/EIR, both sites support a diverse and abundant benthic community, include substantial hard bottom habitat and are productive for managed species such as winter flounder and red hake. Comments from DMF indicate that the proponent should use the DMF Artificial Reef Policy for developing site selection and monitoring and consider application of the site selection model used by DMF for creation of the Hub Line cobble reef. If the proponent wants to include an artificial reef alternative in the Final EIR, it should continue consultation with the TWG to develop alternatives that may better meet the identified goal of providing fish habitat. The Final EIR should define more precisely the potential for impacts associated with the project, assess the loss of soft bottom habitat and related impacts and include a monitoring program to document colonization rates and other indicators of habitat creation.

EPA and CZM support use of parent material to cap the IWS in Massachusetts Bay. EPA comments indicate that the capping of the site is an opportunity to further reduce the remaining risk associated with waste barrels that may still exist at the site. The results of the preliminary capping demonstration, which will be conducted as part of the OHMDP, should be reviewed by the TWG and included in the Final EIR.

The Final EIR should address whether any of the material that will be dredged is appropriate for placement on Winthrop Beach for its beach nourishment program (EEA #10113). The proponent should assess the compatibility of material with Winthrop Beach using the additional geotechnical investigations that will be conducted for the BHDDNIP. The proponent should consult with the DCR and the Town of Winthrop regarding this assessment.

Technical Working Group (TWG)

The EIR clearly states the proponent's commitment to ongoing participation in the project by the TWG. I expect the TWG will participate in the development of the Final EIR, as well as final design, to further develop monitoring and mitigation requirements. Close cooperation between the proponent and state and federal agencies during the design phase of the project must be built in to ensure that final plan meets goals of the proponent while avoiding, minimizing and mitigating project impacts. During dredging operations, the TWG should be convened on a regular basis to assess the success of control measures and review project progress.

CZM has suggested the creation of a technical advisory sub-committee, facilitated by an independent, third-party contractor, to manage unforeseen developments as they arise during the construction phase of the project. The contractor would coordinate with the independent fisheries observer during dredging operations to provide a rapid, coordinated response from agency and community representatives. The Final EIR should indicate whether the proponent will incorporate this measure into its management plan.

Air Quality

I urge the proponent to provide a revised approach to conformity within the Final EIR and to consult with and EPA and MassDEP regarding this approach. As noted previously, comment letters, including letters from MassDEP and EPA, indicate that the proponent should explore additional mitigation strategies, including the use of emission reduction credits to offset project related emissions. The Final EIR should identify how use of lower emitting nonroad engines and extension of the dredging schedule will implemented and enforced and should consider targeting dredging operations in the pre-or post-ozone season. In addition, the Final EIR should identify impacts to marine resources associated with an extended schedule. Consistent with EPA's comment that draft conformity findings should be reviewed prior to the close of the NEPA process and issuance of the Record of Decision (ROD), the Final EIR should provide additional information regarding measures for establishing consistency with general conformity and include a general conformity finding. Consistent with comment letters, I urge the proponent to commit to the purchase of emission reduction credits.

Historic and Archaeological Resources

Comments from MHC indicate that it anticipates continued consultation with ACOE regarding the methodology and results of its cultural resource surveys. Comments from BUAR indicate that it has consulted with ACOE regarding mitigation for previous dredging projects and has been satisfied with findings and recommendations of archaeological surveys conducted to date. BUAR concurs with the recommendation that a remote sensing archaeological survey should be conducted for the areas of potential affect in the Mystic River and Chelsea River channels.

Harbor Infrastructure

The EIR identifies potential conflicts with existing harbor infrastructure including tunnels and utility crossings. It identifies a potential conflict with the 115 Kv Submarine Power Cable that extends from the Reserved Channel to Deer Island and is the primary source of power to the Deer Island Treatment plant. The cable construction, operation and maintenance and associated substations is borne entirely by the MWRA and its ratepayers. The proposed limit of the project may deepen the Reserved Channel at or deeper than the current location of this cable. NSTAR documents indicate that the cable was installed at approximately -50 feet MLLW with variations higher and lower along its course. The permit for the cable required it to be buried at -60 feet MLLW to avoid conflicts with deepening projects. The Draft SEIS/EIR indicates that the

ACOE, which issued a Section 10 permit for the cable, has referred the matter to the U.S. Attorneys' office as an enforcement action. The U.S. Attorney's office is negotiating with MWRA and NSTAR to address the conflict with the BHDDNIP.

MWRA comments express significant concern with the impacts of blasting and dredging on this cable and identify the need for additional survey work to determine the precise location and depth of the cable.

The Final EIR should provide an update on negotiations, indicate who will be responsible for identifying actual locations and depths of existing infrastructure that could be directly affected by the project's construction, who is responsible for related costs, and asses the feasibility and cost of relocating the cable.

MWRA comments also note that work within the Chelsea River must be carefully coordinated with the MWRA to avoid impacts to its 36" water main and three wastewater crossings. In addition, the comments note that this element may require a 8(m) permit.

Mitigation

The Draft SEIS/EIR identifies the following measures to avoid, minimize and mitigate project impacts:

- Sequencing to minimize impacts on fish and shellfish populations;
- Preparation of an "after action report" to provide information on all of the blasting events associated with fish kills;
- Establishment of an interagency underwater blasting technical working group comprised of federal and state resource agencies;
- Use of a fisheries observer, side scan sonar fish finder and fish startle system to minimize impacts to fisheries during blasting;
- Prohibition on blasting when schools of fish, sea turtles or mammals are observed in the vicinity;
- For any disposal of contaminated material, proponent will follow protocol for disposal in CAD cells developed through BHNIP;
- Creation of artificial reef with rock material to preserve space in MBDS and provide mitigation for habitat impacts;
- Remote sensing surveys and borings of the northern portion of the Presidents Road Anchorage and area of the Chelsea River proposed for widening to identify historic resources and proposed rock reef sites;
- Remote sensing surveys of proposed rock reef sites to identify historic resources; and
- Development of a disposal plan at the MBDS and a capping plan at the IWS to avoid located shipwrecks;
- Development of a communications system to provide notice to lobstermen and fishermen prior to drilling, blasting and dredging operations; and

- Replacement of older, higher emitting equipment with newer and cleaner burning equipment in 2011 and beyond and extension of the dredging schedule to reduce annual emissions associated with the project.

The Final EIR should include an updated and revised mitigation section including a summary of all mitigation measures to which the proponent has committed. It should include draft Section 61 Findings for the 401 Water Quality Certificate. Mitigation should address temporary, short-term and long-term impacts.

It should indicate whether the proponent will develop compensatory mitigation plans for direct and indirect mortality of fisheries resources, delayed recovery of habitat and areas of habitat that are permanently lost or altered.

Response to Comments

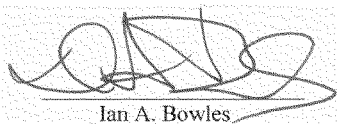
To ensure that the issues raised by commentors are addressed, the Final EIR should include a response to comments. This directive is not intended to, and shall not be construed to, enlarge the scope of the Final EIR beyond what has been expressly identified in the initial scoping Certificate or this Certificate. The Final EIR should include a copy of this Certificate and a copy of each comment letter received. I defer to the proponent as it develops the format for this section, but it should provide clear answers to questions raised.

I note the comment letter submitted by the Town of Winthrop expressing concern with the scale of the proposed project, impacts on fisheries habitat and potential changes to sediment transport patterns. I expect the ACOE will provide a response to those issues that are within the Scope of this Certificate and, in particular, address the potential of the project to affect long-term sediment transport patterns.

Circulation

The Final EIR should be circulated in compliance with Section 11.16 of the MEPA regulations. Copies should be sent to any state agencies from which the proponent will seek permits or approvals, to the list of "comments received" below, to the Conservation Commissions in Boston, Revere and Chelsea and copies should be provided to the public library in Boston, Revere and Chelsea.

June 13, 2008
Date



Ian A. Bowles

Comments received:

6/2/08	Board of Underwater Archaeology (BUAR)
5/28/08	Coastal Zone Management (CZM)
6/3/08	Department of Environmental Protection (DEP)
6/2/08	Division of Marine Fisheries (DMF)
5/5/08	Massachusetts Historical Commission
6/2/08	Massachusetts Water Resources Authority (MWRA)
5/23/08	U.S. Environmental Protection Agency (EPA)
6/2/08	National Marine Fisheries Service (NMFS)
6/2/08	City of Boston/The Environment Department
6/2/08	The Boston Harbor Association (TBHA)
6/2/08	Save the Harbor/Save the Bay
5/30/08	Town of Winthrop/Town Council

IAB/CDB/cdb

The COMMONWEALTH OF MASSACHUSETTS
BOARD OF UNDERWATER ARCHAEOLOGICAL RESOURCES
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June 2, 2008

Curtis L. Thalken
Colonel, District Engineer
New England District
US Army Corps of Engineers
696 Virginia Road
Concord, MA 01742-2751

RE: *Boston Harbor, Massachusetts Navigation Improvement Project - Draft Feasibility Report and Supplemental Environmental Impact Statement and Massachusetts Draft Environmental Impact Report* (EOEA #12958)

Dear Colonel Thalken:

The staff of the Massachusetts Board of Underwater Archaeological Resources has completed its review of Appendix M (Cultural Resources Investigations and Coordination) of the above referenced report and offers the following comments.

The Board has been in regular consultation with the Corps in developing a satisfactory research design and methodology to locate and identify potential submerged archaeological resources that could be impacted by this project. The Board has concurred with the findings and recommendations of the archaeological surveys conducted to date in support of this project (as detailed in the Board's correspondence of 26 August 2002, 18 July, 9 September 2003 and 22 June 2006), specifically for the Main Ship Channel, Reserved Channel and its Turning Area, President Road Channel Reach and Anchorage, and the North Entrance Channel from Broad Sound. Comment BUAR #1

The Board also concurs with this report's recommendation that a remote sensing archaeological survey should be conducted for the areas of potential affect in the Mystic River and Chelsea River Channels, should proposals to deepen these areas be implemented. The Board looks forward to working with the Corps and its consultants in developing a successful surveying strategy for these areas. Comment BUAR #2

Should you have any questions regarding this letter, please do not hesitate to contact me at the address above, by telephone at (617) 626-1141 or by email at victor.mastone@state.ma.us.

Sincerely,

Victor T. Mastone
Director

Cc: Brona Simon, MHC
Marc Paiva, USACE-NED
Bob Boeri, MCZM
Brad Washburn, MCZM
Deirdre Buckley, MEPA
Ellen Berkland, City of Boston

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June 2, 2008

Curtis L. Thalken, Colonel
U.S. Army Corps of Engineers
District Engineer
ATTN: Programs and Project Management Division (Mr. Michael Keegan)
696 Virginia Road
Concord, MA 01742-2751

RE: Feasibility Report and Draft Supplemental Environmental Impact Statement/Environmental Impact Report (Draft SEIS/EIR), Boston Harbor Deep Draft Navigation Improvement Project; Boston, Chelsea, Revere

Dear Colonel Thalken,

The Massachusetts Office of Coastal Zone Management (CZM) has completed its review of the above-referenced Feasibility Report and Draft Supplemental Environmental Impact Statement/Environmental Impact Report (Draft SEIS/EIR) and recommends the preparation of a Final Environmental Impact Statement/Environmental Impact Report for the project.

Project Description

The U.S. Army Corps of Engineers, in partnership with the Massachusetts Port Authority, are proposing to deepen the Port of Boston to allow deeper draft bulk and container vessels to enter without experiencing tidal delays in order to position the port to effectively meet current and future cargo needs of the shipping industry. The proposal recommends the deepening of the Broad Sound North Entrance Channel, the lower Main Ship Channel through President Roads to the Reserved Channel, the President Roads Anchorage Area, the lower Reserved Channel, and the Reserved Channel Turning Area to -48 feet at mean lower low water (MLLW), with an additional two feet of depth in the Entrance Channel (to -50 feet MLLW). The proposal also includes widening the Main Ship Channel to 900 feet through the reaches between President Roads and Castle Island and to 800 feet ahove Castle Island to the Reserved Channel; widening the Reserved Channel Turning Area to 1,600 feet; and further widening in the channel bends at Spectacle Island and Castle Island. The Main Ship Channel would be deepened for an additional distance of 2,600 feet above the expanded Reserved Channel Turning Area to -45 feet MLLW; the 9.1-acre, 35-foot channel lane approach to the Medford Street Terminal in the Mystic River would be deepened to -40 feet MLLW; and the 38-foot Chelsea River Channel and Turning Basin would be deepened to -40 feet MLLW, with accompanying widening of the bridge approaches, the bend between the two bridges, and through a new Chelsea Street bridge opening. These improvements would require the removal and disposal of between 6.6 and 14.8 million cubic yards of parent material and between 450,000 and 1.4 million cubic yards of rock.

Project Comments

CZM supports the proposed improvements to Boston Harbor included in the deepening project. Boston is the premier New England port for bulk and container cargoes, and the improvements will increase the ability of the port to attract larger, deeper draft vessels and thus improve the commercial viability of the port. As the project proceeds through the preparation of the Final EIS/EIR, the design phase, and the state permitting process, the proponents should provide additional information and discussion on the issues identified below.

Technical Working group/Technical Advisory Committee

CZM has participated in the Technical Working Group (TWG) for the completed Boston Harbor Navigation Improvement Project (BHNIP) and continues to believe that the ongoing participation of this group is critical to the success of the proposed project. Close cooperation between the project proponents and state and federal agencies during the design phase of the project must be built in to the process to ensure that the final plan both meets the goals of the proponents while avoiding or minimizing the potential environmental impacts. CZM also suggests the establishment of a smaller technical advisory sub-committee, facilitated by an independent, third-party contractor, to manage situations as they arise during the construction phase of the project. This model was employed during the BHNIP and was very successful in allowing the project to proceed with minimal delays.

Comment CZM #1

Outer and Lower Harbor Resources

The information provided on the general abundance and distribution of the American lobster was sufficient to understand the population characteristics of the project area. However, there was little or dated information on the other potentially impacted natural resources such as shellfish, fishes, benthic infauna and epifauna, and other species of decapod crustaceans (e.g. rock crabs). The lack of site-specific data for the blast areas is of particular concern due to the potential impacts to the relatively stable exposed bedrock seafloor habitat. The area to be blasted is largely different than the proposed dredging areas. The seafloor in the inner and lower harbor is largely comprised of relatively mobile soft sediments that support a dynamic community of benthic infauna and epifauna typical of highly disturbed environments. The area to be blasted in the outer harbor is in an area of hard bottom (bedrock and boulders) that is presumably very stable and not highly disturbed, potentially supporting a stable community. A pre- and post blasting/dredging monitoring program of the impacted areas, particularly the areas to be blasted and outer and lower harbor resources would allow for a sufficient description of the baseline characteristics and potential impacts, while facilitating the monitoring of recovery in the area.

Comment CZM #2

Comment CZM #3

The Draft EIS/EIR indicates the presence of scallops in the outer and lower harbor, with areas of coarser-grain material. Scallops are an important commercial resource and indicative of the presence of coarse-sand to cobble substrate. This substrate is also valuable habitat to a number of marine species, including early benthic phases of Atlantic cod and American lobster. The resource characterization and monitoring should include a variety of techniques to assess benthic habitats, as sediment profile imaging (SPI) is only suitable for collecting data on sessile infauna and epifauna in soft sediments. A combination of underwater observations (e.g., diver-based and/or underwater vehicle), benthic grabs, and SPI would be useful to fully describe the resources. Further details on the ecological characteristics of the outer and lower harbor natural resources would better allow an understanding of potential impacts and the development of mitigation measures and strategies.

Comment CZM #4

Environmental Consequences and Blast Plan

A comprehensive blast plan should be developed to better understand not only the impacts and potential recovery of the area, but to allow for any modifications of the plan that may be required as the project proceeds. The blast plan should include details regarding methods and materials to ensure that the minimum blast effect is generated. The blast plan should also include a

Comment CZM #5

detailed fish-startle system description to be developed in consultation with state and federal regulatory agencies. This system should include strict guidelines on implementation and review procedures to ensure the most effective protection to fishes and resources in the project area. An independent third party observer should also be present during the project to ensure that these procedures are followed or modified on a real-time basis with the TWG.

Comment CZM #6

Consideration should also be given to harvesting American lobsters and rock crabs from the blast areas as part of the plan to limit the impact to these valuable commercial fisheries. Substantial concentrations of attached shellfish such as mussels, encountered in the blast area should also be harvested and relocated as appropriate. These harvested resources could be transported to similar nearby habitat, helping to minimize the impacts associated with the removal of this valuable habitat.

Comment CZM #7

In order to make informed decisions regarding the potential impacts to demersal eggs, benthic invertebrates, or fishes, the pattern of sediment settling around the dredge as well as the concentration of total suspended solids in the sediment plume should be modeled. This information may have been already determined using the SSFATE model, however the data and associated maps were not presented. The only modeling presented in the Draft EIS/EIR relates to the increase in harbor currents upon completion of the deepening project.

Project Sequencing

Comment CZM #8

Boston Harbor is habitat to a number of managed and regulated fisheries. Both anadromous and catadromous species pass through the harbor and are species of concern for the project. Winter flounder use the area for both spawning and rearing. The determination of project sequencing should be addressed to avoid or minimize the effects on the species at different times during the year. Sequencing the most disruptive and potentially damaging aspects of the project (e.g. blasting) to avoid sensitive locations during the critical time of year, while continuing to work in less sensitive areas, would allow for a timely completion of the project. This sequencing should be developed with the input of the Massachusetts Division of Marine Fisheries and the National Marine Fisheries Service.

Beneficial Use

Comment CZM #9

A better understanding of the need for a rock reef using blasted rock in Massachusetts Bay is required to make an appropriate judgment on the proposal. In general, there is not a lack of hard bottom in the bay and it is not likely to be the limiting factor for American lobster populations. The creation of the proposed rock reef for the benefit of the American lobster may not be warranted and may simply replace an existing productive habitat with rocky material. Both sites that are proposed (Broad Sound and Massachusetts Bay) were found to support a diverse and abundant benthic community with numbers of organisms on the order of tens of thousands per square meter. The applicant found that these proposed conversion sites were productive habitat for managed species such as winter flounder and red hake. CZM suggests that rather than convert existing, productive soft bottom habitat to hard bottom, the proponent further evaluate the use of rock material as shore protection and for upland use. In previous correspondence, CZM has identified potential locations for the material.

Comment CZM #10

CZM supports the plan to use parent material, primarily composed of Boston blue clay, to cap the Industrial Waste Site in Massachusetts Bay. This project may result in the elimination of hazardous materials being dispersed to the water column or recovered during (illegal) commercial fishing operations. Results of a preliminary capping demonstration using material obtained from the present maintenance project should be reviewed by the TWG and used to design the capping project.

Federal Consistency

The proposed project is subject to CZM federal consistency review and must be found to be consistent with CZM's enforceable program policies. For further information on this process please contact Robert Boeri, Project Review Coordinator, at (617) 626-1050, or visit the CZM web site at www.state.ma.us/czm/fcr.htm.

Comment CZM #11

Sincerely,

Leslie-Ann McGee
Director
Massachusetts Office of Coastal Zone Management

LAM/bkc/tc/taw/rlb

cc: Karen Adams, U.S. Army Corps of Engineers
Mike Keegan, U.S. Army Corps of Engineers
Catherine Rogers, U.S. Army Corps of Engineers
Jacquelyn Wilkins, Massachusetts Port Authority
Deb Hadden, Massachusetts Port Authority
Brad Washburn, Massachusetts Office of Coastal Zone Management
Ben Lynch, Massachusetts Department of Environmental Protection
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Eileen Feeney, Massachusetts Division of Marine Fisheries
Mark Rousseau, Massachusetts Division of Marine Fisheries
Tim Timmermann, U.S. Environmental Protection Agency
Ed Reiner, U.S. Environmental Protection Agency
Phil Colarusso, U.S. Environmental Protection Agency

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LAURIE BURT
Commissioner

Ian A. Bowles, Secretary
Executive Office of Environmental Affairs
100 Cambridge Street
Boston MA, 02114

RE: Boston Harbor Deep Draft Navigation Improvement Project
EOEA File No. 12958

Attn: MEPA Unit-Deirdre Buckley

Dear Secretary Bowles:

The Massachusetts Department of Environmental Protection (MassDEP) has reviewed the Feasibility Report and Draft Supplemental Environmental Impact Report/Environmental Impact Statement (DSEIR/EIS) for the Boston Harbor Deep Draft Navigation Improvement Project proposed by the U.S. Army Corps of Engineers and Massachusetts Port Authority (Massport). The purpose of the project is to allow access to Boston Harbor by deeper draft vessels without delays due to tidal cycles. The proposed project includes the following changes to the Main Channels, which would result in the removal of approximately 953,000 cubic yards (cy) of rock and 11.1 million cy of dredged material: deepening the 40-foot lane of the Broad Sound North Entrance Channel to 50 feet MLLW and widening it to allow turning of larger vessels; widening and deepening the Main Ship Channel from the Main Ship Channel to Reserved Channel to 48 feet MLLW; deepening the President Roads Anchorage to 48 feet MLLW to accommodate two large vessels at anchor; widening and deepening the lower reach of Reserved Channel; and widening and deepening the Reserved Channel Turning Basin. The project also includes: deepening a 2600 foot length the Main Ship Channel above the Reserved Channel Turning Area to 45 feet MLLW, requiring the removal of approximately 246,300 cy of dredged material and 78,400 cy of rock; deepening a 9 acre area of the Mystic River Channel to 40 feet, generating 67,100 cy of dredged material; and deepening and widening the Chelsea River Channel and Turning Basin to 40 feet MLLW, requiring the removal of 342,600 cy of dredged material and 500 cy of rock. Material unsuitable for disposal at the Massachusetts Bay Disposal Site (MBDS) is proposed to be placed in existing and proposed Confined Aquatic Disposal cells in Boston Harbor, or beneficially reused.

MassDEP generally supports the proposed improvements to support the working port areas of Boston Harbor. The project will require a s.401 Water Quality Certificate under 314 CMR 9.00 to ensure that the dredging and in-state disposal activities meet state Surface Water Quality Standards (314 CMR 4.00). In addition, MassDEP, as noted below, MassDEP will perform an Air Quality General Conformity Determination. Comment DEP #1

Dredging comments

Beneficial Reuse

The DSEIR/EIS proposes to beneficially reuse some of the clay parent material to use as a cap over contaminated material at the Industrial Waste Site (IWS) in Massachusetts Bay. MassDEP recommends that the proponent explore additional options to reuse the material to be generated by this project. Specifically we recommend that the FEIR explore the following:

- The proponents should perform a community outreach effort to provide coastal communities with an opportunity to use the material for projects addressing shoreline erosion, beach renourishment, and other needs. Comment DEP #2
- As sequencing allows, clean material may function as a suitable cap over material to be disposed of in a Confined Aquatic Disposal (CAD) cell. Comment DEP #3
- Rocky material may provide suitable habitat in some instances. MassDEP recommends that the proponents continue to consult with the Division of Marine Fisheries and other resource agencies to develop a suitable habitat enhancement project. Comment DEP #4

Project sequencing:

The FEIR should further develop, to the greatest extent possible, a sequence of the proposed activities. MassDEP believes that appropriate sequencing can serve to minimize or avoid some of the impacts associated with this project. In particular, performing blasting activities should be performed so as to avoid times that may result in impacts to fish spawning. Comment DEP #5

Refinement of the sequence of project activities may also result in environmental benefits during disposal activities. For example, MassDEP generally recommends that the most contaminated dredged material be placed at the bottom of a CAD cell to maximize the separation of such materials from aquatic habitats. Ideally, dredging of the most contaminated material should occur early so that it will be the first to be disposed of in the CAD cell. Similarly, dredging of suitably clean material at an appropriate time could facilitate its use as a cap over the CAD cell. Comment DEP #6

Technical Working Group

MassDEP believes that because of the scale and duration of the project, the Technical Working Group (TWG) will play a critical role in the success of the project. For longer-term design issues, the TWG can provide input on minimizing impacts through the use of Best Management Comment DEP #7

Practices based on Best Available Technology. The proponents should also continue to develop a framework for providing the TWG with regular updates during the construction period, particularly for communicating unexpected occurrences that require a rapid, coordinated response from agency and community representatives. To facilitate the timely response by the TWG, the proponent should provide a third-party contractor that reports to the group. The proponents should also use the TWG to help develop means of communicating with affected users of Boston harbor, particularly fishermen and recreational and commercial boaters.

Air Quality General Conformity Determination

The requirements for General Conformity are contained in section 176(c)(1) of the federal Clean Air Act and in the General Conformity regulations promulgated by EPA in 1993 (40 CFR Part 51, Subpart W, and 40 CFR Part 93). In general, federal actions must support the goals of the State Implementation Plan (SIP) and be shown to not:

- Cause or contribute to new violations of any national ambient air quality standard (NAAQs) in any area;
- Increase the frequency or severity of any existing violation of any NAAQs; or
- Delay timely attainment of any NAAQs or interim emission reductions.

The General Conformity regulations apply to nonattainment areas where the estimated emissions from the action meet or exceed specified emission rates for each NAAQs. Eastern Massachusetts is currently classified as a moderate nonattainment area for the eight-hour ozone standard and, therefore, the emission rates below that are contained in the General Conformity regulations apply to the proposed Boston Harbor Navigation Improvement Project (BHNIP). However, it should be noted that the U.S. Environmental Protection Agency adopted a more stringent eight-hour ozone standard in 2008 of 0.075 ppm. While MassDEP submitted an attainment demonstration to EPA under the eight-hour ozone standard adopted in 1997, additional reductions in ozone precursors may be needed to attain the 2008 standard.

- Volatile organic compounds (VOC) – 50 tons/year
- Nitrogen oxides (NOx)) – 100 tons/year
- Carbon monoxide (CO) – 100 tons/year

In summary, the criteria for determining conformity for ozone nonattainment areas are as follows (see 40 CFR Part 51.858):

- The total of the direct and indirect emissions from the project are included in the SIP;
- The total of the direct and indirect emissions from the project are fully offset within the same nonattainment area through revision to the SIP or a similarly enforceable measure that affects emission reductions so that there is no net increase in emissions of that pollutant;
- The state air agency makes a determination that the total of the direct and indirect emissions from the project would not exceed the emission budgets in the SIP;

- The state air agency makes a commitment to a SIP revision to achieve the necessary reductions prior to the federal action.

The DSEIR/EIS includes a general conformity analysis and presents an emissions analysis for the no action alternative and two additional build alternatives: Alternative 1 – 45 foot deep MLLW navigation channel; and Alternative 2 – 50 foot deep MLLW navigation channel. Both build alternatives show that the emissions would exceed the general conformity deminimus review thresholds. (See Tables 4-4 and 4-7 for Alternatives 1 and 2, respectively.) To address the exceedances and to reduce emissions below the general conformity review thresholds, the DSEIR/EIS proposes two primary emission reduction options for Alternatives 1 and 2 – the replacement of older, higher emitting equipment with newer and cleaner burning equipment in 2011 and beyond and extending the dredging schedule to spread out peak year emissions over the dredging schedule. Comment DEP #8

MassDEP supports the use of lower emitting nonroad engines for the project and notes that this strategy will significantly reduce ozone precursor emission (VOC and NOx) as well as particulate matter emissions. The proponent should verify how this strategy will be implemented and enforced (e.g., through contract specifications). MassDEP also suggests that the proponent explore whether there are any possible engine retrofit opportunities to further reduce emissions.

The extension of the dredging schedule, while it will reduce yearly emissions, will still result in NOx emissions close to the deminimus level under the general conformity requirements. Without this strategy, the proponent would be required to fully offset the increase in NOx emissions. MassDEP suggest the proponent explore additional mitigation strategies including the use of emission reduction credits to avoid these additional emissions. Finally, the proponent should present more detailed information on the dredging schedule within each year and explore targeting dredging operations in the pre- or post-ozone season. As noted above, additional reductions in ozone precursors may be needed to attain the more protective eight-hour standard adopted by EPA earlier this year.

Sincerely,

Philip Weinberg
Associate Commissioner

Cc: Paul Diodati, DMF
Tim Timmermann, EPA
Bob Boeri, CZM

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Paul J. Diodati
Director

Deval Patrick
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Ian A. Bowles
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Mary B. Griffin
Commissioner

June 2, 2008

Ian A. Bowles, Secretary
Executive Office of Environmental Affairs
Attention: MEPA Office, Deirdre Buckley
100 Cambridge Street
Boston, MA 02114-2150

Re: The Boston Deep Draft Project, EEA #12958

Dear Secretary Bowles:

The Division of Marine Fisheries has reviewed the Draft Feasibility Report and Draft Supplemental Environmental Impact Statement/Draft Environmental Impact Report (DEIR) prepared by the U.S. Army Corps of Engineers (the Corps) in partnership with the Massachusetts Port Authority (Massport) for additional dredging in Boston Harbor, Mystic River, and Chelsea River. The DEIR builds on two previous documents: the Final EIR prepared in 1995 for dredging to improve navigation in Boston Harbor and the DEIR prepared in 2006 for maintenance dredging that is occurring now. We offer the following comments for your consideration and recommendations for fisheries habitat concerns that should be more specifically addressed in the Final EIR (FEIR).

Background and resource information

This project continues work begun in 1995 dredging for navigation improvements, and continued through the 2007 maintenance dredging efforts. For operational reasons, work has proceeded for nearly this entire period, often during critical periods for fish spawning and passage. We acknowledge that Boston Harbor is an industrial harbor and a Designated Port Area. However, that designation should not devalue the fisheries resources and habitat found at the proposed work sites, particularly since significant efforts have been made to improve water quality in Boston Harbor. The status of some fisheries that use this ecosystem is considered grave or dire,[1] and requires the utmost consideration for management.

Comment DMF #1

Since virtually every estuarine waterway in Massachusetts is impacted by dredging, there is considerable concern regarding cumulative impacts on the overall ecosystem. Also, because of continuous dredging, these projects change from a potential acute, short-term impact to the fisheries resources, to an impact that is chronic and considerably different in nature. It is clear by the paucity

Comment DMF #2

[1] *MarineFisheries* has banned fishing for river herring due to population concerns. Also, rainbow smelt is listed as a "species of concern" by NMFS.

of impact reports from Boston Harbor and the Providence River that limited lessons have been learned regarding the environmental impacts of previous dredging projects, let alone how a chronic impact would differ from an acute impact.

The wide geographic area of this proposed project supports several species of shellfish and finfish, including lobster (*Homarus americanus*), soft shell clam (*Mya arenaria*), mussels, and winter flounder (*Pseudopleuronectes americanus*). In addition, several diadromous species utilize the area including rainbow smelt (*Osmerus mordax*), Atlantic tomcod (*Microgadus tomcod*), white perch (*Morone americana*), and river herring (*Alosa* spp.) (Chase, 2008). Boston Harbor is classified as Essential Fish Habitat (EFH) for winter flounder by the New England Fisheries Management Council (NEFMC) and the ASMFC classifies spawning areas such as these as Habitat Areas of Particular Concern (HAPCs).

General Comments

Comment DMF #3

This DEIR relies primarily on information collected and examined for previous efforts. This level of information was deemed insufficient in the past, and in many cases did not address the questions being asked. As such, the proponents have not conducted a sufficient impact assessment. Since there is a long history of dredge projects in Boston Harbor, we would anticipate a more directed and comprehensive effort to address specific environmental concerns. Instead, the DEIR provides only a review of previous documents and we are concerned about the precedent this sets.

Comment DMF #4

Many decisions regarding this project are being left to the discretion of the technical working group (TWG) and are promised during the design phase. We commend the open process that Massport and the Corps have established to date. However, given the experience of these proponents in the project location, the significant resources that exist within the Corps to study the impact of dredging on marine habitats, and a recent history of impacts to marine resources resulting from the current and ongoing dredge activities in Boston Harbor, a more concerted effort could have been made to examine potential impacts of this new project.

Direct mortality of fisheries resources

Comment DMF #5

This past year, several fish kills occurred during blasting events in Boston Harbor. This was not addressed in the DEIR. The FEIR should include a full assessment of the reasons behind the fish kills, and a reasoned response to avoid such impacts in the future. A multi-pronged approach is necessary to avoid impact to valuable fisheries resources:

Comment DMF #6

- We recommend the proponents **generate a sequencing plan**. Based on available information, *MarineFisheries* routinely provides recommendations for time-of-year (TOY) work windows to minimize impacts on fisheries resources. However, specific project sequencing should be based on biological surveys (ideally three years) to assess fisheries resources, annual trends, and their use of the affected habitat areas.

Comment DMF #7

- We recommend the proponents **generate a blast plan**. This must include an analysis of the previous fish kills and the efforts being proposed to avoid such impact (e.g. use of additional acoustic fish exclusion devices, standards for their use, consideration of bubble curtains, and adherence to time of year recommendations). Sample plans and standards have already been provided to the proponents, but were not included in the DEIR.

Comment DMF #8

- Since early benthic phase (EBP) lobsters are present year-round in hard bottom habitats (Glenn, 2008), impact to this resource is unavoidable. Therefore, we recommend the proponents **clarify how much hard bottom is impacted, how much is removed, and how much is created by the project within the project site**. The proposed addition of off-site hard bottom habitat as a beneficial use should not be included in this assessment.

Comment DMF #9

- We recommend a specific examination of the recovery time of hard bottom habitats that **includes sampling of EBP lobsters**.

The DEIR notes that softshell clam habitat will be impacted by potential work in the Chelsea River (p. 3-23). *MarineFisheries* expects that the proposed dredging will result in a permanent loss of this habitat by direct removal of shallow water and resulting conversion to an environment that may not support shellfish. The ecosystem function of these shellfish beds, which include softshell clam, razor clam, and blue mussels, may be significant to other fish and invertebrate species foraging in this area. Nevertheless, this habitat impact is not addressed in the DEIR. Therefore, we recommend the following: Comment DMF #10

- The FEIR should include **a clear delineation of the shellfish habitat potentially impacted by dredging and an assessment of the functional loss to other species.**
- We recommend that the applicants coordinate with the State and Federal resource agencies to address **avoidance, minimization and mitigation options for this lost habitat in the FEIR.**

Beneficial use of dredge material

We applaud the Corps continued efforts to explore beneficial uses of dredge material. However, upland reuse and disposal options have not been given due attention.

- We recommend that the proponents **revisit upland disposal options in the FEIR.** Only after upland disposal options have been exhausted should subaqueous habitat conversions be considered. Comment DMF #11
- If a subaqueous disposal is required, we recommend the proponents **revisit the site selection model** for the habitat enhancement in conjunction with the TWG. The currently proposed preferred subaqueous sites, Broad Sound and Massachusetts Bay, already have significant habitat value and substantial hard bottom habitat. Edge habitat and habitat heterogeneity are crucial, so these sites may not be appropriate for disposal of all (or any) of the rock material. We are concerned the proponents are making the assumption that hard bottom habitat is always considered of higher value than supplanted habitat and that artificial reefs have the same ecosystem function as natural reefs. Comment DMF #12
- We encourage the proponents to use the guidance provided by *MarineFisheries*' Artificial Reef Policy for site selection and monitoring. Application of the site selection model used by *MarineFisheries* for creation of the HubLine cobble reef would also improve the evaluation process.

Invasive Species

Dredge barges are in the harbor for many months. They typically travel at low speeds so eliminating hull fouling organisms is not a primary maintenance objective. As such, the barges pose a significant threat to the Boston Harbor environment via the introduction of invasive species. Eradication of marine invasive species has rarely been successful and has been enormously costly,[2] therefore,

- We recommend the **proponents identify measures to prevent the spread of invasive species** in the FEIR. For example, the proponents could require regular inspection of the barges. Such inspection should occur when a barge enters the harbor from use in foreign harbors or those known to have species invasive to New England. The inspection should follow a protocol approved by the technical working group. Comment DMF #13

Monitoring

[2] The cost of eradicating the seaweed, *Caulerpa taxifolia,* from California lagoons ran over $4 M and monitoring continues (Anderson, 2005). Failed attempts at eradication include the green crab, *Carcinus maenas,* on the west coast (Grosholz, 2000), the tunicate, *Didemnum* from barges and pilings in New Zealand and Washington state (Coutts, 2007), and the sea star, *Asteria amurensis* from a bay in Australia (Thresher, 2001).

Comment DMF #14 As previously mentioned, improvement or maintenance dredging has been occurring since 1998 in Boston Harbor. Improvement dredging, by its very definition, is designed to alter the environment as permanently as possible. It is also inaccurate to identify impacts from maintenance dredging as temporary since they are chronic in nature and will result in permanent functional changes of the habitat. We recommend that the chronic impacts associated with ten plus years of dredging be fully addressed.

Comment DMF #15
- We recommend the proponents **include an environmental monitoring system, specifically designed to evaluate the recovery period of impacted areas** should the project move forward.

Comment DMF #16
- We request a **delineation of areas where habitat conversion will take place** due to dredging and/or blasting activities.

Comment DMF #17
- We request that the applicant **provide an estimate of the time needed for recovery** of all impacted habitats.

Mitigation

Even after appropriate avoidance and minimization measures are applied in the project design and sequencing, the proposed project may still result in unavoidable impacts, including habitat conversion and direct and indirect mortality of fisheries resources.

Comment DMF #18
- We recommend that the applicant begin developing **compensatory mitigation plans** for direct and indirect mortality of fisheries resources, delayed recovery of habitat, and areas of habitat that are permanently lost or altered.

Thank you for considering our comments. If you have any questions about this review or require more information please contact Kathryn Ford in our New Bedford office at (508) 990-2860, ext. 145.

Sincerely,

Paul J. Diodati
Director

Cc: M. Keegan, ACOE
C. Boelke, NMFS
B. Boeri, CZM
P. Colarusso, US EPA
C. Bush, Boston Conservation Commission
K. Chin, DEP
T. Evans, M. Rousseau, E. Feeney, F. Germano, DMF
R. Lehan, DFG

References

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May 5, 2008

The Commonwealth of Massachusetts
William Francis Galvin, Secretary of the Commonwealth
Massachusetts Historical Commission

Curtis L. Thalken
Colonel, District Engineer
New England District
US Army Corps of Engineers
696 Virginia Road
Concord, MA 01742-2751

RE: Boston Harbor Deep Draft Navigation Improvements Project, Boston, Chelsea, Everett, MA.
MHC #RC.323. **EEA#12958.**

Dear Mr. Thalken:

Thank you for seeking the comments of the Massachusetts Historical Commission, the office of the Massachusetts State Historic Preservation Officer, for the project referenced above, in regards to the filing of a Draft Supplemental Environmental Impact Statement/Report.

Review of MHC's files indicates that the Corps (COE to Massachusetts Board of Underwater Archaeological Resources, 10/4/2007) proposed to conduct additional identification surveys for historic properties that may be affected by the project. Comment MHC #1

MHC looks forward to reviewing the scope of the proposed identification efforts, continuing to consult on the methodology and results, and to review of the Corps determinations in accordance with 36 CFR 800.

These comments are provided to assist in compliance with Section 106 of the National Historic Preservation Act of 1966, as amended (36 CFR 800) and MEPA (301 CMR 11). Should you have any questions, please feel free to contact Edward L. Bell of my staff.

Sincerely,

Brona Simon
State Historic Preservation Officer
Executive Director
State Archaeologist
Massachusetts Historical Commission

xc:
Marc Paiva, COE-NED
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June 2, 2008

Colonel Curtis L. Thalken
U.S. Army Corps of Engineers
696 Virginia Road
Concord, Massachusetts 01742

Re: Boston Harbor Deep Draft Navigational Improvement
Project - EOEEA #12958
Feasibility Report and Supplemental Environmental Impact Report

Dear Colonel Thalken:

The Massachusetts Water Resources Authority (MWRA) appreciates the opportunity to review the Draft Feasibility Report and Supplemental Environmental Impact Report on the Boston Harbor Deep Draft Navigational Improvement Project. The Reports prepared by the U.S. Army Corps of Engineers (Corps) in partnership with the Massachusetts Port Authority (Massport) discuss proposed channel and associated navigation feature improvements to the Port of Boston. The Massachusetts Water Resources Authority (MWRA) is represented on the Dredging Technical Working Group created by Massport and the Corps in an effort to stay informed and participate in the review of this project in Boston Harbor.

The purpose of the Boston Harbor Navigation Improvement Study is to identify, formulate, evaluate and screen potential alternatives for channel deepening and related improvements at the Port of Boston. The recommended plan proposes to deepen the harbor's main channels and the lower portion of the Reserved Channel at the Conley Terminal from their existing - 40 foot depth at mean lower low water (MLLW) to a depth of between - 48 and - 50 feet MLLW. Additional minor port improvements in the Mystic and Chelsea Rivers and in the Main Ship Channel above the Reserved Channel are also under consideration. In all areas an overdepth dredging allowance of two feet is required, and in addition, in areas where ledge is encountered, (as is the case in the Reserved Channel) an additional two feet of required rock removal will be performed for vessel safety which would bring the Reserved Channel to a finished depth of not less than -52 feet MLLW.

Comment MWRA #1

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MWRA's comments are focused upon the need to protect existing infrastructure in the project area, specifically NSTAR's cable in the Reserved Channel, and MWRA water and sewer lines that may be impacted by the project located in the Chelsea River.

Reserved Channel: NSTAR Cable

MWRA commented on the Environmental Notification Form filed (ENF) in 2003, and at that time raised concerns specifically related to the potential impacts to NSTAR's existing cross-harbor electric cable located in the Reserved Channel that provides power to the MWRA's Deer Island Treatment plant serving over 2.5 million people in the metropolitan Boston area. While the cable is owned by Harbor Electric Energy Corp., a wholly owned subsidiary of NSTAR, the cost of construction, operation and maintenance of the cable and associated substations is borne entirely by MWRA and its ratepayers. The cable and substations were installed at a cost of approximately $40 million and provided power for construction of the $3.5 billion federal court-mandated Boston Harbor Project and presently provides power for the operation of the Deer Island Treatment Plant (DITP).

It appears that the proposed limit of this project will seek to achieve channel depths at or deeper than the current location of NSTAR's 115Kv Submarine Power Cable which feeds the MWRA's Treatment Plant. NSTAR's documents indicate that this cable was installed at approximately –50 feet with variations higher and lower along its course, and that the new dredging project proposes to increase the cut from the existing channel depth of – 40 to a new depth of -50 to -52. The permit required the cable to reach a depth of -60 MLLW which, based upon the "as-built" data of NSTAR's contractor, was not achieved. MWRA has the same concerns now as it did when it commented upon the ENF -- the proposed depths of a newly-deepened channel directly threaten the current location of the cable.

Comment MWRA #2

Comment MWRA #3

Comment MWRA #4

MWRA's primary concern is that any blasting and dredging as part of this proposal near the cable in the Reserved Channel cannot help but pose a direct threat of damage to the cable which would result in the long-term loss of a vital energy link to its Deer Island facility and, in the process, cause a release of insulating oil in the cable to the waters of the harbor, the same waters which have seen dramatic improvement in quality precisely because of the contributions of that wastewater treatment facility. The potential for disruption of this primary source of power to the treatment plant servicing over 43 cities and towns in metropolitan Boston would be catastrophic for MWRA over the lengthy period which would be required to replace that cable. It should be noted that even in the short term, any disruption in the use of the cable would require that MWRA depend upon and use its own generating capability which given today's fuel costs, could result in millions of dollars in annual additional expenditures charged to MWRA's ratepayers, whose municipal budgets are already substantially over-burdened. Additionally, should MWRA's sole source of back-up power fail for any reason, the environmental impacts would be disastrous.

Staff at MWRA have attended meetings with the Corps, NSTAR and the US Justice Department over the past several years in response to the Corps' claim raised in 2005 that NSTAR's cable, in certain stretches, was not laid by its contractor as deeply below the channel floor as required by its permit and in response to the Corps' insistence that corrective work be undertaken to bring the cable's location into compliance with that permit. While NSTAR has, over the past several years, identified and examined several alternative protection strategies that it believes would protect its submarine cable, no concrete progress has been made toward finding a solution that will assure that the cable could survive the channel-deepening project. Of the alternatives considered, NSTAR's preferred option for placing protective mats over the cable cannot be expected to work if the cable's current location is already at or above -52 MLLW. Until additional survey work is completed to determine the precise location and depth of the cable, it is impossible to define a protective measure that NSTAR could reliably employ. MWRA does not believe that consensus has been reached which will assure that channel-deepening to the depths desired by the project can be attained while guaranteeing that no damage will be caused to the infrastructure that is critical to MWRA's operations.

Comment MWRA #5

MWRA has worked with the proponents to try to assure that MWRA's electric source is not jeopardized and equally as important, to assure that any costs associated with the protection or deepening of NSTAR's cable are not passed on to MWRA ratepayers. It is hoped that a reasonable solution will be realized to satisfy MWRA's operational and economic issues. MWRA, as a co-permittee of the Corps' cable permit, is already one of the entities targeted for litigation by the Justice Department if the permit conditions are not met. MWRA can ill afford to expose its ratepayers to the costs of replacing a damaged cable, which cannot be repaired via splicing, to the magnitude of the diesel fuel costs which will become necessary during the multiple years that will be required to replace the cable, if damaged, or worst of all, to the prospects of operating DITP with only a single source of power when the plant was designed to operate with a back-up source.

Chelsea River: Section 38 Water Main and Three Sewer Crossings

It appears that the proposed dredging may impact MWRA's Section 38, a 36" water main that crosses under the Chelsea River. The proposed dredging plan calls for the deepening and widening of the Chelsea River Channel to - 40 feet. Section 38 is located at an approximate elevation – 44, so any future dredging and/or blasting in this area should be carefully coordinated with MWRA.

Comment MWRA #6

In addition to the Section 38 water main, there are three wastewater crossings located under the Chelsea River. These include an abandoned siphon, Section 10, an active deep tunnel Section 101, and an active siphon Section 37.5. Various elevation scales have been used by MDC, MWRA's predecessor, and will need to be researched to assure accuracy prior to dredging. We suggest that the proponent coordinate with MWRA permitting staff to identify specific elevations to determine whether or not there will be an impact to these facilities as an MWRA 8 (m) permit will be required for work in this area.

Comment MWRA #7

Comment MWRA #8

Questions regarding 8 (m) water permitting and MWRA's need to protect our water infrastructure should be directed to Ralph Francesconi at 617 305-5827. Permitting issues related to the wastewater crossings should be directed to Kevin McKenna at 617 305-5956.

MWRA understands that the deepening of the Chelsea River beyond the current -38 foot depth is based on the assumption that the Chelsea Street Bridge would be replaced by the Massachusetts Highway Department and that the Keyspan gas siphon would be removed and relocated. MWRA will continue to monitor progress of these projects and work with the Project Proponents to assure that MWRA's infrastructure is protected as all the alternatives are evaluated during the environmental review process.

Comment MWRA #9

Please contact me at 617 788-1165 if you have questions, need additional information or agency coordination to review MWRA engineering plans. Thank you for the opportunity to comment.

Yours truly,

Marianne Connolly

Marianne Connolly
Program Manager, Regulatory Compliance

cc: Deb Hadden, Massport
Michael Keegan, US Army Corps of Engineers

C: MEPA12958BosHarEIRcomments.doc

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION 1
1 CONGRESS STREET, SUITE 1100
BOSTON, MASSACHUSETTS 02114-2023

OFFICE OF THE
REGIONAL ADMINISTRATOR

May 23, 2008

Curtis L. Thalken, Colonel
District Engineer
ATTN: Programs and Project Management Division (Mr. Michael Keegan)
696 Virginia Road
Concord, Massachusetts 01742-2751

RE: Draft Supplemental Environmental Impact Statement and State Draft Environmental Impact Report (DSEIS/DEIR) for the Boston Harbor Deep Draft Navigation Improvement Dredging, Boston, Massachusetts (CEQ # 20080143)

Dear Colonel Thalken:

In accordance with our responsibilities under the National Environmental Policy Act (NEPA) and Section 309 of the Clean Air Act, we have reviewed the U. S. Army Corps of Engineers, New England District (Corps) Draft Supplemental Environmental Impact Statement (DSEIS) for the Boston Harbor Deep Draft Navigation Improvement Dredging project proposed in various areas of Boston Harbor.[1] The DSEIS was prepared by the Corps in partnership with the Massachusetts Port Authority (Massport).

The DSEIS details Massport's goal to establish a deeper channel for access to the Conley Container Terminal in South Boston and to make port improvements in the Mystic and Chelsea Rivers and in the Main Ship Channel above the Reserved Channel. The proposed channel deepening is intended to help reduce tidal delays currently experienced by containerships and bulk carriers that use Boston Harbor. Other anticipated improvements beyond the Corps work to deepen the Federal channels would include work by Massport to deepen vessel berths at the Conley and Marine terminals. The project is expected to generate a total of 12.1 million cubic yards of non-rock dredged material (parent material) and 1.2 million cubic yards of rock.

The DSEIS proposes disposal of the majority of the dredged material at the Massachusetts Bay Disposal Site (MBDS)[2] and proposes the use of some of the non-rock dredged material (parent material) as cover at the former Industrial Waste Site.[3] Based

[1] This letter serves as our comment on the DSEIS and the Draft Environmental Impact Report prepared under the Massachusetts Environmental Policy Act.

[2] The MBDS is approximately 17 nautical miles east of the entrance to Boston Harbor adjacent to the Stellwagen Bank National Marine Sanctuary.

[3] The Industrial Waste Site is located 20 miles east of Boston in 300 ft. of water.

on our review of the information contained in the DSEIS, EPA has no objections to use of the MBDS for disposal of the dredged material. Also, EPA has no objection to the use of parent material as cover at the former Industrial Waste Site, and we view the proposed capping plan as an opportunity to further reduce the remaining risk associated with waste barrels that may still exist at the site.

We focused our review of the DSEIS on air quality impacts, removal of rock in the project area by blasting, and the potential for beneficial reuse of rock material to construct rock reefs. Each of these issues is discussed to varying degrees in the DSEIS. These issues are discussed below and in detail in the attachment to this letter.

The DSEIS describes a range of potential impacts to air quality that are directly related to the type of dredging equipment utilized and the duration of the work, and proposes a multi-year dredging/construction schedule in order to keep annual emissions low enough to avoid triggering the offset requirements of the Clean Air Act general conformity regulations. We are concerned that the DSEIS focuses on avoiding the need to offset emissions without a vigorous examination of the possible cost to the marine environment as a result of lengthening construction schedules to reduce annual emissions. We request that the Corps provide a full analysis of the environmental tradeoffs and costs of avoiding triggering the air emission offsets. In addition, this analysis should include developing contract provisions to require the cleanest construction equipment available and fully consider offsets as a means to reduce the in-water construction time/marine impacts of the project. We are also concerned that as currently written, the DSEIS postpones the determination on the use or viability of emission credits/offsets until the design phase after completion of the NEPA process and Record of Decision. We do not support this approach because we believe the issue should be fully vetted for public review as part of the EIS. We recommend that the Corps work closely with EPA and other interested state and federal stakeholders to resolve this issue in advance of the publication of the FEIS.

Comment EPA #1

In addition to unresolved air issues the DSEIS lacks information to fully describe the potential impacts associated with proposed rock blasting and the creation of rock reefs--a proposed beneficial use of the dredge material. At a May 19, 2008 interagency meeting the Corps reported that the final extent and amounts of the proposed blasting will not be made known until sometime after the Spring of 2009 when extensive borings will be conducted to characterize the type and quantities of the rock to be removed, and that more specific discussions regarding how the material will be removed will not be possible until that point.

Comment EPA #2

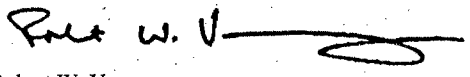
We are concerned that there is only limited information in the DSEIS regarding the potential for impacts and whether measures can be implemented to successfully minimize and mitigate blasting impacts, and that the Corps does not intend to fully address this issue until post EIS design and permitting. In addition, we are also concerned that only limited information is included in the DSEIS regarding the establishment of rock reefs, not enough information to inform a decision whether the proposed sites and potential impacts are acceptable. Our comments in the attachment recommend the establishment

of two advisory panels comprised of state and federal stakeholders (and others as appropriate) to address these outstanding issues.

EPA appreciates the opportunity to offer comments on the DSEIS and encourages the Corps to work closely with EPA and other interested federal and state agencies and other stakeholders to develop strategies to effectively address the air and marine impacts associated with the proposed project. We have rated the disposal of the dredged material at the MBDS and capping of the Industrial Waste Site LO-1 "Lack of Objections-Adequate", in accordance with EPA's national rating system, a description of which is attached to this letter. Moreover, based on a lack of information relative to the extent and impacts of blasting and the proposal to create rock reefs we have rated those aspects of the EIS EO-2 "Environmental Objections–Insufficient Information." We look forward to working with the Corps to resolve these issues and suggest a meeting to discuss our comments more fully. Please feel free to contact Timothy Timmermann of the Office of Environmental Review at 617/918-1025 to set up a meeting.

Comment EPA #3

Sincerely,



Robert W. Varney
Regional Administrator

Attachment

cc:

MEPA Unit

Summary of Rating Definitions and Follow-up Action

Environmental Impact of the Action

LO--Lack of Objections
The EPA review has not identified any potential environmental impacts requiring substantive changes to the proposal. The review may have disclosed opportunities for application of mitigation measures that could be accomplished with no more than minor changes to the proposal.

EC--Environmental Concerns
The EPA review has identified environmental impacts that should be avoided in order to fully protect the environment. Corrective measures may require changes to the preferred alternative or application of mitigation measures that can reduce the environmental impact. EPA would like to work with the lead agency to reduce these impacts.

EO--Environmental Objections
The EPA review has identified significant environmental impacts that must be avoided in order to provide adequate protection for the environment. Corrective measures may require substantial changes to the preferred alternative or consideration of some other project alternative (including the no action alternative or a new alternative). EPA intends to work with the lead agency to reduce these impacts.

EU--Environmentally Unsatisfactory
The EPA review has identified adverse environmental impacts that are of sufficient magnitude that they are unsatisfactory from the standpoint of public health or welfare or environmental quality. EPA intends to work with the lead agency to reduce these impacts. If the potentially unsatisfactory impacts are not corrected at the final EIS stage, this proposal will be recommended for referral to the CEQ.

Adequacy of the Impact Statement

Category 1--Adequate
EPA believes the draft EIS adequately sets forth the environmental impact(s) of the preferred alternative and those of the alternatives reasonably available to the project or action. No further analysis or data collection is necessary, but the reviewer may suggest the addition of clarifying language or information.

Category 2--Insufficient Information
The draft EIS does not contain sufficient information for EPA to fully assess environmental impacts that should be avoided in order to fully protect the environment, or the EPA reviewer has identified new reasonably available alternatives that are within the spectrum of alternatives analyzed in the draft EIS, which could reduce the environmental impacts of the action. The identified additional information, data, analyses, or discussion should be included in the final EIS.

Category 3--Inadequate
EPA does not believe that the draft EIS adequately assesses potentially significant environmental impacts of the action, or the EPA reviewer has identified new, reasonably available alternatives that are outside of the spectrum of alternatives analyzed in the draft EIS, which should be analyzed in order to reduce the potentially significant environmental impacts. EPA believes that the identified additional information, data, analyses, or discussions are of such a magnitude that they should have full public review at a draft stage. EPA does not believe that the draft EIS is adequate for the purposes of the NEPA and/or Section 309 review, and thus should be formally revised and made available for public comment in a supplemental or revised draft EIS. On the basis of the potential significant impacts involved, this proposal could be a candidate for referral to the CEQ.

Additional Detailed Comments on the Draft Supplemental Environmental Impact Statement and State Draft Environmental Impact Report (DSEIS/DEIR) for the Boston Harbor Deep Draft Navigation Improvement Dredging, Boston, Massachusetts

Marine Issues

Blasting

According to the DSEIS, the project will result in the removal of between 450,000 and 1,400,000 cubic yards of rock through dredging and blasting. The duration and magnitude of blasting described in the DSEIS is of a scope that has the potential for serious and significant impacts to fish and marine mammals. The DSEIS highlights the multiple fish kills that resulted from blasting performed in Boston Harbor last fall despite the implementation of preventative measures. Based on that experience, we view the blasting as the most significant source of risk for impact to marine organisms associated with the project. While we understand the difficulty of quantitatively predicting impacts from blasting, we believe that significant effort will be required to develop an acceptable plan to minimize the impacts of blasting on the wide range of marine organisms in Boston Harbor. We appreciate the Corps' and Massport's commitment in the DSEIS to work with federal and state agencies to develop approaches to minimize impacts from blasting. In order for this project to move forward, we believe that the Corps and Massport should:

- **Continue their work to establish an interagency underwater technical working group.** We recommend that the Corps work closely with the working group to identify, discuss and evaluate measures that could be implemented to minimize blasting impacts. These measures should include, but not necessarily be limited to, technological fixes, sequencing, time-of-year restrictions, and examination of whether or not the limits of the channel could be shifted as a means to avoid the areas of rock. We strongly encourage the Corps to establish the working group immediately so that the group's work can be incorporated into the FEIS. We also note that the Draft Feasibility Report (page 186) explains that it may be possible to rip (remove) the bedrock with a large toothed bucket mounted on an excavator. According to the analysis, the viability of that alternate removal method (and the overall magnitude of impacts expected from the rock removal component of the project) will not be known until the design phase of the project. We believe that the development of this critical information should proceed now and be presented in the FEIS, not delayed to the design phase of the project outside of the NEPA/MEPA review process. If the development of that information is delayed and information regarding the impacts of rock removal will be developed after the current NEPA process, the Corps should explain how the information will be made available to the agencies and public for review and comment through a supplemental NEPA process. We also recommend that the

Comment EPA #4

working group be maintained throughout the life of the blasting component of the project to help address any unforeseen developments should they arise. As part of the process we recommend that the working group be convened or informed on a regular basis to gauge success of control measures and review project progress (based on the reported results of the monitoring program described below). Rock removal techniques should be revisited as necessary when additional detailed geologic information becomes available.

Comment EPA #4

- **Commit to an extensive monitoring program spanning the entire project life cycle that will provide real-time information on the impacts of blasting.** The monitoring program should be developed in consultation with the working group and should include reporting protocols to explain the chain of events should large fish kills or marine mammal impacts occur as a result of blasting. EPA looks forward to working with the Corps and participating on the working group to help develop the protocols, including those regarding notification of the group following notable events. The working group in conjunction with the Corps and Massport will then explore options for response actions, operational changes, or additional minimization measures, if they are indicated.

Comment EPA #5

- **Work to make sure that the public is kept fully informed of the blasting program and working group discussions as the project advances.** We recommend that the Corps also consider inviting interested members of the public and industry to join the working group. Transparency in this part of the process will be critical given that the DSEIS does not include complete impact information related to rock removal for the project.

Comment EPA #6

Beneficial Reuse

The DSEIS presents the Massachusetts Bay Disposal Site (MBDS) as the preferred method of disposal for the non-rock dredged material. The DSEIS also provides preliminary information regarding the potential beneficial reuse (disposal) of some or all of the parent material to cap areas of the Industrial Waste Site and use of the blasted rock material to create rock reefs. EPA does not object to the disposal of project generated dredged material at the MBDS. And, in general, we support the Corps and Massport investigation of the potential to beneficially reuse a portion of the dredged material generated by the project.

Comment EPA #7

With respect to the plan to cap areas of the former Industrial Waste Site we note that the risk of a fisherman recovering an intact waste barrel to the surface is fairly remote because the area is technically closed to fishing and many of the barrels have already corroded. Therefore we view the proposed capping plan as an opportunity to further reduce the remaining risk.

Comment EPA #8

Comment EPA #9

With respect to the proposal to establish rock reefs, we support the concept of habitat restoration and enhancement; however, we have concerns about the locations selected for reef development and believe that significantly more information needs to be developed to fully understand the potential for impacts from this use proposal. The DSEIS states that reefs encompassing between 186 and 518 acres could be constructed at the Broad Sound or Massachusetts Bay sites. We have concerns about these particular sites due to the large size of the proposed reefs and the habitat functions these areas now appear to perform. The DSEIS describes the geomorphology of Broad Sound site as 43% gravel and cobble and the Massachusetts Bay site as 50% sand waves. The Corps' recent denial of the proposal to place dredged material at Winthrop Beach due to fisheries concerns (including adverse affects on cod spawning and lobsters) and comments highlighting the value of sand waves for fish in comments recently submitted by the National Marine Fisheries Service on the Minerals Management Service's Cape Wind EIS are relevant to this issue. Both of these instances support our position that the Corps and Massport need to more precisely define the potential for impacts associated with the project. As part of this additional evaluation we believe that the impacts associated with a range of reef sizes for both potential sites should be explored in the FEIS.

EPA strongly recommends that the Corps consider establishing a separate working group comprised of federal and state agencies and other interested stakeholders to address issues associated with rock reef creation. As with the blasting issues detailed above, the results of the working group efforts related to rock reef formation should be incorporated into the FEIS for review and comment. As above, we also believe that the information should be provided during the NEPA process, not later during the design phase of the project. At this point, the DSEIS does not contain sufficient information for EPA to determine whether rock reefs will be an acceptable use of the rock material generated by the project.

Comment EPA #10

Acoustic Monitoring System

The FEIS should evaluate the potential for impacts of blasting on the recently installed buoy listening and monitoring system in the Boston shipping lanes.[4] As you may know, the listening and monitoring system is designed to reduce the likelihood of ships colliding with whales by providing close to real time information to ship captains regarding the presence of whales in the shipping channel. The FEIS should include substantive information, including results of consultation with NOAA, to explain whether any proposed blasting will harm marine mammals and/or the effectiveness of the monitoring system.

In addition, the Corps and Massport should commit to use the data generated by the buoy listening and monitoring system and contract specifications should require that barges and other construction equipment are equipped with the proper communication equipment to receive the updates.

[4] http://www.listenforwhales.org/NetCommunity/Page.aspx?pid=467

Specific comments

DSEIS page 2-25: States that monitoring of the habitat enhancement sites for several years would be important to document colonization rates and provide information for future projects. Yet, there is no commitment in the DSEIS from the Corps or Massport to fund or carry out this monitoring. We believe that if the habitat enhancement (rock reef) efforts advance, the Corps and/or Massport should fund a monitoring plan that is commensurate with the ultimate size of the reefs and is consistent with the input of the working group established to explore this issue (see above).

Comment EPA #11

Comment EPA #12

DSEIS page 3-23: EPA staff have observed European oysters within Boston Harbor along the Winthrop and East Boston shorelines.

Comment EPA #13

DSEIS page 3-83: The DSEIS notes that only transient marine mammals are found in Boston Harbor. We believe that some marine mammals (harbor seals and harbor porpoise) are regular seasonal visitors into the harbor.[5] Harbor porpoise are routinely observed around the Charles River dam in the spring during anadromous fish inward migration. They have also been observed in Chelsea Creek. Harbor seals have been observed year round throughout the harbor.

Comment EPA #14

The FEIS discusses a change in the size and number of vessels projected to come to the port as a result of the development of the project. The FEIS should calculate the change in water usage (for cooling water intake, ballast, etc.) associated with the projected fleet change.

Comment EPA #15

Comment EPA #16

Comment EPA #17

Cumulative Impacts

The FEIS should look at the cumulative impacts of additional barge traffic to MBDS to the risk of vessel collision with whales. Also, this project will cause a conversion of between 1100-1300 acres of soft-bottom to hard substrate. The FEIS should also analyze the cumulative impact to benthic habitat (from both temporary and permanent conversion) from this project and the large number of other projected projects in the harbor.

Air Quality

General Conformity

Comment EPA #18

EPA disagrees with the approach to general conformity described in the DSEIS which leaves the decision on satisfying the Clean Air Act requirements of general conformity to the design phase of the project (see page 4-51 under "Emission Credits" and page 4-75 under "Mitigation"). We believe that under NEPA the Corps has an obligation to include in the EIS the information about how general conformity requirements will be met. The general conformity provisions at 40 CFR 93.150 mandate that the Corps must make a determination that its action conforms prior to engaging in, supporting, providing financial assistance for, licensing or permitting, or approving it. We believe this requires satisfying conformity prior to issuing a Record of Decision for the project. Therefore, we

[5] Dave Wiley, PhD, personal communication, 5-16-2008.

strongly encourage the Corps to work closely with the EPA and other state and federal agencies as appropriate to develop an approach to general conformity, in a fashion that can be presented in the FEIS. We believe that leaving a determination on the use or viability of emission credits until the design phase is inappropriate.

The Corps position on its general conformity obligations presented in the DSEIS is unclear and leads to confusion, as evidenced by the statement on page 5-5 under "Environmental Compliance," which states: "*Clean Air Act, as amended, 42 U.S.C. 7401 et seq*. Compliance: The 'general conformity' requirements of Section 17[6 *sic.*] (c)(1) of the Clean Air Act, 42 U.S.C. 7506(c)(1), will be adhered to by limiting construction and using 'clean' equipment to avoid exceeding air quality standards [general conformity emission applicability thresholds *sic.*] or by purchasing emission credits."

Should the Corps ultimately adopt either Alternative 1 or 2 with Emission Reduction Option 2 (which includes replacement of older equipment with new equipment[6] and increased/spread-out dredging schedule[7]) with enforceable environmental commitments that insure the use of new equipment with more stringent EPA emissions standards, and enforceable dredging schedule, then general conformity would be satisfied by the action falling below emission thresholds. However, should the Corps select not to use equipment with more stringent emission standards and/or shorten the construction schedule, then a general conformity analysis is required. Once project emissions exceed the *de minimis* threshold all emissions of the exceeded pollutant would have to be offset or otherwise accounted for in the state implementation plan.

Comment EPA #18

Should an alternative or construction process be chosen that triggers a general conformity analysis (an alternative without emission reduction option # 2), we point out that a draft conformity analysis must undergo a public review process and a final conformity determination issued by the Corps before issuance of the Record of Decision. We are willing to work closely with the Corps to address these issues.

EPA is concerned that the Corps' has focused more emphasis on efforts to avoid triggering the offset requirements of the general conformity regulations than the need for an analysis of the relative costs and benefits of that avoidance against the other project impacts that may be worsened by stretching the construction schedule out over more years. Those impacts include but are not limited to increased aquatic impacts or

Comment EPA #19

[6] Replace all non-road equipment with newer equipment that would meet EPA Tier 2, 3 and 4 emission standards that would be required for equipment model years 2011 and beyond. (Page 4-50 and 4-51; "This environmental commitment requires replacing all non-road equipment with newer equipment that would meet EPA Tier 3 and 4 emission standards that would be required for equipment model years 2011 and beyond. The clamshell and backhoe engines would need to meet Tier 4 emissions standards and support equipment would need to comply with Tier 3 and Tier 4 emission standards, depending on the equipment category and engine size. Table 4-12 presents the Tier 3 and Tier 4 emission limits based on engine size, in horsepower. In addition, the tugboats would also have to be equipped with engines that meet EPA's Tier 2 marine engine emissions standards presented in Table 4-12."

[7] Alternative One, 45-Foot MLLW Alternative would increase the dredging six months (from 36 to 42 months) while Alternative 2, 50-Foot MLLW Alternative would increase the dredging four years (from 48 months to 73 months over eight calendar years). Air quality shutdown periods would occur every other winter.

increased costs from multiple re-deployments of equipment. EPA requests that the Corps take a hard look at these comparisons before any final decision is made to avoid one impact at the expense of increasing another. With respect to general conformity, EPA notes that offsets for a time-limited project such as this construction may be supplied using time-limited discrete emission reduction credits. The Agency is aware of at least two recent projects that have successfully secured such credits to offset emissions from construction projects. It is possible that such credits may be available in the open market, and it would be important to weigh the cost of such credits against the potential impacts and costs of an extended schedule. In addition, the analysis in Appendix O of the DSEIS does not appear to explore the option of excluding emissions of ozone precursors that occur outside the ozone season from the conformity analysis. The options for a construction schedule presented in Appendix O, Attachment A, Part 4 suggest that a substantial portion of the construction operations will occur during the winter under most of the options. If the project proponent is prepared to accept enforceable commitments that require a portion of its operations to occur outside the ozone season, those emissions attributable to non-ozone season operations may be excluded from the conformity analysis and reduce the emissions subject to the offset requirement.

Comment EPA #20

Comment EPA #21

Emission Reduction and Mitigation

EPA strongly encourages the Corps to require the use of new non-road equipment that would meet EPA Tier 2, 3 and 4 emission standards. As specified in the DSEIS's "Environmental Commitments," section 4.8.4, page 4-50, the clamshell and backhoe engines would meet Tier 4 emissions standards and support equipment would need to comply with Tier 3 and Tier 4 emission standards, depending on the equipment category and engine size. The DSEIS also notes that tugboats would be equipped with engines that meet EPA's Tier 2 marine engine emissions standards.

Comment EPA #22

EPA recommends including an enforceable commitment in the Record of Decision and specifying this environmental commitment in the contract specifications with enforceable provisions to reduce impacts on air quality, consistent with CEQ's NEPA regulations which require that the Record of Decision include mitigation as conditions in the approvals and funding for the project. 40 CFR 1505.3(a) and (b).

National Ambient Air Quality Standard Nonattainment Areas, and Attainment Areas with an Ongoing Maintenance Plan

The DSEIS identifies the project area as located in the Metropolitan Boston Interstate Air Quality Control Region (AQCR), [40 CFR 81.19]. While this is a true statement, it is more relevant in determining applicable Clean Air Act requirements to indicate that the project is in an area that has been designated nonattainment or is subject to a maintenance plan. The relevant areas for the project are the Boston-Lawrence-Worcester (E. Mass), MA moderate eight-hour ozone nonattainment area and the Boston area carbon monoxide attainment area with an associated maintenance plan.

Comment EPA #23

Table 3-11 & Table O-1 Ambient Air Quality Standards

Comment EPA #24

These tables should be updated to reflect recent revisions to the ozone standard. On March 12, 2008, EPA Administrator Stephen L. Johnson signed the final rule revising the National Ambient Air Quality Standards (NAAQSs) for eight-hour ozone to a level of 0.075 parts per million (ppm), specifying the level of the primary standard to the nearest thousandth ppm. EPA also revised the secondary eight-hour ozone standard by making it identical to the revised primary standard. The Federal Register was published March 27, 2008 (73 FR 16436 — 16514) making the revised eight-hour ozone standards effective on May 27, 2008. NAAQSs can be found on EPA's web site at URL address: http://www.epa.gov/air/criteria.html.

Eight-Hour Ozone SIP

Comment EPA #25

Page 3-94 identifies the eight-hour ozone demonstration State Implementation Plan as under development. Please note that the Massachusetts Department of Environmental Protection submitted its eight-hour ozone Reasonable Further Progress (RFP) State Implementation Plan, as well as its eight-hour ozone Attainment Demonstration State Implementation Plan to EPA on January 31, 2008.

General Conformity Regulations

Comment EPA #26

On Tuesday, January 8, 2008, EPA proposed revisions to the general conformity Regulations (73 FR 1402 — 1428). Depending on the timing of the FEIS and the Corps general conformity determination, the Corps may be able to take advantage of the flexibility and benefits offered by a revised final general conformity rule.

CD-ROM disk provided in Attachment B

Comment EPA #27

Page O-11 references a marine vessel MS Excel emissions calculation spreadsheet developed by CDM which was to be included in the CD-ROM disk provided in Attachment B. Our copy of the DSEIS did not include a copy of the CD-ROM. Please submit a copy of the MS Excel spreadsheet for marine vessel emissions to EPA for review.

Page O-14 references a non-road emissions spreadsheet which was to be included in the CD-ROM disk provided in Attachment B. As noted above, our copy of the DSEIS did not include a copy of the CD-ROM. Please submit a copy of the MS Excel spreadsheet for non-road emissions. Page O-14 also references a MS Excel spreadsheet developed by CDM to calculate the on-road annual emissions, which is presented in Attachment A. Please submit a copy of the MS Excel spreadsheet for on-road annual emissions.

Finally, page O-14 references the MOBILE6.2 model input and output files which was to be included on a CD-ROM disk provided in Attachment B. Page O-18 also makes reference to the CD-ROM disk containing MOBILE6.2 input and output files. Because the CD-ROM was not included in our review copy of the DSEIS we respectfully request a copy of all MOBILE6.2 input and output files for review.

We will review the new information contained in the spreadsheets and the CD-ROM and supplement our comments on the DEIS as appropriate based on our review of that information.

UNITED STATES DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
NATIONAL MARINE FISHERIES SERVICE
NORTHEAST REGION
One Blackburn Drive
Gloucester, MA 01930-2298

JUN 2 2008

Colonel Curtis L. Thalken
Attn: Michael Keegan
U.S. Army Corps of Engineers
New England District
696 Virginia Road
Concord, MA 01742-2751

Ian A.Bowles, Secretary
Attn: Deirdre Buckley, MEPA Analyst
Executive Office of Energy and Environmental Affairs
Suite 900
100 Cambridge Street
Boston, MA 02114

Re: Boston Harbor Deep Draft Navigation Improvement Dredging Project, Feasibility Report and Draft Supplemental Environmental Impact Statement; Draft Environmental Impact Report

Dear Colonel Thalken and Secretary Bowles:

The National Marine Fisheries Service (NMFS) has reviewed the Draft Supplemental Environmental Impact Statement (DSEIS) and the Commonwealth of Massachusetts' Draft Environmental Impact Report (DEIR) for the Boston Harbor Deep Draft Navigation Improvement Dredging Project. This project involves the improvement dredging of approximately 12.1 million cubic yards (cy) of material from the Broad Sound entrance channel, the Main Ship channel, the Reserved channel, the Mystic River channel, and the Chelsea River channel. Dredged material from the proposed project will be placed at Massachusetts Bay Disposal Site (MBDS). In addition, approximately 1.2 million cy of rock will be removed from the Broad Sound entrance channel, Main Ship channel, and the Chelsea River channel by blasting.

The Magnuson-Stevens Fishery Conservation and Management Act (MSA) and the Fish and Wildlife Coordination Act require federal agencies to consult with one another on projects such as this. Insofar as a project involves essential fish habitat (EFH), as this project does, this process is guided by the requirements of our EFH regulation at 50 CFR 600.905, which mandates the preparation of EFH assessments and generally outlines each agency's obligations in this consultation procedure. While the EFH assessment contained in the DSEIS/DEIR addresses many of the issues associated with this project, specific information necessary to evaluate anticipated impacts has not been received. This information, as described below, is necessary for NMFS to fully evaluate anticipated

Comment NMFS #1

impacts on fishery resources and habitat. Upon receipt of additional information, NMFS will provide specific EFH conservation recommendations, as appropriate. Comment NMFS #1

Presence of Fishery Resources in Boston Harbor

Boston Harbor provides habitat for a variety of living marine resources, including, but not limited to, the commercially and recreationally important winter flounder (*Pseudopleuronectes americanus*), rainbow smelt (*Osmerus mordax*), alewife (*Alosa pseuodoharengus*), blueback herring (*Alosa aestivalis*), and American lobster (*Homarus americanus*). There is ample evidence that winter flounder utilize the proposed project area for spawning and juvenile development habitat. According to the NOAA Technical Memorandum NMFS-NE-138 (EFH Source Document), winter flounder generally spawn over sand, silt, and mud substrates in nearshore habitats from less than five meters deep, as well as offshore areas at depths of up to 90 meters on Georges Bank (Pereira et al. 1999). With the exception of Georges Bank and Nantucket Shoals populations, mature winter flounder spawn in the shallow waters of inshore bays and estuaries (Pereira et al. 1999). Because winter flounder eggs are demersal and adhesive in nature and larval and young of year winter flounder also prefer shallow inshore waters, spawning, egg development and early juvenile development habitat tend to be close together (Pereira et al. 1999). According to the EFH Source Document, winter flounder eggs and larvae have been collected at temperatures ranging from 0 to about 20.5 degrees Celsius. As such, it is anticipated that winter flounder eggs and larvae would be present within Boston Harbor during the winter, spring, and early summer. In addition, NOAA's Estuarine Living Marine Resources Program has identified winter flounder eggs and larvae as being abundant in Boston Harbor during this portion of the year (US Department of Commerce 1994).

The 2004-2005 final report for the Mystic Power Generating Station along the Mystic River in Everett, Massachusetts contains detailed information regarding the impingement and entrainment of fishery resources as a result of operations. This power station is located upstream of the proposed dredging footprint. As noted within the final report, approximately 16 million winter flounder larvae were entrained into the facility in this 12-month period (Shaw 2006). While this facility is located upstream of the proposed project footprint, this study suggests that inner portions of Boston Harbor are currently being utilized for winter flounder spawning and juvenile development.

The May 1995 Finfish Sampling and Description Report prepared by Normandeau Associates for the Army Corps of Engineers (ACOE) 1995 improvement dredging project of the inner Boston Harbor identified substantial winter flounder presence in the project area. This study included sampling at stations located within the inner and outer harbor. The trawl data identify winter flounder as being the most numerous finfish at each station, and winter flounder catch per unit effort (CPUE) as the highest of all species for all stations combined (Normandeau 1995). In view of these data provided in the reports and publications provided above, NMFS maintains that Boston Harbor and the Mystic and Chelsea Rivers support populations of winter flounder that utilize the area for spawning and juvenile development.

In addition to winter flounder, anadromous rainbow smelt, alewife, and blueback herring currently utilize Boston Harbor, the Mystic River, and the Chelsea River as a migratory pathway between upstream spawning locations and Massachusetts Bay. The 1995 Normandeau study associated with the improvement dredging of Boston Harbor found use of the area by alewife, blueback herring, and rainbow smelt through gill net sampling. Over all stations combined, blueback herring (26%), rainbow smelt (25%), and alewife (15%) were found to be the most abundant species sampled using gill nets (Normandeau 1995). Entrainment studies within the Mystic Station final report for 2004-2005 found that approximately 1.8 million rainbow smelt larvae were entrained in the facility (Shaw 2006). Further, this study found that 497 alewife and 27,379 blueback herring juveniles and adults were subject to impingement resulting from operations (Shaw 2006). As such, NMFS maintains that this area is being utilized by anadromous fish, including blueback herring, rainbow smelt, and alewife. It is important to note that due to the low populations of alewife and blueback herring throughout the Commonwealth of Massachusetts, the Massachusetts Division of Marine Fisheries has prohibited all harvest of these species. In addition, rainbow smelt has been identified as a "species of concern" by NMFS, who is assessing whether the species warrants listing under the Endangered Species Act. These actions underscore the importance of these species in Massachusetts and New England as well as the need for measures which avoid and minimize impacts on anadromous fishery resources.

Comment NMFS #2

The substrate found within the project area also serves as habitat for benthic organisms, such as shellfish and other invertebrates living within and on the surface of the sediment. These organisms contribute to the productivity of the federally managed species as a food source for both juvenile and adult life stages of finfish. The commercially important American lobster has been documented extensively within Boston Harbor by the Massachusetts Division of Marine Fisheries through the 1990-2002 Massachusetts Bay Lobster Trawl Sampling Program.

Issues associated with dredging

The proposed dredging and the resulting suspended sediment and deposition may result in adverse effects to fishery resources and habitats. The EFH Source Document states that winter flounder eggs range in size from 0.74-0.85 mm in diameter, and are demersal and adhesive (Pereira et al. 1999). The eggs have been shown to be adversely affected by minimal levels of sediment deposition. Research conducted at the NMFS Northeast Fisheries Science Center's Milford Lab found that sediment deposition at depths of ½ the egg diameter (~0.5 mm) resulted in reduction in hatch of eggs (David Nelson, personal communication, 2003). In addition, a recent study found that deposition of suspended sediments can have adverse effects on winter flounder eggs at approximately 1.0 mm (Walter Berry, personal communication, 2006). While this study found that deposition at greater than 3mm reduced hatch significantly, there was also a reduction in hatching success (approximately 60 percent down to 35 percent) at deposition levels of 0.5mm-1.0mm (Berry et al. 2006). It is important to note that this study dealt solely with total hatch success, and did not deal with sublethal effects, such as developmental deformities, which may result from burial. There is also evidence that egg burial of approximately 1.0 mm results in increased time for winter flounder eggs to hatch, which results in a greater

Comment NMFS #3

risk of predation (Berry et al. 2006). Furthermore, it has been indicated that larval stages of winter flounder may be susceptible to impacts from suspended sediment due to abrasion (Walter Berry, personal communication, 2006).

As stated above, Boston Harbor, Mystic River, and Chelsea River serve as habitat for a number of anadromous fishery resources. These anadromous fishery resources serve as prey for a number of federally managed species and are considered a component of EFH pursuant to the MSA. In addition, these are NOAA trust resources that are covered under the Fish and Wildlife Coordination Act. NMFS remains concerned that dredging activities and associated plumes of contaminated sediment have the potential to impair migration of anadromous species. Chiasson (1993) found an increase in swimming activity of rainbow smelt when suspended sediments were present. Such alarm reactions have been found to disrupt schooling behavior of fishes (Wildish and Power 1985). In a laboratory study, Wildish and Power (1985) found that rainbow smelt avoided suspended sediment when concentrations were in excess of 20 Mg/L. Furthermore, sublethal effects to estuarine fishes can include decreased feeding, impacts from lowered oxygen levels, as well as impacts on gills and associated respiratory impacts (Wilber and Clarke 2001).

Comment NMFS #4

Comment NMFS #5

The DSEIS/DEIR states that the sediment plume from the dredging is expected to be contained within the vicinity of the proposed dredge area. The primary means for this determination was the use of the SSFATE model for the 2004-2005 Outer Boston Harbor maintenance dredging project, as well as the plume tracking performed for the construction of the CAD cell within Boston Harbor during the previous improvement dredging project in 1998-2002. During the review of the Boston Harbor Inner Harbor Maintenance Dredging project in 2006, NMFS raised concerns regarding the applicability of the SSFATE model used in the suspended sediment dispersion analysis, as described in our May 12, 2006 letter to the ACOE. In a letter dated February 22, 2007, the ACOE developed a water quality monitoring plan for the inner harbor maintenance dredging project to be performed in 2008. This plan includes a real-time dredge plume tracking effort in order to identify the extent of suspended sediment dispersion resulting from dredge operations. Results of this effort should be utilized, in part, to develop a dredge sequencing plan to avoid and minimize adverse effects to fishery resources in certain areas and times when they would be most susceptible to adverse impacts.

