Contract No. DACW 51-01-D-0018-4
NEA Delivery Order 0065
Hunter Research, Inc. Project 06017

U.S. Army Corps
of Engineers
New York District

Geomorphology/Archaeological Borings and GIS Model of the Submerged Paleoenvironment in the New York and New Jersey Harbor and Bight in Connection with the New York and New Jersey Harbor Navigation Project, Port of New York and New Jersey

March 2014

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Under subcontract and prepared in conjunction with:
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Prepared for:	**Under contract to:**
Tetra Tech **451 Presumpscot Street** **Portland, Maine 04103**	**U.S. Army Corps of Engineers** **New York District** **CENAN-PL-EA, 26 Federal Plaza** **New York, New York 10278-0900**

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MANAGEMENT SUMMARY

Project Name. Geomorphology/Archaeological Borings and GIS Model of the Submerged Paleoenvironment in the New York/New Jersey Harbor and Bight in Connection with the New York and New Jersey Harbor Navigation Project, Port of New Jersey and New York, conducted for the US Army Corps of Engineers, New York District (USACE-NYD).

Project Location and Environmental Setting. The project area designation is the New York/New Jersey Harbor and includes a series of navigation channels of the Upper Bay including Ambrose, Anchorage, Kill van Kull, Port Jersey, Newark Bay (South Elizabeth, Elizabeth, Elizabeth Pierhead, Port Newark Pierhead, and Port Newark channels), and Bay Ridge channels. Previous work has been done at these locations. New locations include Raritan Bay, Lower Bay, and the area west of a line connecting Jones Inlet (Long Island) and Long Branch (New Jersey).

Purpose and Goals. The primary objective of this investigation is to develop a model of the submerged paleoenvironment. The model will function as a planning document to assist the USACE-NYD and researchers in identifying areas that may have been suitable for prehistoric and historic settlement and also to delimit areas in which stratigraphic sequences and intact Late Quaternary landforms offer potential for preservation of prehistoric and historic surfaces and sites.

This project will test and refine previous models of archaeological sensitivity thereby serving as a blueprint to guide the USACE-NYD in the avoidance or mitigation of adverse impacts on parcels designated for channel improvements.

Investigation Methods and Results. Examination and consolidation of previous research was undertaken in advance of the present project. Prior to this study, a preliminary model of archaeological sensitivity was assembled from baseline studies at select reaches in the Upper Bay (Schuldenrein 2006). The present study extends the project area to the Lower Bay and began with the systematic collection of cores aligned along three transects spanning the Lower Bay and two to supplement earlier data collection in the Upper Bay. The transects were selected on the basis of potential for yielding information in both closed and open marine and estuarine environments that were considered to have strong potential for intact Late Quaternary stratigraphy. The cores were identified for macrostratigraphy and were then dated and submitted for specialized analysis by biostratigraphers (pollen, microfauna, and malacology) and geologists (sediment stratigraphy and microstratigraphy). A key element in the study is the formulation of a revised sea level curve for the New York Bight. The need for this baseline work was identified as more detailed examination of the buried landform configurations and the stratigraphy underscored trends that had not been recognized by earlier stratigraphers and geomorphologists. The new data, and especially historic maps and Late Quaternary sequences, are being integrated into a Geographic Information Systems (GIS) platform to facilitate a multi-dimensional and integrated landscape model that accommodates the changes registered by the specialists working in each of the sub-disciplines. It also synthesizes the archaeological sensitivity model from a 3-dimensional perspective. The model tracks spatio-temporal trends in landscape availability in response to dynamically changing shore environments for the various periods in prehistory and early history.

Regulatory Basis. The USACE-NYD is constructing navigation channels within the Port of New York/New Jersey to a depth of 50 ft. The Corps as a federal agency is required to identify the cultural resources within the project area and evaluate their eligibility for listing on the National Register of Historic Places (NRHP).

The Federal statutes and regulations authorizing the Corps to undertake these responsibilities include Section 106 of the National Historic Preservation Act, as amended through 1992 and the Advisory Council on Historic Preservation Guidelines for the Protection of Cultural and Historic Properties (36 CFR Part 800).

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Chapter 1
Overview and Introduction

OVERVIEW

This report presents data, results and recommendations from a multidisciplinary study of the history and prehistory of New York and New Jersey Harbor, and part of the New York Bight and Jamaica Bay. Primary outcomes of the research have been the development of a fuller, and more thoroughly documented understanding of the human and physical geography of the presently submerged landscapes surrounding the metropolitan New York City. The study is a synthetic narrative linking the past 15,000 years of environmental change and human occupation. The objective of the work is the creation of an archaeological sensitivity model for this complex setting that enables planning agencies to mitigate the effects of development on irreplaceable cultural resources.

The study supports the U.S. Army Corps of Engineers, New York District (USACE-NYD) in its mission and responsibilities. As an agency of the Federal Government, the District must include in its planning and programming the identification and appropriate treatment of historic properties on or, eligible for, the National Register of Historic Places. This responsibility is codified in Sections 110 and 106 of the National Historic Preservation Act of 1966 (as amended) and in the associated regulations for Section 106 at 36 CFR Part 800.

The District's responsibilities for New York Harbor navigation include the design, implementation and oversight of undertakings that have the potential to adversely affect historic properties (primarily archaeological sites). The challenge facing the District is how best to identify, evaluate and appropriately treat such historic properties, given the effects of contemporary human impacts on the estuarine and marine settings fronting the harbor.

This study is characterized as a "blueprint for assisting…in isolating and delimiting areas that might have been available for settlement during the prehistoric and historic past" (page 153). In other words, while the scope of the project did not envisage the identification of specific archaeological sites, locations where they are likely to remain can be mapped. **Figure 9.1**, **Figure 9.2** and **Figure 10.1** therefore provide a three-part archaeological sensitivity assessment of the study area which can be used in the District's Planning process.

Since the focus of the study is on the potential of this environment to retain significant evidence of past human activity, the chronological range is from about 15,000 years ago (when the area first became viable for human occupation) until the present.

The signal environmental mechanism accounting for landscape change during this period has been the punctuated but ongoing rise in sea level and the consequent flooding and submergence of formerly dry-land areas. While general trends in sea level rise have been generally understood for decades, a major contribution of the current study has been to revise and calibrate the rates and extents of this process (known as the late Quaternary marine transgression) through time. A model charting the transgressive cycle has been developed in detail through the integration of diverse but complementary data sets. The study has assimilated information from sea-bed borings (including a program of vibracores specifically included in the study), landform relations, sequence stratigraphy, radiocarbon dating, and from pollen, foraminifera, and molluscan studies.

The comprehensive revision of the sea-level curve for the New York Bight represents a stand-alone product that incorporates multi-disciplinary data sets generated both from this report and records obtained from published and unpublished sources. It constitutes a significant contribution to the understanding of post-glacial sea-level change on the Atlantic coast of the United States. Moreover, it serves as a guideline for calibrating the former levels of terrestrial surfaces that once marked the edges of the transgressive sea. In this sense they allow archaeologists to determine positions of the migrating coastline to various periods in prehistory and history.

Based on the newly calibrated curve, it is hypothesized that at the height of the last glaciation (about 20,000 years ago) the oceans were almost 100 m (328 ft) below their present level. As the rapidly melting ice sheets returned huge amounts of water to the oceans there was a rapid rise in the first part of the study period (up to 9 mm/0.35 in per year), but in more recent millennia rates of sea level rise slowed appreciably. Rates were on the order of 1.5 to 1.6 mm (less than a tenth of an inch) per year. Within this general pattern there were fluctuations in the rate of rise. Between 2000 and 3000 years ago, for example, there was a pause (or “stillstand”) which was long enough for a shoreline terrace to develop about 4.5 meters (15 feet) below present sea level.

A model of this type has critical implicaions for assessing both the prehistoric location and preservation of archaeological sites. Periods of faster sea-level rise may be conducive to the preservation of sites because of the possibility of rapid burial by sediments, while slower rates of marine transgression can leave sites more exposed to erosion. The inverse may also be true. Thus sediment composition and vegetation records contained within the strata inform as to how these deposits were laid down and whether or not erosion or deposition were favored. In some instances rapid sedimentation by flooding resulted in accelerated erosion while slow accretion served to bury sites in place. In general the present study suggests that sites from earlier prehistoric periods (Paleoindian through Middle Archaic, down to about 7000 years ago) have a better chance of survival in the study area than those from later prehistory. Later prehistoric sites are also more vulnerable to the massive modifications (both filling and removal) that have taken place in historic times since the 17th century, and particularly from the mid-19th century to the present. Historic-period resources are likely to be quite numerous, especially in shoreline or near-shoreline locations where they have been submerged and/or filled.

Taken together the refinement and restructuring of geo-archaeological relations have resulted in a document that provides a utilitarian baseline for planning decisions for the U.S Army Corps of Engineers as it continues to plan for long term maintenance of its navigation channel network. The systematics of geomorphology, sea-level rise, prehistoric and historic settlement geography and, most recently, the large scale impacts of accelerated human impacts on the sea floor are all taken into account in fashioning this planning document for preservation compliance. The geoarchaeological models advanced herein will be put to the test in coming years as planners move ahead in their design and channel maintenance efforts.

Introduction

The US Army Corps of Engineers, New York District (USACE-NYD) is responsible for maintenance of harbors and waterways and is actively involved in dredging existing channels and deepening others to allow greater access to the Port of New York and New Jersey (the Harbor Navigation Project) (**Figure 1.1, Figure 1.2, and Figure 1.3**). Ongoing and anticipated changes involve widening and deepening channels to a depth of 50 ft in specific areas. As a federal agency, the USACE is required to identify cultural resources within its project areas and to evaluate their potential for eligibility for listing on the National Register of Historic Places (NRHP). Federal statutes and regulations identifying these responsibilities include Section 106 of the National Historic Preservation Act, as amended through 1992 and the Advisory Council on Historic Preservation Guidelines for the Protection of Cultural and Historic Properties (36 CFR

Part 800). These responsibilities extend to both land-based and submerged cultural resources. In terms of the Harbor Navigation Project, the shore and near-shore areas of the New York and New Jersey harbors have been subject to filling or removal of former coastal past terrain segments that once sustained and preserved evidence of historic and prehistoric activities.

A critical aspect to understanding the systematics of archaeological preservation in the New York Harbor complex has been the documented progressive encroachment of sea level on the adjacent land areas. Sea level has risen as much as 100 m since the last glaciation of North America ended approximately 20,000 years ago. Rising sea level has progressively inundated the continental shelves and continues to raise, flood, and cover coastal lands. The post-glacial rise in sea level has covered former land surfaces that were attractive as settlements for prehistoric peoples throughout this time period. While the probability of affecting “drowned” cultural resources seems remote, the potential for their identification and protection need to be considered. One of the most efficient methods for avoiding disturbance of submerged cultural resources is to identify and evaluate the former areas of greatest site potential in their former subaerial site settings. Just as land-based cultural resources studies address the potential for archaeological sites on the basis of the geologic and geomorphic settings best suited for past settlement, so too may these same tools be adapted to identifying potential underwater sites. One of the more effective methods of addressing the latter approach is through modeling the rise of post-glacial sea level and the interaction between the sea and its contemporaneous coastal zone through time. Thus, the interface between land and sea, and related coastal, riverine, and marsh environments, can be tracked over time and space to provide clues to which of these loci have the greatest potential for in situ cultural resources. Similarly, the study of offshore stratigraphy from cores aids both to document the position and timing of past sea level stands and to provide fossil pollen and faunal samples for reconstruction of former vegetation and estuarine environmental changes.

As part of USACE’s Section 106 compliance activities related to the Harbor Navigation Project, extensive background research was conducted to examine past studies and especially the logs of the numerous cores taken in the project area. In addition, a series of vibracores was collected in key locations within the Upper and Lower Harbors and Jamaica Bay to aid in the description and dating of sediments, and to provide new samples for micropaleontological analyses. These cores, together with the records of cores from previous studies, helped to determine locations within areas of proposed deepening and widening that may preserve significant irreplaceable data on paleoenvironments as well as now submerged landforms.

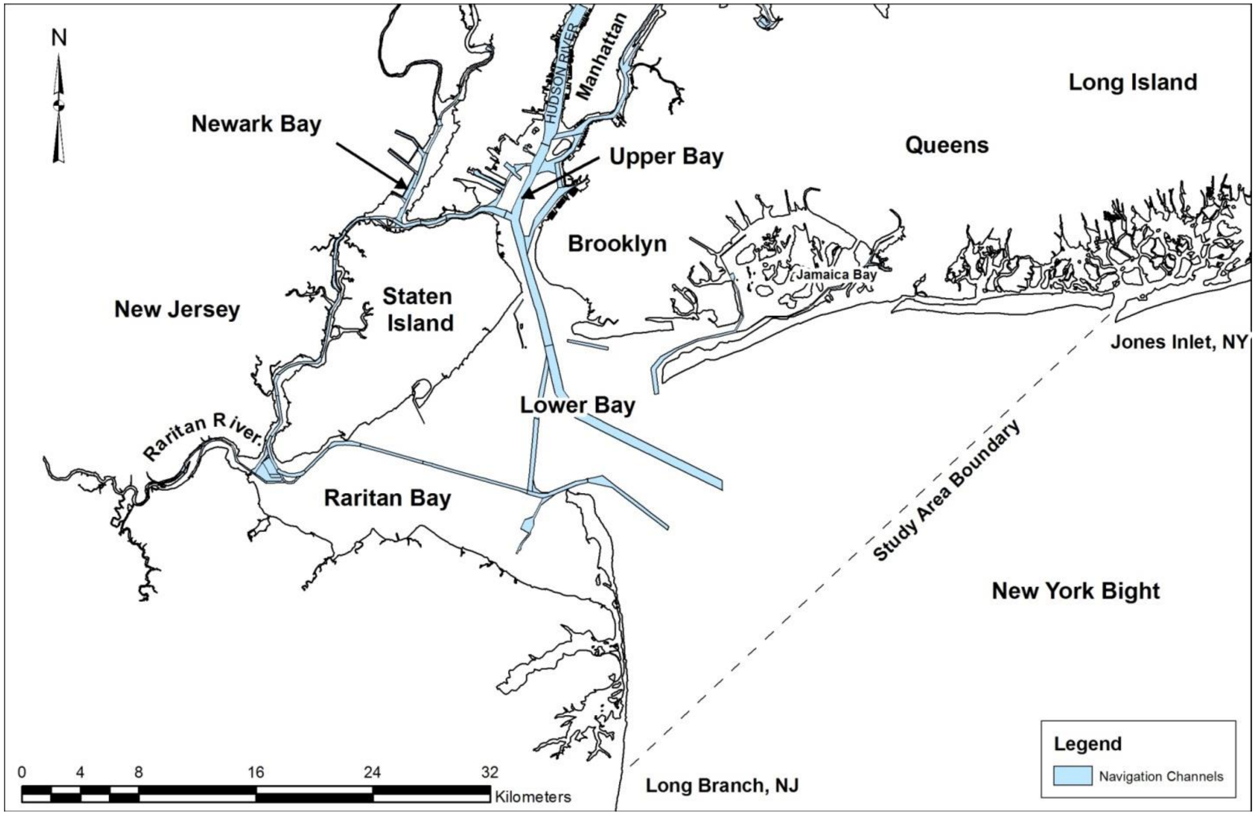

Figure 1.1: Location map for New York Harbor

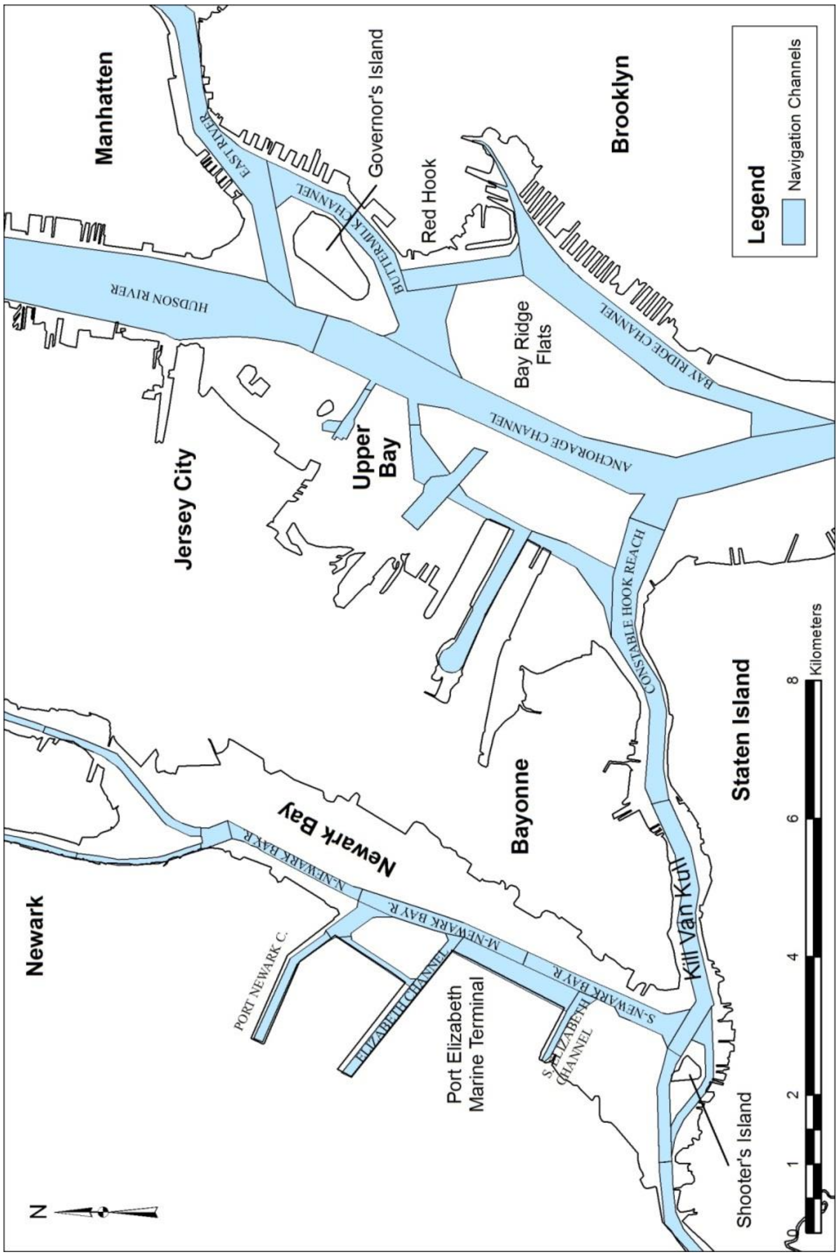

Figure 1.2: Upper New York Harbor and Newark Bay

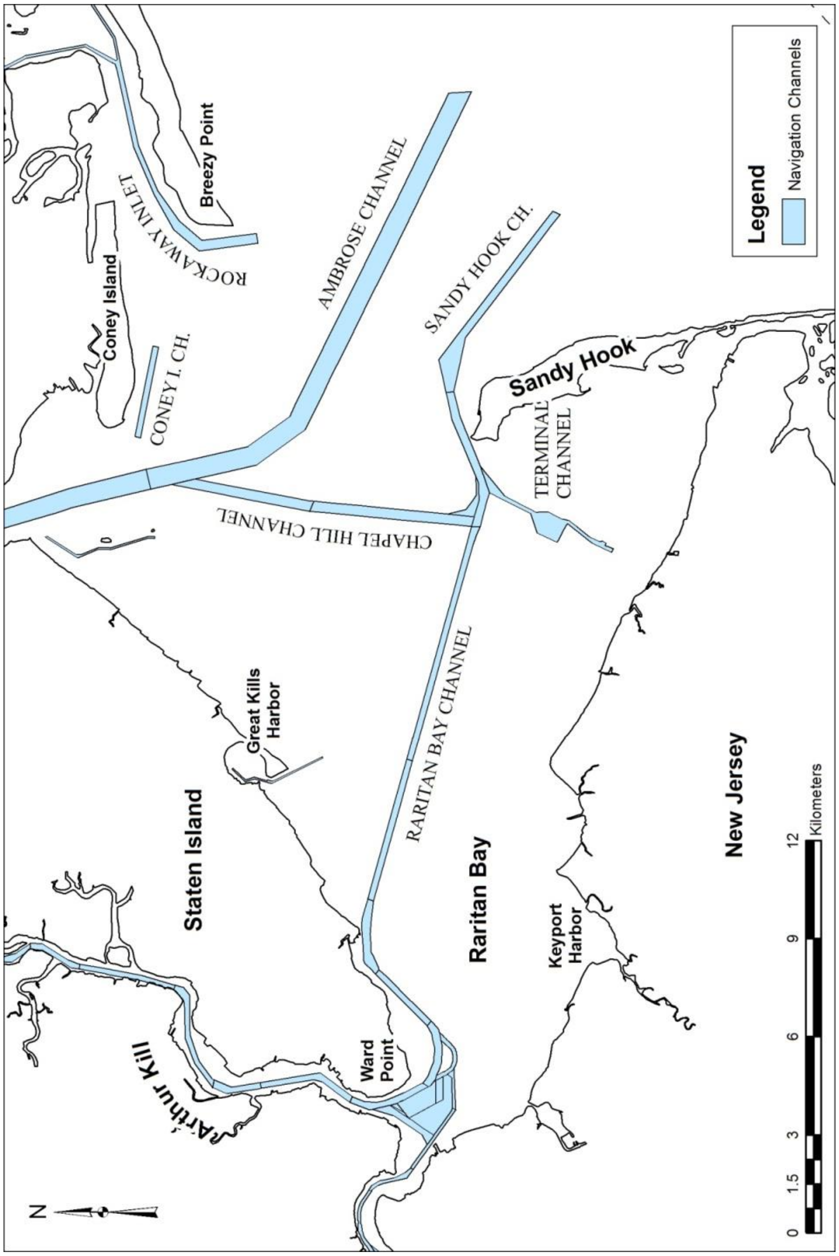

Figure 1.3: Lower New York Harbor and Raritan Bay

Prior studies conducted by Geoarcheology Research Associates (GRA) for the USACE-NYD related to submerged cultural resources in the New York/New Jersey Harbor complex, along with investigations performed by others that are on file with the USACE-NYD, provided data for this larger synthetic model of the now submerged landforms and the probability of their preservation. The model is important for determining areas of sensitivity for past Native American occupation. Previous work by GRA demonstrated the feasibility of archaeological sensitivity modeling and determined areas where additional data should be acquired. The present report is the culmination of working model concepts attained through these earlier studies. Apart from the acquisition and analysis of past reports and data, GRA designed and implemented a strategic subsurface exploration program. A total of 20 new vibracores were extracted in November 2006 and 2007 to investigate stratigraphic and temporal relationships not addressed in previous geotechnical borings and cores, and to develop a more detailed relative sea level history than was formerly available.

On the basis of the material provided in the present study, together with the vast core database provided by the USACE, GRA has developed an inundation model of the Upper New York Harbor and Raritan Bay together with portions of the New York Bight and Jamaica Bay. The graphic model shows approximate prehistoric shoreline positions on a 1,000-year incremental basis that delineates former coastal landforms and helps to pinpoint the contemporaneous environmental settings now submerged beneath the harbor. The provided maps will help to visualize the characteristics of the changing New York and New Jersey shorelines in time and space while at the same time suggesting the habitats most conducive for past human settlement over this period.

The project GIS was used to georeference an 1844 U.S. Coastal Survey map of the New York Harbor region. Almost 12,000 bathymetric soundings were digitized from this map and a digital elevation model (DEM) of the seabed created via a kriging algorithm. This DEM formed the baseline for sea level regression images as it models the submerged landscape of the harbor region before industrial-era dredging activities dramatically transformed it. The GIS was also used to consolidate locational and stratigraphic information from geotechnical borings from a large number of previous studies along with those carried out under the aegis of the current one. Previous studies had recorded boring locations in a number of different coordinate systems (e.g., NJ or NY state plane, UTM, unprojected latitude/longitude). These loci were reprojected into a single system and all available stratigraphic information was entered into a single database that was used within the GIS to visualize and analyze the information in three dimensions.

The present study envisions the submerged landscape of the New York Bight as a series of ancient land surfaces that sustained human populations since the arrival of people into the New World. The detection of these surfaces and their systematic destruction or preservation and burial is the purpose of the work in order to satisfy the obligations of the USACE-NYD under Section 106 of the National Historic Preservation Act (**Chapter 1**). A variety of previous studies have probed the subaqueous sediments underlying the Bight for paleoenvironmental and paleogeographic purposes. This present study is synthetic and proposes to integrate and refine previous models of the buried landscape into a comprehensive GIS-based construct for buried site potential across the New York Bight (**Chapter 2**). The model is centered on a new paradigm for sea level rise that is derived from regional models for the Atlantic Coast bolstered by a coring program explicitly designed for this project (**Chapter 3**). The geological, bathymetric, geomorphic, and hydrographic foundations for the new landscape reconstructions are developed (**Chapter 4**) and the detailed paleoenvironmental results are presented on the basis of the new corings for select portions of the Bight (**Chapter 5**). A systematic paleoenvironmental reconstruction for the Late Quaternary is then presented, largely driven by the new sea level curve, and by interpretations generated from biostratigraphic investigations of the sediment cores (**Chapter 6** and **Chapter 7**). This construct is the basis for a proposed settlement model that plots the surfaces and landscapes that were sequentially available for settlement through time (**Chapter 8** and **Chapter 9**). A series of results and recommendations concludes the presentation (**Chapter 10**). Supporting data sets are incorporated as Appendices. Details of the most recent vibracores, including photographs and stratigraphies, appear in **Appendix A**. A compilation of all available marine radiocarbon dates are featured in a table in **Appendix B**. **Appendix C** is a contribution by Dr. Lynn Wingard on molluscan fauna from the most recent cores. **Appendix D** is a contribution by Dr. Benjamin Horton, who reports on the foraminifers. **Appendix E** presents a pollen analysis by Christopher Bernhard. The qualifications of all contributors appear in **Appendix F**. **Appendix G** is the final "Scope of Work" for this project.

Chapter 2
Research Design

Previous investigations of the New York Harbor, focused on evaluating the potential for submerged prehistoric and historic cultural resources for the Harbor Navigation Project, have relied heavily on the post-glacial rise in sea level to identify, isolate, and explain relative site potential. The history of sea level rise is important because it facilitates reconstruction of the now-submerged former environmental zones, both riverine and marine, that were once most conducive to human habitation. It became clear during the evaluation of these earlier studies that the prevailing models for sea level change were dated and could not accommodate the chronologies and sequences that emerged from the expanding database. Moreover, regional (Atlantic Coast) sea level models have produced curves that were more in line with observations from this study. Hence, the interpretations drawn from subsurface coring in the harbor for the purpose of environmental reconstruction were flawed. To remedy this shortcoming, GRA invested resources as part of the current study to develop a revised relative sea level model that is up to date and accurate for both geological and archaeological researchers as well as engineers and planners.

The fieldwork, conducted in November 2006 and 2007 sea level and utilizing the vibracoring equipment of Alpine Ocean Seismic Survey, Inc., Norwood, NJ, investigated three specific areas, Raritan Bay, Upper New York Harbor, and Jamaica Bay. Raritan Bay was chosen to address two questions. Firstly, given that much of the present array of cultural resource investigations has been aimed at the upper New York Harbor, GRA needed firsthand knowledge of Raritan Bay to observe and assess the effect of rising sea level on coarse-grained sandy sediments in a relatively sheltered environment. Secondly, previous investigations had cited a 1936 study (MacClintock and Richards 1936, cited in Bokuniewicz and Fray 1979) that showed early borings for a proposed bridge crossing from Staten Island (**Figure 2.1**). This model had been central to previous reconstructions of New York Harbor stratigraphies. A profile across Raritan Bay documented a deeply incised channel near the Staten Island shore filled with "mud." The channel was recorded as extending 45.7 m (150 ft) below present sea level. Obtaining a deep core from the "mud" fill of this channel for use in pollen, foraminifer analysis, and radiocarbon dating of organics would provide a record of continuous deposition of fine-grained sediment that documented the post-glacial rise in sea level. Radiocarbon dating of this deep sequence promised to aid in dating the marine transgression. Furthermore, data from this core was anticipated to make an important contribution as the original work has been cited by many past researchers and was apparently unstudied since 1936.

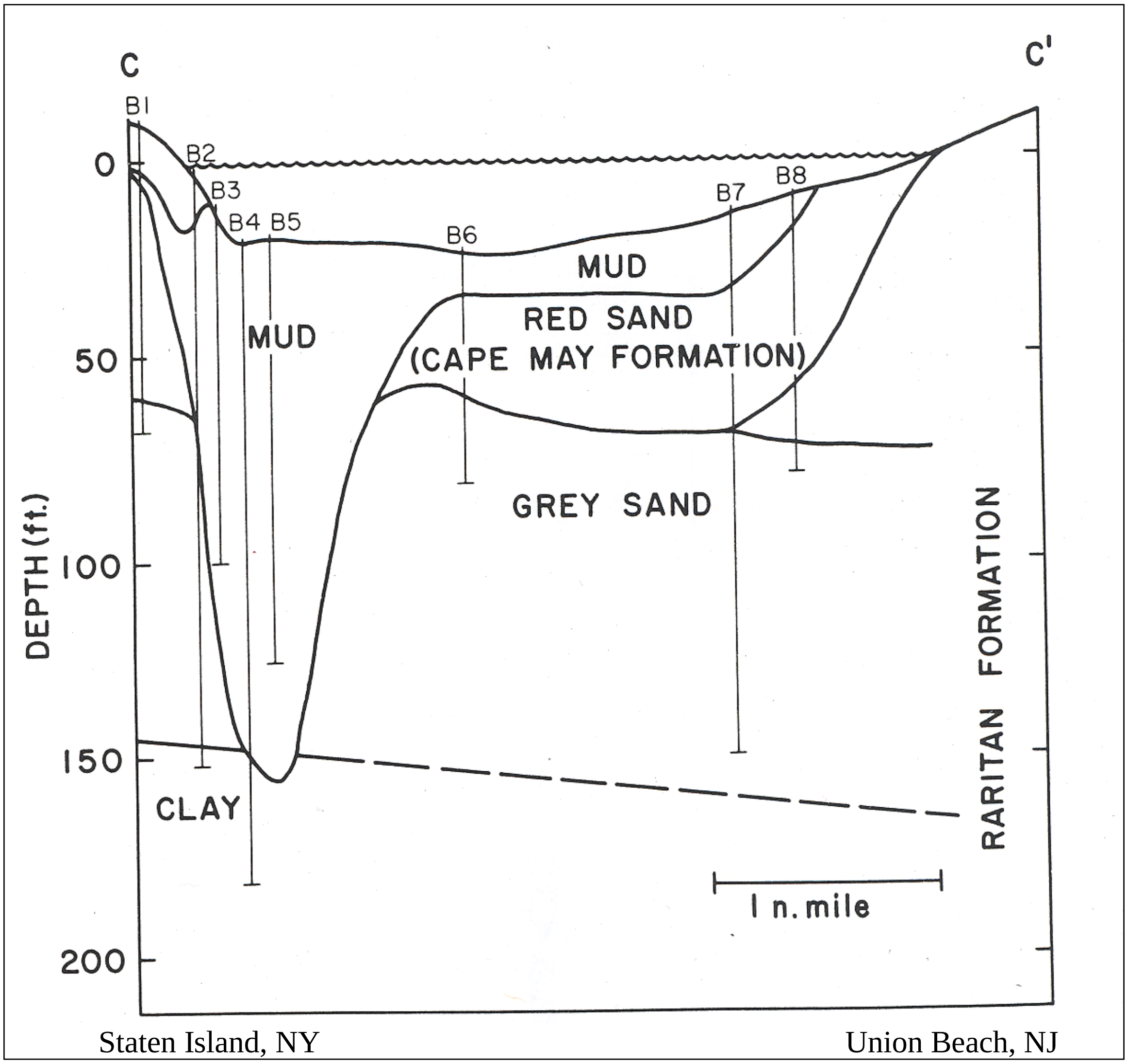

Figure 2.1: Erroneous Subsurface Profile from Seguine Point, Staten Island, NY to Union Beach, NJ. (MacClintock and Richards 1936, cited in Bokuniewicz and Fray 1976).

Nine 12 m (40 ft) vibracores were extruded along two transects in Raritan Bay. These cores are discussed in detail in Chapter 6. A series of five vibracores was placed to reconstruct the MacClintock and Richards (1936) profile between Seguine Point on Staten Island and Conaskonk Point at Union Beach, NJ. The transects provided compelling evidence that the 1936 study was erroneous in its findings. There was no deeply incised channel in any of the locations shown in this early study.

Subsequent researchers are warned to avoid further use of that study. Four additional 12 m (40 ft) vibracores were located along a transect normal to the shoreline at Keansburg, NJ. This series of cores was drilled to record the effects of the marine transgression on a sandy shore subjected to relatively low wave energy. As anticipated, reworked surficial sands were evident. Although it was hoped that wave energy here had been subdued sufficiently to preserve possible paleosols or other evidence of the prior subaerial land surface, these could not be distinguished.

Upper New York Harbor investigations also utilized 12 m (40 ft) vibracores. Two transects were located to address questions raised by earlier GRA studies centered on the Port Jersey area along the west bank of the Hudson River (Schuldenrein et al. 2001). A radiocarbon profile in that study showed an apparent anomalous stratigraphic arrangement of time horizons in estuarine silts and clays. Here cores taken at greater depths on the edge of the estuarine fill adjacent to the Anchorage Channel had younger ages than those further inland. This juxtaposition of ages was counter to the concept of how the marine transgression could be dated. An earlier report suggested that the anomalous and apparently inverted stratigraphy might relate to a period of lower sea level during the overall rise. Alternately, the inverted stratigraphy might reflect slumping of the channel edge.

A series of 40 ft vibracores taken in a similar setting provided an independent view of the stratigraphy and was geared to penetrate the estuarine fill to reach the pre-marine transgressive land surface. This transect was located south of the Liberty Island access channel on relatively undisturbed estuarine silt. Vibracores from shallow (1.8 m/6 ft) to greater (15.5 m/51 ft) depths broadly paralleled the earlier Port Jersey transect. Only the innermost core (C-1) penetrated the estuarine fill and furnished organics suitable for radiocarbon dating. The deeper core located along this transect (C-4) and drilled in 16 m (51 ft) of water penetrated 12 m (40 ft) of estuarine sediment. This core was expected to penetrate the estuarine fill and furnish basal organics to date early flooding of the Hudson Channel when relative sea level was 27.4 m (90 ft) lower than present. Ironically, core C-4 furnished a basal date of 2,520 ± 40 B.P. (2,606 cal yrsbp). The preliminary conclusion is that either estuarine sediment is “draped” over a preexisting irregular land surface and filling deep depressions or incised channels, or slumping of younger estuarine sediment has occurred to collect at the bases of the steep slopes on the edge of the Anchorage Channel. Nonetheless, core C-1 with a basal date of 5,650 ± 40 B.P. (6,473 cal yrsbp) has presented the greatest time depth for a continuous sedimentation record for microfossil analyses. Pollen, foraminifer, and macro-molluscan studies were performed on this core.

Two additional 12 m (40 ft) vibracores were taken in the Upper Harbor. These were drilled on the surface of the Bay Ridge Shoal. The purpose of these cores was to furnish a stratigraphic record of sedimentary deposition that could be correlated across the Anchorage Channel for comparison with sediments of similar type and depth described in an earlier GRA study of Port Jersey (Schuldenrein et al. 2001). Once again, radiocarbon dating produced unanticipated results. Wood fragments found at 10.18 m (33.40 ft) below mean sea level yielded a date of 1,850 ± 40 B.P. (1,806 cal yrsbp).

The final area of investigation in the current study was Jamaica Bay. Coring in this location was designed to provide the marine transgression history for the flooding of a sheltered embayment upon which salt marsh had developed. It was hoped that stratified peat deposits would help date the youngest portions of the marine transgression and anchor the young end of the developing relative sea level reconstruction. Bridge access to Jamaica Bay limited the investigation to 6.1 m (20 ft) vibracores. The objective was to obtain a series of five 6.1 m (20 ft) cores leading from the surface of the Yellow Bar salt marsh southward into progressively deeper water and stratigraphically lower sediment packages. This operation was conducted on November 6, 2007. Falling tides prohibited reaching the surface of the Yellow Bar marsh; however, a continuous record of fine-grained sediment underlying the marsh was obtained. One radiocarbon date, 4,130 ± 40 B.P. (4,432 cal yrsbp), at a depth of 9.8 m (32.14 ft) below mean sea level suggested the transgression history of this portion of the Long Island shore. Unfortunately, none of the five recovered cores included stratified peat deposits.

The re-assessment of the range of available work, published and unpublished, underscored major inconsistencies in the databases. In part, anomalies are attributable to methodological variability as well as fallacious interpretations generated from older sea level models. In the course of the present work, a primary goal was to upgrade previous and present observations and interpretations. In addition, previous GRA reports provided significant data that enabled us to reconstruct the trends of relative sea level change over the past 10,000 years. Consequently, a highly detailed reconstruction for the past 3,000 years was possible (Chapter 3). Specialized analyses were undertaken as appropriate and by segment. Radiocarbon determinations were obtained for samples from the Liberty Island transect (4), the Bay Ridge Shoal (1), and Jamaica Bay (1). The limited number of samples was an indicator that many specimens were either contaminated or provided contexts unsuitable for dating (i.e., minimal organic materials). Samples from the Liberty Island transect and the Bay Ridge Shoal transect were submitted for specialized analyses of foraminifera, pollen, and plant macrofossils. Pollen and foraminifer specimens were productive and documented changing biomes and shifting margins of the estuaries during the Holocene. Forty-foot core C-1 from the Liberty Island transect was sampled at 30 cm (ca. 1 ft) intervals for analyses. Core D-1 from Bay Ridge Shoal was also sampled in this manner to furnish 40 samples. In all, 80 pollen and foraminifer samples were analyzed. Macro-molluscan samples were taken from all cores to aid in the determination of contemporaneous water depths and habitat. Intensive sedimentological examination and mapping led to the development of a baseline stratigraphy. Collective stratigraphic observations and supplementary specialized analysis allowed for reconstruction of the subsurface environments and landscapes by navigation channel (Chapter 9).

In addition to the vibracores collected as part of the present study, results from previous GRA harbor studies for the USACE-NYD were integrated, including the pilot for the present investigation (Schuldenrein et al. 2006), and the Port Jersey and Shooters Island: Newark Bay and Kill Van Kull (Schuldenrein et al. 2000a, 2000b, 2001). Other prior studies directed towards paleoenvironmental reconstruction for submerged sites included work by LaPorta et al. (1999) for portions of Raritan Bay, Arthur Kill, the inner New York Bight, and portions of the Upper Harbor, and by Wagner and Siegel (1997) in the Kill Van Kull. Boring logs with sediment descriptions were also recorded from the collection at the USACE-NYD library along with pertinent geotechnical reports. The following section summarizes the results of initial attempts to formulate a model of archaeological sensitivity based on a series of limited subaqueous testing efforts and the paleoenvironmental sequences and submerged landform histories outlined earlier. The model also incorporates the evidence for subaqueous disturbance that resulted from the past 150 years of navigation channel and near-shore dredging that has occurred within the New York Bight.

Geoarchaeological Investigations to Date

GRA performed four (4) sets of field investigations in the project area between 1999 and 2001 (Schuldenrein 2000a, 2000b, 2001). Supplementary investigations, in conjunction with harbor dredging were also undertaken by La Porta et al. (1999), and by Wagner and Siegel (1997). Their results were integrated into the GRA reports and are referenced again in this presentation.

New York Harbor Study. An extensive set of subsurface borings for the New York Harbor area were analyzed for a pilot study for the USACE-NYD, which established a baseline stratigraphy indexed by radiocarbon analysis and foraminifer, pollen, and plant and macrofossil studies (Schuldenrein 2000a). GRA had access to a total of 114 borings extracted for geotechnical purposes. Additionally, curated samples were examined at the USACE-NYD storage facility at Caven Point, New Jersey.

Geoarchaeological field work was undertaken in November 1998 and involved inspection and sampling of borings from two available drilling platforms. Standard geotechnical procedure was used to recover 0.6 m (2 ft) long split-spoon samples at every five feet in the uppermost sediments. This procedure was later modified to furnish a continuous series of 0.6 m (2 ft) spoons until the sediments appeared to be of Pleistocene age. Samples of bulk organic sediment and plant macrofossils were collected. It was noted that some of the uppermost sediments contained hydrocarbons and other hazardous materials. This was a function of the mixing of dredged materials plus the accumulation of effluents and discharge over the past 150 years.

Seven (7) borings were in the vicinity of the Newark Bay (NB) navigation channel work area; five (5) borings were in the vicinity of the Port Newark (PN); one (1) boring in Port Newark Point (PNP); and two (2) borings in the Elizabeth Channel (E) work area. Two (2) borings were described and sampled during fieldwork in the Claremont channel (CC); three (3) borings in Port Jersey (PJ); and five (5) borings in the Buttermilk Channel (BC). Borings in the other navigation channel work areas had been completed prior to fieldwork.

Thirteen (13) borings in the Anchorage Channel (ANC) work area were described and sampled at the Caven Point curation facility as were seven (7) from Stapleton (STA); and one (1) from Ambrose (AMB). The total number of borings integrated into the GRA database was fifty nine (59), or fifty-two percent of the 114 borings collected for the New York and New Jersey Harbor navigation study.

Port Jersey Study. In addition to the four (4) vibracores taken near Liberty Island as part of the present study, five (5) cores on the Jersey Flats/Port Jersey navigation channel were reexamined for the USACE-NYD (Schuldrenrein 2001). The cores were located along a transect lying in water depths of 3.7 to 9.1 m (12 to 30 ft), according to the bathymetric contours. Based on the revised Holocene sea level rise model presented in Chapter 3, the "Jersey Flats" should have spanned habitable terrain along the Hudson River shore during periods as early as 6,000 B.P. (7,000 cal yrsbp). Thus, submerged cultural resources associated with the Late Archaic or older might be expected if occupation and site preservation were favored by subsequent environments of deposition within the estuary.

Shooters Island: Newark Bay and Kill Van Kull Channels. This study for the USACE-NYD involved subaqueous coring at four (4) locations in connection with mitigation activities at the site of the Arthur-Kill-Howland Hook Marine Terminal Channel project (Schuldenrein 2000b)**.** Borings were spaced approximately 50 m (164 ft) in each cardinal direction from a previous core (AK-95-5) that was formerly identified as having potential for Holocene landscape reconstruction (Wagner and Siegel 1997). Vibracore locations were recorded using a differential global positioning system and ship-board computer linked to the vibrator head. Depths of these four cores ranged from 3 to 5.5 m (7 to 18 ft), three of which provided Middle Holocene dates (ca. 6,100-3,000 B.P.). The sequences were described lithostratigraphically and were examined for plant macrofossils. The data from these observations shows a documentation of relatively high-energy fluvial to near-shore facies directly overlying glacial till or outwash. Stratigraphies are diagnostic of changing estuarine and terrestrial balances in the Middle to Late Holocene. The macrofossil analyses suggested that brackish conditions emerged at approximately the beginning of the Middle Holocene (ca. 6,000 B.P. [7,000 cal yrsbp]), and that by 4,000 B.P. (ca. 4,500 cal yrsbp) an intertidal system was established at this location. The muds at Shooters Island apparently accumulated at a rate of just over 1 m (3 ft) per millennium. Sedimentation rates indicate a brackish intrusion at about 2 m (6.5 ft) between 1,000 and 2,500 B.P. The presence of oyster beds at the same depth is a confirming source of evidence for the same conditions at this depth. These observations are consistent with a 0.3 to 0.6 m (1 to 2 ft) rise in sea level at the same time. Such a period of calm would explain the increase in submerged aquatic beds (preserved in the West Core at this depth). An increase in aquatic vegetation was documented at about 2 m (7 ft) in the South Core as well. The ongoing submergence of Shooters Island is the result of a sustained but subdued sea level rise over the course of the Holocene, beginning at about 6,000 years B.P. (7,000 cal yrsbp). After that time, estuarine clay and silt began to cap sequences. They signify landward marine transgression. Conditions became increasingly brackish until the system was completely intertidal ca. 4,000 years B.P. Increased salinity up the sequence is also registered.

Baseline Model of Cultural Resource Sensitivity

The earlier studies of dredging impacts to the New York Bight produced a baseline model of archaeological sensitivity based on the relationships between cultural resource potential, dynamic landscapes of the past 20,000 years, and the impacts of dredging on former human landscapes. In general the geologic record offers a broad range of data because of several disciplines—geography, marine science, palynology, and sedimentology— have contributed variously to the database. In contrast, the archaeological information is considerably more uneven, since most investigations prior to the implementation of the National Historic Preservation Act (NHPA) were not systematic and the thirty years of subsequent research have produced limited results because of the complex logistics of both subaqueous archaeological exploration and access to cultural deposits in urban and "made" landscapes.

Structuring a Model: Holocene Environments, Site Geography, and Historic Impacts

The formulation of the model of cultural resource sensitivity presented in previous work rests on synthesizing the following three sets of data.

Geomorphic and Paleoenvironmental Trends: Sea level rise is probably the most central factor accounting for changes in Holocene landscape and environmental history. It accounts for modifications to the shape, extent, and biotic potential of the former coastline during particular periods. It is reflected in distinct sedimentation modes during phases of sea level rise. Finally, the pattern of landscape transformation is indexed by dating the sediments associated with depositional environments along the coast.

As discussed earlier, post-glacial sea level rise (after 12,000-10,000 B.P.) resulted in drowning of Continental Shelf, including areas that may have been occupied prehistorically (**Figure 2.2**). The sea level rise to the general area of the New York Bight allows paleoshorelines to be plotted to suggest former areas of prehistoric occupation for the study area here. Between

6,000-2,500 B.P. sea level had risen to within 4.0 m (13 ft) of its present level. Sea level continued to rise at the same rate over the following millennia, although it is now known that slight fluctuations above and below its mean trend took place. Since the 19th century, Industrial Age erosion and contemporary ocean circulation systems have produced unique depositional patterns in the “made” landscapes of New York Harbor.

The habitable Coastal Plain land surface extended at least 97 km (60 mi) onto the present continental shelf during the Paleoindian period (Bloom 1983a: 220-222; Emery and Edwards 1966; Stright 1986: 347-350). The Kraft et al. (1985) paleoshoreline reconstruction for the mid-Atlantic region suggests that there was still an additional 16 km (10 mi) of Coastal Plain at 9,000 B.P. (10,000 cal yrsbp). The succession of Middle Holocene shorelines rapidly approximated the present contours. All other factors considered, stratified shoreline occupations should have existed within the ten mile belt of the Middle Atlantic shore.

The overall pattern of sea level encroachment resulted in distinct modes of sedimentation that are reasonably well understood regionally, but poorly documented locally. The chronology of late glacial to post glacial sedimentation was initially explored by Newman et al. (1969) who identified the emergence, if not the particular morphologies, of the major pre-glacial lakes in the Hudson Valley. Most critically, the depositional signature for alternating clay and silt beds seasonally laid down in the individual lake basins was recognized. After 12,500 B.P. these beds were overridden by glacial meltwater sands whose distributions remain incompletely mapped.

What is clear is that estuarine fines—finer sands, organic silts, and clays—typically cap sand deposits in many differentiated shoreline settings after 6,000 B.P. (ca. 7,000 cal yrsbp). Thus the sands, or dateable organics in them, may date to between 10,000 and 5000 B.P. depending on the depth. The absence of complete chronologies is complicated in near channel settings by ongoing dredging activities that have tended to redistribute the sands.

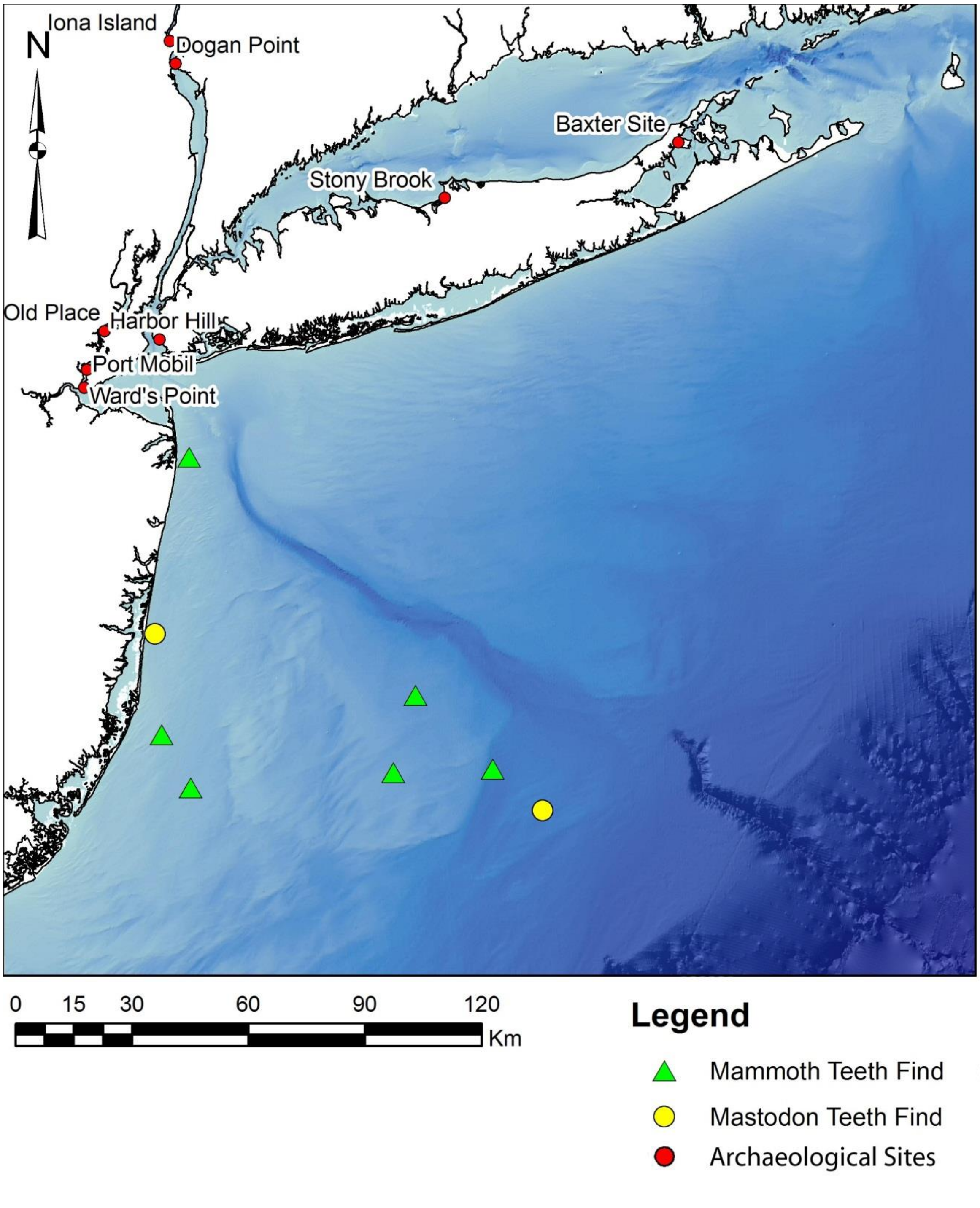

Figure 2.2: Mammoth and mastodon finds on the Continental Shelf and known Paleoindian and Early Archaic sites.

The chronology of Holocene sedimentation remains poorly understood for the New York Harbor area, in part because of the extensive historic reworking of shore facies. Radiocarbon determinations document near shore transformations for the late Pleistocene and peak glacial environments. However, dated materials are rare for terminal deglaciation (especially on the coast); there is a gap in the sequence of dates between 19,000 and 9,500 B.P. Early Holocene dates (ca. 10,000-6,000 B.P.) are present but not abundant, while Middle and Late Holocene determinations are common. These data suggest that after 6,000 B.P. (ca. 7,000 cal yrsbp) regional and local landscape configurations begin to approximate those of the present.

Archaeological Site Geography. Archaeological models of site geography remain relatively poorly known for New York City to the present day (Cantwell and diZerega Wall 2001). This is because archaeological investigation within the city environs has been impeded by urban constraints. The most relevant regional settlement models are those for the upstream segments of the Hudson as well as from neighboring trunk drainages (i.e. Delaware and Susquehanna; see Funk 1976, 1993; Ritchie 1980). These constructs suggest that settlement trends are best reflected in the modifications to landscape caused by changing stream valley morphologies for terrestrial habitats and by rapidly rising sea level for near shore locations. In both situations, "available land" for occupation shifts in response to sedimentation patterns. That tendency was most pronounced during the Early Holocene (i.e. 10,000-6,000 B.P. [11,500-7,000 cal yrsbp]).

After the rate of relative sea level rise leveled off during the Middle Holocene, the newly exposed and lower gradient near shore surfaces opened up for colonization. A corollary to this effect of near-shore stabilization is the increasing stasis of river systems which became confined to preexisting channels by 6,000 B.P. (7,000 cal yrsbp) and whose floodplains subsequently mirror near-present configurations.

Post-glacial landscape transformation and dynamic geomorphic environments are a primary cause for the diffuse preservation records of early archaeological sites. Progressive stability of later Holocene environments accounts for settlement patterns that increasingly follow contemporary environmental zonations. Thus, the infrequent occurrences of Early Archaic sites everywhere in the Northeast are largely explained by their potential containment in sediments and river fills that are submerged or deeply buried, and not accessible by typical survey strategies. In contrast, Late Archaic sites are considerably more abundant and accessible (Ritchie 1980), due to their alignment with contemporary floodplains; the geography of such floodplains has not changed dramatically in the past 3,000 years. It has also been widely recognized that population densities for later prehistoric periods are higher as well. While there is evidence for both population reduction and dispersed settlement during various phases of the Woodland, such trends are explained more in terms of subsistence and scheduling variability rather than by environmental change (Funk 1993). The absence of an extensive record of prehistoric occupation across the metropolitan New York City area is in no small measure a function of non-systematic survey and the uneven record of preservation and compliance. Projecting the Hudson Valley data onto the lower estuary, it is noteworthy that for the Paleoindian period mammoth and mastodon finds were found on the continental shelf and south of the Hudson River channel (Fisher 1955; Whitmore et al. 1967). Indications are that both of these large mammals were plentiful in valley flats that have since been drowned by sea level rise. However, the only known Paleoindian archaeological contexts are in what were formerly upland locations at Port Mobil and Ward's Point on western Staten Island along the Arthur Kill.

Subsequently, the geography of site distributions may be characterized as one of progressive "landward migration," specifically to interior (north and west) locales in response to sea level rise. The bathymetric band between 3 and 9 m (10 and 30 ft) below present mean sea level should be particularly rich in inundated archaeological sites of Middle to Late Archaic age and such sites could have extended across a broad band that would have attracted humans for periods of up to a thousand years prior to their submergence. It has been suggested that humans were frequenting northwestern Staten Island at least by the 9th millennium B.C. (Kraft 1977a, 1977b; Ritchie and Funk 1971), when spruce was beginning to decline relative to pine in the boreal forest. Early Archaic sites, currently bordering shoreline or salt marsh settings represent the vestiges of campsites in the boreal forest alongside small freshwater rivers or ponds. Their apparent low density and isolated distribution suggests that people were visiting them seasonally as part of an annual round, which also included more substantial base camps at locations now submerged within the harbor or on the continental shelf.

Until recently, the lack of diagnostic indicators for earlier Holocene paleoenvironments accounted for inaccurate depictions of the Early Archaic. Reconstructions of salinity, water depth, and other factors affecting shellfish habitat within the Early- to Middle-Holocene estuarine waters would aid in environment and habitat reconstruction for rare Early Archaic sites. This would assist in explaining the sudden appearance of oyster shell bearing sites such as Dogan Point during the 6th millennium B.P. (Brennan 1974, 1977; Claassen 1995b). It is also possible that environmental conditions changed at this point to permit the combined procurement of faunal and floral resources whose previously discontinuous distribution in coastal and interior settings required more "scheduling" of the annual round (Flannery 1968). Continuation of residential mobility at least through the Middle Archaic is supported by Claassen (1995b), however, with an annual round which included both the shellfish, seeds, meat, and hides available at Dogan Point and other unspecified resources available from interior locations such as the Goldkrest site northeast of Albany. Travel by canoes and other watercraft was common throughout the Northeast at least as early as 3,000 B.P. (3,100 cal yrsbp) as substantiated by Woodland culture assemblages found on Ellis Island and Liberty Island (Boesch 1994; Pousson 1986). Similar trends are suggested for the original portion of Governors Island (Herbster et al. 1997) within New York Harbor. More systematic examination of Woodland period contexts is precluded by the diffuse distribution of such sites and their limited documented presence within the project area.

Settlement models for later prehistoric sites are varied, as they must account for the complex subsistence and settlement strategies characteristic of the later Holocene. Another factor accounting for selective preservation of Archaic and even Woodland age sites is depositional patterns in the near shore environment. As implicated earlier, drowning of terminal Pleistocene valleys, realignments of landscapes, and the establishment of new drainage lines during the Early Holocene would have buried or severely reworked the limited sites of the Paleoindian and Early Archaic periods. Middle Archaic sites and settings within the Upper New York Bight of Middle Archaic age may have been vulnerable to the same processes of submergence and destruction. However, it is possible that during the Late Archaic (ca. post 6,000 B.P.) isolated sites at 10 m (33 ft) below mean sea level might have survived intact, since they would have been shielded from previous (alluvial or colluvial) disturbance processes. On Staten Island, many of the earlier period artifacts may have been eroded and redeposited far from their original context. However, later sites in unique settings may have remained intact. Typically, marine transgressions did not preserve archaeological sites with undisturbed systemic context (Rapp and Hill 1998: 78-79; Waters 1992: 270-275).

Most models of sea level rise, even those developed in the 1960s, account for short-term fluctuations in the overall transgressive regime. The initial rapid rate of sea level rise prior to 6,000 B.P. (7,000 cal yrsbp) suggests minimal disturbance due to wave action until sea level began to stabilize after 6,000 B.P.. Rapid submergence of sites followed by rapid burial by sediment should actually preserve artifacts and their spatial patterning better than gradual inundation (Stewart 1999: 571-574; Waters 1992: 275-280). This hypothesis would apply for all sites from upper Late Archaic, Transitional and Woodland to Historic periods. An overriding exception applies to subaerial and even currently subaqueous landscapes which have been extensively modified by historic erosion, recontouring and development. The preservation contexts of all sites are therefore subject to post-depositional modifications.

Historic Impacts on the Channel Settings. Both episodic and cumulative effects of terrain modification during the Industrial period in the New York Bight cannot be underestimated. Historic impacts include modifications to the morphology of the coastline (by additions and removal of land) and impacts to the channel by depth and lateral extent. It is instructive to compare the overall differences between contemporary shore morphology and that of the 19th century in order to understand how historic modifications and land use patterns have affected the geography of the harbor.

An earlier New York Harbor study (Schuldenrein et al. 2006) presented a pilot study of this kind, superposing the present navigation channels onto the positions of both the 1874 and present shoreline for most of the New York Bay navigation channels (Schuldenrein 2000a: Figures 12, 13, and 14). For Newark Bay, Port Newark, Port Newark Point, and Elizabeth Channels, the plots illustrated that the eastern shore remains at approximately the same location as that of the present, but the western shoreline is considerably modified. First, “made land” and docking slips were cut into the old land surface in three separate locations. Next, the shoreline itself was expanded harbor-ward (to the east) on the order of 610 m (2,000 ft). On a larger scale, the segments encompassing Anchorage, Claremont, and Port Jersey Channels revealed similar changes, with the eastern shorelines remaining essentially the same as in 1874, but the western shorelines have been more intensively relandscaped; they were relocated nearly one mile to the west. Finally, for the limited segment investigated along the Buttermilk Channel, the eastern shore is largely the same, but Governors Island has been built out significantly, extending its area by nearly one-half.

The plots and records also documented significant impacts to the channels by extent and depth. Channel excavation typically extended flow lines to depths of 10 to 14 m (35 to 45 ft), although depths up to 17 m (55 ft) have been projected for Ambrose and Anchorage Channels. For cultural resource planning purposes, it should be noted that project impacts are critical not only for surfaces immediately underlying the channels which preserve deposits younger than 7,000 years, but also for adjacent tracts that may preserve intact buried surfaces.

Toward a Working Model of Cultural Resource Sensitivity

The baseline model for cultural resources sensitivity was developed in conjunction with the initial New York Harbor study (Schuldenrein 2000a: Figure 18). It was framed around a crude synthesis of subaqueous stratigraphies from geotechnical cores and an equally limited assessment of the integrity of the sediments recorded in those sequences. The follow up studies for the Shooters Island (and attendant Kill van Kull and Port Newark channels) (Schuldenrein 2000b) and Port Jersey (Schuldenrein 2001) have provided additional subsurface data and a refinement of sensitivity. Additional modifications derived from the GIS-based mapping of bathymetry and reanalysis of the historic maps. Revised interpretations are incorporated into the present discussion.

A baseline composite cultural resource sensitivity plot for the project impact area was generated. The individual channels were identified, as were the locations of cores and borings excavated and examined to date. Sensitivity rankings were presented in terms of **Low**, **Moderate**, and **High** potential for sites, based on the conflation, by channel, of the data collected for assembling the paleoenvironmental, archaeological, and channel impact histories. The key paleoenvironmental relationships used for ranking the sensitivity were presented along with more specific rankings of sensitivity by archaeological component, by depth (below mean sea level) of expected occurrence per the shoreline histories discussed above. Impact areas referred not only to the navigation channels *sensu stricto* but to channel margins as well, since these are likely to be excavated and/or disturbed by channel widening activities and future ship traffic.

A relative scale for site preservation invoking High and Moderate probability was derived from the recognition of deposits below impact levels that correlate with shore, near-shore, estuarine, or floodplain surfaces. These identify the range of buried surfaces that would have sustained human occupation during prehistoric time. For the earlier time frames (i.e. Paleoindian through Middle Archaic) rates of sea transgression were rapid and would have resulted in rapid burial of archaeological deposits. Recognition of deposits likely to contain archaeological evidence resulted in **Moderate** to **High** determinations. **Low** rankings were generally assigned to channel segments in which investigations disclosed presence of a proglacial lake deposit or glacial till, both of which are unlikely to contain archaeological materials because of their subaqueous contexts or Pleistocene antiquity. Radiocarbon ages and the foraminifer data index the chronology and patterns of environmental change respectively. **Low** rankings were also assigned to segments in which bedrock was reached (i.e. Port Newark Point, Elizabeth Channel). For the later time frames (Late Archaic through historic), clear recognition of estuarine or fluvial, alluvial, and near shore deposits was critical. These sediments document presence of a stable surface and/or potentially rich resource biome. The foraminifer data indicate shifts in resource zones that might be tracked by assessing types and frequency changes in the foraminifer types.

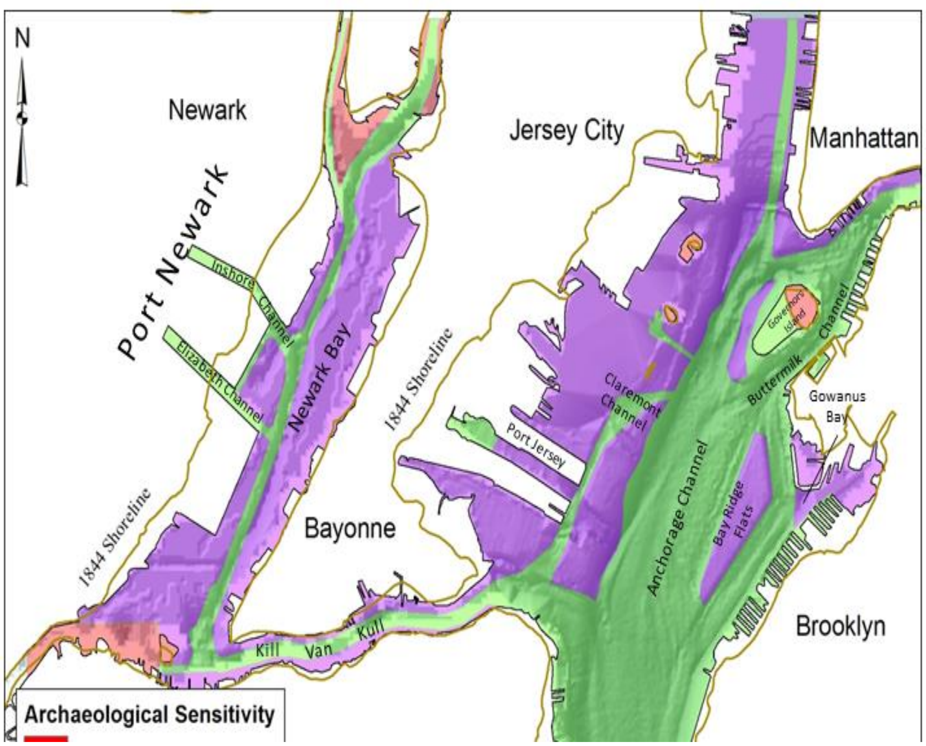

Figure 2.3: Example of archaeological sensitivity denotation.

Primary determinants for the probability rankings are sea level position and extent of disturbance by dredging. Two additional concerns include site probability by period and post-depositional modification. It is assumed that while site expectation might be considered highest for late prehistoric components, integrity is compromised by their presumed location in those near shore settings most susceptible to disturbance by dredging and by earlier reworking by near shore geomorphic process during the long intervals of shore stabilization. Conversely, older sites, traditionally thought to be less dense and less likely to be preserved are more likely to be sealed at depths beneath dredging impact areas. Along similar lines, during the Early Holocene relatively rapid burial of earlier prehistoric components would have resulted in their optimal preservation contexts. In reviewing the geoarchaeological relationships, the following trends were suggested by the baseline site probability model.

1. *There is a relatively high potential for historic finds, even along channel reaches that are acknowledged to have low overall cultural resource potential*. This is because historic sites include contexts that may have been partially modified, but retain some integrity. Accordingly, even century old edifices constructed on "made land" are considered potentially eligible for the National Register of Historic Places (NHRP). Examples would include tanning yards that functioned along older shorelines that remain partially preserved in now submerged or disturbed settings.

2. *With some exceptions—Newark Bay, Claremont, Port Jersey and Anchorage Channel—most segments have Low expectations for later prehistoric remains.* Reference is made to post Late Archaic site potential and locations above the 6-12 m (20-40 ft) bathymetric contours. The Low ranking reflects dredging disturbance to these channels and the probability of mixing of assemblages (i.e. Late Archaic and Woodland) on near shore surfaces during the Late Holocene, as sea level rise was stabilizing. Wave action and shifting beach margins of the estuaries would have affected land expanses and shapes along the coastline. Smaller sites would have been swept away well before historic times. Low and Moderate rankings were assigned to locations flanking channels minimally dredged; here there remains a likelihood of Late Archaic and Woodland site survival.

3. *The Late Archaic marks a threshold for Moderate site potential*. As noted, by 6,000 B.P. (7,000 cal yrsbp) rates of sea level rise diminished and shorelines stabilized. Many sites could have been rapidly buried, thus resulting in retention of site integrity. Moreover, sites of this period are abundant, since in addition to the fact that landscapes began to approximate contemporary configurations, the changing coastlines marked the transitions to estuarine and highly differentiated microenvironments. These would have been excellent as well as prolific settlement loci. Stratigraphically, this portion of the vertical sequence is the break beneath which impacts by dredging were minimal. Thus, the potential for site preservation rises proportionately with increasing depth.

4. *Paleoindian to Middle Archaic site expectations are Moderate or High in several channel segments*. Only Port Newark, Port Newark Point, and Buttermilk Channel have Low site potential rankings. The **Low** ranking was determined because elevations below 9 m (30 ft) in these channels either encounter Late Pleistocene lake beds or bedrock. **Moderate** to **High** rankings are the product of stratigraphic exploration that either revealed a pristine glacio-fluvial facies (possible stream side location at Newark Bay), or Early Holocene near shore facies (Anchorage Channel; dated) or floodplain (Claremont, Port Jersey) contexts. Stapleton and Ambrose Channels, while not examined in detail, provide limited records of analogous Early Holocene sedimentation regimes. In all locations, with the possible exception of Ambrose, the deposits with potential are below the limits of dredging.

Testing the Model

The above hypotheses are testable on several scales. Large scale refinements are generated by more detailed mapping. In the past few years, since the baseline New York Harbor investigations were undertaken, several agencies have completed the mapping and digitizing (GIS) of data sets bearing on local and regional surface geology.

Both the New York and New Jersey Geological Surveys have updated plots of the surficial geology of the coast and terrestrial landforms of the New York Harbor area. Present surfaces are either underlain by bedrock or surficial deposits of Late Quaternary age. In general, the latter reach thicknesses of 1-20 m (3-68 ft) in marine, estuarine, and terrestrial contexts. Because of the complex record of glacial activity, the chrono-stratigraphy of the surface sediments is the key variable in assessing buried site potential for prehistoric deposits. Accordingly, accurate mapping is a key measure of the zonation of landform complexes likely to contain archaeological sediments of a given age.

Substantial refinement has been achieved in mapping complex subsurface lithologies. It has been provisionally possible to correlate between states by comparing descriptions of landform and sediment complexes in the vicinity of state lines and by generalizing unit designations. GIS databases available in both states facilitate such tasks. Surficial geology maps provide an index for observations made over the course of the previous field testing. Ideally, the correspondences between the stratigraphies with broad landform/sediment complexes established by the mapping units would facilitate a stratigraphic sequence and chronology for the New York Harbor area.

Chapter 3
Relative Sea level Rise along the Mid-Atlantic Coast

Global Eustatic Sea Level

Global sea level is ultimately controlled by climate change, which varies the volume of water available in the ocean basins. Simplistically, sea levels can be thought of as being low during periods of glaciation when great volumes of the available earth's water were been removed from the oceans and held in storage as ice on the continents. The converse is true when glaciers melt on the continents and return water to the oceans once more. Geologic records from out continental shelves show sea level to have been at least 100 m (328 ft) lower than present during the last glaciation, ca. 20,000 years ago. The change in volume of sea water in the ocean basins is termed the eustatic sea level.

Accurate determination of global sea level is more complex. Although studied over the past century, sea level records could only be reconstructed in detail after the advent of radiocarbon dating following World War II. Radiocarbon dated sea level records presented during the 1960's (Fairbridge 1961; Shepard 1965) generated subsequent decades of intense debate and research on sea level. Importantly, it appeared unlikely that eustatic sea level could be determined with accuracy because of the complexity of the changing size of the ocean basins due to sea floor spreading or subsidence of the oceanic basins due to the mass of water returned from melting glaciers. Similarly, the temperature of sea water influenced its volume as well, with warming water giving rise to higher levels (steric effects). As a result, the study of sea level change was complicated by the changing position of the earth's crust with respect to the level of the sea and the level of the sea with respect to temperature and the continental shorelines. Current concerns with ongoing rise in sea level contend with the relative position of the sea relative to the land—hence relative sea level. Yet the impact of relative sea level on the continent shores requires a better understanding of eustatic sea level.

In recent years, the eustatic sea level has been reconstructed with greater reliability through the study of "far field" sites. These are records of sea level change determined from islands "far field" from the complex, crustal changes of the continents. In theory, radiometric dating of sea level sensitive markers (specific coral species, etc.) provide the basis for determining the "absolute" level of the sea with respect to its volume as varied by glacier melting and steric effects. The leading models for eustatic sea level are presented by Peltier (2002) and Fleming et al. (1998). Both models rely on estimates of the volumes of glacial meltwater returned to the ocean basins since the last glaciation. Peltier maintains that virtually all of the glacier ice had been returned to the ocean basins by 6,000 to 7,000 year ago suggesting that sea level has been stable since that time. Fleming and his colleagues have maintained that eustatic sea level has risen from 3 to 5 m (ca. 10 to 15 ft) over the past 7,000 years. The arguments are not relative to this study other than to help understand the record of relative sea level changes on the Atlantic coast of the United States and Canada. It is important to recognize that during the melting of continental glaciers, the eustatic level of sea rose rapidly until ca. 7,000 years ago when the rate of rise decreased dramatically.

The pattern of eustatic sea level rise is shown graphically in **Figure 3.1** which is the Fleming et al. (1998) compilation of sea level recorded from "far field" sites. This model illustrates a low sea level of 120 m (394 ft) at the height of the last glaciation.

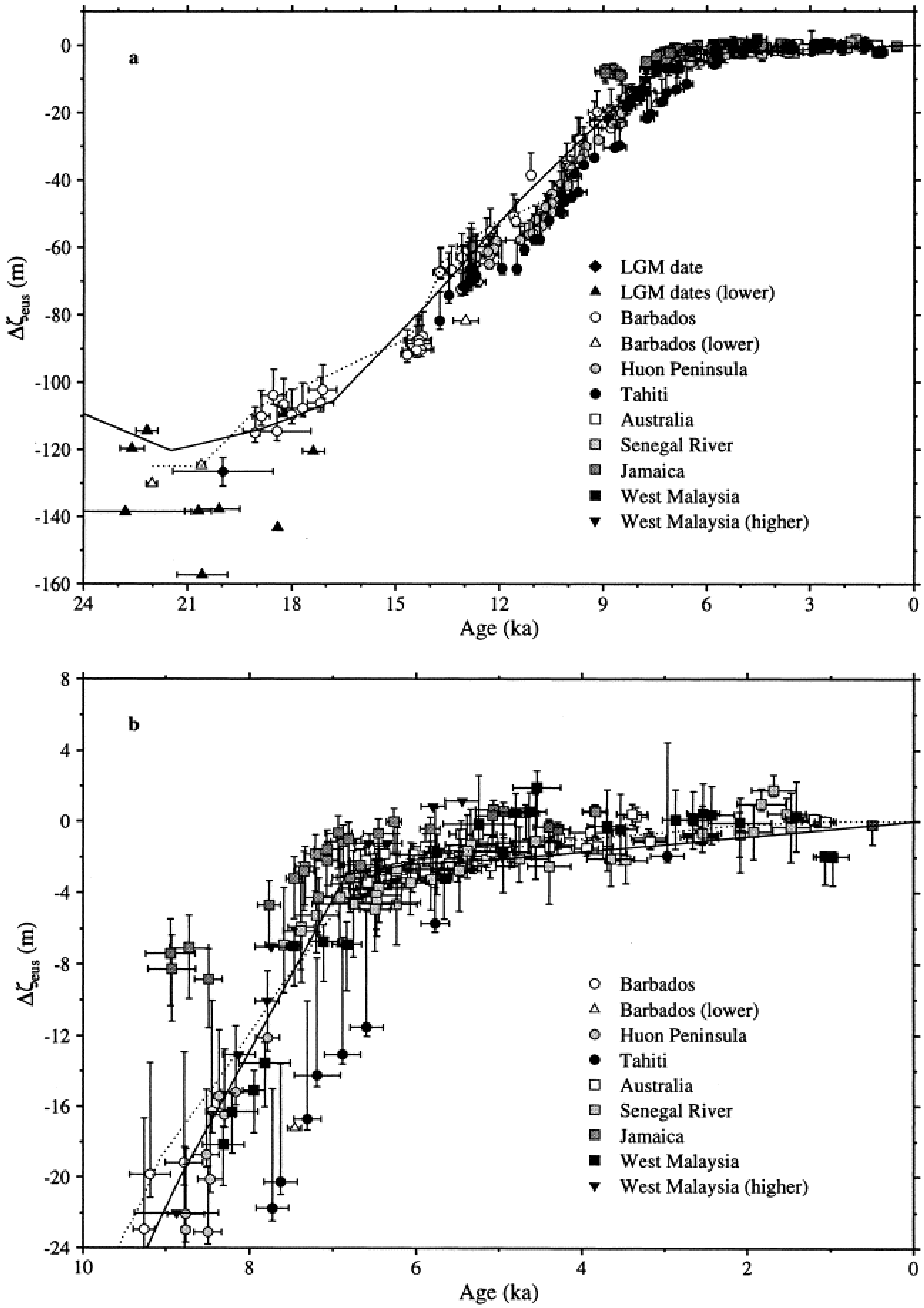

Figure 3.1: Eustatic sea level results (a) from the Last Glacial Maximum to the present day, and (b) for the Holocene. The initial nominal eustatic curve Δζnesl (solid) and a modified eustatic curve Δζmesl (dotted) are also shown (from Fleming et al. 1998).

