North/West Battery Park City Resiliency Project

Portions of Block 142, Lots 25 and 50; Block 16, Lots 3, 15, 20, 100, 125, 140, 150, 160, 225, 7501 (formerly Lot 90), 7502 (formerly Lot 95), 7505 (formerly Lot 65), 7508 (formerly Lot 50), 7509 (formerly Lot 45), and 7511 (formerly Lot 25); and Portions of Streetbeds of Greenwich, North Moore, Harrison, and Route 9A/West Streets

MANHATTAN, NEW YORK COUNTY, NEW YORK

Geomorphological Investigation

SHPO Project Review Number: 22PR07165
LPC Unique Site Identifier: 36492

Prepared for:

Battery Park City Authority
200 Liberty Street, 24th Floor
New York, NY 10281

Prepared by:

AKRF, Inc.
440 Park Avenue South
New York, NY 10016
212-696-0670

SEPTEMBER 2025

Management Summary

SHPO Project Review Number: 22PR07165

LPC Unique Site Identifier: 36492

Involved Agencies: Battery Park City Authority
New York State Department of Transportation
New York State Department of Environmental Conservation
U.S. Army Corps of Engineers

Phase of Survey: Geomorphological Investigation

Location Information
Location: Portion of the streetbed of Greenwich Street south of North Moore Street; Portion of the streetbed of North Moore Street between Greenwich Street and Route 9A/West Street; Portion of the streetbed of Harrison Street between Greenwich Street and Route 9A/West Street; Portions of the streetbed of West Street between North Moore Street and Albany Street; Portion of West Thames Street west of Route 9A/West Street; Portions of Block 142, Lots 25 and 50; Block 16, Lots 3, 15, 20, 100, 125, 140, 150, 160, 225, 7501 (formerly Lot 90), 7502 (formerly Lot 95), 7505 (formerly Lot 65), 7508 (formerly Lot 50), 7509 (formerly Lot 45), and 7511 (formerly Lot 25)
New York, New York
Minor Civil Division: 06101
County: New York County

Survey Area
Length: Approximately 6,000 feet
Width: Approximately 30 to 900 feet
Area: Approximately 15 acres

USGS 7.5 Minute Quadrangle Map: Jersey City

Report Authors: John Stiteler, MS and Elizabeth D. Meade, PhD, RPA

Date of Report: September 2025

Acknowledgements: The authors owe a debt of gratitude to a number of people who were cooperative in the extreme and greatly facilitated the geomorphological fieldwork. These include but certainly are not limited to: Jose Class of Turner Construction; Hamid Hammache, Sophie Avoine, Nicole Couture, Jocelyn Lai, Matias Pinto, and Maria Talero of WSP; and the drilling crews of Vibranalysis, Inc. and AES.

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A. INTRODUCTION

The Battery Park City Authority (BPCA) is proposing the North/West Battery Park City Resiliency Project (NWBPCR Project) to provide coastal flood protection for Battery Park City (BPC) and surrounding areas of Lower Manhattan (see **Figure 1**). The project is intended to protect against coastal storm events and predicted future more intense storms, taking into account climate change and sea level rise, and to reduce coastal storm impacts to residential populations, commercial business, and critical transportation systems. The proposed flood protection is functionally independent from but would connect with the South BPC Resiliency Project (SBPCRP).

B. PROJECT DESCRIPTION

The NWBPCR Project is being designed to provide independent flood risk reduction for the proposed protection area from the 2050s 100-year storm event, inclusive of rainfall, coastal surge, and predicted sea level rise. The proposed flood barrier system would include passive structures (e.g., above-grade concrete walls, below grade concealed walls, etc.) with deployable structures at vehicle and pedestrian crossings. As described in this scope, the term “flood barrier system” is used to identify this potential combination of flood barrier measures. In describing the location of the proposed flood barrier system protection measures, the term “flood barrier alignment” is used. In addition, to protect against interior flooding, improvements are proposed to the City’s drainage infrastructure, including the isolation of the existing underground sewer components. The proposed flood barrier alignment would span the Port Authority Trans-Hudson (PATH) tunnels that run beneath the Project Area; the Port Authority of New York and New Jersey has separately implemented measures to provide flood protection for other assets in the Project Area. The following elements are expected to be included in the final design:

- **Flood Barrier Elements:** the flood barrier system will be comprised of passive and deployable flood barrier elements such as floodwalls and floodgates. Foundations for the flood barrier system are anticipated to extend 50 to 90 feet below the ground surface, pending final geotechnical investigation and final foundation design.
- **Interior Drainage Improvements**: Interior drainage improvements are also proposed to prevent storm surge from unprotected areas from entering the NWBPCR Project Area through the sewer system and to handle runoff and combined drainage that may accumulate during the storm event. A near surface isolation system is proposed to provide interior drainage improvements, which consists of a slide gate within existing regulator structures that would be closed in a flood event. Other drainage improvements include the construction of tide gates at existing stormwater outfalls at Chambers, Albany, and Rector Place and at combined sewer overflows near Rector Park, Vesey Street, and Stuyvesant Plaza. Isolation of other wet or dry utilities crossing the proposed coastal barrier alignment will be implemented as necessary.

The NWBPCR Project would also include landscape and urban design enhancements in a manner consistent with the design excellence standards established by Battery Park City’s long history of high quality public open spaces.

The NWBPCR Project will be implemented pursuant to BPCA's design-build authority. Although the final design will be determined by the design-build contractor, a Project Area has been identified for the purposes of environmental analysis and encompasses all properties for which it is expected that direct physical/subsurface disturbance will be necessary to implement the project (see **Figures 2A and 2B**).

C. SUMMARY OF ENVIRONMENTAL REVIEW

The NWBPCR Project requires permits and approvals from several city, state, and federal agencies. The Proposed Project is therefore subject to the New York State Environmental Quality Review Act (SEQRA) the National Environmental Policy Act (NEPA), and Section 106 of the National Historic Preservation Act ("Section 106"). BPCA is serving as lead agency for the environmental review of the above referenced action. As a state action taking place within New York City, the methodologies for assessing environmental impacts are based on SEQRA and 2021 *City Environmental Quality Review (CEQR) Technical Manual* guidelines.

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Pursuant to CEQR, consultation was initiated with the New York City Landmarks Preservation Commission (LPC) regarding the Project Area's potential archaeological sensitivity. In a comment letter issued on July 18, 2022, LPC determined that the Project Area is potentially archaeologically significant in association with its Indigenous occupation in the precontact period. LPC requested that an archaeological documentary study be prepared to further clarify its archaeological sensitivity. Consultation was also initiated with the New York State Historic Preservation Office (SHPO) pursuant to Section 106. In a comment issued through the New York State Cultural Resource Information System (CRIS) on October 11, 2022, SHPO also requested a Phase 1A Archaeological Documentary Study ("Phase 1A Study") of the Project Area to confirm its archaeological sensitivity. A Phase 1A Study of the Project Area as then delineated was prepared by AKRF in November 2022 that identified areas of archaeological sensitivity within the Project Area as then defined (see **Figure 3A**). In comment letters issued November 29, 2022, and December 9, 2022, LPC and SHPO, respectively, concurred with the conclusions and recommendations of the Phase 1A Study.

A Supplemental Phase 1A Archaeological Documentary Study ("Supplemental Phase 1A Study") was prepared in December 2024 to address project design changes that have occurred since the preparation of the Phase 1A Study in November 2022. As a result of these revisions, the Project Area was refined, and some areas identified as archaeologically sensitive in the Phase 1A Study were removed from the Project Area while additional areas that have not yet been analyzed were added. The Supplemental Phase 1A Study clarified the areas of archaeological sensitivity for the revised Project Area (see **Figure 3B**). In comment letters issued on December 6, 2024, and December 10, 2024, SHPO and LPC, respectively, concurred with the conclusions and recommendations of the Supplemental Phase 1A Study. A supplemental memo documenting minor revisions to the Project Area was submitted to LPC and SHPO in April 2025 that further refined the areas of archaeological sensitivity (see **Figure 3C**). In comment letters issued April 15, 2025 and April 14, 2025, LPC and SHPO, respectively, concurred with the revised sensitivity map.

GEOMORPHOLOGICAL INVESTIGATION

The November 2022 Phase 1A Archaeological Documentary Study concluded that the majority of the Project Area as defined at that time is located in an area of artificial landfill that was created in the 19th and 20th centuries. A small portion of the Project Area in the vicinity of what is now the streetbed of North Moore Street east of the line of Washington Street was part of Manhattan's pre-development landform. The remainder of the Project Area was gradually developed as landfill was used to expand Manhattan's waterfront westward between the 17th and 19th centuries. The Project Area was determined to have low sensitivity for precontact archaeological resources within deeply buried landforms and portions of the Project Area were determined to have sensitivity for archaeological resources associated with 17th and 18th century occupation and with 19th century landfilling activities.

The Phase 1A Archaeological Documentary Study recommended a Phase 1B Archaeological Investigation including a geomorphological investigation and archaeological monitoring to confirm the presence or absence of archaeological resources within the Project Area. A Work Plan for the Geomorphological Investigation was developed in March 2023 to outline the proposed scope of work for the recommended geomorphological investigation. In comment letters dated March 23 and March 30, 2023, LPC and SHPO respectively concurred with the Work Plan.

PHASE 1B ARCHAEOLOGICAL MONITORING DURING CONSTRUCTION

All required archaeological monitoring required during the construction will occur at a later date. The monitoring will be completed pursuant to a separate Archaeological Work Plan to be prepared by the archaeological consultant completing that work.

A. RESEARCH DESIGN

Over the past 25,000 years, the area now occupied by Lower Manhattan was subject to a series of environmental changes: glaciation; formation of a pro-glacial lake; drainage of that lake; scouring and erosion of the lakebed sediments and subsequent alluvial deposition by the Hudson River; and transition to an estuarine environment as a result of on-going post-glacial sea level rise. During the historic period, large amounts of fill were introduced into the shallow eastern edge of the Hudson River channel within the Project Area to allow for development and use. For the most part, each of these environmental changes has left a distinct signature in the sedimentary column underlying the study area, although previous subsurface testing by others suggests that the subsurface may be more properly regarded as a palimpsest than a complete record, with some post-glacial processes having altered or obliterated evidence of previous processes in places. However, the potential exists for the presence of preserved, formerly habitable land surfaces beneath estuarine deposits in the now-inundated portion of the study area and beneath fill in terrestrial areas not yet inundated by sea level rise.

The objectives of the geomorphological investigation of the project site were therefore to collect evidence regarding deeply buried archaeological resources to supplement the findings reached by previous archaeological investigations in the 1980s and 1990s (Hartgen Archaeological Associates, Inc. [Hartgen] 1989; Hartgen and Historical Perspectives Inc. [HPI] 1990; and Historic Conservation and Interpretation, Inc. [HCI] 1983). Specifically, the investigation was designed to allow archaeologists to gain greater understanding of the post-glacial evolution of the local landscape and the related potential for the presence of intact, in-situ cultural material within deeply buried soils within the Project Area. The geomorphological investigation was designed to confirm if the deeply buried resources 30 to 60 feet or more below the ground surface are still present following the extensive development that has occurred in the vicinity of the Project Area since 1983. Furthermore, this investigation documents potential landforms that were later inundated and would be impossible to document using other archaeological means, such as standard testing.

Given the great depth of potentially sensitive soil strata and the fact that the only project impacts at those depths will involve the driving of piles (as opposed to excavation involving dewatering and shoring), it is expected that physical impacts to deeply buried soil layers cannot be archaeologically monitored in a meaningful way. As such, this geomorphological investigation was designed to document those deeply buried layers in sufficient detail so as to preclude the need for further phases of work (e.g., a Phase 2 Archaeological Survey/Evaluation or a Phase 3 Data Recovery). Any impacts to deeply buried soil levels are therefore considered to have been mitigated by the completion of this geomorphological investigation.

B. METHODOLOGY

This geomorphological investigation was completed by monitoring a planned geotechnical soil borings program to collect data about deeply buried soils. The monitoring of the soil borings and all subsequent analysis was conducted in accordance with LPC's "Guidelines for Archaeology work in New York City," issued in 2018,[1] with the standards for Historic and Cultural Resources analyses as specified in the *CEQR*

[1] http://www.nyc.gov/html/lpc/downloads/pdf/pubs/ayguide.pdf

Technical Manual as amended in 2021,[1] and with the "Standards for Cultural Resources Investigations and the Curation of Archaeological Collections in New York State" as issued by the New York Archaeological Council (NYAC) in 1994.[2]

SELECTION OF BORINGS FOR MONITORING

Those borings selected for monitoring were identified to: 1) obtain data from areas not previously sampled as part of the 1983 HCI survey; 2) further characterize and refine the understanding of now-inundated landforms identified in the 1983 HCI study; and 3) assess the potential for the presence of preserved surfaces in terrestrial areas now covered by fill and pavement. Where deemed appropriate in terms of data collection, some borings were monitored from the ground surface until contact was made with bedrock while others were monitored from base of fill to bedrock surface to extrapolate the thickness of the fill. In more terrestrial settings—principally at the northern end of the study area—monitoring began at the surface and was terminated if and when it was determined that sampling had encountered glacial drift (outwash or till). The coring of bedrock is not pertinent to the study described here and was not monitored. The locations of borings that were archaeologically monitored are depicted on **Figures 4A and 4B**.

With the exceptions of Borings B-43 through B-45, all boring locations were located in areas that, within the historic period, were open water along the eastern edge of the Hudson River (see **Figures 5, 6, and 7**). Twenty-eight borings were observed either partially or in their totality by the geomorphologist.[3] Borings monitored in their entirety by the geomorphologist included: B-02A, B-05, B-07, B-08, B-12, B-19, B-20, B-25, B-28, B-32 through B-36, B-38, B-39A, B-40, B-44, and B-55. Borings B-04, B-15, B-17, B-22a, B-23, B-24, B-29, B-31, B-43, B-56 were monitored by the geomorphologist after initial hand excavation of the upper 6 feet. Analysis and description of borings B-05 and B-11 was conducted through same-day examination by the geomorphologist of sample bottles collected by the geotechnical inspectors, along with consultation with the inspectors and examination of their field notes.

The characterization of an additional 20 borings was accomplished through examination of sample jars and boring logs created by geotechnical inspectors present on-site for those borings. Analysis of borings B-01, B-03, B-09, B-11, B-13, B-18, B-21, B-27, B-30, B-37, B-45, B-46, B-47, B-52, B-53, B-54, B-57, and B-58 was conducted entirely through examination by the geomorphologist of the logs and notes provided by the on-site geotechnical inspectors.

Borings at three locations (B-06, B-10, and B-14) were initially monitored by the geomorphologist but work these locations was abandoned at shallow depth after repeated failed drilling attempts.

MONITORING METHODOLOGY

Fieldwork for this investigation consisted of the monitoring of split-spoon borings conducted by others. The monitoring included the examination, description, and interpretation of the soil cores produced by the borings. More than 70 soil borings were advanced as part of the program, nearly 30 of which were archaeologically monitored by geomorphologist John Stiteler, MS. Sampling within the Project Area was accomplished through the use of split-spoon borings carried out by track-mounted rigs—Mobile Drill B45-HD, Geoprobe 7822DT, and Massenza MI3 track rig—all with automatic hammers. Out of concern for the presence of unmarked subsurface utilities, the upper 6 feet of material at each drilling location was hand-

[1] http://www.nyc.gov/html/oec/downloads/pdf/2014_ceqr_tm/09_Historic_Resources_2014.pdf

[2] http://nyarchaeology.org/wp-content/uploads/2013/12/NYACStandards.pdf

[3] Cases where borings were obstructed and attempted again in a nearby location—typically designated by adding the letter A to the end of the boring number (i.e., Boring B-39 and B-39A)—are counted as a single boring in the total number of archaeologically monitored borings.

excavated, using shovels and post-hole diggers. Following hand excavation, split-spoon sampling commenced, using a split-spoon with a 24-inch inner sampling void with a 1.375-inch inner diameter. The spoon was advanced 24 inches in 6-inch increments with the number of hammer-blows per increment recorded. The spoon was then withdrawn and opened by the drillers for inspection by the geotechnical inspectors and the geomorphologist. Sampling was continuous from 6 to 12 feet below surface. Beginning at 12 feet below surface, sampling was intermittent, with each 2-foot spoon sample followed by a 3-foot advance of a roller-bit with no sampling. Thus, sampling was carried out in approximately 40 percent of the vertical column. Sample yields in the spoon advances ranged from the full 24 inches of the sampler to no recovery; 6- to 12-inch recoveries were typical. Split-spoon sampling was carried out to contact with bedrock, at which point rotary coring was employed, usually following a roller-bit advance to remove the weathered, incompetent upper 1 to 3 feet of the bedrock. Horizontal distance between boring locations ranged from 60 to more than 500 feet, with 120 to 150 feet being a common interval.

In several instances, samples were collected using a “Shelby tube,” a thin-walled, hollow steel tube driven into sediments (usually fine-textured sediments) to retrieve a relatively undisturbed sample for analysis of density, permeability, compressibility, and strength. Shelby tubes are not opened and examined in the field but are instead sealed upon being extracted from the boring and opened later at a testing laboratory. Descriptions of the cores collected using Shelby tubes were subsequently added to the boring logs and were available for this analysis.

The sediment cores of the monitored borings were described using standard field parameters (Munsell color, texture, structure, rock fragment content, redoximorphic features, etc.). Particular attention was given to those characteristics pertinent to archaeological potential of the sediments (e.g., presence of buried stable surfaces; relative age of the sediments; depositional dynamics; presence of chronological markers such as coal cinder, glass, brick; etc.). Examination of the cores was conducted concurrently with geotechnical inspection of the cores by inspectors in the employ of environmental consulting firm WSP. As deemed appropriate, to gain a better understanding of site-formation processes and with the consent of the geotechnical inspector, subsamples of core segments were taken for laboratory analysis by others (e.g., particle-size analysis, carbon dating, pollen analysis, etc.).

In the analysis included in this technical report, the stated depths to bedrock frequently vary slightly from that at which the geotechnical boring logs show the commencement of bedrock coring. This is because a zone of weathered bedrock was generally encountered at the alluvium/bedrock boundary and at that point the roller-bit was advanced for several feet before coring of unweathered, intact bedrock was commenced. For the purposes of this study, the upper boundary of weathered bedrock is considered to be the bedrock surface. Thus, if 50 hammer blows resulted in only a one- or two-inch advance of the sampling spoon (recorded in the boring log blow counts as “50/1” or “50/2”), that depth is considered here to mark the surface of bedrock.

Representative photographs of soil borings are included as **Photographs 1 through 8**.

SAMPLE COLLECTION AND LABORATORY ANALYSIS

As described in detail in **Chapter 5, “Results of Survey,”** in five locations where peat was encountered, a sample was retained for carbon dating and possible botanical analysis; four of these peat deposits were sampled. Numerous samples of the organic-rich estuarine sediments and underlying sandy loam were also retained for dating and botanical analysis. Four peat samples and eleven sediment samples were subsequently submitted for radiocarbon dating, along with two wood samples.

After the conclusion of fieldwork, seventeen samples were submitted to the Center for Applied Isotope Studies at the University of Georgia, at Athens for radiocarbon dating (see **Appendix A**). Radiocarbon dates presented in this analysis are the median probability as calculated by the Center for Applied Isotope

Studies at the University of Georgia, based on 2 sigma (95 percent) probability, and are given in years before present (BP). In general, radiocarbon dating of bulk sediments samples is regarded as somewhat problematic, largely because of the possibility of intrusive older or younger carbon from (see discussions in Grimm et al. 2009, Lougheed, et al. 2017). In contrast, material such as rooted peat is regarded as providing more reliable dating results. In this study, peat was available only from a relatively small portion of the overall study area. Hence, along with four samples of peat and two samples of wood, eleven bulk sediment samples were submitted for dating with mixed results.

Eight split samples—including both peat and bulk sediment—were sent for both dating and for pollen analysis to Dr. John Jones at Archaeological Consulting Services in Tempe, AZ, for pollen analysis (see **Appendix B**). However, the original submissions for pollen analysis were irretrievably misplaced at the laboratory. Subsequently, peat or sediment samples from the same depth below surface in adjacent borings were resubmitted for pollen analysis. Substitutions were available for only four of the original submissions. These substitutions are noted where relevant in this analysis. It is acknowledged here that pollen profiles derived from these samples cannot be construed as site-specific, but should be taken as representative of regional vegetative populations that was possibly carried to the Project Area by wind or river currents.

Finally, two subsamples were submitted to Ms. Justine McKnight, Principal Archeobotanist at Justine McKnight Archeobotanical Consultant, LLC, Severna Park, MD, for macrobotanical analysis (see **Appendix C**).

DOCUMENTATION AND RECORDING

In this analysis, elevations above and below sea level are given as positive (above current sea level) or negative (below current sea level) integers. Opening elevations at drilling locations were supplied by WSP using a datum based on the North American Datum of 1983 (NAD83) for horizontal measurements and the North American Vertical Datum of 1988 (NAVD88) for vertical measurements. These opening elevations were then used to extrapolate the vertical provenience of samples in terms of current sea level. For the sake of simplicity, some rounding of elevations and depths was employed in the following discussion of boring profiles. Generally, when an opening elevation at a boring location includes a measurement of less than half a foot (e.g., +12.3 feet) the opening elevation is rounded down to +12 feet in calculating sample depths below surface. Similarly, opening elevations including a measurement above a half foot have been rounded up (e.g., if an opening measurement was +10.7 feet, it is rounded to +11 feet in reporting depths in the profile).

A. QUATERNARY HISTORY OF THE PROJECT AREA

Based on the known limits of Pleistocene glaciation to the west, the Project Area has been near or within the furthest extent of continental glacial ice at least three times over the last 2.4 million years. The most recent glacial advance reached its maximum extent at the southern tip of modern Staten Island and Perth Amboy, New Jersey, around 25,000 years before present (BP) (Stanford et al. 2020). This ice was part of the leading edge of the Hudson-Mohawk Lobe of the Late Wisconsinan (Woodfordian Stage) continental ice mass. It is noted here that researchers are not in agreement on the exact timing, sequence, and mechanics of the events at the last glacial maximum or in the early stages of ice recession. Views on the timing of events such as release of water from glacial lakes may differ by thousands of years and there may be disagreement as to whether events such as certain glacial re-advances did in fact occur. The reconstruction presented below attempts to integrate differing views but is by no means comprehensive.

Advancing glacial ice scoured the relatively soft sedimentary rock of the Stockton Group from the lower Hudson River valley and the Newark Group rock from the nearby ancestral Hackensack and Passaic River valleys, while overriding and rounding the more resistant schists and diabase underlying Manhattan and the diabase of the Bergen Ridge, Laurel Hill, and other high points across the river to the west. A broad, continuous terminal moraine as much as 30 meters high and three kilometers wide (Stanford 2010) formed at the ice limit, a product of ongoing delivery of sediment-laden ice to the wasting ice front. Remnants of the terminal moraine are visible as prominent landforms in Perth Amboy and Metuchen, New Jersey; on Staten Island it makes up an irregular axial ridge from the southwest end of the island, along the lower elevations of the southeast flank of Todt Hill, and terminating on the northeast corner of the island at the Narrows, the reach of harbor between the Upper and Lower New York Bays. Across the Narrows, the moraine manifests as the landform which lends its name to Bay Ridge, Brooklyn and continues northeast as the long, high ridge of the Ronkonkoma Moraine on Long Island.

After a still-stand at the terminus lasting around 750 years, wasting of the glacial mass and recession of the ice margin from the Perth Amboy area commenced at around 24,000 years BP (Stanford et al. 2020). The resulting meltwater was confined between the terminal moraine and the receding ice front and formed a series of transient proglacial lakes which filled the scoured troughs of the Passaic, Hackensack and Hudson River valleys. As the ice mass continued to recede to the north, low points in the ridges separating the parallel troughs were exposed and served as spillways, allowing water to move from one lake to another and ultimately to flow through eroded breaches in the moraine. The transitioning boundaries and water levels of the proglacial lakes over time is reflected in the names applied to the lakes.