Comment NMFS #6

Issues associated with blasting

The DSEIS/DEIR contains limited information regarding anticipated effects resulting from the proposed blasting. Specifically, the DSEIS/ DEIR and EFH assessment does not include an analysis of the location, timing, and methods of the proposed blasting and the anticipated impacts on living marine resources. NMFS acknowledges the need to advance the project, however, this blasting impact information is important in order to fully anticipate adverse effects to fishery resources and to identify suitable minimization techniques. This detailed assessment of impacts should be incorporated into the proposed blasting plan.

Comment NMFS #7

The recent blasting events associated with the Boston Harbor Maintenance Dredging project resulted in a series of fish kills. As noted in the DSEIS/ DEIR, the ACOE is

currently in the process of preparing an "after action report" to provide information and determine what lessons can be learned from the 2007 fish kill events, and to identify corrective measures that can be used to avoid and minimize impacts on fishery resources during the proposed deep draft improvement project. This "after action report" should be incorporated into the recommended blasting plan.

The DSEIS/DEIR discusses the formation of an interagency underwater blasting technical working group in order to discuss construction sequencing and potential constraints as well as operational procedures and equipment for the proposed blasting. NMFS believes that this can be an effective approach in the development of a comprehensive blasting plan. In addition to an assessment of impacts, the blast plan should address potential operational impact minimization measures, sequencing options, impact thresholds, and an adaptive management protocol. This blasting plan should be developed and approved by the interagency technical working group prior to any blast operations.

Comment NMFS #8

Beneficial uses of rock as artificial reefs

According to the DSEIS/DEIR, the ACOE is considering the utilization of the blasted rock to create artificial reefs over an area of approximately 220-530 acres of soft bottom habitat within Broad Sound. The DSEIS/DEIR discuss three alternatives considered as beneficial reuse, including the use of rock for upland construction purposes, use for ongoing shore protection projects, and use of rock as artificial reefs. The document states that upland alternatives and shore protection alternatives were eliminated from consideration due to uncertainty. Due to recent discussions with MassPort regarding the potential use of the Marine Terminal as a transfer facility, NMFS maintains that the upland alternatives should be more fully explored.

Comment NMFS #9

In the context of the beneficial reuse of blasted rock for creating artificial reefs, the DSEIS/DEIR assumes that hard bottomed habitat is preferable to soft bottom habitat. Although less structurally complex, soft bottom habitats serve as habitat for a variety of resources. As noted in the DSEIS/DEIR, soft bottom areas of the Broad Sound preferred reef site are utilized by benthic invertebrates, lobster, and fishery resources such as flounder, red hake, and sculpin. As the Broad Sound reef site contains areas of both hard and soft substrates, the FSEIS/FEIR should consider the loss of soft bottom habitats as a result of the creation of artificial reefs relative to the overall ecosystem functions and values.

Comment NMFS #10

Capping of the former Industrial Waste Site

As noted in the DSEIS/DEIR, the ACOE is considering the use of dredged material to cover potential hazardous and radioactive waste located within the former Industrial Waste Site (IWS) located adjacent to the MBDS. In order to test a methodology for capping of the IWS, a demonstration project is planned for the dredged material disposal in the MBDS associated with the upcoming Boston Harbor Maintenance Dredging project. While the results of the demonstration project will be unavailable for the FSEIS/FEIR, information should be presented to federal and state resource agencies in order to determine if this method is acceptable for use for the IWS capping project.

Comment NMFS #11

Essential Fish Habitat Assessment

As noted in the EFH assessment included in the DSEIS/DEIR, this portion of Boston Harbor serves as EFH for 23 federally managed species, including, but not limited to, Atlantic cod, haddock, pollock, whiting, red hake, white hake, winter founder, yellowtail flounder, windowpane flounder, American plaice, ocean pout, Atlantic mackerel, and summer flounder. As noted above, our ability to assess potential impacts on EFH and associated marine resources was complicated by insufficient information in the document. Section 305(b)(2) of the MSA requires all federal agencies to consult with NMFS on any action authorized, funded, or undertaken by that agency that may adversely affect EFH. Included in this consultation process is the preparation of a complete and appropriate EFH assessment to provide necessary information on which to consult. NMFS recommends that the following additional information regarding project impacts and issues relative to fishery resources and habitats be provided in order for us to fully assess the adverse effects of the proposed project. Upon receipt of this information, NMFS will provide specific EFH conservation recommendations, as appropriate.

1) A sequencing plan should be developed for dredging activities. This plan should avoid and minimize adverse impacts on winter flounder and anadromous fish resulting from increased levels of suspended sediment and deposition. This sequencing plan should be coordinated with federal and state resource agencies.

2) A comprehensive blasting plan should be developed by an interagency underwater blasting technical working group. As noted above, this plan should have a detailed discussion of anticipated impacts on fishery resources, and should address potential operational impact minimization measures, sequencing options, impact thresholds, and an adaptive management protocol. This blasting plan should be approved by the interagency technical working group.

3) Alternative beneficial reuse options that avoid and minimize adverse impacts on biologically productive soft bottom habitats should be evaluated more fully within the FSEIS/FEIR.

4) In order to assess potential impacts resulting from the proposed capping at the IWS, the results of the upcoming demonstration capping project within MBDS should be presented to federal and state resource agencies.

Comment NMFS #12

Endangered Species Act

Three species of federally threatened or endangered sea turtles and three species of endangered whales may be found in Massachusetts waters. The sea turtles in Massachusetts nearshore waters are typically small juveniles with the most abundant being the federally threatened loggerhead (*Caretta caretta*), followed by the federally endangered Kemp's ridley (*Lepidochelys kempi*). Loggerheads and Kemp's ridleys have been documented in waters as cold as 11°C, but generally migrate northward when water

temperatures exceed 16°C. These species are typically present in Massachusetts waters from June through November. Federally endangered leatherback sea turtles (*Dermochelys coriacea*) are located in New England waters during the warmer months as well. While leatherbacks are predominantly pelagic, they may occur close to shore, especially when pursuing their preferred jellyfish prey. Green sea turtles *(Chelonia mydas)* may also occur sporadically in New England waters, and any occurrence in Massachusetts waters is likely to be rare. Sea turtles are known to occur on Stellwagen Bank and in Massachusetts Bay. While no surveys for sea turtles have been conducted in Boston Harbor, suitable forage and habitat exists in this area and it is likely that sea turtles occasionally are present in Boston Harbor.

Federally endangered North Atlantic right whales (*Eubalaena glacialis*) and humpback whales (*Megaptera novaeangliae*) are also found seasonally in Massachusetts waters. North Atlantic right whales have been documented in the nearshore waters of Massachusetts from December through June. Humpback whales feed during the spring, summer, and fall over a range that encompasses the eastern coast of the United States, including Massachusetts Bay. While these whale species are not considered residents of the Boston Harbor area, transients occasionally enter the area as they complete seasonal migrations in nearby Massachusetts Bay. For example, in April 1996 a right whale was documented in Boston Harbor, and in the fall of 2000, a humpback whale was documented in Boston Harbor. Fin (*Balaenoptera physalus*), Sei (*Balaenoptera borealis*), and Sperm (*Physter macrocephalus*) whales are also seasonally present in New England waters, but are typically found in deeper offshore waters and are not likely to occur in Boston Harbor.

Comment NMFS #13

The ACOE requested consultation pursuant to Section 7 of the Endangered Species Act (ESA) of 1973, as amended, regarding the Boston Harbor Deep Draft Navigation Improvement Project in 2005. In a letter dated September 6, 2005, NMFS concurred with the ACOE's determination that the project was not likely to adversely affect listed species. However, at that time, the ACOE had indicated that the removal of 2-6 million cy of material was likely and the ACOE did not indicate to NMFS that blasting would be necessary. As such, the consultation only considered the effects of dredging 2-6 million cy of material, as opposed to the 12.1 million cy currently proposed for removal, and did not contemplate the effects of the currently proposed blasting operations.

Reinitiation of consultation is required and shall be requested by the federal agency or by the Service, where discretionary federal involvement or control over the action has been retained or is authorized by law, and: (a) if new information reveals effects of the action that may affect listed species or critical habitat in a manner or to an extent not previously considered in the consultation; (b) if the identified action is subsequently modified in a manner that causes an effect to the listed species or critical habitat that was not considered in the consultation; or (c) if a new species is listed or critical habitat designated that may be affected by the identified action. As the action has been modified from the action considered by NMFS in the September 6, 2005 letter, reinitiation of consultation is necessary. As such, the ACOE will need to provide NMFS with a determination of effects to listed species that analyzes the potential for impacts of the

Comment NMFS #14

additional dredging as well as from the proposed blasting. In order to determine the likely effects of blasting on listed species, additional information on the underwater noise resulting from the project as well as information on timing, sequencing, and monitoring is necessary. Should you have any questions about these comments, or the reinitiation of consultation, please contact Julie Crocker in NMFS' Protected Resources Division at (978) 281-9300 ext. 6530, or by e-mail (Julie.Crocker@Noaa.gov).

Comment NMFS #15

Conclusion

In summary, NMFS requests additional information be provided in order to fully evaluate potential impacts on listed species, fishery resources, and habitats. Specifically, we recommend that a dredging sequencing and comprehensive blasting plan be developed for this project. Further, we recommend that alternative beneficial reuse options for blasted rock be explored. Finally, NMFS recommends that further coordination regarding the capping demonstration project and proposed capping at the IWS should occur. Upon receipt of this information, NMFS will provide specific EFH conservation recommendations, as appropriate. Additionally, as noted above, section 7 consultation must be reinitiated to consider the effects of the additional dredging as well as the effects of blasting on listed species. Should you have any questions regarding these comments, please contact Christopher Boelke of my staff at (978) 281-9131.

Sincerely,

Peter Colosi

Peter D. Colosi
Assistant Regional Administrator
for Habitat Conservation

cc: US ACOE - Michael Keegan, Cathy Rodgers
US EPA - Robert Varney, Phil Colarusso
US FWS – Vern Lang, Maria Tur
MA DMF - Paul Diodati, Kathryn Ford
MA CZM - Leslie Ann McGee, Bob Boeri
MA DEP - Lealdon Langley, Ken Chin
MassPort Maritime Department - Deb Hadden
MEPA - Deerin Babb-Brott
Boston Conservation Commission – Chris Busch
NOA/PPI – Steve Kokkinakis

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CITY OF BOSTON
THE ENVIRONMENT DEPARTMENT

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June 2, 2008

Ian A Bowles, Secretary
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Colonel Curtis L. Thalken, District Engineer
United States Army Corps of Engineers, New England District
696 Virginia Road
Concord, MA 01742-2751
Attention: Michael Keegan, Project Management Division

Re: Boston Harbor Deep Draft Navigation Improvement Project - Draft Feasibility Report and Supplemental Environmental Impact Statement/Environmental Impact Report

Dear Secretary Bowles and Colonel Thalken:

The City of Boston Environment Department and staff of the City of Boston Conservation Commission have reviewed the Draft Feasibility Report (DFR) and joint Draft Supplemental Environmental Impact Statement/Environmental Impact Report (DSEIS/EIR) for the Boston Harbor Deep Draft Navigation Improvement Project (Deep Draft Project) and offers the following comments.

The U.S. Army Corps of Engineers (ACOE) and the Massachusetts Port Authority (Massport) have proposed the Deep Draft Project which will include increased navigation access to Massport's Conley Container Terminal on the Reserved Channel in South Boston by dredging to a depth of at least -45 feet mean lower low water (MLLW) and improvement dredging in the Mystic and Chelsea Rivers, Main Ship Channel, the Presidents Roads Anchorage and the Broad Sound North Entrance Channel. The project proponents note that the Deep Draft Project is necessary due to existing delays to container ships and bulk carriers caused by insufficient tidal depths; the light loading of vessels, or partial loading or unloading of vessel cargo to meet tidal windows; and the bypassing the Port of Boston by carriers to meet arrival schedules at other East Coast Ports. Other stated reasons for the project include carriers that add larger vessels to their fleets may not include Boston on their itineraries, and recent shipping trends indicating cargo being shifted increasingly from the Port of New York/New Jersey to Boston Harbor.

The Department supports the project and is aware of the need for the proposed improvement dredging due to the limitations that existing drafts place upon current and future vessel traffic, and the importance of Port of Boston's shipping activity to the local and regional economy. Given the

size and scope of this project, and the disruptive nature of dredging upon marine habitat, and impacts on water and air quality, the project environmental mitigation requirements should be thoroughly detailed in the Final SEIS/EIR. The proponents should also continue to work with state and local resource conservation agencies in the development and implementation of mitigation measures and protocols to ensure the protection of the harbor's environmental resources. Comment COB #1

The Deep Draft Project will be one of the most significant dredging projects in Boston Harbor, involving the dredging of between 6.6 and 14.8 million CY of parent material and between 450,000 and 1.4 million CY of rock, affecting over 1,140 acres of harbor bottom. Parent material will either be placed at the Massachusetts Bay Disposal Site (MBDS), and/or utilized for beneficial uses such as the capping of the Industrial Waste Site overlapping MBDS. Beneficial uses or dredged rock may include creation of hard bottom habitat in Massachusetts Bay and Broad Sound (and the armoring of seashore areas within Boston Harbor with problematic coastal erosion). Some unsuitable dredge material may be disposed of in existing or previously permitted Confined Aquatic Disposal (CAD) cells within the harbor. Comment COB #2

The blasting of rock is of particular concern given the four fish-kill events that occurred in the fall of 2007, associated with the Boston Inner Harbor Maintenance Dredge Project (BIHMDP). These events have illustrated the limitations of the blasting mitigation measures, which included insert delays, shock wave attenuation measures, a fish startle system, side scan sonar, and a fisheries observer. A complete review of the adequacy of these measures should be addressed in the ACOE "after action report" on the fish kill events, and discussed with the interagency blasting technical working group, once it is convened. The findings of this report, the mitigation measures used to date and potential new mitigation technologies must be reviewed prior to the completion of the development of a blasting plan for the Deep Draft Project. The project blast plan should require a stoppage of blasting in the event of a fish kill and assessment of possible causes and changes to blast methodology prior to re-commencement of blast activities. The blasting technical working group should also be informed and consulted on all marine mammal or fish kill event. Non-blasting options should also be discussed such as a closed dredge bucket, impact devices, or a large tooth bucket on an excavator, which have been previously employed for ledge removal. The non-blast methodologies should be assessed for the types of impacts they may have on marine species and whether they are viable methods of removing the different types of rock and ledge material found in the harbor. Comment COB #3

The Beneficial Use Alternatives section of the DSEIS/EIR notes several possible applications of dredged parent material, including the capping of the Industrial Waste Site (IWS) in Massachusetts Bay and creation of new rock reef habitat in Broad Sound and Massachusetts Bay. It is our understating that a pilot study is to be conducted with parent material from the BIHMDP to assess the feasibility of using such material to cap the IWS. The findings of this study should be provided and utilized to inform the Deep Draft Project final design. If unsuitable silt material needs to be disposed of into CAD cells within the harbor, disposal activities should not delay the capping of cells utilized for the BIHMDP. Comment COB #4 Comment COB #5

The DSEIS/EIR states that Broad Sound and Mass Bay are the most suitable sites for creation of hard bottom habitat after assessing and ranking five possible habitat enhancement sites. Comment COB #6

However, the site ranking and Hard Bottom Habitat Report rate the Mass Bay site as fourth, it ranks last in benthic habitat quality. The DSEIS/EIR references depth and location constraints as the rationale for selecting Mass Bay. Given the extent of disturbance the project will cause to marine habitat, the beneficial use sites must be selected based upon locations where the greatest enhancement of bottom habitat will occur. The proponent should further substantiate the rationale for not selecting the Magnolia site as a preferred enhancement location. Whether all or a portion of the rock will be used for beneficial use, as well as the size and type of rock most appropriate for bottom habitat should also be addressed. Additionally, the final design should be coordinated with state and federal resource agencies to ensure that the rock is suitable and its placement is properly configured and located in areas where existing rock and cobble habitat is not currently present.

As noted in the DSEIS/EIR, multi-year monitoring of the habitat creation sites is necessary to determine if colonization occurs and if such rock disposal options serve as a beneficial use. The Department is also aware of the need for armoring stone for several coastal areas within Boston Harbor and the Harbor Islands. Use of removed rock for shoreline protection should be discussed further as it may serve to benefit the project proponent as well as state and local landowners within the harbor.

Comment COB #7

The Environmental Consequences section (4.0) should include a discussion of possible impacts of dredge material transport and disposal at the IWS and MBDS upon the adjacent Stellwagen Bank National Marine Sanctuary. With the recent issuance of a Draft Management Plan for the sanctuary, there has been renewed focus on the lack of effective management of the ecosystem, resulting in serious decline of the sanctuary's marine life. The transport of dredge spoil and its disposal must be reviewed to ensure that such activities are not contributing to a decline in viability of sanctuary and the numerous marine species that inhabit the area.

Comment COB #8

Turbidity from dredge activities has the potential of affecting harbor water quality in the vicinity of dredge equipment and adversely impacting important life stages of fish and shellfish. The DSEIS/EIR notes that the means by which the dredge equipment is operated can have an impact upon suspension of sediments and turbidity than the type of bucket used. The proponent should discuss how operational techniques and parameters such as dredge cycle-time, and practices such as scow washing, will be managed to limit turbidity. The document also references prior field monitoring results of dredge buckets and associated turbidity levels, noting greater turbidity associated with conventional buckets, and less with Cable Arm and environmental buckets. The proponent should employ to the greatest extent practicable the use of Cable Arm or environmental dredge buckets during the project to minimize water quality impacts. Closed buckets should be used for dredging of all silty material. Turbidity is problematic for eelgrass beds in particular, which provide important habitat to finfish and shellfish. The Biological Environment section (3.3.1) references eelgrass beds only located in small areas within Hull and Hingham Bay. The Final SEIS/EIR should update the section to include eelgrass beds located along the northwest shoreline of Long Island which have been established as part of the MA Department of Marine Fisheries Eelgrass Restoration Project.

Comment COB #9

Comment COB #10

The Biological Resource Impacts section of the DSEIS/EIR notes that benthic communities within the navigation channel will be destroyed as a result of dredging and blasting, and that such communities are expected to recover and return to pre-dredge conditions within a short period of

time after the project, citing a 1977 Oregon study. The document also states that if significant areas of blue clay are exposed through dredging the number and type of organisms may be reduced. Given the scope of impacts the project will have on benthic habitat, the lack of specific study information on Boston Harbor benthic communities and uncertainty over such communities' ability to reestablish, a biological monitoring program should be developed to adequately assess whether benthic species actually re-colonize in dredged areas within Boston Harbor, and if so, to what extent. Such results can better inform project mitigation measures and provide more accurate information on the environmental impacts of dredge projects in Boston Harbor. Comment COB #11

As with prior and current dredging projects, prior to the start of dredging operations and barge transport of dredged materials, work areas and barge routes should be coordinated with the Boston Harbor Lobstermen's Cooperative and the Massachusetts Lobstermen's Association. To facilitate coordination the contractor should prepare a weekly schedule of dredging and disposal activities and forward it to these organizations at least 48 hours prior to the scheduled work. Comment COB #12

The Air Quality section (4.8), notes that mitigation measures will need to implemented during the project to avoid exceeding annual air quality emissions thresholds for Carbon Monoxide (CO), Nitrogen Oxide (NOx), and Volatile Organic Compound (VOC) emissions. Specifically, utilizing newer, cleaner burning off-road equipment (model year 2011 and beyond), and extending the three year dredge schedule. The shut down periods are proposed to occur in six month periods every two years from October to March. As NOx and VOC's are pre-cursers to ozone, an air pollutant most problematic during the summer months, the proponents should provide more detail as to why dredging is not occurring during the winter months. Comment COB #13

The proponent should ensure that the Technical Working Group continues to meet regularly throughout the duration of the dredge project to review and address any problems and operational changes that may be suggested by the dredge contractor. Comment COB #14

Thank you for the opportunity to offer comment.

Sincerely,

Bryan Glascock
Director

BHDDNIP DFR.SDEIS.EIR 6.03.doc.DBG:CB.cb

2 June 2008

Colonel Curtis Thalken
District Engineer
U.S. Army Corps of Engineers
696 Virginia Road
Concord, MA 01742-2751
ATT: Programs and Project Management

RE: Feasibility Report and Draft Supplemental Environmental Impact Statement, Boston Harbor Deep Draft Navigation Improvement Project

Dear Colonel Thalken:

The Boston Harbor Association is a non-profit, public interest organization founded in 1973 by the League of Women Voters and the Boston Shipping Association to promote a clean, alive, and accessible Boston Harbor. We have reviewed the April, 2008 Feasibility Report and Draft Supplemental Environmental Impact Statement for the Boston Harbor Deep Draft Navigation Improvement Project submitted by the Massachusetts Port Authority and the U.S. Army Corps of Engineers.

The Boston Harbor Association is a member of the proposed project's Technical Working Group, comprised of environmental representatives, scientists, city, state and federal representatives, and local stakeholders, and has

374 Congress Street, Suite 307 ■ Boston, Massachusetts ■ 02210-1897 ■ Telephone (617) 482-1722 ■ Fax (617) 482-9750 ■ www.tbha.org

been kept apprised of the project as well as the results of the prior maintenance dredging project.

Based on a review of the Draft Supplemental Environmental Impact Statement and briefings for the Technical Working Group, The Boston Harbor Association strongly supports the preferred alternative of the Deep Draft Navigation Improvement Project, which calls for deepening the Broad Sound North Entrance Channel of the Harbor to 50 feet, and the Main Ship Channel up to the Reserved Channel, the President Roads Anchorage, the Reserved Channel and its Turning Area to 48 feet.

The proposed alternative, known as Plan B, would allow existing companies calling on Conley Terminal in South Boston to use larger ships, and could potentially help attract additional container lines. During the past decade, the trend has continued where Boston is no longer a significant manufacturing center, but rather, a major distribution center for goods to the Northeast region. The Port of Boston will in the foreseeable future continue to receive extensive tonnage of imports (particularly from Asia) for distribution in the region, with some exports of raw materials such as scrap metal, paper, wood products, and some finished products.

Implementation of Plan B will allow deeper draft vessels into the Port of Boston. Two types of ships were modeled in the Draft Supplemental Environmental Impact Statement: a 4,700 TEU

(twenty-foot equivalent unit, the measurement size for cargo containers) Panamax ship that shippers believe will most likely call on the Port of Boston if deepened, and a larger 5,600 TEU ship which potentially may be used by existing companies if the channel is deepened (page 135, Draft SEIS). According to the Draft SEIS, a fully-loaded Panamax vessel requires 48 feet of water depth in the harbor channels and 50 feet of water depth in the entrance channel (page 135).

In addition, the Draft SEIS (page 71) examined the planned use of the Massport Marine Terminal in South Boston by larger ships. Expanded use of the Marine Terminal would be for bulk carriers with cement, salt, gypsum, frozen seafood, and/or manufactured goods, with larger vessels eventually requiring 45 feet depths (main ship channel deepening above the Reserved Channel Turning Area).

As the project proponents continue to secure the necessary environmental permits, we ask that the following issues be further addressed:

Beneficial Re-use of Dredged Materials: We highly commend Massport and the U.S. Army Corps of Engineers for including a detailed analysis of the potential beneficial re-use of the dredged materials to be generated by this project.

According to the DEIR, two types of the dredged materials may potentially be suitable for re-use. In the first instance, blasted ledge, cobble, gravel, and other stony materials may be suitable

for creation of hard bottom habitat favored by lobsters and other species in Boston Harbor and/or Massachusetts Bay (page 170 of Draft SEIS). Algonquin's Hubline project, for example, re-used some of its materials to create hard-bottom habitat, although on a much smaller scale than proposed for this project.

As indicated in the Draft SEIS, further evaluation needs to occur regarding two potential sites for hard-bottom habitat creation, and a plan needs to be developed for the placement of materials on the ocean floor. In addition, the final Environmental Impact Statement should detail an evaluation and monitoring program to determine how successful the habitat creation and colonization efforts are.

Comment BHA #1

In the second instance, Boston Blue Clay, a stiff impervious clay, will be removed from the President Roads Anchorage and upper channel reaches. The Boston Blue Clay and other unconsolidated materials may potentially be suitable for capping the former Industrial Waste Site in Massachusetts Bay.

The former Industrial Waste Site overlaps and extends north of the current Massachusetts Bay Disposal Site in the Stellwagen Basin, and was used for the disposal of chemical, medical, and radiological wastes from the 1940s to the 1970s (page 174 of the Draft Supplemental Environmental Impact Statement). The waters around the Site were also used for disposal of construction waste, demolition debris, and derelict vessels.

The area in and around the former Industrial Waste Site is currently trawled by fishermen, and capping of the Site would reduce the potential of catching the debris, some of which is quite contaminated, in fishing nets. We strongly support a proposed demonstration project suggested by the project proponents, with care taken to ensure that ambient sediment does not become re-suspended during the disposal process.

Comment BHA #2

Minimizing Impacts to Marine Life: In the past five years, thanks to the efforts of the Massachusetts Water Resources Authority, Boston Water and Sewer Commission, Department of Environmental Protection, City of Boston, and many others, Boston Harbor is cleaner than ever. A number of shellfish beds have re-opened near Logan Airport and Winthrop, and there are many more lobster traps in Boston Harbor.

Consistent with environmental mitigation requirements imposed upon the Algonquin Hubline project, we ask that a communications system be established with the fishing and lobstering communities regarding construction activities and timing to avoid impacts to lobster gear, and/or a monetary fund to compensate lobstermen in the event of damage to lobster traps located outside of the federal navigation channel from dredging or mobilization activities. In the case of the Algonquin project, a $50,000 fund was established for damage to lobster gear outside of the federal navigation channel, which ultimately was not fully

Comment BHA #3

utilized due to limited impact upon lobster traps from that project.

The Draft SEIS notes that four fish mortality events occurred in fall, 2007 during the ledge pinnacle removal project of the Boston Harbor maintenance dredging project. Subsequent to the first mortality event, the Army Corps of Engineers met with its contractor to identify ways to prevent other mortality events. In spite of these measures, three other mortality events occurred during blasting events by the contractor.

Comment BHA #4

We are concerned about the inability of the contractor to prevent fish mortality events during the Harbor maintenance dredging activities last year, and urge the permitting agencies to impose strict requirements upon the project proponents and their contractors to prevent any fish mortality events as part of this project.

Other Environmental Mitigation Measures: Because of adverse environmental impacts from the Algonquin Hubline project, the state permitting agency required, amongst other conditions, a $5 million contribution to the not-for-profit Island Alliance organization to support use of the Harbor Islands.

In the event that adverse environmental impacts are identified with this proposed project, we ask that consideration be given to requiring, amongst other conditions, a monetary contribution to support water transportation in Boston Harbor and Massachusetts Bay if water transportation service

Comment BHA #5

is impacted from construction activities of this project.

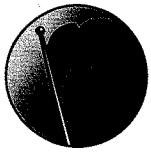
On-going Environmental Oversight: In additional to local, state, and federal regulatory oversight of this project, we ask that a Technical Advisory Group continue to meet regularly to review progress of the project, any monitoring data with the project's independent environmental observer, and to discuss prevention measures in the unlikely event of fish mortality events or other environmental incidences.

Comment BHA #6

Thank you for your consideration. We look forward to timely approval of this much-needed project.

Sincerely,

Vivien Li
Executive Director
The Boston Harbor Association



Save the Harbor
Save the Bay

For Everyone

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June 2, 2008

Colonel Curtis L. Thalken
District Engineer
U.S. Army Corps of Engineers
696 Virginia Road
Concord, MA 01742-2751

Attn: Michael Keegan, Programs and Project Management Division

Re: Boston Harbor Deep Draft Navigation Improvement Project

Dear Colonel Thalken:

As you know, Save the Harbor / Save the Bay supports efforts such as dredging to keep the Port of Boston competitive provided that appropriate safeguards are in place to protect the environment.

I am writing to you today with two serious concerns about the proposed Boston Harbor Deep Draft Navigation Improvement Project that we hope you will address as you consider the feasibility of the proposed project.

Our first concern is air quality: Based on what we have seen, the Corps of Engineers apparently believes that it is simply not feasible to proceed with this project as described and meet air quality standards on a daily basis. Rather than look for a real solution to reduce daily emissions to an acceptabl level and protect the public health and the environment, they appear to have chosen to "game" the numbers.

Comment STH/B #1

It is disingenuous to propose to "work dirty" for 9 months, then suspend work on the project for three or six months, and then average the numbers to artificially meet "annual" air quality standards. There has to be a better- or at least more honest –way.

We are also concerned about the impact of the extensive blasting that this project would require on forage fish such as herring, alewife, rainbow smelt, and menhaden, as well as on the lobster, striped bass, codfish, tautog, pollack and flounder that are so important to our region's fisherman.

Comment STH/B #2

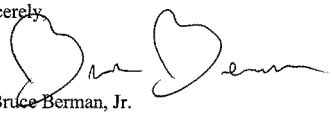
As you may recall, last year the Boston Globe reported that more than 2,000 fish were killed in four separate incidents related to blasting associated with routine maintenance dredging of the Harbor. To date, the Corps has yet to release a final report on the incidents.

Boston Fish Pier, 212 Northern Avenue, Suite 304 West, Boston, Massachusetts 02210
Phone: (617) 451-2860 Fax: (617) 451-0496 www.savetheharbor.org

As a result, we remain concerned that measures presently in place are insufficient to protect these and other marine species during even a "routine" project, and are clearly insufficient to protect the resource during the 18 months or more of daily blasting that the proposed project would require.

Boston Harbor and the Port of Boston are both remarkable resources. We hope that you will work with us to make certain that improvements to the port do not come at the expense of the health of the public, or of our $4.5 billion dollar investment in the harbor we have worked so hard to restore and protect.

Sincerely,



E. Bruce Berman, Jr.
Director of Strategy and Communications
Save the Harbor/Save the Bay

cc: I. Bowles/EOEEA
J. Wilkins/Massport

Boston Fish Pier, 212 Northern Avenue, Suite 304 West, Boston, Massachusetts 02210
Phone: (617) 451-2860 Fax: (617) 451-0496 www.savetheharbor.org

TOWN OF WINTHROP
TOWN COUNCIL

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1 Metcalf Square
Winthrop, Massachusetts 02152

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Carla Vitale
Council Clerk

May 30, 2008

Dear Mr. Keegan,

Attached is a report sent to the Town of Winthrop by a concerned constituent. Please accept it as our comments on the Boston Harbor Deep Draft Navigation Improvement Project. The Town of Winthrop is extremely concerned that the Army Corps of Engineers inappropriately denied the long anticipated and critically necessary share protection on Winthrop Shore Drive.

If the rationale utilized in its Winthrop Beach decision is consistently applied, then the Boston Harbor project should also be denied. If the Boston Harbor project is approved, then we expect that the Army Corps of Engineers will reconsider and reverse its denial of the Winthrop Beach project.

Comment
TOW #1

Very truly yours,

Thomas E. Reilly
Council President

May 7, 2008

U.S. Army Corps of Engineers – New England District
District Engineer
696 Virginia Road
Concord, MA 01742-2751
ATTN: Programs and Project Management Division (Mr. Michael Keegan)

and

Secretary Ian A. Bowles
EOEA, Attn: MEPA Office
[Deirdre Buckley], EOEA No.12958
100 Cambridge Street, Suite 900
Boston MA 02114

RE: Comments on the DSEIS/DEIR for the Boston Harbor Deep Draft Navigation Improvement Project

Dear Secretary Bowles:

The Town of Winthrop is very concerned about the substantial adverse environmental impacts associated with the proposed Boston Harbor deepening project. Specifically, a large portion of Broad Sound and the North Channel areas are designated Essential Fish Habitat (EFH) for cod and American lobster. This designation is based on the oceanographic conditions (basically, water temperature in this case), bottom type, and presence/absence data used by the National Marine Fisheries Service (NMFS) in accordance Magnuson-Stevens Fishery Conservation and Management Act.

Comment TOW #2

As described in detail below, the NMFS will be required to determine that the seaward portion of the proposed Boston Harbor Deep Draft Navigation Improvement Project is an Aquatic Resource of National Importance (ARNI) to be consistent with their conservation recommendations for identical bottom type and EFH concerns at the proposed NOMES Site I borrow site (8 miles offshore of Boston Harbor). Moreover, the SDEIS/DEIR acknowledges that the proposed Boston Harbor project will cause a change in bottom substrate, resulting in a permanent impact to EFH and the associated ARNI. In an attempt to ensure consistent regulatory assessment, we request that both the "technical" personnel responsible for the ARNI determination from the U.S. Army Corps of Engineers and the NMFS be required to perform a scientifically-defensible comparison of EFH impacts associated with the outer harbor dredging and the NOMES Site I dredging prior to the preparation of a FEIS/FEIR. Once reviewed by qualified outside technical experts, this assessment should serve as the basis for EFH conservation

Comment TOW #3

Comment TOW #4

recommendations and hopefully ensure consistent regulatory decision-making for projects impacting cod and American lobster EFH in Massachusetts Bay.

In a recent decision, the U.S. Army Corps of Engineers recently denied the long anticipated shore protection project along Winthrop Shore Drive. The project was denied primarily because of one agency's (the National Marine Fisheries Service or NMFS) opinion regarding the value of offshore sand and gravel habitat to the "sustainability" of the cod population throughout the Northeastern U.S. In a letter from Louis A. Chiarella of NMFS to Christine Godfrey of the U.S. Army Corps New England District (NED) dated December 7, 2006,

NMFS maintain[ed] that gravel and cobble habitats (2mm - 256 mm) are an Aquatic Resource of National Importance [ARNI] due to its role in providing habitat essential to the sustainability of Northeast fisheries..

It is clear from this statement that the NMFS has determined that all gravel and cobble habitats in the Northeast U.S. are in an ARNI and this determination is not restricted to a 100-acre area 8 miles offshore of Boston Harbor. Areas designated as an ARNI prohibit activities that would impact the habitat such as dredging (including the proposed Boston Harbor navigation improvements), cable laying, and port development, but apparently not the equally damaging fishing-related impacts (e.g. bottom trawling and scallop dredging).

A review headed by Dr. Douglas Clarke of the U.S. Army Engineer Research and Development Center in Vicksburg, Mississippi indicated that "the NMFS case is primarily based on previous existing knowledge, presence/absence data, and assessments of critical habitat functions." They concluded that the sand, gravel, and cobble "habitat in question is of sufficient rarity with adequate evidence of significance to justify a high threshold of protection." The U.S. Army Corps North Atlantic Division (NAD) utilized this opinion as confirmation of the NMFS position and denied the use of NOMES Site I as a borrow source for Winthrop Beach.

Since the NMFS conclusions and the Army Corps denial were based strictly on the sediment comprising the ocean floor and whether the area was designated as an Essential Fish Habitat (presence/absence data), an area within Massachusetts Bay that has identical bottom habitat and EFH concerns should be afforded identical treatment and protection by the U.S. Army Corps of Engineers.

The geotechnical data presented in the Draft EIR for the Boston Harbor Deep draft Navigation Improvement Project clearly determined that the "sediments consist mostly of sand, gravel, and rock [cobble and boulder]" within the outer harbor. This information from the DEIR indicates that the sediments within the Boston outer harbor are as coarse as or coarser than the sediments at NOMES Site I. In addition, the DEIR acknowledges that the outer channel is EFH for most of the same species as NOMES Site I, most notably cod and American lobster.

One possible difference is the water depth at NOMES Site I, where the proposed borrow site is located at depths in excess of 80 ft MLLW that likely make it unsuitable for early benthic phase lobster (as proven by the extensive benthic sampling). However, the Boston outer harbor area where deepening is proposed consists of water depths that are highly conducive to early benthic phase lobsters and, therefore should receive a higher level of protection than the NOMES Site I habitat.

As described above, the NMFS has already designated gravel and cobble habitats within the Northeast as an ARNI, based upon EFH and bottom type considerations. Since this ARNI by default includes the Boston outer harbor channel (it has the same bottom type and EFH concerns as NOMES Site I), it will not be possible for the U.S. Army Corps of Engineers to issue a permit on the proposed dredging of the outer harbor channel.

To ensure consistency with recent previous habitat evaluations that have impacted regulatory decisions, the Town of Winthrop requests the following:

- The NMFS and DMF should be required to provide an analysis of the EFH and bottom type of the outer harbor channel relative to NOMES Site I and portions of the approved Hubline that crossed similar habitat. Using objective scientifically-defensible criteria, NMFS and DMF should be asked to develop fisheries conservation recommendations for the Boston outer harbor channel, supported by a clear concise reasoning for these recommendations in relation to the concerns they raised for NOMES Site I.
- Dr. Clarke's team at the Army Corps should review this NMFS/DMF analysis to determine whether they still agree with the ARNI designation for NOMES Site I and, if so, whether it is appropriate to impact one portion of the ARNI (the Boston outer harbor channel) and mandate protection of a different portion (NOMES Site I). This Army Corps team should justify their opinion with sound scientific arguments.
- An independent outside technical review of the analysis and Army Corps review should be performed to corroborate the conclusions and/or results of these other analyses. If this objective outside review should indicate that there is not clear scientific evidence supporting differences between the EFH, as well as bottom type, of NOMES Site I and the Boston outer harbor channel, the Army Corps should adopt this opinion as part of their regulatory decision and deny this portion of the harbor deepening project to protect the ARNI.

All of these analyses and reviews should be funded by the project proponent that has proposed the Boston Harbor deepening. In addition, the Town of Winthrop should be allowed to select the consultant to perform the independent technical review, subject to Army Corps approval based on the consultant's qualifications.

Comment TOW #5

Regardless of the ARNI concerns for the Boston outer harbor, the DEIR lacks the level of geotechnical investigation appropriate for a project of this magnitude. For example, the NMFS indicated that 15 cores at NOMES Site I was not sufficient to characterize the post-dredging substrate of an approximate 100-acre site (~1 core per 7 acres of dredged

area). However, the density of coring performed for the Boston Harbor deepening project is not nearly as dense as the NOMES Site I project. This is especially concerning, since the DEIR acknowledges a high variability in bottom sediments throughout the project footprint. This level of sampling may be sufficient for a dredging contractor to perform the work, but clearly (according to NMFS) is inadequate to characterize the fisheries and benthic habitat that will exist once the deepening project is completed. In addition to these geotechnical concerns, we have the following specific comments regarding the DEIR:

).

- The DEIR does not indicate that the proposed project is within the DMF designated "Cod Conservation Zone". According to the recent Army Corps denial of the Winthrop Beach project, the importance of the "Cod Conservation Zone" to the sustainability of the cod population in the northeast was an important consideration. Since the proposed dredging activities will have a substantial spatial and water quality (turbidity) impact on the "Cod Conservation Zone", the FEIR, Feasibility Report, and FEIS should provide a full assessment of these impacts. Winter flounder may be the primary concern within the upper portion of the Boston Harbor estuary; however, the outer portion of the system is prime American lobster and cod habitat. Turbidity impacts to EFH near the dredge footprint, any proposed mitigation sites, and at the offshore or nearshore dump sites should be included in this analysis. According to the recent Winthrop Beach decision, the discharge of dredged material was deemed to "cause or contribute to substantial degradation of waters of the U.S. including adverse effects on human health, life stages of organisms dependent on the aquatic ecosystem, ecosystem diversity, productivity and stability, and recreational, aesthetic and economic values." The FEIR and FEIS needs to show how the proposed dredging activities, as well as any disposal activities, will not degrade the waters of the U.S. in a similar fashion, especially considering that many of the dredge-related activities will be performed within areas with the same EFH concerns and the disposal areas will create suspended sediment that will directly impact or migrate into areas of gravel and cobble bottom that have been designated an ARNI by the NMFS.

Comment TOW #6

Comment TOW #7

- The FEIR should clearly delineate areas that have previously been dredged versus areas of proposed new dredging/mining (including increased channel area associated with side slopes). In addition, maps clearly indicating bottom type within each of these areas, as well as EFH concerns. Although the DSEIS and DEIR indicate that two very different benthic environments exist within the project footprint, the document does not adequately evaluate these areas as distinct habitats relative to potential impacts associated with the proposed deepening project. For clarity, it would be more appropriate to evaluate the "soft bottom" and "hard bottom" benthic communities and fisheries resources in separate sections. For example cod is an important species of concern for the "hard bottom" associated with the outer harbor channel (Broad Sound and North

Comment TOW #8

Comment TOW #9

Channel); however, the Feasibility Study does not even mention the species as a primary interest. The evaluation of the "hard bottom" habitat, its importance to the fisheries of the Northeast U.S., and the impacts to this habitat associated with the proposed improvement dredging need to be evaluated in significantly more detail.

- The DMF and the NMFS required an intensive one-year fish trawl and benthic survey to evaluate the resources at Since Figure 3-33 clearly indicates that no fisheries data exist within the project area, the fisheries analysis contained within the DSEIS and DEIR is incomplete. We recommend that the project proponent seek guidance from the DCR and or the Sconset Beach Preservation Fund to develop an adequate fisheries evaluation plan. This requirement would be consistent with other recent dredging proposals in Massachusetts state waters, since dredging improvement projects are regulated using the same guidelines as sand/gravel mining. Comment TOW #10
- The DEIR and DSEIS acknowledge that early benthic phase lobsters presently are (a) prevalent in the project area, primarily adjacent to the existing channel, and (b) would lose substantial habitat if the outer channel footprint is increased as proposed. Presumably this destruction of habitat would have similar impacts to the early life stages of the cod population that utilize similar habitat. The FEIR needs to assess the direct impacts associated with this loss of habitat. Unlike the recently denied Winthrop Beach project, it is highly unlikely that this area of "hard bottom" will recover, since it will be within the channel footprint and, therefore maintenance dredging will be allowed to continuously damage the habitat. Due to this concern, compensatory mitigation will be required for this loss of habitat functions and values. Since the Winthrop Beach project was denied because of the "concern" over potential for permanent impacts to identical habitat, it is unclear how the regulatory agencies are going to permit an acknowledged permanent impact to this same habitat. Comment TOW #11

In addition to the fisheries concerns, the Town of Winthrop is very concerned about the proposed dredging project relative to potential changes to wave energy and/or wave direction that could impact the shoreline.The historic navigation channel significantly deepened an area offshore of Winthrop and Yirrell Beaches likely leading to a significant increase in wave energy and the associated alteration of sediment transport patterns. These alterations have directly led to increased erosion at Winthrop Beach and the existing public safety hazard to the residents of Winthrop. Therefore, as part of the environmental review process for the proposed Boston Harbor deepening project, we request that the Army Corps evaluate the long-term impacts of the present North Channel on coastal sediment transport patterns relative to the pre-channel conditions (Figure 2). In addition, this analysis should include an evaluation of the wave climate associated with the proposed channel improvements relative to existing conditions. Comment TOW #12

Due to the inherent bias and/or conflict of interest of the Corps in this situation, we further request that the Corps fund an independent external technical review of this effort by appropriate consultants selected by the Town of Winthrop. As the Army Corps is well aware, independent technical reviews have been performed to address concerns related to Comment TOW #13

other controversial projects (e.g. Canaveral Inlet in Florida). In these cases, the technical experts are selected by the affected party (in this case, the Town of Winthrop). If the historical or proposed navigation improvements cause any alteration in nearshore wave climate to the Winthrop shoreline, the Town will seek damages from the Army Corps in the form of beach nourishment and/or structural improvements as compensatory mitigation.

Comment TOW #14

. In our view, it is not possible for the Army Corps to issue the needed 404 permit based on their recent denial of the NOMES borrow site. Unfortunately, there does not appear to be consistent leadership at the Corps decision-making level(s), which is likely one of the primary reasons for the needless delay and costs associated with the Winthrop Beach project. To be consistent with the NOMES decision, the proposed dredging of the outer channel should be denied with prejudice by the U.S. Army Corps of Engineers.

Very Truly Yours,

PART 3

SECRETARY'S CERTIFICATION OF THE ENVIRONMENTAL NOTIFICTION FORM INCLUDING EIR SCOPING REQUIREMENTS

MASSACHUSETTS EXECUTIVE OFFICE OF ENERGY AND ENVIRONMENTAL AFFAIRS

WITH ATTACHMENTS

The Commonwealth of Massachusetts
Executive Office of Environmental Affairs
251 Causeway Street, Suite 900
Boston, MA 02114-2119

MITT ROMNEY
GOVERNOR
KERRY HEALEY
LIEUTENANT GOVERNOR
ELLEN ROY HERZFELDER
SECRETARY

Tel. (617) 626-1000
Fax (617) 626-1181
http://www.mass.gov/envir

March 10, 2003

CERTIFICATE OF THE SECRETARY OF ENVIRONMENTAL AFFAIRS
ON THE
ENVIRONMENTAL NOTIFICATION FORM

PROJECT NAME	: Boston Harbor Deep Draft Navigation Improvement Project
PROJECT MUNICIPALITY	: Boston, Chelsea and Revere
PROJECT WATERSHED	: Boston Harbor
EOEA NUMBER	: 12958
PROJECT PROPONENT	: Massport
DATE NOTICED IN MONITOR	: February 8, 2003

Pursuant to the Massachusetts Environmental Policy Act (G. L. c. 30, ss. 61-62H) and Section 11.03 of the MEPA regulations (301 CMR 11.00), I hereby determine that this project **requires** the preparation of an Environmental Impact Report (EIR).

Project Description

As described in the Environmental Notification Form (ENF), the project consists of a feasibility study of potential deep-draft navigation channel improvements within Boston Harbor. The US Army Corps of Engineers (ACOE), in partnership with the Massachusetts Port Authority (Massport), is conducting the feasibility study. It will examine the Port of Boston's current and future role in maritime commerce and identify potential levels of future vessel traffic and commerce. The study will explore options for accommodating increased deep draft vessel traffic in Boston Harbor, including no action and channel

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deepening at a range of depths. The study will explore deepening the Entrance Channel, Main Anchorage and Main Ship Channel from -40 feet up to -50 feet mean lower low water (MLLW), the Mystic River Channel from -35 feet up to -40 feet MLLW and the Chelsea River Channel from -38 up to -40 feet MLLW. Channel deepening will be conducted with a mechanical bucket dredge and could generate approximately 6 million cubic yards (cy) of dredged spoils. Resource areas affected by the project include approximately 1,140 acres of Land Under Ocean and Fish Runs located within a Designated Port Area (DPA).

While the full range of disposal options will be addressed in the EIR, Massport has indicated that the majority of the dredged material will be natural clay and till (and to a lesser extent ledge) that is suitable for disposal at the Massachusetts Bay Disposal Site (MBDS). The remaining material is likely to be disposed of in one of the previously permitted Confined Aquatic Disposal (CAD) Cells developed as part of the Boston Harbor Navigation Improvement Project (BHNIP).

Permits and Jurisdiction

The project is undergoing MEPA review and requires the preparation of an EIR pursuant to Section 11.03 (a)(1)(a) because it requires a state permit and will alter more than ten acres of wetlands. The project requires a 401 Water Quality Certification from the Department of Environmental Protection (DEP), an Order of Conditions from the Boston, Chelsea and Revere Conservation Commissions, and Coastal Zone Management (CZM) Federal Consistency review.

Also, the project requires an Environmental Impact Statement (EIS) pursuant to the requirements of the National Environmental Policy Act (NEPA). Both MEPA and NEPA regulations allow (and encourage) joint review documents. Massport has indicated that the federal EIS and state EIR will be submitted as a single document that addresses the requirements of both review processes. The EIS/EIR should fully address both the federal and state scopes although I will ultimately issue a determination of adequacy only for those portions of the document required in the state scope.

Because the proponent is a state agency and is funding half of the project costs, MEPA jurisdiction extends to all aspects of the project that may cause significant Damage to the

Environment including air quality, water quality, threatened and endangered species, marine habitat, and fisheries.

Boston Harbor Navigation Improvement and Berth Dredging Project (#8695)

The planning and permitting process for the BHNIP addressed a number of issues that are directly relevant to the design and implementation of this project. The BHNIP was the first major dredging project in Boston Harbor in thirty years and was unique in terms of size, design, process and construction techniques. It included the maintenance and improvement dredging of the main shipping channels and berths within Boston's Inner Harbor. Over 784,850 cubic yards of dredged material deemed unsuitable for open-water disposal was placed within nine CAD cells constructed within the dredging footprint of navigation channels.

The overall size of the project and the amount of contaminated material (containing elevated levels of metals and organic compounds) raised a number of environmental issues and concerns related to dredging and the disposal of dredged materials. These issues and concerns were outlined in related environmental filings and addressed through project design and permitting. A Technical Advisory Committee (TAC), consisting of resource agencies, environmental advocates, scientists and others, was formed to help advise the proponent and was instrumental to the success of this project through the design, permitting and construction phases. The TAC helped evaluate a wide range of disposal alternatives, develop conditions for the Water Quality Certification, and modify construction and monitoring techniques as necessary.

The BHNIP, which was completed in late 2001, has provided a framework for creating an environmentally acceptable dredging and disposal plan. It furthered our understanding of dredging operations and techniques, provided valuable information about baseline conditions within Boston Harbor, and resulted in the development of guidelines for permitting and constructing CADs to minimize impacts. I expect that the recommendations included in the feasibility study for this proposed project will be informed by the experience developed during the BHNIP and I encourage the proponent to include a summary of lessons learned in the EIR to facilitate understanding of the proposed design and mitigation. In particular, an evaluation of the utility of water quality monitoring methodology, the geographical behavior MEPA.1

of the CAD cells and data related to marine habitat will be useful.

SCOPE

The EIR should follow Section 11.07 of the MEPA regulations for outline and content, as modified by this scope. It should include a copy of this Certificate and of each comment received. The proponent should address the comments to the extent that they are within this scope. The proponent should circulate the EIR to those who commented on the ENF, and to any state agencies from which the proponent will potentially seek permits or approvals. MEPA.2

The draft scope provided by the proponent within the ENF addresses most of the issues that should be included in the EIR including a No Action scenario to establish a baseline and a number of additional alternatives including alternatives for disposal of the dredged material.

Project Description

The EIR should clearly identify where this project and its alternatives overlap with previous improvement and/or maintenance dredging. While Massport is the proponent of this project in terms of MEPA review, it is my understanding that the ACOE will conduct most of the actual dredging and related mitigation while Massport may implement discrete elements of it. The EIR should identify who is responsible for what elements of the project and its related mitigation and whether or not that responsibility shifts depending on the alternative selected. MEPA.3 MEPA.4

Environmental Impacts

The EIR will include a section on environmental impacts of dredging and dredged material disposal including water quality, biological resources, threatened and endangered species, historic and archaeological resources, noise and odor. This section should indicate which impacts are temporary and which are permanent. The EIR should identify wetland resource areas present within the project boundaries on a reasonably scaled plan and it should indicate the significance of the resources. MEPA.5 MEPA.6

The environmental impacts section should include the secondary impacts of the deepening project such as increased ship traffic and an increase in the size of ships entering the harbor. The EIR should examine the impact of these changes to fishing, marine mammals, water quality, air quality and harbor uses. MEPA.7

Cumulative Impacts

A number of comments have suggested that the EIR should address the cumulative impacts of a number of ongoing and planned projects within Boston Harbor and Massachusetts Bay. As noted, a number of small and large scale projects with potential short and long term impacts to marine resources are planned within these areas. These projects are set against a background of impacts to coastal resources from a range of human activities, including use of existing disposal sites, shipping, commercial and recreational fishing, and long term climate changes. I believe these comments emerge from a concern that planning for appropriate activities and uses within our ocean resources are being permitted in the absence of a proactive management and planning framework and highlight the relevance of such an approach. EOEA agencies responsible for coastal planning permitting and decision-making can successfully address this issue over time in a comprehensive manner that could not be demanded of a single project proponent.

However, to assist the permitting agencies in their evaluation of the potential impacts of this project, the EIR should describe ongoing and planned projects within Boston Harbor and Massachusetts Bay to include, at a minimum, the Hub Line gas pipeline project and the proposed Everett Extension, the ACOE maintenance dredging, and the use of an offshore borrow site (NOMES I) by the MDC as a sand source for the Winthrop Shores Reservation and Restoration Project. The description should include a summary of the projects' impacts, individually and cumulatively, including the size of the impacted area, the resources impacted by the projects, and the duration of the impacts. The description should also include a timeline that shows when the projects are planned to occur in relation to the dredging project. Coordination with agencies/organizations regarding existing infrastructure. MEPA.8

Alternatives

A number of project design alternatives will be included in the EIR that vary, incrementally, in the depth and areas of dredging. Dredged material disposal options and sites will be summarized. A preferred design and disposal alternative will be identified. This section should include a discussion of project phasing. Will dredging be conducted only in one area at one time or will multiple areas be dredged at once? What are the volumes of material that will be dredged and disposed of over what time period? It should explore the comparative impacts to the substrate and water column of several smaller deepening efforts as opposed to one larger one and this information should be incorporated into the ACOE cost/benefit analysis. Finally, it should include a discussion of the types of dredges that can be used for this project and compare the benefits and/or drawbacks of each. MEPA.9 MEAP.10

The EIR should include a discussion of maintenance needs, indicate how often maintenance dredging will be required and how associated dredged materials will be disposed. MEAP.11

Coordination with Proposed Projects

As noted previously, a number of projects have been proposed within the general vicinity of this one. The DEIR should lay out a process for coordination with the agencies and organizations responsible for these projects to minimize conflicts and environmental damage. MEPA.12

The Massachusetts Water Resources Authority, NSTAR and the Central Artery/Tunnel Project have requested that the proponent address construction period impacts on existing harbor infrastructure such as utility crossings and the Ted Williams Tunnel, respectively. Impacts to one or more of the buried utilities, particularly the cross harbor electric power cable that is the primary source of power to the Deer Island Treatment plant, could result in very significant adverse effects. The cable construction, operation and maintenance and associated substations is borne entirely by the MWRA and its ratepayers.

The DEIR should lay out a clear process for coordination between parties, indicate who is responsible for identifying actual locations and depths of existing infrastructure that could be directly affected by the project's construction, who is responsible for related costs, and, should include a contingency MEPA.13

plan in the event that a problem occurs. Because the range of dredging depths being considered could result in little or no buffer between the utility cable and the ocean floor, the DEIR should explore the feasibility and cost of relocating the cable.

Technical Working Group (TWG)

As noted earlier, the ongoing participation of technical advisors for the BHNIP was critical to its success. I applaud the proponent's inclusion of a TWG for this project and expect the TWG will help refine the monitoring and mitigation requirements as the project is designed and developed. MEPA.14

Mitigation

The mitigation section should correspond with the areas of impact outlined in previous sections of the proponent's draft scope. Mitigation should address temporary, short-term and long-term impacts. MEPA.15

The proponent should indicate how it will minimize turbidity and migration of dredged sediments during dredging and disposal. The proponent should identify dredging windows and related monitoring activities to minimize and mitigate impacts to fishery resources in, and adjacent to, the dredging and disposal activities. In addition, the proponent should consider beneficial reuse of ledge material to provide benthic habitat and/or shore protection. The state Water Quality Certification, issued by DEP, will be the vehicle for solidifying most mitigation requirements. MEPA.16 MEPA.17 MEPA.18

The EIR should include a summary of all mitigation measures to which the proponent has committed, including mitigation for construction period impacts. The EIR should also include Proposed Section 61 Findings for use by the state permitting agencies. MEPA.19

March 10, 2003
Date

James W. Hunt for
Ellen Roy Herzfelder

EOEA# 12958 ENF Certificate 03/10/03

Comments received:
02/27/03 Department of Environmental Protection (DEP)
02/27/03 Division of Marine Fisheries (DMF)
02/27/03 Coastal Zone Management (CZM)
02/28/03 Massachusetts Water Resources Authority (MWRA)
02/27/03 Massachusetts Turnpike Authority(MTA)/CA/T Project
02/28/03 City of Boston/The Environment Department
02/28/03 The Boston Harbor Association (TBHA)
02/28/03 NSTAR

ERH/CDB/cdb

DB

COMMONWEALTH OF MASSACHUSETTS
EXECUTIVE OFFICE OF ENVIRONMENTAL AFFAIRS
DEPARTMENT OF ENVIRONMENTAL PROTECTION
ONE WINTER STREET, BOSTON, MA 02108 617-292-5500

MITT ROMNEY
Governor

KERRY HEALEY
Lieutenant Governor

ELLEN ROY HERZFELDER
Secretary

EDWARD P. KUNCE
Acting Commissioner

RECEIVED
FEB 28 2003
MEPA

February 27, 2003

Ellen Roy Herzfelder, Secretary
Executive Office of Environmental Affairs
251 Causeway Street, 9th floor
Boston, Massachusetts 02114

Re: EOEA # 12958
Environmental Notification Form
Boston Harbor Deep Draft
Navigation Improvement Project

Attention: Deirdre Buckley

Dear Ms. Herzfelder:

The Department of Environmental Protection (DEP) has reviewed the Environmental Notification Form (ENF) published in the February 8, 2003, *Environmental Monitor* for a Feasibility Study (Boston Harbor Deep Draft Navigation Improvement Project [BHDDNIP]) of potential navigation channel improvements to the Port of Boston and this correspondence includes DEP's consolidated comments.

Project Description

The U.S. Army Corps of Engineers (ACOE), in partnership with Massport as the non-federal sponsor, plans to conduct a Feasibility Study of potential deep draft navigation channel improvements to Boston Harbor. The study will examine the Port of Boston's current and likely future levels of future navigation traffic and commerce through the port. The study will specifically investigate alternatives for accommodating increased deep draft vessel traffic in Boston Harbor, including channel deepening, cargo diversion, and no action to identify whether improvements are warranted. Environmental documentation as required under the Massachusetts Environmental Policy Act (MEPA) and under the National Environmental Policy Act (NEPA) will be conducted as part of the Feasibility Study. DEP notes that this project is categorically required to prepare an EIR.

Background Information

As MEPA is aware, in addition to the BHDDNIP, two additional navigational dredging projects for the Port of Boston have either recently been completed or planned to be performed in the near future; (1) the now-completed Boston Harbor Navigation Improvement and Berth Dredging Project (BHNIP), and (2) a federal maintenance dredging project of the main shipping channel to be undertaken solely by ACOE, proposed to begin the summer of 2003. In late 2001, ACOE/Massport

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DEP on the World Wide Web: http://www.mass.gov/dep
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completed the dredging and sediment management for the BHNIP (EOEA # 8695), which resulted in deepening of key tributaries and portions of the main shipping channel to 40 feet and related berths to depth ranging from 35 to 45 feet. The ACOE project will consist of maintenance dredging of the federal channels up to the CA/T Ted Williams Tunnel.

Comments

1. In addition to the above referenced navigation dredging projects, there are a number of ongoing and/or planned projects within the Boston Harbor environs which should be considered in the scooping of the BHDDNIP EIR. Those projects include, but are not limited to; (1) ongoing Maritimes and Northeast Pipeline/Algonquin Gas Transmission Company Hubline Project (EOEA # 12355); (2) proposed Everett Extension Pipeline Project (extension/modification to Hubline Project); (3) Massachusetts Water Resources Authority (MWRA) ongoing implementation of the Boston Harbor Cleanup; (4) MDC's Back-to-the-Beaches Program; (5) ongoing Central Artery/Tunnel Project, including opening of the Spectacle Island Park (EOEA # 4325); and the numerous shore-side development projects (including Portside @ Pier One/Boston Harbor Shipyard and Marina (EOEA # 12623), Pier 4 (EOEA # 12433), and Fan Pier (EOEA # 12083). DEP.1

   At the February 25th MEPA Scoping Session the issue of cumulative impacts and/or "overlapping" projects, was specifically raised as a significant concern. DEP agrees that this issue should be considered in the development of the EIR Scope.

2. DEP has agreed to actively participate in the BHDDNIP Technical Working Group (TWG). Yvonne Unger (Bureau of Resource Protection/Dredging Program) will be the DEP-designee on the TWG. DEP staff actively participated in the TWG for the previous BHNIP, an activity which was critical to getting consensus on that project. DEP expects that the discussions which will occur as part of the BHDDNIP TWG will be as successful. DEP.2

3. According to the ENF, and as discussed at the Scoping Session, the overwhelming majority of the approximate 6 million of cubic yards of material to be dredged and/or removed will be natural clay and till (and to a lesser extent ledge) which are planned to be barged to the MBDS, but ACOE anticipates that there will be some volume of silt materials that will probably not be allowed to be placed at the MBDS. The Feasibility Study will consider options for the management of this material, including; placement into one or more In-Channel CAD Cells that were permitted as part of the BHNIP, and upland disposition. At the Scoping Session the ACOE spokesperson stated that there currently is extensive capacity in various permitted, but unused, CAD Cells and that ACOE and Massport are likely to propose to place the silts into one or more of these cells. DEP.3

   During the environmental review, permitting, implementation and post-dredging monitoring of the BHNIDP, DEP staff have been directly involved in the consideration and assessment of the CAD Cell disposal activities. In this regard, DEP staff recently performed a review of the "One-Year Monitoring Plan for the Boston Harbor CAD Cells - Summary 2001" document prepared and submitted as a condition of the Water Quality Certification. Based on a review of this report and prior information, DEP is of the opinion that the CAD Cells are functioning properly and that DEP would therefore look favorably at a proposal by ACOE/Massport to

utilize one or more of the unused (or partially filled) cells for disposal of the silty sediment from the BHDDNIP.

DEP would like to also indicate that based on its experiences working on the BHNIDP, CA/T and Hubline Projects, that an upland management option for significant volumes of silty sediment from Boston Harbor will be problematic.

4. At the Scoping Session concerns were raised by representatives from NSTAR and MWRA regarding impacts to utilities (particularly buried power cables) located in areas of the Harbor which would overlap with the proposed dredging footprint. According to the NSTAR representative, there were significant problems during the BHNIDP. Impacts to one or more of the buried utilities, particularly the power cable running down Reserved Channel to Deer Island, could result in very significant adverse effects, therefore DEP strongly recommends that the EIR scope fully address this issue. DEP.4

5. It will be important for the proponent to closely coordinate with relevant local, state and federal resource agencies relative to minimizing and mitigation impacts to fishery resources in, and adjacent to, the dredging and sediment disposal activities. A key element will be defining allowable "dredging windows" and monitoring activities. DEP staff will need to be involved in all such discussions in that the WQC will be the state-permitting vehicle for defining the monitoring requirements, contingency measures, allowable dredging periods, etc. ACOE and Massport should carefully review the WQCs that have been issued by DEP for the BHNIDP, CA/T Ted William Tunnel and Hubline Projects as guides to the activities and conditions that are likely to be included in the BHDDNIP. DEP.5

Feel free to contact Yvonne Unger at 617-292-5893 or me at 617-292-5698 if you have any questions regarding this correspondence.

Very truly yours,

Steven G. Lipman, P.E.
Special Projects Coordinator
Commissioner's Office

Cc: Mike Keagan (ACOE)
Deb Hadden and Jacki Wilkins (Massport)
Deerin Babb-Brott (CZM)
Vin Malkoski (DMF)
Dave Shakespeare, Yvonne Unger, Jim Sprague, Eric Worrall, Lealdon Langley (DEP)

THE COMMONWEALTH OF MASSACHUSETTS
EXECUTIVE OFFICE OF ENVIRONMENTAL AFFAIRS
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251 Causeway Street, Suite 900, Boston, MA 02114-2136
(617) 626-12100 fax: (617) 626-1240

MEMORANDUM

TO:	Ellen Roy Herzfelder, Secretary, EOEA
ATTN:	Deirdre Buckley, MEPA Unit
FROM:	Tom Skinner, Director, CZM
DATE:	February 27, 2003
RE:	EOEA #12958 – Boston Harbor Deep Draft Navigation Improvement Project

The Massachusetts Office of Coastal Zone Management (CZM) has completed its review of the above-referenced Environmental Notification Form (ENF) noticed in the Environmental Monitor dated February 8, 2003. CZM understands that this project categorically requires the preparation of an Environmental Impact Report (EIR).

Project Description

The US Army Corps of Engineers (Corps), in partnership with the Massachusetts Port Authority (Massport), has initiated a feasibility study of potential deep-draft navigation channel improvements to the Boston Harbor. The study will examine the Port of Boston's current and future role in the maritime commerce of the nation, and identify likely levels of future vessel traffic and commerce through the Port. In addition, the study will investigate options for accommodating increased deep draft vessel traffic at Boston Harbor, including channel deepening, cargo diversion, and no action. The costs of implementing alternative options will be measured against estimated benefits to improving commercial transportation costs in order to identify whether improvements are warranted consistent with Corps policies. Plans for channel improvements will result in the deepening of the entrance channel and main anchorage (from –40 feet to up to –50 feet mean lower-low water (MLLW)), the main ship channel (from -40 feet to up to –50 feet MLLW), the Mystic River Channel (from –35 feet to –40 feet MLLW), and the Chelsea River Channel (from –38 to –40 feet MLLW).

Comments

CZM participated in the technical working group for the recently completed Boston Harbor Navigation Improvement Project (BHNIP), which deepened the Harbor to –40 feet MLLW, and looks forward to participating in a similar process for the Boston Harbor Deep Draft Navigation Improvement Project (BHDDNIP). CZM.1

Confined Aquatic Disposal, Water Quality, Fisheries Impacts

As part of the recently completed BHNIP project, the Corps used in-channel confined aquatic disposal (CAD) cells as a method of disposing of dredged sediment deemed unsuitable for disposal at the state approved ocean disposal site. At the MEPA scoping meeting, the Corps indicated its intention to consider use of the unused BHNIP CAD cells (approved under the

BHNIP) for the placement of contaminated dredged material from the currently proposed deepening effort. CZM supports the assessment of the previously approved CAD cells for this purpose. In the EIR, CZM requests that the Corps summarize the "lessons learned" from the recently completed BHNIP with regard to this method of sediment disposal, in addition to recommended changes for the upcoming dredging project based on that information. In particular, an evaluation of the utility of the water quality monitoring methodology, the geographical behavior of the CAD cells, and any other available data related to impacts to marine habitat will be useful for the evaluation of the proposed dredging project. CZM.2

Cost/Benefit Analysis

CZM understands that the Corps must perform a cost/benefit analysis of any project it proposes to construct using federal funds. It is our understanding that this analysis will be performed incrementally for the BHDDNIP project, i.e., the cost/benefit model will be applied to a project that deepens to -42 feet MLLW, -44 feet MLLW, -46 MLLW, etc., up to -50 feet MLLW, and the depth selected will be that which provides the most benefit for the least cost, in accordance with Corps regulations.

The Corps' cost/benefit analysis often leads to the selection of a depth that most parties recognize will not be sufficient to meet even the mid-term needs of the shipping industry. As is often the case, the need for channel depths in excess of the BHNIP selected depth of -40 feet was recognized prior to the completion of that project. With this in mind, CZM requests that the Corps consider, as part of the cost/benefit analysis, the environmental impacts of disturbing the substrate and impacting the water column with several smaller deepening efforts as opposed to one larger one. CZM.3

Coordination With Utility Providers, Other Projects

During the scoping session, concerns were raised by N-Star and the MWRA regarding the respective agencies cables and pipelines which run under Boston Harbor. CZM suggests that the EIR lay out a clear process for coordination between any parties with utilities in the area of the proposed dredging project. The EIR should discuss a similar process for coordination between the other multiple projects taking place in and around Boston Harbor during a similar timeframe. CZM.4

Proposed Outline

The ENF contains a proposed outline for the BHDDNIP draft EIR/SEIS. Except as requested above, the outline appears to cover most of the relevant issues associated with the proposed deepening project. CZM looks forward to seeing the information referenced in the draft outline, and will comment in detail on its findings when the EIR/SEIS becomes available.

Additional Review

As stated in the ENF, this project will be subject to CZM federal consistency. The project must be found to be consistent with CZM's enforceable program policies. For further information on this process, please contact Jane W. Mead, Project Review Coordinator, at 617-626-1219 or visit the CZM web site at www.state.ma.us/czm/fcr.htm. CZM.5

TWS/MG

Cc: Deerin Babb-Brott, Assistant Director
Massachusetts Office of Coastal Zone Management
James Sprague, Section Chief
Northeast Regional Office, MA DEP
Deb Hadden, Deputy Director of Maritime
Massport
Vin Malkoski, Fisheries Biologist
Division of Marine Fisheries

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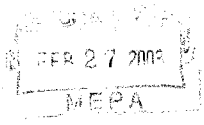
Paul J. Diodati
Director

03

February 27, 2003

Ellen Roy Herzfelder, Secretary
EOEA, Attention: MEPA Office
Deirdre Buckley, EOEA No. 12958
251 Causeway Street, Suite 900
Boston, MA 02114-2150



Dear Secretary Roy Herzfelder:

The Division of Marine Fisheries has reviewed the Environmental Notification Form (EOEA #12958) for the Boston Harbor Deep Draft Navigation Improvement Project with respect to its effect on the marine fisheries resources of the Commonwealth. We offer the following comments for your consideration.

The proposed Scope of Work for the DEIR/DEIS prepared by the Army Corps of Engineers appears to have identified the major resource questions that must be addressed. It is our understanding that the specific data sets and techniques to be used in this evaluation will be identified and defined by the Technical Working Group. In addition, there are several issues not included in the DEIR Scope of Work that need to be addressed:

1. The Corps should identify opportunities for beneficial reuse of dredged materials such as rock and cobble. In some areas, there may be an environmental benefit to leaving the unconsolidated material in place to provide benthic habitat. Other uses would include shore protection or redeployment in another area to enhance benthic habitat. DMF.1

2. The DEIR should include discussion of how this dredging project will contribute to the overall cumulative impact to marine resources and habitat caused by on-going projects in this portion of Massachusetts Bay. At this time, installation of the Hubline gas pipeline is altering nearly 30 square miles of bottom, the Corps is proposing to perform maintenance dredging that will remove approximately 250 acres of sand, cobble, and gravel from Broad Sound, and the MDC is proposing to remove 1 million cubic yards of cobble and gravel (approximately 100 acres) from nearby Massachusetts Bay. Alteration of these habitat areas will result in direct and indirect impacts to fisheries and the loss of habitat functions and value during recovery. For example, cobble and ledge habitat (critical habitat for juvenile cod and lobster) may take upwards of 10 years to recover from radical alterations and may never fully recover. DMF.2

3. Relative to the direct loss of habitat and temporal loss of function, creation of a comprehensive recovery monitoring and mitigation plan will be needed to compensate for these losses. This effort should be guided by the Technical Working Group and the plan included as a condition of project permits. DMF.3

Thank you for the opportunity to comment on this proposal and we look forward to working with the Army Corps and Massport on this project as part of the Technical Working Group. If you have any questions about this review, please contact Vin Malkoski in our Pocasset office at (508) 563-1779, ext. 119.

Sincerely,

Paul J. Diodati
Director

Cc: Timothy Famulare, Boston Conservation Commission
Michael Keegan, ACOE
Mike Johnson & David MacDuffee, NMFS Gloucester
Timothy Timmerman, US EPA
Deerin Babb-Brott & Jane Mead, MCZM
Steve Lipman, MA DEP
Yvonne Unger, MA DEP
Cunningham, Estrella, Kennedy, & Pierce, MDMF

DB

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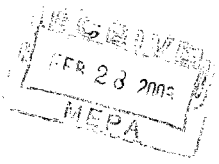
Frederick A. Laskey
Executive Director

February 28, 2003



Ms. Ellen Roy Herzfelder, Secretary
Executive Office of Environmental Affairs
MEPA Unit
251 Causeway Street, Suite 900
Boston, MA 02114

Attn: Dierdre Buckley, EOEA No. 12958

Re: Massport's Boston Harbor Deep Draft Navigational Improvement Project - EOEA #12958

Dear Secretary Roy Herzfelder:

Staff at the Massachusetts Water Resources Authority (MWRA) have reviewed the Environmental Notification Form (ENF) for Massport's Boston Harbor Deep Draft Navigational Improvement Project and attended the scoping session held on Tuesday, February 25, 2003 at the Black Falcon Terminal. Massport and the U.S Army Corps of Engineers (Corps) plan to conduct a feasibility study of potential deep draft navigation channel improvements in Boston Harbor. The study will examine the Port of Boston's current and likely future role in the maritime commerce of the nation and identify likely levels of future navigation traffic and commerce through the port. The costs of implementing alternative options will be measured against estimated benefits in reduced transportation costs in order to identify whether improvements are warranted consistent with Corps policies.

MWRA's comments and concerns are specifically related to the impacts to the existing cross-harbor electric cable that provides power to the Deer Island Treatment plant, the second largest treatment plant in the country. While the cable is owned by Harbor Electric Energy Corp. (a wholly owned subsidiary of Nstar), the cost of construction, operation and maintenance of the cable and associated substations is borne entirely by the MWRA and its ratepayers. The cable and substations were installed at a cost of approximately $40 million as part of the $3.5 billion Federal court mandated Boston Harbor Project.

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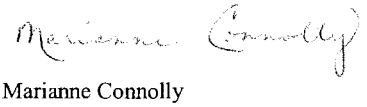
The proposed limit of this project partially coincides with the current location of Nstar's 115Kv Submarine Power Cable which feeds the MWRA's Treatment Plant. As indicated in the ENF, there appears to be an overlap in the proposed deep draft dredging of the Reserve Channel and adjacent entrance to the Reserve Channel and the "as-installed" location of the Submarine Cable. Nstar documents indicate that this cable was installed at –50 feet and that the new dredging project proposes to increase the cut from the existing depth of –40 to the new depth of –42 to –50. It should be noted that the dredging process might result in areas being deepened an additional two feet beyond what is actually proposed.

Therefore, the dredging in the immediate area of the 115Kv Submarine Cable to the new proposed depths may lead to possible damage to the cable, resulting in the release of the insulating oil in the cable to the waters of the harbor and the potential long term disruption of the primary source of power to the treatment plant servicing over 43 cities and towns in metropolitan Boston. MWRA.1

Staff at MWRA need to have serious discussions with the Project Proponents on identifying and examining alternatives to dredging at the Reserve Channel so that impacts to the submarine cable are avoided. MWRA.2 In addition, MWRA requests that the EIR/S identify the cost/benefits of moving the cable, if necessary, determine who pays for this undertaking, and include a contingency plan in the event of damaging the cable (loss of power to the treatment plant as well as water quality impacts with the release of oil contained in the cable.) MWRA.3 MWRA cannot over emphasize the importance of the electric cable in the daily operation of the treatment plant, which services over 2.5 million people. MWRA looks forward to working with the proponents to assure that MWRA's electric source is not jeopardized and to assure that any costs associated with the project are not passed on to MWRA ratepayers.

Thank you for the opportunity to comment.

Yours truly,



Marianne Connolly
Program Manager, Regulatory Compliance

cc: Senator Robert Travaglini
Representative Robert A. DeLeo
Maggie Debbie, MWRA
David Finlay, MWRA
Jeff McLaughlin, MWRA

C: MEPA12958BosHarDredging

OB

Massachusetts Turnpike Authority
Central Artery/Tunnel Project

MAR 3 2003
MEPA

February 27, 2003

Secretary Ellen Roy Herzfelder
Executive Office of Environmental Affairs
Attention: MEPA Office
Ms. Deirdre Buckley, EOEA #12958
251 Causeway Street, Suite 900
Boston, MA 02114

Subject: Boston Deep Draft Navigation Improvement Project
Environmental Notification Form (ENF)

Dear Secretary Roy Herzfelder:

The Central Artery/Tunnel (CA/T) Project staff has reviewed the subject document. The proposed Navigation Improvement Project is located adjacent to the CA/T Project's Ted Williams Tunnel and our Excavated Materials Handling Site at Subara Pier.

The ENF notes that the Ted Williams Tunnel limits channel depths above the Tunnel to the 40 feet now provided; however, our design allows for accommodation of an approximately 600-foot wide, 45-foot deep channel over the Tunnel. In the future, if the channel depth is proposed to be deepened over the Tunnel, these dimensions should be verified.

Our only concern with the proposed dredging project is the deepening next to the Tunnel, especially any blasting in the vicinity of the Tunnel. We request documentation and close coordination with our Project and the MTA to ensure that the channel deepening and any associated construction activities such as blasting will not effect the Ted Williams Tunnel. MTA.1

Massport officials have maintained a cooperative relationship over the years with the CA/T Project and the Massachusetts Turnpike Authority. We anticipate this ongoing cooperative relationship effort will continue during the design review, permitting, and construction processes for the Navigation Improvement Project.

185 Kneeland Street • Boston • Massachusetts • 02111 • Phone 617-951-6000 • Fax 617-457-8198

Massachusetts Turnpike Authority
Central Artery/Tunnel Project

If you have any questions, please contact Ronald Killian, Manager of Environmental Permits and Procedures, at (617) 556-2453.

Sincerely,

MASSACHUSETTS TURNPIKE AUTHORITY

Paul A. Stakutis
Director of Environmental Affairs

PAS/AR/mal

cc: Mr. Michael A. Leone, Massport
Mr. James F. Cashman, MTA

2003-256K
AD-2.1.2
AL-1.2

CITY OF BOSTON
THE ENVIRONMENT DEPARTMENT

Boston City Hall, Room 805 • Boston, MA 02201 • 617/635-3850 • FAX: 617/635-3435

February 28, 2003

Ellen Roy Herzfelder, Secretary
Executive Office of Environmental Affairs
251 Causeway Street, 9th Floor
Boston, MA 02114
Attention: Deirdre Buckley, MEPA Office

MAR 13 2003
MEPA

Re: Boston Harbor Deep Draft Navigation Improvement Project, Environmental Notification Form, EOEA #12958

Dear Secretary Roy Herzfelder:

The City of Boston Environment Department has reviewed the Environmental Notification Form (ENF). We hereby submit the following comments to promote the use of proven environmental strategies and technologies in fulfilling environmental requirements.

PROJECT DESCRIPTION

The U.S. Army Corps of Engineers, and the Massachusetts Port Authority (Massport) propose to conduct a feasibility study of potential deep draft navigation channel improvements to Boston Harbor, known as the Boston Harbor Deep Draft Navigation Improvement Project ("BHDDNIP"). This study will include an examination of the current and likely future role of the Port of Boston in national maritime commerce and identify likely levels of maritime traffic. The study will also investigate alternatives for accommodating increased deep draft vessel traffic and a cost-benefit analysis of these alternatives to include channel deepening, cargo diversion, and no action.

RESPONSE

This Department supports the proposed study to assess the needs of the Port of Boston to accommodate increased maritime commerce. This project will require Orders of Conditions issued by the Boston Conservation Commission ("BCC") pursuant to the Massachusetts Wetlands Protection Act, M.G.L. Ch. 131, s. 40 ("the Act"). The involvement of BCC staff on the Technical Working Group ("TWG") for the recently completed Boston harbor Navigation Improvement Project proved very useful in designing the project to conform with performance BOS.1

Antonia M. Pollak, Director

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Thomas M. Menino, Mayor

standards set by the Act and it s regulations; the Executive Secretary of the BCC has accepted the proponent's invitation to join the TWG for the BHDDNIP.

Several utility crossings were damaged or destroyed during dredging operations of the BHNIP. Repair efforts sometimes involved alteration of wetlands resources protected by the Act. The applicants should work with all affected utility owners to identify the location and depth of utility crossings to prevent unnecessary damage to them during the BHDDNIP. BOS.2

In the past decade, the land under Boston Harbor, which provides habitat to a diverse community of fish and marine invertebrates, some of which are commercially viable species, has been frequently disturbed by major projects, including the construction of the Ted Williams Tunnel crossing, the BHNIP, and the Algonquin Gas Hubline Project. The environmental documentation required under the Massachusetts Environmental Policy Act and the National Environmental Policy Act should carefully assess the cumulative effects of these disruptive projects and consider appropriate mitigation for destruction of marine species habitat that would occur as a result of the BHDDNIP. BOS.3

Thank you for the opportunity to offer comment.

Sincerely,

Bryan Glascock
Acting Director

BHDDNIP.doc.DBG:TJF.tjf/03.02.010

DB

The Boston Harbor Association
for a clean, alive and accessible Boston Harbor

28 February 2003

RECEIVED
MAR 6 2003
MEPA

Secretary Ellen Roy Herzfelder
Executive Office of Environmental Affairs
251 Causeway Street, Suite 900
Boston, MA 02114
Att: MEPA Office

RE: Environmental Notification Form, Boston Harbor Deep Draft Navigation Improvement Project, Boston

Dear Secretary Herzfelder:

The Boston Harbor Association, a non-profit, public interest organization founded in 1973 by the League of Women Voters and the Boston Shipping Association, strongly supports the Massachusetts Port Authority and the U.S. Army Corps of Engineers' efforts to conduct a feasibility study of potential deep-draft navigation channel improvements to Boston Harbor.

The Boston Harbor Association was an active participant in the environmental oversight and planning for the Boston Harbor Navigation Improvement Project completed in 2001. That project deepened the main shipping channel to 40 feet and the associated berths to depths of 35 to 40 feet. Since completion of that project, however, the continued silting of the main shipping channel in other portions of the Harbor now require maintenance dredging to restore the shipping channel to a minimum 40 feet depth.

The economics and efficiencies of cargo transport currently and in the coming decade require the use of larger, state-of-the-art vessels. The Massachusetts Port Authority has done an excellent job of attracting new service to the Port of Boston, most recently, direct outbound ocean service to Asia. In order to be able to continue to attract and keep such cargo service coming to the Port of Boston, however, the shipping channel must be deepened to accommodate larger vessels.

The proposed feasibility study is a much-needed and welcomed step towards deepening of Boston Harbor. We have reviewed the Environmental

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Notification Form, including the attached outline of the feasibility study, and offer the following comments:

Project schedule: The estimated commencement date for the deepening is 2009, with completion in 2011. While we understand that the study will require more than a year to complete, followed by the need for budget appropriations, it is our hope that commencement of the deepening can occur before 2009 if the study supports such action and if funding is available. Any delay beyond then will adversely impact the viability of the Port of Boston. BHA.1

Study introduction: The outline for the feasibility study suggests a section on the "Historical Importance of the Port of Boston" within the chapter on "Project Purpose and Need". We believe that only minimal attention should be given the role of the Port in the 18th, 19th, or even early 20th centuries, and that this section on project purpose and need should focus on the future of the Port of Boston, and the measures that need to be taken to sustain it.. A more crucial discussion is why the region needs to have a Port of Boston, and the economic impacts to the region as a whole without a viable Port. We believe that this section is important in helping to justify the need for funding of the project, and should be written with sufficient facts and details to support the project. BHA.2

We would also suggest that "Discussion of Previous Dredging Projects in the Port of Boston" be moved from the section on Project Purpose and Need to the section on History or Summary of Major Changes from the 1995 EIR/S for the previous project.