Relative Sea Level Change along the Atlantic Coast

Tide gauges along the coasts of the U.S. and Canada provide historic records of **relative** sea level changes. It is clear, however, that there is great variation in the rates of sea level rise from one station to another. This is shown graphically in **Figure 3.2** which shows the rates of relative sea level rise along the U.S. Atlantic coast from Key West, Florida to the Canadian border. Note that the rates of sea level rise recorded by the gauges are on the order of 1.5 to 2.0 mm/yr (0.06 to 0.08 in/yr) for the Florida peninsula and the New England coasts but rise to highs from 3.0 to 4.0 mm/yr (0.12 to 0.16 in/yr) for the Mid-Atlantic coast. These are shown in comparison to the rate of global eustatic sea level rise proposed by Peltier (1995, 2000). Peltier (1995, 2000) and Douglas (1991) relate these anomalously high rates of relative sea level rise to ongoing post-glacial crustal adjustments. More specifically, these researchers point to subsidence along a zone peripheral to the southern limit of glaciation termed a proglacial forebulge. The forebulge represents an uplift of the earth's crust caused by simultaneous depression of the crust in the Hudson Bay region and Laurentian Highlands under great thicknesses of glacier ice. As the crust in the former glacier ice center rises, the forebulge collapses and continues to do so. This ongoing process is termed post-glacial rebound (PGR). Both Peltier and Douglas consider the rate of subsidence of the forebulge (labeled PGR) to be on the order of 1.5 mm/yr (0.06 in/yr). Subsidence increases in rate from a minimum in the Florida peninsula to a maximum between Georgia and Long Island Sound while decreasing further north. In essence, since the crust is subsiding, this rate must be added to the global eustatic rate of sea level rise. Hence, the relative rates of ongoing sea level rise along the Mid-Atlantic coast are on the order of 3.0 mm/yr (0.12 in/yr).

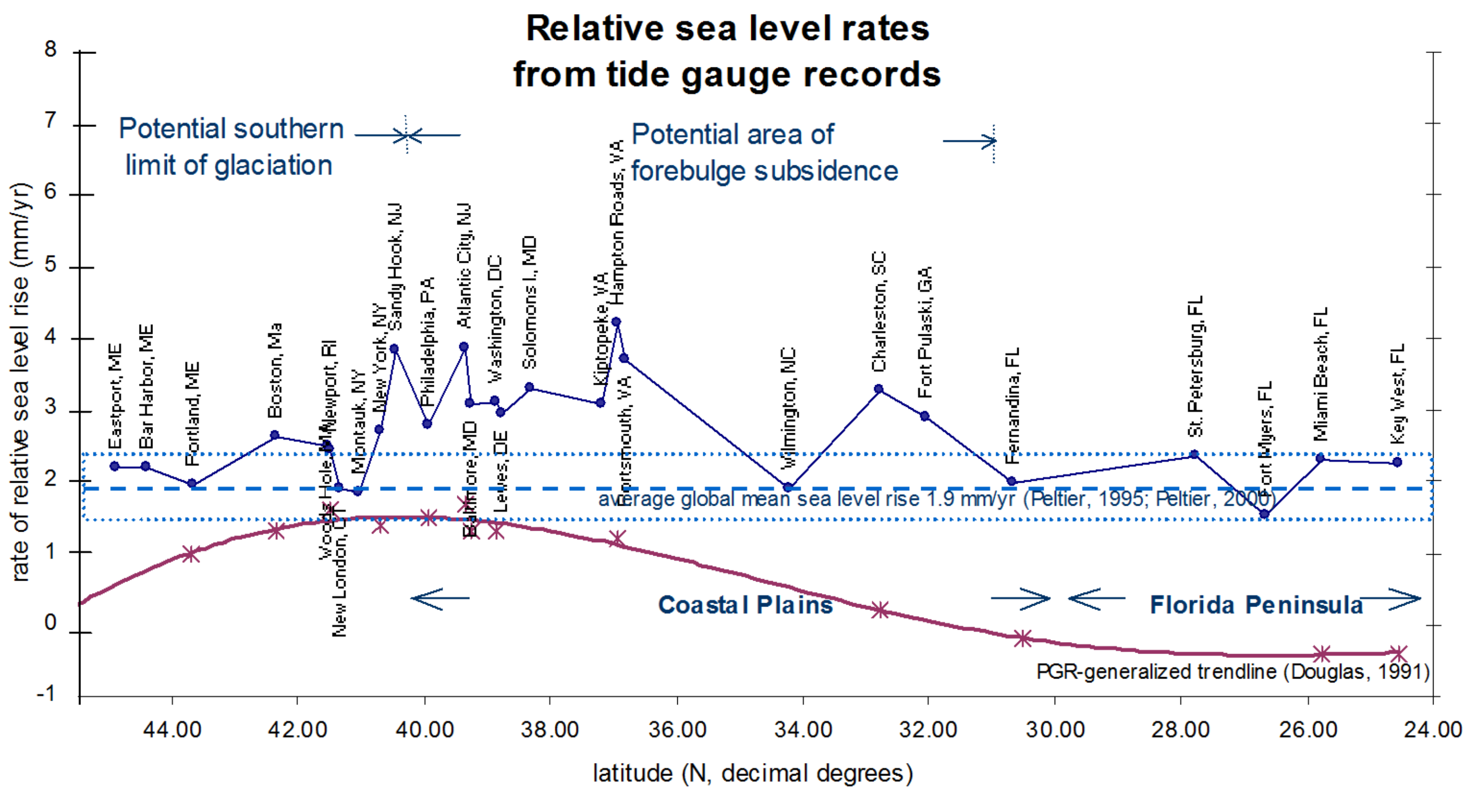

Figure 3.2: Relative rates of sea level rise along the Atlantic Coast as recorded by tide gauges. The rise in rates of subsidence (PGR) delineates the area of proglacial forebulge (figure provided by C.E. Larsen and I. Clark).

Comparative Holocene Sea Level Curves

The combination of eustatic sea level and forebulge subsidence provide an entrée for an understanding of post-glacial relative sea level rise along the Mid-Atlantic coast. But first, it is necessary to show consistency between rates of relative sea level rise on historic and geologic time scales. **Figure 3.2** shows consistency in rates among New York, Philadelphia, and Washington, D.C. but only the first two sites have long enough periods of record to allow close comparison. Baltimore, MD, is another site with a suitably long record. **Figure 3.3** below shows a comparison of these three historic tide gauge records. All three of these are located on areas underlain by crystalline rocks which cannot be expected to show the effects of sediment compaction or anthropogenic subsidence due to groundwater withdrawal. These sites are in contrast to sites at Hampton Roads, VA, Atlantic City, NJ, and Sandy Hook, NJ which show anomalously high rates of relative sea level rise. The latter two lie on the outer edge of the Atlantic Coastal Plain underlain by sedimentary rocks, while the former is located in a zone of probable anthropogenic subsidence due to groundwater withdrawal (Davis 1987). The close agreement in the rates, trends, and patterns among these three tide gauge sites is striking. They form the comparative basis for building a Holocene relative sea level curve for the New York Harbor study area.

Detailed reconstructions of Holocene relative sea level are available from four critical areas: Chesapeake Bay, Delaware Bay, Long Island Sound, and Cape Cod Bay. Each of these sea level records are derived from radiocarbon-dated basal peat lying on sediments resistant to compaction. They represent the best sources for representing the trend of Holocene sea level rise over the past several thousand years. The trends calculated from the radiocarbon-dated peat are shown below in **Figure 3.4**.

Consistent with the historic tide gauge records for the "bedrock-founded" sites shown in **Figure 3.3**, the Clinton, Barnstable, and Chesapeake Bay sites show relative rates of sea level rise at 1.4 mm/yr (0.06 in/yr) while the sites at the mouth of the Delaware Bay show a greater rate: 2.0 mm/yr (0.08 in/yr). The latter is likely affected by the thick sequence of less consolidated sediments and sedimentary rocks underlying this portion of the Atlantic Coastal Plain. Hence the Delaware Bay sites seem to display regional compaction, while the Connecticut and Massachusetts sites are underlain by more consolidated sedimentary rocks (or crystalline rocks). Chesapeake Bay displays the 1.4 mm/yr (0.06 in/yr) rate, but lies at the inner edge of the Atlantic Coastal Plain where sediments and sedimentary rocks form a thin wedge lying on crystalline rocks of the Piedmont region, similar to Philadelphia and New York City.

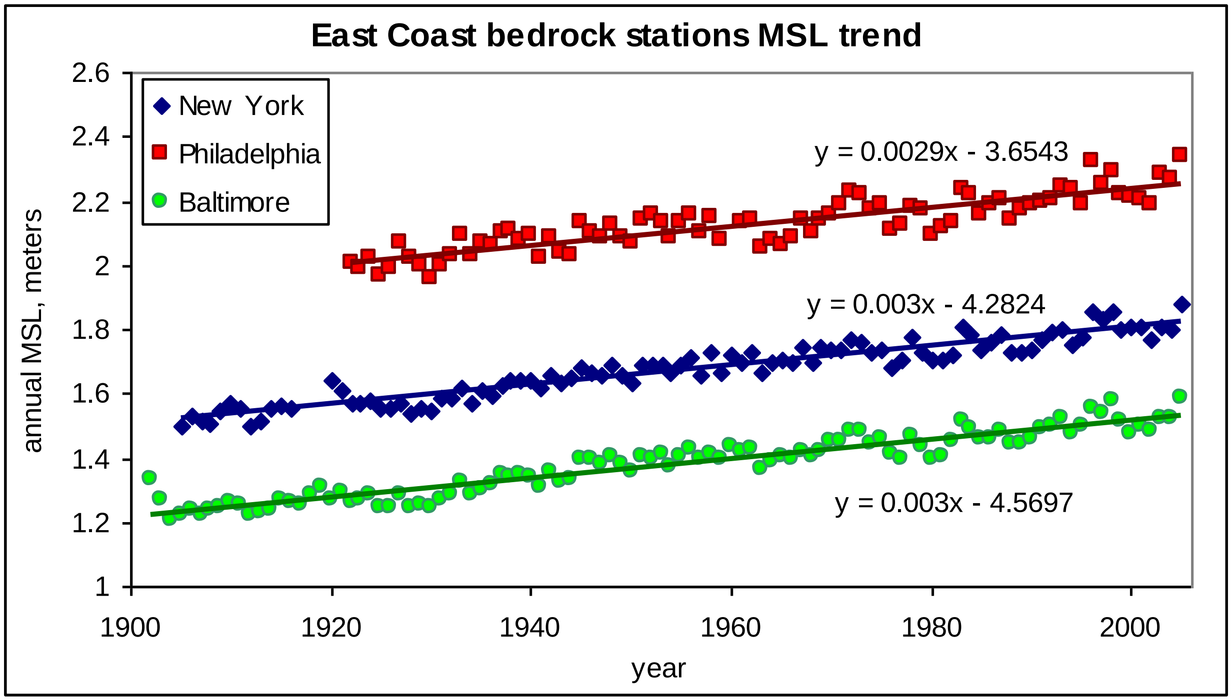

Figure 3.3: Comparison of tide gauges of long term bedrock founded sites. Each site shows a rate of rise of 2.9 to 3.0 mm/yr (0.12 in/yr).

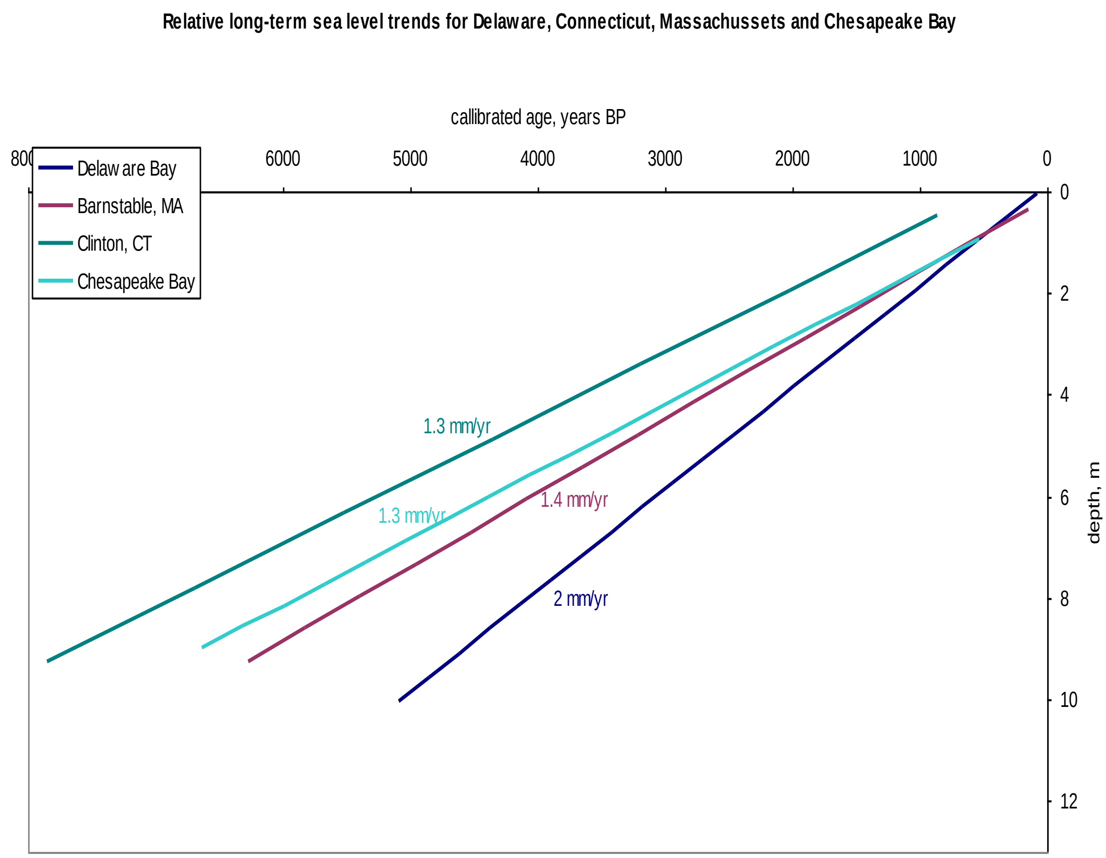

Figure 3.4: Comparative trends of Holocene sea level along the Mid-Atlantic Coast (adapted from Larsen and Clark, 2006).

In terms of the eustatic sea level discussion above, these rates of are considered by Peltier (1997, 2002) and Douglas (1991) to represent the rates of crustal subsidence along the eastern seaboard (**Figure 3.2**). For the purposes of constructing a sea level rise model for the New York Harbor area, the resulting curve of relative sea level should resemble the eustatic pattern shown in **Figure 3.1** lowered by consistent subsidence on the order of 1.4 mm/yr (0.06 in/yr) over at least the past 7,000 years. In concept for New York Harbor then, a rising trend should be expected on the order of 1.4 to 1.5 mm/yr (0.06 in/yr) for at least the past 7,000 years preceded by a more rapid rate of rise following deglaciation. In addition, since the current record of eustatic sea level has been presented in sidereal (calendar) years, radiocarbon ages determined as part of the present study as well as data contributed by other workers to build the model must be calibrated to maintain consistency.

Development of an Accurate Local Relative Sea Level Curve

The Past 10,000 Years. Although the New York area researchers have figured prominently in discussing sea level histories (Fairbridge 1961; Newman et al. 1969), few studies have been specific to New York Harbor or the New York Bight. Psuty (1986) and Psuty and Collins (1986) presented a relative sea level reconstruction on the basis of dated stratigraphy from several New Jersey sites, including two from Raritan Bay. More recently Stanley et al. (2004) have again discussed New Jersey data, but largely focused on the Cape May area which in some ways duplicates the longstanding work on Delaware Bay by Belknap and Kraft (1977) and synthesized most recently by Nikitina et al. (2000). These two complementary studies argue for a rate of relative sea level rise on the order of 2 mm/yr (0.08 in/yr) (as discussed above for the Lewes, DL, and Cape May, NJ area). Other important studies were conducted by Bloom and Stuiver (1963) on the salt marshes of the Clinton, CT area of Long Island Sound followed by Van de Plassche et al. (1998) and most recently by Varekamp and Thomas (1992, 1998). Further to the northeast, Redfield and Rubin (1962) provided a dated record of transgression at the Great Marsh at Barnstable, MA. The majority of work in the 1960's through the 1980's relied on radiocarbon ages. Refined calibration techniques for radiocarbon age dating have since impacted the interpretation of the early studies by allowing the direct comparison of the prehistoric sea level record to the historic data recorded by the tide gauges. Calibration of radiocarbon ages used in past sea level studies in the region points to different interpretations of the data originally presented. For example, earlier studies often showed sharp changes in the rate of sea level rise at various times in the past several thousand years marked by a sharp break in slope of the curve (Psuty 1986; Psuty and Collins 1986; Redfield and Rubin 1962). The break was generally considered to have occurred about 5,000 years ago but can now be understood to be an artifact of uncalibrated radiocarbon dates. Few dated relative sea level curves are available from the New York area that extends beyond 6,000 cal yrsbp. The trend of the rate of rise since this time is nearly linear with probable departures of ± 1 m about the mean trend (Larsen and Clark 2006). This seems to be consistent for the Mid-Atlantic region where there are sufficient data to establish a trend.

During the course of the present study 20 vibracores were taken in Raritan Bay, Jamaica Bay, and the Upper Harbor. Only a few of these provided sufficient organic material for radiocarbon dating of the marine transgression. Others, while datable, were from probable disturbed contexts or were from very young sediments. The data collected in 2006 and 2007 are supplemented by radiocarbon dates from pertinent cores taken by other researchers in the past as well as from cores taken by GRA during previous studies. Radiocarbon ages, calibrated to calendar years before the present, are shown in **Appendix B**. This table provides the elevations of the critical dates and stratigraphy in both meters and feet below mean sea level (m bmsl, and ft bmsl).

Calibration is provided by the Oxford University (OXCAL) system available online (c14.arch.ox.ac.uk/oxcal.html). The mid-point of the calibration range forms the basis for plotting age versus depth to establish a sea level transgression curve for New York harbor. As basal peat ages furnish the only dependable measure for determining contemporaneous sea level elevations, only those samples labeled as basal peat or brackish marsh are used in the calculation. **Figure 3.5** illustrates this curve. Unlike the eustatic sea level curve (**Figure 3.1**) the relative rise of sea level in New York harbor is a smooth curve extending 9,000 years in the past. The data suggest a rising trend over the past 5,000 years at a rate of between 1.4 and 1.5 mm/yr (0.05 and 0.06 in/yr). Prior to 5,000 cal yrsbp, the trend is more difficult to discern, largely due to the scarcity of earlier radiocarbon-dated stratigraphy. Three dated peats from the south shore of Long Island recorded by Field et al. (1979) and another from an incised stream channel along the eastern shore of Staten Island near Ward Point (LaPorta et al. 1999) suggest the rapid rise in sea level immediately following deglaciation at a rate on the order of 2.6 mm/yr (0.10 in/yr). The differing rates of rise are not consistent with the eustatic sea level and clearly do not exhibit the marked break in slope shown in **Figure 3.1**. Earlier dates on wood from the Anchorage Channel (98ANC44) at 20.12 m bmsl (66 ft bmsl) and basal peat overlying sand at 18.6 m bmsl (61 ft bmsl) from the Jersey City viaduct (R15-4) show earlier dates but their interpretation is uncertain. In either case the pre-5,000 cal yrsbp trend is poorly defined.

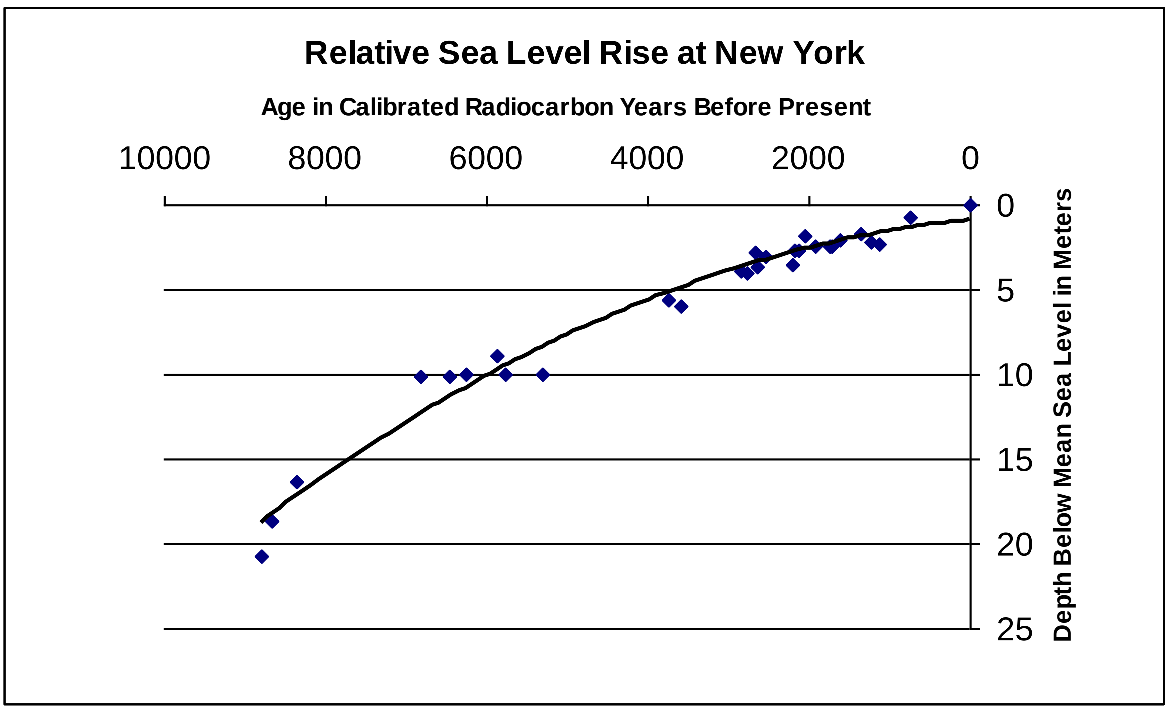

Figure 3.5: Relative sea level at New York determined from ^{14}C-dated brackish marsh deposits and peats.

Trends in the data are better understood when dates from before 7,000 cal yrsbp are interpolated separately from those dating to after 7,000 cal yrsbp. **Figure 3.6** below shows a comparison of linear trends calculated on pre- and post-7,000 cal yrsbp samples shown above. Although there are few post-7,000 samples, there is a clear dichotomy between the two groups. The trend calculated for the post 7,000 cal yrsbp samples shows a rate of rise of 1.6 mm/yr (0.63 in/yr) over this period and is consistent with rates derived from dated stratigraphy from Barnstable and Clinton marshes as well as Chesapeake Bay. The pre-7,000 cal yrsbp trend of 9 mm/yr (0.4 in/yr) suggests the rapid rise following deglaciation and is in agreement with the 10 mm/yr (0.4 in/yr) rate for this period suggested by Flemming et al. (1998). Clearly the curvilinear format is an artifact of the curve fitting technique and does not fit the current knowledge of eustatic sea level.

It is important to note that a recent study of submerged oyster reefs in Tappan Zee (Carbotte et al. 2004) has provided corroborating evidence for the interpretation of relative sea level change over the past 7,000 years. Shell dates, adjusted for dead carbon and subsequently calibrated, have been plotted in green on **Figure 3.6**. The calculated rate of relative sea level rise shown here is 1.6 mm/yr (0.63 in/yr) and the trend calculated for the dated oyster reefs is 1.8 mm/yr (0.7 in/yr) and comparable. This shows that living oyster communities adjusted to water depth and salinity were able to keep pace with the rate of sea level rise for at least a 5,000-year period for which there are data. Carbotte et al. (2004) also note that oyster growth was not continuous through time but showed distinct breaks in colonization. The authors propose that climate change and possible salinity changes related to sea level rise may have been contributing factors to periods conducive to oyster growth. These findings also reflect on distinct periods of oyster harvesting activity recorded in shell middens at Croton Point (Salwen 1964; Newman et al. 1969) and Dogan Point (Claassen 1995) that also point to periods when shellfish were not an important part of the diet at this particular site at these particular periods.

For the purpose of this study, the relative sea level shown in **Figure 3.6** demonstrates the best agreement with the eustatic models argued by both Fleming et al. (1998) and Peltier (1995, 2000) and will be the interpretation used to reconstruct the overall sea level rise history of the New York Harbor area.

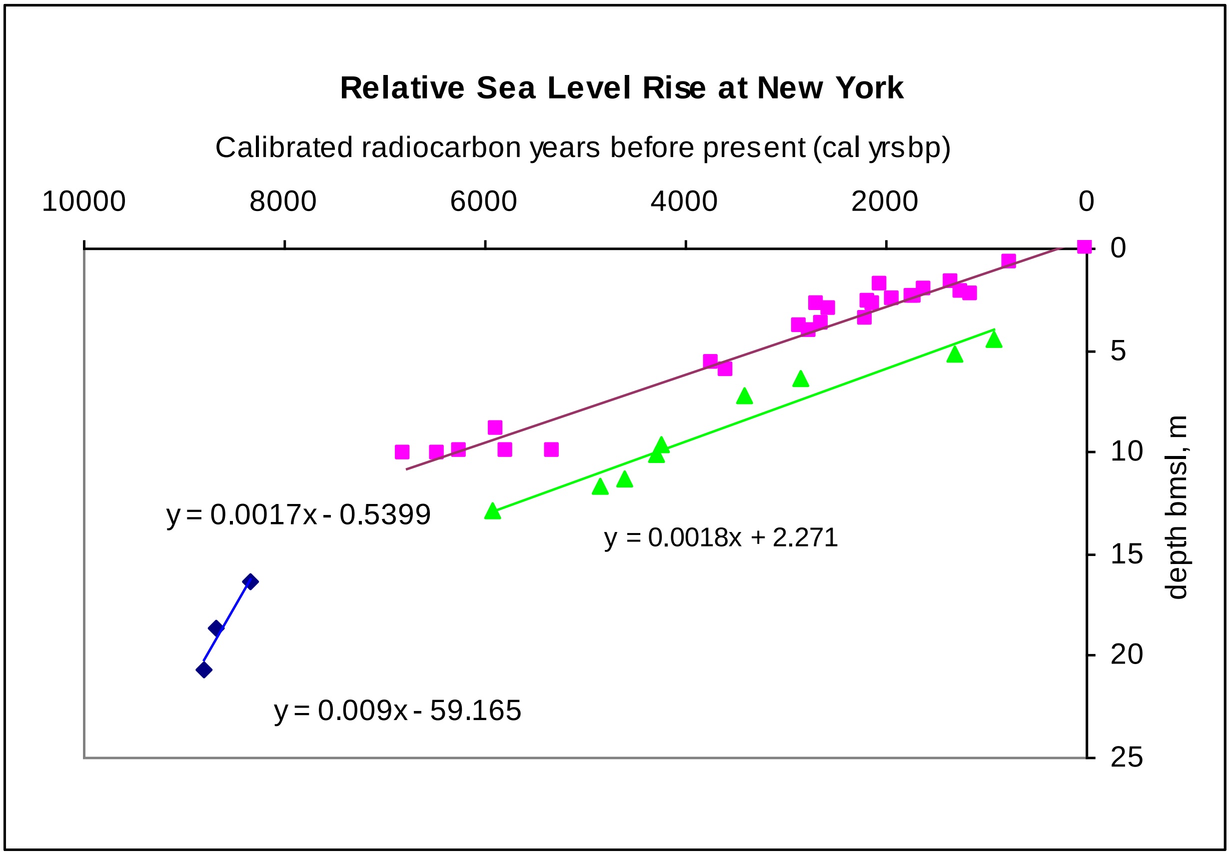

Figure 3.6: Comparison of pre- and post-7,000 cal yrsbp sea level trends. The green line represents dated oyster reefs in the Tappan Zee area (Carbotte et al., 2004)

Detailed Reconstruction of the past 3,000 Years

Techniques for detailed reconstruction of relative sea level positions and rates of rise are in their infancy, however particularly cogent studies have been carried out in the New York area. Salt marsh stratigraphy is a key to determining short term and low amplitude fluctuations of sea level. Because many of the extant saltmarshes are relatively young—on the order of 2,000 years or less—knowledge is limited. Further, the field and laboratory studies required are labor intensive and therefore the results of the studies are not widely known. The concepts are straightforward. Saltmarshes are zoned with specific vegetation types dominant in specific tidal and salinity regimes. **Figure 3.7** demonstrates this concept. The intertidal zone located between mean high water (MHW) and mean low water (MLW) is most conducive to *Spartina alterniflora* and, lithologically, the sediment present contains high amounts of organic material in a matrix of clayey silt. Higher in elevation and away from the increasing reach of the tide, progressively less salt-tolerant vegetation extends up imperceptibly gentle slopes. This progression often proceeds from *Spartina patens* through *Disticulus spicata* to *Scirpus americanus* or *olneyi* and *Juncus* *roemerianus*. In the more freshwater dominant areas upslope, the vegetation may give way to *Typha* sp., the common cattail and the invasive *Phagmites* sp. common to the marshes of New York area.

Because these plant types are salinity dependent, they respond to rising and falling water levels. Together with the underlying sediment, the pollen and seeds for each vegetation zone, as well as the microfauna living in the marsh, changes in past sea level can be tracked through time and space provided there is sufficient material for isotopic age dating. **Figure 3.7** demonstrates the zonation of vegetation and sediment in a tidal setting governed by a stable mean sea level.In this scenario, sediment accretion takes place along the edges of the marsh adjacent to tidal channels carrying suspended sediment. As sediment is added to the marsh edge, the marsh grows laterally and expands. The sedimentary zones or facies within the marsh also spread laterally forming near-horizontal stratigraphic units while simultaneously preserving the pollen and microfauna of the marsh surface. Abundant organic debris at the surface forms a saltmarsh peat layer underlain by organic silts indicative of the intertidal zone. This example can be considered the steady-state example of saltmarsh growth and expansion.

Sediment cores taken at sites A and B in **Figure 3.8** show the attitude of the facies and furnish the fossil record needed to reconstruct the contemporaneous environment. With the steady-state example in mind, the complexity of the saltmarsh to sea level variation can be better understood. **Figure 3.9** illustrates the changing vegetation positions and sedimentary facies during an episode of rising sea level. In this case both the vegetation and underlying sediment rise and move inland with a rising sea level. The sedimentary facies are no longer horizontal but rise and lap onto and cover previous deposits. For example, note the rise and movement of saltmarsh peat inland, now overlying the previously deposited freshwater peat and land surface. Sediment cores taken in this scenario record the transgression of sea level onto the marsh.

For a falling sea level, the pattern reverses allowing the vegetation and stratigraphy to shift back to the lateral accretion model shown in **Figure 3.8**. Each transgression and regression of the sea surface is recorded stratigraphically in an interfingered sequence of lithologic units containing a fossil record of marsh history.

Fletcher et al. (1993) recognized transgressive and regressive facies in saltmarshes at the mouth of Delaware Bay. These researchers identified 5 separate transgressive units over a 5,000-year period, each separated by a period of regression during lowered sea level. Distinct periods of lower sea level were noted at 2,200 and 800 B.P..

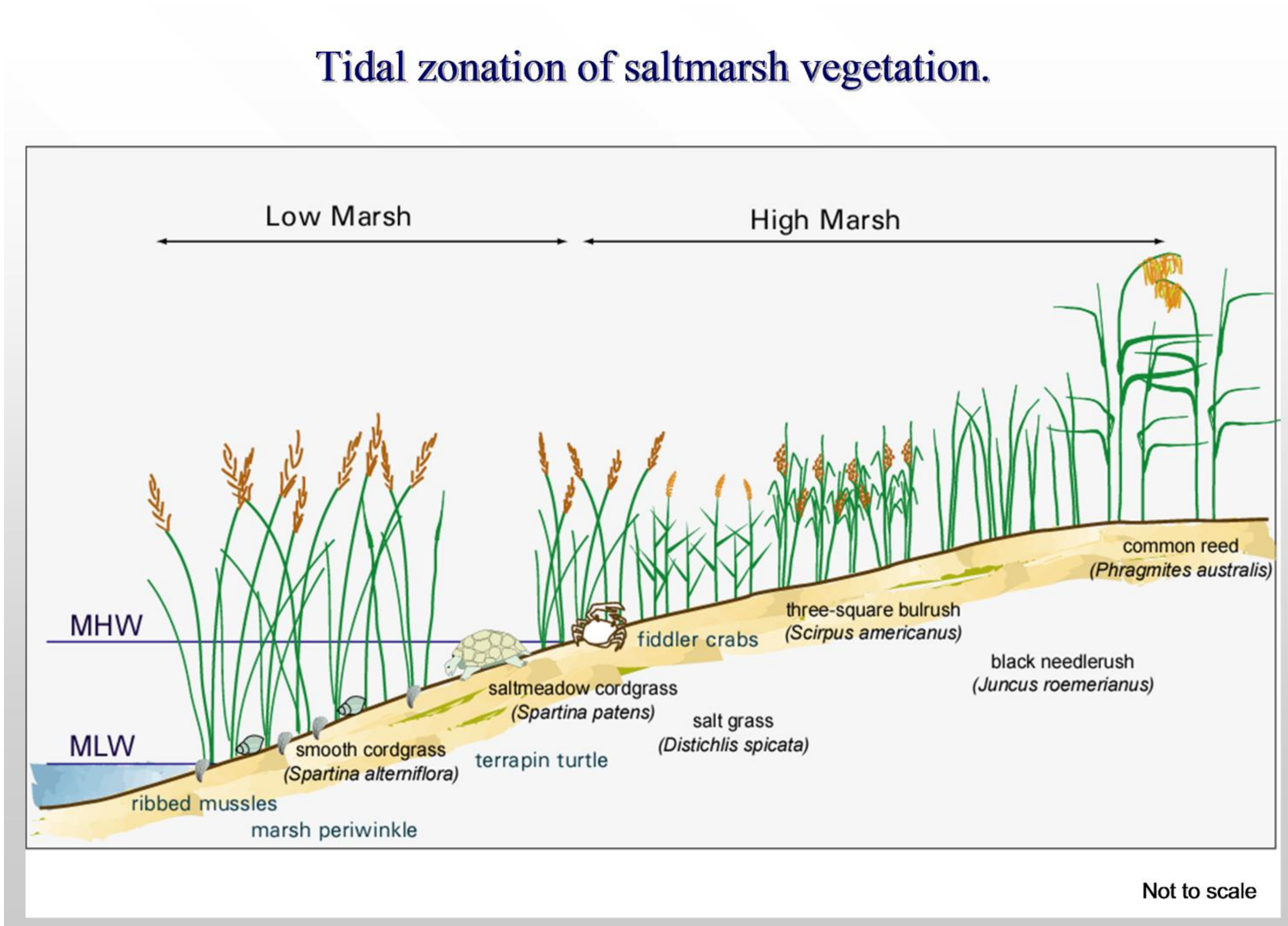

Figure 3.7: Zonation of saltmarsh vegetation (provided by C.E. Larsen and I. Clark).

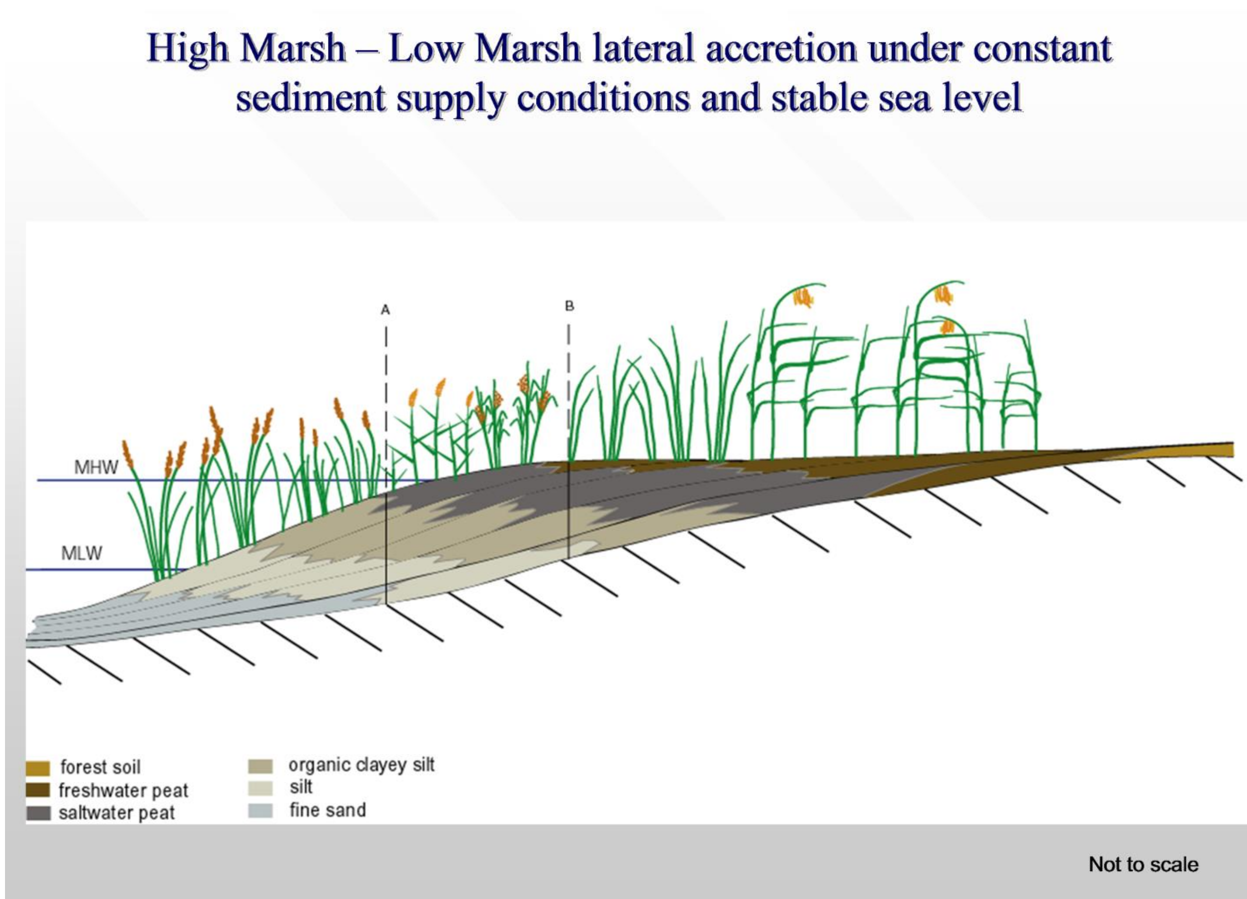

Figure 3.8: Lateral marsh accretion under constant sediment supply and stable mean sea level (provided by C.E. Larsen and I. Clark).

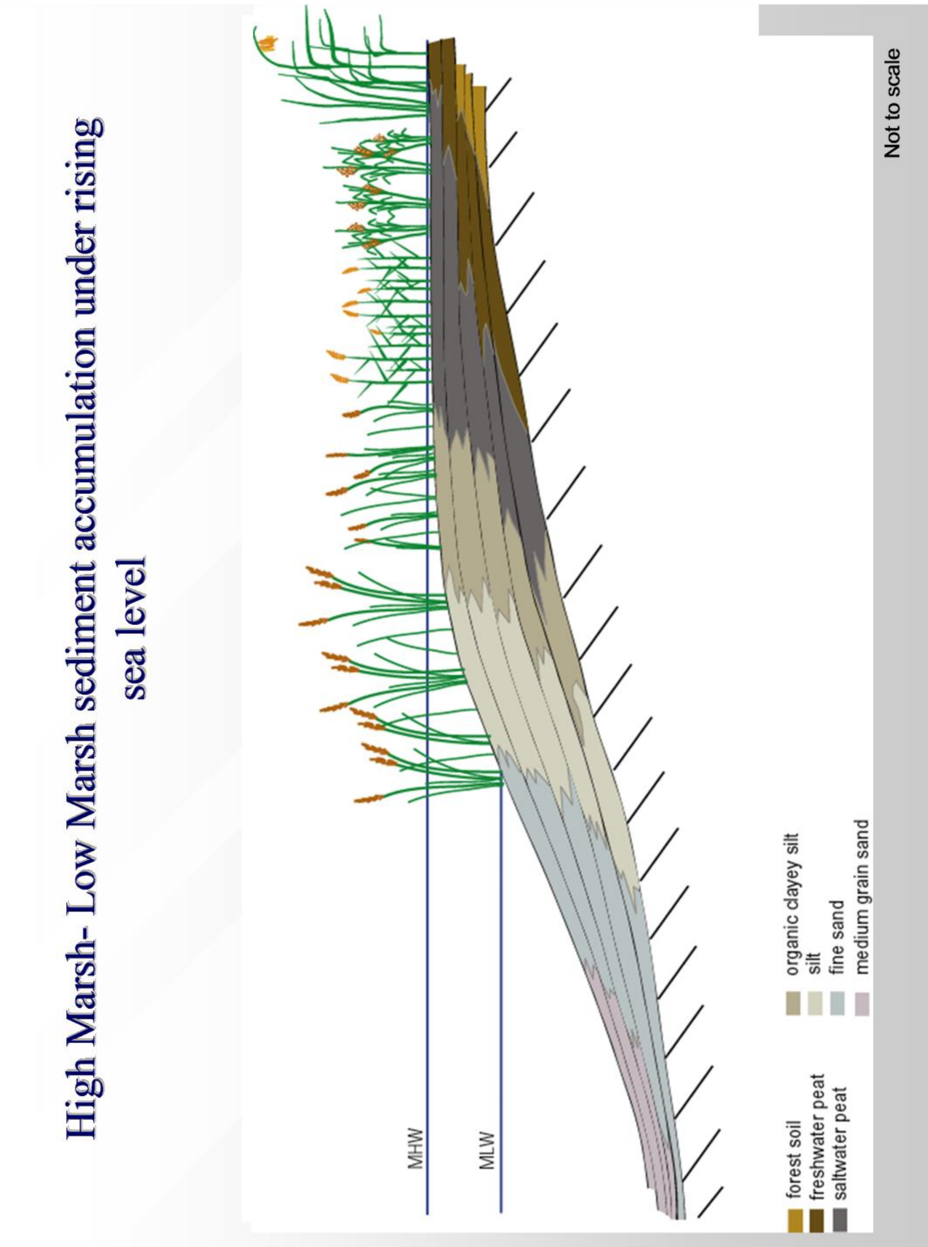

Figure 3.9: Saltmarsh response to sea level rise (provided by C.E. Larsen and I. Clark).

Varekamp and Thomas (1992, 2001) analyzed foraminifers from the saltmarshes of the Connecticut shore of Long Island Sound, and constructed highly detailed records of sea level fluctuations over the past 1,500 years. Significantly, they identified differing rates of sea level rise with acceleration beginning as early as 1,500 years ago. Perhaps more important, they showed a relatively long period of lowered sea level on the order of 30 cm (1 ft) lower than present from 1,200 cal yrsbp to 400 cal yrsbp.

Another extensive and detailed study of salt marsh stratigraphy was conducted along the Raritan River upstream from Raritan Bay by Kenen (1999). Kenen reconstructed an interval of fluctuating higher sea level on the order of 30 cm (1 ft) from ca. 2,500 to 1,000 cal yrsbp. He, too, identified differing rates of relative sea level rise ranging from 2.0 mm/yr to 5.4 mm/yr (0.08 in/yr to 0.21 in/yr). A composite sea level record determined from the Kenen (1999) and Varekamp and Thomas (1992, 2001) studies is presented in **Figure 3.10**. The composite record points to the great scientific value of saltmarshes for unraveling the subtle changes in sea levels of the past and discerning differing rates of sea level rise and fall on a century by century scale. Such detailed records of sea level variation bridge the geologic and historic records to provide a context for both past and modern change in environment.

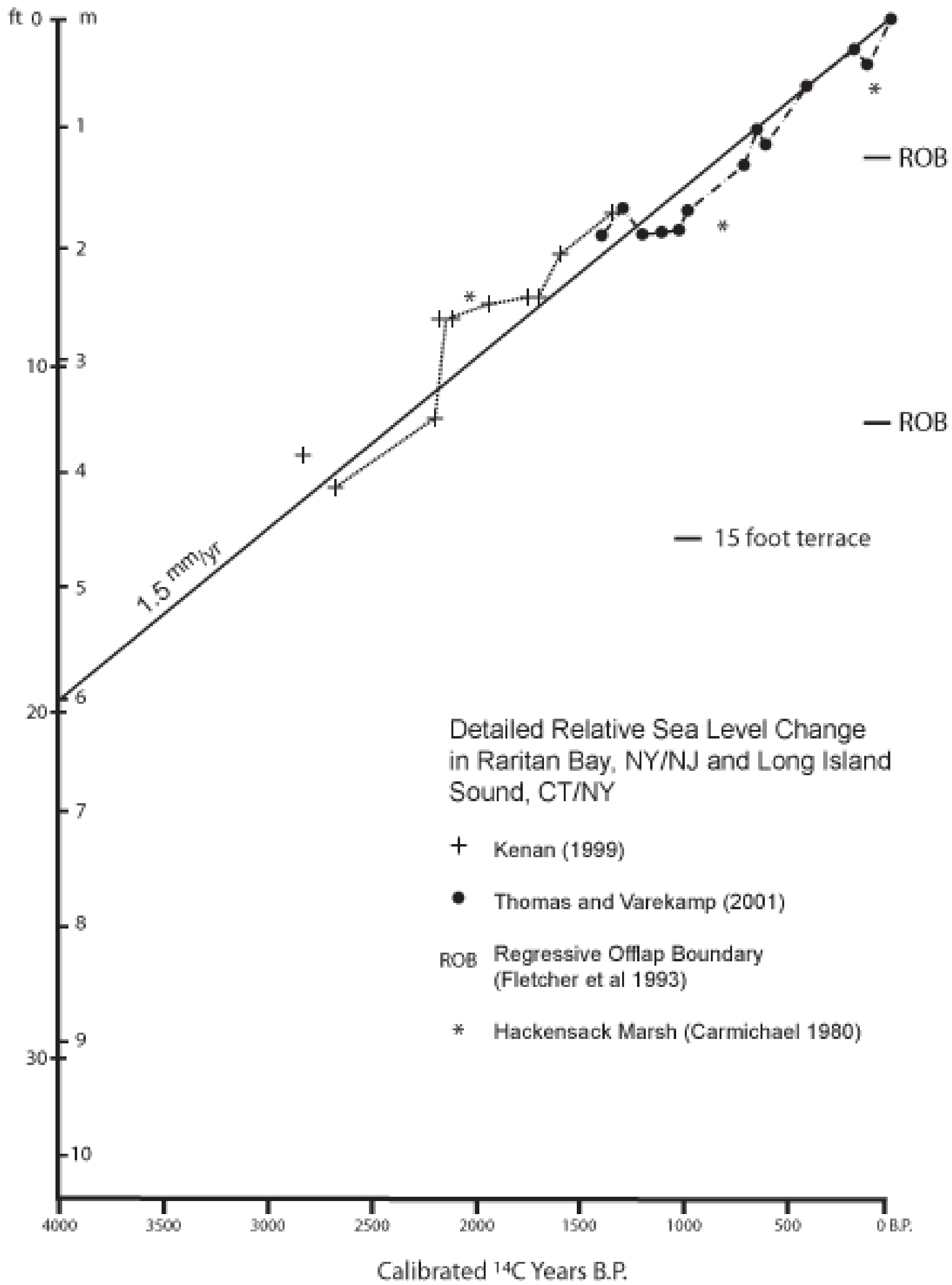

Figure 3.10: Detailed Reconstruction of Late Holocene Sea Level Variation.

Chapter 4
Geological and Environmental Setting

The Late Quaternary landform history of New York Harbor area is function of bedrock geology and events associated with glacial history. The end of the Pleistocene (after 18,000 B.P.) is recorded extensively in the surface and subsurface deposits of the coast and near shore settings of metropolitan New York City and adjacent New Jersey and New York. Variable accumulations of sediment record the region's history of glaciation and deglaciation as well as submergence and emergence as ice sheets formed and global (eustatic) sea level changed during the past million years.

Regional geological and paleoenvironmental studies are extensive. Relevant research has focused on bedrock geology (Isachsen et al. 1991; Schuberth 1968); late Pleistocene and (to a lesser degree) Holocene surficial deposits (Antevs 1925; Averill et al. 1980; Lovegreen 1974; Merguerian & Sanders 1994; Rampino & Sanders 1981; Reeds 1925, 1926; Salisbury 1902; Salisbury & Kummel, 1893; Sirkin 1986; Stanford 1997; Stanford & Harper 1991; Widmer 1964) as well as post-glacial vegetation change (Peteet et al. 1990; Rue & Traverse 1997; Thieme et al. 1996) and sea level rise (Newman et al. 1969; Weiss 1974). More recently, there have been detailed studies of archaeological preservation potential for the under-studied Holocene surficial deposits (GRA 1996a, 1996b; Schuldenrein 1995a, 1995b, 2000; Thieme & Schuldenrein 1996, 1998) and estuarine sediments (GRA 1999; LaPorta et al. 1999; Wagner & Siegel 1997).

Physiography and Bedrock Geology

The New York and New Jersey Harbor is an estuary formed within valleys deepened and widened by the advance and retreat of the great continental (Laurentide) ice sheet of the last Ice Age. The valleys occupy rifts which first developed during the separation of the North American and African continents beginning about 200 million years ago (Isachsen et al. 1991: 50-51). The Atlantic Ocean formed within the largest of these rifts while lesser rifts sliced through Paleozoic continental land masses and left isolated remnants such as the Manhattan Prong east of the Hudson River Valley. The Newark Group rocks underlying most of the Harbor Region formed from primarily alluvial sediments which filled the rifts as they were opening.

The Quaternary deposits of the Harbor Region (**Figure 4.1**) rest unconformably on the Newark Group sedimentary rocks from upper Newark Bay east to the Hudson River. The Stockton, Lockatong, and Brunswick formations of the Newark Group consist of redbed sediments deposited in a Triassic basin which was subsequently faulted and intruded by igneous magma. The most significant intrusion occurred on the eastern edge of the basin at the Palisades sill, adjacent to the Hudson River of today.

East of the Hudson River, the Manhattan Prong consists of outcropping Cambrian to Ordovician igneous and metamorphic lithologies of the New York City Group. Rare outcrops of gneiss or schist occur on Governors Island (Herbster et al. 1997; Schuberth 1968: 82), and in Queens and Brooklyn, but these land masses consist primarily of Quaternary sediments or older marine units of the Atlantic Coastal Plain. A northeast trending axial ridge of gneiss and serpentinite comprises the core of Staten Island against which tens of meters of glacial till were lodged by the Laurentide ice sheet.

Several contributing drainages to Newark Bay follow channels inherited from the great southwest trending Pensauken River system of probable Pliocene age (Stanford 1997). Diversion of the Pensauken River into the Hudson Canyon between the Pliocene and the Pleistocene refocused continental shelf deposition from the Baltimore Canyon area (Poag and Sevon 1989; Stanford 1997) but the Pensauken deposits have been long since scoured way from the Harbor Region. Cretaceous and possible interglacial (oxygen isotope stage 5e) sediments occur at the Narrows but sediments older than the Wisconsinan glaciation are otherwise missing from the lower Hudson as a result of erosion following base-level fall (Weiss 1974: 1567).

Pleistocene Glaciation, Chronology, and Paleoecology

Glaciers advanced across the region at least twice during the Pleistocene (Stanford 1997; Sirkin 1986). Both Illinoisan (ca. 128-300 ka) and pre-Illinoisan (> 300 ka) terminal moraines are mapped in northern New Jersey, and these ice advances may be represented by lower tills on Long Island such as the Montauk (Rampino and Sanders 1981; Merguerian and Sanders 1994). An abundance of gneiss clasts gives the older tills a “dirty” appearance and they can always be distinguished from late Wisconsinan deposits by the presence of some unweathered mudstone, sandstone, and igneous rock clasts in the late Wisconsinan deposits (Stanford 1997).

The Hudson-Mohawk Lobe of the latest, or Wisconsinan, ice sheet advanced to its Harbor Hill terminal moraine by 20,000 years B.P. based on the evidence obtained from Port Washington on Long Island by Les Sirkin (Sirkin 1986: 14; Sirkin and Stuckenrath 1980). Some organic sediments from the preceding, warmer, interstadial period (oxygen isotope Stage 3) appear to have survived beneath or within the till and outwash, and several such sequences were identified in the earlier phases of the Harbor study (Schuldenrein 2000a).

In addition to the oxygen isotope geochronology (Richmond and Fullerton 1986), and the data from Port Washington on Long Island (Sirkin 1986: 14; Sirkin and Stuckenrath 1980), the age of the terminal Wisconsinan Harbor Hill moraine is constrained by basal post-glacial radiocarbon dates from northwestern New Jersey of 19,340 ± 695 B.P. (23,334 cal yrsbp) in a bog on Jenny Jump Mountain (Witte 1997) and 18,570 ± 250 B.P. (21,941 cal yrsbp) in Francis Lake (Cotter 1983). Thieme and Schuldenrein (1998) recently obtained a date of 19,400 ± 60 B.P. (23,061 cal yrsbp) from a loamy sediment overlying glacial till along Penhorn Creek in the Hackensack Meadowlands. A pollen core from Budd Lake in northwestern New Jersey (Harmon 1968) also provides supporting evidence for Sirkin's chronology of the Hudson-Mohawk Lobe. A sample of clay from 11 m (37 ft) below surface was dated to 22,870 ± 720 B.P. (23,003 cal yrsbp) and contained a pollen assemblage dominated by pine (50-60%) and spruce (10-20%) with some oak (5-10%) and *Ambrosiae* dominant in the non-arboreal pollen. A boreal forest or park-like vegetation community is further indicated by pollen assemblages dated to 22,310 ± 2070 B.P. (22,325 cal yrsbp) and 22,040 ± 550 B.P. (22,125 cal yrsbp) from varved silt and clay in the Hackensack Meadowlands (Schuldenrein 1992; Rue and Traverse 1997) although reworked Cretaceous spores and pollen were also present. Pollen sequences documenting post-glacial vegetation change have been registered in the initial New York Harbor study (Schuldenrein 2000a), as well as in the examinations of subsurface sequences at Jersey Flats (Schuldenrein 2001).

The terminal Pleistocene pollen record has been most informative for environmental reconstructions. Full glacial and late glacial pollen assemblages have been variously attributed to "tundra," "taiga," "spruce park," or "boreal forest" vegetation (Davis 1965, 1969; Deevey 1958; Martin 1958; Ogden 1959, 1965; Watts 1979). Several authors have also pointed out that the late Pleistocene vegetation may not have clear analogs in present-day plant communities (Davis 1969; Overpeck et al. 1985, 1992). Herb-dominated assemblages corresponding to the tundra Zone T of Deevey (1958) have been identified in basal samples of cores studied in the region (Sirkin et al. 1970; Peteet et al. 1990). A radiocarbon date of 12,840 ± 110 B.P. (15,190 cal yrsbp) from Alpine Swamp Core A indexes the succession to the spruce-hardwood Zone A (Peteet et al. 1990: 224). Newman et al. (1969) obtained a comparable radiocarbon date of 12,500 ± 600 B.P. (14,830 cal yrsbp) for Zone A in their boring UH-1 from Salisbury Meadow on western Iona Island; Sirkin et al. (1970) report a radiocarbon date of 12,330 ± 300 B.P. (14,459 cal yrsbp) for Zone A in their boring SH-29 from a Coastal Plain bog west of Raritan Bay.

Spruce-dominated assemblages were present in the basal samples of five cores from the Lower Hudson River estuarine sediments analyzed by Weiss (1974), who obtained a radiocarbon date of 10,280±270 B.P. (12,024 cal yrsbp) for the top of Zone A in a core beneath the Tappan Zee Bridge. Abundant spruce pollen was also characteristic of basal samples from borings for the Carlstadt Loop (Rue & Traverse 1997; 3DI 1992) and the North Arlington force main (Thieme & Schuldenrein 1996; Thieme et al. 1996) in the Hackensack Meadowlands. The basal North Arlington assemblage was interpreted to indicate scattered spruce trees on open, tundra-like terrain. An increase in "boreal" species such as spruce and paper birch between 11,000 and

10,000 B.P. was attributed by Peteet et al. (1990) to the Younger Dryas abrupt cooling of global climate.

A more direct cause of the migrations of plant species through the project area can be found in the irregular northwesterly retreat of the Laurentide ice sheet, as previously inferred from southern New England pollen records by Ogden (1959), Davis (1976), and others (Davis & Jacobson 1985; Gaudreau 1988; Gaudreau & Webb 1985). Zone B of Deevey (1958) is thus characterized by declining spruce and increasing pine pollen, with at least three species of pine potentially represented by grains which can be classified into at most two pollen "taxa." Davis (1976:19-21) maps the presence in the Harbor Region of *Pinus banksiana* (jack pine) and/or *Pinus resinosa* (red pine) by 11,000 B.P. and *Pinus strobus* (white pine) by 10,000 B.P. Hemlock, oak, birch, and alder pollen were also quite abundant in the Alpine Swamp Zone B assemblage (Peteet et al. 1990:222). With the change to essentially modern climatic conditions, there is a gradual shift toward an oak-dominated pollen assemblage (Deevey's Zone C), with basal dates of 9,000 ± 100 B.P. (10,088 cal yrsbp) in the Alpine Swamp core (Peteet et al. 1990) and 7,100 ± 180 B.P. (7,962 cal yrsbp) in the Tappan Zee core (Weiss 1974).

During the critical later phases of the Pleistocene, the hydrography at the glacial margin was dynamic and resulted in a glaciolacustrine landscape that involved cyclic retreats and transgressions of linear lakes that approximated the morphologies of structural valleys. A reconstruction of the terminal glacial geography is shown in **Figure 4.3**. Lakes Passaic, Hackensack, Hudson, and Flushing variously crossed the terrain between Long Island and east-central New Jersey. In Newark Bay and the lower reaches of the Hackensack and Passaic River valleys subsurface stratigraphy has revealed uniform lake bed sequences beginning with deep, "varved" proglacial rhythmites (or paired laminations) (Antevs 1925; Lovegreen 1974; Reeds 1925, 1926; Salisbury 1902; Salisbury and Kummel 1893; Stanford, 1997; Stanford and Harper, 1991; Widmer, 1964). Reddish-brown muds derived from Newark Group rocks typify the thicker winter varves while the more heterolithic sandy varves were deposited as the ice melted during the summer. The top of the glaciolacustrine facies is typically an unconformable contact from 4 to 9 m (12 to 30 ft) below the present land surface in the Hackensack Meadowlands (Lovegreen 1974). At the last glacial maximum, approximately the time of deposition of the Harbor Hill moraine (**Figure 4.2**), nearly one percent of the Earth's water was transformed into glacier ice (Strahler 1971). Eustatic sea level consequently plummeted, and a terrestrial coastal plain extended from 39 to 97 km (24 to 60 mi) onto the present continental shelf along the Atlantic coast (Bloom 1983a: 220-222; Emery and Edwards 1966; Stright 1986: 347-350). Sea level rise was extremely rapid in the period immediately following the retreat of the ice (**Figure 3.1**) as meltwater was delivered to the oceans basins from runoff and from proglacial lakes that were impounded by recessional glacial margins. Locally, the lower Hudson and Hackensack River Valleys were sequentially scoured and flooded (Reeds 1925, 1926; Stanford 1997; Stanford and Harper 1991), forming much of the present-day topography surrounding New York and New Jersey Harbor. The basins left behind after the proglacial lakes drained were initially incised by meandering channels and then transformed into tidal marsh in the mid- to late-Holocene (Widmer and Parillo 1959; Thieme and Schuldenrein 1996; Carmichael 1980; Heusser 1949, 1963).

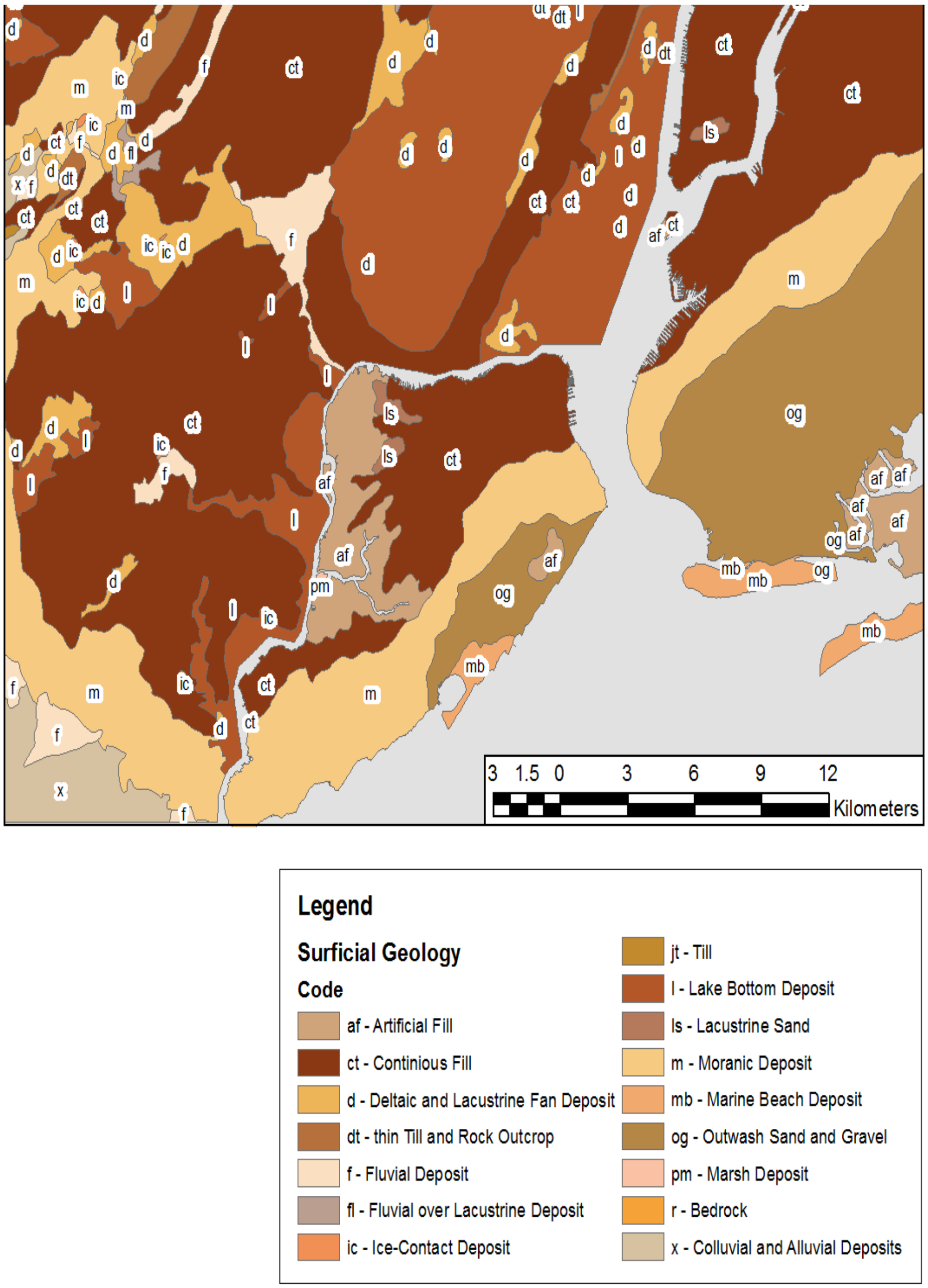

Figure 4.1: Surficial geology of the New York area.

Critical to interpretation of the submerged sediments underlying New York Harbor is the glacial and sea level rise history of the Late Pleistocene and Holocene. New York lies at the southern limit of the last glaciation when glacier ice reached its final position approximately 18,000 years B. P.. The Harbor Hill moraine, extending across Long Island, Staten Island, and Middlesex County, New Jersey marks its terminus. Stone et al. (2002) show the lobate spread of glacier ice across New Jersey and New York (**Figure 4.3**). Stone (personal communication) notes that ice did not remain for an extended period at the terminal moraine, thus only small amounts of outwash were deposited at the outer edge of the moraine. This is of importance in interpreting the submerged deposits beneath the lower harbor and Raritan Bay.

Retreat of glacier ice from the terminal moraine supplied meltwater to proglacial lakes retained behind the moraines. Proglacial lakes occupied preexisting depressions determined by the bedrock geology as well as others created by deposition of glacial sediments. The levels of the proglacial lakes were controlled by the contemporaneous altitudes of spillways through adjacent lowlands or across channels cut into the terminal moraines. This was the case for the New York area where a series of proglacial lakes were retained behind the Harbor Hill moraine. The earliest of these lakes, Lake Bayonne, spread across the New York harbor area and East River while its broader extent occupied the lowlands west of the Palisades sill, including Arthur Kill, Kill Van Kull, and Newark Bay. Lake Bayonne drained southward across the terminal moraine through a spillway at Perth Amboy. The level of Lake Bayonne was controlled by a spillway altitude of 9 m (30 ft). A lower glacial Lake Hackensack of less area drained through the moraine at Perth Amboy as its spillway was eroded more deeply into the Harbor Hill moraine. Further ice retreat from western Long Island allowed additional lowering of lake level to the glacial Lake Hudson level which drained eastward through the East River at Hell Gate. This final lake was contained within the glacially scoured and deepened Hudson River channel that progressively expanded northward with ice retreat until the Mohawk valley lowland was deglaciated about 12,000 BP (13,875 cal yrsbp) (Stone et al. 2002). **Figure 4.3** shows the location and extent of proglacial lakes in the study area.

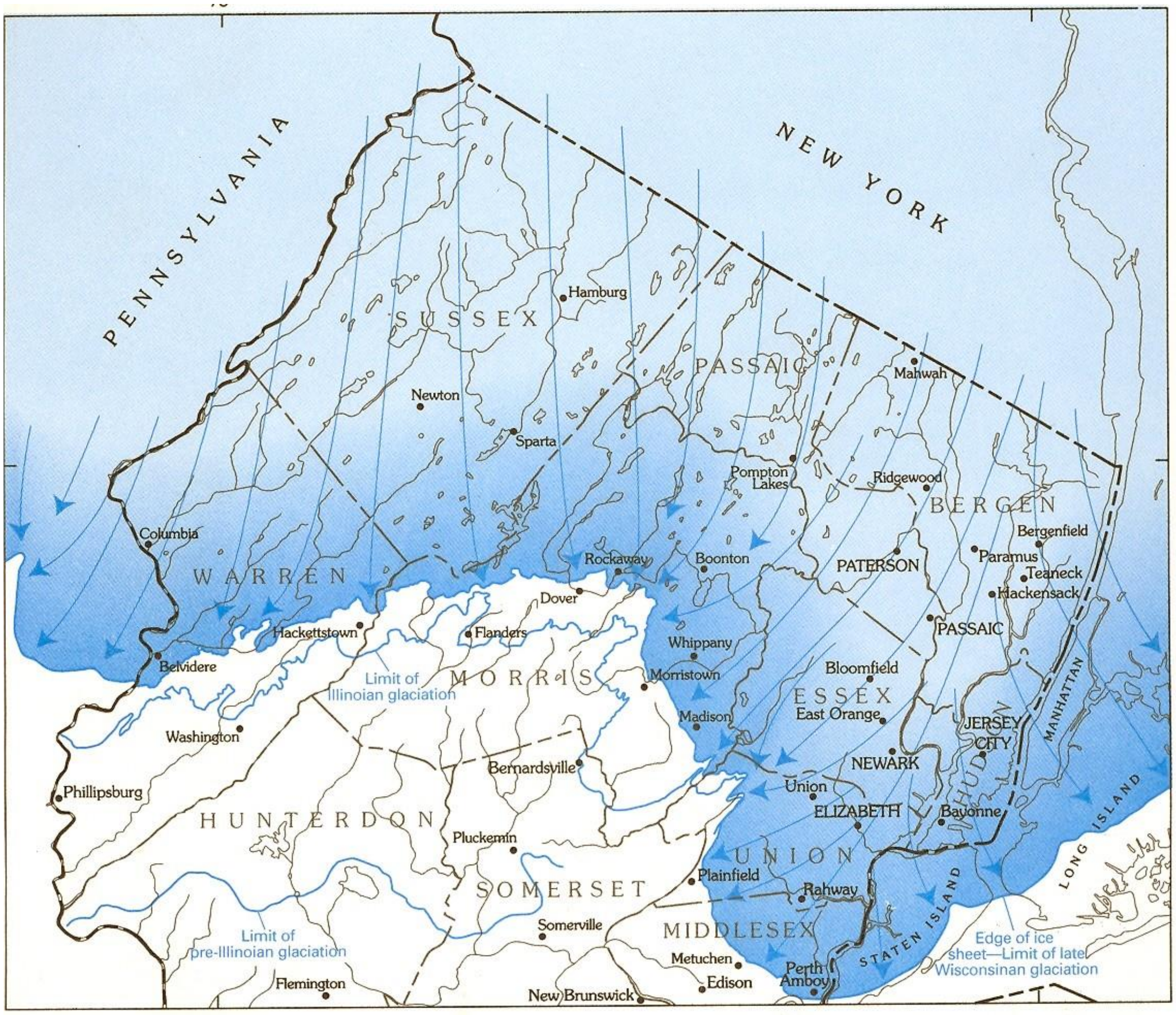

Figure 4.2: Glaciation of New York and New Jersey (from Stone et al. 2002).

The time of deglaciation of the Mohawk River lowland between 13,000 and 12,000 B.P. is a key time in the geologic history of the New York harbor area. About this time drainage of proglacial Lake Iroquois, which occupied the Lake Ontario basin, was free to drain directly to the Hudson River valley and add to the volume of proglacial Lake Hudson. Researchers disagree on the mechanism, but an outlet through the Harbor Hill moraine at the Narrows was opened at about this same time emptying Lake Hudson and gave rise to the present drainage pattern to the Hudson River. Newman and his coauthors (Newman et al. 1969) note that marine and brackish water filled the 27 m-deep (89 ft-deep) channel of the Hudson River at 12,500 ± 600 B.P. (14,830 cal yrsbp) as evidenced by marine and brackish marine microfossils preserved at the base of organic silts beneath peat bogs at Iona Island. It is problematic whether the erosion of the outlet through the Harbor Hill moraine was gradual or catastrophic as recently proposed by Uchupi et al. (2001) and Thieler et al. (2006). Nonetheless, it is clear that flow from the Hudson River eroded a channel and valley across the exposed continental shelf to drain and deposit a delta on the outer shelf at a lowered sea level stand. Most challenging for the understanding of the Hudson River history is the lack of a clear explanation for a direct marine connection between contemporaneous sea level at the edge of the continental shelf and the upper Hudson River valley. For all intents and purposes, the shelf is considered to have been subaerially exposed at this time. Differential isostatic adjustment of the earth's crust following deglaciation is the most reasonable process to suggest with downwarping and depression of the crust beneath glacier ice in the north, and possible compensating uplift of the continental shelf to bring sea level in line with the upper Hudson River channel. Differential uplift of the crust along the upper Hudson Valley relative to the New York Harbor area on the basis of historic tide gauge data has been presented by Fairbridge and Newman (1968), but the complete relationship remains unclear. **Figure 4.4** is a three dimensional representation of the New York Harbor area viewed from the south. The deeply incised channel of the Hudson River is well defined, as is the pre-dredging channel of Arthur Kill, showing its incised outwash channel from Newark Bay to Raritan Bay that marks the overflow from proglacial lakes Bayonne and Hackensack. A broad wedge of sediment, ostensibly derived from outwash from the ice front and carried by the Raritan River and Arthur Kill spillway, fills Raritan Bay and spreads eastward with a lobate front into the New York Bight area. Splayed channels leading from the mouth of the main Hudson channel at the Narrows spread across the mouth of the lower harbor between Sandy Hook and Coney Island. The incised channels of the Raritan River and the Arthur Kill spillway appear to join near Perth Amboy and terminate near Great Kills where they appear to have been filled by littoral sediment derived from longshore drift from the northeast. The incised channels of these drainages were studied by Gaswirth (1999) and are discussed in a later section of this report. Earlier studies by Williams (1974) and Kondolf (1978) discuss the incised Raritan channel passing beneath Sandy Hook and draining to the continental shelf. Kondolf (1978) has suggested that the outer edge of the outwash sand body extending offshore Sandy Hook and Coney Island derives from beach sands and longshore transport from both the south and east along the New Jersey and Long Island shores, but **Figure 4.4** shows no indication of barrier island formation and points to its outwash related history. In fact, this figure suggests that the discontinuous shoal area east of Sandy Hook, and noted as the False Hook on current navigation charts, may be related to the outwash fan but truncated by the flow of tidal currents around the tip of Sandy Hook.