The initial lake, which occupied the Arthur Kill, Newark Bay, the upper New York Bay lowlands, and much of the New York City metropolitan area has been designated Glacial Lake Bayonne. Waters of Lake Bayonne eventually overtopped the moraine and created an outlet to the coastal plain at what is now the Richmond Valley on Staten Island and later near present-day Perth Amboy, New Jersey (Stanford and Harper 1991). Ongoing erosion of the outlet at Perth Amboy allowed creation of an outlet channel within what is now the Arthur Kill. At Tremley Point, just east of Perth Amboy, the channel downcut through till, outwash and recently deposited lake sediments until it encountered a resistant diabase sill. Downcutting of the outlet was effectively stopped at that level and the lake level stabilized upstream in the Hackensack trough. The proglacial lake which subsequently occupied the trough is referred to as Lake Hackensack.

Ongoing ice recession exposed an outlet at Hell Gate, between present-day Manhattan and Astoria, Queens, allowing the lowering of the lake level in the Hudson River valley and differentiating the meltwater body there as Lake Hudson. The water level in Lake Hudson was approximately 40 feet lower than that in Lake Hackensack and over time a spillway was eroded between the two bodies along the present course of Kill Van Kull, allowing some drainage from Lake Hackensack into Lake Hudson. Eventually, ice recession northward up the Hackensack trough exposed a water gap at Sparkill, allowing relatively complete drainage of Lake Hackensack into the lower Hudson Valley (Stanford and Harper 1991).

From the late Pliocene or early Pleistocene to the late Wisconsinan, the course of the Hudson River within the metropolitan area followed a south-trending paleo-valley cutting through the present location of the borough of Queens and now filled by glacial drift (Stanford 2010: pers. comm. 2019).

Drainage of meltwater impounded in the lower Hudson Valley (Lake Hudson) finally occurred with the breaching of the terminal moraine at the point now called the Narrows, possibly as a result of release of meltwater from the Great Lakes basin. The timing of the breakthrough of the moraine has yet to be defined. Thieler, et al. (2007) place it at around 13,350 years BP, a result of catastrophic release of water from Glacial Lakes Vermont, Iroquois, and Albany in the upper and central Hudson River drainage. Stanford (2010) places failure of the moraine dam at around 18,000 years BP, a result of the catastrophic release of water impounded within Glacial Lake Wallkill into Glacial Lake Albany and a resultant outburst from Lake Albany.

An immense amount of meltwater from the lower Hudson Valley and from glacial lakes to the north and northwest was released through the breached moraine and flowed east-southeast toward a shoreline already transgressing westward as worldwide sea level rose. Over much of this distance the meltwater flowed down an existing ancestral Hudson River valley which had been incised into the exposed coastal plain during repeated Pleistocene marine regressions. This now-submerged landscape feature is referred to as the Hudson Shelf Valley. The channel within the valley was active prior to the terminal Wisconsinan outburst, carrying flow produced by precipitation, meltwater flows, and diversion of rivers such as the Raritan over the course of the Middle to Late Wisconsinan period (Thieler, et al. 2007). The flow through the breach at the Narrows dramatically deepened and broadened the ancestral river valley. The reach immediately below the Narrows, adjacent to the current study area, dates largely to the time of the breaching of the moraine; the channel reach immediately below the Narrows lies at a general elevation of around 100 feet (30 meters) below current sea level (ibid).

Within a short time following the drainage of the glacial lakes in the study area, low-order streams began draining the exposed upland surfaces, particularly in the area formed of resistant schist and diabase. Some of these low-order streams probably occupied hollows and courses established by channelized lake water flow as the lakes drained. These post-glacial streams would have had a moderately high gradient, with the gradient increasing dramatically at the upper edge of the valley.

The effects of continental glaciation go far beyond even the vast surface manifestations of erosion and deposition. In envisioning the processes of glacial recession, glacial lake formation and drainage, post-glacial sea level rise, and the evolution of the modern landscape it is necessary to keep in mind the dynamics of crustal depression resulting from continental glaciation. Because immense volumes of global water were temporarily contained in world-wide continental ice masses at the last glacial maximum, global eustatic sea level fell by as much as 390 to 425 feet (Fairbanks 1989; Peltier 2002; Clark, et al. 2009). The exposed coastal plain in the area of New York City and northern New Jersey extended to or nearly to the edge of the Continental Shelf, about 130 miles east of the present shoreline.

Additionally, the presence of the enormous weight of a continental ice mass causes the surface of the Earth's crust to deform and warp downward, forcing the fluid mantle material to flow away from the loaded region. This movement of mantle fluid produces a related phenomenon, a forebulge effect—the temporary elevation of the crust in areas just beyond the glacial limit, caused by the in-migration of the viscous mantle material. Ablation of the ice mass and the removal of the load allows the return flow of mantle material back under the deglaciated area and rebound of the depressed surface, known as isostatic rebound. Due to the extreme viscosity of the mantle, it takes many thousands of years for the land to return to isostatic equilibrium, more or less its pre-glacial state. Because of its position near the ice margin, the study area was subject to crustal depression while the area to the south and southeast, beyond the glacial margin, was not and appears to have experienced some uplift due to a forebulge effect. The extent of crustal depression is related to the thickness of the overlying ice and in the New York City area—at the thinner leading edge of the ice mass—was in the range of 40 to 50 meters or 131 to 164 feet. In order to convey the effect of crustal depression and present a clearer picture of post-glacial conditions, some elevations are given in this report as negative elevations, e.g., -20 meters. This reflects the fact that at the time given for this elevation, it was 20 meters below modern sea level.

In the early post-glacial period, the rate of isostatic rebound was generally outstripped by that of sea level rise as meltwater returned to the world's oceans. One result in the New York City area was that, as sea level rose, marine waters encroached landward via the Hudson Shelf Valley, entering the Hudson Valley proper between 13,000 and 14,000 years BP. Marine waters extended up the glacially-depressed valley as far as Kingston, with the valley constituting a long, narrow marine embayment or fjord. Isostatic rebound over the next several thousand years—now exceeding the rate of sea level rise—slowly returned the gradient of the valley to pre-glacial conditions and the brackish marine/freshwater boundary zone regressed down-valley.

Because of this sea level rise and marine encroachment, the post-glacial Hudson River Valley at the Project Area was never the setting of a through-flowing meltwater stream with adjacent floodplains or other alluvial landforms. The bedrock beneath the Hudson channel is glacially scoured to deeper than -100 meters in the Hoboken area so at no time during deglaciation was the bottom of the valley subaerially exposed. According to Stanford (pers. comm. 2024) "The [Hudson Tubes] tunnel borings indicate that there is little to no glacial sediment in the deepest part of the scour trough, which is instead filled with postglacial estuarine mud." A catastrophic outburst of meltwater from Glacial Lake Iroquois at around 13,350 years BP (Donnelly, et al. 2005; Thieler, et al. 2007; Stanford 2010) scoured the Hudson Valley soon before the onset of the marine incursion at the Narrows, followed several thousand years later—after the onset of isostatic rebound at around 12,000 years BP—by transition to a broad, brackish estuary. Thus, there is no potential for the use of the valley floor by Indigenous peoples following deglaciation. Habitable settings may have been present along the valley walls prior to submersion by sea level rise, though given the glacial carving of the valley and scouring by extremely large and energetic flows any such settings are likely to have been relatively small in area.

B. SEA LEVEL RISE

As noted previously, sea level rise and inundation of the coastal plain offshore from the study area did not occur in a linear, straightforward fashion, either spatially or temporally. In most coastal areas within and adjacent to the glaciated region, the Earth's surface was—and, to a lesser extent, still is—rising over the course of many millennia following ice recession even as sea level was rising, complicating the process of reconstructing rates of coastal inundation. Similarly, subsidence of areas formerly elevated through a forebulge effect allows for accommodation of large volumes of marine waters, further making the rate of relative sea level rise less than linear.

A number of sea-level rise curves have been produced, including several for the mid-Atlantic, New England, and New York City coastal regions (e.g., Belknap and Kraft 1977; Rampino and Sanders 1980). These curves rely largely on radiocarbon dating of peat and other organic material recovered through coring of now-inundated coastal surfaces in the near offshore and correlation of those dates with depth below modern sea level. A complete review of the various constructed curves is beyond the scope of this report but there is broad agreement in their general conclusions. Schuldenrein, et al. (2006; 2007) of Geoarcheology Research Associates have taken a comprehensive approach, correlating coring and radiocarbon data from several projects conducted by those authors in the New York Bight, as well as similar data and preserved cores produced in studies by other researchers. Broadly describing the results of the study, the authors state that they show “a rapid rise in relative sea level at a rate of approximately 9 mm/yr (0.5 inches/yr) from at least 9000 years BP until about 8000 years BP when the rate of rise diminished to a consistent 1.5—1.6 mm/yr (0.06 inches/yr), from 7000 years BP until the present” (Schuldenrein et al. 2007: 54). Schuldenrein et al. (2007) place sea level at 25 feet below modern mean sea level at 5,000 years BP and depict the land/marine margin within the study area at 1,000 years BP at basically the same location as seen today.

Walker, et al. (2023), using basal peat samples from Great Bay in southern New Jersey, 60 miles south of the Wisconsinan terminal moraine, found a rate of sea level rise for the latter half of the Holocene that is in general agreement with that put forth in the correlative study prepared by Schuldenrein, et al. in 2007. Walker et al.’s model indicates an average rise rate of 1.7±0.1mm/year from 5000 years BP to present, producing an overall rise of approximately 8.6 m (28.2 feet).

HCI constructed a sea level curve based on radiocarbon analyses performed on 30 samples of organic matter recovered within or near the current study area and chosen on the basis of their likelihood of being sea level indicators. Their interpretation of the results indicates that:

> *sea level rose progressively from about 13,000 to 10,000 B.P. The rate of sea level rise slowed between 10,000 to 8,000 B.P. Concordantly shoreline features along the Hudson River would have been relatively stable for several thousands of years. After about 8,000 B.P. to about 6,000 B.P., the rate of sea level rise increased. Consequently, the shoreline features were somewhat less stable than previously. After about 6,000 B.P., the rate of sea level rise leveled off again to a more gradual pattern, by which it continues to rise today* (HCI 1983: 64).

C. POST-GLACIAL VEGETATION

In the immediate post-glacial period, the outwash-covered coastal plain lying east of the New York City metropolitan area was a windswept region of very low relief, cut by meltwater channels and subject to a periglacial climatic regime, as was the metropolitan area itself. Vegetation of the inner coastal plain, the Piedmont, and other areas inland in close proximity to the receding ice front would have been that characteristic of the modern sub-polar tundra—largely grasses and low shrubs, probably including some alder and willow in stream hollows and valleys. Fertility on the recently exposed outer Coastal Plain, was likely low as soils would have been sand-dominated and low in nutrients, including soil carbon. This would have been especially true with greater proximity to the continental margin, where soils had been subaerial for a shorter time and thus subject to less weathering and less accumulation of soil carbon. With ongoing ice recession and the beginning of climatic amelioration, forests composed largely or entirely of spruce—broken by numerous wetlands—began to colonize the former glaciated and periglacial settings, including the metropolitan area and coastal areas to the north and west. With further amelioration of the climate, vegetative succession extended over millennia to pine-dominated forests and ultimately to mixed hardwoods.

VEGETATIVE SUCCESSION

Chronostratigraphy, a key concept of paleoenvironmental reconstruction, is based on the premise that the types and amounts of pollen at various levels in stratified soils document patterns of plant distribution through time and that changes in plant distribution are largely the result of climate change. A zone or stratum within soil that is characterized by a specific suite of pollen types is referred to as a chronostratigraphic zone or chronozone.

Two models of chronostratigraphy are commonly used in the northeastern United States: the Blytt-Sernander model and the Pollen Zone model. The Blytt-Sernander model was developed through the study of Danish peat bog formation in the late 19th and early 20th centuries, while the Pollen Zone model was developed in New England during the first half of the 20th century (Deevey 1939; Davis 1965). Both models subdivide the late Pleistocene and Holocene into a series of chronozones of varying duration. While the Blytt-Sernander system uses names that imply the dominant climatic conditions in northern Europe (e.g., Boreal and Atlantic), the chronostratigraphic system for New England refers to the subdivisions based on the dominant types of pollen present in the strata. From oldest to youngest, these are the Herb (Zone T); Spruce (Zone A-1 to A-4); Boreal (Zone B); Oak and Hemlock (C-1); Oak and Hickory (C-2); and Oak and Chestnut (C3) pollen zones (Deevey 1939; Davis 1965:386-397). Pollen Zone C-3 has subsequently been divided into two parts (C-3a and C-3b), with Zone C-3b referring to a later (upper) zone that contains more spruce and pine pollen.

The Pleistocene epoch occurred between 2.6 million years BP and 11,700 years BP. During this time, four major periods of glaciation occurred in northern North America: two Pre-Illinoian; Illinoian; and Wisconsin (Crowl and Sevon 1999:224). Each of the four glacial episodes is separated by a relatively warm interglacial period. Alternating cooler and warmer intervals within a glacial period are referred to as stadials and interstadials, respectively. The interglacial period prior to the Wisconsinan is known as the Sangamon stage. The Holocene epoch, which started at the end of the Younger Dryas period at around 11,700 years BP, is the latest interglacial period.

Although not directly applicable to the current study area, microbotanical data from a number of locations in Pennsylvania provide insights into the floral community of the Mid-Atlantic and southern New England during the late Pleistocene. Data recovered from Pennsylvania are therefore used as a proxy for the New York paleoenvironment as described in this section. These include Rose Lake in Potter County, Kings Gap Pond #1, and Crider's Pond in Cumberland County, Longswamp in Berks County, and Tannersville Bog in Monroe County. At Longswamp, at approximately the same latitude as the current study area but immediately south of the late Wisconsin ice front in eastern Pennsylvania, tundra vegetation with grasses, ericaceous shrubs, and dwarf birch was present, suggesting a cold, dry and windy environment (Watts 1979). Similar vegetation, with no evidence for spruce[1] or other trees, was present at Kings Gap Pond #1 between 16,080 and 14,410 years BP (Delano, et al. 2002). This locale is less than 30 minutes of latitude south of New York City but 90 miles south of the maximum extent of Wisconsinan ice. However, evidence of a non-tundra, spruce forest was present at this time at Crider's Pond, in a similar setting in Cumberland County, 17 miles to the southwest, in sediments as old as 15,000 years BP (Watts 1979). Pollen cores from Crider's Pond indicate that this area, more than 90 miles south of the glacial boundary, was dominated by spruce (*Picea sp*), dwarf birch (*Betula grolandulosa*), and various herbs between 15,000–13,000 years BP (Watts 1979). By around 13,000 years BP jack pine (*Pinus banksiana*), balsam fir (*Abies balsamea*), and speckled alder (*Alnus rugosa*) were present, forming a diverse environment containing both tree and shrub species. Red spruce (*Picea rubens*) was present by 11,500 BP with white pine (*Pinus strobus*) appearing shortly thereafter (Watts 1979).

The Younger Dryas stadial, which occurred at the end of the Pleistocene, marks a world-wide reversal of the warming climate of the Allerod interstadial. Although the pollen record at Browns Pond in the central Appalachians of Virginia suggests a brief cold reversal at 12,260 years BP possibly correlating with the

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[1] Spruce is "generally perceived to be one of the first arboreal plants to colonize deglaciated regions" (McWeeney and Kellogg 2001:193).

Older Dryas (Kneller and Peteet 1999), the absence of evidence for climatic reversal between 11,000–10,000 years BP at this location suggests that the cooling effects of the Younger Dryas may not have extended as far south as Virginia (ibid).

It was during the terminal Pleistocene, approximately 13,500 BP, that humans are believed to have arrived in the Northeast. Microbotanical remains indicate that the terrestrial environment of this region at that time would have included both boreal and deciduous tree species. Deciduous species would have initially been restricted to floodplains and other favorable settings before gradually expanding into more diverse settings.

PRE-BOREAL (10,000–9,000 YEARS BP)

The Pre-Boreal chronozone (lower part of Pollen Zone B) is the first climatic interval of the Holocene. The biotic environment of south-central Pennsylvania from circa 10,000–9,000 years BP was characterized by a closed forest comprised of pine, fir, oak, hemlock, alder and birch. Although the Laurentide ice sheet had receded to the north, weather patterns were still influenced by ongoing deglaciation. At this time the dominant atmospheric circulation pattern for North America was zonal (west to east), which resulted in an increased frequency of cyclonic storms (Knox 1983:30-31; Vento, et al. 2008:16). At this time eastern Canada remained covered by a massive glacial ice sheet, and the sea level was still approximately 66 feet below its present elevation (Conners 1986).

Changes in forest composition in eastern Pennsylvania and the lower Northeast in general around 10,000 years BP suggest that the opening of the Holocene was marked by near modern climatic conditions (Davis 1983). Delcourt and Delcourt (1981) have documented the presence of conifer-oak forests in the Middle Atlantic region at 10,000 years BP that included cold-adapted, mesic species such as birch, elm, ash, ironwood, maple and beech. Oak and hickory pollen are well-represented at 10,000 years BP at Browns Pond in Virginia. Hemlock was present in central Pennsylvania by 9,600 years BP (Watts 1979:462).

Although the data suggest that the Pre-Boreal forest likely contained a substantial component of temperate hardwoods, these species were probably restricted to favorable topographic and edaphic niches, initially occurring as patches within a predominantly coniferous forest. Eisenberg (1978) suggests that during the early post-glacial period oak was also adapted to drier upland sites where soil formation was more advanced. In the southern section of the modern conifer-hardwoods found on the Appalachian Plateau, deciduous species have migrated northward along major valleys and their tributaries (Braun 1950), a situation that may resemble the early to mid-Holocene immigration of deciduous species along stream valleys from glacial refugia in the south.

BOREAL (9,000–8,000 YEARS BP)

The Boreal chronozone (upper half of Pollen Zone B) marks the beginning of a warm period that lasted from circa 9,000–4,500 years BP that has been referred to variously as the North American climatic optimum, the Altithermal, and the Hypsithermal period (Deevey and Flint 1957). Climatic regimes of the Hypsithermal include the warm and dry Boreal episode (9,000–8,000 years BP) and warm and wet Atlantic episode (8,000–4,500 years BP).

During this climate period there was a dramatic expansion of white pine into both uplands and lowlands (Watts 1979). Because pine is an excellent temperature and moisture indicator, it reveals that the climate was both warmer and drier than it had been during the previous thousand years or at any time since (Davis 1983). The increase in pine pollen during the Boreal climatic episode defines important aspects about the prevailing climate and biotic environment. Watts notes that "pines flourish on acid sandy soils where natural fires are frequent and where competition for the larger canopy-forming deciduous trees is restricted," adding that "pines become established on sites where forest has been destroyed by fire, storm blowdowns, or forest clearance, all of which make light gaps" (Watts 1979:462). Although oak, hickory, beech and elm were present they did not reach their peak distributions until circa 5,000 years BP (Prentice et al. 1991:Figure 6).

The warm, dry Boreal climate had a detrimental effect on ponds and low-order streams. Oxidized soils containing damaged or destroyed pollen at sites from Georgia to New Jersey, (including Quicksand Pond, Bartow County, Georgia; Cranberry Glades, Pocahontas County, West Virginia; Big Pond, Bedford County, Pennsylvania; Panther Run, Mifflin County, Pennsylvania; Longswamp, Berks County, Pennsylvania; and Szabo Pond, Middlesex County, New Jersey) indicate that the ponds and bogs dried out more frequently during the mid-Holocene Hypsithermal than in subsequent times (Watts 1979:263). By 6,500 years BP the last remnant of the Laurentide ice sheet had melted on the Quebec-Labrador Plateau, and the Atlantic Ocean had reached its current level (Conners 1986:Table 1; Delcourt and Delcourt 1986:34).

ATLANTIC (8,000–4,500 YEARS BP)

A rapid decrease in pine and an accompanying increase in both oak and hemlock circa 8,000 years BP marks the transition from the drier conditions of the Boreal climatic phase to moister conditions of the Atlantic climatic phase (Pollen Zone C-1; Prentice, et al. 1991:Figure 6; Vento, et al. 2008:17). The Atlantic to Pacific periods (Pollen Zones C-1 to C-2) were dominated by a mixed zonal-meridional atmospheric circulation pattern (Knox 1983:30-31; Vento et al. 2008:16). Meridional (south to north) circulation patterns are associated with heavy, persistent rains and substantial floods.

Although mast-bearing trees continued to increase in abundance during the Atlantic episode, they did not reach their historic levels until the late Holocene or Neoglacial period (i.e., post-5,000 years BP). Chestnut, an exceedingly slow migrant, does not occur in central Pennsylvania until around 5,500 years BP. Many of the arboreal species that became dominant at this time (e.g., oak and chestnut) provided fruits and nuts known to have been used both by humans and by faunal species hunted by humans, such as deer, elk, bear and other small mammals (Davis 1976). stability.

SUB-BOREAL (4,500–3,000 YEARS BP)

The beginning of the Sub-Boreal climatic episode (Pollen Zone C-2) marks the end of the Hypsithermal and the beginning of the Neoglacial period (Vento, et al. 2008:4). Forest of this time was dominated by oak and hickory, and there is a marked reduction in pine, birch and alder (Prentice, et al. 1991:2047). A dramatic decline in hemlock that began around 5,000 years BP (Haas and McAndrews 2000:81) continued throughout this interval.

There are competing hypotheses to explain the reduction of hemlock during the Sub-Boreal interval. Knox (1983), Vento and Rollins (1989), and Vento, et al. (1992; 2008) suggest that the decline of hemlock and its continued suppression during the Sub-Boreal (circa 4,500–3,000 years BP) indicate that warm and dry conditions prevailed at this time. Hemlock is an accurate indicator of drought because of its shallow root system and sensitivity to atmospheric humidity (Fowells 1965; Haas and McAndrews 2000).

The researchers cited above argue that this drying pattern is the result of meridional stabilization of the sub-tropic high zone over the Mid-Atlantic or the increased occurrence of warm-dry zonal flow (much like conditions in the 1930s). This pattern caused a reduction in vegetative cover and greater surface runoff, which promoted vertical accretion on low terraces within stream basins. Although others have proposed that the hemlock decline was the result of disease or insect infestations (e.g., Bhiry and Filion 1996; Davis 1981), most of the evidence suggests that the decline can be attributed to drought (e.g., Haas and McAndrews 2000; Yu, et al. 1997). Whether the overall climate during this period was warm and dry, or more similar to today’s, it is clear that the rapid deposition of coarse sediments along rivers and streams during the Sub-Boreal period was the result of frequent cyclonic storms that caused severe to moderate lateral channel migration of tributaries, with alluviation dominant over incision along major streams.

SUB-ATLANTIC (3,000–1,750 YEARS BP)

The climate of the Sub-Atlantic chronozone (lower Pollen Zone C-3a) was warmer and moister than the preceding interval. In most respects the climate and forest composition of this late Holocene period was very similar to that present at the time of European contact. Like most of the Ridge and Valley province, the forest at that time was characterized as an association of oak and chestnut, with local variations due to slope and altitude. Ridge tops were typically dominated by scarlet, black and chestnut oaks, the upper slopes by red oak; the lower slopes by white oak, red oak, hickory and hemlock, and the valley floors and river terraces by white oak, sugar maple, hemlock, white pine and pitch pine (Braun 1950). Chestnut was a dominant species, though it has been eliminated due to the chestnut blight of the early 20th century. The forest contained pockets of other climax associations that reflected the region's mountainous character and altitudinal variations (ibid). Of these, the mixed mesophytic cove forests would have been particularly well developed.

SCANDIC (1,750–1,200 YEARS BP)

The forest during the Scandic period (middle Pollen Zone C-3a) appears to have been similar to that of the preceding Sub-Atlantic phase. Cooler and moister climatic phases such as the Scandic (1,750–1,200 years BP), as well as the subsequent Pacific (700–500 years BP) and Neo-Boreal (500–50 years BP) phases, effectively arrested A-horizon development while the increased frequency of tropical storms (hurricanes) led to increased runoff, floodplain instability, and the formation of Bw and BC horizons on floodplains and low terraces.