Sediment Disposal: Regarding the disposal of dredged sediments, we assume that disposal methods used for the previous dredging projects will be considered, in addition to other ocean or land disposal sites. BHA.3

Environmental Consequences: Regarding environmental consequences of dredging, we urge that short-term impacts from dredging be identified, as well as the longer-term impacts.

During the previous dredging project, a Technical Advisory Group (TAG) was convened to regularly review the monitoring data with the project's independent environmental observer. We have recently been asked to participate on a similar Advisory Group for this project, and would BHA.4

anticipate that such a group will meet regularly and be an active participant in the environmental oversight of this project, similar to the past TAG.

Coordination with other projects: We urge close coordination between the Algonquin HubLine Project- Everett Extension and this project, in the event that the timing of the projects should overlap. A Notice of Project Change for the Everett Extension of the HubLine Project was recently filed with the Massachusetts MEPA Program and a filing was submitted to the U.S. Federal Energy Regulatory Commission, and it is not clear how long the federal and state regulatory review processes will take before construction of the Extension Project could begin. BHA.5

Coordination with other projects during the time of the project (currently estimated to be 2009 to 2011) should also occur, to minimize any adverse impacts.

Thank you for your consideration.

Sincerely,

Vivien Li
Executive Director

VL: pr

PART 4

COMMENTS AND RESPONSES TO THE ENVIRONMENTAL NOTIFICTION FORM

RESPONSE TO COMMENTS ON ENVIRONMENTAL NOTIFICATION FORM			
Comment Reference	**Comment Summary**	**Response**	**"At A Glance" Quick Section Reference**
MEPA.1	Proponent should include a summary of lessons learned in the EIR to facilitate understanding of the proposed design and mitigation. In particular, evaluate the utility of water quality monitoring methodology, the geographical behavior of the CAD cells and data related to marine habitat.	Experience from the BHNIP has guided development of the dredging and disposal program for the Deep Draft Project. The lessons learned as a result of the extensive environmental monitoring conducted during construction of Phase I and Phase 2 of the BHNIP will be implemented, where applicable, to reduce potential Deep Draft project impacts. Also, fish kills were observed during underwater blasting in the fall of 2007 in Boston Harbor for maintenance dredging in spite of the use of measures such as side scan sonar, fish observers and fish startle systems suggested by resource and permitting agencies to minimize potential impact to fish. An interagency working group has been convened to look at potential measures to further reduce this potential impact. See the Executive Summary Section 1.2 for a detailed summary of BHNIP "lessons learned." Section 4.2.1 *Physical Impacts in Boston Harbor.*	SEIS/EIR Executive Summary Section 1.2 Section 4.2.1
MEPA.2	Circulate the EIR to those who commented on the ENF and to any state agencies from which proponent will seek permits or approvals.	This DSEIS/EIR has been circulated to those who commented on the ENF and to state agencies responsible for issuing permits/authorizations for the project. See Section 10 *Distribution List for DSEIS/EIR.*	Section 10
MEPA.3	The EIR should identify the overlap between this project and previous improvement/maintenance dredging projects.	The relationship between the Deep Draft Project and previous improvement/maintenance projects is discussed in Section 1.2 *Summary of Major Changes*, Section 4.2.1 *Physical Impacts in Boston Harbor*, and Section 4.11 *Cumulative Impacts*; Section 4.2 also contains a figure showing the area boundaries of each dredging project.	Section 1.2 Section 4.2.1 Section 4.11 Figure 4.2

MEPA.4	The EIR should identify responsibilities of Massport and the Corps and whether responsibility shifts based on the alternative selected.	Section 1.1.3 *Congressional Authorization* outlines the Corps and Massport Feasibility Cost-Sharing Agreement (FCSA) for this project. Generally, the Corps is the lead agency for the construction regardless of alternatives selected, and Massport in its role as the non federal sponsor shares in the cost of the construction according to federal dredging cost sharing formulas.	Section 1.1.3
MEPA.5	The EIR section on impacts of dredging and dredged material disposal (water quality, biological resources, threatened and endangered speeies, historic and archaeological resources, noise and odor) should indicate which impacts are temporary and which are permanent.	This issue is discussed in the sections pertaining to Lessons Learned (see response to Comment MEPA.1) and then reviewed extensively throughout Section 4 *Environmental Consequences*. Generally speaking, the majority of impacts associated with dredging operations are temporary impacts. Temporary environmental impacts include turbidity impacts from deepening the channels, disruption of benthic habitat in the navigation channels as well as habitat disruption of lobster habitat in the channels and potential impacts to fish during dredging operations. Impacts from underwater blasting will be minimized by convening an interagency working group to identify practicable measures to reduce fish kills. In terms of dredge disposal operations, Section 4.4 *Disposal Impacts at the Massachusetts Bay Disposal Site* (MBDS) and Section 4.5 *Disposal Impacts at the Industrial Waste Site* (IWS) discuss short term impacts associated with the dredged material disposal plume (several hours), and note the longer term (18 months to 5 years) required for benthic recolonization and community succession to occur with full ecosystem recovery. Permanent impacts associated with this project are primarily associated with dredge disposal in that depositing the material will create mounds, thus altering the seafloor elevation. If dredged material is disposed of at the Industrial Waste Site, a permanent impact is the covering of the concentrated areas of barrels and surrounding sediment, thus reducing the risk to fishermen by isolating potentially contaminated areas from the environment. Another potential permanent benefit of the Deep Draft Project is	Executive Summary Section 4

		the placement of blasted rock in a shallow area with low productivity to provide critical habitat for several stages of commercial important species such as American lobsters. This is discussed in Section 4.3 *Benefits and Impacts at the Potential Habitat Enhancement* Sites.	
MEPA.6	Identify the boundaries and significance of wetland resources in the project area on reasonably scaled plans.	Wetland Resource Areas, as defined under the Massachusetts Wetlands Protection Act, affected by the project are Land Under the Ocean, Fish Runs and Designated Port Areas (DPAs). A plan outlining the overall project boundaries is presented in Figure 1-1. The project area is described in Section 3.2 *Physical Environment.* The discussion encompasses the physical oceanography, water temperature and salinity, water column turbidity, dissolved oxygen, nutrients, and sediment characteristics of Boston Harbor, the Habitat Enhancement Sites, the MBDS, and the IWS. Section 3.3 *Biological Environment* describes the submerged aquatic vegetation, benthic invertebrates, shellfish, lobster, fish, marine and coastal birds, and marine mammals and reptiles in the project area. Designated Port Areas are designated by Massachusetts Coastal Zone Management (CZM) under the provisions of 301 CMR 25.00. DPAs are designated areas in developed ports for the purposes of promoting and protecting marine industrial activities and certain supporting uses. Additional information on DPAs can be found at the CZM website http://www.mass.gov/czm. DPAs affected by the project are Chelsea, South Boston and Mystic River, with the bulk of the work occurring in South Boston. Pursuant to the Wetlands Protection Act, MA General Laws, Chapter 131, Section 40, Notices of Intent will be filed with the Boston, Chelsea and Revere Conservation Commissions when the project is in the design phase.	Figure 1-1 Section 3.2 Section 3.3
MEPA.7	Include secondary impacts of the deepening project such as increased ship	Section 4.12 *Secondary Impacts* generally assesses the landside secondary impacts likely associated with the Deep Draft Project,	Section 4.12 Section 4.8

	traffic and an increase in the size of ships entering the harbor in light of potential impacts to fishing, marine mammals, water quality, air quality and harbor uses.	focusing on ground transportation. The Final SEIS/EIR will expand this discussion. Section 4.8 *Air Quality* incorporates post-construction estimates of ship traffic emissions that consider the number of ship calls, the type, size and age of the ships (the latter especially relevant because newer ships operate more efficiently). Generally, the project would permit more cargo to be transported in fewer, newer ships whose calls would not need to be delayed by high tide cycles as currently occurs. The analysis of indirect emission presented in Section 4.8.3 *Air Emissions Modeling Results* indicates that the Deep Draft Project would reduce pollutant emissions due to changes in fleet mix for all shipping operations (i.e., fewer but larger ships), reduced anchoring activities for petroleum ships and less time for ships to move in and out of the harbor. The decrease would be only slightly offset by a small increase in pollutant emissions from cargo trucking changes that would occur as a result of the project. The secondary impacts noted in the air quality section (i.e., fewer (but larger) ships, no petroleum ship anchoring activities and less time for ships to move in and out of the harbor) are also likely to translate to secondary benefits to marine mammals, water quality, recreational boating, harbor uses and fishing.	Section 4.8.3
MEPA.8	Describe ongoing and planned projects within Boston Harbor and Massachusetts Bay, including a summary of the project's impacts, individually and cumulatively, including the size of the impacted area, the resources impacted by the projects, and the duration of the impacts. Include a timeline showing when the projects are planned to occur in relation to the dredging project.	Section 4.11 *Cumulative Impacts* evaluates the incremental impact of the action when added to other past, present, and reasonably foreseeable future actions. The Secretary's Certificate on the ENF required that a number of specific projects be included in the cumulative impacts section, thus the analysis includes major infrastructure projects as well as private projects in or adjacent to Boston Harbor planned to be undertaken within the timeframe of the Deep Draft Project.	Section 4.11
MEPA.9	In the alternatives assessment include a discussion of project phasing, exploring the comparative impacts to the substrate and	The feasibility investigation examined various deepening alternatives in one foot increments. Federal policy requires that the alternative that provides the highest net annual benefit	

	water column of several smaller deepening efforts as opposed to one large effort. Incorporate information into the cost/benefit analysis.	(annual project benefits minus annual project cost) be recommended if Federal funds are to be invested in the project. From a cost/benefit analysis the recommendation of the project with the highest net benefit represents the best investment of public funds. From a viewpoint of the water column and the substrate, deepening in incremental projects would have a detrimental affect on both. After dredging, the channel bottom is soon repopulated with benthic organisms. Coming in a short period of time later to do additional dredging to further deepen the channel would again displace the benthic organisms and again add suspended sediment into the water column.	
MEPA.10	Discuss the types of dredges that can be used for this project and compare the benefits and drawbacks of each.	Section 2.4 *Alternative Dredging Methods* describes the types of dredges that can be used to remove material from deep draft navigation channels, then assesses which types are suitable given the nature of the material being dredged under the Deep Draft Project (i.e., rock, till, other hard materials, and consolidated clay). A mechanical clamshell bucket dredge is proposed; a clamshell bucket will be used to remove the parent material for the deepening activities.	Section 2.4
MEPA.11	Present maintenance needs, how often maintenance dredging will be required and how associated dredged materials will be disposed.	Boston Harbor has historically had slow shoaling rates. Project features at Boston typically require maintenance on only a 16 to 40 year dredging frequency. There is a complete discussion of the anticipated shoaling rates and maintenance cycles of the various project components located in the Design and Cost Estimate Appendix D-2. As discussed in the Dredged Material Disposal Alternatives section of the feasibility report, less than half of the CAD Cell locations permitted for the 1998-2001 construction were used and the remaining locations will provide a long-term low cost method of disposal for unsuitable dredged materials through at least the next major maintenance cycle in the 2035 timeframe.	
MEPA.12	Coordinate with agencies and organizations responsible for proposed projects: lay out a process for coordination with agencies and	Section 5 *Agency Coordination and Compliance* outlines interagency cooperation. Section 6.3 *Technical Working Group* notes that the TWG is comprised of representatives from	Section 5 Section 6.3 Section 4.11.3

	organizations responsible for other projects to minimize conflicts and environmental damage.	Federal, State, and local resources agencies, environmental advocates, scientists and Port-of-Boston stakeholders. In terms of coordination with projects that may result in cumulative impacts, the analysis in Section 4.11.3 *Summary of Cumulative* Impacts concludes that based on the summary of the cumulative impact of the projects previously presented and the timing, location and magnitude of the projects analyzed, the Deep Draft Project is unlikely to result in significant cumulative impacts to water quality with respect to temperature and salinity, dissolved oxygen concentrations or nutrient concentrations. Temporary cumulative local increases in water column turbidity would result from dredging operations, and the impacts could be more pronounced if one or more of the proposed development projects are being constructed at the same time and in the vicinity of the dredging activities for the Deep Draft Project. Given that many of the projects are subject to obtaining necessary permits and approvals, it is not possible to determine whether some of these projects will occur at the same time as the Deep Draft Project. Implementation of the proposed mitigation measures for dredging and dredged material disposal activities will minimize potential increases to temporary turbidity and biological resources impacts. Positive impacts to subtidal habitat will result from the disposal of dredged rock for rocky bottom habitat enhancement activities within the harbor. Overall, the cumulative impacts of the Deep Draft Project are projected to be insignificant and temporary in nature. The proposed project will primarily deepen only previously disturbed areas in Boston Harbor, and the proposed habitat enhancement will be a positive impact.	
MEPA.13	Address the issues associated with MWRA, CA/T and NSTAR infrastructure by establishing a clear process for coordination between parties, clearly	Section 3.8 *Harbor Infrastructure* identifies the harbor tunnel crossings, sewer tunnel crossings and utility crossings associated with the Deep Draft Project. Section 4.10 assesses potential project impacts to the facilities. No impacts to harbor tunnels or	Section 3.8 Section 4.10 Section 6.3

	designating responsibilities for tasks and cost. Establish a contingency plan. Explore option of relocating utility cable.	sewer tunnel crossings are anticipated. The issue of the MWRA utility crossing is addressed in Section 4.10.3 *Utility Crossings*. A 1989 Corps permit issued to MWRA, Boston Edison (NSTAR's predecessor in interest), and Harbor Energy Electric Company ("HEEC," a wholly-owned subsidiary of Boston Edison) for the NSTAR lines required that they be buried to at least 25 feet below the mud line (or to a minimum –60 feet MLW). At that elevation the lines could be left in place, without modification, under a 45-foot to 50-foot channel improvement. The Corps learned in 2003, however, that the permittees did not comply with the permit requirements for minimum embedded depth for these lines during installation. The Corps engaged in extensive discussions from 2003 to 2004 with NSTAR and the MWRA in an attempt to resolve the permit noncompliance issues. These discussions did not lead to resolution of the issues, and in late 2004 the Corps referred the matter to the U.S. Attorney's office as an enforcement action. The U.S. Attorney's office has engaged in negotiations with NSTAR and MWRA to resolve the issues in a manner that will ensure that the NSTAR cable will not impact the current project. The negotiations have been productive and are ongoing. However, should the matter fail to be resolved through a negotiated settlement, the Corps would recommend that a permit enforcement action be filed in federal District Court, since, as noted above, if the relevant conditions had been satisfied at the time of installation, the cable would be located well below the proposed depths of the current improvement project. This DSEIS/EIR will be available for public review and mailed to utility companies for additional review.	
MEPA.14	Continue the inclusion of the Technical Working Group to help refine the monitoring and mitigation requirements as the project is designed and developed.	Section 6.3 *Technical Working* Group summarizes the meetings of the TWG during the preparation of the DSEIS/EIR. TWG meetings will continue to be held during the design and construction phases as warranted.	Section 6.3
MEPA.15	Mitigation should address temporary,	Section 4.13 *Mitigation* describes mitigation measures to be	Section 4.13

	short-term and long-term impacts.	included in the design of the project to reduce or eliminate impacts from dredging, blasting and dredge materials disposal. Mitigation efforts focus on impacts to air quality, natural resources and commercial lobster operations. As noted in the response to MEPA.5, the majority of project impacts are temporary in nature, thus related mitigation measures will also be implemented over the short-term.	
MEPA.16	Indicate the measures to be employed to minimize turbidity and migration of dredged sediments during dredging and disposal.	Section 4.2.1 *Physical Impacts in Boston Harbor* presents an extensive discussion of turbidity and concludes that a turbidity plume can be produced during dredging but is generally limited to the immediate vicinity of the dredge. The Deep Draft Project will be dredging primarily Boston blue clay and glacial till material, which have substantially less turbidity characteristics than silt, and use of a clamshell bucket will minimize impacts.	Section 4.2.1 Section 4.4
MEPA.17	Identify dredging windows and related monitoring activities to minimize and mitigate impacts to fishery resources in, and adjacent to, the dredging and disposal activities.	Section 4.13 presents the mitigation measures and monitoring activities to minimize impacts to fisheries resources in and adjacent to, dredging and disposal activities. Potential dredging windows for particular areas of the harbor and blasting windows as well as sequencing of project efforts will be discussed further with the resouree agencies.	Section 4.13 Section 4.2.4
MEPA.18	Consider the beneficial reuse of ledge material to provide benthic habitat and/or shore protection.	Section 2.7 *Beneficial Use Alternatives* and Sections 2.8.3 and 2.8.4, *Industrial Waste Site* and *Habitat Enhancement Sites*, respectively, present the alternatives considered for beneficial use in this DSEIS/EIR. Also relevant are Section 4.3 *Benefits and Impacts at the Potential Habitat Enhancement Sites* and Section 4.5 *Disposal Impacts at the Industrial Waste Site.*	Section 2.7 Section 2.8.3 Section 2.8.4 Section 4.3 Section 4.5
MEPA.19	Include a summary of all mitigation measures to which the proponent has committed, including mitigation for construction period impacts. Include Proposed Section 61 Findings for use by the state permitting agencies.	See Section 4.13 *Mitigation Measures.* The Draft Section 61 Finding will be presented in the FSEIS/EIR, based in part on public review of this DSEIS/EIR.	Section 4.13

DEP.1	Consider the issue of cumulative impacts and/or "overlapping" projects.	See response to MEPA.8 comment.	Section 4.11
DEP.2	Continue the utilization of the Technical Working Group.	See response to MEPA.14 comment.	Section 6.3
DEP.3	Consider the use of one or more of the unused (or partially filled) In-Channel CAD Cells for disposal of silty sediment rather than employing an upland management option.	Section 2.8.1 *Confined Aquatic Disposal Cells* notes that there is no expected need for creation of additional confined aquatic disposal (CAD) cells in Boston Harbor for the Deep Draft Project. However, by the time the project is authorized, approved and funded for construction, some minor maintenance dredging of adjacent channel areas not maintained in the operations conducted between 1998 and 2009 may be found necessary. If so, construction of one or more smaller CAD cells from the population of previously approved but unconstructed sites may be required to properly dispose of that material. That will be an action separate and distinct from the Deep Draft Project covered by this SDEIS/EIR. If the Chelsea Street Bridge is replaced before or during construction of this Deep Draft Project, then approximately 120,000 cy of material would be removed to deepen and widen that section of the Chelsea River navigation channel. Some of the material would be disposed into the previously constructed CAD cell C12 or in the permitted IHMDP CAD cells. At this juncture no upland disposal options are under consideration for the Deep Draft Project.	Section 2.8.1
DEP.4	Fully address impacts to utilities (particularly buried power cables) located in areas of the Harbor which would overlap with the proposed dredging footprint.	See response to MEPA.13 comment.	Section 3.8 Section 4.10 Section 6.3
DEP.5	Closely coordinate with relevant local, state and federal resource agencies relative to minimizing and mitigation impacts to	As noted in the Executive Summary and Section 1.2 *Summary of Major Changes from the 1995 Final Environmental Impact Report/Statement,* experience from the BHNIP has guided	Executive Summary Section 1.2

	fishery resources in, and adjacent to, the dredging and sediment disposal activities, define allowable "dredging windows" and monitoring activities, and review previously issued WQCs as guides to likely activities and conditions.	development of the dredging and disposal program for this Deep Draft Project. The lessons learned as a result of the extensive environmental monitoring conducted during construction of Phase 1 and Phase 2 of the BHNIP, will be implemented, where applicable, to reduce potential Deep Draft Project impacts. Environmental monitoring required as part of the BHNIP WQC included: ➢ silt plume tracking during dredging of and after disposal into CAD cells; ➢ water quality testing after disposal into the CAD cells; ➢ biological testing; ➢ dissolved oxygen (DO) testing within and outside the CAD cells; and ➢ fisheries monitoring during blasting operations. Additional investigations, outside the scope of the WQC, were performed during BHNIP construction to address concerns raised by the Technical Advisory Committee or to address potential impacts from changes in operations suggested by the dredging contractor. These additional investigations included: ➢ water quality monitoring of disposal at low tide; ➢ monitoring turbidity while using the Contractor's enclosed bucket; ➢ monitoring turbidity during vessel passage over an uncapped and capped CAD cell; ➢ bathymetric measurements; and ➢ lobster monitoring. Results of the monitoring showed no water quality violations or significant environmental impacts from construction of the project. Little or no silty maintenance material will be removed during the Deep Draft Project. Any unsuitable maintenance material would be disposed into a CAD cell.	

		Additional turbidity studies will be conducted during construction of the Boston Harbor Inner Harbor Maintenance Dredging Project. Monitoring of the turbidity plume from dredging and disposal into the CAD cell will be conducted to confirm SSFATE modeling results and that the plume will not violate water quality standards or impact winter flounder spawning habitat. The results of the monitoring will be available for review upon completion	
DMF.1	Identify opportunities for beneficial reuse of dredged materials, such as for benthic habitat (both in-place or redeployed to another area) or shore protection.	See response to MEPA.18 comment.	Section 2.7 Section 2.8.3 Section 2.8.4 Section 4.3 Section 4.5
DMF.2	Include discussion of how the project will contribute to the overall cumulative impact to marine resources and habitat caused by projects in this portion of Mass. Bay.	See response to MEPA.8	Section 4.11
DMF.3	Create a comprehensive recovery monitoring and mitigation plan to compensate for direct loss of habitat and temporal loss of function, with the guidance of the Technical Working Group.	There will be no permanent loss of habitat from construction of the Deep Draft Project. There will be a benefit if the rock reef in Massachusetts Bay is approved. Lower productive soft bottom habitat will be converted to hard bottom habitat. Mitigation measures will be in place to limit impacts to biological resources in the project area.	
CZM.1	Continue the utilization of the Technical Working Group.	See response to MEPA.14 comment.	Section 6.3
CZM.2	Consider the use of existing CAD Cells for placement of contaminated dredged material, and provide an evaluation of the utility of the water quality monitoring methodology, the geographical behavior of the CAD cells, and any other available data	See response to DEP.3 comment regarding CAD cells. The water quality lessons learned from previous projects, including water quality monitoring data, methodology, etc. has been incorporated into the proposed Deep Draft Project. Lessons learned are highlighted in the Executive Summary, Section 1.2 *Summary of Major Changes form the 1995 Final Environmental*	Section 2.8.1 Executive Summary Section 1.2 Section 4.2

	related to impacts to marine habitat.	*Impact Report/Statement,* and Section 4.2 *General Impacts of Dredging in Boston Harbor.*	
CZM.3	As part of the Corps cost/benefit analysis, consider the environmental impacts of disturbing the substrate and impacting the water column with several smaller deepening efforts as opposed to one larger one.	See Response to MEPA 9 comment	
CZM.4	Lay out a clear process for coordination between any parties with utilities in the area of the proposed dredging project.	See response to MEPA.13 comment.	Section 3.8 Section 4.1 Section 6.3
CZM.5	As stated in the ENF, this project will be subject to federal consistency. The project must be found to be consistent with CZM's enforceable program policies.	Section 5.4 presents the CZM program policies that are applicable to the proposed dredging project and the project's consistency with those policies.	Section 5.4
MWRA.1	Dredging in the immediate area of the 115Kv Submarine Cable to the new proposed depths may lead to possible damage to the cable, resulting in the release of the insulating oil in the cable to the waters of the harbor and the potential long-term disruption of the primary source of power to the (MWRA) treatment plant.	As previously noted, see response to MEPA 13 comment, this cable is the subject of an enforcement referral to the U.S. Attorney's office. The U.S. Attorney's office has engaged in negotiations with NSTAR and MWRA to resolve the issues in a manner that will ensure that the NSTAR cable will not impact the current project. The negotiations have been productive and are ongoing, and in that context MWRA has raised its concerns relating to the NSTAR, and will presumably continue to do so.	Section 3.8 Section 4.10 Section 6.3
MWRA.2	Discussions should occur between the project proponents and MWRA staff to identify and examine alternatives to dredging at the Reserve Channel so that impacts to the submarine cable are avoided.	See response to MWRA.1 comment.	Section 3.8 Section 4.10 Section 6.3
MWRA.3	Identify the costs/benefits of moving the cable, if necessary, determine who pays for	See response to MWRA.1 comment.	Section 3.8 Section 4.10

	such an undertaking, and include a contingency plan in the event of damaging the cable.		Section 6.3

MTA.1	Coordinate with the MTA and provide documentation that the channel deepening and any associated construction activities such as blasting will not affect the Ted Williams Tunnel.	Section 4.2.5 *Blasting Impacts* notes that similar construction techniques used in previous Boston Harbor dredging and blasting projects did not result in any observed damage to piers, bulkheads, tunnels or bridge foundations. Because the same techniques will be used for the Deep Draft Project, it is unlikely that permanent damage to these structures will occur.	Section 4.2.5
BOS.1	Continue the utilization of the Technical Working Group.	See response to MEPA.14 comment.	Section 6.3
BOS.2	Work with all affected utility owners to identify the location and depth of utility crossings to prevent unnecessary damage to wetlands.	See response to MEPA.13 comment.	Section 3.8 Section 4.10 Section 6.3
BOS.3	Assess the cumulative impacts of all projects and consider appropriate mitigation for impacts to marine species habitat.	See response to MEPA.8 comment regarding cumulative impacts assessment. See response to MEPA.15, MEPA.16, and MEPA.19 regarding mitigation measures.	Section 4.11 Section 4.2.1 Section 4.4
BHA.1	Consider the earliest commencement of the deepening to minimize adverse impacts to the viability of the Port of Boston.	The proposed Deep Draft Project will commence as soon as practicable, given the lengthy process required obtain project authorization, approval and funding necessary for construction.	Section 2.8.1
BHA.2	Highlight the current and future economic impacts of the Port of Boston to the region as part of the Purpose and Need Statement, rather than historic impacts.	Section 1 *Introduction* and Section 1.1 *Project Need and Purpose* both touch on the economic forces that make this project critical to the future success of the Boston Harbor ports. The Economic Feasibility Study undertaken by the Corps provides extensive economic analysis on the current and future	Section 1.1

		economic impacts to the ports in relation to the proposed project.	
BHA.3	Consider disposal methods for previous dredging projects for disposal of dredged sediments, in addition to ocean or land disposal options.	This issues associated with dredge material disposal are presented and assessed in Section 2.5 *Disposal Alternatives-Site Selection Process*; Section 2.6 *Disposal Alternatives Identified in the BHNIP FEIR/S*; Section 2.7 *Beneficial Use Alternatives*; and Section 2.8 *Disposal Site Alternatives Evaluated.* Essentially, the disposal sites evaluated in this DSEIS/EIR are confined aquatic disposal cells, MBDS, IWS and the habitat enhancement site. In accordance with Section 2.9.2 *Summary*, beneficial use options will be investigated further with the State Sponsor and EPA during project design.	Section 2.5 Section 2.6 Section 2.7 Section 2.8 Section 2.9.3
BHA.4	Identify short-term as well as long-term dredging impacts.	See response to MEPA.5 comment.	
BHA.5	Coordinate with Algonquin HubLine Project-Everett Extension should the timing of the projects overlap.	Not applicable. Available information indicates that the Everett Extension will not be undertaken by Algonquin Gas.	Section 4.11

NSTAR.1	Our as-built drawings show that the (115kV) cable is located approximately 53 feet below mean low water (MLW) in the Reserve Channel and 63 feet below MLW in the Main Ship channel....If Massport and the Corps dredge the Reserve Channel below the -40 ft. MLW, there will be inadequate cover to protect the cable from cruise ship anchors, etc.	See responses to MEPA.13 comment and MWRA.1 comment.	Section 3.8.3 Section 4.10.3
NSTAR.2	We request that the Corps be required to fund the process of locating and documenting the precise location of the cable.	See response to NSTAR.1 comment.	Section 4.10.3
NSTAR.3	We request that MEPA not allow for additional dredging in the Reserved Channel. We also request that the In-Channel Disposal Cells be made available to private parties to minimize disposal cost of contaminated sediment that is now prohibitively expensive.	Dredging in the Reserved Channel to provide deeper access to Conley Container Terminal/South Boston DPA is absolutely necessary for the successful implementation of this critical project. The Corps is not authorized to construct Confined Aquatic Disposal cells for the use of private parties. Federal law only allows Federal funds to be used for construction of General Navigation Features (GNF) necessary for maintenance of the authorized Federal Channel. Federal Law further requires that a local sponsor provide a cost sharing match for the development of CAD cells required for Federal maintenance activities. Although the Corps could expand the CAD cells for the future use by others it would require that all costs associated with that expansion be provided to the Corps up front prior to the expansion being undertaken. In the case of Boston, the Corps intends to reserve the limited future in-channel CAD cell capacity for the future maintenance requirements of Federal and related State harbor dredging projects.	Section 1.1.2

PART 5

MASSACHUSETTS ENVIRONMENTAL NOTIFICTION FORM AND ATTACHMENTS

AS FILED BY MASSPORT

Aviation Division
Massachusetts Port Authority
One Harborside Drive, Suite 200S
East Boston, MA 02128-2909
TEL (617) 428-2800
www.massport.com

January 31, 2003

Ms. Ellen Roy Herzfelder, Secretary
Executive Office of Environmental Affairs
Attn: MEPA Office
251 Causeway Street, Suite 900
Boston, MA 02114

RE: Boston Harbor Deep Draft Navigation Improvement Project
Environmental Notification Form Submittal

Dear Secretary Roy Herzfelder:

On behalf of the Massachusetts Port Authority (Massport), I am pleased to submit two (2) complete copies of an Environmental Notification Form (ENF) for the Boston Harbor Deep Draft Navigation Improvement Project (BHDDNIP), and a third copy of the first three pages, for inclusion in the *Environmental Monitor* to be published on February 8, 2003. The project is needed to accommodate larger cargo vessels that currently utilize Massport's Conley Container Terminal and that are anticipated to call at the Port of Boston in the future.

Project Description

The U.S. Army Corps of Engineers (Corps), in partnership with Massport as the non-federal sponsor, plans to conduct a feasibility study of potential deep draft navigation channel improvements to the Boston Harbor. The study will examine the Port of Boston's current and likely future role in the maritime commerce of the nation, and identify likely levels of future navigation traffic and commerce through the port. In addition, the study will investigate alternatives for accommodating increased deep draft vessel traffic at Boston Harbor, including channel deepening, cargo diversion, and no action. The costs of implementing alternative options will be measured against estimated benefits to improving commercial transportation costs in order to identify whether improvements are warranted consistent with Corps policies. Environmental documentation as required under the Massachusetts Environmental Policy Act (MEPA) and under the National Environmental Policy Act (NEPA) will be conducted as part of the feasibility study.

Project Need

Cargo vessels frequenting the Port of Boston have grown larger such that many of the vessels that now call at Conley Terminal require more than 40 feet of water, the current authorized depth for the Main Shipping Channel. Although these vessels can "ride the tide" into the terminal since the berths were dredged to 45 feet as part of a prior dredging

project described below, the need to wait for a high tide to move to and from the terminal results in costly delays and in some cases vessels have ceased container loading operations in order to depart before the tide changed. In addition to the need for deeper water to Conley Terminal, the December 2002 Massport Marine Terminal (MMT) Development Issues and Alternatives Analysis indicates that bulk cargo vessels expected to call at MMT/North Jetty will benefit from 45-foot deep channels and berthing areas.

Background Information

In addition to the BHDDNIP which is the subject of this ENF, two additional dredging projects are worth noting for clarification: the now-completed Boston Harbor Navigation Improvement Project and Berth Dredging Project (BHNIP), and a federal maintenance dredging project of the main shipping channel to be undertaken solely by the Corps beginning this summer (2003). Massport has no role in the maintenance dredging project. A brief background discussion may provide useful context concerning the latter two projects.

In late 2001, the Corps completed dredging for the BHNIP. Massport was an active co-sponsor for this project (EOEA# 8695), which resulted in deepening of key tributaries and portions of the main shipping channel to 40 feet[1] and related berths to depths ranging from 35 to 45 feet.

While the planning, permitting, design and construction process for the BHNIP was underway, the main shipping channel into Boston Harbor continued to silt in such that it now needs maintenance dredging to restore it to 40 feet. The Corps is actively moving forward with the maintenance dredging of the federal channels up to the Ted Williams Tunnel Crossing and plans to begin construction in 2003. The proposed maintenance work is a fully federal activity with no associated dredging of berths or other local navigation features. Because all of the material to be removed has been found by the Corps and approved by the EPA to be suitable for ocean disposal, the proposed Boston Harbor maintenance dredging project will involve the disposal of dredged material into ocean waters outside the three-mile limit of the territorial sea. The Corps is currently preparing an Environmental Assessment (EA) for this project.

Coordinated Review Requested

The BHDDNIP is categorically included for the preparation of an Environmental Impact Report (EIR) under MEPA pursuant to Regulation 11.03(3)(a)b, in that it involves dredging greater than ten acres of non-vegetated wetlands. It also will be the subject of an Environmental Impact Statement (EIS) under NEPA. The Corps will be conducting the NEPA review as a Supplement (SEIS) to the EIS prepared for the BHNIP. It is our intent to satisfy both state and federal environmental impact review concurrently, as was done for

[1] Chelsea Creek was only deepened to 38 feet due to certain utility crossings that could not cost-effectively be relocated to a deeper elevation.

the now-completed BHNIP. To that end, we have included a proposed scope and outline for the DEIR/DSEIS as an attachment to the ENF. Further, through early coordination with the MEPA Director and his staff, we were able to schedule a scoping meeting ahead of time as follows:

Date:	Tuesday, February 25, 2003
Location:	Massport Black Falcon Terminal
Time:	11 AM

Technical Working Group

As was done with the BHNIP, we intend to establish a Technical Working Group (TWG), comprised of representatives from the regulatory and Port-of-Boston stakeholders, to assist in the planning and review of the EIR/EIS for the BHDDNIP. A list of the organizations invited to participate on the TWG is enclosed.

Please feel free to contact Deb Hadden (617) 946-4435, or Jacki Wilkins (617) 568- 3558, if you have any questions regarding this filing. For copies of the ENF, please call Cheryl Washington at (617) 568-3525.

Sincerely,

Michael A. Leone
Port Director

Enclosures
ENF Distribution List
TWG List

For Office Use Only *Executive Office of Environmental Affairs*
EOEA No.: MEPA Analyst: Phone: 617-626-

Commonwealth of Massachusetts

Executive Office of Environmental Affairs ■ MEPA Office

ENF

Environmental Notification Form

The information requested on this form must be completed to begin MEPA Review in accordance with the provisions of the Massachusetts Environmental Policy Act, 301 CMR 11.00.

Project Name: ***Boston Harbor Deep Draft Navigation Improvement Project***		
Street: ***N/A***		
Municipality: ***Boston, Chelsea***	Watershed: ***Boston Harbor***	
Universal Tranverse Mercator Coordinates:	Latitude: ***42° 20' N*** Longitude: ***70° 59' W***	
Estimated commencement date: ***2009***	Estimated completion date: ***2011***	
Approximate cost: ***$40-80M***	Status of project design: ***5*** %complete	
Proponent: ***Michael A. Leone, Massport Port Director***		
Street: ***One Harborside Drive Suite 200S***		
Municipality: ***Boston***	State: ***MA***	Zip Code: ***02128***
Name of Contact Person From Whom Copies of this ENF May Be Obtained: ***Cheryl Washington***		
Firm/Agency: ***Massachusetts Port Authority***	Street: ***One Harborside Drive***	
Municipality: ***East Boston***	State: ***MA***	Zip Code: ***02128***
Phone: ***(617) 568-3525***	Fax: ***(617) 568-3515***	E-mail: ***cwashington@massport.com***

Does this project meet or exceed a mandatory EIR threshold (see 301 CMR 11.03)?
☒ Yes ☐ No

Has this project been filed with MEPA before?
☐ Yes (EOEA No.:_____) ☒ No

Has any project on this site been filed with MEPA before?
☒ Yes (EOEA No. ***8695***) ☐ No

Is this an Expanded ENF (see 301 CMR 11.05(7)) requesting:

a Single EIR? (see 301 CMR 11.06(8))	☐ Yes	☒ No
a Special Review Procedure? (see 301CMR 11.09)	☐ Yes	☒ No
a Waiver of mandatory EIR? (see 301 CMR 11.11)	☐ Yes	☒ No
a Phase I Waiver? (see 301 CMR 11.11)	☐ Yes	☒ No

Identify any financial assistance or land transfer from an agency of the Commonwealth, including the agency name and the amount of funding or land area (in acres): ***Massachusetts Port Authority will provide 50% of the funding to the US Army Corps of Engineers for the feasibility study, as well as a portion of the construction costs (to be determined).***

Are you requesting coordinated review with any other federal, state, regional, or local agency?
☒ Yes (Specify: ***National Environmental Policy Act (NEPA) Review***) ☐ No

List Local or Federal Permits and Approvals: ***Orders of Conditions from Boston, Revere and Chelsea Conservation Commissions; NEPA; coordination under Clean Water Act; Clean Air***

Act; Endangered Species Act; Marine Protection Research and Sanctuaries Act of 1973; Essential Fish Habitat: Magnuson- Stevens Fisheries Conservation and Management Act; Fish and Wildlife Coordination Act; and the Preservation of Historic and Archaeological Data Act of 1974.

Which ENF or EIR review threshold(s) does the project meet or exceed (see 301 CMR 11.03):

- ☐ Land
- ☐ Water
- ☐ Energy
- ☐ ACEC
- ☐ Rare Species
- ☐ Wastewater
- ☐ Air
- ☐ Regulations
- ☒ Wetlands, Waterways, & Tidelands
- ☐ Transportation
- ☐ Solid & Hazardous Waste
- ☐ Historical & Archaeological Resources

Summary of Project Size & Environmental Impacts	Existing	Change	Total
LAND			
Total site acreage	~1,140		
New acres of land altered		N/A	
Acres of impervious area	N/A	N/A	N/A
Square feet of new bordering vegetated wetlands alteration		N/A	
Square feet of new other wetland alteration		N/A	
Acres of new non-water dependent use of tidelands or waterways		N/A	
STRUCTURES			
Gross square footage	N/A	N/A	N/A
Number of housing units	N/A	N/A	N/A
Maximum height (in feet)	N/A	N/A	N/A
TRANSPORTATION			
Vehicle trips per day	N/A	N/A	N/A
Parking spaces	N/A	N/A	N/A
WATER/WASTEWATER			
Gallons/day (GPD) of water use	N/A	N/A	N/A
GPD water withdrawal	N/A	N/A	N/A
GPD wastewater generation/ treatment	N/A	N/A	N/A
Length of water/sewer mains (in miles)	N/A	N/A	N/A

State Permits & Approvals

- ☒ Order of Conditions
- ☐ Superseding Order of Conditions
- ☐ Chapter 91 License
- ☒ 401 Water Quality Certification
- ☐ MHD or MDC Access Permit
- ☐ Water Management Act Permit
- ☐ New Source Approval
- ☐ DEP or MWRA Sewer Connection/ Extension Permit
- ☒ Other Permits (including Legislative Approvals) – Specify: ***MCZM Consistency***

CONSERVATION LAND: Will the project involve the conversion of public parkland or other Article 97 public natural resources to any purpose not in accordance with Article 97?

☐ Yes (Specify_____) ☒ No

Will it involve the release of any conservation restriction, preservation restriction, agricultural preservation restriction, or watershed preservation restriction?

☐ Yes (Specify_____) ☒ No

RARE SPECIES: Does the project site include Estimated Habitat of Rare Species, Vernal Pools, Priority Sites of Rare Species, or Exemplary Natural Communities?

☐ Yes (Specify_____) ☒ No

HISTORICAL /ARCHAEOLOGICAL RESOURCES: Does the project site include any structure, site or district listed in the State Register of Historic Place or the inventory of Historic and Archaeological Assets of the Commonwealth?

☐Yes (Specify_____) ☐No

To be determined as part of the Draft EIR/SEIS preparation.

If yes, does the project involve any demolition or destruction of any listed or inventoried historic or archaeological resources?

☐Yes (Specify_____) ☐ No

To be determined as part of the Draft EIR/SEIS preparation.

AREAS OF CRITICAL ENVIRONMENTAL CONCERN: Is the project in or adjacent to an Area of Critical Environmental Concern?

☐Yes (Specify_____) ☒ No

PROJECT DESCRIPTION: The project description should include (a) a description of the project site, (b) a description of both on-site and off-site alternatives and the impacts associated with each alternative, and (c) potential on-site and off-site mitigation measures for each alternative (You may attach one additional page, if necessary.)

The US Army Corps of Engineers (Corps), in partnership with the Massachusetts Port Authority (Massport) has initiated a feasibility study of potential deep-draft navigation channel improvements to the Boston Harbor. The study will examine the Port of Boston's current and likely future role in the maritime commerce of the nation, and identify likely levels of future vessel traffic and commerce through the port. In addition, the study will investigate options for accommodating increased deep draft vessel traffic at Boston Harbor, including channel deepening, cargo diversion, and no action. The costs of implementing alternative options will be measured against estimated benefits to improving commercial transportation costs in order to identify whether improvements are warranted consistent with Corps policies.

(a) Description of the Project Site

Boston Harbor, the largest port in New England, is located on the eastern shore of Massachusetts on Massachusetts Bay. The study area includes the developed port areas of the Cities of Boston and Chelsea, the transportation systems, and navigation facilities providing access to the port.

Existing Conditions (Shown on Figure 1)

Entrance Channels and Main Anchorage: Currently the main entrance channel, the Broad Sound North Channel, is 40 feet deep at mean lower low water (mllw) and 900 feet wide (1,100 feet wide in the turn entrance). The channel also has a northern 35-foot deep and 600-foot wide lane. The 40-foot channel widens to 1,200 feet at the outer confluence of the other two entrance channels to the harbor as it passes south of and alongside the 40-foot anchorage at President Roads.

Main Ship Channel: The Main Ship Channel, between President Roads and the inner confluence generally consists of two lanes, one 40 feet deep and the other 35 feet deep, each 600 feet wide. Below the Ted Williams Tunnel (I-90), the Main Ship Channel's 40-foot lane is located along the southern side of the channel, abreast of the developed industrial waterfront of South Boston. The South Boston Reserved Channel extends westerly off the Main Ship Channel about two miles above the President Roads Anchorage.

Mystic River Channel: The majority of the Mystic River channel above the Inner Confluence and the Tobin Bridge (US-1) was deepened to 40 feet as part of the recent improvement project. The southwestern portion of the channel along the Charlestown shore was left at 35 feet.

Chelsea River Channel: The Chelsea River Channel above the Inner Confluence and the McArdle Bridge was deepened to 38 feet as part of the recent improvement project.

The Ted Williams Tunnel (I-90) crosses beneath the Main Ship Channel at the upstream end of the South

Chelsea River Channel: The Chelsea River Channel above the Inner Confluence and the McArdle Bridge was deepened to 38 feet as part of the recent improvement project.

The Ted Williams Tunnel (I-90) crosses beneath the Main Ship Channel at the upstream end of the South Boston Marine Industrial Park and limits channel depths above this point to the 40 feet now provided. This effectively confines future port development that would require depths greater than 40 feet to areas seaward of the tunnel crossing.

There are several marine cargo facilities located along the lower Main Ship Channel and the Reserved Channel:

- The Conley Container Terminal that is owned and operated by Massport is located at the confluence of the Reserved Channel and the Main Ship Channel.
- The Coastal Oil Terminal is located immediately upstream of the Conley Terminal.
- The Black Falcon Cruise Terminal that is owned and operated by Massport occupies most of the northern bulkhead of the Reserved Channel along the 35-foot reach and upper end of the 40-foot reach.
- The 40-foot dry dock and the Coastal Cement Terminal are located off the 40 foot Federal dry-dock approach channel, immediately upstream of the Reserved Channel.
- The Massport Marine Terminal is located along the Main Ship Channel between the Drydock Channel and the Ted Williams Tunnel.

(b) A description of both on-site and off-site alternatives and the impacts associated with each alternative.

Plans for Channel Improvements (Shown on Figure 2)

Entrance Channel and Main Anchorage: The Broad Sound North Entrance Channel, from the Massachusetts Bay to President Roads and the President Roads Anchorage will be examined for deepening from their current 40-foot depth to up to 50 feet.

Main Ship Channel: The Main Ship Channel reaches from the President Roads Anchorage to the Ted Williams Tunnel, the I-90 tunnel, will be examined for deepening beyond 40 feet to depths as great as 50 feet.

Mystic River Channel: The eastern portion of this 35-foot area will be examined under this study for deepening to 40 feet such that the 40-foot navigation channel abuts the recently deepened 40-foot berth at Massport's Medford Street Terminal in Charlestown.

Chelsea River Channel: The Chelsea River Channel will be examined for deepening to 40 feet. This is now possible because there are plans underway to replace the Chelsea Street Bridge and to replace the natural gas siphon that crosses beneath the channel, neither of which were underway when the feasibility of deepening beyond 38 feet was studied as part of the previous Boston Harbor Navigation Improvement Project.

Each potential project improvement will be evaluated at various alternative depths (i.e., 42 to 50 feet) and will be compared to the No Action Alternative.

In general, because all of these areas are existing navigation channels and anchorage areas that have been dredged in the past, most associated environmental impacts will be temporary in nature.

(c) Potential on-site and off-site mitigation measures for each alternative.

Once the project impacts have been identified as part of the Draft Environmental Impact Report (EIR)/Supplemental Environmental Impact Statement (SEIS) measures to mitigate these impacts will be evaluated and appropriate mitigation will be proposed.

A proposed Draft EIR/SEIS outline is appended to this ENF (Attachment 1).

LAND SECTION – all proponents must fill out this section

I. Thresholds / Permits

A. Does the project meet or exceed any review thresholds related to land (see 301 CMR 11.03(1) ___ Yes _X_ No; if yes, specify each threshold

II. Impacts and Permits

A. Describe, in acres, the current and proposed character of the project site, as follows:

	Existing	Change	Total
Footprint of buildings	*N/A*	*N/A*	*N/A*
Roadways, parking, and other paved areas	*N/A*	*N/A*	*N/A*
Other altered areas (describe) *	*~1,140*	*0*	*~1,140*
Undeveloped areas	*N/A*	*N/A*	*N/A*

**** There will be no change in project site acreage. Approximately 1,140 acres of Land Under Water will be dredged***

B. Has any part of the project site been in active agricultural use in the last three years? ___ Yes _X_ No; if yes, how many acres of land in agricultural use (with agricultural soils) will be converted to nonagricultural use?

C. Is any part of the project site currently or proposed to be in active forestry use? ___ Yes _X_ No; if yes, please describe current and proposed forestry activities and indicate whether any part of the site is the subject of a DEM-approved forest management plan:

D. Does any part of the project involve conversion of land held for natural resources purposes in accordance with Article 97 of the Amendments to the Constitution of the Commonwealth to any purpose not in accordance with Article 97? ___ Yes _X_ No; if yes, describe:

E. Is any part of the project site currently subject to a conservation restriction, preservation restriction, agricultural preservation restriction or watershed preservation restriction? ___ Yes _X_ No; if yes, does the project involve the release or modification of such restriction? ___ Yes _X_ No; if yes, describe:

F. Does the project require approval of a new urban redevelopment project or a fundamental change in an existing urban redevelopment project under M.G.L.c.121A? ___ Yes _X_ No; if yes, describe:

G. Does the project require approval of a new urban renewal plan or a major modification of an existing urban renewal plan under M.G.L.c.121B? Yes ___ No _X_; if yes, describe:

H. Describe the project's stormwater impacts and, if applicable, measures that the project will take to comply with the standards found in DEP's Stormwater Management Policy: ***There will be no addition of impervious surface, therefore the Stormwater Policy is not applicable.***

I. Is the project site currently being regulated under M.G.L.c.21E or the Massachusetts Contingency Plan? Yes ___ No _X_ if yes, what is the Release Tracking Number (RTN)?

J. If the project is site is within the Chicopee or Nashua watershed, is it within the Quabbin, Ware, or Wachusett subwatershed? ___ Yes _X_ No; if yes, is the project site subject to regulation under the Watershed Protection Act? ___ Yes _X_ No

K. Describe the project's other impacts on land: ***Based on testing conducted, by the Army Corps of Engineers under a plan approved by the Environmental Protection Agency, to date it is assumed that most or all of the dredged material will be suitable for open-water disposal at the Massachusetts Bay Disposal Site (MBDS). If any of the material is found unsuitable for MBDS disposal, appropriate disposal alternatives will be identified and evaluated in the Draft EIR/SEIS. It is possible that unsuitable sediments could be disposed of in confined aquatic disposal (CAD) cells beneath sections of the Main Ship Channel, Inner Confluence Area, Mystic River and Chelsea River, similar to what was***

done in the recently completely Boston Harbor Navigation Improvements Project. Therefore no impacts to land are anticipated.

III. Consistency

A. Identify the current municipal comprehensive land use plan and the open space plan and describe the consistency of the project and its impacts with that plan(s): ***The project is consistent with several recent Port Plans. The Port of Boston Competitive Task Force Final Report (December 1998, Vickerman, Zachary & Miller) recommends a series of action items that are necessary to ensure the continued growth and success of the Port of Boston. One of the critical action items states that "Massport should work closely with the Army Corps of Engineers to assess the feasibility of further deepening key portions of the main channel." The supporting text further clarifies that "in order for New England companies to remain competitive by receiving containerized cargo by direct ocean-going service, the channels accessing Conley Terminal must be dredged to at least 45 feet." The proposed project directly fulfills this action item.***

B. Identify the current Regional Policy Plan of the applicable Regional Planning Agency and describe the consistency of the project and its impacts with that plan: ***The project is consistent with applicable policies of the "Boston Region MPO Transportation Plan 2000-2025" regarding other objectives, improved safety and mobility and infrastructure modernization.***

C. Will the project require any approvals under the local zoning by-law or ordinance (i.e. text or map amendment, special permit, or variance)? Yes ___ No _X_ if yes, describe:

D. Will the project require local site plan or project impact review? ___ Yes _X_ No; if yes, describe:

RARE SPECIES SECTION

I. Thresholds / Permits

A. Will the project meet or exceed any review thresholds related to rare species or habitat (see 301 CMR 11.03(2))? ___ Yes _X_ No ***(according to the 2000/2001 Natural Heritage Atlas)*** ; if yes, specify, in quantitative terms:

B. Does the project require any state permits related to rare species or habitat? ___ Yes _X_ No

C. If you answered "No" to both questions A and B, proceed to the Wetlands, Waterways, and Tidelands Section. If you answered "Yes" to either question A or question B, fill out the remainder of the Rare Species section below.

II. Impacts and Permits

A. Does the project site fall within Priority or Estimated Habitat in the current Massachusetts Natural Heritage Atlas (attach relevant page)? ___ Yes ___ No. If yes,

1. Which rare species are known to occur within the Priority or Estimated Habitat (contact: Environmental Review, Natural Heritage and Endangered Species Program, Route 135, Westborough, MA 01581, allowing 30 days for receipt of information)?
2. Have you surveyed the site for rare species? ___ Yes ___ No, if yes, please include the results of your survey.
3. If your project is within Estimated Habitat, have you filed a Notice of Intent or received an Order of Conditions for this project? ___ Yes ___ No; if yes, did you send a copy of the Notice of Intent to the Natural Heritage and Endangered Species Program, in accordance with the Wetlands Protection Act regulations? ___ Yes ___ No

B. Will the project "take" an endangered, threatened, and/or species of special concern in

Not Applicable

accordance with M.G.L. c.131A (see also 321 CMR 10.04)? ___ Yes ___ No; if yes, describe:

C. Will the project alter "significant habitat" as designated by the Massachusetts Division of Fisheries and Wildlife in accordance with M.G.L. c.131A (see also 321 CMR 10.30)? ___ Yes ___ No; if yes, describe:

D. Describe the project's other impacts on rare species including indirect impacts (for example, stormwater runoff into a wetland known to contain rare species or lighting impacts on rare moth habitat):

WETLANDS, WATERWAYS, AND TIDELANDS SECTION

I. Thresholds / Permits

A. Will the project meet or exceed any review thresholds related to wetlands, waterways, and tidelands (see 301 CMR 11.03(3))? _X_ Yes ___ No; if yes, specify, in quantitative terms: ***Dredging of approximately 6 million cubic yards from Land Under the Ocean, Designated Port Area and Fish Runs.***

B. Does the project require any state permits (or a local Order of Conditions) related to wetlands, waterways, or tidelands? _X_ Yes ___ No; if yes, specify which permit: ***Orders of Conditions, 401 Water Quality Certification***

C. If you answered "No" to both questions A and B, proceed to the Water Supply Section. If you answered "Yes" to either question A or question B, fill out the remainder of the Wetlands, Waterways, and Tidelands Section below.

II. Wetlands Impacts and Permits

A. Describe any wetland resource areas currently existing on the project site and indicate them on the site plan: The entire project shown in Figure 2 is located within Land Under the Ocean, Designated Port Areas, and Fish Runs.

B. Estimate the extent and type of impact that the project will have on wetland resources, and indicate whether the impacts are temporary or permanent:

Coastal Wetlands	Area (in square feet) or Length (in linear feet)
Land Under the Ocean	***~ 50 million square feet (~1,140 acres)***
Designated Port Areas	***~ 50 million square feet (~1,140 acres)***
Coastal Beaches	***N/A***
Coastal Dunes	***N/A***
Barrier Beaches	***N/A***
Coastal Banks	***N/A***
Rocky Intertidal Shores	***N/A***
Salt Marshes	***N/A***
Land Under Salt Ponds	***N/A***
Land Containing Shellfish	***N/A***
Fish Runs	***~ 50 million square feet (~1,140 acres)***
Land Subject to Coastal Storm Flowage	***N/A***
Inland Wetlands	
Bank	***N/A***
Bordering Vegetated Wetlands	***N/A***
Land under Water	***N/A***
Isolated Land Subject to Flooding	***N/A***
Bordering Land Subject to Flooding	***N/A***
Riverfront Area	***N/A***

C. Is any part of the project

1. a limited project? ___ Yes _X_ No
2. the construction or alteration of a dam? ___ Yes _X_ No; if yes, describe:
3. fill or structure in a velocity zone or regulatory floodway? ___ Yes _X_ No
4. dredging or disposal of dredged material? _X_ Yes ___ No; if yes, describe the volume of dredged material and the proposed disposal site: ***There will be approximately 6 million cubic yards of dredged material, all or most of which is presumed to be suitable for unconfined open-disposal at the Massachusetts Bay Disposal Site (MBDS). If any of the material is found unsuitable for MBDS disposal, appropriate disposal alternatives will be identified and evaluated in the Draft EIR/SEIS. It is possible that unsuitable sediments could be disposed of in confined aquatic disposal (CAD) cells beneath sections of the Main Ship Channel, Inner Confluence Area, Mystic River and Chelsea River, similar to what was done in the recently completely Boston Harbor Navigation Improvements Project.***
5. a discharge to Outstanding Resource Waters? ___ Yes _X_ No
6. subject to a wetlands restriction order? ___ Yes _X_ No; if yes, identify the area (in square feet):

D. Does the project require a new or amended Order of Conditions under the Wetlands Protection Act (M.G.L. c.131A)? _X_ Yes ___ No; if yes, has a Notice of Intent been filed or a local Order of Conditions issued? ___ Yes _X_ No; if yes, list the date and DEP file number:_____. Was the Order of Conditions appealed? N/A___ Yes ___ No. Will the project require a variance from the Wetlands regulations? ___ Yes _X_ No.

E. Will the project:

1. be subject to a local wetlands ordinance or bylaw? __ Yes _X_ No
2. alter any federally-protected wetlands not regulated under state or local law? ___ Yes _X_ No; if yes, what is the area (in s.f.)?

F. Describe the project's other impacts on wetlands (including new shading of wetland areas or removal of tree canopy from forested wetlands): There will be no impacts to the wetlands following construction activities.

III. Waterways and Tidelands Impacts and Permits

A. Is any part of the project site waterways or tidelands (including filled former tidelands) that are subject to the Waterways Act, M.G.L.c.91? _X_ Yes ___ No; if yes, is there a current Chapter 91 license or permit affecting the project site? _X_ Yes ___ No; if yes, list the date and number: ***It is assumed that there are existing Chapter 91 licenses for portions of the project site, these will be identified during the Draft EIR/SEIS process if needed.***

B. Does the project require a new or modified license under M.G.L.c.91? ___ Yes _X_ No; if yes, how many acres of the project site subject to M.G.L.c.91 will be for non-water dependent use? Current ___ Change ___ Total ___

C. Is any part of the project

1. a roadway, bridge, or utility line to or on a barrier beach? ___ Yes _X_ No; if yes, describe:
2. dredging or disposal of dredged material? _X_ Yes ___ No; if yes, volume of dredged material ***Approximately 6 million cubic yards***
3. a solid fill, pile-supported, or bottom-anchored structure in flowed tidelands or other waterways? ___ Yes _X_ No; if yes, what is the base area? _____
4. within a Designated Port Area? _X_ Yes ___ No

D. Describe the project's other impacts on waterways and tidelands: ***The dredging project will have temporary impacts during construction. A mechanical bucket dredge will be***

used during the project and the material will be placed in scows for transport to the disposal site. Both dredging and disposal activities will result in short term water quality impacts. Extensive monitoring conducted in relation to the Boston Harbor Navigation Improvements Project demonstrated that these impacts were minimal and localized. The long-term impacts of the project include a deepened channel that will accommodate deep draft vessel traffic in Boston Harbor.

IV. Consistency:

A. Is the project located within the Coastal Zone? _X_ Yes ___ No; if yes, describe the project's consistency with policies of the Office of Coastal Zone Management: ***The Draft EIR/SEIS will contain a detailed description of the applicability of each CZM policy to the proposed dredging project. This project will be designed to comply with all applicable CZM policies.***

B. Is the project located within an area subject to a Municipal Harbor Plan? ___ Yes _X_ No; if yes, identify the Municipal Harbor Plan and describe the project's consistency with that plan:

WATER SUPPLY SECTION

I. Thresholds / Permits

A. Will the project meet or exceed any review thresholds related to water supply (see 301 CMR 11.03(4))? ___ Yes _X_ No; if yes, specify, in quantitative terms:

B. Does the project require any state permits related to water supply? ___ Yes _X_ No; if yes, specify which permit:

C. If you answered "No" to both questions A and B, proceed to the Wastewater Section. If you answered "Yes" to either question A or question B, fill out the remainder of the Water Supply Section below.

II. Impacts and Permits

A. Describe, in gallons/day, the volume and source of water use for existing and proposed activities at the project site:

	Existing	Change	Total
Withdrawal from groundwater	_____	_____	_____
Withdrawal from surface water	_____	_____	_____
Interbasin transfer	_____	_____	_____
Municipal or regional water supply	_____	_____	_____

Not Applicable

B. If the source is a municipal or regional supply, has the municipality or region indicated that there is adequate capacity in the system to accommodate the project? ___ Yes ___ No

C. If the project involves a new or expanded withdrawal from a groundwater or surface water source,

1. have you submitted a permit application? ___ Yes ___ No; if yes, attach the application
2. have you conducted a pump test? ___ Yes ___ No; if yes, attach the pump test report

D. What is the currently permitted withdrawal at the proposed water supply source (in gallons/day)? _____Will the project require an increase in that withdrawal?___ Yes ___ No

E. Does the project site currently contain a water supply well, a drinking water treatment facility, water main, or other water supply facility, or will the project involve construction of a new facility? ___ Yes ___ No. If yes, describe existing and proposed water supply facilities at the project site:

	Existing	Change	Total
Water supply well(s) (capacity, in gpd)			
Drinking water treatment plant (capacity, in gpd)			
Water mains (length, in miles)			

F. If the project involves any interbasin transfer of water, which basins are involved, what is the direction of the transfer, and is the interbasin transfer existing or proposed?

G. Does the project involve

1. new water service by a state agency to a municipality or water district? ___ Yes ___ No
2. a Watershed Protection Act variance? ___ Yes ___ No; if yes, how many acres of alteration?
3. a non-bridged stream crossing 1,000 or less feet upstream of a public surface drinking water supply for purpose of forest harvesting activities? ___ Yes ___ No

Not Applicable

H. Describe the project's other impacts (including indirect impacts) on water resources, quality, facilities and services:

III. Consistency -- Describe the project's consistency with water conservation plans or other plans to enhance water resources, quality, facilities and services:

WASTEWATER SECTION

I. Thresholds / Permits

A. Will the project meet or exceed any review thresholds related to wastewater (see 301 CMR 11.03(5))? ___ Yes _X_ No; if yes, specify, in quantitative terms:

B. Does the project require any state permits related to wastewater? ___ Yes _X_ No; if yes, specify which permit:

C. If you answered "No" to both questions A and B, proceed to the Transportation -- Traffic Generation Section. If you answered "Yes" to either question A or question B, fill out the remainder of the Wastewater Section below.

II. Impacts and Permits

A. Describe, in gallons/day, the volume and disposal of wastewater generation for existing and proposed activities at the project site (calculate according to 310 CMR 15.00):

	Existing	Change	Total
Discharge to groundwater (Title 5)			
Discharge to groundwater (non-Title 5)			
Discharge to outstanding resource water			
Discharge to surface water			
Municipal or regional wastewater facility			
TOTAL			

Not Applicable

B. Is there sufficient capacity in the existing collection system to accommodate the project? ___ Yes ___ No; if no, describe where capacity will be found:

C. Is there sufficient existing capacity at the proposed wastewater disposal facility? ___ Yes ___ No; if no, describe how capacity will be increased:

D. Does the project site currently contain a wastewater treatment facility, sewer main, or other wastewater disposal facility, or will the project involve construction of a new facility? ___ Yes ___ No. If yes, describe as follows:

	Existing	Change	Total
Wastewater treatment plant (capacity, in gpd)			
Sewer mains (length, in miles)			
Title 5 systems (capacity, in gpd)			

E. If the project involves any interbasin transfer of wastewater, which basins are involved, what is the direction of the transfer, and is the interbasin transfer existing or proposed?

F. Does the project involve new sewer service by an Agency of the Commonwealth to a municipality or sewer district? ___ Yes ___ No

G. Is there any current or proposed facility at the project site for the storage, treatment, processing, combustion or disposal of sewage sludge, sludge ash, grit, screenings, or other sewage residual materials? ___ Yes ___ No; if yes, what is the capacity (in tons per day):

Not Applicable

	Existing	Change	Total
Storage			
Treatment, processing			
Combustion			
Disposal			

H. Describe the project's other impacts (including indirect impacts) on wastewater generation and treatment facilities:

III. Consistency -- Describe measures that the proponent will take to comply with federal, state, regional, and local plans and policies related to wastewater management:

A. If the project requires a sewer extension permit, is that extension included in a comprehensive wastewater management plan? ___ Yes ___ No; if yes, indicate the EOEA number for the plan and describe the relationship of the project to the plan

TRANSPORTATION -- TRAFFIC GENERATION SECTION

I. Thresholds / Permits

A. Will the project meet or exceed any review thresholds related to traffic generation (see 301 CMR 11.03(6))? ___ Yes _X_ No; if yes, specify, in quantitative terms:

B. Does the project require any state permits related to state-controlled roadways? ___ Yes _X_ No; if yes, specify which permit:

C. If you answered "No" to both questions A and B, proceed to the Roadways and Other Transportation Facilities Section. If you answered "Yes" to either question A or question B, fill out the remainder of the Traffic Generation Section below.

II. Traffic Impacts and Permits

A. Describe existing and proposed vehicular traffic generated by activities at the project site:

Not Applicable

	Existing	Change	Total
Number of parking spaces			
Number of vehicle trips per day			
ITE Land Use Code(s):			

B. What is the estimated average daily traffic on roadways serving the site?

Roadway	Existing	Change	Total
1.			
2.			
3.			

C. Describe how the project will affect transit, pedestrian and bicycle transportation facilities and services:

III. Consistency -- Describe measures that the proponent will take to comply with municipal, regional, state, and federal plans and policies related to traffic, transit, pedestrian and bicycle transportation facilities and services:

ROADWAYS AND OTHER TRANSPORTATION FACILITIES SECTION

I. Thresholds

A. Will the project meet or exceed any review thresholds related to roadways or other transportation facilities (see 301 CMR 11.03(6))? ___ Yes _X_ No; if yes, specify, in quantitative terms:

B. Does the project require any state permits related to roadways or other transportation facilities? ___ Yes _X_ No; if yes, specify which permit:

C. If you answered "No" to both questions A and B, proceed to the Energy Section. If you answered "Yes" to either question A or question B, fill out the remainder of the Roadways Section below.

II. Transportation Facility Impacts

A. Describe existing and proposed transportation facilities at the project site:

	Existing	Change	Total
Length (in linear feet) of new or widened roadway			
Width (in feet) of new or widened roadway			
Other transportation facilities:			

Not Applicable

B. Will the project involve any:

1. Alteration of bank or terrain (in linear feet)? _____
2. Cutting of living public shade trees (number)? _____
3. Elimination of stone wall (in linear feet)? _____

III. Consistency -- Describe the project's consistency with other federal, state, regional, and local plans and policies related to traffic, transit, pedestrian and bicycle transportation facilities and services, including consistency with the applicable regional transportation plan and the Transportation Improvements Plan (TIP), the State Bicycle Plan, and the State Pedestrian Plan:

ENERGY SECTION

I. Thresholds / Permits

A. Will the project meet or exceed any review thresholds related to energy (see 301 CMR 11.03(7))? ___ Yes _X_ No; if yes, specify, in quantitative terms:

B. Does the project require any state permits related to energy? ___ Yes _X_ No; if yes, specify which permit:

C. If you answered "No" to both questions A and B, proceed to the Air Quality Section. If you answered "Yes" to either question A or question B, fill out the remainder of the Energy Section below.

II. Impacts and Permits

A. Describe existing and proposed energy generation and transmission facilities at the project site:

	Existing	Change	Total
Capacity of electric generating facility (megawatts)			
Length of fuel line (in miles)			

Length of transmission lines (in miles) _____ _____ _____
Capacity of transmission lines (in kilovolts) _____ _____ _____

B. If the project involves construction or expansion of an electric generating facility, what are

1. the facility's current and proposed fuel source(s)?
2. the facility's current and proposed cooling source(s)?

C. If the project involves construction of an electrical transmission line, will it be located on a new, unused, or abandoned right of way? ___ Yes ___ No; if yes, please describe:

D. Describe the project's other impacts on energy facilities and services:

III. Consistency -- Describe the project's consistency with state, municipal, regional, and federal plans and policies for enhancing energy facilities and services:

Not Applicable

AIR QUALITY SECTION

I. Thresholds

A. Will the project meet or exceed any review thresholds related to air quality (see 301 CMR 11.03(8))? ___ Yes _X_ No; if yes, specify, in quantitative terms:

B. Does the project require any state permits related to air quality? ___ Yes _X_ No; if yes, specify which permit:

C. If you answered "No" to both questions A and B, proceed to the Solid and Hazardous Waste Section. If you answered "Yes" to either question A or question B, fill out the remainder of the Air Quality Section below.

II. Impacts and Permits

A. Does the project involve construction or modification of a major stationary source (see 310 CMR 7.00, Appendix A)? ___ Yes ___ No; if yes, describe existing and proposed emissions (in tons per day) of:

	Existing	Change	Total
Particulate matter			
Carbon monoxide			
Sulfur dioxide			
Volatile organic compounds			
Oxides of nitrogen			
Lead			
Any hazardous air pollutant			
Carbon dioxide			

Not Applicable

B. Describe the project's other impacts on air resources and air quality, including noise impacts:

III. Consistency

A. Describe the project's consistency with the State Implementation Plan:

B. Describe measures that the proponent will take to comply with other federal, state, regional, and local plans and policies related to air resources and air quality:

SOLID AND HAZARDOUS WASTE SECTION

I. Thresholds / Permits

A. Will the project meet or exceed any review thresholds related to solid or hazardous waste

(see 301 CMR 11.03(9))? ___ Yes _X_ No; if yes, specify, in quantitative terms:

B. Does the project require any state permits related to solid and hazardous waste? ___ Yes _X_ No ; if yes, specify which permit: ***Current presumptions based on testing conducted to date by the Army Corps of Engineers under a plan approved by the Environmental Protection Agency are that no solid or hazardous waste permits will be required. This presumption will be confirmed by detailed examination in the Draft EIR/SEIS and contingencies will be developed if needed.***

C. If you answered "No" to both questions A and B, proceed to the Historical and Archaeological Resources Section. If you answered, "Yes" to either question A or question B, fill out the remainder of the Solid and Hazardous Waste Section below.

II. Impacts and Permits

A. Is there any current or proposed facility at the project site for the storage, treatment, processing, combustion or disposal of solid waste? ___ Yes ___ No; if yes, what is the volume (in tons per day) of the capacity:

	Existing	Change	Total
Storage	_____	_____	_____
Treatment, processing	_____	_____	_____
Combustion	_____	_____	_____
Disposal	_____	_____	_____

B. Is there any current or proposed facility at the project site for the storage, recycling, treatment or disposal of hazardous waste? ___ Yes ___ No; if yes, what is the volume (in tons or gallons per day) of the capacity:

Not Applicable

	Existing	Change	Total
Storage	_____	_____	_____
Treatment, processing	_____	_____	_____
Combustion	_____	_____	_____
Disposal	_____	_____	_____

C. If the project will generate solid waste (for example, during demolition or construction), describe alternatives considered for re-use, recycling, and disposal:

D. If the project involves demolition, do any buildings to be demolished contain asbestos? ___ Yes ___ No

E. Describe the project's other solid and hazardous waste impacts (including indirect impacts):

III. Consistency--Describe measures that the proponent will take to comply with the State Solid Waste Master Plan: Should upland disposal be warranted for some dredge material, reuse opportunities (e.g. landfill cover) will be considered.

HISTORICAL AND ARCHAEOLOGICAL RESOURCES SECTION

I. Thresholds / Impacts

A. Is any part of the project site a historic structure, or a structure within a historic district, in either case listed in the State Register of Historic Places or the Inventory of Historic and Archaeological Assets of the Commonwealth? ___ Yes _X_ No; if yes, does the project involve the demolition of all or any exterior part of such historic structure? ___ Yes ___ No; if yes, please describe:

B. Is any part of the project site an archaeological site listed in the State Register of Historic Places or the Inventory of Historic and Archaeological Assets of the Commonwealth? ___ Yes ___ No; if yes, does the project involve the destruction of all or any part of such archaeological

site? ___ Yes ___ No; if yes, please describe: ***Not yet determined. Will be examined during the Draft EIR/SEIS preparation.***

C. If you answered "No" to all parts of both questions A and B, proceed to the Attachments and Certifications Sections. If you answered, "Yes" to any part of either question A or question B, fill out the remainder of the Historical and Archaeological Resources Section below.

D. Have you consulted with the Massachusetts Historical Commission? ___ Yes _X_ No; if yes, attach correspondence. ***The MHC will be sent a copy of this ENF and will be consulted during the preparation of the Draft EIR/SEIS.***

E. Describe and assess the project's other impacts, direct and indirect, on listed or inventoried historical and archaeological resources: ***Not yet determined. Will be examined during the Draft EIR/SEIS preparation.***

II. Consistency -- Describe measures that the proponent will take to comply with federal, state, regional, and local plans and policies related to preserving historical and archaeological resources: ***MHC/SHPO will be consulted during the Draft EIR/SEIS preparation. Applicable cultural resources, if any, will be addressed in accordance with MHC/SHPO policies.***

ATTACHMENTS:

1. Plan, at an appropriate scale, of existing conditions of the project site and its immediate context, showing all known structures, roadways and parking lots, rail rights-of-way, wetlands and water bodies, wooded areas, farmland, steep slopes, public open spaces, and major utilities.

2. Plan of proposed conditions upon completion of project (if construction of the project is proposed to be phased, there should be a site plan showing conditions upon the completion of each phase).

3. Original U.S.G.S. map or good quality color copy (8-½ x 11 inches or larger) indicating the project location and boundaries

4 List of all agencies and persons to whom the proponent circulated the ENF, in accordance with 301 CMR 11.16(2).

5. Other:

CERTIFICATIONS:

1. The Public Notice of Environmental Review has been/will be published in the following newspapers in accordance with 301 CMR 11.15(1):

Boston Globe	***January 30, 2003***
Boston Herald	***January 30, 2003***

2. This form has been circulated to Agencies and Persons in accordance with 301 CMR 11.16(2).

Date: January 31, 2003

Signature of Responsible Officer or Proponent

Name (print or type)

Michael A. Leone
Massachusetts Port Authority
One Harborside Drive
Boston, MA 02128
Phone (617) 946-4413

Date: January 31, 2003

Signature of person preparing ENF

Name (print or type)

Jacki Wilkins
Massachusetts Port Authority
One Harborside Drive Suite 200s
East Boston, MA 02128
(617) 568-3558

Figure 1

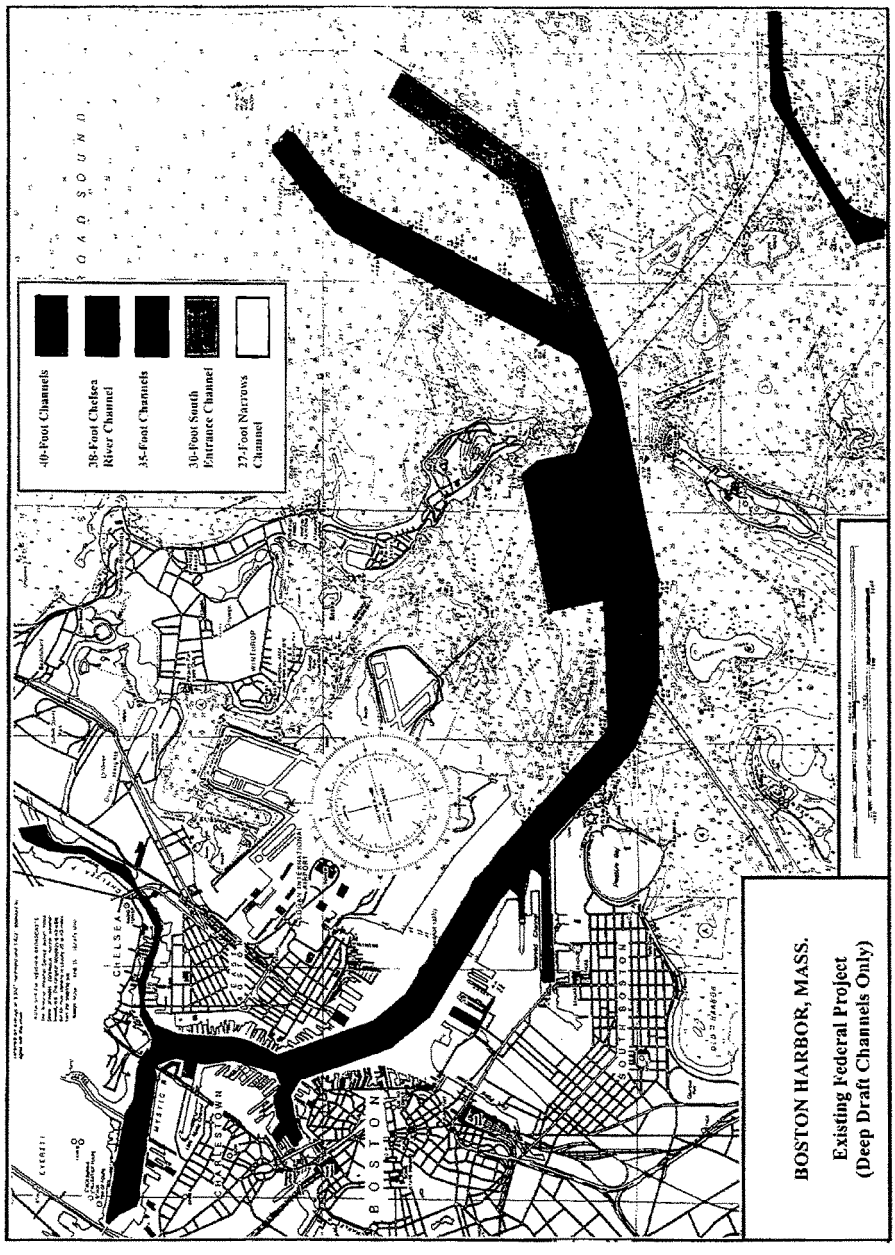
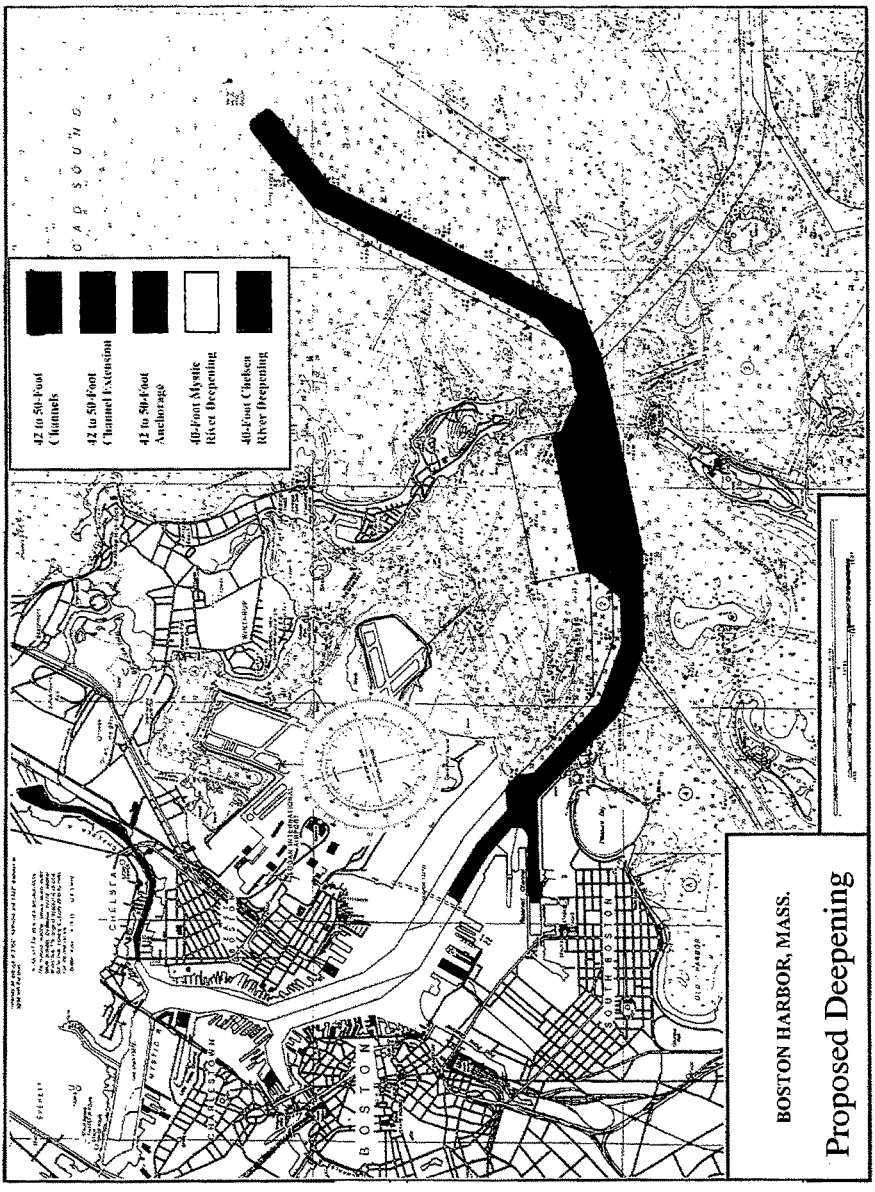

40-Foot Channels
38-Foot Chelsea River Channel
35-Foot Channels
30-Foot South Entrance Channel
27-Foot Narrows Channel
BOSTON HARBOR, MASS.
Existing Federal Project
(Deep Draft Channels Only)

Figure 2


42 to 50-Foot Channels
42 to 50-Foot Channel Extension
42 to 50-Foot Anchorage
40-Foot Mystic River Deepening
40-Foot Chelsea River Deepening
BOSTON HARBOR, MASS.
Proposed Deepening
BOSTON
CHELSEA
EVERETT
CAMBRIDGE
SOMERVILLE

ATTACHMENT 1

Proposed Outline For
The Boston Harbor Deep Draft Navigation Improvement Project
Draft EIR/SEIS

Cover Sheet
Table of Contents
List of Acronyms
Executive Summary (discussion of effects and matrix)

1.0 INTRODUCTION
- 1.1 Project Purpose and Need
  - 1.1.1 Purpose of the Action (clear statement of purpose)
  - 1.1.2 Historical Importance of the Port of Boston
  - 1.1.3 Discussion of Previous Dredging Projects in the Port of Boston
  - 1.1.4 Need for Navigation Improvement (Economic Benefits)
    - 1.1.4.1 Navigational Efficiency
    - 1.1.4.2 Containerized Cargo Volumes
    - 1.1.4.3 Ability to Attract New Shipping Lines
    - 1.1.4.4 Maintain Refined Oil Product Capacity
- 1.2 Procedural History
  - 1.2.1 Congressional Authorization
  - 1.2.2 Public Participation Process
  - 1.2.3 Inter-Agency Coordination
- 1.3 Summary of Major Changes from the 1995 Final EIR/S for Previous Boston Harbor Navigation Improvement Project

2.0 ALTERNATIVES
- 2.1 Project Design Alternatives (Sections include a succinct description of each alternative)
  - 2.1.1 No Action
  - 2.1.2 Project Design Alternatives
- 2.2 Identification of Disposal Alternatives (Sections include a succinct description of each alternative)
- 2.3 Site Screening Process
- 2.4 Alternatives Considered and Eliminated from Detailed Study (alternatives matrix)
  - 2.4.1 Beneficial Use Alternatives
  - 2.4.2 Upland Disposal Alternatives
  - 2.4.3 Other Alternatives
- 2.5 Alternatives Evaluated (alternatives matrix)
- 2.6 Alternative 1: No-Action
- 2.7 Alternative 2: Site 1
- 2.8 Alternative 3: Site 2
- 2.9 Alternative 4: Site 3
- 2.10 Preferred Design and Disposal Alternative

3.0 AFFECTED ENVIRONMENT (brief introduction explaining section for dredging and disposal sites)
- 3.1 Location
- 3.2 Historic Navigation Projects in the Project Area (Types, Quantities, and Locations of Material Disposed from Boston Harbor where known)

ATTACHMENT 1

3.3 Physical Environment
- 3.3.1 Geological Setting
- 3.3.2 Physical Oceanography
- 3.3.3 Sediment Characteristics
  - *3.3.3.1 Physical Characteristics (Grain size, etc)*
  - *3.3.3.2 Metals Distributions*
  - *3.3.3.3 Organic Contaminants*
  - *3.3.3.4 Sediment Quality (toxicity)*

3.4 Water Quality
- 3.4.1 Temperature, Salinity, and Density
- 3.4.2 Water Column Turbidity
- 3.4.3 Dissolved Oxygen
- 3.4.4 Nutrients
- 3.4.5 Contaminants

3.5 Biological Environment (ecology)
- 3.5.1 Benthic Invertebrates
  (Includes infaunal and epifaunal communities; discussion of community and sediment type relationship)
- 3.5.2 Fish (includes life tables for relevant species)
  - *3.5.2.1 Spatial and Temporal Distribution*
  - *3.5.2.2 Commercially Important Fish Distribution*
  - *3.5.2.3 Recreationally Important Fish Distribution*
  - *3.5.2.4 Ecologically Important Fish Distribution*
  - *3.5.2.5 Spawning Strategies (Demersal and Pelagic)*
  - *3.5.2.6 Food and Habitat Requirements*
  - *3.5.2.7 Essential Fish Habitat*
- 3.5.3 Shellfish (includes life tables for relevant species)
  - *3.5.3.1 Spatial and Temporal Distribution of Shellfish*
  - *3.5.3.2 Spawning Strategies*
  - *3.5.3.3 Food and Habitat Requirements*
- 3.5.4 Lobster
- 3.5.5 Marine and Coastal Birds (includes life table for relevant species)
  - 3.5.5.1 *Coastal Species*
  - *3.5.5.2 Marine Species*
- 3.5.6 Marine Mammals and Reptiles (life tables for relevant species)
  - *3.5.6.1 Cetaceans (Whales, Dolphins, Porpoises)*
  - *3.5.6.2 Pinnipeds*
  - *3.5.6.3 Reptiles (Turtles)*
- 3.5.7 Rare, Threatened, Endangered Species and Species of Special Concern (includes life table for relevant species); (References Biological Assessment or other agency coordination as appropriate)
- 3.5.8 Contaminants in Organisms
  - 3.5.8.1 (Subsections include comparison to other nearby sites, recent data and discuss relative to FDA Advisory Levels; one or two paragraphs on potential of human consumption and risk)
  - *3.5.8.2 Benthic Infauna*
  - 3.5.8.3 *Fish and Shellfish*

3.6 Socio-economic Environment
- 3.6.1 Commercial and Recreational Fisheries
  (Discussions of catch Data of Commercially and Recreationally Important Fish and Shellfish)

ATTACHMENT 1

3.6.2 Shipping (Includes discussion of transportation, air quality and noise issues)
3.6.3 Recreational Activities
3.6.4 Natural or Cultural Features of Historical Importance

3.7 Site Specific Disposal Data
3.7.1 Disposal Site 1:
3.7.1.1 Location/bathymetry
3.7.1.2 Physical Oceanography
3.7.1.3 Transport (location and movement in water relative to amenities and beaches, etc.)
3.7.1.4 Sediment Quality
3.7.1.5 Contaminants, toxicity
3.7.1.6 Water Quality
3.7.1.7 Biota/Ecology - Plankton, Benthos, Fish/Shellfish, Birds, Mammals and Reptiles Endangered Species
3.7.1.8 Fishing Activities
3.7.1.9 Shipping/Navigation
3.7.1.10Historic/Archaeological
3.7.1.11Other Human Uses
3.7.2 Site 2:
3.7.2.1 As for Site 1
3.7.3 Site 3:
3.7.3.1 As for Site 1

4.0 ENVIRONMENTAL CONSEQUENCES

Describes approach to evaluating consequences of the alternatives (includes direct, indirect and cumulative impact definitions – general summary of dredging and disposal)

4.1 Environmental Consequences of No Action Alternative
4.2 General Dredging Impacts (General description and consequences of no dredging or disposal, beneficial use and/or upland alternatives)
4.2.1 Water Quality/Sediment Quality
4.2.2 Biological Resources
4.2.3 Threatened and Endangered Species
4.2.4 Historical and Archaeological Resources
4.2.5 Noise and Odor
4.3 General Impacts of Dredge Material Disposal (Including relevant DAMOS Monitoring results)
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BOSTON HARBOR
MASSACHUSETTS

NAVIGATION IMPROVEMENT STUDY

FINAL FEASIBILITY REPORT
AND FINAL SUPPLEMENTAL
ENVIRONMENTAL IMPACT STATEMENT
AND MASSACHUSETTS
FINAL ENVIRONMENTAL IMPACT REPORT

APPENDIX Q

HARBOR BOTTOM MATERIAL
TYPES CLASSIFICATION

PREPARED BY:
OCEAN SURVEYS, INC.
OLD SAYBROOK, CT

THIS APPENDIX UNCHANGED FROM JULY 2008 DRAFT

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6 April 2006

Lisa Lefkovitz
Battelle Duxbury Operations
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SUBJECT: FINAL REPORT NO. 05ES027
SEDIMENT MAPPING
BOSTON HARBOR, BOSTON, MASSACHUSETTS

Dear Ms. Lefkovitz:

Ocean Surveys, Inc. (OSI) is pleased to submit this letter report of findings based on a review of the side scan sonar, core samples, grab samples and subbottom profile data collected as part of a geological study for the proposed Navigation Improvement Project for Boston Harbor, a project to deepen the main shipping channel. OSI has been tasked with correlating coring data with the remote sensing data to enhance the previously presented surface map and generate sediment type maps of the seafloor and the –47 feet MLLW and –50 feet MLLW surfaces.

