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

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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,

fr KF

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
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Duxbury, MA 02322

Prepared By: Ocean Surveys, Inc.
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21 May 2003

TABLE OF CONTENTS

Appendices

Addendum

FIGURES

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.

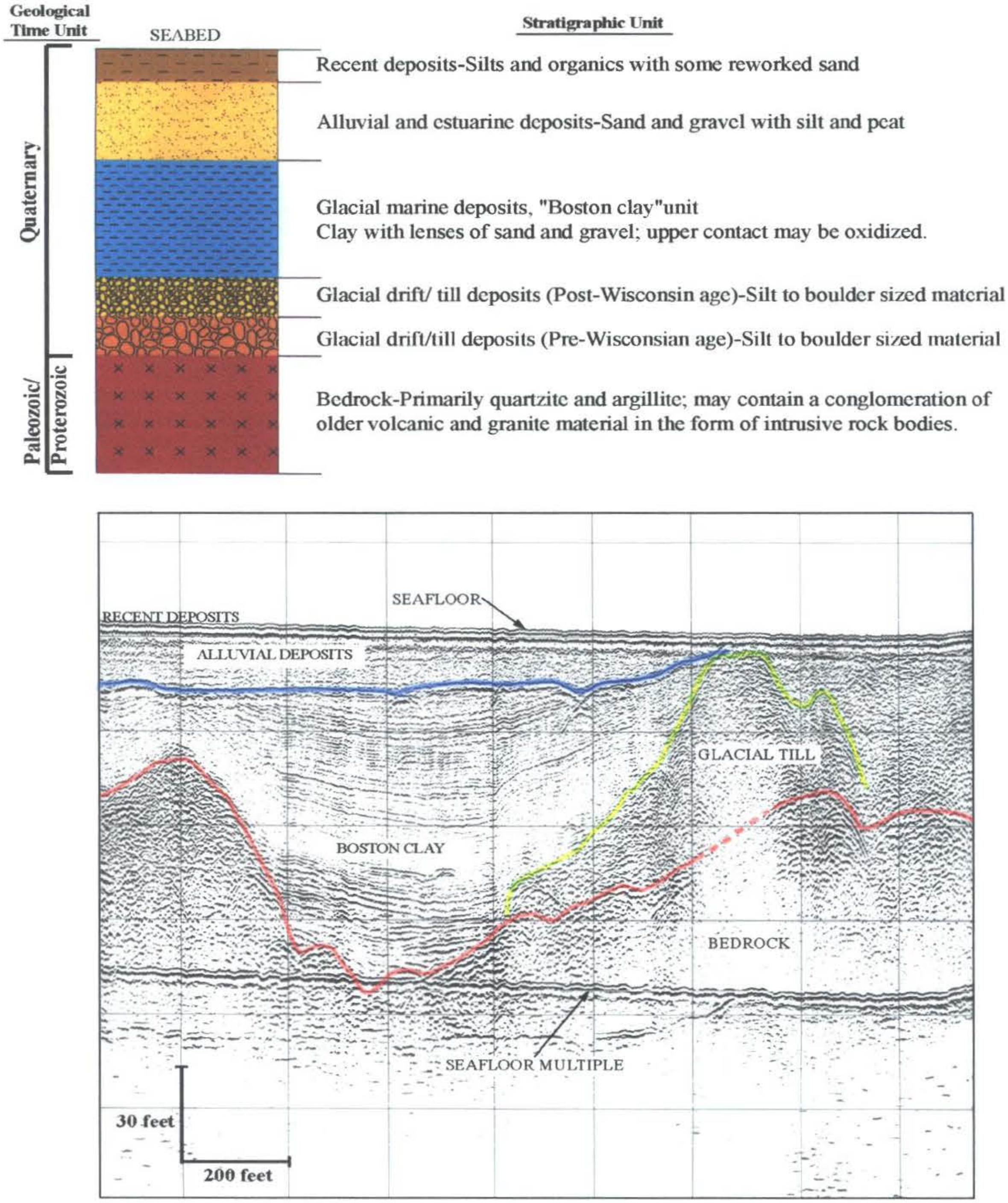

Figure 2. Idealized geologic cross section representing the marine stratigraphic framework that exists in the Boston Harbor area (upper), and the corresponding seismic returns that characterize each of the stratigraphic units (lower).

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.

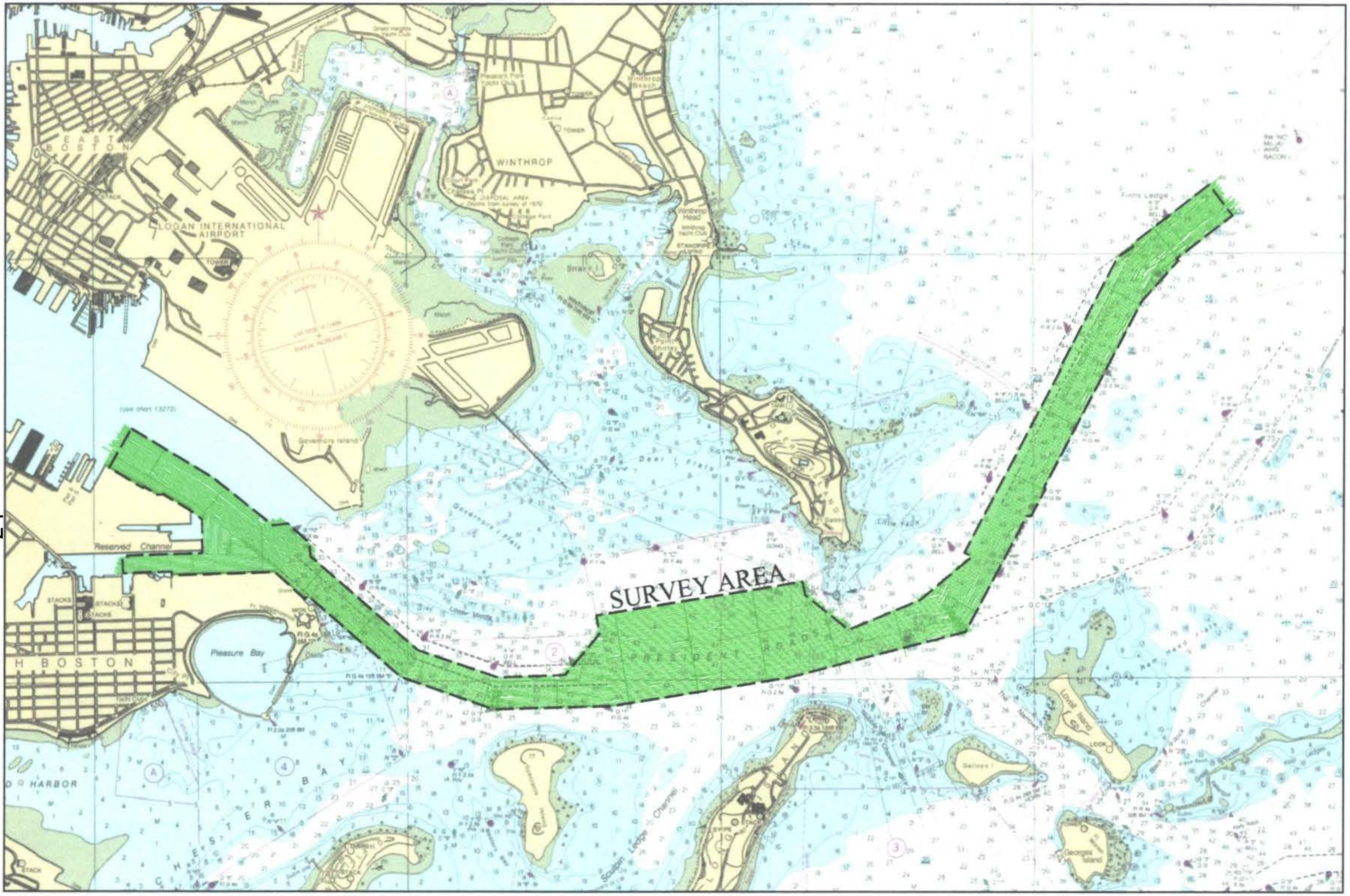

Figure 3. Main harbor tracklines.

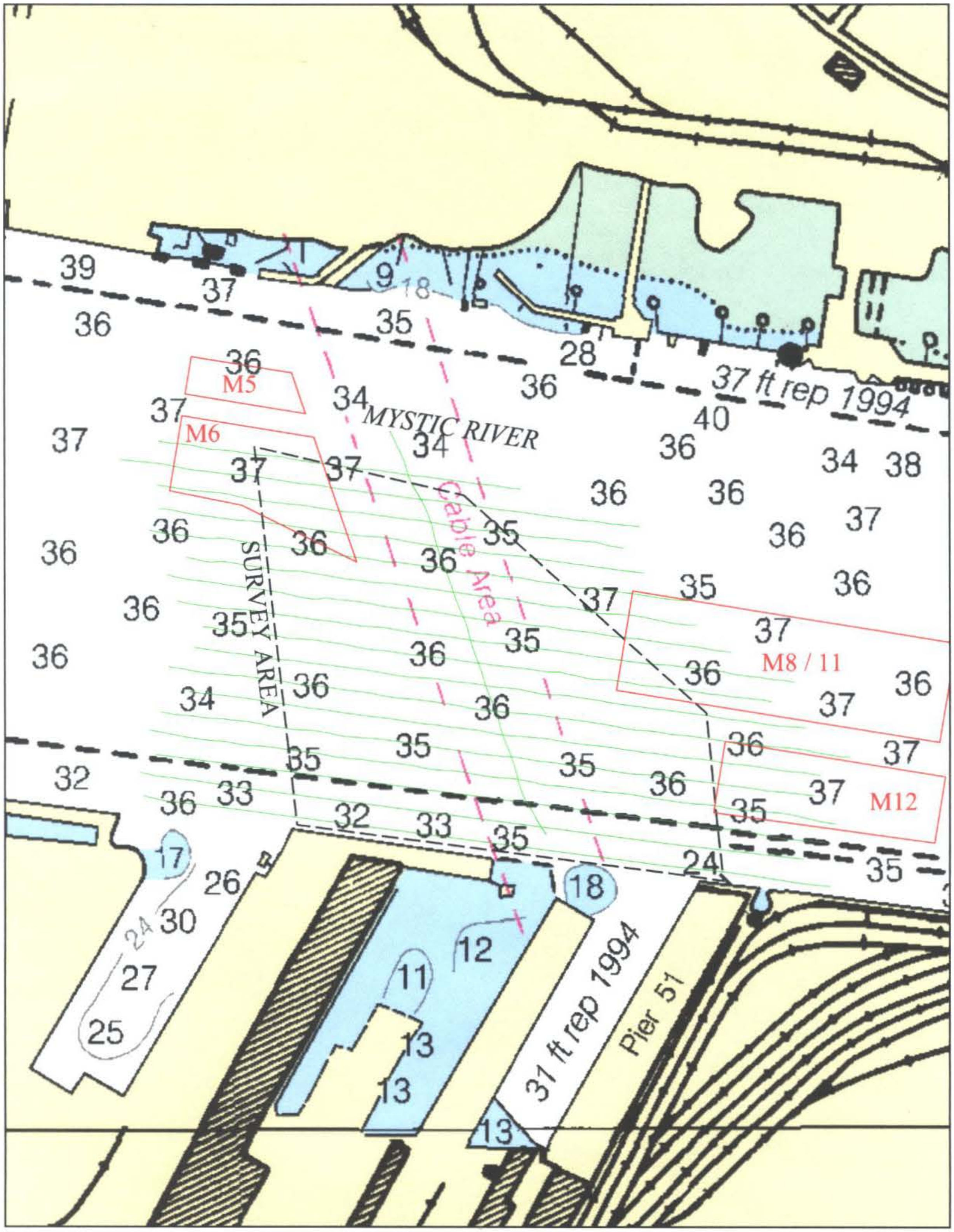

Figure 4. Mystic River site and tracklines (green).

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.

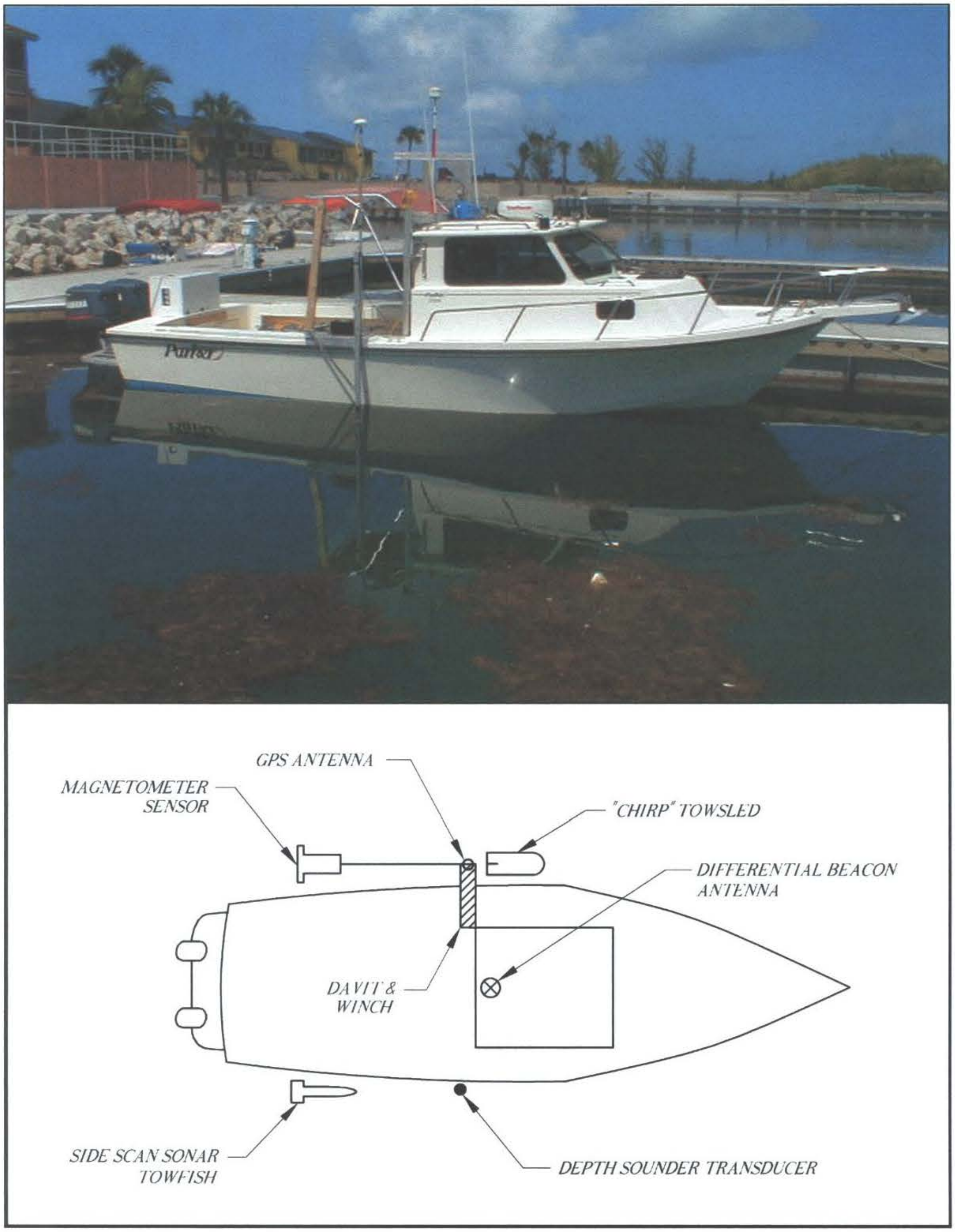

Figure 5. Equipment configuration aboard the survey vessel RV Parker Sport.

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.

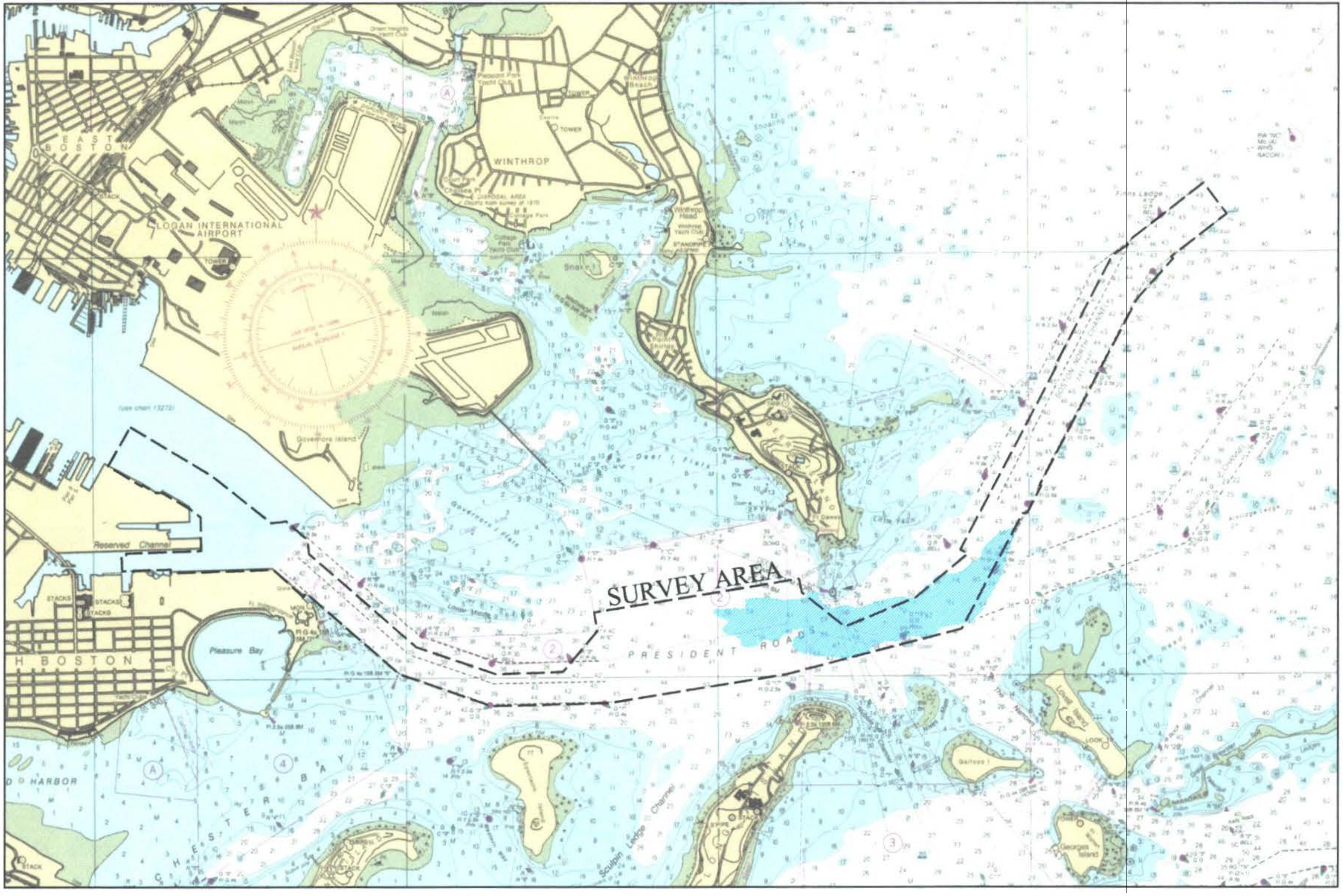

Figure 6. 55 Foot water depth limits (cyan).

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

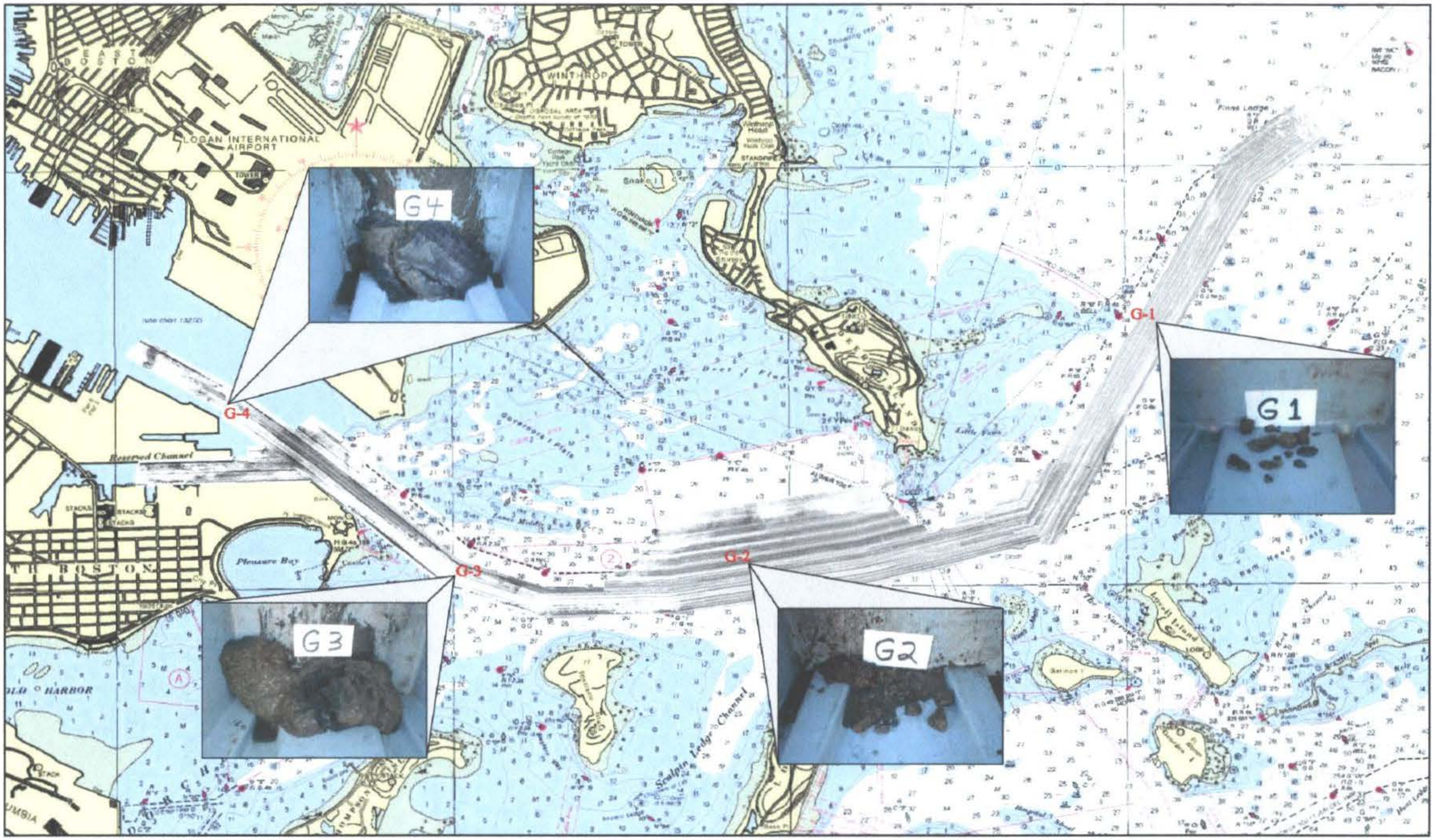

Figure 7. Grab sample locations and photographs of recovered sediments positioned on the side scan sonar mosaic.

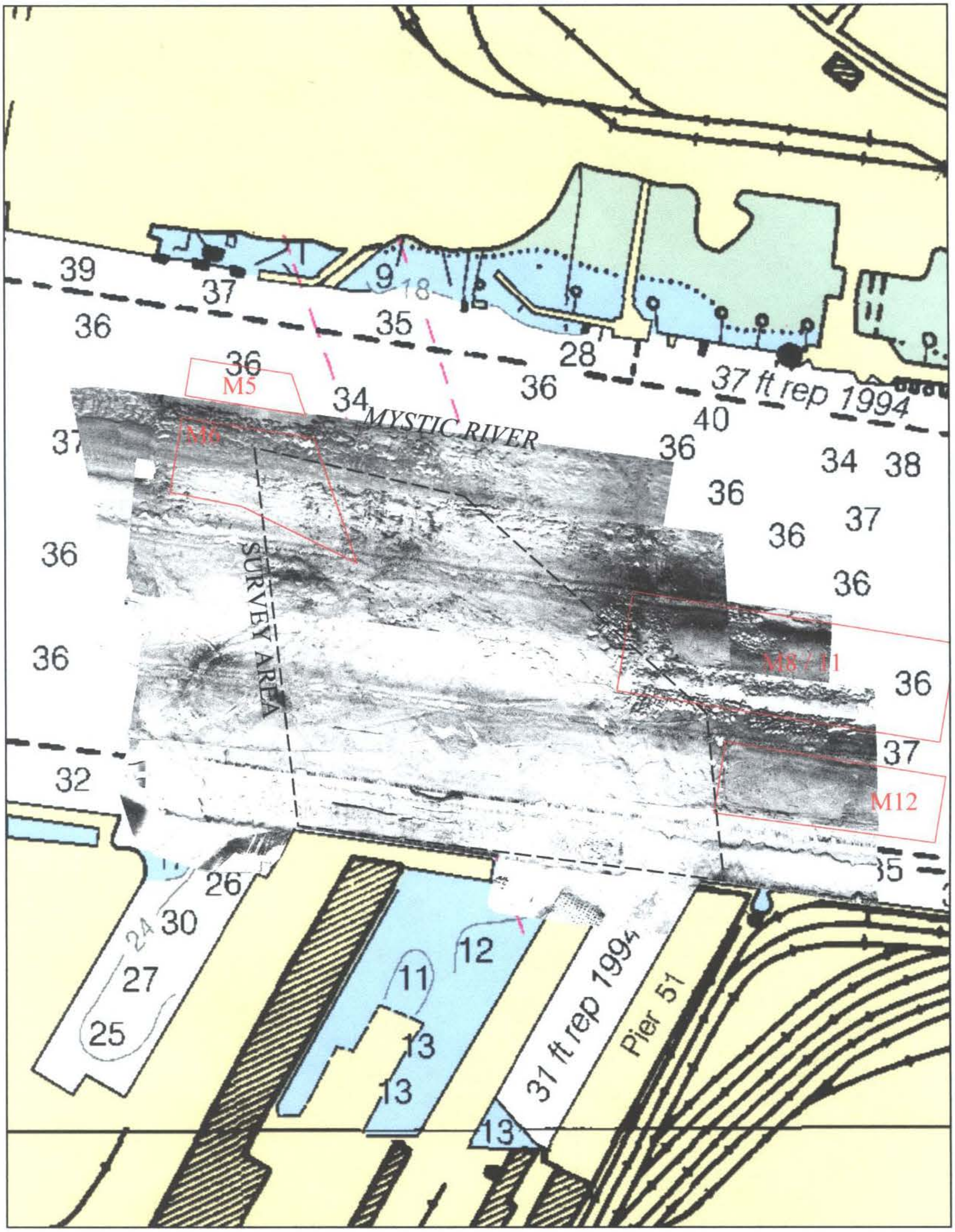

Figure 8. Side scan sonar mosaic in Mystic River site.

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

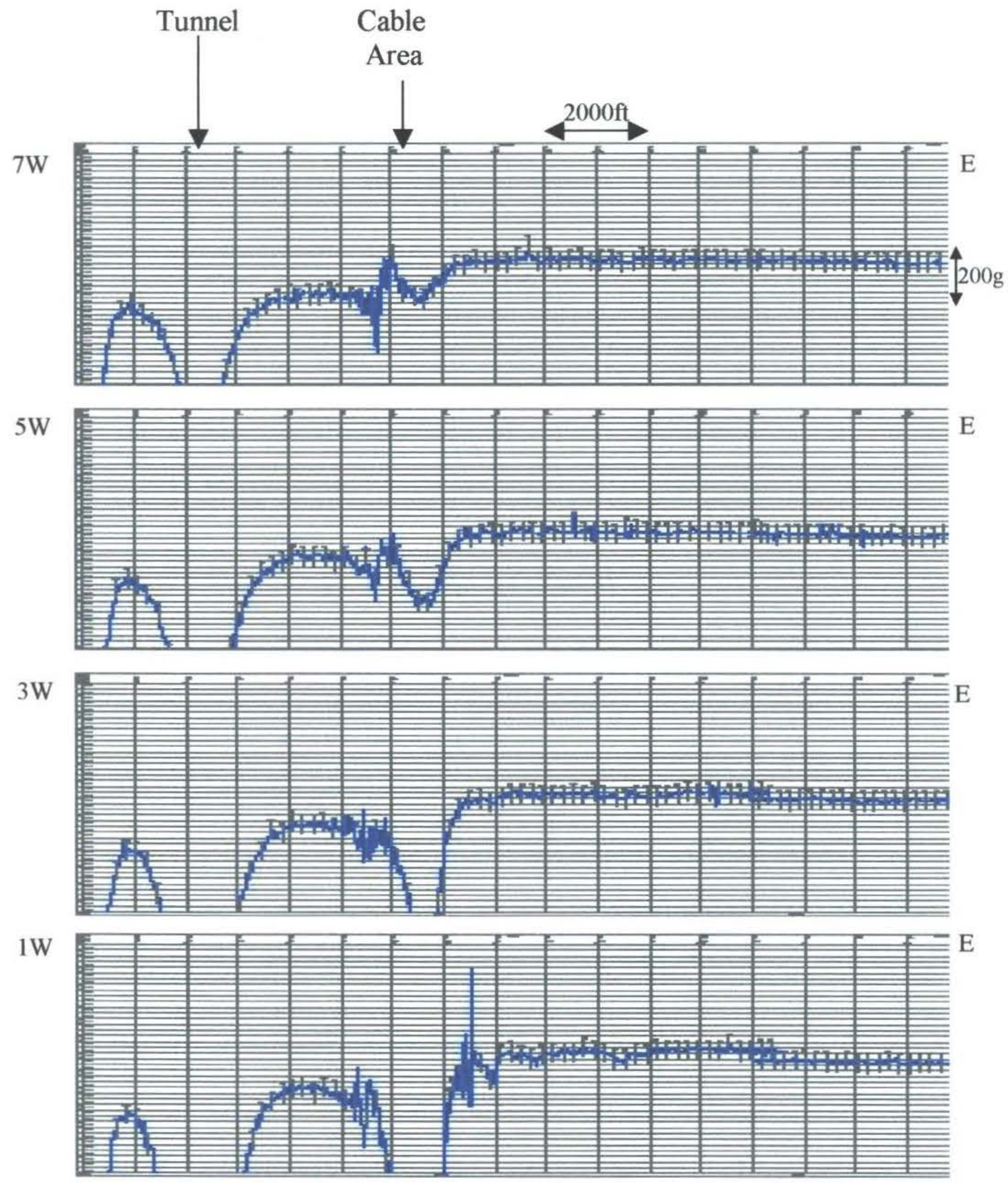

Figure 9. Magnetic intensity profiles along adjacent tracklines illustrating the anomalies in the vicinity of the third harbor tunnel and cable crossing area just south of the Reserve Channel. The profile lengths shown above are approximately 17000ft, starting at the northwestern end of the survey route, 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).

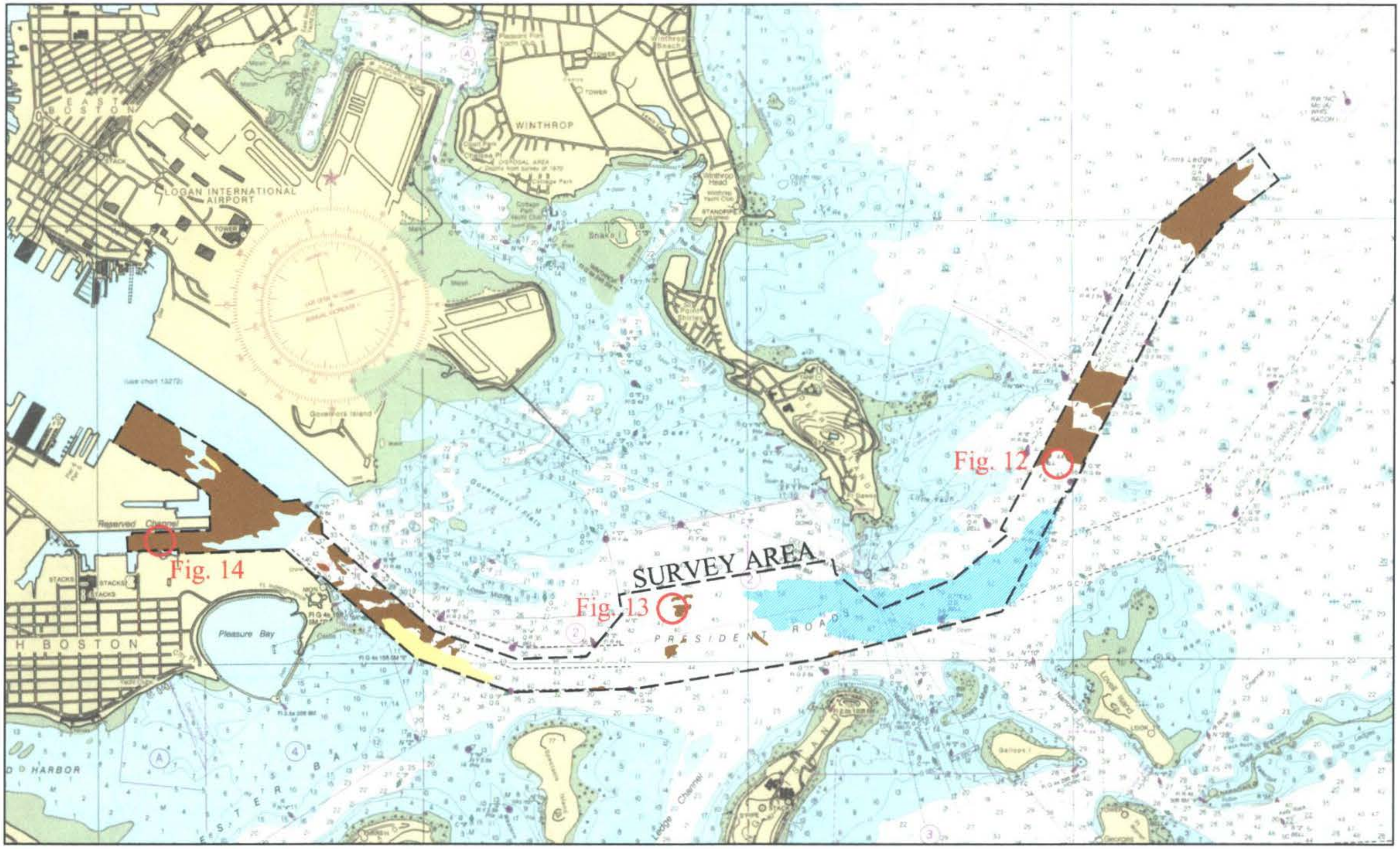

Figure 10. Map of the main survey area showing region with water depths greater than 55 ft (cyan), areas where acoustic basement is Less than 55 ft (brown), and areas containing organic-rich sediments (yellow). Locations of seismic profiles shown in other report figures are also included.

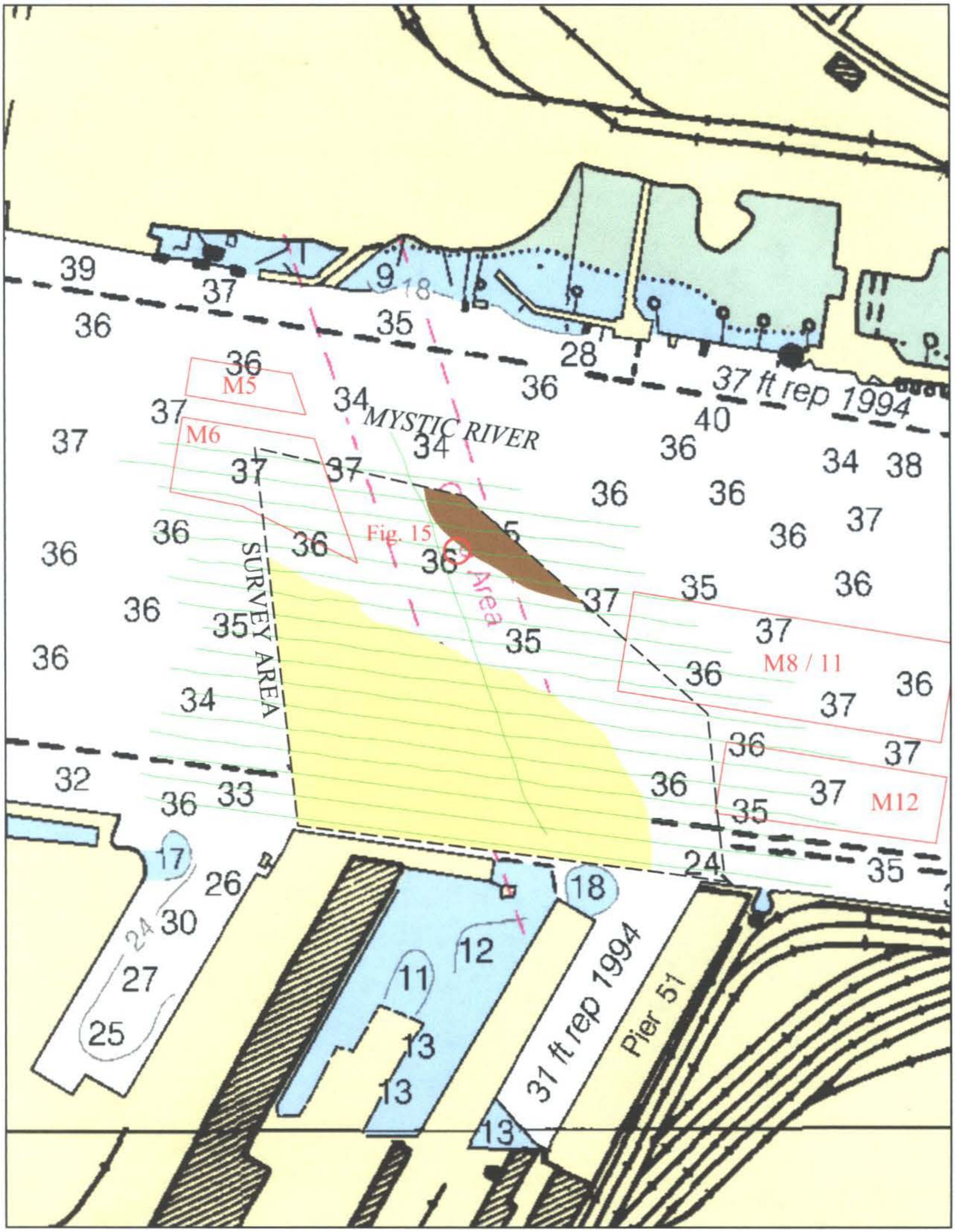

Figure 11. Mystic River geophysical interpretation.

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.

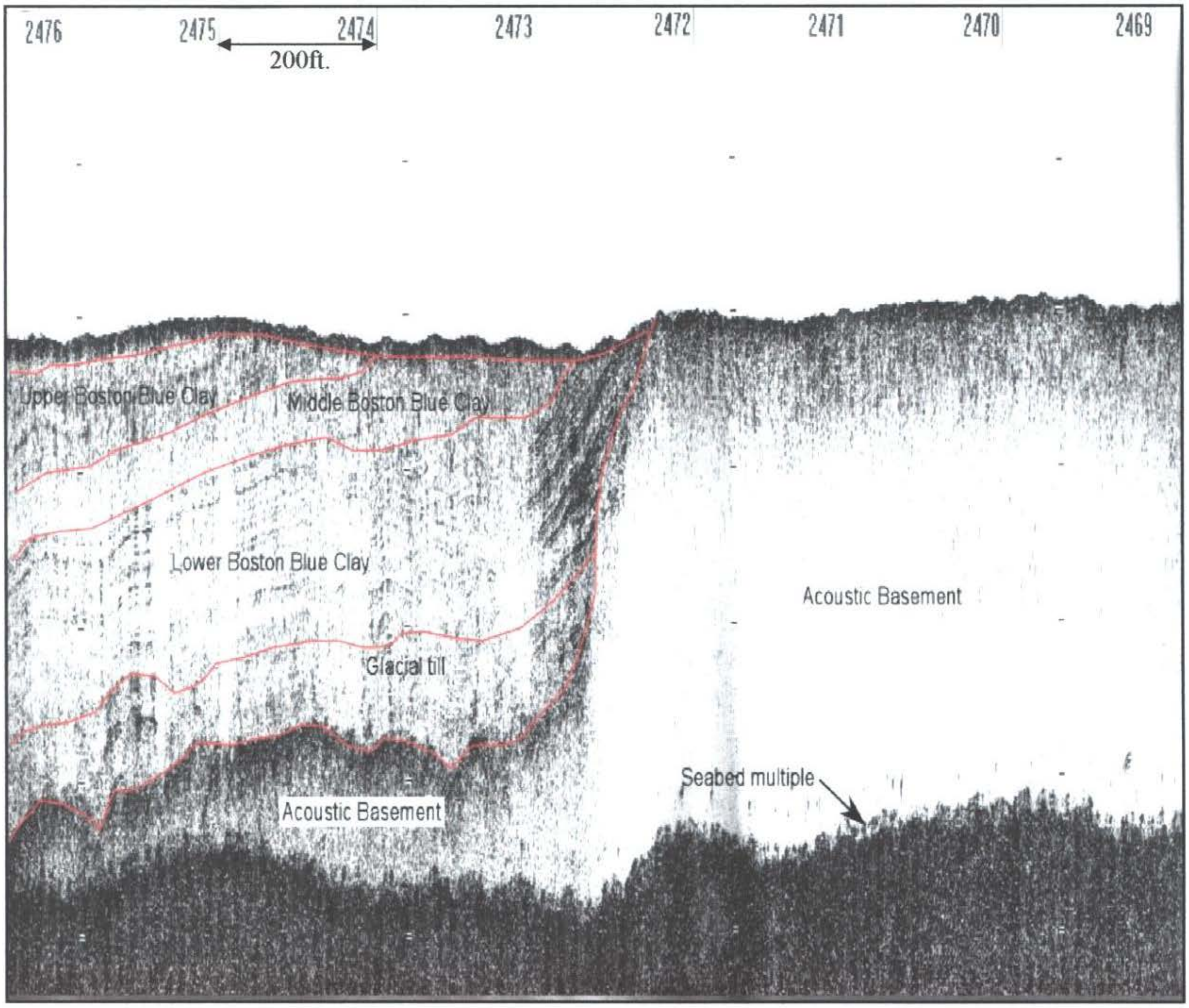

Figure 12. This profile shows an example of the rapid transition from finer unconsolidated material (mainly sand with some gravel on left side of image) to coarse glacial till with bedrock outcrop at the surface (right side of image). This is due to the steeply sloping (? degrees) metamorphic rock which 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.

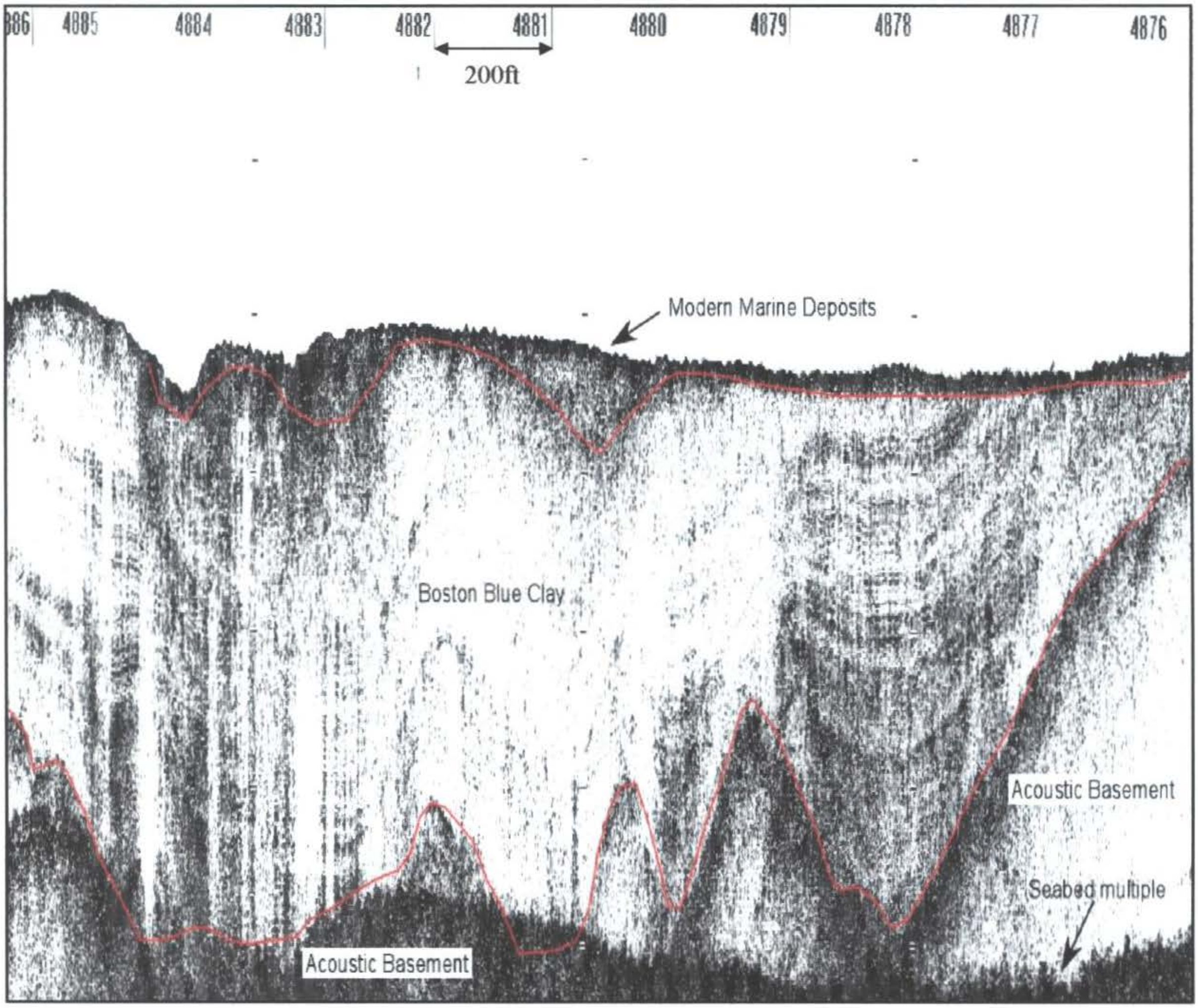

Figure 13. Subbottom profile collected in Anchorage No. 2 in President Roads revealing a relatively thick sediment sequence over acoustic basement / bedrock. The acoustic basement approaches the project depth of interest on the right side of the image.

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.

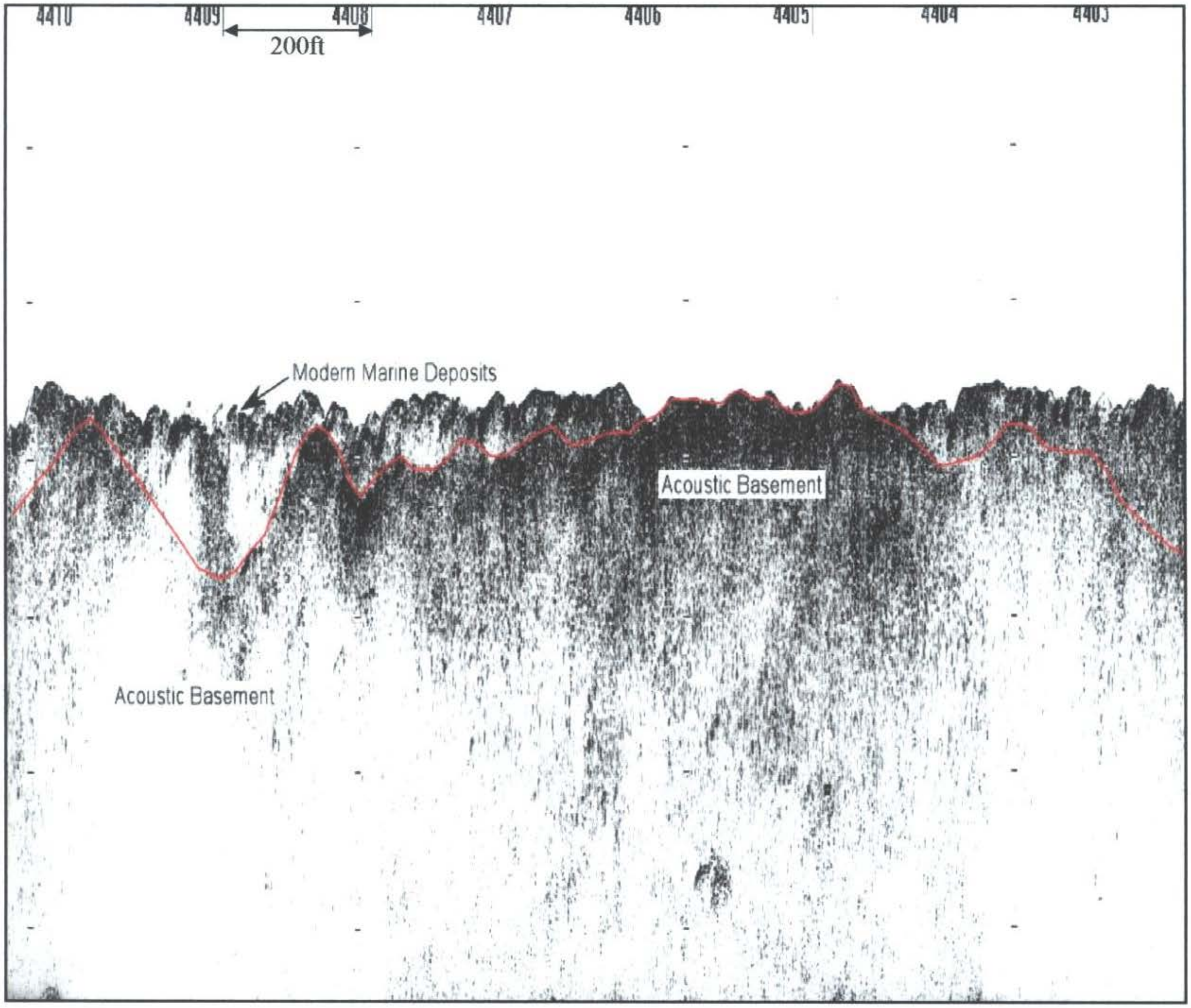

Figure 14. Section of a subbottom profile collected in the Reserve Channel showing the close proximity of the acoustic basement reflector to the bottom. The irregular bottom surface is likely the result of dredging and the constant reworking of surficial sediments from the large ships inbound and outbound 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

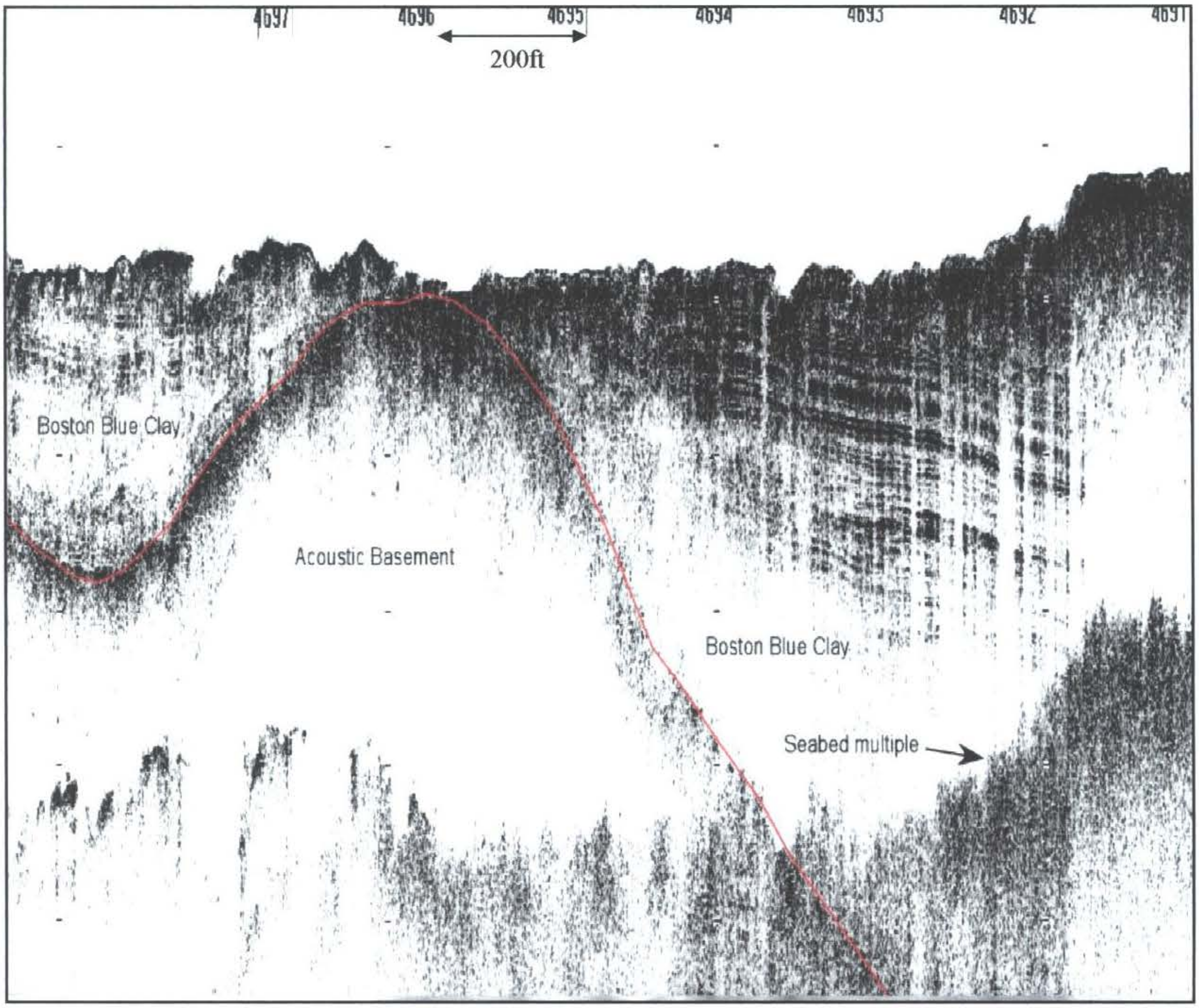

Figure 15. Image of the subbottom stratigraphy that exists below the Mystic River survey site. The acoustic basement reflector slopes up to the riverbed in the northeast corner of the survey area. The thinly laminated sediments visible throughout Boston Harbor mark the presence of the Boston blue clay. 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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United States Geological Survey, 2000, Massachusetts Bay Seafloor Mapping, URL: http://crusty.er.usgs.gov/mbay/mapping.html

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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)

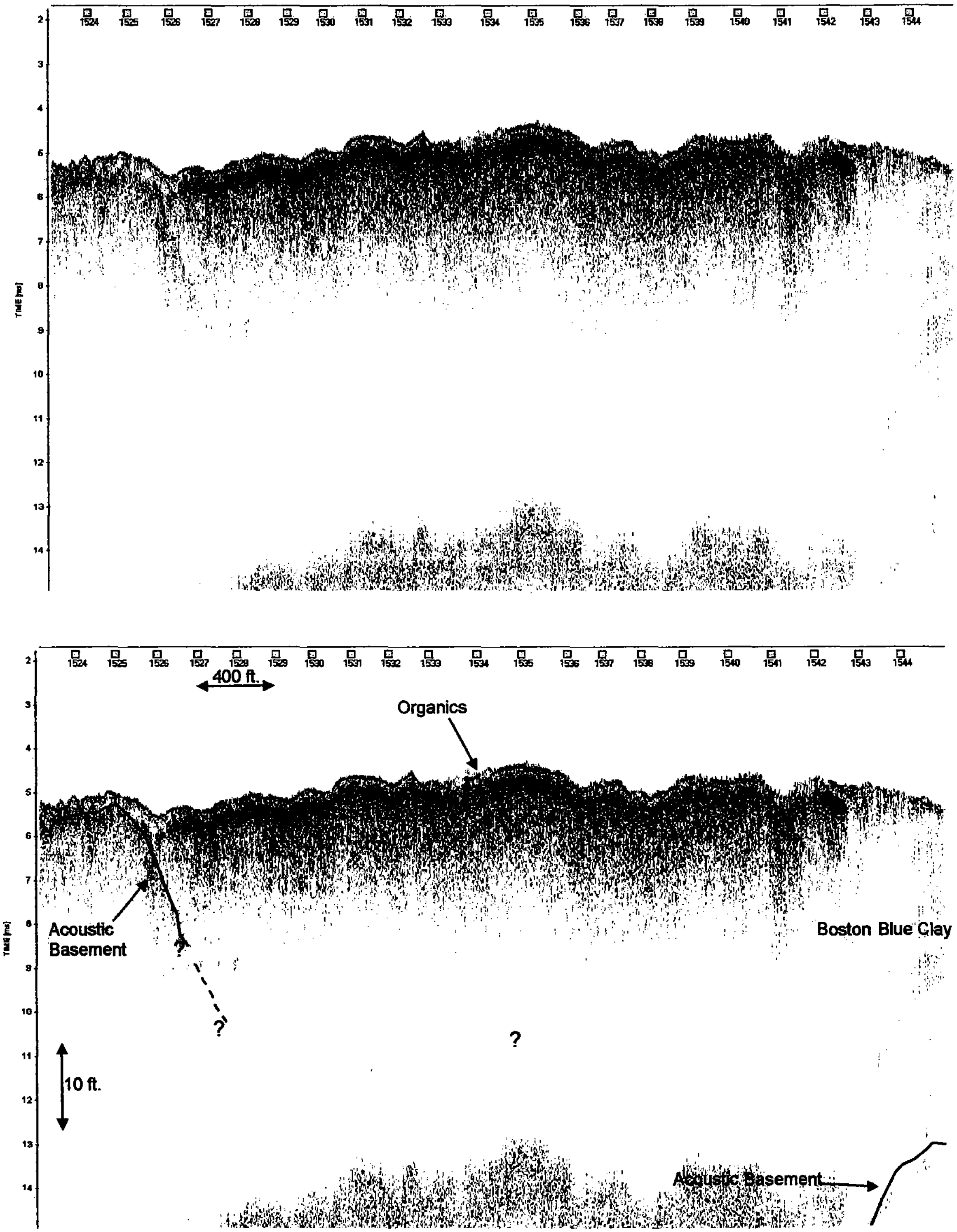

Figure 1. Subbottom profiler record (above) and the same record annotated (below) showing subsurface returns typical of the area.

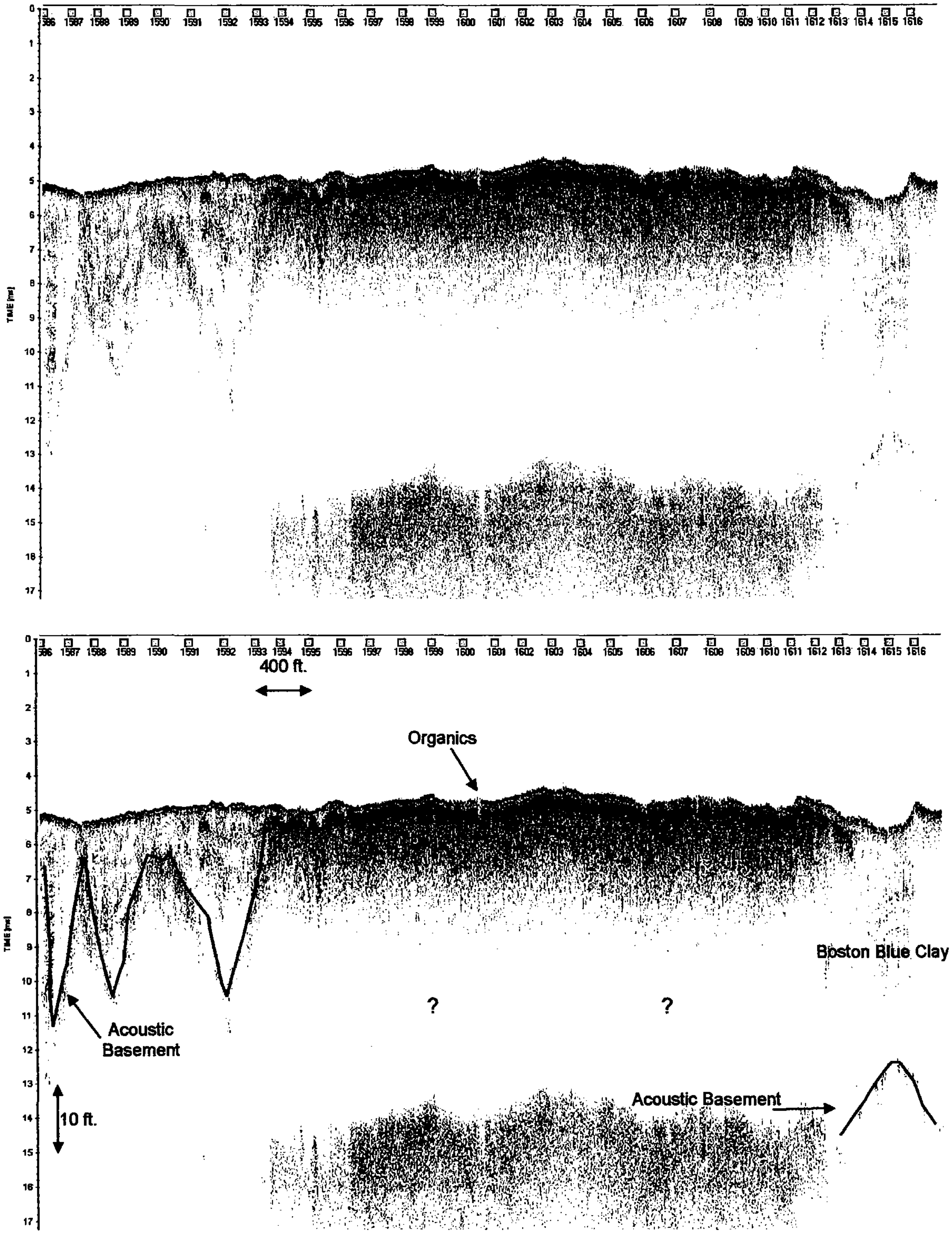

Figure 2. Subbottom profiler record (above) and the same record annotated (below) showing types of returns typical in the area.

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.

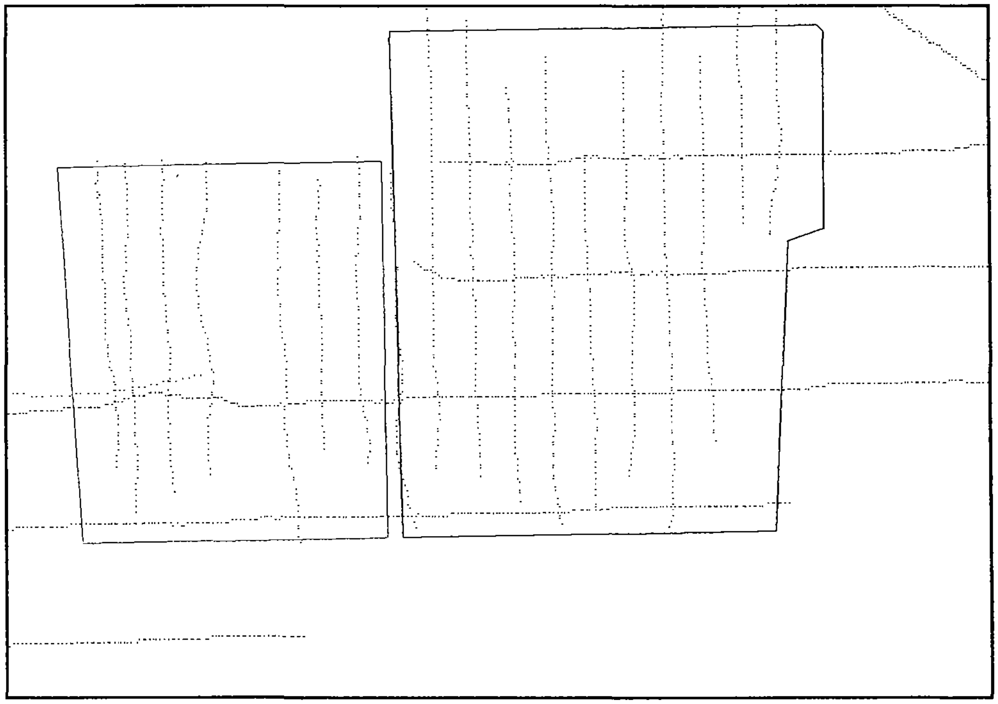

Figure 3. Example of boundaries for Red and Blue Confidence Levels.

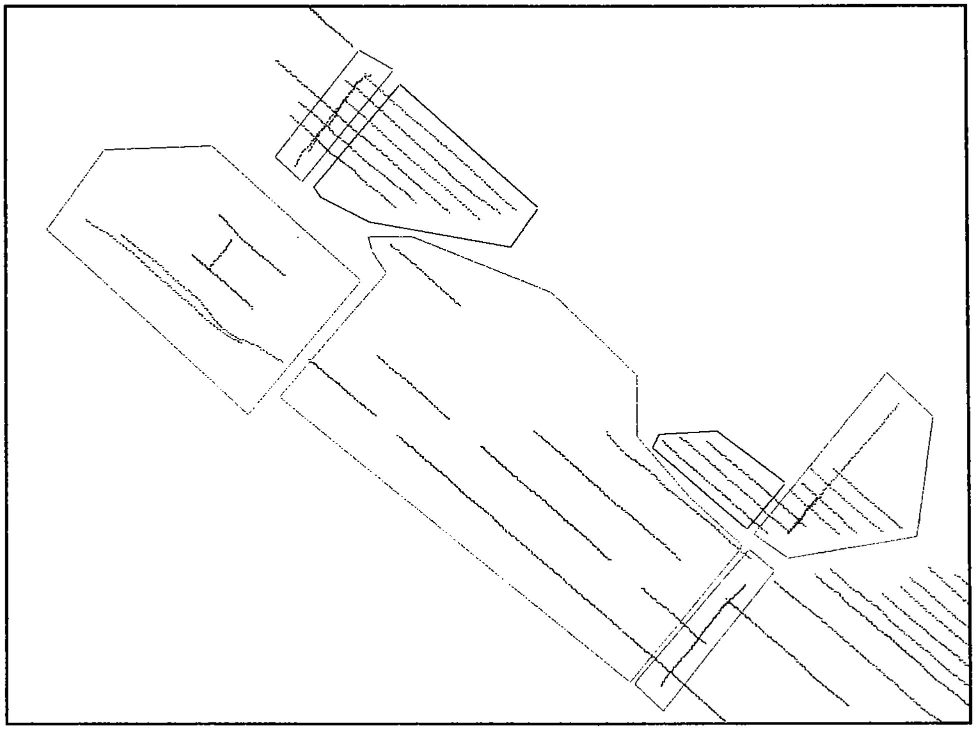

Figure 4. Example of boundaries for Green, Blue and Magenta Confidence Levels.

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)

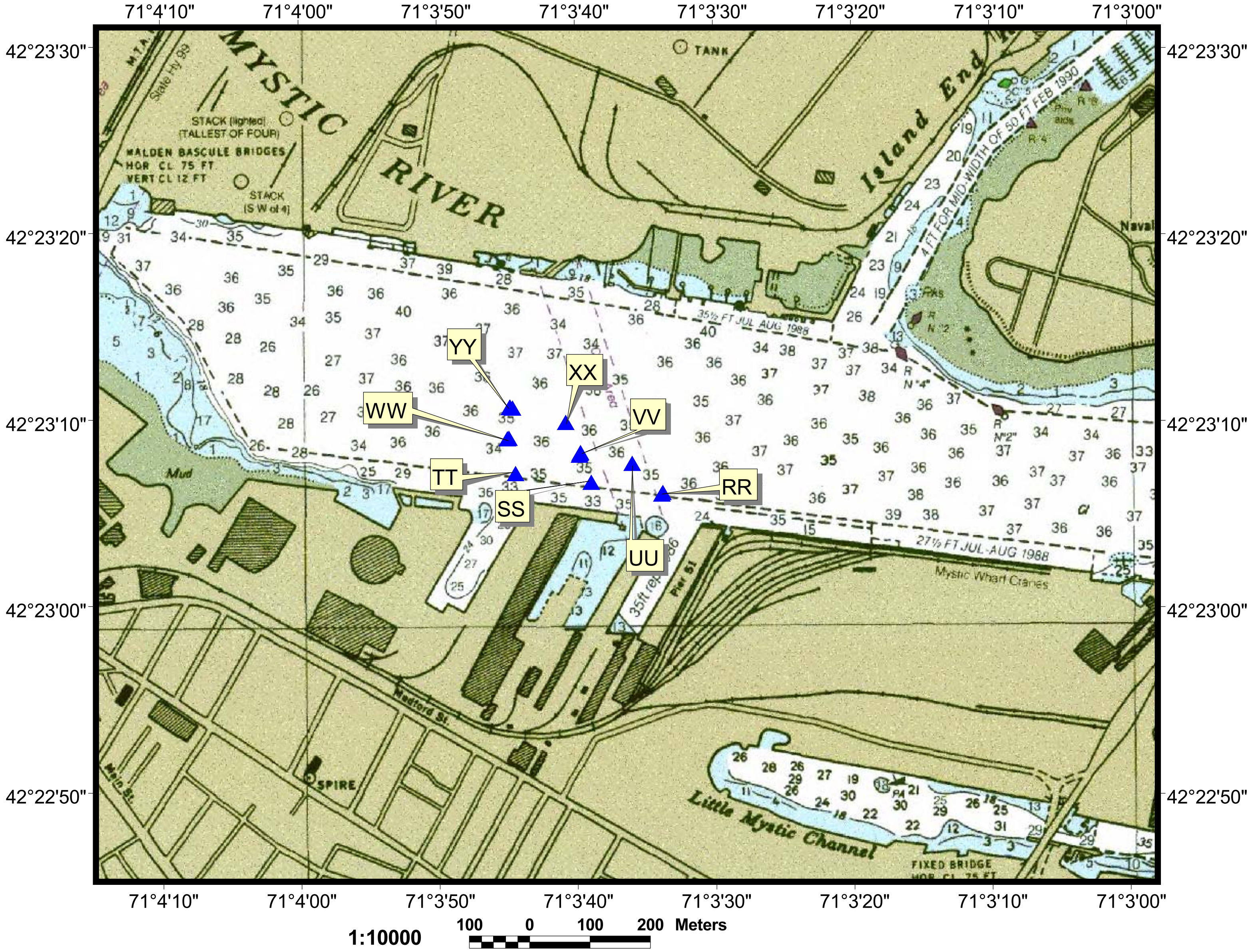

FIGURE K-3

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Ecological and Oceanographic Consultants

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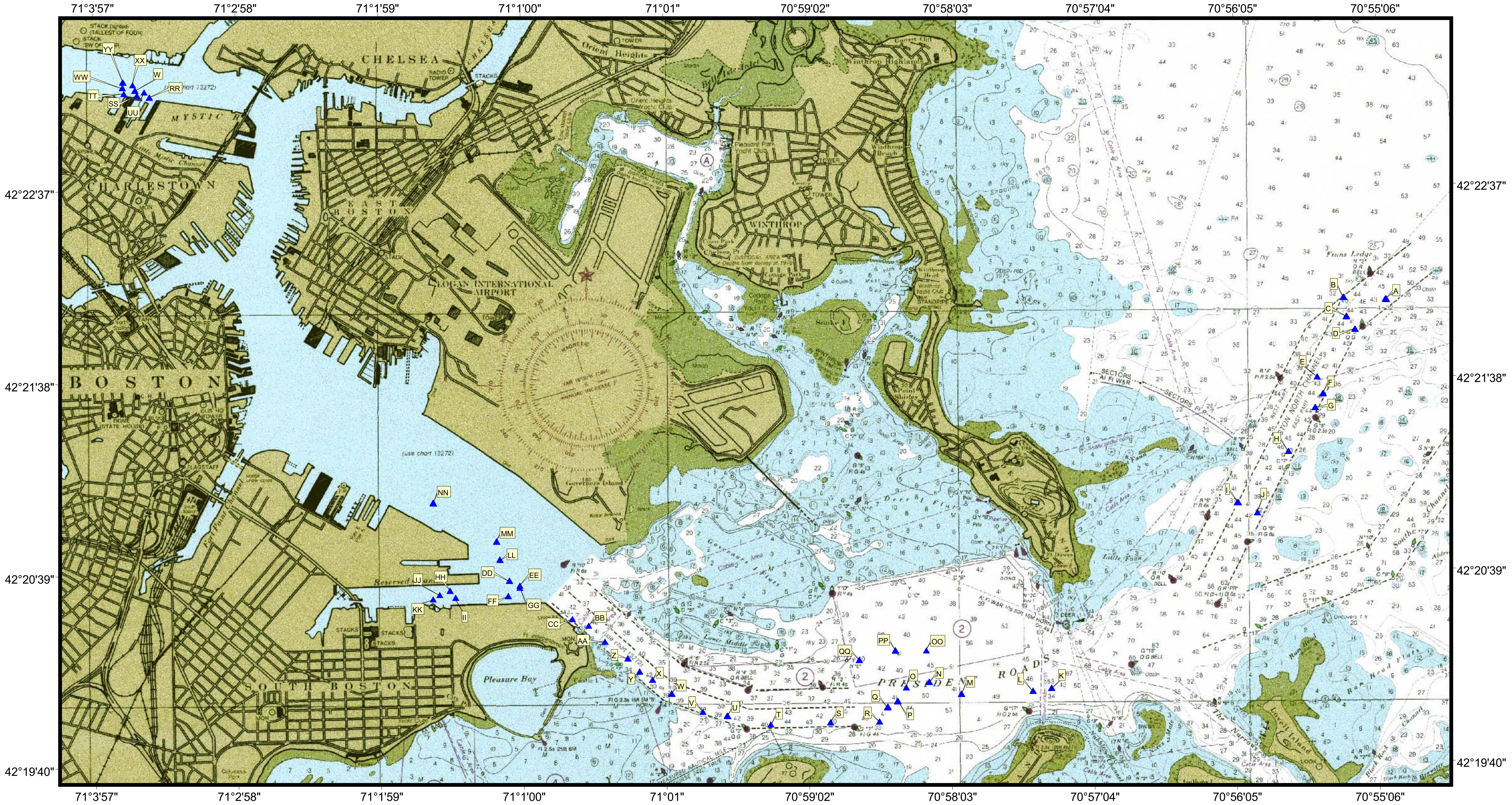
East Falmouth, Massachusetts 02536

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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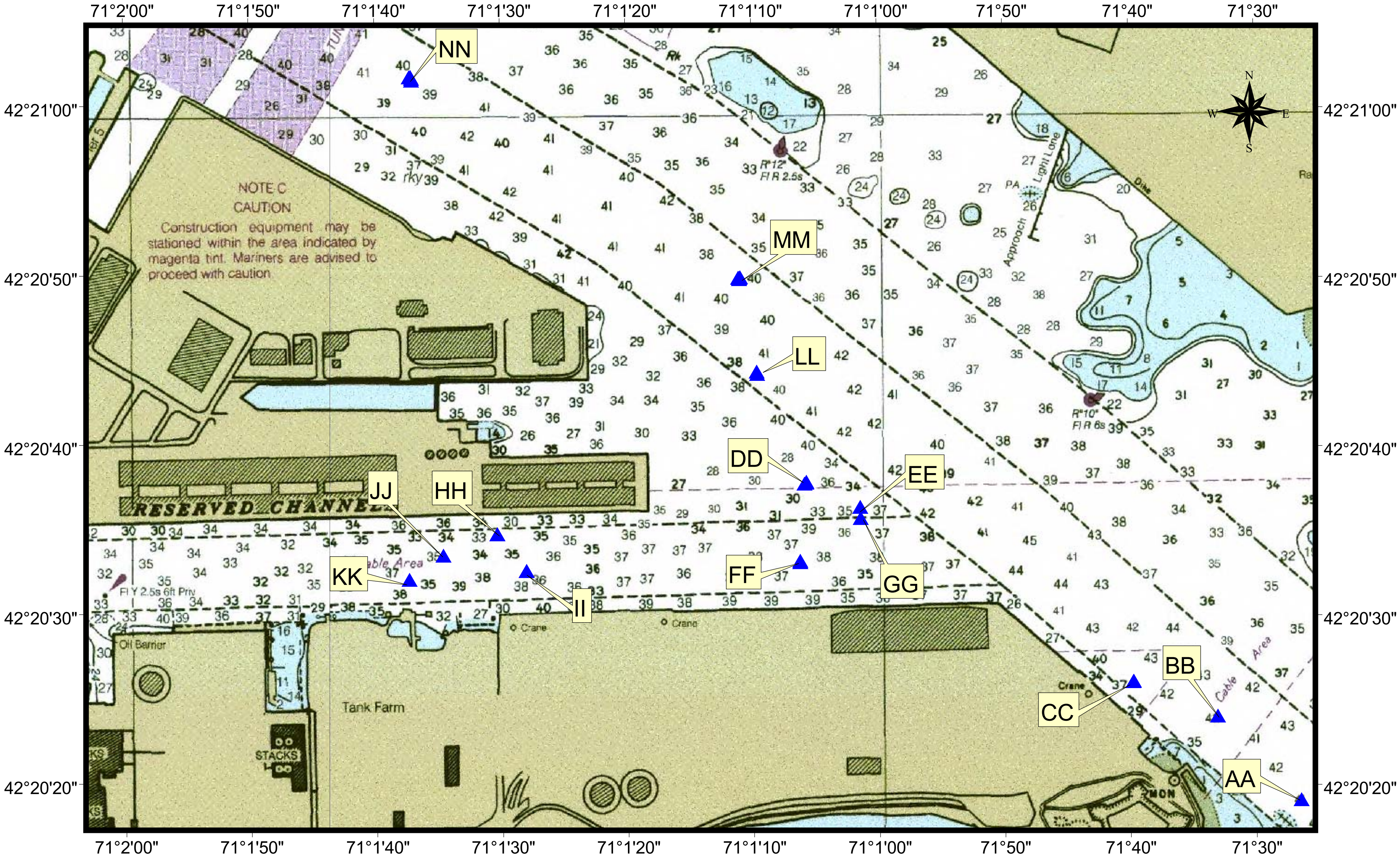
Figure 4. Locations of Sediment Sampling Stations in the Reserved Channel and Adjacent Shipping Channel Collected During the Original Sampling Effort (August 2002)



500 0 500 Meters

1:10000

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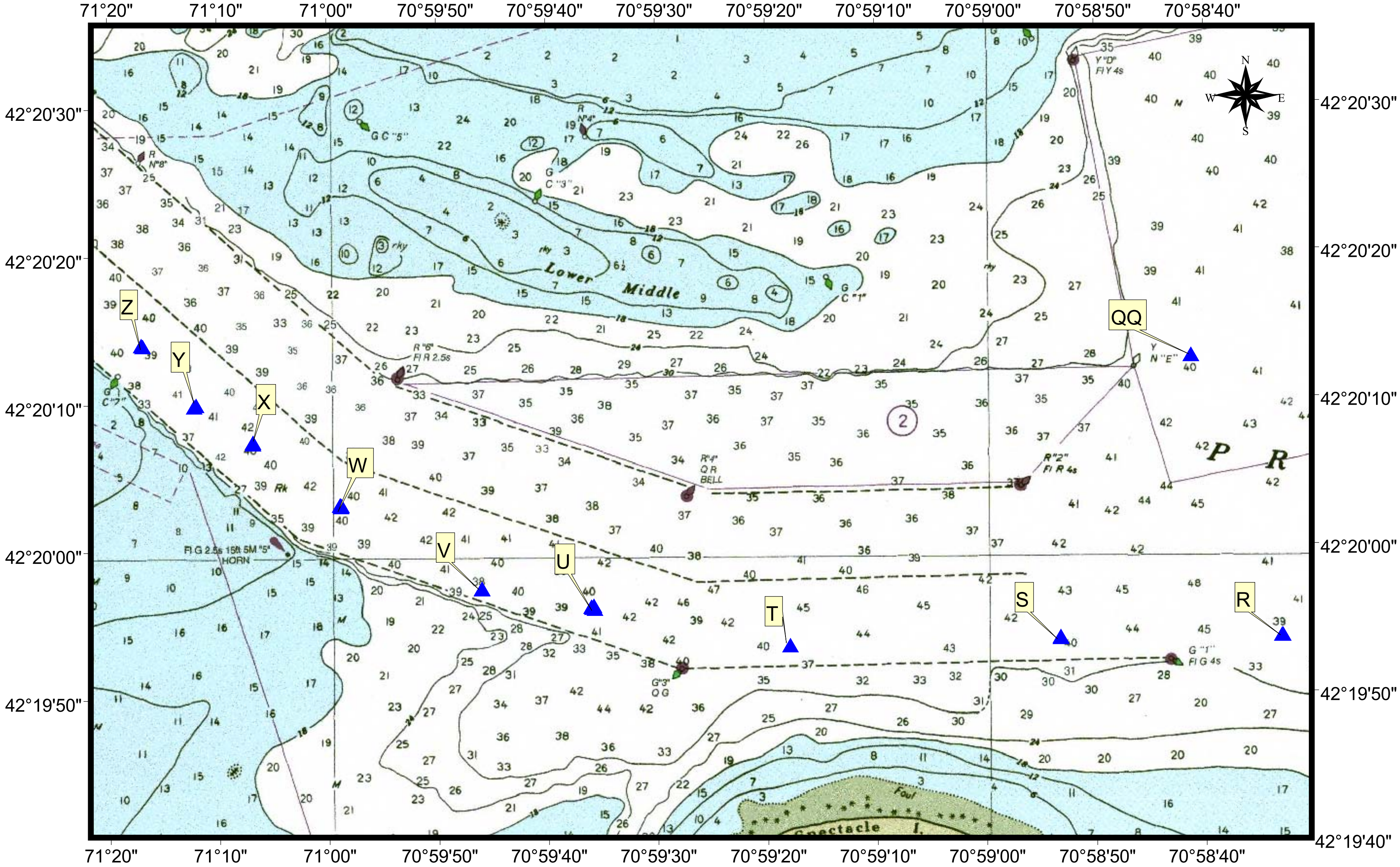
FIGURE K-4

Figure 5. Locations of Sediment Sampling Stations in the President Roads (West) Area Collected During the Original Sampling Effort (August 2002)



1:12000

500 0 500 Meters

FIGURE K-5

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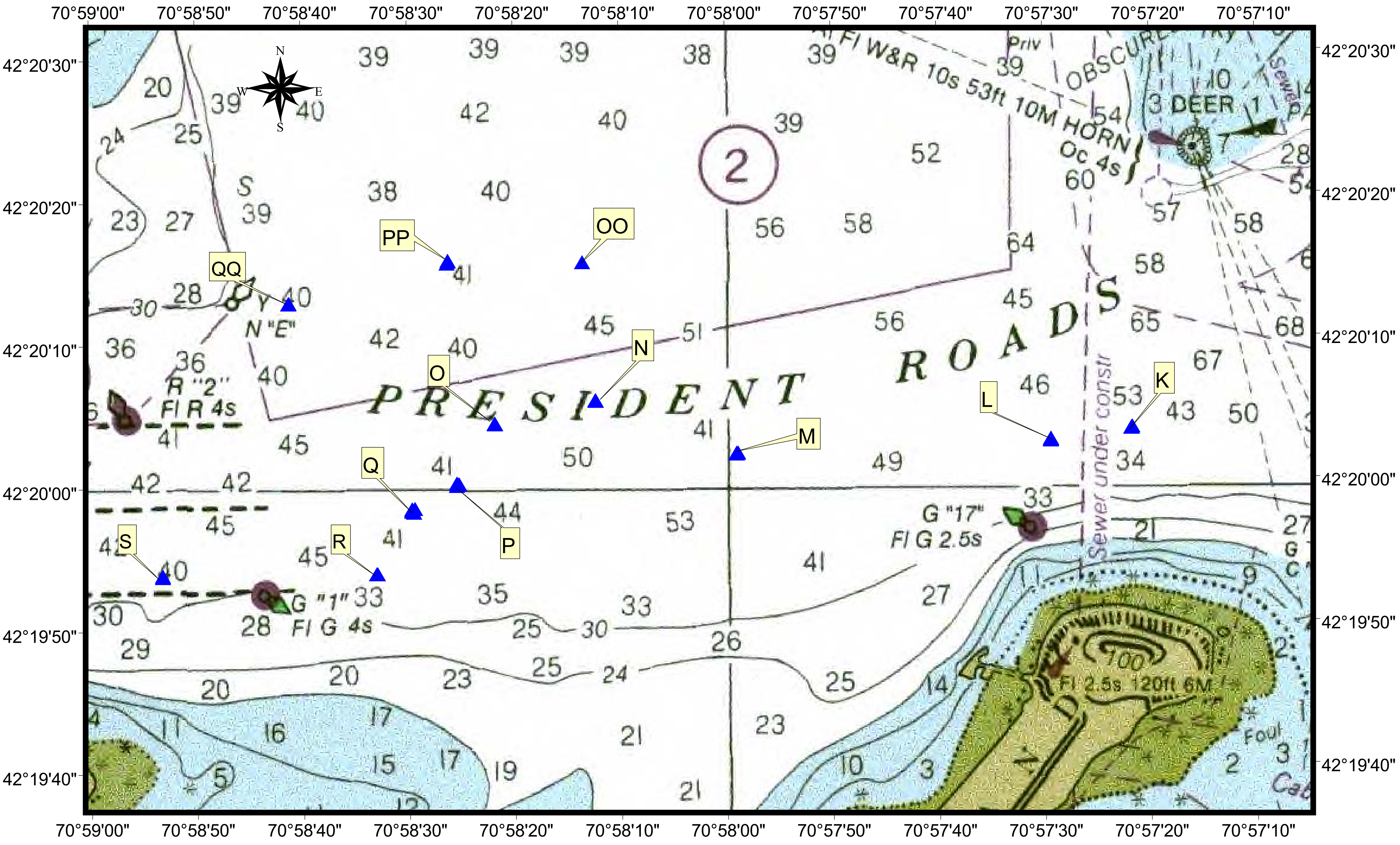
Figure 6. Locations of Sediment Sampling Stations in the President Roads Area Collected During the Original Sampling Effort (August 2002)



1:12000

500 0 500 Meters

FIGURE K-6

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Figure 7. Locations of Sediment Sampling Stations in the North Channel Collected During the Original Sampling Effort (August 2002)

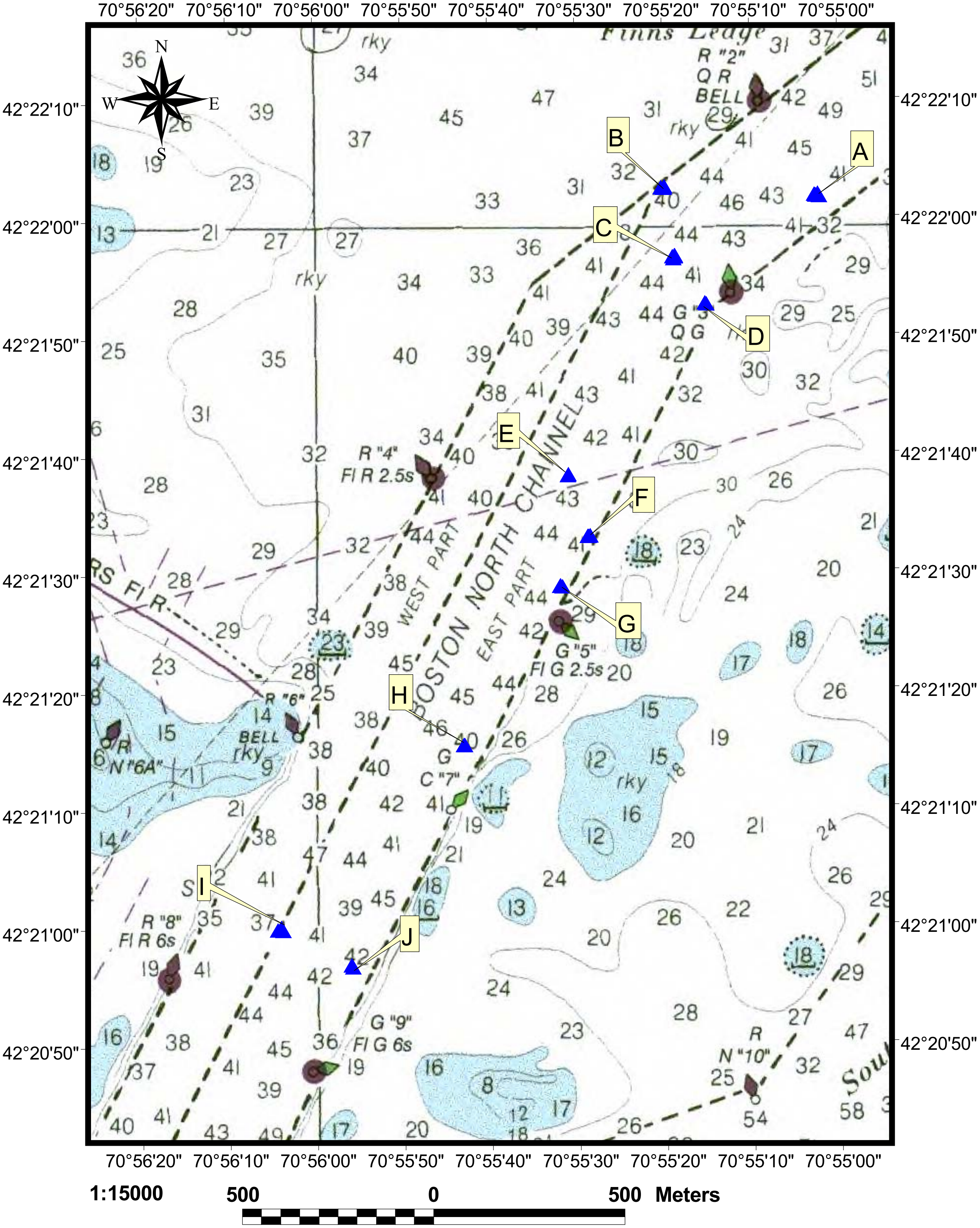

FIGURE K-7

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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

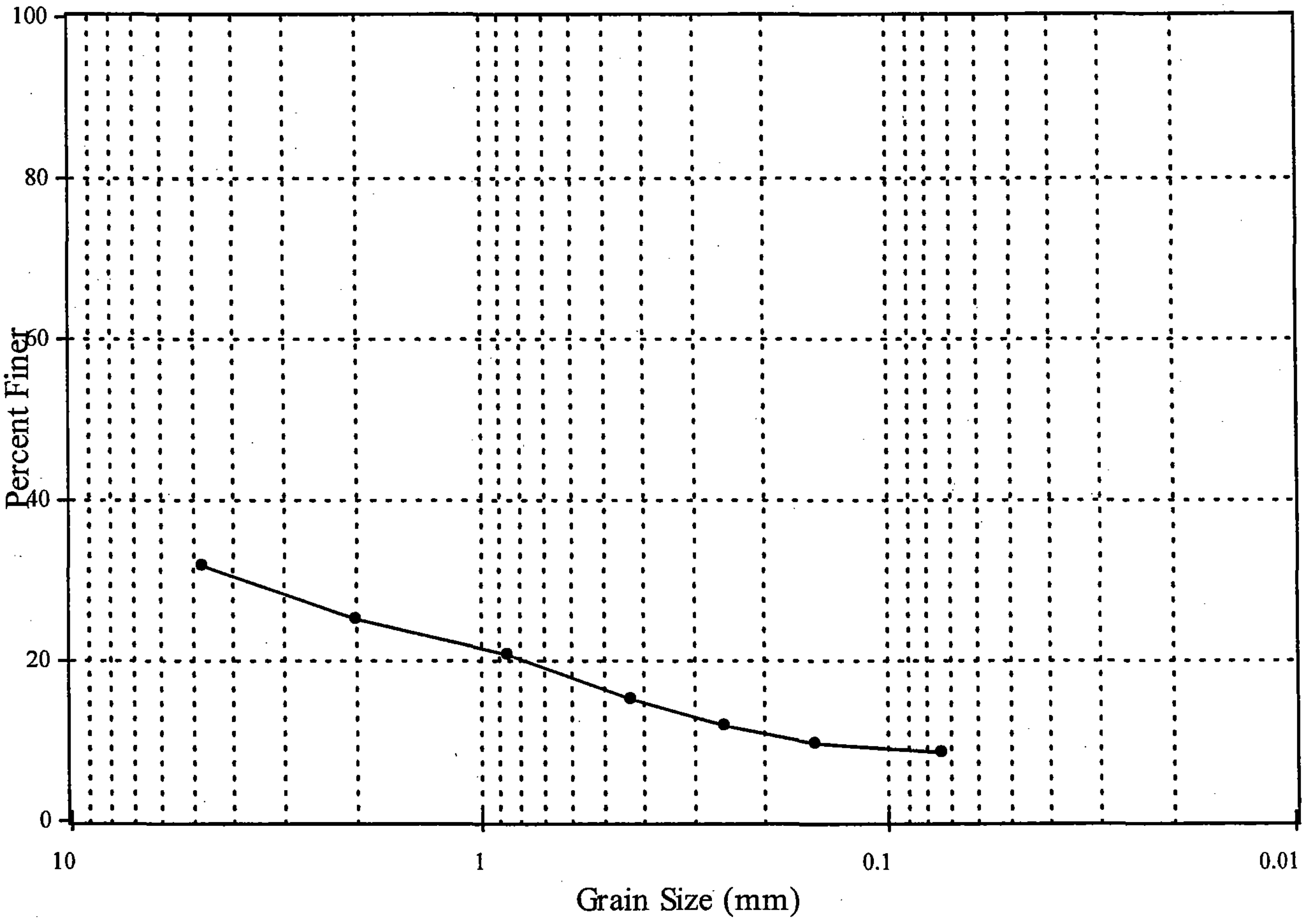
STA Y2 #2	STA Z	ST AA	STA BB	STA CC	STA DD	STA EE	STA FF	STA GG	STA HH	STA II	STA JJ	STA KK	STA LL	STA MM	STA NN	STA OO
%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%
0.00	1.87	0.41	0.56	0.00	16.25	0.08	0.00	0.10	14.41	31.01	35.7	17.45	0.07	0.11	0.00	10.21
0.00	0.74	0.45	0.30	0.43	2.61	0.02	0.02	0.24	7.79	8.25	9.94	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	1.18	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**	Lab Code:	**M-MA030**
Project:	**Boston Harbor Improvement Project**	ETR:	**0208086**
Case:	N/A SDG: N/A	Lab ID:	**0208086-09**
Client ID:	**STA A**	Concentration Units:	**%**
Matrix:	**Sediment**	Received Date:	**8/13/2002**
Collection Date:	**8/13/2002**	Analysis Date:	**8/19/2002**