NEO-ATLANTIC (1,200–700 YEARS BP)

The Neo-Atlantic is associated with the latter half of the Middle Woodland period. The forest during the Neo-Atlantic period (upper Pollen Zone C-3a) was similar to that of the preceding Sub-Atlantic and Scandic phases.

PACIFIC TO MODERN (700–150 YEARS BP)

The forest type associated with the Pacific (700–500 years BP), Neo-Boreal (500–50 years BP), and Modern (50 years BP–present) periods (Pollen Zone C-3b) was similar to that of the preceding Sub-Atlantic through Neo-Atlantic stages but with an increase in spruce and pine. Nearly all of the original forest-cover in the Northeast was removed by the end of the 19th century as a result of lumbering and agricultural activities. The forests of today are exclusively secondary communities which bear little resemblance to the original forest association (Casselberry and Paull 1967; Gifford and Whitebread 1951).

D. WATER SOURCES IN AND NEAR THE PROJECT AREA

The waters of the tidal Hudson River offshore from the study area have been brackish since the marine incursion of 13,000 to 14,000 years BP and, while potentially serving as an important resource procurement source, the river's waters were not suitable for drinking. Historical maps examined for this study show no evidence of perennial surface water (streams, ponds, etc.) on the fast land immediately east of the Project Area. The nearest well-documented source of fresh water would have been the Collect Pond, 0.7 miles to the east and northeast of the Project Area. However, historical maps indicate the presence of three possible freshwater sources a short distance north of the limits of the study area. Ratzer's 1776 map depicting conditions ca. 1767 (see **Figure 5**) shows two small ponds on a hillside a short distance north of the study area, along the east side of a road which was a precursor to modern Greenwich Street, then known as the "Road to Greenwich." The British Headquarters Map of 1782 also shows the ponds, lying several hundred yards north of a foundry known to have been located at what would later be the intersection of North Moore and Greenwich Streets. It is likely that these ponds, like the Collect Pond, were spring-fed. Their form on the 1776 Ratzer map, bounded on the downslope side by the "Road to Greenwich," raises the possibility that they may have been expanded as a result of damming of spring-fed streamflow by construction of the road. The ponds do not appear on the 1797 Taylor-Roberts map.

Historical maps also show a third potential freshwater source immediately east of the northern end of the study area. The Ratzer map, British Headquarters Map, and Taylor Roberts maps all show the head of a broad, shallow valley just north of the intersection of Reade and Chapel Streets. In the 19th century, the path of North Moore Street would cross this valley near the head. The valley, depicted on the historical maps as marshy ground, was a southwestern extension of Lispenard's Meadow. The marshy valley drained to the north via a small brook, a tributary to the larger stream which flowed through the main body of the meadow, carrying outflow from the Collect Pond to the Hudson River. On both the 1776 Ratzer and 1782 British Headquarters maps, the mainstem stream flowing from the Collect Pond and the small stream draining the tributary valley are shown as unnaturally straight, reflecting the fact that they had already been altered to promote drainage of the meadow.

There is a high probability that the marshy character of the shallow valley was a result of Late Holocene sea level rise and that for much of the late post-glacial to Middle Holocene the unnamed stream flowed a higher-gradient course through a more well-drained setting, possibly originating from a spring at the head of the valley just outside the study area. Sea level rise raises base level of coastal streams, reducing their gradient and promoting overbank flooding and transition to a meandering form. Soil drainage is also impeded as infiltrating dense saline waters exert upward pressure on less dense fresh groundwater, raising local water tables. The tributary valley was still depicted as marshy ground on Viele's 1865 map, though no channelized surface flow is indicated.

A. LANDFILL SETTING

The Project Area is located largely in Battery Park City on the left (east) margin of the lowest reach of the Hudson River, immediately upstream from the river's debouchment into Upper New York Bay (New York Harbor). The majority of the Project Area lies on "made land," as described below; only the northern end —beyond the limits of Battery Park City—is located on what has been fast (dry) land since the European colonization of Manhattan beginning in the 17th century.

FORMATION OF LANDFILL IN THE 18TH AND 19TH CENTURIES

The majority of the Project Area was inundated by the Hudson River until the 19th century. Between 1815 and 1860, the waterfront in New York City was intensively developed, resulting in a surge of growth in the city's maritime and shipping industries and making it the most successful port in the country (Albion 1967). The opening of the Erie Canal in 1825 and the development of packet services to distant American and European ports led to expanded reciprocal trade between local merchants, the rest of the country, and the rest of the world. In the years preceding the American Civil War in the mid-19th century, "New York City handled two-thirds of America's imports, and dominated exports and passenger trade" (Novek 1992:24). This in turn attracted merchants to the waterfront areas, resulting in the establishment of one of the nation's most important commercial and shipping districts along the waterfront in Lower Manhattan.

As such, during the first half of the 19th century, significant efforts were made to fill in shallower waters and to construct new, more modern wharves and piers out into deeper waters. This was particularly true of the Hudson River, as New York's shipping industries had been re-focused there in part because technologically advanced steam ships were now too large for the East River piers (Albion 1967). The expansion of Hudson River piers is visible on maps published by Colton in 1836 and Dripps in 1852 (see **Figure 6**). Steamships took over the lucrative fine cargo and passenger businesses which soon moved to the west side of Manhattan, as well. Throughout the late-19th and 20th centuries, the Hudson River was lined with piers and wharves (ibid). As the residential areas of the city had been slowly spreading northward during the mid- and late 19th century, Lower Manhattan remained the focus of New York's commercial endeavors.

In the mid-20th century, that portion of the Project Area lying between South Cove at 3rd Place and the North Esplanade at Stuyvesant High School was open water, with the Hudson River shoreline running to the east in the vicinity of modern Washington and Greenwich Streets. While landfilling along the Hudson River in the vicinity of the Project Area began at the turn of the 18th century and continued through the early 19th century, much of the Project Area was not filled until the 19th and 20th centuries and the Project Area was the location of several dozen shipping piers extending into the Hudson River channel (see **Figures 5 through 7 and Figure 8, Image 1**).

CREATION OF BATTERY PARK CITY IN THE 20TH CENTURY

Once a basic construction approach for Battery Park City had been agreed upon in the late 1960s and early 1970s, preparatory work began for the filling necessary to create the 92-acre site. The first fill introduced was material produced by excavation for the World Trade Center, one block to the east. This produced 20 acres of fill in the central portion of the project area (Urstadt 2005). This initial episode of filling was followed by a hiatus as twelve early 19th to mid-20th century piers were removed, accomplished through destruction of the superstructures followed by extraction of the wooden pilings by cranes (ibid). The introduction of large amounts of fill required construction of bulkheads along the entire 1.25-mile length of the Project Area to contain the unconsolidated fill. In preparation for installation of the bulkheads it was decided that much of the accumulated estuarine silt along the bulkhead line and within the area to be filled would be removed by dredging. It was further decided that rather than remove all of the alluvial silt—down to bedrock—it would be sufficient to remove the saturated and unconsolidated upper part of the silt column down to “a point where its thickness was uniform” (ibid: 129). In the fall of 1973, following construction of bulkheads in the southern portion of the area, sand dredged from the Lower Bay offshore from Staten Island was used to fill 16 acres contiguous to the area filled by material from the World Trade Center, completing filling of the southern half of the project area (ibid) (see **Figure 8, Image 2**). In 1974 and 1975, rock waste produced by excavation of New York City Water Tunnel #3 was used to create the bulkhead around the northern half of the project area and filling of the area with dredged sand was completed by the end of 1976 (ibid).

B. SUMMARY OF SELECTED PREVIOUS ARCHAEOLOGICAL INVESTIGATIONS OF THE PROJECT AREA

Several studies have been conducted which focused on archaeological potential in the overall study area, most notably by HCI (1983) and by Hartgen Archaeological Associates and HPI (1990). Because these studies were prompted by improvements to Route 9A/West Street, much of the investigative effort was focused on a broad linear area lying 600 to 1,000 feet east of the majority of the sampling alignment for this study. The footprints of the two study areas coincide only at the northern end of the current study area, from the northern end of Battery Park City to North Moore Street. However, the authors of the 1983 study incorporated into their study data and description and samples from geotechnical borings conducted outside of the Route 9A/West Street study area, including borings within the current Project Area.

WESTSIDE HIGHWAY RECONSTRUCTION, 1983

As a part of the reconstruction of the West Side Highway (now known as Route 9A/West Street) in 1983, HCI prepared a documentary study to identify areas of archaeological sensitivity within a study area that extended from Battery Place to West 44th Street. Two segments of the 1983 study area were within or near the boundaries of the Project Area. A segment referred to as “Area 1” encompassed a portion of the West Side Highway and an area within the Hudson River to the west north of modern Battery Park City. A segment referred to as “Area 2” included the section of the West Side Highway between Battery Place and the northern line of modern Battery Park City. The current Project Area therefore overlaps with portions of both Areas 1 and 2 in limited areas.

Within Area 1, the Phase 1A study determined that precontact resources both within the highway and out in the Hudson River could be impacted during dredging, filling, and pile driving operations associated with that project and further archaeological analysis was recommended. The area of sensitivity was situated within the Hudson River west of the current Project Area in the area generally bounded by the lines of Jay and North Moore Street. The segment referred to as Area 2 was determined to have archaeological sensitivity associated with the landfilling of that part of Manhattan, including the construction of historic period wharves, piers, docks, and basins within this area. Additional archaeological analysis was recommended for that portion of the study area.

The report incorporates the results of analysis by Mueser, Rutledge, Johnston, and DeSimone of soil boring logs of several hundred geotechnical borings conducted in and near the Project Area. These soil borings were undertaken to identify the boundary between silty estuarine deposition and underlying sand and gravel. The underlying sand was interpreted to be glacial outwash deposited by the retreating Wisconsin glacier and it was assumed that human habitation and activity prior to inundation would have taken place on this surface. In those areas where glacial sand was not present above bedrock, it was assumed that the bedrock surface represented the pre-inundation land surface. Post-glacial sediment accumulation atop the outwash sands in a subaerial setting was assumed to have been minor "and would not be indicated separately in the boring logs from the underlying sands" (HCI 1983: 63). The results of this analysis were used to create a contour map of the post-glacial, pre-inundation landscape.

HCI's contour analysis allowed the identification of now-submerged areas of high ground, coves, bays, and other topographic features "which may have proved attractive for" Indigenous occupation near "coastal sites…found on higher ground near coves or bays and near stream intersections with those coves or bays" (ibid: 85), although the authors note that the location of the former courses of streams flowing into the Hudson River was difficult to reconstruct based on the data from the borings as "the distance between borings and the small size of the streams did not allow such fine-tuned topographic reconstruction" (ibid:85). In the opinion of the authors, "the presence of peat at the interface between the glacial sands and the river bottom silts indicated in the boring logs was interpreted as an indication of once-extant marshes in the project area" and that "the presence of peat indicates areas in which the inundation of the land took place gradually enough for vegetation to take hold in the water-deposited silt, leading to marshy conditions" (ibid:85). This was a post-glacial landscape in a state of constant evolution as the rising Hudson River estuary drowned formerly exposed land surfaces, small bays and coves formed for centuries to millennia in topographic lows, and low knolls and topographic highs became small offshore islands before ultimately being inundated. In total, the HCI report identifies 22 now-submerged landscape features deemed to be "most attractive for [Indigenous] human settlement" (ibid:86). Nearly all of these 22 landscape features lie outside of the testing alignment of the current study, generally being located landward of the current alignment; nine are associated with an area of upland near the north end of the current study area. HCI considered this upland area—conjectured to have been the site of small, transient coves and bays formed as sea level rose and of topographic highs which ultimately became near-shore islands before being completely inundated—to have been "a prime location for [Indigenous] occupation" (ibid:86).

Submerged landscape features identified by HCI that lie in or adjacent to the Project Area are (including the numeral identification assigned by HCI, see **Figure 4**):

- **HCI Landscape Feature 4**: a spit of land forming part of a headland enclosing a small bay northwest of the corner of Liberty Street and Route 9A/West Street, now lying at -40 feet; according to the sea level curve produced by HCI, this land surface would have been inundated in the period between 6,000 and 7,000 BP;
- **HCI Landscape Feature 5**: several areas of marginally high ground in the vicinity of Route 9A/West Street between Albany Street and Liberty Street, now lying at -40 to -30 feet. Located at the mouth of the small bay enclosed by Landscape Feature 4, these topographic highs would have become small islands with ongoing sea level rise and, using the HCI sea level curve, would have been inundated between 6,000 and 7,000 BP;
- **HCI Landscape Feature 6**: a 125 by 350-foot cove situated west of the line of Vesey Street, variously identified by HCI as lying at -40 and -30 feet;[1]
- **HCI Landscape Feature 7**: a topographic high bordering the south side of a bay created by ongoing sea level rise within a low area between Park Place and North Moore Street and now lying at -40 feet;

[1] HCI (1983) identifies Feature 6 at a depth of -40 feet in Table 2, page 57 of the report and at a depth of -30 feet on page 50 of the report.

- **HCI Landscape Feature 10**: a small headland and cove, with high ground on the headland separating the bay from the estuary waters, in the vicinity of Murray Street, now lying at -30 feet;
- **HCI Landscape Feature 16**: a lagoon or cove in the vicinity of Harrison Street at 60 feet below sea level; and
- **HCI Landscape Feature 18/18A**: small coves between Vesey Street and Park Place at 50 feet below sea level.

Based on the contour map produced by HCI the overall upland and associated landscape features now lie at depths ranging from -30 feet to -80 feet within the modern channel of the Hudson River roughly between Chambers Street and Desbrosses Street. Only HCI Landscape Features 7 and 16, associated with the southern and southeastern sides of the northern upland, lie within the alignment sampled for the current study. Boring locations for the current study which fell within the general area of the postulated upland and HCI Landscape Features 7 and 16 include B-30 through B-40 and B-54 through B-58 (discussed below).

MARGINAL STREET ADJACENT TO THE SOUTH RESIDENTIAL NEIGHBORHOOD, 1989

A Phase 1A Study was prepared in 1989 by Hartgen Archaeological Associates, Inc., in association with Historical Perspectives, Inc. (HPI), as part of the proposed development of the Hudson River Esplanade—then known as Marginal Street—between Liberty Street and The Battery, partially overlapping the current Project Area. This investigation analyzed a study area situated east of the southern extent of the Project Area. An area of precontact archaeological sensitivity was identified in the vicinity of the intersection of Morris and Route 9A/West Streets. The archaeologically sensitive soil strata were expected to be situated at a depth of approximately 30 to 40 feet below sea level. Because these depths would not be impacted as a result of the construction of the project and because of the complexities involved in excavating at such great depths, no additional archaeological analysis was recommended. The Phase 1A Study concluded that the study area was located in an area of landfill dating to the mid-19th through 20th centuries and possibly disturbed as a result of subsequent redevelopment. Because of the age and potential disturbance of the fill deposits, the study area was not determined to have archaeological significance associated with the historic period.

ROUTE 9A, 1990

In 1990, Hartgen Archaeological Associates, Inc. in association with HPI prepared a Phase 1A Study in association with the reconstruction of Route 9A/West Street. The report’s study area includes the portion of Route 9A/West Street between Battery Place and Harrison Street, which overlaps the eastern boundary of the Project Area. The study concluded that the study area was formed through landfilling and determined that piers and wharves dating to the 18th and 19th centuries may have been incorporated into the landfill. The study area was determined to be sensitive for landfill deposits and landfill-retaining structures including piers, wharves, and possibly sunken vessels.

The report re-examined the archaeological sensitivity of some of the landscape features identified in the 1983 study prepared by HCI as described above. Given the great depth of these potentially sensitive strata, the study concluded that there was no practical way to confirm the presence or absence of archaeological resources in those areas. The study identified historic period sensitivity in the locations of historical piers that entered the study area in various locations, though only in those areas where waterfront structures pre-dating the mid-19th century were located. The report also identified the potential for sunken vessels to be present in the vicinity of the intersections of Warren and Chambers Street and Route 9A/West Street.

NEW YORK HUDSON RIVER BULKHEAD, 2011

In 2011, Michael Lenardi and the New York State Museum (NYSM) issued a Cultural Resource Survey Report summarizing the results of Phase 1B archaeological monitoring through Phase 3 Data

Recovery/mitigation in association with the construction of Route 9A/West Street between West Thames Street and Chambers Street, including portions of the Project Area. The report focused on two highly sensitive areas: a section of the historical Hudson River Bulkhead—which has been determined to be eligible for listing on the State and National Registers of Historic Places (S/NR)—in the vicinity of West Thames Street, and the median of the intersection Route 9A/West Street and Liberty Street.

As described by NYSM (2011), the Hudson River Bulkhead represents the historical limit of Manhattan's waterfront in the late 19th and early 20th centuries. It was constructed between 1871 and 1935 along the western side of what is now Route 9A/West Street and extends between the Battery and West 59th Street (NYSM 2011:6). During archaeological monitoring, a nearly 60-foot-wide and 10-foot-deep portion of the bulkhead was exposed at the West Thames Street location to facilitate the installation of a new sewer connection. The sewer work impacted a limited (6-foot) portion of the bulkhead and the remainder of the exposed bulkhead and a historical (c. 1908) building foundation remnant that was also observed were documented in place and backfilled. NYSM's analysis suggested that the bulkhead segment was constructed c. 1903 and was consistent with plans and drawings of the bulkhead produced by the City around that time. The site was designated as the Pier 7 Complex Site and assigned NYSM Site number 12322/SHPO Site 06101.018120.

The NYSM report also documents additional wood pilings were encountered during construction within the median of Route 9A/West Street at its intersection with Liberty Street. The pilings were encountered during excavation associated with the reconstruction of the Liberty Street pedestrian bridge, which was damaged as a result of the terrorist attacks on September 11, 2001. NYSM determined that the timber elements were associated with an older ferry terminal formerly along an older bulkhead line established in 1857. The archaeological site was designated as the Liberty Street Pilings Site and assigned NYSM Site number 12321/SHPO Site 06101.018121.

A. INTRODUCTION

In the following discussion of the results of this investigation, the Project Area is broken into two segments: the "Open-Water Reach" and the "Landward Reach."[1] The Open-Water Reach segment consists of the borings conducted in the area that lay within the waters of the Hudson River estuary until Battery Park City was constructed in the 1970s, including Borings B-01 through B-32, and Borings B-46, B-47, B-52, and B-53. The Landward Reach comprises the borings located at the northern end of the Project Area, which includes the 18th to 20th century Hudson River shoreline, the shallow near-shore setting, and the area just east of the shoreline, including Borings B-33 through B-45 and B-54 through B-58. In large part, this distinction is made because of the variation in subsurface sediments between the two reaches, which in turn has an impact on their archaeological interpretation. Along the Open-Water Reach, the potential for the presence of former subaerial surfaces on which Indigenous people may have worked and lived lies in a narrow zone between the base of estuarine sediments and the upper surface of bedrock. In the Landward Reach, underlain by glacial outwash, the potential for such surfaces is limited to the upper zone of soil profiles which developed in the outwash parent material. Essentially no evidence was seen in this study for the presence of developed subaerial soil profiles—the setting for activity by Indigenous people—in the borings of the Open-Water Reach nor, with one exception, in the Landward Reach.

B. CHARACTERIZATION OF MONITORED SOIL BORINGS

This section documents observations made during the monitoring of individual borings as depicted on **Figure 3**. The descriptions given below are limited to those borings monitored by the geomorphologist. Graphic descriptions of all profiles appear in **Figures 9A through 9D** and representative images are included in **Photographs 1 through 8**.

The borings in this section are generally described in geographical succession from northeast to southwest. Borings B-42 through B-45 were located within North Moore Street, which contains the only portion of the Project Area that is not entirely composed of anthropomorphic landfill. Of these, Borings B-43 and B-44 were archaeologically monitored. Thirteen borings—B-34 through B-41 and B-54 through B-58—were conducted within a two-block stretch of Route 9A/West Street between Chambers Street and North Moore Street. Of these borings, eight were observed for this study; Borings B-37, B-41, B-54, B-57, and B-58 were not observed. Of this group, Borings B-40 and B-41, along the east side of the street, was farthest from the channel. Boring B-39/39A, was located along the median of Route 9A/West Street, approximately 65 feet west of B-40, closer to the channel; the remaining observed borings were located along the west side of Route 9A/West Street. Borings B-55 and B-56 were located landward of B-36, with B-56 between the median and northbound lanes of Route 9A/West Street and B-55 on the sidewalk east of Route 9A/West Street. Borings B-32 through B-17 were in an alignment that slowly converged on the current land/channel boundary; all of the boring locations fell within area that was open water prior to 1970.

[1] The use of the term "reach" in this context differs from the segments of the proposed project design that are also referred to as Reaches 1 through 7 in the 2022 Phase 1A Study.

BORING B-44

Opening elevation at Boring B-44 was +11.1 feet. Hand-clearing to 6 feet below the ground surface (bgs) yielded loamy sand containing brick, cobbles, concrete, and asphalt. Two spoon advances from 6 to 10 feet bgs yielded brick and mortar along with very dark grayish brown sand. Beneath this, to -26 feet (37 feet bgs), recovery consisted primarily of medium sand and loamy medium sand with some stringers of silt. Gravel was encountered in the following advances. Samples from -29 to -88 feet were dominated by gravel and cobbles; stringers of sand and silt were also encountered. Bedrock was encountered at -89 feet. Fill appeared to directly overlie truncated sandy glacial drift; no evidence of a former weathered soil profile was observed.

BORING B-43

Opening elevation at Boring B-43, west of B-44, was +8.7 feet. The upper profile was similar to Boring B-44, with brick, concrete, and cobbles dominating in hand-clearing to 6 feet bgs and brick present in spoon recoveries to -1.3 feet. Below this, recoveries were predominantly sand with varying amounts of very fine to coarse gravel and stringers of silt. Bedrock was encountered at -89 feet. As in Boring B-44, no evidence of a former weathered profile was observed.

BORING B-40

Opening elevation at Boring B-40 was +8.5 feet. Recovery from three spoon advances to an overall depth of -3.5 feet included brick, wood, and unglazed redware ceramic. Recovery from -6.5 to -8.5 feet bgs consisted of dark gray sand and silt with much gravel and wood. Little or no recovery in spoon advances and rig chatter during roller bit advances suggested the presence of gravel and cobbles from -8.5 feet to at least -21.5 feet. An attempted spoon advance from -11.5 feet to -13.5 feet was refused on cobbles at -12.7 feet. An attempted spoon advance from -16.5 to -18.5 was refused and rig chatter[1] during a roller bit advance suggested the presence of cobbles to at least -21.5 feet. A spoon advance from -21.5 to -23.5 feet recovered 12 inches of fine to coarse sand. A 9-inch recovery in the advance from -26.5 to -28 feet consisted of 4 inches of dark reddish brown (5YR3/2) sandy loam containing a few pieces of coarse gravel and 5 inches of dark reddish brown (5YR3/3) sandy loam containing little or no gravel and having a relatively high content of clay. This sequence was tentatively identified in the field as a remnant of the upper zone of a developed soil profile. A sample of the darker upper sandy loam was retained for radiocarbon dating. Recovery from this point to -68.5 feet consisted of sand with stringers of silty clay and a small amount of fine to medium gravel. Gravel in a sandy matrix was encountered at -68.5 feet and continued to the surface of bedrock at -87.5 feet.

The gravel and cobbles encountered from around -8.5 to -21.5 feet in Boring B-40 are interpreted here to be early historic period fill, possibly in relation to a quay or dock as this location is near the historic period shoreline. While black estuarine clay was seen at a depth of -17 to -20 feet in adjacent Boring B-41, overlying fine to medium sand, no estuarine clay was noted in Boring B-40. Any clay at the location of Boring B-40 is assumed to have been displaced by the cobbly fill. The underlying sand, roughly from -21.5 to -26.5 feet, is interpreted to be near-shore alluvial deposition, possibly derived from reworking of areas of the glacial outwash along the river's edge.