The side scan sonar and subbottom data ("Chirp" subbottom profiler data) analyzed for this review were collected by OSI during field operations conducted during the periods of 24 September to 8 October 2002 and 6-9 February 2003. Please refer to OSI Report No. 02ES066 for a comprehensive discussion of field procedures, processing techniques and survey results for that investigation. Core data were provided to OSI by the Army Corps of Engineers (ACOE) via Battelle.

The area covered by this investigation includes a 6.8 nautical mile length of the federal channel, with varying widths, from Pier 6 eastward past Deer Island (Figure 1). A total of approximately 240 nautical miles of side scan sonar data were collected for this project including the main shipping channel, Reserve Channel and turning area, Anchorage No. 2 in President Roads, and a proposed Mystic River CAD site.

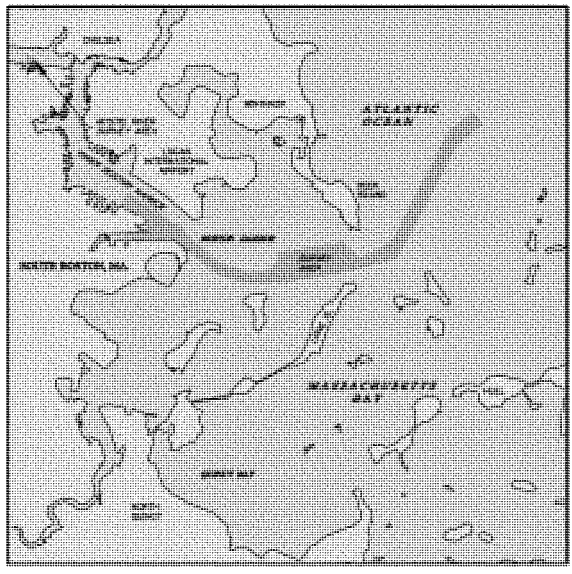

FIGURE Q-1. Location map showing the survey areas in Boston Harbor.

Data Products

Three sets of Microstation drawings, using ACOE base sheets, have been generated to illustrate the results of the mapping tasks. Full size drawing sheets (14 sheets per drawing set, 42 sheets total) have been submitted under separate cover. Electronic drawing files on CD are attached to this report, along with setup procedures for plotting each set of drawings. The procedures are provided electronically (on the CD) and printed at the end of this report.

Modification of the Surface Map

The surficial sediments map was originally generated based on the analysis of available side scan sonar and subbottom profiler records correlated with a very limited number of grab samples (4) completed by OSI. The results of that review are discussed in OSI Final Report #04ES069 (please refer to the report for further discussion). For the present task, the surficial sediments map was further reviewed based on the core data provided by ACOE (see attached table).

The modified surface map is presented in reduced format at the end of this report as Figure Q-2. Based primarily on their acoustic reflective characteristics, the core samples provided and the limited number of grab samples, three material types were identified in the sonar records (Types I-III). Type I materials also include bedrock identified in the subbottom records that is at or near the surface (within 3-5 feet). A sub-type, Type IIIA was also identified using the subbottom profiler records as a Type III sediment containing sufficient organic content to prevent acoustic penetration using a chirp 2-16 kHz. transducer. All material types are listed in the following table.

Material Type	Definition
Type I	Predominantly coarse grained materials consisting of gravel and or bedrock.
Type II	Predominantly poorly sorted fine to coarse grained materials, consisting of coarse to fine grained sand.
Type III	Predominantly fine grained materials, consisting of fine sands, silt and mud.
Type IIIA	Predominantly fine grained materials with organic content, such as silt and mud.

In general, surficial materials in the survey area east of Deer Island Light appear to be a mix of Type I and II, whereas bottom materials west of this point are predominantly Type II. Although apparently localized, Type I materials do exist in President Roads as demonstrated by the material retrieved in Grab sample No. 1. In addition, some localized Type III and IIIA materials were located along the northern edge of the survey area in President Roads.

Proceeding farther west into the harbor, sediments remain primarily Type II and Type III except where bedrock exists close to or on the bottom. Surficial Type III sediments apparently thin westward past navigation buoys Green #3 and Red #4 where Type I sediments were located near the center of the channel. In a few places a veneer of highly aqueous, Type III materials may exist over the coarser materials. Type I materials also exist near the bottom particularly east of Castle Island, in the Reserve Channel, and northwest of the Reserve Channel and turning area.

Sonar images of the bottom in the Mystic River site revealed generally Type II and III materials with some Type I materials located in the northeast corner of this CAD area.

The core findings generally correlated well with the interpretations presented in the surficial sediments map. It is important to note however, that cores were generally not conducted in Type I areas. Therefore, only very limited ground truthing (Grab Sample No. 1) has been accomplished in these areas. In order to verify the material composition of Type 1 areas, more direct sampling should be conducted.

Subsurface Map Generation

Prior to correlation and mapping, the subbottom records were reviewed. Previous analysis of the subbottom data resulted in the mapping of the "acoustic basement". The acoustic basement is defined as a mappable interface (i.e. acoustic reflector) that defines the deepest seismic penetration on a record. Within the survey area, the acoustic basement reflector is generally indicated by a strong semi-continuous seismic return at highly variable depths. The characteristics of the acoustic basement reflector are suggestive of an interface marking the top of rock or overlying till layer, however without specific ground truth correlation the actual composition of the acoustic basement could not be determined.

The subbottom record above the acoustic basement ranged from areas with multiple relatively flat lying reflectors representing internal interfaces within the unconsolidated sediments to areas of little or no reflectors. Areas with little or no reflectors are typically caused by a lack of sufficient contrast in acoustic impedance in the subbottom layers or because shallow subsurface gaseous sediments or other materials impede the acoustic signal penetration. A key factor in accurately determining material composition at a given subsurface depth (-47 and –50 feet MLLW are the mapping depths for this task) is the presence of subbottom layering (on the seismic record) that can be correlated to layer changes described in the cores. Within the unconsolidated section, no individual reflector was distinguishable from record to record that appeared to indicate a significant composition change. Instead, a pattern of reflectors that may represent small composition changes within an overall sedimentary unit was recognized. The lack of a single "tracer" reflector limited the ability to correlate acoustic reflectivity changes in the subbottom data with sediment interfaces encountered in the cores.

Figure Q-3 presents a subbottom profiler section exemplifying the pattern of reflectors that have been interpreted to represent the clay unit as well as the underlying acoustic basement.

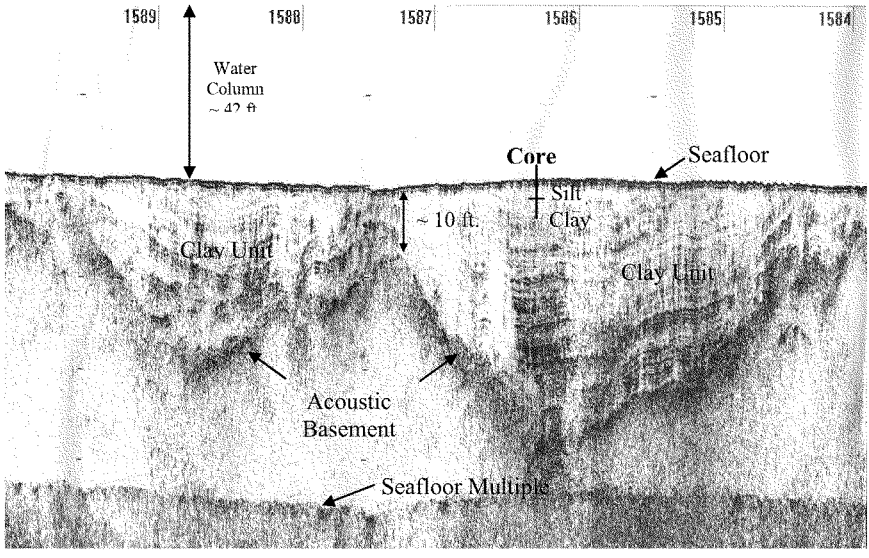

Figure Q-3: "Chirp" subbottom profile record illustrating typical characteristics for clay unit and acoustic basement reflector.

The main objective of this task was to use core data to ground truth subbottom profiler data to estimate material types present within the survey area at the two target depths (-47feet, -50feet MLLW). In order to accomplish this task, several processing and analysis steps were completed. These steps are summarized below:

1. Modify and expand the coring data spreadsheet "summary of stations_surface sed type.xls" to select only cores to be used (highlighted in yellow), extract geographic coordinates and convert to X,Y NAD27, Mass State Plane, 2001, feet, using Corpscon for windows ver 5.1

2. Using previously presented, OSI generated maps, delineate boundaries of the areas where the water depth is greater than the mapping depths (-47, -50feet) and where acoustic basement is expected at or above mapping depths.
3. Overlay the core locations on the map of water depths and extract the water depths at each core location, for inclusion in the core data spreadsheet
4. Using copies of core logs "bos-1-1.pdf" and "bos-2.pdf" summarize core findings in spreadsheet, include total depth of core replicate reported by client, also enter any pertinent information from all other replicates from core location. Estimate depth of bottom of core, using water depth determined above and estimate material at –47 feet and –50 feet based only on core info.
5. Review subbottom record at each core location to correlate core data to subbottom data. In most cases interfaces seen in core data (mostly thin layer of silt overlying clay) will not be discernable in the seismic record because the interface is within the upper few feet of the subsurface. If a relatively thick section of clay is present in the core with no underlying material identified and it correlates to the possible clay layer on the subbottom record, AND that layer continues to a depth below the target depths, the sediment type is estimated to be clay.
6. "Map" the subsurface unit, i.e. clay as far as possible, on the subbottom profiler record in either direction from the core location along the trackline.
7. Delineate boundaries of areas of similar characteristics/estimated sediment types.

In general, the core data reveal that throughout much of the survey area a surficial silt layer, ranging in thickness from a few inches to 3 feet, overlies clay. Based on published descriptions of regional geology, this clay is most likely part of the Boston Blue Clay unit. Of the 69 cores used for this analysis, at least 60 contained some silt at the surface. The remaining cores contained varying assemblages of clay, sand, shell, gravel and rock. Clay was the predominant component in the core samples below the surface layer.

As the core data table shows (attachment), most of the cores did not penetrate to the target depths. Only six cores (FF, CC, BB, OO, EE and GG) penetrated to -47 feet or deeper and none of these penetrated to –50 feet. For Cores FF and CC, penetration to -47 feet occurred in a different core replicate than the one described in the core summary for that location. Because most of the cores did not reach the target depths the core data provided only limited direct evidence of the material at -47 and –50 feet. In cases where clay was found in the core, but not to the target depths, it was assumed clay was present at -47 and –50 feet if several other conditions were met: no additional core attempts for that location had conflicting results (i.e. different material at depth); subbottom records did not indicate that acoustic basement was

present; and subbottom reflectors that were characteristic of a clay unit correlated to the clay found in the core.

In order to construct the surface maps at –47 feet and –50 feet MLLW a classification scheme was developed to present the results of correlation and analysis. The following is a description of each category delineated on the surface maps:

Water – Results of hydrographic surveys, provided by ACOE indicate water is present at the target depth (i.e. water depth greater than or equal to –47 feet and –50 feet).

Acoustic Basement – Previous subsurface mapping indicates that acoustic basement, likely representing rock or till is present at the mapped surface.

Clay, higher confidence – Within the area delineated, cores directly indicate clay at target depth and subbottom records also indicate clay.

Clay, lower confidence – Within the area delineated, no cores reach the target depth. Subbottom records exhibit reflectors that are characteristic of clay.

Unknown – No cores within the area or cores do not reach target depth and coring results were insufficient to extrapolate to target depth. In addition, subbottom records do not provide sufficient insight to estimate material type at target depth, either due to lack of seismic signal penetration (previously mapped as "Organics") or no reflectors at target depth that are characteristic of clay (AB reflector may be present below target depth.)

Subsurface Mapping Results

Surface maps at each target depth have been generated and are presented in 11x17" format. These maps are included at the end of this report as Figures Q-4 and Q-5.

At -47 feet MLLW, (Figure Q-4) significant areas of "Clay, Higher Confidence" are mapped in the eastern part of Reserved Channel, continuing southeastward in the main channel and in the President Roads area. All of the cores that went to at least –47 feet are located within these areas as well as several cores that had clay to the bottom of the core at depths greater than -40 feet. Many of the subbottom returns exhibited characteristics typically associated with a clay unit, as presented in Figure Q-2. In other areas along the main channel (i.e. north of the Reserved channel, 2 areas within the Boston North Channel) no core data were available to provide direct correlation to subbottom records, however many of the subbottom records exhibited similar characteristics as those in areas that could be correlated to clay in the cores. It is estimated that clay is present at –47 feet within these areas although with lower confidence.

An area particularly noteworthy is located along the southern edge of the main channel west of President Road. This area has been classified as unknown. There are several cores located within this area (Y2, X, W, W2, V, U) however the coring results are inconsistent: All of the cores had clay at the bottom but none went deeper than -45' and cores X and V hit "refusal" above –47 feet. No further description is provided so it is not known if refusal was due to compact nature of the clay or a composition change such as till or rock. Seismic penetration was inhibited in this area so subbottom records do not provide insight into the composition of the materials. The depth of the mapped acoustic basement reflector is highly variable in the areas immediately adjacent to this unknown area so it is possible that the acoustic basement (i.e. till or rock) may be present at –47 feet at some locations within this unknown zone.

The map generated for the –50 feet MLLW surface (Figure Q-5) is very similar to the –47 feet MLLW map. A significant difference between the two surfaces is the change in the delineation of the boundaries for water depth and for acoustic basement. Also, the confidence level of all of the interpreted clay areas is relatively lower at –50 feet MLLW because none of the cores penetrated to that depth, therefore the presence of clay in the core had to be extrapolated further. Although there was no direct evidence of clay at –50 feet MLLW, areas where the subbottom record indicated a clear continuation of the acoustic properties interpreted as representing the clay unit down to –50 feet, were classified as "Clay – high confidence".

Since most cores contained silt at the surface it is reasonable to expect a surface layer of silt of variable thickness throughout much of the survey area. The silt-clay interface was not identified acoustically, i.e. no mappable reflectors correlating to the silt-clay interface in the cores were identified on the subbottom records. Therefore it was not possible to delineate any silt that may be present at the target depths; however, it is likely that silt may be encountered along the margins of the areas where water depths are at or below –47 feet and –50 feet. This silt "margin" is the surficial silt in areas where water depths are a few inches to 3 feet (estimated thickness of silt layer in cores) above the mapped depths.

Summary

The surface map previously generated for the survey area has been revised and two subsurface maps have been generated by correlating historic coring results with remote sensing data collected by OSI in 2002 and 2003. The confidence level of the interpretations made in mapping is dependent on the consistency of the core logs and summary table provided to OSI as well as the presence of subsurface reflectors. It is important to refer to the coring results table presented here and the original core logs while reviewing the final maps. Further direct sampling, especially in areas interpreted as coarse material (Type I) is recommended to verify material composition.

OSI appreciates the opportunity to further analyze data collected for this project and continue to support Battelle. If any questions arise regarding the survey or results please call or e-mail at your convenience.

Sincerely,

OCEAN SURVEYS, INC.

Margaret H. Sano

Margaret H. Sano
Project Scientist

MHS/ms
Attachments

Core Data Correlation Summary Table

Sampling Site	Date Sampled	Depth of description	Core Log Description (surface)	NAD27 Easting	NAD27 Northing	Water Depth From Hydro Data	Depth of Penetration/Summary of Description from Hand Written Core Logs**	Depth to Bottom of Core	Est material at 47' (based on all attempts, cores only)	Sub-bottom Record Interpretation with Correlation to Cores
NN	08/27/03	0 to 4.3'	Silt	727721.9	492472.9	39.8	5.2' 52-64" olive clay	45		AB at 42.5
MM	08/28/03	0 to 2.6'	Silt	729695.1	491263.3	39.7	2.6' all silt	42.3		AB at 41.5
LL	08/12/02	0 to 1.9'	Silt	729802.0	490711.5	38.2	4.9' 23-61" grey clay hit refusal	43.1		AB at 40.5
LL*	08/27/03	0 to 3.3'	Silt	729816.4	490703.8	38.3	5.9' 40-70" olive clay	44.2		AB at 40.5
FF	08/12/02	0 to 3.3'	Gray clay	730062.5	489579.7	42.0	4.9' 40-43" some sand, clay 43-51" grey clay hit refusal x2	46.9		This result conflicts with FF from 9/2/03, from subbottom it looks like AB is deeper, assume clay.
FF*	09/02/03	0 to 1'	Silt (one replicate had olive clay)	730065.2	489583.8	40.2	4.2' 12-18" olive clay, 18-24" silt 24-50" olive clay (one replicate 5' all olive clay) - penetration to 6.5'	44.4	clay	Reflectors might be silt/clay interface, can't tell, AB is deeper.
CC	09/02/03	0 to 2.1'	Silt	732057.6	488872.1	40.2	5.2' 26-62" olive clay, one atempt had clay to 75"	45.4	clay	Possible reflector at silt/clay interface. AB close to surface nearby.
BB	08/12/02	0 to 0.5'	Silt	732561.2	488653.6	42.0	3.9' 6-41"grey clay hit refusal	45.9		Good internal reflectors, extends laterally, clay at both 47,50.

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Sampling Site	Date Sampled	Depth of description	Core Log Description (surface)	NAD27 Easting	NAD27 Northing	Water Depth From Hydro Data	Depth of Penetration/Summary of Description from Hand Written Core Logs**	Depth to Bottom of Core	Est material at 47' (based on all attempts, cores only)	Sub-bottom Record Interpretation with Correlation to Cores
BB*	09/03/03	0 to 5.8'	Silt over olive clay	732547.0	488639.7	42.0	5.8' silt over clay, silt layer very thin < 5"	47.8	clay	Clay at both 47,50.
Z	08/14/02	0 to 2.1'	Silt	733781.7	487637.5	40.0	2.1' all silt hit refusal x2	42.1		AB at 44 or less.
Z*	08/27/03	0 to 1.9'	Silt	733785.1	487640.8	40.0	1.9' all silt, hit refusal	41.9		AB at 44 or less.
W	08/25/03	0 to 5.2'	Silt	735139.3	486555.0	38.0	6.1' 32-63"dk sand some silt 63-73" olive clay	44.1		Organics? No penetration, no correlation.
X	08/14/02	0 to 3.6'	Silt	734540.2	486970.0	40.0	3.8' all silt 43" hit refusal x2	43.8		Organics? No penetration, no correlation.
X*	08/27/03	0 to 3.25'	Silt	734540.7	486974.0	40.0	3.2' all silt hit refusal	43.2		Organics? No penetration, no correlation.
V	08/09/02	0 to 3.3'	Silt	736109.7	485978.6	38.0	3.4' 40-42" gravel hit refusal	41.4		Organics? No penetration, no correlation.
V*	08/21/03	0 to 3.9'	Silt	736108.5	485981.5	38.0	4.6' 47-55" dk gry sand and grvl	42.6		Organics? No penetration, no correlation.
U	08/09/02	0 to 2.9'	Silt	736873.6	485854.2	39.3	3.4' 35-41" clay	42.7		On edge of organics, no correlation with core.
U*	08/22/03	0 to 3.9'	Sil	736879.0	485844.5	39.4	5.3' 47-65" olive clay	44.7		Possibly clay, no sign of AB.

Sampling Site	Date Sampled	Depth of description	Core Log Description (surface)	NAD27 Easting	NAD27 Northing	Water Depth From Hydro Data	Depth of Penetration/Summary of Description from Hand Written Core Logs**	Depth to Bottom of Core	Est material at 47' (based on all attempts, cores only)	Sub-bottom Record Interpretation with Correlation to Cores
T	08/14/02	0 to 0.16'	Silt and medium grain sand; few shell pieces	738223.5	485594.9	41.6	2.4' 2-29" clay, hit refusal	44		Deeper, strong reflectors below 50', assume clay at 47, 50.
T*	08/22/03	0 to 0.9'	Silt with shell fragments (one replicate had olive clay with gravel and rocks)	738227.0	485588.9	41.5	2.8' 3-4" olive clay, 5'7" sand w/shell frgmts 8-34" olive clay (different replicate than surface description)	44.3		Possibly clay, AB much deeper.
S	08/14/02	0 to 1.5'	Silt and fine sand	740076.2	485648.7	41.1	2.1' 18-26" clay hit refusal x2	43.2		Probably clay at 47, 50, AB near 55.
S*	08/25/03	0 to 1.3'	Silt	740043.5	485651.4	41.1	4.2' 16-51" olive clay	45.3		Probably clay at 47, 50, AB near 55.
R	08/14/02	0 to 0.5'	Silt and fine sand	741599.0	485674.4	38.5	4.9' 6-35" soft clay, 35-41"organic veg/peat, 41-58" soft dark clay-like, ht refusal xs	43.4		No reflectors near 47, 50 - possibly clay.
R*	08/25/03	0 to 1.16'	Sand with some shell fragments and rocks	741587.4	485665.2	38.4	4.1' 14-20" silt 20-49"olive clay	42.5		No reflectors near 47, 50 - possibly clay.

Sampling Site	Date Sampled	Depth of description	Core Log Description (surface)	NAD27 Easting	NAD27 Northing	Water Depth From Hydro Data	Depth of Penetration/Summary of Description from Hand Written Core Logs**	Depth to Bottom of Core	Est material at 47' (based on all attempts, cores only)	Sub-bottom Record Interpretation with Correlation to Cores
Q	08/09/02	0 to 0.8'	Clay with small amount of sand mixed in	741843.1	486134.6	42.0	.8' clay, hit refusal	42.8		AB is much deeper, but no shallow reflectors to correlate.
Q*	08/14/02	0 to 0.4'	Silt, gravel, small amount of clay	741843.1	486134.6	42.0	.9' 5-10"gravel/stones, hit refusal	42.9		AB is much deeper, but no shallow reflectors to correlate.
AA	08/12/02	0 to 1.25'	Silt	733061.3	488156.2	42.0	3.5' 15-30" grey clay, hit refusal	45.5		No reflector correlates to silt/clay interface. Clay at 47, AB close to 50.
AA*	09/03/03	0 to 1.5'	Silt	733068.7	488146.5	42.0	1.5' all silt, trace clay at bottom(one attempt had 0-12"silt, 12-18"clay, 18-27"silt 27-33" olive clay)	43.5		No reflector correlates to silt/clay interface. Clay at 47, AB close to 50.
J	08/13/02	0 to 0.75'	Many shells, some sand	753351.6	492169.9	40.0	1.1' 9-13" silt and some clay hit refusal	41.1		AB at or near surface in area.
KK	08/08/02	0 to 0.3'	Dark organic silt	727727.8	489466.6	42.0	2.9', bottom 29" boston blue clay, hit refusal 2x	44.9		AB reflector clear, dips below -50, no shallow reflector to correlate w/core.

Sampling Site	Date Sampled	Depth of description	Core Log Description (surface)	NAD27 Easting	NAD27 Northing	Water Depth From Hydro Data	Depth of Penetration/Summary of Description from Hand Written Core Logs**	Depth to Bottom of Core	Est material at 47' (based on all attempts, cores only)	Sub-bottom Record Interpretation with Correlation to Cores
KK*	08/19/03	0 to 1.16'	Dark organic silt	727757.7	489456.6	42.0	2.1' 13-25" olive clay	44.1		AB reflector clear, dips below -50, no shallow reflector to correlate w/core.
JJ	08/08/02	0 to 0.5'	Silt	727928.8	489611.1	42.0	2.0' 6"-9"sand9-16"gravel, clay plug at bottom, hit refusal	44		AB reflector depth highly variable in this area, no direct correlation w/core.
JJ*	08/19/03	0 to 0.58'	Silt	727930.6	489606.8	42.0	2.1' 6-18"sand/grvl, 18-25"sand/olive clay	44.1		AB reflector depth highly variable in this area, no direct correlation w/core.
HH	08/08/02	0 to 0.6'	Silt	728252.3	489739.1	41.9	2' 8-24" sandy clay, hit refusa	43.9		In general AB reflector depth highly variable, shallow near this core (~47).
HH*	08/18/03	0 to 2.4'	Dark organic silt with some sand mixed in	728236.4	489750.1	42.0	3.1' 29-38" olive clay	45.1		In general AB reflector depth highly variable, shallow near this core (~47).
II	08/08/02	0 to 0.8'	Silt	728426.7	489517.6	42.0	2.4' 10-18"sand/grvl mix, 18-29" clay, hit refusal	44.4		AB reflector near surface here, may be cause of refusal on core.
II*	08/18/03	0 to 0.58'	Silt	728424.3	489521.0	42.0	.8' 7-8" grey clay	42.8		AB reflector near surface here.

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Sampling Site	Date Sampled	Depth of description	Core Log Description (surface)	NAD27 Easting	NAD27 Northing	Water Depth From Hydro Data	Depth of Penetration/Summary of Description from Hand Written Core Logs**	Depth to Bottom of Core	Est material at 47' (based on all attempts, cores only)	Sub-bottom Record Interpretation with Correlation to Cores
OO	08/09/02	0 to 0.6'	Silt and silty sand with broken shells	743047.4	487887.8	43.5	2' 2-7"broken shells, sand 7-18"f, med sand, 18-24"clay, hit refusal	45.5		No reflectors near 47, 50 - possibly clay. AB deeper.
OO*	08/29/03	0 to 2'	Medium to coarse sand, some silt	743039.8	487862.2	44.0	3.4' 23-41"very dense olive clay (one attempt had clay to 80")	47.4	clay	No reflector to correlate silt/sand/clay boundary, probably clay near 47, 50 . AB deeper.
PP	08/09/02	0 to 0.6'	Dark sandy silt	742093.2	487895.2	41.4	1.7' 6-19"grey clay, hit refusal	43.1		No reflector near 47, possibly clay; flat reflector ~51, could be AB.
PP*	08/28/03	0 to 2.1'	Sandy silt/silt	742079.2	487879.1	41.6	3.3' 25-39" olive clay, very dense	44.9		No reflector near 47, possibly clay; flat reflector ~51, could be AB.
QQ	08/09/02	0 to 2.8'	Silt	740965.6	487590.2	40.0	3.9' 34"-42"sandy silt, 42-46'CLAY, Hit refusal	43.9		No internal reflectors near 47, 50 - possibly clay. AB deeper.
QQ*	08/28/03	0 to 2.3'	Sandy silt	740954.5	487592.3	40.0	3.7' 18-37" f-md dark sand w/shells 37-43" dense olive clay (one attempt had clay to 61")	43.7		No internal reflectors near 47, 50 - possibly clay. AB deeper.

Sampling Site	Date Sampled	Depth of description	Core Log Description (surface)	NAD27 Easting	NAD27 Northing	Water Depth From Hydro Data	Depth of Penetration/Summary of Description from Hand Written Core Logs**	Depth to Bottom of Core	Est material at 47' (based on all attempts, cores only)	Sub-bottom Record Interpretation with Correlation to Cores
DD	08/12/02	0 to 0.8'	Silt	730089.7	490042.0	43.9	1.3' 10-16" sand few stones, hit refusal	45.2		N reflectors, AB at or near surface, uneven riverbed reflector.
EE	08/12/02	0 to 0.16'	Silt	730421.0	489902.0	42.0	3.8' 2-34" grey clay, 34-46"sandy clay, hit refusal	45.8		AB reflector up and down in this area, appears deeper than 50 at core location.
EE*	09/02/03	0 to 6'	Olive clay	730419.1	489887.5	42.0	6' all olive clay, not as hard	48	clay	AB reflector up and down in this area, appears deeper than 50 at core location, correlates to clay in core at 47.
GG	08/12/02	0 to 0.25'	Silt	730424.1	489834.9	42.0	3.7' 3-40" grey clay, hit refusal	45.7		AB reflector up and down in this area, appears deeper than 50 at core location.
GG*	09/02/03	0 to 7.1'	Olive clay	730421.0	489826.6	42.0	7.2' all olive clay	49.2	clay	AB reflector up and down in this area, appears deeper than 50 at core location, correlates to clay in core at 47.
TT	08/15/02	0 to 4.16'	Silt	718105.8	505162.4	30.4	5' 50-60" clay	35.4		No Reflectors, in CAD site, fill material?, cores didn't go to target depths.

Sampling Site	Date Sampled	Depth of description	Core Log Description (surface)	NAD27 Easting	NAD27 Northing	Water Depth From Hydro Data	Depth of Penetration/Summary of Description from Hand Written Core Logs**	Depth to Bottom of Core	Est material at 47' (based on all attempts, cores only)	Sub-bottom Record Interpretation with Correlation to Cores
TT*	08/19/09	0 to 5.75'	Dark organic silt	718111.3	505172.7	30.5	8' 69-99" olive clay	38.5		No Reflectors, in CAD site, fill material?, cores didn't go to target depths.
WW	08/15/02	0 to 1.25'	Silt	718070.4	505355.0	31.6	2.8' 15-32" clay	34.4		No Reflectors, in CAD site, fill material?, cores didn't go to target depths.
WW*	08/21/03	0 to 3.25'	Silt	718076.8	505356.7	31.5	6.8' 37-81" olive clay	38.3		No Reflectors, in CAD site, fill material?, cores didn't go to target depths.
YY	08/15/02	0 to 9'	Silt	718089.6	505519.5	34.3	2.5' 11-21" silty brown peat, wood debris, 21-22" clean clay 22-26" sandy clay 26-30"peat +clay refusal (appears to be mistype of surface depth from client, should be 0.9' instead of 9')	36.8		No Reflectors, in CAD site, fill material?, cores didn't go to target depths.
YY*	08/21/03	0 to 2.75'	Silt	718090.6	505522.2	34.3	5.8' 33-69" olive clay (went to 9' on one attempt all clay on bottom)	40.1		No Reflectors, in CAD site, fill material?, cores didn't go to target depths.

Sampling Site	Date Sampled	Depth of description	Core Log Description (surface)	NAD27 Easting	NAD27 Northing	Water Depth From Hydro Data	Depth of Penetration/Summary of Description from Hand Written Core Logs**	Depth to Bottom of Core	Est material at 47' (based on all attempts, cores only)	Sub-bottom Record Interpretation with Correlation to Cores
RR	08/15/02	0 to 3.5'	Silt with some sand	718901.7	505053.0	35.1	5.1' 42-43"sand, 43-48" fine sandy clay 48-62" clay	40.2		No Reflectors, in CAD site, fill material?, cores didn't go to target depths.
RR*	08/20/03	0 to 3.8'	Silt	718905.8	505057.8	35.1	5.2' 46-63" clay	40.3		No Reflectors, in CAD site, fill material?, cores didn't go to target depths.
SS	08/15/02	0 to 0.25'	Silt	718516.5	505115.3	31.9	2.8' 3-34" clean clay	34.7		No Reflectors, in CAD site, fill material?, cores didn't go to target depths.
SS*	08/20/03	0 to 1.75'	Silt	718502.1	505114.1	32.1	7.4' 21-89" clay	39.5		No Reflectors, in CAD site, fill material?, cores didn't go to target depths.
VV	08/15/02	0 to 0.16'	Light brown silt	718455.3	505271.3	33.0	3.9' 2-44"silt with clay and trace fine sand	36.9		No Reflectors, in CAD site, fill material?, cores didn't go to target depths.
VV*	08/20/03	0 to 4.25'	Silt	718456.6	505268.1	33.0	6.5' 51-78" olive clay	39.5		No Reflectors, in CAD site, fill material?, cores didn't go to target depths.
XX	08/15/02	0 to 5.25'	Clay with black silt, trace of black sand	718378.2	505441.8	34.4	6.1' 63-71" clay	40.5		No Reflectors, in CAD site, fill material?, cores didn't go to target depths.

Sampling Site	Date Sampled	Depth of description	Core Log Description (surface)	NAD27 Easting	NAD27 Northing	Water Depth From Hydro Data	Depth of Penetration/Summary of Description from Hand Written Core Logs**	Depth to Bottom of Core	Est material at 47' (based on all attempts, cores only)	Sub-bottom Record Interpretation with Correlation to Cores
XX*	08/21/03	0 to 3.25'	Silt	718376.8	505449.3	34.2	5.6' 38-68" olive clay	39.8		No Reflectors, in CAD site, fill material?, cores didn't go to target depths.
UU	08/15/02	0 to 4.5'	Black clay, black silt, trace of sand	718741.2	505217.2	34.6	5.2' 54-59" clay	39.8		No Reflectors, in CAD site, fill material?, cores didn't go to target depths.
UU*	08/20/03	0 to 5.16'	Silt	718752.1	505225.2	34.3	5.1' all silt, no clay(one attempt had clay 51-71")	39.4		No Reflectors, in CAD site, fill material?, cores didn't go to target depths.
NN2	08/15/02	0 to 2.9'	Silt	727729.2	492470.8	39.8	4.5' 35-54" clay	44.3		AB above 47, correlates to refusal.
MM2	08/15/02	0 to 3'	Silt	729692.4	491271.1	39.8	3' all silt refusal	42.8		AB above 47, correlates to refusal.
CC2	08/15/02	0 to 3'	Silt	732057.8	488863.2	40.0	4.4' 36-53" clay	44.4		possible reflector at silt/clay interface. AB close to surface nearby.
Y2	08/15/02	0 to 3.1'	Silt	734136.0	487222.3	40.0	4.4' 37-53" clay	44.4		No reflectors, possible shallow organics, masking below. No correlation with core results.

Sampling Site	Date Sampled	Depth of description	Core Log Description (surface)	NAD27 Easting	NAD27 Northing	Water Depth From Hydro Data	Depth of Penetration/Summary of Description from Hand Written Core Logs**	Depth to Bottom of Core	Est material at 47' (based on all attempts, cores only)	Sub-bottom Record Interpretation with Correlation to Cores
W2	08/15/02	0 to 3.5'	Silt	735142.9	486538.9	38.0	5.6' 42-68" clay	43.6		No reflectors, possible shallow organics, masking below. No correlation with core results.

Columns shaded gray are taken directly from core logs provided by ACOE. (BOS-1-1.PDF, BOS-2.PDF).
*Asterisk(*) added by OSI to distinguish between two cores with the same label.
**Depth summary/core findings transcribed from core logs provided by ACOE.

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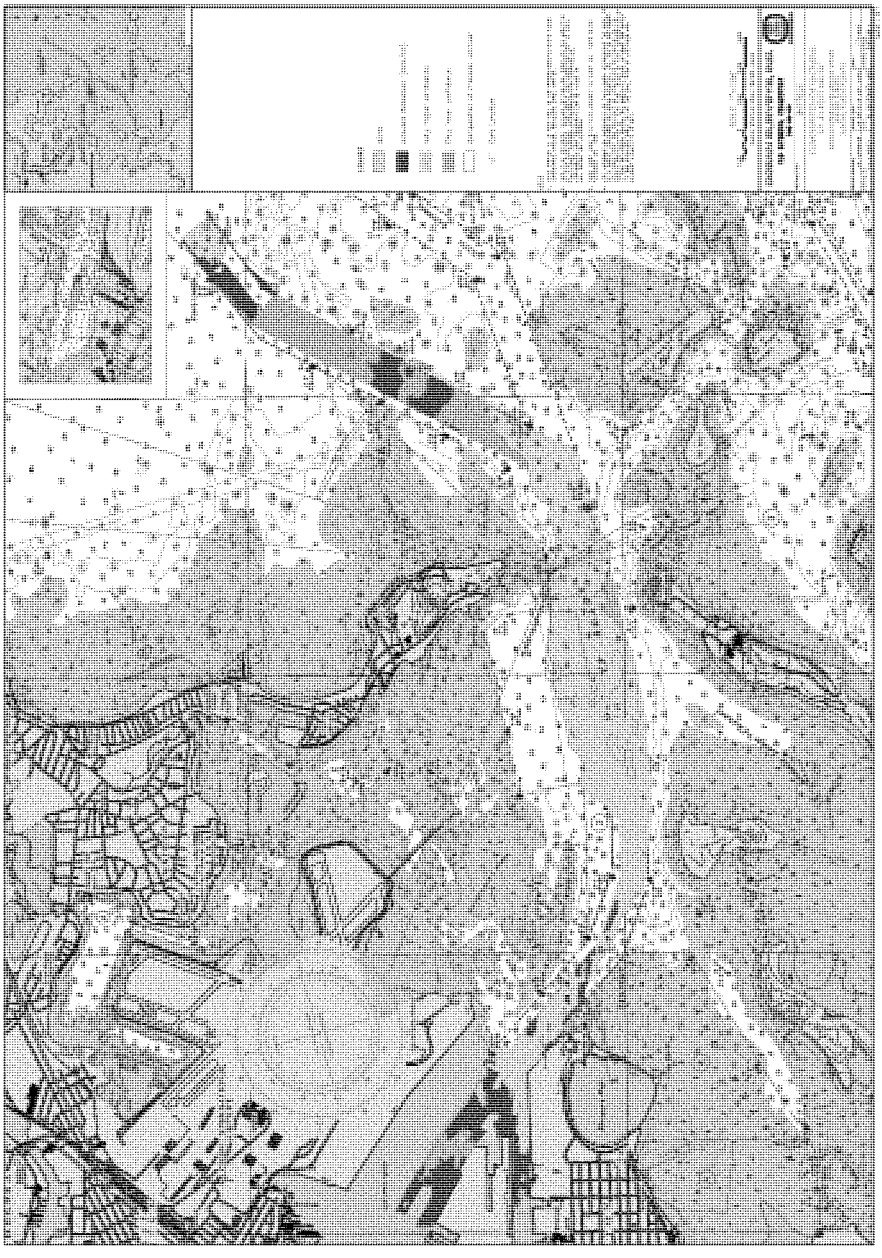

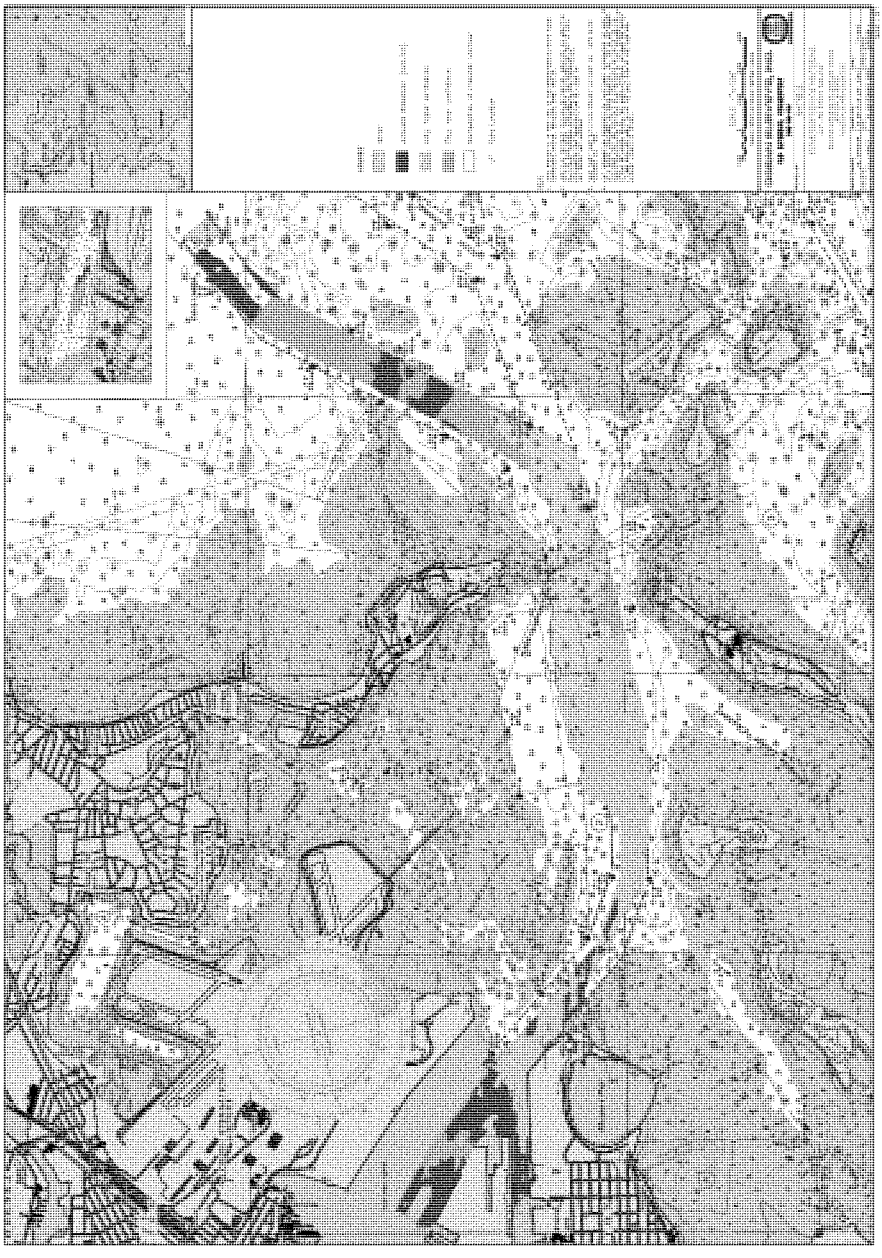

BOSTON HARBOR
MASSACHUSETTS

DEEP DRAFT
NAVIGATION IMPROVEMENT STUDY

FINAL FEASIBILITY REPORT
AND FINAL SUPPLEMENTAL
ENVIRONMENTAL IMPACT STATEMENT
AND MASSACHUSETTS FINAL
ENVIRONMENTAL IMPACT REPORT

APPENDIX R
US ENVIROMENTAL PROTECTION AGENCY
MEMORANDUM
ON CAPPING OF FORMER
INDUSTRIAL WASTE SITE

THIS APPENDIX UNCHANGED FROM JULY 2008 DRAFT

APPENDIX R

US ENVIRONMENTAL PROTECTION AGENCY DOCUMENTS ON CAPPING OF THE FORMER INDUSTRIAL WASTE SITE IN MASSACHUSETTS BAY

CONTENTS

This Appendix to the Feasibility Report and Supplemental Environmental Impact Statement/Massachusetts Environmental Impact Report for the Boston Harbor Deep Draft Navigation Improvement contains three documents.

(1) A Memorandum from the U.S. Environmental Protection Agency, Region I (New England), Ocean and Coastal Protection Unit to the U.S. Army Corps of Engineers, New England District, Engineering Planning Division, dated July 17, 2008, updating the previous views of the agency on the IWS capping proposal.

(2) A Memorandum from the U.S. Environmental Protection Agency, Region I (New England), Ocean and Coastal Protection Unit to the U.S. Army Corps of Engineers, New England District, Engineering Planning Division, dated December 14, 2007 outlining EPA's views and concept for the beneficial use of dredged material from the Boston Harbor improvement dredging project to cap the former Industrial Waste Site in Massachusetts Bay

(3) A Data Analysis Report, dated 31 January 2008, prepared by Vincent J. Capone, Barkentine, Inc., under contract to U.S. EPA, on analysis of side scan sonar data collected by U.S. EPA at the Industrial Waste Site in July 2006

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
NEW ENGLAND
Office of Ecosystem Protection
One Congress Street, Suite 1100, Boston, MA 02114-2023
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MEMORANDUM

To: Mark L. Habel, Chief
Navigation Section, Engineering Planning Division (CENAE-EP-PN)
From: Melville P. Coté, Jr., Manager
Ocean and Coastal Protection Unit
Date: July 17, 2008
Re: Remediation of the former Industrial Waste Site in Massachusetts Bay

The purpose of this memo is to provide an updated map of priority areas for remediation. As promised in our December 20, 2007, memo, we completed a final side scan sonar interpretation in early January 2008. The final report has been forwarded to your office.[1] Based on this interpretation, we revised our priority areas for remediation; they are displayed in Figure 1.

Area 1 is a known area of historical disposal of containers. There are almost 1000 targets listed in this area, most with a medium to high probability of identification as containers. Area 2 is also an area of historical disposal of containers. A high resolution side scan sonar was not performed in this area, so the level of confidence in identifying containers was not as high as in Area 1. The targets, however, appear to be similar to those found in Area 1. Area 3 is an area of lower density of targets. All priority areas avoid shipwrecks identified at the IWS.

The aerial coverage of the three priority areas for capping of containers are listed below. See Figure 1 for locations of each area.

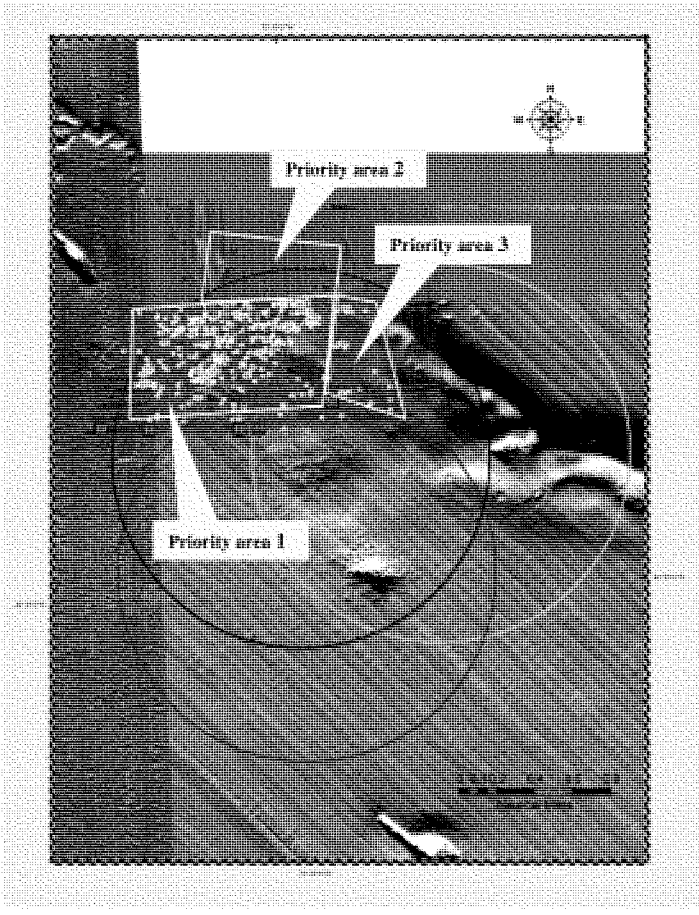
Priority area 1	514 acres
Priority area 2	189 acres
Priority area 3	146 acres
Total	849 acres

[1] Capone, Vincent J. Side Scan Sonar Data Processing and Analysis of US EPA IWS/MBDS Survey 2006. January 31, 2008.

Figure 1. Seafloor bathymetry, disposal sites, side scan sonar mosaic, and identification of targets at the former IWS. Three areas with higher densities of targets are displayed and ranked in order of priority for capping, based on presumed density of containers.

Symbols:

Black circle:	*Former IWS*
Red triangles and stars:	*Priority targets (containers) from surveys in 1991*
Gray symbols:	*Probable barrels, and containers with characteristics of metal*
Purple symbol:	*Shipwrecks*



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MEMORANDUM

To: Mark L. Habel, Chief
Navigation Section, Engineering Planning Division (CENAE-EP-PN)
From: Melville P. Coté, Jr., Manager
Ocean and Coastal Protection Unit
Date: December 14, 2007
Re: Remediation of the former Industrial Waste Site in Massachusetts Bay

The purpose of this memo is to provide background information in support of a proposal by the U.S. Army Corps of Engineers New England District (Corps) to reduce risks associated with historically disposed waste containers at and around the former Industrial Waste Site (IWS) in Massachusetts Bay. The Corps and EPA New England (EPA) are evaluating whether 6 to 15 million cubic yards (CY) of unconsolidated dredged material (mainly "Boston Blue Clay") generated by the Boston Harbor Navigation Improvement Project can be used to cap several of the historically disposed waste container concentrations in the former IWS. At a cap thickness of five feet, 6 million CY would cover about 1.2 square miles of bottom, while 15 million CY would cover 2.9 square miles. This proposed beneficial use represents a one-time opportunity to cap and isolate the bottom sediments and remaining containers and debris at the former IWS.

History of Disposal at the former IWS

Massachusetts Bay was used as a disposal site for industrial, chemical, and low-level radioactive wastes, construction debris, ordnance, and dredged material from the 1940s until 1977, and has continued to be used for dredged material disposal since then. The primary dumping sites included the:

- Industrial Waste Site (IWS; located 20 miles east of Boston at 290 feet depth, also known as the "Foul Area");
- Boston Lightship Disposal Site (BLDS; located 10 miles east of Boston in 150 to 200 feet depth); and
- Marblehead Light Site (MLS; located about 8 to 10 miles southeast of Marblehead at 210 to 230 feet depth).

The history of disposal at the former IWS is outlined in more detail in the Massachusetts Bay Disposal Site evaluation studies (Hubbard *et al.*, 1988), the Draft EIS for Designation of the Massachusetts Bay Disposal Site (EPA, 1989), an assessment of the risks at the former IWS (NOAA 1996), and the 1996 Massachusetts Bay Disposal Site Management and Monitoring Plan

(SMMP; EPA, 1996). Briefly, the former IWS was routinely called the "Foul Area," because the material on the bottom "fouls" or damages commercial fishing nets. From the 1940s to 1977 dredged material, construction debris, barreled industrial waste in 55 gallon drums, waste buckets, encapsulated low-level radioactive waste (in concrete and coffin-shaped containers), munitions, and intentionally sunken derelict vessels were dumped in the northwest quadrant of the former IWS or dispersed around the northern perimeter up to 0.5 nm outside the former IWS (Wiley *et al.*, 1992). Few drums are found farther away from the former IWS.

Radioactive waste disposal ceased in 1959; industrial waste and construction material disposal ceased in 1977 when the overlapping interim Massachusetts Bay Disposal Site (MBDS) was designated by EPA for dredged material disposal only. The IWS was formally de-designated on February 2, 1990 (40CFR 228.12). Subsequent concerns regarding the status of these wastes and their potential effects on the fisheries of Massachusetts Bay and public health have been raised by agencies and environmental groups. In 1989, toxic fumes generated from retrieved barrels near the former IWS caused a debilitating injury to a fisherman. A number of fisherman are said to have retrieved and re-deposited waste containers during their trawling activities. Many of these barrels and other containers have corroded and their contents have presumably been released into the environment, including the surrounding waters and sediments.

Because of this area's past use as a dumping ground, the National Marine Fisheries Service (NMFS) closed the former IWS to harvesting of surf clam and ocean quahogs in 1980 (NOAA, 1996). In 1992, the Food and Drug Administration (FDA) and NMFS reissued this advisory, recommending a note be put on nautical charts, and advising all commercial and recreational fishermen to avoid harvesting bottom dwelling species from the area, including the MBDS (NOAA, 1996). There is, however, evidence of trawling activity within the site as revealed in imagery from a multibeam echosounder (Valentine *et al.*, 1996).

Surveys for Assessing Locations and Threats of Hazardous Waste Disposal

Beginning in 1973, several federal and state agencies have assessed the threats of chemical and low level radioactive wastes at the former IWS to the marine environment (e.g. Curtis and Mardis, 1984). Two surveys have positively identified waste containers and the remains of containers in and around the former IWS. In 1991, the International Wildlife Coalition (Wiley *et al.*, 1992) conducted a study (partially funded by EPA) to prioritize targets from side-scan sonar records and visually investigated them using a video camera on a remotely operated vehicle (ROV). An estimated 10,000 to 20,000 barrels centered near the northern edge of the former IWS were observed. Based on the ROV videos, most of these barrels were corroded or broken. No concrete coffins were observed. The locations of targets and positively confirmed waste containers are displayed in Figure 1, with results from a side scan sonar survey in 2006 (see below).

NOAA led a multi-agency risk assessment in 1992 to collect sediments, fish, and shellfish at sites identified in the 1991 survey for *in situ* and laboratory analyses of chemical contaminants

and radioisotopes. Except for one sediment sample, no radioactivity above background levels was detected (NOAA, 1996).

Assessment of risks

Surveys at the Boston Lightship and Marblehead Light disposal sites by the EPA, NOAA and the Corps have not yielded potentially hazardous containers (Keith *et al.*, 1992; Polaris Imaging and Berger Associates, 1997). Thus, it is assumed that the vast majority of hazardous waste disposal in Massachusetts Bay occurred at the former IWS. Most of the visually observed barrels or drums are corroded or broken and it is assumed that most of the constituents have dispersed. Direct radiation measurements from barrels, or from sediments adjacent to barrels, are at background levels or do not pose risks to human health. The contributing agencies concluded that the low-level radioactive waste or the hazardous substances investigated did not pose an imminent and widespread human health or ecological threat. "However the documented presence and large concentration of waste containers along with known ordnance disposal in some area of the IWS, pose potentially significant occupational risks to users of bottom-tending mobile gear" (NOAA, 1996).

"The existing fishing advisory and the closure for surf clam and ocean quahog harvesting should continue. Further documentation of the locations of likely waste container fields within and contiguous to the IWS should be undertaken. Positions of concentrations of likely waste containers should be noted on nautical charts" (NOAA, 1996).

At a 1998 public meeting, EPA stated that it will: map the location and extent of waste container concentration areas within Massachusetts Bay; conduct a risk assessment for ecological endpoints and human health consumption of seafood in an area of known waste containers; and conduct a periodic sampling of sediment and seafood (fish and shellfish) to evaluate the risk to consumers (EPA, 1998). NOAA, with the USGS and other partners, completed the first task as a GIS product that combines geographical and site-specific information on Massachusetts Bay (USGS, 1999). EPA initiated the second task, a preliminary risk assessment (or "risk screen") in the form of a series of spreadsheet calculations, based on the approach conducted by Tetra Tech for the Gulf of Farrallones Disposal Site off the northern California coast. This risk assessment needs to be completed as part of an environmental assessment for this project.

Recent surveys

In 2006, EPA performed side-scan sonar of the former IWS using a digital dual-frequency Klein 3000 system, deployed from its Ocean Survey Vessel, the OSV Bold. Preliminary results of the interpretation of the side scan sonar records suggest that waste containers, construction debris and other man-made objects are still detectable on the marine floor at the former IWS. A final side-scan sonar interpretation product by a professional sonar analyst will be available in January 2008. This information will be used to determine the locations and spatial extent of historic waste containers proposed for capping and will also be included in the environmental

assessments of the dredging project, the MBDS boundary modification (see below), and the updated SMMP.

Side-scan data were collected using 100 and 500 kHz frequencies, which allow the user to collect data at greater distance from the tow fish. Side-scan tracks and grids were calculated and planned in Klein SonarPro software, transferred to the OSV Bold onboard Nobeltec Navigation system for ship navigation purposes. Side-scan playback and acquisition was processed using Klein SonarPro software. Post-processing was conducted using the Chesapeake Technology software SonarWizMap. Navigation for the side scan transects was conducting using the OSV Bold Raytheon Differential GPS with vessel positioning to an accuracy of +/-5 m.

Transects were performed in three overlapping areas. Using GIS technology, Figure 1 displays the aerial coverage of the major north-south orienting transects that covered the former IWS where barrel fields had been previously identified in 1991 and 1992. During real time imaging, and in playback, over 200 targets were identified in this area. These targets include probable waste containers; construction debris, shipwrecks, geological features and anthropogenic features such as trawl marks and dredged material disposal mounds. EPA scientists have constructed a preliminary mosaic of the side-scan images, and compiled a preliminary identification of these targets. These targets are displayed and categorized in Figure 1. Five polygons were created to cover the majority of suspected and positively identified waste containers, and ranked according to the probable density of waste containers. This ranking, however, is likely to change based on the updated sonar interpretation in January 2008. The aerial coverage of these five polygons range from about 118 to 346 acres and totals about 857 acres (see Table 1).

Table 1. Aerial coverage of five priority areas for capping of containers. See Figure 1 for locations of each area.

Priority area 1	123.56 acres
Priority area 2	123.43 acres
Priority area 3	117.96 acres
Priority area 4	346.28 acres
Priority area 5	145.52 acres
Total	856.75 acres

Regulatory Authority

Dredged material may only be disposed of within the boundaries of the EPA-designated MBDS, which overlaps with the former IWS. To facilitate placement of dredged material in the IWS, EPA is exploring modifying the boundaries of the MBDS to encompass areas outside its current boundary that contain the greatest concentrations of barrels.

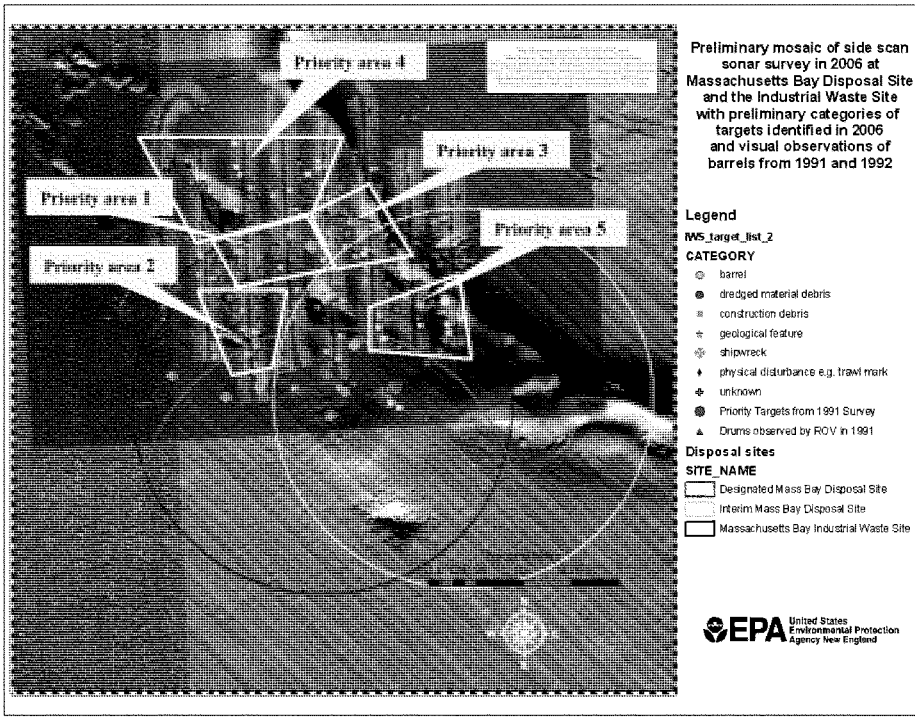
In 1977, the EPA's ocean dumping regulations (40 CFR 228.12) established the interim dredged material disposal site (interim MBDS). In 1993, EPA officially designated the MBDS for long-term use, reconfiguring the boundaries to overlap with both the former IWS and the interim MBDS, and to avoid the part of the former IWS that contained a high concentration of industrial waste barrels and the newly designated Stellwagen Bank National Marine Sanctuary (EPA, 1993). In the Record of Decision, EPA specified that this location was the best alternative because of its historical use and its avoidance of the SBNMS, and because it is in an area of sediment accumulation, so disposal mounds are not expected to suffer erosion. The area of the former IWS with the highest concentration of barrels was not part of the newly designated MBDS because of concerns that disposal of dredged material was not accurate enough to completely cover containers, without potential resuspension of contaminated sediments.

In order to cap and isolate waste containers, disposal outside the current boundaries of the MBDS is required. Because disposal of dredged material in not allowed outside a designated ocean disposal site, several regulatory options have been explored. The most practical option appears to be a modification of the boundaries of the MBDS. The Marine Protection, Research, and Sanctuaries Act (MPRSA) regulations at 40 CFR 228.11(a) provides the EPA site modification authority.

Modifications in disposal site use which involve the withdrawal of designated disposal sites from use or permanent changes in the total specified quantities or types of wastes permitted to be discharged to a specific disposal site will be made through promulgation of an amendment to the disposal site designation set forth in this part 228 and will be based on the results of the analyses of impact described in Sec. 228.10 or upon changed circumstances concerning use of the site.

Because of the opportunity to reduce risks of the historic disposal of the waste containers, and with technological and operational advances in the ability to dispose of dredged material in deeper waters (e.g. SAIC, 2003), EPA believes that the capping and isolation of containers may now be feasible, and thus that the circumstances of the site have changed. This action would require a rulemaking with appropriate environmental impact documentation under the National Environmental Policy Act, which is the same approach used by EPA Region 2 to modify the disposal site boundaries of the New York Bight Dredged Material Disposal Site ("Mud Dump Site") from a two to 16-square mile site, now called the Historic Area Remediation Site. EPA is prepared to pursue this approach in support of the Corps proposed beneficial use project.

Figure 1. Seafloor bathymetry, disposal sites, side scan sonar mosaic, and preliminary identification of targets at the former IWS. Five areas with higher densities of targets are displayed and ranked in order of priority for capping, based on presumed density of containers.



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Side Scan Sonar Data Processing and Analysis of USEPA IWS/MBDS Survey 2006

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January 31, 2008

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Introduction

Barkentine, Inc. was provided with side scan sonar data collected at the Industrial Waste Site ((IWS; formerly known as the "Foul Area") and the Massachusetts Bay Disposal Site (MBDS) in both of which are located in Massachusetts Bay. The data was collected by US Environmental Protection Agency (EPA) personnel aboard the EPA survey vessel *BOLD* during July of 2006.

The IWS/MBDS survey location was a permitted disposal site located approximately fifteen (15) nautical miles north east of Boston in Massachusetts Bay (Figure 1).The site was used for disposal from the late 1940's until the late 1950's. Disposal materials included hazardous and radioactive waste in fifty five (55), thirty (30) and five (5) gallon drums as well as concrete encased drums (Wiley et al., 1992 and NOAA, 1996).

Observations by Barkentine, Inc. (Formally Marine Search & Survey) personnel in 1991 also identified drums partially filled with concrete and disposal material.* In addition to hazardous waste and radioactive material the IWS/MBDS location also received dredge material, rock debris, sunken vessels, munitions, construction debris (Wiley et al., 1992, Personal Observations,* and NOAA, 1996).

In July 2006, the EPA collected side scan sonar data utilizing a Klein System 3000 integrated with a real time differential Global Positioning System (DGPS) onboard *S/V BOLD*. The data was collected in three (3) separate sections of the IWS/MBDS and consisted of three (3) separate data sets.

> Area 1. North-south transects at the Massachusetts Bay Disposal Site (MBDS N-S): 14 transects, 1210 meter line length, 100 meter line spacing, 150 meter sonar range.
>
> Area 2. North-south transects at the Industrial Waste Site (IWS N-S): 15 transects, 1852 meter line length, 200 meter line spacing, 150 meter sonar range.
>
> Area 3. East-west transects at a subset of the IWS (IWS E-W): 11 transects, 2242 meter line length, 125 meter line spacing, 75 meter sonar range.

All three data sets contained both high (500 kHz) and low (100 kHz) frequency data stored in the Klein Sonar Pro XTF format. Only the high frequency (500 kHz) was utilized in this analysis. Two (2) of the data sets (IWS N-S and MBDS N-S) were collected with the sonar set to the one hundred and fifty (150) meter range. The remaining data set (IWS E-W) was collected at the seventy five (75) meter range.

Barkentine, Inc. (BI) imported the data into the Chesapeake Technology Inc.'s processing software SonarWiz.MAP. Each of the data sets was then processed into a sonar mosaic.

Additionally the short range, high frequency, high resolution data was also analyzed to locate and identify possible drum like or potential concrete encasement targets. The target analysis was also conducted in Chesapeake Technologies SonarWiz.MAP. Each target was stored with a thumb nail image and assigned a classification including the confidence level of the identification.

Historical Perspective

Side scan sonar has been successfully utilized to locate fifty five (55) gallon drums and metallic debris on numerous occasions. Figure 2 shows a 500 kHz sonar image of two (2) confirmed, intact fifty five gallon drums imaged with Klein System 3000 sonar in a lake.

In general, analysis of the sonar targets without context, i.e. information about the survey location or target verification, contributes to a broader interpretation of the sonar data. When targets have been verified, the analysis of new targets from the same location results in a higher probability of accurate identifications.

BI was fortunate to participate in several surveys at the IWS/MBDS location which involved collecting sonar data, identifying targets and verifying the targets with an ROV. BI personnel piloted a MiniRover MKII which investigated and visually identified dozens of sonar targets at the IWS/MBDS location (Wiley et al., 1991). Later in 1991 BI personnel also assisted SAIC in a second sonar ROV survey.

During the 1991 ROV survey the International Wildlife Coalition (IWC) examined eighty nine (89) sonar targets of which sixty (60) were verified as drums.[+]

In addition to the IWS/MBDS surveys, BI has also conducted sonar surveys with ROV target verification on other sites containing hazardous waste drums and/or non hazardous 55 gallon drums. These sites included Lake Superior, Coastal New Jersey, Mississippi River and several inland lakes. This extensive experience with intact as well as degraded submerged drums provided a strong historical basis for identifying targets during the analysis of US EPA data collected in July of 2006.

Methodology

Barkentine, Inc. (BI) was provided with three (3) sets of side scan sonar data collected at the IWS/MBDS location. Two of the data sets (IWS N-S and MBDS N-S) were collected with the sonar range set at one hundred and fifty (150) meters. One data set (IWS E-W) was collected with the sonar set to a range of seventy five (75) meters.

Upon receiving the data, BI's objectives were as follows:

1) Create Three Geo-Referenced Mosiacs
2) Interpret Images and Classify Targets
3) Provide EPA with Rational for Classification
4) Provide EPA with Locations of All targets

Barkentine Inc imported the three (3) EPA data sets into separate projects utilizing Chesapeake Technologies, Inc. (CTI) SonarWiz.MAP sonar processing software. Each of the three data sets was treated independently and processed as an independent data set.

Each data set was comprised of dozens of raw sonar files in the XTF format. The raw XTF files were imported into a CTI project which plotted the files over the local nautical chart (NOAA 13200). Turns and data from outside the survey area were removed from the project leaving only contiguous survey lines covering the IWS/MBDS locations.

Each individual survey line was comprised of several XTF sonar files. The files for each line were aggregated for further processing. Each survey line of aggregated files was then subjected to a navigation smoothing process. Any errant GPS fixes were removed and the positional data were subjected to a three hundred (300) point splining function that smoothed the data track. Each aggregated and smoothed file was further processed by manually tracing the first bottom return. The CTI software then removed the water column and applied Time Varied Gain (TVG) to each file. The files were then combined into a high resolution mosaic for each data set. The mosaics were then sent to a professional print shop for hard copy printing.

BI also analyzed the sonar data identifying and classifying targets. Of Primary interest was to discriminate drum and encasement targets from other contacts such as rocks, boulders, lobster traps and construction debris. To discriminate between target types the highest resolution sonar data allows for the best classification. The shorter range sonar data produced higher resolution images. Thus data collected at the seventy five (75) meter range provided the best details to analyze targets. The longer range data (150m range) only allowed for the general enumeration of targets or identification of macro features such as dredge material.

The EPA IWS E-W data set was collected at a sonar range of seventy five (75) m providing the highest resolution information of the three data sets. Barkentine Inc analyzed the seventy five (75) meter range data file by file by locating and identifying the majority of the potential drum like targets within the surveyed IWS area. Each target was analyzed and classified into one (1) of ten (10) different categories. Each classification was represented by a color and icon on subsequent figures. Every target was electronically logged into a digital database which included its sonar image, position and measurements as well as its classification and probability.

The long range data sets did not have the resolution for definitive analysis of drum like targets. Barkentine, Inc. did review the data and log all point targets which may have been associated with drum like targets. This data was provided to the EPA in a digital data format.

All sonar and target analysis was conducted by Vincent J. Capone, M. Sc. who has over 20 years and thousands of hours of side scan sonar experience. He was the ROV pilot for the 1991 survey which investigated dozens of sonar targets in the IWS/MBDS. He also participated in the later sonar/ROV surveys conducted by SAIC and Deep Sea Systems.

Target Analysis & Classification

The goal of the analysis was to provide the EPA with a map of the drum and encasement targets. While analysis of sonar records cannot definitely prove a target is a drum, we can identify the targets which have the highest probability of being drum targets. This analysis is based upon personal experience with confirmed drum targets at this location and over twenty years (20) years side scan sonar experience.

The sonar analyst's skills and experience were critical to the target evaluation since many of the drums were in a degraded state with the characteristics generally associated with metallic debris. In general there were five (5) very similar target types the analyst attempted to differentiate between based upon the sonar target data. The similar target types were drums, partial drums, lobster traps, concrete encasements and rocks/boulders. The characteristics for the different targets types are discussed in detail under each classification definition.

To conduct the analysis in a methodical and scientific manner, BI developed a simple list of criteria to screen targets. When analyzing targets for drum like characteristics, each target was matched against three (3) basic criteria. The criteria were as follows:

a) Size & Shape
b) Metal Characteristics (Ringing and Flaring)
c) Micro - Environment Considerations

Size & Shape

Modern side scan sonar systems interfaced with GPS systems allow for fairly accurate size measurement of targets. By comparing the target size with that of a fifty five (55) gallon drum BI was able to pre-screen numerous targets. If a target had the approximate dimensions of a fifty five (55) gallon drum (0.9m x 0.6m) the target was given further consideration to be classified as a drum like target.

Target size alone is not the ultimate defining factor. Drum targets can be both larger and smaller than standard drum dimensions. Drums which have corroded away will appear smaller and exhibit a different sonar signature. Underwater video from the 1991 survey also showed significant numbers of drums in two or three drum clusters.* Drums encased in concrete will also exhibit size characteristics larger than a standard drum.

In addition to size, shape was also an important characteristic. The shape of the target would often indicate subtle differences that allowed the analyst to further determine how to best classify the target. Drums lying side by side would present a multiple target shape that superseded overall size characteristics.

Size and shape are often more accurately defined by the targets acoustic shadow than the actual target reflection. Metal targets will often produce a reflection larger than the actual target a characteristic known as flaring. Additionally some drum targets have sediment built up around the drum or spilled contents such as concrete creating a more reflective environment directly adjacent the drum. In the aforementioned instances, the target reflection appeared larger than the actual size as indicated by the targets acoustic shadow. Here the shadow provided a more accurate estimate of the above sediment target size. Obviously this analysis is only possible on targets with acoustic shadows.

In addition to dimensions, the analyst also considered the shadow, metallic characteristics such as ringing and flaring and proximity to well defined drum targets and/or proximity to dredge material and or glacial deposits.

Metal Characteristics (Ringing and Flaring)

BI has extensive experience with metallic sonar targets especially submerged drums. By examining numerous sonar targets with divers and ROV's, BI has found a strong positive correlation between ringing/flaring on the sonar record with metal targets. Sonar characteristics of metal targets such as flaring and ringing were important in differentiating metallic targets from rocks boulders and other natural material.

Ringing was term coined early on during the 1991 survey. The term defines a target with multiple returns from a single target. The source of the multiple returns was most likely some type of multi-path; however on some occasions a true reverberation may be noted. The term has continued in use describing the multiple returns related to metallic targets more as a descriptor than the more accurate definition of multi-path. When properly applying the definition Barkentine, Inc. has only found metallic targets produce the ringing characteristics.

Flaring has been defined as when a target produces a sonar return larger than the actual target. Metallic targets and less often rocks have been known to produce this type of response. To derive a true measurement of a flaring contact, only the portion of the target casting a shadow was measured.

Micro - Environmental Considerations

Targets were partially evaluated considering environmental conditions surrounding the contact. Targets within the boundaries of dredge material/rock disposal areas or amongst glacial deposits were more likely to be boulders, rocks or construction debris. Conversely targets outside these areas were more likely to be drum like targets or metallic debris as was shown in the 1991 ROV survey.* While this may slightly under report the number of drum like targets it will significantly reduce the number of false positives.

Another environmental consideration was proximity to shipwrecks. When targets in question were in close proximity (Approximately 5 to 10 meters) to a shipwreck, special consideration was given to the likelihood that the target was associated with those vessels rather than hazardous waste containers.

Some targets exhibited peculiar alignments which also influenced how the analyst interpreted the sonar image. For example Target 003 was a series of drum sized rectangular shapes linearly aligned along the long axis. This configuration is common for lobster traps rather than randomly dropped drums. Because of the alignment and other factors, Target 003 was designated as most probably being lobster traps.

Classifications

Barkentine Inc. separated targets into ten (10) separate classifications giving each a symbol and color. Classifications with similar implications were coded with the same color. For example, dredge material as well as rocks and boulders associated with dredge or rock disposal were both coded with a yellow circle. Drum Like Targets and metallic debris which represented the corroded remains of drums were both coded as red circles.

The classification, icon and color were as follows:

Drum Like Target	**Red Circle Icon**
Metallic Debris	**Red Circle Icon**
Possible Concrete Encasements	**Aqua Boxed X Icon**
Shipwreck	**Blue Circle Icon and Blue Polyline**
Fish	**Blue Circle Icon**
Lobster Trap	**Blue Circle Icon**
Dredge Material or Glacial Deposits	**Yellow Circle / Yellow Polyline**
Rock/Boulder	**Yellow Circle Icon**

None Drum Like Man Made Debris	**Navy Box Icon**
Unknown	**White Circle Icon**

The definition of each classification is as follows:
:

Drum Like Target –Red Circle Icon

Drum Like Target was used to define targets which embodied the characteristics of an intact drum. The highest probability contacts had dimensions roughly equivalent to a drum (Approximately 0.9m x 0.6m) and a rectangular shadow. Targets with only the dimensions or only the shadow were most often given a moderate probability of being a drum target. Based on the 1991 ROV survey any target outside dredge/rock disposal material and outside any glacial deposits was most likely to be a drum or remnants of a drum.

In addition to dimensions, the analyst also considered the shadow, metallic characteristics such as ringing and flaring and proximity to well defined drum targets and/or proximity to dredge material/glacial deposits.

The ROV target documentation in 1991 identified at only one target as a ghost lobster trap. The dimensions for local lobster traps ((0.9m to1.2m) x 0.5m x 0.4m) and drums were very close, especially considering the small errors associated measuring target size with side scan sonars. Other characteristics such as shape, shadow and target density were used to differentiate between the two types of targets.

Metallic Debris – Red Circle Icon

Metallic debris refers to targets which exhibit metal characteristics such as ringing or flaring but did not meet the size and shape criteria of a Drum Like Target.

Metallic debris are most often characterized by ringing and flaring. And as indicated previously, ringing and flaring have been positively correlated with metal targets. Through ROV target verification, BI has determined corroded partial drums will exhibit these characteristics as will other types of metallic debris. Within the confines of the IWS/MBDS most all the ringing targets examined in 1991 were the corroded remains of drums.

These Metallic Debris targets most probably represent the corroding partial remains of the steel drums.

Of the two indicators, ringing is a stronger indicator of a metallic target. Targets which exhibited ringing were given a high probability of being metallic debris and targets which exhibited flaring and no ringing where given a moderate probability of being a metallic target.

Targets smaller than a complete drum which exhibited neither ringing nor flaring but due to proximity to well defined drum targets outside known dredge material/glacial deposits were given a low probability.

In general based on the 1991 ROV survey any target outside dredge and rock disposal material or glacial deposits was most likely to be a drum or remnants of a drum. Some metallic debris was associated with construction materials however during the ROV survey these no drum metallic targets were only noted in close proximity (5-10 meters) to dredge/rock disposal locations.

Shipwreck – Blue Circle Icon and Blue Polyline

Sunken vessels were designated as shipwrecks.

Dredge Material/Glacial Deposits – Yellow Circle Icon and Yellow Polyline

For the purposes of this report the term Dredge Material was used to identify all types of dredge, and rock material deposited in the survey area. Additionally some of the rock material seen on the side scan may also be naturally occurring glacial deposits.

Rock/Boulder – Yellow Circle Icon

Many of the dredge/rock disposal areas contained individually identified rocks or boulders. BI did not attempt to identify all rocks and boulders only those in proximity to drum like targets or outside the obvious dredge/rock disposal locations.

Non-Drum Like – Man Made Debris – Navy Box Icon

Many times targets appeared man made but were obviously not Drum Like or associated with drums such as the metallic debris. An example of this category would be a long piece of pipe. Obviously man made but not

a drum or remains of a drum. These types of targets were designated as Non-Drum Like - Man Made Debris.

This category differs from Unknown Material in that the target is definitely man made such as a piece of pipe but not a drum or encasement.

Possible Concrete Encasements – Aqua Boxed X Icon

Barkentine Inc. classified some targets as possible concrete encasements when the size was larger than a drum with a regular rectangular shape. Reports indicate single drums encased in four (4) to five (5) inches of concrete which would increase the target dimensions to approximately 1.0m x 0.8m. There were also rumors in the early 1990's of concrete coffins approximately two (2) meters in length.*

Rectangular targets larger than expected for a standard fifty five (55) gallon drum were considered as potential encasement targets. To be considered a potential concrete encasement not only did the targets have to exhibit the minimum dimensions but also had to display a strong solid rectangular shape. Some encasement targets demonstrated scouring, which was consistent with a large heavy object in fairly soft sediment.