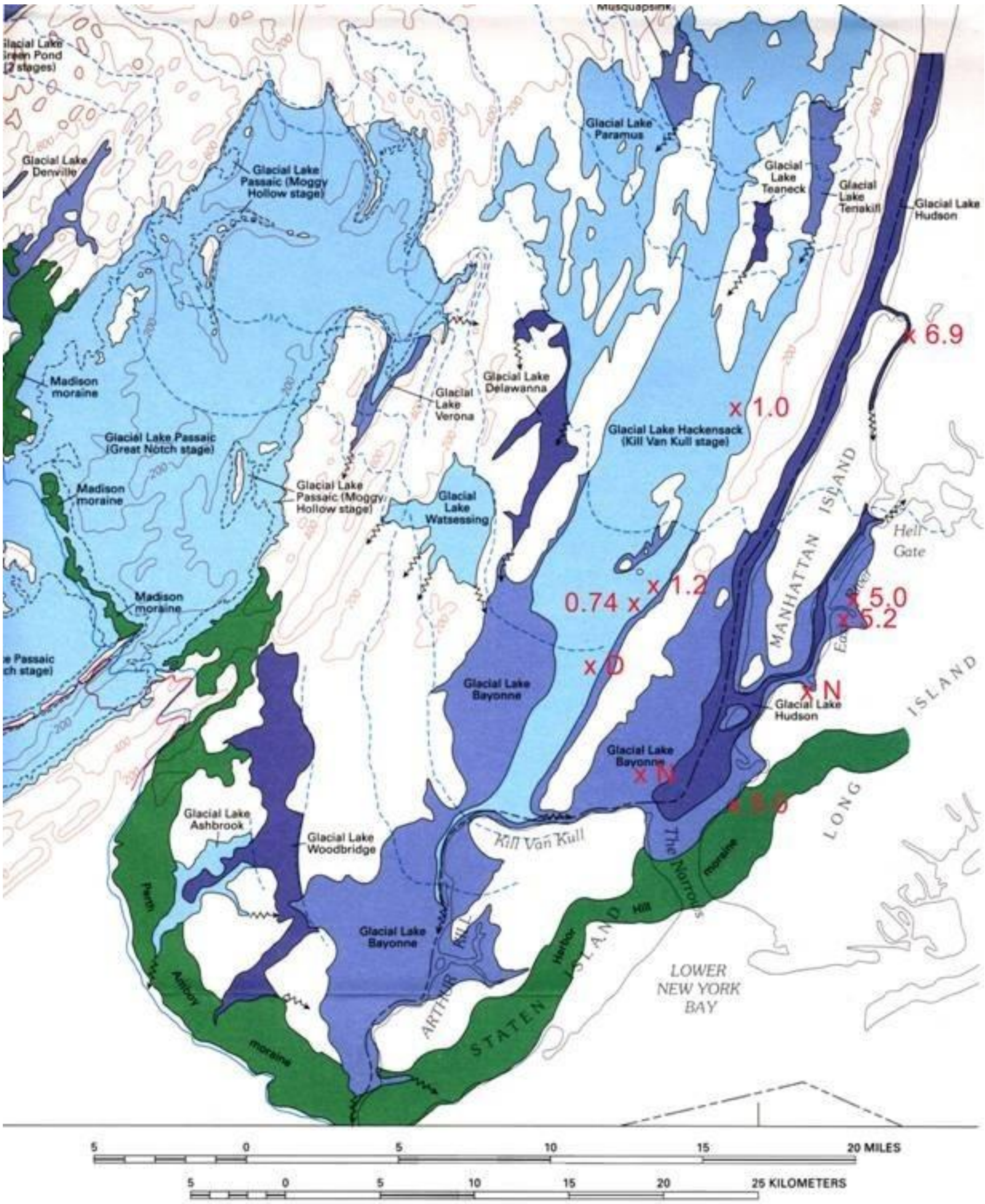

Figure 4.3: Proglacial lakes in the New York Harbor area (from Stone et al. 2002).

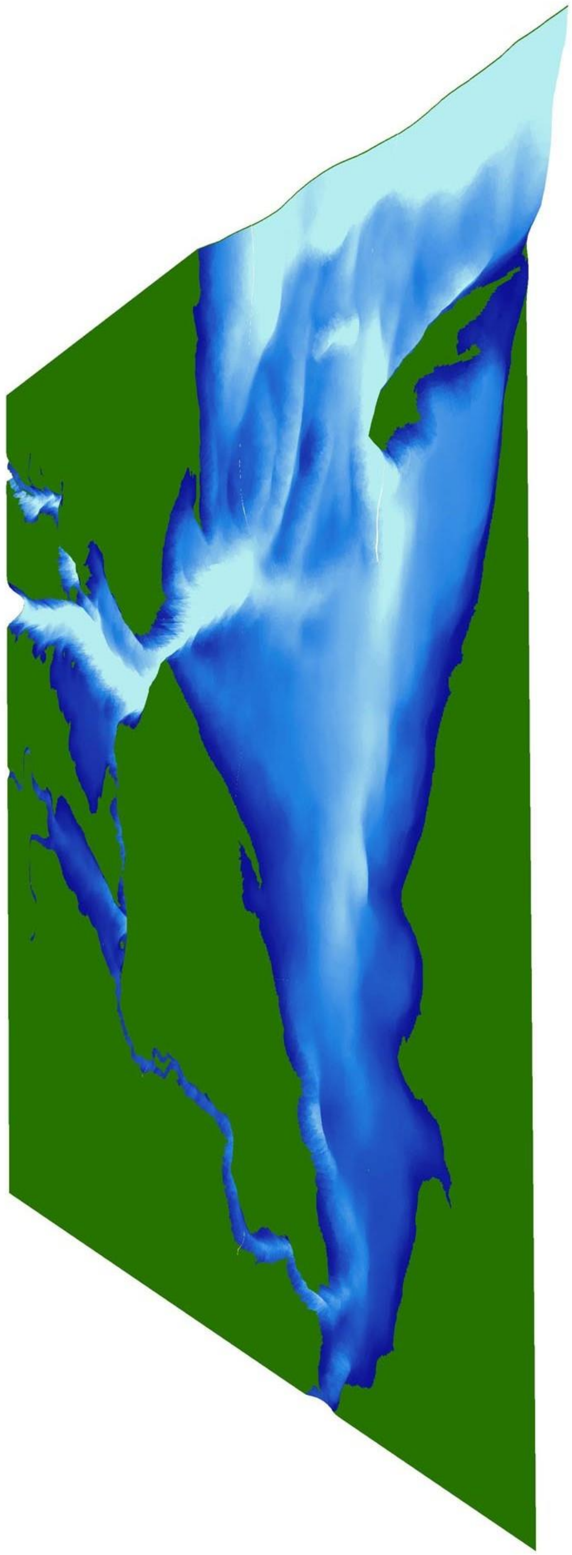

Figure 4.4: 1844 3D bathymetry of New York Harbor viewed from the south

Thieler et al. (2007) present a seismic reflection profile across the area east of the Narrows showing a deeply incised, but filled channel attributed to discharge of the Hudson upon erosion of the Harbor Hill moraine barrier (**Figure 4.5**). This channel was cut to 45 m (148 ft) below present mean sea level in underlying Cretaceous sediments and is filled and overlain by 15 m (49 ft) of younger sediment. The depth of this incised channel relative to Thieler's observation of a subaqueous delta for the Hudson at the edge of the continental shelf (-110 to -120 m [-360 to -394 ft]) underlines the need for a mechanism to reconcile this sea level position relative to the reflooded Hudson river channel at Iona Island.

One of the goals of the present study has been to develop an accurate record of relative sea level rise for the New York Harbor area for use in determining the submerged locations of probable prehistoric human habitation areas. Derivation of the new sea level rise model is addressed in detail in a later chapter and coupled with a detailed submergence reconstruction for the study area. The present model is derived from existing and newly reported radiocarbon analyses from nearby submerged environmental settings acquired during this study or as part of previous GRA studies. This work presents a two-part relative sea level history consistent with "far field" eustatic sea level studies (Fleming et al. 1998). The relative sea level rapidly rises at a rate of approximately 9 mm/yr (3.5 in/yr) from at least 9,000 cal yrsbp until about 8,000 cal yrsbp when the rate decreases to a consistent 1.5 – 1.6 mm/yr (0.6 in/yr) from 7,000 cal yrsbp until the present. The more detailed record of the last 2,000 cal yrsbp shows low amplitude century-scale fluctuations in sea level on the order ± 30 cm (12 in) until the period of historic tide gauge records. The new sea level model utilized here is also consistent with studies by Bloom and Stuiver (1963) for the Connecticut shore, Redfield and Rubin (1962) for Barnstable, Massachusetts, Belknap and Kraft (1977), and Nikitina et al. (2000) for Delaware Bay, as reexamined by Larsen and Clark (2006). This new model (**Figure 3.6**) differs markedly from that used in earlier GRA studies of New York Harbor, as these relied directly on curves presented by Newman et al. (1969).

In general terms, the new relative sea level model can be hindcast to account for reflooding of the incised Hudson channel described by Thieler et al. (2007) for the Narrows at ca. 12,000 B.P. (13,875 cal yrsbp) as well as the marine incursion of the upper Hudson Valley. It cannot, however, resolve the differential positions of the incised channel at the Narrows with the proposed delta at the edge of the continental shelf. The same data indicate progressive flooding of the main Hudson channel until its present configuration. The area currently known as the New Jersey flats begins to be flooded about 7,000 cal yrsbp. Oyster reefs begin to form upriver at Tappan Zee at this time as well and are found at successively shallower depths following the rising sea level (Carbotte et al. 2004). Marine water enters and progressively floods Raritan Bay and Newark Bay about 6,000 cal yrsbp. Significantly, we also recognize an erosional marine terrace at 5 m (17 ft) below modern chart datum (MLLW). This terrace extends from Raritan Bay to Coney Island and includes Flynn's and Romer shoals as well as the East Bank and the False Hook east of Sandy Hook. This terrace indicates a prolonged hesitation in sea level rise between 2,000 and 3,000 cal yrsbp. The terrace also limits the ages of the above shoals to predate this time. Marshes upstream from the present mouth of the Raritan River as well as the Hackensack marshes begin to become saline after 3,000 cal yrsbp and subsequently develop into salt marshes. It is suspected that portions of Jamaica Bay underwent a similar history, but sufficient data do not yet support this assertion.

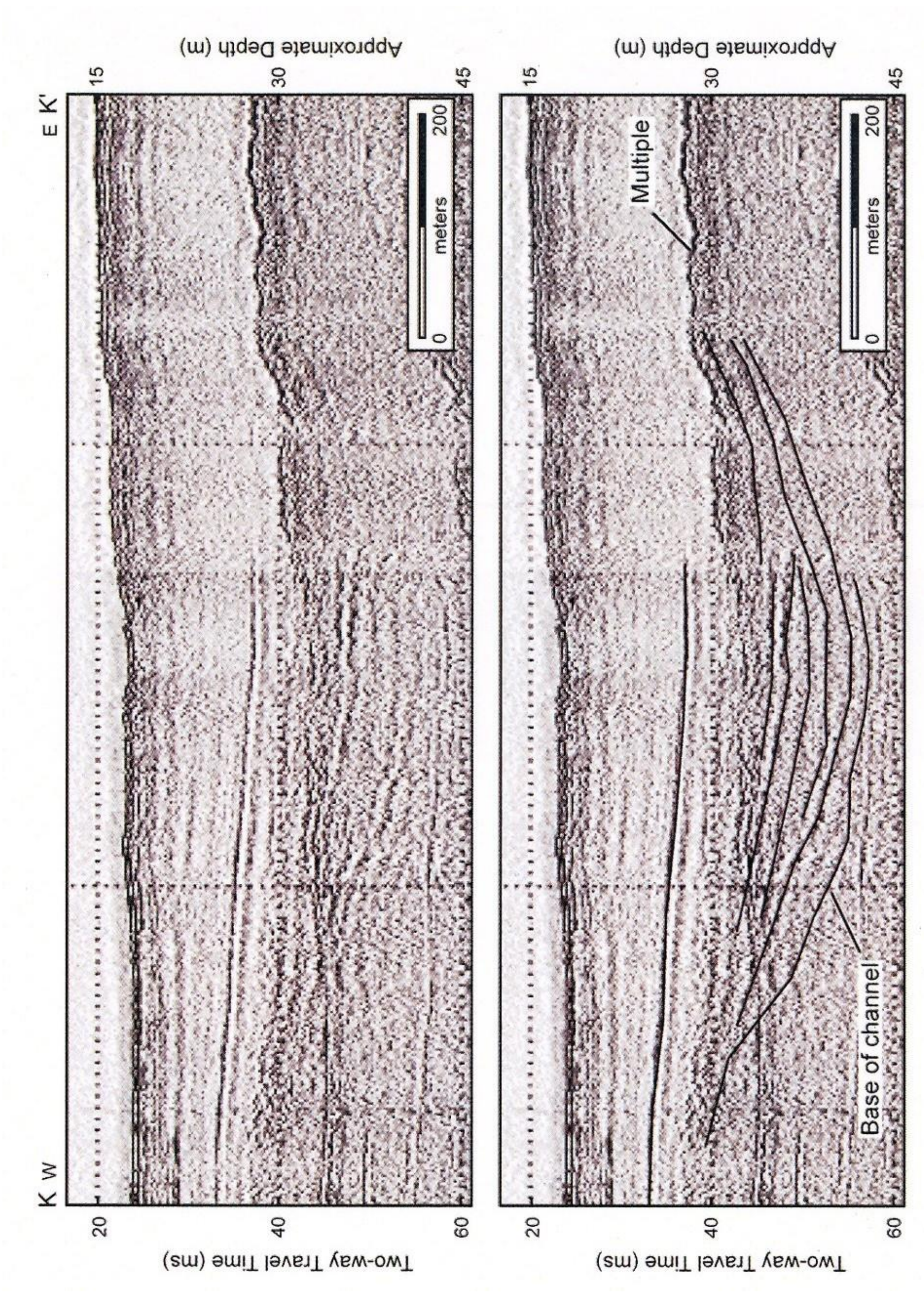

Figure 4.5: Seismic profile east of the Narrows (from Thieler et al. 2007)

Post-Pleistocene Geography

Recent studies on Staten Island (Schuldenrein 1996a, 1996b), Ellis Island (Pousson 1986), and Governors Island (Herbster et al. 1997; Thieme and Schuldenrein 1999) suggest some of the complexity of Quaternary depositional environments in the lower Hudson River valley as well as the variable preservation of archaeologically sensitive deposits. While the generic stratigraphy can be said to consist of Wisconsinan ice-contact and meltwater deposits capped by quartzose sheet sands, grain-size analyses of basal sands on Governors Island indicated a combination of glaciofluvial, ice-contact, and fluviomarine deposition (Thieme and Schuldenrein 1999).

There is very little evidence of soil formation or stability of Holocene shorelines until after 7,000 cal yrsbp, although some submerged contexts may in fact be present within the harbor itself. As proposed for the northeastern United States in general by Nicholas (1988), Mid-Holocene terrestrial sediment packages have occasionally been identified in the project vicinity at the margins of freshwater ponds or marshes (e.g., Thieme and Schuldenrein 1996). The most recent example of this is at the Collect Pond in lower Manhattan (Schuldenrein 2000). However, early- to mid-Holocene sediments are virtually absent in the estuarine valley fills.

In Newark Bay and the lower reaches of the Hackensack and Passaic River valleys there is a different and more uniform sequence that was discovered at the interface of the terminal Pleistocene glacio-lacustrine varves discussed earlier. Here, relatively late Holocene peat often overlies the contact except for where sediment was stored by one of the pre-estuarine river systems. In North Bergen, Thieme and Schuldenrein (1998) identified a stratigraphic column wherein a fining upward alluvial sequence—sandy loam to fine silt—Indicates deposition on the natural levee of a meandering stream (Brown 1997: 70-81; Waters 1992: 134-135). A buried soil within this Holocene floodplain facies was dated to 3,650 ± 70 B.P (3,977 cal yrsbp) while plant stem fragments from overlying tidal marsh were dated to 1,130 ± 60 B.P (1,075 cal yrsbp) (Thieme and Schuldenrein, 1998).

A representative section for the submerged depositional contexts of landforms in the general New York Harbor area is shown in **Figure 5.6**. This is also a general model for shoreline evolution, chronology, and stratigraphy, and it is reinterpreted from an earlier GRA reconstruction at Jersey Flats (Schuldenrein 2001). As shown, core locations JF-1 and JF-3 core are separated by approximately 600 m (1969 ft) across which the harbor floor steps from approximately -3 m to -9 m MSL (-10 ft to -20 ft MSL). Much of this change occurs at a step or terrace "riser" immediately landward of the JF-3 location. The model postulates three time-transgressive surfaces along an east to west transect between Port Jersey and Anchorage Channel. At this location, an indicator of this development is a series of *Aligena* shell beds that register still stands of the sea. They record a certain depth of water (for the sediment-water interface) that has advanced landward as an indicator of sea level rise. The core sequence did not definitively isolate the Pleistocene-Holocene contact but a date of 9,400±150 B.P. (10,690 cal yrsbp, Beta-127019) for Anchorage Channel boring 98ANC44 (Schuldenrein et al. 2000a: Appendix 3) is a reasonable temporal benchmark.

Early-Middle Holocene sedimentary sequences are projected from regional chronologies and the relative sea level model developed in the present study. Based on this relative sea level curve, a transgressive shoreward coastline has some measure of support from dates at JF-1 (3,460 ± 70 B.P. [3,736 cal yrsbp], Beta-150701) and JF-6 (3,360 ± 70 B.P. [3,586 cal yrsbp Beta-15074). The model assumes that the inverted sequence at JF-3 is completely disturbed, perhaps by mixing of the recent subtidal sediments or, alternatively, by channeling and dredging activities in the historic past. Thus, recent and localized scour and fill along the terrace riser probably accounts for the thin intercalations of dark gray clay and grayish brown sand from 2 to 3 m (7 to 9 ft) below the sediment-water interface in core JF-3a.

The upper portion of the sequence identifies the Late Holocene shoreline, reworked by historic tidal scour and fill. This portion of the sequence, extending to depths of at least 1 m (3 ft), is consistent for all the cores. At Jersey Flats, the pollen and other biostratigraphic evidence suggests that uppermost core stratigraphy everywhere appears to be contemporaneous with Euro-American settlement and the present shoreline position. In the study, it was determined that the JF-4 core location has the best potential for preserving deposits which predate the post-glacial marine transgression and estuary formation within the lower Hudson valley. Paleoecological analysis indicated that JF-4 preserves the most intact vegetation succession. If intact early- to mid-Holocene sediments are actually present, and particularly if these are from a terrestrial fluvial depositional environment, the JF-4 core location would have moderate to high potential for submerged cultural resources.

More generally, buried soils are the most sensitive indicators for stable surfaces and are, thus, the most critical measures for subsurface prehistoric cultural resources (Holliday 1992: 101-104; Rapp 1998: 34-36; Waters 1992: 74-77). Buried soils have been identified primarily within the interval 4,000-2,000 B.P. (4,527-1,982 cal yrsbp) for terrestrial settings in the project vicinity (Schuldenrein et al. 1996a, 1996b; Herbster et al. 1997; Schuldenrein 1995a, 1995b; Thieme and Schuldenrein 1998, 1999). In some locations, such as on Governors Island and the north shore of Staten Island, the buried soils are at, or even slightly below, mean sea level. Earlier, as yet undocumented, soil forming intervals may be represented by stratigraphy which has been submerged, although no buried soils were definitively identified from geotechnical borings during the present study.

Chapter 5
Sediment Cores

This chapter describes the sediment lithologies observed during the inspection of split cores. Examination of the cores took place in the Alpine Ocean Seismic Survey, Inc. storage facility in Norwood, NJ rather than in the field to ensure optimal recovery, under controlled conditions, of samples for paleoecological (i.e. pollen, foraminifers, and shell) and radiometric (radiocarbon dating) analyses. The recovery of these cores was critical for developing a paleoecological and chronological framework (**Chapter 7** and **Appendices C**, **D**, and **E**).

It is emphasized that the lithostratigraphic underpinnings of the present study were generated on the strength of field observations and broader guidelines established by the best calibrated successions assembled by earlier Quaternary researchers, most notably Newman et al. (1969). The range and variability of geologically based stratigraphies used by the numerous teams working in the New York Harbor and Bight are simply too uneven to distill into a universal and overarching sequence. The GRA sediment-stratigraphy registers the major geomorphic transitions, incorporates the latest batteries of radiometric dates and, to this point, serves as the most comprehensive Late Quaternary sequence for the Bight.

In all, twenty (20) cores were collected. Five transects, located in Raritan Bay, the Upper New York Harbor, and Jamaica Bay were selected for vibracoring. The core samples were extracted into flexible, semi-opaque poly tubing and immediately sealed to prevent contamination and to maintain stable conditions (**Figure 5.1**). Coring locations, water depth, penetration depth, and actual recovery were recorded. The percentages of recovery relative to penetration depth varied by transect relative to differences in lithology. The depth of penetration versus recovery for each core are presented in core stratigraphic descriptions (**Appendix A**), while averages by transect are presented below (**Table 5.1**). Transects A and B, which are located in Raritan Bay, had generally poorer recovery than transects C, D, and E, which are located in Upper New York Harbor and Jamaica Bay. This is probably due to lithology differences between the coarser sands (which are prone to compaction in vibracore sampling) found in the Raritan Bay transects as compared to the generally higher clay content encountered in the Upper New York Harbor and Jamaica Bay transects. The core was described using the recovered samples with no retrofitting of the stratigraphy to the penetration depths.

Table 5.1: Average Penetration and Recovery by Transect

Transect Name	Average Penetration (m)	Average Recovery (m)	Percentage Recovered
A. Seguine Point–Union Beach	9.88	6.00	61%
B. Keansburg	11.05	8.19	74%
C. Liberty Island	10.93	9.60	88%
D. Bay Ridge Flats	12.00	10.38	86%
E. Yellow Bar Marsh	5.85	5.02	86%

Figure 5.1: Core recovery, Raritan Bay.

After recovery the cores were stored and examined at the Alpine Ocean Seismic Survey, Inc. storage facility in Norwood, New Jersey (**Figure 5.2**). The cores were not refrigerated. They were split, the lithostratigraphy was documented, and paleoecological and radiometric dating samples were collected by GRA staff. Lithostratigraphy here refers to the description of principal sediment characteristics of discrete layers and the identification of major stratigraphic unconformities between deposits. Results of the radiocarbon dating are found in **Chapter 3**, while special studies of shells, foraminifers, and pollen are found in **Appendices C**, **D**, and **E**. A split of each core was resealed (**Figure 5.3**) and archived at the Army Corps of Engineers storage facility at Caven Point, NJ. The core lithologies and interpreted stratigraphy are presented below by project area and transect.

Raritan Bay

Seguine Point – Union Beach Profile (Cores A0-A5). A total of five (5) localities (A0 – A4) were vibracored (**Figure 5.4**). Two localities required additional cores to maximize recovery resulting in seven (7) total core recoveries. Core locality A-2 had the upper 5.14 m (16.86 ft) recovered in one core (A-2/R1) while a second core was collected from approximately 5.10 m (16.73 ft) to approximately 7.70 m (25.26 ft) below the water/sea bottom contact. Core locality A-3 was also sampled by multiple cores due to poor recovery, largely due to complications associated with attempting to core through lithologically dissimilar strata. Core A-3/R1 recovered a representative sequence; however though the sample penetrated 10.67 m (35.01 ft) only 4.57 m (14.99 ft) was recovered. In order to better sample the deposits, a second series of cores (A-3/R2-3) was recovered. This two-stepped coring consisted of taking one core from the upper coarser sandy sediments, then taking a second core that began collection below the coarse sandy sediments. This method provided a 12.5 m (41.01 ft) long core sample that was more representative of the sediments.

The cores provide an approximately 6.2 km (3.9 mi) cross section of Raritan Bay from Seguine Point, Staten Island, NY at the north to Union Beach, NJ at the south (**Figure 5.5**). As mentioned in Chapter 2, this location was chosen to duplicate the results of an often cited geologic cross section across Raritan Bay made in 1936 as part of a bridge construction study (McClintock and Richards, 1936, cited in Bokuniewicz and Fray, 1976; Gaswirth, 1999, and Thieler et al., 2007). Recovered cores ranged in length from 2.65 to 12.5 m (8.69 to 41.01 ft). Descriptions can be found in **Appendix A**. No radiocarbon samples were collected from the cores due to lack of potentially datable carbon, however, six (6) shell samples from the cores were examined (**Appendix C**).

The cores along the Seguine Point to Union Beach transect in Raritan Bay encountered four (4) lithostratigraphic units:

Stratum IV: Very dark gray reworked sandy marine sediments

Stratum III: Truncated, stacked, fining upwards glacio-fluvial sequences with polygenetic phreatic weathering at its lower contact

Stratum II: Poorly sorted glacial till

Stratum I: Highly weathered Cretaceous clays and sands

Figure 5.2: Processing core samples, Alpine Ocean Seismic Surveys, Inc.

Figure 5.3: Cores prepared for curation at the Caven Point facility.

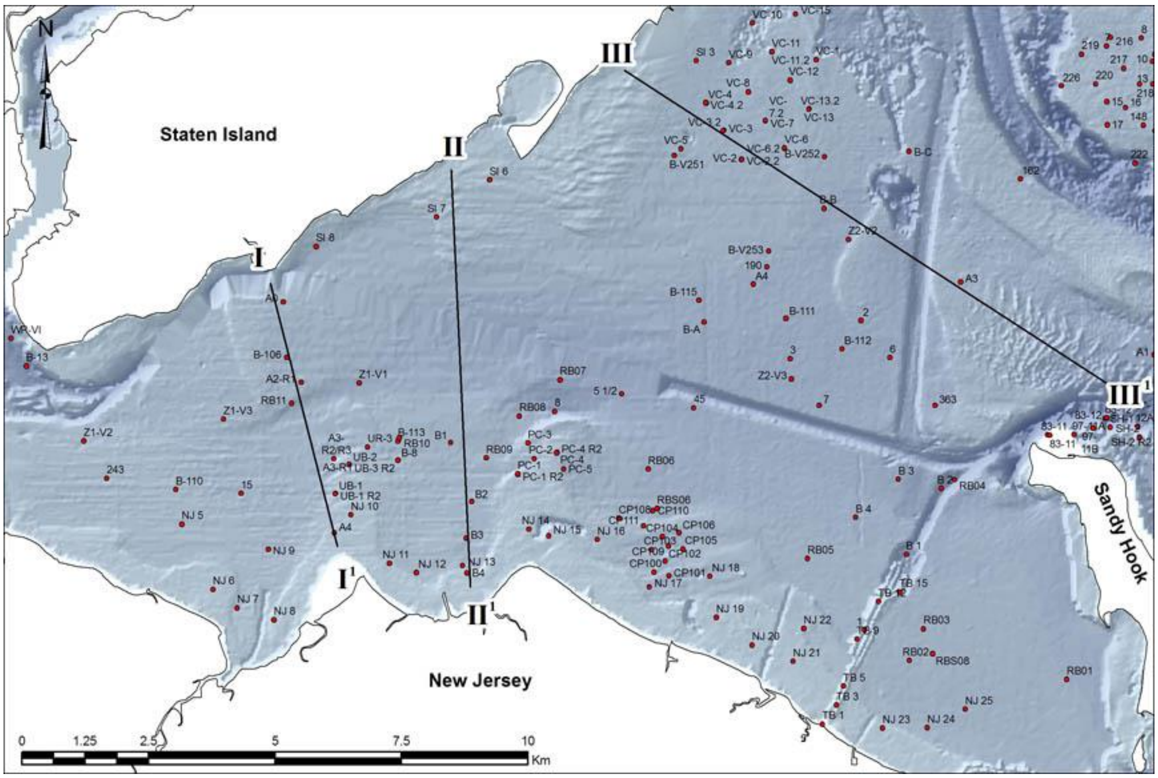

Figure 5.4: Raritan Bay transects along profiles I-I', II-II', and III-III' as well as assembled study core locations.

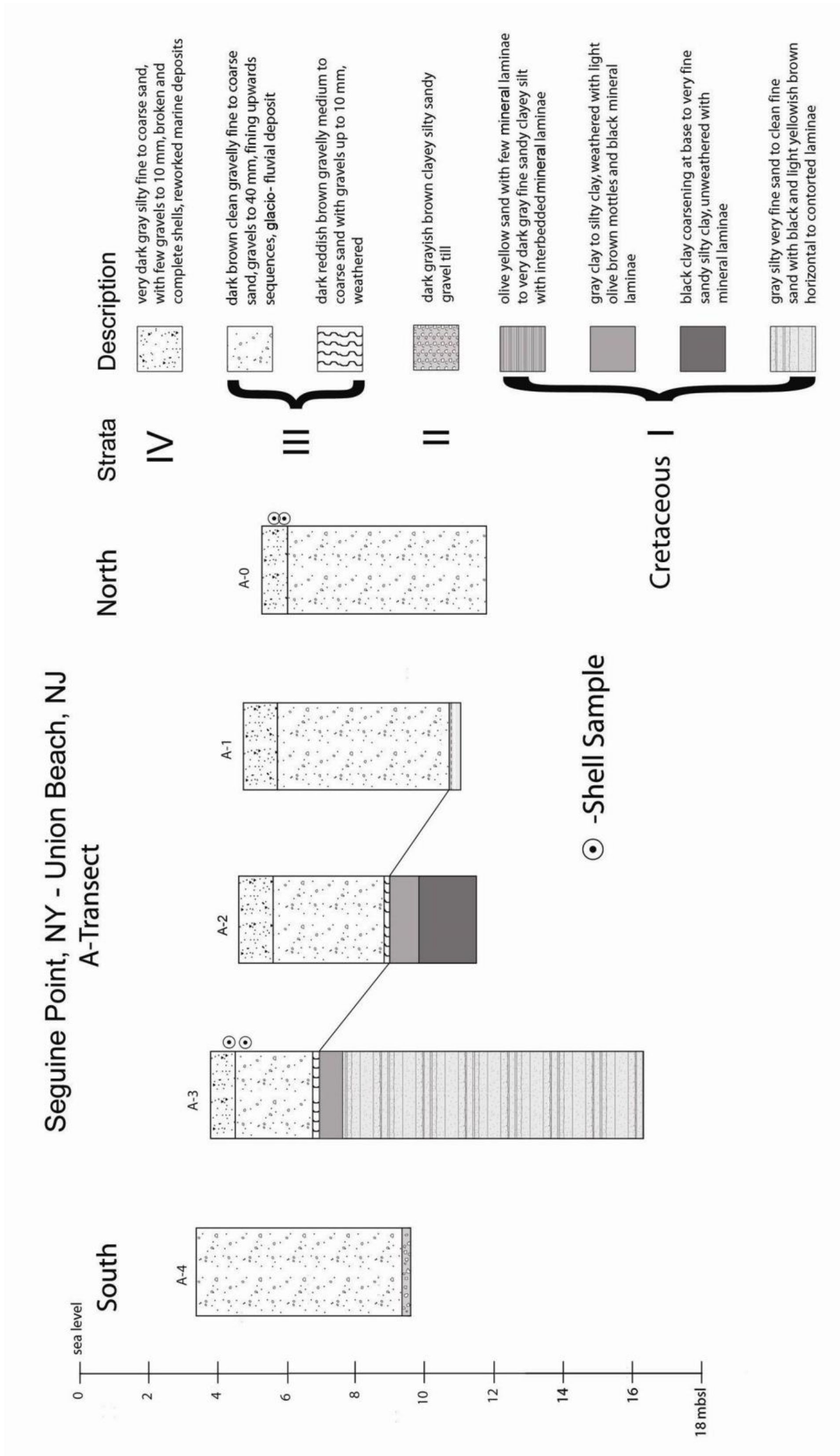

Figure 5.5: Seguine Point-Union Beach transect

The uppermost sediments (**Stratum IV**) are reworked marine deposits to a depth of 1 m. They consist of very dark gray (10YR3/1) silty, fine to medium sand with broken shell fragments. These deposits were found in all the cores except for A-4 at the southern end of this transect. The thickness of this uppermost deposit ranges from 0.69 to 0.98 m (2.26 to 3.2 ft). The deposits are texturally similar to the underlying sandy fluvial deposits, however the presence of marine shell and organics indicate that the extant fluvial sediments were likely reworked by sea level transgression through the Holocene. Six marine mollusk samples were recovered from Core A-0 and A-3 and characterized by depositional environment (**Appendix C**).

Below, the marine deposits are a truncated, but otherwise undisturbed, dark brown (7.5YR3/2) clean, poorly-sorted, gravelly, fine to coarse sand of **Stratum III**. The gravel fraction is sub- to well-rounded, and ranges in size from 10 to 40 mm (0.49 to 1.57 in). Sequences of fining upward were found in these deposits, indicating a series of high-energy fluvial events, which may have been associated with fluvio-glacial conditions. The deposits ranged in thickness from approximately 2.26 to 4.95 m (7.41 to 16.24 ft). No paleosols or textural unconformities which would suggest preserved stable surfaces during this depositional period were observed. Core A-0 terminated at 6.5 m (21.33 ft) below the sediment/water interface in these fluvial sediments without encountering a deeper stratigraphic break.

A thin, weathering horizon is found at the base of **Stratum III,** where the horizon comes into contact with the lithologically dissimilar, heavily weathered Cretaceous clays of **Stratum I**. This horizon exists in Cores A-2 and A-3. In A-2 it is expressed as a 0.13 m (0.43 ft) thick horizon of dark reddish brown (5YR3/4) hard, fine to coarse sand with few well rounded and cemented gravels up to 10 mm (0.39 in) in size. In Core A-3 the horizon is 0.10 m (0.33 ft), and is manifested as a color change from brown (7.5YR4/2) to reddish brown (5YR3/4) in a gravelly, medium to coarse sand that is otherwise similar to the overlying deposits. The reddening of sediment color indicates pedogenic alteration due primarily to the weathering of iron (Fe). This saturated condition is likely a function of water collecting atop the impervious Cretaceous clays, weathering the base of **Stratum III**.

Underlying Core A-4 on the southern end of the “A” transect near Conaskonk Point, NJ is dark grayish brown (2.5Y4/2) clayey silty sandy gravel. This lithology was only observed in core A-4, and is identified as **Stratum II**. This poorly sorted deposit is similar to a diamict or glacial till.

A major stratigraphic unconformity was observed beneath the sandy fluvio-glacial deposits of **Stratum III** in cores A-1, A-2, and A-3. **Stratum I** is identified as a deeply weathered unconsolidated Upper Cretaceous clays, silts and sands. The Cretaceous deposits are southeast dipping quart-rich clay and sand deposits which form aquifers and aquicludes (Gaswirth, 1999). The locations of cores A-0, A-1, and A-2 are mapped as Raritan Formation, while cores A-3 and A-4 fall within the Magothy Formation (Gaswirth, 1999; Minard, 1969). The upper portion of this deposit is a 0.5 to 1.0 m (1.6 to 3.28 ft) thick deeply weathered gray (2.5Y6/1) clay with weak olive yellow (10YR6/6) weathering stains and black mineral lamellae. In core A-2 the clayey sediments continued with an additional 1.5 m (4.9 ft) thick dark gray (10YR4/1) clay that coarsened to very fine sandy silty clay at the base. Below these clays, a gray (2.5Y6/1) well-sorted fine sand with distinct laminations was observed in A-3. The fine sands of this lower portion of the Cretaceous deposit are interbedded with distorted (possibly by injection), subhorizontal to broken vertical black (10YR2/1) and light yellowish brown (10YR6/4) organic and mineral silty fine laminae.

Figure 5.6 shows an interpretation of the stratigraphy along the Seguine Point-Union Beach transect I-I'. The five new vibracores obtained from the present study as well as an additional core from an earlier Union Bay study (Alpine, unpublished), UB-3 are plotted on a bathymetric profile across Raritan Bay in the same location as the 1936 stratigraphic profile by McClintock and Richards (1936) cited by Bokuniewicz and Fray (1976) and discussed in Chapter 2 (**Figure 2.1**). Their figure was scaled and the boring locations were selected to resample the deep incised valley shown. **Figure 5.6** shows the actual subsurface conditions and negates the often used information attributed to these authors. The cores along this transect show the surface covered by a thin veneer of silty, fine to coarse grained sand. North of Conasconk Point this fine to coarse sand overlies medium, dark brown to reddish brown coarse sandy gravel that fines upslope to a clean fine to coarse sand. Downslope and near the center of the bay, the gravel gives way to reddish brown medium grained sand that extends northward across the bay to the edge of the Raritan Bay West Reach channel. The reddish brown color and coarse grain size of the sediments are normally attributed to Pleistocene outwash sediments (Bokuniewicz and Fray, 1976; Gaswirth 1999). These coarse sediments overlie weathered, stiff clay to the north that generally is considered to represent the Cretaceous Raritan Formation. To the south, stiff clay overlies a thick sequence of gray silty very fine sand with black and light yellowish brown subhorizontal laminae. The clay and underlying fine sand are considered to be the Cretaceous Magothy Formation (Gaswirth, 1999). Core UB-3 in the central portion of the bay and approximately above Gaswirth's (1999) proposed buried paleochannel of the Pleistocene Raritan River shows brown fine and medium sand overlying gray silty and gravelly sands. The gray sands at the base of this boring likely represent reworked Cretaceous Magothy Formation which displays similar characteristics. Thus, **Figure 5.7** shows an unconformity outlining an incised sand filled channel as well as a Cretaceous surface sloping from south to north beneath the bay. Clearly there is no evidence of a deep "mud-filled" channel extending ca. 45 m (150 ft) below present sea level. Two shallow troughs are present on the floor of the bay at this location. Both of these troughs may mark the position of former incised outwash channels. The northern trough was labeled the Pleistocene Arthur Kill paleochannel, and the central trough the Pleistocene Raritan paleochannel. The age of these channels is problematical as Gaswirth obtained only one radiocarbon date for the sediments at the base of the Pleistocene valley fill. This date was 31,740 ± 1830 B.P., thus the paleochannel may predate the final glaciation of the area.

Keansburg Profile (Cores B1-B4). Four (4) vibracores were collected along the Keansburg profile (**Figure 5.4**) using a Vibracore as shown in **Figure 5.7**. The cores are located along a transect beginning at Keansburg, NJ and continuing to the northwest for 3.1 km (1.9 mi) across the southern half of Raritan Bay (**Figure 5.8**). Core recovery ranged in thickness from 2.65 to 12.5 m (8.69 to 41.0 ft). Depths to the Raritan Bay bottom ranged from 3.32 to 4.51 m (10.89 to 14.79 ft) below sea level in cores B-4 through B-2 on the southernmost portion of the profile, while core B-1 was far deeper at 11.28 m (37.01 ft). No radiocarbon samples were analyzed from the Keansburg Profile. Two (2) shell samples were collected; one shell from 0.15 m (0.49 ft) below the top of core B-1, and one shell from 1.35 m (4.43 ft) below the top of core B-3. Descriptions can be found in **Appendix C**.

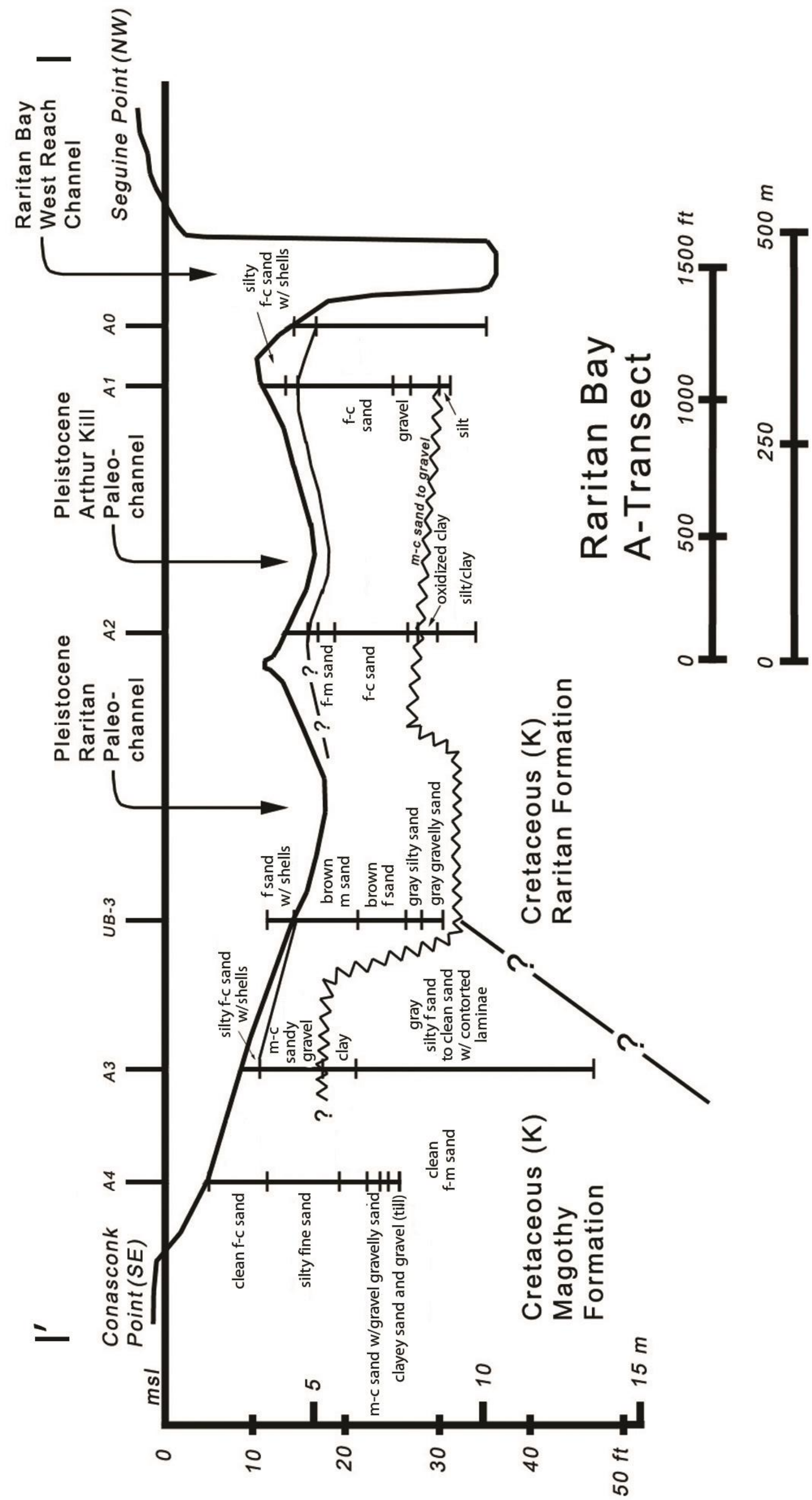

Figure 5.6: Stratigraphic profile I-I', Seguine Point to Union Beach.

Figure 5.7: 40-ft vibracore, Raritan Bay.

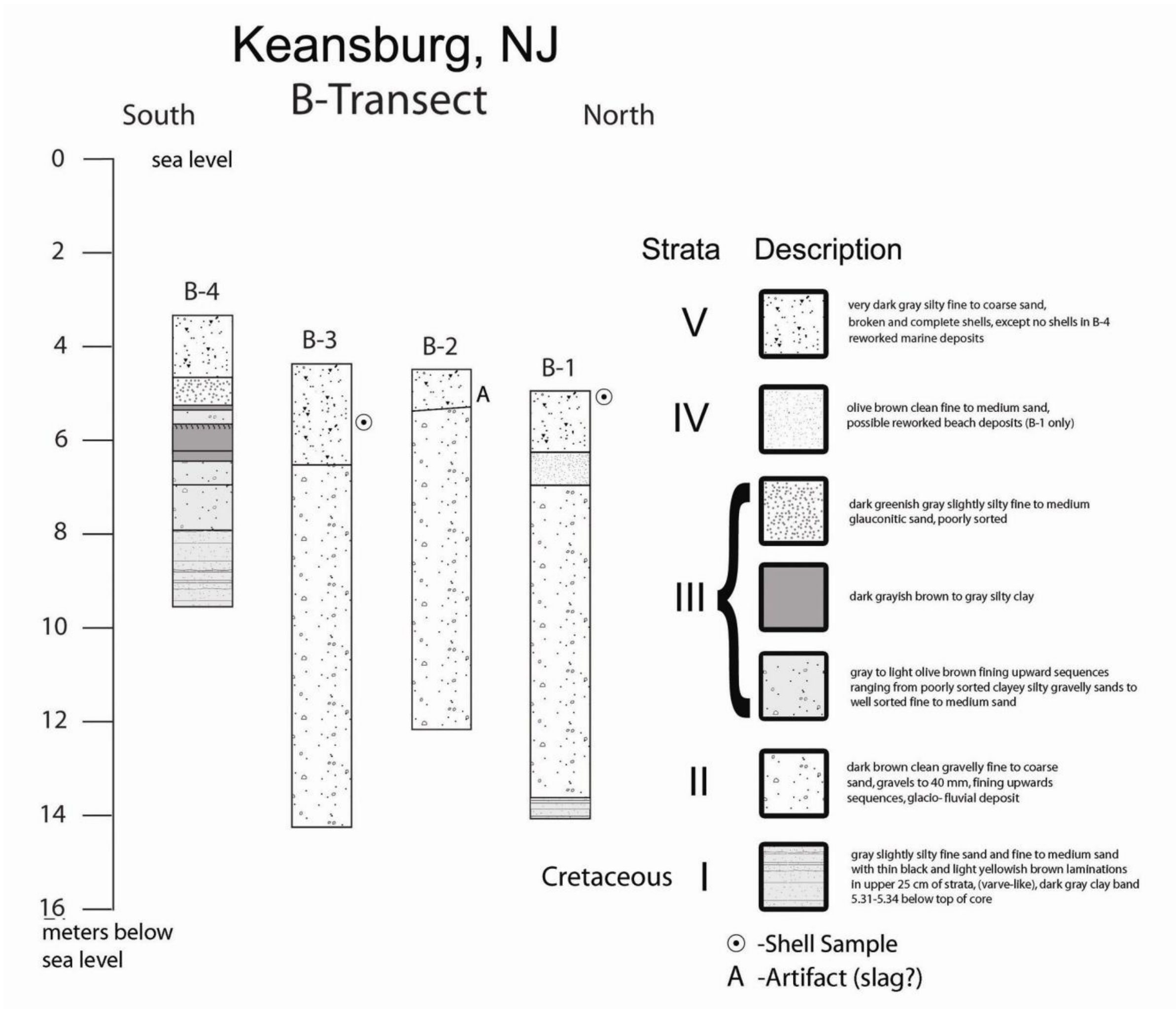

Figure 5.8: Keansburg transect.

The cores along the Keansburg transect in Raritan Bay encountered five (5) lithostratigraphic units:

Stratum V:	Very dark gray reworked clayey, silty, sandy marine sediments
Stratum IV:	Olive brown, clean, fine sand, possible reworked beach (B-1 only)
Stratum III:	Complex of glaconitic sands, weathered clays, and well sorted brown sands associated with colluvial and alluvial settings along submerged portions of Waackaack Creek (B-4 only)
Stratum II:	Truncated, stacked, and fining upwards fluvial sequences with polygenetic, phreatic weathering at its lower contact
Stratum I:	Highly weathered Cretaceous sands

Stratum V consisted of a very dark gray (10YR3/1) clayey sandy silt to silty fine sand ranging in thickness from 0.80 to 2.15 m. Occasional fine broken shell fragments are found throughout this stratum in cores B-1 to B-3. Two slag-like fragments were found in core B-2 between 0.45 and 0.89 m, indicating historical deposition of these deposits. Core B-2 has a dark yellowish brown (10YR3/4) fine to medium clean sand overlying Stratum V which, considering the historic object recovered immediately below, suggests that this sand was deposited very recently.

Stratum IV consisted of olive brown (2.5Y4/3) fine to medium clean sand, with a thickness of 0.70 m, between 1.3 and 2.0 m below the water/sea floor interface. This Stratum was only observed in B-1. These clean sands may represent a preserved and reworked beach surface, which implies a period of stability during the Holocene transgression. The B-1 core is the only setting with a potentially preserved beach deposit atop the truncated glacio-fluvial deposits.

Stratum III is a complex series of sediments and soils found only in Core B-4 that are more likely associated with submerged portions of Waackaack Creek than buried paleochannels of the ancestral Raritan River. The deposit ranges from between 1.35 m and 3.62 m below the top of the core. The top of the deposit from 1.35 m to 1.93 m is a dark greenish gray (GLEY1 4/1) slightly silty fine to medium glauconitic sand. Sand continues below this horizon from 1.93 to 2.11 m with an olive brown poorly sorted clayey silty gravelly sand. From 2.11 m to 2.31 m is a dark gray (10YR4/1) silty clay with organics. Below the clay from 2.31 m to 2.38 m is a reddish gray (2.5Y5/1) fairly well sorted fine to medium sand, with abrupt contacts above and below. From 2.38 m to and irregular contact at 2.85 m to 3.05 m is a dark grayish brown (10YR4/2) silty clay with a weathered reddish yellow (7.5YR6/8) oxidized zone in the upper five (5) cm of the horizon. The dark grayish brown (10YR4/2) silty clay continues from 2.85 m to 3.05 m contact to 3.23 m. From 3.23 m to 3.62 m is a fining upward sequence of black (10YR2/1) very silty fine to medium sand with gravels at the base that fines upwards to a sandy silt. This undated sequence of deposits appears to represent a wedge of alluvium and colluvium at the southern margin of Raritan Bay. Stratum III can be interpreted as a fining upward fluvial deposit capped by alluvial overbank muds, which experienced limited pedogenic weathering. The deposits were then capped by glauconitic sands, which may derive from colluvial wash or a high energy fluvial deposit from weathering glauconitic bedrock, which can be found in the upland portions of the Waackaack Creek drainage.

Stratum II is analogous to Stratum III as identified in the Seguine Point to Union Beach transect. Sediments range from fining upward sequences of olive brown (2.5Y4/3) clean coarse to fine sand in core B-1, to brown (10YR5/3) interbedded, clean, fine to medium sands to gravelly sands with gravels up to 30-40 mm in core B-2. Stratum II is found in all of the cores, including a 0.95 m thick package of these deposits between the underlying Cretaceous Stratum I sands below and the Stratum III complex of deposits associated with the submerged Waackaack Creek.

Stratum I was identified at the base of Cores B-1 and B-4. Unlike the expression of the Cretaceous deposits along the Seguine Point – Union Beach transect, these deposits are not capped by deeply weathered clays. Instead, these deposits are analogous to the gray sands observed deep in Stratum I along the Seguine Point – Union Beach transect. The sediments are gray (10YR5/1) well-sorted fine sand with common, horizontal to subhorizontal distinct black (10YR2/1) 5 to 15 mm thick lamina.

The Keansburg transect extends further east and "downstream" in the drowned valley of the Raritan River. **Figure 5.9** shows a continuation of the characteristic reddish brown fine to coarse sand and gravel of the Pleistocene valley fill present in the Seguine Point – Union Beach transect, II-II'. These deposits underlie the southern slope of the bay and are known as the "Keansburg Sands" as reported by Bokuneiwicz and Fray (1976), although the line of vibracores lies in an area mapped as West Raritan mud in their report. The Pleistocene sands and gravels were penetrated in cores B-1 and B-4 where the same gray fine grained sand with black and yellowish laminae was encountered as in cores A-1, A-2, and A-3, indicating the Cretaceous Magothy Formation. Although Gaswirth (1999) maps the area of B-4 as being underlain by the Cretaceous Merchantville Formation, the sediments are more similar to the Magothy sands. The submerged floodplain of the ancestral Raritan River shows fluvial characteristics. For example, prominent breaks in slope suggest the presence of a terrace at -6 m (-20 ft) below sea level. This may signify a hesitation in sea level rise at this position. Evidence of the rising sea level is also present as a thin wedge of clean, olive brown fine to medium sand that appears to have been a transgressive beach deposit that appears to pinch out upslope. A similar unit of very dark gray silty fine to coarse sand appears to pinch out at -4.6m (-15 ft) between cores B-1 and B-2. Another noticeable break in slope is present on the north side of the bay at -4.6m (-15 ft) at the base of a sand apron associated with the Orchard Shoal. The probable position of southeastward dipping Cretaceous formations is below the Pleistocene outwash and alluvium. The central portion of the drowned Raritan River valley is generally underlain by estuarine clayey silt that covers Pleistocene sand and gravel. Gaswirth's (1999) core RB08 is projected on to the cross section and marks the position of the radiocarbon sample with the 31,740 ± 1830 B.P. age at the base of the Pleistocene gravel. This limits the age of the overlying deposits.

Submerged Terraces in Lower New York Harbor. Close examination of NOAA Chart 12327 of New York Harbor shows clear indications of continuous terrace surfaces at approximately -4.6 m (-15 ft) in depth that extend from the area east of Great Kills across the harbor to the East Bank shoal offshore Coney Island. The terrace is also present on the surface of Romer Shoal and Flynns Knoll. **Figure 5.10** is a cross section of a portion of this area drawn southeastward from Great Kills towards Sandy Hook and across Flynns Knoll, III-III'. The submerged topography shows clear evidence of a -4.6 m (-15 ft) terrace between the base of the Orchard Shoal across the surface of Flynns Knoll. This suggests an erosional terrace indicative of a temporary "stillstand" in sea level rise, or a low fluctuation similar to that shown in the detailed sea level curve shown in **Figure 3.10**. This depth also relates to the break in slope described above. Since the surface is continuous and traceable across the lower harbor, it is considered evidence for the relative stability of the deposits underlying this portion of the harbor. Other researchers (for example Williams and Duane 1974, and Bokuniewicz and Fray 1976) have considered the lower harbor to have been a "sink" for sediments moving in longshore transport along the Long Island and New Jersey shores. Also, Williams (personal communication) has pointed to sand waves at the harbor entrance as indications of sediment movement into the harbor from offshore. The presence of terraces, however, suggests that the sediments beneath the lower harbor have had a relatively stable surface for at least 3,000 years, dated on the basis of the sea level curve (**Figure 3.6**). Relative stability of the surface of the lobate fan of sediment spreading out from Raritan Bay and the Narrows supports the idea of this fan as a preexisting outwash feature reworked by channels from the ancestral Hudson River and Raritan River and later sculpted by tidal current action. This hypothesis, however, requires additional study.

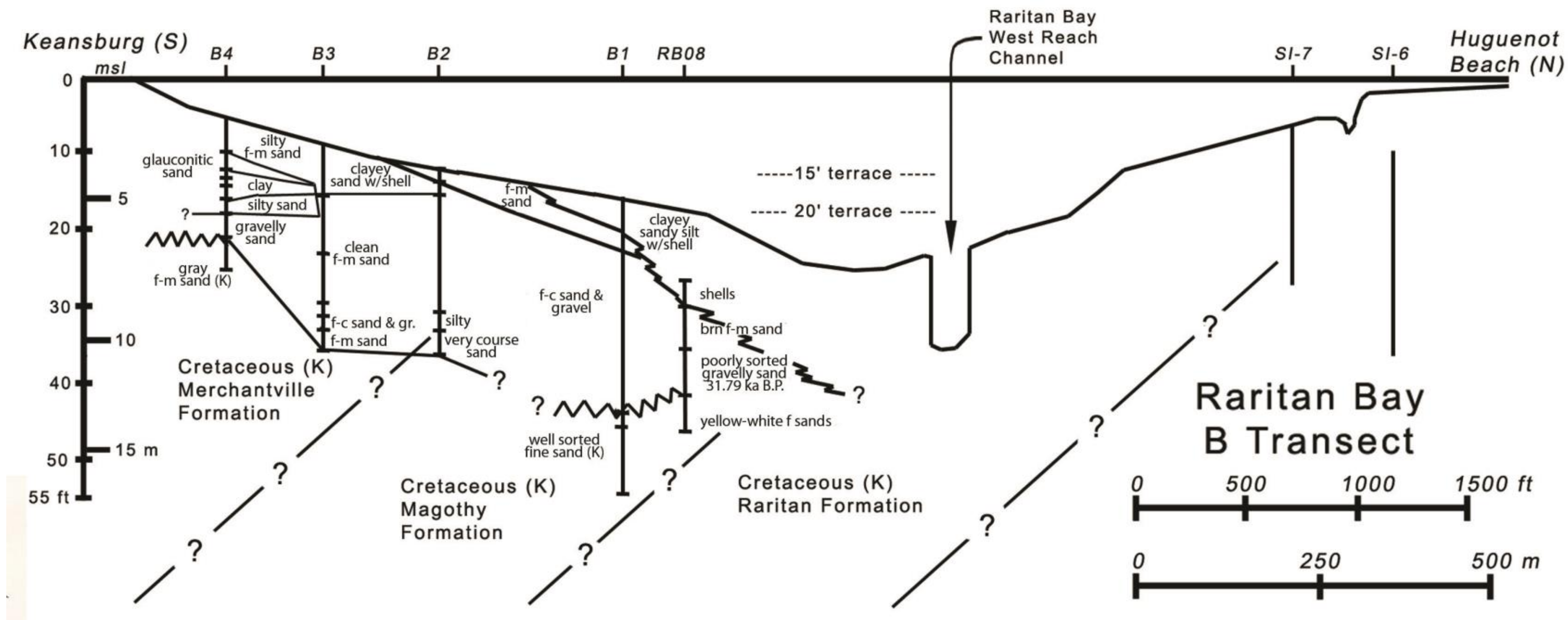

Figure 5.9: Stratigraphic profile II-II', Keansburg to Hugenot Beach.

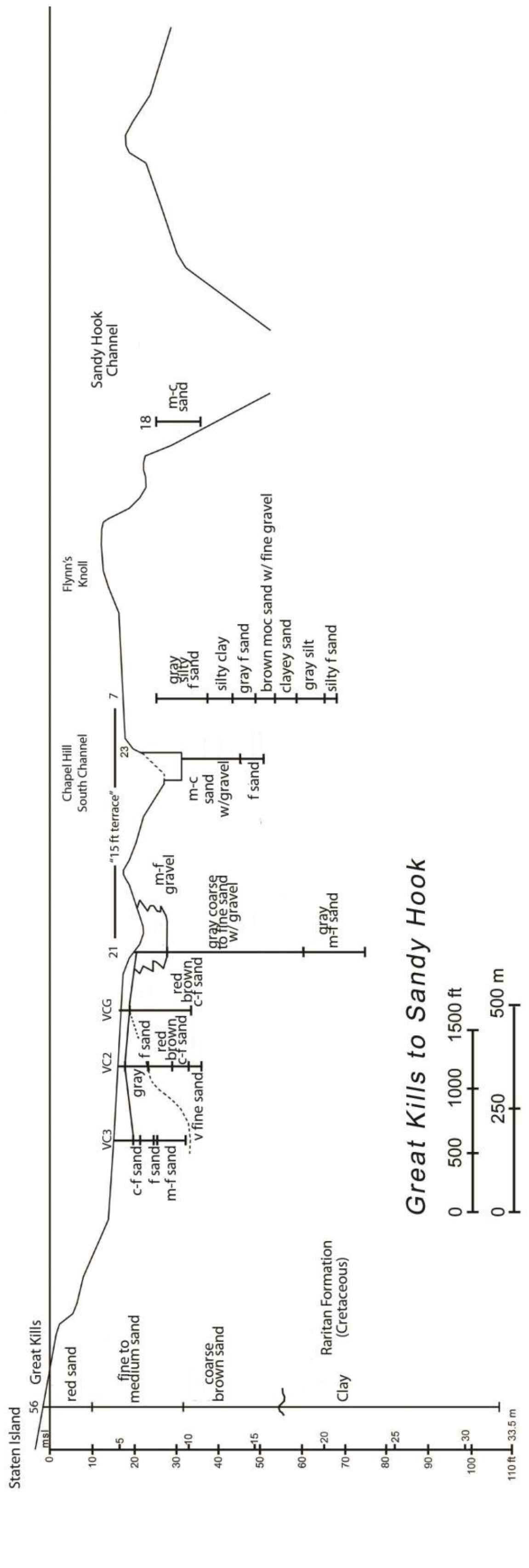

Figure 5.10: Great Kills- Sandy Hook profile III-III.'

Upper New York Harbor

Liberty Island Profile (Cores C1-C4). Four (4) localities (C-1 to C-4) were sampled with a total of four (4) cores extracted using a vibracore (**Figure 5.11**). The Liberty Island transect was located south of Liberty Island (**Figure 5.12**) and was oriented along a northwest to southeast azimuth. The cores provide an approximately 0.85 km cross section of the western half of Upper New York Harbor, from the Jersey Flats to the west to the margins of the Anchorage Channel in the center of the Harbor to the east (**Figure 5.13**). Cores C-1 and C-2 were located on the Jersey Flats, at a shallow depth of 1.95 m and 2.90 m below sea level. Cores C-3 and C-4 are located on the margin of the Jersey Flats and at the base of the slope to the Hudson Anchorage, with depths of 8.84 m and 15.79 m below sea level. The recovered cores range in thickness from 8.4 m to 11.48 m. Detailed descriptions can be found in **Appendix A**. Samples for radiocarbon dating, shell identification, and pollen analysis were collected from this transect. Pollen and foraminifer samples were collected from core C-1 (**Appendices D and E**). A total of three (3) radiocarbon samples were collected from cores C-1 and C-4. A total of sixteen (16) shell samples from the across transect were examined (**Appendix C**).

Figure 5.11: Coring along Liberty Island.

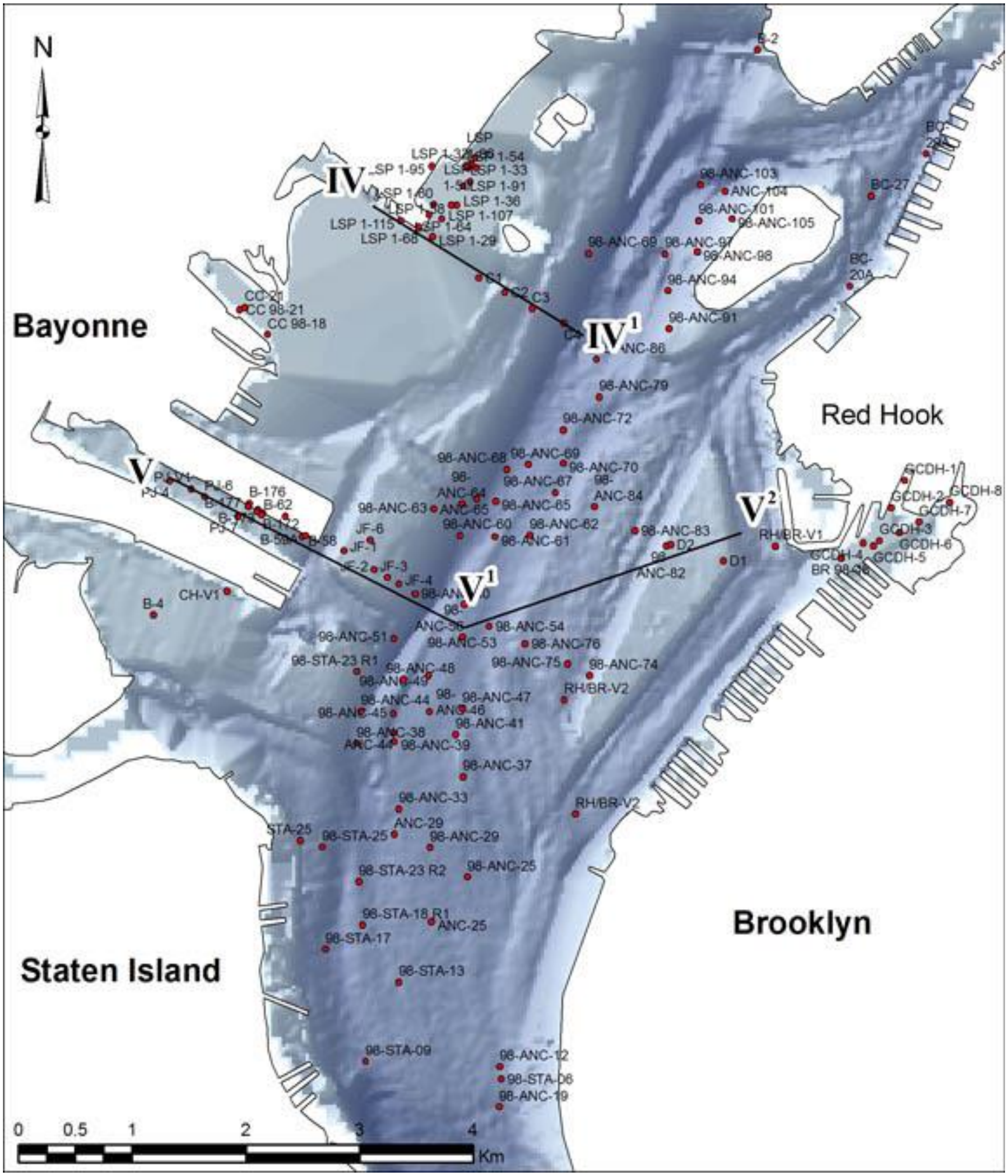

Figure 5.12: Upper Harbor core locations showing new cores along profiles IV-IV' and V-V.'

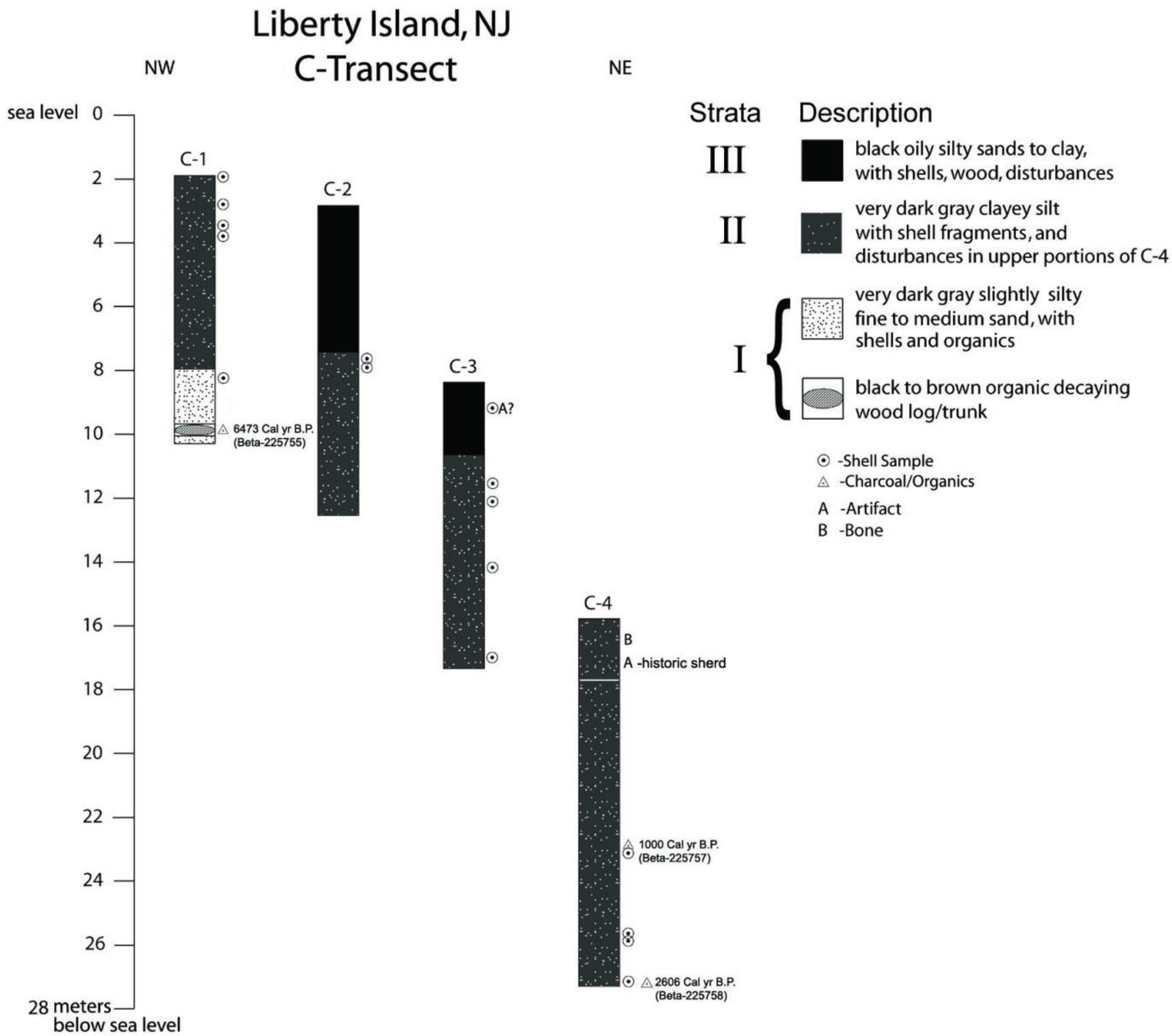

Figure 5.13: Liberty Island transect.

The cores along the Liberty Island transect in Upper New York Harbor encountered three (3) lithostratigraphic units:

Stratum III:	Black oily clay muck, recent historical disturbances and limited biological activity
Stratum II:	Very dark gray clayey silt, marsh deposits with common marine shell fragments and shell hash lenses. Historic ceramic recovered in upper portions of the stratum. The extremely young radiocarbon ages determined for the deposit suggests it has slumped down from the upper slopes to fill an incised depression along the west side of the Anchorage Channel.
Stratum I:	Very dark gray silty fine to medium sand, that becomes cleaner with depth, common marine shell fragments, and partially decayed organics

Stratum III was only identified in cores C-2 and C-3. It ranges in thickness from 2.25 m thick in C-3 to 4.60 m in C-2. It is a black (10YR2/1) oily clay muck that has a scent of H_2S, diesel, and oil. In C-3 there are clay intrusions and shell fragments, however the shell fragments are in far lower concentrations than the undisturbed deposits of Stratum II. One small slag fragment was identified in this stratum of the obviously historically disturbed stratum.

Stratum II was identified in all four cores. The stratum consists of a very dark gray (10YR3/1) clayey silt with common shell fragments of oyster and mussel. The deposits are estuarine in nature. Cores C-2, C-3, and C-4 reached their terminal depths within Stratum II. It is 6.05 m thick in core C-1, and is present at the surface. This suggests that core C-1 is a relatively undisturbed profile as opposed to the cores with the Stratum III overburden. The stratum has seen only limited historical disturbance, however its orientation along the slope of the Hudson Anchorage Channel in cores C-3 and C-4 indicates that Stratum II has slumped deep into the Anchorage Channel due to colluvial processes. Core C-4 has two temporal controls from Stratum II. An historic ceramic sherd was recovered 1.4 m below the top of the core. A radiocarbon date from a sample 7.25 m below the channel bottom, which was already 15.79 m below the water surface was dated at 1090 ± 40 BP (1000 cal yrsbp, Beta 225757). This young date so deep below the floor of the Anchorage Channel indicates that Stratum II sediments have been transported down slope to this depth and location or, alternatively, that young sediment has filled a deep depression at the base of the adjacent slope

Stratum I was only identified in core C-1. A 2.35 m thick section of this Stratum was observed from 6.05 to 8.40 m below the Harbor bottom at the base of core C-1. It consists of a very dark gray (10YR3/1) silty fine to medium sand with common marine shells and decayed organics. The sands become cleaner with depth. The abundant organics in this horizon facilitated the analysis of a radiocarbon samples. From a depth below the top of the core of 7.78 to 8.15 m (25.52 to 26.74 ft) a decayed log was recovered. A section of wood from the outer rings of the log dated to 5650 ± 90 BP (6473 cal yrsbp, Beta-225755) These mid-Holocene dates and the relationship between the overlying clayey marine sediments and the underlying coarser sands of Stratum I represent the inundation of the land surface by sea level rise.

The Liberty Island transect is put into its broader stratigraphic context in **Figure 5.14,** which shows cores C-1 through C-4 plotted along an east-west section (IV-IIV') drawn on bathymetry derived from NOAA Chart 12327. Additional borings (LSP 1-118, LSP 1-105, LSP 1-68, and LSP 1-107) obtained from the New York District USACE core library are projected on to an expanded profile along the Liberty Island channel. The profile shows the surface of what has been collectively called the "Jersey Flats", known historically for its oyster beds. The "flats" extend westward from the edge of the Anchorage Channel to shallow water at the head of the channel. The new vibracores are shown at the entrance of the channel south of Bedloe's Island. The figure outlines the surface of the "flats" underlain by dark gray organic silt that pinches out in a peat deposit at the edge of a former saltmarsh deposited on the surface of crystalline rocks (LSP 1-105, LSP 1-68). The organic silt is underlain by dark gray gravelly sand lying on the surface of the crystalline rocks. This sand represents the reworked surface of more extensive fluvial sand underlying the Hudson River channel. The organic silt thickens to the east while maintaining the shallow depths of the flats. The flats terminate between cores C-2 and C-3 where the landform drops off into the deeper water of the Anchorage Channel. With the exception of core C-1, the Liberty Island core recovered dark gray clayey silt for their entire ca. 12.2 m (40 ft) lengths. Cores C-3 and C-4 both contain shell rich zones. Core C-4 shows wood in mid depth dated at 1,090 ± 90 B.P. (1,000 cal yrsbp) and a basal date of 2520 ± 40 (2,606 cal yrsbp). The historic ceramic sherd location is shown at the base of a black, oily clayey silt deposit that has a maximum thickness at the edge of the flats in core C-2. Anomalously young radiocarbon ages such as those in core C-4 may derive from slumping of younger deposits from the edge of the adjacent steeper slopes. The location and depth of a radiocarbon-dated wood sample obtained from the sand underlying the estuarine clayey silt in core C-1 is also shown. The wood, dated at 5,650 ± B.P. (6473 cal yrsbp) is shown in its stratigraphic position. This date, representing drowned river edge forest, provides a limit on the timing of the inundation of the western edge of the Hudson River channel.