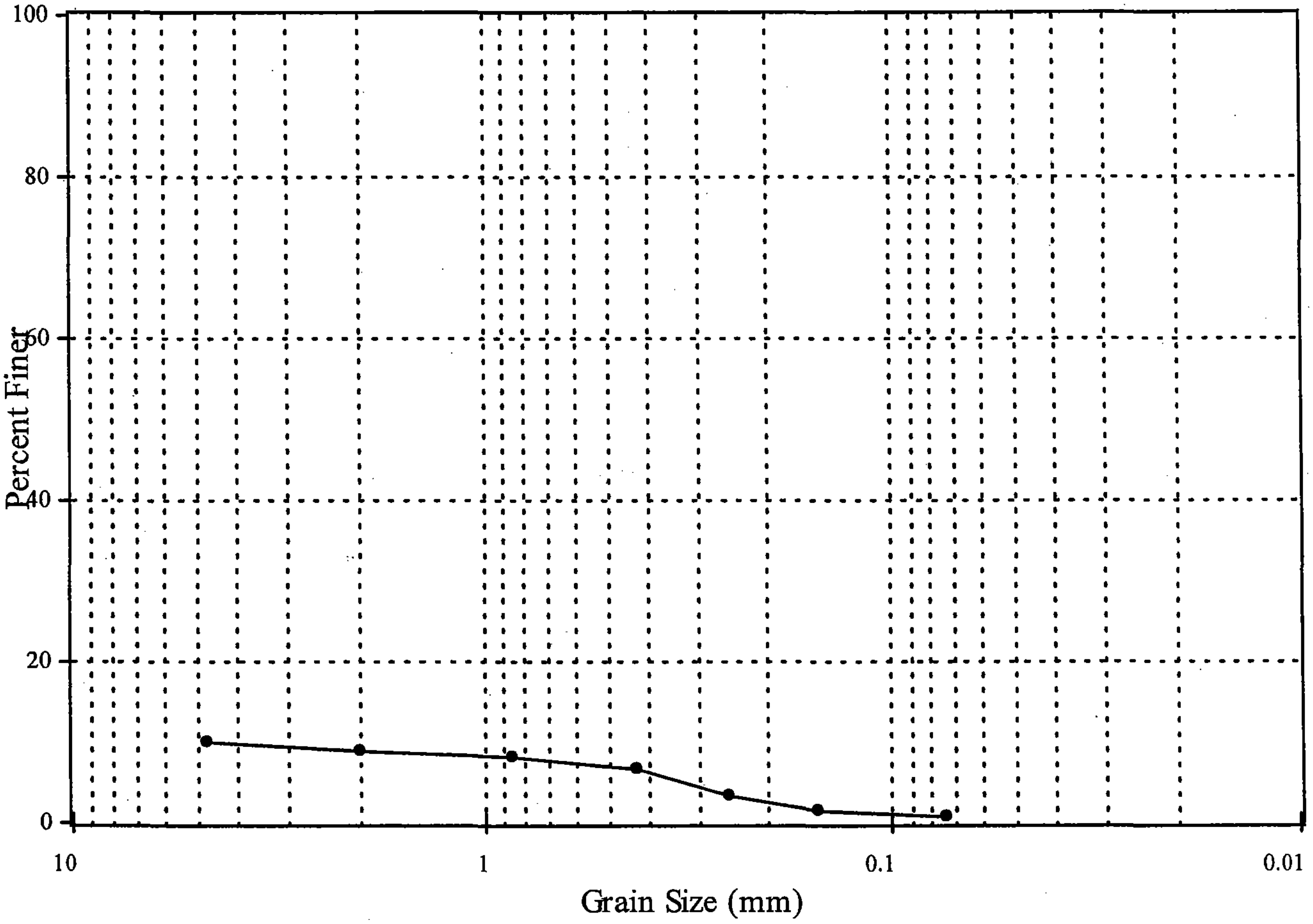
Sieve Number	Diameter Range	Percent Retained	Description
#4	>4.76 mm	68.29	Gravel
#10	<4.76 mm - 2.00 mm	6.38	Coarse Sand
#20	<2.00 mm - 0.85 mm	4.75	Medium Sand
#40	<0.85 mm - 0.425 mm	5.23	Medium Sand
#60	<0.425 mm - 0.25 mm	3.56	Fine Sand
#100	<0.25 mm - 0.15 mm	2.08	Fine Sand
#200	<0.15 mm - 0.074 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

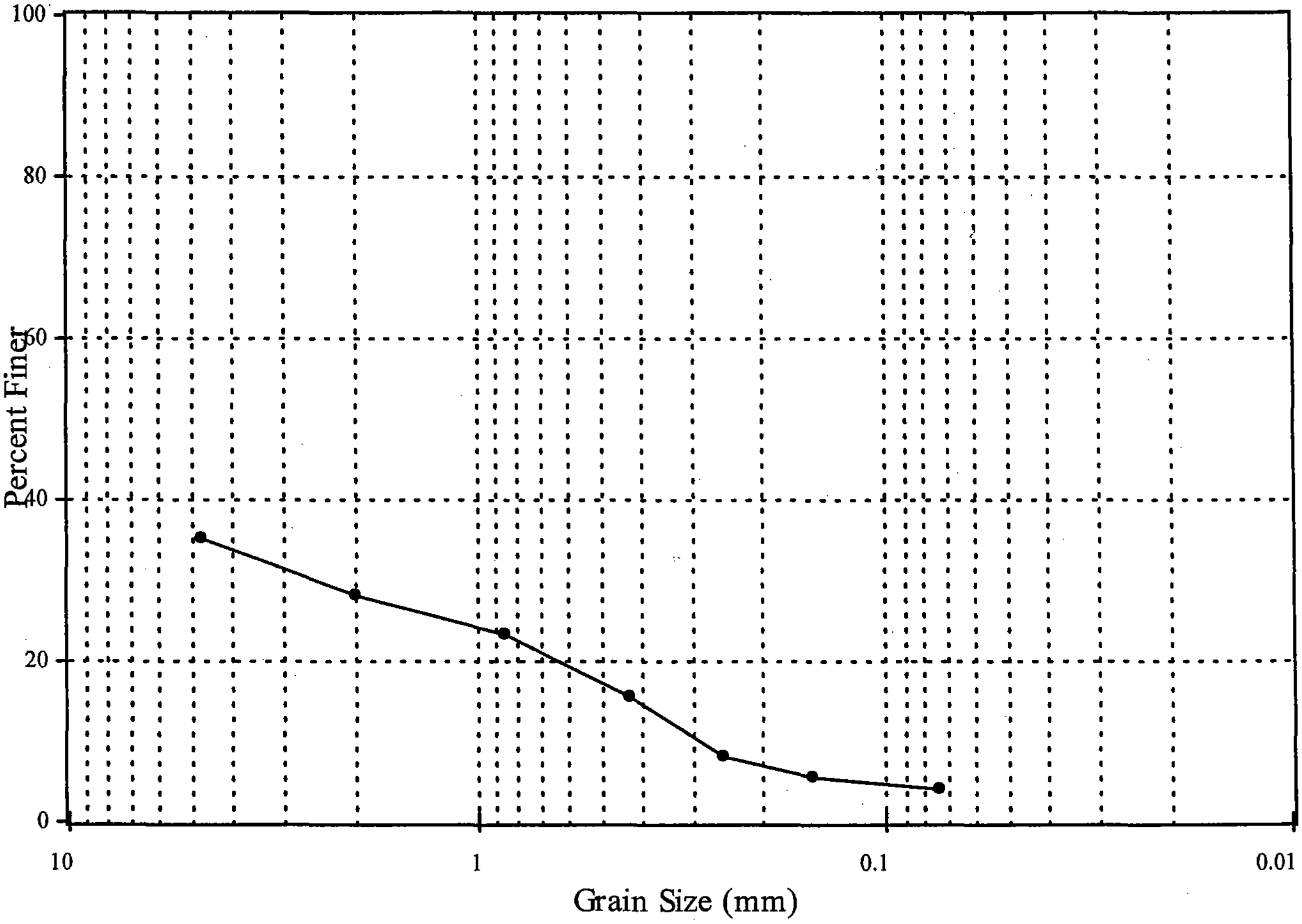
N/A - Not Applicable

08/21/02 11:24

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**

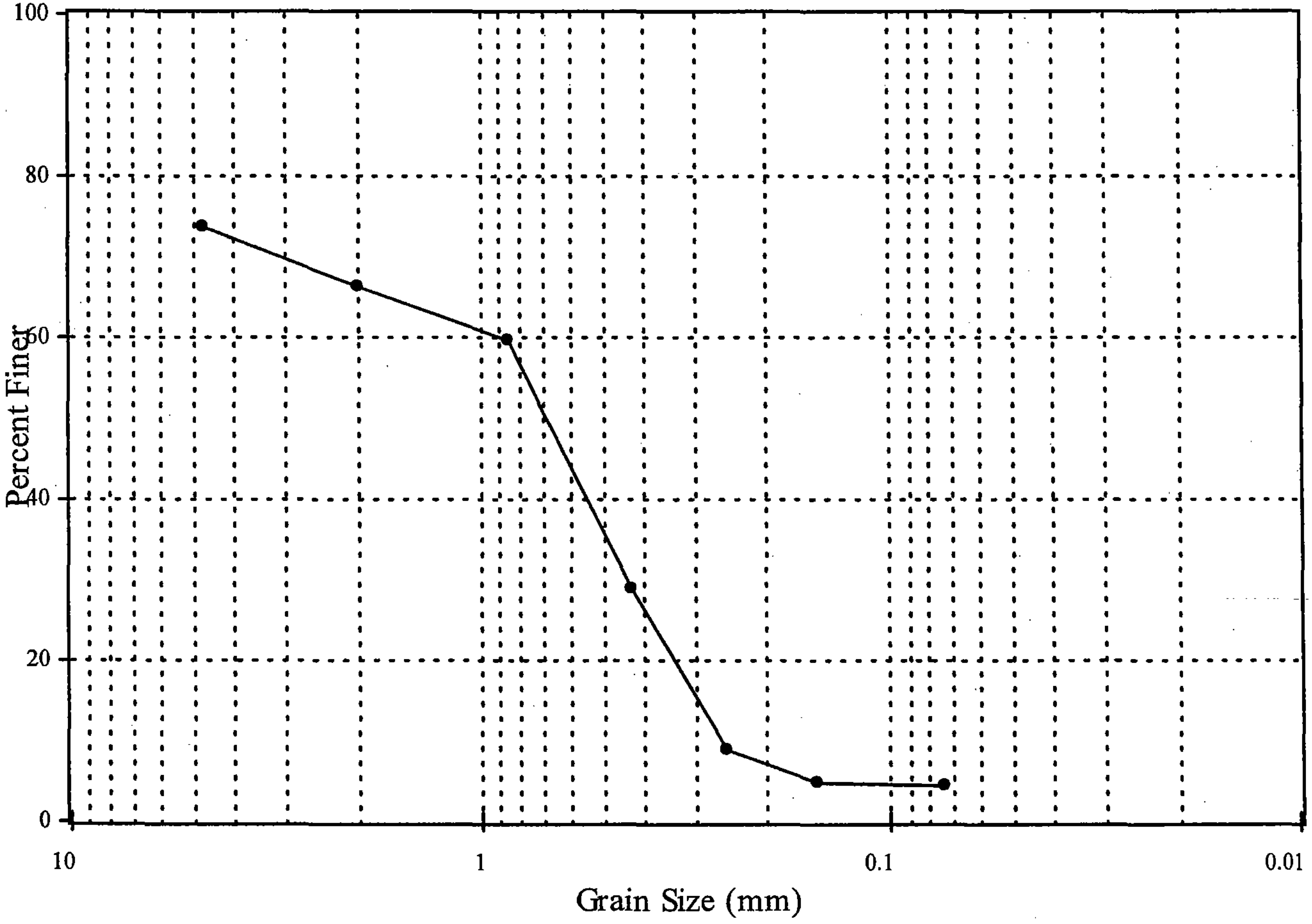


Sieve Number	Diameter Range	Percent Retained	Description
#4	>4.76 mm	64.82	Gravel
#10	<4.76 mm - 2.00 mm	6.98	Coarse Sand
#20	<2.00 mm - 0.85 mm	4.95	Medium Sand
#40	<0.85 mm - 0.425 mm	7.64	Medium Sand
#60	<0.425 mm - 0.25 mm	7.34	Fine Sand
#100	<0.25 mm - 0.15 mm	2.71	Fine Sand
#200	<0.15 mm - 0.074 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**	Lab Code:	**M-MA030**
Project:	**Boston Harbor Improvement Project**	ETR:	**0208086**
Case:	N/A SDG: N/A	Lab ID:	**0208086-06**
Client ID:	**STA E**	Concentration Units:	**%**
Matrix:	**Sediment**	Received Date:	**8/13/2002**
Collection Date:	**8/13/2002**	Analysis Date:	**8/17/2002**



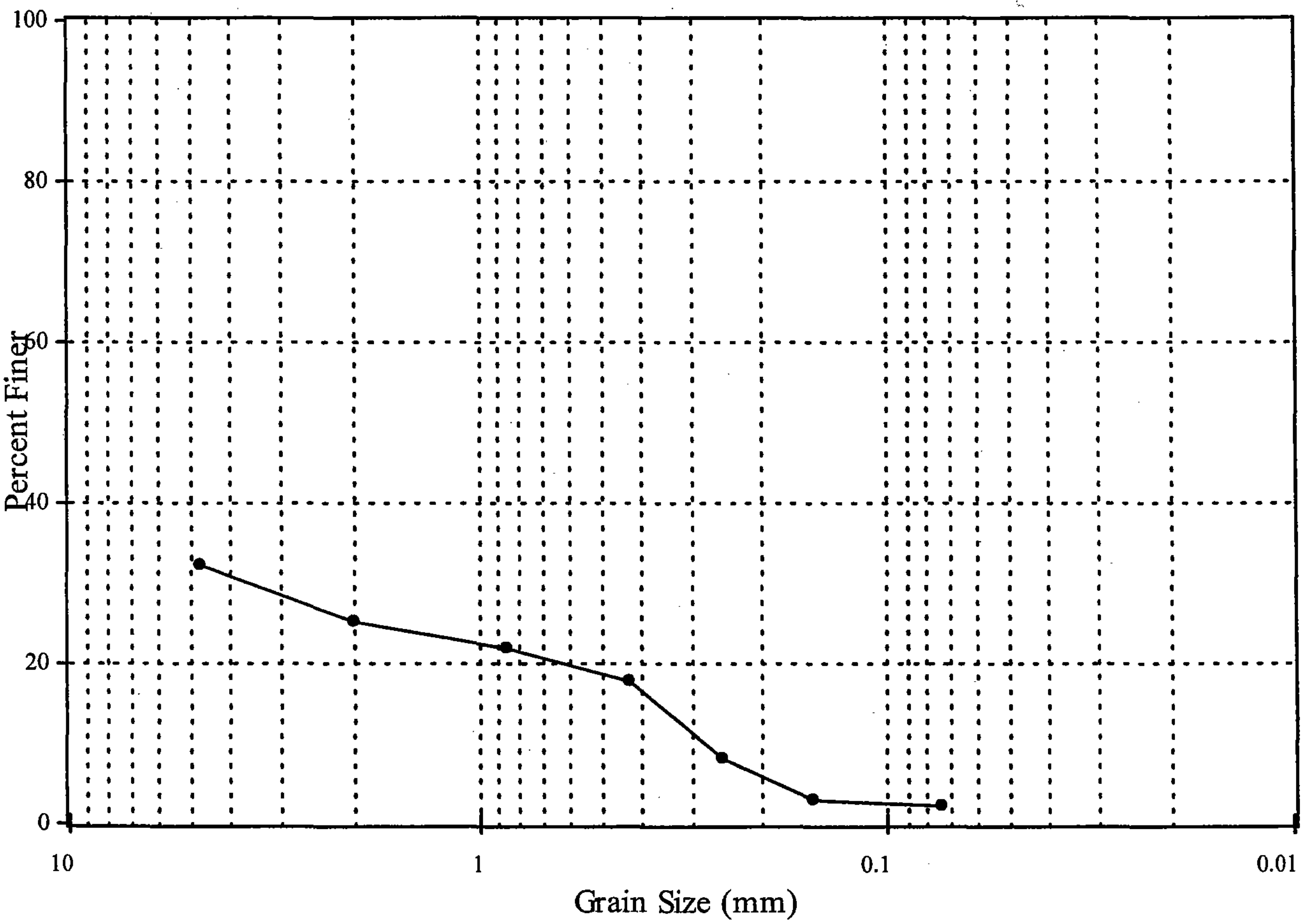
Sieve Number	Diameter Range	Percent Retained	Description
#4	>4.76 mm	26.40	Gravel
#10	<4.76 mm - 2.00 mm	7.20	Coarse Sand
#20	<2.00 mm - 0.85 mm	6.79	Medium Sand
#40	<0.85 mm - 0.425 mm	30.58	Medium Sand
#60	<0.425 mm - 0.25 mm	19.98	Fine Sand
#100	<0.25 mm - 0.15 mm	4.33	Fine Sand
#200	<0.15 mm - 0.074 mm	0.44	Fine Sand
Passing #200	<0.074 mm	4.10	Silt/Clay

N/A - Not Applicable

08/21/02 11:24

Wet Sieve Analysis

Client:	**Army Corps of Engineers**	Lab Code:	**M-MA030**
Project:	**Boston Harbor Improvement Project**	ETR:	**0208086**
Case:	N/A SDG: N/A	Lab ID:	**0208086-05**
Client ID:	**STA F**	Concentration Units:	**%**
Matrix:	**Sediment**	Received Date:	**8/13/2002**
Collection Date:	**8/13/2002**	Analysis Date:	**8/17/2002**



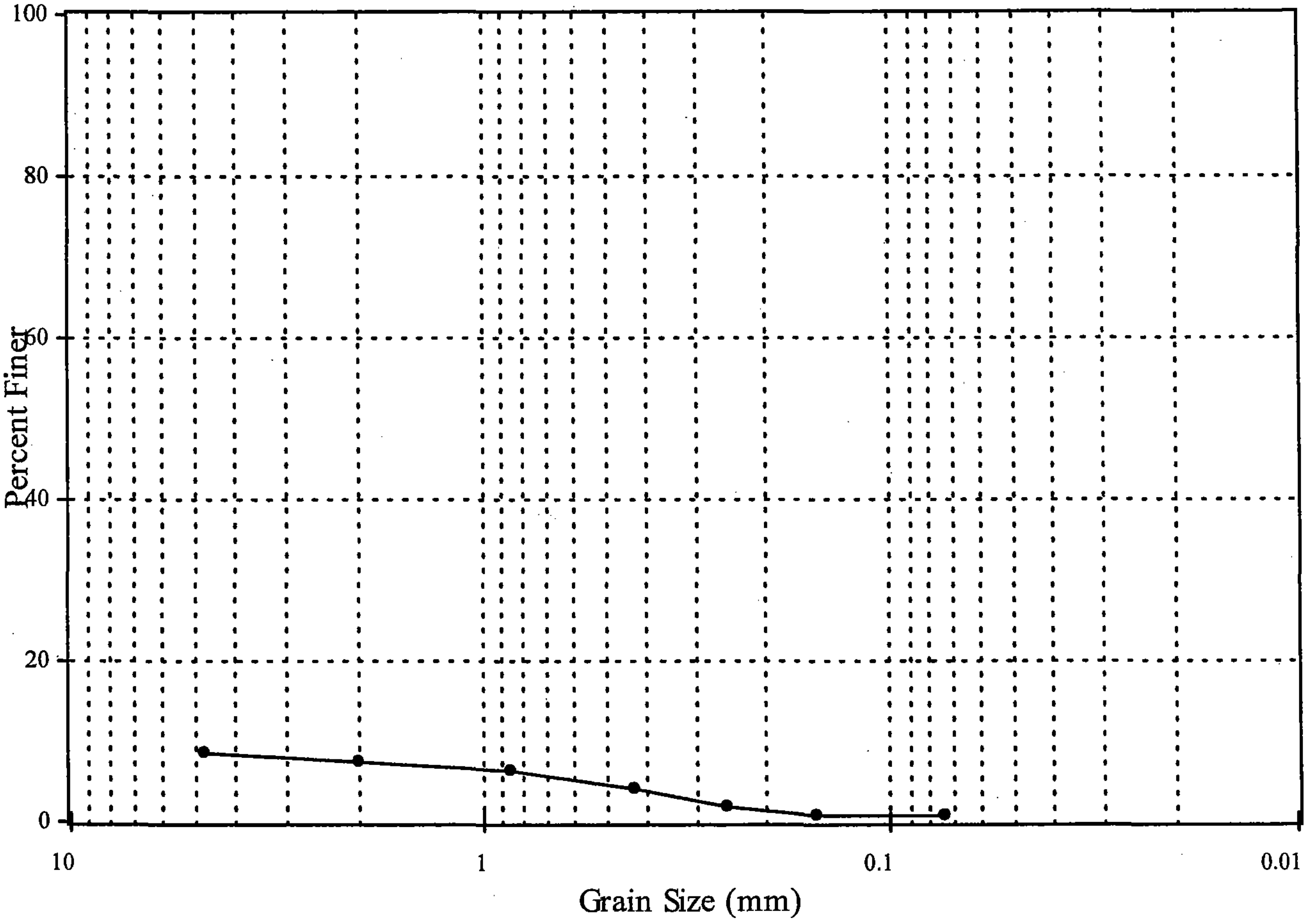
Sieve Number	Diameter Range	Percent Retained	Description
#4	>4.76 mm	67.88	Gravel
#10	<4.76 mm - 2.00 mm	6.91	Coarse Sand
#20	<2.00 mm - 0.85 mm	3.30	Medium Sand
#40	<0.85 mm - 0.425 mm	4.19	Medium Sand
#60	<0.425 mm - 0.25 mm	9.73	Fine Sand
#100	<0.25 mm - 0.15 mm	5.15	Fine Sand
#200	<0.15 mm - 0.074 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**

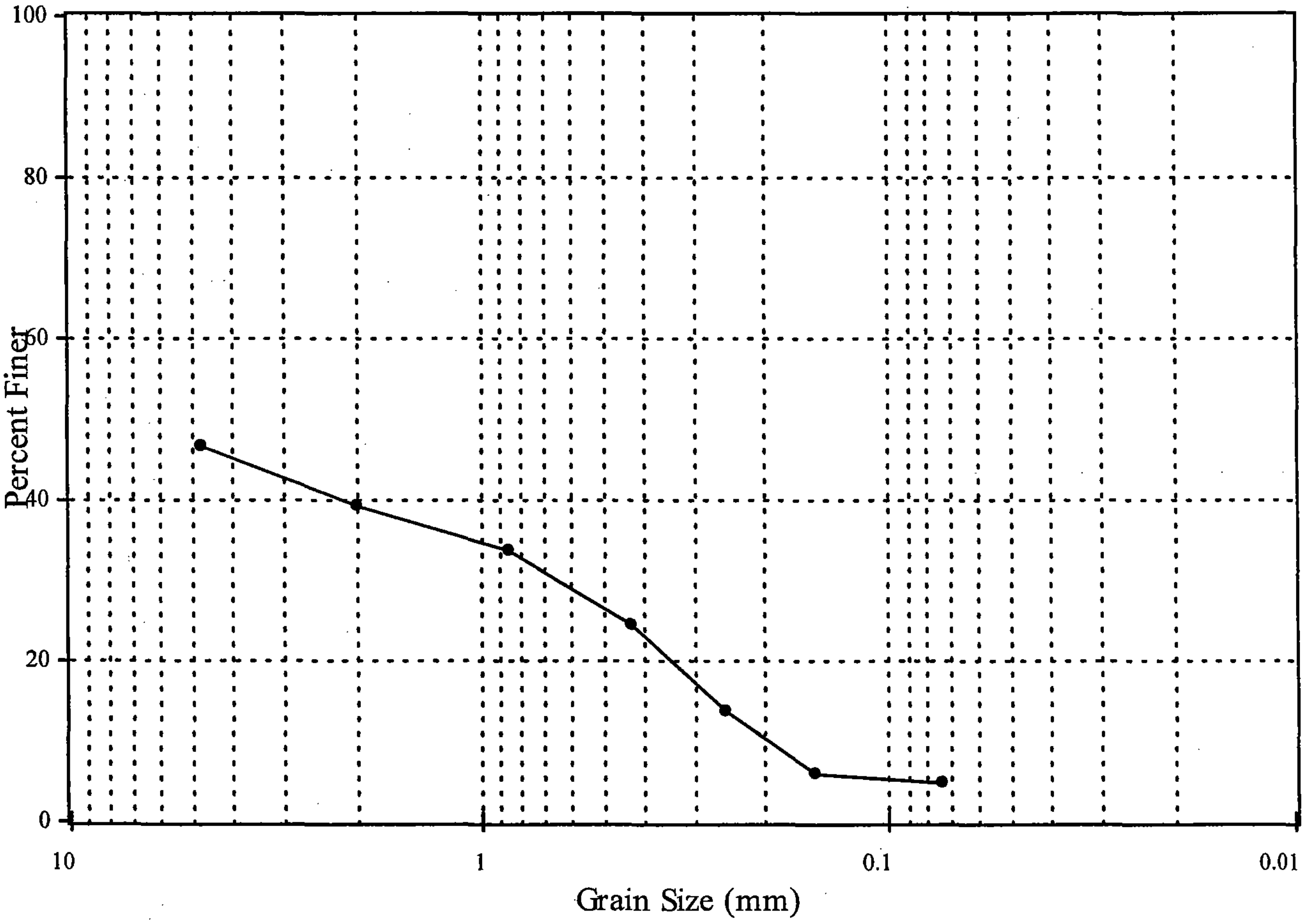


Sieve Number	Diameter Range	Percent Retained	Description
#4	>4.76 mm	91.47	Gravel
#10	<4.76 mm - 2.00 mm	1.19	Coarse Sand
#20	<2.00 mm - 0.85 mm	1.08	Medium Sand
#40	<0.85 mm - 0.425 mm	2.17	Medium Sand
#60	<0.425 mm - 0.25 mm	2.36	Fine Sand
#100	<0.25 mm - 0.15 mm	0.84	Fine Sand
#200	<0.15 mm - 0.074 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**	Lab Code:	**M-MA030**
Project:	**Boston Harbor Improvement Project**	ETR:	**0208086**
Case:	N/A SDG: N/A	Lab ID:	**0208086-03**
Client ID:	**STA H**	Concentration Units:	**%**
Matrix:	**Sediment**	Received Date:	**8/13/2002**
Collection Date:	**8/13/2002**	Analysis Date:	**8/17/2002**

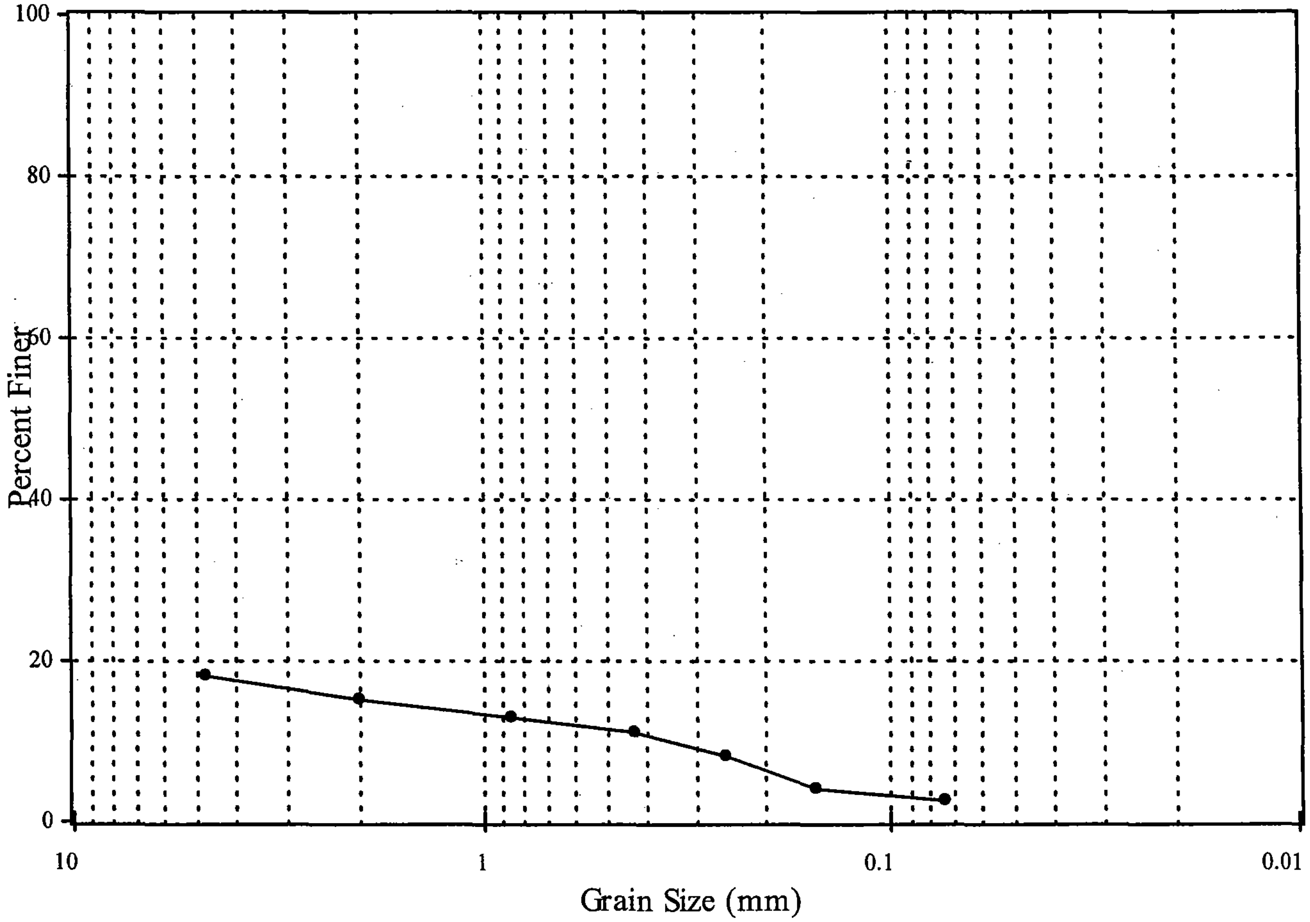


Sieve Number	Diameter Range	Percent Retained	Description
#4	>4.76 mm	53.19	Gravel
#10	<4.76 mm - 2.00 mm	7.71	Coarse Sand
#20	<2.00 mm - 0.85 mm	5.50	Medium Sand
#40	<0.85 mm - 0.425 mm	9.13	Medium Sand
#60	<0.425 mm - 0.25 mm	10.83	Fine Sand
#100	<0.25 mm - 0.15 mm	7.59	Fine Sand
#200	<0.15 mm - 0.074 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**	Lab Code:	**M-MA030**
Project:	**Boston Harbor Improvement Project**	ETR:	**0208086**
Case:	N/A SDG: N/A	Lab ID:	**0208086-02**
Client ID:	**STA I**	Concentration Units:	**%**
Matrix:	**Sediment**	Received Date:	**8/13/2002**
Collection 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

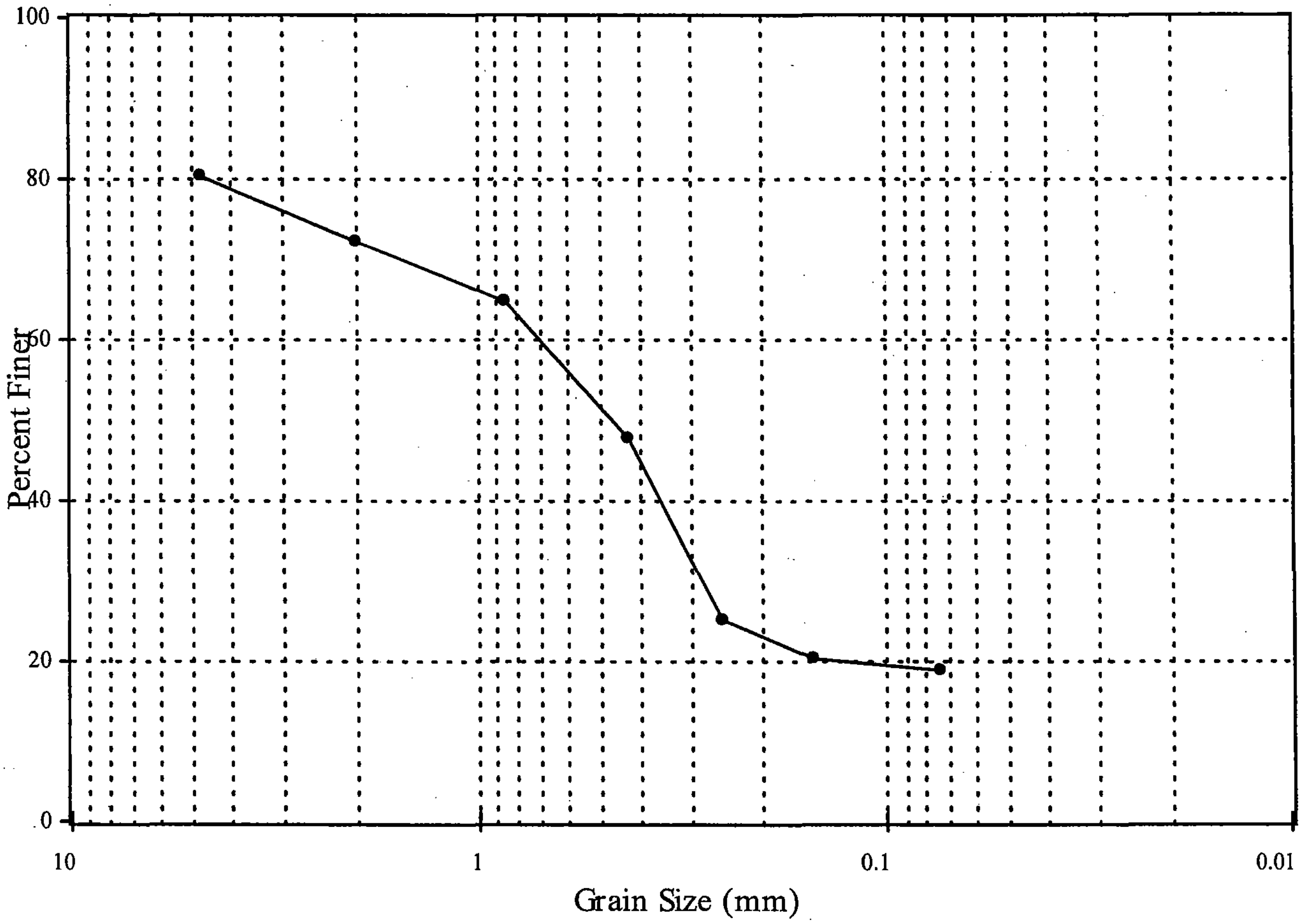
N/A - Not Applicable

08/21/02 11:24

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**



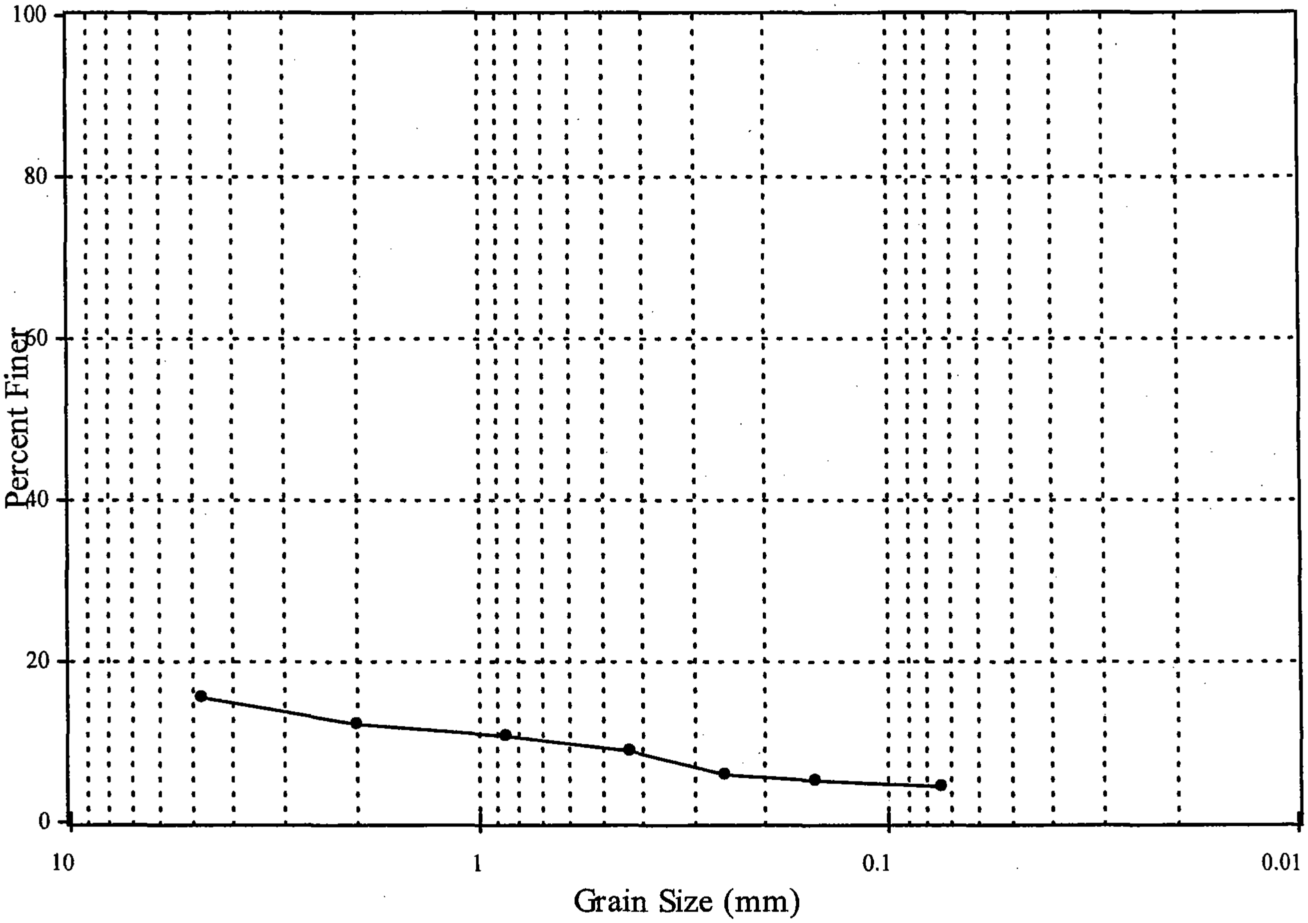
Sieve Number	Diameter Range	Percent Retained	Description
#4	>4.76 mm	19.78	Gravel
#10	<4.76 mm - 2.00 mm	7.94	Coarse Sand
#20	<2.00 mm - 0.85 mm	7.37	Medium Sand
#40	<0.85 mm - 0.425 mm	16.95	Medium Sand
#60	<0.425 mm - 0.25 mm	22.72	Fine Sand
#100	<0.25 mm - 0.15 mm	4.98	Fine Sand
#200	<0.15 mm - 0.074 mm	1.42	Fine Sand
Passing #200	<0.074 mm	18.78	Silt/Clay

N/A - Not Applicable

08/21/02 11:24

Wet Sieve Analysis

Client: **Army Corps of Engineers**		Lab Code: **M-MA030**
Project: **Boston Harbor Improvement Project**		ETR: **0208086**
Case: **N/A**	SDG: **N/A**	Lab ID: **0208086-10**
Client ID: **STA K**		Concentration Units: **%**
Matrix: **Sediment**		Received Date: **8/13/2002**
Collection Date: **8/13/2002**		Analysis Date: **8/19/2002**



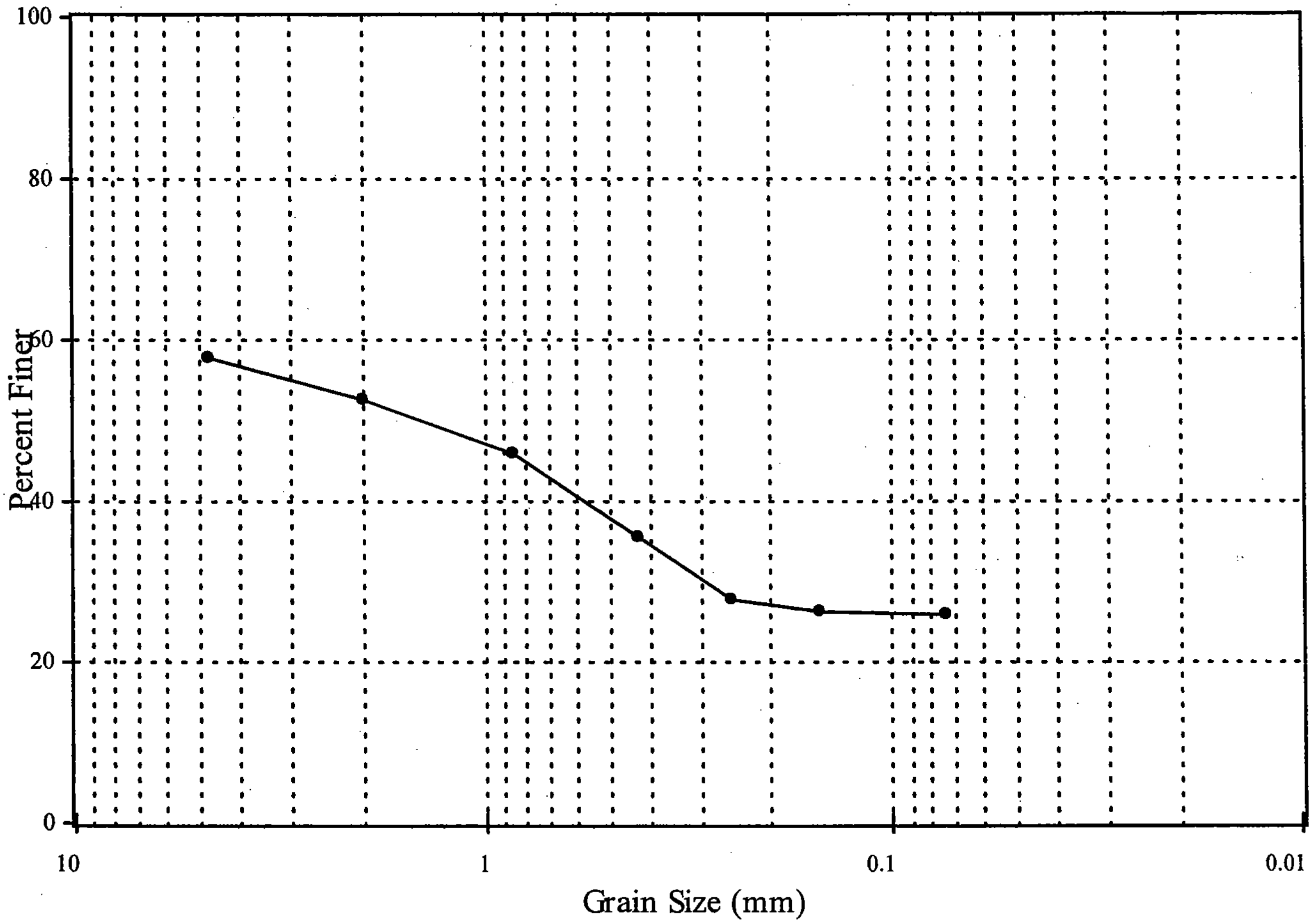
Sieve Number	Diameter Range	Percent Retained	Description
#4	>4.76 mm	84.36	Gravel
#10	<4.76 mm - 2.00 mm	3.42	Coarse Sand
#20	<2.00 mm - 0.85 mm	1.56	Medium Sand
#40	<0.85 mm - 0.425 mm	1.85	Medium Sand
#60	<0.425 mm - 0.25 mm	2.73	Fine Sand
#100	<0.25 mm - 0.15 mm	0.97	Fine Sand
#200	<0.15 mm - 0.074 mm	0.63	Fine Sand
Passing #200	<0.074 mm	4.36	Silt/Clay

N/A - Not Applicable

08/21/02 11:24

Wet Sieve Analysis

Client:	**Army Corps of Engineers**	Lab Code:	**M-MA030**
Project:	**Boston Harbor Improvement Project**	ETR:	**0208086**
Case:	N/A SDG: N/A	Lab ID:	**0208086-11**
Client ID:	**STA L**	Concentration Units:	**%**
Matrix:	**Sediment**	Received Date:	**8/13/2002**
Collection Date:	**8/13/2002**	Analysis Date:	**8/19/2002**



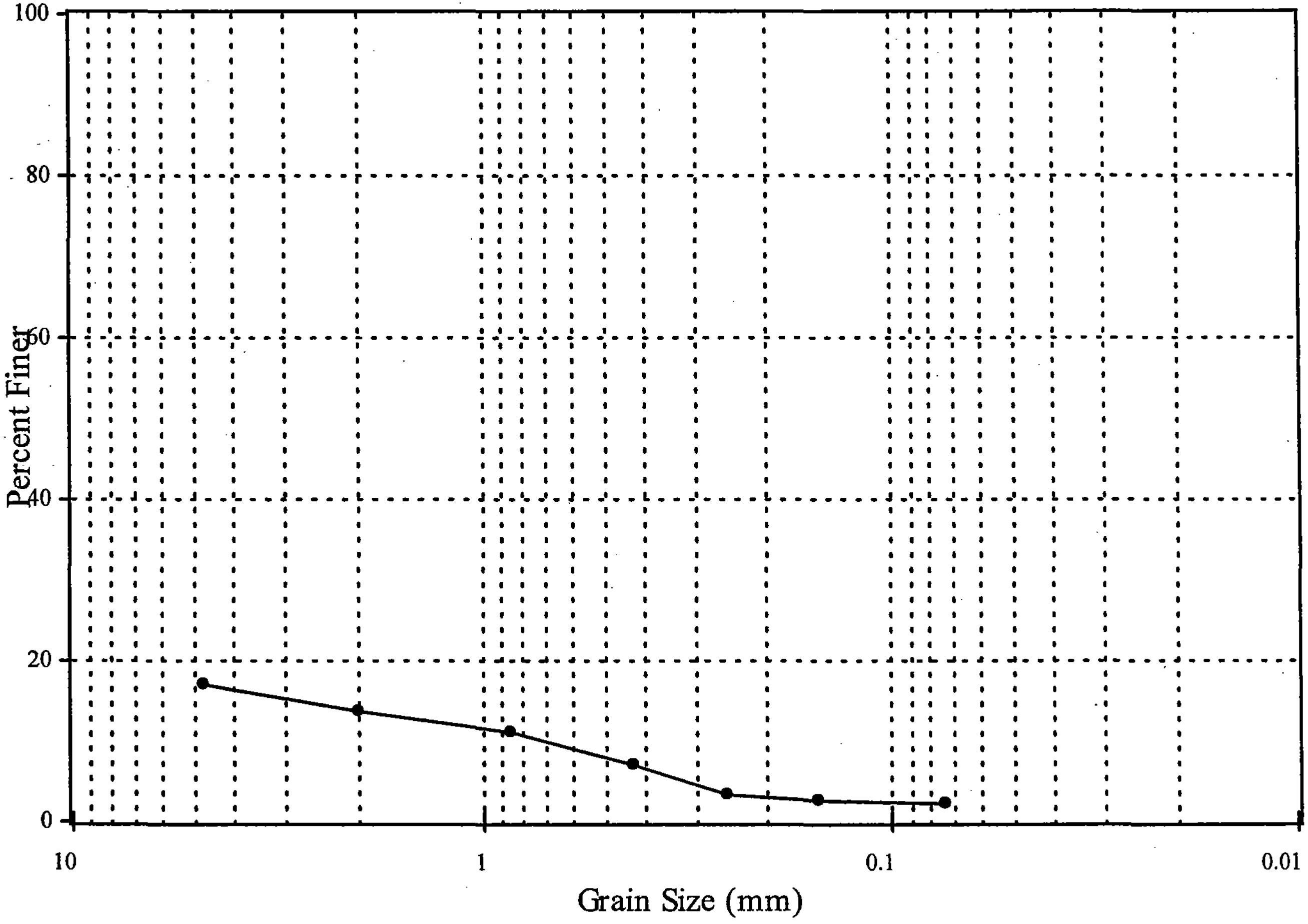
Sieve Number	Diameter Range	Percent Retained	Description
#4	>4.76 mm	42.28	Gravel
#10	<4.76 mm - 2.00 mm	5.18	Coarse Sand
#20	<2.00 mm - 0.85 mm	6.50	Medium Sand
#40	<0.85 mm - 0.425 mm	10.46	Medium Sand
#60	<0.425 mm - 0.25 mm	7.86	Fine Sand
#100	<0.25 mm - 0.15 mm	1.35	Fine Sand
#200	<0.15 mm - 0.074 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**

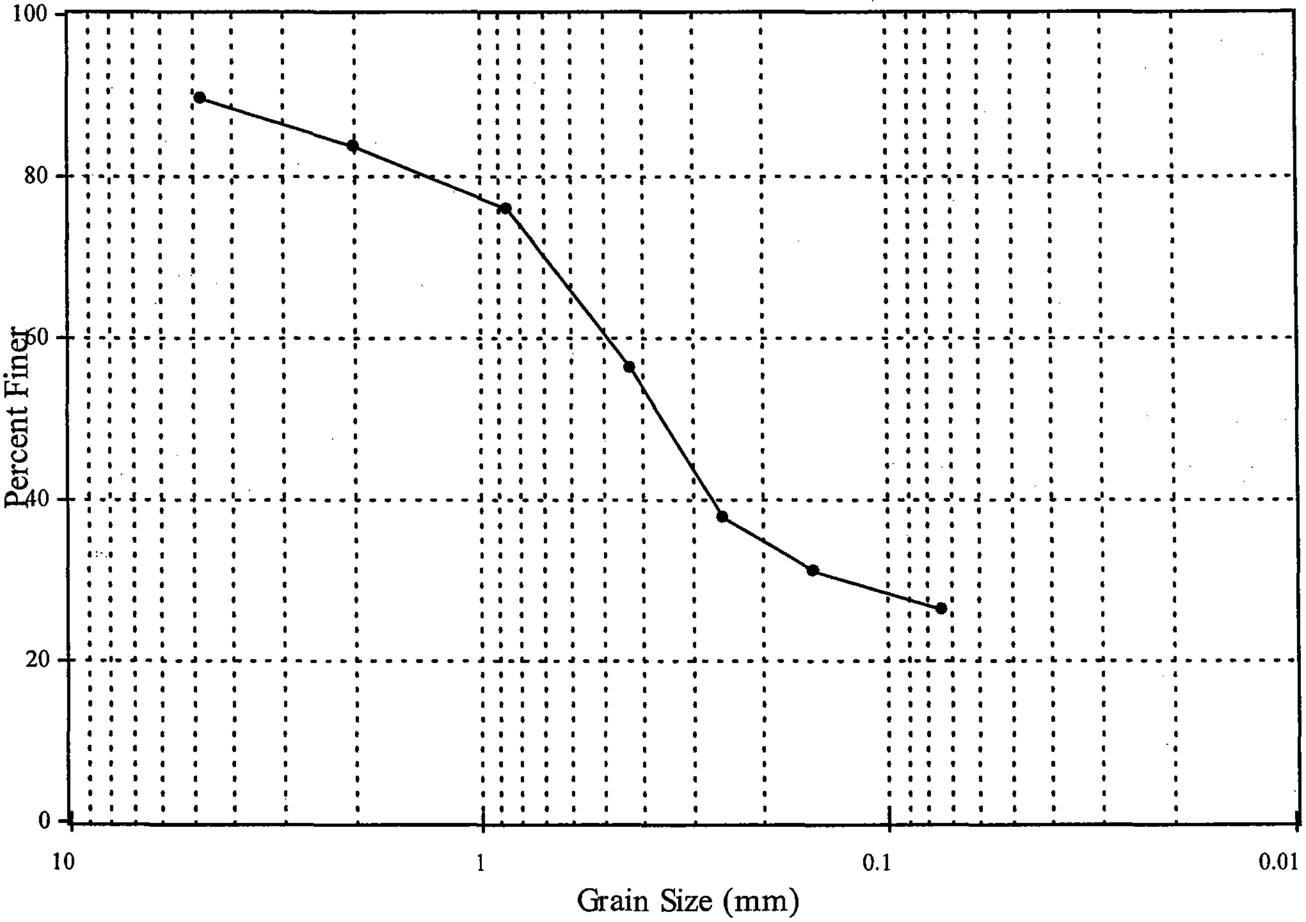


Sieve Number	Diameter Range	Percent Retained	Description
#4	>4.76 mm	82.87	Gravel
#10	<4.76 mm - 2.00 mm	3.52	Coarse Sand
#20	<2.00 mm - 0.85 mm	2.44	Medium Sand
#40	<0.85 mm - 0.425 mm	3.95	Medium Sand
#60	<0.425 mm - 0.25 mm	3.72	Fine Sand
#100	<0.25 mm - 0.15 mm	0.94	Fine Sand
#200	<0.15 mm - 0.074 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**		Lab Code: **M-MA030**
Project:	**Boston Harbor Improvement Project**		ETR: **0208094**
Case:	N/A	SDG: N/A	Lab ID: **0208094-08**
Client ID:	**STA N**		Concentration Units: **%**
Matrix:	**Sediment**		Received Date: **8/15/2002**
Collection Date:	**8/14/2002**		Analysis Date: **8/20/2002**



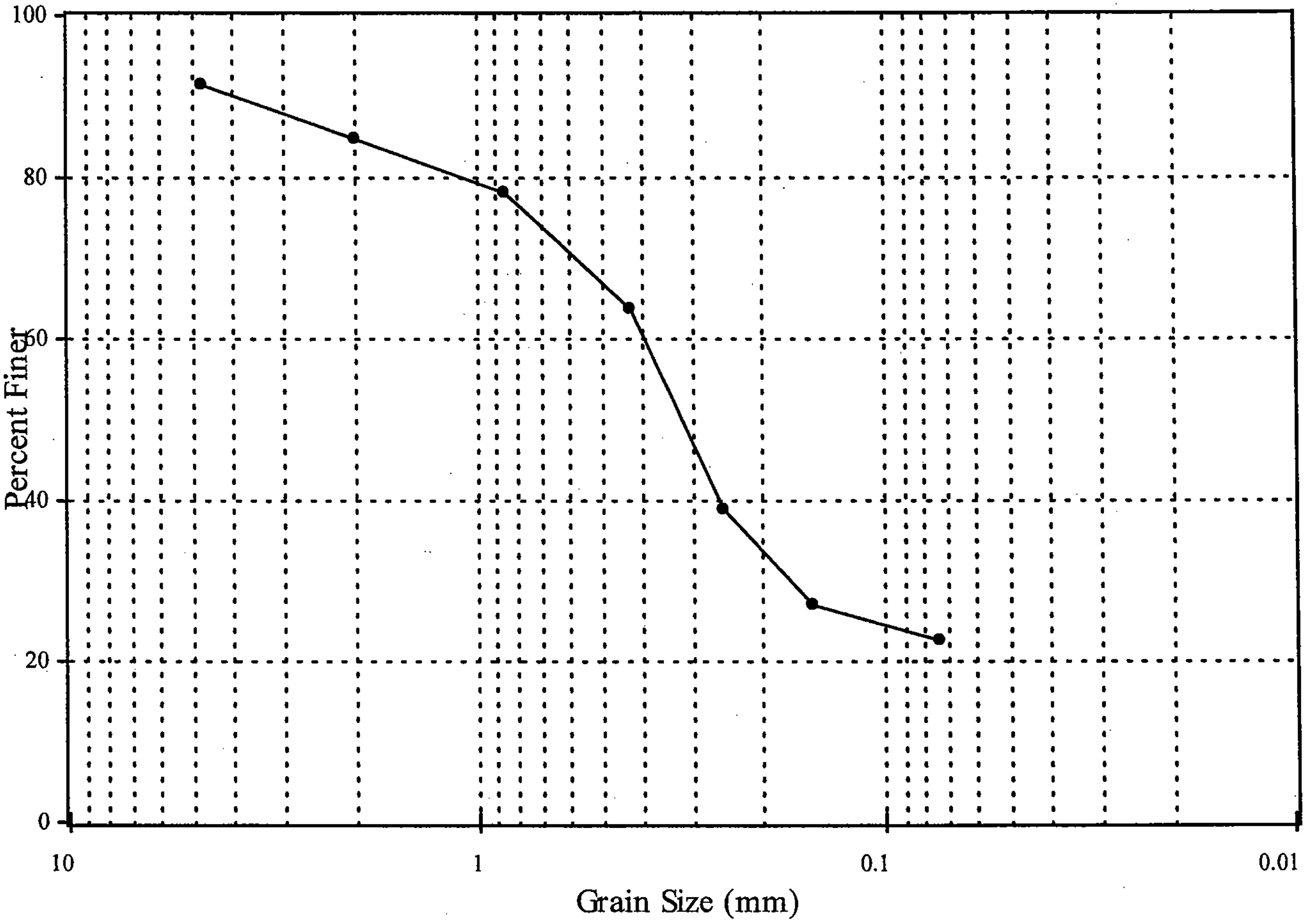
Sieve Number	Diameter Range	Percent Retained	Description
#4	>4.76 mm	10.23	Gravel
#10	<4.76 mm - 2.00 mm	5.89	Coarse Sand
#20	<2.00 mm - 0.85 mm	7.88	Medium Sand
#40	<0.85 mm - 0.425 mm	19.66	Medium Sand
#60	<0.425 mm - 0.25 mm	18.56	Fine Sand
#100	<0.25 mm - 0.15 mm	6.52	Fine Sand
#200	<0.15 mm - 0.074 mm	5.13	Fine Sand
Passing #200	<0.074 mm	26.05	Silt/Clay

N/A - Not Applicable

08/21/02 13:03

Wet Sieve Analysis

Client:	**Army Corps of Engineers**	Lab Code:	**M-MA030**
Project:	**Boston Harbor Improvement Project**	ETR:	**0208094**
Case:	N/A SDG: N/A	Lab ID:	**0208094-07**
Client ID:	**STA O**	Concentration Units:	**%**
Matrix:	**Sediment**	Received Date:	**8/15/2002**
Collection Date:	**8/14/2002**	Analysis Date:	**8/20/2002**



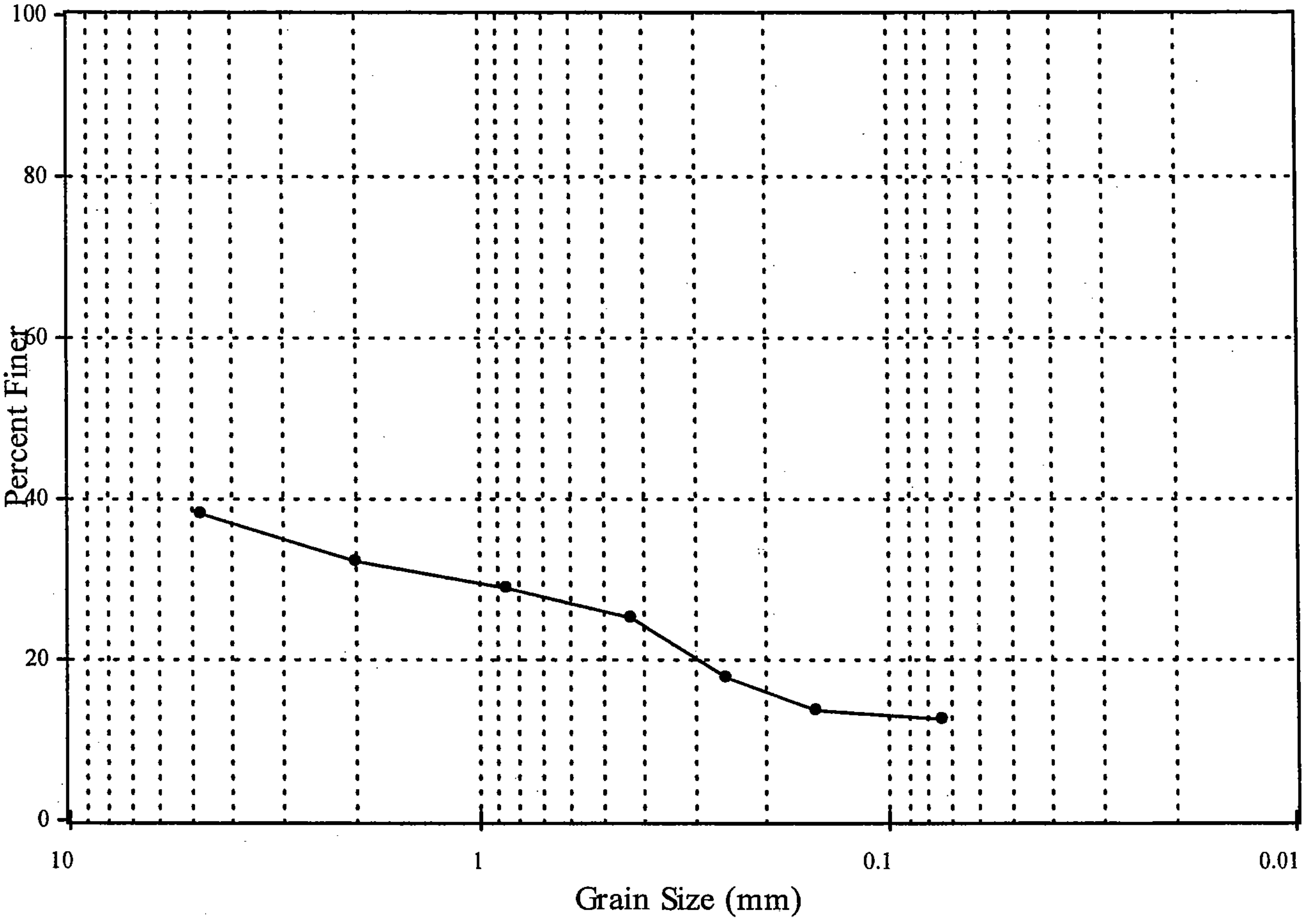
Sieve Number	Diameter Range	Percent Retained	Description
#4	>4.76 mm	8.60	Gravel
#10	<4.76 mm - 2.00 mm	6.54	Coarse Sand
#20	<2.00 mm - 0.85 mm	6.89	Medium Sand
#40	<0.85 mm - 0.425 mm	14.17	Medium Sand
#60	<0.425 mm - 0.25 mm	25.03	Fine Sand
#100	<0.25 mm - 0.15 mm	11.85	Fine Sand
#200	<0.15 mm - 0.074 mm	4.32	Fine Sand
Passing #200	<0.074 mm	22.48	Silt/Clay

N/A - Not Applicable

08/21/02 13:02

Wet Sieve Analysis

Client:	**Army Corps of Engineers**	Lab Code:	**M-MA030**
Project:	**Boston Harbor Improvement Project**	ETR:	**0208094**
Case:	N/A SDG: N/A	Lab ID:	**0208094-06**
Client ID:	**STA P**	Concentration Units:	**%**
Matrix:	**Sediment**	Received Date:	**8/15/2002**
Collection Date:	**8/14/2002**	Analysis Date:	**8/20/2002**



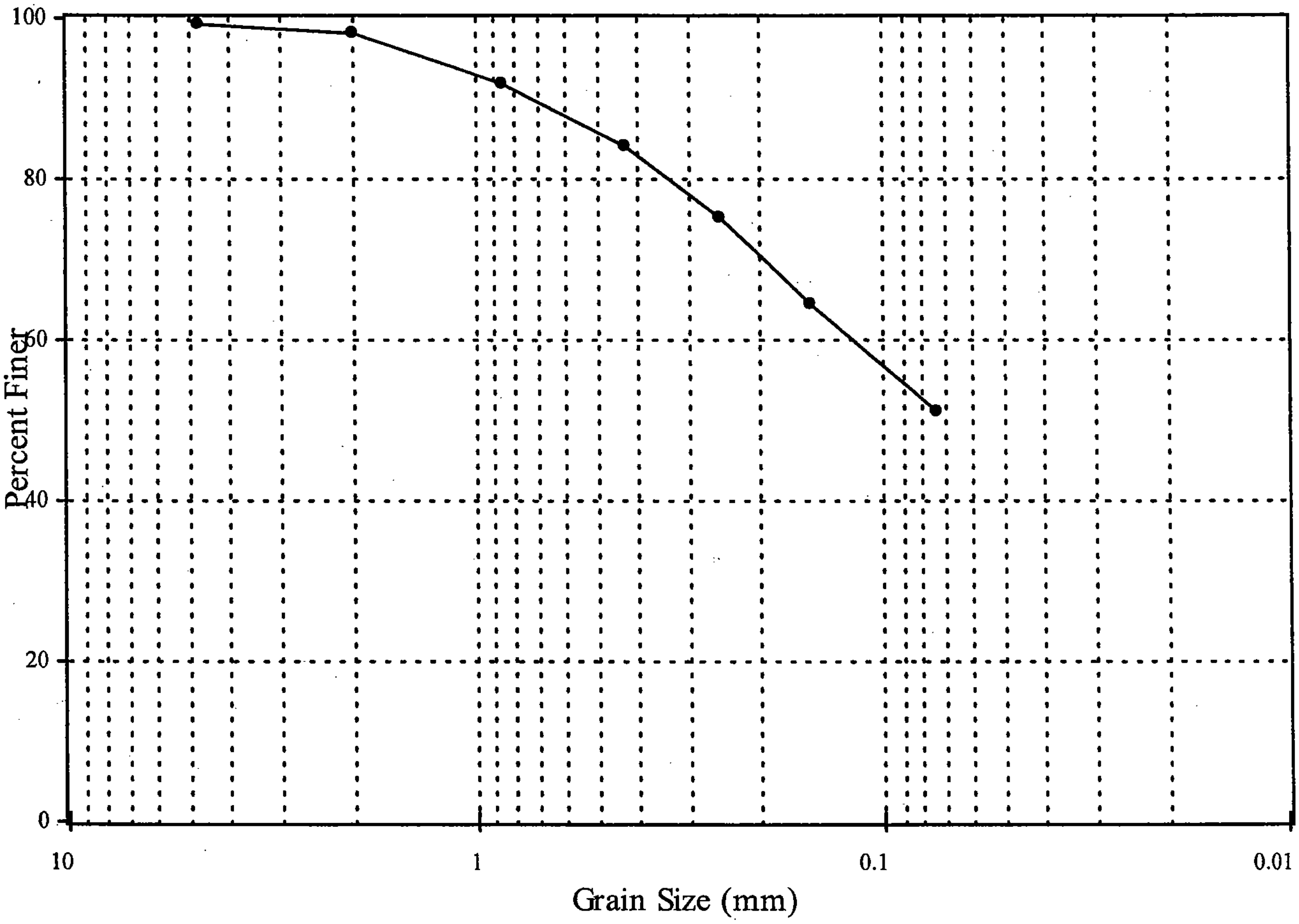
Sieve Number	Diameter Range	Percent Retained	Description
#4	>4.76 mm	61.81	Gravel
#10	<4.76 mm - 2.00 mm	5.90	Coarse Sand
#20	<2.00 mm - 0.85 mm	3.24	Medium Sand
#40	<0.85 mm - 0.425 mm	3.94	Medium Sand
#60	<0.425 mm - 0.25 mm	7.22	Fine Sand
#100	<0.25 mm - 0.15 mm	4.08	Fine Sand
#200	<0.15 mm - 0.074 mm	1.38	Fine Sand
Passing #200	<0.074 mm	12.21	Silt/Clay

N/A - Not Applicable

Woods Hole Group

Wet Sieve Analysis

Client:	**Army Corps of Engineers**	Lab Code:	**M-MA030**
Project:	**Boston Harbor Improvement Project**	ETR:	**0208080**
Case:	N/A SDG: N/A	Lab ID:	**0208080-10**
Client ID:	**STA Q**	Concentration Units:	**%**
Matrix:	**Sediment**	Received Date:	**8/9/2002**
Collection Date:	**8/9/2002**	Analysis Date:	**8/12/2002**



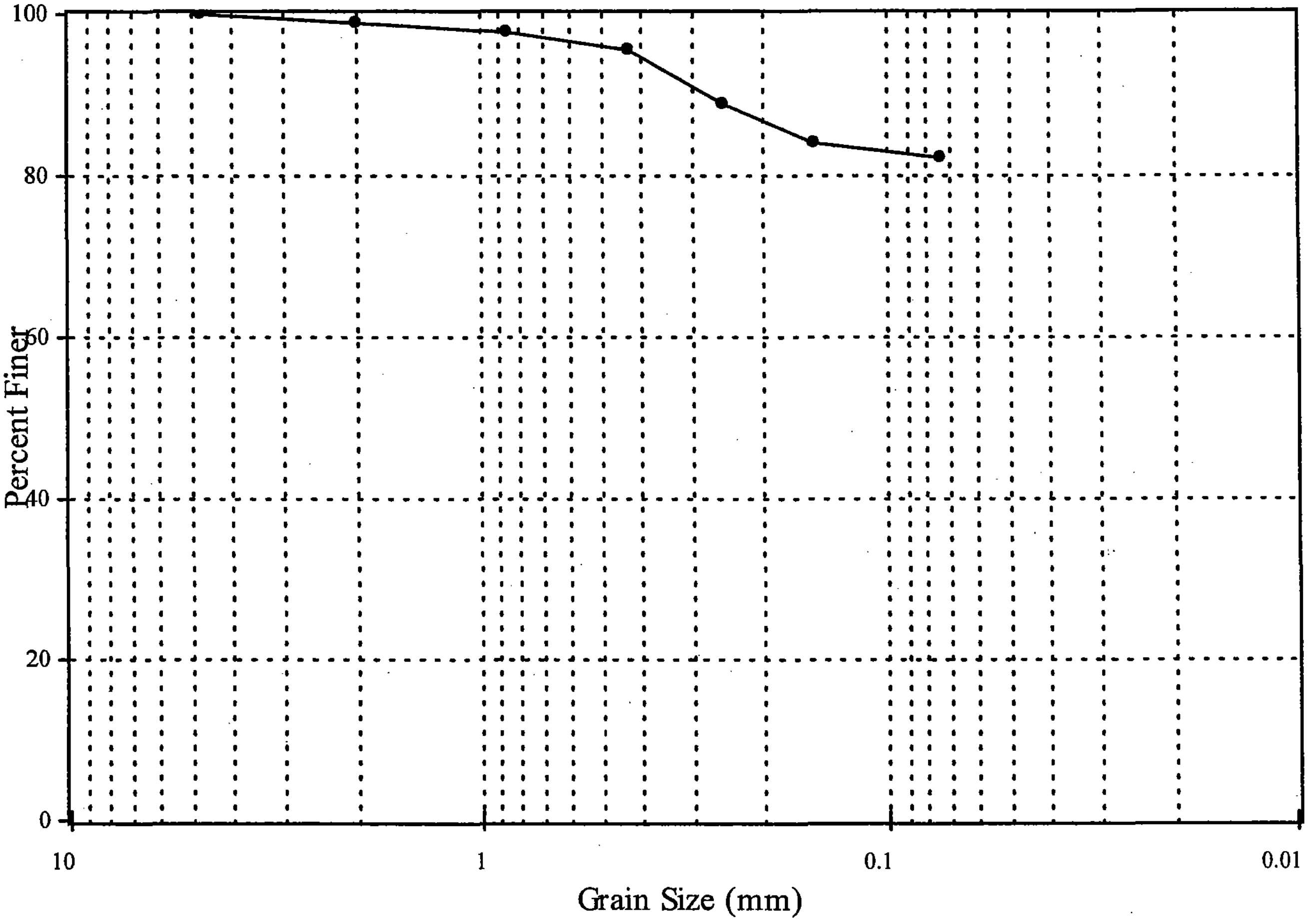
Sieve Number	Diameter Range	Percent Retained	Description
#4	>4.76 mm	0.86	Gravel
#10	<4.76 mm - 2.00 mm	0.86	Coarse Sand
#20	<2.00 mm - 0.85 mm	6.40	Medium Sand
#40	<0.85 mm - 0.425 mm	7.78	Medium Sand
#60	<0.425 mm - 0.25 mm	8.93	Fine Sand
#100	<0.25 mm - 0.15 mm	10.89	Fine Sand
#200	<0.15 mm - 0.074 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**



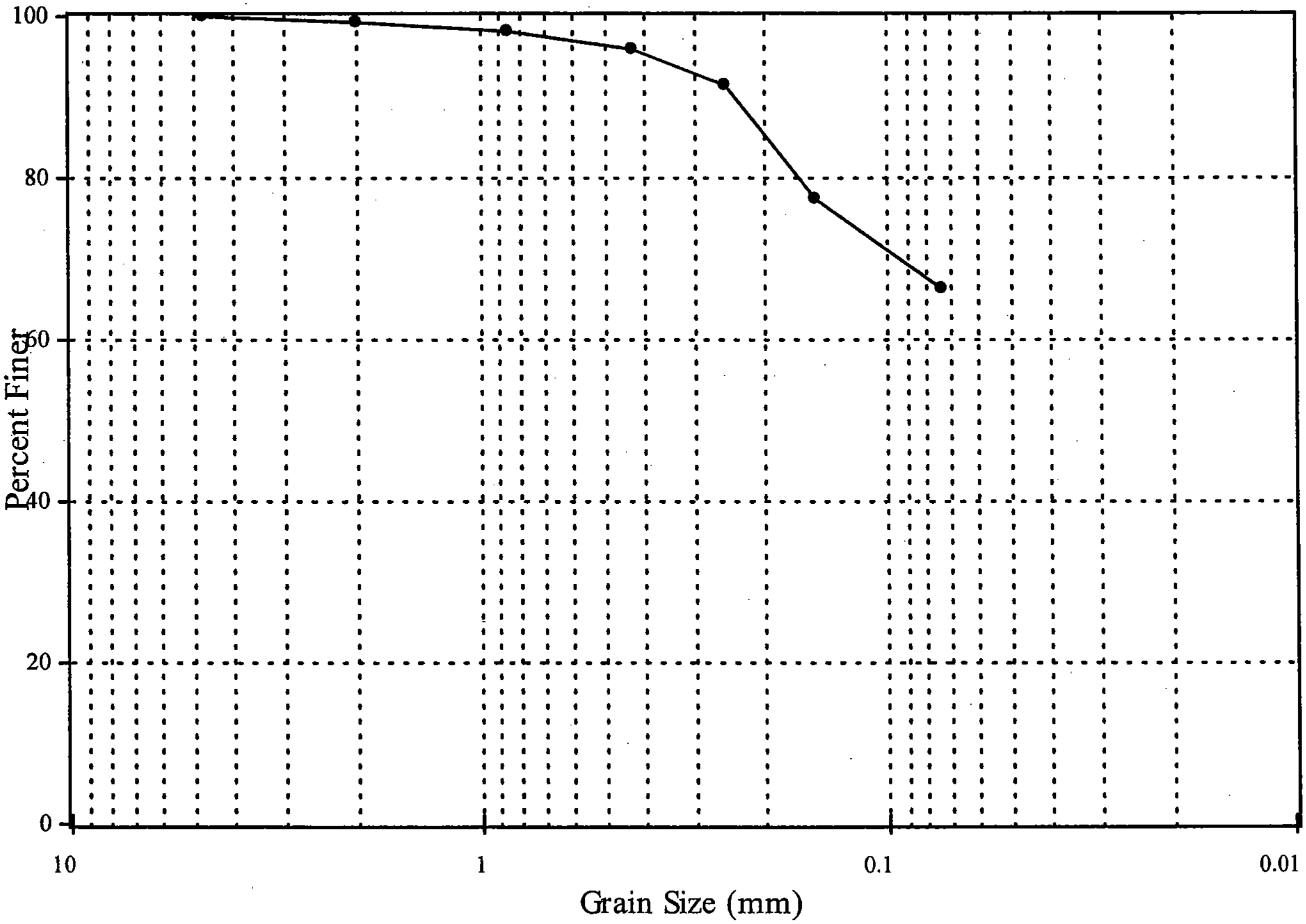
Sieve Number	Diameter Range	Percent Retained	Description
#4	>4.76 mm	0.17	Gravel
#10	<4.76 mm - 2.00 mm	0.94	Coarse Sand
#20	<2.00 mm - 0.85 mm	1.26	Medium Sand
#40	<0.85 mm - 0.425 mm	2.17	Medium Sand
#60	<0.425 mm - 0.25 mm	6.39	Fine Sand
#100	<0.25 mm - 0.15 mm	4.84	Fine Sand
#200	<0.15 mm - 0.074 mm	2.10	Fine Sand
Passing #200	<0.074 mm	82.11	Silt/Clay

N/A - Not Applicable

08/21/02 12:52

Wet Sieve Analysis

Client:	**Army Corps of Engineers**	Lab Code:	**M-MA030**
Project:	**Boston Harbor Improvement Project**	ETR:	**0208094**
Case:	N/A SDG: N/A	Lab ID:	**0208094-04**
Client ID:	**STA S**	Concentration Units:	**%**
Matrix:	**Sediment**	Received Date:	**8/15/2002**
Collection Date:	**8/14/2002**	Analysis Date:	**8/20/2002**



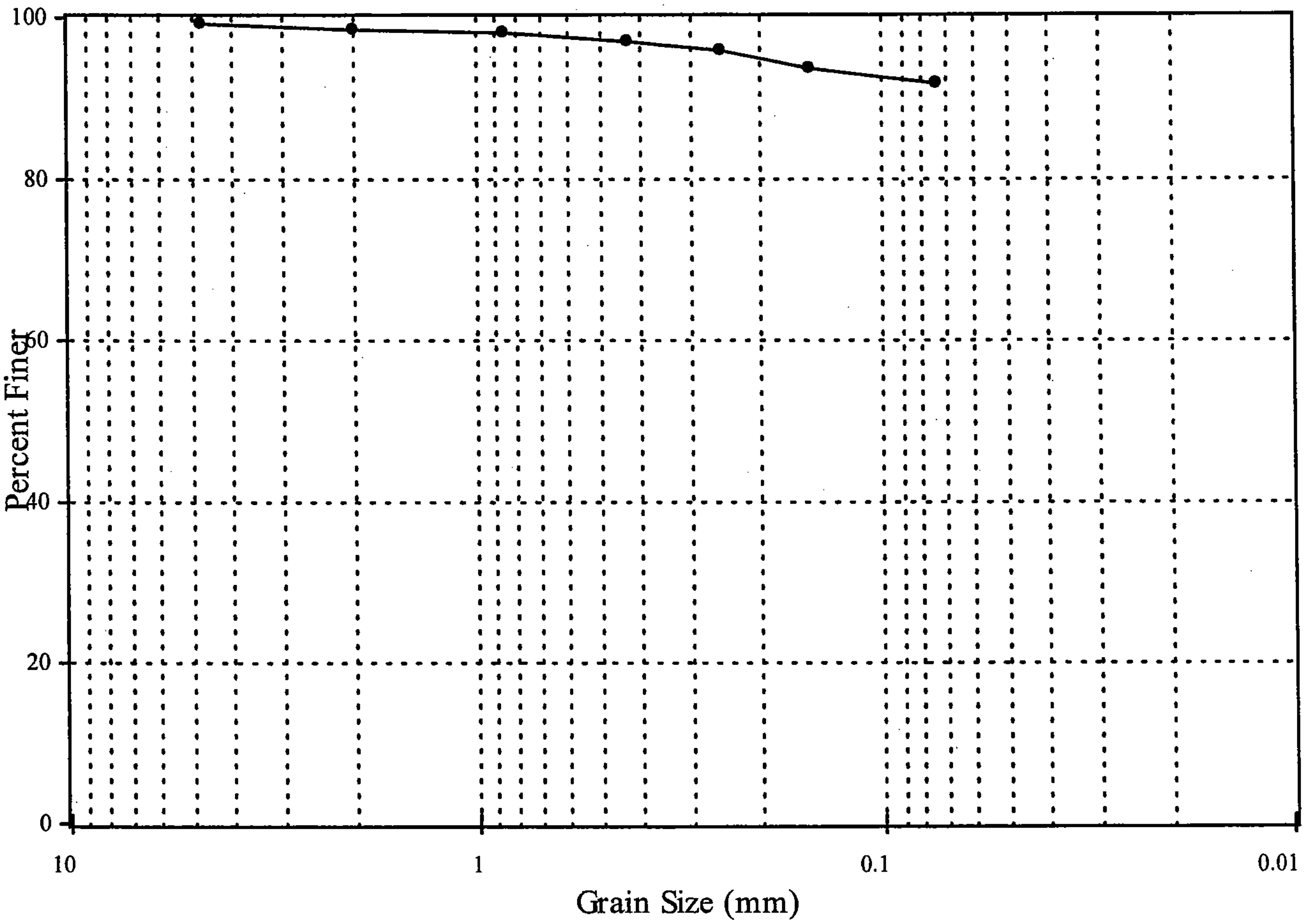
Sieve Number	Diameter Range	Percent Retained	Description
#4	>4.76 mm	0.12	Gravel
#10	<4.76 mm - 2.00 mm	0.51	Coarse Sand
#20	<2.00 mm - 0.85 mm	1.28	Medium Sand
#40	<0.85 mm - 0.425 mm	2.04	Medium Sand
#60	<0.425 mm - 0.25 mm	4.44	Fine Sand
#100	<0.25 mm - 0.15 mm	14.07	Fine Sand
#200	<0.15 mm - 0.074 mm	11.37	Fine Sand
Passing #200	<0.074 mm	66.13	Silt/Clay

N/A - Not Applicable

08/21/02 12:46

Wet Sieve Analysis

Client:	**Army Corps of Engineers**	Lab Code:	**M-MA030**
Project:	**Boston Harbor Improvement Project**	ETR:	**0208094**
Case:	N/A SDG: N/A	Lab ID:	**0208094-03**
Client ID:	**STA T**	Concentration Units:	**%**
Matrix:	**Sediment**	Received Date:	**8/15/2002**
Collection Date:	**8/14/2002**	Analysis Date:	**8/20/2002**



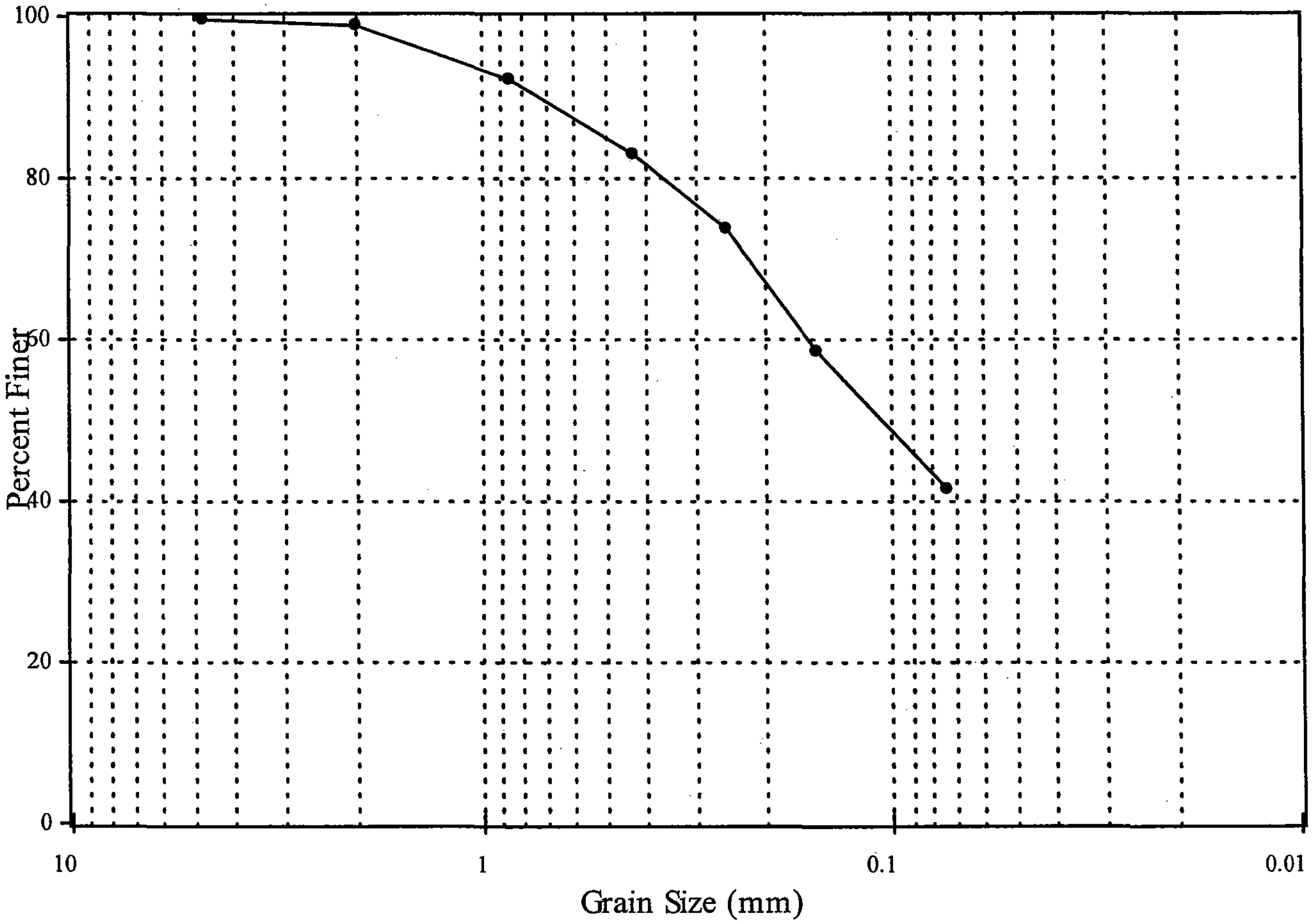
Sieve Number	Diameter Range	Percent Retained	Description
#4	>4.76 mm	0.92	Gravel
#10	<4.76 mm - 2.00 mm	0.52	Coarse Sand
#20	<2.00 mm - 0.85 mm	0.49	Medium Sand
#40	<0.85 mm - 0.425 mm	0.90	Medium Sand
#60	<0.425 mm - 0.25 mm	1.18	Fine Sand
#100	<0.25 mm - 0.15 mm	2.47	Fine Sand
#200	<0.15 mm - 0.074 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**



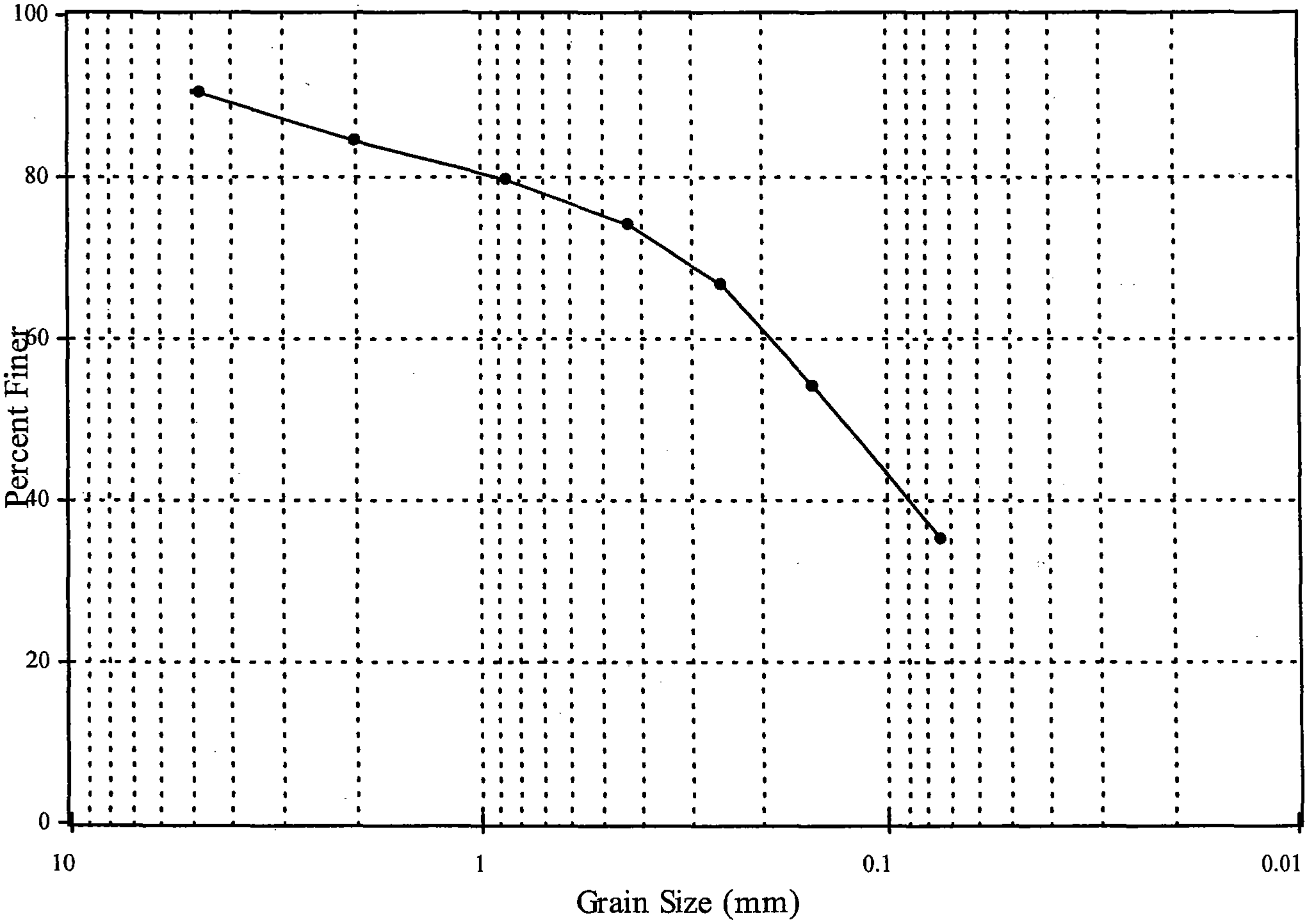
Sieve Number	Diameter Range	Percent Retained	Description
#4	>4.76 mm	0.30	Gravel
#10	<4.76 mm - 2.00 mm	0.97	Coarse Sand
#20	<2.00 mm - 0.85 mm	6.50	Medium Sand
#40	<0.85 mm - 0.425 mm	9.15	Medium Sand
#60	<0.425 mm - 0.25 mm	9.26	Fine Sand
#100	<0.25 mm - 0.15 mm	15.36	Fine Sand
#200	<0.15 mm - 0.074 mm	17.05	Fine Sand
Passing #200	<0.074 mm	41.36	Silt/Clay

N/A - Not Applicable

08/21/02 11:22

Wet Sieve Analysis

Client:	**Army Corps of Engineers**			Lab Code: **M-MA030**
Project:	**Boston Harbor Improvement Project**			ETR: **0208080**
Case:	N/A	SDG:	N/A	Lab ID: **0208080-09**
Client ID:	**STA V**			Concentration Units: **%**
Matrix:	**Sediment**			Received Date: **8/9/2002**
Collection 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

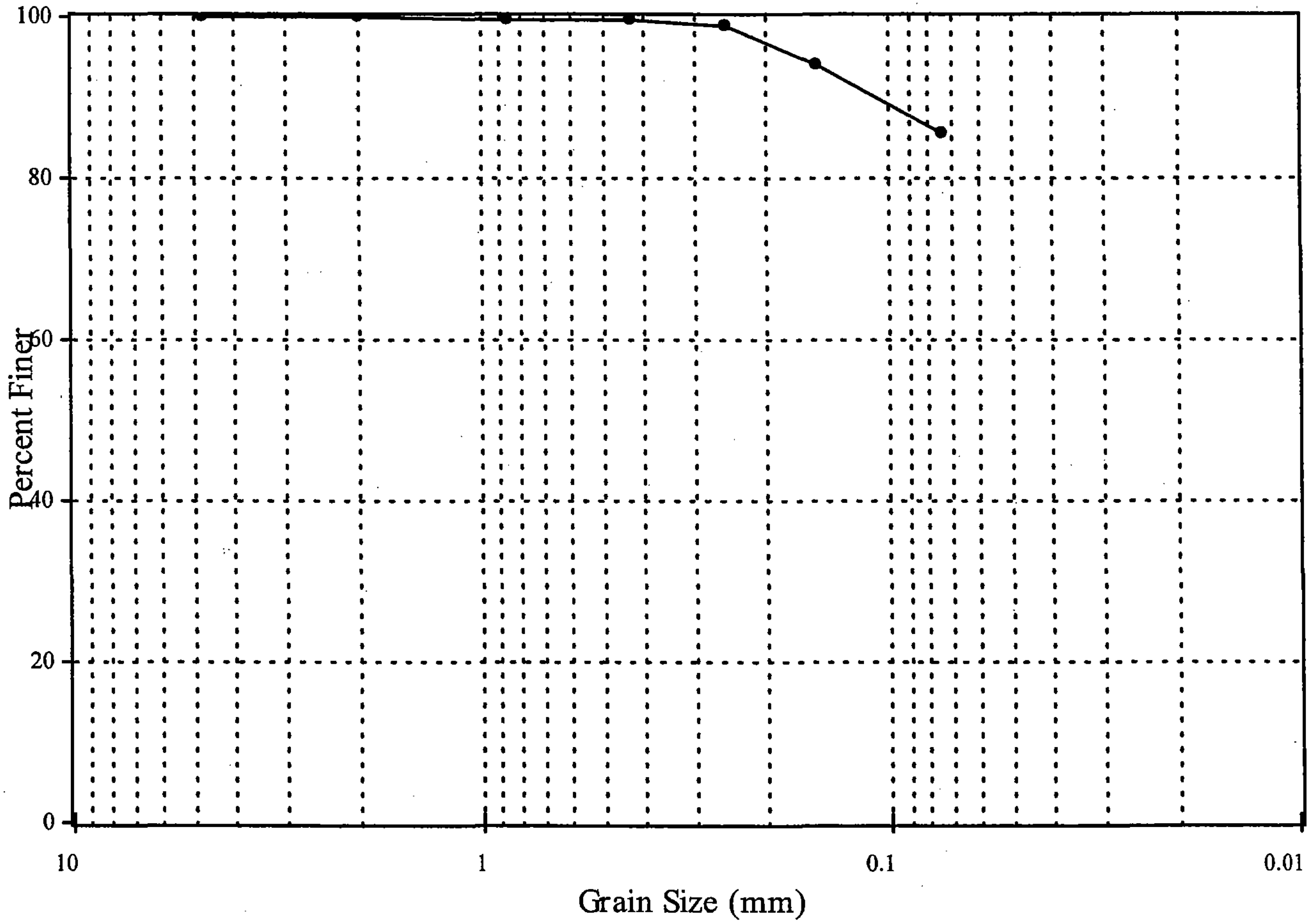
N/A - Not Applicable

08/21/02 11:23

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**



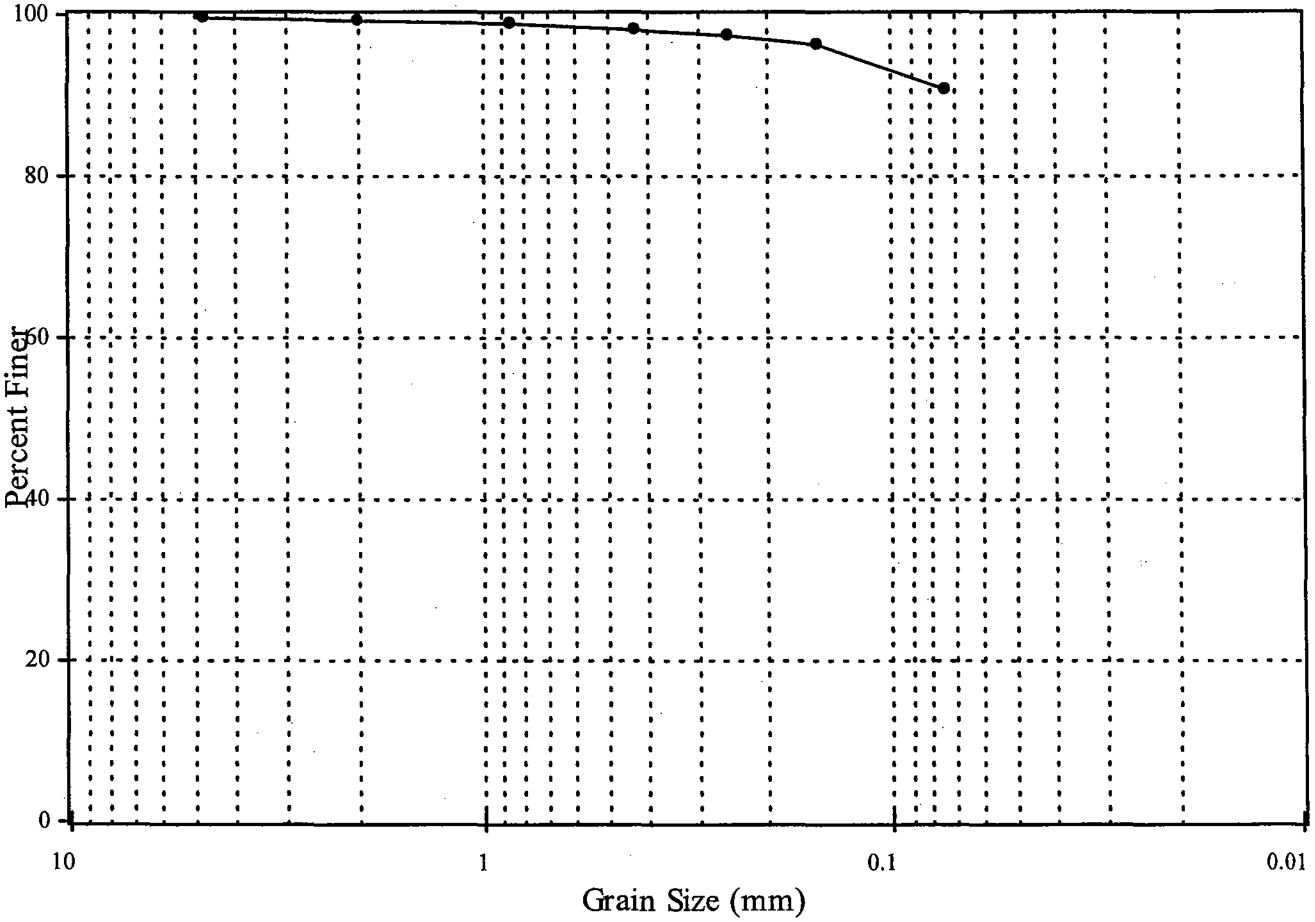
Sieve Number	Diameter Range	Percent Retained	Description
#4	>4.76 mm	0.00	Gravel
#10	<4.76 mm - 2.00 mm	0.00	Coarse Sand
#20	<2.00 mm - 0.85 mm	0.27	Medium Sand
#40	<0.85 mm - 0.425 mm	0.23	Medium Sand
#60	<0.425 mm - 0.25 mm	0.65	Fine Sand
#100	<0.25 mm - 0.15 mm	4.76	Fine Sand
#200	<0.15 mm - 0.074 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