Lobster Trap - Blue Circle Icon

Targets which exhibited clean crisp rectangular signatures within the proper size constraints and with fishing gear characteristics were designated as lobster traps. Lobster traps utilized locally were found to be two sizes; 0.9m x 0.5m x 0.4m and 1.2m x 0.56m x 0.4m.

BI's sonar analyst has extensive experience imaging both drums and lobster traps. While lobster traps have similar dimensions to 55 gallon drums several characteristics differentiate traps from drums.

Lobster traps are slightly smaller in width and height than a drum. The traps tend to have less solid a return than an intact drum but have a more rectangular structure than a corroded drum remnant.

When appropriate, additional factors such as alignment were used to help characterize the target as a lobster trap. Lobster traps are deployed in strings with the long axis of the trap aligned with the string. ROV and sector sonar observations of the drums indicated a stochastic pattern. Thus as with Target 003 the alignment of several rectangular contacts would suggest a higher probability of being a string of traps rather than drums.

Since the characteristics are very similar to drums there could be some lobster traps which were designated as drums and vice versa. Previous onsite ROV operations have shown a very high density of drums and very low density of lobster traps. Of the 89 targets examined by the IWC only one (1) target was a lobster trap.*

Unknown Material – White Circle Icon

Targets which could not be identified as a Drum Like or Dredge Material/Rocks/Glacial Deposits but did appear to have shape or size characteristics close to drums were designated as Unknown Material. In general these targets had no definitive shape or shadow normally associated with Drum Like targets and occurred outside the confines of dredge material and glacial deposits. These targets also did not possess the distinctive ringing associated with metallic targets.

Fish – Blue Circle Icon

Targets which exhibited the classic characteristics of fish schools were identified as such. Fish schools typically present a diffuse cloud like target with detached shadows.

For each classification Barkentine also assigned a confidence level. Every classified target was also rated as having a high, moderate or low probability of being as classified. The confidence level reflected the analyst's certainty in his classification of the target. In general because of this analyst's experience with ROV observations at this location, confidence levels were better than at a location where no verification had been executed.

Target Accuracy

BI examined features in the sonar data prior to smoothing to determine the repeatable accuracy of the target data. Most of the positional error was probably due to the long cable lengths and the layback algorithm used by Sonar Pro to calculate the towfish position. If the towfish was not transmitting depth information, the Sonar Pro layback will resort to a theoretical cantenary equation which results in a larger layback error. Additionally the version of Sonar Pro used to collect the data will sometimes produce poor representations of towfish position in sharp turns at long cable lengths. Now available new versions of Sonar Pro may be more accurate.

To adjust the data for such errors BI measured the distance between specific points on adjacent lines to determine the layback error. We found the pre-adjustment error to be as much as but not greater than forty (40) meters. The layback was adjusted in CTI until significant features of adjacent lines matched within the mosaic. The layback error was probably greater towards the ends of the survey lines where cable adjustments were being executed.

BI found that prior to any adjustments match points could be offset by as much as forty (40) meters. After adjustment the alignment was significantly better. To better determine the post adjustment accuracy BI matched points on a shipwreck comparing the IWS N-S positions with IWS E-W positions. The difference between post processed points was approximately twenty five (25) meters.

The true accuracy would be best defined by comparing a larger number of points between the two data sets. Unfortunately the range and resolution differences did not allow accurate comparison of numerous small targets such as drums or rocks. Only one (1) large shipwreck target appeared in multiple data sets.

Results

Barkentine Inc. carefully analyzed the high resolution, 75 meter range sonar data. The analysis resulted in over one thousand (1000) contacts designated into ten (10) different categories (Figure 3). An image of each target along with pertinent information is available in digital target Appendix I.

Red circles represent materials which were most likely related to steel drum in various states of decay. The aqua boxed X icons represented potential concrete encasements. Blue icons represented shipwrecks, schools of fish and lobster traps while yellow represents materials related to dredge and rock material disposal and /or natural glacial deposits. Non-drum man made objects were represented by navy box icons and unknown non native materials by white circles.

The one thousand and thirty seven (1037) targets represented a sampling of the targets but not every single target in the sonar data set. Because of the enormous number of contacts, BI focused on drum like, metallic debris and encasement targets and did not record every possible rock, dredge material or non native target.

Targets related to drums dominate the north west and north center of the IWS E-W survey area (Figure 4). From approximately 42-26.55 N to 42-26.18 N and from 070-35.94 W to 070-34.75 W appears to have the highest concentration of drum like targets

and metallic debris. The exception to the aforementioned bounded box would be the south east corner which appears to contain mostly dredge material.

This concentration of drum like and metallic debris targets most likely continues further north to 42-26.82 as indicated by the large number of unidentified point targets found in the IWS N-S sonar records (Fig. 5).

Analysis of the IWS E-W survey area also suggested two areas of possible encasement targets. Figures 6 and 7 indicate the concentration of possible encasement targets as shown by the aqua boxed X icons. The potential encasement targets in Figure 6 are centered about a location of approximately 42-26.17 N / 070-35.61 W. The potential encasement targets in Figure 7 are centered about a location of approximately 42-26.21 N / 070-36.03 W. The yellow polylines in Figures 6 and 7 denote areas of dredge and rock disposal. An enlargement of a possible encasement target is shown in Figure 8. Small point targets and scouring are both visible in the image.

BI also examined the long range data (IWS N-S and MBDS N-S) for large targets. Large objects such as shipwrecks and dredge material were observed. However the range/resolution of the data prevented detailed small target analysis. Figure 9 illustrates the mapped areas of dredge /rock material disposal on the IWS N-S mosaic. Shipwrecks and dredge/rock disposal material in the MBDS are shown in Figure 10.

BI was able to enumerate unidentified point targets in both long range data sets. While these targets did not receive the scrutiny of the short range data the distribution of small point targets most probably represents additional information regarding the distribution of drums. As was mentioned previously, any sonar target investigated during the early 1990's, outside the boundaries of dredge, construction or natural hard bottom material was almost always drum related. Thus the undesignated point targets associated with the long range sonar data most likely reflect the distribution of drum remains.

The aforementioned targets and locations were provided to the EPA in an ASCII data format. The area of such targets was designated by a polylines and provide to the EPA via an electronic dxf file.

Discussion

The analysis of the targets was based upon BI experience in the IWS/MBDS area as well as side scan sonar/ROV operations on other submerged drum sites. No interpretation of sonar imagery can be as reliable as actual visual verification and the analysis provides BI's best interpretation.

The results of the detailed target analysis provide a good representation of the distribution of drum like targets and metallic debris within the IWS E-W survey area. The actual number of drum related targets within the survey area was probably much higher than quantified in this analysis. Based upon sonar and visual analysis of the targets in 1991 all most all the targets outside dredge material/glacial deposit areas were drum related.

Additionally the area directly under the sonar towfish (Nadir Zone) has substantially less resolution than other portions of the sonar record. Small targets within these nadir zones were not counted. So the total number of drum like targets is higher than reported in this analysis just by the nature of the under reporting in the nadir zone.

A third reason for the probable under reporting of drum like targets was related to the state of decomposition. BI did not report targets composed of a few strongly reflecting pixels. These targets did not provide sufficient definition for a true analysis. However during the IWC ROV survey, targets which appeared as a few bright pixels on the sector sonar were often found to be remnants of drums.* Many of these small targets were observed but not counted in this analysis.

The seventy five (75) meter range digital sonar data collected by the EPA was of a higher resolution than collected on previous surveys. With the higher quality data it was possible to analyze targets with much greater accuracy than on earlier surveys. The increased resolution made it possible with a reasonable probability to identify potential concrete encasements which was not possible with earlier sonar surveys.

The new Klein System 3000 high frequency, short range data offered significantly more resolution than previous surveys completed in the early 1990s. Smaller beam angles and advancements in signal processing provided more definition at short ranges that enabled the analyst to better distinguish between target types and identify potential encasement targets.

During the IWC ROV investigation of the IWS/MBDS no encasement targets were located. That survey did locate a few drums which had been partially filled with concrete.[+] The two clusters of potential encasement targets probably represent a small percentage of the total since burial, aquatic vegetation and other factors can easily obscure encasement characteristics. Only those targets which strongly resembled a concrete encased drum were included in this category. None of the targets were marked as a high probability since no video verification has ever been successfully completed on this type of target.

Barkentine, Inc. respectfully reserves the right to amend this report should new information become available.

Citations

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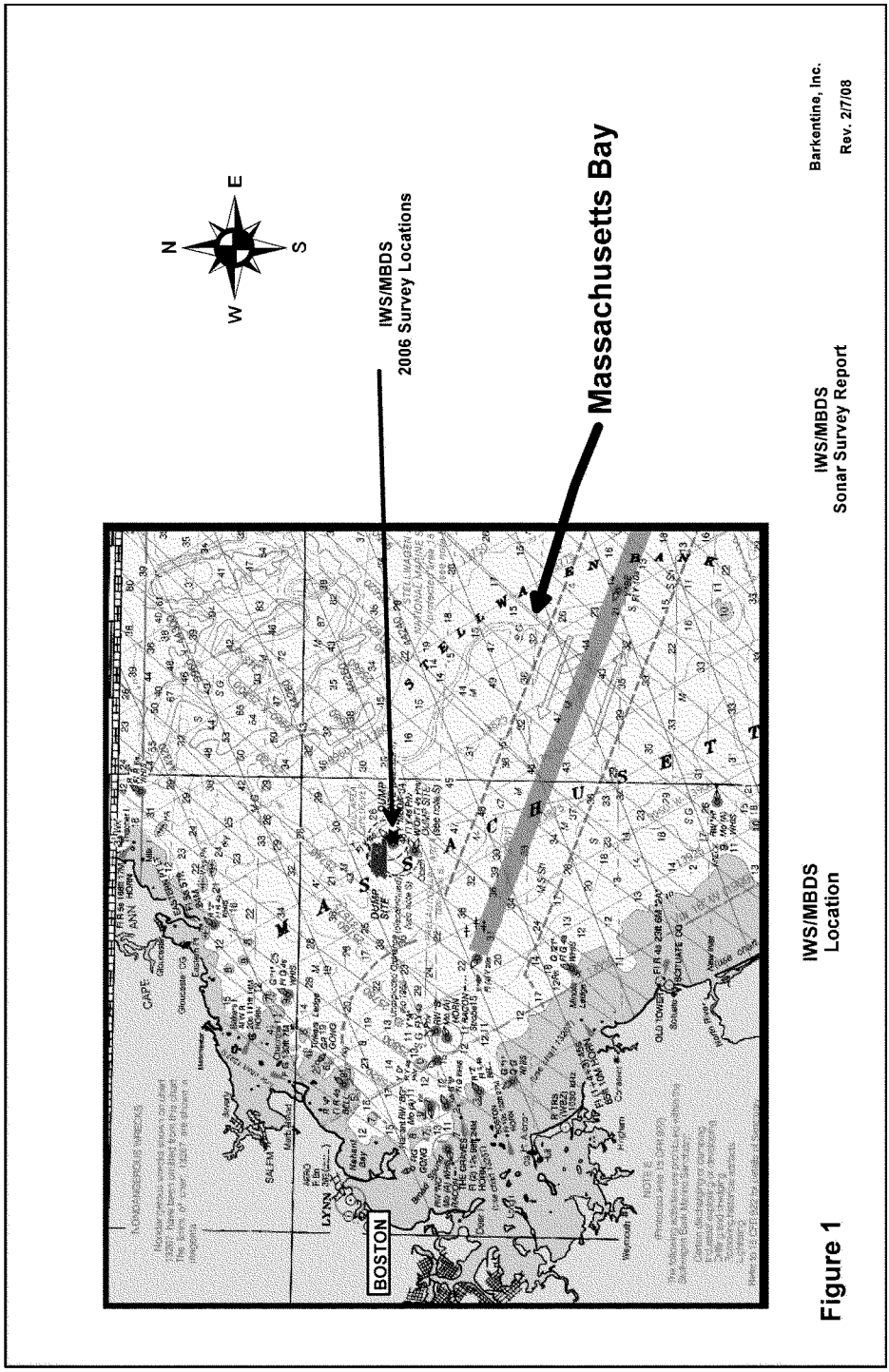
+ Wiley Testimony before the Subcommittee on Fisheries and Wildlife Conservation, November 4, 1991

Wiley, D.N, V. Capone, D.A. Carey, and J.P. Fish. 1992. Location survey and condition inspection of waste containers at the Massachusetts Bay Industrial Waste Site and surrounding areas, Internal Report submitted to US EPA Region 1. International Wildlife Coalition, Falmouth, MA. 59 pp.

* Personal Recollections from Field Operations at the IWS and MBDS locations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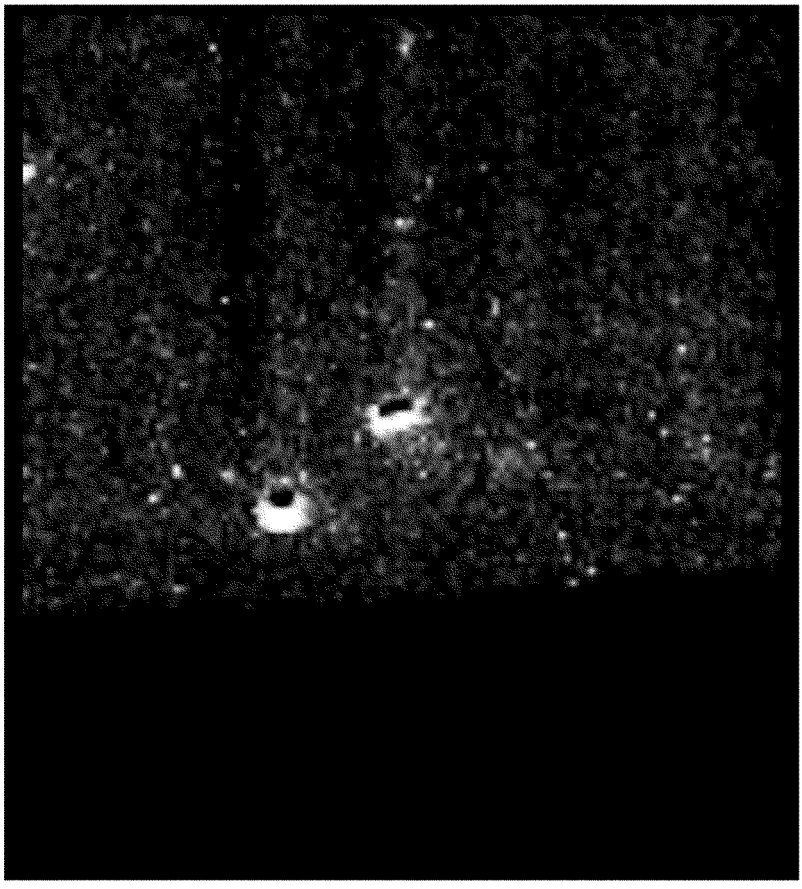
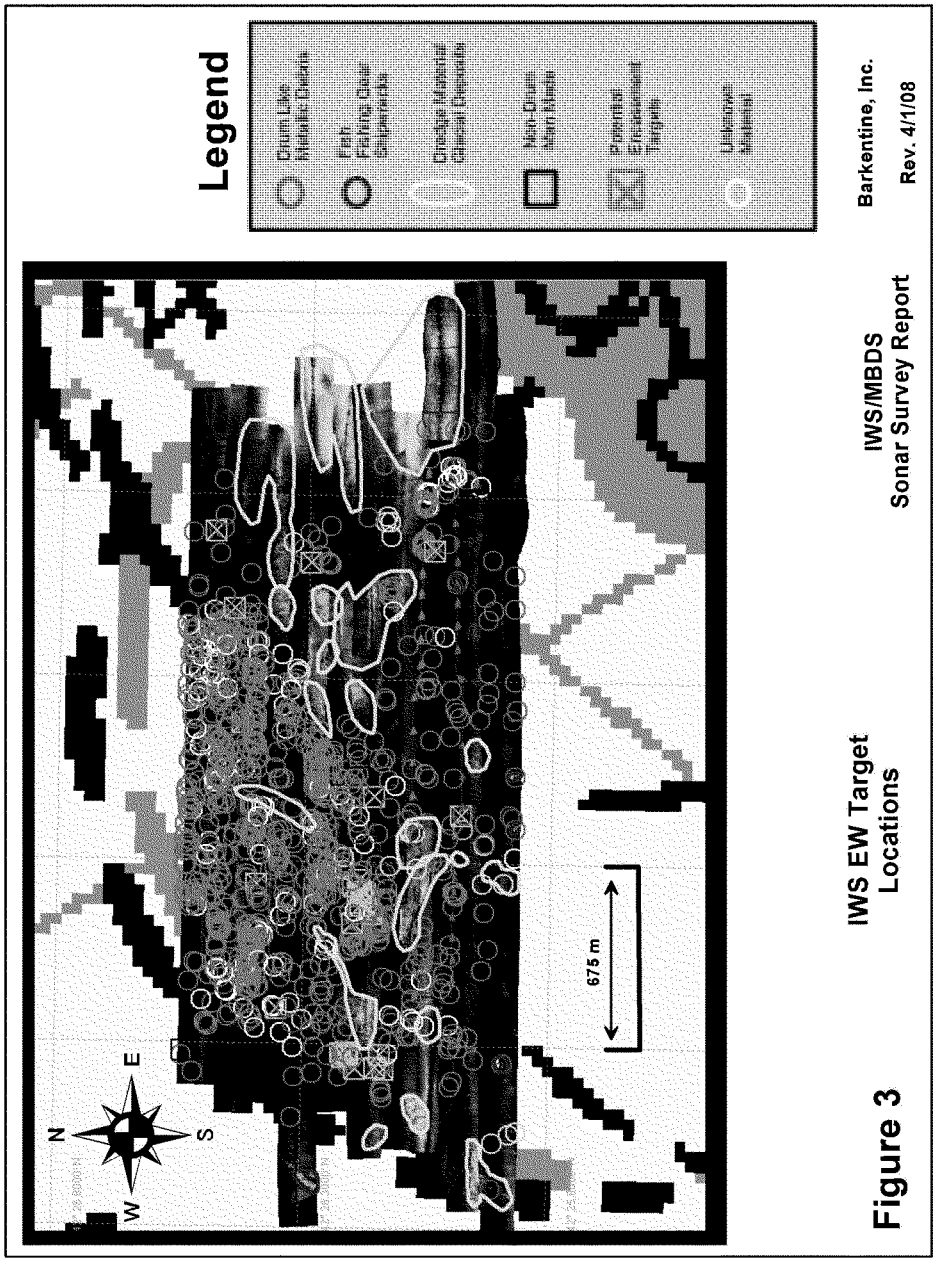
IWS/MBDS
2006 Survey Locations
Massachusetts Bay
BOSTON
IWS/MBDS
Location
IWS/MBDS
Sonar Survey Report
Barkentine, Inc.
Rev. 2/7/08

Figure 1



Two Confirmed and Intact 55 Gallon Drums
Imaged with a Klein System 3000 Sonar
in a Fresh Water Lake

Figure 2


Legend
Drum Like
Metallic Debris
Fish
Fishing Gear
Submarine
Dredge Material
Glacial Deposits
Non-Drum
Non Metallic
Possible
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Targets
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Sonar Survey Report
Barkentine, Inc.
Rev. 4/1/08

Figure 3

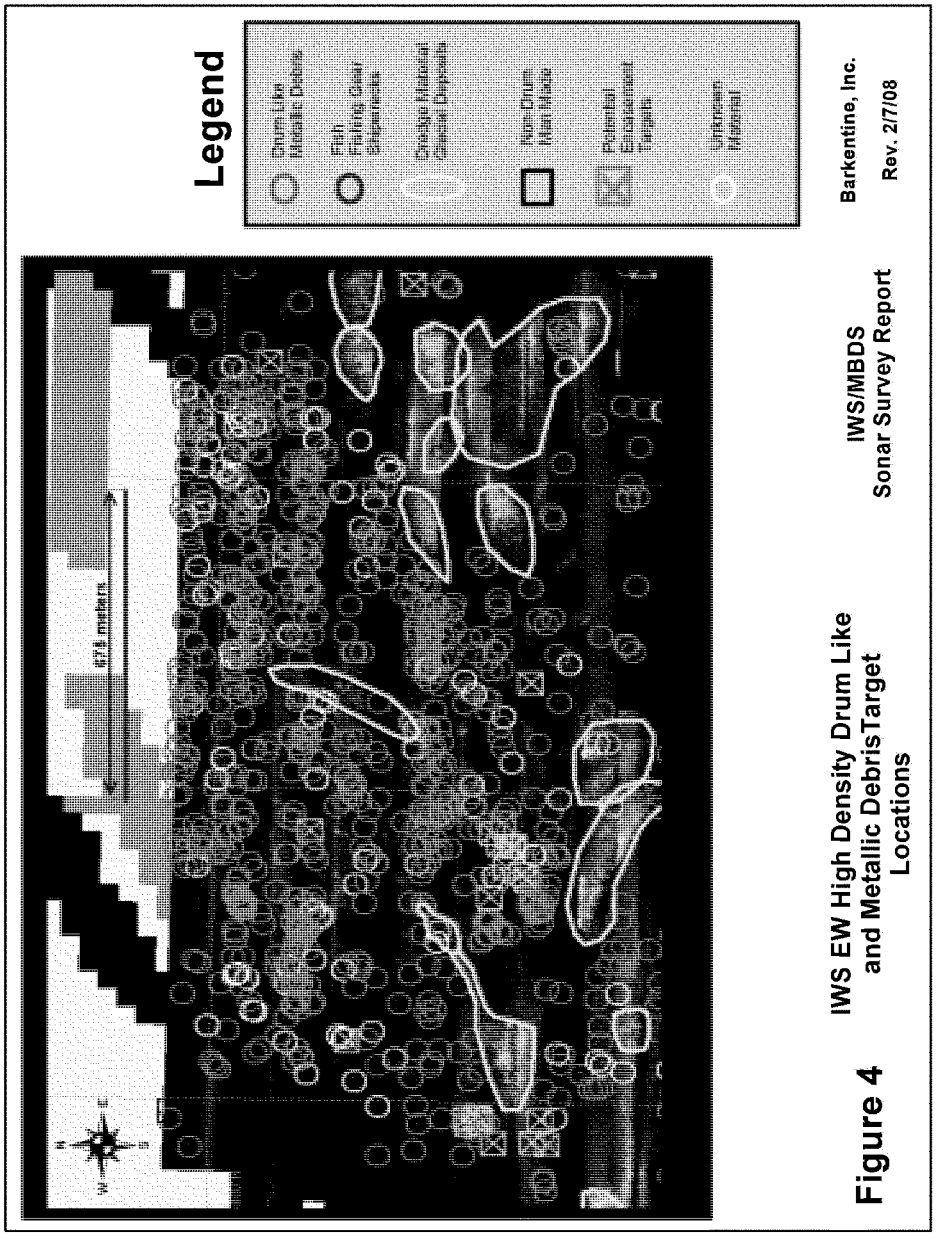

Figure 4 IWS EW High Density Drum Like and Metallic DebrisTarget Locations

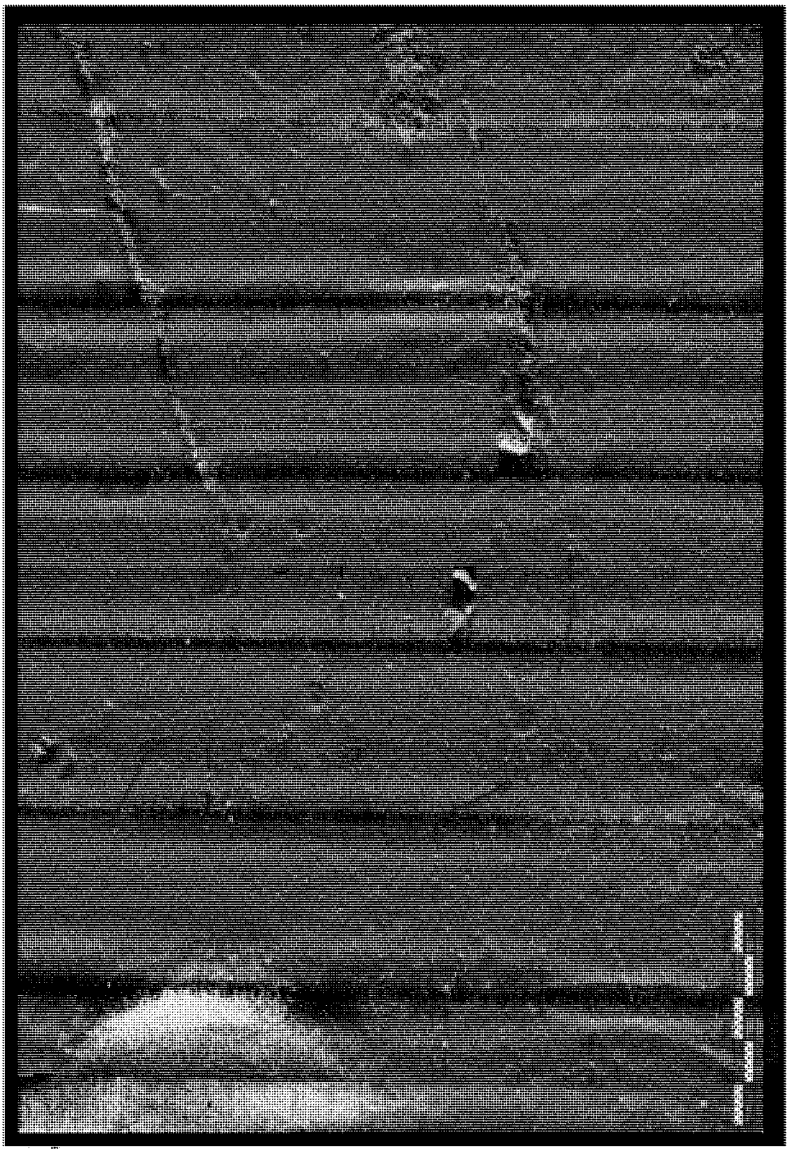

Figure 5

Unidentified Point Targets
on IWS NS Mosaic
North of IWS EW Mosaic

IWS/MBDS
Sonar Survey Report

Barkentine, Inc.
Rev. 2/7/08

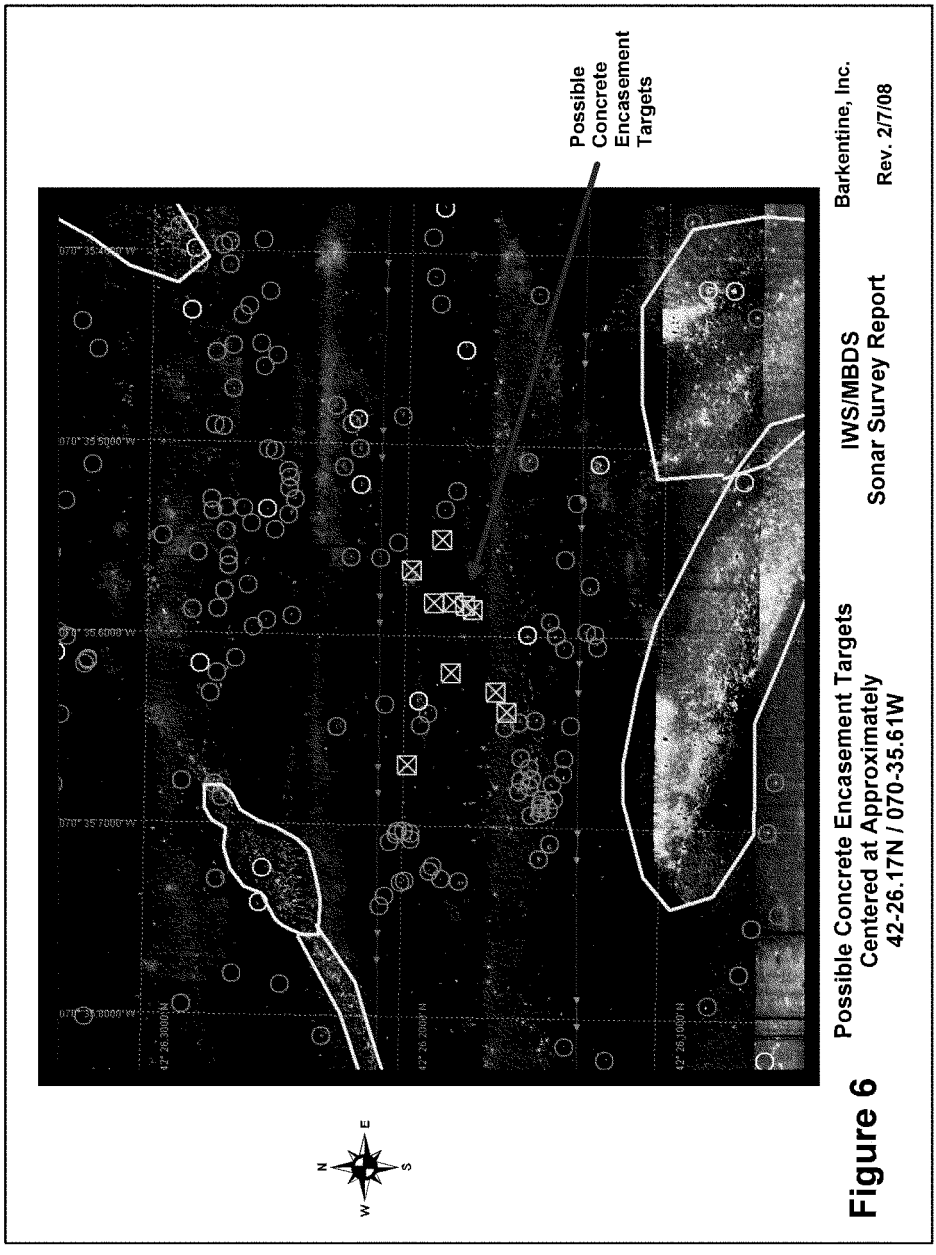
Possible
Concrete
Encasement
Targets
IWS/MBDS
Sonar Survey Report
Barkentine, Inc.
Rev. 2/7/08
Possible Concrete Encasement Targets
Centered at Approximately
42-26.17N / 070-35.61W
N
E
S
W

Figure 6

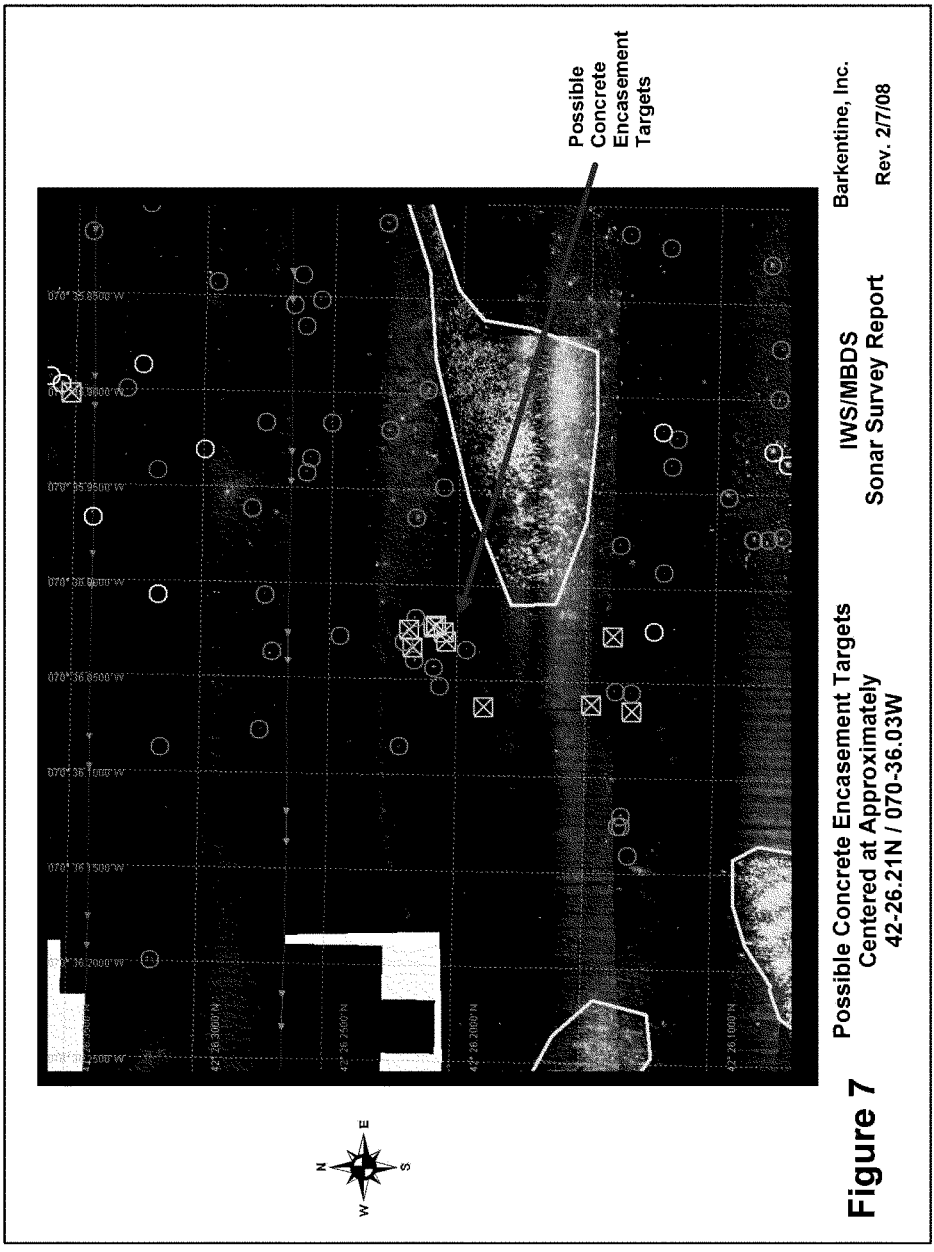
Possible
Concrete
Encasement
Targets
IWS/MBDS
Sonar Survey Report
Barkentine, Inc.
Rev. 2/7/08
Possible Concrete Encasement Targets
Centered at Approximately
42-26.21N / 070-36.03W
N
E
S
W

Figure 7

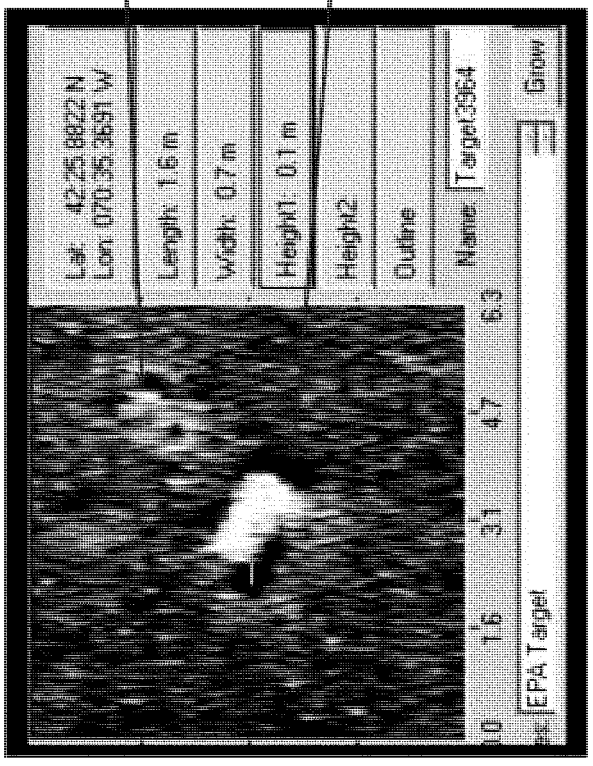

Figure 8

Enlarged Sonar Image
of a
Possible Concrete Encasement Target

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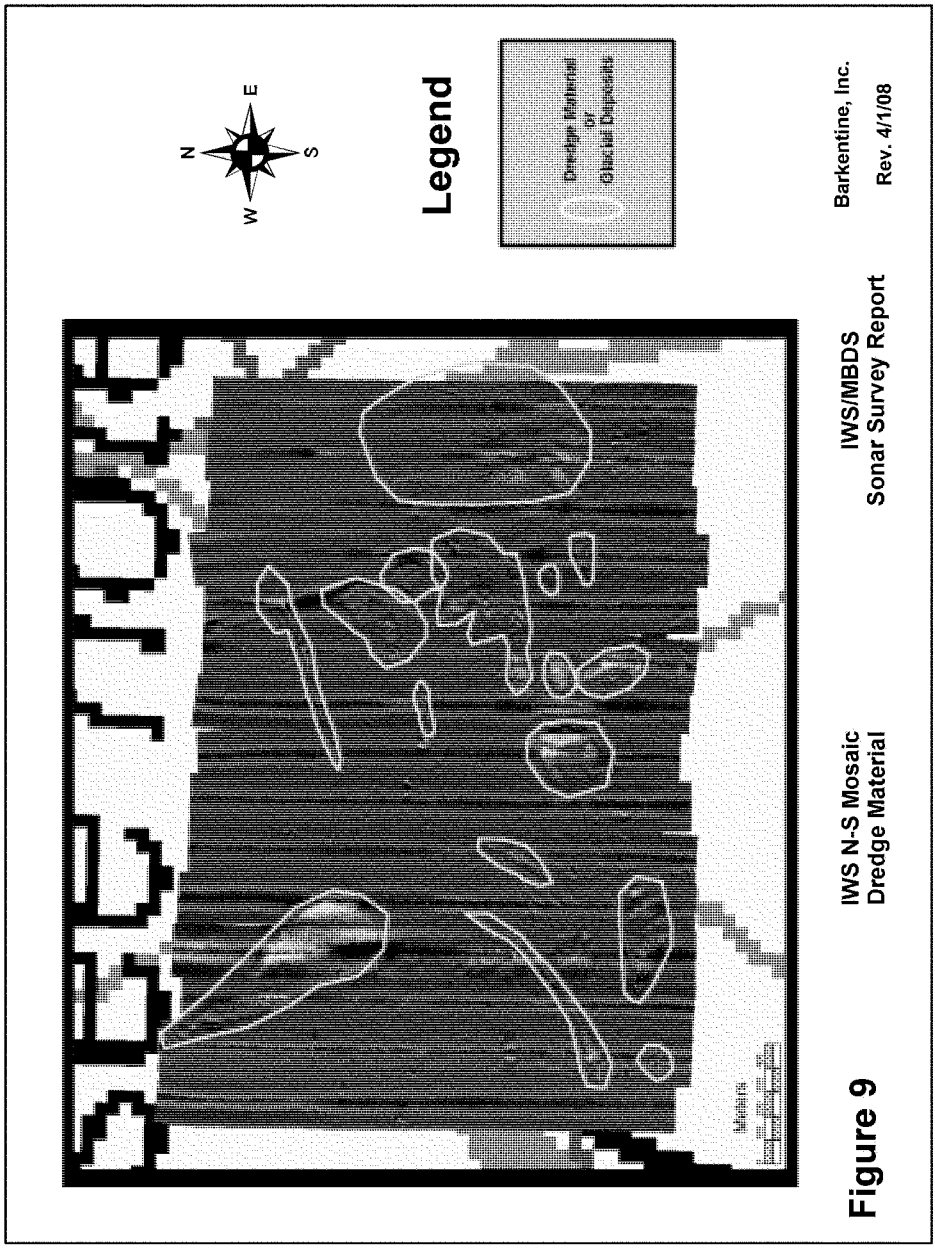
Legend
Dredge Material or Glacial Deposits
N
E
S
W
Meters
IWS N-S Mosaic
Dredge Material
IWS/MBDS
Sonar Survey Report
Barkentine, Inc.
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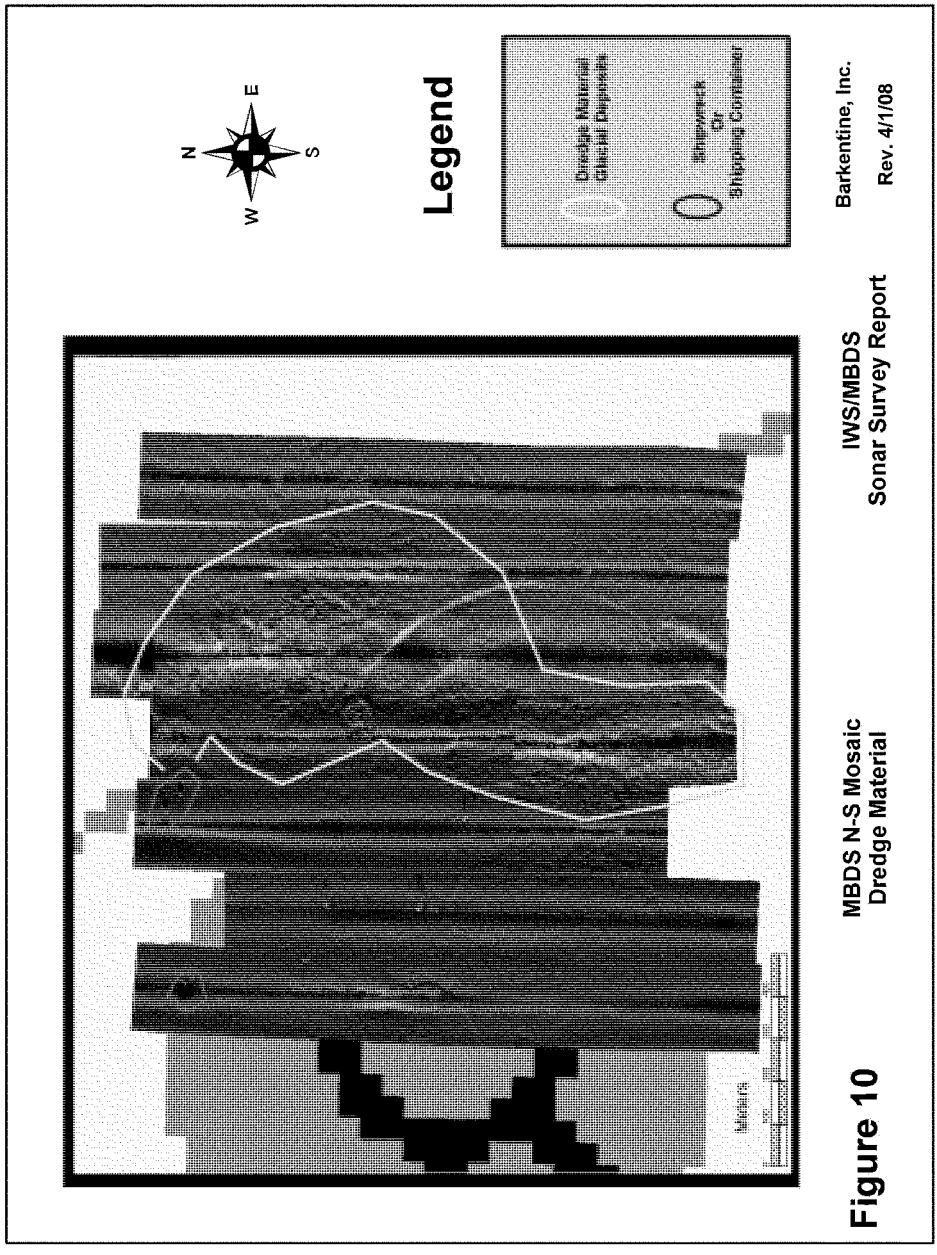
Figure 9


N
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Legend
Dredge Material
Glacial Deposits
Shipwreck
Or
Shipping Container
Barkentine, Inc.
Rev. 4/1/08
IWS/MBDS
Sonar Survey Report
MBDS N-S Mosaic
Dredge Material
Meters

Figure 10

BOSTON HARBOR
MASSACHUSETTS

DEEP DRAFT
NAVIGATION IMPROVEMENT STUDY

FINAL FEASIBILITY REPORT
AND FINAL SUPPLEMENTAL
ENVIRONMENTAL IMPACT STATEMENT
AND MASSACHUSETTS FINAL
ENVIRONMENTAL IMPACT REPORT

APPENDIX S

BENEFICIAL USE OF DREDGED MATERIAL
FOR HARD BOTTOM HABIATAT CREATION

BIOLOGICAL RESOURCE DATA SUMMARY
AND SITE RANKING

(THIS APPENDIX UNCHANGED FROM 2008 DRAFT)

APPENDIX S
BOSTON HARBOR NAVIGATION IMPROVEMENT STUDY

BENEFICIAL USE OF DREDGED MATERIAL FOR ENHANCED HARD BOTTOM HABIATAT

BIOLOGICAL RESOURCE DATA SUMMARY AND SITE RANKING

FINAL REPORT

Contract Number DACW33-03-D-004
Delivery Order No. 05

To:

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North Atlantic Division
New England District
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JANUARY 2006

US ARMY CORPS
OF ENGINEERS
New England District

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1.0 INTRODUCTION

The U.S. Army Corps of Engineers, New England District (NAE) (the Corps), and the Massachusetts Port Authority (Massport) are preparing a joint Supplemental Environmental Impact Statement/Report (SEIS/R) for the Boston Harbor Deep Draft Navigation Improvement Project. The purpose of the joint SEIS/R is to evaluate the feasibility of deep draft navigation improvements to the Boston Harbor, Massachusetts Federal Navigation Project. The project will explore alternatives for accommodating increased deep draft vessel traffic in Boston Harbor including a no action alternative. Alternatives will include incremental deepening schemes for the Broad Sound North Entrance Channel, President Roads Ship Channel (there are some sections of the channel that need to be deepened) and Anchorage area, Reserved Channel and a portion of the Main Ship channel from -40 feet (ft) up to -50 ft mean lower low water (MLLW), a portion of the Mystic River channel from -35 ft to -40 ft MLLW and the Chelsea River channel from -38 ft to -40 ft MLLW.

While the full range of disposal alternatives will be investigated, it is expected that the majority of the material will be suitable for placement at the Massachusetts Bay Disposal Site. During the dredging, rock and cobble material will be blasted or dredged from the various channels to be deepened as par of any improvement project. It is being proposed that portions of this rock/cobble material be used to enhance hard-bottom habitat within Massachusetts Bay. The purpose of this report is to characterize the baseline conditions within five potential enhancement sites and to perform an initial ranking of the sites in order of suitability, based on criteria identified and discussed by the Corps and the project's technical working group. Once the sites are ranked in order of suitability, additional investigations will then be conducted on the most suitable site(s) to determine the load bearing capacity of the substrate to support disposal of rock and cobble.

2.0 APPROACH

This section describes the technical approach taken to identify the potential enhancement sites, characterize the baseline conditions within each site, and rank the sites in order of suitability.

2.1 Site Identification

The Corps held a meeting on August 3, 2004 with the Massachusetts Lobstermen Association, the Boston Harbor lobstermen, Massachusetts Division of Marine Fisheries (MADMF), and Massport. During the meeting, potential enhancement sites were identified that are 1) in water that is 30 feet (ft) or deeper, 2) not readily used by the lobstermen, and 3) are not used by the fishermen (according to the lobstermen). The sites identified for hard-bottom enhancement are located in Nantasket Roads, Massachusetts Bay, Broad Sound, Nahant Bay, and Magnolia (Figure 1).

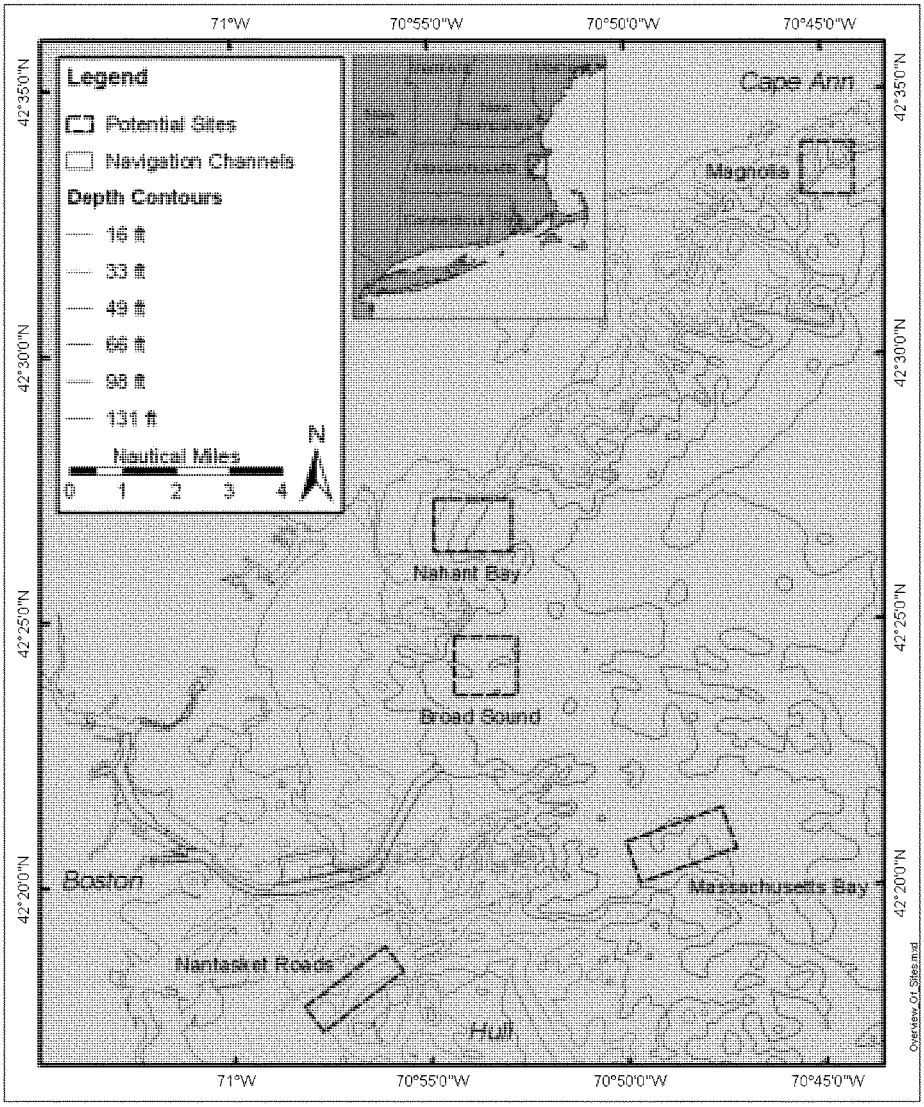


Figure 1. Potential Sites for Hard-bottom Enhancement.

2.2 Biological Resource Surveys

In September 2004, a series of surveys (sidescan, Sediment Profile Imaging [SPI], and benthic) was conducted to collect information to describe the benthic community at five potential enhancement sites (Nantasket Roads, Massachusetts Bay, Broad Sound, Magnolia, and Nahant Bay). Each of these surveys is described briefly below; more details are provided in the respective survey reports (Corps, 2004a; Corps, 2004b; Corps, 2004c).

2.2.1 Sidescan Sonar Survey

Between September 1 and 8, 2004, aquatic remote sensing investigations were conducted at each of the five potential enhancement sites to classify the benthic substrate composition within each of the sites (Corps, 2004a). Side-scan sonar data were collected within each site and a towed underwater video sled was deployed at five locations within each site to ground-truth sonar data and to provide more detailed descriptions of benthic substrates and visible biota. Each video drift lasted between 5 and 15 minutes. At least one benthic grab sample was collected within each site during the sidescan sonar survey and was co-located with video drift transects. Contents of the grabs collected during the side scan sonar survey were digitally photographed and described based on grain size and texture.

Mosaics were created from the sidescan data collected and were provided in geo-referenced JPEG formats and HTML web-enabled format suitable for viewing and analysis with Environmental Systems Research Institute, Inc. (ESRI) ArcGIS Desktop software (i.e., Arcview®, ArcExplorer®), AutoCAD®, and other GIS software. Maps of dominant benthic substrates (i.e., ledge/rock, cobble, gravel-cobble mix, coarse sand through small cobble mix, coarse sand and gravel, sand, muddy sand, and mud) were also created based on the evaluation of sidescan sonar, video, and benthic grab-sample data. Based on interpretation of the sidescan mosaics and video observations, suitable locations for the Sediment Profile Imaging (SPI) survey were selected and mapped. SPI locations were chosen based on identification of soft-bottom areas representing the range of soft-bottom habitat types within a given site.

2.2.2 Sediment Profile Imaging (SPI) Survey

To characterize the benthic habitats at the proposed disposal sites, an SPI survey was conducted on September 11, 2004. Seven stations were located within each area (Figure 2) based on preliminary review of the sidescan data collected as described above (Corps, 2004b). Sites were chosen that represented soft bottom that could easily be penetrated by the SPI camera and that represented the range of soft-bottom habitat types within each area. Areas that could not be sampled by using SPI methodology (e.g., hard-bottom areas) were characterized by other means such as sidescan and video. At each station, a digital Hulcher sediment profile camera was deployed twice. A video feed from the digital camera to the surface vessel allowed monitoring of camera operation and image capture in real time. All sediment profile images were analyzed visually with data on all features being recorded in a preformatted spreadsheet file. The least disturbed image, usually the last in the series, was analyzed digitally with Adobe PhotoShop and NTIS Image programs.

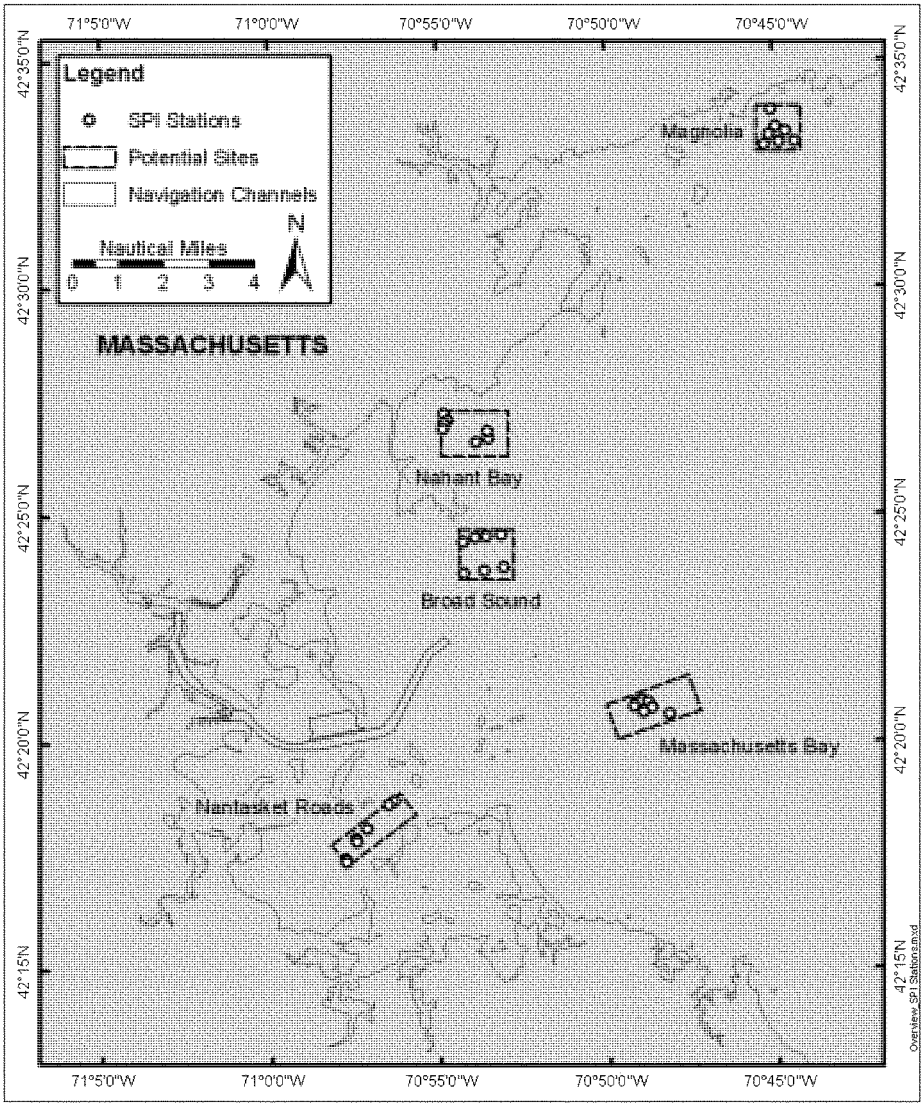


Figure 2. Sediment Profile Imaging Sampling Locations.

The SPI results were used to determine the typical range of values for the apparent Redox Potential Discontinuity (RPD), surface roughness (whether biologically or physically induced),

grain size (composite of grain size throughout entire photograph), presence of any layering in the sediment, presence of methane or other evidence of low dissolved oxygen, and a comparison of benthic organisms observed by those collected from the grab samples. These data were used to determine whether or not there were important differences in benthic community and habitat parameters among sites and whether or not these differences in benthic community or habitat parameters were associated with differences in grain size of the substrate. The SPI surface type and underlying sediment data were used to determine which sites are appropriate to support rock rubble.

Sediment profile data were also used to estimate successional stage of the fauna (Rhoads and Germano, 1986). Characteristics associated with pioneering or colonizing (Stage I) assemblages (as described by Odum, 1969), such as dense aggregations of small polychaete tubes at the surface and shallow apparent RPD layers, are easily seen in sediment profile images. Advanced or equilibrium (Stage III) assemblages also have characteristics that are easily seen in profile images, such as deep apparent RPD layers and subsurface feeding voids. Stage II is intermediate to Stages I and III, and has characteristics of both (Rhoads and Germano, 1986). A set of SPI parameters are evaluated to estimate successional stage with the generalized associations described in Table 1 (- = not associated with, + = associated with, ++ = moderately associated with, +++ = strongly associated with).

Table 1. Relationship of SPI Parameters with Successional Stage.

Parameter	Successional Stage		
	I	II	III
	<1	1-3	>2
Max depth RPD (cm)	<2	>2	>4
Small Tubes	+++	++	+
Large Tubes	-	++	+++
Burrows	-	++	+++
Feeding Voids	-	+	+++
Small Infauna	+++	++	+
Large Infauna	-	+	++
Epifauna	+	++	++

The organism-sediment index (OSI) is a multi-parameter index, developed by Rhoads and Germano (1986) from data provided by the sediment profile images, to characterize benthic habitat quality in soft-bottom estuarine and coastal embayments (Corps, 2004b). The OSI defines quality of benthic habitats by evaluating the depth of the apparent RPD, successional stage of macrofaunal organisms, the presence of gas bubbles in the sediment (an indication of high rates of methanogenesis that are associated with high carbon inputs to the sediments), and visual signs of the presence of low dissolved oxygen conditions (sulfide covered tubes, anaerobic sediment at the interface, bacterial mats) at the sediment-water interface. The OSI ranges from −10, poorest quality habitats, to +11, highest quality habitats.
Although Rhoads and Germano (1986) established the index for estuaries and coastal waters, OSI values >6 indicate good habitat conditions and are generally associated with bottoms that are

not heavily influenced by stress. The OSI level that defines this breakpoint for dynamic offshore bottoms, such as Massachusetts Bay, Broad Sound, and Nahant Bay, has not been determined and could be higher or lower than 6 (Corps, 2004b). Diaz *et al.* (2003) recalibrated the OSI for use in Chesapeake Bay, a temperate coastal embayment, and found that an OSI of 3 was the breakpoint between stressed and non-stressed habitat based on comparison with a benthic index of biotic integrity (Weisberg et al. 1997). Thus for this report, the OSI is used as a relative indicator of habitat conditions with higher OSI values associated with higher benthic habitat quality.

2.2.3 Benthic Survey

On September 16 and 17, 2004, sediment grab sampling was conducted at three stations within each of the five potential hard-bottom enhancement sites in and around Boston Harbor, MA (Corps, 2004c) (Figure 3). Station coordinates were determined based on the sidesean and SPI data collected during earlier surveys (Corps, 2004a; Corps, 2004b) and were chosen to represent the range of soft-bottom sediments within each area. At each of the benthic infauna stations, sediment was collected for infauna, grain-size distribution, and total organic carbon (TOC) analyses.

Several ecological metrics were calculated for each infauna sample within a geographic subset—total abundance, total species, Shannon Diversity (H') calculated using $\log_2$, Pielou's (1966) Evenness (J'), log-series *alpha* diversity (May, 1975), and the ten most abundant species. The software package BioDiversity Professional, Version 2 (© 1997 The Natural History Museum / Scottish Association for Marine Science) was used to perform calculations of total species, log-series *alpha*, H', and J'. Log-series *alpha* is a diversity measure used to characterize infaunal communities. Rosenzweig (1995) showed that several diversity estimators increase markedly with increasing sample size and advocated using Simpson's diversity or log-series *alpha*, because neither exhibited much sample-size bias. Log-series *alpha* is used here as an unbiased estimator of species richness. Log-series *alpha* is completely insensitive to the changes in species evenness. For this report, H' was calculated by using $\log_2$ because that is closest to Shannon's original intent (E. Gallagher personal communication, 2001). H' would have a value of 0 if there was only one species in a sample and would be at a maximum when all species in the sample have the same number of individuals. In practice, values of H' range from < 0 to just greater than 6. Because H' values calculated by using different logarithms vary substantially, the reader must be cautious when comparing values calculated for this report with those presented elsewhere.

Rarefaction analysis [$E(S_n)$, the expected number of species in a sample of size n] (Sanders, 1968; Hurlbert, 1971) on pooled (i.e., summed abundances) samples from each station was also conducted. Rarefaction is a numerical analysis that allows for comparisons of species richness among samples that have unequal sizes (Ludwig and Reynolds, 1988). The approach, which was developed by Sanders (1968) and corrected by Hurlbert (1971), estimates the numbers of species expected in a sample of n individuals from a population of N individuals represented by S species. The results allow the number of species expected for a given sample size to be compared within and across sites.

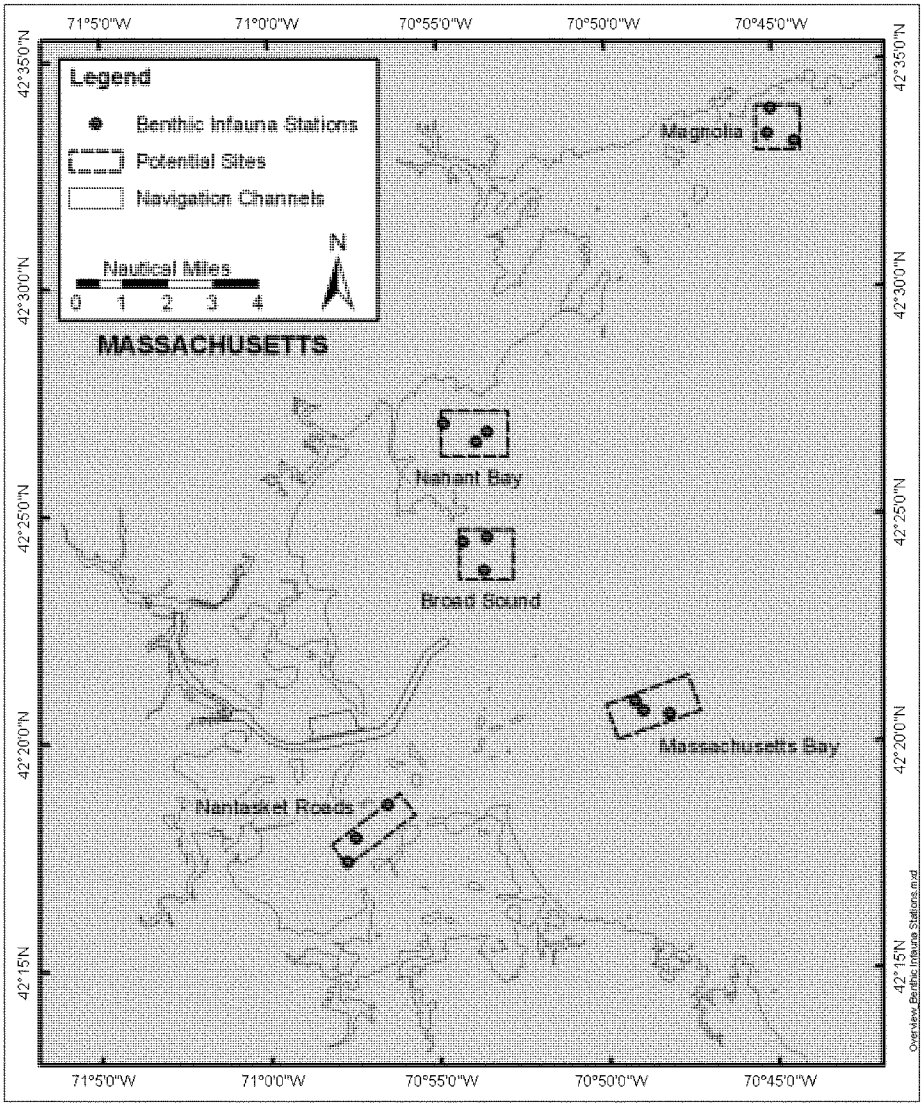


Figure 3. Benthic Survey Grab Sampling Locations.

2.3 Other Available Data

Additional biological data sources were located that describe the fish, shellfish, and lobster communities in and around the five potential enhancement sites and were used, along with the benthic community data collected by the Corps, to characterize the biological productivity and rank the suitability of the potential sites.

2.3.1 Essential Fish Habitat

The 1996 amendments to the Magnuson-Stevens Fishery Conservation and Management Act (16 U.S.C. 1801-1882, April 13, 1976) strengthened the ability of NMFS and the Fishery Management Councils to "protect and conserve the habitat of marine, estuarine, and anadromous finfish, mollusks, and crustaceans." This habitat, referred to as essential fish habitat (EFH), is defined as "those waters and substrate necessary to fish for spawning, breeding, feeding, or growth to maturity." The Magnuson-Stevens Act requires the Fishery Management Councils to describe and identify EFH for managed species and to draft Management Plans for these species that describe ways to minimize, to the extent practicable, adverse effects on EFH from fishing practices and to identify other actions to encourage the conservation and enhancement of EFH.

The NMFS 10 x 10 minute squares that encompass the five potential enhancement sites (Figure 4) were queried to determine which of the Federally managed species and their respective life-history stages have EFH designated within those sites (NOAA, 2005a). The latitude and longitude coordinates for these squares are listed in Table 2.

Table 2. Coordinates of EFH Squares that Encompass Potential Enhancement Sites.

Boundary	North	East	South	West
Square 3	42° 30.0' N	70° 50.0' W	42° 20.0' N	71° 00.0' W
Square 4	42° 20.0' N	70° 50.0' W	42° 10.0' N	71° 00.0' W
Square 5	42° 40.0' N	70° 40.0' W	42° 30.0' N	70° 50.0' W
Square 6	42° 30.0' N	70° 40.0' W	42° 20.0' N	70° 50.0' W

Separate maps were compiled by NMFS to show the EFH for seven skate species (NOAA, 2005a). Skate species with EFH in coastal Massachusetts waters, including those within the potential enhancement sites, are the little skate (*Raja erinacea*) (juvenile and adult), thorny skate (*Amblyraja radiata*) (juvenile), and winter skate (*Raja ocellata*) (juvenile). EFH maps, based on the areas of highest relative abundance for each of these species and life stages during NMFS trawl surveys (1963 - 1999), are shown in Figure 5. Only the shaded squares in U.S. waters represent the EFH designation.

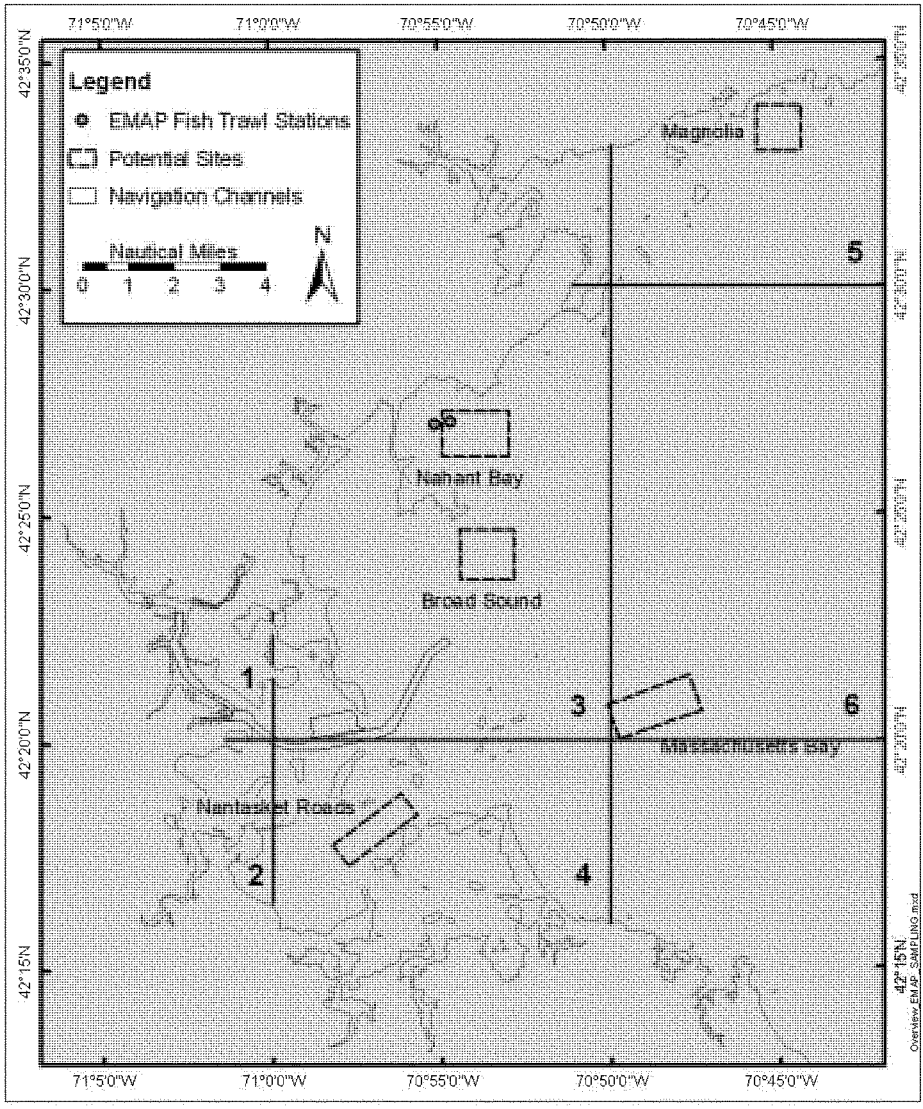
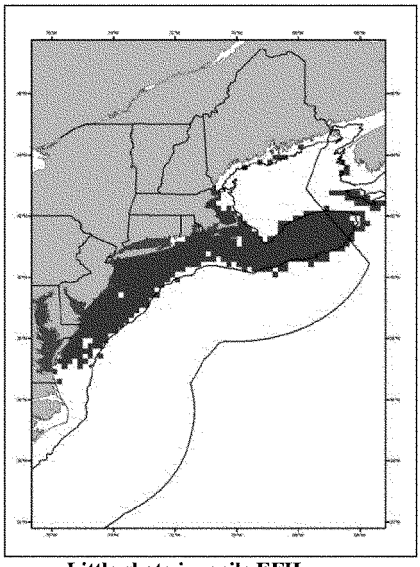
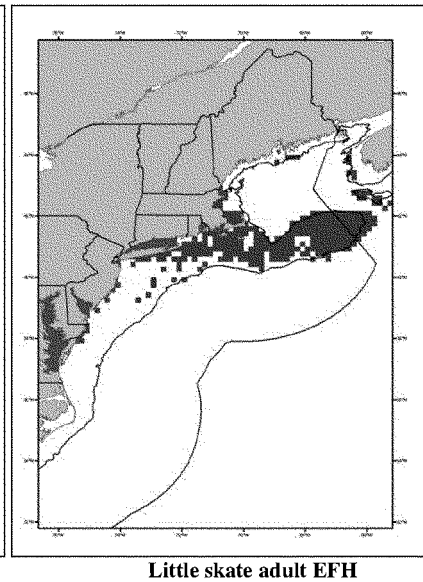


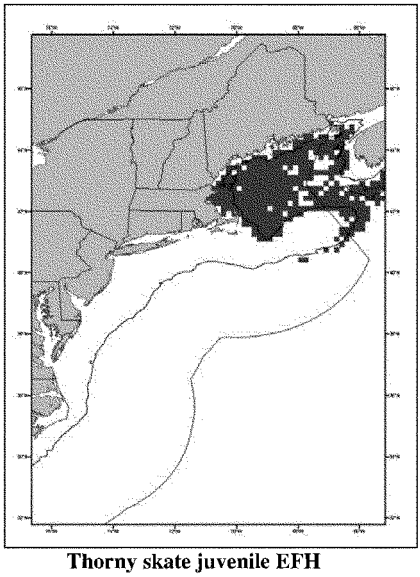
Figure 4. 10 x 10 Minute EFH Squares and EMAP Sampling Stations.



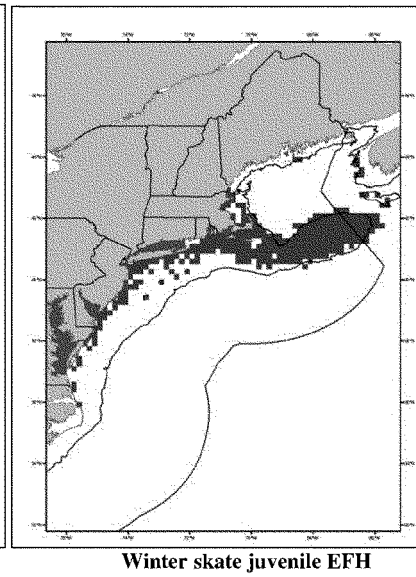
Little skate juvenile EFH
(58% of the observed range of this life stage)



Little skate adult EFH
(57% of the observed range of this life stage)



Thorny skate juvenile EFH
(66% of the observed range of this life stage)



Winter skate juvenile EFH
(48% of the observed range of this life stage)

Figure 5. EFH Designation in Coastal Massachusetts for Skate Species.

2.3.2 Environmental Monitoring Assessment Program

The U.S. Environmental Protection Agency's Environmental Monitoring and Assessment Program (EMAP) is a research program to develop the tools necessary to monitor and assess the status and trends of national ecological resources. EMAP assesses the condition of the Nation's coastal resources through the National Coastal Assessment (NCA), an integrated, comprehensive monitoring program among the coastal states. One of the stations (MA00-0093-A) from the September 2000 EMAP NCA fish trawl survey was located within, and one (MA00-0091-A) was adjacent to, the Nahant Bay site (EPA, 2005) (Figure 4).

2.3.3 Shellfish Suitability Areas

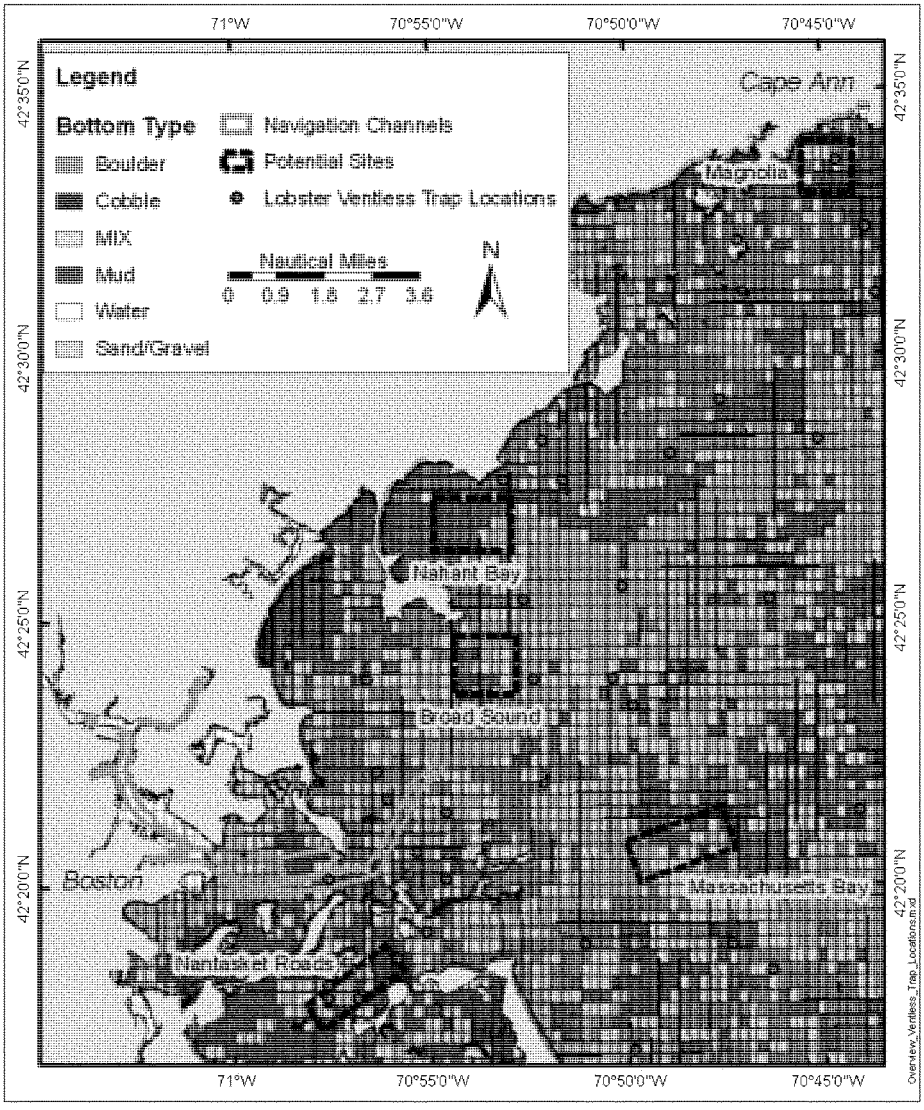
The MADMF, in collaboration with the Massachusetts Office of Coastal Zone Management (CZM) and the NOAA Coastal Services Center (CSC), developed a map of shellfish suitability areas that shows the approximate locations of potential habitats suitable for ten species of shellfish along the coast of Massachusetts. These areas were determined to be suitable for shellfish based on the expertise of the MADMF, the opinion of local Massachusetts Shellfish Constables, and information contained in maps and studies of shellfish in Massachusetts. These areas include sites where shellfish have historically been sighted but may not currently support any shellfish.

2.3.4 Ventless Trap Lobster Survey

In an ongoing ventless trap study conducted by MADMF, efforts are underway to characterize the importance of substrate type and depth to lobster abundance and size distribution (Glenn *et al.*, 2005). Fixed stations within Massachusetts Bay, including stations within the Nantasket Roads and Magnolia sites, were sampled during a pilot study in 2004 and are currently being sampled for a multi-year survey (Figure 6). Sampling occurs aboard commercial vessels, twice monthly from May through November, using a six-trap haul, on which vented and ventless traps are alternately strung on the trawl line. The sampling involves 80 randomly selected, but fixed stations in Massachusetts Bay with each stratum (depth and substrate) represented by at least seven stations.

2.4 Site Ranking

The site ranking process involved the review and evaluation of available biological and physical data, as well as considerations of other uses of the waters within the five potential sites. The following sections describe the criteria and methods used to rank the potential sites in order of suitability for hard-bottom enhancement.



Source: Glenn *et al.*, 2005

Figure 6. Ventless Trap Lobster Sampling Locations and Bottom Type Characteristics.

2.4.1 Criteria

Five criteria were used to perform an initial ranking of the five potential enhancement sites in order of suitability, based on the biological productivity, bottom type, capacity, other uses, and navigable distance of the sites. Each criterion is described below.

1. The first criterion was the biological productivity of each site. Sites with lower productivity, as determined by benthic habitat community or the OSI, were given higher priority for hard-bottom enhancement. Successional stage, OSI, and rarefaction data collected during the SPI and benthic surveys were used to rank the benthic communities at the five potential sites relative to one another. Since changes in the bottom substrate through the placement of rock/cobble material would likely impact species other than benthic infauna, data describing the fish, shellfish, and lobster populations within the sites were used to supplement the benthic infauna data in determining the suitability of each of the sites for hard-bottom enhancement.

2. The second criterion was the existing bottom type for each site. During the disposal, rock and/or cobble will be placed on soft substrate, not on existing rock bottoms. Sites with abundant existing rock bottom habitat were given lower priority. Sites were still considered if they contained some rock bottom that did not significantly reduce the volume of area available for disposal of rock and/or cobble. If the location of the existing rock bottom was in the middle of the site, the site was eliminated from further consideration.

3. The third criterion is the capacity of each site to accommodate the dredged rock/cobble from the navigation channel. Site capacity (cubic yards [cy]) was calculated as the area of soft bottom (in square yards [yd^2]) multiplied by a maximum rock/cobble height of 3 ft (i.e., 1 yd) (C. Rogers, personal communication, 2005). Water depth within the sites was also considered when evaluating site capacity. Priority was given to sites that can receive all of the rock/cobble so that disposal at more than one site will not be necessary.

4. The fourth criterion evaluated the potential for the interference of disposal with other uses, such as fishing or navigation. The site selected for placement of rock/cobble cannot interfere with these activities.

5. The fifth criterion is proximity to the navigation channel. If no significant difference was found between sites, based on the previous four criteria, then the site(s) closest to the navigation channel were given higher priority.

Based on the results of the initial ranking presented in this report, additional investigations will then be conducted on the most suitable site(s) to determine the load bearing capacity of the substrate to support disposal of rock and cobble.

2.4.2 Ranking Method

During the site ranking, all available data were assembled, reviewed, and summarized (see Section 3 of this report) according to the five criteria listed above. The five criteria and

corresponding values at each of the potential sites were then compiled into a table, and the sites were ranked from most suitable to least suitable by criterion (see Section 4).

To assist in the ranking, three levels of quantitative ranking values were developed based on the OSI and rarefaction data used to rank the benthic communities at the five potential sites. The natural break method was used to derive the ranking criteria values for the benthic community by identifying breakpoints between classes of data using a statistical formula (Jenk's optimization). Jenk's method minimizes the sum of the variance within each of the classes. Natural Breaks finds groupings and patterns inherent in the data. These natural breakpoints serve to rank the benthic community productivity at each of the five potential enhancement sites in relation to one another.

The results of the site ranking by criteria were listed in a table, and because no one site was consistently ranked as the most suitable across the ranking criteria, four ranking classes (from most suitable [1] to least suitable [4]), were assigned to the list of sites within each criterion. To determine the most suitable site overall, based on the rankings using individual criteria, the occurrence of each site within the top two suitability classes (Class 1 and Class 2) was counted. The site(s) that was ranked within Classes 1 and 2 the most times was determined to be the most suitable site for hard-bottom enhancement. Likewise, the site that was listed in those classes the least number of times was determined to be the least suitable. The key biological, physical, and site use data used in determining the final site ranking were also presented and discussed. The site ranking results are presented in Section 4 of this report.