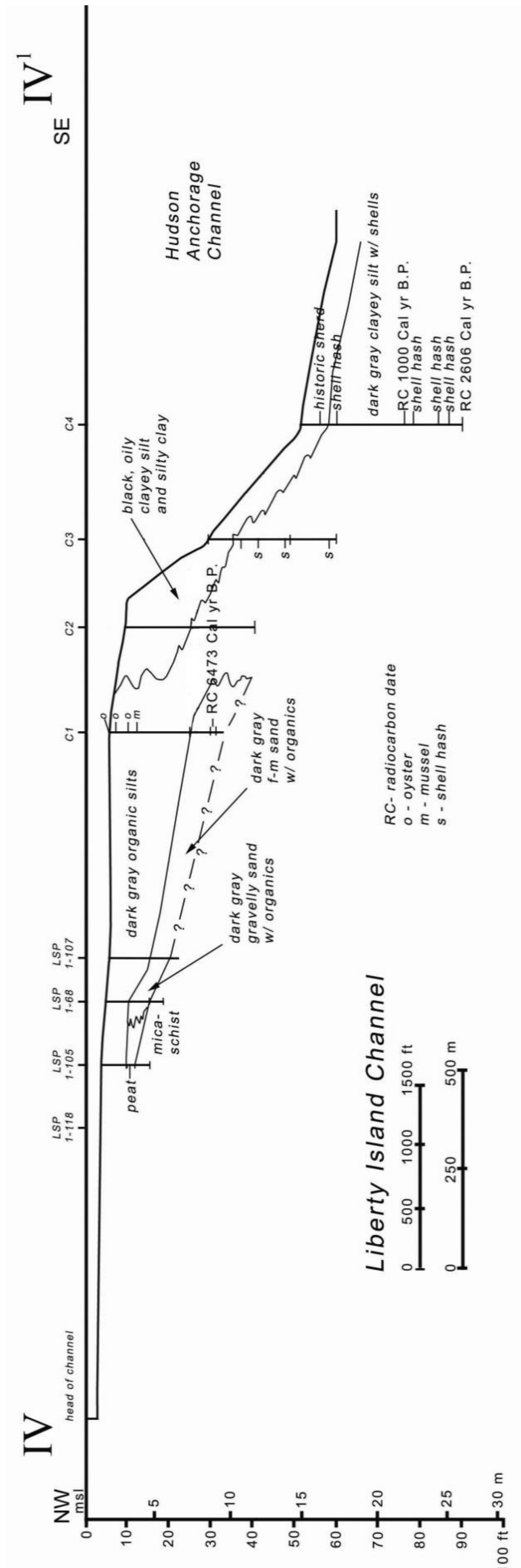

Figure 5.14: Liberty Island stratigraphic profile IV-IV.

Bay Ridge Flats Profile (New cores D1-D2). Two (2) cores (D-1 to D-2) were obtained (**Figure 5.15**) from the Bay Ridge Flats. The transect was located on the east side of Upper New York Harbor on the Bay Ridge Flats on an east to west azimuth located west of Brooklyn, and south of Governors Island in Gowanus Bay. The two cores provide an approximately 0.50 km cross section of the Bay Ridge Flats. The recovered cores ranged in length from 9.7 m to 11 m. Detailed descriptions are found in **Appendix A**. Samples for radiocarbon dating, shell identification, and pollen analysis were collected from this transect. Pollen and foraminifer samples were collected from core D-1 (**Appendices E and D**). The radiocarbon sample collected from the core D-1 yielded a date of 1850 ± 40 /B.P. (1806 cal yrsbp, Beta-228847). One shell sample from core D-1 was collected for identification (**Appendix C**).

The cores of the Bay Ridge Flats transect in Upper New York Harbor encountered two (2) litho-stratigraphic units:

Stratum II: Modern sand bar deposits of very dark grayish brown slightly silty fine to medium sand interbedded with horizons of black oily clays to sands with inclusions of wood and shell fragments

Stratum I: Estuarine deposits of very dark gray fine sandy clayey silt and sand fining with depth to silty clay, with common marine shell fragments and shell hash lenses

The modern **Stratum II** sand bar deposits consisted of very dark grayish brown (10YR3/2) slightly silty fine to medium sand. These sands were interbedded with historical disturbances of black (10YR2/1) oily clays and sands that included shell and wood fragments. Stratum II ranged in thickness from 2.20 m in core D-1 to only 1.25 m in core D-2.

Stratum I consists of estuarine deposits analogous to sediments identified as Stratum II in the Jersey Flats transect on the west side of New York Harbor. These deposits consist of very dark gray (10YR3/1) fine sandy clayey silt that fines to a silty clay with depth. Shell concentrations range from occasional shell fragments throughout the recovery as seen in core D-2 to multiple distinct shell hash concentrations in core D-1. A sandstone pebble was recovered in core D-2 at a depth of 4.05 m. The lack of soils, coarse fragments, or cultural material precludes the identification of this pebble as a cultural object. Stratum I was the basal deposit encountered in both cores, which reached maximum depths below the Harbor bottom of 11 m and 9.7 m below surface, respectively.

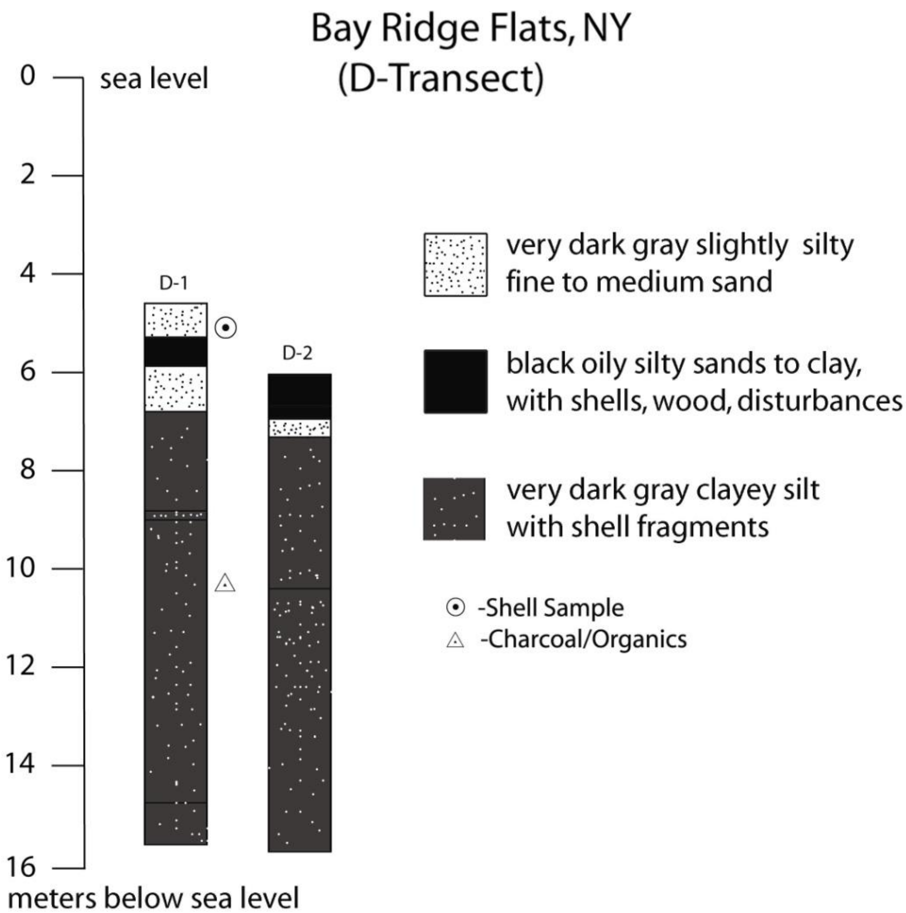

Figure 5.15: Bay Ridge Flats transect.

The Bay Ridge cores were taken to provide possible correlation of deposits of similar depth and form across the main Anchorage Channel and to obtain a more complete record of the depositional history of the harbor than was possible in the earlier study of the Port Jersey (Schuldenrein et al., 2001). **Figure 5.16** places these two cores in stratigraphic context with more detailed subsurface information available from the Port Jersey area. A composite profile (V-V') across the Anchorage Channel includes cores obtained in the earlier study (Schuldenrein et al., 2001) as well as several geotechnical boring logs obtained from the New York District USACE core library. The Port Jersey cores are projected on to a common profile to better understand the subsurface relationships. Like the Liberty Island channel, this portion of the Jersey Flats is marked by shallow water extending westward to the now covered historic shoreline of this embayment. For example, historic fill is shown above gray, clayey estuarine silt in geotechnical borings B-172, B-62, B-59A and B-58. Here again, the western flank of the Anchorage Channel is characterized by a steep slope dipping eastward to the floor of the channel. The greater amount of sediment underlying the flats at this location is estuarine silt that thins to the west. It overlies brown, fine to coarse grained fluvial sands representing Pleistocene outwash deposits. These outwash sands, in turn overlie the irregular surface of crystalline rocks at depth. An incised channel in the crystalline rocks filled by Pleistocene gravels is shown in borings B-172, B-62, B-59A, and B-58. Radiocarbon ages were determined from three previous GRA borings. JF-1 provided an age of 3,460 ± 40 B.P. (3,736 cal yrsbp). Estuarine silt from JF-6 was dated to 3,360 ±40 B.P. (3,586 cal yrsbp). These two dated cores provide a reasonable timing for the time of inundation for this portion of the flats. Two other dates obtained from core JF-3, 1,970 ± 60 B.P. (1,927 cal yrsbp) and 2,360 ±70 B.P. (2,606 cal yrsbp), were considered anomalous and came from the edge of the channel. These also suggested movement and redeposition or young sediment along the flanks of the channel. The Anchorage Channel as shown is asymmetrical with the deepest portion on the west at the base of the slope to the Jersey Flats. The channel is underlain by thick gray, estuarine clayey silt that is underlain by fluvial sand and gravel. The Bay Ridge Flats rise to the east and represent the final remnant of a more extensive shoal area now isolated by dredged navigation channels. Cores D-1 and D-2 are shown in relative position. One radiocarbon date obtained from wood in mid core D-1, 1,850 ± 40 (1,806 cal yrsbp) is anomalously young given its depth and location. The depositional history of the Bay Ridge Flats, given that age determination is unclear, requires further investigation.

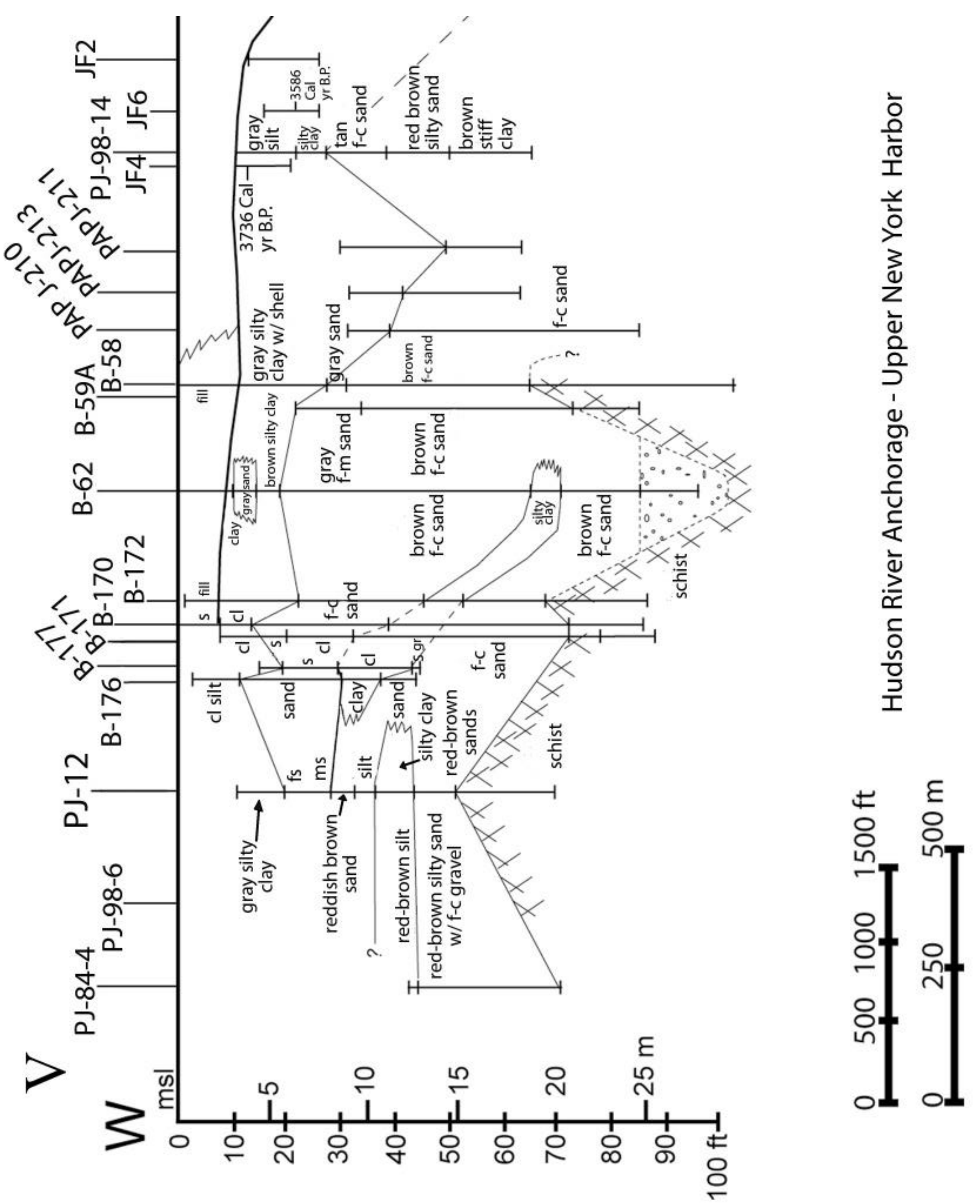

Figure 0.16(a): Port Jersey-Bay Ridge Flats stratigraphic profile V-V', western section.

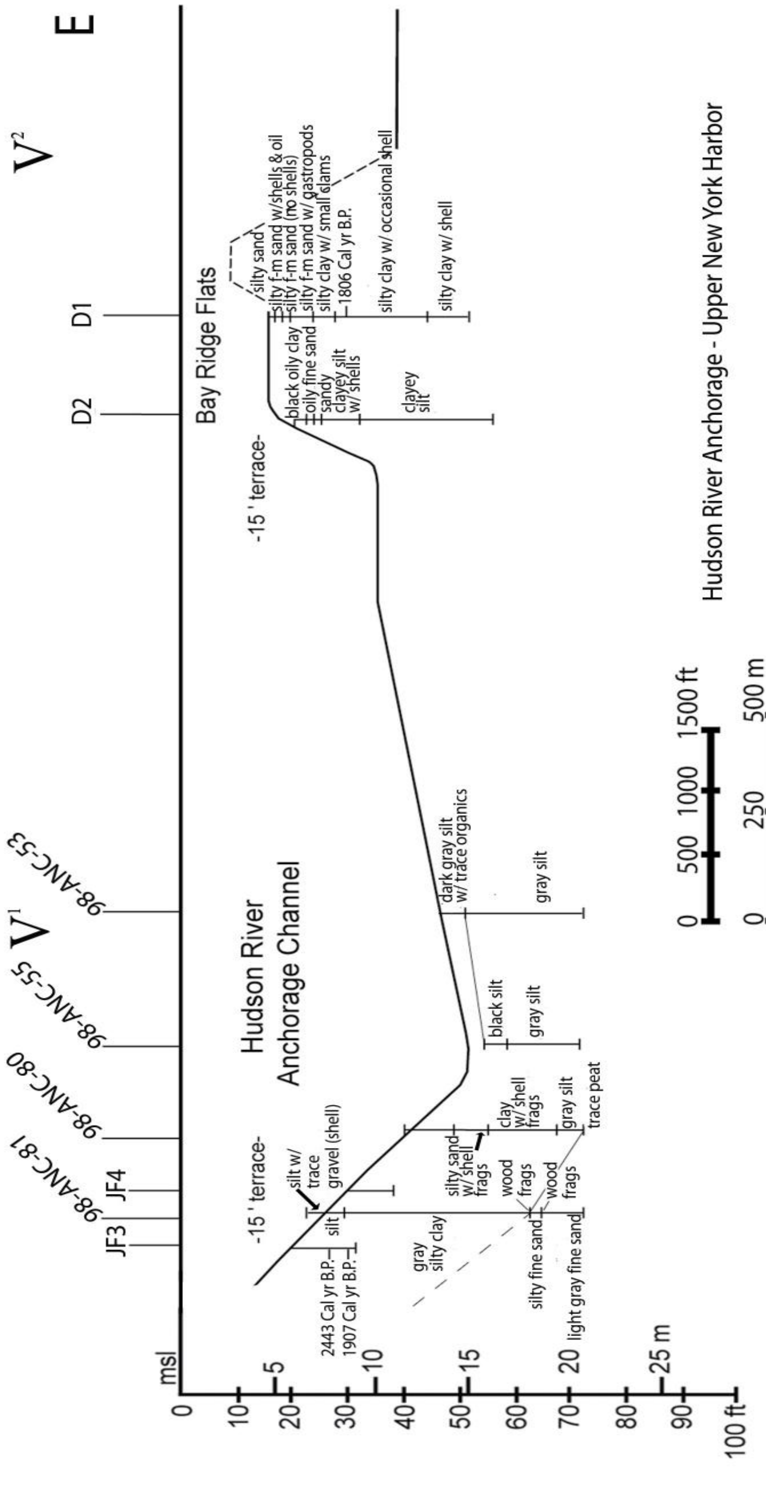

Figure 5.16(b): Port Jersey-Bay Ridge Flats stratigraphic profile V-V', eastern section.

Jamaica Bay

Yellow Bar Marsh Profile (Cores E1-E5). Five (5) cores (E-1 to E-5) were taken in Jamaica Bay (**Figure 5.17**). The sampling strategy used differed from the other areas studied. Due to the shallow water depth in Jamaica Bay a smaller barge was used which collected shorter cores. Core recovery ranged from 3.90 m to 5.65 m. The transect was oriented on a northeast to southwest azimuth from the southern end of Yellow Bar Hassock to south of Ruffle Bar between Ruffle Bar and Little Egg Marsh (**Figure 6.19**). The bottom depths of Jamaica Bay varied greatly between core locations. Cores E-1 and E-2 were located on the edge of the Yellow Bar Hassock, and were very shallow. Water depths ranged between 0.76 m and 0.88 m. Cores E-3, E-4, and E-5 were located in the channel between Ruffle Bar and Little Egg Marsh. Water depths were 6.68 m, 6.10 m, and 6.89 m respectively.

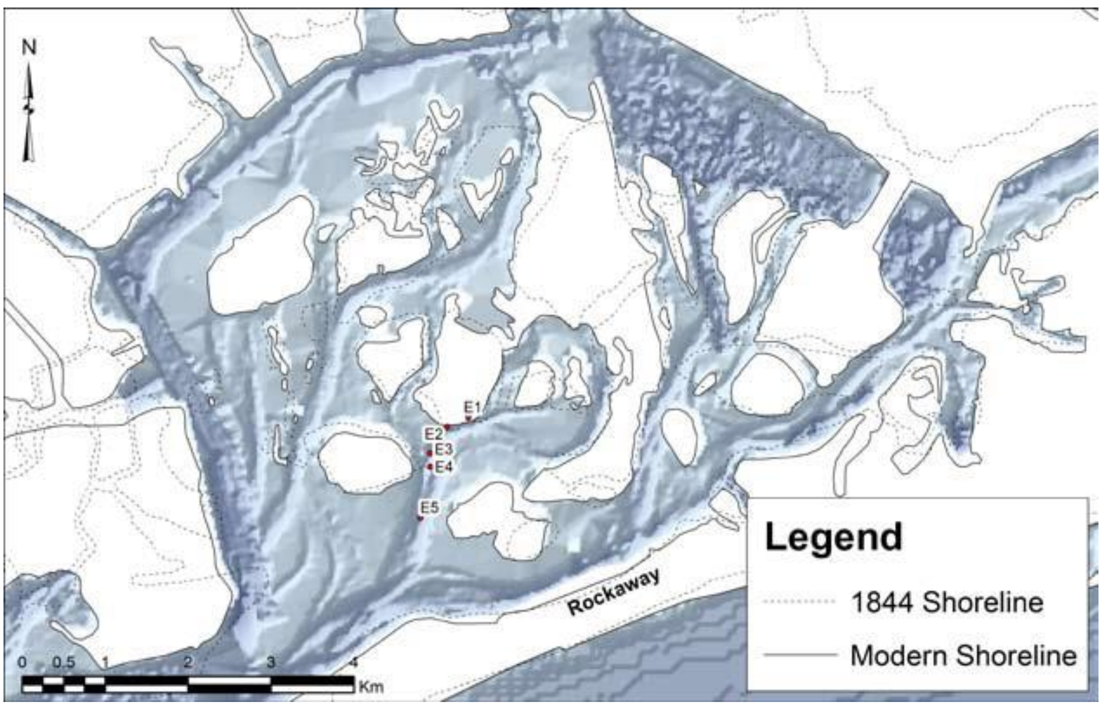

Figure 5.17: Jamaica Bay core locations.

The Yellow Bar Marsh cores from Jamaica Bay encountered six (6) lithostratigraphic units:

Stratum VI:	black oily silty clay with disturbed organics
Stratum V:	gray well sorted bar sands
Stratum IV:	gray sand with bedded black mineral lamellae found only in the channel
Stratum III:	very dark gray sands above marsh deposits with shell fragments
Stratum II:	marsh deposits of very dark gray fine sandy silt to clayey silt with shell fragments
Stratum I:	gray silty fine sand below marsh deposits with shell fragments

Stratum VI was only recovered in cores E-3, E-4, and E-5 in the channel. The black (10YR2/1) oily organic silty clay ranges in thickness from 0.42 m to 0.80 m. The stratum was only present at the top of the cores at the interface of the water and Bay floor bottom. The stratum had a faint H_2S smell and abrupt lower boundary. These observations coupled with the stratigraphic position on the bay bottom, and the oily texture of the deposit suggests that the deposit is a historically recent deposit. The upper 0.10 m of core E-2 is a disturbed dark gray (10YR4/1) sand, but it lacks oily deposits.

Stratum V was recovered in cores E-3, E-4 and E-5.

Stratum IV was only recovered in cores E-3, E-4, and E-5 in the channel. The deposits were a gray (10YR5/1) fining upward sequence of medium to fine sand with occasional 10 mm thick very dark gray subhorizontally dipping silt lamina (10YR3/1). This deposit was identified as the terminal deposit in core E-5, while cores E-3 and E-4 had a gray to very dark gray (10YR5/1, 3/1) fine to coarse sands lacking laminae. Wood fragments were recovered at a depth of 2.52 m below the top of the core E-3 (9.2 m below sea level). A radiocarbon analysis dated this sample to 4130 ± 40 B.P. (4432 cal yrsbp, Beta-228848). This sample recovered from a channel is not considered *in situ*.

Stratum III was recovered in E-1 and E-2.

Stratum II was also identified in cores E-1 and E-2 on the southern end of the Yellow Bar Hassock. Stratum II is a dark gray to very dark gray (10YR4/1, 3/1) clayey silt that coarsens upwards to a clayey silty fine sand. Shell fragments are found throughout the stratum, with three (3) shell hash lenses in the upper clayey silty fine sand portions of stratum II in core E-2. The stratum was encountered 1.48 m and 1.65 m below the sea floor bottom. Core E-1 was the only core that exposed the full thickness of the deposit (2.12 m) while core E-2 terminated in stratum II at 4.88 m below the Bay bottom. Stratum II is analogous to organic clayey marsh deposits of stratum II in the Liberty Island transect and stratum I in the Bay Ridge Flats transect in the New York Harbor.

Stratum I was only recovered in the base of core E-1. It consisted of a gray (10YR5/1) silty fine sand with shell fragments that extended from a depth of 3.60 m below surface to the base of the extracted core at 3.90 m. This stratum is analogous to Stratum I identified in the Liberty Island transect in the New York Harbor. In both settings gray fine sand with shell is found below marsh deposits of organic clayey silts. This facies relationship conforms to model of marsh formation under rising sea level.

Chapter 6
Paleoecological Overview

Tracing the history of past environmental change in the New York Harbor area is a key to evaluating the potential for past human habitation. Sediment lithology is a clue to the depositional environment in which deposits were laid down, but the biological evidence is more informative in many ways. As an example, it was possible to reconstruct the past record of temperature and salinity changes through detailed analyses of foraminifera. Similarly it was possible to derive clues to past floral communities in the region through pollen records preserved in cores. The latter especially give an idea of the ages of sediments in subsurface through comparison with more complete regional pollen records. Both pollen and microfauna such as foraminifers provide a general view of past environmental conditions. Pollen in New York Harbor, for example, is not only derived from ongoing pollen rain throughout the area, but also pollen transported downriver from areas of different vegetation far upstream in the Hudson. Pollen analysis is a regional indicator at best. Benthic foraminifers, on the other hand, are bottom dwellers and populate the bottom sediments of the marine environment in which they are found. They too can be transported by tidal currents to give mixed assemblages. Most useful for discerning the immediate environmental setting for sediments is the macromolluscan fauna consisting of gastropods and of bivalves like oysters and pelecypods. These larger bottom dwellers give an immediate record of the environmental setting of the sediment studied.

Previous Studies

Past paleoecological studies conducted by GRA as part of the Harbor Navigation Project have utilized all of the above approaches. Past analyses have utilized the expertise of Dr. Ellen Thomas (foraminifers) and Dr. Richard Orson (pollen and macro-mollusks). Their reports appear in past studies of Shooters Island and the Jersey Flats. Their work is the foundation for the present study. Different researchers have been utilized for the present report. This study also utilized previous work on pollen and microfossils by LaPorta and his coworkers. Macro-mollusks have been identified by Dr. Georgiana Lynn Wingard, pollen by Christopher Bernhardt and foraminifers by Dr. Benjamin Horton. Dr. Wingard has studied mollusks along the entire Atlantic coast. Christopher Bernhardt has similar experience. Dr. Horton is an internationally known researcher specializing in sea level rise through the use of foraminifer studies. Since previous work by GRA, several important studies have been completed by Lamont-Doherty Earth Observatory on the Hudson estuary. The latter studies give more immediate information on pollen, sedimentation, salinity changes, and shellfish (oyster) colonization further upstream in the Tappan Zee area. Radiocarbon ages from salt marshes as well as submerged oyster reefs in Tappan Zee have formed an independent check on the relative sea level history presented here. Many of the recent Lamont-Doherty findings relate directly to past and present GRA studies.

Past GRA paleoecological studies were site specific while the present study seeks to present a broader view of past environmental changes in New York Harbor. Two Upper Harbor cores were chosen for study. These cores, C-1, and D-1, were from opposite sides of the harbor (e.g. Liberty Island and the Bay Ridge shoal). The former was chosen because it promised the greatest time depth. Core C-1 yielded a basal date on wood of 6473 cal yrsbp. Provided this 12.2 m (40 ft) core was not disturbed, virtually the complete environmental history over this time span was anticipated. Core D-1 was chosen as a check on core C-1 as it had a similar surface elevation and promised to represent the same sedimentary sequence. Both cores were 12.2 m (40.0 ft) in length. They were sampled at 30 cm (ca. 1 ft) intervals. Surprisingly, core D-1 was age dated at 1806 cal yrsbp at a depth of 10 m (33 ft). It was clear that the two cores did not correlate temporally across the harbor. A detailed analysis of these cores is presented in **Chapter 5** and **Appendix A**.

The Shooter's Island cores were from shallow water at the entrance to Newark Bay. They extended little more than 5.5 m (18 ft) below mean sea level. All cores bottomed in fluvial gravelly sands and were overlain by estuarine clayey silt. First and foremost, the analysis attested that there had been no upland or tidal marsh vegetation present in the core. Fluvial gravelly sands graded to fine sands at a depth of 4.9 m (16 ft) were inundated at least since 3200 cal yrsbp on the basis of the relative sea level curve (**Figure 3.6, Figure 3.10**) and had remained underwater since that time. At 3.4 m (11 ft) depth, oysters began to appear about 2200 cal yrsbp and an oyster reef was in place at 2.0 m (6.5 ft) by 1320 cal yrsbp. Presence of oysters pointed to an increase in brackish water (salinity) at the mouth of Newark Bay. While increased salinity could result from decreased freshwater runoff from the Passaic and Hackensack rivers, this same period corresponds with rise in sea level **(Figure 3.10**) at the same time period and in concert with thriving oyster habitat further upstream in Tappan Zee (Carbotte et al., 2004). The oyster reef was overlain by sediments with remnants of submerged aquatic vegetation pointing to a shallower water column and a possible decrease in the marine submergence rate. Here again the change in molluscan fauna and vegetation are contemporaneous with a fall in sea level corresponding with the onset of the Little Ice Age. Thus this significant change may result from both climate and sea level driving forces. In the upper 1 m (3 ft) of the core, surf clams appear pointing to deeper water conditions in the last 500 years.

Another paleoecological analysis of cores from the Jersey Flats explored a different environment on the steep slope on the western edge of the Anchorage Channel. Two cores were studied but core JF-2 provided the most complete data set. Cores here did not extend to bottom of the estuarine fill, but rather began with subtidal habitats. At a depth of 3.3 m (11 ft) the presence of the pelecypod Eastern *Aligena* and the gastropod *Sayella fusca* suggests that the water was brackish. By 2.65 m (8.8 ft) periwinkle (*Littorina irrorata*) fragments are found suggesting low tide zones or marshes in the vicinity. From 2.65 m to 2.7 m (8 to 7.2 ft) the development of a "clam bar" indicated this site was near the head of tide or at least was in a low tide zone. From 2.0 to 1.0 m (6.5 to 3.5 ft) there were few clams consistent with a deepening water column consistent with rising sea level. This core was topped by a final "clam bar" populated by surf clams and pointed to deeper water conditions.

Detailed Studies from Tappan Zee

Earlier paleoecological studies of Tappen Zee Bay conducted by Lamont-Doherty Earth Observatory were important to the interpretations drawn within this study. A study by Carbotte et al. (2004) on submerged oyster reefs has also been critical to the understanding of potentially submberged cultural resources. Work by Pekar et al. (2004) documents salinity changes in the lower Hudson estuary over the past 7,000 years. Pollen work by Pederson et al. (2005) and Peteet (personal communication) gives us long term records of vegetation and climate change in the project area as well as the history of salt marsh development in response to relative sea level changes.

Pekar et al. (2004) infer paleosalinity reconstructions on the basis of benthic foraminifera and associated biofacies. The study shows an initial high summertime salinity of 20 to 25‰ beginning at about 6,000 years ago decreasing to 10 to 15‰ by 2,000 years ago. The latter salinities are generally consistent with the modern salinity range. A period of high frequency salinity changes marked the transition to lower summer time salinity at about 3,600 years ago. The sedimentation rates in Tappan Zee were relatively low and similar to the rate of relative sea level rise although it's noted that rates were lowest over the past 2,400 years in shallow water with increased rates further downstream between 2,300 and 1,300 years ago. Variations in sedimentation rates are attributed to the migrations of a salt water wedge migrating up and downstream from the mouth of the estuary. The Lamont-Doherty researchers refer to this wedge of saltwater intrusion as the ETM or Estuarine Turbidity Maximum, considered the zone where fine grained sediment (largely clay minerals), carried downstream by the Hudson River, flocculate and tend to drop out of the water column. Their conclusions suggest that estuarine sedimentation was highly localized, signifying complex depositional patterns.

The development of oyster reefs in the Tappan Zee (as well as Shooters Island, see above) has not been continuous. Carbotte et al., (2004) have noted that oysters thrived between 6,100 and 5,600 cal yrsbp and 2,400 to 500 cal yrsbp, but virtually disappeared between 5,000 and 4,000 cal yrsbp associated with the onset of a cooler climate. Additionally, they point to a more recent demise of oysters in the estuary between 900 and 500 cal yrsbp which may have accompanied the cooler climates of the Little Ice Age. Radiocarbon dated oysters from the study's core SD30 (the most continuous record in the study) have been incorporated into this investigation's relative sea level model (**Figure 3.6**) as they reflect the same rate of sea level rise. The Carbotte et al. (2004) study data also show a clear low phase and decrease in the rate of sea level rise between 5,000 and 3,500 cal yrsbp with a rate of 2 to 4 mm/yr (0.1 to 0.2 in/yr) toward the end. Overall, the long term rate of relative sea level rise shown by the Tappan Zee oysters is on the order of 1.7 to 1.8 mm/yr (0.067 to 0.071 in/yr) as is this study's calculated rate.

The Tappan Zee oyster studies also provide a background to archeological investigations at Croton Point (Newman et al. 1969) and at Dogan Point (Brennan, 1974 and Claassen, 1995). Shell middens at Dogan Point, for example, show that oyster harvesting by Late Archaic populations began as early as 6,000 cal yrsbp. Distinctly large oysters characterize the base of the shell midden at Dogan Point and date between 5,900 and 5,100 cal yrsbp (Brennan, 1974, Little, 1995). Smaller oysters are dated in two distinct horizons at the site (5,100 to 4,000 and 1,800 to 1,500 cal yrsbp) separated by a 2,000-year hiatus. While the archeological interpretation might suggest changes in dietary patterns or cultural groups (the hiatus is contemporaneous with the end of the Late Archaic period and includes the more agriculturally oriented Early Woodland period), the hiatus is present in the fossil record, as well, and points to significant temperature and salinity changes in the estuary, making it less conducive to oyster growth.

A detailed study of the Piermont Marsh (Pederson et al., 2005) not only provides us with a regional view of vegetation and climate change over the past 2,000 years, but also the contemporaneous changes within the marsh. These, in turn, reflect changes in the local watershed as well as the ongoing changes in sea level as the marsh adjusted to the rising sea level. One of the key findings of this study is the suggested correspondence between high concentrations of charcoal and the timing of the Medieval Warm Phase (1,200 to 700 cal yrsbp). Pederson et al (2005) attributes these concentrations of charcoal to drought conditions and frequent fires related to warmer climate conditions in the region, as well as changes in sedimentation rates over the past 2,000 years. Additionally, they show a decrease in sedimentation rate from .3 mm/yr (0.01 in/yr) during the Medieval Warm Phase, increasing to 2.9 mm/yr (0.11 in/yr) and 5.9 mm/yr (0.23 in/yr) and then decreasing to background rates of 1.1 and 1.4 mm/yr (0.043 and 0.055 in/yr). The overall sedimentation rate for the Piermont Marsh core was ca. 1.8 mm/yr consistent with the rate of relative sea level rise determined by Carbotte et al.'s (2004) oyster reef trend and the sea level model presented. Also important for this study, are the varying trends and rates of sedimentation documented by Pederson et al. (2005). Close examination of their sedimentation results suggests an overall decrease in rates between 1,000 and 300 cal yrsbp. When viewed against the background sedimentation rate of 1.8 mm/yr (0.071 in/yr) between 1,600 and 1,000 cal yrsbp, the study suggests an overall period of lower sedimentation rates which correspond with the period of lower relative sea level presented by Thomas and Varekamp (2001) of Connecticut salt marshes, used here in **Figure 3.10**. These pollen studies not only track changes in climate and local runoff, but also are an independent marker of relative sea level change in the Hudson estuary.

An additional study by Slagle et al. (2006) discusses infilling of the estuary. It identifies three distinct unconformities representing erosional surfaces or periods of non-deposition in the sedimentary record at Tappan Zee. Maximum ages for the unconformities are 3,655, 2,200, and 1520 cal yrsbp. It also identifies two sedimentary facies apparently overlapping the above unconformities. A deeper sedimentary unit identified as a delta and dated to ca 1,700 years accumulated at rates of 2 to 4 mm/yr (and lapped onto the 2,200 cal yrbp surface of erosion or non-deposition. Identification of a delta suggests sediment contribution from a nearby fluvial source. A shallower depositional facies accumulated at a slower rate of 1 to 2 mm/yr (0.1 to 0.2 in/yr) and tended to cover the above delta deposit. The data suggest that the shallow flats at Tappan Zee were no longer depositional sites but rather the site of alternating periods of erosion and deposition sensitive to small fluctuations in sea level and climate conditions.

Applications to New York Harbor

The detailed paleoecological studies conducted by Lamont-Doherty provide a useful context for previous studies of mollusks, foraminifers, and pollen conducted by GRA and other researchers. By necessity, the GRA studies are coarse-grained in comparison. It is useful, however, to compare the findings of the earlier studies at Shooters Island and the Jersey Flats with the Tappan Zee area. This is shown graphically using the new relative sea level reconstruction as a background. **Figure 6.1** shows the relative sea level trend contrasted with the Carbotte et al. (2004) radiocarbon dated oyster sequence from their core SD30. Also shown are the approximate dates of the inundation of the Jersey Flats (ca. 6,000 cal yrsbp), Raritan Bay (ca. 5,000 cal yrsbp) and Newark Bay (ca. 3.500 cal yrsbp). It is assumed, based on radiocarbon dates (from the Hudson River at Iona Island and the outwash channel of Arthur Kill), that the main incised channel of the Hudson River was inundated by brackish water as early as 12,000 radiocarbon years B.P. (ca. 14, 500 cal yrsbp). The figure also shows the intervals of active oyster growth at Tappan Zee.

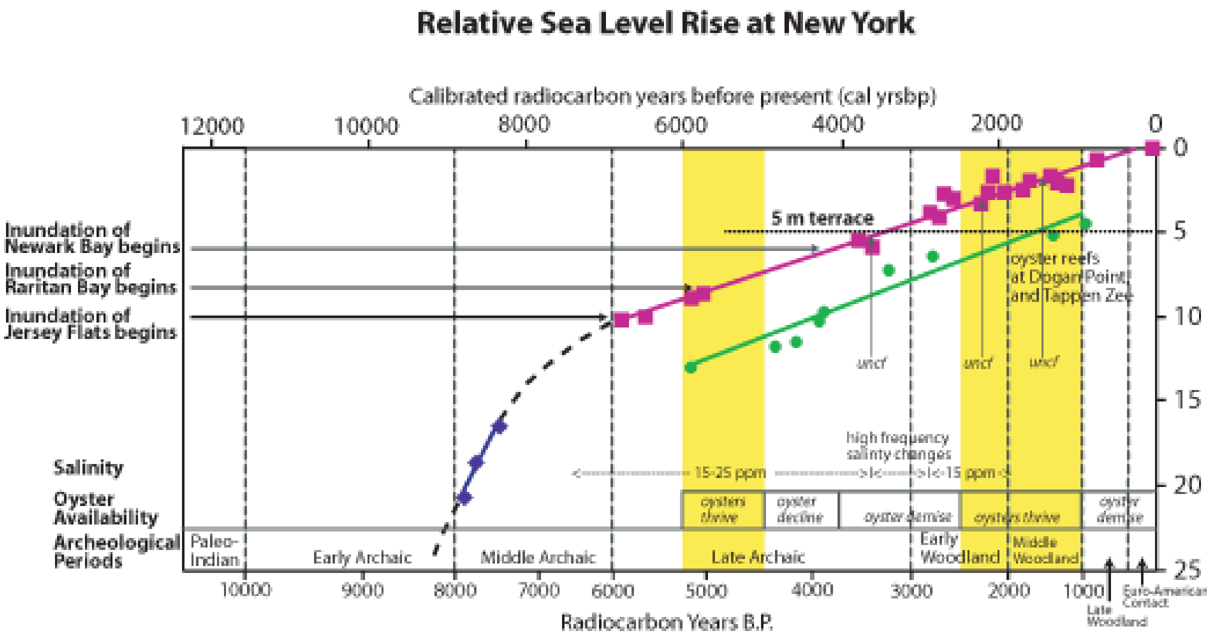

Figure 6.1: Relative sea level compared with Tappan Zee oysters, salinity, and unconformities.

The inundation history of the Jersey Flats area appears to parallel that at Tappan Zee. The earliest basal radiocarbon dates of 6,473 and 5,769 cal yrsbp gathered at Liberty Island correspond with the earliest known appearance of oysters further upstream. That incursion marks the intrusion of marine water into the shallower flanks of the Hudson, both in the Harbor and upstream. The inundation is congruent with the observed increase in salinity to 25^{o}/$_{o}$, which subsequently decreased to 15 ^{o}/$_{o}$ by 3,500 cal yrs bp. At Shooters Island oysters began to populate the entrance to Newark Bay at about 2,200 cal yrsbp corresponding to the return of oysters at Tappan Zee after at least a 1,000 year hiatus.

In summary, Figure 6.1 represents the convergence of the latest diagnostic indicators to produce a comprehensive model of sea level rise for New York Harbor. The data incorporate the most recently upgraded lithostratigraphic (geological), biostratigraphic (mollusk and shell), and radiometric (carbon, wood, and shell-based dates) data sets. Taken together, these data sets reliably calibrate rates of sea-level rise because they draw on multi-disciplinary sources. The foundations of this model are traceable to the Newman et al. (1969) baseline model that was tied to the major geomorphic and stratigraphic sequences developed for New York Harbor. That model, however, was based on limited radiometric determinations and shell-stratigraphies that were not well calibrated. Moreover, the regional (Atlantic Coast) models that were drawn on were equally uneven. The GRA construct integrates the more refined regional and local models—the latter (in part) generated from this study—to establish the most accurate sea-level rise curve to date. As discussed subsequently, the model also guides spatio-temporal expectations for buried archaeological site distributions. Finally it is hoped that the sea-level curve can serve as a baseline for understanding of the paleoecology of the New York Harbor as well as the Hudson estuary. It should enable other researchers and cultural resources specialists to better anticipate the geographic location of submerged prehistoric archaeological sites.

Chapter 7
Environmental Reconstruction and Prehistoric Landscape

The following portion of this study is designed to present a graphic characterization of the inundation of the New York Harbor study area for aid in understanding both its sedimentary history and in the determination of the potential for submerged prehistoric archaeological sites. A digital elevation model (DEM) showing topography merged with shorelines and bathymetry from the earliest dependable charts (New York Bay and Harbor and Environs, U.S. Coast Survey, 1844) has been constructed from U.S. Geological Survey topographic data and digitization of the 1844 bathymetry and shoreline data. The resulting model (**Figure 8.1**) shows the harbor study area in 1844 prior to dredging and significant land fill operations. Important for future Federal interests are the original shoreline positions for both the Jersey Flats and Jamaica Bay, which have undergone extensive modification over the past 150 years.

To conceptually set the stage, **Figure 7.1** shows the deeply incised channel of the Hudson River upstream from the Narrows as well as the incised channel of the East River through Hell Gate to Long Island Sound. The original shorelines of the Jersey Flats and Jamaica Bay are useful markers. The Hackensack and Passaic rivers entered Newark Bay from the north and the incised channel of the precursor to the Hackensack River was visible and drained to the Hudson through the Kill Van Kull. South of the Narrows, the Hudson channel gave way to a more subdued topography characterized by an array of splayed channels separated by interfluves that have historically been shoals limiting access to the harbor and directing maritime traffic into Raritan Bay through a deeper channel at the tip of Sandy Hook. Though they were indistinct, the channels at the mouth of the Narrows apparently drained eastward to the edge of the incised Hudson Shelf Valley and ultimately to the Continental Shelf. Arthur Kill was inundated, though there are indications that its incision began at Newark Bay, the position of the former glacier ice front and subsequent proglacial lake that drained through its channel. The mouth of the Raritan River lies to the west of Raritan Bay, though the bottom surface outlines the general course of the ancestral channel of the Raritan River, which merged with the Hudson channel north of Sandy Hook. The Navesink and Shrewbury rivers entered their conjoined estuaries behind the barrier island at the base of Sandy Hook, which had not yet prograded to its current position.

Using the relative sea level model (**Figure 3.6**) it is possible to interpret and display sea level at its 9,000 cal yrsbp position (-22m, -72 ft) and view the previously exposed landscape (**Figure 7.2**). This also allows for visually interpreting the flooding of the New York Bight and upper and lower harbors on an incremental, 1,000 year basis. For example, **Figure 7.2** shows the landscape at 9,000 cal yrsbp, a period that postdates the draining of the proglacial lakes held behind the Harbor Hill moraine. These draining lakes apparently incised the Hudson Shelf Channel across the Continental Shelf at a lowered sea level stand. The Hudson, Raritan, Hackensack, and possibly Arthur Kill rivers drained across reworked outwash from both the Raritan River and the leading edge of the Harbor Hill Moraine. It is uncertain how the sequencing of the former Hudson channels occurred, thus there are four identifiable channels draining to the head of the Hudson Shelf Channel. It is also uncertain what the configuration of the ancestral Raritan River was, as earlier work by Gaswirth (1999) focused on the outflow from high volume glacial outwash channels, shows the Raritan passing South of Sandy Hook's midpoint. For ease of presentation the Raritan River is represented following the lowest trough across the current Raritan Bay to join the Hudson River, draining directly into the Hudson Shelf Channel. The Navesink and Shrewsbury rivers drained directly from the contemporaneous shoreline to the east. Additionally, alluviation of floodplains is anticipated to have occurred along all incised river drainages. That said, the figure shows the landscape at the time of the transition between the Early and Middle Archaic archaeological periods. Any Early Archaic prehistoric occupation (11,500 to 9,000 cal yrsbp) would have extended further seaward onto the exposed shelf. Both Paleoindian and Early Archaic archaeological sites are found on Staten Island where they possibly overlooked game migration routes along the Raritan River and Arthur Kill. Any evidence for earlier Paleoindian occupations extends from the present subaerial land surface to a shoreline deeper and farther to the east. Preserved sites of the Early Archaic through Paleoindian periods are expected to be deeply buried along the floodplains of the incised river channels.

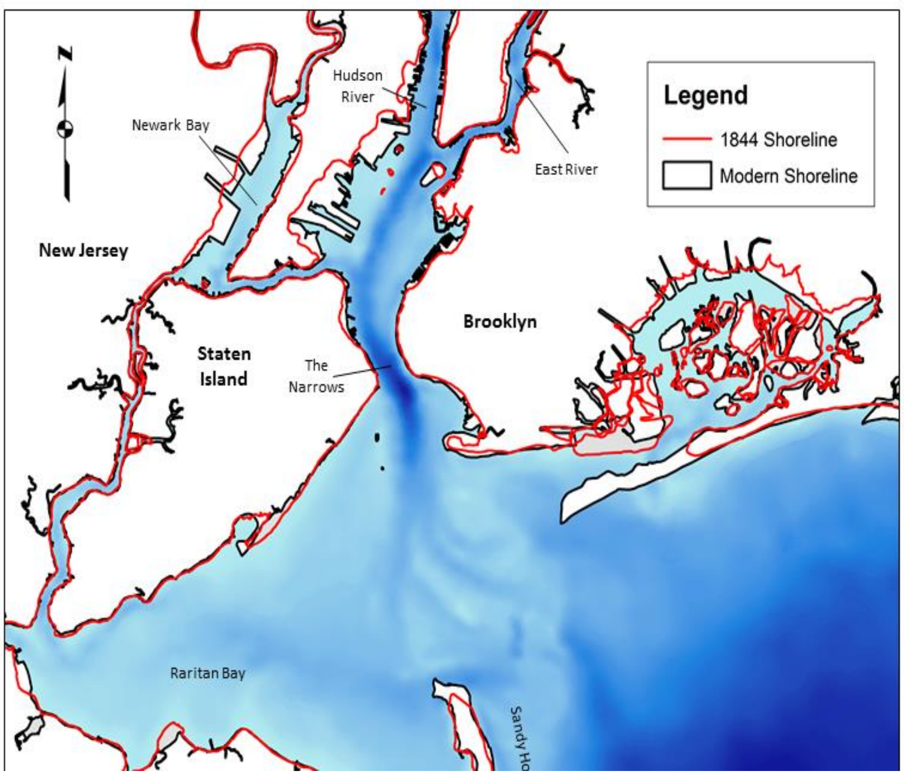

Figure 7.1: 1844 Bathymetry of project area showing modern shoreline.

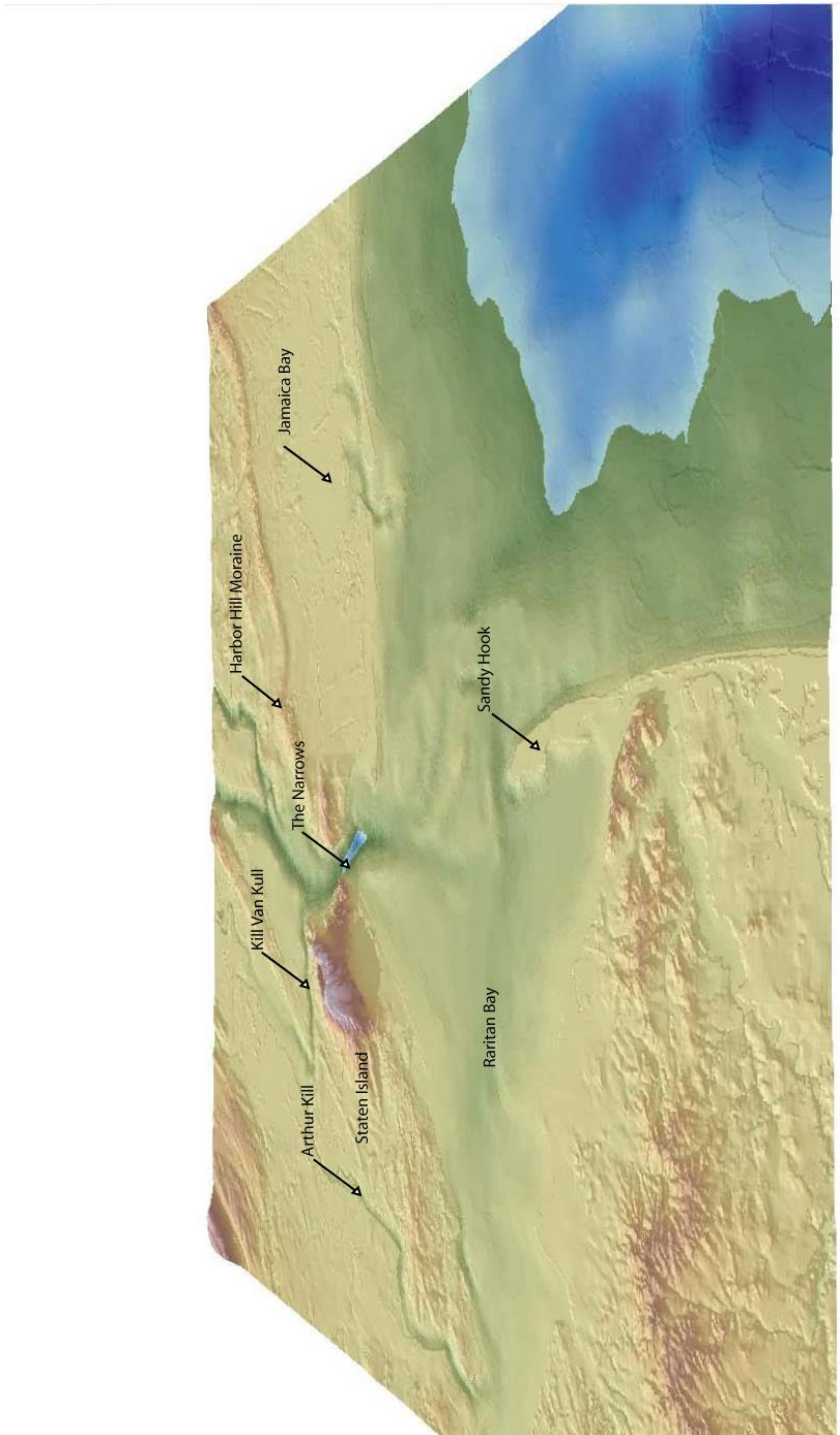

Figure 7.2: Sea level ca. 9,000 cal yrsbp (ca. 8,000 B.P.) at -22 m (-72 ft), Early Archaic.

By 8,000 cal yrsbp (**Figure 7.3**), with sea level at -16 m (-52 ft) the landscape was little changed, reflecting upon the relative steepness of slopes draining to the Hudson Shelf Channel, while river channels further inland followed their earlier courses. This was the height of the Middle Archaic period, characterized by small groups of hunter-gatherers utilizing riverine systems. **Figure 7.4** shows the relative sea level position at 7,000 cal yrsbp at -11 m (-35 ft), marking the transition between the Middle Archaic and Late Archaic periods. By this time, sea level had risen to edge of an apparent outwash fan extending seaward from Raritan Bay and the Narrows. There were clear connections between the main Hudson channel and Long Island Sound through the East River and Hell Gate. Multiple channels draining the Hudson to the Bight continued to be present, though for the first time, the remnants of former Hudson channels began to emerge at the edge of the outwash fan. A deeper embayment extended inland to join with the northernmost channel across the fan. A second channel to the south exited the fan at a similar reentrant. The interfluve between these channels suggests that the outwash fan predated the opening of the Hudson channel at the Narrows and that flow from the Hudson eroded channels at the edge of the fan. This apparent incision suggests that these channels were the earliest in the sequence as incision points for preceding lower sea levels. Thus it would seem that channels across the fan migrated from north to south as time transgressed. In terms of archaeology, the now submerged surface between the modern shoreline and that of 7,000 years ago was potentially occupied by groups from the Late Archaic through Paleoindian periods.

At that time, the rate of relative sea level rise slowed to an average rate of about 1.5 mm/yr (0.06 in/yr). By 6,000 cal yrsbp (**Figure 7.5**) coastal environment settings began to stabilize. This marked the initiation of oyster growth as far upriver as Tappan Zee and possibly on the Jersey Flats as marine water transgressed up the flanks of the main Hudson channel, reworking fluvial sand and gravel by wave action. While it isn't clearly understood what the connection between the Hudson channel and the open water of the Bight was, runoff from the Hudson River drainage basin was clearly sufficient enough to maintain an open channel that was subject to tidal currents. This was the time of the onset of increased salinity at Tappan Zee. The Raritan River, together with possible flow from Arthur Kill, crossed the open surface of the outwash fan to reach the open marine water east of present day Sandy Hook. The Hackensack and Passaic rivers drained directly into the main Hudson River channel through Kill Van Kull. There continues to be a direct deep water connection between Long Island Sound and the Hudson via the East River and Hells Gate. Virtually all of the present Raritan Bay, the seaward edge of the outwash fan to present-day Coney Island, the Jersey Flats, and land surface between Brooklyn and Manhattan were all exposed and open for Late Archaic prehistoric habitation.

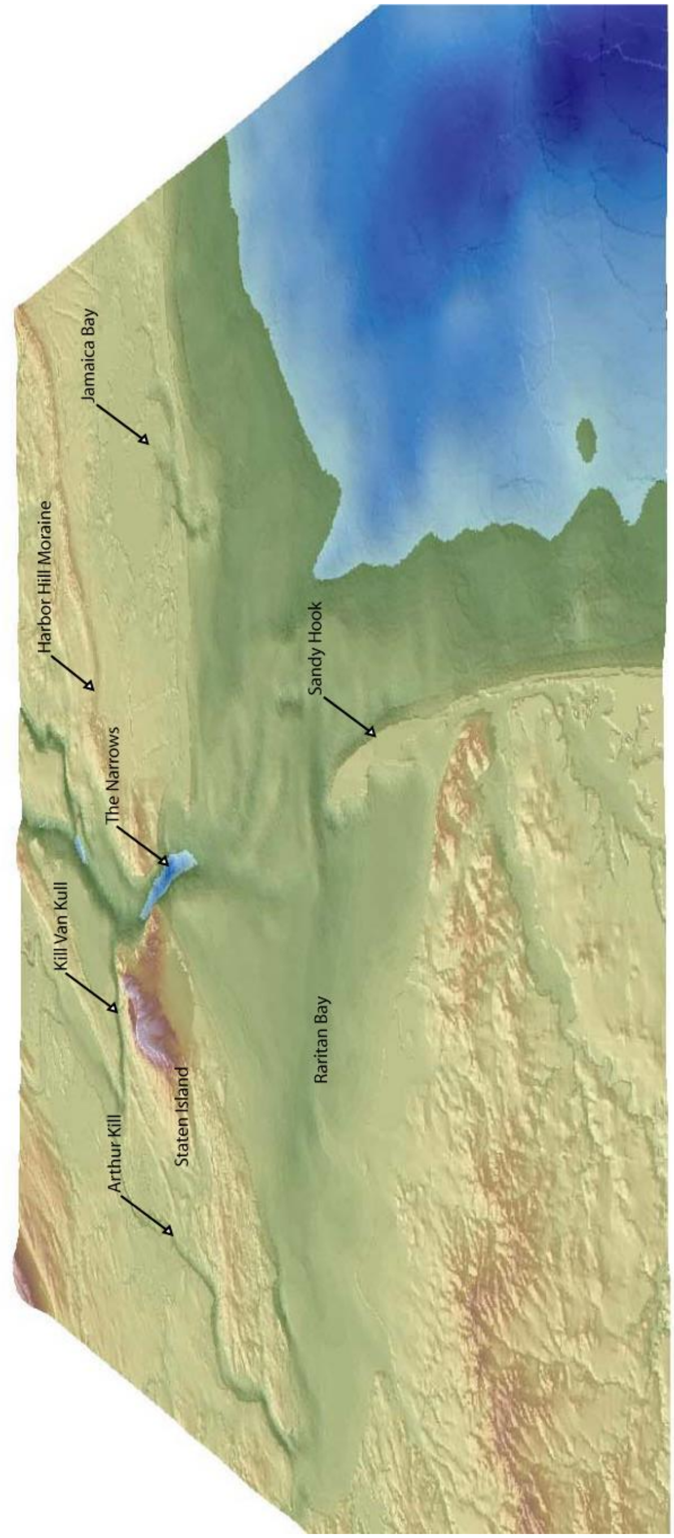

Figure 7.3: Sea level ca. 8,000 cal yrsbp (ca. 7,000 B.P.) at -16 m (-52 ft), Middle Archaic.

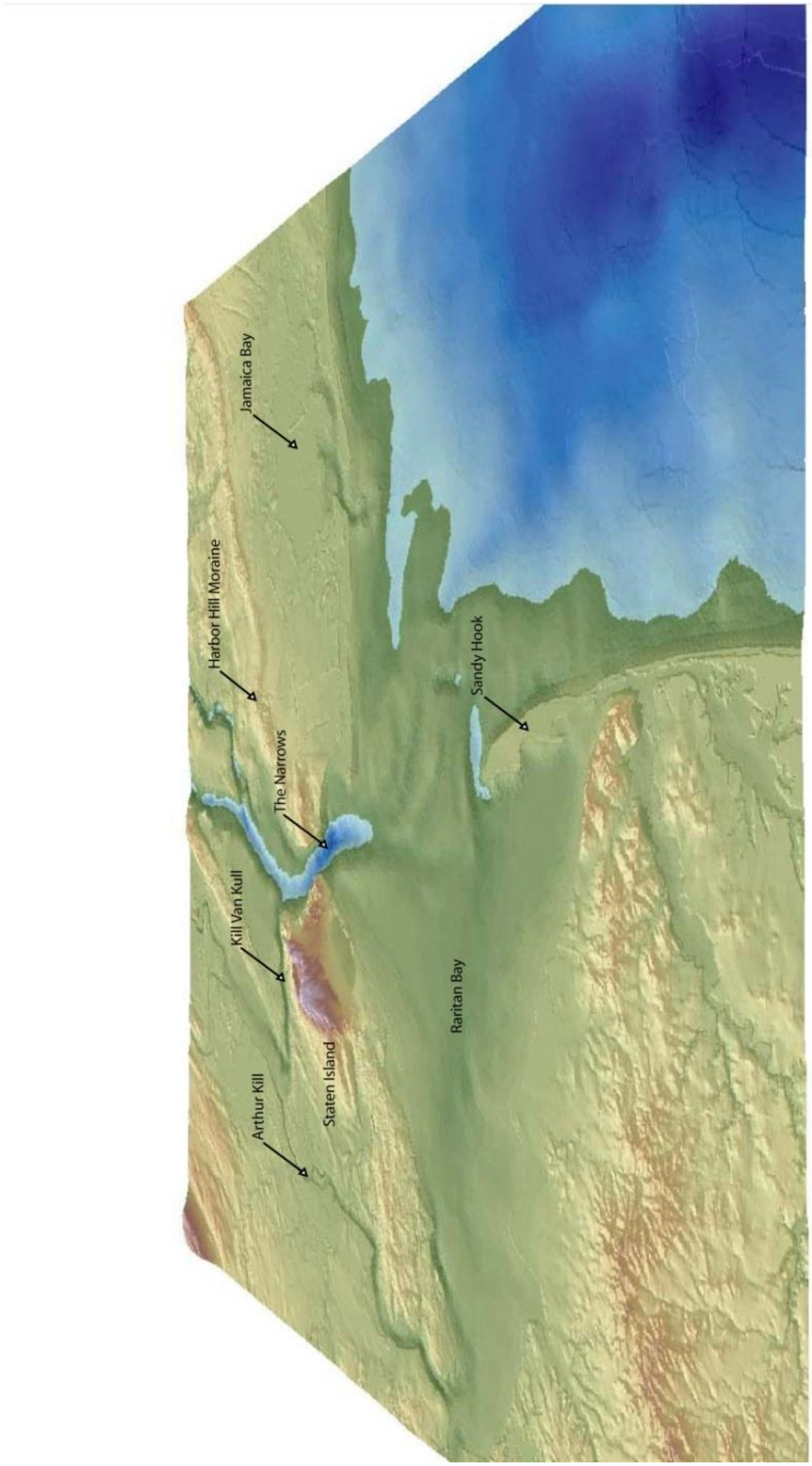

Figure 7.4: Sea level ca. 7,000 cal yrsbp (ca. 6,000 B.P.) at -10.7 m (-35 ft), Middle Archaicto Late Archaic transition

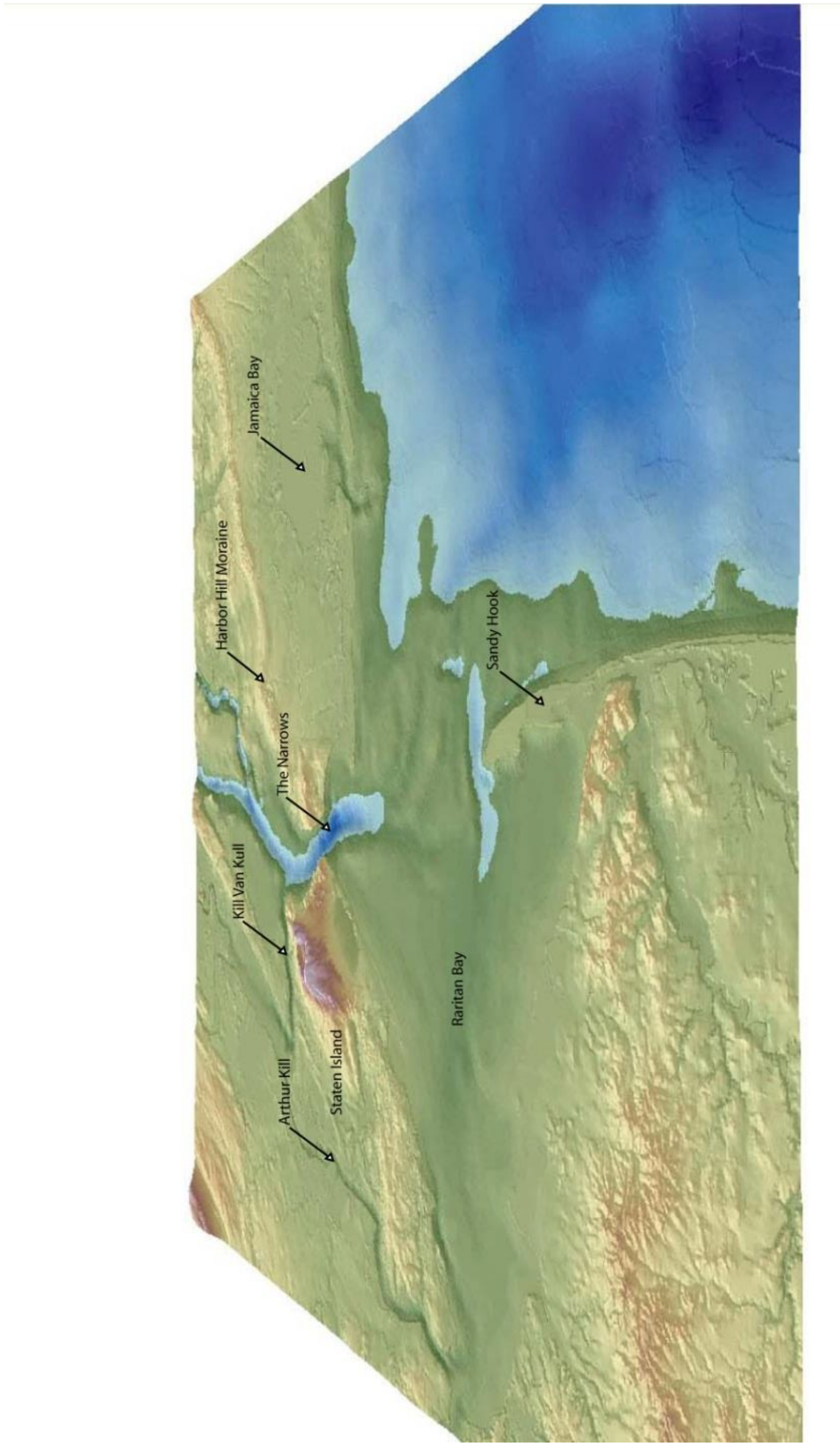

Figure 7.5: Sea level ca. 6,000 cal yrsbp (5,200 B.P.) at -9 m (-30 ft), Late Archaic

At 5,000 cal yrsbp (**Figure 7.6**), as sea level rose to within 7.6 m (25 ft) of the present mean sea level, the active channels of the Hudson seem to have been better defined, emptying offshore through two probable channels. The lower portion of the Raritan River began to flood and define itself as a narrow estuary, although the Raritan River and Arthur Kill continued to maintain separate channels, emptying into this narrow estuary. Farther north, the Hackensack and Passaic rivers continued to remain active, emptying into the Hudson River via the Kill Van Kull. That sea level stand marks the beginning of a thousand year period of oyster decline in Tappan Zee for yet unknown reasons, but possibly related to salinity changes. Since 7,000 cal yrsbp, when direct linkage between Long Island Sound and the Hudson appears to have begun, dissimilar tidal regimes apparently began to interact and influence tidal currents in the upper and lower harbor. Here again, the area was open to Late Archaic period use by bands of hunter-gatherers utilizing riverine and coastal settings.

Over the succeeding 1000 years, the sea rose to -6 m (-20 ft) relative to present sea level (**Figure 7.7**). A fully flooded Hudson estuary was recognizable as it spread out from the confines of the main incised channel and into an expanding estuary in the central portion of present Raritan Bay. Interfluves separating the previous splayed channels of the Hudson across the outwash fan then began to appear as distinct islands, recognized as linear shoals on early, pre-dredging maps of New York Harbor. One of these islands, east of modern Sandy Hook, occupies the eastern edge of the outwash fan at the mouth of the outer harbor. This feature is known on navigation charts as the “False Hook”. It is suspected that another similar island underlies Sandy Hook and acted as a platform for the spit to develop as longshore sediment moved northward along the New Jersey barrier island system. There is an indication that the incised channel of the Kill Van Kull began to flood at that time, and reached the mouth of the Hackensack River in the vicinity of present Shooters Island. That period, ca. 4,000 cal yrsbp, marked the final years of the Late Archaic period and the probable transition to a form of horticulture in addition to the hunting and gathering subsistence pattern. Perhaps concomitantly this also marked a period of oyster demise at Tappan Zee, removing a significant shellfish resource in the prehistoric diet.

By the end of the Late Archaic period at 3,000 cal yrsbp (**Figure 7.8**) during the transition to a more agriculturally based Early Woodland period, sea level stood at -4.6 m (-15 ft). The outer edges of the outwash fan were inundated at this time, leaving narrow linear islands that marked the locations of present-day Flynn Knoll and Romer Shoal. The present East Bank shoal off of Coney Island was exposed as well. Marine water extended further into Raritan Bay and began to define the southern shoreline of Staten Island as the Raritan River drained to the bay through the incised former outwash spillway channel of Arthur Kill. Marine water also flooded the deep Arthur Kill channel. Continued flooding of the Kill Van Kull deepened marine water, which extended further upstream to become the mouth of the Hackensack River. The Hudson estuary continued to invade the sloping edges of the main channel in the area of the Upper Harbor and widened the channel. Distinct islands occupied shoals off Brooklyn near Bay Ridge. Inundation of the Jersey Flats also continued, although it is not represented in **Figure 7.8**, as sedimentation had largely filled in the area by 1844, when bathymetry was composed. Again, the area below the present sea level was available for Paleoindian to Woodland occupation.

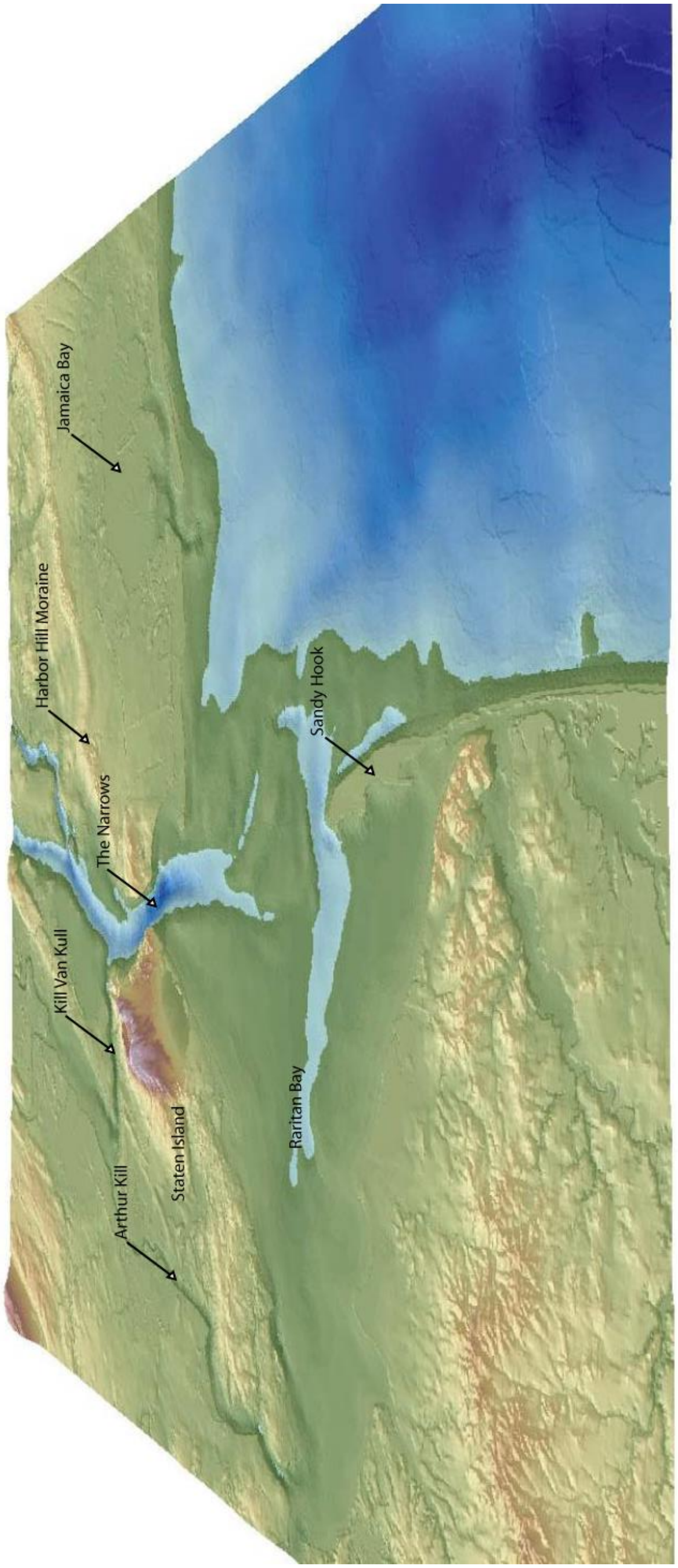

Figure Sea level ca. 5,000 cal yrsbp (ca. 4,500 B.P.) at -7.6 m (-25 ft), Late Archaic

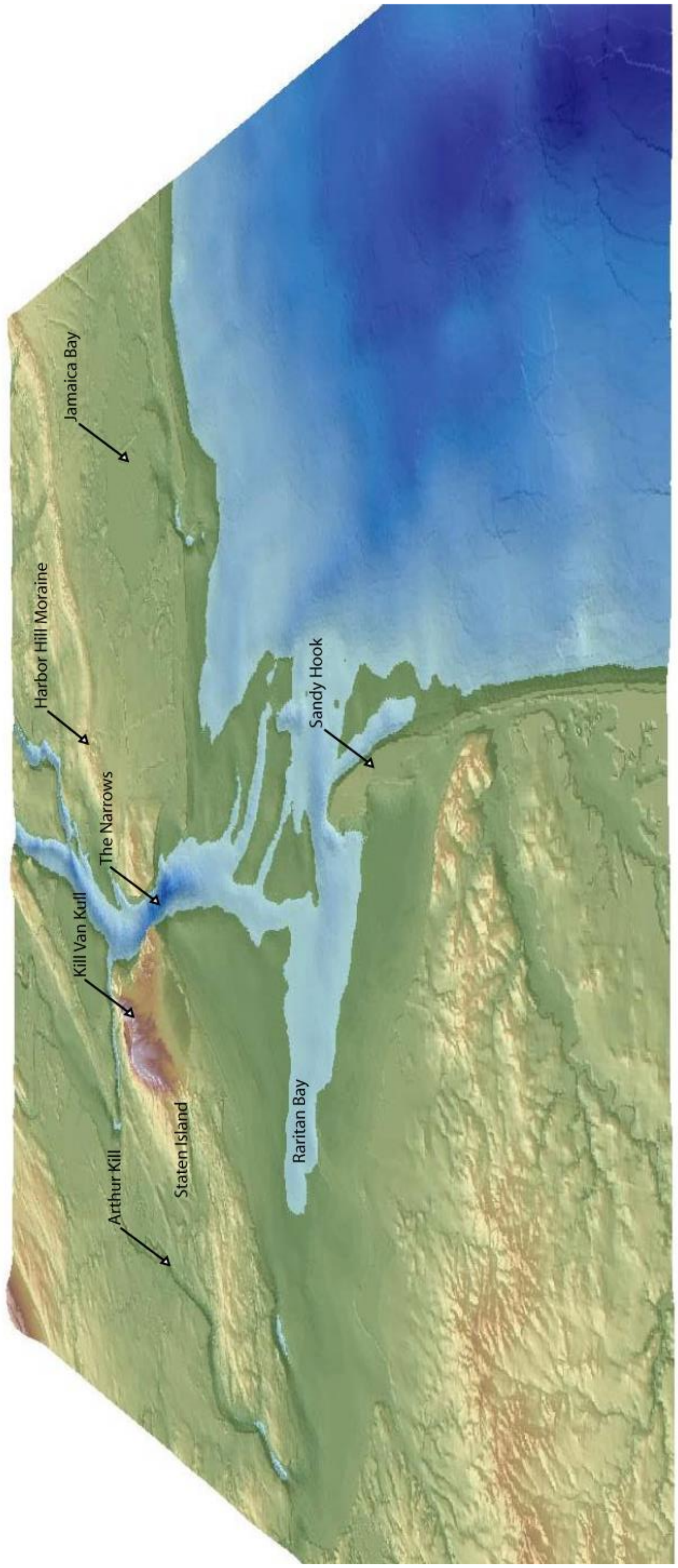

Figure 7.7: Sea level ca. 4,000 cal yrsbp (ca. 3,700 B.P.) at -6 m (-20 ft), Late Archaic

Figure 7.8: Sea level ca. 3,000 cal yrsbp (ca. 3,000 B.P.) at -4.5 m (-15 ft), Late Archaic to Early Woodland Transition

New York harbor began to attain its near-modern configuration by 2,000 cal yrsbp (**Figure 7.9**), when sea level stood at -3 m (-10 ft). Islands were still present at the mouth of the harbor and occupied the locations of the present East Bank and Romer Shoal. The former West Bank shoal, (now largely removed by dredging) also appeared as a distinct island. GRA investigations of Raritan Bay and the Lower Harbor have identified an apparent “still stand” or low fluctuation along the rising trend of sea level between 3,000 and 2,000 cal yrsbp marked by erosional surfaces at -4.6 m (-15 ft) that defined the islands shown in this image. Temporally, this period of “still stand” seems to correspond with a long period of oyster “demise” in Tappan Zee that ended fairly abruptly before 2,000 cal yrsbp and near the close of the Early Woodland period when oysters again became prevalent. This correspondence suggests that lower salinity associated with a fall in sea level and retreat of the salt water wedge in the estuary may have occurred. By 2,000 cal yrsbp sea level back-flooded Arthur Kill to its pre-dredged depth at its headwaters near present Newark Bay. The Raritan River emptied directly into Raritan Bay, which was still confined within the earlier, and then drowned, channel of the river. It’s suspected that Sandy Hook may have begun its formation around this time (2,000 cal yrsbp). In the Upper Harbor the Bay Ridge Shoal was present as a distinct island between Manhattan and Brooklyn. The Kill Van Kull continued its expansion of marine water along the lower reach of the Hackensack River and may have extended as far upstream as Newark along its incised channel. Little is known at this timeabout Jamaica Bay beyond the 1844 configuration of the Rockaway Beach barrier island. **Figure 7.9** does, however, show back barrier channels leading inland to the present Jamaica Bay marshes as well as shoals on either side of the inlet. The shoreline pattern shown in **Figure 7.9** marks the time of transition from Early Woodland to Middle Woodland periods and an increased dependence on agriculture. Concomitantly, the Tappan Zee studies (Carbotte et al. 2004) point to the return of oysters in the estuary, perhaps suggesting more favorable temperature and salinity conditions at the end of the low phase or “still stand” in sea level during the preceding 1,000 years. Coastal settlements were likely prevalent during this period along small drainages entering the harbor areas. Late Archaic through Middle Woodland use of shellfish (oysters) has been documented by Claassen (1995) for Dogan Point north of Tappan Zee. The study summarizes similar shell-bearing sites along the lower Hudson and also points to that subsistence pattern and timing. Thus, shell middens associated with this and earlier shoreline positions may have been common along now submerged tributary drainages.