BORINGS B-39 AND B-39A

Opening elevation at Boring B-39 was +9.2 feet. Beneath 12 feet of fill (cinder, brick, gravel, wood), wood —possibly a pier piling—was encountered and sampled with great difficulty from -6 to -13 feet (15 to 22

[1] "Rig chatter" refers to vibration of the drilling rig, transmitted from the advancing roller-bit, and generally is an indication that the bit has encountered large gravel, cobbles, boulders, or bedrock.

feet bgs). The rig was moved approximately 5 feet to the north and a second attempt was made (Boring B-39A). Opening elevation of Boring B-39A was +9.2 feet. The hand-cleared upper 6 feet consisted of brick, gravel, and concrete in sand. Spoon recovery from +3 to -8 feet consisted of black to gray sand with varying amounts of gravel. Recovery in advances from -11 to -13 and -16 to -18 feet consisted of black (Gley1 2.5/N) estuarine silty clay with a few fine shell fragments. Very dark gray loamy coarse sand and fine gravel, containing less gravel with depth, was encountered from -18 to -28 feet. A sample of sediment from -18 feet was retained for radiocarbon dating. A Shelby tube was pushed from -18 to -20 and upon retrieval of the tube it was noted that the lower end of the sample consisted of very dark gray (Gley1 3/N) loamy coarse sand and fine gravel. A spoon sample from -20 to -22 feet bgs consisted of the same very dark gray sand and gravel seen in the Shelby tube. A spoon advance from -26 to -28 feet consisted of very dark gray (7.5YR3/1) medium sand coarsening with depth. A piece of wood fiber at the base of the sample was retained for radiocarbon dating. Spoon advances from -31 to -53 feet bgs returned only a few rounded pieces of gravel. From -54 to -85 feet recovery consisted of sand with trace amounts of fine gravel. Bedrock was encountered at -85 feet.

BORING B-38

Opening elevation at Boring B-38 was +7.2 feet. Recoveries to -15 feet all contained gravel, brick fragments, and wood fiber and the spoon sample from -18 to -20 feet contained much wood and bark. Coal, cinders, and wood were present in spoon samples to -25 feet. Wood fibers were present in a Shelby tube sample to -27 feet. A spoon advance from -27 to -29 feet yielded 6 inches of black clay overlying 3 inches of sand and gravel and 4 inches of black clay containing gravel and shell fragments. A sample of the lower clay (from roughly -28 to -29 feet) was retained for radiocarbon dating. Beneath the estuarine clay was silty very fine sand with much mica (-33 to -35 feet), coarsening with depth to coarse sand with increasing content of gravel. This sequence is interpreted to consist of fine estuarine sand overlying glacial outwash. Rig chatter and a lack of recovery in the spoon advance from -83 to -85 feet suggested the presence of cobbles or boulders. Bedrock was encountered at -87 feet.

BORING B-36

Opening elevation at Boring B-36 was +7.2 feet. Recovery to 12 feet bgs (-5 feet), including the hand-cleared upper 6 feet, consisted of sand with gravel and brick fragments. Recovery from -5 feet to -20 feet consisted of black (Gley1 2.5/N) clay contained wood, bark, coal and cinder in the upper 9 feet and coal and cinder throughout. A Shelby tube sample from -20 to -22 feet was later described as consisting of black clay containing coal cinder throughout. Thinly stratified very dark gray (Gley1 3/N) clay was encountered from -22 to -24 feet. A bulk sediment sample retained from -24 feet was collected for radiocarbon dating. The spoon advance from -28 to -30 feet yielded very dusky red (2.5YR2.5/2) coarse sand with fine and very fine gravel. Recovery from that point to the upper boundary of bedrock at -91 feet consisted of coarse to fine gravel with varying amounts of very fine to medium sand.

BORING B-56

In Boring B-56 (opening elevation +9 feet), 75 feet east of B-36, recovery to -45 feet consisted almost entirely of gravel with some fine sand. From -45 feet to the upper boundary of bedrock at -101 feet, recovery was dominated by reddish-brown sand with varying amounts of very fine to medium gravel. No fine-grained estuarine sediments or former terrestrial surfaces were identified.

BORINGS B-55 AND B-55A

In Boring B-55, 65 feet east of B-56 (opening elevation +9 feet), recovery to -3 feet included brick and gravel. Black (Gley1 2.5/N) sandy clay loam with a strong organic odor and containing much fine to coarse rounded gravel and a few shell fragments was recovered in the advance from -11 to -13 feet. Much oyster shell was noted in the wash from the roller-bit advance from -13 to -16 feet. Recovery below this consisted of very dusky red (2.5YR2.5/2) medium sand coarsening with depth and containing increasing amounts of gravel to -33 feet. At -33 feet the casing broke while being driven. The hole was abandoned and Boring B-55A was opened a few feet to the west; Boring B-55A was advanced without sampling to -31 feet. Recovery from that point to bedrock at -91 feet consisted of reddish-brown sand with varying amounts of fine and very fine gravel.

BORING B-35

Opening elevation at Boring B-35 was +7.7 feet. Most samples to -14 feet included brick fragments, wood, shell, and round and angular gravel. Black estuarine clay was recovered in the advances from -17 to -29 feet. An abrupt boundary separated black (Gley1 2.5/N) loamy medium sand with much rounded gravel from underlying very dark gray (5YR3/1) loamy medium sand free of gravel between -32 and -34 feet. Together with this, the presence of very dark brown (7.5YR2.5/2) loamy fine sand with a low gravel content overlying very dusky red (2.5YR2.5/2) medium sand with a higher gravel content suggested the possible presence of a developed soil profile between -33 and -39 feet. Recovery from that point to the upper boundary of bedrock at -94 feet consisted of reddish-brown sand with varying gravel content.

BORING B-34

Opening elevation at Boring B-34 was +7.6 feet. Recovery to -19 feet included much gravel and brick; black estuarine clays were encountered at around -19 feet. An advance from -19.5 to -21.5 yielded 9 inches of black clay over wood. Wood was also encountered in the next advance and required use of the roller-bit to clear; two consecutive spoon advances from -27.5 to -31.5 feet yielded black clay with many wood fibers, probably from roller-bit boring of the overlying wood. Dusky red (2.5YR3/2) gravelly sand was encountered at -32.5 feet and continued, with variation in color, texture, and gravel content to bedrock at -98.5 feet.

BORING B-33

Opening elevation at Boring B-33 was +8.5 feet. Fill extended to -33 feet and included much brick, gravel, and cinder; angular schist gravel predominated in the lower fill and there were several instances of no recovery as the opening to the spoon was apparently blocked by large schist fragments. A thin band of estuarine clay encountered at -33 feet was underlain by coarse sand and very coarse rounded gravel. Sand and gravel, dominated by reddish-brown sand, extended to the surface of bedrock at -81.5 feet.

BORING B-32

Opening elevation at Boring B-32 was +10.5 feet. Recovery to -17.5 feet consisted largely of angular schist gravel fill. Recovery from -17.5 to -61.5 feet was dominated by very dark gray (5Y3/1) fine to medium sand with varying content of shell fragments and varying but low content of fine and very fine gravel. From -61.5 feet to the surface of bedrock at -69 feet recovery consisted of reddish-brown sand with fine rounded gravel and occasional shell fragments. No fine-textured estuarine sediments were identified in the boring. The change in sand color from dark gray to reddish brown was interpreted to mark a transition from estuarine deposition to underlying reworked outwash sand. A sample of the dark gray sand which appeared to contain very fine organic matter, was retained from the advance from -54.5 to -56.5 feet.

BORING B-31

Opening elevation at Boring B-31 was +19 feet. Recovery to -33 feet consisted of fine and medium sand. The advance from -36 to -38 feet consisted of thinly stratified black clay and silty clay with very fine shell, coal, and brick fragments. Recovery below this, to -48 feet was a similar matrix; no coal or brick was noted but a small piece of leather was observed at -43 feet. The clay and silty clay was underlain by black (2.5Y2.5/1) very gravelly silt, with rock fragment size apparently increasing with depth as both roller-bit boring and spoon advance were increasingly difficult. Bedrock was encountered at -68 feet.

BORING B-29

Opening elevation at Boring B-29 was +16.4 feet. Recovery to -43.5 feet (60 feet bgs) consisted of gray to brown sand fill with frequent shell fragments. From -43.5 feet to -55 feet (including a Shelby tube from -45.5 to -47.5 feet), recovery consisted of black clay and silty clay with coal and cinder throughout and brick fragments in the upper 2 feet. These inclusions appear to be associated with historic period deposition, intrusion via incision or gravity, or disturbance (e.g., dredging) to that depth. Black very fine sand from -55 to -55.5 feet also contained coal and cinder. From -55.5 to -66.5 feet recovery consisted of stratified clay, silty clay and very fine sand, with thin inclusions of peat at -65 feet to -65.5 feet. A sample of the peat was retained for dating. The next advance, from -65.5 feet to -67.5 feet contained a thick sample of peat overlain by stratified, black (Gley1 2.5/N) clay, silty clay, and very fine sand. A sample of this peat was also retained for dating. Withdrawal of this sample was followed by pushing and withdrawal of a Shelby tube and a 4-foot advance of the roller-bit. Subsequent analysis of the Shelby tube sample showed that clay with pockets of peat extended to at least -69.6 feet. Bedrock was encountered at the conclusion of the roller-bit advance, at -73.5 feet. Two samples of the peat were collected for radiocarbon dating.

BORING B-28

Opening elevation at Boring B-28 was +15.8 feet. Recovery to -36 feet (52 feet bgs) consisted of very dark gray (10YR3/1) fine and medium sand with common shell fragments and occasional coal and cinder fragments. Stratified black clay and silty clay from -36 to -50 feet contained much coal and cinder. Recovery from -54 feet to -60 feet consisted of black clay and silty clay containing common shell fragments and wood fibers. An advance from -64 to -66 feet consisted of very dark gray (Gley1 3/N) clay silty clay with thin strata of peat throughout. This was underlain by stratified dark olive brown (2.5Y3/3) silt and very fine sand from -69 to -71 feet. Bedrock was encountered at approximately -73.5 feet.

BORINGA B-25 AND B-25A

An initial attempt to start Boring B-25 was stopped by a concrete obstruction at 5 feet bgs and the rig was moved 1.25 feet north. Opening elevation at Boring B-25a was +13.1 feet. Recovery to -39 feet consisted of sand with common shell as seen in previous borings on this alignment. Black organic estuarine clay and silty clay recovered from -39 feet to -58 feet contained coal and cinder throughout. Recovery from -62 to -64 feet consisted of silty clay containing shell fragments; the tip of the spoon contained peat. Recovery from an advance from -67 feet to -67.7 feet consisted of gravelly loam over weathered schist bedrock at -67.7 feet.

BORING B-24

Opening elevation at Boring B-24 was +13.5 feet. As in previous borings on this alignment, the fill extended to -38.5 feet and consisted of gray to brown sand with common shell fragments. Beneath the fill, black estuarine clay containing coal and cinder was observed to a depth of -58 feet. Below this, from -62 to -66 feet was very dark gray (Gley1 3/N) silt with common shell and some stringers of peat. Peat recovered at -63 to -63.5 feet was retained for dating. Sand and gravel or weathered bedrock was encountered at -65.5 feet. The roller-bit was advanced to -69 feet, where coring of intact bedrock was commenced.

BORING B-23

Opening elevation at Boring B-23 was +12.1 feet. Gray to brown sand fill extended to at least -35 feet (47 feet bgs). A spoon advance from -33 to -35 feet yielded gray medium to fine sand; the following advance, from -38 feet to -40 feet, yielded black estuarine clays. The estuarine clays extended to -61 feet; coal and cinder were included to a depth of at least -54 feet and a small piece of rubber was noted in the recovery from -52 to -54 feet. Recovery from -58 feet to -61.3 feet consisted of black estuarine clays containing shell fragments. Thin stringers of peat were present between -60 and -61.3 feet. Bedrock was encountered at -61.3 feet.

BORINGS B-22 AND B-22A

Opening elevation at Boring B-22 was +11.6 feet. A pipe obstruction was encountered at 4.5 feet bgs. The hole was abandoned and the rig moved 4 feet southwest where Boring B-22A was commenced. Sand fill extended to around -41 feet. A boundary between the sand fill and the underlying black estuarine clays was noted in a spoon advance from -39.5 feet to -41.5 feet. The fine-textured estuarine deposits extended to -61.5 feet and contained coal cinder and coal throughout the column. Recovery from -60.5 to -62.5 feet consisted of 12 inches of black silty clay containing fine shell fragments and 12 inches of stratified black clay and peat. A sample of peat from -62 feet was retained for dating. Bedrock was encountered just below the stratified clay and peat, at -63.3 feet, with a thin layer of gravelly sand containing shell and wood fragments. The peat recovered at -62 feet yielded a date of 9468 years BP.

BORING B-20

Opening elevation at Boring B-20 was +13.0 feet. Sand fill with a good deal of angular gravel was encountered at the surface, immediately beneath a paver, and extended to at least -49 feet. Sandy samples from -17 feet to -49 feet also contained a good deal of angular gravel and a few bands of black, fine-textured estuarine deposits. Recovery from -52 to -54 feet consisted of very dark gray (Gley1 3/N) very fine sand showing thin strata of darker material, suggesting that this was alluvial deposition rather than fill. As with Boring B-19, black sandy clay with a few thin stringers of fine sand was recovered from -56 to -57 feet. Recovery from the next spoon advance, from -57 to -59 feet, yielded black silty clay containing a few pieces of subangular gravel. This material was firm in consistence, in contrast to the soft, plastic consistence of most of the clays and silts interpreted to be estuarine deposits. No shell was noted in this material. The next advance, beginning at -62.0, was refused on bedrock at -62.5 feet and yielded a small amount of medium to fine sand containing fine gravel.

BORING B-19

Opening elevation at Boring B-19 was +12.1 feet. Gray to brown sand fill with shell fragments extended to -19 feet. Below this point, fill consisted of mixed sand and angular gravel, with gravel frequently dominating, to -54 feet. These fill deposits are believed to have originated at the World Trade Center site. A thick, circular piece of sheet metal recovered at -43 feet appeared to have been produced by the spoon cutting through thick sheet metal. A clear boundary between the fill and underlying black estuarine clays was noted at around -54 feet. As in Boring B-20, black sandy clay with a few thin stringers of fine sand recovered from -56 to -57 feet was very firm in consistence as contrasted to estuarine deposits seen in this and other borings. No shell was noted in this material. A sample from -56.5 feet was submitted for dating and yielded a date of 3111 years BP. Weathered schist bedrock was encountered at around -59 feet and coring of intact bedrock commenced at -61.5 feet.

BORING B-17

Opening elevation at Boring B-17 was +12.4 feet. Sand fill was encountered immediately beneath a paver and thin underlying concrete and extended to -35 feet. A spoon advance from -37.5 to -38.5 feet recovered a thin stratum of black estuarine clay containing shell fragments, directly overlying weathered schist bedrock. Following an advance of the roller-bit, coring of intact bedrock was commenced at -44.5 feet.

BORING B-15

Opening elevation at Boring B-15 was +13.8 feet. Sand fill interpreted to have been sourced at the World Trade Center construction site extended from beneath a granite paver to -8 feet. Below this point, the fill was almost entirely angular schist gravel but included thin strata of sand and fine-textured estuarine deposits. A sample from -41 to -43 feet that consisted largely of angular schist gravel included six fragments of historic period ceramics that appeared to be salt-glazed crockery. The next advance, from -46 to -48 feet consisted of sub-rounded coarse gravel in black silty clay. A sample of this material taken at -47 feet was submitted for dating and returned a date of 5605 years BP. Rig chatter was noted in the next advance of the roller-bit, suggesting the presence of gravel or weathered bedrock and gravel recovered by the spoon in an advance from -51 to -53 feet was interpreted to be weathered bedrock. Following a roller-bit advance, coring of intact bedrock commenced at -55 feet.

BORING B-12A

Opening elevation at Boring B-12A was +14.8 feet. Fill—including brick, cinder, ceramic, glass, and wood —was present to the surface of weathered bedrock at -47 feet.

BORING B-08

Opening elevation at Boring B-08 was +10.3 feet. Beneath 12 feet of sand containing brick fragments and gravel, recovery to -17 feet (27 feet bgs) consisted of angular schist gravel and to -27 feet consisted of medium and coarse sand containing angular and subangular gravel. All material to this depth is interpreted to be fill. Recovery from -27 to -46 feet consisted of reddish-black (2.5YR2.5/1) fine and medium sand containing fine shell fragments and showing evidence of thin stratification. Beneath this, a thin layer (2 inches) of black sandy clay containing subangular gravel directly overlaid schist bedrock at around -47 feet. A sample of the black sandy clay was retained and submitted for dating, returning a median probability date of 3333 years BP.

BORING B-07

Boring B-07 encountered a pipe at 3 feet bgs. The rig was moved 3.6 feet northwest and Boring B-07a was initiated. Opening elevation was +11.0 feet. Recovery to -11 feet consisted of sand containing brick fragments and rounded gravel. Recovery from -11 to -30 feet was angular gravel. Recovery from -30 to -51 feet was very dark gray (7.5YR3/1) coarse to medium sand containing fine brick fragments to -36 feet and a small amount of shell below that. Some thin strata of black clay were noted below -44 feet. Weathered schist bedrock was encountered at around -50 feet and coring of bedrock began at -53.5 feet.

BORING B-05

Opening elevation at Boring B-05 was +12.6 feet. Recovery to around -23 feet consisted of dark grayish brown (10YR4/2) fine to medium sand containing fine shell fragments. Below this, to a depth of -28 feet, two spoon advances yielded very dark gray (10YR3/1) medium to coarse sand containing shell fragments, stringers of black silty clay, and possible fine brick fragments. Black (Gley1 2.5/N) silty clay was encountered at -28 feet and extended to the surface of bedrock at -39.5 feet. A sample of black clay containing organic matter noted at -38.5 to -39 feet bgs was retained for radiocarbon dating.

BORING B-04

Opening elevation at Boring B-04 was 10.8 feet. Recovery to -26 feet consisted of sand containing shell fragments. Wood was encountered at -30 feet and made drilling from that point difficult. A sample of the wood retained for dating was found to be too recent for radiocarbon dating, indicating that it was less than 90 years old. Weathered bedrock was encountered at -45.5 feet.

BORINGS B-02 AND B-02A

Boring B-02 encountered a concrete obstacle at 7 feet bgs and the rig was moved 20 feet southwest where Boring B-02A was conducted. Opening elevation at Boring B-02A was +9.7 feet. Recovery to -22 feet consisted largely of gravel with several advances yielding no recovery; rig chatter during the next roller-bit advance suggested that gravel was present to at least -24 feet. Recovery from -25 to -37 feet consisted of dark brown to gray-black medium to coarse sand containing fine shell fragments and a small amount of fine gravel. A 9-inch recovery in an advance from -40 to -42 feet consisted of black estuarine clay over a small amount of very dark gray (7.5YR3/1) very fine sand containing fine shell and wood fragments. A sample of the clay immediately overlying the sand (and assigned an estimated depth of -41 feet) was retained for dating; the clay subsequently yielded a date of 3469 years BP. The roller-bit was advanced from -42 to -48 feet without sampling. Much rig chatter was noted in this advance, suggesting the presence of large gravel, cobbles, or weathered bedrock. The roller-bit was refused at -48 feet and coring of bedrock commenced at that depth.

C. RESULTS OF LABORATORY ANALYSIS

As described in above and in Chapter 2, "Research Design and Methodology," a number of peat, sediment, and wood samples were collected and submitted for radiocarbon dating, pollen analysis, or macrobotanical analysis. This section summarizes the results of the laboratory analysis that was completed for this study.

RESULTS OF RADIOCARBON DATING

A summary of all radiocarbon dating results as determined by the Center for Applied Isotope Studies at the University of Georgia, at Athens (see **Appendix A**) is included in **Table 5-1** and interpretations of these findings for individual boring locations are presented below. The dates, presented in years BP, represent median probability dates, or the middle date within a range of possible dates. As described in this section, the dates from the recovered samples in some cases support the results of the survey completed by HCI in 1983 but, in other locations, appear to suggest that deeply buried soils have been disturbed as a result of natural forces or historic period development. In general, as presented in the previous chapter, the subsurface of the Project Area is a dynamic setting in terms of both natural and anthropogenic processes and there are several potential sources of disturbance to the sediments of the Open-Water Reach, both natural and anthropogenic. In the steep setting of the Open-Water Reach, river currents, particularly those resulting from high flows or storm surges, have the potential to incise existing subaqueous sediments, creating swales and hollows in which more recent sediments may then accumulate, potentially skewing radiocarbon dates.

Table 5-1
Summary of Radiocarbon Dates

Boring	Depth (ft)	Sample Type	Median Probability Date (years BP)
B-02A	-41	Sediment	3469
B-04	-31	Wood	90
B-05	-39	Sediment	6525
B-08	-47	Sediment	3333
B-15	-47	Sediment	5605
B-19	-56.5	Sediment	3111
B-20	-58.75	Sediment	6774
B-22A	-62	Peat	9468
B-24	-63 to -63.5	Peat	9546
B-29	-65 to -65.5	Peat	9073
B-29	-67 to -67.5	Peat	9962
B-32	-54.5 to -56.5	Sediment	6548
B-36	-24	Sediment	1569
B-38	-28 to -29	Sediment	2589
B-39A	-18	Sediment	1396

Table 5-1 (cont'd)
Summary of Radiocarbon Dates

Boring	Depth (ft)	Sample Type	Median Probability Date (years BP)
B-39A	-29	Wood	181
B-40	-26.5	Sediment	6236
Source: University of Georgia Center for Applied Isotope Studies 2024 (see **Appendix A**)			

Over the course of the early 19th to the mid-20th century, scores to hundreds of wooden pier pilings were driven into the sediments on the river bottom, displacing and compressing them. Over that period, pilings were undoubtedly extracted and replaced in the course of pier maintenance and expansion. Ultimately, all pilings within the proposed Battery Park City project area were extracted in the early 1970s (Urstadt 2005). Extraction of the pilings created the potential for disturbance of the lowest sediments by the vacuum created as the pilings were withdrawn and the potential for recent deposition to fall into the resulting voids. More widespread disturbance of the sediments occurred as much of the estuarine silt and clay within the Battery Park City footprint was removed by dredging. Although it was intended that only the upper part of the silt column would be removed—down to "a point where its thickness was uniform" (Urstadt 2005: 129)—it seems likely that it may have been difficult to control the uniformity of the dredging given the varying depth to bedrock. Removal of silt and clay in a given area also created a potential for saturated sediments nearby to flow into the resulting void. In addition, the deposition of scores of feet of sand and stone fill itself undoubtedly caused compaction and distortion of saturated sediments, particularly any remaining fine-textured sediments. In two non-monitored borings, B-01 and B-53, fill was present to the surface of bedrock; in a third, B-12A, estuarine clay containing coal cinder, brick, and wood was present directly over bedrock. In Boring B-08, gray-black clay directly overlying bedrock at -46 feet returned an anomalously recent median probability date of 3333 years BP. In three additional borings within the Open-Water Reach, historic period markers such as coal, cinder, and brick were present to depths of -58 to -60 feet, 3 to 10 feet above bedrock.

The potential for sediment disturbance and reworking in the study area clearly raises the possibility that dates from bulk sediment samples—which as described in **Chapter 2, "Research Design and Methodology,"** can be problematic—almost certainly do not accurately date the setting from which they were recovered. Regarding the samples discussed below, the four peat samples are considered to have the greatest integrity as they appeared to be recovered from intact, in-situ settings near the base of the sediment column. Of the remaining eleven samples, even those which adhere to the law of superposition—which states that in an undeformed vertical sequence, sediments of younger age stratigraphically overlie sediments of greater age—virtually none are in alignment with what would be in keeping with accepted sea level rise curves.

DATING OF WOOD SAMPLES

A wood sample was recovered from a depth of -29 feet within Boring B-39A, located in the eastern portion of Route 9A/West Street between Harrison and North Moore Streets. The sample yielded a median probability date of 181 years BP. However, a bulk sediment sample of organic silty clay from -18 feet in Boring B-39A yielded a median probability date of 1396 years BP. A second wood sample was recovered from a depth of -31 feet within Boring B-04, located in the southern portion of the Project Area between the western termini of 2nd Place and 3rd Place. That sample yielded a date of less than 90 years BP. In the cases of both wood samples, the wood is interpreted to be derived either from remnant pier pilings (particularly in the case of Boring B-39A) or from other historic period anthropogenic sources, such as scuttled boats. As described previously, Boring 39A was initiated 5 feet to the north of Boring B-39, which encountered wood from -6 to -13 feet and was abandoned because of the difficulty of sampling and advancing casing.