3.0 SITE DESCRIPTIONS

Data collected from each of the biological resource surveys, and other available data, were used to describe the physical and biological setting, as well as the current use, of each of the five potential enhancement sites.

3.1 Physical Setting

3.1.1 Nantasket Roads

The Nantasket Roads site is rectangular, measuring approximately 2 miles by 0.7 miles enclosing an area of 1.47 square miles (mi^2). This site is relatively shallow, with depths ranging from zero (ledge outcrops) to approximately 50 ft (Corps, 2004a).

The dominant substrate texture classes were (in decreasing order of dominance): coarse sand and gravel, sand, ledge/rock, and mud (Figure 7). Soft bottom (i.e., sand or softer) covered 0.38 mi^2, or 26% of the site. Sand was located along the northern edge of the site, with the majority of the bottom consisting of coarse sand and gravel. Anthropogenic debris and fixed fishing gear (e.g., lobster traps) were widespread at this site (Corps, 2004a). All the SPI stations at Nantasket Roads were silty (Corps, 2004b) (Figure 7). The three infaunal stations within Nantasket Roads (NR2, NR4, NR7) were located in small patches of soft substrates interspersed among broad stretches of sandy gravel (and shell) pavement (Corps, 2004c). Sediments generally were evenly mixed coarse and fine textures, although the fine fraction was predominant at NR2. TOC content was moderate, ranging from 1.2% to 2.3%.

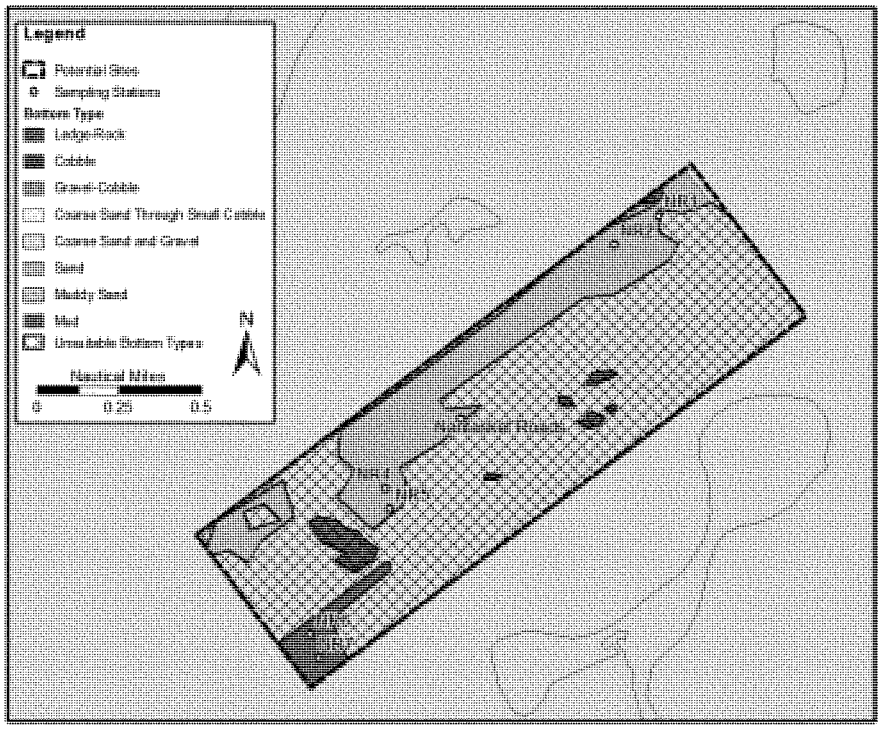


Figure 7. Dominant Substrate Classes at the Nantasket Roads Site.

3.1.2 Massachusetts Bay

The Massachusetts Bay site is rectangular, measuring approximately 2.2 miles by 1 mile enclosing an area of 2.12 mi^2. This site was the deepest of the survey areas, with depths ranging from approximately 75 ft to 110 ft (Corps, 2004a).

The dominant substrate texture classes were (in decreasing order of dominance): sand, coarse sand and gravel, mud, and cobble (Figure 8). A wide area of mud was located in the center of the site, surrounded by extensive areas of hard bottom to the east and southwest. Soft bottom covered 1.06 mi^2, or 50% of the site. Anthropogenic debris and fixed fishing gear (e.g., lobster traps) were widespread at this survey area (Corps, 2004a). Side-scan sonar imagery identified many ring-shaped features, interpreted to be small mounds of disposed coarse material (e.g., construction debris). Sand waves of varying size were also widespread at the Massachusetts Bay site (Corps, 2004a). SPI stations at the Massachusetts Bay were sandy or silty (Corps, 2004b) (Figure 8). The three infaunal stations within the Massachusetts Bay site (MB1, MB4, MB7) were located within a broad area of fine to medium sand or very fine sandy mud surrounded by extensive areas of hard bottom (Corps, 2004c). Sediments generally were evenly mixed coarse

and fine textures at stations MB1 and MB4, but were predominantly fine at station MB7. TOC content was low at stations MB1 and MB4, just less than 1%, and moderate at station MB7, about 3%.

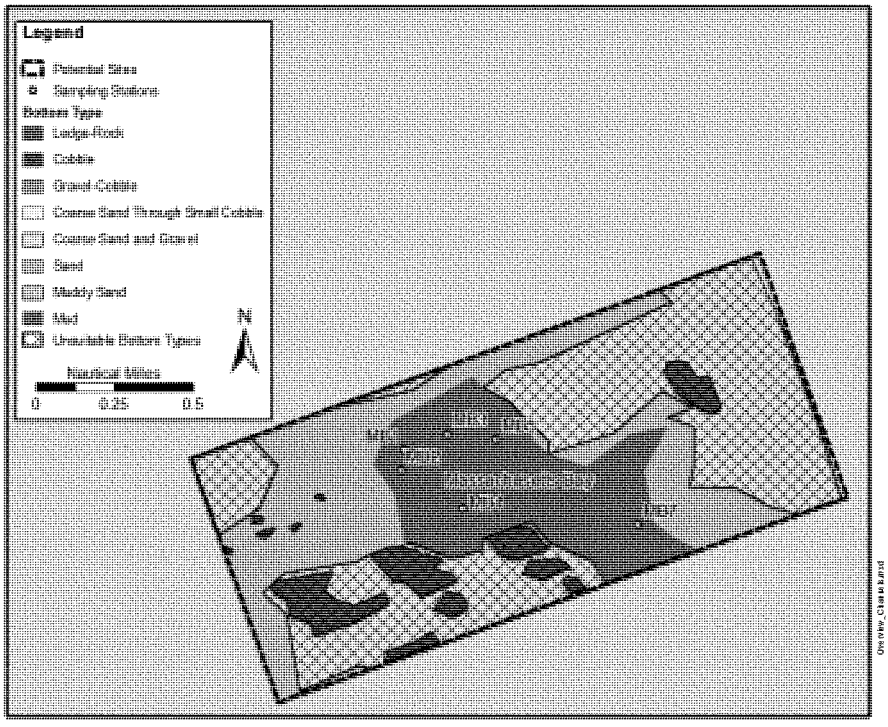


Figure 8. Dominant Substrate Classes at the Massachusetts Bay Site.

3.1.3 Broad Sound

The Broad Sound site is square, measuring approximately 1.4 miles by 1.3 miles, enclosing an area of 1.73 mi^2. This site was of intermediate depth, with depths ranging from approximately 45 ft to 90 ft (Corps, 2004a).

The dominant substrate texture classes were (in decreasing order of dominance): muddy sand and a gravel/cobble mix (Figure 9). The coarser gravel/cobble mix roughly bisected the site along an east/west orientation. Soft bottom covered 0.99 mi^2, or 57% of the site. SPI stations at the Broad Sound site were both sandy and silty (Corps, 2004b) (Figure 9). The northern sampling stations were separated from southern stations by a broad swath of hard bottom, including coarse gravel and small cobbles (Corps, 2004c). The three infaunal stations within the Broad Sound site (BR1, BR3, BR6) were located in two large areas of sand or muddy sand.

Sediments were moderately coarse at station BR1 (61% sand + gravel) and fine at stations BR3 and BR6 (66% and 78% silt + clay). TOC content was very low at station BR1 (0.5%) and low at stations BR3 and BR6 (1.3%– 1.9%).

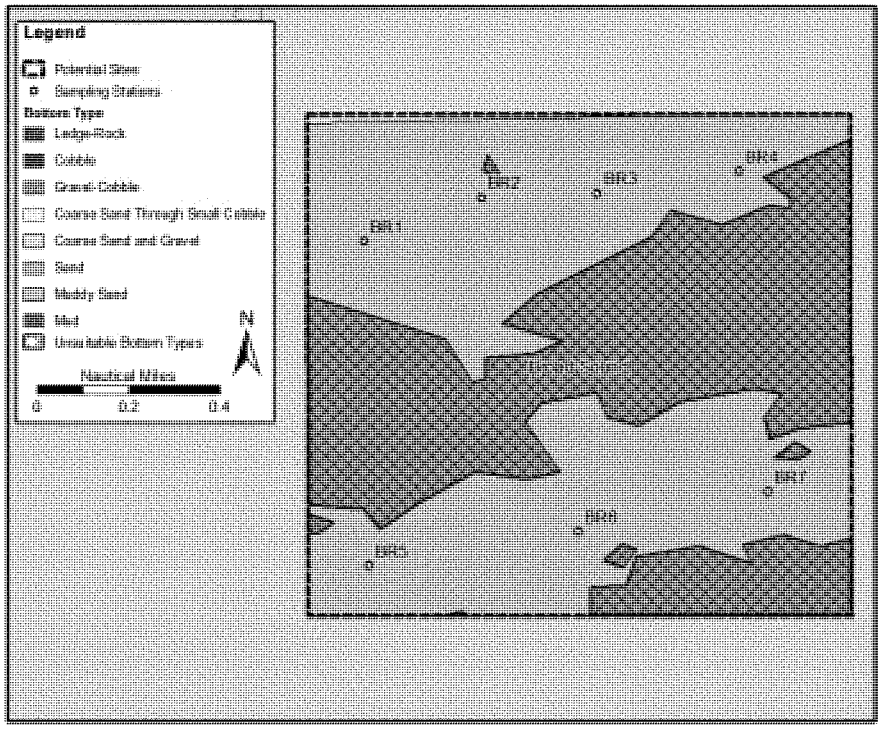


Figure 9. Dominant Substrate Classes at the Broad Sound Site.

3.1.4 Nahant Bay

The Nahant Bay site is rectangular, measuring approximately 1.7 miles by 1.1 miles, enclosing an area of 1.92 mi^2. This site was of intermediate depth, with depths ranging from approximately 30 ft to 75 ft (Corps, 2004a).

The dominant substrate texture classes were (in decreasing order of dominance): sand and a mixture of coarse sand to small cobble (Figure 10). Coarser material appeared to be concentrated along the northern, southern, and western site boundaries. Soft bottom covered 1.34 mi^2, or 70% of the site. Bottom type at all of the SPI stations within Nahant Bay was fine- and medium-sand to very fine sand (Corps, 2004b). The three infaunal stations within the Nahant Bay site (NB3, NB5, NB7) were located within a broad area of soft bottom with many small patches of hard-bottom material separating the northwestern station (NB3) from the other

two (Corps, 2004c) (Figure 10). Sediments were predominantly coarse at stations NB3 and NB7 (80%– 97% sand + gravel) and mixed at station NB5 (43% silt + clay). TOC content was very low at stations NB3 and NB7 (<0.5%) and low at station NB5 (1.2%).

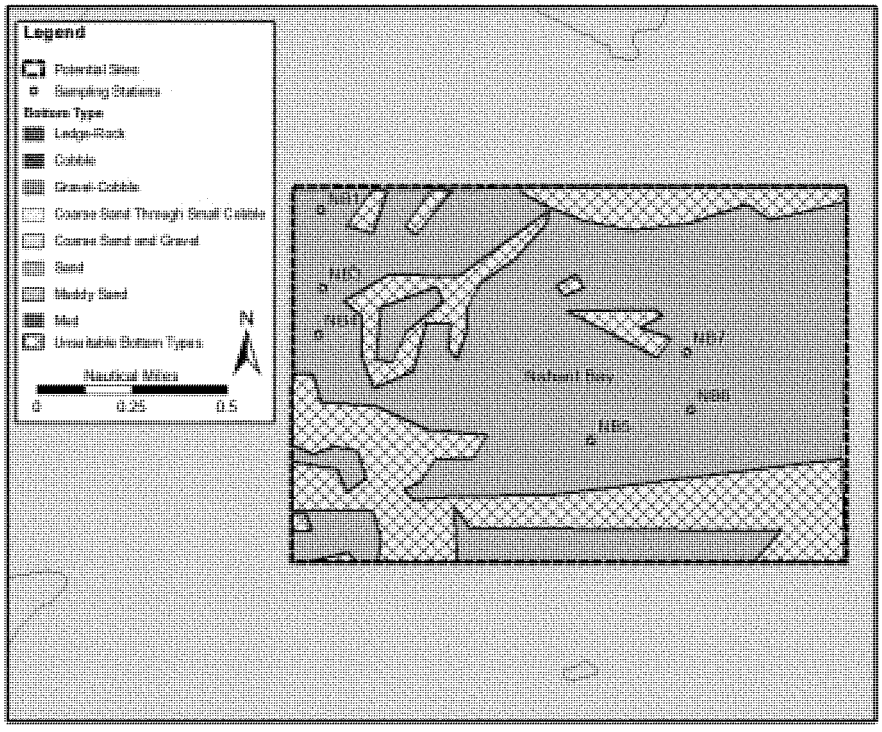


Figure 10. Dominant Substrate Classes at the Nahant Bay Site.

3.1.5 Magnolia

The Magnolia site is square, measuring approximately 1.1 miles by 1.1 miles, enclosing an area of 1.28 mi^2. This site was of shallow to intermediate depth, with depths ranging from approximately zero (ledge outcrops) to 95 ft (Corps, 2004a).

The dominant substrate texture classes were (in decreasing order of dominance): sand (generally smooth and well-sorted), ledge/rock, and a coarse sand/gravel mix (Figure 11). Areas of ledge/rock and coarse sand and gravel were concentrated in the northern half of the site. Soft bottom covered 0.83 mi^2, or 65% of the site. The bottom type at all of the SPI stations was sand, mostly very fine sand (Corps, 2004b) (Figure 11). The three infaunal stations within the Magnolia site (MA1, MA3, MA7) were located within a broad reach of soft-bottom substrate partially surrounded by patches of hard-bottom material (Corps, 2004c). Sediments were

predominantly coarse at all three stations, ranging form 76% to 89% sand + gravel. TOC content was very low at all three stations, 0.2%.

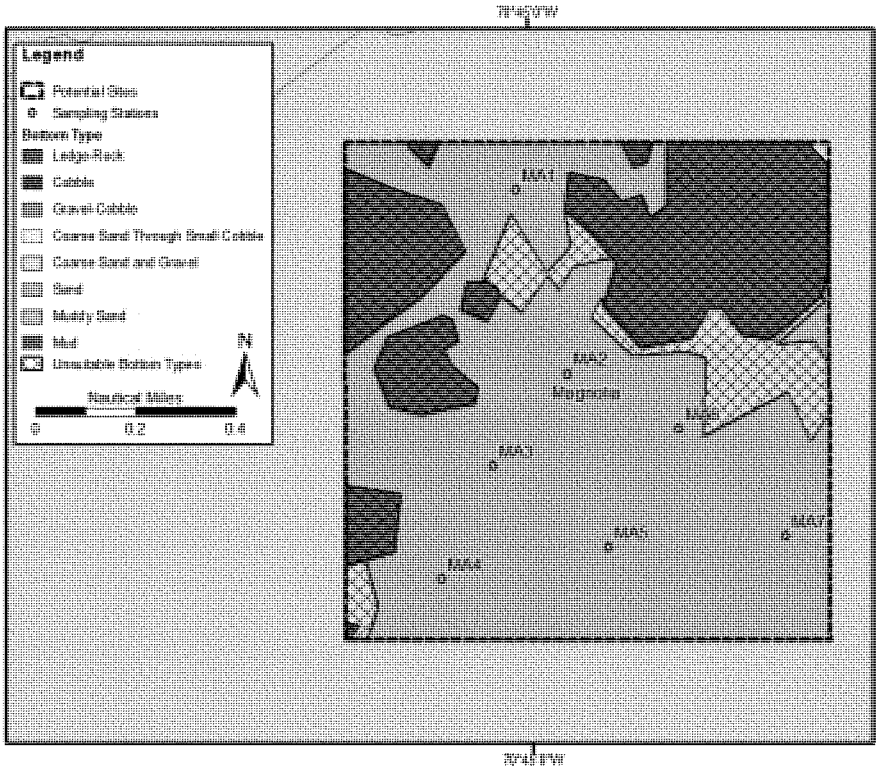


Figure 11. Dominant Substrate Classes at the Magnolia Site.

3.2 Biological Setting

The biological setting of the five potential enhancement sites is characterized using data regarding the benthic, finfish, shellfish, and lobster populations present within these sites.

3.2.1 Benthos

The quality of benthic habitat was characterized using a number of parameters listed in Section 2.2.3, namely successional stage, OSI, and rarefaction data. Other measures of benthic quality include benthic infauna abundance and variability.

Nantasket Roads

OSI at the Nantasket Roads SPI stations ranged from 5.5 to 10. Infaunal abundance varied almost three-fold across the three Nantasket Roads stations, ranging from 892 to 2,361 individuals per sample, or approximately 22,000 to 59,000/m^2 (Corps, 2005). Variability (coefficient of variation, CV) among the samples collected within each station ranged from 19 to 54%. The number of species occurring at each station also varied considerably, ranging from 13 to 24 species per sample. Variability in species numbers at each station was moderately low (12% to 22%). Species diversity among the Nantasket Roads stations was low with log-series alpha ranging from 2.1 to 3.7 and Shannon's *H'* ranging from 2.0 to 2.9. Variability in species diversity within each station was moderately low, with CVs for log-series alpha ranging from 10% to 20%.

The predominant taxa present at each of the three Nantasket Roads stations varied. At two of the stations, the three most abundant taxa were the same; the annelid worms *Aricidea catherinae* (polychaete), Tubificidae (oligochaete), and *Scoletoma hebes* (polychaete). These three taxa accounted for about 86% of the species-level infaunal abundance at those stations. The amphipods *Leptocheirus pinguis* and *Ampelisca abdita* were relatively uncommon, accounting for only about 1% to 3% of the species level infaunal abundance at the two stations. At the third station, the predominant species were the amphipod *Leptocheirus pinguis* and *Ampelisca abdita*, which accounted for about 28% and 17%, respectively, of the species-level infaunal abundance at the station. The three worms that were most abundant at the first two stations were also common at the third station, but only accounted for about 38% of the species-level infaunal abundance there.

Moon snails, sulfur sponge, cerianthid anemones, and hydroids were observed in the video drifts from this site (Corps, 2004a). Many amphipod tubes were also observed in the mud bottom.

Massachusetts Bay

OSI at the Massachusetts Bay SPI stations ranged from 6.0 to 9.0 (Corps, 2004b). Infaunal abundance varied slightly more than two-fold across the three Massachusetts Bay stations, ranging from 438 to 1067 individuals per sample, or approximately 11,000 to 27,000/m^2 (Corps, 2005). Variability was moderate to high (CV = 22 to 103%) among the samples collected at each of the three Massachusetts Bay stations. The number of species occurring at each station also varied moderately, ranging from 21 to 31 species per sample. Variability in species numbers within each station was moderately low (19 to 26%). Species diversity among the Massachusetts Bay stations was moderately low and consistent among all three stations with log-series alpha ranging from 5.5 to 6.7 and Shannon's *H'* ranging from 3.3 to 3.5. Variability in species diversity within each station was moderately low (15% to 26%).

Most of the numerically dominant taxa at the three Massachusetts Bay stations were polychaete worms. All of these worms, especially *Prionospio steenstrupi*, *Tharyx acutus*, *Mediomastus californiensis*, *Levinsenia gracilis*, and *Spio limicola*, are typically among the predominant species in Massachusetts Bay (Kropp *et al.*, 2002; Maciolek *et al.*, 2003). The small deposit-feeding clam, *Nucula delphinodonta*, also was relatively abundant and is a common taxon among Massachusetts Bay samples (Kropp *et al.*, 2002; Maciolek *et al.*, 2003).

Several seastars and sand shrimp were observed at the soft-bottom video transects. On the gravel and cobble bottom, and in areas of sand waves, hydroids and sulfur sponge were observed.

Broad Sound

OSI at the Broad Sound SPI stations ranged from 4.0 to 7.5 (Corps, 2004b). Infaunal abundance varied less than two-fold across the three Broad Sound stations, ranging from 1,367 to 2,429 individuals per sample, or about 34,000 to 61,000/m^2 (Corps, 2005). Variability was low to high among the samples collected in Broad Sound (CVs = 15% to 78%). The number of species occurring at each station was relatively consistent, ranging from 28 to 35 species per sample. Variability in species numbers within each station was moderately low (13% to 23%). Species diversity among the Broad Sound stations was moderately low and consistent among all three stations with log-series alpha ranging from 4.5 to 6.7 and Shannon's *H'* ranging from 2.9 to 3.9. Variability in species diversity within each station was low to moderate, with CVs for log-series alpha ranging from 12% to 33%.

The species composition of the samples from the three Broad Sound stations was also typical for Massachusetts Bay sediments. Polychaete worms again accounted for the largest proportion of the species-level infaunal abundance. *Prionospio steenstrupi*, *Tharyx acutus*, *Mediomastus californiensis*, *Levinsenia gracilis*, and *Spio limicola* characterized the samples from two of the stations. Despite the numerical importance of *Prionospio steenstrupi* and *Mediomastus californiensis* at the third station, the fauna at that station differed from the other two in that the polychaete *Owenia fusiformis* accounted for 22% of the species-level infaunal abundance there. Additionally, the isopod crustacean, *Edotia montosa*, was among the ten most abundant taxa at one station, but was uncommon or not found at the other two stations. The small bivalve mollusc *Nucula delphinodonta* was third or fourth most abundant species among the Broad Sound stations.

Northern starfish were also observed in the video transects from within this site (Corps, 2004a).

Nahant Bay

OSI at the Nahant Bay SPI stations ranged from 5.0 to 8.0 (Corps, 2004b). Infaunal abundance varied twelve-fold across the three Nahant Bay stations, ranging from 172 to 2,066 individuals per sample, or about 4,300 to 52,000/m^2 (Corps, 2005). Variability was low to moderate (CV = 9% to 44%) among the samples collected at all three stations. The number of species occurring at each station varied, ranging from 15 to 31 species per sample. Variability in species numbers within each station was moderately low (18% to 31%). Species diversity among the Nahant Bay stations was moderately low and consistent among all three stations with log-series alpha ranging from 4.2 to 5.3 and Shannon's *H'* ranging from 2.2 to 2.9. Variability in species diversity within each station was low to moderate, with CVs for log-series alpha ranging from 13% to 44%.

As might be expected by the differences in depth, grain-size regime, and distance between NB3 and the other two Nahant Bay stations, the fauna at station NB3 differed substantially from that at the other two stations. The predominant species at NB3 were those typically associated with sandy substrates, amphipods (*Psammonyx nobilis*, *Unciola irrorata*, and *Protohaustorius* sp. B), sand dollars (*Echinarachnius parma*), and bivalve molluscs (*Tellina agilis*, *Spisula solidissima*, and *Siliqua costata*). The most abundant species at the station, the polychaete *Spiophanes bombyx*, inhabits a variety of substrate types. A more typical Massachusetts Bay fauna comprised the deeper stations, NB5 and NB7. Characteristic species included the polychaete worms *Prionospio steenstrupi*, *Owenia fusiformis*, *Aricidea catherinae*, *Mediomastus*

californiensis, and the nut clam *Nucula delphinodonta*. *Spiophanes bombyx* also was among the ten most abundant taxa at the two deeper stations.

At one of the video drifts, sand dollars were extremely abundant on the fine hard sand bottom type. Also observed at the Nahant site were seastars and sulfur sponge (Corps, 2004a).

Magnolia

OSI at the Magnolia SPI stations ranged from >3.5 to 7.0 (Corps, 2004b). Infaunal abundance varied about two-fold across the three Magnolia stations, ranging from 385 to 826 individuals per sample, or about 9,600 to 26,600/m^2 (Corps, 2005). Variability was low to moderate (CV = 22% to 32%) among the samples collected at all three stations. The number of species occurring at each station was fairly consistent, ranging from 25 to 35 species per sample, and variability in species numbers within each station was low (13% to 21%). Species diversity among the Magnolia stations was moderately low and consistent among all three stations with log-series alpha ranging from 5.4 to 7.7 and Shannon's *H'* ranging from 2.5 to 3.5. Variability in species diversity within each station was low, with CVs for log-series alpha ranging from 18% to 25%.

Many of the most abundant taxa among the Magnolia stations, especially station MA1, are characteristic of very sandy substrates. Although several species of polychaete worms were numerically important at station MA1, sand-dwelling crustaceans, such as *Crassicorophium crassicorne* (amphipod), *Tanaissus psammophilus* (tanaid), and *Eudorella pusilla* (cumacean), were relatively abundant. Sand dollars (*Echinarachnius parma*) accounted for 10% of the species-level infaunal abundance there. The polychaete worm *Spiophanes bombyx* was numerically predominant at all three Magnolia stations; and the worm *Prionospio steenstrupi*, *Owenia fusiformis*, and *Aricidea catherinae* were common at stations MA3 and MA7. The small clam *Nucula delphinodonta* and the isopod crustacean *Edotia montosa* were relatively abundant the two deeper stations (MA3, MA7).

3.2.2 Fish

Species having EFH designated in the four 10 x 10 minute squares that encompass the five potential enhancement sites include 2 shellfish species (see Section 3.2.3 for discussion of shellfish resources), 2 squid species, and 24 finfish species (NOAA, 2005a) (Table 3). Skates, such as little skate (juvenile and adult), thorny skate (juvenile), and winter skate (juvenile) also have EFH in coastal Massachusetts waters which include all five of the potential sites. In addition, several species of finfish were observed in the video-drift footage collected within the five potential sites (Corps, 2004a) and in EMAP trawls collected within the Nahant Bay site.

Table 3. Species with EFH within the Five Potential Enhancement Sites.

Species	Nantasket Roads (Square 4)	Massachusetts Bay (Square 6)	Broad Sound (Square 3)	Nahant Bay (Square 3)	Magnolia (Square 5)
Finfish					
Atlantic cod *(Gadus morhua)*	E,L,J,A	E,L,J,A	E,L,J,A	E,L,J,A	E,L,J,A
haddock *(Melanogrammus aeglefinus)*	E,L	E,L,J	E,L	E,L	E,L,J
pollock *(Pollachius virens)*	E,L,J,A	E,L,J,A	E,L,J,A	E,L,J,A	E,L,J,A
whiting *(Merluccius bilinearis)*	E,L,J,A	E,L,J,A	E,L,J,A	E,L,J,A	E,L,J,A
red hake *(Urophycis chuss)*	E,L,J,A	E,L,J,A	E,L,J,A	E,L,J,A	E,L,J,A
white hake *(Urophycis tenuis)*	E,L,J,A	E,L,J,A	E,L,J,A	E,L,J,A	E,L,J,A
redfish *(Sebastes fasciatus)*		L,J,A			L,J,A
witch flounder *(Glyptocephalus cynoglossus)*		E,L,A			
winter flounder *(Pseudopleuronectes americanus)*	E,L,J,A	E,L,J,A	E,L,J,A	E,L,J,A	E,L,J,A
yellowtail flounder *(Pleuronectes ferruginea)*	E,L,J,A	E,L,J,A	E,L,J,A	E,L,J,A	E,L,J,A
windowpane flounder *(Scophthalmus aquosus)*	E,L,J,A	E,L,J,A	E,L,J,A	E,L,J,A	E,L,J,A
American plaice *(Hippoglossoides platessoides)*	E,L,J,A	E,L,J,A	E,L,J,A	E,L,J,A	E,L,J,A
ocean pout *(Macrozoarces americanus)*	E,L,J,A	E,L,J,A	E,L,J,A	E,L,J,A	E,L,J,A
Atlantic halibut *(Hippoglossus hippoglossus)*	E,L,J,A	E,L,J,A	E,L,J,A	E,L,J,A	E,L,J,A
Atlantic sea herring *(Clupea harengus)*	L,J,A	L,J,A	L,J,A	L,J,A	L,J,A
monkfish *(Lophius americanus)*		E,L			
bluefish *(Pomatomus saltatrix)*	J,A	J,A	J,A	J,A	J,A
Atlantic butterfish *(Peprilus triacanthus)*	E,L,J,A	E,L,J,A	E,L,J,A	E,L,J,A	E,L,J,A
Atlantic mackerel *(Scomber scombrus)*	E,L,J,A	E,L,J,A	E,L,J,A	E,L,J,A	E,L,J,A
summer flounder *(Paralichthys dentatus)*	A		A	A	A
scup *(Stenotomus chrysops)*	J,A	J,A	J,A	J,A	J,A
spiny dogfish *(Squalus acanthias)*		J,A			
bluefin tuna *(Thunnus thynnus)*	J,A	J,A	J,A	J,A	J,A
black sea bass *(Centropristis striata)*	J,A		A	A	A
Squid					
long-finned squid *(Loligo pealei)*	J,A	J,A	J,A	J,A	J,A
short-finned squid *(Illex illecebrosus)*	J,A	J,A	J,A	J,A	J,A

Table 3 (cont.). Species with EFH within the Five Potential Enhancement Sites.

Species	Nantasket Roads (Square 4)	Massachusetts Bay (Square 6)	Broad Sound (Square 3)	Nahant Bay (Square 3)	Magnolia (Square 5)
Shellfish					
Atlantic sea scallop *(Placopecten magellanicus)*	E,L,J,A	E,L,J,A	E,L,J,A	E,L,J,A	E,L,J,A
surf clam *(Spisula solidissima)*	J,A	J,A	J,A	J,A	J,A
Skates					
little skate (*Raja erinacea*)	J,A (in coastal Massachusetts water)				
thorny skate (*Amblyraja radiata*)	J (in coastal Massachusetts water)				
winter skate (*Raja ocellata*)	J (in coastal Massachusetts water)				

Source: NOAA, 2005a
E = eggs; L = larvae; J = juvenile; A = adult

These species included flounders, sculpin, hakes, cunner, ocean pout, skates, sea raven, and alewife.

In general, sediments within the five potential enhancement sites consisted mostly of sand, coarse sand and gravel, cobble, and rock, with isolated areas of fine sediments (i.e, mud). In the areas of finer sediment, demersal species including the American plaice, Atlantic halibut, summer flounder, winter flounder, windowpane flounder, witch flounder, red and white hake, and yellowtail flounder may be present (NOAA, 2005b). Other demersal species (black sea bass, cod, haddock, ocean pout, pollock, redfish, and scup) prefer more structured hard-bottom areas and may be present in areas with rocky or gravelly bottom. Pelagic species, such as Atlantic butterfish, Atlantic sea herring, juvenile bluefish, and monkfish, are likely to be present in areas with sand and/or gravel bottom. Atlantic mackerel, bluefin tuna, and long- and short-finned squid are pelagic species that are associated with all substrate types. Forage and shore species, such as cunner, sculpin, skates, and spiny dogfish, may also be present within the five potential sites. Little skate and juvenile thorny and winter skate prefer sandy, gravelly, or muddy substrates.

Nantasket Roads
EFH for 20 finfish species is designated within Square 4, which encompasses the Nantasket Roads site. Juvenile flounders and sculpins were observed during the video transects within this site (Corps, 2004a).

Massachusetts Bay
EFH for 22 finfish species is designated within Square 6, which encompasses the Massachusetts Bay site (Table 3). Of the four squares, Square 6 is the only one that contains EFH for witch flounder (*Glyptocephalus cynoglossus*), monkfish (*Lophius americanus*), and spiny dogfish (*Squalus acanthias*). Several red hake were observed at the soft-bottom video transects within this site (Corps, 2004a). In the gravel and cobble bottom and in areas of sand waves, cunner, flounder, sculpin, and ocean pout were observed.

Broad Sound

EFH for 20 finfish species is designated within Square 3, which encompasses the Broad Sound site (Table 3). Flounder, red hake, and sculpin were observed in the video transects from within this site (Corps, 2004a).

Nahant Bay

EFH for 20 finfish species is designated within Square 3, which encompasses the Nahant Bay site (Table 3). Red hake, juvenile sculpin, ocean pout, and flounder were observed in the video drifts within this site (Corps, 2004a). During the September 2000 EMAP NCA fish trawl survey, 1,053 individuals from 10 taxa were collected in one trawl from the sampling station (MA00-0093-A) within the Nahant Bay site, and 374 individuals from 7 taxa were collected in one trawl from the sampling station (MA00-0091-A) just outside of the Nahant Bay site (EPA, 2005). The species and number of individuals collected are listed in Table 4.

Table 4. EMAP Trawl Data from Within the Nahant Bay Site.

Species	Total Abundance (#)	
	MA00-0093-A	MA00-0091-A
Atlantic butterfish (*Peprilus triacanthus*)	700	67
little skate (*Raja erinacea*)	237	189
winter flounder (*Pseudopleuronectes americanus*)	48	25
windowpane flounder (*Scophthalmus aquosus*)	35	13
winter skate (*Raja ocellata*)	28	9
scup (*Stenotomus chrysops*)	1	0
sea raven (*Hemitripterus americanus*)	1	0
silver hake (*Merluccius bilinearis*)	1	0
spotted hake (*Urophycis regia*)	1	0
white hake (*Urophycis tenuis*)	1	0
alewife (*Alosa pseudoharengus*)	0	1
summer flounder (*Paralichthys dentatus*)	0	3

Magnolia

EFH for 21 finfish species is designated within Square 5, which encompasses the Magnolia site (Table 3). Fish recorded in the video drifts at this site included juvenile and adult flounders and skates (Corps, 2004a).

3.2.3 Shellfish

MADMF potential shellfish habitats for sea scallops, blue mussels (*Mytilus edulis*), and ocean quahog (*Arctica islandica*) occur within at least one of the five potential enhancement sites (Figure 12), which are discussed in more detail below. Sea scallops (all life stages) and surf clams (*Spisula solidissima)* (juvenile and adults only) have EFH designated within all four of the 10 x 10 minute squares, which encompass the five potential sites (Table 3). Sea scallops, rock crabs (*Cancer* spp.), and hermit crabs were observed in the video drift footage from at least one of the five potential sites (Corps, 2004a).

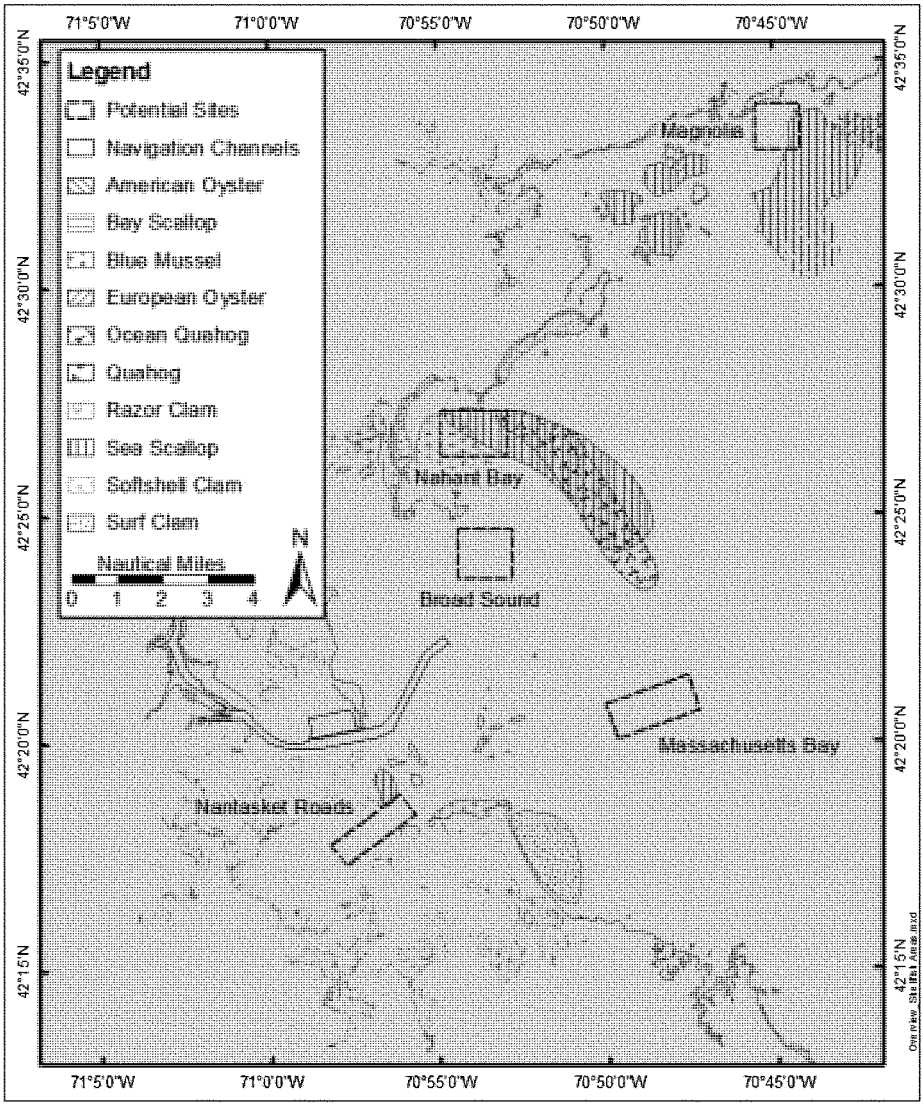


Figure 12. Shellfish Suitability Areas in Relation to the Five Potential Sites (MADMF, 2004).

North of Cape Cod, sea scallop populations are generally scattered in shallow water less than 66 feet deep and are most often associated with sandy sediments (Hart, 2001). Blue mussels are most abundant in the intertidal and shallow subtidal zones and are attached to rocks, pilings, and other solid objects (Canada Department of Fisheries and Oceans, 2003a). Ocean quahogs typically live in fine-sand sediments at depths of 30 to 480 feet (Abbott, 1974). The largest concentrations of surf clams usually occur in well-sorted, medium sand, but may also occur in fine sand and silty-fine sand (Cargnelli *et al.*, 1999). Rock crabs prefer rocky habitat but can be found on all types of bottoms (Gosner, 1978; Estrella, 2003).

Nantasket Roads

An area of potential sea scallop habitat exists near the northern corner of the Nantasket Roads site (Figure 12), and sea scallops were the predominant marine organism observed in the drift video footage within this site (Corps, 2004a). They were plentiful in the coarse sand and gravel bottom.

Massachusetts Bay

None of the potential shellfish habitats identified by MADMF occur within the Massachusetts Bay site (Figure 12). Rock crabs (*Cancer* spp.) were predominant in the mud/sand bottom drift video footage within this site (Corps, 2004a).

Broad Sound

None of the potential shellfish habitats identified by MADMF occur within the Broad Sound site (Figure 12). Rock crabs were the predominant marine biota at the muddy/sand and gravel/cobble bottom video transects (Corps, 2004a). Many sea scallops were noted at the gravel bottom areas. Hermit crabs were also observed.

Nahant Bay

Potential habitats for sea scallop, blue mussel, and ocean quahog occur within the Nahant Bay site (Figure 12). Rock crabs and small hermit crabs were the predominant invertebrates along most of the Nahant Bay video transects (Corps, 2004a).

Magnolia

Potential habitats for blue mussel and sea scallop occur within the Magnolia site (Figure 12). Many rock crabs were observed in burrows in the coarse sand bottom video transect (Corps, 2004a).

3.2.4 Lobster

Data from the October through November 2004 ventless trap pilot study (16 sampling trips, 40 stations, 3 depth strata, 4 substrate strata for 936 trap hauls) provided initial information on the size distribution of lobsters in various types of bottom habitats in the Massachusetts Bay/Boston Harbor area. As expected from previous studies, juvenile (30-58 mm) and adolescent (59-70 mm CL) lobsters were more common in the shelter-providing habitats of boulder and cobble than in sand/gravel or mud (Figure 13), and were more common in shallow waters (0-15 m depth) (Figure 14). Again, these data reflect the needs of smaller juveniles for shelter-providing habitats that offer protection against predators. In contrast, sublegal-sized adult lobsters (71-82 mm CL) were nearly equally distributed in all habitats at all depths sampled, and were more

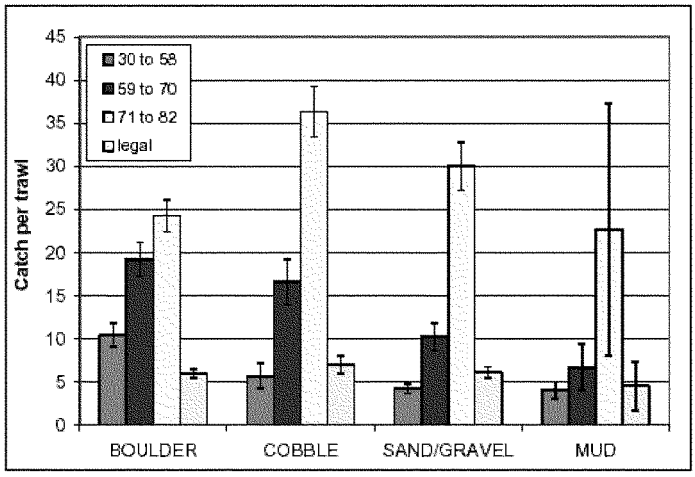


Figure 13. Catch-per-trawl during the ventless trap study of four size classes of lobster by sediment type: juveniles (30-58 mm CL), adolescents (59-70 mm CL), sub-legals (71-82 mm CL), and legal (>83 mm CL). Bars represent ± one standard error.

Source: Glenn *et al.*, 2005.

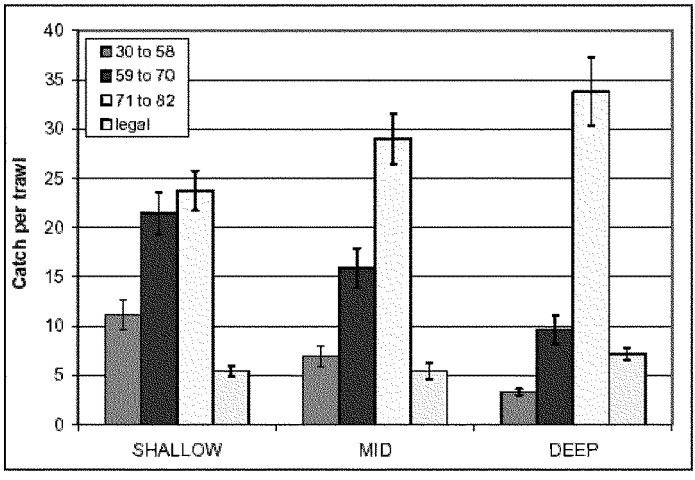


Figure 14. Catch-per-trawl during the ventless trap study of four size classes of lobster by depth: juveniles (30-58 mm CL), adolescents (59-70 mm CL), sub-legals (71-82 mm CL), and legal (>83 mm CL); Shallow, 0-15 m; Mid, 16-30 m; Deep, >30 m. Bars represent ± one standard error.

Source: Glenn *et al.*, 2005.

abundant than legal-sized adult lobsters (> 83 mm CL), indicative of the highly exploited nature of this resource (Glenn *et al.*, 2005). Both of these larger size classes of lobsters have fewer

inshore predators than do the smaller size class lobsters and, thus, fewer restrictions in habitat usage.

The results of the ventless trap program can be used to generally describe the expected distribution of lobster within the five potential enhancement sites based on the substrate present and depth of these sites. Based on the substrate classifications identified by the ventless trap study, juvenile and adolescent lobsters are expected to be more abundant at the Magnolia, Nahant Bay, and Broad Sound sites, which were characterized as containing predominantly boulder, cobble, and sand/gravel substrate (Figure 6). Conversely, the Massachusetts Bay and Nantasket Roads sites, which contain mostly sand/gravel and mud, would be expected to contain less juvenile and adolescent lobsters relative to the other three sites. However, based on water depth, Nantasket Roads, which falls into the "Shallow" category (Figure 14), is more likely to have greater numbers of juvenile and adolescent lobsters and less sublegal-sized adults than the other five sites. In addition, the Massachusetts Bay site, which falls into the "Deep" category, is expected to have fewer juvenile and adolescent lobsters and more sublegal-sized adults.

3.3 Site Use

The ranking criteria state that site(s) selected for placement of rock/cobble cannot interfere with other human uses, such as fishing or navigation. Because potential sites were selected by lobstermen as areas that are not readily used by them or by fishermen, it is assumed that these sites do not contain significant areas of commercial fishing or lobstering. However, fixed fishing gear (e.g., lobster traps) was widespread within the Nantasket Roads and Massachusetts Bays sites (Corps, 2004a). The HubLine natural gas pipeline, operated by Algonquin Gas Transmission Company, runs through most of the Nantasket Roads site (Figure 15). A majority of the pipeline that occurs within the site is buried to a depth of greater than 10 feet. However, a portion of the pipeline was laid on the surface and armored with concrete mat at the southwest end where it exits the site (TRC Environmental, personal communication, 2005). No shipwrecks were located in any of the potential sites (Figure 15) (NOAA, 2003).

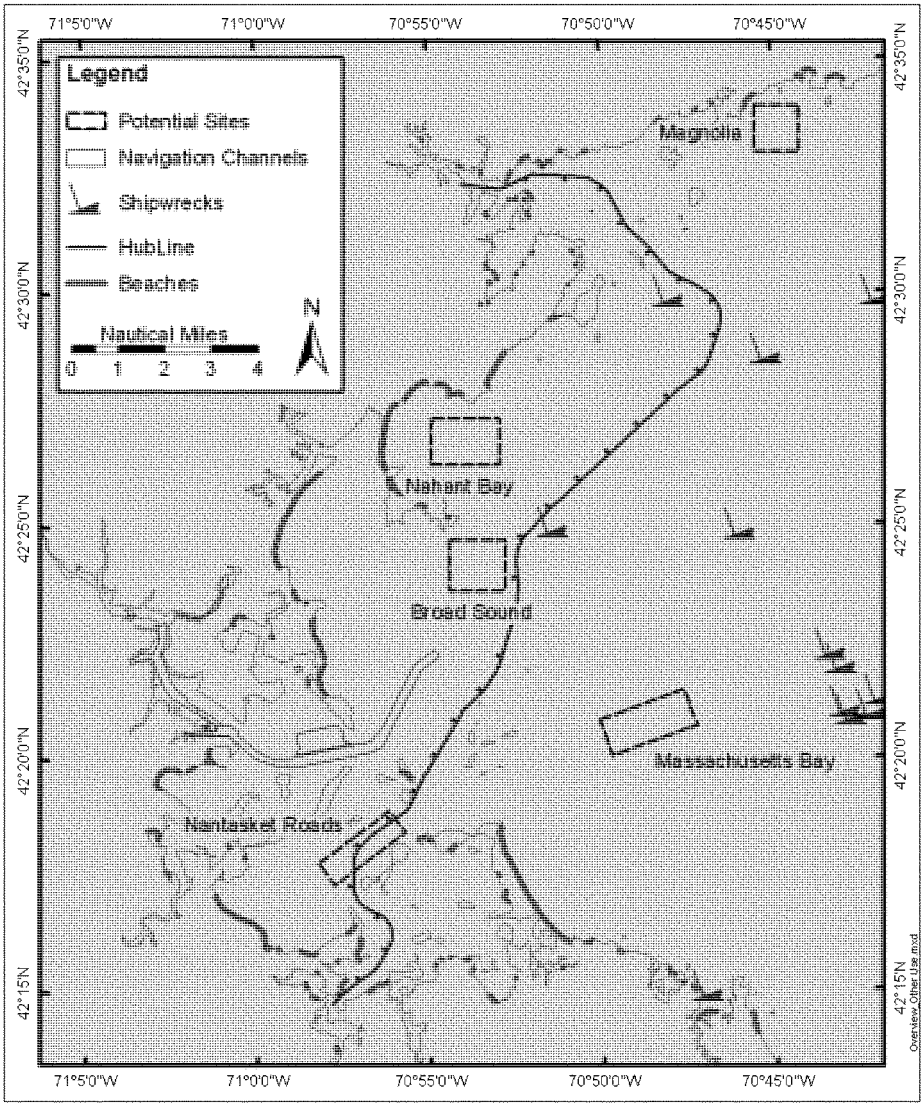


Figure 15. Other Human Uses.

4.0 RANKING

This section integrates information presented in Section 3.0 with the five ranking criteria described in Section 2.4 to allow a comparison among the five potential enhancement sites. Table 5 summarizes the key information for each site. The site comparisons and ranking are described in detail below.

Table 5. Ranking Criteria Summary Table.

Ranking Criteria	Nantasket Roads Depth: 0 - 50 ft	Massachusetts Bay Depth: 75 - 110 ft	Broad Sound Depth: 45 - 90 ft	Nahant Bay Depth: 30 - 75 ft	Magnolia Depth: 0 - 95 ft
Benthic Habitat Quality	Mainly Stage II & III species present, higher OSI, lower expected no. of species/sample	Mainly Stage II & III species present, higher OSI and expected no. of species/sample	Mix of successional stages, lower OSI, higher expected no. of species/sample	Mainly Stage I & II species present, intermediate OSI, intermediate expected no. of species/sample	Mainly Stage I species present, lower OSI, higher no. of expected species/sample
Fish	EFH for long-finned and short-finned squid, skates, and 20 finfish species Juvenile flounder and sculpin observed	EFH for long-finned and short-finned squid, skates, and 22 finfish species Red hake observed on soft bottom. Cunner, flounder, sculpin, and ocean pout observed on gravel/cobble bottom and sand waves.	EFH for long-finned and short-finned squid, skates, and 20 finfish species Flounder, red hake, and sculpin observed	EFH for long-finned and short-finned squid, skates, and 20 finfish species Red hake, juvenile sculpin, ocean pout, and flounder observed 1053 individuals from 10 taxa collected in one EMAP trawl	EFH for long-finned and short-finned squid, skates, and 21 finfish species Juvenile and adult flounder and skates observed
Shellfish	EFH for sea scallop and surf clam Potential sea scallop habitat Sea scallops observed, plentiful on the coarse sand and gravel bottom	EFH for sea scallop and surf clam Rock crabs dominant in the mud/sand bottom	EFH for sea scallop and surf clam Rock crabs dominant at muddy/sand and gravel/cobble bottom. Many sea scallops at gravel bottom. Hermit crabs observed.	EFH for sea scallop and surf clam Potential habitats for blue mussel, sea scallop, ocean quahog Rock crabs and small hermit crabs dominant invertebrates	EFH for sea scallop and surf clam Potential habitats for blue mussel, sea scallop Numerous rock crabs observed in burrows in the coarse sand.

Table 5 (cont.). Ranking Criteria Summary Table.

Ranking Criteria	Nantasket Roads	Massachusetts Bay	Broad Sound	Nahant Bay	Magnolia
Lobster	Less juvenile and adolescent lobsters based on substrate present. More juveniles and adolescents and less sublegals adults based on water depth.	Less juvenile and adolescent lobsters based on substrate present and water depth. More sublegal adults based on water depth.	More juvenile and adolescent lobsters based on substrate present. Intermediate numbers of juveniles, adolescents, and sublegals based on water depth.	More juvenile and adolescent lobsters based on substrate present. Intermediate numbers of juveniles, adolescents, and sublegals based on water depth.	More juvenile and adolescent lobsters based on substrate present. Intermediate numbers of juveniles, adolescents, and sublegals based on water depth.
Bottom Type Quality	Predominantly coarse sand and gravel, with 26% soft bottom	Predominantly sand, with 50% soft bottom	Predominantly muddy sand, with 57% soft bottom	Predominantly sand, with 70% soft bottom	Predominantly sand, with 65% soft bottom
Capacity of Soft Bottom (cy) - 500,000 to 1.4 M cy of rock/cobble will be generated	1.2 M cy	3.3 M cy	3.1 M cy	4.2 M cy	2.6 M cy
Other Human Uses	fixed fishing gear (e.g., lobster traps) was widespread HubLine passes through site	fixed fishing gear (e.g., lobster traps) was widespread	None	None	None
Navigable Distance from Navigation Channel (mi)	6.6	10.8	7.6	10.8	21.6

4.1 Biological Productivity

The first criterion to consider in the site ranking is the biological productivity of each site. Sites with lower productivity, as determined by benthic habitat community or the OSI, were given higher priority for hard-bottom enhancement. Since changes in the bottom substrate through the placement of rock/cobble material would likely impact organisms other than benthic infauna, data describing the fish, shellfish, and lobster populations within the sites were used to supplement the benthic infauna data in determining the suitability of each of the sites for hard-bottom enhancement. Sites where placement of rock/cobble would not be likely to negatively impact these other organisms were given higher priority for hard-bottom enhancement.

4.1.1 Benthos

The infaunal communities found among the five sites sampled in September 2004 were very well developed and were comprised primarily of species typically found in Massachusetts Bay or Boston Harbor infaunal communities. None of the communities appeared to be severely stressed and showed little influence of anthropogenic impacts. The infaunal communities found among the five potential sites were distinguished primarily by the differences in geographic location and physical parameters, primarily sediment texture, of the stations. The fauna at the Nantasket Roads stations within Boston Harbor clearly separated from the open-water stations and was characterized by estuarine taxa. Most of the open-water stations were relatively similar faunistically, with differences among them primarily related to sediment grain-size regime. Two shoreward sandy stations (MA1, NB3) were very different from all other stations.

Biogenic activity was higher at stations within Nantasket Roads, Massachusetts Bay, and Broad Sound sites, and lower at stations within the Nahant Bay and Magnolia sites (Corps, 2004b). The distribution of OSI between sites was related primarily to the distribution of sediment types and level of bioturbation, with higher OSI values (8 and greater) typically being associated with intermediate Stage II or equilibrium Stage III fauna and biologically dominated stations.

The three levels of quantitative values for each of the benthic community ranking criteria (successional stage, OSI, and rarefaction data) are presented in Table 6, along with the number of stations within each site that fell into each of the criteria classes. Most of the stations (four of seven) at the Massachusetts Bay and Nantasket Roads sites had intermediate Stage II assemblages at or near the sediment surface, and all seven stations had equilibrium Stage III fauna at depth in the sediments. The Magnolia and Nahant Bay stations, however, had pioneering Stage I species present at all the SPI stations, with Stage II species present at depth in the sediments at some of the stations. The Massachusetts Bay site had the most stations (6) in the upper OSI class (7.6–10), followed by Nantasket Roads, which had four stations in the upper class. Most of the Magnolia stations (5) were in the lowest OSI class (3.5–5.5). The rarefaction analysis indicates that Broad Sound and Magnolia generally had more expected number of species per sample than the other three sites. Two of the three Nantasket Roads stations fell in the lower expected species class. Considering these data, the most suitable sites (i.e., those with the lowest benthic productivity) are the physically dominated Magnolia and Nahant Bay sites, followed by Broad Sound, Nantasket Roads, and Massachusetts Bay.

4.1.2 Fish

The Massachusetts Bay site contains EFH for the most number of fish species (22), followed by the Magnolia site (21). The other three sites (Nantasket Roads, Broad Sound, and Nahant Bay) each contain EFH for 20 fish species. Of the five sites, the Massachusetts Bay site contained the largest area (0.5 mi^2) of fine sediment substrate (i.e. mud), which is important habitat for spawning adults of several species, such as American plaice, Atlantic halibut, various flounder species, and red hake. The only other area of mud within the five sites was a small patch (0.05 mi^2) in the Nantasket Roads site. Based on the relative importance of the existing substrate within the five potential sites to fish productivity, the most suitable sites for hard-bottom enhancement are Nantasket Roads, Broad Sound, and Nahant Bay. The least suitable site is Massachusetts Bay.

Table 6. Benthic Community Ranking Criteria.

Benthic Ranking Criteria	Classes	Nantasket Roads	Massachusetts Bay	Broad Sound	Nahant Bay	Magnolia
		Number of Stations				
Successional Stage[1]	I			1		5
	I – II			3	6	2
	I - III	3	3	1	1	
	II – III	4	4	2		
OSI	3.5 - 5.5	1		2	2	5
	5.6 - 7.5	2	1	5	4	2
	7.6 - 10	4	6		1	
Rarefaction Analysis[2]	<15	2				
	15 – 29	1	2	1	3	1
	30 – 35		1	2		2

[1] Stage I-III refers to the presence of pioneering Stage I species present on or near the sediment surface and equilibrium Stage III species present below the sediment surface. Stage II-III is the presence of intermediate successional stage species at the surface with equilibrium species at depth in the sediments.

[2]The rarefaction analysis is the expected number of species in a sample size of 410 organisms, the largest common abundance for all samples collected.

4.1.3 Shellfish

Potential shellfish habitat identified by MADMF is located within the boundaries of the Nantasket Roads, Nahant Bay, and Magnolia sites, with most of the Nahant Bay covered by potential shellfish habitat. Sea scallops were also present on the coarse sand/gravel bottom in the Nantasket Roads and Broad Sound sites. The placement of rock/cobble should avoid areas that contain shellfish beds, since they would be destroyed by this activity. Therefore, the site with lower shellfish productivity, and thus those that are more suitable for hard-bottom enhancement, is the Massachusetts Bay site, followed by Broad Sound. The Nantasket Roads, Nahant Bay, and Magnolia sites are least suitable based on the potential and observed presence of shellfish habitat in these sites.

4.1.4 Lobster

Nantasket Roads is expected to contain more juvenile and adolescent lobsters than the other four sites based on water depth within the site. However, the identified substrate within the site (i.e., sand/gravel and mud, with small isolated areas of hard bottom) does not provide as much shelter (i.e., protection against predators) as rock or cobble substrate. In addition, sublegal-sized adults, which are less abundant in shallow waters, are most abundant on cobble substrate. Therefore, it is anticipated that the lobster population within the Nantasket Roads site would benefit the most from hard-bottom enhancement. The Magnolia, Nahant Bay, and Broad Sound sites contain predominantly boulder, cobble, and sand/gravel substrates (based on the ventless trap bottom type characterization) and are generally deeper than the Nantasket Roads site. The lobster populations within these sites may not benefit as much from the placement of rock/cobble as would the lobsters within the Nantasket Roads site. The deepest site, Massachusetts Bay, is likely to contain fewer juveniles and adolescents and more sublegal- and legal-sized adults,

which are less restricted by habitat usage. This lobster population within this site would be expected to have the least positive impact from hard-bottom enhancement. Therefore, Nantasket Roads was ranked as the most suitable for enhancement using the lobster productivity criteria, and Massachusetts Bay as the least suitable.

4.2 Bottom Type

The second criterion to consider is the existing bottom type for each site. Rock and/or cobble will be placed on soft substrate and not on existing rock bottom. Sites with abundant existing rock bottom habitat are given lower priority. Sites may contain some rock bottom if 1) it does not significantly reduce the volume of area available for disposal of rock and/or cobble or 2) the location of the existing rock bottom does not preclude the site from further consideration (i.e. rock bottom is located in the middle of the site).

The predominant bottom type at the five sites ranges from coarse sand and gravel (Nantasket Roads), to sand (Massachusetts Bay, Nahant Bay, Magnolia) to muddy sand (Broad Sound). The Massachusetts Bay, Nahant Bay, and Magnolia sites all have areas of soft bottom (i.e., mud or sand) in the center of each site. The Broad Sound site has two large areas of muddy sand at the northern and southern sides of the site, with a broad swath of hard bottom (including coarse gravel and small cobbles) running through the center from east to west. In the Nantasket Roads site, soft bottom (i.e., sand) is located in a narrow swath along the northern edge of the site. Therefore, based on bottom type within the site and the location of the soft bottom, Massachusetts Bay, Nahant Bay, and Magnolia are the most suitable sites, followed by the Broad Sound site. Nantasket Roads is the least suitable site because of the small area and location of soft bottom present.

4.3 Capacity

An extension of the second criterion above is the capacity of each site to accommodate the dredged rock/cobble from the navigation channel. Site capacity (cy) was calculated as the area of soft bottom (yd^2) multiplied by a maximum rock/cobble height (i.e., 1 yd) (C. Rogers, personal communication, 2005). Water depth within the sites was also considered when evaluating site capacity. Priority was given to sites that can accept all of the rock/cobble, with the possibility of using more than one site if no site had adequate capacity.

The blasting or dredging within the Boston Harbor navigation channels, which is necessary to increase the channel depths from -40 ft up to -50 ft MLLW, is expected to generate between 500,000 and 1.4 M cy of rock and cobble. All of the potential sites have enough soft bottom area to accommodate the minimum estimated amount of rock/cobble. The Nahant Bay site has the largest capacity (4.2 M cy) based on the area of soft bottom within the site. Massachusetts Bay, Broad Sound, and Magnolia have similar site capacities (3.3 – 2.6 M cy), and Nantasket Roads has the least capacity (1.2 M cy), which is slightly less than the maximum anticipated volume of rock/cobble material (1.4 M cy). In addition, rocky outcroppings and water depths of less than 16 ft occur within portions of the Nantasket Roads and Magnolia sites. Therefore, some soft bottom areas within these sites may not be deep enough to allow the placement of rock/cobble without interfering with navigation and other human activities within the site. Based on site

capacity and depth, the Nahant Bay site is the most suitable, and the Nantasket Roads site is the least suitable.

4.4 Other Uses

The fourth ranking criterion states that site(s) selected for placement of rock/cobble cannot interfere with other uses, such as fishing or navigation. The presence of widespread lobster traps within the Nantasket Bay and Massachusetts Bay sites indicate that these are areas of lobstering. Also, the HubLine natural gas pipeline runs through most of the length of the Nantasket Roads site and placement of rock/cobble over the buried or armored portions of the pipeline within the site may interfere with the maintenance and repair activities. Therefore, based on other human uses, the Magnolia, Nahant Bay, and Broad Sound sites are the most suitable, and the Massachusetts Bay, and Nantasket Roads sites are the least suitable.

4.5 Distance to Navigation Channel

If no significant differences were found among sites based on the above criteria, then the site(s) closest to the navigation channel was given higher priority. The navigable distance from the blasting and dredging location to each of the potential sites was calculated by using the hypothetical routes presented in Figure 16. Nantasket Roads is the site with the shortest navigable distance (6.6 mi) from the blasting site, followed by the Broad Sound site (7.6 mi), the Nahant Bay and Massachusetts Bay sites (10.8 mi), and the Magnolia site (21.6 mi).

4.6 Final Ranking Results

The ranking of the potential sites by criterion, in order of most suitable to least suitable, are summarized in Table 7. If no major differences were determined between sites, then the sites are listed within the same ranking class in the table. For example, for the benthic habitat criterion, the Magnolia and Nahant Bay sites were both determined to be most suitable, and the Massachusetts Bay site was least suitable.

The Broad Sound site was ranked within Class 1 or 2 most often (8 times), followed by the Nahant Bay and Magnolia sites (6 times), and the Nantasket Roads and Massachusetts Bay sites (4 times) (Table 7). The Nahant Bay site was ranked as the most suitable site for five of the screening criteria, but because most of the site is covered by potential shellfish habitat, it is not recommended as a suitable site for hard bottom enhancement. Though the Magnolia site also contains potential scallop habitat, the habitat is confined to a small area along the eastern boundary of the site and could be avoided during rock/cobble placement. The Nantasket Roads site is the least suitable, since it contains primarily coarse sand and gravel and does not have enough capacity to receive all of the dredged rock/cobble. The presence of the HubLine within this site also precludes it from being a suitable enhancement site.

Based on the initial site ranking performed in this report, the list of potential enhancement sites in the order of most suitable to least suitable is:

- Broad Sound
- Magnolia
- Nahant Bay
- Massachusetts Bay
- Nantasket Roads

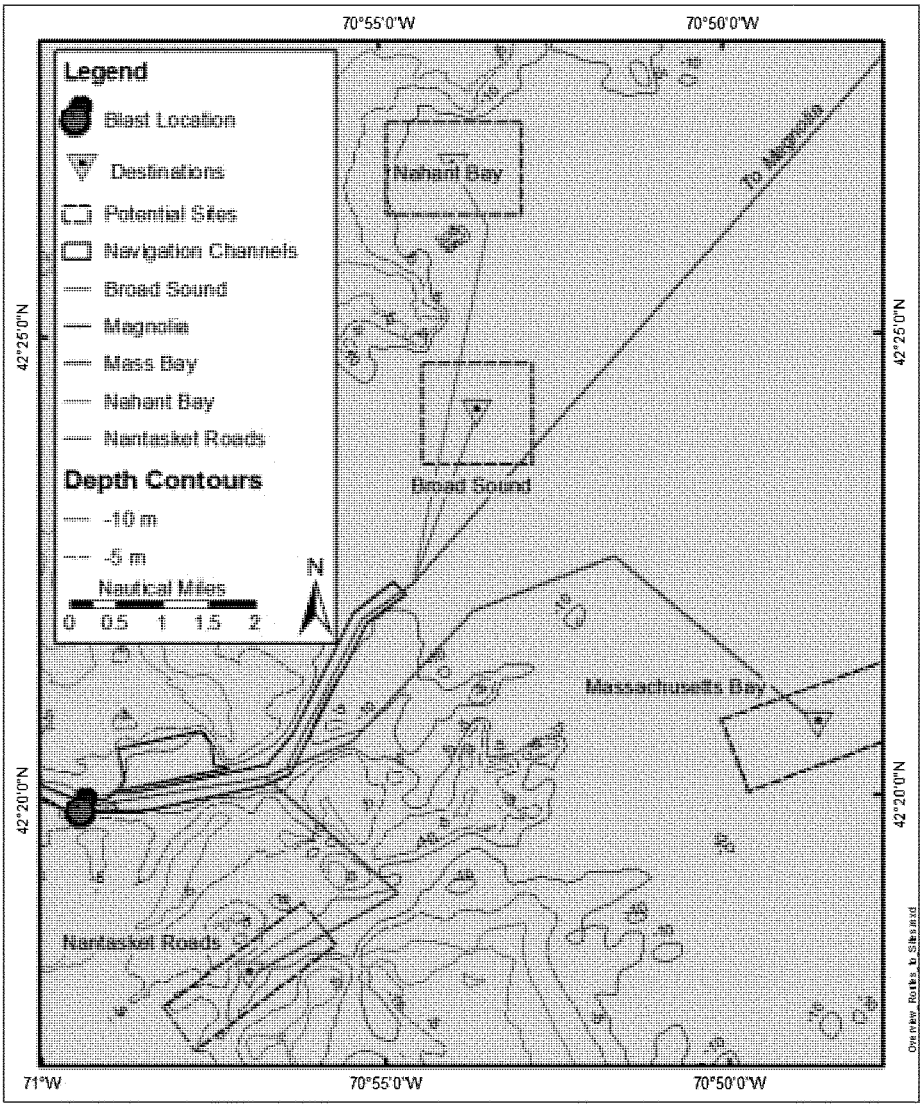


Figure 16. Hypothetical Routes Used to Calculate Navigable Distance to Potential Sites.

Table 7. Final Site Ranking by Criteria.

Ranking	Ranking Class	Benthic Habitat Quality	Fish	Shellfish	Lobster	Bottom Type Quality	Capacity of Soft Bottom	Other Human Uses	Navigable Distance
Most suitable	1	MA, NB	NR, BS, NB	MB	NR	MB, NB, MA	NB	BS, NB, MA	NR
	2	BS	MA	BS	MA, NB, BS	BS	MB, BS, MA	MB, NR	BS
	3	NR	MB	NR, MA, NB	MB	NR	NR		NB, MB
Least suitable	4	MB							MA

NR = Nantasket Roads; BS = Broad Sound, NB = Nahant Bay, MB = Massachusetts Bay, MA = Magnolia

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BOSTON HARBOR
MASSACHUSETTS

DEEP DRAFT
NAVIGATION IMPROVEMENT STUDY

FINAL FEASIBILITY REPORT
AND FINAL SUPPLEMENTAL
ENVIRONMENTAL IMPACT STATEMENT
AND MASSACHUSETTS
FINAL ENVIRONMENTAL IMPACT REPORT

APPENDIX T

ESSENTIAL FISH HABITAT EVALUATION

(THIS APPENDIX UNCHANGED FROM JULY 2008 DRAFT)

BOSTON HARBOR ESSENTIAL FISH HABITAT

The 1996 amendments to the Magnuson-Stevens Fishery Conservation Management Act strengthen the ability of the National Marine Fisheries Service and the New England Fishery Management Council to protect and conserve the habitat of marine, estuarine, and anadromous finfish, mollusks, and crustaceans. This habitat is termed "essential fish habitat", and is broadly defined to include "those waters and substrate necessary to fish for spawning, breeding, feeding, or growth to maturity." Managed species listed for the 10' x 10' square of latitude and longitude which includes Boston Harbor are: Atlantic cod, haddock, pollock, whiting, red hake, white hake, winter flounder, yellowtail flounder, windowpane flounder, American plaice, ocean pout, Atlantic halibut, Atlantic sea scallop, Atlantic sea herring, long finned squid, short finned squid, Atlantic butterfish, Atlantic mackerel, summer flounder, scup, black sea bass, surf clam, and bluefin tuna. The same species are listed for the 10' x 10' square of latitude and longitude which includes the Massachusetts Bay Disposal Site (MBDS), except for: pollock, summer flounder, scup, black sea bass, and surf clam. Species listed in the MBDS square that are not listed for Boston Harbor include redfish, witch flounder, and monkfish.

The following lists the managed species and their appropriate life stage history for the designated 10' x 10' square for Boston Harbor and the MBDS.

Atlantic cod (*Gadus morhua*)

Eggs: Surface waters around the perimeter of the Gulf of Maine, George's Bank, and the eastern portion of the Continental Shelf off southern New England. Generally, the following conditions exist where cod eggs are found: sea surface temperatures below 12^0 C, water depths less than 110 meters, and a salinity range from 32-33‰. Cod eggs are most often observed beginning in the fall, with peaks in the winter and spring.

Larvae: Pelagic waters of the Gulf of Maine, Georges Bank, and the eastern portion of the Continental Shelf off of southern New England. Generally, the following conditions exist where cod larvae found: sea surface temperatures below 10^0 C, water depths from 30 to 70 meters, and a salinity range from 32-33‰. Cod larvae are most often observed in the spring.

Juveniles: Bottom habitats with a substrate of cobble or gravel in the Gulf of Maine, Georges Bank, and the eastern portion of the Continental Shelf off southern New England. Generally, the following conditions exist where cod juveniles found: water temperatures below 20^0 C, water depths from 25 to 75 meters, and a salinity range from 30-35‰.

Adults: Bottom habitats with a substrate of rocks, pebbles, or gravel in the Gulf of Maine, Georges Bank, southern New England, and the middle Atlantic south to Delaware Bay. Generally, the following conditions exist where cod adults are found:

water temperatures below 10^0 C, water depths from 10 to 150 meters, and a wide range of oceanic salinities.

Spawning Adults: Bottom habitats with a substrate of smooth sand, rocks, pebbles, or gravel in the Gulf of Maine, Georges Bank, southern New England, and the middle Atlantic south to Delaware Bay. Generally, the following conditions exist where spawning cod adults are found: water temperatures below 10^0 C, water depths from 10 to 150 meters, and a wide range of oceanic salinities. Cod are most often observed spawning during fall, winter, and early spring.

Haddock (*Melanogrammus aeglefinus*)

Eggs: Surface waters over Georges Bank southwest to Nantucket Shoals and the coastal areas of the Gulf of Maine. Generally, the following conditions exist where haddock eggs are found: sea surface temperatures below 10^0 C, water depths from 50 to 90 meters, and salinity ranges from 34 – 36‰. Haddock eggs are most often observed during the months from March to May, April being most important.

Larvae: (Just Boston Harbor) Surface waters over Georges Bank southwest to the middle Atlantic south to Delaware Bay. Generally, the following conditions exist where haddock larvae are found: sea surface temperatures below 14^0 C, water depths from 30 to 90 meters, and salinity ranges from 34 – 36‰. Haddock larvae are most often observed during the months from January through July with peaks in April and May.

Pollock (*Pollachius virens*)

Eggs: Pelagic waters of the Gulf of Maine and Georges Bank. Generally, the following conditions exist where pollock eggs are found: sea surface temperatures below 17^0 C, water depths from 30 to 270 meters, and salinity ranges from 32 – 32.8‰. Pollock eggs are most often observed from October through June with peaks from November to February.

Larvae: Pelagic waters of the Gulf of Maine and Georges Bank. Generally, the following conditions exist where pollock larvae are found: sea surface temperatures below 17^0 C, water depths from 10 to 250 meters. Pollock larvae are often observed from September to July with peaks from December to February.

Juveniles: Bottom habitats with aquatic vegetation or a substrate of sand, mud or rocks in the Gulf of Maine and Georges Bank. Generally, the following conditions exist where pollock juveniles are found: water temperatures below 18^0 C, water depths from 0 to 250 meters, and salinities between 29-32‰.

Adults: Bottom habitats in the Gulf of Maine and Georges Bank and hard bottom habitats (including artificial reefs) off southern New England and the middle Atlantic south to New Jersey. Generally, the following conditions exist where pollock adults are

found: water temperatures below 14^0 C, water depths from 15 to 365 meters, and salinities between 31-34‰.

Spawning Adults: Bottom habitats with a substrate of hard, stony or rocky bottom in the Gulf of Maine and hard bottom habitats (including artificial reefs) off southern New England and the middle Atlantic south to New Jersey. Generally, the following conditions exist where pollock adults are found: water temperatures below 8^0 C, water depths from 15 to 365 meters, and salinities between 32-32.8‰. Pollock are most often observed spawning during the months September to April with peaks from December to February.

Whiting (*Merluccius bilinearis*)

Eggs: Surface waters of the Gulf of Maine, Georges Bank, the continental shelf off southern New England, and the middle Atlantic south to Cape Hatteras. Generally the following conditions exist where most whiting eggs are found: sea surface temperatures below 20^0 C, water depths between 50 to 150 meters. Whiting eggs are observed all year, with peaks from June through October.

Larvae: Surface waters of the Gulf of Maine, Georges Bank, the continental shelf off southern New England, and the middle Atlantic south to Cape Hatteras. Generally the following conditions exist where most whiting larvae are found: sea surface temperatures below 20^0 C, water depths between 50 to 130 meters. Whiting larvae are observed all year, with peaks from July through September.

Juveniles: Bottom habitats of all substrate types in the Gulf of Maine, on Georges Bank, the Continental Shelf off southern New England, and the middle Atlantic south to Cape Hatteras. Generally, the following conditions exist where most whiting juveniles are found: water temperatures below 21^0 C, water depths from 20 to 270 meters, and salinities greater than 20‰.

Adults: Bottom habitats of all substrate types in the Gulf of Maine, on Georges Bank, the Continental Shelf off southern New England, and the middle Atlantic south to Cape Hatteras. Generally, the following conditions exist where most whiting juveniles are found: water temperatures below 21^0 C, water depths from 20 to 270 meters, and salinities greater than 20‰.

Spawning Adults: Bottom habitats of all substrate types in the Gulf of Maine, on Georges Bank, the Continental Shelf off southern New England, and the middle Atlantic south to Cape Hatteras. Generally, the following conditions exist where most spawning whiting adults are found: water temperatures below 13^0 C and water depths from 30 to 325 meters.

Red hake (*Urophycis chuss*)

Eggs: Surface waters of the Gulf of Maine, Georges Bank, the continental shelf off southern New England, and the middle Atlantic south to Cape Hatteras. Generally the following conditions exist where hake eggs are found: sea surface temperatures below 10^0 C along the inner continental shelf with salinity less than 25‰. Hake eggs are most often observed during the months from May to November, with peaks in June and July.

Larvae: Surface waters of the Gulf of Maine, Georges Bank, the continental shelf off southern New England, and the middle Atlantic south to Cape Hatteras. Generally the following conditions exist where red hake larvae are found: sea surfaee temperatures below 19^0 C, water depths less than 200 meters and salinity greater than 0.5‰. Red hake larvae are most often observed from May through December, with peaks September to October.

Juveniles: Bottom habitats with a substrate of shell fragments, including areas with an abundance of live scallops, in the Gulf of Maine, on Georges Bank, the Continental Shelf off southern New England, and the middle Atlantic south to Cape Hatteras. Generally, the following conditions exist where red hake juveniles are found: water temperatures below 16^0 C, depths less than 100 meters and a salinity range from 31 - 33‰.

Adults: Bottom habitats in depressions with a substrate of sand and mud in the Gulf of Maine, on Georges Bank, the Continental Shelf off southern New England, and the middle Atlantic south to Cape Hatteras. Generally, the following conditions exist where red hake adults are found: water temperatures below 12^0 C, depths from 10 to 130 meters, and a salinity range from 33 - 34‰.

Spawning Adults: Bottom habitats in depressions with a substrate of sand and mud in the Gulf of Maine, the southern edge of Georges Bank, the Continental Shelf off southern New England, and the middle Atlantic south to Cape Hatteras. Generally, the following conditions exist where spawning red hake adults are found: water temperatures below 10^0 C, depths less than 100 meters, and salinity less than 25‰. Red hake are most often observed spawning during the months from May – November, with peaks in June and July.

White hake (*Urophycis tenuis*)

Eggs: Surface waters of the Gulf of Maine, Georges Bank, and southern New England. White hake eggs are most often observed in August and September.

Larvae: Pelagic waters of the Gulf of Maine, the southern edge of Georges Bank, and southern New England to the middle Atlantic. White hake larvae are most often observed in May in the mid-Atlantic area and August and September in the Gulf of Maine and Georges Bank.

Juveniles: *Pelagic stage* – Pelagic waters of the Gulf of Maine, the southern edge of Georges Bank, and southern New England to the middle Atlantic. White hake juveniles in the pelagic stage are most often observed from May through September. *Demersal stage* – Bottom habitats with seagrass beds or a substrate of mud or fine-grained sand in the Gulf of Maine, the southern edge of Georges Bank, and southern New England to the middle Atlantic. Generally, the following conditions exist where white hake juveniles are found: water temperatures below 19 ° C and depths from 5 - 225 meter.

Adults: Bottom habitats with a substrate of mud or fine-grained sand in the Gulf of Maine, the southern edge of Georges Bank, and southern New England to the middle Atlantic. Generally, the following conditions exist where white hake adults are found: water temperatures below 14 ° C and depths from 5 - 325 meter.

Spawning Adults: Bottom habitats with a substrate of mud or fine-grained sand in deep water in the Gulf of Maine, the southern edge of Georges Bank, and southern New England to the middle Atlantic. Generally, the following conditions exist where white hake adults are found: water temperatures below 14 °C and depths from 5 - 325 meter. White hake are most often observed spawning during the months April – May in the southern portion of their range and August – September in the northern portion of their range.

Redfish (*Sebastes fasciatus*)

Larvae: Pelagic waters in the Gulf of Maine and southern Georges Bank. Generally, the following conditions exist where redfish larvae are found: sea surface temperatures below 15 °C and water depths between 50 and 270 meters. Redfish larvae are most often observed from March through October, with a peak in August.

Juveniles: Bottom habitats with a substrate of silt, mud or hard bottom in the Gulf of Maine and on the southern edge of Georges Bank. Generally, the following conditions exist where redfish juveniles are found: water temperatures below 13°C, depths from 25 – 400 meters, and a salinity range from 31 - 34‰.

Adults: Bottom habitats with a substrate of silt, mud or hard bottom in the Gulf of Maine and on the southern edge of Georges Bank. Generally, the following conditions exist where redfish adults are found: water temperatures below 13°C, depths from 50 – 350 meters, and a salinity range from 31 - 34‰.

Spawning Adults: Bottom habitats with a substrate of silt, mud or hard bottom in the Gulf of Maine and on the southern edge of Georges Bank. Generally, the following conditions exist where redfish adults are found: water temperatures below 13°C, depths from 50 – 350 meters, and a salinity range from 31 - 34‰. Redfish females are most often observed spawning (larvae) during the months from April through August.

Witch flounder (*Glyptocephalus cynoglossus*)

Eggs: Surface waters of the Gulf of Maine, Georges Bank, the continental shelf off southern New England, and the middle Atlantic south to Cape Hatteras. Generally, the following conditions exist where witch flounder eggs are found: sea surface temperatures below 13 °C over deep water with high salinities. Witch flounder eggs are most often observed during the months from March through October.

Larvae: Surface waters to 250 meters in the Gulf of Maine, Georges Bank, the continental shelf off southern New England, and the middle Atlantic south to Cape Hatteras. Generally, the following conditions exist where witch flounder larvae are found: sea surface temperatures below 13 °C over deep water with high salinities. Witch flounder larvae are most often observed from March through November, with peaks in May to July.

Juveniles: Bottom habitats with a fine-grained substrate in the Gulf of Maine and along the outer continental shelf from Georges Bank south to Cape Hatteras. Generally, the following conditions exist where witch flounder juveniles are found: water temperatures below 13 °C, depths from 50 – 450 meters, although they have been observed as deep as 1500 meters, and a salinity range from 34 - 36‰.

Adults: Bottom habitats with a fine-grained substrate in the Gulf of Maine and along the outer continental shelf from Georges Bank south to Chesapeake Bay. Generally, the following conditions exist where witch flounder adults are found: water temperatures below 13 °C, depths from 25 – 300 meters, and a salinity range from 32 - 36‰.

Spawning Adults: Bottom habitats with a fine-grained substrate in the Gulf of Maine and along the outer continental shelf from Georges Bank south to Chesapeake Bay. Generally, the following conditions exist where spawning witch flounder adults are found: water temperatures below 15 °C, depths from 25 – 360 meters, and a salinity range from 32 - 36‰. Witch flounder are most often observed spawning during the months from March through November, with peaks in May to August.