Throughout the subsequent 1,000 years (**Figure 7.10**) continued rise in sea level presented a more recognizable landscape, shoreline, and riverine drainage pattern. One thousand years ago, sea level was about 1.5 m (5 ft) lower than the present level. Newark Bay was flooded to the confluence of the Hackensack and Passaic rivers and connected to the Hudson River through Kill Van Kull. The Jersey Flats were clearly inundated. The Arthur Kill channel had been flooded and nearly connected with Kill Van Kull and Newark Bay. The mouth of the Raritan River was inundated, indicating the spread of estuarine conditions upstream from Raritan Bay. The southeastern shore of Staten Island remained exposed. Studies of Raritan Bay suggest that an earlier barrier island system and spit similar to the modern Great Kills spit may have existed at that time. Most of the islands capping the shoals at the entrance to the harbor were largely gone with remnants present on the Romer Shoal, the West Bank, and at the entrance to the Rockaway inlet and entrance to Jamaica Bay. Inundation of preexisting lowlands at the present mouth of Jamaica Bay apparently began at this point, marking the onset of conditions conducive to salt marsh growth and development. Archaeologically, this shoreline configuration corresponds with the transition between Middle Woodland and Late Woodland periods. It closely approximates the conditions present in the few centuries prior to European entry into the area in the 17th century.

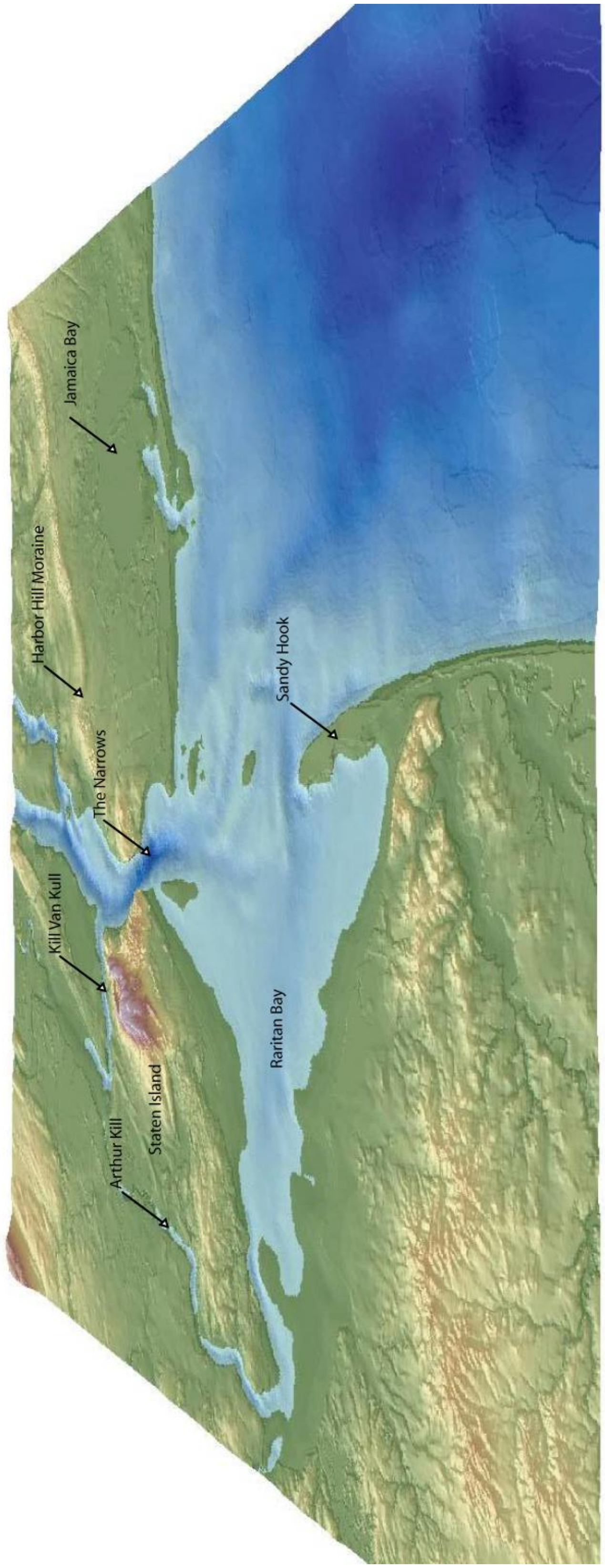

Figure 7.9: Sea level ca. 2,000 cal yrsbp (ca. 2,000 B.P.) at -3 m (-10 ft), Early to Middle Woodland Transition

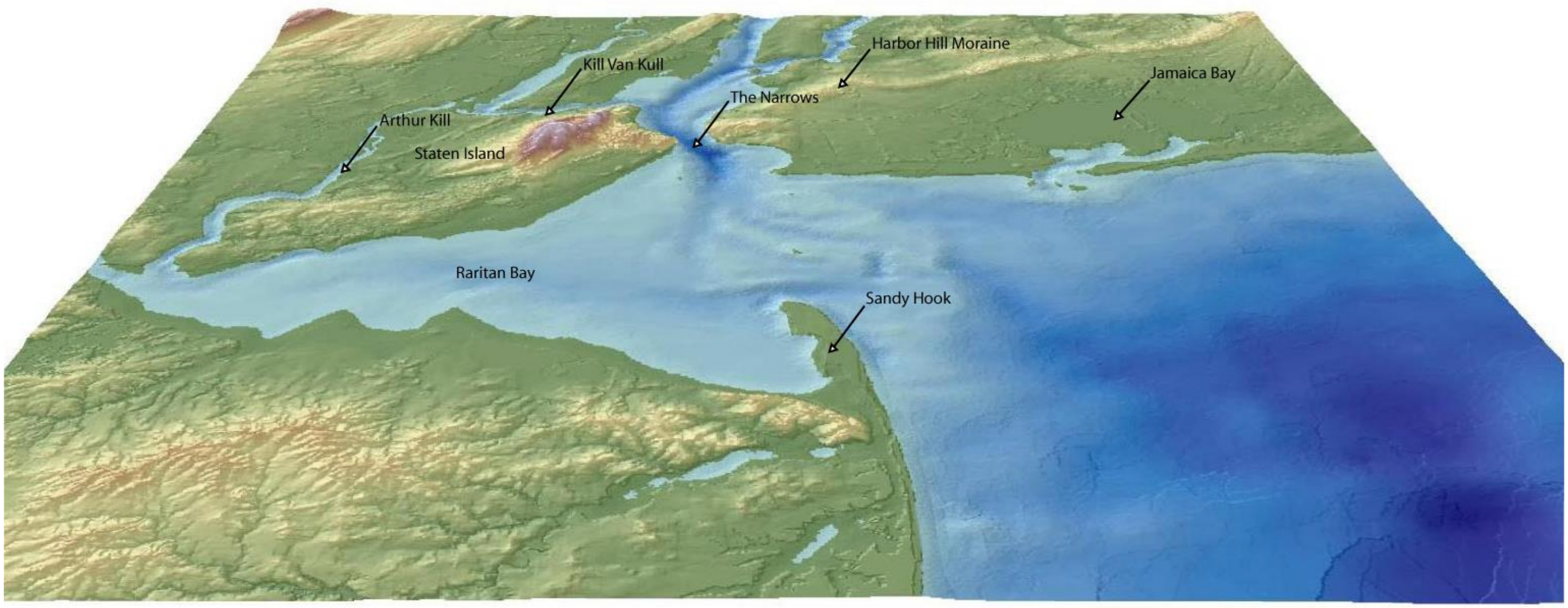

Figure 0.10: Sea level ca. 1,000 cal yrsbp (ca. 1,000 B.P.) at -1.5 m (-5 ft)

Figure 7.11 depicts a return to the historic condition, albeit a la 1844. In the Upper Harbor the Jersey Flats were fully inundated as were the Bay Ridge shoals. Governors Island, Bedloes Island, and Ellis Island all remained above sea level. Paulus Hook stands out prominently in its former pre-filling configuration at Jersey City. Newark Bay was directly connected to the Upper Harbor and Raritan Bay through Arthur Kill and Kill Van Kull. In the Lower Harbor, Raritan Bay, and the Bight, the shoreline and submerged landscape shown by bathymetry were visible in their pre-dredged conditions. Significant, in terms of modern concerns over wetland loss due to sea level rise, is the flooding of Jamaica Bay over the preceding 1,000 years and development of extensive salt marshes.

New York Harbor has witnessed significant changes since 1844. Historic sea level has risen approximately 30 cm (1 ft) since the beginning of the 20th century (**Figure 3.3**) and extensive harbor modifications have been made since the harbor was mapped in detail in 1844. **Figure 7.12** displays those changes with a comparison of the 1844 and 1985 bathymetry.

Relative changes in depth between these two defined periods are shown in shaded colors with reds indicating increasing depth over time and greens reflecting decreasing depth. Lighter shades denote lesser magnitude changes. Thus, dark reds clearly show areas of historic dredging within the Upper Harbor and the Ambrose channel. Subordinate dredged navigation channels are shown in red in Newark Bay, across the entrance of Raritan Bay (the Raritan Bay East Reach and Chapel Hill channel), and at the entrance to Arthur Kill at Perth Amboy. Other dredged channels linked the Navesink and Shrewsbury rivers to Raritan Bay through a back barrier channel at the base of Sandy Hook. Dredged channels defined the periphery of Jamaica Bay where they replaced former salt marshes. Lighter shades of pink outline areas of slight bottom-deepening, probably the result of historic sea level rise. Nonetheless, these areas outline important bottom features. For example, the meandering former channel of the Pleistocene Raritan River (Gaswirth 1999) is seen to have been outlined in pink along the southern shore of Raritan Bay and leading to Sandy Hook, where it drained prior to the deposition of the spit. Similarly, greens show areas of decreasing depth as in the case of shoaling or other deposition. The deep greens shown offshore at the head of the Hudson Shelf Channel represent areas of historic dumping. Green around Breezy Point at the entrance to Rockaway Inlet and Jamaica Bay indicates past shoaling caused by westward longshore transport of sediment along the south shore of Long Island while red indicates maintenance dredging of the Rockaway Inlet channel.

The model developed here is a static one, although coastal sedimentary processes are highly dynamic and capable of distributing sediment in complex ways. A simple, static method was chosen as a starting point for understanding the sea level transgression history for New York Harbor. The data presented in this section succinctly outline the types of coastal environmental changes that can be reconstructed by using an ever-expanding knowledge of relative sea level history.

Figure 7.11: 1844 sea level and shoreline

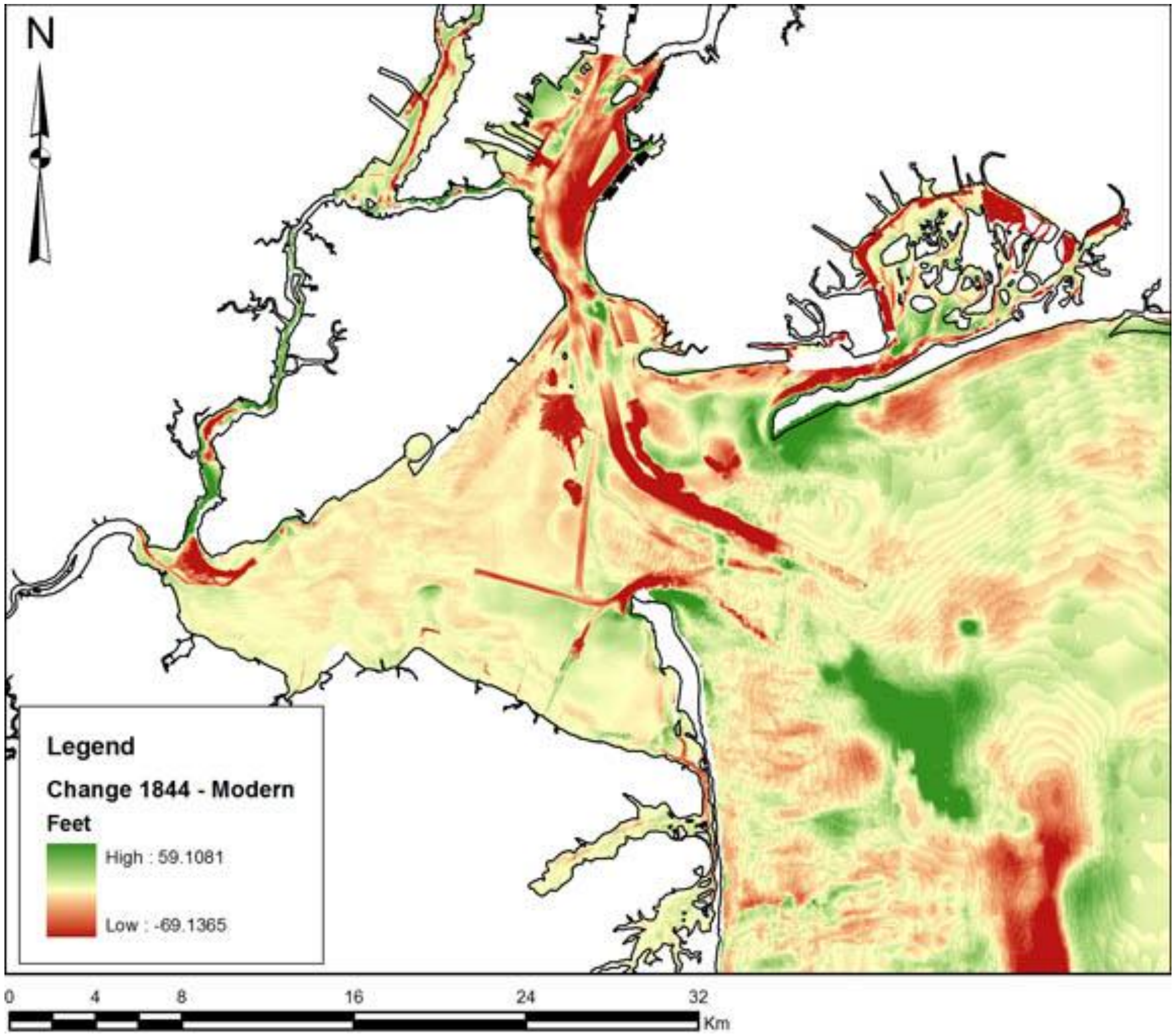

Figure 7.12: Historic bathymetric change 1844-1985. Relative changes in depth between these two defined periods are shown in shaded colors with reds indicating increasing depth over time and greens reflecting decreasing depth. Yellow indicates no change in depth between 1844 and 1985.

Chapter 8
The Archaeological Geography of Human Settlement and Site Preservation

In general, prehistoric deposits are sparsely distributed within both naturally deposited sediments and their weathered counterparts or soil, as large segments of the pristine landscape have been removed and new landforms constructed. As this study shows, even submerged surfaces have been either overridden or exhumed, with reworked materials often capping deeply-scoured substrate. Next, because of the scale of historic activity in the area, surficial materials of the 19th, 20th, and 21st centuries reflect human impacts on the landscape which, over the past 100 to 150 years have affected landform relations almost as greatly as the natural events in the last ten millennia. Accordingly, much of the regional sediment cover, both terrestrial and submerged, reflects the effects of industrial-age and subsequent human activity on the near shore environment. In order to date, interpret, and assess the cultural resource potential of these deposits, it is necessary to understand the chronologies and patterns of occupation in and along the shifting margins of New York Harbor.

Prehistory. There is minimal evidence for prehistoric activity in areas that are currently submerged, although there are limited efforts underway to reconstruct potential site environments on the continental shelf (Merwin 2002). However, data to date are questionable and testing programs are neither extensive nor systematic. There is no significant submerged site database for prehistoric sites in the New York Harbor area.

The earliest accepted occupations of the present New York Harbor area would have begun during the Paleoindian cultural period, ca. 11,500-8,000 years B.P. (13,390-8,890 cal yrsbp). As discussed earlier, relative sea level was at least 15 to 37 m (50 to 120 ft) below present throughout the period (**Figure 2.2**) and the habitable Coastal Plain land surface extended from 7.3 to 18 m (24 to 60 mi) to the edge of the continental shelf (Bloom 1983a: 220-222; Emery and Edwards 1966; Stright 1986: 347-350).

Mammoth and mastodon finds on the continental shelf and within the Hudson River channel (Fisher 1955; Whitmore et al. 1967) indicate that both of these large mammals were sufficiently abundant to have permitted focal hunting adaptations. Nevertheless, recent Paleoindian site excavations in the Northeast suggest a more varied subsistence (Adovasio et al. 1977, 1978; Gardner 1977, 1983; Funk and Steadman 1994; McNett et al. 1985). Exploitation of marine fish and shellfish in settings now submerged beneath the harbor would not be surprising given the broad-spectrum diet of plants, birds, small mammals, and freshwater fish now suggested for Paleoindians in the Northeast.

Early prehistoric occupation begins with a series of sites with diagnostic artifacts from either the Late Paleoindian or Early Archaic (10,000-8,000 B.P. [11,600-8,890 cal yrsbp]) cultural periods. The most unique landscape that preserves (relatively) extensive evidence for these earliest prehistoric periods is the western shore of Staten Island (Kraft 1977a, 1977b; Ritchie and Funk 1971). Intact landforms survive because to date they have largely escaped development. At Port Mobil, fluted points, end and side scrapers, and unifacial stone tools were among over 51 lithic artifacts recovered from a sandy slope between 6 and 12 m (20 and 40 ft) above sea level. Fluted points were also found on Charlestown Beach south of Port Mobil. Projectile points classified as Kirk, Kanawha, LeCroy, and Stanly have been recovered from the Hollowell and Ward's Point sites at the island's southwestern tip of the Island. The Old Place site near the crossing of the Goethals Bridge appears to be primarily a Middle Archaic (8,000 to 6,000 B.P.[8890 to 6900 cal yrsbp]) through Late Archaic (6,000 to 3,000 B.P.[6900-3150 cal yrsbp]) encampment, although a radiocarbon date of 7,260 ± 140 B.P., 8106 cal yrsbp (I-4070) was obtained on hearth charcoal associated with Stanly, LeCroy, and Kirk points.

Early prehistoric sites represent only a very small portion of settlement networks, which extended across Harbor Region surfaces, subsequently by sea level rise. The rate of transgression slowed at approximately 7,000 cal yrsbp (Fairbanks 1989; Peltier 2001; Fleming et al. 1998). This timing accounts for the abundance of Late Archaic sites in settings that are now at or slightly below present shoreline positions. Of five inundated sites along shores or tidal stream banks on Long Island reported by Stright (1990), all are Late Archaic or Woodland period encampments.

The magnitude of landscape change diminished significantly after the Middle Holocene. Between 5000 to 3000 B.P., as this study has confirmed, near-shore environments began to stabilize. Late Archaic hunter-gatherers of coastal New York and New Jersey specialized in the exploitation of shellfish and other marine resources (Brennan 1974; Kraft and Mounier 1982; Ritchie 1980: 165-167). Although Brennan (1977) argued for antecedents extending back to the Early Archaic, his only evidence was the date of 6,950 ± 100 B.P., 7786 cal yrsbp (L-1381) from the deepest level of the Dogan Point shell midden (Little 1995). Dogan Point did have a small Middle Archaic component, as evidenced by both the radiocarbon chronology and presence of Neville, Stark, and other large side-notched projectile points (Claassen 1995a). The main shellfish-gathering period, however, dates from 5,900 to 4,400 B.P. and 6730 to 5070 cal yrsbp (Claassen 1995b: 131), correlating with other shell midden sites in the Lower Hudson such as the Twombly Landing site below the Palisades near Edgewater, New Jersey (Brennan 1968).

Settlement geography and site structure increase in variability from the Late Archaic onward. As noted by Funk (1991:51), shell matrix and shell bearing sites on Martha's Vineyard (Ritchie 1969), Nantucket (Pretola and Little 1988), Fishers Island (Funk and Pfeiffer 1988), and Long Island (Ritchie 1980: 164-178; Stright 1990: 442-443) are all younger than 4,500 years. Older shell middens may once have existed along coastlines that are now beneath the sea. In addition to the more ephemeral hunting camps of the earlier cultural periods, this type of prehistoric culture resource is likely to be preserved in several contexts within the Harbor navigation channels.

The transition between the Archaic and Woodland periods in the Northeast is marked by the presence of ceramics and, in many areas, by the first remains of cultivated plants. The Woodland period is generally divided into three stages, Early (3,000-2,000 B.P. [3145-1982 cal yrsbp]), Middle (2,000-1,000 B.P. [1982-902 cal yrsbp]), and Late (1,000 B.P. to European contact). In coastal New York, however, the Windsor and East River "traditions" were defined by Smith (1950, 1980) as distinct ethnic groups manifested in several contemporaneous phases.

The North Beach phase of the Windsor tradition is contemporaneous with shell-bearing Terminal Archaic sites of the Orient phase. In several sites on Long Island, Windsor ceramics have been found associated with steatite vessels and Orient fishtail points. After the Middle Woodland the Clearview phase of the Windsor tradition is succeeded by the Sebonac phase of the Late Woodland Period. Sebonac sites are most common in Connecticut, although the phase is named for a site on eastern Long Island excavated by Harrington (1924).

Later Windsor tradition sites coincide with the earliest, Bowmans Brook phase of the East River tradition on Staten Island (Smith 1950, 1980). Bowmans Brook begins ca. A.D. 1000 and its geographic range eventually included western Long Island, Manhattan, and the lower Hudson River Valley (Ritchie 1980: 268-270). The type site on the northwestern shore of Staten Island was investigated by Skinner in 1906 (Skinner 1909: 5-9; Smith 1950: 176-177).

Larger features are characteristic of Woodland sites. Pits filled with shell and other refuse ranged from four to six feet in diameter and from three to six feet in depth. The pottery is either stamped or incised and tempered with grit or occasionally shell.

The Late Woodland to Euroamerican transition is registered locally by the Clasons Point phase of the East River tradition (ca. A.D. 1300). The type site on the north side of the East River in the Bronx was excavated by Skinner in 1918 (Skinner 1919: 75-124; Smith 1950: 168-169). The few known village sites are approximately an acre in size and are located on higher landforms well above any tidal submergence (Ritchie 1980: 270-272). The pottery is typically shell-tempered but there is a wide range of both vessel forms and surface decoration. European trade goods have been found in the upper levels of some Clasons Point phase sites.

History of the Harbor and the Navigation Channel Network. Historic maps shed light on the nature of the Harbor transformation over the past four centuries since Euroamerican colonization. **Figure 8.1** illustrates the geography of New York Harbor during the mid-19th century. That shoreline was somewhat, but not substantially different from that encountered by Florentine navigator Giovanni da Verrazano who sailed between the straits that now bear his name in 1524. Locally Verrazano's voyage initiated European exploration that culminated in the colonization of Upper New York Harbor. Trade goods from this period have been found in the upper levels of some Clasons Point phase sites (Ritchie 1980: 270-272) and the native inhabitants are known to have been Algonquin relatives of the Delaware (Homberger 1994: 16). They sold the island they called Manhattan to the Dutch for trinkets in 1626 and moved west of the Bronx River. Dutch settlement was first localized near the tip of Manhattan Island, commanding naval access to both the Hudson River and the East River (Homberger 1994: 20). By 1639 (**Figure 8.2**), Dutch plantations thinly lined the East River and three small villages on Long Island were combined to form Breukelen in 1642 (Homberger 1994: 30). Buildings on the East River waterfront were constructed on an unstable and muddy shoreline until after Peter Stuyvesant became Director-General in 1647 (Homberger 1994: 32); there is considerable potential for early historic as well as prehistoric archaeological contexts beneath the present piers and seawalls (Cantwell and deZerega Wall 2001).

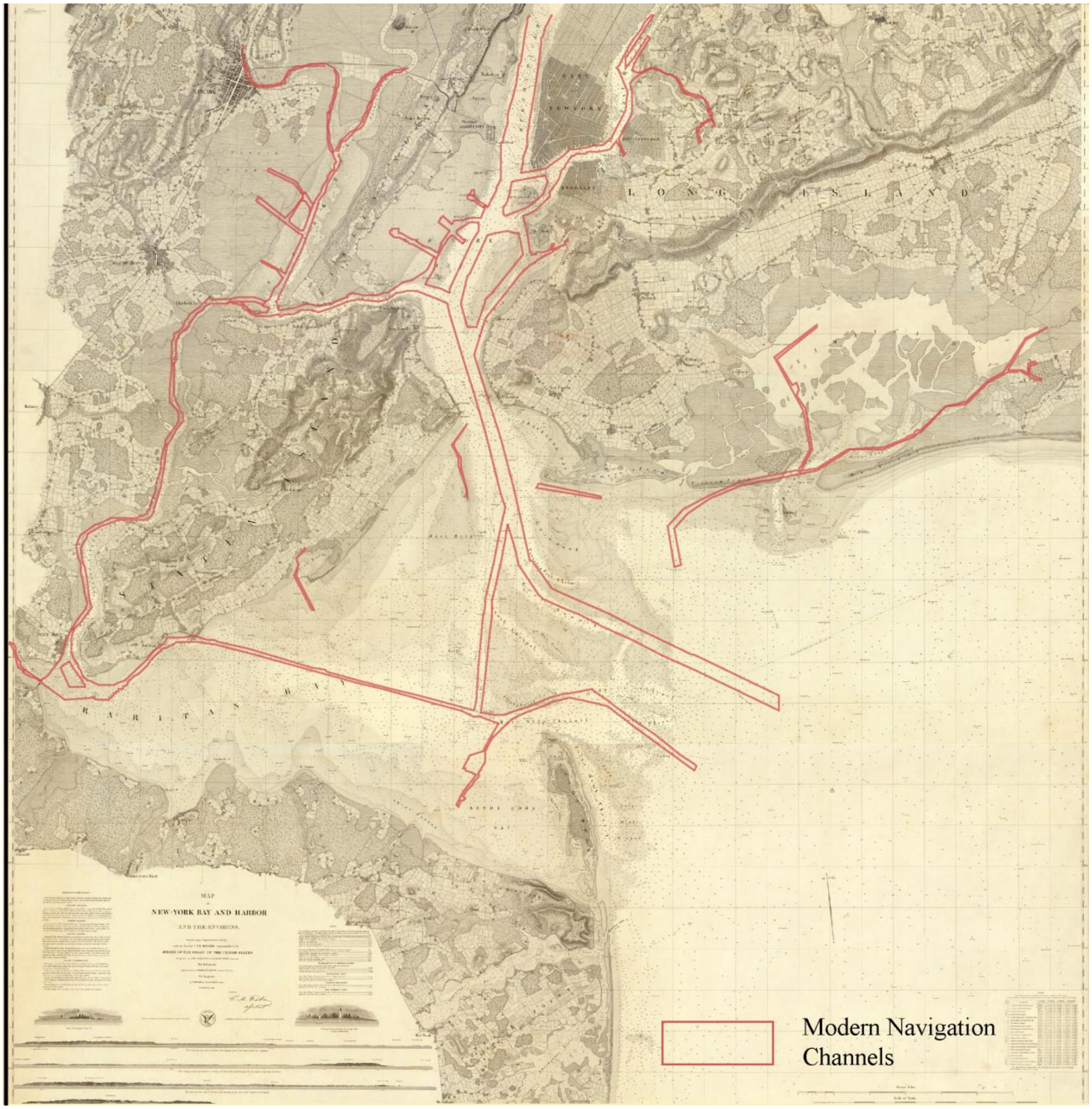

Figure 8.1: Modern dredged navigation channels overlaid on 1844 map of New York Bay and Harbor (US Coast Survey 1844).

Dutch commercial activity and settlement of the Upper Bay expanded steadily because of the virtually land-locked harborage, well protected from ocean gales, that was afforded by the Narrows between Brooklyn and Staten Island. At its most constricted point, this passage is less than three-quarters of a mile wide, where it is presently spanned by the Verrazano- Narrows Bridge (Water Resources Support Center, 1988). Historically, this constriction does not appear to have changed significantly **(Figure 8.2)**. The natural geography of the New York and New Jersey Harbor region nonetheless posed certain challenges for early maritime commerce. Unlike the naturally deep harbors of Boston, Quebec and Norfolk, which could accommodate any vessel afloat during the eighteenth and early nineteenth centuries, the lower portion of New York Harbor had a controlling depth of 21 ft at low tide and the upper bay contained numerous areas of shoals and treacherous currents. Prior to the first dredging of the harbor, larger vessels could approach New York only through the Main Ship Channel, which required navigation of a narrow passage between Sandy Hook and a series of shoals that blocked most of the Lower Bay (Albion, 1939; Newberry, 1978). Smaller vessels could utilize the Swash, "Fourteen Feet," or East (later known as Ambrose, see below) channels. Only isolated channels in Upper Bay (Buttermilk Channel) were considerably more hospitable for commerce. In 1837, Lieutenant R. T. Gedney conducted a Coast Survey study that charted an outer alternative channel that still bears his name.

Public funding for harbor improvement was initiated with a New York City municipal appropriation of $13,861 in 1851. The effort was designed to remove rocks and reefs in the Hells Gate entrance to the East River. This effort was supplemented two years later by a federal appropriation of $20,000 (Albion 1939:28). However, most efforts at Harbor improvement during this period were privately funded and poorly coordinated. The dredging of underwater property was under the jurisdiction of the New York City Street Commissioner and the unregulated construction of piers and wharfs was found to be a hindrance to the economic potential of the harbor (Homans 1859; New York State Harbor Encroachment Commission 1864). In 1870, the city and state legislature established the New York City Department of Docks, appointing General George McClellan of Civil War fame to serve as engineer-in-chief. Since all of the new wharfs and piers would ultimately be owned by the municipality, the Department of Docks represents the first sustained attempt at municipal ownership and administration of port facilities in the United States. In1921 this agency was renamed the Division of Surveys and Dredging. McClellan's first task was to invite public proposals and comment with a view of developing a Master Plan for piers, wharfs, and seawalls around the island of Manhattan. The subsequent processes of seawall construction and landfill reconfigured the geography of Manhattan Island to its present shape. It is now thirty percent larger than the landform initially encountered by the first Dutch settlers.

McClellan’s plan called for the excavation of some six hundred soil borings around the entire perimeter of Manhattan. As described in the 1871 Annual Report, these borings were performed by various techniques, including: hand rod, Woodcock, and artesian well boring machine (Betts 1997; New York City Department of Docks 1872). At least some of the logs from these borings are apparently still held in the New York City Municipal Archives.

Figure 8.2: Dutch settlement on the Hudson in 1639 (Vingboons 1639)

Ultimately Harbor maintenance and enhancement was bolstered by federal assistance. Municipal and federal efforts worked in conjunction with each other. In 1872 Congress commissioned a survey of Buttermilk Channel, the narrow passage between Governors Island and the city of Brooklyn (**Figure 8.3**). The survey located a large shoal with a minimum depth of 9.5 ft at the junction with the East River. This shoal was in the track of navigation, making it unsafe to maneuver large vessels in the vicinity of the Brooklyn wharves. The proposed dredging was conducted from October1 through November 3, 1884 (U.S. Bureau of Engineers, 1885). The shoal was removed to a depth of 24 to 26 ft below mean low water in a zone extending 850 ft from the wharves. The estimated cost of this work was $210,000. By 1976 Buttermilk Channel had been enlarged to a width of 1,000 ft and a depth of 34 to 40 ft below mean low water (Hammon 1976).

Figure 8.3: Governors Island and the Buttermilk Channel (US Coastal Survey 1844).

On July 5, 1884 a congressional appropriation of $200,000 facilitated a survey for deepening Gedney's Channel, marking the first attempt to improve a navigation channel in the Lower Bay (Edwards 1893; U.S. Engineer Bureau 1886). That project was the first large-scale dredging project in New York Harbor, and formed the basis for subsequent channel maintenance programs in support of commercial boat traffic. Perhaps the key long term component of the appropriation was funding of a detailed survey of the Lower New York Bay. Detailed investigations included current and tide records, borings to a depth of three feet below bottom, and detailed bathymetric maps showing the location of the 7.3 m (24 ft) contour in 1835, 1855, 1881, and 1884. Despite dramatic changes in the configuration and location of several landforms, for example the Sandy Hook peninsula, the bottom profile had changed very little between 1835 and1884. The survey also found that in 1884 the minimum depth in Gedney's Channel at mean low tide was 6.83 m (22.3 ft). The mean high tide rose to 1.5 m (4.8 ft), giving a controlling depth at high tide of 8.26 m (27.1 ft). The report noted that the largest steamships running out of New York drew 8.5 m (28 ft) when fully loaded, but few vessels were loaded to capacity. The 1886 Engineers Report also discussed options for creating a safe navigable channel along or near Spuyten Duyvil Creek between Manhattan and the Bronx. This project would not come to fruition until the completion of the Harlem River Ship Canal in 1923.

The Gedney's Channel dredging contract was awarded to Elijah Brainard at a cost of 54 cents per cubic yard. The program commenced on September 26th, 1885, and by the beginning of November, 1886 303,869 cubic yards had been dredged from the channel (Edwards 1893). On the basis of the Engineer's Report (U.S. Engineer Bureau 1886: 737-739) it is possible to reconstruct the stratigraphic sequence encountered during the dredging. The dredging first encountered a bed of live mussels ranging from six to ten inches thick. Some of the mussels were quite large and large quantities of dead shells and a very fine powder of pulverized mussel shells was also encountered. The mussel layer was underlain by a stratum of "pea gravel" to which the mussels often adhered. Beneath the upper stratum of pea gravel the dredging encountered interbedded layers of fine sand and water-worn quartz gravel. The gravel ranged in size from "the size of a pea to the size of a goose egg." About 70% of the gravel was classified as "pea gravel." The dredging also encountered a few large pieces of water-worn sandstone, the largest of which measured 330 mm by 200 mm by 127 mm (13 in by 8 in by 5 in). Finally, at the western end of the channel the dredging encountered a stratum of very compact "blue clay" at 10 to 11 m (33 to 35 ft) beneath mean low water. The report notes that this clay is "evidently a very old formation." By 1889 the dredging program had resulted in an unobstructed navigable channel with a 9-m (30- ft) controlling depth at mean low water and a depth of 10.6 m (34.8 ft) at high tide.

Increased harbor traffic coupled with the large size of vessels that utilized the Harbor resulted in additional harbor development. On June 3, 1896 Congress authorized a survey with a view to providing a 11-m (35-ft) channel at mean low water from the Narrows to the sea. It was recommended that the East Channel be dredged to maintain a channel of 12-m (40-ft) depth and

600-m (2,000-ft) width. The funds were appropriated by the River and Harbor act of 1899. The East Channel was renamed by an Act of Congress in 1900 to "Ambrose Channel," in honor of Mr. John Wolf Ambrose, who had worked diligently for the improvement of New York Harbor. The channel continues officially to be known by this name (U.S. Engineer Bureau, 1939). The project was completed in 1914, providing a mean low water controlling depth of 12 m (40 ft) and a width of 600 m (2,000 ft). A total of approximately 60,350,400 cubic meters (66,000,000 cubic yards) of material was removed under the project.

The Federal Rivers and Harbors Act gave the U.S. Engineers Bureau (now the U.S. Army Corps of Engineers) control over all navigable waters in the United States in 1888. The Bureau was given the order to establish bulkhead and pierhead lines. With the 1898 consolidation of Greater New York under a single municipal government, the Department of Docks also became responsible for city-owned ferries and ferry terminals and was renamed the Department of Docks and Ferries (Betts 1997; Hoag 1911). Meanwhile, the development of the New Jersey portion of the harbor lagged, in part because of the lack of a comprehensive, cooperative approach to waterfront use. A 1914 report by the New Jersey Harbor Commission, entitled "New Jersey's Relation to the Port of New York" noted that New York City's waterfront development had cost more than one-hundred million dollars and that waterfront development produced annual revenue in excess of four and one-half million dollars. The report recommended creation of a permanent New Jersey Harbor Commission with statutory authority to regulate all waterfront development in the state.

Following World War I, it was becoming increasingly apparent that the long-standing New York-New Jersey animosity was hindering unified development of New York Harbor. In 1921 the Port of New York Authority was created as the first interstate agency permitting compacts between states. It assumed responsibility for Harbor maintenance since the port included portions of New Jersey and New York. In 1972 the name of the agency was changed to the Port Authority of New York and New Jersey (Port of New York Authority 1946; Port Authority of New York and New Jersey 1996).

As dredging of the recently renamed Ambrose Channel was nearing completion, the River and Harbor Act of March 4, 1913, authorized a survey for a channel 12 m (40 ft) deep and 600 m (2,000 ft) wide as an extension of Ambrose Channel through Upper Bay. The funds for the dredging were appropriated by the Act of August 8, 1917. Commonly known as the Anchorage Channel, this project was completed in 1929. A similar large-scale project was initiated in the Stapleton vicinity, located above the Narrows on the northeast shore of Staten Island. This area offered a substantially undeveloped stretch of waterfront approximately1,900 m (6,300 ft) in length (U.S. Engineer Bureau 1939). Piers over 300 m (1,000 ft) long could be constructed in this area, where the natural water depth at the pier head line exceeded 12 m (40 ft). By 1939, most of the navigation channels had already been covered by maintenance programs. Only the Port Elizabeth, Port Newark, and Port Jersey areas remained relatively undeveloped.

The most recent maintenance efforts have included the removal of drift and debris from shorelines of the entire New York Harbor (Hammon 1976; U.S. Army Corps of Engineers 1971). The New York Harbor Collection and Removal of Drift Project ultimately timber and steel vessels, 100 dilapidated piers, wharves, and miscellaneous shore structures, and 23.6 million cubic feet of timber drift and debris (Hammon 1976: 32). One of the highest concentrations of derelict vessels was located in the Port Jersey Channel. The drift removal project was initiated in 1976, in conjunction with development of Liberty State Park in Jersey City.

The sequence of historic modifications to New York Harbor's shoreline and bathymetry is shown in **Figure 8.4.** These projections were generated from historic maps that were assembled, digitized, and analyzed using georeferenced GIS data sets. The 1844 shoreline **(Figure 8.5)** has been superposed on the existing coastal contours of the Upper Bay. The projection shows that the harbor and near shore margins effectively conformed to the boundaries of the natural landscape. Following the mid-nineteenth century, as barge and boat traffic increased shipping facilities were built up and filling activities resulted in coastal modifications extended the once natural landforms bay ward, especially in Brooklyn and Manhattan. The most significant expansions to the shipping facilities were engineered along the former isthmus between the Lower Hackensack/Newark Bay and Hudson Rivers. This is the landform bounded by the Arthur Kill Channel, Newark Bay, and Elizabeth channels to the west; the Kill Van Kull to the south; and most dramatically by the Port Jersey and Claremont Channels to the east. The east-west reach of the peninsula was nearly doubled by landfill attendant to commercial and port expansion.

Figure 8.5 shows the steep flanks of the incised Hudson River channel. The difference between the early and contemporary bathymetry of the harbor is a function of accelerated rates of infilling initiated by near shore sedimentation due to consistent dredging and channel widening. **Figure 7.12** underscores the changes to bathymetry for the Upper and Lower Bay since 1844. This GIS-based plot establishes a framework for examining the depth of dredging along the channels over the past 150 years. The contemporary plot verifies the long-term maintenance of the Ambrose channel, the main transport artery into the metropolitan area. Accordingly, the deepest portions of this channel extend from -7.3 to 9.8 m (–24 to –32 ft). Most navigation channels are at least -3 to -4 m (–10 to –13 ft) in depth. **Figure 7.12** shows that, on average, over the past 150 years Ambrose channel has undergone a net deepening of 2 to 4 m (5 to 12 ft), largely in the southeastern approach to New York City and along the key traffic lines north of the Narrows and into the approach to Manhattan. Deepening in the latter area is not confined to present channels but to surrounding portions of the bay floor as well. In general, the result of long term channel maintenance across the New York Harbor has resulted in lowering of the bay floor by an average of 0.9 to 1.12 m (3 to 4 ft).

The bathymetry of the Lower Bay was not greatly modified during the mid-20th century. **Figure 8.4** shows that the Ambrose channel was substantially widened to the east and significantly deepened in its north end. However, across the greater reach of Raritan Bay floor depths remained intact at 1.5 to 4 m (5 to 13 ft). It is critical to note, however, that sustained and scheduled dredging activities, especially over the past 50 years were directed at maintenance (and not necessarily deepening and widening) of channels for navigation purposes. Thus, the GIS maps do not offer indications of the frequency of dredging but provide a time transgressive picture of net changes to the morphology of the bay floor. Records suggest that stringent monitoring of patterns and frequency of sedimentation dictate the schedule of dredging based on volume and congestion of vessel traffic. Weights of vessels also impact dredging timetables and procedures.

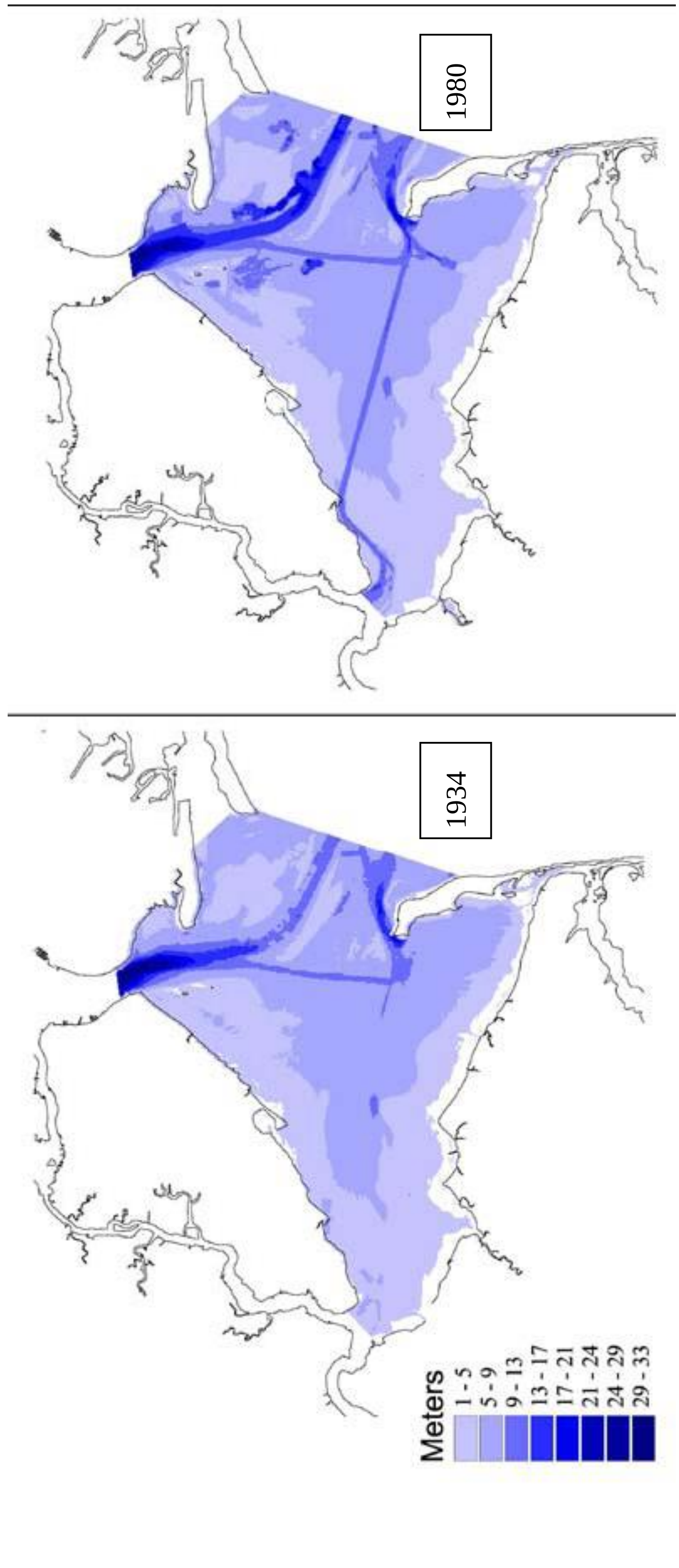

Figure 8.4: Historic dredging 1934 to 1980.

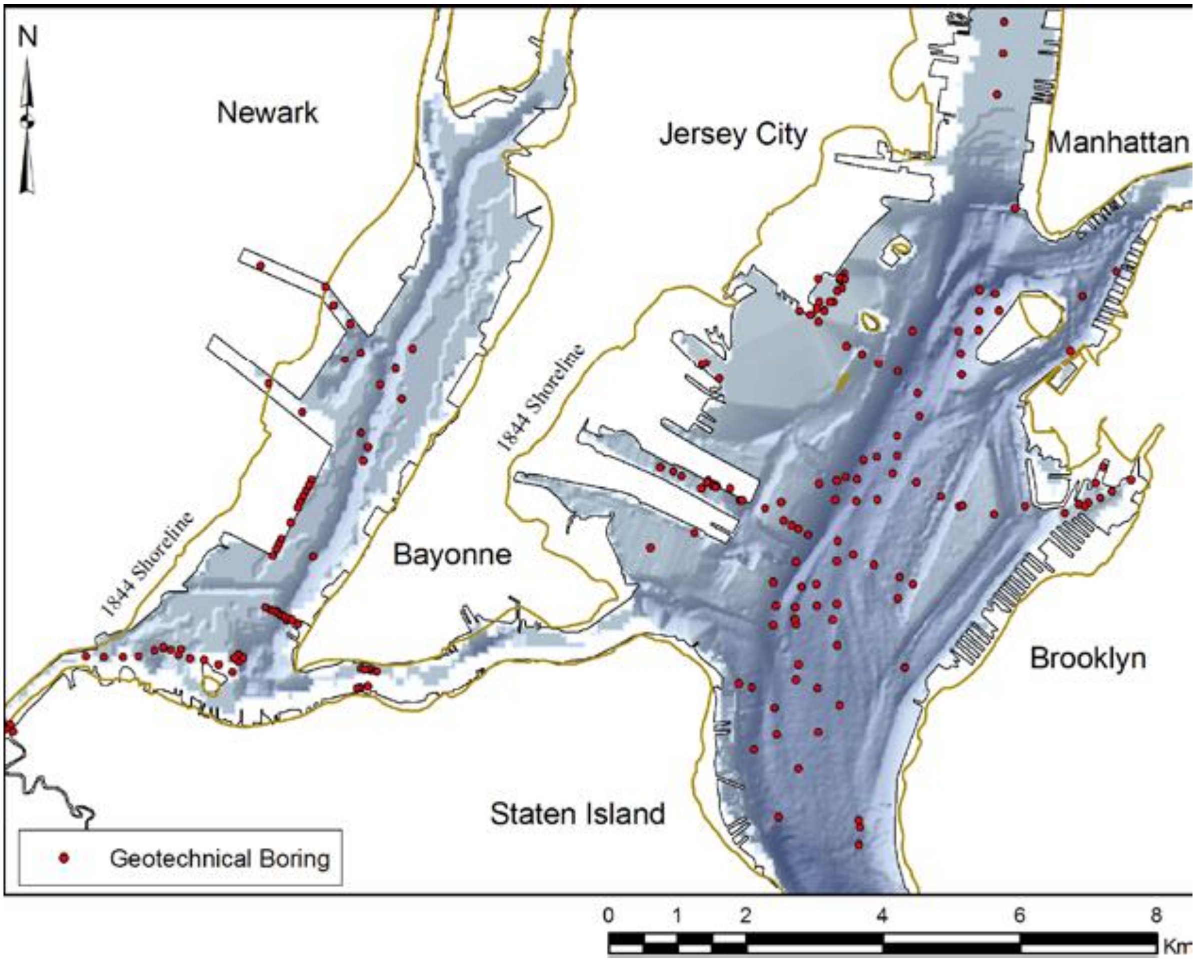

Figure 8.5: Shoreline change in the Upper Harbor since 1844.

GRA’s initial studies (GRA 2000a, 2000b, 2001, 2006) proposed that most of the active navigation channels have been dredged below the elevation of any terrestrial surfaces younger than 7,000 B.P. Many were presumed to preserve no Holocene surfaces whatsoever. It is not necessarily the case that all sediments beneath the channel floors are Pleistocene or older, however, since thick estuarine packages of Holocene age have been reported throughout the harbor (Carmichael, 1980; Heusser, 1949; LaPorta et al., 1999; Lovegreen, 1974; Newman et al., 1969; Weiss, 1967, 1974; Wagner and Siegel, 1997). In some cases the contexts of Holocene packages, even when dated, may represent secondary displacements of thick and possibly even contaminated organic or hydrocarbon-enriched sediment packages (GRA 2001).

GRA’s long term research suggests that archaeological compliance and management planning must be mindful of dredging schedules and strategies. The present research in particular demonstrates that systemic mobilization of sediments in shoreline environments is an essential component in the evaluation of their archaeological potential. These issues are as critical as geomorphological and paleoenvironmental data. This research has demonstrated that ancient and contemporary sedimentation processes allow for the refinement and expansion of the baseline model for archaeological sensitivity. It is hoped that this model for archaeological sensitivity in the historically dynamic submerged environments of New York Harbor will serve as a guide to planners concerned with mitigating impacts on cultural resources discussed in the following sections.

Chapter 9
Assessing the Potential for Preserved Prehistoric Sites

Previous Work

The pilot study that preceded this report (Schuldenrein et al. 2006) focused on the development of an archaeological sensitivity model for Upper New York Harbor. It developed a methodology for defining zones of **High**, **Moderate**, and **Low** Potential on a channel-by-channel basis. Site potential was determined from information provided from cores taken as a part of that and previous GRA studies as well as other cultural resource investigations and study of samples from geotechnical borings curated at the USACE-NYD storage facilities at Caven Point, NJ. Potential was evaluated using the criteria presented in **Chapter 2**. Most significantly, however, the initial model was based on a sampling of only those channel segments that were scheduled for immediate mitigation. Accordingly, it was not possible to consider the entire New York Bight as a macro-landscape from which the systematics of archaeological geography and site preservation could be generated.

Those individual channel evaluations showing zones of site potential are presented again in this chapter as part of a synthesis of potential for the entire Harbor Navigation Project study area. With the exception of two channels -- the Ambrose Channel and Port Jersey -- the criteria for assignment of potential as presented in that report were expanded. On the basis of more recent investigations, the Ambrose Channel was downgraded to Low potential and the entire Port Jersey area to Moderate potential. The present study looks in detail at the Lower Harbor. This area was broken into zones: Raritan Bay including Arthur Kill; Long Island and the Narrows including the Ambrose Channel; the inner Bight; and Jamaica Bay. Jamaica Bay was included as it is an area significant to broader USACE-NYD concerns as well as pivotal to the development of a sea level model which is prerequisite to understanding the structure of the submerged landscape and its archaeological potential. The generalized impact of relative sea level rise on the study area is evident from the graphics included in **Chapter 8**. Although reworking of the landscape has taken place during inundation of the area and by wave and tidal current action, it is clear that major portions of the former land surface has been preserved, albeit under a veneer of later sediment.

Raritan Bay and the Arthur Kill Channel

Figure 9.1 is a detailed digital bathymetric model of the Lower Harbor bounded by Great Kills on the north, Sandy Hook and Long Island on the east, and the mouth of Arthur Kill on the west. Apart from the obvious dredged navigation channels, traces of three prominent landscape features are visible on the floor of the bay. First and foremost, prominent traces of meanders are visible offshore Union Beach and Keansburg, New Jersey in positions consistent with the pattern shown by Gaswirth (1999) for the former Pleistocene Raritan River outwash channel.

A sinuous channel abuts the south shore of the bay and apparently exits the bay under Sandy Hook through a channel identified offshore in seismic profiles by Williams and Duane (1974). The approximate course of this former Raritan River channel is shown in **Figure 9.1**. Also identified by Gaswirth (1999) and discernible here is the course of the former trench of the Pleistocene Arthur Kill that carried overflow from proglacial lakes retained behind the Harbor Hill moraine. While not the “mud” filled channel proposed by McClintock and Richards in 1936 (**Figure 2.1**), the former Arthur Kill channel appears to be close to shore at Seguine Point and beneath the dredged West Reach navigation channel. This channel is shown joining the former Raritan River channel in a mid-bay position as suggested by Gaswirth (1999).

Both of these drainage trenches are filled by 10 to 15 ft (3 to 4.5 m (10 to 15 ft) of later sediment which also appears to cover the red brown Pleistocene sands and gravels over much of the bay. This study only penetrated the Raritan River channel in one location, B3, on the Keansburg transect where the Cretaceous surface has been cut to a deeper level than the adjacent core B4. The channel is filled by gray fine to medium sand at core B3. The sea level inundation model indicates that the floor of Raritan Bay did not begin to become inundated until about 5,000 years ago and did not reach its near modern shoreline position until 2,000 years ago. This has critical archaeological implications. The submerged landscape was exposed for Woodland through Paleoindian occupations. Given the presence of PaleoindianPaleoindian and Early Archaic archaeological sites on Staten Island along the Arthur Kill, it is highly likely that the former Pleistocene-age drainage lines were cut across terrestrial terrain and carried water from the uplands at this time. It is also possible that these early sites represented camps frequented by hunters following game along the former Pleistocene drainage channels. That said, none of the cores yielded evidence of clearly identifiable floodplain sediments or soils associated with these channels. These channels were apparently not inundated until quite late. It is not known when or how they were filled, whether by subsequent fluvial sediment or by reworked marine deposits during the transgression. At some time drainage shifted to the central part of the present Raritan Bay as shown in the sea level models in the preceding chapter. Whether this was forced by progressive progradation of Sandy Hook to the north or some other mechanism is unclear Despite the fact that this feature is so prominent and it cannot be overlooked, it was apparently subject to considerable sedimentation and ongoing erosional and depositional cycles. It should be assigned a **Low** potential for submerged Late Archaic through PaleoindianPaleoindian sites.

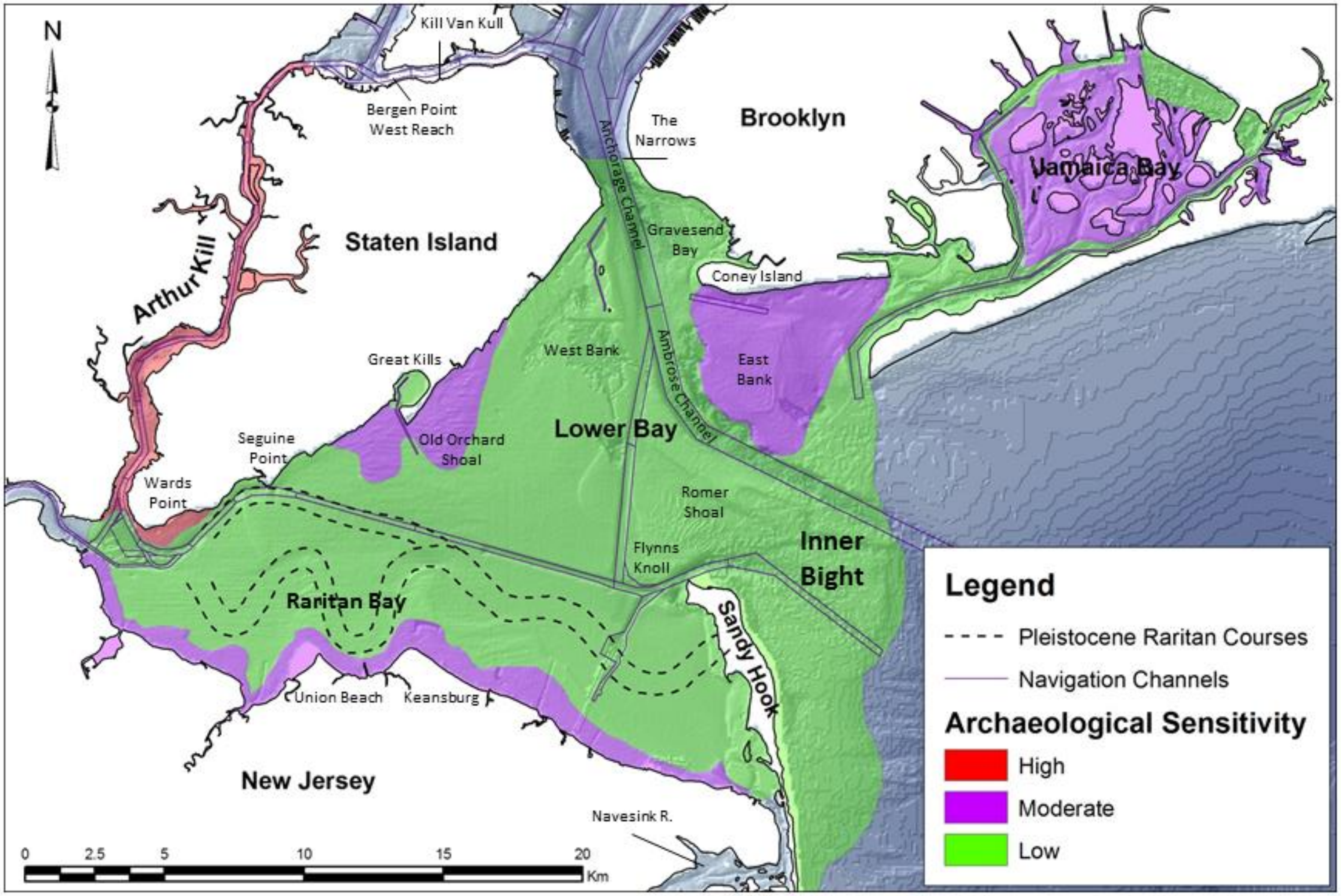

Figure 9.1: Composite map of archeological potential superimposed on bathymetry of the Lower Harbor and Inner Bight.

Figure 5.9 shows a cross section of Raritan Bay at Keansburg, New Jersey. This section shows that sediments bearing marine shells represent only a thin 1.5-m (5-ft) veneer overlying the Pleistocene fluvial sediments beneath the bay. Perhaps significantly there were no marine shells identified in core B-3 from the suggested fill of the buried Raritan outwash channel. Of note, however is the suggested presence of identifiable -6.0 and -4.5 m (-20 and -15 ft) terrace features along the later talweg of the submerged Raritan River. These features are dated relatively to 4,000 and 3,000 years ago respectively, and correspond with the final portion of the Late Archaic period. Significantly, this period also corresponds with the documented demise of oyster colonization (Carbotte et al., 2004) further upstream. The oyster demise may be related to "stillstands" or lower sea level at periods up river that altered the salinities necessary for oyster growth. It is not clear whether these same conditions would have applied to the mouth of the estuary immediately adjacent marine water. Yet, this area, as well as that flanking the banks of this former narrow estuary of the Raritan River, must be considered as having a **Moderate** potential for submerged sites.

As a caveat, however, this zone lies at a depth greater than the currently dredged operational depth of the West Reach Channel to be 11 m (35 ft) below mean lower low water (MLLW). Therefore, it should pose no problems unless deeper navigation channels are required in the future.

The north shore of Raritan Bay presents a somewhat different scenario. Identifiable offshore Great Kills are shoals referred to as Old Orchard Shoal, on NOAA chart 12327. The south shore of Staten Island is the high wave energy shore of the bay. This is indicated by groin fields showing westward longshore sediment transport giving rise to a former spit across the mouth of Great Kills, now marked by a structurally protected spit forming the entrance to Great Kills harbor. Close examination of the navigation charts coupled with the landform expression on the above chart suggests that the area offshore Staten Island to a depth of -4.6 m (-15 ft) may represent a drowned barrier island analogous to those along the shore of Long Island that terminated at the Old Orchard Shoal. As a result, this portion of the shore of the bay has been deemed to have a **Moderate** potential for submerged sites. This area is also sensitive for shellfish harvesting suggesting that it may have also been a popular prehistoric shellfish harvesting area during the Woodland period. Similarly, the importance of shellfish harvesting may preclude the sediments on this side of the bay being disturbed for other purposes. Also important *vis a vis* the Staten Island shoreline is the known presence of Early Archaic and Paleoindian sites in the vicinity of Wards Point at the mouth of Arthur Kill. This same location was noted in LaPorta et al. (1999) as having a submerged peat bed beneath the dredged channel dated at 7950 ± 70 B.P. (8,803 cal yrsbp) which places it in the Early to Middle Archaic range.

The early sites in this vicinity likely indicate use of freshwater marshes at the mouth of Arthur Kill as a subsistence resource. As a result, this general area has been assigned a **High** potential for submerged site presence and preservation. This is and has been an important area for maintenance of a navigation channel subject to further dredging. Given the richness of wetlands and salt marshes as a habitat for waterfowl and as a spawning area for various marine species, the Arthur Kill becomes an area of prime importance for deeply buried or submerged cultural resources. The great expanses of marshes that once covered the northwestern shore of Staten Island and nearby New Jersey in association with the number of early archaeological sites in the area attest to the importance of wetlands as a human subsistence resource. Peteet et al. (2007) report a basal peat date of 11,100 B.P. for a Staten Island freshwater marsh. This early date places added importance on the Arthur Kill area. As result, Arthur Kill and its fringing marshes is considered to have high archaeological potential along the full length of its channel.

Traditionally, stream mouths, or the confluence of streams, have been important loci for Native American settlement in historic times and in evidence prehistorically. In Raritan Bay, stream mouth areas are most prevalent along the south shore of the bay where they are often associated with salt marshes. The south shore accordingly should be highlighted as an area of interest for the preservation of submerged sites. This shore is a low wave energy area conducive to site preservation. The nearshore portion of the south shore of the bay has been assigned to the category of Moderate potential.

In overview, the site preservation potential for Raritan Bay is dictated by the extent of sediment reworking in the core section of the Lower Bay. Much of the sediment displacement is a function of dredge activity, per examination of the historic bathymetric data. Preliminary indications are that even prior to historic dredging wave-action and resulting sediment mobilization would have destroyed or buried intact near-shore and terrestrial features at the margins of the transgressive sea (during the Early to Middle Holocene). Accordingly, archaeological sensitivity in that portion of the project area is considered to be **Low**. A **Moderate** potential ranking is assigned to the north shore flanking the Raritan outlet because it may represent an aggrading near-shore landform or relict fluvio-deltaic feature. Sediment-stratigraphy is inconclusive and such settings were preferred by Middle to Late Archaic peoples. **High** preservation in this geographic unit is confined to the outer floodplain (submerged and locally exposed) of the Arthur Kill, which was spared from extensive flooding and (onshore) relandscaping to the present day.

Western Long Island, the Narrows, and Ambrose Channel

For ease of organization, these three areas have been grouped into a single category. The pre-dredging topography described from the1844 navigation chart shows that the channel at the Narrows was originally flanked by a western shoal termed the West Bank and another on the east was described as the East Bank. The East Bank was shown as contiguous with Coney Island and Gravesend Bay. Coney Island was clearly an active barrier island with a back barrier salt marsh much like those farther to the east today. The Ambrose Channel provided a direct deep-water access to the harbor when it was dredged between the East Bank and the West Bank through the former East Channel. To the south of the modern Ambrose Channel lie the Romer Shoal and Flynns Knoll separated by the Swash Channel. In the assessment of the submerged landforms, the various shoals and historic channels across the mouth of the Lower Harbor were considered to be relicts of a previous Hudson River channel network now capped by a veneer of later sediment. As mentioned earlier, the presence of submerged terraces and especially the -15 ft terrace suggest that the surface of these landforms is unlikely to have been disturbed during the last 3,000 years. This terrace can be identified on the surface of each of these shoals as well as the West Bank and East Bank.

The channel at the Narrows lies below the planned depth for navigation and is not considered to present difficulty with respect to cultural resources. It should be added, however, that Charles Dill of Alpine Ocean Seismic Survey, Inc. describes peat deposits from a core approximately 30 ft (9 m) beneath the bottom in the vicinity of the Narrows. Large areas of the West Bank and Gravesend Bay have been dredged for sand and gravel for use in construction projects. Both the West Bank and East Bank were mapped as being underlain by fine to medium-grained sands by (Bokuniewicz and Fray 1976); and this is corroborated by research into core records. In the sea level rise model, the surfaces of shoal areas were not inundated until after 2,000 cal yrsbp and have doubtless undergone sorting and redistribution of surface sediment since that time. The East Bank shoal is contiguous with the mainland at Coney Island and would have been available to prehistoric populations for occupation. The West Bank shoal is also contiguous with Staten Island although it has been substantially destroyed by dredging operations.

On the basis of the sediment studies and sea level rise model, the East Bank is considered to be the only area with archaeological potential, which is assessed to be of **Moderate** likelihood. The Romer Shoal and Flynns Knoll doubtless extended above the water surface as islands in the past. It remains unclear as to whether these were inhabited or not. This study finds that they are of less importance than other sites in Raritan Bay; thus, they are assessed as **Low** potential areas. The dredged Ambrose Channel was classified as Moderate to High potential in an earlier GRA report, on the basis of limited core information. If consideration is limited to the existing dredged channel, recent seismic profiles across the Lower Harbor by Thieler et al. (2007), show the Pleistocene channel of the Hudson east of the Narrows to have incised to a depth of ca. 46 m (150 ft) below present sea level; it was overlain by ca. 15 m (50 ft) of younger sediment. Dredging has already removed the overlying sediment package over much of its length. Thus, the Ambrose channel can be downgraded to **Low** potential. **Figure 9.1** presents a composite map of archaeological potential for the Lower Harbor including Raritan Bay and extends eastward to include Jamaica Bay and the Inner New York Bight.

There is limited potential (**Moderate**) for buried site preservation at the margins of the natural landforms northeast of the (disturbed) Ambrose channel where intact sediments may be preserved along the southwest margin of Brooklyn. Archaeological deposits would appear to date to a period of stabilization during the end of the Middle Holocene, when wave action was minimized and sediment reworking was laterally confined.

Jamaica Bay

Investigations were undertaken in Jamaica Bay to provide potential information on the formation of salt marshes during the ongoing marine transgression. Jamaica Bay falls within purview of the U.S. National Park Service as part of Gateway National Recreation Area. Work was performed under Permit # GATE-2006- SCI-0019. As noted earlier, it was not possible to obtain cores from the actual marsh surface at the Yellow Bar Marsh as anticipated due to water depths. Personal communication with Dorothy Peteet of Lamont-Doherty Earth Observatory, as well as Peteet et al. (2007), supports the sea level rise conclusion that the formation of salt marshes in Jamaica Bay is a very young event. This study concurs with Peteet et al. that the marshes here are less than 1,000 years old and that the current marsh has developed in a preexisting depression on the surface of glacial outwash. The outline of this depression as well as the centripetal drainage network entering it can be plainly seen on the digital elevation models in the chapter on environmental reconstruction using the sea level model. Consequently, Jamaica Bay does not appear to be a classic back barrier salt marsh like that at South Oyster Bay behind the Jones Beach barrier island. Jamaica Bay is a clear anomaly. Other than relatively thin estuarine silt layers covered by fine sand adjacent to the Yellow Bar marsh the five cores taken in this location did not give any indication of submerged land surfaces within 12 m (40 ftft) of present sea level. Marine shell fragments were not recovered lower than (9 m) 30 ft below present sea level although the bedding on the well sorted fine-grained sands below the marsh suggests a littoral history. However, the deepest core was obtained from an active channel deposit.

Pending further investigation, it is hypothesized that the fine-grained sands decrease in thickness towards the edges of the Jamaica Bay depression and its former shoreline now circumscribed by a dredged channel. Archaeologically the pre-sea level rise surface beneath the Jamaica Bay salt marshes would have been available for prehistoric occupation extending from the Woodland back to the Paleoindian periods. On this basis, it is suggested that Jamaica Bay, with the exception of the present dredged channels, that have obviously been reworked historically, be considered to have **Moderate** potential for prehistory beneath the existing marsh. It is recommended that future dredging activities for navigation or marsh restoration consider the presence of deeply buried sites.

Jamaica Bay remains an offset cove, whose exposure to intensive sediment reworking in historic times was variable. The sediment stratigraphy is not conclusive as to whether or not capping deposits represent veneers burying intact estuarine deposits or whether the upper meter of sediment is completely retransported. Intact ecological features persist in the area bolstering the evidence for at least relict Holocene features. Thus an archaeological site preservation potential of **Moderate** can be assigned here.

The Inner New York Bight

The Inner New York Bight as currently referenced comprises the area seaward from Sandy Hook and extending from Long Branch, New Jersey on the south to Jones Inlet on the Long Island shore and east of Jamaica Bay. Various geotechnical borings have been taken along the barrier islands, for the purpose of evaluating offshore sand and gravel resources for beach nourishment and restoration. The locations of core logs examined for this study are shown incompiled maps of boring and core locations (**Figure 5.4, Figure 5.12, Figure 5.17**). Extensive work was done in the vicinity of Sea Bright, New Jersey as well as offshore Jones Beach. Earlier discussion noted the presence of evidence of Pleistocene megafauna on the continental shelf south of the Hudson Shelf channel suggesting the possible presence of Paleoindian hunters in the same area during the low Pleistocene sea level low stand. More pertinent to this study are the shallower waters nearer to the present shoreline. **Figure 7.2** and **Figure 7.3**, for example, show the approximate location of the shoreline at 9,000 and 8,000 cal yrsbp. The exposed landscape offshore the barrier island systems mark the general areas available to both Early and Middle Archaic as well as Paleoindian hunters in the Inner Bight area and at depths consistent with the future navigation channel needs in New York Harbor. It is only after 7,000 cal yrsbp, when the rate of sea level rise slowed, that environmental settings along the coasts began to stabilize so that shellfish colonization and coastal fisheries pattern could become predictable as subsistence resources. This type of resource establishment is exemplified by the dated colonization of oysters in Tappan Zee at about this time.

In terms of the Inner Bight, **Figure 7.5** gives and insight into the former landscape. The shoreline outlines the outer edge of the outwash fan spreading out from the Raritan Bay and the Hudson River valley. The major portion of this fan passes beneath Sandy Hook and extends southward to the Navesink River. Like much of Raritan Bay, this area was progressively inundated so that Late Archaic groups most likely utilized the coastal and marine resources of this narrow portion of the shore. Like Late Archaic groups at Croton Point and Dogan Point as far up the Hudson River at Tappan Zee similar types of subsistence strategies can be expected to have been practiced along the coast. Where this stretch of the shore in a sheltered environment, it would be assessed as having moderate to high potential for submerged sites.

In general these landscapes have been subject to extensive wave action. Accordingly, it is suggested that in situ archaeological evidence has been disturbed or eroded over the past 6,000 years. This portion of the shore is considered to have **Low** archaeological potential. The coastal areas of the Long Island shoreline offshore the present barrier islands do not present areas as extensive as those near Sea Bright, New Jersey. The narrow bands of areas exposed during lower sea level along the Long Island shore are likewise exposed to high wave energy, thus the assessment of **Low** potential is extended to this portion of the Inner Bight as well.

Upper New York Harbor and Newark Bay

Newark Bay. The Newark Bay navigation channel has been studied intensely to determine the geotechnical problems associated with dredging to required future channel depths. These have involved the depth and attitude of the bedrock surface that underlies the channel as well as deeply incised Pleistocene sediment filled channels in the bedrock surface (Beda et al., 2003). This study by necessity looks beyond the confines of the narrow channel and its feeder channels to Port Newark, Port Newark Point, and the Elizabeth Channel. The pre-engineered topography and bathymetry shown in the 1844 charts, stratigraphic study of cores from Kill Van Kull, and the new relative sea level model show that Newark Bay was occupied by the meandering channel of the prehistoric Hackensack River until about 4,000 years ago when it began to be inundated by rising sea level. It can be anticipated that brackish marshes began forming along the edges of the valley edges and spread laterally with rising sea level and expanding in area to fill the present basin. Carmichael (1980) has described the later portion of the present Hackensack marshes and notes changing vegetation and salinity.