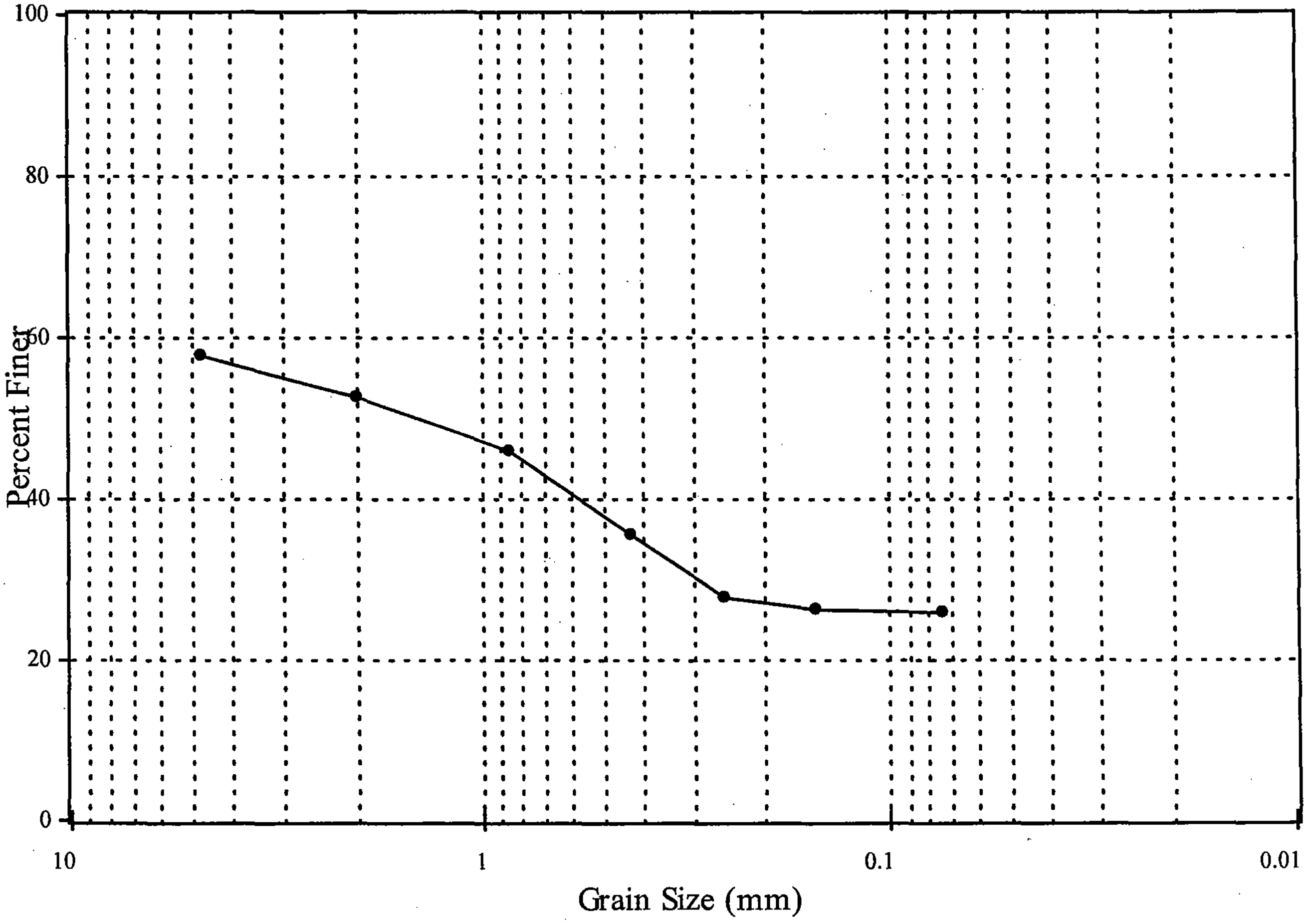
N/A - Not Applicable

08/21/02 11:23

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**



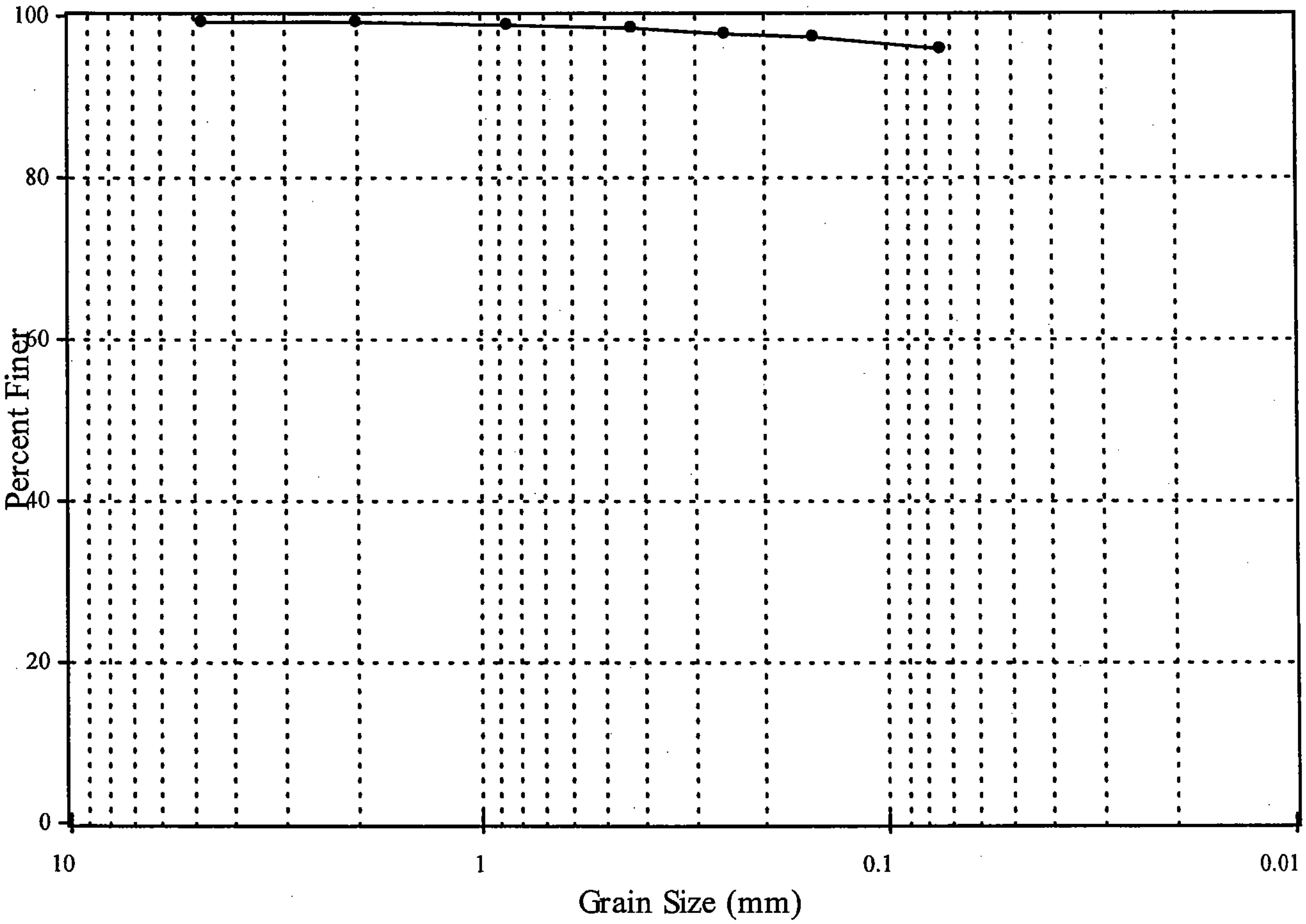
Sieve Number	Diameter Range	Percent Retained	Description
#4	>4.76 mm	42.28	Gravel
#10	<4.76 mm - 2.00 mm	5.18	Coarse Sand
#20	<2.00 mm - 0.85 mm	6.50	Medium Sand
#40	<0.85 mm - 0.425 mm	10.46	Medium Sand
#60	<0.425 mm - 0.25 mm	7.86	Fine Sand
#100	<0.25 mm - 0.15 mm	1.35	Fine Sand
#200	<0.15 mm - 0.074 mm	0.63	Fine Sand
Passing #200	<0.074 mm	25.56	Silt/Clay

N/A - Not Applicable

08/21/02 11:24

Wet Sieve Analysis

Client:	**Army Corps of Engineers**	Lab Code: **M-MA030**
Project:	**Boston Harbor Improvement Project**	ETR: **0208085**
Case:	**N/A** SDG: **N/A**	Lab ID: **0208085-09**
Client ID:	**STA BB**	Concentration Units: **%**
Matrix:	**Sediment**	Received Date: **8/13/2002**
Collection Date: **8/12/2002**		Analysis Date: **8/16/2002**



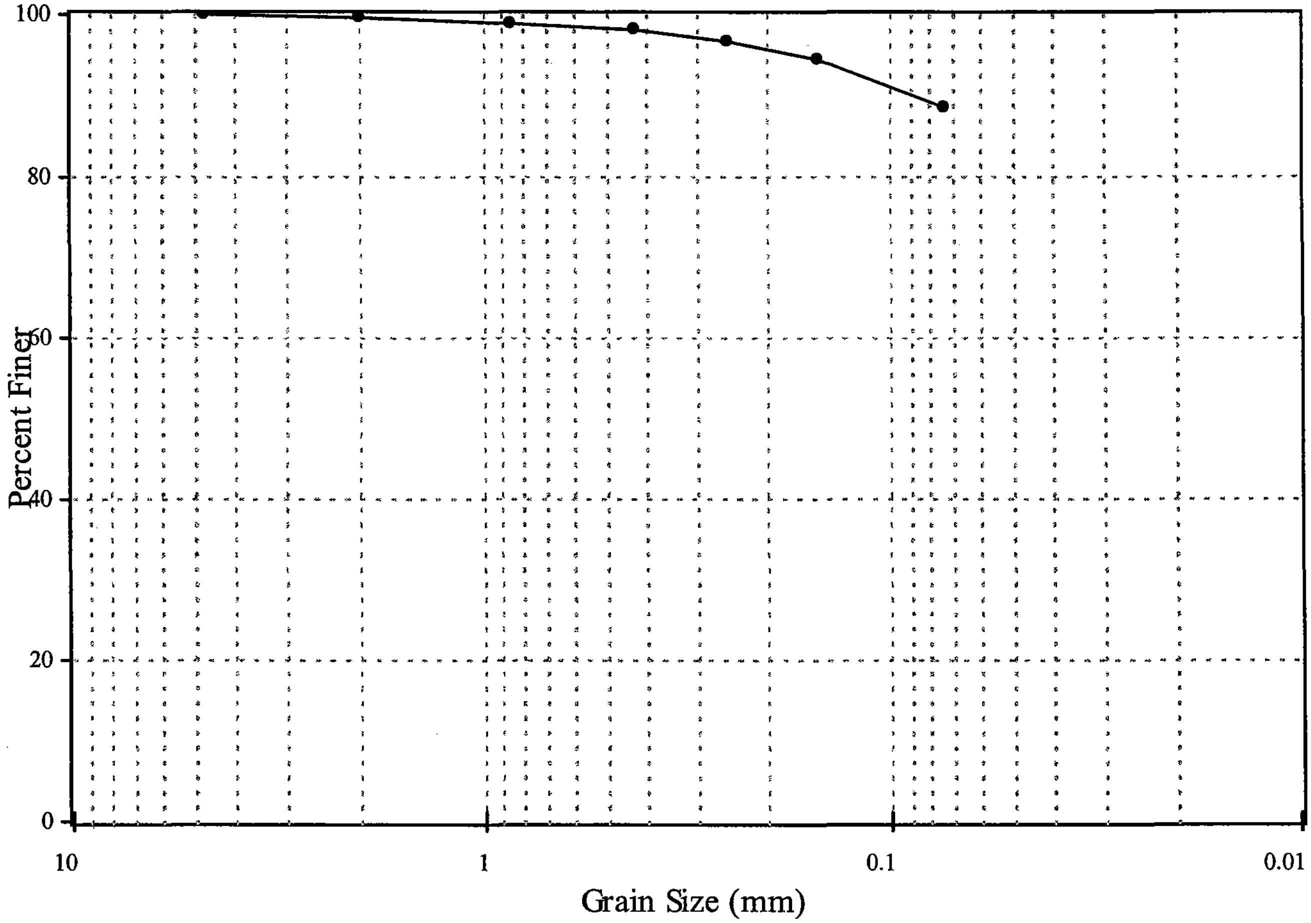
Sieve Number	Diameter Range	Percent Retained	Description
#4	>4.76 mm	0.56	Gravel
#10	<4.76 mm - 2.00 mm	0.30	Coarse Sand
#20	<2.00 mm - 0.85 mm	0.22	Medium Sand
#40	<0.85 mm - 0.425 mm	0.43	Medium Sand
#60	<0.425 mm - 0.25 mm	0.64	Fine Sand
#100	<0.25 mm - 0.15 mm	0.45	Fine Sand
#200	<0.15 mm - 0.074 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**



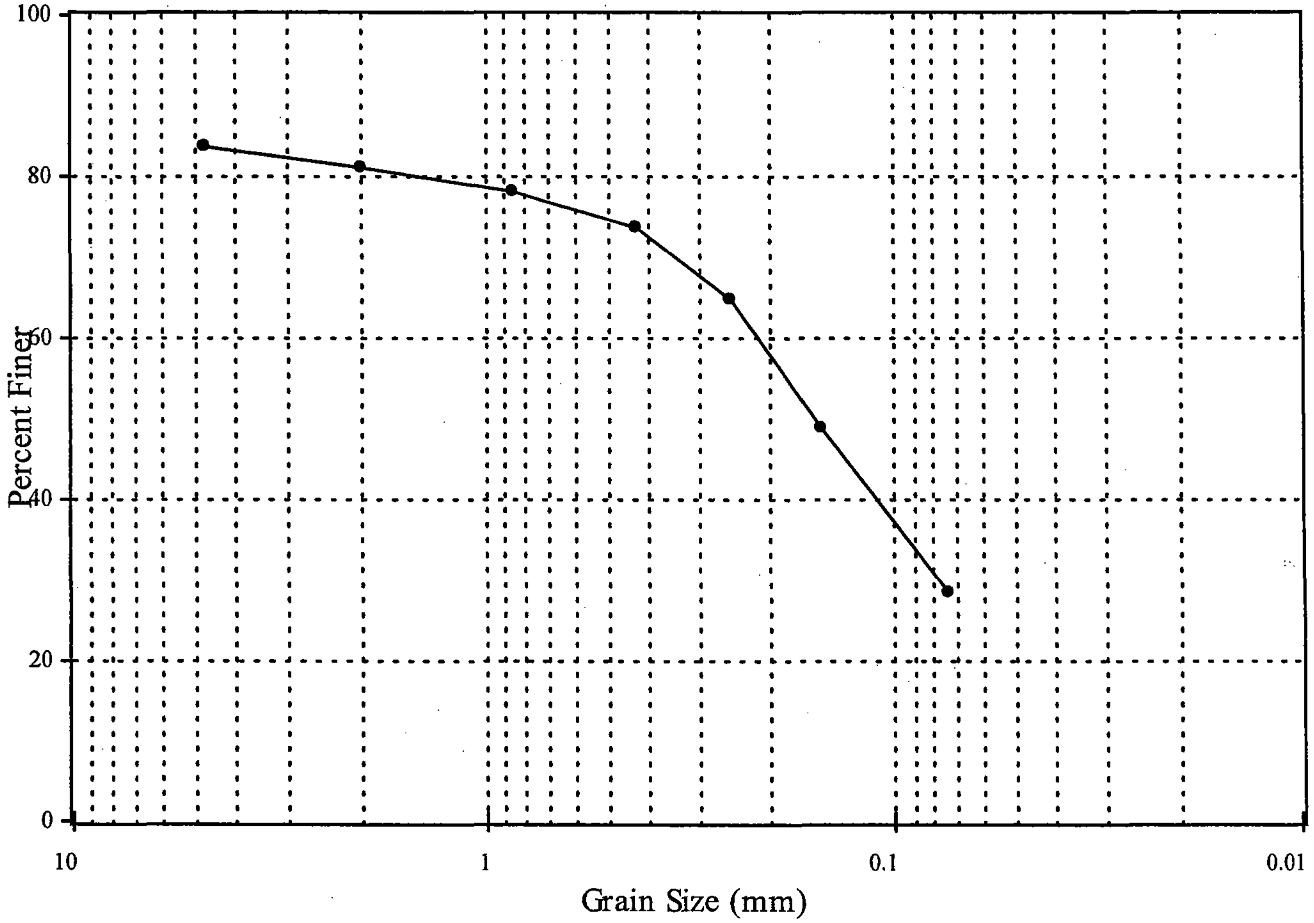
Sieve Number	Diameter Range	Percent Retained	Description
#4	>4.76 mm	0.00	Gravel
#10	<4.76 mm - 2.00 mm	0.43	Coarse Sand
#20	<2.00 mm - 0.85 mm	0.62	Medium Sand
#40	<0.85 mm - 0.425 mm	0.97	Medium Sand
#60	<0.425 mm - 0.25 mm	1.34	Fine Sand
#100	<0.25 mm - 0.15 mm	2.16	Fine Sand
#200	<0.15 mm - 0.074 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

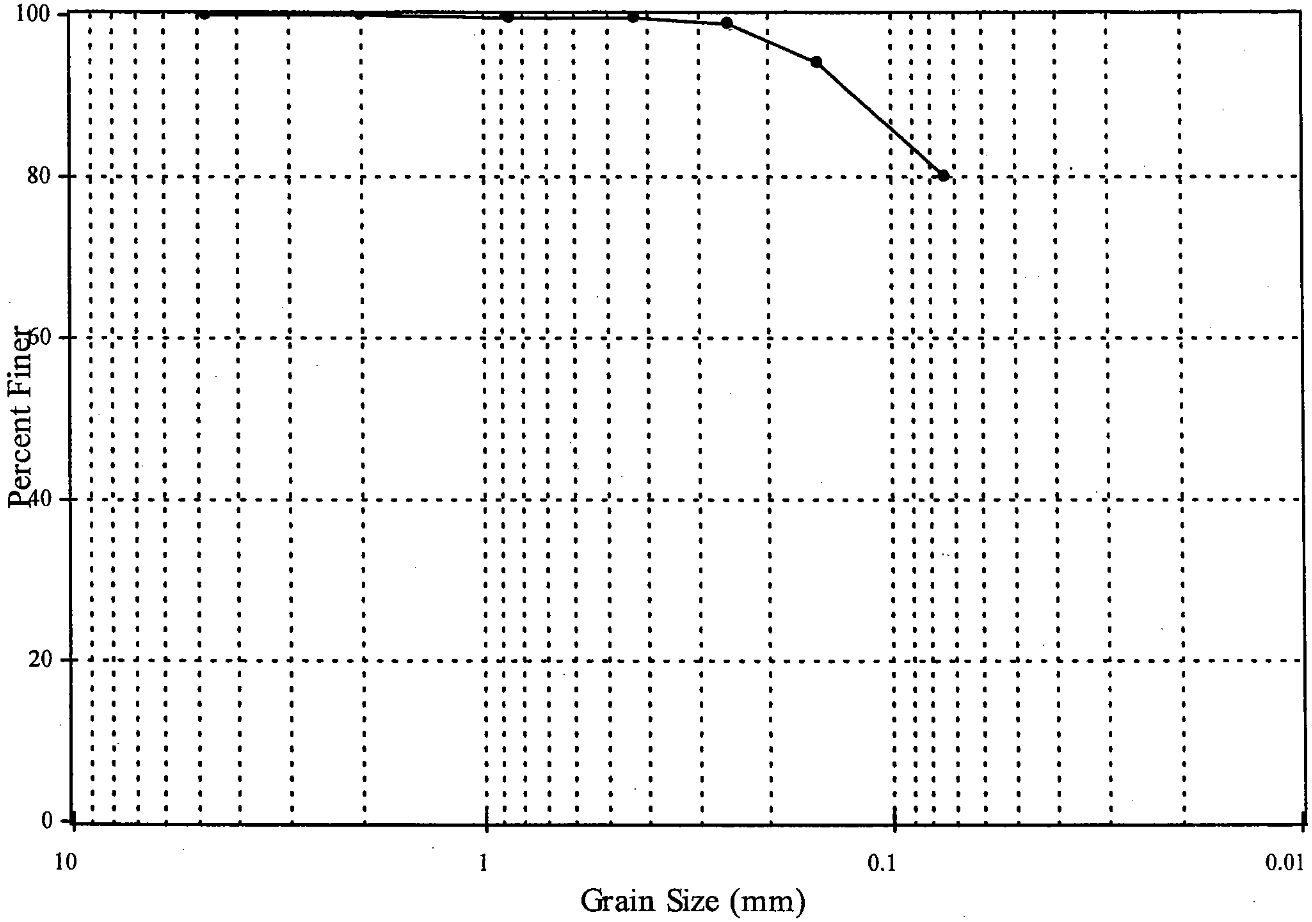
N/A - Not Applicable

08/21/02 11:23

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**



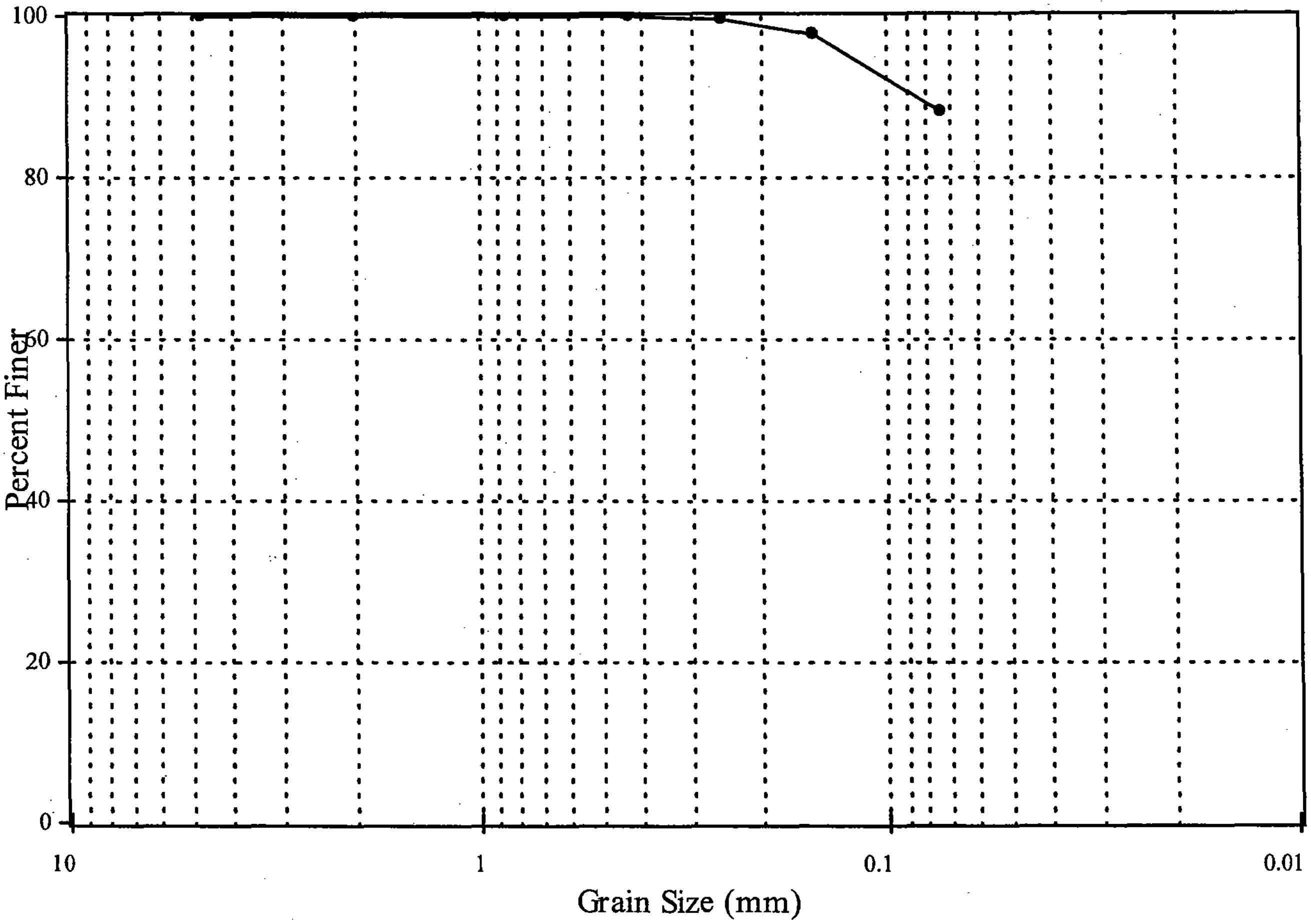
Sieve Number	Diameter Range	Percent Retained	Description
#4	>4.76 mm	0.08	Gravel
#10	<4.76 mm - 2.00 mm	0.02	Coarse Sand
#20	<2.00 mm - 0.85 mm	0.11	Medium Sand
#40	<0.85 mm - 0.425 mm	0.18	Medium Sand
#60	<0.425 mm - 0.25 mm	0.80	Fine Sand
#100	<0.25 mm - 0.15 mm	4.80	Fine Sand
#200	<0.15 mm - 0.074 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

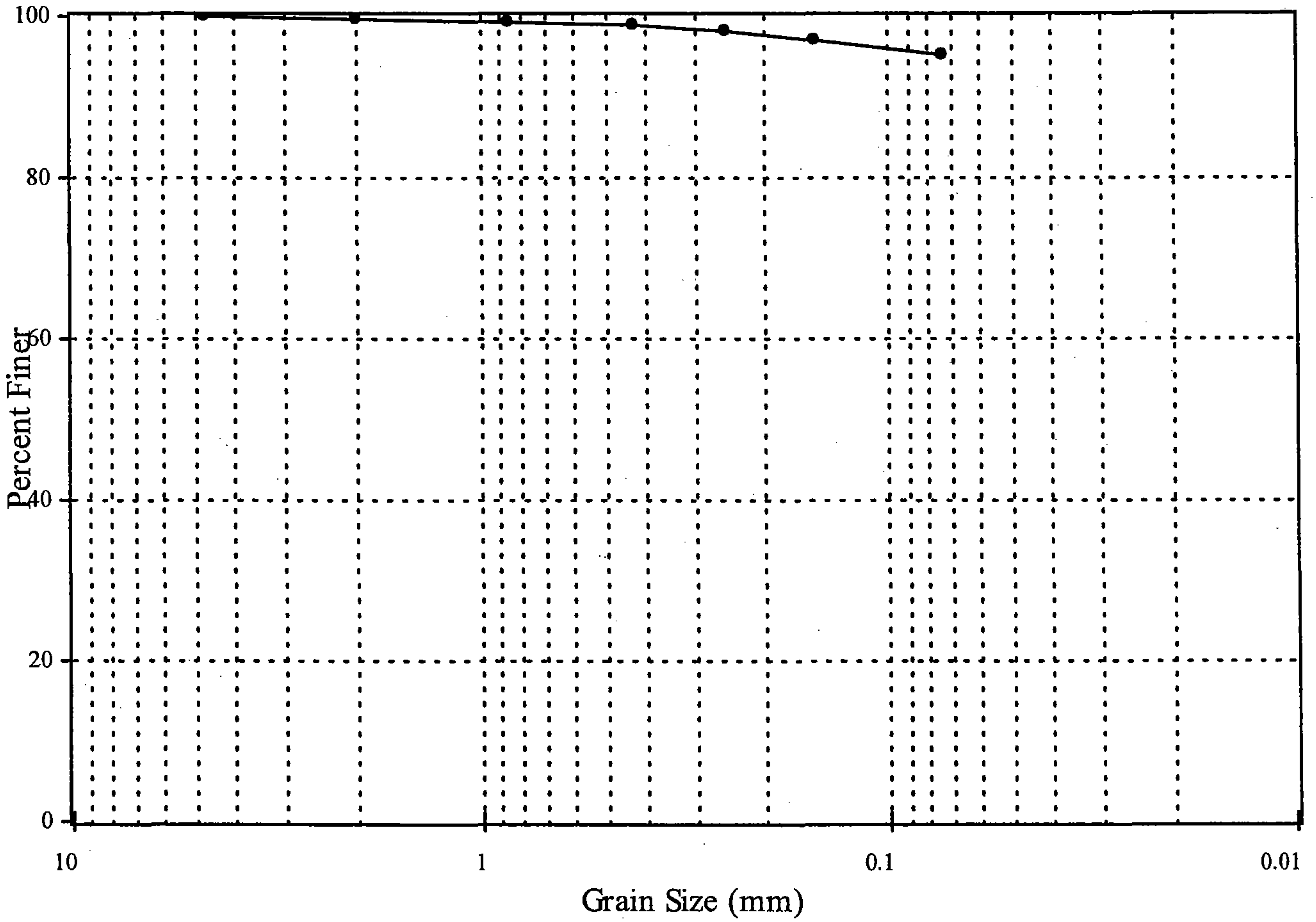
N/A - Not Applicable

08/21/02 11:23

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**

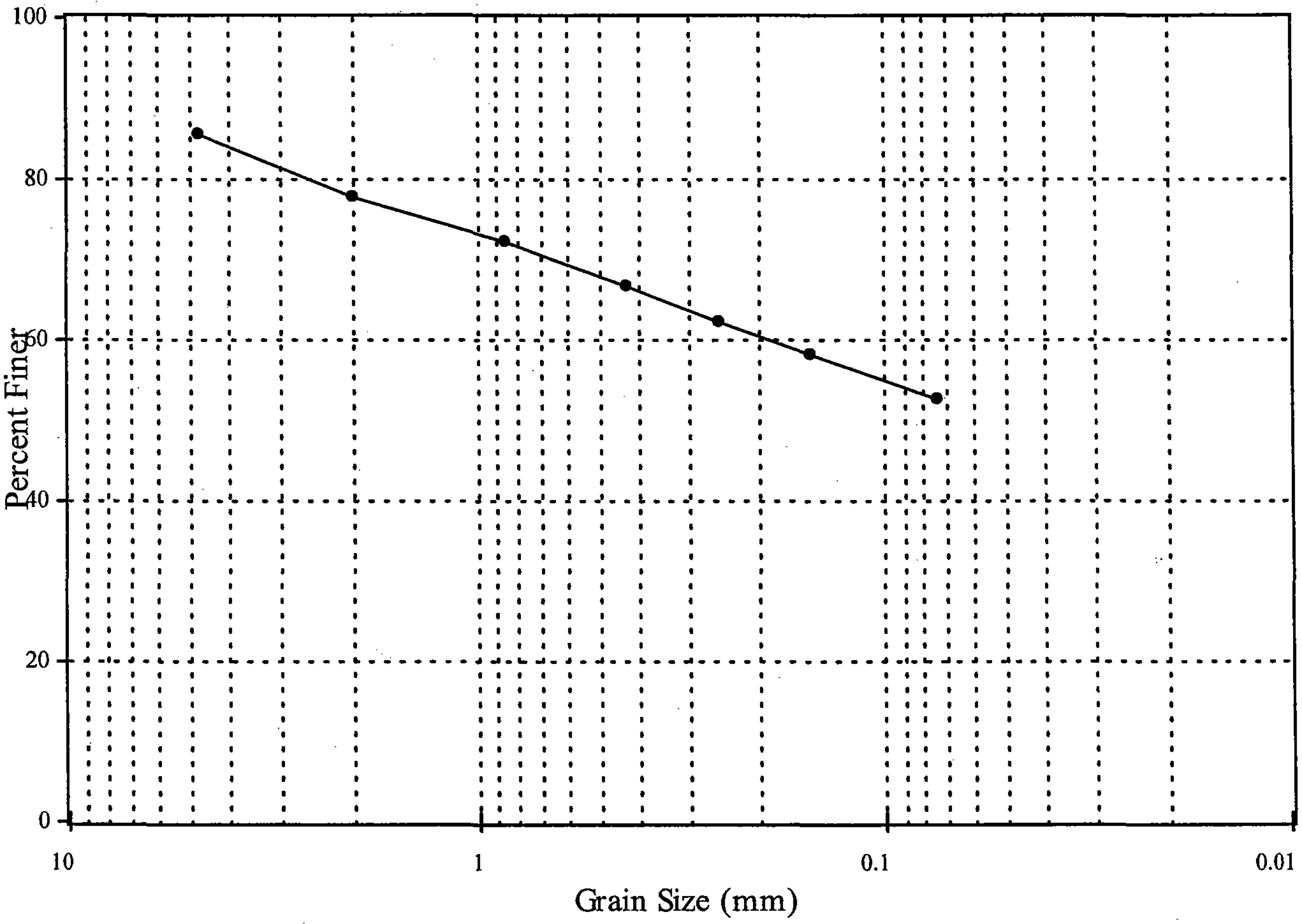


Sieve Number	Diameter Range	Percent Retained	Description
#4	>4.76 mm	0.10	Gravel
#10	<4.76 mm - 2.00 mm	0.24	Coarse Sand
#20	<2.00 mm - 0.85 mm	0.32	Medium Sand
#40	<0.85 mm - 0.425 mm	0.40	Medium Sand
#60	<0.425 mm - 0.25 mm	0.80	Fine Sand
#100	<0.25 mm - 0.15 mm	1.13	Fine Sand
#200	<0.15 mm - 0.074 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**	Lab Code:	**M-MA030**
Project:	**Boston Harbor Improvement Project**	ETR:	**0208080**
Case:	N/A SDG: N/A	Lab ID:	**0208080-03**
Client ID:	**STA HH**	Concentration Units:	**%**
Matrix:	**Sediment**	Received Date:	**8/9/2002**
Collection Date:	**8/8/2002**	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

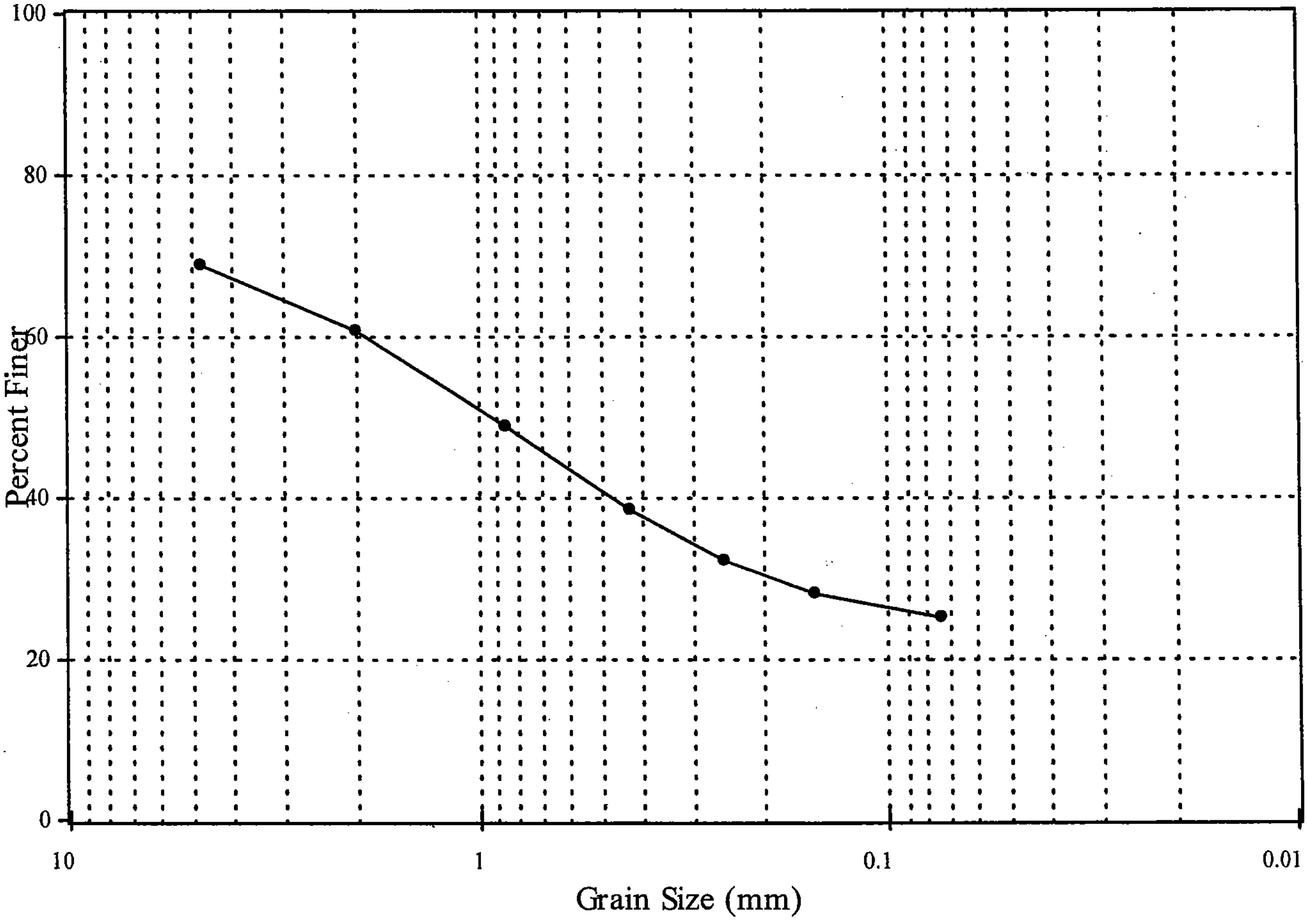
N/A - Not Applicable

08/21/02 11:22

Woods Hole Group

Wet Sieve Analysis

Client:	**Army Corps of Engineers**	Lab Code:	**M-MA030**
Project:	**Boston Harbor Improvement Project**	ETR:	**0208080**
Case:	N/A SDG: N/A	Lab ID:	**0208080-04**
Client ID:	**STA II**	Concentration Units:	**%**
Matrix:	**Sediment**	Received Date:	**8/9/2002**
Collection Date:	**8/8/2002**	Analysis Date:	**8/12/2002**



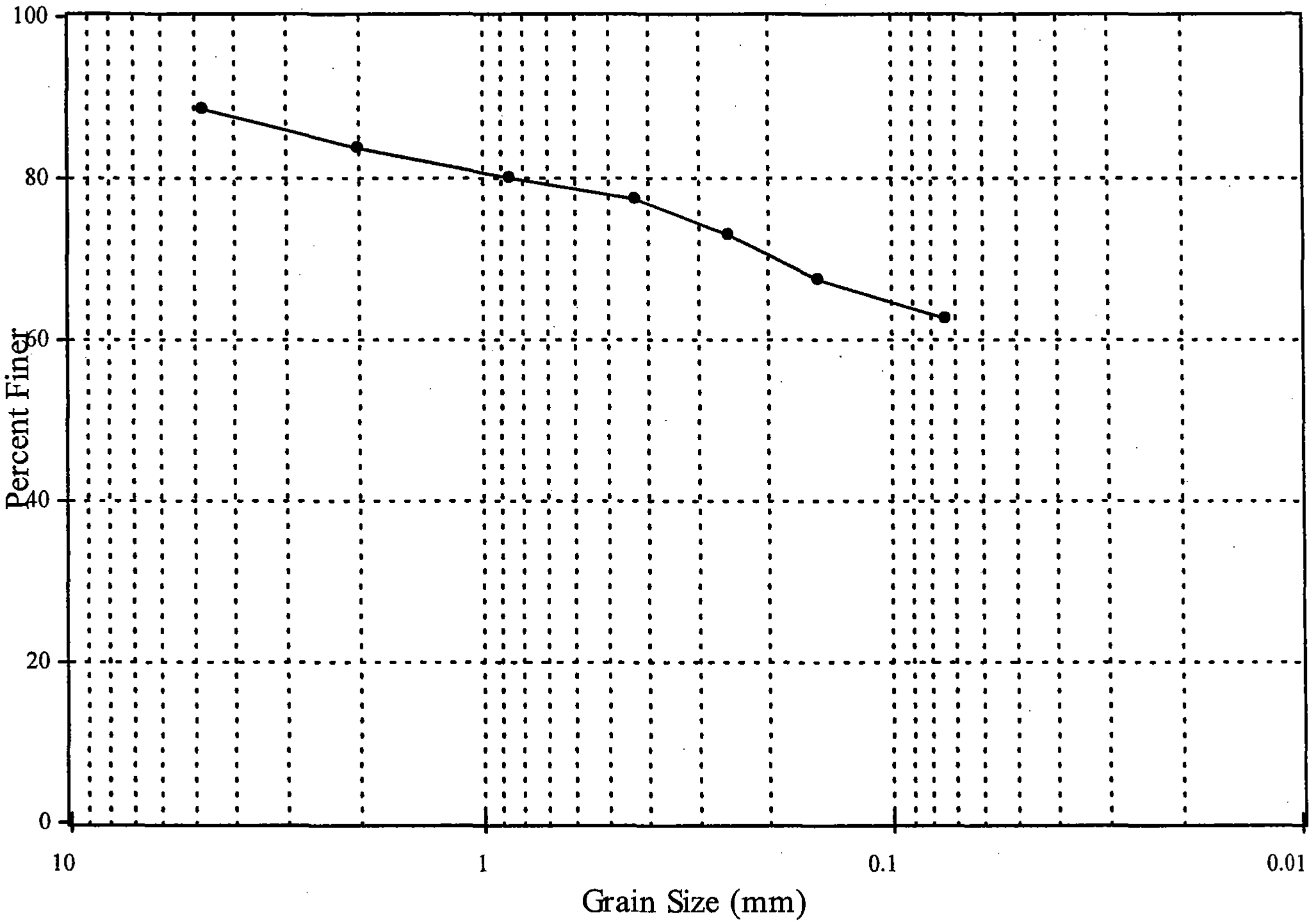
Sieve Number	Diameter Range	Percent Retained	Description
#4	>4.76 mm	31.01	Gravel
#10	<4.76 mm - 2.00 mm	8.25	Coarse Sand
#20	<2.00 mm - 0.85 mm	11.81	Medium Sand
#40	<0.85 mm - 0.425 mm	10.57	Medium Sand
#60	<0.425 mm - 0.25 mm	6.06	Fine Sand
#100	<0.25 mm - 0.15 mm	4.29	Fine Sand
#200	<0.15 mm - 0.074 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**



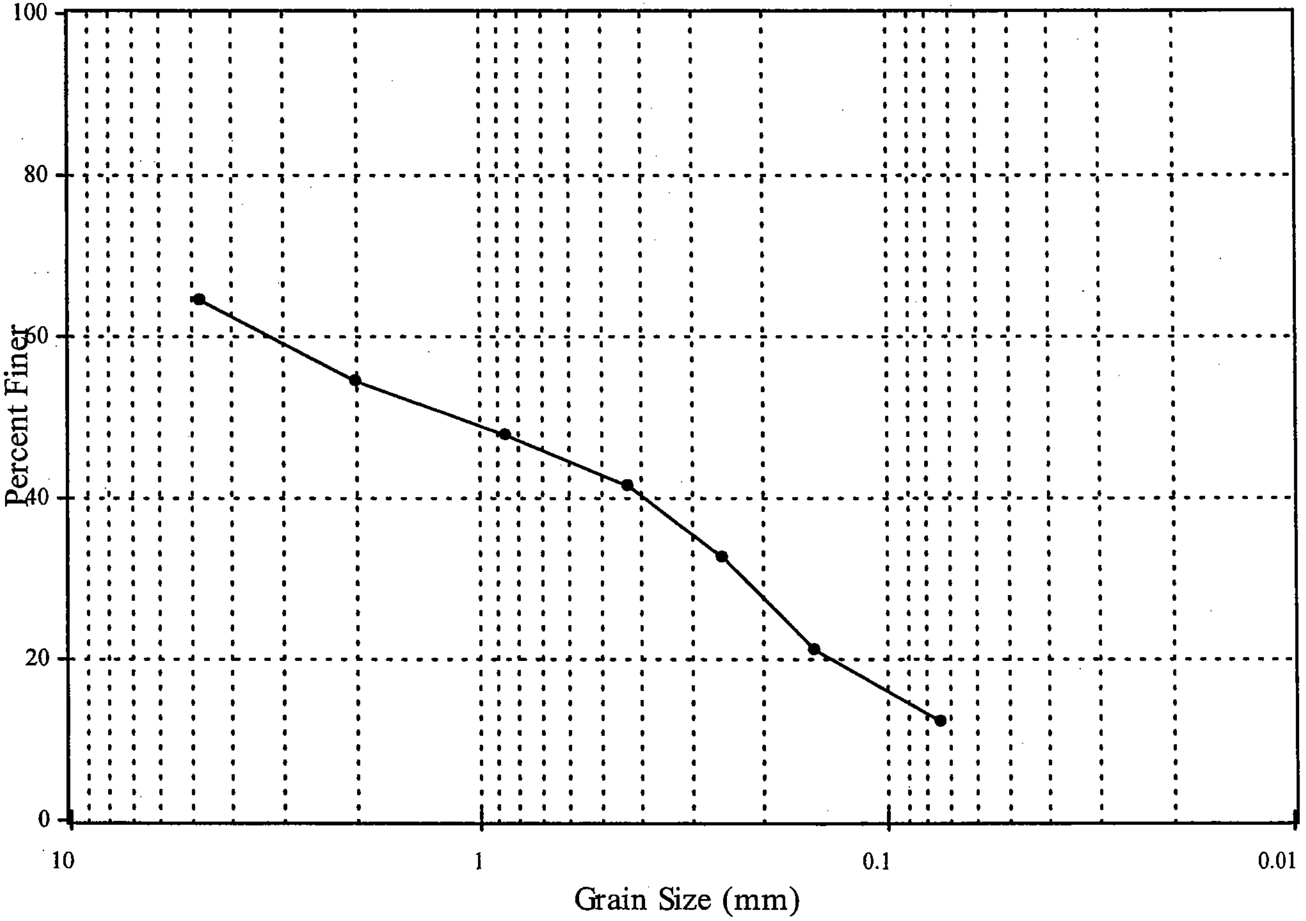
Sieve Number	Diameter Range	Percent Retained	Description
#4	>4.76 mm	11.58	Gravel
#10	<4.76 mm - 2.00 mm	4.78	Coarse Sand
#20	<2.00 mm - 0.85 mm	3.49	Medium Sand
#40	<0.85 mm - 0.425 mm	2.87	Medium Sand
#60	<0.425 mm - 0.25 mm	4.31	Fine Sand
#100	<0.25 mm - 0.15 mm	5.73	Fine Sand
#200	<0.15 mm - 0.074 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**



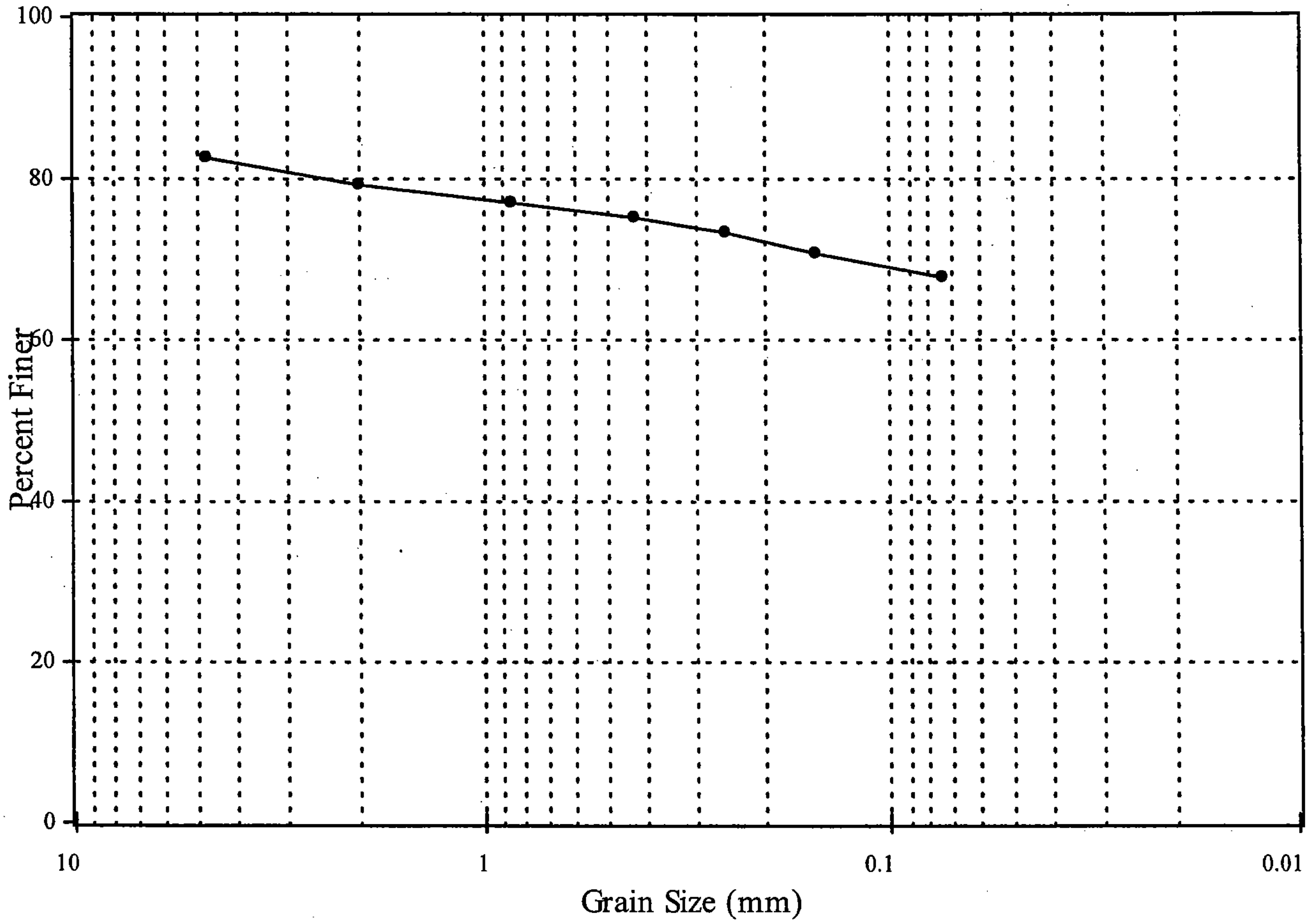
Sieve Number	Diameter Range	Percent Retained	Description
#4	>4.76 mm	35.67	Gravel
#10	<4.76 mm - 2.00 mm	9.94	Coarse Sand
#20	<2.00 mm - 0.85 mm	6.69	Medium Sand
#40	<0.85 mm - 0.425 mm	6.05	Medium Sand
#60	<0.425 mm - 0.25 mm	9.09	Fine Sand
#100	<0.25 mm - 0.15 mm	11.35	Fine Sand
#200	<0.15 mm - 0.074 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**



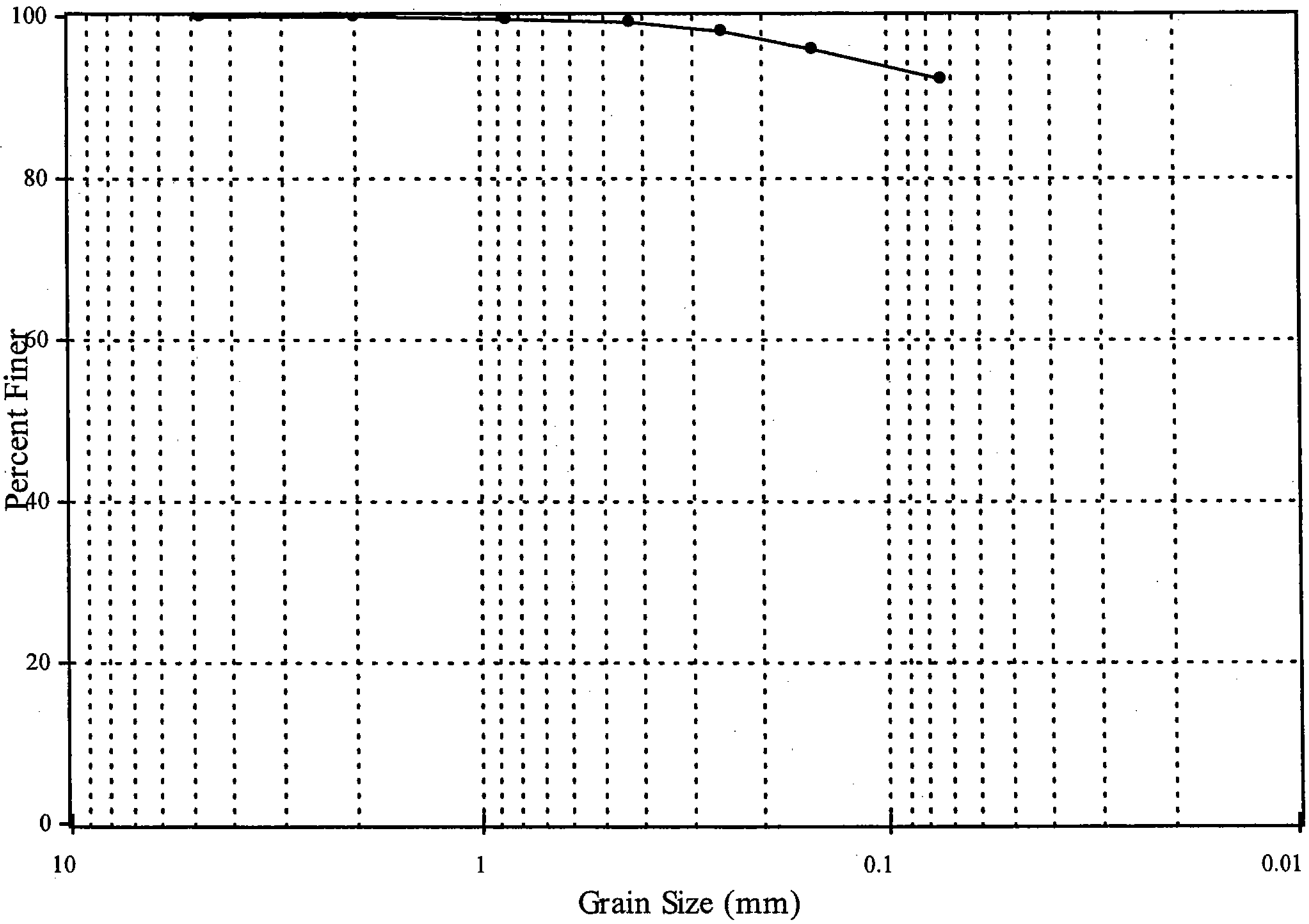
Sieve Number	Diameter Range	Percent Retained	Description
#4	>4.76 mm	17.45	Gravel
#10	<4.76 mm - 2.00 mm	3.36	Coarse Sand
#20	<2.00 mm - 0.85 mm	2.15	Medium Sand
#40	<0.85 mm - 0.425 mm	1.80	Medium Sand
#60	<0.425 mm - 0.25 mm	2.03	Fine Sand
#100	<0.25 mm - 0.15 mm	2.50	Fine Sand
#200	<0.15 mm - 0.074 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**

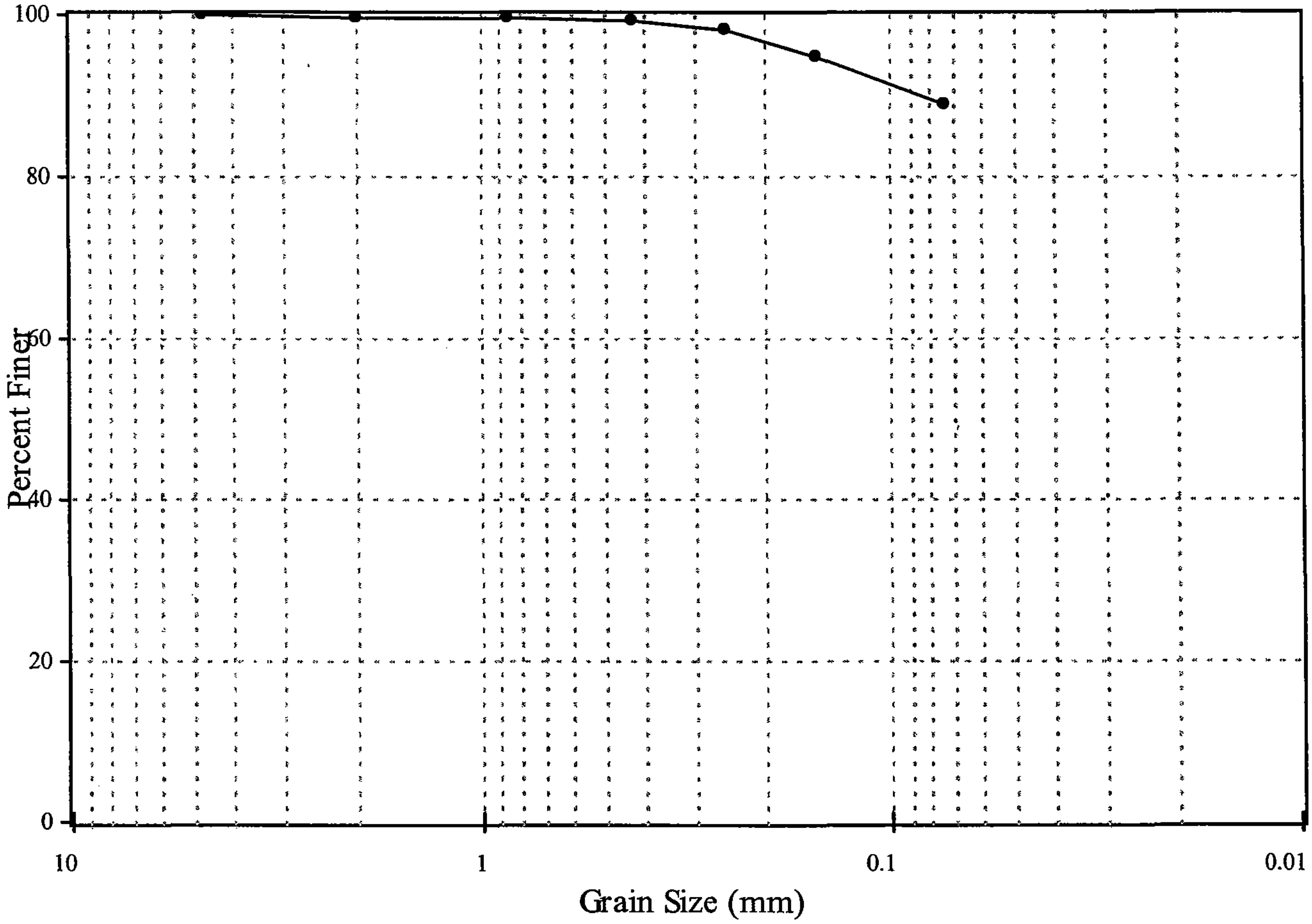


Sieve Number	Diameter Range	Percent Retained	Description
#4	>4.76 mm	0.07	Gravel
#10	<4.76 mm - 2.00 mm	0.05	Coarse Sand
#20	<2.00 mm - 0.85 mm	0.15	Medium Sand
#40	<0.85 mm - 0.425 mm	0.38	Medium Sand
#60	<0.425 mm - 0.25 mm	1.08	Fine Sand
#100	<0.25 mm - 0.15 mm	2.44	Fine Sand
#200	<0.15 mm - 0.074 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**	Lab Code:	**MA00030**
Project:	**Boston Harbor Improvement Project**	ETR:	**0208085**
Case:	N/A SDG: N/A	Lab ID:	**0208085-02**
Client ID:	**STA MM**	Concentration Units:	**%**
Matrix:	**Sediment**	Received Date:	**8/13/2002**
Collection Date:	**8/12/2002**	Analysis Date:	**8/16/2002**

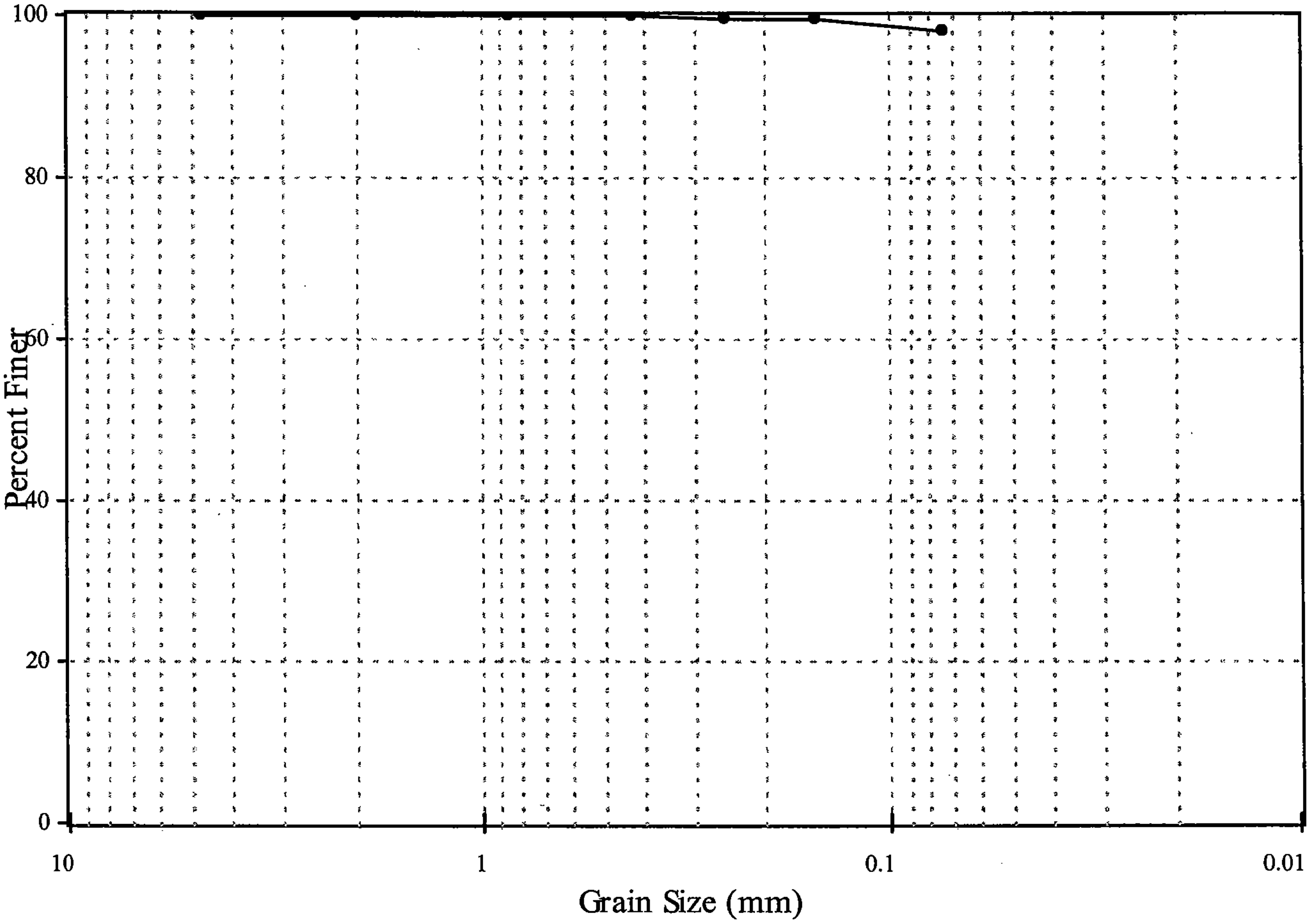


Sieve Number	Diameter Range	Percent Retained	Description
#4	>4.76 mm	0.11	Gravel
#10	<4.76 mm - 2.00 mm	0.16	Coarse Sand
#20	<2.00 mm - 0.85 mm	0.25	Medium Sand
#40	<0.85 mm - 0.425 mm	0.32	Medium Sand
#60	<0.425 mm - 0.25 mm	1.18	Fine Sand
#100	<0.25 mm - 0.15 mm	3.21	Fine Sand
#200	<0.15 mm - 0.074 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**	Lab Code:	**MA00030**
Project:	**Boston Harbor Improvement Project**	ETR:	**0208085**
Case:	N/A SDG: N/A	Lab ID:	**0208085-01**
Client ID:	**STA NN**	Concentration Units:	**%**
Matrix:	**Sediment**	Received Date:	**8/13/2002**
Collection Date:	**8/12/2002**	Analysis Date:	**8/12/2002**



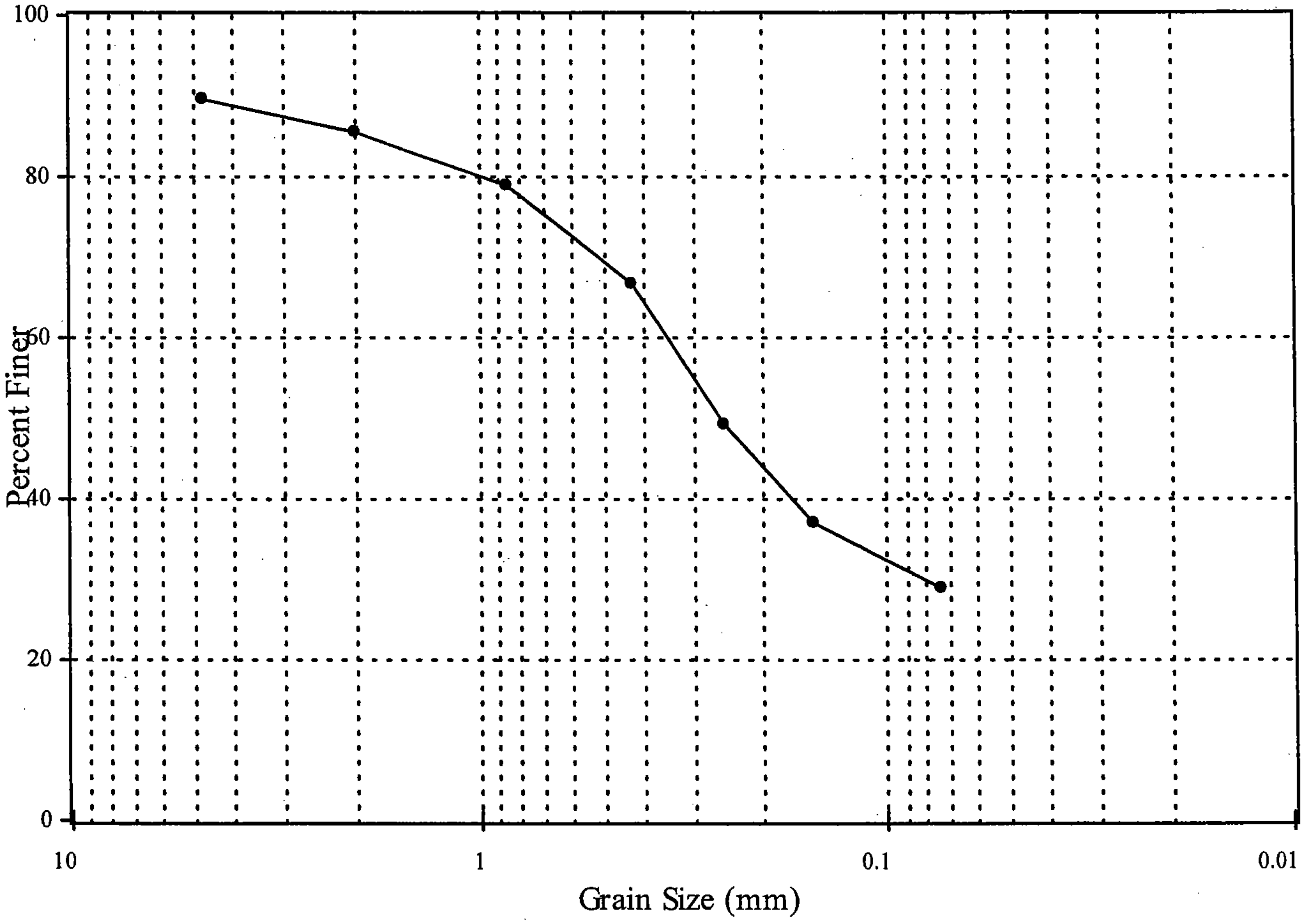
Sieve Number	Diameter Range	Percent Retained	Description
#4	>4.76 mm	0.00	Gravel
#10	<4.76 mm - 2.00 mm	0.00	Coarse Sand
#20	<2.00 mm - 0.85 mm	0.03	Medium Sand
#40	<0.85 mm - 0.425 mm	0.08	Medium Sand
#60	<0.425 mm - 0.25 mm	0.13	Fine Sand
#100	<0.25 mm - 0.15 mm	0.30	Fine Sand
#200	<0.15 mm - 0.074 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**

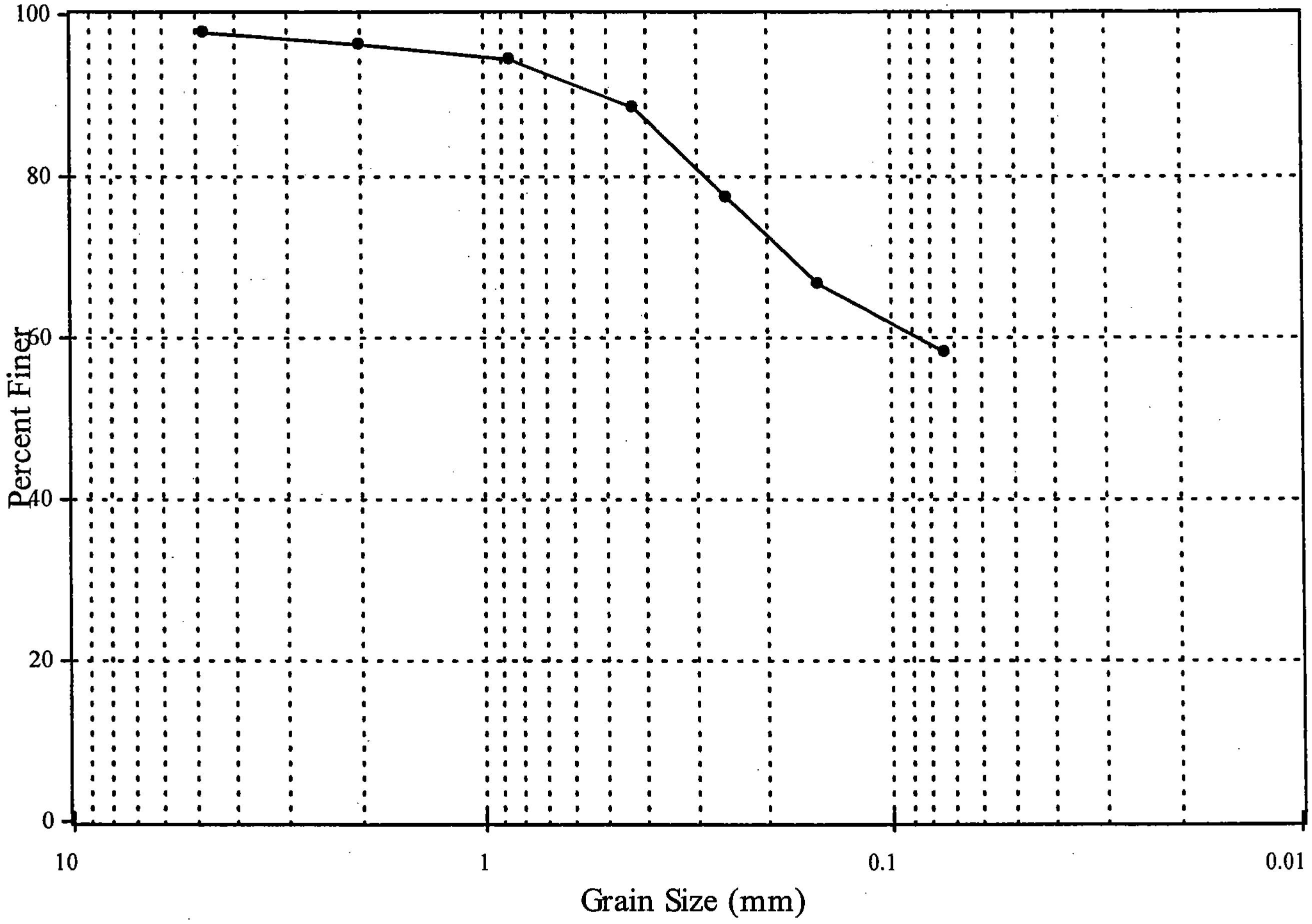


Sieve Number	Diameter Range	Percent Retained	Description
#4	>4.76 mm	10.21	Gravel
#10	<4.76 mm - 2.00 mm	4.35	Coarse Sand
#20	<2.00 mm - 0.85 mm	6.54	Medium Sand
#40	<0.85 mm - 0.425 mm	12.29	Medium Sand
#60	<0.425 mm - 0.25 mm	17.52	Fine Sand
#100	<0.25 mm - 0.15 mm	12.19	Fine Sand
#200	<0.15 mm - 0.074 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**	Lab Code:	**M-MA030**
Project:	**Boston Harbor Improvement Project**	ETR:	**0208080**
Case:	N/A SDG: N/A	Lab ID:	**0208080-06**
Client ID:	**STA PP**	Concentration Units:	**%**
Matrix:	**Sediment**	Received Date:	**8/9/2002**
Collection 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

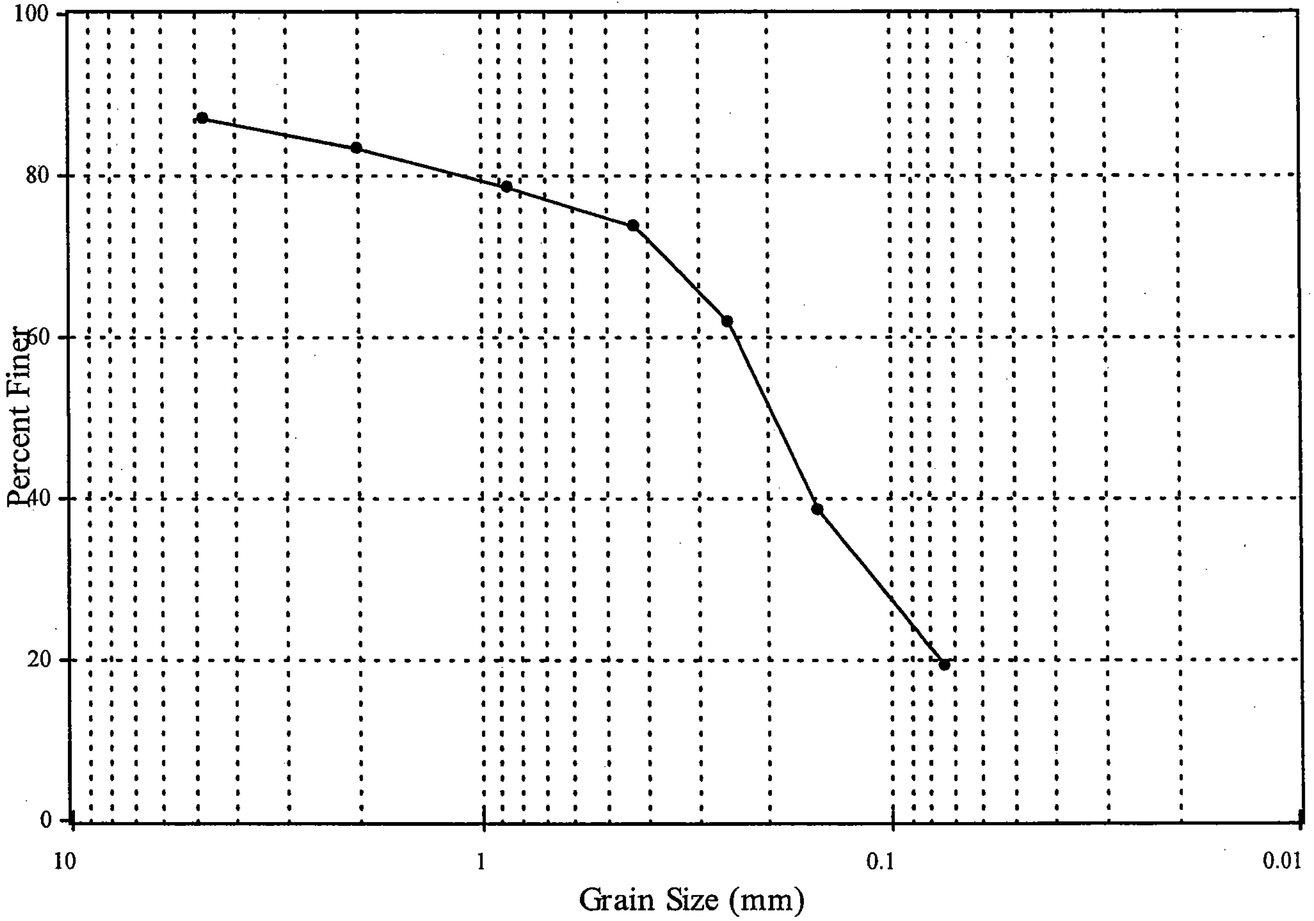
N/A - Not Applicable

08/21/02 11:22

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**

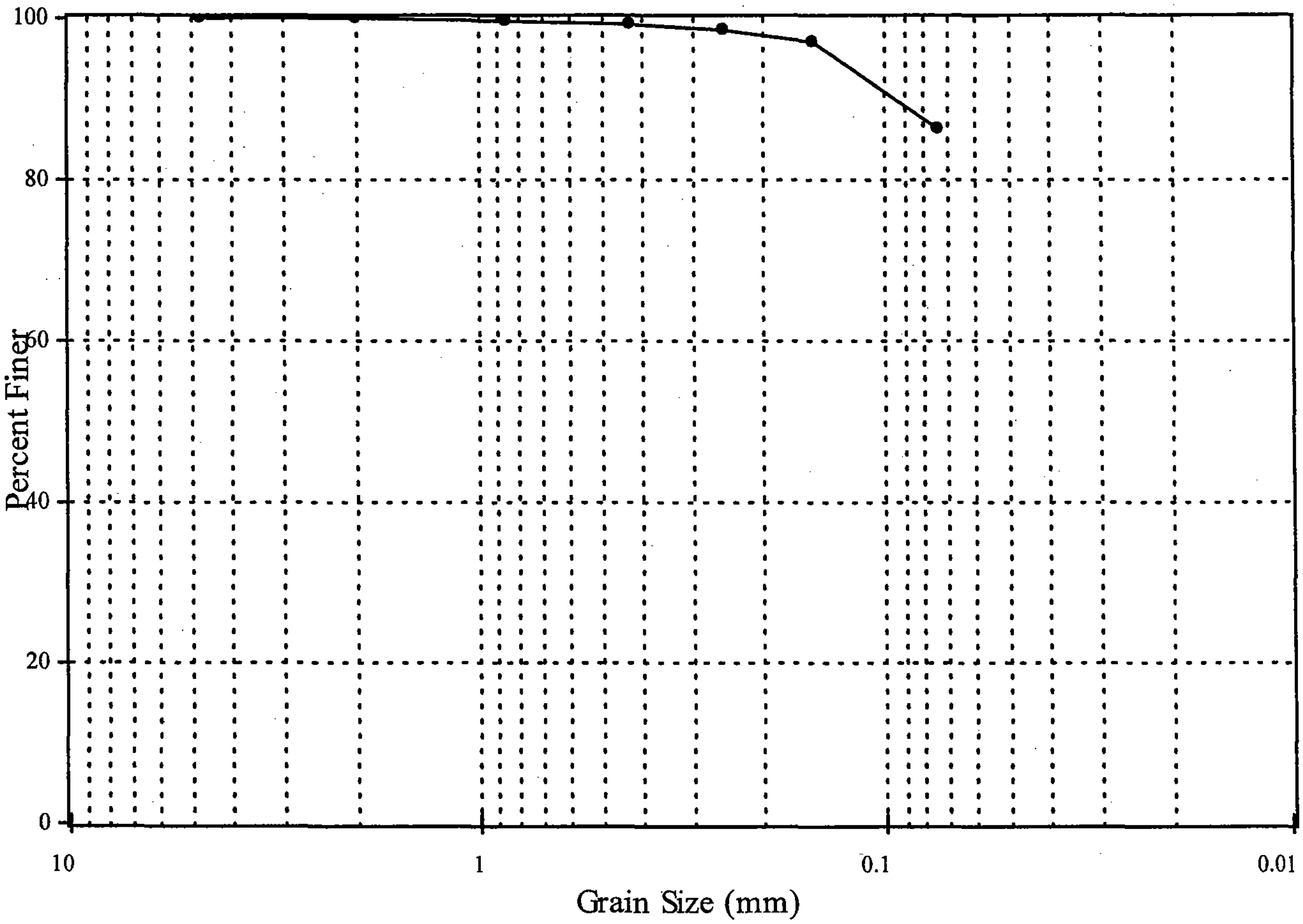


Sieve Number	Diameter Range	Percent Retained	Description
#4	>4.76 mm	12.95	Gravel
#10	<4.76 mm - 2.00 mm	3.75	Coarse Sand
#20	<2.00 mm - 0.85 mm	4.74	Medium Sand
#40	<0.85 mm - 0.425 mm	4.95	Medium Sand
#60	<0.425 mm - 0.25 mm	11.83	Fine Sand
#100	<0.25 mm - 0.15 mm	23.13	Fine Sand
#200	<0.15 mm - 0.074 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**	Lab Code:	**M-MA030**
Project:	**Boston Harbor Improvement Project**	ETR:	**0208095**
Case:	N/A SDG: N/A	Lab ID:	**0208095-05**
Client ID:	**STA RR #1**	Concentration Units:	**%**
Matrix:	**Sediment**	Received Date:	**8/15/2002**
Collection 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

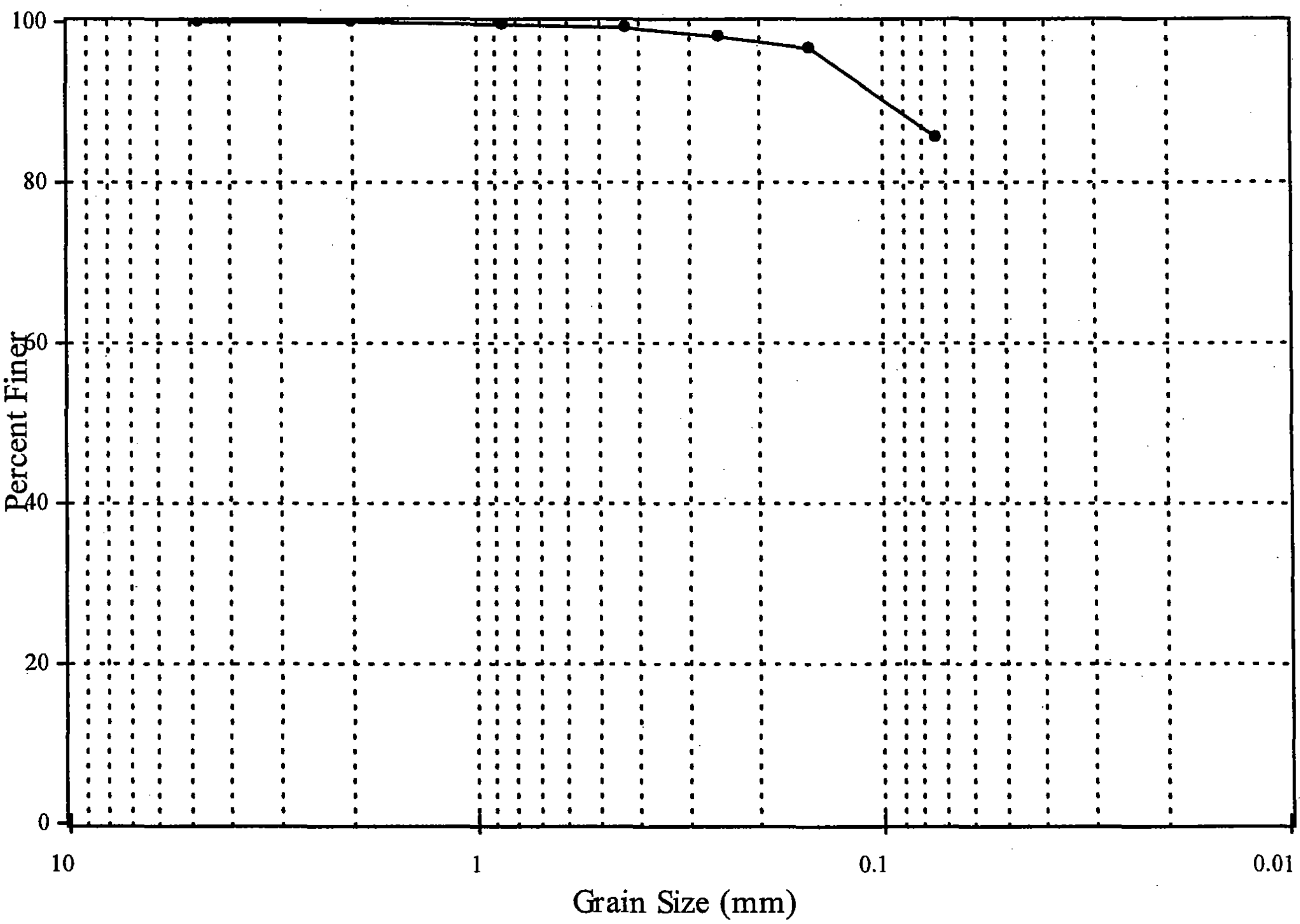
N/A - Not Applicable

08/21/02 13:30

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**

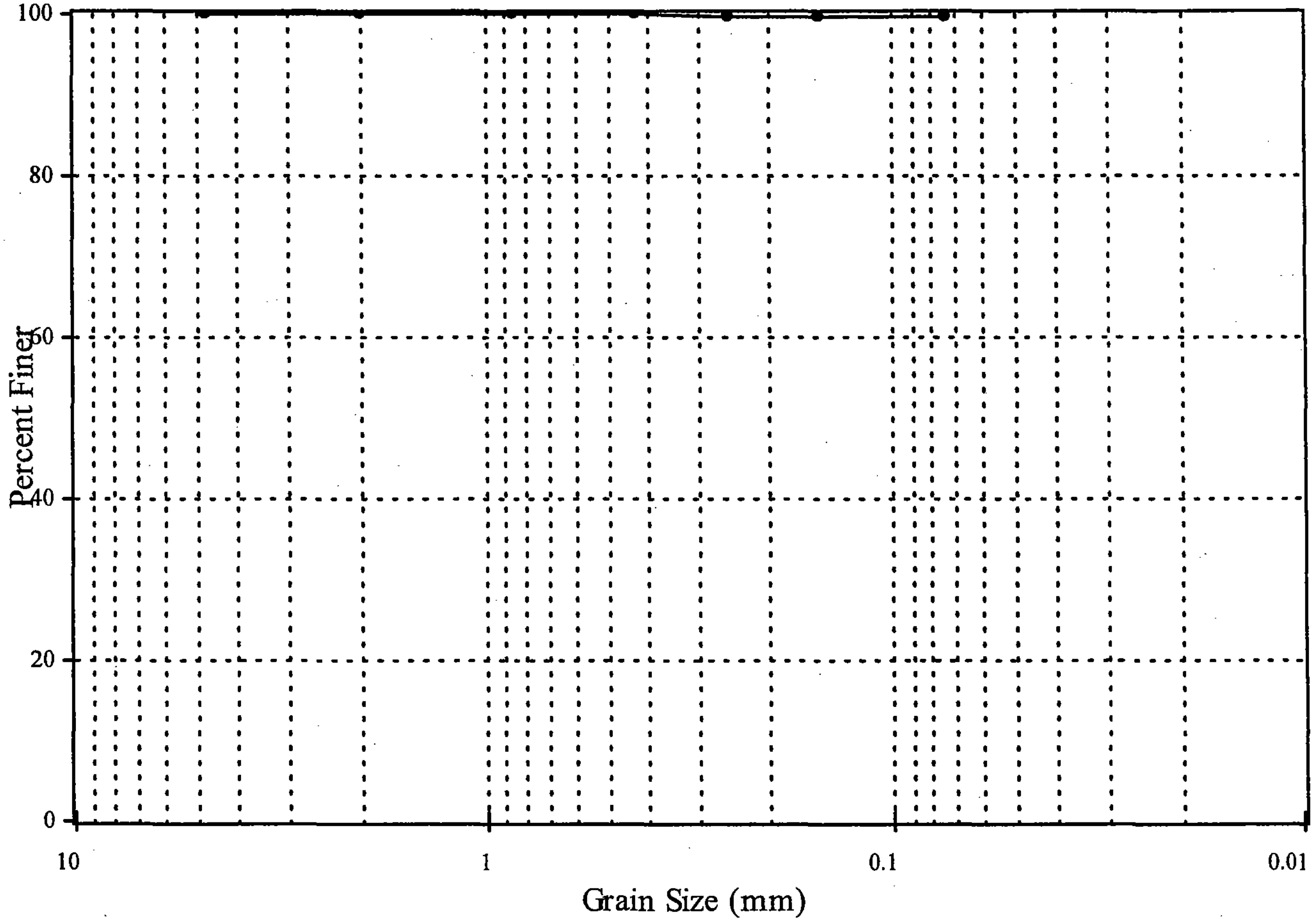


Sieve Number	Diameter Range	Percent Retained	Description
#4	>4.76 mm	0.00	Gravel
#10	<4.76 mm - 2.00 mm	0.17	Coarse Sand
#20	<2.00 mm - 0.85 mm	0.18	Medium Sand
#40	<0.85 mm - 0.425 mm	0.50	Medium Sand
#60	<0.425 mm - 0.25 mm	0.87	Fine Sand
#100	<0.25 mm - 0.15 mm	1.62	Fine Sand
#200	<0.15 mm - 0.074 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		Lab Code: **M-MA030**
Project: Boston Harbor Improvement Project		ETR: **0208095**
Case: N/A	SDG: N/A	Lab ID: **0208095-06**
Client ID: **STA RR #2**		Concentration Units: **%**
Matrix: **Sediment**		Received Date: **8/15/2002**
Collection 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

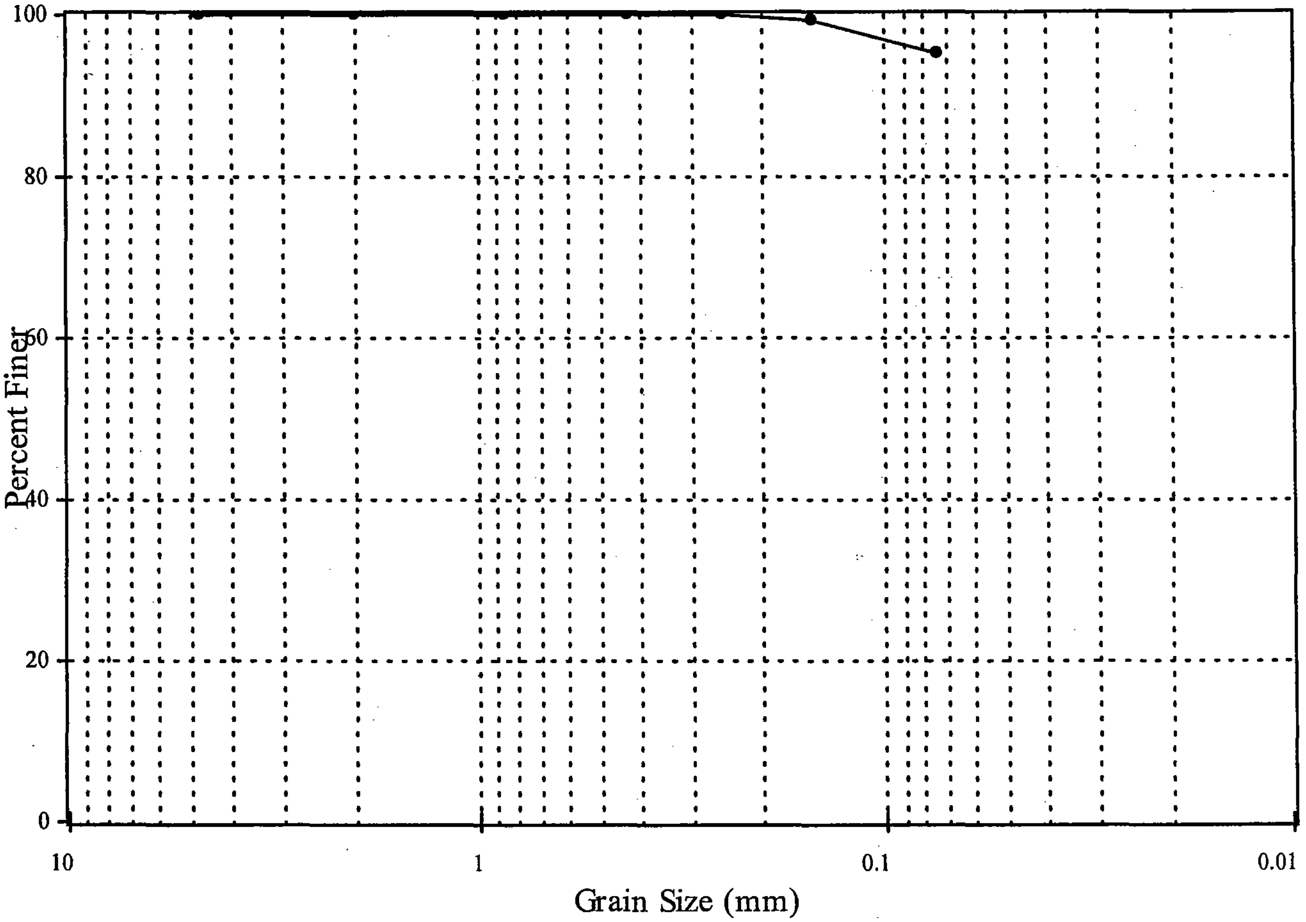
N/A - Not Applicable

08/21/02 13:32

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

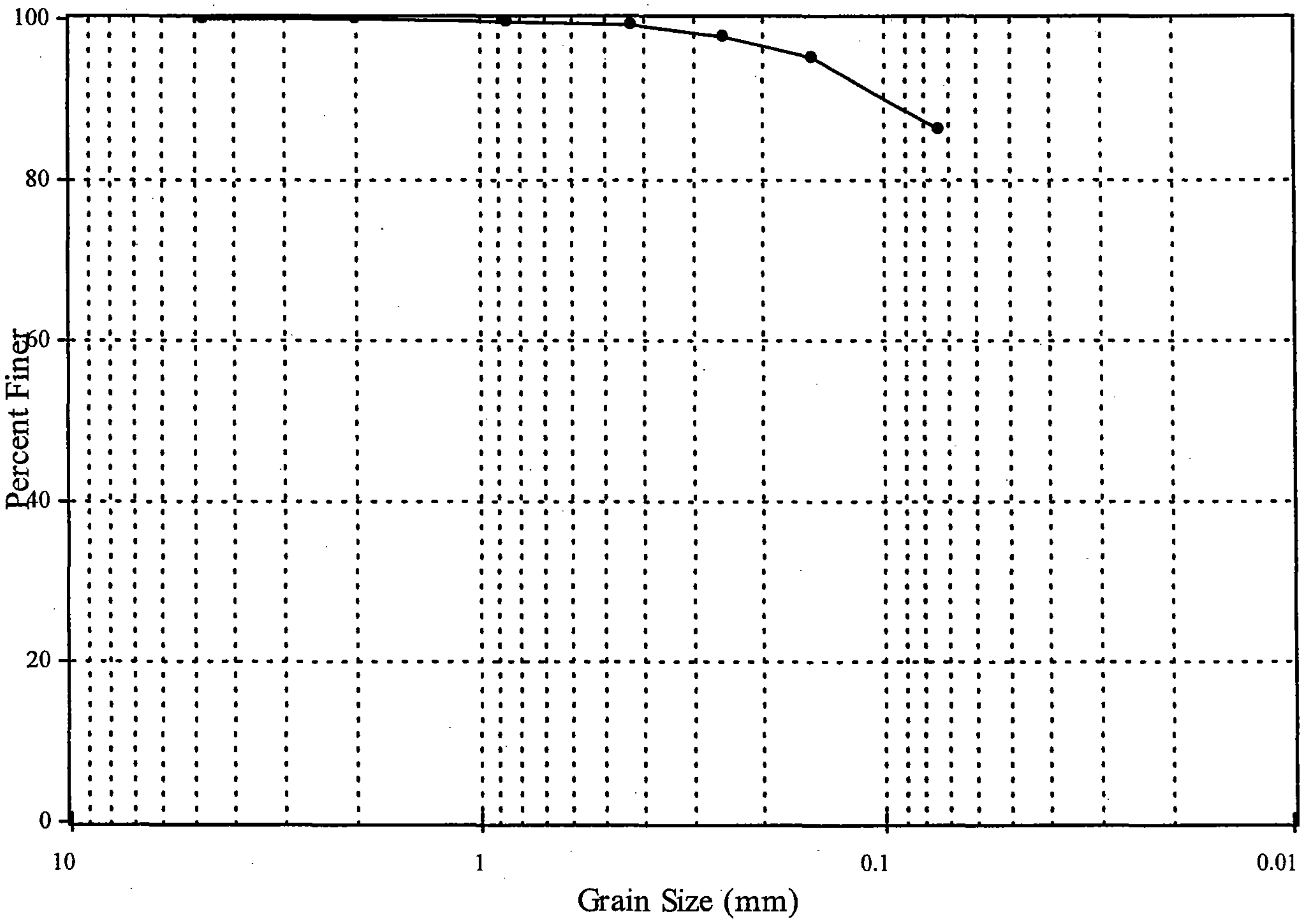
N/A - Not Applicable

08/21/02 13:34

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**



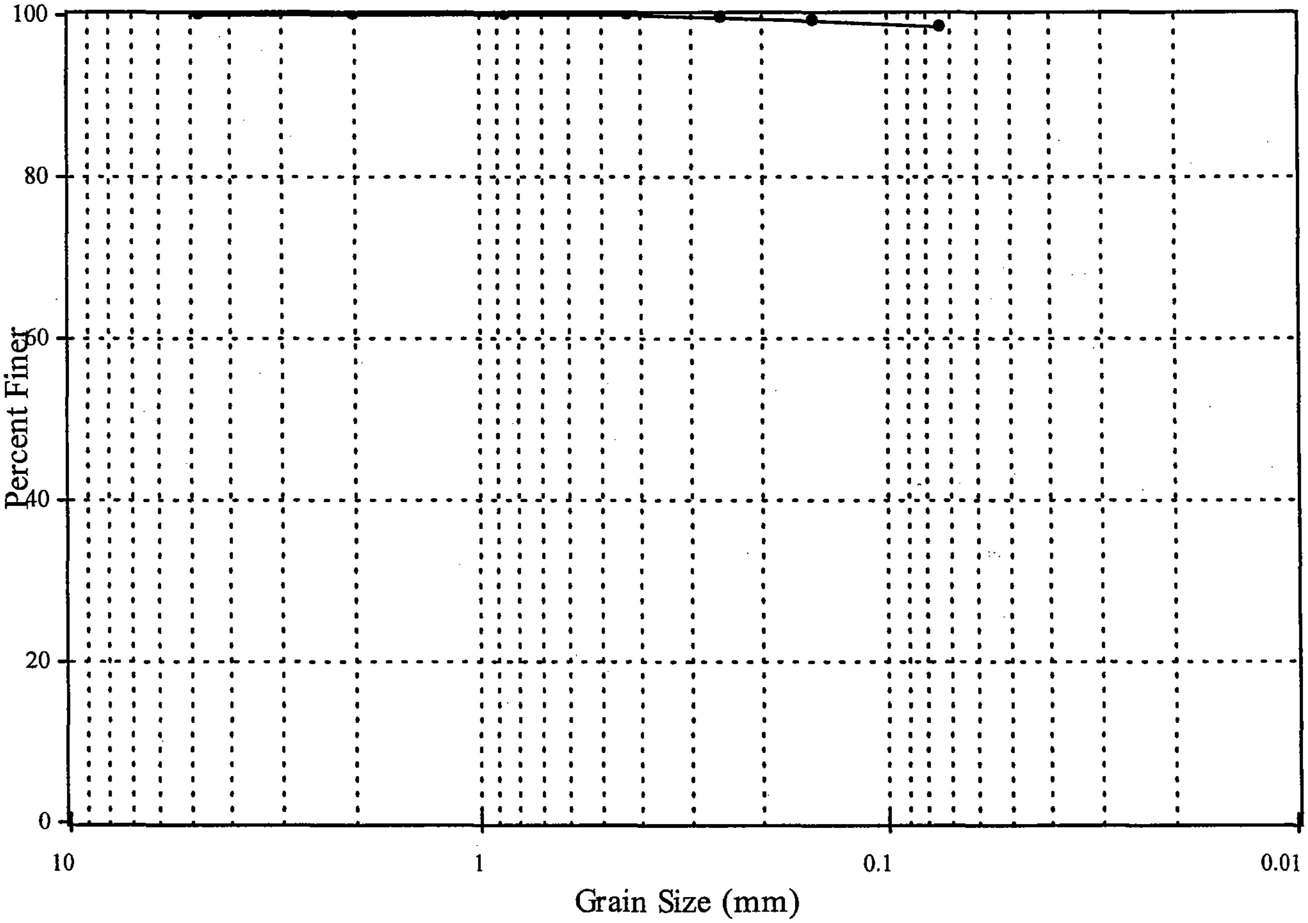
Sieve Number	Diameter Range	Percent Retained	Description
#4	>4.76 mm	0.00	Gravel
#10	<4.76 mm - 2.00 mm	0.03	Coarse Sand
#20	<2.00 mm - 0.85 mm	0.17	Medium Sand
#40	<0.85 mm - 0.425 mm	0.66	Medium Sand
#60	<0.425 mm - 0.25 mm	1.27	Fine Sand
#100	<0.25 mm - 0.15 mm	2.52	Fine Sand
#200	<0.15 mm - 0.074 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**