Winter flounder (*Pseudopleuronectes americanus*)

Eggs: Bottom habitats with a substrate of sand, muddy sand, mud, and gravel on Georges Bank, the inshore areas of the Gulf of Maine, southern New England, and the middle Atlantic south to the Delaware Bay. Generally, the following conditions exist where winter flounder eggs are found: water temperatures below 10 °C, salinities between 10 - 30‰ and water depths less than 5 meters. On Georges Bank, winter flounder eggs are generally found in water less than 8 ° C, and less than 90 meters deep. Winter flounder eggs are often observed from February to June with a peak in April on Georges Bank.

Larvae: Pelagic and bottom waters of Georges Bank, the inshore areas of the Gulf of Maine, southern New England, and the middle Atlantic south to the Delaware Bay.

Generally, the following conditions exist where winter flounder larvae are found: sea surface temperatures less than 15^0 C, salinities between 4 - 30‰, and water depths less than six meters. On Georges Bank, winter flounder larvae are generally found in water less than 8° C, and less than 90 meters deep. Winter flounder larvae are often observed from March to July with peaks in April and May on Georges Bank.

Juveniles: *Young-of-the-Year*: Bottom habitats with a substrate of mud or fine-grained sand on Georges Bank, the inshore areas of the Gulf of Maine, southern New England and the middle Atlantic south to the Delaware Bay. Generally, the following conditions exist where winter flounder young-of-the-year are found: water temperatures below 28° C, and depths from 0.1 – 10 meters, and salinities between 5 - 33‰. *Age 1 + Juveniles*: Bottom habitats with a substrate of mud or fine-grained sand on Georges Bank, the inshore areas of the Gulf of Maine, southern New England and the middle Atlantic south to the Delaware Bay. Generally, the following conditions exist where juvenile winter flounder are found: water temperatures below 25° C, and depths from 1 – 50 meters, and salinities between 10 - 30‰.

Adults: Bottom habitats including estuaries with a substrate of mud, sand and gravel on Georges Bank, the inshore areas of the Gulf of Maine, southern New England and the middle Atlantic south to the Delaware Bay. Generally, the following conditions exist where adult winter flounder are found: water temperatures below 25° C, and depths from 1 – 100 meters, and salinities between 15 - 33‰.

Spawning Adults: Bottom habitats including estuaries with a substrate of sand, muddy sand, mud, and gravel on Georges Bank, the inshore areas of the Gulf of Maine, southern New England and the middle Atlantic south to the Delaware Bay. Generally, the following conditions exist where spawning adult winter flounder are found: water temperatures below 15° C, depths less than 6 meters, except on Georges Bank where they spawn as deep as 80 meters, and salinities 5.5 - 36‰. Winter flounder are most often observed spawning during the months of February to June.

Yellowtail flounder (*Pleuronectes ferruginea*)

Eggs: Surface waters of Georges Bank, Massachusetts Bay, Cape Cod Bay, and the southern New England continental shelf south to Delaware Bay. Generally, the following conditions exist where yellowtail eggs are found: sea surface temperatures below 15^0 C, water depths from 30-90 meters and a salinity range from 32.4-33.5‰. Yellowtail flounder eggs are most often observed during the months from mid-March to July, with peaks in April to June in southern New England.

Larvae: Surface waters of Georges Bank, Massachusetts Bay, Cape Cod Bay, the southern New England shelf and throughout the middle Atlantic south to the Chesapeake Bay. Generally, the following conditions exist where yellowtail larvae are found: sea surface temperatures below 17^0C, water depths from 10 – 90 meters, and a salinity range from 32.4 – 33.5‰. Yellowtail flounder larvae are most often observed

from March through April in the New York bight and from May through July in southern New England and southeastern Georges Bank.

Juveniles: Bottom habitats with a substrate of sand or sand and mud on Georges Bank, the Gulf of Maine, and the southern New England shelf south to Delaware Bay. Generally, the following conditions exist where yellowtail flounder juveniles are found: water temperatures below 15^0 C, depths from 20 to 50 meters and a salinity range from 32.4 – 33.5‰.

Adults: Bottom habitats with a substrate of sand or sand and mud on Georges Bank, the Gulf of Maine, and the southern New England shelf south to Delaware Bay. Generally, the following conditions exist where yellowtail flounder adults are found: water temperatures below 15^0 C, depths from 20 to 50 meters and a salinity range from 32.4 – 33.5‰.

Spawning Adults: Bottom habitats with a substrate of sand or sand and mud on Georges Bank, the Gulf of Maine, and the southern New England shelf south to Delaware Bay. Generally, the following conditions exist where spawning yellowtail flounder adults are found: water temperatures below 17^0 C, depths from 10 to 125 meters and a salinity range from 32.4 – 33.5‰.

Windowpane flounder (*Scopthalmus aquosus*)

Eggs: Surface waters around the perimeter of the Gulf of Maine, on Georges Bank, southern New England, and the middle Atlantic south to Cape Hatteras. Generally, the following conditions exist where windowpane flounder eggs are found: sea surface temperatures less than 20^0 C, water depths less than 70 meters. Windowpane flounder eggs are often observed from February to November with peaks in May and October in the middle Atlantic and July through August on Georges Bank.

Larvae: Pelagic waters around the perimeter of the Gulf of Maine, on Georges Bank, southern New England, and the middle Atlantic south to Cape Hatteras. Generally, the following conditions exist where windowpane flounder larvae are found: sea surface temperatures less than 20^0 C, water depths less than 70 meters. Windowpane flounder larvae are often observed from February to November with peaks in May and October in the middle Atlantic and July through August on Georges Bank.

Juveniles: Bottom habitats with a substrate of mud or fine-grained sand around the perimeter of the Gulf of Maine, on Georges Bank, southern New England and the middle Atlantic south to Cape Hatteras. Generally, the following conditions exist where windowpane flounder juveniles are found: water temperatures below 25^0 C, water depths from 1 – 100 meters, and a salinity range from 5.5 – 36‰. (Just Boston Harbor)

Adults: Bottom habitats with a substrate of mud or fine-grained sand around the perimeter of the Gulf of Maine, on Georges Bank, southern New England and the middle Atlantic south to the Virginia-North Carolina border. Generally, the following

conditions exist where windowpane flounder adults are found: water temperatures below 26.8^0 C, water depths from 1 – 75 meters, and salinities between 5.5 – 36‰. (Just Boston Harbor)

Spawning Adults: Bottom habitats with a substrate of mud or fine-grained sand in the Gulf of Maine, Georges Bank, southern New England and the middle Atlantic south to the Virginia-North Carolina border. Generally, the following conditions exist where spawning windowpane flounder adults are found: water temperatures below 21^0 C, water depths from 1 – 75 meters, and salinities between 5.5 – 36‰. Windowpane flounder are most often observed spawning during the months February – December with a peak in May in the middle Atlantic. (Just Boston Harbor)

American plaice (*Hippoglossoides platessoides*)

Eggs: Surface waters of the Gulf of Maine and Georges Bank. Generally, the following conditions exist where most American plaice eggs are found: sea surface temperatures below 12^0 C, water depths between 30 and 90 meters and a wide range of salinities. American plaice eggs are observed all year in the Gulf of Maine, but only from December through June on Georges Bank, with peaks in both areas in April and May.

Larvae: Surface waters of the Gulf of Maine, Georges Bank and southern New England. Generally, the following conditions exist where most American plaice larvae are found: sea surface temperatures below 14^0 C, water depths between 30 and 130 meters and a wide range of salinities. American plaice larvae are observed between January and August, with peaks in April and May.

Juveniles: Bottom habitats with fine-grained sediments or a substrate of sand or gravel in the Gulf of Maine and Georges Bank. Generally, the following conditions exist where most American plaice juveniles are found: water temperatures below 17^0 C, water depths between 45 and 150 meters, and a wide range of salinities.

Adults: Bottom habitats with fine-grained sediments or a substrate of sand or gravel in the Gulf of Maine and Georges Bank. Generally, the following conditions exist where most American plaice adults are found: water temperatures below 17^0 C, water depths between 45 and 175 meters, and a wide range of salinities.

Spawning Adults: Bottom habitats of all substrate types in the Gulf of Maine and Georges Bank. Generally, the following conditions exist where most spawning American plaice adults are found: water temperatures below 14^0 C, water depths less than 90 meters, and a wide range of salinities. Spawning begins in March and continues through June.

Ocean Pout (*Macrozoarces americanus*)

Eggs: Bottom habitats in the Gulf of Maine, Georges Bank, southern New England and the middle Atlantic south to Delaware Bay. Due to low fecundity, relatively few eggs (<4,200) are laid in gelatinous masses, generally in hard bottom sheltered nests, holes, or crevices where they are guarded by either female or both parents. Generally, the following conditions exist where ocean pout eggs are found: water temperatures below 10^0 C, depths less than 50 meters, and a salinity range from 32-34‰. Ocean pout egg development takes two to three months during late fall and winter.

Larvae: Bottom habitats in the Gulf of Maine, Georges Bank, southern New England and the middle Atlantic south to Delaware Bay. Larvae are relatively advanced in development and are believed to remain in close proximity to hard bottom nesting areas. Generally, the following conditions exist where ocean pout larvae are found: sea surface temperatures below 10^0 C, depths less than 50 meters, and salinities greater than 25‰. Ocean pout larvae are most often observed from late fall through spring.

Juveniles: Bottom habitats, often smooth bottom near rocks or algae in the Gulf of Maine, Georges Bank, southern New England and the middle Atlantic south to Delaware Bay. Generally, the following conditions exist where ocean pout juveniles are found: water temperatures below 14^0 C, depths less than 80 meters, and salinities greater than 25‰.

Adults: Bottom habitats in the Gulf of Maine, Georges Bank, southern New England and the middle Atlantic south to Delaware Bay. Generally, the following conditions exit where ocean pout adults are found: water temperatures below 15^0 C, depths less than 110 meters, and a salinity range from 32-34‰.

Spawning Adults: Bottom habitats with a hard bottom substrate, including artificial reefs and shipwrecks, in the Gulf of Maine, Georges Bank, southern New England and the middle Atlantic south to Delaware Bay. Generally, the following conditions exist where spawning ocean pout adults are found: water temperatures below 10^0 C, depths less than 50 meters, and a salinity range from 32-34‰. Ocean pout spawn from late summer through early winter, with peaks in September and October.

Atlantic halibut (*Hippoglossus hippoglossus*)

Eggs: Pelagic waters to the sea floor of the Gulf of Maine and Georges Bank. Generally, the following conditions exist where Atlantic halibut eggs are found: water temperatures between 4 and 7^0 C, water depths less than 700 meters, and salinities less than 35‰. Atlantic halibut eggs are observed between late fall and early spring, with peaks in November and December.

Larvae: Surface waters of the Gulf of Maine and Georges Bank. Generally, the following conditions exist where Atlantic halibut larvae are found: salinities between 30 and 35‰.

Juveniles: Bottom habitats with a substrate of sand, gravel, or clay in the Gulf of Maine and Georges Bank. Generally, the following conditions exist where Atlantic halibut juveniles are found: water temperatures above 2^0 C, water depths from 20 - 60 meters.

Adults: Bottom habitats with a substrate of sand, gravel, or clay in the Gulf of Maine and Georges Bank. Generally, the following conditions exist where Atlantic halibut adults are found: water temperatures below 13.6^0 C, water depths from 100 - 700 meters, and salinities between 30.4 – 35.3‰.

Spawning Adults: Bottom habitats with a substrate of soft mud, clay, sand, or gravel in the Gulf of Maine and Georges Bank, as well as rough or rocky bottom locations along the slopes of the outer banks. Generally, the following conditions exist where spawning Atlantic halibut adults are found: water temperatures below 7^0 C, water depths less than 700 meters, and salinities less than 35‰. Atlantic halibut are most often observed spawning between late fall and early spring, with peaks in November and December.

Atlantic sea scallop (*Placopecten magellanicus)*

Eggs: Bottom habitats in the Gulf of Maine, Georges Bank, southern New England the middle Atlantic south to the Virginia-North Carolina border. Eggs are heavier than seawater and remain on the seafloor until they develop into the first free-swimming larval stage. Generally, sea scallop eggs are thought to occur where water temperatures are below 17^0 C. Spawning occurs from May through October, with peaks in May and June in the middle Atlantic area and in September and October on Georges Bank and in Gulf of Maine.

Larvae: Pelagic waters and bottom habitats with a substrate of gravelly sand, shell fragments, and pebbles, or on various red algae, hydroids, amphipod tubes and bryozoans in the Gulf of Maine, Georges Bank, southern New England and the middle Atlantic south to the Virginia-North Carolina border. Generally, the following conditions exist where sea scallop larvae are found: sea surface temperatures below 18^0 C and salinities between 16.9‰ and 30‰.

Juveniles: Bottom habitats with a substrate of cobble, shells and silt in the Gulf of Maine, Georges Bank, southern New England and the middle Atlantic south to the Virginia-North Carolina border that support the highest densities of sea scallops. Generally, the following conditions exist where most sea scallop juveniles are found: water temperatures below 15^0 C, and water depths from 18-110 meters and salinities above 16.5‰.

Adults: Bottom habitats with a substrate of cobble, shells, coarse/gravelly sand, and sand in the Gulf of Maine, Georges Bank, southern New England and middle Atlantic south to the Virginia-North Carolina border that support the highest densities of sea scallops. Generally, the following conditions exist where most sea scallop adults are

found: water temperatures below 21^0 C, water depths from 18-110 meters, and salinities above 16.5‰.

Spawning Adults: Bottom habitats with a substrate of cobble, shells, coarse/gravelly sand, and sand in the Gulf of Maine, Georges Bank, southern New England and the middle Atlantic south to the Virginia-North Carolina border that support the highest densities of sea scallop adults are found: water temperatures below 16^0 C, depths from 18-110 meters, and salinities above 16.5‰. Spawning occurs from May through October, with peaks in May and June in the middle Atlantic area, and in September and October on Georges Bank and in the Gulf of Maine.

Atlantic sea herring (*Clupea harengus*)

Larvae: Pelagic waters in the Gulf of Maine, Georges Bank, and southern New England that comprise 90% of the observed range of Atlantic herring larvae. Generally, the following conditions exist where Atlantic herring larvae are found: sea surface temperatures below 16^0 C, water depths from 50 - 90 meters, and salinities around 32‰. Atlantic herring larvae are observed between August and April, with peaks from September through November.

Juveniles: Pelagic waters and bottom habitats in the Gulf of Maine, Georges Bank, southern New England and the middle Atlantic south to Cape Hatteras. Generally, the following conditions exist where Atlantic herring juveniles are found: water temperatures below 10^0 C, water depths from 15 - 135 meters, and salinity range from 26 to 32‰.

Adults: Pelagic waters and bottom habitats in the Gulf of Maine, Georges Bank, southern New England and the middle Atlantic south to Cape Hatteras. Generally, the following conditions exist where Atlantic herring adults are found: water temperatures below 10^0 C, water depths from 20 - 130 meters, and salinities above 28‰.

Spawning Adults: Bottom habitats with a substrate of gravel, sand, cobble and shell fragments, but also on aquatic macrophytes, in the Gulf of Maine, Georges Bank, southern New England and the middle Atlantic south to Delaware Bay. Generally, the following conditions exist where spawning Atlantic herring adults are found: water temperatures below 15^0 C, water depths from 20 - 80 meters, and salinity range from 32 to 33‰. Herring eggs are spawned in areas of well-mixed water, with tidal currents between 1.5 and 3.0 knots. Atlantic herring are most often observed spawning during the months from July through November.

Monkfish (*Lophius americanus*)

Eggs: Surface waters of the Gulf of Maine, Georges Bank, southern New England, and the middle Atlantic south to Cape Hatteras. Generally, the following conditions exist where monkfish egg veils are found: sea surface temperatures below 18^0 C and water

depths from 15 – 1000 meters. Monkfish egg veils are most often observed during the months from March to September.

Larvae: Pelagic waters of the Gulf of Maine, Georges Bank, southern New England and the middle Atlantic south to Cape Hatteras. Generally, the following conditions exist where monkfish larvae are found: water temperatures 15^0 C and water depths from 25 – 1000 meters. Monkfish larvae are most often observed during the months from March to September.

Juveniles: Bottom habitats with substrates of a sand-shell mix, algae covered rocks, hard sand, pebbly gravel, or mud along the outer continental shelf in the middle Atlantic, the mid-shelf off southern New England, and all areas of the Gulf of Maine. Generally, the following conditions exist where monkfish juveniles are found: water temperatures below 13^0 C, depths from 25 – 200 meters, and a salinity range from 29.9 – 36.7‰.

Adults: Bottom habitats with substrates of a sand-shell mix, algae covered rocks, hard sand, pebbly gravel, or mud along the outer continental shelf in the middle Atlantic, the mid-shelf off southern New England, along the outer perimeter of Georges Bank, and all areas of the Gulf of Maine. Generally, the following conditions exist where monkfish adults are found: water temperatures below 15^0 C , depths from 25 – 200 meters, and a salinity range from 29.9 – 36.7‰.

Spawning Adults: Bottom habitats with substrates of a sand-shell mix, algae covered rocks, hard sand, pebbly gravel, or mud along the outer continental shelf in the middle Atlantic, the mid-shelf off southern New England, along the outer perimeter of Georges Bank, and all areas of the Gulf of Maine. Generally, the following conditions exist where spawning monkfish adults are found: water temperatures below 13^0 C , depths from 25 – 200 meters, and a salinity range from 29.9 – 36.7‰. Monkfish are observed spawning most often during the months from February to August.

Bluefish *(Pomatomus saltatrix)*

Juveniles: Pelagic waters over the continental shelf and all major estuaries. Generally juvenile bluefish occur in North Atlantic estuaries from June through October within the "mixing" and "seawater" zones. Distribution of juveniles by temperature, salinity, and depth over the continental shelf is un-described.

Adults: Pelagic waters over the continental shelf and all major estuaries. Generally adult bluefish occur in North Atlantic estuaries from June through October within the "mixing" and "seawater" zones. Bluefish adults are highly migratory and distribution varies seasonally and according to the size of the individuals comprising the schools. Bluefish are generally found in normal shelf salinities (> 25 parts per trillion (ppt)).

Long finned squid (*Loligo pealei*)

Juveniles: Pelagic waters found over the continental shelf, from the Gulf of Maine through Cape Hatteras in areas that encompass the highest 75% of the catches where juvenile squid were collected. Generally, juvenile long finned squid are collected from shore to 700 feet and in temperatures between 4^0 F and 27^0 F.

Adults: Pelagic waters found over the continental shelf, from the Gulf of Maine through Cape Hatteras in areas that encompass the highest 75% of the catches where adult squid were collected. Generally, adult long finned squid are collected from shore to 1000 feet and in temperatures between 39^0 F and 81^0 F.

Short finned squid (*Illex illecebrosus*)

Juveniles: Pelagic waters found over the continental shelf, from the Gulf of Maine through Cape Hatteras in areas that encompass the highest 75% of the catches where juvenile squid were collected. Generally, juvenile short finned squid are collected from shore to 600 feet and in temperatures between 36^0 F and 73^0 F.

Adults: Pelagic waters found over the continental shelf, from the Gulf of Maine through Cape Hatteras in areas that encompass the highest 75% of the catches where adult squid were collected. Generally, adult short finned squid are collected from shore to 600 feet and in temperatures between 39^0 F and 66^0 F.

Atlantic butterfish (*Peprilus triacanthus*)

Eggs: Pelagic waters found over the continental shelf, from the Gulf of Maine through Cape Hatteras in areas that encompass the highest 75% of the catches where butterfish eggs were collected. The "mixing" and/or "seawater" portions of all the estuaries where butterfish are "common", "abundant", or "highly abundant" on the Atlantic coast, from Passamaquoddy Bay, Maine to James River, Virginia. Generally, butterfish eggs are collected from shore to 6000 feet and in temperatures between 52^0 F and 63^0 F.

Larvae: Pelagic waters found over the continental shelf, from the Gulf of Maine through Cape Hatteras in areas that encompass the highest 75% of the catches where butterfish larvae were collected. The "mixing" and/or "seawater" portions of all the estuaries where butterfish are "common", "abundant", or "highly abundant" on the Atlantic coast, from Passamaquoddy Bay, Maine to James River, Virginia. Generally, butterfish larvae are collected from 33 feet to 6000 feet and in temperatures between 48^0 F and 66^0 F.

Juveniles: Pelagic waters found over the continental shelf, from the Gulf of Maine through Cape Hatteras in areas that encompass the highest 75% of the catches where butterfish juvenile were collected. The "mixing" and/or "seawater" portions of all the estuaries where butterfish are "common", "abundant", or "highly abundant" on the Atlantic coast, from Passamaquoddy Bay, Maine to James River, Virginia. Generally,

butterfish larvae are collected from 33 feet to 1200 feet and in temperatures between 37^0 F and 82^0 F.

Adults: Pelagic waters found over the continental shelf, from the Gulf of Maine through Cape Hatteras in areas that encompass the highest 75% of the catches where butterfish adults were collected. The "mixing" and/or "seawater" portions of all the estuaries where butterfish are "common", "abundant", or "highly abundant" on the Atlantic coast, from Passamaquoddy Bay, Maine to James River, Virginia. Generally, adult butterfish are collected in depths from 33 feet to 1200 feet and in temperatures between 37^0F and 82^0F.

Atlantic mackerel (*Scomber scombrus*)

Eggs: EFH is the pelagic waters found over the Continental Shelf (from the coast out to the limits of the EEZ), from the Gulf of Maine through Cape Hatteras, North Carolina; in areas that encompass the highest 75% of the catch where Atlantic mackerel eggs were collected. EFH is also the "mixing" and/or "seawater" portions of all the estuaries where Atlantic mackerel are "common", "abundant", or "highly abundant" on the Atlantic coast, from Passamaquoddy Bay, Maine to James River, Virginia. Generally, Atlantic mackerel eggs are collected from shore to 50 feet and temperatures between 41^0 F and 73^0 F.

Larvae: EFH is the pelagic waters found over the Continental Shelf (from the coast out to the limits of the EEZ), from the Gulf of Maine through Cape Hatteras, North Carolina; in areas that encompass the highest 75% of the catch where juvenile Atlantic mackerel were collected in NEFSC trawl surveys. EFH is also the "mixing" and/or "seawater" portions of all the estuaries where Atlantic mackerel are "common", "abundant", or "highly abundant" on the Atlantic coast, from Passamaquoddy Bay, Maine to James River, Virginia. Generally, Atlantic mackerel larvae are collected in depths between 33 feet to 425 feet and temperatures between 43^0 F and 72^0 F.

Juveniles: EFH is the pelagic waters found over the Continental Shelf (from the coast out to the limits of the EEZ), from the Gulf of Maine through Cape Hatteras, North Carolina; in areas that encompass the highest 75% of the catch where juvenile Atlantic mackerel were collected in NEFSC trawl surveys. EFH is also the "mixing" and/or "seawater" portions of all the estuaries where Atlantic mackerel are "common", "abundant", or "highly abundant" on the Atlantic coast, from Passamaquoddy Bay, Maine to James River, Virginia. Generally, juvenile Atlantic mackerel are collected from shore to 1,050 feet and temperatures between 39^0 F and 72^0 F.

Adults: EFH is the pelagic waters found over the Continental Shelf (from the coast out to the limits of the EEZ), from the Gulf of Maine through Cape Hatteras, North Carolina; in areas that encompass the highest 75% of the catch where adult Atlantic mackerel were collected in NEFSC trawl surveys. EFH is also the "mixing" and/or "seawater" portions of all the estuaries where Atlantic mackerel are "common", "abundant", or "highly abundant" on the Atlantic coast, from Passamaquoddy Bay,

Maine to James River, Virginia. Generally, adult Atlantic mackerel are collected from shore to 1,250 feet and temperatures between 39^0 F and 61^0 F.

Summer flounder (*Paralicthys dentatus*)

Adults: North of Cape Hatteras, EFH is the demersal waters over the continental shelf from the Gulf of Maine to Cape Hatteras, in the highest 90% of the area where adult summer flounder were collected. Generally, summer flounder inhabit shallow coastal and estuarine waters during the warmer months and move offshore on the outer continental shelf at depths of 500 feet in colder months. Inshore, EFH is the estuaries where summer flounder were identified as being common, abundant, or highly abundant for the "mixing" and "seawater" salinity zones.

Scup (*Stenotomus chrysops*)

Juveniles: North of Cape Hatteras, EFH is the demersal waters over the continental shelf from the Gulf of Maine to Cape Hatteras, in the highest 90% of the area where juvenile scup were collected. Generally, juvenile scup are found in water temperatures greater than 45^0 F and where salinities are greater than 15 ppt. Inshore, EFH is the estuaries where scup were identified as being common, abundant, or highly abundant for the "mixing" and "seawater" salinity zones. Juvenile scup are generally found in water temperatures greater than 45^0 F and where salinities are greater than 15 ppt. Juvenile scup, in general during the summer and spring are found in estuaries and bays between Virginia and Massachusetts. They are found in association with various sands, mud, mussel and eelgrass bed type substrates.

Adults: North of Cape Hatteras, EFH is the demersal waters over the continental shelf from the Gulf of Maine to Cape Hatteras, in the highest 90% of the area where adult scup were collected. Wintering adults (November through April) are usually offshore, south of New York to North Carolina, in waters above 45^0 F. Inshore, EFH is the estuaries where scup were identified as being common, abundant, or highly abundant for the "mixing" and "seawater" salinity zones.

Black sea bass (*Centropristus striata*)

Juveniles: North of Cape Hatteras, EFH is the demersal waters over the continental shelf from the Gulf of Maine to Cape Hatteras, in the highest 90% of the area where juvenile black sea bass were collected. Temperature preference is for areas warmer than 6^0 F with salinities greater than 18 ppt. Juvenile black sea bass are found in association with rough bottom, shellfish, and eelgrass beds, man-made structures in sandy-shelly areas; offshore clam beds and shell patches may also be used during the winter. They are found in coastal areas between Massachusetts and Virginia, but they winter offshore from New Jersey and south. Inshore, EFH is the estuaries where black sea bass were identified as being common, abundant, or highly abundant for the "mixing" and "seawater" salinity zones. Juveniles are found in the estuaries in the summer and spring.

Adults: North of Cape Hatteras, EFH is the demersal waters over the continental shelf from the Gulf of Maine to Cape Hatteras, in the highest 90% of the area where adult black sea bass were collected. Wintering adults (November through April) are usually offshore, south of New York to North Carolina. Temperatures above 6^0 F seem to be the minimum requirements. Structured habitats (natural and man-made), sand and shell are the substrate preference. Inshore, EFH is the estuaries where adult black sea bass were identified as being common, abundant, or highly abundant for the "mixing" and "seawater" salinity zones. Black sea bass are generally found in estuaries from May through October.

Surf clam (*Spisula solidissima*)

Juveniles and adults: Throughout the substrate to a depth of three feet within Federal waters from the eastern edge of Georges Bank and the Gulf of Maine throughout the Atlantic EEZ, in areas that encompass the top 90% of the area where surf clams were caught. Surf clams generally occur from the beach zone to depth of about 200 feet, but beyond about 125 feet abundance is low.

Spiny Dogfish (*Squalus acanthias*)

Juveniles: EFH ranges from the Gulf of Maine through Cape Hatteras, North Carolina. Generally, dogfish are collected in depths between 33 feet and 1,280 feet and temperatures between 37^0F and 68^0F. EFH is also the "seawater" portions of all the estuaries where dogfish are common or abundant on the Atlantic coast, from Passamaquoddy Bay, Maine to Cape Cod Bay, generally in water temperatures ranging between 37^0F and 82^0F.

Adults: EFH ranges from the Gulf of Marine through Cape Hatteras, North Carolina across the continental shelf. Generally, dogfish are collected in depths between 33 feet and 1,476 feet and temperatures between 37^0F and 66^0F. EFH is also the "seawater" portions of all estuaries where dogfish are common o abundant on the Atlantic coast, from Passamaquoddy Bay, Maine to Cape Cod Bay generally in water temperatures ranging between 37^0F and 82^0F.

Bluefin tuna (*Thunnus thynnus*)

Juveniles and subadults: All inshore and pelagic surface waters warmer than 12^0 C of the Gulf of Maine and Cape Cod Bay from Cape Ann, east including waters of the Great South Channel; continuing south to and including Nantucket Shoals to off Cape Hatteras. In pelagic surface waters warmer than 12^0 C between the 25 to 200 meter isobaths.

BOSTON HARBOR
MASSACHUSETTS

DEEP DRAFT
NAVIGATION IMPROVEMENT STUDY

FINAL FEASIBILITY REPORT
AND FINAL SUPPLEMENTAL
ENVIRONMENTAL IMPACT STATEMENT
AND MASSACHUSETTS FINAL
ENVIRONMENTAL IMPACT REPORT

APPENDIX U

BENTHIC RESOURCE DATA
FOR BOSTON HARBOR

(THIS APPENDIX UNCHANGED FROM JULY 2008 DRAFT)

BOSTON HARBOR BENTHIC RESOURCE DATA

The samples collected by MWRA provide information about the general faunal communities present and the changes that they have undergone since the EIS was issued in 1995. However, it is important to note that there is one major sampling difference between the MWRA program and the other studies (Pellegrino, 2003; Massport, 2003) discussed in this section. The MWRA infaunal samples are rinsed in the field over a 300-μm-mesh sieve, whereas samples from the other two studies were rinsed over 500-μm-mesh sieves. This difference means that MWRA samples will contain more individuals than the other studies' samples and very likely will also be comprised of more species. Therefore, the data for MWRA stations are not directly comparable to data from the other two studies, although they are presented here to provide background information, especially concerning temporal trends in the communities.

One of the important revelations from the MWRA program is that infaunal abundance can vary tremendously from year-to-year. Annual fluctuations in abundance appeared to be largest from 1992 through about 1998 and seem to have lessened within the last four to five years (Maciolek *et al.*, 2005). However, some changes have still been relatively large (*e.g.*, a 13-fold change in abundance at station T05A from 2002 to 2003) and often are related to large fluctuations in abundance of colonizing species such as the amphipod *Ampelisca abdita* and the polychaete worm *Polydora cornuta*. Infaunal abundances have ranged as high as 500,000/m^2 since 1991, but most stations have had abundances much less than half that number within the last five years for which data are available (1999–2003). These data emphasize that an abundance value for a station that is determined for one year only should be considered only relative to other values determined for stations also sampled that year. The one-year abundance value does not necessarily provide a reliable estimate of the infaunal abundance at a particular location for any other year.

The information presented in this section is derived from two sampling approaches: the collection of sediment profile images (SPI) and the collection of grab samples from which infaunal animals were removed, identified, and counted. SPI data provide information about key habitat characteristics and processes, whereas grab samples allow for the description of infaunal community structure. The two techniques provide different types of information about the benthos and are best used as complementary data sources (Rumohr and Karakassis, 1999). Brief summaries of each approach and descriptions of the types of data described in this section are included in the two text boxes.

Sections of the Mystic River, Chelsea River, and the Reserved Channel and Turning Basin were dredged between May 1998 and September 2000. Portions of the outer harbor region, the lower Main Ship Channel, and the Presidents Roads Anchorage area were dredged between August 2004 and June 2005. Dredging of the Lower and Inner Harbor will begin in 2008. The implications of this dredging on the benthic characterizations are discussed within the following sections for each harbor area.

Mystic River - The only information available, since 1995, about the benthos in the Mystic River portion of the affected environment is from a Corps survey conducted in September 2003 (Pellegrino, 2003) (Figure 3-4 in SEIS/EIR). Three stations were sampled in an area of the Mystic River that is about -35 feet deep MLLW. Sediment data for areas near the stations showed mud or silt present. The three samples showed extremely low infaunal abundances, ranging from 75 to 100 indivduals/m^2; one sample had no animals (Figure U-1). Only five species were found among the three samples (Figure U-2), which were dominated by polychaete worms (*Aricidea catherinae*, *Nephtys incisa*, *Tharyx acutus*). Species diversity could only be estimated for one sample, and Shannon's *H'* was 1.8. Rarefaction analysis was not performed on samples from the Mystic River because the sample sizes were too small to yield meaningful curves.

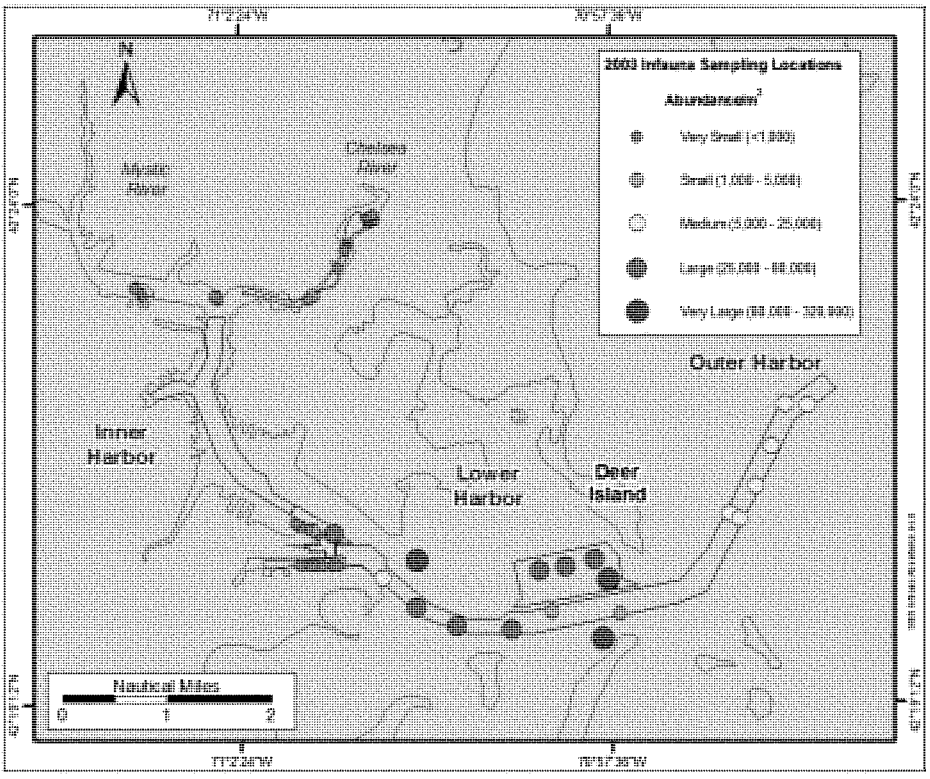
The stations sampled in 2003 were in an area that was not dredged between 1998 and 2000. Therefore, no direct impact of the dredging on the benthos was found in 2003 and the faunal community is certainly representative of that portion of the Mystic River. Indirect dredging impacts, such as increased turbidity, would not be expected to have an impact on the community that would be detectable at least three years after dredging.

Chelsea River - Information about the benthos in the Chelsea River is derived from the Corps (Pellegrino, 2003) and Massport surveys (Massport, 2003). The Upper Chelsea River was sampled at seven stations by the Corps along the length of the river, and at three stations by Massport at each of four berth areas (Irving Oil, Gulf Oil, Conoco Phillips, Global Petroleum) (Figure 3-4 in SEIS/EIR). Sediments in the upper Chelsea River were mostly gravel and sand (Figure 3-1 in SEIS/EIR). Water depths generally ranged from about -33 to -38 feet MLLW.

At the four Corps stations that were located upstream of the Chelsea Street Bridge, infaunal abundance was very low, ranging from 25 to 125 individuals/m^2 (Figure U-1). Species numbers were also low, with only one to three species found at each station (Figure U-2). Only polychaete worms (*Nephtys incisa*, *Prionospio steenstrupi*, *Pectinaria gouldii*, *Aricidea catherinae*) were present among the samples. Downstream of the Chelsea Street Bridge infaunal abundances were higher than in samples taken upstream of the bridge but were still very low, ranging from 525 to 1,550 individuals/m^2 (Figure U-1). Species numbers were also slightly greater than upstream numbers, ranging from 6 to 10 species per station (FigureU-2). Polychaetes (*Polydora cornuta*, *Tharyx acutus*, *Nephtys incisa*) were the predominant taxonomic group of animals, although the sand shrimp, *Crangon septemspinosa*, and two mollusk species (a snail, *Ilyanassa trivitatta* and a clam, *Nuculana tenuisulcata*) were also present. Species diversity within the Chelsea River was very low to moderate with Shannon's *H'* ranging from 1.7 to 3.1. Rarefaction analysis was not performed on samples from the Chelsea River because the sample sizes were too small to yield meaningful curves.

The Gulf Oil, Global Petroleum, and Irving Oil berth areas are located upstream of the Chelsea St. Bridge (Massport, 2003). Infaunal abundances among the berth-area samples

were similar to those from the other upper river samples, with most ranging from 0 to 200 individuals/m^2 (three of the samples had no animals), although two samples (one Irving Oil, one Global Petroleum) approached 1,300 individuals/m^2 (Figure U-1). Species numbers were low, ranging from 1 to 12 species per sample (Figure U-2). Polychaetes (principally *Polydora cornuta* and Cirratulidae spp.) were the predominant organisms among the samples. The Conoco Phillips berth, located just downstream from the Chelsea Street Bridge, showed infaunal abundances (300-2,200 individuals/m^2) that were similar to nearby Corps stations, but were much higher than the upstream berth-area stations (Figure U-1). Species numbers (4-16 per sample) showed a similar pattern (Figure U-2). The predominant taxa were primarily the polychaetes *Polydora cornuta* and Cirratulidae spp., but samples also included the mysid crustacean *Neomysis americana*.



Source: Pellegrino, 2003; Massport, 2003

Figure U-1. Infaunal Abundance from 2003 Sampling

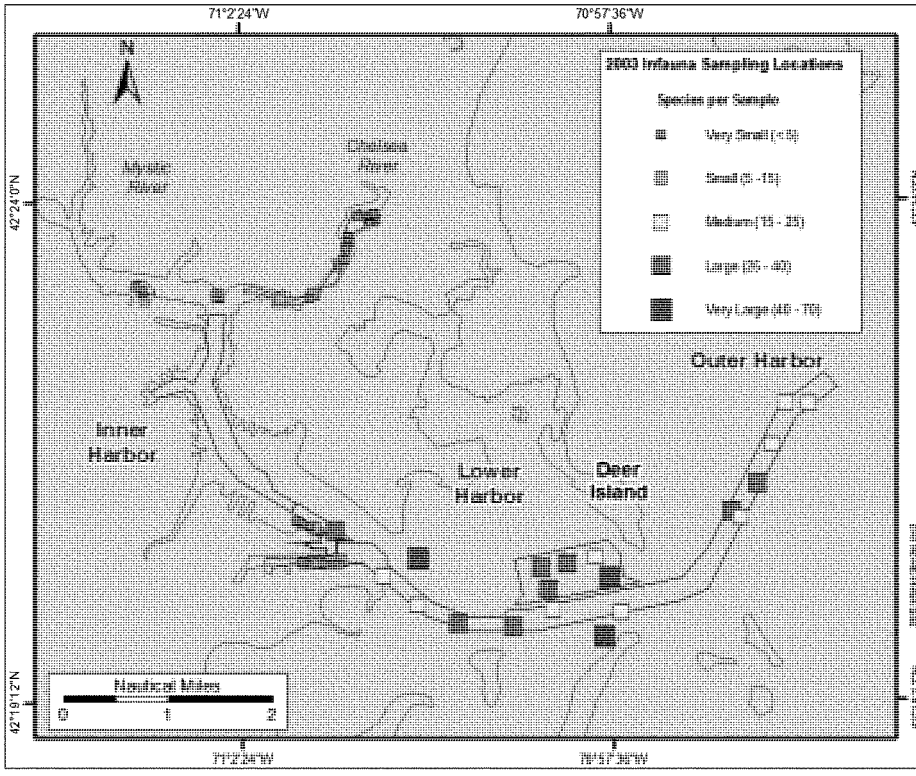


Figure U-2. Number of Species per Sample from 2003 Sampling
Source: Pellegrino, 2003; Massport, 2003

Sediments in the Chelsea-Sandwich berth area, which is within the Inner Confluence (where the Mystic and Chelsea Rivers meet), were mostly sandy (Figure 3-1 in SEIS/EIR). Water depths generally ranged from about -23 to -36 ft MLLW. One of the three samples from the Chelsea-Sandwich Berths area, located where the Chelsea River meets the Mystic River, contained only one snail (*Ilyanassa trivitatta*). The other two samples had infaunal abundances of 2,100 and 5,900 indivduals/m^2 (Massport, 2003) (Figure U-1). The fauna consisted primarily of polychaetes (Cirratulidae spp., *Lepidonotus squamatus*), oligochaete worms, and nematode worms.

Much of the Chelsea River channel and the Inner Confluence were dredged between 1998 and 2000. Most of the stations sampled by the Corps and Massport in 2003 were within the recently dredged channel and, thus, represent benthic communities present at least three years after dredging. Because the rates of recovery from disturbance for communities in this type of habitat are not known, it is not possible to estimate whether or not the communities found in 2003 represent a benthos that has fully recovered from the dredging. Stations at the Irving Oil and Global Petroleum berths were not within the dredged channel and likely represent typical conditions for the area. In the vicinity of the Inner Confluence, three benthic stations were sampled during the Massport (2003) survey. One of these (CS-1), which was probably located on the edge of the dredged area, was found to have only one snail in the grab sample. This could reflect a lingering impact from the dredging, but the sample was noted as possibly not from a full grab sample.

Inner Harbor - The data sets available for the characterization of the Inner Harbor area included the Corps 2003 study (Pellegrino, 2003) that sampled the Reserved and Main Channels, the Massport berth area study that sampled Conley Terminal and the North Jetty, and MWRA SPI studies that sampled the Inner and Lower Harbors (Figure 3-4 in SEIS/EIR). Sediments in the Reserved Channel area have been characterized as predominantly mud; those in the Main Channel have been characterized as primarily mud with scattered areas of sand (Figure 3-1 in SEIS/EIR). Water depths ranged from -39 to -44 feet MLLW in the Reserved Channel and from -29 to -43 ft MLLW in the Main Channel.

In the Reserved Channel, infaunal abundance ranged from 450 to 1,950 individuals/m^2 at the three Corps stations (Pellegrino, 2003) and from 125 to 2,500 individuals/m^2 at Conley Terminal (Massport, 2003) (Figure U-1). Taxon numbers were similar for both studies ranging from four to 14 species at the Reserved Channel stations (Pellegrino, 2003) and 5 to 22 taxa per sample at Conley Terminal (Massport, 2003) (Figure U-2). Diversity among the Reserved Channel samples was very low to moderate with Shannon's H' ranging from 1.1 to 3.4. The fauna within the Reserved Channel was characterized by polychaetes (*Nephtys incisa*, *Scoletoma fragilis*, *Polydora cornuta*, Lumbrineridae), the snail *Ilyanassa trivittata*, and the lophophorate worm *Phoronis architecta*. Rarefaction analysis was not performed on samples from the Inner Harbor because the sample sizes were too small to yield meaningful curves.

Infaunal abundances at the two Corps stations in the Main Channel were relatively high, about 10,000 and 38,000 individuals/m^2 (Pellegrino, 2003) (Figure U-1). Species numbers at the two stations were similar with 20 and 28 species per sample (Figure U-2). Shannon diversity ($H' \approx 3$) was moderate in the channel. The fauna was characterized predominantly by polychaetes (*Aricidea catherinae*, *Tharyx acutus*, *Scoletoma hebes*), although amphipods (*Ampelisca abdita*, *Leptocheirus pinguis*, *Orchomenella minuta*) were also relatively abundant. Rarefaction analysis showed higher diversity than in the Lower and Outer Harbor Main Channel stations, but was considered mid-range when compared with the other harbor stations (Figure U-3). The North Jetty samples were different from the Corps samples. Infaunal abundance at the North Jetty was an order of magnitude lower, ranging from 1,500 to 3,800 individuals/m^2 (Massport, 2003) (Figure U-1). Taxon numbers were generally lower, with 10 to 21 taxa present per sample (Figure U-2). Polychaetes (Lumbrineridae spp., *Marenzellaria viridis*, Capitellidae spp.) were predominant and the snail *Ilyanassa trivittata* was relatively abundant in three of the North Jetty samples. In contrast to the Main Channel stations, crustaceans were rare at the North Jetty stations (Massport, 2003).

Two MWRA stations, R09 and R10, both of which were sampled only by SPI, are located near the Main Channel section of the Inner Harbor (Figure 3-4 in SEIS/EIR). Station R09 is close to the Main Channel station MM. Both MWRA stations have shown relatively consistent indications of stress, as indicated by the Organism Sediment Index (OSI) over about the last 10 years of harbor monitoring (Maciolek *et al.*, 2005). Station R10, located off the World Trade Center/Commonwealth Pier, has consistently been one of most stressed stations sampled in the harbor with OSI values around 3.7 from 2000 to 2003. Station R09 has shown slightly higher values for the OSI, but they have been at or just less than 6.0 for four of the last five years. Both stations are dominated by physical, not biological processes, and have silty-fine-sand (R09) or silt-clay (R10) sediments. The infaunal successional stage at each station is usually Stage I or Stage I-II, which is also indicative of frequent stress.

All of the stations sampled during the 2003 Corps survey in the Reserved Channel were within the area dredged between 1998 and 2000. The stations located in the Main Ship Channel were dredged in 2004 to 2007. The Conley Terminal stations (Massport 2003) appear to be on the margin of the dredged channel. The descriptions based on the 2003 data from these sites represent benthic communities present at least three years after dredging. Because the rates of recovery from disturbance for communities in this type of habitat are not known, it is not possible to estimate whether or not the communities found in 2003 represent a benthos that has fully recovered from the dredging. It is expected that the most recently dredged/or soon to be dredged area would not be at full recovery levels for at least a year. The nearby MWRA station (R09) was not within the dredged area.

Lower Harbor - Information about the benthos in the Lower Harbor area is from the Corps 2003 study (Pellegrino, 2003) that sampled the Main Channel and Presidents Roads Anchorage, and the MWRA SPI and infaunal studies that sampled in, and adjacent

to, both areas (Figure 3-4 in SEIS/EIR). The Main Channel stations are separated into those northwest of Spectacle Island and those in Presidents Roads for this discussion.

The Main Channel area northwest of Spectacle Island (Corps stations X, U, S) showed moderately high infaunal abundance ranging from 37,000 to 53,000 individuals/m^2 (Pellegrino, 2003) (Figure U-1). Species numbers were moderate, ranging from 24 to 28 species per sample (Figure U-2). Species diversity was moderately low (H' = 2.4 to 2.9). The successional Stage II amphipod, *Ampelisca abdita*, was the predominant species, followed by the polychaetes *Aricidea catherinae*, *Scoletoma hebes*, and *Tharyx acutus*. Oligochaete sp. A was also common. Rarefaction showed lower diversity in this area than at other Main Channel stations (Figure U-3), but was mid-range compared to other harbor stations. Water depth in the Main Channel was about -40 ft MLLW, and the nearby sediments were classified as sand or sandy mud.

MWRA stations T02, R44, and R08 provide information about the benthos in the area north of the Main Channel. Stations R08 and R44 have been sampled only by SPI. Station R08 has had an average OSI over the last eight years of 4.5, indicative of stress, and the station still showed moderate stress in 2003, with an OSI value of 6.0 (Maciolek *et al.*, 2005). The only infaunal community identified at the station has consisted solely of successional Stage I pioneering fauna, which are also indicative of a stressed habitat. Station R44 showed indications of stress from 1996 to 2000, but since 2000 has shown relatively healthier habitat conditions with an OSI reaching 10.0 in 2003 (Maciolek *et al.*, 2005). Sediment at R44 also showed improved conditions with successional Stage II-III fauna present in 2003, and biophysical processes dominating.

Station T02, sampled via SPI and grab sampler, was once thought to be in a highly polluted area with an impoverished fauna (Maciolek *et al.*, 2005). Conditions at the station have improved as conditions have changed with the modification of discharges into the harbor. Infaunal abundances increased considerably in 1994 and 1995, decreased in 1996, and remained less than 62,500 individuals/m^2 from 1996 to 2002, before increasing to about 127,000 individuals/m^2 in 2003 (Maciolek *et al.*, 2005). There has been a shift in predominant species from pioneering taxa and those sometimes associated with stress (*e.g.*, the polychaetes *Streblospio benedicti* and *Polydora cornuta* and the oligochaete *Tubificoides* nr. *Pseudogaster*) to others such as *Aricidea catherinae*, *Nephtys cornuta*, and *Tubificoides apectinatus* that are often indicative of more stable conditions. Species numbers were about 50 per sample in 2003, the highest number at station T02 since 1994. SPI data generally have shown that the station is stressed with OSI values less than 6. However, in 2003 the OSI value (10.0) was the highest calculated in 12 years of monitoring. The fauna at the station consisted of successional Stage II-III taxa (Maciolek *et al.*, 2005).

The Presidents Roads Main Channel (Corps Stations O, L) showed low infaunal abundances of about 4,000 individuals/m^2 (Pellegrino, 2003) (Figure U-1). However, because there were about 22 species per sample (Figure U-2), diversity was moderately high, with Shannon H' values of about 3.4 and 3.7. The evenness estimate for these

stations was high ($J' \approx 0.8$), which indicates relatively low numerical dominance by any species. The predominant species included polychaetes *Tharyx acutus*, *Scoletoma hebes*, *Harmothoe imbricata*, the snail *Ilyanassa trivittata*, and the brittle star *Amphipholis squamata*. The amphipod *Ampelisca abdita* was rare. Water depths in the Presidents Roads channel were about -50 ft MLLW, and the sediments were primarily sandy (Figure 3-1 in SEIS/EIR). Rarefaction analysis showed that these two channel stations had higher diversity than all but one other harbor sample (Figure U-3), and that infaunal abundances were low.

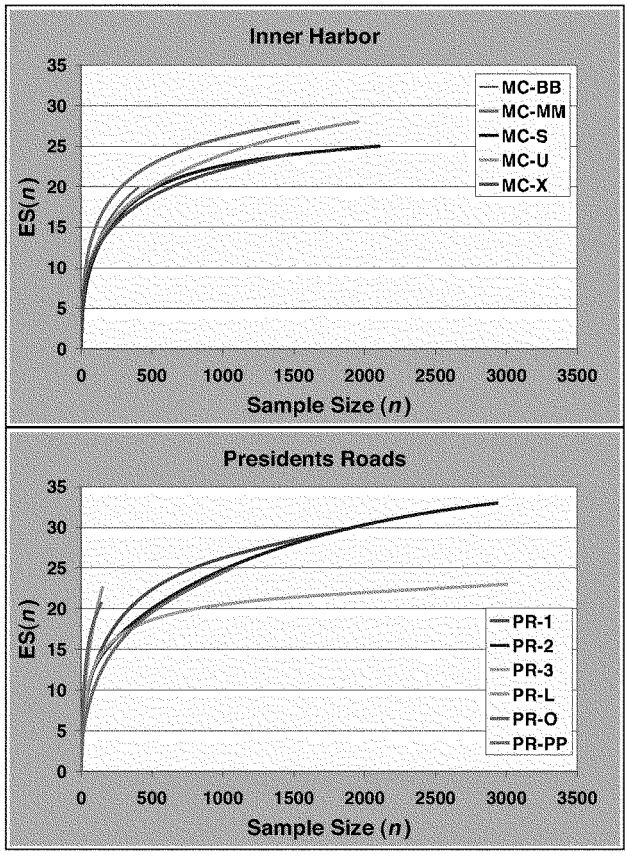
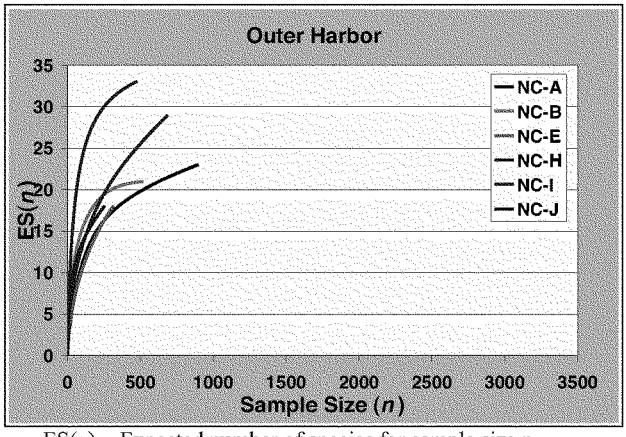


Figure U-3. Rarefaction curves for samples collected from the Boston Harbor study area in September 2003 (prepared from data in Pellegrino, 2003).



ES(n) = Expected number of species for sample size n

Figure U-3 (Continued). Rarefaction curves for samples collected from the Boston Harbor study area in September 2003 (prepared from data in Pellegrino, 2003).

The September 2003 survey showed that stations within the Presidents Roads Anchorage (Corps stations PR-1, PR-2, PR-3, PR-PP) had moderate (~26,000 individuals/m^2) to relatively high (~48,000 to 75,000 individuals/m^2) infaunal abundances (Pellegrino, 2003) (Figure U-1). Species numbers were also relatively high (Figure U-2), with 23 to 33 species per sample, and H' ~2.2 to 2.8. *Ampelisca abdita* was the predominant organism at stations PR-1, PR-2, and PR-3 with abundances of about 27,000 to 41,000 individuals/m^2; however, the species was absent from station PR-PP. Additional species at stations PR-1, PR-2, and PR-3 included other amphipod species (*Leptocheirus pinguis* and *Orchomenella minuta*), polychaetes (*Tharyx acutus*, *Prionospio steenstrupi*, and two species of *Phyllodoce*), and an oligochaete worm (oligochaete sp. A). At station PR-PP, the predominant taxa included the polychaete worms *Aricidea catherinae*, *Prionospio steenstrupi*, and *Mediomastus ambiseta*. Water depths within the Presidents Roads Anchorage (about -40 feet MLLW) were similar at all stations. Sediments were sandy to sandy-mud. Rarefaction analysis showed mid-range diversity and relatively high abundance versus other harbor samples (Figure U-3).

Two MWRA stations, R02 and T05A, are located within the Presidents Roads Anchorage (Figure 3-4 in SEIS/EIR). Station R02, located in the northeast corner of the area, has been sampled by SPI since 1992. Habitat quality here has fluctuated considerably from year-to-year with OSI values in some years showing indications of marked stress (OSI < 6), but in other years showing relatively good conditions with an OSI greater than 8 (Maciolek *et al.*, 2005). There have been no identifiable annual trends in OSI values. The most recent (2003) data show good habitat quality at station R02 (OSI = 8.3), with a successional Stage II community. The sediments were affected

mainly by biological processes. Station T05A, which is characterized annually by SPI and grab samples, is fully exposed to the mouth of the harbor. SPI data show that the benthic habitat at this station has periodically shown signs of stress with OSI values ranging from 2.3 to 7.0 since 1995 (Maciolek *et al.*, 2005). In 2003, SPI data showed a relatively good habitat (OSI = 7.0) at station T05A, with a successional Stage II community, and biological processes affecting the sediment. Infaunal community parameters (measured by grab sample analyses) have shown considerable annual variation. Abundances ranged from as high as about 530,000 individuals/m^2 in 1997 to as low as about 25,000 individuals/m^2 in 2000 (Maciolek *et al.*, 2005). Annual fluctuations can be as large as a 40-fold increase in one year (1996–1997), followed by an almost four-fold decrease the next year (1997–1998). The periodic high abundances are primarily attributed to sudden increases in populations of the polychaete *Polydora cornuta* and the amphipod *Ampelisca abdita.* In 2003, abundances were the second highest recorded at the station, reaching ~317,000/m^2, with amphipods accounting for more than 90% of the total abundance.

The area of the Lower Harbor south of the Main Ship Channel can be characterized using data collected from MWRA stations R06, R45, and T03. The former two stations were sampled only by SPI. Station R06, located off the northern tip of Long Island, is fully exposed to the mouth of the harbor. Its location probably contributes to the stressed conditions typically shown at the station; OSI values for most years prior to 2003 have been <6.0 (Maciolek *et al.*, 2005). In 2003, the OSI value showed an improvement to 8.0. Station R45, however, has consistently been ranked as one of the higher quality habitats in the harbor, with OSI values ranging from 8.3 to 10.0 since 1995 (Maciolek *et al.*, 2005). Station T03, which was characterized by SPI and infaunal grab samples, showed high infaunal abundance in 2003 (216,600 individuals/m^2), about half of which was the amphipod *Ampelisca abdita* (Maciolek *et al.*, 2005). Sixty-four species were found at this station in 2003, representing the highest mean number reported for the station. *Ampelisca abdita* is often predominant, as are other amphipods, such as *Leptocheirus pinguis*, *Crassicorophium bonelli*, *Unciola irrorata*, and *Photis pollex.* Oligochaete worms of the genus *Tubificoides* are often numerically important, with *T. apectinatus* joining or replacing *T.* nr. *pseudogaster* as the predominant oligochaete. The polychaete *Aricidea catherinae* is also often numerically important. SPI data have shown that this station is generally one of the best with regards to habitat quality in the harbor. The average OSI over the last 12 years is 8.6. In 2003, the OSI was 10.0, with successional Stage II-III fauna present and *Ampelisca abdita* mats common (Maciolek *et al.*, 2005).

All of the stations sampled in the Lower Harbor area by the Corps in 2003, and the MWRA stations (R02, T05A) located within the Presidents Roads Anchorage area, were in the area dredged from October 2004 to June 2005. Therefore, the communities that were described above represent those present more than a year prior to a major disturbance to the harbor bottom and are not typical of the communities likely present there now.

Outer Harbor - The data set that best describes the Outer Harbor region is from the September 2003 field program conducted by the Corps and includes stations A, B, E, H, I, and J (Pellegrino, 2003) (Figure 3-4 in SEIS/EIR). Stations sampled by the MWRA and HubLine programs are not close enough to the study area to provide useful descriptions of the habitats. Waters in the outer harbor channel are generally about -35 to -42 feet deep MLLW and the sediments there are poorly characterized. Abundances among the Corps stations were relatively low to moderate, ranging from 6,400 to 22,400 individuals/m^2 (Figure U-1). Species numbers ranged from 18 to 33 species per sample (Figure U-2). Species diversity varied from low to moderately high ($H' = 1.3$ to 4.1) and evenness fluctuated from low ($J' = 0.3$) to high ($J' = 0.8$). There was no noticeable pattern with increasing distance of the stations from the harbor. The predominant taxa in this area included high numbers of the clam *Hiatella arctica* at station NC-A (18,550 individuals/m^2), which accounted for 83% of the abundance there. Predominant taxa at other stations included the polychaetes *Aricidea catherinae* and *Tharyx acutus*, the worm oligochaete sp. A, and an unidentified archiannelid worm at NC-E. This latter species is most likely *Polygordius* sp. A, which is the only archiannelid that has been identified in the Massachusetts Bay area (Maciolek *et al.*, 2005). Rarefaction analysis showed high diversity for one sample (NC-I), but mid-range diversity for the other samples (Figure U-3). Abundance at all stations was relatively low.

All of the stations sampled in the Outer Harbor area by the Corps in 2003 were in the area dredged from August 2004 to October 2004. Therefore, the communities that were described above represent those present about a year prior to a major disturbance to the harbor bottom and may not be typical of the communities likely present there now.

BOSTON HARBOR
MASSACHUSETTS

DEEP DRAFT
NAVIGATION IMPROVEMENT STUDY

FINAL FEASIBILITY REPORT
AND FINAL SUPPLEMENTAL
ENVIRONMENTAL IMPACT STATEMENT
AND MASSACHUSETTS FINAL
ENVIRONMENTAL IMPACT REPORT

APPENDIX V

SHELLFISH LIFE HISTORY INFORMATION
FOR BOSTON HARBOR

(THIS APPENDIX UNCHANGED FROM JULY 2008 DRAFT)

BOSTON HARBOR SHELLFISH INFORMATION

The following section describes the life history, landing data and growing areas of the commercially important shellfish that may occur in Boston Harbor.

Softshell Clam: The softshell clam (*Mya arenaria*) is found along the Atlantic coast from Labrador to South Carolina and in bays and sounds in the bottom sediments of intertidal and subtidal waters up to depths of 30 feet (Newell and Hidu, 1986). Fine sediments (soft mud and sand, compact clay) are the preferred substrate of softshell clams, but they also grown in coarse gravel and stones. Spawning peaks in the summer (June through September). The planktonic larval stage of the softshell clam lasts for 12 to 14 days in the water column and then settles to the bottom, where it develops a foot and attaches to the bottom. Juvenile seed clams (5 mm long) may migrate up to several hundred yards toward shore, with movement peaking in the fall. Adult clams live in permanent burrows that are up to 16 inches deep. They feed mainly on plankton (*i.e.*, flagellates and diatoms) but can also feed on bacteria and organic detritus. Predators include birds, fish, shrimp, crabs, snails, and worms.

The softshell clam (*Mya arenaria*) is the most common commercially harvested shellfish within Massachusetts (MA DMF, 2005). Management of the beds is under the jurisdiction of the MA DMF. Most of the productive softshell clam beds within the project area are closed, except for conditionally restricted areas near Logan Airport in North Boston Harbor and areas near the Neponset River and Dorchester Bay (Figure 3-10). The largest landings in Boston Harbor have historically come from the Airport (GBH5.2) and Snake Island (GBH5.5) locations in North Boston Harbor (Table 3-3). The largest landings in the Neponset River and Dorchester Bay area are from Carson Beach (GBH3.6). Clams are harvested and transported by licensed and bonded master diggers to a shellfish purification plant in Newburyport, where they are held for at least three days in a system supplied with clean, flowing seawater. Once the contaminants have been purged, the clams are returned to commercial harvesters for sale and consumption.

Blue mussel: Blue mussels, *Mytilus edulis*, are distributed from the Arctic to South Carolina (Canada Department of Fisheries and Oceans, 2003a). They are found from slightly brackish estuaries to deep offshore waters but are most abundant in the intertidal and shallow subtidal zones. Mussels have fibers called byssal threads (commonly called the "beard") that are used to anchor to rocks, pilings, or other mussels. Mussels spawn between May and August, with fertilization occurring in the water column (Canada Department of Fisheries and Oceans, 2003a). Embryos become free-swimming planktonic larvae, which are present in the water column for three to four weeks. Between mid-June and late July, the larval mussel metamorphoses into a juvenile and attaches itself to a solid surface. The juvenile mussel can detach itself and change locations (either by crawling with their foot or floating in the water column) until a suitable hard substrate is found at which time the mussel permanently attaches itself and matures to an adult. Mussels can tolerate wide ranges in salinity and temperature. They are filter feeders that feed primarily on phytoplankton, as well as decomposed macrophytes or detritus. Mussel larvae are a food source for zooplankton; juvenile and adult mussels are preyed on mainly by sea ducks, starfish, crabs, and humans. They are harvested

commercially from Maine to Long Island, New York (Maine Department of Marine Resources [ME DMR], 2003). Mussels can be harvested year round and are usually taken by hand with a rake or from a boat with a drag.

Razor clam: Razor clams, *Ensis directus*, are generally found in intertidal to subtidal areas from Labrador to Florida (Gosner, 1978). They are very proficient at digging into the sand to avoid predation. Only the top part of the quickly retractable siphon of the clam is exposed to filter food particles from the water. Similar to blue mussels, razor clams do not typically occur in offshore waters. They are harvested both commercially and recreationally.

Atlantic Surf Clam: The Atlantic surf clam, *Spisula solidissima*, inhabits sandy continental shelf habitats from the southern Gulf of St. Lawrence to Cape Hatteras, North Carolina (Cargnelli *et al.*, 1999). The largest concentrations of Atlantic surf clams usually occur in well-sorted, medium sand but may also occur in fine sand and silty-fine sand. Surf clams inhabit waters from the surf zone to a depth of 420 ft but are more common at depths less than 240 ft. Areas of coarse grain size (*i.e.*, pebbles or cobbles) are virtually devoid of surf clams (Murawski, 1979). Atlantic surf clams are filter feeders that pump water through their siphons over the gills to trap food, mainly plankton. Their planktonic larvae remain in the water column for about three weeks. Many predators, including snails, shrimp, crabs, and fish (haddock and cod), feed on surf clams (Cargnelli *et al.*, 1999). Commercial concentrations in Massachusetts are found primarily on Georges Bank. Recreational fishing is insignificant.

Sea scallop: The sea scallop, *Placopecten magellanicus*, occurs in the western North Atlantic continental shelf waters from Newfoundland to North Carolina (Hart, 2001). North of Cape Cod, populations are generally scattered in shallow water less than 66 feet deep and are most often associated with sandy sediments. Spawning occurs in late summer/early fall, and scallop larvae are present in the water column for four to eight weeks before settling to the bottom. The commercial fishery for scallops occurs year round, with dredges and otter trawls used as the primary harvesting equipment. Sea scallops are most heavily fished on Georges Bank and off the New Jersey coastline between 132 and 330 ft in waters cooler than 20 °C. Recreational fishing is insignificant.

Cancer Crabs: *Cancer* sp. crabs are one of the most common shallow-water crabs in New England waters (Gosner, 1978). Rock crabs (*Cancer irroratus*) are distributed from Labrador to South Carolina, and north of Cape Cod they are found in intertidal areas. Rock crabs prefer rocky habitat but can be found on all types of bottoms. Jonah crabs (*Cancer borealis*) are usually found deeper than rock crabs and prefer exposed, rocky habitat, though they are common on muddy substrates in deeper waters (Gosner, 1978; Estrella, 2003). Egg-bearing females live in pits that they dig in soft sediments (Canada Department of Fisheries and Oceans, 2003b). Breeding occurs in the fall just after the females have mated. Male crabs molt later in the winter.

Table B-1. Life History and Habitat of Shellfish Species in the Project Area

Species	Distribution	Water Depth	Substrate Type	Feeding Strategy	Spawning	Larvae
Softshell clam *Mya arenaria*	Labrador to South Carolina	Intertidal to subtidal (~30 ft)	Fine sediments or coarse gravel and stones	Filter feeder	Summer	Planktonic
Blue mussel *Mytilus edulis*	Artic to South Carolina	Intertidal and shallow sub-tidal to offshore	Attached to rocks, pilings and other solid objects	Filter feeder	Almost year-round with peaks in summer	Planktonic
Razor clam *Ensis directus*	Labrador to Florida	Bays, estuaries, shallow areas	Sand and sandy mud	Filter feeder	Summer through fall	Planktonic
Atlantic surf clam *Spisula solidissima*	Continental shelf waters from Gulf of St. Lawrence to North Carolina	< 240 ft	Medium sand	Filter feeder	Summer and early fall	Planktonic
Atlantic sea scallop *Placopecten magellanicus*	Continental shelf waters from Newfoundland to North Carolina	132-660 ft, <66 ft north of Cape Cod	Sandy	Filter feeder	Late summer and early fall	Planktonic
Rock crab *Cancer irroratus*	Labrador to South Carolina	Intertidal north of Cape Cod, <2,600 ft	All types of bottom types, rocks/crevices	Omnivorous	Summer	Planktonic
Jonah crab *Cancer borealis*	Nova Scotia to Florida	Deeper than rock crab	Rock or mud	Mussels, snails, urchins, crabs	Summer	Planktonic

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Table B-2. Softshell Clam Landing Data in Boston Harbor for 1997 thru 2005.

Area	Area Name	Location	Racks								
			1997	1998	1999	2000	2001	2002	2003	2004	2005
GBH5.1	North Boston Harbor	The Shores	2359	2764	5329	2837	3040	1509	62	557	305
GBH5.2	North Boston Harbor	Airport	4579.5	3832.5	2137	3108.5	3213	371.5	4635.5	1784.5	1088.5
GBH5.3	North Boston Harbor	Governors Island	2618	2238	1489	1414	1211	71	985	546	114
GBH5.4	North Boston Harbor	Wood Island	1857	1713	1049	759	175	80	439	550	2452
GBH5.5	North Boston Harbor	Snake Island	4531	4457	3820	1955	1857	505	361	1338	537
GBH5.9	North Boston Harbor	Orient Heights	NA	NA	NA	NA	344	21	0	0	0
GBH3.6	Neponset R./Dorchester Bay	Carson Beach	NA	NA	NA	NA	NA	3650	1225	492	104
GBH3.9	Neponset R./Dorchester Bay	Thompson	NA	NA	NA	NA	NA	1708	339	360	133
GBH3.10	Neponset R./Dorchester Bay	Long Island	NA	NA	NA	NA	NA	350	20	0	25

Source: Glenn Casey, MA DMF, personal communication, 2006.
Rack = industry unit of measurement equivalent to approximately 50 lbs.
NA = not available

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Cancer crabs produce hundreds of thousands of eggs, which they lay and keep under their abdomen for about one year. The eggs hatch into planktonic larvae in the summer, which remain in the water column from mid-June to mid-September. In the fall, the larvae molt into small crabs (megalops) and settle both in cobble and sand (Palma *et al.* 1998). Juvenile crabs (less than 0.6 inches carapace width) concentrate in sheltered areas in shallow depths (Canada Department of Fisheries and Oceans, 2003b).

Rock crabs are omnivorous and are an important prey item for lobsters. Cancer crabs are currently a by-catch fishery with modest consumer demand (Estrella, 2003).

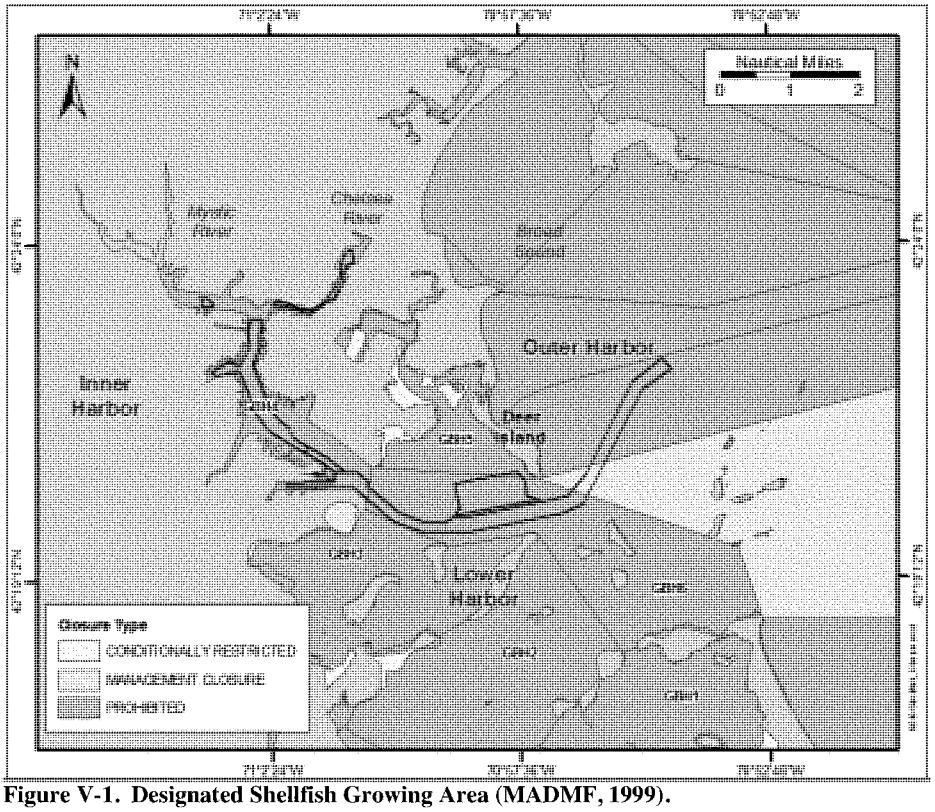

Figure V-1. Designated Shellfish Growing Area (MADMF, 1999).

BOSTON HARBOR
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APPENDIX W

COASTAL AND MARINE BIRDS
IN BOSTON HARBOR
AND MASSACHUSETTS BAY

(This Appendix Not Revised Since 2008 Draft)

COASTAL AND MARINE BIRDS IN BOSTON HARBOR AND MASSACHUSETTS BAY

The following is a summary and list of birds that may occur in the project area:

Pelagic birds - Several species of pelagic birds have been identified in the Boston Harbor area, including Wilson's storm-petrel, common murre, the common loon and red-throated loon. These birds are classified as generally open ocean birds during the winter in tropical seas and do not come near the coast except when nesting or breeding in the spring and summer. Prey for pelagic birds include those organisms that may be collected in the open ocean waters, including fish, crustaceans, shellfish, and plankton. Foraging strategies (i.e., feeding techniques) vary from skimming over the surface and plucking small organisms from the water, to diving to great depths for extended periods to gather fish, shrimp, or benthic organisms such as crabs and shellfish. The common loon has been documented as being caught in fishing nets at 200 feet below the water's surface.

Shorebirds - Shorebirds found in the Boston Harbor area not only nest on coastal shore areas, but are unique in that they also forage in these shoreline areas. Shorebirds inhabit coastlines, open beaches, tidal flats, and marshes. The shorebirds in the Boston Harbor area at one time included the piping plover, but it has not been recorded in the area since 1983. Oystercatchers are large, conspicuous birds that were hunted to near-extinction along the Atlantic Coast. Given total protection, they have once again become numerous and now nest in numbers as far north as Massachusetts, where just a few years ago they were very rare. American oystercatchers nest on the Boston Harbor Islands. Shorebirds in general run along the sand or mud and stop to probe the substrate for worms, snails, or small crustaceans living in the substrate. Besides the American oystercatchers, migrating shorebirds, such as black-bellied plovers, semipalmated plovers, greater yellowlegs, lesser yellowlegs, whimbrels, ruddy turnstones, purple sandpipers, sanderlings, semipalmated sandpipers, western sandpipers, and white-rumped sandpipers, have been detected on 16 of the Boston Harbor Islands (Paton *et al.*, 2005). These birds tend to feed by sight, preying upon oysters, clams, and mussels or probe for marine worms and other food items in the intertidal zone.

Waterfowl - Many different waterfowl species have been identified and recorded in Boston Harbor area, including bufflehead ducks, the common goldeneye, hooded- and red-breasted merganser, the ruddy duck, the American black duck, the greater scaup, gadwall, Canada goose, brant goose, canvasback, common eider, harlequin duck, surf scoter, white-winged scoter and black scoter. Waterfowl are migratory and spend the majority of the time on the water searching for food such as invertebrates, plants, and small fish. Most of these species breed in coastal waters of northern Canada and winter along the Atlantic coast and have been recorded in the Boston Harbor area. Waterfowl come ashore to breed in inland regions or along the coastlines. Many of these species have been observed diving and swimming at great depths underwater for prey. Diving ducks, such as scaup, can dive to 25 feet to forage for clams, invertebrates, fish, and underwater plants. Sea ducks, such as scoters and eiders, have been observed diving to depths over 100 feet to feed on shellfish such as mussels and crustaceans.

Colonial Water Birds - This category of birds is characterized by the colonies of nests that they build along the coasts. Colonial water birds generally inhabit sandy or rocky islands, coastal beaches, salt marshes, bays, and estuaries. These birds have a variety of feeding techniques ranging from wading through the water grabbing fish and invertebrates to hovering over the water surface and diving into the water to catch fish. Most of the colonial water birds feed in the coastal areas with shallow water depths in search small fish. The diet of most coastal water birds includes fish, various crustaceans, mollusks, and plankton. Several colonial water birds have been observed in the coastal areas of Boston Harbor, including the common tern, least tern, sooty shearwater, northern gannet, double-crested cormorant, great cormorant, great blue heron, green heron, great egret, snowy egret, black crowned night heron, Bonaparte's gull, herring gull, laughing gull, great black-backed gull, ring-billed gull, blacked-legged kittiwake, and razor bill.

Raptors - Raptors are birds of prey that are classified as hunting birds that search for food while in flight. Their diet may consist of fish, other birds, and even small mammals. The bald eagle and peregrine falcon are two examples of raptors that can be observed in the Boston Harbor area. These birds generally nest and perch in the upland habitat of tall trees to survey their area and use the shoreline and open ocean for feeding. The bald eagle is listed threatened on the Federal list and both birds are listed as endangered on the state list. They are discussed in Section 3.5.6 of the SEIS.

Marsh Birds - Marsh birds are found in shallow estuaries, coastal bays, and marshes where they feed and breed. Examples of marsh birds observed in the coastal areas of the Boston Harbor area include the horned grebe, red-necked grebe, mute swan, pie-billed grebe, eared grebe, and American bittern. Many of these species move to the coastal areas during the fall and winter. Marsh birds exhibit a variety of feeding techniques, including swimming and diving or wading and grabbing prey. Diets for these birds generally consist of fish, crustaceans, and aquatic plants. Marsh birds are also common in freshwater ponds and rivers.