DATING OF PEAT AND SEDIMENT SAMPLES

In Boring B-02A, organic-rich clay recovered at -41 feet, within 7 feet of unweathered bedrock, yielded a median probability date of 3469 years BP. This clay was both overlain and underlain by sand containing fine shell fragments. The presence of the shell suggests that this is estuarine deposition rather than a remnant of a subaerial soil. However, the date of 3469 years BP for soils situated at a depth of -41 feet does not accord well with any of the widely accepted sea level curves for the study area, all of which place inundation of that elevation several thousand years earlier.

In Boring B-05—at the intersection of South End Avenue and 3rd Place—black silty clay was encountered at -28 feet and extended to the surface of bedrock at -39.5 feet. A sample of black clay containing organic matter, taken just above the bedrock contact returned a median probability date of 6525 years BP. This date is interpreted to represent the onset of inundation by rising sea level and the beginning of deposition of organic-rich estuarine clay. This is broadly in keeping with—though several hundred years later than—the onset of inundation at this elevation indicated by the sea level rise curve formulated by HCI. This lag may reflect the fact that fine-textured estuarine sediments almost certainly did not begin to accumulate concurrently with the onset of inundation but required a stable water column of up to several feet before conditions would be right for suspended clay to begin to settle out.

A sample of the black sandy clay recovered from Boring B-08—located west of the western terminus of Albany Street—was retained and submitted for dating, returning a median probability date of 3333 years BP. This date is 3500 to 4000 years later than would be expected for the onset of inundation at this elevation and is interpreted to be a result of scouring and reworking of sediments by currents.

In Boring B-15, located northeast of South Cove, a sample of subrounded gravel in black silty clay retained from approximately -47 feet yielded a median probability date of 5605 years BP. This subrounded gravel may be colluvial in origin—material which moved downslope under the influence of flowing water, gravity, and the effects of freezing and thawing. The 5605 BP date is considerably too late for this elevation (the HCI sea level curve places onset of inundation at around 7000 years BP) and is interpreted to be a result of disturbance, including compression and compaction of saturated sediments by the overlying fill. Alternatively, as noted for Boring B-05, this date may represent the lag between the onset of inundation of the bedrock surface and sufficient sea level rise to allow a stable water column from which fine-textured sediments might settle. In this case, approximately 4 feet of fine estuarine sediment had already accumulated before the sampled material was deposited.

In Boring B-19, located near the western terminus of Vesey Street, a sample of black estuarine clay from -56.5 feet was submitted for dating and yielded a median probability date of 3111 years BP. A date of 3111 BP is clearly anomalous for this depth, where the HCI sea level curve would predict onset of inundation at around 7200 years BP. It is impossible to know if this anomalously deep date is a result of deformation of the sediments through human agency or is a result of incision of the sediments by currents and subsequent infilling by deposition of younger sediments. Presence of the thin sand stringers within the clay-dominated sediments lends some support to the proposition that this may be an incised channel, with fluctuations in current speed and energy. Similar stringers were noted at the same depth in adjacent Boring B-20. Pollen analysis from this sample is discussed in the following section.

In Boring B-20, located approximately 128 feet north of Boring B-19, a sample from -58.75 feet was retained for dating and returned a median probability date of 6774 years BP. As described for the previous borings, the 6774 BP date, approximately one thousand years after HCI predicted the onset of inundation for that elevation, may reflect disturbance of sediments, the shortcomings of dating bulk sediments, or the lag time required to accumulate at least 4 feet of overlying fine-textured estuarine sediments.

In Boring B-22A, located within River Terrace south of Murray Street, a peat sample was recovered at -62 feet, 1.3 feet above bedrock. The sample yielded a median probability date of 9468 years BP. In Boring B-24, located within River Terrace north of Murray Street, a peat sample was recovered at -63 to -63.5 feet. The sample yielded a median probability date of 9546 years BP. Pollen analysis from these samples is discussed in the following section. In Boring B-29, located within River Terrace north of Warren Street, a peat recovered at -65 feet to -65.5 feet yielded a median probability radiocarbon date of 9073 years BP. A subsample of this peat was submitted for pollen analysis as described below. As described below, a second sample of peat recovered from -67.0 to -67.5 feet yielded a median probability date of 9962 years BP.

In Boring B-32, located north of the intersection of River Terrace and Chambers Street, a sample dark gray sand was retained from the advance from -54.5 to -56.5 feet. Submitted for dating, the sample returned a median probability date of 6548 years BP. This date is approximately 1,300 years later than would be expected based on sea level rise curves; the discrepancy is attributed to reworking of sediments by river and estuary currents.

In Boring B-36, located on the west side of Route 9A/West Street south of Harrison Street, a bulk sediment sample retained from -24 feet yielded a median probability radiocarbon date of 1569 years BP. The sample submitted for dating was chosen because thin stratification suggested that it may have been part of an intact packet of slackwater deposition. However, the 1569 years BP date is several millennia later than would be predicted by any of the recognized sea level curves for New York Bight (Schuldenrein, et al. 2007) and the curve presented by HCI (1983) would put inundation at this elevation at around 6000 years BP. The younger-than-expected date may be a result of disturbance such as dredging and subsequent slumping and infilling by nearby sediments. Or, inasmuch as historic period markers were found within 2 feet above the sample, it is possible that younger carbon infiltrated the sampled sediment and skewed the date.

In Boring B-38, located on the western side of Route 9A/West Street approximately 280 feet north of Boring B-36, a sample of the lower clay from an approximate depth of -28 to -29 feet was retained for radiocarbon dating and returned a median probability date of 2589 years BP. This date is approximately 4,000 years later than would be projected by local sea level curves. As described for Boring B-36, this skewed date may be a result of dredging and subsequent infilling from material higher in the sediment column or a result of infiltration of younger carbon.

In Boring B-39A, located on the eastern side of Route 9A/West Street between Harrison and North Moore Streets, A sample from -18 feet, consisting of black (Gley 2.5/N) silty clay containing fine mica, was retained for radiocarbon dating and later returned a median probability date of 1396 years BP. This date is approximately 2,600 years after inundation of the surface would have occurred, according to the HCI (1983) sea-level rise curve. The sample was recovered 2 feet above sand interpreted to be part of a truncated glacial outwash deposit. As noted for several previous borings, this discrepancy may be a result of a lag before the beginning of clay deposition in the estuarine setting, incision of sediments and deposition of younger carbon, compaction of the saturated sediments by the weight of fill, or some combination of these. Ultimately, the date is of little use in interpretation of site formation processes, apart from further illustrating the dynamism of the study area.

In Boring B-40, located approximately 70 feet northwest of Boring B-39A, a sample of dark sandy loam was retained for radiocarbon dating, subsequently returning a median probability date of 6236 years BP. This date from sediment identified as a remnant of former surface is closely in keeping with the timing of inundation for this elevation as extrapolated from the HCI (1983) sea level rise curve.

RESULTS OF POLLEN AND MACROBOTANICAL ANALYSIS

As described in **Chapter 2, "Research Design and Methodology,"** four subsamples of peat were submitted to Archaeological Consulting Services in Tempe, AZ for pollen analysis (see **Appendix B**) and two subsamples of peat were submitted to Justine McKnight, Archeobotanical Consultant, LLC (see **Appendix C**). A summary of the pollen analysis is included in **Table 5-2** and presented below. As discussed previously, the pollen profiles derived from the samples are not specific to the vegetation of the Project Area, but are representative of regional vegetative populations. Some of the identified pollen would have been carried an unknown distance on the wind, the Project Area's maritime setting creates the possibility that pollen may have been carried by the Hudson River from upstream in its basin, although this is assumed to constitute a relatively minor source.

Table 5-2
Summary of Pollen and Macrobotanical Analysis

Boring	Depth (ft)	Sample Type	Results of Analysis
B-19 (Pollen)	-56.5	Black Estuarine Clay	Chestnut and hickory
B-23 (Pollen)	-62	Peat	Ragweed; pine; oak; sedges; goldenrod; grasses; alder; other
B-24 (Macrobotanical)	-63 to -63.5	Peat	Grass stem and leaf; marine shell; and gastropods
B-25 (pollen)	-63 to -63.5	Peat	Oak; alder; pine; grasses; ragweed; goldenrod; sedges; chestnut; fern; other
B-28 (pollen)	-65 to -65.5	Peat	Oak; pine; ragweed; hemlock; sedges; maple; other
B-29 (Macrobotanical)	-65 to -65.5	Peat	Wood (spruce, pine, and unspecified coniferous, both burned and unburned); grass stem and leaf; carbonized thorn; sedge, rush, and mustard seeds (burned and unburned)
Source: See **Appendix B and Appendix C**			

In Boring B-19, located near the western terminus of Vesey Street, a sample of black estuarine clay from -56.5 feet was submitted for pollen analysis. Pollen analysis conducted on the sample contained markers of chestnut and hickory.

A subsample of peat from a depth of -62 feet within Boring B-22A was originally submitted for pollen analysis. Following the loss through laboratory error, a comparable peat sample from a depth equivalent to the dated sample was submitted from Boring B-23, located 120 feet to the north-northeast near the intersection of River Terrace and Murray Street. The pollen profile consisted of, in descending order:

- *Ambrosia*—ragweed: 19 percent;
- *Pinus* (pine tree): 18 percent;
- *Quercus* (oak tree): 16.5 percent;
- *Cyperaceae* (sedges)—small: 8 percent;

- *Cyperaceae* (sedges)—medium: 6.5 percent;
- *Solidago* (goldenrod): 4.5 percent;
- *Poaceae* (grasses): 3.5 percent;
- *Alnus* (alder): 3 percent; and
- Less than 2 percent each of *Apiaceae* (Queen Anne's lace, water hemlock, etc.); *Alismataceae* (arrowhead plant, water plantain); *Asteraceae* (daisy, sunflower); legumes; impatiens; tendril climbers (Virginia creeper, etc.); smartweed/knotweed; rose family; sumac; cattail/bur-reed; *Carpinus* (hornbeam family); *Castanea* (chestnut); beech; ash; *Ilex* (holly/winterberry family); *Salix* (willow); cypress; and *Tsuga* (hemlock).

In Boring B-24, located within River Terrace north of Murray Street, a peat sample was recovered at -63 to -63.5 feet. A subsample of the peat submitted for macrobotanical analysis contained grass (*Poaceae*) stem and leaf material and wood (species indeterminate). Marine shell and small gastropods were also present in the sample. Following loss of a sample through laboratory error from the same boring, a sample of peat from an equivalent depth in Boring B-25, 100 feet to the north-northeast, was submitted for pollen analysis. Pollen analysis of a subsample of the peat yielded a profile of (in descending order):

- *Quercus* (oak tree): 27 percent;
- *Alnus* (alder): 17.5 percent;
- *Pinus* (pine family): 12.5 percent;
- *Poaceae* (grasses): 7.0 percent;
- *Ambrosia*—ragweed family: 5.5 percent;
- *Solidago* (goldenrod): 5.5 percent;
- *Cyperaceae* (sedges)—small: 3.5 percent;
- *Cyperaceae* (sedges)—medium: 3.5 percent;
- *Castanea* (chestnut): 3.0 percent
- *Osmunda* (fern family): 3.0 percent; and
- 2 percent or less of *Cheno-Ams* (amaranth, redroot pigweed, etc.); legumes; impatiens; tendril climbers (Virginia creeper, etc.); knotweed; rose family; *Betula* (birch); *Carpinus* (hornbeam family); ash; *Myrica* (bayberry, myrtle); *Prunus* (cherry); cypress; and *Tsuga* (hemlock).

A subsample of the peat recovered from a depth of approximately -65 feet in Boring B-29 (which dated to 9073 years BP) was submitted for macrobotanical and pollen analysis. The macrobotanical analysis indicated the presence of wood—spruce, pine and unspecified coniferous, both unburned or partially burned—grass stem and leaf tissue, one carbonized thorn. The analysis also identified ten seeds, including sedge (*Carex*), sedge family (*Cyperaceae*), rush (*Scirpus*), and tentatively identified mustard family (*Brassicaceae*). All of the seeds were described as burned or partially burned. The original sample submitted for pollen analysis was lost through laboratory error and a sample from an equivalent depth in Boring B-28, located approximately 85 feet to the southwest, was substituted. The pollen profile included:

- *Quercus* (oak tree): 42.5 percent;
- *Pinus* (pine tree): 17.5 percent;
- *Ambrosia* (ragweed family): 6.5 percent;
- *Tsuga* (hemlock): 5.5 percent;
- *Cyperaceae* (sedges)—small: 4.5 percent;
- *Acer* (maple tree): 3.5 percent; and

- 2 percent or less of *Cyperaceae* (sedges)—medium; *Poaceae* (grasses); *Vitis* (grape family); *Alnus* (alder); *Castanea* (chestnut); *Juglans* (walnut); *Picea* (spruce); and *Salix* (willow family).

Chapter 6: Discussion and Interpretation

A. INTRODUCTION

This geomorphological investigation of the North/West Battery Park City Resiliency Project Area was undertaken by geomorphologist John Stiteler, MS with several objectives in mind. Primary among these objectives were: 1) characterization of the post-glacial landscape within the Project Area prior to its inundation by post-glacial sea level rise; 2) identification of pre-inundation surfaces that might have been used by Indigenous populations as habitation or resource procurement settings; and 3) assessment of the degree to which former inhabitable surfaces and any archaeological resources contained therein might have been preserved despite subsequent disturbance and development, including dredging, landfilling, and the driving and removal of piles.

B. GENERAL SOIL PROFILES

The general stratigraphic pattern seen in the borings, including the hand-excavated upper zone, was a sequence consisting of: 1) concrete or asphalt 2) fill 3) fine-textured organic-rich estuarine sediments; and 4) bedrock. Boring stratigraphy in the former shallow water and shoreline zone of the Landward Reach generally consists of: paving and fill; clay-rich estuarine deposits thinner than those observed in the Open-Water Reach; glacial outwash; and bedrock. The estuarine deposits were absent in the borings along North Moore Street, where profiles consisted of: pavement and fill; glacial outwash; bedrock.

In five of the monitored borings, a thin layer of peat lay between the lower boundary of the fine estuarine sediments and the bedrock and in a few cases the peat was directly underlain by a thin zone of gravelly sandy loam. In each case where peat was encountered, a sample was retained for carbon dating and possible botanical analysis; numerous samples of the organic-rich estuarine sediments and underlying sandy loam were also retained for dating and botanical analysis. Four peat samples, eleven sediment samples, and two wood samples were subsequently submitted for radiocarbon dating.

GROUND SURFACE

The ground surface of each of the soil borings was recorded in the field by the geotechnical staff. The ground surface is largely level, with minor differences between the Open-Water Reach and the Landward Reach. Within the Landward Reach, the elevation is most variable along North Moore Street, the location of the only fast land within the Project Area. Along North Moore Street, the ground surface slopes down to the west from an elevation of approximately 12.5 feet NAVD88 near Greenwich Street to an elevation of approximately 8.3 feet NAVD88 at Route 9A/West Street. The remainder of the Landward Reach along Route 9A/West Broad Street is generally level, with ground surface elevations ranging between approximately 8.1 feet NAVD88 and 9.1 feet NAVD88. The ground surface elevation within the Open-Water Reach, which is entirely on anthropogenic landfill, varies as a result of landscaping and landscape design within the parks, open space, and roads that make up Battery Park City. The ground surface generally ranges between 10 and 19 feet NAVD88.

FILL MATERIAL

Fill was encountered in all drilling locations throughout the Project Area. The thickness of the fill layer generally ranged from 40 to 50 feet in borings proximal to the river and diminished with distance from the modern channel. The nature of the fill varied to some extent over the length of the study area. Throughout much of the northern half of the Project Area, fill consisted of medium to fine, brown to gray sand containing varying amounts of fine rounded gravel, fine mollusk shell fragments, and occasional fragments of brick, coal, coal cinder, and glass. In the central part of the study area, from North Cove for a short distance north (borings B-15 to B-20), fill included angular schist gravel interspersed, in a few borings, with strata of sand. The angular schist is interpreted to largely be material from the World Trade Center bathtub excavation. Fill south of North Cove was somewhat more heterogeneous and included sand, wood, and brick and rock rubble. Fill was also more mixed in the landward portions of the north end—where initial filling is conjectured to have taken place previous to the mid-20th century—and consisted of cobbles, gravel, clay, sand, brick rubble, and coal cinder.

ESTUARINE SEDIMENTS

The fine-textured estuarine sediments included very fine sand and fine sandy clay but were dominated by organic-rich clay and silty clay, generally dark gray to black (Munsell Gley1 4/N to 2.5/N). This stratum generally ranged from 12 to 25 feet in thickness and markers such as coal, coal cinder, and brick fragments were often present throughout much of the column. Presence of these markers at a given point within the sediment column does not necessarily reflect their deposition contemporaneously with the clay and silty clay but may be a result of downward movement through the loose, saturated sediments, incision of the clays by tidal or river currents, disturbance related to dock construction or dredging, etc.

Borings B-33 through B-56 were located at the north end of the Project Area and were the farthest from the modern channel of all the sampling locations. B-42 through B-45 were conducted on the south side of North Moore Street, at the north end of the Project Area. Of these, borings B-43 and B-44 were observed for this study. Of the 28 borings monitored by the geomorphologist, these two were at the greatest distance from the Hudson River channel.

BEDROCK

Although the depth to bedrock in borings along the length of the Project Area shows the variation that would be expected over short distances, the overall trend along the Open-Water Reach is that of increasing depth to bedrock from south to north. The depth of the bedrock ranges from -40 feet in Boring B-03 to -68 feet in Boring B-32. Depth to bedrock under the Landward Reach is even greater, ranging from -78 feet in Boring B-33 to -101 feet in Boring B-56, reflecting deeper glacial incision in that location. Scott Stanford, formerly of the New Jersey Geological and Water Resources Survey, has stated that bedrock within the Hudson River channel near Hoboken, just north of the Project Area, is glacially scoured to depths greater than -328 feet (Stanford, pers. comm. 2024).

C. INTERPRETATION OF THE OPEN-WATER REACH

In this study, the pre-inundation conditions in the Open-Water Reach are considered to have consisted of a mosaic of exposed bedrock and vegetated areas of relatively thin soil overlying bedrock. Based on previous studies of depth to bedrock or till in the reach of river which includes the Battery Park City project area, the pre-inundation slope of the valley wall was characterized by a decline of around 100 vertical feet over 1000 feet horizontal distance (Stanford, pers. comm. 2025). This is a generalized gradient and does not disallow the potential for the presence of small, non-contiguous, flat to very gently sloping surfaces. While the sampling conducted for this study identified the depth to bedrock, it cannot assist in defining the nature of the bedrock surface at any given boring location. That is, it is impossible to determine whether the bedrock surface at the point of sampling was horizontal or sloping or, if sloping, to what degree and in what direction.

With the breaching of the moraine obstruction at The Narrows and the resultant catastrophic outflow, variously proposed to have occurred at around 18,000 years BP (Stanford 2010) and 13,350 years BP

(Thieler et al. 2007), the valley wall along the Open-Water Reach was scoured of glacial lake sediments and till. In such a setting—the moderately steep wall of a broad valley scoured by glacial ice in the geologically-recent past and subsequently scoured by high-energy flows of sediment-poor lake discharge—there would be only a few possible pathways to the accumulation of post-glacial soil parent material on flat or gently sloping bedrock outcrops. Sub-aerial soils which developed in the Open-Water Reach prior to its inundation by sea level rise would most likely have developed in post-glacial colluvium and/or in wind-blown silt. Colluvium is a mixture of poorly sorted soil-sized particles and rock fragments which move downslope under the influence of gravity, freeze-thaw, overland flow of water, etc. and accumulate at breaks in slope where gradient decreases.

In nine of the thirty-one borings conducted in the Open-Water Reach of the Project Area, no sediment sample was obtained from the last 1 to 5 feet above weathered bedrock, either because the roller bit was advanced without sampling in that increment or because spoon advances within that depth increment yielded no recovery. In these locations, no definitive judgment can be made regarding the presence of pre-inundation, subaerial sediments.

In five borings, all clustered near the south end of the Project Area—Borings B-03, B-07A, B-52, B-13, and B-15— weathered bedrock was directly overlain by dark sand containing fine mollusk shell fragments and interpreted to be estuarine deposition. In seven borings, all in the south half of the Project Area (Borings B-04, B-05, B-46, B-47, B-12A, B-17, and B-20), weathered bedrock was directly overlain by silty estuarine clay. In Boring B-12A, fragments of brick and coal cinder were present in the silty clay directly over the bedrock. In two additional borings—B-1 and B-53—bedrock was directly overlain by gravelly fill. At each of these locations, there is no potential for the presence of *in-situ* cultural material.

In the borings in which bedrock was found to be directly overlain by estuarine clays or sands, it is impossible to know whether the bedrock surfaces were bare of sediment as sea level rose or if post-glacial colluvial or aeolian sediment was present as sea level encroached on the surfaces. Where sediment had accumulated and thin soil profiles were present, it is entirely likely that, in this sloping, west-facing setting on the shore of a broad expanse of water, erosion by wind-driven waves occurred as inundation proceeded. Offering some support for this, sediment directly overlying bedrock in a number of locations included rounded to subangular gravel suggestive of erosional lag. As stated previously, whether post-glacial sediments were formerly present or not, the settings in which estuarine sands or clays directly overlie bedrock offer no potential for the presence of *in situ* cultural material.

Peat was recovered from at or near the base of the split-spoon sampling in ten contiguous borings near the north end of the Open-Water Reach of the Project Area: Borings B-21 to B-30. Over this approximately 1,000-foot span of alignment, the presence of the peat appears to have been confined to a zone ranging from -61 to -70 feet; however, this may in part be an effect of a lack of sampling between the deepest recovered sample of peat and the surface of bedrock in several borings. At the southern end of the stretch where peat was recovered—Borings B-21 through B-23—the peat directly overlaid bedrock. As the surface of bedrock declined to the north, there was a 4- to 10-foot elevation difference between the lower boundary of the lowest sampled peat and the surface of bedrock. However, once again, this may be an effect of roller-bit advance without sampling as no data is recorded in those intervals. As discussed in the previous chapter, four samples of peat were submitted for radiocarbon dating and yielded median probability dates ranging from 9962 to 9073 years BP. These samples also included pollen and macrobotanical remains consistent with areas containing a variety of trees as well as other low vegetation.

Mapping of the bedrock or till surface within and near the current Project Area by Mueser, Rutledge, Johnston, and DeSimone (HRI 1983, Appendix B) suggests that the area in which peat was recovered in this study—Borings B-21 to B-29—lies within a narrow embayment opening to the south (downstream). The embayment is depicted as being bounded by bedrock at an elevation of -70 to -61 feet. Within the area depicted as an embayment, bedrock was encountered in the current study at depths of -62 to -74 feet, with the depth increasing to the north, toward the closed end of the embayment. This setting, essentially a shallow bowl, would allow for ponding of water, creating the conditions for peat growth. Such a setting, while potentially serving as a resource-procurement site, would not be suitable for human habitation. The median 2-sigma dates obtained from the peat, ranging from 9962 to 9073 years BP, slightly pre-date that projected by the HRI 1983 sea-level rise curve for the -70 to -61 foot elevations. It is possible that water accumulating in the shallow bowl initially may have been a combination of meteoric water (rainfall and snowmelt) with possible inputs during high flows on the river. However, based on the presence of strata of clay within the peat and the presence of fine marine shell, it is more likely that a fissure or other opening in the bedrock high on the west side of the embayment allowed entrance of estuary water into the bowl. The data used by Mueser, Rutledge, Johnston, and DeSimone is coarse-grained, not allowing for identification of an such an opening. Justine McKnight, who conducted the botanical analysis on two samples from this setting stated that "it cannot be argued with any confidence that the assemblage represents fresh rather than brackish-water taxa. Unfortunately, the assemblage is small and imprecise (remains identified to the family or genus level, and all include species that thrive in either environment)" (McKnight pers. comm., 2025). What does appear to be more certain is that the portion of the boring alignment where peat was recovered was, to some degree, protected from the scouring waves and currents to which the rest of the Open-Water Reach was subjected. This protection appears to have been afforded by the presence of elevated bedrock to the north and west.