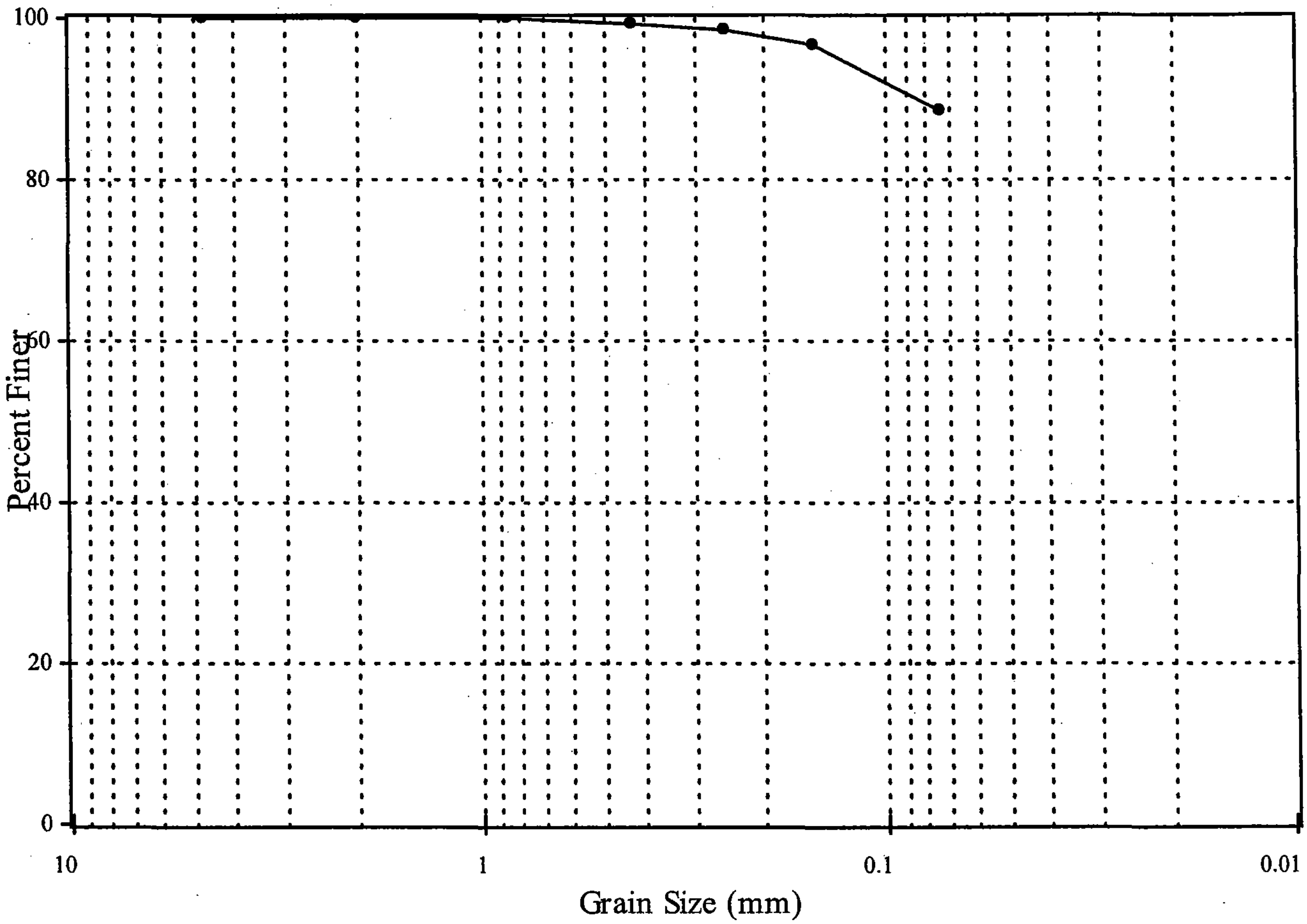


Sieve Number	Diameter Range	Percent Retained	Description
#4	>4.76 mm	0.00	Gravel
#10	<4.76 mm - 2.00 mm	0.00	Coarse Sand
#20	<2.00 mm - 0.85 mm	0.00	Medium Sand
#40	<0.85 mm - 0.425 mm	0.13	Medium Sand
#60	<0.425 mm - 0.25 mm	0.32	Fine Sand
#100	<0.25 mm - 0.15 mm	0.13	Fine Sand
#200	<0.15 mm - 0.074 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**	Lab Code:	**M-MA030**
Project:	**Boston Harbor Improvement Project**	ETR:	**0208095**
Case:	N/A SDG: N/A	Lab ID:	**0208095-11**
Client ID:	**STA UU #1**	Concentration Units:	**%**
Matrix:	**Sediment**	Received Date:	**8/15/2002**
Collection 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

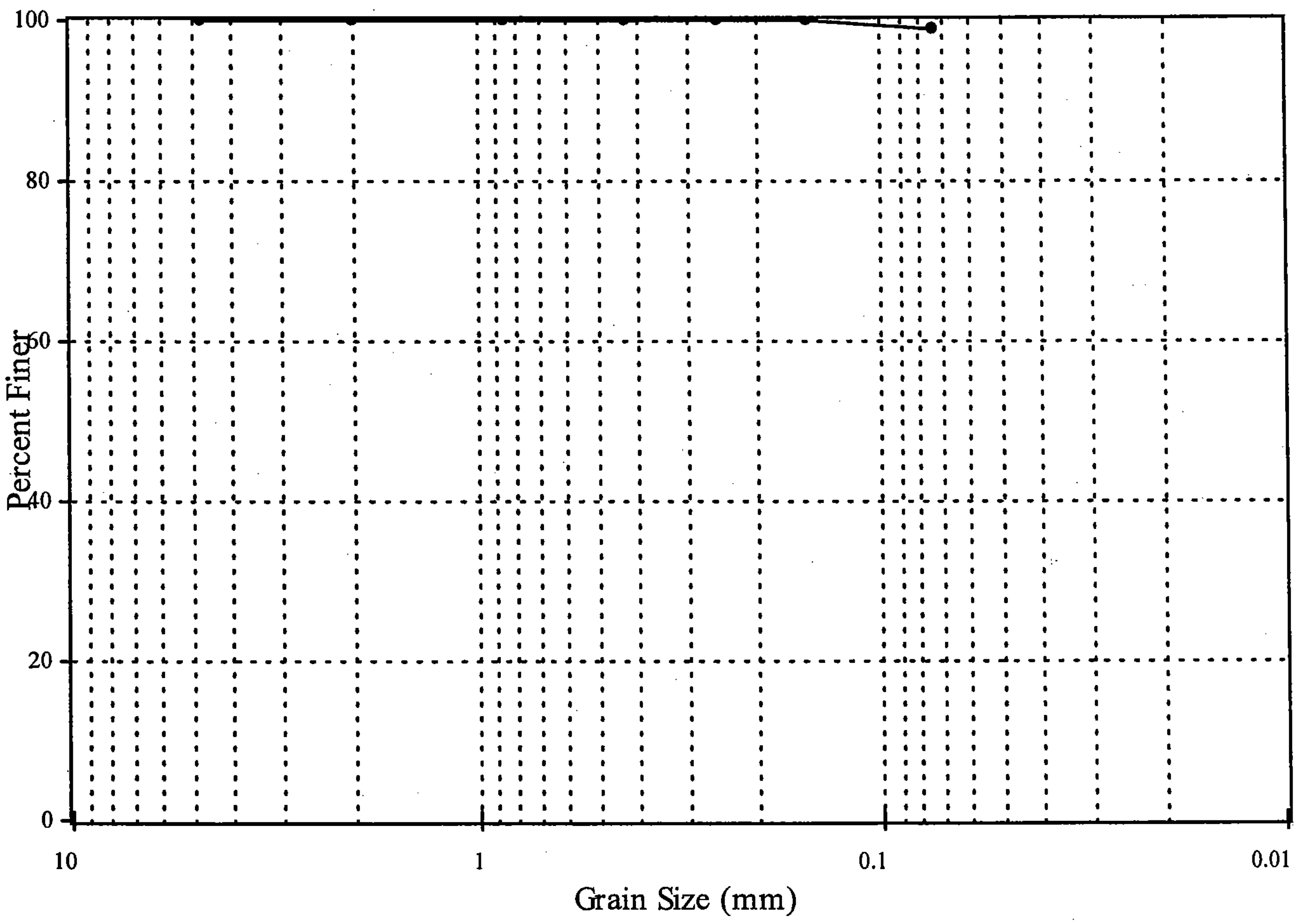
N/A - Not Applicable

08/21/02 13:39

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**



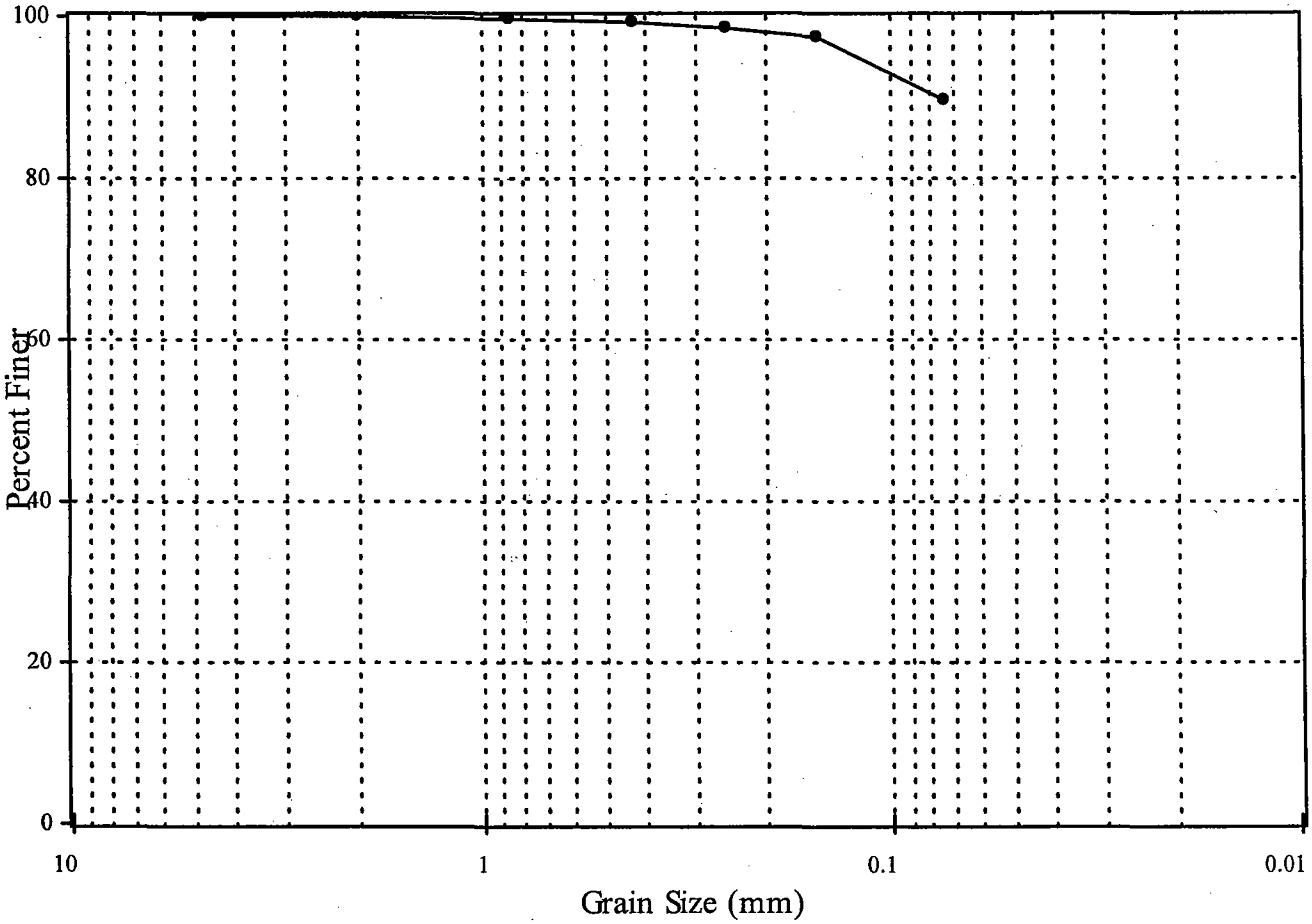
Sieve Number	Diameter Range	Percent Retained	Description
#4	>4.76 mm	0.00	Gravel
#10	<4.76 mm - 2.00 mm	0.00	Coarse Sand
#20	<2.00 mm - 0.85 mm	0.00	Medium Sand
#40	<0.85 mm - 0.425 mm	0.00	Medium Sand
#60	<0.425 mm - 0.25 mm	0.00	Fine Sand
#100	<0.25 mm - 0.15 mm	0.07	Fine Sand
#200	<0.15 mm - 0.074 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**



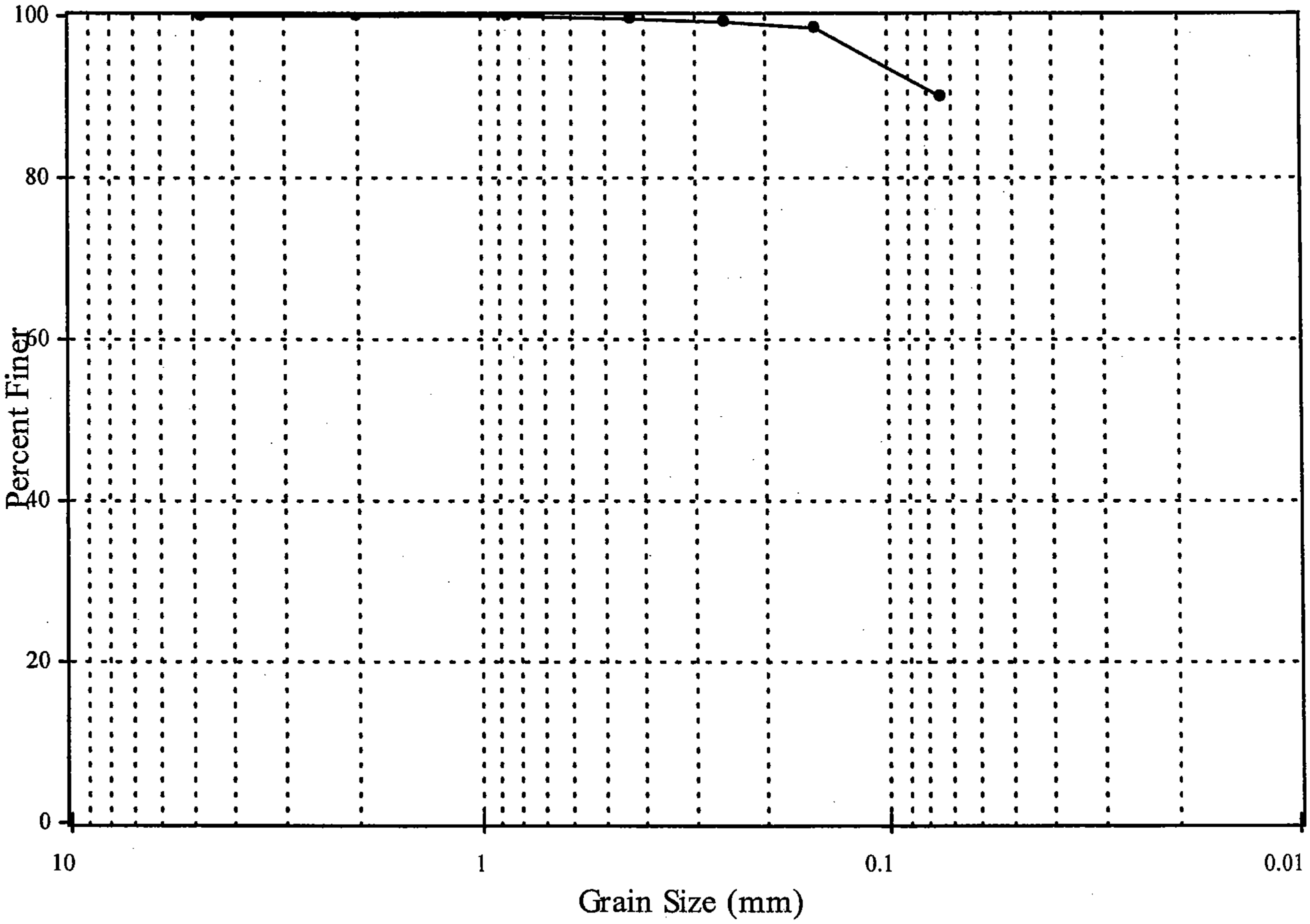
Sieve Number	Diameter Range	Percent Retained	Description
#4	>4.76 mm	0.00	Gravel
#10	<4.76 mm - 2.00 mm	0.02	Coarse Sand
#20	<2.00 mm - 0.85 mm	0.22	Medium Sand
#40	<0.85 mm - 0.425 mm	0.34	Medium Sand
#60	<0.425 mm - 0.25 mm	0.73	Fine Sand
#100	<0.25 mm - 0.15 mm	1.38	Fine Sand
#200	<0.15 mm - 0.074 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

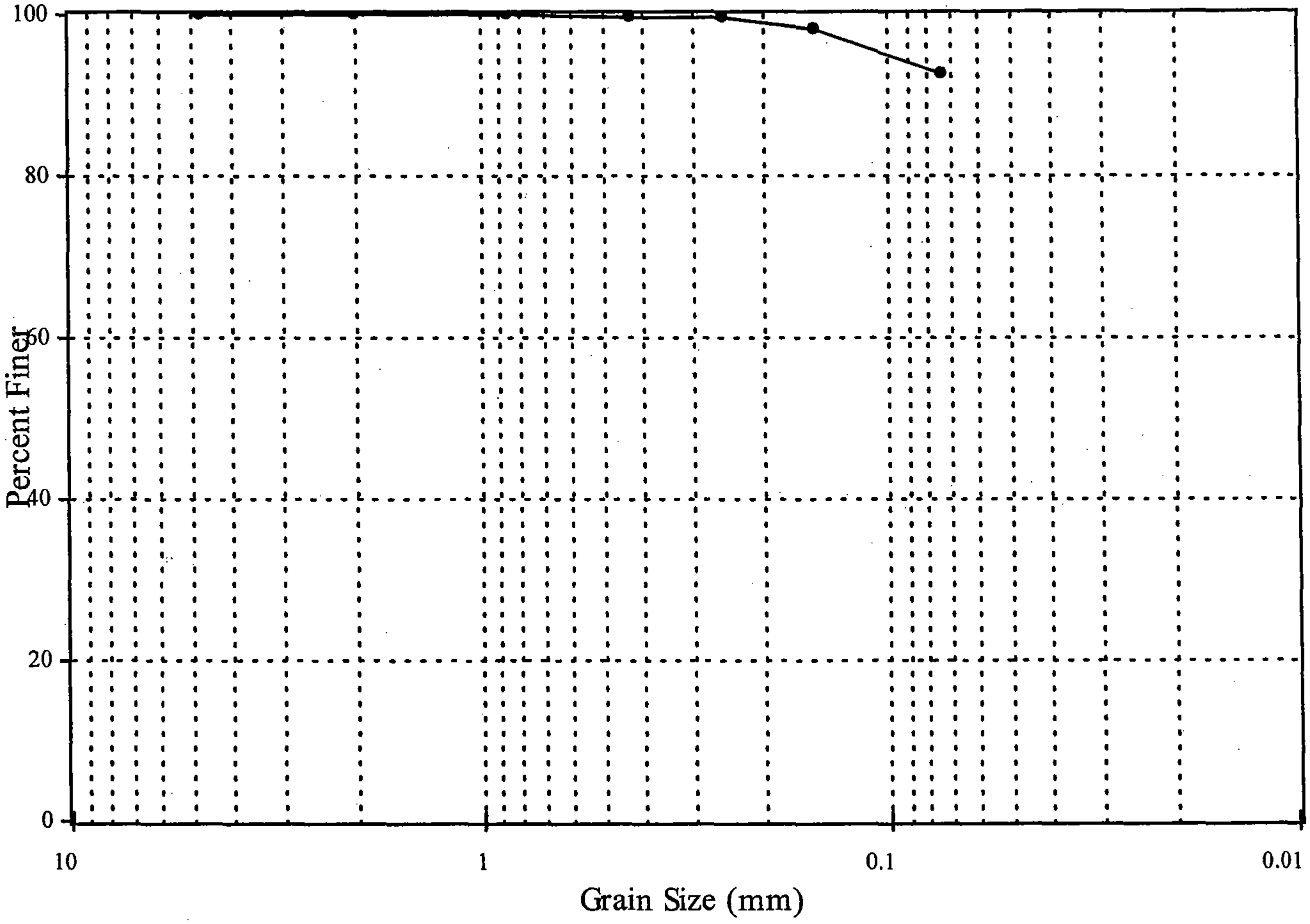
N/A - Not Applicable

08/21/02 13:11

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

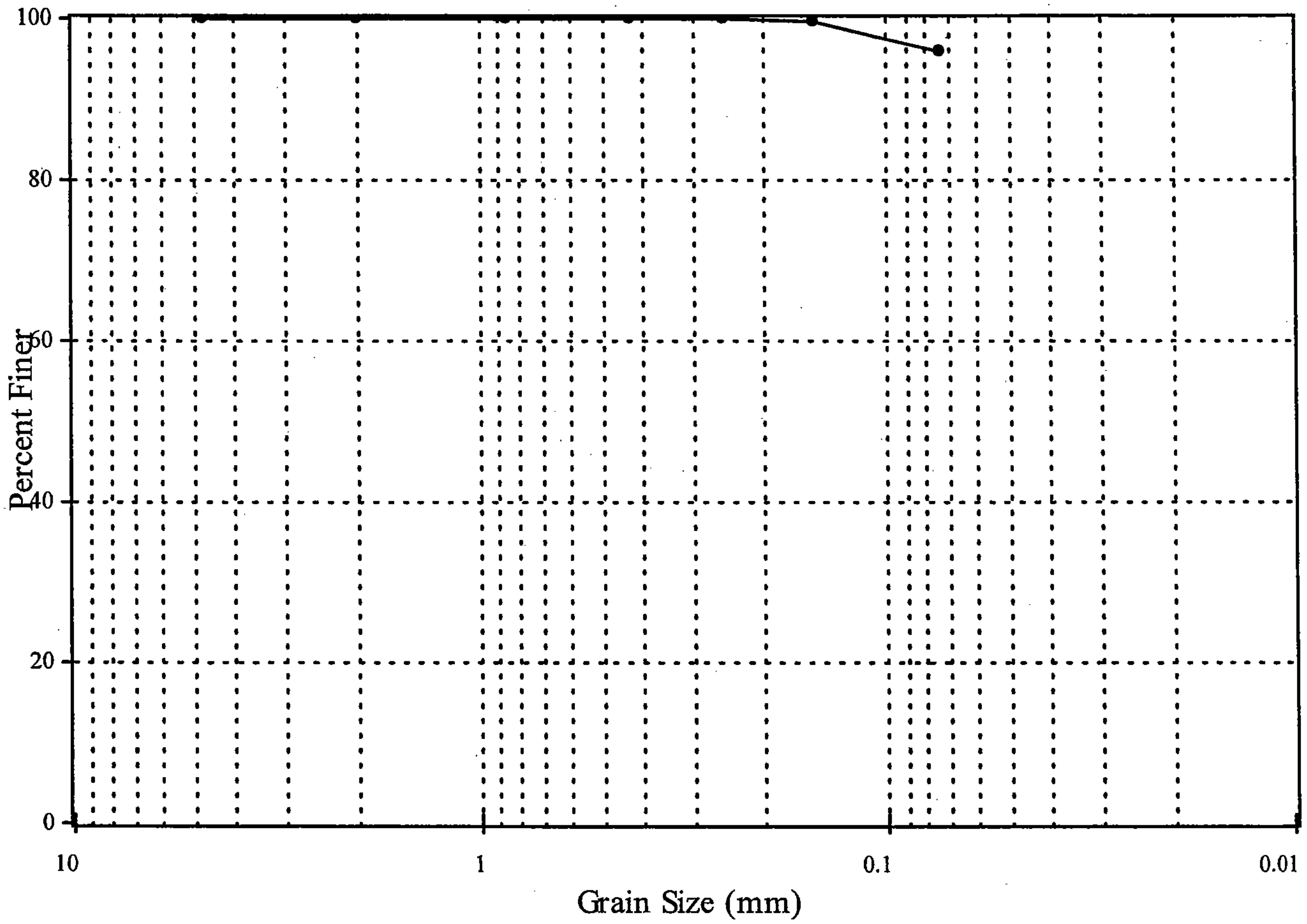
N/A - Not Applicable

08/21/02 13:35

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**

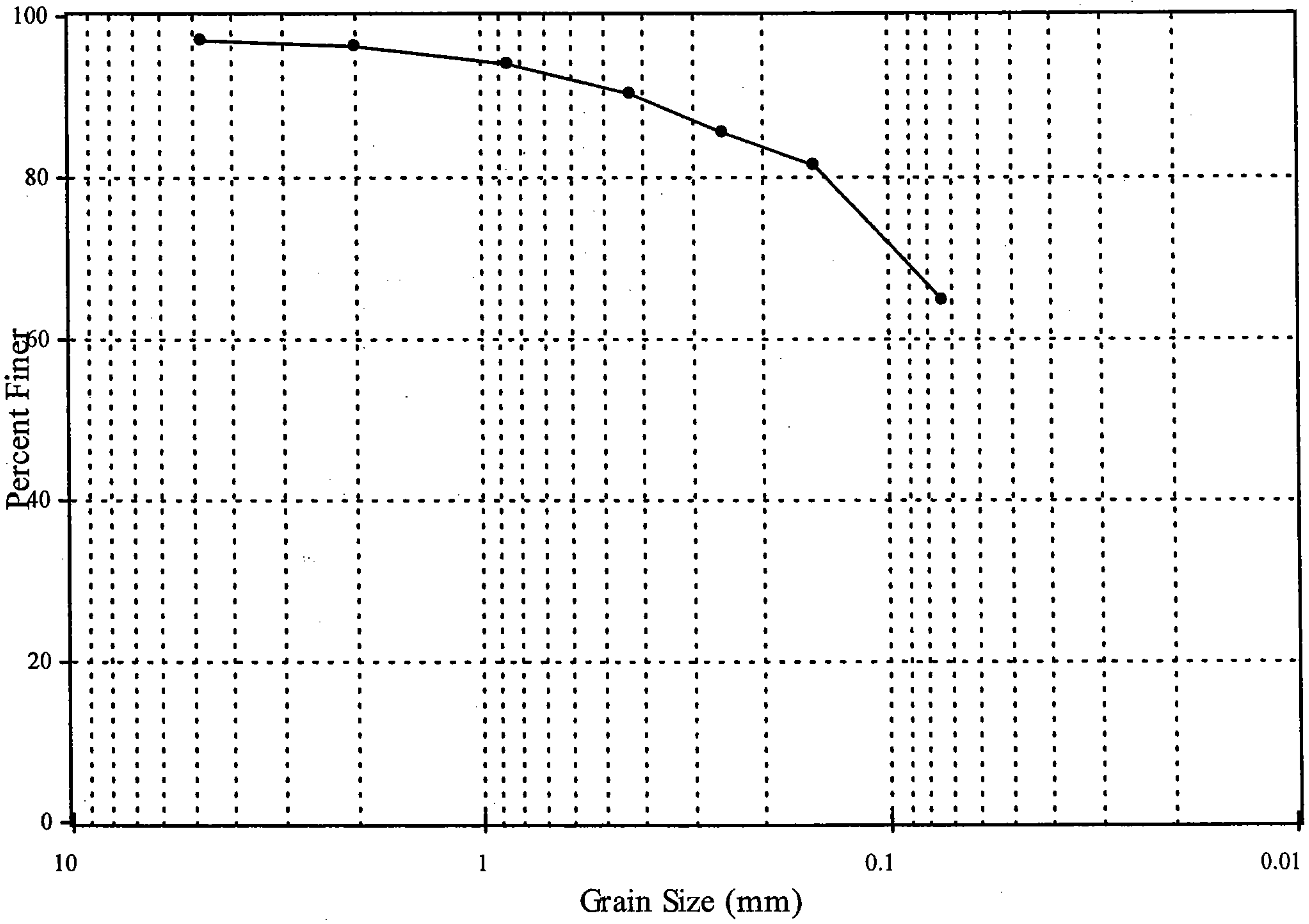


Sieve Number	Diameter Range	Percent Retained	Description
#4	>4.76 mm	0.00	Gravel
#10	<4.76 mm - 2.00 mm	0.00	Coarse Sand
#20	<2.00 mm - 0.85 mm	0.04	Medium Sand
#40	<0.85 mm - 0.425 mm	0.04	Medium Sand
#60	<0.425 mm - 0.25 mm	0.03	Fine Sand
#100	<0.25 mm - 0.15 mm	0.23	Fine Sand
#200	<0.15 mm - 0.074 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**	Lab Code:	**M-MA030**
Project:	**Boston Harbor Improvement Project**	ETR:	**0208095**
Case:	N/A SDG: N/A	Lab ID:	**0208095-04**
Client ID:	**STA YY**	Concentration Units:	**%**
Matrix:	**Sediment**	Received Date:	**8/15/2002**
Collection Date:	**8/15/2002**	Analysis Date:	**8/21/2002**



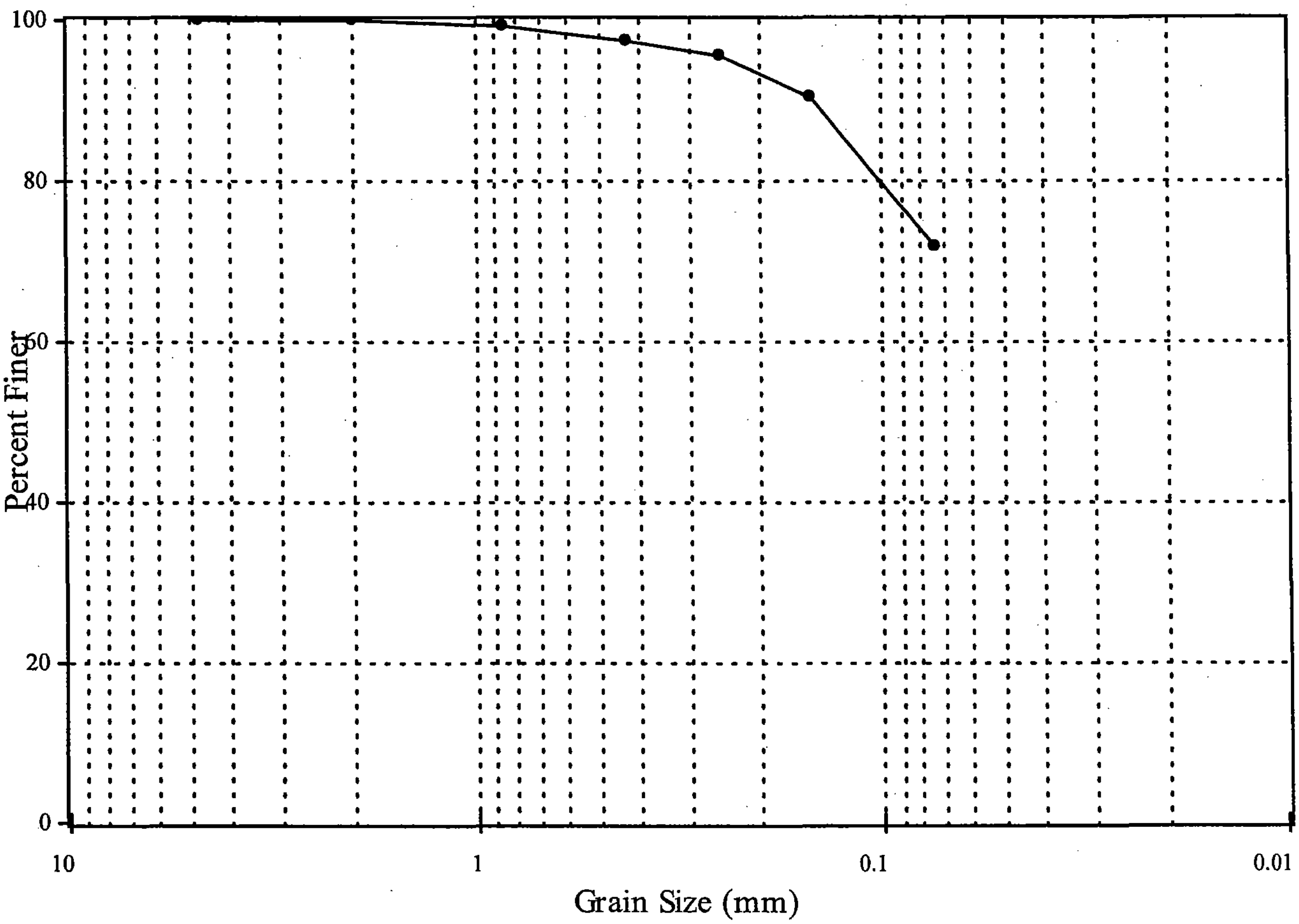
Sieve Number	Diameter Range	Percent Retained	Description
#4	>4.76 mm	3.01	Gravel
#10	<4.76 mm - 2.00 mm	0.80	Coarse Sand
#20	<2.00 mm - 0.85 mm	1.96	Medium Sand
#40	<0.85 mm - 0.425 mm	4.05	Medium Sand
#60	<0.425 mm - 0.25 mm	4.46	Fine Sand
#100	<0.25 mm - 0.15 mm	4.17	Fine Sand
#200	<0.15 mm - 0.074 mm	16.87	Fine Sand
Passing #200	<0.074 mm	64.63	Silt/Clay

N/A - Not Applicable

08/21/02 13:28

Wet Sieve Analysis

Client:	**Army Corps of Engineers**	Lab Code:	**M-MA030**
Project:	**Boston Harbor Improvement Project**	ETR:	**0208095**
Case:	**N/A** SDG: **N/A**	Lab ID:	**0208095-16**
Client ID:	**STA CC2 #1**	Concentration Units:	**%**
Matrix:	**Sediment**	Received Date:	**8/15/2002**
Collection Date:	**8/15/2002**	Analysis Date:	**8/21/2002**

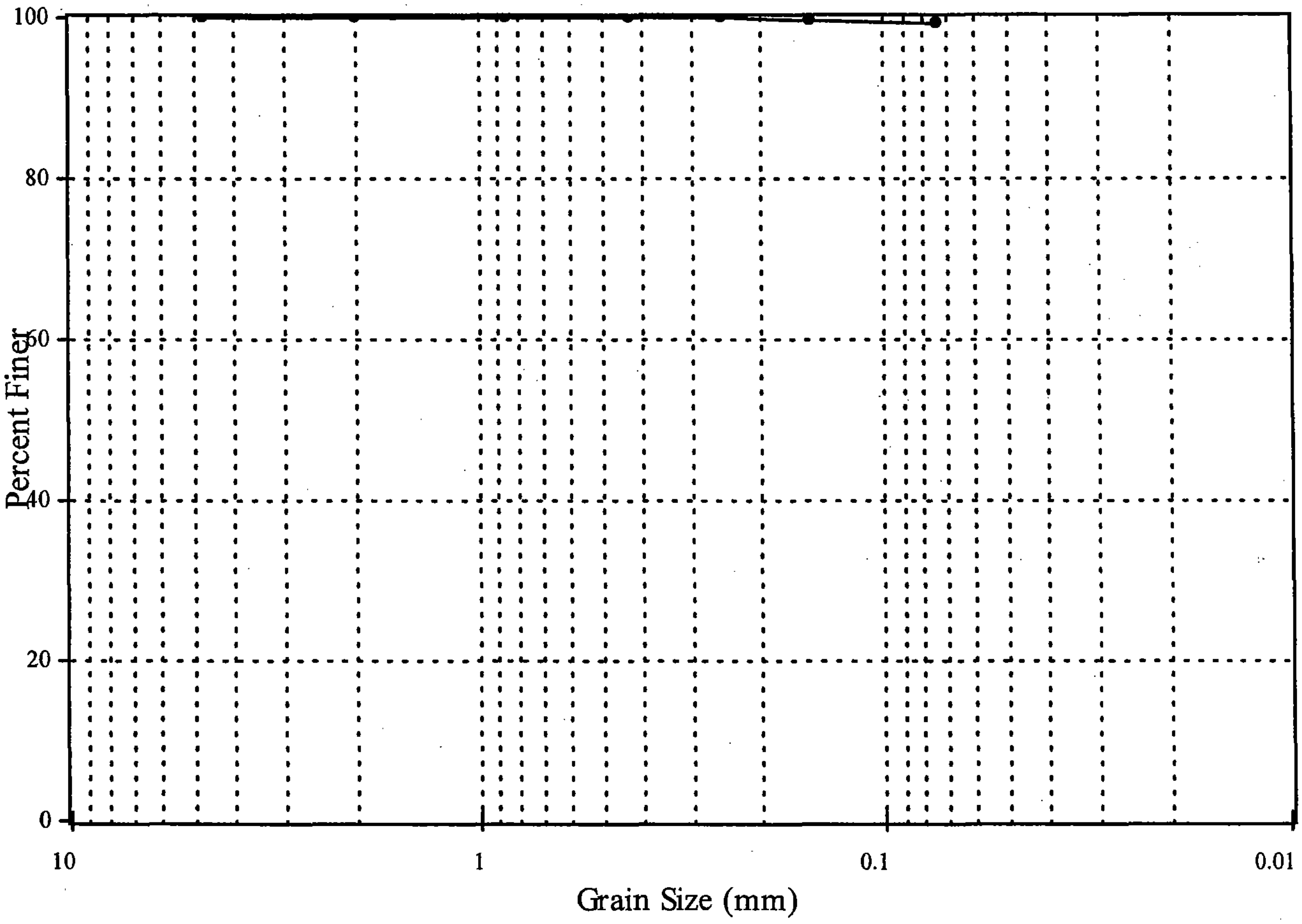


Sieve Number	Diameter Range	Percent Retained	Description
#4	>4.76 mm	0.00	Gravel
#10	<4.76 mm - 2.00 mm	0.18	Coarse Sand
#20	<2.00 mm - 0.85 mm	0.62	Medium Sand
#40	<0.85 mm - 0.425 mm	1.62	Medium Sand
#60	<0.425 mm - 0.25 mm	2.04	Fine Sand
#100	<0.25 mm - 0.15 mm	5.03	Fine Sand
#200	<0.15 mm - 0.074 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**	Lab Code:	**M-MA030**
Project:	**Boston Harbor Improvement Project**	ETR:	**0208095**
Case:	N/A SDG: N/A	Lab ID:	**0208095-17**
Client ID:	**STA CC2 #2**	Concentration Units:	**%**
Matrix:	**Sediment**	Received Date:	**8/15/2002**
Collection Date:	**8/15/2002**	Analysis Date:	**8/20/2002**



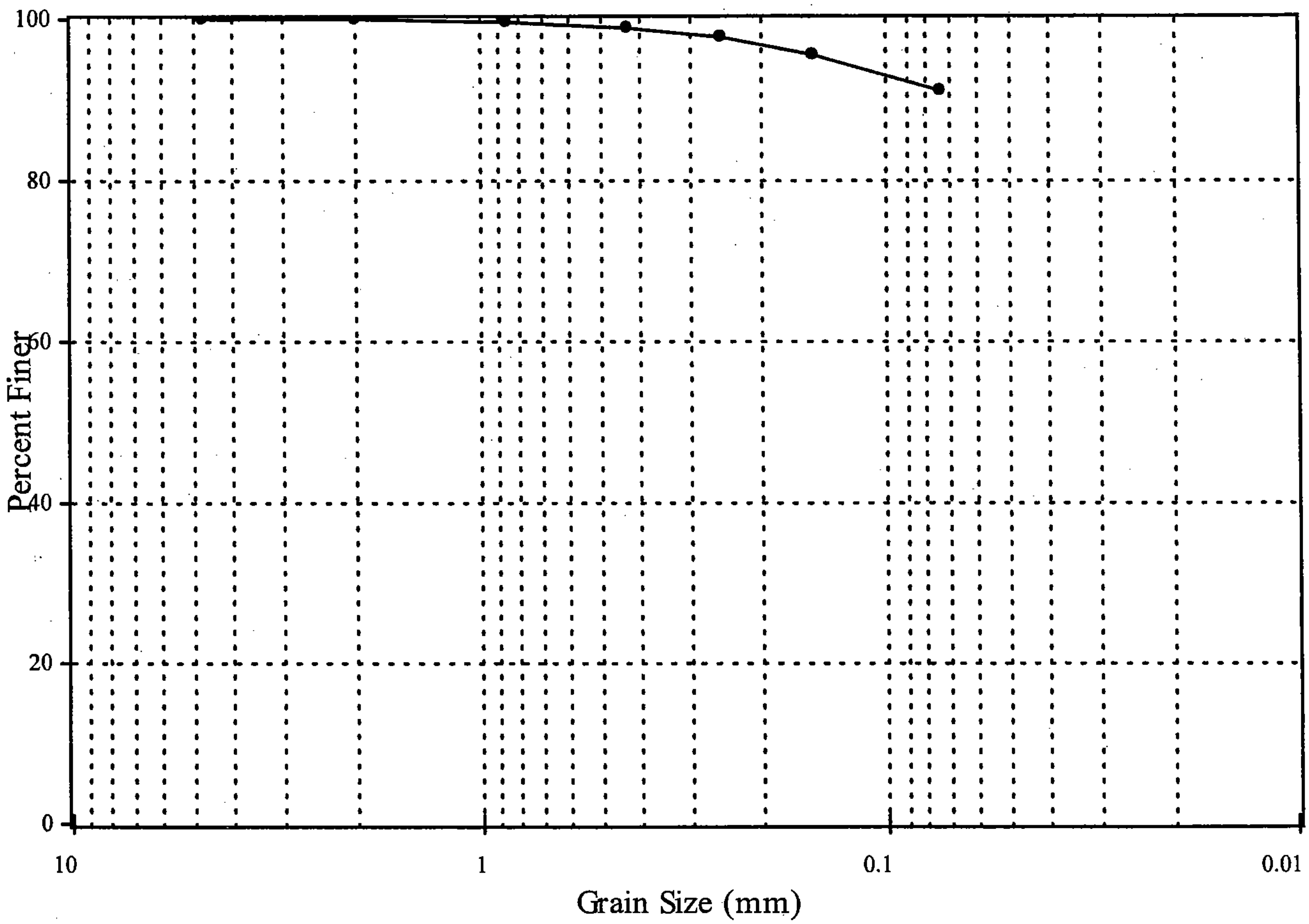
Sieve Number	Diameter Range	Percent Retained	Description
#4	>4.76 mm	0.00	Gravel
#10	<4.76 mm - 2.00 mm	0.00	Coarse Sand
#20	<2.00 mm - 0.85 mm	0.01	Medium Sand
#40	<0.85 mm - 0.425 mm	0.03	Medium Sand
#60	<0.425 mm - 0.25 mm	0.06	Fine Sand
#100	<0.25 mm - 0.15 mm	0.16	Fine Sand
#200	<0.15 mm - 0.074 mm	0.58	Fine Sand
Passing #200	<0.074 mm	99.17	Silt/Clay

N/A - Not Applicable

08/21/02 13:49

Wet Sieve Analysis

Client:	**Army Corps of Engineers**	Lab Code:	**M-MA030**
Project:	**Boston Harbor Improvement Project**	ETR:	**0208095**
Case:	N/A SDG: N/A	Lab ID:	**0208095-15**
Client ID:	**STA MM2**	Concentration Units:	**%**
Matrix:	**Sediment**	Received Date:	**8/15/2002**
Collection Date:	**8/15/2002**	Analysis Date:	**8/21/2002**



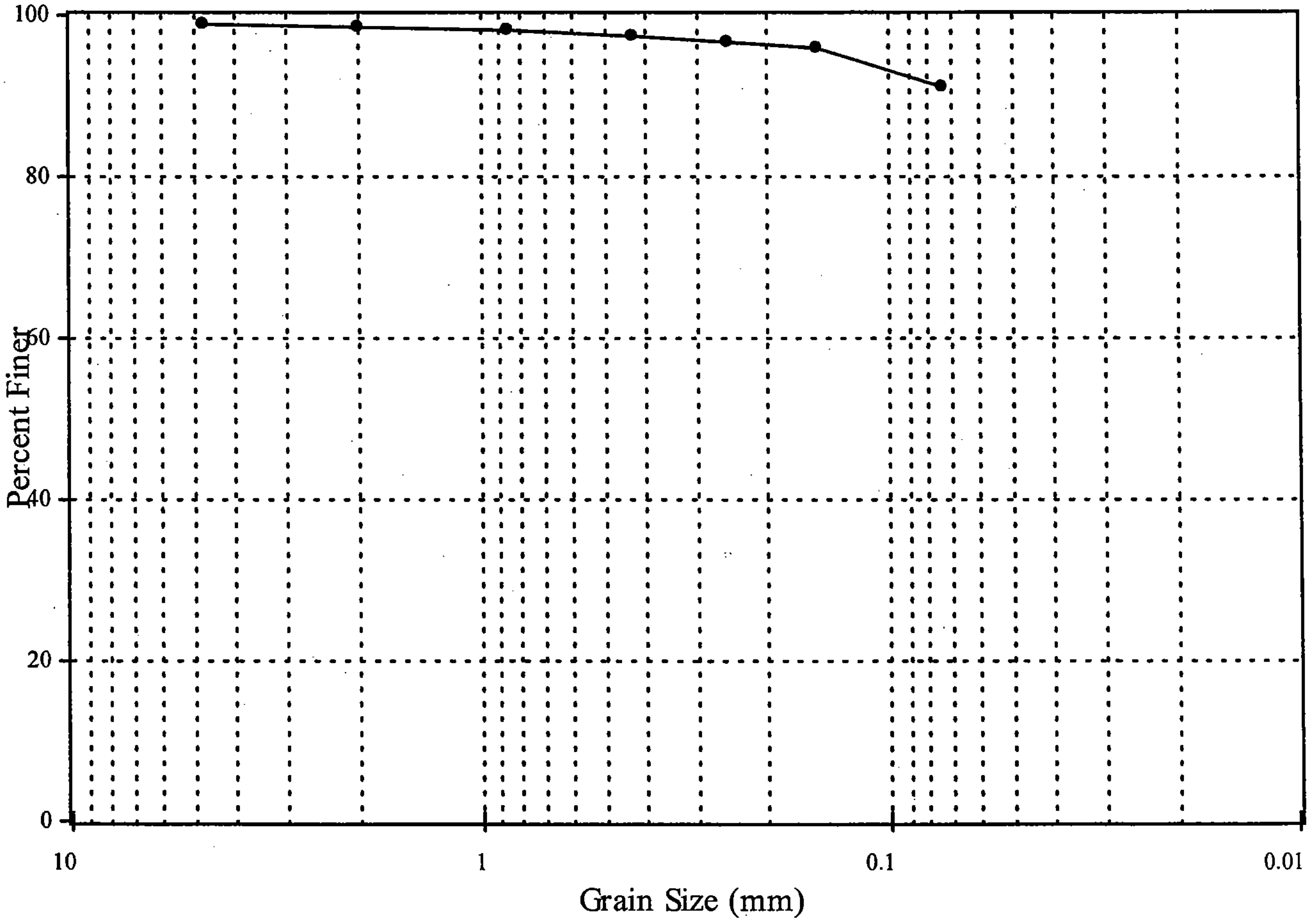
Sieve Number	Diameter Range	Percent Retained	Description
#4	>4.76 mm	0.00	Gravel
#10	<4.76 mm - 2.00 mm	0.00	Coarse Sand
#20	<2.00 mm - 0.85 mm	0.40	Medium Sand
#40	<0.85 mm - 0.425 mm	0.70	Medium Sand
#60	<0.425 mm - 0.25 mm	1.07	Fine Sand
#100	<0.25 mm - 0.15 mm	2.34	Fine Sand
#200	<0.15 mm - 0.074 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

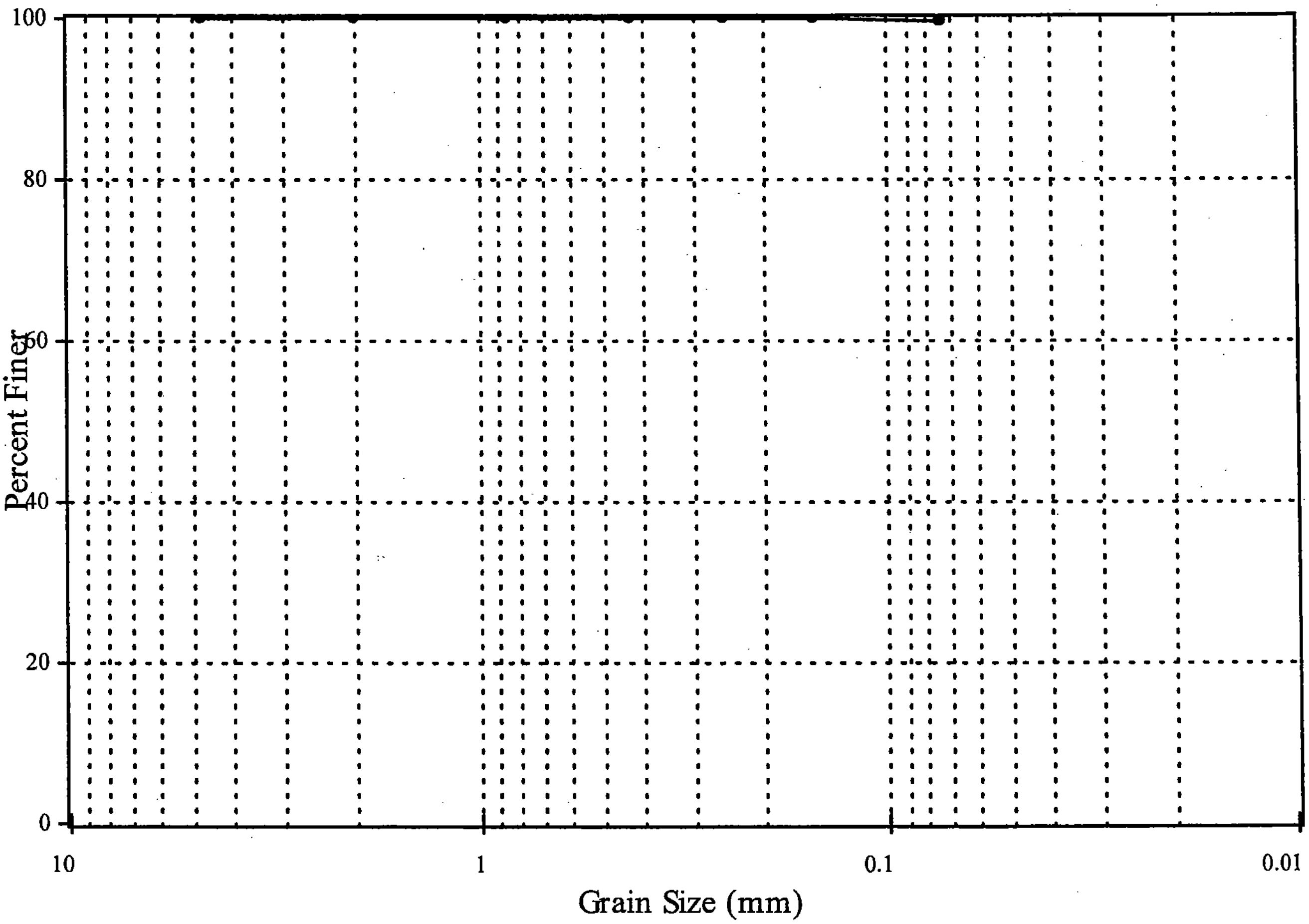
N/A - Not Applicable

08/21/02 15:32

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**

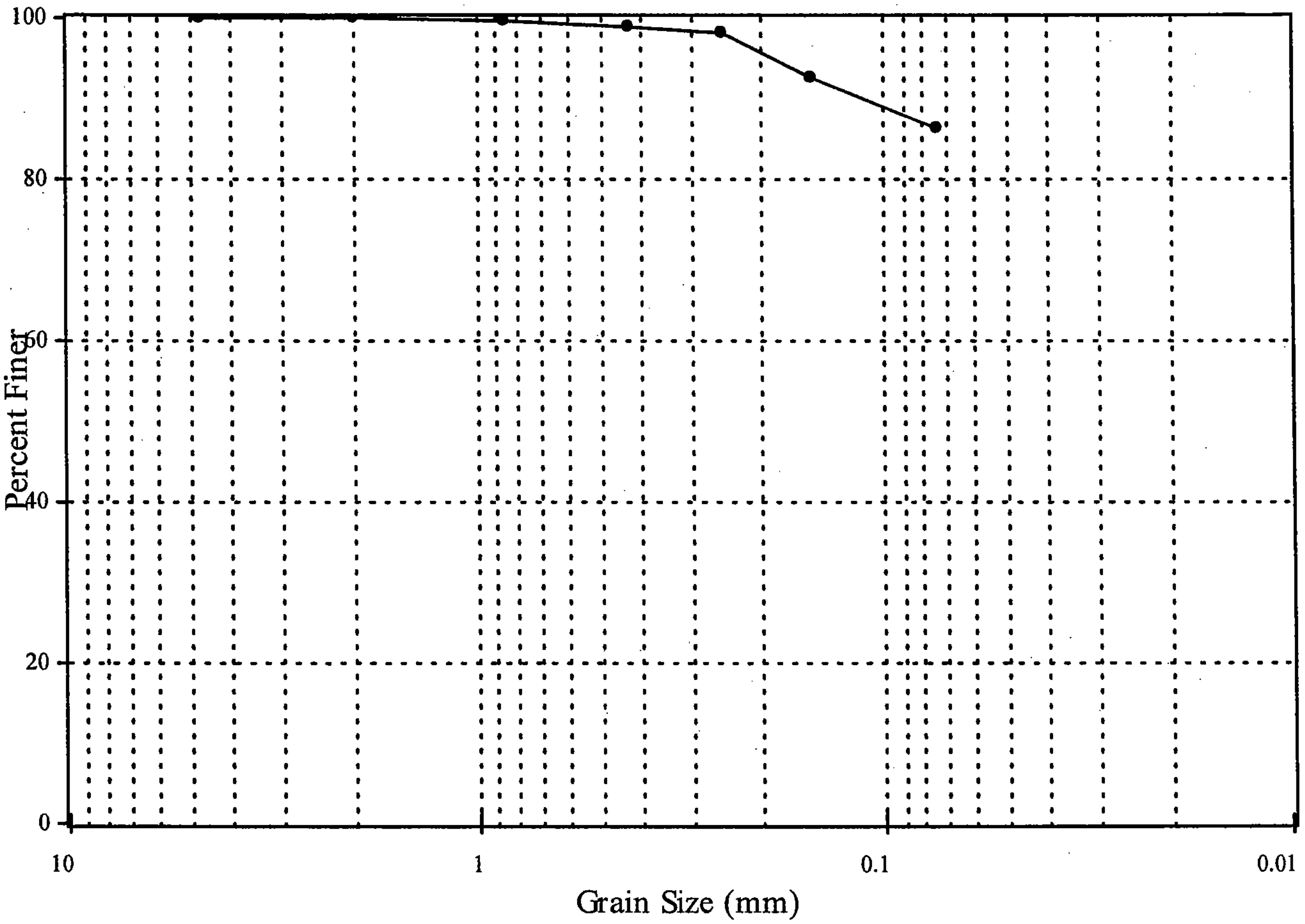


Sieve Number	Diameter Range	Percent Retained	Description
#4	>4.76 mm	0.00	Gravel
#10	<4.76 mm - 2.00 mm	0.00	Coarse Sand
#20	<2.00 mm - 0.85 mm	0.02	Medium Sand
#40	<0.85 mm - 0.425 mm	0.01	Medium Sand
#60	<0.425 mm - 0.25 mm	0.02	Fine Sand
#100	<0.25 mm - 0.15 mm	0.07	Fine Sand
#200	<0.15 mm - 0.074 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**	Lab Code:	**M-MA030**
Project:	**Boston Harbor Improvement Project**	ETR:	**0208095**
Case:	N/A SDG: N/A	Lab ID:	**0208095-20**
Client ID:	**STA W2 #1**	Concentration Units:	**%**
Matrix:	**Sediment**	Received Date:	**8/15/2002**
Collection Date:	**8/15/2002**	Analysis Date:	**8/20/2002**



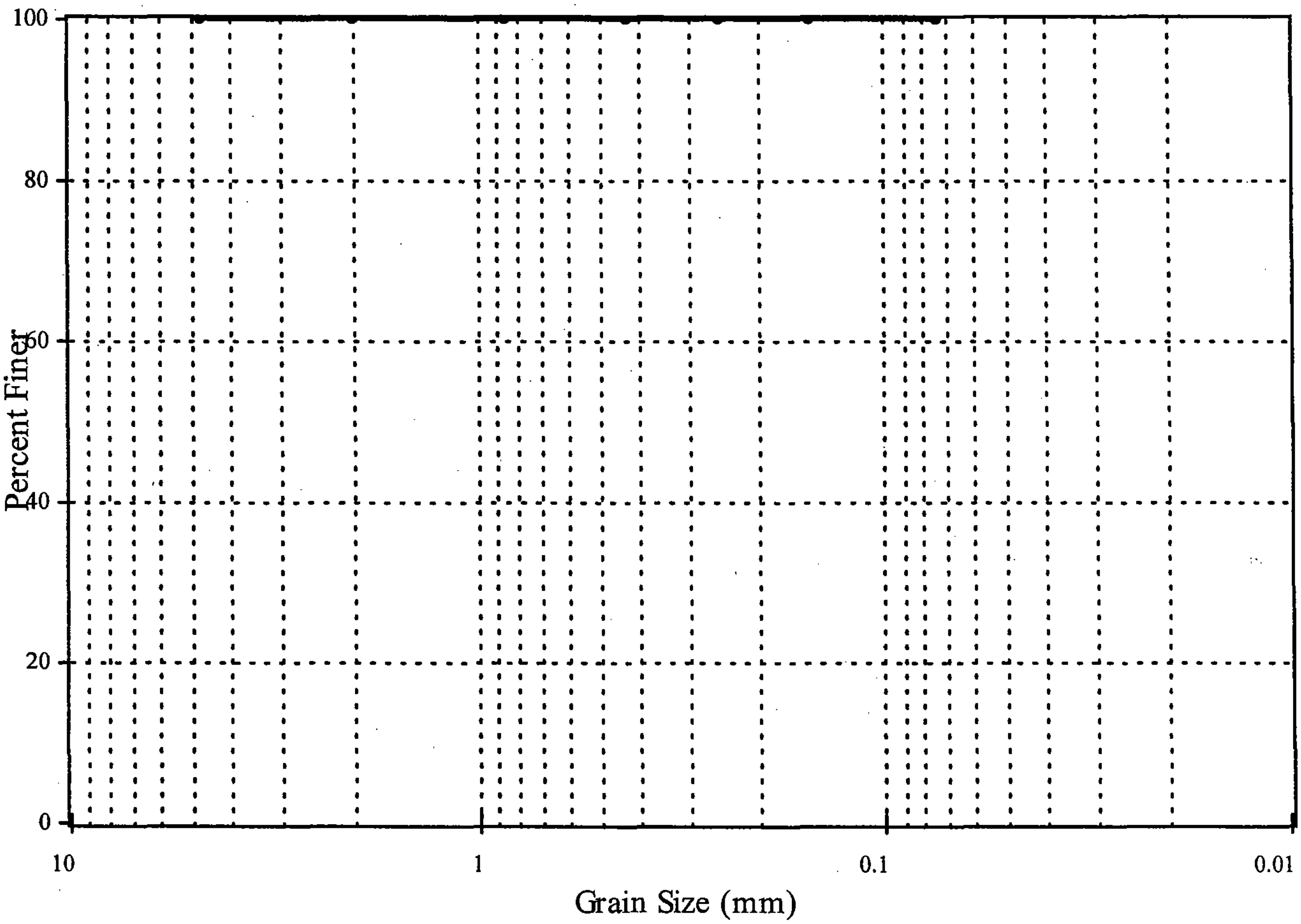
Sieve Number	Diameter Range	Percent Retained	Description
#4	>4.76 mm	0.00	Gravel
#10	<4.76 mm - 2.00 mm	0.01	Coarse Sand
#20	<2.00 mm - 0.85 mm	0.25	Medium Sand
#40	<0.85 mm - 0.425 mm	0.73	Medium Sand
#60	<0.425 mm - 0.25 mm	0.89	Fine Sand
#100	<0.25 mm - 0.15 mm	5.42	Fine Sand
#200	<0.15 mm - 0.074 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**

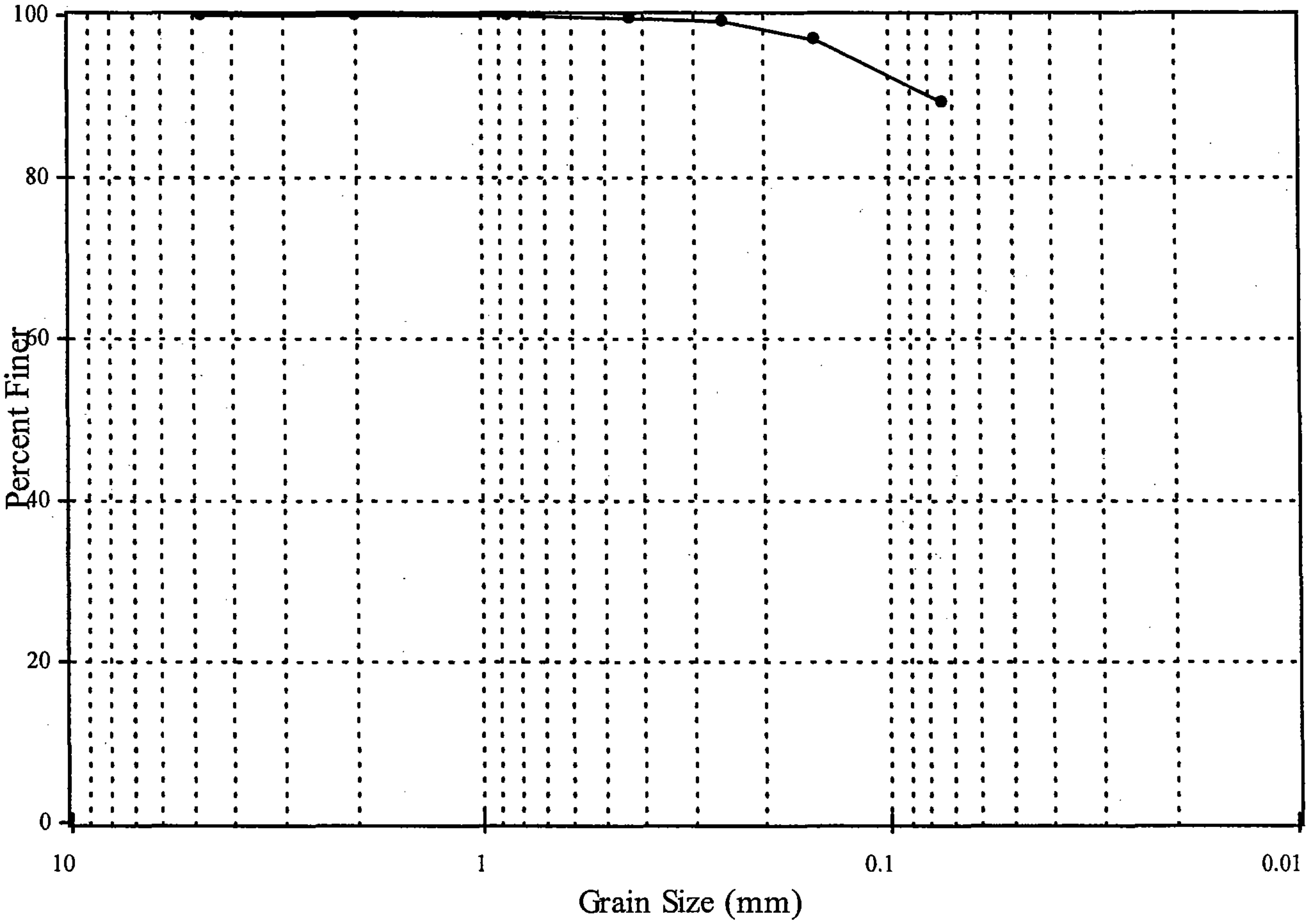


Sieve Number	Diameter Range	Percent Retained	Description
#4	>4.76 mm	0.00	Gravel
#10	<4.76 mm - 2.00 mm	0.00	Coarse Sand
#20	<2.00 mm - 0.85 mm	0.00	Medium Sand
#40	<0.85 mm - 0.425 mm	0.00	Medium Sand
#60	<0.425 mm - 0.25 mm	0.01	Fine Sand
#100	<0.25 mm - 0.15 mm	0.02	Fine Sand
#200	<0.15 mm - 0.074 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**	Lab Code:	**M-MA030**
Project:	**Boston Harbor Improvement Project**	ETR:	**0208095**
Case:	N/A SDG: N/A	Lab ID:	**0208095-18**
Client ID:	**STA Y2 #1**	Concentration Units:	**%**
Matrix:	**Sediment**	Received Date:	**8/15/2002**
Collection 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

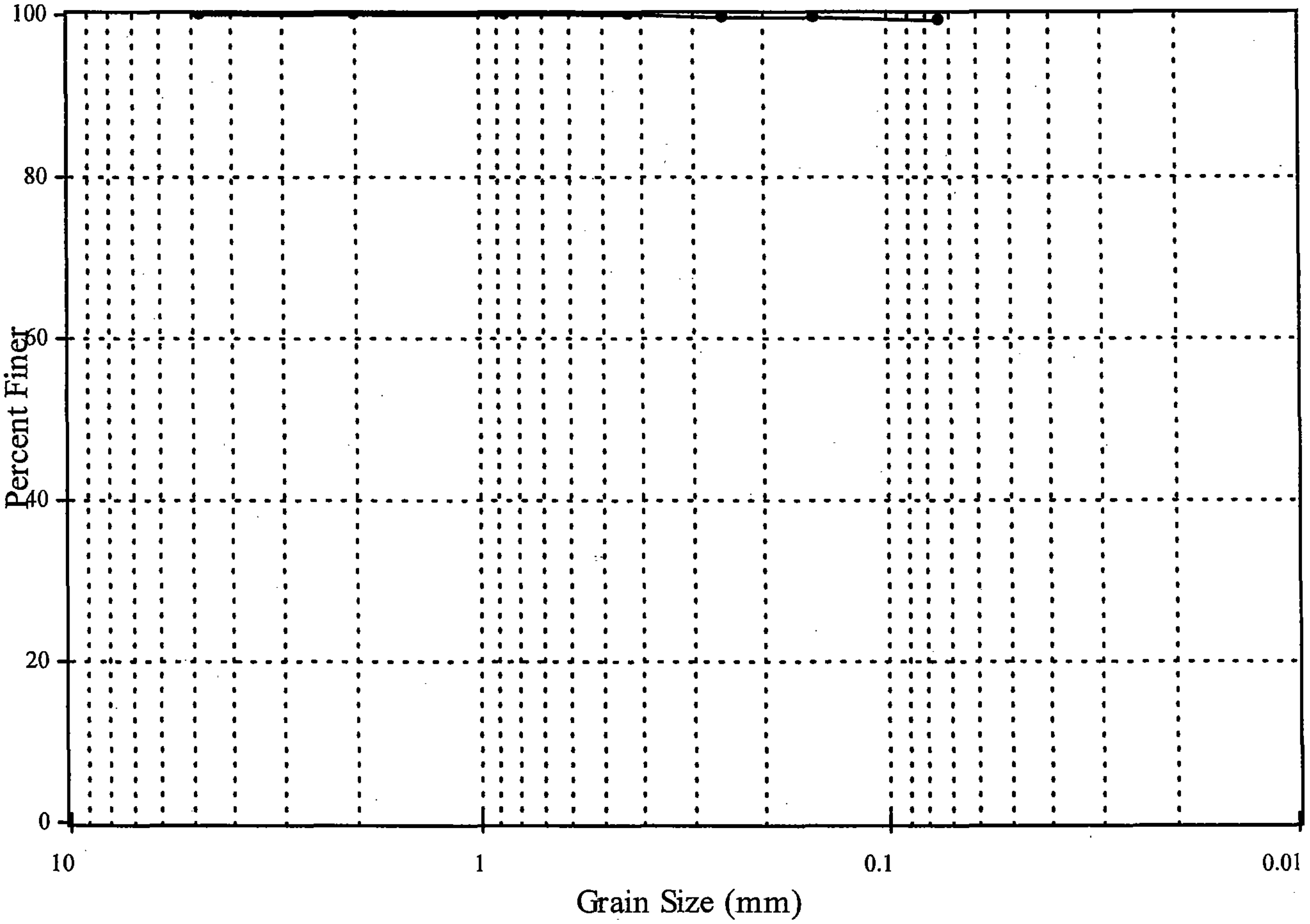
N/A - Not Applicable

08/21/02 15:35

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

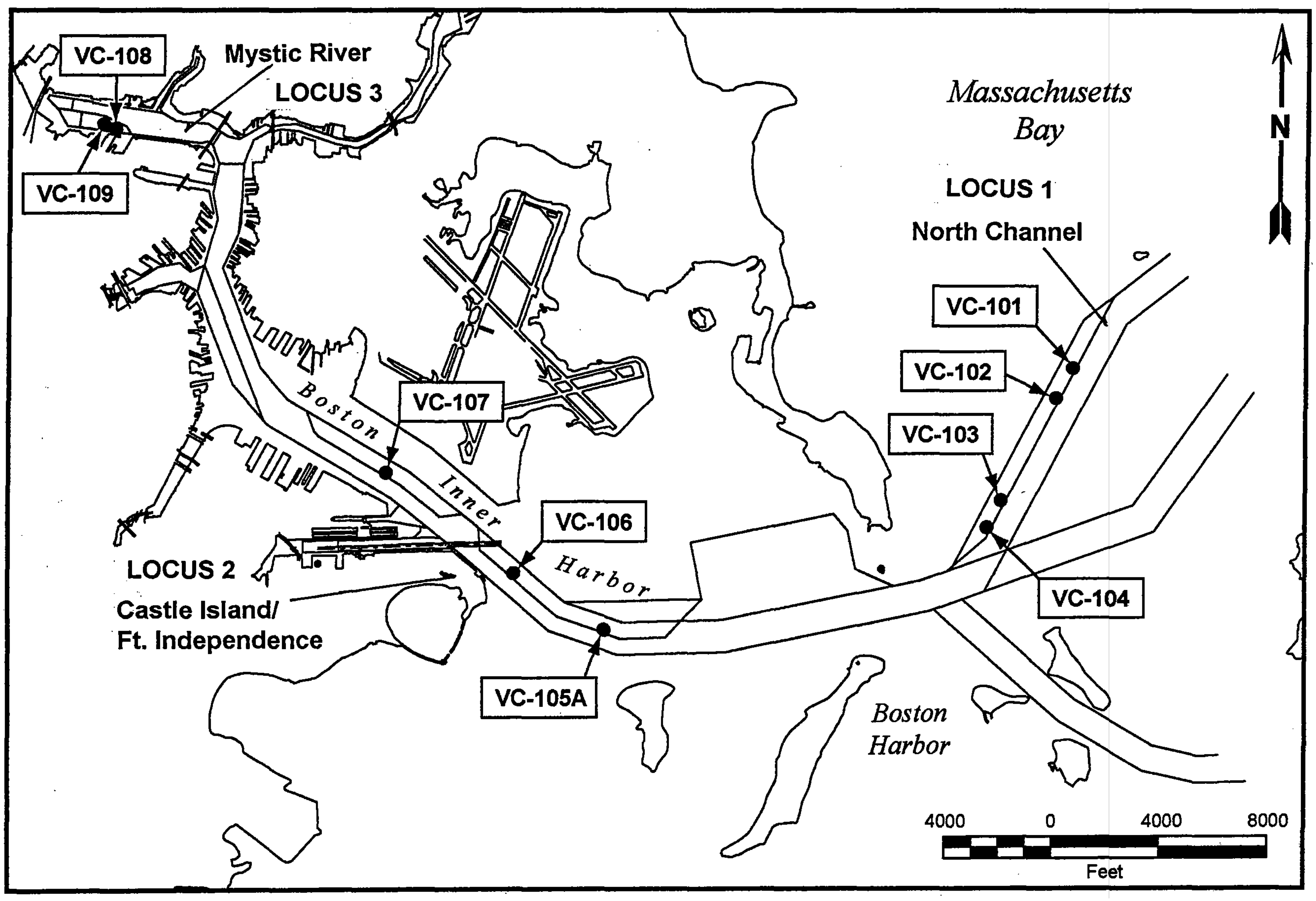


Figure 3. Map indicating the location of vibratory cores in Boston Harbor.

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.

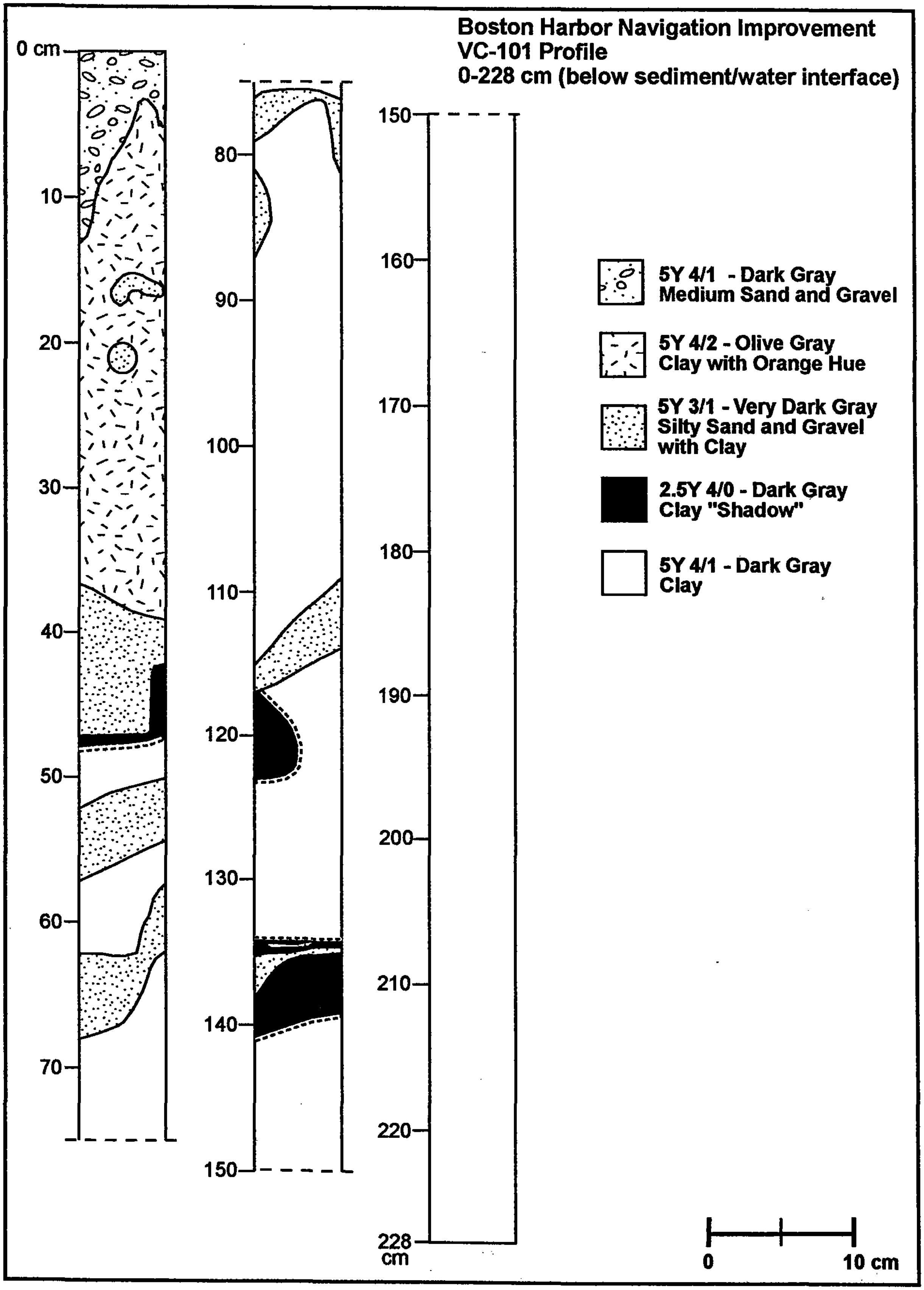


Figure 9. Profile of Vibratory Core VC-101 taken in the North Channel.

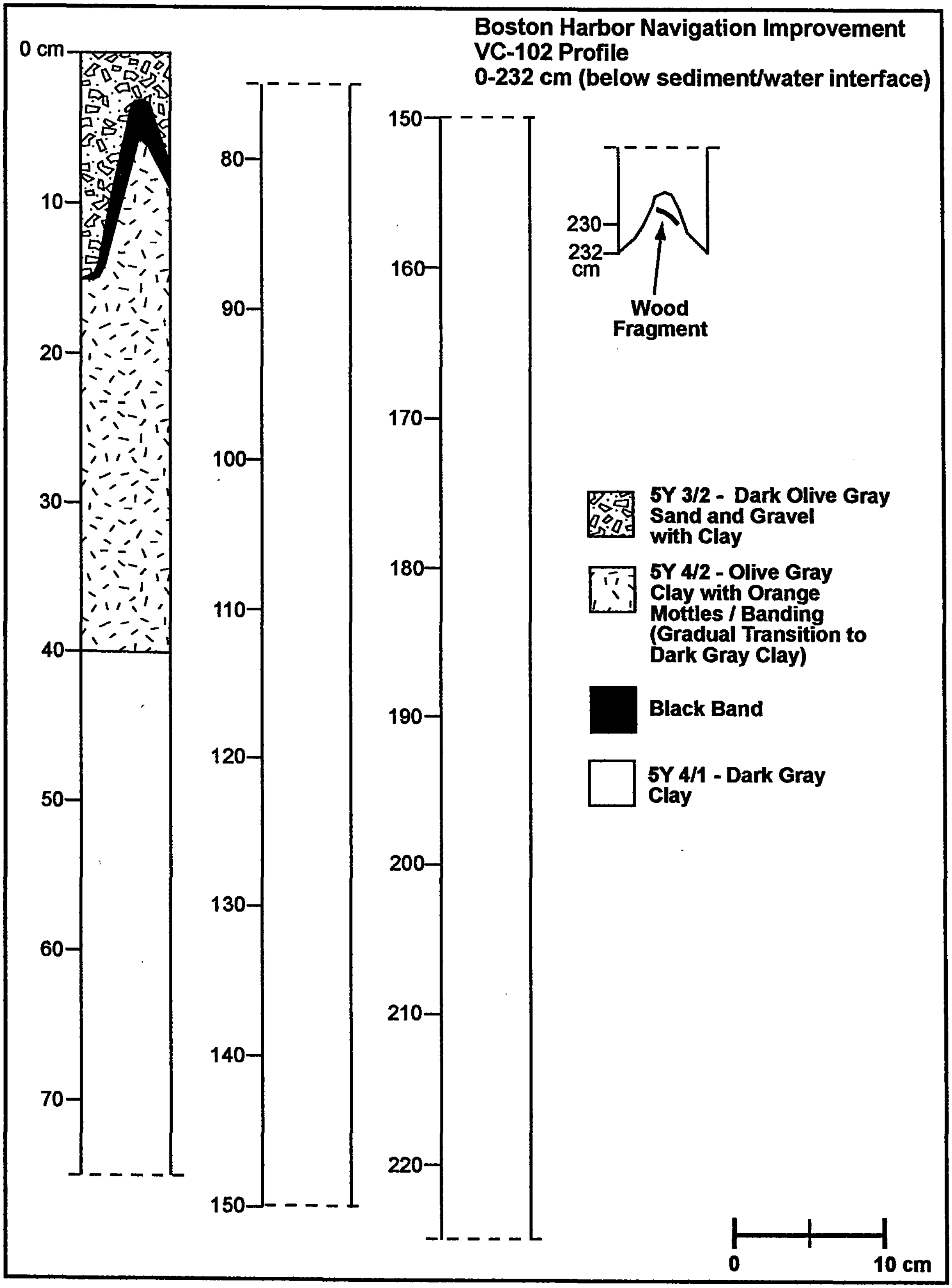


Figure 11. Profile of Vibratory Core VC-102 taken in the North Channel.

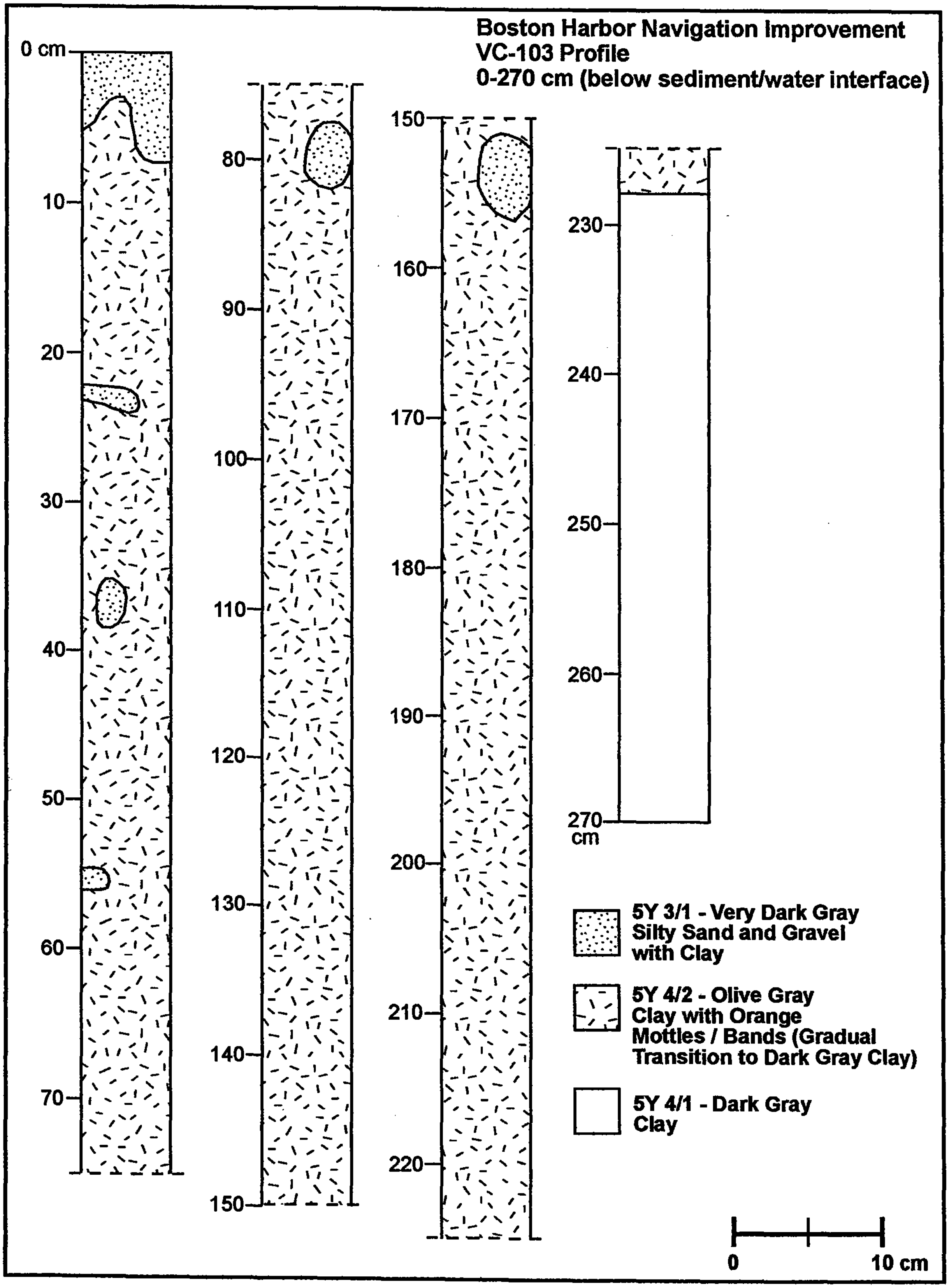


Figure 13. Profile of Vibratory Core VC-103 taken in the North Channel.

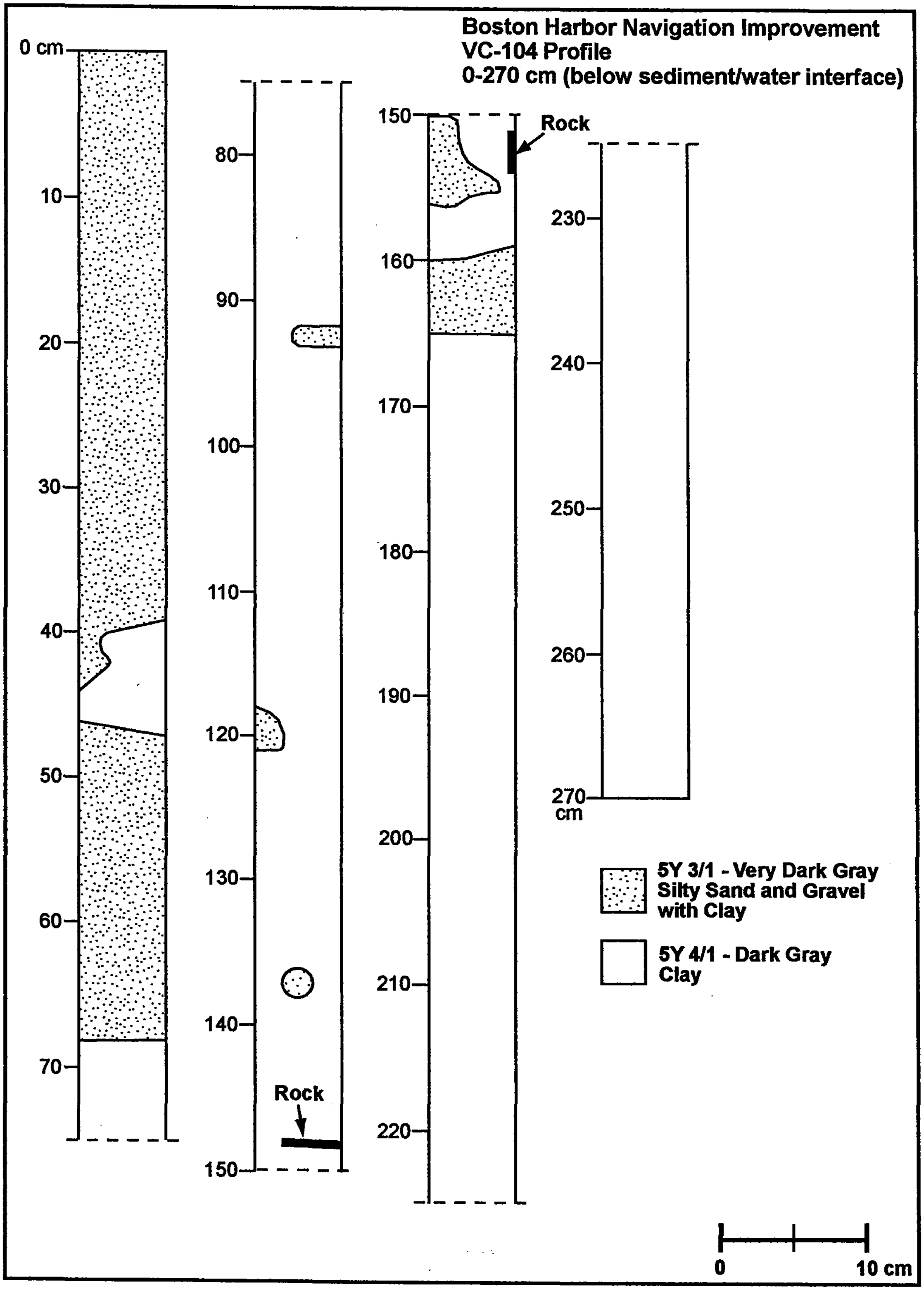


Figure 15. Profile of Vibratory Core VC-104 taken in the North Channel.

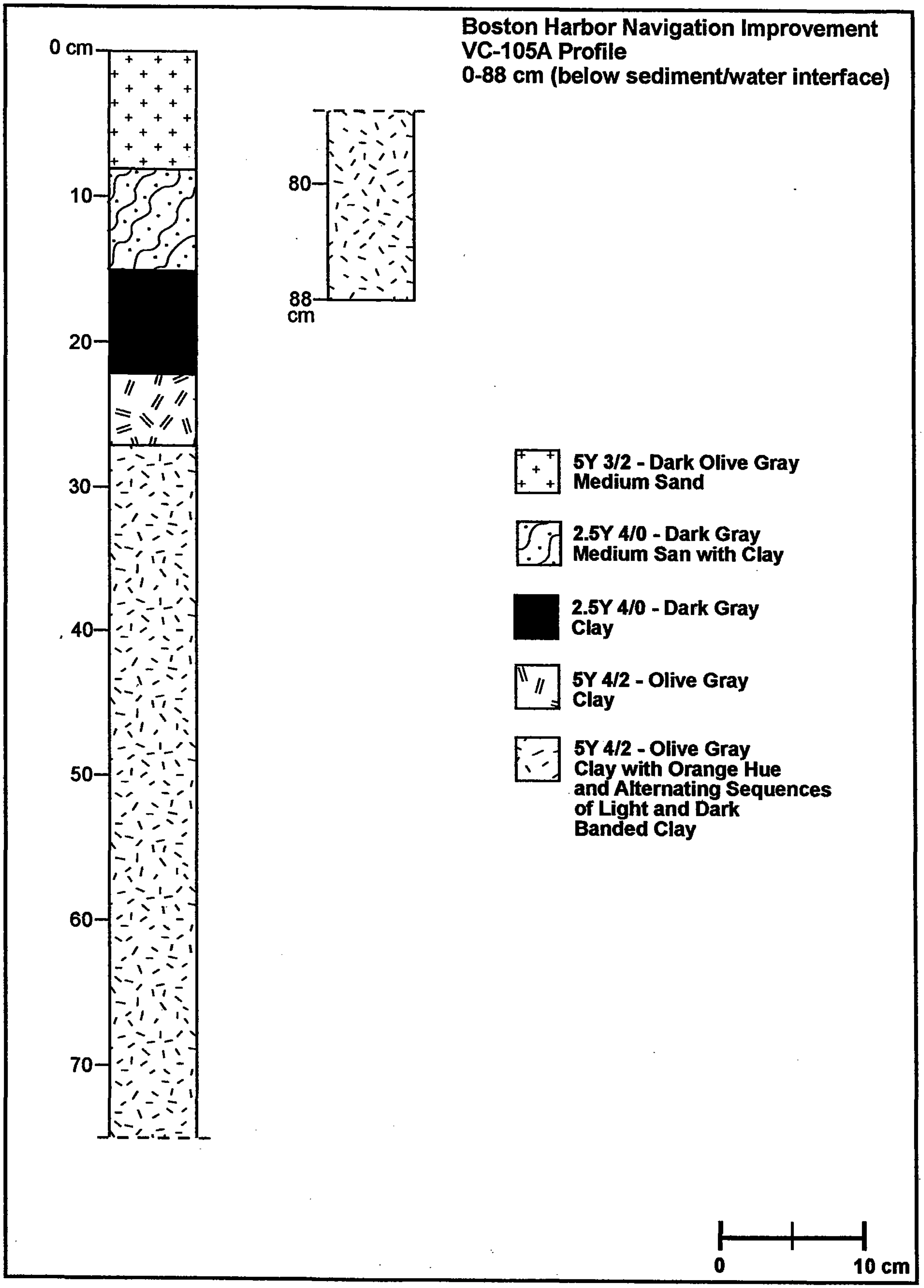


Figure 17. Profile of Vibratory Core VC-105A taken in the channel east of Castle Island.