Table W-1 (Continued) List of Coastal and Marine Birds Recorded in the Boston Harbor and Massachusetts Bay Areas						
Common Name	**Scientific Name**	**Classification**	**Habitat**	**Prey**	**Feeding Technique**	**Status**
Common Loon	*Gavia immer*	Pelagic	Shoreline in spring to breed and nest; in winter, open ocean and bays along coast from Maine to Texas	Principal food source is fish, also shellfish, frogs, aquatic insects	Dives deeply in pursuit of prey; have been caught in nets as much as 200 ft below the water's surface	Species of Special Concern in Massachusetts
Red throated Loon	*Gavia stellata*	Pelagic	Winters along ocean coast during migration; breeds mostly on fresh water	Small or medium sized fish (cod, herring, sprat, sculpins); occasionally crustaceans, mollusks, frogs, fish spawn and insects	Dives recorded at 7–30 ft and average for 1 minute. Prefer clear water for foraging and don't fish at night	No special status
Wilson's Storm-petrel	*Oceanites oceanicus*	Pelagic	Offshore waters	Feeds on small crustaceans, fish and oil from carcasses	Picks prey from the surface of the water while hovering	No special status
Common Murre	*Uria aalge*	Pelagic	Migrate along the coast in the fall to areas where winter food is plentiful	Feed on fish, squid, krill	Dive by flapping their half-open wings, as if flying underwater. Dives to 100 m are common	No special status
Ruddy turnstone	*Arenaria interpres*	Shorebird	Winters on coasts; mudflats, sandbars, sandy or muddy shores, beaches and rocky coasts	Aquatic invertebrates and insects	Uses bill to open barnacles, dig holes, and flip aside stones, shells, and seaweed in pursuit of food	No special status

Table W-1 (Continued) List of Coastal and Marine Birds Recorded in the Boston Harbor and Massachusetts Bay Areas						
Common Name	**Scientific Name**	**Classification**	**Habitat**	**Prey**	**Feeding Technique**	**Status**
Sander-Ling	*Calidris alba*	Shorebird	During migration and in winter: Sandy ocean beaches, mudflats, sandy edges of inland lakes and rivers	Small crustaceans and mollusks	As waves come roaring in, the birds run up on the beach just ahead of the breaker, then sprint after the retreating water to feed on exposed organisms	No special status
White rumped sandpiper	*Calidris fuscicollis*	Shorebird	During migration, found in mudflats, flooded fields, shallow marshes, beaches, sandbars	Insects, marine worms, mollusks, crustaceans, leaches, seeds, and vegetation	Picks food from the ground and by methodically probes the sediments with its bill	No special status
Purple sandpiper	*Calidris maritime*	Shorebird	Rocks in coastal areas	Insects, small mollusks, seeds, berries, and algae	Forages for food by picking from the surface or probing sediment with bill	No special status
Semi-palmated sandpiper	*Calidris pusilla*	Shorebird	Winters on and migrates along coastal beaches, mudflats and salt marshes	Aquatic invertebrates and seeds	Picking up food by sight	No special status
Semi-palmated plover	*Charadrius semi-palmatus*	Shorebird	During migration and in winter it can be found on mudflats, salt marshes & lakeshores	Crustaceans and mollusks	Forages from the surface, running and scanning for food in short bursts	No special status
Whimbrel	*Numenius phaeopus*	Shorebird	Winters on coastal marshes, prairies, shores, and mud flats	Feeds on crabs, shrimps, mollusks, and worms	Probe deeply into mud with bill, may also pick off food found on the surface	No special status

Table W-1 (Continued) List of Coastal and Marine Birds Recorded in the Boston Harbor and Massachusetts Bay Areas						
Common Name	**Scientific Name**	**Classification**	**Habitat**	**Prey**	**Feeding Technique**	**Status**
Black bellied plover	*Pluvialis squatarola*	Shorebird	Winters on the beaches, mudflats, and coastal marshes	Small crabs, worms, mollusks, and crustaceans.	Forages for food by run, stop and peck	No special status
Lesser yellowlegs	*Tringa flavipes*	Shorebird	In the winter can be found along the shores of lakes and rivers, in marshy ponds and in coastal marshes and mudflats	Aquatic invertebrates and terrestrial insects, also small fish	Forage by pecking and grabbing up prey	No special status
Greater yellowlegs	*Tringa melanoleuca*	Shorebird	Marshes, mudflats, and flooded fields	Small fish, aquatic and terrestrial invertebrates, and berries	Forages by probing its bill into the substrate, but also skims the surface	No special status
American Oystercatcher	*Haematopus palliatus*	Shorebird	Coastal waters	Marine invertebrates (mollusks, crabs and worms), and occasionally fish	Probes the sand, rocks, and other substrates in the coastal waters	No special status
Bufflehead	*Bucephala albeola*	Waterfowl	Winters on salt bays and estuaries	Freshwater and saltwater aquatic invertebrates (insects, crustaceans, mollusks)	Feed in open, shallow water; dives for food and swallows while underwater	No special status
Common Goldeneye	*Bucephala clangula*	Waterfowl	Winters on coastal bays and estuaries	Mollusks, aquatic plants and insects	Dives for prey	No special status
Hooded Merganser	*Lophodytes cucullatus*	Waterfowl	Winters on coastal marshes and inlets	Small fish, frogs, aquatic insects	Dives for fish in long, rapid, underwater dives	No special status
Red-breasted Merganser	*Mergus serrator*	Waterfowl	Winters mainly on salt water	Fish	Swift, underwater dives	No special status

Table W-1 (Continued) List of Coastal and Marine Birds Recorded in the Boston Harbor and Massachusetts Bay Areas						
Common Name	**Scientific Name**	**Classification**	**Habitat**	**Prey**	**Feeding Technique**	**Status**
Ruddy Duck	*Oxyura jamaicensis*	Waterfowl	Winters on marshes and in shallow coastal bays	Pondweeds and other aquatic plants, midge larvae	Surface diver; excellent underwater swimmer; strains bottom material through bill	No special status
American Black Duck	*Anas rubripes*	Waterfowl	Marshes, lakes, streams, coastal mudflats, estuaries. Outside of breeding season, lives on open lagoons and on the coast, even in rough sea waters	Aquatic plants, also invertebrates (insects, mollusks, crustaceans)	Grazing, probing, dabbling for prey; occasionally dives	No special status
Gadwall	*Anas strepera*	Waterfowl	Lakes, reservoirs and estuaries	Aquatic vegetation & invertebrates	Dabbles for prey	No special status
Greater Scaup	*Aythya marila*	Waterfowl	Brackish lakes, bays, and ponds; in winter, often on salt water bays and estuaries of the Atlantic coast	Green plant matter, seeds, mollusks	Grazing and probing for prey; dives for mollusks	No special status
Canvasback	*Aythya valisineria*	Waterfowl	Bays and estuaries in the winter	Aquatic vegetation & invertebrates	Dives for prey	No special status
Brant Goose	*Branta bernicla*	Waterfowl	Saltwater bays and estuaries in the winter	Submerged vegetation	Feed during low tide, pull plants up from bottom	No special status
Canada Goose	*Branta canadensis*	Waterfowl	Usually inland but sometimes in coastal waters, particularly in spring and fall	Plants	Grazing and dabbling for prey	No special status

Table W-1 (Continued) List of Coastal and Marine Birds Recorded in the Boston Harbor and Massachusetts Bay Areas						
Common Name	**Scientific Name**	**Classification**	**Habitat**	**Prey**	**Feeding Technique**	**Status**
Common Eider	*Somateria mollissima*	Waterfowl	Rocky coasts; breeds from Canada to Massachusetts ; winters south to Long Island; Most sea going of all waterfowl, never leaving the salt water	Mussels and other shellfish	Dives for prey	No special status
Harlequin Duck	*Histrionicus histrionicus*	Waterfowl	Rocky wave-lashed coasts and jetties in winter; prefers the rugged seacoast	Loose snails, limpets, barnacles, small shrimp, crabs, small fish	Diving for fish or pulling prey off rocks	No special status
Surf Scoter	*Melanitta perspicillata*	Waterfowl	Winters almost entirely on the ocean and in large coastal bays	Mollusks and crustaceans	Diving for food	No special status
White-winged Scoter	*Melanitta fusca*	Waterfowl	Winters mainly on ocean and large coastal bays	Mollusks, crabs, starfish, sea urchin, some fish	Dives for mussels at depths of 15-40 ft	No special status
Black Scoter "Common Scoter"	*Melanitta nigra*	Waterfowl	Winters on ocean and in large salt bays	Mussels and other mollusks, barnacles, chitins, limpets	Feeds off rocks and reefs	No special status
Common Tern	*Sterna hirundo*	Colonial water bird	Sandy or rocky islands, sand dunes or barrier beaches; breeds along Atlantic coastline	Primarily sand lance (up to 22 cm) but also other small fish, crustaceans, invertebrates	Feeds close to shore in water less than 15 inches deep; sometimes in deeper water over schools of predatory fish; dives and dips for prey	Species of special concern in Massa-chusetts
Least Tern	*Sterna antillarum*	Colonial water bird	Coastal beaches and barrier islands	Fish less than 8-94 cm; minnows, sand lance, herring, hake	Hover, dive, skim the surface of the water	Species of special concern in Massachusetts

Table W-1 (Continued) List of Coastal and Marine Birds Recorded in the Boston Harbor and Massachusetts Bay Areas						
Common Name	**Scientific Name**	**Classification**	**Habitat**	**Prey**	**Feeding Technique**	**Status**
Sooty Shearwater	*Puffinus griseus*	Colonial water bird	Open ocean; arrive on east coast in May as part of great migratiou; one of most abundant birds in the world	Fish	Dives from surface and swims underwater with wings	No special status
Northern Gannet	*Morus bassanus*	Colonial water bird	Open seas	Fish	Dives into sea after fish, sometimes plunging headlong from heights as great as 50 ft or more	No special status
Double-crested Cormorant	*Phalacrocorax auritus*	Colonial water bird	Coastlines; marine and inland waters	Fish, crustaceans, amphibians from fresh water	Swims low in water to feed; dives and catches their prey underwater	No special status
Great Cormorant	*Phalacrocorax carbo*	Colonial water bird	Sea cliffs, rocky coasts, and inshore waters; winters from Maine to New Jersey	Fish; in coastal waters during breeding season, herring and eel	Dives for fish	No special status
Great Blue Heron (Blue form)	*Ardea herodias*	Colonial water bird	Lakes, ponds, rivers, marshes	Fish or frogs primarily; occasionally small mammals, reptiles, and birds	Fishes day and night but prefer dawn and dusk; wades in shallow water and spears the food	No special status
Green Heron	*Butorides virescens*	Colonial water bird	Marshes	Food consists Primarily of fish and insects but also crustaceans, mollusks, other invertebrates, amphibians and reptiles	Seizes the prey with a jab of its bill	No special status

Table W-1 (Continued) List of Coastal and Marine Birds Recorded in the Boston Harbor and Massachusetts Bay Areas						
Common Name	**Scientific Name**	**Classification**	**Habitat**	**Prey**	**Feeding Technique**	**Status**
Great Egret	*Casmerodius albus*	Colonial water bird	Freshwater and salt marshes, tidal flats, nests in colonies	Fish, frogs, snakes, crayfish	Wades in shallow water and spears the prey	No special status
Snowy Egret	*Egretta thula*	Colonial water bird	Marshes, swamps, ponds, lakes, shallow coastal areas and tidal flats; occasionally found in dry fields	Fishes, shrimp, crayfish, fiddler crabs, snakes, snails, aquatic and terrestrial insects, small lizards, young frogs and aquatic vegetation	Use one foot to stir up the bottom, flushing prey into view. Will also hover, then drop to the water to catch prey in their bills	No special status
Black Crowned Night Heron	*Nycticorax nycticorax*	Colonial water bird	Wooded swamps, coastal dune forests, vegetated dredged material islands scrub thickets, or mixed phragmites marshes	Fish, amphibians, reptiles, crayfish, mussels, dragonflies and nymphs, and small rodents	Forages, waits motionless for prey	No special status
Glossy Ibis	*Plegadis falcinellus*	Colonial water bird	Marshy lakeshores and coastal lagoons	Aquatic invertebrates, insects, and snakes	Probes mud and silt with its bill looking for prey	No special status
Willet	*Catoptrophorus sem-palmatus*	Colonial water bird	Coastal marshes and beaches and mudflats	Aquatic insects, marine worms, small fishes, small crustaceans and mollusks; occasionally seeds and grasses	Forages in mudflats, intertidal areas, and shallow marsh waters; snatches up food from the surface or the water or it probes in the mud with its long bill	No special status

Table W-1 (Continued) List of Coastal and Marine Birds Recorded in the Boston Harbor and Massachusetts Bay Areas						
Common Name	**Scientific Name**	**Classification**	**Habitat**	**Prey**	**Feeding Technique**	**Status**
Bonaparte's Gull	*Larus philadelphia*	Colonial water bird	Ocean bays, coastal waters, islands, and lakes	Fish, crustaceans, snails, marine worms	Feed by dipping to the surface of the water. Occasionally they drop into the water, take a few deep strokes, then glide to the surface	No special status
Herring Gull	*Larus argentatus*	Colonial water bird	Common in all aquatic habitats	Aquatic and marine animals, clams, shellfish	Scavenger	No special status
Great Black-backed Gull	*Larus marinus*	Colonial water bird	Coastal beaches, estuaries, lagoons	Anything smaller than itself, including, small ducks, fish, shellfish	Scavenger	No special status
Laughing Gull	*Larus atricilla*	Colonial water bird	Salt marshes, bays, estuaries; very rare inland	Insects, fish, shellfish, crabs	Carnivore, scavenger, dives for prey	No special status
Ring-billed Gull	*Larus delawarensis*	Colonial water bird	Lakes and rivers; many move to salt water in winter	Fish, small mammals and rodents	Scavenger	No special status
Black- legged Kittiwake	*Rissa tridactyla*	Colonial water bird	Cliffs and seacoasts; generally spends the entire winter on the open ocean	Small fish and plankton	Only gull that occasionally dives and swims underwater to capture food	No special status
Razorbill	*Alca torda*	Colonial water bird	Coastal waters	Fish, shrimp, and squid	Very adept at diving and have been caught in gill nets as deep as 60 ft	No special status

Table W-1 (Continued) List of Coastal and Marine Birds Recorded in the Boston Harbor and Massachusetts Bay Areas						
Common Name	**Scientific Name**	**Classification**	**Habitat**	**Prey**	**Feeding Technique**	**Status**
Bald Eagle	*Haliaeetus leucocephalus*	Raptor	Coastal areas, estuaries, large inland waterways; overwintering along the Atlantic coastlines and islands	Fish, other birds (waterfowl and seabirds), small mammals, carrion	Swooping from a perch or by coursing low over the water and dropping straight down when a fish is spotted	Federal and State listed as threatened
Horned Grebe	*Podiceps auritus*	Marsh bird	Population moves to coast in fall; once on wintering grounds, they seldom fly	Insects, crustaceans, small fish; on wintering grounds, mollusks are also consumed	Excellent swimmer and diver; during dives it may stay submerged for up to three minutes and travel 490-660 ft horizontally in that time	No special status
Red-necked Grebe	*Podiceps grisegena*	Marsh bird	Coastal bays and estuaries during migration and winter	Fish, crustaceans, and aquatic insects	Diving and propelling through the water	No special status
Mute Swan	*Cygnus olor*	Marsh bird	Freshwater ponds, rivers, coastal lagoons, bays; in winter, common on marine waters	Aquatic vegetation, aquatic insects, fish, frogs	Plunge head below water surface	No special status
American Coot	*Fulica americana*	Marsh bird	Open ponds and marshes; winters on coastal bays and inlets; feeds with ducks	Aquatic plants	Swims and dives for food	No special status
Pie-billed Grebe	*Podilymbus podiceps*	Marsh bird	Marshes, ponds; saltwater in winter if freshwater freezes	Fish, crustaceans, aquatic insects, crayfish	Dives for food	No special status

Table W-1 (Continued) List of Coastal and Marine Birds Recorded in the Boston Harbor and Massachusetts Bay Areas						
Common Name	**Scientific Name**	**Classification**	**Habitat**	**Prey**	**Feeding Technique**	**Status**
Eared Grebe	*Podiceps nigricollis*	Marsh bird	Prefers freshwater wetlands with large expanses of open water; open bays and ocean in winter	Aquatic insects, small crustaceans, and fish	Grazing, probing, dives for prey	No special status
American Bittern	*Botaurus lentiginosus*	Marsh bird	Saltwater marshes during migration and winter; does not nest iu colonies	Insects, amphibians, crayfish, small fish and mammals	Forages; waits motionless for prey then catches and shakes or bites to kill	No special status

BOSTON HARBOR
MASSACHUSETTS

DEEP DRAFT
NAVIGATION IMPROVEMENT STUDY

FINAL FEASIBILITY REPORT
AND FINAL SUPPLEMENTAL
ENVIRONMENTAL IMPACT STATEMENT
AND MASSACHUSETTS FINAL
ENVIRONMENTAL IMPACT REPORT

APPENDIX X

MARINE MAMMALS
IN BOSTON HARBOR
AND MASSACHUSETTS BAY

(This Appendix Not Revised Since 2008 Draft)

MARINE MAMMALS IN BOSTON HARBOR AND MASSACHUSETTS BAY

The following is a summary and list of marine mammals that may occur in the project area:

Harbor Seal (*Phoca vitulina concolor*) - The harbor seal, also known as the common seal, is found throughout coastal waters of the Atlantic Ocean from Canada to southern New England, New York, and adjoining seas (Waring *et al.*, 2004) above 30° N latitude. Harbor seals spend the late spring, summer, and early fall between New Hampshire and the Arctic, where they breed and care for newly born pups. A general southward movement from the Bay of Fundy to southern New England waters occurs in fall and early winter, mostly consisting of juveniles and subadults. Whitman and Payne (1990) have suggested that this age-related dispersal may reflect the higher energy requirements of younger individuals. After overwintering in southern New England and New York coastal waters, the vast majority of the population migrates to the northern waters of New Hampshire, Maine, and Canada in the spring for the pupping season (mid-May through June). No pupping areas have been identified in the project areas.

The harbor seal is not listed as threatened or endangered under the Endangered Species Act (ESA), and it is not considered a strategic stock (i.e., a stock whose mortality is at a level that will destroy the population) by NMFS.

White-sided Dolphin (*Lagenorhynchus acutus*) - The white-sided dolphin occurs in temperate and polar waters in the North Atlantic Ocean, typically over the continental shelf to the 330-foot depth contour. White-sided dolphins are potential, but rare visitors to the outer project areas in Massachusetts Bay. The white-sided dolphin is not listed as threatened or endangered under the ESA and is not considered a strategic stock by NMFS. The habitat range of the white-sided dolphin is generally in deeper waters of the continental shelf and therefore would rarely be found in the inner Boston Harbor, but have been sighted around the Boston Harbor Islands.

Harbor Porpoise (*Phocoena phocoena*) - The harbor porpoise is primarily an inshore species. During the summer, harbor porpoises are concentrated in the northern Gulf of Maine and the southern Bay of Fundy region, generally in waters less than 490 feet deep. This stock of harbor porpoises migrates south into the mid-Atlantic region during the fall and spring months; they are widely distributed from New Jersey to Maine. Low densities of harbor porpoises are found in waters off New York and north to Canada in the winter. No specific migratory routes to the Gulf of Maine/Bay of Fundy region have been identified. The best estimate for the abundance of the Gulf of Maine/Bay of Fundy population is 89,700 animals, with a minimum population estimate of 74,695 (Waring *et al.*, 2004).

During the period of 1994 to 2001, 831 harbor porpoise strandings were reported from Maine to North Carolina, with only 27 strandings in 2000. Massachusetts alone had 219 strandings during this period. No specific information on locations in Massachusetts was available. NMFS considers the Gulf of Maine/Bay of Fundy harbor porpoise stock

as a strategic stock, though the stock has preliminarily been removed from the ESA candidate species list by the NMFS (Waring *et al.*, 2004). The preferred nearshore habitat of the harbor porpoise makes it a potential species to be found in the Boston Harbor area. The harbor porpoise has been recorded as far into the harbor area as Chelsea Creek (New England Aquarium, per communication Phil Colarusso, U.S. EPA).

Gray Seal (*Halichoerus grypus*) - The gray seal is found on both sides of the North Atlantic. The western North Atlantic population occurs from New England to Labrador (Waring *et al.*, 2004). Gray seals inhabit temperate and sub-arctic waters and are found from Maine to Long Island Sound in the United States. There are two breeding concentrations in eastern Canada, one at Sable Island and a second that breeds on the pack ice in the Gulf of St. Lawrence. A small number of animals and pupping have been observed on several isolated islands along the Maine coast and in Nantucket-Vineyard Sound, Massachusetts.

Gray seals are the second most common pinniped along the Atlantic coast of the US, living on remote, exposed islands, shoals, and unstable sandbars. Pupping occurs from late December through mid-February. There are no regular seasonal migrations, but young individuals wander extensively during their first two years of life. Gray seals feed on a wide variety of fish (Lesage and Hammil, 2001) as well as squid, octopus, crustaceans and even a seabird or two. The majority of dives are to depths of 230 to 328 feet, but gray seals can dive to depths greater than 1,312 feet.

Minke Whale (*Balaenoptera acutorostrata*) - Minke whales occur throughout polar, temperate, and tropical waters. The minke whale is the third most abundant great whale in the Atlantic Ocean within 200 nmi of the U.S. coastline (Winn, 1982). Minke whales off the east coast of the Unites States are part of the Canadian east coast population, one of four minke populations recognized in the North Atlantic. The range of this population extends south from Canada to the Gulf of Mexico, but distribution is primarily concentrated in New England waters, with most sightings occurring in the spring and summer months. Based on surveys conducted in 1995 and 1999, the best available current abundance estimate for minke whales in the western North Atlantic is 4,018 animals, with a minimum estimate of 3,515 animals (Waring *et al.*, 2004). This species is found in open seas primarily over continental shelf waters, but it occasionally enters bays, inlets, and estuaries. Minke whales may occasionally visit Boston Harbor and Massachusetts Bay, as is made evident by a recent minke whale mortality report. In 2001, a minke whale was found dead in Massachusetts Bay (42° 21'N 70° 43'W) with fairly fresh entanglement marks on the tail stock and across the tail flukes (Waring *et al.*, 2004).

The minke whale is not listed as threatened or endangered under the ESA, as depleted under the MMPA, or as a strategic stock by NMFS.

BOSTON HARBOR
MASSACHUSETTS

DEEP DRAFT
NAVIGATION IMPROVEMENT STUDY

FEASIBILITY REPORT
AND FINAL SUPPLEMENTAL
ENVIRONMENTAL IMPACT STATEMENT
AND MASSACHUSETTS
FINAL ENVIRONMENTAL IMPACT REPORT

APPENDIX Y

FINAL AFTER ACTION REPORT
ON FISHERIES IMPACTS RESULTING FROM
FALL 2007 BLASTING ACTIVITIES
FOR ROCK REMOVAL FROM THE
FEDERAL NAVIGATION PROJECT

THIS APPENDIX REPLACES THE DRAFT VERSION INCLUDED IN THE AUGUST 2008 DRAFT

FINAL

AFTER ACTION BLAST REPORT

ON FISH KILLS RESULTING FROM ROCK BLASTING IN THE BOSTON HARBOR FEDERAL NAVIGATION PROJECT -BOSTON, MASSACHUSETTS- (FALL 2007)

PREPARED BY:

U.S. Army Corps of Engineers
New England District

JUNE 2008

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AFTER ACTION REPORT

I. Introduction

A. Purpose of the Report

The purpose of this After Action Blast Report (AABR) is to (1) document the project activities that resulted in fish kills, (2) the follow-up actions taken, and (3) the lessons learned during rock removal operations during 2007 from the Federal navigation channel and anchorage area in Boston Harbor, Boston, Massachusetts. The lessons learned from these blast events will be used to prepare a comprehensive blast plan for the upcoming Boston Harbor Deep Draft Navigation Improvement Project. In addition to the lessons learned from the events described in this AABR, a comprehensive blast plan to be developed for the Boston Harbor Deep Draft Project will also incorporate pertinent information obtained through literature reviews, advice from technical experts, lessons learned from other dredging/rock removal projects, results of resource agency coordination, and input from the project technical working group (TWG) sub-committee established specifically for this effort.

B. Project Description

It was discovered during maintenance dredging of the Boston Harbor Federal navigation channels in 2004 and 2005 that several areas of rock extended above the authorized navigation channel depths. These rock areas were located in the Main Ship Channel, President Roads Anchorage, and in the Broad Sound North Channel (see Figure 1). To eliminate this hazard to navigation and achieve authorized depths, it was necessary to remove this rock through blasting. A contract to remove the rock was awarded on March 15, 2007 to RDA Construction Corp. of Quincy, Massachusetts. RDA Construction began work in Boston Harbor in September 2007. They began to drill and blast in the President Roads Anchorage the week of October 1, 2007 and continued work until December 23, 2007 when operations were suspended in the Broad Sound North Channel due to safety concerns resulting from rough winter weather conditions. RDA Construction resumed work in April 2008. A hydraulic ram was used in the Broad Sound North Channel to remove the remaining rock material in the spring and summer of 2008. Table 1 provides the location, volumes of material removed, dates, and rock removal methods, and disposal location from the three harbor rock locations.

Table 1. Information on Rock Removed From Each Section in Boston Harbor

Rock Removal Location	Amount (cy)	Dates	Method of Removal	Disposal Location
President Roads Anchorage	1,029	Oct-Nov 2007	Blast	Ocean
Main Ship Channel	235	November 2007	Blast	CAD cell
Broad Sound North Channel	42 729	December 2007 April–June 2008	Blast Hydraulic Ram	Ocean Ocean

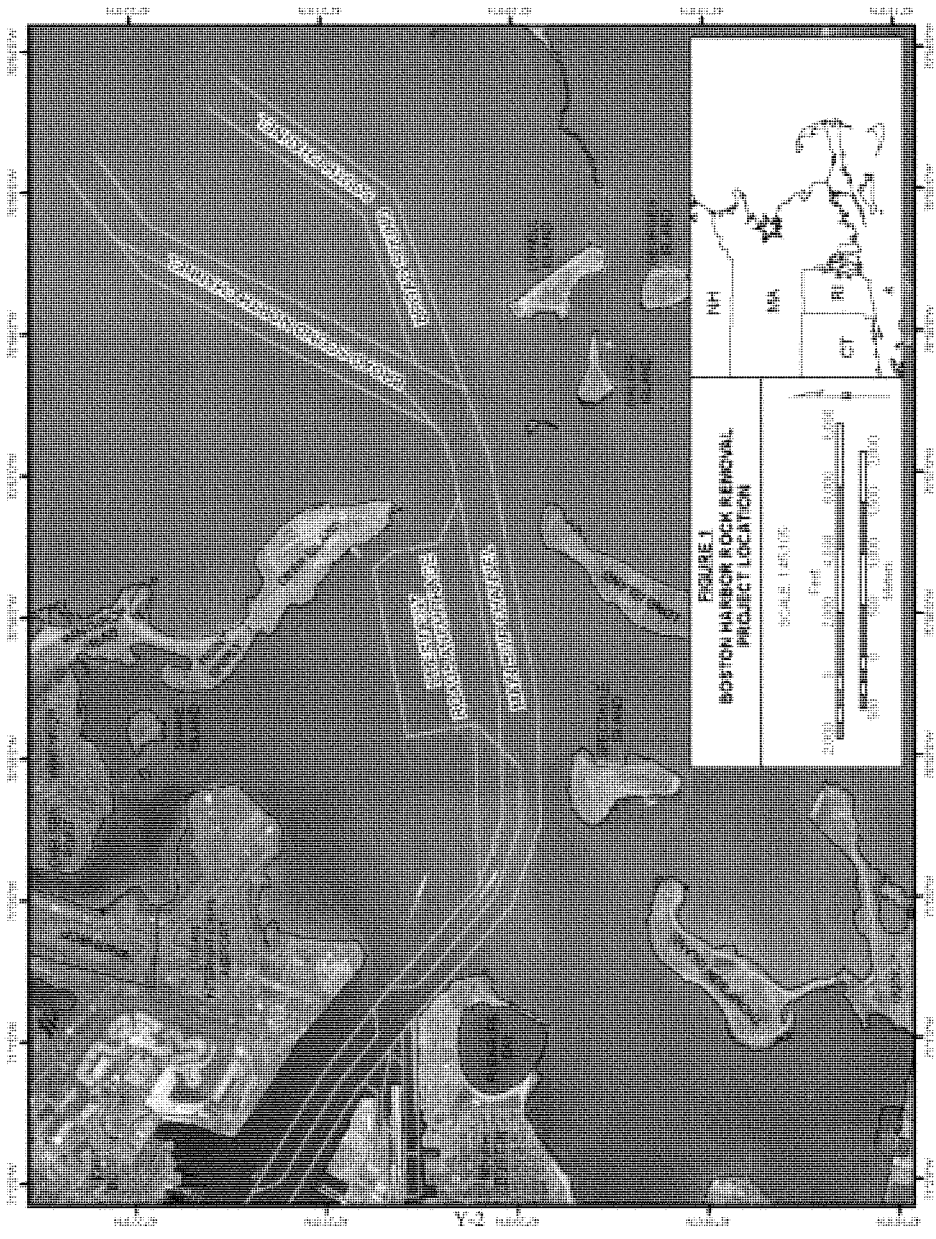
FIGURE 1
BOSTON HARBOR ROCK REMOVAL
PROJECT LOCATION
NH
MA
RI
CT

C. Operational and Construction Measures to Reduce Fish Impacts from Underwater Blasting

Blasting generates underwater shock waves which radiate from the point of the blast. These shock waves can injure or kill fish that transit or inhabit the impact area. Injuries can result either directly from the blast or when air bladders of the fish are impaired. To reduce the potential for fishery impacts, blast procedures were established for this project and approved by regulatory agencies prior to construction. These procedures seek to reduce shock waves in the overlying water column and deter schools of fish from the area at the time of blasting. Construction procedures implemented to reduce the shock wave included using inserted delays of a fraction of a second and stemming. Stemming is a method used to deaden the shock wave reaching the over-laying water column by placing stone or similar material into the top of the borehole. Operational procedures implemented to reduce potential impacts to fisheries in the areas of blasting included the use of side scan sonar to detect and avoid passing schools of fish during blasting, a fish startle system to deter fish of the Clupeid family (i.e. blueback herring and alewife) from entering the blast area, and a fish observer to oversee and coordinate these efforts and determine the appropriate blast time to avoid fishery impacts. The credentials of the fish observer, Eric Rydbeck of Normandeau Associates, were approved by the National Marine Fisheries Service (NMFS) on September 25, 2007 and MA Division of Marine Fisheries (MA DMF) on September 28, 2007.

The fish observer used hydroacoustic monitoring (i.e. side-scan sonar) prior to any blasting event to determine that schools of fish were not located within or transiting the blast zone area. In addition to the side-scan sonar, a fish startle system (Sonalysts, Inc.) was employed which is capable of deterring fish from the Clupeid family using high amplitude sound at specific frequencies.

The established procedure implemented by the fish observer during blast events was to first deploy the side scan equipment off a support vessel that navigated around the blast site to check for the presence of fish in the area. However, the presence of blast cords in the water column limited the ability of the vessel to completely circle around the area. As a result, only approximately 320° to 340° around the blast site could be monitored using this technique. The side scan sonar covers 150 feet on either side of the vessel. The fish observer made as many passes around the blast site as needed to feel confident there were no fish in the area. A minimum of two passes with no observed fish were conducted prior to approving the initiation of the blasting procedure.

The fish startle system was deployed prior to each blast event, regardless of whether fish were observed in the area, and removed from the water approximately five minutes before the blast for all events regardless if fish were observed in the area. The fish startle system was located on the blast barge and was deployed in the area of blasting to a depth of 10 feet off the seafloor, consistent with operating procedures described in the manufacture's manual. The fish startle system was removed from the water prior to the blast. The manufacturer of the fish startle system indicated that the fish startle system

can be removed from the water column up to 10 minutes before the blast and still be effective.

D. Blasting Specifications, Procedures and Safety Plan

Explosive products manufactured by Orica, USA were 2 or 2 ½" by 16", 40% gelatin charges. Non-electric delay blasting caps manufactured by Orica, USA were used. The bore holes were a minimum three inches in diameter, spaced a minimum of five feet apart, with a minimum five foot overburden. The average drill depth of the hole was eight feet with a minimum of three feet of stemming utilizing 1/8" peastone.

Drilling was conducted from the barge with a Joy Mini-mustang equipped with a drilling nose to center the drill bit on the channel floor. The drilling nose was advanced to the floor via cable and winch on a drill. The drill steel was advanced to the nose. The diver guided the bit and still into the nose. The diver then surfaced and then the borehole was dug to the proper depth. The diver returned to the floor with a section of a PVC pipe, the nose was lifted and the PVC pipe inserted into the drill hole to keep the hole open and free from bottom silt. This was repeated until the area was completely drilled.

Packages of explosives and cap were assembled on the deck of the barge using 80 foot Nonel caps. Those packages were then lowered to the diver via a tag line weighted to the bottom. The diver inserted the package into the open hole through the PVC sleeve. The peastone was then lowered via a tag line and the hole stemmed. The Blaster marked and secured the surface delay on the deck of the barge. The process was repeated until the shot was fully loaded and stemmed. The circuit was "snapped" together on the deck of the barge in proper sequence to a "shock tube" lead-in-line. Surface delays were attached to plastic jugs with the lead line shock tube beading back to the barge for initiation by the Blaster. After clearing the vessel traffic and barge personnel, the whistle system described below was sounded and the blast fired. There was no drilling during loading operations. Each operation is completed prior to the next operation. The line was run out to a safe distance from the blast site to the Blaster.

Prior to initiating the blast, a whistle signal system was sounded at which time all equipment and personnel were moved from the danger zone. The whistle system began with warning signal of a one-minute series of long whistles five minutes prior to the blast. The second blast signals were identified by a series of short whistles which were sounded one minute to the blast. After the second set of signals and before initiation, the Blaster visually checked with each guard to obtain the final all-clear. The all-clear signal was sounded with one prolonged whistle once the blast was made and the inspection finalized.

After the blast, the Blaster inspected for misfires and then sounded the all-clear. If a misfire was noted, the following OSHA recommendations were followed:

- If a misfire was found, the Blaster provided proper safeguards for excluding all employees from the danger zone.

- No other work began except those necessary to remove the hazard of the misfire and the employees necessary to do the work remained in the danger zone.
- No attempt was made to extract explosives from any charged or misfired hole; a new primer would be installed and the hole re-blasted.
- If there were any misfires while using cap and fuse, all employees would remain away from the charge for at least one hour. Misfires were to be handled under the direction of the Blaster. All wires would be carefully traced and a search made for unexploded charges.
- No drilling, digging, or picking was permitted until all missed holes were detonated or the authorized representative has approved that work could proceed.

No blasting occurred between sunset and sunrise. All blasting was required to be completed 45minutes before sunset. Once blasting was completed for the day, the explosives were returned to the truck and transported back to permanent storage at Orica USA in Templeton, MA. No explosives were stored on site overnight.

II. Information on Blasting in Boston Harbor Fall 2007

Blasting was initiated on October 5, 2007 to remove rock from Boston Harbor. No fish kills were experienced through the first seven blasts in the President Roads Anchorage area. A total of 14 blast events occurred in the fall of 2007 in Boston Harbor, of which four resulted in a fish kill of varying magnitude. The first fish kill event occurred during the eighth blast event on October 24, 2007. Table 2 below provides the location, dates, tidal conditions, and other pertinent information for all blast events. Figure 2 shows the blasting locations and the dates for each location.

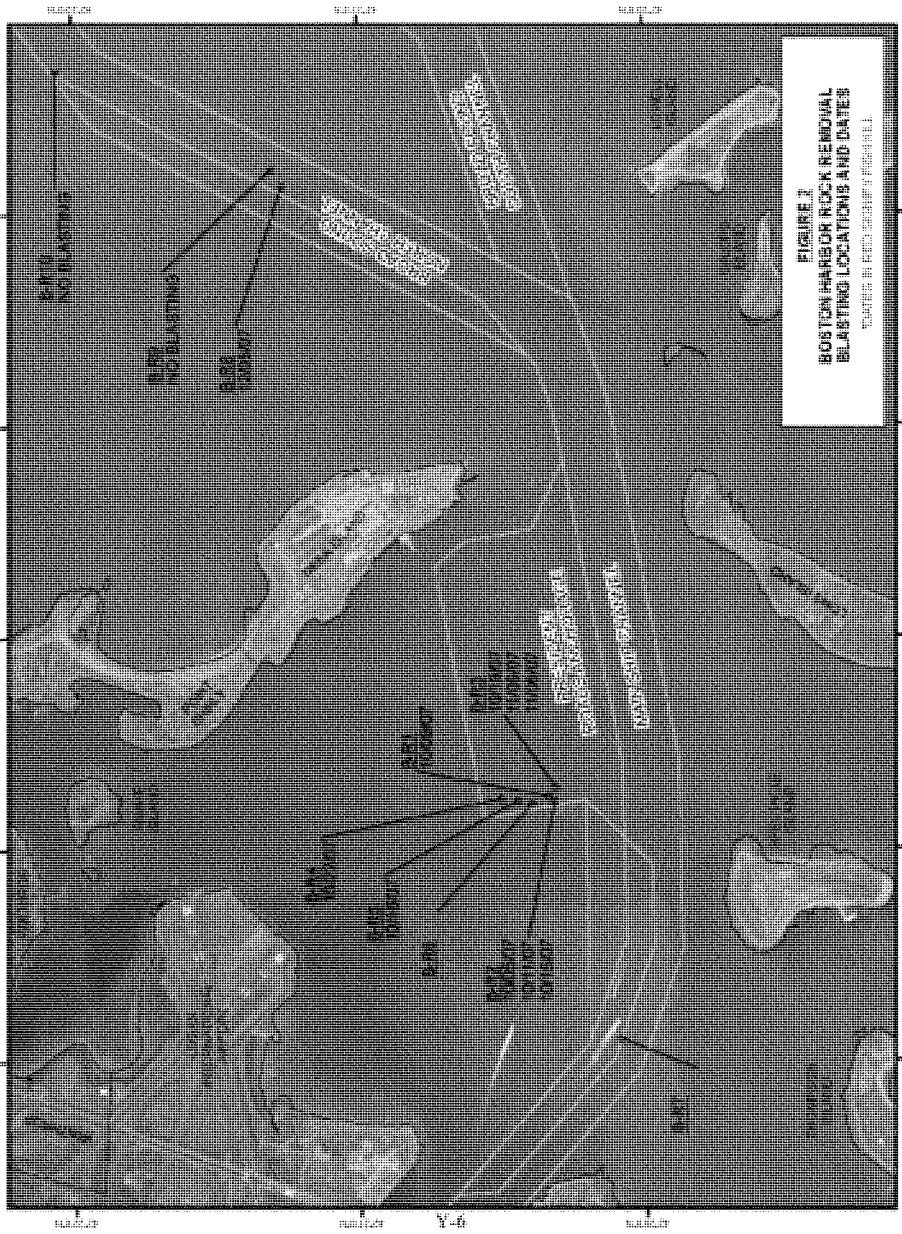
FIGURE 2
BOSTON HARBOR ROCK REMOVAL
BLASTING LOCATIONS AND DATES

Table 2. Information on Each Blast Event

Date (2007)	Location*	Weather Low/High/Rain (^{0}F/inches)	Tide	Time of Blast (PM)	Current Speed (mph)	No. of Bore Holes	Explosive (pounds)	Fish Kill
October 5	PR Anchorage	67/75	2h03m after high tide	3:18	5	34	819	No
October 9	PR Anchorage	52/61	30m before high tide	4:25	15	25	624	No
October 11	PR Anchorage	52/63/.50"	1h21m after high tide	1.23	10	36	897	No
October 15	PR Anchorage	52/66	33m after high tide	2:59	10	34	836	No
October 16	PR Anchorage	52/70	1h08m before high tide	2:00	12	29	702	No
October 19	PR Anchorage	65/70/.50"	2h58m before high tide	2:45	7	30	819	No
October 22	PR Anchorage	65/72	34m before low tide	1:52	10	28	819	No
October 24	**PR Anchorage**	**56/64**	**3h20m before low tide**	**12:54**	**7**	**14**	**351**	**Yes**
October 29	**PR Anchorage**	**37/65**	**12m after high tide**	**2:17**	**10**	**31**	**858**	**Yes**
November 5	PR Anchorage	40/55/.62"	2h08m after low tide	4:05	10	32	858	No
November 6	PR Anchorage	37/51	59m after low tide	3:46	15	34	854.1	No
November 9	**Main Ship Channel**	**32/43**	**45m before low tide**	**4:05**	**5**	**29**	**819**	**Yes**
November 14	**Main Ship Channel**	**37/60**	**3h39m after low tide**	**1:49**	**15/20**	**8**	**214.5**	**Yes**
December 5	North Channel	24/32	55m after low tide	3:11	10	22	565.5	No

*PR Anchorage=President Roads Anchorage

III. Fish Kill Events During Blasting

Despite the construction and operational fish avoidance procedures implemented, as described above in Section C, four fish mortality events were experienced over a three-week period during blast operations in the President Roads Anchorage and Main Ship Channel areas. Table 3 below provides the dates, locations, and information on approximate number of fish observed killed from each blast event. Appendix A provides the number of dead fish species collected for each fish kill event. The length and weight for individuals collected and recorded for three of the four blast events are presented in Appendix B. Length and weights for fish collected during the first blast event, October 24, 2007, were not available. The details for each fish kill event are described below.

Table 3. Date, Location, and Approximate Number of Fish Killed

Date	Location	Approximate Number of Observed Fish Killed
October 24, 2007	President Roads Anchorage	150
October 29, 2007	President Roads Anchorage	1,000
November 9, 2007	Main Ship Channel	900-1,000
November 14, 2007	Main Ship Channel	300

A. Fish Kill Number 1

1. Event Specifics

The first fish kill event occurred on October 24, 2007. The fish observer made two passes on a support vessel with the side scan sonar around the blast zone. The initial sweep identified what was believed to be a school of fish near the surface within the blast area. A second sweep was conducted and no schools of fish were observed. The startle system was removed and the blast sequence initiated. See Section C above. The blast was detonated at 12:54 pm.

After blasting occurred approximately 150 dead or injured fish were observed floating at the surface. The fish observer collected the floating fish, which he counted and identified to species. For this event, 124 rainbow smelt (*Osmerus mordax*), two alewife (*Alosa pseudoharengus*), 23 cunner (*Tautogolabrus adspersus*), three red hake (*Urophycis chuss*), and one butterfish (*Peprilus triacanthus*) were collected.

2. Discussion of a Possible Cause and Corrective Action(s) Taken

The Corps contract specification for rock removal activities required that "If at any time during the implementation of the project, a significant fish kill or significant water quality problem occurs, and can be attributed to the project, all site activities impacting the water shall cease until the source of the problem is identified. Adequate mitigating measures shall be followed as outlined in the contingency plan or upon discussion with the appropriate state and local agencies." Upon observation of the fish kill, the Corps resident engineer directed that all blasting activity cease until a mitigation/contingency

plan could be developed through coordination with affected resource agencies (NMFS, MA DMF, and the MA Department of Environmental Protection (MA DEP)). Based on the information received, NMFS stated that they considered this a significant fish kill.

As a follow-up corrective action, the Corps performed a system review to ensure that all equipment was working properly, calibration and monitoring protocols were implemented correctly, and identify corrective measures, if any, to minimize the potential for reoccurrence of a similar event. To verify that the equipment was working properly, a technician from Sonalysts (fish startle system) checked the equipment and confirmed that the system was in fact fully operational and functioning properly.

The fish startle system was located on the blast barge, deployed to a depth of 10 feet off the bottom, and removed from the water approximately one minute prior to the blast, as also outlined in the manufacturer's procedures.

After confirmation that all equipment was properly functioning and that all operational procedures had been followed, it was determined that the fish kill was most likely due to the movement of fish into the blast area after it had been scanned and cleared by the sonar system. Although two passes were made around the blast area and no fish were observed in the second pass, it is probable that fish had moved into the area through a previously scanned and cleared zone while the vessel was completing its sweeping activity of another section of the blast perimeter.

The side scan sonar projects from the vessel down to the bottom at an angle. This could result in a small "inverted cone" of the water column not being seanned as the vessel transits the perimeter of the blast site. To increase the field of vision within the water column, a modified scanning procedure was to be implemented for all future blast events. The fish observer on the sonar vessel was instructed to begin screening for schools of fish as close as possible to the blast center. He then was to move out in a spiral to capture nearly the entire water column from the surface to the bottom throughout the blast area. It was thought that this technique would minimize the potential for fish schools to enter the blast zone undetected.

B. Fish Kill Number 2

1. Event Specifics

The second fish kill occurred during the ninth blast event on October 29, 2007. At approximately 12:30 pm the loading of the charges was completed. At 12:50 pm the fish startle system was deployed from the blast support barge located within the blasting zone. At 1:00 pm the side scan sonar was deployed and activated off a support vessel that moved along the perimeter of the blast zone monitoring for schools of fish. The side scan sonar vessel traversed the majority of the blast zone circumference but avoided that portion of the area where the down tubes are located which could result in severed lines and unexploded charges. The fish observer identified schools of fish transiting the area and subsequently performed additional sweeps (approximately 20) which showed varying

amounts of fish within and transiting the area. The fish observer observed and noted that there were unusually high numbers of fish in the area. The side scan sonar had indicated that fish were rapidly moving in and out of the blast area.

As the day progressed, less fish were observed transiting through the area. The fish observer, Contractor and the Corps construction representatives evaluated the situation to try and determine what if any operational conditions might potentially be attracting fish to the blast area and what steps could be taken to discourage fish from entering the project area. Based on the sonar observations it was speculated that the fish were potentially being attracted to the shadow projecting from the barge within the water column. It was also possible that suspended organic debris in the blast area resulting from a nearby dredging operation removing rock from earlier blasts could also be attracting fish to the area. It was generally concluded that moving the barge back from the blast zone as an implementable measure that may serve to reduce fish in the area.

At 2:02 pm the barge started to pull back from the blast zone. Once this was accomplished, the Contractor assumed that it was necessary to commit to initiating the blast sequence within 10 minutes since the fish startle system was relocated beyond the range of effectiveness for the entire blast zone. Vendor specifications state that the startle system should be deployed until 10 minutes before the blast since fish would not return to the area until 15 minutes after deactivation.

In the event blasting does not occur, the barge can not be moved back into the blast area due to the presence of the down tubes that run from the barge to the charges set along the bottom. Moving the blast barge into the area after it is "backed out" would likely entangle the down tubes which could result in an incomplete blast posing a significant safety hazard to both the crew and other vessels.

The charges were set off at approximately 2:17 pm and dead fish were observed floating in the blast zone. The fish observer estimated that approximately 1,000 small bait fish floated to the surface after the blast. He began to collect the fish for analysis and identification. Seagulls were feeding on some of the floating fish during the collection. The fish collected post-blast included 103 alewife, 18 blueback herring (*Alosa aestivalis*), 30 menhaden (*Brevoortia tyrannus*), 38 Atlantic herring (*Clupea harengus harengus*), 16 rainbow smelt, five cunner, and four red hake. The fish were then delivered to MA Division of Marine Fisheries (Ms. Tay Evans). Fish lengths and weights were also recorded and are included in Appendix B.

2. Discussion of a Possible Cause and Corrective Action(s) Taken

The resulting fish kill appears to be the result of a miscommunication between the fish observer and the Contractor who believed he needed to execute the blast within 10 minutes of the removal of the fish startle system from the area and not wait for an "all clear" from the fish observer. As a result of this blast event, the following changes to blast protocols were instituted to minimize the potential for additional fish kills:

- Fish Startle System: The Contractor is to deploy the fish startle system on an alternate and more mobile vessel instead of on the blast barge. This is to allow the fish startle system to remain operational and mobile in the blast area while the blast barge is being pulled back from the area to minimize potential "attraction" to the barge shadow. It will also allow the startle system to be redeployed to the area in the event blasting is not initiated since it will have the ability to enter the area so as to not impact down tubes.
- Dredging at Adjacent Areas: Dredging at adjacent areas will be curtailed if it is determined that it is the source of any detrital plumes impacting the blast area which could potentially be acting as an attractant to fish. Dredging would be allowed to continue only during portions of a tidal cycle that results in a plume trajectory away from the blast zone.
- Improved Communication: All parties will be clearly informed of communication pathways and roles and responsibilities relative to fish observance and blast initiation. It will be emphasized that it is the sole responsibility of the fish observer to give the "all clear" signal to initiate the blasting sequence based on fish observations. The fish observer would not signal for initiation of the blast sequence until he determined, through use of the side scan sonar and any other observations that there were no schools of fish present in the blast area. The only overriding condition would be the need to initiate the blast sequence for safety reasons as directed by the safety officer. One example would be when it would be necessary to initiate a blast sequence to comply with the "45minutes prior to sunset" provision. At this point blasting must be initiated due to safety considerations and to comply with safety regulations. All involved parties are to be made aware of these protocols and the need for clear and constant communication between the fish observer and the blast barge personnel.

It is also noted that the blasting safety officer reserves the right to override the fish observer in the event that a situation develops which could jeopardize human safety. The safety officer would communicate the reasons for the override to the fish observer prior to the initiation of the blast sequence which would be documented in both the blast report and the fish observer report. An additional overriding safety requirement is that once the blast sequence is initiated with the first five minute warning blast, the blast must continue according to safety regulations.

C. Fish Kill Number 3

1. Event Specifics

The third fish kill was observed after the 12th blast event on November 9, 2007. Normal sequencing protocols were followed which incorporated the corrective actions identified after the second fish kill event. The fish startle system was deployed at 3:38 pm and removed at 4:02 pm. Schools of fish were observed sporadically on the side scan sonar transiting through the area. The barge was moved 250 feet outside the blast area. Once it was determined that no fish were in the area, an "all clear" signal was given by the fish observer and the blasting sequence was initiated. Blasting occurred at 4:05pm,

approximately 45 minutes before sunset. The corrective actions implemented after fish kill #2 were implemented for this blast event.

After the blast, approximately 900 to 1,000 fish were observed floating on the surface. Less than 100 fish were collected with a dip net until no more fish were observed at the surface. As in previous events seagulls fed on the floating fish. The majority of the fish collected were blueback herring (80) and menhaden (14). The length, weight, and species of fish collected were recorded.

2. Discussion of a Possible Cause and Corrective Action(s) Taken

For safety reasons, blasting needed to be initiated 45 minutes before sunset. Although no fish were observed when the "all clear" signal was given by the fish observer, it is possible that because fish had been previously seen sporadically transiting the project area on the side scan, that some of these fish moved into the blast area after the "all clear" signal was given.

D. Fish Kill Number 4

1. Event Specifics

The fourth and last fish kill event occurred after the 13th blast event on November 14, 2007. Approximately 300 fish were observed floating or being eaten by the seagulls, far less fish than the last fish kill event. About one-fourth the amount of explosives was used for the third fish kill than was used for this blast event. Only six fish were collected, mainly due to gusty winds and wave action which carried the fish out of the area. All the fish collected were menhaden. Lengths and weights were recorded and presented in Appendix B.

2. Discussion of a Possible Cause and Corrective Action(s) Taken

As in Event #3, the corrective actions recommended after Fish Kill Event Number 2 were implemented during this event. The fish startle system was located on a separate boat, no dredge plume from adjacent dredging operations were observed in the area, and the blasting sequence was not initiated until after the fish observer has swept the area and had given an "all clear" signal.

After this event it was agreed that the Corps agreed would prepare an "After Action Report" to document the blasting operations and fish kill events to discuss lessons learned and possible recommendations for consideration in the development of a comprehensive blasting plan for the upcoming Boston Harbor Deep Draft Project.

E. Note

After the last blast event on December 5, 2007, it was noted that one fish, a menhaden (97 mm long and weighing 8 grams), was observed floating at the surface in the Broad

Sound North Channel. There were no other fish observed floating at the surface after the blast.

IV. Lessons Learned and Corrective Actions to be Instituted for Future Blast Events

Based on the events that occurred in 2007 during rock removal operations, the following recommendations should be considered for implementation for future blasting events.

A. Communication Plans

1. Fish Observer/Contractor Communication Plan

The contract specification on fish protection will clearly identify, with the exception of an overriding safety issue as identified in the previous sections, that it is the sole responsibility of the fish observer to determine when conditions are favorable for the blasting sequence to be initiated based on fishery observations. The fish observer will give approval for initiation of the blast sequence until s/he has determined, through use of appropriate technology, that no schools of fish are present in the blast area. However, it is recognized that the on-site safety officer has the authority and responsibility to override the fish observer's determination at those times when either safety concerns or regulatory compliance becomes an issue. The specifications will outline required protocol and the need for clear and constant communication between the fish observer and the blast barge personnel.

2. Fish Observer Reports

The fish observer will prepare an after action report for all blast events monitored, regardless of whether the event resulted in a fish kill. The report should include the date and time monitoring was initiated, deployment and retrieval of the fish startle system, the time of the blast, current speed and direction, tidal conditions, and weather observations throughout the day, and other pertinent observations. The fish observer will note if fish were observed in the project area prior to blasting and if there were any dead or injured fish after the blast. The fish observer must record the number of fish killed or injured, and species including representative sizes and weights. Any equipment or operational issues that may have contributed to the fish kill will also be noted.

The fish observer will report his/her findings to the Resident Engineer for each day of blasting. The Resident Engineer will compile the previous week's reports and forward to the Project Manager or Study Manager and the Environmental Resources Team Member. If a fish kill is observed, the Resident Engineer will notify the Project Manager or Study Manager and the Environmental Resources Team Member immediately. Pertinent information along with the fish observer's report will be forwarded to the above parties as soon as possible. Based on the fish observer's report, the Project Manager, or Study Manager, will convene a meeting with the Resident Engineer and appropriate personnel

to discuss events and to determine what, if any, corrective actions can be taken to reduce the changes of further fish kills.

3. External Communication Plan

In the event of a fish kill, the Project Manager or Environmental Team Member will notify the appropriate resource agencies as soon as possible after the event. Additional communication will occur as soon as all pertinent facts and issues surrounding the event have been determined. In the case of the Boston Harbor Deep Draft Project, the NMFS, U.S. EPA, MA DEP, MA DMF, MA Coastal Zone Management Office, and Massport will receive a copy of the fish observers report along with other factual information. If determined necessary, a meeting and/or conference call will be scheduled between the Corps, Massport, and the resource agencies to discuss and identify potential corrective measures. These measures will then be forwarded along with the fish observer report to the agencies.

B. Operational Changes to Minimize Potential for Fisheries Impact

The Contractor will deploy the fish startle system on an alternate vessel instead of the blast barge to allow greater coverage of the blast area and extend duration of the systems deterrence action just prior to blasting. This will allow the fish startle system to stay deployed in the blast area while allowing the blast barge to be pulled back from the area to minimize potential fish "attraction" to the barge shadow in the water column.

It is possible that a dredging plume may serve as an attractant to the fish towards the blast zone. Consequently, it is recommended that any dredging activities adjacent to the area of blasting occur when tidal conditions allow for the transport of resuspended material to move any residual plumes away from the blast area(s).

Additional conversation among the Corps, their blasting contractor, and the fish observer resulted in identifying some additional operational steps that could potentially be taken for future blasting events to help deter the presence of fish in the blast area. These included the use of setting off small charges in the blast area to "scare" the fish from the area or perhaps using bait to attract the fish to another area. After further discussion with the blasting contractor the use of small charges as a deterrent was dismissed since the blast is set off through a percussion process. Small charges could prematurely set of the blast for a percussion process which would constitute a significant safety hazard. Small charges can only be used when electric charges are used.

"Baiting" was another suggestion to draw fish away from the blast zone. However, it would likely act as an attractant for other fish and could make the situation worse. Also, since the target species (herring) are primarily planktonic feeders, appropriate bait was questionable.

V. Discussions for Development of a Blast Plan

In order to move the development of a formal blast plan for both the upcoming Boston Harbor Deep Draft Project and other similar type Corps projects forward, scheduled meetings should be held with the blast subgroup of the Technical Working Group for the Boston Harbor Deep Draft Project. This subgroup would identify blast issues that require further discussion, research, and resolution for incorporation into the plan. At a minimum, the following items should be included for discussion:

- Significance – What constitutes a significant fish kill and what would determine the need for corrective actions, and mitigative measures?
- Mitigation Measures and Operational Approaches – What are the available mitigation measures that can be incorporated into the blast plan? What approaches should be considered and incorporated into the dredge plan to minimize impacts to fisheries?
- Time of Year and Sequencing – Time of year and sequencing approaches based on the presence of fish resources should be explored with the resource agencies as a mitigative tool to minimize blasting impact to fishery resources.

Discussion with the resource agencies should occur to determine, based on the species of concern prevalent in the harbor, and the amount of rock to be blasted in the various harbor locations, what time of year blasting should occur in the harbor and in which location or tributaries.

C. Plan of Action for Fish in the Blast Zone

A discussion of alternatives, if any, should be considered for those times when the side scan sonar survey indicates large numbers of fish are in the blast zone throughout the day and the charges have been set. According to the fish observer (personal communication June 17, 2008), no fish were observed on the side scan sonar during the non-fish kill events. (The exception to this is the first fish kill; during this event, no smelt were observed on the sonar.) This would indicate that, in general, the sonar can and did detect schools of fish in the blast area. There may be days when a suitable time to initiate blasting is not available due to the presence of fish observed in the blast area. Alternatives, if available, should be explored when this condition arises. Safety may dictate that blasting will need to be initiated, even if there are schools of fish in the area.

APPENDIX A

Table A-1. Number and Fish Species Collected By Blast Date

Common Name	Latin Name	Fish Kill Dates (2007)				Total Number of Fish Collected
		October 24	October 29	November 9	November 14	
Alewife	*Alosa pseudoharengus*	2	103			**105**
Atlantic herring	*Clupea harengus harengus*		38			**38**
Blueback herring	*Alosa aestivalis*		18	80		**98**
Butterfish	*Peprilus triacanthus*	1				**1**
Cunner	*Tautogolabrus adspersus*	23	5			**28**
Menhaden	*Brevoortia tyrannus*		30	14	6	**50**
Rainbow smelt	*Osmerus mordax*	124	16			**140**
Red hake	*Urophycis chuss*	3	4			**7**
Total Number of Fish Collected		**153**	**214**	**94**	**6**	**467**

APPENDIX B

Table B-1. Length and Weight of Fish Species Collected October 29, 2007

Alewife		Atlantic Herring		Blueback Herring		Cunner		Menhaden		Rainbow Smelt		Red Hake	
L (mm)	W (g)	L (mm)	W (g)	L (mm)	W (g)	L (mm)	W (g)	L (mm)	W (g)	L (mm)	W (g)	L (mm)	W (g)
135	18	138	20	123	17	58	3	98	8	103	5	92	4
157	28	118	11	139	19	55	2	99	9	105	6	80	3
145	26	136	18	155	27	75	8	100	9	125	10	72	2
142	22	158	25	143	22	53	2	102	7	135	14	62	1
137	20	143	22	127	14	38	1	100	11	117	8		
167	37	160	30	120	12			99	10	105	6		
138	19	140	20	125	13			92	7	111	8		
153	29	156	30	137	18			82	5	120	8		
167	38	140	21	143	17			83	7	92	4		
226	94	150	22	120	12			95	7	123	11		
146	23	152	22	119	11			92	8	100	5		
147	24	152	28	117	12			102	11	127	11		
194	70	150	26	137	19			95	7	130	12		
135	19	170	40	141	20			100	9	115	9		
146	26	182	43	120	13			100	9	111	7		
1X*	17	160	30	132	18			81	7	112	7		
167	40	143	23	139	20			85	5				
150	26	152	24	120	13			100	9				
156	27	136	20	122	13			98	8				
148	26	169	33					85	6				
130	17	150	24					110	13				
145	25	134	27					92	7				
145	25	138	20					93	8				
139	20	177	41					113	13				
132	18	162	33					89	6				
150	23	165	34					88	7				
150	26	140	18					100	10				
160	32	130	17					92	7				
145	30	145	21					93	7				
169	39	148	24					100	9				
144	23	140	20										

*1X = No Tail

Table B-1 (cont.). Length and Weight of Fish Species Collected October 29, 2007

Alewife		Atlantic Herring		Blueback Herring		Cunner		Menhaden		Rainbow Smelt		Red Hake	
L (mm)	W (g)	L (mm)	W (g)	L (mm)	W (g)	L (mm)	W (g)	L (mm)	W (g)	L (mm)	W (g)	L (mm)	W (g)
155	27	141	20										
150	27	142	22										
135	20	158	30										
145	22	138	20										
138	19	144	24										
153	28	150	25										
153	32	128	16										
152	28												
177	40												
138	20												
157	32												
148	24												
162	32												
130	17												
133	19												
165	36												
145	23												
158	30												
135	18												
135	20												
157	32												
142	21												
134	18												
150	26												
157	29												
136	20												
156	27												
155	30												
141	20												
155	29												
137	19												
158	34												

Table B-1 (cont.). Length and Weight of Fish Species Collected October 29, 2007

Alewife		Atlantic Herring		Blueback Herring		Cunner		Menhaden		Rainbow Smelt		Red Hake	
L (mm)	W (g)	L (mm)	W (g)	L (mm)	W (g)	L (mm)	W (g)	L (mm)	W (g)	L (mm)	W (g)	L (mm)	W (g)
149	25												
142	23												
171	38												
149	23												
158	31												
143	23												
138	22												
129	17												
151	27												
156	29												
155	29												
155	29												
135	20												
168	37												
139	20												
135	17												
156	27												
177	45												
138	20												
157	28												
140	22												
129	16												
161	31												
161	35												
152	28												
130	17												
167	36												
139	20												
147	24												
147	25												
148	24												
145	23												

Table B-1 (cont.). Length and Weight of Fish Species Collected October 29, 2007

Alewife		Atlantic Herring		Blueback Herring		Cunner		Menhaden		Rainbow Smelt		Red Hake	
L (mm)	W (g)	L (mm)	W (g)	L (mm)	W (g)	L (mm)	W (g)	L (mm)	W (g)	L (mm)	W (g)	L (mm)	W (g)
145	24												
150	25												
166	33												
149	25												
173	40												
150	26												
142	21												
128	16												

Table B-2. Length and Weight of Fish Species Collected November 9, 2007

Blueback Herring				Menhaden	
Length (mm)	Weight (g)	Length (mm)	Weight (g)	Length (mm)	Weight (g)
99	7	102	8	75	4
100	7	94	6	108	12
89	5	93	6	96	9
93	6	88	5	83	6
98	7	98	6	70	4
90	5	94	6	61	2
95	6	100	7	70	3
103	8	97	7	64	2
93	6	92	6	81	5
94	6	93	6	54	2
97	8	97	7	80	5
95	8	97	7	60	2
113	11	90	6	59	2
105	9	93	6	57	2
96	8	97	7		
101	9	96	6		
108	10	106	9		
90	6	87	5		
98	7	104	9		
103	9	92	6		
96	6	88	5		
99	7	104	8		
104	8	94	7		
85	5	98	7		
95	7	96	7		
93	6	99	7		
103	8	100	8		
101	7	90	6		
113	10	91	5		
94	6	90	5		
94	6	97	7		
96	7	94	5		
108	9	90	6		
92	6	91	6		
96	7	85	5		
90	6	99	7		
100	7	96	7		
92	6	99	7		
91	6	110	9		
90	6	99	7		

Table B-3. Length and Weight of Fish Species Collected November 14, 2007

Menhaden	
Length (mm)	**Weight (g)**
90	6
62	2
50	1
61	2
51	1
65	3

BOSTON HARBOR
MASSACHUSETTS

DEEP DRAFT
NAVIGATION IMPROVEMENT STUDY

FINAL FEASIBILITY REPORT
AND FINAL SUPPLEMENTAL
ENVIRONMENTAL IMPACT STATEMENT
AND MASSACHUSETTS
FINAL ENVIRONMENTAL IMPACT REPORT

APPENDIX Z

UNDERWATER SOUND RESULTS
FOR BLASTING IN BOSTON HARBOR
SEPTEMBER 2012 ROCK REMOVAL

THIS APPENDIX HAS REPLACED THE REPORT INCLUDED IN THE JULY 2008 DRAFT

tech environmental
FOCUSED KNOWLEDGE. REAL SOLUTIONS.

September 10, 2012

Mr. Craig Burnham
Burnham Associates Inc.
14 Franklin Street
Salem, Ma 01970

Re: Underwater Sound Results for Blasting in Boston Harbor – September 6, 8 and 10 Blasts

Dear Craig:

Tech Environmental (TE) is please to provide this report on the underwater sound monitoring done during the blasts on September 6, 8, and 10 to clear navigational hazards in Boston Harbor.

Methods and NMFS Sound Criteria

Undersea sound measurements were made with a calibrated Bruel & Kjaer (B&K) model 8104 Hydrophone on a custom-made 100-meter cable, connected through a charge amplifier to a calibrated B&K model 2250 Type 1 Sound Analyzer. TE positioned the hydrophone in the lower third of the water column, and began logging sound levels at least 1 minute prior to the blast event and continued 1 minute after the blast event. The sampling train is designed to measure undersea sound over a spectrum of 12 Hz to 20 kHz, which covers the hearing range of most marine mammals. The equipment measured sound pressure levels (rms) in dBL re 1 micro-Pascal (μPa) and data were logged at 100-ms intervals. Both broadband and 1/3-octave band measurements were made.

The National Marine Fisheries Service (NMFS) guidelines, as listed in Section 1.3.3.1(d) of your permit, are as follows. The onset of Level A (injury) harassment is 205 dB re 1 μPa^2-sec. The onset of Level B harassment is 182 dB re 1 μPa^2-sec (non-injury/physiological) and 177 dB re 1 μPa^2-sec (behavioral). The Level B thresholds apply for the energy flux density (EFD) in any 1/3-octave band. Demonstrating that the broadband EFD does not exceed 177 dB re 1 μPa^2-sec satisfies all three NMFS guidelines.

From the time series sound pressure level measurements, EFD was calculated using the method by Madsen[1]:

$$\text{EFD [dB re 1 } \mu Pa^2\text{-sec]} = \text{rms-Sound Pressure Level [dB}_{rms}\text{ re 1 } \mu Pa] + 10*\log_{10}(T),$$

where the duration T is given by the time that incorporates 90% of the total energy of the impulse wave.

[1] Madsen, P.T., "Marine mammals and noise: problems with rms sound pressure levels for transients," J. Acoust. Soc. Am. **117**(6), June 2005.

Blast Report Data

On September 6, the blast event occurred at 4:11 p.m. and consisted of 12 delays (each consisting of a 17 to 32 lb charge) timed 25-ms apart with an approximate total duration of 300 milliseconds (ms). The total powder loaded was 314 pounds of Hydromite. The hydrophone was positioned at a setback distance of 600 feet from the detonation area.

On September 8, the blast event occurred at 11:17 a.m. and consisted of 15 delays (each consisting of a 6.25 to 33.5 lb charge) timed 25-ms apart with an approximate total duration of 375 milliseconds (ms). The total powder loaded was 407 pounds of dynamite. The hydrophone was positioned at a setback distance of 783 feet from the detonation area.

On September 10, the blast event occurred at 11:42 a.m. and consisted of 17 delays (each consisting of a 17.8 to 38.8 lb charge) timed 25-ms apart with an approximate total duration of 425 milliseconds (ms). The total powder loaded was 554 pounds of dynamite. The hydrophone was positioned at a setback distance of 930 feet from the detonation area.

Measured Underwater Sound Pressure Levels and EFD

Figures 1, 2 and 3 present the 100-ms rms-sound pressure levels (dB_{rms} re 1 µPa) as a function of time for the blasts on September 6, 8 and 10, respectively. The series of detonators going off produce the initial rise in sound pressure level. Then, the blast wave arrives at the hydrophone. Given the proximity to Castle Island and the relatively shallow waters of the harbor (38 to 50 feet at the time of the blasts), there were echoes of the pressure wave from shore and the harbor bottom, extending the acoustic event out to about 3 seconds in length in each case. The duration T, representing 90% of the total cumulative energy of the event, is a much shorter time due to the logarithmic nature of the decibel scale.

Blast 1 - September 6

The rms-sound pressure level corresponding to the ramp-up 5% threshold of total cumulative energy is 170 dB_{rms} re 1 µPa. The distance on the graph between the 170 dB values at ramp-up and ramp-down is approximately T = 0.9 seconds.

The rms-sound pressure level over T was calculated as the energy-average of the nine 100-ms values within the 90%-pulse area and equals 187.6 dB_{rms} re 1 µPa. The calculated broadband EFD is thus 187.6 – 0.5 = **187.1 dB re 1 μPa^2-sec** at a setback distance of **600 feet** for a maximum powder/delay of 32 pounds (Hydromite).

Blast 2 - September 8

The rms-sound pressure level corresponding to the ramp-up 5% threshold of total cumulative energy is 169 dB_{rms} re 1 µPa. The distance on the graph between the 169 dB values at ramp-up and ramp-down is approximately T = 0.9 seconds.

The rms-sound pressure level over T was calculated as the energy-average of the nine 100-ms values within the 90%-pulse area and equals 187.6 dB_{rms} re 1 µPa. The calculated broadband EFD is thus 186.6 – 0.5 = **186.1 dB re 1 μPa^2-sec** at a setback distance of **783 feet** for a maximum powder/delay of 32 pounds (dynamite).

Blast 3 - September 10

The rms-sound pressure level corresponding to the ramp-up 5% threshold of total cumulative energy is 166 dB_{rms} re 1 µPa. The distance on the graph between the 166 dB values at ramp-up and ramp-down is approximately T = 0.8 seconds.

The rms-sound pressure level over T was calculated as the energy-average of the eight 100-ms values within the 90%-pulse area and equals 184.2 dB_{rms} re 1 µPa. The calculated broadband EFD is thus 184.2 – 1.0 = **183.2 dB re 1 μPa^2-sec** at a setback distance of **930 feet** for a maximum powder/delay of 32 pounds (dynamite).

Comparison of Results to NMFS Criteria

Blast 1 - September 6

The measured EFD of 187.1 dB re 1 μPa^2-sec is below the NMFS Level A (injury) threshold for the setback distance of 600 feet. Whereas the broadband EFD is above the Level B (non-injury/ physiological) and Level B (behavioral) thresholds, it was necessary to look at the data for the individual 1/3-octave bands and find the band with the highest EFD, which is the band with the highest rms-sound pressure level within the period T. These data are graphed in Figure 4. **The 125 Hz band has the highest EFD at 179.2 dB re 1 μPa^2-sec**. The 50 Hz band has the second-highest EFD at 176.1 dB re 1 μPa^2-sec. Whereas the highest band EFD is slightly above the NMFS Level B (behavioral) threshold of 177 dB re 1 μPa^2-sec, the exclusion zone for this blast needs to be increased slightly. Attenuation of 2.2 dB is achieved under spherical wave spreading (which is the best approximation for close source-receiver distances) by increasing the distance from 600 feet to 773 feet.

Blast 2 - September 8

The measured EFD of 186.1 dB re 1 μPa^2-sec is below the NMFS Level A (injury) threshold for the setback distance of 783 feet. Whereas the broadband EFD is above the Level B (non-injury/ physiological) and Level B (behavioral) thresholds, it was necessary to look at the data for the individual 1/3-octave bands and find the band with the highest EFD, which is the band with the highest rms-sound pressure level within the period T. These data are graphed in Figure 4. **The 315 Hz band has the highest EFD at 177.4 dB re 1 μPa^2-sec**. Whereas the highest band EFD rounded to a whole decibel meets the NMFS Level B (behavioral) threshold of 177 dB re 1 μPa^2-sec, the exclusion zone for this blast is 783 feet.

Blast 3 - September 10

The measured EFD of 183.2 dB re 1 μPa^2-sec is below the NMFS Level A (injury) threshold for the setback distance of 930 feet. Whereas the broadband EFD is above the Level B (non-injury/ physiological) and Level B (behavioral) thresholds, it was necessary to look at the data for the individual 1/3-octave bands and find the band with the highest EFD, which is the band with the highest rms-sound pressure level within the period T. These data are graphed in Figure 4. **The 400 Hz band has the highest EFD at 177.2 dB re 1 μPa^2-sec**. Whereas the highest band EFD rounded to a whole decibel meets the NMFS Level B (behavioral) threshold of 177 dB re 1 μPa^2-sec, the exclusion zone for this blast is 930 feet.

Conclusions

The exclusion zone is determined by the distance needed to reduce the peak 1/3-octave band Energy Flux Density (EFD) to 177 dB re 1 μPa^2-sec or less, the most restrictive of the three NMFS underwater sound guidelines. The underwater sound measurements made during the September 6 and 8 blasts in Boston Harbor both established an exclusion zone distance of roughly 780 feet to ensure compliance with all NMFS Level A and Level B harassment thresholds. The measurements made during the September 10 blast, however, suggest a much larger exclusion zone distance of 930 feet is necessary.

Normalized by distance, the peak 1/3-octave band EFD for the September 10 blast released 35% more energy than the September 8 blast. Both of those blasts used dynamite, and the September 10 blast had a total powder charge 36% larger than that of the September 8 blast. We conclude that if future blasts on this project do not exceed the total powder charge of the September 10 blast (554 pounds) that an exclusion zone of 930 feet should be sufficient to ensure compliance with the NMFS Level A and Level B thresholds. These results are specific to the site of the blast (type of sediment, water depth, water currents, charge layout, distance to shore) and the charges used. Sound levels for other blasts in Boston Harbor may reveal slightly different results.

Please call if you have any questions.

Sincerely yours,

TECH ENVIRONMENTAL, INC.

Peter H. Guldberg

Peter H. Guldberg, INCE, CCM
President
3583/Report Sept 10 2012

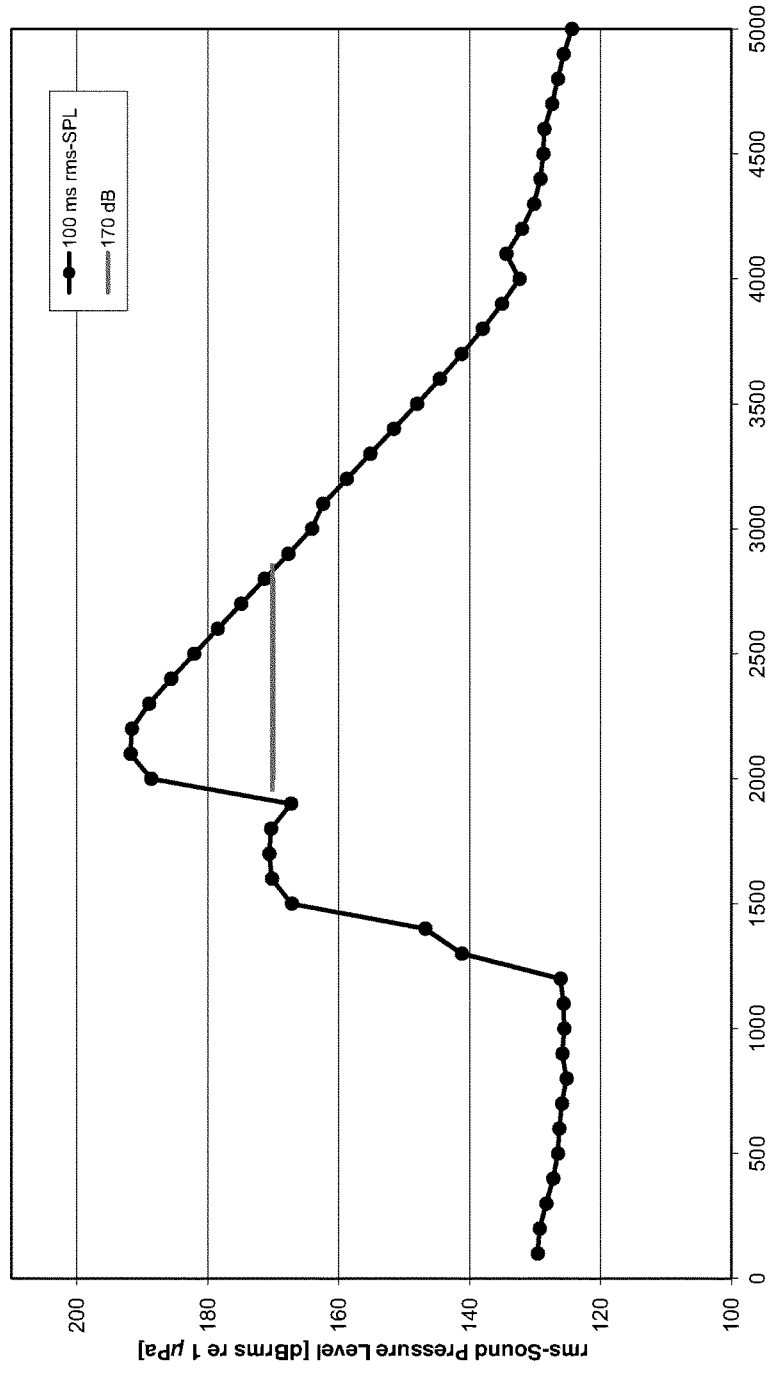

Figure 1. Underwater Blast Event #1 Boston Harbor September 6, 2012

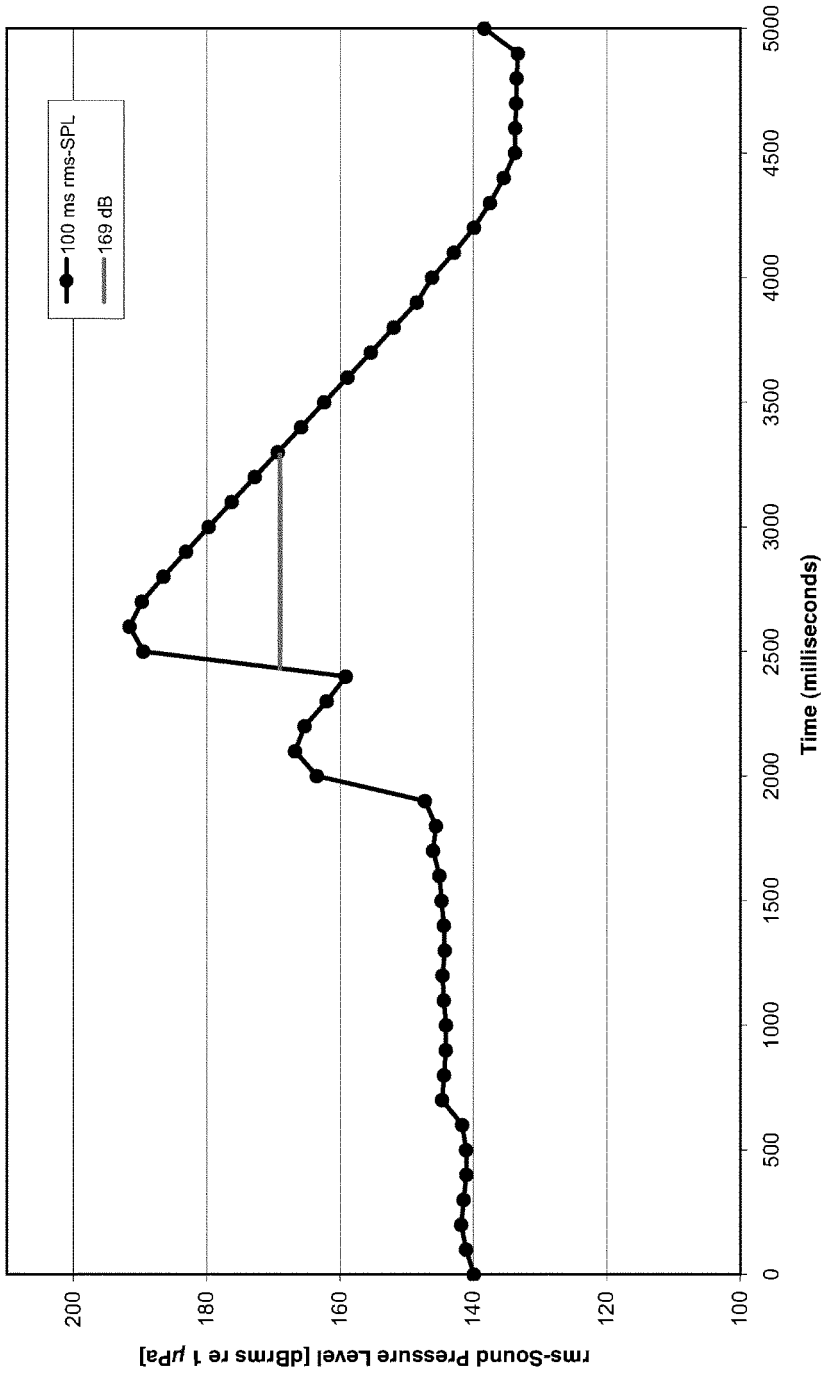

Figure 2. Underwater Blast Event #2 Boston Harbor
September 8, 2012

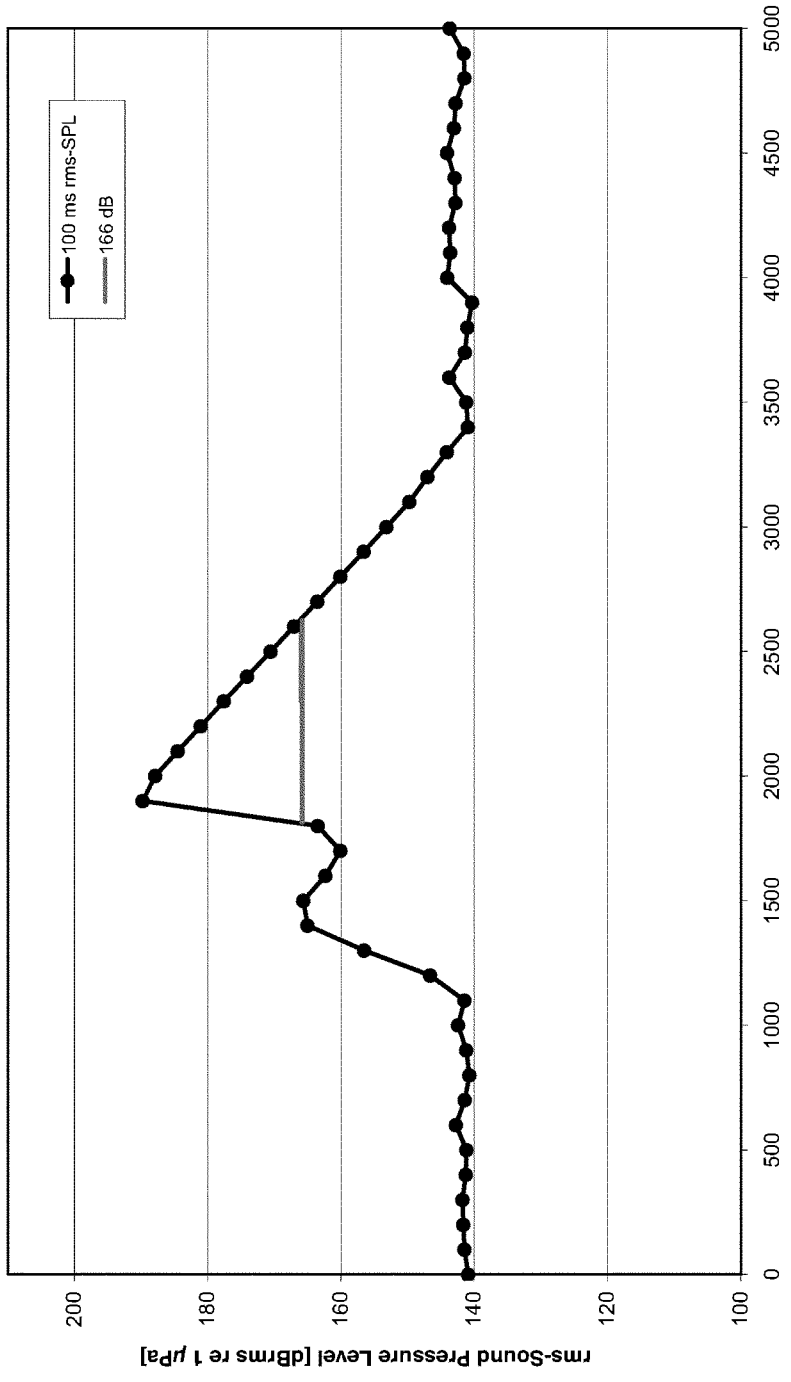

Figure 3. Underwater Blast Event #3 Boston Harbor
September 10, 2012

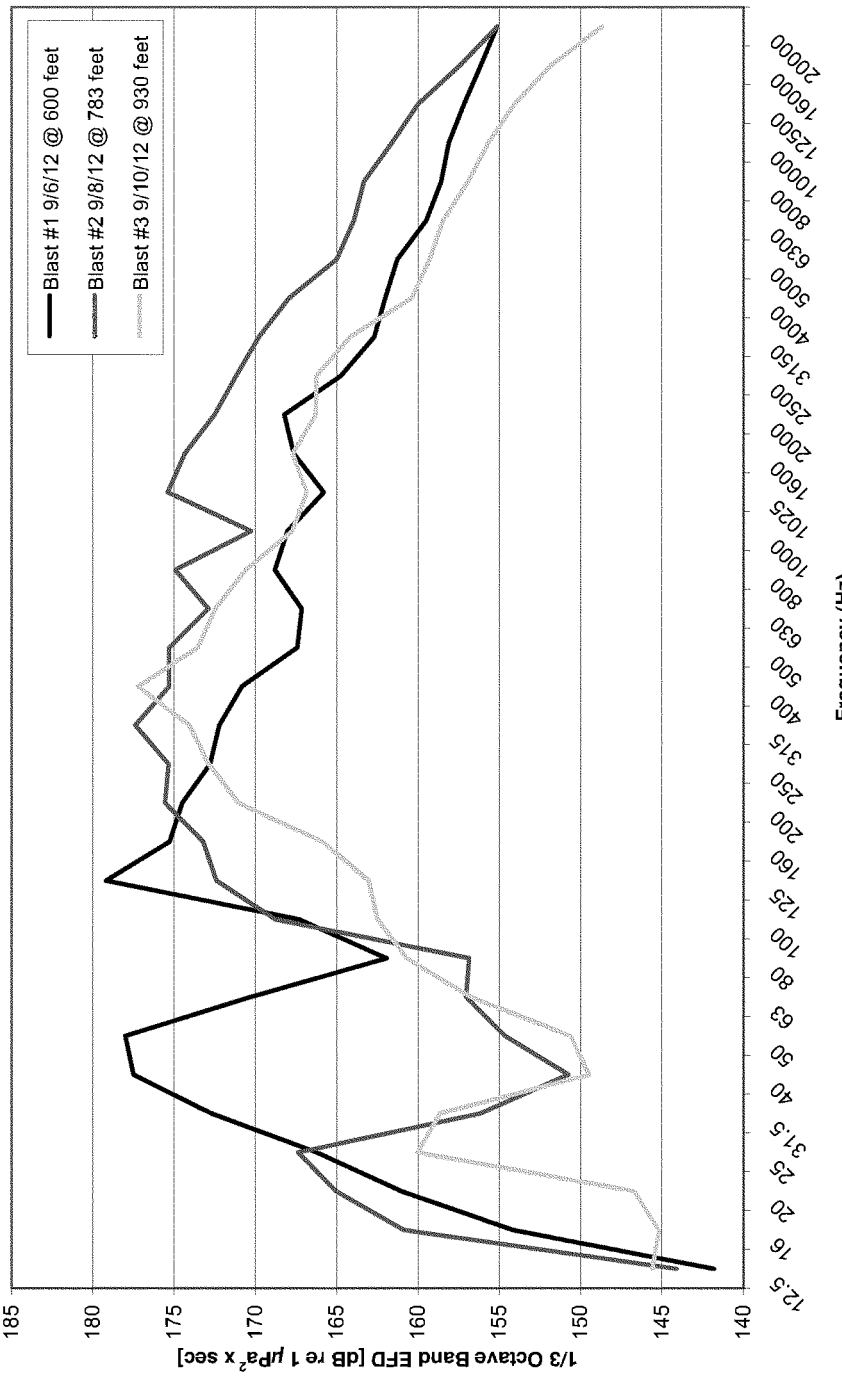

Figure 4. 1/3 Octave Band Energy Flux Density From Blast Events