D. INTERPRETATION OF THE LANDWARD REACH

In the Landward Reach, the majority of the borings were conducted in an area that was also open water during the Late Holocene and much of the historic period; however, this was a shallow, near-shore zone, inundated later than the Open-Water Reach. Parts of this area would have been shoreline within the historic period, inundated twice daily at high tide. More easterly borings B-43 through B-45, along North Moore Street, were conducted in an area that was fast land when Europeans first entered the estuary.

In the setting of the Landward Reach, all past human activity would have taken place at or quite near the surface of the glacial sediments. This glacial parent material would have been relatively stable for the roughly 20,000 years between glacial recession and inundation by Late Holocene sea level rise or commencement of large-scale anthropogenic impacts within the historic period. The stability of the landscape made it possible for soil-formation processes to proceed. Detailed description of these processes, the combined effects of climate, organic activity, characteristics of the parent material, landscape relief, and time is beyond the scope of this investigation. However, the most pertinent and most noticeable effect of soil formation processes is the formation of soil horizons, distinct layers within the soil column, characterized by specific physical, chemical, and biological properties. Taken together, these form the soil profile.

A basic soil profile consists of an A horizon, one or more B horizons of various nature, and a C horizon (unweathered and unaltered parent material). Because weathering is most active at the ground surface and because organic material from plants and animals accumulates there, the uppermost mineral horizon (the A horizon) is most strongly expressed and easily identified. Though the organic matter content of A horizons is typically less than 5 percent, its effect—particularly the visual effect—is disproportionate, imparting a light brown to black color easily distinguished from the underlying soil horizons.

In most settings, the A horizon of a developed profile is directly underlain by one or more B horizons. B horizons are zones of accumulation of soil constituents (such as clay, iron, manganese and aluminum), both those leached from the overlying A and/or B horizon and those produced in-situ by weathering. Among the most common B horizons in the temperate eastern United States are Bw (cambic) horizons, Bt, Bg, Bh, Bs, Bhs, and Bx (fragipan) horizons. Only Bw and Bt horizons will be discussed here.

A Bw is a weakly expressed B horizon, sometimes called a "color B." The Bw designation is applied by default to upper subsurface horizons in which weathering, alteration of the soil parent material and accumulation of clay, iron and other elements have occurred but not to a sufficient degree to meet the criteria for designation as any of the other B horizons.

A Bt horizon is a subsurface horizon that is the site of deposition of clay transported down-profile from one or more overlying horizons. In stable settings, especially in temperate and sub-tropical areas with high rainfall, clay is continually being produced by weathering in upper soil horizons and is transported down-profile by infiltrating soil water. Presence of Bt horizons and the degree of their development are indicators of the age and stability of sediments.

With a single exception, no evidence was observed of a preserved soil solum (A and Bw or Bt horizons) developed on the outwash. Such former surfaces appear to have been removed either through natural processes (e.g., wave erosion) or by processes associated with urbanization (e.g., cutting, grading, roadbed preparation, etc.). As always, there is some possibility that a relatively thin buried soil solum may have escaped detection because of the discontinuous sampling methodology employed in the boring program.

The single exception to the lack of preserved, developed soil profiles was noted in Boring B-40. There, in a relatively small sample recovery (9 inches) from a spoon advance from -26 to -28 feet, a thin zone of dark sandy loam was observed overlying slightly lighter sandy loam with a moderately higher content of clay. This was suggestive of a remnant A horizon overlying a Bw horizon and a sample of the darker sandy loam was retained for radiocarbon dating, returning a median probability date of 6236 years BP. The 3 feet of sediment immediately overlying this was unsampled (roller-bit advance); an advance from -21 to -23 feet, 5 to 6 feet above the dated sample yielded dark gray fine to medium estuarine sand with no historic period inclusions noted. Inundation of a surface at this elevation (-26 to -28 feet) at around 6200 years BP is in keeping with the sea level rise curve presented by HRI in Appendix B of their 1983 report. It is unclear why at least a partial soil profile should have been preserved along this section of shoreline while surfaces at most other points along the testing transect appear to have been subject to wave erosion. Mueser, Rutledge, Johnston, and DeSimone's reconstruction of pre-inundation topography (in HRI 1983, Appendix B) indicates the presence of several topographic highs just offshore from the site of Boring B-40 and these may have acted as breakwaters, reducing wave energy. If this is the case, although no other remnant soil profiles were noted in any of numerous nearby borings, the potential for small, non-contiguous areas of preserved Mid-Holocene surfaces in this area cannot be entirely ruled out.

E. CONCLUSIONS

The landscape of the North/West Battery Park City Resiliency Project study area has been in a state of almost constant change for the last 25,000 years. Following burial, depression, and incision by glacial ice, at least part of the study area was submerged beneath the waters of a meltwater lake for several millennia. The drainage of the former glacial lake is variously asserted to have taken place at around 18,000 years BP and 13,350 years BP. At that time, the eastern wall and a portion of the proximal edge of the Hudson River Valley, which make up the study area, became a subaerial landscape potentially suitable for human occupation. As a result of post-glacial sea level rise over the course of the Holocene epoch, the area was again slowly inundated by the brackish waters of the Hudson River estuary. Based on comparison of depth to bedrock in this and earlier studies and on a topographic reconstruction produced by HCI 1983, much of the valley wall is interpreted here to have been moderately to steeply sloping, though as in any such setting it is likely that there were small areas of little or no slope. The mapping of the bedrock surface by HCI (1983) includes the presence of a bedrock high—essentially a small knoll—at the north end of the current study area. While a lack of access to fresh water within the current study area may have posed an impediment to habitation there, the bedrock knoll, any flat areas along the constantly rising shoreline, and any small embayments would undoubtedly have provided foci for resource procurement.

This study consisted primarily of analysis of relatively limited data, provided by 1.375-inch diameter samples largely obtained at 100 to 400 foot intervals, along with review of previous studies. With a single exception, no evidence of developed soil profiles—indicative of surface stability—were observed in this boring program. Several factors may account for this. In the glacially-scoured and meltwater-swept setting of the Open-Water Reach, parent material for soils would have been in short supply, consisting largely of post-glacial colluvium, material which moved downslope under the influence of gravity, surface water flow, and freeze-thaw, along with some windblown material (aeolian inputs). More importantly, from an archaeological perspective, the evidence seen in the boring recoveries seems to suggest that any stable soils formerly present have been removed. Within the Open-Water Reach of the study area, this erosion would have resulted from the action of wind-driven waves, river and tidal currents, and possibly cataclysmic storm surges. Within the more gently-sloping Landward Reach, where well-expressed soil profiles developed on glacial outwash would almost certainly have been present by the Middle to Late Holocene. The truncation of profiles there appears to have been a result of both wave action and urban development (cutting and grading), possibly including near-shore dredging along piers and wharfs. A developed profile was identified only in boring B-40 and consisted of a thin remnant of a subsurface horizon (Bw or Bt horizon). In this non-depositional setting, cultural material would have been largely or completely confined to the missing A horizon.

The data available for this study strongly suggest that although Indigenous populations almost certainly made use of the now-submerged and filled study area there is a very low potential for the presence of intact, in-situ sites, features, or cultural material within the tested alignment. No further archaeological analysis is recommended for deeply buried soil strata.

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2023 “North/West Battery Park City Resiliency Project: Portions of Block 142, Lots 25 and 50; Block 16, Lots 3, 12, 15, 20, 70, 100, 120, 125, 140, 150, 160, 210, 215, 225, 7501 (formerly Lot 90), 7502 (formerly Lot 95), 7505 (formerly Lot 65), 7509 (formerly Lot 45), and 7511 (formerly Lot 25); and Portions of Streetbeds of Greenwich, North Moore, Harrison, and Route 9A/West Streets; Manhattan, New York County, New York; Work Plan for Geomorphological Investigation.” Prepared for: Battery Park City Authority; New York, NY.

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Figures

8.12.25

Data source: USGS The National Map, https://basemap.nationalmap.gov/arcgis/rest/services/USGSTopo/MapServer

0 2,000 FEET

2025 Project Area

2022 Project Area

Approximate coordinates of Project Site:
74°0'53"W 40°42'48"N

USGS Topographic Map – Jersey City Quadrangle

NORTH-WEST BATTERY PARK CITY RESILIENCY

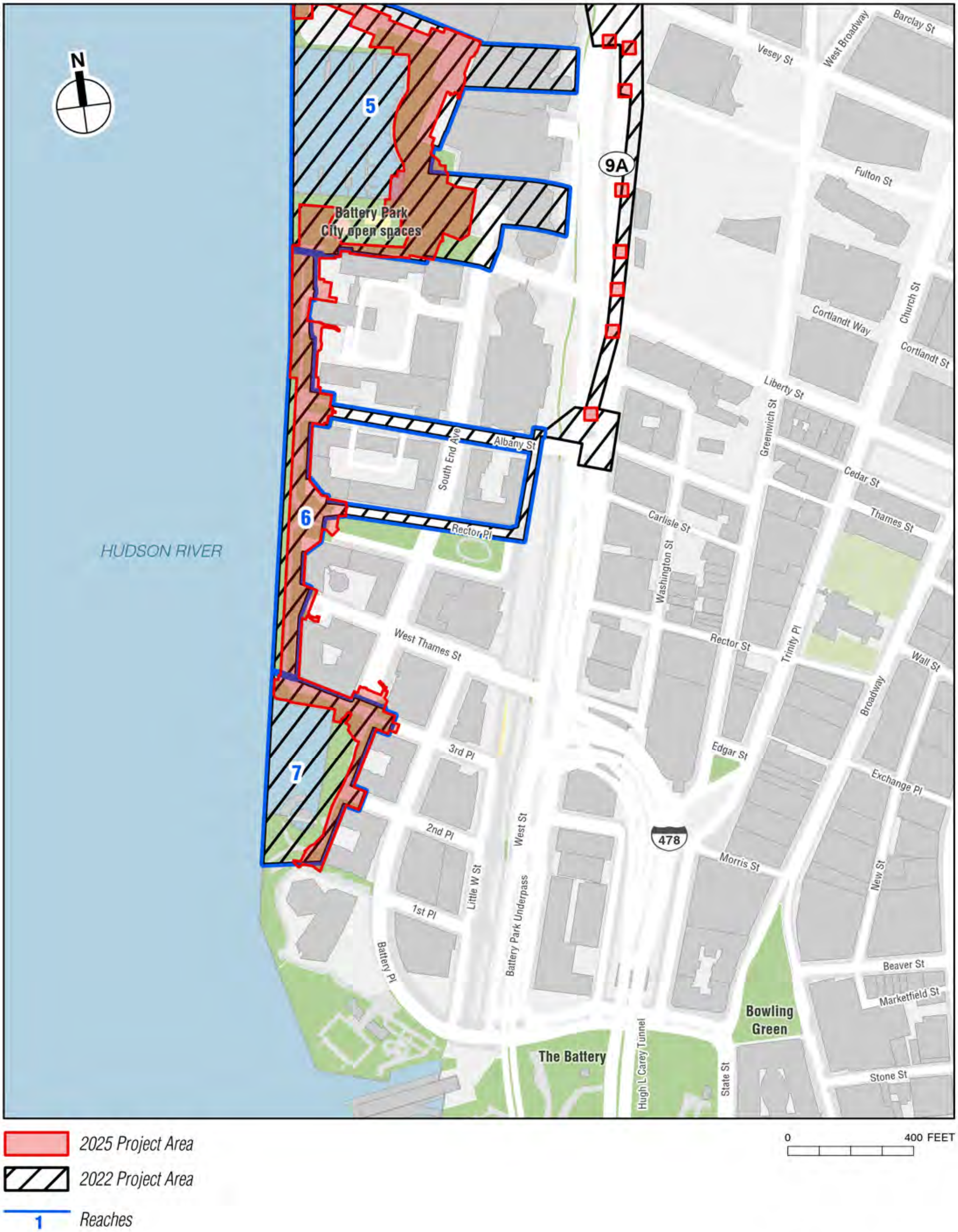
Figure 1

8.12.25

Project Location

Figure 2A

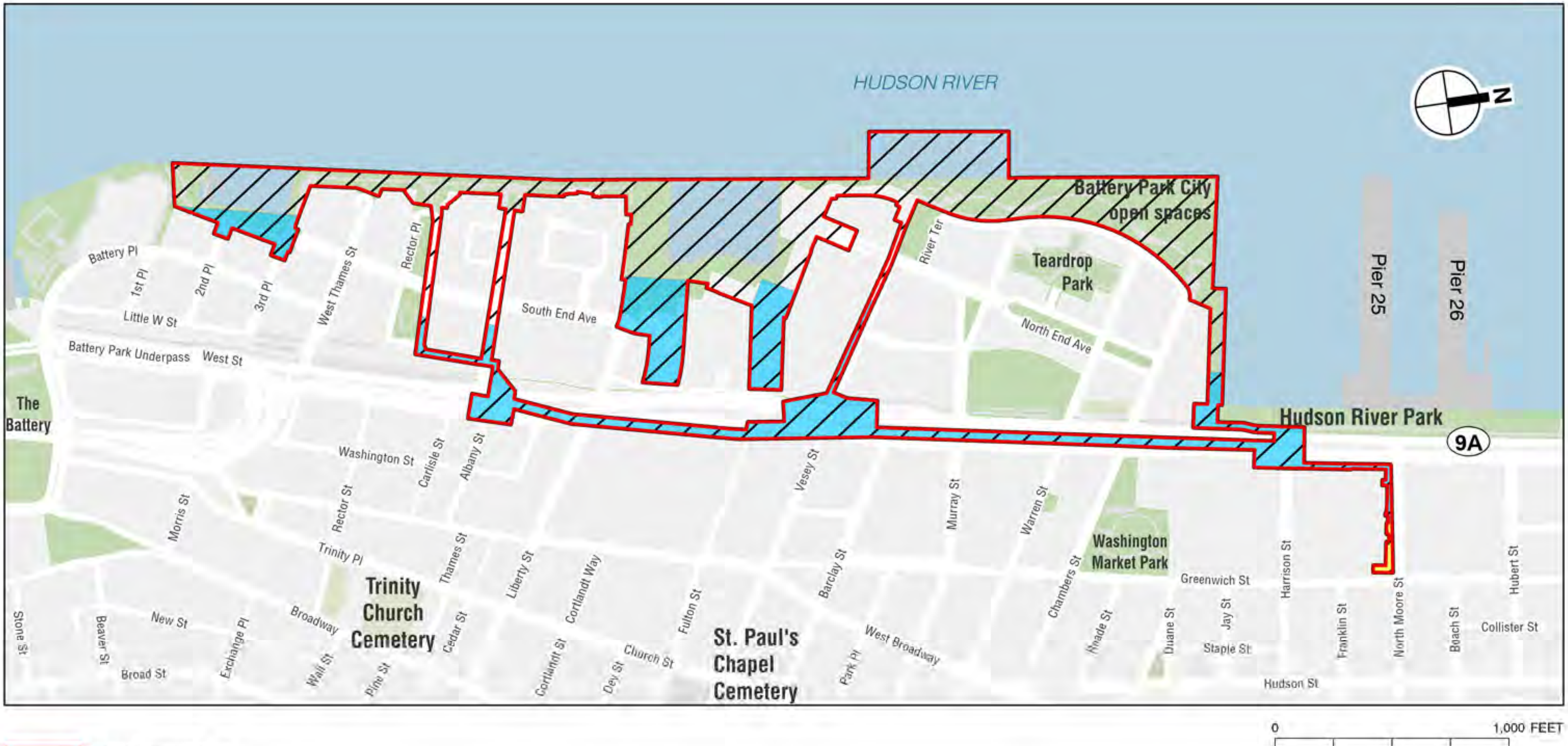
NORTH/WEST BATTERY PARK CITY RESILIENCY



Project Location

NORTH/WEST BATTERY PARK CITY RESILIENCY

Figure 2B



2022 Project Area

Location of Recommended Geomorphological Analysis Where Project Impacts are Greater than 30 feet in Depth

Areas sensitive for pre-1850 landfill resources in undisturbed areas

Areas with historic period sensitivity in undisturbed areas

Areas of Archaeological Sensitivity Identified in the 2022 Phase 1A Study

Figure 3A

2024 Project Area

Location of Recommended Geomorphological Analysis Where Project Impacts are Greater than 30 feet in Depth

Areas sensitive for pre-1850 landfill resources in undisturbed areas

Areas with historic period sensitivity in undisturbed areas

Areas of Archaeological Sensitivity
Identified in the 2024 Supplemental Phase 1A Study

Figure 3B

NORTH/WEST BATTERY PARK CITY RESILIENCY

8.12.25

Project Area

Location of Recommended Geomorphological Analysis Where Project Impacts are Greater than 30 feet in Depth