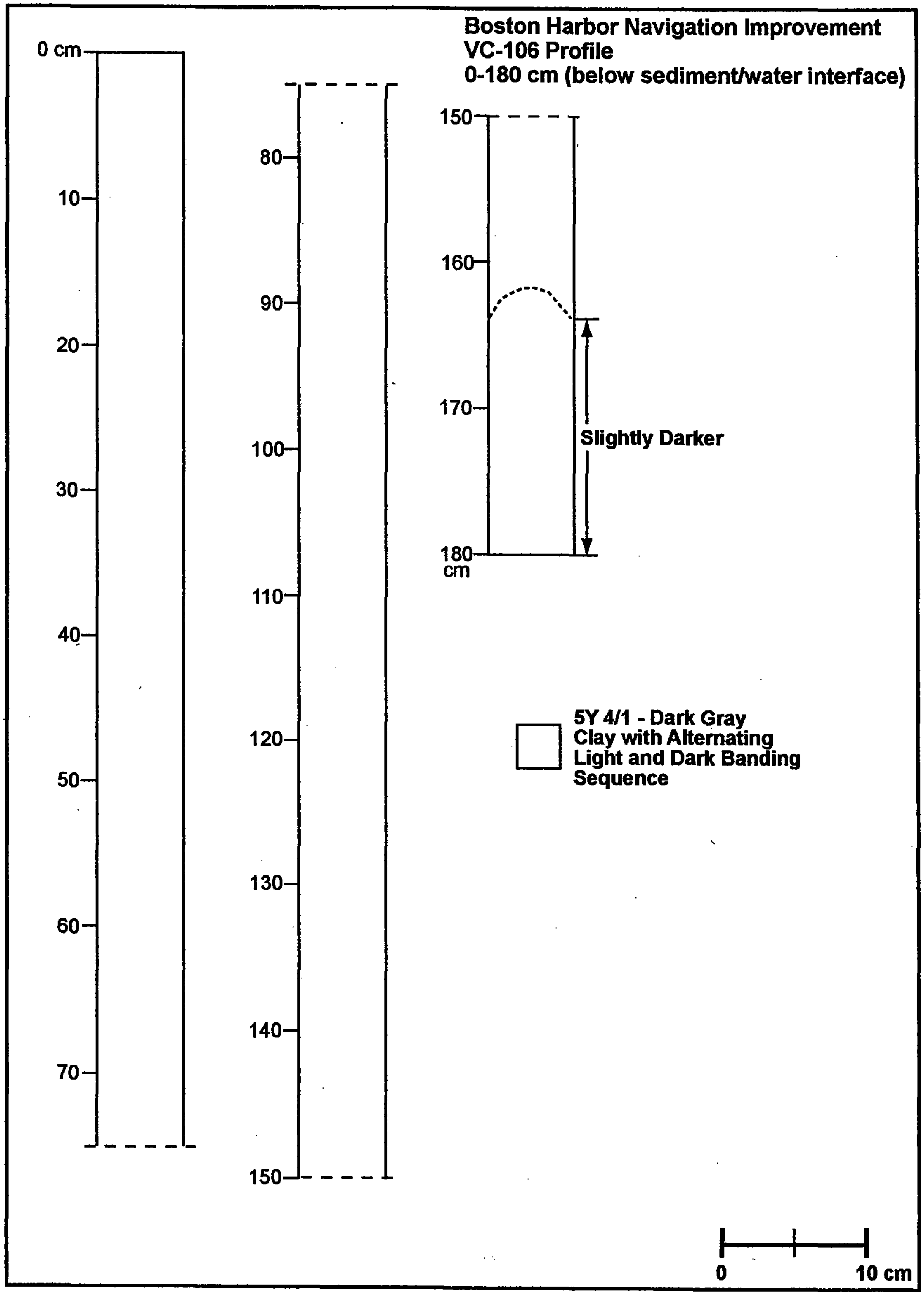


Figure 19. Profile of Vibratory Core VC-106 taken in the channel east of Castle Island.

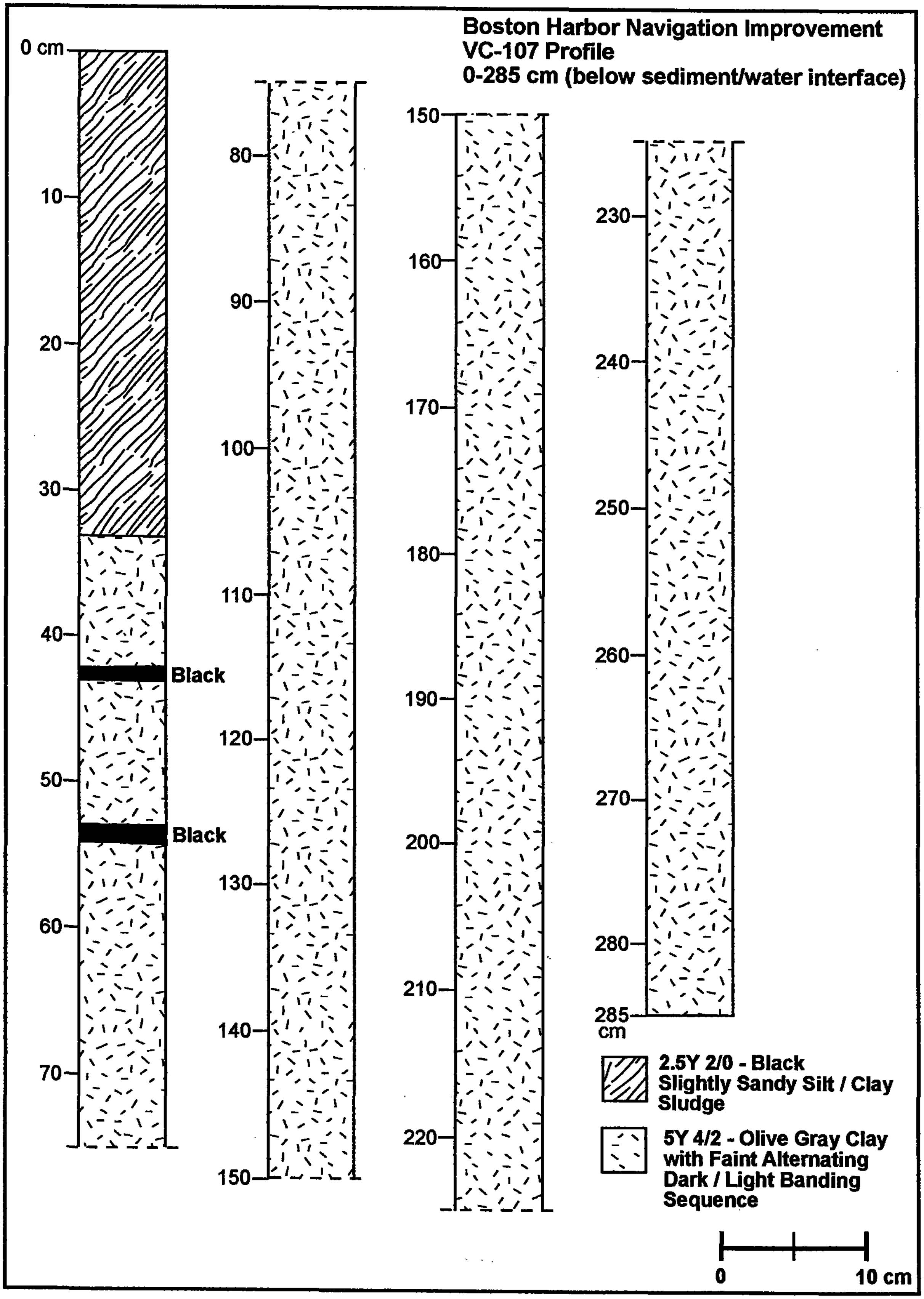


Figure 20. Profile of Vibratory Core VC-107 taken in the channel north of Castle Island.

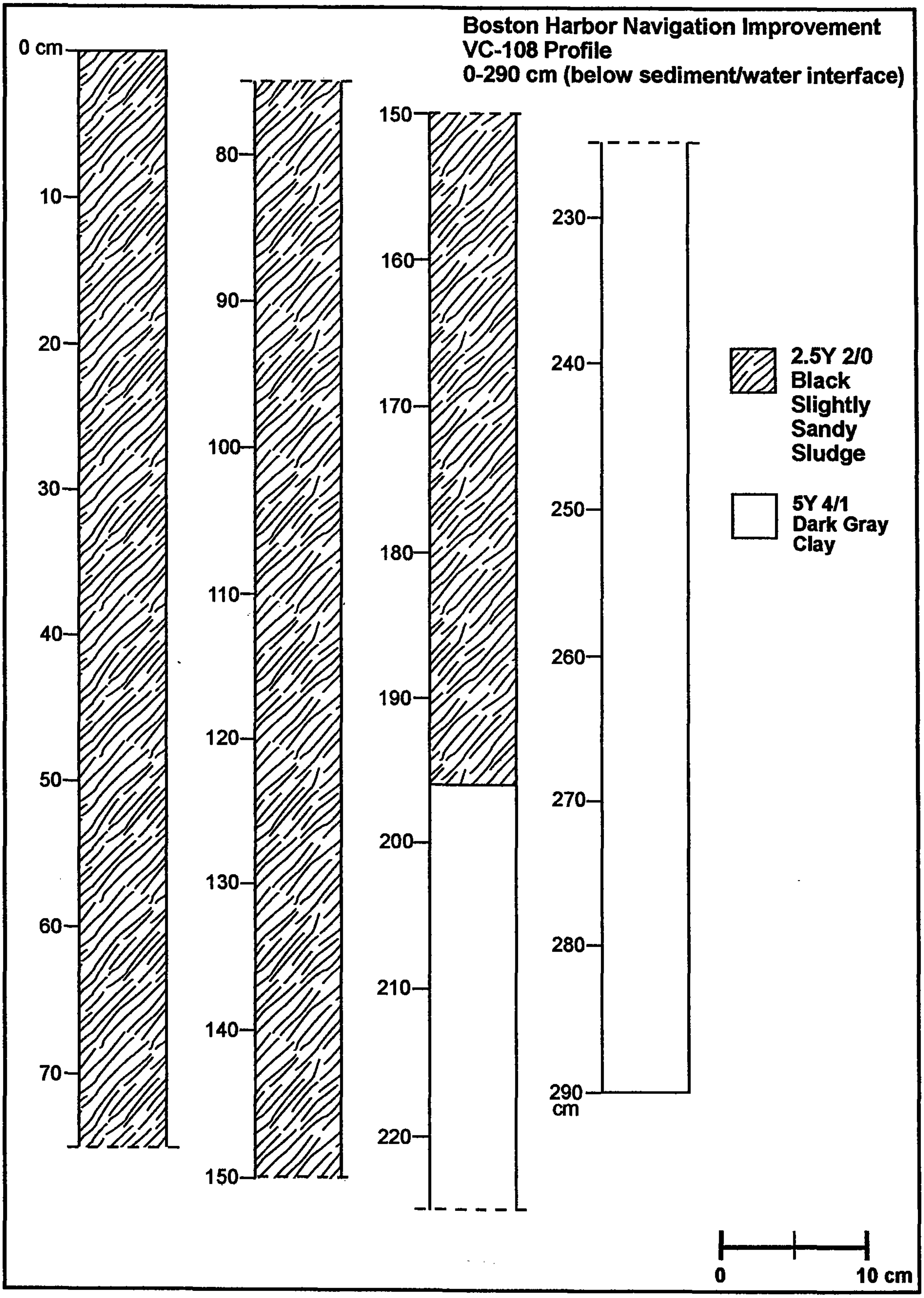


Figure 21. Profile of Vibratory Core VC-108 taken in the Mystic River.

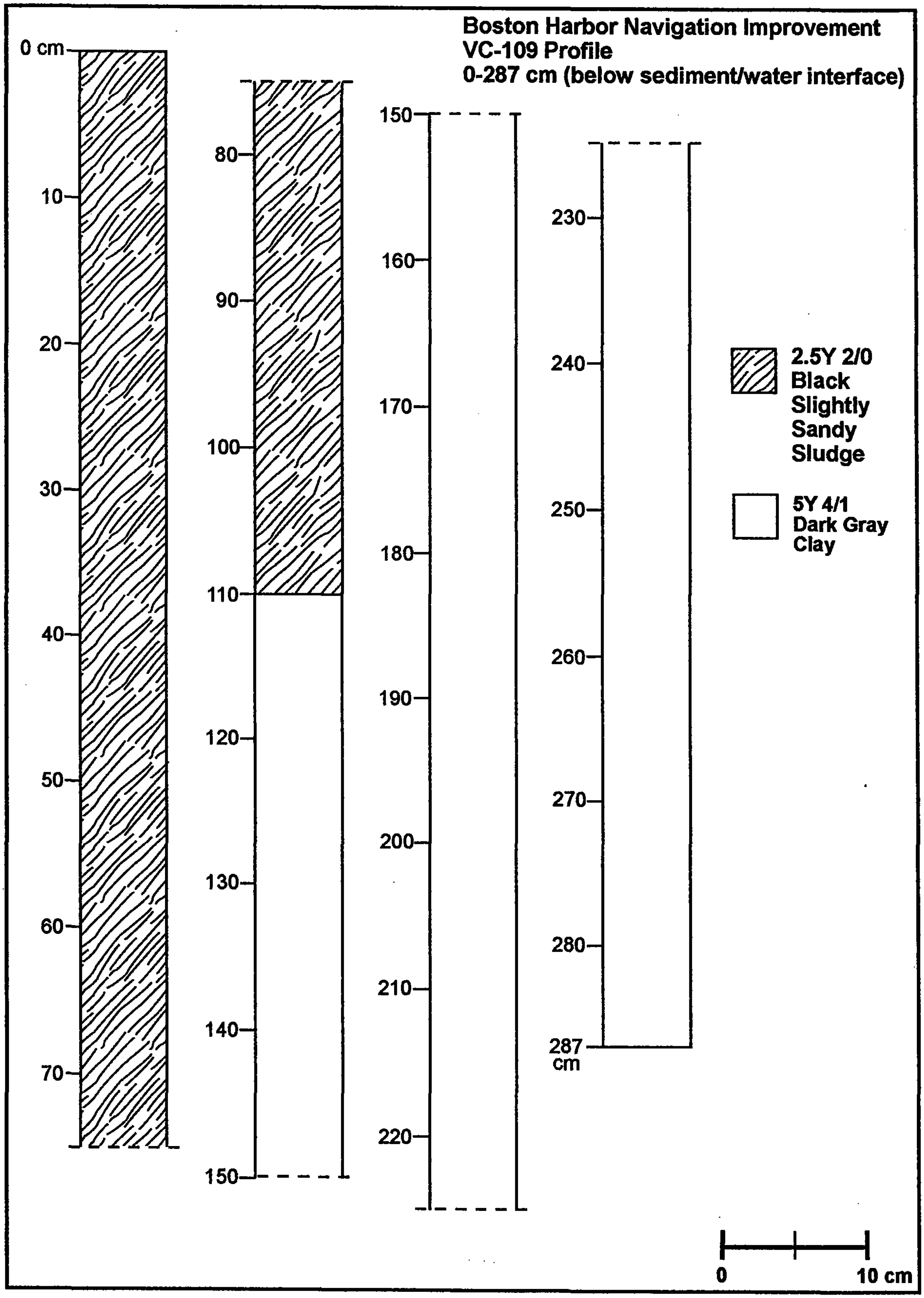


Figure 22. Profile of Vibratory Core VC-109 taken in the Mystic River.

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	~ 0-4.8' 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	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	VIBRACORE LOG	
COORDINATES:	N 486,516.5 ft , E 735,184.7ft NAD83	DRILLED BY:	TG&B / Mark Avakian	PAGE 1 of 1	**RC04-W**
WATER DEPTH:	38.7 ft at 0830 hrs	LOGGED BY:	B. Sawa		
MUD LINE ELEVATION (MLLW):	-38.7 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					Maintenance Layer	(0-4.8'): **ORGANIC SOIL (OL);** Organic Silt; homogeneous; organic odor; roots fibers; black.
2.5						
5	P1	13	12.5		Improvement Layer	(4.8-12.5') **LEAN CLAY (CL);** Homogeneous; medium plasticity; gray.
7.5				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	VIBRACORE LOG	
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	PAGE 1 of 1	RC04-X
MUD LINE ELEVATION (MLLW):	-40.8 ft	NUMBER OF PENETRATIONS:	1		

PEN. OF TUBE FT.	SAMPLE			REMARKS	GRAPHIC LOG	SOIL AND ROCK DESCRIPTIONS
	TYPE & NO.	PEN FT.	REC FT.			
0				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.
2.5	P1	5	4.5			(4.0-4.5'): **LEAN CLAY (CL)**; Angular gravel up to 1", grayish-black.
						Bottom of Vibracore, 5ft (EL -45.8 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

Φ 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	PAGE 1 of 1	RC04-Y
WATER DEPTH:	46.4 ft at 0911hrs	LOGGED BY:	B. Sawa		
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-RCO4-Y]		
5	P1	10	5	~5.5'		(0.5-5.0') **LEAN CLAY (CL)**; Homogeneous; low plasticity; gray.
7.5					Improvement Layer	
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	PAGE 1 of 1	RC04-Z
WATER DEPTH:	49.9 ft at 1600 hrs	LOGGED BY:	B. Sawa		
MUD LINE ELEVATION (MLLW):	-42.9 ft	NUMBER OF PENETRATIONS:	1		

PEN. OF TUBE FT.	SAMPLE			REMARKS	GRAPHIC LOG	SOIL AND ROCK DESCRIPTIONS
	TYPE & NO.	PEN FT.	REC FT.			
0 – 7.0	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).

Depth scale (ft): 0, 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

Φ GEI Consultants, Inc.

VIBRACORE LOCATION:	Boston Harbor LL	DRILL DATE(S):	3/31/04 - 3/31/04	VIBRACORE LOG
COORDINATES:	N 490,686.7 ft , E 729,798.0 ft NAD 83	DRILLED BY:	TG&B / Mark Avakian	PAGE 1 of 1
WATER DEPTH:	46.9 ft at 0900 hrs	LOGGED BY:	B. Sawa	**RC04-LL**
MUD LINE ELEVATION (MLLW):	-39.7 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					Maintenance Layer	(0-7.8'): **ORGANIC SOIL (OL)**; Organic Silt; homogeneous; organic odor; molluscs; black.
2.5						
5	P1	12	10.3			
7.5				[B-RC04-LL] Only Improvement Layer collected	Improvement Layer	(7.8-10.3') **LEAN CLAY (CL)**; Homogeneous; medium plasticity; gray.
10						Bottom of Vibracore, 12.0 ft (EL -51.7ft 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

Φ 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			REMARKS	GRAPHIC LOG	SOIL AND ROCK DESCRIPTIONS
	TYPE & NO.	PEN FT.	REC FT.			
0					Maintenance Layer	(0-4.5'): **ORGANIC SOIL (OL)**; Organic Silt; homogeneous; organic odor; large gravel up to 1 inch; black.
2.5	P1	4.5	4.5	No Improvement Layer collected Refusal at 4.5 ft		
						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

Φ GEI Consultants, Inc.

VIBRACORE LOCATION:	Boston Harbor NN	DRILL DATE(S):	4/8/04 - 4/8/04	VIBRACORE LOG	
COORDINATES:	N 492,505.3 ft, E 727,750.0 ft NAD83	DRILLED BY:	TG&B / Mark Avakian	PAGE 1 of 1	**RC04-NN**
WATER DEPTH:	42.5 ft at 0900 hrs	LOGGED BY:	B. Sawa		
MUD LINE ELEVATION (MLLW):	-42.8 ft	NUMBER OF PENETRATIONS:	1		

PEN. OF TUBE FT.	SAMPLE			REMARKS	GRAPHIC LOG	SOIL AND ROCK DESCRIPTIONS
	TYPE & NO.	PEN FT.	REC FT.			
0				~1.4'	M. Layer	(0-1.4'): **ORGANIC SOIL (OL)**; Organic Silt; homogeneous; organic odor; molluscs; black.
2.5					Improvement Layer	(0.4-0.8'): **LEAN CLAY (CL)**; Homogeneous; low plasticity; olive-gray.
5	P1	10	6.7	Only Improvement Layer collected [B-RC04-NN]		(0.8-1.4'): **ORGANIC SOIL (OL)**; Organic Silt; homogeneous; organic odor; molluscs; roots; worm; black. (1.4-6.7'): **LEAN CLAY (CL)**; Homogeneous; stiff; medium plasticity; greenish-gray.
7.5						
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

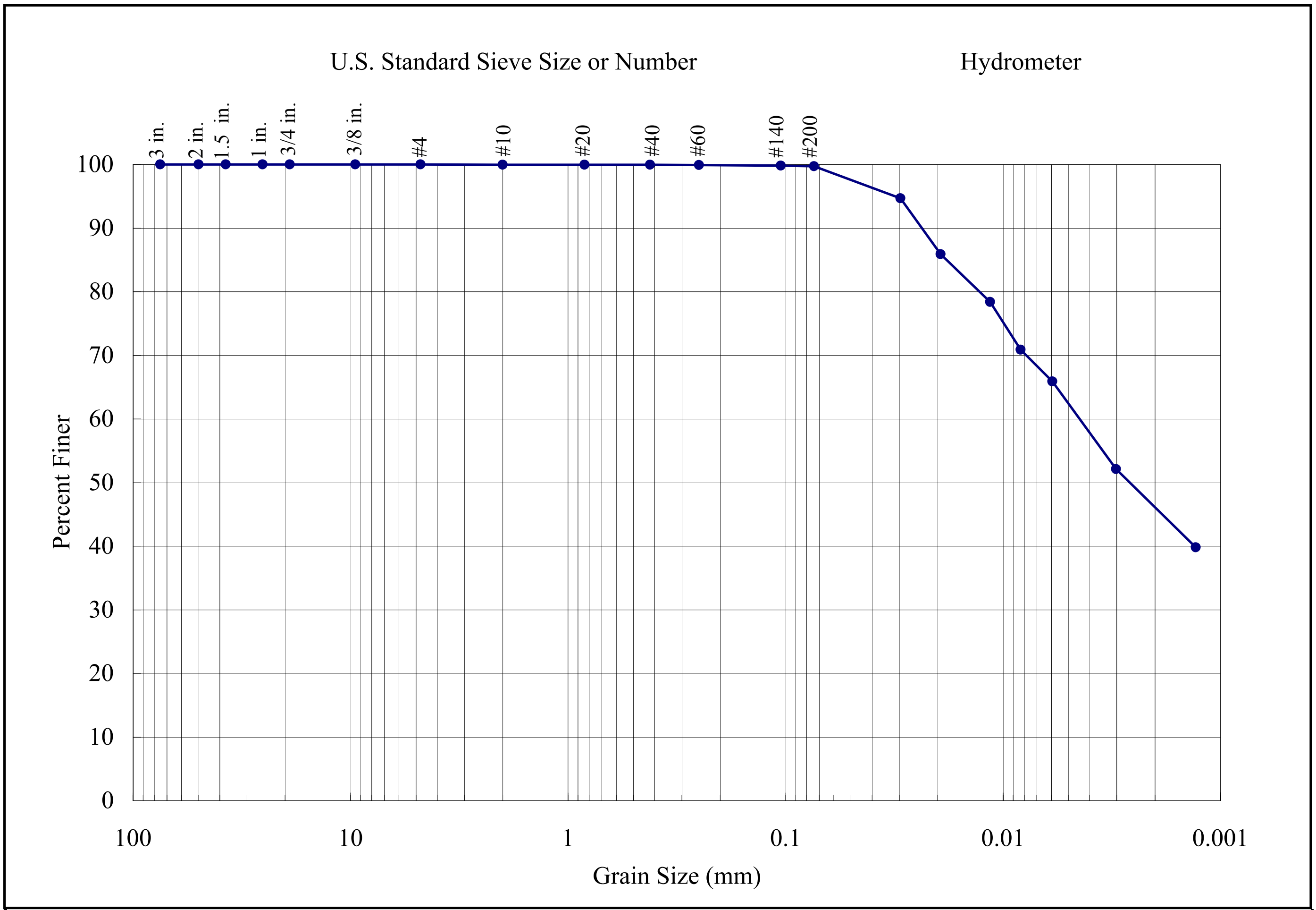
NOTES:

VIBRACORE ID =2 5/8"

"[ ]"--INDICATES SAMPLE IDENTIFICATION

Boston Harbor Sediment Sampling
Project 03176-2

Φ GEI Consultants, Inc.



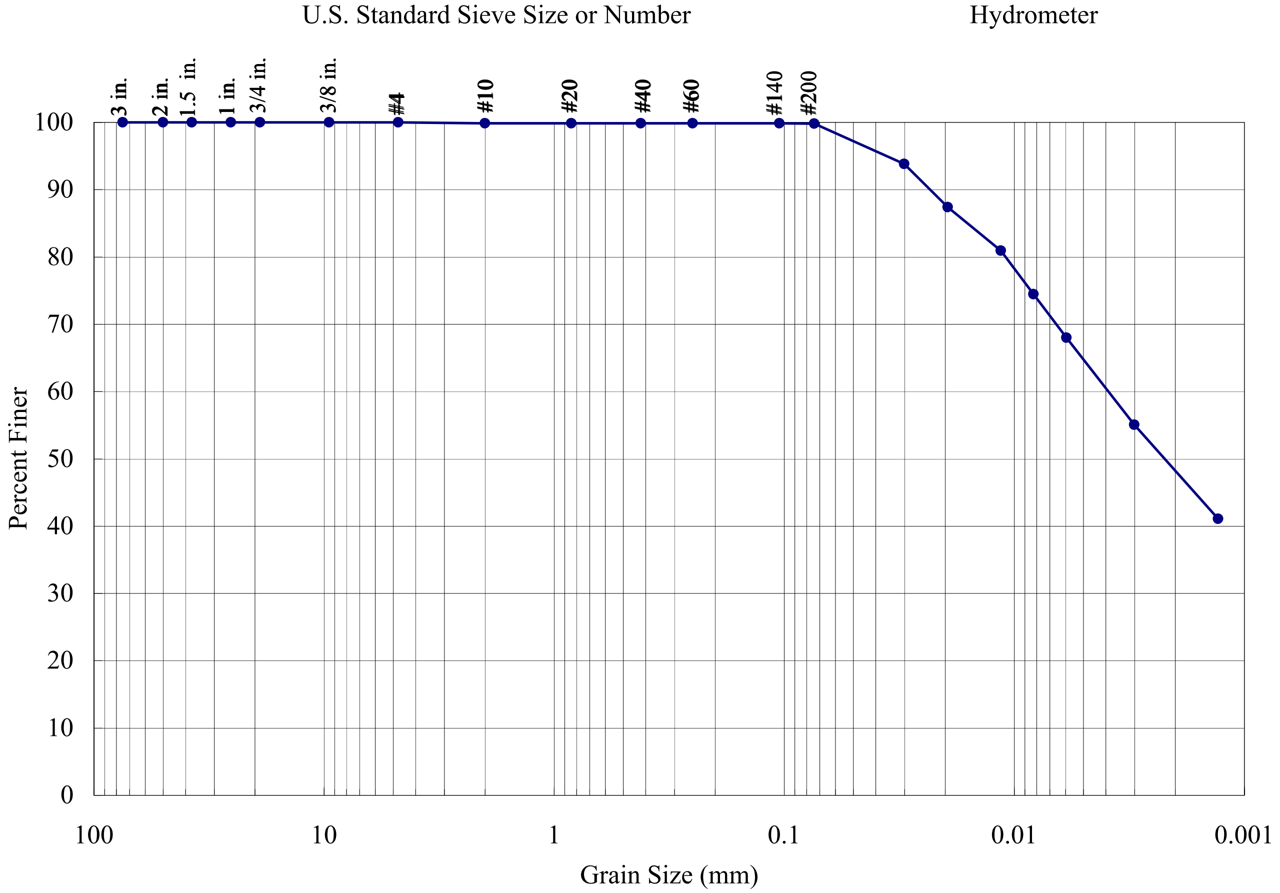
ASTM D422 (Particle-Size Analysis of Soils)

% Cobble >3"	% Gravel <3" - #4	% Sand Coarse #10	 Medium #20-#40	 Fine #60-#200	% Fines Silt 0.074-0.005 mm	 Clay <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



ASTM D422 (Particle-Size Analysis of Soils)

% Cobble >3"	% Gravel <3" - #4	% Sand Coarse #10	% Sand Medium #20-#40	% Sand Fine #60-#200	% Fines Silt 0.074-0.005 mm	% Fines Clay <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

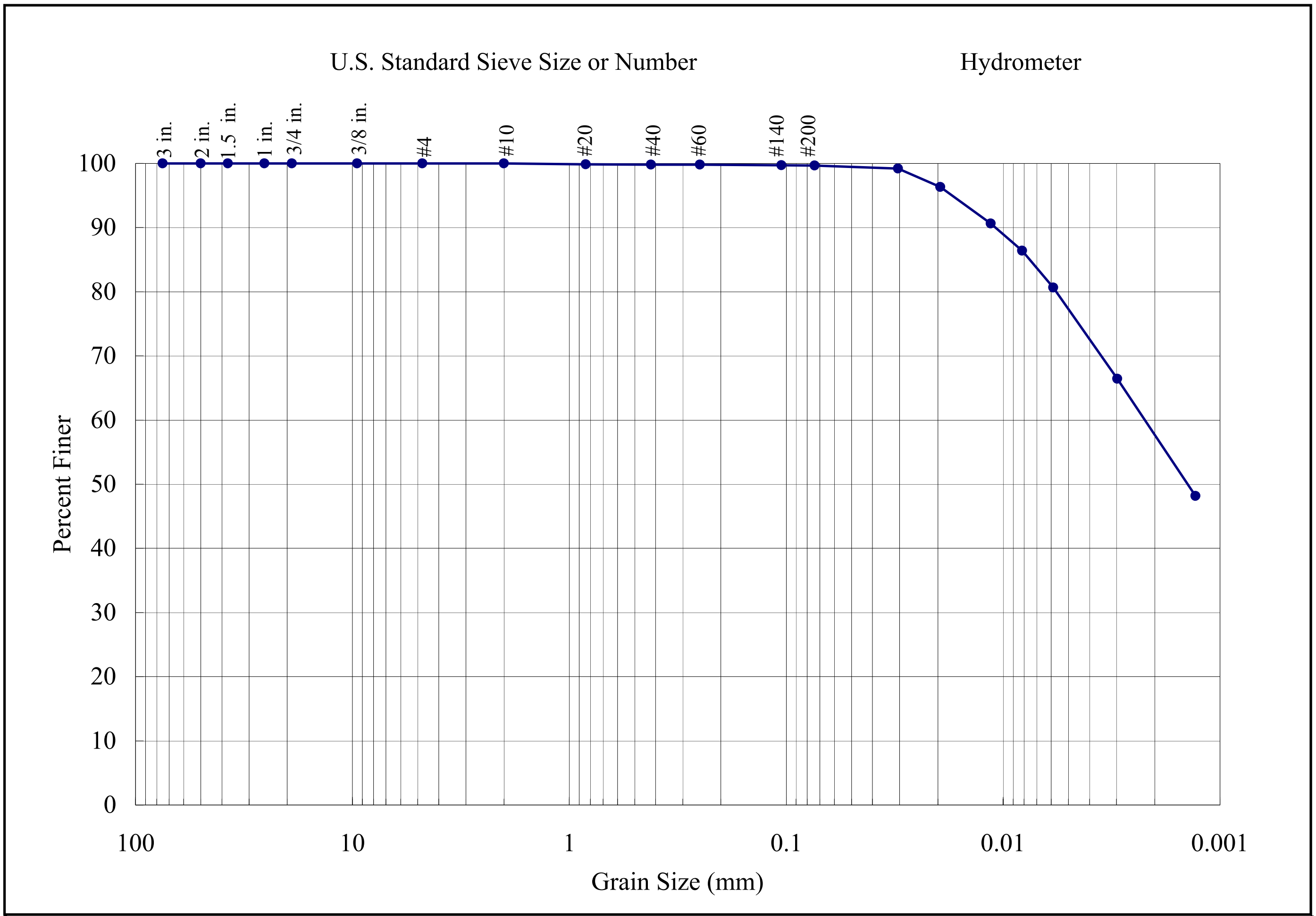
Material Description	USCS
Fat Clay, Greenish Gray (5Y 6/1)	CH

Project Description

Boston Harbor

AMS, Inc. Project Manager:

Client P/N: G606405
AMS P/N: 2004-03-18
Client ID: Recon-LL-D
AMS ID: 19505
Date Analyzed: 4/20/2004



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

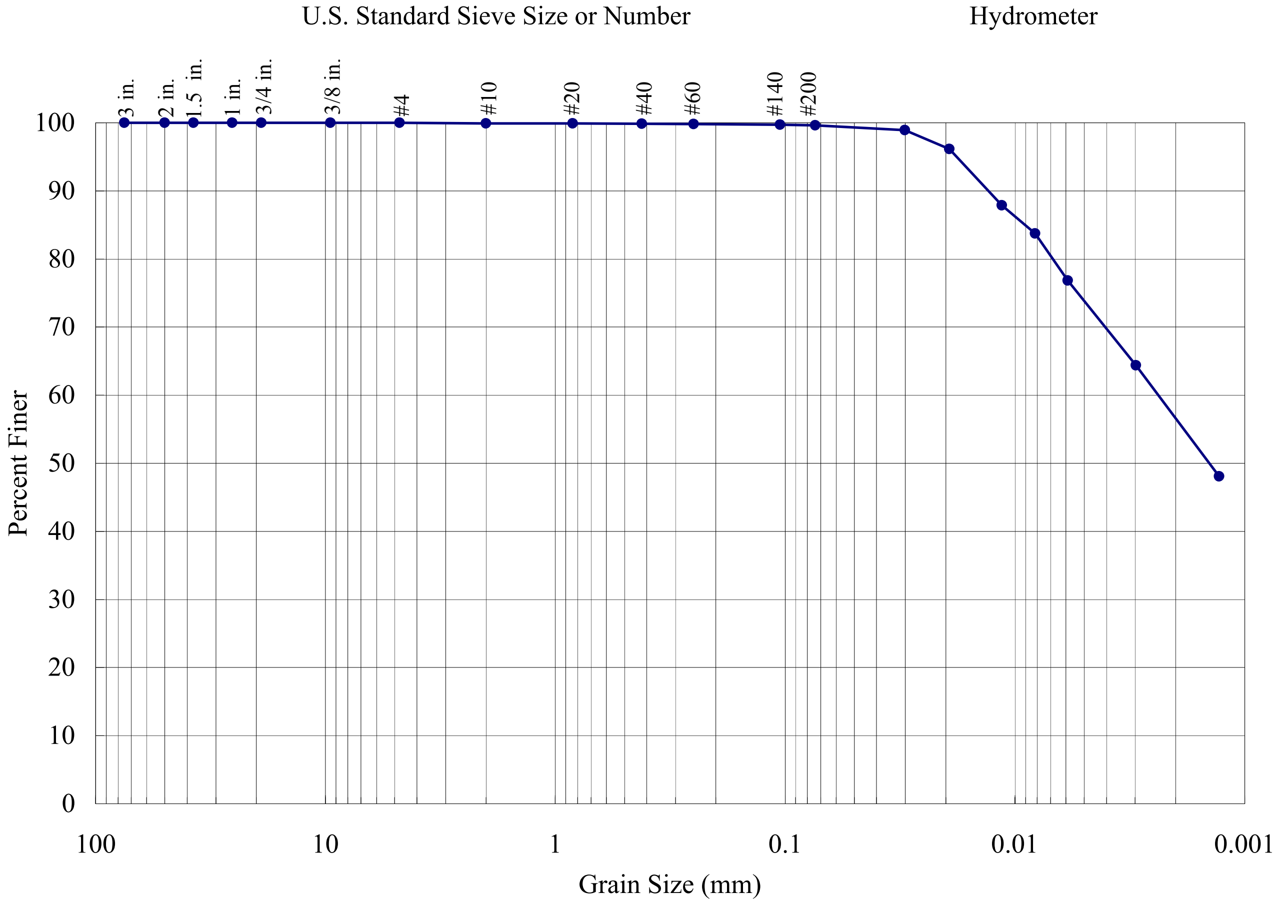
Material Description	USCS
Fat Clay, Greenish Gray (5Y 6/1)	CH

Project Description

Boston Harbor

AMS, Inc. Project Manager:

Client P/N: G606405
AMS P/N: 2004-03-18
Client ID: Recon-W-D
AMS ID: 19506
Date Analyzed: 4/20/2004



ASTM D422 (Particle-Size Analysis of Soils)

		% Sand			% Fines	
% Cobble	% Gravel	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

AMS, Inc. Project Manager:

Client P/N: G606405
AMS P/N: 2004-03-18
Client ID: Recon-NN-D
AMS ID: 19507
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

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 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.

(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

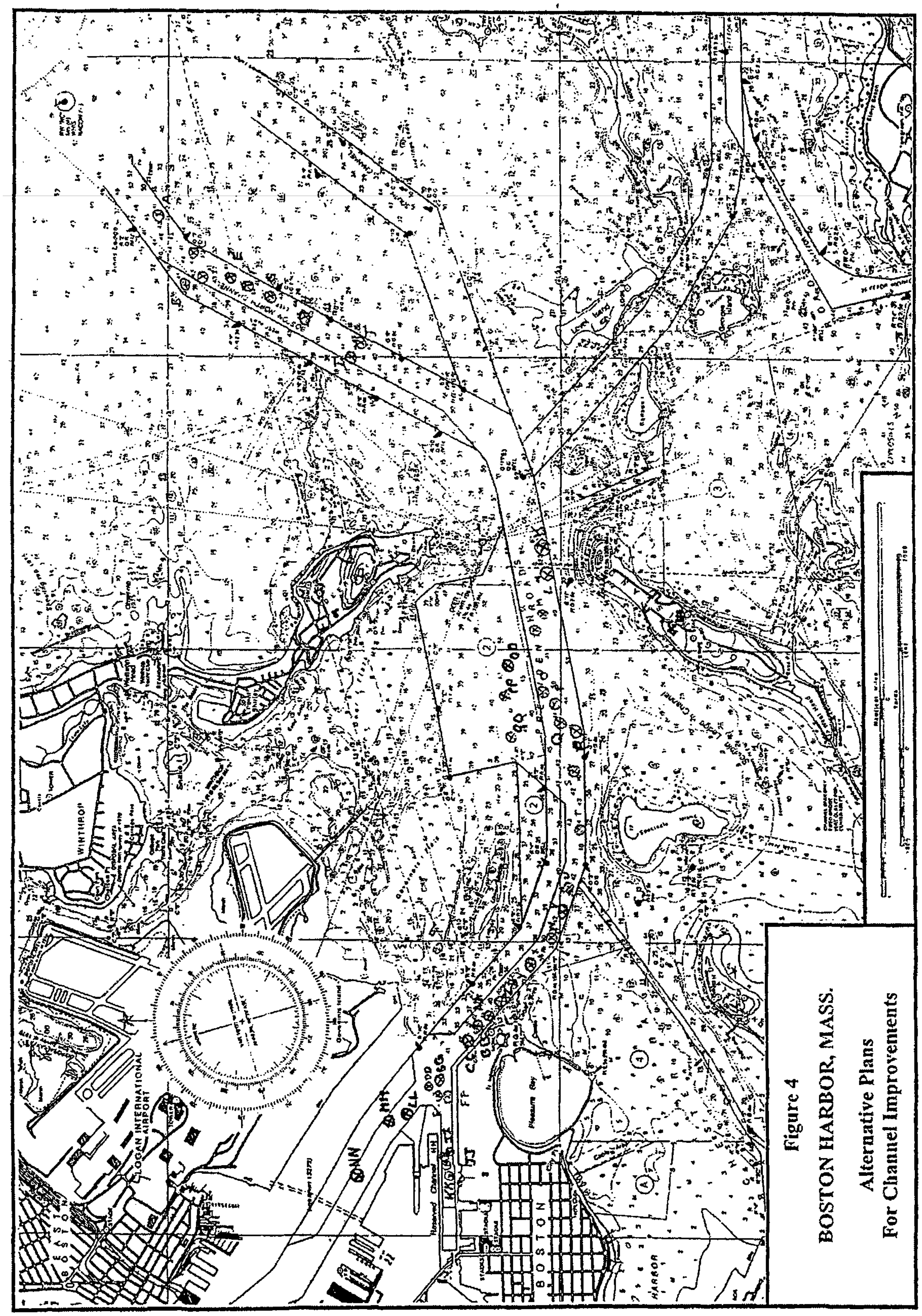
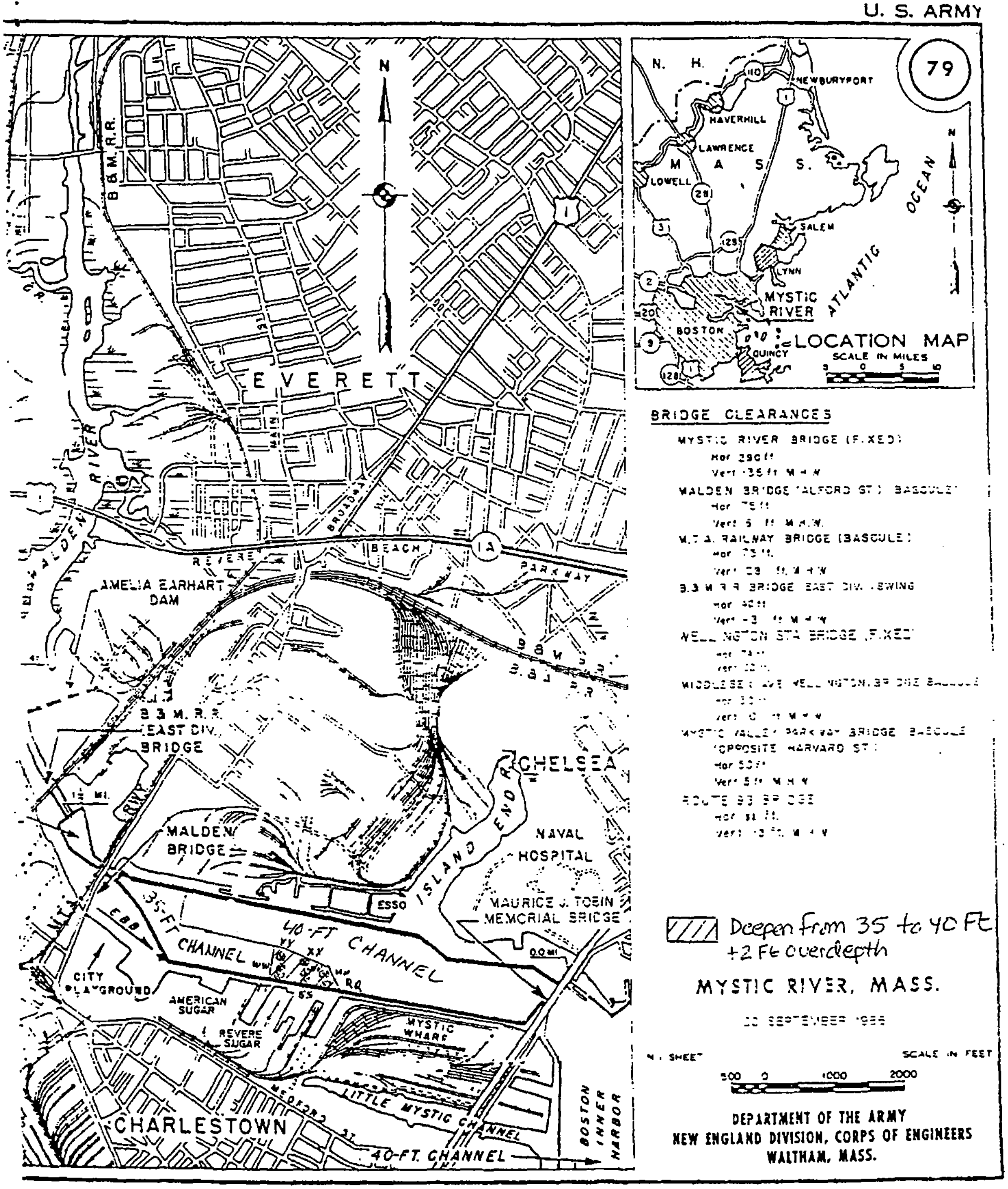


Figure 4

BOSTON HARBOR, MASS.

Alternative Plans
For Channel Improvements

Subject: Suitability Determination for Boston Harbor Deep Draft Improvement, Boston, Massachusetts, Application Number 200102386.



▨ Deepen from 35 to 40 Ft +2 Ft overdepth

MYSTIC RIVER, MASS.

30 SEPTEMBER 1955

DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION, CORPS OF ENGINEERS
WALTHAM, MASS.

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

TABLE OF CONTENTS

ATTACHMENTS

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.

<u>Pre-Contact Context</u>

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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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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TABLE OF CONTENTS

LIST OF FIGURES

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.

LIST OF TABLES

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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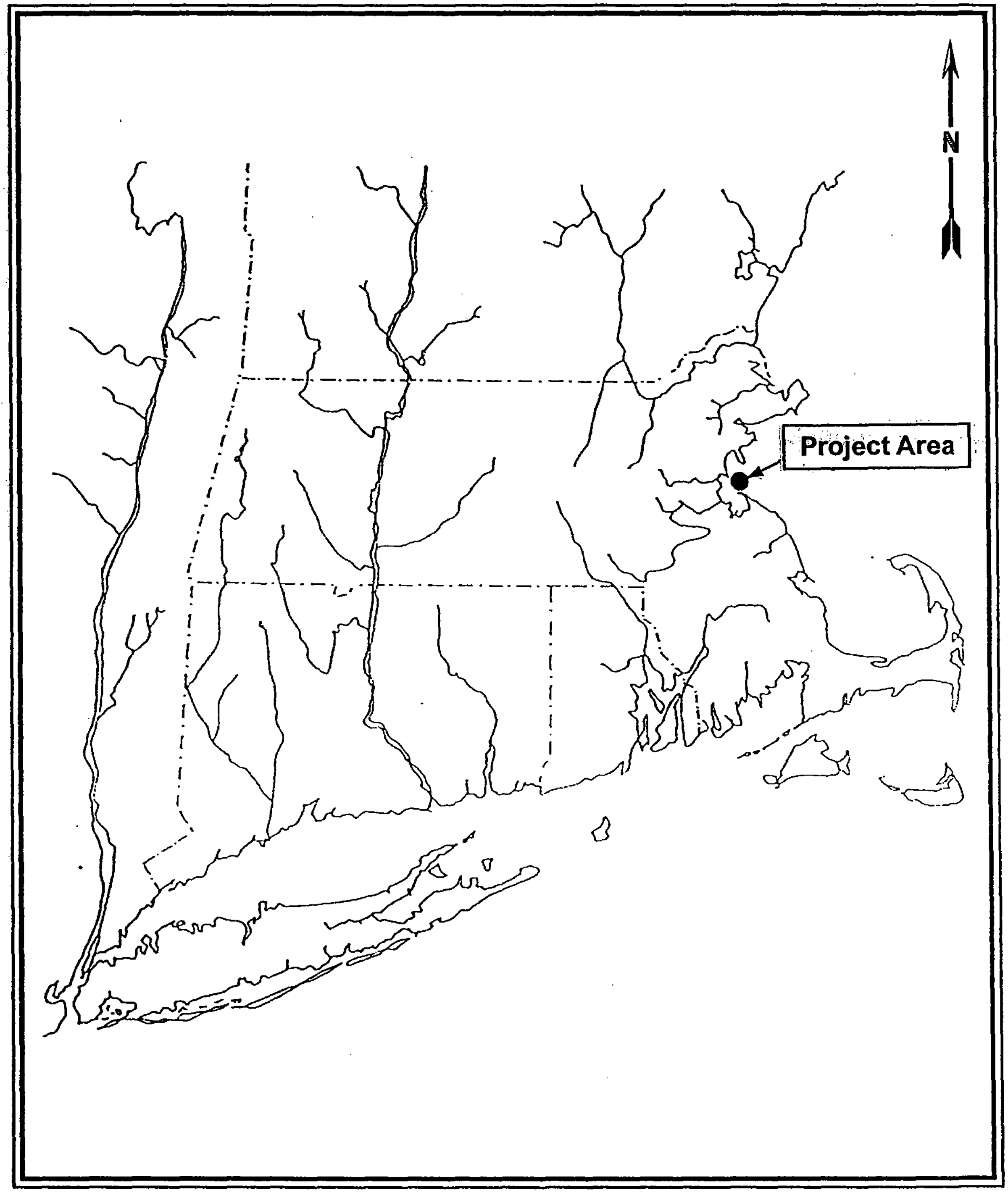

Figure 1. Project area location in the southern New England region.

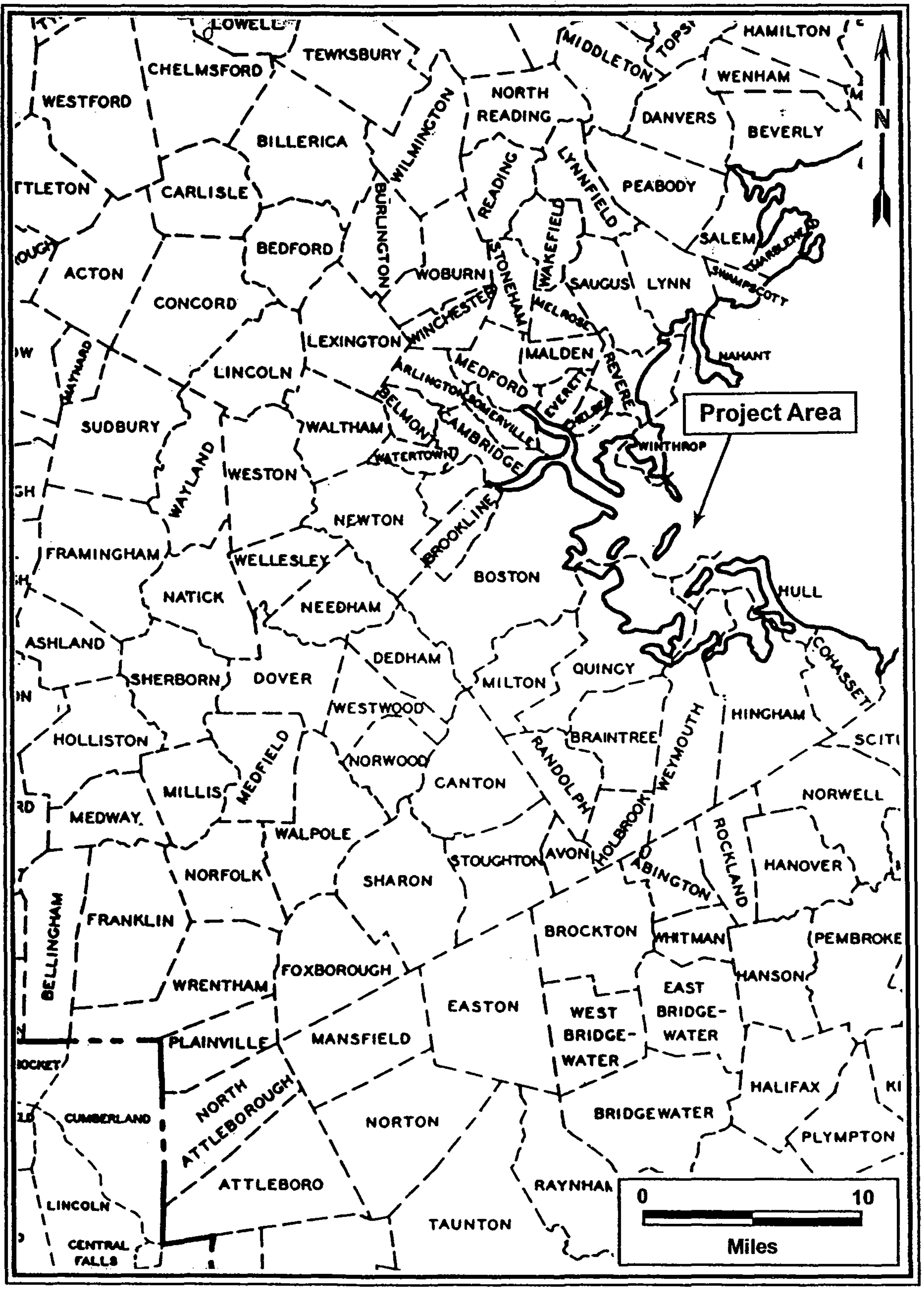

Figure 2. Location of project area in Boston.

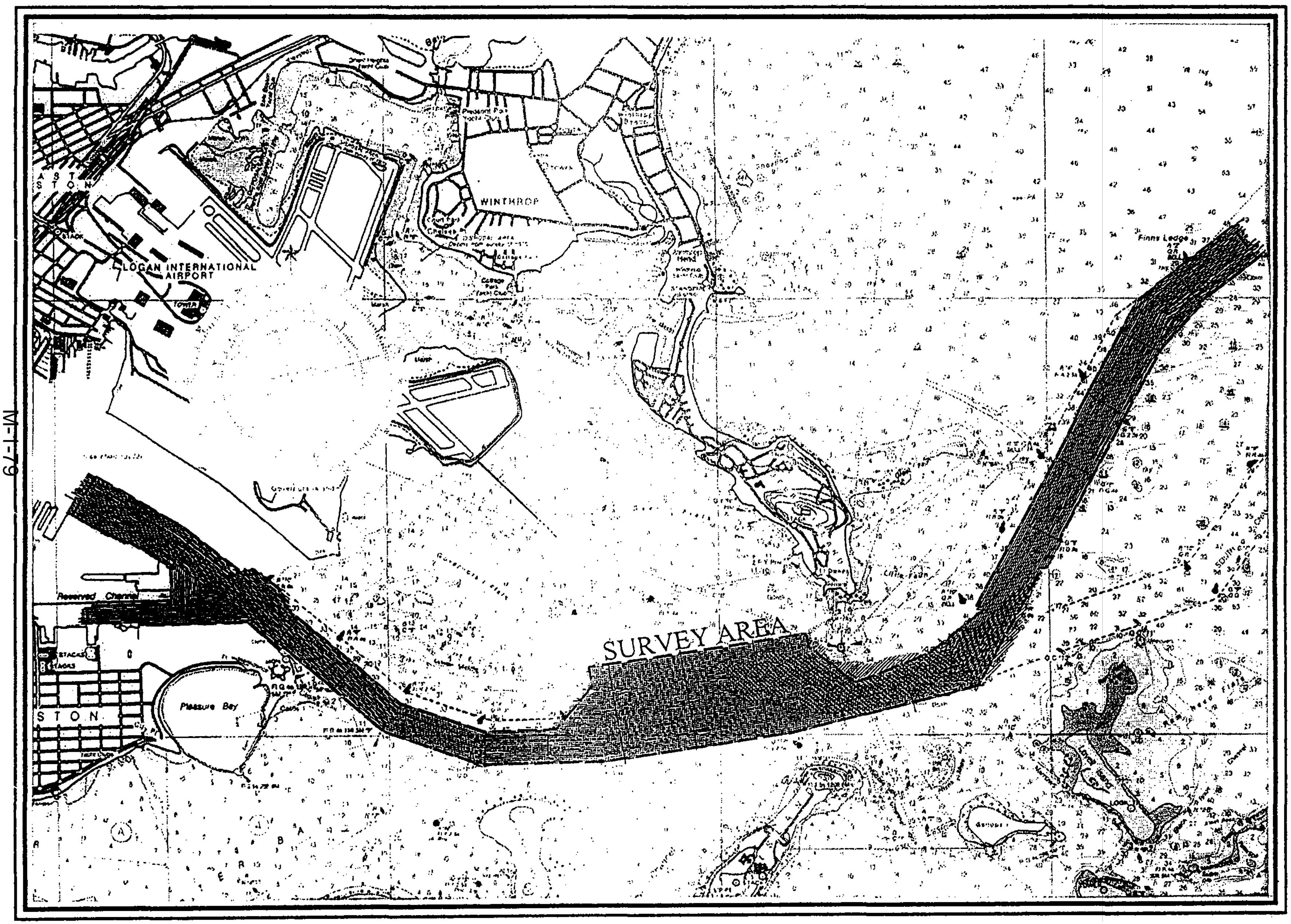

Figure 3. Map indicating the project area in Boston Harbor.

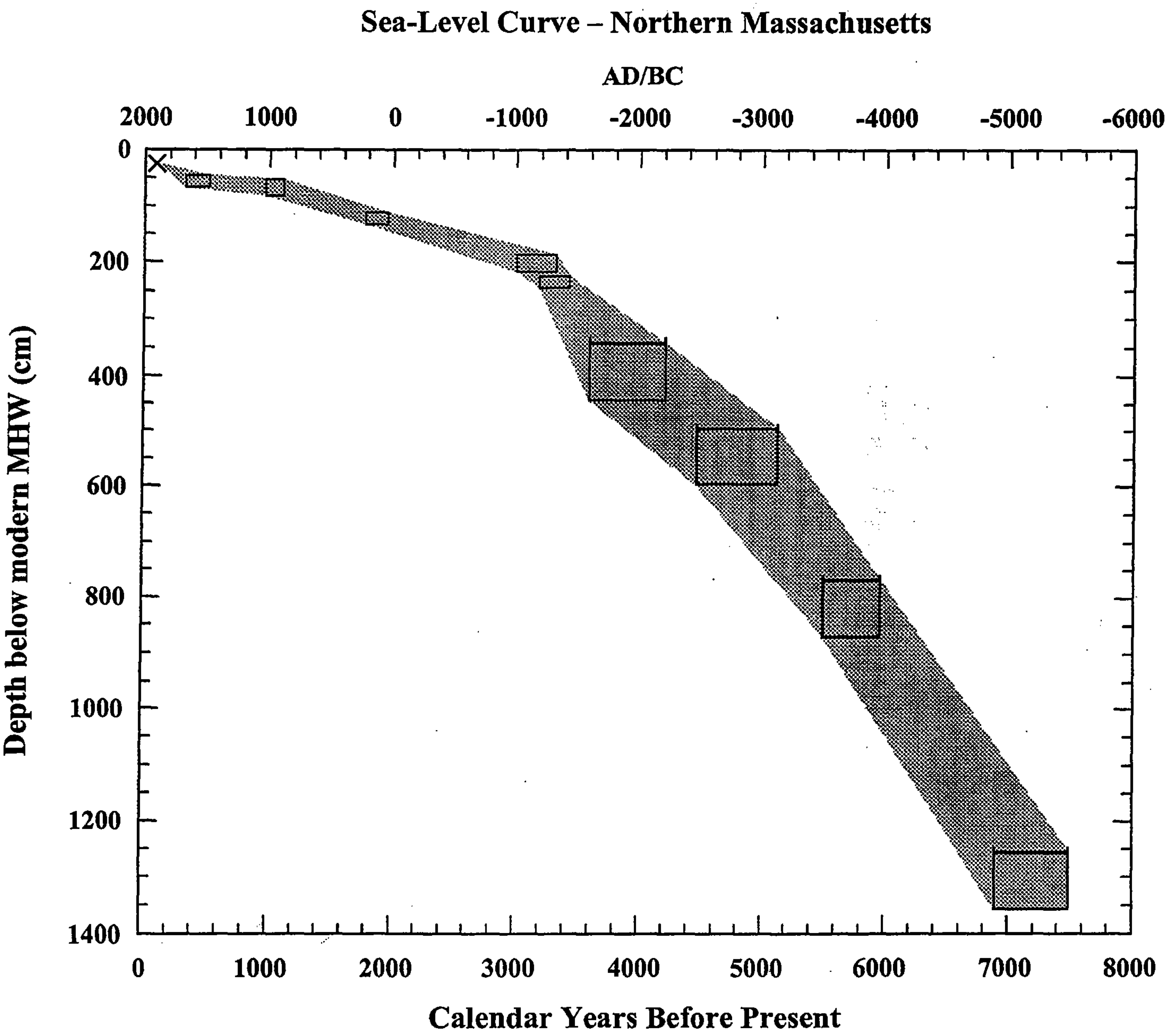

Figure 4. Composite sea-level curve for northern Massachusetts based on C-14 dated basal salt marsh remains (adapted from Donnelly, 2000)

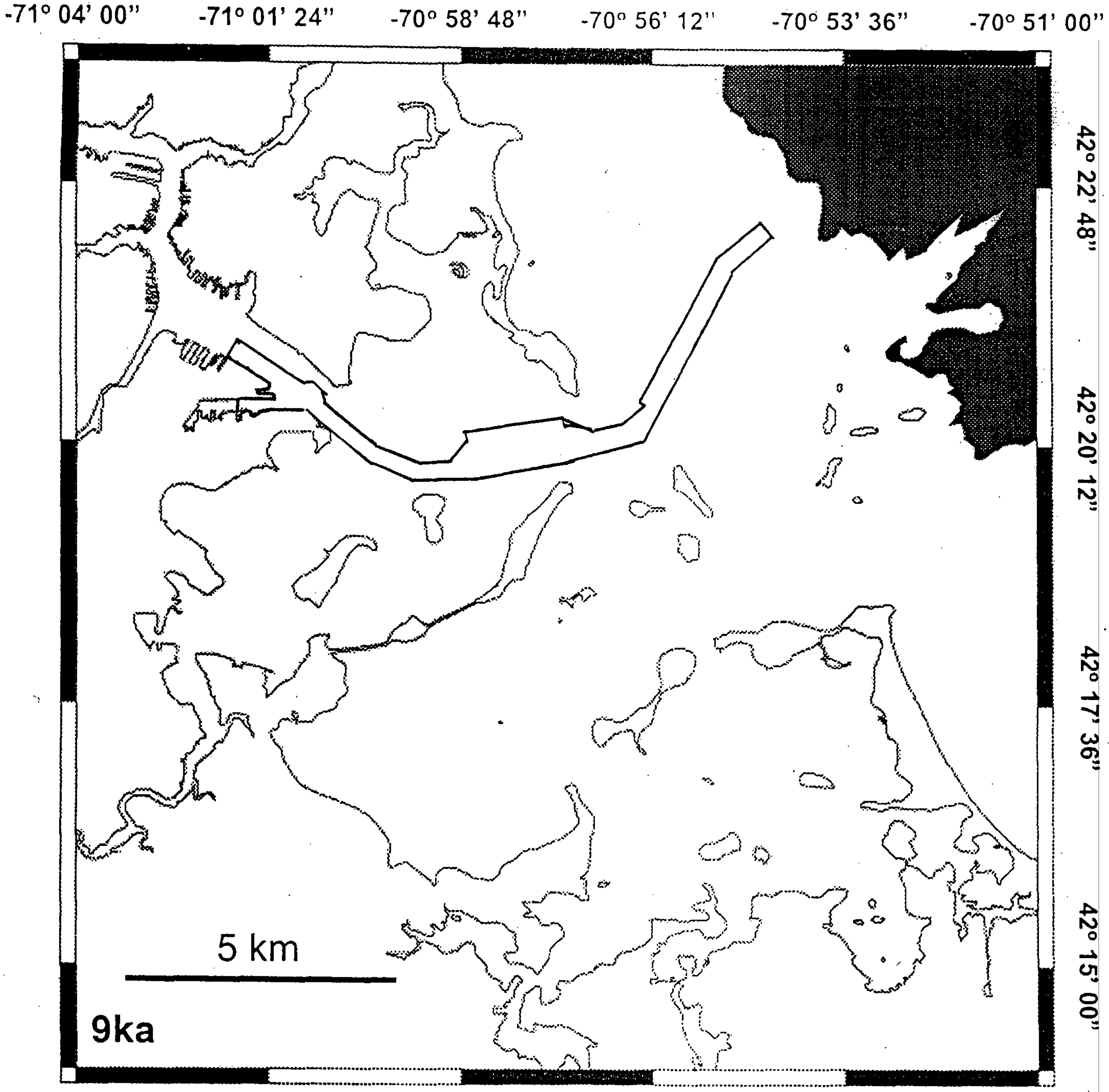

Figure 5. Paleogeography of the Boston Harbor at 9 ka when sea level was approximately 20 meters below modern sea level (marine waters are shown in blue).

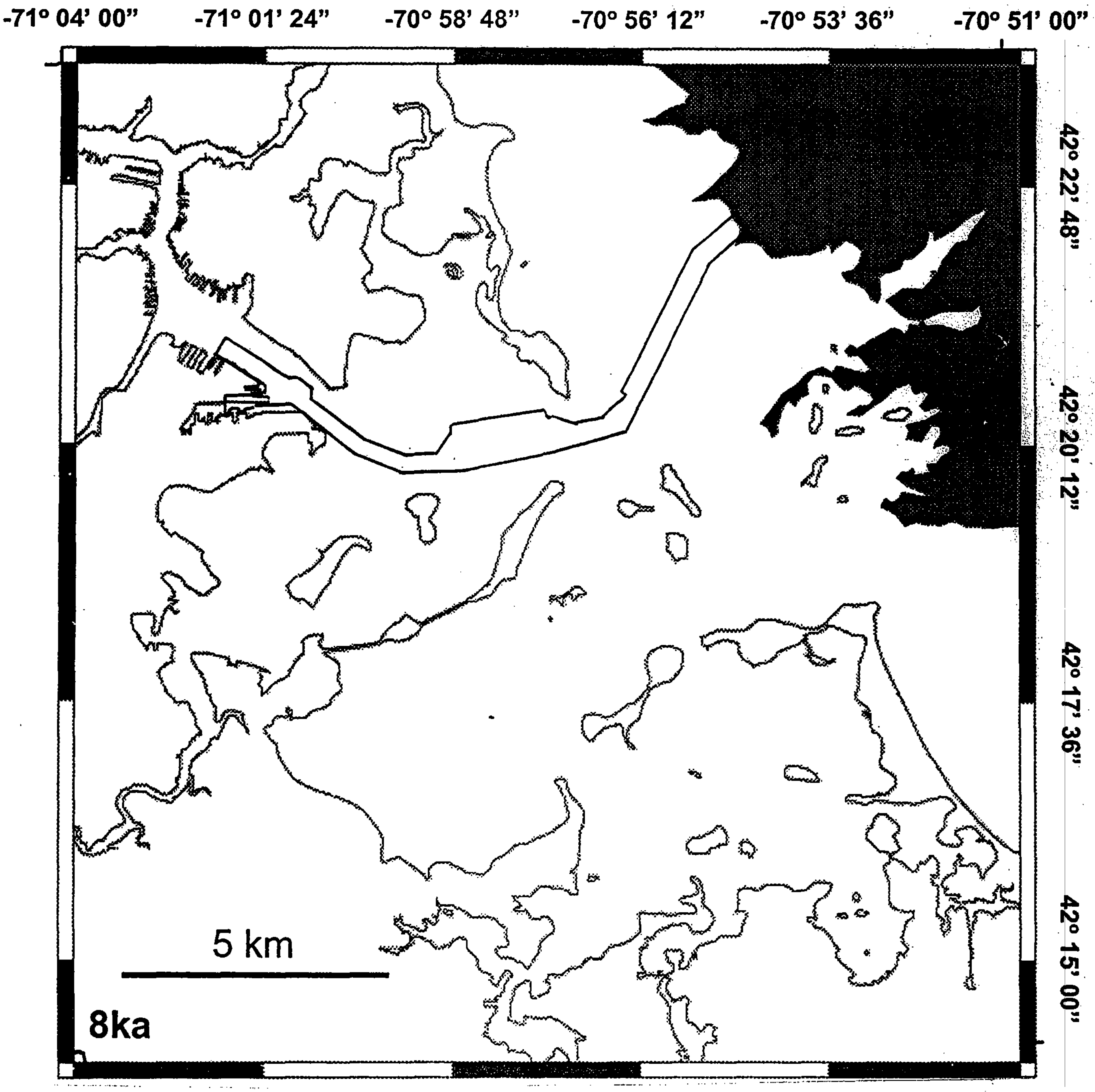

Figure 6. Paleogeography of the Boston Harbor at 8 ka when sea level was approximately 16 meters below modern sea level (marine waters are shown in blue).

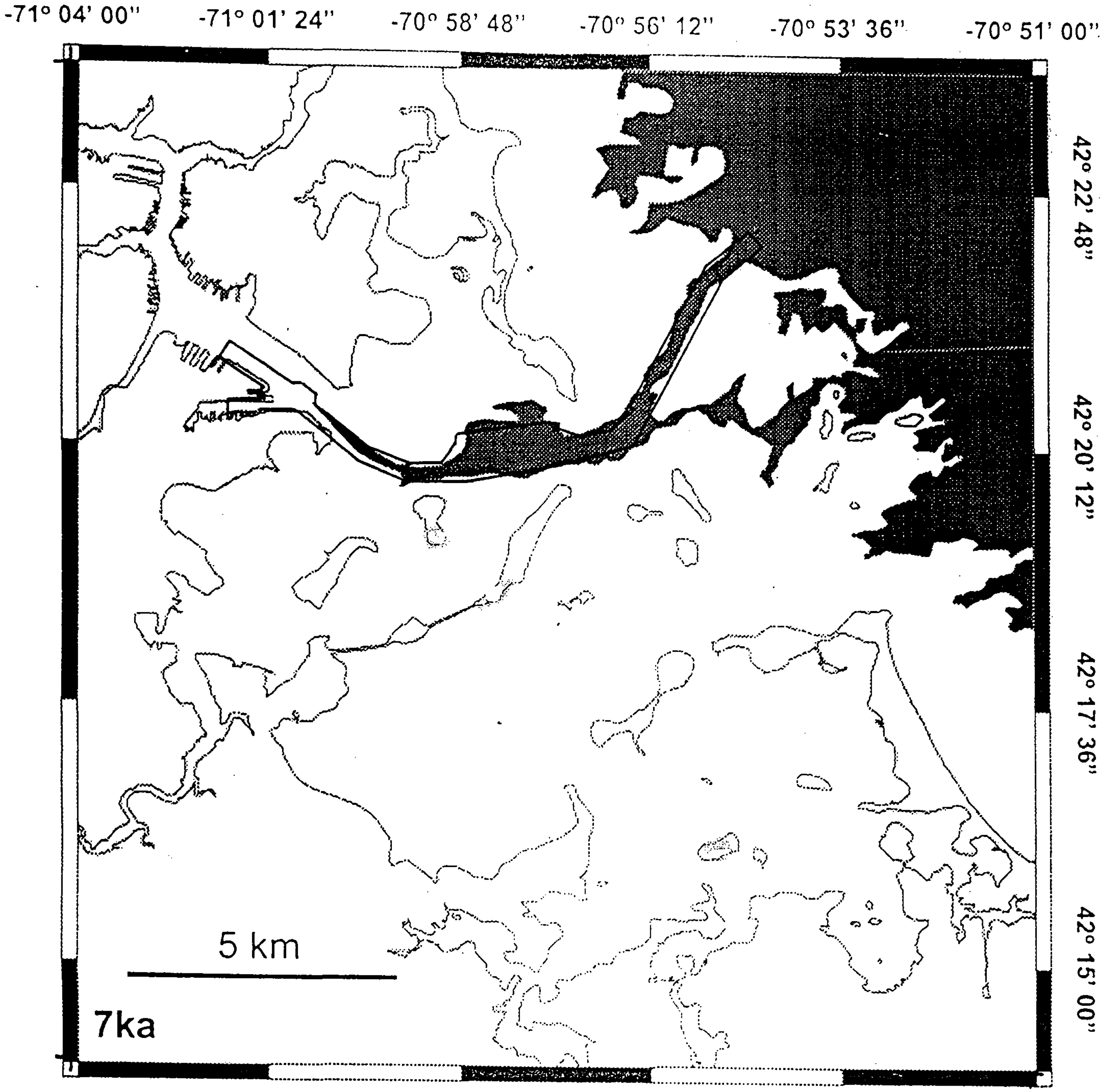

Figure 7. Paleogeography of the Boston Harbor at 7 ka when sea level was approximately 12 meters below modern sea level (marine waters are shown in blue).

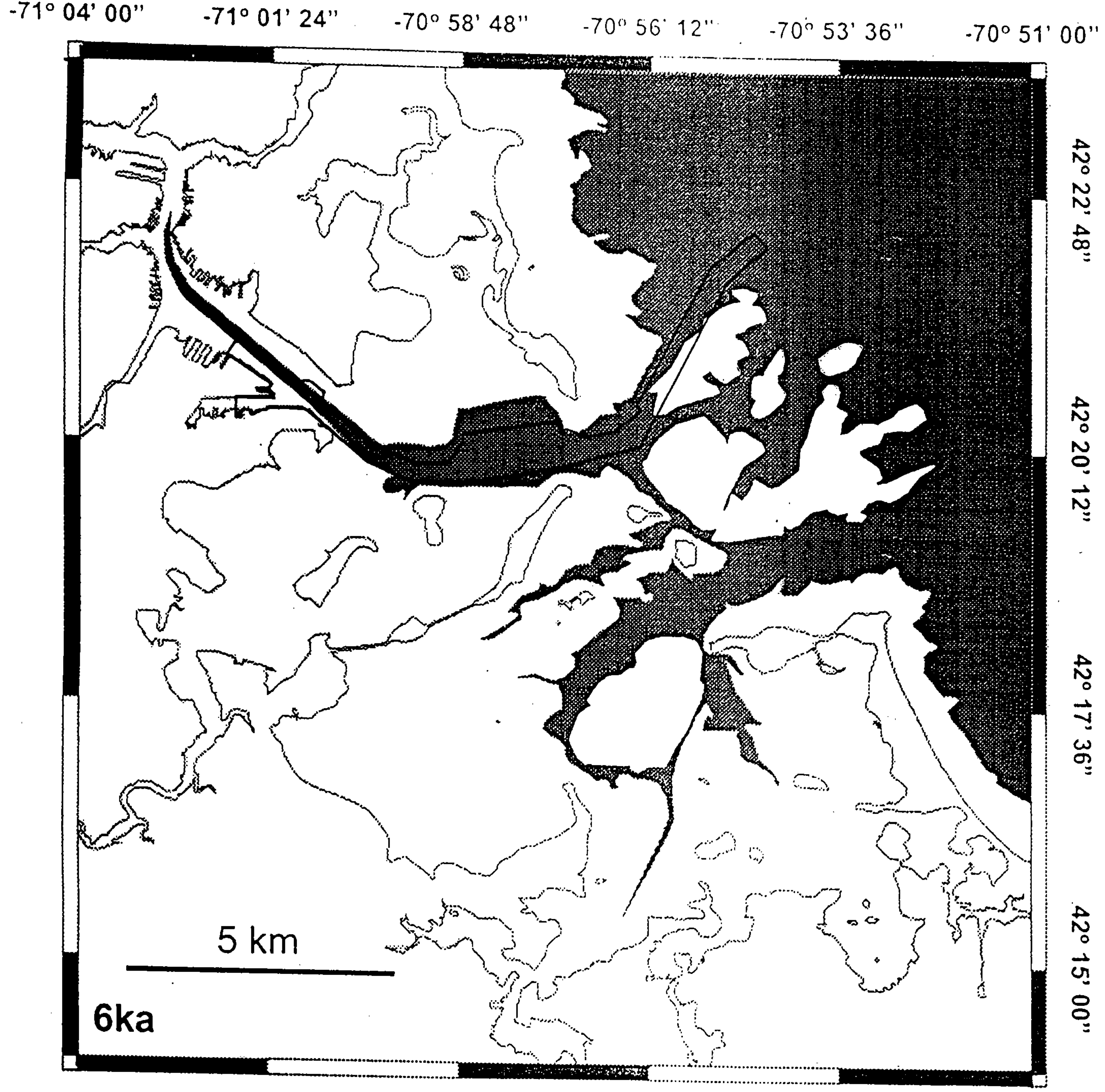

Figure 8. Paleogeography of the Boston Harbor at 6 ka when sea level was approximately 8 meters below modern sea level (marine waters are shown in blue).

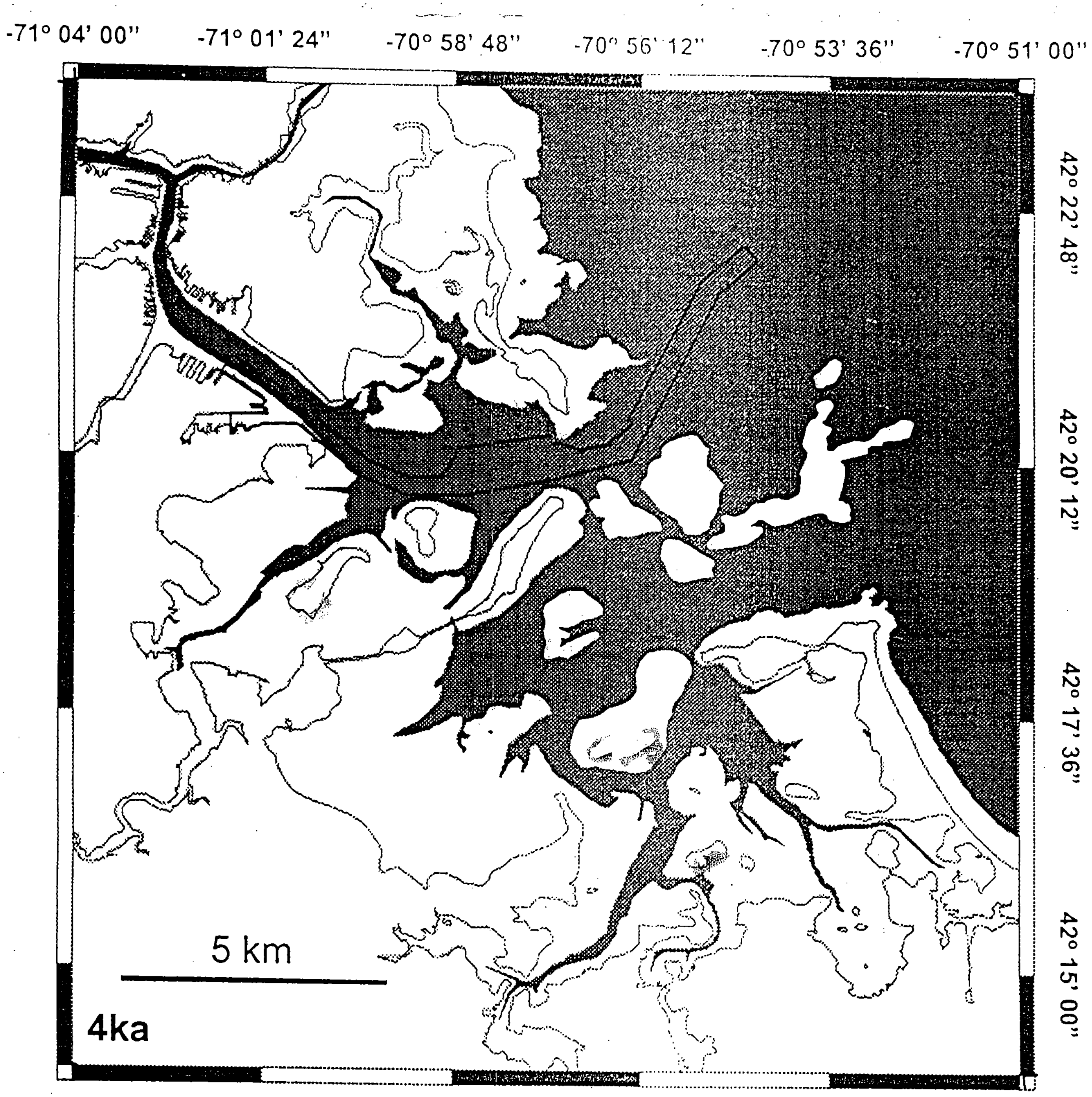

Figure 9. Paleogeography of the Boston Harbor at 4 ka when sea level was approximately 4 meters below modern sea level (marine waters are shown in blue).

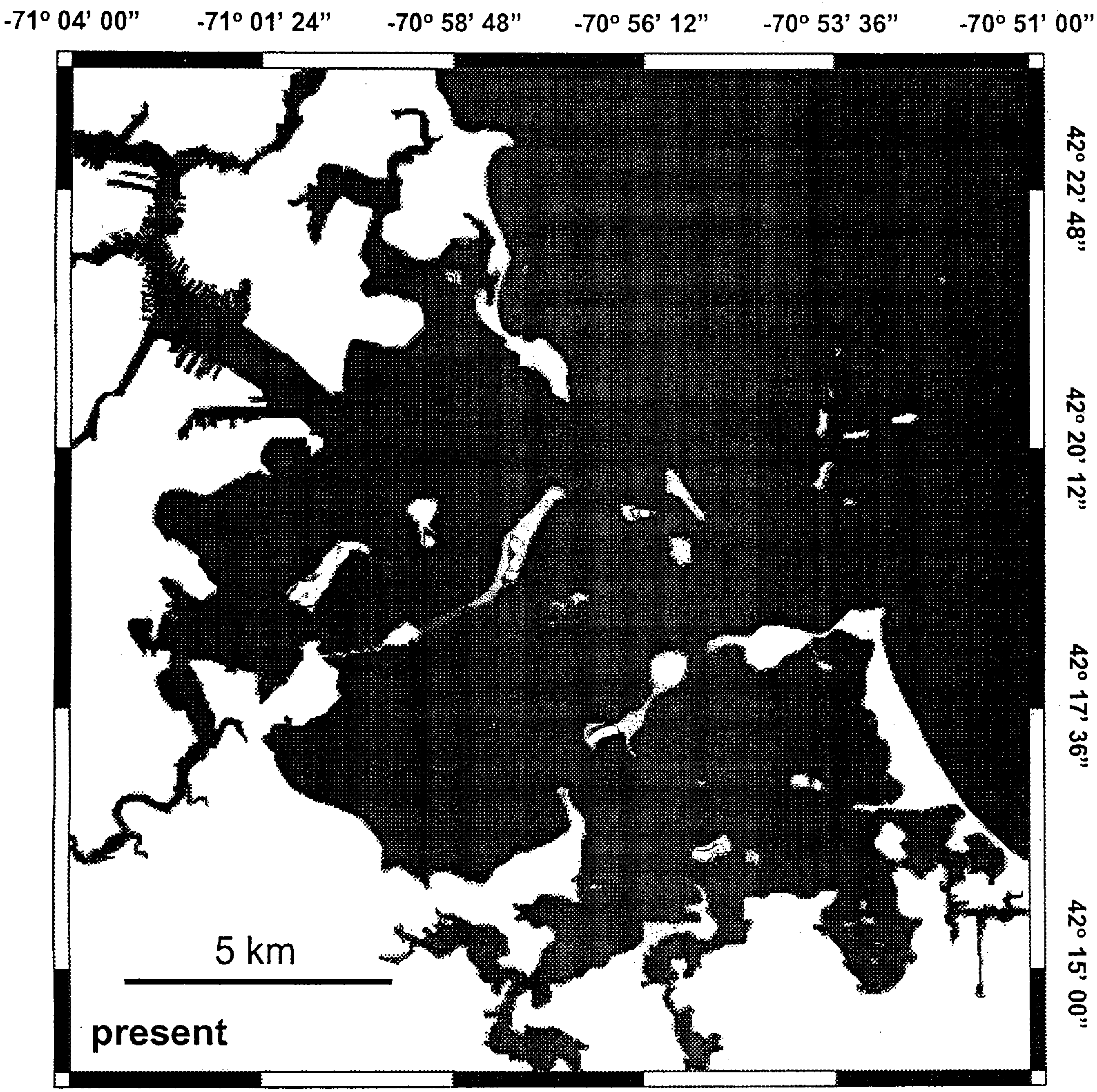

Figure 10. Paleogeography of the Boston Harbor at modern sea levels.

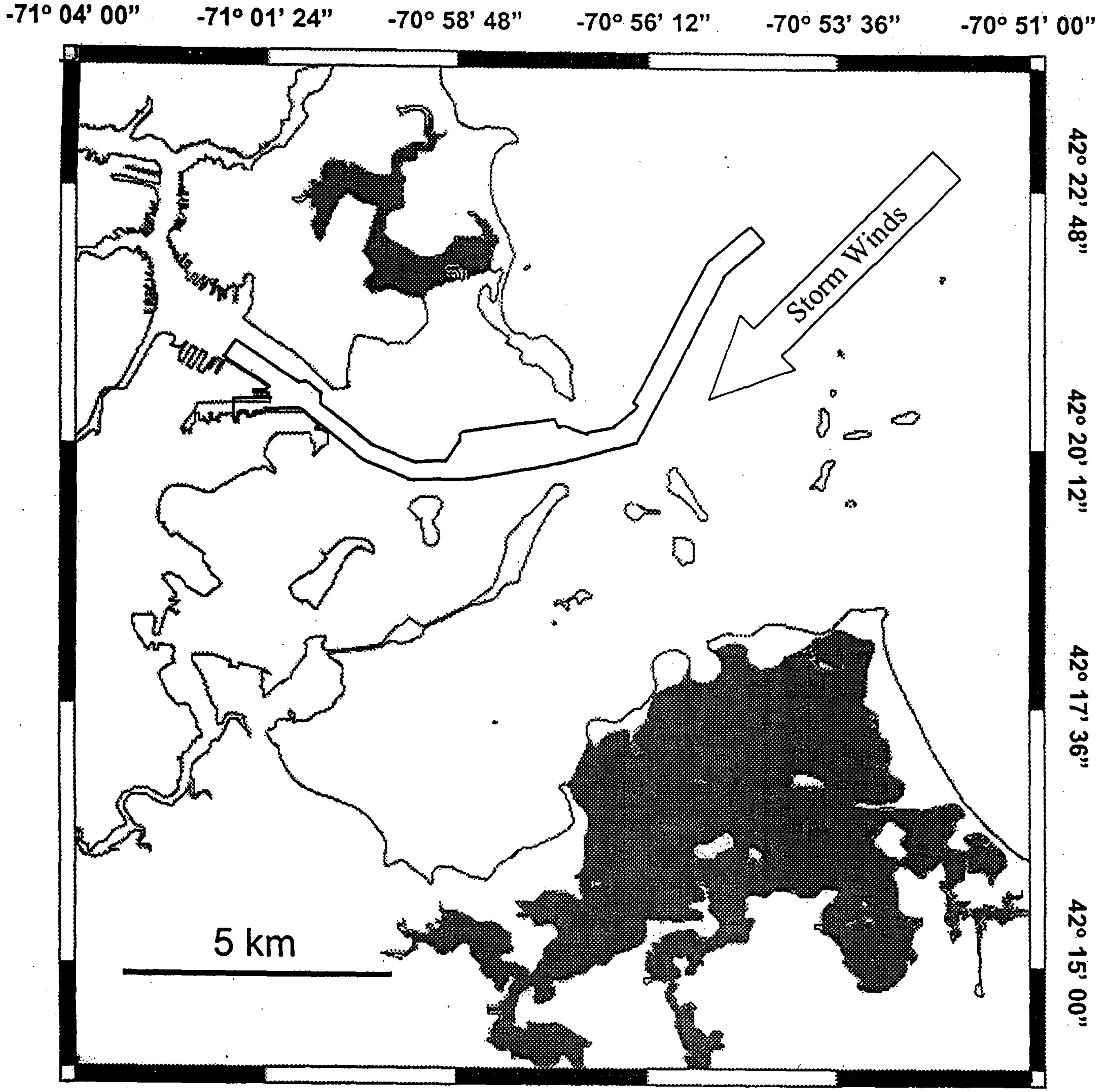

Figure 11. Areas of highest potential for intact archaeological sites (gray; areas most protected from storms waves and currents).

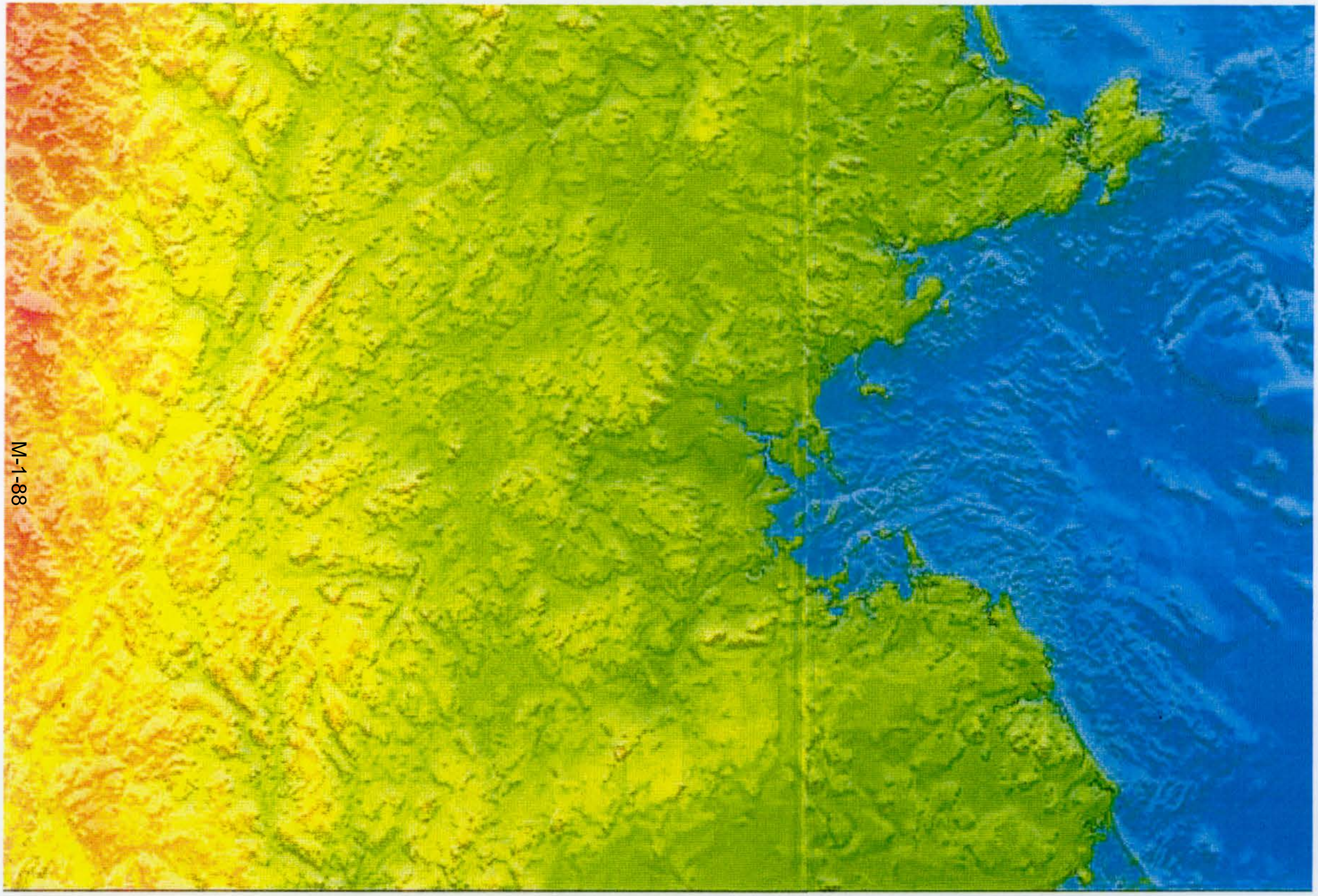

Figure 12. Present day geography of the Boston Harbor (marine waters are shown in blue).

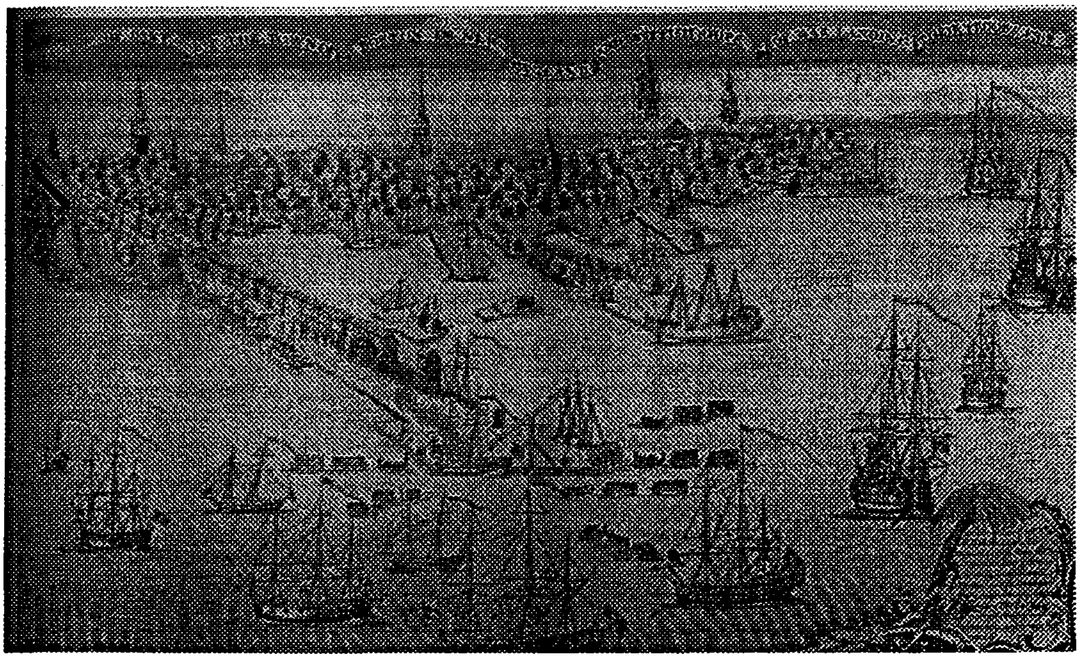

Figure 13. The Boston Waterfront in 1768. Engraving by Paul Revere. Winterthur Museum.

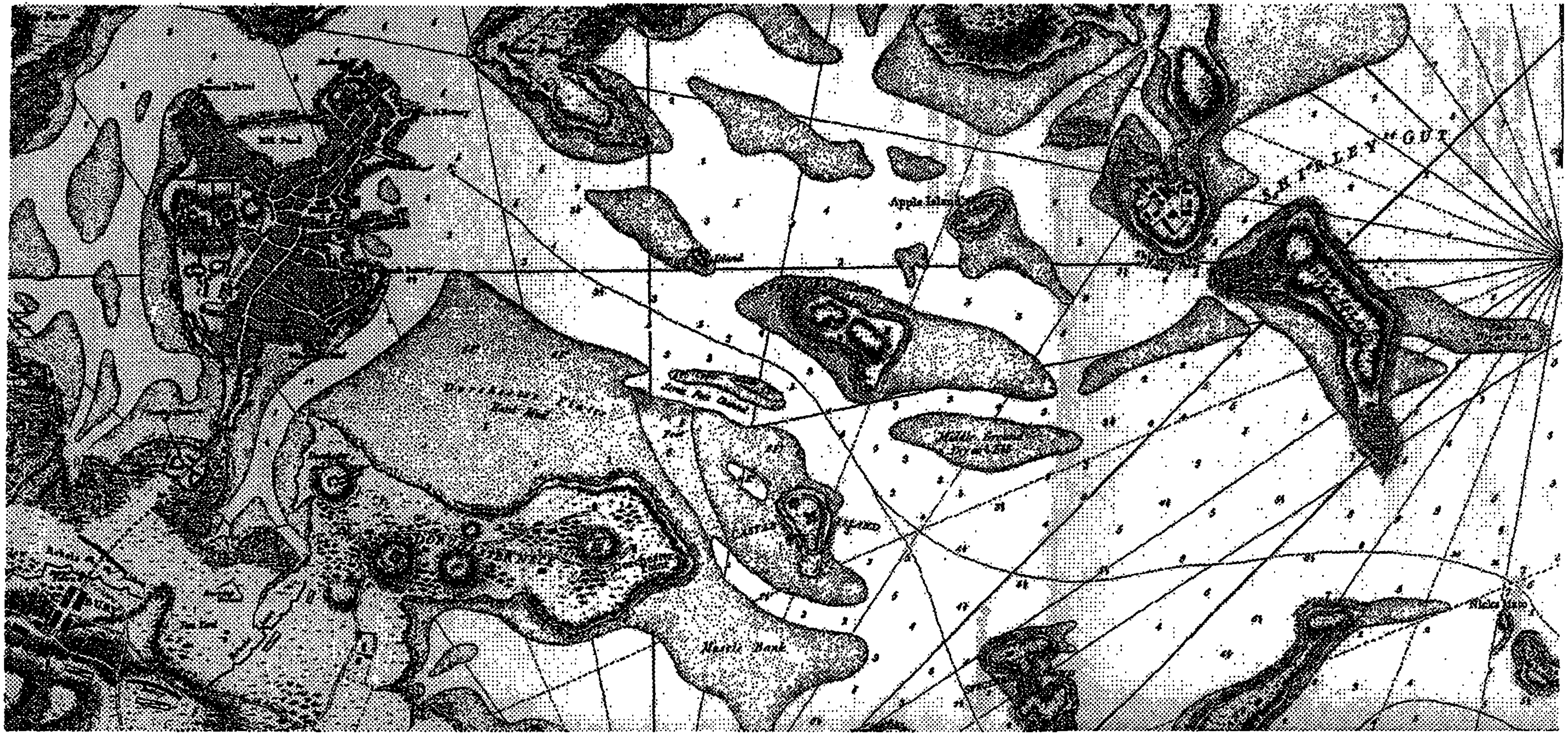

Figure 14. British Map of Boston Harbor, depths are in fathoms 1778.