Archaeologically, the Hackensack River valley, now covered by the marshes, might have afforded rich subsistence base for Paleoindian through Late Archaic groups that were situated on higher terrain along the valley margins. The expanding fringes of the marshes can be considered to have offered the same resource base to Woodland period groups as well. The main dredged channel has been assigned a Low potential while the marsh peripheries have been assigned a **Moderate** potential. The Port Newark and Elizabeth Channels maintain their Low potentials as previously dredged channels. Port Newark Point is included within the overall **Moderate** potential category given to Newark Bay.

Upper New York Harbor. For the purposes of this discussion of archaeological potential, the Upper Harbor includes contiguous channels and areas. These are the Anchorage Channel, Claremont Channel, Port Jersey, Buttermilk Channel, and Stapelton Channel.

Thirteen cores were examined as part of GRA’s previous investigation to better understand the Anchorage Channel. Critical to that study was a radiocarbon date on organic fragments from weathered fluvial deposits at 20 m (66 ft) below sea level in core 98ANC64, overlain by thick estuarine silt and clay that floors the Hudson in this area. A determination of 9,400 ± 150 (10,690 cal yrsbp) suggested the dated deposits were of a potential Early Archaic affinity and appeared to represent a riverine environment. Other cores from the Anchorage Channel also contained organics from fluvial sands beneath the estuarine fill (98AC80 and 98ANC81) from between 21 and 27 m (70 and 90 ft) below sea level. This was an indication that there was a potential for relatively old prehistoric sites at depth. The depth of the channel at these locations is on the order of 18 m (60 ft) below sea level and below proposed future dredging requirements or plans. The Anchorage Channel was assigned a Low priority on this basis although they should be noted as potentially important future sites for further investigation. The present study adds a context to the Anchorage Channel cores because of the revised sea level model. **Figure 5.16** is a cross section of the Hudson from Port Jersey to the Bay Ridge Flats and across the Anchorage Channel. It is clear from this section that the organic zones at the base of the estuarine silt are continuous with the underlying former land surface composed of crystalline bedrock covered in turn by Pleistocene fluvial gravels. Radiocarbon ages from the silts point to a time of deposition between 3,500 and 3,700 years ago for the upper portions of the Jersey Flats. Anomalously young ages were found on the slope of the Jersey Flats in core JF-6. Across the harbor another anomalously young date on wood fragments, 1,850 ± 40 B.P. (1,806 cal yrsbp) was found in the new core D-1 from the Bay Ridge Flats at a depth of 10 m (33 ft) below sea level. An additional cross section, **Figure 5.13** along the Liberty Island channel, gives a better representation of the depositional history in the harbor. Here a marine transgression on to a former land surface is more clearly defined with estuarine silt overlapping fluvial outwash sands with *in situ* trees. These are dated at 5,650 ± 90 B.P. (6473 cal yrsbp) and 5,000 ± 40 B.P. (5,769 cal yrsbp) and give a reasonable indication for the inundation of the western shore of the harbor. Examination of the bathymetry in the harbor also identifies a black oily mud, in the core C-2, as the product of relatively recent filling of an early dredged channel.

This disturbed edge of the Jersey flats was given a **High** potential in GRA's earlier report, but it is now downgraded it to **Moderate**, in keeping with the remainder of the Jersey Flats. The Jersey Flats including the Claremont and Port Jersey channels are now classified as **Moderate** potential. The depositional history of the Bay Ridge Flats is not yet understood, thus, it has been given a **Moderate** potential. Across the harbor in the vicinity of the Bay Ridge Flats there is evidence for recent dredging along the west side that has removed formerly intact sediment. That area is now included in the expanded **Low** potential area of the Anchorage Channel. Along similar grounds, the Buttermilk Channel retains a **Low** potential classification. The individual study areas of the Upper Harbor are included on a map of composite archaeological potential in **Figure 9.2.** In conjunction with **Figure 9.1**, these maps are designed for use in overall planning for compliance requirements for future specific projects. Most importantly, these maps together with the information furnished in this study provide a needed context to view the complex environmental history of the New York Harbor area.

A synthetic overview of archaeological site potential for the entire study area is presented in the next section. The objectives of that overview are to provide a baseline for developing systemic mitigation strategies for the U.S. Army Corps as their channel maintenance plan for the New York and New Jersey Harbor and Bight.

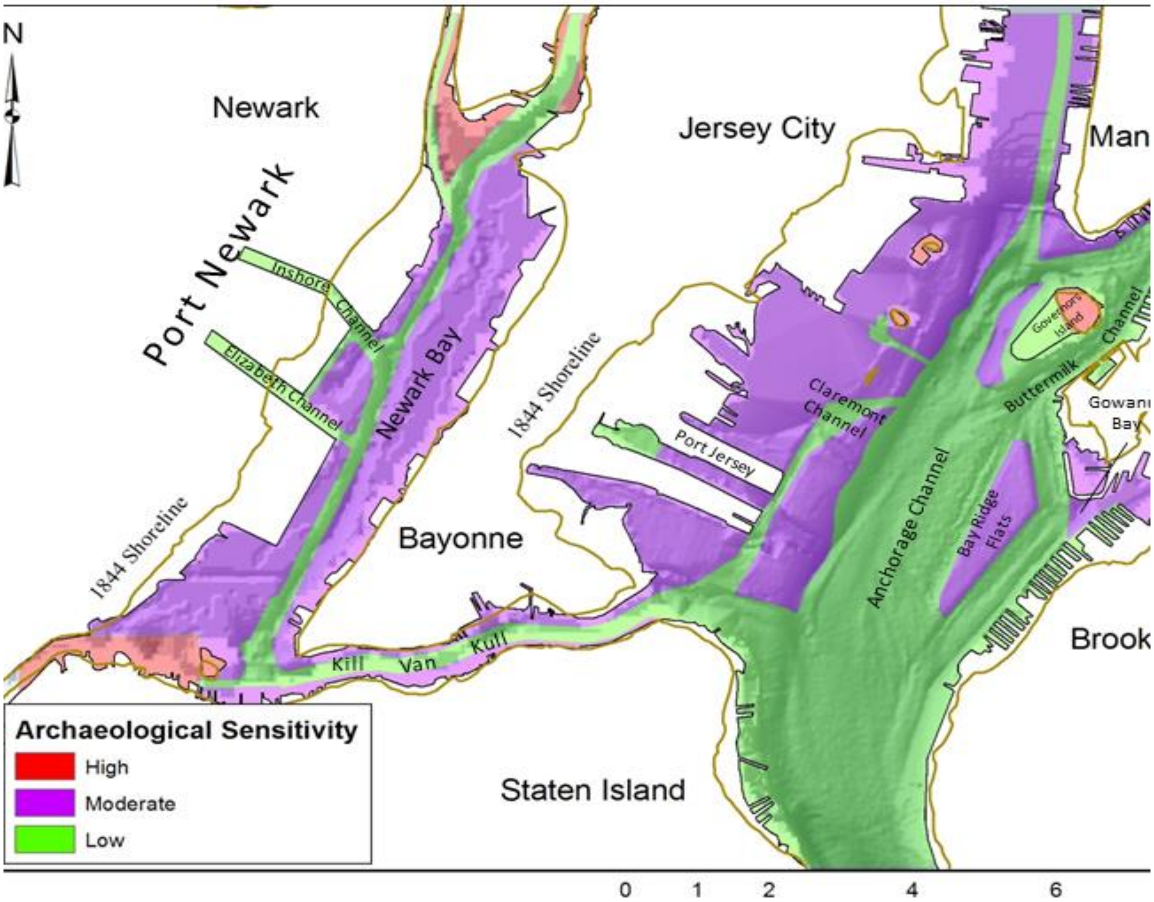

Figure 9.2: Composite map of archaeological potential superimposed on bathymetry of the Upper Harbor and Newark.

Chapter 10
Conclusions and Recommendations

The objective of this project has been the development of a model of submerged paleoenvironments within the Upper and Lower Harbor segments of the New York Bight that bear on the systematics of cultural resource preservation potential. The model is built on previous geoarchaeological research undertaken by the present project team and other researchers. The present need is to synthesize previous work on the submerged landforms, to develop clear associations between buried landscapes and buried prehistoric resources, and to identify gaps in the matrix of landform and archaeological site associations. Identifying these gaps would help to structure a limited field testing program that would produce a comprehensive model of archaeological sensitivity. Such a sensitivity model allows the USACE-NYD to develop specific protocols for cultural resource work in areas of the Bight subject to subsurface impacts to the channel and bay floor.

The present document is ultimately a planning document, or blueprint, for assisting the USACE-NYD and researchers in isolating and delimiting areas that might have been available for settlement during the various periods of the prehistoric and historic past.

The methodology for achieving these goals involved performance of three basic tasks as follows:

1. Reviewing previous geoarchaeological results and performing field work to refine landform and stratigraphic relationships that inform on archaeological resource location and preservation;

2. Integrating the matrix of buried landscape and archaeological relationships in a comprehensive organizational framework using a Geographic Information System (GIS) format;

3. Developing an archaeological probability model that allows for informed assessments of segments of the Bight slated for potentially adverse impacts

The performance of each of these tasks is summarized in turn. It is noted that item 3 constitutes the Recommendations of this study.

Previous Results and Follow up Fieldwork

This report is the culmination of a near decade-long effort in assembling and assimilating data sets from various individual projects which collectively provided clues on the systematics of submerged landscapes and archaeological preservation. The formulation of an overarching model, one that would allow planners and managers to develop archaeological site prediction modules in advance of Harbor-wide improvement projects, was previously untenable. This is because earlier efforts were confined to assessments of specific channels or locations within the Bight. Accordingly, mitigation efforts were not afforded broader landform and site expectation assessments based on a Bight-wide set of geoarchaeological associations. Discussions with the USACE-NYD in 1998 led to a long term mitigation strategy that addressed both the near term requirements of the Section 106 process (i.e. the need for immediate mitigation efforts at Harbor Channels scheduled for adverse impacts) and longer term goals of providing planners with a Bight-wide, model of archaeological sensitivity that could be utilized for future management plans.

Practically, the implementation of that strategy involved the formulation of an inductive model of archaeological sensitivity that was built on identifying the integrity of buried or "drowned" landforms (i.e. terraces, meander belts) and identifying potentially sealed and intact surfaces for the terrain delimited by the impact zone (i.e. Jersey Flats, Shooter's Island). The key to determining integrity was the development and dating of lithostratigraphies for the impact zones. These sequences were assembled through systematic coring, designed and implemented by GRA personnel, and supplemented by available geotechnical boring records. It is noted that these lithostratigraphies, while streamlined for present purposes, remain provisional for the Bight generally, given the variable and uneven stratigraphic frameworks applied by earlier researchers. Bio-stratigraphic records provided an additional database and archaeological sensitivity maps were prepared for each project zone based on databases and the dating of buried organic horizons. While archaeological sites, *sensu stricto*, were never identified, laterally continuous facies for Late Holocene estuarine deposits and occasional alluvial sequences provided a guideline for recognizing "available surfaces for occupation" for given slices of prehistoric time. The application of a consistent investigative methodology geared towards assessing the integrity of Holocene columns and dating stratigraphic breaks allowed expansion of the inductive model and refinement of the stratigraphies across broader reaches of the Harbor.

Five separate studies were undertaken and in 2006, the USACE-NYD issued an SOW to assimilate the results of project-specific investigations and to create archaeological sensitivity modules for 14 reaches and channels of the New York Bight (Schuldenrein 2006: Figure 5.1). These modules were examined synthetically and a series of recommendations were made that facilitated expansion and projection of the sensitivity model across the Bight. That model became the empirical core of the present report.

The research design and methodology underlying this synthesis are straightforward. They emerged from the need to develop a comprehensive model for landscape evolution in the subaqueous terrain, which in turn, provides a reliable measure of prehistoric geography. The individual modules structured in the earlier report were incomplete, driven by an uneven record of subsurface geological data and, perhaps even more significantly, by a sea level model that was both dated and partially obsolete. Accordingly, an unanticipated need for fine-tuning the archaeological sensitivity paradigm involved a complete rebuilding of the sea level curve for the Holocene marine cycles of the New York City area. While the recommended Research Design of the earlier report rightly pointed out the need for collecting additional paleogeographic and environmental data, it was originally thought that these data would "fill in gaps" that would link up the individual modules. In the course of collecting the data, however, the potential for updating the then extant New York area sea level curve became a focus of the data collection effort. Accordingly, the present report has emerged as a more reliable construct for both paleogeographic and archaeological sensitivity.

The data collection effort was concentrated in the Lower Bay and its upstream periphery, areas that were determined to have the greatest potential for preserving intact submerged Quaternary sequences. The cores also sampled the most diverse micro-environments housed in the subaqueous terrains. Limited coring upstream allowed refinement and rethinking of the initial sequences, specifically successions developed in the earlier phases of the New York Bight research. It was then possible to retrofit these observations into what is now emerging as the first comprehensive model of Late Quaternary landscape evolution for this part of the world.

Ongoing sedimentological and bio-stratigraphic studies have allowed, and will continue to allow, researchers to systematically reconstruct the submerged terrain with a degree of detail previously unattainable. This is because 3-dimensional mapping, the use of historic maps and the integration of observations into GIS formats facilitates construction of the buried landscape on a segment by segment basis. While there are still gaps between segments, the framework of the present study is sufficiently comprehensive to identify broad spatio-temporal trends in Late Quaternary landscape evolution.

Integrating the matrix of buried landscapes and archaeological relationships: The GIS model

The new model of archaeological sensitivity is illustrated in **Figure 10.1**. It represents the most accurate depiction of archaeological site sensitivity, based on the comprehensive geoarchaeological and stratigraphic work assembled and synthesized in the present research efforts. **Figure 10.1** has also utilized GIS templates for historic mapping as well as data sets that have been digitally manipulated to filter out shoreline and subaqueous disturbance patterns.

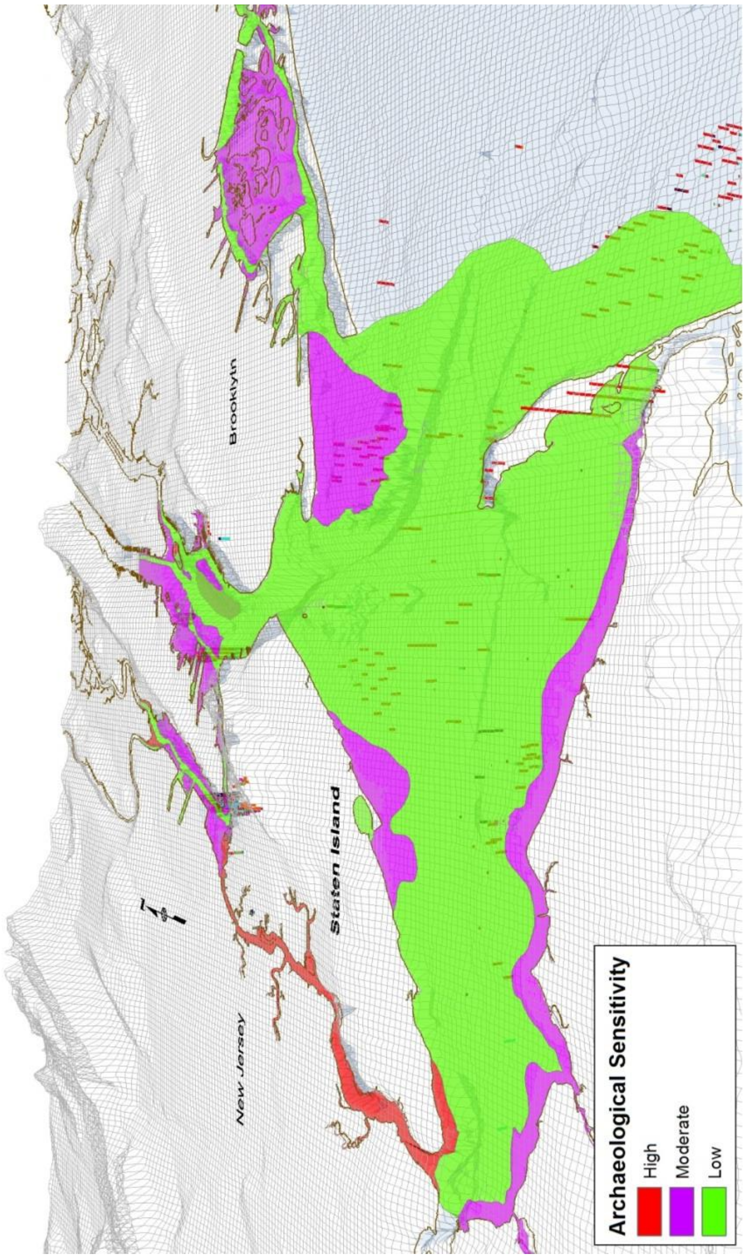

Figure 10.1: 3D view of sensitivity model and borings.

GIS-facilitated multi-layered mapping enables the depiction and interpretation of patterned changes in geomorphology, paleogeographic groupings, and archaeological site distributions. The GIS model was initially structured from terrain elevation models that charted near-shore and subaqueous elevations and incorporated recently mapped surface geology data. Previously assembled information sets were combined with those obtained from the new field work to generate baseline sedimentological and stratigraphic associations. Digitized versions of the data modules were then produced. A total of 25 image sets depict the composite interpretations of the data in this platform.

More specifically, the original proposal for this study targeted the generation of seven (7) specific GIS based products (see Schuldenrein et al., 2006).

(1) *Historic terrain and bathymetric plots*. 1844 bathymetric plots of the New York Bight were presented as a baseline for documenting subaqueous contours. It was proposed that additional time-based projections be developed. Such projections were successfully generated.

(2) *Shoreline models for prehistoric and historic terrain*. Sea level curves were constructed that track shoreline contours and migrations by millennial intervals. These track changing configurations of terrestrial (stream lines), estuarine, marsh, and marine margins for these time frames. The original plan was to obtain resolution at 500 year intervals but the present model is configured on the basis of the reworked sea level curve. It provides considerably more accurate projections.

(3) *Surficial geology of the shore and subaqueous terrain of the Bight*. GRA's initial study illustrated the maps that were available for various sections of the Bight. These were so diverse and based on such a broad variety of sedimentological and geomorphic criteria that comprehensive integration would require a complete reworking of primary data sets. A GIS model for surface and subsurface Quaternary landforms was built which accommodated landforms that are a product of or were affected by marine transgressions and regressions. It is possible that additional refinements can be incorporated.

(4) *GIS plots of subsurface lithostratigraphy*. The layer plotted the late Quaternary lithostratigraphy based on an assimilation of the bore logs, first by the individual channel reaches and subsequently for the entire project area. This proved to be the most complex task for the GIS because comprehensive lithostrata have never been codified, nor can they be readily transformed into a single data set. Accordingly, the prospect of grouping diverse accounts of lithostratigraphies is minimal without a more fundamental sorting of landforms. The latter is not yet possible.

(5) *GIS plots of biostratigraphy*. The layer integrates the foraminifera, macrofossil, and pollen records to sort out habitats through time. This is an independent measure of the zonation of nearshore environments established by the shoreline model, and the fit between the sequences and the landform zonations is consistent.

(6) *GIS plots and simulation of prehistoric and historic site geography*. This construct projects likely settings of sites based on known patterns of settlement in near shore environments through time (i.e., for Paleoindian, Archaic, Woodland, Contact and historic periods) based on a dynamic model of fluctuating nearshore margins and attendant environments. That model is then "fitted" against the submerged landscape maps developed for this study. A first iteration of these projections was successfully implemented.

Projection of a refined model of archaeological sensitivity. The baseline models were refined on the strength of the present investigations. The predictive model for the major navigation channels and surrounding areas is advanced and illustrated in **Figure 10.1**.

Recommendations: An archaeological probability model for planning

Figure 9.1, Figure 9.2 and **Figure 10.1** chart the archaeological sensitivity of the project area. These sensitivity designations are intended to guide future cultural resource compliance strategies related to dredging activities. The designations follow a tripartite probability ranking (**Low, Moderate, High)** representing the union of two factors: the likelihood that given locations were occupied or variously utilized in the past, and the probability that material evidence of such use has been preserved. Both of these factors were taken into account in determining designations. For example, an area with a high probability of prehistoric or historic use but with a low probability of preservation was designated as **Moderate**. Only areas with both a high probability of prehistoric or historic use and a high probability of preservation have been designated as **High**.

Table 10.1 ranks archaeological sensitivity probability by geomorphic and stratigraphic contexts. High and moderate probability rankings are determined by associations with landforms with intact dated sequences of Holocene age. In general, mitigation strategies include detailed programs of coring and landform evaluations that can determine integrity of channel margins or bay floors. **High** probability areas that cannot be avoided will likely require mitigation in the form of corings, sampling and analyses. **Moderate** probability areas will necessitate additional exploration to determine the integrity of sequences, their antiquity, and the stability of attendant landforms in the historic or prehistoric past. **Low** probability areas will require no additional work.

Archaeological Sensitivity	Landscape and Stratigraphy	Recommendations
High	Contemporary near shore settings and discrete marine, terrestrial or sub-tidal features; landform segments affixed to contemporary land masses and unaffected by historic sediment mobilization.	Should be avoided. If that is not possible, further work would include coring (subaqueous contexts) and deep testing (near shore or terrestrial contexts); mitigation includes geomorphic , sedimentological and biostratigraphic sampling supplemented by absolute dating. Results should be entered into the GIS model.
Moderate	Landform segments partially affected by terrestrial historic re-landscaping, or where stratigraphy remains unknown; generally affixed to contemporary shorelines or isolated and shielded micro-environments.	Detailed exploration of select and representative reaches of the affected segment or landform; studies need to resolve antiquity of landform through dating and assessments of landform integrity. Results should be entered into the GIS model.
Low	Interior portions of Bight that have already been affected by historic mobilizations of sediment and subaqueous impacts due to dredging and historic boat traffic; modern sediment accumulated over pre-occupation sediment stratigraphies.	No response required.

Table 10.1: Probability Model and Recommended Strategies for Planning

Summarily, this study has produced a dynamic and integrated human ecological model. The use of GIS produced a dynamic model for environmental change and human geography that will continue to evolve as future studies are conducted and new data are entered into the model. The sensitivity model will help structure decisions made by cultural resource managers working in the Harbor and Bight.

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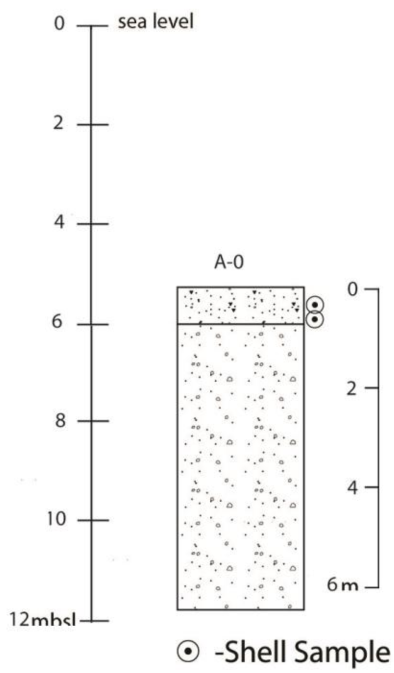
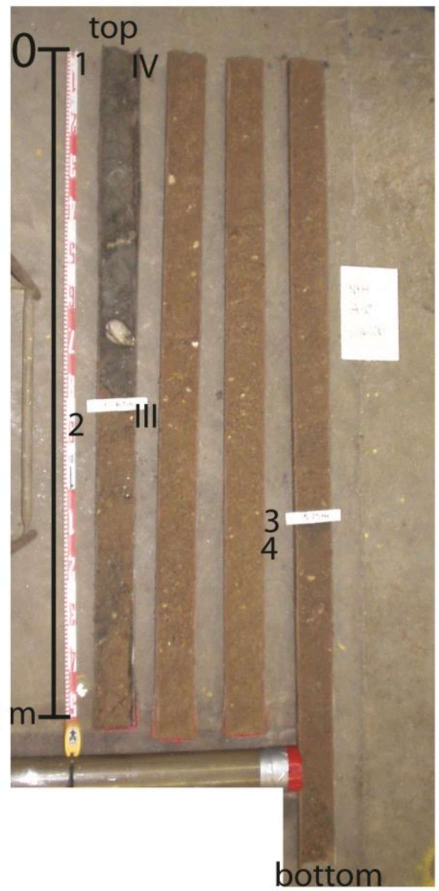
Appendix A
Borings (cores and data)

Core A-0

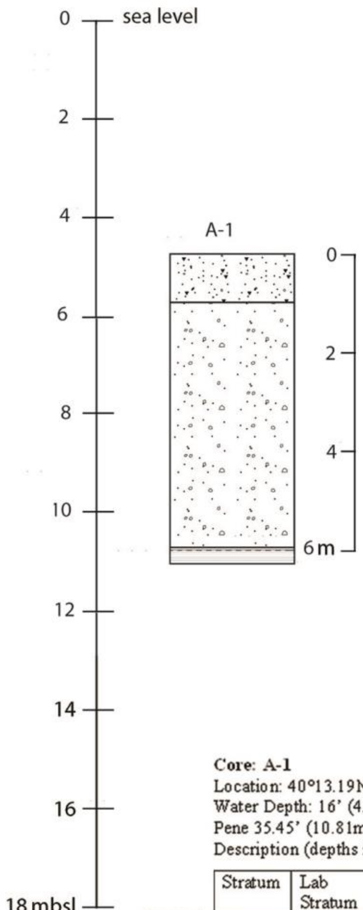


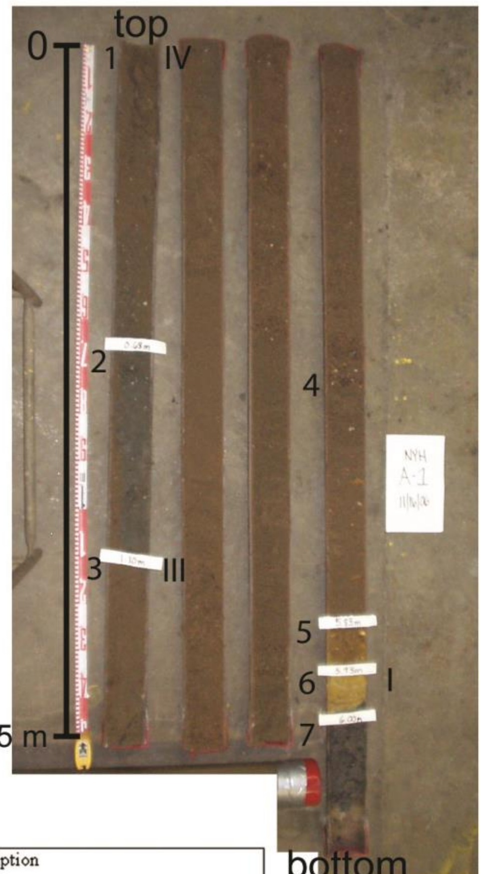


Core: A-0
Location: 40° 30.26N 74°11.59W
Water Depth: 17.8' (5.43m)
Pene 39' (11.89m), Recov. 21' (6.40m)
Description (depths in meters below core top)

Stratum	Lab Stratum	Depth (m)	Munsell Color	Description
IV	1	0-0.75	10YR3/1	clayey silty fine to coarse sand, with intact clam shells and broken shells with greatest concentration in upper 0-15 cm, abrupt lower boundary
III	2	0.75-5.75	7.5YR4/2	clean poorly sorted gravelly fine to coarse angular to subangular sand, with well rounded to subrounded gravels to 5-10 cm, abrupt lower boundary
	3	5.75-5.78	7.5YR3/1	silty fine sand, abrupt lower boundary
	4	5.78-6.50	7.5YR4/3	slightly poorly sorted gravelly silty fine to coarse sand with rounded to subrounded gravel to 5-10 cm

Core A-1

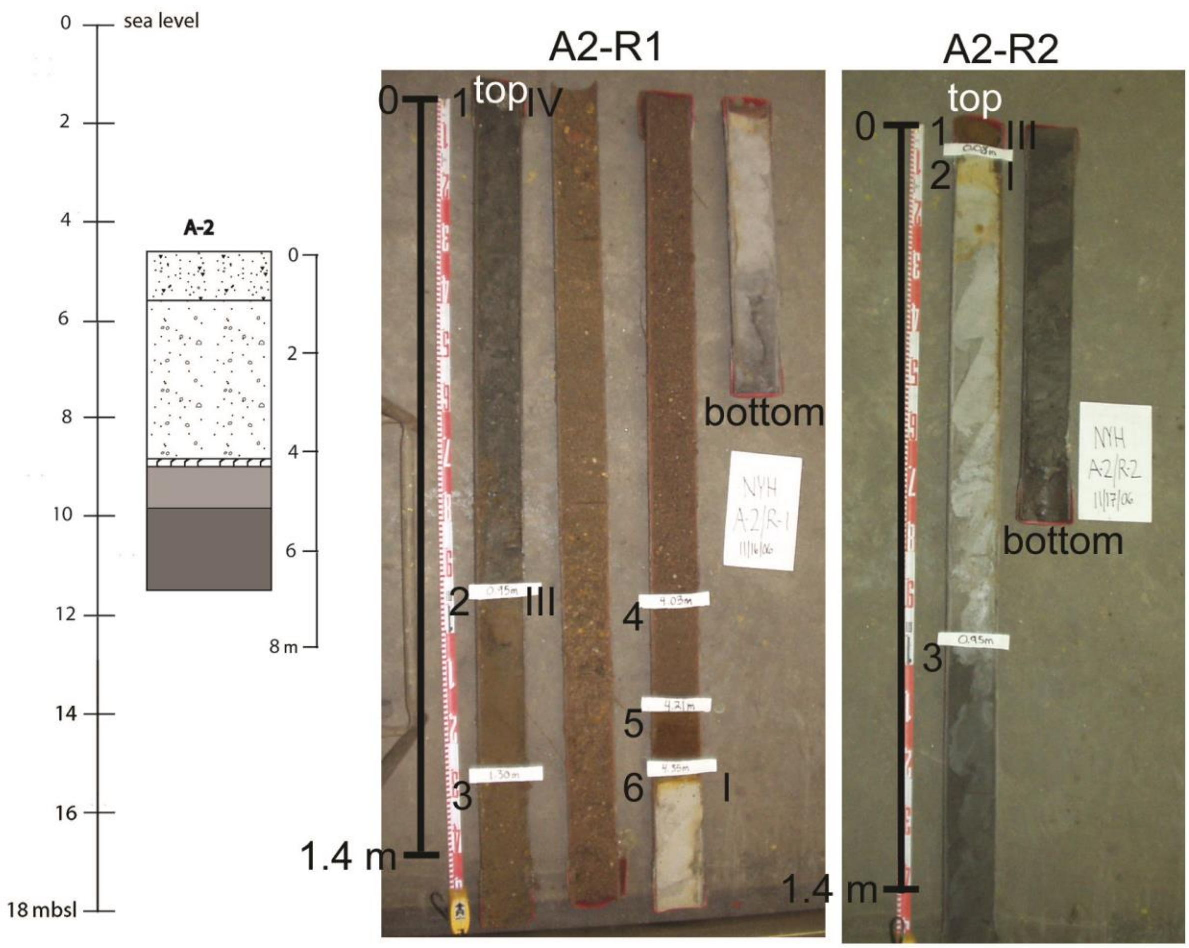




Core: A-1
Location: 40°13.19N 74°11.53W
Water Depth: 16' (4.88m)
Pene 35.45' (10.81m), Recov 12.6' (3.84m)
Description (depths in meters below core top)

Stratum	Lab Stratum	Depth (m)	Munsell Color	Description
IV	1	0-0.65	10YR4/2	slightly silty fine to medium sand, with broken shell fragments, abrupt lower boundary
	2	0.65-0.98	10YR3/1	silty fine to medium sand with broken shell fragments, abrupt lower boundary
III	3	0.98-5.30	7.5YR3/2	clean poorly sorted gravelly rounded to subrounded fine to coarse sand, with few subrounded gravels up to 15 mm, with well sorted fine sand from 2.0-2.60, 3.70-4.30, abrupt lower boundary
	4	5.30-5.82	7.5YR4/2	gravelly slightly silty poorly sorted fine to coarse sand, with subrounded gravels up to 10 mm, abrupt lower boundary
	5	5.82-5.95	7.5YR4/3	fine to medium sandy gravel, with rounded gravels to 20 mm, abrupt lower boundary
I	6	5.95-6.00	2.5Y6/6	fine sand, with weak organic laminations, 2 weak 1 mm thick lamina, 1 distinct 2 mm thick lamina near base, abrupt lower boundary
	7	6.00-6.20	10YR3/1	fine sandy clayey silt, with fine horizontally interbedded discontinuous lamina

Core A-2



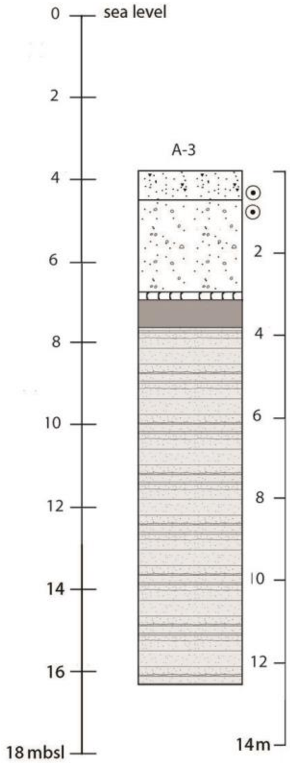
Core: A2-R1
Location: 40°29.40N 74°11.35W
Water Depth: 15.5' (4.72m)
Pene 21.24' (6.47m), Recov 16.7' (5.10m)
Description (depths in meters below core top)

Stratum	Lab Stratum	Depth (m)	Munsell Color	Description
IV	1	0-0.95	10YR3/1	gravelly silty clayey fine to coarse sands, poorly sorted gravels subrounded to well rounded up to 10 mm, clam shell on top only, abrupt lower boundary
III	2	0.95-1.30	7.5YR3/2	well sorted fine to medium sand, no shell, abrupt lower boundary
	3	1.30-4.03	7.5YR4/3	gravelly poorly sorted fine to coarse sand with subrounded gravel up to 40 mm, well sorted fine sand from 1.85-2.48, abrupt lower boundary
	4	4.03-4.21	7.5YR3/2	fine to medium sand, poss elluvial, abrupt lower boundary
	5	4.21-4.35	5YR3/4	medium to coarse sand, few subrounded to well rounded gravels to 10 mm, poss illuvial, abrupt lower boundary with 3 cm transition of weathered clay
I	6	4.35-5.14	2.5Y6/1	clay with weak 10YR6/6 weathering stains to approx. 4.65 m, below is 10YR4/1 clay with some 10YR6/6 yellow weathering stains, and some dark 10YR3/1 indistinct mottles

Core: A2-R2
Location: 40°29.40N 74°11.35W
Water Depth: 15.5' (4.72m)
Pene 24.7' (7.53m) w/ jet down to 18 (5.49), Recov 6.7' (2.04m) below jet
Description (depths in meters below core top)

Stratum	Lab Stratum	Depth (m)	Munsell Color	Description
III	1	0-0.08	5YR3/4	fine to coarse sand, with few well rounded 5 mm gravels, hard, moderately cemented, abrupt lower boundary
I	2	0.08-0.92	2.5Y6/1	clay, from top (0.08 to 0.25) is 10YR6/8 moderate to strong weathering, from 0.08-0.13 matrix is weathered to 2.5Y6/4, below from 0.13-0.25 weathering is distinct wavy horizontal to subhorizontal fine filaments and nodules, gradual lower boundary
	3	0.92-2.65	10YR3/1	clay at top, slightly coarsening to a very fine sandy silty clay at base with very fine charcoal flecks diffuse throughout upper clay portion

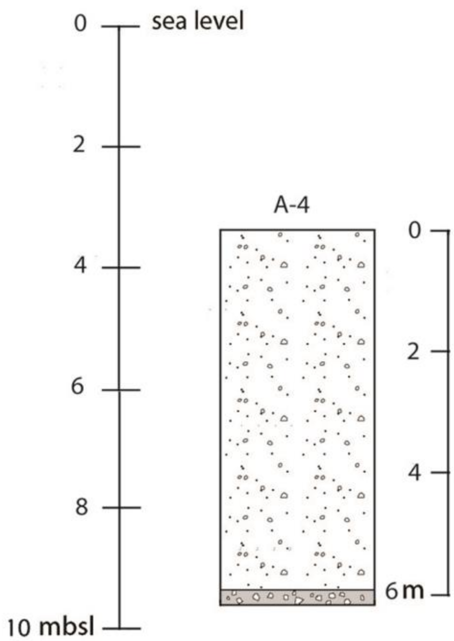
Core A-3

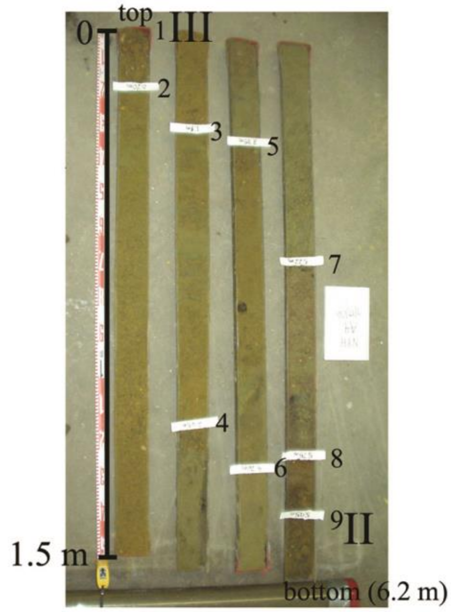


Core: A-3 R2/R3
Location: 40°28.58N 74°10.9W
Water Depth: 13.1' (3.99m)
Pene R2: 34.28' (10.45m), R3: jet to 18' (5.49m), drill to 39' (11.89m) Recov R2: 16.8', R3: 24.1' (7.35m), total recovery 41' (12.50m)
Description (depths in meters below core top)

Stratum	Lab Stratum	Depth (m)	Munsell Color	Description
IV	1	0-0.22	10YR3/2	poorly sorted fine to coarse sands, with occasional well to subrounded gravel to 5 mm, few broken shell fragments, abrupt lower boundary
	2	0.22-0.38	10YR2/1	silty fine to medium sand, with common broken and complete shells, abrupt lower boundary
	3	0.38-0.69	10YR3/2	slightly silty fine sand, common broken shell with highest concentration at base, abrupt lower boundary
III	4	0.69-1.0	10YR5/2	fine to medium sand with occasional well rounded gravels to 15 mm, no shell, abrupt lower boundary
	5	1.0-2.95	7.5YR4/2	gravelly medium to coarse sand, common, poorly sorted subangular gravels to 20 mm, moderately well sorted fine to medium sand from 1.85-2.18, abrupt lower boundary
	6	2.95-3.12	5YR3/4	gravelly medium to coarse sand, subrounded gravels up to 60 mm, abrupt lower boundary
	7	3.12-3.15	10YR5/3	silty clayey fine sand, abrupt lower boundary
I	8	3.15-3.81	2.5Y6/1	clay, with very few, very weak 10YR5/6 indistinct fine mottles to depth with moderate amount of 10YR2/1 weak, fine horizontal lamina throughout, abrupt lower boundary
	9	3.81-12.50	2.5Y6/1	silty very fine sand with 10YR2/1 and 10YR6/4 lamina, 3.81-4.22: lamina contorted, disturbed, possibly by injection; 4.22-5.05: slightly silty very fine sand with distinct horizontal lamina of 10YR6/4 silty very fine sand and 10YR4/1 silty clay; 5.05-8.15: slightly silty very fine sand contorted irregular subhorizontal to vertical, possible disturbances due to coring, abrupt lower boundary, 8.15-9.85: horizontally bedded fine sand with few fine 10YR2/1 and 10YR6/4 fine 5 mm thick lamina, gradual lower boundary; 9.85-10.05: subhorizontal distinct 10YR2/1 3 mm lamina; 10.05-11.10: very fine sand with occasional 10YR2/1 distinct fine (3mm) and 10YR6/4 indistinct (5 mm) lamina, clear lower boundary; 11.10-11.60: very fine sand, occasional slightly contorted 10YR2/1 lamina increasing in lamina thickness and frequency to a "stacked sequence" between 11.45-11.60, abrupt lower boundary; 11.60-12.50: clean very fine sand with very few (~2-3) lamina

Core A-4

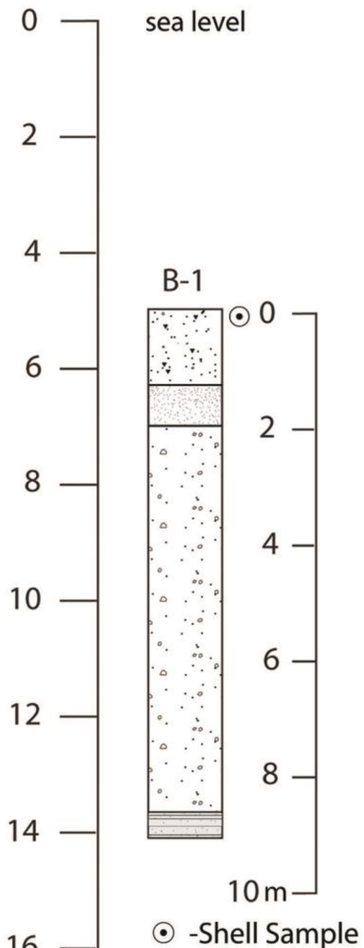


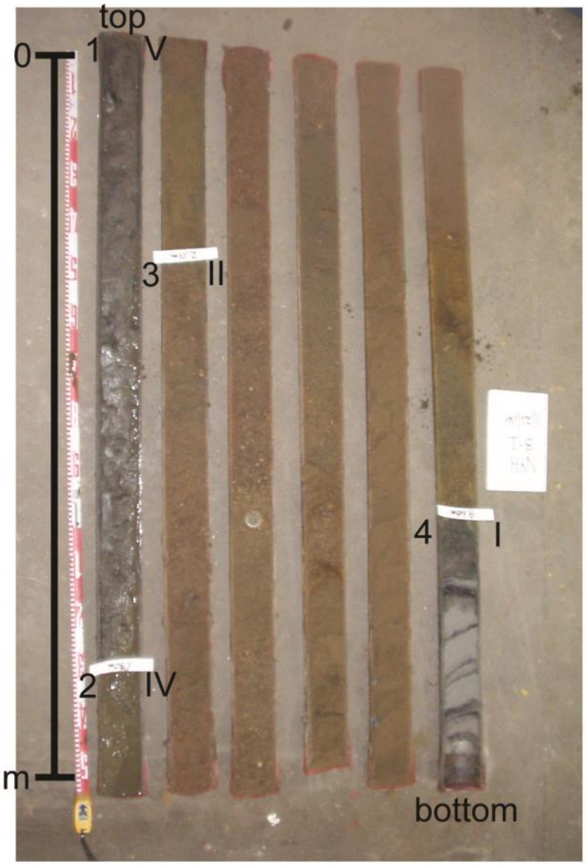


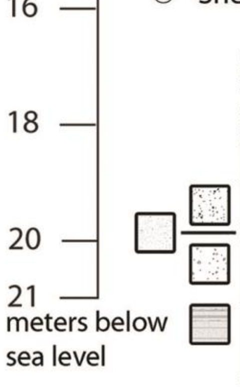
Core: A-4
Location: 40°27.79N 74°10.9W
Water Depth: 11.5' (3.51m)
Pene 34' (10.36m), Recov 20' (6.10m)
Description (depths in meters below core top)

Stratum	Lab Stratum	Depth (m)	Munsell Color	Description
III	1	0-0.20	10YR5/4	fine to coarse gravelly sand, with gravels up to 40 mm at top, abrupt lower boundary
	2	0.20-1.80	10YR5/4	clean fine to coarse sand, fining upward from medium to coarse at base to medium to fine at top, occasional gravel up to 40 mm at base, abrupt lower boundary
	3	1.80-2.65	2.5Y4/3	fine to medium sand fining upward to fine sand at top, well rounded gravel up to 20 mm at base, abrupt lower boundary
	4	2.65-3.40	2.5Y4/2	silty fine sand, with thin gravel lense at 3.15, abrupt lower boundary
	5	3.40-4.26	2.5Y4/3	fine to medium sand, to coarse silty sand at base, angular red crystalline rock at 3.85, abrupt lower boundary
	6	4.26-5.21	2.5Y5/2	clean fine to medium sand, fining upwards from coarse to medium sand at base, abrupt at base
	7	5.21-5.75	2.5Y5/3	medium to coarse sand with fine gravel, fines upward from coarse sand to fine gravel at base, gravels up to 70 mm, abrupt lower boundary
	8	5.75-5.95	5YR4/3	fining upward gravelly coarse sand to medium to coarse sand at top, gravels to 70 mm, weathered, forms into lower gravelly till, abrupt lower boundary
II	9	5.95-6.20	2.5Y4/2	clayey silty sandy gravel (till)

Core B-1



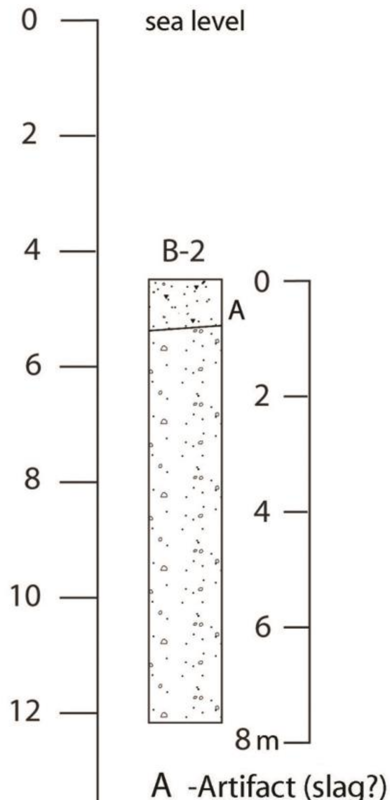


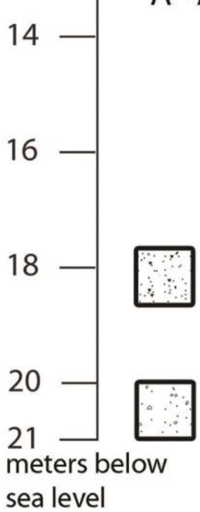


Core: B-1
Location: 40°28.74N 74°09.26W
Water Depth: 16.5' (5.03m)
Pene 37' (11.28m), Recov 30'6" (9.30m)
Description (depths in meters below core top)

Stratum	Lab Stratum	Depth (m)	Munsell Color	Description
V	1	0-1.30	10YR3/1	clayey sandy silt, with occasional fine broken shell throughout, abrupt lower boundary
IV	2	1.30-2.01	2.5Y4/3	clean fine to medium sand, poss. reworked beach? abrupt lower boundary
II	3	2.01-8.68	2.5Y4/3	clean fine to coarse sand, with fining upward sequence of poorly sorted fine to coarse sands to moderately well sorted fine to medium sands, weathered sandstone boulder at 8.25, abrupt lower boundary
I	4	8.68-9.15	10YR5/1	well sorted fine sand with common, horizontal to subhorizontal distinct 10YR2/1 5 mm to 15 mm thick lamina, 20 mm thick 10YR2/1 lamina couplet at 8.88, lower portion 8.82-9.15 include few gravels in moderately sorted fine to medium sand

Core B-2

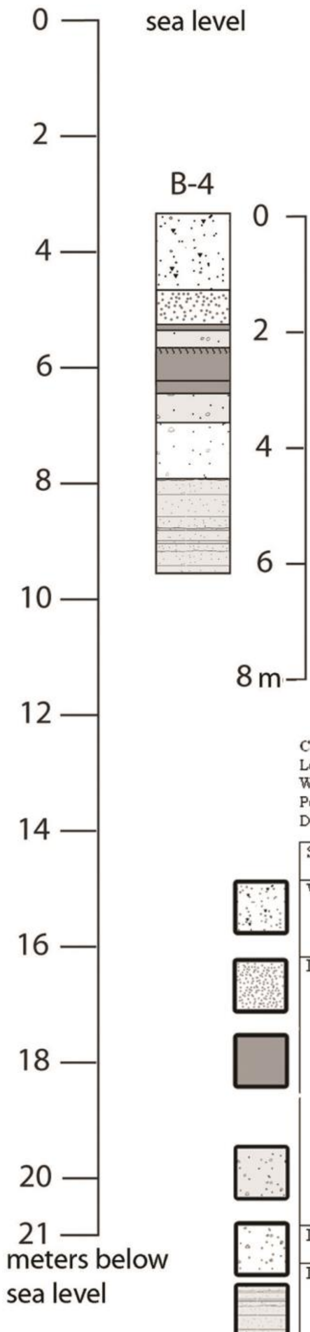


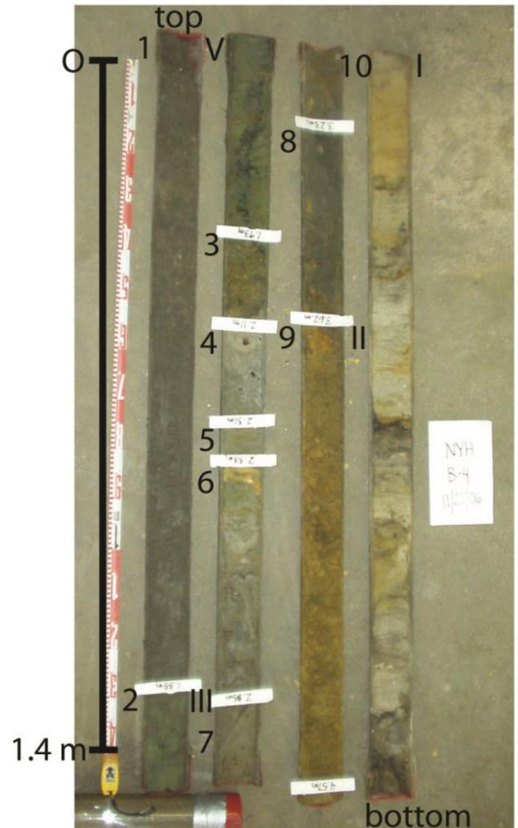


Core: B-2
Location: 40°28.11N 74°08.98W
Water Depth: 14.8' (4.51m)
Pene 34' (10.36m), Recov 24'6" (7.47m)
Description (depths in meters below core top)

Stratum	Lab Stratum	Depth (m)	Munsell Color	Description
V	1	0-0.45	10YR3/4	clean fine to medium sand, abrupt lower boundary
	2	0.45-0.80/0.89	10YR3/1	silty fine sand with common small broken shells and 2 black slag-like cultural objects, abrupt lower boundary
II	3	0.80/0.89-7.30	10YR5/3	interbedded clean fine to medium sands to gravelly sands with gravels up to 30-40 mm
	4	7.30-7.50	5YR4/4	coarse sandy gravel, gravels up to 5 cm X 2 cm, abrupt lower boundary
	5	7.50-7.60	2.5Y4/1	very silty fine sand

Core B-4

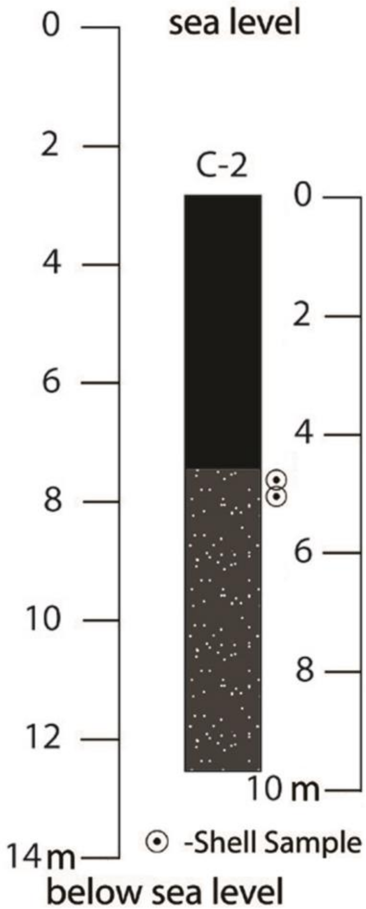


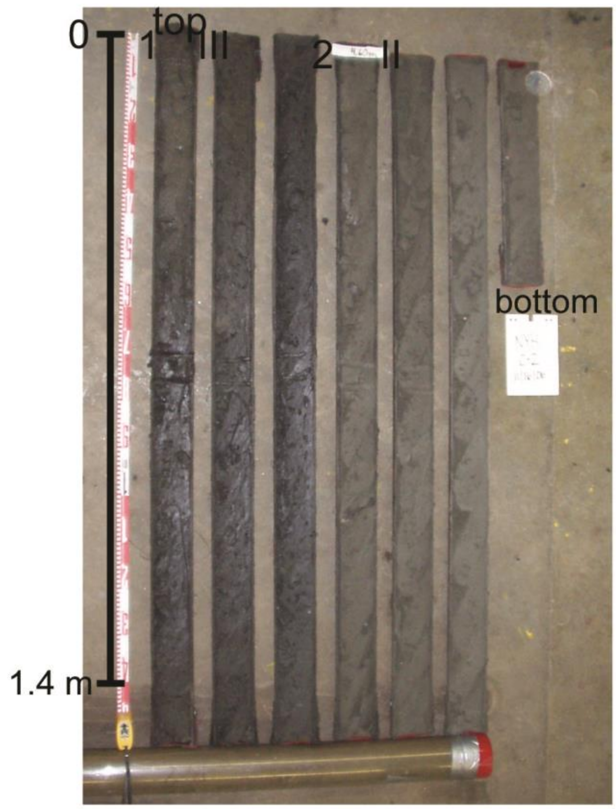


Core: B-4
Location: 40°27.35N 74°09.05W
Water Depth: 10.9' (3.32m)
Pene 34' (10.36m), Recov 20' (6.10m)
Description (depths in meters below core top)

Stratum	Lab Stratum	Depth (m)	Munsell Color	Description
V	1	0-1.35	10YR3/1 at base to 10YR3/2 at top	silty to slightly silty fine to medium sand, coarsening upwards from base, abrupt lower boundary
III	2	1.35-1.93	GLEY1 4/5GY	slightly silty fine to medium glauconitic sand
	3	1.93-2.11	2.5YR4/3	poorly sorted clayey, silty, sandy gravelly sand
	4	2.11-2.31	10YR4/1	silty clay with organics, abrupt lower boundary
	5 6	2.31-2.38 2.38-2.85/3.05	2.5Y5/1 10YR4/2	fairly well sorted fine to medium sand silty clay with 7.5YR6/8 oxidized zone in upper 5 cm
	7	2.85/3.05-3.23	10YR4/2	slightly silty clay, abrupt lower boundary
	8	3.23-3.62	10YR2/1	very silty fine to medium sand with gravel at base, fining upwards to sandy silt, abrupt lower boundary
II	9	3.62-4.57	2.5Y5/3	poorly sorted gravelly sand with gravels up to 5 cm
I	10	4.57-6.12	2.5Y6/1	slightly silty fine sand and fine to medium sand with thin 10YR2/1 and occasional horizontally bedded oxidized 2.5Y6/4 laminations in upper 4.57-4.82, dark gray clay band from 5.31-5.34

Core C-2

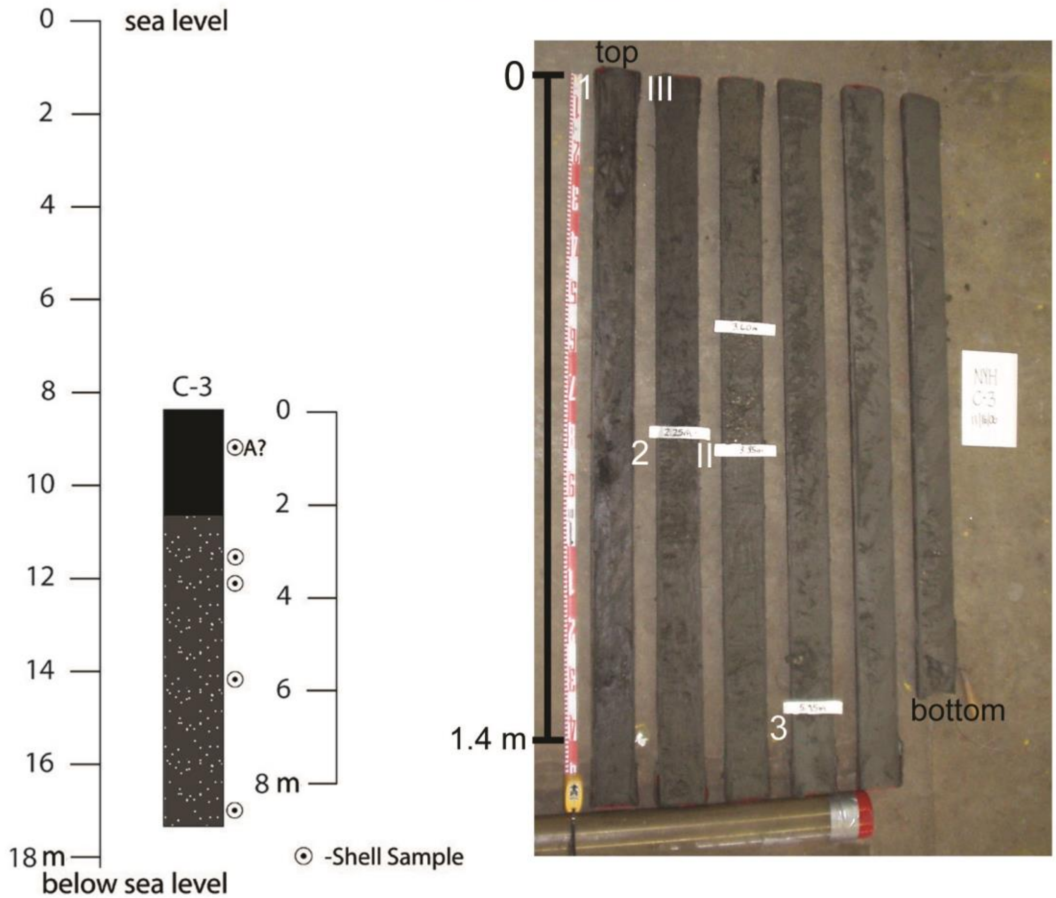




Core: C-2
Location: 40°41.12N 74°02.82W
Water Depth: 9.5' (2.90m)
Pene 35.8' (10.91m), Recov 31.8' (9.69m)
Description (depths in meters below core top)

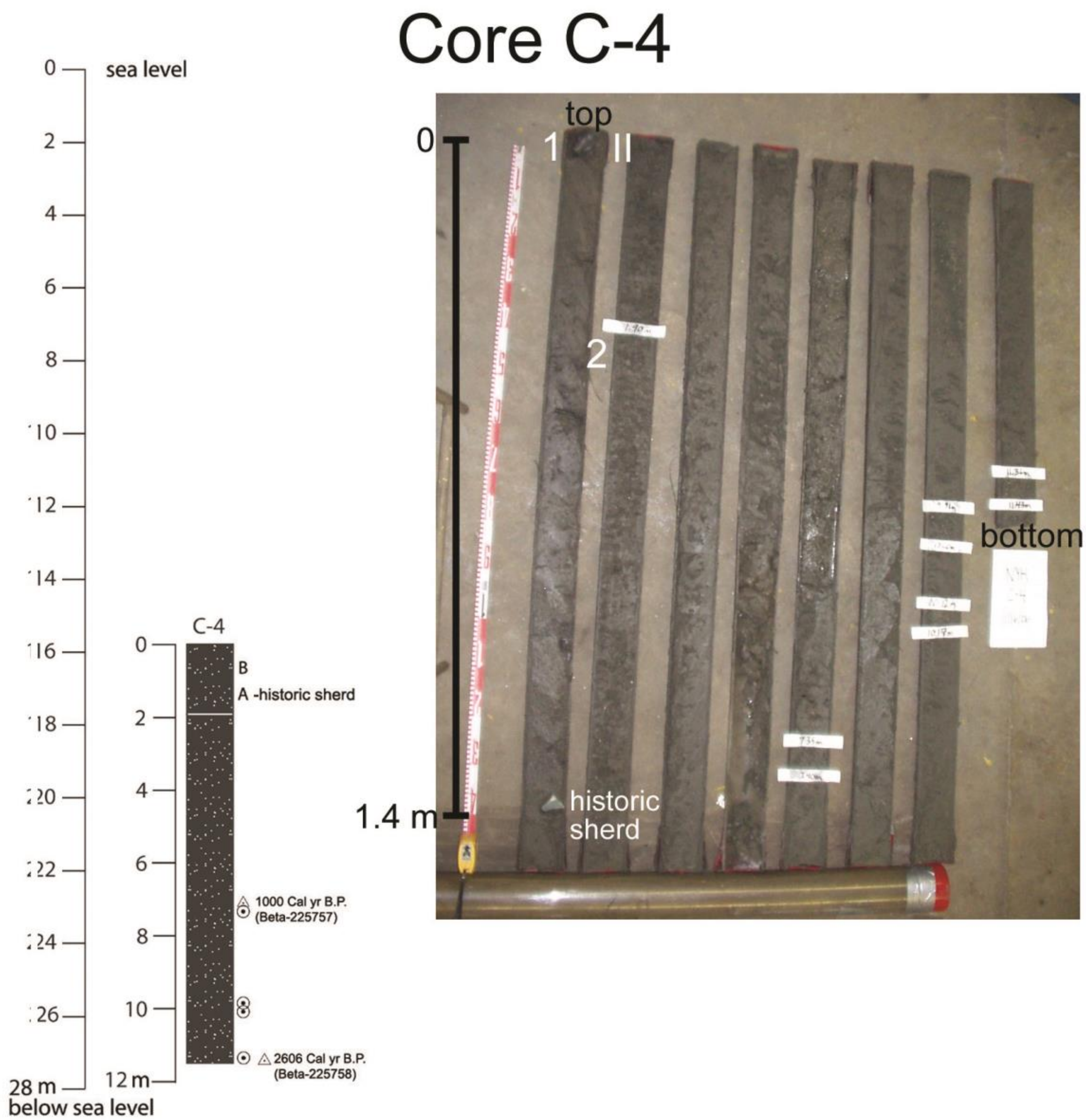
Stratum	Lab Stratum	Depth (m)	Munsell Color	Description
III	1	0-4.60	10YR2/1	oily clay muck, no shell, H_2S smell, abrupt lower boundary
II	2	4.60-9.70	10YR3/1	silty clay with fine shell fragments throughout

Core C-3



Core: C-3
Location: 40°41.04N 74°02.65W
Water Depth: 29' (8.84m)
Pene 38.26' (11.66m), Recov 29.26' (8.92m)
Description (depths in meters below core top)

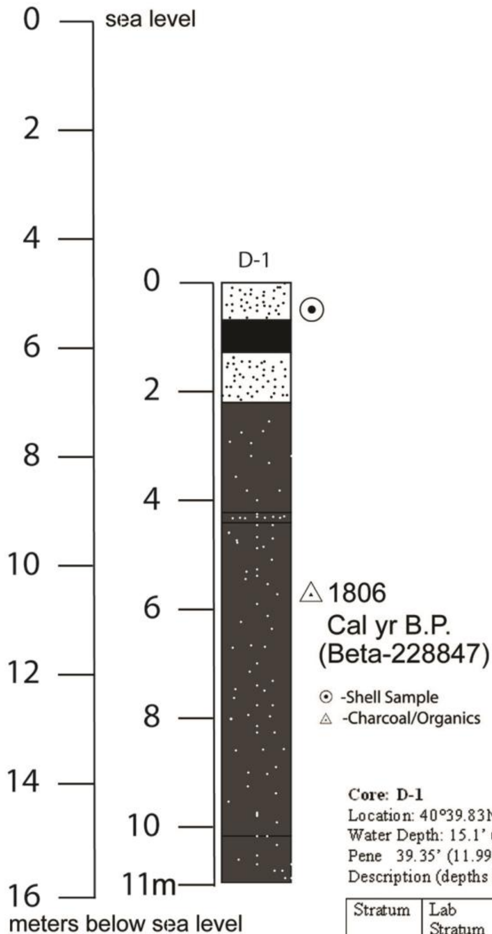
Stratum	Lab Stratum	Depth (m)	Munsell Color	Description
III	1	0-2.25	10YR2/1	oily clay muck, very occasional shell fragments, inclusions of brown clay streaks, weak diesel/oil smell, abrupt lower boundary
II	2	2.25-5.95	10YR3/1	silty clay with shell fragments throughout, including shell hash lenses, abrupt lower boundary
	3	5.95-8.95	10YR4/1	clay, very occasional broken shell fragments, shell concentration of small broken fragments from 8.65-8.70

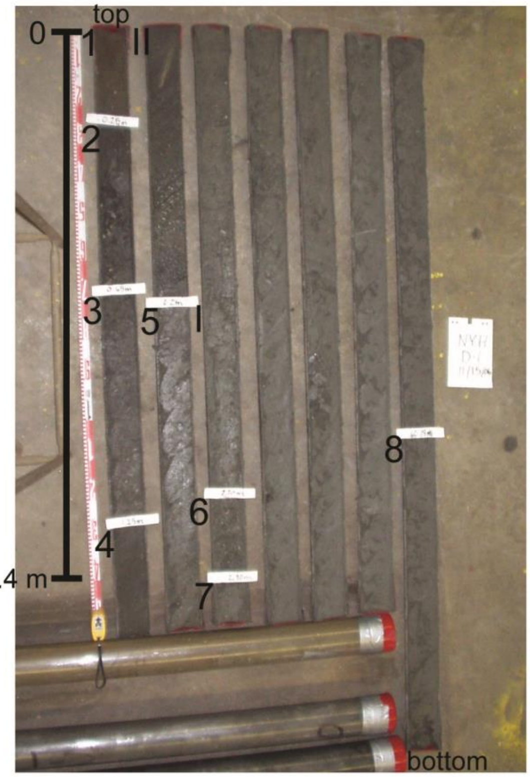


Core: C-4
Location: 40°40.97N 74°02.45W
Water Depth: 51.8' (15.79m)
Pene 39.38' (12.00m), Recov 37.4' (11.40m)
Description (depths in meters below core top)

Stratum	Lab Stratum	Depth (m)	Munsell Color	Description
II	1	0-1.90	10YR2/1	silty clay, with 10YR3/1 subhorizontal clay inclusions (ie disturbance) very occasional shell fragments, 0.60: fish bone, 1.40: ceramic sherd, abrupt lower boundary
	2	1.90-11.48	10YR3/1	silty clay with distinct shell hash lenses of small broken shell with occasional small broken shell found throughout, voids from 5.55-6.10 and 6.85-7.00 due to core slipping from tube during collection, organics collected from 11.60

Core D-1

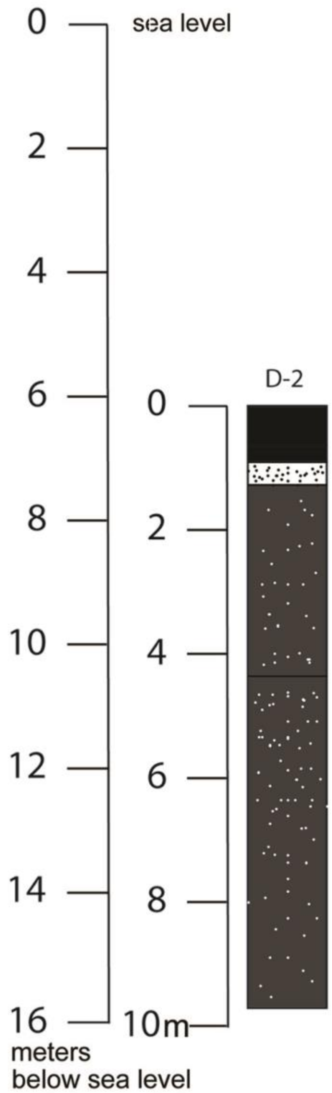


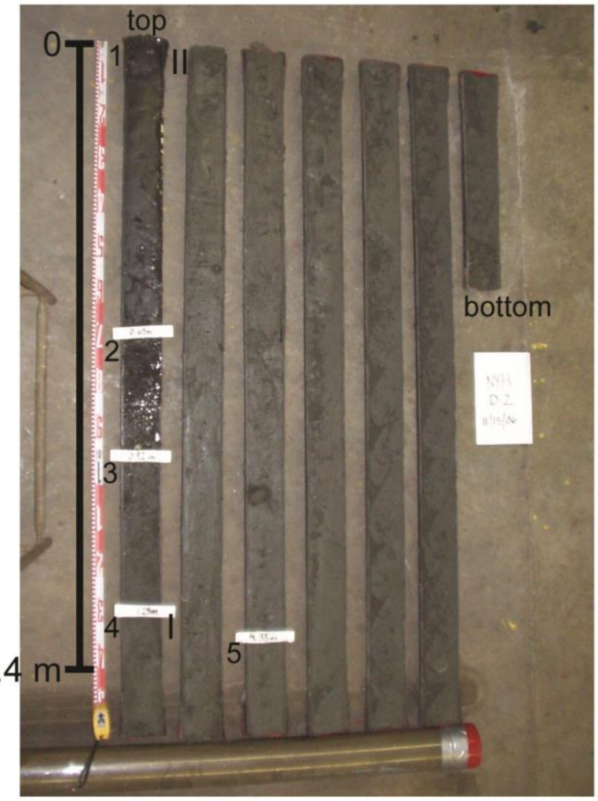


Core: D-1
Location: 40°39.83N 74°01.47W
Water Depth: 15.1' (4.60m)
Pene 39.35' (11.99m), Recov 36.2' (11.03m)
Description (depths in meters below core top)

Stratum	Lab Stratum	Depth (m)	Munsell Color	Description
II	1	0-0.25	10YR3/2	slightly silty fine to medium sand, abrupt lower boundary
	2	0.25-0.68	10YR2/1	slightly silty fine to medium sand with large shell fragments, has oily smell, smooth lower boundary
	3	0.68-1.25	10YR3/1	silty fine to medium sand, no shells
	4	1.25-2.20	10YR3/1	slightly silty fine to medium sand, very occasional snail shell fragment, 1 clay filled burrow, gradual lower boundary
I	5	2.20-4.22	10YR2/1	silty clay, with shells, including small clam, abrupt lower boundary
	6	4.22-4.40	10YR3/1	clay, increased shell concentrations, abrupt lower boundary
	7	4.40-10.18	10YR3/1	silty clay, occasional shell fragments throughout
	8	10.18-11.00	10YR3/1	silty clay, no shell

Core D-2

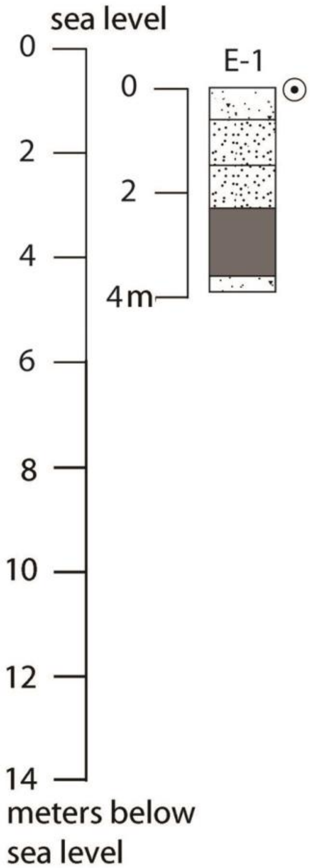


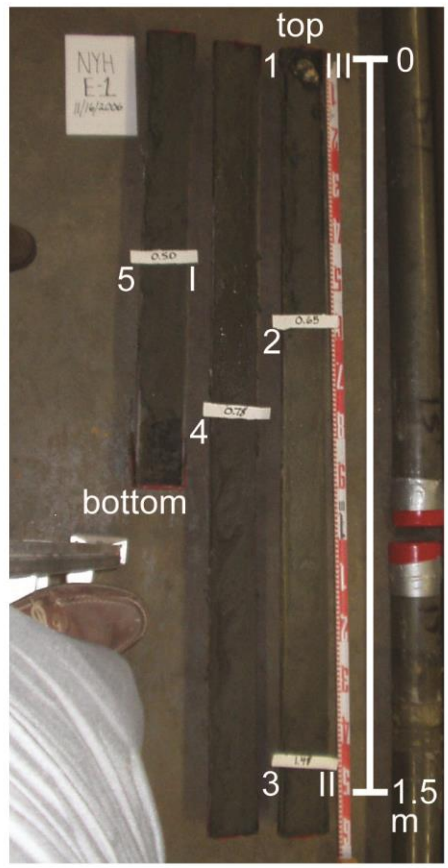


Core: D-2
Location: 40°39.91N 74°01.80W
Water Depth: 19.9' (6.07m)
Pene 39.37' (12.0m), Recov 31.9' (9.72m)
Description (depths in meters below core top)

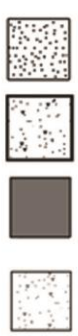
Stratum	Lab Stratum	Depth (m)	Munsell Color	Description
II	1	0-0.65	10YR2/1	oily clay, no shells, abrupt lower boundary
	2	0.65-0.90	10YR2/1	oily clayey silty fine to medium sand, with shells, wood, abrupt lower boundary
	3	0.90-1.25	10YR3/1	slightly silty medium sand
I	4	1.25-4.35	10YR3/1	fine sandy clayey silt with occasional shell fragments throughout, sandstone pebble at 4.05, gradual lower boundary
	5	4.35-9.70	10YR3/1	clayey silt with occasional shell fragments

Core E-1



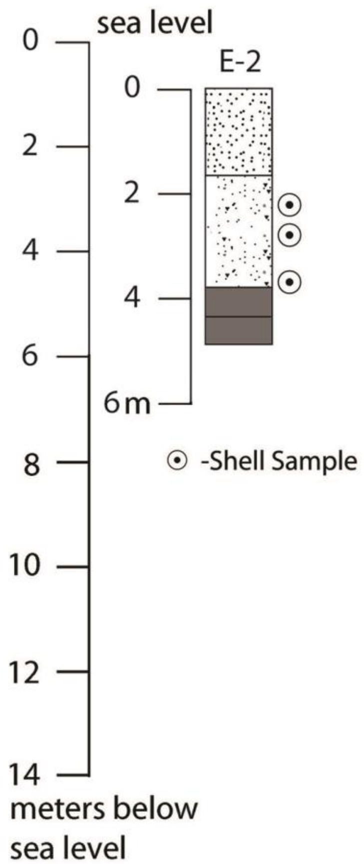


Core: E-1
Location: 40°36.22N 73°50.58W
Water Depth: 2.5' (0.76m)
Pene 15.9' (4.85m), Recov 12.9' (3.93m)
Description (depths in meters below core top)