Areas sensitive for pre-1850 landfill resources in undisturbed areas

Areas with historic period sensitivity in undisturbed areas

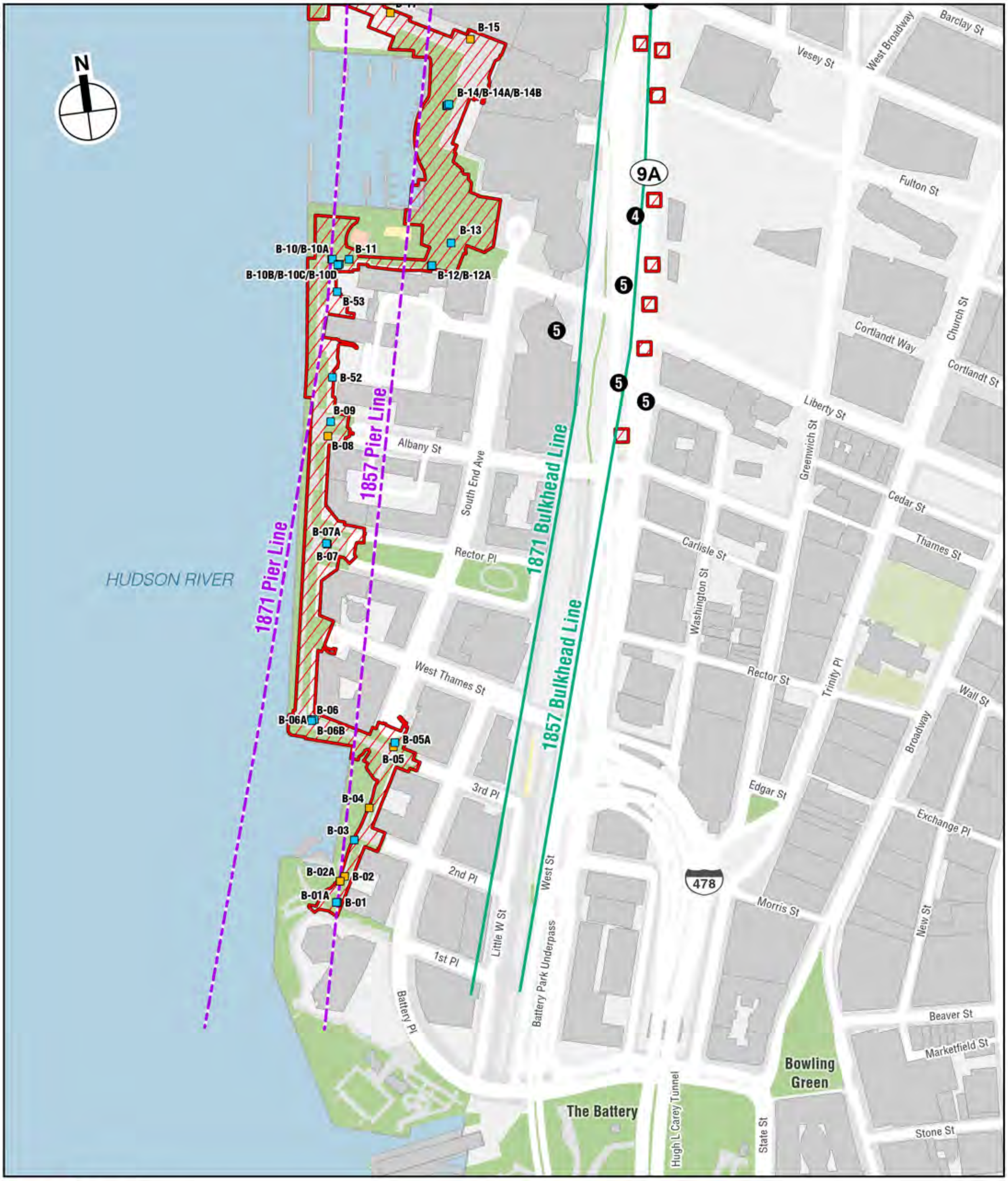
NORTH/WEST BATTERY PARK CITY RESILIENCY

Areas of Archaeological Sensitivity Identified in 2025

Figure 3C

Previously Identified Sensitivity

Figure 4A



Project Area

General Locations of Precontact Landforms Identified by HCI 1983

Monitored Boring

Other Boring

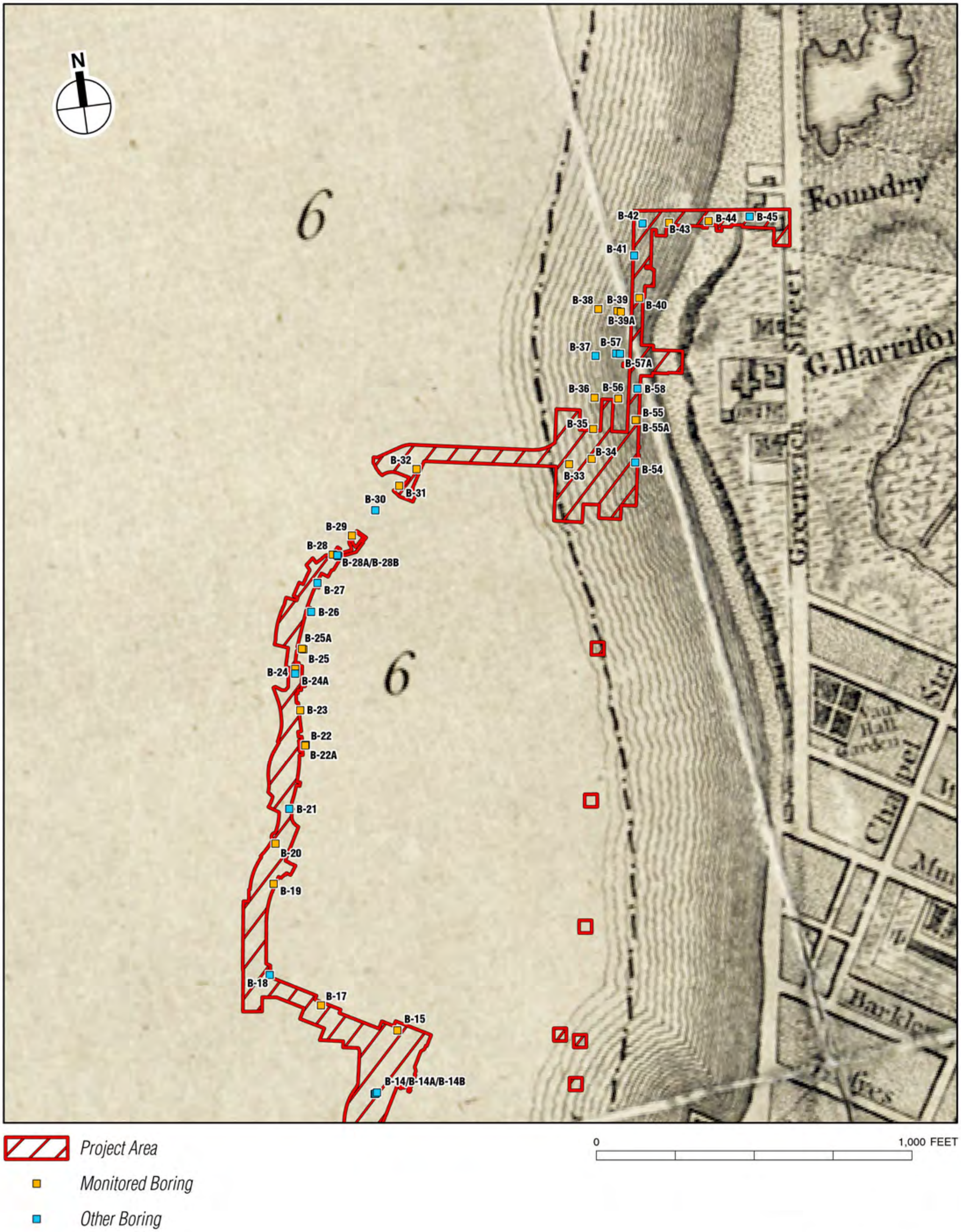
Historical Pier Lines

Historical Bulkhead Lines

0 400 FEET

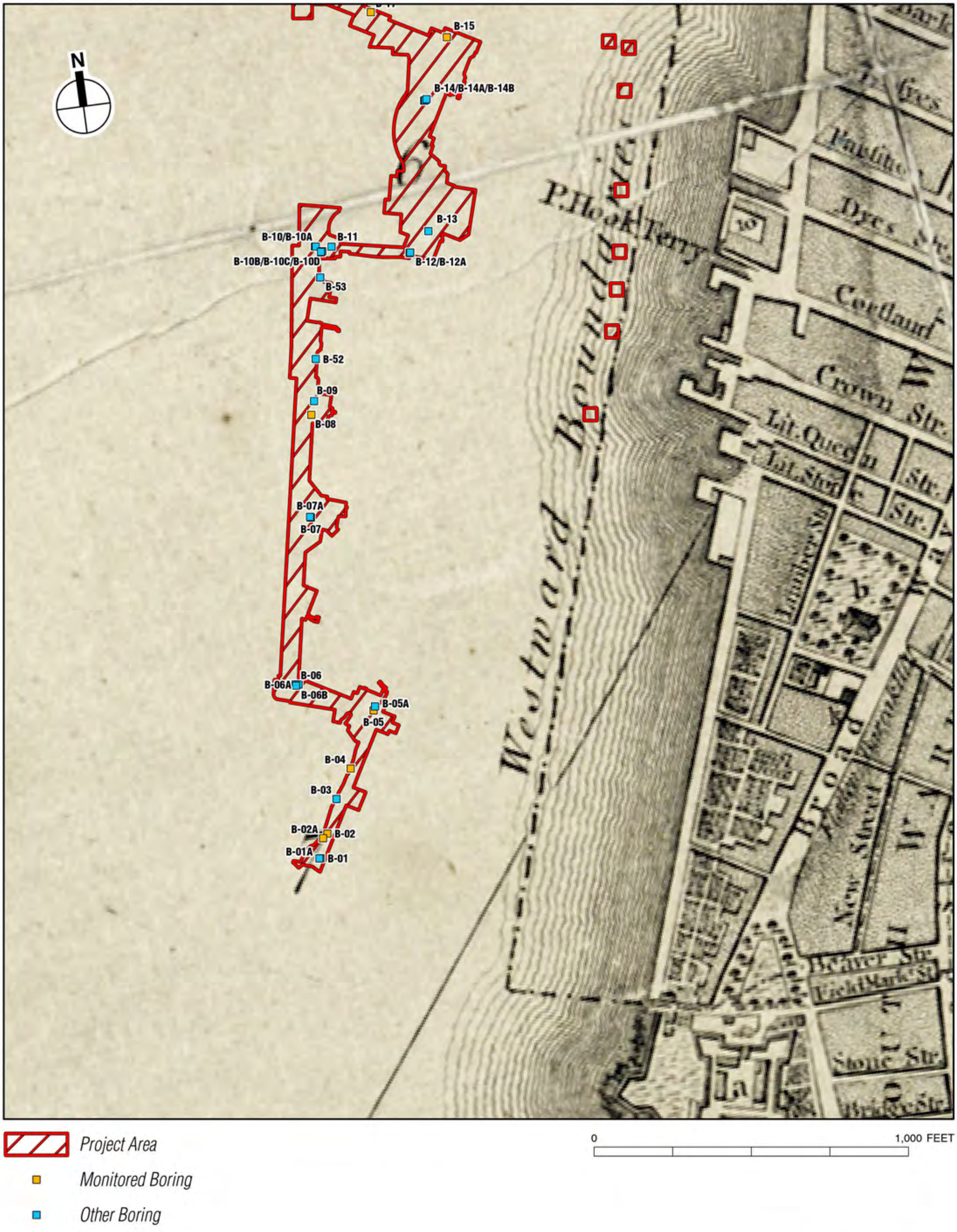
Previously Identified Sensitivity

Figure 4B



1776 Ratzer Map

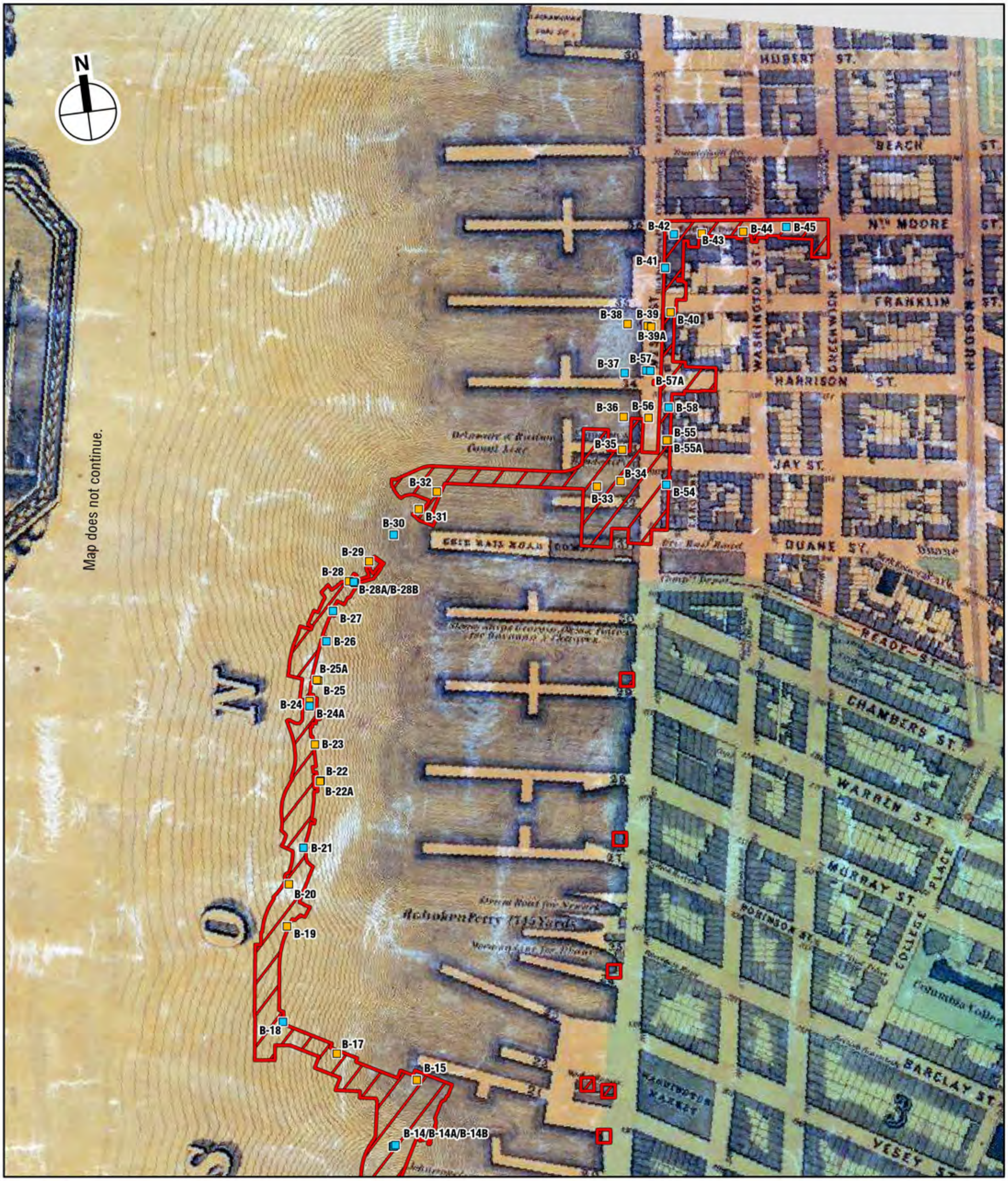
Figure 5A



1776 Ratzer Map

Figure 5B

8.13.25



1852 Dripps Map

Figure 6A

NORTH/WEST BATTERY PARK CITY RESILIENCY

Project Area

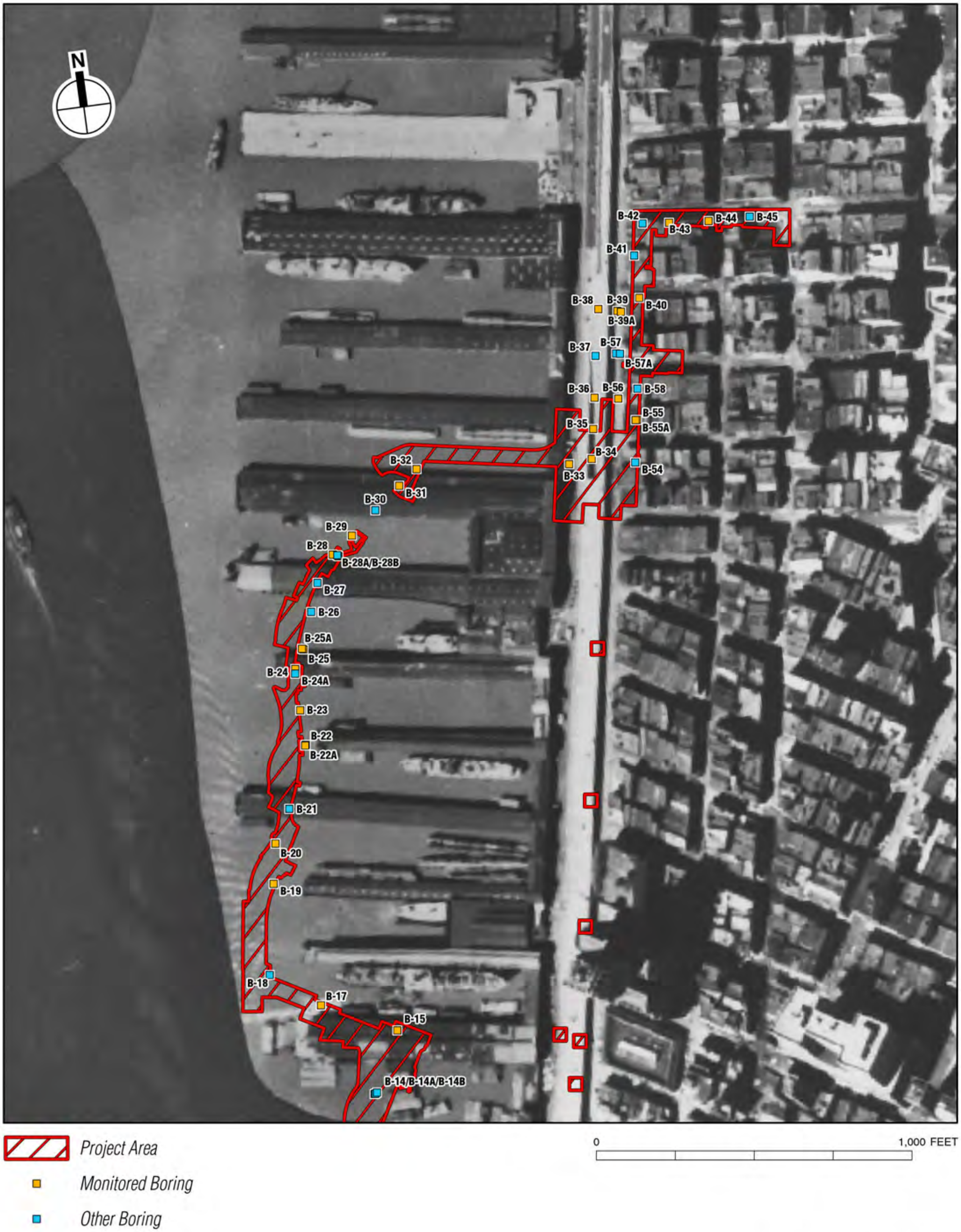
Monitored Boring

Other Boring

0 1,000 FEET

1852 Dripps Map

Figure 6B



1951 Aerial Map

NORTH/WEST BATTERY PARK CITY RESILIENCY

Figure 7A

8.13.25

Project Area

Monitored Boring

Other Boring

0 1,000 FEET

1951 Aerial Map

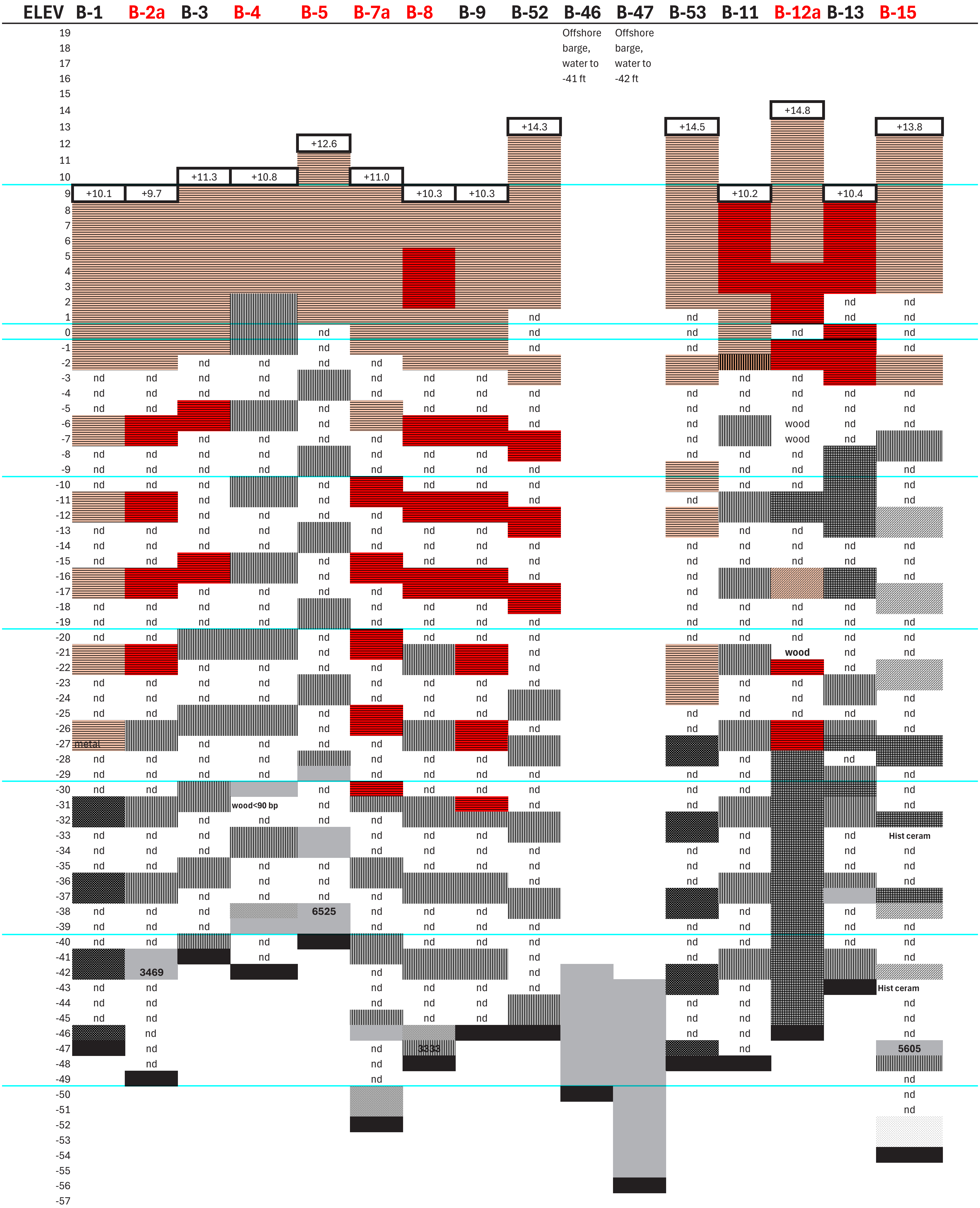
Figure 7B

NORTH/WEST BATTERY PARK CITY RESILIENCY

Image of the Hudson River Piers in 1958 **1**
(Source: Battery Park City Authority)

Filling of the Battery Park City area in the late 1960s/early 1970s **2**
(Source: Battery Park City Authority)

Historical Images
Figure 8

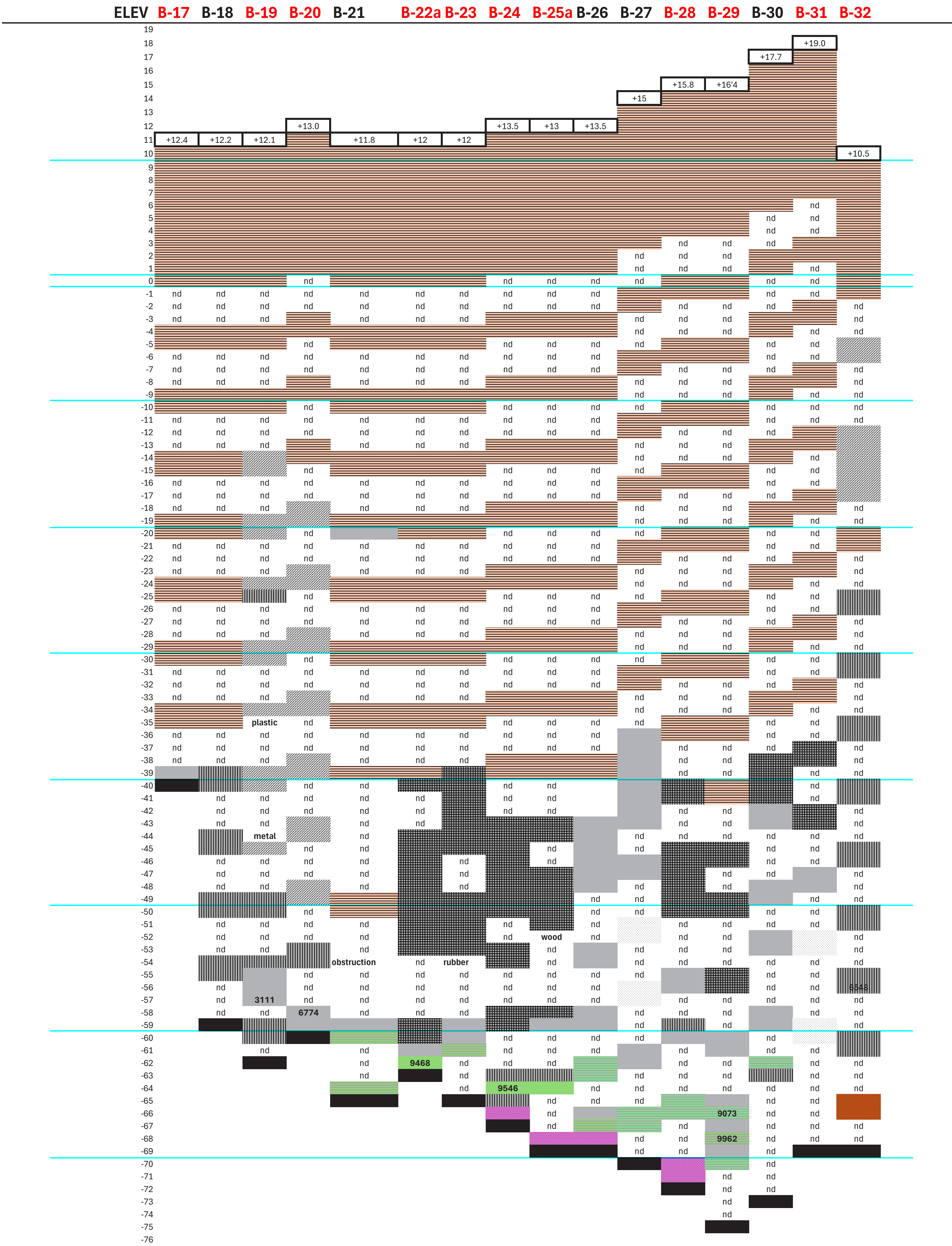


Asphalt or concrete pavers
Fill, incl brick, mortar, asphalt, gravel, angular stone
Sandy fill containing gravel, brick, concrete, coal, cinder, etc.
Fill - rock waste from WTC construction site
Estuarine clay, silty clay, sandy clay containing shell fragments, coal, brick, cinder, etc
Estuarine clay, silty clay, sandy clay with shell fragments, no coal, brick, cinder, etc noted
6525 Estuarine clay, silty clay, sandy clay with shell fragments; no coal, brick, cinder, etc noted (with C14 date)
Gray, black, dark brown sand, oranic-rich, with shell fragments, wood - estuarine deposition
5605 Gray, black, dark brown sand, oranic-rich, with shell fragments, wood - estuarine deposition (with C14 date)
Alluvial sand with brick, coal, cinder, wood - Historic or reworked within Historic period
Alluvial sand with shell fragments, fine gravel - no Historic markers noted/recorded
Alluvial sand with fine gravel, no shell fragments or Historic markers noted/recorded
Alluvial gravel

Interbedded clay and peat
Peat (undated)
9073 Peat (with C14 date)
Loam, silt or fine sand interpreted to be part of former subaerial profile
Red-brown to brown sand, varying gravel content, no shell noted; interpreted to be glacial outwash
Cobbles and gravel in sandy matrix - interpreted to be glacial outwash
Top of Rock
nd No data - unsampled rollerbit advance or no recovery in spoon