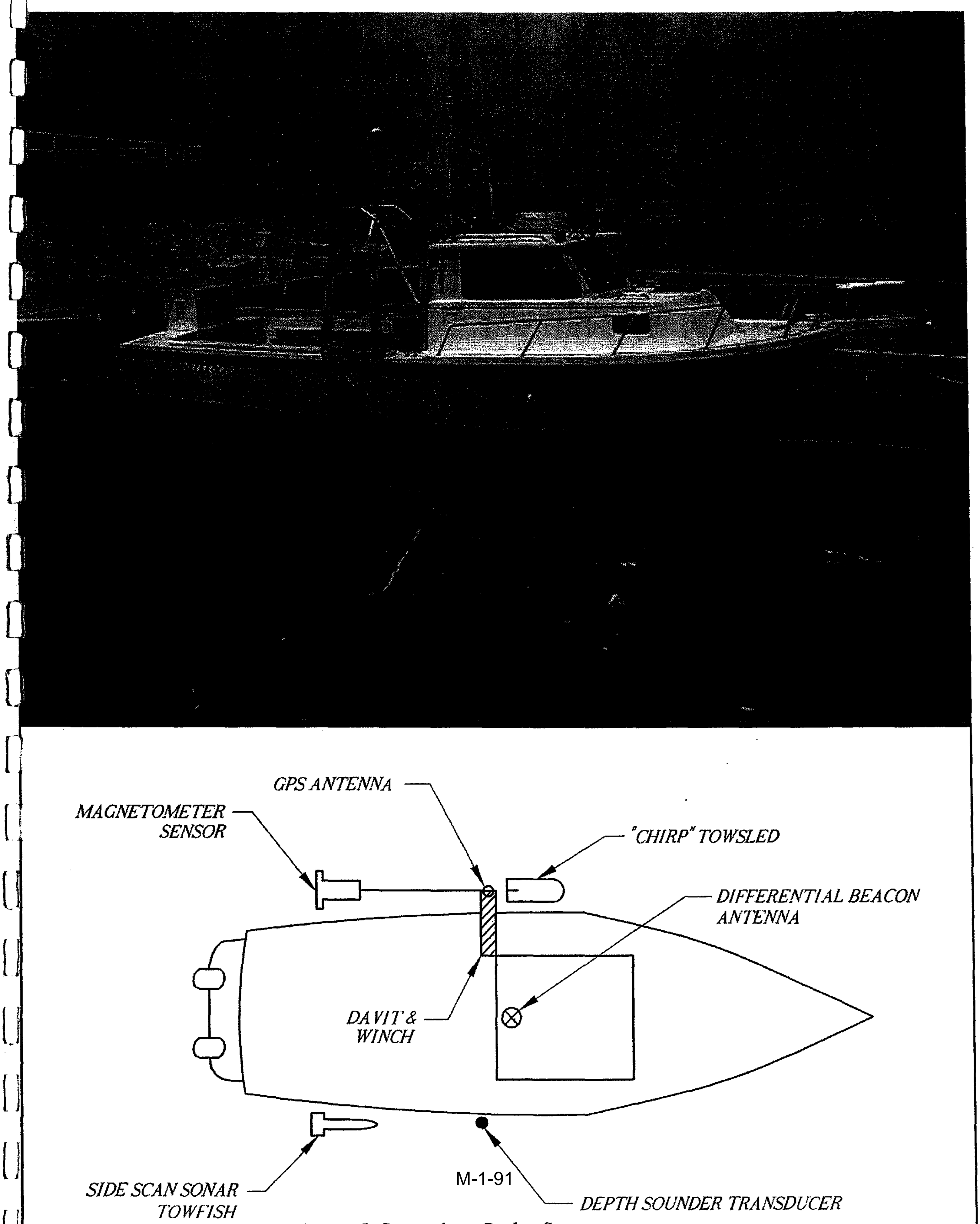

Figure 15. Survey boat *Parker Sport*.

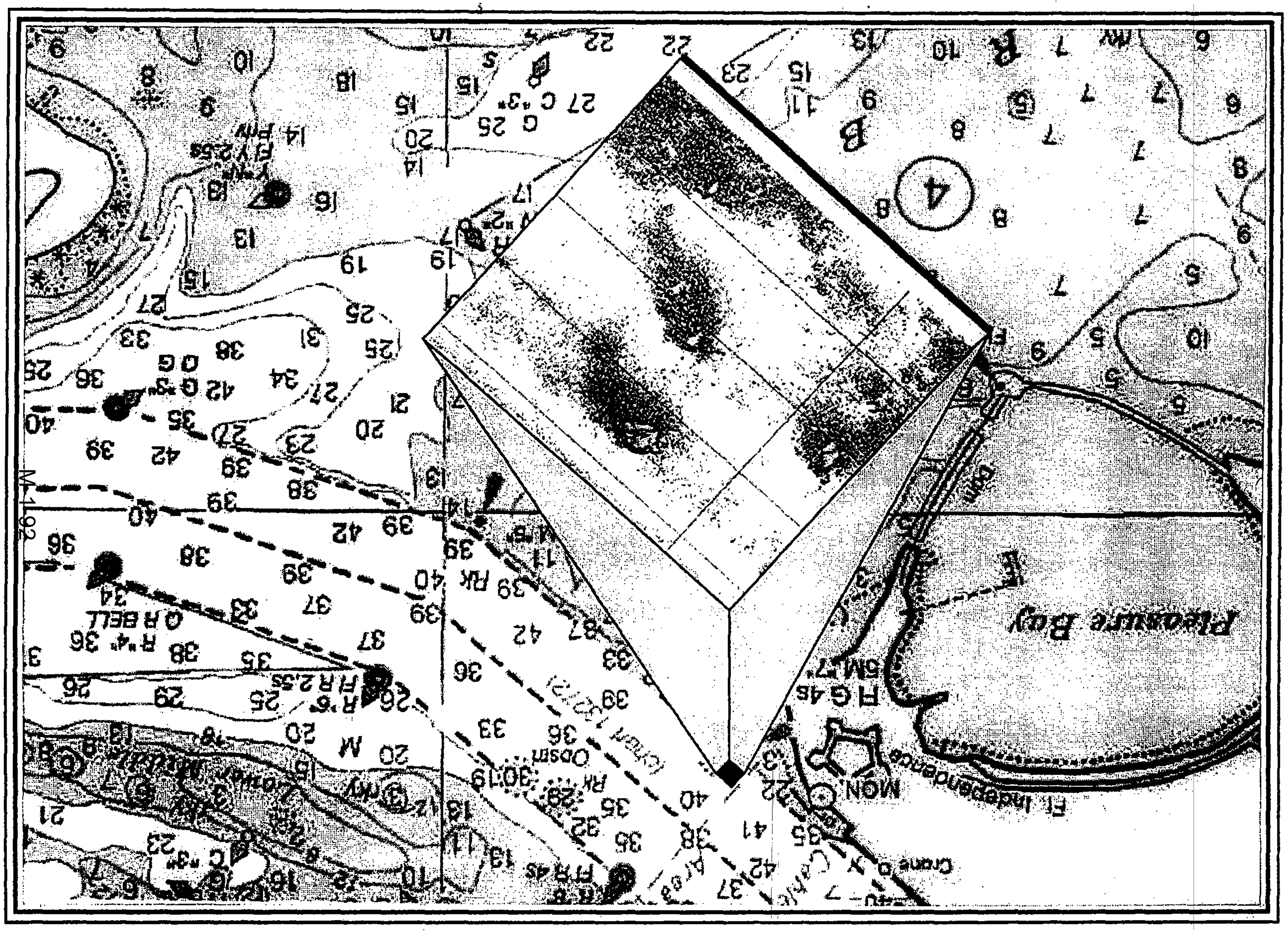

Figure 16. Side scan sonar images of Targets 1, 2, and 3 near Castle Island. Image by OSI.

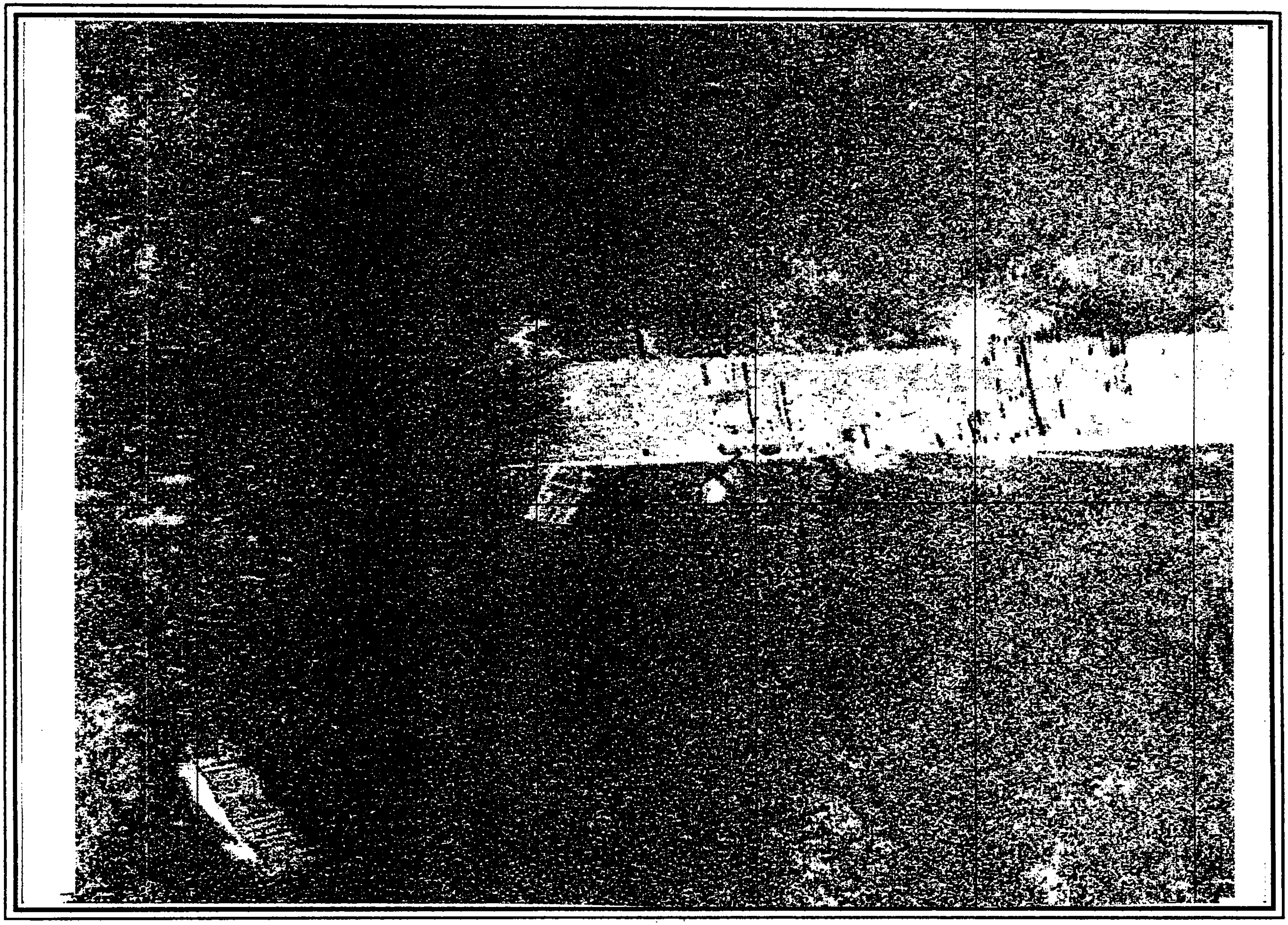

Figure 17. Side scan sonar image of Targets 4 and 5: two sections of a barge.

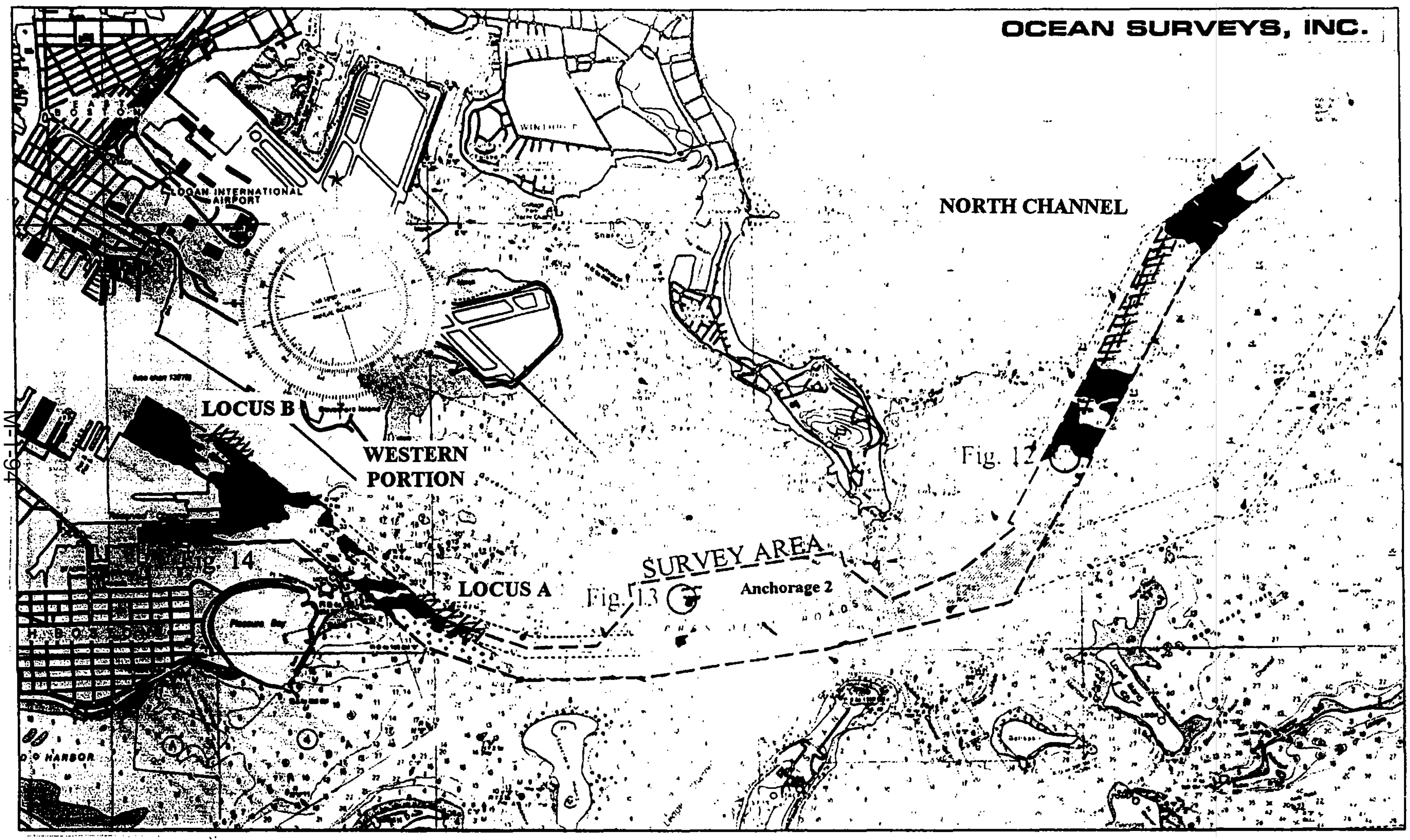

Figure 18. Map of the main survey area indicating areas recommended for core testing for cultural resources. Dark areas indicate acoustic basement of less than 55 feet (bedrock or glacial till). Stippled areas represent former estuarine deposits; hatchured areas recommended testing. Map provided by Ocean Surveys, Inc.OSI Report 02ES066-D.

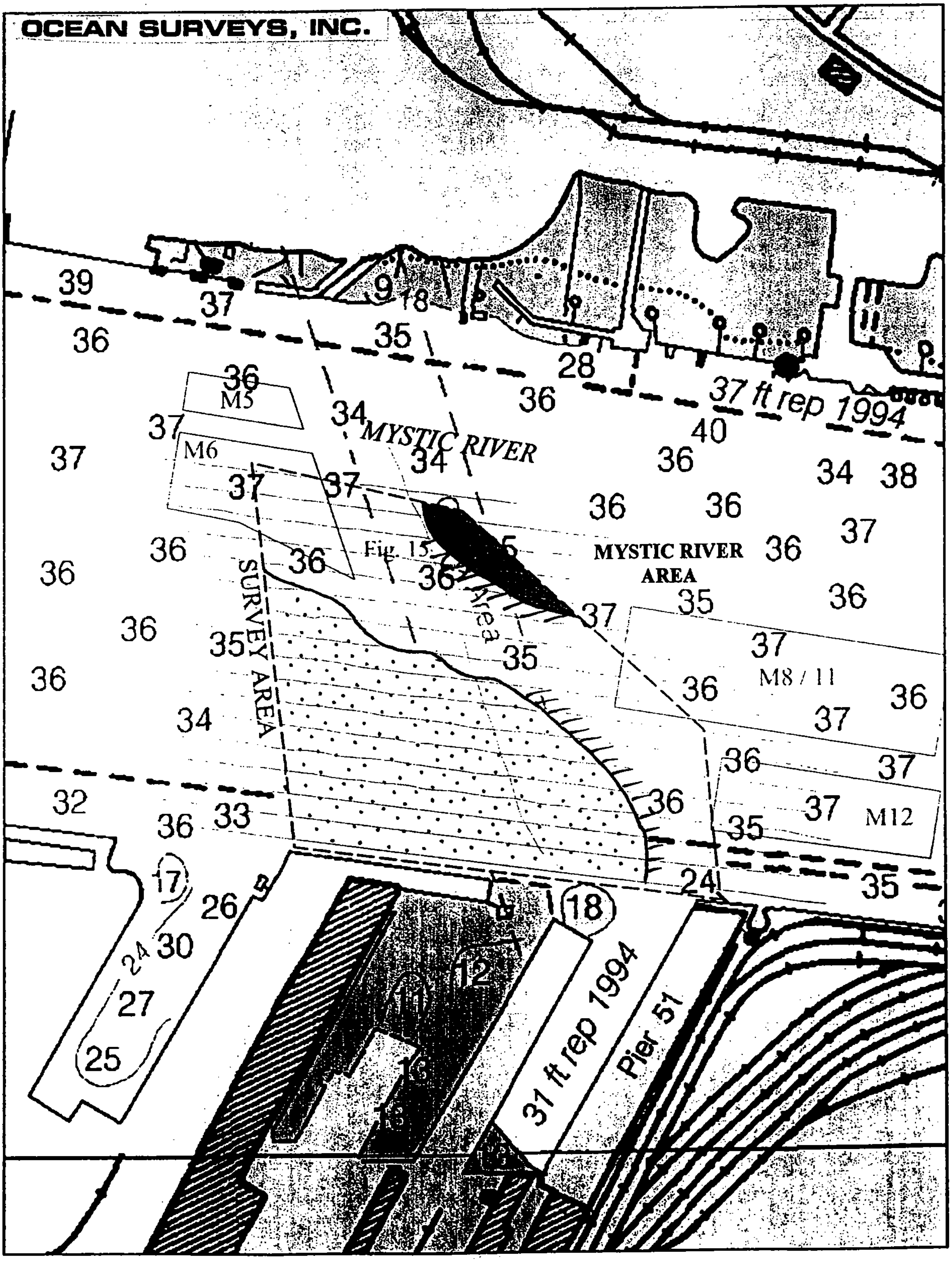

Figure 19. Map of the Mystic River area indicating areas recommended for core testing for cultural resources. Dark areas indicate acoustic basement of less than 55 feet (bedrock or glacial till). Stippled areas represent former estuarine deposits; hatchured areas recommended testing. Map provided by 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 atl atl 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

Justin Bailey, Geophysicist, OSI
David Bernstein, Archaeologist, State University of New York at Stony Brook
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
Alice Grant, State Historic Preservation Office, Delaware
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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.

TABLE OF CONTENTS

TABLE OF CONTENTS (CONTINUED)

CHAPTER **PAGE**

APPENDICES

LIST OF FIGURES

LIST OF TABLES

TABLE **PAGE**

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

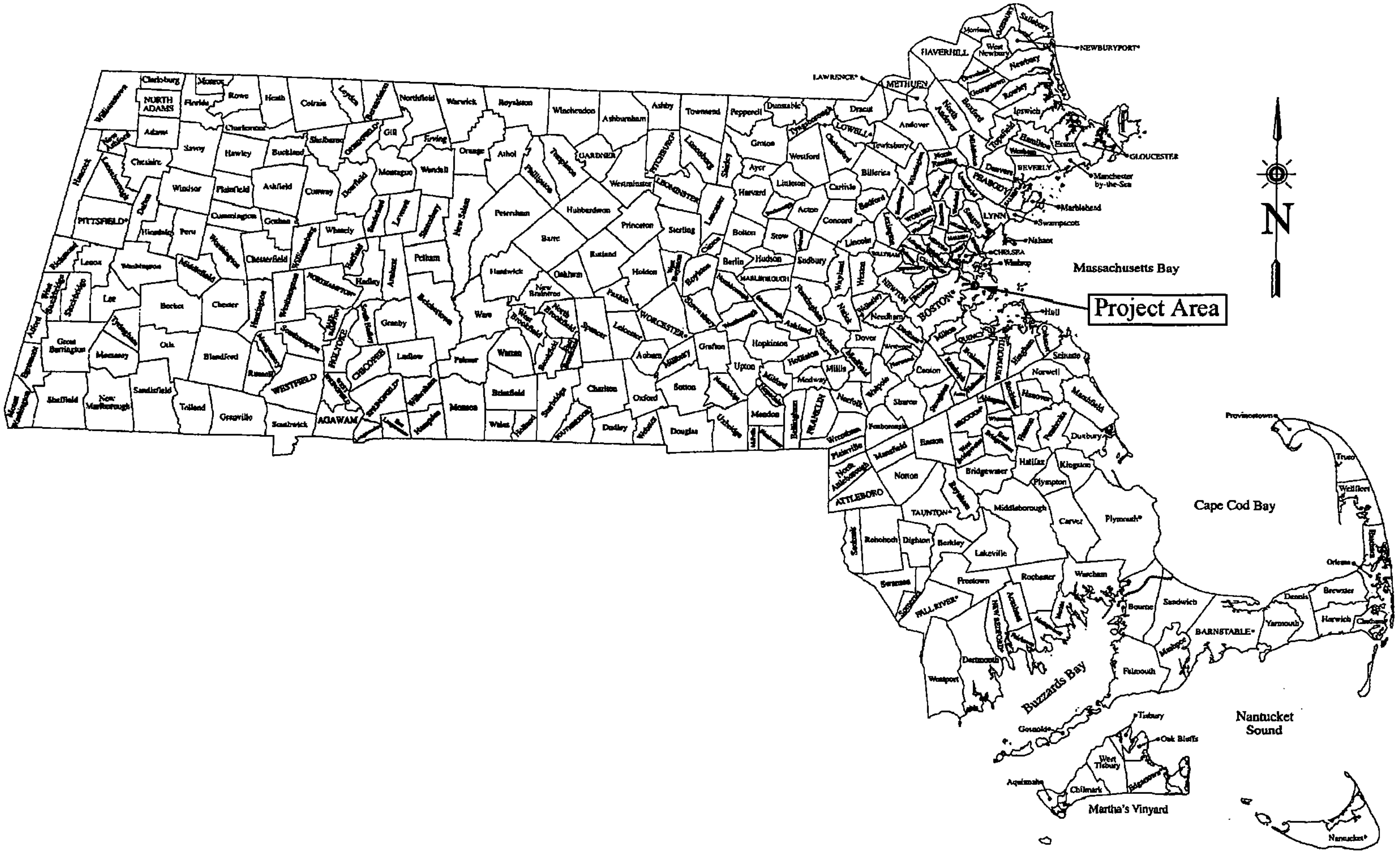


Figure 1-1. Location of the Boston Harbor Deep Draft Navigation Improvements Project study area, Boston, Massachusetts.

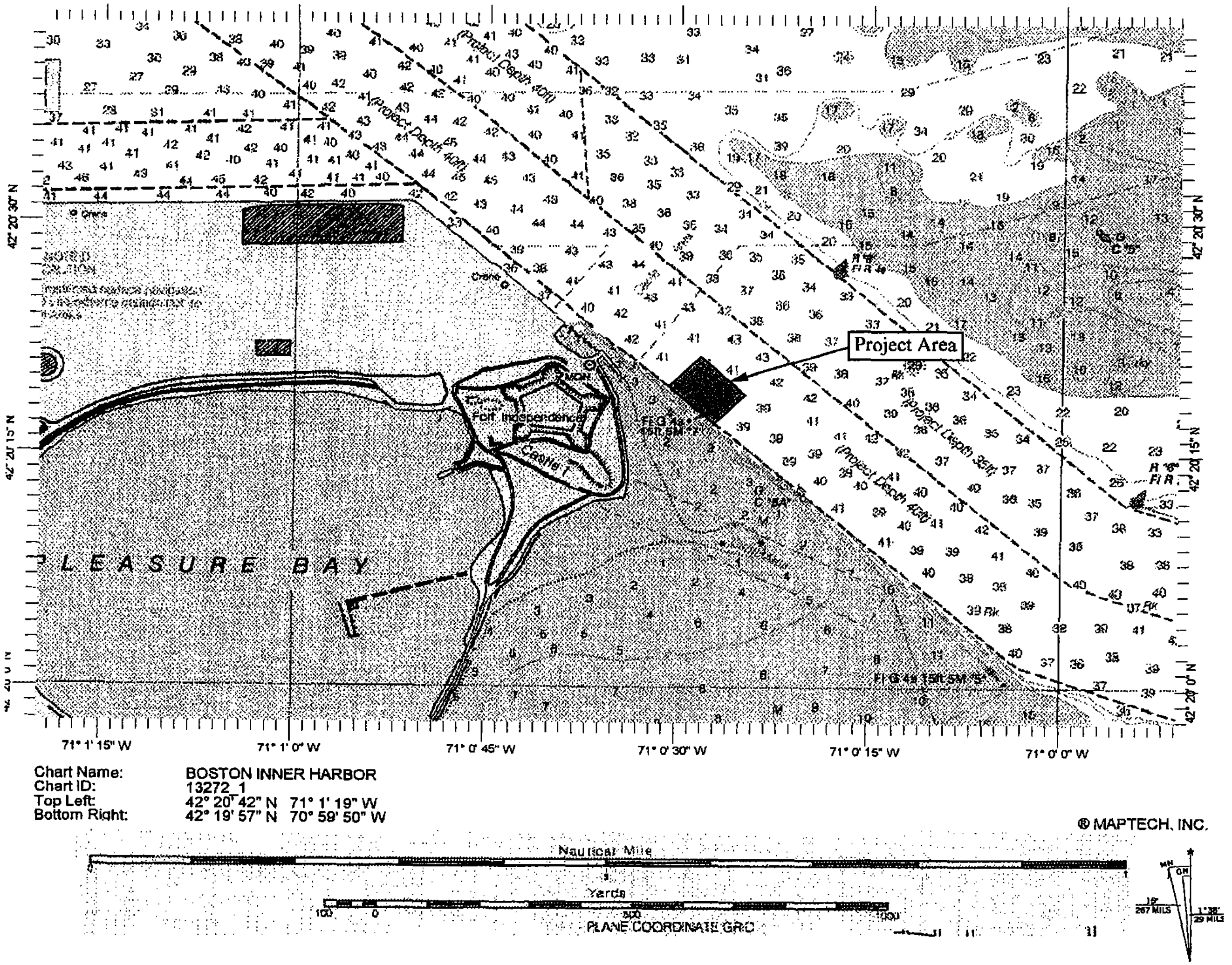


Figure 1-2. Location of the Boston Harbor Deep Draft Navigation Improvements Project study area on NOAA navigation chart 13270.

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

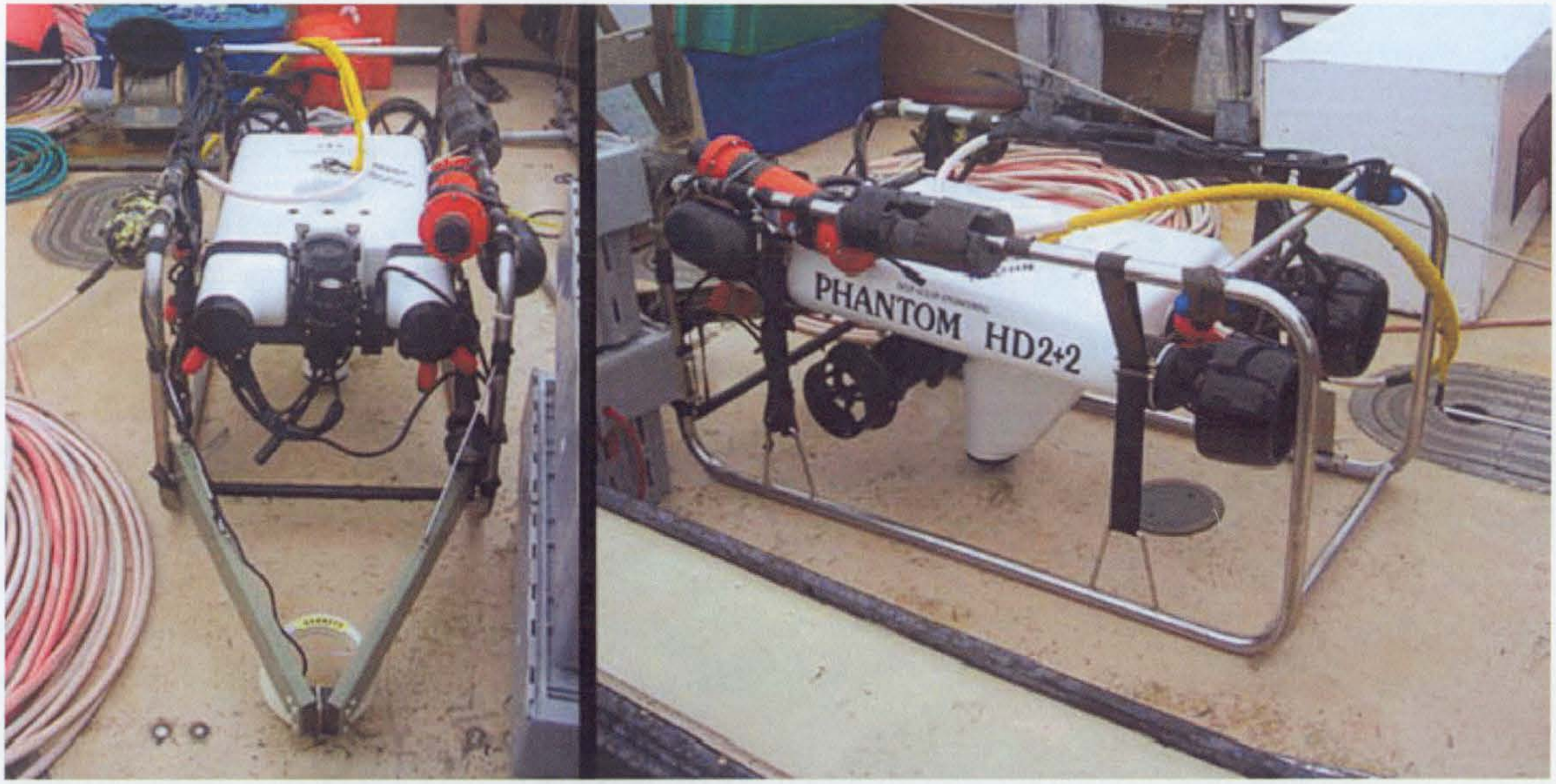


Figure 2-1. Deep Ocean Engineering Phantom HD2 remotely operated vehicle (ROV) including underwater video camera, laser measuring device, and underwater metal detector.

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.

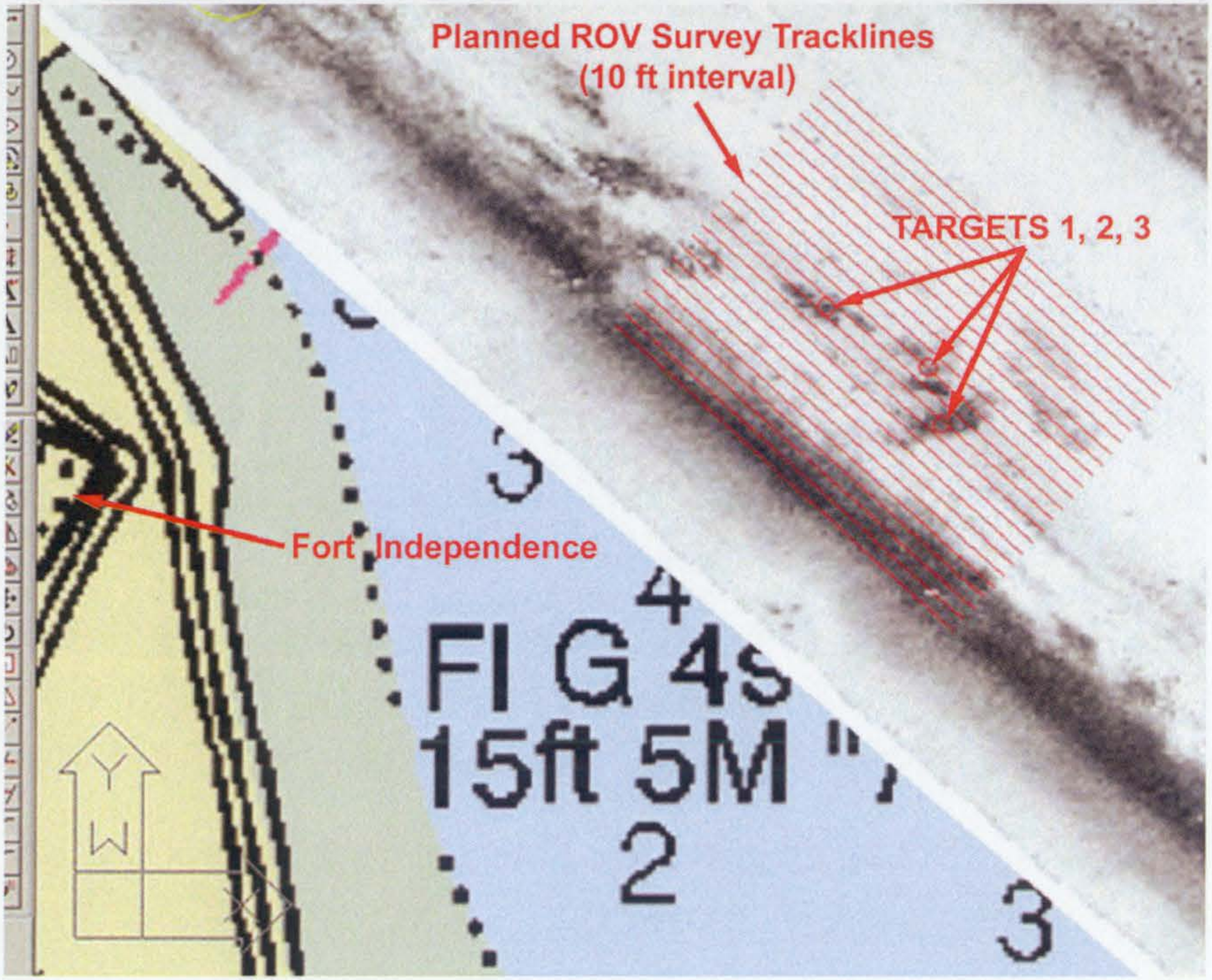


Figure 2-2. Planned remotely operated vehicle (ROV) survey lines displayed over sonar image of the three magnetic anomaly targets.

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.

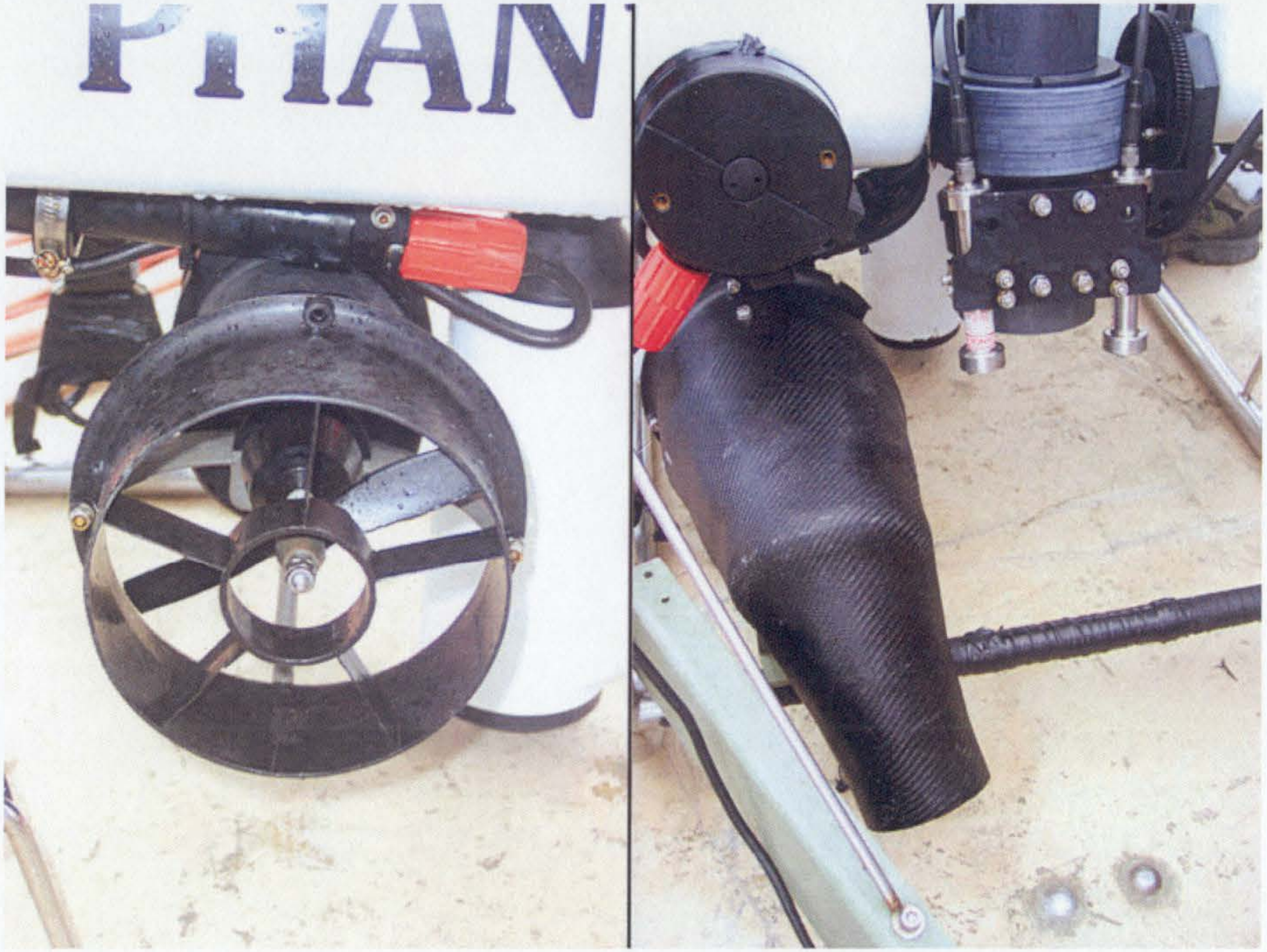


Figure 2-3. Remotely operated vehicle (ROV) thruster (left) and thruster-wash deflector (right).

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).

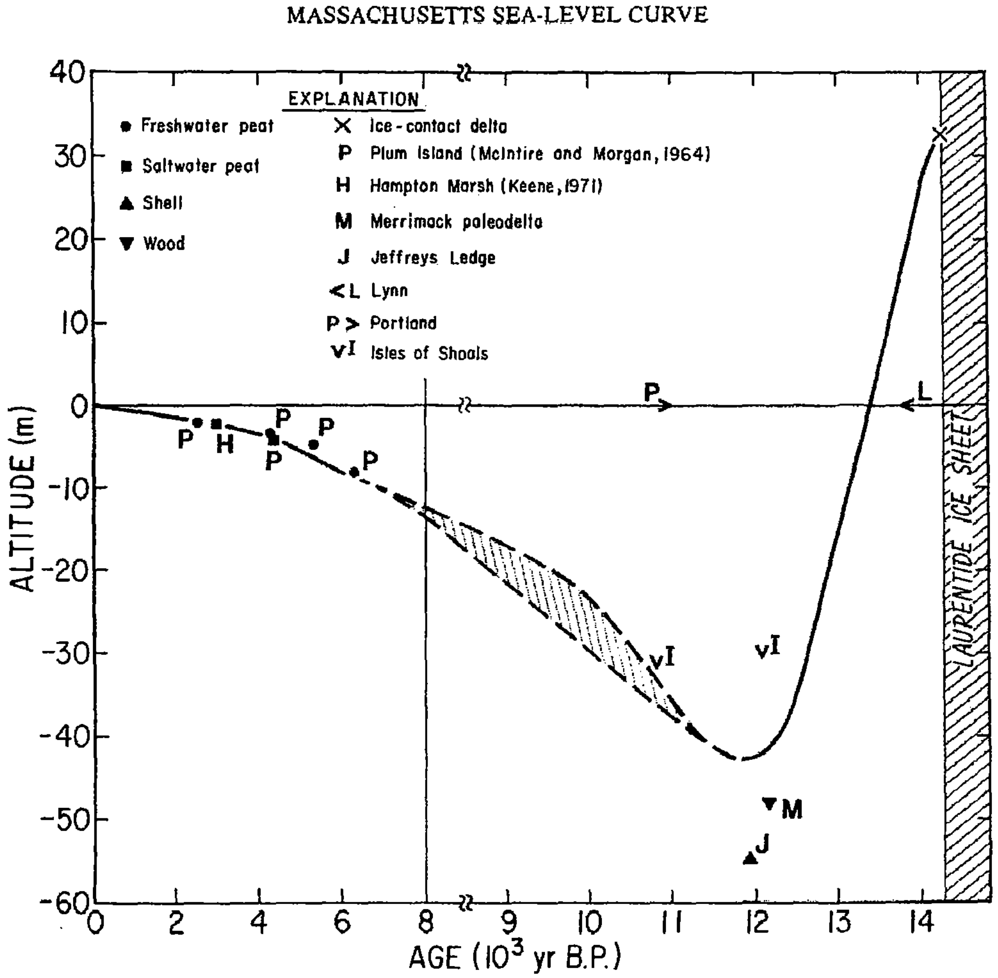


Figure 3-1. Relative sea level curve for northeastern Massachusetts and adjacent inner continental shelf, including Massachusetts Bay (source: Oldale et al. 1993).

Boston Harbor Deep Draft Project, September 2003

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 the eroded substrata before being drowned and preserved as water depth increased across the harbor (Knebel et al. 1992). Researchers collecting seismic sub-bottom profiling data throughout Boston Harbor and the Massachusetts Bay area have documented a marine sedimentary unit that ranges from moderately layered to virtually transparent in the acoustic record present within depressions and on the flanks of sub-bottom highs with a maximum thickness of approximately 17 feet (Knebel et al. 1992). Holocene sediments composing the Boston Harbor marine unit are lithologically diverse with textures that range from clayey silts to sands and include local concentrations of gravel. The unit also includes scattered shells, layers of shell hash (typically less than 4 inches thick), plant fragments, beds of organic-rich detritus (typically less than six inches thick), and at the base of the unit, clasts of glacio-marine mud (Knebel et al. 1992). Geophysical data from the USGS, Knebel, Oldale, and others describing the modern environmental conditions of the sea floor in Boston Harbor indicate that erosion from waves and currents associated with shoreface retreat (beginning about 4,000 years B.P) has extensively eroded and reworked most of the previously deposited sediments within the harbor. Channel maintenance undertaken since the turn of the twentieth century, consisting primarily of dredging the channel to approximately 16 feet below its natural depth, has also greatly disturbed natural sediments in the study area. All three targets are situated within the dredged channel.

The U.S. Geological Survey (USGS) has mapped and interpreted the modern seabed geology of Boston Harbor using an extensive inventory of side-scan sonagraphic data supplemented with available bathymetric, sedimentary, sub-bottom, and bottom-current data adopted from the work of Knebel and Circe (1995) and others. From these data, the USGS has identified three distinct seabed or "benthic" environments characterized by erosion, sediment reworking, and sediment deposition that have developed in the upper limits of the older sedimentary units within the harbor in response to the relatively modern wave and current conditions (Knebel et al. 1992) (USGS 2000a). Inside the southwestern part of Boston Harbor, shallow areas around the islands have been eroded by near-shore wave action that in many 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

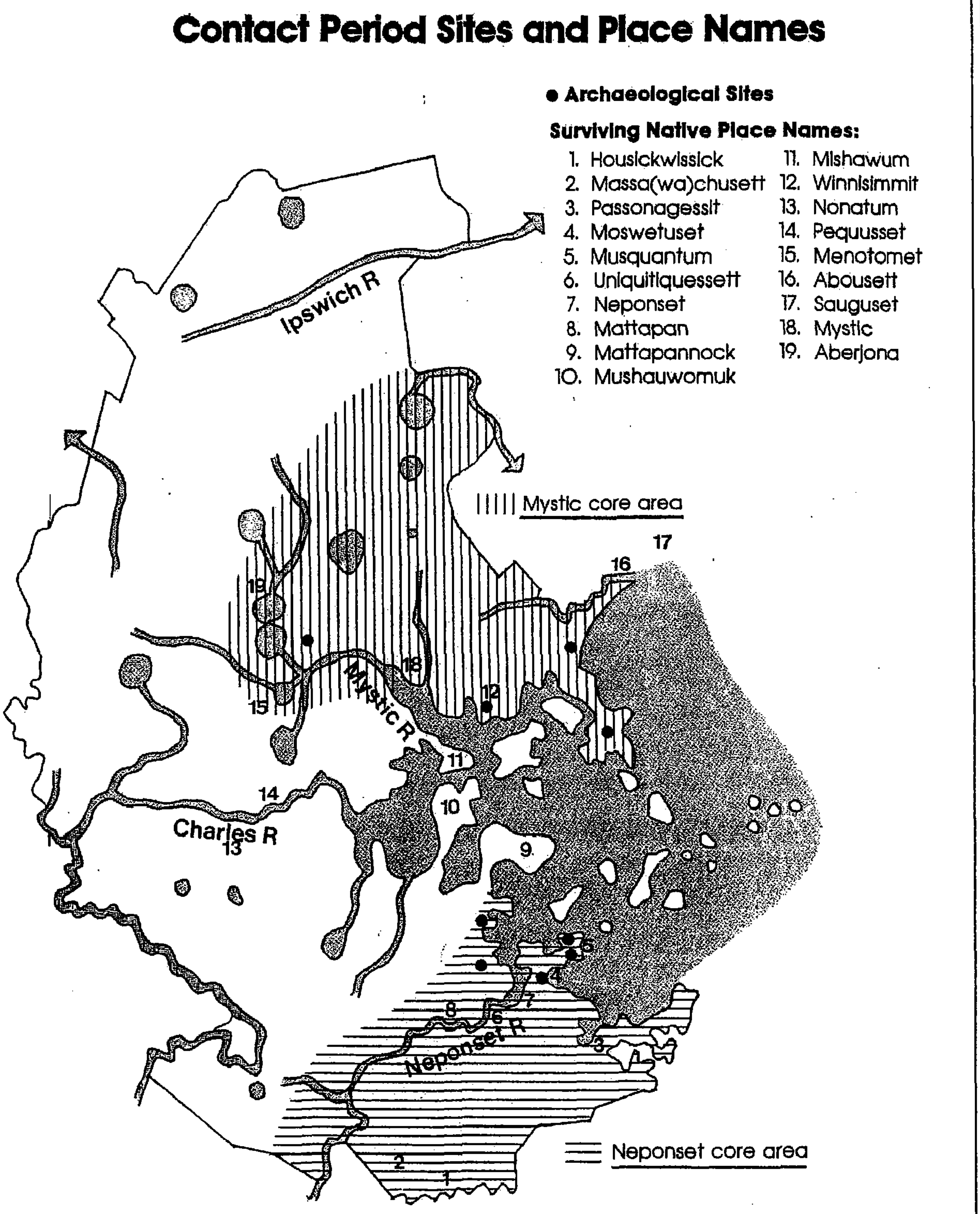


Figure 4-1. Contact Period Native American core areas within the Boston Harbor drainage (source MHC 1982).

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) established that the fishweir was utilized between about 4700 to 3700 years B.P. by people of the Small Stemmed Lithic Tradition following establishment of the Boston estuary. Supplemental work in proximity to the fishweir (Mrozowski et al. 1999, 2000) has resulted in a clearer understanding of the filling of Boston's Back Bay and the potential for preservation of archaeological sites in an urban context.

Following about 4000 years B.P., the large pond side and riverine zone sites (Goat Acre, Spy Pond) continued to be used as base camps by Susquehanna Tradition groups. A similar focus on the head of tidal/estuarine section of the Saugus River was also likely. Diagnostic lithic projectile points (Atlantic type) have also been found at a number of other smaller sites along the lower Mystic and Saugus rivers suggesting that these coastal/estuarine environments were a focus of Susquehanna settlement. Rhyolite lithic materials from the Wakefield section of the Lynn volcanic geological complex appear to have been an important source of lithic materials for Susquehanna Tradition prehistoric groups settled in the northern Boston Basin.

Settlement appears to have intensified in the coastal zone around Boston Harbor with decreased coastal inundation and the stabilization of shorelines ca. 2,500 years ago (Dincauze 1974). At this time, exploitation of various shellfish species by hunter-gatherer groups intensified. Many shell midden sites were created at locations in the Boston Harbor district used for shellfish processing and temporary, seasonal settlement. Few temporary camps (i.e., Water Street, Town Dock Pottery sites) occupied by Early Woodland Period hunter-gatherers have been found buried under deposits of historic/modern period fill near former salt marsh and shoreline locations between the mouths of the Charles and Mystic rivers in Charlestown. Activities conducted at these sites included production of chipped-stone tools and limited resource processing (Ritchie 1992; Shaw 1984). Early Woodland Period lithic materials, including Meadowood-type projectile points, have also been recovered near the confluence of the Alewife Brook and the Mystic River (Dincauze 1974). A recently unearthed hearth feature, which produced an 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

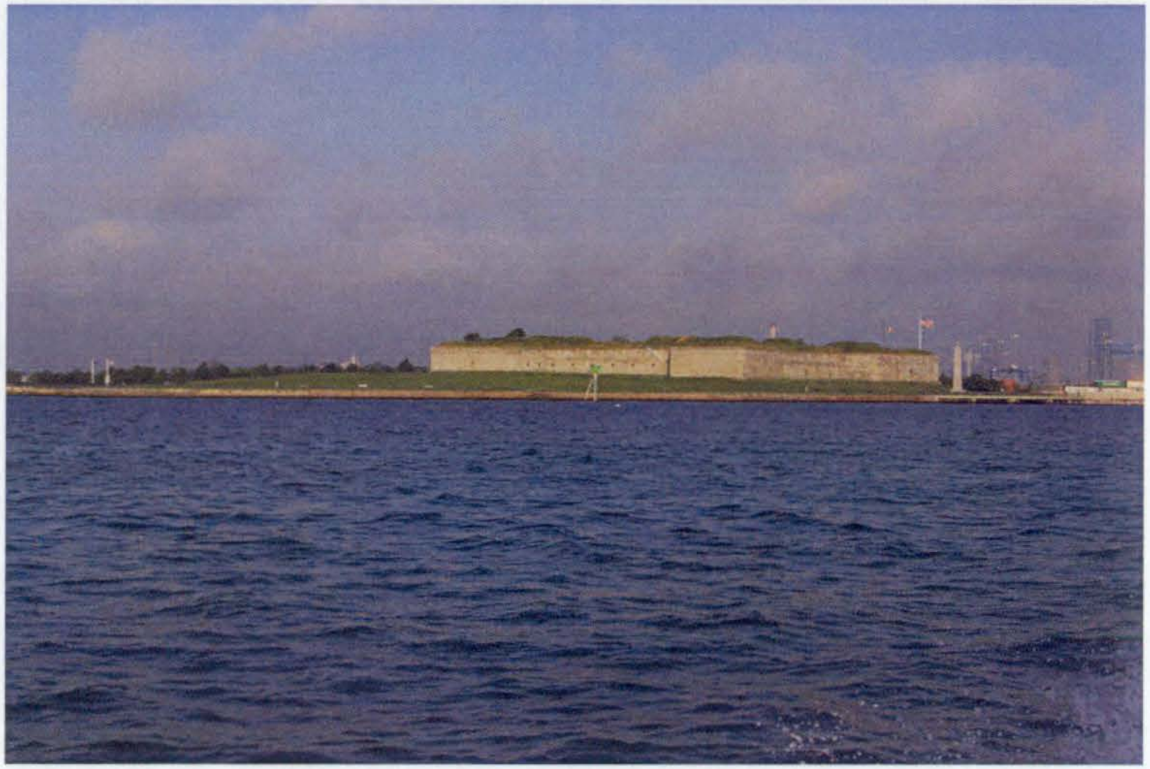


Figure 5-1. View of Fort Independence and Castle Island from the Boston Harbor Deep Draft Navigation Improvements Project study area.

Boston Harbor Deep Draft Project, September 2003 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

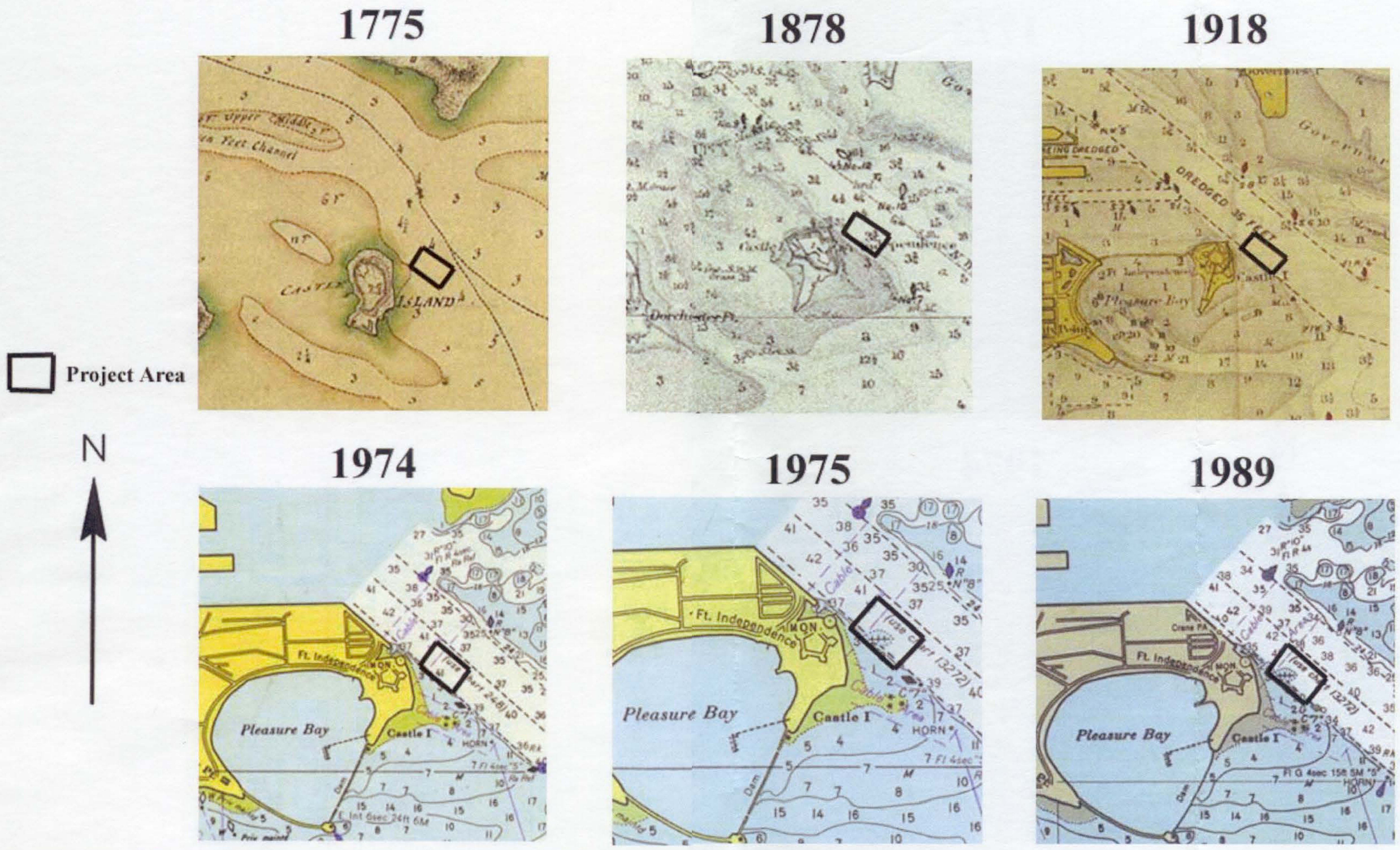


Figure 6-2. ROV video image of steel-wire mesh lobster traps and naturally occurring rock that are the sources of the magnetic and acoustic anomalies comprising Targets 1, 2, and 3.

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

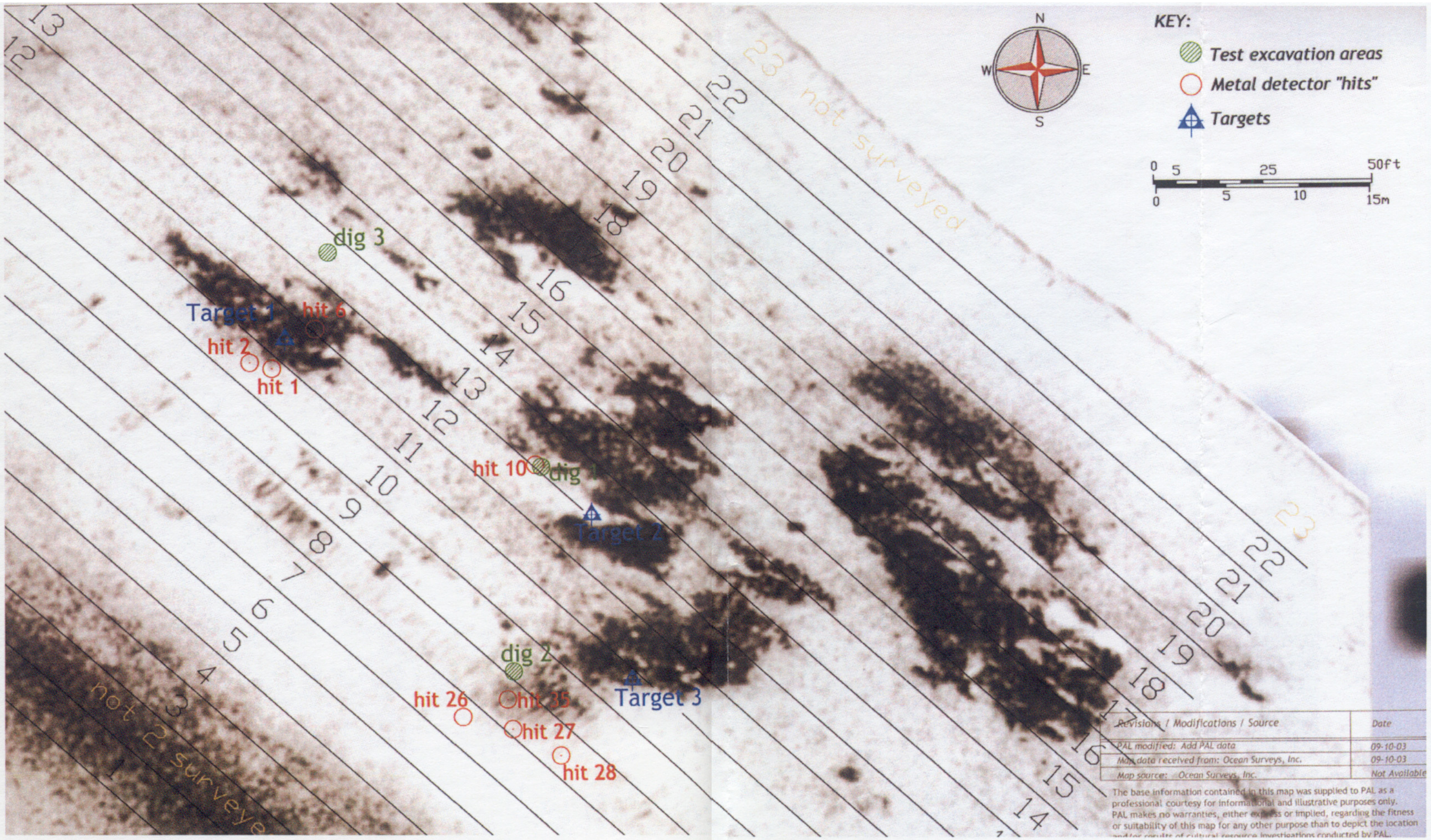
Background research indicated that prehistoric Native American populations extensively utilized the surrounding lands and islands within Boston Harbor prior to European contact. Thompson Island, for example, approximately 1 mile south of Castle Island, contains at least 17 recorded ancient Native archaeological 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 refloated. 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.



Revisions / Modifications / Source	Date
PAL modified: Add PAL data	09-10-03
Map data received from: Ocean Surveys, Inc.	09-10-03
Map source: Ocean Surveys, Inc.	Not Available

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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.

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.

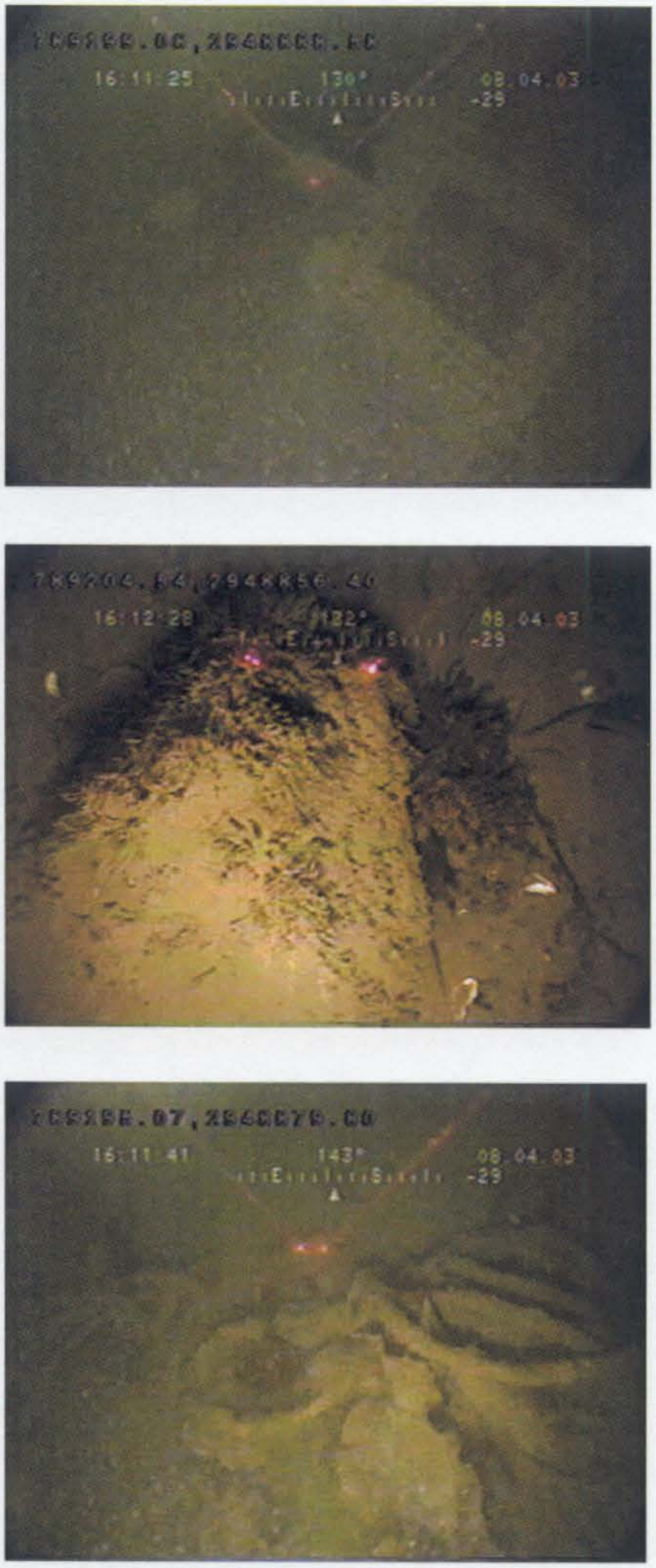

Figure 6-2. ROV video image of steel-wire mesh lobster traps and naturally occurring rock that are the sources of the magnetic and acoustic anomalies comprising Targets 1, 2, and 3.
Boston Harbor Deep Draft Project, September 2003

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

PAL

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

The Commonwealth of Massachusetts
William Francis Galvin, Secretary of the Commonwealth
Massachusetts Historical Commission

July 31, 2003

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
(617) 727-8470 • Fax: (617) 727-5128
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The Commonwealth of Massachusetts
Executive Office of Environmental Affairs
251 Causeway Street, Suite 900
Boston, Massachusetts 02114-2119

BOARD OF
UNDERWATER
ARCHAEOLOGICAL
RESOURCES

Tel. (617) 626-1000
Fax (617) 626-1181
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

M-2-85

VTM/dwt

File
Boston Harbor [illegible]
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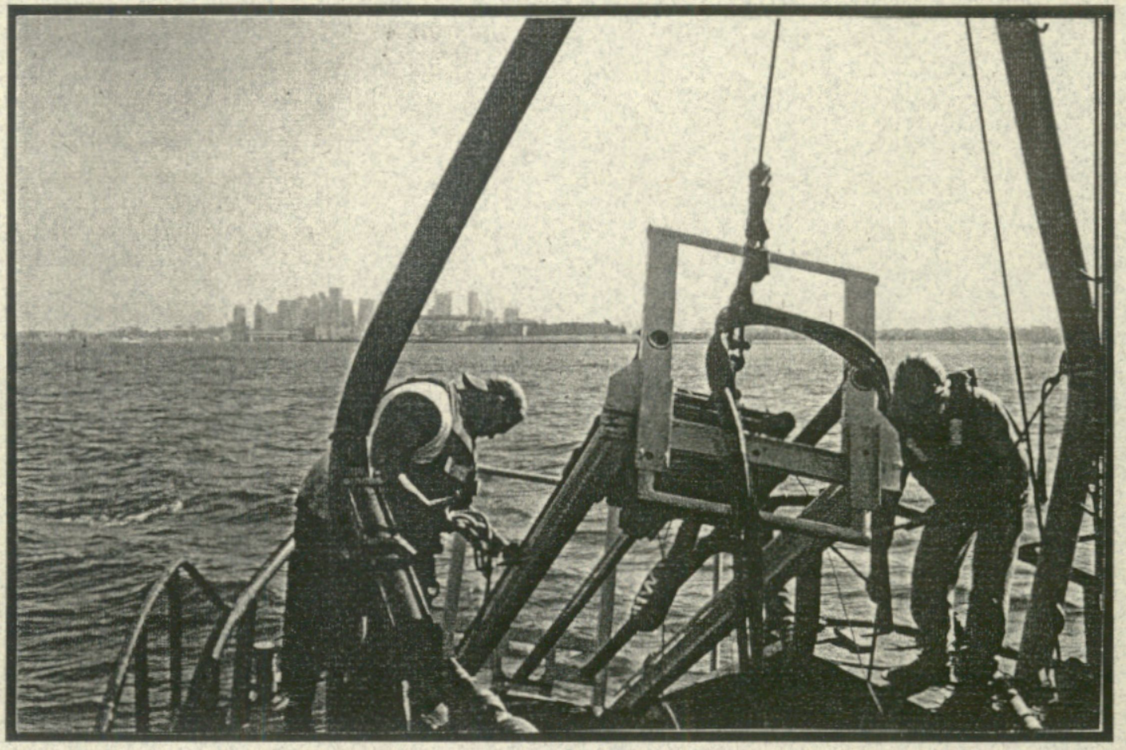
APPENDIX B

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

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

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.

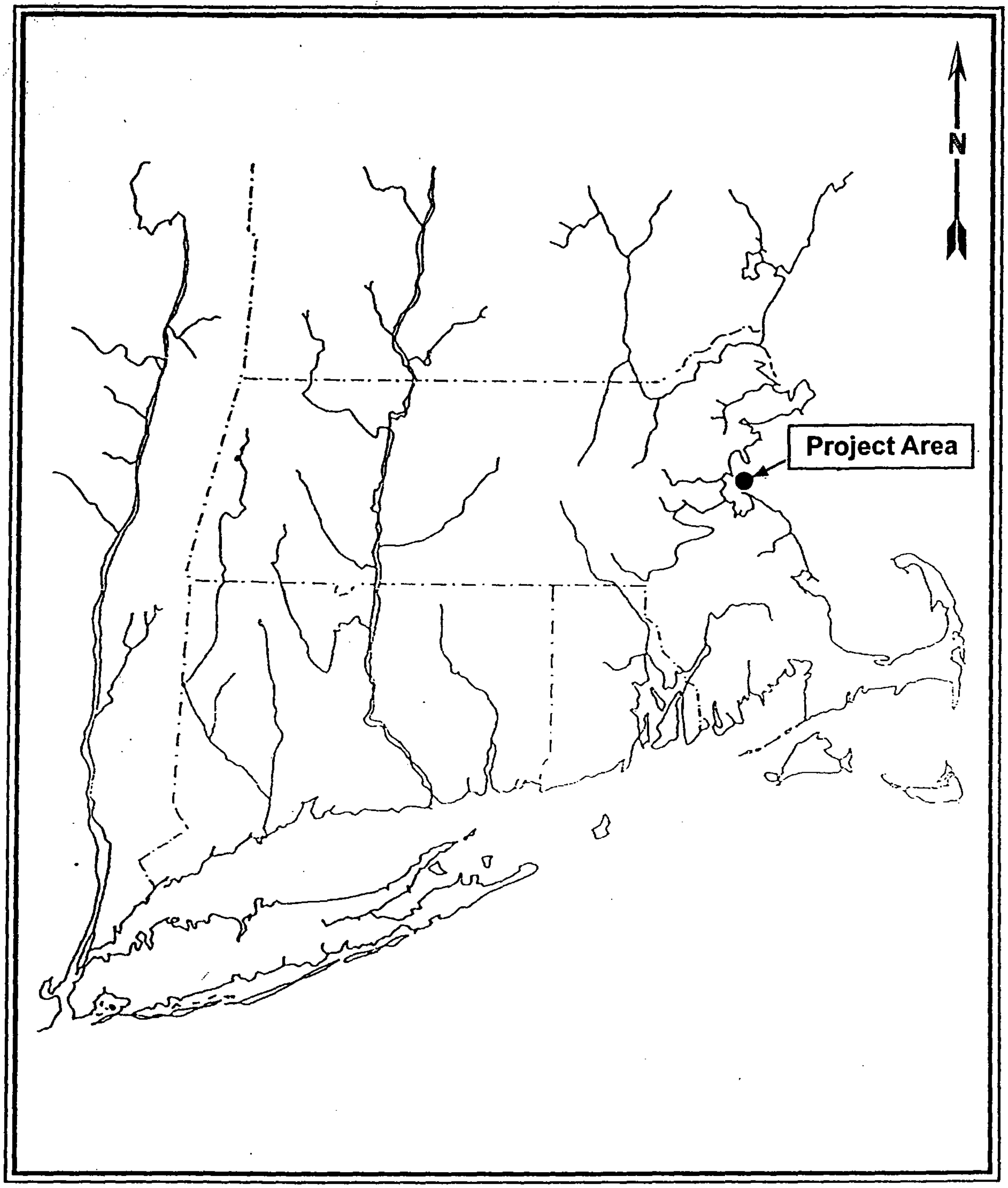


Figure 1. Project area location in the southern New England region.

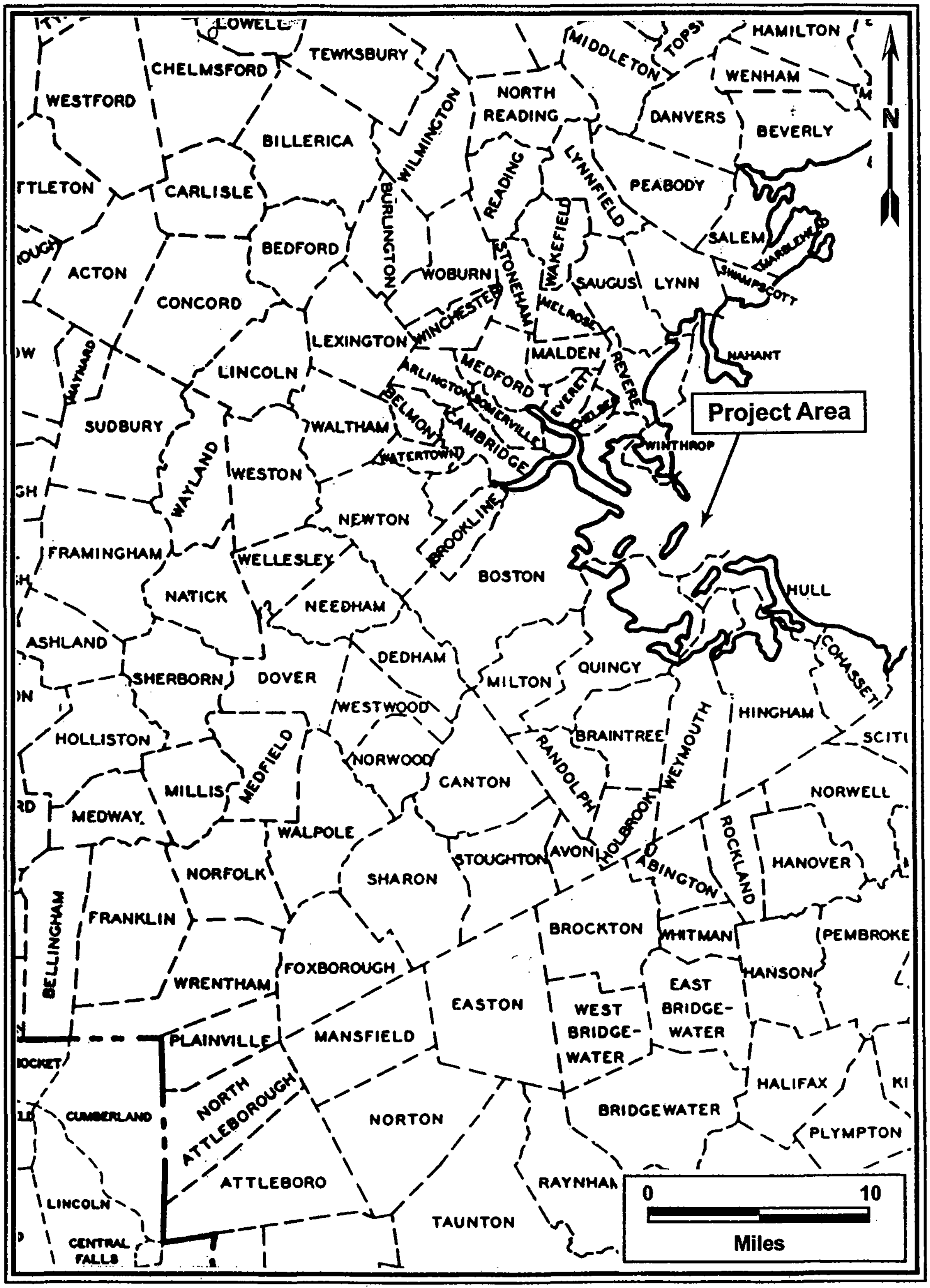


Figure 2. Location of project area in Boston.

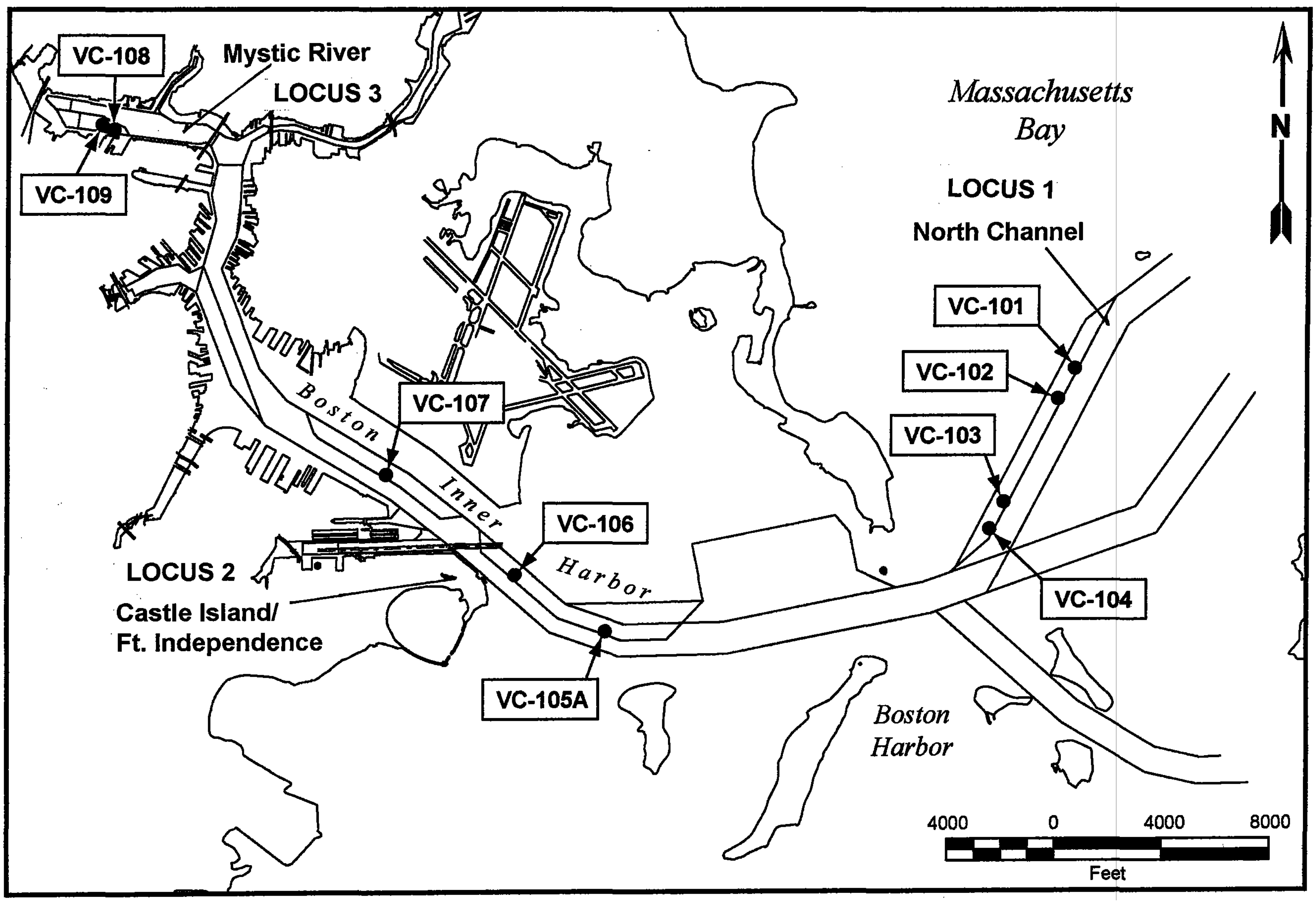


Figure 3. Map indicating the location of vibratory cores in Boston Harbor.

Figure 4. Survey Vessel *Buoy Maker* at the location of Core VC-103.

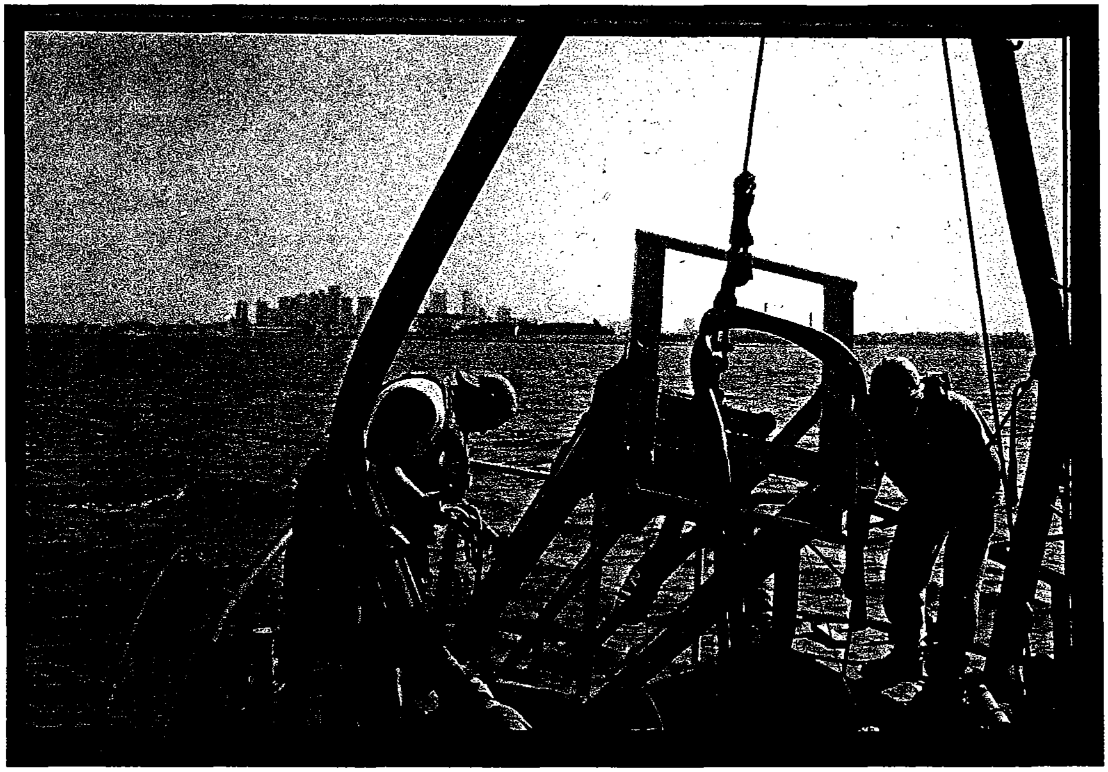


Figure 5. Vibratory core mechanism being raised. Boston skyline in background.

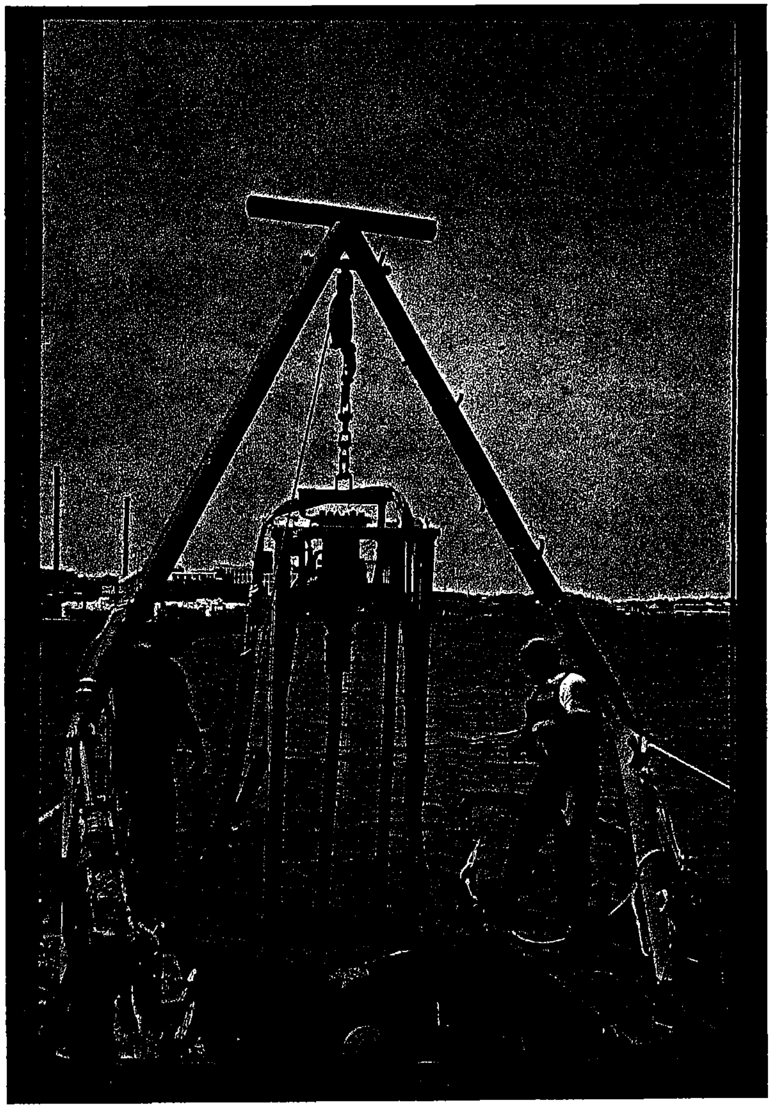


Figure 6. "A"-frame mounted on the bow of the *Buoy Maker*, used to lower and retrieve vibratory cores.

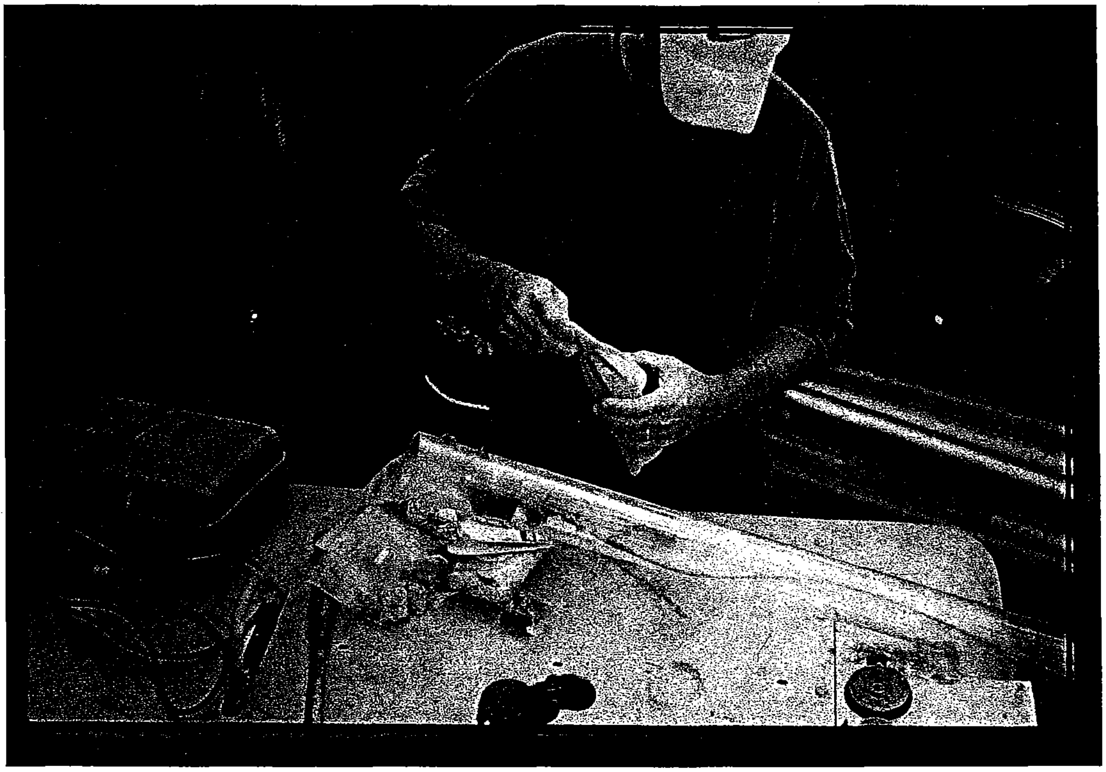


Figure 7. Preparation of polycarbonate cores prior to coring.

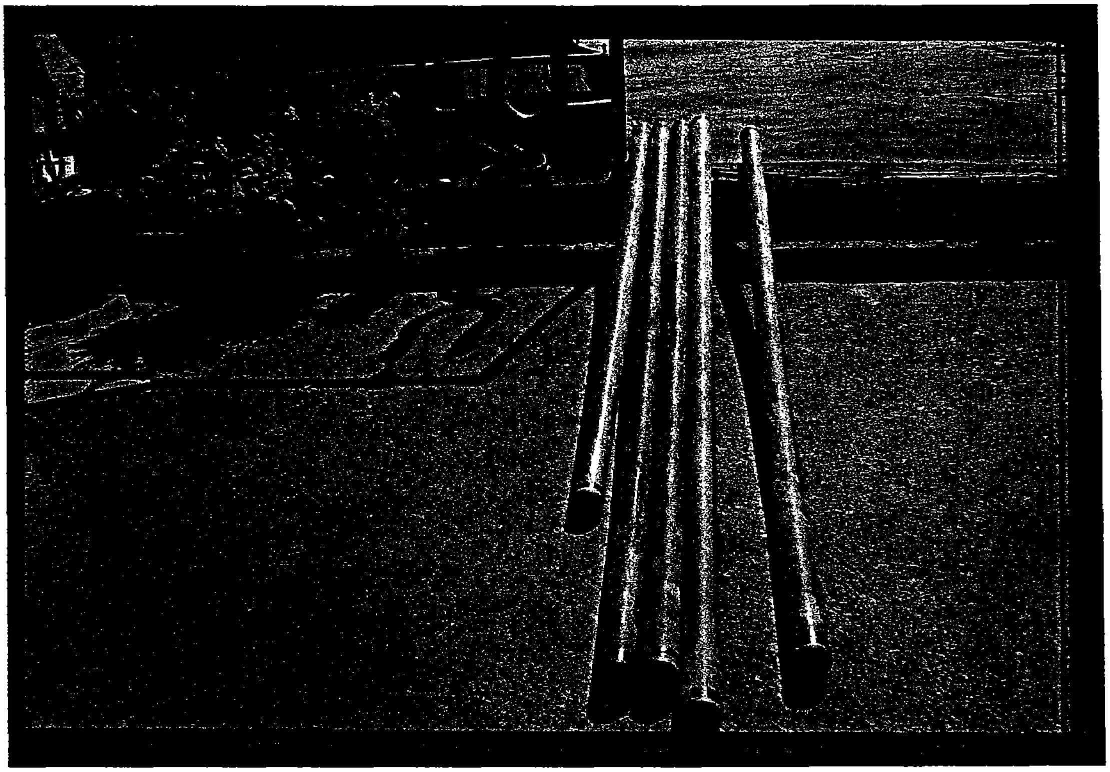


Figure 8. Polycarbonate cores awaiting shipment to lab.

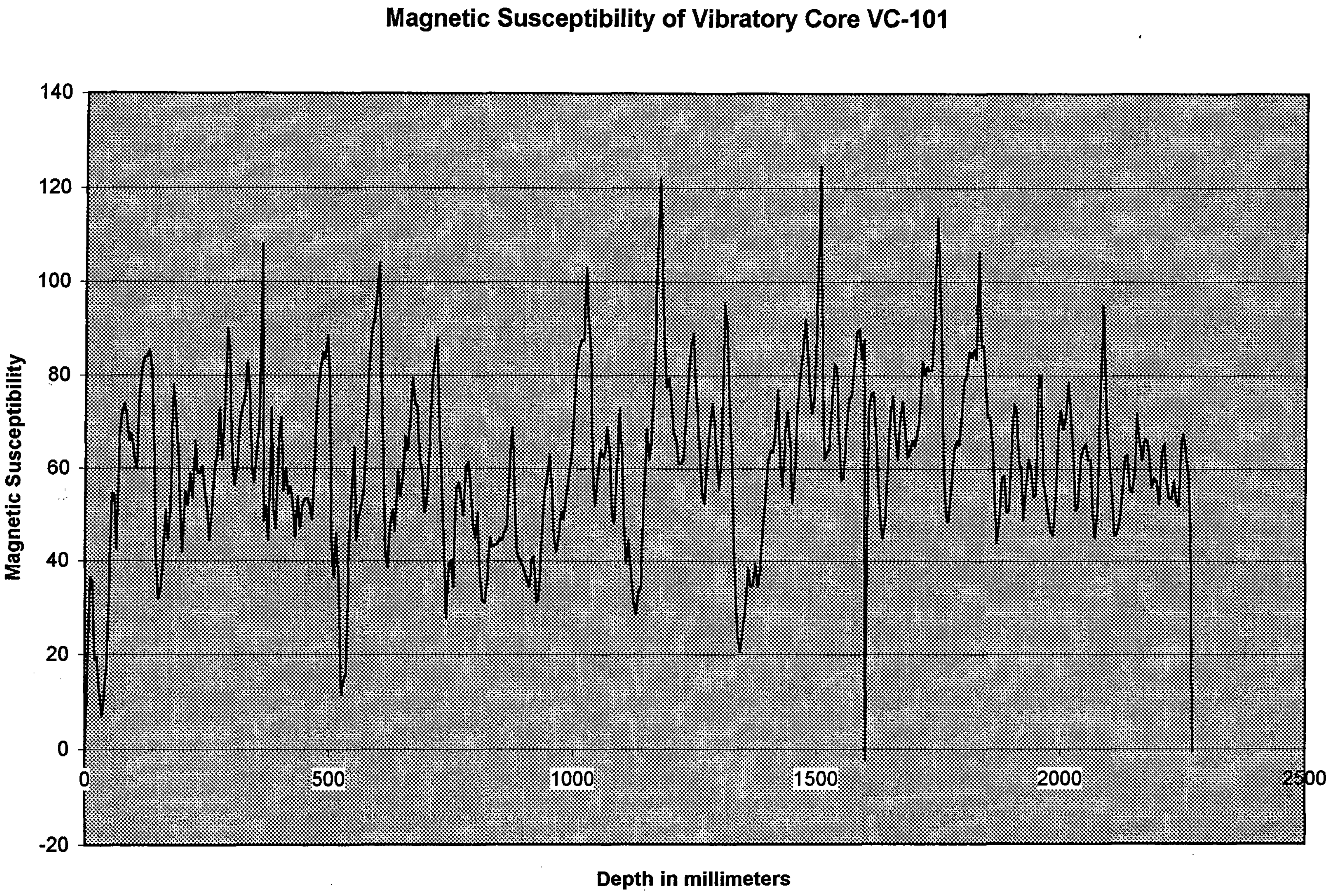


Figure 10. Magnetic Susceptibility of Core VC-101.

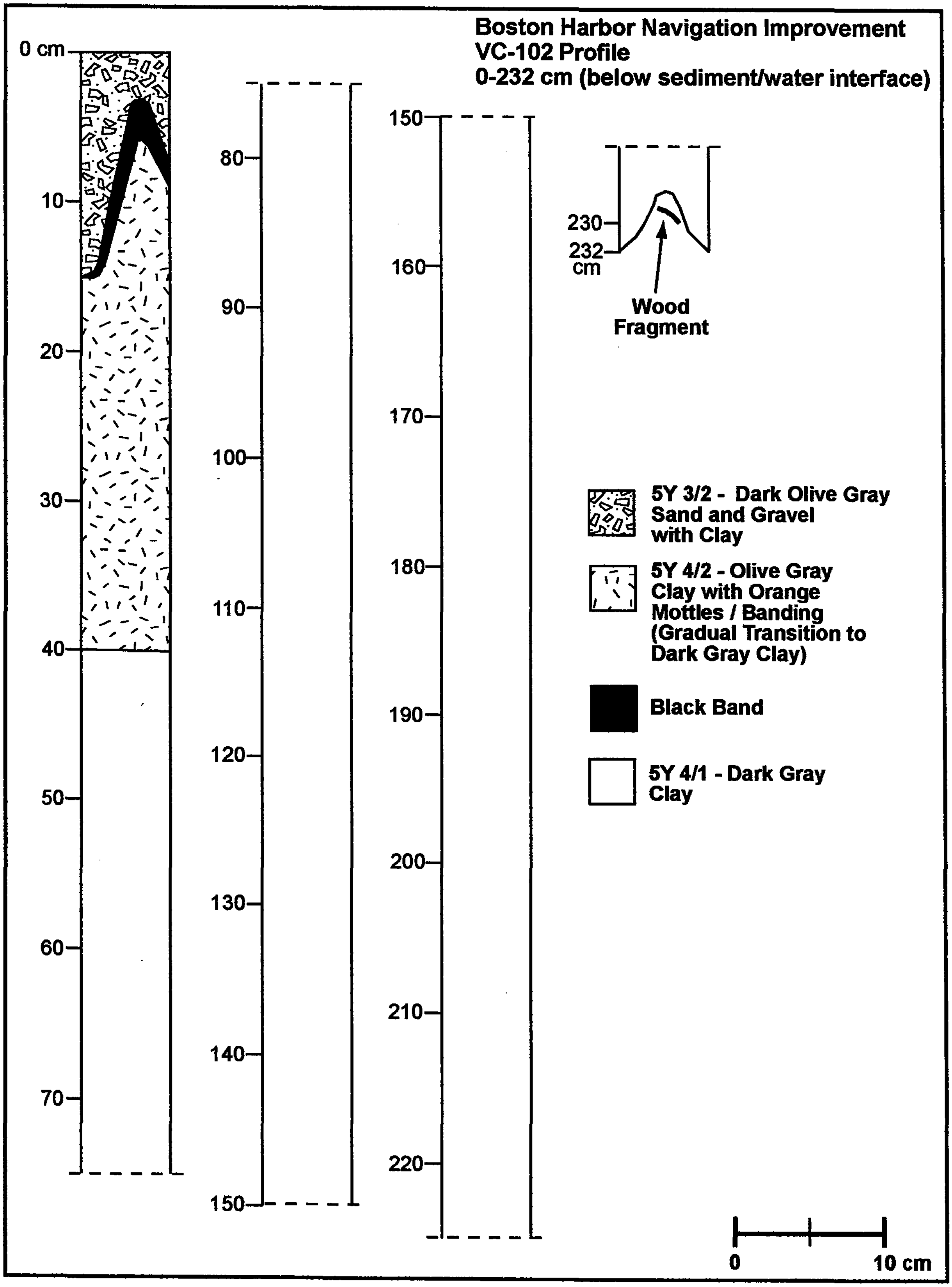


Figure 11. Profile of Vibratory Core VC-102 taken in the North Channel.