Stratum	Lab Stratum	Depth (m)	Munsell Color	Description
III	1	0-0.60	10YR3/1	fine sandy clayey silt grading to fine sand at base, clam at surface
	2	0.60-1.48	10YR5/1	well sorted subangular fine to medium sand grading to silt at top and bottom, gradual lower boundary
II	3	1.48-2.30	10YR3/1	clayey silty fine sand, gradual lower boundary
	4	2.30-3.60	10YR3/1	clayey fine sandy silt, gradual lower boundary
I	5	3.60-3.90	10YR3/1	silty fine sand with shell fragments

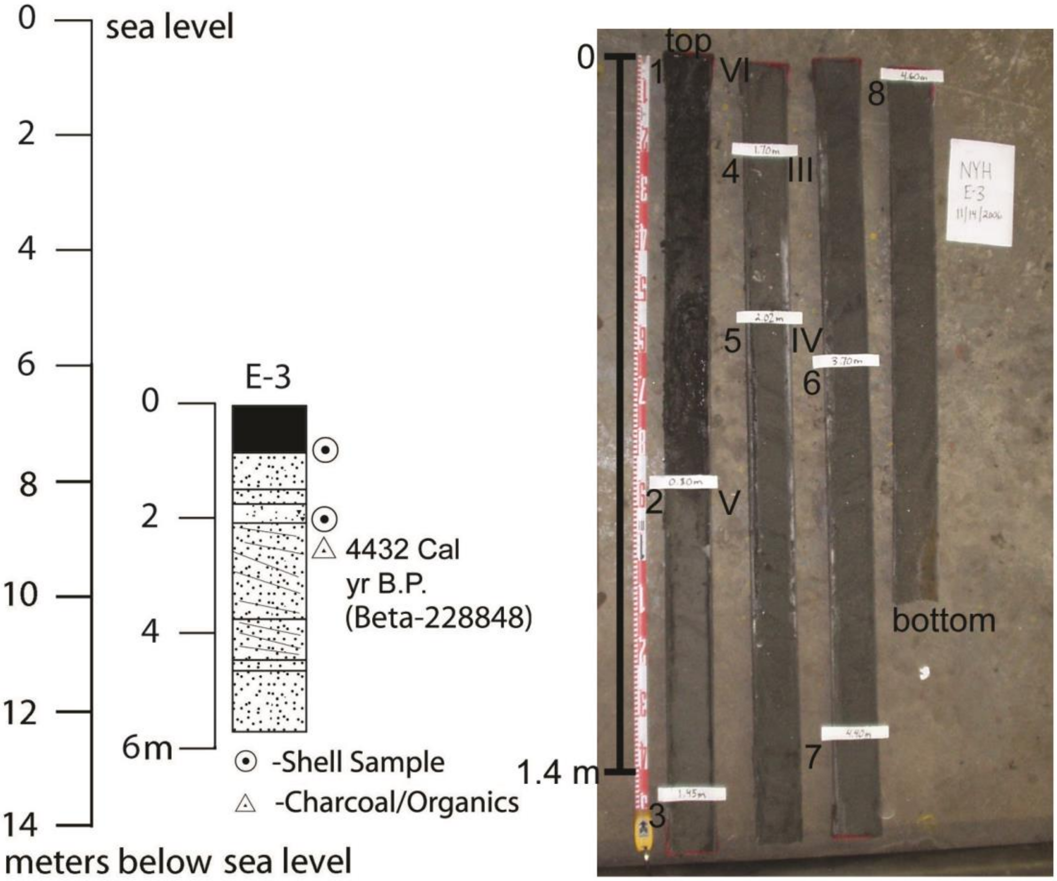
Core E-2



Core: E-2
Location: 40°36.16N 73°50.76W
Water Depth: 2.9' (0.88m)
Pene 20' (6.10m), Recov 16.8' (5.12m)
Description (depths in meters below core top)

Stratum	Lab Stratum	Depth (m)	Munsell Color	Description
VI	-	0-0.10	10YR3/1	Disturbed, dark gray silty fine sand
	1	0.10-1.65	10YR5/1	well sorted fine sand, clear lower boundary with an increase in silt with depth
III	2	1.65-3.80	10YR4/1	clayey silty fine sand, saturated, three shell hash lenses, clear lower boundary
II	3	3.80-4.35	10YR3/1	clayey silt, small shell fragments
	4	4.35-4.88	10YR3/1	clayey sandy silt

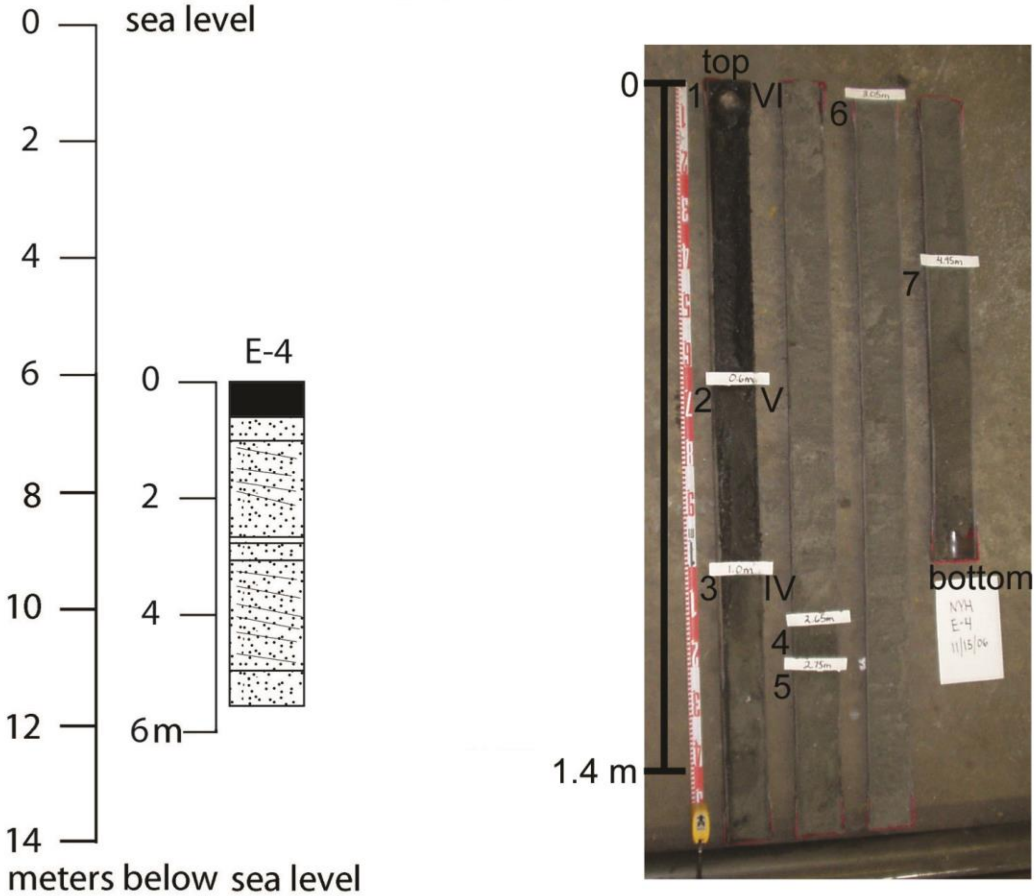
Core E-3



Core: E-3
Location: 40°35.99N 73°53.91W
Water Depth: 21.9' (6.68m)
Pene 20' (6.10m), Recov 18.5' (5.64m)
Description (depths in meters below core top)

Stratum	Lab Stratum	Depth (m)	Munsell Color	Description
VI	1	0-0.80	10YR2/1	organic silty clay muck, abrupt lower boundary
V	2	0.80-1.45	10YR5/1	fine sand
	3	1.45-1.70	10YR5/1	medium to coarse sand
III	4	1.70-2.03	10YR5/1	fine to medium sand, with shell hash including jingle shell at base of strat
IV	5	2.03-3.70	10YR4/1	fine to medium sand, with occasional 5 mm thick 10YR3/1 silt lamina subhorizontal dipping 30-40°, with organic fragments collected for 14C and ID
	6	3.70-4.40	10YR4/1	coarse sand, interbedded with occasional 10YR3/1 10 mm thick silt lamina, subhorizontal dipping 30-40°
	7	4.40-4.60	10YR5/1	fine sand
	8	4.60-5.65	10YR4/1	medium to coarse subangular to subrounded sand

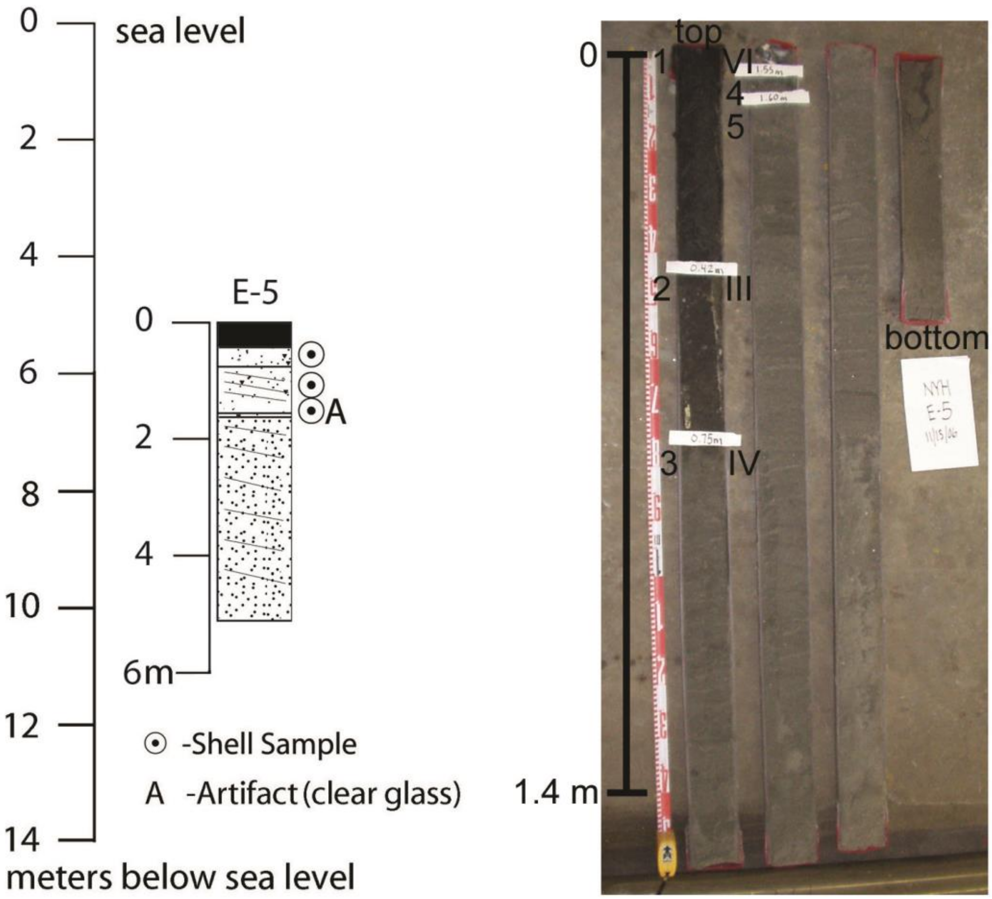
Core E-4



Core: E-4
Location: 40°35.99N 73°50.91W
Water Depth: 20' (6.10m)
Pene 20' (6.10m), Recov 18' (5.49m)
Description (depths in meters below core top)

Stratum	Lab Stratum	Depth (m)	Munsell Color	Description
VI	1	0-0.60	10YR2/1	organic silty clay muck, smell of H_2S
V	2	0.60-1.00	10YR3/1	organic silty fine sand
IV	3	1.00-2.65	10YR5/1	fining upward sequence of medium to fine sand, with fairly indistinct fine subhorizontal dark mineral lamellae above 2.30, abrupt lower boundary
	4	2.65-2.75	10YR5/1	slightly clayey silty fine sand, with small shell fragments, abrupt lower boundary
	5	2.75-3.05	10YR5/1	fine to medium sand
	6	3.70-4.40	10YR5/1	fining upward from medium to fine sand, with fairly indistinct fine subhorizontal dark mineral lamellae, abrupt lower boundary
	7	4.95-5.55	10YR3/1	slighty silty fine to coarse sand with medium sands dominant

Core E-5



Core: E-5
Location: 40°35.57N 73°51.00W
Water Depth: 22.6' (6.89m)
Pene 20' (6.10m), Recov 16.8' (5.12m)
Description (depths in meters below core top)

Stratum	Lab Stratum	Depth (m)	Munsell Color	Description
VI	1	0-0.42	10YR2/1	organic silty clay muck, smell of H_2S, clear lower boundary
III	2	0.42-0.75	10YR3/1	silty fine sand, with shell fragments including razor clam, abrupt lower boundary
IV	3	0.75-1.55	10YR5/1	fining upward sequence from fine to medium sand at base to fine sand at top, occasional fine subhorizontal lamina of dark minerals, shell hash with oyster and gastropod shells at base, abrupt lower boundary
	4	1.55-1.60	10YR4/1	silty fine sand with shell and broken glass, abrupt upper and lower boundary
	5	1.60-5.10	10YR5/1	well sorted fining upward sequence from fine to medium sands at base to fine sand at top, very occasional horizontal to subhorizontal dark mineral lamellae

Appendix B
Radiocarbon Ages

Location	Elevation		Material	Lithofacies	Age	Calibrated Age	Midpoint	Lab Number	Source
	mbmsl	ftbmsl			14C yrs BP	cal yrs BP Oxcal			
Anchor Channel - 98ANC44	20.12	66	wood	Fluvial sand	9400+/-150	11121 - 10258	10690	Beta 127019	Schuldenrein et al., 2000
Arthur Kill - WP-VI	**20.73**	**68**	**peat**	**Fluvial sand**	**7950+/-70**	**8998 - 8607**	**8803**	**?**	**LaPorta et al. 1999**
Arthur Kill - Shooters Is.	2.3	7.55	wood	Fluvial sand	3040+/-120	3549 - 2881	3215	Beta 137984	Schuldenrein et al., 2000
Arthur Kill - Shooters Is.	4.6	15.09	bulk sediment	Estuarine silt	4340+/-80	5285 - 4655	4970	Beta 137986	Schuldenrein et al., 2000
Arthur Kill - Shooters Is.	2.56	8.4	bulk sediment	Estuarine silt	6100+/-60	7162 - 6798	6980	Beta 137985	Schuldenrein et al., 2000
Hackensack Marsh -	0.1	0.33	reed muck	Freshwater marsh	240+/-110	489 - minus 3	241	RL-1030	Carmichael, 1980
Hackensack Marsh -	**0.7**	**2.3**	**sedge peat**	**Brackish marsh**	**810+/-110**	**935 - 556**	**746**	**RL-1031**	**Carmichael, 1980**
Hackensack Marsh -	**1.8**	**5.91**	**sedge peat**	**Brackish marsh**	**2060+/-120**	**2338 - 1740**	**2039**	**RL-1032**	**Carmichael, 1980**
Hackensack Marsh -	**2.8**	**9.19**	**woody peat**	**Forested wetland?**	**2610+/-130**	**2992 - 2350**	**2671**	**RL-1033**	**Carmichael, 1980**
Hackensack Marsh -	2.3	7.55	peat	Freshwater marsh?	2025+/-300	2742 - 1384	2063	I-510	Heusser, 1962
Jersey City, NJ - R15-4	**2.2**	**7.4**	**organics in silt**	**Estuarine silt**	**1320+/40**	**1304 - 1175**	**1240**	**Beta 171330**	**Schuldenrein 2006**
Jersey City, NJ - R15-4	**8.9**	**29.1**	**organics in silt**	**Estuarine silt**	**5130+/-40**	**5986 -5749**	**5868**	**Beta 171331**	**Schuldenrein 2006**
Jersey City, NJ - R15-4	10.1	33.1	shell	Estuarine silt	4670+/-50	5580 - 5306	5443	Beta 171332	Schuldenrein 2006
Jersey City, NJ - R15-4	**10.1**	**33.1**	**organics in silt**	**Estuarine silt**	**5980+/-50**	**6943 - 6678**	**6811**	**Beta 171333**	**Schuldenrein 2006**
Jersey City, NJ - R15-4	16.6	54.3	peat	Freshwater marsh?	9140+/-70	10497 - 10198	10348	Beta 171334	Schuldenrein 2006
Pine Creek Marsh, NJ	**2.71**	**8.7**	**basal peat**	**Brackish marsh**	**2130+/-60**	**2315 - 1951**	**2133**	**Beta 76536**	**Kenen, 1999**
Pine Creek Marsh, NJ	**2.1**	**6.7**	**basal peat**	**Brackish marsh**	**1690+/-70**	**1809 - 1412**	**1610**	**Beta 76537**	**Kenen, 1999**
Pine Creek Marsh, NJ	**3.85**	**12.5**	**basal peat**	**Brackish marsh**	**2710+/-60**	**2986 - 2744**	**2845**	**Beta 79340**	**Kenen, 1999**
Pine Creek Marsh, NJ	**2.7**	**8.7**	**basal peat**	**Brackish marsh**	**2170+/-70**	**2335 - 2001**	**2168**	**Beta 79341**	**Kenen, 1999**
Pine Creek Marsh, NJ	**2.42**	**8**	**basal peat**	**Brackish marsh**	**1780+/-70**	**1866 - 1547**	**1706**	**Beta 79342**	**Kenen, 1999**
Pine Creek Marsh, NJ	**3.54**	**11.5**	**basal peat**	**Brackish marsh**	**2210+/-70**	**2348 - 2041**	**2195**	**Beta 79343**	**Kenen, 1999**
Pine Creek Marsh, NJ	**1.67**	**5.47**	**basal peat**	**Brackish marsh**	**1410+/-80**	**1518 - 1175**	**1347**	**Beta 79344**	**Kenen, 1999**
Pine Creek Marsh, NJ	**2.42**	**8**	**basal peat**	**Brackish marsh**	**1820+/-80**	**1896 - 1566**	**1731**	**Beta 90574**	**Kenen, 1999**
Pine Creek Marsh, NJ	**2.48**	**8.2**	**basal peat**	**Brackish marsh**	**1970+/-80**	**2121 - 1726**	**1923**	**Beta 90575**	**Kenen, 1999**
Pine Creek Marsh, NJ	**4.06**	**13.5**	**basal peat**	**Brackish marsh**	**2690+/80**	**3003 - 2518**	**2760**	**Beta 90577**	**Kenen, 1999**
South Shore Long Island	**18.6**	**61.02**	**peat**	**Brackish marsh**	**7750+/-125**	**8980 - 8361**	**8671**	**I-5880**	**Field et al., 1979**
South Shore Long Island	**16.4**	**53.8**	**peat**	**Brackish marsh**	**7585+/-125**	**8641 - 8057**	**8349**	**I-?**	**Field et al., 1979**
Liberty Island C-1	**10.1**	**33.14**	**wood**	**Wood in fluvial sand**	**5650+/-90**	**6651 - 6295**	**6473**	**Beta 225755**	**This report**
Liberty Island C-4	23.04	75.6	wood in silt	Estuarine silt	1090+/-40	1073 - 927	1000	Beta 225757	This report
Liberty Island C-4	27.26	89.46	organics in silt	Estuarine silt	2520+/-40	2746 - 2466	2606	Beta 225758	This report
Bay Ridge Flats D-1	10.18	33.41	wood	Estuarine silt	1850+/-40	1897 - 1715	1806	Beta 228847	This report
Jamaica Bay E-3	9.8	32.14	organics in sand	fine to med sand	4130+/-40	4567 - 4296	4432	Beta 228848	This report
Jersey Flats JF-1	**5.6**	**18.3**	**organics in silt**	**Estuarine silt**	**3460+/-40**	**3839 - 3633**	**3736**	**Beta 150701**	**Schuldenrein et al., 2005**
Jersey Flats JF-6	**5.96**	**19.56**	**organics in silt**	**Estuarine silt**	**3360+/-40**	**3692 - 3480**	**3586**	**Beta 150704**	**Schuldenrein et al., 2005**
Jersey Flats JF-3	9.7	31.8	organics in silt	Estuarine silt	1970+/-60	2112 - 1741	1927	Beta 150703	Schuldenrein et al., 2005
Jersey Flats JF-3	8.7	28.6	organics in silt	Estuarine silt	2360+/-70	2706 - 2180	2443	Beta 150702	Schuldenrein et al., 2005
Thomas Paine Park B-1	**2.3**	**7.5**	**peat**	**Brackish marsh**	**1220+/-60**	**1282 - 989**	**1136**	**Beta 130393**	**Schuldenrein et al., 2001**
Thomas Paine Park B-1	**3**	**10**	**peat**	**Brackish marsh**	**2490+/-60**	**2735 - 2364**	**2550**	**Beta 130394**	**Schuldenrein et al., 2001**
Sandy Hook, NJ	27	88.6	organics in silt	Estuarine silt	9860+/-300	12566 - 10502	11534		Minard, 1969
Tappan Zee, SD30	4.4	14.44	oyster	Estuarine silt	1940+/-35*	*	927	NOSAMS	Carbotte et al., 2004
Tappan Zee, SD30	5.11	16.77	oyster	Estuarine silt	2370+/-60*	*	1307	Zurich	Carbotte et al., 2004
Tappan Zee, SD30	6.38	20.93	shell	Estuarine silt	3720+/-50*	*	2853	NOSAMS	Carbotte et al., 2004
Tappan Zee, SD30	7.2	23.62	shell	Estuarine silt	4160+/-35*	*	3425	NOSAMS	Carbotte et al., 2004
Tappan Zee, SD30	9.66	31.69	shell	Estuarine silt	4800+/-65*	*	4244	NOSAMS	Carbotte et al., 2004
Tappan Zee, SD30	10.1	33.14	shell	Estuarine silt	4820+/-65*	*	4287	NOSAMS	Carbotte et al., 2004
Tappan Zee, SD30	11.31	37.11	shell	Estuarine silt	5060+/-40*	*	4608	NOSAMS	Carbotte et al., 2004
Tappan Zee, SD30	11.63	38.16	shell	Estuarine silt	5250+/-65	*	4851	NOSAMS	Carbotte et al., 2004
Tappan Zee, SD30	12.86	42.19	shell	Estuarine silt	6150+/-65*	*	5931	NOSAMS	Carbotte et al., 2004
Tappan Zee, SD30	13.61	44.65	oyster	Estuarine silt	6270+/-70*	*	6058	Zurich	Carbotte et al., 2004
Tappan Zee, SD11	3.62	11.88	oyster	Estuarine silt	2560+/-35*	*	1522	LLNL	Carbotte et al., 2004
Tappan Zee, SD11	5.18	16.99	shell	Estuarine silt	4230+/-40*	*	3473	LLNL	Carbotte et al., 2004
Tappan Zee, SD11	9.64	31.63	shell	Estuarine silt	6295+/-45*	*	6133	LLNL	Carbotte et al., 2004
Tappan Zee, LWI-79	6.32	20.73	oyster	Estuarine silt	3050+/-60*	*	2091	Zurich	Carbotte et al., 2004
Tappan Zee, LWI-25	4.88	16.01	oyster	Estuarine silt	1765+/-55*	*	728	Zurich	Carbotte et al., 2004
Tappan Zee, LWI-56	5.35	17.55	oyster	Estuarine silt	3280+/-65*	*	2346	Zurich	Carbotte et al., 2004
Tappan Zee, LWI-4	11.96	39.24	oyster	Estuarine silt	2135+/-60*	*	1164	Zurich	Carbotte et al., 2004
Tappan Zee, CD02-08	12.31	40.39	oyster	Estuarine silt	2080+/-40*	*	1028	LLNL	Carbotte et al., 2004
Raritan Bay RB-08	11.7	38.39	wood fragments	coarse sand	31740+/-1830			Beta 90133	Gaswirth, S.B., 1999
Arthur Kill Marsh	8	26.2	peat	Freshwater marsh	11100	13189 - 12873	13031		Peteet et al., in press
Piermont Marsh	13.7	45	peat	marsh	5700	6719 - 6299	6509		Peteet et al., in press
Croton Marsh	**10**	**32.8**	**peat**	**marsh**	**4630**	**5589 - 5040**	**5315**		**Peteet et al., in press**
Iona Marsh	**10**	**32.8**	**peat**	**marsh**	**5500**	**6494 - 6002**	**6248**		**Peteet et al., in press**

***Highlighted rows indicate dates used in shoreline curve**

CALIBRATION OF RADIOCARBON AGE TO CALENDAR YEARS

(Variables: C13/C12=-25.4:lab. mult=1)

Laboratory number: **Beta-225755**

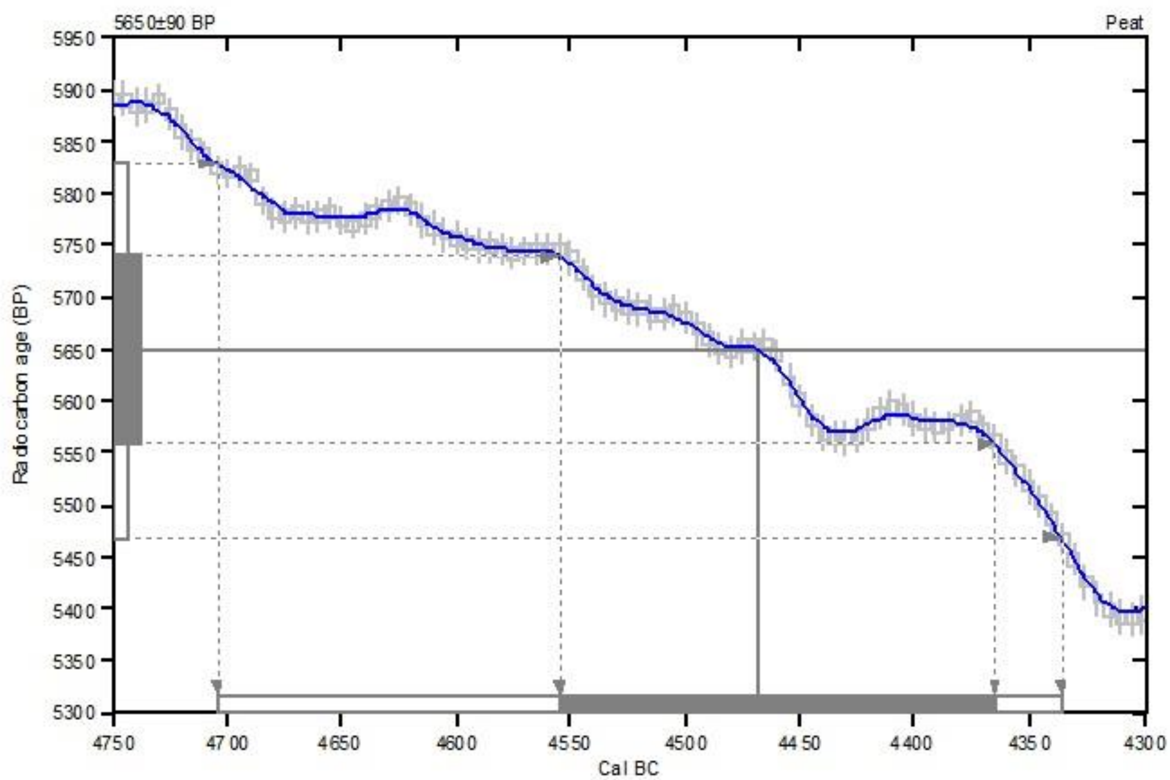
Conventional radiocarbon age: **5650±90 BP**

2 Sigma calibrated result: (95% probability) **Cal BC 4700 to 4340 (Cal BP 6660 to 6290)**

Intercept data

Intercept of radiocarbon age with calibration curve: Cal BC 4470 (Cal BP 6420)

1 Sigma calibrated result: (68% probability) Cal BC 4560 to 4360 (Cal BP 6500 to 6320)



References:

Database used

INTCAL04

Calibration Database

INTCAL04 Radiocarbon Age Calibration

IntCal04: Calibration Issue of Radiocarbon (Volume 46, nr 3, 2004).

Mathematics

A Simplified Approach to Calibrating C14 Dates

Talma, A. S., Vogel, J. C., 1993, Radiocarbon 35(2), p317-322

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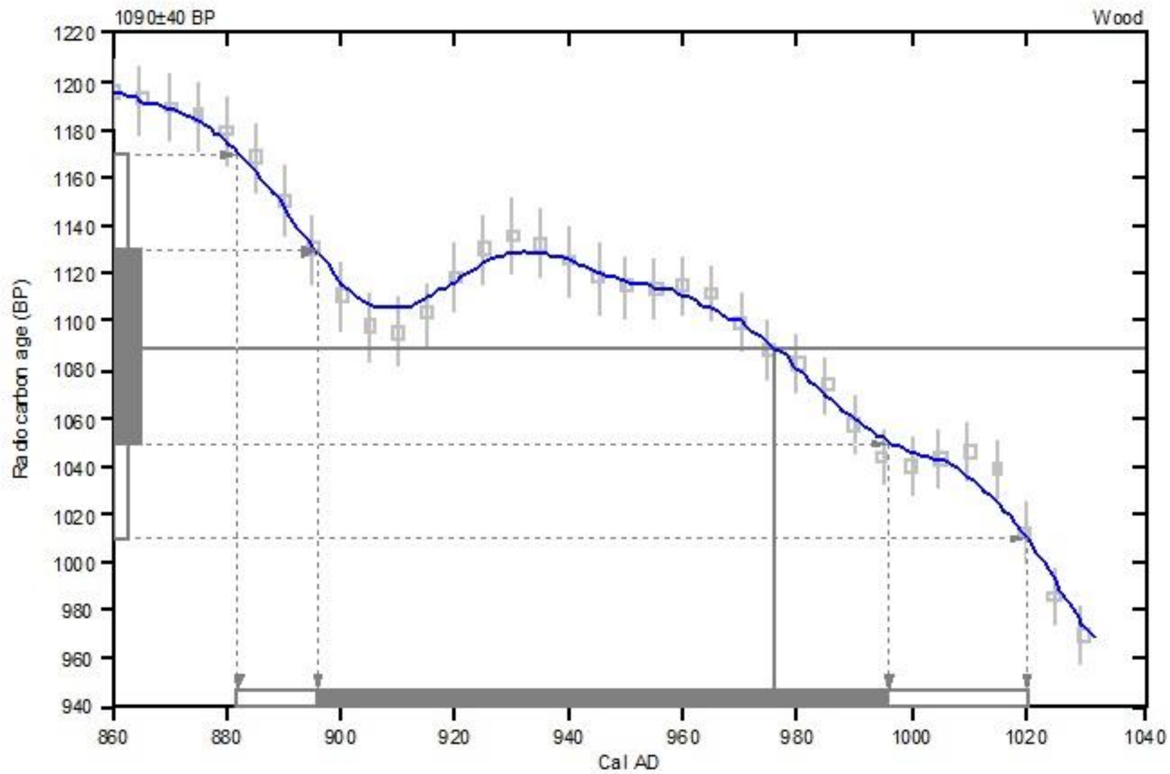
CALIBRATION OF RADIOCARBON AGE TO CALENDAR YEARS

(Variables: C13/C12=-23.9:lab. mult=1)

Laboratory number:	**Beta-225757**
Conventional radiocarbon age:	**1090±40 BP**
2 Sigma calibrated result: (95% probability)	**Cal AD 880 to 1020 (Cal BP 1070 to 930)**

Intercept data

Intercept of radiocarbon age with calibration curve:	Cal AD 980 (Cal BP 970)
1 Sigma calibrated result: (68% probability)	Cal AD 900 to 1000 (Cal BP 1050 to 950)



References:

Database used
INTCAL04
Calibration Database
INTCAL04 Radiocarbon Age Calibration
IntCal04: Calibration Issue of Radiocarbon (Volume 46, nr 3, 2004).
Mathematics
A Simplified Approach to Calibrating C14 Dates
Talma, A. S., Vogel, J. C., 1993, Radiocarbon 35(2), p317-322

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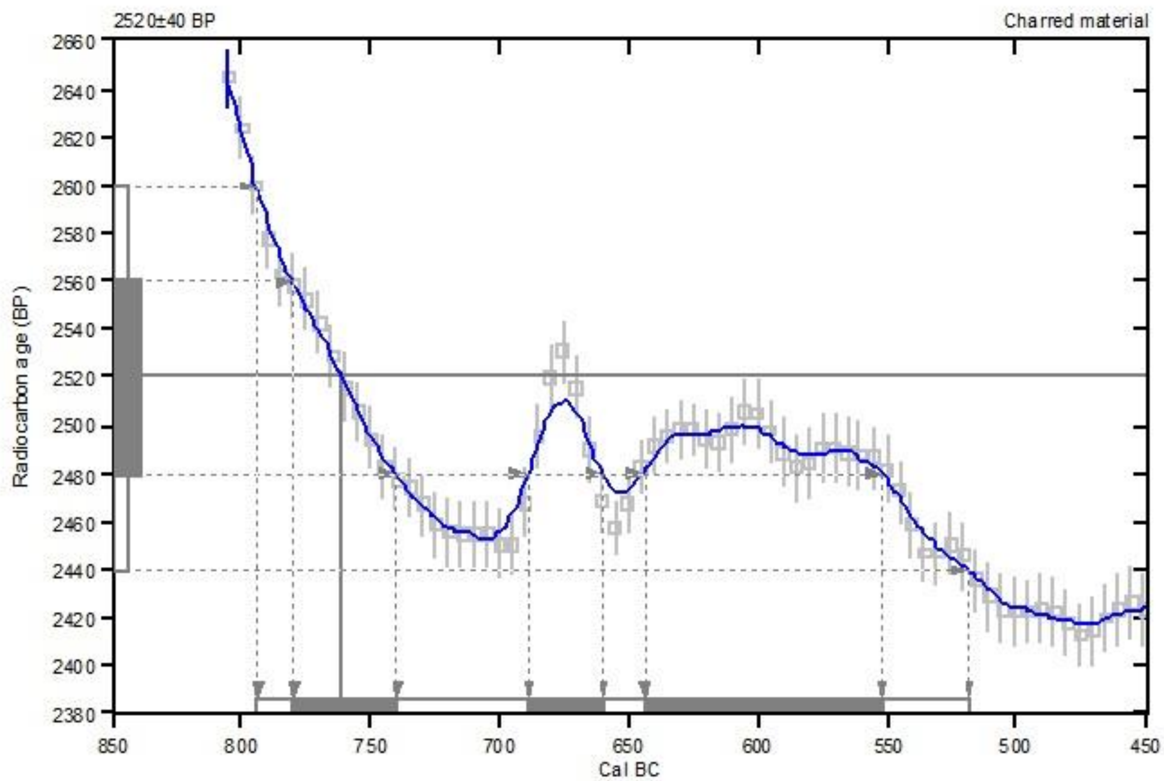
CALIBRATION OF RADIOCARBON AGE TO CALENDAR YEARS

(Variables: C13/C12=-14.2:lab. mult=1)

Laboratory number:	**Beta-225758**
Conventional radiocarbon age:	**2520±40 BP**
2 Sigma calibrated result: (95% probability)	**Cal BC 790 to 520 (Cal BP 2740 to 2470)**

Intercept data

Intercept of radiocarbon age with calibration curve:	Cal BC 760 (Cal BP 2710)
1 Sigma calibrated results: (68% probability)	Cal BC 780 to 740 (Cal BP 2730 to 2690) and Cal BC 690 to 660 (Cal BP 2640 to 2610) and Cal BC 640 to 550 (Cal BP 2590 to 2500)



References:

Database used
INTCAL04
Calibration Database
INTCAL04 Radiocarbon Age Calibration
IntCal04: Calibration Issue of Radiocarbon (Volume 46, nr 3, 2004).
Mathematics
A Simplified Approach to Calibrating C14 Dates
Talma, A. S., Vogel, J. C., 1993, Radiocarbon 35(2), p317-322

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CALIBRATION OF RADIOCARBON AGE TO CALENDAR YEARS

(Variables: C13/C12=-26.8:lab. mult=1)

Laboratory number: **Beta-228847**

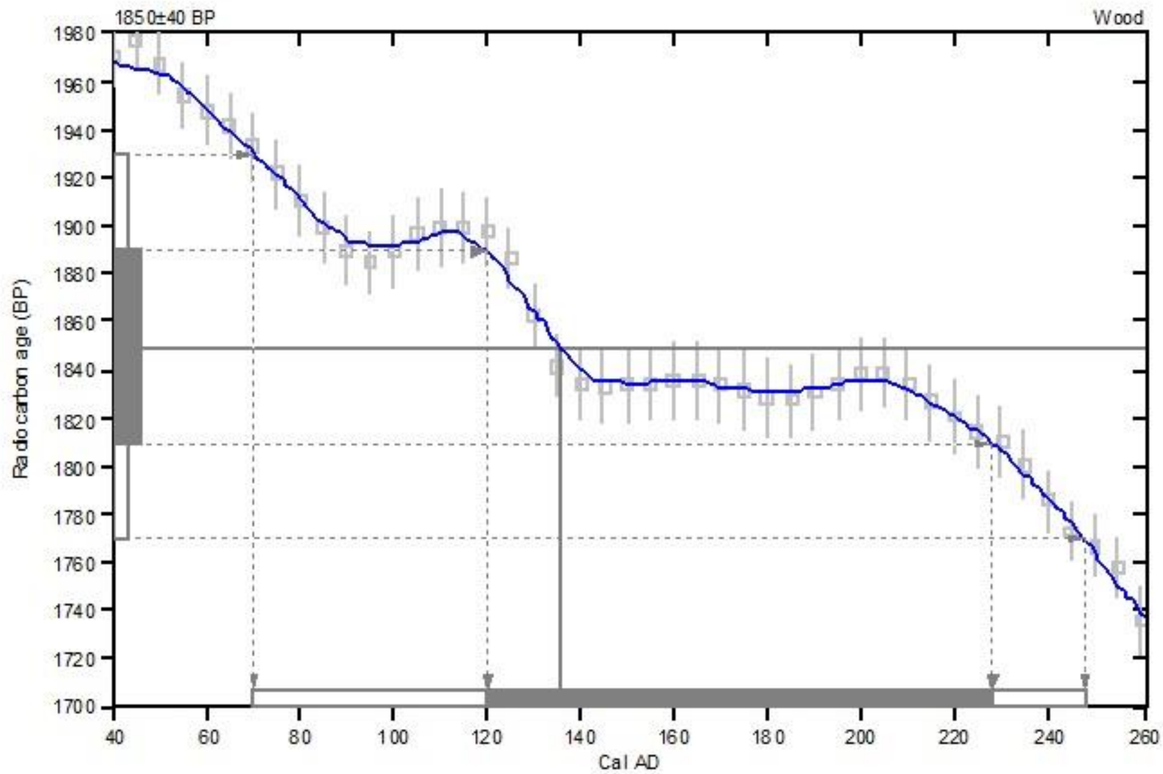
Conventional radiocarbon age: **1850±40 BP**

2 Sigma calibrated result: (95% probability) **Cal AD 70 to 250 (Cal BP 1880 to 1700)**

Intercept data

Intercept of radiocarbon age with calibration curve: Cal AD 140 (Cal BP 1810)

1 Sigma calibrated result: (68% probability) Cal AD 120 to 230 (Cal BP 1830 to 1720)



References:

Database used

INTCAL04

Calibration Database

INTCAL04 Radiocarbon Age Calibration

IntCal04: Calibration Issue of Radiocarbon (Volume 46, nr 3, 2004).

Mathematics

A Simplified Approach to Calibrating C14 Dates

Talma, A. S., Vogel, J. C., 1993, Radiocarbon 35(2), p317-322

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CALIBRATION OF RADIOCARBON AGE TO CALENDAR YEARS

(Variables: C13/C12=-15.9:lab. mult=1)

Laboratory number: **Beta-228848**

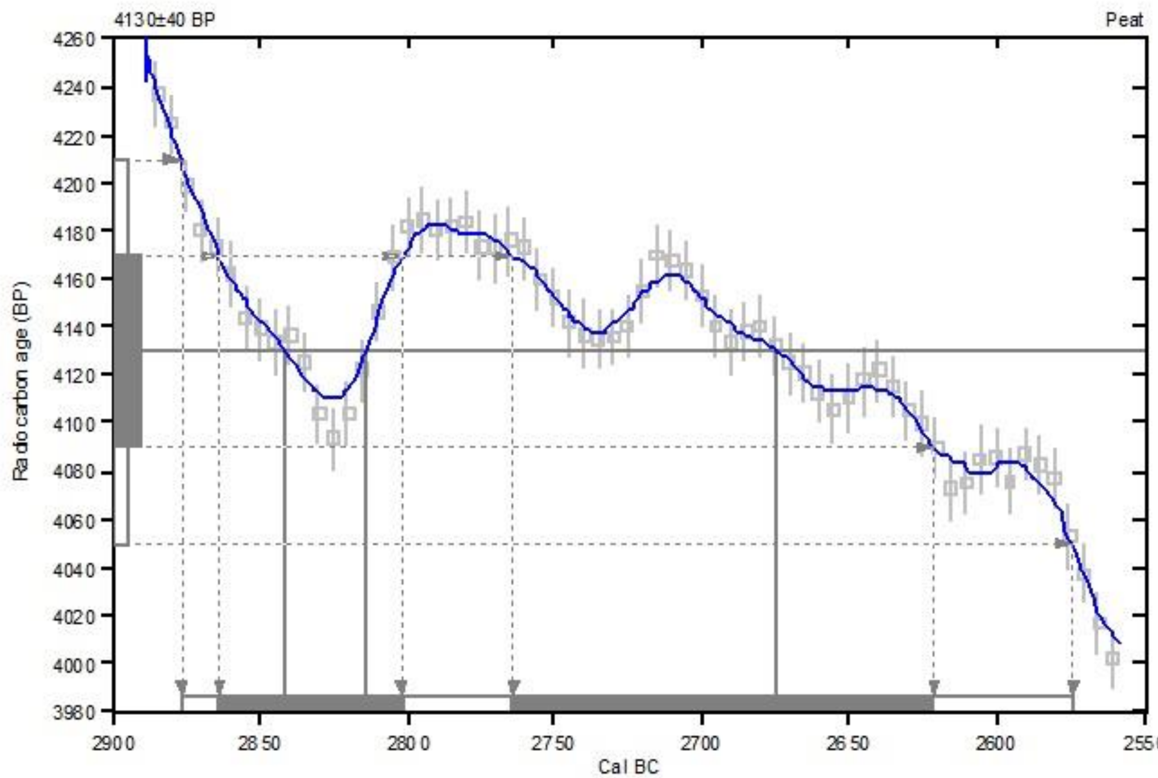
Conventional radiocarbon age: **4130±40 BP**

2 Sigma calibrated result: **Cal BC 2880 to 2570 (Cal BP 4830 to 4520)**
(95% probability)

Intercept data

Intercepts of radiocarbon age
with calibration curve: Cal BC 2840 (Cal BP 4790) and
Cal BC 2810 (Cal BP 4760) and
Cal BC 2670 (Cal BP 4620)

1 Sigma calibrated results: Cal BC 2860 to 2800 (Cal BP 4810 to 4750) and
(68% probability) Cal BC 2760 to 2620 (Cal BP 4710 to 4570)



References:

Database used
INTCAL04
Calibration Database
INTCAL04 Radiocarbon Age Calibration
IntCal04: Calibration Issue of Radiocarbon (Volume 46, nr 3, 2004).
Mathematics
A Simplified Approach to Calibrating C14 Dates
Talma, A. S., Vogel, J. C., 1993, Radiocarbon 35(2), p317-322

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Appendix C
Mollusc Analysis

NY Harbor Area: Molluscs Examined

Request::Curt Larsen

15 Samples from 6 cores

Date In: Spring 2007

Date Out: 9/10/2007

Samples processed by Carlos Budet; sorted by Ruth Ortiz; and identified and categorized by G. Lynn Wingard.

Molluscan species listed in separate Excel File

.

Methods:

Samples were washed through an 850 micron sieve. Fraction less than 850 microns was discarded. Samples were sorted for mollusks and other organic remains. There were three categories of sorting based on the volume of organic material:

1) All of sample scanned and organic remains > 850 microns removed from residue except for the most abundant species. Abundant species removed to point of determining general character of population.

2) All organic remains >850 microns removed from residue.

3) All specimens >850 microns that could be identified were removed from the residue. The remainder of the sample residue >850 microns consists of unidentifiable shell fragments.

Specimens were identified to species level if possible. Each taxonomic group in each sample was divided into 3 generalized abundance categories:

rare - < 5 specimens;

common – 5-15 specimens;

abundant - > 15 specimens.

General condition of the specimens in each group also was noted:

pristine (shells intact and still have luster and/or color);

whole (shells intact but luster all or mostly gone);

worn (shells show obvious signs of wear; may or may not be intact);

broken (> 50% of shell present; has luster);

fragments (< 50% of shell present – any degree of surface condition).

Also, whether adults and juveniles were present was noted for each group.

Ecologic information on species was derived from a number of sources and from field data on modern mollusks (http://sofia.usgs.gov/exchange/flaecohist/).

Results and Discussion:

Samples from **Core A-3 R2/R3** (0.65-0.70 mbs [2.1-2.3 ftbs]) and **Core B-3** (0.60-0.65 mbs [2.0-2.1 ftbs]) in Raritan Bay contain only a few molluscan fragments. The taxa that are present are consistent with either estuarine or marine deposition. In comparison to samples from other cores, the lack of benthic remains in these samples could potentially be indicative of very rapid deposition or a very unfavorable benthic habitat.

Nine of the ten samples from cores **C-2, C-3,** and **C-4** in the Liberty Island transect contain abundant mollusks. The single sample from **C-2** (5.30-5.25 mbs [17.4-17.2 ftbs) contains relatively few mollusks, but the same species are found in cores **C-3** and **C-4** farther out from the island. The predominant molluscan species in samples from **C-3** and **C-4** is *Mulinia lateralis,* with the exception of the sample from 8.65-8.70 mbs (28.4-28.5 ftbs) in **C-3**. The species is present in large numbers, mostly whole or pristine preservation, and both adults and juveniles are present, indicating the specimens are *in situ*. *Mulinia* comprise a significant component of many Atlantic Coast estuaries (Abbott, 1974; Franz and Harris, 1982; Holland and others, 1977; Knox, 1986; Weiss, 1995), tolerating broad ranges of salinity (15 to >40 ppt (Andrews, 1971)), and substrates (mud, clay and sand (Andrews, 1971; Holland and others, 1977)). Knox (1986, p. 184) identifies *Mulinia lateralis* as "very fecund, grows rapidly, matures quickly, and as such is adapted for opportunistic exploitation of resources".

The prevalence of *Mulinia* in these samples from **C-3** and **C-4** many indicate an opportunistic species moving into a changing environment and/or an environment with an available food supply. Associated with *Mulinia* in relatively significant numbers in these samples are *Acteocina canaliculata*, and *Nucula proxima*, also typical of estuarine assemblages with highly variable salinities, shallow water, and fine sand or mud (Abbott, 1974; Weiss, 1995). The presence of oyster fragments in **C-3** from samples at 2.43-2.47, 3.25-3.30, and 3.75-3.80 mbs (7.97-8.10, 10.7-10.8, 12.3-12.7 ftbs) indicates an oyster bed may have been nearby during deposition of this section of the core. The sample from 3.75 to 3.80 mbs (12.3-12.7 ftbs) in **C-3** contains hydrobiids and *Petricolaria pholadiformis*, which may indicate relatively shallow water deposition. Hydrobiids are classified to species level primarily on soft tissue parts, therefore, it is impossible to determine which species is present, but the shell form here is consistent with *Hydrobia totteni*, common in salt-marsh ponds and on seaweeds (Weiss, 1995). *Petricolaria pholadiformis* commonly bores in clay and peat-moss (Abbott, 1974), and is often associated with shallow nearshore to marshy environments. In addition to the prominence of *Mulinia lateralis*, *Acteocina canaliculata*, and *Nucula proxima* in **C-4**, a Pyramidellidae (probably *Turbonilla elegantula*), *Tellina* sp. cf. *T. agilis*, and *Yoldia limatula* are common in many of the samples. The *Anadara* in **C-4** samples from 7.35 to 11.45 mbs (24.11 to 37.57 ftbs), indicate deeper water deposition than **C-3** samples, yet the hydrobiids are also present in **C-4** at 11.30 to 11.45 mbs (37.07 to 37.57 ftbs). All other species in **C-3** and **C-4** (see species occurrence table) are consistent with deposition in a shallow estuarine environment subject to highly variable salinity conditions.

Samples from Jamaica Bay Core **E-2** contain significantly fewer total mollusks than samples from cores C3 and C4. No single species dominates all of the samples, but *Gemma gemma*, a minute infaunal filter feeding clam that is considered a very common shallow water species and is frequently found in Atlantic estuaries (Abbott, 1974; Franz and Harris, 1982; Weiss, 1994) is present in all samples. Hydrobiids also are present in all 3 samples from **E-2**. All other molluscan species (see species occurrence table) are consistent with deposition in a shallow estuarine environment with variable salinity conditions.

References Cited

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Weiss, H.W., 1995, Marine Animals of Southern New England and New York: Bulletin 115, Connecticut Dept. Environmental Protection.

Appendix D-E
Foraminiferal & Pollen Analysis

Pollen Analysis of Sediment Samples from New York Harbor Core C1

Analyst: Christopher Bernhardt

Interpretation: The top 600 cm of the core demonstrates a regional pollen signature. Pine pollen (Pinus) is dominant with oak (Quercus), birch (Betula), hickory (Cayra), and hemlock (Tsuga) pollen sub-dominant. There four trees distribute their pollen over a large area; thererfore, it is assumed that changes in their abundance is regional in nature and does not reflect changes in local marshes or other plant communities. Based on other pollen studies from the Atlantic coast of the United States, fluctuations in pine are most likely regional in nature and related to changes in temperature and/or precipitation (Willard et al, 2005). The abundance of ragweed (Ambrosia) in the top meter of the core tends to indicate that this sediment is post-Colonial in age (Carmichael, 1980; Pederson et al, 2005). Based on other sediment cores collected from the Hudson River (Peteet et al, 2007; Pedeson et al, 2005; Carmichael, 1980) increased percentages of grass (Poaceae), chenopod (Chenopodaceae), and ragweed pollen indicate that the top 250 cm (98 in) could represent the last 400 years of deposition, however radiometric age control for the upper 250 cm (98 in) would make the sedimentation rate more certain.

The bottom 200 cm (98 in) of the core is likely to represent a different vegetational environment from the upper core section. Pine is no longer dominant and oak becomes more abundant. Marsh pollen, Cyperaceae, Chenopodiaceae (chenopods), and Poaceae, increases in the bottom intervals of core C1. The increase in marsh pollen reflects local changes (not regional) in vegetation because marsh pollen is usually not transported long distances. Identification to species level of chenopod pollen is not reliable using light microscopy (Personal observation), however it must be noted that pollen of certain species of chenopod can be indicative of saline conditions. Based on the below foram data, it could be assumed that the pollen around 780 cm (307 in) indicates a saline marsh habitat. The increased abundance of fern spores also indicates that the sediments in this interval were either marsh like or close to land. The low abundance of pine pollen potentially serves as a biostratigraphic marker for the early Holocene. Willard et al. 2005, consistently find pine pollen is below 30% in Early Holocene sediments from the Chesapeake Bay, while percentages higher than 30% are usually indicative of Late Holocene sediments (Willard et al, 2005). Once again, while further dating would confirm the sedimentation history, the near absence in Betula pollen after 700 cm (276 in), could confirm that these sediments are older than 4000 years before present. Sediment cores from the Hudson Highlands indicate a general decline in Betula pollen after 4000 years (Maenza-Gmelch, 1997).

Methodology: Pollen was isolated from sediment samples using standard palynological preparation techniques (Traverse 1988). Samples were processed with HCl and HF to remove carbonates and silicates respectively, acetolyzed (1 part sulfuric acid: 9 parts acetic anhydride) in a boiling water bath for 10 minutes, neutralized, and treated with 10% KOH for 10 minutes in a water bath at 70° C. After neutralization, residues were sieved with 149 µm and 10 µm nylon mesh to remove the coarse and clay fractions, respectively. When necessary, samples were swirled in a watch glass to remove mineral matter. After staining with Bismarck Brown, palynomorph residues were mounted on microscope slides in glycerin jelly.

References:

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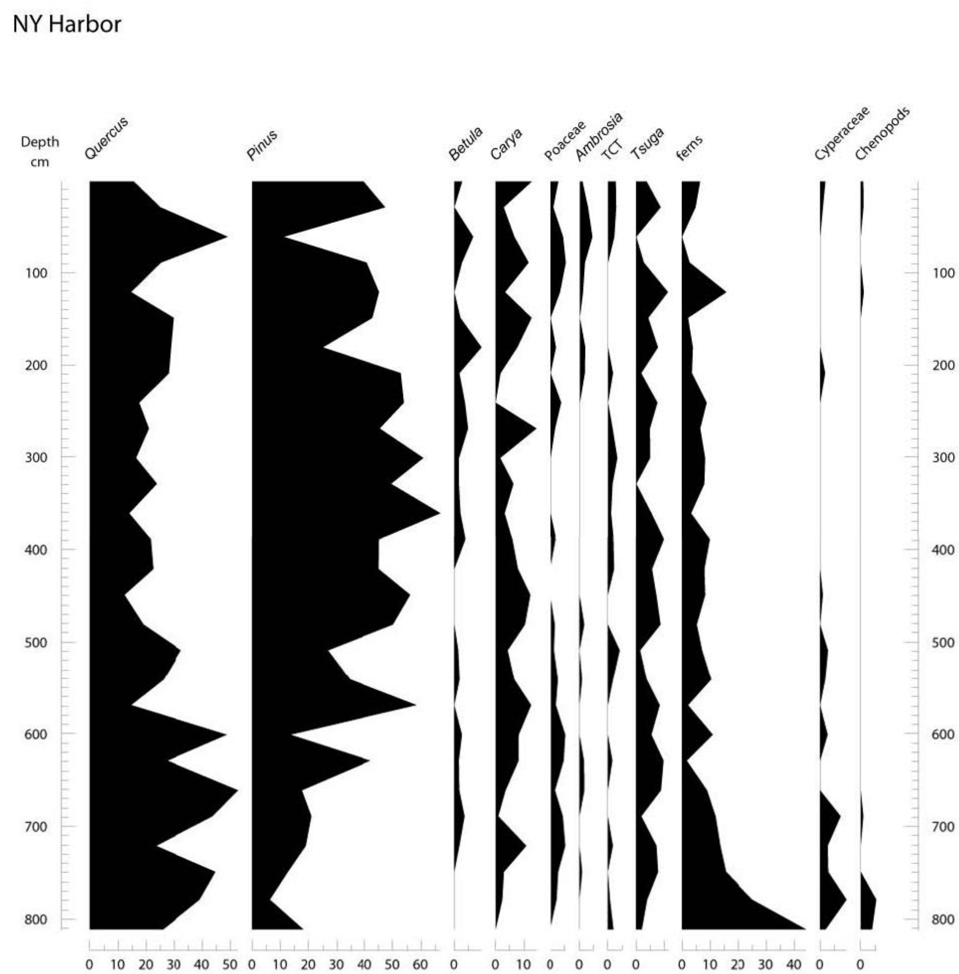
Data: See Attached Excel File

Figure 1. Percent Abundance of Major Pollen Taxa from New York Harbor Core C1



Percent Pollen Abundance Data for Core C-1

Species	0-2cm	28-30cm	60-62cm	88-90cm	120-122cm	148-150cm	180-182cm	208-210	240-242cm	268-269cm	300-302cm	328-330cm	360-362cm
Quercus	15.6	25.0	48.9	25.2	14.6	29.8	28.8	28.1	17.5	21.0	16.4	23.8	14.0
SA0	0.9	2.9	0.0	0.0	3.4	2.1	3.8	3.5	5.0	6.5	3.3	7.9	0.0
Pinus	39.4	47.1	11.1	40.5	44.9	42.6	25.0	52.6	53.8	45.2	60.7	49.2	66.7
UK	1.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Betula	2.8	0.0	6.7	2.7	0.0	2.1	9.6	1.8	3.8	4.8	1.6	1.6	2.2
Carya	12.8	2.9	6.7	11.7	3.4	12.8	7.7	1.8	0.0	14.5	1.6	6.3	3.2
Poaceae	2.8	1.0	4.4	5.4	3.4	0.0	1.9	0.0	3.8	1.6	0.0	0.0	0.0
Ambrosia	0.9	2.9	4.4	1.8	1.1	0.0	1.9	1.8	0.0	0.0	0.0	0.0	0.0
P03	1.8	0.0	2.2	0.9	0.0	2.1	5.8	0.0	1.3	0.0	0.0	0.0	0.0
TCT	2.8	2.9	2.2	0.0	0.0	0.0	0.0	1.8	0.0	1.6	3.3	1.6	1.1
Acer	0.9	0.0	2.2	0.0	0.0	0.0	1.9	1.8	0.0	0.0	0.0	1.6	0.0
Tsuga	3.7	8.7	0.0	2.7	11.2	4.3	7.7	1.8	7.5	4.8	4.9	0.0	5.4
Asteraceae	0.9	0.0	2.2	0.0	1.1	0.0	1.9	0.0	1.3	0.0	0.0	1.6	0.0
SC0	5.5	1.9	0.0	2.7	12.4	0.0	0.0	0.0	3.8	0.0	4.9	0.0	3.2
Cyperaceae	1.8	1.0	0.0	0.0	0.0	0.0	0.0	1.8	0.0	0.0	0.0	0.0	0.0
PC0	1.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.6	0.0
Juglans	0.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Euphorbia	0.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Chenopods	0.9	1.0	0.0	0.0	1.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Myrica	0.9	0.0	0.0	1.8	0.0	4.3	0.0	3.5	0.0	0.0	0.0	0.0	0.0
Typha	0.0	1.0	2.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Ulmus	0.0	1.0	0.0	0.0	1.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Corlyus	0.0	1.0	0.0	0.0	1.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
PC3	0.0	0.0	2.2	0.9	0.0	0.0	0.0	0.0	1.3	0.0	0.0	0.0	0.0
Nyssa	0.0	0.0	2.2	2.7	1.1	0.0	0.0	0.0	1.3	0.0	0.0	0.0	0.0
Ostrya	0.0	0.0	2.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Fagus	0.0	0.0	0.0	0.9	0.0	0.0	1.9	0.0	0.0	0.0	0.0	1.6	1.1
Fraxinus	0.0	0.0	0.0	0.0	0.0	0.0	1.9	0.0	0.0	0.0	1.6	0.0	2.2
picea	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.6	0.0	1.1
tilia	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.6	0.0
alnus	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.6	0.0
onagraceae	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
liriodendron	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
salix	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
sassafrass	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
pink	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Species	388-390cm	420-422cm	448-450cm	480-482cm	508-510cm	540-542cm	568-570cm	600-602cm	628-630cm	660-662cm	688-690cm	720-722cm	748-750cm	778-780cm	810-812cm
Quercus	21.6	22.5	12.2	19.0	32.4	26.2	14.6	48.6	27.4	52.6	43.6	23.4	44.7	39.1	26.0
SA0	5.9	3.4	4.1	3.4	7.0	5.6	2.1	10.8	1.6	3.5	7.3	9.0	6.8	7.8	4.0
Pinus	45.1	44.9	56.1	50.0	26.8	34.6	58.3	13.5	41.9	17.5	20.9	18.9	12.6	6.3	18.0
UK	0.0	1.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.8	0.0	0.8	2.0
Betula	3.9	0.0	0.0	0.0	1.4	1.9	0.0	2.7	1.6	1.8	3.6	1.8	0.0	0.0	0.0
Carya	5.9	7.9	12.2	10.3	4.2	6.5	12.5	8.1	8.1	3.5	0.9	10.8	2.9	2.3	0.0
Poaceae	2.0	0.0	0.0	1.7	1.4	2.8	2.1	5.4	4.8	1.8	4.5	5.4	2.9	2.3	0.0
Ambrosia	0.0	0.0	0.0	1.7	0.0	0.9	0.0	0.0	1.6	1.8	0.0	0.0	1.0	0.0	0.0
P03	0.0	2.2	1.0	0.0	1.4	3.7	0.0	0.0	0.0	0.0	0.0	0.9	0.0	1.6	0.0
TCT	2.0	2.2	0.0	0.0	4.2	1.9	0.0	0.0	1.6	0.0	0.0	1.8	0.0	0.8	2.0
Acer	0.0	0.0	0.0	1.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Tsuga	9.8	5.6	7.1	8.6	1.4	3.7	8.3	5.4	9.7	8.8	1.8	7.2	7.8	3.9	2.0
Asteraceae	0.0	1.1	0.0	0.0	2.8	0.0	0.0	0.0	0.0	0.0	0.0	0.9	0.0	1.6	0.0
SC0	3.9	4.5	4.1	1.7	0.0	4.7	0.0	0.0	0.0	5.3	4.5	4.5	8.7	17.2	40.0
Cyperaceae	0.0	0.0	1.0	0.0	2.8	1.9	0.0	2.7	0.0	0.0	7.3	2.7	2.9	9.4	2.0
PC0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Juglans	0.0	0.0	0.0	0.0	1.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Euphorbia	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Chenopods	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.9	0.0	0.0	5.5	4.0
Myrica	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.9	0.0	0.0	0.0	0.0
Typha	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Ulmus	0.0	1.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.9	0.0	0.8	0.0
Corlyus	0.0	0.0	0.0	0.0	2.8	0.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
PC3	0.0	0.0	0.0	0.0	0.0	1.9	2.1	0.0	0.0	1.8	0.0	0.9	0.0	0.8	0.0
Nyssa	0.0	2.2	0.0	0.0	0.0	0.0	0.0	0.0	1.6	0.0	0.9	0.9	2.9	0.0	0.0
Ostrya	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Fagus	0.0	0.0	0.0	0.0	0.0	1.9	0.0	0.0	0.0	1.8	0.0	0.9	1.9	0.0	0.0
Fraxinus	0.0	0.0	0.0	0.0	1.4	0.0	0.0	0.0	0.0	0.0	0.9	0.0	1.0	0.0	0.0
picea	0.0	1.1	2.0	1.7	4.2	0.0	0.0	0.0	0.0	0.0	0.9	0.9	1.0	0.0	0.0
tilia	0.0	0.0	0.0	0.0	1.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
alnus	0.0	0.0	0.0	0.0	1.4	0.9	0.0	0.0	0.0	0.0	0.9	0.9	0.0	0.0	0.0
onagraceae	0.0	0.0	0.0	0.0	1.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
liriodendron	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.7	0.0	0.0	0.0	1.8	0.0	0.0	0.0
salix	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.9	0.0	0.0	0.0
sassafrass	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.7	0.0	0.0	0.0
pink	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.9	0.0	0.0

Foraminiferal Analysis of Sediment Samples from New York Harbor Core C1

Analyst: Simon Engelhart

Interpretation: The foraminiferal assemblages divide the C1 core into two distinct zones. This distinction is based primarily on the presence/absence of the two dominant calcareous species *Elphidium excavatum* and *Ammonia parkinsoniana*. The top 6 m (20 ft) of the core contains both calcareous and agglutinated foraminifera. The environment is likely to be a shallow water body based on the presence of *Elphidium excavatum*. The combination of this species and *Ammonia parkinsoniana* is typical of a transition environment between marine and marsh sediments especially when coupled with the low species diversity (only four identifiable calcareous species). This section of the core also contains numerous agglutinated species, which is consistent with these forminifer being washed in from nearby marsh sediments, reinforcing the interpretations of a shallow transitional environment.

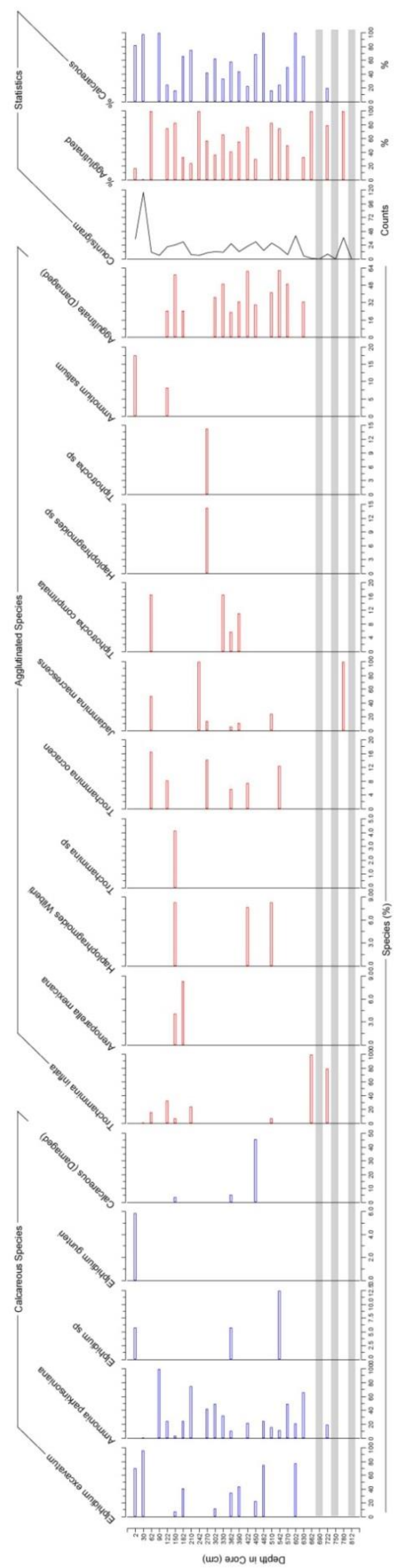
The bottom zone (6.30-8.12 m/20.67-26.64 ft) is characterized by a sudden absence of calcareous foraminifera (with the exception of sample 6.30 and 7.22 m (20.67 and 26.64 ft), which show reduced counts of calcareous species and reduced diversity). Counts per gram are usually lower in this section of core, compared to the upper zone but there is an increase in sample 7.80 m (25.6 ft). This sample is of interest because it has a monospecific assemblage of *Jadammina macresecens*. This species is indicative of a saltmarsh environment, which correlates with the increase in organic nature of the sediment at this depth. The bottom zone contains three samples that contained no foraminifera, indicated by grey boxes on the figure. The sudden increase in the abundance of *Trochammina inflata* in samples 6.62 and 7.22 m (21.72 and 23.69 ft) is also indicative of a move to a more marsh like environment, with a shallowing in water depth from the upper zone.

It is also interesting to note that the mineralogy of the substrate changed between the two zones. The upper zone contained many fine silts with few larger grains, whilst the lower zone was dominated by large quartz grains. These results are also supported by the change in the pollen assemblages at the same point in the core.

In conclusion, the foraminiferal assemblages demonstrate that the C1 core can be subdivided into two differing paleoenvironments. The top section of the core is indicative of a shallow water environment, whilst the bottom section of the core is indicative of a shallower more marsh like environment. It is apparent that sample 7.80 m (25.59 ft) is indicative deposition within a saltmarsh.

Methodology: Foraminifera were separated from the samples following the standard methods of Scott and Medioli (1978). The sample was treated with sodium hexametaphosphate to disperse the clays and silts before being washed through a 500 and 63-micron sieve. The 500 micron and above fraction was saved and analyzed for larger foraminifera, though none were found in core C1. The 500 – 63 micron fraction was analyzed with all foraminifera present being counted and contributing to the final total. Sample weights were noted to allow the calculation of number of foraminifera per gram.

Data: See attached excel file



Percent Foraminifera Abundance Data for Core C-1

Species	0-2cm	28-30cm	60-62cm	88-90cm	120-122cm	148-150cm	180-182cm	208-210	240-242cm	268-269cm	300-302cm	328-330cm	360-362cm
Ammonia parkinsoniana	0.0	1.7	0.0	100.0	25.0	4.2	25.0	75.0	0.0	42.9	50.0	33.3	11.8
Elphidium excavatum	70.6	96.6	0.0	0.0	0.0	8.3	41.7	0.0	0.0	0.0	12.5	0.0	35.3
Elphidium gunteri	5.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Elphidium sp	5.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.9
Calcareous (Unidentifiable)	0.0	0.0	0.0	0.0	0.0	4.2	0.0	0.0	0.0	0.0	0.0	0.0	5.9
Ammotium salsum	17.6	0.0	0.0	0.0	8.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Arenoparella mexicana	0.0	0.0	0.0	0.0	0.0	4.2	8.3	0.0	0.0	0.0	0.0	0.0	0.0
Haplophragmoides sp	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	14.3	0.0	0.0	0.0
Haplophragmoides Wilberti	0.0	0.0	0.0	0.0	0.0	8.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Jadammina macrescens	0.0	0.0	50.0	0.0	0.0	0.0	0.0	0.0	100.0	14.3	0.0	0.0	5.9
Tiphotrocha comprimata	0.0	0.0	16.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	16.7	5.9
Tiphotrocha sp	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	14.3	0.0	0.0	0.0
Trochammina inflata	0.0	1.7	16.7	0.0	33.3	8.3	0.0	25.0	0.0	0.0	0.0	0.0	0.0
Trochammina ocracen	0.0	0.0	16.7	0.0	8.3	0.0	0.0	0.0	0.0	14.3	0.0	0.0	5.9
Trochammina sp	0.0	0.0	0.0	0.0	0.0	4.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Aggultinate (Unidentifiable)	0.0	0.0	0.0	0.0	25.0	58.3	25.0	0.0	0.0	0.0	37.5	50.0	23.5
Counts/gram	**34.7**	**116.0**	**12.0**	**6.0**	**21.4**	**24.0**	**29.3**	**7.0**	**6.1**	**11.1**	**12.7**	**11.8**	**27.0**
% Agglutinated	17.6	1.7	100.0	0.0	75.0	83.3	33.3	25.0	100.0	57.1	37.5	66.7	41.2
% Calcareous	82.4	98.3	0.0	100.0	25.0	16.7	66.7	75.0	0.0	42.9	62.5	33.3	58.8

Species	388-390cm	420-422cm	448-450cm	480-482cm	508-510cm	540-542cm	568-570cm	600-602cm	628-630cm	660-662cm	688-690cm	720-722cm	748-750cm	778-780cm	810-812cm
Ammonia parkinsoniana	0.0	23.1	0.0	25.0	16.7	12.5	50.0	22.2	66.7	0.0	0.0	20.0	0.0	0.0	0.0
Elphidium excavatum	44.4	0.0	23.1	75.0	0.0	0.0	0.0	77.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Elphidium gunteri	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Elphidium sp	0.0	0.0	0.0	0.0	0.0	12.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Calcareous (Unidentifiable)	0.0	0.0	46.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Ammotium salsum	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Arenoparella mexicana	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Haplophragmoides sp	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Haplophragmoides Wilberti	0.0	7.7	0.0	0.0	8.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Jadammina macrescens	11.1	0.0	0.0	0.0	25.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100.0	0.0
Tiphotrocha comprimata	11.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Tiphotrocha sp	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Trochammina inflata	0.0	0.0	0.0	0.0	8.3	0.0	0.0	0.0	0.0	100.0	0.0	80.0	0.0	0.0	0.0
Trochammina ocracen	0.0	7.7	0.0	0.0	0.0	12.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Trochammina sp	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Aggultinate (Unidentifiable)	33.3	61.5	30.8	0.0	41.7	62.5	50.0	0.0	33.3	0.0	0.0	0.0	0.0	0.0	0.0
Counts/gram	**13.0**	**22.8**	**30.2**	**14.8**	**27.3**	**18.6**	**7.7**	**40.0**	**5.7**	**1.5**	**0.0**	**8.3**	**0.0**	**37.0**	**0.0**
% Agglutinated	55.6	76.9	30.8	0.0	83.3	75.0	50.0	0.0	33.3	100.0	0.0	80.0	0.0	100.0	0.0
% Calcareous	44.4	23.1	69.2	100.0	16.7	25.0	50.0	100.0	66.7	0.0	0.0	20.0	0.0	0.0	0.0

Appendix F
Qualifications of Project Personnel

Joseph Schuldenrein, Ph.D.

President and Principal Archeologist

Dr. Joseph Schuldenrein is Principal Archeologist and President of Geoarcheology Research Associates (GRA). A former Fulbright Fellow in Geology and Archaeology (Hebrew University, Israel) and Fellow of the Field Museum of Chicago, Dr. Schuldenrein received his Ph.D. in environmental archeology at the University of Chicago in 1983. His professional experience includes work across the entire Eastern Woodlands as well in all geographic areas west of the Mississippi River. Internationally he has consulted on projects in Central Europe, the entire Middle East, India and eastern and southern Africa. He is involved in research on Human Origins, early civilizations (South Asia) and site formation process in the Middle Atlantic region of North America and elsewhere. Dr. Schuldenrein has served as Principal Investigator on over 80 archeological and paleoenvironmental projects with a wide variety of clients in the federal, state, local and private sectors. He is the liaison between the Register of Professional Archeologists (RPA) and the Society for Archaeological Sciences (SAS), as well as past president of the Professional Archaeologists of New York City (PANYC). He has published widely in key professional journals including American Antiquity, Journal of Field Archaeology, Geoarchaeology, Journal of Archeological Sciences, and has contributed to numerous edited volumes.

In recent years, Dr. Schuldenrein has been extensively involved in large scale project management, attempting to integrate the various disciplines within CRM. He is also active in the Society for American Archaeology's drive to restructure educational priorities in higher education towards empirical and applied objectives. Dr. Schuldenrein has been a reviewer on numerous funding and granting panels and has appeared on television and radio to advance the exposure of professional archeology.