B-2a Boring monitored by geomorphologist
B-3 Data derived from boring logs

Soil Profiles
Figure 9a



- Asphalt or concrete pavers
- Fill, incl brick, mortar, asphalt, gravel, angular stone
- Sandy fill containing gravel, brick, concrete, coal, cinder, etc.
- Fill - rock waste from WTC construction site
- Estuarine clay, silty clay, sandy clay containing shell fragments, coal, brick, cinder, etc
- Estuarine clay, silty clay, sandy clay with shell fragments, no coal, brick, cinder, etc noted
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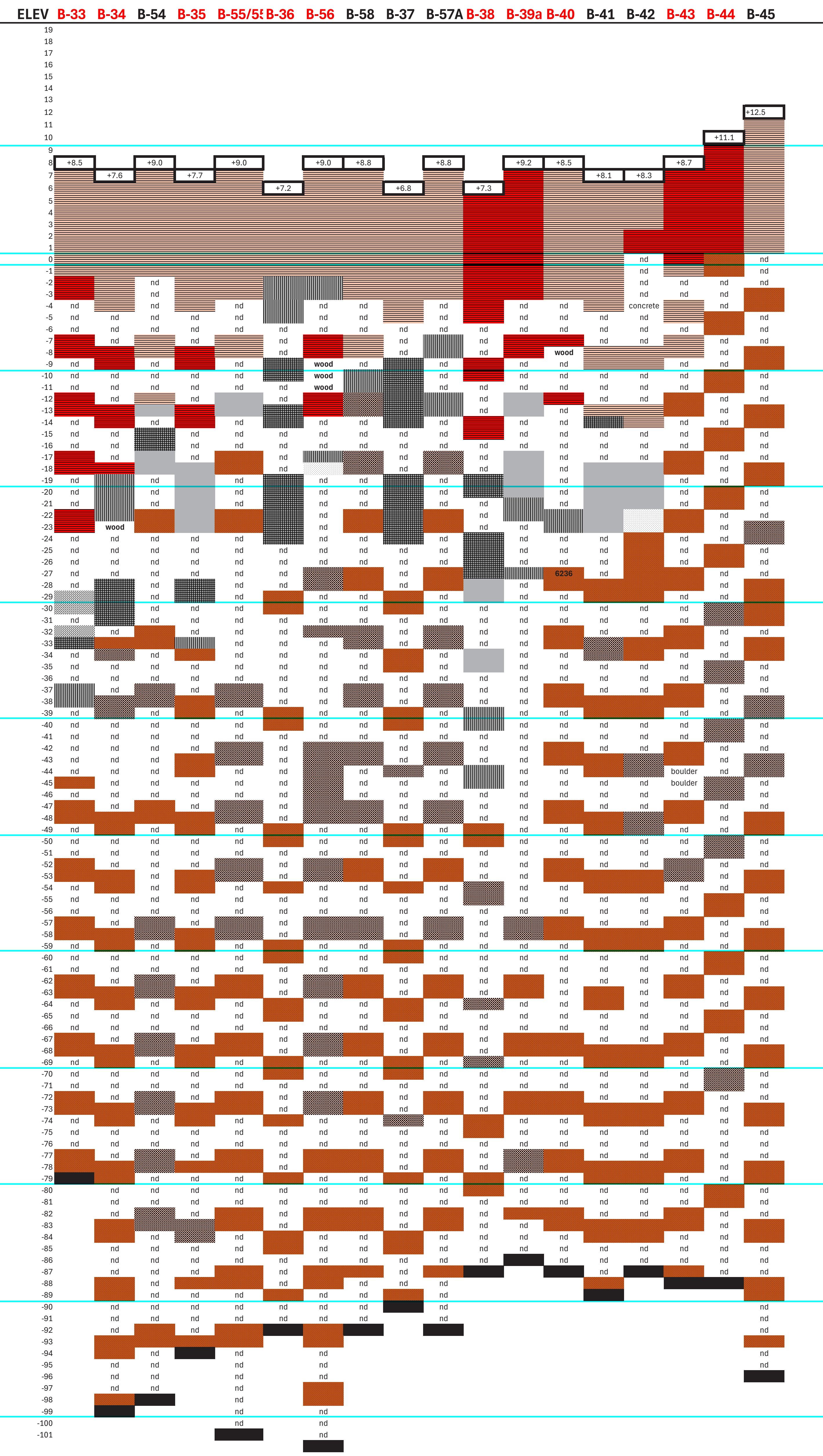
- 5605 Gray, black, dark brown sand, oranic-rich, with shell fragments, wood - estuarine deposition (with C14 date)
- Alluvial sand with brick, coal, cinder, wood - Historic or reworked within Historic period
- Alluvial sand with shell fragments, fine gravel - no Historic markers noted/recorded
- Alluvial sand with fine gravel, no shell fragments or Historic markers noted/recorded
- Alluvial gravel
- Interbedded clay and peat
- Peat (undated)
- 9073 Peat (with C14 date)
- Loam, silt or fine sand interpreted to be part of former subaerial profile
- Red-brown to brown sand, varying gravel content, no shell noted; interpreted to be glacial outwash
- Cobbles and gravel in sandy matrix - interpreted to be glacial outwash
- Top of Rock
- nd No data - unsampled rollerbit advance or no recovery in spoon

B-2a Boring monitored by geomorphologist
B-3 Data derived from boring logs



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Fill, incl brick, mortar, asphalt, gravel, angular stone
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Estuarine clay, silty clay, sandy clay containing shell fragments, coal, brick, cinder, etc
Estuarine clay, silty clay, sandy clay with shell fragments, no coal, brick, cinder, etc noted
6525 Estuarine clay, silty clay, sandy clay with shell fragments; no coal, brick, cinder, etc noted (with C14 date)
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Alluvial sand with brick, coal, cinder, wood - Historic or reworked within Historic period
Alluvial sand with shell fragments, fine gravel - no Historic markers noted/recorded
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Cobbles and gravel in sandy matrix - interpreted to be glacial outwash
Top of Rock
nd No data - unsampled rollerbit advance or no recovery in spoon

B-2a Boring monitored by geomorphologist
B-3 Data derived from boring logs

Soil Profiles
Figure 9c

Photographs

Photograph 1: Boring B-23, 30 to 32 feet below ground surface (bgs) (-18 to -20 feet): typical sand fill, including coal cinder and fine shell

Photograph 2: Boring B-23, 64 to 66 feet bgs (-52 to -54 feet): typical estuarine organic silty clay, contained wood, much coal cinder

Photograph 3: Boring B-23, 70 to 72 feet bgs (-58 to -60 feet): typical estuarine organic silty clay, contained wood, no Historic markers noted

Photograph 4: Boring B-29, 80-82 feet bgs (-64 to -66 feet) typical estuarine organic silty clay, contained shell; peat visible near top of sample, no historic period markers noted

Photograph 5: Boring B-29, 82-84 feet bgs (-66 to -68 feet) typical estuarine organic silty clay, contained shell; peat visible near middle of sample, no historic period markers noted

Photograph 6: Boring B-42, 29-31 feet bgs (-21 to -23 feet) gravelly glacial outwash sand, reworked by wave action, upper zone stained by overlying organic-rich estuarine sediments

Photograph 7: Boring B-42, 45-47 feet bgs (-37 to -39 feet) gravelly glacial outwash sand

Photograph 8: Boring B-42, 55-57 feet bgs (-47 to -49 feet) glacial outwash gravel

Appendix A:
Radiocarbon Dating

The University of Georgia

Center for Applied Isotope Studies

RADIOCARBON ANALYSIS REPORT

February 6, 2024

John Stiteler
AKRF
201 Connecticut Hill Road
Newfield, NY 14867

Dear Mr. Stiteler,

Enclosed please find the results of ^{14}C Radiocarbon AMS analyses and Stable Isotope Ratio $\delta^{13}C$ analyses for the samples received by our laboratory on January 12, 2024.

UGAMS#	Sample ID	Material	$\delta^{13}C$,‰	^{14}C age, years BP	±	pMC	±
67449	1	peaty clay	-25.92	8850	35	33.23	0.14
67450	2	peat	-23.39	8140	30	36.29	0.14
67451	3	peat	-26.47	8600	30	34.3	0.14
67452	4	peat	-23.52	8430	30	35.03	0.13
67453	5	clay	-25.26	5950	30	47.7	0.17
67454	6	clay	-25.57	2950	25	69.22	0.21
67455	7	f. sand	-24.91	5750	30	48.89	0.20
67456	8	clay	-25.74	4880	30	54.44	0.18
67457	9	clay	-25.50	3110	25	67.89	0.21
67458	10	clay	-25.47	3260	25	66.62	0.20
67459	11	clay	-24.91	5730	30	49.02	0.17
67460	12	wood	-26.78	90	20	98.88	0.27
67461	13	wood	-25.04	200	20	97.5	0.27
67462	14	clay	-25.25	2520	25	73.04	0.23
67463	15	sand loam	-20.52	5430	30	50.89	0.17
67464	16	clay	-24.30	1680	25	81.13	0.25
67465	17	clay	-25.71	1530	25	82.69	0.26

The bulk sediment samples after root separation by sieving through 125µm nylon screen and following acid treatment with 1N hydrochloric acid at 80°C for 1 hour were washed with deionized water using centrifuge to pH=4-5, then they were dried at 105°C. The dry samples was combusted at 900°C in the evacuated sealed quartz ampoule in the presents of CuO. The resulting carbon dioxide was cryogenically purified from the other reaction products and catalytically converted to graphite using the method of Vogel et al. (1984) Nuclear Instruments and Methods in Physics Research B5, 289-293. Graphite $^{14}C/^{13}C$ ratios were measured using the CAIS 0.5 MeV accelerator mass spectrometer. The sample ratios were compared to the ratio measured from the Oxalic Acid I (NBS SRM 4990). The sample $^{13}C/^{12}C$ ratios were measured separately using a stable isotope ratio mass spectrometer and expressed as δ13C with respect to PDB, with an error of less than 0.1‰. The quoted uncalibrated dates have been given in radiocarbon years before 1950 (years BP), using the ^{14}C halflife of 5568 years. The error is quoted as one standard deviation and reflects both statistical and experimental errors. The date has been corrected for isotope fractionation.

Sincerely,

Alexander Cherkinsky, Ph.D.
Senior Research Scientist

RADIOCARBON CALIBRATION PROGRAM*
CALIB REV8.2

*To be used in conjunction with:
Stuiver, M., and Reimer, P.J., 1993, Radiocarbon, 35, 215-230.

1
67449
peaty clay
Radiocarbon Age BP 8850 +/- 35
Calibration data set: intcal20.14c # Reimer et al. 2020

% area enclosed		cal BP age ranges	relative area under probability distribution
68.3 (1 sigma)	cal BP	9803 - 9841	0.135
		9890 - 9962	0.340
		9988 - 10013	0.115
		10022 - 10041	0.074
		10061 - 10126	0.337
95.4 (2 sigma)	cal BP	9753 - 9972	0.507
		9977 - 10158	0.493

Median Probability: 9962

2
67450
peat
Radiocarbon Age BP 8140 +/- 30
Calibration data set: intcal20.14c # Reimer et al. 2020

% area enclosed		cal BP age ranges	relative area under probability distribution
68.3 (1 sigma)	cal BP	9012 - 9034	0.267
		9048 - 9093	0.587
		9107 - 9122	0.146
95.4 (2 sigma)	cal BP	9000 - 9136	0.938
		9180 - 9199	0.031
		9234 - 9260	0.031

Median Probability: 9073

3
67451
peat
Radiocarbon Age BP 8600 +/- 30
Calibration data set: intcal20.14c # Reimer et al. 2020

% area enclosed		cal BP age ranges	relative area under probability distribution
68.3 (1 sigma)	cal BP	9531 - 9555	1.000
95.4 (2 sigma)	cal BP	9496 - 9504	0.012

		9526 - 9631	0.946
		9641 - 9662	0.040
		9674 - 9676	0.002

Median Probability: 9546

4
67452
peat
Radiocarbon Age BP 8430 +/- 30
Calibration data set: intcal20.14c # Reimer et al. 2020

% area enclosed		cal BP age ranges	relative area under probability distribution
68.3 (1 sigma)	cal BP	9434 - 9488	0.954
		9515 - 9518	0.046
95.4 (2 sigma)	cal BP	9329 - 9342	0.021
		9418 - 9530	0.979

Median Probability: 9468

5
67453
clay
Radiocarbon Age BP 5950 +/- 30
Calibration data set: intcal20.14c # Reimer et al. 2020

% area enclosed		cal BP age ranges	relative area under probability distribution
68.3 (1 sigma)	cal BP	6737 - 6797	0.804
		6818 - 6841	0.196
95.4 (2 sigma)	cal BP	6675 - 6854	0.987
		6873 - 6880	0.013

Median Probability: 6774

6
67454
clay
Radiocarbon Age BP 2950 +/- 25
Calibration data set: intcal20.14c # Reimer et al. 2020

% area enclosed		cal BP age ranges	relative area under probability distribution
68.3 (1 sigma)	cal BP	3072 - 3160	1.000
95.4 (2 sigma)	cal BP	3002 - 3178	0.975
		3194 - 3206	0.025

Median Probability: 3111

7
67455
f. sand

Radiocarbon Age BP 5750 +/- 30
Calibration data set: intcal20.14c # Reimer et al. 2020

% area enclosed		cal BP age ranges	relative area under probability distribution
68.3 (1 sigma)	cal BP	6494 - 6565	0.763
		6585 - 6607	0.198
		6615 - 6620	0.039
95.4 (2 sigma)	cal BP	6450 - 6475	0.046
		6480 - 6640	0.954

Median Probability: 6548

8
67456
clay
Radiocarbon Age BP 4880 +/- 30
Calibration data set: intcal20.14c # Reimer et al. 2020

% area enclosed		cal BP age ranges	relative area under probability distribution
68.3 (1 sigma)	cal BP	5586 - 5604	0.619
		5633 - 5650	0.381
95.4 (2 sigma)	cal BP	5488 - 5503	0.027
		5580 - 5660	0.966
		5695 - 5702	0.007

Median Probability: 5605

9
67457
clay
Radiocarbon Age BP 3110 +/- 25
Calibration data set: intcal20.14c # Reimer et al. 2020

% area enclosed		cal BP age ranges	relative area under probability distribution
68.3 (1 sigma)	cal BP	3263 - 3289	0.386
		3333 - 3370	0.614
95.4 (2 sigma)	cal BP	3244 - 3309	0.436
		3316 - 3388	0.564

Median Probability: 3333

10
67458
clay
Radiocarbon Age BP 3260 +/- 25
Calibration data set: intcal20.14c # Reimer et al. 2020

% area enclosed		cal BP age ranges	relative area under probability distribution
68.3 (1 sigma)	cal BP	3414 - 3420	0.034

		3447 - 3489	0.931
		3543 - 3546	0.035
95.4 (2 sigma)	cal BP	3400 - 3430	0.128
		3442 - 3497	0.698
		3501 - 3513	0.031
		3523 - 3560	0.142

Median Probability: 3469

11
67459
clay
Radiocarbon Age BP 5730 +/- 30
Calibration data set: intcal20.14c # Reimer et al. 2020

% area enclosed		cal BP age ranges	relative area under probability distribution
68.3 (1 sigma)	cal BP	6453 - 6469	0.105
		6483 - 6561	0.843
		6591 - 6598	0.053
95.4 (2 sigma)	cal BP	6413 - 6417	0.007
		6442 - 6629	0.993

Median Probability: 6525

Invalid age for calibration curve intcal20.14c

Sample	Radiocarbon age
12	90.0

VALID RADIOCARBON AGES FOR THIS CALIBRATION DATA
MUST BE BETWEEN 95 AND 50193 YRS BP

13
67461
wood
Radiocarbon Age BP 200 +/- 20
Calibration data set: intcal20.14c # Reimer et al. 2020

% area enclosed		cal BP age ranges	relative area under probability distribution
68.3 (1 sigma)	cal BP	0 - 9	0.159
		151 - 158	0.106
		162 - 174	0.208
		176 - 186	0.138
		199 - 208	0.123
		272 - 289	0.265
95.4 (2 sigma)	cal BP	0 - 23	0.163
		146 - 218	0.585
		266 - 294	0.251

Median Probability: 181

14
67462
clay
Radiocarbon Age BP 2520 +/- 25
Calibration data set: intcal20.14c # Reimer et al. 2020

% area enclosed		cal BP age ranges	relative area under probability distribution
68.3 (1 sigma)	cal BP	2519 - 2529	0.070
		2537 - 2586	0.457
		2615 - 2634	0.197
		2699 - 2723	0.276
95.4 (2 sigma)	cal BP	2494 - 2599	0.553
		2612 - 2645	0.187
		2683 - 2736	0.260

Median Probability: 2589

15
67463
sand loam
Radiocarbon Age BP 5430 +/- 30
Calibration data set: intcal20.14c # Reimer et al. 2020

% area enclosed		cal BP age ranges	relative area under probability distribution
68.3 (1 sigma)	cal BP	6205 - 6244	0.724
		6268 - 6284	0.276
95.4 (2 sigma)	cal BP	6190 - 6295	1.000

Median Probability: 6236

16
67464
clay
Radiocarbon Age BP 1680 +/- 25
Calibration data set: intcal20.14c # Reimer et al. 2020

% area enclosed		cal BP age ranges	relative area under probability distribution
68.3 (1 sigma)	cal BP	1535 - 1587	0.972
		1680 - 1683	0.028
95.4 (2 sigma)	cal BP	1528 - 1614	0.877
		1671 - 1690	0.123

Median Probability: 1569

17
67465
clay

Radiocarbon Age BP 1530 +/- 25
Calibration data set: intcal20.14c # Reimer et al. 2020

% area enclosed		cal BP age ranges	relative area under probability distribution
68.3 (1 sigma)	cal BP	1361 - 1411	1.000
95.4 (2 sigma)	cal BP	1348 - 1420	0.804
		1434 - 1441	0.011
		1450 - 1475	0.100
		1486 - 1514	0.085

Median Probability: 1396

References for calibration datasets:
Reimer P, Austin WEN, Bard E, Bayliss A, Blackwell PG, Bronk Ramsey C, Butzin M
Edwards RL, Friedrich M, Grootes PM, Guilderson TP, Hajdas I, Heaton TJ, Hogg A
Kromer B, Manning SW, Muscheler R, Palmer JG, Pearson C, van der Plicht J, Reim
Richards DA, Scott EM, Southon JR, Turney CSM, Wacker L, Adolphi F, Büntgen U,
Fahrni S, Fogtmann-Schulz A, Friedrich R, Köhler P, Kudsk S, Miyake F, Olsen J
Sakamoto M, Sookdeo A, Talamo S. 2020.
The IntCal20 Northern Hemisphere radiocarbon age calibration curve (0-55 cal kB
Radiocarbon 62. doi: 10.1017/RDC.2020.41.

Comments:
* This standard deviation (error) includes a lab error multiplier.
** 1 sigma = square root of (sample std. dev.^2 + curve std. dev.^2)
** 2 sigma = 2 x square root of (sample std. dev.^2 + curve std. dev.^2)
where ^2 = quantity squared.
[ ] = calibrated range impinges on end of calibration data set
0* represents a "negative" age BP
1955* or 1960* denote influence of nuclear testing C-14

NOTE: Cal ages and ranges are rounded to the nearest year which may be too precise in many instances. Users are advised to round results to the nearest 10 yr for samples with standard deviation in the radiocarbon age greater than 50 yr.

Appendix B:
Pollen Analysis

Table 3. Battery Park Pollen Percentages.

Pollen Taxon/Sample	B-19	B-23	B-25	B-28
Apiaceae (Umbelliferae - queen Anne's lace, water hemlock, etc)	0.5	1.5		
Alismataceae (water-plantain, arrowhead plant, etc.)		0.5		
Ambrosia -type (ragweed)	7.5	19	5.5	6.5
Solidago -type (goldenrod)	1	4.5	5.5	5
High Spine Asteraceae (daisy/sunflower family)	1	1.5		
Cheno-Ams (lamb's quarter, redroot pigweed, etc)	0.5		1	
Cyperaceae - small (sedge)	3	8	3.5	4.5
Cyperaceae - medium (sedge)	2	6.5	3.5	2
Fabaceae (legumes)	0.5	0.5	2	0.5
Impatiens (touch-me-not)		1		
Parthenocissus (tendril climbers - Virginia creeper, etc)		0.5		
Poaceae (grasses)	5	3.5	7	2
Polygonaceae (smartweed, knotweed)		1		
Polygonum (knotweed)			0.5	
Rosaceae (rose family)	1	0.5	0.5	
Rhus (sumac family)		1.5		
Typha (cattail family/bur-reed)		0.5		
Vitis (grape family)				0.5
Acer (maple)	3		0.5	3.5
Alnus (alder)	1.5	3	17.5	1.5
Betula (birch)	3		0.5	
Carpinus (hornbeam family)	1.5	0.5	0.5	
Carya (hickory)	4.5			
Castanea (chestnut)	4	2	3	0.5
Fagus (beech)	0.5	0.5		
Fraxinus (ash family)		1	1	
Ilex (holly/winterberry family)		0.5		
Juglans (walnut)				1
Myrica (bayberry/myrtle family)	1.5		1	
Nyssa (tupelo)	0.5			
Osmunda (fern family)	1		3	
Picea (spruce)				0.5
Pinus (pine family)	30	18	12.5	17.5
Prunus (cherry family)			0.5	
Quercus (oak family)	17.5	16.5	27	42.5
Salix (willow)		1		1
TCT (cypress)	1.5	0.5	0.5	0.5
Tilia (basswood/linden family)	0.5			
Tsuga (hemlock)	5	0.5	1	5.5
Indeterminate	3.5	5.5	5.5	5
Total Pollen Percentage	101	100	103	100
Total Grains Counted	200	200	200	200
Tracer Spores	93	88	115	111

Appendix C:
Macrobotanical Analysis

Report on the Analysis of Two Flotation Samples Secured from the Hudson River off Manhattan Island, New York

Justine McKnight, Archeobotanical Consultant LLC
July 9, 2024

Recent geomorphological investigations off Manhattan Island included the collection of estuary silt from beneath the Hudson River. Samples were secured via split spoon borings (inner diameter of 1.5 inches), and two core samples measuring 50 milliliters and 150 ml in sediment volume were submitted for macrobotanical analysis. The samples were moist, and moisture levels were maintained to maximize the preservation of plant remains. The samples were not dried prior to flotation processing. Samples were individually processed using a Flote-Tech flotation system equipped with 1.0 mm coarse fraction and 0.284 mm fine fraction screens. The Flote-Tech system is a multi-modal flotation system that facilitates the separation and recovery of plant macro-remains from the soil matrix by employing water agitation and forced air. Floted portions were air dried and passed through a 2 mm geological sieve, producing standard size classes of material for materials sorting.

Organic preservation was excellent, with carbonized and unburned botanical remains intact with in the core samples. Recovered floral remains were subjected to a general descriptive analysis, and taxonomic identification of wood, seeds, and leaf/stem was attempted. Materials 2 mm or greater in size were examined with a binocular microscope under low magnification (10X to 40X) and sample matrices and categories of plant materials (wood, seed, miscellaneous plant material) were described. Wood and stem/leaf tissues were embedded in core sediments and were incompletely liberated by soil flotation. The less than 2 mm fractions were examined under low magnification for the remains of seeds and fruits. Analysis followed standard practices for the study of flotation-recovered plant macroremains (Fritz and Nesbitt 2014; Pearsall 2000). Plant artifacts were identified to the genus level when possible, to the family level when limited diagnostic information was available, and to the species level only when the assignment could be made with absolute certainty. All identifications were made with the aid of standard texts (Edlin 1969; Hoadley 1990; Panshin and deZeeuw 1980; Martin and Barkley 1961) and secured by comparison with plant specimens from a modern reference collection representative of the flora of New York (USDA 2024).

Sample #001

Sample #001 consisted of 150 ml of silt with fibric peat, wood, Poaceae stem, and indeterminate plant matter. Organics were visibly bedded within sediment. Mica flecks, soil peds, insect body parts and egg cases, sand and small gravel were observed in the flotation residuum. Macrobotanical remains recovered through flotation included unburned and partially carbonized wood fibers: Spruce (*Picea*), pine (*Pinus*), and indeterminate coniferous types were identified. A carbonized thorn was also recovered. Seeds totaled 10 specimens, with sedge (*Carex*), rush (*Scirpus*), sedge family (Cyperaceae), and tentatively identified mustard family (Brassicaceae) recorded.

Table 01: Results from flotation samples

Sample Number	#001	#002
Original soil volume (milliliters)	150	50
MATRIX DESCRIPTION, presence		
organic fibric material	x	x
woody fibers	x	
carbonized woody fibers	x	x
insect body parts	x	x
insect egg cases	x	
mica	x	x
gastropods, small		x
soil peds	x	x
sand/small gravel	x	x
marine shell		x
WOOD	x	
Picea sp. (possibly *P. mariana*) spruce (unburned, partially burned)	x	
Pinus sp. (pine) (unburned, partially burned)	x	
coniferous (unburned and partially burned)	x	
indeterminate -compressed and distorted		x
MISCELLANEOUS, NON-CARBONIZED (specimen count)	1	x
weight (grams)	0.01	
Poaceae (grass) stem/leaf tissue	x	x
thorn (carbonized)	1	
SEEDS (specimen count)	10	
weight (grams)	0.01	
Carex sp. (sedge) seed (partially burned)	6	
cf. Brassicaceae (mustard) seed (burned)	1	
Scirpus sp. (bulrush) seed (partially burned)	1	
Cyperaceae (sedge) seed (unburned)	2	

Sample #002

Sample #002 was composed of 50 ml of silty sediment containing visible deposits of fibric peat, monocot leaf/stem tissue, carbon, insect body parts, soil peds, and woody material. Mica flecks, gastropod, shell fragments, and sand/gravel were noted. The flotation sample produced macroplant remains including partially carbonized wood that was compressed and distorted. Taxonomic identification was not possible based on available features. Grass (Poaceae) stem and leaf material were also observed.

Plate 01: Sedge (*Carex*) was the most common seed type identified (Sample #001).
(scale = 1mm grid)

Plate 02: Sample 002 prior to flotation with visible inclusions of wood charcoal.
(scale = 1mm increments)

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