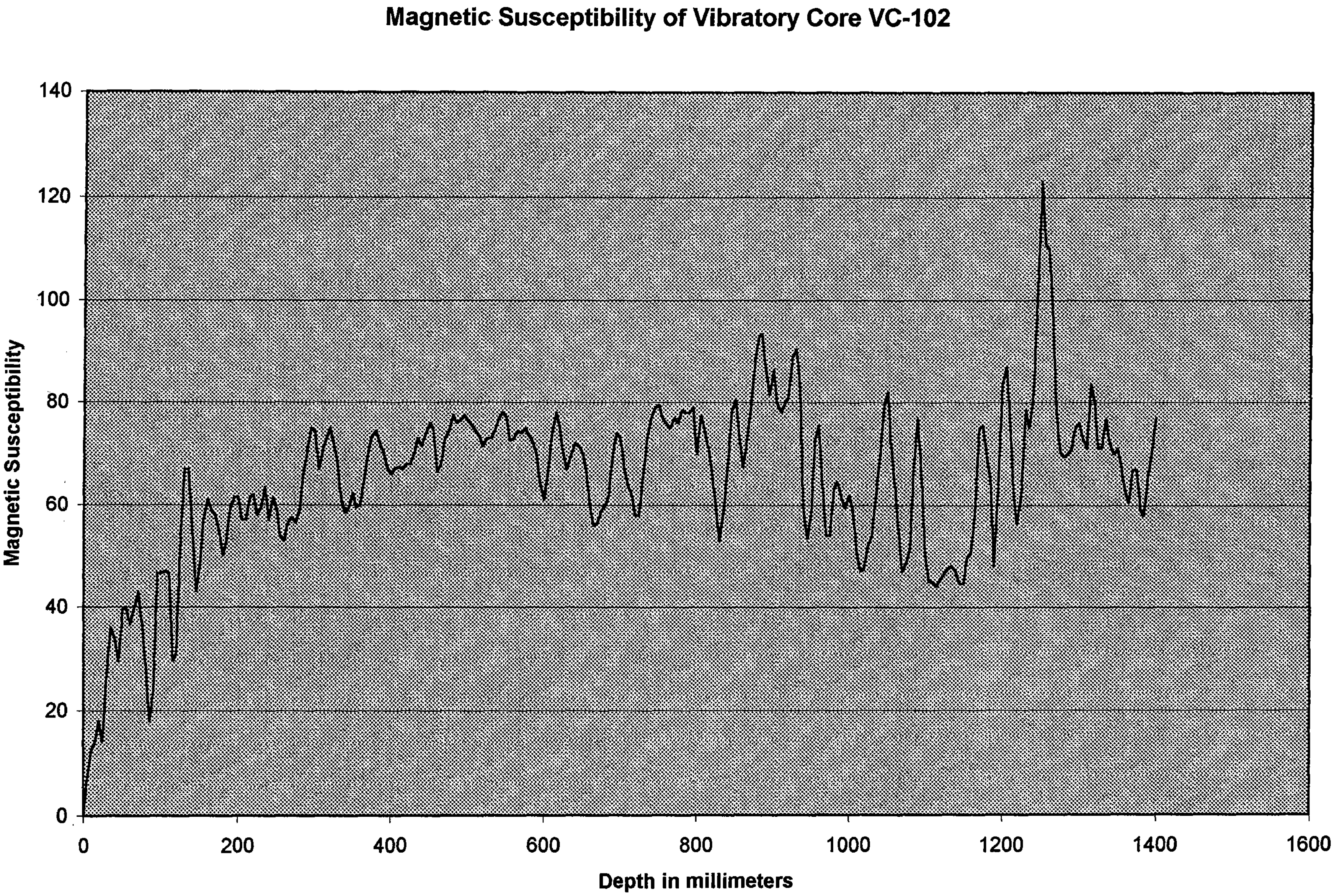


Figure 12. Magnetic Susceptibility of Core VC-102.

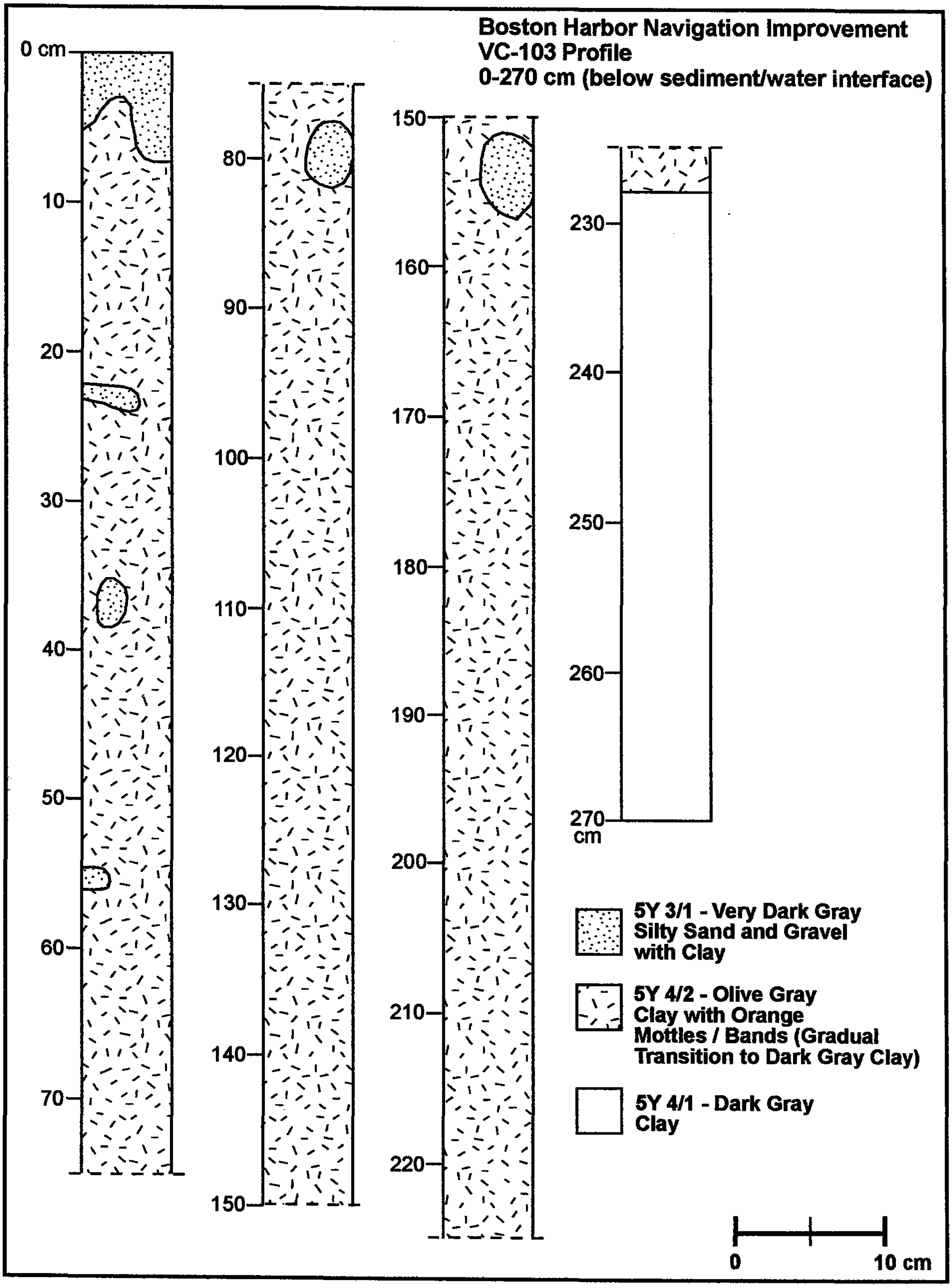


Figure 13. Profile of Vibratory Core VC-103 taken in the North Channel.

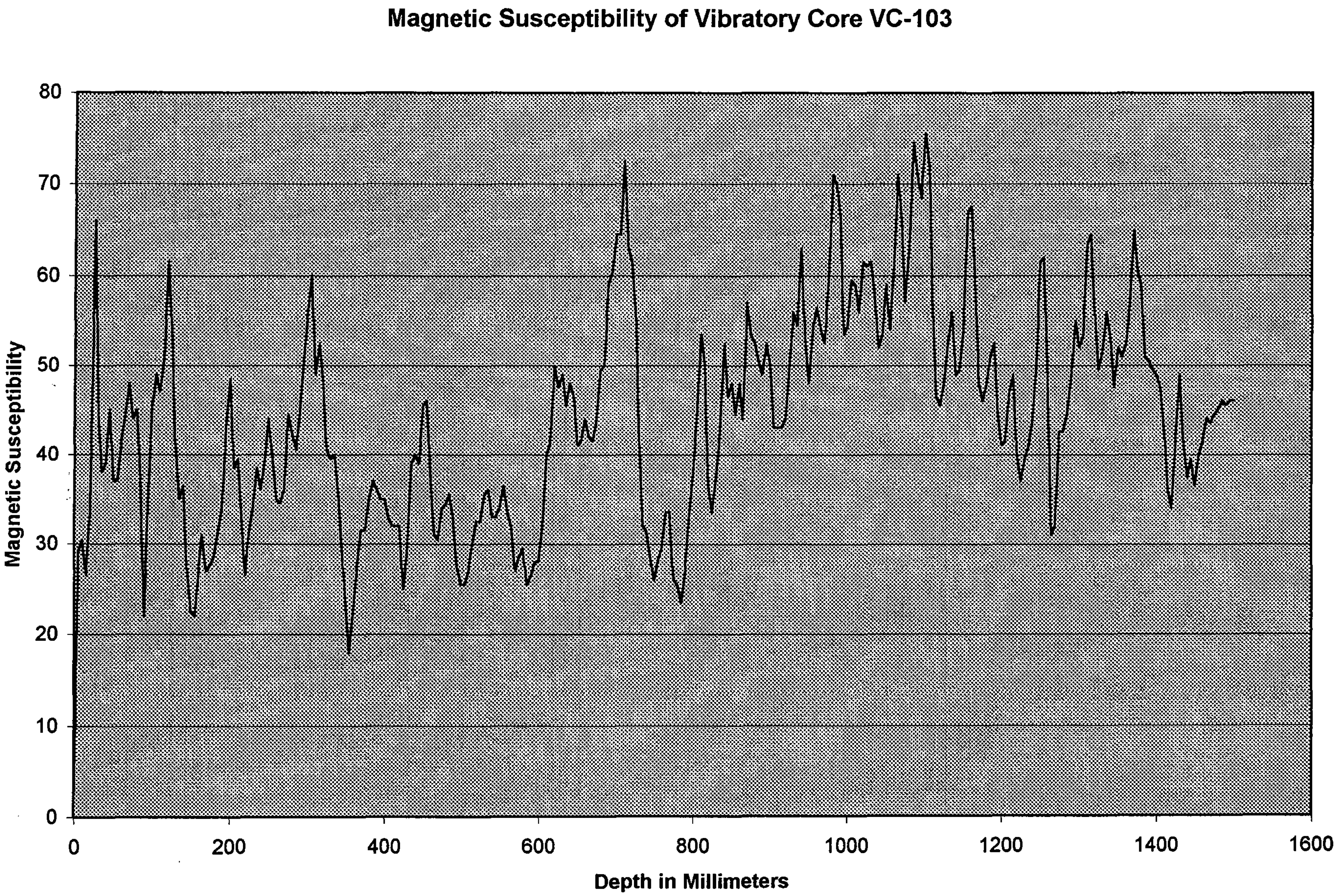


Figure 14. Magnetic Susceptibility of Core VC-103.

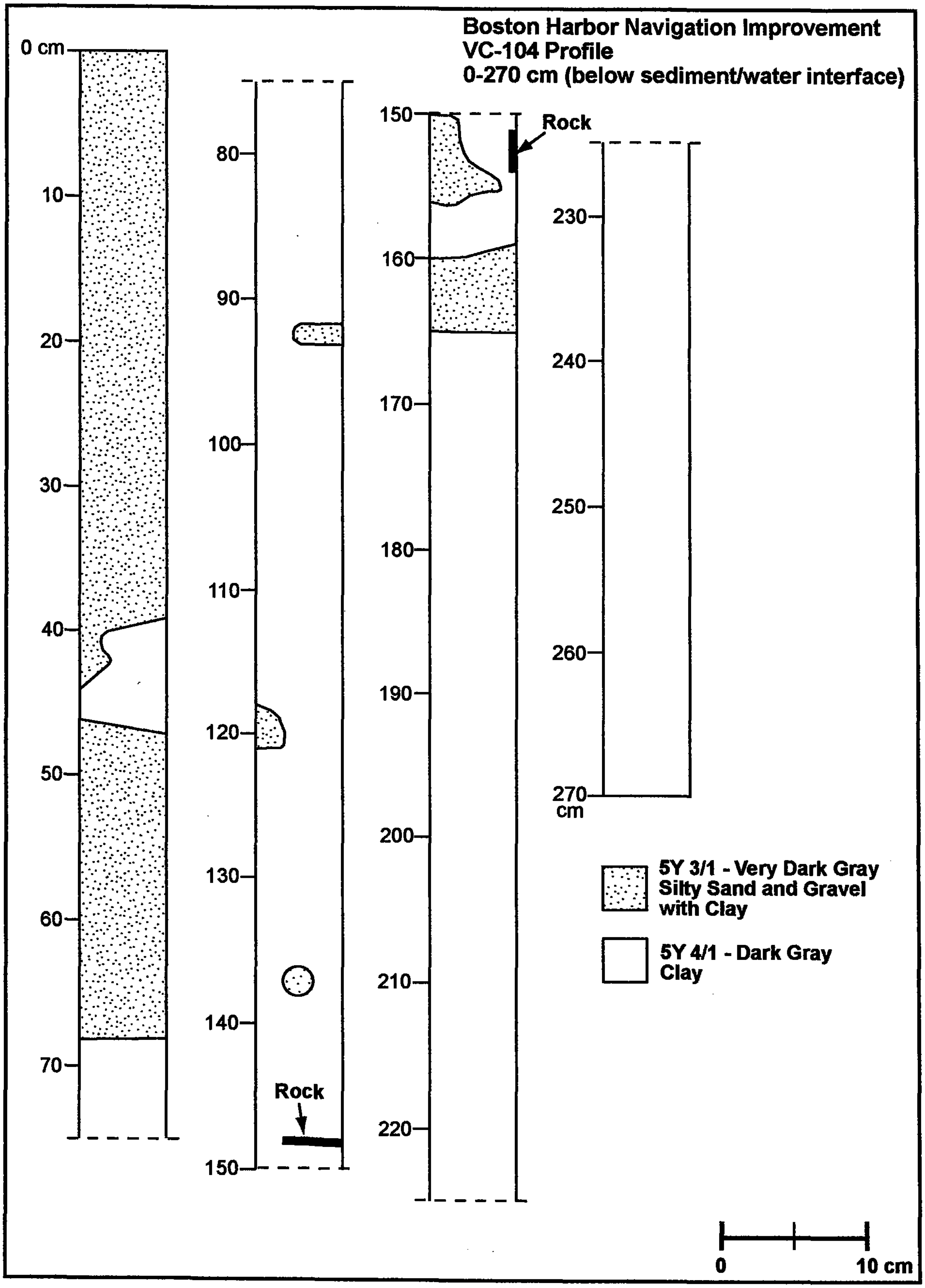


Figure 15. Profile of Vibratory Core VC-104 taken in the North Channel.

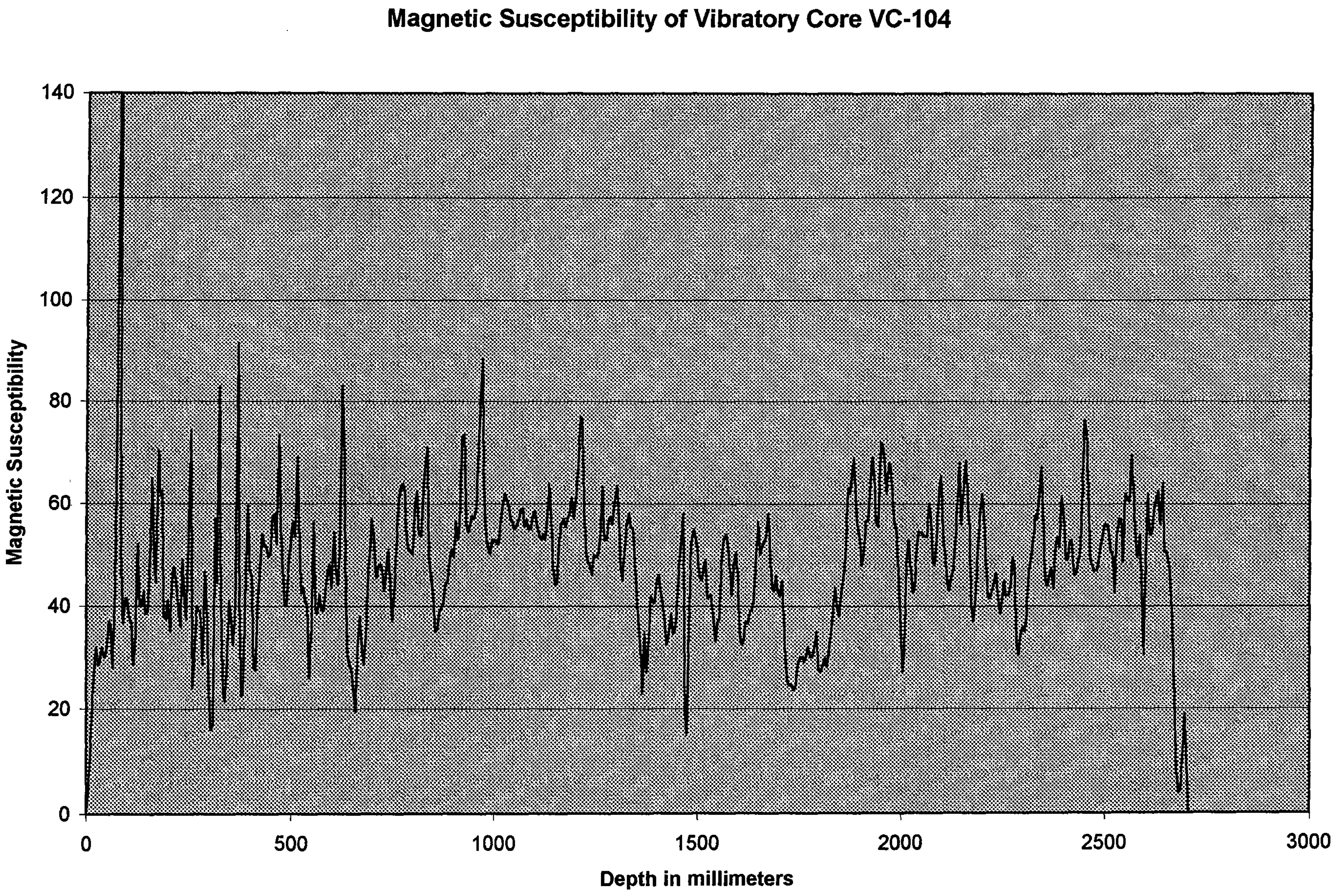


Figure 16. Magnetic Susceptibility of Core VC-104.

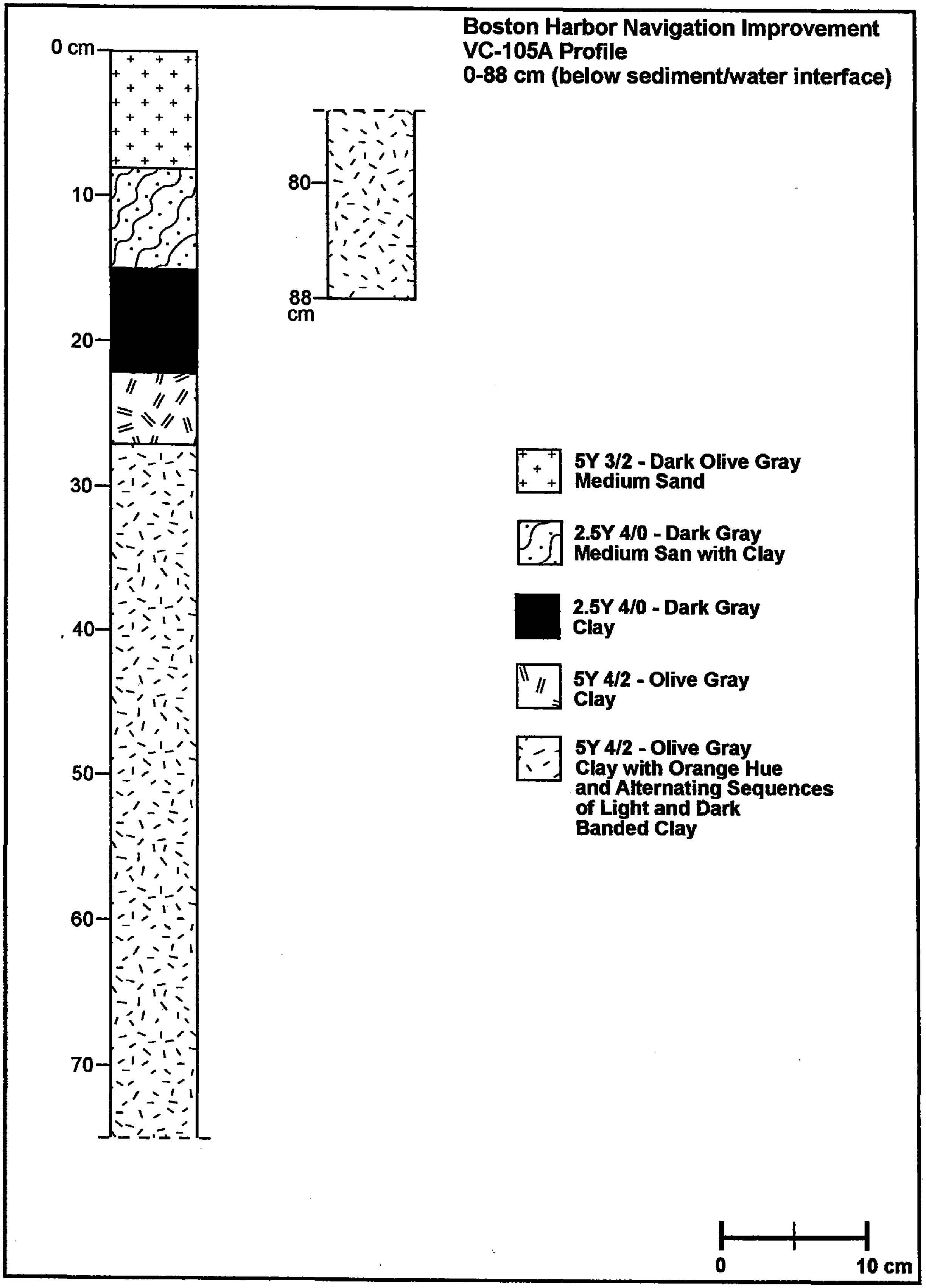


Figure 17. Profile of Vibratory Core VC-105A taken in the channel east of Castle Island.

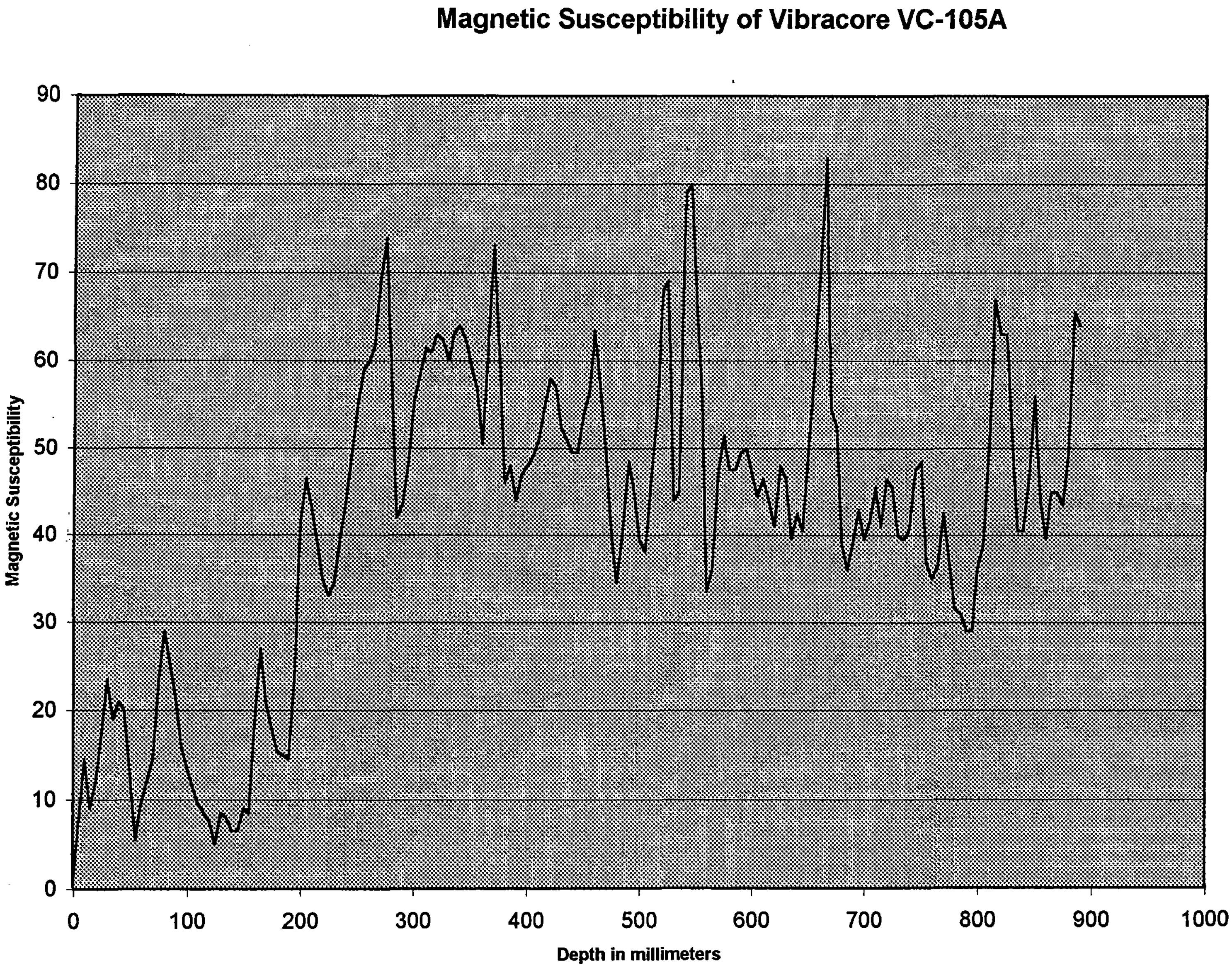


Figure 18. Magnetic Susceptibility of Core VC-105A.

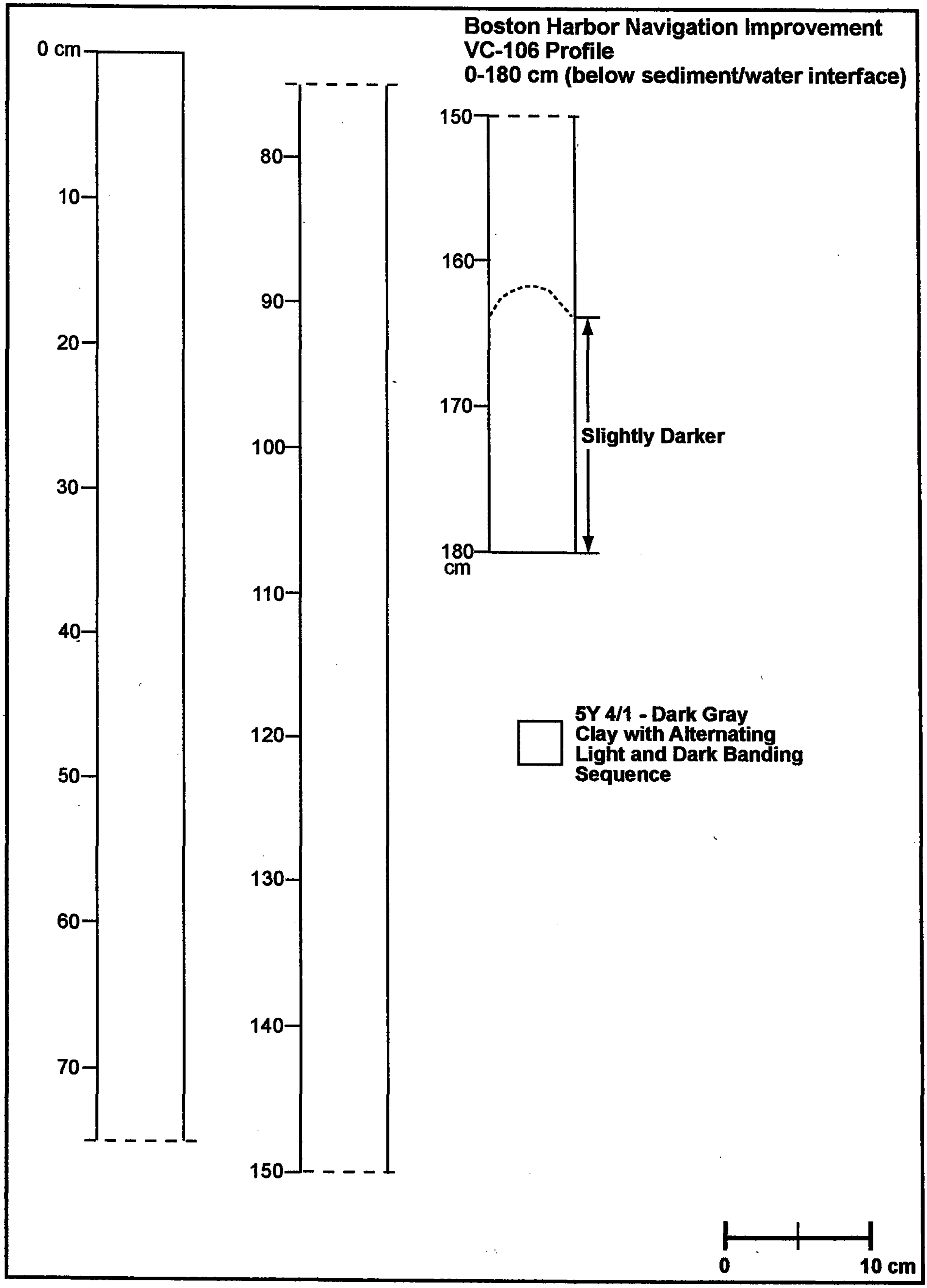


Figure 19. Profile of Vibratory Core VC-106 taken in the channel east of Castle Island.

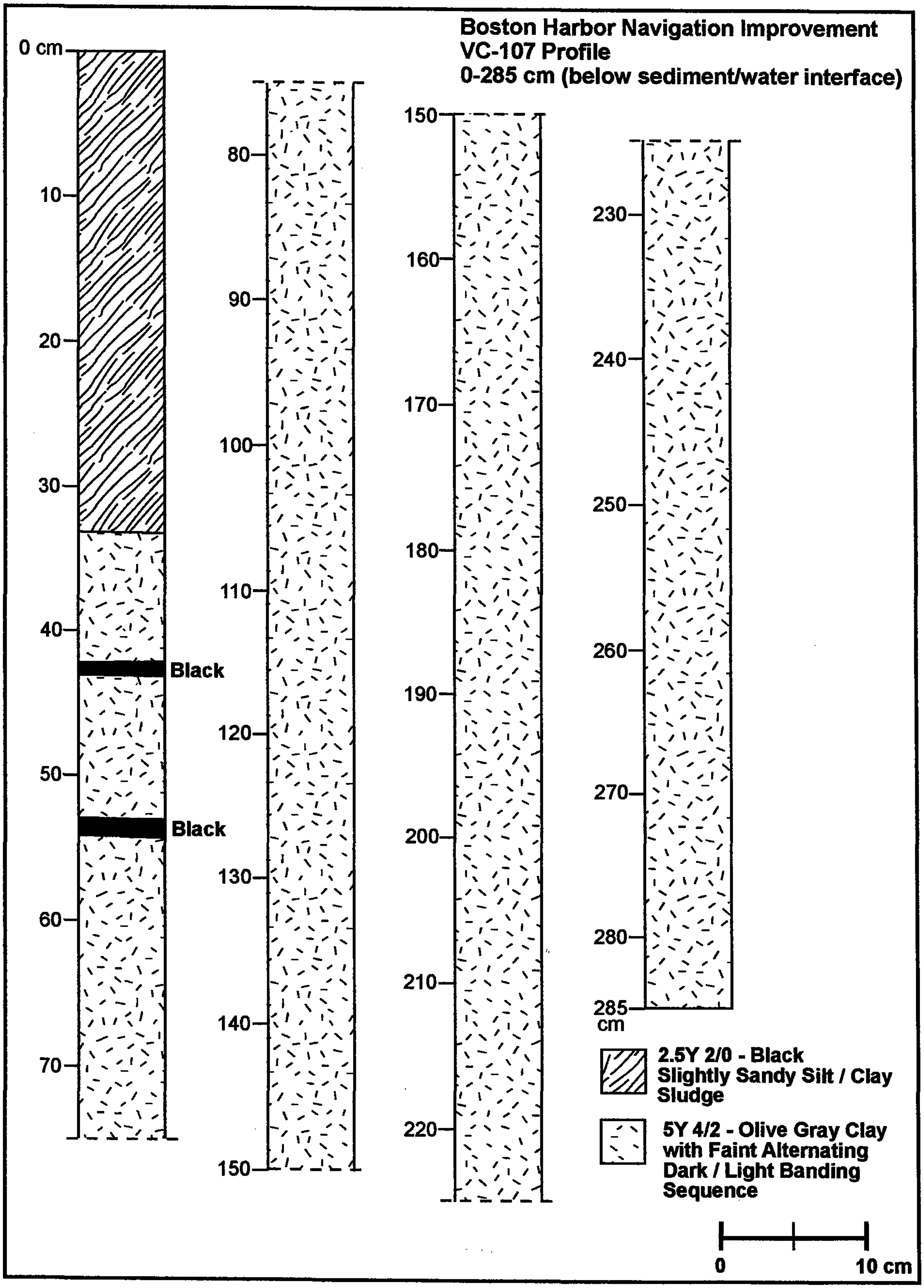


Figure 20. Profile of Vibratory Core VC-107 taken in the channel north of Castle Island.

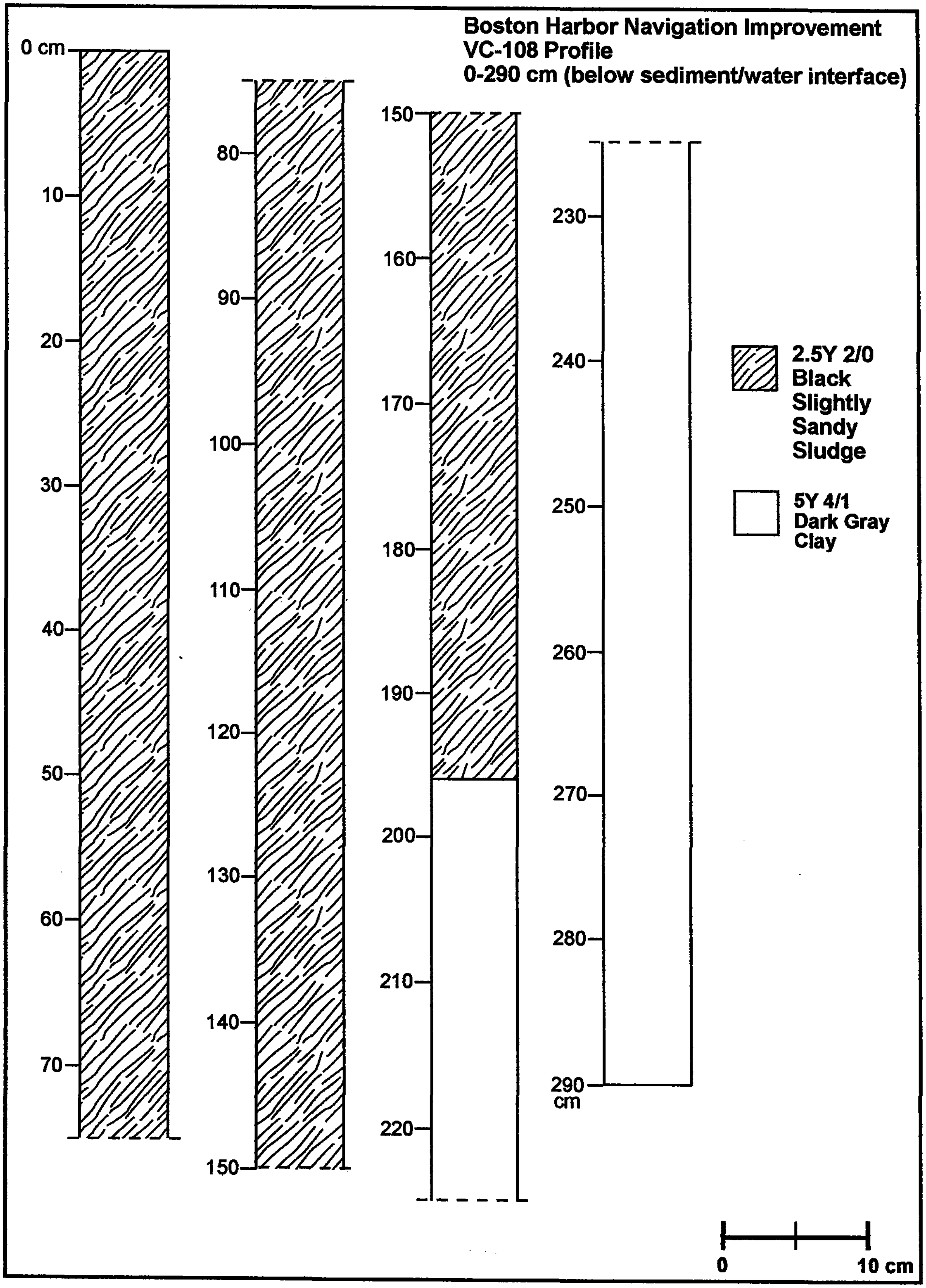


Figure 21. Profile of Vibratory Core VC-108 taken in the Mystic River.

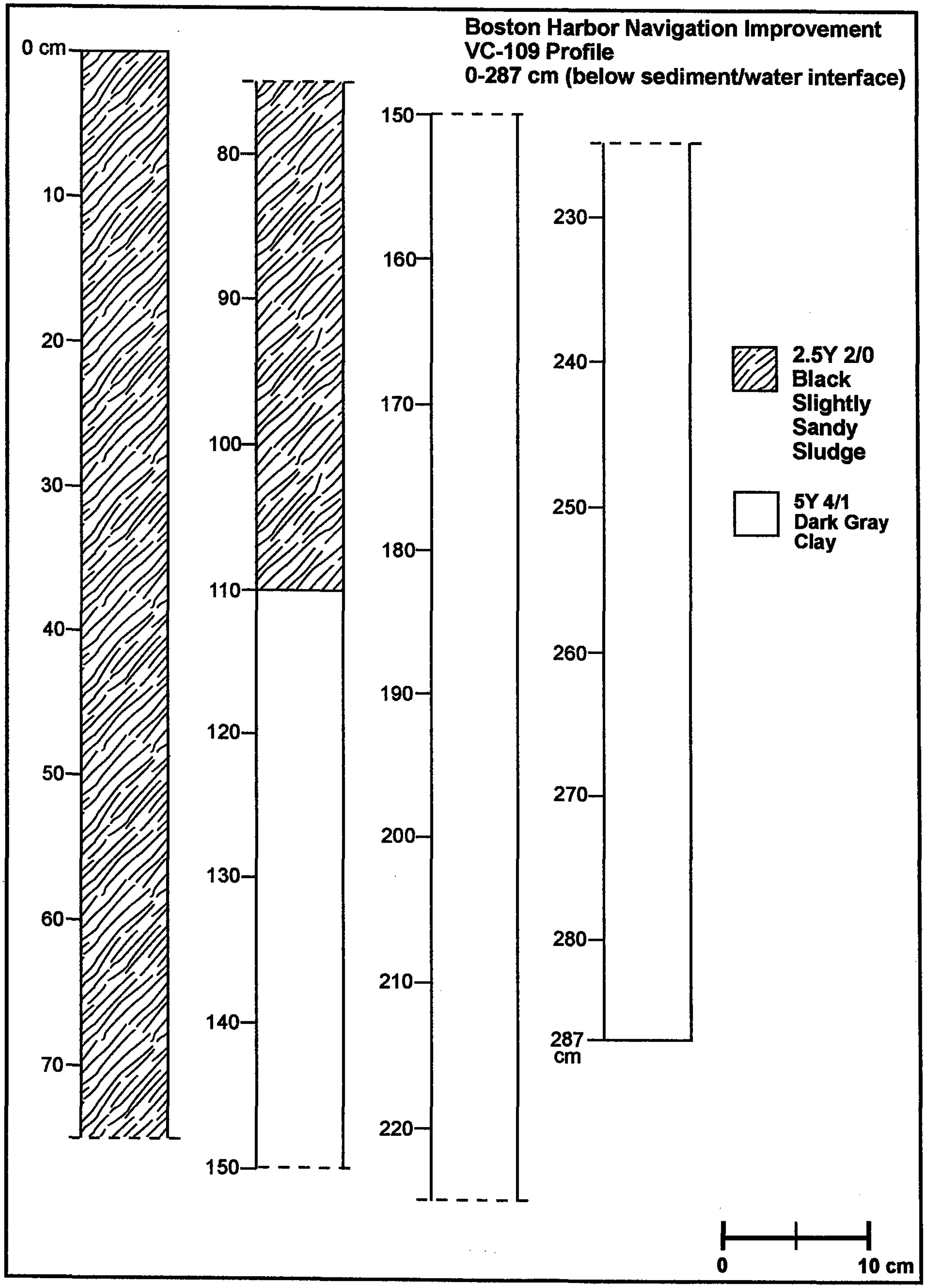


Figure 22. Profile of Vibratory Core VC-109 taken in the Mystic River.

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

Prepared by:

Battelle
397 Washington Street
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(781) 934-0571

SEPTEMBER 2005

US ARMY CORPS
OF ENGINEERS
New England District

Battelle
The Business of Innovation

TABLE OF CONTENTS

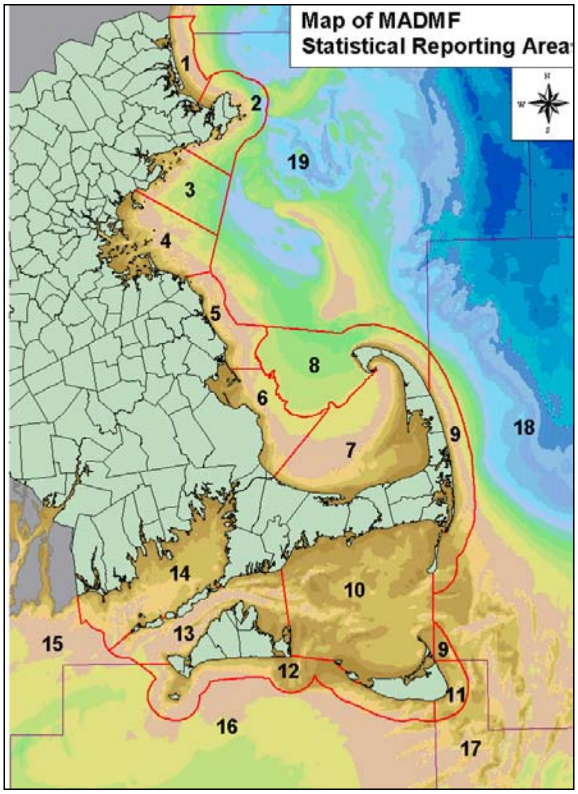
LIST OF TABLES

LIST OF FIGURES

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.

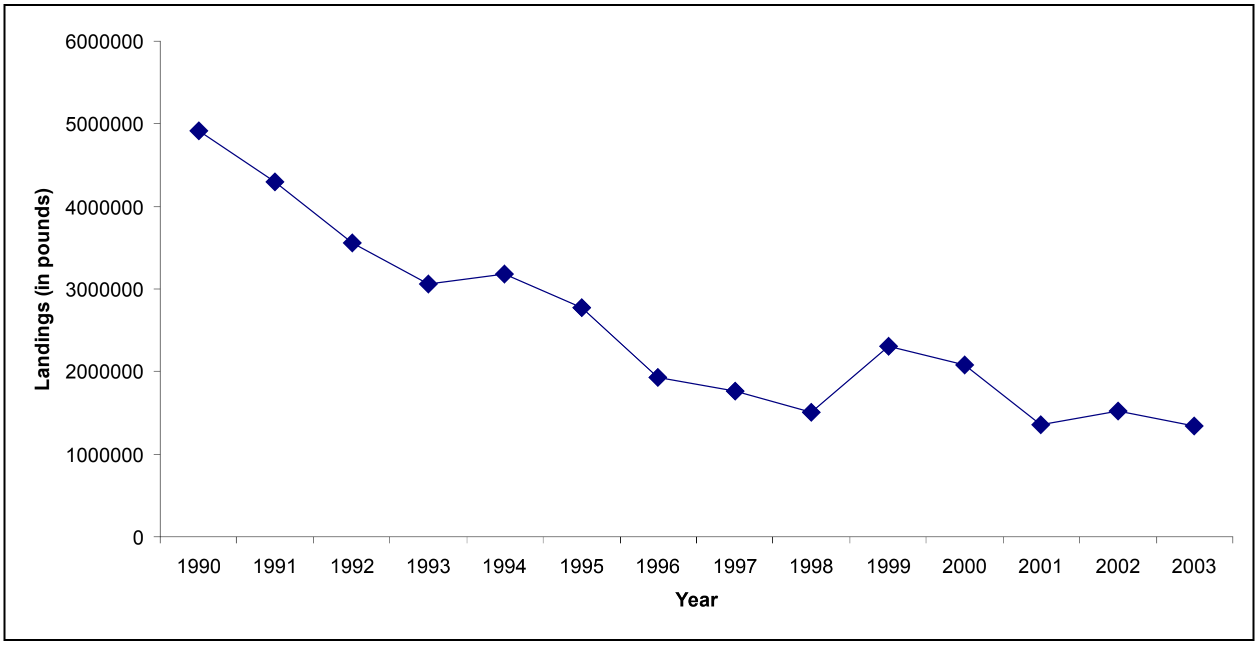


Figure 2. Annual landings in pounds for State-managed Area 4 which includes Boston Harbor and Massachusetts Bay.

Data 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).

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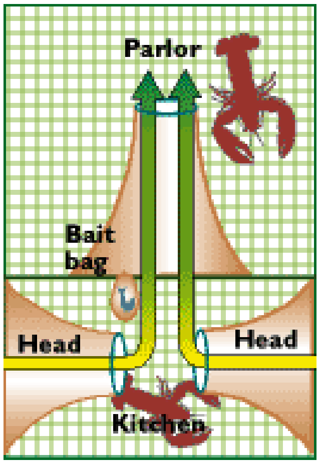
[2] The kitchen of a trap is the end where the lobster enters, attracted by the bait bag secured within. The entrance, or door, is typically funnel-shaped, with the narrowest end of the funnel opening into the kitchen. This arrangement makes it difficult for the lobsters to fall out of the kitchen (and 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

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[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 10ºC, 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

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[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).

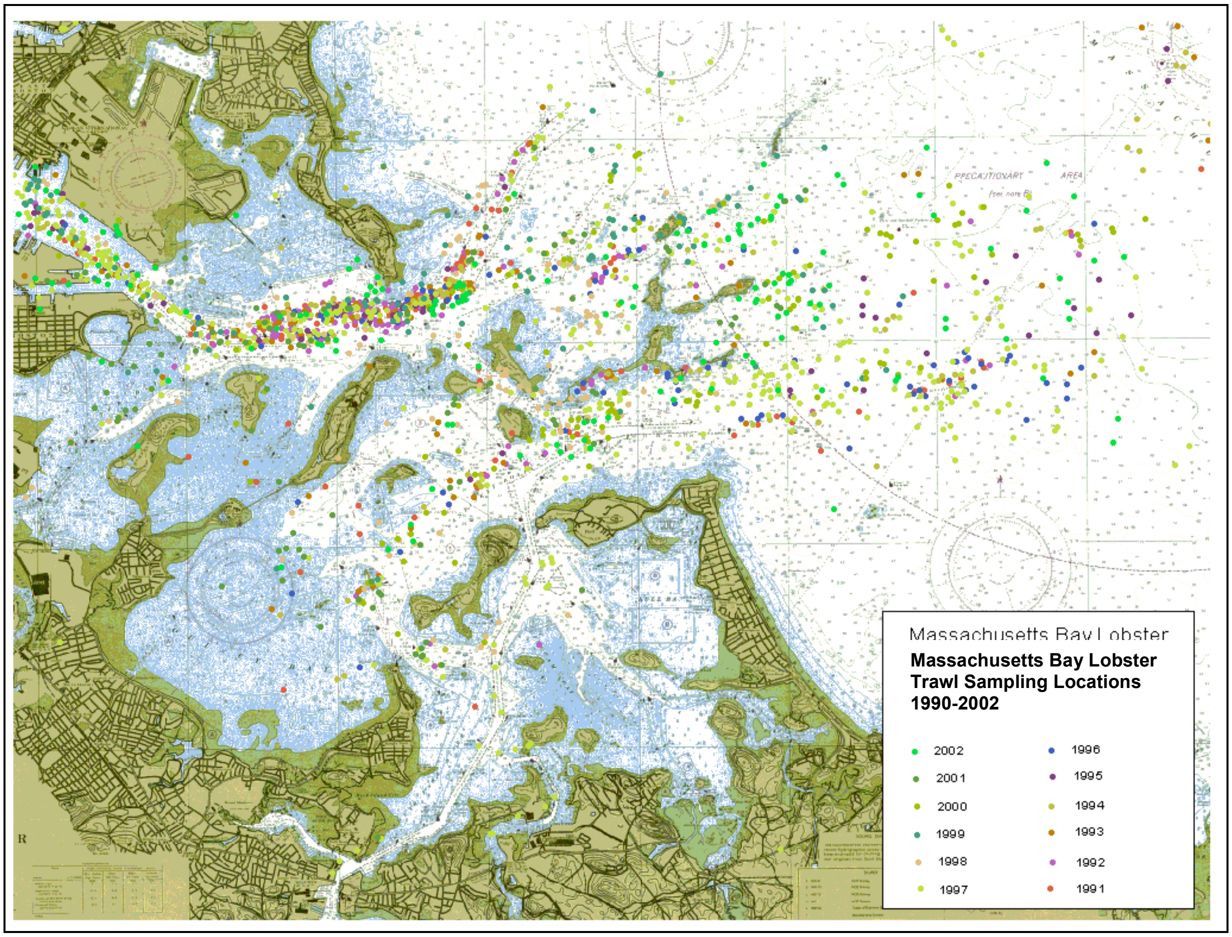

Figure 4. MADMF Boston Harbor and Massachusetts Bay sea sampling locations for the years 1991-2002.

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.

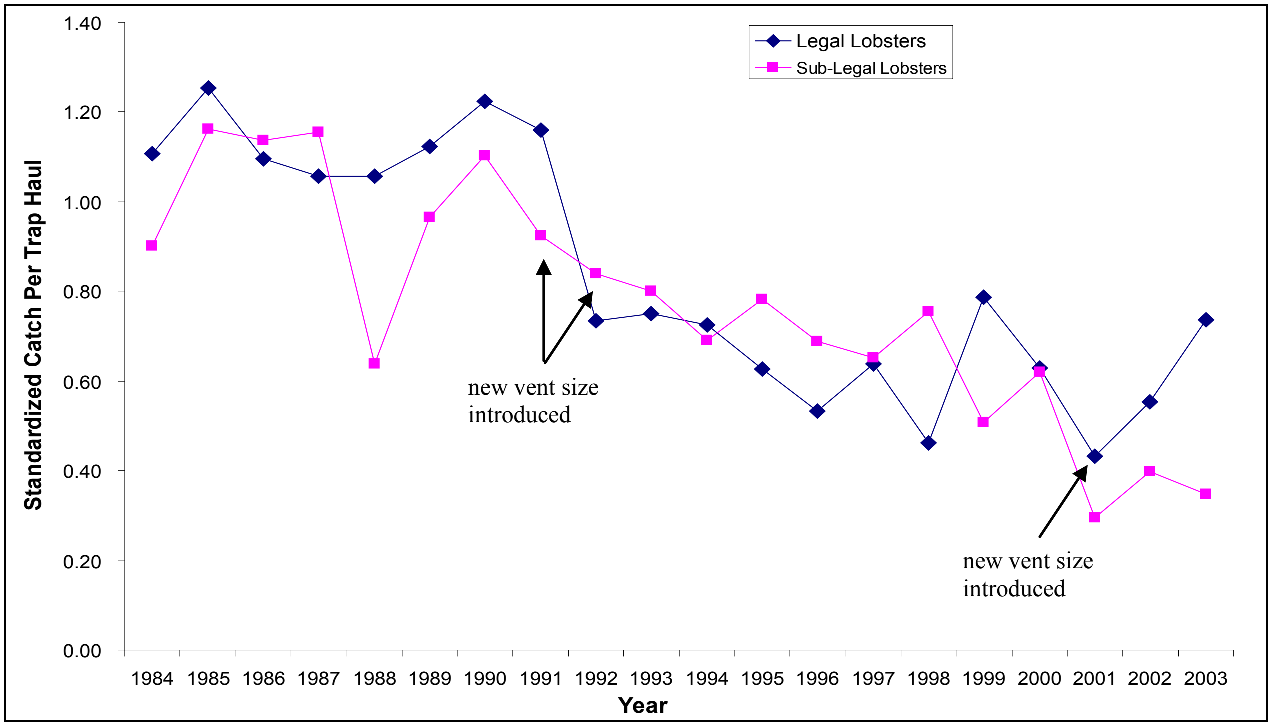

Figure 5. Catch per trap haul in Boston Harbor from the MADMF sea sampling program conducted for marketable (legal) lobsters, standardized to three set-over-days and non-marketable (sub-legal) lobsters, standardized to the same number of set-over-days.

Data Source: Robert Glenn, Coastal Lobster Investigations Project, MADMF, Pocasset, MA.

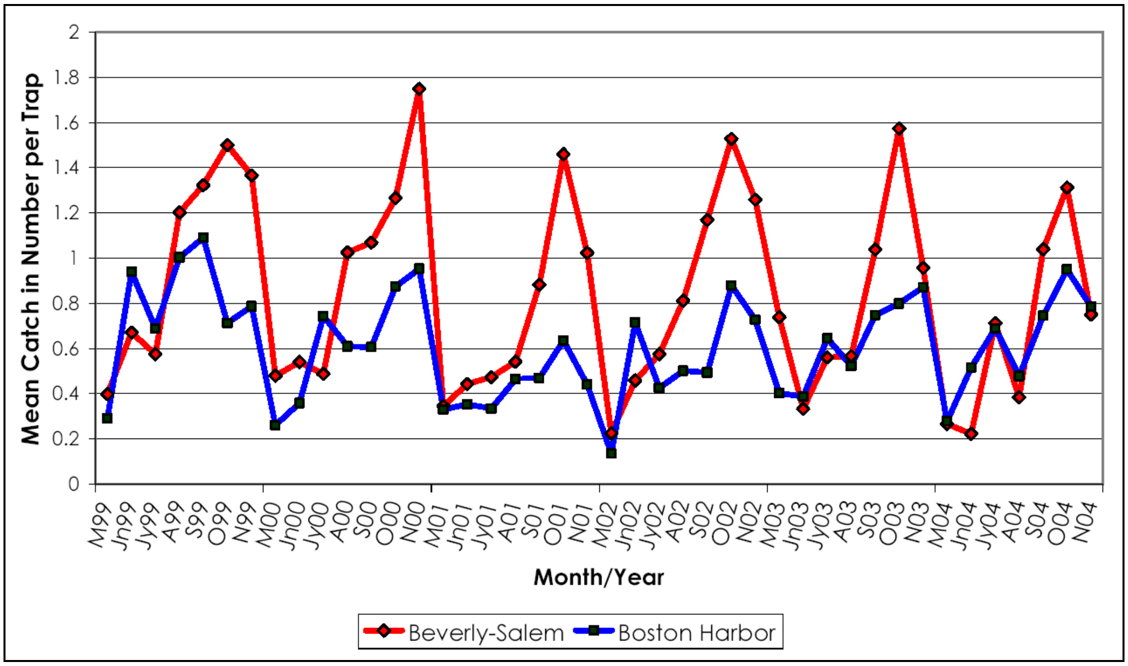

Figure 6. May-November sea sampling catch per trap haul standardized for three set-over days for Beverly-Salem and Boston Harbor for the years 1999-2004.

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).

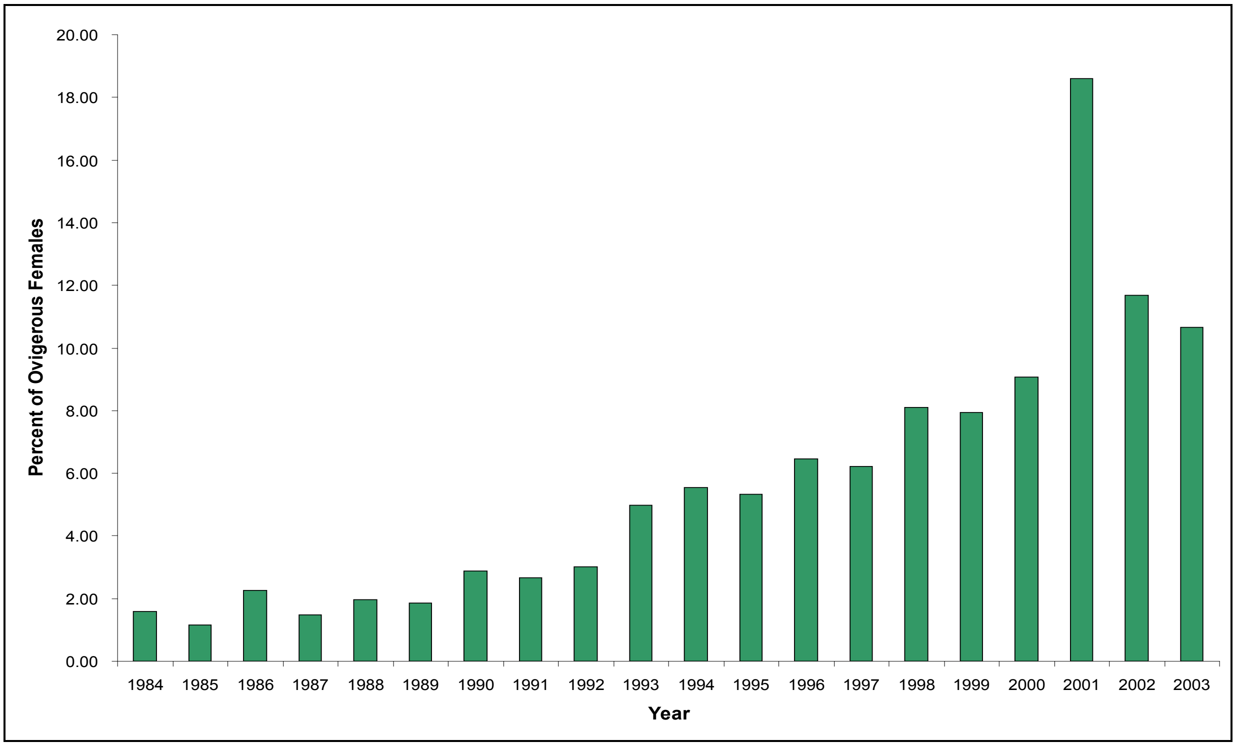

Figure 7. Percent of ovigerous females in the MADMF sea sampling program for Area 4 from 1984-2003.

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.

Area 4 was further subdivided into four subregions A, B, C, and D (see Figure 9) to show any potential variance in the project area from the remaining subregions. No trend was apparent in the marketable size of lobsters for any of the subregions. As mentioned above, the overall trend in the number of lobsters (including the ovigerous females and sublegal sized lobsters) caught is declining. It appears that the catch of ovigerous lobsters is greater in subregion B than in the other subregions, suggesting that this area may have a higher proportion of ovigerous female lobsters (see Figure 10). It also appears that the catch of sub-legal lobsters is greater in the outer subregions, suggesting that these areas may have a higher proportion of sub-legal lobsters (see Figure 11). However, it is important to note that only a small fraction of lobsters present in an area will actually be collected in traps, and to determine the actual abundance of ovigerous females or sub-legal lobster would require a different type of experimental design and more sophisticated statistical analysis. The 2005 ventless trap survey by MA DMF seeks an alternative methodology to assess sub-adult and adult populations. Even so, initial data suggest that the trends seen in subregion B are representative, as the percentage of female lobsters, both sub-legal and legal sized, is greater at the Outer Harbor sampling sites than it is at the Inner Harbor sites for all seasons (Figure 12). However, there is less variability by season in the

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[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).

proportion of female sub-legal lobsters, but this is not the case for female legal sized lobsters. Legal sized females comprise more of the catch in spring and fall months than in summer months for most stations near the navigation channel whether in the Inner or Outer Harbor (Figure 13). Differences are even more dramatic when examining the percentage of sub-legal and legal sized females that are ovigerous: sub-legal ovigerous females are found in all seasons in low percentages, but mostly at the Outer Harbor sites abutting the navigational channel. In contrast, legal sized ovigerous females are found only in summer months at Inner Harbor sites that abut the navigation channel. Whether these differences in abundance are due to inherent differences between sites or are reflective of behavioral differences between ovigerous and non-ovigerous females is unknown, but comparisons between abundances of these two groups of lobsters suggest the latter as an explanation.

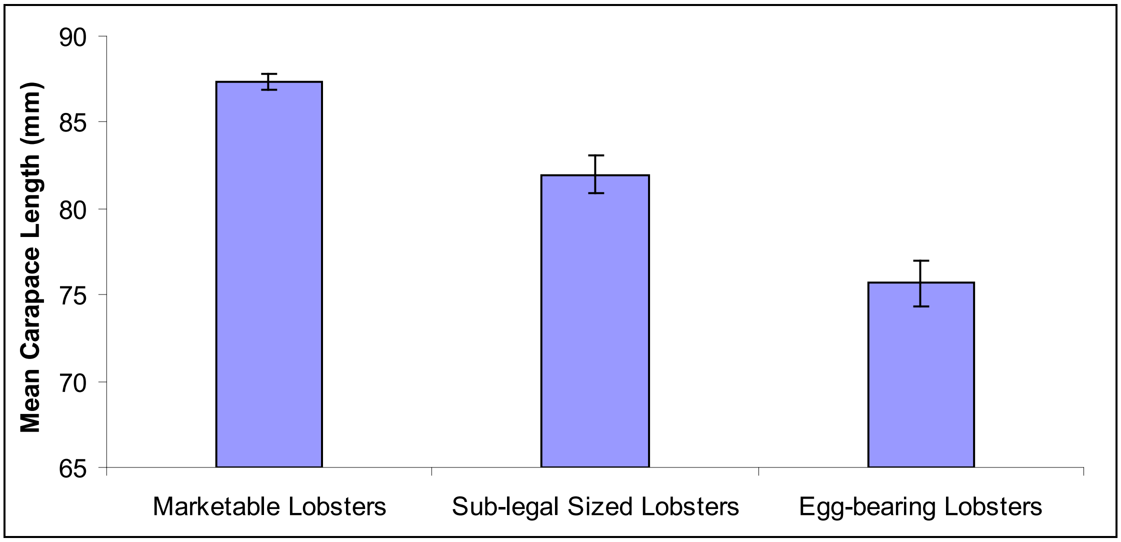


Figure 8. Mean carapace length of legal-sized (marketable), sub-legal sized, and ovigerous (egg-bearing) females represented in the MADMF sea sampling program for Area 4 from 1984 to 2003.

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

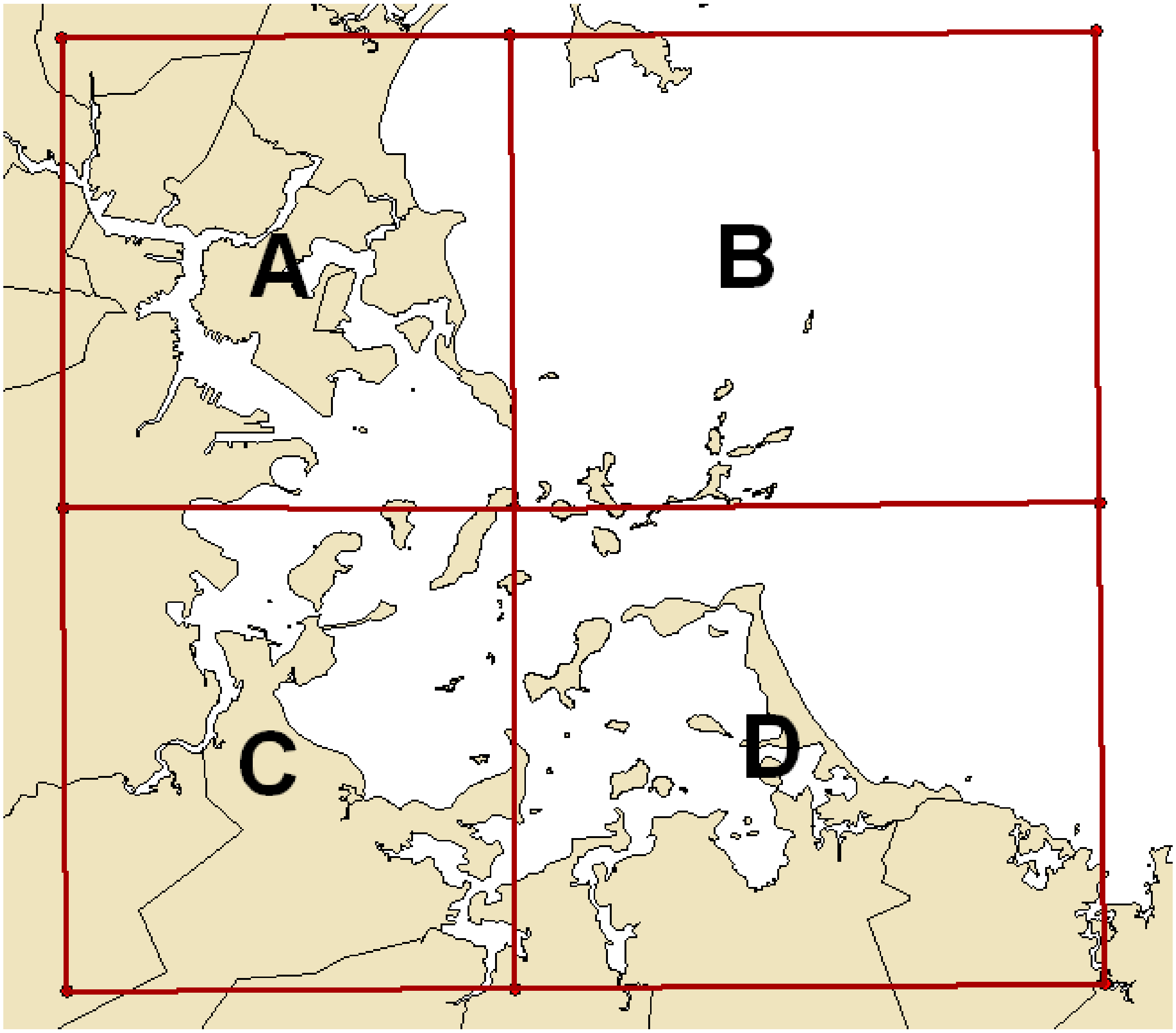


Figure 9. Location of Subregions A, B, C, and D in Area 4

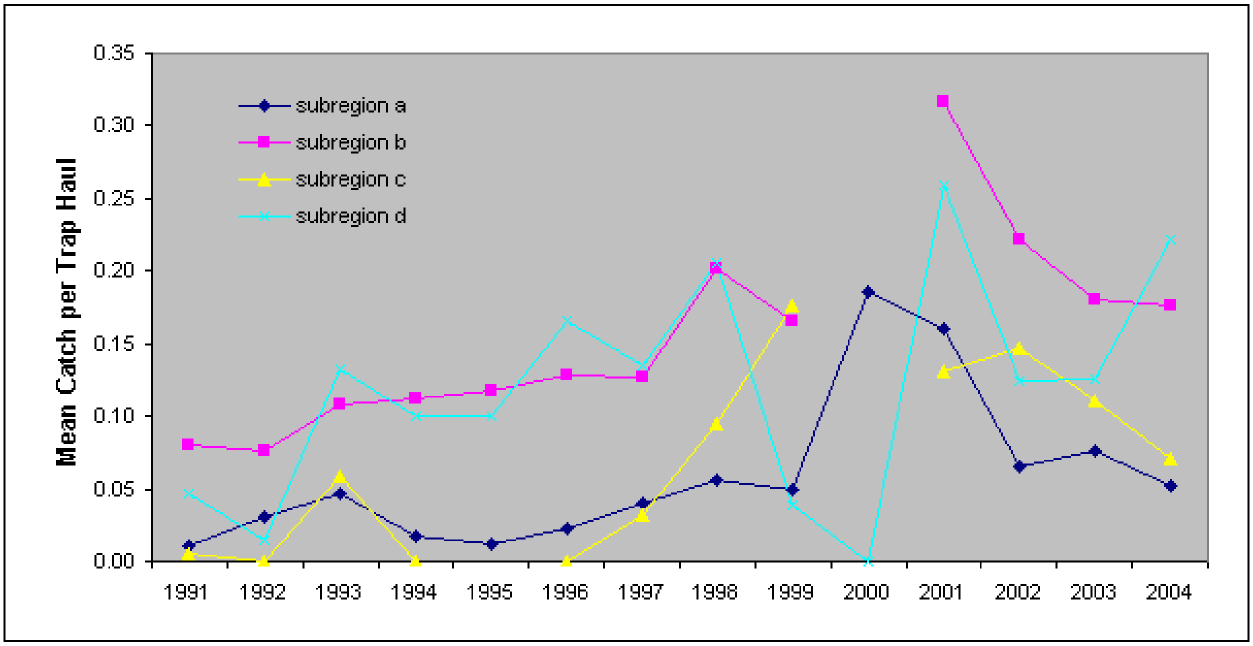


Figure 10. Mean Catch per Trap Haul for Ovigerous Females from Subregions A, B, C, and D in Area 4.

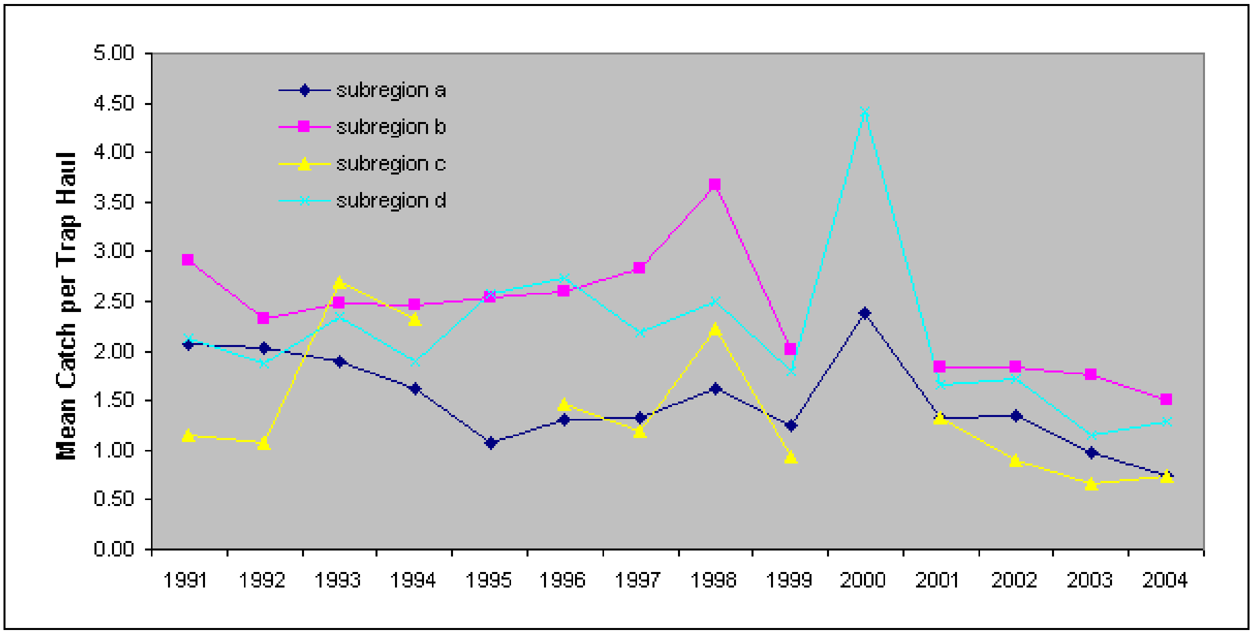
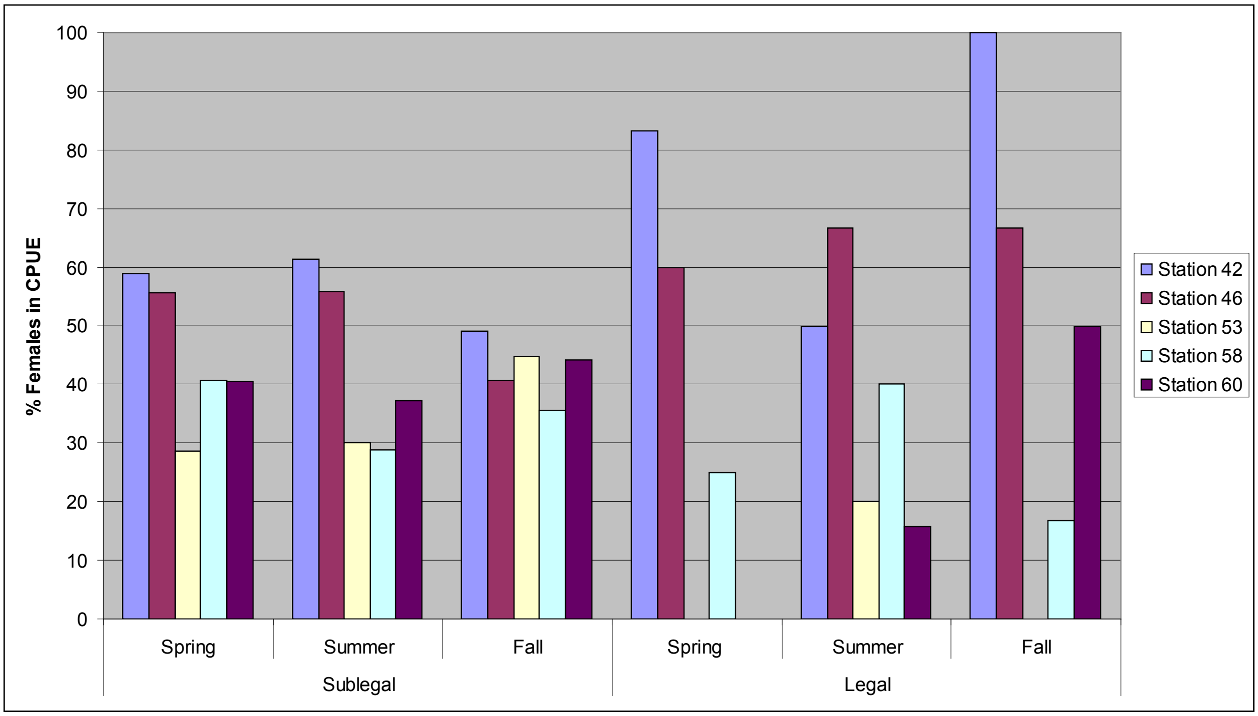
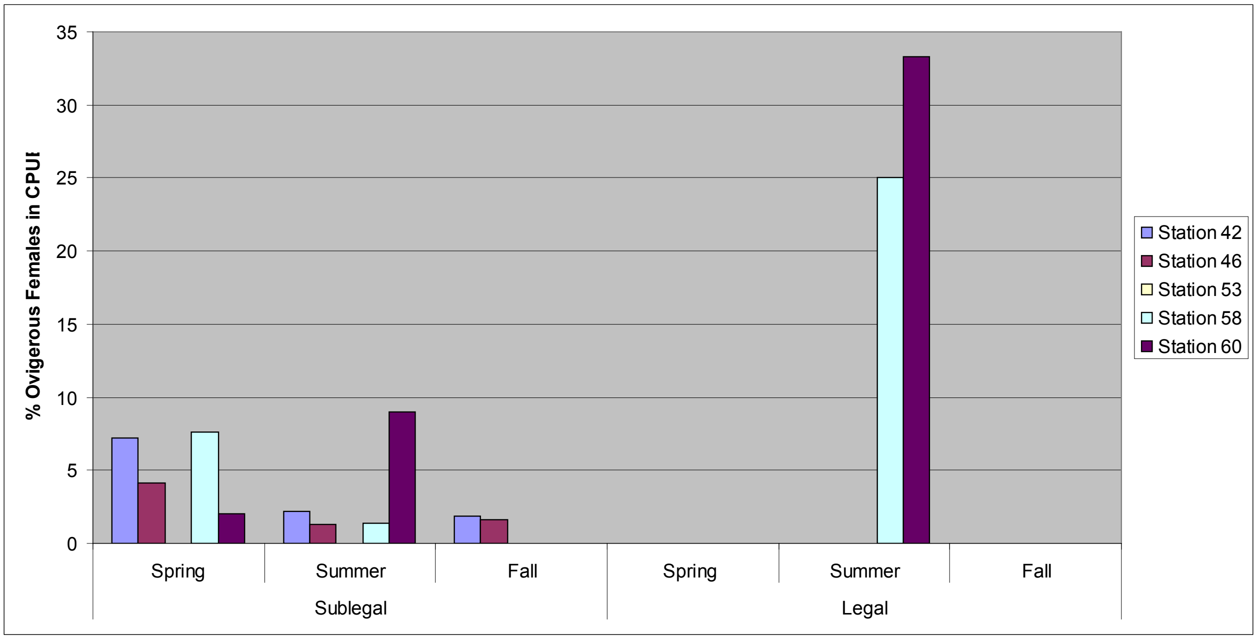


Figure 11. Mean Catch-per-Trap Haul for Sub-legal Sized Lobsters from Subregions A, B, C, and D in Area 4



Source: Robert Glenn, Coastal Lobster Investigations Project, MA DMF, Pocasset, MA.

Figure 12. Percent Females Sampled in the 2005 MA DMF Ventless Survey for Stations in the Vicinity of the Navigation Channel



Source: Robert Glenn, Coastal Lobster Investigations Project, MA DMF, Pocasset, MA.

Figure 13. Percent Ovigerous Females in the 2005 MA DMF Ventless Survey for Stations in the Vicinity of the Navigation Channel

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, N-11 l 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,

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[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.

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 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 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 13). 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.

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 15).

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 16). 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 17). 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.

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[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.

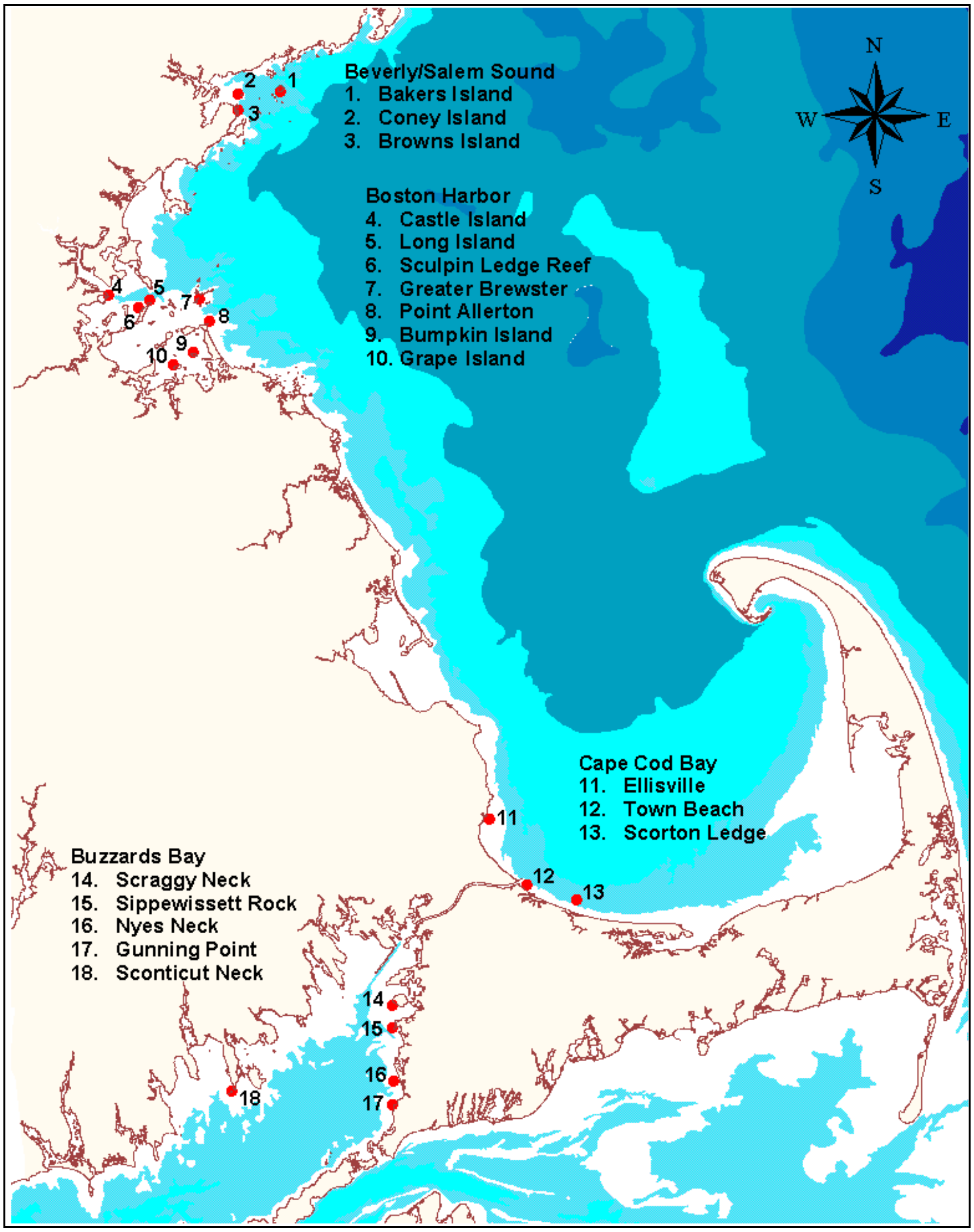

Figure 14. EBP sampling sites within Massachusetts State waters selected on the basis of the presence and quality of appropriate substrate at each location, as well as exposure to prevailing summer winds to ensure wind driven larval transport.

Data from Robert Glenn, Coastal Lobster Investigations Project, MADMF, Pocasset, MA.

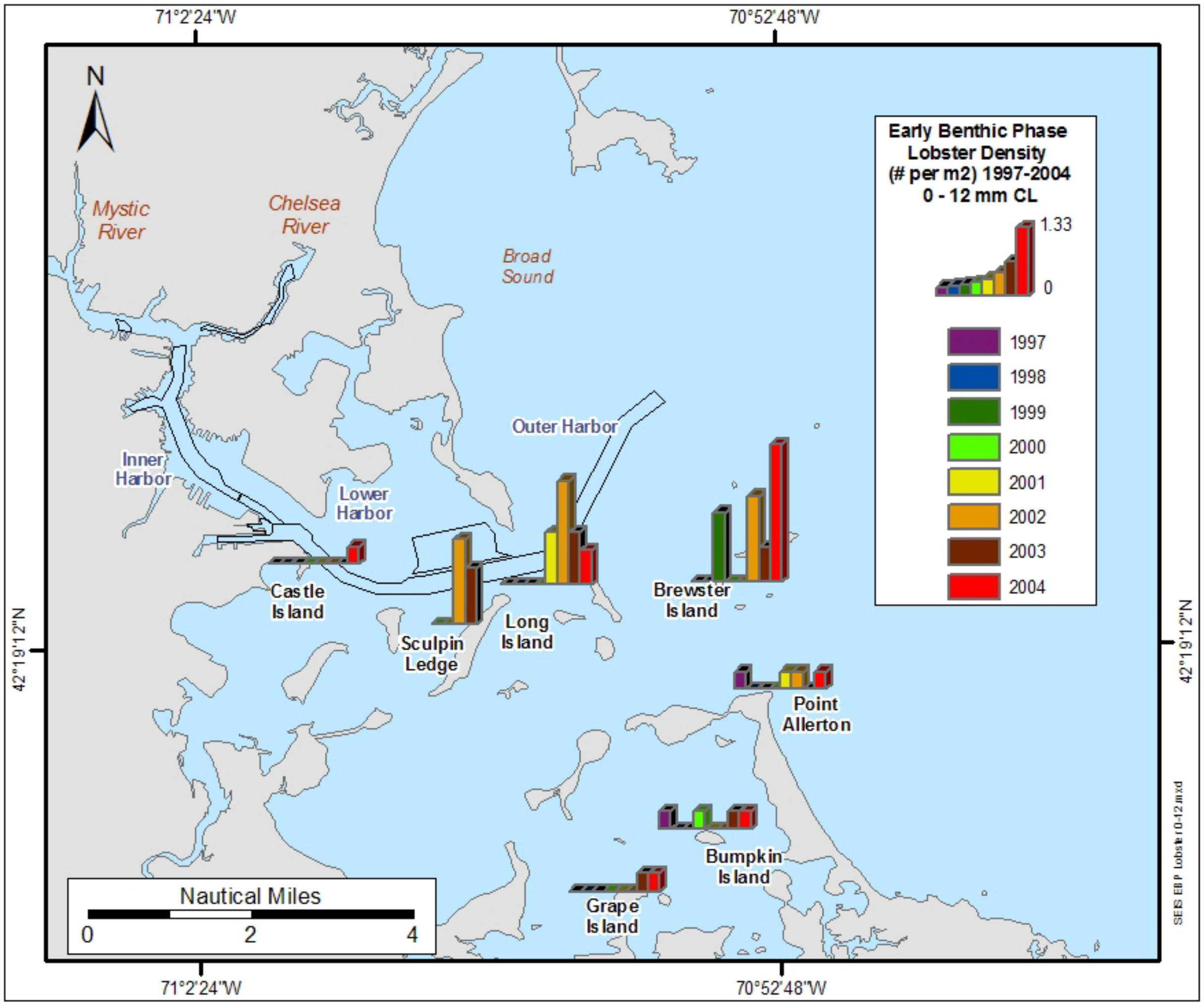

Figure 15. Average annual densities of EBP lobsters (0-12 mm CL) for sampling sites within Boston Harbor, 1997-2004.

Source: Robert Glenn, Coastal Lobster Investigations Project, MADMF, Pocasset, MA.

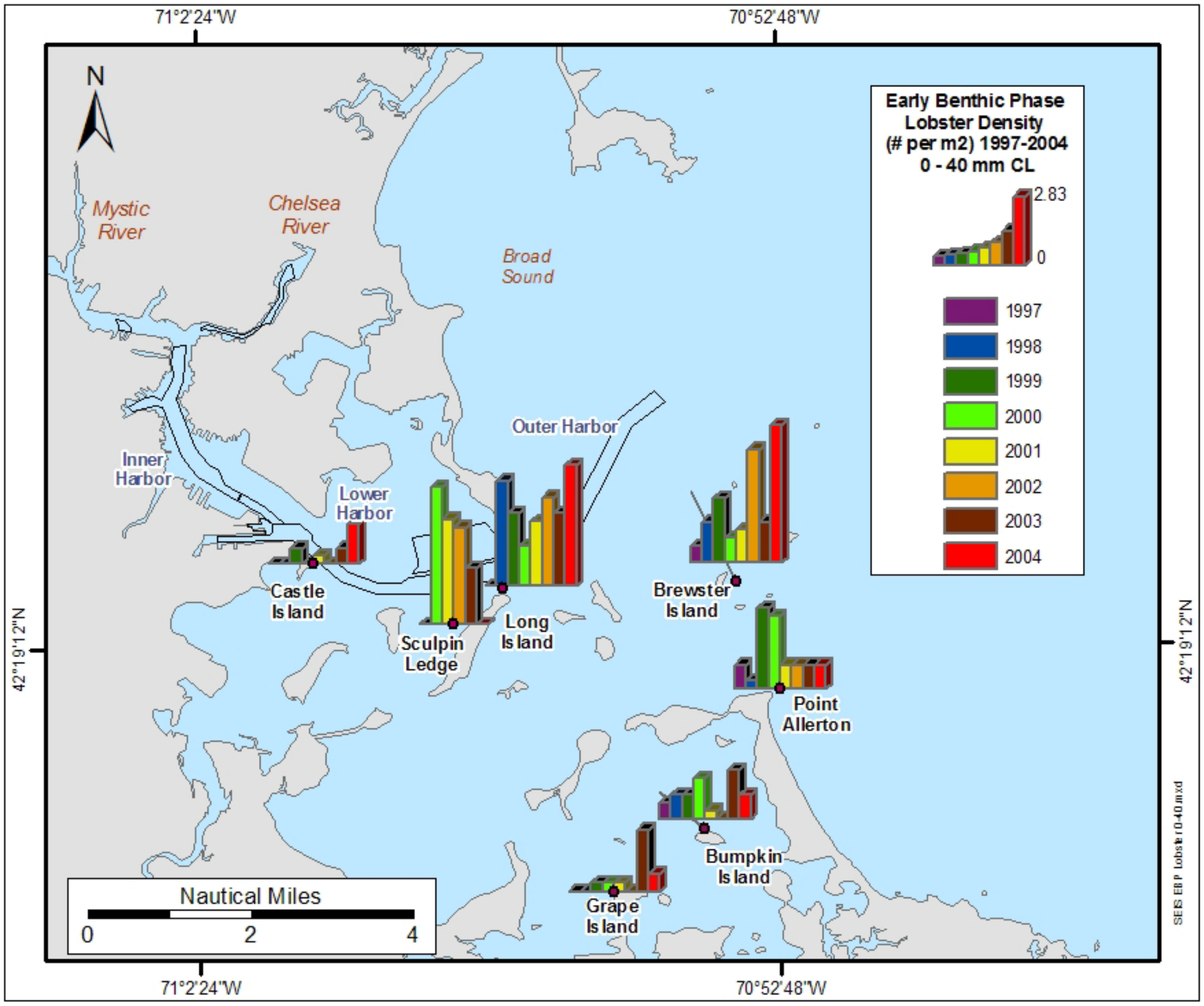

Figure 16. Average annual densities of EBP lobsters (0-40 mm CL) for sampling sites within Boston Harbor, 1997-2004.

Source: Robert Glenn, Coastal Lobster Investigations Project, MADMF, Pocasset, MA.

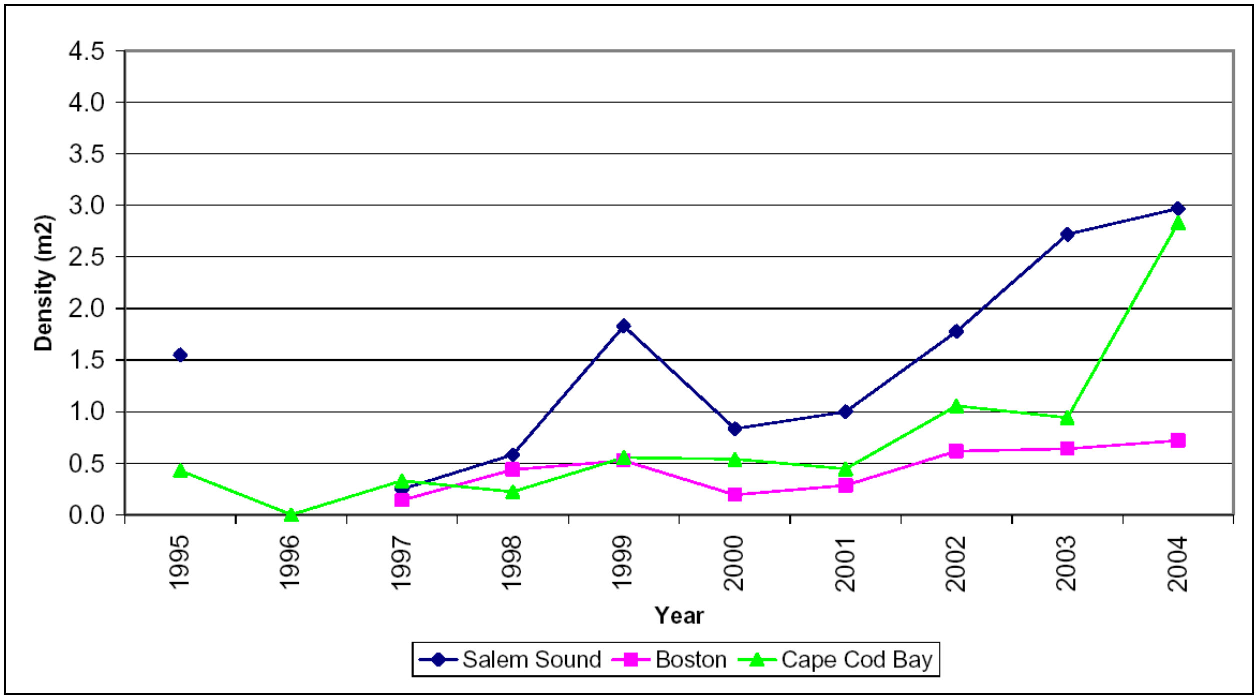

Figure 17. Densities of EBP lobsters (0-25 mm CL) in the Massachusetts portion of the Gulf of Maine.

Data Source: Robert Glenn, Coastal Lobster Investigations Project, MADMF, Pocasset, MA.

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 18). 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 18). 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 18).

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 19) 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

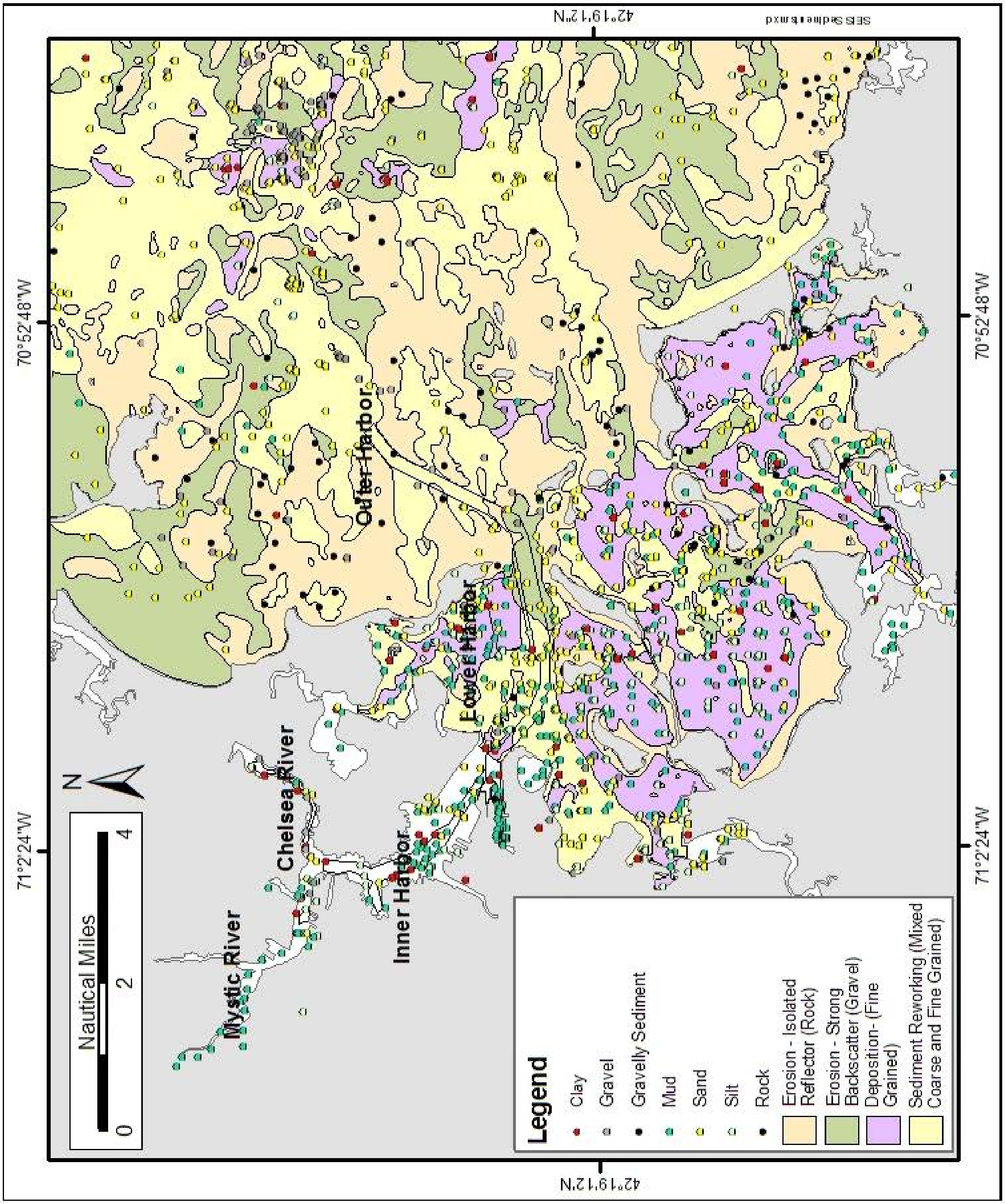

Figure 18. Sedimentary environments and sediment bottom type in Boston Harbor and Massachusetts Bay.