Education

Ph.D. 1983	University of Chicago Anthropology
M.A. 1976	University of Chicago Anthropology
B.A. 1971	State University of New York at Stony Brook Anthropology

Employment History

1989-present	President/Principal Archeologist, Geoarcheology Research Associates, Riverdale, New York
1997-present	Visiting Scholar, Department of Anthropology, New York University, New York, New York
1988-1989	Principal Archeologist and Geomorphologist, John Milner Associates, Inc., West Chester, Pennsylvania
1982-1988	Senior Cultural Resource Manager, Gilbert/Commonwealth, Reading, Pennsylvania
1980-82	Cultural Resource Manager, Gilbert/Commonwealth, Jackson, Michigan

Fellowships and Grants

1967-71	New York State Regents Scholarship
1974-75	University Fellowship, Department of Anthropology, University of Chicago
1975-76	Field Museum of Chicago Fellowship
1976-78	Fulbright-Hays Fellowship for Overseas Research Government of Israel Research Grant

Honors and Committee Appointments

1999	Executive Board, Archeology Division, American Anthropological Association
1999	Chair, SAA Committee on Finance and Investments
1998	Invited Participant on SAA Sponsored Workshop on Methods for the Improvement of Undergraduate and Graduate Education in Public Archeology and Cultural Resources Management. Wakulla Springs, FL
1996	Program Committee and Reviewer, 61st Annual SAA Conference, New Orleans, LA
1996	President of the Professional Archaeologists of New York City (PANYC)
1996	Reviewer for Geo-Archeology: An International Journal, Journal of Field Archaeology, and American Antiquity
1993-1995	Board Member of the Professional Archaeologists of New York City (PANYC)
1994-present	Society for American Archaeology (SAA) Task Force on Consulting Archaeology
1993-1995	Society for American Archaeology (SAA) Membership Committee
1992-94	Board Member SOPA; Society for Archaeological Sciences (SAS) Representative to SOPA
1991-94	SOPA Certification Committee for Archeometry and Archeological Sciences
1986-87	Grant and Proposal Reviewer, Anthropology Program, National Science Foundation.
1986	Listing in Who's Who in the Midwest, 1987 (21st) edition.
1986	Reviewer for Geo-Archeology: An International Journal.
1985	Invited panelist to workshop on Applications of High Technology to Archeological Cultural Resource Management Issues. Organized by Office of Technology Assistance, Washington, D.C.

Selected Publications

2007	Harappan Geoarchaeology Reconsidered: Holocene Landscapes and Environments of the Greater Indus Plain (with R.P. Wright and M. Afzal Khan). In Settlement and Society: Essays Dedicated to Robert McCormick Adams (E. Stone, ed.): 83-116. Cotsen Institute of Archaeology, Volume 3. UCLA.
2007	A Reassessment of the Holocene Stratigraphy of the Wadi Hasa Terrace and Hasa Formation, Jordan. Geoarchaeology 22 (6): 559-588.
2007	Landscape Archaeology in Lower Manhattan: The Collect Pond as an Evolving Cultural Landmark in Early New York City (with R. Yamin). In Envisioning Landscape: Situations and Standpoints in Archaeology and Heritage (D. Hicks, L. McAtackney, and G. Fairclough, eds): 75-100. Left Coast Press, Walnut Creek, CA.
2007	Emergence of Geoarchaeology in Research and Cultural Resource Management: Part II. The SAA Archaeological Record 7 (1): 16-24
2006	Emergence of Geoarchaeology in Research and Cultural Resource Management: Part I. The SAA Archaeological Record 6 (5): 11-14.
2005	The Beas River Landscape and Settlement Survey: Preliminary Results from the Site of Vaniwal (with R.P. Wright, M. Afzal Khan, and S. Malin-Boyce). In South Asian Archaeology 2003 (U. Franke-Vogt and H.-J. Weisshaar eds): 101-110. Proceedings of Seventeenth International Conference of the European Association of South Asian Archaeologists (7-11 July, 2003, Bonn). Aachen.

2004 Landscapes, Soils, and Mound Histories of the Upper Indus Valley, Pakistan: New Insights on the Holocene Environments Near Ancient Harappa (with R.P. Wright, M.R. Mughal, and M. Afzal Khan). Journal of Archaeological Science 31 (6): 777-797.

2003 Landscapes, Activity, and the Acheulean to Middle Paleolithic Transition in the Kaladgi Basin, India (with M.D. Petraglia and R. Korisettar). Eurasian Prehistory 1(2): 3-24.

2003 Landscape Change, Human Occupation, and Archaeological Site Preservation at the Glacial Margin: Geoarchaeological Perspectives from the Sandts Eddy Site (36Nm12), Middle Delaware Valley, Pennsylvania. In Geoarchaeology of Landscapes in the Glaciated Northeast (D.L. Cremeens and J.P. Hart eds.): 181-210. New York State Museum Bulletin 497. Albany, New York.

2003 Prehistoric Landscapes and Settlement Geography along the Wadi Hasa, West-Central Jordan. Part II: Towards a Model of Palaeoecological Settlement for the Wadi Hasa (with G.A. Clark). Environmental Archaeology 8: 1-16.

2003 An Extensive Middle Paleolithic Quarry Landscape in the Kaladgi Basin, Southern India (with M. Petraglia, R. Korisettar, and M. Noll). Antiquity 77 (295).

2002 Geoarchaeological Perspectives on the Harappan Sites of South Asia. In Indian Archaeology in Retrospect, Volume II (Protohistory) (Settar, S. and Korisettar, R., eds.): 47-80. New Delhi, India. Manohar and Indian Council of Historical Research.

2001 Urbanism in the Indus Valley: Environment and Settlement on the Beas River (with R.P. Wright and M.A. Khan). In Dialogue Among Civilizations: The Indus Valley Civilization (M.A. Halim and A. Ghafoor, eds): 102-113. Special UNESCO Volume. Government of Pakistan, Islamabad

2001 Prehistoric Landscapes and Settlement Geography along the Wadi Hasa, West-Central Jordan. Part I: Geoarchaeology, Human Palaeoecology and Ethnographic Modelling (with G.A. Clark). Environmental Archaeology 6: 25-40.

2001 Stratigraphy, Sedimentology, and Site Formation at Konispol Cave, Southwest Albania. Geoarchaeology 16(5): 559-602.

2000 Pennsylvania Geoarcheology and Cultural Resource Management: An Assessment of Achievements and Shortcomings. Journal of Middle Atlantic Archaeology 16: 13-26.

2000 Archeological Education and Private Sector Employment (with J.H. Altschul). In Teaching Archaeology in the Twenty-First Century (S. J. Bender and G.S. Smith, eds.): 59-64. Society for American Archaeology. Washington, D.C.

2000 Refashioning Our Profession: Practical Skills, Preservation, and Cultural Resource Management. In Teaching Archaeology in the Twenty-First Century (S. J. Bender and G.S. Smith, eds.): 133-139. Society for American Archaeology. Washington, D.C.

1999 Reply to Comment by William R. Farrand on "Konispol Cave, Southern Albania, and Correlations with Other Aegean Caves Occupied in the Late Quaternary" Geoarchaeology 14(5): 473-478.

1999 Charting a Middle Ground in the NAGPRA Controversy: Secularism in Context. Bulletin of the Society for American Archaeology 17 (4): 22-23.

1999 The Palaeolithic of Southernmost Albania (with F.B. Harrold and others). In The Palaeolithic Archaeology of Greece and Adjacent Areas (G.N. Bailey, E. Adam, E. Panagopoulou, C. Perles and K. Zachos, eds.): 361-372. British School at Athens Studies 3. Nottingham.

1998 Wyoming Valley Landscape Evolution and the Emergence of the Wyoming Valley Culture (with D.M. Thieme). Pennsylvania Archaeologist 68(2): 1-17.

1998 Geomorphology and Stratigraphy of Prehistoric Sites along the Wadi al-Hasa. In The Archaeology of the Wadi al-Hasa, West Central Jordan, Volume I: Surveys, Settlement Patterns and Paleoenvironments (N. Coinman, ed.): 205-228. Anthropological Research Papers No. 50. Arizona State University

1998 Changing Career Paths and the Training of Professional Archaeologists: Observations from the Barnard College Forum: Part II. Bulletin of the Society for American Archaeology 16 (3): 26-29.

1998 Konispol Cave, Southern Albania, and Correlations with Other Aegean Caves Occupied in the Late Quaternary. Geoarchaeology 13(5): 501-526.

1998 Changing Career Paths and the Training of Professional Archaeologists: Observations from the Barnard College Forum: Part I. Bulletin of the Society for American Archaeology 16 (1): 31-33.

1998 The Eastern Al-Hasa Late Pleistocene Project: A Preliminary Report on the 1997 Season. (with D. I. Olszewski and others). Annual of the Department of Antiquities of Jordan 42:53-74.

1997 Chronostratigraphic Contexts of Middle Paleolithic Horizons at the 'Ain Difla Rockshelter (WHS 634), West-Central Jordan (with G.A. Clark and others). In The Prehistory of Jordan II. Perspectives from 1997. Studies in Early Near Eastern Production, Subsistence, and Environment 4 (H.G.K. Gebel, Z. Kafafi, and G.O. Rollefson, eds.): 77-100. Berlin, ex oriente.

1997 WHS 1065 (Tor at-Tariq): An Epipaleolithic Site in its Regional Context (with M.P. Neeley and others). In Studies in the History and Archaeology of Jordan VI: 219-225.

1997 Prehistory and Holocene Floodplain Evolution Along the Inner Coastal Plain of Virginia: A Case Study From the Chickahominy Drainage (with D. Blanton). In Proceedings of the Second International Conference on Pedoarchaeology (A.C. Goodyear and J.E. Foss, eds.): 75-95. University of South Carolina Press.

1997 High Resolution Paleoclimatic Trends for the Holocene Identified Using Magnetic Susceptibility Data from Archaeological Excavation in Caves (with B. Ellwood and others). Journal of Archaeological Science 24: 569-573.

1996 Geoarchaeology and the Mid-Holocene Landscape History of the Greater Southeast. In Archaeology of the Mid-Holocene Southeast,(Kenneth E. Sassaman and David G. Anderson, eds.): 3-27. University Press of Florida.

1995 The Care and Feeding of of Archaeologists: A Plea for Pragmatic Training in the 21st Century. Bulletin of the Society for American Archaeology 13 (3): 22-24.

1995 Prehistory and the Changing Holocene Geography of Dogan Point. In Dogan Point: A Shell Matrix Site in the Lower Hudson Valley. Publications in Northeastern Anthropology No. 14 (C. Claassen, ed.): 39-64.

1995 Geochemistry, Phosphate Fractionation and the Detection of Activity Areas at Prehistoric North American Sites. In Pedological Perspectives in Archaeology Research Proceedings, (Mary Collins, ed.): Soil Science Society of America Special Publication No. 44: 107-132

1994 Wadi el Hasa: Geomorphology and Prehistory. American Journal of Archaeology 98(3):528-529.

1994 Alluvial Site Geoarcheology of the Middle Delaware Valley: A Fluvial Systems Paradigm. Journal of Middle Atlantic Archaeology 10:1-21.

1994 Landscape and Prehistoric Chronology of West-Central Jordan (with G.A. Clark). Geoarchaeology 9(1)31-55.

1992 Wadi Al-Hasa Paleolithic Project - 1992: Preliminary Report (with G.A. Clarke and others). Annual of the Department of Antiquities of Jordan 36:13-23.

1992 The Padula Site (36Nm12) and Chert Resource Exploitation in the Middle Delaware River Valley (with C. Bergman and others). Archaeology of Eastern North America 20:39-45.

1991 Archaeology of the Lower Black's Eddy Site, Bucks County, Pennsylvania: A Preliminary Report (with R. Kingsley and others). Pennsylvania Archaeologist 61(1):19-75.

1991 Coring and the Identity of Cultural-Resource Environments: A Comment on Stein. American Antiquity 56(1):131-137.

1990 Depositional History of an Archeologically Dated Floodplain, Haw River, North Carolina (with C.E. Larsen). In Geological Society of America, Centennial Special Volume 4 (N. Lasca and J. Donahue, eds.): 161-181. Geological Society of America, Boulder.

1988 Excavations at Middle, Upper and Epipaleolithic Sites in the Wadi Hasa, West Central Jordan (with G.

A. Clark and others). In The Prehistory of Jordan (A. N. Garrard and H. G. Gebel, eds.), B.A.R. International Series 396:209-285.

1986 Paleoenvironment, Prehistory, and Accelerated Slope Erosion Along the Central Coastal Plain of Israel: A Geoarcheological Case Study. Geoarcheology 1(1):61-81.

1986 Geoarchaeology of the Kurkar Ridges on the Coastal Plain of Israel. Oxford Polytechnic Discussion Papers in Geography: No. 23. Oxford.

1984 Towards a Geo-archeological Context for Saginaw Valley Prehistory: A Perspective from CRM. Michigan Academician 16(3):353-369.

1983 Late Quaternary Paleo-environments and Prehistoric Site Distributions in the Lower Jordan Valley, Israel. Ph.D. Dissertation, University of Chicago.

1983 Early Archaic Settlement on the Southeastern Atlantic Slope: A View From the Rucker's Bottom Site, Elbert County, Georgia (with David G. Anderson). North American Archeologist 4(3):177-210.

1983 Mississippian Period Settlement in the Southern Piedmont: Evidence from the Rucker's Bottom Site, Elbert County, Georgia (with David G. Anderson). Southeastern Archeology 2(2):98-117.

1981 Late Quaternary Paleo-environments and Prehistoric Site Distributions in the Lower Jordan Valley: A Preliminary Report (with P. Goldberg). Paleorient 7:57-75.

1980 Gilgal, A Pre-Pottery Neolithic Site in the Lower Jordan Valley (with T. Noy and E. Tchernov). Israel Exploration Journal 30:63-82.

1978 Paleo-geographic Implications of Prehistoric Settlement Systems in the Central Illinois Valley. Anthropology 2:47-63.

1978 Late Quaternary Stratigraphy and Prehistory of the Lower Jordan Valley. Metequfat Ha'even 17.

1976 Bio-physical and Paleo-ecological Dimensions of Site Settlement Variability in the Central Riverine (Midwestern) Archaic. M.A. Thesis, University of Chicago.

1976 Occupational Terraces and Natural Stratigraphy in the Central Illinois Valley: The Beardstown Terrace Complex. Transactions of the Illinois Academy of Sciences 69:122-44.

Selected Presentations at Professional Meetings

2009 "The River Runs Through It": Can We Get Beyond Alluvial Geoarchaeology? Pennsylvania Statewide Conference on Heritage, Byways to the Past X, Harrisburg, Pennsylvania.

2009 Geoarchaeology at Leetsdale: Reconstructing Prehistoric Landscapes of the Upper Ohio Valley. Geological Society of America, Annual Meeting, Portland, Oregon.

2008 From Harappa to the Hudson: Archaeo-climatic Modeling in Global Context. Society for American Archaeology Annual Meetings in Vancouver, British Columbia.

2008 Geoarchaeology on the Edge: Submerged, near-Shore and off-Shore Landscapes of New York Harbor and Early Manhattan Island. Geological Society of America Meeting, Houston, Texas.

2008 Working with the military: Not evil, just necessary. World Archaeological Congress, Dublin, Ireland.

2008 Landscape archaeology of contemporary genocide:Exhumation of a mass grave in Muthanna Province, Iraq. Society for Historical Archaeology, Albuquerque, New Mexico.

2007 "Landscapes at the Edge": Geomorphology and Archaeology at the Margins of Raritan Bay. Middle Atlantic Archaeological Conference. Virginia Beach, Virginia.

2007 Innovative Uses of OSL Dating for Interpreting Suspected Prehistoric Quarries: A Case Study in the Glaciated Terrain of Northeast Pennsylvania, USA. New World Luminescence Dating and Dosimetry Workshop, Chicago, Illinois.

2007	Archaeoclimatology: Applications of a Century-Resolution, Site-Specific, Climate Model to Indus Culture History. Annual Meeting of the Society for American Archaeology, Austin, Texas.
2007	The Changing Face of Geoarchaeological Investigations in CRM: Lessons Learned and Future Planning. New York Archaeological Council Meeting, Albany, New York.
2007	The Emergence of the Tanning Industry In Lower Manhattan--A Landscape Perspective. Professional Archaeologists of New York City (PANYC) 27th annual public program.
2006	Landscape History and Geoarchaeological Systematics of the Delaware Valley. Geological Society of America Meeting, Philadelphia, Pennsylvania.
2006	Geoarchaeological Systematics of Delaware Valley Landscapes: Regional and Extra-Regional Correlations. Eastern States Archological Federation 73rd Annual Meeting.
2006	Geoarchaeology and Site Formation in Complex Depositional Environments: Paradigms for Planning. Transportation Research Board of the National Academies 85th Annual Meeting.
2006	"Beneath These Mean Streets": Reconstructions of Lower Manhattan's Prehistoric and Historic Landscapes. Geoarcheology 6, Exeter, United Kingdom.
2004	Geoarchaeological Perspectives on Prehistoric Settlement of the Wadi el Hasa. Eastern Mediterranean/Near Eastern Geoarchaeology Meeting of Arbeitskreis Geoarchäologie, University of Tübingen, Germany.
2004	Regional Stratigraphy and Human Paleoecology of the Jordan Rift Valley. Geological Society of America Meeting, Denver, Colorado.
2003	"Yours for $24": The Richness of Manhattan's Buried Archeological Landscapes. Geological Society of America Meeting, Seattle, Washington.
2003	The Great American Disconnect: Traditional archaeology, cultural resources and the emerging global archeological paradigm. World Archaeological Congress, Washington, D.C.
2000	Geoarchaeology in New Jersey and Beyond. Archaeological Society of New Jersey, Spring Meeting, Newark, NJ.
1999	An Overview of Geoarcheological Applications for DOT Projects in the Northeast. Transportation Research Board Summer Workshop, Madison, Wisconsin.
2000	Modeling site formation and preservation in northeastern Pennsylvania: examples from the Susquehanna and Delaware Valley floodplains. The New York Natural History Conference VI, Albany, New York.
1999	Historic sedimentation and site formation process in the Middle Atlantic Province. Middle Atlantic Archaeological Conference, Harrisburg, Pennsylvania.
1996	Early Holocene Paleo-geography of the Middle Atlantic Region: Synthetic Perspectives. Presented at the Sixty-first Annual Meeting of the Society for American Archaeology, New Orleans, Louisiana.
1995	Prehistory and Geography of the Northern Aegean: Perspectives from Konispol Cave, Northern Albania. Presented at the Ninety-first Annual Meeting of the Association of American Geographers, Chicago, Illinois.
1994	Alluvial Site Geoarcheology of the Eastern Woodlands: Towards a Pan-Regional Paradigm. Presented at the Fifty-first Southeastern Archaeological Conference, Lexington, Kentucky.
1994	Prehistoric Geography of the Hudson Valley: Interdisciplinary Perspectives. Presented at the Reconstructing Past Landscapes: Methods and Case Studies Symposium, Barnard College, New York City. Sponsored by the Professional Archaeologists of New York City.
1994	"Small Site" Pedo-Archeology: Research Strategies for Limited Scopes of Work (Dennis Blanton). Presented at the Second International Conference on Pedo-Archaeology, Columbus, South Carolina.
1994	The Changing Holocene Geography of Dogan Point: Archaic Period Perspectives. Conference on the Archaeology of the Hudson Valley, New York State Museum, Albany, New York.

1993 Patterned Variability in Soil Environments and Archeological Deposits Across North America. Presented at the 85th Annual Meeting of the American Society of Agronomy, Crop Science of America, and Soil Science Society of America, Cincinnati, Ohio.

1993 Earth Science Perspectives on Archeology. Presented at the Harrisburg Area Geological Society in collaboration with Pennsylvania Archeological Week.

1993 The Geomorphic Background to Prehistoric Occupation of the Middle Delaware Valley. Presented at the Fifty-eighth Annual Meeting of the Society for American Archaeology, St. Louis, Missouri.

1993 Landscape Archeology and the Formulation of Site Sensitivity Models in Pennsylvania. Presented at the 1993 Middle Atlantic Archaeology Conference, Ocean City, Maryland.

1992 The Geoarcheology of Pennsylvania Drainages: Guidelines for Research and CRM Planning. Presented at the Fifty seventh Annual Meeting of the Society for American Archaeology, Pittsburgh.

1992 Floodplain Dynamics, Site Formulation, and Interpretations of the Archeological Record: A Case Study from the Mayview Site, Upper Ohio Valley. Presented at the 1992 Middle Atlantic Archaeology Conference, Ocean City, Maryland.

1991 Geo-archeological Observations in West-Central Jordan. Presented at the Fifty fifth Annual Meeting of the Society for American Archeology, New Orleans.

1991 Guns in My Backyard: The Evolution of a Military Neighborhood in Staten Island. Presented at the Eleventh Annual Symposium of the Archaeology of New York City, New York.

1989 Soil Phosphate "Prints" and the Detection of Activity Loci at Prehistoric Sites. Presented at the Fifty fourth Annual Meeting of the Society for American Archeology, Atlanta.

1988 Implications of Subsoil Lamellae for Reconstructing Prehistoric Occupation Surfaces. Presented at the Fryxell Symposium on Inter-disciplinary Archeological Studies, Fifty-third Annual Meeting of the Society for American Archeology, Phoenix.

1986 Dynamic Paleo-geography and the Prehistoric Occupation of the Upper Savannah River Valley. Presented at the Symposium on Paleogeographic Research in the United States, Fifty-first Annual Meeting of the Society for American Archeology, New Orleans.

1985 Processes of Geological and Archeological Sedimentation at a Pawnee Hunting Site, 25LP8, Nebraska. Presented at the Forty-third Annual Plains Conference, Iowa City, Iowa.

1984 A Preliminary Report of Archeological and Environmental Investigations at 25LP8, Nebraska (with D. C. Roper). Presented at the Forty-second Annual Plains Conference, Lincoln, Nebraska.

1984 The Geomorphic Background to Prehistoric Settlement at Piñon Canyon, Colorado. Presented at the Forty-ninth Annual Meeting of the Society for American Archeology, Portland.

1984 Geoarcheological, Historic Archeological, and Historic Investigations at Blue Water Bridge, Port Huron, Michigan (with J. R. Kern). Presented at the Annual Meeting of the Society for Historic Archeology,Williamsburg, Virginia.

1983 Human Ecology and Prehistory Along the Savannah River: A Geo-archeological Perspective (with David G. Anderson). Presented at the Symposium on Science and Archeology in the Southeast, Forty-eighth Annual Meeting of the Society for American Archeology, Pittsburgh.

1983 The Prehistory and Environmental Background to Settlement in the Red Rock Reservoir, Central Des Moines River Valley, Iowa (with D. C. Roper). Presented at the Twenty-ninth Midwest Archeological Conference, Iowa City.

1982 Geo-archeological Investigations at Rucker's Bottom, a Multi-component Site at the Richard B. Russell Reservoir, Georgia. Presented at the Forty-seventh Annual Meeting of the Society for American Archeology, Minneapolis.

1982 Archeo-stratigraphy and Geomorphic Dynamism at the Palmahim sites, Israel. Presented at the Eleventh International Congress on Sedimentology, Hamilton, Ontario, Canada.

1982 The Early Archaic Component at the Rucker's Bottom Site, Georgia (with David G. Anderson).

Presented at the Thirty-ninth Annual Meeting of the Southeastern Archeological Conference, Memphis.

1981 Holocene Alluviation Sequences and the Archaic Succession in the Southeastern Interior: Observations on Synchroneity in the Geoarcheological Record. Presented at the Forty-sixth Annual Meeting of the Society for American Archeology, San Diego.

1980 Late Quaternary Environments and Prehistoric Occupation of the Lower Jordan Valley. Presented at the Forty-fifth Annual Meeting of the Society for American Archeology, Philadelphia.

1980 The Application of Micromorphological Analysis to Archeological Soils: A Case Study from the lower Jordan Valley. Presented at the Annual Meeting of the Geological Society of America, Atlanta.

1978 Soil Catenary Relations and Prehistoric Site Distributions Along the Coastal Plain of Israel. Presented at the Israel Geological Society Congress on "The Quaternary of the Coastal Plain," Jerusalem, Israel.

1975 Early Prehistory and Geomorphology Along the Central Illinois Valley. Presented at the Twentieth Annual Midwestern Archeological Conference, Ann Arbor.

Symposia Chaired at Professional Meetings

1992 Geoarchaeology and Site Mitigation Concepts, Applications and Regulatory Requirements. Symposium sponsored by Z-Environmental Services, Harrisburg, PA.

1992 Management of Cultural Resources. Fifty seventh Annual Meeting of the Society for American Archeology, Pittsburgh.

1991 Geoarcheology from Forensics to Landscapes. Fifty fifth Annual Meeting of the Society for American Archeology, New Orleans.

1981 The Haw River Archeological Project: Methodological Advances in Southeastern Prehistory and Geoarcheology. Forty-sixth Annual Meeting of the Society for American Archeology, San Diego.

Professional Affiliations

American Anthropological Association

Archaeological Institute of America

American Quaternary Association

International Society of Sedimentologists

Geological Society of America

National Geographic Society

New York State Archaeological Association

Professional Archaeologists of New York City

Register of Professional Archaeologists
Smithsonian Association

Society for American Archaeology

Society for Archaeological Science

Society for Pennsylvania Archeology

Southeastern Archaeological Conference

Curtis E. Larsen, Ph.D.

Geoarcheologist

Recently retiring after a twenty six year career with the United States Geological Survey, Curtis Larsen now works as a geomorphologist for GRA on a project-by-project basis. While working for the USGS Curtis was involved in project management and research projects across the United States. Much of his research focused on understanding the relationship between climate change and sea level rise, particularly in the Mid-Atlantic and the Chesapeake Bay. Other significant work while with the USGS included studies of climate, lake levels and geomorphology of the Great Lakes. Prior to working for the USGS Curtis worked as a project manager for a cultural resource firm and undertook projects in the Southeast and the Great Lakes. His dissertation research while attending the University of Chicago was conducted in the Persian Gulf and the Eastern Arabian Peninsula and focused on long term human/landscape interactions in the Bahrain Islands. His research is published in *The Journal of Coastal Research, Shore and Beach, Geoarcheology, Quaternary Science Reviews, The Journal of Great Lakes Research*, numerous special publications and open file reports with the USGS, as well as in edited volumes and his dissertation by the University of Chicago Press. With GRA he applies his expertise to projects in off- and near-shore settings.

Education

Ph.D. 1980	University of Chicago Anthropology/Archaeology
M.A. 1971	Western Washington University Anthropology/Archaeology
B.S. 1964	University of Illinois Geology/Math & Physics

Employment History

2006–present	Geoarcheology Research Associates, Riverdale, New York. — Geoarcheologist on a project-by-project basis.
1980–2006–Career:	United States Geological Survey, Reston, Virginia.
2003–2006	Research geologist (GS-14), International Programs Office. Served as area specialist for USGS programs and activities in Europe, Russia, and the states of the former Soviet Union. Duties carried out in tandem with research shown below.
1997–2006	Research geologist (GS-14), Eastern Earth Surface Processes and Climate History Teams. Research on global sea level rise focused on Chesapeake Bay and the Mid Atlantic Coast.
1995–1997	Deputy Eastern Regional Geologist (GS-15). Management of Eastern Region Geologic Division policy and research funding with Regional Geologist.
1982–1995	Research Geologist (GS-13, GS-14), Eastern Mineral Resources Branch. Research on heavy mineral placer deposits as well as climate related lake level history of the Great Lakes.
1980 to 1982	Environmental Scientist (GS-13), Environmental Affairs Office. Served as Bureau Historic Preservation Officer and as the principal authority in areas of cultural and archeological resources. 1977 to 1980: Archeologist, Environmental Planning Division, Gilbert Commonwealth Assoc., Inc., Jackson, MI. Responsible for planning, implementation, and completion of various archeological resource and geological projects for Federal and private sector clients. Projects included archeological surveys and excavations as well as environmental planning studies.

1976 to 1977	Doctoral Candidate, studied museum collections and other materials related to my dissertation topic in the Persian Gulf region at the University of Aarhus, Aarhus, Denmark. Funded by George C. Marshall Scholarship provided by the Denmark-America Fund and the American Scandinavian Foundation.
1975 to 1976	Doctoral Candidate, dissertation field research, Persian Gulf Region. Conducted archeological and geological fieldwork in Bahrain and eastern Saudi Arabia. This work included appraisals of geomorphology, hydrology, geologic structure, and Quaternary stratigraphy. Research was aimed at documenting long-term land use patterns on the Bahrain Islands, and determining paleoenvironmental changes in eastern Arabia and Bahrain.
1974 to 1975	Instructor at the University of North Carolina--Wilmington, Wilmington, North Carolina. Taught introductory courses in general anthropology, New World archeology, world prehistory, and environmental archeology. Held committee memberships and advised undergraduate students. Left position to complete dissertation research.
1973 to 1974	Geologist and Research Assistant with the Illinois State Geological Survey, Urbana, Illinois. Conducted coastal geomorphological research and fieldwork along Lake Michigan shorelines. Investigated evidence for Holocene fluctuations in Lake Michigan levels as exposed in outcrop and subsurface.

Books

Larsen, Curtis E., 1983, Life and Land Use on the Bahrain Islands, the Geoarcheology of an Ancient Society, The University of Chicago Press, Chicago and London, 339 p.

Articles and Published Reports

Larsen, C.E. and Inga Clark, 2006, A search for scale in sea level studies, Journal of Coastal Research, Vol. 22, pp. 788-800.

Clark, Inga, C.E. Larsen, and M. Herzog, 2004, Evolution of equilibrium slopes at Calvert Cliffs, Maryland, a method of estimating the timescale of slope stabilization, Shore and Beach, Vol. 72, pp. 17-23.

Herzog, Martha, C.E. Larsen, and Michele McRae, 2002, Slope Evolution at Calvert Cliffs, Maryland, Measuring the Change from Eroding Bluffs to Stable Slopes, U.S. Geological Survey Open-File Report OF-02-332. On USGS website as:http://pubs.usgs.gov/of/2002/of02-332/

Clark, Inga, C.E. Larsen, and Michele McRae, 2002, Historic bluff retreat and stabilization at Flag Harbor, Chesapeake Bay, Maryland, U.S. Geological Survey Open-File Report OF-02-331. On USGS website as:http://pubs.usgs.gov/of/2002/of02-331/

Larsen, C.E., 1999, A century of Great Lakes research: finished or just beginning, in Halsey, J.R., ed., Retrieving Michigan's Buried Past, Cranbrook Inst. of Science Bulletin 64, p. 1-30

Larsen, C.E., 1999, Cultural resources and the U.S. Geological Survey, CRM (Special Issue, A Sesquicentennial Overview of CRM at the Interior Department), Vol. 22, no. 4, p. 38-40.

Larsen, C.E., 1998, The Geological Background to Sea Level Rise in Chesapeake Bay. U.S. Geological Survey Fact Sheet FS-102-98, 4 p. On USGS website as: http://pubs.usgs.gov/fs/fs102-98/

Colman, S.M., Clark, J.A., Clayton, L., Hansel, A.K., and Larsen, C.E., 1994, Deglaciation, lake levels, and meltwater discharge in the Lake Michigan basin, in Teller, J.T., and Kehew, A.E., eds, Late glacial history of large proglacial lakes and meltwater runoff along the Laurentide Ice Sheet, Quaternary Science Reviews, Vol. 13, p. 879-890.

Larsen, C.E., 1994, Beach ridges as monitors of isostatic uplift in the upper Great Lakes, Journal of Great Lakes Research, vol. 20, p. 108-134.

Larsen, C.E., 1993, Heavy minerals at the Fall Zone--a theoretical model of grain size, density, and gradient, in Berger, B.R., and Detra, P.S., eds., Advances for United States and international mineral resources, developing a framework and exploration technologies, U.S. Geological Survey Bulletin 2039, p. 167-180.

Larsen, C.E., 1991, Relative lake level changes in the upper Great Lakes--reconstructing the pattern of postglacial warping

with accuracy: in Folger, D.W., Colman, S.M., and Barnes, P.W., eds, Southern Lake Michigan Coastal Erosion Study Workshop, February 5-6, 1991, U.S. Geological Survey Open-File Report 91-284, p. 33-40.

Larsen, C.E., and Schuldenrein, J., 1990, The depositional history of an archaeologically-dated floodplain, Haw River, North Carolina, in Lasca, N.P., and Donahue, J.D., eds, Archaeological Geology of North America: Geological Society of America, Centennial Special Volume 4, p. 161-181.

Larsen, C.E., Hill, R.H., Kulik, D.M., Brown, M.K., and Scott, D.C., 1988, Mineral resources of the Cedar Mountain Wilderness Study Area, Washakie and Hot Springs Counties, Wyoming: U.S. Geological Survey Bulletin 1756-B, 17 p.

Larsen, C.E., 1988, Book Review: Quaternary Glaciations in the Northern Hemisphere, V. Sibrava, D.W. Bowen, and G.M. Richard, eds, 1986, Quaternary Science Reviews, v. 5, 510 p., in Geoarchaeology, v. 4, p. 376-380.

Larsen, C.E., 1987, Long term trends in Lake Michigan levels, a view from the geological record, in Proceedings of the First Indiana Dunes Research Conference: Symposium on Shore Processes, National Park Service, Atlanta, Ga., p. 5-22.

Larsen, Curtis E., 1987, Geologic History of Lake Algonquin and the Upper Great Lakes, U.S. Geological Survey Bulletin 1801, 36 p.

Larsen, C.E., 1986, Book review: Masters, P.M. and Flemming, N.C., eds. 1983, Quaternary Coastlines and Marine Archaeology: Academic Press, Geoarchaeology, v. 1, p. 313-315.

Hansel, A.K., Mickelson, D.M., Schneider, A.F., and Larsen, C.E., 1985, Late Wisconsin and Holocene History of the Lake Michigan Basin, in Karrow, P.F., and Calkin, P., eds. Quaternary Evolution of the Great Lakes: Geological Association of Canada, Special Paper 30. p. 39-53.

Larsen, C.E., 1986, Variation in Holocene land use patterns on the Bahrain Islands: Construction of a land-use model, in Al-Khalifa, S.H.A., and Rice, M., eds., Bahrain through the Ages, The Archaeology: Routledge and Kegan Paul, London, p. 25-46.

Larsen, C.E., 1985, Lake level, uplift and outlet incision, the Nipissing and Algoma Great Lakes, in Karrow, P.F., and Calkin, P., eds. Quaternary Evolution of the Great Lakes: Geological Association of Canada, Special Paper 30, p. 63-77.

Larsen, C.E., 1985, Chapter 2, Water Resources of the Past, in Water Atlas of Saudi Arabia, Ministry of Agriculture and Water, Kingdom of Saudi Arabia, p. 9-16.

Larsen, C.E., 1985, A Stratigraphic Study of Beach Features on the Southern Shore of Lake Michigan: New Evidence of Holocene Lake Lake Level Fluctuations: Illinois State Geological Survey Environmental Geology Notes 112, 31 p.

Larsen, C.E., 1985, Geoarcheological interpretation of Great Lakes, Lakeshore Environments, in Stein, J.K., and Farrand, W.R., eds., Archaeological Sediments in Context: Peopling of the Americas Edited Series, no. 1, Institute for Quaternary Studies, University of Maine, Orono, p. 99-110.

Larsen, C.E., l983, The early environment and hydrology of ancient Bahrain, in D.F. Potts, ed., Dilmun: New studies in the Archaeology and History of Bahrain: Berliner Beiträge zum Vordern Orient, no. 2, D. Reimer Verlag, Berlin, p. 1-34.

Larsen, C.E., l983, Life and Land Use on the Bahrain Islands: The Geoarcheology of an Ancient Society: The University of Chicago Press, Chicago, Illinois, 339 p.

Larsen, C.E., Beckely, B.S., and Bierschenk, W.H., 1982, Reconnaissance investigations of selected galleries in the Western Province, Saudi Arabia: report prepared for the Ministry of Agriculture and Water, Riyadh, Saudia Arabia through the USGS, Office of International Hydrology, Reston.

Larsen, C.E., 1982, Geoarcheology of the Haw River, in Claggett, S.R. and Cable, J.S., assemblers, The Haw River sites: Archeological investigations at two stratified sites in the North Carolina Piedmont, v. 1, p. 145-222.

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Michael Aiuvalasit, M.A.

Staff Geoarcheologist

Mr. Aiuvalasit specializes in conducting investigations of the geological context, paleoenvironmental record, and site formation processes of archeological sites. Since 2001 Mr. Aiuvalasit has held a variety of positions for cultural resource firms, including lab director, staff archeologist, assistant lithic analyst, and field archeologist. He has authored both archeological and geoarcheological reports for cultural resource investigations in Texas, New Jersey, Pennsylvania, and New York, and coauthored or presented papers on research conducted in Mexico, Texas, New Mexico, and New York. Currently he is completing the reports on geoarcheological studies at seven prehistoric data recovery investigations in upstate New York. He is listed in the Register of Professional Archaeologists (RPA), and is a member of the Society for American Archaeology (SAA), Geological Society of America (GSA), and other local societies. He has current HAZWOPER and Confined Space Entry training. He received training at the University of Texas and Texas A&M University.

Education

M.A. 2006	Texas A&M University Anthropology/Archaeology
B.A. 2001	University of Texas Anthropology/Archaeology/History

Employment History

2006–2011	Project Geoarcheologist Geoarcheology Research Associates Riverdale, New York
2005–2006	Field Archaeologist Environment and Archaeology, Inc, Kittatiny Archaeological Research Inc., Gray and Pape Inc.
2002–2004	Staff Archaeologist and Lab Manager Hicks and Company Austin, Texas
1999–2002	Field Archaeologist, various CRM companies in Texas and New Mexico.

Fellowships and Grants

2005	Texas Archeological Society Donors Fund Research Grant
2005	Council of Texas Archeologists Student Research Grant
2005	Teaching Assistantship (Texas A&M University, Department of Anthropology)

Publications

Aiuvalasit, Michael, James A. Neely and Mark Bateman 2010. New Radiometric dating of water management features at the prehistoric Purrón Dam Complex, Tehuacán Valley, Puebla, México. Journal of Archeological Sciences doi:10.1016/j.jas.2009.12.019.

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Aiuvalasit, Michael and Rachel Feit. 2003. Upper Tannehill/Lower Fort Branch Sewer Line Upgrade Archeological Survey. Hicks & Co. Archeology Series 122.

Selected Presentations at Professional Meetings

2010	Alluvial Geoarchaeology of the Susquehanna River sites. Society for American Archaeology.
2008	Geoarchaeology on the Edge: Submerged, near-Shore and off-Shore Landscapes of New York Harbor and Early Manhattan Island. Geological Society of America.
2007	The Purrón Dam Complex Revisited: Results of a Pilot Geoarchaeological Investigation at a Prehistoric Water Management System in the Tehuacán Valley of Southern México. Geological Society of America
2007	Geoarchaeology of Deweyville Terraces. Society for American Archaeology
2006	The Geoarchaeology of Deweyville Terraces in Texas: Implications for Paleoindian Studies. Texas Archaeological Society
2001	The Parallel Mischaracterizations of Golden Age Spain's and Pre-Hispanic Americas Landscape and Agriculture. World History Association of Texas

Mark A. Smith, Ph.D.

Staff Archeologist

Dr. Mark Smith specializes in Geographic Information Systems (GIS) and mapping applications for cultural resource surveys and excavations. He is the primary cartographic specialist for GRA and is trained in the use and application of various surveying systems (e.g., Total Station, GPS, etc.). Dr. Smith is also experienced in nautical archeology having received his M.A. in the subject at Texas A&M University and participated in underwater excavations off the coast of Turkey and in the Caribbean. His dissertation research at New York University entailed an analysis of settlement geography in the Punjab, Pakistan, during the Early Historic and Medieval Periods. Dr. Smith has field experience in the Eastern United States, the Eastern Mediterranean, the Middle East, South Asia and the Caribbean. He has directed CRM projects in the Northeast and recently he held the position of Field Director for the Regime Crimes Liaison Office Iraq Mass Graves Team.

Education

Ph.D. 2007	New York University Anthropology
M. Phil 1999	New York University Anthropology
M.A. 1995	Texas A&M University Anthropology
B.A. 1989	University of Arizona Anthropology

Employment History

1998–2011	Staff Archaeologist/GIS coordinator, Geoarcheology Research Associates Riverdale, NY
2006	Field Director, Regime Crime Liaison Office, U.S. Department of State Baghdad, Iraq
2005–2006	GIS Coordinator/Assistant Field Director, Regime Crime Liaison Office, U.S. Department of State Baghdad, Iraq
2004	Research Assistant, New York University New York, NY
2000–2004	Assistant Archaeologist/GIS Consultant, John Milner Associates, Inc. Croton-on-Hudson, NY
2002	GIS consultant, New York University New York, NY

Awards and Fellowships

1996–2004	Graduate Teaching Assistant, New York University
1999	George Franklin Dales Foundation Scholarship
1998	Salwen Fellowship for dissertation Research
1991	Institute of Nautical Archaeology Scholarship
1990	Institute of Nautical Archaeology Scholarship

Publications

Smith, M. A. and Boyle, J. 2003. Using GIS to Analyze Farms and Farmstead Architecture in the Finger Lakes national Forest. In GIS in Historical Archaeology / Case Study from Central New York, James A. Delle and Patrick Heaton, editors. Northeastern Historical Archaeology, 32: 45-56.

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Smith, M. A. 1994. The Bronze Age shipwreck at Uluburun, Turkey. In S. R. Rao (ed.) The Role of Universities and Research Institutes in Marine Archaeology. Goa: Society for Marine Archaeology.

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Malin-Boyce, S., M. A. Smith, and J. Schuldenrein. 2001. Phase 1A and Phase 1B Archaeological Surveys Proposed Stony Point Substation Site, Town of Stony Point, Rockland County, New York. Report prepared by Geoarcheology Research Associates, Inc., Riverdale, N.Y. for Orange and Rockland Utilities, Inc., Spring Valley, N.Y.

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Malin-Boyce, S., M. A. Smith, and J. Schuldenrein. 2001. Supplement 6 to Phase IB Archaeological Investigation, Stagecoach Storage Project, Town of Owego and Town of Nichols, Tioga County, New York. Report prepared by Geoarcheology Research Associates, Inc., Riverdale, N.Y. for Foster Wheeler Environmental Corp., Livingston, N.J.

Heaton, P. J., M. A Smith and J I. Klein. 2001. A GIS Based Archaeological Sensitivity Model for use in Conjunction with the

Public Water Supply Installations Project Village of High Falls, Ulster County, New York. A report prepared for John Milner Associates, Croton-on-Hudson, New York.

Schuldenrein, J., D. M. Thieme, M. A. Smith and T. Epperson. 2000. A Geomorphological and Archeological Study in Connection with the New York and New Jersey Harbor Navigation Study, Upper and Lower Bay, Port of New York. A report prepared for Barry A. Vittor & Associates, Inc.

Regime Crimes Liason Office Reports

Smith, M. A., D. Z. C. Hines, N. J. Brighton, M. K. Trimble, C. S. Steele (editors). 2007. Forensic Investigation of Mass Grave KAR0024, Karbala Province, Iraq. United States Army Corps of Engineers, St. Louis District, Mandatory Center of Expertise for Archaeological Curation and Collections Management. Submitted to Department of Justice, Regime Crimes Liaison Office, United States Embassy Baghdad, Iraq.

Trimble, M. K., N. J. Brighton, D. Z. C. Hines, M. A. Smith (editors). 2007. Forensic Survey Along the Tar-as-Saiyid, Karbala Province, Iraq. United States Army Corps of Engineers, St. Louis District, Mandatory Center of Expertise for Archaeological Curation and Collections Management. Submitted to Department of Justice, Regime Crimes Liaison Office, United States Embassy Baghdad, Iraq.

Hines, D. Z. C., S. Malin-Boyce, M. A. Smith, C. S. Steele (editors). 2006 Archaeological and Forensic Reconnaissance of Potential Mass Graves Sites: Iraq, 2005-2006. United States Army Corps of Engineers, St. Louis District, Mandatory Center of Expertise for Archaeological Curation and Collections Management. Submitted to Department of Justice, Regime Crimes Liaison Office, United States Embassy Baghdad, Iraq.

Hines, D. Z. C., M. A. Smith, N. J. Brighton (editors). 2006. Forensic Investigation of Mass Grave KAR0008, Karbala Province, Iraq. United States Army Corps of Engineers, St. Louis District, Mandatory Center of Expertise for Archaeological Curation and Collections Management. Submitted to Department of Justice, Regime Crimes Liaison Office, United States Embassy Baghdad, Iraq.

Selected Papers/Posters Presented

2008 The Application of GIS in Forensic Archaeology, Karbala, Iraq. A paper presented at the 2008 Meeting of the International Association of Forensic Scientists, New Orleans, Louisiana.

2008 (with Stephen A. Chomko) GIS Applications in Mass Graves Documentation and Analyses. A paper presented at the 41st Annual Conference on Historical and Underwater Archaeology, Albuquerque, New Mexico.

2003 The geomorphic background to human settlement in the New Jersey Meadowlands: New Perspective. A poster presented at the Meadowlands Symposium, New Jersey Meadowlands Commission, Lyndhurst, NJ.

2000 The archaeology of abandoned farmsteads in Hector Township, New York. A poster presented at the 33rd Conference on Historical and Underwater Archaeology, Quebec City, Quebec.

1999 Analysis of 19th and 20th century farmsteads in Hector Township: Integrating CAD, CPS and GIS. A poster presented at the 64th Annual Meeting of the Society for American Archaeology, Chicago, Illinois.

1997 (with James Delle) Archaeology, the tourist industry, and the state. A paper presented (by James Delle) at the 97th Annual Meeting of the American Anthropological Association, Washington, D.C.

1994 The Bronze Age shipwreck at Uluburun, Turkey. A paper presented at the Third Indian Conference on Marine Archaeology of Indian Ocean Countries, Karnataka State University, Karnataka, India.

Appendix G
Scope of Work

Scope of Work
and
Request for Proposal
For
Geomorphology/Archaeological Borings
And
GIS Model of the Submerged Paleoenvironment
In the New York/New Jersey Harbor and Bight
In Connection with the
New York and New Jersey Harbor Navigation Project
2000 Port of New York and New Jersey

I. Introduction

The U.S. Army Corps of Engineers, New York District (Corps), is constructing navigation channels within the Port of New York - New Jersey (the Harbor Navigation Project) to 15 m (50 ft) depth. As a federal agency, the Corps, is required to identify cultural resources within its project areas and evaluate their eligibility for listing on the National Register of Historic Places (NRHP). The Federal statutes and regulations authorizing the Corps to undertake these responsibilities include Section 106 of the National Historic Preservation Act, as amended through 1992 and the Advisory Council on Historic Preservation Guidelines for the Protection of Cultural and Historic Properties (36 CFR Part 800).

As part of the Corps' Section 106 compliance work, background research was conducted and a series of cores were excavated and examined to determine locations within the areas of proposed deepening and, more importantly, associated widening, that might preserve stratigraphy containing significant data on the paleoenvironment. This initial work was conducted to determine the feasibility of developing a model of the now submerged landforms and landform preservation and from that determine the sensitivity of areas for Native American occupation. Geoarcheology Research Associates (GRA), consultants to the Corps, developed a preliminary sensitivity model. The previous work also determined areas where additional data should be acquired. They subsequently developed a working framework and direction for honing the preliminary model. This scope of work contains the tasks to develop the model using a Geographic Information System. Up to forty (40) brings will be excavated in locations determined by the geomorphologist based on review of previous work. The data recovered from these borings will be used to refine the model. The model will be provided to the Corps in a format that can be used by the Corps and shared with interested organizations.

A Programmatic Agreement for the project was signed in 2000 and amended in 2003. The stipulations addressing off shore Native American resources appear below.

Stipulation II. TREATMENT OF HISTORIC PROPERTIES.

The New York District shall adhere to the following treatment strategies in order to avoid adverse effect to historic properties.

A. The New York District shall excavate a limited number of borings in locations determined by a qualified geomorphologist within or adjacent to the Ambrose, Anchorage, Kill Van Kull, Arthur Kill, Newark Bay, South Elizabeth and Bay Ridge Channels as well as in the Jersey Flats at Port Jersey. These sediments will be subject to foraminifera, pollen and Carbon-14 analysis. The results of this work will be incorporated into a sensitivity model of now inundated former prehistoric occupation areas. This work will be entered into a Geographic Information System (GIS) compatible with other GIS data developed for the Study.

B. The New York District shall notify appropriate institutions and organizations of the availability of the prehistoric sensitivity model on GIS. A list of appropriate institutions and organizations will be developed by the New York District and will be submitted to the SHPO(s) for review. If the New York District does not receive a response from the SHPO(s) within 45 days of receipt the New York District will notify availability to the institutions and organizations on the list submitted for review.

II. Study Area

The Harbor Navigation Project as a whole is limited to selected navigation channels including Ambrose, Anchorage, Kill Van Kull, Arthur Kill, Port Jersey, Newark Bay (includes South Elizabeth Channel, Elizabeth Channel, Elizabeth Pierhead Channel, Port Newark Pierhead Channel and Port Newark Channel) and Bay Ridge Channels (Figure 1). These channels are being deepened to 15 m (50 ft).

Cultural resources studies to date have been limited to the harbor and the channels listed above as well as Stapleton and Claremont Channels; two channels for which no further work is proposed. For purposes of this scope the study area will include the harbor channels listed above, Raritan Bay, Lower Bay and part of the New York Bight defined as the area west of a line drawn between Jones Inlet on Long Island and Long Branch, New Jersey (Figure 2). As habitat mitigation sites may be located outside the harbor itself and Ambrose Channel extends outside the harbor, a more regional approach may be beneficial to the Corps in its project planning.

III. Purpose

The purpose of the investigations outlined in this scope is to develop a model of the now submerged paleoenvironment. This model should assist the Corps and researchers in determining areas that might have been suitable for habitation and also indicate those areas that stratigraphy from periods of occupation might remain intact. Also under this scope is the acquisition of additional data through the excavation of off-shore borings/vibra cores to refine the model. This study is not designed to specifically locate cultural material. The overall goal of this cultural resource work will be to determine those locations within the study areas that are potentially sensitive for prehistoric resources.

IV. Previous Research

The work outlined in this scope will build on previous work conducted for the Harbor Navigation Project and for the Corps' Dredged Material Management Plan (DMMP). Recently Geoarcheology Research Associates prepared a preliminary model with directions for further research and model development. They based this on a previous a harbor-wide study that included research, the excavation of a limited number of borings and pollen, foraminifera and Carbon-14 analyses. They also conducted more detailed work for discrete portions of the harbor (Arthur Kill and Port Jersey). The Arthur Kill and Port Jersey work were guided by previous studies by LaPorta, Sohl and Brewer and Wagner and Siegel (Wagner and Siegel 1997; LaPorta, Sohl and Brewer 1999). GRA developed a preliminary archaeological sensitivity model for prehistoric resources within the harbor.

A second regional study within the harbor was conducted in connection with the DMMP. The results of this study indicate that even in existing navigation channels, deeply buried deposits may preserve prehistoric sites. However, most of the pertinent deposits are within the uppermost 9 m (30 ft) of sediments (LaPorta, Sohl, and Brewer 1998). This study looked at several locations within the harbor, two large areas in Raritan Bay and an area in the bight.

Most reports cited in the text above have been provided to the consultant by the Corps. Other reports can be obtained from the Corps as needed.

V. Contractor Services and Required Investigations

A. The general services to be provided under this contract are those required to conduct research and prepare a report on the prehistoric environment of the study area described above in Section II, and develop a working GIS model of now buried landforms and their sensitivity to have had, and to retain, prehistoric resources, as described in Sections I and III, above. Borings or corings will be excavated offshore to obtain data relevant for the model.

B. The Contractor shall be responsible for conducting, in the manner prescribed, the work detailed below. Failure to fully meet the requirements of this scope of work may be cause for termination of work for default of the contract, or for an evaluation of unsatisfactory upon completion of the project.

C. This scope of work requires the completion of the following tasks:

Task 1 - Prepare Health & Safety Plan and Hazard Analysis Plan

a. The Health and Safety Plan (HASP) and a Hazard Analysis Plan shall be prepared. The HASP will serve as a safety plan and research strategy for all work. The HASP and all work will comply with Engineering Manual EM 385-1-1, "Safety and Health Requirements Manual" dated 3 November 2003 and all other applicable regulations and guidelines. Appendix A of this manual provides a minimum basic outline for the plans. The Corps can provide samples of plans. The manual is available on-line at http://www.hq.usace.army.mil/soh/hqusace_soh.htm.

b. **District acceptance of the Health and Safety Plan must be obtained before any fieldwork is undertaken**.

c. The HASP will also indicate the location of proposed tests and provide an overall strategy for conducting the work.

Task 2 – Excavation of Borings and Sample Preparation

No more than forty (40) vibracores shall be excavated, unless the time allotted for fieldwork allows for more. The location of these cores will be determined by the geomorphologist prior to initiating fieldwork, as appropriate, based on background material. The locations can be refined based on field results.

A continuous profile, using a medium diameter bore (80 to 100 mm/3 to 4 in diameter), or 2-foot split spoon sampling device, should be obtained through Holocene deposits and into the terminal Pleistocene deposits, if present. A geomorphologist familiar with local submerged Pleistocene/Holocene deposits will be on board the vessel as borings are taken and will determine the depths to which continuous cores must be collected. The cores will not exceed 9 m (30 ft) of sediment and may be terminated prior to that depth, under the direction of the geomorphologist, if the Holocene/Pleistocene deposits of archaeological interest are encountered and examined before 9 m (30 ft) is reached. If bedrock is encountered the borings shall be terminated. If soils appear disturbed through natural or human action the coring may be terminated. The work shall not exceed twenty nine (29) days including operation, contingency and preparation. Location of cores shall be recorded with a differential global positioning system (DGPS).

The retrieved cores shall be recorded in standard log format or as directed by the geomorphologist. The cores themselves shall be labeled as appropriate and shall include project name, date, core hole identification and top and bottom of the cored interval will be clearly labeled on both ends of core boxes. The lid on the inside of the core box will show boring or core hole identification, depth and location of the top of the core and depth and location of bottom of core.

Immediately following retrieval of the vibracoring device at each station, the core liner will be removed from the vibracorer, carefully capped to prevent loss of sediment, marked with a unique station identifier, and placed on ice in a container aboard the survey vessel. Cores should be stored in a vertical position to retain stratigraphy and facilitate testing. Cores shall be held on ice or under refrigeration, as needed, aboard the vessel and while being held ashore at the Corps' Caven Point facility where they may be temporarily stored during the course of the field investigation. The samples may be prepared at Caven Point for shipping to the appropriate laboratories. The duration of temporary storage and use of the Caven Point facility may not exceed 2 weeks from the final day of fieldwork. The contractor is responsible for assuring proper handling of samples. If results are deemed unacceptable due to improper handling or transport, it will be the contractor's financial responsibility to resample.

Task 3 - Sediment Testing

Samples will be taken from the cores and examined for evidence of cultural material and paleoenvironmental data. Modern sediments will not be tested. All samples selected for further analysis will undergo palynological testing (not to exceed 400 samples). Foraminifera (or macrofossils) and Carbon-14 analyses will be undertaken for only those sediments determined by the geomorphologist as likely to yield significant information. The number of samples to be tested for foraminifera/macrofossils by the geomorphologist will not exceed a total of 400 samples. Carbon-14 testing will not exceed 60 samples. The facilities undertaking the analyses must, at a minimum, abide by local, state and federal OSHA standards and other applicable safety regulations and guidelines.

Task 4 - Data Analysis and GIS Model

The Contractor will assemble and interpret all data collected for this study with the purpose of collating it in the preparation of the model. Recommendations for the model and suggested data layers were developed under previous work (see Attachment 1). These recommendations should form the basis of the GIS work. A report detailing the work undertaken under this scope will be prepared. The report will also describe the model and how it works, how it was developed and use and appropriateness of the data. The report requirements are outlined in Section VI, below, and shall be followed as applicable to this work.

The Corps' GIS staff will be available to provide information on existing Corps project datasets and Corps GIS requirements. All GIS products shall be fully compatible with ESRI GIS software, to work with the Corps' existing harbor datasets. The term "compatible" means that data can be accessed directly by the target system without translation, preprocessing, or post-processing of the digital data files. It is the responsibility of the contractor to ensure this level of compatibility.

All GIS data (including geospatial data acquisition and map development for use in a GIS) shall conform to the most current release of the Spatial Data Standard for Facilities, Infrastructure and Environment (SDSFIE). The most current release of the SDSFIE is available for download from the Corps' CADD/GIS Technology Center's Internet Website (http://tsc.wes.army.mil). All delivered digital GIS data files shall also be submitted in strict compliance with the SDSFIE for the target GIS software system. This work must be in compliance with ER 1110-1-8156: Policies, Guidance and Requirements for Geospatial Data and Systems, dated1 August 1996.

The contractor shall provide metadata files for all geospatial and GIS data and products under this contract. The metadata file shall conform to the Spatial Data Transfer Standards (SDTS)/Federal Information Processing Standard (FIPS) 173, and Federal Geographic Data Committee and to the SDSFIE. "Corpsmet" is the preferred metadata generating software and can be obtained free from the USACE Geospatial Data Clearinghouse Node (http://corpsgeo1.usace.army.mil).

A draft version of any GIS product shall be submitted to the Corps according to the schedule below, Section VII. The draft files will be reviewed by the Corps' GIS staff to ensure compatibility. Comments by the GIS staff shall be addressed and incorporated into the final product. Once finalized, Fifteen (15) copies of all data and files developed under this contract shall be delivered to the Corps in digital format. All digital files shall be provided on compact disk, read-only memory (CD-ROM) in ISO-9660 format, or Digital Versatile Disk (DVD) compatible with the Corps' target GIS hardware. A "Readme.txt" file must be included in the delivered digital media that includes normal transmittal information (see Attachment 2). Use of the Internet to transfer files between the contractor and the Corps is an option, as approved by the Corps' Contracting Officer. The report generated through this project shall be included in .pdf format on the CD-ROM or DVD with the model.

The external label for each digital media shall contain, as a minimum, the following:

"US Army Corps of Engineers, New York District"
Contract Number and Delivery Order
Contractor name
Format and version of the operating system
Name and version of the utility software used for preparation (eg., compression/decompression) and copying files to the media.
Sequence number of digital media
List of the names on the digital media (as space permits)

Task 5 - <u>Report Preparation</u>

The Contractor shall prepare interim, draft and final reports. The final report will incorporate all comments received from the Corps and other reviewing agencies.

The report produced by a cultural resource investigation is of potential value not only for its specific recommendations but also as a reference document. To this end, the report must be a scholarly statement that can be used as a basis for any future cultural resources work. It must meet both the requirements for cultural resource protection and scientific standards of current research as defined in 36 CFR Part 800 and the Councils Handbook.

1. One copy of each interim report will be submitted to the Corps, according to the time schedule established in Section VII "Project Schedule", below. The interim report will provide a brief summary of the work conducted to date and the work yet to be completed. It shall present any preliminary results of the research.

2. Four copies of the draft report will be prepared and submitted to the ContractingOffice according to the schedule established in Section VII, "Project Schedule", below. The draft report will be reviewed by the Corps, the NJHPO, the NYSHPO and the New York City Landmarks Preservation Commission. All comments of the reviewing agencies and will be transmitted to the Contractor prior to the submission of the final report.

3. Fifteen (15) copies of the final report shall be submitted to the Contracting Office according to the schedule established below in Section VII, "Project Schedule". The final report shall address all comments made on the draft report.

Task 6 - <u>Project Management</u>

The Contractor will be responsible for ensuring that all deliverables are provided on schedule and that all terms of this scope of work are satisfied.

<u>VI. Report Format and Content</u>

A. The draft and final reports shall have the following characteristics, <u>as applicable</u>, to this study:

   1. The draft and final copies of the cultural resources report shall reflect and report on the work outlined in Section V (Required Investigations) above. They shall be suitable for publication and be prepared in a format reflecting contemporary organizational and illustrative standards of professional archaeological journals. The draft report will be revised to address all review comments.

   2. The report produced by a cultural resources investigation is of potential value not only for its specific recommendations, but also as a reference document.

To this end, the report must be a scholarly statement that can be used as a basis for any future cultural resources evaluation. It must meet both job requirements for cultural resources protection and scientific standards as defined in 36 CFR Part 800 and in the "The Treatment of Archeological Properties: A Handbook" (1980) published by the Advisory Council on Historic Preservation.

3. All interim, draft and final copies of the report shall reflect and report on the work required by this scope.

B. **PAGE SIZE AND FORMAT.** Each report shall be produced on 8 1/2" x 11" archivally stable paper, single spaced with double spacing between paragraphs. The printing of the text should be letter quality. All text pages, including figures, tables, plates and appendices must be consecutively numbered.

C. Final copies of the report, with original photographs, shall be submitted in a hard-covered binder suitable for shelving.

D. The **TITLE PAGE** of the report shall include the municipalities and counties incorporated by the project area, the author(s) including any contributor(s). The Principal Investigator should be identified and is required to sign the original copies of the report. If the report has been written by someone other than the contract Principal Investigator, then the cover of the publishable report must bear the inscription "*Prepared Under the Supervision of (NAME), Principal Investigator"*. The Principal Investigator in this case must also sign the original copies of the report.

E. A **MANAGEMENT SUMMARY** or **ABSTRACT** shall appear before the **TABLE OF CONTENTS** and **LIST OF FIGURES**. It should include a brief project description including the location and size of the project area, the methods of data collection, the results of the study, evaluations and identification of impacts and recommendations. It should also include the location of where copies of the report are on file.

F. The **TABLE OF CONTENTS** will include a list of all figures, plates and tables presented in the report.

G. The **INTRODUCTION** will state the project's purpose and goals as defined by the Scope of Work and will include the applicable regulations for conducting this work and will contain a general statement of the work conducted and the recommendations proposed.

H. The **BACKGROUND RESEARCH** must be sufficient to provide a detailed description and evaluation of the prehistoric research of the project area. This section should include a summary of the existence of sites and a description of previous work conducted in the area. The following information should be presented and discussed as applicable to the study:

1. The **ENVIRONMENTAL SETTING**, including bathymetry, soils, and geology.

2. An **ANALYSIS** of paleoenvironment.

3. **PAST AND PRESENT LAND USES** and current conditions.

4. A **DISCUSSION** of prehistoric and historic cultural history of project locale. This section should provide contexts for research questions, survey methods, etc.

5. A **REVIEW** of known sites, previous investigations and research in the project area and vicinity.

I. A **RESEARCH DESIGN** will outline the purpose of the investigation, basic assumptions about the location and type of cultural resources within the project area. The following shall also be included:

1. **RESEARCH OBJECTIVES** and **THEORETICAL CONTEXT**

2. Specific **RESEARCH PROBLEMS** or questions.

3. **METHODS** to be employed to address the research objectives and questions.

4. A **DISCUSSION** of the expected results, including hypotheses to be tested.

J. A **METHODS** section, if applicable, shall include:

1. A **DESCRIPTION OF FIELD METHODS** employed, including rationale, discussion of biases and problems or obstacles encountered.

2. A **DEFINITION** of site used in the survey.

K. **RESULTS, INTERPRETATIONS AND RECOMMENDATIONS:** A discussion of the results in terms of the background cultural context, research design, goals, research problems, and potential research questions.

L. A **REFERENCES CITED** section will list all references and citations located within the text, including all figures, plates or maps, and within any appendices. All sources (persons consulted, maps, archival documentation, etc.) maybe listed together. This list must be in a format used by professional archaeological journals, such as *American Antiquity.*

M. **APPENDICES** shall include, but not be limited to:

1. A copy of relevant boring/subsurface exploration data used in the report.

2. The **QUALIFICATIONS** of the Principal Investigator and any other key personnel used.

3. The final **SCOPE OF WORK**.

O. **PHOTOGRAPHS** will be glossy black and white prints no smaller than 5" x 7". Photographic illustrations should be securely mounted by use of an archivally stable mounting medium. Photograph captions for site overviews must include direction or orientation. At a minimum, captions should identify feature or location, direction, photographer and date of exposure. **All photographs should be fully captioned on the reverse of the photograph in case they should be removed from the report**. Photographs should be counted as "Figures" in a single running series of illustrations, plates, etc. High quality prints of digital images are acceptable and must be printed on photo paper for the final report. A CD ROM containing images must be submitted in a pocket bound to three (3) copies the final report.

P. **GRAPHIC PRESENTATION OF THE RESULTS.**

1. All pages, including graphic presentations, will be numbered sequentially.

2. All graphic presentations, including maps, charts and diagrams, shall be referred to as "Figures". All figures must be sequentially numbered and cited by number within the body of the text.

3. All figures, plates and tables should be incorporated into the text on the page following their citation. They should not be appended.

4. All tables shall have a number, title, appropriate explanatory notes and a source note.

5. All figures shall have a title block containing the name of the project, county and state.

6. All maps, including reproductions of historic maps, must include a north arrow, accurate bar scale, delineation of the project area, legend, map title and year of publication.

7. The report must include the project area(s) accurately delineated on a U.S.G.S. 7.5' topographic map and a county soils survey map, if available for that area. A NOAA chart may also be submitted on which the project area(s) is delimited.

VII. Project Schedule

A. All reports should be submitted in a timely manner as stipulated below:

1. An interim report will be submitted to the Corps upon completion of fieldwork. The interim report shall discuss what work has been accomplished and what work has yet to be completed. It shall also state any problems the Contractor has encountered in conducting the work and can contain requests for information.

2. The draft report will be submitted to the Corps not later than seven (7) months after notice to proceed. The draft report will be reviewed by the Corps, the NYSHPO, the NJHPO and New York City Landmarks Preservation Commission. One copy of the draft report will be returned to the Contractor with comments. The final report will address all comments provided with the draft report.

3. The final report will be submitted to the Corps four (4) weeks after the Contractor receives the draft report with comments.

B. The number of copies for the interim, draft, and final reports will be submitted, according to the above schedule, as follows:

1. One copy of the interim report.

2. Four copies of the draft report and the draft GIS model on CD-ROM

3. Fifteen (15) copies of the final report; one of which will be unbound and will contain original photographs and drawings, if applicable. Three bound copies, suitable for shelving, which will also contain original photographs or digital images on photo paper. Two bound copies will also be submitted but photocopies of the photographs are acceptable.

4. Fifteen (15) copies of the CD-ROM containing the model will be submitted with the final report.

C. Scheduled completion date for the work specified in this scope is nine months from date of award.

VIII. Additional Contract Requirements

A. Agencies, institutions, corporations, associations or individuals will be considered qualified when they meet the minimum criteria given below. As part of the supplemental documentation, a contract proposal and appendices to the draft and final report must include vitae for the **PRINCIPAL INVESTIGATOR** and **MAIN SUPERVISORY PERSONNEL** in support of their academic and experiential qualifications for the research, if these individuals were not included in the original contract proposal. The Principal Investigator must also be a qualified geomorphologist. Additional personnel should consist of an archaeologist that meets the qualifications presented below. Personnel must meet the minimum professional standards stated below:

1. Archaeological Project Director or Principal Investigator (PI). Persons in charge of an archaeological project or research investigation contract, in addition to meeting the appropriate standards for archaeologist, must have a doctorate or equivalent level of professional experience as evidenced by a publication record that demonstrates experience in project formulation, execution, and technical monograph reporting. Suitable professional references may also be made available to obtain estimates regarding the adequacy of prior work. If prior projects were of a sort not ordinarily resulting in a publishable report, a narrative should be included detailing the proposed project director's previous experience along with references suitable for to obtain opinions regarding the adequacy of this earlier work.

2. Geomorphologist. Personnel hired for their special knowledge and expertise in geomorphology should have a Master's degree or better and experience and a publication record demonstrating a substantial contribution to the field through research. For this project, the individual must have experience in the interpretation of sediments on the Continental Shelf, particularly with regard to the potential for archaeological resources. The individual should also ideally be able to interpret seismic data.

3. Archaeologist. The minimum formal qualifications or individuals practicing archaeology as a profession area a B.A. or B.S. degree from an accredited college or university, followed by two years of graduate study with concentration in anthropology and specialization in archaeology during one of these programs, and at least two summer field schools or their equivalent under the supervision of an archaeologist of recognized competence. A Master's thesis or its equivalent in research and publications is highly recommended, as is the PhD degree. Individuals lacking such formal qualifications may present evidence of a publication record and references from archaeologists who do meet these references. In addition, the archaeologist should also have experience in the prehistoric archaeology of the southern New York - northern New Jersey area.

4. Standards for Consultants. Personnel hired or subcontracted for their special knowledge and expertise must carry academic and experiential qualifications in their own fields of competence. Such qualifications are to be documented by means of vitae attachments to the proposal or at a later time if the consultant has not been retained at the time of proposal.

B. Principal Investigators shall be responsible for the validity of the material presented in their reports. In the event of a controversy or court challenge, Principal Investigators shall be required to testify on behalf of the government in support of findings presented in their reports.

C. Neither the Contractor nor his representatives shall release any sketch, photograph, report or other data, or material of any nature obtained or prepared under this contract without the specific written approval of the Contracting Officer prior to the time of final acceptance by the government.

D. The Contractor shall furnish all labor, transportation, instruments, survey equipment, boats and other associated materials to perform the work required by this Scope of Work.

E. The Contractor shall return all copies of reports provided by the Corps when the final report is submitted.

IX. Fiscal Arrangements

A. Partial payments of the total amount allocated will be dispersed upon the receipt of invoices. Invoices will be submitted with the interim report, and every month there after will reflect the amount expended. The total amount of all monthly invoices shall not total more than 90% of the agreed work order amount. The remaining 10% of the agreed work order amount shall be paid upon the receipt and acceptance of the final report, all reports provided by the Corps, etc. and receipt of the final invoice. **No invoice payments will be made if it is does not include an accompanying interim or draft report.**

B. Invoice payments will be made pursuant to the "Prompt Payment" clause of the contract.

Attachment 1.

The primary GIS data bases include:

(7) *Historic terrain and bathymetric plots*. The present study establishes the 1844 bathymetric plots of the New York Bight as a baseline for documenting subaqueous contours. Progressive terrain modifications are plotted for 1866 and then for several time frames in the 20th century. Future projections are also charted.

(8) *Shoreline models for prehistoric and historic terrain*. Sea level curves are used to isolate shoreline contours by 100-500 year intervals in the Holocene. These track changing configurations of terrestrial (stream lines), estuarine, marsh, and marine margins for these time frames.

(9) *Surficial geology of the shore and subaqueous terrain of the Bight*. Maps recently been produced for the eastern margins of the Bight (New Jersey side; Stone et al, 2002) that track the glacial margins, lake basins and Holocene surface deposits. Independent work has been done in New York as well (New York side; Sanders and Merguerian 1994). The GIS model will attempt to link these independent studies and establish a comprehensive map of the surface and subsurface Quaternary landforms, including those that are a product of or were affected by marine transgressions and regressions.

(10) *GIS plots of subsurface lithostratigraphy*. The layer involves plots of the late Quaternary lithostratigraphy based on an assimilation of the bore logs, first by the individual channel reaches and subsequently for the entire project area.

(11) *GIS plots of biostratigraphy*. The layer integrates the foram, macrofossil, and pollen records to sort out habitats through time. This is an independent measure of the zonation of nearshore environments established by the shoreline model (item 2 above).

(12) *GIS plots and simulation of prehistoric and historic site geography*. This projects likely settings of sites based on known patterns of settlement in near shore environments through time (ie, for Paleoindian, Archaic, Woodland, Contact and historic periods) based on the model of changing nearshore environments through time.

(13) *Projection of a refined model of archaeological sensitivity*. The former models are assessed and reworked from the plots constructed in the GIS data set. A predictive model for the major navigation channels and surrounding areas is advanced.

Summarily, this next phase of the study will develop a dynamic human ecological model that begins with the systematic collection and analysis of the most recent field data. It processes these data together with digitized spatial and temporal mapping layers (GIS template). Field and mapping sets passed through the GIS filter will then produce a model for environmental change and human geography that will help structure planning decisions for cultural resource planners.

Attachment 2.

Transmittal Information

A transmittal letter containing, at a minimum, the following information shall accompany each digital media submittal to the Corps. The transmittal letter shall be dated and signed by the appropriate contractor's representative. The transmittal letter shall be provided in hard copy and a digital copy of the letter shall be included in .pdf on the digital media submitted to the Corps.

a. The information included on the external label of each media unit (e.g., disk, tape), along with the total number being delivered, and a list of the names and descriptions of the files on each one.
b. Brief instructions for transferring the files from the media to the Corps' target GIS.
c. Certification that all delivery media are free of known computer viruses. A statement including the name(s) and release date(s) of the virus-scanning software used to analyze the delivery media, the date the virus scan was performed, and the operator's name shall be included in the certification. The release or version date of the virus-scanning software shall be the current version which has detected the latest known viruses at the time of the delivery of the digital media
d. A statement indicating that the contractor will retain a copy of all delivered digital media (with all files included) for at least one year, during this period, will provide up to 5 (five) additional copies of each to the Corps, if requested, at no additional cost.

In addition, the following documentation information shall be provided to the Corps as an attachment to the hard copy of the transmittal letter. A digital copy of the documentation in a .pdf format shall be provided on the digital media submitted to the Corps.

a. Description of how the data were acquired and input into the GIS
b. Brief development history for each graphic and non-graphic file on the submitted digital media (e.g., content, when developed, modified, etc.)
c. Reference files and symbols library names. A list and file location of all new symbols created for the project, which were not provided with the GFM
d. Level/layer assignments and lock settings, where applicable
e. Fonts, and line styles/types used
f. Metadata files in the Corps-approved format
g. Database schema and instruction for its use. A list of all database files associated with was drawing, as well as a description of the database format and schema design.
h. Plotting instructions on tape/diskette and paper. The plotter configuration (e.g., name and model of plotter), pen settings, and any specific plotting instructions.
i. A list of all deviations from the Corps' specified or provided standards.
j. A list of any non-IGES crosshatch/patterns used.

Any recommended modifications necessary to make the data available for future use with a different type of GIS or with other "life-cycle" activities.

REFERENCES

Geoarcheology Research Associates (GRA)

2000a Geomorphological and Archaeological Study of New York and New Jersey Harbor Navigation Study, Upper and Lower Bay, Port of New York and New Jersey, Hudson, Essex and Union Counties, New Jersey, Kings, Richmond and New York Counties, New York.

2000b A Geomorphological and Archaeological Study, Northeast of Shooters Island, Hudson and Union Counties, New Jersey, in Connection with the Arthur Kill-Howland Hook Marine Terminal Channel Project.

2001 Geomorphological Study, Port Jersey, City of Bayonne and Jersey City, Hudson County, in Connection with the New York and New Jersey Harbor Navigation Study.

LaPorta, Philip C., Linda Sohl and Margaret Brewer

1999 Preliminary Draft Cultural Resource Assessment of Proposed Dredged Material Management Alternative Sites in the New York Harbor-Apex Region, Affecting the Coastal Areas of New York, Queens, Kings, and Richmond Counties in New York and Bergen, Hudson, Middlesex and Monmouth Counties, New Jersey. On file, U.S. Army Corps of Engineers, New York District.

Wagner, Daniel P., Ph.D. and Peter E. Siegel, Ph.D.

1997 A Geomorphological and Archaeological Analysis of the Arthur Kill - Howland Hook Marine Terminal Channel, Richmond County, New York and Union County, New Jersey. On file, U.S. Army Corps of Engineers, New York District.