Note: Bottom type locations are approximate.
Data Source: USGS, 1999

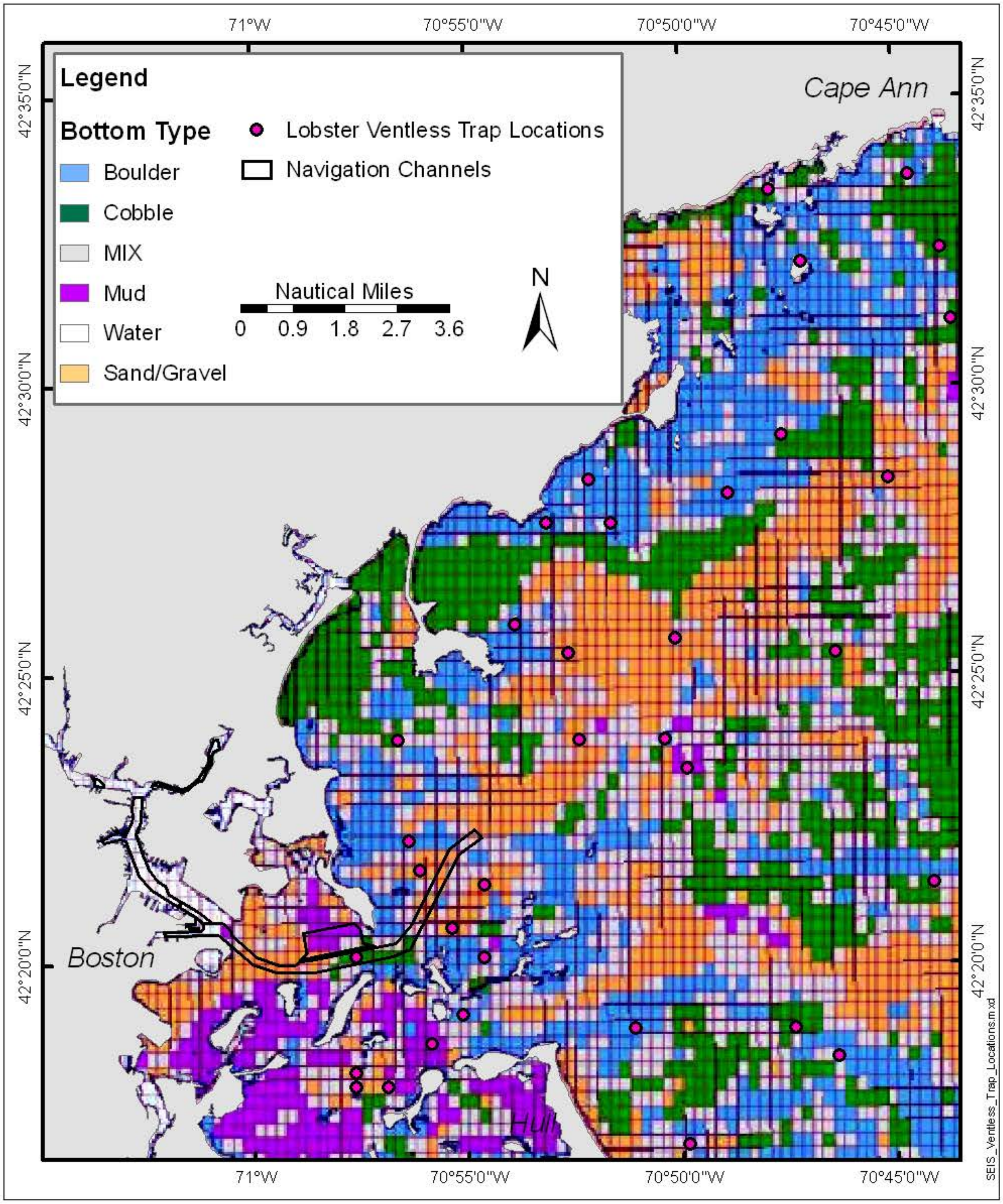

Figure 99. Map of the MADMF Massachusetts Bay ventless trap study area with the 2005 sample locations and strata.

Data Source: Glenn *et al.*, 2005.

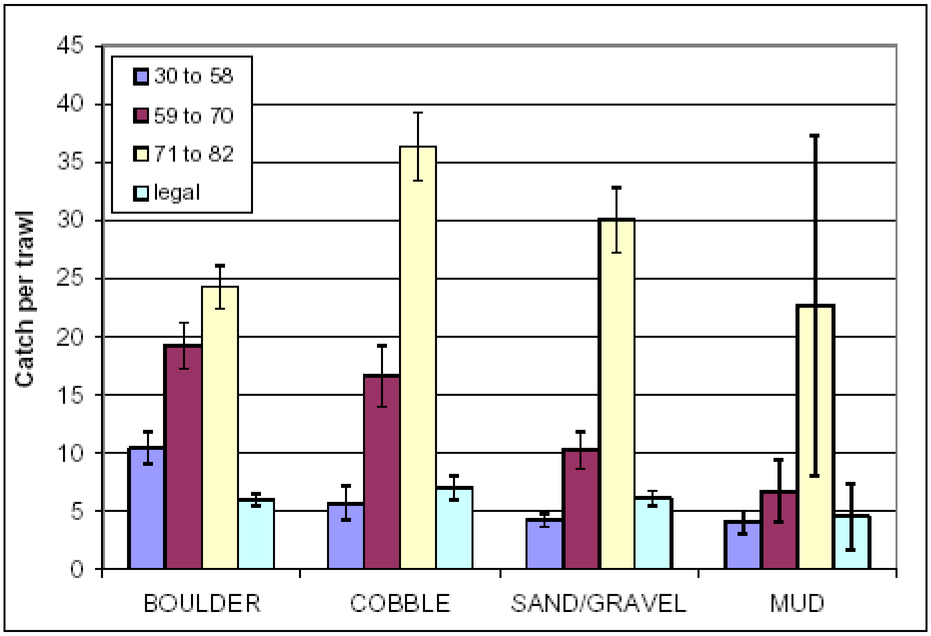

Figure 20. Catch-per-trawl during the ventless trap study of four size classes of lobster by sediment type: juveniles (30-58 mm CL), adolescents (59-70 mm CL), sub-legals (71-82 mm CL), and legal (>83 mm CL). Bars represent standard error.

Data Source: Glenn *et al.*, 2005.

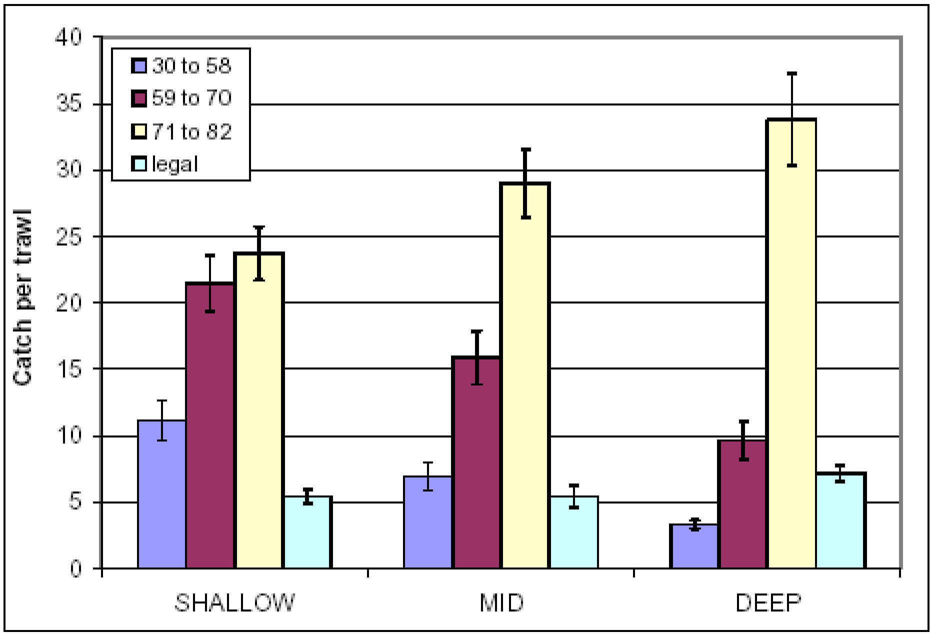

Figure21. Catch-per-trawl during the ventless trap study of four size classes of lobster by depth: juveniles (30-58 mm CL), adolescents (59-70 mm CL), sub-legals (71-82 mm CL), and legal (>83 mm CL); Shallow, 0-15 m; Mid, 16-30 m; Deep, >30 m. Bars represent standard error.

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 20), and were more common in shallow waters (0-15 m depth) (Figure 21). 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 18), 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.

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[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] $\quad$ 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] $\quad$ 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**.

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[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] $ER = EF_{(MOBILE6.2)} \text{ x } VMT/yr\ /907185$

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

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[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.

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[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

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[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

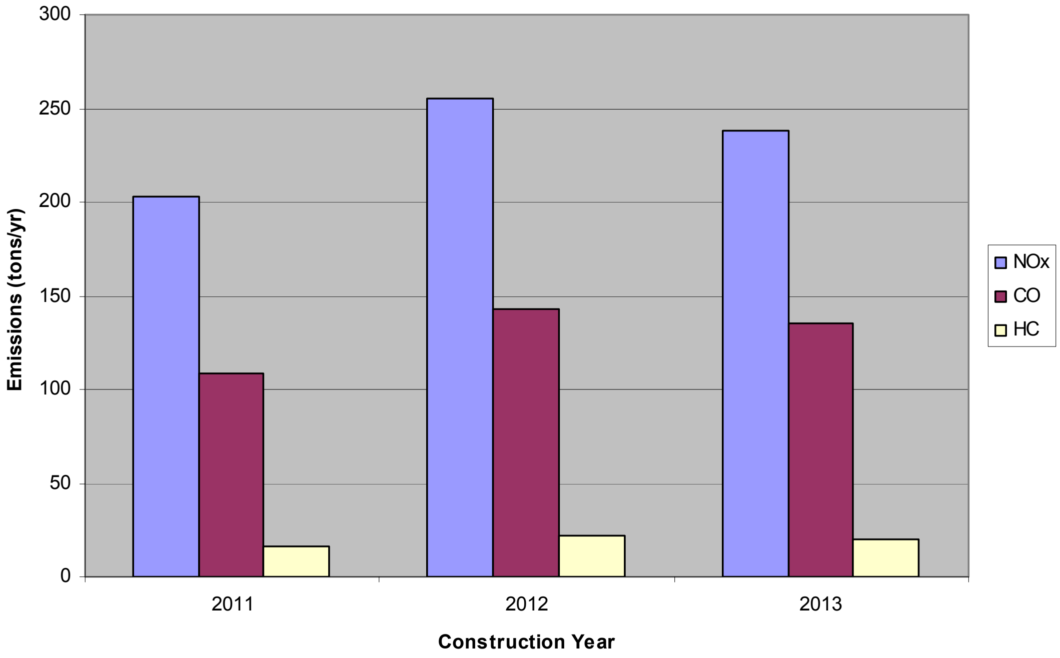


Figure O-2
Alternative 1 (45-Ft MLLW)
Emissions Reduction Option 1
Construction Total Emissions

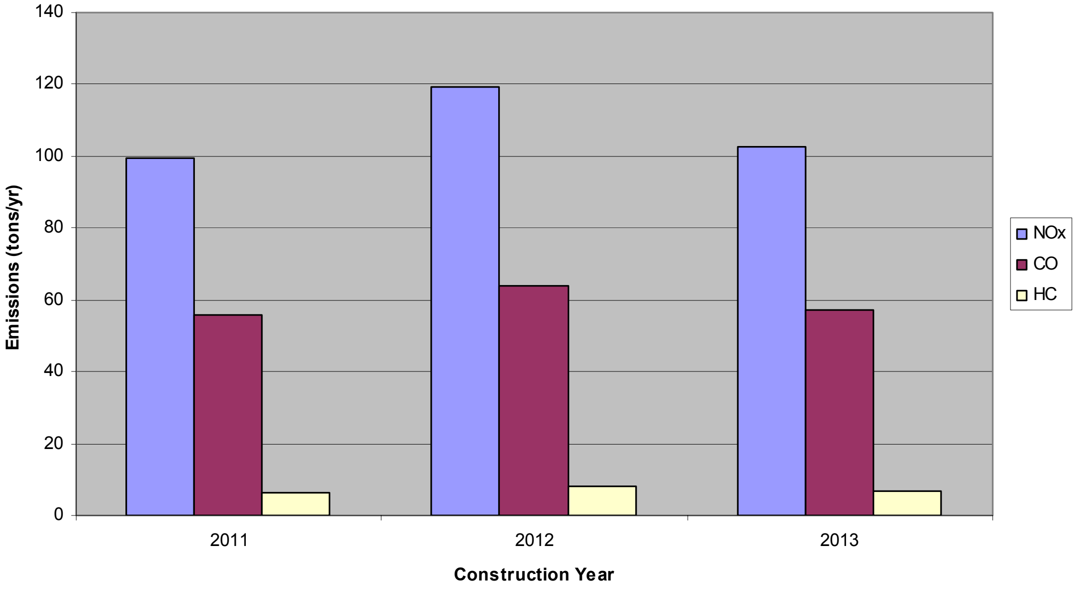
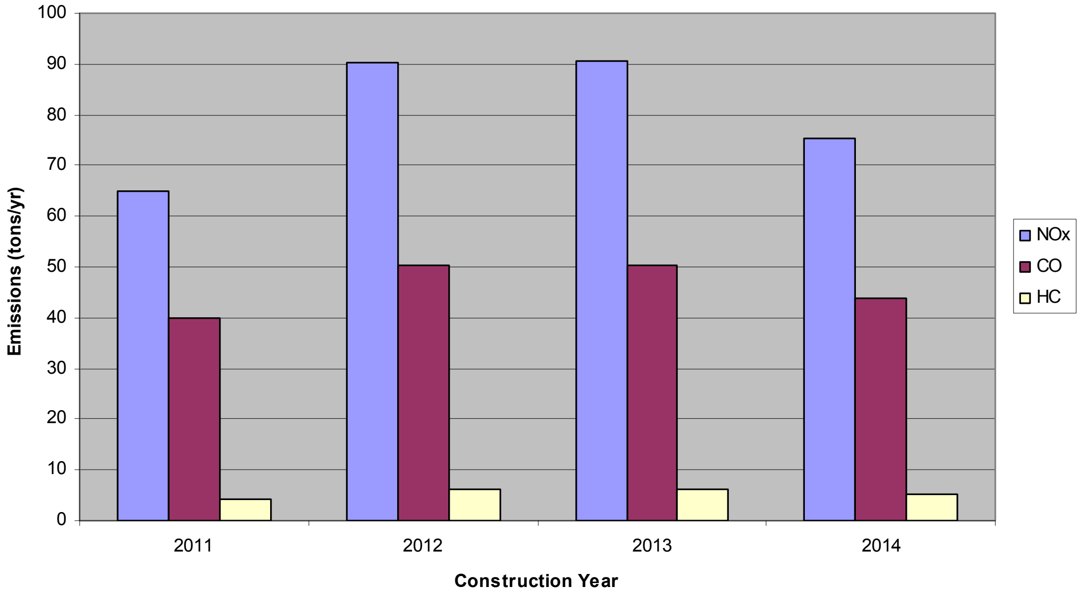


Figure O-3
Alternative 1 (45-Ft MLLW)
Emissions Reduction Option 2
Construction Total Emissions



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)												***General Conformity Thresholds (tons/yr)***
Year	***Pollutant***	***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	$PM_{2.5}$	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

		Emissions (tons/yr)												General Conformity Thresholds (tons/yr)
Year	Pollutant	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

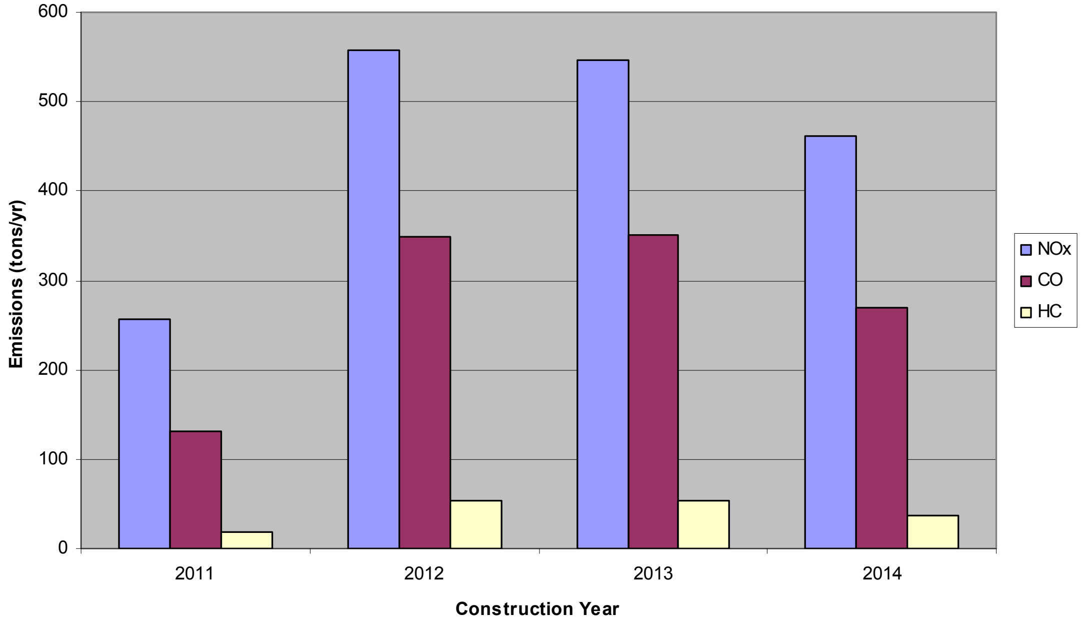
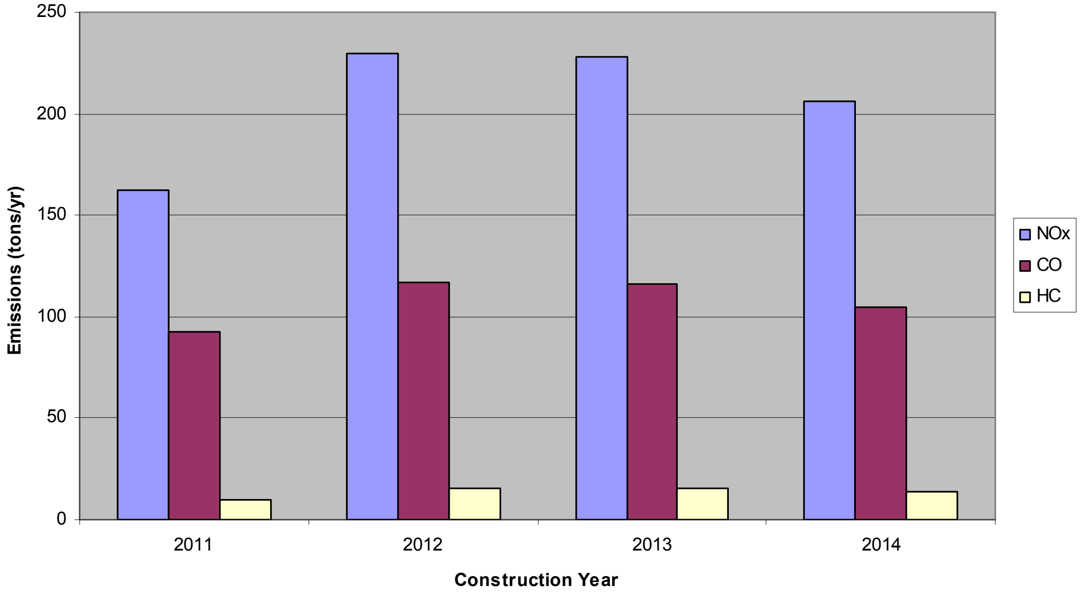
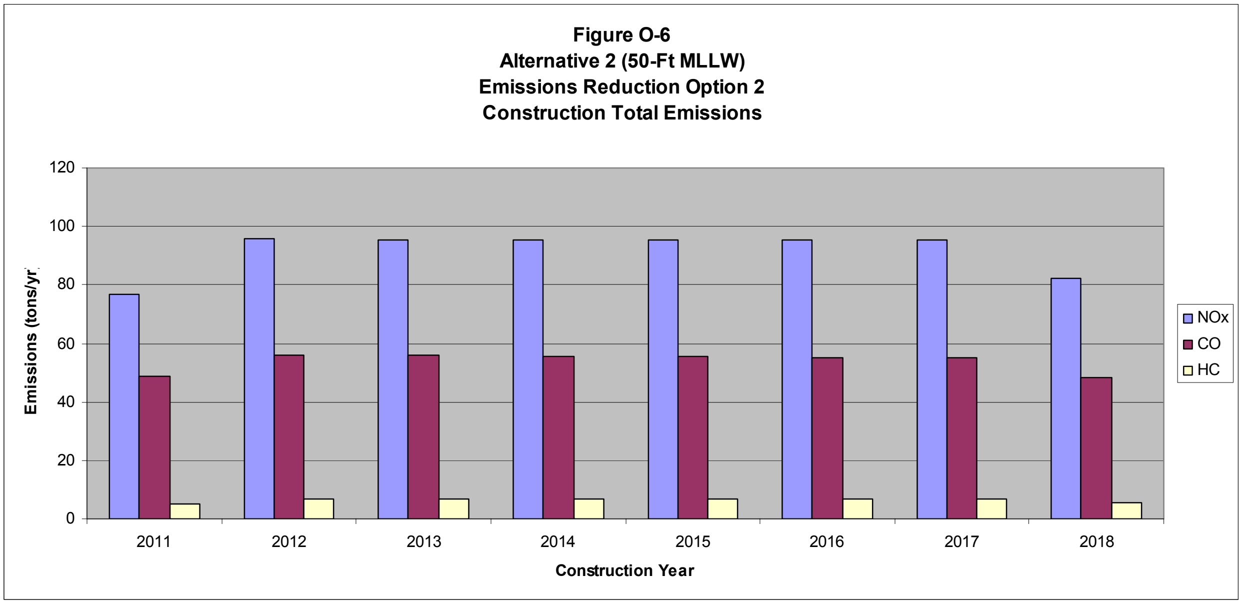


Figure O-5
Alternative 2 (50-Ft MLLW)
Emissions Reduction Option 1
Construction Total Emissions





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.

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[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

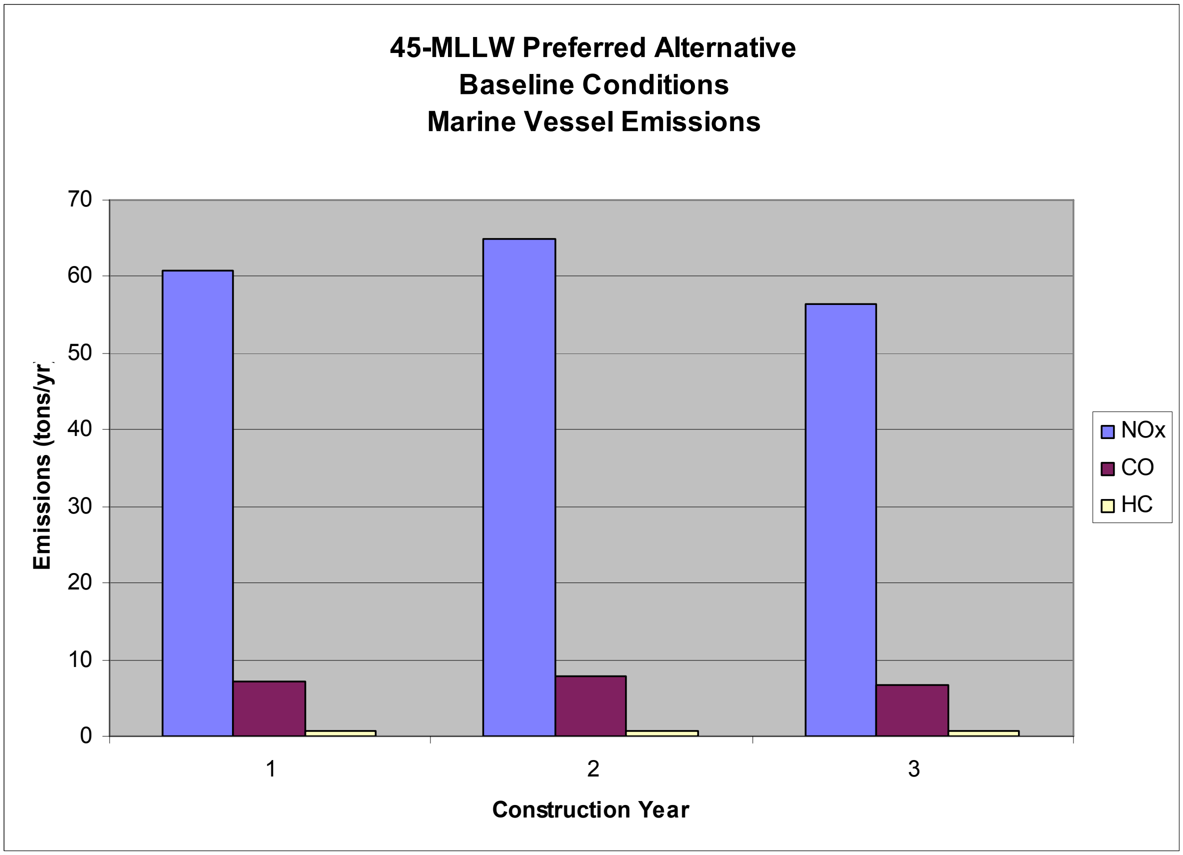
PART 1

DIRECT EMISSIONS CALCULATIONS

ALTERNATIVE 1

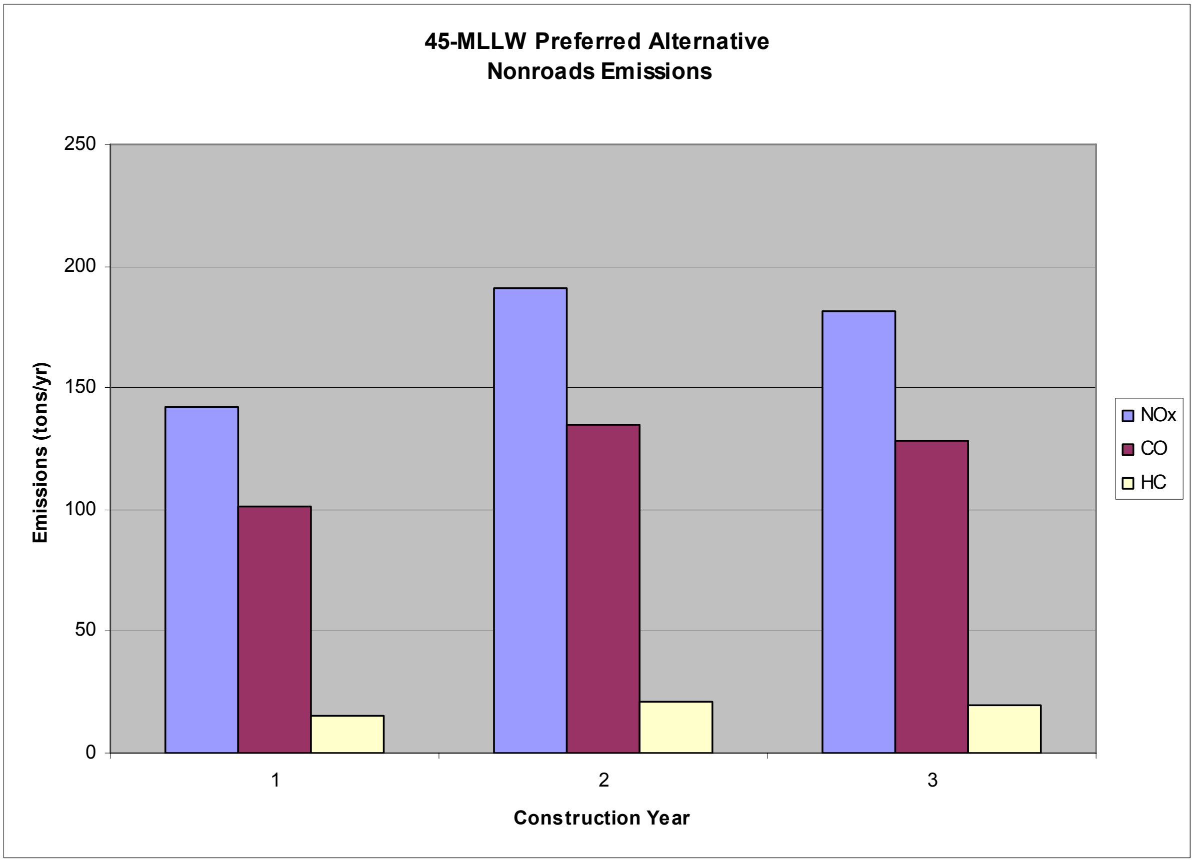
Boston Harbor, Massachusetts - Navigation Improvement Study
45-MLLW Depth Preferred Alternative
Uncontrolled Conditions
Marine Vessel Total Emissions

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



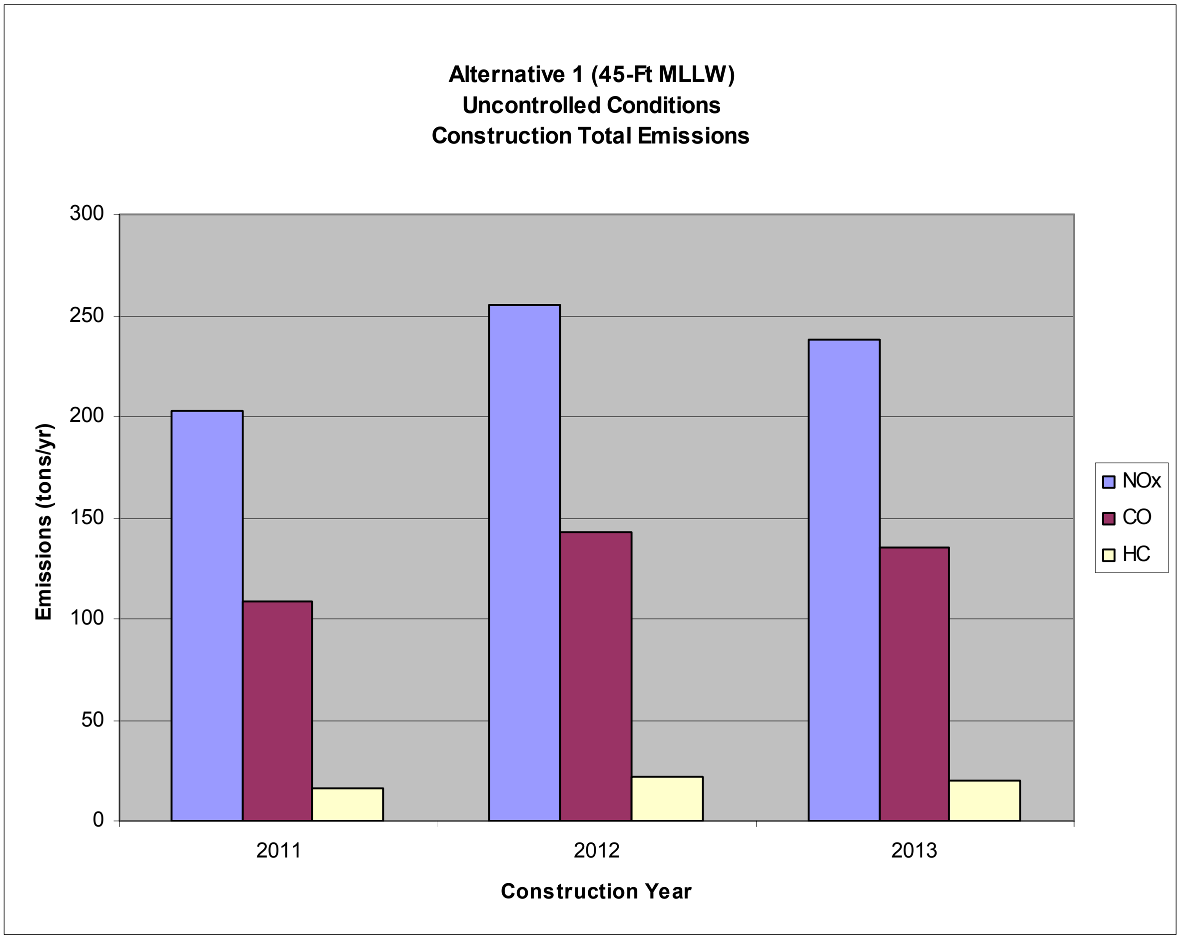
Boston Harbor, Massachusetts - Navigation Improvement Study
45-MLLW Preferred Alternative
Uncontrolled Conditions
Nonroads Equipment Total Emissions (tons/yr)

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



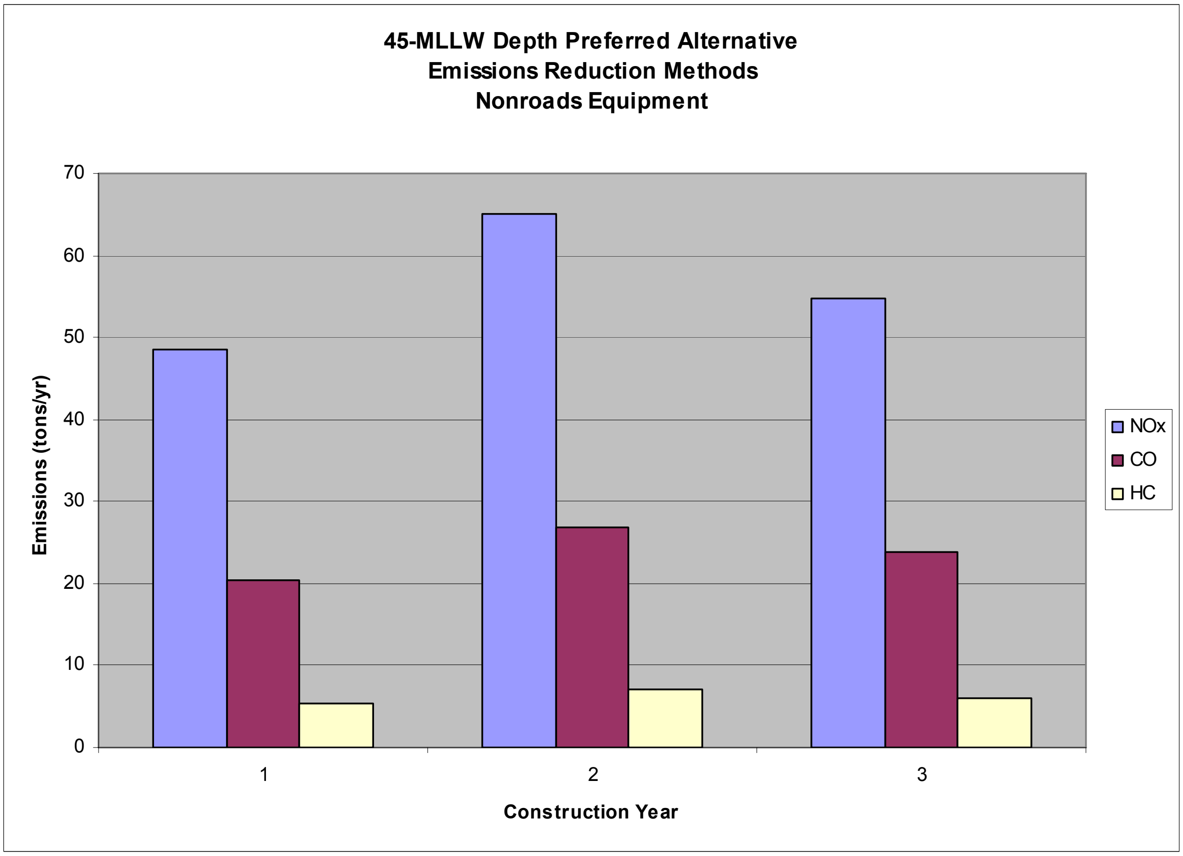
Boston Harbor, Massachusetts - Navigation Improvement Study
45-MLLW Preferred Alternative
Uncontrolled Conditions
Summary of Total Annual Emissions (tons/yr)

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



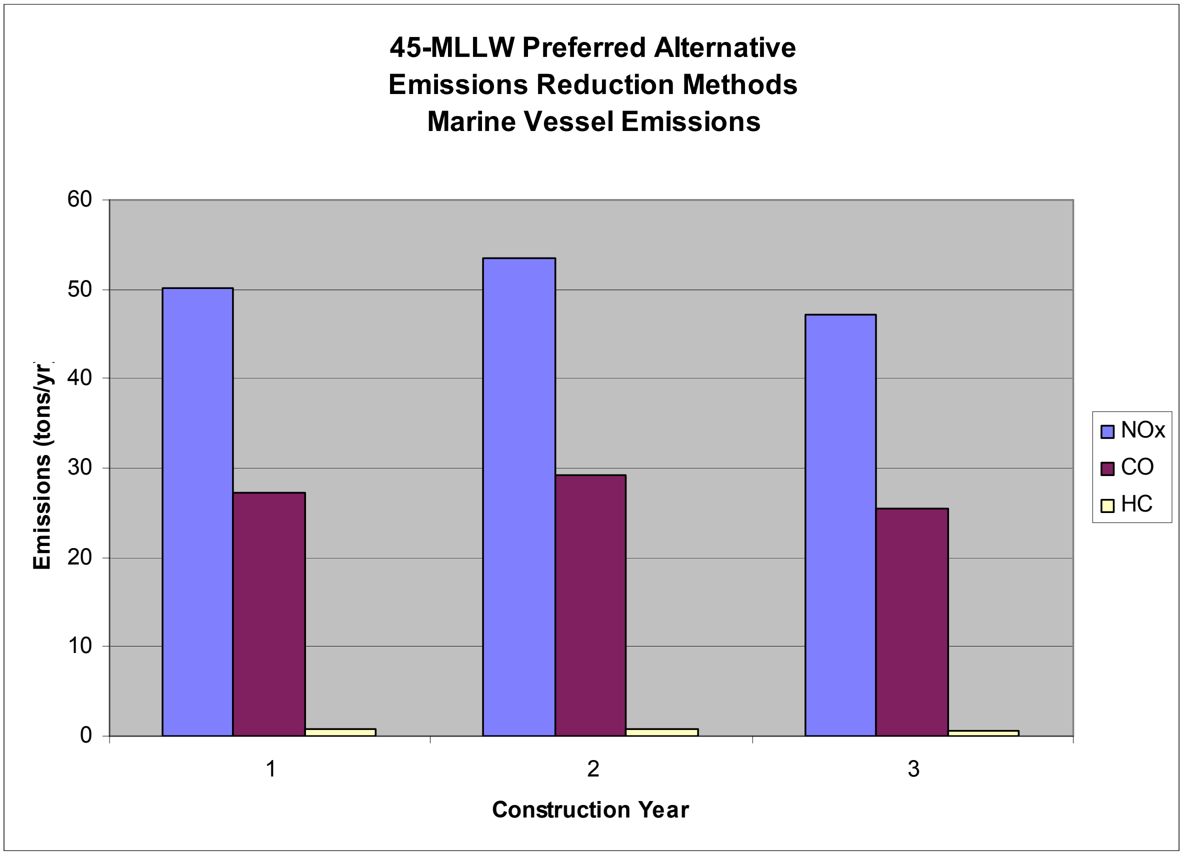
Boston Harbor, Massachusetts - Navigation Improvement Study
45-MLLW Depth Preferred Alternative
Emissions Reduction Methods
Nonroads Equipment Total Emissions (tons/yr)

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



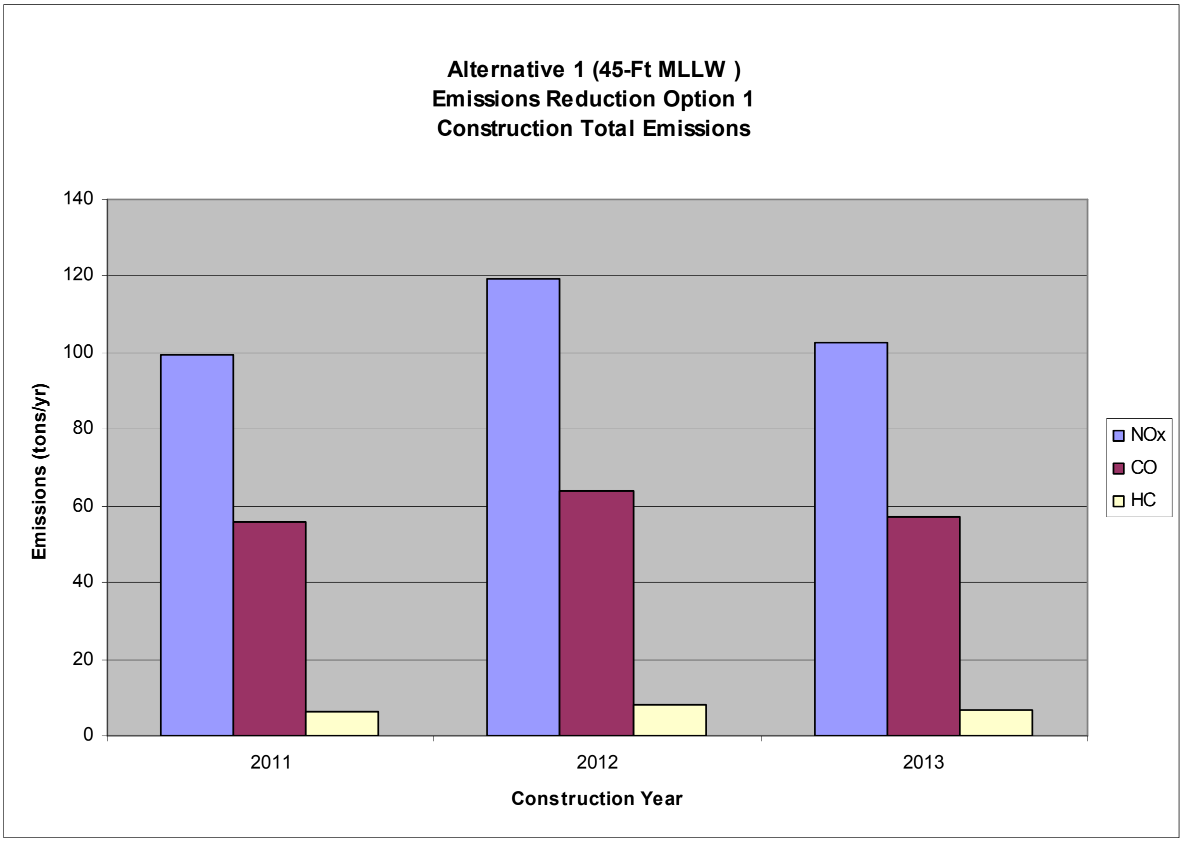
Boston Harbor, Massachusetts - Navigation Improvement Study
45-MLLW Depth Preferred Alternative
Emissions Reduction Methods
Marine Vessel Total Emissions

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



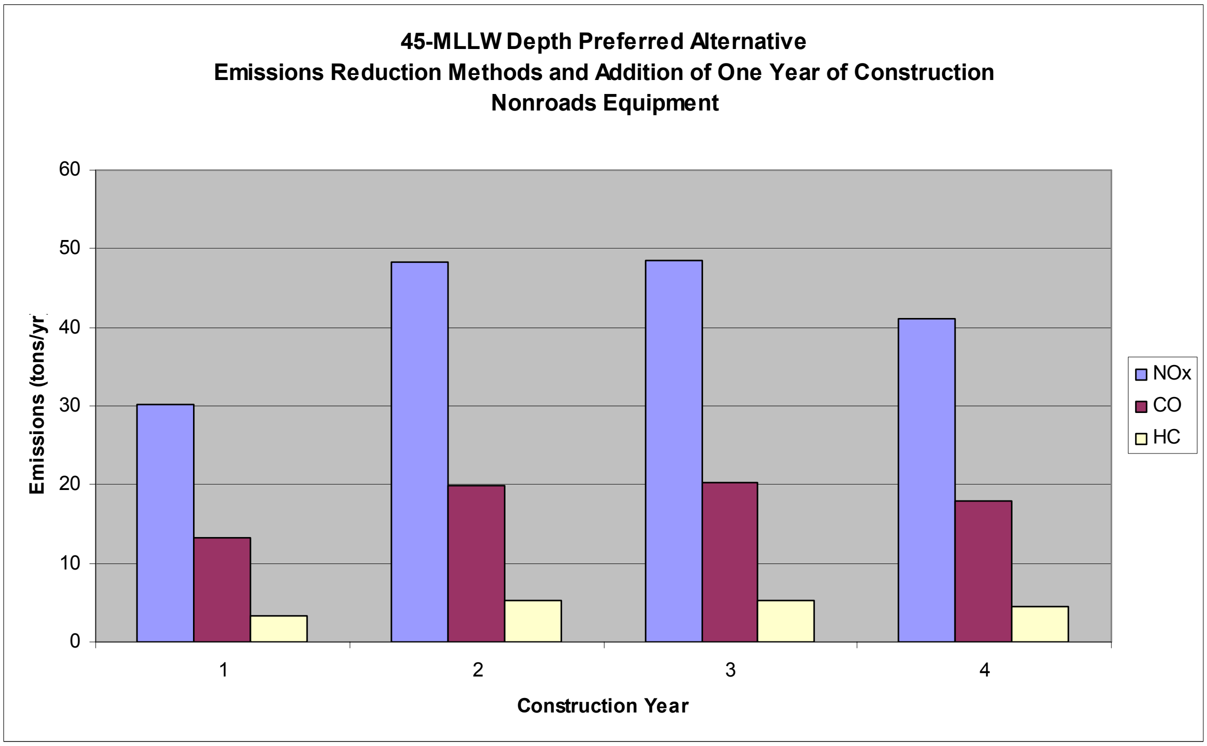
Boston Harbor, Massachusetts - Navigation Improvement Study
45-MLLW Depth Preferred Alternative
Emissions Reduction Methods
Summary of Total Annual Emissions (tons/yr)

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



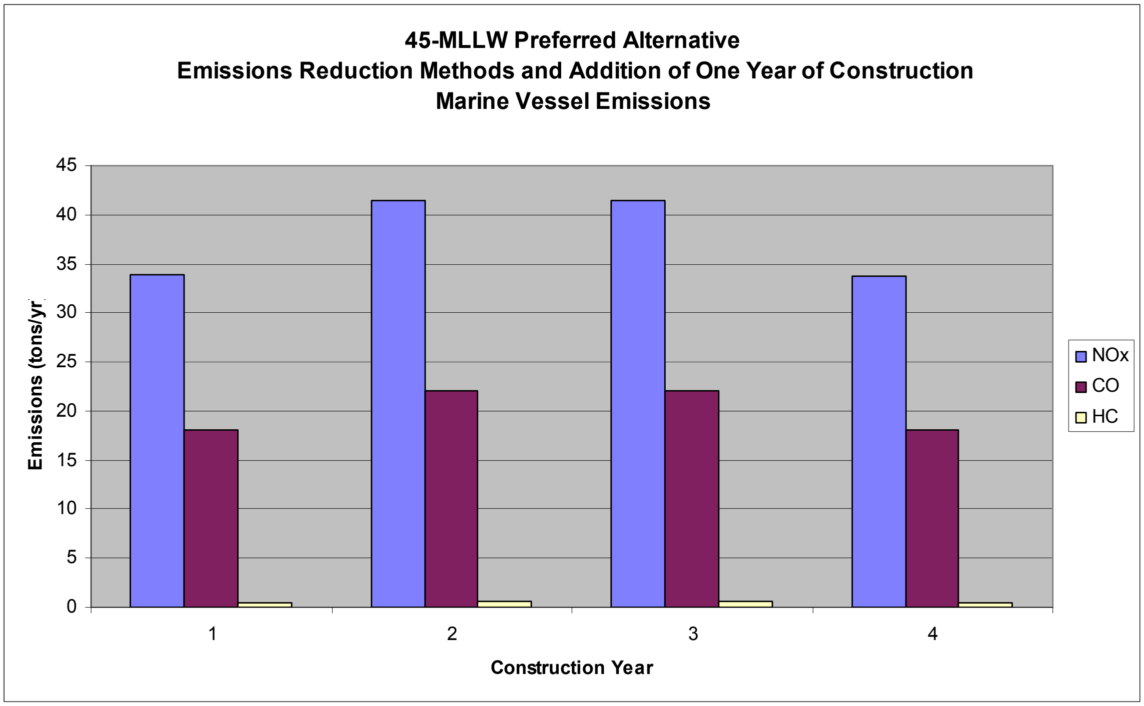
Boston Harbor, Massachusetts - Navigation Improvement Study
45-MLLW Depth Preferred Alternative
Emissions Reduction Methods and Addition of One Year of Construction
Nonroads Equipment Total Emissions (tons/yr)

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



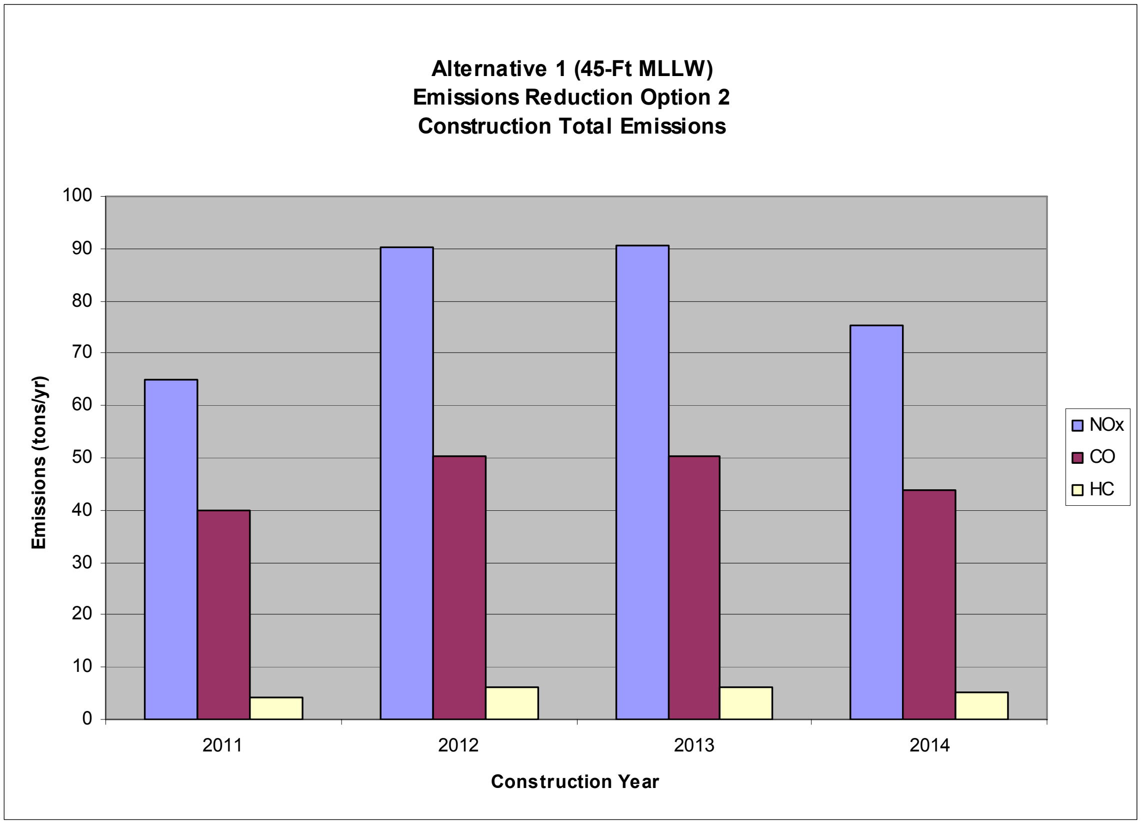
Boston Harbor, Massachusetts - Navigation Improvement Study
45-MLLW Depth Preferred Alternative
Emissions Reduction Methods and Addition of One Year of Construction
Marine Vessel Total Emissions

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

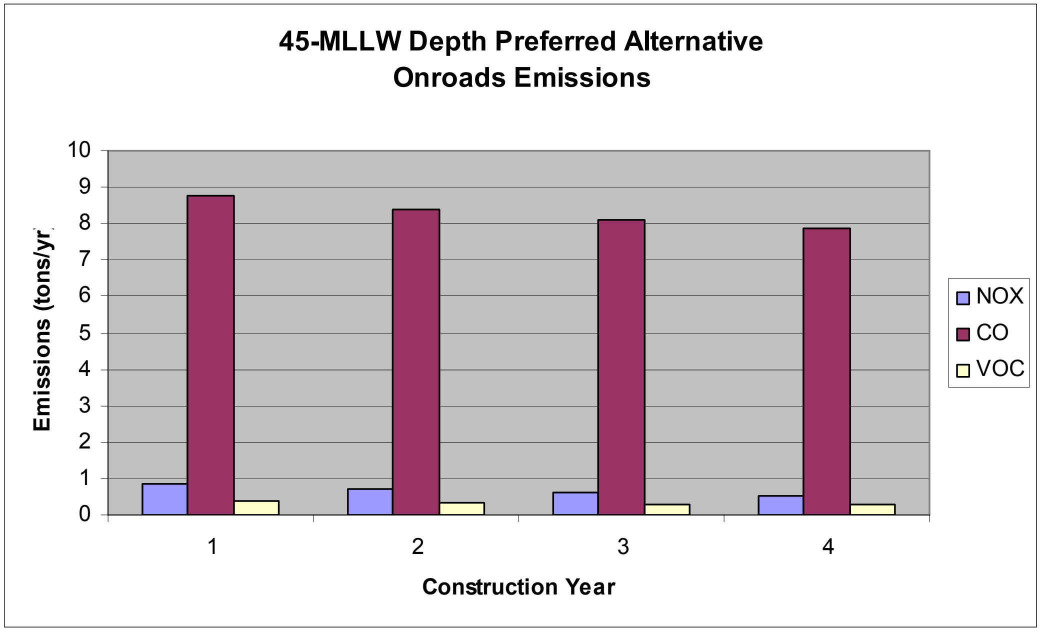
45-MLLW Depth Preferred Alternative Vehicle Trips Data

	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.



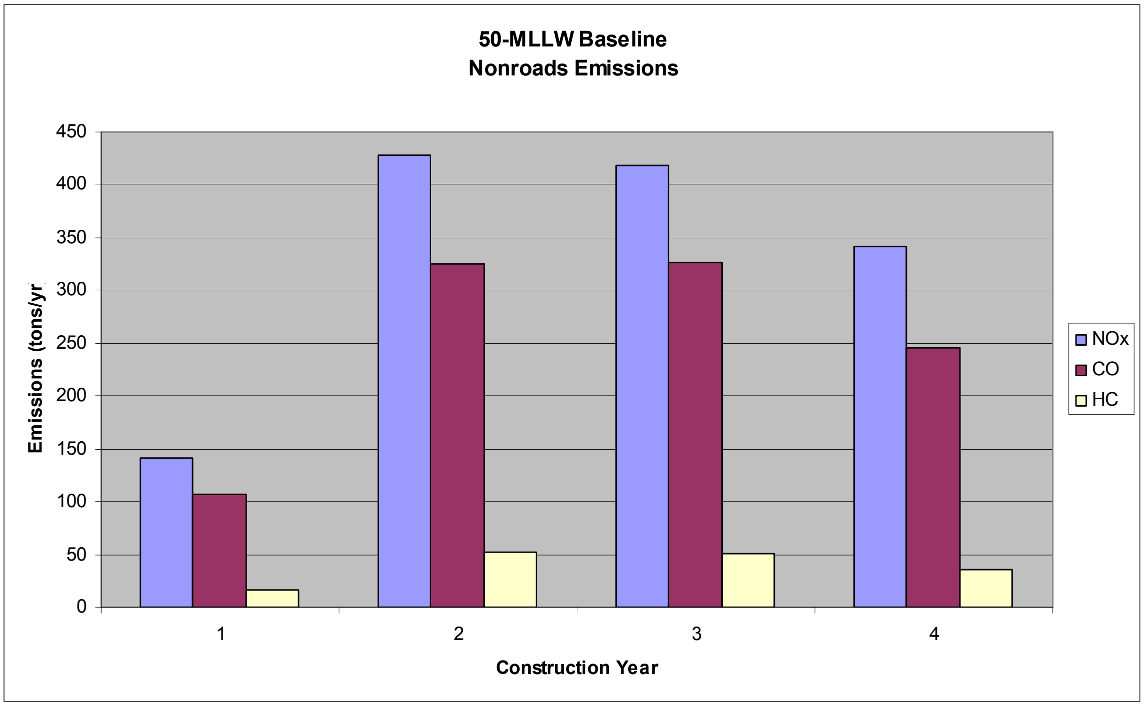
PART 2

DIRECT EMISSIONS CALCULATIONS

ALTERNATIVE 2

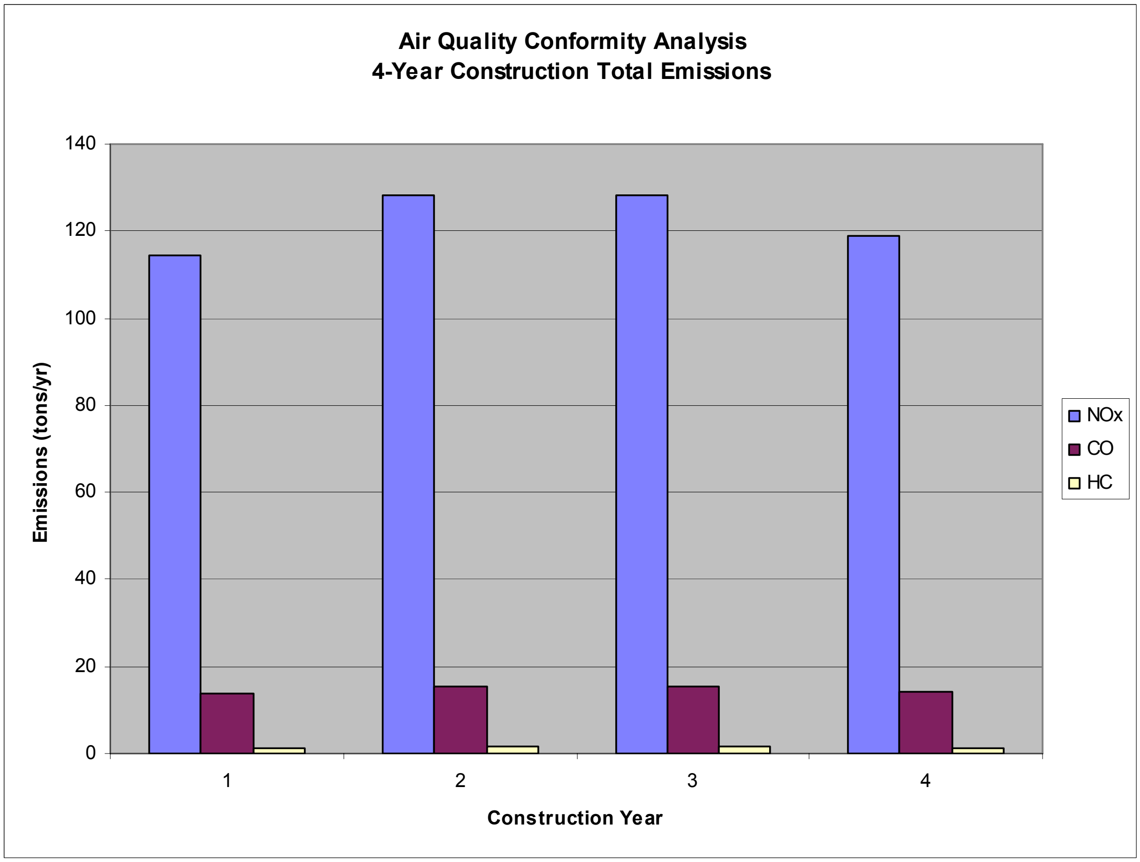
Boston Harbor, Massachusetts - Navigation Improvement Study
50-MLLW Uncontrolled
Nonroads Equipment Total Emissions (tons/yr)

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



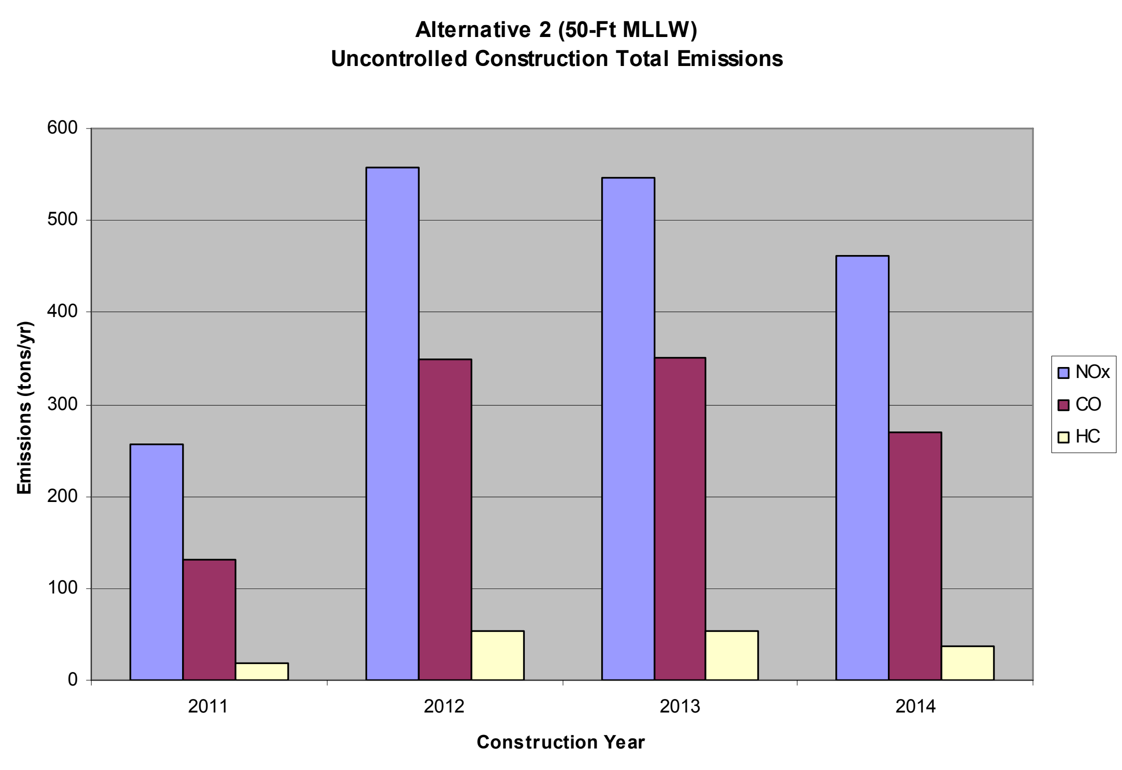
Boston Harbor, Massachusetts - Navigation Improvement Study
50-MLLW Uncontrolled
Marine Vessel Total Emissions (tons/yr)

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**



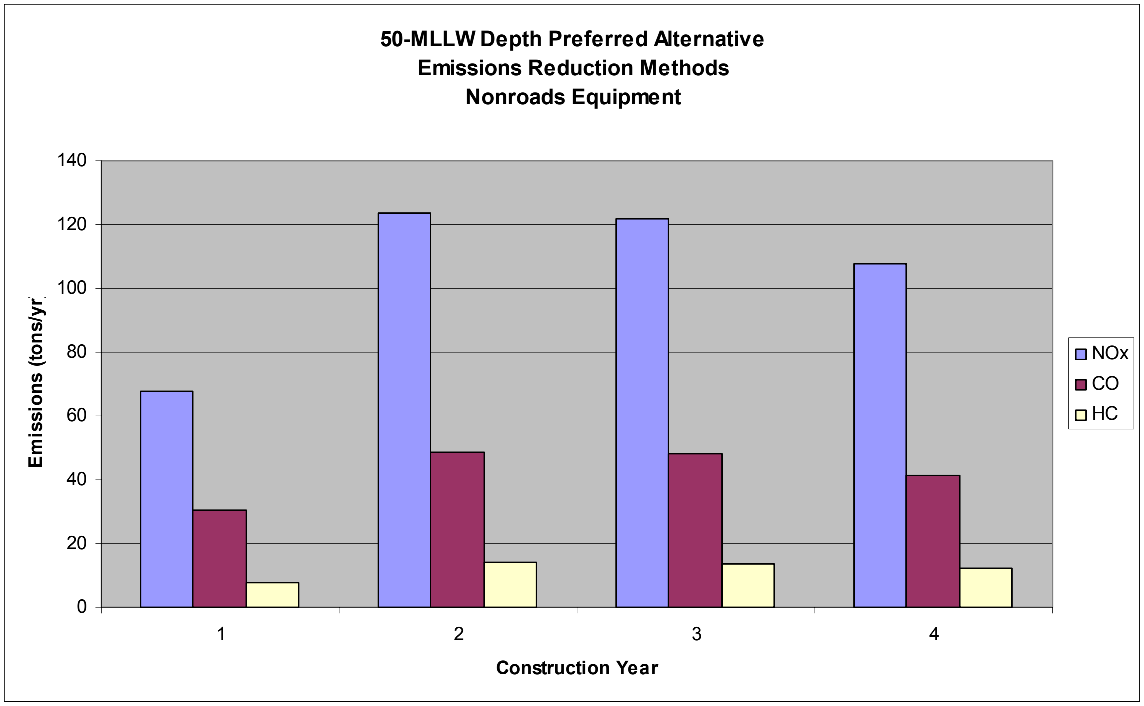
Boston Harbor, Massachusetts - Navigation Improvement Study
50-MLLW Uncontrolled
Summary of Total Annual Emissions (tons/yr)

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



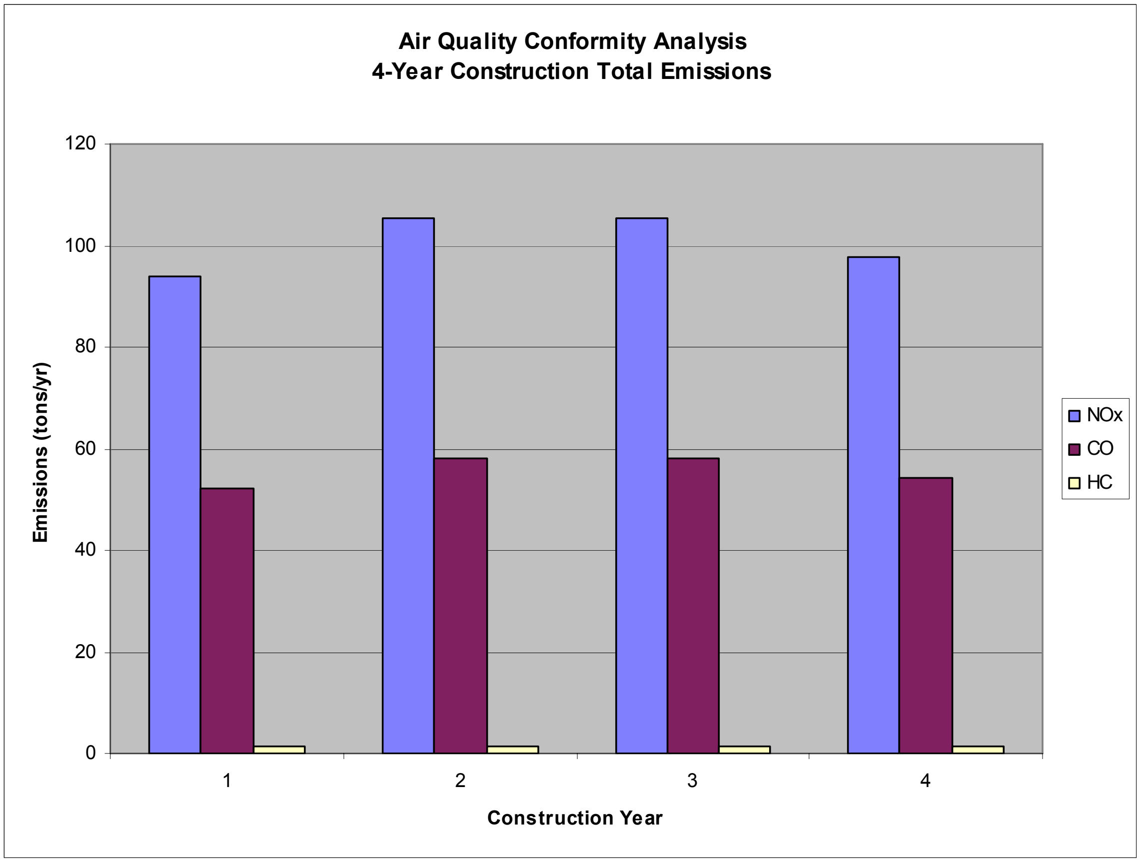
Boston Harbor, Massachusetts - Navigation Improvement Study
50-MLLW Depth Preferred Alternative
Emissions Reduction Methods
Nonroads Equipment Total Emissions (tons/yr)

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



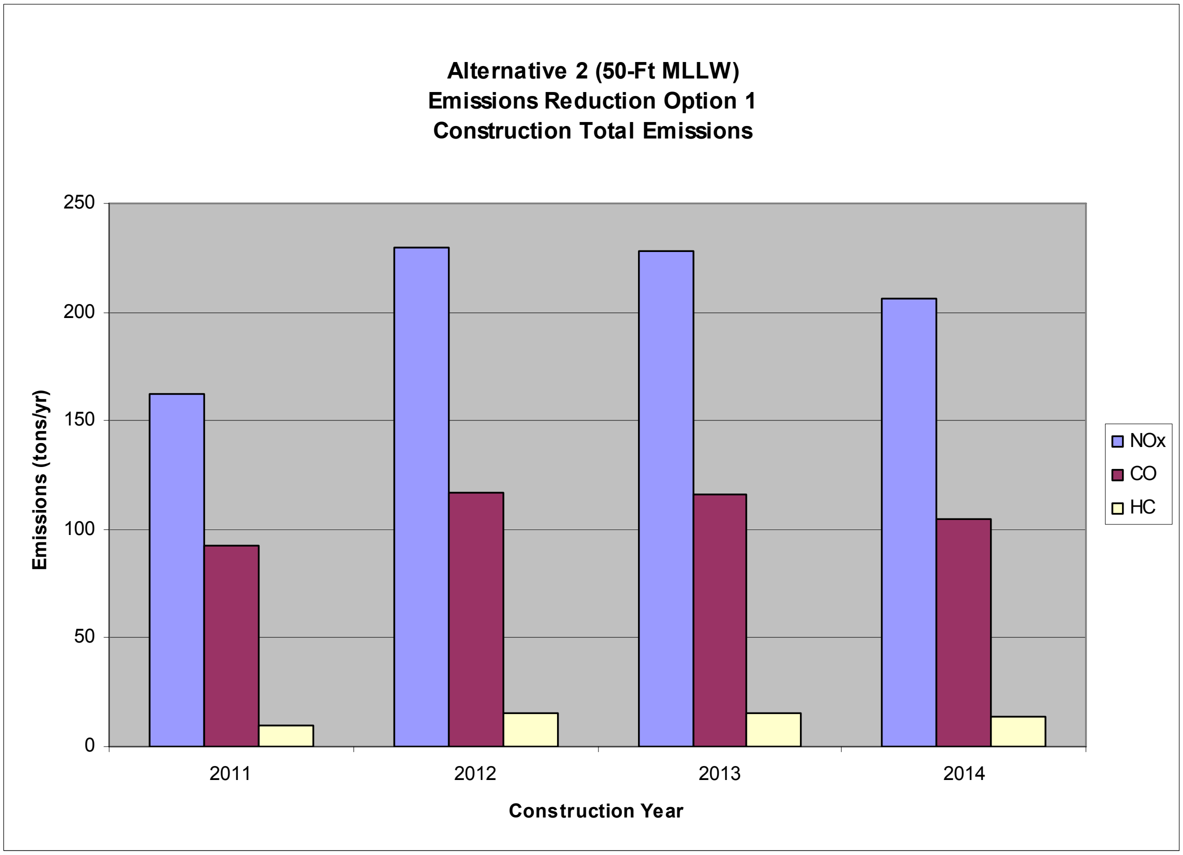
Boston Harbor, Massachusetts - Navigation Improvement Study
50-MLLW Depth Preferred Alternative
Emissions Reduction Methods
Marine Vessel Total Emissions (tons/yr)

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**



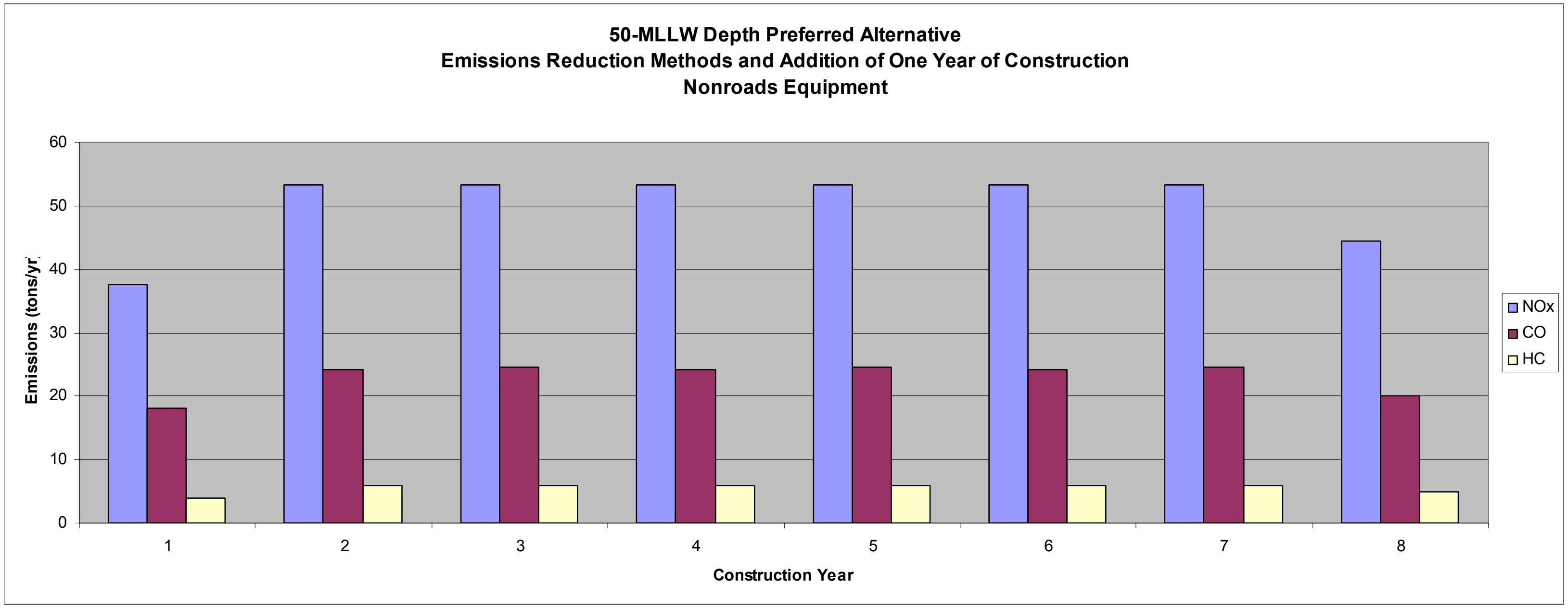
Boston Harbor, Massachusetts - Navigation Improvement Study
50-MLLW Preferred Alternative
Emissions Reduction Methods
Summary of Total Annual Emissions (tons/yr)

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



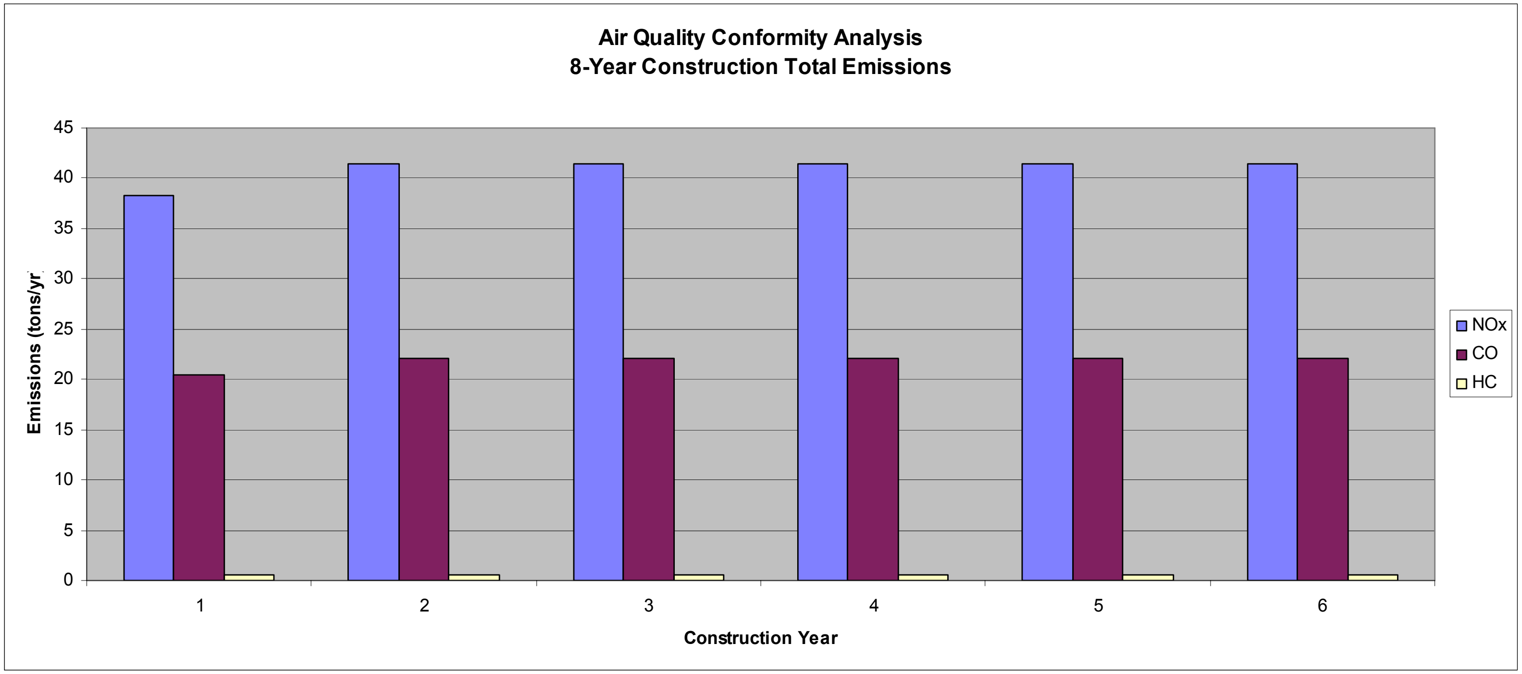
Boston Harbor, Massachusetts - Navigation Improvement Study
50-MLLW Depth Preferred Alternative
Emissions Reduction Methods and Addition of Four Years of Construction
Nonroads Equipment Total Emissions (tons/yr)

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



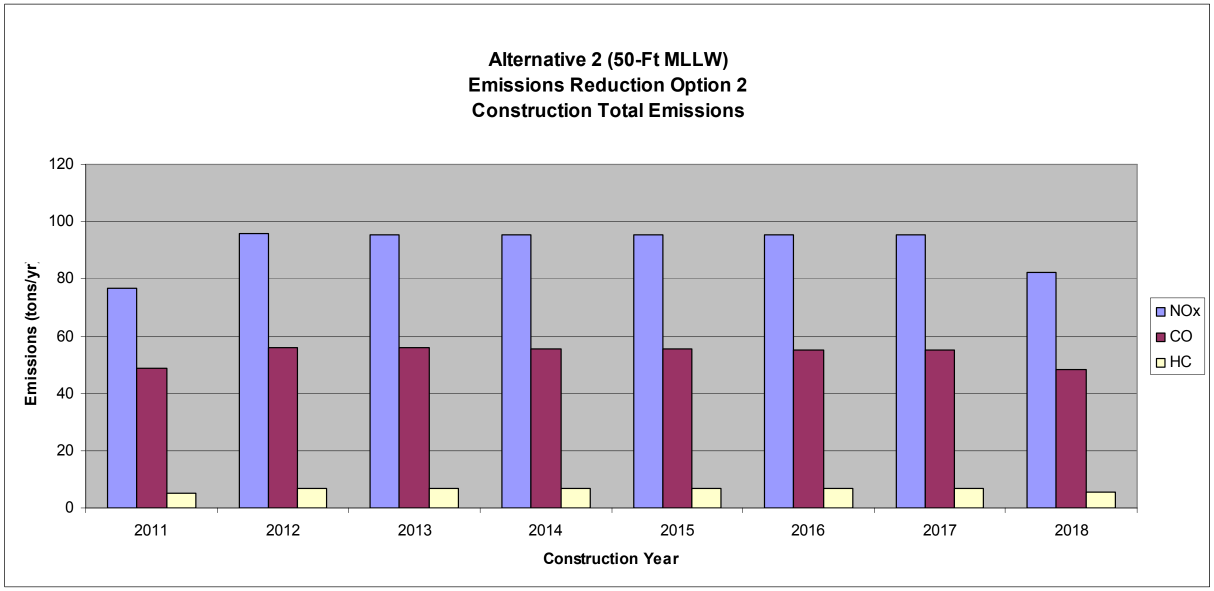
Boston Harbor, Massachusetts - Navigation Improvement Study
50-MLLW Depth Preferred Alternative
Emissions Reduction Methods and Addition of Four Years of Construction
Marine Vessel Total Emissions (tons/yr)

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

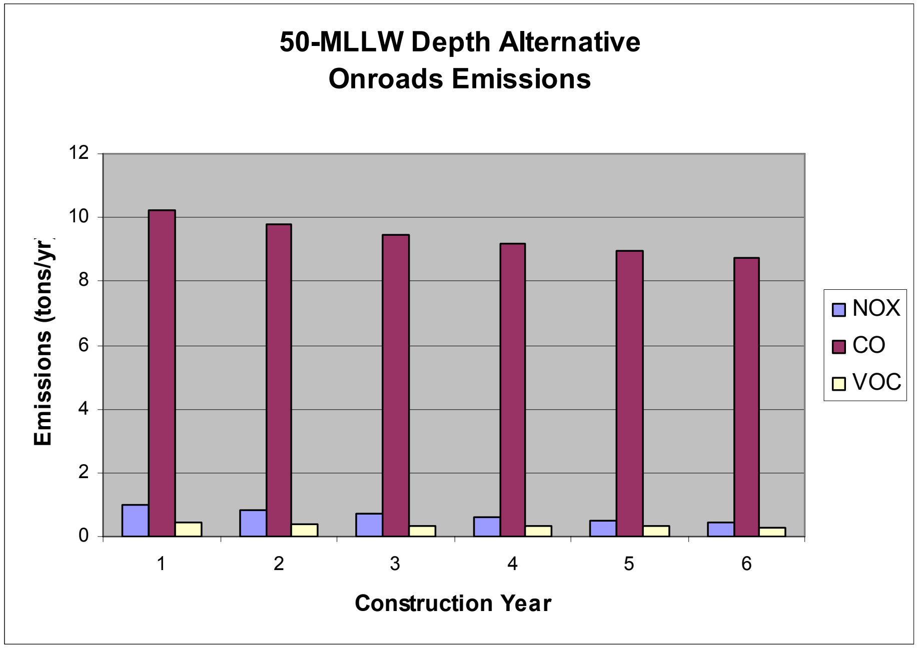


50-MLLW Depth Alternative Vehicle Trips Data

	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	COSCO Containership	Bulk Carrier	Bulk Carrier	Petroleum Ship	Petroleum Ship	Petroleum Ship	Petroleum Ship	Petroleum Ship	Truck Trip	Total
		4,000 TEUs	5,100 TEUs	25,000 DWT	40,000 DWT	<20,000 DWT	20,000 DWT	25,000 DWT	35,000 DWT	>35,000 DWT	Emissions	
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	COSCO Containership	Bulk Carrier	Bulk Carrier	Petroleum Ship	Petroleum Ship	Petroleum Ship	Petroleum Ship	Petroleum Ship	Truck Trip	Total
		5,600 TEUs	5,600 TEUs	40,000 DWT	60,000 DWT	<20,000 DWT	20,000 DWT	25,000 DWT	35,000 DWT	>35,000 DWT	Emissions	
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	3.5	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

YEAR	HDD Truck VMT/YR	MOBILE6.2 Heavy Duty Diesel (HDD) Truck Emission Factor (g/mi)						Emissions (tons/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

YEAR	HDD Truck VMT/YR	MOBILE6.2 Heavy Duty Diesel (HDD) Truck Emission Factor (g/mi)						Emissions (tons/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

YEAR	HDD Truck VMT/YR	MOBILE6.2 Heavy Duty Diesel (HDD) Truck Emission Factor (g/mi)						Emissions (tons/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

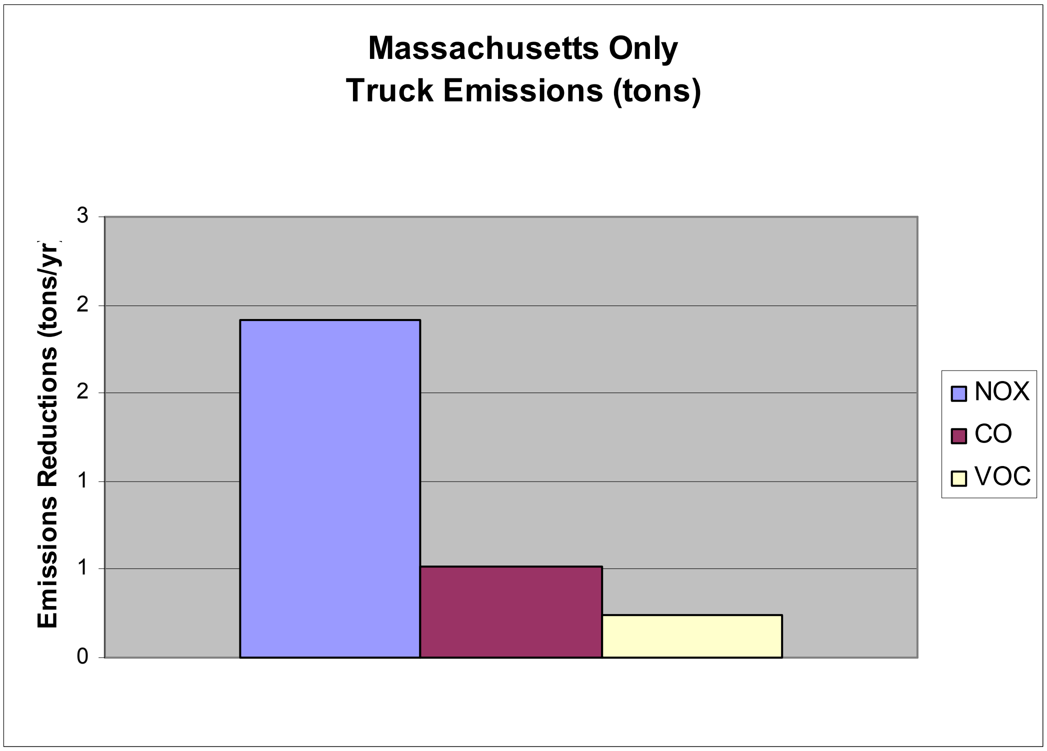
YEAR	HDD Truck VMT/YR	MOBILE6.2 Heavy Duty Diesel (HDD) Truck Emission Factor (g/mi)						Emissions (tons/yr)					
		NOX	CO	VOC	PM10	PM2.5	SO2	NOX	CO	VOC	PM10	PM2.5	SO2
2016	766,276	2.265	0.607	0.288	0.0905	0.0606	0.013	1.91	0.51	0.24	0.08	0.05	0.01

New England Region Emissions (2016)

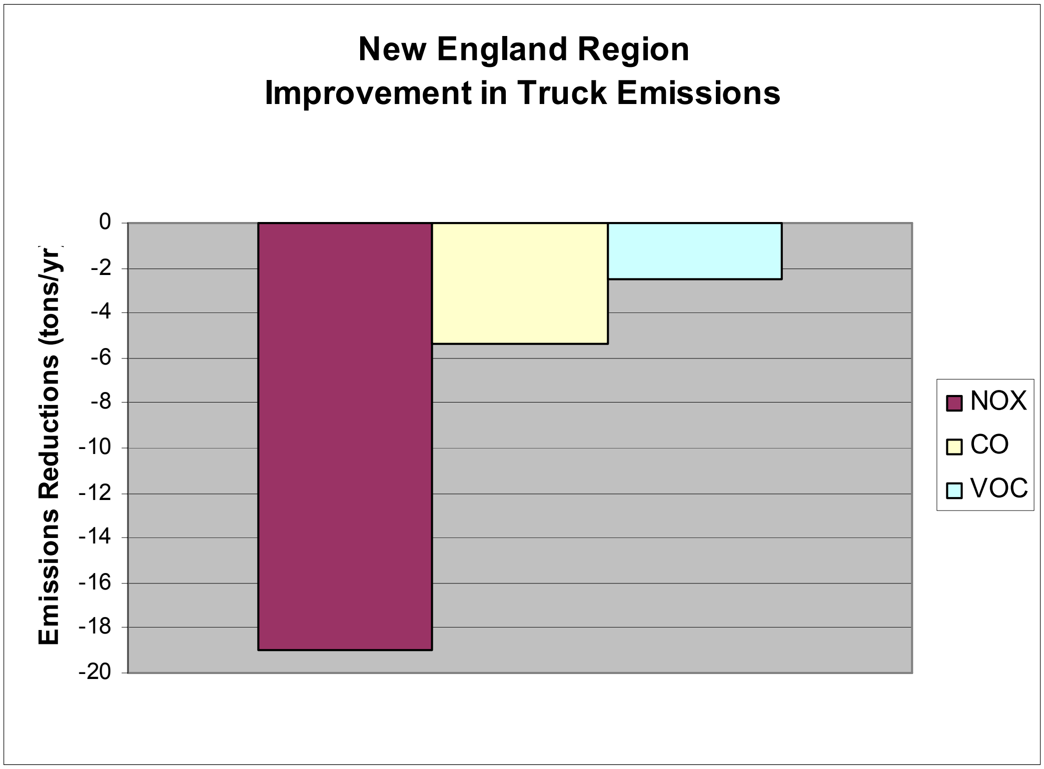
With Project Indirect Emission - Net Change in Truck Vehicle Miles Traveled

STATE	HDD Truck VMT/YR	MOBILE6.2 Heavy Duty Diesel (HDD) Truck Emission Factor (g/mi)						Emissions (tons/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)



New England Region
Improvement in Truck Emissions

PART 4

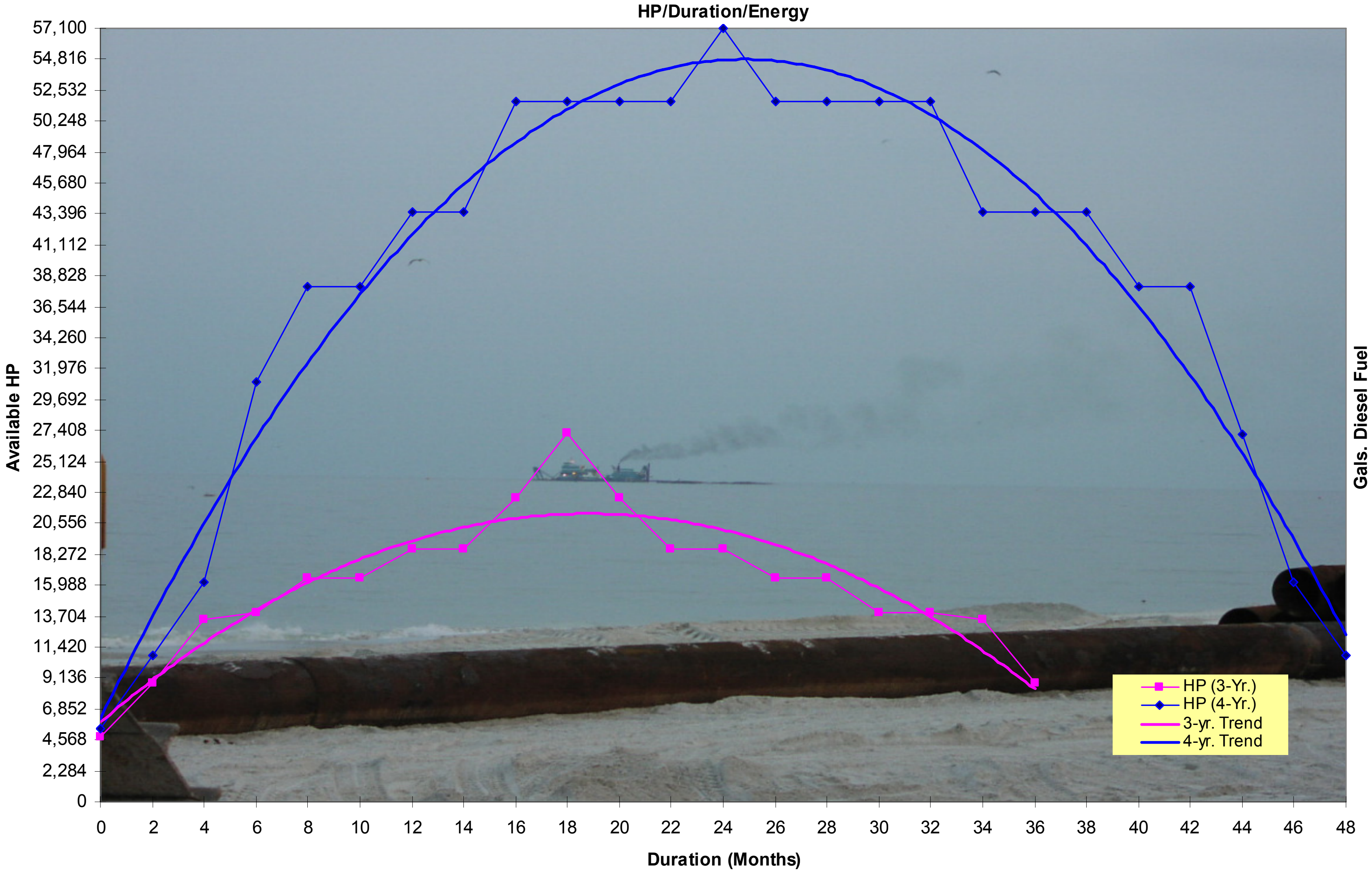
DREDGING SCHEDULE AND SUPPORT INFORMATION

	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	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	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	▨	▨	▨
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	▨	▨	▨
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	▨	▨	▨
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	▨	▨	▨
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	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			

PLANT-EQUIPMENT / PHASE / OPERATION (4-yr. / 50' MLLW / 16,139,000 CY)	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./Mgnt. 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/Field 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
Mobilization/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 CB#1 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. 'non-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 CB#2 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. 'non-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
Drill Towers/Blast Platform Barge START (drilling/blasting)				x	x	x	x	x	x	x	x	x	x (x)	x	x	x	x	x	x	x	x	x	x	x	
Service Barge, Misc. Support Equipment/Machinery, Rigging/Staging	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
Explosives Barge				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
Dredge Mechanical/Backhoe BB#1 START (remove rock/ledge/hard bottom)					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. 'non-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
See Additional Emitters / 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
HP (3-Yr.)
HP (4-Yr.)
3-yr. Trend
4-yr. Trend

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

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